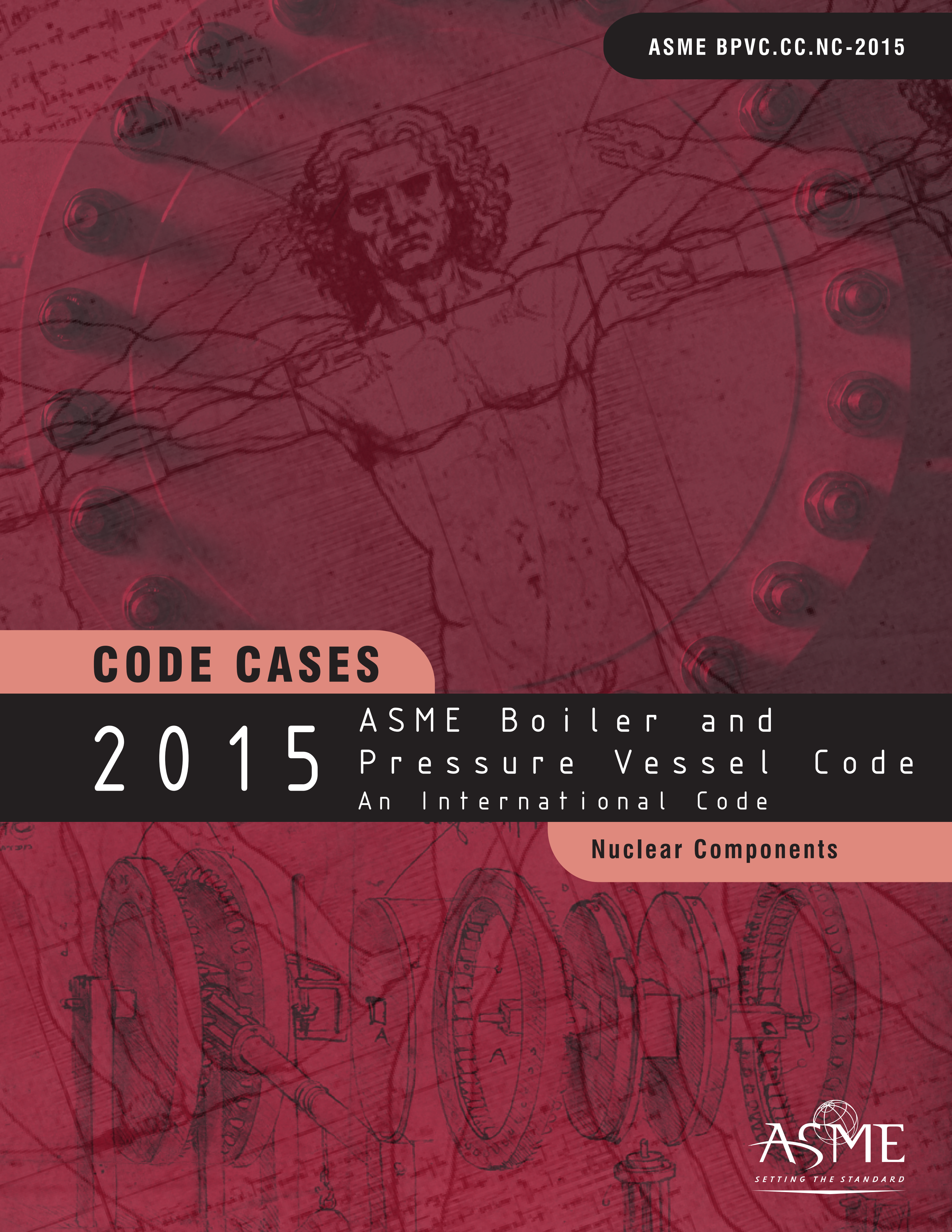

ASME BPVC.CC.NC-2015

CODE CASES

2015 ASME Boiler and Pressure Vessel Code

An International Code

Nuclear Components

ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

2015 ASME Boiler & Pressure Vessel Code

2015 Edition July 1, 2015

CODE CASES

Nuclear Components

The American Society of Mechanical Engineers

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This international code or standard was developed under procedures accredited as meeting the criteria for American National Standards and it is an American National Standard. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

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The endnotes and preamble in this document (if any) are part of this American National Standard.

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Certification Mark

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* The 2015 Edition of Section III is the last edition in which Section III, Division 1, Subsection NH, *Class 1 Components in Elevated Temperature Service*, will be published. The requirements located within Subsection NH have been moved to Section III, Division 5, Subsection HB, Subpart B for the elevated temperature construction of Class A components.

INTERPRETATIONS

Interpretations of the Code have historically been posted in January and July at http://cstools.asme.org/interpretations.cfm. Interpretations issued during the previous two calendar years are included with the publication of the applicable Section of the Code in the 2015 Edition. Interpretations of Section III, Divisions 1 and 2 and Section III Appendices are included with Subsection NCA.

Following the 2015 Edition, interpretations will not be included in editions; they will be issued in real time in ASME's Interpretations Database at http://go.asme.org/Interpretations. Historical BPVC interpretations may also be found in the Database.

CODE CASES

The Boiler and Pressure Vessel Code committees meet regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2015 Code Cases book: “Boilers and Pressure Vessels” or “Nuclear Components.” Supplements will be sent or made available automatically to the purchasers of the Code Cases books up to the publication of the 2017 Code.

SUMMARY OF CHANGES

The 2015 Edition of the Code Cases includes Code Case actions published through Supplement 7 to the 2013 Edition.

Changes given below are identified on the pages by a margin note, **(15)**, placed next to the affected area. Errata, if any, are identified by a margin note, **(E)**, placed next to the affected area.

Page	*Location*	*Change*
iv	List of Sections	Revised
viii	Notes to Numeric Index	Updated
ix	Numeric Index	Updated
xiii	Subject Index	Updated
xix	Index of Material Specifications Referred to in Cases	Updated
xxiii	Applicability Index for Section XI Cases	Updated
xxxix	Guideline for Cross-Referencing Section XI Cases	Table 1, General Note (a) revised
1 *(N-192-3)*	N-192-3	Annulled
1 *(N-284-4)*	N-284-4	Page 12 corrected by errata
1 *(N-319-3)*	N-319-3	Page 1 corrected by errata
1 *(N-405-1)*	N-405-1	Page 2 corrected by errata
1 *(N-493)*	N-493	Annulled
1 *(N-513-4)*	N-513-4	Pages 2, 3, 5, and 7 corrected by errata
1 *(N-597-3)*	N-597-3	Pages 3, 4, and 6 through 9 corrected by errata
1 *(N-638-8)*	N-638-8	Revised
1 *(N-645-1)*	N-645-1	Annulled
1 *(N-646)*	N-646	Annulled
1 *(N-657)*	N-657	Annulled
1 *(N-695-1)*	N-695-1	Revised
1 *(N-759-2)*	N-759-2	Pages 8 though 15 corrected by errata
1 *(N-786-1)*	N-786-1	Revised
1 *(N-830)*	N-830	Page 1 corrected by errata
1 *(N-851)*	N-851	Added
1 *(N-852)*	N-852	Added

CROSS-REFERENCING AND STYLISTIC CHANGES IN THE BOILER AND PRESSURE VESSEL CODE

There have been structural and stylistic changes to BPVC, starting with the 2011 Addenda, that should be noted to aid navigating the contents. The following is an overview of the changes:

Subparagraph Breakdowns/Nested Lists Hierarchy

- First-level breakdowns are designated as (a), (b), (c), etc., as in the past.
- Second-level breakdowns are designated as (1), (2), (3), etc., as in the past.
- Third-level breakdowns are now designated as (-a), (-b), (-c), etc.
- Fourth-level breakdowns are now designated as (-1), (-2), (-3), etc.
- Fifth-level breakdowns are now designated as (+a), (+b), (+c), etc.
- Sixth-level breakdowns are now designated as (+1), (+2), etc.

Footnotes

With the exception of those included in the front matter (roman-numbered pages), all footnotes are treated as endnotes. The endnotes are referenced in numeric order and appear at the end of each BPVC section/subsection.

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees has been moved to the front matter. This information now appears in all Boiler Code Sections (except for Code Case books).

Cross-References

It is our intention to establish cross-reference link functionality in the current edition and moving forward. To facilitate this, cross-reference style has changed. Cross-references within a subsection or subarticle will not include the designator/identifier of that subsection/subarticle. Examples follow:

- *(Sub-)Paragraph Cross-References.* The cross-references to subparagraph breakdowns will follow the hierarchy of the designators under which the breakdown appears.
  - If subparagraph (-a) appears in X.1(c)(1) and is referenced in X.1(c)(1), it will be referenced as (-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(c)(2), it will be referenced as (1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).
- *Equation Cross-References.* The cross-references to equations will follow the same logic. For example, if eq. (1) appears in X.1(a)(1) but is referenced in X.1(b), it will be referenced as eq. (a)(1)(1). If eq. (1) appears in X.1(a)(1) but is referenced in a different subsection/subarticle/paragraph, it will be referenced as eq. X.1(a)(1)(1).

(**15**)

NOTES TO NUMERIC INDEX

- All Code Cases remain available for use until annulled by the ASME Boiler and Pressure Vessel Standards Committees. Code Cases will be reviewed routinely for possible incorporation into the body of the ASME Boiler and Pressure Vessel Code.
- Supplement 7 is the last supplement published for the 2013 edition. Supplement 8 is incorporated into the 2015 edition.
- Cases may be used beginning with the date of approval shown on the Case.
- Annulled Cases will remain in the Numeric Index and Subject Index until the next Edition, at which time they will be deleted.
- Newly revised cases supersede previous versions. Previous code case number will be added in the "Annulled Date/ Supersedes" column next to the newly revised code case.
- The digit following a Case Number is used to indicate the number of times a Case has been revised.
- The Cases are arranged in numerical order, and each page of a Case is identified at the top with the appropriate Case Number.

Legend of Abbreviations

Supp. = Supplement

R = Reinstated

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Subject	Case

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APPLICABILITY INDEX FOR SECTION XI CASES (15)

This Index provides the range of Section XI Editions and Addenda applicable to each Section XI Case.

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-34	Inservice Inspection of Welds on Nuclear Components	1970 Edition	1971 Edition with the Summer 1973 Addenda
N-72	Partial Postponement of Category B-C Examinations for Class 1 Components	1974 Edition	1977 Edition with the Winter 1977 Addenda
N-73	Partial Postponement of Category B-D Examinations for Class 1 Components	1974 Edition	1977 Edition with the Winter 1977 Addenda
N-98	Ultrasonic Examination — Calibration Block Tolerances [Note (1)]:		
	(a) For Division 1	1974 Edition	1977 Edition with the Summer 1978 Addenda
	(b) For Division 2	1974 Edition with the Winter 1975 Addenda	Not applicable
N-112	Acceptance Standards Class 2 and 3 Components	1974 Edition	1974 Edition with the Winter 1975 Addenda
N-113	Basic Calibration Block for Ultrasonic Examination of Welds 10 in. to 13 in. Thick	1971 Edition with the Summer 1973 Addenda	1974 Edition with the Summer 1976 Addenda
N-113-1	Basic Calibration Block for Ultrasonic Examination of Welds 10 in. to 14 in. Thick	1971 Edition with the Summer 1973 Addenda	2001 Edition
N-118	Examination — Acceptance Standards for Surface Indications in Cladding	1974 Edition with the Summer 1974 Addenda	1974 Edition with the Winter 1975 Addenda
N-166	Reference by Section XI to N626.1-1975 for Qualification and Duties of Authorized Nuclear Inservice Inspection	1974 Edition	1977 Edition
N-167	Minimum Section Thickness Requirements for Repair of Nozzles	1974 Edition	1977 Edition with the Winter 1977 Addenda
N-198	Exemption From Examination for ASME Class 2 Piping Located at Containment Penetrations	1974 Edition with the Summer 1976 Addenda	1977 Edition with the Winter 1977 Addenda
N-198-1	Exemption From Examination for ASME Class 1 and 2 Piping Located at Containment Penetrations	1974 Edition with the Summer 1976 Addenda	1992 Edition with the 1993 Addenda
N-209	Conditional Acceptance of Identifiable Isolated or Random Rounded Indications		
	(a) For Class 1 Systems	1974 Edition	1980 Edition with the Winter 1980 Addenda
	(b) For Class 2 Systems	1974 Edition with the Summer 1976 Addenda	1983 Edition
N-210	Exemptions to Hydrostatic Test After Repairs	1974 Edition	1977 Edition with the Winter 1977 Addenda
N-211	Recalibration of Ultrasonic Equipment Upon Change of Personnel		
	(a) To meet requirements of I-4230	1971 Edition with the Summer 1973 Addenda	1974 Edition with the Summer 1976 Addenda
	(b) To meet requirements of III-3330	1977 Edition	1980 Edition
N-216	Alternative Rules for Reactor Vessel Closure Stud Examination	1977 Edition	1977 Edition with the Winter 1977 Addenda
N-234	Time Between Ultrasonic Calibration Checks		
	(a) To meet requirements of I-4230	1971 Edition with the Summer 1973 Addenda	1974 Edition with the Summer 1976 Addenda
	(b) To meet requirements of III-3330	1977 Edition	1980 Edition
N-235	Ultrasonic Calibration Checks per Section V	1974 Edition with the Winter 1976 Addenda	1977 Edition with the Summer 1979 Addenda
N-236	Repair and Replacement of Class MC Vessels	1974 Edition	1983 Edition with the Winter 1984 Addenda
N-236-1	Repair and Replacement of Class MC Vessels	1974 Edition	1989 Edition with the 1990 Addenda

Code Case No.	Title	Applicability	
		From	Up to and Including
N-252	Low Energy Capacitive Discharge Welding Method for Temporary or Permanent Attachments to Components and Supports	1971 Edition	1980 Edition with the Winter 1980 Addenda
N-278	Alternative Ultrasonic Calibration Block Configuration, I-3131 and T-434.3		
	(a) To meet requirements of I-3131	1974 Edition	1974 Edition with the Summer 1976 Addenda
	(b) To meet requirements of T-434.3	1977 Edition	1983 Edition with the Winter 1984 Addenda
N-288	Hydrostatic Test Requirements for Class 1 and 2 Components	1974 Edition	1980 Edition with the Winter 1980 Addenda
N-306	Calibration Block Material Selection, Appendix I, I-3121 [Note (2)]	1974 Edition with the Summer 1975 Addenda	1974 Edition with the Summer 1976 Addenda
N-307	Revised Ultrasonic Examination Volume for Class 1 Bolting, Examination Category B-G-1, When the Examinations Are Conducted From the Center- Drilled Hole	1974 Edition	1983 Edition with the Winter 1984 Addenda
N-307-1	Revised Ultrasonic Examination Volume for Class 1 Bolting, Table IWB-2500-1, Examination Category B-G-1, When the Examinations Are Conducted From the Center-Drilled Hole	1974 Edition	1998 Edition with the 1999 Addenda
N-307-2	Revised Ultrasonic Examination Volume for Class 1 Bolting, Table IWB-2500-1, Examination Category B-G-1, When the Examinations Are Conducted From the End of the Bolt or Stud or From the Center- Drilled Hole	1974 Edition	1998 Edition with the 1999 Addenda
N-307-3	Ultrasonic Examination of Class 1 Bolting, Table IWB-2500-1, Examination Category B-G-1	1974 Edition	1998 Edition with the 1999 Addenda
N-308	Documentation of Repairs and Replacements of Components in Nuclear Power Plants	1974 Edition	1980 Edition with the Winter 1981 Addenda
N-311	Alternative Examination of Outlet Nozzle on Secondary Side of Steam Generators	1977 Edition with the Winter 1977 Addenda	2004 Edition
N-322	Examination Requirements for Integrally Welded or Forged Attachments to Class 1 Piping at Containment Penetrations	1977 Edition with the Summer 1978 Addenda	1992 Edition with the 1993 Addenda
N-323	Alternative Examinations for Integrally Welded Attachments to Vessels	1974 Edition	1974 Edition with the Winter 1976 Addenda
N-323-1	Alternative Examination for Welded Attachments to Pressure Vessels	1980 Edition with the Winter 1981 Addenda	1995 Edition with the 1996 Addenda
N-334	Examination Requirements for Integrally Welded or Forged Attachments to Class 2 Piping at Containment Penetrations	1977 Edition with the Summer 1978 Addenda	1980 Edition with the Summer 1980 Addenda
N-335	Rules for Ultrasonic Examination of Similar and Dissimilar Metal Piping Welds	1974 Edition	1980 Edition with the Winter 1981 Addenda
N-335-1	Rules for Ultrasonic Examination of Similar and Dissimilar Metal Piping Welds	1974 Edition	1980 Edition with the Winter 1981 Addenda
N-343	Alternative Scope of Examination of Attachment Welds for Examination Categories B-H, B-K-1, and C-C	1974 Edition	1980 Edition with the Winter 1981 Addenda
N-355	Calibration Block for Angle Beam Ultrasonic Examination of Large Fittings in Accordance With Appendix III-3410 [Note (3)]	1974 Edition with the Winter 1975 Addenda	1983 Edition
N-356	Certification Period for Level III NDE Personnel	1977 Edition with the Winter 1977 Addenda	1983 Edition
N-375	Rules for Ultrasonic Examination of Bolts and Studs	1980 Edition	1980 Edition with the Winter 1981 Addenda
N-375-1	Rules for Ultrasonic Examination of Bolts and Studs	1980 Edition	1980 Edition with the Winter 1981 Addenda
N-375-2	Rules for Ultrasonic Examination of Bolts and Studs	1971 Edition	1983 Edition
N-389	Alternative Rules for Repairs, Replacements, or Modifications	1974 Edition with the Summer 1975 Addenda	1986 Edition with the 1987 Addenda
N-389-1	Alternative Rules for Repairs, Replacements, or Modifications	1974 Edition with the Summer 1975 Addenda	1992 Edition with the 1993 Addenda
N-390	Evaluation Criteria for Flaws Located in a Flange or Shell Region Near a Structural Discontinuity	1974 Edition with the Summer 1975 Addenda	1983 Edition with the Summer 1983 Addenda
N-401	Eddy Current Examination	1974 Edition with the Summer 1976 Addenda	1989 Edition with the 1989 Addenda

Code Case No.	Title	Applicability	
		From	Up to and Including
N-401-1	Eddy Current Examination	1974 Edition with the Summer 1974 Addenda	1989 Edition with the 1989 Addenda
N-402	Eddy Current Calibration Standard Material	1980 Edition with the Winter 1980 Addenda	1989 Edition with the 1989 Addenda
N-402-1	Eddy Current Calibration Standards	1980 Edition with the Winter 1980 Addenda	1989 Edition with the 1989 Addenda
N-406	Alternative Rules for Replacement	1977 Edition with the Summer 1978 Addenda	1986 Edition
N-408	Alternative Rules for Examination of Class 2 Piping	1974 Edition	1983 Edition
N-408-1	Alternative Rules for Examination of Class 2 Piping	1974 Edition	1983 Edition
N-408-2	Alternative Rules for Examination of Class 2 Piping	1974 Edition	1989 Edition
N-408-3	Alternative Rules for Examination of Class 2 Piping	1974 Edition	1989 Edition
N-409	Procedure and Personnel Qualification for Ultrasonic Detection and Sizing of Intergranular Stress Corrosion Cracking in Austenitic Piping Welds	1974 Edition	1986 Edition with the 1986 Addenda
N-409-1	Procedure and Personnel Qualification Requirements for Ultrasonic Detection and Sizing of Intergranular Stress Corrosion Cracking in Austenitic Piping Welds	1974 Edition	1986 Edition with the 1987 Addenda
N-409-2	Procedure and Personnel Qualification Requirements for Ultrasonic Detection and Sizing of Intergranular Stress Corrosion Cracking in Austenitic Piping Welds	1974 Edition	1989 Edition
N-409-3	Procedure and Personnel Qualification Requirements for Ultrasonic Detection and Sizing of Intergranular Stress Corrosion Cracking in Austenitic Piping Welds	1974 Edition	1989 Edition
N-415	Alternative Rules for Testing Pressure Relief Devices	1974 Edition	1983 Edition with the Winter 1984 Addenda
N-416	Alternative Rules for Hydrostatic Testing of Repair or Replacement of Class 2 Piping	1974 Edition	1989 Edition with the 1990 Addenda
N-416-1	Alternative Pressure Test Requirement for Welded Repairs or Installation of Replacement Items by Welding Class 1, 2, and 3	1974 Edition	1998 Edition
N-416-2	Alternative Pressure Test Requirement for Welded Repairs, Fabrication Welds for Replacement Parts and Piping Subassemblies, or Installation of Replacement Items by Welding, Class 1, 2, and 3	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-416-3	Alternative Pressure Test Requirement for Welded or Brazed Repairs, Fabrication Welds or Brazed Joints for Replacement Parts and Piping Subassemblies, or Installation of Replacement Items by Welding or Brazing, Classes 1, 2, and 3	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-416-4	Alternative Pressure Test Requirement for Welded or Brazed Repairs, Fabrication Welds or Brazed Joints for Replacement Parts and Piping Subassemblies, or Installation of Replacement Items by Welding or Brazing, Classes 1, 2, and 3	1977 Edition with the Summer 1978 Addenda	2001 Edition with the 2002 Addenda
N-419	Extent of VT-1 Examinations, Category B-G-1 of Table IWB-2500-1	1977 Edition with the Summer 1978 Addenda	1983 Edition with the Winter 1984 Addenda
N-424	Qualification of Visual Examination Personnel	1977 Edition with the Summer 1978 Addenda	1983 Edition
N-426	Extent of VT-1 Examinations, Category B-G-2 of Table IWB-2500-1	1977 Edition with the Summer 1978 Addenda	1983 Edition with the Winter 1984 Addenda
N-427	Code Cases in Inspection Plans	1971 Edition	1986 Edition
N-429	Alternate Rules for Ultrasonic Instrument Calibration	1980 Edition with the Winter 1980 Addenda	1983 Edition with the Winter 1983 Addenda
N-429-1	Alternative Rules for Ultrasonic Instrument Calibration	1980 Edition with the Winter 1980 Addenda	1986 Edition with the 1986 Addenda
N-432	Repair Welding Using Automatic or Machine Gas Tungsten-Arc Welding (GTAW) Temper Bead Technique	1971 Edition with the Summer 1973 Addenda	1989 Edition with the 1990 Addenda
N-432-1	Repair Welding Using Automatic or Machine Gas Tungsten-Arc Welding (GTAW) Temper Bead Technique	1971 Edition with the Summer 1973 Addenda	2013 Edition
N-435	Alternative Examination Requirements for Vessels With Wall Thickness 2 in. or Less	1974 Edition with the Summer 1975 Addenda	1986 Edition
N-435-1	Alternative Examination Requirements for Vessels With Wall Thickness 2 in. or Less	1974 Edition with the Summer 1975 Addenda	1995 Edition
N-436	Alternative Methods for Evaluation of Flaws in Austenitic Piping	1983 Edition	1986 Edition

Code Case No.	Title	Applicability From	Up to and Including
N-436-1	Alternative Methods for Evaluation of Flaws in Austenitic Piping	1983 Edition	1986 Edition
N-437	Use of Digital Readout and Digital Measurement Devices for Performing Pressure Tests	1974 Edition	1986 Edition
N-444	Preparation of Inspection Plans	1974 Edition with the Summer 1975 Addenda	1986 Edition with the 1986 Addenda
N-445	Use of Later Edition of SNT-TC-1A for Qualification of Nondestructive Examination Personnel	1977 Edition with the Summer 1978 Addenda	1986 Edition
N-446	Recertification of Visual Examination Personnel	1977 Edition with the Summer 1978 Addenda	1986 Edition
N-448	Qualification of VT-2 and VT-3 Visual Examination Personnel	1977 Edition with the Summer 1978 Addenda	1986 Edition with the 1987 Addenda
N-449	Qualification of VT-4 Visual Examination Personnel	1977 Edition with the Summer 1978 Addenda	1983 Edition with the Winter 1983 Addenda
N-457	Qualification Specimen Notch Location for Ultrasonic Examination of Bolts and Studs	1983 Edition with the Winter 1983 Addenda	1992 Edition with the 1993 Addenda
N-458	Magnetic Particle Examination of Coated Materials	1980 Edition with the Winter 1981 Addenda	1995 Edition
N-458-1	Magnetic Particle Examination of Coated Materials	1980 Edition with the Winter 1981 Addenda	1995 Edition
N-460	Alternative Examination Coverage for Class 1 and Class 2 Welds	1974 Edition	2007 Edition
N-461	Alternative Rules for Piping Calibration Block Thickness	1974 Edition with the Summer 1975 Addenda	1995 Edition
N-461-1	Alternative Rules for Piping Calibration Block Thickness	1974 Edition with the Summer 1975 Addenda	1995 Edition
N-463	Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping That Exceed the Acceptance Standards of IWB-3514.2	1983 Edition with the Winter 1983 Addenda	1989 Edition with the 1989 Addenda
N-463-1	Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping That Exceed the Acceptance Standards of IWB-3514.2	1983 Edition with the Winter 1983 Addenda	1989 Edition with the 1989 Addenda
N-465	Alternative Rules for Pump Testing	1974 Edition with the Winter 1975 Addenda	1986 Edition with the 1987 Addenda
N-465-1	Alternative Rules for Pump Testing	1974 Edition with the 1975 Addenda	1995 Edition with the 1995 Addenda
N-471	Acoustic Emissions for Successive Inspections	1974 Edition	1998 Edition with the 1999 Addenda
N-472	Use of Digital Readout and Digital Measurement Devices for Performing Pump Vibration Testing	1974 Edition	1986 Edition with the 1987 Addenda
N-473	Alternate Rules for Valve Testing	1974 Edition with the Summer 1975 Addenda	1986 Edition with the 1987 Addenda
N-473-1	Alternative Rules for Valve Testing	1974 Edition with the 1975 Addenda	1995 Edition with the 1995 Addenda
N-478	Inservice Inspection for Class CC Concrete Components of Light-Water Cooled Power Plants	1974 Edition	1986 Edition with the 1987 Addenda
N-479	Boiling Water Reactor (BWR) Main Steam Hydrostatic Test	1977 Edition with the Winter 1977 Addenda	1989 Edition with the 1989 Addenda
N-479-1	Boiling Water Reactor (BWR) Main Steam Hydrostatic Test	1977 Edition with the Winter 1977 Addenda	1989 Edition with the 1990 Addenda
N-480	Examination Requirements for Pipe Wall Thinning Due to Single Phase Erosion and Corrosion	1974 Edition	1992 Edition with the 1993 Addenda
N-481	Alternative Examination Requirements for Cast Austenitic Pump Casings	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 1999 Addenda
N-485	Eddy Current Examination of Coated Ferritic Surfaces as an Alternative to Surface Examination	1980 Edition with the Winter 1981 Addenda	1989 Edition with the 1990 Addenda
N-485-1	Eddy Current Examination of Coated Ferritic Surfaces as an Alternative to Surface Examination	1980 Edition with the Winter 1981 Addenda	1995 Edition
N-486	Inservice Inspection, Repair, and Replacement Requirements for Class MC and Metallic Liners of Class CC Components	1974 Edition	1989 Edition
N-489	Alternative Rules for Level III NDE Qualification Examinations	1974 Edition with the Summer 1975 Addenda	1989 Edition with the 1989 Addenda
N-490	Alternative Vision Test Requirements for Nondestructive Examiners	1974 Edition with the Summer 1975 Addenda	1989 Edition with the 1990 Addenda

Code Case No.	Title	Applicability	
		From	Up to and Including
N-490-1	Alternative Vision Test Requirements for Nondestructive Examiners	1974 Edition with the Summer 1975 Addenda	1989 Edition with the 1990 Addenda
N-491	Alternative Rules for Examination of Class 1, 2, 3, and MC Component Supports of Light-Water Cooled Power Plants	1977 Edition with the Summer 1978 Addenda	1989 Edition with the 1989 Addenda
N-491-1	Alternative Rules for Examination of Class 1, 2, 3, and MC Component Supports of Light-Water Cooled Power Plants	1977 Edition with the Summer 1978 Addenda	1989 Edition with the 1989 Addenda
N-491-2	Alternative Rules for Examination of Class 1, 2, 3, and MC Component Supports of Light-Water Cooled Power Plants	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-494	Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514.2	1974 Edition with the Winter 1975 Addenda	1995 Edition
N-494-1	Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514.2	1974 Edition with the Winter 1975 Addenda	1995 Edition
N-494-2	Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514.2	1974 Edition with the Winter 1975 Addenda	1995 Edition
N-494-3	Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Class 1 Ferritic Piping that Exceed the Acceptance Standards of IWB-3514.2 and in Class 1 Austenitic Piping that Exceed the Acceptance Standards of IWB-3514.3	1974 Edition with the Winter 1975 Addenda	1995 Edition
N-494-4	Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Piping that Exceed the Acceptance Standards	1983 Edition	2001 Edition
N-495	Hydrostatic Testing of Relief Valves	1977 Edition	1989 Edition with the 1990 Addenda
N-496	Helical-Coil Threaded Inserts	1977 Edition with the Summer 1978 Addenda	1989 Edition with the 1990 Addenda
N-496-1	Helical-Coil Threaded Inserts	1977 Edition with the Summer 1978 Addenda	1995 Edition
N-496-2	Helical-Coil Threaded Inserts	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-498	Alternative Rules for 10-Year Hydrostatic Pressure Testing for Class 1 and 2 Systems	1974 Edition with the Summer 1975 Addenda	1992 Edition with the 1992 Addenda
N-498-1	Alternative Rules for 10-Year System Hydrostatic Testing for Class 1, 2, and 3 Systems	1974 Edition with the Summer 1975 Addenda	1998 Edition with the 2000 Addenda
N-498-2	Alternative Requirements for 10-Year System Hydrostatic Testing for Class 1, 2 and 3 Systems	1974 Edition with the Summer 1975 Addenda	1998 Edition with the 2000 Addenda
N-498-3	Alternative Requirements for 10-Year System Hydrostatic Testing for Class 1, 2 and 3 Systems	1974 Edition with the Summer 1975	1998 Edition with the 2000 Addenda
N-498-4	Alternative Requirements for 10-Year System Hydrostatic Testing for Class 1, 2 and 3 Systems	1974 Edition with the Summer 1975	1998 Edition with the 2000 Addenda
N-503	Limited Certification of Nondestructive Examination Personnel	1977 Edition with the Summer 1978 Addenda	1992 Edition
N-504	Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping	1977 Edition with the Summer 1978 Addenda	1986 Edition with the 1987 Addenda
N-504-1	Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping	1977 Edition with the Summer 1978 Addenda	1995 Edition
N-504-2	Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1995 Addenda
N-504-3	Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-504-4	Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping	1977 Edition with the Summer 1978 Addenda	2004 Edition with the 2006 Addenda
N-508	Rotation of Serviced Snubbers and Pressure Relief Valves for the Purpose of Testing	1977 Edition	1989 Edition with the 1990 Addenda
N-508-1	Rotation of Serviced Snubbers and Pressure Relief Valves for the Purpose of Testing	1977 Edition	1995 Edition with the 1995 Addenda
N-508-2	Rotation of Serviced Snubbers and Pressure Relief Valves for the Purpose of Testing	1977 Edition	1998 Edition with the 2000 Addenda
N-508-3	Rotation of Serviced Snubbers and Pressure Relief Valves for the Purpose of Testing	1977 Edition with the Winter 1978 Addenda	2001 Edition with the 2003 Addenda

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-508-4	Rotation of Snubbers and Pressure Retaining Items for the Purpose of Testing or Preventive Maintenance	1989 Edition	2007 Edition with the 2008 Addenda
N-509	Alternative Rules for the Selection and Examination of Classes 1, 2, and 3 Integrally Welded Attachments	1977 Edition with the Summer 1978 Addenda	1995 Edition
N-512	Assessment of Reactor Vessels with Low Upper Shelf Charpy Impact Energy Levels	1986 Edition with the 1987 Addenda	1992 Edition with the 1992 Addenda
N-512-1	Assessment of Reactor Vessels with Low Upper Shelf Charpy Impact Energy Levels	1986 Edition with the 1987 Addenda	1995 Edition
N-513	Evaluation Criteria for Temporary Acceptance of Flaws in Class 3 Piping	1977 Edition with the Summer 1978 Addenda	2001 Edition
N-513-1	Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping	1977 Edition with the Summer 1978 Addenda	2001 Edition
N-513-2	Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping	1977 Edition with the Summer 1978 Addenda	2001 Edition with the 2003 Addenda
N-513-3	Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping	1983 Edition with the Winter 1985 Addenda	2007 Edition with the 2008 Addenda
N-513-4	Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping	1995 Edition with the 1996 Addenda	2013 Edition
N-514	Low Temperature Overpressure Protection	1986 Edition with the 1987 Addenda	1992 Edition with the 1992 Addenda
N-515	Class 1 Mechanical Joint- Pressure Tests	1980 Edition with the Winter 1980 Addenda	1989 Edition with the 1990 Addenda
N-516	Underwater Welding	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1995 Addenda
N-516-1	Underwater Welding	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1995 Addenda
N-516-2	Underwater Welding	1974 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-516-3	Underwater Welding	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-516-4	Underwater Welding	1995 Edition with the 1996 Addenda	2013 Edition
N-517	Quality Assurance Program Requirements for Owners	1977 Edition with the Summer 1978 Addenda	1995 Edition
N-517-1	Quality Assurance Program Requirements for Owners	1977 Edition with the Summer 1978 Addenda	2004 Edition with the 2006 Addenda
N-521	Alternative Rules for Deferral of Inspections of Nozzle-to-Vessel Welds, Inside Radius Sections and Nozzle- to-Safe End Welds of Pressurized Water Reactor (PWR) Vessel	1977 Edition	1995 Edition
N-522	Pressure Testing of Containment Penetration Piping	1974 Edition	1995 Edition with the 1996 Addenda
N-523	Mechanical Clamping Devices for Class 2 and 3 Piping	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-523-1	Mechanical Clamping Devices for Class 2 and 3 Piping	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-523-2	Mechanical Clamping Devices for Class 2 and 3 Piping	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-524	Alternative Examination Requirements for Longitudinal Welds in Class 1 and 2 Piping	1974 Edition with the Summer 1975 Addenda	1995 Edition
N-526	Alternative Requirements for Successive Inspections of Class 1 and 2 Vessels	1974 Edition	2010 Edition with the 2011 Addenda
N-528-1	Purchase, Exchange, or Transfer of Material Between Nuclear Plant Sites	1977 Edition with the Summer 1978 Addenda	2004 Edition with the 2005 Addenda
N-532	Alternative Requirements to Repair and Replacement Documentation Requirements and Inservice Summary Report Preparation and Submission as Required by IWA-4000 and IWA-6000	1974 Edition with the Summer 1975 Addenda	1998 Edition with the 2000 Addenda
N-532-1	Alternative Requirements to Repair and Replacement Documentation Requirements and Inservice Summary Report Preparation and Submission	1981 Edition with the Winter 1983 Addenda	1998 Edition with the 2000 Addenda

Code Case No.	Title	Applicability	
		From	Up to and Including
N-532-2	Alternative Requirements to Repair/Replacement Activity Documentation Requirements and Inservice Summary Report Preparation and Submission	1981 Edition with the Winter 1983 Addenda	2001 Edition with the 2002 Addenda
N-532-3	Alternative Requirements to Repair/Replacement Activity Documentation Requirements and Inservice Summary Report Preparation and Submission	1981 Edition with the Winter 1983 Addenda	2001 Edition with the 2003 Addenda
N-532-4	Repair/Replacement Activity Documentation Requirements and Inservice Summary Report Preparation and Submission	1983 Edition with the Winter 1983 Addenda	2007 Edition with the 2008 Addenda [see Guideline for Cross-Referencing Section XI, Table 1, General Note (b)]
N-532-5	Repair/Replacement Activity Documentation Requirements and Inservice Inspection Summary Report Preparation and Submission	1995 Edition with the 1996 Addenda	2010 Edition
N-533	Alternative Requirements for VT-2 Visual Examination of Class 1 Insulated Pressure-Retaining Bolted Connections	1986 Edition	1998 Edition with the 2000 Addenda
N-533-1	Alternative Requirements for VT-2 Visual Examination of Class 1, 2, and 3 Insulated Pressure Retaining Bolted Connections	1989 Edition	1998 Edition with the 2000 Addenda
N-534	Alternative Requirements for Pneumatic Pressure Testing	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1997 Addenda
N-535	Alternative Requirements for Inservice Inspection Intervals	1977 Edition	1995 Edition with the 1995 Addenda
N-537	Location of Ultrasonic Depth-Sizing Flaws	1989 Edition with the 1989 Addenda	2001 Edition
N-538	Alternative Requirements for Length Sizing Performance Demonstrations in Accordance with Appendix VIII, Supplements 2, 3, 10, 11, and 12	1989 Edition with the 1989 Addenda	1995 Edition with the 1995 Addenda
N-541	Alternative Requirements for Performance Demonstration in Accordance with Appendix VIII, Supplements 4 and 6	1992 Edition with the 1993 Addenda	1995 Edition
N-542	Alternative Requirements for Nozzle Inside Radius Section Length Sizing Performance Demonstration	1989 Edition with the 1989 Addenda	1995 Edition
N-543	Alternative to Performing Periodic Calibration Checks	1977 Edition with the Summer 1978 Addenda	1989 Edition
N-544	Repair/Replacement of Small Items	1977 Edition with the Summer 1978 Addenda	1995 Edition
N-545	Alternative Requirements for Conduct of Performance Demonstration Detection Test of Reactor Vessel	1989 Edition	2004 Edition
N-546	Alternative Requirements for Qualification of VT-2 Examination Personnel	1977 Edition	1995 Edition with the 1997 Addenda
N-547	Alternative Examination Requirements for Pressure Retaining Bolting of Control Rod Drive (CRD) Housings	1980 Edition with the Winter 1980 Addenda	1995 Edition
N-552	Alternative Methods — Qualification for Nozzle Inside Radius Section from the Outside Surface	1989 Edition with the 1989 Addenda	2004 Edition
N-552-1	Alternative Methods — Qualification for Nozzle Inside Radius Section from the Outside Surface	2004 Edition	2010 Edition with the 2011 Addenda
N-553	Inservice Eddy Current Surface Examination of Pressure Retaining Pipe Welds and Nozzle-to-Safe End Welds	1977 Edition	1995 Edition with the 1996 Addenda
N-553-1	Eddy Current Surface Examination	1977 Edition	1995 Edition with the 1996 Addenda
N-554	Alternative Requirements for Reconciliation of Replacement Items	1977 Edition	1995 Edition with the 1995 Addenda
N-554-1	Alternative Requirements for Reconciliation of Replacement Items	1977 Edition	1995 Edition with the 1996 Addenda
N-554-2	Alternative Requirements for Reconciliation of Replacement Items and Addition of New Systems	1977 Edition	1998 Edition
N-554-3	Alternative Requirements for Reconciliation of Replacement Items and Addition of New Systems	1977 Edition	2001 Edition with the 2002 Addenda
N-555	Use of Section II, V, and IX Code Cases	1977 Edition with the Summer 1978 Addenda	2001 Edition
N-556	Alternative Requirements for Verification of Acceptability of Replacements	1977 Edition	1992 Edition with the 1993 Addenda
N-557	In-Place Dry Annealing of a PWR Nuclear Reactor Vessel	1974 Edition with the Summer 1975 Addenda	1995 Edition

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-557-1	In-Place Dry Annealing of a PWR Nuclear Reactor Vessel	1974 Edition with the Summer 1975 Addenda	1995 Edition
N-560	Alternative Examination Requirements for Class 1, Category B-J Piping Welds	1974 Edition	2004 Edition
N-560-1	Alternative Examination Requirements for Class 1, Category B-J Piping Welds	1974 Edition	2004 Edition
N-560-2	Alternative Examination Requirements for Class 1, Category B-J Piping Welds	1977 Edition	2004 Edition
N-561	Alternative Requirements for Wall Thickness Restoration of Class 2 and High Energy Class 3 Carbon Steel Piping	1977 Edition	2004 Edition
N-561-1	Alternative Requirements for Wall Thickness Restoration of Class 2 and High Energy Class 3 Carbon Steel Piping	1977 Edition	2004 Edition with the 2005 Addenda
N-561-2	Alternative Requirements for Wall Thickness Restoration of Class 2 and High Energy Class 3 Carbon Steel Piping	1977 Edition	2013 Edition
N-562	Alternative Requirements for Wall Thickness Restoration of Class 3 Moderate Energy Carbon Steel Piping	1977 Edition	2004 Edition
N-562-1	Alternative Requirements for Wall Thickness Restoration of Class 3 Moderate Energy Carbon Steel Piping	1977 Edition	2004 Edition with the 2005 Addenda
N-562-2	Alternative Requirements for Wall Thickness Restoration of Class 3 Moderate Energy Carbon Steel Piping	1977 Edition	2013 Edition
N-563	Grading of Examinations, IWA-2320	1986 Edition with the 1988 Addenda	1992 Edition
N-566	Corrective Action for Leakage Identified at Bolted Connections	1983 Edition with the Winter 1984 Addenda	2004 Edition
N-566-1	Corrective Action for Leakage Identified at Bolted Connections	1983 Edition with the Winter 1984 Addenda	2004 Edition
N-566-2	Corrective Action for Leakage Identified at Bolted Connections	1983 Edition with the Winter 1984 Addenda	2004 Edition with the 2006 Addenda
N-567	Alternative Requirements for Class 1, 2, and 3 Replacement Components	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-567-1	Reconciliation Requirements for Class 1, 2, and 3 Replacement Components	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-568	Alternative Examination Requirements for Welded Attachments	1974 Edition with the Summer 1975 Addenda	1989 Edition with the 1990 Addenda
N-569	Alternative Rules for Repair by Electrochemical Deposition of Class 1 and 2 Steam Generator Tubing	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-569-1	Alternative Rules for Repair by Electrochemical Deposition of Class 1 and 2 Steam Generator Tubing	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-573	Transfer of Procedure Qualification Records Between Owners	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1996 Addenda
N-574	NDE Personnel Recertification Frequency	1974 Edition with the Summer 1975 Addenda	1995 Edition with the 1996 Addenda
N-575	Alternative Examination Requirements for Full Penetration Nozzle-to-Vessel Welds in Reactor Vessels with Set-On Type Nozzles	1989 Edition	2013 Edition
N-576	Repair of Class 1 and 2 SB-163, UNS N06600 Steam Generator Tubing	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 2000 Addenda
N-576-1	Repair of Class 1 and 2 SB-163, UNS N06600 Steam Generator Tubing	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 2000 Addenda
N-576-2	Repair of Class 1 and 2 SB-163, UNS N06600 Steam Generator Tubing	1995 Edition with the 1996 Addenda	2010 Edition with the 2011 Addenda
N-577	Risk-Informed Requirements for Class 1, 2, and 3 Piping, Method A	1977 Edition	2004 Edition
N-577-1	Risk-Informed Requirements for Class 1, 2, or 3 Piping, Method A	1977 Edition	2004 Edition
N-578	Risk-Informed Requirements for Class 1, 2, and 3 Piping, Method B	1977 Edition	2004 Edition
N-578-1	Risk-Informed Requirements for Class 1, 2, or 3 Piping, Method B	1977 Edition	2004 Edition
N-583	Annual Training Alternative	1986 Edition with the 1988 Addenda	1998 Edition

Code Case No.	Title	Applicability	
		From	Up to and Including
N-586	Alternative Additional Examination Requirements for Class 1, 2, and 3 Piping, Components, and Supports	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-586-1	Alternative Additional Examination Requirements for Class 1, 2, and 3 Piping, Components, and Supports	1977 Edition with the Summer 1978 Addenda	2007 Edition with the 2008 Addenda
N-587	Alternative NDE Requirements for Repair/Replacement Activities	1977 Edition with the Summer 1978 Addenda	1995 Edition with the 1997 Addenda
N-588	Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in Reactor Vessels	1986 Edition with the 1987 Addenda	1995 Edition with the 1997 Addenda
N-589	Class 3 Nonmetallic Cured-In-Place Piping	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-589-1	Class 3 Nonmetallic Cured-In-Place Piping	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-590	Alternative to the Requirements of Subsection IWE, Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Plants	1992 Edition	1995 Edition with the 1997 Addenda
N-591	Alternative to the Requirements of Subsection IWL, Requirements for Class CC Concrete Components of Light-Water Cooled Plants	1992 Edition	1995 Edition with the 1996 Addenda
N-592	ASNT Central Certification Program	1974 Edition	1998 Edition
N-593	Alternative Examination Requirements for Steam Generator Nozzle-to-Vessel Welds	1974 Edition	2004 Edition
N-593-1	Examination Requirements for Steam Generator Nozzle-to-Vessel Welds	1974 Edition	2013 Edition
N-593-2	Examination Requirements for Steam Generator Nozzle-to-Vessel Welds	1974 Edition	2013 Edition
N-597	Requirements for Analytical Evaluation of Pipe Wall Thinning	1974 Edition	2004 Edition
N-597-1	Requirements for Analytical Evaluation of Pipe Wall Thinning	1974 Edition	2004 Edition
N-597-2	Requirements for Analytical Evaluation of Pipe Wall Thinning	1974 Edition	2013 Edition
N-597-3	Evaluation of Pipe Wall Thinning	1974 Edition	2013 Edition
N-598	Alternative Requirements to Required Percentages of Examinations	1977 Edition	1995 Edition with the 1997 Addenda
N-599	Alternatives to Qualification of Nondestructive Examination Personnel for Inservice Inspection of Metal (Class MC) and Concrete (Class CC) Containments	1992 Edition with the 1992 Addenda	1995 Edition with the 1997 Addenda
N-600	Transfer of Welder, Welding Operator, Brazer, and Brazing Operator Qualifications Between Owners	1977 Edition with the Summer 1978 Addenda	2010 Edition with the 2011 Addenda
N-601	Extent and Frequency of VT-3 Visual Examination for Inservice Inspection of Metal Containments	1989 Edition	1995 Edition with the 1997 Addenda
N-603	Alternative to the Requirements of IWL-2421, Sites With Two Plants	1989 Edition with the 1991 Addenda	1995 Edition with the 1996 Addenda
N-604	Alternative to Bolt Torque or Tension Test Requirements of Table IWE-2500-1, Category E-G, Item E8.20	1989 Edition	1995 Edition with the 1997 Addenda
N-605	Alternative to the Requirements of IWE-2500(c) for Augmented Examination of Surface Areas	1989 Edition	1995 Edition with the 1997 Addenda
N-606	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-606-1	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique for BWR CRD Housing/Stub Tube Repairs	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-606-2	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique for BWR CRD Housing/Stub Tube Repairs	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-609	Alternative Requirements to Stress-Based Selection Criteria for Category B-J Welds	1977 Edition	2004 Edition with the 2005 Addenda
N-609-1	Alternative Requirements to Stress-Based Selection Criteria for Category B-J Welds	1977 Edition	2010 Edition
N-613	Ultrasonic Examination of Full Penetration Nozzles in Vessels, Examination Category B-D, Item No’s. B3.10 and B3.90, Reactor Vessel-to-Nozzle Welds, Figures IWB-2500-7(a), (b), and (c)	1989 Edition with the 1989 Addenda	2007 Edition with the 2008 Addenda

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-613-1	Ultrasonic Examination of Full Penetration Nozzles in Vessels, Examination Category B-D, Item No's. B3.10 and B3.90, Reactor Nozzle-to-Vessel Welds, Figures IWB-2500-7(a), (b), and (c)	1989 Edition with the 1989 Addenda	2007 Edition with the 2008 Addenda
N-613-2	Ultrasonic Examination of Full Penetration Nozzles in Vessels, Examination Category B-D, Reactor Nozzle- to-Vessel Welds and Nozzle Inside Radius Section, Figures IWB-2500-7(a), (b), (c), and (d)	1989 Edition	2013 Edition
N-615	Ultrasonic Examination as a Surface Examination Method for Category B-F and B-J Piping Welds	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 2000 Addenda
N-616	Alternative Requirements for VT-2 Visual Examination of Classes 1, 2, and 3 Insulated Pressure-Retaining Bolted Connections	1983 Edition with the Winter 1984 Addenda	2001 Edition with the 2002 Addenda
N-617	Alternative Examination Distribution Requirements for Table IWC-2500-1 Examination Category C-G, Pressure Retaining Welds in Pumps and Valves	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 1999 Addenda
N-618	Use of a Reactor Pressure Vessel as a Transportation Containment System	1983 Edition	2013 Edition
N-619	Alternative Requirements for Nozzle Inner Radius Inspections for Class 1 Pressurizer and Steam Generator Nozzles	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-622	Ultrasonic Examination of RPV and Piping, Bolts, and Studs	1989 Edition with the 1989 Addenda	2001 Edition
N-623	Deferral of Inspections of Shell-to-Flange and Head-to- Flange Welds of a Reactor Vessel	1977 Edition with the Summer 1978 Addenda	1998 Edition
N-624	Successive Inspections	1977 Edition with the Summer 1978 Addenda	2007 Edition
N-627	VT-1 Visual Examination in Lieu of Surface Examination for RPV Closure Nuts	1977 Edition with the 1978 Addenda	1989 Edition
N-629	Use of Fracture Toughness Test Data to Establish Reference Temperature for Pressure Retaining Materials	1977 Edition with the Summer 1978 Addenda	2010 Edition with the 2011 Addenda
N-630	Alternatives to VT-1C and VT-3C Visual Examination for Inservice Inspection of Concrete and VT-1 Visual Examination for Inservice Inspection of Anchorage Hardware and Surrounding Concrete for Concrete Containments	1992 Edition with the 1992 Addenda	1995 Edition with the 1996 Addenda
N-638	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-638-1	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1977 Edition with the Summer 1978 Addenda	2007 Edition with the 2008 Addenda
N-638-2	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2004 Edition
N-638-3	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2004 Edition
N-638-4	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2004 Edition
N-638-5	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2004 Edition
N-638-6	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2010 Edition
N-638-7	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2010 Edition
N-638-8	Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique	1980 Edition with the Winter 1981 Addenda	2010 Edition
N-639	Alternative Calibration Block Material	1986 Edition with the 1987 Addenda	2013 Edition
N-640	Alternative Reference Fracture Toughness for Development of P-T Limit Curves	1986 Edition with the 1987 Addenda	1998 Edition
N-641	Alternative Pressure-Temperature Relationship and Low Temperature Overpressure Protection System Requirements	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-643	Fatigue Crack Growth Rate Curves for Ferritic Steels in PWR Water Environment	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-643-1	Fatigue Crack Growth Rate Curves for Ferritic Steels in PWR Water Environment	1977 Edition with the Summer 1978 Addenda	2004 Edition

Code Case No.	Title	Applicability	
		From	Up to and Including
N-643-2	Fatigue Crack Growth Rate Curves for Ferritic Steels in PWR Water Environment	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-647	Alternative to Augmented Examination Requirements of IWE-2500	1977 Edition with the Summer 1978 Addenda	1998 Edition with the 2000 Addenda
N-648	Alternative Requirements for Inner Radius Examinations of Class 1 Reactor Vessel Nozzles	1977 Edition with the Summer 1978 Addenda	2004 Edition
N-648-1	Alternative Requirements for Inner Radius Examinations of Class 1 Reactor Vessel Nozzles	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-648-2	Alternative Requirements for Inner Radius Examinations of Class 1 Reactor Vessel Nozzles	1983 Edition with the Winter 1983 Addenda	2013 Edition
N-649	Alternative Requirements for IWE-5240 Visual Examination	1989 Edition	1998 Edition with the 2000 Addenda
N-651	Ferritic and Dissimilar Metal Welding Using SMAW Temper Bead Technique Without Removing the Weld Bead Crown of the First Layer	1977 Edition with the Summer 1978 Addenda	2013 Edition
N-652	Alternative Requirements to Categories B-G-1, B-G-2, and C-D Bolting Examination Methods and Selection Criteria	1977 Edition	2001 Edition
N-652-1	Alternative Requirements to Categories B-G-1, B-G-2, and C-D Bolting Examination Methods and Selection Criteria	1977 Edition	2001 Edition with the 2003 Addenda
N-652-2	Alternative Requirements to Categories B-G-1, B-G-2, and C-D Bolting Examination Methods and Selection Criteria	1977 Edition	2010 Edition
N-653	Qualification Requirements for Full Structural Overlaid Wrought Austenitic Piping Welds	1989 Edition with the 1989 Addenda	2004 Edition
N-653-1	Qualification Requirements for Full Structural Overlaid Wrought Austenitic Piping Welds	1989 Edition with the 1989 Addenda	2013 Edition
N-654	Acceptance Criteria for Flaws in Ferritic Steel Components 4 in. and Greater in Thickness	1974 Edition	2013 Edition
N-658	Qualification Requirements for Ultrasonic Examination of Wrought Austenitic Piping Welds	1989 Edition with the 1989 Addenda	2001 Edition
N-660	Risk-Informed Safety Classification for Use in Risk- Informed Repair/Replacement Activities	1980 Edition with the Winter 1981 Addenda	2013 Edition
N-661	Alternative Requirements for Wall Thickness Restoration of Classes 2 and 3 Carbon Steel Piping for Raw Water Service	1977 Edition	2004 Edition with the 2005 Addenda
N-661-1	Alternative Requirements for Wall Thickness Restoration of Classes 2 and 3 Carbon Steel Piping for Raw Water Service	1977 Edition	2004 Edition with the 2005 Addenda
N-661-2	Alternative Requirements for Wall Thickness Restoration of Classes 2 and 3 Carbon Steel Piping for Raw Water Service	1977 Edition	2013 Edition
N-662	Alternative Repair/Replacement Requirements for Items Classified in Accordance With Risk-Informed Processes	1980 Edition with the Winter 1981 Addenda	2001 Edition with the 2002 Addenda
N-662-1	Alternative Repair/Replacement Requirements for Items Classified in Accordance With Risk-Informed Processes	1995 Edition with the 1996 Addenda	2007 Edition with the 2009 Addenda
N-663	Alternative Requirements for Classes 1 and 2 Surface Examinations	1986 Edition	2010 Edition with the 2011 Addenda
N-664	Performance Demonstration Requirements for Examination of Unclad Reactor Pressure Vessel Welds, Excluding Flange Welds	1989 Edition with the 1989 Addenda	2001 Edition with the 2002 Addenda
N-665	Alternative Requirements for Angle Beam Measurements Using Refracted Longitudinal Wave Search Units	1983 Edition with the Winter 1985 Addenda	2001 Edition with the 2002 Addenda
N-666	Weld Overlay of Class 1, 2, and 3 Socket Welded Connections	1980 Edition with the Winter 1981 Addenda	2004 Edition
N-666-1	Weld Overlay of Class 1, 2, and 3 Socket Welded Connections	1995 Edition with the 1996 Addenda	2010 Edition with the 2011 Addenda
N-683	Method for Determining Maximum Allowable False Calls When Performing Single-Sided Access Performance Demonstration in Accordance With, Appendix VIII, Supplements 4 and 6	1989 Edition with the 1989 Addenda	2001 Edition with the 2002 Addenda
N-685	Lighting Requirements for Surface Examination	1998 Edition	2001 Edition with the 2003 Addenda
N-686	Alternative Requirements for Visual Examinations, VT-1, VT-2, and VT-3	1989 Edition with the 1990 Addenda	1998 Edition with the 2000 Addenda
N-686-1	Alternative Requirements for Visual Examinations, VT-1, VT-2, and VT-3	1989 Edition with the 1990 Addenda	2004 Edition

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-691	Application of Risk-Informed Insights to Increase the Inspection Interval for Pressurized Water Reactor Vessels	1986 Edition	2004 Edition with the 2006 Addenda
N-694	Evaluation Procedure and Acceptance Criteria for PWR Reactor Vessel Upper Head Penetration Nozzles	1983 Edition	2001 Edition with the 2003 Addenda
N-694-1	Evaluation Procedure and Acceptance Criteria for PWR Reactor Vessel Head Penetration Nozzles	1983 Edition	2001 Edition with the 2003 Addenda
N-694-2	Evaluation Procedure and Acceptance Criteria for PWR Reactor Vessel Head Penetration Nozzles	1983 Edition	2001 Edition with the 2003 Addenda
N-695	Qualification Requirements for Dissimilar Metal Piping Welds	1989 Edition with the 1989 Addenda	2001 Edition with the 2003 Addenda
N-695–1	Qualification Requirements for Dissimilar Metal Piping Welds	2001 Edition	2013 Edition
N-696	Qualification Requirements for Appendix VIII Piping Examinations Conducted From the Inside Surface	1989 Edition with the 1989 Addenda	2001 Edition with the 2003 Addenda
N-696-1	Qualification Requirements for Mandatory Appendix VIII Piping Examinations Conducted From the Inside Surface	2001 Edition	2013 Edition
N-697	Pressurized Water Reactor (PWR) Examination and Alternative Examination Requirements for Pressure Retaining Welds in Control Rod Drive and Instrument Nozzle Housings	1977 Edition	2001 Edition with the 2003 Addenda
N-700	Alternative Rules for Selection of Classes 1, 2, and 3 Vessel Welded Attachments for Examination	1995 Edition with the 1996 Addenda	2001 Edition with the 2003 Addenda
N-702	Alternative Requirements for Boiling Water Reactor (BWR) Nozzle Inner Radius and Nozzle-to-Shell Welds	1986 Edition	2013 Edition
N-705	Evaluation Criteria for Temporary Acceptance of Degradation in Moderate Energy Class 2 or 3 Vessels and Tanks	1983 Edition with the Winter 1985 Addenda	2013 Edition
N-706	Alternative Examination Requirements to Table IWB-2500-1 and Table IWC-2500-1 for PWR Stainless Steel Residual and Regenerative Heat Exchangers	1977 Edition	2004 Edition with the 2005 Addenda
N-706-1	Alternative Examination Requirements to Table IWB-2500-1 and Table IWC-2500-1 for PWR Stainless Steel Residual and Regenerative Heat Exchangers	1977 Edition	2010 Edition with the 2011 Addenda
N-711	Alternative Examination Coverage Requirements for Examination Category B-F, B-J, C-F-1, C-F-2, and R-A Piping Welds	1989 Edition	2013 Edition
N-712	Class 1 Socket Weld Examinations	1986 Edition	2010 Edition with the 2011 Addenda
N-713	Ultrasonic Examination in Lieu of Radiography	1986 Edition	2013 Edition
N-716	Alternative Piping Classification and Examination Requirements	1989 Edition	2004 Edition with the 2006 Addenda
N-716–1	Alternative Piping Classification and Examination Requirements	1995 Edition	2013 Edition
N-722	Additional Examinations for PWR Pressure Retaining Welds in Class 1 Components Fabricated With Alloy 600/82/182 Materials	1980 Edition	2013 Edition
N-722-1	Additional Examinations for PWR Pressure Retaining Welds in Class 1 Components Fabricated With Alloy 600/82/182 Materials	1980 Edition	2013 Edition
N-722-2	Visual Examinations for PWR Pressure Retaining Welds in Class 1 Components Fabricated With Alloy 600/82/182 Materials	1980 Edition	2013 Edition
N-729	Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds	1980 Edition	2004 Edition
N-729-1	Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds	1980 Edition	2004 Edition
N-729-2	Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds	1980 Edition	2004 Edition
N-729-3	Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds	1995 Edition with the 1996 Addenda	2013 Edition

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-729-4	Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds	1995 Edition with the 1996 Addenda	2013 Edition
N-730	Roll Expansion of Class 1 Control Rod Drive Bottom Head Penetrations in BWRs	1989 Edition	2007 Edition with the 2008 Addenda
N-730-1	Roll Expansion of Class 1 Control Rod Drive Bottom Head Penetrations in BWRs	1995 Edition with the 1996 Addenda	2007 Edition with the 2009 Addenda
N-731	Alternative Class 1 System Leakage Test Pressure Requirements	1989 Edition	2013 Edition
N-733	Mitigation of Flaws in NPS 2 (DN 50) and Smaller Nozzles and Nozzle Partial Penetration Welds in Vessels and Piping by Use of a Mechanical Connection Modification	1983 Edition	2004 Edition with the 2006 Addenda
N-735	Successive Inspections of Class 1 and 2 Piping Welds	1995 Edition with the 1996 Addenda	2013 Edition
N-739	Alternative Qualification Requirements for Personnel Performing Class CC Concrete and Post-tensioning System Visual Examinations	1992 Edition with the 1992 Addenda	2004 Edition with the 2006 Addenda
N-739-1	Alternative Qualification Requirements for Personnel Performing Class CC Concrete and Post-tensioning System Visual Examinations	1992 Edition with the 1992 Addenda	2004 Edition with the 2006 Addenda
N-740	Dissimilar Metal Weld Overlay for Repair of Class 1, 2, and 3 Items	1980 Edition with Winter 1981 Addenda	2004 Edition with the 2006 Addenda
N-740-1	Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items	1980 Edition with Winter 1981 Addenda	2004 Edition with the 2006 Addenda
N-740-2	Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items	1986 Edition with the 1988 Addenda	2007 Edition with the 2008 Addenda
N-747	Reactor Vessel Head-to-Flange Weld Examination	1989 Edition	2013 Edition
N-749	Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range	1998 Edition with the 2000 Addenda	2013 Edition
N-751	Pressure Testing of Containment Penetration Piping	1989 Edition	2013 Edition
N-753	Vision Tests	1986 Edition with the 1988 Addenda	2004 Edition with the 2006 Addenda
N-754	Optimized Structural Dissimilar Metal Weld Overlay for Mitigation of PWR Class 1 Items	1986 Edition with the 1988 Addenda	2010 Edition
N-754–1	Optimized Structural Dissimilar Metal Weld Overlay for Mitigation of PWR Class 1 Items	1995 Edition with the 1996 Addenda	2010 Edition with the 2011 Addenda
N-755	Use of Polyethylene (PE) Plastic Pipe	1995 Edition with the 1995 Addenda	2013 Edition
N-755-1	Use of Polyethylene (PE) Plastic Pipe	1995 Edition with the 1995 Addenda	2013 Edition
N-762	Temper Bead Procedure Qualification Requirements for Repair/Replacement Activities Without Postweld Heat Treatment	1995 Edition with the 1995 Addenda	2010 Edition
N-762-1	Temper Bead Procedure Qualification Requirements for Repair/ Replacement Activities Without Postweld Heat Treatment	1995 Edition with the 1995 Addenda	2010 Edition
N-765	Alternative to Inspection Interval Scheduling Requirements of IWA-2430	1989 Edition	2007 Edition with the 2008 Addenda
N-766	Nickel Alloy Reactor Coolant Inlay and Onlay for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Dissimilar Metal Welds in Class 1 Items	1986 Edition with the 1988 Addenda	2013 Edition
N-766–1	Nickel Alloy Reactor Coolant Inlay and Onlay for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Dissimilar Metal Welds in Class 1 Items	1995 Edition with the 1996 Addenda	2013 Edition
N-769	Roll Expansion of Class 1 In-Core Housing Bottom Head Penetrations in BWRs	1989 Edition	2007 Edition with the 2008 Addenda
N-769-1	Roll Expansion of Class 1 In-Core Housing Bottom Head Penetrations in BWRs	1989 Edition	2007 Edition with the 2009 Addenda
N-769-2	Roll Expansion of Class 1 In-Core Housing Bottom Head Penetrations in BWRs	1995 Edition with the 1996 Addenda	2007 Edition with the 2009 Addenda

Code Case No.	Title	Applicability From	Applicability Up to and Including
N-770	Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities	1989 Edition	2013 Edition
N-770-1	Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities	1989 Edition	2013 Edition
N-770-2	Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities	1989 Edition	2013 Edition
N-770-3	Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities	1989 Edition	2013 Edition
N-770-4	Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities	1989 Edition	2013 Edition
N-771	Alternative Requirements for Additional Examinations of Class 2 or 3 Items	1992 Edition	2007 Edition with the 2009 Addenda
N-773	Alternative Qualification Criteria for Eddy Current Examinations of Piping Inside Surfaces	1995 Edition with the 1996 Addenda	2013 Edition
N-775	Alternative Requirements for Bolting Affected by Borated Water Leakage	1989 Edition	2010 Edition with the 2011 Addenda
N-776	Alternative to IWA-5244 Requirements for Buried Piping	1989 Edition	2010 Edition
N-778	Alternative Requirements for Preparation and Submittal of Plans, Schedules, and Preservice and Inservice Inspection Summary Reports	1989 Edition	2007 Edition with the 2009 Addenda
N-780	Alternative Requirements for Upgrade, Substitution, or Reconfiguration of Examination Equipment When Using Appendix VIII Qualified Ultrasonic Examination Systems	1989 Edition with the 1989 Addenda	2013 Edition
N-784	Experience Credit for Ultrasonic Examiner Certification	1995 Edition	2010 Edition
N-786	Alternative Requirements for Sleeve Reinforcement of Class 2 and 3 Moderate Energy Carbon Steel Piping	1995 Edition with the 1996 Addenda	2013 Edition
N-786–1	Alternative Requirements for Sleeve Reinforcement of Class 2 and 3 Moderate Energy Carbon Steel Piping	1995 Edition with the 1996 Addenda	2013 Edition
N-788	Third Party NDE Certification Organizations	1995 Edition	2013 Edition
N-789	Alternative Requirements for Pad Reinforcement of Class 2 and 3 Moderate-Energy Carbon Steel Piping for Raw Water Service	1995 Edition with the 1996 Addenda	2013 Edition
N-789–1	Alternative Requirements for Pad Reinforcement of Class 2 and 3 Moderate-Energy Carbon Steel Piping for Raw Water Service	1995 Edition with the 1996 Addenda	2013 Edition
N-795	Alternative Requirements for BWR Class 1 System Leakage Test Pressure Following Repair/Replacement Activities	1998 Edition with the 1999 Addenda	2013 Edition
N-798	Alternative Pressure Testing Requirements for Class 1 Piping Between the First and Second Vent, Drain, and Test Isolation Devices	1992 Edition with the 1993 Addenda	2013 Edition
N-799	Dissimilar Metal Welds Joining Vessel Nozzles to Components	1995 Edition	2010 Edition
N-800	Alternative Pressure Testing Requirements for Class 1 Piping Between the First and Second Injection Valves	1992 Edition with the 1993 Addenda	2013 Edition
N-803	Similar and Dissimilar Metal Welding Using Ambient Temperature Automatic or Machine Dry Underwater Laser Beam Welding (ULBW) Temper Bead Technique	1980 Edition	2010 Edition

Code Case No.	Title	Applicability	
		From	Up to and Including
N-805	Alternative to Class 1 Extended Boundary End of Interval or Class 2 System Leakage Testing of the Reactor Vessel Head Flange O-Ring Leak-Detection System	1992 Edition	2013 Edition
N-806	Evanuation of Metal Loss in Class 2 and 3 Metallic Piping Buried in a Back-Filled Trench	1995 Edition	2013 Edition
N-813	Alternative Requirements for Preservice Volumetric and Surface Examination	1989 Edition	2013 Edition
N-823	Visual Examination	2001 Edition with the 2003 Addenda	2010 Edition with the 2011 Addenda
N-823–1	Visual Examination	2001 Edition with the 2003 Addenda	2010 Edition with the 2011 Addenda
N-824	Ultrasonic Examination of Cast Austenitic Piping Welds From the Outside Surface	2001 Edition	2013 Edition
N-825	Alternative Requirements for Examination of Control Rod Drive Housing Welds	1995 Edition with the 1996 Addenda	2013 Edition
N-826	Ultrasonic Examination of Full Penetration Vessel Weld Joints in Figures IWB-2500-1 Through IWB-2500-6	1995 Edition with the 1996 Addenda	2013 Edition
N-829	Austenitic Stainless Steel Cladding and Nickel Base Cladding Using Ambient Temperature Machine GTAW Temper Bead Technique	1995 Edition with the 1996 Addenda	2013 Edition
N-830	Direct Use of Master Fracture Toughness Curve for Pressure-Retaining Materials of Class 1 Vessels	1992 Edition	2013 Edition
N-839	Similar and Dissimilar Metal Welding Using Ambient Temperature SMAW Temper Bead Technique	1995 Edition with the 1996 Addenda	2013 Edition
N-840	Cladding Repair by Underwater Electrochemical Deposition in Class 1 and 2 Applications	1995 Edition with the 1996 Addenda	2013 Edition
N-842	Alternative Inspection Program for Longer Fuel Cycles	2007 Edition with the 2008 Addenda	2013 Edition
N-843	Alternative Pressure Testing Requirements Following Repairs or Replacements for Class 1 Piping Between the First and Second Injection Isolation Valves	1980 Edition	2013 Edition
N-845	Qualification Requirements for Bolts and Studs	1995 Edition with the 1996 Addenda	2013 Edition
N-849	In Situ VT-3 Examination of Removable Core Support Structures Without Removal	2007 Edition with the 2008 Addenda	2013 Edition
N-851	Use of Fracture Toughness Test Data to Establish Reference Temperature for Pressure Retaining Materials	1977 Edition with the Summer 1978 Addenda	2015 Edition

NOTES:

(1) Applies to the 1974 Edition of Section V.

(2) Applies to the 1974 Edition with the Winter 1976 Addenda of Section V.

(3) Applies to the 1980 Edition of Section V.

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GUIDELINE FOR CROSS-REFERENCING SECTION XI CASES (15)

1 GENERAL

Table 1 applies to Cases listed in the General Note (a) at the bottom of the table. If a Case is not listed in the General Note (a), Table 1 does not apply.

1.1 Purpose. Table 1 provides the user of Cases a tool to identify the appropriate references in a Section XI Edition or Addenda, different from the one on which the Case is based. This allows management of the applicability of various Cases without having to revise the Cases.

1.2 How to Use the Table. Locate the column with the Section XI Edition or Addenda on which the Case is based. Move down that column to the reference in question. Follow that row to the column with the Edition or Addenda on which the Owner's current Section XI program is based. The appropriate reference for the program Edition or Addenda is the intersection of the reference row and the program Edition or Addenda column.

EXAMPLE: **Using Case N-666-1.** Case N-666-1 references are based on the 2004 Edition; however, the program is based on the 1998 Edition.

To use Table 1 in this situation, first find the column containing the Edition or Addenda on which the Case is based. Case N-666-1 is based on the 2004 Edition. Move down that column to the row containing the reference in question. For this example, use IWA-6300. Move across that row to the column containing the program Edition or Addenda. In this example the program uses 1998 Edition. The reference in the intersection of the row with IWA-6300 and the column for the 1998 Edition is "IWA-6300 and IWA-4180." To use this Case with the 1998 Edition of Section XI, the user would refer to both IWA-6300 and IWA-4180 for requirements.

Table 1
Cross-Reference List for Section XI Cases

A11	E10	A09	A08	E07	A06	A05	E04	A03	A02	E01	A00	A99		A97	A96
A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200	A-2200		A-2200	A-2200
A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210	A-2210		A-2210	A-2210
A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300	A-2300		A-2300	A-2300
A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000	A-4000		A-4000	A-4000
A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150	A-4150		A-4150	A-4150
A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160	A-4160		A-4160	A-4160
...	...	...	...	...	...	...	...	...	A-4180	A-4180	A-4180	A-4180		A-4180	A-4180
...	...	...	...	...	...	...	...	...	A-4180(d)	A-4180(d)	A-4180(d)	A-4180(d)		A-4180(d)	A-4180(d)
A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220	A-4220		A-4220	A-4220
A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410	A-4410		A-4410	A-4410
A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4411	A-4410(a)	A-4410(a)		A-4410(a)	A-4410(a)
A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420	A-4420		A-4420	N/A
A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440	A-4440		A-4440	A-4440
A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540	A-4540		A-4540	A-4540
A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611	A-4611		A-4611	A-4611
...	...	...	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)	A-6210(c), (d), (e)		A-6210(c), (d), (e)	A-6210(c), (d), (e)
...	...	...	A-6210(f)	A-6210(f)	A-6210(f)	A-6210(f)	A-6210(f)	A-6210(f)	...	...	...	...	...	...	...
...	...	...	A-6220	A-6220	A-6220	A-6220	A-6220	A-6220	A-6220	A-6220	A-6220	A-6220		A-6220	A-6220
...	...	...	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b), (c), (d)	A-6230(b),	A-6230(b), (c), (d)	A-6230(b), (c), (d)
...	...	...	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)	A-6240(b)		A-6240(b)	A-6240(b)
A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300	A-6300		A-6300	A-6300
...	...	...	A-6350	A-6350	A-6350	A-6350	A-6350	A-6350	...	...	...	...	...	...	...
B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514	B-3514		B-3514	B-3514
B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600	B-3600		B-3600	B-3600
B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630	B-3630		B-3630	B-3630
B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640	B-3640		B-3640	B-3640
...	...	...	...	...	...	...	...	...	B-3650	B-3650	B-3650	B-3650		B-3650	B-3650
C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600	C-3600		C-3600	C-3600
C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640	C-3640		C-3640	C-3640
...	...	...	...	...	...	...	...	...	C-3650	C-3650	C-3650	C-3650		C-3650	C-3650

Table 1
Cross-Reference List for Section XI Cases (Cont'd)

A11	E10	A09	A08	E07	A06	A05	E04	A03	A02	E01	A00	A99		A97	A96
D-3600	D-3600	D-3600	D-3600	D-3600	D-3600	D-3600	D-3600	D-3600	...	...	...	...	...	...	...
D-3640	D-3640	D-3640	D-3640	D-3640	D-3640	D-3640	D-3640	D-3640	...	...	...	...	...	...	...

Legend:
A = IWA
B = IWB
C = IWC
D = IWD

GENERAL NOTES:
(a) This table is for use with Cases N-532-4, N-576-2, N-638–7, N-666-1, N-754-1, N-786-1, N-829, and N-839.
(b) When using Case N-532-4 with Code Editions and Addenda and later than the 2005 Addenda, the paragraph references listed in Table 1 shall apply.

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Approval Date: February 12, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-4-13
Special Type 403 Modified Forgings or Bars, Class 1 and CS
Section III, Division 1

Inquiry: May Special Type 403 Modified forgings or bars be used in the construction of Section III, Class 1 and CS components in accordance with Section III, Division 1, and what special requirements apply to this material?

Reply: It is the opinion of the Committee that Special Type 403 Modified forgings or bars may be used for Section III Class 1 and CS components, and the following specified special requirements apply in addition to the applicable requirements specified in Section III.

Steel forgings or bars (AISI Type 403 Modified) conforming to the following chemical analysis, having specified minimum mechanical properties shown below, and complying with the specified additional requirements may be used in the construction.

(a) Chemistry

(AISI Type 403 Modified)

	Percent
Carbon	0.06 to 0.13
Manganese	0.25 to 0.80
Phosphorus, max.	0.03
Sulfur, max.	0.03
Chromium	11.50 to 13.00
Nickel, max.	0.50
Silicon, max.	0.50

(b) Mechanical properties in the annealed condition as received shall conform to the following requirements:

	ksi (MPa)
Tensile strength, min.	70 (480)
Yield strength, min.	40 (275)
Elongation in 2 in., min.	22%
Reduction of area, min.	50%

(c) Condition 1 material shall be given an austenitizing heat treatment, followed by air cooling or quenching in liquid media, salt bath, or oil and air cooled to room temperature, and then tempered 1125°F (605°C) minimum for 4 hr. Mechanical properties for Condition 1 material shall conform to the following requirements.

	Condition 1, ksi (MPa)
Tensile strength, min.	110 (760)
Yield strength, min.	90 (620)
Elongation in 2 in., min.	16%
Reduction in area, min.	50%
Brinell Hardness	226 to 277 or equivalent

Condition 2 material shall be given an austenitizing heat treatment, followed by air cooling or quenching in liquid media, salt bath, or oil and air cooled to room temperature, and then tempered at 1250°F (675°C) minimum. Mechanical properties for Condition 2 material shall conform to the following requirements.

	Condition 2, ksi (MPa)
Tensile strength, min.	100 (690)
Yield strength, min.	80 (550)
Elongation in 2 in., min.	15%
Reduction in area, min.	45%

Toughness requirements shall be per NB-2300 for Class 1, and NG-2300 for Class CS, except that the drop-weight tests are not required. The acceptance standards of NB-2332 or NG-2331 and NG-2332 shall apply.

(d) The material shall conform to all other requirements of SA-182 Grade F6a for forgings, and SA-276 Type 403 for bars.

(e) The maximum operating temperature shall not exceed 700°F (370°C).

(f) Design stress intensity, yield, and tensile strength values as shown in Tables 1 and 2 for the heat-treated condition may be used when the material has enhanced properties due to the special heat treatment described in *(c)* above.

(g) Where the method of fabrication requires welding after heat treatment, it shall be done by applying austenitic stainless steel or nickel alloy weld deposits prior to heat treatment and only on regions designed to the design stress intensity values in Table 1 for annealed properties.

The minimum thickness of this weld shall be $^3/_{16}$ in. (5 mm) and the maximum $^1/_2$ in. (13 mm). Such weld deposits shall be liquid penetrant examined. Attachments to these weld deposits may be made austenitic stainless or nickel alloy welds subsequent to heat treatment, and the thickness shall not exceed that of the previously deposited weld. No welding on the ferritic base metal is permitted after heat treatment, and no welding is permitted at any time in the regions designed to allowable stresses higher than those given in Tables 1 and 2 for annealed properties. All welding shall meet the requirements of Section IX except that the tests shall be made after final heat treatment of the specimen, and longitudinal bend test specimen of QW-160, Section IX, may be used.

Table 1
Design Stress Intensity Values for Type 403 Modified Material Class 1 and CS Components

		Heat Treated	
Temperature (°F)	Annealed Design Stress Intensity S_m, ksi	Condition 1 Design Stress Intensity S_m, ksi	Condition 2 Design Stress Intensity S_m, ksi
−20 to 100	23.3	36.7	33.3
200	23.3	36.7	33.3
300	22.9	35.9	32.7
400	22.5	35.3	32.1
500	22.1	34.8	31.6
600	21.6	33.9	30.8
650	21.2	33.3	30.2
700	20.6	32.4	29.5

Table 1M
Design Stress Intensity Values for Type 403 Modified Material Class 1 and CS Components

		Heat Treated	
Temperature (°C)	Annealed Design Stress Intensity S_m, MPa	Condition 1 Design Stress Intensity S_m, MPa	Condition 2 Design Stress Intensity S_m, MPa
−30 to 40	161	253	230
65	161	253	230
100	161	253	230
125	160	251	228
150	158	248	225
200	155	244	222
250	153	240	219

Table 1M
Design Stress Intensity Values for Type 403 Modified Material Class 1 and CS Components (Cont'd)

		Heat Treated	
Temperature (°C)	Annealed Design Stress Intensity S_m, MPa	Condition 1 Design Stress Intensity S_m, MPa	Condition 2 Design Stress Intensity S_m, MPa
300	150	236	214
325	148	232	211
350	145	228	207
375[Note (1)]	142	223	202

NOTE:
(1) The maximum operating temperature is 370°C, the value listed at 375°C is provided for interpolation purposes only.

(h) For Class 1 construction, machined transitions between adjoining heavy and thin-walled sections shall consist of a taper of at least 3 to 1, with a radius at each end of at least twice the thickness of the thin wall. It is not the intent of this paragraph to eliminate integral flanges or other similar configurations, but to provide a control on machined transitions similar to that provided by NB-3361 for welded configurations.

(i) All heat-treated parts shall be examined for quench cracks by a liquid penetrant method. All cracks shall be removed, and a crack which cannot be removed within the minimum required thickness of the shell is cause for rejection.

(j) For material heat treated Condition 1, hardness checks shall be made after heat treatment at not more than 5 ft intervals, with a minimum of three different locations representing approximately the center and each end. The average of individual hardness readings at each location shall not be less than 226 Brinell or more than 277 Brinell or equivalent.

(k) Fatigue evaluation with these materials shall be in accordance with NB-3222.4 for Section III, Class 1 design and NG-3222.4 for Section III, Class CS using the design fatigue strength curves of Tables I-9.0.

(l) This Case number shall be identified in the marking of the material, on the certification for the material and on the Data Report Form for the component.

Table 2
Yield and Tensile Strength Values for Type 403 Modified Material Class 1 and CS Components

	Material Condition					
	Annealled		Condition 1		Condition 2	
Temperature (°F)	Yield Strength, (ksi)	Tensile Strength, (ksi)	Yield Strength, (ksi)	Tensile Strength, (ksi)	Yield Strength, (ksi)	Tensile Strength, (ksi)
−20 to 100	40.0	70.0	90.0	110.0	80.0	100.0
200	36.8	70.0	82.8	110.0	73.6	100.0
300	35.5	68.6	79.9	107.8	71.0	98.0
400	34.9	67.4	78.5	105.9	69.8	96.3
500	34.4	66.4	77.4	104.3	68.8	94.8
600	33.7	64.7	75.8	101.7	67.4	92.5
650	33.1	63.5	74.5	99.8	66.2	90.7
700	32.4	61.9	72.8	97.3	64.7	88.4
750	31.4	59.9	70.7	94.2	62.8	85.6
800	30.2	57.5	68.0	90.4	60.4	82.1
850	28.8	54.6	64.8	85.9	57.6	78.0
900	27.1	51.3	61.0	80.7	54.2	73.3
950	25.2	47.6	56.6	74.8	50.3	68.0
1000	23.0	43.5	51.7	68.3	45.9	62.1

Table 2M
Yield and Tensile Strength Values for Type 403 Modified Material Class 1 and CS Components

	Material Condition					
	Annealled		Condition 1		Condition 2	
Temperature (°C)	Yield Strength, (MPa)	Tensile Strength, (MPa)	Yield Strength, (MPa)	Tensile Strength, (MPa)	Yield Strength, (MPa)	Tensile Strength, (MPa)
−30 to 40	276	483	621	758	552	689
65	261	483	587	758	522	689
100	252	483	567	758	504	689
125	248	479	558	752	496	684
150	245	473	551	743	490	675
175	242	469	546	736	485	669
200	241	465	542	731	482	665
225	239	462	538	726	479	660
250	238	459	535	721	476	656
275	236	455	531	715	472	650
300	234	450	526	707	468	643
325	231	444	520	697	462	634
350	227	435	511	684	454	622
375	222	425	500	668	445	607
400	216	412	487	648	433	589
425	209	398	470	625	418	568
450	200	380	450	597	400	543
475	190	360	428	566	380	514
500	178	338	402	531	357	482
525	165	313	372	492	331	447
550	151	286	340	450	302	409

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Approval Date: December 6, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-60-6
Material for Core Support Structures
Section III, Division 1

Inquiry: What materials, in addition to those listed in Tables 2 and 2, Section II, Part D, Subpart 1, may be used for core support structures constructed to the requirements of Subsection NG of Section III, Division 1?

Reply: It is the opinion of the Committee that the materials and stress intensity values listed in Table 1 may be used in the construction of core support structures in addition to those listed in Tables 2A and 2B, Section II, Part D, Subpart 1. The following additional requirements shall be met.

(a) All other requirements of Subsection NG of Section III, Division 1, shall be met.

(b) Strain hardened SA-479 shall be identified with this Case number.

(c) Where welds are applied to strain hardened material, the stress intensity in the sections of the material where the temperatures during welding exceed 800°F (425°C) shall not exceed values for annealed materials.

(d) Yield strength values are listed in Table 2.

(e) Tensile strength values are listed in Table 3.

(f) Chemical composition for Ni-Cr-Fe, SB-637 Types 1 and 2 is listed in Table 4.

(g) Heat treatments for Ni-Cr-Fe, SB-637 Types 1 and 2 and Grade 718 Type 2 are listed in Table 5.

(h) Room temperature mechanical properties for Ni-Cr-Fe, SB-637 Types 1 and 2 and Grade 718 Type 2 are listed in Table 6.

Table 1
Materials Properties, Subsection NG Tensile Stress Intensity Values, S_m, ksi

Nominal Composition	S No.	Prod. Form	Spec. No.	Type/ Grade	Alloy Desig/ UNS No.	Notes	Min. Yield Str.	Min. Ult. Tens. Str.	Design Stress Intensity, S_m, ksi, Not to Metal Temperature, °F, 100	200	300	400	500	700	750	800
18Cr-8Ni	8	TSF	SA-193	B8	S30400	(2),(7),(10)	30.0	75.0	20.0	20.0	20.0	18.6	17.5	15.8	15.5	15.2
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(2),(7),(10)	30.0	75.0	20.0	20.0	20.0	19.3	18.0	16.3	16.1	15.9
18Cr-10Ni-Ti	8	TSF	SA-193	B8T	S32100	(2),(7),(10)	30.0	75.0	20.0	20.0	20.0	20.0	19.3	17.5	17.2	16.9
18Cr-10Ni-Cb	8	TSF	SA-193	B8C	S34700	(2),(7),(10)	30.0	75.0	20.0	20.0	20.0	20.0	20.0	18.7	18.5	18.3
25Ni-15Cr-2Ti	...	TSF	SA-453	660	S66286	(2),(5),(7)	85.0	130.0	43.3	43.3	43.3	43.3	42.5	40.9	...	...
18Cr-8Ni	8	Smls. tube	A511-08	MT 304	S30400	(2),(6),(7), (11)	20.0	20.0	20.0	18.6	17.5	16.6	16.2	15.2	20.0	20.0
18Cr-8Ni	8	Smls. tube	A511-08	MT 304L	S30403	(2),(6),(7), (11)	25.0	70.0	16.7	16.7	16.7	15.8	14.7	13.5	13.3	13.0
16Cr-12Ni-2Mo	8	Smls. tube	A511-08	MT 316	S31600	(2),(6),(7), (11)	30.0	75.0	20.0	20.0	20.0	19.3	18.0	16.3	16.1	15.9
16Cr-12Ni- 2Mo	8	Smls. tube	A511- 08	MT 316L	S31603	(2),(6),(7), (11)	25.0	70.0	16. 7	16. 7	16. 7	15. 7	14. 8	7 13. 5	13. 2	12. 9
18Cr-8Ni	8	Wld. tube	A554-08a	MT 304	S30400	(2),(6),(7), (11)	30.0	75.0	20.0	20.0	20.0	18.6	17.5	15.8	15.5	15.2
18Cr-8Ni	8	Wld. tube	A554-08a	MT 304L	S30403	(2),(6),(7), (11)	25.0	70.0	16.7	16.7	16.7	15.8	14.7	13.5	13.3	13.0
16Cr-12Ni-2Mo	8	Wld. tube	A554-08a	MT 316	S31600	(2),(6),(7), (11)	30.0	75.0	20.0	20.0	20.0	19.3	18.0	16.3	16.1	15.9
16Cr-12Ni-2Mo	8	Wld. tube	A554-08a	MT 316L	S31603	(2),(6),(7), (11)	25.0	70.0	16.7	16.7	16.7	15.7	14.8	13.5	13.2	12.9
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 1	N07750	(2),(5)	90.0	140.0	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.6
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 2	N07750	(2),(5)	115	170.0	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.6
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 3	N07750	(2),(5)	100	160.0	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.1
72Ni-16Cr-8Fe	...	Bar, forging	SB-637	Type 1	N07752	(2),(5)	100	160	53.3	52.1	50.9	50.1	49.3	47.4	46.8	...
72Ni-16Cr-8Fe	...	Bar, forging	SB-637	Type 2	N07752	(2),(5)	85.0	140	50.0	50.0	50.0	50.0	50.0	50.0	50.0	...
16Cr-12Ni-2Mo	8	Bar, shapes	SA-479	316	S31600	(1),(2),(7),(8)	60.0	85.0	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.4
16Cr-12Ni-2Mo	8	Bars, shapes	SA-479	316	S31600	(1),(2),(7),(9)	65.0	85.0	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.5
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(7)	50.0	90.0	30.0	30.0	28.9	27.9	27.5	26.2	25.9	25.5
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(7)	65.0	95.0	31.7	31.7	30.5	29.4	29.4	29.4	29.3	29.1
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(3),(5) (7)	80.0	100	33.3	33.3	32.9	32.1	31.9	31.9	31.8	31.4
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(4),(5) (7)	95.0	110	36.7	36.7	36.1	35.3	35.1	35.1	34.9	34.6
13Cr-0.5Mo	6	Forged fittings	SA-182	F6b	S41026	(2)	90	110	36.7	36.7	35.9	35.3	34.8	32.4	...	...
Ni-Cr-Fe	...	Bar, forging	SB-637	718 Type 2	N07718	...	100	160	53.3	53.3	53.3	53.5	52.4	50.0	49.4	...

GENERAL NOTE: TSF — Threaded Structural Fasteners.

Table 1
Materials Properties, Subsection NG Tensile Stress Intensity Values, S_m, ksi (Cont'd)

NOTES:

(1) Strain hardened. (The tensile properties for these items shall meet the minimum specified. These materials shall conform to all other requ ents of the referenced specification. Surface hardness as shown in SA-479 is not required.)

(2) Yield strength values are listed in Table 2 or Table Y-1.

(3) Maximum tensile strength–140,000 psi (965 MPa).

(4) Maximum tensile strength–150,000 psi (1035 MPa).

(5) The designer shall consider the effects of temperature and environment on the material properties of precipitation hardening alloys and cold austenitic stainless steels.

(6) Supplementary requirement S-2 for tensile testing of the specification is mandatory.

(7) At temperatures above 100°F (40°C), the design stress intensity values may exceed $66^2/_3$% and may also reach 90% of the yield strength (0.2% at temperature. This may result in a permanent strain of as much as 0.1%. When this amount of deformation is not acceptable, the designer should reduce the design intensity to obtain an acceptable deformation. Section II, Part D, Subpart 1, Table Y-2 lists multiplying factors which, when applied to the yield strength values Table Y-1 in Section II, Part D, Subpart 1, will give a design stress intensity that will result in lower levels of permanent strain.

(8) Over 2 in. (50 mm).

(9) Up to and including 2 in. (50 mm).

(10) Class 1.

(11) Supplementary requirement for tensile testing of the specification is mandatory.

Table 1M
Materials Properties, Subsection NG Tensile Stress Intensity Values, S_m, MPa

Nominal Composition	S-No.	Prod. Form	Spec.No.	Type/ Grade	Alloy Desig/ UNS No.	Notes	Min. Yield Str.	Min. Ult. Tens. Str	Design Stress Intensity, S_m, MPa Temperature, °C, Not to Exceed								
									40	100	150	200	250	350	375	400	425
18Cr-8Ni	8	TSF	SA-193	B8	S30400	(2),(7),(10)	205	515	138	138	138	129	122	111	109	107	105
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(2),(7),(10)	205	515	138	138	138	133	126	114	112	111	110
18Cr-10Ni-Ti	8	TSF	SA-193	B8T	S32100	(2),(7),(10)	205	515	138	138	138	138	134	123	120	119	117
18Cr-10Ni-Cb	8	TSF	SA-193	B8C	S34700	(2),(7),(10)	205	515	138	138	138	138	138	131	129	127	126
25Ni-15Cr-2Ti	...	TSF	SA-453	660	S66286	(2),(5),(7)	585	895	299	299	299	299	294	284	282	...	...
18Cr-8Ni	8	Smls. tube	A511-08	MT 304	S30400	(2),(6),(7), (11)	205	515	138	138	138	129	122	111	109	107	105
18Cr-8Ni	8	Smls. tube	A511-08	MT 304L	S30403	(2),(6),(7), (11)	170	485	115	115	115	109	103	94	93	92	90
16Cr-12Ni-2Mo	8	Smls. tube	A511-08	MT 316	S31600	(2),(6),(7), (11)	205	515	138	138	138	133	126	114	112	111	110
16Cr-12Ni-2Mo	8	Smls. tube	A511-08	MT 316L	S31603	(2),(6),(7), (11)	170	485	115	115	115	109	103	94	93	91	89
18Cr-8Ni	8	Wld. tube	A554-08a	MT 304	S30400	(2),(6),(7), (11)	205	515	138	138	138	129	122	111	109	107	105
18Cr-8Ni	8	Wld. tube	A554-08a	MT 304L	S30403	(2),(6),(7), (11)	170	485	115	115	115	109	103	94	93	92	90
16Cr-12Ni-2Mo	8	Wld. tube	A554-08a	MT 316	S31600	(2),(6),(7), (11)	205	515	138	138	138	133	126	114	112	111	110
16Cr-12Ni-2Mo	8	Wld. tube	A554-08a	MT 316L	S31603	(2),(6),(7), (11)	170	485	115	115	115	109	103	94	93	91	89
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 1	N07750	(2),(5)	620	965	322	322	322	322	322	322	322	322	321
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 2	N07750	(2),(5)	795	1170	391	391	391	391	391	391	391	391	390
70Ni-15.5Cr-7Fe	...	Bar, forging	SB-637	Type 3	N07750	(2),(5)	690	1105	367	367	367	367	367	367	367	367	366
72Ni-16Cr-8Fe	...	Bar, forging	SB-637	Type 1	N07752	(2),(5)	690	1005	367	358	351	346	341	330	326	323	...
72Ni-16Cr-8Fe	...	Bar, forging	SB-637	Type 2	N07752	(2),(5)	585	965	345	345	345	345	345	345	345	345	...
16Cr-12Ni-2Mo	8	Bars, shapes	SA-479	316	S31600	(1),(2),(7),(8)	415	585	195	194	185	179	177	177	177	177	175
16Cr-12Ni-2Mo	8	Bars, shapes	SA-479	316	S31600	(1),(2),(7),(9)	450	585	195	194	185	179	177	177	177	177	176
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(7)	345	620	207	206	199	193	190	183	180	178	176
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(7)	450	655	218	217	210	204	203	203	203	202	201
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(3),(5), (7)	550	690	230	229	227	222	220	220	220	219	217
16Cr-12Ni-2Mo	8	TSF	SA-193	B8M	S31600	(1),(2),(4),(5), (7)	655	760	253	252	249	244	242	242	242	241	239
13Cr-0.5Mo	6	Forged fittings	SA-182	F6b	S41026	(2)	620	760	253	252	247	244	241	228	223	...	...
Ni-Cr-Fe	...	Bar, forging	SB-637	718 Type 2	N07718	...	689	1103	367	367	367	367	362	348	344	340	...

GENERAL NOTE: TSF — Threaded Structural Fasteners.

Table 1M
Materials Properties, Subsection NG Tensile Stress Intensity Values, S_m, MPa (Cont'd)

NOTES:

(1) Strain hardened. (The tensile properties for these items shall meet the minimum specified. These materials shall conform to all other requiremen referenced specification. Surface hardness as shown in SA-479 is not required.)

(2) Yield strength values are listed in Table 2 or Table Y-1.

(3) Maximum tensile strength–140,000 psi (965 MPa).

(4) Maximum tensile strength–150,000 psi (1035 MPa).

(5) The designer shall consider the effects of temperature and environment on the material properties of precipitation hardening alloys and cold austenitic stainless steels.

(6) Supplementary requirement S-2 for tensile testing of the specification is mandatory.

(7) At temperatures above 100°F (40°C), the design stress intensity values may exceed $66\frac{2}{3}$% and may also reach 90% of the yield strength (0.2% temperature. This may result in a permanent strain of as much as 0.1%. When this amount of deformation is not acceptable, the designer should reduce the design stress to obtain an acceptable deformation. Section II, Part D, Subpart 1, Table Y-2 lists multiplying factors which, when applied to the yield strength values shown on Table Y-1 II, Part D, Subpart 1, will give a design stress intensity that will result in lower levels of permanent strain.

(8) Over 2 in. (50 mm).

(9) Up to and including 2 in. (50 mm).

(10) Class 1.

(11) Supplementary requirement for tensile testing of the specification is mandatory.

Table 2
Materials Properties, Subsection NG Tensile Yield Strength, S_y, ksi

Nominal Composition	Prod. Form	Spec. No.	Type/Grade	Alloy Desig/UNS No.	Notes	Min. Yield Str.	Yield Strength, S_y, ksi, For Metal Temperature, Not to Exceed 100	200	300	400	500	600	700	750	800
18Cr-8Ni	Smls. tube	A511-08	MT 304	S30400	...	30.0	30.0	25.0	22.4	20.7	19.4	18.4	17.6	17.2	16.9
18Cr-8Ni	Smls. tube	A511-08	MT 304L	S30403	...	25.0	25.0	21.4	19.2	17.5	16.4	15.5	15.0	14.7	14.5
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316	S31600	...	30.0	30.0	25.9	23.4	21.4	20.0	18.9	18.2	17.9	17.7
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316L	S31603	...	25.0	25.0	21.3	19.0	17.5	16.4	15.6	15.0	14.7	14.4
18Cr-8Ni	Wld. tube	A554-08a	MT 304	S30400	...	30.0	30.0	25.0	22.4	20.7	19.4	18.4	17.6	17.2	16.9
18Cr-8Ni	Wld. tube	A554-08a	MT 304L	S30403	...	25.0	25.0	21.4	19.2	17.5	16.4	15.5	15.0	14.7	14.5
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316	S31600	...	30.0	30.0	25.9	23.4	21.4	20.0	18.9	18.2	17.9	17.7
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316L	S31603	...	25.0	25.0	21.3	19.0	17.5	16.4	15.6	15.0	14.7	14.4
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 1	N07750	...	90.0	90.0	87.7	86.4	85.3	84.5	84.1	83.8	83.7	83.6
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 2	N07750	...	115	115	112	110	109	108	108	107	107	107
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 3	N07750	...	100	100	99.0	95.2	94.0	93.1	92.5	92.0	91.9	91.8
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 1	N07752	...	100	100	97.1	95.2	93.4	92.0	90.0	90.1	89.9	...
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 2	N07752	...	85.0	85.0	82.4	81.2	80.4	79.9	79.8	79.8	79.8	...
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	(1)	60.0	60.0	55.1	52.1	49.8	48.3	47.5	46.3	45.4	44.5
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	(1)	65.0	65.0	61.1	57.7	54.9	53.5	52.5	51.0	50.4	49.7
13Cr-0.5Mo	Forged fittings	SA-182	F6b	S41026	...	90	90.0	82.8	79.9	78.5	77.4	75.8	72.8	70.7	68.0
Ni-Cr-Fe	Bar, forging	SB-637	718 Type 2	N07718	...	100	100	95.5	93.0	91.8	91.1	90.3	88.9	88.2	...

NOTES:
(1) Over 2 in. (50 mm).
(2) Up to and including 2 in. (50 mm).

Table 2M
Materials Properties, Subsection NG Tensile Yield Strength, S_y, MPa

Nominal Composition	Prod. Form	Spec. No.	Type/Grade	Alloy Desig/UNS No.	Notes	Min. Yield Str.	Yield Strength, S_y, MPa, For Metal Temperature, Not to Exceed									
							40	100	150	200	250	300	325	375	400	425
18Cr-8Ni	Smls. tube	A511-08	MT 304	S30400	...	205	205	170	154	144	135	129	126	121	119	117
18Cr-8Ni	Smls. tube	A511-08	MT 304L	S30403	...	170	171	146	132	122	114	109	106	103	101	100
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316	S31600	...	205	206	177	161	149	140	132	129	125	123	122
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316L	S31603	...	170	171	145	131	121	114	109	107	103	101	99
18Cr-8Ni	Wld. tube	A554-08a	MT 304	S30400	...	205	205	170	154	144	135	129	126	121	119	117
18Cr-8Ni	Wld. tube	A554-08a	MT 304L	S30403	...	170	171	146	132	122	114	109	106	103	101	100
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316	S31600	...	205	206	177	161	149	140	132	129	125	123	122
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316L	S31603	...	170	171	145	131	121	114	109	107	103	101	99
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 1	N07750	...	620	620	604	596	589	584	581	579	578	577	576
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 2	N07750	...	795	792	771	760	752	746	742	740	738	737	736
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 3	N07750	...	690	689	679	656	649	643	639	637	634	634	633
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 1	N07752	...	690	367	358	351	346	341	335	333	326	323	...
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 2	N07752	...	585	345	345	345	345	345	345	345	345	345	...
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	(1)	415	412	377	359	345	335	329	326	318	313	307
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	(2)	450	447	418	397	380	371	364	360	351	347	343
13Cr-0.5Mo	Forged fittings	SA-182	F6b	S41026	...	620	619	568	561	542	535	526	520	500	487	470
Ni-Cr-Fe	Bar, forging	SB-637	718 Type 2	N07718	...	689	688	658	641	634	629	624	621	612	607	...

NOTES:
(1) Over 2 in. (50 mm).
(2) Up to and including 2 in. (50 mm).

Table 3
Materials Properties, Subsection NG Tensile Strengths, S_u, ksi

Nominal Composition	Prod. Form	Spec. No.	Type/Grade	Alloy Desig/UNS No.	Spec. Min. T.S.	Tensile Strength Values, S_u, ksi For Metal Temperature, °F, Not to Exceed								
						100	200	300	400	500	600	650	750	800
18Cr-8Ni	Smls. tube	A511-08	MT 304	S30400	75	75.0	71.0	66.2	64.0	63.4	63.4	63.4	63.3	62.8
18Cr-8Ni	Smls. tube	A511-08	MT 304L	S30403	70	70.0	66.1	61.2	58.7	57.5	56.9	56.7	56.0	55.4
16Cr-12Ni-2Mo	Smls. tube	A 511-08	MT 316	S31600	75	75.0	75.0	72.9	71.9	71.8	71.8	71.8	71.5	70.8
16Cr-12Ni-2Mo	Smls. tube	A 511-08	MT 316L	S31603	70	70.0	68.1	64.0	62.2	61.8	61.7	61.6	61.1	60.5
18Cr-8Ni	Wld. tube	A554-08a	MT 304	S30400	75	75.0	71.0	66.2	64.0	63.4	63.4	63.4	63.3	62.8
18Cr-8Ni	Wld. tube	A554-08a	MT 304L	S30403	70	70.0	66.1	61.2	58.7	57.5	56.9	56.7	56	55.4
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316	S31600	75	75.0	75.0	72.9	71.9	71.8	71.8	71.8	71.5	70.8
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316L	S31603	70	70.0	68.1	64.0	62.2	61.8	61.7	61.6	61.1	60.5
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 1	N07750	140	140	140	140	140	140	140	140	140	140
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 2	N07750	170	170	170	170	170	170	170	170	170	170
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 3	N07750	160	160	160	160	160	160	160	160	160	159
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 1	N07752	160	160	156	153	150	148	145	144	140	...
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 2	N07752	150	150	147	146	144	143	141	140	139	...
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	85.0	85.0	85.0	80.3	77.6	77.1	77.1	77.1	77.1	76.6
18Cr-8Ni	Nuts	SA-194	8	S30400	75	75.0	71.0	66.0	64.3	63.5	63.5	63.5	63.1	62.6
18Cr-10Ni-Cb	Nuts	SA-194	8C	S34700	75	75.0	71.8	65.9	62.1	60.0	59.0	58.9	58.8	58.8
6Cr-12Ni-2Mo	Nuts	SA-194	8M	S31600	75	75.0	75.0	72.9	71.9	71.8	71.8	71.8	71.5	70.8
13Cr-0.5Mo	Forged fittings	SA-182	F6b	S41026	110	110	110	107.8	105.9	104.3	101.7	99.8	94.2	90.4
Ni-Cr-Fe	Bar, forging	SB-637	718 Type 2	N07718	160.0	160.0	160.0	160.0	160.0	157.2	153.7	151.8	148.1	...

GENERAL NOTE: The tabulated values of tensile strength and yield strength are those which the Committee believes are suitable for use calculations required by this Case. At temperatures above room temperature the values of tensile strength tend toward an average or expected value be as much as 10% above the tensile strength trend curve adjusted to the minimum specified room temperature tensile strength. At temperatures above temperature the yield strength values correspond to the yield strength trend curve adjusted to the minimum specified room temperature yield strength. the tensile strength nor the yield strength values correspond exactly to either average or minimum as these terms are applied to a statistical treatment homogeneous set of data. Neither the ASME Material Specifications nor the rules of this Case require elevated temperature testing for tensile or yield strengths production material for use in Code components. It is not intended that results of such tests, if performed, be compared with these tabulated tensile yield strength values for ASME Code acceptance/rejection purposes for materials. If some elevated temperature tests results on production material than these tabulated values by a large amount (more than the typical variability of material and suggesting the possibility of some error) further investigation by retest or other means should be considered.

Table 3M
Materials Properties, Subsection NG Tensile Strengths, S_u, MPa

Nominal Composition	Prod. Form	Spec. No.	Type/Grade	Alloy Desig/UNS No.	Spec. Min. T.S.	Tensile Strength Values, S_u, MPa For Metal Temperature, °C, Not to Exceed									
						40	100	150	200	250	300	325	375	400	425
18Cr-8Ni	Smls. tube	A511-08	MT 304	S30400	515	516	486	456	442	438	437	437	437	436	433
18Cr-8Ni	Smls. tube	A511-08	MT 304L	S30403	485	482	452	422	406	398	393	392	388	386	382
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316	S31600	515	516	486	456	442	438	437	437	437	436	433
16Cr-12Ni-2Mo	Smls. tube	A511-08	MT 316L	S31603	485	482	452	422	406	398	393	392	388	386	382
18Cr-8Ni	Wld. tube	A554-08a	MT 304	S30400	515	516	486	456	442	438	437	437	437	436	433
18Cr-8Ni	Wld. tube	A554-08a	MT 304L	S30403	485	482	452	422	406	398	393	392	388	386	382
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316	S31600	515	516	486	456	442	438	437	437	437	436	433
16Cr-12Ni-2Mo	Wld. tube	A554-08a	MT 316L	S31603	485	482	452	422	406	398	393	392	388	386	382
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 1	N07750	965	965	965	965	965	965	965	965	965	965	964
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 2	N07750	1170	1170	1170	1170	1170	1170	1170	1170	1170	1170	1170
70Ni-15.5Cr-7Fe	Bar, forging	SB-637	Type 3	N07750	1105	1105	1105	1105	1105	1105	1105	1105	1105	1105	1100
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 1	N07752	1105	1100	1075	1050	1040	1020	1005	998	979	968	...
72Ni-16Cr-8Fe	Bar, forging	SB-637	Type 2	N07752	1035	1035	1015	1005	994	984	975	969	959	956	...
16Cr-12Ni-2Mo	Bar, shapes	SA-479	316	S31600	585.0	586	582	553	537	532	532	532	532	531	528
18Cr-8Ni	Nuts	SA-194	8	S30400	515	516	485	455	444	439	438	438	437	435	432
18Cr-10Ni-Cb	Nuts	SA-194	8C	S34700	515	516	490	454	430	416	409	407	405	405	405
16Cr-12Ni-2Mo	Nuts	SA-194	8M	S31600	515	517	515	502	496	495	495	495	495	493	488
13Cr-0.5Mo	Forged fittings	SA-182	F6b	S41026	760	758	757	743	731	721	706	697	668	648	625
Ni-Cr-Fe	Bar, forging	SB-637	718 Type 2	N07718	1103	1103	1103	1103	1103	1103	1089	1075	1045	1034	...

GENERAL NOTE: The tabulated values of tensile strength and yield strength are those which the Committee believes are suitable for use in design calculations required by this Case. At temperatures above room temperature the values of tensile strength tend toward an average or expected value which may be as 10% above the tensile strength trend curve adjusted to the minimum specified room temperature tensile strength. At temperatures above room temperature strength values correspond to the yield strength trend curve adjusted to the minimum specified room temperature yield strength. Neither the tensile stren the yield strength values correspond exactly to either average or minimum as these terms are applied to a statistical treatment of a homogeneous set of data. the ASME Material Specifications nor the rules of this Case require elevated temperature testing for tensile or yield strengths of production material for use in omponents. It is not intended that results of such tests, if performed, be compared with these tabulated tensile and yield strength values for ASME Code acceptance/rejection purposes for materials. If some elevated temperature tests results on production material are lower than these tabulated values by a large amount (more than pical variability of material and suggesting the possibility of some error) further investigation by retest or other means should be considered.

Table 4
SB-637 Types 1 and 2 Chemical Requirements

Element	Percent
Carbon	0.020 – 0.060
Manganese	1.00 max.
Silicon	0.50 max.
Phosphorus	0.008 max.
Sulfur	0.003 max.
Chromium	14.50 – 17.00
Cobalt	0.050 max.
Columbium + Tantalum	0.70 – 1.20
Titanium	2.25 – 2.75
Alumunium	0.40 – 1.00
Boron	0.007 max.
Iron	5.00 – 9.00
Copper	0.50 max.
Zirconium	0.050 max.
Vanadium	0.10 max.
Nickel	70.00 min.

Table 5
SB-637 Heat Treatment

Solution Annealing	Precipitation Hardening
Grade 718 Type 2	
1850°F to 1922°F, hold 1 to 2 h, cool by water or oil quenching	1300°F ± 15°F, hold 6 h +1h -0 min., air cool

Table 6
SB-637 Grade 718 Type 2 Mechanical Properties

Property	U.S. Customary	Metric
Yield Strength (ksi/MPa)	100	689
Tensile Strength (ksi/MPa)	160	1103
Elongation in 2 in. %	20	
Reduction of Area %	20	
Hardness	267 – 363 HBW 27 – HRC	

Approval Date: May 11, 1994

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-62-7
Internal and External Valve Items, Classes 1, 2, and 3
Section III, Division 1

Inquiry: Under what rules shall line valve items other than valve bodies, valve bonnets, valve items welded to valve bodies and bonnets and bolting which joins valve bodies and bonnets be constructed? Also, what alternate rules may be used for Class 1 valve items, such as (a) disks covered by NB-3546.2 and (b) stems covered by NB-3546.3(a) of Section III?

Reply: It is the opinion of the Committee that internal and external valve items for Section III, Class 1, 2, and 3 line valves may be constructed in accordance with the following rules.

1 INTRODUCTION

1.1 These rules apply to materials, design, fabrication, inspection and examination of internal and external valve items for Class 1, 2, and 3 line valves. Internal and external valve items are those items of a valve other than valve bodies, valve bonnets, valve items welded to valve bodies and bonnets (but not including internal permanent attachments), and bolting which joins valve bodies and bonnets. As an alternative to the requirements of Section III, internal permanent attachments, disks, and those valve items covered by NB-3546.3(a) may be constructed in accordance with the requirements of this Case.

1.2 *Category* as used herein is the grouping of various internal and external valve items for the purpose of applying the rules of this Case. Categories for typical valve types are shown in Figures 1 through 10. The figures are not to scale, and are not intended to convey any preference for valve type or design, but are provided as a guide to the Manufacturer to identify the various internal and external items of a valve for categorization. In determining categories for valve items of valve types not specifically illustrated, a valve or valve detail which is most nearly representative shall apply. Categories 1 and 2 are those valve items presently covered by Subsections NB, NC, and ND. Categories 3 through 8 are internal and external valve items which may be constructed in accordance with this Case. See Table 1.2-1.

2 GENERAL REQUIREMENTS

2.1 RESPONSIBILITIES AND DUTIES

It is the responsibility of the Valve Manufacturer to assign each valve item of a valve to the proper category and to indicate the categories in the Design Report and/or on a general assembly drawing.

2.2 Category 3 through 8 items for Class 1, 2 and 3 valves shall be manufactured under the Valve Manufacturers Quality Assurance Program or Quality Control System, as applicable, except that Material Manufacturers or material suppliers for Category 4 through 8 valve items are not required to comply with NCA-3800.

2.3 The Design Report for Class 1 valves (NB-3562) shall include an analysis of the primary stresses for Category 3, 4, 5, and 6 items (see 4).

2.4 Use of this Case number shall be shown on the applicable Data Report Form.

3 MATERIALS

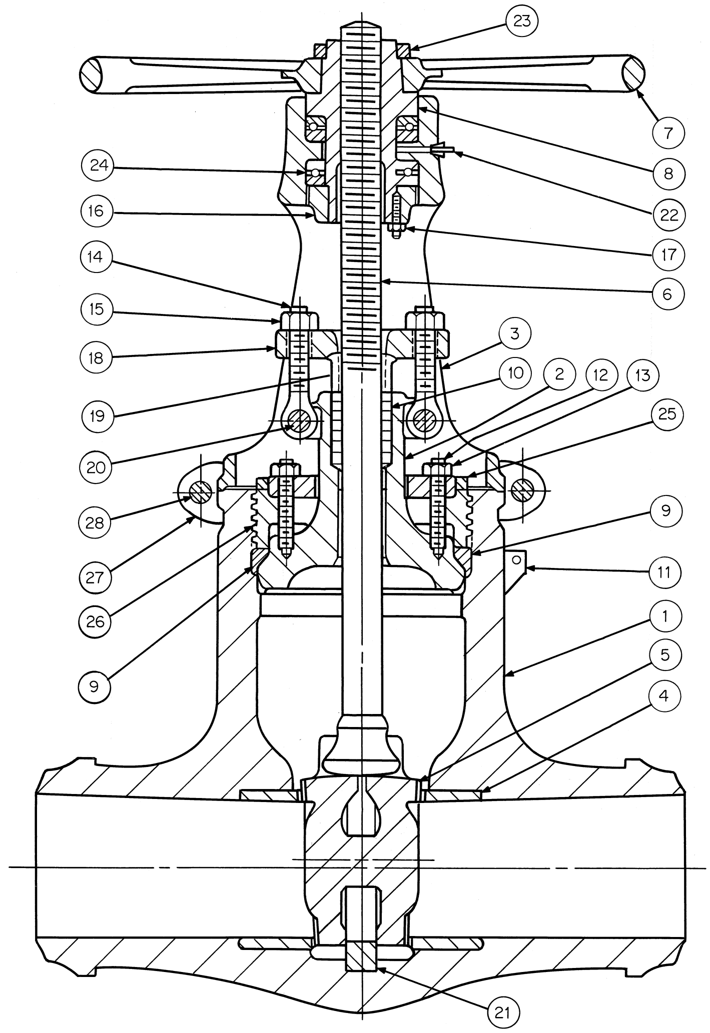
3.1 GENERAL REQUIREMENTS FOR MATERIALS

3.1.1 Scope of Principal Terms Employed. The term *material* as used in this Case applies to those valve items produced to material specifications permitted by Section III, and other material permitted by this Case.

3.1.2 Permitted Material Specifications

(a) Materials used for Category 3 and 4 valve items shall conform to the requirements of one of the specifications for materials given in Table 3.1.2-1 of this Case for Class 1, 2, and 3 valves; materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, for Class 1 and 2 valves; materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, for Class 3 valves; and to the special requirements of this Case which apply to the valve item

Figure 1
Gate Value



Key to Figure 1

Cat.	Valve Item	Name (Typical)
1	1	Body
	2	Bonnet
	11	Lifting Lug
3	5	Gate (Wedge)
	6	Stem
	26	Gasket Retaining Ring
4	4	Seat Ring
	21	Guide (when welded to body)
6	14	Gland Bolt
	15	Gland Nut
	3	Yoke
	18	Gland Flange
	20	Hinge Pin
	27	Clamp Ring
	28	Clamp Ring Bolting

Figure 1
Gate Value (Cont'd)

Key to Figure 1

Cat.	Valve Item	Name (Typical)
7	12	Lifting Stud (Bolt)
	13	Lifting Nut
	16	Yoke Retaining Nut
	8	Yoke Nut
	19	Gland
	22	Grease Fitting
	17	Lock Bolting
	24	Bearings
	21	Guide (when mechanically held)
	25	Lifting Plate
8	9	Gasket
	10	Packing

GENERAL NOTE: Not covered by Code requirement.
7 Handwheel
23 Handwheel Nut

for which the material is used. All of the requirements of the material specification and of this Case shall be satisfied.

(b) Materials used for Category 6 valve items shall conform to the requirements of one of the specifications for materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, for Class 1 and 2 valves, and materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, for Class 3 valves.

(c) Category 5, 7, and 8 valve items may be made from any material suitable for the intended service. Consideration shall be given to stress relaxation when selecting materials for Category 5 items.

(d) The Valve Manufacturer shall provide a list which identifies the material used for each Category 3, 4, 5, 6, 7, or 8 valve item. This list may be a bill of materials or a separate list.

(e) Where the tensile strength, yield strength, hardness, tempering temperature or aging temperature listed in Table 3.1.2-1 differs from the requirements of the material specification, the minimum requirements listed in Table 3.1.2-1 shall apply.

3.1.3 Special Requirements Conflicting with Permitted Material Specifications.

(a) Special requirements stipulated in this Case shall apply in lieu of the requirements of the materials specifications wherever the special requirements conflict with the material specification requirements. Where the special requirements include an examination, test, or treatment which is also required by the materials specification, the examination, test, or treatment need be performed only once. Any required nondestructive examinations shall be performed as specified in 5.3. Any examination, repair, test, or treatment required by the material specification or this Case may be performed by the Material Manufacturer or the Valve Manufacturer. The Material Manufacturer shall obtain approval from the Valve Manufacturer for the weld repair of materials (5.4).

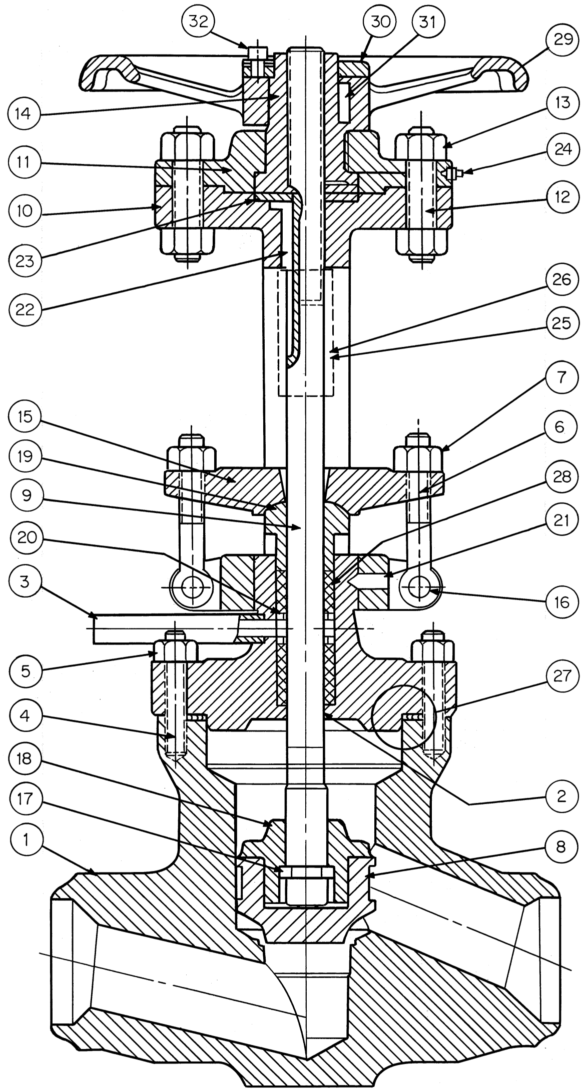
(b) For materials listed in Table 3.1.2-1 for Category 3 and 4 valve items, the tensile test requirements of the material specification may be performed on representative samples of each heat of material used, for each specified heat treatment. The tensile strength, yield strength, and hardness results shall meet or exceed the minimum specified values listed in the table. Where the material will be used to fabricate various valve item sizes in different heat treated thicknesses, the Manufacturer shall assure himself that the heat treatment specified will be effective for the entire size range.

3.1.4 Allowable Stress Values. Allowable Stress Values, *S,* are listed in Table 3.1.2-1 of this Case or Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, [3.1.2(a)]. For Table 3.1.2-1, the allowable stress values are based on trend curves adjusted to the minimum specified room temperature tensile and yield strengths shown in the table. (The listed values are allowable stress values and are not design stress intensity values.)

3.1.5 Certification of Materials

(a) Materials for Category 3 and 4 valve items, including all welding and brazing materials shall be certified in accordance with NA-3767.4 of Section III. Copies of all Certified Material Test Reports shall be made available to the Inspector.

Figure 2
Globe Valve



Key to Figure 2

Cat.	Valve Item	Name (Typical)
1	1	Body
	2	Bonnet
	3	Auxiliary Connection
2	4	Bonnet Stud (Bolt)
	5	Bonnet Nut
3	8	Disc
	9	Stem
4	17	Disc Stem Union
	18	Stem Collar

Figure 2
Globe Valve (Cont'd)

Key to Figure 2

Cat.	Valve Item	Name (Typical)
6	10	Yoke (when nonintegral)
	11	Yoke Cover (Flange)
	12	Yoke Cover Bolt
	13	Yoke Cover Nut
	15	Gland Flange
	6	Gland Bolt
	7	Gland Nut
	16	Hinge Pins
7	19	Gland
	20	Lantern Ring
	21	Set Screw-Locking
	22	Key
	24	Grease Fitting
	25	Name Plate
	26	Rivet
	14	Yoke Nut
	23	Washer
8	27	Gasket
	28	Packing

GENERAL NOTE: Not included in this Case.
25 Name Plate
26 Rivet
29 Handwheel
30 Handwheel Nut
31 Yoke Nut Key
32 Lock Screw

(b) For Category 5 and 6 valve items, a Certificate of Compliance with the Material Specification, Grade, Class and heat treated condition, as applicable, shall be provided.

(c) Certified Material Test Reports or Certificates of Compliance are not required for Category 7 and 8 valve items.

3.1.6 Welding, Brazing and Hardsurfacing Materials. All welding and brazing materials used on Category 3 and 4 valve items shall meet the requirements of NB-2400. Hardsurfacing materials shall meet the requirements of AWS-A5.13 or as otherwise specified by the Valve Manufacturer (5.6.2).

3.1.7 Material Identification

3.1.7.1 Class 1 and 2 Valve Items

(a) The identification of materials for Category 3 and 4 valve items used for Class 1 and 2 valves shall consist of marking or tagging the material with the applicable specification number, grade, heat number, or heat code and any additional marking required to facilitate traceability of the reports of the results of all tests and examinations performed on the material, except that heat number identification is not required for valves with piping connections NPS 2 and less. Alternatively, a marking symbol and/or code may be used which identifies the material with the Material Certification and such symbol or code shall be explained in the certificate (3.1.5). For identification and marking during fabrication by the Valve Manufacturer, see 5.2.

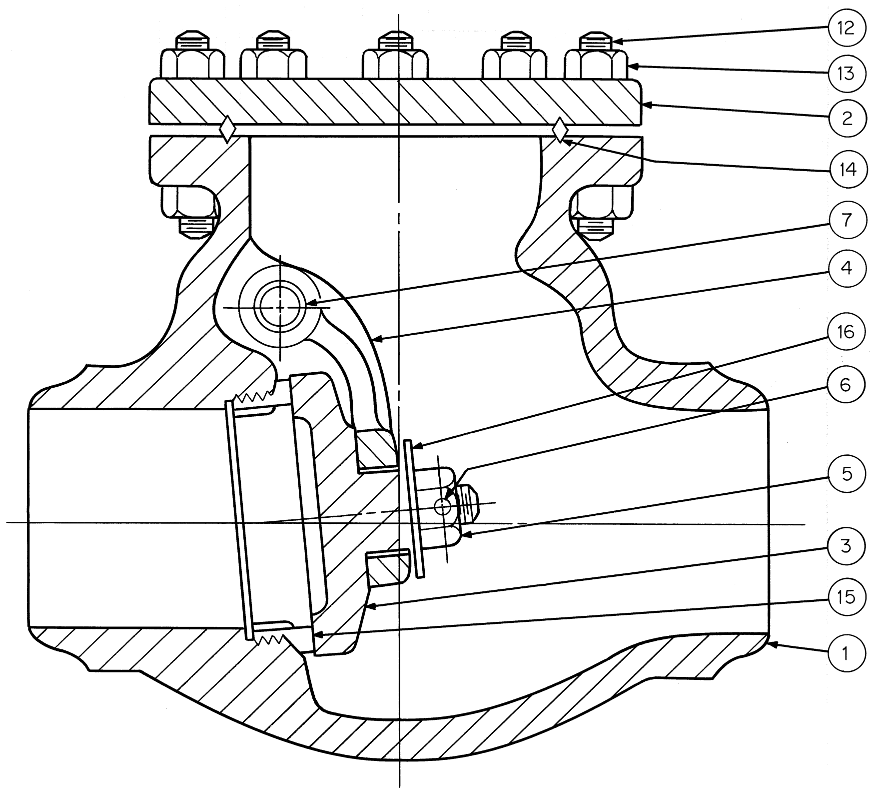
(b) The identification of materials for Category 5, 6, 7, and 8 valve items used for Class 1 and 2 valves shall consist of marking or tagging the material or its container in accordance with the marking requirements of the applicable material specification.

(c) Materials may be marked by any method which will not result in any harmful contamination or sharp discontinuities. Stamping, when used, shall be done with blunt-nosed-continuous or blunt-nosed-interrupted-dot die stamps.

3.1.7.2 Class 3 Valve Items. The identification of materials for Category 3 through 8 valve items used for Class 3 valves shall consist of marking the material or its container in accordance with the requirements of the applicable material specification.

3.1.7.3 Welding, Brazing and Hardsurfacing Material Identification. Welding, brazing, and hardsurfacing materials shall be clearly identified by legible marking on the package or container to ensure positive identification of the material.

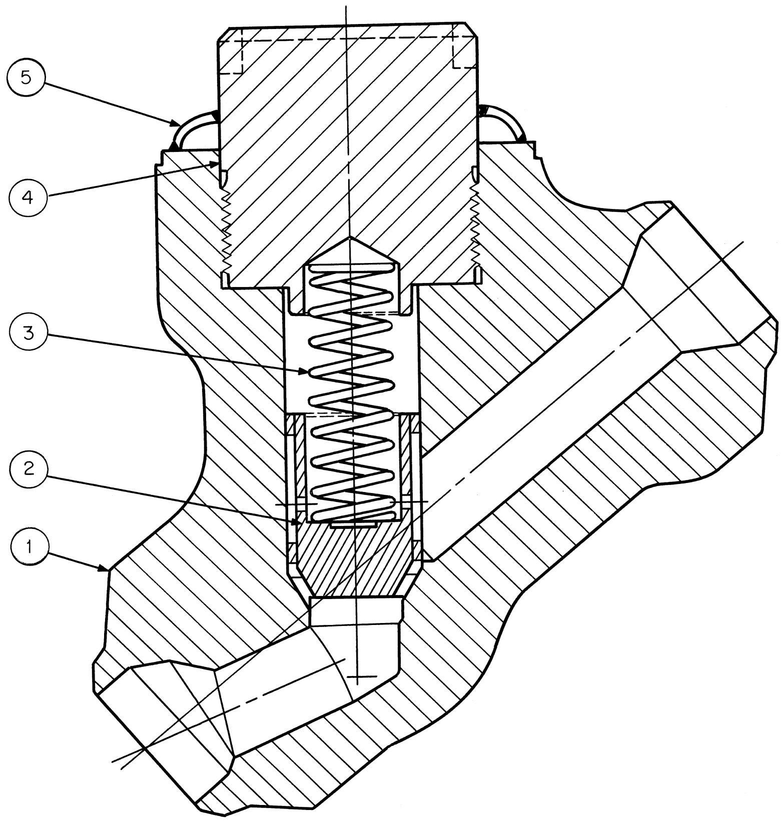
Figure 3
Swing Check Valve



Key to Figure 3

Cat.	Valve Item	Name (Typical)
1	1	Body
	2	Cap
2	12	Cap Bolt Studs
	13	Cap Bolt Stud Nuts
3	3	Disc
	7	Hinge Pin
	4	Hinge
4	15	Seat Ring
6	5	Disc Nut
7	6	Disc Nut Pin
8	16	Disc Washer
	14	Cap Ring Gasket

Figure 4
Globe Check Valve



Key to Figure 4

Cat.	Valve Item	Name (Typical)
1	1	Body
	4	Cover
	5	Canopy
3	2	Disc
5	3	Spring

3.2 FRACTURE TOUGHNESS REQUIREMENTS FOR MATERIALS

3.2.1 Materials to Be Impact Tested

3.2.1.1 Materials for Which Impact Testing Is Required. Materials for Category 3 valve items for Class 1 valves and for Class 2 and 3 valves when required by the design specification shall be impact tested in accordance with the requirements of 3.2, except that materials meeting any of the following conditions do not require impact testing.

(a) Materials with a nominal section thickness of $^5/_8$ in. and less;

(b) Bars with a nominal cross-sectional area of 1 sq in. and less;

(c) All thicknesses of materials for valves with a nominal pipe size 6 in. diameter and smaller;

(d) Materials for valves with all pipe connections of $^5/_8$ in. nominal wall thickness and less;

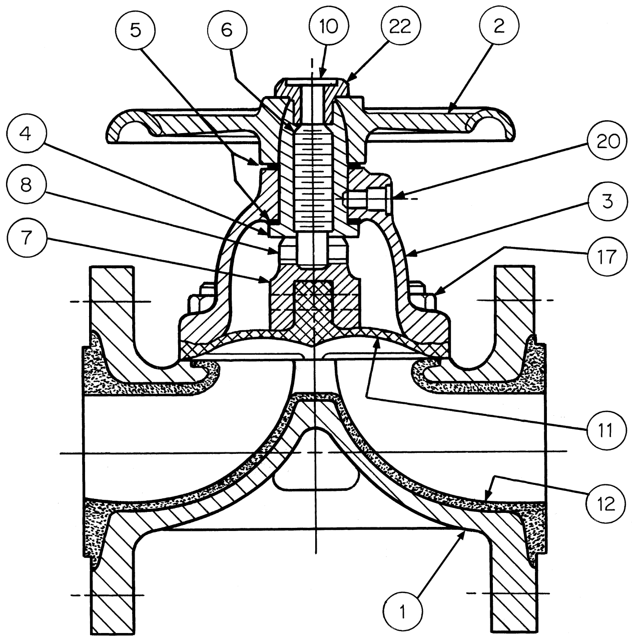
(e) Austenitic stainless steels;

(f) Nonferrous materials.

3.2.2 Impact Test Procedure

3.2.2.1 Charpy V-Notch Tests. The Charpy V-Notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A test shall consist of a set of 3 full-size 10 × 10 mm specimens. The test temperature, lateral expansion, absorbed energy, and percent shear fracture shall be reported in the Certified Materials Test Report.

Figure 5
Diaphragm Valve

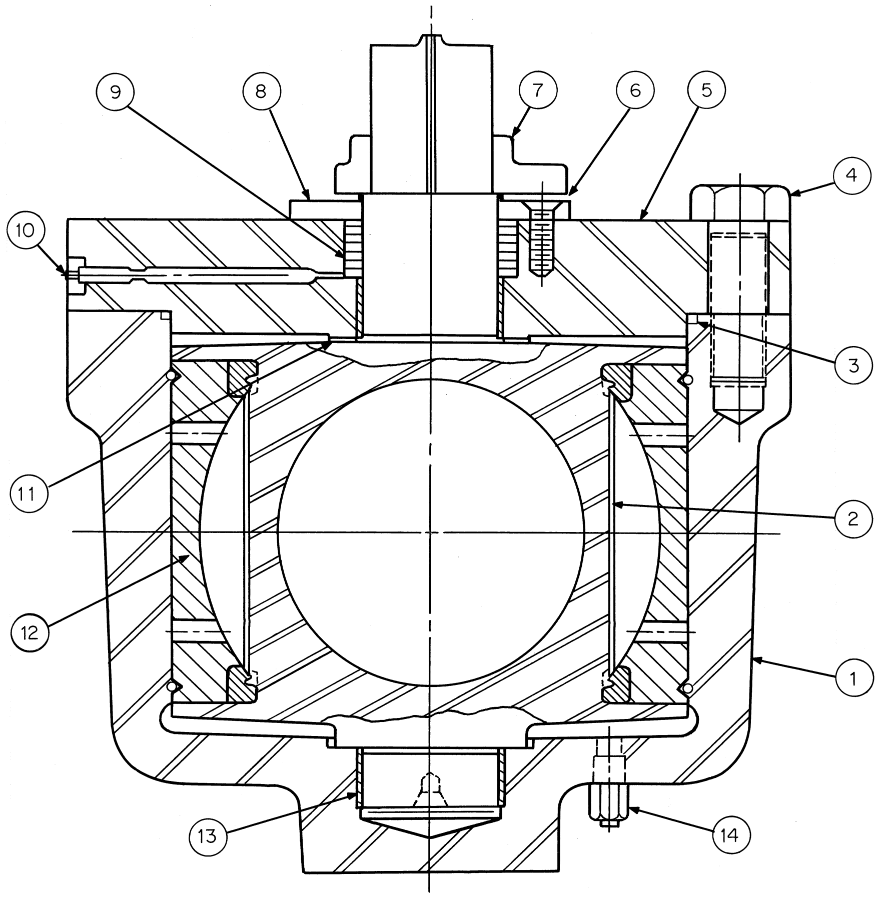


Key to Figure 5

Cat.	Valve Item	Name (Typical)
1	1	Body
	3	Bonnet
	20	Pipe Plug
2	17	Bonnet Bolting
3	6	Stem
	7	Compressor
	8	Compressor Pin
7	4	Stem Nut
	5	Spacer
8	11	Diaphragm
	12	Liner

GENERAL NOTES:
(a) Not included in this Case.
 2 Handwheel
 22 Handwheel Retainer
 10 Name Plate
(b) This figure is shown for definition of items only. It is to be used only when this type valve is permitted in Section III, Division 1 construction.

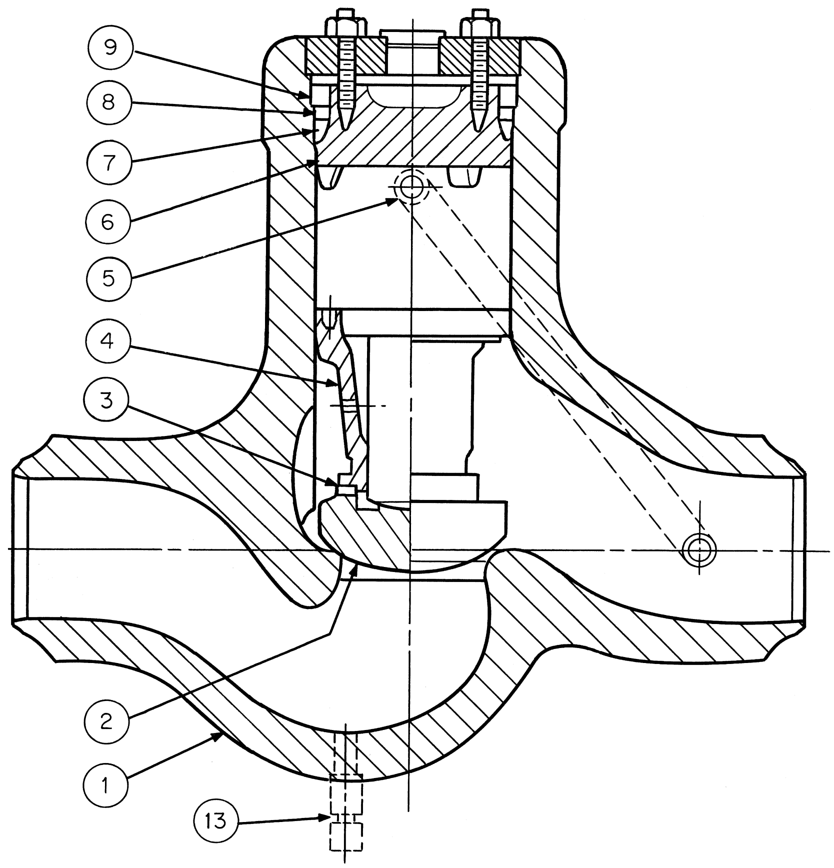
Figure 6
Plug Valve



Key to Figure 6

Cat.	Valve Item	Name (Typical)
1	1	Body
	5	Cover
	14	Vent Plug
2	4	Cover Capscrew
3	2	Plug
6	6	Gland Capscrew
	8	Gland
7	7	Stop Collar
	10	Grease Fitting
	11	Thrust Bearing
	13	Bushing
8	3	Cover O-Ring
	9	Stem Packing
	12	Seat Insert

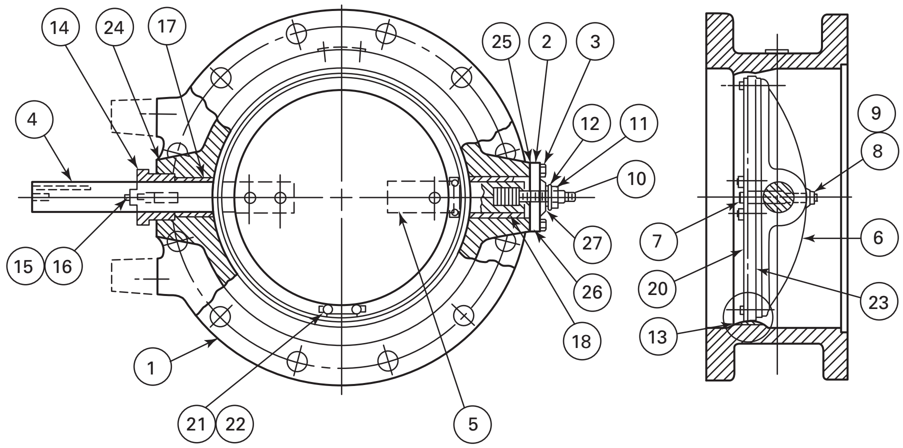
Figure 7
Globe Check Valve



Key to Figure 7

Cat.	Valve Item	Name (Typical)
1	1	Body
	5	Equalizer
	6	Pressure Seal Cover
	13	Drain Nipple
3	9	Gasket Retainer
	2	Disc
6	4	Body Guided Disk Nut
7	3	Locking Key
	8	Spacer Ring
	10	Cover Retainer Fasteners
	11	Cover Retainer Fasteners
	12	Cover Retainer
8	7	Pressure Seal Gasket

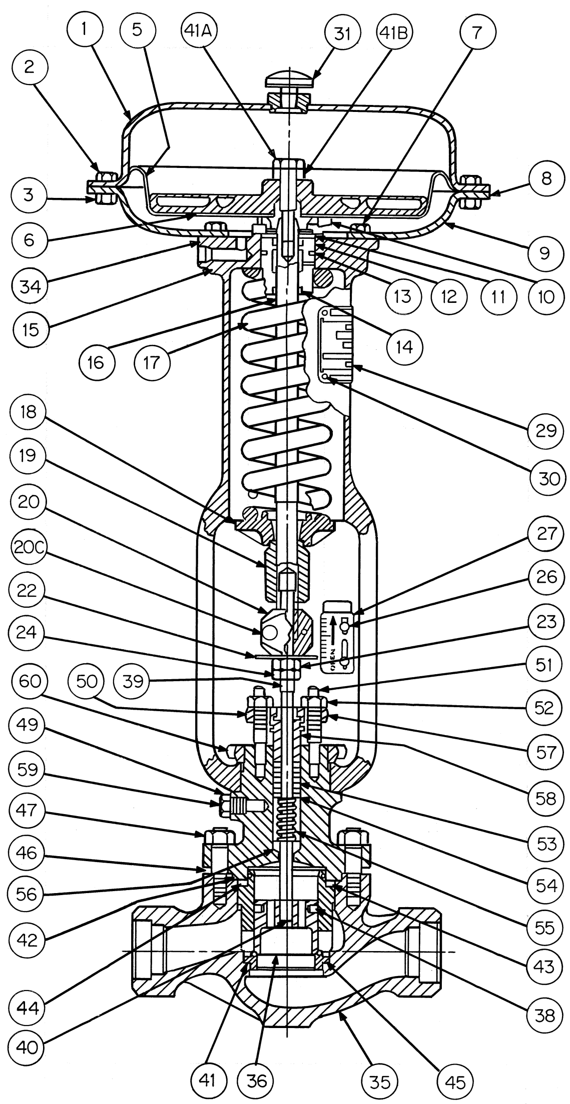
Figure 8
Butterfly Valve



Key to Figure 8

Cat.	Valve Item	Name (Typical)
1	1	Body
	2	Shaft Cover
	10	Thrust Adjustment Screw
2	3	Shaft Cover Bolting
3	4	Front Shaft
	5	Stub Shaft
	6	Disk
	7	Disc Pin
4	8	Disc Pin Nut
	13	Body Liner
	20	Clamping Ring
	21	Clamping Ring Bolt
	22	Clamping Ring Bolt Lock
	23	Disc Seat (Metallic)
6	15	Stuffing Box Stud
	16	Stuffing Box Nut
7	9	Disc Pin Washer
	11	Thrust Adjustment Nut
	12	Thrust Adjustment Washer
	14	Stuffing Box Gland
	17	Shaft Bearing
	18	Thrust Bearing
8	23	Disc Seat (Non-Metallic)
	24	Packing
	25	Gasket
	26	O-Ring
	27	Retaining Ring
	13	Body Liner (Non-Metallic)

Figure 9
Control Valve



Key to Figure 9

Cat.	Valve Item	Name (Typical)
1	35	Body
	49	Bonnet
	59	Pipe plug
2	46	Bonnet Stud (Bolt)
	47	Bonnet Nut
3	36	Disc (Plug)
	39	Disc (Stem)
4	41	Seat Ring
	37	Cage (when seat retaining)
5	17	Actuator Spring
	55	Packing Spring

Figure 9
Control Valve (Cont'd)

Key to Figure 9

Cat.	Valve Item	Name (Typical)
6	18	Spring Seat
	15	Yoke
	60	Yoke Lock Nut
	50	Packing Flange
	51	Packing Flange Bolt
	52	Packing Flange Nut
	58	Packing Follower
	56	Packing Box Ring
	40	Groove Pin
	16	Actuator Stem
7	19	Spring Adjustor
	20	Stem Connector
	20C	Stem Connector Cap Screw
	23	Nut
	24	Jam Nut
	37	Cage (when not seat retaining)
8	9	Gasket
	42	Gasket
	44	Gasket, Spiral Wound
	45	Gasket, Seat Ring
	43	Gasket, Cage
	53	Packing
	57	Upper Wiper
	38	Piston Ring

GENERAL NOTE: Not Included in this Case.

12	Seal Bushing	27	Travel Indicator Scale
13	O-Ring	26	Indicator Screw
14	O-Ring	10	Diaphragm Plate (Lower)
8	Diaphragm Case (Lower)	6	Diaphragm Plate (Upper)
1	Diaphragm Case (Upper)	11	Snap Ring
2	Diaphragm Case Bolt	29	Name Plate
3	Diaphragm Case Nut	30	Screw
5	Diaphragm	31	Vent
7	Diaphragm Stud	34	Travel Stop
54	Washer	41A	Nut
22	Travel Indicator	41B	Locknut

3.2.2.2 Location and Orientation of Test Specimens. Impact test specimens shall be removed from the locations and orientations specified by the Materials Specification for tensile test specimens in each product form.

3.2.2.3 Material Conditions for Impact Testing. Impact testing shall be performed on specimens representing the condition of the item after final heat treatment and material forming operations.

3.2.3 Test Requirements and Acceptance Standards. Three Charpy V-Notch specimens shall be tested at a temperature equal to or lower than the lowest service temperature. All three specimens shall meet or exceed 15 mils lateral expansion (0.015 in.). Lowest service temperature is the minimum temperature of the fluid retained by the valve, or, alternatively, the calculated volumetric average metal temperature expected during normal operation, whenever the pressure within the valve exceeds 20% of the preoperational system hydrostatic test pressure. The lowest service temperature shall be specified in the Design Specification.

3.2.4 Retests

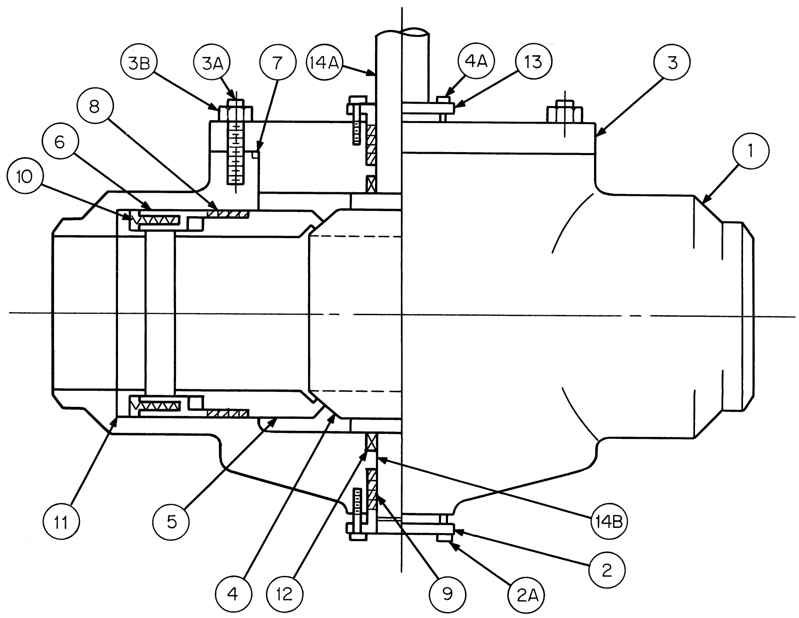
(a) One retest at the same temperature may be conducted provided:

(1) the average of the test results meet the minimum requirements,

(2) not more than one specimen per test is below the minimum requirements, and

(3) the specimen not meeting the minimum requirements is not lower than 5 mils below the specified requirements.

Figure 10
Ball Valve



Key to Figure 10

Cat.	Valve Item	Name (Typical)
1	1	Body
	2	Bearing Plate
	3	Bonnet
2	2A	Bearing Plate Bolt
	3A	Bonnet Stud
	3B	Bonnet Nut
3	4	Ball
	14A	Stem
	14B	Trunion
4	5	Spool/Seat
5	10	Spring
6	13	Gland Flange
	4A	Gland Bolt
7	6	Spring Retainer
	11	Spring Cover
	12	Trunion Bearing
8	7	Gasket
	8	Spool Packing
	9	Trunion Seal

Table 1.2-1
Summary of Requirements

Typical Valve Items	Category No. and Valve Class	Design Report [Note (1)]	Certified Materials Test Report	Mag. Part./ Liq. Penet. Examination	Impacts Charpy V	Material Identif.
Body Bonnet	Category 1 Class (all)	Subsection NB, NC and ND				
Bonnet-Bolting	Category 2 Class (all)	Subsection NB, NC and ND				
Discs Stems	Category 3					
	Class 1	X	X	X [Note (2)]	X	X
	Class 2	...	X	X [Note (3)]	X [Note (4)]	X
	Class 3	...	X	...	X [Note (4)]	[Note (5)]
Seat-Rings	Category 4					
	Class 1	X	X	X	X	...
	Class 2	...	X	...	X	...
	Class 3	...	X	...	[Note (5)]	...
Springs	Category 5					
	Class 1	X	[Note (6)]	X	...	[Note (5)]
	Class 2	...	[Note (6)]	...	...	[Note (5)]
	Class 3	...	[Note (6)]	...	...	[Note (5)]
Yokes Gland-Flange Gland-Bolts	Category 6					
	Class 1	X	[Note (6)]	...	...	[Note (5)]
	Class 2	...	[Note (6)]	...	...	[Note (5)]
	Class 3	...	[Note (6)]	...	...	[Note (5)]
Lantern-Ring Gland Yoke Nut Grease Fitting	Category 7					
	Class 1	...	...	...	...	[Note (5)]
	Class 2	...	...	...	...	[Note (5)]
	Class 3	...	...	...	...	[Note (5)]
Packing Gaskets Seals Piston Rings	Category 8 Class (all)	...	...	...	...	...

NOTES:
(1) A Design Report is required for Class 1 valves larger than 4 in. NPS (NB-3560).
(2) Radiography or ultrasonic examination of cast materials and valve disks for valves over 2 in. NPS is required.
(3) Case materials only.
(4) When required for the valve per Design Specification.
(5) The quality control system shall cover identification in accordance with 3.1.7.1 and 3.1.7.2.
(6) Material Manufacturer's Certificate of Compliance.

(b) A retest consists of two additional specimens taken as near as practicable to the failed specimens. For acceptance of the retest, both specimens shall meet the minimum requirements.

4 DESIGN REQUIREMENTS

4.1 GENERAL DESIGN REQUIREMENTS

The requirements of 4 apply to Category 3, 4, 5, and 6 valve items used for Class 1 valves; Category 3, 4, and 5 valve items used for Class 2 valves; and Category 3 and 4 valve items used for Class 3 valves. Only Class 1 valve items for valves larger than NPS 4 are required to be included in a Design Report.

4.2 DESIGN CONDITIONS

The design pressure and temperature conditions are defined in 4.2.1 or 4.2.2. The design pressure and temperature for the valve items covered by this Case shall be determined by either 4.2.1 or 4.2.2.

4.2.1 Design Pressure and Temperature. The design pressure shall be taken equal to the standard calculation pressure, p_s, according to NB-3545.1. The associated design metal temperature shall be 500°F and the allowable stresses of the materials at that temperature shall apply.

4.2.2 Alternative Design Pressure and Temperature. As an alternative to 4.2.1, the design calculation pressure may be taken as that pressure corresponding to the 100°F valve pressure rating for Class 1 values in accordance with Tables NB-3531-1 through NB-3531-7. The associated design temperatures shall be 100°F and the allowable stresses of the materials at that temperature shall apply. For Class 2 and 3 valves, NC-3500 and ND-3500 shall be used for pressure temperature ratings.

4.3 DESIGN COMPUTATIONS

The specific combinations and values of loadings, including mechanical loadings, which are considered in evaluating the primary stresses (4.2) are those anticipated during normal operating conditions. When variations in pressure or temperature in excess of normal operating conditions are expected to occur, they shall be included in the design specification. The actual mechanical loads resulting from these conditions shall be used in the computations made to show compliance with the stress limits of 4.3.1, 4.3.2, and 4.3.3. Upset, emergency, and faulted conditions shall be considered and shall be in accordance with NB-3520.

4.3.1 Design of Category 3, 4 and 6 Valve Items

4.3.1.1 Stress Limits. The stress limits for materials for Category 3, 4, and 6 valve items for normal operating conditions shall be as follows:

(a) The primary-membrane stress shall not exceed the design allowable stress, S (see 3.1.4).

(b) The primary-membrane plus primary bending stress shall not exceed 1.5 S.

(c) Localized stresses associated with contact loading of seating surfaces do not require substantiation by analysis.

4.3.2 Design of Category 5 Valve Items. The Valve Manufacturer shall perform an analysis which shall include stress and fatigue considerations.

4.3.3 Design of Category 7 and 8 Valve Items. This Case does not specify design rules, stress limits, or analytical requirements for Category 7 and 8 Valve items.

4.4 FATIGUE EVALUATION

For Class 1 valves, when the Design Specification (NA-3250) includes such operating conditions that the valve is not exempted from fatigue analysis by the rules of NB-3222.4(d), it is recommended that consideration be given to cyclic stress duty.

5 FABRICATION REQUIREMENTS

Category 3 through 8 valve items shall be fabricated in accordance with the requirements of 5 and shall be manufactured from materials which meet the requirements of 3.

5.1 CERTIFICATION OF MATERIALS AND FABRICATION BY VALVE MANUFACTURER

The Valve Manufacturer shall provide certification that all treatments, tests, repairs or examinations performed on valve items are in compliance with the requirements of this Case. Reports of all required treatments and the results of all required tests, repairs, and examinations performed shall be maintained in accordance with NA-4900.

5.2 MATERIALS IDENTIFICATION

Material for Category 3 and 4 valve items for Class 1 and 2 valves shall carry identification markings, either directly on the item or on a separate tag that accompanies the item, which will remain distinguishable until the item is assembled in the valve. All other materials shall be identified by a control procedure, as specified by a Quality Assurance program, which ensures that the specified materials are used.

5.3 EXAMINATION OF MATERIALS

Materials for Category 3, 4, and 5 valve items for Class 1 valves and cast materials for Category 3 valve items for Class 2 valves with piping connections over NPS 2 shall be examined by the magnetic particle or liquid penetrant method in accordance with Section V. In addition, cast materials for Category 3 valve items and all disks for Class 1 valves with piping connections over NPS 2 shall be examined by the applicable radiographic or ultrasonic methods and acceptance standards in accordance with

NB-2500. The examination may be performed by the Material Manufacturer or the Valve Manufacturer (3.3.1). Acceptance standards for magnetic particle and liquid penetrant examination shall be as follows:

(a) Only indications with major dimensions greater than $^1/_{16}$ in. shall be considered relevant.

(b) The following relevant indications are unacceptable:

(1) Any linear indications greater than $^1/_{16}$ in. long for materials less than $^5/_8$ in. thick; greater than $^1/_8$ in. long for materials from $^5/_8$ in. thick to under 2 in. thick; and $^3/_{16}$ in. long for materials 2 in. thick and greater.

(2) Rounded indications with dimensions greater than $^1/_8$ in. for thicknesses less than $^5/_8$ in. and greater than $^3/_{16}$ in. for thicknesses $^5/_8$ in. and greater.

(3) Four or more indications greater than $^1/_{16}$ in. in a line separated by $^1/_{16}$ in. or less edge to edge.

(4) Ten or more indications greater than $^1/_{16}$ in. in any 6 sq in. of area whose major dimension is no more than 6 in. with the dimensions taken in the most unfavorable location relative to the indications being evaluated.

Materials for Category 6, 7, and 8 valve items for Class 1 valves and for Category 3 through 8 valve items for Class 2 and 3 valves shall be examined in accordance with the material specification.

5.3.1 Time of Examination.. Magnetic particle or liquid penetrant examination shall be performed on the final surfaces of the items, except that threaded items may be examined prior to threading. Examinations shall be performed prior to any coating or plating. Lapping of seating surfaces to reduce leakage or lapping of bearing surfaces shall not require re-examination. Radiographic or ultrasonic examinations of cast materials, when required, shall be performed in accordance with NB-2577.

5.3.2 Elimination of Surface Defects

(a) Unacceptable surface defects shall be removed by grinding or machining, provided:

(1) The remaining thickness of the section is not reduced below the minimum required by the design;

(2) The depression, after grinding or machining, is blended uniformly into the surrounding surface and the depression does not affect the function of the item;

(3) After grinding or machining, the area is examined by the method which originally disclosed the defect to assure that the defect has been removed or the indication reduced to an acceptable size.

(b) If grinding or machining reduces the thickness of the section below the minimum required by the design, the item may be repaired in accordance with 5.4.

5.4 REPAIR BY WELDING OF CLASS 1, 2, AND 3 VALVE ITEMS

Category 5 valve items may not be repair welded. Category 3, 4, 6, 7, and 8 valve items for Class 1, 2, and 3 valves may be repaired by welding provided the requirements of the following subparagraphs are met:

5.4.1 Defect Removal.. The defect shall be removed or reduced to an acceptable size by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair.

5.4.2 Qualification of Welding Procedures and Welders

5.4.2.1 Except as permitted in 5.4.2.2, the welding procedure and welders or welding operators shall be qualified in accordance with Section IX, and NB, NC, ND-4000 as applicable.

5.4.2.2 Heat-treated materials listed in Table 3.1.2-1 which are not capable of passing bend tests required by Section IX for procedure or performance qualification may be qualified as required for fillet welding in accordance with QW-180. In addition, a minimum of two cross sections of the qualification test plate (assembly) shall be ground and etched with a suitable etchant and visually examined at 10× magnification. The weld metal and adjacent base material of the ground and etched cross sections shall be free of cracks.

5.4.3 Blending of Repaired Areas. After repair, the surface shall be blended into the surrounding surface.

5.4.4 Examination of Repair Welds. Each repair weld of materials listed in Table 3.1.2-1, Category 3 and 4 valve items for Class 1 valves and cast Category 3 valve items for Class 2 valves, shall be examined by the method that originally exposed the defect and the finished surface shall be examined by either the magnetic particle or liquid penetrant method in accordance with Section V. The acceptance standards shall be those specified in 5.3(a) and 5.3(b).

5.4.5 Heat Treatment after Repair.

(a) Materials listed in Table 3.1.2-1, which are repaired by welding shall be heat treated after repair. Such heat treatment shall be the heat treatment specified for the finished item. The heat treatment shall be verified by a hardness test performed on the item showing hardness conforming to the minimum hardness value, or equivalent hardness value, listed in Table 3.1.2-1 for the material.

(b) Materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, which are repaired by welding shall be heat treated after repair in accordance with the heat treatment requirements of NB, NC, ND-2500.

5.4.6 Repair Weld Report. A record shall be made of each defect repair of Category 3 and 4 valve items in which the depth of the repair cavity exceeds the lesser of $^3/_8$ in. or 10% of the section thickness. The record shall include the location and size of the repaired cavity, the welding materials, the welding procedure, the heat treatment and the examination results.

5.5 INTERNAL PERMANENT ATTACHMENT WELDS

Items which are attached by welding to the internal surface of the body or bonnet may be attached by full penetration, partial penetration, or fillet welds. The attachment and weld joint shall meet the design requirements of 4.

5.6 WELDING REQUIREMENTS

Except as permitted in 5.4.2 and 5.6.1, all welds shall be made using qualified welding procedures and welders or welding operators in accordance with Section IX.

5.6.1 Special Welds.. Fillet welds and partial penetration welds $^1/_4$ in. and less in size may be made in the fabrication of valve items or between value items where either of the items is a material listed in Table 3.1.2-1 provided the procedures and welders are qualified as follows:

(a) A test assembly shall be made for each combination of materials to be welded.

(b) The test assembly shall be a duplicate of the production weld joint or a groove butt weld $^1/_4$ in. minimum thickness.

(c) The test assembly shall be sectioned (a minimum of four cross sections), ground, etched with a suitable etchant, and visually examined at 10× magnification. All surfaces of the weld and adjacent base material(s) shall be free of cracks.

5.6.2 Hardsurfacing. Hardsurfacing shall be performed using qualified procedures and personnel in accordance with NB-4380 of Section III.

5.6.3 Examination of Welds. All welds including hardsurfacing shall be examined by the magnetic particle or liquid penetrant method in accordance with Section V. Except for seating surfaces for which all indications shall be removed, acceptance standards shall be as follows:

5.6.3.1 Acceptance Standards

(a) Only indications with major dimensions greater than $^1/_{16}$ in. shall be considered relevant.

(b) The following relevant indications are unacceptable:

(1) Any linear indications greater than $^1/_{16}$ in. long;

(2) Rounded indications greater than $^3/_{16}$ in.;

(3) Four or more rounded indications greater than $^1/_{16}$ in. in a line separated by $^1/_{16}$ in. or less edge to edge;

(4) Ten or more rounded indications greater than $^1/_{16}$ in. in any 6 sq in. of surface with the major dimension of this area are not to exceed 6 in., with the area taken in the most unfavorable location relative to the indications being evaluated.

5.6.4 HEAT TREATMENT OF WELDS

5.6.4.1 Postweld heat treatment of welds which join materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, shall be in accordance with the postweld heat treatment requirements of NB-4620.

5.6.4.2 Postweld heat treatment of welds which join materials listed in Table 3.1.2-1 to materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1, shall be in accordance with the postweld heat treatment requirements of NB-4620. Special techniques, such as local postweld heat treatment, may be necessary to avoid changing the base material properties of the item in locations not adjacent to the weld.

5.6.4.3 Postweld heat treatment of welds for joining materials listed in Table 3.1.2-1 shall be in accordance with the heat treatment specified for the material of the finished item; i.e., the heat treatment required to obtain the tensile strength, yield strength, or hardness listed in Table 3.1.2-1. For fillet welds and partial penetration welds $^1/_4$ in. and less in size, postweld heat treatment is neither required nor prohibited.

Table 3.1.2-1
Allowable Stress Values, S, for Materials, for Internal and External Items for Class 1, 2 and 3 Valves [Note (4)]

Material	Product Form	Spec. No.	Type or Grade	Diameter or Thickness, In.	Condition	Tensile Strength psi, Min.	Brinell Hardness Minimum	Yield Strength psi, Min.	Minimum Tempering or Aging Temp., °F	Allowable Stress, kips/in. Temps. Not Exceeding, °F								
										Notes	100	200		400	500	600	650	700
13Cr	FFBS	A 182-75	F6	Up to 8″ incl.	...	165,000	351	132,000	900	(1)(5)(6)	55.0	50.6		48.0	47.3	46.1	...	44.0
13Cr	Plate	A 240-75	410,410S	Up to 8″ incl.	...	136,000	293	112,000	1025	(1)(5)(6)	45.3	41.8		39.6	39.0	38.0	...	36.3
13Cr	Tube	A 268-75	TP410	Up to 8″ incl.	...	125,000	269	100,000	1075	(5)(6)	41.7	38.4		36.4	35.8	34.9	...	33.4
13Cr	Bar, Shapes	A 276-75	403,410	Up to 8″ incl.	...	120,000	255	95,000	1100	(5)(6)	40.0	36.8		35.0	34.4	33.5	...	32.0
13Cr	Billets, Bars	A 314-75	403,410	Up to 8″ incl.	...	116,000	248	92,000	1125	(5)(6)	38.7	35.6		33.8	33.0	32.4	...	31.0
13Cr	Billets, Bars	A 314-75	416,416Se	Up to 8″ incl.	...	110,000	235	90,000	1175	(5)(6)	36.7	33.8		32.1	31.6	30.7	...	29.4
13Cr	Castings	A 217-75	CA15	Up to 8″ incl.	...	100,000	212	80,000	1275	(6)	33.3	30.7		29.2	28.7	27.9	...	26.7
13Cr	Bar, Shapes	A 479-75	410	Up to 8″ incl.	...	90,000	192	65,000	1375	(6)	30.0	27.6		26.2	25.8	25.2	...	24.1
13Cr	Bars	A 582-75	416,416Se	Up to 8″ incl.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13Cr	Bar, Shapes	A 276-75	420	Up to 8″ incl.	A	95,000	196	50,000	NA	(6)(8)	31.6	29.2		27.7	27.2	26.5	...	25.4
13Cr	Bar, Shapes	A 276-75	420	Up to 8″ incl.	QT	250,000	477	195,000	750	(1)(3)(5)(6)	...	...	...	...	...	...	...	...
13Cr	Bar, Shapes	A 276-85a	420	Over 8″ to 12″	QT	220,000	430	180,000	600	(1)(2)(5)(6)(9)	...	...	...	...	...	...	...	...
13Cr	Bar, Shapes	A 276-85a	420	Over 12″ to 14″	QT	200,000	400	160,000	900	(1)(2)(5)(6)(9)	...	...	...	...	...	...	...	...
1Cr-0.2Mo	Bar, Rod	A 331-74	4140	Up to 2″ incl.	HT	180,000	353	155,000	800	(5)(6)	60.0	58.0		57.5	57.0	55.8	53.8	51.8
1Cr-0.2Mo	Bar, Rod	A 331-74	4340	Up to 2″ incl.	HT	178,000	353	156,000	1000	(5)(6)	59.3	57.4		57.0	56.4	55.2	53.3	51.3
18Cr	Bar, Shapes	A 276-75	440C	Up to 8″ incl.	HT	285,000	578	275,000	600	(1)(3)(5)(6)(7)	...	...	...	...	...	...	...	...
13Cr	Bar, Shapes	A 565-74	615	Up to 8″ incl.	HT	140,000	302	110,000	1100	(3)(5)	...	...	...	...	...	...	...	...
12Cr	Bar, Shapes	A 565-74	616	Up to 8″ incl.	HT	140,000	302	110,000	1100	(3)(5)	...	...	...	...	...	...	...	...
17Cr-4Ni-4Cu	Bar, Shapes	A 564-74	630	8″ max	...	190,000	388	170,000	900	(1)(5)	63.3	59.8		56.0	54.6	54.0	53.0	...
17Cr-4Ni-4Cu	Castings	AMS-5355B	...	8″ max	...	155,000	331	145,000	1025	(1)(5)	51.6	48.8		45.6	44.6	44.0	43.3	...
17Cr-4Ni-4Cu	Castings	AMS-5398A	...	8″ max	...	145,000	302	125,000	1075	(5)	48.3	45.6		42.6	41.6	41.1	40.5	...
...	...	...	...	...	...	140,000	311	115,000	1100	(5)	46.6	44.0		41.4	40.4	39.8	39.0	...
...	...	...	...	...	...	135,000	277	105,000	1150	(5)	45.0	42.5		39.8	39.0	38.3	37.6	...
17Cr-7Ni-1A1	Bar, Shapes	A 564-74	631	6″ max	PH	170,000	352	140,000	1050	(5)	56.7	53.7		50.5	49.1	47.6	45.5	...
15Cr-6Ni-1.5Cu	Bar, Shapes	A 564-74	XM25	Up to 8″ incl.	STr	125,000	262	95,000	NA	(5)	41.7	37.7		37.0	37.0	36.9	...	...
15Cr-6Ni-1.5Cu	Bar, Shapes	A 564-74	XM25	Up to 8″ incl.	PH	180,000	363	170,000	900	(1)(2)(5)	60.0	55.0		51.0	49.7	48.6	48.0	47.1
15Cr-6Ni-1.5Cu	Bar, Shapes	A 564-74	XM25	Up to 8″ incl.	PH	145,000	262	135,000	1050	(2)(5)	48.3	45.3		42.0	40.8	39.8	39.1	38.3
15Cr-6Ni-1.5Cu	Bar, Shapes	A 564-74	XM12	8″ max	...	155,000	...	145,000	1025	(1)(2)(3)(5)	...	...	...	...	...	...	...	...
15Cr-6Ni-1.5Cu	Bar, Shapes	A 564-74	XM12	8″ max	...	145,000	...	125,000	1075	(1)(2)(3)(5)	...	...	...	...	...	...	...	...
26Ni-15Cr-Mo-Ti	Bolting	A 453-75	660	...	A or B	130,000	248	85,000	1325	(2)	43.3	42.8		42.5	41.8	41.3	...	40.8
18Cr-12Ni-2Mo	Bar, Shapes	A 638-70	660	...	1 or 2	130,000	248	85,000	1300	...	43.3	42.8		42.5	41.8	41.3	...	40.8
18Cr-12Ni-2Mo	Bar, Shapes	A 276-75	316	Up to $\frac{3}{4}$	B	125,000	...	100,000	NA	(5)(6)	41.7	37.9		34.5	34.3	34.3	...	34.3
18Cr-12Ni-2Mo	Bar, Shapes	A 276-75	316	$\frac{3}{4}$ to 1	B	115,000	...	80,000	NA	(6)	38.3	34.9		31.8	31.6	31.6	...	31.6
18Cr-12Ni-2Mo	Bar, Shapes	A 276-75	316	1 to $1\frac{1}{4}$	B	105,000	...	65,000	NA	(6)	35.0	31.8		29.1	28.8	28.8	...	28.8
18Cr-12Ni- 2Mo	Bar, Shapes	A 276-75	316	$1\frac{1}{4}$ to $1\frac{1}{2}$	B	100,000	...	50,000	NA	(6)	33.3	30.3		27.7	26.8	26.4	...	25.7
Ni-Cr-Fe	Bar, Shapes	B 637-84a	718	...	PH	185,000	331	150,000	1325	(5)	60.0	59.7		55.8	55.2	55.0	...	55.0

Table 3.1.2-1
Allowable Stress Values, S, for Materials, for Internal and External Items for Class 1, 2 and 3 Valves (4)] (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Diameter or Thickness, In.	Condi-tion	Tensile Strength psi, Min.	Brinell Hardness Minimum	Yield Strength psi, Min.	Minimum Tempering or Aging Temp., °F	Notes	Allowable Stress, kips/in. Temps. Not Exceeding, °F 100	200		400	500	600	650	700
Ni-Cr-Fe	Bar, Shapes	B 637-84a	688T2	4	PH	170,000	302	115,000	1350	(3)(5)	...	...	...	...	...	...	...	...
Co-Cr-W-Ni	Bar, Shapes	AMS-5759D	...	4	CDr	150,000	311	100,000	1100	(2)(3)(5)	...	...	...	...	...	...	...	...
Co-Cr-W	Bar, Shapes	Comm.	...	...	STr	150,000	352	90,000	1000	(2)(3)(5)	...	...	...	...	...	...	...	...
Co-Cr-W	Castings	AMS-5373A	...	...	As Cast	125,000	375	75,000	NA	(2)(3)	...	...	...	...	...	...	...	...
Co-Cr-W	Castings	AMS-5387	...	...	As Cast	115,000	375	95,000	NA	(2)(3)(5)	...	...	...	...	...	...	...	...
27Cr-5Mo-Co	Castings	A 567-74	Gr. 1	...	PH	120,000	352	100,000	1350	(2)(3)(5)	...	...	...	...	...	...	...	...
27Cr-5Mo-Co	Castings	AMS-5385C	...	...	PH	120,000	352	100,000	1350	(2)(3)(5)	...	...	...	...	...	...	...	...
12Cr-Cb	Bar	SA-479	XM30	...	QT	125,000	302	100,000	1100	(2)(3)(5)	41.7	39.0		36.3	35.5	34.5	...	33.3

NOTES:
(1) Not to be used for Category 3 Valve Items, except for safety valve disks and nozzles, when the nozzles are internally contained by the external body control valve disks in automatic flow control valves, when the primary function of the valve is flow control; and line valve disks in valves with inlet connections NPS 2 and
(2) Welding of these materials is not permitted.
(3) For those materials in this table which do not have allowable stresses assigned, use $^{1}/_{4}$ of room temperature specified minimum tensile strength, 650°F inclusive.
(4) The material shall be identified with this Case number in addition to the identification requirements of 3.1.7.1. Where the tensile strength, yield strength, hardness, tempering temperature or aging temperature listed in Table 3.1.2-1 differ from the requirements of the material specification, the minimum requirements listed in Table shall apply.
(5) The maximum tensile strength shall not exceed the specified minimum tensile strength by more than 40.0 ksi.
(6) In addition to the requirements of 3.1.7.1 these materials shall be marked with the minimum specified tensile strength, in ksi, and this Case number.
(7) This material shall not be used at temperatures higher than 450°F.
(8) Carbon content shall not exceed 0.35%.
(9) Use $^{1}/_{4}$ of the room temperature minimum specified tensile strength for assigned allowable stresses, up to 600°F, inclusive.

Approval Date: November 8, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-71-19
Additional Materials for Subsection NF, Class 1, 2, 3, and MC Supports Fabricated by Welding
Section III, Division 1

Inquiry: What materials, in addition to those listed in Section II, Part D, Tables 1A, 1B, 2A, 2B, and Y-1, may be used for Section III, Division 1, Classes 1, 2, 3, or MC supports constructed to the requirements of Subsection NF when the items are fabricated by welding?

Reply: It is the opinion of the Committee that as alternatives to the materials listed in the Tables of Section II, Part D referenced in Table NF-2121(a)-1, the design stress intensity and allowable stress values, the yield strength, and the ultimate tensile strength values,[1] for the material specifications listed in Tables 1, 2, 3, 4 and 5 of this Case may be used in welded construction of Classes 1, 2, 3, and MC supports for Section III, Division 1. These materials may also be used for nonwelded construction.

The following additional requirements shall apply.

1 GENERAL REQUIREMENTS

1.1 The requirements of Subsection NF shall be met except as modified by this Case.

2 MATERIALS

2.1 Welding is not permitted on carbon and low alloy steels containing more than 0.35% carbon.

2.2 When the Material columns in Tables 1 through 5 reference AISI grades, only materials meeting the chemical composition range requirements of the specific AISI grades listed shall be used, with the exception that 0.60% maximum silicon is permitted for castings.

2.3 Materials in Table 1 through 5 that are listed as an AISI composition may be accepted as satisfying the requirements of the ASTM specification provided the chemical requirements of the AISI specification are within the specified range of the designated ASTM specification, and certification of the material shall be in accordance with the requirements of the NCA-3860.

2.4 When an ASTM specification does not specify either minimum tensile or yield strengths, the values listed in this Case shall be met by the material.

2.5 The material shall be furnished in accordance with the requirements of NF-2600. Structural steel rolled shapes and structural tubing permitted by this Code Case may be repair welded in accordance with NF-2610(e).

2.6 The thickness referenced in this Case is the nominal thickness of the weld, the base material or the thinner of the sections being joined, whichever is least. For fillet welds, the nominal thickness is the throat thickness, and for partial penetration welds and material repair welds, the nominal thickness is the depth of weld groove or weld preparation.

2.7 Where impact tests are required by this Case or the Design Specification, impact testing shall be performed in accordance with NF-2331.

[1] The tabulated values of tensile strength and yield strength are those which the Committee believes are suitable for use in design calculations required by Section III, Division 1. At the temperatures above room temperature, the values of tensile strength tend toward an average or expected value which may be as much as 10% above the tensile strength trend curve adjusted to the minimum specified room temperature tensile strength. At temperatures above room temperature, the yield strength values correspond to the yield strength trend curve adjusted to the minimum specified room temperature yield strength. Neither the tensile strength nor the yield strength values correspond exactly to either "average" or "minimum," as these terms are applied to a statistical treatment of a homogeneous set of data.
Neither the ASME or ASTM Material Specifications nor the rules of Section III, Division 1, require elevated temperature testing for tensile or yield strengths of production material for use in Code components. It is not intended that results of such tests, if performed, be compared with these tabulated tensile and yield strength values for ASME Code acceptance/rejection purposes for materials. If some elevated temperature test results on production material appear lower than the tabulated values by a large amount (more than the typical variability of material suggesting the possibility of some error), further investigation by retest or other means should be considered.

3 CLASSIFICATIONS

3.1 The materials in this Case have been grouped in S-Number groupings of base metals similar to the P-Number groupings in QW/QB-422, of Section IX.

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400	500		650	700	750	800
Carbon Steels																			
AISI 1015	P–1	1	Bar	A108-99	1015CW	...	1,6	40	60	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1018	P–1	1	Bar	A108-99	1018CW	...	1,6	40	60	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1020	P–1	1	Bar	A108-99	1020CW	...	1,6	40	60	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1015	P–1	1	Tube	A513-98	1015CW	...	1,6	55	65	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A513-98	1020CW	...	1,6	60	70	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A513-98	1025CW	...	1/7	65	75	18.3	18.3	18.3	18.3	...	...	...	...	...	...
AISI 1026	P–1	3	Tube	A513-98	1026CW	...	1,7	70	80	18.3	18.3	18.3	18.3	...	...	...	...	...	...
AISI 1018	P–1	2	Tube	A519-96	1018CW	...	1,6	60	70	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A519-96	1020CW	...	1,6	60	70	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1022	P–1	2	Tube	A519-96	1022CW	...	1,6	60	70	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1018	P–1	1	Tube	A519-96	1018HR	...	...	32	50	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1020	P–1	1	Tube	A519-96	1020HR	...	...	32	50	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1022	P–1	1	Tube	A519-96	1022HR	...	...	32	50	16.7	16.7	16.7	16.7	...	...	...	...	...	...
AISI 1025	P–1	1	Tube	A519-96	1025HR	...	...	35	55	18.3	18.3	18.3	18.3	...	...	...	...	...	...
AISI 1026	P–1	1	Tube	A519-96	1026HR	...	...	35	55	18.3	18.3	18.3	18.3	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A519-96	1025CW	...	1,5,7	65	75	18.3	18.3	18.3	18.3	...	...	...	...	...	...
AISI 1026	P–1	2	Tube	A519-96	1026CW	...	1,5,7	65	75	18.3	18.3	18.3	18.3	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	A	...	...	25	42	14.0	14.0	14.0	14.0	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	B	...	...	30	45	15.0	15.0	15.0	15.0	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	C	...	...	33	48	16.0	16.0	16.0	16.0	...	...	...	...	...	...
...	S–1	1	Sheet	A653-99	A	...	15	33	45	15.0	15.0	15.0	15.0	...	...	...	...	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	B	10	30	60	20.0	20.0	20.0	20.0	20.0		20.0	...	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	B	10	30	60	20.0	20.0	20.0	20.0	20.0		20.0	...	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	B	10	30	60	20.0	20.0	20.0	20.0	20.0		20.0	...	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	B	10	30	60	20.0	20.0	20.0	20.0	20.0		20.0	...	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	B	10	30	60	20.0	20.0	20.0	20.0	20.0		20.0	...	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	C	10	33	66	22.0	22.0	22.0	22.0	22.0		22.0	...	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	C	10	33	66	22.0	22.0	22.0	22.0	22.0		22.0	...	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	C	10	33	66	22.0	22.0	22.0	22.0	22.0		22.0	...	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	C	10	33	66	22.0	22.0	22.0	22.0	22.0		22.0	...	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	C	10	33	66	22.0	22.0	22.0	22.0	22.0		22.0	...	...	...
AISI 1020	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
AISI 1022	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
AISI 1025	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
AISI 1026	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
AISI 1030	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	10,18,19	50	85	28.3	28.3	28.3	28.3	...	...	...	...	...	...
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	10,18,19	50	85	28.3	28.3	28.3	28.3	...	...	...	...	...	...
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	9,10,17	55	90	30.0	30.0	30.0	30.0	...	...	...	...	...	...

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400	500		650	700	750	800
Carbon Steels (Cont'd)																			
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	9,10,17	55	90	30.0	30.0	30.0	30.0	...	...	...	...	...	...
...	P–1	2	Bar	A675-90a	75	...	21	37.5	75	25.0	25.0	25.0	25.0	25.0		25.0	...	...	...
...	P–1	1	Bar	SA-675	65	...	...	32.5	65	21.7	21.7	21.7	21.7	21.7		21.7	...	...	...
...	P–1	2	Bar	SA-675	70	...	...	35	70	23.3	23.3	23.3	23.3	23.3		23.3	...	...	...
Low Alloy Steels																			
AISI 4130	S–4	3	Castings	A148-93b	90-60	...	2,8	60	90	30.0	30.0	30.0	30.0	30.0		30.0	30.0	...	...
AISI 4320	S–4	3	Castings	A148-93b	90-60	...	2,8	60	90	30.0	30.0	30.0	30.0	30.0		30.0	30.0	...	...
AISI 4330	S–4	3	Castings	A148-93D	90-60	...	2,8	60	90	30.0	30.0	30.0	30.0	30.0		30.0	30.0	...	...
Ni–Cr–Mo	S–11C	1	Castings	SA-487	10	B	...	100	125	41.7	41.7	41.7	41.7	41.7		41.7	41.7	...	...
Ni–Cr–Mo–V	P–11A	5	Forgings	SA-508	4N	2	...	100	115	38.3	38.3	38.3	37.9	37.7		...	...	...	...
...	P–11B	1	Plate	A514-94a	A	...	22	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	4	Plate	A514-94a	B	...	22	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	2	Plate	A514-94a	E	...	20	90	100	33.3	33.3	33.3	33.3	33.3		33.2	32.6	...	...
...	P–11B	2	Plate	A514-94a	E	...	3	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	3	Plate	A514-94a	F	...	3	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	S–11B	6	Plate	A514-94a	J	...	22	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	8	Plate	A514-94a	P	...	20	90	100	33.3	33.3	33.3	33.3	33.3		33.2	32.6	...	...
...	P–11B	8	Plate	A514-94a	P	...	3	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	9	Plate	A514-94a	Q	...	20	90	100	33.3	33.3	33.3	33.3	33.3		33.2	32.6	...	...
...	P–11B	9	Plate	A514-94a	Q	...	3	100	110	36.7	36.7	36.7	36.7	36.7		36.5	35.9	...	...
...	P–11B	1	Plate	SA-517	A	...	22	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
...	P–11B	4	Plate	SA-517	B	...	22	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
...	P–11B	2	Plate	SA-517	E	...	20	90	105	35.0	35.0	35.0	35.0	35.0		34.0	33.2	...	...
...	P–11B	2	Plate	SA-517	E	...	3	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
...	P–11B	3	Plate	SA-517	F	...	3	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
...	S–11B	6	Plate	SA-517	J	...	22	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
...	P–11B	8	Plate	SA-517	P	...	4	90	105	35.0	35.0	35.0	35.0	35.0		34.0	33.2	...	...
...	P–11B	8	Plate	SA-517	P	...	3	100	115	38.3	38.3	38.3	38.3	38.3		37.2	36.4	...	...
$2\frac{1}{4}$Cr–lMo	P–5C	4	Plate	SA-542	A,B	1	...	85	105	35.0	35.0	35.0	35.0	34.8		34.0	33.6	...	...
$2\frac{1}{4}$Cr–lMo	P–5C	5	Plate	SA-542	A,B	2	...	100	115	38.3	38.3	38.3	38.3	38.1		37.3	36.8	...	...
$2\frac{1}{4}$Cr–1Mo	P–5C	3	Plate	SA-542	A,B	3	...	75	95	31.7	31.7	31.7	31.7	31.5		30.8	30.4	...	...
$2\frac{1}{4}$Cr–lMo	P–5C	1	Plate	SA-542	A,B	4	...	60	85	28.3	28.3	28.3	28.3	28.2		27.5	27.2	...	...
Ni-Cr–Mo	P–11A	5	Plate	SA-543	B,C	1	...	85	105	35.0	35.0	35.0	34.6	34.4		...	...	...	...
Ni–Cr–Mo	P–11B	10	Plate	SA-543	B,C	2	...	100	115	38.3	38.3	38.3	37.9	37.6		...	...	...	...
Ni–Cr–Mo	P–3	3	Plate	SA-543	B,C	3	...	70	90	30.0	30.0	30.0	29.7	29.5		...	...	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	42	...	32	42	60	20.0	20.0	20.0	20.0	20.0		20.0	20.0	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	42	...	32	42	60	20.0	20.0	20.0	20.0	20.0		20.0	20.0	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	50	...	32	50	65	21.7	21.7	21.7	21.7	21.7		21.7	21.7	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	50	...	32	50	65	21.7	21.7	21.7	21.7	21.7		21.7	21.7	...	...

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F								
										100	200	300	400	500	650	700	750	800
Low Alloy Steels (Cont'd)																		
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	12,32	42	63	21.0	21.0	21.0	21.0	21.0	21.0	21.0	...	...
Mn–Ni–Cr–Cu-V	P–3	1	Plate	A588-97a	A,B	...	12,32	42	63	21.0	21.0	21.0	21.0	21.0	21.0	21.0	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,13,32	46	67	22.3	22.3	22.3	22.3	22.3	22.3	22.3	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,13,32	46	67	22.3	22.3	22.3	22.3	22.3	22.3	22.3	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,14,33	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.3	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,14,33	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.3	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Shapes	A588-97a	A,B	...	9,14,33	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.3	...	...
Mn–Cb	P–1	1	Bar	A633-95	A	...	17	42	63	21.0	21.0	21.0	21.0	21.0	21.0	20.8	...	...
Mn–Cb	P–1	1	Plate	A633-95	A	...	17	42	63	21.0	21.0	21.0	21.0	21.0	21.0	20.8	...	...
Mn–Cb	P–1	1	Shapes	A633-95	A	...	17	42	63	21.0	21.0	21.0	21.0	21.0	21.0	20.8	...	...
Mn–Cb	P–1	2	Bar	A633-95	C,D	...	3	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.1	...	...
Mn–Cb	P–1	2	Plate	A633-95	C,D	...	3	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.1	...	...
Mn–Cb	P–1	2	Shapes	A633-95	C,D	...	3	50	70	23.3	23.3	23.3	23.3	23.3	23.3	23.1	...	...
Mn–Cb-Ni-Cu	P–1	1	Bar	A633-95	C,D	...	4	46	65	21.7	21.7	21.7	21.7	21.7	21.7	21.5	...	...
Mn–Cb-Ni-Cu	P–1	1	Plate	A633-95	C,D	...	4	46	65	21.7	21.7	21.7	21.7	21.7	21.7	21.5	...	...
Mn–Cb-Ni-Cu	P–1	1	Shapes	A633-95	C,D	...	4	46	65	21.7	21.7	21.7	21.7	21.7	21.7	21.5	...	...
Mn–V–N	P–1	3	Bar	A633-95	E	...	5,14	60	80	26.7	26.7	26.7	26.7	26.7	26.7	26.4	...	...
Mn–V–N	P–1	3	Plate	A633-95	E	...	5,14	60	80	26.7	26.7	26.7	26.7	26.7	26.7	26.4	...	...
Mn–V–N	P–1	3	Shapes	A633-95	E	...	5,14	60	80	26.7	26.7	26.7	26.7	26.7	26.7	26.4	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	33.3	33.3	33.3	33.3	33.3	33.3	33.3	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	35.0	35.0	35.0	35.0	35.0	35.0	35.0	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	35.0	35.0	35.0	35.0	35.0	35.0	35.0	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	35.0	35.0	35.0	35.0	35.0	35.0	35.0	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	35.0	35.0	35.0	35.0	35.0	35.0	35.0	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	35.0	35.0	35.0	35.0	35.0	35.0	35.0	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	36.7	36.7	36.7	36.7	36.7	36.7	36.7	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	36.7	36.7	36.7	36.7	36.7	36.7	36.7	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	36.7	36.7	36.7	36.7	36.7	36.7	36.7	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	36.7	36.7	36.7	36.7	36.7	36.7	36.7	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	36.7	36.7	36.7	36.7	36.7	36.7	36.7	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	38.3	38.3	38.3	38.3	38.3	38.3	38.3	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	38.3	38.3	38.3	38.3	38.3	38.3	38.3	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	38.3	38.3	38.3	38.3	38.3	38.3	38.3	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	38.3	38.3	38.3	38.3	38.3	38.3	38.3	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	38.3	38.3	38.3	38.3	38.3	38.3	38.3	...	...

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F: 100	200	300	400	500	650	700	750	800
Low Alloy Steels (Cont'd)																		
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	41.7	41.7	41.7	41.7	41.7	41.7	41.7	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	41.7	41.7	41.7	41.7	41.7	41.7	41.7	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	41.7	41.7	41.7	41.7	41.7	41.7	41.7	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	41.7	41.7	41.7	41.7	41.7	41.7	41.7	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	41.7	41.7	41.7	41.7	41.7	41.7	41.7	...	...
Age Hardening Steels																		
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	1	11	85	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	11	85	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	11	85	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	1	23	80	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	23	80	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	23	80	90	30.0	30.0	30.0	30.0	30.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	24	65	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	24	65	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	24	65	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	25	60	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	25	60	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	25	60	72	24.0	24.0	24.0	24.0	24.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	26	55	65	21.7	21.7	21.7	21.7	21.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	26	55	65	21.7	21.7	21.7	21.7	21.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	26	55	65	21.7	21.7	21.7	21.7	21.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	3	27	75	85	28.3	28.3	28.3	28.3	28.3	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	27	75	85	28.3	28.3	28.3	28.3	28.3	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	27	75	85	28.3	28.3	28.3	28.3	28.3	...	...	...	...
Cr–Ni–Cu– Mo–Cb	S–12	1	Bar	A710-95	A	3	26	65	75	25.0	25.0	25.0	25.0	25.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	26	65	75	25.0	25.0	25.0	25.0	25.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	26	65	75	25.0	25.0	25.0	25.0	25.0	...	...	...	...

NOTE: *Notes follow Table 5.

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports

Material	P-No. or S-No..	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Allowable Stress, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400	500		650	700	750	800
Carbon Steels																			
AISI 1015	P–1	1	Bar	A108-99	1015CW	...	1,6,35	40	60	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1018	P–1	1	Bar	A108-99	1018CW	...	1,6,35	40	60	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1020	P–1	1	Bar	A108-99	1020CW	...	1,6,35	40	60	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1015	P–1	1	Tube	A513-98	1015CW	...	1,6,35	55	65	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A513-98	1020CW	...	1,6,35	60	70	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A513-98	1025CW	...	1,7,35	65	75	15.7	15.7	15.7	15.7	...	...	...	...	...	...
AISI 1026	P–1	3	Tube	A513-98	1026CW	...	1,7,35	70	80	15.7	15.7	15.7	15.7	...	...	...	...	...	...
AISI 1018	P–1	2	Tube	A519-96	1018CW	...	1,6,35	60	70	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A519-96	1020CW	...	1,6,35	60	70	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1022	P–1	2	Tube	A519-96	1022CW	...	1,6,35	60	70	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1018	P–1	1	Tube	A519-96	1018HR	...	35	32	50	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1020	P–1	1	Tube	A519-96	1020HR	...	35	32	50	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1022	P–1	1	Tube	A519-96	1022HR	...	35	32	50	14.3	14.3	14.3	14.3	...	...	...	...	...	...
AISI 1025	P–1	1	Tube	A519-96	1025HR	...	35	35	55	15.7	15.7	15.7	15.7	...	...	...	...	...	...
AISI 1026	P–1	1	Tube	A519-96	1026HR	...	35	35	55	15.7	15.7	15.7	15.7	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A519-96	1025CW	...	1,5,7,35	65	75	15.7	15.7	15.7	15.7	...	...	...	...	...	...
AISI 1026	P–1	2	Tube	A519-96	1026CW	...	1,5,7,35	65	75	15.7	15.7	15.7	15.7	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	A	...	35	25	42	12.0	12.0	12.0	12.0	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	B	...	35	30	45	12.9	12.9	12.9	12.9	...	...	...	...	...	...
...	S–1	1	Sheet	A611-97	C	...	35	33	48	13.7	13.7	13.7	13.7	...	...	...	...	...	...
...	S–1	1	Sheet	A653-99	A	...	15,35	33	45	12.9	12.9	12.9	12.9	...	...	...	...	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1330	S–1	1	Forgings	A668-96e1	...	B	10,35	30	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	C	10,35	33	66	18.9	18.9	18.9	18.9	...	...	...	...	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	C	10,35	33	66	18.9	18.9	18.9	18.9	...	...	...	...	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	C	10,35	33	66	18.9	18.9	18.9	18.9	...	...	...	...	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	C	10,35	33	66	18.9	18.9	18.9	18.9	...	...	...	...	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	C	10,35	33	66	18.9	18.9	18.9	18.9	...	...	...	...	...	...
AISI 1020	S–1	2	Forgings	A668-96e1	...	D	10,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1022	S–1	2	Forgings	A668-96e1	...	D	10,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1025	S–1	2	Forgings	A668-96e1	...	D	10,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1026	S–1	2	Forgings	A668-96e1	...	D	10,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1030	S–1	2	Forgings	A668-96e1	...	D	10,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No..	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Allowable Stress, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400	500		650	700	750	800
Carbon Steels (Cont'd)																			
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	10,18,19,35	50	85	24.3	24.3	24.3	24.3	...	...	...	...	...	...
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	10,18,19,35	50	85	24.3	24.3	24.3	24.3	...	...	...	...	...	...
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	9,10,17,35	55	90	25.7	25.7	25.7	25.7	...	...	...	...	...	...
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	9,10,17,35	55	90	25.7	25.7	25.7	25.7	...	...	...	...	...	...
...	P–1	2	Bar	A675-90a	75	...	21,35	37.5	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
...	P–1	1	Bar	SA-675	65	...	35	32.5	65	18.6	18.6	18.6	18.6	...	...	...	...	...	...
...	P–1	2	Bar	SA-675	70	...	35	35	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
Low Alloy Steels																			
AISI 4130	S–4	3	Castings	A148-93b	90-60	...	2,8,35	60	90	25.7	25.7	25.7	25.7	25.7		...	...	...	...
AISI 4320	S–4	3	Castings	A148-93b	90-60	...	2,8,35	60	90	25.7	25.7	25.7	25.7	25.7		...	...	...	...
AISI 4330	S–4	3	Castings	A148-93b	90-60	...	2,8,35	60	90	25.7	25.7	25.7	25.7	25.7		...	...	...	...
Ni–Cr–Mo	S–11C	1	Castings	SA-487	10	B	35	100	125	35.7	35.7	35.7	35.7	35.7		35.7	35.7	...	...
Ni–Cr–Mo–V	P–11A	5	Forgings	SA-508	4N	2	35	100	115	32.9	32.9	32.9	32.5	32.3		...	...	...	...
...	P-11B	1	Plate	A514-94a	A	...	22,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	P-11B	4	Plate	A514-94a	B	...	22,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	P-11B	2	Plate	A514-94a	E	...	20,35	90	100	28.6	28.6	28.6	28.6	28.6		28.6	28.0	...	...
...	P-11B	2	Plate	A514-94a	E	...	3,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	P-11B	3	Plate	A514-94a	F	...	3,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	S–11B	6	Plate	A514-94a	J	...	22,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	P-11B	8	Plate	A514-94a	P	...	20,35	90	100	28.6	28.6	28.6	28.6	28.6		28.6	28.0	...	...
...	P-11B	8	Plate	A514-94a	P	...	3,35	100	110	31.4	31.4	31.4	31.4	31.4		31.4	30.8	...	...
...	P-11B	9	Plate	A514-94a	Q	...	20,35	90	100	28.6	28.6	28.6	28.6	28.6		28.6	28.0	...	...
...	P-11B	9	Plate	A514-94a	Q	...	3,35	100	110	31.4	31.4	31.4	31. 4	31.		31. 4	30.8	...	...
...	P-11B	1	Plate	SA-517	A	...	22,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
...	P-11B	4	Plate	SA-517	B	...	22,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
...	P-11B	2	Plate	SA-517	E	...	20,35	90	105	30.0	30.0	30.0	30.0	30.0		30.0	29.4	...	...
...	P-11B	2	Plate	SA-517	E	...	3,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
...	P-11B	3	Plate	SA-517	F	...	3,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
...	S–11B	6	Plate	SA-517	J	...	22,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
...	P-11B	8	Plate	SA-517	P	...	4,35	90	105	30.0	30.0	30.0	30.0	30.0		30.0	29.4	...	...
...	P-11B	8	Plate	SA-517	P	...	3,35	100	115	32.9	32.9	32.9	32.9	32.9		32.9	32.2	...	...
$2^1/_4$Cr–1Mo	P–5C	4	Plate	SA-542	A,B	1	35	85	105	30.0	30.0	30.0	30.0	29.7		29.2	28.9	...	...
$2^1/_4$Cr–1Mo	P–5C	5	Plate	SA-542	A,B	2	35	100	115	32.9	32.9	32.9	32.9	32.5		31.9	31.6	...	...
$2^1/_4$Cr–1Mo	P–5C	3	Plate	SA-542	A,B	3	35	75	95	27.1	27.1	27.1	27.1	27.0		26.1	26.1	...	...
$2^1/_4$Cr–1Mo	P–5	1	Plate	SA-542	A,B	4	35	60	85	24.3	24.3	24.3	24.3	24.2		23.6	23.3	...	...
Ni–Cr–Mo	P–11A	5	Plate	SA-543	B,C	1	35	85	105	30.0	30.0	30.0	29.7	29.5		28.7	28.2	...	...
Ni–Cr–Mo	P–11B	10	Plate	SA-543	B,C	2	35	100	115	32.9	32.9	32.9	32.5	32.3		31.4	31.0	...	...

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No..	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Allowable Stress, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F: 100	200	300	400	500	650	700	750	800
Carbon Steels (Cont'd)																		
Ni–Cr–Mo	P–3	3	Plate	SA-543	B,C	3	35	70	90	25.7	25.7	25.7	25.5	25.3	24.6	24.2	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	42	...	35	42	60	17.1	17.1	17.1	17.1	17.1	17.1	17.1	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	42	...	35	42	60	17.1	17.1	17.1	17.1	17.1	17.1	17.1	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	50	...	35	50	65	18.6	18.6	18.6	18.6	18.6	18.6	18.6	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	50	...	35	50	65	18.6	18.6	18.6	18.6	18.6	18.6	18.6	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	12,32,35	42	63	18.0	18.0	18.0	18.0	18.0	18.0	18.0	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	12,32,35	42	63	18.0	18.0	18.0	18.0	18.0	18.0	18.0	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,13,32,35	46	67	19.1	19.1	19.1	19.1	19.1	19.1	19.1	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,13,32,35	46	67	19.1	19.1	19.1	19.1	19.1	19.1	19.1	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,14,33,35	50	70	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,14,33,35	50	70	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Shapes	A588-97a	A,B	...	9,14,33,35	50	70	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...
Mn–Cb	P–1	1	Plate	A633-95	A	...	17,35	42	63	18.0	18.0	18.0	18.0	18.0	18.0	17.8	...	...
Mn–Cb	P–1	1	Shapes	A633-95	A	...	17,35	42	63	18.0	18.0	18.0	18.0	18.0	18.0	17.8	...	...
Mn–Cb	P–1	2	Plate	A633-95	C,D	...	3,35	50	70	20.0	20.0	20.0	20.0	20.0	20.0	19.8	...	...
Mn–Cb	P–1	2	Shapes	A633-95	C,D	...	3,35	50	70	20.0	20.0	20.0	20.0	20.0	20.0	19.8	...	...
Mn–Cr–Ni–Cu	P–1	1	Plate	A633-95	C,D	...	4,35	46	65	18.6	18.6	18.6	18.6	18.6	18.6	18.4	...	...
Mn–Cr–Ni–Cu	P–1	1	Shapes	A633-95	C,D	...	4,35	46	65	18.6	18.6	18.6	18.6	18.6	18.6	18.4	...	...
Mn–V–N	P–1	3	Plate	A633-95	E	...	5,14,35	60	80	22.9	22.9	22.9	22.9	22.9	22.9	22.3	...	...
Mn–V–N	P–1	3	Shapes	A633-95	E	...	5,14,35	60	80	22.9	22.9	22.9	22.9	22.9	22.9	22.3	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	10,19,35	75	100	28.6	28.6	28.6	28.6	28.6	28.6	28.6	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	10,19,35	75	100	28.6	28.6	28.6	28.6	28.6	28.6	28.6	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	10,19,35	75	100	28.6	28.6	28.6	28.6	28.6	28.6	28.6	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	10,19,35	75	100	28.6	28.6	28.6	28.6	28.6	28.6	28.6	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	10,19,35	75	100	28.6	28.6	28.6	28.6	28.6	28.6	28.6	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	9,10,16,35	80	105	30.0	30.0	30.0	30.0	30.0	30.0	...	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	9,10,16,35	80	105	30.0	30.0	30.0	30.0	30.0	30.0	...	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	9,10,16,35	80	105	30.0	30.0	30.0	30.0	30.0	30.0	...	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	9,10,16,35	80	105	30.0	30.0	30.0	30.0	30.0	30.0	...	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	9,10,16,35	80	105	30.0	30.0	30.0	30.0	30.0	30.0	...	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,10,19,35	85	110	31.4	31.4	31.4	31.4	31.4	31.4	31.4	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,10,19,35	85	110	31.4	31.4	31.4	31.4	31.4	31.4	31.4	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,10,19,35	85	110	31.4	31.4	31.4	31.4	31.4	31.4	31.4	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,10,19,35	85	110	31.4	31.4	31.4	31.4	31.4	31.4	31.4	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,10,19,35	85	110	31.4	31.4	31.4	31.4	31.4	31.4	31.4	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18,35	95	115	32.9	32. 9	32. 9	32.9	32.	32 .9	32.9	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18,35	95	115	32.9	32.9	32.9	32.9	32.9	32.9	32.9	...	...

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No..	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Allowable Stress, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F								
										100	200	300	400	500	650	700	750	800
Carbon Steels (Cont'd)																		
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18,35	95	115	32.9	32.9	32.9	32.9	32.9	32.9	32.9	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18,35	95	115	32.9	32.9	32.9	32.9	32.9	32.9	32.9	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18,35	95	115	32.9	32.9	32.9	32.9	32.9	32.9	32.9	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17,35	105	125	35.7	35.7	35.7	35.7	35.7	...	...	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17,25	105	125	35.7	35.7	35.7	35.7	35.7	...	...	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17,35	105	125	35.7	35.7	35.7	35.7	35.7	...	...	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17,35	105	125	35.7	35.7	35.7	35.7	35.7	...	...	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17,35	105	125	35.7	35.7	35.7	35.7	35.7	...	...	...	...
Age Hardening Steels																		
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	1	11,35	85	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	11,35	85	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	11,35	85	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	1	23,35	80	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	23,35	80	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	23,35	80	90	25.7	25.7	25.7	25.7	25.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	24,35	65	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	24,35	65	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	24,35	65	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	25,35	60	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	25,35	60	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	25,35	60	72	20.6	20.6	20.6	20.6	20.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	26,35	55	65	18.6	18.6	18.6	18.6	18.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	26,35	55	65	18.6	18.6	18.6	18.6	18.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	26,35	55	65	18.6	18.6	18.6	18.6	18.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	3	27,35	75	85	24.3	24.3	24.3	24.3	24.3	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	27,35	75	85	24.3	24.3	24.3	24.3	24.3	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	27,35	75	85	24.3	24.3	24.3	24.3	24.3	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	3	26,35	65	75	21.4	21.4	21.4	21.4	21.4	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	26,35	65	75	21.4	21.4	21.4	21.4	21.4	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	26,35	65	75	21.4	21.4	21.4	21.4	21.4	...	...	...	...

NOTE: *Notes follow Table 5.

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400			650	700	750	800
Carbon Steels																			
AISI 1015	P–1	1	Bar	A108-99	1015CW	...	1,6	40	60	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1018	P–1	1	Bar	A108-99	1018CW	...	1,6	40	60	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1020	P–1	1	Bar	A108-99	1020CW	...	1,6	40	60	32.0	29.2	28.3	27.4	...	...	...	...	...	...
...	P–1	1	Plate	SA-283	C	...	...	30	55	30.0	27.3	26.6	25.7	...	...	...	...	...	...
...	P–1	1	Pipe	A381-96	...	Y35	...	35	60	35.0	31.9	31.0	30.0	28.3		25.6	25.2	...	...
...	P–1	1	Tblr. shapes	A500-99	B	...	...	46	58	46.0	41.9	40.8	39.4	37.2		33.3	33.1	...	...
...	P–1	1	Tblr. shapes	A500-99	C	...	...	50	62	50.0	45.6	44.3	42.9	40.4		36.3	36.0	...	...
...	P–1	1	Rnd. tube	A500-99	B	...	...	42	58	42.0	38.3	37.2	35.9	33.9		30.4	30.2	...	...
...	P–1	1	Rnd. tube	A500-99	C	...	...	46	62	46.0	41.9	40.8	39.4	37.2		33.3	33.1	...	...
...	P–1	1	Strl. tube	A501-99	...	...	...	36	58	36.0	32.8	31.9	30.8	29.1		26.1	25.9	...	...
AISI 1015	P–1	1	Tube	A513-98	1015CW	...	1,6	55	65	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A513-98	1020CW	...	1,6	60	70	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A513-98	1025CW	...	1,7	65	75	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1026	P–1	3	Tube	A513-98	1026CW	...	1,7	70	80	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1018	P–1	2	Tube	A519-96	1018CW	...	1,6	60	70	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1020	P–1	2	Tube	A519-96	1020CW	...	1,6	60	70	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1022	P–1	2	Tube	A519-96	1022CW	...	1,6	60	70	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1018	P–1	1	Tube	A519-96	1018HR	...	...	32	50	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1020	P–1	1	Tube	A519-96	1020HR	...	...	32	50	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1022	P–1	1	Tube	A519-96	1022HR	...	...	32	50	32.0	29.2	28.3	27.4	...	...	...	...	...	...
AISI 1025	P–1	1	Tube	A519-96	1025HR	...	...	35	55	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1026	P–1	1	Tube	A519-96	1026HR	...	...	35	55	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1025	P–1	2	Tube	A519-96	1025CW	...	1,5,7	65	75	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1026	P–1	2	Tube	A519-96	1026CW	...	1,5,7	65	75	35.0	31.9	31.0	30.0	...	...	...	...	...	...
AISI 1020	S–1	1	Forgings	A521-96	...	CC	...	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1025	S–1	1	Forgings	A521-96	...	CC	...	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1030	S–1	1	Forgings	A521-96	...	CC	...	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1020	S–1	2	Forgings	A521-96	...	CE	...	37	75	37.0	33.7	32.8	31.7	29.9		26.9	26.6	...	...
AISI 1025	S–1	2	Forgings	A521-96	...	CE	...	37	75	37.0	33.7	32.8	31.7	29.9		26.9	26.6	...	...
AISI 1030	S–1	2	Forgings	A521-96	...	CE	...	37	75	37.0	33.7	32.8	31.7	29.9		26.9	26.6	...	...
...	P–1	1	Pipe	SA-524	I	...	...	35	60	35.0	31.9	31.0	30.0	...	...	...	...	...	...
...	P–1	1	Pipe	SA-524	II	...	...	30	55	30.0	27.3	26.6	26.7	...	...	...	...	...	...
...	S–1	1	Sheet	A570-98	33	...	...	33	52	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
...	S–1	1	Strip	A570-98	33	...	...	33	52	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
...	S–1	1	Sheet	A570-98	36	...	...	36	53	36.0	32.8	31.9	30.8	29.1		26.1	25.9	...	...
...	S–1	1	Strip	A570-98	36	...	...	36	53	36.0	32.8	31.9	30.8	29.1		26.1	25.9	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F									
										100	200	300	400			650	700	750	800
Carbon Steels (Cont'd)																			
...	S–1	1	Sheet	A570-98	45	...	...	45	60	45.0	41.0	39.9	38.5	36.4		32.6	32.4	...	...
...	S–1	1	Strip	A570-98	45	...	...	45	60	45.0	41.0	39.9	38.5	36.4		32.6	32.4	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	B	10	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	B	10	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	B	10	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	B	10	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	B	10	30	60	30.0	27.3	26.6	25.7	24.3		21.8	21.6	...	...
AISI 1020	S–1	1	Forgings	A668-96e1	...	C	10	33	66	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
AISI 1022	S–1	1	Forgings	A668-96e1	...	C	10	33	66	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
AISI 1025	S–1	1	Forgings	A668-96e1	...	C	10	33	66	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
AISI 1026	S–1	1	Forgings	A668-96e1	...	C	10	33	66	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
AISI 1030	S–1	1	Forgings	A668-96e1	...	C	10	33	66	33.0	30.1	29.2	28.3	26.5		24.1	23.8	...	...
AISI 1020	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	37.5	34.2	33.2	32.1	30.3		27.2	27.0	...	...
AISI 1022	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	37.5	34.2	33.2	32.1	30.3		27.2	27.0	...	...
AISI 1025	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	37.5	34.2	33.2	32.1	30.3		27.2	27.0	...	...
AISI 1026	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	37.5	34.2	33.2	32.1	30.3		27.2	27.0	...	...
AISI 1030	S–1	2	Forgings	A668-96e1	...	D	10	37.5	75	37.5	34.2	33.2	32.1	30.3		27.2	27.0	...	...
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	10,18,19	50	85	50.0	45.6	44.3	42.9	40.4		36.3	36.0	...	...
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	10,18,19	50	85	50.0	45.6	44.3	42.9	40.4		36.3	36.0	...	...
AISI 1030	S–1	3	Forgings	A668-96e1	...	F	9,10,17	55	90	55.0	50.2	48.6	47.1	44.5		39.9	39.6	...	...
AISI 1330	S–1	3	Forgings	A668-96e1	...	F	9,10,17	55	90	55.0	50.2	48.6	47.1	44.5		39.9	39.6	...	...
...	P–1	2	Bar	A675-90a	75	...	21	37.5	75	37.5	34.2	33.2	32.1	30.3		27.4	27.0	...	...
...	P–1	1	Bar	SA-675	65	...	...	32.5	65	32.5	29.6	28.8	27.9	26.3		23.8	23.4	...	...
...	P–1	2	Bar	SA-675	70	...	...	35	70	35.0	31.9	31.0	30.0	28.3		25.6	25.2	...	...
Low Alloy Steels																			
AISI 4130	S–4	3	Castings	A148-93b	90-60	...	2,8	60	90	60.0	58.2	55.9	52.8	50.1		...	...	...	...
AISI 4320	S–4	3	Castings	A148-93b	90-60	...	2,8	60	90	60.0	58.2	55.9	52.8	50.1		...	...	...	...
AISI 4330	S–4	3	Castings	A148-93b	90-60	...	2,8	60	90	60.0	58.2	55.9	52.8	50.1		...	...	...	...
AISI 8620	S–3	3	Bar	A331-95	8620CW	...	1,5	75	90	35.0	31.9	31.0	30.0	...	...	...	...	...	...
Ni–Cr–Mo	S–11C	1	Castings	SA-487	10	B	...	100	125	100.0	97.0	93.2	88.0	83.5		83.0	83.0	...	...
Ni–Cr–Mo–V	P–11A	5	Forgings	SA-508	4N	2	...	100	115	100.0	94.2	91.2	89.2	87.7		...	...	...	...
...	P–11B	1	Plate	A514-94a	A	...	22	100	110	100.0	95.5	92.5	89.8	87.6		84.3	83.0	...	...
...	P–11B	4	Plate	A514-94a	B	...	22	100	110	100.0	95.5	92.5	89.8	87.6		84.3	83.0	...	...
...	P–11B	2	Plate	A514-94a	E	...	20	90	100	90.0	86.0	83.3	80.8	78.8		75.9	74.7	...	...
...	P–11B	2	Plate	A514-94a	E	...	3	100	110	100.0	95.5	92.5	89.8	87.6		84.3	83.0	...	...
...	P–11B	3	Plate	A514-94a	F	...	3	100	110	100.0	95.5	92.5	89.8	87.6		84.3	83.0	...	...
...	S–11B	6	Plate	A514-94a	J	...	22	100	110	100.0	95.5	92.5	89.8	87.6		84.3	83.0	...	...
...	P–11B	8	Plate	A514-94a	P	...	20	90	100	90.0	86.0	83.3	80.8	78.8		75.9	74.7	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F 100	200	300	400		650	700	750	800
Low Alloy Steels (Cont'd)																		
...	P–11B	8	Plate	A514-94a	P	...	3	100	110	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	9	Plate	A514-94a	Q	...	20	90	100	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
...	P–11B	9	Plate	A514-94a	Q	...	3	100	110	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	1	Plate	SA-517	A	...	22	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	4	Plate	SA-517	B	...	22	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	2	Plate	SA-517	E	...	20	90	105	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
...	P–11B	2	Plate	SA-517	E	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	3	Plate	SA-517	F	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	S–11B	6	Plate	SA-517	J	...	22	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
...	P–11B	8	Plate	SA-517	P	...	4	90	105	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
...	P–11B	8	Plate	SA-517	P	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
2¼Cr–1Mo	P–5C	4	Plate	SA-542	A,B	1	...	85	105	85.0	81.6	79.6	78.1	76.8	74.4	73.4	...	...
2¼Cr–1Mo	P–5C	5	Plate	SA-542	A,B	2	...	100	115	100.0	92.4	89.5	87.6	86.1	83.4	82.1	...	...
2¼Cr–1Mo	P–5C	3	Plate	SA-542	A,B	3	...	75	95	75.0	72.0	70.3	68.9	67.7	65.6	64.1	...	...
2¼Cr–1Mo	P–5C	1	Plate	SA-542	A,B	4	...	60	85	60.0	57.6	56.2	55.1	54.1	52.5	51.8	...	...
Ni–Cr–Mo	P–11A	5	Plate	SA-543	B,C	1	...	85	105	85.0	80.0	77.5	75.9	74.5	...	...	...	...
Ni–Cr–Mo	P–11B	10	Plate	SA-543	B,C	2	...	100	115	100.0	94.2	91.2	89.2	87.7	...	...	...	...
Ni–Cr–Mo	P–3	3	Plate	SA-543	B,C	3	...	70	90	70.0	65.9	63.8	62.4	61.4	59.5	58.7	...	...
Mn–Cb–V	P–1	1	Bar	A572-99a	42	...	...	42	60	42.0	40.0	38.3	36.8	35.2	32.7	31.8	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	42	...	...	42	60	42.0	40.0	38.3	36.8	35.2	32.7	31.8	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	42	...	...	42	60	42.0	40.0	38.3	36.8	35.2	32.7	31.8	...	...
Mn–Cb–V	P–1	1	Bar	A572-99a	50	...	...	50	65	50.0	47.5	45.6	43.8	41.8	38.9	37.9	...	...
Mn–Cb–V	P–1	1	Plate	A572-99a	50	...	...	50	65	50.0	47.5	45.6	43.8	41.8	38.9	37.9	...	...
Mn–Cb–V	P–1	1	Shapes	A572-99a	50	...	...	50	65	50.0	47.5	45.6	43.8	41.8	38.9	37.9	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	12,32	42	63	42.0	40.0	38.3	36.8	35.2	32.7	31.8	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	12,32	42	63	42.0	40.0	38.3	36.8	35.2	32.7	31.8	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,13,32	46	67	46.0	43.8	41.9	40.3	38.6	35.8	34.8	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,13,32	46	67	46.0	43.8	41.9	40.3	38.6	35.8	34.8	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Bar	A588-97a	A,B	...	9,14,33	50	70	50.0	47.5	45.6	43.0	41.8	38.9	37.9	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Plate	A588-97a	A,B	...	9,14,33	50	70	50.0	47.5	45.6	43.0	41.8	38.9	37.9	...	...
Mn–Ni–Cr–Cu–V	P–3	1	Shapes	A588-97a	A,B	...	9,14,33	50	70	50.0	47.5	45.6	43.0	41.8	38.9	37.9	...	...
½Cr–¼Ni–Si	P–11B	1	Forgings	SA-592	A	...	4	90	105	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
½Cr–¼Ni–Si	P–11B	1	Forgings	SA-592	A	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
1¾Cr–½Mo–Cu	P–11B	2	Forgings	SA-592	E	...	4	90	105	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
1¾Cr–½Mo–Cu	P–11B	2	Forgings	SA-592	E	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
¾Ni–½Cr–½Mo–V	P–11B	3	Forgings	SA-592	F	...	4	90	105	90.0	86.0	83.3	80.8	78.8	75.9	74.7	...	...
¾Ni–½Cr–½Mo–V	P–11B	3	Forgings	SA-592	F	...	3	100	115	100.0	95.5	92.5	89.8	87.6	84.3	83.0	...	...
Mn–Cu–V	P–1	2	Tube	A618-99	II	...	30	50	70	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F								
										100	200	300	400		650	700	750	800
Low Alloy Steels (Cont'd)																		
Mn–Cu–V	P–1	2	Tube	A618-99	II	...	31	46	67	46.0	41.7	38.4	35.0	31.8	30.9	30.5	...	...
Mn–V	P–1	1	Tube	A618-99	III	...	...	50	65	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...
Mn–Cb	P–1	1	Plate	A633-95	A	...	...	42	63	42.0	38.2	35.1	31.9	29.1	28.2	27.8	...	...
Mn–Cb	P–1	1	Shapes	A633-95	A	...	...	42	63	42.0	38.2	35.1	31.9	29.1	28.2	27.8	...	...
Mn–Cb	P–1	1	Plate	A633-95	C,D	...	4	46	65	46.0	41.8	38.4	35.0	31.8	30.9	30.4	...	...
Mn–Cb	P–1	1	Shapes	A633-95	C,D	...	4	46	65	46.0	41.8	38.4	35.0	31.8	30.9	30.4	...	...
Mn–Cb	P–1	2	Plate	A633-95	C,D	...	3	50	70	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...
Mn–Cb	P–1	2	Shape	A633-95	C,D	...	3	50	70	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...
Mn–Cr–Ni–Cu	P–1	1	Plate	A633-95	C,D	...	4	46	65	46.0	41.8	38.4	35.0	31.8	30.9	30.4	...	...
Mn–Cr–Ni–Cu	P–1	1	Shapes	A633-95	C,D	...	4	46	65	46.0	41.8	38.4	35.0	31.8	30.9	30.4	...	...
Mn–Cr–Ni–Cu	P–1	2	Plate	A633-95	C,D	...	3	50	70	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...
Mn–Cr–Ni–Cu	P–1	2	Shapes	A633-95	C,D	...	3	50	70	50.0	45.4	41.7	38.0	34.6	33.6	33.1	...	...
Mn–V–N	P–1	3	Plate	A633-95	E	...	5,14	60	80	60.0	54.5	50.1	45.6	41.4	40.3	39.7	...	...
Mn–V–N	P–1	3	Shapes	A633-95	E	...	5,14	60	80	60.0	54.5	50.1	45.6	41.4	40.3	39.7	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	75.0	70.1	67.7	65.8	63.8	59.0	57.0	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	75.0	70.1	67.7	65.8	63.8	59.0	57.0	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	75.0	70.1	67.7	65.8	63.8	59.0	57.0	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	75.0	70.1	67.7	65.8	63.8	59.0	57.0	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	10,19	75	100	75.0	70.1	67.7	65.8	63.8	59.0	57.0	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	80.0	74.8	72.3	70.3	68.1	63.1	60.9	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	80.0	74.8	72.3	70.3	68.1	63.1	60.9	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	80.0	74.8	72.3	70.3	68.1	63.1	60.9	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	80.0	74.8	72.3	70.3	68.1	63.1	60.9	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	K	9,10,16	80	105	80.0	74.8	72.3	70.3	68.1	63.1	60.9	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	85.0	79.5	76.8	74.6	72.4	67.0	64.6	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	85.0	79.5	76.8	74.6	72.4	67.0	64.6	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	85.0	79.5	76.8	74.6	72.4	67.0	64.6	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	85.0	79.5	76.8	74.6	72.4	67.0	64.6	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,10,19	85	110	85.0	79.5	76.8	74.6	72.4	67.0	64.6	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	95.0	88.5	85.4	83.0	80.0	74.6	72.0	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	95.0	88.5	85.4	83.0	80.0	74.6	72.0	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	95.0	88.5	85.4	83.0	80.0	74.6	72.0	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	95.0	88.5	85.4	83.0	80.0	74.6	72.0	...	...
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,18	95	115	95.0	88.5	85.4	83.0	80.0	74.6	72.0	...	...
AISI 4130	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	105.0	98.1	94.8	92.2	89.4	82.9	79.8	...	...
AISI 4320	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	105.0	98.1	94.8	92.2	89.4	82.9	79.8	...	...
AISI 4330	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	105.0	98.1	94.8	92.2	89.4	82.9	79.8	...	...
AISI 8620	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	105.0	98.1	94.8	92.2	89.4	82.9	79.8	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	P-No. or S-No.	Group No.	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply to Obtain psi) for Metal Temperatures Exceeding, °F								
										100	200	300	400		650	700	750	800
Low Alloy Steels (Cont'd)																		
AISI 8630	S–4	3	Forgings	A668-96e1	...	L	2,9,10,17	105	125	105.0	98.1	94.8	92.2	89.4	82.9	79.8	...	...
Age Hardening Steels																		
Cr–Ni–Cu–Mo– Cb	S–12	1	Bar	A710-95	A	1	11	85	90	85.0	80.0	77.1	74.1	71.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	11	85	90	85.0	80.0	77.1	74.1	71.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	11	85	90	85.0	80.0	77.1	74.1	71.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	1	23	80	90	80.0	75.3	72.6	69.4	67.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	1	23	80	90	80.0	75.3	72.6	69.4	67.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	1	23	80	90	80.0	75.3	72.6	69.4	67.6	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	24	65	72	65.0	61.1	56.5	56.8	54.9	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	24	65	72	65.0	61.1	56.5	56.8	54.9	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	24	65	72	65.0	61.1	56.5	56.8	54.9	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	25	60	72	60.0	56.5	54.1	52.4	50.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	25	60	72	60.0	56.5	54.1	52.4	50.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	25	60	72	60.0	56.5	54.1	52.4	50.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	2	26	55	65	55.0	51.8	47.6	48.1	46.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	2	26	55	65	55.0	51.8	47.6	48.1	46.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	2	26	55	65	55.0	51.8	47.6	48.1	46.5	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	3	27	75	85	75.0	70.6	68.0	66.0	65.4	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	27	75	85	75.0	70.6	68.0	66.0	65.4	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	27	75	85	75.0	70.6	68.0	66.0	65.4	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Bar	A710-95	A	3	26	65	75	65.0	61.2	57.0	56.6	54.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Plate	A710-95	A	3	26	65	75	65.0	61.2	57.0	56.6	54.7	...	...	...	...
Cr–Ni–Cu–Mo–Cb	S–12	1	Shapes	A710-95	A	3	26	65	75	65.0	61.2	57.0	56.6	54.7	...	...	...	...

NOTE: *Notes follow Table 5.

Table 4
Yield Strength Values, S_y, for Bolting Materials for Classes 1, 2, 3, and MC Supports

Material	P-No. or S-No.	Group No.	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1,000 to Obtain psi) for Metal Temperatures Not Exceeding, °F									
									100	200	300	400	500		650	700	750	800
Carbon Steels																		
C–Mn	P–1	1	SA-36	...	...	28,34	36	58	36.0	32.8	31.9	30.8	29.1		26.1	25.9	...	...
Austenitic Stainless Steels																		
18Cr–8Ni	S–8	1	SA-193	B8	1	...	30	75	30.0	25.0	22.5	20.7	19.4		17.9	17.7	17.3	16.8
18Cr–8Ni	S–8	1	SA-193	B8A	1A	...	30	75	30.0	25.0	22.5	20.7	19.4		17.9	17.7	17.3	16.8
18Cr–10Ni–Cb	S–8	1	SA-193	B8C	1	...	30	75	30.0	27.5	25.6	23.9	22.5		21.0	20.6	20.5	20.3
18Cr–10Ni–Cb	S–8	1	SA-193	B8CA	1A	...	30	75	30.0	27.5	25.6	23.9	22.5		21.0	20.6	20.5	20.3
16Cr–12Ni–2Mo	S–8	1	SA-193	B8M	1	...	30	75	30.0	25.8	23.3	21.4	19.9		18.5	18.1	17.8	17.6
16Cr–12Ni–2Mo	S–8	1	SA-193	B8MA	1A	...	30	75	30.0	25.8	23.3	21.4	19.9		18.5	18.1	17.8	17.6
18Cr–10Ni–Ti	S–8	1	SA-193	B8T	1	...	30	75	30.0	25.4	22.7	20.6	19.1		17.8	17.5	17.3	17.2
18Cr–10Ni–Ti	S–8	1	SA-193	B8TA	1A	...	30	75	30.0	25.4	22.7	20.6	19.1		17.8	17.5	17.3	17.2
18Cr–8Ni	S–8	1	SA-194	8A	...	29	...	...	...	...	...	...	...	...	...	...	...	...
18Cr–10Ni–Cb	S–8	1	SA-194	8CA	...	29	...	...	...	...	...	...	...	...	...	...	...	...
16Cr–12Ni–Mo	S–8	1	SA-194	8MA	...	29	...	...	...	...	...	...	...	...	...	...	...	...
18Cr–10Ni–Ti	S–8	1	SA-194	8TA	...	29	...	...	...	...	...	...	...	...	...	...	...	...
18Cr–8Ni–S	S–8	1	SA-320	B8F	1	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni–S	S–8	1	SA-320	B8FA	1A	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni	S–8	1	SA-320	B8A	1	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni	S–8	1	SA-320	B8	1A	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–10Ni–Cb	S–8	1	SA-320	B8C	1	...	30	75	30.0	27.5	25.6	23.9	...	...	...	...	...	...
18Cr–10Ni–Cb	S–8	1	SA-320	B8CA	1A	...	30	75	30.0	27.5	25.6	23.9	...	...	...	...	...	...
18Cr–10Ni–Ti	S–8	1	SA-320	B8T	1	...	30	75	30.0	25.4	22.7	20.6	...	...	...	...	...	...
18Cr–10Ni–Ti	S–8	1	SA-320	B8TA	1A	...	30	75	30.0	25.4	22.7	20.6	...	...	...	...	...	...
16Cr–12Ni–2Mo	S–8	1	SA-320	B8M	1	...	30	75	30.0	25.8	23.3	21.4	...	...	...	...	...	...
16Cr–12Ni–2Mo	S–8	1	SA-320	B8MA	1A	...	30	75	30.0	25.8	23.3	21.4	...	...	...	...	...	...

NOTE: *Notes follow Table 5.

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Not Exceeding, °F									
							100	200	300	400	500	600		700	750	800
Carbon Steels																
...	Bar	SA-36	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
...	Plate	SA-36	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
...	Shapes	SA-36	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
AISI 1015	Bar	A108-99	1015CW	...	40	60	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1018	Bar	A108-99	1018CW	...	40	60	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1020	Bar	A108-99	1020CW	...	40	60	50.0	50.0	50.0	50.0	...	...	...	...	...	...
...	Plate	SA-283	C	...	30	55	55.0	55.0	55.0	55.0	...	...	...	...	...	...
...	Pipe	A381-96	...	Y35	35	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
...	Tblr. shapes	A500-99	B	...	46	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
...	Tblr. shapes	A500-99	C	...	50	62	62.0	62.0	62.0	62.0	...	...	...	...	...	...
...	Rnd. tube	A500-99	B	...	42	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
...	Rnd. tube	A500-99	C	...	46	62	62.0	62.0	62.0	62.0	...	...	...	...	...	...
...	Strl. tube	A501-99	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
AISI 1015	Tube	A513-98	1015CW	...	55	65	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1020	Tube	A513-98	1020CW	...	60	70	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1025	Tube	A513-98	1025CW	...	65	75	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1026	Tube	A513-98	1026CW	...	70	80	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018CW	...	60	70	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020CW	...	60	70	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022CW	...	60	70	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018HR	...	32	50	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020HR	...	32	50	50.0	50.0	50.0	50.0	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022HR	...	32	50	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025HR	...	35	55	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026HR	...	35	55	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025CW	...	65	75	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026CW	...	65	75	55.0	55.0	55.0	55.0	...	...	...	...	...	...
AISI 1020	Forgings	A521-96	...	CC	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1025	Forgings	A521-96	...	CC	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1030	Forgings	A521-96	...	CC	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1020	Forgings	A521-96	...	CE	37	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1025	Forgings	A521-96	...	CE	37	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1030	Forgings	A521-96	...	CE	37	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
...	Pipe	SA-524	I	...	35	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
...	Pipe	SA-524	II	...	30	55	55.0	55.0	55.0	55.0	...	...	...	...	...	...
...	Sheet	A570-98	33	...	33	52	52.0	52.0	52.0	52.0	...	...	...	...	...	...
...	Sheet	A570-98	36	...	36	53	53.0	53.0	53.0	53.0	...	...	...	...	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
							100	200	300	400	500		650	700	750	800
Carbon Steels (Cont'd)																
...	Sheet	A570-98	45	...	45	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
...	Sheet	A611-97	A	...	25	42	42.0	42.0	42.0	42.0	...	...	...	...	...	...
...	Sheet	A611-97	B	...	30	45	45.0	45.0	45.0	45.0	...	...	...	...	...	...
...	Sheet	A611-97	C	...	33	48	48.0	48.0	48.0	48.0	...	...	...	...	...	...
...	Sheet	A653-99	A	...	33	45	45.0	45.0	45.0	45.0	...	...	...	...	...	...
AISI 1020	Forgings	A668-96e1	...	B	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1022	Forgings	A668-96e1	...	B	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1025	Forgings	A668-96e1	...	B	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1026	Forgings	A668-96e1	...	B	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1030	Forgings	A668-96e1	...	B	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1020	Forgings	A668-96e1	...	C	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1022	Forgings	A668-96e1	...	C	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1025	Forgings	A668-96e1	...	C	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1026	Forgings	A668-96e1	...	C	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1030	Forgings	A668-96e1	...	C	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1020	Forgings	A668-96e1	...	D	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1022	Forgings	A668-96e1	...	D	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1025	Forgings	A668-96e1	...	D	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1026	Forgings	A668-96e1	...	D	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1030	Forgings	A668-96e1	...	D	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1030	Forgings	A668-96e1	...	F	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1330	Forgings	A668-96e1	...	F	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1030	Forgings	A668-96e1	...	F	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
AISI 1330	Forgings	A668-96e1	...	F	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
...	Bar	A675-90a	75	...	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
...	Bar	SA-675	65	...	32.5	65	65.0	65.0	65.0	65.0	...	...	...	...	...	...
...	Bar	SA-675	70	...	35	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
Low Alloy Steels																
AISI 4130	Castings	A148-93b	90-60	...	60	90	90.0	90.0	90.0	90.0	90.0	90.0		90.0	...	...
AISI 4330	Castings	A148-93b	90-60	...	60	90	90.0	90.0	90.0	90.0	90.0	90.0		90.0	...	...
9Cr–1Mo	Castings	SA-217	C12	...	60	90	90.0	89.6	87.2	86.6	86.2	85.0		82.0	...	...
AISI 8620	Bar	A331-95	8620CW	...	75	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
Ni–Cr–Mo	Castings	SA-487	10	B	100	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
Ni–Cr–Mo–V	Forgings	SA-508	4N	2	100	115	115.0	115.0	115.0	113.9	113.1	111.4	110.0	108.1	...	...
...	Plate	A514-94a	A	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	B	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	E	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
							100	200	300	400	500		650	700	750	800
Low Alloy Steels (Cont'd)																
...	Plate	A514-94a	E	...	90	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.9	...	...
...	Plate	A514-94a	F	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	J	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	P	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	P	...	90	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.9	...	...
...	Plate	A514-94a	Q	...	100	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	107.7	...	...
...	Plate	A514-94a	Q	...	90	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.9	...	...
...	Plate	SA-517	A	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Plate	SA-517	B	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Plate	SA-517	E	...	90	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	102.8	...	...
...	Plate	SA-517	E	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Plate	SA-517	F	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Plate	SA-517	J	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Plate	SA-517	P	...	90	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	102.8	...	...
...	Plate	SA-517	P	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
$2^1/_4$Cr–1Mo	Plate	SA-542	A,B	1	85	105	105.0	105.0	105.0	105.0	104.0	103.1	102.1	101.0	...	...
$2^1/_4$Cr–1Mo	Plate	SA-542	A,B	2	100	115	115.0	115.0	115.0	115.0	113.9	112.9	111.8	110.6	...	...
$2^1/_4$Cr–1Mo	Plate	SA-542	A,B	3	75	95	95.0	95.0	95.0	95.0	94.6	93.2		91.4	...	...
$2^1/_4$Cr–1Mo	Plate	SA-542	A,B	4	60	85	85.0	85.0	85.0	85.0	84.6	83.4		81.7	...	...
Ni–Cr–Mo	Plate	SA-543	B,C	1	85	105	105.0	105.0	105.0	104.0	103.3	101.9	100.4	98.8	...	...
Ni–Cr–Mo	Plate	SA-543	B,C	2	100	115	115.0	115.0	115.0	113.9	113.1	111.5	109.9	108.4	...	...
Ni–Cr–Mo	Plate	SA-543	B,C	3	70	90	90.0	90.0	90.0	98.1	88.6	87.3		84.7	...	...
Mn–Cb–V	Bar	A572-99a	42	...	42	60	60.0	60.0	60.0	60.0	60.0	60.0		60.0	...	...
Mn–Cb–V	Plate	A572-99a	42	...	42	60	60.0	60.0	60.0	60.0	60.0	60.0		60.0	...	...
Mn–Cb–V	Shapes	A572-99a	42	...	42	60	60.0	60.0	60.0	60.0	60.0	60.0		60.0	...	...
Mn–Cb–V	Bar	A572-99a	50	...	50	65	65.0	65.0	65.0	65.0	65.0	65.0		65.0	...	...
Mn–Cb–V	Plate	A572-99a	50	...	50	65	65.0	65.0	65.0	65.0	65.0	65.0		65.0	...	...
Mn–Cb–V	Shapes	A572-99a	50	...	50	65	65.0	65.0	65.0	65.0	65.0	65.0		65.0	...	...
Mn–Ni–Cr–Cu–V	Bar	A588-97a	A,B	...	42	63	63.0	63.0	63.0	63.0	63.0	63.0		63.0	...	...
Mn–Ni–Cr–Cu–V	Plate	A588-97a	A,B	...	42	63	63.0	63.0	63.0	63.0	63.0	63.0		63.0	...	...
Mn–Ni–Cr–Cu–V	Bar	A588-97a	A,B	...	46	67	67.0	67.0	67.0	67.0	67.0	67.0		67.0	...	...
Mn–Ni–Cr–Cu–V	Plate	A588-97a	A,B	...	46	67	67.0	67.0	67.0	67.0	67.0	67.0		67.0	...	...
Mn–Ni–Cr–Cu–V	Bar	A588-97a	A,B	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		70.0	...	...
Mn–Ni–Cr–Cu–V	Plate	A588-97a	A,B	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		70.0	...	...
Mn–Ni–Cr–Cu–V	Shapes	A588-97a	A,B	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		70.0	...	...
...	Forgings	SA-592	A,E,F	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	112.6	...	...
...	Forgings	SA-592	A,E,F	...	90	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	102.8	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
							100	200	300	400	500		650	700	750	800
Low Alloy Steels (Cont'd)																
Mn–Cu–V	Tube	A618-99	II	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		69.3	...	...
Mn–Cu–V	Tube	A618-99	II	...	46	67	67.0	67.0	67.0	67.0	67.0	67.0		66.3	...	...
Mn–V	Tube	A618-99	III	...	50	65	65.0	65.0	65.0	65.0	65.0	65.0		64.4	...	...
Mn–Cb	Plate	A633-95	A	...	42	63	63.0	63.0	63.0	63.0	63.0	63.0		62.4	...	...
Mn–Cb	Shapes	A633-95	A	...	42	63	63.0	63.0	63.0	63.0	63.0	63.0		62.4	...	...
Mn–Cb	Plate	A633-95	C,D	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		69.3	...	...
Mn–Cb	Shapes	A633-95	C,D	...	50	70	70.0	70.0	70.0	70.0	70.0	70.0		69.3	...	...
Mn–Cb–Ni–Cu	Plate	A633-95	C,D	...	46	65	65.0	65.0	65.0	65.0	65.0	65.0		64.4	...	...
Mn–Cb–Ni–Cu	Shapes	A633-95	C,D	...	46	65	65.0	65.0	65.0	65.0	65.0	65.0		64.4	...	...
Mn–V–N	Plate	A633-95	E	...	60	80	80.0	80.0	80.0	80.0	80.0	80.0		78.2	...	...
Mn–V–N	Shapes	A633-95	E	...	60	80	80.0	80.0	80.0	80.0	80.0	80.0		78.2	...	...
AISI 4130	Forgings	A668-96e1	...	K	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4320	Forgings	A668-96e1	...	K	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4330	Forgings	A668-96e1	...	K	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 8620	Forgings	A668-96e1	...	K	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 8630	Forgings	A668-96e1	...	K	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4130	Forgings	A668-96e1	...	K	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...	...
AISI 4320	Forgings	A668-96e1	...	K	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...	...
AISI 4330	Forgings	A668-96e1	...	K	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...	...
AISI 8620	Forgings	A668-96e1	...	K	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...	...
AISI 8630	Forgings	A668-96e1	...	K	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...	...
AISI 4130	Forgings	A668-96e1	...	L	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4320	Forgings	A668-96e1	...	L	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4330	Forgings	A668-96e1	...	L	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 8620	Forgings	A668-96e1	...	L	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 8630	Forgings	A668-96e1	...	L	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4130	Forgings	A668-96e1	...	L	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4320	Forgings	A668-96e1	...	L	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4330	Forgings	A668-96e1	...	L	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 8620	Forgings	A668-96e1	...	L	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 8630	Forgings	A668-96e1	...	L	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4130	Forgings	A668-96e1	...	L	105	125	125.0	125.0	125.0	125.0	125.0	125.0	...	...	...	...
AISI 4320	Forgings	A668-96e1	...	L	105	125	125.0	125.0	125.0	125.0	125.0	125.0	...	...	...	...
AISI 4330	Forgings	A668-96e1	...	L	105	125	125.0	125.0	125.0	125.0	125.0	125.0	...	...	...	...
AISI 8620	Forgings	A668-96e1	...	L	105	125	125.0	125.0	125.0	125.0	125.0	125.0	...	...	...	...
AISI 8630	Forgings	A668-96e1	...	L	105	125	125.0	125.0	125.0	125.0	125.0	125.0	...	...	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F 100	200	300	400	500		650	700	750	800
Age Hardening Steels																
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	1	85	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	1	85	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	1	85	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	1	80	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	1	80	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	1	80	90	90.0	90.0	90.0	90.0	90.0	90.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	2	65	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	2	65	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	2	65	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	2	60	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	2	60	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	2	60	72	72.0	72.0	72.0	72.0	72.0	72.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	2	55	65	65.0	65.0	65.0	65.0	65.0	65.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	2	55	65	65.0	65.0	65.0	65.0	65.0	65.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	2	55	65	65.0	65.0	65.0	65.0	65.0	65.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	3	75	85	85.0	85.0	85.0	85.0	85.0	85.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	3	75	85	85.0	85.0	85.0	85.0	85.0	85.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	3	75	85	85.0	85.0	85.0	85.0	85.0	85.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Bar	A710-95	A	3	65	75	75.0	75.0	75.0	75.0	75.0	75.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Plate	A710-95	A	3	65	75	75.0	75.0	75.0	75.0	75.0	75.0	...	...	...	...
Cr–Ni–Cu–Mo–Cb	Shapes	A710-95	A	3	65	75	75.0	75.0	75.0	75.0	75.0	75.0	...	...	...	...
Bolting Materials																
C–Mn	Thd. rod	SA-36	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
18Cr–8Ni	...	SA-193	B8	1	30	75	75.0	71.0	66.0	64.4	63.5	63.5		63.5	63.1	62.7
18Cr–8Ni	...	SA-193	B8A	1A	30	75	75.0	71.0	66.0	64.4	63.5	63.5		63.5	63.1	62.7
18Cr–10Ni–Cb	...	SA-193	B8C	1	30	75	75.0	71.8	66.0	61.9	60.2	59.4		58.6	58.6	58.6
18Cr–10Ni–Cb	...	SA-193	B8CA	1A	30	75	75.0	71.8	66.0	61.9	60.2	59.4		58.6	58.6	58.6
16Cr–12Ni–2Mo	...	SA-193	B8M	1	30	75	75.0	75.0	73.4	71.8	71.8	71.8		71.8	71.4	71.0
16Cr–12Ni–2Mo	...	SA-193	B8MA	1A	30	75	75.0	75.0	73.4	71.8	71.8	71.8		71.8	71.4	71.0
18Cr–10Ni–Ti	...	SA-193	B8T	1	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
18Cr–10Ni–Ti	...	SA-193	B8TA	1A	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
18Cr–8Ni	...	SA-194	8	1	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
18Cr–8Ni	...	SA-194	8A	1A	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
18Cr–10Ni–Cb	...	SA-194	8C	1	30	75	75.0	71.8	66.0	61.9	...	...	...	...	...	...
18Cr–10Ni–Cb	...	SA-194	8CA	1A	30	75	75.0	71.8	66.0	61.9	...	...	...	...	...	...
16Cr–12Ni–2Mo	...	SA-194	8M	1	30	75	75.0	75.0	73.4	71.8	...	...	...	...	...	...
16Cr–12Ni–2Mo	...	SA-194	8MA	1A	30	75	75.0	75.0	73.4	71.8	...	...	...	...	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding, °F									
							100	200	300	400	500		650	700	750	800
Bolting Materials (Cont'd)																
18Cr–10Ni–Ti	...	SA-194	8T	1	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
18Cr–10Ni–Ti	...	SA-194	8TA	1A	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
18Cr–8Ni	...	SA-320	B8	1	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
18Cr–8Ni	...	SA-320	B8A	1A	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
18Cr–10Ni–Cb	...	SA-320	B8C	1	30	75	75.0	71.8	66.0	61.9	...	...	...	...	...	...
18Cr–10Ni–Cb	...	SA-320	B8CA	1A	30	75	75.0	71.8	66.0	61.9	...	...	...	...	...	...
18Cr–10Ni–Ti	...	SA-320	B8T	1	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
18Cr–10Ni–Ti	...	SA-320	B8TA	1A	30	75	75.0	73.4	69.3	68.5	...	...	...	...	...	...
17Cr–8Ni–S	...	SA-320	B8F	1	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
17Cr–8Ni–S	...	SA-320	B8FA	1A	30	75	75.0	71.0	66.0	64.4	...	...	...	...	...	...
16Cr–12Ni–2Mo	...	SA-320	B8M	1	30	75	75.0	75.0	73.4	71.8	...	...	...	...	...	...
16Cr–12Ni–2Mo	...	SA-320	B8MA	1A	30	75	75.0	75.0	73.4	71.8	...	...	...	...	...	...

NOTES:
(1) When welding is performed on these materials,the design stress intensity or allowable stress values is based on an ultimate tensile strength of except for AISI 1025CW and AISI 1026CW, which are based on 55.0 ksi. The yield strength values are those for hot rolled materials: 32.0 ksi for AISI 1015CW, and 1020CW; for AISI 1025CW, 1026CW, and 8620CW.
(2) There is no standard AISI composition 4330. By agreement with the material manufacturer, the carbon content of AISI 4320 can be ordered to 0.33%.
(3) Up to 2$^1/_2$ in. incl.
(4) Over 2$^1/_2$ in. to 40 in.
(5) These materials are limited for use only for component standard supports.
(6) Max. BHN 215.
(7) Max. BHN 225.
(8) The elongation and reduction of area requirements for this material may be specified as 17% and 35% minimum, respectively.
(9) By agreement between Purchaser and Material Manufacturer, these materials may be procured to the lower specified minimum ultimate ten ngth and minimum yield strength values given in this table.
(10) For each forging 250 lb and less, the marking requirements of A668 shall be met by a suitable code or symbol identified by the manufacturer Certificate of Compliance or Certified Material Test Report.
(11) Up to $^5/_{16}$ in. incl.
(12) Over 5 in. to 8 in. incl.
(13) Over 4 in. to 5 in. incl.
(14) Plates up to 4 in. inclusive and all structural shapes.
(15) Proper ventilation for the welder is required when welding on galvanized steel (Ref. ANSI Z49.1).
(16) Up to 7 in. incl.
(17) Up to 4 in. incl.
(18) Over 4 in. to 7 in. incl.
(19) Over 7 in. to 10 in. incl.
(20) Over 2$^1/_2$ in. to 6 in. incl.

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

NOTES (CONT'D):
(21) Max. Carbon 0.35% for welded connections.
(22) Up to $1\frac{1}{4}$ in. incl.
(23) Over $\frac{5}{16}$ in. to $\frac{3}{4}$ in.
(24) Up to 1 in.
(25) Over 1 in. to 2 in.
(26) Over 2 in.
(27) Up to 2 in.
(28) Threaded rods only.
(29) No yield strength or tensile strength specified. Assumed to be the same strength as SA-193 bolting material of the equivalent grade for nut calculation.
(30) Up to $\frac{3}{4}$ in. incl.
(31) Over $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. incl.
(32) Maximum tensile strength shall not exceed specified minimum tensile strength by more than 30 ksi, perSA-6/SA-6M, S18.
(33) Maximum tensile strength shall not exceed specified minimum tensile strength by more than 25 ksi, perSA-6/SA-6M, S18.
(34) Specifications for compatible nuts are provided in SA-193 and SA-320. Nuts may also be fabricated from the same material specification as the and threaded rods, and the same stress values may be used.
(35) The allowable stress values are based on the revised criterion of tensile strength divided by 3.5, where applicable.

4 WELDING QUALIFICATIONS

4.1 Welding procedure qualifications, welder and welding operator performance qualifications for S-Number materials shall be in accordance with NF-4320 utilizing corresponding P-Number base materials.

4.2 Base metals not assigned S-Numbers or P-Numbers shall require separate procedure qualification.

5 CONSUMABLES CONTROL

5.1 Due consideration shall be given to protection of electrodes and fluxes for all welding processes in order to minimize moisture absorption and surface contamination.

5.2 Carbon and low alloy steel electrodes shall be supplied with a diffusible hydrogen limit of H4 for SMAW electrodes and H8 for flux cored electrodes SMAW electodes shall be supplied in hermetically sealed containers. Immediately after the opening of the hermetically sealed container or removal of the electrodes from drying ovens, electrodes shall be stored in ovens held at a temperature of at least 250°F. E70XX electrodes that are not used within 4 hr, E80XX within 2 hr, E90XX within 1 hr, and E100XX within $^1/_2$hr after the opening of the hermetically sealed container or removal of the electrodes from a drying or storage oven shall be dried before use unless evidence is presented to and accepted by the Authorized Nuclear Inspector which indicates that the brand of electrode used may be exposed for longer periods of time without exceeding a moisture content of 0.4% by weight.

6 TIME OF EXAMINATION

6.1 CAUTIONARY NOTE

In addition to the requirements of NF-5120, consideration should be given to the application of magnetic particle or liquid penetrant examination after a sufficient time at ambient temperature to detect delayed cracking. This precaution is not necessary for examination after postweld heat treatment.

7 EFFECTS OF WELDING

7.1 CAUTIONARY NOTE

Consideration should be given to the possibility of reheat cracking and deterioration of toughness properties during postweld heat treatment of susceptible materials.

8 REQUIREMENTS FOR WELDING S-NUMBER 1 GROUP-NUMBER 1 MATERIALS

8.1 PREHEAT

8.1.1 Preheat is not required when the base metal temperature is 50°F and above for material thickness up to and including $1^1/_2$ in. A preheat of 200°F minimum is required for material thickness greater than $1^1/_2$ in.

8.2 POSTWELD HEAT TREATMENT

8.2.1 Postweld heat treatment is not required when the material thickness is $1^1/_2$ in. or less. When the material thickness is greater than $1^1/_2$ in., up to and including 4 in., PHWT is not required provided the material, including heat affected zone and weld metal, meets the impact testing requirement given in 8.3.1.

8.2.2 When not exempted by 8.2.1, the postweld heat treatment shall be performed in accordance with NF-4622.

8.3 IMPACT TEST REQUIREMENTS

8.3.1 When material with thickness greater than $1^1/_2$ in. up to and including 4 in. is not postweld heat treated, the lateral expansion at the lowest service temperature specified shall be 25 mils minimum (NF-2300).

8.4 ADDITIONAL REQUIREMENTS

8.4.1 For steels with vanadium and columbium in combination exceeding 0.10% or with vanadium alone exceeding 0.08%, which are given a postweld heat treatment above 700°F, the requirements for impact testing of 8.3.1 shall be met for these materials by separate welding procedure qualification. (This requirement should also be considered for steels in which vanadium and columbium are not specified but which may include these elements.)

9 REQUIREMENTS FOR WELDING S-NUMBER 1 GROUP NUMBER 2 AND 3 MATERIALS

9.1 PREHEAT

9.1.1 Preheat is not required when base metal temperature is 50°F and above for material thickness up to and including 1 in. A preheat of 200°F minimum is required for material thickness greater than 1 in.

9.2 POSTWELD HEAT TREATMENT

9.2.1 Postweld heat treatment is not required for material which has a maximum carbon content of 0.30% or less and a thickness of 1 in. or less, nor for material which has a maximum carbon content of 0.30% or less and a thickness greater than 1 in. up to and including 4 in., provided the material, including heat affected zone and weld metal, meets the impact requirements given in 9.3.1.

9.2.2 When not exempted by 9.2.1, the postweld heat treatment shall be performed in accordance with NF-4622.

9.3 IMPACT TEST REQUIREMENTS

9.3.1 When material with thickness greater than 1 in. up to and including 4 in. is not postweld heat treated, the lateral expansion at the lowest service temperature specified shall be 25 mils minimum (NF-2300).

9.4 ADDITIONAL REQUIREMENTS

9.4.1 For steels with vanadium and columbium in combination exceeding 0.10% or with vanadium alone exceeding 0.08%, which are given a postweld heat treatment above 700°F, the requirements for impact testing of 9.3.1 shall be met for these materials by separate welding qualifications. (This requirement should also be considered for steels in which vanadium and columbium are not specified but which may include these elements.)

10 REQUIREMENTS FOR WELDING S-NUMBER 3 GROUP NUMBER 1 MATERIALS

10.1 PREHEAT

10.1.1 A preheat of 150°F minimum is required for material thicknesses up to and including $1^1/_2$ in. A preheat of 250°F minimum is required for material thickness greater than $1^1/_2$ in.

10.2 POSTWELD HEAT TREATMENT

10.2.1 No postweld heat treatment is required for material which has a maximum carbon content of 0.25% or less and a thickness up to and including 4 in. (102 mm) provided the material, including heat affected zone and weld metal, meets the impact requirements given in 10.3.1 below.

10.2.2 When not exempted by 10.2.1 above, the postweld heat treatment shall be performed in accordance with NF-4622.

10.3 IMPACT TEST REQUIREMENTS

10.3.1 When material is not postweld heat treated, for material over $^5/_8$ in. thick up to and including 1 in., the lateral expansion at the lowest service temperature specified shall be 15 mils minimum; for material thicknesses greater than 1 in. up to and including 4 in., the lateral expansion at the lowest service temperature shall be 25 mils minimum (NF-2300).

10.4 ADDITIONAL REQUIREMENTS

10.4.1 For steels with vanadium and columbium in combination exceeding 0.10% or with vanadium alone exceeding 0.08%, which are given a postweld heat treatment above 700°F, the requirements for impact testing of 10.3.1 shall be met for these materials by separate welding qualifications. (This requirement should also be considered for steels in which vanadium and columbium are not specified but which may include these elements.)

11 REQUIREMENTS FOR WELDING S-NUMBER 3 GROUP NUMBER 3 AND 4 MATERIALS

11.1 PREHEAT

11.1.1 A preheat temperature of 200°F minimum is required for material thicknesses up to and including $1^1/_2$ in. A preheat temperature of 300°F minimum is required for material thicknesses greater than $1^1/_2$ in.

11.2 POSTWELD HEAT TREATMENT

11.2.1 No postweld heat treatment is required for material which has a maximum carbon content of 0.25% or less and a thickness up to and including 4 in. provided the material, including heat affected zone and weld metal, meets the impact requirements given in 11.3.1.

11.2.2 When not exempted by 11.2.1, the postweld heat treatment shall be performed in accordance with NF-4622.

11.3 IMPACT TEST REQUIREMENTS

11.3.1 When material is not postweld heat treated, for material over $^5/_8$ in. thick up to and including 1 in., the lateral expansion at the lowest service temperature specified shall be 15 mils minimum; for material thicknesses greater than 1 in., up to and including 4 in., the lateral expansion at the lowest service temperature specified shall be 25 mils minimum (NF-2300).

12 REQUIREMENTS FOR WELDING S-NUMBER 4 GROUP NUMBER 2 AND 3 MATERIALS

12.1 The requirements for welding S-No. 4 materials are the same as those for P-No. 4 materials.

13 REQUIREMENTS FOR WELDING S-NUMBER 5 GROUP NUMBER 2 AND 3 MATERIALS

13.1 The requirements for welding S-No 5 materials are the same as those for P-No. 5 materials.

14 REQUIREMENTS FOR WELDING S-NUMBER 8 GROUP NUMBER 1 MATERIALS

14.1 The requirements for welding S-No. 8 materials are the same as those for P-No. 8 materials.

15 REQUIREMENTS FOR WELDING S-NUMBER 11A, S-NUMBER 11B, AND S-NUMBER 11C MATERIALS

15.1 WELDING QUALIFICATIONS

15.1.1 Welding procedure qualifications and welder and welding operator qualification shall be made in accordance with Section III and as given herein.

15.1.2 Welding procedure qualification of Section IX shall be by WPS and Procedure Qualification Records (PQR) for these materials and combinations of other materials with these materials. When joints are made between two different types or grades of base material, a procedure qualification shall be made for the applicable combinations of materials, even though procedure qualification tests have been made for each of the two base materials welded to itself. (Materials of the same nominal chemical analysis and mechanical properties range, even though of different product forms, may be considered as the same type or grade.)

15.2 The following, in addition to the essential variables in Section IX, QW-250, shall be considered as essential variables requiring requalification of the welding procedure.

15.2.1 A change in filler metal SFA classification or to a weld metal not covered by an SFA specification.

15.2.2 An increase in the maximum or a decrease in the minimum specified preheat or interpass temperatures. The specified range of preheat temperatures shall not exceed 150°F.

15.2.3 A change in the heat treatment (procedure qualification tests shall be subjected to heat-treatment essentially equivalent to that encountered in fabrication of the item or item parts including the maximum total aggregate time at temperature or temperatures and cooling rates).

15.2.4 A change in the type of current (AC or DC), polarity, or a change in the specified range for amperage, voltage, or travel speed.

15.2.5 A change in the thickness (T) of the welding procedure qualification test plate as given in (a) or (b) below:

(a) For welded joints which are quenched and tempered after welding, an increase in thickness (the minimum thickness qualified in all cases is $^1/_2$ in.

(b) For welded joints which are not quenched and tempered after welding, any change as follows:

(1) For thickness less than $^5/_8$ in., any decrease in thickness. (The maximum thickness qualified is $2T$.)

(2) For thickness $^5/_8$ in. and over, any departure from the range of $^5/_8$ in. to $2T$.

15.3 CONSUMABLES CONTROL

15.3.1 Welding filler metal containing more than 0.06% vanadium shall not be used for welded joints which are postweld heat treated.

15.4 POSTWELD HEAT TREATMENT PROCEDURE

15.4.1 Postweld heat treatment shall be at a minimum temperature of 1075°F and a maximum temperature limited only by the ability to meet the specified mechanical properties, but in no case exceeding the tempering temperature recorded on the Certified Material Test Report. Minimum holding time at the postweld heat treating temperature shall be 1 hr/in. of weld thickness, with 1 hr minimum holding time.

15.5 PREHEAT

15.5.1 A minimum preheat temperature of 100°F is required for material thickness up to and including $^1/_2$ in. A minimum preheat temperature of 200°F is required for material thicknesses above $^1/_2$ in. up to and including $1^1/_2$ in. A minimum preheat temperature of 300°F (150°C) is required for material thickness above $1^1/_2$ in.

15.6 POSTWELD HEAT TREATMENT

15.6.1 The preheat temperature required by 15.5.1 shall be maintained for 2 hr after the weld joint is completed. Postweld heat treatment shall be in accordance with 15.4.1.

15.6.2 Postweld heat treatment in accordance with 15.4.1 may be omitted for material which has a maximum carbon content of 0.23% or less and a thickness up to and including 4 in. provided the material, including heat affected zone and weld metal, meets the impact requirements given in 15.8.1.

15.7 JOINT DESIGN RESTRICTIONS

15.7.1 Convex fillet welds as shown in Fig. NF-4427-1 are not permitted.

15.8 IMPACT TEST REQUIREMENTS

15.8.1 When material is not postweld heat treated per 15.4.1 for material over $^5/_8$ in. thick and up to and including 1 in., the lateral expansion at the lowest service temperature specified shall be 15 mils minimum. For material thicknesses greater than 1 in. up to and including 4 in., the lateral expansion at the lowest service temperature specified shall be 25 mils minimum (NF-2300).

16 REQUIREMENTS FOR WELDING S-NUMBER 12 GROUP NUMBER 1 MATERIAL

16.1 PREHEAT

16.1.1 Preheat is not required when the base metal temperature is 50°F and above for material thickness up to and including $1^1/_2$ in. A preheat of 200°F minimum is required for material thickness greater than $1^1/_2$ in.

16.2 POSTWELD HEAT TREATMENT

16.2.1 Postweld heat treatment is not required when the material thickness is $1^1/_2$ in. or less. When the material thickness is greater than $1^1/_2$ in., postweld heat treatment is not required provided the material, including heat affected zone and weld metal, meets the impact testing requirement given in 16.3.1.

16.2.2 When not exempted by 16.2.1, the postweld heat treatment shall be performed in accordance with NF-4622, except that it shall be at least 1000°F and shall not exceed 1150°F for Class 1 and Class 2 material, and 1175°F for Class 3 material.

16.3 IMPACT TEST REQUIREMENTS

16.3.1 When material with thickness greater than $1^1/_2$ in., up to and including 4 in. is not postweld heat treated, the lateral expansion at the lowest service temperature specified shall be 25 mils minimum.

17 REQUIREMENTS FOR WELDING P-NUMBER MATERIALS

17.1 The requirements of 8 through 16 may also be used for welding of materials with the corresponding P-Number Group Number.

18 IDENTIFICATION

18.1 This Case and revision number shall be listed on the applicable documentation accompanying shipment.

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Approval Date: December 11, 1981

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-131-1
Material for Internal Pressure Retaining Items for Pressure Relief Valves, Classes 1, 2, and 3
Section III, Division 1

Inquiry: What materials may be used for the internal pressure retaining items of pressure relief valves, other than body, bonnet and bolting, for Section III, Division 1, Class 1, 2, and 3 construction?

Reply: It is the opinion of the Committee that internal pressure retaining items other than bodies, bonnets and bolting (which are presently covered by applicable provisions of NB, NC and ND) for Section III, Division 1, Class 1, 2, and 3 pressure relief valves may be made of materials other than Tables 1A, 1B, 2A, and 2B of Section II, Part D with Table 1 of this Case, under the following conditions.

(a) The nondestructive examination requirements of NB-2000, NC-2000, and ND-2000 (as applicable), which apply to the product form in which the material is used, are satisfied.

(b) The Material Certification and Material Identification requirements of Section III, Division 1 are satisfied.

(c) Where the tensile strength, yield strength, hardness, or heat treatment listed in Table 1 differ from the requirements of the listed material specification the requirements listed in Table 1 shall apply.

(d) Materials shall be identified by this Case number.

Table 1
Materials for Pressure Relief Valve Internal Items for Class 1, 2 and 3 Safety, Safety Relief and Valves

Material	Product Form	Spec. No.	Grade	Diam.	Cond.	Tensile Strength, ksi	Brinell Hardness	Yield Strength	Temp. or Temp.	Notes
19-9DL	Bar	A 458-71	651	8″	Sol. H.T.	100.0	185	50.0	900	(3)
19-9DL	Forging	A 477-71	651	8″	Sol. H.T.	100.0	185	50.0	900	(3)
17Cr-4Ni-4Cu	Bars, Shapes	A 564-74	630	8″	...	190.0	388	170.0	900	(1),(2),(3),(4)
13Cr	Bars, Shapes	A 479-75	410	Up to 8″	...	100.0	192	65.0	1375	(1),(2),(3)
18Cr	Bars, Shapes	A 276-75	440C	Up to 8″	H.T.	285.0	578	275.0	1375	(1),(2),(3),(4)
Co-Cr-W-Ni	Bars, Shapes	AMS-5759D	...	4″	CDr	150.0	311	100.0	1100	(1),(2),(3),(4)
Co-Cr-W	Bars, Shapes	Comm.	...	4″	STr	150.0	352	90.0	1000	(1),(2),(3),(4)
Co-Cr-W	Bars, Shapes	AMS-5373A	...	4″	As	125.0	375	75.0	1000	(1),(2),(3)
Co-Cr-W	Castings	AMS-5387	...	4″	Cast	115.0	375	90.0	1000	(1),(2),(3),(4)
13Cr	Bars, Shapes	A 565-74	615	Up to 8″	H.T.	140.0	302	110.0	1100	(1),(2),(3),(4)
13Cr	Bars, Shapes	A 565-74	616	Up to 8″	H.T.	140.0	302	110.0	1100	(1),(2),(3),(4)

NOTES:
(1) Not to be used for nozzles.
(2) Welding of these materials is not permitted.
(3) For allowable stresses, use $1/4$ of room temperature specified minimum tensile strength, up to 650°F inclusive.
(4) The maximum tensile strength shall not exceed the specified minimum tensile strength by more than 40.0 ksi.

Approval Date: July 18, 1985

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-133-3
Use of SB-148 Alloys 952 and 954, Class 3
Section III, Division 1

Inquiry: Under what rules may Section III, Division 1, Class 3 valves utilizing material specification SB-148, Alloys 952 or 954, be used in Section III, Division 1, Class 3 construction?

Reply: It is the opinion of the Committee that flanged end valves and NPS 2 and smaller socket welded end valves, manufactured from material specification SB-148, Alloys 952 or 954, may be used for Section III, Division 1, Class 3 construction in accordance with the pressure temperature ratings listed below, provided all other requirements of Subsection ND are met. Bolting materials shall be SB-150, Alloys 614 or 630 or other bolting materials permitted by the Design Specification. Use of this Case number shall be shown on the applicable Code Data Report Form.

Service Temp., °F	Pressure, psig			
	Class 150	Class 300	Class 150	Class 300
	952		954	
100	190	500	230	600
200	175	460	220	575
300	160	430	215	565
400	160	430	200	560

GENERAL NOTE: It is cautioned that, depending on design and service environment, the use of bolting dissimilar to the body and bonnet materials may require provisions for protection against galvanic corrosion.

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Approval Date: December 5, 1985

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-154-1
Projection Resistance Welding of Valve Seats, Classes 1, 2, and 3
Section III, Division 1

Inquiry: Under what rules may Section III, Division 1, Classes 1, 2, and 3 valves be constructed when the projection resistance welding process[1] is used to weld seat rings to valve bodies and disks in valves 4 in. nominal pipe size and less? What alternative rules may be used for welding procedure qualification, as referenced in NB-4330, NC-4330, and ND-4330, under the conditions described below?

Reply: It is the opinion of the Committee that Section III, Division 1, Classes 1, 2, and 3 valves may be constructed to the rules of Section III, Division 1, except that fabrication shall be modified as required by this Case when the projection resistance welding process is used to weld seat rings to valve bodies and disks in valves NPS 4 and less. As an alternative to the requirements of NB-4330, NC-4330, and ND-4330 of Section III, Division 1, welding procedures shall be qualified in accordance with the rules of this Case under the conditions described below.

1 GENERAL REQUIREMENTS

1.1 Welding procedures and welding operators shall be qualified in accordance with the applicable rules of Section IX and this Case.

A tempering heat treatment shall be applied to ferritic materials and may be included as part of the projection resistance welding procedure.

1.2 Use of this Case shall be identified on the Data Report Form.

2 WELDING PROCEDURE QUALIFICATION

2.1 ESSENTIAL VARIABLES

The welding procedure shall be qualified as a new procedure specification and shall be completely requalified when any of the changes listed below are made. Other changes may be made in the welding procedure without requalification; provided the procedure specification is amended to show these changes.

(a) A change of the valve body or disk material listed under one P-Number in QW-422 of Section IX to a material listed under another P-Number or to any other material.

(b) A change in the nominal composition of seat ring material.

(c) A change in the nominal dimensions of the seat ring or a change in the nominal dimension of the weld preparation including the number, spacing and design of projections on the valve body or disk.

(d) A change in the nominal dimensions of the electrode.

(e) A change in electrode force (lb) for any part of the welding cycle more than plus 20% or minus 10% from that qualified.

(f) A change in welding current (amperes) more than plus or minus 10% from that qualified.

(g) A change in welding time (cycles) from that qualified.

(h) A change in the holding time (cycles) under pressure after welding from that qualified.

(i) A change in the tempering heat treat current (amperes) more than plus or minus 10% from that qualified.

(j) A change in the tempering heat treat time (cycles) from that qualified.

(k) A change in the type or model of welding equipment.

2.2 TEST ASSEMBLY

A procedure qualification test assembly shall be welded using the joint geometry and essential variables that are to be used for production welding.

[1] Projection resistance welding is a resistance welding process wherein coalescence is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by electrodes. The resulting welds are localized at predetermined points by the design of the parts to be welded. The localization is usually accomplished by projections, embossments or intersections.

2.3 EXAMINATION OF TEST ASSEMBLY

The test assembly shall be sectioned (a minimum of four cross sections), ground etched with a suitable etchant and visually examined at 10× magnification. The weld and base material shall be free of cracks, lack of fusion and other linear indications. The average size of the weld shall not be less than that specified in the welding procedure.

2.4 SEAT TO BODY WELD

A push-out test shall be performed on each welded test assembly. A hole shall be drilled in the welded test assembly so that a load can be applied to the seat ring in the direction that it would be forced out. The load to push out the seat ring from the valve body shall not be less than 0.67 times the minimum specified ultimate tensile strength of a section of the body material equal in area to an annulus with an inside diameter equal to the inner diameter of the welding surface of the ring and the outside diameter equal to the outer diameter of the welding surface of the ring.

3 WELDING PERFORMANCE QUALIFICATION

The welding operator shall be qualified using the same welding equipment that will be used in production and shall be required to set up the machine and make the necessary adjustments for welding.

The requirements for performance qualification shall be the same as for procedure qualification.

A welding operator qualified to weld in accordance with one WPS is also qualified to weld in accordance with other WPS's using the projection resistance welding process.

4 PRODUCTION TESTING

4.1 GENERAL

Two consecutive acceptable welded test assemblies shall be made immediately prior to each production welding run and one acceptable welded test assembly shall be made at the conclusion of each production welding run for both the seat to body weld and the seat to disk weld. The length of a production welding run shall be defined (depending on the type and quantity of the product being welded) by the manufacturer. The welded test assemblies shall be made using the welding machine and qualified welding procedure that are to be used in production. The seat to disk weld shall be tested in accordance with 2.3. The seat to body weld shall be tested in accordance with 2.4. In the event that any of the welded test assemblies are unacceptable, additional tests and examinations shall be performed to determine the acceptability of all production welds made using the same welding machine and welding procedure since the last acceptable welded test assembly.

Approval Date: January 21, 1982

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-155-2
Fiberglass Reinforced Thermosetting Resin Pipe
Section III, Division 1

Inquiry: What are the rules for construction of Section III, Division 1, Class 3, fiberglass reinforced thermosetting resin piping (RTRP) systems?

Reply: It is the opinion of the Committee that fiberglass reinforced thermosetting resin piping systems may be constructed to the rules of Section III, Division 1, Class 3, provided the following requirements are met.

(a) The general requirements in NCA-1000 through NCA-8000 and ND-1000 shall apply except as modified by -1000 of this Case.

(b) The rules for Materials in this Case shall replace the rules of ND-2000.

(c) The requirements for Design in ND-3000 shall apply except as modified by -3000 of this Case.

(d) The rules for Fabrication and installation in -4000 of this Case shall replace the rules of ND-4000.

(e) The rules for Examination in -5000 of this Case shall replace the rules of ND-5000.

(f) The rules for Testing in ND-6000 shall apply except as modified by -6000 of this Case.

(g) The rules for over Pressure Protection in ND-7000 shall apply except as modified by -7000 of this Case.

(h) The rules for Nameplates, Stamping and Reports in ND-8000 shall apply except as modified by -8000 of this Case.

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FIGURES

TABLES

-1000 GENERAL REQUIREMENTS

-1100 SCOPE

-1110 Aspects of Construction Covered by These Rules

(a) This Case contains rules for the construction of RTRP Class 3 piping, piping subassemblies, and appurtenances at temperatures not exceeding qualification conditions (-2600) (-4200) but in no case at temperatures greater than 180°F for polyester structural wall materials and 250°F for epoxy structural wall materials. Design pressures shall not exceed 500 psi for temperatures of 180°F and less or 250 psi for temperatures over 180°F not to exceed 250°F. Use of these materials is not permitted in continuous steam service at pressures over 5 psig.

(b) Terms relating to plastics and fiberglass shall be in accordance with Section X of the Code. Terms not covered in Section X shall be in accordance with ASTM D883 or Mandatory Appendix IV of this Case. The definitions of Mandatory Appendix IV of this Case shall govern where there is a difference.

(c) The rules of Subsection NCA shall be met except as modified below:

(1) Permitted Material Specifications are contained in -2000 of this Case.

(2) The Definitions of NCA-3810 shall apply as modified by -2000 of this Case. The Material Manufacturer NCA-3812 shall be responsible for the quality of constituent materials (-2112), such as, laminates, glass fibers and resins. The control of the quality of constituent materials (-2400) shall be described in the Material Manufacturer's Quality Program. The quality program and audit requirements of NCA-3853 do not apply to manufacturers of constituent materials as defined in -2400.

(3) Substitute "joining" for "welding," and substitute "joiner" for "welders and welding operators" and delete reference to Section IX wherever these terms appear.

(d) The rules of Article ND-1000 shall be met except as modified below:

In ND-1610(j) substitute "joining" for "welding or brazing" and delete reference to ND-2400. In ND-1610(k) substitute "joiners" for "welders and welding operators and brazers (ND-4300)." In ND-1610(l) substitute "joining" in place of "welding or brazing." In ND-1620(c) delete "repaired by welding."

-1200 QUALITY CONTROL SYSTEM

-1210 General

(a) Material Manufacturers (-2112) and Material Suppliers (-2113) shall have and maintain a Quality Control System or Materials Identification and Verification Program, as applicable, in accordance with the requirements of NCA-3800 except as modified by -1110(c)(2) above.

(b) Certificate Holders using the material permitted by this Case shall establish and maintain a Quality Control System which will assure that all requirements of this Case have been met in accordance with NCA-4135 except as modified by -1110(c) above.

(c) Fittings which are manufactured by joining methods similar to those covered by -4000 of this Case shall be inspected by an Authorized Nuclear Inspector and stamped with the NPT symbol. In addition to the NPT symbol, the numeral, 3, shall be stamped below and outside the official Code symbol. All applicable requirements of -4000 of this Case shall be met. The Authorized Inspector shall certify by signing the Data Report Form NM-1 in accordance with NCA-5290.

-1300 CERTIFICATES OF AUTHORIZATION AND STAMPING

-1310 Material Manufacturers and Material Suppliers (NCA-3810)

Material Manufacturers and Material Suppliers shall hold a Quality System Certificate (Materials) verifying the adequacy of the Material Manufacturers Quality System Program and Material Suppliers Identification and Verification Program.

-1320 Certificate Holders

(a) NPT Certificate Holders. Organizations fabricating piping subassemblies shall hold a Certificate of Authorization to apply the NPT Code Symbol Stamp. Where a Certificate Holder is also a Material Manufacturer or Material Supplier, he may elect to obtain a separate Quality System Certificate (Materials) or include the material manufacture or material supply in the scope of the Certificate of Authorization to apply the NPT Code Symbol Stamp provided his Quality Program also covers these activities.

(b) NA Certificate Holders. Organizations performing installation activities in accordance with -4000 and -5000 of this Case shall obtain a Certificate of Authorization to apply the NA Code Symbol Stamp.

(c) N Certificate Holders. Organizations taking overall responsibility for a piping system in accordance with NCA-3510 shall obtain a Certificate of Authorization to apply the N Code Symbol. Where the N Certificate Holder, in addition to taking overall responsibility, installs piping systems in accordance with -4000 and -5000 of this Case, he may elect to obtain a separate Certificate of Authorization to apply the NA Code Symbol or include installation activities in the scope of the Certificate of Authorization to apply the N Code Symbol Stamp provided his Quality Program covers these activities.

-2000 MATERIALS

-2100 GENERAL REQUIREMENTS FOR MATERIALS

-2110 Scope

-2111 Terms

The term materials as used in this Case shall apply to the pipe and fittings manufactured in accordance with -2000 of this Case and the materials used in joining them and shall be defined as follows:

-2111.1 Pipe. Reinforced thermosetting resin pipe (RTRP) material shall be manufactured by the filament winding (FW) process in accordance with ASTM D2996 or D 3517 and the requirements of Mandatory Appendix II of this Case. The principal reinforcement material in the circumferential direction shall be continuous glass roving. Reinforcement in the axial direction may be continuous glass roving, chopped glass or undirectional glass tape. Pipe classes in accordance with ASTM D2310, Type I, Grades 1 and 2; Classes A, C, E, F, and H are permitted.

-2111.2 Fittings. Reinforced thermosetting resin fittings including flanges shall be manufactured by; Filament winding (Type I), centrifugally cast (Type II) (flanges and stub ends only), hand fabricated (Type IV), spray-up (Type V) or molded (Type VI). Fittings classified as RTR Type I, Grade 1 and Classes A, B, C, E, F, and H; RTR Type I, Grade 2, Classes B and C; RTR Type II, Grade 1, Class A; RTR Type IV, Grades 1 and 2, Classes A, C, E, F; Type V, Grade 2, Classes A and E; Type VI, Grades 1 and 2, Class A, in accordance with Mandatory Appendix I are permitted. Pressure laminated fittings (Type III) are not allowed.

-2111.3 Auxiliary Material. Auxiliary materials are those used in the joining or support of the pipe and fittings and include joint adhesives, joint overlay materials, gaskets, O-rings, O-ring lubricants, and pipe support materials. Auxiliary materials shall meet the requirements of -2300.

-2112 Material Manufacturer

As used in this Case, the Material Manufacturer is the organization which manufactures and certifies material in compliance with requirements of this Case. The Material Manufacturer shall perform or shall supervise and directly control one or more of the operations which affect the material properties to meet the requirements of the basic material specification, and shall verify the satisfactory completion of all other requirements performed by other organizations prior to his certification.

-2113 Material Supplier

As used in this Case, the Material Supplier is an organization which supplies products of Material Manufacturers but does not perform any operations which affect the materials properties required by the basic material specification, except when so authorized in a Quality System Certificate (Materials).

-2120 Material Properties and Dimensions

Properties of the materials permitted in -2111 shall be determined in accordance with the applicable test methods or procedures stated in this Case as shown in Mandatory Appendix II. The dimensions and tolerances of pipe shall be in accordance with the specification and Table 3 of D 2996 shall be extended as indicated in Table II-4.4-3. Fitting materials dimensions and tolerances shall be in accordance with the requirements of Mandatory Appendix I.

-2200 MATERIAL MANUFACTURE

-2210 Internal Corrosion Resistant Liner

When internal corrosion resistant liner materials are used they may consist of thermosetting or thermoplastic resin. The resin content for the thermosetting resin liner shall be a minimum of 75% by weight as determined by ASTM D2584.

-2211 Structural Wall

The structural wall shall contain reinforcement embedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments or dyes.

-2212 Exterior Layer

The exterior layer may be composed of thermosetting resin, thermosetting or thermoplastic coatings. Additives such as ultraviolet absorbers, fire retardants, dyes, pigments or filler may also be added if specified.

-2300 AUXILIARY MATERIALS

-2310 Joint Adhesive Materials

Joint adhesive materials used to join pipe to pipe and pipe to fittings shall comply with the requirements specified in the qualified procedures, and shall meet the strength requirements of -3662 of this Case. Each batch of adhesive shall be tested and reported on Form RTRP-2. Requirements shall be specified in the qualified procedures.

-2320 Overwrap, Laminate Joint Materials

Overwrap, laminate joint materials shall consist of layers of glass fiber reinforcement laminated in place with a resin system meeting the requirements of Mandatory Appendix II, 5. Overwrap materials employed in combination with bonded joints and in butt-and-wrap joints shall meet the applicable requirements of -3661 independent of joint bond strength and shall resist deterioration in the same manner as the pipe material. The type of material used shall be specified in the qualified procedure.

-2330 Bolting Material

Bolting materials shall conform to the requirements of ND-2127 except that washers are mandatory in accordance with ND-2125.

-2340 Miscellaneous Auxiliary Materials

Miscellaneous auxiliary materials, such as, gaskets, O-rings, lubricants, and solvents shall be specified in and meet the requirements of the Design Specification, and shall be included in the qualification tests required by -4220 of this Case.

-2350 Pipe Support Materials

Pipe support materials shall meet the requirements of Subsection NF.

-2400 CONSTITUENT MATERIALS

Constituent materials are those, such as thermosetting resins, reinforcement, and other solid or liquid materials which, when combined as a composite structure produce material meeting the requirements of this Case for the products listed in -2111. The Material Manufacturer shall be responsible for and verify that the constituent materials of pipe, fittings, and auxiliaries meet the requirements of this Case stated in Mandatory Appendices I and II.

-2500 DETERIORATION OF MATERIALS IN SERVICE

Consideration of corrosion of materials in service is generally outside the scope of this Case. It is the responsibility of the Owner to select materials suitable for the conditions stated in the Design Specifications with specific attention being given to the effects of service conditions on the properties of the materials. Attention shall be given to possible degradation due to exposure to radiation when it is present, including sunlight.

-2600 QUALIFICATION OF MATERIALS

-2610 General

Pipe and fittings shall meet the mechanical property requirements and be qualified in accordance with Mandatory Appendix I and Mandatory Appendix II of this Case.

-2700 CERTIFICATION OF MATERIALS

Materials shall be certified as required in NCA-3867.4 Certified Material Test Reports are required for all materials, except that Form RTRP-1 (Mandatory Appendix III) shall be completed in addition to a Certified Material Test Report for Constituent Materials. The CMTR shall include reports of all Quality Control Tests performed on the material and a reference to the Material Manufacturer's Qualification Test Report.

-2800 MATERIAL IDENTIFICATION

Material shall be marked in accordance with the marking requirements of Mandatory Appendix I or Mandatory Appendix II, as applicable. Materials shall be controlled during manufacture and construction so that they are identifiable as acceptable at all times. Bonding and laminating materials shall be controlled during the repair of material and during manufacture and installation so that they are identifiable as acceptable material until actually consumed.

-2900 EXAMINATION AND REPAIR OF MATERIAL

Material shall be visually examined and repaired in accordance with Tables 2900-1A and 2900-1B, Tables 2900-2A and 2900-2B, Tables 2900-3A and 2900-3B, and Table 2900-4. No indication depth is permitted which is greater than 12.5% of the required structural wall thickness. Gasket sealing surfaces shall be smooth and shall meet the criteria given in Tables 2900-1A and 2900-1B for the liner surface.

-3000 DESIGN

The Design Rules in this section of the Case shall be met for RTR piping systems applicable to Section III, Division 1, Class 3.

-3100 GENERAL

The requirements of Subarticle ND-3100 shall be complied with except as modified in -3112.2 through -3133.3.

Table 2900-1A
Visual Examination Criteria and Repair Requirements for Inside Surface Area of RTRP Pipe and Filament Wound, Hard Fabricated, and Spray-Up Fittings 16 in. Nominal Size and Smaller

		Acceptance Limit [Note (1)] No Repair Required		Acceptance Limit [Note (1)] Repair Required		
Indication	Description	Max Dimension	No./ft^2	Max Dimension	No./ft^2	Required Repair and/or Comment
A. Air Bubble (void)	Air entrapment within and between the piles of liner reinforcement usually spherical in shape	The lesser of $^1/_{32}$ in. diameter or $^1/_2$ the liner thickness	No limit			No repair allowed
B. Chip	Small piece broken off an edge or surface	$^1/_{16}$ in. long by lesser of $^1/_{32}$ in. or $^1/_2$the liner thickness deep	10			No repair allowed
C. Crack	An actual separation of laminate, visible on opposite surfaces, and extending *through* the thickness	None permitted				Not permitted
D. Crazing	Fine cracks at or under surface					Not permitted
E. Dry-Spot	Area where reinforcement has not been thoroughly wetted with resin	None permitted				Not permitted
F. Lack of Fill-Out	Area, occurring usually in a radius area where the resin has drained from the reinforcement	1 in. wide by $^1/_8$ in. deep				No repair allowed
G. Pitts (Pinholes)	Small crater in surface	$^1/_{16}$ in. long by lesser of $^1/_{32}$ in. or $^1/_2$ the liner thickness deep	10			No repair allowed
H. Scratch	Shallow mark, groove, furrow, or channel caused by improper handling, storage or extraction of part from form			Lesser of $^1/_{32}$ in. or $^1/_2$ the liner thickness	No limit	Coat with liner resin
I. Wrinkle	In a laminate, an imperfection that has the appearance of a wave molded into one or more plies of fabric or other reinforcement material	Unlimited if no cracks	No limit			No repair required

NOTE:
(1) Where either the maximum acceptable size or number of an indication is exceeded, the product is unacceptable.

Table 2900-1B
Visual Examination Criteria and Repair Requirements for Outside Surface Area of RTRP Pipe and Filament Wound, Hand Fabricated, and Spray-Up Fittings 16 in. Nominal Size and Smaller

		Acceptance Limit [Note (1)] No Repair Required		Acceptance Limit [Note (1)] Repair Required		
Indication	Description	Max Dimension	No./ft^2	Max Dimension	No./ft^2	Required Repair and/or Comment
A. Burn	Showing evidence of thermal decomposition, through discoloration, distortion, or destruction of the surface of the laminate					Not permitted
B. Chip	Small pieces broken off an edge or surface			$^3/_8$ in. by $^1/_{16}$ in. deep	20	Coat with resin
C. Crack	An actual separation of laminate, visible on opposite surfaces, and extending *through* the thickness					Not permitted
D. Crazing	Fine cracks at or under surface exposing reinforcement					Not permitted
E. Drip, Resin	Resin protrusion	$^1/_8$ in. high	No limit	Any size greater than $^1/_8$ in. high	No limit	Grind excess
F. Dry Spot	Area where reinforcement has not been thoroughly wetted with resin			1 in. across	2	Coat with resin
G. Fish-Eye	Small globular mass which has not blended completely into the surrounding material and is particularly evident in a transparent or translucent material	$^1/_8$ in. high	No limit	Any size greater than $^1/_8$ in. high	No limit	Grind excess
H. Fracture	Rupture of laminate surface without complete penetration					Not permitted
I. Lack of Fillout	Area occurring usually in a radius area where the resin has drained from the reinforcement			1 in.	2	Coat with resin
J. Pimple	Small, sharp or conical elevation on exterior surface of laminate	$^1/_8$ in. high	No limit	Any size greater than $^1/_8$ in. high	No limit	Grind excess
K. Pit (Pinhole)	Small crater in surface	$^1/_8$ by $^1/_{16}$ in. deep	20			No repair allowed
L. Scratch	Shallow mark, groove, furrow, or channel caused by improper handling, storage or extraction of part from form	No exposed reinforcement	No limit	$^1/_{32}$ in. deep into exposed reinforcement	20	Coat with resin

NOTE:
(1) Where either the maximum acceptable size or number of an indication is exceeded, the product is unacceptable.

Table 2900-2A
Visual Examination Criteria and Repair Requirements for Inside-Surfaces of RTRP Pipe and Fittings Greater Than 16 in. Diameter

Discrepancy	Description	Acceptance Limit — No Repair Required: Max Dimension	Acceptance Limit — No Repair Required: No./ft^2	Permitted Repairs	Comments
A. Air Bubble (Void)	Air entrapment within and between the plies of liner reinforcement usually spherical in shape	$^1/_{32}$ in. diameter	10	[Note (1)] or [Note (3)]]	Repair to be made between plies only if liner surface fractures with a 2 lb. force applied using an instrument with a $^1/_2$ in. minimum radius of curvature
B. Cracks or Crazing in Liner	Cracks at or under surface or extending through thickness of liner	$^1/_4$ in. long	...	[Note (1)]	None
C. Dry-Spot	Area where liner material was not thoroughly wetted with resin	$^1/_2$ in. diameter	...	[Note (1)] or [Note (2)]]	Use “2” if smaller than $^1/_2$ in. diameter
D. Lack of Fillout	An area, occurring usually in a radius area where the resin has drained from the reinforcement	$1^1/_2$ in. long by $^1/_8$ in. deep	...	[Note (3)]	If larger than “max dimension” use “1”
E. Pitts (Pinholes)	Smaller crater in surface	$^1/_8$ in. diameter by $^1/_2$ the liner thickness	...	[Note (2)]	If larger than “max dimension” use “1”
F. Scratch	Shallow mark, groove furrow or channel caused by improper handling, or extraction of part from form	$^1/_2$ liner thickness	No limit	[Note (2)]	If more than $^1/_2$ liner thickness use “1”
G. Wrinkle	In a laminate, an imperfection that has the appearance of a wave molded into one or more plies of reinforcement material	No limit	...	None Required	Use repair “1” for voids or fragile crest
H. Chip or Delamination	A small piece of liner broken off an edge or surface or separation of liner from pipe wall	$^1/_2$ liner thickness	...	[Note (1)]	...

NOTES:
(1) Replace liner material in the discrepant area.
(2) Postcoat with liner resin and wax additive.
(3) Fill void with a resin putty.

Table 2900-2B
Visual Examination Criteria and Repair Requirements for Outside Surfaces of RTRP Pipe and Fittings Greater Than 16 in. Diameter

		Acceptance Limit — No Repair Required			
Discrepancy	Description	Max Dimension	No./ft^2	Permitted Repairs	Comments
A. Burn	Thermal decomposition evidenced by distortion and/or destruction of the surface	No repair necessary up to 5% of wall thickness	5	[Note (1)]	No repair permitted if decomposition extends beyond 35% of wall thickness
B. Chip	Small piece broken from edge or surface	$^1/_4$ in. by $^1/_{16}$ in. deep	20	[Note (2)]	If deeper than $^1/_{16}$ in. use "1"
C. Crack	Separation of the laminate extending through the wall and visible on opposite surfaces	None permitted	0	None	...
D. Cut Roving	Broken or cut outer rovings due to scraping or scuffing during handling	None permitted	...	[Note (1)]	...
E. Crazing	Fine cracks in the postcoat surface	$^1/_{16}$ in. width	...	[Note (2)]	...
F. Dry Spot	Area where reinforcement was not thoroughly wetted with resin	None permitted	...	[Note (2)]	...
G. Fracture	Rupture of laminate surface without complete penetration	None permitted	...	[Note (1)]	...
H. Lack of fillout	Void areas between parallel filament rovings	Single plane, noncrossing filament rovings	...	[Note (2)]	...
I. Pits (Pinholes)	Small craters in surface	$^1/_8$ in. diameter with no exposed reinforcement	25	[Note (2)]	...
J. Scratch	Shallow mark, groove, furrow, or channel caused by improper handling	No exposed reinforcement	...	[Note (2)]	...

NOTES:
(1) Overlay 6 in. beyond damaged area with 1.3 times thickness of material removed.
(2) Postcoat with structural wall resin and wax additive.

-3110 Nomenclature

The Nomenclature used in -3000 is given in -3110.1.

-3110.1 Nomenclature Used in the Design

A, A_1, A_2 = reinforcement area
B = additional wall thickness, for stresses due to moments, erosion, mechanical damage, etc.
D = mean pipe diameter
D_i = inside pipe diameter
E = geometric mean modulus of elasticity
E_{LT} = tensile longitudinal modulus
E_{LC} = compressive longitudinal modulus
E_l = tensile modulus of pipe liner
E_{HT} = circumferential tensile modulus
E_{HF} = circumferential flexural modulus
i = intensification factor
K = = allowable stress multiplier
F_1, F_2, F_3 = available adhesive shear length
L_{msa} = minimum shear length of adhesive
L_{mso} = minimum shear length of overlay
L_{msob} = minimum shear length of overlay in branch
L_{msoh} = minimum shear length of overlay in header
M_A = resultant moment due to sustained loads
M_B = resultant moment due to occassional loads
M_C = resultant moment due to thermal expansion and pressure elongation
P = internal design pressure
P_{max} = peak pressure
r = mean radius of pipe
S_{ALP} = allowable structural longitudinal stress for pipe
S_{LT} = longitudinal tensile strength
S_{ACP} = allowable structural circumferential stress for pipe
S_{HT} = hoop tensile strength
S_{ASO} = allowable shear stress of overlay
S_{LC} = longitudinal compressive strength
S_{ATO} = allowable tensile stress of overlay

Table 2900-3A
Visual Examination Criteria and Repair Requirements for Structural Wall of RTRP Pipe and Filament Wound, Hand Fabricated, and Spray-Up Fittings 16 in. Nominal Size and Smaller

		Acceptance Limit [Note (1)] No Repair Required		Acceptance Limit [Note (1)] Repair Required		
Indication	Description	Max Dimension	No./ft²	Max Dimension	No./ft²	Required Repair and/or Comment
A. Air Bubble (Void)	Air entrapment within and between the plies of reinforcement usually spherical in shape	$^1/_{32}$ in. diameter	6			No repair allowed
B. Burn	Showing evidence of thermal decomposition through discoloration distortion, or destruction of the surface of the laminate					Not permitted
C. Delamination	Separate between layers of material. Usually appears as a thin, light shaded (whitish) layer	1 in. across	1			No repair allowed
D. Dry-Spot	Area where reinforcement has not been thoroughly wetted with resin			1 in. across	2	Coat with resin
E. Foreign Inclusion	Particles of a substance included in a laminate which seems foreign to its composition	$^1/_{16}$ in.	2			No repair allowed
F. Wormhole	Elongated air entrapment which is either in or near the surface of a laminate and may be covered with a thin film of curved resin	$^1/_{32}$ in. diameter by 1 in. long	6			No repair allowed

NOTE:
(1) Where either the maximum acceptable size or number of an indication is exceeded, the product is unacceptable.

S_{ASA} = allowable shear stress of adhesive
T_L = longitudinal thrust loads
t_n = nominal composite wall thickness of pipe
= t_m + manufacturing tolerances + liner + exterior dress-coating
t_l = thickness of the liner
t_{nb}, t_{nh} = nominal wall thickness of branch, header
t_e = thickness of reinforcement
t_{eb}, t_{eh} = reinforcement thickness in branch, header
t_{mo} = thickness of overlay
t_m = minimum structural wall thickness, equal to the greater of t_{mc} or t_{ml}
t_{mb}, t_{mh} = minimum structural wall thickness of branch, header
t_{mc}, t_{ml} = minimum structural wall thickness, based on circumferential pressure stress, longitudinal pressure stress
Z = section modulus
ν = Poisson's ratio
β = linear coefficient of thermal expansion

-3112.2 Design Temperature (ND-3112.2). Change all references from "metal" to "material," delete references to Tables 1A, 1B, Section II, Part D Subpart 1 and add the following sentence. Where the system is exposed to the sun, the heating of the pipe material due to sunlight shall be considered in determining the Design Temperature.

-3133 Components under External Pressure (ND-3133)

-3133.3 Cylindrical Shells and Tubular Products (ND-3133.3). Replace ND-3133.3 with the following: The following external pressure design rules apply only to components used in nonburied applications. The Designer is also cautioned to verify that the moment of inertia of the stiffner, if any, is sufficient as required by ND-3133.5.

For components to be used in buried applications, refer to -3133.9.

(a) The thickness of cylinders under uniform, external pressure shall be determined by the procedures given in *(1)* through *(3)* below.

(1) Assume a value of t_m. Determine the ratio of L/D_o. If L/D_o is greater than 50, calculate P_{a1} by the following equation:

$$P_{a1} = \frac{Et_m{}^3}{2\left(1 - \upsilon^2\right)D_o{}^3}$$

If L/D is less than or equal to 50, calculate Pa_1 by the following equation:

$$P_{a1} = 0.5706\frac{Et_m{}^2}{LD_o}\left(\left(1 - \upsilon^2\right)^{-3}\frac{t_m{}^2}{D_o^2}\right)^{1/4}$$

Table 2900-3B
Visual Examination Criteria and Repair Requirements for Structural Wall of RTRP Pipe and Fittings Greater Than 16 in. Diameter

Discrepancy	Description	Acceptance Limit — No Repair Required: Max Dimension	Acceptance Limit — No Repair Required: No./ft^2	Permitted Repairs	Comments
A. Air Bubble (Void)	Air entrapment within and between the plies of reinforcement usually spherical in shape	$^1/_4$ in. Diameter or $^1/_5$ of the structural wall thickness, whichever is less	8	[Note (1)] Any size greater but not affecting more than $^1/_4$of the wall thickness	See comment under A, Table 2900-1B
B. Burn	Showing evidence of thermal decomposition through discoloration, distortion, or destruction of the surface of the laminate	$^1/_4$ in. Diameter or $^1/_5$ of the structural wall thickness whichever is less	8	[Note (1)] Any size greater but not affecting more than $^1/_4$ of the wall thickness	See comment under A, Table 2900-1B
C. Delamination At Ends of Pipe	Separation between layers of material. Usually appears as a thin, light shaded (whitish) layer	1 in. Diameter Across	...	[Note (2)]	"1" to be used if delamination appears in last two outer layers
D. Dry-Spot	Area where reinforcement has not been thoroughly wetted with resin	3 in. Diameter	...	[Note (1)]	...
E. Foreign Inclusion	Particles of a substance included in a laminate which seems foreign to its composition	$^1/_8$ in. Thick × 1 in. Diameter	2	[Note (1)]	...
F. Voids (Bridging)	Small air inclusions entrapped between the rovings of the filament winding	$^3/_{16}$ in. Diameter and In Only one filament direction	...	[Note (2)]	...

NOTES:
(1) Overlay 6 in. beyond damaged area with 1.3 times the affected thickness.
(2) Fill affected area with winding resin.

Table 2900-4
Visual Examination Criteria and Repair Requirements for RTRP Molded and Centrifugally Cast Fittings 16 in. Nominal Size and Smaller

Indication	Description	Acceptance Limit [Note (1)] No Repair Required: Max Dimension	Acceptance Limit [Note (1)] No Repair Required: No./ft^2 [Note (2)]	Acceptance Limit [Note (1)] Repair Required: Max Dimension	Acceptance Limit [Note (1)] Repair Required: No./ft^2 [Note (2)]	Required Repair and/or Comment
A. Blister	Humps or mounds on inner or outer surface caused by expansion of trapped gas as mold pressure is released	$^1/_4$ in. diameter not in bonding surface	4			Blisters not permitted in bonding surface
B. Crack	Material separation or fracture					Not permitted
C. Delamination	Appear as light spots of dry or separated glass	$^1/_2$ in. across	3			Not permitted
D. Void	Insufficient material to fill mold completely. Part incomplete or not well filled out. Prepreg staples not completely consolidated and fused					Not permitted

NOTES:
(1) Where either the maximum acceptable size or number of an indication is exceeded, the product is unacceptable.
(2) If surface is less than 1 sq. ft., the number indicated shall be per fitting.

(2) Also calculate a value of the maximum allowable working pressure, P_{a2}, by the following equation:

$$P_{a2} = 2S_{AC}\left(\frac{t_m}{D_o}\right)\left(1 - \frac{t_m}{D_o}\right)$$

where S_{AC} is allowable design compressive stress in the circumferential direction (Table -3133-1).

(3) The smaller value of Pa_1, calculated in (1), or Pa_2, calculated in (2), shall be used for Pa. Compare Pa with the Design Pressure, P. If Pa is smaller than P, select a greater value of t_m and repeat the procedure until a value for Pa is obtained which is equal to, or greater than, P.

-3133.6 Cylinders under Axial Compression. In course of preparation.

ND-3133.6 does not apply.

-3133.9 Buried Pipe. Where piping components are buried underground the methods of design outlined in the Bureau of Reclamation Standard No. REC-ERC-77-1[1] may be used as an alternative method for determining deflection.

The calculated and measured diametrical deflection of the pipe wall shall not exceed 5%.

-3600 PIPING DESIGN (ND-3600)

The requirements of Subarticle ND-3600 shall be met except as modified by the following.

-3611 Acceptability (ND-3611)

The requirements of ND-3611 shall be replaced by the following:

The requirements for acceptability of a piping system are given in the following subparagraphs.

-3611.1 Allowable Stress Values. Allowable stress values to be used for the design of piping systems are given in Table -3611-1 for straight pipe and Table I-1 of Mandatory Appendix I for fittings.

-3611.2 Stress Limits.

(a) Design and Service. Loadings shall be specified in the Design Specification.

(b) Design Loadings. The sum of stresses due to design internal pressure, weight, thermal expansion and other sustained loads shall not exceed S_{ALP}. This requirement is satisfied by meeting eq. -3652.1(8).

(c) Service Loadings. The following Service Limits shall apply to Service Loadings as designated in the Design Specification.

(1) Level A Service Limits. The sum of stresses due to design pressure, weight, thermal expansion, and sustained loads shall not exceed the allowable longitudinal stress S_{ALP} in Table -3611-1. This requirement is satisfied by meeting eq. -3611-1 (8). The calculated circumferential stress due to internal pressure shall not exceed the allowable circumferential stress S_{ACP} in Table -3611-1.

(2) Level B Service Limits. The sum of stresses produced by maximum internal pressure, thermal expansion, live and dead loads, and those produced by occasional loads, such as wind and earthquake identified in the Design Specifications as acting during the Service Loadings [NCA-2142.2(a)] for which these limits are designated shall not exceed 1.2 times the allowable longitudinal stress value S_{ALP} in Table -3611-1. This requirement is satisfied by meeting eq. -3611-1 (9). When Level B limits apply, the calculated circumferential stress due to maximum internal pressure shall not exceed 1.2 times the allowable circumferential stress S_{ACP} in Table -3611-1.

(3) Level C Service Limits. The sum of the longitudinal stresses produced by internal pressure, thermal expansion, live and dead load, and those produced by occasional loads identified in the Design Specifications as acting during the Service Loadings [NCA-2142(a)] for which these limits are designated shall not exceed 1.4 times the allowable longitudinal stress S_{ALP} in Table -3611-1. This requirement is satisfied by meeting eq. -3652.2(9), using a stress limit of 1.4 S_{ALP} in lieu of 1.2 S_{ALP}. When Level C Limits apply, the calculated circumferential stress due to maximum internal pressure shall not exceed 1.4 times the allowable circumferential stress S_{ACP} in Table -3611-1.

(4) Level D Service Limits. The sum of the longitudinal stresses produced by internal pressure, thermal expansion, live and dead load, and those produced by occasional loads identified in the Design Specifications as acting during the Service Loadings [NCA-2142(a)] for which these limits are designated shall not exceed 1.8 times the allowable longitudinal stress S_{ALP} in Table -3611-1. This requirement is satisfied by meeting eq. -3652.2(9), using a stress limit of 1.8 S_{ALP} in lieu of 1.2 S_{ALP}. When Level D limits apply, the calculated circumferential stress due to maximum internal pressure shall not exceed 1.8 times the allowable circumferential stress S_{ACP} in Table -3611-1.

-3612 Pressure-Temperature Ratings for Piping (ND-3612)

It is recognized that variations in pressure and temperature inevitably occur, and therefore the piping system shall be considered safe for occasional operation for short periods at higher than the Design Pressure or Temperature as limited in -3611.2 and in 4.1.3 of Mandatory Appendix II.

[1] Available from the National Technical Information Service, Operations Division, Springfield, Virginia 22151.

Table -3133-1
Material Compressive Strength

Designation Code [Note (1)]	Minimum Ult. Short Term Compressive Stress psi [Note (2)]	Allowable Design Compressive Stress, S_{AC}, psi
1	4000	670
1a	7000	1170
1b	10000	1670
2	13000	2170
2a	16000	2670
2b	19000	3170
3	22000	3670
3a	25000	4170
3b	28000	4670
4	31000	5170
4a	34000	5670
4b	37000	6170
5	40000	6670

NOTES:
(1) In accordance with Section 4.3, Mandatory Appendix II of this Case.
(2) Determine in accordance with ASTM D695, Mandatory Appendix II, 4.2.3.

-3613 Allowances (ND-3613)

In applying the requirements of ND-3613 to this Case, wall thickness may include the thickness of the liner for purposes of corrosion resistance or corrosion allowance.

-3613.2 Threading/Grooving (ND-3613.2). Replace the word "cut" in ND-3613.2 with the words "thread or groove."

-3622 Dynamic Effects (ND-3622)

The following requirement is in addition to the requirements of ND-3622.1.

(a) Design shall be such as to minimize impact forces caused by either external or internal conditions.

-3640 Pressure Design of Piping Products (ND-3640)

The requirements of ND-3641.1 shall be replaced by the following requirements:

-3641.1 Straight Pipe under Internal Pressure. The minimum composite thickness of pipe wall, t_m, required for Design Pressures and for temperatures not exceeding the Design Temperature, including allowances for mechanical strength, shall not be less than the greater of the thickness determined by Eqs. (1) and (3) as follows:

CIRCUMFERENTIAL CALCULATION

$$t_{mc} = \frac{PD_O}{2S_{ACP}} + B \tag{1}$$

Table -3611-1
Allowable Tensile Design Stresses in Pipe Meeting the Requirements of D2992
[Note (1)]

ab*HDB* Designation Code [Note (2)]	Min *HDB* [Note (3)]	S_{ACP} [Note (4)]	S_{ALP} [Note (4)], [Note (5)]	Notes
A	2400	2400	1200	[Note (6)]
B	3020	3000	1500	[Note (6)]
C	3830	3800	1900	[Note (6)]
D	4800	4800	2400	[Note (6)]
E	6000	6000	3000	[Note (6)]
F	7600	7600	3800	[Note (6)]
G	9600	9600	4800	[Note (6)]
H	12000	12000	6000	[Note (6)]
Q	4800	2400	1200	...
R	6000	3000	1500	...
S	7600	3800	1900	...
T	9600	4800	2400	...
U	12000	6000	3000	...
W	15300	7600	3800	...
X	19000	9500	4750	...
Y	24000	12000	6000	...
Z	30000	15000	7500	...

NOTES:
(1) Temperature limits in accordance with section 4.1.3, Mandatory Appendix II.
(2) Designation Code in accordance with Mandatory Appendix II of this Case.
(3) HDB = hydrostatic design basis strength given in the above Table for the classification applicable to the pipe as determined by the qualification test. Values for designations A through H are the minimum required stresses to failure in 150,000,000 cycles by D2992 Method A. Values for designations Q through Z are the minimum required stresses to failure in 100,000 hr by D2002 Method B.
(4) The use of these allowale stress values is limited to services where the number of full pressure cycles is limited to 100,000 cycles during the design life of the system. For services requiring more than 100,000 cycles, use one-half the values shown for S_{ACP} and S_{ALP}.
(5) S_{ALP} may be taken as the higher of this value or a value of S_{ALP} determined by $S_{ALP} = S_{UL}K_L$.
where
S_{UL} = minimum required longitudinal tensile strength given in Table II-4.4-1, Mandatory Appendix II, for the designation applicable to the pipe as determined by the qualification test.
$K_L = \frac{S_{ACP}}{S_{UC}}$
S_{UC} = minimum required hoop tensile strength given in Table II-4.4-1, Mandatory Appendix II, of this Case.
(6) The HDB as determined by Procedure A is not a requirement but is acceptable as a design basis. When pipe has been qualified by both Method A and Method B, the HDB as determined by Method B is acceptable as the design basis.

$$P = \frac{2S_{ACP}(t_{mc} - B)}{D_O} \quad (2)$$

LONGITUDINAL CALCULATION[2]

$$t_{ml} = \frac{PD_O}{4S_{ALP}} + B \quad (3)$$

$$P = \frac{4S_{ALP}(t_{ml} - B)}{D_O} \quad (4)$$

where

t_m = larger of t_{mc}, t_{ml} = minimum required composite wall thickness determined by primary circumferential (eq. (1)) or longitudinal (eq. (3)) stress in inches. If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness is to be taken into account. The minimum wall thickness may include several noncontributing layers that have been considered in establishing the stress allowables. The minimum wall thickness excludes the liner thickness and/or exterior dress-coating. After the minimum pipe wall thickness, t_m, is determined from the greater of Eqs. (1) and (3), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance.

P = Internal Design Pressure, psi. When computing the Design Pressure for a pipe or a definite minimum wall thickness by Eqs. (2) and (4), the value of P obtained by these equations may be rounded to the next higher unit of 5.

D_o = outside diameter of pipe, inches. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness excluding the liner at the thinner end of the pipe may be used to calculate this pressure. Care must be exercised to assure that the value of D_o is for the maximum possible outside diameter allowable under the purchase specification.

S_{ACP}, S_{ALP} = maximum allowable composite circumferential and longitudinal stress, respectively, in wall material due to internal pressure, at the Design Temperature, psi. The values of S_{ACP} and S_{ALP} shall be taken from Table -3611-1 for the respective material and Design Temperature.

B = an additional thickness in inches which shall be used as stipulated in (a) through (d) below.

(a) To compensate for either material removed or wall thinning or both due to grooving as in ND-3613.2.

(b) To provide for mechanical strength of the pipe. Small diameter, thin wall pipe is susceptible to mechanical damage during installation, operation, or maintenance. Accordingly, means shall be employed to protect such piping against these types of loads if they are not considered as Design Loads. Increased wall thickness is one way of contributing to prevention of mechanical damage.

(c) To provide for erosion. Since erosion varies widely from installation to installation, it is the responsibility of designers to determine the proper amounts which must be added for this condition as in ND-3613.1. Increasing liner thickness is an acceptable alternative to increasing the composite wall thickness when compensating for erosion.

(d) To provide for additional stresses due to moments. In this type of piping, designing for pressure only might cause allowable stresses to be reached in either the circumferential or longitudinal directions, leaving no margin for additional stresses due to moments. In preliminary design, when large moments are expected in the longitudinal directions, it is suggested that the Factor B in eq. (3) be increased by an amount equal to the value of the first term. For final design, this factor must be adjusted as necessary, to meet eqs. -3652.1(8) and -3652.2(9).

-3642 Curved Segments of Pipe (ND-3642)

In lieu of the requirements of ND-3642.1 and ND-3642.2, the following shall apply:

-3642.1 Elbows. Except as permitted by -3642.2 of this Case, elbows shall meet the requirements of Mandatory Appendix I.

-3642.2 Mitered Elbows. Mitered elbows are not required to meet the requirements of Mandatory Appendix I provided the miters meet the requirements of -3644 and -4200 of this Case and the pipe from which they are made meets the requirements of -2111 and -3641 of this Case.

-3643 Intersections (ND-3643)

-3643.1 Requirements. *ND-3643.1 applies with the following exceptions:*

The requirements in ND-3643.1(c) shall be replaced with the following:

(c) Branch connections in piping may be made by using one of the products or methods set forth in (1) through (4) below.

[2] Equations (3) and (4) may not apply for pipe in which the hydrostatic axial loads are not supported by the pipe wall as may occur in systems using bell and spigot joints and thrust blocks. The equations may be modified to reflect the anticipated axial service loads (see -3652).

(1) A branch connection may be made by attaching the branch pipe directly to the run pipe, in accordance with the requirements of -3643.3 of this Case.

(2) Open-molded, in accordance with the requirements of -3643.2.

(3) Filament wound, in accordance with the requirements of -3643.2.

(4) Compression-molded, in accordance with the requirements of -3643.2.

-3643.2 Branch Connections Not Requiring Reinforcement (ND-3643.2). Replace ND-3643.2 with the following:

Reinforcement is not required if the branch connection is made as a fitting in accordance with Mandatory Appendix I. Such branch connections may be of the open molded, filament wound, or compression-molded types.

-3643.3 *ND-3643.3 applies with the following exceptions:*

Replace ND-3643(a) with the following:

(a) A branch connection may be made by attaching the branch pipe directly to the run pipe and adding reinforcement in accordance with (b) and (c) below:

The requirements of ND-3643.3(b) shall be replaced with the following:

(b) Branch connections made to the requirements of -3643.3 and -4200 are not required to meet the requirements of Mandatory Appendix I. The use of such branch connections is limited to nonflammable, noncyclic services with incompressible fluids at pressures of 100 psi (689 kPa) and less, and gaseous vents to the atmosphere. Branch connections used in other services or at higher pressures shall meet the requirements of Mandatory Appendix I. Noncyclic service is service of less than 7000 full pressure or temperature cycles during the expected lifetime of the piping system.

(c) See ND-3643.3(c). Where ND-3643.3(c) refers to Figs. ND-3643.3(c)(1)-1 and ND-3643.3(c)(1)-2, it shall be taken to refer to Figure -3643.3(c)-1 for FRP pipe.

Revise the definition of t_e to the following:

t_e = thickness of reinforcement

Add the following to the list of Nomenclature:

S_{ACP} = allowable composite circumferential stress in pipe

S_{ATO} = allowable tensile stress in overlay reinforcement, Table -3643-1

L_{msob} = minimum overlay branch, shear length required

L_{msoh} = minimum overlay run, shear length required

Replace ND-3643.3(c)(3) with the following:

(3) Reinforcement Area and Shear Length. The required reinforcement area in square inches for the branch connections and the minimum shear length of the overlay in inches shall be in accordance with *(-a)* through *(-f)*.

(-a) The required reinforcement area shall be

$$2(2-\sin\alpha)\,t_{nh}\,d_1\frac{S_{ACP}}{S_{ATO}}$$

(-b) One hundred % of the required reinforcement shall be within the limits of Reinforcement Zone 1 as defined in (5)(-a) below.

(-c) Sixty % of the required reinforcement shall be within the limits of Reinforcement Zone 2 as defined in (5)(-b) below.

(-d) In no case shall excess thickness in the header pipe or branch pipe being joined be counted as reinforcement.

(-e) The minimum shear length of the header overlay shall be

$$L_{msoh}=t_h\frac{S_{ACP}}{S_{ASO}}$$

S_{ASO} = allowable shear strength for the overlay bound (Table -3643-2)

The minimum shear length for the branch pipe shall be

$$L_{msob}=t_b\frac{S_{ACP}}{S_{ASO}}$$

(-f) When the ratio of S_{ACP}/S_{ASO} is less than 1, the value of 1 shall be used in satisfying the requirements of this paragraph.

Replace ND-3643.3(c)(4) with the following:

(4) Areas Contributing to Reinforcement. Material needed to meet the reinforcement required by -3643.3(c) must be within the limits of Reinforcement Zones 1 and 2 as determined in ND-3643.3*(c)(5)* and may include the following areas:

A_1, A_2 = Areas providing reinforcement in Zone 1 and Zone 2.
A_3, A_4 = Areas A_5, A_6 providing reinforcement in
A_5, A_6 = Zone 1.

Replace ND-3643.3(c)(5) with the following:

(5) Reinforcement Zones

The zones are parallelograms of length and width, defined as follows:

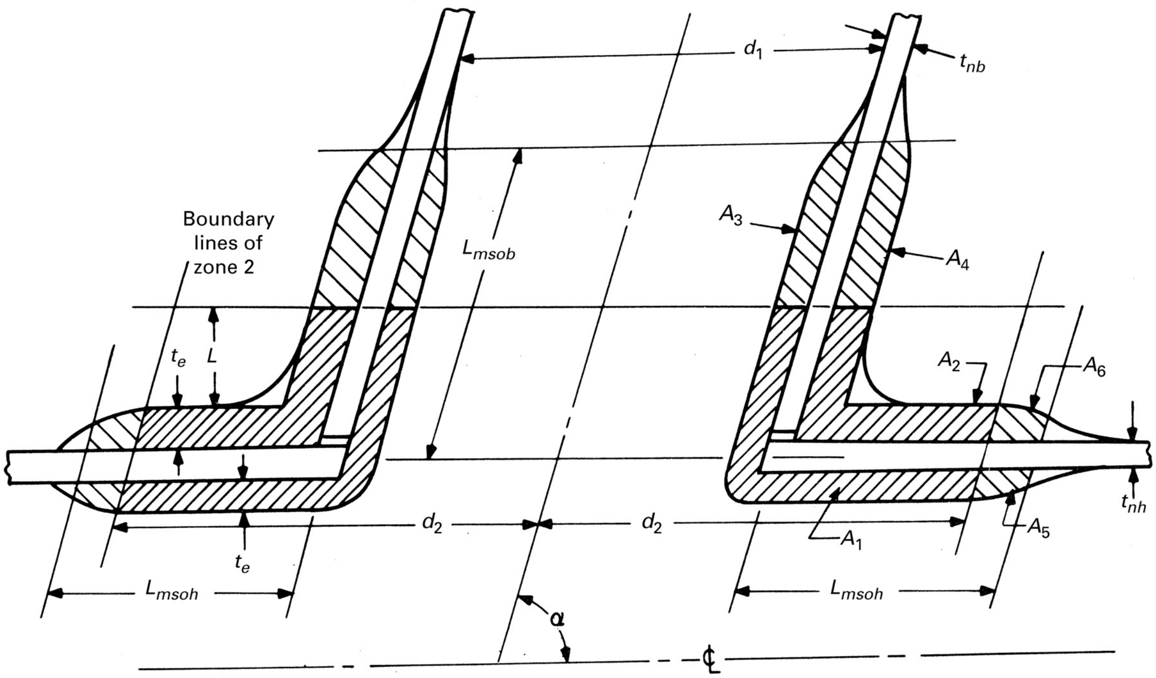
(-a) Zone 1 — The length of the parallelogram shall extend from each side of the center line of the branch pipe to a distance of $L_{msoh}+\left(d_1+t_{nb}\right)/2$. The width shall

Table -3643-1
Overlay Tensile Stress

Min. Ult. Short Term Tensile Stress, psi [Note (1)]	Allowable Design Tensile Stress of Overlay, S_{ATO}, psi
20,000	3300

NOTE:
(1) Determined in accordance with ASTM D638.

Figure -3643.3(c)-1
Reinforcement of Branch Connections



GENERAL NOTE: Explanations of Areas

$$\text{Required reinforcement area} = 2t_{nh}(d_1)(2 - \sin\alpha)\frac{S_{ACP}}{S_{ATO}}$$

t_{nh}, t_{nb} = Nominal wall of header, branch.
A_1, A_2 = Areas of reinforcement within Zone 1 and Zone 2.
A_3, A_4, A_5, A_6 = Areas of reinforcement within Zone 1.

NOTES:
(1) Sixty % of required total replacement areas must be contained within A_1 and A_2.
(2) L_{msob} and L_{msoh} are the minimum shear lengths of overlay applied to the header and branch, respectively.
(3) When the end of the overlay is tapered, the required shear length may not be considered past the point where the overlay thickness has decreased to 50% of t_e.
(4) It is desirable to place reinforcement on both the inside and outside of the branch connection. If size does not permit the practice, the overlay may be placed outside the branch only.

start at a distance of t_e, from the inside surface of the run pipe, and extend to a distance of $L_{msob} - t_{nb} / 2$, from the outside surface of the run pipe.

(-b) Zone 2 — The length of the parallelogram shall extend from each side of the center line of the branch center line a distance of d_2. The width shall start at a distance of t_e, from the inner surface of the header pipe, and extend a distance of $L + t_e$, from the outer surface of the header pipe.

Replace ND-3643.3(c)(6)(a) with the following:

(6) Reinforcement of Multiple Openings

(-a) When any two or more adjacent openings are so closely spaced that their reinforcement zones overlap, the two or more openings shall be reinforced in accordance with -3643.3 with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for separate openings. No portion of the cross section shall be considered as applying to more than one opening or be evaluated more than once in a combined area.

Replace ND-3643.3(c)(7) with the following:

(7) Rings, Pads and Saddles

Table -3643-2
Overlay Shear Strength

Min. Ult. Short Term Shear Strength of Overlay, psi [Note (1)]	Allowable Design Shear Stress of Overlay, S_{ASO}, psi
500	250
1000	500
1500	750
2000	1000
2500	1250
3000	1500

NOTE:
(1) Determined in accordance with ASTM D2517, Section 8.8.

(-a) Reinforcement provided in the form of rings, pads, or saddles shall have sufficient thickness, material strength, and bond shear length to meet the requirements of -3643.3(c)(1) through -3643.3(c)(6) of this Case.

(-b) Alternatively if a saddle-pipe assembly meets the requirements of Mandatory Appendix I, the requirements of (-a) above need not be met.

-3643.4 Integrally Reinforced Outlets (See Fig. ND-3643.4-1). ND-3643.4 does not apply to RTRP.

-3643.6 Branch Connections Subject to External Pressure.

(a) The reinforcement area for branch connections subject to external pressure shall be 50% of the required reinforcement area under internal pressure.

(b) The required branch and run shear lengths shall be the same as the required shear lengths under internal pressure.

(c) Procedures established for connections subject to internal pressure shall also apply for connections subject to external pressure.

-3644 Miters (ND-3644)

Replace ND-3644 with the following:

Mitered joints may be used in RTRP piping systems under the conditions stipulated in (a) through (f) below.

(a) The thickness of a segment of a miter shall be determined in accordance with -3641.1. The required thickness thus determined does not allow for the discontinuity stresses which exist at the junction between segments. The discontinuity stresses are reduced for a given miter as the number of segments is increased. These discontinuity stresses may be neglected for miters in nonflammable, nontoxic, noncyclic services with incompressible fluids at pressures of 100 psi (689 kPa) and under, and for gaseous vents to atmosphere. Miters to be used in other services or at higher pressures shall meet the requirements of Mandatory Appendix I.

(b) The number of full pressure or thermal cycles shall not exceed 7000 during the expected lifetime of the piping system.

(c) The angle θ in Fig. ND-3673.2(b)-1 shall not be more than 15 deg.

(d) The center line distances between adjacent miters shall be a minimum of $S = 2L_{mso} + D_O \sin\theta$

(e) Butt and strap joints shall be used to join segments together. Manufacture and design shall be in accordance with -3665, where the thickness of the overlay and shear length shall be increased as required to compensate for bending moments of -3672.

(f) As an alternative to the requirements of -3644, fittings made with miter joints shall meet the requirements of Mandatory Appendix I.

-3645 Attachments

The requirements of ND-3645 shall be replaced with the following:

(a) External and internal attachments shall be designed so that local stresses occurring as the result of induced bending moments, forces generated by thermal gradients between dissimilar materials, pressure and thermal elongations, and other occurrences do not exceed allowable stresses. All attachments shall be constructed to minimize stress concentrations and preserve the flexibility of the system.

(b) For supported pipe, refer to ND-3676.9.

(c) Adhesive shear strengths for bonded attachments shall be in accordance with Table -3662-1.

-3646 Closures

The requirements of ND-3646 shall be met, except that (c) shall be replaced with the following:

(c) Connections to closures may be made by fiber glass overlaying or threading, and the reinforcement of the connection shall comply with -3643 of this Case. If the size of the opening is greater than one-half the inside diameter of the closure, the opening shall be designed as a reducer in accordance with ND-3648.

-3647 Pressure Design of Flanged Joints and Blanks (ND-3647)

-3647.1 Flanged Joints. The requirements of ND-3647.1 shall be met except that the allowable pressure ratings and dimensions for RTR flanges shall be as given in Mandatory Appendix V and the following requirements shall be met.

(a) RTR Flanges and blanks may be used in Class 3 piping systems. RTR flanges shall only be used for sealing against flat-faced flanges. The use of raised-face flanges within the bolt circle without a filler ring, or diaphragm-type ring flanges made of RTR or joined to RTR flanges are prohibited unless the flange has been specifically designed for this type of connection.

-3647.2 Permanent Blanks (ND-3647.2).

(a) Permanent blanks made of RTR may be used provided d_6 in eq. (8) of ND-3647.2 is defined as follows:

d_6 = the inside diameter of the gasket O-ring or flat-faced flange.
S = $S_u/6$, where S_u is tensile strength as determined by the Method of ASTM D638.

(b) Blanks for use with RTR flanges shall be full-faced blanks.

(c) Temporary blanks (ND-3647.3).

When an RTR blank is used for test purposes only, it shall have a minimum thickness of not less than the pressure design thickness, *t*, calculated from eq. (8), of ND-3647.2 except that P shall not be less than the test pressure.

-3647.4 Flanges (ND-3647.4). Flanges constructed from RTR may be used in Class 3 piping systems for sealing against other RTR or steel flat-faced flanges. Flanges shall be designed to resist bending and axial pull-out forces calculated in the analysis.

-3647.5 Gaskets (ND-3647.5). Gaskets for use with RTR flanges shall be either the full-faced or O-ring type, and the gasket material shall be an elastomer material in accordance with the conditions of ND-3647.5(a).

-3647.6 Bolting (ND-3647.6). The requirements of ND-3647.6 apply for bolting.

-3648 Reducers (ND-3648)

RTR reducers shall be designed in accordance with Eqs. -3641.1(1) and -3641.1(3) and analyzed in accordance with -3652.4 and -3672.

-3649 Pressure Design of Other Pressure Retaining Piping Products (ND-3649)

Expansion joints shall comply with ND-3649.

-3650 Analysis of Piping Systems — General Requirements (ND-3650)[3]

-3651 Scope

ND-3651 applies except that eq. ND-3652.3(10) in ND-3652.3 shall not apply to RTR piping systems. ND-3652 applies except that ND-3652.3 does not apply, and the requirements of -3652.1, -3652.2 and -3652.4 shall be met in lieu of those in ND-3652.1 and ND-3652.2.

-3652.1 Design Loads. The effects of pressure, pressure elongation, thermal expansion, weight, and other sustained mechanical loads shall meet the requirements of eq. (8).

$$\frac{PD_O}{4t_m} + 0.75\frac{iM_A}{Z} + \frac{iM_C}{Z} \le 1.0S_{ALP} \qquad (8)$$

where

P = internal Design Pressure, psi
D_o = outside diameter of pipe, in.
t_M = minimum composite wall thickness as defined in -3641.1, in.
M_A = resultant moment-loading on cross section due to weight and other sustained loads, in.-lb
Z = section modulus of pipe, in.^{3} (-3652.4).
i = stress intensification factor (-3673.2). The product of 0.75 i shall never be taken as less than 1.0
M_C = resultant moment due to thermal expansion and pressure elongation, in.-lb. Also include moment effects due to anchor displacement resulting from thermal expansion
S_{ALP} = allowable composite longitudinal stress from Table -3611-1 for straight pipe, and Table 7 of Mandatory Appendix I for fittings, psi

-3652.2 Occasional Loads. The effect of pressure, thermal expansion, weight, other sustained loads, and occasional loads including earthquake shall meet the requirements of eq. (9).

$$\frac{P_{max}D_O}{4t_m} + 0.75\frac{i(M_A + M_B)}{Z} + \frac{iM_C}{Z} \le 1.2S_{ALP} \qquad (9)$$

Terms same as eq. -3652.1(8), except

P_{max} = peak pressure, psi
M_B = resultant moment-loading on cross section due to occasional loads, such as, thrusts from relief- and safety-valve loads from pressure and flow transients, and seismic, if the design specifications require the calculation of moments due to seismic and non-repeated anchor displacements. For seismic, use only one-half the range. Effects of anchor displacement due to seismic must be included.

Reference to eqs. -3662(10) and -3662(11) and to ND-3652.3 in ND-3652.4(a) does not apply to RTR piping constructed in accordance with this Case.

-3652.4 Determination of Moments and Section Modulus (ND-3652.4). *ND-3652.4 shall apply except that subpar. (b) shall be modified to read:*

(b) For the purposes of eqs. -3652.1(8) and -3652.2(9) of this Case, the section modulus for straight-through components, curved pipe, elbows for full-outlet branch connections, may be calculated as follows:

$$Z = \frac{\pi D^2}{4}t_m$$

where

D = mean diameter, in.

[3] The pressure term in eqs. (8) and (9) may not apply for pipe in which the hydrostatic axial loads are not supported by the pipe wall as may be the case in pipe systems with nonrestrained joints and thrust blocks. The term may be modified to reflect the anticipated axial service loads.

t_m = minimum composite wall thickness, as defined in -3641.1, in.

-3660 Design of Restrained Joints

-3661 Scope

Restrained joints are defined in -4321. The following types of restrained joints may be used in RTR piping systems.

(a) Bell and spigot adhesive-bonded joints (-3662).

(b) Bell and spigot adhesive-bonded joints with laminated fiberglass overlay (-3663).

(c) Bell and spigot gasket joints with laminated fiberglass overlay (-3664).

(d) Butt and strap joints (-3665).

(e) Flanged joints (-3671.1).

Restrained joints shall meet the applicable requirements of -3662 through -3665.

-3662 Bell and Spigot Adhesive Bonded Joints

Adhesive bonded joints are permitted provided the available socket length of the bell and the minimum shear strength of the adhesive satisfy the requirements of Eqs. (10) or (13).

$$L_{msa} = \frac{1}{S_{ASA}}\sqrt{F_1^2 + F_2^2} \qquad (10)$$

where

$$F_1 = \frac{M_A + M_C}{\pi r^2} + \frac{P_r}{2} + \frac{T_L}{2\pi r} \qquad (11)$$

L_{msa} = minimum required adhesive shear length, in. (see Figure -3662-1).
S_{ASA} = allowable adhesive shear stress, psi, (see Table -3662-1).
r = mean pipe radius, in.
M_A = same as Nomenclature of -3652.1
M_C = same as Nomenclature of -3652.1
T_L = longitudinal thrust loads, lb
P = Design Pressure, psi

$$F_2 = \frac{M_r}{2\pi r^2} \qquad (12)$$

where

M_T = torsional moment, in. lb.

$$L_{msa} = \frac{S_{ALP}}{S_{ASA}} t_m \qquad (13)$$

where

t_m = minimum composite wall thickness, as defined in -3641.1, in.

-3663 Bell and Spigot Adhesive Bonded Joints With Laminated Fiberglass Overlay

A laminated fiberglass overlay may be used over a bell and spigot adhesive bonded joint as an alternative to the requirements of -3662. In such cases the total overlay shear length shall be determined by Eqs. (14) or (15) (Figure -3663-1).

$$L_{mso} = \frac{\sqrt{F_1^2 + F_2^2}}{S_{ASO}} - \frac{S_{ASA} L_{sa}}{S_{ASO}} \qquad (14)$$

$$L_{mso} = \frac{S_{ALP}}{S_{ASO}} t_m - \frac{S_{ASA}}{S_{ASO}} L_{sa} \qquad (15)$$

L_{mso} = minimum shear length of overlay, in. (see [Note (3)] of Figure -3643.3(c)-1)
S_{ASO} = allowable shear stress of the overlay, psi
L_{sa} = bell and spigot adhesive shear length, in. F_1 and F_2, as defined in -3662.

The required minimum overlay thickness shall be in accordance with eq. (16) (Figure -3663-1).

$$t_{mo} = \frac{L_{mso} S_{ASO}}{S_{ASO}} \qquad (16)$$

S_{ATO} = allowable tensile stress of the overlay, psi.
t_{mo} = minimum thickness of overlay, in.

-3664 Bell and Spigot Gasket Joints With Laminated Fiberglass Overlay

A laminated fiberglass overlay may be used to provide longitudinal strength in gasket joints. The minimum shear length shall be per eq. (17) or (18). The minimum overlay thickness shall be per eq. (19) or (20) (Figure -3664-1).

Table -3662-1
Adhesive Shear Strength

Min Ult. Short Term Shear Strength of Adhesive, psi [Note (1)]	Allowable Design Shear Stress of Adhesive, S_{ASA}, psi
400	70
600	100
800	130
1000	170
1200	200
1400	230
1600	270
1800	300
2000	330

NOTE:
(1) Determined in accordance with ASTM D2517

$$L_{mso} = \frac{1}{S_{ASO}}\sqrt{F_1^2 + F_2^2} \quad (17)$$

where

S_{ASO} = allowable shear stress of the overlay, psi, Table -3643-2.
L_{mso} = minimum shear length of overlay, in. (See Figure -3643.3(c)-1, Note (3)

F_1 and F_2 are as defined in -3662.

$$L_{mso} = \frac{S_{ALP}\, t_m}{S_{ASO}} \quad (18)$$

$$t_{m0} = \frac{T_L + \pi r^2 P + 2M_A r}{2\pi r\, S_{ATO}} \quad (19)$$

$$t_{m0} = \frac{S_{ALP}\, t_m}{S_{ATO}} \quad (20)$$

where

t_{mo} = minimum thickness of overlay, in.
S_{ATO} = allowable tensile stress of overlay, psi (see Table -3643-1)

-3665 Butt and Strap Joints

The minimum required thickness of the overlay materials shall be per eq. -3664(19) or -3664(20). The minimum shear length shall be per eq. -3664(17) or -3664(18) (Figure -3665-1).

-3671 Selection and Limitation of Nonrestrained Piping Joints (ND-3671)

Expanded or rolled joints (ND-3671.2), flared, flareless and compression-type joints (ND-3671.4), and brazed and soldered joints (ND-3671.6) shall not be used.

-3671.1 Flanged Joints (ND-3671.1). Replace ND-3671.1 with the following: Flanged joints shall meet the requirements of -3647 of this Case.

-3671.3 Threaded Joints (ND-3671.3). *Threaded joints may be used in accordance with this Case. Pressure and temperature limitations shall be within the limits stated in -1110(a) of this Case.*

(c) Replace ND-3671.3*(c)* with the following: Mechanical cutting of threads on RTR pipe is not permitted. Threads, when used, shall meet the requirements of ASTM D1694.

Add the following additional paragraph to ND-3671.3:

(d) Threaded pipe shall meet the requirements of ND-3613.2 except when the threaded ends are increased in thickness to compensate for the threads.

-3671.8 Gasketed Joints (Unrestrained). Unrestrained joints are defined in -4322. Gasketed bell and spigot joints may be used, provided longitudinal restraints are provided. Flexible elastomeric seals may be used as the sole sealing element where the contained and surrounding environment is not injurious to the gasket at the design pressure and temperature. The elastomeric seal shall be held in circumferential compression within an annular cavity, in either the spigot or bell ends of the pipe. The performance of this joint shall meet or exceed the requirements of ASTM D3139.

The user and designer of this connection are cautioned to apply special longitudinal restraints in the form of harnessing lugs, laminated fiberglass overlays, or special anchors that may reduce the flexibility of the system. These special restraints are required to prevent separation of the joint and may apply a longitudinal stress in the pipe. Metal harnesses, anchors, or supports shall comply with Subsection NF. Where longitudinal restraints are not used, the designer shall consider angular joint rotation, thermal contraction and the Poisson effect in designing the length of the joint so as to eliminate joint pullout due to those conditions.

-3672 Expansion and Flexibility (ND-3672)

-3672.1 General Requirements (ND-3672.1). The requirements for expansion and flexibility given in ND-3672, when applied to elongation due to pressure may be a significant factor and must be considered in the flexibility analysis. The effects of stresses due to thermal expansion, pressure elongation, and other

Figure -3662-1
Bell and Spigot Adhesive Bonded Joint

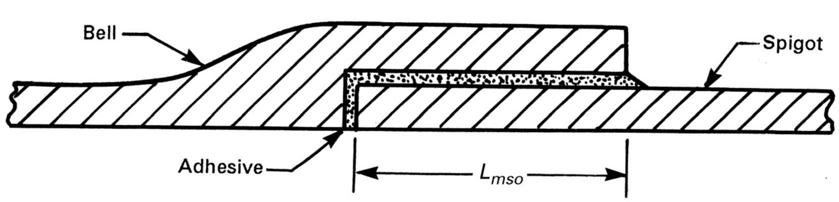
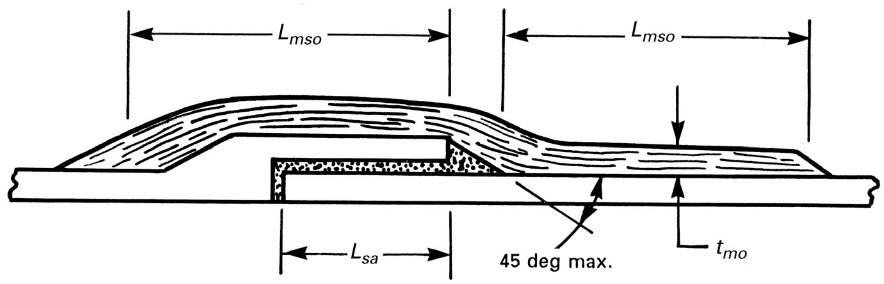


Figure -3663-1
Bell and Spigot Adhesive Bonded Joint With Laminated Fiberglass Overlay



movements shall be combined with stressed due to other causes in accordance with -3650 of this Case, in lieu of ND-3650.

-3672.2 Properties. Thermal expansion data and moduli of elasticity shall be determined in accordance with the following paragraphs in lieu of the tables referred to in ND-3672.2.

(a) Thermal expansion of the system shall be calculated using a coefficient of linear thermal expansion of 15 × 10^{-6}/F unless a measurement of the actual coefficient is performed using the method of ASTM D696-70.

(b) The longitudinal modulus of elasticity shall be as given in Table II-4.4-1, Mandatory Appendix II.

-3672.3 Thermal Expansion and Pressure Elongation Range (ND-3672.3). For flexibility analysis, the total elongation shall be the sum of the thermal expansion range plus the pressure elongation range. The thermal expansion coefficient shall be determined from -3672.1 as the difference between the unit expansion for the highest material temperature and the lowest material temperature resulting from operating and shutdown conditions. When RTR is exposed consideration shall be given to temperature rise due to heating by the sun. The pressure elongation range shall be based on the difference in the highest and lowest pressure resulting from operating and shutdown conditions. The pressure elongation shall be determined by using Young's modulus in the longitudinal direction.

-3672.4 Moduli of Elasticity (ND-3672.4). For purposes of flexibility calculations in the longitudinal direction, the modulus of elasticity shall be based on the geometric mean of the longitudinal compressive, E_{LC}, and tensile, E_{LT}, modulus as indicated by eq. (21).

$$E = \sqrt{E_{LT} \times E_{LC}} \quad (21)$$

where

E_{LT} = tensile, longitudinal modulus, psi from Table II-4.4-1, Mandatory Appendix II, determined according to ASTM D2996 using longitudinally oriented strain gages

E_{LC} = compressive, longitudinal modulus, psi from Table II-4.4-1, Mandatory Appendix II, according to ASTM D695 using longitudinally oriented strain gages

Figure -3664-1
Bell and Spigot Gasket Joint With Laminated Fiberglass Overlay

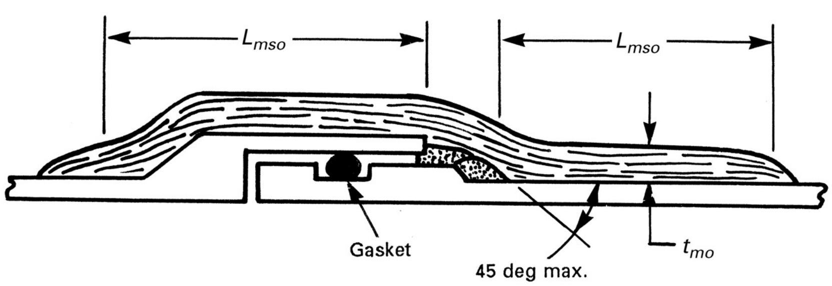
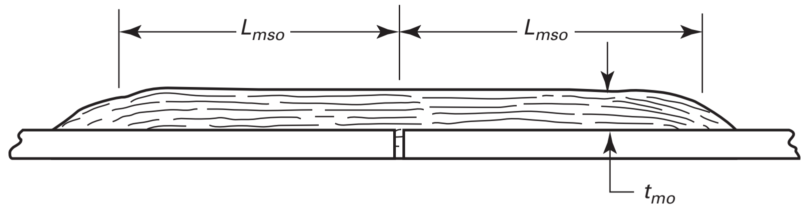


Figure -3665-1
Butt and Strap Joint



-3672.5 Poisson's Ratio (ND-3672.5)

Poisson's ratio, when required for flexibility calculations, shall be taken as 0.25. As an alternative Poisson's ratio may be determined using the test method of ASTM D2105 with longitudinally and circumferentially oriented strain gages.

-3672.6 Stresses (ND-3672.6). The allowable stress range in ND-3672.6(a) and ND-3611.2 do not apply to RTRP.

-3672.9 Stress Calculations (ND-3672.9). Calculations for the stresses shall be based on the least cross-sectional area of the pipe or fitting using minimum dimensions at the point of local strain. Thermal expansion stresses shall be based on the modulus of elasticity at the Design Temperature. Allowable stress and permissible additive stresses shall be in accordance with -3650.

-3672.10 Moment of Inertia and Cross-Sectional Area. For purpose of flexibility analysis the moment of inertia and cross-sectional area shall be based on the nominal thickness t_n, as defined in Table -3110.

-3673 Analysis (ND-3673)

Revise ND-3673 as follows:

In lieu of the values of k and i given in ND-3673.2(b) the following shall be used. As required by 6.3 of Mandatory Appendix I, fitting Design Pressure rating shall be at least equal to that of pipe.

For all configurations k = 1.

For fittings whose wall thickness is three times that of the pipe or greater use i = 2.3, or as an alternative experimental values determined in accordance with the method described below may be used.

For fittings of thickness ratios less than three times that of the pipe the value of i shall be determined experimentally using the methods described in "Fatigue Tests of Piping Components" by A.R.C. Markl, ASME Transactions, 1952 Paper No. 51-PET-21 also published in "Pressure Vessel and Piping Design." The base line test for i = 1.0 shall be a test of straight pipe with a change in thickness similar in geometry to the upset forging used in the Markl tests.

The following test procedures shall be followed in experimentally determining the stress intensification factor "i":

(a) Obtain force deflection curves from testing straight pipe specimens in a fatigue testing machine before starting the test where the pipe and geometry is similar to Fig. 18 of Markl's paper using data to establish applied moments.

(b) Conduct a series of deflection-controlled fatigue tests on straight pipe and plot the results on a single log-log curve.

(1) Obtain a force deflection curve from testing the pipe component using data to establish applied moments.

(2) Conduct a series of deflection-controlled fatigue tests on each piping component. Plot the results of each fitting component superimposed on the straight pipe log-log curve.

(c) Calculate the stress intensification factor as outlined in Markl's paper where the following conditions shall be met.

(1) The geometry of the test fixture and tested components shall be established such that data points are valid *only* if a failure occurs in or adjacent to the test fitting, and away from the end grips buildup area for straight pipe.

(2) In computing the stress in the fitting and the pipe due to applied moments the section modulus of the pipe shall be used.

Replace ND-3673.2(c) with the following: The total expansion range including pressure elongation as determined from ND-3672.3 shall be used in all calculations. Not only expansion, but linear and angular movements of the equipment to which the pipe is attached shall be considered.

-3676.9 Supports — General

(a) The rules of ND-3679.9 shall apply where the referenced supports of Subsection NF are utilized, but special provisions must be applied at the attachment of supports to fiberglass reinforced plastic pipe:

(b) Welding cannot be used to attach supports to pipe.

(c) During installation, precautions shall be taken to prevent overheating of the RTRP if welding or other heating operation is done in close proximity to the pipe.

(d) Special design consideration shall be given at attachment points, to avoid overstressing the pipe, as noted in -3645 (ND-3645).

(e) RTRP material exhibits a much lower modulus of elasticity than steel and this may require the designer to use shorter span lengths between supports. The stresses induced in the piping system by supports shall be considered by the designer and shall include, but not be limited to, the following:

(1) Pipe-span deflection,

(2) Command maximum longitudinal/midspan flexural stress,

(3) Local longitudinal flexural stresses at the horns of the saddle,

(4) Shear stress,

(5) Thermal and pressure expansion and contraction of the pipe line, and

(6) Weight effects of valves and attachments.

(f) The pipe shall be supported on a saddle whose bearing shall have a width of at least $^1/_4$ the nominal pipe diameter and contact a minimum of 120 deg of the pipes' surface. Other types of pipe supports which avoid point loading and sliding abrasion of the pipe wall may be used.

(g) Vertical pipe runs may be supported by a bonded collar contacting 360 deg of the pipes' surface. When that type of support is used the designer shall consider at least the tensile loading and bending loading in the pipe. A friction clamp shall not be used to support the pipe.

-3690 Dimensional Requirements for Piping Products (ND-3690)

Dimensions of piping components shall be in accordance with the requirements of this Case and the design.

-4000 FABRICATION AND INSTALLATION REQUIREMENTS

-4100 GENERAL REQUIREMENTS

-4110 Scope

RTR piping subassemblies shall be manufactured and installed in accordance with the rules of this Case.

-4120 Certification of Materials and Fabrication by N Certificate Holder

-4121 Means of Certification

The Certificate Holders utilizing the provisions of this Case for an RTRP Subassembly or System shall certify, by preparation of the appropriate Data Report (NPP-1 and N-5) that the materials used comply with the requirements of -2000 and that the fabrication or installation comply with the requirements of this Case. The method for applying the Code symbol, shall be reviewed and accepted by the Authorized Inspector.

-4121.1 Certification of Tests and Examinations. If the N Certificate Holder performs tests, repairs, or examinations required by this Case, the N Certificate Holder shall certify that he has fulfilled that requirement. Reports of all required tests, repairs and examinations performed shall be available to the Inspector.

-4122 Materials Identification

Material for pressure retaining parts shall carry the identification markings required by the material specification and by this Case which will remain distinguishable until the component is assembled or installed. If the original identification markings are cut or the material is divided, the same marks shall either be accurately transferred to the parts prior to cutting or a coded marking shall be used to assure identification of each piece of material during subsequent fabrication or installation. In either case, an as-built sketch or a tabulation of material shall be made identifying each piece of material with the Certified Materials Test Report, where applicable, and the coded marking. Adhesives and laminating material shall be identified and controlled so that they can be traced to each component or installation of a piping system, or else a control procedure shall be employed which ensures that the specified materials are used.

-4123 Testing of Adhesives, Bonding and Laminating Materials

All adhesives, bonding and laminating materials shall meet the requirements of -2000 of this Case.

-4130 Elimination and Repair of Material Defects

Defects in materials which were detected on delivery or which are discovered during the manufacture or installation may be eliminated or repaired by laminating provided the defects are removed, repaired, and examined in accordance with the requirements of -2900.

-4200 QUALIFICATION OF JOINING METHODS AND JOINER FOR ADHESIVE BONDED AND LAMINATED OVERLAY JOINTS

-4210 General

Prior to manufacture or fabrication of adhesive bonded and laminated overlay joints [-3661(a), -3661(b), -3661(c), and -3661(d)] the Certificate Holder shall prepare and qualify complete written procedure specifications for the fabrication of the joints. The procedure specification shall include but not be limited to the essential variables and nonessential variables given in -4221.1 and -4221.2.

-4211 Qualification of Joiners

Prior to joining pipe and fittings, personnel shall be qualified in accordance with written procedures. The qualification test for the joiner shall consist of making a joint as specified in -4220(a) for qualification of procedures using the same procedure to be used in production joints, and the joint shall be tested in accordance with -4220(b). Qualification on one procedure does not qualify a joiner for any other procedure.

-4212 Responsibility for Qualification of Joining Procedures and Joiners

Each Certificate Holder is responsible for the joining done by his organization and he shall establish the procedure and conduct the tests required by this -4200 in order to qualify both the joining procedures and the joiners who apply those procedures.

-4220 Qualification Tests

Procedure specifications shall be qualified as follows:

(a) An assembly shall be fabricated in accordance with the procedure specifications. The assembly shall consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint. The size of the pipe used for the assembly shall be as follows:

(1) When the largest size to be joined is 4 in. or smaller, the test assembly shall be the same nominal diameter as the largest size to be joined.

(2) When the largest size to be joined is greater than 4 in. nominal diameter, the test assembly shall be made of pipe having nominal diameter either 4 in. or 25% of the nominal diameter of the largest pipe to be joined, whichever is greater.

(b) When the assembly has been cured it shall be subjected to a hydrostatic pressure test to at least four times the design pressure of the pipe as determined by the rules of -3641.1. The test shall be conducted such that the joint is loaded in both the circumferential and longitudinal direction. For joints which are intended to be used in piping systems which have restrained ends so as to eliminate the axial pressure load, a restrained end hydro test may be performed. Such a test, however, qualifies joints which are used in a restrained system only and do not qualify the joint for a system unrestrained in the axial direction.

(c) The joints shall not leak or separate when tested in accordance with *(b)*.

-4221 Joining Variables

Essential variables are those variables of the joining process in which a change, as described under the specific variable, is considered to affect the mechanical properties of the joint and shall require revision and requalification of the procedure specification.

-4221.1 Essential Variables — Adhesive Bonded and Overlay Joints. A change in one or more of the following essential variables of the joining procedure shall require revision of the procedure specification and requalification:

(a) Fiberglass type, finish, manufacturing process or formulation.

(b) Resin Specification property changes that exceed the specified tolerance for that property as given on Form RTRP-1 (Mandatory Appendix III).

(c) Constituent Material Amounts in the composite including percent of glass or filler. For adhesives the permissible change is shown on Form RTRP-2.

(d) Curing Agent property changes that exceed the specified tolerance for that property as given on Form RTRP-1.

(e) Curing Schedule changes outside specified ranges.

(f) Joining Material types, finish, and changes in resin or content of fillers and reinforcements.

(g) Joint Geometry type (as defined in -3660) or a change of more than 5 deg in the angle between axes of the joined components.

-4221.2 Nonessential Variables — Adhesive Bonded and Overlay Joints. A change in one or more of the following nonessential variables for joining require revision of the procedure specification but do not require requalification.

(a) Joint Geometry Tolerances. A change in the diameter, wall thickness and tolerances specified for a given joint configuration, including alignment.

(b) Joint Preparation. A change in joint preparation including cutoff, surface preparation and cleaning methods.

-4300 FABRICATION AND INSTALLATION REQUIREMENTS

-4310 Procedures

All operations performed on pipe or fittings in the course of manufacture and installation shall be performed in accordance with written procedures. Procedures for fabrication of adhesive bonded joints shall be qualified by qualification tests in accordance with -4220.

-4320 Joint Types

Adhesive and nonbonded joint types are permitted. Permissible adhesive joint types are shown in -3660.

-4321 Restrained Joints

Bonded and laminated or mechanically restrained joints shall be capable of sustaining the longitudinal pullout or thrust forces and moments due to contraction or expansion of the piping and any anticipated external or internal forces or moments. Restrained joints include:

(a) Bell and spigot adhesive bonded joints (-3662).

(b) Bell and spigot adhesive bonded joints with laminated fiberglass overlay (-3663).

(c) Bell and spigot gasket joints with laminated fiberglass overlay (-3664).

(d) Butt and strap joints (-3665).

(e) Flanged joints (-3647).

(f) Other mechanical joints (-4650).

-4322 Unrestrained Joints

Unrestrained joints shall be capable of sustaining forces caused by internal or external loadings exclusive of axial tensile loads or other loads that would tend to separate the joint. Unrestrained joints include:

(a) Bell and spigot with elastomeric seals (-3671.8).

(b) Flexible couplings.

Joints of the unrestricted type are not capable of sustaining longitudinal pressure loads, and shall be restrained by harnessing devices or anchors capable of accommodating the longitudinal loads and limiting deflection of the pipe at the joints.

-4325 Adhesive Bonded Joints

Three types of adhesive bonded joints are permitted as follows:

(a) Tapered bell and spigot.

(b) Straight bell and spigot.

(c) Tapered bell and straight spigot.

-4400 DIMENSIONS AND TOLERANCES

-4410 Tapered Ends

Tapered ends shall consist of tapered spigots with either integral bells or sleeve couplings. The male or female ends shall conform to the dimensions, angles and tolerances of Table 2, Mandatory Appendix I.

-4420 Straight Bell and Spigot, Tapered Bell and Straight Spigot

Dimensions and tolerances for these joint types shall be in accordance with Table I-1, Mandatory Appendix I.

-4500 JOINING REQUIREMENTS

-4510 Bell and Spigot Joints With Elastomeric Seal

-4511 Unrestrained

(a) Bell and spigot joints shall be formed as a permanent part of the pipe when the elastomeric gasket is to be the sole sealing element. An exception could be a bell × bell coupling manufactured from the same master as the pipe used in conjunction with a spigot × spigot pipe unit.

(b) Joints shall be capable of allowing angular deflection, straight pull and offset loads without leaking at the specified test pressures of -5300.

(c) Elastomeric seals shall be of a composition compatible with the service as specified in the joining procedure.

(d) Joint configuration shall be reproducible within the dimensional tolerances set forth in the joining procedure.

(e) Gaskets may be retained in either the bell or the spigot provided that when the joint is assembled the ring is prevented from being displaced.

(f) Joint sealing surfaces shall be free of any imperfections which would interfere with the sealing characteristics of the elastomeric ring.

-4512 Restrained

(a) Restrained joints shall meet the requirements of -4511(a) through -4511(f) with the following additional requirements.

(b) Joints may be prevented from opening or deflecting when subjected to thrust or other loads through the use of steel harness arrangements or by applying a fiberglass laminate overwrap. See butt and strap joints for fabrication requirements of lamination (-4520).

(c) Steel harness strength shall be at least equal to four times the strength required for the combined service conditions.

(d) Fiberglass laminate.

-4520 Butt and Strap Joints

Butt and strap joints are those whereby plain, square ends of pipe or fittings of the same nominal size are joined by an exterior and, when required, interior fiberglass thermosetting resin laminate. Typical configurations are shown in Figure -3665-1. Butt and strap joints are considered restrained. Minimum bond lengths and laminate thicknesses shall be determined in accordance with -3665.

-4600 RULES FOR JOINING

-4610 Adhesive Bonded, Tapered Bell and Spigot Joints

-4611 Cutting

All cuts shall be square and clean. Frayed or delaminated edges are not permitted. Clamps or other holding devices used during cutting shall be designated to prevent damage to the material being cut.

Material through 16 in. nominal diameter prepared for joining shall be cut square within the requirements of Table -4611. For larger sizes the cut shall be within ±1 deg of the specific angle.

-4612 Tapers

Pipe bell and spigot ends shall be tapered to meet the dimensional requirements and shall be accomplished with tools and in accordance with procedures qualified by the Material Manufacturer or Certificate Holder as applicable.

Table -4611
Cutting Requirements

Nominal Pipe Diam, In.	Tolerance, In.
1 to 6	± $^1/_4$
8 to 16	± $^3/_8$

-4613 Surface Preparation

Surfaces to be bonded shall be clean and sound with no loose fibers or frayed edges. Surfaces shall be compatible with the specific adhesive to be used, and prepared as required by the procedure specification.

-4614 Adhesive Application and Joining

(a) The adhesive shelf life shall not have expired.

(b) Adhesive shall be mixed, applied, and cured as required by the procedure specification. Adhesive that has started to gel shall not be used.

(c) All machined or cut edges shall be sealed with adhesive. Any excess adhesive remaining after assembly shall be removed or filleted.

(d) Care shall be exercised to prevent joint movement until the adhesive is fully cured.

-4620 Adhesive Bonded, Straight or Tapered Bell and Spigot

-4621 Cutting

The requirements of -4611 shall apply.

-4622 Tapers

The requirements of -4612 shall apply where tapers are specified.

-4623 Surface Preparation

The outside surface of the spigot shall be prepared as required by the procedure specification at least $^1/_2$ in. beyond the fitting depth. The requirements of -4613 shall also apply.

-4624 Adhesive Application and Joining

(a) The requirements of -4614 shall apply.

-4630 Unrestrained Bell and Spigot Joints With Elastomeric Seals

-4631 Preassembly

Prior to assembling the joint, sealing surfaces and gaskets (seals) shall be examined to assure freedom from any foreign matter that may affect the sealing characteristics.

-4640 Butt and Strap Joints

-4641 Cutting

The requirements of -4611 shall apply. The ends to be joined shall fit within a specified gap, the gap being no larger than the smaller of one pipe wall thickness or $^1/_2$ in.

-4642 Surface Preparation

The surfaces to be joined by bonding shall be lightly abraded. The requirements of -4611 shall also apply.

-4643 Lamination

Where multiple reinforcement layers are to be applied, edges shall be staggered to prevent line up. The joints shall be immobilized until curing is complete.

-4644 Internal Surfaces

Internal laminates are prepared and joined in accordance with the requirements of -4643. In addition, however, exposed reinforcement or areas yielding uneven or disturbed flow are not permitted.

-4650 Locked Mechanical Devices

-4651 Coupling Devices

The coupling shall seal and restrain the pipe. Coupling may be a threaded device (see -4321 and -4322) that is self sealing or sealed with an elastomer. An elastomer-sealed bell and spigot system may be clamped, screwed, or ring locked.

-4652 Classification

Locked mechanical joints shall be classified as rigid for deflections less than 2 deg and flexible for deflection greater than 2 deg.

-4653 Joining

(a) The bonding of a coupling such as a threaded adapter, sleeve or bushing shall be in accordance with -4614.

(b) Care shall be taken not to disturb the lock of the mated joint when installing additional lengths. In no case is the joint to be relocated until all adhesive connections have fully cured.

-5000 EXAMINATION

-5100 GENERAL REQUIREMENTS FOR EXAMINATION

-5110 Procedures, Qualifications and Evaluation

-5111 General Requirements

Examination of manufactured piping subassemblies or installed piping systems shall be in accordance with the rules of this section of this Case. Examinations shall be performed by personnel who have been qualified as required by -5400. The results of examinations shall be evaluated in accordance with -5300.

-5112 Examination Procedures

All examinations performed under this Case shall be executed in accordance with detailed written procedures which have been proven by actual demonstration, to the satisfaction of the Authorized Inspector. The procedure shall comply with the appropriate paragraphs of this Case as applicable for the particular examination method. Written procedures, records of demonstration of procedure capability, and personnel qualification shall be made available by the Manufacturer or Installer and to the

Authorized Inspector on request. At least one copy of the procedure shall be readily available to the applicable examination personnel for reference and use.

-5120 Time of Examination of Joined Pipe and Fittings

Acceptance examination of joints shall be conducted upon completion of curing.

-5130 Verification of Joining Material

Prior to examination of any joint, records shall be reviewed by the Authorized Inspector and shall verify that only those joining materials used in qualification (-4200) have been used in the preparation of the joint.

-5200 EXAMINATION OF JOINTS

-5210 Categories of Joints to Be Examined

-5211

Only those joint types permitted in -4320 are acceptable. Such joints shall be examined in accordance with this Case.

-5300 ACCEPTABLE STANDARDS

-5310 General Requirements

Unacceptable joints shall be removed. Repair of unacceptable joints is not permitted. Acceptance standards for joints shall be as stated in this section of the Case and acceptance standards for pipe and fitting material adjacent to joints shall be in accordance with -2900 of this Case.

-5320 Visual Acceptance Standards

-5321 Bonded Bell and Spigot Joints

All bonded bell and spigot joints shall be visually examined and shall evidence complete filling of the bond annular volume and shall show no evidence of bubbles, voids, delamination, cracks, softness or tackiness. Joints showing any of these types of indications are unacceptable and shall be replaced.

-5322 Overwrapped, Laminated Joints

All over-wrapped, laminated joints shall be visually examined and shall meet the requirements of -2900. Joints not meeting the requirements of -2900 are unacceptable and shall be replaced.

-5323 Other Joints

Joints other than those of -5321 and -5322 but which are permitted in -4320 shall be examined in accordance with -5330.

-5330 Leak Testing

All joints of -5322 shall be leak tested in accordance with one of the methods of Section V, other than pneumatic, and shall show no evidence of leakage at system operating pressure when held for a minimum of ten minutes. Joints showing evidence of leakage are unacceptable and shall be replaced.

-5400 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL

-5410 General Requirements

It shall be the responsibility of the Manufacturer or Installer to assure that all personnel performing operations under this Case are competent and knowledgeable of the applicable examination requirements to the degree specified in this Case. All examinations required by this Case shall be performed and the results evaluated by qualified examination personnel. The assignment of responsibilities to individual personnel will be at the discretion of the Manufacturer or Installer.

-5420 Personnel Qualification

-5421 Qualification Procedure

(a) Personnel performing examination shall be qualified in accordance with the requirements of this Case for the technique and methods used. For examination methods not covered by this Case, personnel shall be qualified by the Manufacturer or Installer to comparable levels of competency by subjection to comparable examinations on the particular method involved. The practical portion of the qualification shall be performed using the Manufacturer's or Installer's procedure on parts representative of the Manufacturer's or Installer's product.

(b) The emphasis shall be on the individual's ability to perform the examination in accordance with the applicable procedure for the intended application.

(c) For examination methods that consist of more than one operation or type, it is permissible to use personnel qualified to perform one or more operations. As an example, one person may be used who is qualified to conduct the examination and another may be used who is qualified to interpret and evaluate the examination results.

-5422 Verification by Inspector

The Inspector has the duty to verify the Manufacturer's or Installer's certification of examination of personnel and has the prerogative to audit the program and require requalification of personnel when the Inspector has reason to question the performance of that individual.

-5430 Records

Personnel qualification records shall be retained.

-6000 TESTING

-6100 GENERAL REQUIREMENTS

-6110 Testing of Components, Appurtenances, and Systems

-6111 Testing of Systems

Prior to initial operation, the installed system shall be tested in the presence of the Authorized Inspector in accordance with ND-6113.

-7000 PROTECTION AGAINST OVERPRESSURE

-7100 GENERAL REQUIREMENTS

-7110 Scope

Consideration in the design of systems to the rules of this Case shall include the need for protection against overpressure. Where it is determined that overpressure protection is required, the detailed requirements shall be stated in the Design Specification (NCA-3250) and construction shall be in accordance with the rules of ND-7000.

-8000 NAMEPLATES, STAMPING AND REPORTS

-8100 GENERAL REQUIREMENTS

-8110 Scope

The requirements for nameplates, stamping and reports for components constructed in accordance with this Case shall be as given in Article NCA-8000.

MANDATORY APPENDIX I
SPECIFICATION FOR REINFORCED THERMOSETTING RESIN PIPE FITTINGS

1 SCOPE

1.1

This specification covers reinforced thermosetting resin pipe fittings. Included are requirements for materials, workmanship, joints, dimensions, and performance.

2 APPLICABLE DOCUMENTS

2.1 ASTM STANDARDS

D618	Conditioning Plastics and Electrical Insulating Materials for Testing.
D883	Definitions of Terms Relating to Plastics.
D1599	Test for Short-Time Rupture Strength of Plastic Pipe, Tubing, and Fittings.
D1600	Abbreviations of Terms Relating to Plastics.
D2122	Determining Dimensions of Thermoplastic Pipe and Fittings.
D2583	Test for Indentation Hardness of Plastics by means of a Barcol Impressor.
D2310	Classification for Machine-Made Reinforced Thermosetting Resin Pipe.
D2992	Test for Hydrostatic Design Basis for Rein-forced Thermosetting Resin Pipe and Fittings.
D2996	Specification for Filament Wound Reinforced Thermosetting Resin Pipe.
D2997	Specification for Centrifugally Cast Reinforced Thermosetting Resin Pipe.
D3262	Reinforced Plastic Mortar Sewer Pipe.
D3517	Specification for Reinforced Plastic Mortar Pressure Pipe.

3 NOMENCLATURE

3.1 GENERAL

Nomenclature is in accordance with ASTM Nomenclature D 883, Relating to Plastics, and abbreviations are in accordance with ASTM Abbreviations D 1600, Terms Relating to Plastics, unless otherwise indicated. The term RTRP is the abbreviation for Reinforced Thermosetting Resin Pipe.

4 MATERIALS

4.1

Fittings manufactured in accordance with this specification shall be composed of reinforcement imbedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

4.2

The resins, reinforcements, and other materials, when combined as a composite structure, shall produce a fitting which will meet the performance requirements of this specification.

5 CLASSIFICATION

5.1

This standard covers reinforced thermosetting resin fittings, defined by method of manufacture (Type), the raw materials used (Grade), and by the liner material (Class). It covers the following types, grades and classes of fittings.

5.1.1 Types

5.1.1.1 Type I — Filament Wound. A fitting manufactured by the filament winding process whereby the hoop and axial tensile strength is derived primarily from a continuous fibrous glass strand roving or roving tape, either previously or subsequently resin-impregnated, onto the outside of a mandrel or form in a predetermined pattern under controlled tension.

5.1.1.2 Type II — Centrifugally Cast. A fitting symmetrical about its longitudinal axis manufactured by placing resin, reinforcement and other materials in a mold which is then rotated and heated.

5.1.1.3 Type IV — Hand Fabricated. A fitting manufactured by applying reinforcement, resin, and other materials onto a mandrel or form by hand in a predetermined manner, or a fitting such as a miter bend or tee that is made from two or more components which are joined together by applying reinforcement, resin, and other materials by hand over the junctions of the various pieces by hand in a predetermined manner.

5.1.1.4 Type V — Spray-Up. A fitting manufactured by applying resin, chopped fibrous glass strand, and other materials onto mandrel or form in a predetermined manner by pneumatic means.

Table I-1
Hydrostatic Design Basis Categories

Cyclic Test Method [Note (1)]			Static Test Method		
Category Designation	Min HDB [Note (2)],[Note (3)] Hoop Stress psi (MPa), (min)	Design Stress [Note (3)],[Note (4)]	Category Designation	Min HDB Hoop Stress [Note (2)],[Note (3)] psi (MPa), (min)	Design Stress [Note (3)],[Note (4)]
A	800 (5.5)	800 (5.5)	Q	2400 (16.6)	1200 (8.3)
B	1000 (6.9)	1000 (6.9)	R	3000 (20.7)	1500 (10.3)
C	1250 (8.6)	1250 (8.6)	S	3750 (25.9)	1875 (12.9)
D	1562 (10.8)	1562 (10.8)	T	4688 (32.3)	2344 (16.2)
E	1953 (13.5)	1953 (13.5)	U	5860 (40.4)	2930 (20.2)
F	2441 (16.8)	2441 (16.8)	W	7324 (50.5)	3662 (25.2)
G	3052 (21.0)	3052 (21.0)	X	9155 (63.1)	4577 (31.6)
H	3815 (26.3)	3815 (26.3)	Y	11444 (78.9)	5722 (39.5)
			Z	14305 (98.6)	7153 (49.3)

NOTES:
(1) The cyclic test method is acceptable as an alternative method for qualification of fittings.
(2) Values shown are minimum stress values for the categories.
(3) Hoop stress based on inside diameter and wall thickness of the largest diameter section normal to the fitting center line using the equation:

$$S = \frac{P(D - t)}{2t}$$

(4) The use of these design stress values is limited to services where the number of full pressure cycles is limited to 100,000 cycles during the design life of the system. For services requiring more than 100,000 cycles, use one-half of the values shown for design stress.

5.1.1.5 Type IV — Molded. A fitting manufactured by placing resin, reinforcement, and other materials in a mold. Compressive force may or may not be used to insure that the mold is completely filled and the desired density of the finished product is obtained.

NOTE: Fittings may be manufactured using combinations of two or more of the above methods of manufacture.

5.1.2 Grades

5.1.2.1 Grade 1 — Glass fiber reinforced epoxy resin

5.1.2.2 Grade 2 — Glass fiber reinforced polyester resin

5.1.3 Classes

5.1.3.1 Class A — No liner

5.1.3.2 Class B — Polyester resin liner — nonreinforced

5.1.3.3 Class C — Epoxy resin liner — nonreinforced

5.1.3.4 Class E — Polyester resin liner — reinforced

5.1.3.5 Class F — Epoxy liner — reinforced

5.1.3.6 Class H — Thermoplastic resin liner — (specify material, PVC polyethelyne, etc.)

5.1.4 Designation Requirements. The materials designation code shall consist of the grade designation in an arabic numeral followed by one or both of the hydrostatic design bases shown in Table I-1. Thus a complete material code shall consist of a number and one or two letters.

5.1.4.1 Examples

(a) I1AA for a filament wound, glass fiber reinforced epoxy resin fitting with no liner and with a 800 psi hydrostatic design basis.

(b) IV 2BET for a hand fabricated glass fiber reinforced polyester resin fitting with a nonreinforced polyester resin liner and with a 1,560 psi cycle and a 4,690 psi static hydrostatic design basis.

6 REQUIREMENTS

6.1 WORKMANSHIP

The manufacture of these fittings shall be in accordance with good commerical practice so as to produce fittings meeting the requirements of this specification. Fittings shall be free from visible cracks, holes, foreign inclusions, blisters and other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The requirements of -2900 shall be met.

6.2 DIMENSIONS AND TOLERANCES

6.2.1 Diameter. The minimum inside diameter of the fittings bore shall be not less than the minimum specified inside diameter of the corresponding size of pipe for which the fitting is designed to be used. The diameter shall be measured in accordance with 7.4.

6.2.2 Socket and Spigot Dimensions. Dimensions of all joints shall comply with the design requirements given in this Case applicable to the type of joint.

6.2.2.1 Straight Adhesive Joint. A straight adhesive joint is defined as one in which the components to be joined do not have matching tapers and are joined by a suitable adhesive. The dimensions of the socket for a straight adhesive joint shall be in accordance with Table I-1 when measured in accordance with 7.4.

6.2.2.2 Tapered Adhesive Joint. A tapered adhesive joint is defined as one in which the components to be joined have tapers joined by a suitable adhesive. Dimensions of the male (pipe) tapers and the matching female tapers shall be in accordance with either Table 2 or Table 3 when measured in accordance with 7.4.

6.2.2.3 Joints using elastomeric seals shall be in accordance with ASTM Designation D 3139.

6.3 PERFORMANCE

Fittings meeting this specification shall be categorized by a long-term static hydrostatic design basis shown in Table I-1 when tested in accordance with 7.5. As an alternative the long term cyclic hydrostatic design basis determined in accordance with Procedure A of ASTM D2992 may be used to categorize fittings as indicated in Table I-1. Fittings manufactured under this Appendix shall have a design pressure at least equal to the design pressure specified for the pipe for which the fitting is designed to be used. Design values shall be one-half of the minimum specified for the category. The requirements of Mandatory Appendix II, 2 and 4.1 shall apply to qualification of fittings.

6.4 PRESSURE TEST

Fittings sampled in accordance with 7.3 shall be subjected to an internal hydrostatic or pneumatic pressure of 1.5 times the rated pressure of the pipe for which the fitting is designed to be used, for a minimum of 2 min without leakage. Hydrostatic pressure leakage is defined as any presence of water on the outside surface of the fitting. Pneumatic pressure leakage is defined as any presence of air bubbles on or eminating from the outside surface of the fitting with the fitting completely immersed in water.

6.5 QUALITY CONTROL TESTS

Quality control tests shall be defined by the fitting manufacturer in his quality control system and shall be performed to verify conformance with the requirements of the procedure specification.

7 METHODS OF TEST

7.1 CONDITIONING

When conditioning is required, and in all cases of disagreement, condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity for not less than 48 hr prior to test, in accordance with Procedure A of ASTM Method D 618.

7.2 TEST CONDITIONS

Conduct the tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5% relative humidity, unless otherwise specified in the test method or in this specification.

7.3 SAMPLING

Samples of fittings to determine conformance of the material to the test requirements specified in 6.4 shall be taken at random from each lot as defined in 7.3.1.

7.3.1 Lot. A lot shall be a number of fittings, not to exceed 100, of one kind, of the same nominal size and wall thickness, of the same designation code (as defined in Section 5), manufactured by the same procedure and the same production run. Each lot shall be identified by a marking symbol or number to trace it to the test report in which the result of all tests for the lot are recorded.

7.3.2 Retest. In the event of failure of the sample fitting to pass any of the quality control tests specified in 6.5, two additional samples taken at random from the same lot shall be tested. The results of both retests shall conform to the requirements. If either sample fails to pass the test the lots shall be rejected.

7.4 DIMENSIONS AND TOLERANCES

7.4.1 Wall Thickness and Diameter. Determine in accordance with ASTM Method D 2122.

7.4.1.1 Liner Thickness. If the test specimens contain liner, determine the average thickness in accordance with 7.4.1.1.2 and subtract it from the average total wall thickness so that the thickness recorded is the reinforced wall thickness.

7.4.1.1.1 Apparatus. An optical scale comparator 7 to 10×, having a reticle graduated in 0.1 mm (or 0.005 in.) divisions, or smaller.

7.4.1.1.2 Procedure. Cut the end of the test specimen square, remove burrs, and sand the cut smooth, using 200 grit (or finer) sandpaper. Thoroughly wash the sanded edge with clean water to remove resin and glass dust, then blot dry. Measure liner thickness at the cut end by setting a major scale division of the reticle at the apparent interface between the liner and reinforced wall. Then read inward toward the center of the fitting and observe the liner thickness, estimating to the nearest 0.05 mm (0.002 in). Make at least four measurements, 90 deg apart, and report the maximum and minimum values and their average.

7.5 LONG TERM STATIC PRESSURE STRENGTH

Determine in accordance with Procedure B of ASTM Method D 2992.

8 MARKING

8.1

Each fitting shall be marked with the following information in such a manner that it remains legible until installed.

8.1.1 Nominal fitting size. Indicate all outlet sizes.

8.1.2 Identification of the fitting in accordance with the designation code given in Section 5.

8.1.3 ASTM Designation D 2310 with which the fitting complies.

8.1.4 Manufacturer's name (or trademark).

8.1.5 The Case number.

8.1.6 The Test Report number.

MANDATORY APPENDIX II SUPPLEMENTARY REQUIREMENTS FOR RTRP

1 SCOPE AND PURPOSE

RTR pipe material manufactured in accordance with this specification shall be made by the filament winding procedure with or without the addition of inert fillers. The material shall be manufactured in accordance with written Procedure Specifications prepared by the Material Manufacturer. The Manufacturer shall qualify the procedure in accordance with the requirements of this Appendix.

1.1 QUALIFICATION OF PROCEDURES

For qualification of the procedure, the Manufacturer shall conduct tests on specimens or material manufactured in accordance with his written procedures.

1.2 PURPOSE

The purpose of the qualification test is to establish performance characteristics of the material, and to define the product by classification. The tests to establish properties shall be performed prior to production of material to meet this specification.

1.3 RECORDS AND TEST RESULTS

Records and test results of the qualification testing shall be recorded in the Manufacturers Qualification Test Report. Form RTRP-6 shall be used to record the fabrication control of variables during manufacture of pipe for qualification and production.

2 ESSENTIAL VARIABLES

Essential variables are those variables of the production process in which a change, as described under the specific variable, is considered to affect the mechanical properties of the product and shall require revision and requalification of the procedure specification in accordance with 4.1.4. The essential variables of the filament winding process are as follows:

2.1 TYPE OF FIBERGLASS

A change in the glass finish, glass manufacturing process or glass type or formulation shall constitute a change in an essential variable.

2.2 RESIN SPECIFICATION

A change in properties of the resin that exceeds the specified tolerance for that property as given on Form RTRP-1 (Mandatory Appendix III) shall constitute an essential variable.

2.3 AMOUNTS OF CONSTITUENT MATERIALS

A Change in the Percent of Glass or Filler in the Structural Composite Constitutes an Essential Variable.

2.4 VARIABLES OF WINDING PROCESS

A change in the process variables listed in Form RTRP-6 shall be an essential variable.

2.5 COMPOSITION OF CURING AGENT

A change in curing material which exceeds the specified range given in Form RTRP-1 shall be an essential variable.

2.6 CURING SCHEDULE

A change in the time or temperature outside of the specified ranges in the curing schedule shall be an essential variable.

3 NONESSENTIAL VARIABLES

Changes in variables other than those listed in 2.0 are considered nonessential, that is, they may be made without requalification of the procedure provided the Procedure Specification is modified to show the changes. The following nonessential variables shall be covered in the procedure in such a way that the changes can be performed within the procedure.

3.1 WALL THICKNESS

The procedure shall specify the range of wall thickness to which it applies.

3.2 WEIGHT PER FOOT OF LENGTH

The procedure shall list the range of weight per foot of length of material to which it is applicable.

3.3 THE COMPOSITION AND TYPE OF LINER

The type of liner, although not an essential variable must be considered when tests are performed on the test models.

3.4 WINDING TENSION

A change in winding tension outside of the range established in the Procedure Specification shall be a nonessential variable.

4 QUALIFICATION TESTS

4.1 HYDROSTATIC DESIGN BASIS (HDB) TESTS

The Manufacturer shall conduct tests to establish the hydrostatic design basis for pipe which he manufactures. The qualification test shall be conducted in accordance with ASTM Specification D 2992, "Standard Method for Obtaining Hydrostatic Design Basis for Reinforced Thermosetting Resin Pipe and Fittings," Procedure B, as modified by this Appendix. Alternatively, Procedure A of Specification D 2992 may be used, but where material has been qualified by both Procedure A and Procedure B, the basis for design shall be Procedure B.

(a) Pipe specimens produced for qualification in accordance with this Case shall be tested in accordance with the requirements of this section. Test results shall be recorded in the qualification test report.

(b) Short term material properties (determined by the test methods in Section 4.2) shall be determined from pipe of the same composition as the pipe used in the HDB test (Section 4.1). These short term material properties will be related to the allowable values of the quality control tests required in Section 6.0 of this Appendix.

Strain gages may be placed on the pipe in order to monitor hoop and longitudinal strain magnitudes. The pipe may be tested with ends constrained (no longitudinal pressure stress in the pipe wall) provided no hydrostatic design basis value is assigned to the material in the longitudinal direction. The test procedures, results, and calculations shall be in accordance with the following:

(c) Scaling

To demonstrate that the hydrostatic design basis is valid for other pipe diameters and thicknesses, the samples tested shall be of three distinct thicknesses. Each sample must be of the same composition. The following shall be used to develop the regression line:

(1) Minimum number of tests — 18.

(2) Where there are three or more distinct thicknesses of pipe to be produced under the procedure to be qualified at least three distinct thicknesses of pipe shall be tested.

Where there are 1 or 2 distinct thicknesses of pipe to be produced under the procedure to be qualified, all distinct thicknesses shall be tested.

(A 25% change in the structural wall thickness constitutes a change in distinct thickness.)

(3) At least three samples shall be tested at each thickness.

(4) Data from each thickness shall be within three separate decade levels.

(5) The thickest samples shall be at least twice as thick as the thinnest sample and shall be at least half as thick as the thickest pipe to be produced under the procedure being qualified, except when the samples being tested are the thinnest and thickest to be qualified.

(6) The thickness-to-diameter ratio cannot be greater than 0.05 for all samples. Scaling is not valid when the thickness-to-diameter ratio exceeds 0.05.

4.1.1 Hydrostatic pressure stress calculations shall be in accordance with ASTM D2153 or Appendix X2 of ASTM D3517 with the following modifications:

4.1.1.1 When ASTM D2153 is employed, the hoop stress in the composite wall shall be calculated as follows:

if

$$t/D_o \leq 0.05,$$

$$S_c = \frac{PD_o}{2t_{eq}} \tag{1a}$$

if

$$t/D_o > 0.05,$$

$$S_c = \frac{PD_o}{2t_{eq}}\left(\frac{D_o}{D_o - t_{eq}}\right) \tag{1b}$$

where

$$t_{eq} = \frac{E_l}{E_H}t_l + t$$

S_c = circumferential tensile stress in the composite wall of the pipe, in pounds per square inch
E_l = hoop tensile modulus of liner, in pounds per square inch
E_H = hoop tensile modulus of the composite pipe wall less liner in pounds per square inch
t = measured composite wall thickness, excluding nominal liner and exterior dress coating in inches
t_l = nominal liner thickness in inches
P = internal hydrostatic pressure, in pounds per square inch
D_o = average outside diameter of pipe in inches

Pipe which is to be assigned a longitudinal hydrostatic design basis value shall be tested with ends unconstrained and the assigned stress basis shall be one-half of the HDB circumferential stress provided the (HDB) is determined in accordance with eq. (1a) or (1b).

4.1.1.2 When Appendix X2 of ASTM D3517 is employed, the stress calculations for determining the Hydrostatic Design Basis (HDB) shall be as follows:

$$S_g = \frac{PD}{2A_gN_c \sin\alpha} \tag{2}$$

where

S_g = tensile stress in the hoop oriented fiberglass rovings, in pounds per square inch
A_g = cross-sectional area of one hoop oriented fiberglass roving, in square inches per roving

N_c = total number of hoop oriented fiberglass rovings per lineal inch of pipe thickness t in rovings per inch
D = average outside diameter of pipe
α = angle between the plane of the hoop oriented fiberglass rovings and the bore of the pipe (helix wind angle), in degrees

The HDB is determined by employing formula (2) is expressed in terms of hoop oriented fiberglass roving stress and shall be converted to hoop stress in the composite wall for classification purposes as follows:

$$(HDB)_1 = \frac{(HDB)_2 A_g N_c \sin\alpha}{\frac{E_l}{E_{HT}} t_l + t_m} \tag{3}$$

where

$(HDB)_1$ = Hydrostatic Design Basis expressed in terms of the hoop stress in the composite wall, in pounds per square inch
$(HDB)_2$ = Hydrostatic Design Basis expressed in terms of the hoop oriented fiberglass stress, in pounds per square inch
t_m = Minimum Composite pipe wall thickness excluding nominal liner and exterior dress coating, inches

4.1.2 Determination of Pipe Composition. The composition and construction of each pipe or fitting which undergoes the pressure test in accordance with ASTM D2992 will be determined by using ASTM D2584-72. Each sample of pipe or fittings shall be tested for composition and construction separately.

The angle of wind, as measured from the longitudinal axis of the material, shall be maintained within ± 2 deg from the specified angle, when measured on the exterior surface of the material.

4.1.3 Temperature Qualification

4.1.3.1 Temperature Limits. A minimum of one full series of hydrostatic tests (18 samples minimum) in accordance with ASTM D2992 and these specifications is required to establish the HDB and corresponding qualification temperature. The qualification temperature shall be defined as the mean fluid temperature experienced during HDB testing, provided the lowest temperature experienced is not less than 20°F below the mean for more than 1% of the test duration. If the lowest temperature experienced is less than 20°F below the mean, for more than 1% of the test duration, the qualification temperature shall be the lowest fluid temperature experienced during HDB testing plus 20°F.

The ambient and fluid temperature experienced during testing shall be reported.

Products shall be used in service with Design Temperatures not in excess of 20°F over the qualification temperature provided the Design Temperature does not exceed 100°F. Design Temperature shall be either the mean anticipated peak fluid temperature, if the peak temperature is 20°F or more above the mean. For Design Temperatures in excess of 100°F, the Design Temperatures shall not exceed the qualification temperature.

When the Design Temperature exceeds the limit described in the preceding paragraphs, a specific derating factor shall be established in accordance with Section 4.1.3.2 to determine applicable stress levels, but in no case shall Design Temperatures exceed 180°F for polyester materials nor 250°F for epoxy materials.

4.1.3.2 Derating for Temperature.

(a) To qualify pipe for a Design Temperature 50°F or less in excess of that for which it has previously qualified, a minimum of six samples shall be tested in accordance with ASTM D2992 and this Case at a minimum of three stress levels. The data points shall be within three decades of failure time or number of cycles, and shall have at least two samples beyond 1000 hr or 100,000 cycles. The ratio between the calculated lower 95% confidence stress level (at 100,000 hr or 150,000,000 cycles) for the elevated temperature test series, and the full, 18 sample, HDB stress level shall establish the derating factor.

(b) To qualify pipe for a Design Temperature more than 50°F in excess of that for which it has previously qualified, a full series (18 sample minimum) of hydrostatic tests shall be run in accordance with ASTM D2992.

(c) To qualify pipe for a Design Temperature between two temperatures for which it has previously qualified, but outside of the temperature range allowed in 4.1.3.1, no additional tests are required. The derating factor of the pipe at the intermediate temperature shall be directly proportional to the values of the HDB and the temperatures previously qualified.

4.1.4 Altered Construction. When changes are made in the essential variables of the procedure or the material system used to fabricate the pipe, as defined in 2 of this Appendix, such changes can be qualified by testing a minimum of 6 samples at a minimum of three stress levels. The data points shall be within three decades of failure time and must have at least two points beyond 1,000 hr or 100,000 cycles. The data shall be extrapolated to 100,000 hr or 150,000,000 cycles and compared to the Hydrostatic Design Basis. If the extrapolated value falls at or above the lower confidence limit, the change is qualified. If the extrapolated value falls below the lower confidence limit, the change is not qualified and a new Hydrostatic Design Basis shall be established.

4.2 DETERMINATION OF PROPERTIES FOR USE IN DESIGN

The following properties shall be established for pipe of the same design as that used for the Hydrostatic Design Basis test.

4.2.1 Circumferential Tensile Strength, S_{HT} and Modulus, E_{HT}

(a) Short Term

The short term circumferential tensile strength and modulus shall be determined in accordance with ASTM D1599, ASTM D2290 or ASTM D638. Poisson's ratio and the stress-strain relationships shall also be reported in addition to the ASTM test report requirements.

(b) Long Term

The long term circumferential tensile test shall be conducted in accordance with Section 4.1 of this Appendix.

4.2.2 Circumferential Flexural Modulus, E_{HF}. The circumferential modulus shall be determined using the results of ASTM D790 or ASTM D2412 test method, with the provisions of paragraphs 12.1.1 and 12.1.2 of ASTM D3262 and the following calculation.

The parallel plate loading test (ASTM D2412) yields the pipe "stiffness factor," *SF.* The stiffness factor is defined as flexural modulus of elasticity, E_{HF}, times the circumferential moment of inertia, *I,* of the pipe wall. That is,

$$SF = E_{HF} I$$

$$I = \frac{t^3}{12}$$

Therefore:

$$E_{HF} = \frac{12}{t^3}(SF)$$

4.2.3 Longitudinal Compressive Strength, S_{LC} and Modulus, E_{LC}

(a) Short Term

The edgewise compressive strength and modulus of the pipe wall shall be determined in accordance with ASTM D695.

(b) Long Term

The long term compressive strength, S_{LC}, of the pipe wall shall be determined by multiplying the short term strength as determined in (a) by the ratio of long term circumferential strength to the short term circumferential strength defined in Sections 4.2.1(b) and 4.2.1(a), respectively.

4.2.4 Longitudinal Tensile Strength, S_{LT}, and Modulus, E_{LT}

(a) Long Term

The testing shall be done in accordance with ASTM D638 or D 2105. The specimens shall be taken from sections of pipe deemed to represent the pipe's axial properties.

For ASTM D638 samples, the sample geometry and end configuration may be altered to provide more representative sample and results of the pipe construction being tested.

The width of the specimen shall be a minimum of 6 in. Specimen shall be fabricated with a reduced cross section which shall be 1 in. minimum. The reduced section may be produced with two slots no less than $^1/_8$ in. wide on both sides of the specimen. In no case shall the alteration affect the properties of the test section of the sample.

(b) The Long Term

The long term tensile strength of the pipe wall shall be determined by multiplying the short term strength as determined in (a) by the ratio of long term circumferential strength to the short term circumferential strengths defined in Sections 4.2.1(b) and 4.2.1(a), respectively.

4.2.5 Modulus of Elasticity of the Liner, E_l. Make a flat laminate constructed from the same materials used in making the material liner. The composition shall be tested as defined in Section 4.1.2 to verify that the composition closely compares to the material liner.

This laminate shall be tested in accordance with ASTM D638. A minimum of ten coupons shall be tested to define an average tensile modulus and standard deviation. The average tensile modulus is then defined as E_l, if the standard deviation is less than 10% of E_l.

4.2.6 Visual Examination. Each pipe section shall be visually examined for production variations such as: indentations, cracks, porosity, air bubbles, lack of resin, excess resin, thin areas, wrinkling, delamination and foreign materials.

4.2.7 Dimensional Examinations. Inside diameter measurements shall be taken at a point approximately 3 in. from both ends of the pipe section using a caliper with graduations of $^1/_{16}$ in. or less. Take two 90 deg opposing measurements at each point of measurement and average the readings to determine the inside diameter. The dimensions shall comply with the diameters and tolerances given in Table II-4.4-3. Measure pipe lengths with a steel tape with graduations of $^1/_8$ in. or less. Measure wall thickness with a micrometer caliper or gage with graduations of at least 0.01 in. and take a series of four measurements equally spaced, around the circumference of the pipe.

4.2.8 Barcol Hardness. The barcol hardness of the liner shall be tested according to ASTM D2583.

4.4 CLASSIFICATION

4.4.1 General. Pipe meeting this specification is classified by type, grade, class, Hydrostatic Design Basis, and by a secondary cell classification system which defines the basic mechanical properties of the pipe. These types, grades, classes, Hydrostatic Design Basis categories and cell classification designations are as follows:

4.4.1.1 Types. Type 1 filament wound

4.4.1.2 Grades.

(a) Grade 1 — glass fiber reinforced epoxy resin pipe

Table II-4.4-1
Minimum Mechanical Property Requirements

Designation Order No.	1st	2nd	3rd	4th	5th	6th
Mechanical Property Designation Code	Ult. Short Term Circum. Tens. Stress psi	Ult. Short Term Long, Tens. Stress psi	Longitudinal Tensile Modulus, 10^6 psi	Apparent Pipe Stiff Factor, in. (2) lb/in. Circum. Tensile Modulus 10^6 psi	Ult. Compressive Stress psi	
ASTM Test Method	D 1599	D 2105	D 2105	D 2412	D 1599	D 695
0a	...	2,000	...	...	...	...
0b	...	3,000	...	...	...	...
0c	...	4,000	...	...	...	...
0d	...	6,000	...	...	...	...
1	10,000	8,000	1.00	40	1.00	4000
1a	16,700	10,300	1.33	90	1.33	7000
1b	23,300	12,700	1.67	150	1.67	10000
2	30,000	15,000	2.00	200	2.00	13000
2a	33,300	18,300	2.33	470	2.33	16000
2b	36,700	21,700	2.67	730	2.67	19000
3	40,000	25,000	3.00	1000	3.00	22000
3a	43,300	28,300	3.33	1170	3.33	25000
3b	46,700	31,700	3.67	1330	3.67	28000
4	50,000	35,000	4.00	1500	4.00	31000
4a	53,300	38,300	4.33	1670	4.33	34000
4b	56,700	41,700	4.67	1830	4.67	37000
5	60,000	45,000	5.00	2000	5.00	40000
6	63,300	48,300	5.33	...	5.33	...
7	66,700	52,700	5.67	...	5.67	...
8	70,000	55,000	6.00	...	6.00	...

(b) Grade 2 — glass fiber reinforced polyester resin pipe

4.4.1.3 Classes.

(a) Class A — no liner

(b) Class C — epoxy resin liner, non-reinforced

(c) Class E — polyester liner, reinforced

(d) Class F — epoxy resin liner, reinforced

(e) Class H — thermoplastic resin liner (specify)

4.4.2 Hydrostatic Design Basis. Test methods for classifying the Hydrostatic Design Basis of the pipe are provided. Pipe meeting this specification may be classified using either the cyclic test method or the static test method, or both, and the designations are shown in Table . These design basis categories shall be used in accordance with ASTM D2996 Appendix A1 as modified by this specification.

4.4.3 Mechanical Properties. Table II-4.4-1 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE: All possible combinations covered by the above classification system may not be commercially available.

4.4.4 Designation Code. The pipe designation code shall consist of the abbreviation RTRP, followed by the type and grade in arabic numerals, the class and static or cyclic Hydrostatic Design Basis level in capital letters, and six arabic numbers with or without lower case letter

Table II-4.4-2

	(1) Type	(2) Grade	(3) Class	(4) Long Term Strength HDB	(5) Short Term Rupt.	(6) Long Ten. Str.	(7) Long Ten. Mod.	(8) Stiff Fact.	(9) Circ. Ten. Mod.	(10) Comp. Str.	(11) Max. Temp.
RTRP —	I	1	F	A —	1	3a	3	4a	2	1b	40 C
		ASTM D2310 No change					ASTM D2996 Modified				

Table II-4.4-3
Nominal Diameter Dimensions and Tolerances

Nominal Pipe Size, in.	Diameter [Note (1)]	Tolerances	Nominal Pipe Size, in.	Diameter [Note (1)]	Tolerances
1	1.315	+0.060 -0.060	12	12.750	+0.125 -0.056
$1^1/_2$	1.900	±0.060 -0.018	14	14	$\pm^1/_4$
			16	16	$\pm^1/_4$
2	2.375	+0.060 -0.018	18	18	$\pm^1/_4$
			20	20	$\pm^1/_4$
$2^1/_2$	2.875	+0.060 -0.018	24	24	$\pm^1/_4$
			30	30	$\pm^5/_{16}$
3	3.500	+0.060 -0.018	36	36	$\pm^3/_8$
			42	42	$\pm^7/_{16}$
4	4.500	+0.060 -0.018	48	48	$\pm^1/_2$
			54	54	$\pm^1/_2$
6	6.625	+0.066 -0.028	60	60	$\pm^1/_2$
			66	66	$\pm^1/_2$
8	8.625	+0.086 -0.040	72	72	$\pm^1/_2$
10	10.750	+0.108 -0.048	84	84	$\pm^1/_2$
			Larger than 84	Nom. dia.	$\pm^1/_2$

NOTE:
(1) For NPS 12 and smaller, the diameter listed is the outside diameter. For nominal pipe sizes larger than 12 in. the inside diameter is given as the basic dimension.

subscripts identifying, respectively, the cell classification designations of the short term rupture strength, longitudinal tensile strength, tensile modulus, apparent stiffness, circumferential tensile modulus, and compressive strength and qualification test requirements.

Example: RTRP-II FA-13a34a21b-40. Referring to Table II-4.4-1. Such a designation would describe a filament-wound, glass fiber reinforced epoxy pipe having a reinforced liner; a cyclic pressure strength exceeding 2400 psi; a short term rupture strength exceeding 100,000 psi: A longitudinal tensile strength exceeding 28,300 psi; a longitudinal tensile modulus (2) exceeding 3×10^6 psi; an apparent stiffness exceeding 1500 in.-lb/in. A circumferential tensile modulus exceeding 2×10^6 psi, and a compressive strength exceeding 10,000 psi and a maximum qualification temperature of 40 C.

5 CONSTITUENT MATERIALS

Constituent materials are those, such as, thermosetting resins, reinforcement, and other solid or liquid materials which, when combined as a composite structure produce materials meeting the requirements of this Case in the product listed in -2111. The Material Manufacturer shall be responsible that the constituent materials of pipe, fittings, and auxiliaries meet the requirements of this Case.

5.1 RESINS

Thermosetting resin shall be cured epoxy or cured unsaturated polyester as defined in ASTM D883, and shall be tested in accordance with the test methods listed in Form RTRP-1 shown as Mandatory Appendix III.

5.2 FIBERS

Glass fiber and organic fiber veil materials used to produce a resin rich surface on the pipe wall shall be compatible with the resin system used in the manufacture of the material.

5.3 CURING AGENTS

The curing agent(s) combined with the resin system and the method of incorporation shall be the same as those in the Qualification Tests (4.0).

5.4 STRUCTURAL WALL

5.4.1 Only fiberglass roving, roving tape or strand reinforcement of the borosilicate Type “E” glass is permitted. This constituent material shall have a finish compatible with the intended resin material, the manufacturing technique, and shall be stored in accordance with the constituent manufacturer's instructions.

5.4.2 Resins shall be of the same generic types as in 5.1 but not necessarily the same as the inner corrosion-resistant liner or exterior layer.

5.5 FILLERS, DILUENTS AND FLEXIBILIZERS

Fillers, diluents or flexibilizers may be used in the manufacture of the material provided the use of such materials is recorded and included in the qualification test (4).

6 QUALITY CONTROL TESTING

6.1 GENERAL

(a) The tests and examination stipulated in this paragraph are intended to ensure that the pipe and/or pipe systems produced comply with certain minimum physical requirements with respect to laminate structure and composition, as evidenced by tests conducted on specimens.

(b) The results of all tests and examinations defined in this Section shall be recorded and kept on file by the Manufacturer, and be made available to the Inspector.

6.2 SAMPLING TESTS EACH PIPE

Each length of pipe shall be examined or tested for the following:

(a) Meeting the composition requirements of RTRP Form-1;

(b) Reporting pipe data on RTRP Form 4;

(c) Visual examination per 4.2.6;

(d) Dimensional requirement per 4.2.7;

(e) Hardness of pipe liner per 4.2.8.

6.3 RANDOM SAMPLING

(a) General

No less than one sample shall be selected at random from the first 100 ft of pipe and every 1000 ft produced thereafter, to determine the conformance of the product to the quality control test requirements of this paragraph. If the results of any test do not conform to the prescribed requirements, that test shall be repeated on two additional sets of samples from different lengths of that same lot, each of which shall conform to the requirements specified. If either of these two additional samples fail, the lot shall be rejected. A lot shall be defined as 1000 linear ft of pipe of the same size, type and class produced during the same production run.

(b) The following short term material property tests shall be determined from each random test lot:

(1) 4.2.1(a) Testing for S_{HT}, E_{HT}, Poisson's ratio, and stress-strain.

(2) 4.2.3(a) Testing for S_{LC}, E_{LC}.

(3) 4.2.4(a) Testing for S_{LT}, E_{LT}, Poisson's ratio and stress-strain curves.

(4) 4.2.5 Testing for E_I

The test results from these quality control tests shall not fall below 90% of the test results determined during the qualification testing (Section 4.0). If the test result is less than 90% of the qualification test results, additional testing shall be performed on each length of pipe and only those lengths meeting 90% of the qualification test results shall be accepted.

7 MARKING

7.1

Each pipe shall be marked with the following information in such a manner that it remains legible until installed.

(a) Nominal size of pipe;

(b) Identifying the pipe in accordance with the designation code given in Section 4.4.4;

(c) Manufacturer's name (or trade mark);

(d) This Case number;

(e) The Test Report number.

MANDATORY APPENDIX III
RTRP FORMS

See next page

Form RTRP-1
Constituent Material Test Report of Essential Variables

Manufacturer's Name ______________________ Design Temp./Press. ______________________

			Resin	Curing Material	Reinforcing Materials	Filler Materials	Liner Resin	Liner Curing Agent	Date
Material Manufacturer Material Designation									
Batch/Lot Date of Manufacturer									
Manufacturers' Value									
Test	ASTM								
Viscosity, cps 25°C (77°F)	D 445 & D 2393	(1)	25.0	25.0			25.0	25.0	
		(2)							
		(3)							
Color Gardner	D 1544	(1)	1 unit	2 units			1 unit	2 units	
		(2)							
		(3)							
Hydroxyl No. Solids, MgK OH/gm	(P) E 222	(1)	8.0				8.0		
		(2)							
		(3)							
Weight/Epoxide Equivalent	(E) D 1652	(1)	10				10		
		(2)							
		(3)							
Acid No. Solids, MgK OH/gm	(P) D 1639	(1)	4				4		
		(2)							
		(3)							
Amine Value Mol Active Hydrogen	(E)	(1)		25				25	
		(2)							
		(3)							
Weight/Gallon 25°C (77°F)		(1)	2	1			2	1	
		(2)							
		(3)							
Pot Life by Viscosity 1#, 25°C		(1)	30				30		
		(2)							
		(3)							
Flexural Strength	D 790	(1)	10%				10%		
		(2)							
		(3)							
Styrene Monomer Content, %	(P)	(1)	2				2		
		(2)							
		(3)							
Barcol Hardnes 25°C (77°F)	D 2583	(1)	3 units				3 units		
		(2)							
		(3)							
Moisture Content, %	(E) E 203	(1)			.05	.05			
		(2)							
		(3)							
Ignition Loss %, Weight	D 2584	(1)			.2				
		(2)							
		(3)							
Yield, Yd/Lb		(1)			50 units				
		(2)							
		(3)							

(P) Polyester
(E) Epoxy

NOTES:
(1) Tolerance.
(2) Value used in Qualification Test.
(3) Test.

The above material tests have been performed and are certified correct.

____
Manager of Quality Control

Form RTRP-2
Adhesive Material Test Report

Manufacturer's Name ______________________ Design Temp./Press. ______________________

Manufactured for ______________________ Grade ______________ Joint Type ______________

			Resin Material	Curing Material	Reinforcing Material	Filler Materials	Additive Materials		Composite Material
Material Manufacturer Material Designation									
Batch/Lot Date of Mfr.									
Manufacturer's Value									
Test Title	Test Method ASTM								
Viscosity, cps 23°C (73.4°F)	D 2393	(1)	25.0 cps				25.0 cps	25.0 cps	
		(2)							
		(3)							
Color Gardner	D 1544	(1)					1 unit	2 units	
		(2)							
		(3)							
Pot Life Working at ______ Temp.		(1)							5 min
		(2)							
		(3)							
Mixing Composition		(1)			2%	2%			10%
		(2)							
		(3)							
Adhesive Shear Strength Min. @ (73.4°F) @ Design Temp. __________ °F	D 2517	Min.							(4)
		(3)							

NOTES:
(1) Tolerance.
(2) Value used in Qualification Test.
(3) Test.
(4) Enter value from Table 3662-1.

The above material tests have been performed and are certified correct.

____

Manager of Quality Control

Form RTRP-6
Record for Fabrication Control and Qualification of Pipe

Procedure Specification No. ____________________

A change in any of the essential variables denoted by an asterick in succeeding paragraphs requires a new Procedure Specification. Tolerances shall be included where applicable.

Qualification Test Report No. ____________________

Nominal Pipe Diameter ____________________

*Fiberglass ____________________
(Manufacturer and Designation, Ends per Roving, Glass Composition, Filament Diameters, Yield per End)

*Sizing or Finish ____________________ Percent by Weight: ____________________ Type: ____________________

*Resin System ____________________
(Manufacturer and Designation)

Filler(s), Other Than Resin Extender: ____________________

*Curing Agent(s) ____________________
(Manufacturer and Designation)

Resin Curing Agent Ratio Tolerances ____________________

Maximum Allowable Viscosity of Catalized Resin: ____________________

Viscosity of Resin System ____________ cps (min) to ____________ cps (max) @ ____________ °F

*Manner of Impregnation ____________________
(prepreg, wet wind, postpreg)

*Weight Percent Glass in Structural Wall: ____________________

*Variables of Winding Process ____________________

Helix Angle(s): ____________ (Measured on cylinder between longitudinal axis and band path)

Pattern Description: ____________________

Band Density: Helical ____________________ ends/in.

Band Width and Thickness, Helical: th. ____________ in. width ____________ in.

Band Velocity: Helical ____________________ ft/min (max)

Form RTRP-6
Record for Fabrication Control and Qualification of Pipe (Cont'd)

Layer Sequence ______________________ Ratio Hel./Circ. in Cylinder: ______________________
[Note (1)]

Circumferential Density: ______________________ ends/in.

Circumferential Width: ______________________ in., thickness: ______________________ in.

Circumferential Band Velocity: ______________________ ft/min

*Curing Schedule: ____________ °F for ____________ hr ____________ min

____________ °F for ____________ hr ____________ min

____________ °F for ____________ hr ____________ min

____________ °F for ____________ hr ____________ min

Manner of Measuring Temperature: Oven Air ______________________

Winding Surface ______________________

Mandrel ______________________ Other ______________________
(Describe)

Liner ______________________
(Material Specification or Manufacturer Designation, Thickness, Type Resin System, Weight Percent Reinforcement, Method of Installation)

Exterior Layer ______________________
(Type Resin, Thickness)

NOTE:
(1) Use X to indicate layer of helical windings.
O to indicate full layer of circumferential windings (down and back).
o to indicate half layer of circumferential windings (one pass).
4 to indicate reinforcement placed in the longitudinal direction.
C to indicate reinforcement placed in random direction (chopped strand).
F to indicate filler placed in a layer (one pass).

Where a range of values or a tolerance applies, state the applicable range or tolerance.

MANDATORY APPENDIX IV
GLOSSARY OF TERMS

adhesive: a material designed to join two other materials together by surface attachment (bonding).

chopper roving: a collection of noncontinuous glass strands gathered without mechanical twist. Each strand is made up of glass filaments bonded together with a finish or size for application by chopper gun.

chopper strand mat: a collection of randomly oriented glass fiber strands, chopped or swirled together with a binder in the form of a blanket.

continuous roving: a collection of continuous glass strands wound into a cylindrical package without mechanical twist.

curing agent: a reactive material which when combined with a resin material reacts, or polymerizes (crosslinks) with the resin. Also referred to as a hardener.

diluent: a reactive modifying material, usually liquid, which reduces the concentration of resin material to facilitate handling characteristics and improve wetting.

filler: an inert material added to resinous mixtures to impart mechanical properties, surface texture and reduce costs.

fire retardent resin: a specially compounded material combined with a resin material designed to reduce or eliminate the tendency to burn.

flexibilizer: a modifying liquid material added to a resinous mixture designed to allow the finished component the ability to be flexed or less rigid and more prone to bending.

grout: a heavily filled paste material used to fill crevices and transactions between piping components.

liner: the inside surface of a piping component to protect the structure from chemical attack and prevent leakage under stress.

release agent: a material applied to the surface of a mold in a thin film which prevents resins from bonding to the mold surface and is not detrimental to the intended service of the product.

stiffness factor: the measurement of a pipe's ability to resist deflection as determined in accordance with ASTM D2412.

thermoplastic resin: a resin material which does not react or polymerize and which flows with the application of heat and solidifies when cooled. A material which can be reformed.

thermosetting resin: a resin material which when reacted with a airing agent polymerizes or undergoes crosslinking to become infusible with heating. Materials which cannot be reformed.

thixatropic agent: a material added to the resin to impart high static shear strength (viscosity) and low dynamic shear strength. A material which can be stirred but will not flow.

ultraviolet absorber: a material which when combined in a resin mixture will selectively absorb ultraviolet rays.

woven roving: a heavy glass fiber fabric reinforcing material made by the weaving of glass fiber roving.

MANDATORY APPENDIX V
SPECIFICATION FOR RTR FLANGES

1 SCOPE

1.1

This specification pertains to reinforced thermosetting resin flanges. Included are requirements for materials, workmanship, performance, and dimensions. Flanges may be produced integrally with a pipe or fitting, may be produced with a socket for adhesive bonding to a pipe or fitting, may be two piece type consisting of a stub end and a loose flange ring, or may be of the type used in conjunction with either a metallic or nonmetallic backup ring.

2 APPLICABLE DOCUMENTS

2.1 ASTM STANDARDS

D618	Conditioning Plastics and Electrical Insulating Materials for Testing
D883	Definitions of Terms Relating to Plastics
D1600	Abbreviations of Terms Relating to Plastics
D2122	Determining Dimensions of Thermoplastic Pipe and Fittings
D2583	Test for Indentation Hardness of Plastics by Means of a Barcol Impressor

2.2 ANSI STANDARDS

B16.1-1975	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800
B16.5-1977	Steel Pipe Flanges, and Flanged Fittings

3 NOMENCLATURE

3.1 GENERAL

Nomenclature is in accordance with ASTM D883, "Definitions of Terms Relating to Plastics," and abbreviations are in accordance with ASTM D1600, "Abbreviations of Terms Relating to Plastics," unless otherwise indicated. The term RTRP is the abbreviation for Reinforced Thermosetting Resin Pipe.

4 MATERIALS

4.1

Flanges manufactured in accordance with this specification shall be composed of reinforcement imbedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes.

4.2

The resins, reinforcements, and other materials, when combined as a composite structure, shall produce a fitting which will meet the performance requirements of this specification.

4.3

The gaskets used shall be in accordance with the conditions stated in -3647.5.

5 CLASSIFICATION

5.1 GENERAL

This standard covers reinforced thermosetting resin flanges defined by Type (method) of manufacture, Grade (generic type) of resin and Class (configuration) of joining system used.

5.1.1 Types

5.1.1.1 Type 1 — Filament-Wound Flanges. Flanges manufactured by winding continuous fibrous glass strand roving or roving tape, either pre-impregnated or impregnated during winding, into a flange cavity under controlled tension.

5.1.1.2 Type 2 — Centrifugally Cast Flanges. Flanges made by placing resin, reinforcement and other materials in a mold which is then rotated and heated.

5.1.1.3 Type 3 — Compression Molded Flages. Flanges made by applying external pressure and heat to a molding compound which is confined within a closed mold.

5.1.1.4 Type 4 — Contact Molded Flanges. Flanges manufactured by hand application of the materials of construction (resin, reinforcements, etc.) onto an open mold or form by hand, according to a predetermined fabricating technique.

5.1.2 Grades

5.1.2.1 Grade 1 — Epoxy

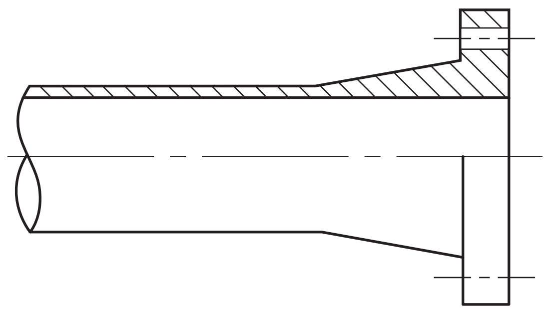
5.1.2.2 Grade 2 — Polyester

5.1.2.3 Grade 3 — Furan

5.1.3 Classes

5.1.3.1 Class 1 — Integrally Molded Flange (Figure V-5-1). A flange that is manufactured directly on a pipe section, pipe stub or fitting.

Figure V-5-1
Integrally Molded Flange



5.1.3.2 Class 2 — Tapered Bell and Spigot Adhesive Joint Flange (Figure V-5-2). A flange, single or two piece, that is manufactured with a tapered socket to be used in conjunction with a pipe or fitting with a tapered spigot section and a suitable adhesive. This joining method provides an interference fit over the entire length of the bond line.

5.1.3.3 Class 3 — Tapered Bell and Straight Spigot Adhesive Joint Flange (Figure V-5-3). A flange that is manufactured with a tapered socket to be used with pipe or fitting with untapered spigot section and a suitable adhesive. This joining method provides an interference fit at the bottom of the socket.

5.1.3.4 Class 4 — Straight Bell and Spigot Adhesive Joint Flange (Figure V-5-4). A flange that is manufactured with an untapered socket for use with a pipe or fitting with untapered spigot and a suitable adhesive. This joint provides no interference fit.

5.2 DESIGNATION REQUIREMENT

Each flange shall be designated by the abbreviation RTR followed by the type, grade and class in arabic numerals. By example, the designation of a filament-wound, epoxy flange with a tapered adhesive joint is RTR-112.

Figure V-5-2
Tapered Bell and Spigot Adhesive Joint Flange

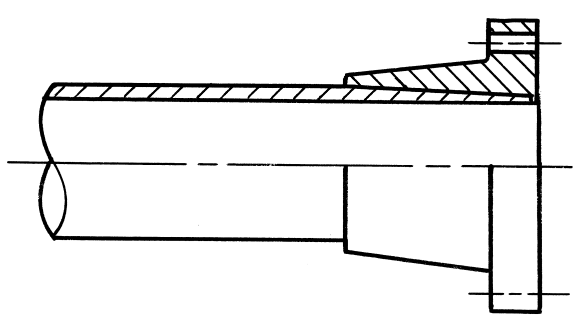
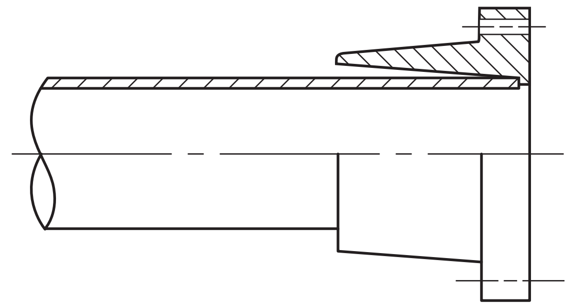


Figure V-5-3
Tapered Bell and Straight Spigot Adhesive Joint Flange



NOTE: Flanges with identical classification from different manufacturers may not be interchangeable due to nonstandardization of pipe and/or socket diameter, socket length, and taper angle.

6 REQUIREMENTS

6.1 WORKMANSHIP

Flanges shall be visually examined and show no indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin starved areas. The flanges shall conform to Table 2900-4 or Table 2900-4A and gasket sealing surfaces shall conform to 2900.

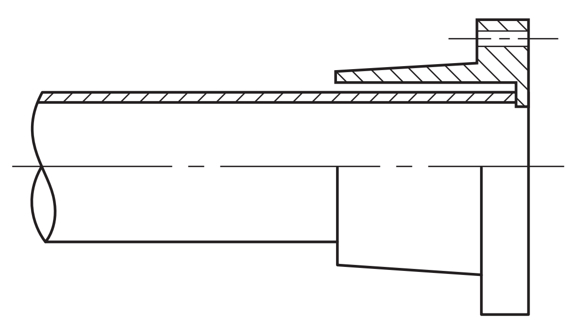
6.2 CURE

Flanges shall be of uniform cure.

6.3 DIMENSIONS AND TOLERANCES

6.3.1 Flange and Bolt Dimensions. All flanges 25 in. in diameter and smaller shall conform in bolt circle, number and size of bolt holes, and outside diameter to ANSI B16.5 for 150 lb steel flanges. Flanges larger than 24 in. diameter shall conform to the same extent to ANSI B16.1 for 125 lb Cast Iron Flanges.

Figure V-5-4
Straight Bell and Spigot Adhesive Joint Flange



6.3.2 Flange Face. The flange face shall be perpendicular to the axis of the fitting within $^1/_2$ deg and shall be flat to $\pm^1/_{32}$ in. for sizes up to and including 18 in. diameter and $\pm^1/_{16}$ in. for larger diameters.

6.3.3 Washer Bearing Surface. Washer bearing surface shall be flat and parallel to the flange face within $\pm^1/_2$ deg.

6.4 PERFORMANCE

Flanges shall meet or exceed the following performance requirements when joined for testing according to the Manufacturer's recommended practice for field installation.

6.4.1 Sealing. When tested in accordance with Section 7.5 flanges shall withstand a pressure of four times the rated Design Pressure without leakage.

6.4.2 Bolt Torque. When tested in accordance with Section 7.6 flanges shall, without visible sign of damage, withstand a bolt torque of at least four times that torque required for sealing of the flange at its rated pressure.

7 SAMPLING

7.1 PROCEDURE A

This procedure is for flanges manufactured as a commodity product (those flanges not manufactured for a specific order or application).

7.1.1 Sample of flanges to determine conformance of the material to the test requirements specified in 7.5 and 7.6 shall be taken at random from each lot as defined in 7.3.1.2.

7.1.2 A lot shall be a number of flanges not to exceed 100, of each kind, of the same nominal size and wall thickness, of the same designation code (as defined in Section 5), manufactured by the same procedure and production run. Each lot shall be identified by a marking symbol or number to trace it to the test report in which the result of all tests for the lot are recorded.

7.1.3 In the event of failure of the sample flange to pass any of the quality control tests specified in 7.5 and 7.6 two additional samples taken at random from the same lot shall be tested. The results of both retests shall conform to the requirements. If either sample fails to pass the test the lot shall be rejected.

7.2 PROCEDURE B

For each application where flanges are classified as custom manufactured, the Manufacturer is required to possess documentation of current testing of representative flange samples according to the requirements of Section 6.4. The Manufacturer shall be required to maintain quality assurance records which show that the flanges are of comparable materials, dimensional tolerances, and workmanship as those tested. For the purpose of this standard, "current testing" is defined as having occurred within the three year period prior to the date of sale.

NOTE: Procedure B is intended to be used where random sampling is not practical due to the limited quantity or large diameter of flanges purchased.

7.4 DIMENSIONS AND TOLERANCES

Flange dimensions shall be measured with micrometers or vernier calipers, or other suitable measuring devices accurate to within ±0.001 in. Diameters shall be determined by averaging a minimum of four measurements, equally spaced circumferentially.

7.5 TEST FOR SEALING

Flanged components complying in general arrangement with Figure V-7.5-1 shall be bolted together using the gasket and bolt torque recommended for standard field installation by the flange Manufacturer. The assembly shall then be pressure tested and be required to hold the test pressure as defined in 6.4 for a period of 168 hr without leakage. Retorquing to the Manufacturer's specified level after initial pressurization is permitted. Leakage is defined as the presence of any water on the outside of the pipe, flange, or fitting. The test may be conducted at ambient temperature and humidity conditions. When elevated temperature rating is required the test shall be conducted at the desired rating temperature ±5 °F.

7.6 TEST FOR MAXIMUM BOLT TORQUE

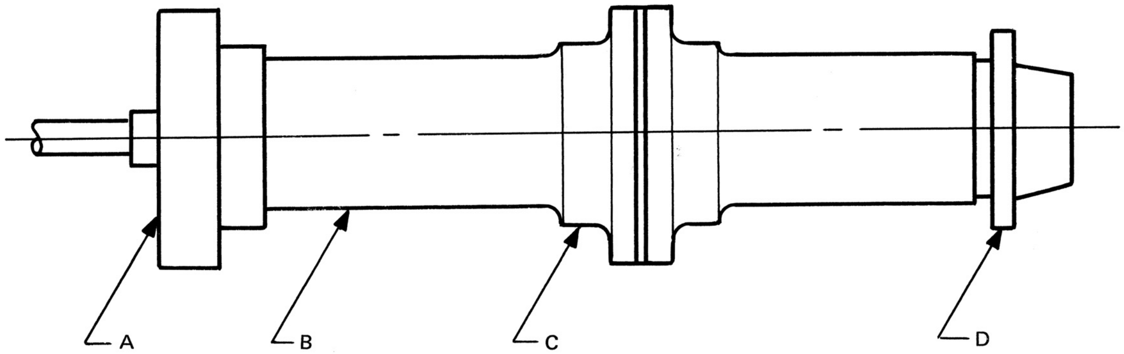
Using the gasket and hardware to be used with the flange, bolt the flange against a raised face steel flange. Tighten the nuts by hand until they are snug. Prior to fit-up, the nuts, bolts, and washers should be well lubricated, using a non-fluid thread lubricant. A spacer ring may be used between the RTR flanges. Establish uniform pressure over the flange face by tightening bolts in 5 ft-lb (7 N-M) increments per the sequence shown in Figure V-7.5-2. For flanges with more than 12 bolts, similar alternating bolt tightening sequences shall be used. Increase the bolt torque uniformly until no leakage occurs at the specified pressure rating then increase bolting torque uniformly until flange failure occurs or until all bolts have been torqued to four times the level required to stop leak. Any sign of flange damage (crumbling, flaking, cracking or other breaking) shall constitute failure.

8 REPORT

8.1

The report shall include the following:

Figure V-7.5-1
Test Assembly Configuration



Legend:
A – end plate, end cap or quick closure with coupling for pressure source/vent line
B – reinforced thermosetting resin pipe (RTRP)
C – test flange set
D – end plate, end cap or quick closure

8.1.1 Complete identification of the specimens including material, Manufacturer's name and Code number, classification (according to Section 5) pressure rating, and date of manufacture. Manufacturing process and essential variables shall be defined.

8.1.2 Complete identification of the gasket or O-ring included material, Manufacturer's name and Code number, dimensions and durometer hardness.

8.1.3 Flange dimensions, including nominal size, diameters, thicknesses, etc., of each test flange.

8.1.4 Test environment including conditioning time.

8.1.5 Date of test.

8.1.6 Description of each test assembly.

8.1.7 Sealing test pressure, time to failure and type(s) of failure.

8.1.8 Maximum bolt torque and type(s) of failure.

8.1.9 Complete listing of the number and type of tests conducted for flanges as described in this report.

8.1.10 The barcol hardness of each test flange and the average barcol hardness of all flanges tested.

9 MARKING

9.1 Each flange shall be marked with the following information in such manner that it remains legible under normal handling and installation practices.

9.1.1 The number of this Case.

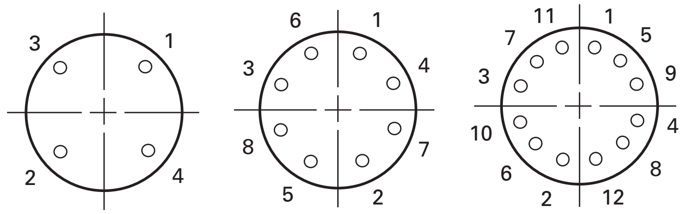
9.1.2 Identification of the flange in accordance with the designation code given in Section 5.2.

9.1.3 Nominal flange size.

9.1.4 The pressure rating of the flange.

9.1.5 Manufacturer's name (or trademark) and product designation.

Figure V-7.5-2
Bolt Torquing Sequence



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(15)

Case N-192-3
Use of Braided Flexible Connectors, Classes 2 and 3
Section III, Division 1

ANNULLED

Annulment Date: January 7, 2015

Reason: Has been incorporated.

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Approval Date: July 13, 1981

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-205
Use of Ductile Iron SA-395, Class 3
Section III, Division 1

Inquiry: Is it permissible in the construction of Class 3 pipe and fittings for service water, conforming to the requirements of Section III, Division 1, to use ductile iron conforming to SA-395 and the additional requirements listed below?

Reply: It is the opinion of the Committee that the material specified in the Inquiry may be used in the construction of Class 3 piping systems for service water under the rules of Section III, Division 1 of the Code provided the following additional requirements are met:

(a) Service shall be confined to water or salt water.

(b) Design Pressure shall not exceed 150 psi, and Design Temperature shall not exceed 200°F.

(c) The design shall be in accordance with the requirements of Section III, Division 1, of Subsection ND. The allowable stress shall not exceed 12,000 psi. Slip joints with elastomeric gaskets are permitted. Caulked joints and welded joints are prohibited.

(d) Repair by plugging, peening, welding, impregnation, or stitching is not permitted. Repair by grinding is permitted in accordance with ND-2578.

(e) Each pipe and fitting shall be subjected to hydrostatic test of not less than 500 psi for not less than 5 min. No leaks are permitted.

(f) The Material Manufacturer shall have a Quality Assurance Program in accordance with NCA-3800 of Section III, Division 1.

(g) The material shall be identified by this Case number by the Material Manufacturer.

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Approval Date: August 14, 1981
(ACI) Approval Date: March 6, 1978

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-213
Welded Radial Shear Bar Assemblies
Section III, Division 2

Inquiry: What requirements may be used in the construction of concrete containments complying with rules of Section III, Division 2, for the materials, fabrication, and examination of welded radial shear bar assemblies in reinforcing systems, similar to those shown in Figure 1?

Reply: It is the opinion of the Committee that the following requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials, fabrication, and examination of welded radial shear bar assemblies in reinforcing systems, similar to those shown in Figure 1.

1 MATERIALS

1.1 Material for reinforcing bars shall be in accordance with ASTM A706, and shall comply with the special material testing requirements of CC-2330. Reinforcing bars shall be identified in accordance with CC-2320.

1.2 Material for the flat shear bars shall be in accordance with mechanical properties of one of the following:

Specification	Min. Yld. Strength	Min. Ten. Strength
SA-537, Cl. 2	60,000 psi	80,000 psi
ASTM A572, Gr. 60	60,000 psi	75,000 psi
ASTM A572, Gr. 65	65,000 psi	80,000 psi
ASTM A633, Gr. E	60,000 psi	80,000 psi

1.3 Welding materials shall comply with the requirements of CC-4334.

1.4 Certified Material Test Reports shall be provided in accordance with CC-2130.

2 FABRICATION

Welded joints between reinforcing bars and shear bars shall be in accordance with CC-4334, except that the flux cored arc process may also be used, employing welding materials conforming to SFA-5.20.

3 IN-PROCESS TESTING

3.1 WELDED JOINT PERFORMANCE TEST

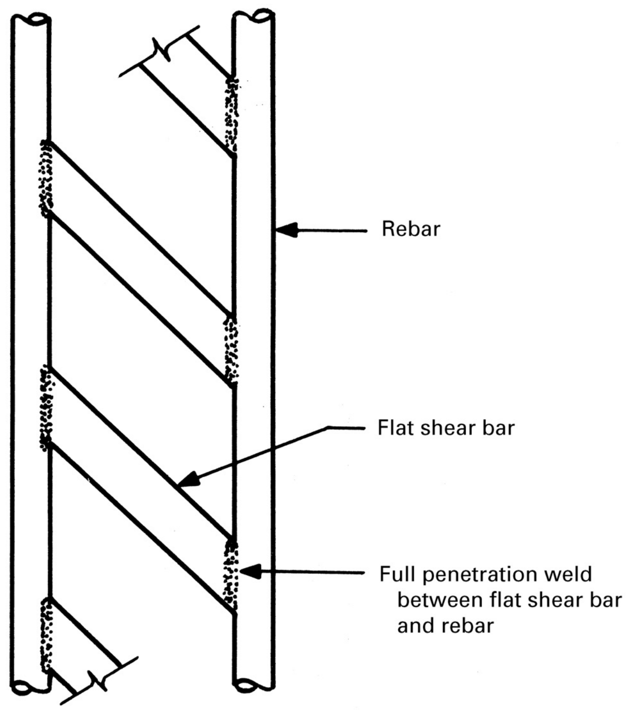
(a) A continuing welded joint performance test shall be made by removing 2% of the production joints and preparing the specimen as shown in Figure 1. The tensile load on each welded joint shall equal or exceed the load necessary to stress the flat bar to 125% of its minimum yield strength.

(b) Alternatively, welded joint performance tests may be made using sister test specimens made with material from the same heats of rebar and flat bar as the production joints to be represented. Each sister test specimen may be considered as a test of two welded joints. The welding procedure used to prepare the sister test specimens shall be the same as for the production welded joints.

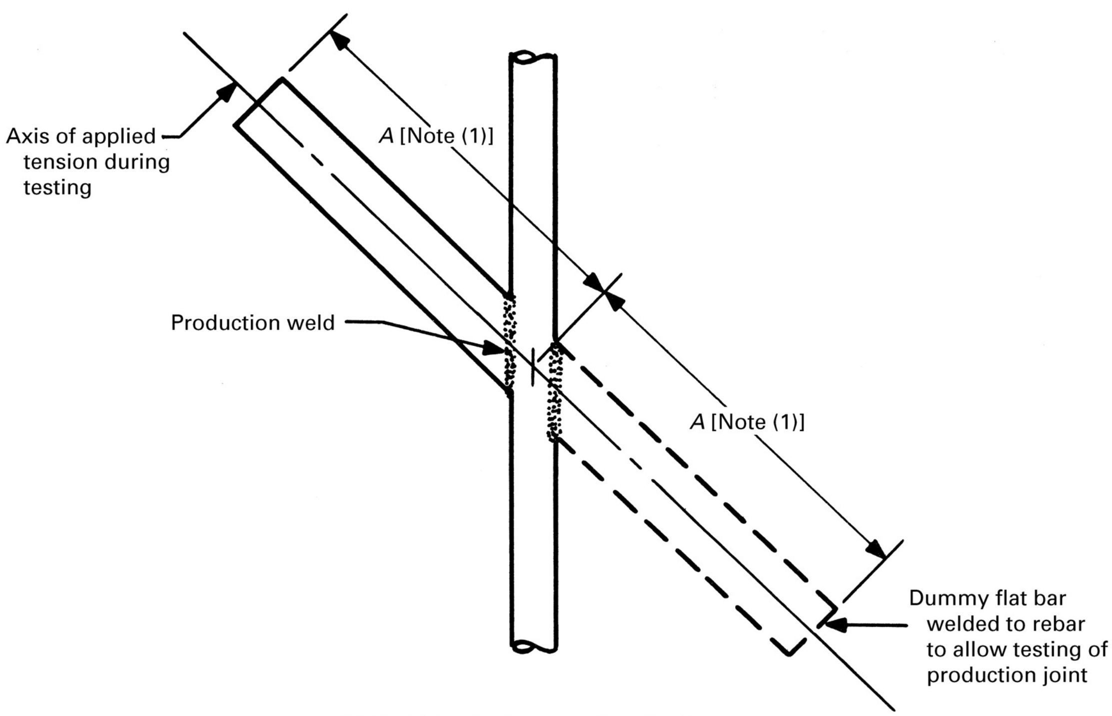
(c) If any production welded joint fails to meet the tensile strength requirements, two additional production welded joints shall be tested. If either of these fail to meet the tensile strength requirements, welding shall be halted. Welding shall not be resumed until the cause of the failures has been resolved and corrected in accordance with the Certificate Holder's Quality Assurance Program. Those production welded joints represented by the failures shall be rejected and replaced by satisfactory joints. If, at any time, failure occurs in the weld to the flat bar added for testing purposes, a retest shall be permitted.

(d) If any sister test specimen fails to meet the tensile strength requirement, two welded joints shall be removed from a production assembly and tested. The acceptance of the group of production welded joints represented shall be based upon these additional test specimens meeting the same requirements described in (c).

Figure 1



Partial Radial Shear Bar Assembly



Welded Joint Performance Test Specimen

NOTE:
(1) At least $^1/_2$ minimum dimension required by tensile testing equipment.

3.2 REINFORCING BAR PERFORMANCE TEST

(a) In addition to the welded joint performance tests, a rebar tensile test specimen shall be prepared by removing 1% of the production welded joints. The specimen shall be as shown in Figure 2. In the case where a sister test specimen has been used in the welded joint performance test, the rebar tensile test specimen may also be a sister test specimen. The tensile strength of each of these test specimens shall equal or exceed the minimum tensile strength requirements of the rebar.

(b) If any production test specimen fails to meet the minimum tensile strength requirements of the rebar, two additional specimens shall be tested. If either of these fail to meet the requirements, welding shall be halted. Welding shall not be resumed until the cause of the failures has been resolved and corrected in accordance with the Certificate Holder's Quality Assurance Program. Those production welded joints represented by the failures shall be rejected and replaced by satisfactory joints.

(c) If any sister test specimen fails to meet the minimum tensile strength requirements of the rebar, two specimens shall be removed from a production assembly and tested. The acceptance of the group of production welded joints represented shall be based upon these additional test specimens meeting the same requirements described in (b).

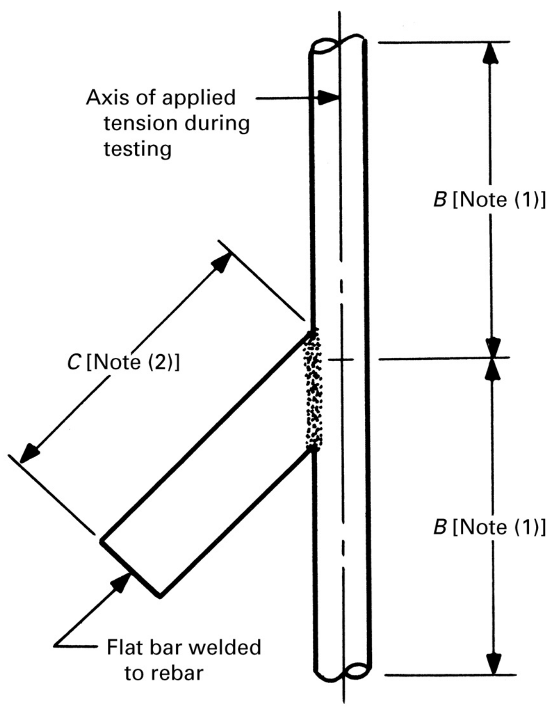
4 EXAMINATION

Welded joints shall be visually examined in accordance with CC-5331.

5 DATA REPORTS

The use of this Code Case shall be indicated on the Fabricator's or Constructor's Data Report.

Figure 2
Reinforcing Bar Performance Test Specimen



NOTES:
(1) At least $\frac{1}{2}$ minimum dimension required for tensile testing equipment.
(2) Any convenient dimension.

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Approval Date: July 15, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-249-15
Additional Materials for Subsection NF, Class 1, 2, 3, and MC Supports Fabricated Without Welding
Section III, Division 1

Inquiry: What materials in addition to those listed in Section II, Part D, Tables 1A, 1B, 2A, 2B and Y1, may be used for Section III, Division 1, Classes 1, 2, 3, or MC supports constructed to the requirements of Subsection NF when the items are fabricated without welding?

Reply: It is the opinion of the Committee that the -additional materials, design stress intensity and allowable stress values, the yield strength, and the ultimate tensile strength values,[1] listed in Tables 1, 2, 3, 4 and 5 of this Code Case may be used in the construction of Class 1, 2, 3, and MC supports fabricated without welding for Section III, Division 1, in addition to those listed in Table NF-2121(a)-1.

The following additional requirements shall apply.

(a) The requirements of Subsection NF shall be met except as modified by this Case.

(b) Repair welding is not permitted on carbon and low alloy steels containing more than 0.35% carbon, nor on precipitation hardened or age-hardened steels, nor on the free machining steels permitted in (c) below, unless permitted by the material specification. Weld repairs of base material shall be made on annealed material and such repaired material shall be reheat treated in accordance with the material specification.

(c) When the Material column in Tables 1 through 5 references AISI grades, only materials meeting the chemical composition requirements of the specific AISI grades listed shall be used, with the exception that 0.60% maximum silicon is permitted for castings. Free machining modifications of the specific AISI grades listed may be used at the same design stress intensities, allowable stresses and yield strengths of the reference grades but their use is limited to 400°F (200°C) maximum temperature.

(d) When the ASTM specification referenced in Tables 1 through 4 does not specify minimum tensile and yield strengths, the values listed under the appropriate columns shall be met by the material.

(e) The maximum measured ultimate tensile strength (UTS) of the support material should not exceed 170 ksi (117 MPa) unless consideration is given to the susceptibility of high-strength materials to brittleness and stress corrosion cracking. Certain applications may exist where a UTS value of up to 190 ksi (131 MPa) could be considered acceptable for a material.

(1) For these applications, the Design Specification should specify impact testing for piping supports in accordance with NF-2300. Component supports shall meet the requirements of NF-2300.

(2) The Design Specification shall include requirements for the consideration of the effects of sustained loads, environment, residual stress, and heat treatment on the susceptibility to stress corrosion cracking of these high strength materials.

(3) The Design Documents shall include confirmation that the material is not subject to stress corrosion cracking by virtue of the fact that a corrosive environment is not present, the support has essentially no residual stresses nor assembly stresses, and it does not experience frequent sustained load in service.

[1] The tabulated values of tensile strength and yield strength are those which the Committee believes are suitable for use in design calculations required by Section III, Division 1. At the temperatures above room temperature, the values of tensile strength tend toward an average or expected value which may be as much as 10% above the tensile strength trend curves adjusted to the minimum specified room temperature tensile strength. At temperatures above room temperature, the yield strength values correspond to the yield strength trend curve adjusted to the minimum specified room temperature yield strength. Neither the tensile strength nor the yield strength values correspond exactly to either "average" or "minimum," as these terms are applied to a statistical treatment of a homogenous set of data.Neither the ASME or ASTM Material Specifications nor the rules of Section III, Division 1, require elevated temperature testing for tensile or yield strengths of production material for use in Code components. It is not intended that results of such tests, if performed, be compared with these tabulated tensile and yield strength values for ASME Code acceptance/rejection purposes for materials. If some elevated temperature test results on production material appear lower than the tabulated values by a large amount (more than the typical variability of material suggesting the possibility of some error), further investigation by retest or other means should be considered.

(f) Materials in Tables 1 through 5 that are listed as an AISI composition may be accepted as satisfying the requirements of the ASTM specification provided the chemical requirements of the AISI specification are within the specified range of the designated ASTM specification, and certification of the material shall be in accordance with the requirements of NCA-3860.

(g) The material shall be furnished with the requirements of NF-2600.

(h) This Case and revision number shall be listed on the applicable documentation accompanying shipment.

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding,									
								100	200	300	400	500	600		700	750	800
Carbon Steels																	
AISI 1015	Bar	A108-99	1015CW	...	4	40	60	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1018	Bar	A108-99	1018CW	...	4	40	60	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1020	Bar	A108-99	1020CW	...	4	40	60	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1045	Bar	A108-99	1045CW	...	...	100	120	40.0	40.0	40.0	40.0	...	...	...	...	...	...
AISI 1050	Bar	A108-99	1050CW	...	...	125	140	46.7	46.7	46.7	46.7	...	...	...	...	...	...
AISI 1117	Bar	A108-99	1117	...	...	60	70	23.3	23.3	23.3	23.3	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	...	100	115	38.3	38.3	38.3	38.3	...	...	...	...	...	...
AISI 12L14	Bar	A108-99	1214	...	...	55	65	21.7	21.7	21.7	21.7	...	...	...	...	...	...
AISI 1015	Tube	A513-98	1015CW	...	4	55	65	21.7	21.7	21.7	21.7	...	...	...	...	...	...
AISI 1020	Tube	A513-98	1020CW	...	4	60	70	23.3	23.3	23.3	23.3	...	...	...	...	...	...
AISI 1025	Tube	A513-98	1025CW	...	5	65	75	25.0	25.0	25.0	25.0	...	...	...	...	...	...
AISI 1026	Tube	A513-98	1026CW	...	5	70	80	26.7	26.7	26.7	26.7	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018CW	...	4	60	70	23.3	23.3	23.3	23.3	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020CW	...	4	60	70	23.3	23.3	23.3	23.3	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022CW	...	4	60	70	23.3	23.3	23.3	23.3	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025CW	...	3,5	65	75	25.0	25.0	25.0	25.0	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026CW	...	3,5	65	75	25.0	25.0	25.0	25.0	...	...	...	...	...	...
Low Alloy Steels																	
AISI 4130	Castings	A148-93b	105-85	...	32	85	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4140	Castings	A148-93b	105-85	...	32	85	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4320	Castings	A148-93b	105-85	...	32	85	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4340	Castings	A148-93b	105-85	...	32	85	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4130	Castings	A148-93b	115-95	...	33	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4140	Castings	A148-93b	115-95	...	33	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4320	Castings	A148-93b	115-95	...	33	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4340	Castings	A148-93b	115-95	...	33	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4130	Castings	A148-93b	135-125	...	...	125	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4140	Castings	A148-93b	135-125	...	...	125	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4320	Castings	A148-93b	135-125	...	...	125	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4340	Castings	A148-93b	135-125	...	...	125	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4140	Tube	A519-96	4140SR	...	...	100	120	40.0	40.0	40.0	40.0	...	...	...	...	...	...
AISI 4142	Tube	A519-96	4142SR	...	...	100	120	40.0	40.0	40.0	40.0	...	...	...	...	...	...
5Ni-Cr-Mo-V	Forgings	A579-99	12a	...	...	140	150	50.0	49.5	48.0	47.0	47.0	47.0		44.0	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,13	75	100	33.3	33.3	33.3	33.3	33.3	33.3		33.3	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,13	75	100	33.3	33.3	33.3	33.3	33.3	33.3		33.3	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,9,11,12	80	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,9,11,12	80	105	35.0	35.0	35.0	35.0	35.0	35.0		35.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,13	85	110	36.7	36.7	36.7	36.7	36.7	36.7		36.7	...	...

Table 1
Design Stress Intensity Values, S_m, for Class 1 Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Design Stress Intensity, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding,									
								100	200	300	400	500	600		700	750	800
AISI 4340	Forgings	A668-96e1	...	L	6,13	85	110	36.7	36.7	36.7	36.7	36.7	36.7		36.7	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,12	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,12	95	115	38.3	38.3	38.3	38.3	38.3	38.3		38.3	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,11	105	125	41.7	41.7	41.7	41.7	41.7	41.7		41.7	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,11	105	125	41.7	41.7	41.7	41.7	41.7	41.7		41.7	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,13,44	110	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,13,44	110	135	45.0	45.0	45.0	45.0	45.0	45.0		45.0	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,9,12	115	140	46.7	46.7	46.7	46.7	46.7	46.7		46.7	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,12	115	140	46.7	46.7	46.7	46.7	46.7	46.7		46.7	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,9,11	120	145	48.3	48.3	48.3	48.3	48.3	48.3		48.3	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,11	120	145	48.3	48.3	48.3	48.3	48.3	48.3		48.3	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,13	130	160	53.3	53.3	53.3	53.3	53.3	53.3		53.3	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,12	135	165	55.0	55.0	55.0	55.0	55.0	55.0		55.0	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,11	140	170	56.7	56.7	56.7	56.7	56.7	56.7		56.7	...	...
High Alloy Steels																	
Precipitation Hardened Steels																	
26Ni-15Cr-2Ti	Bar	SA-453	660	A,B	31	85	130	43.3	43.3	43.3	43.3	43.3	43.3		43.3	...	...
Copper and Copper Alloys																	
Alum. Bronze	Bar	SB-150	C64200	...	...	25	70	16.7	14.0	13.5	11.0	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C61400	...	...	30	70	20.0	19.8	19.6	19.2	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C63000	...	11	42.5	85	28.3	27.8	26.9	26.3	...	...	...	...	...	...
Alum. Bronze	Plate	SB-169	C61400	...	...	28	65	18.7	18.5	18.3	17.9	...	...	...	...	...	...
Alum. Bronze	Castings	SB-271	C95400	...	...	30	75	20.0	18.6	18.6	18.6	...	...	...	...	...	...
80-10-10	Castings	SB-584	C93700	...	...	12	30	8.0	7.1	6.7	6.5	...	...	...	...	...	...

NOTE: *Notes follow Table 5.

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, Ksi	Min. Ultimate Tensile Strength, Ksi	Allowable Stress, ksi Multiply by 1000 psi) for Metal Temperatures Not Exceeding,									
								100	200	300	400	500	600		700	750	800
Carbon Steels																	
AISI 1015	Bar	A108-99	1015CW	...	4,59	40	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1018	Bar	A108-99	1018CW	...	4,59	40	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1020	Bar	A108-99	1020CW	...	4,59	40	60	17.1	17.1	17.1	17.1	...	...	...	...	...	...
AISI 1045	Bar	A108-99	1045CW	...	59	100	120	34.3	34.3	34.3	34.3	...	...	...	...	...	...
AISI 1050	Bar	A108-99	1050CW	...	59	125	140	40.0	40.0	40.0	40.0	...	...	...	...	...	...
AISI 1117	Bar	A108-99	1117	...	59	60	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	59	100	115	32.9	32.9	32.9	32.9	...	...	...	...	...	...
AISI 12L14	Bar	A108-99	1214	...	59	55	65	18.6	18.6	18.6	18.6	...	...	...	...	...	...
AISI 1015	Tube	A513-98	1015CW	...	4,59	55	65	18.6	18.6	18.6	18.6	...	...	...	...	...	...
AISI 1020	Tube	A513-98	1020CW	...	4,59	60	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1025	Tube	A513-98	1025CW	...	5,59	65	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1026	Tube	A513-98	1026CW	...	5,59	70	80	22.9	22.9	22.9	22.9	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018CW	...	4,59	60	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020CW	...	4,59	60	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022CW	...	4,59	60	70	20.0	20.0	20.0	20.0	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025CW	...	3,5,59	65	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026CW	...	3,5,59	65	75	21.4	21.4	21.4	21.4	...	...	...	...	...	...
Low Alloy Steels																	
AISI 4130	Castings	A148-93b	105-85	...	32,59	85	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4140	Castings	A148-93b	105-85	...	32,59	85	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4320	Castings	A148-93b	105-85	...	32,59	85	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4340	Castings	A148-93b	105-85	...	32,59	85	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4130	Castings	A148-93b	115-95	...	33,59	95	115	32.9	32.9	32.9	32.9	32.9	32.9		32.9	...	...
AISI 4140	Castings	A148-93b	115-95	...	33,59	95	115	32.9	32.9	32.9	32.9	32.9	32.9		32.9	...	...
AISI 4320	Castings	A148-93b	115-95	...	33,59	95	115	32.9	32.9	32.9	32.9	32.9	32.9		32.9	...	...
AISI 4340	Castings	A148-93b	115-95	...	33,59	95	115	32.9	32.9	32.9	32.92	32.9	32.9		32.9	...	...
AISI 4130	Castings	A148-93b	135-125	...	59	125	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4140	Castings	A148-93b	135-125	...	59	125	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4320	Castings	A148-93b	135-125	...	59	125	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4340	Castings	A148-93b	135-125	...	59	125	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4140	Tube	A519-96	4140SR	...	59	100	120	34.3	34.3	34.3	34.3	...	...	...	...	...	...
AISI 4142	Tube	A519-96	4142SR	...	59	100	120	34.3	34.3	34.3	34.3	...	...	...	...	...	...
5Ni-Cr-Mo-V	Forgings	A579-99	12a	...	59	140	150	42.9	42.4	41.1	40.3	40.3	40.3		37.7	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,13,59	75	100	28.6	28.6	28.6	28.6	28.6	28.6		28.6	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,13,59	75	100	28.6	28.6	28.6	28.6	28.6	28.6		28.6	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,9,11,12,59	80	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,9,11,12,59	80	105	30.0	30.0	30.0	30.0	30.0	30.0		30.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,13,59	85	110	31.4	31.4	31.4	31.4	31.4	31.4		31.4	...	...

Table 2
Allowable Stress Values, *S*, for Classes 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, Ksi	Min. Ultimate Tensile Strength, Ksi	Allowable Stress, ksi Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F									
								100	200	300	400	500	600		700	750	800
AISI 4340	Forgings	A668-96e1	...	L	6,13,59	85	110	31.4	31.4	31.4	31.4	31.4	31.4		31.4	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,12,59	95	115	32.9	32.9	32.9	32.9	32.9	32.9		32.9	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,12,59	95	115	32.9	32.9	32.9	32.9	32.9	32.9		32.9	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,11,59	105	125	35.7	35.7	35.7	35.7	35.7	35.7		35.7	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,11,59	105	125	35.7	35.7	35.7	35.7	35.7	35.7		35.7	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,13,44,59	110	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,13,44,59	110	135	38.6	38.6	38.6	38.6	38.6	38.6		38.6	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,9,12,59	115	140	40.0	40.0	40.0	40.0	40.0	40.0		40.0	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,12,59	115	140	40.0	40.0	40.0	40.0	40.0	40.0		40.0	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,9,11,59	120	145	41.4	41.4	41.4	41.4	41.4	41.4		41.4	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,11,59	120	145	41.4	41.4	41.4	41.4	41.4	41.4		41.4	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,13,59	130	160	45.7	45.7	45.7	45.7	45.7	45.7		45.7	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,12,59	135	165	47.1	47.1	47.1	47.1	47.1	47.1		55.0	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,11,59	140	170	48.6	48.6	48.6	48.6	48.6	48.6		48.6	...	...
High Alloy Steels																	
Precipitation Hardened Steels																	
26Ni-15Cr-2Ti	Bar	SA-453	660	A,B	31,59	85	130	37.1	37.1	37.1	37.1	37.1	37.1		37.1	...	...
Copper and Copper Alloys																	
Alum. Bronze	Bar	SB-150	C64200	...	59	25	70	16.7	14.0	13.5	...	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C61400	...	59	30	70	20.0	19.6	19.0	17.8	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C63000	...	11,59	42.5	85	24.3	24.0	23.6	23.3	...	...	...	...	...	...
Alum. Bronze	Plate	SB-169	C61400	...	59	28	65	18.6	18.2	17.7	16.5	...	...	...	...	...	...
Alum. Bronze	Castings	SB-271	C95400	...	59	30	75	20.0	18.6	18.6	18.4	...	...	...	...	...	...
80-10-10	Castings	SB-584	C93700	...	59	12	30	8.0	7.1	6.7	6.6	...	...	...	...	...	...

NOTE: *Notes follow Table 5.

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F									
								100	200	300	400	500	600		700	750	800
						Carbon Steels											
AISI 1015	Bar	A108-99	1015CW	...	4	40	60	40.0	36.5	35.4	34.2	...	...	...	...	...	...
AISI 1018	Bar	A108-99	1018CW	...	4	40	60	40.0	36.5	35.4	34.2	...	...	...	...	...	...
AISI 1020	Bar	A108-99	1020CW	...	4	40	60	40.0	36.5	35.4	34.2	...	...	...	...	...	...
AISI 1045	Bar	A108-99	1045CW	...	...	100	120	100.0	91.2	88.4	85.6	...	...	...	...	...	...
AISI 1050	Bar	A108-99	1050CW	...	...	125	140	125.0	114.0	110.5	107.0	...	...	...	...	...	...
AISI 1117	Bar	A108-99	1117	...	...	60	70	60.0	54.7	53.0	51.4	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	...	100	115	100.0	91.2	88.4	85.6	...	...	...	...	...	...
AISI 12L14	Bar	A108-99	1214	...	...	55	65	55.0	50.2	48.6	47.1	...	...	...	...	...	...
...	Wire	A228-93	...	...	14	250	270	250.0	220.5	202.5	187.5	...	...	...	...	...	...
AISI 1038	Bar	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1038	Bolt	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1541	Bar	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1541	Bolt	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1015	Tube	A513-98	1015CW	...	4	55	65	55.0	50.2	48.6	47.1	...	...	...	...	...	...
AISI 1020	Tube	A513-98	1020CW	...	4	60	70	60.0	54.7	53.0	51.4	...	...	...	...	...	...
AISI 1025	Tube	A513-98	1025CW	...	5	65	75	65.0	59.3	57.5	55.6	...	...	...	...	...	...
AISI 1026	Tube	A513-98	1026CW	...	5	70	80	70.0	63.8	61.9	59.8	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018CW	...	4	60	70	60.0	54.7	53.0	51.4	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020CW	...	4	60	70	60.0	54.7	53.0	51.4	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022CW	...	4	60	70	60.0	54.7	53.0	51.4	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025CW	...	3,5	65	75	65.0	59.3	57.5	55.6	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026CW	...	3,5	65	75	65.0	59.3	57.5	55.6	...	...	...	...	...	...
AISI 1035	Forgings	A521-96	...	CG	12,13	50	85	50.0	45.6	44.3	42.9	40.4	37.0		36.0	...	...
AISI 1040	Forgings	A521-96	...	CG	12,13	50	85	50.0	45.6	44.3	42.9	40.4	37.0		36.0	...	...
AISI 1035	Forgings	A521-96	...	CG	11	55	90	55.0	50.2	48.6	47.1	44.5	40.7		39.6	...	...
AISI 1040	Forgings	A521-96	...	CG	11	55	90	55.0	50.2	48.6	47.1	44.5	40.7		39.6	...	...
AISI 1035	Forgings	A668-96e1	...	B	6	30	60	30.0	27.3	26.6	25.7	24.5	22.2		21.6	...	...
AISI 1035	Forgings	A668-96e1	...	C	6	33	66	33.0	30.1	29.2	28.3	26.5	24.4		23.8	...	...
AISI 1035	Forgings	A668-96e1	...	D	6	37.5	75	37.5	34.2	33.2	32.1	30.3	27.7		27.0	...	...
AISI 1035	Forgings	A668-96e1	...	F	6,12,13	50	85	50.0	45.6	44.3	42.9	40.4	37.0		36.0	...	...
AISI 1040	Forgings	A668-96e1	...	F	6,12,13	50	85	50.0	45.6	44.3	42.9	40.4	37.0		36.0	...	...
AISI 1045	Forgings	A668-96e1	...	F	6,12,13	50	85	50.0	45.6	44.3	42.9	40.4	37.0		36.0	...	...
AISI 1035	Forgings	A668-96e1	...	F	6,9,11	55	90	55.0	50.2	48.6	47.1	44.5	40.7		39.6	...	...
AISI 1040	Forgings	A668-96e1	...	F	6,9,11	55	90	55.0	50.2	48.6	47.1	44.5	40.7		39.6	...	...
AISI 1045	Forgings	A668-96e1	...	F	6,9,11	55	90	55.0	50.2	48.6	47.1	44.5	40.7		39.6	...	...
Low Alloy Steels																	
AISI 4130	Castings	A148-93b	105-85	...	32	85	105	85.0	82.5	79.2	74.8	71.0	70.5		70.5	...	...
AISI 4140	Castings	A148-93b	105-85	...	32	85	105	85.0	82.5	79.2	74.8	71.0	70.5		70.5	...	...
AISI 4320	Castings	A148-93b	105-85	...	32	85	105	85.0	82.5	79.2	74.8	71.0	70.5		70.5	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F								
								100	200	300	400	500	600	700	750	800
AISI 4340	Castings	A148-93b	105-85	...	32	85	105	85.0	82.5	79.2	74.8	71.0	70.5	70.5	...	...
AISI 4130	Castings	A148-93b	115-95	...	33	95	115	95.0	92.1	88.5	83.5	79.3	78.9	78.9	...	...
AISI 4140	Castings	A148-93b	115-95	...	33	95	115	95.0	92.1	88.5	83.5	79.3	78.9	78.9	...	...
AISI 4320	Castings	A148-93b	115-95	...	33	95	115	95.0	92.1	88.5	83.5	79.3	78.9	78.9	...	...
AISI 4340	Castings	A148-93b	115-95	...	33	95	115	95.0	92.1	88.5	83.5	79.3	78.9	78.9	...	...
AISI 4130	Castings	A148-93b	135-125	...	...	125	135	125.0	121.1	116.5	110.0	104.3	103.9	103.9	...	...
AISI 4140	Castings	A148-93b	135-125	...	...	125	135	125.0	121.1	116.5	110.0	104.3	103.9	103.9	...	...
AISI 4320	Castings	A148-93b	135-125	...	...	125	135	125.0	121.1	116.5	110.0	104.3	103.9	103.9	...	...
AISI 4340	Castings	A148-93b	135-125	...	...	125	135	125.0	121.1	116.5	110.0	104.3	103.9	103.9	...	...
AISI 4150	Bar	A322-91	4150	...	...	100	115	100.0	93.5	90.2	87.8	85.1	81.4	76.0	...	...
AISI 4130	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 4140	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 4145	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 4320	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 4340	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 8260	Bar	A434-90a	...	BB	24	90	110	90.0	84.1	81.3	79.0	76.6	73.3	68.4	...	...
AISI 4130	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 4140	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 4145	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 4320	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 4340	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 8260	Bar	A434-90a	...	BB	25	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.0	...	...
AISI 4130	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4140	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4145	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4320	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4340	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 8260	Bar	A434-90a	...	BB	26	75	100	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4130	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4140	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4145	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4320	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4340	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 8260	Bar	A434-90a	...	BB	12	75	95	75.0	70.1	67.7	65.8	63.8	61.0	57.0	...	...
AISI 4130	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...
AISI 4140	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...
AISI 4145	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...
AISI 4320	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...
AISI 4340	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...
AISI 8260	Bar	A434-90a	...	BB	27	65	90	65.0	60.7	58.6	57.1	55.3	52.9	49.4	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F								
								100	200	300	400	500	600	700	750	800
AISI 4130	Bar	A434-90a	...	BC	24	110	130	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4140	Bar	A434-90a	...	BC	24	110	130	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4145	Bar	A434-90a	...	BC	24	110	130	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4320	Bar	A434-90a	...	BC	24	110	130	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4340	Bar	A434-90a	...	BC	24	110	130	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4130	Bar	A434-90a	...	BC	25	105	125	105.0	98.1	94.8	92.2	89.4	85.5	79.8	...	...
AISI 4140	Bar	A434-90a	...	BC	25	105	125	105.0	98.1	94.8	92.2	89.4	85.5	79.8	...	...
AISI 4145	Bar	A434-90a	...	BC	25	105	125	105.0	98.1	94.8	92.2	89.4	85.5	79.8	...	...
AISI 4320	Bar	A434-90a	...	BC	25	105	125	105.0	98.1	94.8	92.2	89.4	85.5	79.8	...	...
AISI 4340	Bar	A434-90a	...	BC	25	105	125	105.0	98.1	94.8	92.2	89.4	85.5	79.8	...	...
AISI 4130	Bar	A434-90a	...	BC	26	95	115	95.0	88.5	85.4	83.0	80.6	77.0	72.0	...	...
AISI 4140	Bar	A434-90a	...	BC	26	95	115	95.0	88.5	85.4	83.0	80.6	77.0	72.0	...	...
AISI 4145	Bar	A434-90a	...	BC	26	95	115	95.0	88.5	85.4	83.0	80.6	77.0	72.0	...	...
AISI 4320	Bar	A434-90a	...	BC	26	95	115	95.0	88.5	85.4	83.0	80.6	77.0	72.0	...	...
AISI 4340	Bar	A434-90a	...	BC	26	95	115	95.0	88.5	85.4	83.0	80.6	77.0	72.0	...	...
AISI 4130	Bar	A434-90a	...	BC	12	85	110	85.0	79.5	76.8	74.6	72.4	69.1	64.6	...	...
AISI 4140	Bar	A434-90a	...	BC	12	85	110	85.0	79.5	76.8	74.6	72.4	69.1	64.6	...	...
AISI 4145	Bar	A434-90a	...	BC	12	85	110	85.0	79.5	76.8	74.6	72.4	69.1	64.6	...	...
AISI 4320	Bar	A434-90a	...	BC	12	85	110	85.0	79.5	76.8	74.6	72.4	69.1	64.6	...	...
AISI 4340	Bar	A434-90a	...	BC	12	85	110	85.0	79.5	76.8	74.6	72.4	69.1	64.6	...	...
AISI 4130	Bar	A434-90a	...	BC	27	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.9	...	...
AISI 4140	Bar	A434-90a	...	BC	27	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.9	...	...
AISI 4145	Bar	A434-90a	...	BC	27	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.9	...	...
AISI 4320	Bar	A434-90a	...	BC	27	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.9	...	...
AISI 4340	Bar	A434-90a	...	BC	27	80	105	80.0	74.8	72.3	70.3	68.1	65.1	60.9	...	...
AISI 4130	Bar	A434-90a	...	BD	24	130	155	130.0	121.5	117.2	114.1	110.7	105.7	98.8	...	...
AISI 4140	Bar	A434-90a	...	BD	24	130	155	130.0	121.5	117.2	114.1	110.7	105.7	98.8	...	...
AISI 4145	Bar	A434-90a	...	BD	24	130	155	130.0	121.5	117.2	114.1	110.7	105.7	98.8	...	...
AISI 4320	Bar	A434-90a	...	BD	24	130	155	130.0	121.5	117.2	114.1	110.7	105.7	98.8	...	...
AISI 4340	Bar	A434-90a	...	BD	24	130	155	130.0	121.5	117.2	114.1	110.7	105.7	98.8	...	...
AISI 4130	Bar	A434-90a	...	BD	25	120	150	120.0	112.1	108.4	105.2	102.1	97.6	91.1	...	...
AISI 4140	Bar	A434-90a	...	BD	25	120	150	120.0	112.1	108.4	105.2	102.1	97.6	91.1	...	...
AISI 4145	Bar	A434-90a	...	BD	25	120	150	120.0	112.1	108.4	105.2	102.1	97.6	91.1	...	...
AISI 4320	Bar	A434-90a	...	BD	25	120	150	120.0	112.1	108.4	105.2	102.1	97.6	91.1	...	...
AISI 4340	Bar	A434-90a	...	BD	25	120	150	120.0	112.1	108.4	105.2	102.1	97.6	91.1	...	...
AISI 4130	Bar	A434-90a	...	BD	26	110	140	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4140	Bar	A434-90a	...	BD	26	110	140	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4145	Bar	A434-90a	...	BD	26	110	140	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4320	Bar	A434-90a	...	BD	26	110	140	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...
AISI 4340	Bar	A434-90a	...	BD	26	110	140	110.0	102.9	99.4	96.6	93.6	89.5	83.6	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F									
								100	200	300	400	500	600		700	750	800
AISI 4130	Bar	A434-90a	...	BD	12	105	135	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4140	Bar	A434-90a	...	BD	12	105	135	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4145	Bar	A434-90a	...	BD	12	105	135	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4320	Bar	A434-90a	...	BD	12	105	135	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4340	Bar	A434-90a	...	BD	12	105	135	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4130	Bar	A434-90a	...	BD	27	100	130	100.0	93.5	90.2	87.8	85.1	81.4		76.0	...	...
AISI 4140	Bar	A434-90a	...	BD	27	100	130	100.0	93.5	90.2	87.8	85.1	81.4		76.0	...	...
AISI 4145	Bar	A434-90a	...	BD	27	100	130	100.0	93.5	90.2	87.8	85.1	81.4		76.0	...	...
AISI 4320	Bar	A434-90a	...	BD	27	100	130	100.0	93.5	90.2	87.8	85.1	81.4		76.0	...	...
AISI 4340	Bar	A434-90a	...	BD	27	100	130	100.0	93.5	90.2	87.8	85.1	81.4		76.0	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	2	21	90	105	90.0	84.8	82.1	80.3	79.0	77.6		75.4	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	3	21	100	110	100.0	94.2	91.2	89.2	87.8	86.2		83.8	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	4	21	110	120	110.0	103.7	100.4	98.2	96.5	94.9		92.2	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	5	21	120	130	120.0	113.1	109.5	107.1	105.3	103.5		100.6	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	6	21	130	140	130.0	122.5	118.6	116.0	114.1	112.1		109.0	...	...
AISI 4140	Tube	A519-96	4140SR	...	...	100	120	100.0	93.5	90.2	87.8	...	...	...	...	...	...
AISI 4142	Tube	A519-96	4142SR	...	...	100	120	100.0	93.5	90.2	87.8	...	...	...	...	...	...
5Ni–Cr–Mo–V	Forgings	A579-99	12a	...	...	140	150	140.0	138.6	134.0	129.5	127.7	126.3		117.6	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,13,20	75	100	75.0	70.1	67.7	65.8	63.8	61.0		57.0	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,13,20	75	100	75.0	70.1	67.7	65.8	63.8	61.0		57.0	...	...
AISI 4140	Forgings	A668-96e1	...	K	6,9,11,12,20	80	105	80.0	74.8	72.3	70.3	68.1	65.1		60.9	...	...
AISI 4340	Forgings	A668-96e1	...	K	6,9,11,12,20	80	105	80.0	74.8	72.3	70.3	68.1	65.1		60.9	...	...
AISI 4135	Forgings	A668-96e1	...	L	6,13,20	85	110	85.0	79.5	76.8	74.6	72.4	69.1		64.6	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,13,20	85	110	85.0	79.5	76.8	74.6	72.4	69.1		64.6	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,13,20	85	110	85.0	79.5	76.8	74.6	72.4	69.1		64.6	...	...
AISI 4135	Forgings	A668-96e1	...	L	6,9,12,20	95	115	95.0	88.5	85.4	83.0	80.6	77.0		72.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,12,20	95	115	95.0	88.5	85.4	83.0	80.6	77.0		72.0	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,12,20	95	115	95.0	88.5	85.4	83.0	80.6	77.0		72.0	...	...
AISI 4135	Forgings	A668-96e1	...	L	6,9,11,20	105	125	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4140	Forgings	A668-96e1	...	L	6,9,11,20	105	125	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4340	Forgings	A668-96e1	...	L	6,9,11,20	105	125	105.0	98.1	94.8	92.2	89.4	85.5		79.8	...	...
AISI 4135	Forgings	A668-96e1	...	M	6,13,20,44	110	135	110.0	102.9	99.4	96.6	93.6	89.5		83.6	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,13,20,44	110	135	110.0	102.9	99.4	96.6	93.6	89.5		83.6	...	...
AISI 4330	Forgings	A668-96e1	...	M	6,13,20,44	110	135	110.0	102.9	99.4	96.6	93.6	89.5		83.6	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,13,20,44	110	135	110.0	102.9	99.4	96.6	93.6	89.5		83.6	...	...
AISI 4135	Forgings	A668-96e1	...	M	6,9,12,20	115	140	115.0	107.5	103.8	101.0	98.0	93.6		87.5	...	...
AISI 4140	Forgings	A668-96e1	...	M	6,9,12,20	115	140	115.0	107.5	103.8	101.0	98.0	93.6		87.5	...	...
AISI 4330	Forgings	A668-96e1	...	M	6,9,12,20	115	140	115.0	107.5	103.8	101.0	98.0	93.6		87.5	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,12,20	115	140	115.0	107.5	103.8	101.0	98.0	93.6		87.5	...	...
AISI 4135	Forgings	A668-96e1	...	M	6,9,11,20	120	145	120.0	112.1	108.4	105.2	102.1	97.6		91.1	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F									
								100	200	300	400	500	600		700	750	800
AISI 4140	Forgings	A668-96e1	...	M	6,9,11,20	120	145	120.0	112.1	108.4	105.2	102.1	97.6		91.1	...	...
AISI 4330	Forgings	A668-96e1	...	M	6,9,11,20	120	145	120.0	112.1	108.4	105.2	102.1	97.6		91.1	...	...
AISI 4340	Forgings	A668-96e1	...	M	6,9,11,20	120	145	120.0	112.1	108.4	105.2	102.1	97.6		91.1	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,13,20	130	160	130.0	121.5	117.2	114.1	110.7	105.7		98.8	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,12,20	135	165	135.0	126.1	121.9	118.5	115.0	109.9		102.7	...	...
AISI 4340	Forgings	A668-96e1	...	N	6,9,11,20	140	170	140.0	131.0	126.3	123.0	119.1	114.0		106.3	...	...
High Alloy Steels																	
Martensitic Stainless Steels																	
17Cr	Bar	A276-98b	440C	...	22,28,56	210	275	210.0	205.9	205.2	204.4	200.0	195.8	...	...	...	...
17Cr	Bar	A276-98b	440C	...	19,22,29,56	275	285	275.0	...	...	...	...	...	...	...	...	...
13Cr	Bar	A276-98b	420	...	58	65	95	65.0	57.5	56.1	55.3	54.5	53.8	...	...	...	...
13Cr	Bar	A582-95b	416	...	23	40	70	40.0	38.1	36.9	35.7	...	...	...	...	...	...
13Cr–Se	Bar	A582-95b	416Se	...	23	40	70	40.0	38.1	36.9	35.7	...	...	...	...	...	...
Precipitation Hardened Steels																	
26Ni–15Cr–2Ti	Bar	SA-453	660	A	31	85	130	85.0	82.5	81.0	81.0	81.0	81.0		81.0	81.0	81.0
13Cr–8Ni–2Mo	Bar	SA-564	XM-13	...	30	165	175	165.0	154.6	148.5	143.0	138.1	133.8		128.4	...	...
13Cr–8Ni–2Mo	Forgings	SA-564	XM-13	...	30	165	175	165.0	154.6	148.5	143.0	138.1	133.8		128.4	...	...
15Cr–5Ni–3Cu	Bar	SA-564	XM-12	H1025	...	145	155	145.0	136.0	130.7	125.8	121.7	117.2		112.9	...	...
15Cr–5Ni–3Cu	Forgings	SA-564	XM-12	H1025	...	145	155	145.0	136.0	130.7	125.8	121.7	117.2		112.9	...	...
15Cr–5Ni–3Cu	Bar	SA-564	XM-12	H1075	...	125	145	125.0	117.1	112.6	108.3	104.8	101.0		97.2	...	...
15Cr–5Ni–3Cu	Forgings	SA-564	XM-12	H1075	...	125	145	125.0	117.1	112.6	108.3	104.8	101.0		97.2	...	...
17Cr–4Ni–4Cu	Bar	SA-564	630	H1150	...	105	135	105.0	97.1	93.0	89.8	87.0	84.7		...	...	...
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1150	...	105	135	105.0	97.1	93.0	89.8	87.0	84.7		...	...	...
17Cr–4Ni–4Cu	Bar	SA-564	630	H1100	...	115	140	115.0	106.3	101.9	98.3	95.2	92.8		...	...	...
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1100	...	115	140	115.0	106.3	101.9	98.3	95.2	92.8		...	...	...
17Cr–4Ni–4Cu	Bar	SA-564	630	H1075	...	125	145	125.0	115.6	110.7	106.9	103.5	100.9		...	...	...
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1075	...	125	145	125.0	115.6	110.7	106.9	103.5	100.9		...	...	...
17Cr–4Ni–4Cu	Plate	SA-693	630	H1150	...	105	135	105.0	97.1	93.0	89.8	87.0	84.7		...	...	...
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1150	...	105	135	105.0	97.1	93.0	89.8	87.0	84.7		...	...	...
17Cr–4Ni–4Cu	Strip	SA-693	630	H1150	...	105	135	105.0	97.1	93.0	89.8	87.0	84.7		...	...	...
17Cr–4Ni–4Cu	Plate	SA-693	630	H1100	...	115	140	115.0	106.3	101.9	98.3	95.2	92.8		...	...	...
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1100	...	115	140	115.0	106.3	101.9	98.3	95.2	92.8		...	...	...
17Cr–4Ni–4Cu	Strip	SA-693	630	H1100	...	115	140	115.0	106.3	101.9	98.3	95.2	92.8		...	...	...
17Cr–4Ni–4Cu	Plate	SA-693	630	H1075	...	125	145	125.0	115.6	110.7	106.9	103.5	100.9		...	...	...
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1075	...	125	145	125.0	115.6	110.7	106.9	103.5	100.9		...	...	...
17Cr–4Ni–4Cu	Strip	SA-693	630	H1075	...	125	145	125.0	115.6	110.7	106.9	103.5	100.9		...	...	...
Stainless Steels																	
20Cr–6Ni–8Mn	Plate	SA-240	XM-17	...	...	50	90	50.0	...	...	...	...	...	...	...	...	...
20Cr–6Ni–8Mn	Sheet	SA-240	XM-17	...	...	60	100	60.0	...	...	...	...	...	...	...	...	...
20Cr–6Ni–8Mn	Strip	SA-240	XM-17	...	...	60	100	60.0	...	...	...	...	...	...	...	...	...

Table 3
Yield Strength Values, S_y, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 Obtain psi) for Metal Temperatures Not Exceeding, °F									
								100	200	300	400	500	600		700	750	800
18Cr–8Ni	Wire	A580-83	302	B	14	100	125	100.0	83.3	75.0	69.0	...	...	...	...	...	...
18Cr–8Ni	Wire	A580-83	304	B	14	100	125	100.0	83.3	75.0	69.0	...	...	...	...	...	...
16Cr–12Ni–2Mo	Wire	A580-83	316	B	14	100	125	100.0	83.3	75.0	69.0	...	...	...	...	...	...
18Cr–13Ni–3Mo	Wire	A580-83	317	B	14	100	125	100.0	83.3	75.0	69.0	...	...	...	...	...	...
18Cr–8Ni	Bar	A582-95b	303	...	18,23	30	75	30.0	25.0	22.5	20.7	19.4	18.2		17.7	17.3	16.0
18Cr–8Ni–Se	Bar	A582-95b	303Se	...	23	30	75	30.0	25.0	22.5	20.7	19.4	18.2		17.7	17.3	16.0
Copper and Copper Alloys																	
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	7	25	57	25.0	...	...	...	...	...	...	...	...	...
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	8	25	55	25.0	...	...	...	...	...	...	...	...	...
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	2	20	50	20.0	...	...	...	...	...	...	...	...	...
60Cu–38Zn–2Pb	Forgings	B124-99	C37700	M30	...	18	50	18.0	16.3	14.9	14.2	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C64200	...	...	25	70	25.0	21.0	20.2	...	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C61400	...	...	30	70	30.0	29.7	29.4	28.8	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C63000	...	11	42.5	85	42.5	41.7	40.4	39.5	...	...	...	...	...	...
Alum. Bronze	Plate	SB-169	C61400	...	...	28	65	28.0	27.7	27.4	26.9	...	...	...	...	...	...
Alum. Bronze	Castings	SB-271	C95400	...	...	30	75	30.0	27.9	27.9	27.9	...	...	...	...	...	...
80-10-10	Castings	SB-584	C93700	...	...	12	30	12.0	10.6	10.0	9.9	...	...	...	...	...	...
Copper and Nickel Alloys																	
50Ni–17Cr–Mo–Cb	Plate	B670-95	...	...	16	150	180	150.0	...	...	...	...	...	...	...	...	...
50Ni–17Cr–Mo–Cb	Sheet	B670-95	...	...	16	150	180	150.0	...	...	...	...	...	...	...	...	...

NOTE: *Notes follow Table 5.

Table 4
Yield Strength Values, S_y, for Bolting Materials for Classes 1, 2, 3, and MC Supports

Material	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 to Temperatures Not Exceeding							for Metal		
							100	200	300	400	500	600	650		750	800
						...										
						Carbon Steels										
C–Mn	SA-36	...	...	34	36	58	36.0	32.8	31.9	30.8	29.1	26.6	26.1		...	...
AISI 1045	A108-99	1045CW	...	...	100	120	100.0	91.2	88.4	85.6	...	...	...	...	...	...
AISI 1050	A108-99	1050CW	...	...	125	140	125.0	114.0	110.5	107.0	...	...	...	...	...	...
AISI 1141	A108-99	1141	...	37	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1144	A108-99	1144	...	38	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 12L14	A108-99	1214	...	37	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1144	A108-99	1144	...	37	105	125	105.0	95.8	92.8	89.8	...	...	...	...	...	...
...	SA-194	2H	...	36	...	...	...	...	...	...	...	...	...	...	...	...
...	SA-307	A	...	42,45	36	60	36.0	32.8	31.9	30.8	29.1	26.6	26.1		...	...
AISI 1035	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1040	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
AISI 1541	SA-325	1	...	1,51,52	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
...	SA-449	...	...	39,42,46,47	92	120	92.0	83.9	81.3	78.8	...	...	...	...	...	...
...	SA-449	...	...	40,42,46,47	81	105	81.0	73.9	71.6	69.3	...	...	...	...	...	...
...	SA-449	...	...	41,42,46,47	58	90	58.0	52.9	51.3	49.7	...	...	...	...	...	...
AISI 1035	SA-574	...	...	55	135	170	135.0	123.1	119.3	115.6	...	...	...	...	...	...
AISI 1040	SA-574	...	...	55	135	170	135.0	123.1	119.3	115.6	...	...	...	...	...	...
AISI 1541	SA-574	...	...	55	135	170	135.0	123.1	119.3	115.6	...	...	...	...	...	...
Low Alloy Steels																
AISI 4037	SA-320	L7A	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4137	SA-320	L7A	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4140	SA-320	L7A	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4037	SA-320	L7B	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4137	SA-320	L7B	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4140	SA-320	L7B	...	...	105	125	105.0	98.0	94.1	91.5	...	...	...	...	...	...
AISI 4137	A490-97	1	...	42,53,54	130	150	130.0	121.5	117.2	114.1	110.7	105.7	102.5		...	...
AISI 4140	A490-97	1	...	42,53,54	130	150	130.0	121.5	117.2	114.1	110.7	105.7	102.5		...	...
AISI 4142	A490-97	1	...	42,53,54	130	150	130.0	121.5	117.2	114.1	110.7	105.7	102.5		...	...
AISI 4145	A490-97	1	...	42,53,54	130	150	130.0	121.5	117.2	114.1	110.7	105.7	102.5		...	...
AISI 4340	A490-97	1	...	42,53,54	130	150	130.0	121.5	117.2	114.1	110.7	105.7	102.5		...	...
AISI 4037	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4042	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4137	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4140	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4145	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4340	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4137	SA-574	...	...	35,43,55	135	170	135.0	126.2	121.7	118.5	115.0	109.8	106.4		...	...
AISI 4037	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9	110.3		...	...

Table 4
Yield Strength Values, S_y, for Bolting Materials for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Ultimate Tensile Strength, ksi	Yield Strength, ksi (Multiply by 1000 psi) for Metal Temperatures Not Exceeding									
							100	200	300	400	500	600		700	750	800
AISI 4042	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9		106.4	...	...
AISI 4137	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9		106.4	...	...
AISI 4140	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9		106.4	...	...
AISI 4145	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9		106.4	...	...
AISI 4340	SA-574	...	...	7,35,55	140	180	140.0	130.8	126.2	122.9	119.2	113.9		106.4	...	...
Precipitation Hardened Steels																
26Ni–15Cr–2Ti	SA-453	660	A	31,55	85	130	85.0	82.5	81.0	81.0	81.0	81.0		81.0	81.0	81.0
13Cr–8Ni–2Mo	SA-564	XM-13	...	30,55	165	175	165.0	154.6	148.5	143.0	138.1	133.3		128.4	...	...
Austenitic Stainless Steels																
18Cr–8Ni–S	SA-320	B8F	1	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni–S	SA-320	B8FA	1A	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni–Se	SA-320	B8F	1	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...
18Cr–8Ni–Se	SA-320	B8FA	1A	...	30	75	30.0	25.0	22.5	20.7	...	...	...	...	...	...

NOTE: *Notes follow Table 5.

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
Carbon Steels																	
AISI 1015	Bar	A108-99	1015CW	...	...	40	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1018	Bar	A108-99	1018CW	...	...	40	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1020	Bar	A108-99	1020CW	...	...	40	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1045	Bar	A108-99	1045CW	...	...	100	120	120.0	120.0	120.0	120.0	...	...	...	...	...	...
AISI 1050	Bar	A108-99	1050CW	...	...	125	140	140.0	140.0	140.0	140.0	...	...	...	...	...	...
AISI 1117	Bar	A108-99	1117	...	...	60	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	...	100	115	115.0	115.0	115.0	115.0	...	...	...	...	...	...
AISI 12L14	Bar	A108-99	1214	...	...	55	65	65.0	65.0	65.0	65.0	...	...	...	...	...	...
...	Wire	A228-93	...	...	...	250	270	270.0	270.0	270.0	270.0	...	...	...	...	...	...
AISI 1015	Tube	A513-98	1015CW	...	...	55	65	65.0	65.0	65.0	65.0	...	...	...	...	...	...
AISI 1020	Tube	A513-98	1020CW	...	...	60	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
AISI 1025	Tube	A513-98	1025CW	...	...	65	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1026	Tube	A513-98	1026CW	...	...	70	80	80.0	80.0	80.0	80.0	...	...	...	...	...	...
AISI 1018	Tube	A519-96	1018CW	. .	...	60	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
AISI 1020	Tube	A519-96	1020CW	...	...	60	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
AISI 1022	Tube	A519-96	1022CW	...	...	60	70	70.0	70.0	70.0	70.0	...	...	...	...	...	...
AISI 1025	Tube	A519-96	1025CW	...	...	65	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1026	Tube	A519-96	1026CW	...	...	65	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1035	Forgings	A521-96	...	CG	...	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1040	Forgings	A521-96	...	CG	...	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1035	Forgings	A521-96	...	CG	...	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
AISI 1040	Forgings	A521-96	...	CG	...	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
AISI 1035	Forgings	A668-96e1	...	B	...	30	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 1035	Forgings	A668-96e1	...	C	...	33	66	66.0	66.0	66.0	66.0	...	...	...	...	...	...
AISI 1035	Forgings	A668-96e1	...	D	...	37.5	75	75.0	75.0	75.0	75.0	...	...	...	...	...	...
AISI 1035	Forgings	A668-96e1	...	F	...	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1040	Forgings	A668-96e1	...	F	...	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1045	Forgings	A668-96e1	...	F	...	50	85	85.0	85.0	85.0	85.0	...	...	...	...	...	...
AISI 1035	Forgings	A668-96e1	...	F	...	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
AISI 1040	Forgings	A668-96e1	...	F	...	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
AISI 1045	Forgings	A668-96e1	...	F	...	55	90	90.0	90.0	90.0	90.0	...	...	...	...	...	...
Low Alloy Steels																	
AISI 4130	Castings	A148-93b	105-85	...	...	85	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4140	Castings	A148-93b	105-85	...	...	85	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4320	Castings	A148-93b	105-85	...	...	85	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4340	Castings	A148-93b	105-85	...	...	85	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4130	Castings	A148-93b	115-95	...	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4140	Castings	A148-93b	115-95	...	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F								
								100	200	300	400	500	600	700	750	800
AISI 4320	Castings	A148-93b	115-95	...	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4340	Castings	A148-93b	115-95	...	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4130	Castings	A148-93b	135-125	...	...	125	135	135.0	135.0	135.0	135.0	135.0	135.0	135.0	...	...
AISI 4140	Castings	A148-93b	135-125	...	...	125	135	135.0	135.0	135.0	135.0	135.0	135.0	135.0	...	...
AISI 4320	Castings	A148-93b	135-125	...	...	125	135	135.0	135.0	135.0	135.0	135.0	135.0	135.0	...	...
AISI 4340	Castings	A148-93b	135-125	...	...	125	135	135.0	135.0	135.0	135.0	135.0	135.0	135.0	...	...
9Cr–1Mo	Castings	SA-217	C12	...	...	60	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4150	Bar	A322-91	4150	...	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4130	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4140	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4145	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4320	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4340	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 8260	Bar	A434-90a	...	BB	...	90	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4130	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4140	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4145	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4320	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4340	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 8260	Bar	A434-90a	...	BB	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4130	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4140	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4145	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4320	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4340	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 8260	Bar	A434-90a	...	BB	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	...	...
AISI 4130	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 4140	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 4145	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 4320	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 4340	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 8260	Bar	A434-90a	...	BB	...	75	95	95.0	95.0	95.0	95.0	95.0	95.0	95.0	...	...
AISI 4130	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4140	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4145	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4320	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4340	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 8260	Bar	A434-90a	...	BB	...	65	90	90.0	90.0	90.0	90.0	90.0	90.0	90.0	...	...
AISI 4130	Bar	A434-90a	...	BC	...	110	130	130.0	130.0	130.0	130.0	130.0	130.0	130.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F 100	200	300	400	500	600	700	750	800
AISI 4140	Bar	A434-90a	...	BC	...	110	130	130.0	130.0	130.0	130.0	130.0	130.0	130.0	...	...
AISI 4145	Bar	A434-90a	...	BC	...	110	130	130.0	130.0	130.0	130.0	130.0	130.0	130.0	...	...
AISI 4320	Bar	A434-90a	...	BC	...	110	130	130.0	130.0	130.0	130.0	130.0	130.0	130.0	...	...
AISI 4340	Bar	A434-90a	...	BC	...	110	130	130.0	130.0	130.0	130.0	130.0	130.0	130.0	...	...
AISI 4130	Bar	A434-90a	...	BC	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
AISI 4140	Bar	A434-90a	...	BC	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
AISI 4145	Bar	A434-90a	...	BC	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
AISI 4320	Bar	A434-90a	...	BC	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
AISI 4340	Bar	A434-90a	...	BC	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0	125.0	...	...
AISI 4130	Bar	A434-90a	...	BC	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4140	Bar	A434-90a	...	BC	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4145	Bar	A434-90a	...	BC	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4320	Bar	A434-90a	...	BC	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4340	Bar	A434-90a	...	BC	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0	115.0	...	...
AISI 4130	Bar	A434-90a	...	BC	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4140	Bar	A434-90a	...	BC	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4145	Bar	A434-90a	...	BC	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4320	Bar	A434-90a	...	BC	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4340	Bar	A434-90a	...	BC	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0	110.0	...	...
AISI 4130	Bar	A434-90a	...	BC	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4140	Bar	A434-90a	...	BC	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4145	Bar	A434-90a	...	BC	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4320	Bar	A434-90a	...	BC	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4340	Bar	A434-90a	...	BC	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0	105.0	...	...
AISI 4130	Bar	A434-90a	...	BD	...	130	155	155.0	155.0	155.0	155.0	155.0	155.0	155.0	...	...
AISI 4140	Bar	A434-90a	...	BD	...	130	155	155.0	155.0	155.0	155.0	155.0	155.0	155.0	...	...
AISI 4145	Bar	A434-90a	...	BD	...	130	155	155.0	155.0	155.0	155.0	155.0	155.0	155.0	...	...
AISI 4320	Bar	A434-90a	...	BD	...	130	155	155.0	155.0	155.0	155.0	155.0	155.0	155.0	...	...
AISI 4340	Bar	A434-90a	...	BD	...	130	155	155.0	155.0	155.0	155.0	155.0	155.0	155.0	...	...
AISI 4130	Bar	A434-90a	...	BD	...	120	150	150.0	150.0	150.0	150.0	150.0	150.0	150.0	...	...
AISI 4140	Bar	A434-90a	...	BD	...	120	150	150.0	150.0	150.0	150.0	150.0	150.0	150.0	...	...
AISI 4145	Bar	A434-90a	...	BD	...	120	150	150.0	150.0	150.0	150.0	150.0	150.0	150.0	...	...
AISI 4320	Bar	A434-90a	...	BD	...	120	150	150.0	150.0	150.0	150.0	150.0	150.0	150.0	...	...
AISI 4340	Bar	A434-90a	...	BD	...	120	150	150.0	150.0	150.0	150.0	150.0	150.0	150.0	...	...
AISI 4130	Bar	A434-90a	...	BD	...	110	140	140.0	140.0	140.0	140.0	140.0	140.0	140.0	...	...
AISI 4140	Bar	A434-90a	...	BD	...	110	140	140.0	140.0	140.0	140.0	140.0	140.0	140.0	...	...
AISI 4145	Bar	A434-90a	...	BD	...	110	140	140.0	140.0	140.0	140.0	140.0	140.0	140.0	...	...
AISI 4320	Bar	A434-90a	...	BD	...	110	140	140.0	140.0	140.0	140.0	140.0	140.0	140.0	...	...
AISI 4340	Bar	A434-90a	...	BD	...	110	140	140.0	140.0	140.0	140.0	140.0	140.0	140.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
AISI 4130	Bar	A434-90a	...	BD	...	105	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4140	Bar	A434-90a	...	BD	...	105	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4145	Bar	A434-90a	...	BD	...	105	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4320	Bar	A434-90a	...	BD	...	105	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4340	Bar	A434-90a	...	BD	...	105	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4130	Bar	A434-90a	...	BD	...	100	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	...	...
AISI 4140	Bar	A434-90a	...	BD	...	100	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	...	...
AISI 4145	Bar	A434-90a	...	BD	...	100	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	...	...
AISI 4320	Bar	A434-90a	...	BD	...	100	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	...	...
AISI 4340	Bar	A434-90a	...	BD	...	100	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	2	...	90	105	105.0	105.0	105.0	104.0	103.3	101.9		98.8	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	3	...	100	110	110.0	110.0	110.0	108.9	108.1	106.7		103.5	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	4	...	110	120	120.0	120.0	120.0	118.8	118.0	116.4		112.9	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	5	...	120	130	130.0	130.0	130.0	128.7	127.8	126.1		122.3	...	...
3Ni–Cr–Mo–V	Forgings	A471-94	...	6	...	130	140	140.0	140.0	140.0	138.5	137.7	135.8		131.7	...	...
AISI 4140	Tube	A519-96	4140SR	...	...	100	120	120.0	120.0	120.0	120.0	...	...	...	...	...	...
AISI 4142	Tube	A519-96	4142SR	...	...	100	120	120.0	120.0	120.0	120.0	...	...	...	...	...	...
5Ni–Cr–Mo–V	Forgings	A579-99	12a	...	...	140	150	150.0	148.5	144.0	141.0	141.0	141.0		132.0	...	...
AISI 4140	Forgings	A668-96e1	...	K	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0		100.0	...	...
AISI 4340	Forgings	A668-96e1	...	K	...	75	100	100.0	100.0	100.0	100.0	100.0	100.0		100.0	...	...
AISI 4140	Forgings	A668-96e1	...	K	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4340	Forgings	A668-96e1	...	K	...	80	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
AISI 4135	Forgings	A668-96e1	...	L	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0		110.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0		110.0	...	...
AISI 4340	Forgings	A668-96e1	...	L	...	85	110	110.0	110.0	110.0	110.0	110.0	110.0		110.0	...	...
AISI 4135	Forgings	A668-96e1	...	L	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Forgings	A668-96e1	...	L	...	95	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4135	Forgings	A668-96e1	...	L	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4140	Forgings	A668-96e1	...	L	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4340	Forgings	A668-96e1	...	L	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4140	Forgings	A668-96e1	...	M	...	110	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4340	Forgings	A668-96e1	...	M	...	110	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4135	Forgings	A668-96e1	...	M	44	110	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4330	Forgings	A668-96e1	...	M	44	110	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4140	Forgings	A668-96e1	...	M	...	115	140	140.0	140.0	140.0	140.0	140.0	140.0		140.0	...	...
AISI 4340	Forgings	A668-96e1	...	M	...	115	140	140.0	140.0	140.0	140.0	140.0	140.0		140.0	...	...
AISI 4135	Forgings	A668-96e1	...	M	44	115	140	140.0	140.0	140.0	140.0	140.0	140.0		140.0	...	...
AISI 4330	Forgings	A668-96e1	...	M	44	115	140	140.0	140.0	140.0	140.0	140.0	140.0		140.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
AISI 4140	Forgings	A668-96e1	...	M	...	120	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4340	Forgings	A668-96e1	...	M	...	120	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4135	Forgings	A668-96e1	...	M	44	120	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4330	Forgings	A668-96e1	...	M	44	120	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4340	Forgings	A668-96e1	...	N	...	130	160	160.0	160.0	160.0	160.0	160.0	160.0		160.0	...	...
AISI 4340	Forgings	A668-96e1	...	N	...	135	165	165.0	165.0	165.0	165.0	165.0	165.0		165.0	...	...
AISI 4340	Forgings	A668-96e1	...	N	...	140	170	170.0	1707-0	105.0	170.0	170.0	170.0		170.0	...	...
Stainless Steels																	
20Cr–6Ni–8Mn–Mo	Plate	SA-240	XM-17	...	...	50	90	90.0	...	...	...	...	...	...	...	...	...
20Cr–6Ni–8Mn–Mo	Sheet	SA-240	XM-17	...	...	60	100	100.0	...	...	...	...	...	...	...	...	...
20Cr–6Ni–8Mn–Mo	Strip	SA-240	XM-17	...	...	60	100	100.0	...	...	...	...	...	...	...	...	...
18Cr–8Ni	Wire	A580-98	302	B	...	100	125	125.0	118.3	110.0	103.7	...	...	...	...	...	...
18Cr–8Ni	Wire	A580-98	304	B	...	100	125	125.0	118.3	110.0	103.7	...	...	...	...	...	...
16Cr–12Ni–2Mo	Wire	A580-98	316	B	...	100	125	125.0	118.3	110.0	103.7	...	...	...	...	...	...
18Cr–13Ni–3Mo	Wire	A580-98	317	B	...	100	125	125.0	118.3	110.0	103.7	...	...	...	...	...	...
18Cr–8Ni	Bar	A582-95b	303	...	...	30	75	75.0	71.0	66.0	64.4	63.5	63.5		63.5	63.1	62.7
18Cr–8Ni–Se	Bar	A582-95b	303Se	...	...	30	75	75.0	71.0	66.0	64.4	63.5	63.5		63.5	63.1	62.7
High Alloy Steels																	
Martensitic Stainless Steels																	
17Cr	Bar	A276-98b	440C	...	56	210	275	275.0	275.0	275.0	274.2	269.2	261.2		...	...	...
17Cr	Bar	A276-98b	440C	...	56	275	285	285.0	...	...	...	...	...	...	...	...	...
13Cr	Bar	A276-98b	420	...	58	65	95	95.0	95.0	95.0	94.7	...	...	...	...	...	...
13Cr	Bar	A582-95b	416	...	...	40	70	70.0	...	...	...	...	...	...	...	...	...
13Cr–Se	Bar	A582-95b	416Se	...	...	40	70	70.0	...	...	...	...	...	...	...	...	...
Precipitation Hardened Steels																	
26Ni–15Cr–2Ti	Bar	SA-453	660	A	...	85	130	130.0	130.0	130.0	130.0	130.0	130.0		130.0	130.0	128.0
13Cr–8Ni–2Mo	Bar	SA-564	XM-13	...	...	165	175	175.0	175.0	175.0	174.8	169.4	164.6		156.9	...	...
13Cr–8Ni–2Mo	Forgings	SA-564	XM-13	...	...	165	175	175.0	175.0	175.0	174.8	169.4	164.6		156.9	...	...
15Cr–5Ni–3Cu	Bar	SA-564	XM-12	H1025	...	145	155	155.0	155.0	155.0	155.0	145.4	141.5		136.7	...	...
15Cr–5Ni–3Cu	Forgings	SA-564	XM-12	H1025	...	145	155	155.0	155.0	155.0	155.0	145.4	141.5		136.7	...	...
15Cr–5Ni–3Cu	Bar	SA-564	XM-12	H1075	...	125	145	145.0	145.0	145.0	140.4	136.1	132.4		127.9	...	...
15Cr–5Ni–3Cu	Forgings	SA-564	XM-12	H1075	...	125	145	145.0	145.0	145.0	140.4	136.1	132.4		127.9	...	...
17Cr–4Ni–4Cu	Bar	SA-564	630	H1150	...	105	135	135.0	135.0	135.0	131.4	128.5	126.7		124.4	120.8	118.1
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1150	...	105	135	135.0	135.0	135.0	131.4	128.5	126.7		124.4	120.8	118.1
17Cr–4Ni–4Cu	Bar	SA-564	630	H1100	...	115	140	140.0	140.0	140.0	136.3	133.2	131.4		129.1	126.3	122.4
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1100	...	115	140	140.0	140.0	140.0	136.3	133.2	131.4		129.1	126.3	122.4
17Cr–4Ni–4Cu	Bar	SA-564	630	H1075	...	125	145	145.0	145.0	145.0	141.1	138.0	136.1		133.7	130.8	126.8
17Cr–4Ni–4Cu	Forgings	SA-564	630	H1075	...	125	145	145.0	145.0	145.0	141.1	138.0	136.1		133.7	130.8	126.8

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F 100	200	300	400	500	600		700	750	800
17Cr–4Ni–4Cu	Plate	SA-693	630	H1150	...	105	135	135.0	135.0	135.0	131.4	128.5	126.7		124.4	120.8	118.1
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1150	...	105	135	135.0	135.0	135.0	131.4	128.5	126.7		124.4	120.8	118.1
17Cr–4Ni–4Cu	Strip	SA-693	630	H1150	...	105	135	135.0	135.0	135.0	131.4	128.5	126.7		124.4	120.8	118.1
17Cr–4Ni–4Cu	Plate	SA-693	630	H1100	...	115	140	140.0	140.0	140.0	136.3	133.2	131.4		129.1	126.3	122.4
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1100	...	115	140	140.0	140.0	140.0	136.3	133.2	131.4		129.1	126.3	122.4
17Cr–4Ni–4Cu	Strip	SA-693	630	H1100	...	115	140	140.0	140.0	140.0	136.3	133.2	131.4		129.1	126.3	122.4
17Cr–4Ni–4Cu	Plate	SA-693	630	H1075	...	125	145	145.0	145.0	145.0	141.1	138.0	136.1		133.7	130.8	126.8
17Cr–4Ni–4Cu	Sheet	SA-693	630	H1075	...	125	145	145.0	145.0	145.0	141.1	138.0	136.1		133.7	130.8	126.8
17Cr–4Ni–4Cu	Strip	SA-693	630	H1075	...	125	145	145.0	145.0	145.0	141.1	138.0	136.1		133.7	130.8	126.8
Nickel Alloys	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
50Ni–17Cr–Mo–Cb	Plate	B670-95	...	...	...	150	180	180.0	...	...	...	...	...	...	...	...	...
50Ni–17Cr–Mo–Cb	Sheet	B670-95	...	...	...	150	180	180.0	...	...	...	...	...	...	...	...	...
Bolting Materials																	
C–Mn	Bar	SA-36	...	...	...	36	58	58.0	58.0	58.0	58.0	...	...	...	...	...	...
AISI 1045	Bar	A108-99	1045CW	...	...	100	120	120.0	120.0	120.0	120.0	...	...	...	...	...	...
AISI 1050	Bar	A108-99	1050CW	...	...	125	140	140.0	140.0	140.0	140.0	...	...	...	...	...	...
AISI 1141	Bar	A108-99	1141	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 12L14	Bar	A108-99	1214	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 1144	Bar	A108-99	1144	...	...	105	125	125.0	125.0	125.0	125.0	...	...	...	...	...	...
...	Bar	SA-194	2H	...	...	...	...	105.0	105.0	105.0	105.0	...	...	...	...	...	...
...	Bar	SA-307	A	...	...	36	60	60.0	60.0	60.0	60.0	...	...	...	...	...	...
AISI 4037	Bar	SA-320	L7A	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4037	Bolt	SA-320	L7A	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4137	Bar	SA-320	L7B	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4137	Bolt	SA-320	L7B	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4140	Bar	SA-320	L7	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4140	Bolt	SA-320	L7	...	...	105	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
18Cr–8Ni–S	Bar	SA-320	B8F	1	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–S	Bolt	SA-320	B8F	1	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–S	Bar	SA-320	B8FA	1A	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–S	Bolt	SA-320	B8FA	1A	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–Se	Bar	SA-320	B8F	1	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–Se	Bolt	SA-320	B8F	1	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–Se	Bar	SA-320	B8FA	1A	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
18Cr–8Ni–Se	Bolt	SA-320	B8FA	1A	...	30	75	75.0	70.0	66.0	64.0	...	...	...	...	...	...
...	Bar	SA-325	...	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 1038	Bar	SA-325	1	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 1038	Bolt	SA-325	1	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
AISI 1541	Bar	SA-325	1	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 1541	Bolt	SA-325	1	...	...	81	105	105.0	105.0	105.0	105.0	...	...	...	...	...	...
AISI 4037	Bar	SA-354	BC	...	49,50	109	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4037	Bolt	SA-354	BC	...	49,50	109	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4340	Bar	SA-354	BC	...	49,50	109	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4340	Bolt	SA-354	BC	...	49,50	109	125	125.0	125.0	125.0	125.0	125.0	125.0		125.0	...	...
AISI 4037	Bar	SA-354	BC	...	49,50	99	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4037	Bolt	SA-354	BC	...	49,50	99	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bar	SA-354	BC	...	49,50	99	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bolt	SA-354	BC	...	49,50	99	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
...	Bar	SA-354	BD	...	48	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
...	Bolt	SA-354	BD	...	48	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
...	Bar	SA-354	BD	...	48	115	140	140.0	144.0	140.0	140.0	140.0	140.0		140.0	...	...
...	Bolt	SA-354	BD	...	48	115	140	140.0	140.0	140.0	140.0	140.0	140.0		140.0	...	...
...	Bar	SA-449	...	...	...	92	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
...	Bar	SA-449	...	...	...	81	105	105.0	105.0	105.0	105.0	105.0	105.0		105.0	...	...
...	Bar	SA-449	...	...	...	58	90	90.0	90.0	90.0	90.0	90.0	90.0		90.0	...	...
AISI 4137	Bar	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4137	Bolt	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4140	Bar	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4140	Bolt	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4142	Bar	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4142	Bolt	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4145	Bar	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4145	Bolt	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4340	Bar	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4340	Bolt	A490-97	1	...	...	130	150	150.0	150.0	150.0	150.0	150.0	150.0		150.0	...	...
AISI 4340	Bar	SA-540	B21,B22	1	...	150	165	165.0	165.0	165.0	165.0	165.0	165.0		165.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	1	...	150	165	165.0	165.0	165.0	165.0	165.0	165.0		165.0	...	...
AISI 4340	Bar	SA-540	B23,B24	1	...	150	165	165.0	165.0	165.0	165.0	165.0	165.0		165.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	1	...	150	165	165.0	165.0	165.0	165.0	165.0	165.0		165.0	...	...
AISI 4340	Bar	SA-540	B21,B22	2	...	140	155	155.0	155.0	155.0	155.0	155.0	155.0		155.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	2	...	140	155	155.0	155.0	155.0	155.0	155.0	155.0		155.0	...	...
AISI 4340	Bar	SA-540	B23,B24	2	...	140	155	155.0	155.0	155.0	155.0	155.0	155.0		155.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	2	...	140	155	155.0	155.0	155.0	155.0	155.0	155.0		155.0	...	...
AISI 4340	Bar	SA-540	B21,B22	3	...	130	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	3	...	130	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4340	Bar	SA-540	B23,B24	3	...	130	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	3	...	130	145	145.0	145.0	145.0	145.0	145.0	145.0		145.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
AISI 4340	Bar	SA-540	B21,B22	4	...	120	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	4	...	120	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4340	Bar	SA-540	B23,B24	4	...	120	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	4	...	120	135	135.0	135.0	135.0	135.0	135.0	135.0		135.0	...	...
AISI 4320	Bar	SA-540	B21,B22	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4320	Bolt	SA-540	B21,B22	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bar	SA-540	B21,B22	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4320	Bar	SA-540	B23,B24	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4320	Bolt	SA-540	B23,B24	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bar	SA-540	B23,B24	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	5	...	100	115	115.0	115.0	115.0	115.0	115.0	115.0		115.0	...	...
AISI 4320	Bar	SA-540	B21,B22	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4320	Bolt	SA-540	B21,B22	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4340	Bar	SA-540	B21,B22	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4340	Bolt	SA-540	B21,B22	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4320	Bar	SA-540	B23,B24	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4320	Bolt	SA-540	B23,B24	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4340	Bar	SA-540	B23,B24	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 4340	Bolt	SA-540	B23,B24	5	...	105	120	120.0	120.0	120.0	120.0	120.0	120.0		120.0	...	...
AISI 1035	Bar	SA-574	...	...	...	135	170	170.0	170.0	170.0	170.0	...	...	...	...	...	...
AISI 1040	Bar	SA-574	...	...	...	135	170	170.0	170.0	170.0	170.0	...	...	...	...	...	...
AISI 1541	Bar	SA-574	...	...	...	135	170	170.0	170.0	170.0	170.0	...	...	...	...	...	...
AISI 1035	Bar	SA-574	...	...	...	140	180	180.0	180.0	180.0	180.0	...	...	...	...	...	...
AISI 1040	Bar	SA-574	...	...	...	140	180	180.0	180.0	180.0	180.0	...	...	...	...	...	...
AISI 1541	Bar	SA-574	...	...	...	140	180	180.0	180.0	180.0	180.0	...	...	...	...	...	...
AISI 4037	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4037	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4042	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4042	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4137	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4137	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4140	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4140	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4145	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4145	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4340	Bar	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4340	Bolt	SA-574	...	...	43	135	170	170.0	170.0	170.0	170.0	170.0	170.0		170.0	...	...
AISI 4037	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

Material	Product Form	Spec. No.	Type or Grade	Class	Notes*	Min. Yield Strength, ksi	Min. Ultimate Tensile Strength, ksi	Ultimate Tensile Stress Values, ksi (Multiply 1000 to Obtain psi) for Metal Temperatures Exceeding °F									
								100	200	300	400	500	600		700	750	800
AISI 4037	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4042	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4042	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4137	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4137	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4140	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4140	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4145	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4145	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4340	Bar	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
AISI 4340	Bolt	SA-574	...	...	7	140	180	180.0	180.0	180.0	180.0	180.0	180.0		180.0	...	...
Copper and Copper Alloys																	
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	...	25	57	57.0	...	...	...	...	...	...	...	...	...
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	...	25	55	55.0	...	...	...	...	...	...	...	...	...
62Cu–35Zn–3Pb	Bar	B16-92	C36000	H02	...	20	50	50.0	...	...	...	...	...	...	...	...	...
62Cu–35Zn–2Pb	Forgings	B124-99	C37700	M30	...	18	50	50.0	45.5	40.0	34.0	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C64200	...	...	25	70	70.0	70.0	70.0	...	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C61400	...	...	30	70	70.0	68.6	66.5	62.3	...	...	...	...	...	...
Alum. Bronze	Bar	SB-150	C63000	...	11	42.5	85	85.0	84.1	82.5	81.6	...	...	...	...	...	...
Alum. Bronze	Plate	SB-169	C61400	...	...	28	65	65.0	63.7	61.8	57.9	...	...	...	...	...	...
Alum. Bronze	Castings	SB-271	C95400	...	...	30	75	75.0	70.5	67.5	64.5	...	...	...	...	...	...
80-10-10	Castings	SB-584	C93700	...	...	12	30	30.0	26.8	24.8	24.5	...	...	...	...	...	...

NOTES:
(1) This material may be made from ASTM A546-82.
(2) Over 1 in. to 2 in. incl.
(3) These materials are limited for use only for component standard supports.
(4) Max. BHN 215.
(5) Max. BHN 225.
(6) For each forging 250 lb net weight and less, the marking requirements of A668 shall be met by a suitable code or symbol identified by the Manufacturer in his Certificate of Compliance or Certified Material Test Report. The hardness test requirement may be performed only on the tensile test specimen.
(7) $^1/_2$ in. and under.
(8) Over $^1/_2$ in. to 1 in. incl.
(9) By agreement between Purchaser and Material Manufacturer, these materials may be procured to the lower specified minimum ultimate tensile gth and minimum yield strength values given in this Table.
(10) **DELETED**
(11) 4 in. and under.
(12) Over 4 in. to 7 in. incl.
(13) Over 7 in. to 10 in. incl.
(14) This material may be used only in fully constrained applications, such as thread inserts, so that failure of the wire would not affect the function component support.

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

NOTES (CONT'D):

(15) Solution heat-treated and hardened (1325°F for 8 hr, furnace cooled to 1150°F, held to a total of 18 hr, air cooled).
(16) Half hard.
(17) Hot rolled.
(18) Hot finished, heat treated.
(19) E4340H may be used with the molybdenum range increased by agreement to 0.40% max.
(20) The minimum specified yield strength shall be taken at 0.2% offset.
(21) This material may be used only in fully constrained applications such as valve disk or flow restrictor balls or mechanical snubber parts such that failure of these parts does not significantly affect the function of the item. Design stresses are limited to 0.4 S_y.
(22) For bar sizes under $^1/_2$ in. nominal size, this material may be ordered to A581-80.
(23) $1^1/_2$ in. and under.
(24) Over $1^1/_2$ in. to $2^1/_2$ in. incl.
(25) Over $2^1/_2$ in. to 4 in. incl.
(26) Over 7 in. to $9^1/_2$ in. incl.
(27) Austenitize 1850°F to 1950°F, oil quench, temper at 700°F min.
(28) Austenitize 1850°F to 1950°F, oil quench, temper at 600°F min.
(29) A564 Type XM-13 shall be modified so that age-hardening treatment shall be 1050°F only.
(30) For gages less than $^1/_4$ in. in diameter, wire to AMS 5737 may be supplied, with or without heads. These values also apply to material that solution treated in a vacuum at 1650°F for 30 min and oil quenched and aged at 1325°F for $^1/_2$ to $1^1/_2$ hr and air cooled.
(31) The Elongation and Reduction of Area requirements for Grade 105-85 may be specified as 14% and 30%, respectively.
(32) The Elongation and Reduction of Area requirements for Grade 115-95 may be specified as 11% and 25%, respectively.
(33) Threaded rods only.
(34) Minimum tempering temperature shall be 850°F.
(35) No yield or tensile strength specified. Assume to be the same as SA-325 Type 1 bolts for nut design calculations.
(36) 3 in. maximum diameter, cold drawn and tempered.
(37) 10 in. maximum diameter.
(38) $^1/_4$ in. to 1 in. incl.
(39) Over 1 in. to $1^1/_2$ in. incl.
(40) Over $1^1/_2$ in. to 3 in. incl.
(41) Nuts may be as listed in SA-563, Table XI.
(42) Over $^1/_2$ in.
(43) There is no standard AISI composition 4330. By agreement with the material manufacturer, the carbon content of AISI 4340 can be ordered 0.27% to 0.33%, the molybdenum as 0.40% to 0.60%, the vanadium as 0.04% to 0.10%, and the silicon to 0.35% max.
(44) Use SA-563 nongalvanized or galvanized heavy hex Grades A, B, C, D, and DH. Same allowable stresses as bolts.
(45) Use SA-563 nongalvanized heavy hex Grades B, C, C3, D, DH, and DH3. Same allowable stresses as bolts.
(46) Use SA-563 galvanized heavy hex Grades C, D, and DH. Same allowable stresses as bolts.
(47) Use SA-563 nongalvanized heavy hex Grades DH and DH3. Same allowable stresses as bolts.
(48) Use SA-563 nongalvanized Grades C, C3, D, DH, and DH3. Same allowable stresses as bolts.
(49) Use SA-563 galvanized grade DH. Same allowable stress as bolts.
(50) Use SA-563 nongalvanized $^1/_2$ in. to $1^1/_2$ in. Grades C, C3, D, DH, and DH3. Same allowable stresses as bolts.
(51) Use SA-563 galvanized $^1/_2$ in. to $1^1/_2$ in. Grade DH. Same allowable stress as bolts.
(52) Use SA-563 nongalvanized $^1/_2$ in. to $1^1/_2$ in. Grades DH and DH3. Same allowable stresses as bolts.
(53) Use SA-563 nongalvanized $^1/_2$ in. to $1^1/_2$ in. Grade DH3. Same allowable stress as bolts.

Table 5
Ultimate Tensile Stress Values, S_u, for Classes 1, 2, 3, and MC Supports (Cont'd)

NOTES (CONT'D):

(54) Specifications for compatible nuts are provided in SA-193 and SA-320. Nuts may also be fabricated from the same material specification as the and threaded rods, and the same stress values may be used.

(55) For compressive applications, tensile testing is not required and each size from a lot shall be accepted on the basis of hardness testing of three Each test specimen shall meet R_c53 min. in the final heat treated condition.

(56) Use SA-563 nongalvanized heavy hex Grades A, B, C, C3, D, DH, and DH3. Same allowable stresses as bolts.

(57) Austenitize at 1800°F minimum, rapid cool by forced air or oil, temper at 1300°F minimum.

(58) The allowable stress values are based on the revised criterion of tensile strength divided by 3.5, where applicable.

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Approval Date: July 30, 1986
(ACI) Approval Date: March 17, 1978

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-258-2
Design of Interaction Zones for Concrete Containments Section III, Division 2

Inquiry: What rules apply for the design of an interaction zone between a steel shell portion of a containment and the Section III, Division 2 concrete?

Reply: It is the opinion of the Committee that for Section III, Division 2 containments, the interaction zone may be designed using the following rules.

(a) The interaction zone is that portion of the concrete containment where concrete is used in conjunction with the steel shell for load resisting purposes.

(b) The steel shell portion of the interaction zone shall meet the requirements of Section III, Divison 1, except structural acceptance testing shall be in accordance with (f).

(c) The concrete containment in the interaction zone shall meet the requirements of Section III, Division 2.

(d) The design and analysis of the interaction zone shall be made considering the interaction of the steel shell and the concrete. In the interaction analysis and design, anchorage shall be provided. Between anchor points, full bonding and absence of bonding between the Division 1 shell and the Division 2 concrete shall be considered. Justification shall be provided that intermediate bonding is not a limiting case.

(e) Joints in that portion of the steel shell backed by concrete shall have been tested for leak tightness using a gas medium test prior to being covered by concrete and as described in CC-5536.1. Welds shall be inspected and tested prior to embedment in accordance with NE-5250, except that NE-5250(a) does not apply.

(f) The following rules shall apply for structural acceptance testing.

(1) Test pressure shall be in accordance with NE-6320, but not less than 1.15 P_a. Test temperature shall be in accordance with NE-6312.

(2) Test pressure shall be applied in accordance with CC-6211 for measurements or observations of the concrete portions of the shell. In addition, after 50% of test pressure has been reached, extra pressure increments (approximately halfway between the measurement plateaus) shall be taken to pressurize the steel portion of the shell in accordance with NE-6313.

(3) Examination of the steel shell in accordance with NE-6324 shall be performed.

(4) Deflection measurement requirements of CC-6232 will be satisfied by radial deflection measurements taken within the top 5 ft of the interaction zone on four azimuths.

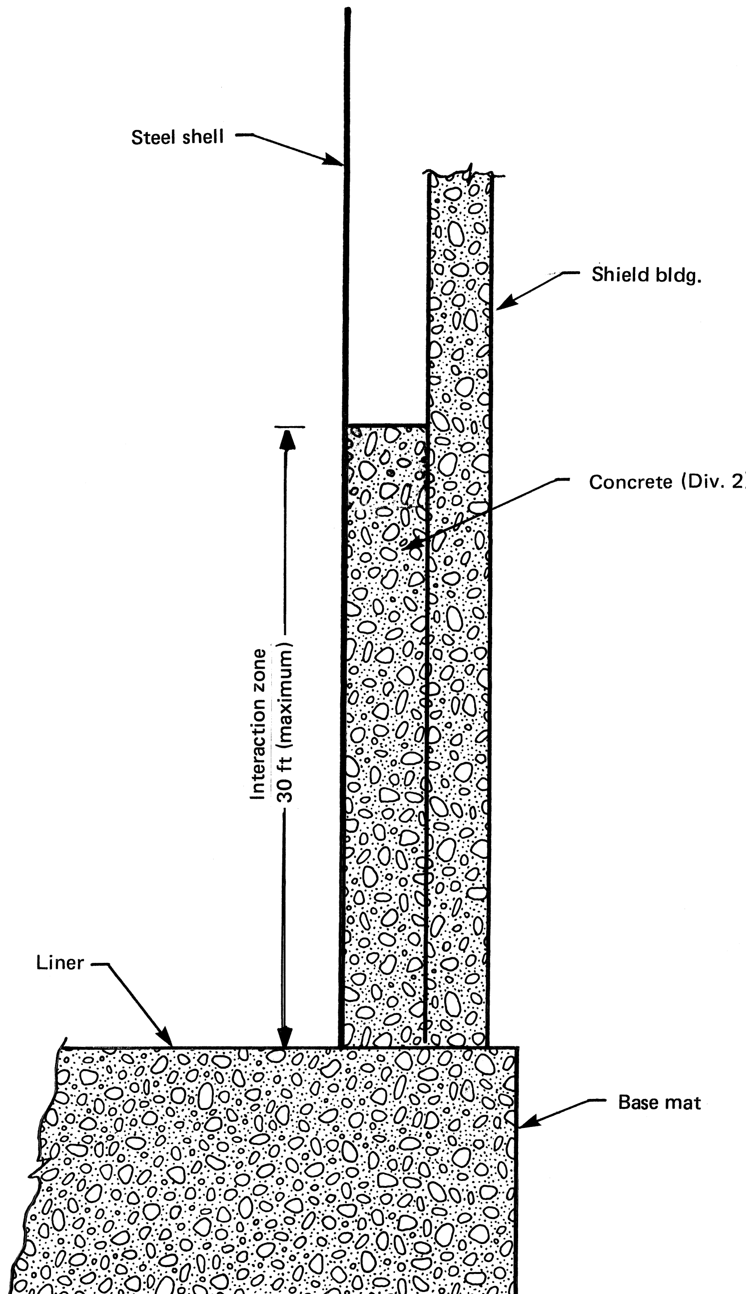
(5) Crack inspection requirements of CC-6233 do not apply.

(6) The requirements of CC-6213(c) do not apply.

(7) All other requirements of CC-6000 shall apply for the concrete portion of the shell.

See Figure 1 on the next page for limitation of the interaction zone.

Figure 1
Limitation of the Interaction Zone



Approval Date: October 8, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-284-4
Metal Containment Shell Buckling Design Methods, Class MC, TC, and SC Construction
Section III, Division 1; Section III, Division 3

Inquiry: Are there alternatives to the requirements of NE-3222, WB-3133, or WC-3133 for determining allowable compressive stresses for Section III, Division 1, Class MC construction and Section III, Division 3, Class TC and SC construction?

Reply: It is the opinion of the Committee that, for Section III, Division 1, Class MC construction and Section III, Division 3, Class TC and SC construction, the provisions of this Case, as follow, may be used as an alternative to the requirements of NE-3222, WB-3133, or WC-3133.

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-1000 METAL CONTAINMENT SHELL BUCKLING DESIGN METHODS

-1100 INTRODUCTION

-1110 Scope

The design of a class MC, TC or SC containment vessel against buckling shall be based on the requirements of Subsections NE, WB, or WC of the Code. NE-3133, WB-3133, or WC-3133 provides specific design rules for unstiffened or ring stiffened cylindrical shells, spherical shells and formed heads under external pressure and unstiffened cylinders under axial compression. NE-3222 provides general guidelines for other shell geometries and loading conditions for Class MC construction. The purpose of this Case is to provide stability criteria for determining the structural adequacy against buckling of containment shells with more complex shell geometries and loading conditions than those covered by NE-3133, WB-3133, or WC-3133. Such effects as symmetrical or unsymmetrical dynamic loading conditions, circumferential and/or meridional stiffening for heads as well as cylindrical shells, combined stress fields, discontinuity stresses and secondary stresses are considered in the stability evaluation.

Acceptable stress analysis procedures and methods for determining stress components to be used in the stability evaluation are given. The buckling capacity of the shell is based on linear bifurcation (classical) analyses reduced by capacity reduction factors which account for the effects of imperfections and nonlinearity in geometry and boundary conditions and by plasticity reduction factors which account for nonlinearity in material properties.

-1111 Limitations. The procedures of -1710 and -1720 assume an axisymmetric structure. All containment vessels have penetrations which are nonaxisymmetric with respect to the containment vessel. Studies and experience have shown that penetrations which are fully reinforced according to the Code rules, and which have an inside diameter that is small compared to the vessel diameter, will not reduce the buckling strength of the overall structure. Paragraphs -1710 and -1720 may be used without special consideration of properly reinforced penetrations that have an inside diameter not greater than 10% of the vessel diameter. The effect of larger penetrations shall be considered in the Design Report.

The rules of this Case are applicable to shells with radius-to-thickness ratios of up to 1000 and shell thickness of $^1/_4$ in. or greater. Any vessel design using less conservative procedures or involving cases not covered by this Case shall be justified in the Design Report.

-1120 Basic Buckling Design Values

The basic allowable buckling stress values permitted by the Code are specified in NE-3131(b), NE-3133 and NE-3222 for Class MC construction and are specified in WB-3133 or WC-3133 for Class TC or SC construction.

The basic Code buckling rules as well as the rules of this Code Case are based on the fabrication requirements of NE-4222, WB-4222, or WC-4222.

The methods of buckling evaluation are given in -1700. The buckling evaluation is made by either of two methods. The first method is contained in -1710 and utilizes formulae and interaction equations which must be satisfied. The alternate method involves checking the adequacy against buckling as computed by computer codes in accordance with -1720 or -1730. The procedures for these methods are outlined below and summarized in -1800.

For both methods the following items are calculated: (1) a set of stress components, σ_i, from applied loads are computed in accordance with -1300, (2) a factor of safety, FS, is determined from -1400, (3) capacity reduction factors, α_{ij}, are computed from -1500, and (4) plasticity reduction factors, η_i, are obtained from -1600.

When using the formulae in -1710, theoretical elastic buckling stresses for special loading cases ($\sigma_{\phi ej}$, σ_{rej}, $\sigma_{\phi\theta ej}$, and σ_{hej}) are computed from -1712. The corresponding allowable stresses for elastic and inelastic buckling (e.g., $\sigma_{xa} = \alpha_{\phi j}\ \sigma_{\phi j}/FS$, and $\sigma_{xc} = \eta_\phi\ \sigma_{xa}$) are then computed in -1713. The interaction equations of -1713 are then used to determine the adequacy of design for other than the special loading cases.

When the buckling evaluation is by computer codes per -1720 and -1730, sets of amplified stress components $\sigma_{is} = \sigma_i FS/\alpha_{ij}$ and $\sigma_{ip} = \sigma_{is}/\eta_i$ are calculated and compared with the linear bifurcation predictions of the computer codes.

-1200 NOMENCLATURE

A_i = cross-sectional area of stiffener (no effective shell included), sq in. $i = \phi$ for meridional (longitudinal or stringer) stiffeners, $i = \theta$ for circumferential (ring) stiffeners

C_i = elastic buckling coefficients

$= \dfrac{\sigma_{ieL}R}{Et}$

$C_{\theta r}$, $C_{\theta h}$ = elastic buckling coefficients in hoop direction for cylinders under uniform external pressure, $\sigma_\phi = 0$ and $\sigma_\phi = 0.5\sigma_\theta$, respectively

E = modulus of elasticity of the material at Design Temperature, psi

FS = factor of safety

$G = \dfrac{E}{2(1+\mu)}$

h_s = width or depth of elements of a stiffener, in.

I_i = moment of inertia of stiffener in the i direction, about its centroidal axis, in.^{4}

I_{Ei} = moment of inertia of stiffener plus effective width of shell ℓ_e ($\ell_e = \ell_{e\phi}$ for circumferential stiffeners and $\ell_e = \ell_{e\theta}$ for meridional stiffener), about centroidal axis of combined section, in the i direction, in.^{4}

$$= I_i + A_i z_i^2 \frac{\ell_e t}{A_i + \ell_e t} + \frac{\ell_e t^3}{12}$$

I_{FE} = value of $I_{E\theta}$ which makes a large stiffener fully effective, that is, equivalent to a bulkhead

i = ϕ, θ, or $\phi\theta$ corresponding to meridional direction or stress component, circumferential direction or stress component, and in-plane shear stress component, respectively

= 1 or 2 corresponding to ϕ or θ above where 1 corresponds to the larger compression stress and 2 corresponds to the smaller compression stress

= x, h, r, τ to denote the special loading cases of axial (or meridional) compression alone, hydrostatic external pressure, radial external pressure, and in-plane shear

J_i = torsional constant of stiffener for general non-circular shapes use $\Sigma(h_s t_s^3/3)$, in.^{4}

j = L, S, G corresponding to local buckling (buckling of shell plate between stiffeners or boundaries), stringer buckling (buckling between rings of the shell plate and attached meridional stiffeners, and general instability (overall collapse), respectively

K = the ratio of the axial membrane force per unit length to the hoop compressive membrane force per unit length

$$= \frac{\sigma_\phi t_\phi}{\sigma_\theta t_\theta}$$

$$K_s = 1 - \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau a}}\right)^2$$

L = overall length of cylinder, in.

L_B = length of cylinder between bulkheads or lines of support with sufficient stiffness to act as bulkheads, in. Lines of support which act as bulkheads include end stiffeners which satisfy -1714.1(b)(2), a circumferential line on an unstiffened head at one-third the depth of the head from the head tangent line, a circumferential line at point of embedment in or anchorage to a concrete foundation, and the cylinder to head junction when the head is designed in accordance with this Case for stiffened heads.

L_s = one-half of the sum of the distances L_B on either side of an end stiffener, in.

ℓ_i = distance in i direction between lines of support, in. A line of support includes any intermediate size stiffening ring which satisfies the requirements of this Case in addition to the lines of support included in the definition for L_B.

ℓ_{si} = one-half of the sum of the distances ℓ_i on either side of an intermediate size stiffener, in.

ℓ_{ei} = effective width of shell acting with the stiffener in the i direction, in.

= $1.56\sqrt{Rt}$ unless otherwise noted

M_i = $\ell_i/\sqrt{Rt}$

M_s = $\ell_{si}/\sqrt{Rt}$

M = smaller of M_ϕ and M_θ

m = number of half waves into which shell will buckle in the meridional direction

n = number of waves into which shell will buckle in the circumferential direction

R = shell radius, in.

R_c = radius to centroidal axis of the combined stiffener and effective width of shell, in.

R_1, R_2 = effective stress radius for toroidal and ellipsoidal shells in the ϕ and θ directions, respectively, in. See Figure -1713.1.3-1

t = shell thickness, in.

t_s = thickness of elements of a stiffener, in.

$$t_\phi, t_\theta, t_{\phi\theta} = \frac{A_\phi}{\ell_\theta} + t, \frac{A_\theta}{\ell_\phi} + t, 0.5\,(t_\phi + t_\theta)$$

z_i = distance from centerline of shell to centroid of stiffener (positive when stiffeners are on outside), in.

α_{ij} = capacity reduction factors to account for the difference between classical theory and predicted instability stresses for fabricated shells ($\alpha_{iS} = \alpha_{iG}$)

η_i = plasticity reduction factor to account for non-linear material behavior, including effects of residual stress

$$\lambda, \bar{\lambda} = \frac{\pi R}{\ell_\phi}, \frac{\pi R}{L_B}$$

λ_c = the lowest multiples of the prebuckling stress states σ_{is} and σ_{ip} which cause linear bifurcation buckling

μ = Poisson's ratio

σ_i = calculated membrane stress components due to applied loads, psi

σ_{iej} = theoretical elastic instability stresses, psi

σ_{ia}, σ_{ic} = allowable stresses for elastic and inelastic buckling, respectively, psi

σ_{is} = amplified stress components to be used for elastic bifurcation buckling stress evaluation, psi

= $\sigma_i \cdot FS/\alpha_{ij}$

σ_{ip} = amplified stress components to be used for inelastic bifurcation buckling stress evaluations, psi

= σ_{is}/η_i

σ_{rej}, σ_{hej} = theoretical elastic instability stresses in the hoop direction for cylinders under external pressure, K = 0 and K = 0.5, respectively, psi

σ_y = tabulated yield stress of material at Design Temperature, psi. (Section II, Part D, Subpart 1, Table Y-1)

-1300 STRESS ANALYSIS PROCEDURES

The governing factor in the buckling analysis of a containment shell is the compressive membrane stress zones in the vessel arising from the static or dynamic response of the vessel to the applied loadings. The procedures of this Case call for static or dynamic linear shell analyses. Geometric nonlinear analysis may be used. The analysis should account for the dynamic effects associated with any dynamically applied loads. The shell analysis may be performed by the axisymmetrical shell of revolution method of -1310 or by alternate methods. The more elaborate, three-dimensional thin shell analysis method of -1320 may be used if the vessel geometry and/or the magnitude of any attached masses are such that axisymmetric shell of revolution analysis is not appropriate. Thermal and other secondary stresses will be treated the same as primary stresses. Fluid-structure interaction should be included in the dynamic analysis.

-1310 Axisymmetric Shell of Revolution Analysis

Most containment vessels can be adequately modeled as axisymmetric structures for determining their overall response to the applied loads. The mass of local attachments should be smeared around the shell at the applicable elevations. A separate, uncoupled analysis of significant attached masses can be performed, if required. Non-axisymmetric loadings shall be applied by use of an adequate number of Fourier harmonics. Ring stiffeners, if any, can be modeled discretely or an equally accurate representation shall be used and verified in the Design Report. Longitudinal stiffeners on cylinders and radial stiffeners on doubly-curved shells can be modeled as an orthotropic layer, if the stiffener spacing is close enough to make the shell plate between stiffeners fully effective. A method for determining the effective width of shell for longitudinally stiffened cylinders is given in -1712.2.2. This method may also be applied to doubly curved shells when the capacity reduction factors are determined on the basis of an equivalent cylinder.

-1320 Three-Dimensional Thin Shell Analysis

For those vessels containing major attachments capable of signifcantly altering the overall response of the vessel, the coupling effects of the vessel and the attachment may have to be accounted for. This can be done by the use of a three-dimensional thin shell finite element analysis or an equally valid analysis which shall be verified in the Design Report. The model used for such analysis should be refined enough to adequately account for coupling effects of the vessel and its attachments and to provide an accurate estimate of stresses due to applied static and dynamic loadings. The procedure given in -1310 for modeling stiffeners should be followed.

-1330 Determination of Stress Components for Buckling Analysis and Design

The internal stress field which controls the buckling of a cylindrical, spherical, toroidal or ellipsoidal shell consists of the longitudinal membrane, circumferential membrane, and in-plane shear stresses. These stresses may exist singly or in combination, depending on the applied loading. Only these three stress components are considered in the buckling analysis.

For the dynamic loading case, the stress results from a dynamic shell analysis are screened for the maximum value of the longitudinal compression, circumferential compression, or in-plane shear stress at each area of interest in the shell. The maximum value thus chosen is taken together with the other two concurrent stress components (here one or both components may be tension) to form a set of quasi-static buckling stress components. For each particular area of interest, three sets of quasi-static buckling stress components corresponding to the three maximum values are used to investigate the buckling capacity of the shell. The analyst should also review the results of the dynamic analysis for additional sets of quasi-static stress components which may represent a more severe condition than those defined above, and include them in the buckling investigation.

When the applied loading causes static or quasi-static stresses which vary in longitudinal and/or circumferential directions within the particular area of interest, each set of stress components along any circumference may be assumed to act uniformly over the entire circumference. For three-dimensional thin shell bifurcation analysis, the actual stress fields may be used.

When combining the effects of different applied loads which act concurrently, each of the three stress components is summed algebraically. If the sum of the longitudinal or circumferential components is tension, then that stress component may be set to zero.

-1400 FACTORS OF SAFETY

The basic compressive allowable stress values will correspond to a factor of safety of two in this Case. This factor is applied to buckling stress values that are determined by classical (linear) analysis and have been reduced by capacity reduction factors determined from lower bound values of test data.

The stability stress limits will correspond to the following factors of safety, *FS,* in this Case:

(a) For Design Conditions and Level A and B Service Limits, FS = 2.0.

(b) For Level C Service Limits the allowable stress values are 120% of the values of (a). Use FS = 1.67.

(c) For Level D Service Limits the allowable stress values are 150% of the values of (a). Use FS = 1.34.

The factors of safety given above are used in the buckling evaluation of -1700 and are the minimum values required for local buckling. The buckling criteria given in -1700 require that the buckling stresses corresponding to stringer buckling and general stability failures be at least 20% higher than the local buckling stresses.

-1500 CAPACITY REDUCTION FACTORS

The buckling capacity as determined by linear bifurcation (classical) analysis is not attained for actual shells. The reduction in capacity due to imperfections and nonlinearity in geometry and boundary conditions is provided through the use of capacity reduction factors, α_{ij}, given below for shells which meet the tolerances of NE-4220, WB-4220, or WC-4220.

Three modes of buckling are considered in this Case. These are: (1) local buckling which is defined as the buckling of the shell plate between stiffeners, (2) stringer buckling which is defined as the buckling between circumferential rings of the shell plate and the attached meridional stiffeners and (3) general instability which is defined as overall collapse of the combined shell and stiffeners. All stiffeners must be proportioned to preclude local buckling of the web or flange of a stiffener. One set of α_{ij} values is given for local buckling and a second set for stringer buckling and general instability.

These capacity reduction factors can be used for both internally or externally stiffened shells as well as unstiffened shells. The influence of internal pressure on a shell structure may reduce the initial imperfections and therefore higher values of capacity reduction factors may be acceptable. Justification for higher values of α_{ij} must be given in the Design Report. This capacity increase may also be applied to the equivalent sphere used in the buckling design of a toroidal or ellipsoidal shell under internal pressure.

-1510 Local Buckling

In the following paragraphs no increase in buckling stress is recognized for values of M_i less than 1.5.

-1511 Cylindrical Shells — Stiffened or Unstiffened

(a) Axial Compression (See Figures -1511-1 and -1511-2)

Use the larger of the values determined for $\alpha_{\phi L}$ from (1) and (2).

(1) Effect of R/t

$$\alpha_{\phi L} = 0.207 \text{ for } R/t \geq 600$$

$$\left.\begin{aligned} \alpha_{\phi L} &= 1.52 - 0.473 \log_{10}(R/t) \\ \alpha_{\phi L} &= \frac{300\sigma_y}{E} - 0.033 \end{aligned}\right\} \text{Use smaller value for } R/t < 600$$

(2) Effect of Length

$$\alpha_{\phi L} = 0.627 \text{ if } M_\phi < 1.5$$
$$\alpha_{\phi L} = 0.837 - 0.14M_\phi \text{ if } 1.5 \leq M_\phi < 1.73$$
$$\alpha_{\phi L} = \frac{0.826}{M_\phi^{0.6}} \text{ if } 1.73 \leq M_\phi < 10$$
$$\alpha_{\phi L} = 0.207 \text{ if } M_\phi \geq 10$$

(b) Hoop Compression

$$\alpha_{\theta L} = 0.8$$

(c) Shear (See Figure -1511-1)

$$\alpha_{\phi\theta L} = 0.8 \text{ if } R/t \leq 250$$
$$\alpha_{\phi\theta L} = 1.323 - 0.218 \log_{10}(R/t) \text{ if } 250 < R/t < 1000$$

-1512 Spherical Shells — Stiffened or Unstiffened.

See Figure -1512-1 then see -1713.1.2 for method of calculating *M.*

(a) Uniaxial Compression

$$\alpha_{\phi L} = \alpha_{\theta L} = \alpha_{1L}$$
$$\alpha_{1L} = \alpha_{2L}/0.6 \quad \text{(But not to exceed 0.75)}$$

See (b) for α_{2L}

(b) Equal Biaxial Compressive Stresses

$$\alpha_{\phi L} = \alpha_{\theta L} = \alpha_{2L}$$
$$\alpha_{2L} = 0.627 \quad \text{if } M < 1.5$$
$$\alpha_{2L} = 0.837 - 0.14M \quad \text{if } 1.5 \leq M < 1.73$$
$$\alpha_{2L} = \frac{0.826}{M^{0.6}} \quad \text{if } 1.73 \leq M < 23.6$$
$$\alpha_{2L} = 0.124 \quad \text{if } M \geq 23.6$$

(c) Unequal Biaxial Compressive Stresses. Use α_{1L} and α_{2L} in accordance with -1713.1.2.

(d) Shear. Buckling evaluation will be made using principal stresses.

-1513 Toroidal and Ellipsoidal Shells.

Use the values of α_{iL} given for spherical shells in accordance with -1512.

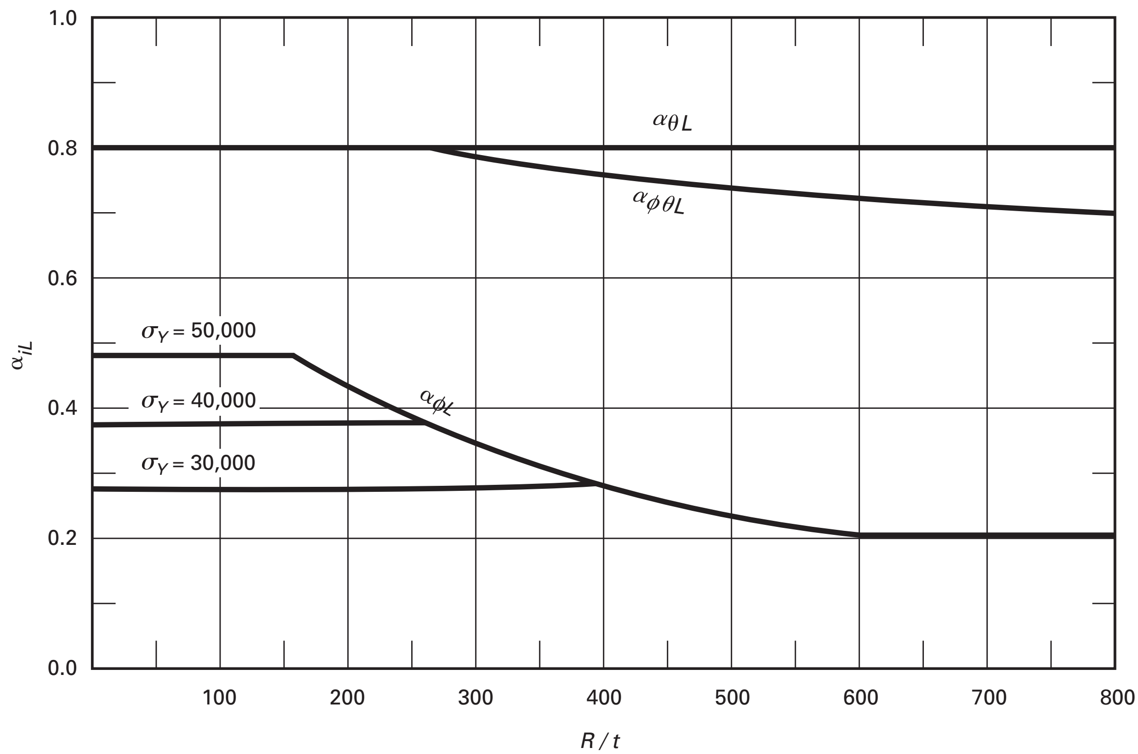
-1520 Stringer Buckling and General Instability

-1521 Cylindrical Shells — Ring and/or Stringer Stiffened

(a) Axial Compression

$$\alpha_{\phi G} = 0.72 \quad \text{if } \bar{A} \geq 0.20$$
$$\alpha_{\phi G} = (3.6 - 5.0\,\alpha_{\phi L})\bar{A} + \alpha_{\phi L} \quad \text{if } 0.06 \leq \bar{A} < 0.20$$
$$\alpha_{\phi G} = \alpha_{\phi L} \quad \text{if } \bar{A} < 0.06$$

Figure -1511-1
Capacity Reduction Factors for Local Buckling of Stiffened and Unstiffened Cylindrical Shells (Use Larger Value of $\alpha_{\phi L}$ From Figure -1511-1 and Figure -1511-2)



where $\alpha_{\phi L}$ is determined from -1511(a)(1) and $\overline{A}$ is given by the following relationships:

$$\text{For stringers only: } \overline{A} = \frac{A_\phi}{\ell_{s\theta} t}$$

$$\text{For rings only: } \overline{A} = \frac{A_\theta}{\ell_{s\phi} t}$$

For rings and stringers: $\overline{A}$ = smaller of above values for $\overline{A}$.

NOTE: Assume that the stiffener is not effective if $\overline{A} < 0.06$.

(b) Hoop Compression

$$\alpha_{\theta G} = 0.80$$

(c) Shear

$$\alpha_{\phi\theta G} = 0.80 \text{ if } R/t \le 250$$
$$\alpha_{\phi\theta G} = 1.323 - 0.2181 \log_{10}(R/t) \quad \text{if } 250 < R/t < 1000$$

-1522 Spherical Shells — One-Way or Two-Way (Orthogonal) Stiffeners

(a) Meridional Compression and/or Hoop Compression

$$\alpha_{\phi G} = \alpha_{\theta G} = 0.1013$$

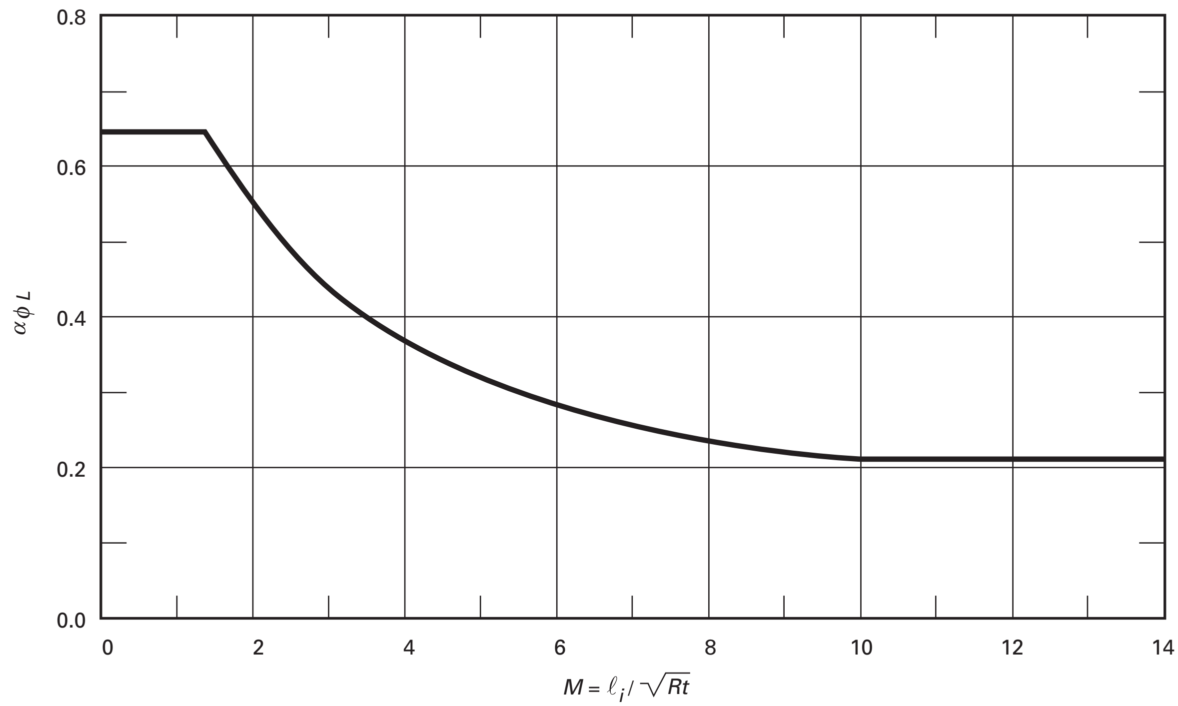
-1523 Toroidal and Ellipsoidal Shells — One-Way or Two-Way (Orthogonal) Stiffeners. Use the value of α_{iG} given for spherical shells.

-1600 PLASTICITY REDUCTION FACTORS

The elastic buckling stresses for fabricated shells are given by the product of the classical buckling stresses and the capacity reduction factors, i.e., $\sigma_{iej}\ \alpha_{ij}$. When these values exceed the proportional limit of the fabricated material, plasticity reduction factors, η_i, are used to account for the non-linear material properties. The inelastic buckling stresses for fabricated shells are given by $\eta_i\ \sigma_{iej}\ \alpha_{ij}$.

Two sets of equations are given for determination of the plasticity reduction factors. For buckling evaluation by formulas (see -1710) the factors are expressed in terms of $\alpha_{ij}\ \sigma_{iej}$. For bifurcation buckling analysis with a computer program (see -1720 and -1730) the factors

Figure -1511-2
Capacity Reduction Factors for Local Buckling of Stiffened and Unstiffened Cylindrical Shells (Use Larger Value of $\alpha_{\phi L}$ From Figure -1511-1 and -1511-2)



are expressed in terms of $\sigma_i\ FS$ because σ_{iej} is an unknown quantity. This approach will always be conservative since $\sigma_i\ FS \le \eta_i\ \alpha_{ij}\ \sigma_{iej}$.

-1610 Factors for Buckling Analysis by Formulas (See Figure -1610-1)

-1611 Cylindrical Shells

Let

$$\Delta = \frac{\alpha_{ij}\sigma_{iej}}{\sigma_y}$$

(a) Axial Compression

$$\eta_\phi = 1.0 \qquad \text{if } \Delta \le 0.55$$
$$\eta_\phi = \frac{0.45}{\Delta} + 0.18 \qquad \text{if } 0.55 < \Delta \le 1.6$$
$$\eta_\phi = \frac{1.31}{1 + 1.15\Delta} \qquad \text{if } 1.6 < \Delta < 6.25$$
$$\eta_\phi = \frac{1}{\Delta} \qquad \text{if } \Delta \ge 6.25$$

(b) Hoop Compression

$$\eta_\theta = 1 \qquad \text{if } \Delta \le 0.67$$
$$\eta_\theta = \frac{2.53}{1 + 2.29\Delta} \qquad \text{if } 0.67 < \Delta < 4.2$$
$$\eta_\theta = \frac{1}{\Delta} \qquad \text{if } \Delta \ge 4.2$$

(c) Shear

$$\eta_{\phi\theta} = 1.0 \qquad \text{if } \Delta \le 0.48$$
$$\eta_{\phi\theta} = \frac{0.43}{\Delta} + 0.1 \qquad \text{if } 0.48 < \Delta < 1.7$$
$$\eta_{\phi\theta} = \frac{0.6}{\Delta} \qquad \text{if } \Delta \ge 1.7$$

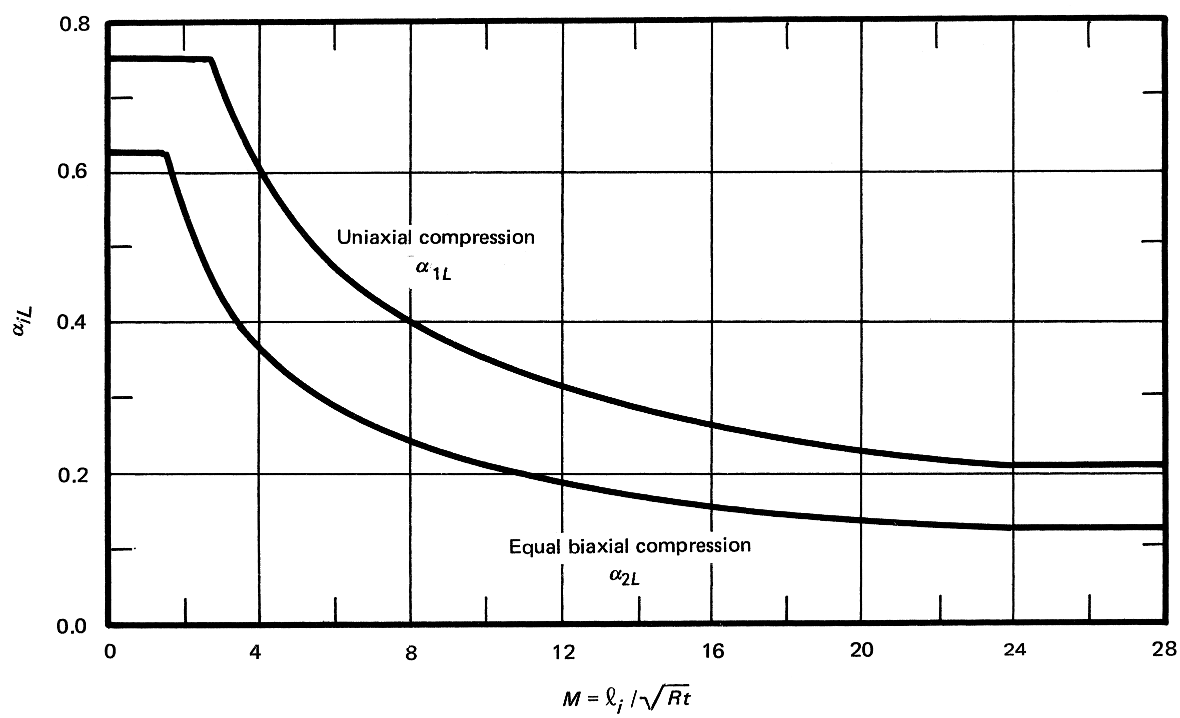
-1612 Spherical Shells

(a) Meridional Compression and/or Hoop Compression. Use the values given in -1611(a).

-1613 Toroidal and Ellipsoidal Shells

(a) Meridional Compression and/or Hoop Compression. Use the values given in -1611(a).

Figure -1512-1
Capacity Reduction Factors for Local Buckling of Stiffened and Unstiffened Spherical Shells



-1620 Factors for Bifurcation Buckling Analysis (See Figure -1620-1)

If the computed values of σ_ϕ or σ_θ (see -1711 for methods for treatment of discontinuity stresses) exceed σ_y/FS or $\sigma_{\phi\theta}$ exceeds 0.6 σ_y/FS, the design is inadequate and modifications are needed to lower the value of σ_i.

-1621 Cylindrical Shells

(a) Axial Compression

$$\eta_\phi = 1.0 \qquad \text{if } \frac{\sigma_\phi FS}{\sigma_y} \le 0.55$$

$$\eta_\phi = \frac{0.18}{1 - \dfrac{0.45\sigma_y}{\sigma_\phi FS}} \qquad \text{if } 0.55 < \frac{\sigma_\phi FS}{\sigma_y} \le 0.738$$

$$\eta_\phi = 1.31 - 1.15\frac{\sigma_\phi FS}{\sigma_y} \qquad \text{if } 0.738 < \frac{\sigma_\phi FS}{\sigma_y} \le 1.0$$

(b) Hoop Compression

$$\eta_\theta = 1 \qquad \text{if } \frac{\sigma_\theta FS}{\sigma_y} \le 0.67$$

$$\eta_\theta = 2.53 - 2.29\frac{\sigma_\theta FS}{\sigma_y} \qquad \text{if } 0.67 < \frac{\sigma_\theta FS}{\sigma_y} \le 1.0$$

(c) Shear

$$\eta_{\phi\theta} = 1.0 \qquad \text{if } \frac{\sigma_{\phi\theta} FS}{\sigma_y} \le 0.48$$

$$\eta_{\phi\theta} = \frac{0.1}{1 - \dfrac{0.43\sigma_y}{\sigma_{\phi\theta} FS}} \qquad \text{if } 0.48 < \frac{\sigma_{\phi\theta} FS}{\sigma_y} \le 0.6$$

-1622 Spherical Shells

(a) Meridional Compression and/or Hoop Compression. Use the values given in -1621(a).

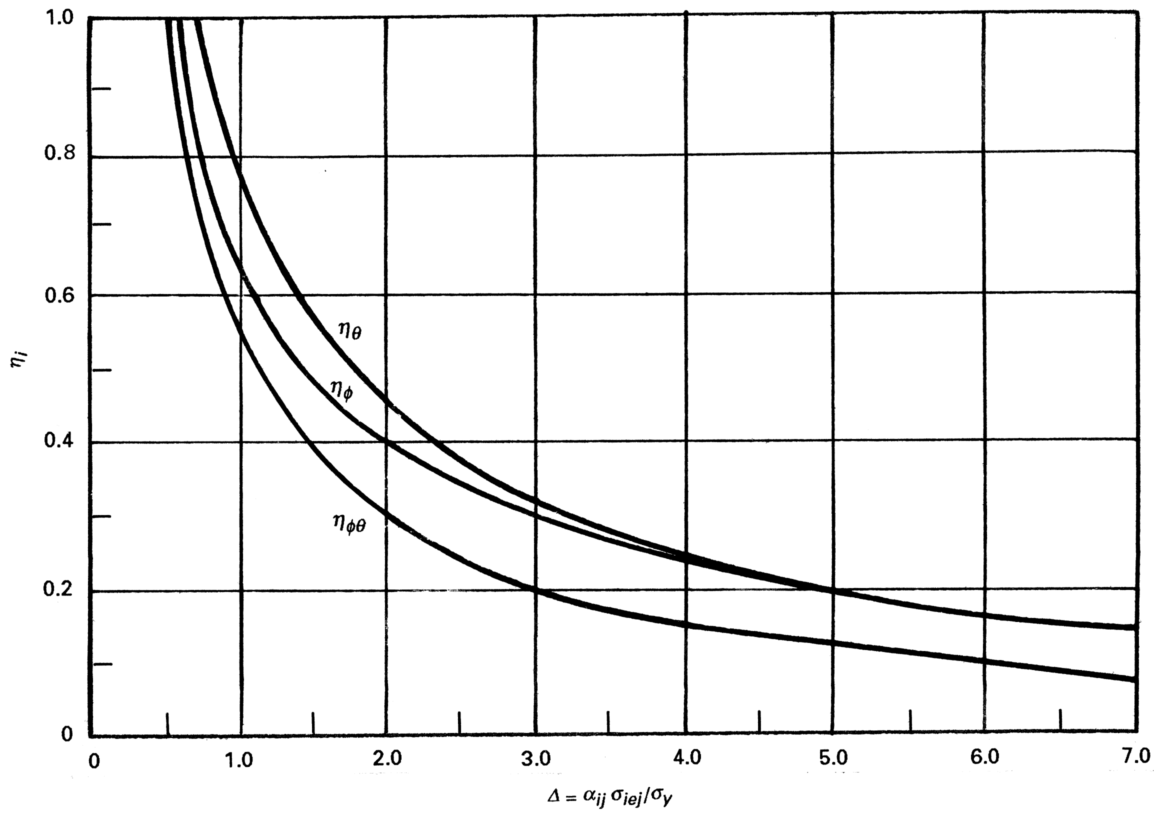
-1623 Toroidal and Ellipsoidal Shells

(a) Meridional Compression and/or Hoop Compression. Use the values given in -1621(a).

-1700 BUCKLING EVALUATION

The buckling evaluation may be performed by one of a number of different approaches. Three acceptable alternative approaches are given in -1710, -1720, and -1730. In -1710 formulas are given for the buckling evaluation. An axisymmetric shell of revolution and a three-dimensional thin shell computer code are used for the buckling evaluations given in -1720 and -1730, respectively. Generally, the same computer program is used for both the linear elastic stress analysis, as described in -1300 and the buckling evaluation.

Figure -1610-1
Plastic Reduction Factors for Buckling Analysis by Formula



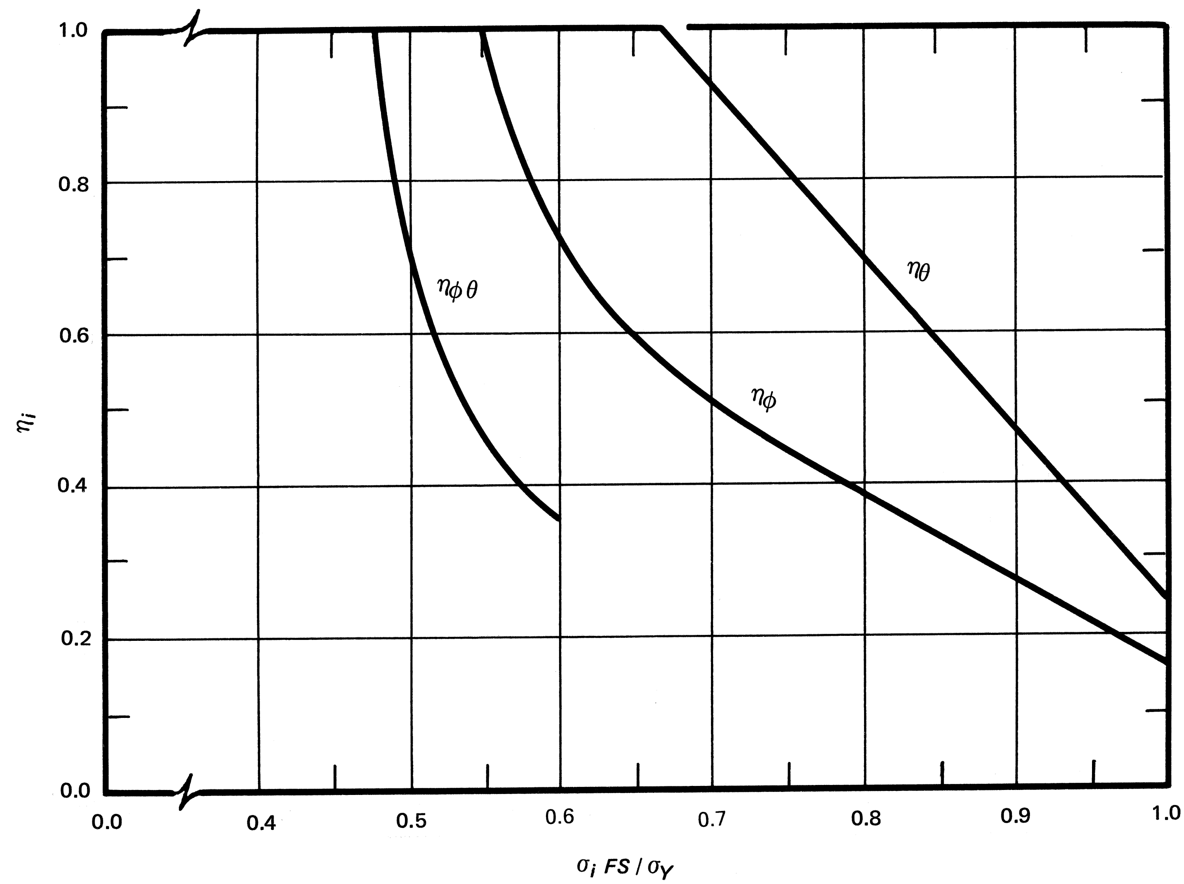
For each of three approaches it is recommended that a separate buckling evaluation be made for (a) local buckling of the shell plate between stiffening elements (b) buckling between circumferential stiffeners of combined shell plate and attached meridional stiffeners and (c) general instability or overall collapse of the combined shell and stiffening system. For some geometries, the critical load values predicted for the general instability mode may be significantly larger than those for the local buckling mode. This is not necessarily a good indicator of the reserve strength of the design for these geometries since actual failure may occur from excessive deformation before the predicted general instability load can be reached. A static and/or dynamic analysis is performed for each specified loading and the stresses computed in accordance with -1300. The stresses are combined for each specified Service Limit to determine the buckling stress components, σ_i.

For buckling evaluation by formula, the stress components σ_i are inserted in the interaction equations given in -1713. Simple equations are also given in -1712 for determining the classical buckling stresses of shells for the special stress states (load cases) of axial or meridional compression alone, hydrostatic external pressure (K = 0.5), radial external pressure (K = 0), and inplane shear alone. The allowable stress values for these special stress states are given by $\sigma_{ia} = \alpha_{ij}\ \sigma_{iej}/FS$ for elastic buckling stresses and by $\sigma_{ic} = \eta_i\ \sigma_{ia}$ for inelastic buckling stresses. The allowable buckling stresses for the special stress states are used in the interaction equations in -1713 for determining the allowable stresses for combined stress states.

The classical buckling stresses may also be determined for nonuniform stress fields from the computer codes used for the methods of -1720 and -1730. Therefore, when using the values of -1500 for α_{ij}, simply supported edges should be assumed for determination of theoretical values by computer. In this Case, the edge of the shell is assumed to be simply supported if at the edge the radial and circumferential displacements are zero and there is no restraint against rotation or translation in the meridional direction. Also there is no restraint against rotation in the circumferential direction for panels between meridional stiffeners.

For buckling evaluation by use of a computer code, amplified stress components σ_{is} and σ_{ip} are determined from $\sigma_{is} = \sigma_i\ FS/\alpha_{ij}$ and $\sigma_{ip} = \sigma_{is}/\eta_i$. The method of -1720 is based upon an axisymmetric shell of revolution

Figure -1620-1
Plasticity Reduction Factors for Bifurcation Buckling Analysis



linear bifurcation analysis. The shell model is assumed to be axisymmetric with simple support boundary conditions and the stress components σ_{is} and σ_{ip} are assumed to be uniformly distributed around the circumference. Each set of amplified stress components is compared with the classical buckling capacity of the shell model as discussed in -1720. If the classical buckling capacity is equal to or greater than λ_c times the stress components, σ_{is} and σ_{ip}, the design is adequate. A value of λ_c = 1.0 is recommended for local buckling and 1.2 for stringer buckling and general instability modes of failure.

For those cases where significant nonaxisymmetric conditions exist and a three-dimensional stress analysis has been performed, the buckling evaluation approach of -1730 may be used. For such three-dimensional thin shell buckling analysis the calculated state of stress may be used in determining the amplified stress components σ_{is} and σ_{ip} for input to the program.

For any of the above approaches, the effects of local discontinuities and attached masses, if not included with the general shell buckling analysis, should be investigated. For openings reinforced in accordance with the area replacement rules of Subsections NE, WB, and WC, it can be assumed that the reduction in the buckling capacity of the shell is negligible. Stresses in the shell due to penetration loads shall be given consideration, to preclude localized buckling of the shell.

-1710 By Formulae

-1711 Discontinuity Stresses.

Application of certain thermal or mechanical loads may result in high local discontinuity membrane stresses. To assume that the maximum value of such localized stresses act uniformly over the entire portion of the shell under study will result in an overly conservative design. An acceptable alternative and conservative method of analysis is to use the average values of the membrane stress components within a meridional distance of $\sqrt{Rt}$ from a point of fixity or 0.5 $\sqrt{Rt}$ on each side of a discontinuity for determination of σ_i. The average stress values are to be used in calculating total stress components for performing the buckling analyses of -1713.

An acceptable alternative to the averaging method would be to caculate the uniaxial theoretical buckling stress values for the actual meridional stress distribution by use of a computer program. These more accurate values of theoretical buckling stresses can then be used for the buckling evaluation of -1713 in lieu of values calculated per -1712.

-1712 Theoretical Buckling Values.. The buckling stresses given by the following equations correspond to the minimum values determined from theoretical equations for shells with classical simple support boundary conditions under uniform stress fields. Paragraph -1712.1 gives equations for determining the classical buckling stresses of unstiffened shells or the panels between stiffeners of stiffened shells. Paragraph -1712.2 gives equations for determining the theoretical stringer buckling and general instability stresses for stiffened shells.

Equations are presented for calculating the theoretical classical elastic bifurcation buckling values for the unique loading cases of axial compression, radial pressure, hydrostatic pressure, and shear. In addition to their use in predicting buckling for these conditions, the values are also used in the interaction equations of -1713 for combined loading cases. The subscripts r and h denote radial and hydrostatic loading cases, respectively.

-1712.1 Local Buckling

-1712.1.1 Cylindrical Shells — Unstiffened and Ring Stiffened (See Figure -1712.1.1-1)

(a) Axial Compression

$$\sigma_{\phi eL} = C_\phi Et/R$$

$$C_\phi = 0.630 \qquad \text{if } M_\phi \le 1.5$$

$$C_\phi = \frac{0.904}{M_\phi^2} + 0.1013M_\phi^2 \qquad \text{if } 1.5 < M_\phi < 1.73$$

$$C_\phi = 0.605 \qquad \text{if } M_\phi \ge 1.73$$

(b) External Pressure

(1) No End Pressure ($K = 0$)

$$\sigma_{\theta eL} = \sigma_{reL} = C_{\theta r} Et/R$$

$$C_{\theta r} = 1.616 \qquad \text{if } M_\phi \le 1.5$$

$$C_{\theta r} = \frac{2.41}{M_\phi^{1.49} - 0.338} \qquad \text{if } 1.5 < M_\phi < 3.0$$

$$C_{\theta r} = \frac{0.92}{M_\phi - 1.17} \qquad \text{if } 3.0 \le M_\phi < 1.65\frac{R}{t}$$

$$C_{\theta r} = 0.275\frac{t}{R} + \frac{2.1}{M_\phi^4}\left(\frac{R}{t}\right)^3 \qquad \text{if } M_\phi \ge 1.65\frac{R}{t}$$

(**E**) *(2)* End Pressure Included ($K = 0.5$)

$$\sigma_{\theta eL} = \sigma_{heL} = C_{\theta h} E\frac{t}{R}$$

$$C_{\theta h} = 0.988 \qquad \text{if } M_\phi \le 1.5$$

$$C_{\theta h} = \frac{1.08}{M_\phi^{1.07} - 0.45} \qquad \text{if } 1.5 < M_\phi < 3.5$$

$$C_{\theta h} = \frac{0.92}{M_\phi - 0.636} \qquad \text{if } 3.5 \le M_\phi < 1.65\frac{R}{t}$$

$$C_{\theta h} = 0.275\frac{t}{R} + \frac{2.1}{M_\phi^4}\left(\frac{R}{t}\right)^3 \qquad \text{if } M_\phi \ge 1.65\frac{R}{t}$$

(c) Shear

$$\sigma_{\phi\theta eL} = C_{\phi\theta}Et/R$$

$$C_{\phi\theta} = 2.227 \qquad \text{if } M_\phi \le 1.5$$

$$C_{\phi\theta} = \frac{4.82}{M_\phi^2}\left(1 + 0.0239M_\phi^3\right)^{1/2} \qquad \text{if } 1.5 < M_\phi < 26$$

$$C_{\phi\theta} = \frac{0.746}{\sqrt{M_\phi}} \qquad \text{if } 26 \le M_\phi < 8.69\frac{R}{t}$$

$$C_{\phi\theta} = 0.253\left(\frac{t}{R}\right)^{1/2} \qquad \text{if } M_\phi \ge 8.69\frac{R}{t}$$

-1712.1.2 Cylindrical Shells — Stringer Stiffened or Ring and Stringer Stiffened

(a) Axial Compression (See Figure -1712.1.1-1). The following equation applies when $M_\theta < 2M_\phi$; otherwise use the equation given in-1712.1.1(a):

$$\sigma_{\phi eL} = C_\phi Et/R$$

$$C_\phi = 1.666 \qquad \text{if } M_\phi \le 1.5$$

$$C\phi = \frac{3.62}{M_\phi^2} + 0.0253M_\phi^2 \qquad \text{if } 1.5 < M_\phi < 3.46$$

$$C_\phi = 0.605 \qquad \text{if } M_\phi \ge 3.46$$

(b) External Pressure. The following equations apply when $M_\theta < 1.15\sqrt{M_\phi}$; otherwise use the equations given in -1712.1.1(b):

$$n^2 = (\pi R/\ell_\theta)^2$$

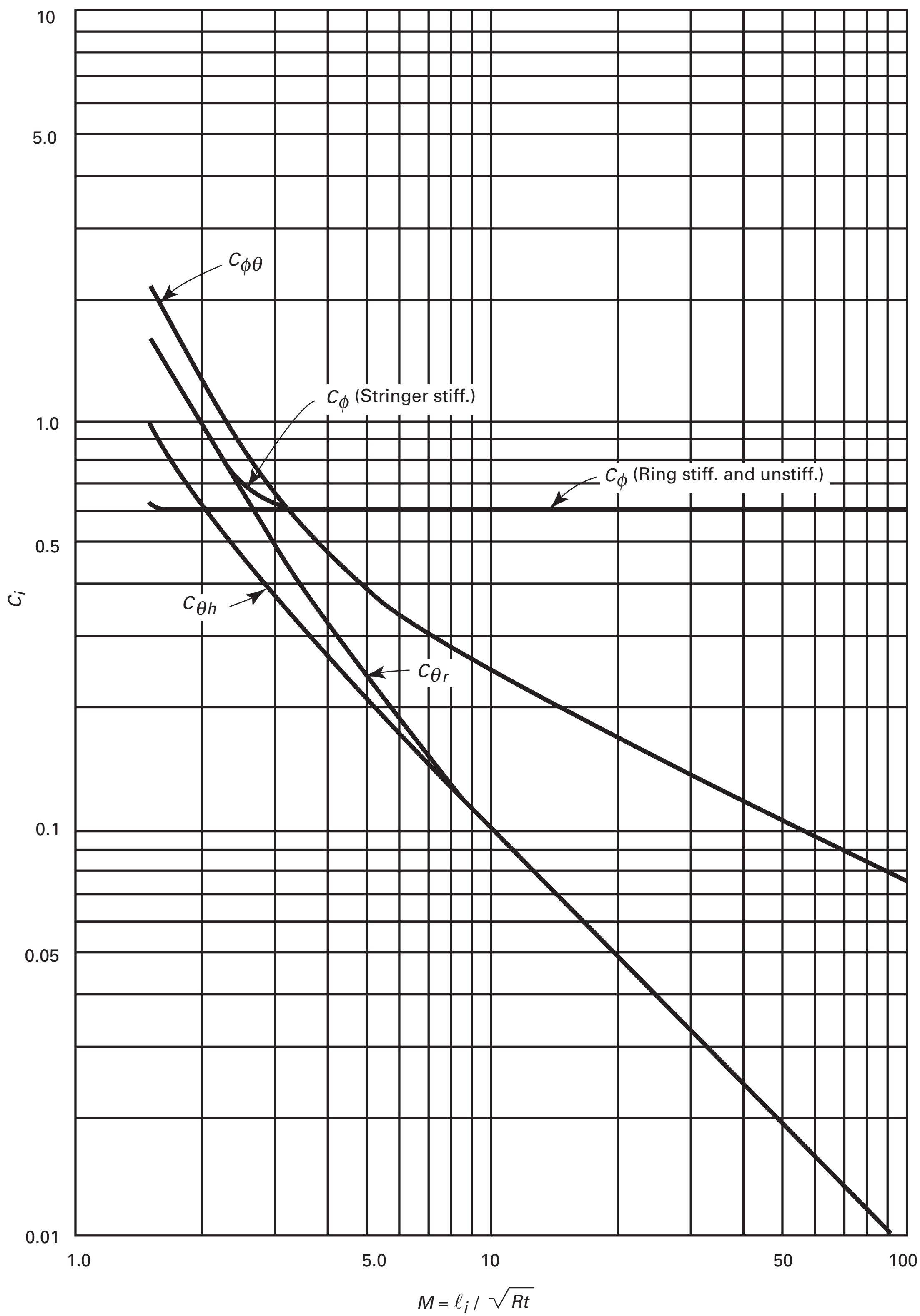
(1) No End Pressure ($K = 0$)

$$\sigma_{\theta eL} = \sigma_{reL} = C_{\theta r} Et/R$$

$$C_{\theta r} = \frac{1}{n^2 - 1}\left[\frac{\left(n^2 + \lambda^2 - 1\right)^2}{10.92}\left(\frac{t}{R}\right) + \frac{\lambda^4}{\left(n^2 + \lambda^2\right)^2}\left(\frac{R}{t}\right)\right]$$

(2) End Pressure Included ($K = 0.5$)

Figure -1712.1.1-1
Theoretical Local Buckling Stress Coefficients for Stiffened and Unstiffened Cylindrical Shells



$$\sigma_{\theta eL} = \sigma_{heL} = C_{\theta h} Et/R$$

$$C_{\theta h} = \frac{1}{n^2 + 0.5\lambda^2 - 1}\left[\frac{(n^2 + \lambda^2 - 1)^2}{10.92}\left(\frac{t}{R}\right) + \frac{\lambda^4}{(n^2 + \lambda^2)^2}\left(\frac{R}{t}\right)\right]$$

(c) Shear (See Figure -1712.1.2-1). The following equations apply when $M < 26$ and $a/b \leq 3.0$, where a = greater of ℓ_ϕ and ℓ_θ and b = smaller of ℓ_ϕ and ℓ_θ and $M = b/\sqrt{Rt}$; otherwise use the equations given in -1712.1.1(c):

$$\sigma_{\phi\theta eL} = C_{\phi\theta} Et/R$$

$$C_{\phi\theta} = \frac{1}{M^2}\left[4.82(1 + 0.0239M^3)^{1/2} + 3.62\left(\frac{b}{a}\right)^2\right]$$

-1712.1.3 Spherical Shells — Stiffened or Unstiffened

(a) Equal Biaxial Compressive Stress. Equations are the same as -1712.1.1(a).

$$\sigma_{\phi eL} = \sigma_{\theta eL} = C\,Et/R$$

$$C = 0.630 \qquad \text{if } M \leq 1.5$$

$$C = \frac{0.904}{M^2} + 0.1013M^2 \qquad \text{if } 1.5 < M < 1.73$$

$$C = 0.605 \qquad \text{if } M \geq 1.73$$

(b) Unequal Biaxial Compressive Stress. Not used in interaction relationships of -1713.

(c) Shear. When shear is present, the principal stresses will be calculated and substituted for σ_ϕ and σ_θ in the buckling equations.

-1712.1.4 Toroidal and Ellipsoidal Shells — Stiffened or Unstiffened.

Toroidal and ellipsoidal shells shall be analyzed as equivalent spheres.

-1712.2 Stringer Buckling and General Instability

-1712.2.1 Cylindrical Shells — Ring Stiffened

(a) Axial Compression

$$\sigma_{\phi eG} = 0.605E\frac{t}{R}\left(1 + \frac{A_\theta}{\ell_{s\phi} t}\right)^{1/2}$$

(b) External Pressure

Determine the value of n which minimizes σ_{ieG} in the equations which follow:

(1) No End Pressure ($K = 0$)

$$\sigma_{reG} = \frac{E\bar{\lambda}^4}{(n^2 - 1)(n^2 + \bar{\lambda}^2)^2} + \frac{EI_{E\theta}(n^2 - 1)}{\ell_{s\phi} R_c^2 t}$$

(2) End Pressure Included ($K = 0.5$)

$$\sigma_{heG} = \frac{E\bar{\lambda}^4}{(n^2 + 0.5\bar{\lambda}^2 - 1)(n^2 + \bar{\lambda}^2)^2} + \frac{EI_{E\theta}(n^2 - 1)}{\ell_{s\phi} R_c^2 t}$$

(c) Shear

$$\sigma_{\phi\theta eG} = \frac{3.46E}{L_B^{1/2} R^{3/4}}\left(\frac{I_{E\theta}}{\ell_{s\phi} t}\right)^{5/8}$$

-1712.2.2 Cylindrical Shells — Stringer Stiffened or Ring and Stringer Stiffened.

The theoretical elastic buckling stresses for both stringer buckling and general instability are given by the equations which follow. Stringer buckling is defined as the buckling between rings of the stringer and attached plate and general instability is defined as the buckling mode in which the rings and attached plate deform radially.

The elastic buckling stress is denoted σ_{iej} where i is the stress direction and j is the buckling mode; $j = S$ for stringer buckling and $j = G$ for general instability. The stringer buckling stress is determined by letting the cylinder length equal the ring spacing, $L_j = \ell_\phi$ and the general instability stress by letting $L_j = L_B$.

The values of m and n to use in the following equations are those which minimize σ_{iej} where $m \geq 1$ and $n > 2$. The following values are to be used for $\ell_{e\phi}$ and $\ell_{e\theta}$. When $\ell_{e\phi} < \ell_\phi$ or $\ell_{e\theta} < \ell_\theta$, set $\mu = 0$.

(a) Axial Compression.

$$\ell_{e\phi} = \ell_\phi$$

$$\ell_{e\theta} = \ell_\theta \qquad \text{if } \ell_\theta \leq 1.288tQ$$

$$\ell_{e\theta} = 1.9tQ\left(1 - \frac{0.415tQ}{\ell_\theta}\right) \qquad \text{if } \ell_\theta > 1.288tQ$$

where

$$Q = \sqrt{\frac{E}{\sigma_{\phi ej}\,\alpha_{\phi G}}} \geq \sqrt{\frac{E}{\sigma_y}}$$

For stringer buckling:

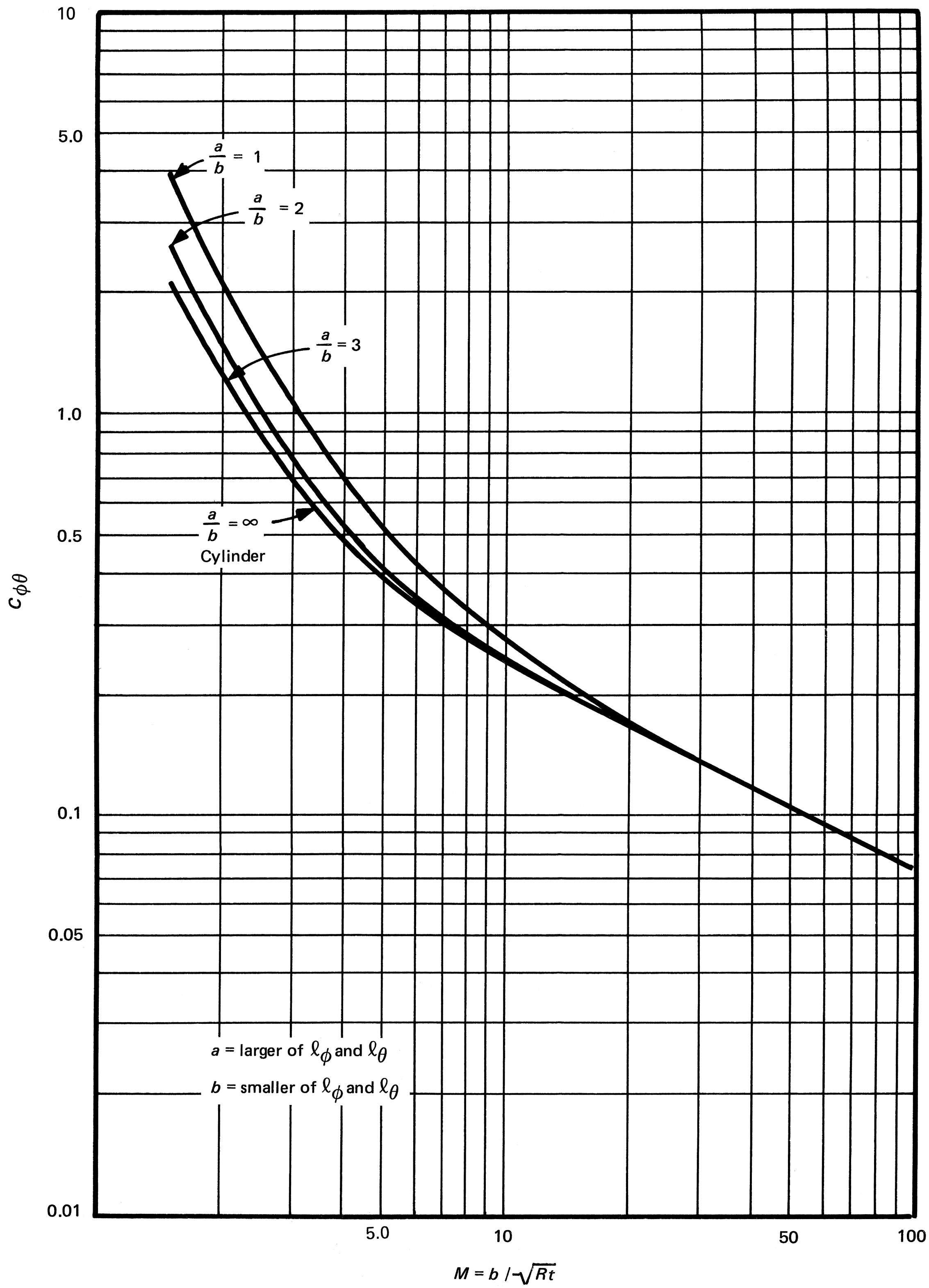
$$j = S, A_\theta = I_\theta = J_\theta = 0, t_\theta = t, L_j = \ell_\phi$$

For general instability:

$$j = G, L_j = L_B$$

See -1521(a) for $\alpha_{\phi G}$ and the equation below for $\sigma_{\phi ej}$. When $\ell_{e\theta} < \ell_\theta$, the values for $\sigma_{\phi ej}$ must be determined by iteration since the effective width is a function of the buckling stress.

Figure -1712.1.2-1
Theoretical Local Buckling Stress Coefficients for Stringer Stiffened Cylinder Subjected to In-Plane Shear



$$\sigma_{\phi ej} = \frac{A_{33} + \left(\frac{A_{12}A_{23} - A_{13}A_{22}}{A_{11}A_{22} - A_{12}^2}\right)A_{13} + \left(\frac{A_{12}A_{13} - A_{11}A_{23}}{A_{11}A_{22} - A_{12}^2}\right)A_{23}}{\left(\frac{m\pi}{L_j}\right)^2 t_\phi}$$

where

$$A_{11} = E_\phi\left(\frac{m\pi}{L_j}\right)^2 + G_{\phi\theta}\left(\frac{n}{R}\right)^2$$

$$A_{22} = E_\theta\left(\frac{n}{R}\right)^2 + G_{\phi\theta}\left(\frac{m\pi}{L_j}\right)^2$$

$$A_{33} = D_\phi\left(\frac{m\pi}{L_j}\right)^4 + \overline{D}_{\phi\theta}\left(\frac{m\pi}{L_j}\right)^2\left(\frac{n}{R}\right)^2 + D_\theta\left(\frac{n}{R}\right)^4 + \frac{E_\theta}{R^2} + \frac{2C_\theta}{R}\left(\frac{n}{R}\right)^2$$

$$A_{12} = (E_{\phi\theta} + G_{\phi\theta})\left(\frac{m\pi}{L_j}\right)\left(\frac{n}{R}\right)$$

$$A_{23} = \frac{E_\theta}{R}\left(\frac{n}{R}\right) + C_\theta\left(\frac{n}{R}\right)^3$$

$$A_{13} = \frac{E_{\phi\theta}}{R}\left(\frac{m\pi}{L_j}\right) + C_\phi\left(\frac{m\pi}{L_j}\right)^3$$

$$E_\phi = \frac{Et}{1-\mu^2}\left(\frac{\ell_{e\theta}}{\ell_\theta}\right) + \frac{EA_\phi}{\ell_\theta}$$

$$E_{\phi\theta} = \frac{\mu Et}{1-\mu^2}$$

$$E_\theta = \frac{Et}{1-\mu^2}\left(\frac{\ell_{e\phi}}{\ell_\phi}\right) + \frac{EA_\theta}{\ell_\phi}$$

$$G_{\phi\theta} = \frac{Gt}{2}\left(\frac{\ell_{e\phi}}{\ell_\phi} + \frac{\ell_{e\theta}}{\ell_\theta}\right)$$

$$D_\phi = \frac{Et^3}{12(1-\mu^2)}\left(\frac{\ell_{e\theta}}{\ell_\theta}\right) + \frac{EI_\phi}{\ell_\theta} + \frac{EA_\phi z_\phi^2}{\ell_\theta}$$

$$D_\theta = \frac{Et^3}{12(1-\mu^2)}\left(\frac{\ell_{e\phi}}{\ell_\phi}\right) + \frac{EI_\theta}{\ell_\phi} + \frac{EA_\theta z_\theta^2}{\ell_\phi}$$

$$\overline{D}_{\phi\theta} = \frac{\mu Et^3}{6(1-\mu^2)} + \frac{Gt^3}{6}\left(\frac{\ell_{e\phi}}{\ell_\phi} + \frac{\ell_{e\theta}}{\ell_\theta}\right) + \frac{GJ_\phi}{\ell_\theta} + \frac{GJ_\theta}{\ell_\phi}$$

$$C_\phi = \frac{EA_\phi z_\phi}{\ell_\theta}$$

$$C_\theta = \frac{EA_\theta z_\theta}{\ell_\phi}$$

(b) External Pressure

Stringer Buckling ($j = S$)

$$\ell_{e\phi} = 1.56\sqrt{Rt} \text{ but not greater than } \ell_\phi$$

$$\ell_{e\theta} = \ell_\theta$$

$$A_\theta = I_\theta = J_\theta = 0,\ t_\theta = t,\ L_j = \ell_\phi$$

General Instability ($j = G$)

$$\ell_{e\phi} = 1.56\sqrt{Rt} \text{ but not greater than } \ell_\phi$$

$$\ell_{e\theta} = \ell_\theta,\ L_j = L_B$$

$$\sigma_{\theta ej} = \frac{A_{33} + \left(\frac{A_{12}A_{23} - A_{13}A_{22}}{A_{11}A_{22} - A_{12}^2}\right)A_{13} + \left(\frac{A_{12}A_{13} - A_{11}A_{23}}{A_{11}A_{22} - A_{12}^2}\right)A_{23}}{\left[K\left(\frac{m\pi}{L_j}\right)^2 + \left(\frac{n}{R}\right)^2\right]t_\theta}$$

where

A_{xy} = values given in (a) above.

(c) Shear

$$\sigma_{\phi\theta eG} = \frac{3.46Et_\phi^{3/8}}{L_B^{1/2}R^{3/4}t_{\phi\theta}}\left(\frac{I_{E\theta}}{\ell_{s\phi}}\right)^{5/8}$$

-1712.2.3 Spherical Shells — One-Way or Two-Way (Orthogonal) Stiffeners

(a) Equal Biaxial Compressive Stress

$$\sigma_{\phi eG} = \sigma_{\theta eG} = \frac{2.00Et_1^{1/4}}{Rt_2^{3/4}}\left(\frac{I_{E1}}{\ell_{s2}}\right)^{1/3}\left(\frac{I_{E2}}{\ell_{s1}}\right)^{1/6}$$

Subscripts 1 and 2 correspond to ϕ and θ where $I_{E1} \geq I_{E2}$ and $t_1 \geq t_2$. For one-way stiffening $I_{E2} = \ell_{s1}\, t^3/12$.

-1712.2.4 Toroidal and Ellipsoidal Shells — Meridional And/or Circumferential Stiffeners.

Toroidal and ellipsoidal shells may be analyzed as equivalent spheres.

-1713 Interaction Equations for Local Buckling.

The equations which follow can be used to evaluate the local buckling capacity of the shell. The form of such interaction relationships depends on whether the critical stresses are in the elastic or inelastic range. If any of the uniaxial critical stress values exceed the proportional limit of the fabricated material, the inelastic interaction relationships of -1713.2 should be satisfied, in addition to the elastic interaction relationships of -1713.1. If the calculated meridional or hoop stress is tension, it should be assumed zero for the interaction evaluation. An increase in the critical axial compressive stress due to hoop tension may be included in the analysis, if justified in the Design Report. Methods for treatment of discontinuity stresses are given in -1711.

The theoretical buckling values can be determined from -1712.1 or from a computer program by the procedures given in -1700 and -1711. If the relationships of -1713.1 and -1713.2 are satisfied, the design is adequate to prevent local buckling.

The buckling capacities for the stringer buckling and general instability modes can be determined in a similar manner by substituting the capacity reduction factors and theoretical buckling values for these modes into the interaction equations. This Code Case recommends that the buckling capacity for these modes be 20% greater than for the local buckling mode. This is accomplished by changing the right-hand side of the interaction equations to 1.2 rather than 1.0. An acceptable alternative is to determine the stiffener sizes by the equations given in -1714. This method will be more conservative.

-1713.1 Elastic Buckling.

The relationships in the following paragraphs must be satisfied.

-1713.1.1 Cylindrical Shells.

The allowable stresses for the special load cases of axial (meridional) compression alone, hydrostatic external pressure, radial external pressue, and in-plane shear alone are given by

$$\sigma_{xa} = \frac{\alpha_{\phi L}\sigma_{\phi eL}}{FS}, \sigma_{ha} = \frac{\alpha_{\theta L}\sigma_{heL}}{FS}$$
$$\sigma_{ra} = \frac{\alpha_{\theta L}\sigma_{reL}}{FS}, \text{ and } \sigma_{\tau a} = \frac{\alpha_{\phi\theta L}\sigma_{\phi\theta eL}}{FS}$$

These stresses are used in the interaction equations which follow for combined stress states. The allowable stresses can be determined, if desired, for any stress by letting $\sigma_\phi = \sigma_\theta\ Kt_\theta/t_\phi$. The resulting values for σ_ϕ, σ_θ, and $\sigma_{\phi\theta}$ are allowable stress values $\sigma_{\phi a}$, $\sigma_{\theta a}$, and $\sigma_{\phi\theta a}$. The allowable stresses are given by these equations when the expressions on the left are equal to 1.0 for local buckling and 1.2 for stringer buckling and general instability. For further explanation of the interaction equations see Figure -1713.1-1.

See -1400, -1511, and -1712.1.1 for *FS*, α_{iL}, and σ_{ieL}, respectively. Alternatively, σ_{ieL} may be determined by a computer program using the procedure given in -1700 and -1711.

(a) Axial Compression Plus Hoop Compression ($K < 0.5$). No interaction check is required if $\sigma_\theta < \sigma_{ha}$

$$\frac{\sigma_\theta}{\sigma_{ra} - 2\sigma_\phi\left(\dfrac{\sigma_{ra}}{\sigma_{ha}} - 1\right)\dfrac{t_\phi}{t_\theta}} \le 1.0$$

(b) Axial Compression Plus Hoop Compression ($K \ge 0.5$.) No interaction check is required if $\sigma_\phi \le 0.5\sigma_{ha}\ t_\theta/t_\phi$

$$\frac{\sigma_\phi - 0.5\,\sigma_{ha}\,t_\theta/t_\phi}{\sigma_{xa} - 0.5\,\sigma_{ha}\,t_\theta/t_\phi} + \left(\frac{\sigma_\theta}{\sigma_{ha}}\right)^2 \le 1.0$$

(c) Axial Compression Plus In-Plane Shear

$$\frac{\sigma_\phi}{\sigma_{xa}} + \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau a}}\right)^2 \le 1.0$$

(d) Hoop Compression Plus In-Plane Shear

$$\frac{\sigma_\theta}{\sigma_{ra}} + \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau a}}\right)^2 \le 1.0$$

(e) Axial Compression Plus Hoop Compression Plus In-Plane Shear

For a given shear ratio $(\sigma_{\phi\theta}/\sigma_{\tau a})$ determine the value for K_s from the following equation:

$$K_s = 1 - \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau a}}\right)^2$$

and substitute the values of $K_s\ \sigma_{xa}$, $K_s\ \sigma_{ra}$ and $K_s\ \sigma_{ha}$ for σ_{xa}, σ_{ra} and σ_{ha}, respectively, in the equations given in (a) or (b) above.

-1713.1.2 Spherical Shells.

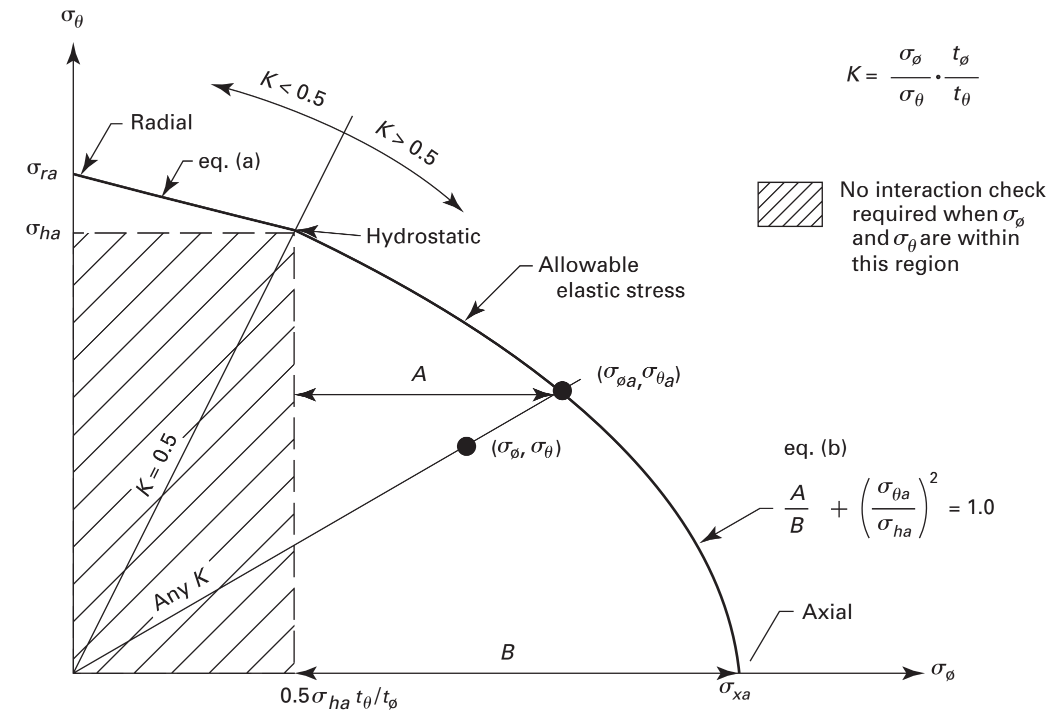
The allowable stresses for the special load cases of uniaxial compression and uniform external pressure are given by the equations which follow and are used in the interaction equation for other biaxial compression stress states. If one stress component is in tension, the tensile stress may be set to zero and the shell considered as a uniaxial compression case.

$$\sigma_{1a} = \frac{\alpha_{1L}\sigma_{\phi eL}}{FS} \text{ and } \sigma_{2a} = \frac{\alpha_{2L}\sigma_{\phi eL}}{FS}$$

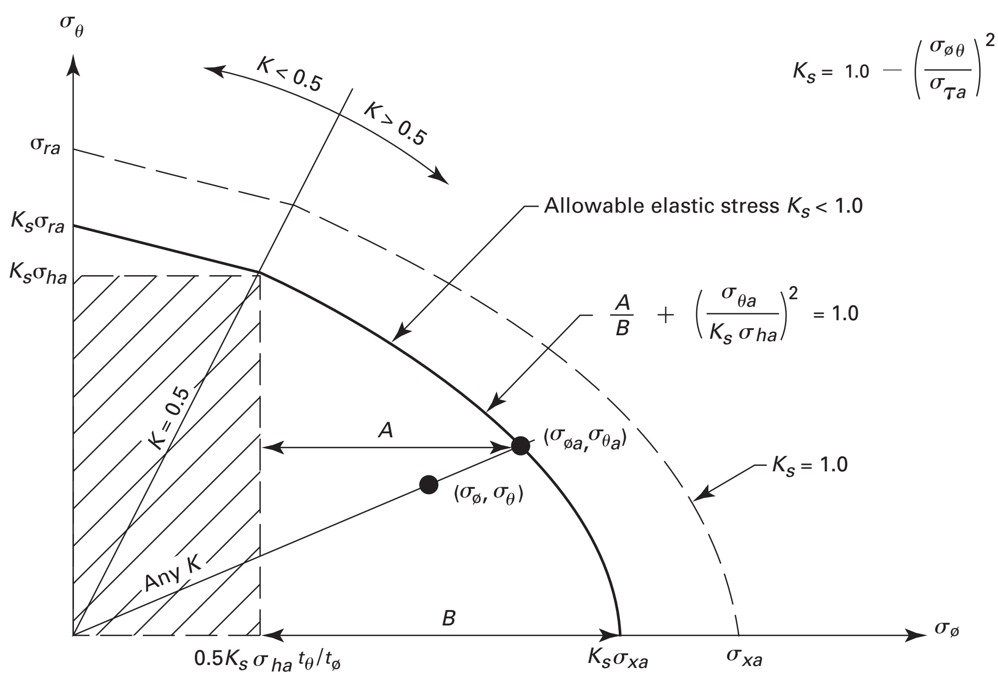
where

FS = see -1400

Figure -1713.1-1
Interaction Curves for Elastic Buckling of Cylinders Under Combined Loads



(a) Axial Compression Plus Hoop Compression



(b) Axial Compression Plus Hoop Compression Plus In-Plane Shear

α_{1L} = see -1512(a)
α_{2L} = see -1512(b)

and

$\sigma_{\phi eL}$ = see -1712.1.3. The length ℓ_i to use for calculating M is equal to the diameter of the largest circle which can be inscribed within the lines of support. The length is to be measured along the arc.

When $\sigma_{\phi\theta} \neq 0$, determine the principal stresses corresponding to stress components σ_i and substitute for σ_ϕ and σ_θ in the expressions below for σ_1 and σ_2.

σ_1 = larger compression stress of σ_ϕ and σ_θ
σ_2 = smaller compression stress of σ_ϕ and σ_θ

(a) Uniaxial Compression

$$\frac{\sigma_1}{\sigma_{1a}} \leq 1.0$$

(b) Biaxial Compression

$$\frac{\sigma_1 - \sigma_2}{\sigma_{1a}} + \frac{\sigma_2}{\sigma_{2a}} \leq 1.0$$

-1713.1.3 Toroidal and Ellipsoidal Shells.. The allowable stresses for the special stress states of uniaxial compression and equal biaxial compression are given by the equations which follow and these values are used in the interaction equation for other stress states.

$$\sigma_{1a} = \frac{\alpha_{1L}\sigma_{1eL}}{FS} \text{ and } \sigma_{2a} = \frac{\alpha_{2L}\sigma_{2eL}}{FS}$$

where *FS*, α_{1L}, α_{2L}, and $\sigma_{\phi eL}$ are defined in -1713.1.2. Calculate σ_{1eL}, and σ_{2eL} from the following procedure. See Figure -1713.1.3-1 for R_1 and R_2.

σ_{1eL} = $\sigma_{\phi eL}$ = theoretical buckling stress for sphere under equal biaxial stress based on R associated with σ_1. $R = R_1$ if $\sigma_1 = \sigma_\theta$ and $R = R_2$ if $\sigma_1 = \sigma_\phi$
σ_{2eL} = $\sigma_{\phi eL}$ = theoretical buckling stress for sphere under equal biaxial stress based on R associated with σ_2. $R = R_1$ if $\sigma_2 = \sigma_\theta$ and $R = R_2$ if $\sigma_2 = \sigma_\phi$

When $\sigma_{\phi\theta} \neq 0$, determine the principal stresses corresponding to the stress components σ_i and substitute for σ_ϕ and σ_θ in the expressions for σ_1 and σ_2 given in -1713.1.2.

Also determine radii R_1 and R_2 which correspond to the principal stress directions.

(a) Uniaxial Compression. See -1713.1.2(a).

(b) Biaxial Compression. See -1713.1.2(b).

-1713.2 Inelastic Buckling.

The relationships in the following paragraphs must also be satisfied when any of the values of $\eta_i < 1$. No interaction equations are given for meridional compression plus hoop compression because it is conservative to ignore interaction of the two stress components when buckling is inelastic. See Figure -1713.2-1.

-1713.2.1 Cylindrical Shells.

The allowable stresses for the special stress states of axial compression alone, radial external pressure and inplane shear alone are given by:

$$\sigma_{xc} = \eta_\phi\sigma_{xa}, \sigma_{rc} = \eta_\theta\sigma_{ra} \text{ and } \sigma_{\tau c} = \eta_{\phi\theta}\sigma_{\tau a}$$

See -1610 for η_i and -1713.1.1 for σ_{ia}.

(a) Axial Compression or Hoop Compression

$$\frac{\sigma_\phi}{\sigma_{xc}} \leq 1.0, \frac{\sigma_\theta}{\sigma_{rc}} \leq 1.0$$

(b) Axial Compression Plus In-Plane Shear

$$\frac{\sigma_\phi}{\sigma_{xc}} + \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau c}}\right)^2 \leq 1.0$$

(c) Hoop Compression Plus In-Plane Shear

$$\frac{\sigma_\theta}{\sigma_{rc}} + \left(\frac{\sigma_{\phi\theta}}{\sigma_{\tau c}}\right)^2 \leq 1.0$$

-1713.2.2 Spherical Shells.

In the equation which follows:

$$\sigma_{1c} = \eta_\phi\sigma_{1a}$$

where η_ϕ corresponds to stress σ_{1a} *FS*. See -1713.1.2 for σ_1 and σ_{1a} and -1612 for η_ϕ.

(a) Uniaxial or Biaxial Compression

$$\sigma_1 \leq \sigma_{1c}$$

-1713.2.3 Toroidal and Ellipsoidal Shells.

In the equations which follow:

$$\sigma_{1c} = \eta_1\sigma_{1a} \text{ and } \sigma_{2c} = \eta_2\sigma_{2a}$$

where η_1 corresponds to stress σ_{1a} *FS* and η_2 corresponds to stress σ_{2a} *FS*. See -1713.1.3 for σ_1, σ_2, σ_{1a}, σ_{2a} and -1613 for η_1 and η_2.

(a) Uniaxial Compression Plus Shear

$$\sigma_1 \leq \sigma_{1c}$$

(b) Biaxial Compression Plus Shear. The following two relationships must be satisfied:

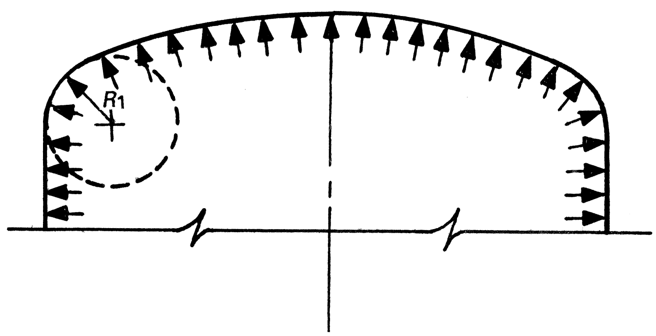
$$\sigma_1 \leq \sigma_{1c}$$

$$\sigma_2 \leq \sigma_{2c}$$

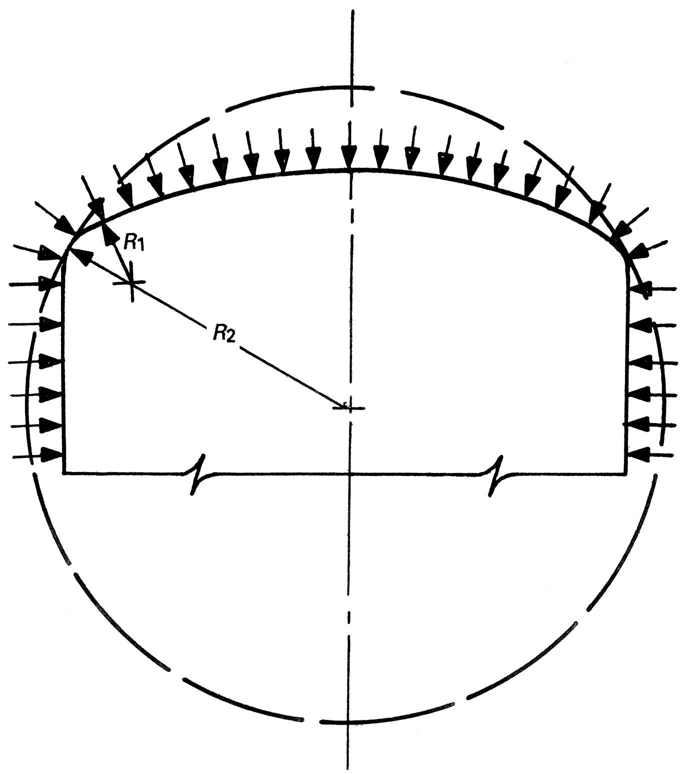
-1714 Sizing of Stiffeners.

The size of stiffeners required to prevent stringer buckling and general instability failures can be determined from the interaction equations given in -1713 by using the appropriate values for σ_{iej} and α_{ij} and changing the

Figure -1713.1.3-1
Radii R_1 and R_2 for Toroidal and Ellipsoidal Head

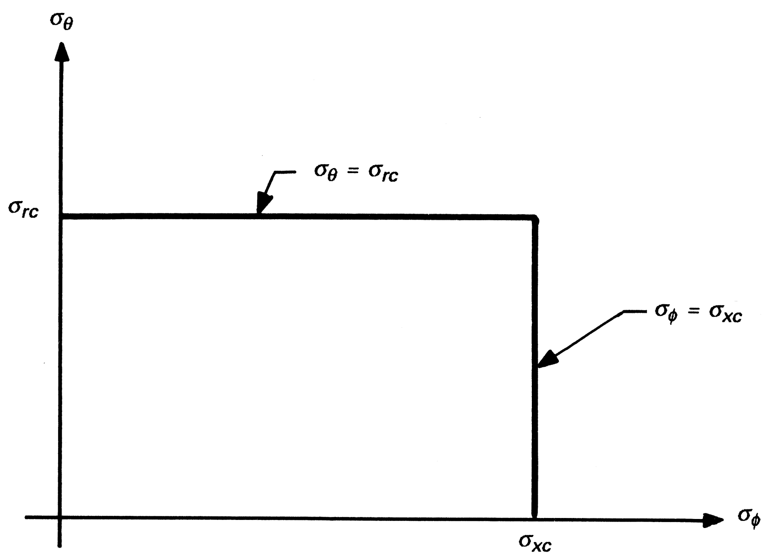


(a)

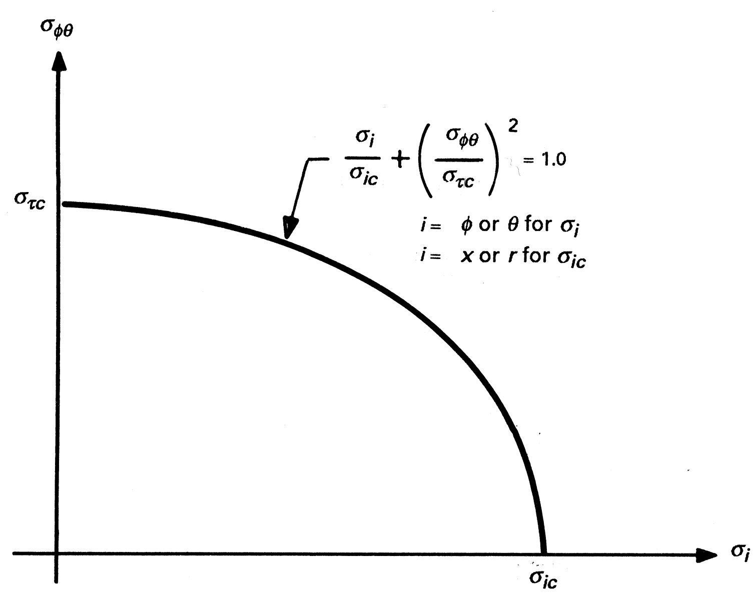


(b)

Figure -1713.2-1
Interaction Curves for Inelastic Buckling of Cylinders Under Combined Loads



(a) Axial Compression Plus Hoop Compression



(b) Axial Compression or Hoop Compression Plus In-Plane Shear

right side of the equalities from 1.0 and 1.2 or by the following equations. These equations are based upon the recommendation that the stringer buckling and general instability stresses be 20% greater than the average of the local shell buckling stresses in the adjacent panels. The method for sizing stiffeners will always be conservative because the stiffener size determined from the following equations will be adequate for each of the uniaxial buckling stress components. For ring stiffened cylinders and stiffened spherical heads simple equations are given for sizing stiffeners. The equations for a stringer stiffened cylinder are more complex and require a computer for solving. The method for sizing stiffeners is based upon the following relationship:

$$\sigma_{iej} = \frac{1.2\sigma_{ieL}\alpha_{iL}}{\alpha_{iG}}$$

The above requirement is conservative under combined stress states and for inelastic buckling as well as elastic buckling. In the case of combined stress states provide a stiffener with the largest value of the moment of inertia calculated for each uniaxial stress state.

-1714.1 Cylindrical Shells — Ring Stiffened

(a) Axial Compression

$$A_\theta \geq \left(\frac{0.334}{M_s^{0.6}} - 0.063\right)\ell_{s\phi}t \text{ and } A_\theta \geq 0.06\ell_{s\phi}t$$

The following equation is based upon the recommendation that the effective stiffener section provides a bending stiffness equal to that of an unstiffened shell having the same buckling stress.

$$I_{E\theta} \geq \frac{5.33\ell_{s\phi}t^3}{M_s^{1.8}}$$

(b) Hoop Compression

(1) Intermediate Size Ring

$$I_{E\theta} \geq \frac{1.2\sigma_{\theta eL}\ell_{s\phi}R_c^2 t}{E\left(n^2 - 1\right)}$$

$\sigma_{\theta eL}$ = stress determined from -1712.1.1(b) for $M_\phi = M_s$

$$n^2 = \frac{1.875R^{3/2}}{L_B t^{1/2}}$$

Use $n = 2$ for $n^2 < 4$ and $n = 10$ for $n^2 > 100$.

(2) End Stiffeners — Rings Which Act as Bulkheads

$$I_{FE} = \frac{1.5\sigma_{\theta F}L_s R_c^2 t}{E\left(n^2 - 1\right)}$$

where

A_1 = area of large ring plus $\ell_\phi t$, in.^{2}

A_2 = area of intermediate size rings plus $\ell_\phi t$, in.^{2}

I_{FE} = the value of $I_{E\theta}$ which makes a large stiffener fully effective, that is, equivalent to a bulkhead. The effective width of shell $\ell_{e\phi} = 1.56\sqrt{Rt}A_1/A_2$

n = number of buckling waves determined for $\sigma_{\theta B}$ where $\sigma_{\theta B}$ is the stress determined from -1712.2.1(b) for a cylinder where the large stiffeners are assumed to be the same size as the small stiffeners and $\bar{\lambda} = \pi R/L$

$\sigma_{\theta F}$ = average value of stress over distance L_s where stress is determined from -1712.2.1(b) for a cylinder with $L = L_B$

(c) Shear

$C_{\phi\theta}$ = value determined from -1712.1 for $M_\phi = M_s$

$I_{E\theta}$ = $0.184\ C_{\phi\theta}M_s{}^{0.8}t^3\ell_{s\phi}$

-1714.2 Cylindrical Shells — Stringer Stiffened or Ring and Stringer Stiffened

(c) Axial Compression

$$\sigma_{\phi eS} \geq \frac{1.2\sigma_{\phi eL}\alpha_{\phi L}}{\alpha_{\phi G}} \text{ and } \sigma_{\phi eG} \geq \frac{1.2\sigma_{\phi eL}\alpha_{\phi L}}{\alpha_{\phi G}}$$

See -1511(a) for $\alpha_{\phi L}$, -1521(a) for $\alpha_{\phi G}$, -1712.1.2(a) for $\sigma_{\phi eL}$ and -1712.2.2(a) for $\sigma_{\phi eS}$ and $\sigma_{\phi eG}$.

(d) Hoop Compression

$$\sigma_{\theta eS} \geq 1.2\sigma_{reL}$$

and

$$\sigma_{\theta eG} \geq 1.2\sigma_{reL}$$

See -1712.1 for σ_{reL} and -1712.2.2(b) for $\sigma_{\theta eS}$ and $\sigma_{\theta eG}$. Assume $K = 0$.

(e) Shear

$$\sigma_{\phi\theta eG} \geq 1.2\sigma_{\phi\theta eL}$$

See -1712.1.2(c) and -1712.2.2(c) for $\sigma_{\phi\theta eL}$ and $\sigma_{\phi\theta eG}$, respectively.

-1714.3 Spherical Shells

(a) One-Way Stiffeners

$$I_{E\phi} = \frac{62.4\ell_{s\theta}t^3}{M_s^{1.8}}\left(\frac{t}{t_\phi}\right)^{3/4}$$

The above equation is for meridional stiffeners. Interchange θ with ϕ for circumferential stiffeners.

(b) Two-Way (Orthogonal) Stiffeners

$$\sigma_{ieG} \geq \frac{5.92Et}{M_s^{0.6}R}$$

The value for σ_{ieG} is determined from -1712.2.3 and M_s is the smaller of the values corresponding to the θ and ϕ directions.

-1714.4 Toroidal or Ellipsoidal Shells.

Toroidal and ellipsoidal shells shall be analyzed as equivalent spheres by substituting R_2 for R in the equations of -1714.3. See Figure -1713.1.3-1 for R_2.

-1720 AXISYMMETRIC SHELL OF REVOLUTION BIFURCATION ANALYSIS

An axisymmetric shell of revolution linear bifurcation analysis may be used for the buckling evaluation of the containment vessel. Two sets of stress components, σ_{is} and σ_{ip} are calculated by the procedure given in -1700. The stress components σ_{is} are elastic whereas the stress components σ_{ip} are used for buckling evaluation when one or more of the stress components is in the inelastic range. Independent buckling evaluations are to be made for components σ_{is} and σ_{ip}. If all stress components are elastic, $\sigma_{is} = \sigma_{ip}$ and no evaluation need be made of stress components σ_{ip}.

The buckling stresses of cylinders under combined loads compare closely with the distortion energy theory when the uniaxial buckling stresses in the meridional and circumferential directions are equal to the yield stress of the material. This state of stress is considered in the stress intensity criteria of NE-3210, WB-3210, or WC-3210. When the uniaxial buckling stresses in either the meridional or circumferential directions are in the inelastic range, no interaction effect between these two stress components need be considered. Therefore stress components $\sigma_{\phi p}$ can be set to zero when investigating combinations of $\sigma_{\theta p}$ and $\sigma_{\phi\theta p}$. Similarly, $\sigma_{\theta p}$ may be set to zero when investigating combinations of $\sigma_{\phi p}$ and $\sigma_{\phi\theta p}$.

The stress components σ_{ip} are applied as quasistatic prebuckling stress states. The computer code will analyze the selected shell model for linear bifurcation buckling and determine the lowest multiple, λ_c, of the prebuckling stress state which causes buckling. A minimum value of $\lambda_c = 1.0$ is recommended for the local buckling mode of failure and a value of $\lambda_c = 1.2$ is recommended for the stringer buckling and general instability modes of failure. The design is adequate when the computed values of λ_c are equal to or greater than the minimum recommended values.

-1730 THREE-DIMENSIONAL THIN-SHELL BIFURCATION ANALYSIS

This paragraph gives the provisions for buckling evaluations of containment shells by use of three-dimensional computer programs for thin shells. The three-dimensional computer codes are more elaborate than those used for axisymmetric shell of revolution linear bifurcation analysis and are mostly based on finite element principles. The advantages of three-dimensional codes are that circumferential variation of geometry, material properties and loadings which exist due to presence of cutouts, penetrations, stiffeners and other attachments can be considered in the analysis. The choice of computer code should be based upon the type of problem to be solved and the degree of accuracy desired.

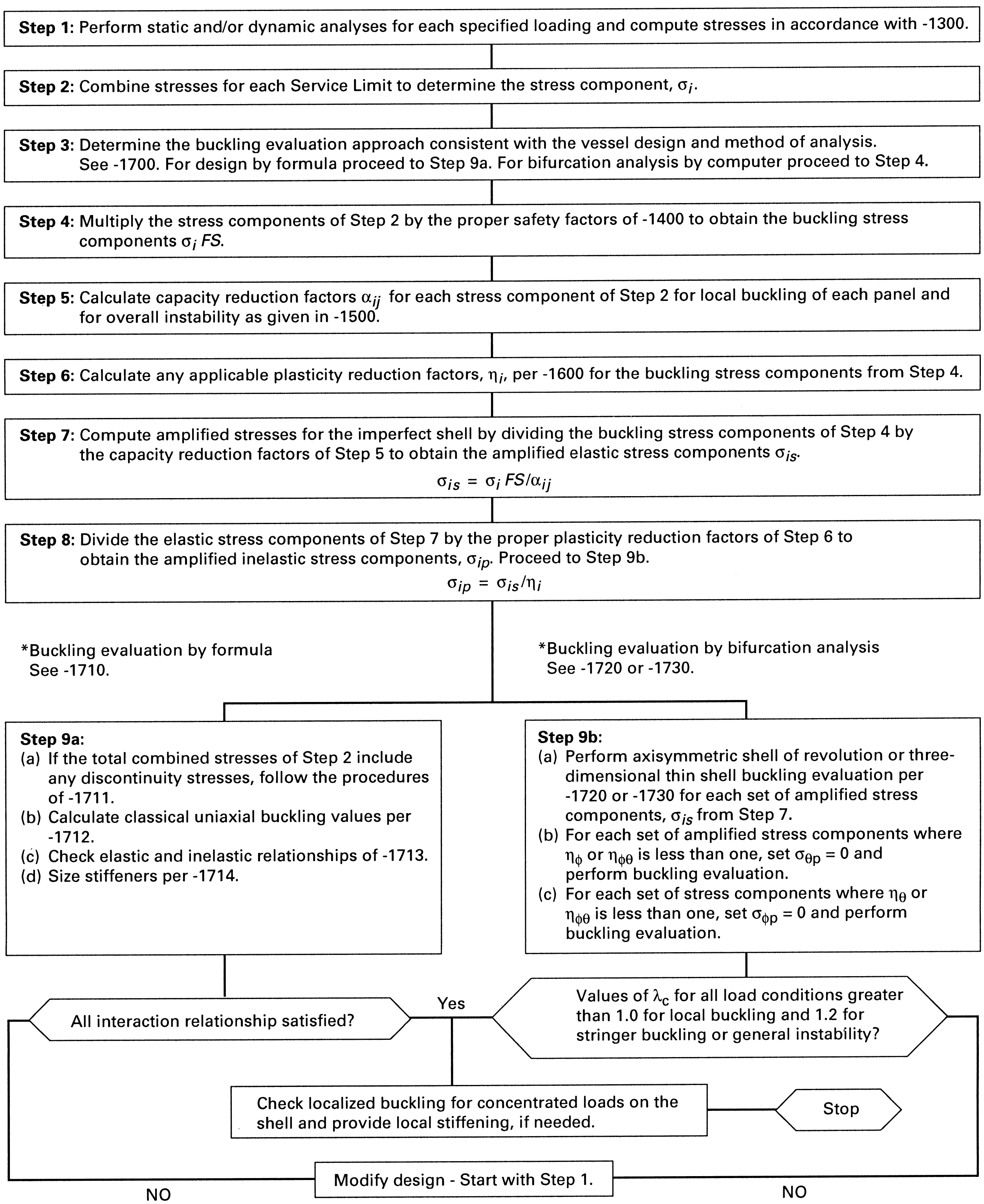
Two sets of stress components, σ_{is} and σ_{ip} are calculated by the procedure given in -1700. Independent buckling evaluations are to be made for these sets of stress components where $\sigma_{ip} \neq \sigma_{is}$. When considering the stress components σ_{ip} it is conservative to assume that there is no interaction between meridional compression and hoop compression (see -1720). Therefore stress components $\sigma_{\phi p}$ can be set to zero when investigating combinations of $\sigma_{\theta p}$ and $\sigma_{\phi\theta p}$. Similarly, $\sigma_{\theta p}$ can be set to zero when investigating combinations of $\sigma_{\phi p}$ and $\sigma_{\phi\theta p}$.

The stress components σ_{is} and σ_{ip} are applied as quasi-static prebuckling stress states. The computer code will analyze the selected shell model for linear bifurcation buckling and determine the lowest multiple, λ_c, of the prebuckling stress state which causes buckling. A minimum value of $\lambda_c = 1.0$ is recommended for the local buckling mode of failure and a value of $\lambda_c = 1.2$ is recommended for the stringer buckling and general instability modes of failure. The design is adequate when the computed values of λ_c are equal to or greater than the minimum recommended values.

-1800 SUMMARY

Table -1800-1 summarizes the rules of this Case to aid the designer in using these rules. The containment shell must also satisfy all other applicable Code criteria.

Table -1800-1
Flowchart



Approval Date: April 4, 1983

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-290-1
Expansion Joints in Class 1, Liquid Metal Piping
Section III, Division 1

Inquiry: Under what rules for materials, design, fabrication and installation, examination, testing, overpressure protection, marking, stamping and preparation of reports, shall expansion joints be constructed for service in Section III, Division 1, Class 1, liquid metal piping, and what additional rules shall be met when metal temperatures of such expansion joints exceed those for which allowable stress values are given in Section II, Part D, Subpart 1, Tables 2A, 2B and 4?

Reply: It is the opinion of the Committee that, for piping within the temperature range allowed for Section III, Division 1, under Section II, Part D, Subpart 1, Tables 2A, 2B and 4 or under the rules for Class 1 elevated temperature piping, the construction of expansion joints shall satisfy the rules of Subsection NB as modified by this Case. The modifications and additions in this Case are provided in the format of Subsection NB. The references to other NB paragraphs are consistent when this Case is merged with Subsection NB. Thus, a reference from one paragraph to another means from one paragraph of Subsection NB as modified by this Case to another paragraph of Subsection NB as modified by this Case. The stamping and Data Report shall indicate this Case number and the revision applied.

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-1000 INTRODUCTION

-1100 SCOPE

-1110 Rule Coverage and Definitions

(a) The rules of this Case cover only construction of Class 1 bellow-type expansion joints intended to provide additional flexibility for the thermal expansion of piping. The rules of this Case do not apply to the construction of bellows which are used as an integral part of a Code pressure vessel or which can be considered as specially welded seals, such as omega and canopy seals (NB-4360).

(b) Use of the word "bellows" shall refer only to the convoluted flexible element forming a part of the primary pressure retaining boundary, its end tangents, and end attachment welds. Subcomponents of the expansion joint covered by -3750 shall be termed "expansion joint hardware." The words "secondary pressure boundary" shall refer to the redundant bellows required in -3711.5 and its end attachment welds. The primary pressure retaining boundary shall be constructed according to the rules contained in this Case. The "secondary pressure boundary" referred to above shall be constructed according to the applicable Class 2 rules for bellows.

(c) The expansion joints covered under this Case shall include the bellows, all expansion joint hardware, including supports attached directly to the expansion joint, and the secondary pressure boundary. The installation field welds or flange bolts attaching the expansion joint to the adjacent piping are not included within this Case.

(d) Reference in this Case to "low temperatures" or "elevated temperatures" shall be considered as defined in (1), (2), and (3) below:

(1) "Low temperatures" shall be defined as metal temperatures that are within the temperature range for which allowable stress values exist in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4.

(2) "Elevated temperatures" shall be defined as metal temperatures that exceed those for which allowable stress values exist in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4 unless the requirements of (3) below are met.

(3) If the N Certificate Holder has demonstrated that elevated temperatures do not introduce significant creep effects, then the low-temperature design rules of this Case may be applied using material stress intensity values obtained from the rules for construction of Class 1 components in elevated temperature service. The experimental data or calculations based on experimental data or both shall be fully documented in the Design Report and shall demonstrate that the elevated temperature service does not introduce significant creep effects.

(e) Parts of the expansion joint may be divided into distinct zones that operate either at low or elevated temperatures, and the applicable criteria satisfied independently for each portion. However, the zone boundaries and applicable design parameters shall be fully described in the Design Report.

-1120 Temperature and Time Limits

The rules of this Case shall not be used for Class 1 expansion joints that will be subjected to combinations of service or test temperatures and times that are beyond the range for which allowable stress intensity values are given for the material. See -3741(b).

-1140 Responsibilities

The responsibilities set forth in NCA-3000 for the various Certificate Holders shall apply. In addition, the various parties involved in the construction of the expansion joints under the rules of this case have specific responsibilities as follows:

-1141 Owner's Responsibilities.

(a) Defining the fluid inertia forces in the Design Specification (-3722.1)

(b) Defining the service level for a postulated leak event in the Design Specification (-3724)

(c) Indicating in the Design Specification the type of analysis (elastic or inelastic) and expansion joint stiffness assumptions used to determine the expansion joint loads (-3742.4)

(d) Defining alternate strain limits criteria in the Design Specification (-3742.6)

(e) Defining the methodology to be used to develop life test histograms in the Design Specification [-3773.1(a)]

(f) Documenting alternative methodology to be used to develop life test histograms in the Design Specification [-3773.1(b)]

(g) Defining acceptable level of cleanliness in the Design Specification (-4140)

(h) Defining requirements for drainage in the Design Specification (-3711.9)

(i) Defining alternative of supplementary Service Level D limits in the Design Specification (-3742.4)

(j) Defining alternative methods of determining the squirm pressure in the Design Specification [-3772(d)]

-1142 N Certificate Holder's Responsibilities. The N Certificate Holder accepting overall responsibility for the piping in which the expansion joint is to be installed shall be responsible for the design of the expansion joint. The N Certificate Holder shall certify that the rules of this Case have been satisfied. This certification shall be attached to the N-5 Data Report. Additional specific responsibilities follow.

(a) Verifying that the items under -1141 have been included in the Design Specifications

(b) Establishing if low temperature or elevated temperature design rules must be applied [-1110(d)(3)]

(c) Describing zone boundaries and applicable design parameters in the Design Report [-1110(e)]

(d) Documenting installation requirements in specifications, procedures, or instructions to assure conformance with the design intent [-3649.1(c)]

(e) Evaluating imposed piping motions, piping loads, and bellows pressure thrust and spring rate loadings (-3721)

(f) Including justification in the Design Report if small deflection theory is used in the bellows analysis [-3742(b)(2)]

(g) Demonstrating by analysis or test the safety margins against instability provided in Table -3752.3(a) [-3752.3(a)]

(h) Evaluating the material's time-dependent behavior when the maximum metal temperature is an elevated temperature and documenting these evaluations in the Design Report (-3761)

(i) Including the techniques used for acceleration of time in the Design Report [-3772(d)]

(j) Including the techniques used for measurement of strain and the acceleration of time in the Design Report [-3772(e)]

(k) Reconciling surface irregularities on bellows used for life tests and including these reconciliations in the Design Report [-3772(b)]

(l) Including methods of acceleration in the Design Report when accelerated testing is used in the life test [-3773.1(a)]

(m) Including in the Design Report the stress calculations and damage evaluations required to demonstrate that the basic test histogram satisfies the requirements of -3774.2 [-3774.*3(a)]*

(n) Describing and documenting in the Design Report the design demonstration testing (-3775)

(o) Certifying by a Registered Professional Engineer the completeness and accuracy of the data included in Item *(*a), (-3775)

(p) Documenting the cleanliness requirements in specifications, procedures, or instructions (-4140)

(q) Defining the "effective restoration" of material properties (-4212)

(r) Verifying that the system has been acceptably constructed with respect to design (-4833.1)

(s) Defining the requirements for permanent bellows protection covers (-3711.2)

(t) Reconciling deviations from bellows tolerance requirements [-4224.1(a)]

(u) Considering installation-induced joint rotations in the expansion joint design [-3649.1(b)]

(v) Obtaining approval from the Owner of tolerance deviations in the as-built bellows [-4224.1(a)]

-1143 Authorized Nuclear Inspector's Responsibilities. The responsibilities of the Authorized Nuclear Inspector are set forth in NCA-5200. These include witnessing of acceptance testing (-3785).

-1144 Responsibilities of the Certificate Holder (N or NA) Responsible for Installation.

(a) Inspecting bellows expansion joint assemblies prior to installation (-4821)

(b) Preparing the procedures for field handling and storage operations and providing them to the N Certificate Holder accepting overall responsibility for the piping (-4822)

(c) Verifying cleanliness prior to installation (-4823)

(d) Preparing installation procedure and providing it to the N Certificate Holder accepting overall responsibility for the piping (-4831)

(e) Complying with installation requirements of (-4832)

-1145 Expansion Joint Fabrication. The expansion joint shall be fabricated in accordance with Design Drawings and Specifications and in accordance with the rules of this Case. The Certificate Holder accepting overall responsibility for the piping may fabricate the expansion joint or subcontract the fabrication to another Certificate Holder (N or NPT) whose Certificate of Authorization includes the scope of work to be performed. Fabrication of the expansion joint shall comply with the requirements of -2800, -4131 thru -4424, -5000, -8100(a) and -8100(b).

-2000 MATERIALS

-2121 Permitted Materials

(a) Except as modified by this Case, all materials shall comply with the rules of NB-2000.

(b) When pressure-retaining materials will be used in service at elevated temperatures, the material rules for Class 1 components in elevated temperature service also shall be satisfied.

(c) Materials to be used in the fabrication of expansion joint hardware that are associated with the pressure-retaining, load transfer, or motion limiting functions of an expansion joint shall be considered pressure-retaining material. Excluded from this consideration are items such as bearings, bushings, seals, packing, lubricating, and cladding materials.

(d) Materials to be used in the fabrication of the primary pressure-retaining bellows also shall satisfy the requirements of -2800.

(e) Materials for the secondary pressure boundary shall satisfy NC-3649.1(d). When these materials will be used in service at elevated temperature, the material rules for Class 2 components in elevated temperature service shall be satisfied.

-2125 Materials Data. Materials data to be used in the design analysis or computation of acceleration parameters in the design demonstration tests are presented in Appendix I and the rules for construction of Class 1 components in elevated temperature service.

Table -2830-1
Permissible Bellows Material Specifications (Piping, Tubing)

Material	Notes	Spec. No.	Product Form	Grades
Type 304SS and 316SS	(1),(3)	SA-213	Seamless Tube	TP304, TP304H TP316, TP316H
Type 304LSS, 316LSS, and 321SS	(2),(3)	SA-213	Seamless Tube	TP304L, TP316L TP321, TP321H
Type 304SS and 316SS	(1),(3)	SA-376	Seamless Pipe	TP304, TP304H TP316, TP316H
Type 304LSS, 316LSS, and 321SS	(2),(3)	SA-376	Seamless Pipe	TP304L, TP316L TP321, TP321H
Ni-Cr-Fe (Alloy 600)	(2),(3)	SB-167	Seamless Pipe & Tube	All Conditions
Ni-Cr-Mo-Cb (Alloy 625)	(2),(3)	SB-444	Seamless Pipe & Tube	All Conditions
Ni-Fe-Cr (Alloy 800H)	(1),(3)	SB-407	Seamless Pipe & Tube	Solution Treated

NOTES:
(1) These materials are permitted in service at elevated temperature provided they satisfy the material rules for Class 1 components in elevated temperature service.
(2) These materials are not permitted in service at elevated temperatures.
(3) The hydrostatic test called out in the material specification is not required.

-2800 BELLOWS TUBE MATERIALS

-2810 Scope of Principal Terms Employed

(a) The term "bellows tube" is defined as the tubular product form to be convoluted into a bellows that is either procured from a Material Manufacturer or Material Supplier, or, fabricated by the N or NPT Certificate Holder from other material product forms in accordance with the rules of this Case.

(b) The term "lot" refers to bellows tubes of the same diameter, thickness, and condition (temper) that are made from the same product form (plate, strip, sheet, pipe, tube) of the same heat of material.

-2820 General Requirements for Bellows Tubes

The bellows tube may either be a seamless or welded tube. The bellows tube must comply with the requirements of this subsubarticle. In addition, the seamless bellows tube and the welded bellows tube must comply with the requirements of -2830 and -2840, respectively.

-2821 Surface Finish. The surface finish of bellows tubes shall be either "2B", "2D", or "bright annealed" as defined in ASTM A480.

-2822 Grain Size. The grain size of bellows tubes shall be 5 or finer for tubes fabricated from plate stock, and 7 or finer for seamless tubes and tubes fabricated from sheet or strip. The grain size number shall be determined by the "comparison" method in ASTM E112.

-2823 Circumference Tolerance. The tolerance on the bellows tube circumference shall be the larger of ±0.02 in. or ±0.002 times the nominal outside tube circumference.

-2824 Edge Cuts. The bellows tube shall include no material whose grain size or material properties are altered by the edge cutting process.

-2825 Qualification. One tube from each lot of tubes shall be formed with two or more convolutions. The convolution depth shall be equal to or greater than the nominal bellows convolution depth and the convolution pitch shall be less than or equal to the nominal bellows convolution pitch. One convolution shall be subjected to the surface and cross-section examinations in (a) and (b) below:

(a) Surface Examination — The internal and external surfaces of the convolution shall meet the liquid penetrant acceptance criteria of -5350.

(b) Cross Section Examination — One longitudinal section will be taken through the bellows parent material and an additional longitudinal section shall be taken through a bellows longitudinal weld, if such welds exist. The sections shall be polished and etched and examined at 100 × magnification for cracks. Discernible surface cracks or internal cracks shall be cause for rejection of the lot of tubes.

-2830 Acceptance Criteria for Seamless Bellows Tubes

An acceptable seamless bellows tube is one that satisfies the requirements of -2820 and conforms to one of the material specifications listed in Table -2830-1.

-2840 Acceptance Criteria for Welded Bellows Tubes

An acceptable welded bellows tube is one that satisfies the requirements of -2820 and conforms to the requirements of -2841 and -2842 below.

-2841 Material for Welded Bellows Tubes. Material (plate, sheet, or strip) for welded bellows tubes shall conform to the requirements of one of the material specifications listed in Table -2841-1.

-2842 Longitudinal Tube Welds

-2842.1 Weld Qualification. Weld procedures and welders shall be qualified in accordance with Section IX, plus the applicable requirements in Section III, Division 1.

-2842.2 Weld Type and Location. Only full penetration butt welds, single or double welded, with or without filler metal are permitted for the longitudinal tube welds. GTAW, plasma, EB, are the only allowable processes. The use of flux is prohibited. If more than one weld is required to fabricate the desired tube diameter, then welds shall be equally spaced about the tube diameter within ±10 deg. Peening of the longitudinal tube weld is not permitted.

-2842.3 Alignment Requirements. The rules of NB-4230 shall apply to the longitudinal tube welds except that the maximum offset shall not exceed the greater of $\frac{1}{8}$ t or 0.005 in. The welding of temporary attachments shall not be permitted except that weld start and end tabs may be used but shall be mechanically removed at completion of welding.

-2842.4 Unfinished Weld Geometry. The thickness through the weld bead, as welded, shall be between 1.05 and 1.20 times the adjacent metal thickness, however, the additional thickness at the weld shall not be less than 0.005 in. nor be greater than 0.01 in. Material thickness greater than $\frac{1}{8}$ in. may be mechanically removed (grinding, machining, etc.) to meet this requirement, provided -2856 is additionally satisfied. Undercutting or depressions below the material surface are not allowed.

-2842.5 Weld Finishing. Longitudinal tube welds shall be planished for tube thicknesses equal to or less than $\frac{1}{8}$ in. by simultaneously rolling under pressure both the inside and outside surfaces of the weld. The weld thickness shall be planished to within 5% of the thickness of the adjacent base metal. No undercutting is allowed. Transition angles between the parent material and the weld nuggets shall not exceed 7 deg.

-2850 Bellows Tube Examinations

-2851 Liquid Penetrant Examination. The bellows tube shall satisfy the requirements of either (a) or (b) below.

(a) The material (plate, sheet, strip) for welded bellows tube shall satisfy the liquid penetrant criteria of -5350. After welding the tube and before weld finishing, the bellows tube shall be determined by visual examination to be free of injurious defects such as notches, crevices, material buildup or upsetting, weld spatter, which may serve as points of local stress concentration. Suspect surface areas shall be further examined by liquid penetrant and visual examination in accordance with -5350 and -5390, respectively. Before weld finishing, longitudinal tube welds and adjacent metal for at least $\frac{1}{2}$ in. on either side of the weld shall be examined by the liquid penetrant method. The acceptance standards of -5350 shall be used.

(b) The bellows tube shall be fully inspected by liquid penetrant and visual surface examination and shall meet the criteria contained in -5350 and -5390, respectively. For a welded bellows tube, the inspection shall be performed prior to weld finishing.

-2852 Radiographic Examination. After weld finishing, longitudinal tube welds shall be 100% radiographically examined in accordance with NB-5110, except the acceptance standards of -5320 shall be used.

-2860 Defect Removal and Repair

(a) Defects in bellows tube parent material may be removed only by abrasive material-removal processes. The abraded area shall be smoothly blended into the adjacent areas and have a final surface finish of 32 micro-inches RMS or better. See -4214.

Table -2841-1
Permissible Material for Welded Bellows Tubes (Plate, Sheet, Strip)

Material	Notes	Spec. No.	Product Form	Grades
Type 304SS and 316SS	(1)	SA-240	Plate, Sheet, Strip	TP304, TP304H TP316, TP316H
Type 304LSS, 316LSS, and 321SS	(2)	SA-240	Plate, Sheet, Strip	TP304L, TP316L TP321, TP321H
Ni-Cr-Fe (Alloy 600)	(2)	SB-168	Plate, Sheet, Strip	All Conditions
Ni-Cr-Mo-Cb (Alloy 625)	(2)	SB-443	Plate, Sheet, Strip	All Conditions
Ni-Fe-Cr (Alloy 800H)	(1)	SB-409	Plate, Sheet, Strip	Solution Treated

NOTES:
(1) These materials are permitted in service at elevated temperature provided they satisfy the material rules for Class 1 components in elevated temperature service.
(2) These materials are not permitted in service at elevated temperatures.

(b) Defects in longitudinal tube welds may be removed by abrasive material removal processes or may be repaired by welding. The accumulated length of weld repairs during fabrication shall be limited to 2% of the total weld length, and the number of repetitive grindings of a specific weld area shall be limited to two. The repaired weld must conform to the weld geometry requirements of -2842.4 and -2842.5. The repaired defects shall be reexamined per -2851 and -2852.

-3000 DESIGN

-3600 PIPING DESIGN

-3620 Design Considerations

-3624 Loadings, Displacements, and Restraints. The design of piping shall take into account the forces and moments resulting from thermal expansion and contraction, equipment displacements and rotations, the restraining effects of hangers, supports and other localized loadings, and the flexibility and pressure thrust effects of expansion joints.

-3649.1 Expansion Joints. Metal bellows expansion joints may be incorporated in the design of piping if they conform to the requirements of -3700 and the following.

(a) The unrestrained hydrostatic end force caused by fluid pressure, and the loads caused by bellows spring force and hardware friction, shall be considered in the piping design. Whenever the hydrostatic end force of an unrestrained expansion joint is imposed on the piping, design features shall be provided to control or limit excessive displacements of the piping. Piping restraints, cross connections of the expansion joint ends, or other means shall be provided where required. Restraints attached to an expansion joint shall meet the requirements in -3751(c).[1]

(b) The N Certificate Holder accepting overall responsibility for the piping shall consider the effect of variations in equipment position and fabrication tolerances when establishing procedural requirements for installation [-3649.1(c)] of the piping. Provisions shall be included in the design to permit compensation for dimensional variations in the system in order to avoid the imposition of piping strain which may result in unplanned motion of the joint assembly. Installation induced joint motions due to final closure weld shrinkage and fitup tolerances assumed in the system design analysis shall be considered in the design of the expansion joint.

(c) The N Certificate Holder accepting overall responsibility for the piping shall document in specifications or instructions all installation requirements necessary to assure conformance with the design intent (-4831) and to the detail needed to permit an engineering verification of such compliance (-4833).

(d) An expansion joint assembly may be designed with an initial (preset) lateral offset, length change or angular rotation to reduce equipment reactions, or increase the working range of the joint assembly. However, presetting an expansion joint assembly shall not be combined with a preloaded condition in the connected piping, other than the reaction loads resulting from release of temporary restraints on the preset expansion joint.

(e) The expansion joint shall be located in areas accessible for scheduled inservice inspection, maintenance, removal, and replacement.

-3700 EXPANSION JOINT DESIGN

-3710 General Design Requirements

In the cases of conflict between NB-3000 or rules governing elevated temperature design of Class 1 components and -3700, the requirements of -3700 shall apply.

-3711 Physical Requirements

-3711.1 Flow Sleeves. Flow sleeves or other devices shall be utilized which reduce flow-induced vibration, thermal shock and/or erosion of the bellows convolutes.

-3711.2 Bellows Protection Covers. The N Certificate Holder shall define the requirements for permanent bellows protection covers. Temporary protection covers may be required to satisfy -4832(e).

-3711.3 Pressure Reinforcements. Rules for designs employing pressure reinforcement in the convoluted portion of the primary pressure retaining bellows are currently under preparation by the Committee. In the interim, the coverage of this Case is limited to unreinforced designs.

-3711.4 Position Indicating Devices. Expansion joint assemblies shall be provided with a position indicating device(s) that shall include a scale of the full range of movement(s) available, and both the installed and normal operating position(s) planned in the design.

-3711.5 Redundancy. Each primary pressure retaining bellows, including end connections, shall be enclosed by a redundant bellows that provides a secondary pressure boundary. Special design features shall be employed that provide the capability of monitoring both the primary and secondary pressure boundaries for leakage.

-3711.6 Openings in and Connections to Bellows. Openings and connections to bellows expansion elements are prohibited.

[1] The EJMA Standards may be used as a guide in determining anchor and guide layouts: Standards of the Expansion Joint Manufacturers Association, Inc., 4th Ed., 1975. Expansion Joint Manufacturers Association, 131 Madison Ave., New York, N.Y. 10017.

-3711.7 Pinned Link and Hinged Expansion Joints. Pinned link, hinged, or similar expansion joints designs intended to angulate in a single plane, may only be used where the piping is restrained or guided to limit movement to the designed direction. Where a hinged design is provided, the joint assembly shall be clearly and permanently marked to show the proper installation orientation in the piping system.

-3711.8 Flow Direction. Expansion joints designed for a specific flow direction shall be permanently marked to show the direction of flow. Marking on the bellows is prohibited.

-3711.9 Drainage. Requirements shall be defined in the Design Specification for drainage capabilities.

-3711.10 Liquid Metal Service. For liquid metal service, the Design Specification shall require suitable provisions such as heat tracing to avoid damage to bellows on heatup due to expansion of liquid metal entrapped inside convolutions or between convolutions and an internal flow sleeve.

-3711.11 Multi-ply Bellows. Rules for designs employing multi-ply primary pressure retaining bellows are under development by the Committee. In the interim, the coverage of this Code Case is limited to single ply designs.

-3711.12 Handling Devices. Special design features shall be provided for handling of the expansion joint during installation in a manner not detrimental to the joint's capability. See -4800.

-3720 Loadings

-3721 Loading Criteria. The provisions of NB-3110 shall apply. In addition, the N Certificate Holder shall evaluate imposed piping motions (including installation induced motions when specified), piping loads, and bellows pressure thrust and spring rate loadings.

-3722 Dynamic Effects

-3722.1 Inertia. The Design Specification shall define the fluid inertia forces such as those caused by pulsating flow, flow turbulence, fluid hammer, or momentum change.

-3722.2 Vibration. When mechanical excitations and frequencies are specified in the Design Specification, the expansion joint shall be designed so that all significant vibration modes have natural frequencies at least 50% lower or higher than the excitation frequency unless all significant vibratory loadings are included in the Design Demonstration Testing (-3770). Specific consideration shall be given to the transverse (lateral) beam and axial (accordion) modes. The effect of fluid mass shall be included in the computations.

-3723 Weight Effects. Expansion joints shall be designed to accommodate the live load effects of any contained fluid, the fixed weights of adjacent piping and insulation, and other weight loads transferred to the expansion joint.

-3724 Postulated Leak. The expansion joints shall be designed to withstand the pressure due to a postulated leak of either the primary pressure boundary or secondary pressure boundary under an application of the highest service pressure. The Design Specification shall define the service level for this event.

-3730 Expansion Joint Design and Analysis Criteria

The design and analysis of expansion joints, when subjected to the individual or combined effects of the loadings defined in -3720, shall be performed in accordance with this Subsubarticle. A Design Report shall be prepared (and certified by a Registered Professional Engineer knowledgeable in expansion joint design) in sufficient detail to show that the design criteria of -3730 have been met when the expansion joint is subjected to the loadings of -3720.

-3731 Design of Primary Pressure Retaining Bellows. The design of primary pressure retaining bellows (-3711.5) when subjected to the individual or combined effects of the loadings defined in -3720, shall be in accordance with the rules of -3740 and shall meet the testing requirements of -3770 and -3780.

-3732 Design of Expansion Joint Hardware. The design of expansion joint hardware when subjected to the individual or combined effects of the loadings defined in -3720, shall be in accordance with the rules of -3750 and shall meet the testing requirements of -3770 and -3780.

-3733 Design of Secondary Pressure Boundary. The design of the secondary pressure boundary (-3711.5) when subjected to the individual or combined effects of the loadings defined in -3720, shall be in accordance with -3760 and meet the testing requirements of -3770 and -3780.

-3740 Primary Pressure Retaining Bellows Design

-3741 General Requirements.

(a) Bellows constructed to this Case shall have convolution cross section shapes that are essentially U-shaped.

(b) The stress intensity limits and material data in Appendix I and the rules for construction of Class 1 components in elevated temperature service shall be used for bellows.

-3742 Analytical Requirements.

(a) In satisfying the requirements of -3742, stress intensities (NB-3215) shall be calculated based on the classifications presented in Table -3742-1. When specific

classification of a stress does not appear in Table -3742-1, the stress shall be classified in accordance with the guidelines in NB-3200.

(b) Except for calculation of P_m in the convolutes, the analytical stress calculations used to demonstrate compliance with the requirements of -3742 shall satisfy the requirements of (1) through (5) below:

(1) The analytical geometry model used must consider localized thinning and shape variations. The convolute geometry, thinning, and shape variations used in the analysis shall be reconciled with those of the delivered bellows. Reconciliation shall be demonstrated by the cross-sectioning of a replicate bellows. A replicate bellows is defined as a bellows satisfying the similitude requirements contained in -3771 and the acceptance test of -3782. Appendix P of AFRPL-TR-68-22[2] may be used as a guide to the methodology of sectioning and measurement.

(2) The stress analysis of the bellows shall consider the effect of shape change due to pressurization. If small deflection theory is used in the bellows analysis, justification shall be included in the Design Report.

(3) The method of analysis shall include the enhancement of motion loadings in angulating bellows due to pressure loadings.

(4) When computing displacement induced stresses, the analytical model shall address the effect of variations in stiffness of individual convolutions in order to assess the possibility of strain concentration in a weak convolute and to assess disproportionate distribution of motion between convolutes.

(5) The stresses due to twisting motions imposed on the bellows shall be considered simultaneously with other stresses. These stresses may be caused by gimbaling about two axes, misalignment of hinge axes, or pin clearances.

-3742.1 Design Loadings.[3] The calculated linear elastic stress intensity values for the Design Loadings shall satisfy the following general primary-membrane stress intensity limit.

$$P_m \le S_m \text{ (for the tempuratures less than 800°F)} \tag{1}$$

$$P_m \le S_0 \text{(for elevated temperatures)}$$

P_m shall be calculated in the convolutes using:

$$P_m = \frac{p\bar{A}}{A_c} + 0.5p$$

where

$\bar{A}$ = maximum cross-sectional area of the fluid enclosed by any single convolute (see Figure -3742.1-1). This shall include the maximum increase in area due to pressure and motion loadings.

A_c = cross-sectional area of the convolute used to define A (see Figure -3742.1-1).

P = design pressure.

The bellows dimensions used in the above definitions shall be reconciled with those of the delivered bellows. Reconciliation shall be demonstrated by the cross-sectioning of a replicate bellows as defined in -3742(b)(1).

In determining the classification (P_m or P_L) of the primary membrane stress intensity in the end tangents, the geometry-stress intensity guidance presented in NB-3213.10 shall be applied over the end tangent length.

-3742.2 Level a and B Service Limits. The calculated linear elastic stress-intensity values for Level A and B Service Limits [NCA-2142.2(b)(1) and (2)] shall satisfy the conditions of (a) through (d) below.

(a) The general primary-membrane stress intensity, derived from P_m, for Level A and B Service Limits, shall not exceed S_{mt}.

$$P_m \le S_{mt} \tag{2}$$

where S_{mt} is determined for the time, *t*, corresponding to the total duration of the particular loading during the entire service life, and for the temperature, *T*, corresponding to the maximum wall-averaged temperature that occurs during the particular loading.

P_m in the convolutes shall be calculated in accordance with the equations given in -3742.1 for Level A and B Service Loadings. In determining the classification (P_L or P_m) of the primary membrane stress intensity in the end tangents, the geometry-stress intensity guidance presented in NB-3213.10 shall be applied over the end tangent length.

(b) When time, *t*, in (a) above is less than the total specified service life of the component, and *T* in (a) above is an elevated temperature, the cumulative effect of all the loadings shall be evaluated by the use-fraction sum presented below.

$$\sum_i \left(\frac{t_i}{t_{im}}\right) \le B \tag{3}$$

where

B = use-fraction factor and is equal to 1.0 (or less if so specified in the Design Specification)

[2] T. M. Trainer et al., "Final Report on the Development of Analytical Techniques for Bellows and Diaphragm Design," AFRPL-TR-68-22, Battelle Memorial Institute, March 1968.

[3] Due to the complex nature of expansion joint operation and the possibility that motion-induced stresses may govern the design, excessive design loadings should be avoided as they may adversely affect the development of the best bellows design for actual service conditions.

Table -3742-1
Classification of Stress Intensity in Bellows

Location	Origin of Stress	Type of Stress [Note (1)]	Classification
Convolutions	Pressure, mechanical loads or weight	Membrane	P_m, P_L
		Bending	P_b
	End displacements,[Note (3)] axial temperature gradient	Membrane	Q
		Bending	
	Through-the-wall temperature gradient	Equivalent linear stress	Q
		Nonlinear portion of stress distribution	F
Any	Any	Stress concentration (notch effect)	F
End Tangents	Pressure, mechanical loads or weight	Membrane remote from discontinuities	P_m, P_L
		Bending remote from discontinuities	P_b
		Membrane at discontinuity	P_L
		Bending at discontinuity	Q
	End displacements,[Note (3)] axial temperature gradient	Membrane	Q
		Bending	
Reinforcement [Note (2)]	Pressure	Membrane	P_m, P_L
		Bending	P_b
	Thermal gradient	Equivalent linear stress	Q
		Nonlinear portion of stress	F

NOTES:
(1) As defined in NB-3200.
(2) Reinforcement placed at the end tangents to resist a portion of the pressure loading.
(3) Displacements imposed on the ends of the expansion joint due to piping thermal expansion or other effects.

t_i = the total duration of a specific loading resulting in a stress intensity, P_{mi}, at elevated temperature, T_i, during the entire service life of the component. Note, Σt_i must equal the elevated temperature service life of the component.

t_{im} = maximum allowed time under a specific loading resulting in a stress intensity, P_{mi}. It is determined by entering the S_t-vs-time graphs with the value P_{mi}.

(c) The combined primary-membrane-plus-bending stress intensities, derived from P_L and P_b for Level A and B Service Limits shall not exceed the smaller of $1.5K_1S_m$ and K_1S_t when combined in the following manner:

$$P_L + P_b \leq 1.5K_1S_m \tag{4}$$

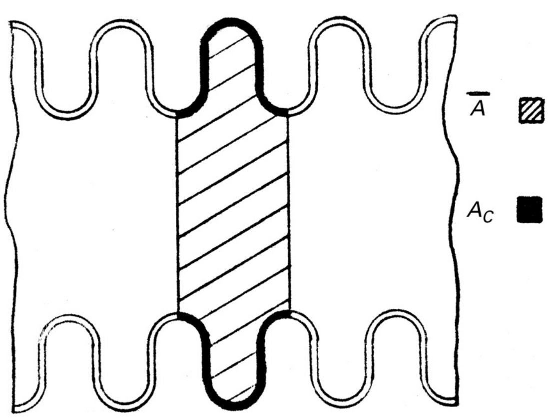
and

$$P_L + \frac{P_b}{K} \leq K_1S_t \tag{5}$$

where

K_1 is a shape effect factor. Values for this factor are under development by the Committee. In the interim, K_1 shall be set equal to unity. S_m and S_t are determined for the time, *t,* that corresponds to the total duration of the particular loading during the entire service life, and for temperature, *T,* corresponding to the maximum wall-averaged temperature that occurs during the particular loading. When *T* is not an elevated temperature, equation (5) need not be satisfied.

Figure -3742.1-1
Definition of $\overline{A}$, and A_c



$$\overline{K} = \begin{cases} 1.25, \text{for the belows 1} \\ \dfrac{+K, \text{ for reinforcement}}{2} \end{cases}$$

The factor, K, is the section factor for the cross section of the reinforcement being considered. Values of K for various sections are given in Table A-9221(a)-1.

(d) When t in (c) above is less than the total service life of the component, and T in (c) above is an elevated temperature, the cumulative effect of all the $(P_L + P_b/\overline{K})$ affected loadings shall be evaluated in the following manner:

$$\sum_i \frac{t_i}{t_{ib}} \leq 1.0 \tag{6}$$

where

t_i = the total duration of a specific loading resulting in a stress intensity, $(P_L + P_b/\overline{K})_i$, at elevated temperature, T_i, during the entire service life of the component. Note, Σt_i must equal the elevated temperature service life of the component.

t_{ib} = maximum allowed time under a specific loading resulting in a stress intensity, $(P_L + P_b/\overline{K})_i$. It is determined by entering the S_t-vs-time graphs with the value $(P_L + P_b/\overline{K})/K_1$.

-3742.3 Level C Service Limits. The elastically calculated stress-intensity values under Level C Service Limits [NCA-2142.2(b)(3)] shall satisfy the conditions of (a) through (d) below.

(a) The general primary-membrane stress intensity, derived from P_m for Level C Service Limits, shall not exceed the smaller of 1.2 S_m and 1.0 S_t

$$P_m \leq \begin{cases} 1.2\, S_m \\ 1.0\, S_t \end{cases} \tag{7}$$

where S_m and S_t are determined for the total duration of the particular loading during the entire service life, and for temperature, T, corresponding to the maximum wall-averaged temperature that occurs during the particular loading. When T is not an elevated temperature, the 1.0 S_t limit of equation (7) need not be met.

P_m in the convolutes shall be calculated in accordance with the equations given in 3742.1 for Level C Service Loadings. In determining the classification (P_L or P_m) of the primary membrane stress intensity in the end tangents, the geometry-stress intensity guidance presented in NB-3213.10 shall be applied over the end tangent length.

(b) In addition, when T in (a) above is an elevated temperature, the use-fraction sum associated with general primary-membrane stresses, presented in -3742.2(b), shall be satisfied for all increments of primary loading subject to Level A, B, and C Service Limits.

(c) The combined primary-membrane-plus-bending stress intensities, derived from P_L and P_b for Level C Service Limits, shall not exceed the smaller of 1.8 $K_1 S_m$ and $K_1 S_t$ when combined in the following manner:

$$P_L + P_b \leq 1.8\, K_1 S_m \tag{8}$$

and

$$P_L + \frac{Pb}{\overline{K}} \leq K_1 S_t \tag{9}$$

where, K_1 and $\overline{K}$ are defined in -3742.2(c), and S_m and S_t are determined for the time that corresponds to the total duration of the particular loading during the entire service life, and for temperature, T, corresponding to the maximum wall-averaged temperature that occurs during the particular loading. When T is not an elevated temperature, equation (9) need not be satisfied.

(d) In addition, when T in (c) above is an elevated temperature, the use-fraction sum associated with primary-membrane-plus-bending stresses, presented in -3742.2(d), shall be satisfied for all increments of primary loading subject to Level A, B, and C Service Limits.

-3742.4 Level D Service Limits. Unless alternative or supplementary criteria are defined in and made applicable by the Design Specification, the primary stress intensity limits for Level D Service Limits [NCA-2142.2(b)(4)] are presented in (a) through (d) below. The type of analysis (elastic or inelastic) and expansion joint stiffness assumptions used to determine the expansion joint loads shall be indicated in the Design Specification (see F-1322.1).

(a) The general primary-membrane stress intensity, derived from P_m for Level D Service Limits, shall not exceed the smaller of $^2/_3\, S_R$ and one of the Level D Service Limits in Appendix F:

$$P_m \leq \begin{cases} \text{limit in Appendix F for} (P_m) \\ ^2/_3\, S_R \end{cases} \tag{10}$$

where

S_R is determined for the time, t, corresponding to the total duration of this event, and for the temperature, T, corresponding to the maximum wall-averaged temperature that occurs during the event. When T is not an elevated temperature, the $^2/_3\, S_R$ limit need not be met.

P_m in the convolutes shall be calculated in accordance with the equations given in -3742.1 for Level D Service Loadings. In determining the classification (P_L or P_m) of the primary-membrane stress intensity in the end tangents, the geometry-stress intensity guidance presented in NB-3213.10 shall be applied over the end tangent length.

(b) In addition, when T in (a) above is an elevated temperature, the use-fraction sum associated with general primary-membrane stresses, presented in -3742.2(b), shall be satisfied for all service loadings (Level A, B, C, and D Service Limits), but with the following modification: use a stress value of 1.5 P_{mi}(instead of P_{mi}) and obtain the t_{im} values from S_R curves (instead of S_t curves).

(c) The combined primary-membrane-plus-bending stress intensities, derived from P_L and P_b for Level D Service Limits, shall not exceed the smaller of $^2/_3\ K_1 S_R$ and one of the Level Service D Limits in Appendix F (for primary membrane-plus-bending) when combined in the following manner:

$$P_L + \frac{P_b}{\overline{K}} \leq \begin{cases} \text{limit in Appendix F for}(P_L + P_b) \\ ^2/_3 K_1\, S_R \end{cases} \tag{11}$$

where K_1 and $\overline{K}$ are defined in -3742.2(c) and S_R is determined for the time that corresponds to the total duration of this event, and for temperature, T, corresponding to the maximum wall-averaged temperature that occurs during this event. When T is not an elevated temperature, the $^2/_3\ K_1 S_R$ limit need not be met, and $\overline{K}$ shall be taken as unity.

(d) In addition, when T in (c) above is an elevated temperature, the use-fraction sum associated with primary-membrane-plus bending stresses in bellows, presented in -3742.2(d), shall be satisfied for all service loadings, but with the following modification: use a stress value of

$$1.5\left(P_L + \frac{p_b}{\overline{K}}\right)K_1 \text{ (instead of}(P_L + P_b/\overline{K})/K_1$$

and obtain the t_{ib}values from S_R curves (instead of S_T curves).

-3742.5 Test Loadings. The definition of Test Loadings in NCA-2145 shall be considered to include the acceptance testing required in -3780 and NB-6000 pressure tests of the piping system in which the expansion joint is installed. Pressure tests shall be considered as a Level B Service loading. During any static pressure testing or in satisfying the acceptance testing requirements of -3780, the conditions in (a) and (b) below shall be met:

(a) The general primary-membrane stress intensity, shall not exceed 90% of the tabulated yield strength at temperature:

$$p_m \leq 0.9 S_y \tag{12}$$

where S_y is determined at the test temperature.

P_m in the convolutes shall be calculated in accordance with the equations given in -3742.1. In determining the classification (P_L or P_m) of the primary-membrane stress intensity in the end tangents, the geometry-stress intensity guidance presented in NB-3213.10 shall be applied over the end tangent length.

(b) The primary-membrane-plus-bending stress intensity shall not exceed 135 percent of the minimum yield stress at temperature when combined in the following manner:

$$P_L + \frac{p_b}{K} \leq 1.35 K_1 S_y \tag{13}$$

where

K_1 and $\overline{K}$ are defined in -3742.2(c) with $\overline{K}$ set equal to 1.0 when the maximum wall-averaged temperature during testing is not an elevated temperature.

-3742.6 Strain Limits. The strains resulting from the specified operating conditions shall be considered. This consideration shall include the effects of ratcheting. Either the criteria presented in subparagraphs (a) through (h) below, or the Pressure Test of -3772(e), shall be used for all loadings under Level A, B, and C Service Limits unless alternate acceptance criteria are provided in the Design Specification.

(a) The maximum accumulated inelastic strain shall not exceed the values in (1)–(3) below:

(1) Strains averaged through the thickness; 1%.

(2) Strains at the surface, due to an equivalent linear distribution of strain through the thickness; 2%.

(3) Local strains at any point; 5%.

The above limits apply to computed strains accumulated over the expected operating lifetime of the component under consideration, and computed for some steady-state period at the end of this time during which significant transients are not occurring. These limits apply to the maximum positive value of the three principle strains. A positive strain is defined as one for which the length of the element in the direction of the strain is increased. The principal strains are computed for the strain components (ε_x, ε_y, ε_z, ε_{xy}, ε_{xz}, ε_{yz}). When the strain is computed at several locations through the thickness, the strains are first averaged and linearized on a component level and then combined to determine the principal strains for comparison to the limits on average and surface strains defined above. The limits for local strains are based on the computed strains at the point of interest.

Inelastic strains accumulated in a weld region, except as permitted below, shall not exceed one-half the strain values for the parent material. When longitudinal seam welds in bellows tubes have been planished in accordance with -2856, the strain values for the parent material may be used.

(b) When the maximum wall-averaged temperature during the entire service life of the bellows is not an elevated temperature, the strain limits in (a) are not applicable, and the requirements of either NB-3222.2 plus NB-3222.5, NB-3228.1, or NB-3228.3 shall be met with the following modifications:

(1) Use of NB-3228.1 shall be in lieu of satisfying only the strain and deformation limits of -3742.6.

(2) The deformations which occur prior to shakedown, defined in NB-3228.1(b), shall be limited such that the maximum change in spacing between convolutions does not exceed 7%.

(3) NB-3228.1(c) does not apply.

(4) NB-3228.3(c) does not apply.

(5) The K_e values defined in NB-3228.3(b) shall be used to multiply the motion ranges used in the Life Tests of -3773.

(c) When the maximum wall-averaged temperature during the entire service life of the bellows is an elevated temperature, the strain limits of (a) are considered to have been satisfied if the requirements of (b) are met and, in addition, the requirements of (1) through (3) below are satisfied:

(1)

$$\sum_i \frac{ti}{t_{id}} \leq 0.1$$

where

t_i = total duration of time during the service lifetime that the metal is at temperature, T_i. Note that the service lifetime shall never be greater than the sum of all t_i.

t_{id} = maximum allowable time as determined by entering S_R curves at temperature T_i and a stress value of 1.5 times the S_y associated with T_i, denoted as 1.5 $S_{y/Ti}$. If 1.5 $S_{y/Ti}$ is above the stress values provided in the S_R curves, this test cannot be satisfied. When 1.5 $S_{y|Ti}$ is below the lowest stress value provided in the S_R curves, the constant temperature line may be extrapolated to larger t_{id} values using the highest slope on the S_R curves for that material.

(2)

$$\sum_i \epsilon_i \leq 0.2\%$$

where ε_i is the creep strain that would be expected from a stress level of 1.25 $S_{y|Ti}$ applied for the total duration of time during the service lifetime that the metal is at T_i. When the design lifetime is separated into several time periods, then the service lifetime shall not be greater than the sum of all the time periods. That is:

$$\sum_i t_i/T_i \geq \text{service lifetime}$$

(3) For the $3S_m$ limit in NB-3222.2, use the lesser of $3S_m$ and $3\overline{S}_m$. For the S_m values in NB-3228.1, use the lesser of S_m and $3\overline{S}_m/3.3S_m = (1.5S_m + S_{rH})$ when only one extreme of the stress difference (that produces the maximum range of the primary plus-secondary stress intensity, $P + Q$) occurs at an elevated temperature.

$3\overline{S}_m = (S_{rH} + S_{rC})$ when both extremes of the stress differences (that define the maximum range of $P + Q$) occur at elevated temperatures.

S_{rH}, S_{rC} = relaxation strengths associated with the temperatures at the hot and cold extremes of the stress cycle. The hot temperature condition is defined as the maximum operating temperature of the stress cycle. The hot time is equal to the portion of service life when wall-averaged temperatures exceed 800°F (427°C). The cold temperature is defined as the colder of the two temperatures corresponding to the two stress extremes in the stress cycle. The cold time is again equal to the portion of service life when wall-averaged temperatures exceed 800°F (427°C).

In this criterion, total service life may not be further subdivided into temperature-time blocks. The two relaxation strengths, S_{rH}; and S_{rC}, may be determined by performing a pure uniaxial relaxation analysis starting with an initial stress of 1.5 S_m and holding the initial strain throughout the time interval equal to the time of service above 800°F (427°C).

(d) When the maximum wall-averaged temperature during the entire service life is an elevated temperature, inelastic analysis to determine accumulated strains shall be used in conjunction with (a) to demonstrate structural integrity unless any of the elastic methods of (f) through (h) or (c) has demonstrated compliance. The strain calculations required for an inelastic analysis shall satisfy the requirements of -3742(b) with the word "stress" replaced by "strain."

(e) When elastic analyses are used, the strain limits of (a) are considered to have been met if the conditions of any one of (f), (g), or (h) below is satisfied. The stress calculations required for an elastic analysis shall satisfy the requirements in -3742(b).

In addition, the following guidelines and definitions in (1) through (5) below shall be used in (f), (g), or (h) below:

(1) An individual cycle, as defined in the Design Specification cannot be split into several subcycles to satisfy these requirements.

(2) At least one cycle must be defined which includes the maximum secondary stress range, Q_r, and the maximum value of $\left(P_L + P_b/\overline{K}\right)$ which occurs during *all* Loadings subject to Level A and B Service Limits.

(3) Any number of cycles can be grouped together and evaluated separately according to the conditions of (f), (g), or (h) below.

(4) The following definitions apply to (f) and (g) below

$$X' = \frac{\left(P_L + \frac{P_b}{\overline{K}}\right)\max}{S_y^A} \tag{14}$$

$$Y' = \frac{(Qr)\max}{S_y^A} \tag{15}$$

where S_y^A is the average of the material yield strength values at the maximum and minimum wall-averaged temperatures during the particular secondary stress range being evaluated and $(P_L + P_b/\overline{K})_{\max}$ is the maximum value of the primary stresses, adjusted for bending via $\overline{K}$, during the particular loading being evaluated, and $(Q_r)_{\max}$ is the maximum range of the secondary stress during the particular loading being considered.

(5) The following stress definitions apply to (h) below:

$$\overline{X} = \frac{\left(2\sigma^p_{m,m} + \sigma^d_{m,m}\right) - \left(\sigma^p_{m,c} + \sigma^{dm,c}\right)}{2S_y^c - \left|\sigma^p_{m,c} + \; + \sigma^{dm,c}\right|}$$

$$\overline{Y} = \frac{2\left(\sigma^p_{b,m} + \sigma^d_{b,m}\right)}{2S_y^c - \left|\sigma^p_{m,c} + \sigma^d_{m,c}\right|}$$

$$SR(stress\ ratio) = \frac{\left|\sigma^p_{m,m} + \sigma^d_{m,m}\right|}{\left|\sigma p^p_{m,m} + \sigma^d_{m,m}\right| + \left|\sigma^p_{b,m}\right|}$$

$$\overline{\sigma}c = {}^1\!/_2\left[\overline{Z}\left(2S_y^c - \left|\sigma^p_{m,c} + \sigma^d_{m,c}\right|\right) + \sigma^p_{m,c} + \sigma^d_{m,c}\right]$$

where

$\sigma^k_{i,j}$ = elastically computed principal stress components, or range of principal stress components, where the subscripts *i* and *j*, and superscript *k*, designate the type of stress, respectively. In particular:

i = *m* or *b* distinguishes between a membrane or linearized bending stress component, respectively.

j = *m* or *c* distinguishes between the meridional (along the convolutes) or circumferential (hoop) directions, respectively.

k = *p* or *d* distinguishes between pressure or displacement induced stresses, respectively.

S_y^c is the material yield value corresponding to the wall-averaged temperature at the cold end of the displacement loading cycle being evaluated.

The sign convention assumed is that tension membrane stresses or bending stresses with tension on the outer surface are positive stresses.

For pressure loadings, $\sigma^p_{i,j}$, is computed for the maximum pressure existing during the particular loading being evaluated. For displacement loadings, $\sigma^d_{i,j}$ is computed as the value of stress at the hot end of the particular loading cycle being evaluated minus the stress value at the cold end of the particular loading cycle being evaluated.

(f) The elastic stresses computed according to (e)(4) shall satisfy:

$$X' + Y' \le \frac{S_q}{S_y^A} \tag{16}$$

where S_q is the lesser of the average value of the materials yield strength for the highest and lowest average wall temperature occurring during the loadings being evaluated, or 1.25 S_t at 10^4 hr taken at the highest average wall temperature during the loadings being evaluated.

(g) The elastic stresses computed according to (e)(4) shall satisfy:

$$X' + Y' \le 1 \tag{17}$$

provided that the average wall temperature at one of the stress extremes defining each secondary stress range, Q_r, is not an elevated temperature. This temperature is defined for purposes of this paragraph as that at which S_m equals S_t at 10^5 hr.

(h) For those loading cycles consisting of only pressure and displacement loadings, the criteria of (f) and (g) above may be superseded as described in this subparagraph, provided the average wall temperature at one of the displacement loading extremes is below that temperature at which S_m equals S_t at 10^5 hr. The following computations provide upperbound values on accumulated membrane and bending inelastic strains for particular loading cycles. The accumulated membrane inelastic strains, ε_m, summed over all loading cycles during the service life shall be limited to 1%. The accumulated bending inelastic strains, ε_b, summed over all loading cycles during the service life shall be limited to 2%.

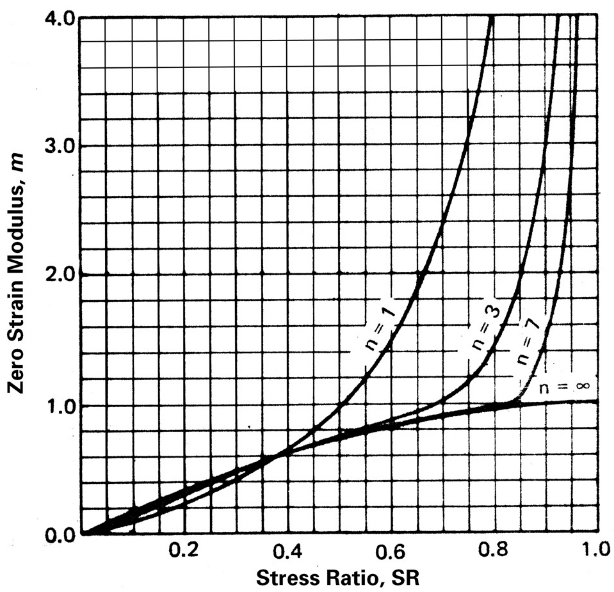
ε_m for each cyle of loading is obtained from the average isochronous curves contained in the rules for construction of Class 1 components at elevated temperature. The curves corresponding to the maximum wall-averaged temperature during the loading cylce and time duration of the loading cycle are entered at a stress level of 1.25 $\sigma_w \cdot \varepsilon_m$ is the inelastic strain associated with this stress level. ε_b is obtained by multiplying ε_m by the factor $(1 + m)/m$, where m is the zero strain modulus obtained from Figure -3742.6(h)-1.

The total service life may be subdivided into temperature-time blocks and the strain increment for each block may be evaluated separately. The times used in selecting the isochronous curves shall sum to the total service life.

To obtain σ_w, the upperbound midplane stress, the following procedure is followed:

(1) Compute the dimensionless bending stress parameter, $\overline{X}$, and dimensionless being stress parameter, $\overline{Y}$, as defined in -3742.6.

Figure -3742.6(h)-1
Zero Strain Modulus



GENERAL NOTE: n = creep law exponent when creep strain is expressed in a form A $(\sigma/\sigma_o)^n$.

(2) Compute X' and Y' according to -3742.6 except use S_y^C instead of S_y^A.

(3) Enter Figure -3742.6(h)-2 with $|\overline{X}|$ and $|\overline{Y}|$ to determine $|\overline{Z}|$. The sign of $\overline{Z}$ and $\overline{X}$ are always the same.

(4) Enter Figure -3742.6(h)-2 with X' and Y' to determine Z'. Assign the sign of X' to Z'.

(5) Check the required conditions:

(-a) $|\overline{Z}| \leq 1.0$

(-b) $|Z'| \leq 1.0$

(6) Compute $\overline{\sigma}_c$ as defined in (e)(5).

(7) Compute σ'_c using the relationship $\sigma'_c = Z' \cdot S_y^C$

(8) If the pressure varies within the loading cycle under consideration, increase $\overline{\sigma}_c$ and σ'_c by the pressure $\sigma^p_{m,m}$ range.

(9) Check the required conditions:

(-a)

$$\overline{\sigma}_c \leq S_y^H$$

(-b) $\sigma'_c \leq S_y^H$

where S_y^H is the material yield value corresponding to the wall-averaged temperature at the hot end of the displacement loading cycle being evaluated.

(10) Determine the dimensionless midplane stress, σ_m, from Figure -3742.6(h)-3.

(11) Compute $\overline{\sigma}_W$ and σ'_w using the relationships:

(-a)

$$\overline{\sigma}_W = \sigma_W\left(\left|\sigma^p_{m,m}\right| + \left|\sigma^p_{b,m}\right|\right) + \overline{\sigma}_c - \left|\sigma^p_{m,m} + \sigma^d_{m,m}\right|$$

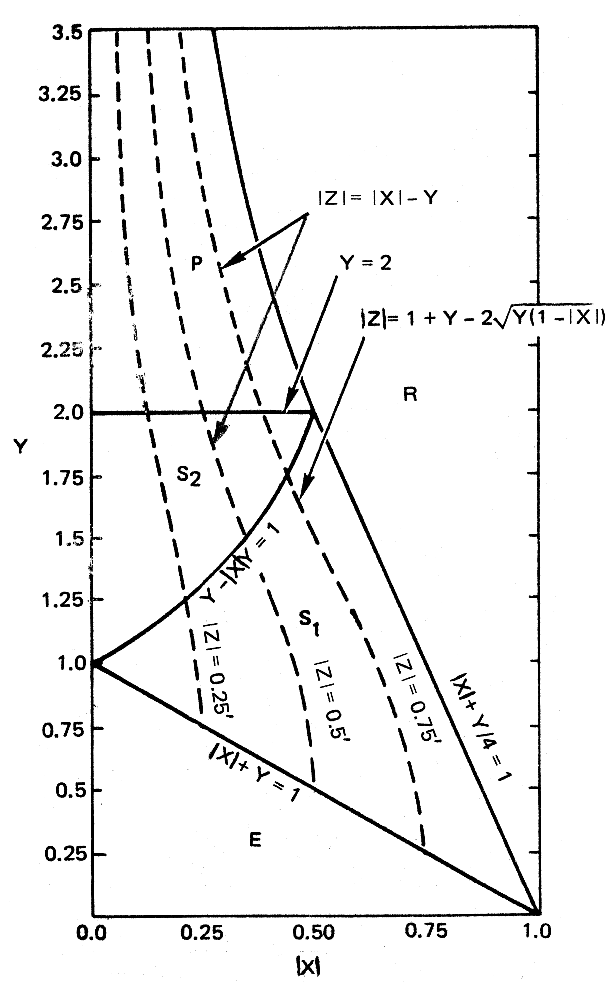
(-b)

$$\sigma' w = \sigma w\left(\left|\sigma^p_{m,m}\right| + \left|\sigma^p_{b,m}\right|\right) + \sigma' c - \left|\sigma^p_{m,m} + \sigma^d_{m,m}\right|$$

(12) Select σ_w as the larger of $\overline{\sigma}_W$ and σ'_w.

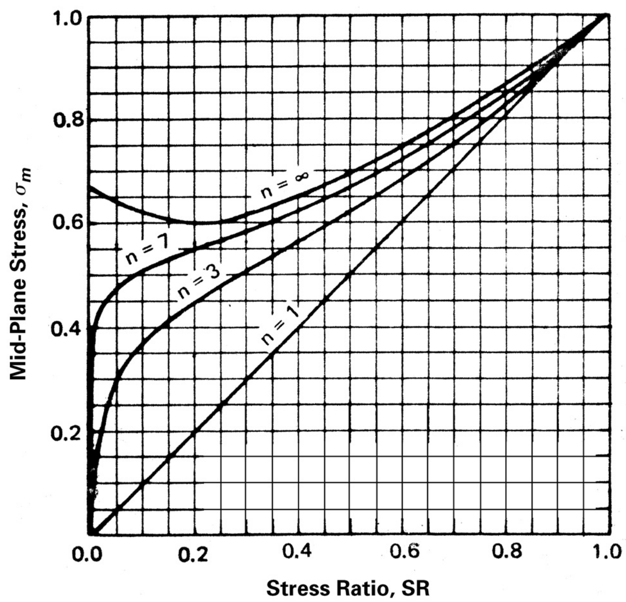
-3742.7 Fatigue and Creep Fatigue. Analytical rules governing failures under cyclic operation are currently under consideration by the Committee. Until such time that these become available, the life testing of -3773 must be performed.

Figure -3742.6(h)-2
Determination of $|Z|$



GENERAL NOTE: $|Z|$ refers to $|\overline{Z}|$ or $|Z'|$, $|X|$ refers to $|\overline{X}|$ or X', and Y refers to Y or Y' per -3742.6(h).

Figure -3742.6(h)-3
Dimensionless Midplane Stress Value



GENERAL NOTE: n = creep law exponent when creep strain is expressed in a form A $(\sigma/\sigma_o)^n$.

-3742.8 Stability Evaluation. The design shall be considered adequate against unacceptable instabilities, provided the pressure testing requirements of -3772 have been met.

-3743 Design of End Attachment Welds. The permissible types of end attachment welds are described in -4245. The expansion joint assemblies used in the Life Tests of -3773 shall have end attachment welds of the same geometry and made by the same process as in the delivered expansion joint. Satisfaction of the life testing requirements shall be considered demonstration of adequate weld design.

-3750 Expansion Joint Hardware Design

-3751 Acceptability. An acceptable design of the expansion joint hardware is one that satisfied the applicable requirements set forth in subparagraphs (a) through (f) below while under the loadings in -3720 and meets the applicable testing requirements of -3770 and -3780.

(a) Pressure Retaining Items

(1) Piping elements, pipe fittings, and flanges within an expansion joint assembly shall be designed for low-temperature service in compliance with all requirements of NB-3600. For service at elevated temperature, the rules for design of Class 1 piping in elevated temperature service shall be satisfied. The design of integral attachments to these pressure retaining items shall additionally satisfy the requirements of -3753.1.

(2) Pressure-retaining items other than piping elements, such as bellows attachment rings, shall be designed for low-temperature service to the requirements of NS-1200. For service at elevated temperature, the rules for design of Class 1 components in elevated temperature service shall be satisfied.

(b) Thrust Restraints and Motion Limiters

Thrust restraints and motion limiting devices incorporated within an expansion joint assembly shall be designed in compliance with the applicable rules of -3752 and -3753.

Examples of such items are:

(1) Hinges and gimbal rings, used to limit the motion of bellows to an angular rotation in either one or more directions.

(2) Tie rods used to restrain axial motion in an expansion joint assembly containing one or more bellows.

(c) External Supports and Restraints

External supports or restraints connecting to an expansion joint assembly from the load carrying building structure or adjacent piping, shall be designed for low temperature service in compliance with all the requirements of Subsection NF. For service at elevated temperature, the rules for design of Class 1 piping supports in elevated temperature service shall be satisfied.

(d) Flow Sleeves

Flow sleeves and their attachments shall be designed for low-temperature service to the requirements of NB-3200. For elevated temperature service, the rules for design of Class 1 components in elevated temperature service shall be satisfied. The jurisdictional boundaries for design are defined in NCA-3254.1(c). Adequate sleeve clearances shall be maintained over the total service motion range.

(e) Bolts

The design of bolts for low-temperature service shall satisfy the requirements of NB-3230. For elevated temperature service, the criteria for load controlled stresses on bolts and strain requirements on bolting contained in the rules for design of Class 1 components at elevated temperature shall be satisfied.

(f) Welded Joints

Welded joints for low-temperature service shall be full penetration welds designed in accordance with NB-3350 Category B. For elevated temperature service, the rules for design of Category B welded construction in Class 1 vessels in elevated temperature service shall be satisfied.

-3752 Design Requirements for Thrust Restraints and Motion Limiters. The design of thrust restraints and motion limiters shall satisfy the requirements of either -3752.1, or -3752.2 and meet the special requirements of -3752.3.

-3752.1 Design-by-Analysis. An acceptable design procedure for low temperature service is design-by-analysis in accordance with the rules of NB-3200. An acceptable design procedure for elevated temperature service is to satisfy the rules for design of Class 1 components in elevated temperature service.

-3752.2 Design-by-Testing. For low-temperature service, an acceptable design procedure is to use load rating in combination with cyclic testing. For elevated temperature service, rules are not available for design by testing. Load rating consists of imposing a total load on one or more duplicate full-size samples of the thrust restraint or motion limiter equal to or less than the load under which it fails to perform its specified function. The load ratings for Level A, B, and C Service Limits shall be determined by means of the equations in (a) and (b) below. For Level D Service Limits, the experimental methods of Appendix F may be used.

(a) The symbols used in this paragraph are defined as follows:

N = number of test samples.
T.L. = test load equal to or less than the load under which the item fails to perform its specified function.
S_m = allowable general primary membrane stress intensity value at the design temperature.
S_u = specified minimum ultimate tensile strength (room temperature) of the material used in the item.

(b) The load ratings for the following service operating conditions shall be determined by the following equations:

$$\text{Level A Service Load Rating} = \text{T.L.} \times 1.0\,(S_m/S_u)\left(\frac{2N}{2N+1}\right)$$

$$\text{Level B Service Load Rating} = \text{T.L.} \times 1.0\,(S_m/S_u)\left(\frac{2N}{2N+1}\right)$$

$$\text{Level C Service Load Rating} = \text{T.L.} \times 1.2(S_m/S_u)\left(\frac{2N}{2N+1}\right)$$

Table -3752.3(a)
Time-independent Buckling Safety Margins [Note (1)]

Design Loadings [Note (2)]	3.0
Service Loadings	
Level A	3.0
Level B	3.0
Level C	2.5
Level D	1.5
Testing [Note (3)]	2.25

NOTES:
(1) $$\text{Safety Margin} = \frac{\text{Load (strain) that would cause instability}}{\text{Design or expected load (strain)}}$$
(2) Changes in configuration induced by service need not be considered in calculating the buckling load.

Table -3752.3(a)
Time-independent Buckling Safety Margins [Note (1)] (Cont'd)

NOTES (CONT'D):
(3) The Safety Margin applies only to Acceptance Testing (-3780).

Table -3752.3(b)
Time Dependent Buckling Factors

Service Limits	
Level A	1.5
Level B	1.5
Level C	1.5
Level D	1.25

Cyclic loading shall be designed for by performing cyclic testing in accordance with the procedures and requirements of Appendix II-1500, unless the life testing (-3773) adequately covers this cyclic loading criterion.

-3752.3 Special Requirements. The design of thrust restraints and motion limiters shall satisfy the following requirements:

(a) For those structural configurations where time-independent column or plate buckling can occur, the N Certificate Holder shall demonstrate, by analysis or test, the safety margins against instability provided in Table -3752.3(a):

(b) For those structural configurations where load controlled time-dependent column or plate buckling can occur, it shall be demonstrated that instability will not occur during the specified lifetime for a load history obtained by multiplying the specified service loads by the factors given in Table -3752.3(b). Time dependent strain controlled buckling need not be considered.

(c) Protection against nonductile fracture shall be provided. An acceptable procedure for nonductile failure prevention is given in Appendix G.

-3753 Special Requirements for Expansion Joint Hardware. The following requirements consider the general design arrangement and functional performance of expansion joint hardware.

-3753.1 Integral Attachments.

(a) Integral attachments shall not be made to elbows or tees incorporated in an expansion joint assembly. Integral attachments may be made to flanges or pipe spools incorporated in an expansion joint assembly.

(b) Where an integral attachment is added to the outside surface of a flange or pipe stool within an expansion joint assembly, thermal stresses, stress concentrations, and localized loads imposed on pressure retaining members shall be taken into account in checking for compliance with the design stress criteria.

-3753.2 Axially Restrained Expansion Joints.

(a) The design of an expansion joint assembly may require axial restraints in the form of tie-rods, axial link bars, hinges, or gimbal rings to restrain a change in axial length but permitting lateral (offset) or angular movement in the bellows element. Axial restraints shall be designed to accommodate the thrust loads from internal pressure as well as loads caused by thermal expansion, weight, seismic motions and, in some arrangements, the mass of intermediate spools or hardware within the joint assembly.

(b) When tie-rods are used as axial restraints, a minimum of four rods are required.

(1) Each rod shall be designed to take an equal share of the total load, as defined in -3753.2. The possibility of disproportionate loading conditions shall be considered in the design evaluations.

(2) The rods shall be connected through the assembly attachment end plates or brackets by means of welded load collars. Spherical washer sets shall be provided between the load collars and loaded face of the attachment plates.

(c) When pinned link bars, hinges, or gimbal rings are used:

(1) The link bar pins, hinge plate pins, or gimbal ring pins shall be designed for loading in double shear.

(2) Each link or hinge assembly, or gimbal hinge shall be designed to accommodate a minimum of 50% of the total load defined in -3752.2(a). The possibility of disproportionate loading conditions shall be considered in the design evaluations.

-3753.3 Pin Clearances. When pin connected members are utilized, the effect of pin clearances and pin alignment shall be considered in the design, particularly with respect to motion loadings induced on the bellows.

-3760 Secondary Pressure Boundary Design

-3761 Design Requirements. The design of the secondary pressure boundary shall satisfy the requirements of NC-3649.4. When the maximum metal temperature at any time during the entire service life is an elevated temperature, the N Certificate Holder shall evaluate the material's time-dependent behavior. These evaluations shall be included in the Design Report. Elevated temperature material data shall be obtained from the rules for design of Class 2 and 3 components at elevated temperature.

-3770 Design Demonstration

(a) Expansion joint designs intended to provide additional flexibility for thermal expansion of Class 1 piping must be subjected to a design demonstration as specified in the following subparagraphs.

(b) The expansion joints used in the design demonstration must satisfy the requirements of -4000. The bellows shall be constructed by the same process and from the same material (specification and grade) as the bellows in the to-be-stamped expansion joint. Additionally, bellows used in the design demonstration must satisfy the similitude requirements of -3771.

(c) For purposes of -3770 only, elevated temperature shall be construed as temperatures that do not permit satisfaction of the time-temperature limits of -3742.6(c)(1) and -3742.6(c)(2).

-3771 Bellows Similitude Requirements. To assure replication between the bellows used in the design demonstration and the bellows in the to-be-stamped expansion joint, the following requirements must be met for every bellows used for Design Demonstration testing:

(a) For expansion joints that will operate at elevated temperature [-3770(c)], the bellows must be fabricated from the same lot [-2810(b)] of tubes as the to-be-stamped bellows.

(b) The geometry must be nominally the same as the to-be-stamped bellows and satisfy the tolerance requirements of -4224.1.

(c) The axial motion, load characteristics of the bellows shall be measured over a range equivalent to the maximum motion range subject to Service Levels A, B, or C limits. This shall be accomplished without internal pressure. The data shall be used in satisfying the Acceptance Testing Requirements of -3782.

(d) At both ends of the motion range used in the tests of (c) above, a measurement of the sidewall spacing between all convolutions shall be made. The change in sidewall spacing of each convolution shall be defined as a fraction of the average of that convolution's two sidewall spacings existing at both ends of the motion range. The change in sidewall spacing of any convolution shall not differ from that of any other convolution by more than 20%.

-3772 Bellows and Secondary Pressure Boundary Pressure and Strain Tests.

(a) The object of these tests is to demonstrate the pressure, P_d, to cause permanent time-independent deformation in the bellows convolutions, to demonstrate the internal pressure, P_{CR}, that will cause the bellows to become both time-independently and time-dependently unstable (squirm), and as an alternate to -3742.6, demonstrate that acceptable strain limits are maintained.

(b) For joints used in purely axial motion, pressure tests shall be performed with the bellows fixed in the straight position with displacement magnitudes enveloping those for which they are designed (i.e., two test positions are required). For joints used purely in rotation (or offset), the pressure tests shall be performed with the bellows fixed at an angle (or offset) greater than or equal to the maximum rotation angle (or offset) expected in service. For joints used in a combination of motions, the pressure tests shall be performed with the bellows fixed at the least stable superposition of all possible motion combinations. For joints subjected to rotation movement,

or universal joints subjected to lateral offset movement, an instability condition as previously defined may or may not appear. Instead, movement of the convolutions may occur due to the superposition of a lateral pressure component on the applied rotation. That portion of the bellows deformation due to the design rotation angle or offset movement should not be included in the deformation used to define squirm.

(c) The demonstrated minimum distortion pressure, P_d, shall satisfy the equation:

$$P_d \geq 1.5\, C_T P \tag{17}$$

where:

P_d shall be defined as the pressure which results in a 7% permanent decrease in sidewall spacing (after release of pressure) between adjacent convolutions. C_T is the temperature correction on test pressure:

$$C_T = \frac{S_y \text{ at the test temperature}}{S_y \text{ at the design temperature}}$$

P is the design pressure.

(d) The demonstrated minimum squirm pressure, P_{CR}, shall satisfy the equation:

$$P_{CR} \geq P' \tag{18}$$

where P_{CR} shall be defined as having occurred if under internal pressure an initially symmetrical bellows deforms, resulting in uneven spacing of adjacent convolutions at any point on the circumference. Unless otherwise specified in the Design Specification, this deformation shall be construed as unacceptable squirm when the ratio of the maximum convolution pitch under internal pressure to the convolution pitch before application of pressure exceeds 1.20. In the case of universal expansion joints, which consist of two bellows joined by an intermediate spool, compliance with these criteria shall be satisfied by the entire assembly. No external restraints on the bellows shall be employed during squirm testing other than those that will exist after installation.

P' is a single test pressure selected to demonstrate capability of the bellows to operate without time-independent squirm.

$$P' \text{ is the maximum of: } \left\{ \begin{array}{l} 2.0\dfrac{E_T}{E_D} \text{ times the design pressure.} \\ 2.0E_T \text{ times the maximum value of } (P_S/E_S) \text{ for all loadings} \\ \quad \text{subject to Levels A and B Service Limits.} \\ 1.7 \text{ times the maximum value of } (Ps/Es) \text{ for all loadings subject to Level C Service Limits.} \\ 1.0E_T \text{ times the maximum value of } (Ps/Es) \text{ for all loadings subject to Level D Service Limits.} \end{array} \right.$$

where (P_s/E_s) are values of service pressure divided by the modulus of elasticity for the bellows material at the wall-averaged temperature during application of the service pressure. E_T is the modulus of elasticity for the bellows material at the test temperature, and E_D is the modulus of elasticity of the bellows material at design temperature.

When elevated temperature service exists, the following testing, in addition to that specified above, shall be performed on the same bellows to include the effect of accumulated creep distortions on instability:

$$P_{CR} \geq \overline{P} \text{ shall be demonstrated}$$

where, $\overline{P}$ is a single test pressure or combination of test pressures selected to demonstrate capability of the bellows to operate under a modified lifetime load histogram without time-dependent squirm. The modification to the lifetime load histogram shall be an increase of those elevated temperature pressures subject to Service Levels A, B, and C pressures by the factor 1.5. The maximum modified pressure subject to Service Levels A, B, or C limits shall be applied at the end of the test at the corresponding service temperature.

The time factor may be accelerated by using any valid creep theory. The techniques used for acceleration of time shall be included as part of the Design Report.

(e) As an alternate to the analysis techniques of -3742.6, the strain limits of -3742.5(a) and -3742.5(b) may be demonstrated by test using, as a minimum, the distortion producing environments of the lifetime load histogram. The time factor for the lifetime load histogram may be accelerated by using any valid creep theory. The techniques used for the measurement of strain and, where applicable, the acceleration of time, shall be included as part of the Design Stress Report.

(f) A minimum of three tests are required for the primary pressure retaining bellows at each position tested. One test at each position is required for the redundant pressure boundary, utilizing the same pressure and strain criteria as used for primary pressure retaining bellows. Creep effects need not be considered for the redundant pressure boundary test.

-3773 Life Tests

(a) Five complete expansion joints shall be tested to determine their capability to survive the load environment for which they were designed. Five assemblies must survive the required testing to demonstrate an adequate design. Survival of the primary pressure retaining bellows and secondary pressure boundary is defined as capability to meet the leak test requirements of -3784. Survival of the hardware is defined as maintenance of structural and functional integrity.

(b) Only the primary pressure retaining bellows must demonstrate capability to survive the complete life test. The secondary pressure retaining bellows and hardware

need only demonstrate capability to survive the initial portion of the life test that induces damage equivalent to that induced during five basic test histograms. See -3774.2. Since the test environment will be established for the primary pressure retaining bellows, the total test life may induce damage in the secondary pressure boundary or hardware that is greater than the damage induced during five service lifetimes. Therefore, repairs to the secondary pressure boundary or hardware are permitted, after demonstration of their capability to survive the equivalence of five service lifetimes, to allow continuance of the life test to demonstrate the primary pressure retaining bellows capabilities.

(c) All cyclic loadings, subject to Service Levels A, B, or C limits, that do not meet all the requirements of NB-3222.4(d) shall be represented in the life test histogram, and the cyclic test loadings shall be at least as severe as the service loadings. The following modifications to NB-3222.4(d) are required when the expansion joint is to be operated at elevated temperature:

(1) Reference to S_m shall be construed as reference to S_{mt} at service temperature and for the time equal to the duration of one cycle of load application.

(2) Reference to S_a for loading cycles with maximum metal temperatures at elevated temperature shall be construed as reference to one-half the product of the total strain range, ε_a, and the modulus of elasticity, *E,* at that temperature ε_a shall be obtained from the design fatigue strain range curves for elastic analysis in the design rules for Class 1 components in elevated temperature service.

(d) Consideration shall be given to the possibility of reduction in service life due to the mean-stress effects of sustained loadings, both strain and load controlled, when establishing the life test histogram.

(e) Where environment effects cause degradation, they shall be accounted for in the life testing.

-3773.1 Life Test Methodology.

(a) It is the responsibility of the Owner to define in the Design Specification, the methodology to develop life test histograms to demonstrate capability of the expansion joint to survive its service environment. Accelerated testing may be utilized, provided the method of acceleration is in the Design Report. The acceleration technique shall include as a minimum consideration of the damaging and interacting effects of creep, fatigue, thermal shock, and plasticity.

(b) The methodology contained in -3774 may be used to develop life test histograms. However, alternate methodology may be applied by the N Certificate Holder subject to the approval by the Owner. The Owner's approval shall be indicated by incorporating the alternative methodology into the Design Specification.

-3774 Life Test Histogram Development

-3774.1 Objective. The objective of this subparagraph is to provide rules that may be used by Owners and N Certificate Holders with respect to development of life test histograms for demonstration of capability of expansion joints, designed to the rules of this Case, to survive their service environment.

-3774.2 Basic Test Histogram. A basic test histogram shall be defined that produces damage to the primary pressure retaining bellows equal to or greater than that which would occur under the lifetime load histogram provided in the Design Specification. Where the number of service loading cycles is less than 10^4, the number of cycles may not be reduced in the development of the basic test histogram. The evaluation of damage shall be established as follows:

(a) For expansion joints which will operate during service with primary pressure retaining bellows subject only to low temperatures, the evaluation of damage shall be by prediction of a cumulative usage factor, *U,* per the requirements of NB-3224(e)(5).

(b) For expansion joints which will operate during service with primary pressure retaining bellows subjected to elevated temperatures, the evaluation of damage shall be construed as prediction of a total creep-fatigue damage, *D,* as defined in the creep-fatigue acceptability criteria for construction of Class 1 components in elevated temperature service. The ratio of fatigue damage fraction to creep damage fraction for the lifetime load histogram shall be maintained during the basic test histogram establishment.

-3774.3 Evaluative Techniques.

(a) The stress (or strain) calculations, and damage evaluations required to demonstrate -3774.2 has been met, shall be performed by a consistent procedure for both the lifetime load histogram and basic test histogram, shall satisfy the requirements of -3742(b), and shall be included in the Design Report. Material values used in the calculations shall satisfy the requirements of -2125.

(b) Elastic predictions of *D* in -3774.2(b) can only be utilized to establish a basic test histogram when it results in $D \leq 1.0$ for the lifetime load histogram evaluation.

-3774.4 Life Test Histogram. The life test histogram shall be established from the basic test histogram in accordance with the applicable procedures in (a) or (b) below:

(a) For expansion joints which will operate during service with primary pressure retaining bellows subject only to low temperatures, the basic test histogram shall be performed *N* times, where *N* is defined as follows:

(1) *N* equals 5.0 when *U,* computed in -3774.2(a) for the lifetime load histogram, is less than or equal to unity.

(2) *N* equals 20.0 when *U,* computed in -3774.2(a) for the lifetime load histogram, is greater than unity.

(b) For expansion joints that will operate during service with primary pressure retaining bellows subject to elevated temperatures, the basic test histogram shall be performed N times, where N is defined as follows:

(1) N shall equal the larger of 5.0 or $(N' - 1)$ when D, computed in -3774.2(b) for the lifetime load histogram does not exceed the applicable (elastic or inelastic) creep-fatigue damage interaction envelope contained in the creep-fatigue acceptability criteria for the construction of Class 1 components in elevated temperature service, where:

N' = the smallest integer greater than or equal to $6(N_1/N_D{}^2)$.

N_1 = the number of times the service life histogram would need to be repeated to result in a computed fatigue damage fraction or creep damage fraction equal to 1.0. The value of N_1 is to be the smaller of the two values computed using the fatigue damage fraction and the creep damage fatigue.

N_D = the number of times the service histogram would need to be repeated to result in a computed D value equal to the value on the applicable (elastic or inelastic) creep-fatigue damage interaction curve contained in the creep-fatigue acceptability criteria for construction of Class 1 components in elevated temperature service.

(2) N shall equal 20.0 when D, computed in -3774.2(b) using the inelastic analysis, exceeds the creep-fatigue damage envelope contained in the creep-fatigue acceptability criteria for Class 1 components in elevated temperature service.

-3775 Certification of Testing. The Design Demonstration testing shall be fully described and the data presented as part of the Design Report. The completeness and accuracy of the data shall be certified by a Registered Professional Engineer competent in the field of experimental testing.

-3780 Acceptance Testing

The purpose of acceptance testing is to demonstrate the adequacy of the to-be-stamped expansion joint and to insure that the bellows is a replica of the analytically justified and demonstrated design. These shall include as a minimum proof pressure, spring rate verification, motion demonstration, and leak detection tests.

-3781 Proof Pressure Test. The expansion joint shall be subjected to the testing of NB-6000. This may be performed at ambient temperature with the bellows fixed in its neutral position. The expansion joint shall not leak and shall maintain its structural integrity during the test. Also, there shall be no visual evidence of meridional yielding or squirm as defined in -3772.

-3782 Spring Rate Verification Test. The axial motion, load characteristics of the bellows shall be measured over the range equivalent to the maximum motion range subject to Service Level A, B, or C limits specified in the Design Specification. This shall be accomplished without internal pressure and shall provide consistency with the Design Demonstration Tests [-3771(c)]. The motion-load characteristics shall lie within the envelope of the data of the Design Demonstration Testing. The convolution to convolution criteria of -3771(d) shall be demonstrated.

-3783 Motion Demonstration Test. The completed assembly shall be subjected to the maximum motion range subject to Service Levels A, B or C loadings prescribed in the Design Specification to ensure no interferences exist and minimum design clearances are met over the operating range.

-3784 Leak Detection Test. Both the expansion joint primary pressure retaining bellows and the redundant bellows, or suitable alternate, shall be helium leak tested per Section V, Article 10, T-1060. Pressures applied shall not exceed the maximum Service Level A pressure.

-3785 Certification of Testing. The acceptance testing shall be witnessed by the Authorized Nuclear Inspector and certified to be in compliance with -3780.

-4000 FABRICATION AND INSTALLATION REQUIREMENTS

-4131 Repair of Material

-4131.1 Defects in Bellows Tubes.

(a) In bellows tubes parent material, defects that are discovered on delivery or that are discovered during the process of fabrication or installation may be removed in accordance with -2860(a).

(b) In longitudinal tube welds, defects that are discovered on delivery or that are discovered during the process of fabrication prior to convoluting may be removed and reexamined in accordance with -2860(b).

-4131.2 Defects in Bellows. In bellows, defects in either parent material or longitudinal welds that are discovered after convoluting may be removed in accordance with -2860(a), provided the repaired area meets the thickness tolerances of -4224.1.

-4140 Cleanliness

It is the responsibility of the Owner to define in the Design Specification the required level of cleanliness that the expansion joints must receive at the point of manufacture and that must be maintained at the construction site. As a minimum, the Class B level of cleanliness defined in ANSI N45.2.1-1973, shall be used. However, alternative levels of cleanliness may be applied by the N Certificate Holder subject to the approval by the Owner. The Owner's approval shall be indicated by incorporating the alternative level of cleanliness in the Design Specification. The N Certificate Holder is responsible for documenting the cleanliness requirements for any given application in design drawings or specifications associated with the cleaning of the expansion joints. The method of verification of cleanliness shall also be documented. Such documentation shall be provided in sufficient detail to form the basis for cleanliness verification inspection at the construction site.

-4212 Bellows Forming Processes.

(a) During the fabrication of bellows intended for elevated temperature service, any process may be used to form the seamless or welded tubes into a convoluted shape provided the original material properties are effectively restored by heat treatment. A final forming to eliminate warpage occurring during heat treatment shall be permitted without subsequent heat treatment provided the tolerances specified in -4224 are met immediately prior to the heat treatment which induced the warpage. In these cases, the requirements of -4224.2(c) need to be satisfied at only one location which is no closer than 10 deg of circumferential arc to a weld.

(b) Cold-worked materials may be employed in bellows intended for low-temperature service, however, consideration shall be given to the possibility of stress-corrosion cracking during service.

-4214 Minimum Thickness of Fabricated Materials. If any fabrication or defect removal operation reduces the expansion joint hardware thickness below the minimum required to satisfy the rules of -3750, the material may be repaired in accordance with NB-4130.

-4215 Special Requirements for Bellows Tubes. The bellows tube shall also comply with the requirements of -2820.

-4216 Surface Examinations of Final-Formed Bellows. Following final forming, the entire bellows shall be determined to be free of injurious defects such as notches, crevices, material buildup or upsetting, weld spatter, which may serve as points of local stress concentration. Suspect surface areas shall be further examined by liquid penetrant and visual examination in accordance with -5350 and -5390, respectively. In addition, the full radii of the outer surface of the crowns and the inner surface of the roots shall meet the liquid penetrant criteria of -5350.

-4224 Tolerances for Expansion Joints

-4224.1 Tolerances for Final-Formed Bellows.

(a) The design of the bellows shall be such that the following tolerances can be met. Any deviations from these tolerances in the as-built bellows shall be reconciled in the final Design Report. As part of the Owner's review and Certification of the Final Design Report, the Owner shall review and approve any such deviations in the as-built bellows.

(b) Tolerances shall be per Figure -4224.1-1 and Table -4224.1 and shall apply when the part is held in a free-standing position unless the part is sufficiently flexible to require fixturing, or the specified tolerance specifically allows fixturing. The part is sufficiently flexible for fixturing if either (1) or (2) below are met. The tolerances shall then apply when the part is held by both end tangents to maintain the required length and/or allowable parallel offset.

(1) The convoluted length changes more than 1% when held by one end tangent and rotated from the centerline-vertically-upward position to the centerline-vertically-downward position (see Figure -4224.1-2).

(2) The end-center offset is greater than 0.002 times the convoluted length and it always occurs in the downward direction during the rotation through one complete revolution about the centerline when held by one end tangent with its centerline horizontal (see Figure -4224.1-3).

(c) Tolerances shall apply simultaneously; i.e., the part shall not be such that when held in one position, some tolerances are met, and in moving the part to another position, other tolerances are met.

(d) In addition to the profile tolerances in Figure -4224.1-1, the continuous change of curvature on the surface of all convolutions shall nowhere have a radius smaller than 0.35 times S_c when checked over an arc not less than 45 deg. In other words, if a ball of 0.35 S_c radius were rolled around the concave side of the convolution, at no instant would it touch two points further apart than 45 deg on the ball surface. (See Figure -4224.1-4.)

-4224.2 Clarification of Figure -4224.1-1 and Table -4224.1.

(a) The bellows intended to be placed into service and replicate bellows used for Design Demonstration Testing (see -3761) shall meet the tolerances in Figure -4224.1-1 and Table -4224.1. For purposes of this subparagraph, these bellows will be termed a "design lot."

(b) The tolerance callouts in Figure -4224.1-1 shall be interpreted in accordance with ANSI Y14.5-1973.

(c) The dimensions in Table -4224.1, excepting the end-tangent-end-inside diameter, shall be measured at every 90 deg of bellows circumference, no closer than 10 deg to a weld.

(d) The column of basic tolerances are to be met at all required locations within each bellows. The basic tolerance values are to be computed based on the nominal dimensions specified on the design drawing.

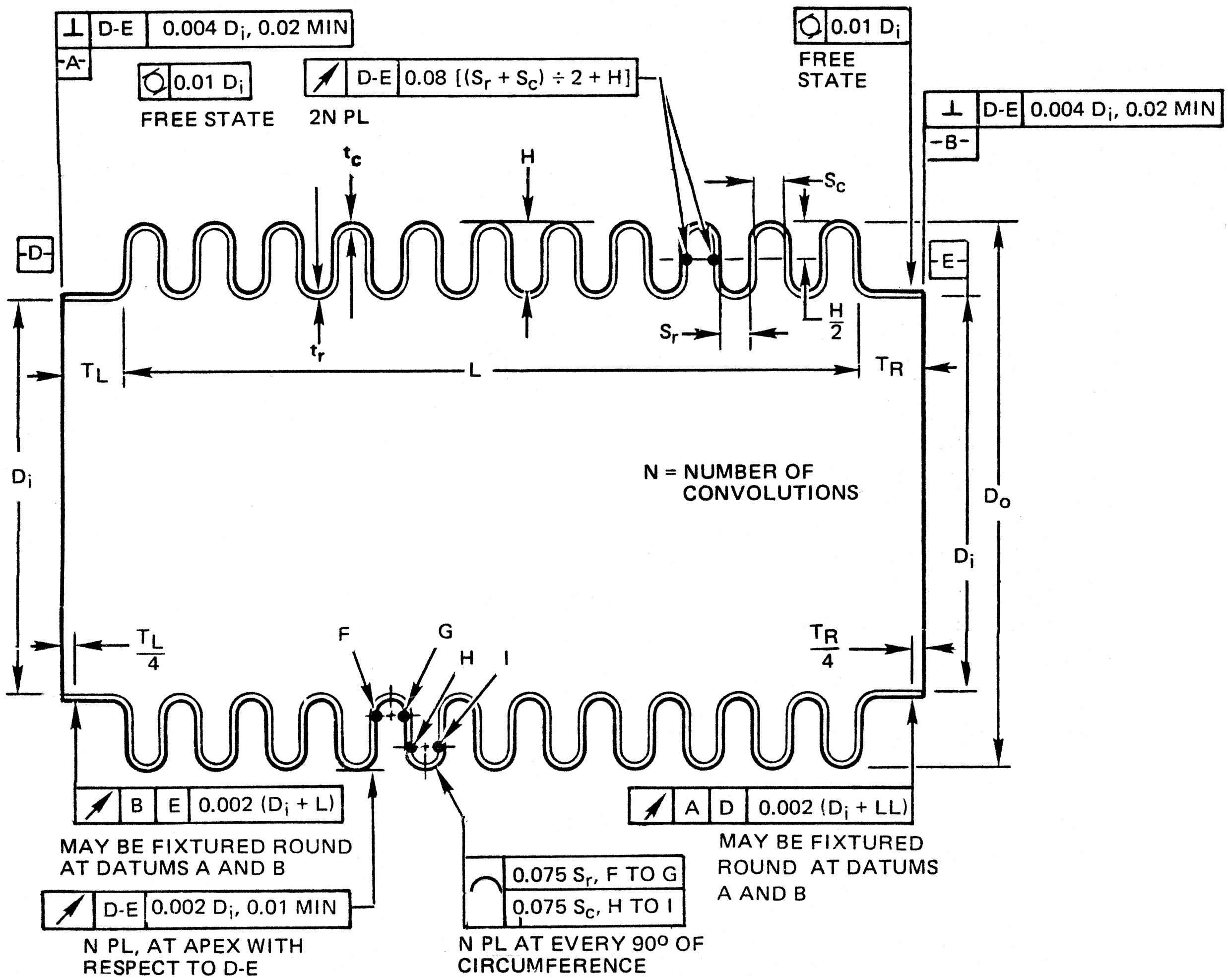
(e) The column of convolution repeatability tolerances are to apply separately to each bellows within the design lot.

(f) The column of bellows repeatability tolerances are to apply to the set of average measurement values (one per bellows) computed for all bellows in the design lot.

-4224.3 Tolerances for Expansion Joint Assemblies.

(a) Pin (bearing) axes for hingetype or gimbal-type expansion joints shall be centered along the bellows convoluted length within .01 × L and pass within .01 × D_i of the bellows centerline when the joint is in a straight position.

Figure -4224.1-1
Bellows Profile Tolerances and Nomenclature



(L and D_i are nominal dimensions defined in Figure -4224.1-1). The gimbal pin axes shall be perpendicular to each other within 0.5 deg.

(b) The overall installation lengths of an expansion joint assembly shall meet the tolerances listed below:

(1) $\pm^1/_{16}$ in. for lengths of 3 ft.

(2) $\pm^1/_8$ in. for lengths of 3 to 12 ft.

(3) $\pm^3/_{16}$ in. for lengths greater than 12 ft.

-4231.2 Temporary Attachments and Their Removal. No attachment shall be made to the end attachment ring closer than $2T$ from the bellows circumferential weld, where T is the bellows end tangent thickness. No temporary welded attachments shall be made to the bellows.

-4232 Maximum Offset of Aligned Sections.

(a) Alignment of hardware sections shall satisfy the requirements of NB-4232.

(b) Maximum offset or mismatch of the bellows end tangent with respect to the end attachment ring shall not exceed $T/8$ where T is the bellows end tangent thickness. Fairing of offsets of the bellows end tangent to end attachment ring joints is not required. Counterboring of these joints is not permitted.

-4233 Alignment Requirements When Component inside Surfaces Are Inaccessible. When the inside surfaces of hardware are inaccessible, the alignment requirements shall be as stipulated in NB-4233. The alignment requirements of -4232(b) shall apply to the bellows end tangent to end attachment ring joint regardless of inside surface accessibility.

-4245 Circumferential Weld Joints in Bellows. Circumferential weld joints in the convoluted portion of the bellows are prohibited. Circumferential weld joints attaching the primary pressure boundary bellows to the end attachment rings shall be butt-type, full penetration

Table -4224.1
Bellows Tolerances

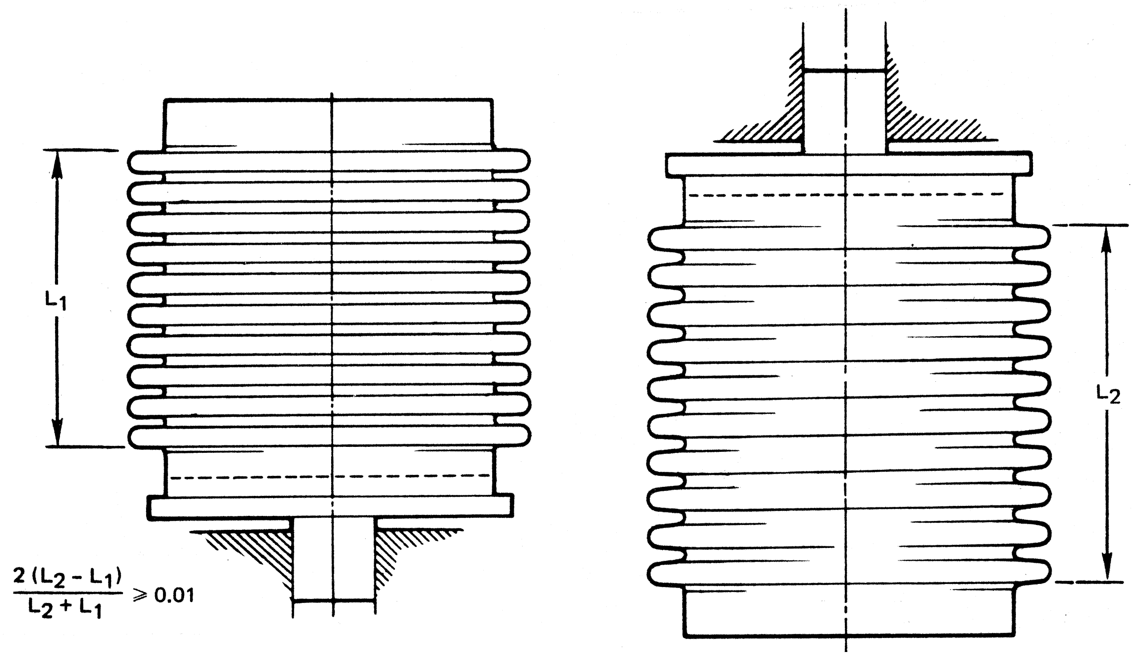
Dimension	I.D.	Basic Tolerance	Convolution Repeatability Tolerance	Repeatability Tolerance
Convolution Height	H	$\pm 0.06H$	$0.97\ H_{avg}$ [Note (2)] $\leq H_i \leq 1.03\ H_{avg}$	$\frac{(H_{\text{avg}})_{\text{max}}}{(H_{\text{avg}})_{\text{min}}} \leq 1.01$
Crown Apex Thickness ($t_c = t_{nominal} \pm$ tolerance)	t_c	$\pm[1.05 - 0.95\ (D_i/D_o)^{1/2}]t$	$0.94(t_c)_{\text{avg}} \leq (t_c)_{\text{i}} \leq 1.06\ (t_c)_{\text{avg}}$	$\frac{((t_c)_{\text{avg}})_{\text{max}}}{((t_c)_{\text{avg}})_{\text{min}}} \leq 1.06$
Root Apex Thickness ($t_r = t_{nominal} \pm$ tolerance)	t_r	$\pm 0.10t$	$0.94(t_r)_{\text{avg}} \leq (t_r)_{\text{i}} \leq 1.06\ (t_r)_{\text{avg}}$	$\frac{((t_r)_{\text{avg}})_{\text{max}}}{((t_r)_{\text{avg}})_{\text{min}}} \leq 1.06$
Convoluted Length	L	$\pm 0.015L$	Not Applicable	$\frac{(L_{avg})_{\text{max}}}{(L_{avg})_{\text{min}}} \leq 1.01$
End Tangent End Inside Diameter	D_i	$\pm 1.5t$(.01 min.)[Note (1)]	Not Applicable	None required
Convolution Outside Diameter	D_o	$\pm 0.005D_o$(0.1 min.)	$0.997\ (D_o)_{\text{avg}} \leq (D_o)_{\text{i}} \leq 1.003\ (D_o)_{\text{avg}}$	$\frac{((D_o)_{avg})_{\text{max}}}{((D_o)_{avg})_{\text{min}}} \leq 1.002$
Sidewall Spacing at Crown	S_c	$\pm 0.075\ (S_c)$	$0.95(S_c)_{\text{avg}} \leq (S_c)_{\text{i}} \leq 1.05\ (S_c)_{\text{avg}}$	None required
Sidewall Spacing at Root	S_r	$\pm 0.075(S_r)$	$0.95\ (S_r)_{\text{avg}} \leq (S_r)_{\text{i}} \leq 1.05\ (S_r)_{\text{avg}}$	None required
End Tangent Length	T_L	$\pm 0.03(T_L)$	Not applicable	None required

NOTES:

(1) May be determined by internal or external periphery (pi-tape) measurements.

(2) H_{avg} is the average value of all convolution height measurements required, i.e., $H_{\text{avg}} = \sum_{I=1}^{4(N+1)} H_i/4(N+1)$ where i is an individual measurement value. A similar nomenclature is utilized in the table for the other dimensions.

Figure -4224.1-2
Requirement for Proving Sufficient Flexibility to Allow Axial Fixturing



welds of the type shown in Figure -4245. The circumferential weld joints attaching the secondary pressure boundary component to the adjacent assembly may be of the type shown in Fig. NC-4810(c)-1.

-4246 Longitudinal Tube Welds. Longitudinal tube welds shall comply with the requirements of -2842.

-4381 Requirements for Hard Surfacing on Pressure Retaining Surfaces. Hard surfacing of the expansion joint hardware shall be performed prior to welding the bellows into the expansion joint. Hard surfacing of the bellows is not permitted.

-4422 Peening. Peening of the expansion joint hardware shall comply with the requirement of NB-4422. Peening of the bellows welds is not permitted.

Figure -4224.1-3
Requirement for Proving Sufficient Flexibility to Allow Offset Fixturing

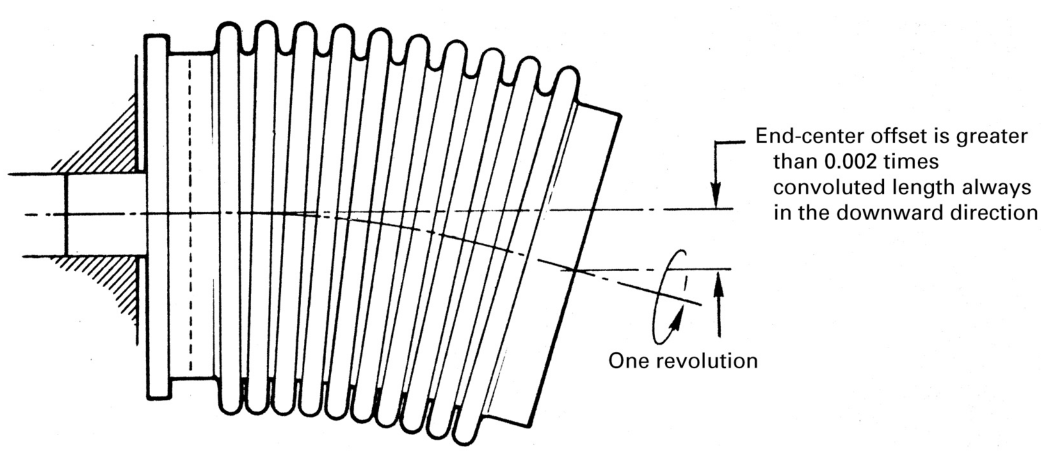
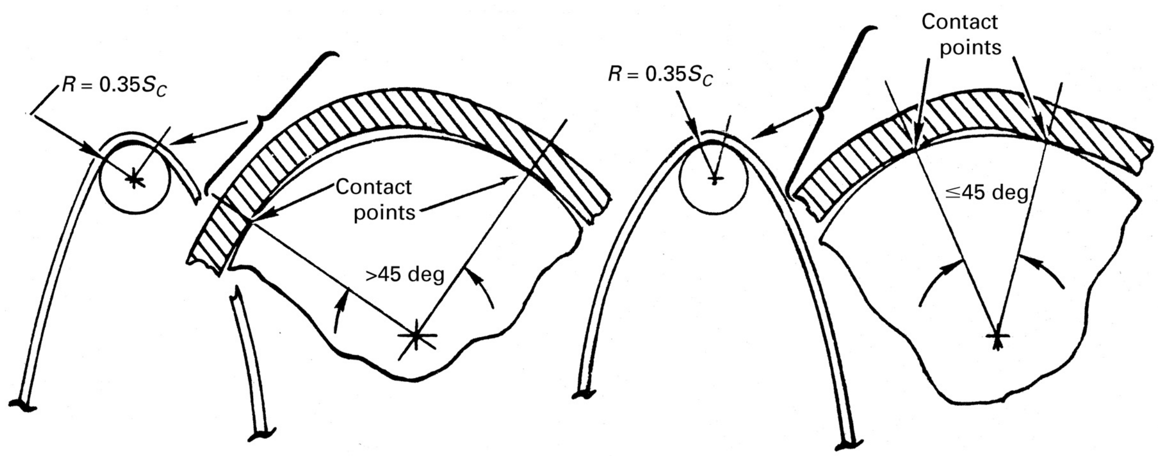


Figure -4224.1-4
Ball Analogy for Curvature Tolerance



-4424 Surfaces of Welds.

(a) Except for longitudinal tube welds, surfaces of welds shall satisfy the requirements of NB-4424. The reinforcement of cylindrical section welds in the hardware shall satisfy NB-4426.2, and reinforcement for other geometrical sections shall satisfy NB-4426.1.

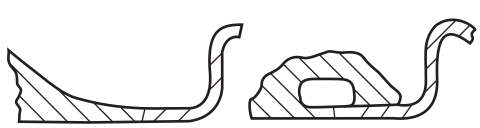
(b) No undercutting of the bellows-to-end-attachment-ring welds is permitted and these welds must additionally satisfy the requirements of -4245.

-4800 INSTALLATION OF PIPING EXPANSION JOINTS

-4810 General Requirements

The rules of -4800 apply only to the field installation of metal bellows expansion joints in piping. These rules are further limited to complete expansion joint units, as assembled and shipped for installation in piping by means of butt welded joint connections. Field assembly or field modification of expansion joint assemblies are not covered by these rules.

Figure -4245
Types of Permissible Primary Pressure Boundary Bellows End Attachment Welds



-4820 Requirements Prior to Installation

-4821 Field Inspection. Metal bellows expansion joint assemblies shall be visually inspected by the N or NA Certificate Holder responsible for installation after unpacking and after field storage prior to installation. The inspections shall be made to determine that no damage has occurred either in shipping or in field storage. Inspection shall include, but will not be limited to:

(a) Inspection for damage to pressure retaining subcomponents, such as bellows and load transfer hardware. Accessible surfaces of bellows shall be inspected and meet the acceptance requirements of -5390.

(b) Inspection for damaged or missing motion-limiting devices and temporary assembly configuration restraints.

(c) Approval of the N Certificate Holder responsible for the bellows is required prior to disassembling the expansion joint for inspection. However, such a disassembly is not required by this case.

-4822 Field Handling Procedure. The field handling and storage operations shall be defined by the N or NA Certificate Holder responsible for installation to assure that no damage will occur in those operations. These procedures shall be provided to the N Certificate Holder accepting overall responsibility for the piping. The following specific requirements shall apply:

(a) A metal bellows expansion joint should not be removed from its shipping container or pallet prior to installation, except for performance of the inspection requirements of -4821.

(b) An expansion joint should only be lifted by attachments to the hardware specifically provided for that purpose in -3711.12. During any handling operation, care shall be exercised to avoid damage from impact or from dropping an assembly.

-4823 Field Cleanliness Verification. In preparation for installation, an expansion joint assembly shall be examined by the N or NA Certificate Holder responsible for installation to verify compliance with the requirements and documentation of -4140.

-4830 Installation Requirements

-4831 Installation Procedure. An operational procedure for the installation-erection of Class 1 piping containing an expansion joint assembly shall be prepared by either the N or NA Certificate Holder responsible for installation which shall accommodate all special requirements in -3649.1(e). The operational procedure shall be provided to the N Certificate Holder accepting overall responsibility for the piping. This procedure may include, but shall not be limited to:

(a) A determination by accurate survey of the relative spatial location of equipment and penetration connection points relative to the required configuration of the piping.

(b) A controlled spool and component assembly sequence to avoid erection strain in the piping and/or unplanned displacement of the expansion joint assembly.

(c) Use of one or more final closure spools shop machined to fit the as-built conditions of the remaining portion of the piping or the intended field modification of certain overlength spools to achieve the same effect.

(d) The engineering verification of the acceptability of the closure condition at the specified final piping closure points required in -4833.2(c).

(e) Special instructions regarding the placement of temporary supports or restraints during installation, and the disposition of permanent supports and restraints.

(f) Use of special position and support load measurements, both in the process of installation and in the final engineering verification required in -4833.

-4832 Installation of Expansion Joints. During the installation of an expansion joint, the N or NA Certificate Holder responsible for installation shall comply with the installation procedure defined under the requirements of -4831. In addition, the following requirements must be satisfied:

(a) All temporary shipping bars, brackets, or other locking devices on expansion joints shall not be removed or modified until completion of the piping erection including placement of all supports, restraints, and anchors.

(b) The installed length or configurations of an expansion joint assembly, as described in the design drawings, shall never be changed to accommodate an installation fitup unless approval is obtained from the Certificate Holder responsible for the design of the bellows as evidenced by a certified revision to the Design Report. Likewise, the as-built dimensions and clearances of permanent tie rods or other movement limiting devices shall not be modified for any purpose unless reconciled in a certified revision of the Design Report.

(c) Flow direction markings (-3711.8) on an expansion joint shall be properly oriented with the design direction of flow.

(d) When a pinned link or hinged expansion joint is installed, the joint shall be properly oriented in the piping utilizing the orientation markings (-3711.7) provided for this purpose.

(e) The convoluted bellows elements of an expansion joint shall at all times be protected against weld spatter and mechanical damage during erection.

(f) Care shall be taken during erection to ensure that an expansion joint assembly is supported either by the connected piping or temporary supports. An expansion joint shall not be exposed to the unsupported weight of a connected pipe spool.

(g) Piping which includes an expansion joint assembly shall not be hydrostatically tested or pressure flushed until all permanent anchors, guides, or other restraints are installed on the piping. All temporary shipping bars, brackets, or other locking devices, shall be removed after completion of erection and prior to system pressurization.

-4833 Verification of Installation Design Compliance

-4833.1 Piping Installation Review. During and after the erection of a Class 1 piping installation containing an expansion joint, the N Certificate Holder accepting overall responsibility for the piping shall verify that the installation has been acceptably constructed with respect to the requirements of -3649.1 and -4800.

-4833.2 Acceptability. The criteria for acceptability of the installation of Class 1 piping containing an expansion joint shall include but will not be limited to the following:

(a) Verification by actual measurement of the spatial position of the installed piping, the equipment and penetration connection points, the location of supports, restraints, and other subcomponents to determine that:

(1) All elements are within defined erection position tolerances, or;

(2) Where variations beyond tolerances occur, the measurements made may be used for reanalysis of the piping installation design and/or expansion joint [see -4832(b)].

(b) Verification of the acceptability of the position of the expansion joint(s) within the piping installation, including:

(1) The orientation or arrangement of the expansion joint(s) is acceptable for the erected position of the piping installation.

(2) The expansion joint(s) have not been displaced from their designed installation configuration axially, in offset, or in rotation [see -4832(b)].

(c) Verification that an essentially strain-free condition exists in the piping installation other than from the effects of the distribution of the support deadweight of the

installation. This may be demonstrated in the achievement of the acceptability of fitups at the final field weld closure points with no externally applied forces.

-4840 Installation Welding and Examination

Field welding and examination for the installation of expansion joints shall comply with the requirements for piping connection welds in NB-4400 and NB-5000, respectively.

-4900 SECONDARY PRESSURE BOUNDARY

The fabrication and installation rules for the secondary pressure boundary are contained in NC-4800.

-5000 EXAMINATION

-5320 Radiographic Acceptance Standards

The acceptance standards in NB-5320 shall be applicable to required radiographic examinations of welds in the expansion joint hardware.

Original or reworked longitudinal seam welds in bellows tubes that are shown by radiography to have any of the types of discontinuities listed below are unacceptable:

(a) Any type of crack or zone of incomplete fusion or penetration.

(b) Any other indication shall be unacceptable when:

(1) The number and size of indications in any 1 in. of longitudinal length are such that the value of K in the following equation exceeds the maximum of 0.005 in. or 0.15 t_m, where t_m is the nominal material thickness.

$$K = (D_1)(N_1) + (D_2)(N_2) + \ldots (D_n)(N_n) + \ldots$$

where

D_n = indication dimension for one size of indication having a maximum dimension of 0.005 in. or larger, and measured to the nearest 0.001 in.

K_n = number of indications of maximum dimension D_n.

(2) Clustered indications, 0.005 in. and larger, that if interconnected, would reduce the effective wall thickness by more than 25%. A cluster is defined as any group of two or more indications having maximum separations of 0.010 in. or less.

(c) Foreign inclusions, other than tungsten, shall be cause for rejection. The acceptability of tungsten inclusions shall be evaluated per (b) above.

-5350 Liquid Penetrant Acceptance Standards

(a) The acceptance standards in NB-5350 shall be applicable to required liquid penetrant examinations of weldments and surfaces in expansion joint hardware.

(b) For required liquid penetrant examinations of bellows tube welds, bellows end attachment welds, or bellows parent material, the evaluation of indications shall be per NB-5351. The liquid penetrant system employed shall be capable of detecting calibrated cracks of depths 0.001 in. or deeper with widths 0.00005 or wider in cracked test panels. A relevant indication shall be considered an indication whose major dimension exceeds the smaller of $t/4$ and $^1/_{16}$ in., but not less than 0.010 in. where t is the nominal bellows wall thickness. The following indications are unacceptable:

(1) Any cracks or linear indications.

(2) Relevant indications with dimensions greater than the smaller of $3t/8$ or $^3/_{16}$ in.

(3) Four or more relevant indications in a line separated by $^1/_{16}$ in. or less edge to edge.

(4) Ten or more relevant indications in any 6 in.^{2} of surface with the major dimension of this area not to exceed 6 in. with the area taken in the most unfavorable location relative to the indications being evaluated.

-5390 Visual Surface Examination Acceptance Standards

Surface irregularities (e.g., scratches) shall not exceed a depth equal to the larger of 5% the nominal material thickness or 0.002 in.

-5600 SECONDARY PRESSURE BOUNDARY

The examination requirements for the secondary pressure boundary are contained in NC-5700.

-6000 TESTING

-6111.3 Testing of Expansion Joints. Expansion joints satisfying the requirements of -3781 shall be considered to have met the requirements of NB-6111.

-6225 Test Pressure for Piping Containing Expansion Joints. The expansion joint component, connected piping, and other components within the overpressure system shall receive a pressure test at a pressure within the range defined below:

(a) Minimum System Pressure Test at a pressure defined in NB-6000. For systems operating at elevated temperatures, the rule for testing of Class 1 components in elevated temperature service shall be satisfied.

(b) Maximum System Pressure Test at a pressure which will result in bellows stresses which do not exceed the stress limits in -3742.5.

-7000 PROTECTION AGAINST OVERPRESSURE

-7100 GENERAL REQUIREMENTS

The rules in NB-7000 for protection against overpressure shall be satisfied for the expansion joint and the connected piping. For systems to be operated at elevated temperature, the rules for overpressure protection of Class 1 components in elevated temperature service shall be satisfied.

-8000 NAMEPLATES, STAMPING, AND REPORTS

-8100 GENERAL REQUIREMENTS

The requirements for nameplates, code symbol stamping, and data reports shall be as given in NCA-8000 with the additional requirements:

(a) The NPT Symbol stamp shall be employed.

(b) The Certificate Holders' Data Report Forms N-2 and N-5 shall be used. However, as an alternative to the N-2 Data Report Form, the procedures provided in NCA-8233.2 may be used.

(c) The N Certificate Holder accepting overall responsibility for the piping shall certify that the rules of this case have been satisfied. This certification shall be attached to the N-5 Data Report.

Approval Date: May 25, 1983
(ACI) Approval Date: September 26, 1983

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-312
Use of Stud Welds to Anchor Section III, Division 1, Class MC Vessels to Section III, Division 2, Class CC Concrete Containment Structures
Section III, Division 2

Inquiry: May stud welds, and studs as described below, be used to provide the means of anchoring the containment shell constructed to the rules of Section III, Division 1, Subsection NE to the concrete containment structure constructed to the rules of Section III, Division 2, Subsection CC?

Reply: It is the opinion of the Committee that stud welds, and studs as described below, may be used to anchor the containment shell constructed to Section III, Division 1, Subsection NE to the concrete containment structure constructed to Section III, Division 2, Subsection CC, provided that:

(a) studs shall not exceed $^7/_8$ in. in diameter when welding in the flat position and $^3/_4$ in. in diameter for all other welding positions;

(b) stud material shall meet the requirements of CC-2620;

(c) the welding procedure and the welding operators shall be qualified in accordance with the requirements of CC-4533 and NE-4311.1;

(d) the surface shall be prepared in accordance with the requirements of NE-4412;

(e) production weld testing shall be performed in accordance with the requirements of CC-4534;

(f) examination of the stud welds shall be in accordance with CC-5524;

(g) PWHT shall be performed in accordance with the requirements of NE-4620 for the containment shell material;

(h) loads transmitted to the containment vessel shell through the studs shall be included in the design and analysis of the shell in accordance with Subsection NE;

(i) this Case number and revision shall be shown on the applicable Data Report Form.

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Approval Date: February 14, 1983

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-315
Repair of Bellows
Section III, Division 1

Inquiry: Under what rules may repairs by welding be made on bellows elements for Section III, Division 1, Class 2, 3, and MC construction?

Reply: It is the opinion of the Committee that, for Section III, Division 1, Class 2, 3, and MC construction, repairs by welding may be made on bellows elements by an N-Certificate Holder, provided that:

(a) The size of the repair shall be limited to 4 sq in. for each repair.

(b) Prior to performing the repair to the bellows element, the repair shall be qualified on a full scale facsimile bellows by depositing weld metal as described below to simulate the production repair, particularly in terms of the actual welding parameters, the accessibility that will be seen in the production weld, and the materials to be welded. The facsimile bellows weld repair shall be examined in accordance with (e), and shall be pneumatically or hydrostatically tested in accordance with the applicable requirements of NC-6000, ND-6000, and NE-6000 in the presence of the ANI.

(c) The N-Certificate Holder shall prepare, or cause to be prepared, a revision to the Design Report listing tests and calculations that ensure that the repaired bellows meets the requirements of the Design Specification. The effect of the repair on the design of the bellows (NC-3649.4, ND-3649.4, and NE-3366.2) shall be evaluated by testing a facsimile bellows, or portion thereof, that has been repaired in accordance with this Case to the requirements of NE-3365.2(e)(2) or NC-3649.4(e)(2) and ND-3649.4(e)(2), as appropriate, except that only one facsimile bellows is required to be tested. In determining K_s, the number of replicate tests shall be taken as 0. The revised Design Report shall be certified by the N-Certificate Holder and reviewed by the Owner, as required by NCA-3000.

(d) Following fatigue testing, prooftesting shall be demonstrated by a hydrostatic test of the facsimile bellows in accordance with the applicable requirements of NC-6000, ND-6000, and NE-6000, in lieu of the rupture test required by NE-3365.2(e)(2) or NC-3649.4(e)(2) and ND-3649.4(e)(2).

(e) Following completion of the fatigue and hydrostatic tests, the repaired areas shall be examined by the liquid penetrant or magnetic particle method, in accordance with NC-5000, ND-5000, and NE-5000.

(f) Welders and welding procedures shall be qualified for groove welding, in accordance with Section III, Division 1, and Section XI. Welding shall be performed using the GTAW process.

(g) Prior to making the repair on the actual bellows, the welder shall demonstrate on a prototype test assembly, under conditions (including accessibility and position) that will be seen when making the production repair weld, the capability to make a weld repair accetpable to the ANI.

(h) Repairs shall be made by deposition of weld metal or by butt welding repair that does not alter the original design configuration.

(i) The root pass and final pass of the weld repair shall be examined by the liquid penetrant or magnetic particle method, in accordance with the requirements of NC-5000, ND-5000, and NE-5000.

(j) The completed repair shall be subjected to a hydrostatic or pneumatic test, in accordance with NC-6000, ND-6000, and NE-6000.

(k) This Case number shall be identified in the Data Report for the component or system.

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Approval Date: January 17, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-319-3
Alternate Procedure for Evaluation of Stresses in Butt Welding Elbows in Class 1 Piping
Section III, Division 1

Inquiry: What procedure may be used for evaluating stresses in butt welding elbows per ANSI B16.9, MSS-SP87, or ANSI B16.28 in Class 1 pipe under Section III, Division 1, as an alternative to the stress indices and flexibility factors given in NB-3680?

Reply: It is the opinion of the Committee that the procedure listed below may be used for evaluating stresses in butt welding elbows per ANSI B16.9 MSS-SP87, or ANSI B16.28 in Class 1 pipe under Section III, Division 1.

1 LIMITATIONS OF APPLICABILITY

1.1 The elbows are welded on both ends to straight pipes of the same nominal thickness as the elbows, and the length of those straight pipes is not less than two times the nominal outside diameter of the elbow.

1.2 In conducting the piping system analysis (NB-3672.6), the flexibility matrix f_{ij} relating the displacement vector δ_i to the force vector F_j according to the matrix equation

$$\delta_i = f_{ij} F_j; \quad ij = 1, 2 \ldots, 6,$$

where δ_i is the column matrix of displacement components at end A of the elbow relative to end B (see Figure 1)

$$\delta_i = \left\{u_{xa}, u_{ya}, u_{za}, \theta_{xa}, \theta_{ya}, \theta_{za}\right\},$$

and F_j is the column matrix of force components at end A

$$F_j = \left\{F_{xa}, F_{ya}, F_{za}, M_{xa}, M_{ya}, M_{za}\right\}$$

shall include the following or equivalent coefficients of flexural regidity (missing terms are equal to 0.0).

$f_{11} = K_z g_1 \, (6\alpha_0 - 8 \sin \alpha_0 + \sin 2\alpha_0)$
$f_{12} = f_{21} = -K_z g_1 \, (3 - 4 \cos \alpha_0 + \cos 2\alpha_0)$
$f_{16} = f_{61} = -\, 4K_z g_2 \, (\alpha_0 - \sin \alpha_0)$
$f_{22} = k_z g_1 \, (2\alpha_0 - \sin 2\alpha_0)$
$f_{26} = f_{62} = 4k_z g_2 \, (1 - \cos \alpha_0)$
$f_{33} = g_1[k_x(1 + v)(6\alpha_0 - 8 \sin \alpha_0 + \sin 2\alpha_0) + k_y(2\alpha_0 - \sin 2\alpha_0)]$
$f_{34} = f_{43} = g_2[k_x(1 + v)(2\alpha_0 - 4 \sin \alpha_0 + \sin 2\alpha_0) + k_y (2\alpha_0 - \sin 2\alpha_0)]$
$f_{35} = f_{53} = -g_2[k_x(1 + v)(3 - 4 \cos \alpha_0 + \cos 2\alpha_0) + k_y(1 - \cos 2\alpha_0)]$
$f_{44} = g_3[k_x(1 + v)(2\alpha_0 + \sin 2\alpha_0) + k_y \, (2\alpha_0 - \sin 2\alpha_0)]$
$f_{45} = f_{54} = g_3[k_x(1 + v) - k_y](1 - \cos 2\alpha_0)$
$f_{55} = g_3[k_x(1 + v)(2\alpha_0 - \sin 2\alpha_0) + k_y(2\alpha_0 + \sin 2\alpha_0)]$
$f_{66} = 4g_3 k_z \alpha_0$

1.3 In conducting the piping system analysis (NB-3672.6), the following flexibility factors for elbows are used in the analysis.

$$k_x = 1.0$$

$$k_y = \frac{1.25}{h}\left[\frac{1}{1 + (Pr/tE)X_k}\right], \text{ but not less than 1.0}$$

$$k_z = \frac{1.65}{h}\left[\frac{1}{1 + (Pr/tE)X_k}\right] \text{for } \alpha_0 \geq 180 \text{ deg}$$

$$k_z = \frac{1.30}{h}\left[\frac{1}{1 + (Pr/tE)X_k}\right] \text{for } \alpha_0 = 90 \text{ deg}$$

$$k_z = \frac{1.10}{h}\left[\frac{1}{1 + (Pr/tE)X_k}\right] \text{for } \alpha_0 = 45 \text{ deg}$$

$$k_z = 1.0\left[\frac{1}{1 + (Pr/tE)X_k}\right] \text{for } \alpha_0 = 0 \text{ deg}$$

Linear interpolation with α_0 shall be used for α_0 between 180 deg and 0 deg; k_z shall not be less than 1.0.

2 NOMENCLATURE (E)

k_x = flexibility factor for torsional moment M_{xa}
k_y = flexibility factor for out-of-plane bending moment M_{ya}
k_z = flexibility factor for in-plane bending moment M_{za}

g_1 = $R^3/4EI$
g_2 = $R^2/4EI$
g_3 = $R/4EI$
α_0 = arc angle of the elbow, radians
h = tR/r^2
R = bend radius, in.
P = internal pressure, psi
r = pipe or elbow mean radius, in.
t = pipe or elbow nominal wall thickness, in.
X_k = $6(r/t)^{4/3}(R/r)^{1/3}$
E = modulus of elasticity
I = plane moment of inertia
ν = 0.3 = Poisson's ratio
C_{2x} = C_{2y} = $1.71/h^{0.53}$, but not less than 1.0
C_{2z} = $1.95/h^{2/3}$ for $\alpha_0 \geq 90$ deg
= $1.75/h^{0.56}$ for $\alpha_0 = 45$ deg
= 1.0 for $\alpha_0 = 0$

Linear interpolation with α_0 shall be used, but C_{2z} shall not be less than interpolated for α_0 = 30 deg and not less than 1.0 for any α_0.

3 PROCEDURE

The procedure of NB-3650 shall be used except that:

3.1 Replace $B_2 M_i$ in eq. (9) with:

$$0.67[(C_{2x}M_x)^2 + (C_{2y}M_y)^2 + (C_{2z}M_z)^2]^{1/2}$$

3.2 Replace $C_2 M_i$ or $C_2\ M_i^*$ in eqs. (10) through (14) with:

$$[(C_{2x}M_x)^2 + (C_{2y}M_y)^2 + (C_{2z}M_z)^2]^{1/2}$$

The definitions of types of loadings given under eqs. (9), (10), and (12) in NB-3652 and NB-3653 apply to the moment components M_x, M_y, and M_z.

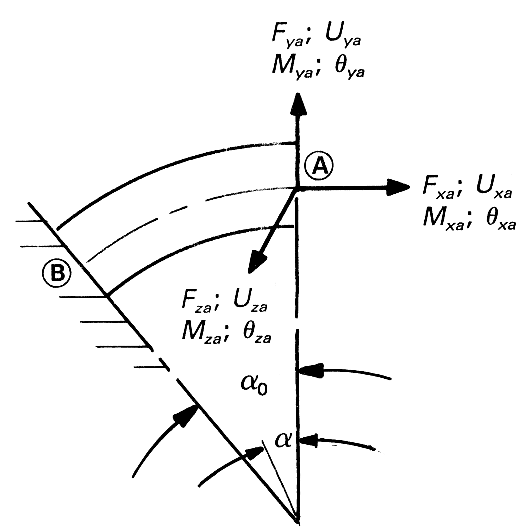
4

Analysis complying with this Case shall be included in the Design Report for the piping system.

5

Use of this Case shall be noted on the applicable Data Report Form.

Figure 1
Definition of Forces, Moments, Displacements, and Rotations



Approval Date: July 16, 1982

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-351
Use of Subsize Charpy V-Notch Specimens
Section III, Division 1

Inquiry: Is it permissible to use subsize Charpy V-notch specimens in construction to the requirements of Section III, Division 1?

Reply: It is the opinion of the Committee that subsize Charpy V-notch specimens may be used in construction to the rules of Section III, Division 1, provided the following additional requirements are met.

(a) Use of subsize specimens shall be limited to material that normally has absorbed energy values in excess of 180 ft lb when tested with full size Charpy specimens.

(b) The sie of the subsize Charpy specimens shall be 10 mm × 6.7 mm, meeting the requirements of SA-370.

(c) The impact testing requirements of NX-2320 and the retest requirements of NX-2350 shall be met.

(d) The acceptance standard shall be 75 ft lb min. for each subsize specimen. Lateral expansion and percentage shear shall be reported for information.

(e) The impact test temperature shall be no higher than the minimum Design Temperature, and shall be determined in accordance with the applicable requirements of Section III, Division 1.

(f) This Case number shall be identified in the applicable documentation.

(g) All other applicable rules of Section III, Division 1, shall be met.

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Approval Date: February 14, 1983

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-369
Resistance Welding of Bellows
Section III, Division 1

Inquiry: Is it permissible to join plies of bellows elements by resistance welding prior to making the attachment weld to the end connector for Section III, Division 1, Class 2, 3, and MC construction?

Reply: It is the opinion of the Committee that plies of bellows elements may be joined by resistance welding prior to making the attachment weld to the end connector for Section III, Division 1, Class 2, 3, and MC construction, provided that:

(a) The joining of the bellows elements by resistance welding is a manufacturing aid, and shall not be a structural (load carrying) weld. The bonded edges shall be trimmed through the weld nugget, providing a homogeneous edge for welding to the end connector.

(b) The process shall be limited to individual ply thicknesses that are greater than 0.005 in. but less than 0.25 in., or any combination thereof.

(c) A welding procedure specification (WPS) in which the following are essential variables shall be prepared and qualified; any change shall require preparation and qualification of a new procedure.

(1) A change in the specification, type, or grade of material in any number.

(2) A change in the thickness of the thinnest member of the base material of more than 10%, or change in the overall thickness of the joint of more than 10%.

(3) A change in the number of layers to be welded.

(4) A change in the resistance welding machine settings and process control parameters.

(5) A change in equipment from that used for the qualification of the WPS.

(d) The qualification test coupons shall be prepared in accordance with the WPS to provide at least three spot welds or a 2 in. length of continuous weld, and shall be examined as follows:

(1) weld surfaces shall be visually examined and shall be free from cracks, electrode pickup, flash, or pits.

(2) Transverse cross sections of each spot weld and a longitudinal section through the center of the continuous weld shall be etched to reveal the weld nugget and heat affected zone, and shall be visually examined. Each section shall be free from cracks or other defects in the weld nugget or base metal.

(e) Each production weld shall be examined as described in (d)(1).

(f) Use of this Case shall be identified in the Data Report.

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Approval Date: October 8, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-373-3
Alternative PWHT Time at Temperature for P-No. 5A or P-No. 5B Group 1 Material, Classes 1, 2, and 3
Section III, Division 1

Inquiry: What alternative PWHT time at temperature may be used for the requirement of Table NB/NC/ND-4622.1-1, and what alternative heating and cooling rates may be used for those specified in NB/NC/ND-4623 when using induction heating or other suitable methods for the local PWHT of $^1/_2$ in. or smaller welds joining P-No. 5A or 5B Group 1, 4 in. O.D. or smaller tubes to trepanned bosses in P-No. 5A or P-No. 5B Group 1 tubesheets in Section III, Division 1, Classes 1, 2, and 3 construction?

Reply: It is the opinion of the Committee that, as an alternative to the PWHT requirements referenced in Table NB/NC/ND-4622.1-1 and NB/NC/ND-4623, the local PWHT of $^1/_2$ in. or smaller welds joining P-No. 5A or P-No. 5B Group 1, 4 in. O.D. and smaller tubes to trepanned bosses in P-No. 5A or P-No. 5B Group 1 tubesheets for Section III, Division 1, Classes 1, 2, and 3 construction may be accomplished using heating or other suitable methods, provided:

(a) The alternative time and temperature shall have a Larson-Miller parameter equal to or greater than that corresponding to the requirements of Table NB/NC/ND-4622.1-1.

(b) The use of increased heating and cooling rates shall result in a profile not exceeding the measured surface hardness profile resulting from the heating and cooling rates that satisfy NB/NC/ND-4623 requirements.

(1) Minimum holding temperature and time as specified in Table NB/NC/ND-4622.1-1 for P-No. 5A or P-No. 5B Group 1 materials shall be the comparison basis for microhardness testing.

(2) Compliance with this requirement shall be demonstrated by applying both heat treat cycles to identical weld assemblies simulating tube and tubesheet thermal heat sink effects.

(3) Microhardness survey data consisting of a minimum of ten readings each from the weld metal, the heat affected zones, and the adjacent base metals shall be averaged for each area and compared. For the purpose of this comparison, the high and low hardness readings from each area shall be discarded.

(c) The temperature of the component or item from the edge of the controlled band shall be gradually diminished to avoid harmful thermal gradients.

(d) This Case number shall be shown in the Data Report.

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Approval Date: July 24, 1989

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-405-1
Socket Welds
Section III, Division 1

Inquiry: May appurtenances that connect to nozzles of a Section III, Division 1, Class 1, vessel be designed and constructed employing joint designs in accordance with rules not currently covered in Section III?

Reply: It is the opinion of the Committee that all Section III, Division 1, Class 1, welded joints for construction of appurtenances, including internal piping, that form the barrier to the loss of fluid from the vessel and by which the appurtenances connect to nozzles of the vessel at or beyond the first circumferential weld joint in welded connections, the face of the first flange in bolted flange connections, or the first threaded joint in screwed connections shall be in accordance with all of the requirements for the component proper. However, the appurtenances with outside diameter equal to that of 2 in. standard pipe size and less may be constructed using weld joints in accordance with Figure 1, provided the following requirements are met.

(a) The design of the joint shall be such that stresses will not exceed the limits described in NB-3220 and tabulated in Tables 2A and 2B.

(b) A fatigue strength reduction factor of not less than 4 shall be used in fatigue analyses of the joints.

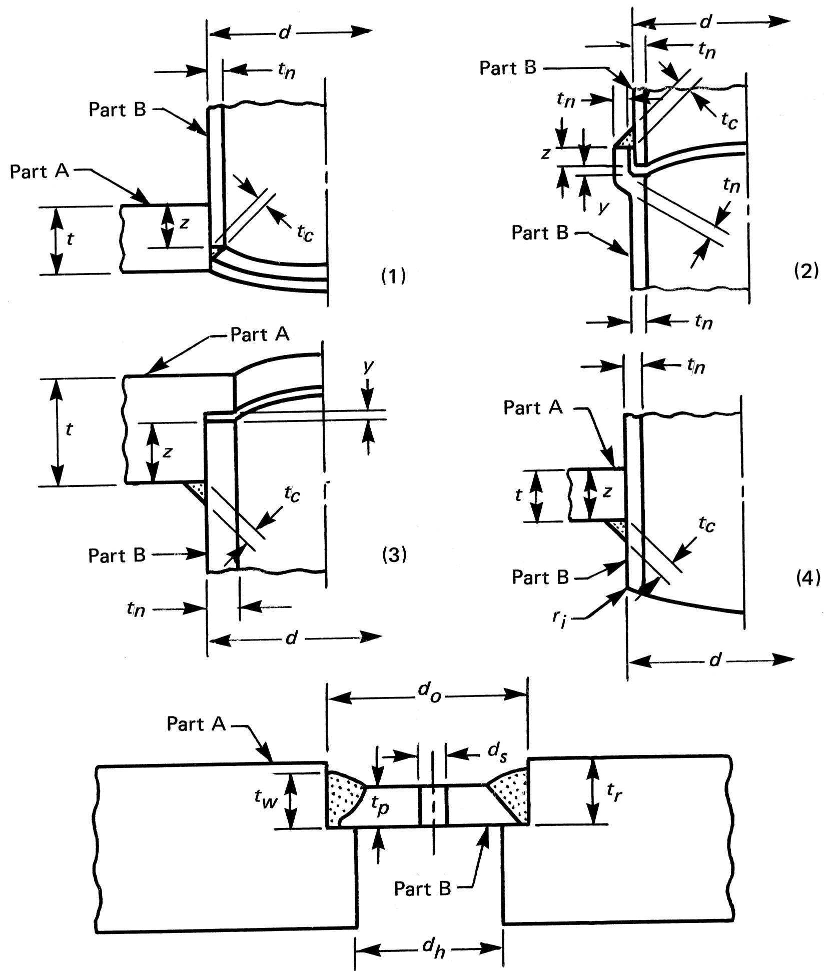
(c) The finished welds shall be examined by a magnetic particle or by a liquid penetrant method in accordance with Section V and the acceptance standards of NB-5000.

(d) End closure connections may be made with fillet welds or partial penetration welds provided the conditions stated above are met.

(e) This Case number shall be shown on the Data Report Form for the vessel.

(E)

Figure 1
Weld Connections for Appurtenances 2 in. Pipe Size and Smaller That are Attached to Nozzles



(5) [Note (1)]

Legend:

c_{max} = diametral clearance between connecting parts
= 0.045 in.
d = outside diameter of Part B and shall be 2 in. max. pipe size
d_h = diameter of the hole and shall be $2^3/_8$ in. max.
d_o = inside diameter of counterbore of Part A and shall be $2^1/_2$ in. max.
$d_o - d_h$ = 0.050 in. min.
$d_{s\ max}$ = 1 in. or t_r, whichever is less
$r_{i\ min.}$ = $^1/_4\ t_n$ or $^3/_4$ in., whichever is less
t = thickness of part penetrated
$t_{c\ min}$ = $0.7t_n$
t_n = nominal thickness of connecting part
t_p = thickness of Part B
$t_{p\ min.}$ = 2 × required calculated thickness of Part B
t_r = depth of counterbore ≥ t_p
t_w = weld thickness and shall be ≥ t_p
$y_{min.}$ = $^1/_{32}$ in.
z = depth of engagement and shall be $^3/_8$ in. min. for pipe sizes $^1/_2$ in. to 2 in. and shall be $^1/_4$ in. min. for pipe sizes under $^1/_2$ in.

GENERAL NOTE: Part A shall be attached to a nozzle of the vessel in accordance with the requirements for the vessel proper. Part B shall be attached either to Part A or to another Part B by the joints shown above or in accordance with the requirements of the vessel proper.

NOTE:
(1) Either weld preparation is acceptable.

Approval Date: January 12, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-416-4
Alternative Pressure Test Requirement for Welded or Brazed Repairs, Fabrication Welds or Brazed Joints for Replacement Parts and Piping Subassemblies, or Installation of Replacement Items by Welding or Brazing, Classes 1, 2, and 3
Section XI, Division 1

Inquiry: What pressure test may be performed in lieu of a hydrostatic pressure test for welded or brazed repairs, fabrication welds or brazed joints for replacement parts and piping subassemblies, or installation of replacement items by welding or brazing?

Reply: It is the opinion of the Committee that in lieu of performing a hydrostatic pressure test for welded or brazed repairs, fabrication welds or brazed joints for replacement parts and piping subassemblies, or installation of replacement items by welding or brazing, a system leakage test may be used provided the following requirements are met.

(a) Prior to or immediately upon return to service, a visual examination (VT-2) shall be performed on welded or brazed repairs, fabrication, and installation joints in conjunction with a system leakage test, using the 1992 Edition of Section XI or later Editions and Addenda, in accordance with IWA-5000, at nominal operating pressure and temperature.

(b) Only brazed joints and welds made in the course of a repair/replacement activity require pressurization and VT-2 visual examination during the test.

(c) Brazed joints and welds in replacement parts and piping assemblies, fabricated by the Repair/Replacement Organization or fabricated in accordance with the Construction Code without hydrostatic pressure test, shall be tested as required by (a) above.

(d) Use of this Case shall be documented on an NIS-2 form.

If the original version of this Case (N-416) were used to defer a Class 2 hydrostatic test, the deferred test may be eliminated when the requirements of this revision are met.

Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-432-1
Repair Welding Using Automatic or Machine Gas Tungsten-Arc Welding (GTAW) Temper Bead Technique
Section XI, Division 1

Inquiry: May the automatic or machine GTAW process be used as an alternative to the SMAW process for performing the temper bead technique on Class 1 components?

Reply: It is the opinion of the Committee that repair to P-Nos. 1, 3, 12A, 12B, and 12C[1] base material and associated welds may be made by the automatic or machine GTAW temper bead technique without the specified postweld heat treatment requirements of Section III, provided the requirements of 1 through 5 below are met. The depth of repair is not limited provided the test assembly meets the requirements of 2.1.

1 GENERAL REQUIREMENTS

(a) The requirements of IWA-4000, as applicable, shall be met.

(b) Only the automatic or machine GTAW process using cold wire feed shall be used. No arc oscillation shall be used.

(c) Welding materials shall be controlled during repair so that they are identified as acceptable material until consumed.

(d) The neutron fluence in the repair areas shall be taken into account when establishing the weld metal composition limits.

(e) Peening shall not be permitted.

2 WELDING QUALIFICATIONS

The Welding Procedure Specification and the welding operators shall be qualified in accordance with Section IX and additional requirements of Section III, as modified by 2.1, 2.2, and 3(c) and 3(d).

2.1 PROCEDURE QUALIFICATIONS

(a) The test assembly materials for the welding procedure qualification shall be of the same specification type, grade, and class as the materials being repaired. The test assembly shall receive a postweld heat treatment that is at least equivalent to the time and temperature applied to the materials being repaired. The procedure and performance qualification tests may be combined, provided Section IX requirements are met. The test assembly dimensions, including joint details, shall be documented on the PQR.

(b) The test assembly thickness shall be at least five times the depth of repair, but need not exceed the thickness of the material to be repaired provided the required test specimens can be removed. When the thickness of the base metal to be repaired is greater than 2 in., the depth of the cavity in the test assembly shall be the greater of 1 in. or the depth of the cavity to be repaired. However, in no case shall the procedure qualification test assembly be less than 2 in. thick, nor shall the depth of the cavity in the test assembly be less than 1 in.

(c) The test assembly dimensions surrounding the cavity shall be at least the thickness of the component at the location of the repair or 6 in., whichever is greater. If the repair weld is to be performed remotely, the procedure qualification test assembly shall be completed with the same or duplicate sensing and control equipment to be used for the repair. The test assembly shall simulate the position and obstructions of the actual repair.

(d) The root width and the included angle of the cavity in test assembly shall be no greater than the minimum specified to be used in the repair.

(e) This test assembly may be used to qualify procedures for weld buildup of pressure retaining materials. For this application, the depth of the cavity shall not be less than the thickness of the weld buildup or 1 in., whichever is greater. In addition, the area of the cavity shall not be less than the area of the weld buildup to be applied or 54 sq. in., whichever is less.

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III, and subsequently reclassified in a later edition of Section IX.

(f) For all applications, the test assembly and cavity shall be of sufficient size to obtain the required test specimens.

(g) Welding material shall meet the requirements of Sections IX, and III, and the Edition and Addenda shall be stated in the repair program. The appropriate toughness testing requirements of NB-2000 shall be completed for the weld materials used.

(h) Welding procedure qualification destructive tests shall be performed in accordance with Sections IX and III for groove welds, and the Edition and Addenda shall be stated in the repair program. Dropweight tests, impact tests, side bend tests, and all weld metal tension tests of the weld deposit are required. A reference nilductility transition temperature (RT_{NDT}) of the weld metal and base metal shall be established in accordance with NB-2000. If RT_{NDT} is less than or equal to 60°F, the qualification test shall be considered acceptable. If RT_{NDT} is greater than 60°F, the qualification test shall be rejected and a requalification of the procedure shall be performed. Test specimens shall be obtained from the completed test assembly at the maximum practical depth of repair.

(i) Impact testing of the procedure qualification test assembly HAZ shall be conducted as follows.

The T_{NDT} of the unaffected base material shall be determined by dropweight test to establish the test temperature for the C_v tests. The C_v specimens representing the HAZ material and the unaffected base material shall be tested at the (T_{NDT} + 60°F) temperature of the unaffected base material. The HAZ C_v absorbed energy and lateral expansion shall be equal to or greater than the unaffected base material at the (T_{NDT} + 60°F) temperature of the base material.

2.2 PERFORMANCE QUALIFICATION

The welding operator shall be qualified in accordance with Section IX and the following additional requirements. If the repair weld is to be performed where physical obstructions impair the welding operator's ability to perform, the welding operator shall also demonstrate the ability to deposit sound weld metal in the positions required, using the same parameters and simulated physical obstructions that are involved in the repair. Also, if the repair weld is to be performed remotely, the performance qualification test shall be completed with the same or duplicate sensing and control equipment to be used for the repair. For these applications, only nondestructive examination of the weld is required. The procedure and welding operator performance qualification tests may be combined, provided Section IX requirements are met.

3 REPAIR WELDING

Welding of the cavity or area being repaired shall be in accordance with the following.

(a) The cavity or area to be repaired by welding and a band around the cavity or area shall be preheated to 300°F minimum. This temperature shall be maintained for at least 30 min before welding is started, during welding, and until starting the postweld heat treatment of 450°F to 550°F described in (e) below. The width of the band shall be at least three times the thickness (3T) of the component to be welded, but need not exceed 10 in. The component thickness (T) shall be determined for the area to be welded prior to formation of the cavity. The interpass temperature shall not exceed 450°F.

(b) Thermocouples and recording instruments shall be used to monitor the preheat, interpass, and postweld heat treatment temperatures. Thermocouples shall be attached by welding or mechanical methods.

(c) The first three layers of the cavity shall be buttered as shown in Figure 1, Steps 1 through 3.

(d) The essential welding variables shall be controlled as follows.

(1) The weld heat input for each of the first three layers shall be controlled to within 10% of that used in the procedure qualification test.

(2) The remainder of the weld deposit shall be completed (see Figure 1, Step 4) with the heat input equal to or less than that used for layers beyond the third in the procedure qualification.

(3) The finished surface of the repair shall be essentially flush with the surface of the component surrounding the repair.

(4) The technique described in this paragraph shall be performed in the procedure qualification test.

(e) At the completion of welding, the 3T band as defined in (a) above shall be maintained in the range of 450°F to 550°F for at least 2 hr.

4 EXAMINATION

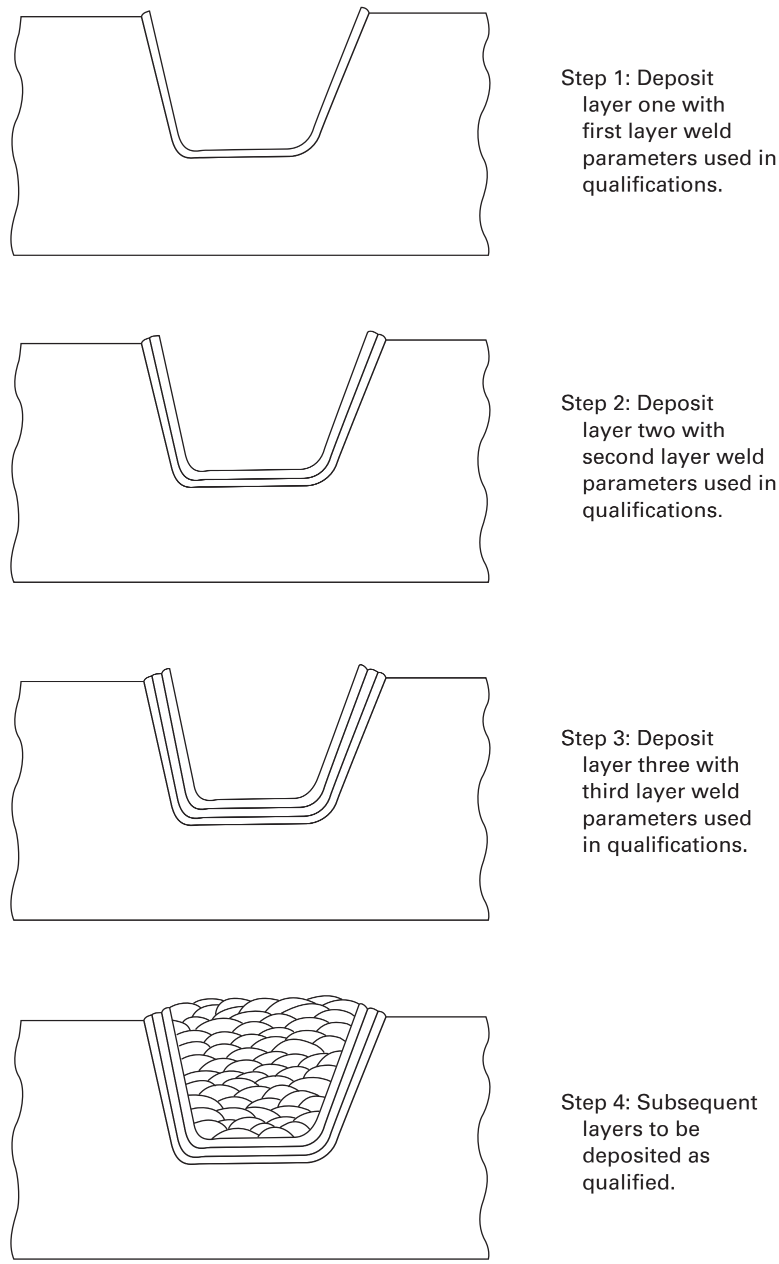
(a) The repair area and the 3T band as defined in 3(a) shall be nondestructively examined after the completed weld has returned to ambient temperature. The nondestructive examination of the repair welded region shall include radiography, if practical, ultrasonic examination, and surface examination.

(b) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

5 DOCUMENTATION

The use of this Code Case shall be recorded on Form NIS-2 or other applicable documents.

Figure 1
Automatic or Machine (GTAW) Temper Bead Technique



GENERAL NOTE: Care shall be taken when installing weld reinforcement beads that contact a base material that requires Construction Code PWHT. These weld beads shall be deposited in a manner that assures tempering of the ferritic weld metal, and base metal heat affected zone.

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Approval Date: March 8, 1989

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-452
Specialized Subcontracted Welding Process (Electron Beam Welding)
Section III, Division 1

Inquiry: It it permissible in the fabrication of Section III, Class 1, 2, and 3 items for an N Certificate Holder to subcontract Electron Beam Welding (EBW) of P-No. 8 materials not exceeding $^5/_8$ in. in thickness to an organization not holding an ASME Certificate of Authorization?

Reply: It is the opinion of the Committee that an N Certificate Holder may subcontract EBW (Electron Beam Welding) of P-No. 8 materials not exceeding $^5/_8$ in. in thickness to an organization not holding an ASME Certificate Authorization, provided all of the following conditions are met.

(a) The activities to be performed by the subcontractor are included within the N Certificate Holder's Quality Assurance Program.

(b) The N Certificate Holder's Quality Assurance Program shall include requirements for direct technical control of the EBW subcontractor. Technical control includes controlling the performance of all ASME Code required examinations, inspections, and tests including documentation and record retention.

(c) The Certificate Holder's Quality Assurance Program shall be reviewed and accepted by the Authorized Inspection Agency to confirm the above prior to any subcontracted EBW and to confirm that provisions have been made by the N Certificate Holder for the ANI to have access to all areas and functions to perform his duties, including those of procedure development and qualification performed by the subcontractor for the N Certificate Holder.

(d) The N Certificate Holder is responsible for surveying and accepting the Quality Assurance Program of the subcontractor for the subcontracted operation.

(e) The N Certificate Holder assures that the subcontractor uses written procedures and personnel qualified as required by the Code.

(f) The N Certificate Holder shall be responsible for controlling the quality and for assuring that all material and parts submitted to the Authorized Inspector for acceptance, conform to the applicable requirements of the Code.

(g) Use of this Case is identified on the Code Data Form.

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Approval Date: December 12, 1995

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-453-3
Nickel-Chromium-Molybdenum-Copper Stainless Steel (UNS N08925 and N08926) for Class 2 and 3 Construction
Section III, Division 1

Inquiry: May austenitic stainless steels (UNS N08925 and N08926) bars conforming to ASTM B649, plates conforming to ASTM B625, seamless pipe conforming to ASTM B677 and welded pipe conforming to ASTM B673 and fabricated to the dimensional requirements of ASTM B464 be used in construction of Section III, Division 1, Class 2 and 3 components?

Reply: It is the opinion of the Committee that austenitic stainless steels (UNS N08925 and N08926) bar, plate, seamless pipe and welded pipe, as described in the *Inquiry*, may be used in the construction of components complying with the rules of Section III, Division 1, Class 2 and 3 providing the following additional requirements are met.

(a) Welding procedure qualifications and welder performance qualifications shall be conducted as prescribed in Section IX and additional requirements of Section III for both alloys.

(b) Welding electrodes or filler metals shall conform to SFA-5.11 ENiCrMo-3 or ENiCrMo-4, or SFA-5.14 ERNiCrMo-3 or ERNiCrMo-4.

(c) The allowable stresses of Table 1 shall be used.

(d) Heat treatment during or after construction is neither required nor prohibited.

(e) This Case number shall be shown in the Manufacturer's Data Report.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Bar, Plate and Seamless Pipe Stress, ksi		Welded Pipe Stress, ksi [Note (1)]	
	N08925	N08926	N08925	N08926
Room Temperature	21.7	23.5	18.5	20.0
200	21.7	23.5	18.5	20.0
300	20.9	21.3	17.8	18.1
400	19.6	19.9	16.7	16.9
500	18.3	18.7	15.6	15.9
600	17.3	17.9	14.7	15.2
650	16.9	17.7	14.4	15.0
700	16.9	17.6	14.4	15.0
750	16.9	17.5	14.4	14.9
800	16.9	...	14.4	...

NOTE:
(1) A 0.85 joint efficiency factor has been applied.

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Approval Date: April 30, 1992

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-454-1
Nickel-Chromium-Molybdenum-Copper Stainless Steels (UNS N08925 and N08926) Wrought Fittings for Class 2 and 3 Construction
Section III, Division 1

Inquiry: May austenitic stainless steels (UNS N08925 and N08926) bar and plate conforming to ASTM B649 and B 625, respectively, and fabricated into wrought fittings conforming to ASTM B366 be used in construction of Section III, Division 1, Class 2 and 3 components?

Reply: It is the opinion of the Committee that austenitic stainless steels (UNS N08925 and N08926) fittings, as described in the Inquiry, may be used in the construction of components complying with the rules of Section III, Division 1, Class 2 and 3 providing the following additional requirements are met.

(a) Welding procedure qualifications and welder performance qualifications shall be conducted as prescribed in Section IX and additional requirements of Section III for both alloys.

(b) Welding electrodes or filler metals shall conform to SFA-5.11 ENiCrMo-3 or ENiCrMo-4, or SFA-5.14 ERNiCrMo-3 or ERNiCrMo-4.

(c) The allowable stresses of Table 1 shall be used.

(d) Heat treatment during or after construction is neither required nor prohibited.

(e) This Case number shall be shown in the Manufacturer's Data Report.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Stress, ksi [Note (1)]	
	N08925	N08926
Room Temperature	18.5	20.0
200	18.5	20.0
300	17.8	18.1
400	16.7	16.9
500	15.6	15.9
600	14.7	15.2
650	14.4	15.0
700	14.4	15.0
750	14.4	14.9
800	14.4	...

NOTE:
(1) A 0.85 joint efficiency factor has been applied.

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Approval Date: April 30, 1992

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-455-1
Nickel-Chromium-Molybdenum-Copper Stainless Steels (UNS N08925 and N08926) Forged Flanges and Fittings for Class 2 and 3 Construction
Section III, Division 1

Inquiry: May austenitic stainless steels (UNS N08925 and N08926) wrought bar and billet conforming to ASTM B649 and fabricated into forged flanges and fittings conforming to ASTM B462 be used in construction of Section III, Division 1, Class 2 and 3 components?

Reply: It is the opinion of the Committee that austenitic stainless steels (UNS N08925 and N08926) forged flanges and fittings, as described in the Inquiry, may be used in the construction of components complying with the rules of Section III, Division 1, providing the following additional requirements are met.

(a) Welding procedure qualifications and welder performance qualifications shall be conducted as prescribed in Section IX and additional requirements of Section III for both alloys.

(b) Welding electrodes or filler metals shall conform to SFA-5.11 ENiCrMo-3 or ENiCrMo-4, or SFA-5.14 ERNiCrMo-3 or ERNiCrMo-4.

(c) The material shall be furnished in the stabilized annealed condition. The recommended heat treatment for both materials shall consist of heating to a temperature of 2010°F to 2100°F (1100°C to 1150°C) followed by quenching in water or rapidly cooling by other means.

(d) The allowable stresses of Table 1 shall be used.

(e) Heat treatment during or after construction is neither required nor prohibited.

(f) This Case number shall be shown in the Manufacturer's Data Report.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Stress, ksi	
	N08925	N08926
Room Temperature	21.7	23.5
200	21.7	23.5
300	20.9	21.3
400	19.6	19.9
500	18.3	18.7
600	17.3	17.9
650	16.9	17.7
700	16.9	17.6
750	16.9	17.5
800	16.9	...

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Approval Date: July 27, 1988

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-460
Alternative Examination Coverage for Class 1 and Class 2 Welds
Section XI, Division 1

Inquiry: What alternative rules may be used for Section XI, Division 1, examination of Class 1 welds (IWB-2500) or Class 2 welds (IWC-2500) when the entire examination volume or area cannot be examined due to interference by another component or part geometry?

Reply: It is the opinion of the Committee that when the entire examination volume or area cannot be examined due to interference by another component or part geometry, a reduction in examination coverage on any Class 1 or Class 2 weld may be accepted provided the reduction in coverage for that weld is less than 10%. The applicable examination records shall identify both the cause and percentage of reduced examination coverage.

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Approval Date: June 14, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-469-1
Martensitic Stainless Steel for Classes 1, 2, and 3 Components
Section III, Division 1

Inquiry: Is it permissible in the construction of components conforming to the requirements of Section III, Division 1, Class 1, 2, and 3 to use quench and tempered martensitic steel forgings conforming to the requirements of ASTM A473-87, Type 431T (UNS S43100)?

Reply: It is the opinion of the Committee that ASTM A473-87, Type 431T (UNS S43100) forgings may be used in the construction of Section III, Division 1, Class 1, 2, and 3 components provided the following requirements are met.

(a) The maximum design metal temperature shall not exceed 650°F.

(b) The maximum design stress intensity, allowable stress, yield strength, and ultimate strength values shall be as shown in Table 1.

(c) The minimum tempering temperature shall be 1100°F. The minimum yield and ultimate strength after tempering shall be 90 ksi and 115 ksi, respectively.

(d) This material shall not be used for welded construction.

(e) All other requirements of Section III, Division 1 shall be met.

(f) This Case number shall be listed on the Data Report Form for the component.

Table 1
Maximum Values of Design Stress Intensity, Allowable Stress, Yield Strength, and Ultimate Strength, ksi

For Metal Temperature Not Exceeding, °F	Design Stress Intensity S_m, ksi	Allowable Stress S, ksi [Note (1)]	Yield Strength S_y, ksi	Ultimate Strength S_u, ksi
100	38.3	32.9	90.0	115.0
200	38.3	32.9	83.9	115.0
300	38.2	32.8	80.7	114.7
400	37.5	32.1	78.6	112.5
500	36.9	31.7	77.2	110.8
600	36.3	31.1	76.1	108.9
650	35.9	30.8	75.5	107.7

NOTE:
(1) These stresses are based on the 3.5 factor on tensile strength.

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Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-483-3
Alternative Rules to the Provisions of NCA-3800, Requirements for Purchase of Material
Section III, Division 1; Section III, Division 3

Inquiry: What alternative to the provisions of NCA-3800, NB-2130, NC-2130, ND-2130, NE-2130, NF-2130, and NG-2130, NB-2190, NC-2190, ND-2190, NE-2190, NF-2190, and NG-2190, NB-2610(a), NC-2610(a), ND-2610(a), NE-2610(a), NF-2610(a), and NG-2610(a), and WA-3800 may be used by an N-type Certificate Holder or Owner[1] to purchase material from an organization that has not been qualified to the requirements of NCA-3800?

Reply: It is the opinion of the Committee that as an alternative to the requirements of NCA-3800, NB-2130, NC-2130, ND-2130, NE-2130, NF-2130, and NG-2130, NB-2190, NC-2190, ND-2190, NE-2190, NF-2190, and NG-2190, NB-2610(a), NC-2610(a), ND-2610(a), NE-2610(a), NF-2610(a), and NG-2610(a), and WA-3800, the N-type Certificate Holder or Owner may purchase material in accordance with the following requirements:

1 CERTIFIED MATERIAL TEST REPORT

A Certified Material Test Report (CMTR) is required in accordance with NCA-3867.4(a) through (d).[2] A Certificate of Compliance (C of C) may be used in lieu of a CMTR, as permitted by NCA-3867.4(b). The CMTR or C of C shall be provided by the Material Manufacturer. When a CMTR is furnished, the material shall have material identification markings traceable to the CMTR.

2 N-TYPE CERTIFICATE HOLDER

The N-Type Certificate Holder or Owner shall verify that each piece, or container of small items, of each lot, is marked with the marking required by the material specification, such as specification, grade, class, or type. When a CMTR is furnished, the N-type Certificate Holder or Owner shall verify the heat number or heat code on each piece, or container of small items, of each lot for traceability to the CMTR, and shall verify that all requirements of the material specification are met and documented on the CMTR. Symbols or code numbers, when used, shall be explained on the CMTR.

3 N-TYPE CERTIFICATE HOLDER TESTING

The N-Type Certificate Holder or Owner shall perform testing to satisfy himself that the material described in the CMTR or C of C, as applicable, is the same as the material received. Testing requirements are specified in 4 through 5.

4 CHEMISTRY REQUIREMENTS

The N-Type Certificate Holder or Owner shall analyze sufficient chemical constituents of the material to satisfy himself that the material described in the CMTR or C of C, as applicable, is the same as the material received. Chemical analysis shall be performed in accordance with SA-751, Standard Methods, Practices, and Definitions for Chemical Analysis of Steel Products. Chemical composition determination procedures shall comply with the relevant ASTM standards, when these exist, and with the analytical-apparatus-manufacturer's recommendations. Alternatively, the testing may be done using the same procedures, methods, and specifications required by the applicable material specification. The tests of 4.1 and 4.2 shall be performed.

4.1 Each piece shall be tested as follows: verification testing for chemical constituents will vary with alloy category, and shall include at least the elements identified in (a) through (c) below.

[1] For this case, the Owner is a utility operating under the provisions of Section XI.

[2] When using this Case with the 1992 Edition with the 1994 Addenda, the later Editions and Addenda, the reference to NCA-3867.4(a) through (d) shall be taken as NCA-3860, the reference to NCA-3867.4(b) shall be taken as NCA-3862(g), and the Material Manufacturer shall be taken as the Material Organization that manufactured the material and certified the material to the material specification.

(a) Carbon and Low Alloy Steels. Verification testing for carbon and low alloy steels shall include determination of chromium, copper, manganese, molybdenum, and nickel content. Columbium (niobium), titanium, and vanadium content shall be determined if limits are provided in the material specification.

(b) Stainless Steels. Verification testing for stainless steel shall include determination of chromium and nickel content. Aluminum, cerium, copper, manganese, molybdenum, tantalum, titanium, and vanadium content shall be determined if limits are provided in the material specification.

(c) Other Metals and Alloys. Verification testing for other metals and alloys, such as copper, nickel, aluminum, copper-nickel, and aluminum-bronze, shall be performed for all metallic elements, such as aluminum, chromium, cobalt, copper, iron, lead, manganese, magnesium, molybdenum, nickel, titanium, and zinc, with limits specified by the material specification. Verification testing is required only when the material specification requires a chemical analysis.

4.2 When a CMTR is required, one piece from each heat shall also be tested in accordance with SA-751 for all chemical elements specified by the material specification.

4.3 The results for the elements required to be included in the chemical analysis shall meet the chemical analysis requirements of the applicable material specification, including any applicable product analysis tolerances.

4.4 In addition to meeting the provisions of 4.3, the results for the elements required to be included in the chemical analysis shall be compared with the values reported in the CMTR, to validate the information reported in the CMTR. For material furnished with a C of C, the results for the elements shall be compared with the values reported in the applicable material specification. Minor differences in mean values of test results and differences due to lack of homogeneity in the product are expected. The maximum variation of each element of the chemical analysis results from the CMTR values shall not exceed the lesser of 15% of the value reported on the CMTR or 0.5%.

4.5 If any piece tested does not meet the acceptance criteria, the piece shall be rejected, or it may be retested as follows: Retest shall consist of two additional tests of the item. Different test methods that will provide more accurate results may be used, and material surfaces may be reprepared prior to the retest. If either of the two retest results is unaccepatable, the piece shall be rejected. Alternatively, the item may be retested by one of the wet chemical referee methods of SA-751, unless the original sample test was done using one of these methods. The retest results shall meet the acceptance criteria of 4.3 through 4.4.

4.6 If a piece fails to meet the acceptance criteria of 4.3 through 4.5, the piece and the lot shall be rejected; alternatively, each remaining piece of the lot shall be tested in accordance with 4.2, 5.1, 5.2, 5.3 and 5.4, as applicable.

5 MECHANICAL PROPERTY REQUIREMENTS

Material specifications contain a variety of requirements for mechanical properties, e.g., tensile and yield strength, hardness, and ductility in the form of elongation and reduction of area limits. Some specifications also contain ductility requirements in the form of bending, flaring, or flattening tests. NB-2300, NC-2300, ND-2300, NE-2300, NF-2300, and NG-2300 specifies impact test requirements for specific materials and product sizes. The tests of 5.1, 5.2 and 5.3 shall be performed.

5.1 When a CMTR is required, one piece from each heat or lot shall also be tensile tested in accordance with SA-370. The tensile test results shall be within 15% of the values reported on the CMTR and shall meet the tensile properties specified in the material specification.

5.2 When the applicable material specification specifies a minimum or maximum hardness limit, each piece shall be tested for hardness in accordance with the requirements of the material specification. The measured hardness test results shall meet the specified hardness of the material specification.

5.3 When impact testing is required for the material one piece from each lot shall be tested in accordance with NB-2300, NC-2300, ND-2300, NE-2300, NF-2300, and NG-2300. The impact results shall meet the acceptance criteria required for the material.

5.4 If any item does not meet the acceptance criteria, the item shall be rejected, or it may be retested as follows: A retest shall consist of two additional tests of the item. When a retest for hardness is required, different test methods that will provide more accurate results may be used, and material surfaces may be reprepared prior to the retest. If either of the two retest results is unacceptable, the item shall be rejected.

5.5 If an item fails to meet the acceptance criteria of 5.1 through 5.4 the item and the lot shall be rejected. Alternatively, each remaining piece of the lot shall be tested in accordance with 4.2, 5.1, 5.2, 5.3, and 5.4, as applicable.

6 N-TYPE CERTIFICATE HOLDER OR OWNER VERIFICATION

The N-Type Certificate Holder or Owner shall verify that all applicable test required by NB-2200, NC-2200, ND-2200, NE-2200, NF-2200, and NG-2200, NB-2300, NC-2300, ND-2300, NE-2300, NF-2300, and NG-2300, and NB-2400 NC-2400, ND-2400, NE-2400, NF-2400, and NG-2400 and performed by the Material Manufacturer are documented on the CMTR. If such tests have not been performed by the Material Manufacturer, they shall be performed by the N-Type Certificate Holder or Owner. In addition, the N-Type Certificate Holder or Owner shall perform all applicable examinations and repairs required by NB-2500, NC-2500, ND-2500, NE-2500, NF-2500, and NG-2500. The Owner's NDE personnel shall be qualified in accordance with Section III.

7 PROCEDURE

The procedures for accepting material in accordance with this Case shall be made available to the Authorized Nuclear Inspector prior to acceptance of the material.

8 IDENTIFICATION

Use of this Case shall be identified on the material certification records. Records of all testing shall be included with the Certified Material Test Report or Certificate of Compliance. as applicable. These records shall be made available to the Authorized Nuclear Inspector.

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Approval Date: March 12, 1997

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-491-2
Alternative Rules for Examination of Class 1, 2, 3, and MC Component Supports of Light-Water Cooled Power Plants
Section XI, Division 1

Inquiry: What alternative examination requirements to those stated in Section XI, Division 1, Subsection IWF may be used when determining the component supports subject to examination and establishing requirements for component supports?

Reply: It is the opinion of the Committee that the following alternative rules may be used for determining component supports subject to examination and for establishing examination requirements for Class 1, 2, 3, and MC component supports under Subsection IWF, Section XI, Division 1.

TABLE OF CONTENTS

TABLES

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

This Case provides alternative rules for inservice inspection of Class 1, 2, 3, and MC component supports.

-1200 COMPONENT SUPPORTS SUBJECT TO EXAMINATION AND TEST

-1210 Examination Requirements

The examination requirements shall apply to the following:

(a) piping supports;

(b) supports other than piping supports.

-1220 Snubber Inspection Requirements

The inservice inspection requirements for snubbers shall be in accordance with the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program.

-1230 Supports Exempt from Examination

Component supports exempt from the examination requirements of -2000 are those connected to components and items exempted from examination under IWB-1220, IWC-1220, IWD-1220, and IWE-1220. In addition, portions of supports that are inaccessible by being encased in concrete, buried underground, or encapsulated by guard pipe are also exempt from the examination requirements of -2000.

-1300 SUPPORT EXAMINATION BOUNDARIES

Support examination boundaries shall be in accordance with IWF-1300.

-2000 EXAMINATION AND INSPECTION

-2100 SCOPE

The requirements of this Case apply to the examination and inspection of component supports, but not to the inservice test requirements of IWF-5000.

-2200 PRESERVICE EXAMINATION

-2210 Initial Examination

(a) All examinations listed in Table -2500-1 shall be performed completely, once, as a preservice examination. These preservice examinations shall be extended to include 100% of all supports not exempted by -1230.

(b) Examinations for systems that operate at a temperature greater than 200°F during normal plant operation shall be performed during or following initial system heatup and cooldown. Other examinations may be performed prior to initial system heatup and cooldown.

-2220 Adjustment, Repair, and Replacement

(a) Prior to return of the system to service, the applicable examinations listed in Table -2500-1 shall be performed on component supports that have been adjusted in accordance with -3000, repaired, or replaced.

(b) For systems that operate at a temperature greater than 200°F during normal plant operation, the Owner shall perform an additional preservice examination on the affected component supports during or following the subsequent system heatup and cooldown cycle unless determined unnecessary by evaluation. This examination shall be performed during operation or at the next refueling outage.

-2400 INSPECTION SCHEDULE

-2410 Inspection Program

(a) Inservice examinations shall be performed either during normal system operation or plant outages.

(b) The required examinations shall be completed in accordance with the inspection schedule provided in Table -2410-1 or Table -2410-2.

(c) The inspection period specified in *(b)* above may be decreased or extended by as much as one year to enable an inspection to coincide with a plant outage, within the limitations of IWA-2400.

(d) Following completion of Program A after 40 yr, successive inspection intervals shall follow the 10 yr inspection interval of Program B.

Table -2410-1
Inspection Program A

Inspection Interval	Inspection Period, Calendar Years of Plant Service	Minimum Examinations Completed, %	Maximum Examinations Credited, %
1st	3	100	100
2nd	7	33	67
	10	100	100
3rd	13	16	34
	17	40	50
	20	66	75
	23	100	100
4th	27	8	16
	30	25	34
	33	50	67
	37	75	100
	40	100	...

Table -2410-2
Inspection Program B

Inspection Interval	Inspection Period, Calendar Years of Plant Service Within the Interval	Minimum Examinations Completed, %	Maximum Examinations Credited, %
1st	3	16	34
	7	50	67
	10	100	100
Successive	3	16	34
	7	50	67
	10	100	100

-2420 Successive Inspections

(a) The sequence of component support examinations established during the first inspection interval shall be repeated during each successive inspection interval, to the extent practical.

(b) When a component support must be subjected to corrective measures in accordance with -3000, that support shall be reexamined during the next inspection period listed in the inspection schedules of the inspection programs of -2410.

(c) When additional corrective measures are not required during the next inspection period as a result of the examinations required by *(b)* above, the inspection schedule may revert to the requirements of (a) above.

-2430 Additional Examinations

(a) When component supports must be subjected to corrective measures in accordance with -3000, the component supports immediately adjacent to those for which corrective action is required shall be examined. Also, the examinations shall be extended to include additional supports within the system, equal in number and of the same type and function as those scheduled for examination during the inspection period.

(b) When corrective measures in accordance with -3000 are required as a result of the additional examinations, the remaining component supports within the system of the same type and function as in *(a)* above shall be examined.

(c)

(1) When corrective measures in accordance with -3000 are required as a result of the additional examinations in (b) above, examinations shall be extended to include all nonexempt supports potentially subject to the same failure modes that required corrective measures in accordance with (a) and (b) above.

(2) These additional examinations shall include nonexempt component supports in other systems when support failures requiring corrective measures indicate non-system-related support failure modes.

(d) When corrective measures are required by (c)(1) above, the Owner shall examine those exempt component supports that could be affected by the same observed failure modes and could affect nonexempt components.

-2500 EXAMINATION REQUIREMENTS

The following shall be examined in accordance with Table -2500-1.

(a) mechanical connections to pressure retaining components and building structure;

(b) weld connections to building structure;

(c) weld and mechanical connections at intermediate joints in multiconnected integral and nonintegral supports;

(d) clearances of guides and stops, alignment of supports, and assembly of support items;

(e) hot or cold settings of spring supports and constant load supports.

(f) accessible sliding surfaces.

-2510 Supports Selected for Examination

Component and piping supports shall be examined in accordance with Table -2500-1. Component supports to be examined shall be the supports of those components that are required to be examined under IWB-2500, IWC-2500, IWD-2500, and IWE-2500 by volumetric, surface, or visual (VT-1 or VT-3) examination methods. Piping supports to be examined shall be the supports of piping not exempted under IWB-1220, IWC-1220, IWD-1220, and IWE-1220.

-2520 Method of Examination

The methods of examination shall comply with those in Table -2500-1. Alternative methods of examination meeting the requirements of IWA-2240 may be used.

-3000 STANDARDS FOR EXAMINATION EVALUATIONS

-3100 EVALUATION OF EXAMINATION RESULTS

-3110 Preservice Examinations

-3111 General

The preservice examinations performed to meet the requirements of -2000 shall be evaluated by comparing the examination results with acceptance standards specified in -3400.

-3112 Acceptance

-3112.1 Acceptance by Examination. Component supports whose examinations do not reveal conditions described in -3410(a) shall be acceptable for service.

Table -2500-1
Examination Categories

EXAMINATION CATEGORY F-A, SUPPORTS						
Item No. [Note (1)]	**Support Type Examined**	**Examination Requirements/ Fig. No.**	**Examination Method**	**Acceptance Standard**	**Extent of Examination (See -2500)**	**Frequency of Examination [Note (4)]**
F1.10	Class 1 Piping Supports	IWF-1300-1	Visual, VT-3	-3410	25% of Class 1 [Note (2)]	inspection interval
F1.20	Class 2 Piping Supports	IWF-1300-1	Visual, VT-3	-3410	15% of Class 2 [Note (2)]	inspection interval
F1.30	Class 3 Piping Supports	IWF-1300-1	Visual, VT-3	-3410	10% of Class 3 [Note (2)]	inspection interval
F1.40	Supports Other than Piping Supports (Class 1, 2, 3, and MC)	IWF-1300-1	Visual, VT-3	-3410	100% of the supports [Note (3)]	inspection interval

NOTES:

(1) Item numbers shall be categorized to identify support types by component support function (e.g., A = supports such as one-directional rod hangers supports such as multi-directional restraints; and C = supports that allow thermal movement, such as springs).

(2) The total percentage sample shall be comprised of supports from each system (e.g., Main Steam, Feedwater, or RHR), where the individual sample proportional to the total number of nonexempt supports of each type and function within each system.

(3) For multiple components other than piping, within a system of similar design, function, and service, the supports of only one of the multipl ents are required to be examined.

(4) To the extent practical, the same supports selected for examination during the first inspection interval shall be examined during each successiv inspection interval.

-3112.2 Acceptance by Correction. Component supports whose examinations reveal conditions described in -3410(a) shall be unacceptable for service until such conditions are corrected by one or more of the following:

(a) adjustment and reexamination in accordance with -2200 for conditions such as

(1) detached or loosened mechanical connections;

(2) improper hot or cold settings of spring supports and constant load supports;

(3) misalignment of supports; or

(4) improper displacement settings of guides and stops.

(b) repair in accordance with IWA-4000 and reexamination in accordance with -2200;

(c) replacement in accordance with IWA-7000 and reexamination in accordance with -2200.

-3112.3 Acceptance by Evaluation or Test.

(a) As an alternative to the requirements of -3112.2, a component support or a portion of a component support containing relevant conditions that do not meet the acceptance standards of -3410 shall be acceptable for service without corrective measures if an evaluation or test demonstrates the component support is acceptable for service.

(b) If a component support or a portion of a component support, has been evaluated or tested and determined to be acceptable for service in accordance with (a), the Owner may perform corrective measures to restore the component support to its original design condition. The requirements of -2220 are not applicable after corrective measures of -3112.2(a) are performed.

(c) Records and reports shall meet the requirements of IWA-6000.

-3120 Inservice Examinations

-3121 General

Inservice nondestructive examinations performed during or at the end of successive inspection intervals to meet the requirements of Table -2500-1 and conducted in accordance with the procedures of IWA-2200 shall be evaluated by comparing the results of examinations with the acceptance standards specified in -3400.

-3122 Acceptance

-3122.1 Acceptance by Examination. Component supports whose examinations do not reveal conditions described in -3410(a) shall be acceptable for continued service. Verified changes or conditions from prior examinations shall be recorded in accordance with IWA-6220.

-3122.2 Acceptance by Correction. Component supports whose examinations reveal conditions described in -3410(a) shall be unacceptable for continued service until such conditions are corrected by one or more of the following:

(a) adjustment and reexamination in accordance with -2200 for conditions such as;

(1) detached or loosened mechanical connections;

(2) improper hot or cold settings of spring supports and constant load supports;

(3) misalignment of supports; or

(4) improper displacement settings of guides and stops.

(b) repair in accordance with IWA-4000 and reexamination in accordance with -2200;

(c) replacement in accordance with IWA-7000 and reexamination in accordance with -2200.

-3122.3 Acceptance by Evaluation or Test

(a) As an alternative to the requirements of -3122.2, a component support or a portion of a component support containing relevant conditions that do not meet the acceptance standards of -3410 shall be acceptable for continued service without corrective measures if an evaluation or test demonstrates the component support is acceptable for continued service.

(b) If a component support or a portion of a component support, has been evaluated or tested and determined to be acceptable for continued service in accordance with (a), the Owner may perform corrective measures to restore the component support to its original design condition. The requirements of -2220 are not applicable after corrective measures of -3122.2(a) are performed.

(c) Records and reports shall meet the requirements of IWA-6000.

-3200 SUPPLEMENTAL EXAMINATIONS

Examinations that detect conditions that require evaluation in accordance with the requirements of -3100 may be supplemented by other examination methods and techniques (IWA-2000) to determine the character of the flaw (i.e., size, shape, and orientation). Visual examinations that detect surface flaw that exceed -3400 criteria shall be supplemented by either surface or volumetric examinations.

-3400 ACCEPTANCE STANDARDS

-3410 Acceptance Standards — Component Support Structural Integrity

(a) Component support conditions which are unacceptable for continued service shall include the following:

(1) deformations or structural degradations of fasteners, springs, clamps, or other support items;

(2) missing, detached, or loosened support items;

(3) arc strikes, weld splatter, paint scoring, roughness, or general corrosion on close tolerance machined or sliding surfaces;

(4) improper hot or cold settings of spring supports and constant load supports;

(5) misalignment of supports;

(6) improper clearances of guides and stops.

(b) Except as defined in *(a)* above, the following are examples of non-relevant conditions:

(1) fabrication marks (e.g., from punching, layout, bending, rolling, and machining);

(2) chipped or discolored paint;

(3) weld splatter on other than close tolerance machined or sliding surfaces;

(4) scratches and surface abrasion marks;

(5) roughness or general corrosion which does not reduce the load bearing capacity of the support;

(6) general conditions acceptable by the material, Design, or Construction Specifications.

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Case N-493
Alternative Radiographic Acceptance Criteria for Vessels Used as Shipping Casks, Class 1
Section III, Division 1

ANNULLED

Annulment Date: February 9, 2015

Reason: No longer needed.

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Approval Date: January 12, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-494-4
Pipe Specific Evaluation Procedures and Acceptance Criteria for Flaws in Piping that Exceed the Acceptance Standards
Section XI, Division 1

Inquiry: As an alternative to the requirements of IWB-3640 for Class 1 piping, IWC-3640 for Class 2 piping, or IWD-3640 for Class 3 piping, may Class 1, 2, or 3 ferritic or austenitic piping containing a flaw exceeding the acceptance standards of IWB-3514.1, IWC-3514, or IWD-3500, respectively, be evaluated when actual pipe material strength or toughness properties are available?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWB-3640 for Class 1 piping, IWC-3640 for Class 2 piping, or IWD-3640 for Class 3 piping, flaws in Class 1, 2, or 3 ferritic or austenitic piping exceeding the acceptance standards of IWB-3514.1, IWC-3514, or IWD-3500, respectively, may be evaluated for continued service in accordance with the following procedure.

1 EVALUATION PROCEDURES AND ACCEPTANCE CRITERIA

Piping containing a flaw exceeding the acceptance standards of IWB-3514.1, IWC-3514, or IWD-3500 may be evaluated by analytical procedures to determine acceptability for continued service to the next inspection or to the end of service lifetime. The pipe containing the flaw is acceptable for continued service during the evaluated time period if the criteria of 1.2 are satisfied. The evaluation shall be the responsibility of the Owner and shall be submitted to the regulatory and enforcement authorities having jurisdiction at the plant site.

1.1 EVALUATION PROCEDURES

Evaluation procedures based on use of a failure assessment diagram such as in Nonmandatory Appendix A or Nonmandatory Appendix B of this Case shall be used, subject to the following:

(a) The evaluation procedures and acceptance criteria are applicable to ferritic and austenitic piping NPS 4 (DN 100) or larger and portions of adjoining pipe fittings within a distance of $\sqrt{R_2 t}$ from the weld centerline, where R_2 is the outside radius and t is the thickness of the pipe.

(b) For ferritic piping, the evaluation procedures and acceptance criteria are applicable to seamless or welded wrought carbon steel pipe and fittings with specified minimum yield strength not greater than 40 ksi (280 MPa), and associated weld materials.

(c) For austenitic piping, the evaluation procedures and acceptance criteria are applicable to pipe, fittings, and associated weld materials that are made of wrought stainless steel, Ni-Cr-Fe alloy, or cast stainless steel with ferrite level less than 20% or 20 FN (ferrite number); with specified minimum yield strength less than 45 ksi (310 MPa).

1.2 ACCEPTANCE CRITERIA

(a) Flaws in ferritic or austenitic piping characterized to have depths greater than 75% of the wall thickness at the end of the evaluation period are unacceptable. Other flaws exceeding the acceptance standards of IWB-3514.1, IWC-3514, or IWD-3500 may be evaluated using the analytical procedures of Nonmandatory Appendix A of this Case for ferritic piping, or Nonmandatory Appendix B of this Case for austenitic piping. Piping containing these other flaws is acceptable for continued service during the evaluation period when the criteria in (1) and (2) below are satisfied.

(1) For each specific set of loading conditions, one or more assessment points with coordinates (S_r', K_r'), shall be inside the failure assessment curve. For lower shelf and transition temperatures, only one assessment point is required to be calculated. For upper shelf temperatures, a series of assessment points for various amounts of ductile flaw extension may be required to be calculated to meet this criterion.

(2) The S_r' coordinate of the assessment point that satisfies criterion (1) above shall satisfy

$$S_r' \leq S_r^{\text{cutoff}}$$

where S_r^{cutoff} is the limit load cutoff on the applicable failure assessment diagram.

(b) Formulae for (S_r', K_r') and S_r^{cutoff} applicable to ferritic and austenitic piping are given in Nonmandatory Appendix A of this Case. The values of (S_r', K_r') and S_r^{cutoff} are functions of actual pipe stresses, required structural factors, pipe material properties, end of evaluation period flaw length and depth, and flaw orientation. The failure assessment curve is independent of flaw orientation, flaw depth, flaw aspect ratio, and pipe radius to thickness ratio.

2 APPLICABILITY

This Case is applicable to the 1983 Edition and later Editions and Addenda. Reference in this Case to Appendices A and C of Section XI shall apply to Appendices A and C of the 2004 Edition. For Editions and Addenda prior to the 2004 Edition, Class 1 pipe flaw evaluation procedures may be used for other piping classes. As a matter of definition, the current term “structural factor” is equivalent to the term “safety factor” in earlier Editions and Addenda.

NONMANDATORY APPENDIX A
EVALUATION OF FLAWS IN FERRITIC PIPING

A-1000 INTRODUCTION

A-1100 SCOPE

(a) This Appendix provides a method for determining acceptability for continued service of ferritic piping containing flaws that exceed the allowable flaw standards of IWB-3514.1, IWC-3514, or IWD-3500. The evaluation methodology is based on a failure assessment diagram approach that includes consideration of the following failure mechanisms:

(1) brittle fracture described by linear elastic fracture mechanics;

(2) elastic plastic fracture mechanics, when ductile flaw extension occurs prior to reaching limit load;

(3) limit load failure of the pipe cross section, which is reduced by the flaw area, for ductile materials where the limit load is assured.

(b) This Appendix accounts for actual pipe material toughness properties through input of either the J_R resistance curve that characterizes ductile flaw extension, or the fracture toughness J_{Ic}. Flaws are evaluated by comparing the actual pipe applied stress, for the flaw size at the end of the evaluation period, with the allowable stress, using the graphical procedure of a failure assessment diagram approach. All combinations of applied stresses P_m, P_b, and P_e are permitted in the evaluation.

(c) This Appendix provides requirements for flaw modeling and flaw growth. Flaw growth analysis is based on fatigue. When stress corrosion cracking (SCC) is active, the growth shall be added to the growth from fatigue. The acceptance criteria of 1.2 shall include structural factors on failure for the three failure mechanisms described above. The acceptance criteria shall be used to determine acceptability of the flawed piping for continued service until the next inspection, or until the end of service lifetime, or to determine the time interval until a subsequent inspection.

A-1200 PROCEDURE OVERVIEW

The following is a summary of the analytical procedure:

(a) Determine the flaw configuration from the measured flaw in accordance with IWA-3000, using A-2000 of this Case.

(b) Resolve the actual flaw into circumferential and axial components using A-2000 of this Case.

(c) Determine the stresses normal to the flaw at the location of the detected flaw for normal, upset, emergency, faulted and test conditions.

(d) Perform a flaw growth analysis, as described in A-3000 of this Case, to establish the end of the evaluation period flaw dimensions, a_f and ℓ_f.

(e) Obtain actual pipe material properties, E, σ_y, σ_f, and the J_R resistance curve or J_{Ic}, at the temperatures required for analysis.

(f) Calculate the appropriate vertical cutoff, S_r^{cutoff}, for the flaw configuration of interest, circumferential or axial, using the formulae in A-4211 or A-4212 of this Case.

(g) Using the formulae in I-4300 of this Case, calculate the assessment point coordinates (S_r', K_r'), for the piping stresses P_m, P_b and P_e for circumferential flaws, or p (pressure) for axial flaws, using the specified structural factors in Table A-4400-1 or Table A-4400-2 of this Case, respectively.

(h) Plot the assessment points calculated in (g) above on the failure assessment diagram in Figure A-4200-1 of this Case and apply the acceptance criteria of 1.2 to determine the acceptability of the pipe for continued service.

A-1300 NOMENCLATURE

The following nomenclature is used in this Appendix.

a = initial flaw depth
Δa = ductile flaw extension
a_f = maximum depth to which the detected flaw is calculated to grow by the end of the evaluation period
a' = sum of flaw depth plus ductile flaw extension
C_o = material constant in fatigue growth equation
da/dN = fatigue flaw growth rate
E = Young's modulus
E' = $E/(1 - \mu^2)$
f_c = geometry correction term that accounts for flaw depth and wall thickness relative to pipe inside radius
$f(z)$ = bulging factor correction
F_m = parameter for circumferential flaw membrane stress intensity factor
F_b = parameter for circumferential flaw bending stress intensity factor
F_1 = total geometry correction factor for interior axial part-through-wall flaw in pressurized pipe
J_e = linear elastic J-integral calculated from stress intensity factor K_I
J_{Ic} = measure of toughness at crack initiation at upper shelf, transition, and lower shelf temperatures

J_R = J-integral resistance to ductile tearing at prescribed Δa value obtained from accepted test procedures
K_I = mode I stress intensity factor
ΔK_I = maximum range of K_I fluctuation during transient
K_r = ordinate of failure assessment diagram curve
K_r' = brittle fracture component of assessment point defined by ratio of stress intensity factor to material fracture toughness
K_{Ir} = stress intensity factor for residual stress
ℓ = initial flaw length
ℓ_f = maximum length to which detected flaw is calculated to grow at end of evaluation period
ℓ_{crit} = critical flaw length for stability of an axial through-wall flaw
M_2 = parameter for circumferential collapse stress
M_1', M_2', M_3' = geometry correction factor for interior axial part-through-wall flaw in pressurized pipe: accounts for flaw aspect -ratio, a/ℓ
n = material constant in fatigue flaw growth equation
p = internal pressure
P_m = primary membrane stress in the pipe at the flaw
$P_{m\ell}$ = membrane stress at collapse limit load with zero primary bending stress
P_m' = membrane stress at reference limit load for any combination of primary stresses
P_b = primary bending stress in the pipe at the flaw
P_b' = bending stress at collapse limit load for any combination of primary stresses
P_e = secondary bending stress at the flaw location, including thermal expansion and seismic anchor movement
P_ℓ = internal pressure at collapse limit load for axial flaw
P_o = reference limit load pressure
Q = flaw shape parameter
R = mean radius of pipe
R_c = sum of flaw depth and inside radius of pipe
R_1 = inside radius of pipe
R_2 = outside radius of pipe
S_r = abscissa of failure assessment diagram curve
S_r' = limit load component of assessment point, defined for circumferential flaws by ratio of applied stress to stress at reference limit load, and for axial flaws as ratio of pressure to reference limit load pressure
$S_r^{\ cutoff}$ = maximum value of S_r at vertical (limit load) boundary of failure assessment diagram curve
SF_b = structural factor on primary bending stress for circumferential flaws
SF_m = structural factor on primary membrane stress for circumferential or axial flaws
t = pipe wall thickness
x = parameter a/t
z = global limit load geometry factor
β = angle to neutral axis of flawed pipe, radians
γ = factor in reference limit load expression for P_m' reflecting ratio of P_b to P_m
Γ_m = factor in reference limit load expressions reflecting effect of flaw size
θ = one-half of final flaw angle (see Figure A-4211-1 of this Case), radians
μ = Poisson's ratio
σ_f = flow stress as defined in Section XI, Appendix C
σ_h = hoop stress in the pipe at the flaw
σ_y = yield strength
ψ = angle used in defining $P_{m\ell}$, radians

A-2000 FLAW MODEL FOR ANALYSIS

A-2100 SCOPE

This Article provides requirements for flaw shape, multiple flaws, flaw orientation, and flaw location used to determine acceptance.

A-2200 FLAW SHAPE

The flaw shall be completely bounded by a rectangular or circumferential planar area in accordance with the methods described in IWA-3300.Figure A-2200-1 and Figure A-2200-2 of this Case illustrate flaw characterization for circumferential and axial pipe flaws, respectively.

A-2300 PROXIMITY TO CLOSEST FLAW

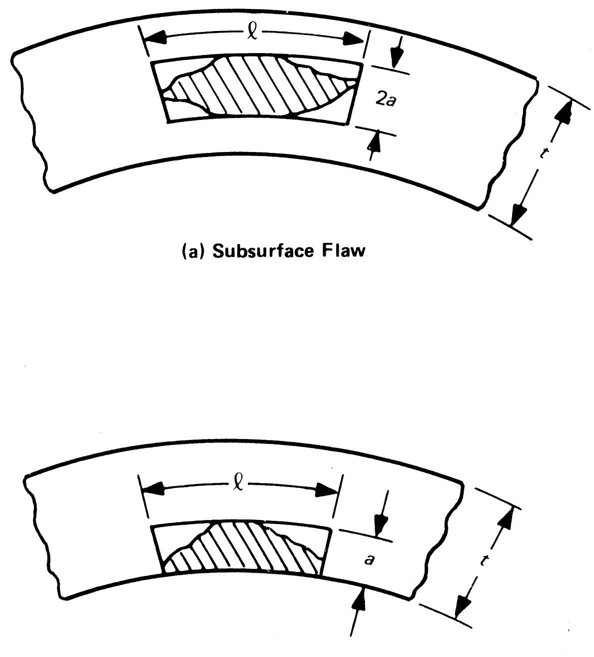
For multiple neighboring flaws, when the shortest distance between the boundaries of two neighboring flaws is within the proximity limits specified in IWA-3300, the neighboring flaws shall be bounded by a single rectangular or circumferential planar area in accordance with IWA-3300.

A-2400 FLAW ORIENTATION

Flaws that lie in neither an axial[1] nor a circumferential[2] plane shall be projected onto these planes in accordance with the rules of IWA-3340. The axial and circumferential

[1] A plane containing the pipe axis.
[2] A plane perpendicular to the pipe axis.

Figure A-2200-1
Flaw Characterization — Circumferential Flaws



flaws obtained by these projections shall be evaluated separately in accordance with this Appendix. Figures A-2400-1, A-2400-2, and A-2400-3 of this Case illustrate flaw characterization for skewed flaws.

A-2500 FLAW LOCATION

For analysis, the stresses due to system loading shall be computed at the flaw location. Surface or subsurface flaw characterizations shall be used, depending on the type of flaw. Subsurface flaws within the proximity limit of IWA-3340 to the surface of the component shall be evaluated as surface flaws and shall be bounded by a rectangular or circumferential planar area with the base on the surface.

A-3000 FLAW GROWTH ANALYSIS

A-3100 SCOPE

This Article provides the methodology for determination of subcritical flaw growth during the evaluation -interval.

A-3200 SUBCRITICAL FLAW GROWTH ANALYSIS

When a flaw is characterized in terms of an equivalent axial or circumferential flaw, the maximum depth, a_f, and the maximum length, ℓ_f, at the end of the evaluation period shall be determined. Subcritical flaw growth due to fatigue shall be evaluated. When stress corrosion cracking (SCC) is determined to be an active flaw growth mechanism for the pipe being evaluated, SCC shall also be evaluated. Residual stresses shall be included for both growth mechanisms.

A-3210 SUBCRITICAL FLAW GROWTH DUE TO FATIGUE

(a) Fatigue flaw growth shall be computed by

$$da/dN = C_o\left(\Delta K_I\right)^n$$

where K_I is the applied stress intensity factor, and n and C_o are constants dependent on the material and environmental conditions.

(b) A cumulative fatigue flaw growth calculation shall be performed using operating conditions and transients that apply during the evaluation period. Each transient shall be considered in approximate chronological order as follows.

(1) Determine ΔK_I.

(2) Determine the incremental flaw growth corresponding to ΔK_I from the fatigue flaw growth rate curve of A-4300 of Section XI, Appendix A.

(c) After all transients have been considered, the procedure of (a) and (b) above yields the final flaw sizes, a_f and ℓ_f, at the end of the evaluation period, considering only fatigue flaw growth.

A-3220 Flaw Growth Due to Stress Corrosion Cracking (SCC)

Subcritical flaw growth due to SCC has not been observed to be a significant flaw growth mechanism in ferritic piping. When growth due to SCC is determined to be active, characterization shall be the responsibility of the Owner.

A-4000 FAILURE ASSESSMENT DIAGRAM ANALYSIS

A-4100 SCOPE

This Article describes the failure assessment diagram procedure for the evaluation of flaws in ferritic piping. The procedure requires:

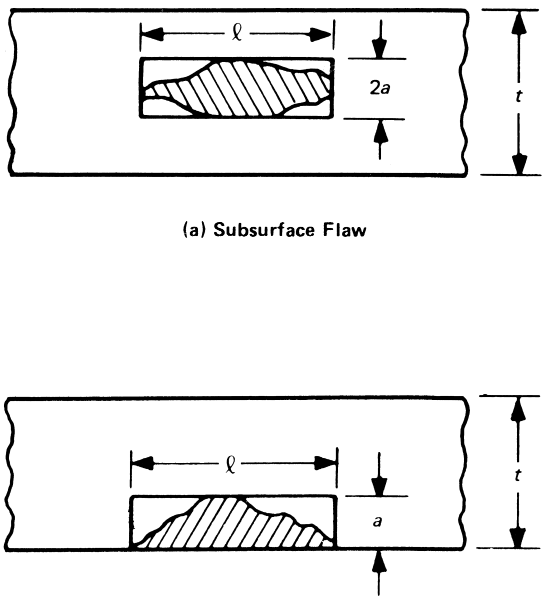
(a) a failure assessment diagram curve;
(b) failure assessment point coordinates;
(c) flaw acceptance determination

A-4200 FAILURE ASSESSMENT DIAGRAM CURVE

The failure assessment diagram given in Figure A-4200-1 of this Case is applicable for ferritic piping having:

(a) part-through-wall circumferential flaws under any combination of primary membrane, primary bending, and secondary stresses (see Figure A-4211-1 of this Case); and

Figure A-2200-2
Flaw Characterization — Axial Flaws



(b) Surface Flaw

(b) part-through-wall axial flaws under internal pressure (see Figure A-4212-1 of this Case).

Figure A-4200-1 of this Case shall be used for circumferential flaws of depths up to 75% of the pipe wall thickness and lengths up to one-half the inside circumference of the pipe.

Figure A-4200-1 of this Case shall also be used for axial flaws of depths up to 75% of the pipe wall thickness and lengths up to ℓ_{crit}, where ℓ_{crit} is given by the limit load stability condition for through-wall flaws:

$$\ell_{crit} = 1.58(Rt)^{1/2}\left[\left(\sigma_f/\sigma_h\right)^2 - 1\right]^{1/2}$$

The failure assessment diagram shown in Figure A-4200-1 of this Case has a vertical cutoff for upper bound limits on S_r. The value of the cutoff is given in A-4210 of this Case. The failure assessment diagram curve is limited to $R/t \leq 15$.

A-4210 Failure Assessment Diagram Curve Cutoff for Limit Load

The vertical cutoff of the failure assessment diagram curve is provided for the following conditions:

(a) part-through-wall circumferential flaws (see Figure A-4211-1 of this Case) under any combination of primary membrane and primary bending stress:

(b) part-through-wall axial flaws (see Figure A-4212-1 of this Case) under internal pressure.

A-4211 Circumferential Flaw Cutoff

(a) For pure membrane stress, $P_b = 0$, the limit load cutoff for S_r is given by

$$S_r^{cutoff} = P_{m\ell}/P'_m$$

where

$$P_{m\ell} = \sigma_f\left[1 - \left(a/t\right)\left(\theta/\pi\right) - 2\psi/\pi\right]$$

$$\Psi = \arcsin\left[0.5\left(a/t\right)\sin\theta\right]$$

$$P'_m = \sigma_y \Gamma_m$$

where Γ_m is defined in (b) below.

(b) For membrane plus bending stresses, the limit load cutoff for S_r is given by

$$S_r^{cutoff} = \frac{SF_m}{P'_m}\left(\frac{P_m}{P_b}\right)\left[\frac{P'_b}{SF_b} - P_m\left(1 - \frac{1}{SF_m}\right)\right]$$

where

$$P_m{}' = \sigma_y \gamma \Gamma_m$$

$$\gamma = \frac{-\pi P_b}{8P_m} + \left[\left(\frac{\pi P_b}{8P_m}\right)^2 + 1\right]^{0.5}$$

$$\Gamma_m = \frac{\left[R_2^2 - R_c^2 + \left(1 - \frac{\theta}{\pi}\right)\left(R_c^2 - R_1^2\right)\right]}{\left(R_2^2 - R_1^2\right)}$$

$$R_c = R_1 + a$$

SF_m and SF_b are the structural factors on primary membrane stress and primary bending stress, respectively, specified in Table A-4400-1 of this Case. For circumferential flaws not penetrating the compressive region of the pipe cross-section, $\theta + \beta \leq \pi$

$$P'_b = \frac{2\sigma_f}{\pi}\left[2\sin\beta - \left(a/t\right)\sin\theta\right]$$

where

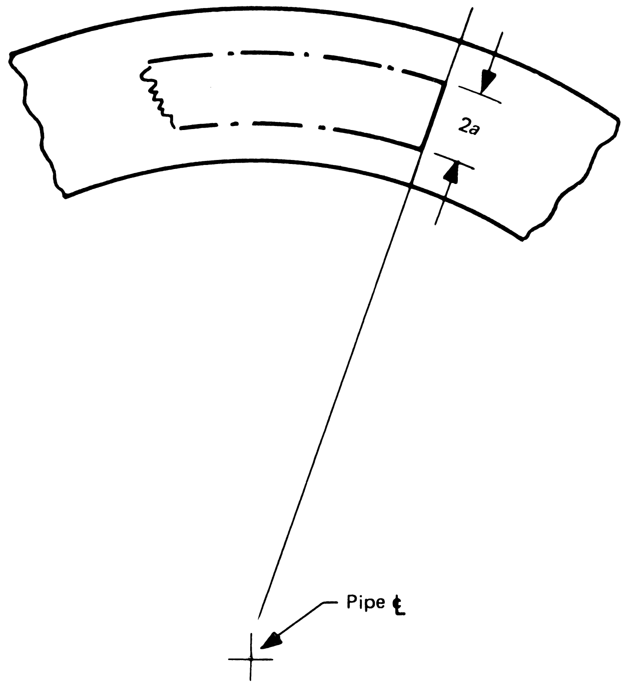
$$\beta = \frac{1}{2}\left[\pi - \frac{a}{t}\theta - \frac{\pi P_m}{\sigma_f}\right]$$

For longer flaws penetrating the compressive region of the pipe cross-section, $\theta + \beta > \pi$

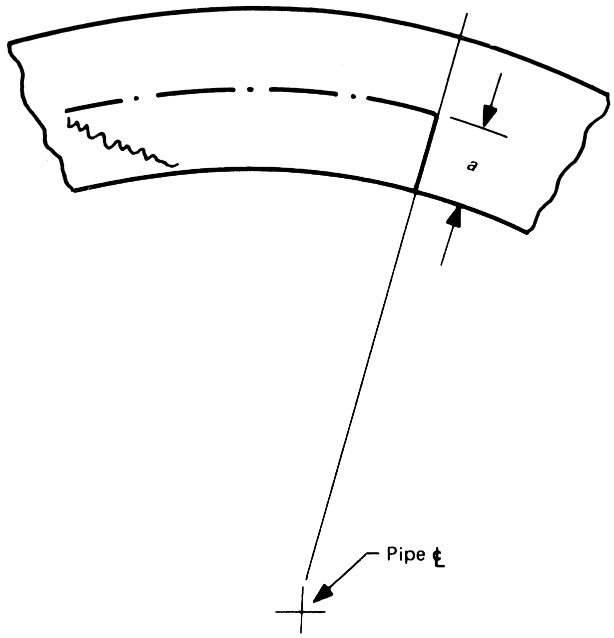
$$P'_b = \frac{2\sigma_f}{\pi}\left(2 - \frac{a}{t}\right)\sin\beta$$

where

Figure A-2400-1
Flaw Characterization — Skewed Axial Flaws Projected into Axial Plane

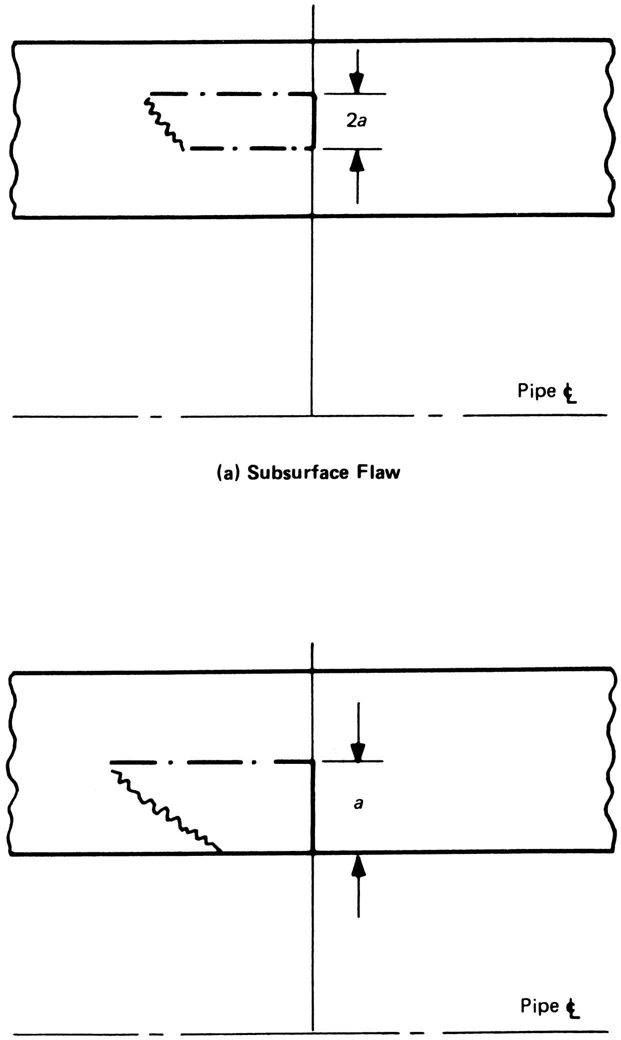


(a) Subsurface Flaw



(b) Surface Flaw

Figure A-2400-2
Flaw Characterization — Skewed Circumferential Flaw Projected into Circumferential Plane



$$\beta = \frac{\pi}{2 - a/t}\left[1 - a/t - \frac{P_m}{\sigma_f}\right]$$

(c) For pure bending stress, $P_m = 0$, the limit load cutoff for S_r is given by

$$S_r^{\text{cutoff}} = \left(\pi/4\right)P_b'/\left(\sigma_y \Gamma_m\right)$$

where $P_b{}'$ and Γ_m are as defined in (b) above.

A-4212 Axial Flaw Cutoff

For axial flaws in pipes under internal pressure the limit load cutoff for S_r is given by

$$S_r^{\text{cutoff}} = P_\ell / P_o$$

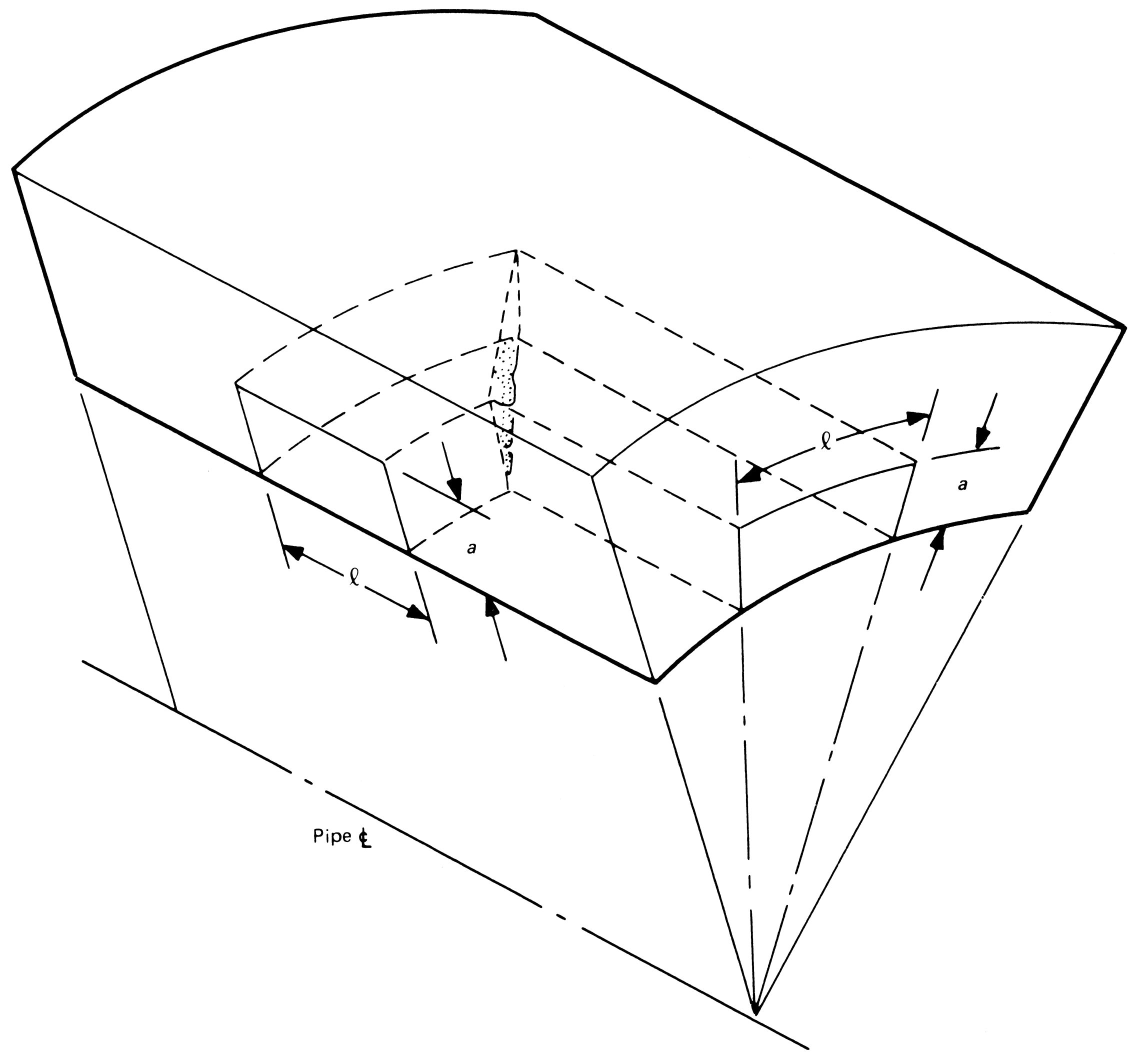
where

$$P_o = \left(\frac{2}{\sqrt{3}}\right)\left(\frac{t}{R_1}\right)[1 - x + x/f(z)]\sigma_y$$

$$f(z) = \left(1 + 1.61z\right)^{0.5}$$

$$z = \frac{0.1542\ell^2}{at\left(R_1/t + 0.5\right)}$$

Figure A-2400-3
Flaw Characterization — Compound Skewed Flaw Projected into Circumferential and Axial Plane



$$P_\ell = \left(t/R_1\right)\sigma_f\left[\left(1 - x\right)/\left(1 - x/M_2\right)\right]$$

where

$$x = a/t$$

$$M_2 = \left\{1 + \left[1.61\ell^2/\left(4Rt\right)\right]\right\}^{0.5}$$

A-4300 FAILURE ASSESSMENT POINT COORDINATES

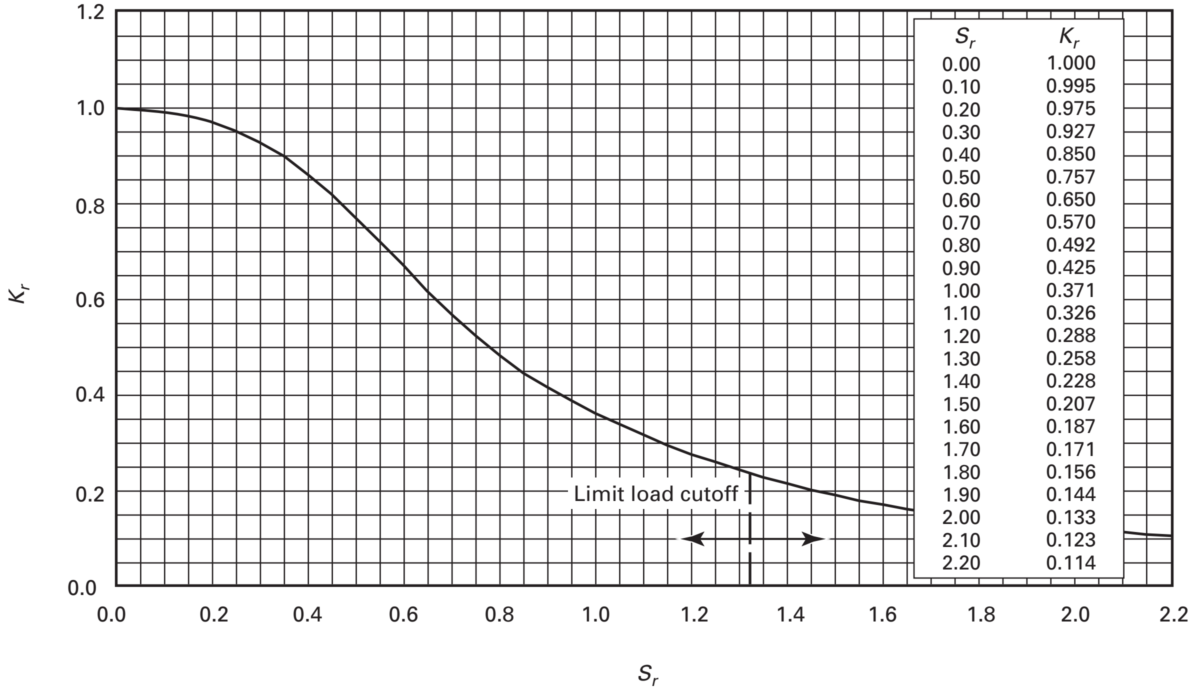
The failure assessment point coordinates, $S_r{}'$ and $K_r{}'$, shall be calculated for the end of the evaluation period flaw dimensions and for stresses at the location of, and normal to, the flaw using the J_R resistance curve data, where ductile flaw extension at upper shelf temperatures may occur prior to reaching limit load, or using J_{Ic} fracture toughness data at transition or lower shelf temperatures.

A-4310 Circumferential Flaws

The equations necessary to calculate the failure assessment point coordinates, $S_r{}'$ and $K_r{}'$, for part-through-wall circumferential flaws for a specified amount of ductile flaw extension, Δa, are given below. When the temperature is in the transition or lower shelf region, J_R shall be replaced by J_{Ic} and Δa shall be zero. When the primary membrane stress, P_m, is not zero, the coordinate $S_r{}'$ is given by

$$S_r' = \left(SF_m\right)P_m/P_m'$$

Figure A-4200-1
Failure Assessment Diagram for Part-Through-Wall Circumferential and Axial Flaws



S_r	K_r
0.00	1.000
0.10	0.995
0.20	0.975
0.30	0.927
0.40	0.850
0.50	0.757
0.60	0.650
0.70	0.570
0.80	0.492
0.90	0.425
1.00	0.371
1.10	0.326
1.20	0.288
1.30	0.258
1.40	0.228
1.50	0.207
1.60	0.187
1.70	0.171
1.80	0.156
1.90	0.144
2.00	0.133
2.10	0.123
2.20	0.114

GENERAL NOTE: S_r^{cutoff} shall be obtained from A-4211 or A-4212 of this Case.

where SF_m is the specified structural factor on primary membrane stress in Table A-4400-1 of this Case, $P_m{}'$ is recalculated for each value of Δa, and

$$P_m' = \sigma_y \gamma \Gamma_m$$

$$\gamma = \frac{-\pi P_b}{8P_m} + \left[\left(\frac{\pi P_m}{8P_m}\right)^2 + 1\right]^{0.5}$$

$$\Gamma_m = \frac{\left[R_2^2 - R_c^2 + \left(1 - \frac{\theta}{\pi}\right)\left(R_c^2 - R_1^2\right)\right]}{\left(R_2^2 - R_1^2\right)}$$

Figure A-4211-1
Circumferential Flaw

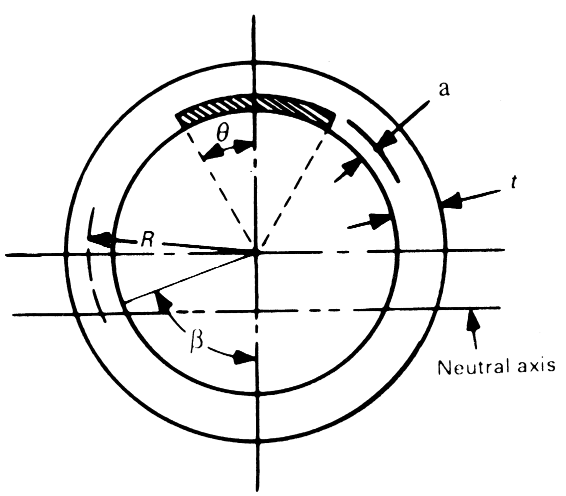
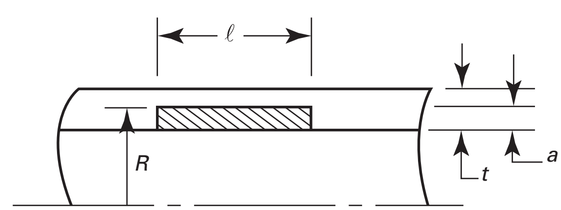


Figure A-4212-1
Axial Flaw



$$R_c = R_1 + a + \Delta a$$

where Γ_m is recalculated for each value of Δa. When the primary membrane stress, P_m, is zero, the coordinate $S_r{}'$ is given by

$$S_r' = \frac{\pi P_b (SF_b)}{4 \sigma_y \Gamma_m}$$

SF_b is the specified structural factor on primary bending stress in Table A-4400-1 of this Case. The coordinate $K_r{}'$ is given by

$$K_r' = \sqrt{J_e / J_R}$$

for any value of P_m, where J_e and J_R are also re-calculated for each value of Δa.

The linear elastic J-integral is given by

$$J_e = K_I^2 / E'$$

where

$$K_I = (SF_m) P_m \sqrt{\pi a'} F_m + [(SF_b) P_b + P_e] \sqrt{\pi a'} F_b + K_{Ir}$$

$$F_m = 1.1 + \left(a'/t\right)\left[0.15241 + 16.722\left(\frac{a'\theta}{t\pi}\right)^{0.855} - 14.944\left(\frac{a'\theta}{t\pi}\right)\right]$$

$$F_b = 1.1 + \left(a'/t\right)\left[-0.09967 + 5.0057\left(\frac{a'\theta}{t\pi}\right)^{0.565} - 2.8329\left(\frac{a'\theta}{t\pi}\right)\right]$$

$$a' = a + \Delta a$$

In the above equations, a' is updated after each increment of ductile flaw extension, while θ is fixed at its end-of-evaluation-period value. Residual stresses shall be included with a structural factor of 1.0.

A-4320 Axial Flaws

The formulae necessary to calculate the failure assessment point coordinates. $S_r{}'$and $K_r{}'$for part-through-wall axial flaw with a specified amount of ductile flaw extension, Δa, are given below. When the temperature is in the transition or lower shelf region, J_R shall be replaced by J_{Ic} and Δa shall be zero. The coordinate $S_r{}'$ is given by

$$S_r' = (SF_m) p / P_o$$

where SF_m is the specified structural factor for membrane stress given in Table A-4400-2 of this Case and P_o is re-calculated for each value of Δa,

$$P_o = \left(\frac{2}{\sqrt{3}}\right)\left(\frac{t}{R_1}\right)[1 - x + x / f(z)] \sigma_y$$

$$f(z) = (1 + 1.61z)^{0.5}$$

$$z = \frac{0.1542 \ell^2}{at(R_1/t + 0.5)}$$

$$a' = a + \Delta a$$

$$x = a'/t$$

The coordinate K_r' is given by

$$K_r' = \sqrt{J_e / J_R}$$

where J_e and J_R are also recalculated for each value of Δa. The linear elastic J-integral is given by

$$J_e = K_I^2 / E'$$

and

$$K_1 = (SF_m) p (R_1/t) F_1 \sqrt{\pi a'/Q} + K_{Ir}$$

$$Q = 1 + 4.593 (a/\ell)^{1.65}$$

$$F_1 = 0.97[M_1' + M_2' (a'/t)^2 + M_3' (a'/t)^4] f_c$$

$$f_c = [(R_2^2 + R_1^2)/(R_2^2 - R_1^2) + 1 - 0.5\sqrt{a'/t}] t / R_1$$

$$M_1' = 1.13 - 0.18 (a/\ell)$$

$$M_2' = -0.54 + 0.445/(0.1 + a/\ell)$$

$$M_3' = 0.5 - 1/(0.65 + 2a/\ell) + 14(1 - 2a/\ell)^{24}$$

In the equations above, a' is updated after each increment of ductile flaw extension, while a/ℓ is fixed at its end-of-evaluation-period value. Residual stresses shall be included with a structural factor of 1.0.

Table A-4400-1
Specified Structural Factors for Circumferential Flaws

Service Level	Membrane Stresses, SF_m	Bending Stresses, SF_b
A	2.7	2.3
B	2.4	2.0
C	1.8	1.6
D	1.3	1.4

Table A-4400-2
Specified Structural Factors for Axial Flaws

Service Level	Membrane Stresses, SF_m
A	2.7
B	2.4
C	1.8
D	1.3

A-4400 FLAW ACCEPTANCE DETERMINATION

Evaluation of flaws using the failure assessment diagram procedure requires application of structural factors. The structural factors SF_m and SF_b applied to primary membrane stresses and primary bending stresses, respectively, are given in Table A-4400-1 of this Case for circumferential flaws and Table A-4400-2 of this Case for axial flaws.

(a) For lower shelf and transition temperatures, set Δa to zero and J_R to J_{Ic} at the temperature of interest in the calculation of the failure assessment point coordinate. Plot the assessment point on the failure assessment diagram in Figure A-4200-1 of this Case and apply the acceptance criteria of 1.2 to determine the acceptability of the pipe for continued service.

(b) For upper shelf temperatures when ductile flaw extension may occur prior to reaching limit load, calculate a series of assessment points for various amounts of ductile flaw extension, Δa, and plot the points on the failure assessment diagram in Figure A-4200-1 of this Case. Apply the acceptance criteria of 1.2. to determine the acceptability of the pipe for continued service.

NONMANDATORY APPENDIX B
EVALUATION OF FLAWS IN AUSTENITIC PIPING

B-1000 INTRODUCTION

B-1100 SCOPE

(a) This Appendix provides a method for determining acceptability for continued service of austenitic piping containing flaws exceeding the allowable flaw standards of IWB-3514.1, IWC-3514, or IWD-3500. The evaluation methodology is based on a failure assessment diagram approach that includes consideration of the following failure mechanisms:

(1) brittle fracture described by linear elastic fracture mechanics;

(2) elastic plastic fracture mechanics, when ductile flaw extension occurs prior to reaching limit load;

(3) limit load failure of the pipe cross section reduced by the flaw area, for ductile materials when the limit load is assured.

(b) This Appendix accounts for actual pipe material toughness properties through input of either the J_R resistance curve that characterizes ductile flaw extension, or the fracture toughness, J_{Ic}. Flaws are evaluated by comparing the actual pipe applied stress, for the flaw size at the end of the evaluation period, with the allowable stress, using the graphical procedure of a failure assessment diagram approach. All combinations of applied stresses P_m, P_b, and P_o are permitted in the evaluation.

(c) The acceptance criteria of 1.2 shall include structural factors on failure for the three failure mechanisms described above. The acceptance criteria shall be used to determine acceptability of the flawed piping for continued service until the next inspection, or until the end of service lifetime, or to determine the time interval until a subsequent inspection.

B-1200 PROCEDURE OVERVIEW

The following is a summary of the analytical procedure:

(a) Determine the flaw configuration from the measured flaw in accordance with IWA-3000, using A-2000 of this Case.

(b) Resolve the actual flaw into circumferential and axial components using A-2000 of this Case.

(c) Determine the stresses normal to the flaw at the location of the detected flaw for normal, upset, emergency, faulted, and test conditions.

(d) Perform a flaw growth analysis, as described in Section XI, C-3200, to establish the end of the evaluation period flaw dimensions, a_f and ℓ_f.

(e) Obtain actual pipe material properties, E, σ_y, σ_f, and the J_R resistance curve or J_{Ic}, at the temperatures required for analysis.

(f) Calculate the appropriate vertical cutoff, S_r^{cutoff}, for the flaw configuration of interest, circumferential or axial, using the formulae in A-4211 or A-4212 of this Case.

(g) Using the formulae in A-4300 of this Case, calculate the assessment point coordinates (S_r', K_r'), for the piping stresses P_m, P_b and P_o for circumferential flaws, or p (pressure) for axial flaws, using the specified structural factors in Table A-4400-1 or Table A-4400-2, respectively, of this Case.

(h) Plot the assessment points calculated in (g) above on the failure assessment diagram in Figure B-4000-1 of this Case, and apply the acceptance criteria of 1.2 to determine the acceptability of the pipe for continued service.

B-1300 NOMENCLATURE

The nomenclature is identical to that given in A-1300 of this Case.

B-2000 FLAW MODEL FOR ANALYSIS

The procedures of A-2000 of this Case shall be used.

B-3000 FLAW GROWTH ANALYSIS

The procedures of Section XI, C-3200 shall be used.

B-4000 FAILURE ASSESSMENT DIAGRAM ANALYSIS

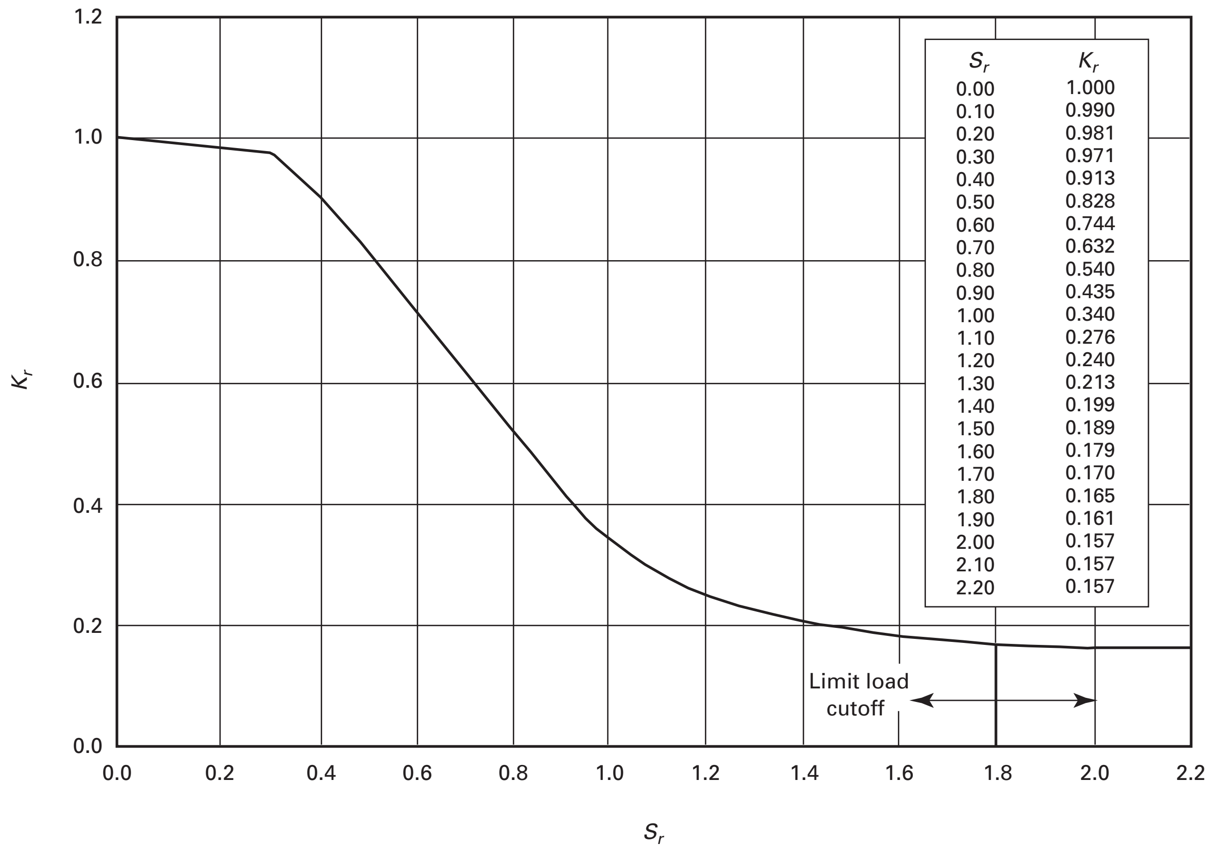
(a) The failure assessment diagram procedure of A-4000 of this Case shall be used, except that the failure assessment diagram for austenitic piping in Figure B-4000-1 of this Case shall be used in lieu of Figure A-4200-1. Figure B-4000-1 of this Case is applicable to austenitic piping having:

(1) part-through-wall circumferential flaws under any combination of primary membrane, primary bending, and secondary stresses (see Figure A-4211-1 of this Case);

(2) part-through-wall axial flaws under internal pressure (see Figure A-4212-1 of this Case).

(b) Figure B-4000-1 of this Case shall be used for circumferential flaws of depths up to 75% of the pipe wall thickness and lengths up to one-half the inside circumference of the pipe, and Figure B-4000-1 of this Case shall also be used for axial flaws of depths up to 75% of the

Figure B-4000-1
Failure Assessment Diagram for Part-Through-Wall Circumferential and Axial Flaws



S_r	K_r
0.00	1.000
0.10	0.990
0.20	0.981
0.30	0.971
0.40	0.913
0.50	0.828
0.60	0.744
0.70	0.632
0.80	0.540
0.90	0.435
1.00	0.340
1.10	0.276
1.20	0.240
1.30	0.213
1.40	0.199
1.50	0.189
1.60	0.179
1.70	0.170
1.80	0.165
1.90	0.161
2.00	0.157
2.10	0.157
2.20	0.157

GENERAL NOTE: S_r^{cutoff} shall be obtained from A-4211 or A-4212 of this Case.

pipe wall thickness and lengths up to ℓ_{crit} where ℓ_{crit} is given by the limit load stability condition for through-wall flaws:

$$\ell_{crit} = 1.58(Rt)^{1/2}\left[(\sigma_f/\sigma_h)^2 - 1\right]^{1/2}$$

The failure assessment diagram shown in Figure B-4000-1 of this Case has a vertical cutoff for upper bound limits on S_r. The value of the cutoff is given in A-4210 of this Case. The failure assessment diagram curve is limited to R/t < 20.

Approval Date: September 18, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-496-2
Helical-Coil Threaded Inserts
Section XI, Division 1

Inquiry: What rules apply to the use of helical-coil threaded inserts in pressure retaining items under Section XI, Division 1?

Reply: It is the opinion of the Committee that helical-coil threaded inserts may be used in pressure retaining items provided the following requirements are met:

(a) The installation of the helical-coil threaded inserts shall be performed in accordance with IWA-4000 (IWA-7000, IWB-7000, and IWC-7000, or IWD-7000, as applicable, for Editions and Addenda prior to the 1991 Addenda).

(b) Helical-coil threaded inserts shall satisfy the design requirements of the Construction Code for the specified loadings to be applied to the threaded connection. For materials not listed in the Construction Code, primary stresses shall not exceed $^2/_3$ of the minimum specified yield strength or $^1/_4$ of the minimum specified tensile strength of the applicable material, whichever is lower.

(c) Helical-coil threaded inserts shall be purchased in accordance with (1) or (2) below:

(1) The Owner's Quality Assurance Program meeting IWA-1400(n);

(2) When the Repair/Replacement Organization is other than the Owner, the Repair/Replacement Organization's Quality Assurance Program shall be documented and shall comply with the applicable quality assurance program criteria of 10CFR50 Appendix B supplemented as necessary to be consistent with the Owner's Quality Assurance Program: NQA-1, Parts II and III, Basic Requirements and Supplements; or NCA-4000.

(d) Helical-coil threaded inserts shall be supplied with a Certified Material Test Report that provides traceability to the item, material specification, chemical composition, grade or class, and mechanical properties and heat treated condition prior to final forming.

(e) Helical-coil threaded inserts shall be installed in accordance with the manufacturer's instructions.

(f) Use of this Case shall be documented in the appropriate Owner's Report.

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Approval Date: February 15, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-498-4
Alternative Requirements for 10-Year System Hydrostatic Testing for Class 1, 2, and 3 Systems
Section XI, Division 1

Inquiry: What alternative rules may be used in lieu of those required by Section XI, Division 1, Table IWB-2500-1, Categories B-E and B-P, Table IWC-2500-1, Category C-H, and Table IWD-2500-1, Categories D-A, D-B, and D-C, as applicable, for the 10-year system hydrostatic test?

Reply:

(a) It is the opinion of the Committee that as an alternative to the 10-year system hydrostatic test required by Table IWB-2500-1, Categories B-E and B-P, the following rules shall be used.

(1) A system leakage test (IWB-5221) shall be conducted at or near the end of each inspection interval, prior to reactor startup.

(2) The boundary subject to test pressurization during the system leakage test shall extend to all Class 1 pressure retaining components within the system boundary.

(3) Prior to performing the VT-2 visual examination, the system including portions isolated during normal operation shall be pressurized to a pressure not less than the pressure corresponding with 100% rated reactor power. No holding time is required prior to performing the VT-2 visual examination. The system shall be maintained at this pressure during performance of the VT-2 visual examination.

(4) Test temperatures and pressures shall not exceed limiting conditions for the hydrostatic test curve as contained in the plant Technical Specifications.

(5) The VT-2 visual examination shall include all components within the boundary identified in *(a)*(2) above.

(6) Test instrumentation requirements of IWA-5260 are not applicable.

(b) It is the opinion of the Committee that, as an alternative to the 10-year system hydrostatic test required by Table IWC-2500-1, Category C-H, the following rules shall be used.

(1) A system pressure test shall be conducted at or near the end of each inspection interval or during the same inspection period of each inspection interval of Inspection Program B.

(2) The boundary subject to test pressurization during the system pressure test shall extend to all Class 2 components included in those portions of systems required to operate or support the safety system function up to and including the first normally closed valve, including a safety or relief valve, or valve capable of automatic closure when the safety function is required.

(3) Prior to performing the VT-2 visual examination, the system shall be pressurized to that pressure obtained while the system, or portion of the system, is inservice performing its normal operating function; or, at the pressure developed during a test conducted to verify system operability (e.g., to demonstrate system safety function or satisfy technical specification surveillance requirements). When utilizing a test conducted to verify system operability for the performance of the VT-2 examination and multiple safety-related modes of operation exist or multiple functional tests are available, the operational mode or test that is performed at the highest pressure shall be used. No holding time is required prior to performing the VT-2 visual examination. The system shall be maintained at this pressure during performance of the VT-2 visual examination.

(4) The VT-2 visual examination shall include all components within the boundary identified in (2) above.

(5) Test instrumentation requirements of IWA-5260 are not applicable.

(c) It is the opinion of the Committee that, as an alternative to the 10-year system hydrostatic test required by Table IWD-2500-1, Categories D-A, D-B, or D-C (D-B for the 1989 Edition with the 1991 and subsequent Addenda), as applicable, the following rules shall be used.

(1) A system pressure test shall be conducted at or near the end of each inspection interval or during the same inspection period of each inspection interval of Inspection Program B.

(2) The boundary subject to test pressurization during the system pressure test shall extend to all Class 3 components included in those portions of the system required to operate or support the safety system function

up to and including the first normally closed valve, including a safety or relief valve, or valve capable of automatic closure when the safety function is required.

(3) Prior to performing the VT-2 visual examination, the system shall be pressurized to that pressure obtained while the system, or portion of the system, is inservice performing its normal operating function; or, at the pressure developed during a test conducted to verify system operability (e.g., to demonstrate system safety function or satisfy technical specification surveillance requirements). When utilizing a test conducted to verify system operability for the performance of the VT-2 examination and multiple safety-related modes of operation exist or multiple functional tests are available, the operational mode or test that is performed at the highest pressure shall be used. No holding time is required prior to performing the VT-2 visual examination. The system shall be maintained at this pressure during performance of the VT-2 visual examination.

(4) The VT-2 visual examination shall include all components within the boundary identified in (2) above.

(5) Test instrumentation requirements of IWA-5260 are not applicable.

Approval Date: October 14, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-500-4
Alternative Rules for Standard Supports for Classes 1, 2, 3, and MC
Section III, Division 1

Inquiry: What alternative rules to Section III, Subsection NCA and NF may be used for the construction of Class 1, 2, 3, and MC Standard Supports?

Reply: It is the opinion of the Committee that as an alternative to the requirements of NCA and NF, Class 1, 2, 3, and MC Standard Supports except dampers (NF-3412.5), snubbers and struts (Type 47, Fig. A1 of ANSI/MSS SP-58-2009) and their associated attachments may be constructed to ANSI/MSS SP-58-2009 "Pipe Hangers and Supports — Materials, Design and Manufacture" and the following additional requirements:

1 MATERIALS

1.1 The materials and allowable stresses listed in Tables A2 and A2M of ANSI/MSS SP-58-2009 may be used, except for ASTM specifications A48, A126, A395, and A536 castings within Tables A2 and A2M.

1.2 The use of other materials per 3.2 of ANSI/MSS SP-58-2009 is limited to material specifications permitted for use for any type or class of support under Subsection NF including those permitted by a Code Case applicable to Subsection NF, except that the allowable stresses shall be calculated in accordance with ANSI/MSS SP-58-2009.

1.3 Certified Material Test Reports in accordance with NCA-3862.1 shall be supplied with the Standard support for all materials except carbon steel materials with a specified minimum tensile strength of 75,000 psi or less, exempt materials as identified in NF-2121(b), or small products as defined in NF-2610(c).

1.4 The identification of materials requiring Certified Material Test Reports shall meet the requirements of NCA-3856.

2 DESIGN

2.1 For Design and Service Level A, stresses shall not exceed those of ANSI/MSS SP-58-2009.

2.2 For Service Level B, stresses shall not exceed 1.33 times those of ANSI/MSS SP-58-2009.

2.3 For Service Level C, stresses shall not exceed 1.50 times those of ANSI/MSS SP-58-2009.

2.4 For Service Level D, stresses shall not exceed 2.0 times those of ANSI/MSS SP-58-2009.

2.5 The stresses caused by Test loadings shall be limited to 80% of the tabulated value of yield stress.

2.6 For all service levels, tensile and compressive stresses shall not exceed 70% of the tabulated value of ultimate tensile strength at the service temperature and shear stresses shall not exceed 42% of the tabulated value of ultimate tensile strength at the service temperature. Stresses shall not exceed 50% of critical buckling stress for Design, Level A and Level B and 67% of critical buckling stress for Level C, Level D and Test. Consideration shall be given to combinations of stresses.

2.7 The requirements of NF-3330 "High Cycle Fatigue Design for Class 1" shall be met for Class 1 supports.

2.8 The requirements of NF-3225 "Design of Bolting" and NF-3324.6 "Design Requirements for Bolted Joints" shall be met.

2.9 Section 11.3 of ANSI/MSS SP-58-2009 shall not be used. Supports may be designed by load rating in accordance with NF-3480 using the allowable stresses in 2.1 through 2.8.

3 QUALITY ASSURANCE

3.1 The standard supports shall be manufactured under a quality assurance program which meets the requirements specified by the purchaser.

4 OTHER REQUIREMENTS

4.1 The use of this Case shall be in accordance with NCA-1140 and shall be listed on the applicable data report for the component which utilizes the standard support.

4.2 All welds shall be visually examined to the acceptance standards of NF-5360.

Approval Date: July 14, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-504-4
Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping
Section XI, Division 1

Inquiry: Under the rules of IWA-4120, in Editions and Addenda up to and including the 1989 Edition with the 1990 Addenda, in IWA-4170(b) in the 1989 Edition with the 1991 Addenda up to and including the 1995 Edition, and in IWA-4410 in the 1995 Edition with the 1995 Addenda and later Editions and Addenda, a defect may be reduced to an acceptable flaw in accordance with the provisions of either the Construction Code or Section XI. As an alternative, is it permissible to reduce a defect to a flaw of acceptable size by increasing the pipe wall thickness by deposition of weld reinforcement material on the outside surface of the pipe?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4120 in Editions and Addenda up to and including the 1989 Edition with the 1990 Addenda, in IWA-4170(b) in the 1989 Edition with the 1991 Addenda up to and including the 1995 Edition, in IWA-4410 in the 1995 Edition with the 1995 Addenda up to and including the 1996 Addenda, in IWA-4420 in the 1995 Edition with the 1997 Addenda and later Editions and Addenda, in IWA-4810(a) in the 1992 Edition with the 1994 Addenda through the 1995 Edition, and in IWA-4520(a) in the 1995 Edition with the 1995 Addenda and later Editions and Addenda, a defect in austenitic stainless steel piping may be reduced to a flaw of acceptable size in accordance with IWB-3640 from the 1983 Edition with the Winter 1985 Addenda, or later Editions and Addenda, by deposition of weld reinforcement (weld overlay) on the outside surface of the pipe, provided the following requirements are met:

(a) The repair shall be performed in accordance with a Repair Program[1] satisfying the requirements of IWA-4000 in the Edition and Addenda of Section XI applicable to the plant in-service inspection program, or later Edition and Addenda.

(b) Reinforcement weld metal shall be low carbon (0.035% max.) austenitic stainless steel applied 360 deg around the circumference of the pipe, and shall be deposited in accordance with a qualified welding procedure specification identified in the Repair Program. The submerged arc method shall not be used for weld overlay.

(c) Prior to deposition of the weld reinforcement, the surface to be repaired shall be examined by the liquid penetrant method. Indications greater than $^1/_{16}$ in. are unacceptable and shall be prepared for weld reinforcement in accordance with (1) or (2) below:

(1) Unacceptable indication shall be excavated to the extent necessary to create a cavity that can be repaired using qualified welding procedures.

(2) One or more layers of weld overlay shall be applied to seal unacceptable indications in the area to be repaired without excavation. The thickness of these layers shall not be included in meeting weld reinforcement design thickness requirements.

(d) If the preparation of (c)(1) or (c)(2) above is required, the area where the weld reinforcement is to be deposited, including any local repairs or initial weld overlay layers, shall be examined by the liquid penetrant method, and shall contain no indications greater than $^1/_{16}$ in. prior to application of the structural layers of the weld overlay.

(e) The weld reinforcement shall consist of a minimum of two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The first layer of weld metal with delta ferrite content of least 7.5 FN shall constitute the first layer of the weld reinforcement design thickness. Alternatively, first layers of at least 5 FN may be acceptable based on evaluation.

(f) Design of the weld reinforcement shall provide for access for the examinations required by (i) and (j) below, and shall be in accordance with (1), (2), or (3) below.

(1) For circumferentially oriented flaws greater than 10% of the pipe circumference, axial flaws equal to or greater than 1.5 in. in length, or 5 or more axial flaws of any length, the weld reinforcement shall provide the necessary wall thickness to satisfy the flaw evaluation procedures of IWB-3640 from the 1983 Edition with the Winter 1985 Addenda, or later Editions and Addenda, for the flaw

[1] When applying this Case to Editions and Addenda later than the 1989 Edition, reference to Repair Program shall be read as Repair Plan or Repair/Replacement Plan, as applicable.

as found by the examination. For determination of the design thickness, the flaw shall be assumed to be 100% through the original pipe wall thickness for the entire circumference of the pipe. The axial length and end slope of the reinforcement shall be sufficient to provide for load redistribution from the pipe into the deposited weld metal and back into the pipe without violating applicable stress limits of Section III for primary local and bending stresses and secondary peak stresses. (These requirements will usually be satisfied if the overlay full thickness length extends axially at least $0.75\sqrt{Rt}$ beyond each end of the observed flaws, where R and t are the outer radius and nominal wall thickness of the pipe, prior to depositing the weld overlay, and the end slope is no steeper than 45 deg.)

(2) When there are fewer than five axial flaws, each less than 1.5 in. in length, and short circumferential flaws, the combined length of which does not exceed 10% of the pipe circumference, an alternative weld reinforcement thickness may be used. In determining the combined length of circumferential flaws for comparison with this limit, multiple flaws shall be treated as one flaw of length equal to the sum of the lengths of the individual flaws characterized in accordance with IWA-3300. For determination of the design thickness, the flaw shall be assumed to be 100% through the original pipe wall thickness with circumferential length equal to the combined circumferential length of the flaws. Following application of weld reinforcement, the as-found flaw shall meet the flaw acceptance criteria of IWB-3640 from the 1983 Edition with the Winter 1985 Addenda or later Editions and Addenda. The axial length and end slope requirements shall meet the criteria of (1) above.

(3) For weldments with four or fewer axial flaws, each less than 1.5 in. in length, and no circumferential flaws, the weld reinforcement shall have sufficient thickness to satisfy the requirements of (e) above. No additional structural reinforcement is required. The axial length of the weld overlay shall cover the weldment and the heat affected zone on each side of the weldment, with a minimum overlap of $^1/_2$ in. on each end of the observed flaws. The end slope shall meet the criteria of (1) above.

(g) An evaluation of the repaired weldment, as well as other welds and components in the system affected by the weld reinforcement, shall be performed in accordance with (1) through (3) below.

(1) The Owner shall comply with IWA-1400(p) from the 1989 Edition with the 1990 Addenda or later Editions and Addenda.

(2) For repaired welds the evaluation shall consider residual stresses produced by the weld overlay with other applied loads on the system. The effects of water backing on the repair weld shall be considered. The evaluation shall demonstrate that the requirements of IWB-3640 from the 1983 Edition with the Winter 1985 Addenda, or later Editions and Addenda, are satisfied for the design life of the repair, considering potential flaw growth due to fatigue and the mechanism believed to have caused the flaw. The flaw growth evaluation shall be performed in accordance with Appendix C. When structural credit is taken for SAW or SMAW weld metal in the original pipe weldment or SMAW weld metal in the weld overlay, the evaluation requirements of IWB-3640 for SAW or SMAW welds, as applicable, shall be applied.

(3) The evaluation of other welds and components in the system shall consider potential increases in loading, including shrinkage effects, due to all weld overlays in the system, and shall identify and record the magnitude and location of the maximum shrinkage stress developed. These welds and components shall meet the applicable stress limits of the Construction Code. Shrinkage stresses shall be included with other applied loads on the system in any IWB-3640 flaw evaluations required for the system. In addition, the effect of shrinkage from weld overlays on the affected portion of the system restraints, supports, and snubbers shall be evaluated to determine whether design tolerances are exceeded.

(h) The completed repair shall be pressure tested in accordance with IWA-5000. If the flaw penetrated the original pressure boundary prior to welding, or if any evidence of the flaw penetrating the pressure boundary is observed during the welding operation, a system hydrostatic test shall be performed in accordance with IWA-5000. If the system pressure boundary has not been penetrated, a system leakage, inservice, or functional test shall be performed in accordance with IWA-5000.

(i) Preservice examination of the completed repair shall be performed in accordance with IWB-2200. For all classes of components, liquid penetrant and ultrasonic examination of the completed weld repair shall be performed. Examination procedures shall be specified in the Repair Program. The acceptance standards of Table IWB-3514-2 shall apply for planar flaws. The acceptance standards of Table IWB-3514-3 shall apply for laminar flaws provided the reduction in coverage of the examination volume is less than 10%. The dimensions of the uninspectable volume are dependent on the coverage achieved with the angle beam examination. Additionally, any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. The assumed planar flaw shall meet the inservice examination acceptance standards of Table IWB-3514-2. Both axial and circumferential flaws shall be assumed. As an alternative to the assumed planar flaw, radiography in accordance with the Construction Code shall be used to examine the uninspectable volume in the weld overlay. The radiographic acceptance criteria of the Construction Code shall apply. Ultrasonic examinations shall verify the integrity of the newly applied weld reinforcement. Examinations shall also be performed to identify the original flaws in the outer 25% of the underlying pipe wall as a benchmark for subsequent examinations of the overlay. Grinding and machining of the

as-welded overlay surface may be used to improve the surface finish for such examinations, when the overlay thickness is not reduced below design requirements.

(j) Nondestructive examinations shall include the weld and volume identified in (i) above.

(k) After completion of all repair activities, the affected restraints, supports, and snubbers shall be VT-3 visually examined to determine if design tolerances are met.

(l) All other applicable requirements of IWA-4000 and IWB-4000, IWC-4000, or IWD-4000 shall be met.

(m) Use of this Case shall be documented on Form NIS-2.

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Approval Date: July 27, 1992

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-505
Alternative Rules for the Examination of Butt Welds Used as Closure Welds for Electrical Penetration Assemblies in Containment Structures
Section III, Division 1

Inquiry: Under what conditions may liquid penetrant examination (NE-5350) or magnetic particle examination (NE-5340) of the root pass and completed weld be used in lieu of radiography as required by NE-5221 for Category B full penetration butt welds used as closure welds for electrical penetration assemblies?

Reply: It is the opinion of the Committee that surface examination of the root pass and completed weld in accordance with NE-5340 or NE-5350 may be substituted for radiographic examination required in NE-5221 for Category B butt welds in electrical penetration assemblies subject to the following limitations:

(a) The allowable stress for the weld joint shall be multiplied by a factor of 0.8;

(b) P-1 base materials shall be used for construction;

(c) For welds thicker than a nominal $^3/_8$ in., an intermediate surface examination shall be performed at approximately half the weld thickness to be deposited;

(d) All other requirements of Section III shall be met;

(e) This Case number shall be listed on the Data Report Form.

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Approval Date: January 26, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-508-4
Rotation of Snubbers and Pressure Retaining Items for the Purpose of Testing or Preventive Maintenance
Section XI, Division 1

Inquiry: What alternative rules to those stated in IWA-4000 (IWA-7000 for Editions and Addenda prior to the 1991 Addenda) may be used when, for the purpose of testing or preventive maintenance, snubbers and pressure retaining items are rotated from stock and installed on components (including piping systems) within the Section XI boundary?

Reply: It is the opinion of the Committee that, as an alternative to the provisions of IWA-4000 (IWA-7000 for Editions and Addenda prior to the 1991 Addenda), snubbers, pumps, pressure relief valves,[1] control rod drive mechanisms, or pressure retaining items of pump seal packages may be rotated from stock and installed on components (including piping systems) within the Section XI boundary provided the following requirements are met:

(a) The rotation shall be only for testing or preventive maintenance of the removed items;

(b) Items being removed and installed shall be of the same design and construction;

(c) Items being removed shall have no evidence of failure at the time of removal;

(d) Items being rotated shall be removed and installed only by mechanical means;

(e) Items being installed shall previously have been in service;

(f) The Owner shall track the items, by unique item identification, to ensure traceability of the installed location and inservice inspection and testing records;

(g) Use of an Inspector and an NIS-2 Form are not required except as provided in (h);

(h) Repair/Replacement activities on removed items, if required, shall be performed in accordance with IWA-4000 (IWA-4000 or IWA-7000 for Editions and Addenda prior to the 1991 Addenda).

[1] Examination and testing requirements for snubbers and testing requirements for pumps and valves are provided in the ASME Code for Operation and Maintenance of Nuclear Power Plants (OM Code).

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Approval Date: December 12, 1994

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-510-1
Borated Stainless Steel for Class CS Core Support Structures and Class 1 Component Supports
Section III, Division 1

Inquiry: May material conforming to ASTM A887-89, Grade A, Types 304B, 304B1, 304B2, 304B3, 304B4, 304B5 and 304B6, be used in the construction of Section III, Subsections NF, Class 1 Component Supports, and Subsection NG, Class CS Core Support Structures?

Reply: It is the opinion of the Committee that material complying with ASTM A887-89, Grade A, Types 304B, 304B1, 304B2, 304B3, 304B4, 304B5 and 304B6, may be used in the construction of Section III, Subsections NF, Class 1 Component Supports, and Subsection NG, Class CS Core Supports Structures, with the following requirements:

(a) Design stress intensity values, S_m, shall be those listed in Table 1.

(b) Yield strength values, S_y, and ultimate tensile strength values, S_u, shall be those listed in Table 2.

(c) If analysis for cyclic operation is required, fatigue evaluation shall be in accordance with the procedures of NF-3330 or NG-3222.4, as appropriate, using Figure 1 and Table 3, as necessary.

(d) Charpy V-notch impact tests in accordance with the provisions of this paragraph shall be made on this material.

(1) Impact test procedures and apparatus shall conform to the applicable paragraphs of SA-370.

(2) The impact test temperature shall not be higher than the lowest service temperature, as defined in NF-2300 or NG-2300, as appropriate.

(3) Each set of impact test specimens shall consist of three specimens.

(4) The impact test specimens shall be of the Charpy V-notch type and shall conform in all respects to Fig. 11 (Type A) of SA-370. The standard (10 mm × 10 mm) specimens, when obtainable, shall be used for nominal thicknesses of 0.438 in. or greater, except as otherwise permitted in (5) below.

(5) For material from which full size (10 mm × 10 mm) specimens cannot be obtained, either due to material shape or thickness, the specimens shall be the largest possible standard subsize specimens obtainable or specimens of full material nominal thickness which may be machined to remove surface irregularities. Alternatively, such material may be reduced in thickness to produce the largest possible Charpy subsize specimens. Impact tests are not required where the maximum obtainable Charpy specimen has a width along the notch of less than 0.099 in.

(6) The applicable minimum energy requirements for all specimen sizes shall be those specified in ASTM A887-89, multiplied by the ratio of the actual specimen width along the notch to the width of a full size (10 mm × 10 mm) specimen.

(7) The applicable minimum lateral expansion opposite the notch for all specimen sizes shall not be less than 15 mils.

(8) The minimum impact energy or lateral expansion for any single specimen shall not be less than $\frac{2}{3}$ of the average impact energy or lateral expansion measured for three specimens.

(9) When the requirements of (8) are not met, a retest of three specimens shall be made in accordance with the requirements of SA-370, 22.

(e) Welding of this material is not permitted.

(f) Thermal cutting is not permitted unless at least $\frac{1}{8}$ in. of the thermally cut surface is mechanically removed.

(g) The applicable requirements of Section III, Division 1, for Class 1 Component Supports or Class CS Core Support Structures, shall be met.

(h) This Code Case shall not be used for the construction of Class CS Core Support Structures or Class 1 Component Supports where design fluences exceed 1×10^{17} neutrons/cm^2.

(i) This Case number shall be identified on the Material Manufacturer's certification for the material, and on the Data Report Form furnished by the N-Type Certification Holder.

Table 1
Design Stress Intensity Values S_m, ksi

	Grade A	
Temperature °F	Types 304B, 304B1, 304B2, and 304B3	Types 304B4, 304B5, and 304B6
100	20.0	20.0
200	20.0	20.0
300	20.0	20.0
400	20.0	20.0
500	20.0	20.0
600	20.0	20.0

Table 1
Design Stress Intensity Values S_m, ksi (Cont'd)

	Grade A	
Temperature °F	Types 304B, 304B1, 304B2, and 304B3	Types 304B4, 304B5, and 304B6
650	20.0	20.0
700	19.7	20.0
750	19.2	20.0

Table 2
Yield Strengths, S_y, and Ultimate Tensile, Strength, S_u, ksi

	Grade A			
	Types 304B, 304B1, 304B2, and 304B3		Types 304B4, 304B5, and304B6	
Temperature °F	S_y	S_u	S_y	S_u
100	30.0	75.0	30.0	75.0
200	27.5	73.5	28.2	75.0
300	26.0	69.6	27.0	72.3
400	24.8	68.0	26.1	70.0
500	23.8	67.5	25.1	69.1
600	22.8	67.5	24.1	68.8
650	22.4	67.5	23.7	68.6
700	21.9	67.3	23.5	68.5
750	21.4	66.8	23.4	68.3

Table 3
Fatigue Design Curve Values for Borated Stainless Steel, Grade A, Types 304B, 304B1, 304B2, 304B3, 304B4, 304B5, and 304B6

	Values of S_a (ksi)	
Number of Cycles, N	w/Zero Mean Stress	w/Maximum Mean Stress
1 E1	2.668 E2	2.668 E2
2 E1	2.014 E2	2.014 E2
5 E1	1.433 E2	1433 E2
1 E2	1.114 E2	1.114 E2
2 E2	9.342 E1	9.342 E1
5 E2	7.508 E1	7.508 E1
1 E3	6.374 E1	6.374 E1
2 E3	5.433 E1	5.433 E1
5 E3	4.390 E1	4.390 E1
1 E4	3.745 E1	3.745 E1
2 E4	3.291 E1	3.291 E1
5 E4	2.881 E1	2.458 E1
1 E5	2.674 E1	1.846 E1
2 E5	2.528 E1	1.537 E1
5 E5	2.398 E1	1.317 E1
1 E6	2.333 E1	1.222 E1

GENERAL NOTES:
(a) 1 E1 is equal to 1×10^1, etc.

Table 3
Fatigue Design Curve Values for Borated Stainless Steel, Grade A, Types 304B, 304B1, 304B2, 304B3, 304B4, 304B5, and 304B6 (Cont'd)

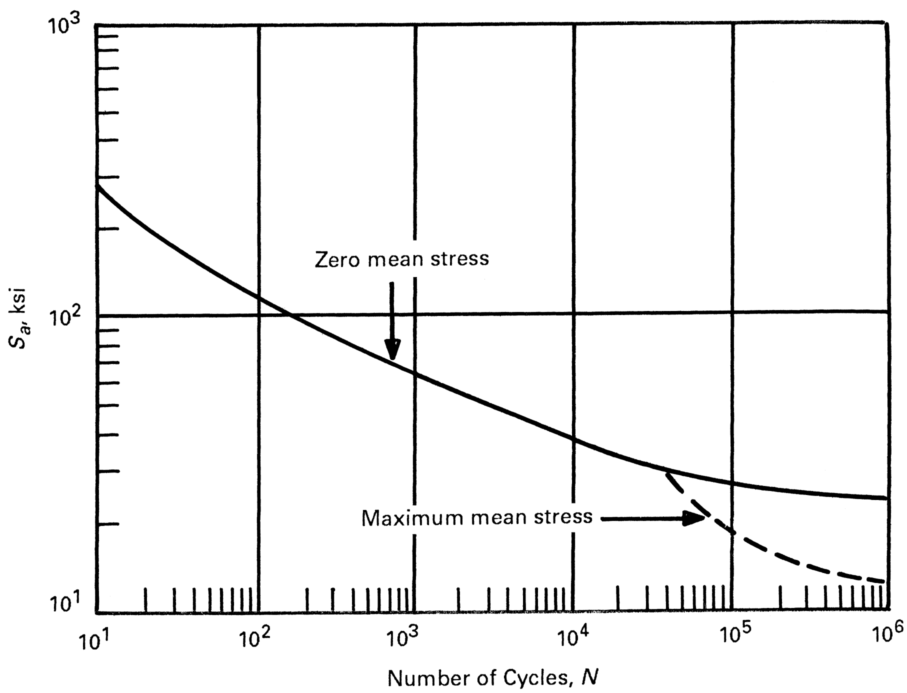
GENERAL NOTES (CONT'D):

(b) Between N = 1.5 E1 and 1 E6 cycles, values of S_a for the case of zero mean stress can be interpolated using the following sixth order polynomial equation correlating $\log_{10} S_a$(ksi) and $\log_{10} N$:

$$\log_{10} S_a(\text{ksi}) = 2.767 - (0.74619 * \log_{10} N) - (0.50573 * (\log_{10} N)^2) + (0.32211 * (\log_{10} N)^3) - (0.09181 * (\log_{10} N)^4) + (0.01242 * (\log_{10} N)^5) - (0.00641 * (\log_{10} N)^6)$$

This equation has a correlation coefficient (r^2) equal to 0.999942.

Figure 1
Fatigue Design Curve for Grade A, Types 304B, 304B1, 304B2, 304B3, 304B4, 304B5, and 304B6



GENERAL NOTE: E = 28.3 × 10^6 psi

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Approval Date: February 12, 1993

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-511
Design Temperatures for Atmospheric and 0–15 psi Storage Tanks
Section III, Division 1

Inquiry: As an alternative to the provisions of NC-3821.2, ND-3821.2 and NC-3921.2, ND-3921.2, may Section III Class 2 and 3 atmospheric storage tanks and 0–15 psi storage tanks be designed to temperatures up to 250°F?

Reply: It is the opinion of the Committee that atmospheric storage tanks and 0–15 psi storage tanks may be designed to temperatures up to 250°F using the allowable stresses given in appropriate stress tables for the appropriate temperatures. This Case does not provide rules for limiting loadings and strains resulting from thermal effects such as differential thermal expansion and thermal cycling that may exist in tanks operating at temperatures exceeding 200°F. Where significant thermal effects will be present, the Owner shall define such effects. The Certificate Holder shall propose, subject to the approval of the Owner and the ANI, details that will provide strength and integrity equivalent to those provided by details specified by Subarticles NC-3800, ND-3800 and NC-3900, ND-3900 in the absence of such effects.

This Case shall be identified for tanks on the Data Report Form.

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Approval Date: May 7, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-513-4
Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping
Section XI, Division 1

Inquiry: What requirements may be used for temporary acceptance of flaws, including through-wall flaws, in moderate energy Class 2 or 3 piping including elbows, bent pipe, reducers, expanders, and branch tees, without performing a repair/replacement activity?

Reply: It is the opinion of the Committee that the following requirements may be used to accept flaws, including through-wall flaws, in moderate energy Class 2 or 3 piping including elbows, bent pipe, reducers, expanders, and branch tees, without performing a repair/replacement activity for a limited time, not exceeding the time to the next scheduled refueling outage.

1 SCOPE

(a) These requirements apply to the ASME Section III, ANSI B31.1, and ANSI B31.7 piping, classified by the Owner as Class 2 or 3 that is accessible for inspection. The provisions of this Case do not apply to the following:

(1) pumps, valves, expansion joints, and heat exchangers, except as provided in (b)

(2) weld metal of socket welded joints

(3) leakage through a flange joints

(4) threaded connections employing nonstructural seal welds for leakage protection

(b) This Case may be applied to heat exchanger external tubing or piping, provided the flaw is characterized in accordance with 2(a) and leakage is monitored.

(c) The provisions of this Case apply to Class 2 or 3 piping in liquid systems whose maximum operating temperature does not exceed 200°F (93°C) and whose maximum operating pressure does not exceed 275 psig (1.9 MPa).

(d) The following flaw evaluation criteria are permitted for pipe and tube including elbows, bent pipe, reducers, expanders, and branch tees. The straight pipe flaw evaluation criteria are permitted for adjoining fittings and flanges to a distance of $(R_o t)^{1/2}$ from the weld centerline.

(e) The piping design Code shall be used in determining the stress indices B_1 and B_2, and stress intensification factor, i, for flaw evaluation following Code applicability limits in terms of component geometry, such as D_o/t_{nom} ratio. If the piping design Code does not provide stress indices, Section III, 2004 Edition or later Editions and Addenda may be used to define B_1 and B_2.

(f) The provisions of this Case demonstrate the integrity of the item and not the consequences of leakage. It is the responsibility of the Owner to consider effects of leakage in demonstrating system operability and performing plant flooding analyses.

2 PROCEDURE

(a) The flaw geometry shall be characterized by volumetric inspection methods or by physical measurement. The full pipe circumference at the flaw location shall be inspected to characterize the length and depth of all flaws in the pipe section.

(b) Flaw shall be classified as planar or nonplanar.

(c) When multiple flaws, including irregular (compound) shape flaws, are detected, the interaction and combined area loss of flaws in a given pipe section shall be accounted for in the flaw evaluation.

(d) A flaw evaluation shall be performed to determine the conditions for flaw acceptance. Section 3 provides accepted methods for conducting the required analysis.

(e) Frequent periodic inspections of no more than 30 day intervals shall be used to determine if flaws are growing and to establish the time, at which the detected flaw will reach the allowable size. Alternatively, a flaw growth evaluation may be performed to predict the time at which the detected flaw will grow to the allowable size. The flaw growth analysis shall consider the relevant growth mechanisms such as general corrosion or wastage, fatigue, or stress corrosion cracking. When a flaw growth analysis is used to establish the allowable time for temporary operation, periodic examinations of no more than 90 day intervals shall be conducted to verify the flaw growth analysis predictions.

(f) For through-wall leaking flaws, leakage shall be monitored daily to confirm the analysis conditions used in the evaluation remain valid.

(g) If examinations reveal flaw growth rate to be unacceptable, a repair/replacement activity shall be performed.

(h) Repair/replacement activities shall be performed no later than when the predicted flaw size from either periodic inspection or by flaw growth analysis exceeds the acceptance criteria of 4, or during the next scheduled refueling outage, whichever occurs first. Repair/replacement activities shall be in accordance with IWA-4000.

(i) Evaluations and examination shall be documented in accordance with IWA-6300. The Owner shall document the use of this Case on the applicable data report form.

3 FLAW EVALUATION

Planar flaws in straight pipe shall be evaluated in accordance with the requirements in 3.1. Nonplanar flaws in straight pipe shall be evaluated in accordance with the requirements in 3.2. Through-wall flaws in elbows and bent pipe shall be evaluated in accordance with the requirements in 3.3. Through-wall flaws in reducers, expanders, and branch tees shall be evaluated in accordance with the requirements in 3.4 and 3.5, respectively. Flaw growth evaluation shall be performed in accordance with the requirements in 3.6. Nonferrous materials shall be evaluated in accordance with the requirements in 3.7.

For all flaw evaluations, all Service Level load combinations shall be evaluated to determine the most limiting allowable flaw size.

3.1 PLANAR FLAWS IN STRAIGHT PIPE

(a) For planar flaws, the flaw shall be bounded by a rectangular or circumferential planar area in accordance with the methods described in Section XI Nonmandatory Appendix C. IWA-3300 shall be used to determine when multiple proximate flaws are to be evaluated as a single flaw. The geometry of a through-wall planar flaw is shown in Figure 1.

(E) *(b)* For planar flaws in austenitic piping, the evaluation procedure in Nonmandatory Appendix C shall be used. Flaw depths up to 100% of wall thickness may be evaluated. When through-wall circumferential flaws are evaluated, the formulas for evaluation given in C-5320 or C-6320, as applicable, of Nonmandatory Appendix C may be used, with the flaw depth to thickness ratio, a/t, equal to unity.

When through-wall axial flaws are evaluated, the allowable flaw length is:

$$\ell_{all} = 1.58\sqrt{Rt}\left[\left(\frac{\sigma_f}{(SF_m)Z\sigma_h}\right)^2 - 1\right]^{1/2} \quad (1)$$

$$\sigma_h = pD_o/2t \quad (2)$$

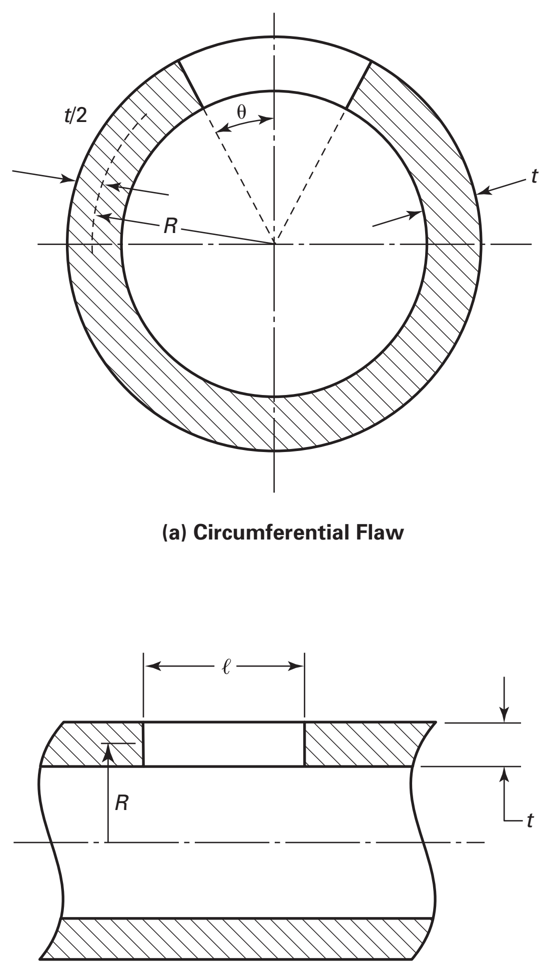
$$\sigma_f = (S_y + S_u)/2 \quad (3)$$

where

D_o = pipe outside diameter
p = pressure for the loading condition
SF_m = structural factor on primary membrane stress as specified in C-2622
S_u = Code specified ultimate tensile strength
S_y = Code specified yield strength
σ_f = flow stress
Z = load multiplier for ductile flaw extension (equal to 1.0 when using limit load criteria)

Material properties at the temperature of interest shall be used.

Figure 1
Through-Wall Flaw Geometry



(a) Circumferential Flaw

(b) Axial Flaw

(**E**) *(c)* For planar flaws in ferritic piping, the evaluation procedure of Nonmandatory Appendix C shall be used. Flaw depths up to 100% of wall thickness may be evaluated. Flaw depth, a, is defined in Figures C-4310-1 and C-4310-2. When through-wall circumferential flaws are evaluated in accordance with C-5300 or C-6300, the flaw depth to thickness ratio, a/t, shall be set to unity. When applying the Nonmandatory Appendix C screening criteria for through-wall axial flaws, a/t shall be set to unity, and the reference limit load hoop stress, σ_l, shall be defined as σ_y/M_2. When through-wall axial flaws are evaluated in accordance with C-5400 or C-6400, the allowable length is defined by eqs. (b)(1) through (b)(3), with the appropriate structural factors from Nonmandatory Appendix C, C-2622. When through-wall flaws are evaluated in accordance with C-7300 or C-7400, the formulas for evaluation given in C-4300 may be used, but with values for F_m, F_b, and F applicable to through-wall flaws. Relations for F_m, F_b, and F that take into account flaw shape and pipe geometry (R/t ratio) shall be used. The appendix to this Case provides equations for F_m, F_b, and F for a selected range of R/t. Geometry of a through-wall crack is shown in Figure 1.

3.2 NONPLANAR FLAWS IN STRAIGHT PIPE

(a) The evaluation shall consider the depth and extent of the affected area and require that the wall thickness exceed $t_{\min}$ for a distance that is the greater of 2.5 $\sqrt{Rt_{\text{nom}}}$ or $2L_{m,\text{avg}}$ between adjacent thinned regions, where R is the mean radius of the piping item based on nominal wall thickness and $L_{m,\text{avg}}$ is the average of the extent of L_m below $t_{\min}$ for adjacent areas (see Figure 2). Alternatively, the adjacent thinned regions shall be considered a single thinned region in the evaluation.

(**E**) *(b)* For nonplanar flaws, the pipe is acceptable when either (1) and (2), or (2) and (3) are met.

(1) The remaining pipe thickness, t_p, is greater than or equal to the minimum wall thickness $t_{\min}$:

$$t_{\min} = \frac{pD_o}{2(S + 0.4p)} \qquad (4)$$

where

p = maximum operating pressure at flaw location
S = allowable stress at operating temperature

(2) The remaining degraded pipe section meets the longitudinal stress limits in the design Code for the piping.

(3) As an alternative to (1), an evaluation of the remaining pipe thickness, t_p, may be performed as given below. The evaluation procedure is a function of the depth and the extent of the affected area as illustrated in Figure 3.

(-a) When W_m is less than or equal to 0.5 $(R_o t)^{1/2}$, where R_o is the outside radius and W_m is defined in Figure 3, the flaw can be classified as a planar flaw and evaluated in accordance with 3.1(a) through 3.1(c), above. When the above requirement is not satisfied, (-b) shall be met.

(-b) When $L_{m(t)}$ is not greater than $(R_o t_{\min})^{1/2}$, t_{aloc} is determined from Curve 1 of Figure 4, where $L_{m(t)}$ is defined in Figure 3. When the above requirement is not satisfied, (-c) shall be met.

(-c) When L_m is less than or equal to 2.65 × $(R_o t_{\min})^{1/2}$ and t_{nom} is greater than $1.13t_{\min}$, t_{aloc} is determined by satisfying both of the following equations:

$$\frac{t_{\text{aloc}}}{t_{\min}} \geq \frac{1.5\sqrt{R_o t_{\min}}}{L}\left[1 - \frac{t_{\text{nom}}}{t_{\min}}\right] + 1.0 \qquad (5)$$

$$\frac{t_{\text{aloc}}}{t_{\min}} \geq \frac{0.353L_m}{\sqrt{R_o t_{\min}}} \qquad (6)$$

When the above requirements are not satisfied, (-d) shall be met.

(-d) When the requirements of (-a), (-b), and (-c) above are not satisfied, t_{aloc} is determined from Curve 2 of Figure 4.

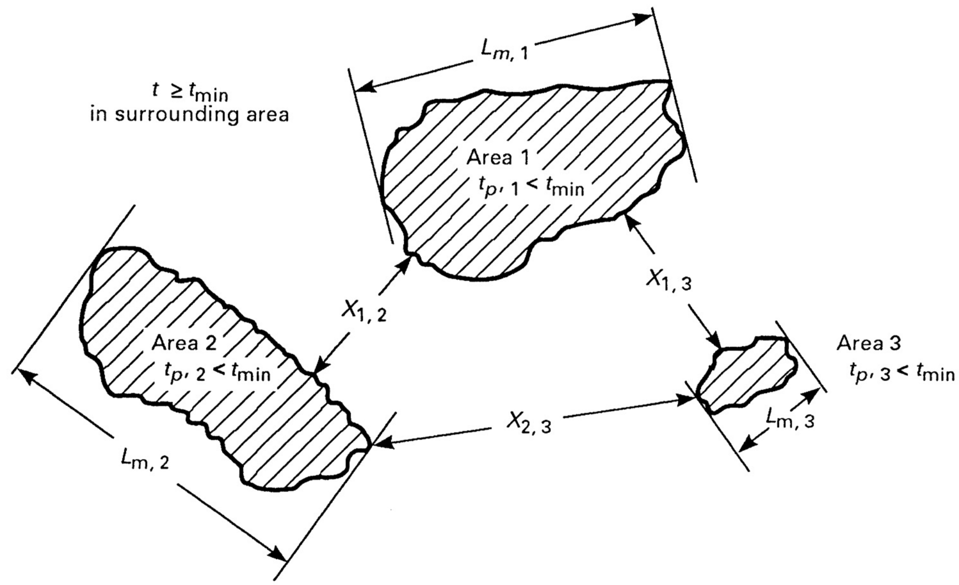
(c) When there is through-wall leakage along a portion of the thinned wall, as illustrated in Figure 5, the flaw may be evaluated by the branch reinforcement method. The thinned area including the through-wall opening shall be represented by a circular penetration at the flaw location. Only the portion of the flaw lying within t_{adj} need be considered as illustrated in Figure 6. When evaluating multiple flaws in accordance with (a), only the portions of the flaws contained within t_{adj} need be considered.

The minimum wall thickness, $t_{\min}$, shall be determined by (b)(1), eq. (4). For evaluation purposes, the adjusted wall thickness, t_{adj}, is a postulated thickness as shown in Figure 6. The pipe wall thickness is defined as the thickness of the pipe in the non-degraded region as shown in Figure 6, illustration (a). The diameter of the opening is equal to d_{adj} as defined by t_{adj} as shown in Figure 6, illustration (a). The postulated value for t_{adj} shall be greater than $t_{\min}$ and shall not exceed the pipe wall thickness. The t_{adj} value may be varied between $t_{\min}$ and the pipe wall thickness to determine whether there is a combination of t_{adj} and d_{adj} that satisfies the branch reinforcement requirements.

The values of t_{adj} and d_{adj} of Figure 6, illustration (b) shall satisfy:

$$d_{\text{adj}} \leq \frac{1.5\sqrt{Rt_{\text{adj}}}\,(t_{\text{adj}} - t_{\min})}{t_{\min}} \qquad (7)$$

Figure 2
Separation Requirements for Adjacent Thinned Areas



Legend:

$L_{m,\ avj}$ = 0.5 ($L_{m,\ i}$ + $L_{m,\ j}$)
$L_{m,\ i}$ = maximum extent of thinned area i
$X_{i,\ j}$ = minimum distance between areas i and j

GENERAL NOTE: Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to combination.

The remaining ligament average thickness, $t_{c,\text{avg}}$, over the degraded area bounded by d_{adj} shall satisfy:

$$t_{c,\text{avg}} \geq 0.353 d_{\text{adj}} \sqrt{\frac{p}{S}} \tag{8}$$

In addition, the pipe section including the equivalent hole representation shall meet the longitudinal stress limits in the design Code for the piping.

If a flaw growth analysis is performed, the growth in flaw dimensions shall consider the degradation mechanisms as relevant to the application. The flaw is acceptable when there is sufficient thickness in the degraded area to provide the required area reinforcement.

(d) Alternatively, if there is a through-wall opening along a portion of the thinned wall as illustrated in Figure 5 the flaw may be evaluated as two independent planar through-wall flaws, one oriented in the axial direction and the other oriented in the circumferential direction. The minimum wall thickness t_{min}, shall be determined by (b)(1), eq. (4). The allowable through-wall lengths in the axial and circumferential directions shall be determined by varying t_{adj} shown in Figure 5 from t_{nom} to t_{min}. The allowable through-wall flaw lengths based on t_{adj} shall be greater than or equal to the corresponding L_{axial} and L_{circ} (see Figure 5) as determined from 3.1(a) and 3.1(b) or 3.1(c), as appropriate. The remaining ligament average thickness, $t_{c,\text{avg}}$, over the degraded area bounded by L_{axial} and L_{circ} shall satisfy (c), eq. (8).

3.3 THROUGH-WALL FLAWS IN ELBOWS AND BENT PIPE

Through-wall flaws in elbows and bent pipe may be evaluated using the straight pipe procedures given in 3.1 or 3.2(d), provided the stresses used in the evaluation are adjusted, to account for the geometry differences, as described below. Alternative methods may be used to calculate the stresses used in evaluation.

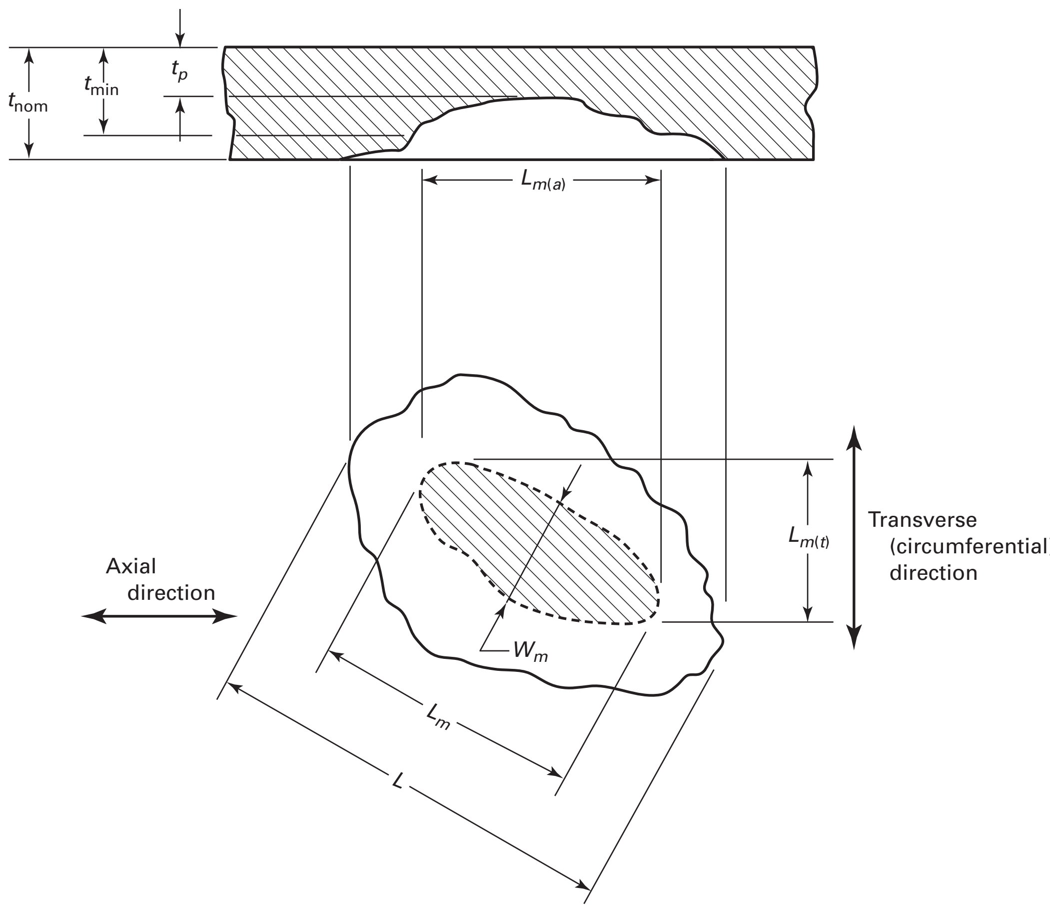
The hoop stress, σ_h, for elbow and bent pipe evaluation shall be as follows:

$$\sigma_h = \left(\frac{pD_o}{2t}\right)\left[\frac{2R_{\text{bend}} + R_o \sin\phi}{2\left(R_{\text{bend}} + R_o \sin\phi\right)}\right] + \left(\frac{1.95}{h^{2/3}}\right)\frac{R_o M_b}{I} \tag{9}$$

where

h = flexibility characteristic
I = moment of inertia based on evaluation wall thickness, t
M_b = resultant primary bending moment
R_{bend} = elbow or bent pipe bend radius
ϕ = circumferential angle defined in Figure 7

Figure 3
Illustration of Nonplanar Flaw Due to Wall Thinning (E)



Equation (9) is only applicable for elbows and bent pipe where $h \geq 0.1$.

The axial membrane pressure stress, σ_m, for elbow and bent pipe evaluation shall be as follows:

$$\sigma_m = B_1\left(\frac{pD_o}{2t}\right) \tag{10}$$

where

B_1 = primary stress index as defined in Section III for the piping item
= 0.5 for elbows and bent pipe

The axial bending stress, σ_b, for elbow and bent pipe evaluation shall be as follows:

$$\sigma_b = B_2\left(\frac{D_oM_b}{2I}\right) \tag{11}$$

where

B_2 = primary stress index as defined in Section III for the piping item

The thermal expansion stress, σ_e, for elbow and bent pipe evaluation shall be as follows:

$$\sigma_e = i\left(\frac{D_oM_e}{2I}\right) \tag{12}$$

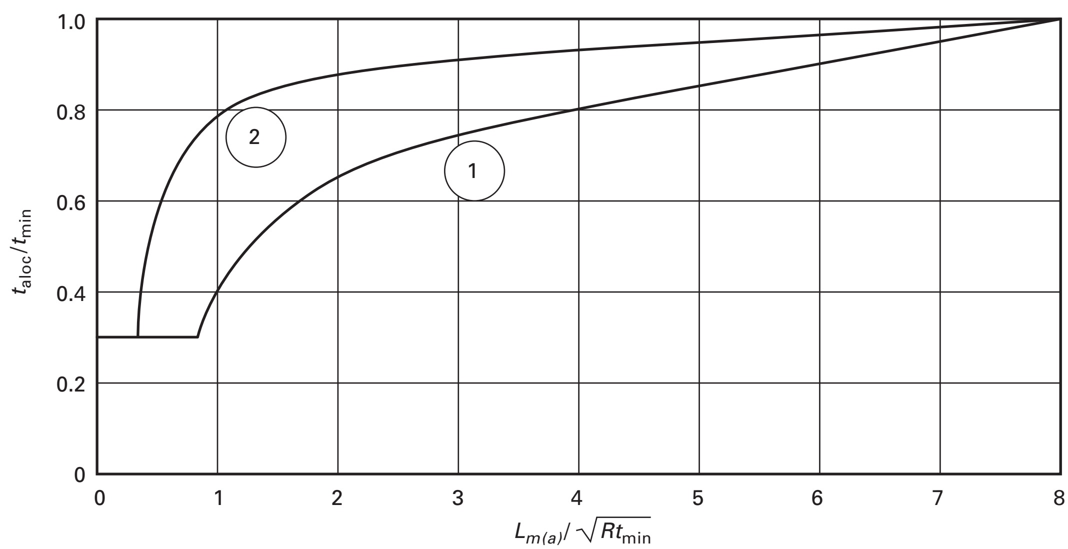
where

i = stress intensification factor as defined in the design Code for the piping item
M_e = resultant thermal expansion moment

3.4 THROUGH-WALL FLAWS IN REDUCERS AND EXPANDERS (E)

Through-wall flaws in reducers and expanders may be evaluated using the straight pipe procedures given in 3.1 or 3.2(d), provided the stresses used in the evaluation are adjusted, to account for the geometry differences, as described below. Alternative methods may be used to calculate the stresses used in evaluation. Figure 8 illustrates the reducer and expander zones discussed below. Evaluation of flaws in the small end transition zone is outside the scope of this Case.

Figure 4
Allowable Wall Thickness and Length of Locally Thinned Area



The hoop stress, σ_h, and axial membrane pressure stress, σ_m, for reducer or expander evaluation shall be as follows:

$$\sigma_h = \left(\frac{pD_o}{2t}\right) \tag{13}$$

$$\sigma_m = B_1\left(\frac{pD_o}{2t}\right) \tag{14}$$

where

D_o = small-end O.D. for flaws in the small-end and the large-end O.D. for all other flaws

The axial bending stress, σ_b, and thermal expansion stress, σ_e, for reducer or expander evaluation shall be as follows:

$$\sigma_b = B_2\left(\frac{D_oM_b}{2I}\right) \tag{15}$$

$$\sigma_e = i\left(\frac{D_oM_e}{2I}\right) \tag{16}$$

where

I = moment of inertia based on degraded section

3.5 THROUGH-WALL FLAWS IN BRANCH TEES

Branch reinforcement requirements shall be met in accordance with the design Code. If the design Code did not require reinforcement, for evaluation purposes, a reinforcement region is defined as a region of radius D_i of the branch pipe from the center of the branch connection. Through-wall flaws in branch tees outside of the reinforcement region may be evaluated using the straight pipe procedures given in 3.1 or 3.2(d), provided the stresses used in the evaluation are adjusted, to account for the geometry differences, as described below. Alternative methods may be used to calculate the stresses used in evaluation. Evaluation of flaws in the region of branch reinforcement is outside the scope of this Case.

The hoop stress, σ_h, and axial membrane pressure stress, σ_m, for branch tee evaluation shall be determined from eq. 3.4(13) and eq. 3.4(14), respectively. The outside diameter for each of these equations shall be for the branch or run pipe, depending on the flaw location.

The axial bending stress, σ_b, and thermal expansion stress, σ_e, for branch tee evaluation shall be determined from eq. 3.4(15) and eq. 3.4(16) respectively.

3.6 FLAW GROWTH EVALUATION

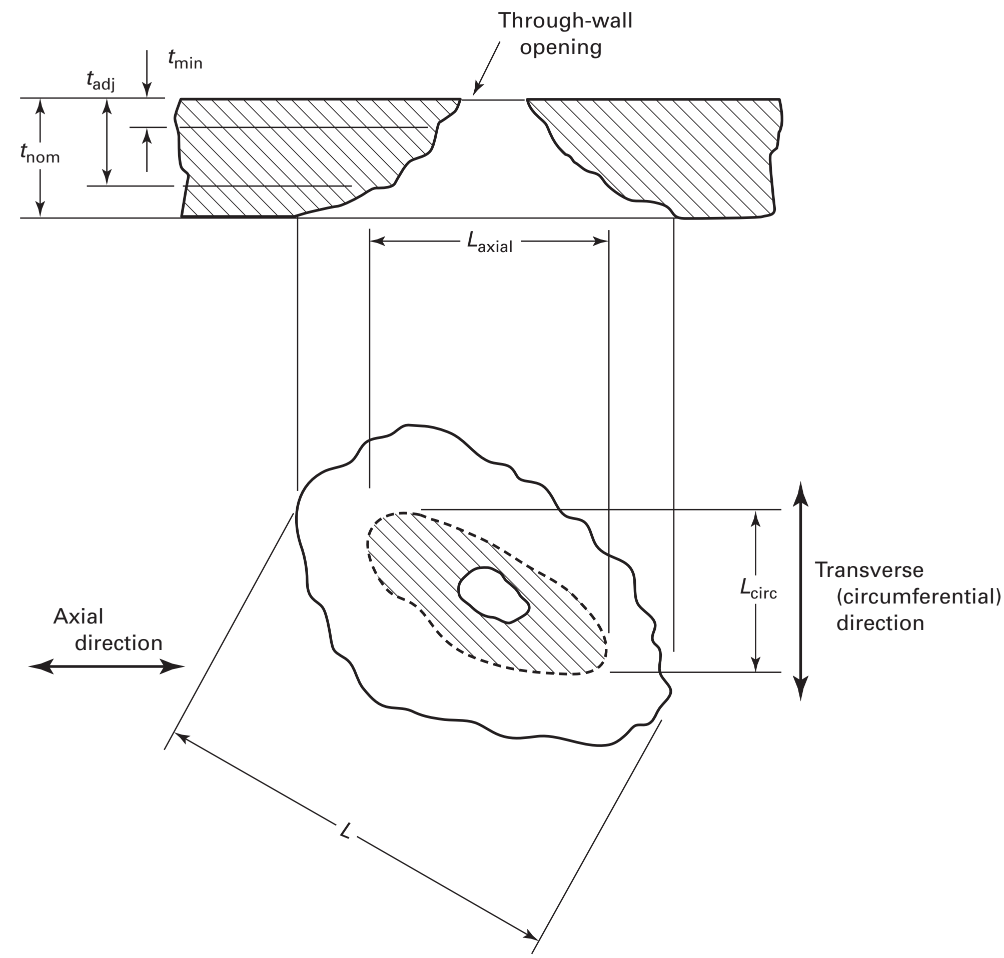
If a flaw growth analysis is performed, the growth analysis shall consider both corrosion and crack-growth mechanisms as relevant to the application.

In performing a flaw growth analysis, the procedures in Article C-3000 may be used as guidance. Relevant growth rate mechanisms shall be considered. When stress corrosion cracking (SCC) is active, the following growth rate equation shall be used:

$$da/dt = S_T C K_{max}^n \tag{17}$$

(E)

Figure 5
Illustration of Through-Wall Nonplanar Flaw Due to Wall Thinning



where da/dt is flaw growth rate in inches/hour, K_{max} is the maximum stress intensity factor under long-term steady state conditions in ksi in.$^{0.5}$, S_T is a temperature correction factor, and C and n are material constants.

For intergranular SCC in austenitic steels, where $T \le$ 200°F (93°C).

$$C = 1.79 \times 10^{-8}$$
$$n = 2.161$$
$$S_T = 1$$

For transgranular SCC in austenitic steels, where $T \le$ 200°F (93°C).

$$C = 1.79 \times 10^{-7}$$
$$n = 2.161$$
$$S_T = 3.71 \times 10^{8} \left[10^{(0.01842\ T\ -\ 12.25)}\right]$$

The temperature, T, is the metal temperature in degrees Fahrenheit. The flaw growth rate curves for the above SCC growth mechanisms are shown in Figures 9 and 10. Other growth rate parameters in eq. (17) may be used, provided they are supported by appropriate data.

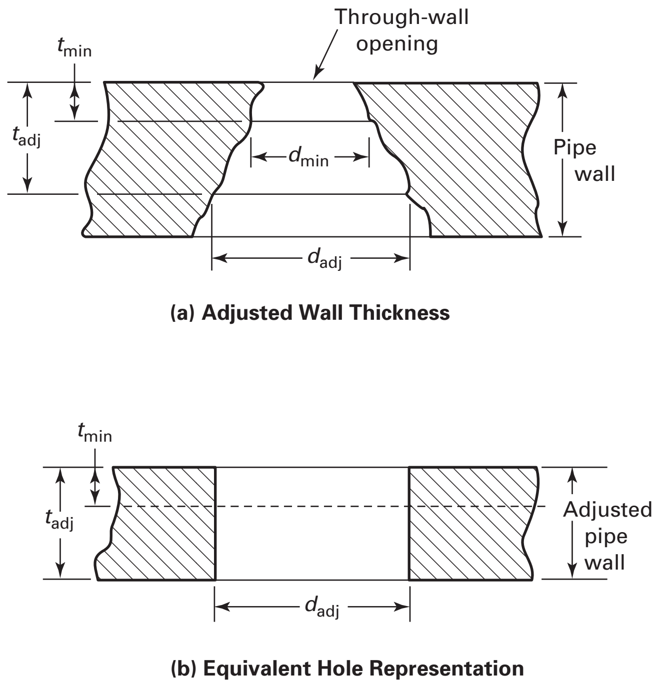
3.7 NONFERROUS MATERIALS

For nonferrous materials, nonplanar and planar flaws may be evaluated following the general approach of 3.1 through 3.6. For planar flaws in ductile materials, the approach given for austenitic pipe may be used; otherwise, the approach given for ferritic pipe should be applied. Structural factors provided in 4 shall be used. It is the responsibility of the evaluator to establish conservative estimates of strength and fracture toughness for the piping material.

4 ACCEPTANCE CRITERIA

Piping containing a circumferential planar flaw is acceptable for temporary service when flaw evaluation provides a margin using the structural factors in

Figure 6
Illustration of Adjusted Wall Thickness and Equivalent Hole Diameter



Nonmandatory Appendix C, C-2621. For axial planar flaws, the structural factors for temporary acceptance are as specified in Nonmandatory Appendix C, C-2622. Straight pipe containing a nonplanar part through-wall flaw is acceptable for temporary service if the remaining pipe section meets the longitudinal stress limits in the design Code for the piping and $t_p \geq t_{aloc}$, where t_{aloc} is determined from 3.2(b). Straight pipe containing a nonplanar part through-wall flaw is acceptable for temporary service when the flaw conditions of 3.2(c) or 3.2(d) are satisfied. An elbow or bent pipe containing a nonplanar through-wall flaw is acceptable for temporary service if the flaw conditions of 3.3 are satisfied. A reducer or expander containing a nonplanar through-wall flaw is acceptable for temporary service if the flaw conditions of 3.4 are satisfied. A branch tee containing a nonplanar through-wall flaw is acceptable for temporary service if the flaw conditions of 3.5 are satisfied.

Figure 7
Circumferential Angle Defined

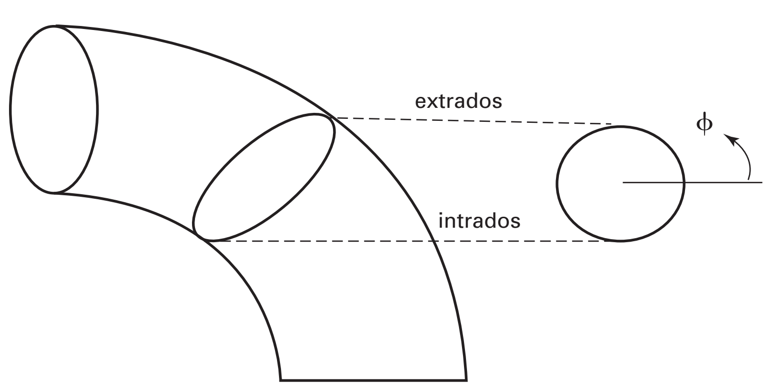
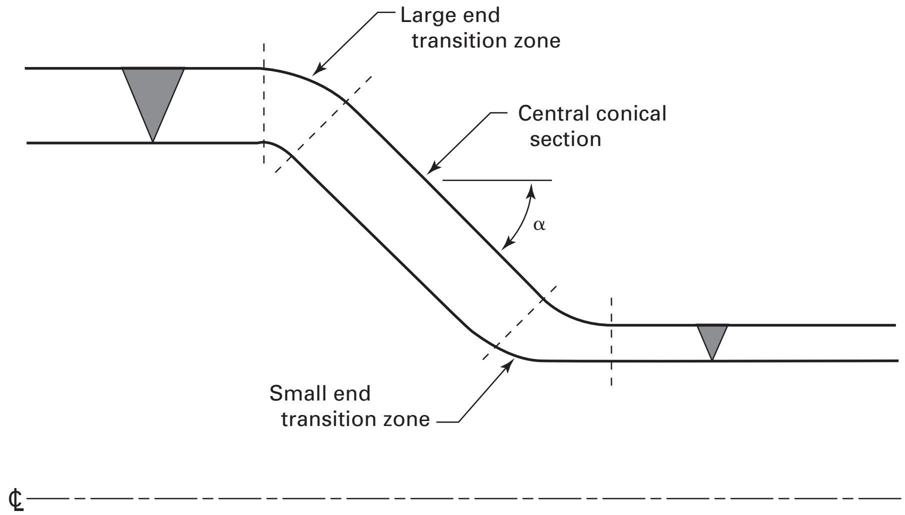


Figure 8
Zones of a Reducer or Expander



GENERAL NOTE: Transition zones extend from the point on the ends where the diameter begins to change to the point on the central cone where the cone angle is constant.

5 AUGMENTED EXAMINATION

An augmented volumetric examination or physical measurement to assess degradation of the affected system shall be performed as follows:

(a) From the engineering evaluation, the most susceptible locations shall be identified. A sample size of at least five of the most susceptible and accessible locations, or, if fewer than five, all susceptible and accessible locations shall be examined within 30 days of detecting the flaw.

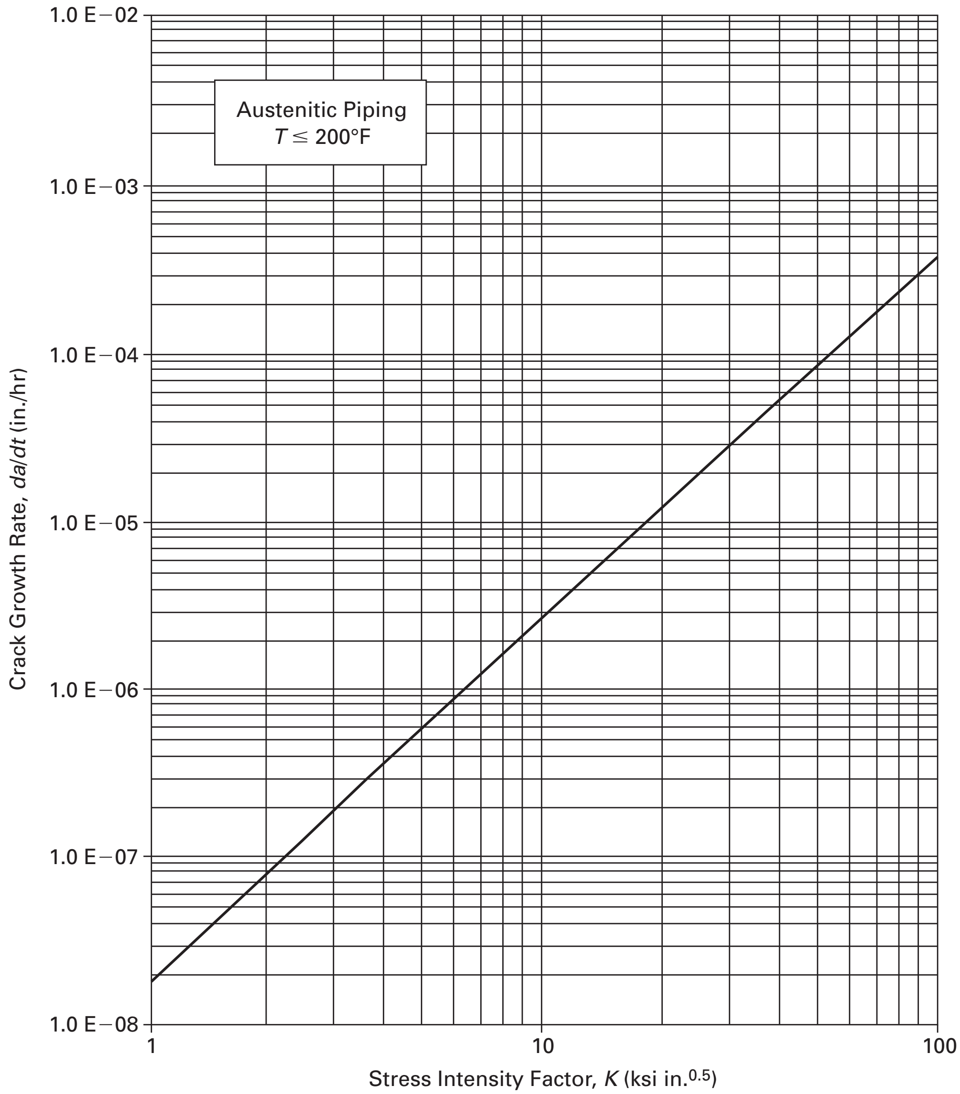
(b) When a flaw is detected, an additional sample of the same size as defined in (a) shall be examined.

(c) This process shall be repeated within 15 days for each successive sample, until no significant flaw is detected or until 100% of susceptible and accessible locations have been examined.

6 NOMENCLATURE

a = flaw depth
B_1, B_2 = Section III primary stress indices
c = half crack length
C = coefficient in the crack growth relationship
da/dt = flaw growth rate for stress corrosion cracking
d_{adj} = diameter equivalent circular hole at t_{adj}
D_i = inside pipe diameter
d_{min} = diameter of equivalent circular hole at t_{min}
D_o = outside pipe diameter
F = nondimensional stress intensity factor for through-wall axial flaw under hoop stress
F_b = nondimensional stress intensity factor for through-wall circumferential flaw under pipe bending stress
F_m = nondimensional stress intensity factor for through-wall circumferential flaw under membrane stress
h = flexibility characteristic
i = stress intensification factor
I = moment of inertia based on evaluation thickness, t
K_{max} = maximum stress intensity factor under long term steady state conditions
L = maximum extent of a local thinned area with $t < t_{nom}$
L_{axial} = length of idealized through-wall planar flaw opening in the axial direction of the pipe, as illustrated in Figure 5
L_{circ} = length of idealized through-wall planar flaw opening in the circumferential direction of the pipe, as illustrated in Figure 5
L_m = maximum extent of a local thinned area with $t < t_{min}$
$L_{m(a)}$ = axial extent of wall thinning below t_{min}
$L_{m(t)}$ = circumferential extent of wall thinning below t_{min}
$L_{m,avg}$ = average of the extent of L_m below t_{min} for adjacent thinned areas
$L_{m,i}$ = maximum extent of thinned area, i
M_2 = bulging factor for axial flaw
M_b = resultant primary bending moment
M_e = resultant thermal expansion moment
n = exponent in the crack growth relationship

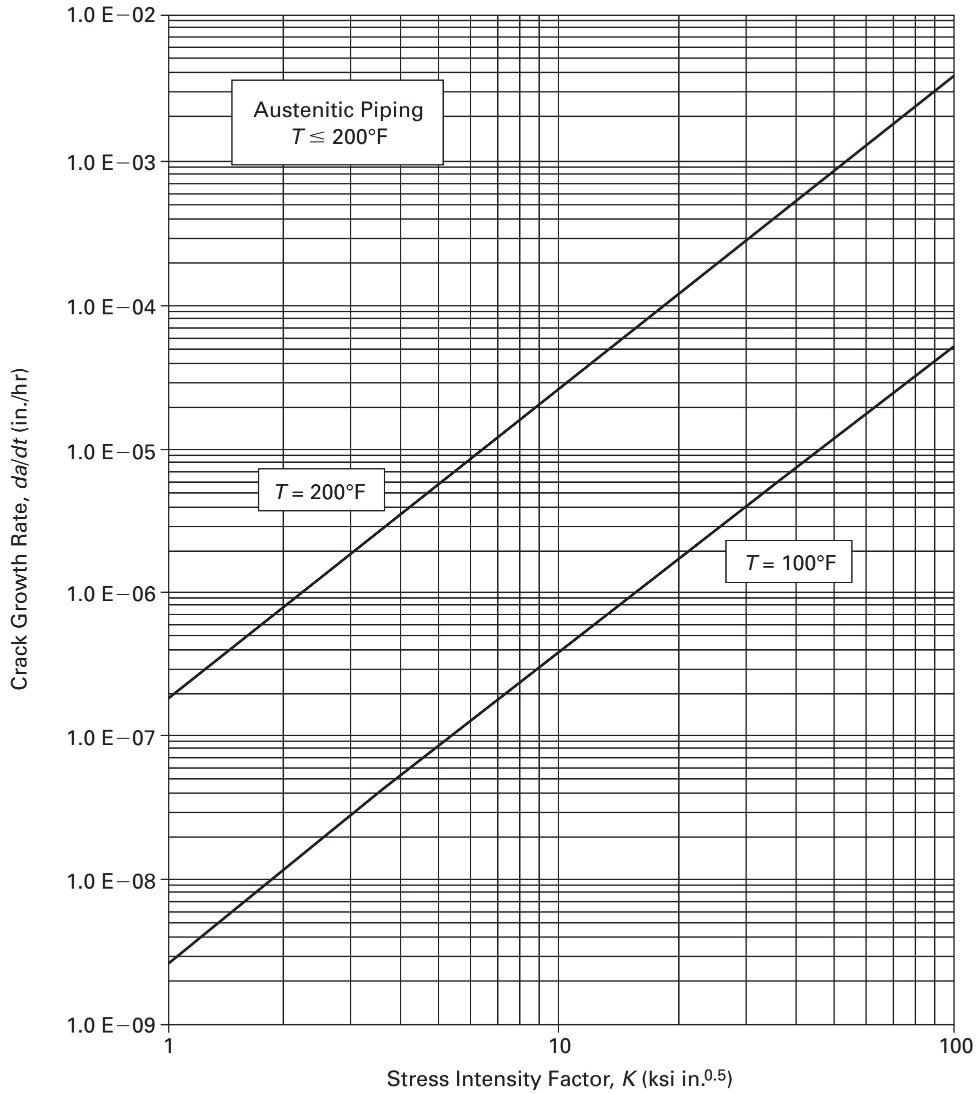
Figure 9
Flaw Growth Rate for IGSCC in Austenitic Piping



GENERAL NOTE: (SI conversion: 1.0 in./hr = 7.06 x 10^{-3} mm/sec; 1.0 ksi in.$^{0.5}$ = 1.099 MPa m$^{0.5}$; °C = [°F − 32]/1.8).

p = maximum operating pressure at flaw location
R = mean pipe radius
R_{bend} = elbow or bent pipe centerline bend radius
R_o = outside pipe radius
S = allowable stress at operating temperature
SF_m = structural factor on primary membrane stress
S_T = coefficient for temperature dependence in the crack growth relationship
S_u = Code-specified ultimate tensile strength
S_y = Code-specified yield strength
T = metal temperature
t = evaluation wall thickness, surrounding the degraded area
t_{adj} = adjusted wall thickness which is varied for evaluation purposes in the evaluation of a through-wall nonplanar flaw
t_{aloc} = allowable local thickness for a nonplanar flaw
$t_{c,avg}$ = average remaining wall thickness covering degraded area with through-wall leak bounded by d_{adj}
t_{min} = minimum wall thickness required for pressure loading
t_{nom} = nominal wall thickness
t_p = minimum remaining wall thickness
W_m = maximum extent of a local thinned area perpendicular to L_m with $t < t_{min}$

Figure 10
Flaw Growth Rate for TGSCC in Austenitic Piping



GENERAL NOTE: (SI conversion: 1.0 in./hr = 7.06 x 10^{-3} mm/sec; 1.0 ksi in.$^{0.5}$ = 1.099 MPa m$^{0.5}$; °C = [°F − 32]/1.8).

$X_{i,j}$ = minimum distance between thinned areas i and j
Z = load multiplier for ductile flaw extension
ℓ = total crack length = $2c$
ℓ_{all} = allowable axial through-wall flaw length
Φ = circumferential angle from elbow or bend flank
α = maximum cone angle at the center of a reducer
θ = half crack angle for through-wall circumferential flaw
λ = nondimensional half crack length for through-wall axial flaw
σ_b = axial bending stress for primary loading
σ_e = axial thermal expansion stress
σ_f = material flow stress
σ_h = pipe hoop stress due to pressure and bending moment (for elbows and bent pipe)
σ_l = reference limit load hoop stress
σ_m = axial pressure stress
σ_y = material yield strength at temperature, as defined in C-4300

7 APPLICABILITY

Reference to Nonmandatory Appendix C in this Case shall apply to Nonmandatory Appendix C of the 2004 Edition or later editions or addenda. For editions or addenda prior to the 2004 Edition, Class 1 pipe flaw evaluation procedures may be used for other piping classes. As a matter of definition, the current term “structural factor” is equivalent to the term “safety factor,” which is used in earlier editions and addenda.

MANDATORY APPENDIX I
RELATIONS FOR F_m, F_b, AND F FOR THROUGH-WALL FLAWS

I-1 DEFINITIONS

For through-wall flaws, the crack depth, a, will be replaced with half crack length, c, in the stress intensity factor equations in C-7300 and C-7400 of Section XI, Nonmandatory Appendix C. Also, Q will be set equal to unity in C-7400.

I-2 CIRCUMFERENTIAL FLAWS

For a range of R/t between 5 and 20, the following equations for F_m and F_b may be used:

$$F_m = 1 + A_m(\theta/\pi)^{1.5} + B_m(\theta/\pi)^{2.5} + C_m(\theta/\pi)^{3.5}$$

where

A_m = $-2.02917 + 1.67763\ (R/t) - 0.07987\ (R/t)^2 + 0.00176\ (R/t)^3$
B_m = $7.09987 - 4.42394\ (R/t) + 0.21036\ (R/t)^2 - 0.00463\ (R/t)^3$
C_m = $7.79661 + 5.16676\ (R/t) - 0.24577\ (R/t)^2 + 0.00541\ (R/t)^3$

$$F_b = 1 + A_b(\theta/\pi)^{1.5} + B_b(\theta/\pi)^{2.5} + C_b(\theta/\pi)^{3.5}$$

where

A_b = $-3.26543 + 1.52784\ (R/t) - 0.072698\ (R/t)^2 + 0.0016011\ (R/t)^3$
B_b = $11.36322 - 3.91412\ (R/t) + 0.18619\ (R/t)^2 - 0.004099\ (R/t)^3$
C_b = $-3.18609 + 3.84763\ (R/t) - 0.18304\ (R/t)^2 + 0.00403\ (R/t)^3$

In the above equations:

R = mean pipe radius
t = evaluation wall thickness
θ = half crack angle = c/R

Equations for F_m and F_b are accurate for R/t between 5 and 20 and become increasingly conservative for R/t greater than 20. Alternative solutions for F_m and F_b may be used when R/t is greater than 20.

I-3 AXIAL FLAWS

For internal pressure loading, the following equation for F may be used:

$$F = 1 + 0.072449\lambda + 0.64856\lambda^2 - 0.2327\lambda^3 + 0.038154\lambda^4 - 0.0023487\lambda^5$$

where

c = half crack length
λ = $c/(Rt)^{1/2}$

The equation for F is accurate for λ between 0 and 5. Alternative solutions for F may be used when λ is greater than 5.

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Approval Date: September 4, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-516-4
Underwater Welding
Section XI, Division 1

Inquiry: What alternative welding methods to those required by IWA-4000 may be used when repair or replacement of P-No. 1, P-No. 8, and P-No. 4X materials are to be performed underwater?

Reply: It is the opinion of the Committee that the following alternative welding methods may be used in lieu of those required by IWA-4000 when repair or replacement of P-No. 1, P-No. 8, and P-No. 4X materials are to be performed underwater. All other applicable requirements of Section XI shall be met.

1 SCOPE AND GENERAL REQUIREMENTS

(a) These requirements[1] are for dry or wet underwater welding.

(b) The terms and definitions of ANSI/AWS D3.6-89, "Specification for Underwater Welding" shall be used.

(c) Repair or replacement of P-No. 1, P-No. 8, and P-No. 4X materials and associated welds may be performed underwater provided the welding procedures and welders or welding operators are qualified in accordance with Section IX as modified by 2, 3, or 5, as applicable.

(d) Dry underwater welding may be performed with GMAW, GTAW, LBW, PAW, SMAW, or a combination of these processes.

(e) Wet underwater welding may be performed with GMAW (FCAW-type only), LBW, SMAW, or a combination of these processes.

(f) This Case may not be used for welding of irradiated materials other than P-No. 8 materials, containing less than 0.1 APPM measured or calculated helium content generated through irradiation.

2 ADDITIONAL VARIABLES FOR DRY UNDERWATER WELDING

2.1 PROCEDURE QUALIFICATION

Welding Procedure Specifications for dry underwater welding shall be qualified in accordance with the requirements of Section IX and applicable impact testing requirements of the Construction Code for groove welds. The following variables also apply.

(a) Additional essential variables:

(1) a change in the method for underwater transport and storage of filler material (e.g., from sealed packages to exposed);

(2) addition or deletion of waterproof or supplementary coatings for the filler metal or a change in the type of any waterproof or supplementary coatings;

(3) a change in depth beyond that qualified in accordance with Table 2.1-1;

(4) a change in the nominal background gas composition;[2]

(5) for SMAW and FCAW, use of a larger diameter electrode than that used in qualification.

(6) for P-No. 1 material, a decrease in the minimum distance from the point of welding to the wetted surface in any direction, when the minimum distance is less than 6 in.;

(7) for P-No. 1 material, the supplementary essential variables of Section IX apply to non-impact-tested base metal when the minimum distance from the point of welding to the wetted surface in any direction is less than 6 in.

(b) Additional nonessential variables:

(1) for SMAW and FCAW, an increase in time of electrode exposure to the underwater environment;

(2) a change in the method of protecting, removing moisture from, or otherwise conditioning bare filler metal and bare electrodes in the underwater environment.

[1] ANSI/AWS D3.6-89, "Specification for Underwater Welding" contains additional technical information that the Owner or user may find useful. Additional variables or controls may be considered for specific applications.

[2] Background gas is gas that displaces water and is not necessarily intended to shield the arc. The gas may or may not be breathable.

Table 2.1-1
Depth Limitations for Underwater Welding Qualification

Type of Welding	Max. Depth Qualified [Note (1)]	Min. Depth Qualified [Note (2)]
Dry welding	D plus 33 ft	D minus 33 ft
Wet welding with A-No. 8 filler metal	D plus 10 ft	D minus 33 ft
Wet welding with F-No. 4X filler metals	D	D minus 33 ft
Wet welding with other than A-No. 8 and F-No. 4X filler metals	D plus 33 ft	D minus 33 ft [Note (3)]

GENERAL NOTE: D is qualification test depth.

NOTES:
(1) For the maximum depth qualified, depth shall be measured from the lower extremity of the test weldment with a tolerance of plus or minus 9 in.
(2) For the minimum depth qualified, depth shall be measured from the upper extremity of the test weldment with a tolerance of plus or minus 9 in.
(3) Welds at depths less than 10 ft require qualification at the production weld minimum depth.

2.2 PERFORMANCE QUALIFICATION

Welders and welding operators for dry underwater welding shall be qualified in accordance with Section IX and the variables listed below. When a welder or welding operator has not welded with a process in a dry underwater environment for at least 6 months, the qualifications for that underwater process shall expire.

(a) A change in welding mode (i.e., dry chamber, dry spot or habitat).

(b) A change in the SFA specification AWS filler metal classification, or, if not conforming to an AWS filler metal classification, a change in the manufacturer's trade name for the electrode or filler metal.

(c) Addition or deletion of supplementary coatings for the filler metal or a change in the type of any supplementary coatings.

(d) A change in depth beyond that qualified in accordance with Table 2.1-1.

(e) For SMAW and GMAW, use of a larger diameter electrode than that used during performance qualification.

3 ADDITIONAL VARIABLES FOR WET UNDERWATER WELDING

3.1 PROCEDURE QUALIFICATION

Welding Procedure Specifications for wet underwater welding shall be qualified to the requirements of Section IX for groove welds except that for P-No. 1 base metals, the supplementary essential variables of Section IX apply to non-impact-tested base metal. The following variables also apply.

(a) Additional essential variables:

(1) a change in the method for underwater transport and storage of filler material (e.g., from sealed packages to exposed);

(2) addition or deletion of waterproof or supplementary coatings for the filler metal or a change in the type of any waterproof or supplementary coatings;

(3) a change in electrode diameter beyond the range used in qualification;

(4) a change in depth beyond that qualified in accordance with Table 2.1-1;

(5) a change in the SFA specification AWS filler metal classification, or, if not conforming to an AWS filler metal classification, a change in the manufacturer's trade name for the electrode or filler metal;

(6) addition of welding positions other than those qualified in accordance with Table 2.1-2;

(7) a change from upward to downward, or vice versa, in the progression specified for any pass of a vertical weld;

(8) a change from the stringer bead technique to the weave bead technique, or vice versa. For P-No. 8 and P-No. 4X base metals, this variable applies only to the vertical position;

(9) a change from AC to DC, or vice versa; and, in dc welding, a change from electrode negative (straight polarity) to electrode positive (reverse polarity) or vice versa;

(10) a change from wet backside to dry backside for backing thickness less than $^1/_4$ in.

(11) for P-No. 1 base metal carbon equivalents as calculated in accordance with eq. (1), an increase in the carbon equivalent beyond that of the procedure qualification test coupon;

$$\mathrm{CE} = \mathrm{C} + \frac{Mn + Si}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \qquad (1)$$

The chemical analysis for carbon equivalent calculations for the production base material may be obtained from the mill test certificate or chemical analysis. If it is not practical to obtain chemical analysis for *Cr, Mo, V, Ni* and *Cu,* the carbon equivalent may be determined by using 0.1 for the term

$$\left[\frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}\right]$$

(12) an increase in the time of electrode exposure to water at qualification depth;

(13) for P-No. 1 base materials, a change from multi-pass per side to single pass per side.

(b) Additional nonessential variables:

(1) a decrease in included angle, a decrease in root opening, or an increase in root face.

3.2 PERFORMANCE QUALIFICATION

Welders and welding operators for wet underwater welding shall be qualified in accordance with Section IX and the variables listed below. For P-No. 1 base metals, if mechanical bend testing is attempted in lieu of radiographic examination and the coupons fail the requirements of QW-302.1, immediate retesting may be by radiographic examination in accordance with QW-302.2. When a welder or welding operator has not welded with a process in a wet underwater environment for at least 6 months, the qualifications for welding with that process underwater shall expire.

(a) A change in the SFA specification AWS filler metal classification, or, if not conforming to an AWS filler metal classification, a change in the manufacturer's trade name for the electrode or filler metal.

(b) Addition or deletion of waterproof or supplementary coatings for the filler metal or a change in the type of any waterproof or supplementary coatings.

(c) A change from salt or borated water to fresh water.

(d) Use of a larger diameter electrode than that used during performance qualification.

(e) A change in depth beyond that qualified in accordance with Table 2.1-1.

(f) Addition of welding positions other than those qualified in accordance with Table 2.1-2.

(g) A change in polarity or type of power source (e.g., rectifier, motor-generator, inverter).

(h) A change from stringer bead to weave technique.

(i) A change in welder's view from beneath to above the water surface.

(j) A decrease in the included angle, a decrease in root opening, or an increase in the root face.

4 FILLER METAL QUALIFICATION

Filler metal qualification testing is required for

- each heat and lot of filler metal used for wet welding
- each heat and lot of flux-coated or flux-cored electrode used for dry welding
- each waterproof coating type
- each supplementary coating type

Testing shall be in accordance with the following requirements:

(a) An all-weld-metal coupon and a weld pad shall be prepared using the production welding procedure at a depth such that the depth of the production weld will be within the depth limitations of Table 2.1-1.

(1) For material that conforms to an SFA specification, the coupons shall be prepared in accordance with the applicable SFA specification.

Table 2.1-2
Procedure and Performance Qualification — Type and Position

Qualification Test		Position and Type of Weld Qualified [Note (1)]			
		Plate		Pipe	
Weld	Plate or Pipe Positions	Groove	Fillet	Groove	Fillet
Plate-groove	1G	F	F	F	F
	2G	H	H	H	H
	3G	V	V		
	4G	O	O		
Pipe-groove	1G	F	F	F	F
	2G	H	H	H	H
	5G	F,V,O	F,V,O	F,V,O	F,V,O
	6G	All	All	All	All

NOTE:
(1) Positions of welding.
F = Flat
H = Horizontal
V = Vertical
O = Overhead

(2) For material that does not conform to an SFA specification, the coupons shall be prepared in accordance with the SFA specification most nearly matching that material (e.g., for ferritic covered electrodes, SFA 5.1).

(b) The coupons shall be tested as follows:

(1) The ferrite number shall be directly measured from the weld pad for austenitic stainless steel, QW-442 A-No. 8 filler metal.

(2) One all-weld-metal specimen shall be tension tested.

(3) As-deposited chemical composition shall be determined from the weld pad in accordance with the applicable SFA specification or the SFA specification most nearly matching that material.

(4) For ferritic weld metal. Charpy V-notch absorbed energy shall be determined in accordance with 5(b), and when applicable, the Construction Code.

(c) Acceptance criteria:

(1) The ferrite number shall meet the requirements of the Construction Code.

(2) The ultimate tensile strength shall meet the minimum tensile strength specified for either of the base metals to be joined.

(3) The chemical composition shall meet the applicable SFA specification requirements for the as-deposited chemical composition. For material that does not conform to a SFA specification, the chemical composition shall meet the requirements specified in the WPS.

(4) Charpy V-notch absorbed energy shall meet the requirements of 5(c) and, when applicable, the Construction Code.

5 ALTERNATIVE PROCEDURE QUALIFICATION REQUIREMENTS

(a) As an alternative to the bend test requirements of Section IX, Charpy V-notch tests may be used when qualifying procedures for wet underwater welding of P-No. 1 base material.

(b) Charpy V-notch tests of the weld metal and heat affected zone (HAZ) of the procedure qualification shall be performed at 32°F. Number, location, and orientation of the test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the longitudinal specimen axis shall be perpendicular to the fusion line.

(2) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens. The absorbed energy and the test temperature, as well as the orientation and location of the tests performed, shall be reported in the Procedure Qualification Record.

(c) The averages of the three weld metal impact tests and the three HAZ impact tests shall each be not less than 25 ft.-lb.

(d) Charpy V-notch tests of the weld metal are not required for austenitic (A-No. 8) or nickel-base (F-No. 4X) filler material.

6 EXAMINATION

When it is impractical to perform the examinations required by this Division or the Construction Code because of the underwater environment, the following alternative requirements apply.

6.1 SURFACE EXAMINATION

In lieu of any required surface examination, the following apply:

(a) When practical, a surface examination shall be conducted with an ultrasonic or eddy current surface examination procedure qualified for the underwater environment.

(b) When ultrasonic and eddy current surface examination is not practical, the surface shall be visually examined with a procedure meeting the requirements of IWA-2200.

(c) Ultrasonic, eddy current and visual surface indications shall be evaluated using the surface examination acceptance criteria of the Construction Code, Section III, or Section XI, Division 1.

(d) Personnel performing visual examinations shall be qualified in accordance with IWA-2300 for performance of VT-1 visual examinations and shall have received additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

6.2 VOLUMETRIC EXAMINATION

In lieu of any required volumetric examination, the following apply:

(a) When practical, a volumetric examination shall be conducted with an ultrasonic examination procedure. The ultrasonic examination shall be conducted in accordance with Section V, Article 5. Indications shall be evaluated using the volumetric acceptance criteria of the Construction Code, Section III, or this Division.

(b) When ultrasonic volumetric examination is not practical, a nondestructive surface examination shall be performed on the root pass and on the finished weld. When it is impractical to perform a surface examination on either the root or the finished weld, the provisions of 6.1 apply.

Approval Date: July 30, 1998

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-517-1
Quality Assurance Program Requirements for Owners
Section XI, Division 1

Inquiry: What alternatives to possession of a Certificate of Authorization or Quality System Certificate (Materials), required by IWA-4221(a) and (b)[1] may be used by an Owner to perform the following activities?

(a) Qualification of Material Organizations[2] in accordance with NCA-3800;

(b) Utilization of unqualified source material in accordance with NCA-3855.5(a) and (b);[3]

(c) Acceptance of small products in accordance with NB-2610(b), NC-2610(b), ND-2610(b), NE-2610(b), NF-2610(b) and NB-2610(b), NC-2610(c), ND-2610(c), NE-2610(c), NF-2610(c).

Reply: It is the opinion of the Committee that as an alternative to possession of a Certificate of Authorization or Quality System Certificate (Materials), required by IWA-4221(a) and (b),[1] the provisions of this Case may be used by an Owner to perform the activities identified in the Inquiry, provided the following requirements are met:

(a) This Case may be used only for the nuclear plants operated by the Owner performing these activities;

(b) The Owner's Quality Assurance Program[4] required by IWA-1400(n) shall describe how these activities are controlled;

(c) When qualifying Material Organizations,[2] the Owner shall use NCA-3800 of the 1995 Edition with the 1997 Addenda;

(d) When accepting small products, the Owner shall perform the activities required of the Certificate Holder by NB-2610(b), NC-2610(b), ND-2610(b), NE-2610(b), NF-2610(b). The Quality Assurance Program of IWA-1400(n) may be used in lieu of NCA-4000.

(e) When utilizing unqualified source material,[5] the Owner shall perform the activities required of the Certificate Holder by NCA-3855.5(b);[6]

(f) Activities performed in accordance with this Case shall be subject to monitoring by the Authorized Nuclear Inservice Inspector;

(g) When utilizing unqualified source material[5] or accepting small products, use of this Case shall be recorded on a Certified Material Test Report or a Certificate of Compliance, as applicable.

[1] IWA-7210(b) and (c) in Editions and Addenda prior to the 1991 Addenda, or IWA-4170(c) and (d) in the 1991 Addenda up to and including the 1995 Edition.

[2] Material Manufacturers and Material Suppliers in Editions and Addenda up to and including the 1993 Addenda.

[3] Upgrading stock material in accordance with NCA-3867.4(e) and (f) in Editions and Addenda up to and including the 1993 Addenda.

[4] The Quality Assurance Program may be documented in implementing procedures.

[5] Upgrading stock material in Editions and Addenda up to and including the 1993 Addenda.

[6] NCA-3867.4(f) in Editions and Addenda up to and including the 1993 Addenda.

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Approval Date: December 11, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-520-6
Alternative Rules for Renewal of Active or Expired Certificates for Plants Not in Active Construction
Section III, Division 1

Inquiry: What alternative requirements (NCA-8100) may be used for the renewal of active or expired Certificates held by the Owner/Designee/Certificate Holder of a nuclear power plants not in active construction, where fabrication and installation activities at the Owner's site have been interrupted?

Reply: It is the opinion of the Committee that an active Certificate, or one that has been permitted to expire, as specified in the Inquiry, may be renewed at the applicant's facilities by the Society, provided the following alternative rules are met:

1 CURRENT ASME CERTIFICATES OF AUTHORIZATION OR NS CERTIFICATE HOLDERS

(a) The applicant shall notify the Society and the Authorized Inspection Agency of its intent to use this Code Case.

(b) The applicant is responsible for documenting compliance with the provisions of NCA-1140.

(c) The Quality Assurance Program previously accepted by the Society shall be continually implemented (NCA-8140), and any revisions to the program shall be acceptable to the Authorized Inspection Agency.

(d) An agreement with an Authorized Inspection Agency shall be maintained by Certificate Holder in accordance with NCA-8130.

(e) For active Certificates not later than 6 months prior to the date of expiration of the Certificate, the applicant shall apply for renewal of the certificate. The renewal application shall reference this Code Case. A letter from the Authorized Inspection Agency recommending the renewal of the Certificate shall accompany the application.

(f) For Certificates held by Owner's Designee/Certificate Holder, an audit as required by the Society shall be conducted prior to the renewal of the Certificate.

2 EXPIRED ASME CERTIFICATES OF AUTHORIZATION OR NS CERTIFICATE HOLDERS

(a) Where the Certificate Holder has permitted the Certificates to expire, and has returned the Code Symbol Stamps or ASME Certification Mark to the Society, and the Owner plans to contract with a new Certificate Holder to complete construction of the nuclear facility, the expired Certificate Holder may apply to the Society for temporary Certificates of Authorization, and such Certificates and applicable ASME Certification Mark shall be issued by the Society subject to the following conditions:

(1) The scope of the certificates shall be limited to the Code Edition and Addenda to, which the nuclear plant has been docketed. No new Code work may be performed under these temporary Certificates. Repair welding of material imperfections and existing welds shall not be performed.

(2) An Authorized Inspection Agency shall be employed to review the completed work, monitor, verify compilation and completion of all documentation such as Data Report Forms, and supporting Data Packages.

(3) The Authorize Nuclear Inspector (ANI) shall certify all partial Data Reports and authorize the temporary Certificate Holder to stamp the previously completed work with the appropriate ASME Certification Mark and Certification Mark Designator.

(4) The Quality Assurance Program previously accepted by the Society shall be implemented (NCA-8140) and any revisions to the program shall be acceptable to the Authorized Inspection Agency. All required revisions to the Quality Assurance Manual shall be reviewed and accepted by the Authorized Nuclear Inspector Supervisor (ANIS) prior to implementation. The revised program shall govern all activities required to document and stamp all previously completed work.

(5) A survey or audit by the Society shall be required for the issuance of the requested temporary Certificates and ASME Certification Mark to the expired Certificate Holder. Code activities performed prior to the issuance of the temporary Certificates shall be subject to the acceptance of the Inspector (NCA-8153).

(6) The Owner shall apply to the Society for an Owner's Certificate (NCA-8162), and the evaluation interview by the Society shall include a review of the scope of activities to be performed under the temporary Certificates. A complete list of all work remaining to be documented and stamped shall be provided to the AIA prior to completion of all work. The Regulatory Authority and the Jurisdictional and Enforcement Authority (if applicable) shall be notified of the completion of these activities.

(7) The term of the temporary Certificates shall be for 1 yr, and may be extended twice by the Society upon receipt of a request submitted by certified mail for an additional period not to exceed 1 yr each. Subsequent renewals shall be treated as renewals of active Certificates.

(8) The Owner shall maintain the Owner's Certificate in accordance with existing Code requirements until all Code activity has been completed, and the N-3 Data Report Form has been completed and filed [NCA-8180(c)].

(9) The temporary Certificates and ASME Certification Mark shall be returned to the Society when all previously completed work has been documented and stamped.

(b) The responsibility for material and supporting documentation procured to the original Construction Code, during initial construction, may be transferred to the new Certificate Holder, provided the following requirements are met:

(1) The material is only for use to complete the construction of items originally included as part of expired Certificate Holder's scope.

(2) The material is identified and traceable to a Certified Material Test Report and applicable procurement documentation.

(3) The transfer process shall be defined and controlled by the Certificate Holders, documented in their Quality Assurance manuals, and reviewed and verified by the Authorized Nuclear Inspector Supervisor.

(c) The renewal application shall include a complete listing of any Code activites to be performed. A certificate providing for activities to meet the provisions of NB/NC/ND/NE/NF/NG-2000; NB/NC/ND/ND/NF/NG-4000; NB/NC/ND/NE/NF/NG-5000; and NB/NC/ND/NE-6000 shall not be issued without a survey as required by the Society.

(d) At least 6 months prior to performance of any Code activities not listed in the last renewal application, to meet the provisions of NB/NC/ND/NE/NF/NG-2000; NB/NC/ND/NE/NF/NG-4000; NB/NC/ND/NE-6000, the Certificate Holder shall apply to the Society for a renewal survey.

(e) An audit as required by the Society shall be conducted prior to the renewal of the Certificate.

(f) The ASME Certification Mark shall be returned to the Society prior to issuance of the renewal Certificate.

Approval Date: December 9, 1993

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-525
Design Stress Intensities and Yield Strength Values for UNS N06690 With a Minimum Specified Yield Strength of 30 ksi, Class 1 Components
Section III, Division 1

Inquiry: Is it permissible in the construction of Class 1 components conforming to the requirements of Section III, Division 1, to use a nickel-chromium-iron UNS N06690 conforming to SB-166, SB-167 and SB-168 except that the minimum yield strength shall be in conformance with Table 1?

Reply: It is the opinion of the Committee that the material specified in the Inquiry may be used in the construction of Class 1 components under the rules of Section III, Division 1, provided the following additional requirements are met.

(a) The stress intensity and minimum yield strength values shall be as shown in Table 1.

(b) For external pressure the required thickness shall be determined in accordance with NB-3133 using Fig. NFN-4 of Section II, Part D.

(c) Welding Procedures and Performance Qualification shall be in accordance with Section IX and Section III. The material shall be considered to be P-No. 43.

(d) This Case number shall be listed on the Data Report Form for the component.

Table 1
Design Stress Intensity and Yield Strength Values

Temperature	Design Stress Intensity S_m, ksi	Yield Strength, ksi
100	20.0	30.0
200	20.0	27.1
300	20.0	25.5
400	20.0	24.6
500	20.0	23.8
600	20.0	23.6
700	20.0	23.6
800	20.0	23.6

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Approval Date: August 9, 1996

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-526
Alternative Requirements for Successive Inspections of Class 1 and 2 Vessels
Section XI, Division 1

Inquiry: What alternative requirements may be used for re-examinations required by IWB-2420(b) or IWC-2420 (b) for vessel volumes found by volumetric examination to contain subsurface flaws?

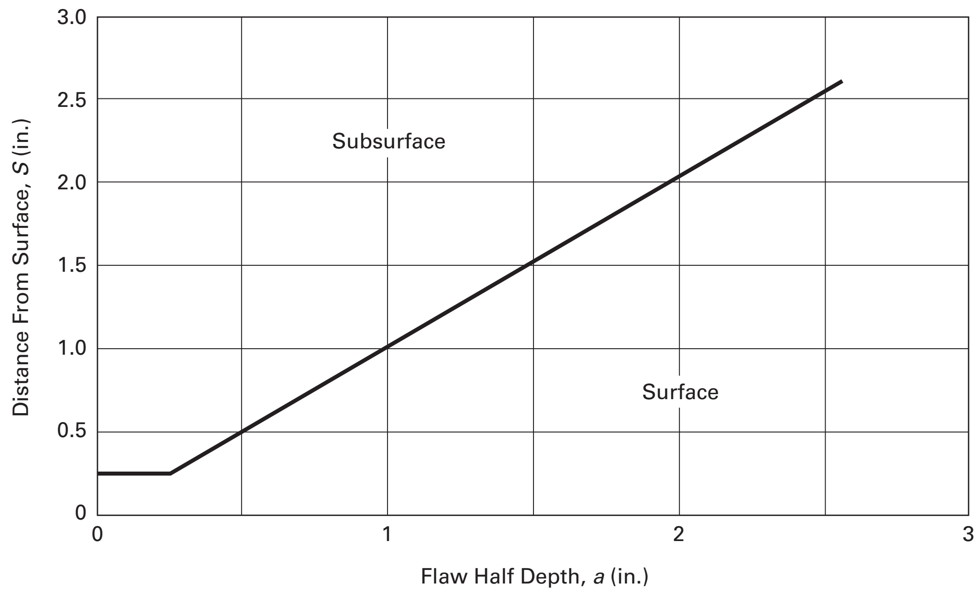
Reply: It is the opinion of the Committee that re-examinations in accordance with IWB-2420(b) or IWC-2420(b) of vessels examination volumes containing subsurface flaws are not required, provided the following are met:

(a) The flaw is characterized as subsurface in accordance with Figure 1.

(b) The NDE technique and evaluation that detected and characterized the flaw, with respect to both sizing and location, shall be documented in the flaw evaluation report.

(c) The vessel containing the flaw is acceptable for continued service in accordance with IWB-3600, and the flaw is demonstrated acceptable for the intended service life of the vessel.

Figure 1
Successive Examination (Surface Proximity Rule)



Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-528-1
Purchase, Exchange, or Transfer of Material Between Nuclear Plant Sites
Section XI, Division 1

Inquiry: As an alternative to the administrative requirements of Section III[1] imposed by IWA-4220 (IWA-7210 in Editions and Addenda prior to the 1991 Addenda; IWA-4170 for the 1991 Addenda through the 1995 Edition, no Addenda), what requirements apply to Owners when material meeting the definition in IWA-9000 is purchased, exchanged, or transferred between nuclear plant sites provided the following requirements are met?

Reply: It is the opinion of the Committee that, as an alternative to the administrative requirements of Section III imposed by IWA-4220 (IWA-7210 in Editions and Addenda prior to the 1991 Addenda; IWA-4170 for the 1991 Addenda through the 1995 Edition, no Addenda), material meeting the definition in IWA-9000 may be purchased, exchanged, or transferred between nuclear plant sites, provided the following requirements are met:

(a) Materials shall have been furnished to the supplying plant in accordance with NA-3700/NCA-3800.

(b) Since receipt by the supplying plant, the material was not placed in service, welded, brazed, nor subjected to any operation that might affect the mechanical properties of the material (e.g., heat treatment or forming).

(c) Documentation required by NA-3700/NCA-3800 shall be provided to the receiving plant with the material.

(d) When the material is fabricated in accordance with specific dimensional requirements in addition to those provided in a national standard (e.g., nonwelded valve bonnet or nonwelded pump casing), the evaluation of suitability required by IWA-4160 (IWA-7220 in Editions and Addenda prior to the 1991 Addenda; IWA-4150 for the 1991 Addenda through the 1995 Edition, no Addenda) shall include an evaluation of the material for its intended application, including any differences that might affect form, fit, or function.

(e) The receiving plant shall obtain certification for the following:

(1) The supplying plant purchased the material in accordance with NA-3700/NCA-3800 and maintained it in accordance with their Quality Assurance Program.

(2) Since receipt by the supplying plant, the material was not placed in service, welded, brazed, nor subjected to any operation that might affect the mechanical properties of the material (e.g., heat treatment or forming).

(f) Use of this Case shall be documented on the NIS-2 for repair or replacement using material obtained in accordance with the provisions of this Case.

[1] Administrative requirements refer to possession of a Certificate of Authorization or Quality System Certificate (Materials).

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Approval Date: December 12, 1994

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-530
Provisions for Establishing Allowable Axial Compressive Membrane Stresses in the Cylindrical Walls of 0-15 psi Storage Tanks, Classes 2 and 3 Section III, Division 1

Inquiry: As an alternative to the provisions of NC-3922, ND-3922, what provisions may be used to establish allowable axial compressive membrane stresses in the right circular cylindrical walls of 0-15 psi, Classes 2 and 3, Section III, Division 1 Storage Tanks?

Reply: It is the opinion of the Committee that the provisions described below, which are based upon a recognition of the effect of internal pressures, may be used to establish allowable axial compressive membrane stresses in the right circular cylindrical walls of 0-15 psi, Classes 2 and 3, Section III, Division 1 Storage Tanks.

TABLE OF CONTENTS

1 LIMITS OF APPLICATION

The application of this Case is subject to the following limitations:

(a) These provisions apply to the right circular cylindrical walls of Classes 2 and 3 tanks otherwise designed and constructed to the rules of NC-3900 and ND-3900.

(b) The specific criteria given herein are for the establishment of allowable axial membrane compressive stresses for those locations on the cylindrical walls where the corresponding total internal radial pressure (e.g., hydrostatic pressure + vapor over pressure + hydrodynamic pressures from loading such as earthquake) is equal to or greater than the external pressure. Except as noted in (c), no specific provisions are given for locations on the cylindrical walls where the internal pressure is less than the external pressure.

(c) This Case does not provide criteria for hoop compressive membrane stresses. If applicable, the Design Specification shall provide for such conditions. However, the use of this Case requires that Eqs. 6(12a), 6(12b), 6(12c), and 6(12d) be satisfied for those locations were the hoop stress is compressive and the axial stress is tensile.

(d) The provisions of this Case apply for tanks where the height of the cylindrical wall, H, divided by the radius of the midsurface of wall, R, is equal to or less than 0.95 times the square root of the ratio of the radius to the thickness of the wall, (R/t), i.e., $\left(H/R\right) \leq 0.95\sqrt{R/t}.$ (See 2 for definitions of H, R, and t.)

(e) All other requirements of NC/ND-3900 shall be satisfied.

2 NOMENCLATURE

The symbols used in this Case have the following definitions:

E = modulus of elasticity of the cylindrical wall material, at the corresponding temperature, given in the appropriate Table TM, Section II, Part D, Subpart 2; ksi

FS = Factor of Safety applied to $\sigma_{a,u}$ in order to establish $\sigma_{a,allow}$; dimensionless (see 5)

H = height of the right circular cylindrical wall portion of the tank; inches

L_x = length of measurement over which construction tolerance deviations are measured; inches, (see 7)

p = net internal radial pressure, i.e., internal radial pressure minus external pressure; ksi, [see 1(b)]

R = nominal radius of the midsurface of the cylindrical wall; inches

S = allowable tensile stress of the cylindrical wall material, at the corresponding temperature, given in the appropriate Table 1A or 1B, Section II, Part D, Subpart 1; ksi

S_y = yield strength of the cylindrical wall material, at the corresponding temperature, given in Table Y-1 of Section II, Part D, Subpart 1; ksi

t = nominal (supplied) thickness of the cylindrical wall minus any allowances established in the Design specification for corrosion, erosion, etc.; inches

Δ_x = geometric imperfection; inches, (see 7)

α_o = buckling capacity reduction factor for a cylindrical wall with no net internal radial pressure; dimensionless, [see eqs. 3(1a) and 3(1b)]

α_p = buckling capacity reduction factor that includes the effect of net internal radial pressure; dimensionless, [see eq. 3(b)(3)]

β = nondimensional parameter used in the formulation of axial compressive stress criteria; dimensionless, [see eq. 3(g)(7)]

λ_p = slenderness parameter that includes the effect of net internal radial pressure; dimensionless, [see eq. 3(g)(8)]

ν = Poisson's Ratio of the cylindrical wall material given in Table NF-1, Section II, Part D, Subpart 2; dimensionless. If no values is given for the material, use $\nu = 0.3$

ρ = parameter involving internal pressure; dimensionless, [see eq. 3(a)(2)]

σ_a = axial membrane compressive stress (compressive stress is positive); ksi (see 6)

$\sigma_{a,allow}$ = allowable value of the axial membrane compressive stress (compressive stress is positive); ksi, [see eq. 4(b)(11)]

$\sigma_{a,u}$ = lower bound for the axial membrane buckling stress (compressive stress is positive); ksi, (see 3)

σ_{cl} = classical linear elastic (bifurcation) buckling stress (compressive stress is positive) for a cylinder of perfect geometry ideal boundary conditions; ksi, [see eq. 3(d)(4)]

σ_{eff} = lower bound for the total effective membrane buckling or collapse stress; ksi, (see 3)

σ_h = hoop membrane stress (tensile stress is positive); ksi, [see eq. 3(e)(5)]

3 AXIAL COMPRESSIVE STRESS CRITERIA

The allowable axial membrane compressive stress is expressed as a function of the lower bound value of stress at which buckling could be expected to occur, $\sigma_{a,u}$, and a Factor of Safety. The Factor of Safety is specified in 5 for different Service Level Assignments. The quantity $\sigma_{a,u}$ is established from the criteria set forth in this paragraph. A buckling capacity reduction factor, α_o, is defined by eq. (1a) or eq. (1b).

$$\alpha_o = \frac{0.83}{\sqrt{1.0 + 0.01\ R/t}} \text{ for } R/t \le 212 \tag{1a}$$

$$\alpha_o = \frac{0.70}{\sqrt{0.1 + 0.01\ R/t}} \text{ for } R/t > 212 \tag{1b}$$

(a) This buckling capacity reduction factor, α_o, corresponds to a cylinder subjected to axial compression with no net internal radial pressure. The influence of a net internal radial pressure acting on the cylindrical walls is expressed with the aid of a dimensionless parameter, ρ, defined by eq. (2).

$$\rho = \frac{p}{E}\left(\frac{R}{t}\right)^{\frac{3}{2}} \tag{2}$$

(b) A value of the buckling capacity reduction factor that acknowledges the benefit of a net internal radial pressure α_p, is determined from eq. (3).

$$\alpha_p = \alpha_o + (1 - \alpha_o)\frac{\rho}{\rho + 0.007} \tag{3}$$

(c) For the purpose of establishing the allowable axial compressive stress at any location on the cylindrical wass, the value of the net internal radial pressure that exists at that location, coincident with the compressive stress, shall be used to establish ρ and hence α_p. When more than one value of net internal pressure may accompany a given axial stress, it shall be demonstrated that the controlling combination of internal pressure and axial stress has been established. This is accomplished by implementing the procedures established in this case using both the minimum and the maximum values of the net internal pressures that may exist for the condition being evaluated.

(d) The classical linear elastic buckling stress for a cylinder of perfect geometry subjected to compressive axial loads is given by eq. (4).

$$\sigma_{cl} = \frac{E}{\sqrt{3\left(1 - v^2\right)}}\left(\frac{t}{R}\right) \tag{4}$$

(e) The hoop tensile stress from internal pressure that accompanies the axial compressive stress shall be established from membrane theory in accordance with eq. (5).

$$\sigma_h = p\frac{R}{t} \tag{5}$$

(f) Here the value of the net internal radial pressure acting on the wall, *p*, shall be the same as that used to compute ρ in eq. (a)(2). Hoop tensile stress is considered positive.

(g) With the values of the parameters established above, the required quantity $\sigma_{a,u}$ is one of four unknowns ($\sigma_{a,u}$ σ_{eff} β and λ_p) in the four simultaneous equations given as Eqs. (6), (7), (8) (9a) and (9b).

$$\sigma_{eff} = \sqrt{\sigma_{a,u}^2 + \sigma_h^2 + \sigma_{a,u}\sigma_h} \tag{6}$$

$$\beta = \frac{\sigma_{a,u}}{\sigma_{eff}} \tag{7}$$

$$\lambda_p = \sqrt{\frac{\beta S_y}{\alpha_p \sigma_{cl}}} \tag{8}$$

$$\frac{\sigma_{eff}}{S_y} = \frac{0.75}{\lambda_p^2} \text{ for } \lambda_p \ge 1.414 \tag{9a}$$

$$\frac{\sigma_{eff}}{S_y} = (1.0 - 04123\,\lambda_p^{1,2}) \text{ for } \lambda_p < 1.414 \tag{9b}$$

(h) When the hoop stress is zero, these equations can be solved explicitly for $\sigma_{a,u}$. In the more general case, a method such as outlined below in 4 must be used.

4 ALLOWABLE AXIAL MEMBRANE COMPRESSIVE STRESSES

Any method of solving the system of equations given in 3 is satisfactory. Provided herein is one acceptable method. Note that eq. 3(g)(6) can be rearranged as shown in eq. (10).

$$\sigma_{a,u} = \sqrt{(\sigma_{eff}^2 - 0.75\,\sigma_h^2)} - 0.5\,\sigma_h \tag{10}$$

(a) The algorithm proceeds as follows:

Step A Compute parameters α_o, ρ, α_p, σ_{cl}, and σ_h for the set of conditions being evaluated.
Step B Estimate a value of β [note eq. 3(g)(7)], call the value β′.
Step C Compute λ_p from eq. 3(g)(8) using β′ for β.
Step D Compute σ_{eff} from eq. 3(g)(9a) and 3(g)(9b).
Step E Compute $\sigma_{a,u}$ from eq. (10).
Step F Compute β from eq. 3(g)(7).

Step G Compare the computed value of β (Step F) with the estimated value, β'. If the computed value of β is close to the estimated value β' (i.e., within plus or minus 2%), note the value of $\sigma_{a,u}$ obtained from Step E for use as described below. If not, select a revised β estimate, β', and return to Step C.

(b) The allowable value of the axial compressive membrane stress, $\sigma_{a,allow}$, shall be established from eq. (11).

$$\sigma_{a,allow} = \frac{\sigma_{a,u}}{FS} \tag{11}$$

(c) In eq. (b)(11), the minimum values of the factors of safety against buckling, FS, are provided in 5 for the different Service Levels.

(d) As an alternative to solving the equations of 3 by methods such as described above, the curves plotted in Nonmandatory Appendix A to this Case may be used for ferrous materials of various yield strength at temperatures not exceeding 300°F. Linear interpolation between the curves is permitted.

5 AXIAL COMPRESSIVE STRESS FACTORS OF SAFETY

The factors of safety, FS, for use in establishing the allowable values of axial membrane compressive stress with eq. 4(b)(11) shall be as follows:

Service Level	Factor of Safety, FS
A	2
B	2
C	$^5/_3$
D	$^4/_3$

6 CORRESPONDING ALLOWABLE HOOP MEMBRANE STRESSES

When the allowable axial membrane compressive stress is established by the use of this Case, the requirements of this paragraph, expressed in eqs. (12a) through (12d), shall also be satisfied. The hoop membrane stress may be computed by use of eq. 3(e)(5), or results from more detailed stress analyses may be used, but the largest value of coincident pressure shall be considered for each value of corresponding axial stress. For designs qualified by use of this Case, the requirements of eqs. (12a) through (12d) shall also apply for those situations where the cylindrical wall is in a state of hoop membrane compression in combination with axial membrane tension. With the value of S established from the appropriate Table 1A, or 1B from Section II, Part D, Subpart 1, the following requirements expressed as eqs. (12a), (12b), (12c), and (12d) shall be satisfied.

$$|\sigma_a| + |\sigma_h| \leq 1.0S, \text{ for Service Level A} \tag{12a}$$

$$|\sigma_a| + |\sigma_h| \leq 1.1S, \text{ for Service Level B} \tag{12b}$$

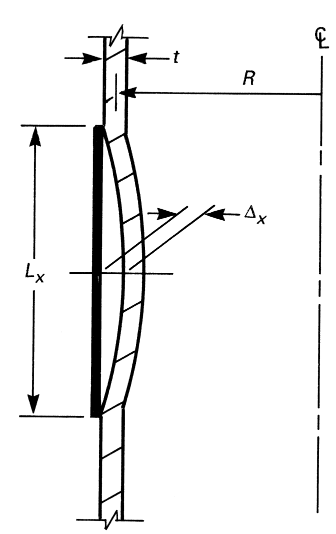
$$|\sigma_a| + |\sigma_h| \leq 1.5S, \text{ for Service Level C} \tag{12c}$$

$$|\sigma_a| + |\sigma_h| \leq 2.0S, \text{ for Service Level D} \tag{12d}$$

7 CONSTRUCTION TOLERANCES

In addition to the applicable requirements established in NC-4220 and ND-4220, a tolerance shall apply on bulges or flat spots in the cylindrical walls that result from vertical elements of the cylinder being other than straight lines. This tolerance is expressed in terms of the quantities illustrated in Figure 7-1, Meridional Straightness Tolerance. A straight rod is to be positioned either inside or outside the tank, as appropriate, for the deviation being evaluated. The length of the rod, L_x shall be $4\sqrt{Rt}$, plus or minus 10%. The amplitude of the deviation, Δ_x, shall not exceed 1% of L_x. These tolerance requirements, which are in addition to those given in NC/ND-4220, apply only to regions of the cylindrical walls where allowable compressive stresses are established through application of this Case.

Figure 7-1
Meridional Straightness Tolerance



8 DOCUMENTATION AND IDENTIFICATION

Calculations demonstrating that the requirements specified above have been satisfied shall be included as part of the Design Report. This Case number shall be shown on the Data Report Form.

NONMANDATORY APPENDIX A
PLOTS

A-1 INTRODUCTION

The graphs plotted in this Appendix may be used for ferrous materials at temperatures not greater than 300°F.[1] They establish the allowable axial membrane compressive stress ehn that axial compressive stress occurs at a location on the tank wall where the net internal radial pressure is equal to or greater than zero. Linear interpolation between curves is permitted. To establish the allowable axial membrane compressive stress for a given Service Level (S.L.), the value read from the ordinate of the curve shall be divided by the appropriate Factor of Safety (FS), consistent with the Service Level assigned by the Design Specification to the loading combination being evaluated. The value of S_y shall be the yield strength of the material, at the corresponding temperature, obtained from Table Y-1, of Section II, Part D, Subpart 1.

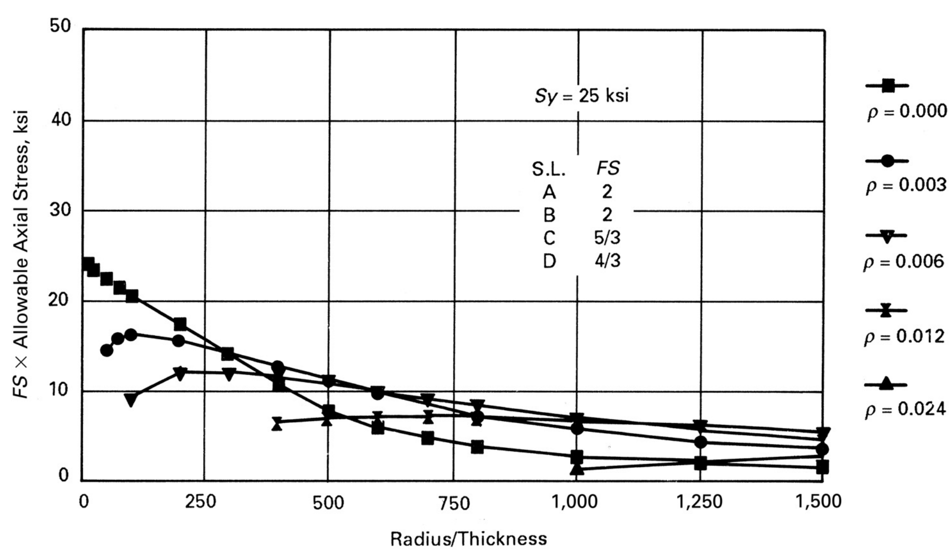
A-2 GENERAL REQUIREMENTS

The value of ρ [see eq. 3(a)(2)] shall be computed from the pressure at the location of interest and under the same loading conditions as those that produce the axial membrane compressive stress being evaluated. When more than one value of net internal pressure may accompany a given axial stress, it shall be demonstrated that the controlling combination of internal pressure and axial stress has been established. This is accomplished by implementing the procedures established in this case using both the minimum and the maximum values of the net internal pressures that may exist for the condition being evaluated.

A-3 USE OF TABULAR VALUES

Tabular representation of the data in Figure A-1 through A-5 is provided in Table A-1.1 through A-6.1. Note that the data in these tables is for ferrous materials at temperatures equal to or less than 300°F. Other Code temperature limit may also apply.

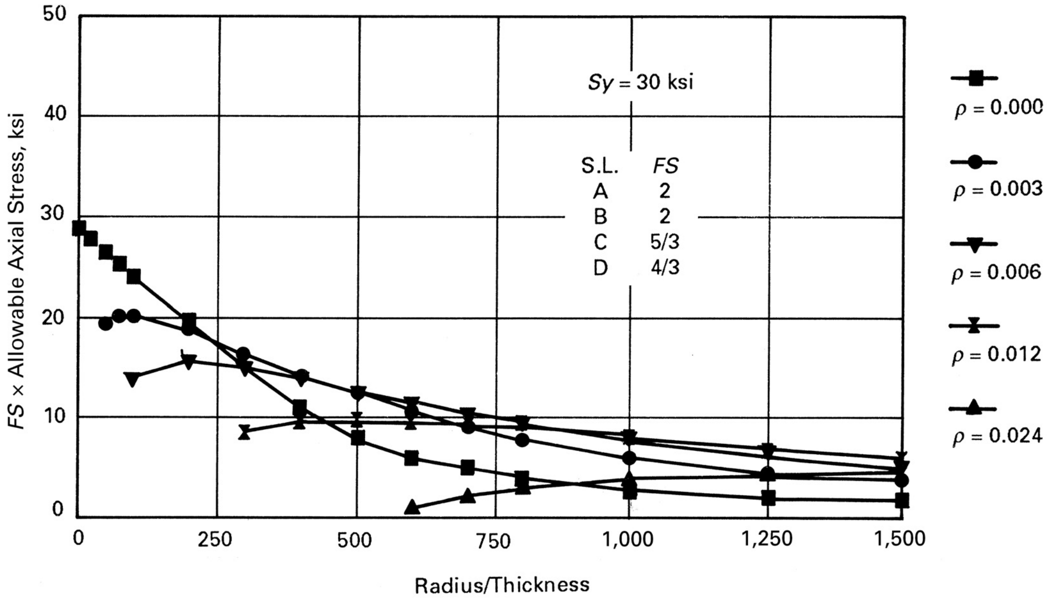
Figure A-1
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 25 ksi at Temperatures ≤300°F



GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

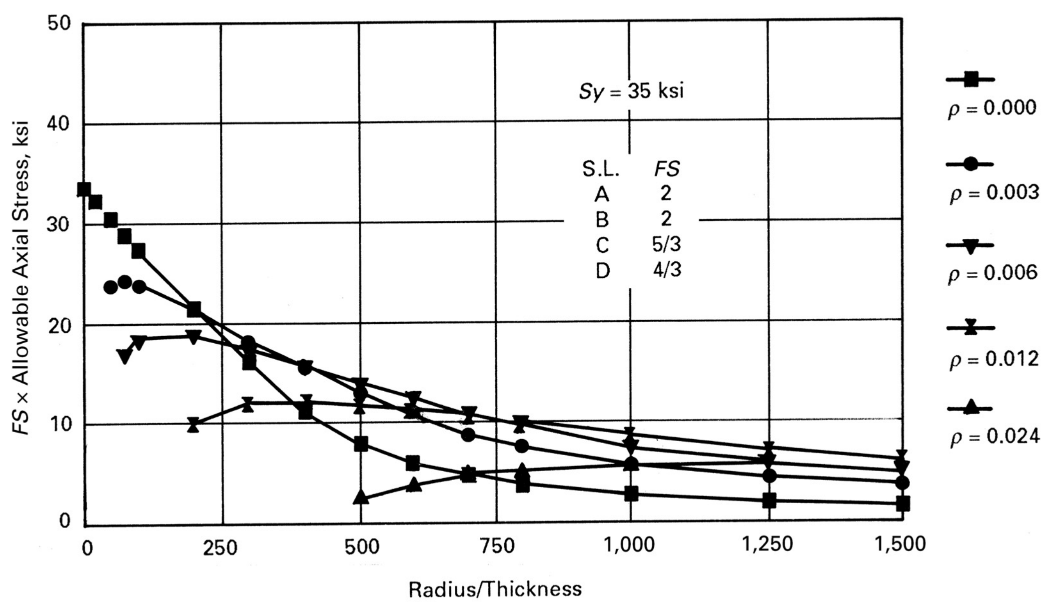
[1] The curves in this Appendix are for E = 28,000,000 psi and ν = 0.3. For the purpose of this Appendix, these values are acceptable approximations to the values provided in Section II, Part D for ferrous materials at temperatures not greater than 300°F.

Figure A-2
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 30 ksi at Temperatures ≤300°F



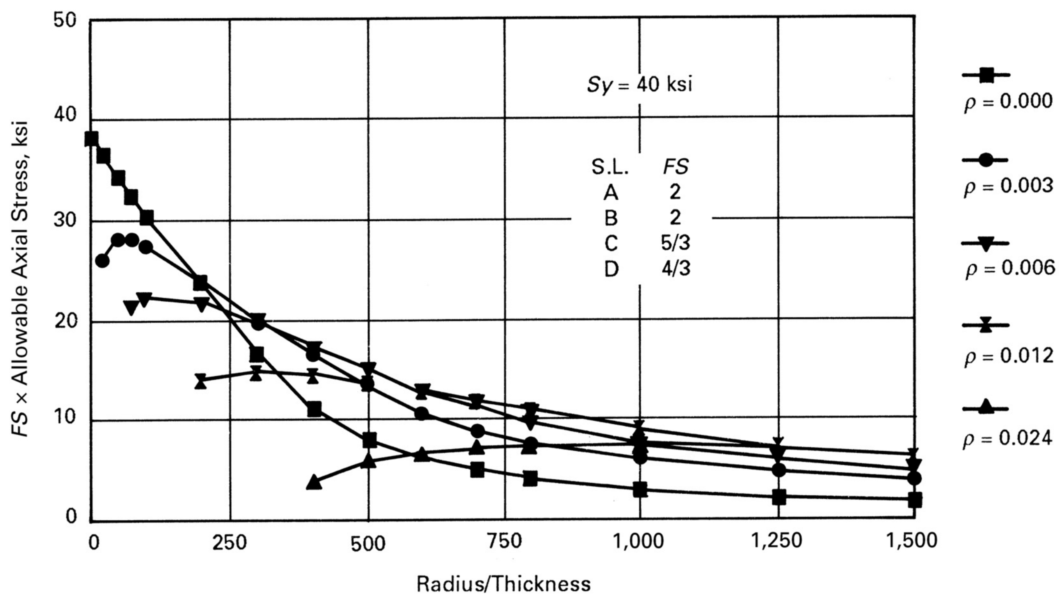
GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

Figure A-3
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 35 ksi at Temperatures ≤300°F



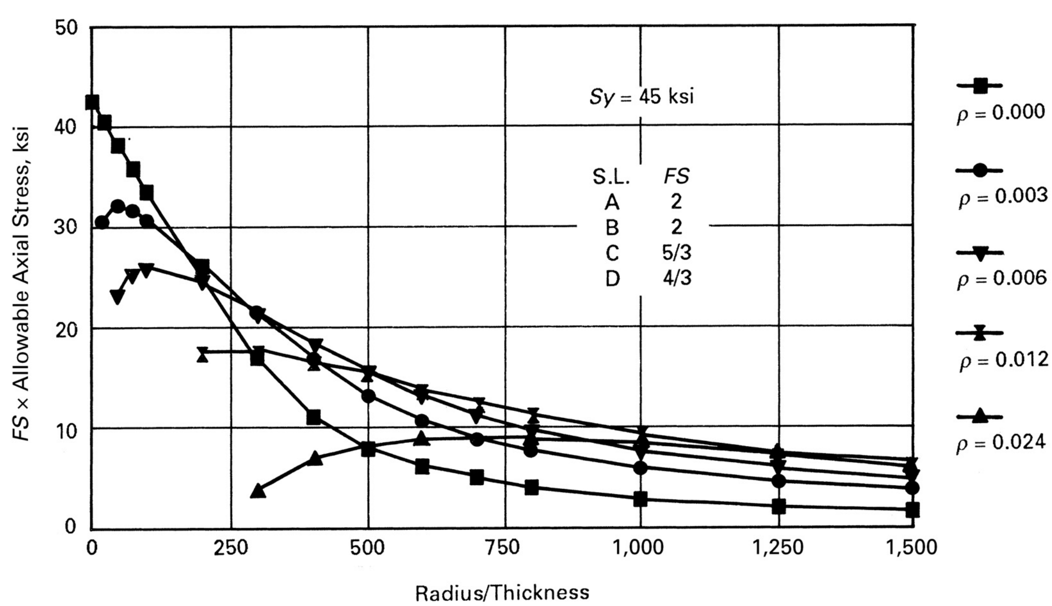
GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

Figure A-4
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 40 ksi at Temperatures ≤300°F



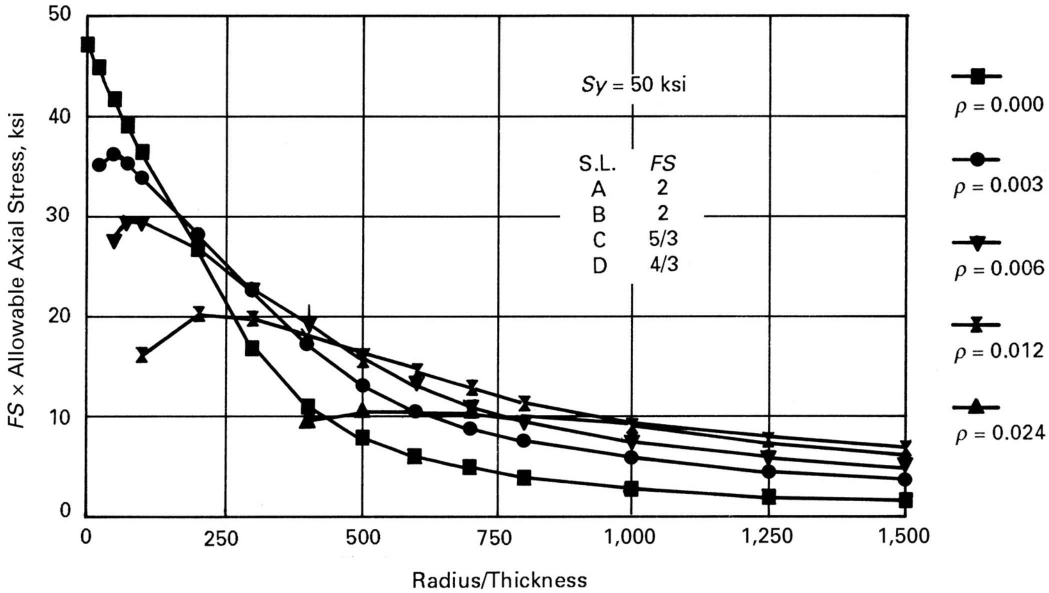
GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

Figure A-5
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 45 ksi at Temperatures ≤300°F



GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

Figure A-6
Factor of Safety Times Allowable Axial Membrane Compressive Stress Versus Radius Over Thickness for Ferrous Materials With Yield Strengths of 50 ksi at Temperatures ≤300°F



GENERAL NOTE: Curves are for ferrous materials, temperature ≤300°F; other code temperature limits may also apply.

Table A-1.1
Tabular Values for Figure A-1

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	24.05	...	...	...	...
25	23.30	...	...	...	...
50	22.28	14.72	...	...	...
75	21.36	15.83	...	...	...
100	20.50	16.17	9.16	...	...
200	17.29	15.60	11.96	...	...
300	14.01	14.21	12.07	...	...
400	10.79	12.73	11.56	6.27	...
500	7.88	11.30	10.87	6.97	...
600	6.00	9.94	10.11	7.23	...
700	4.77	8.67	9.34	7.26	...
800	3.91	7.50	8.60	7.16	...
1000	2.80	5.77	7.23	6.76	1.53
1250	2.01	4.45	5.77	6.13	2.42
1500	1.53	3.61	4.73	5.48	2.87

Table A-2.1
Tabular Values for Figure A-2

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	28.73	...	...	...	...
25	27.72	...	...	...	...
50	26.35	19.31	...	...	...
75	25.13	20.02	...	...	...
100	23.97	20.06	13.82	...	...
200	19.69	18.59	15.47	...	...
300	15.28	16.45	14.84	8.55	...
400	10.98	14.32	13.76	9.47	...
500	7.88	12.31	12.57	9.64	...
600	6.00	10.45	11.39	9.49	1.07
700	4.77	8.79	10.27	9.17	2.14
800	3.91	7.50	9.22	8.77	2.92
1000	2.80	5.77	7.37	7.88	3.82
1250	2.01	4.45	5.77	6.80	4.28
1500	1.53	3.61	4.73	5.48	4.36

Table A-3.1
Tabular Values for Figure A-3

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	33.38	...	...	...	...
25	32.08	...	...	...	...
50	30.33	23.68	...	...	...
75	28.77	24.02	16.71	...	...
100	27.29	23.76	18.08	...	...
200	21.80	21.32	18.65	9.98	...
300	16.17	18.36	17.27	11.90	...
400	10.98	15.52	15.57	12.16	...
500	7.88	12.91	13.88	11.84	2.54
600	6.00	10.56	12.27	11.27	3.91
700	4.77	8.79	10.78	10.61	4.76
800	3.91	7.50	9.43	9.91	5.26
1000	2.80	5.77	7.37	8.57	5.69
1250	2.01	4.45	5.77	7.11	5.67
1500	1.53	3.61	4.73	5.91	5.40

Table A-4.1
Tabular Values for Figure A-4

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	38.00	...	...	...	...
25	36.39	25.91	...	...	...
50	34.22	27.90	...	...	...
75	32.28	27.86	21.10	...	...
100	30.45	27.28	22.06	...	...
200	23.66	23.82	21.56	13.80	...
300	16.68	19.98	19.40	14.83	...
400	10.98	16.38	17.06	14.46	3.62
500	7.88	13.14	14.83	13.64	5.53
600	6.00	10.56	12.78	12.67	6.49
700	4.77	8.79	10.95	11.67	6.99

Table A-4.1
Tabular Values for Figure A-4 (Cont'd)

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
800	3.91	7.50	9.44	10.70	7.20
1000	2.80	5.77	7.37	8.94	7.14
1250	2.01	4.45	5.77	7.16	6.68
1500	1.53	3.61	4.73	5.91	6.10

Table A-5.1
Tabular Values for Figure A-5

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	42.58	...	...	...	...
25	40.64	30.56	...	...	...
50	38.02	32.00	23.10	...	...
75	35.68	31.56	25.24	...	...
100	33.47	30.66	25.81	...	...
200	25.27	26.11	24.24	17.26	...
300	16.84	21.32	21.25	17.43	3.73
400	10.98	16.93	18.25	16.43	6.76
500	7.88	13.14	15.48	15.12	8.13
600	6.00	10.56	13.00	13.74	8.13
700	4.77	8.79	10.95	12.41	8.85
800	3.91	7.50	9.44	11.18	8.76
1000	2.80	5.77	7.37	9.06	8.24
1250	2.01	4.45	5.77	7.16	7.39
1500	1.53	3.61	4.73	5.91	6.54

Table A-6.1
Tabular Values for Figure A-6

R/t	ρ = 0.000	ρ = 0.003	ρ = 0.006	ρ = 0.012	ρ = 0.024
10	47.14	...	...	...	...
25	44.84	35.09	...	...	...
50	41.74	35.98	27.58	...	...
75	38.97	35.15	29.20	...	...
100	36.35	33.89	29.39	16.19	...
200	26.64	28.19	26.71	20.42	...
300	16.84	22.41	22.87	19.74	...
400	10.98	17.19	19.17	18.12	9.56
500	7.88	13.14	15.85	16.30	10.42
600	6.00	10.56	13.01	14.53	10.57
700	4.77	8.79	10.95	12.89	10.38
800	3.91	7.50	9.44	11.42	10.01
1000	2.80	5.77	7.37	9.06	9.06
1250	2.01	4.45	5.77	7.16	7.86
1500	1.53	3.61	4.73	5.91	6.79

Approval Date: January 4, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-532-5
Repair/Replacement Activity Documentation Requirements and Inservice Inspection Summary Report Preparation and Submission
Section XI, Division 1

Inquiry: What alternatives to the requirements of Section XI, and other Section XI Code Cases, may be used for completion of Form NIS-2, and preparation and submittal of the inservice inspection summary report, including Forms NIS-1 and NIS-2?

Reply: It is the opinion of the Committee that as an alternative to the requirements of Section XI and other Section XI Code Cases, the following provisions may be used whenever completion of Form NIS-1, Form NIS-2, or an inservice inspection summary report is required.

1 REPAIR/REPLACEMENT CERTIFICATION RECORD

(a) The Owner's Repair/Replacement Program shall identify use of this Case.

(b) A Repair/Replacement Plan shall be prepared for all repair/replacement activities, including rerating. The Repair/Replacement Plan shall be prepared in accordance with IWA-4150 and shall be given a unique identification number.

(c) Upon completion of all required activities associated with the Repair/Replacement Plan, the Owner shall prepare a Repair/Replacement Certification Record, Form NIS-2A.

(d) Form NIS-2A shall be presented to the Inspector for the required signature.

(e) Form NIS-2A shall be completed after satisfying all Section XI requirements necessary to place the item in service and prior to inclusion in an Owner's Activity Report.

(f) The completed Form NIS-2A shall be maintained by the Owner, as required for Form NIS-2.

(g) The Owner shall maintain an index of Repair/Replacement Plans.

2 OWNER'S ACTIVITY REPORT

An Owner's Activity Report, Form OAR-1, shall be processed as specified below within 90 calendar days of the completion of each refueling outage.

(a) A listing of items with flaws or relevant conditions that exceeded the acceptance criteria of Division 1 and that required evaluation to determine acceptability for continued service shall be provided with the information and format of Table 1. This information is required whether or not the flaw or relevant condition was discovered during a scheduled examination or test.

(b) An abstract for repair/replacement activities that were required due to an item containing a flaw or relevant condition that exceeded Division 1 acceptance criteria shall be provided with the information and format of Table 2. This information is required even if the discovery of the flaw or relevant condition that necessitated the repair/replacement activity did not result from an examination or test required by Division 1. If the acceptance criteria for a particular item is not specified in Division 1, the provisions of IWA-3100(b) shall be used to determine which repair/replacement activities are required to be included in the abstract.

(c) If no items met the criteria of (a) or (b), the term “None” should be recorded in the applicable table.

(d) If there are multiple inspection plans with different intervals, periods, Editions, or Addenda, they shall be identified on Form OAR-1.

(e) Form OAR-1 shall be certified by the Owner and presented to the Inspector for the required signature.

(f) The completed Form OAR-1 shall be submitted to the regulatory and enforcement authorities having jurisdiction at the plant site.

FORM NIS-2A REPAIR/REPLACEMENT CERTIFICATION RECORD

OWNER'S CERTIFICATE OF CONFORMANCE

I certify that the ______________________ activities represented by Repair/Replacement Plan number ________________ conform to the requirements of Section XI necessary to place the item in service.

Edition and Addenda of Section XI used: ______________________________

Code Cases used for repair/replacement activities: ______________________________
(if applicable, including cases modified by Case N-532 and later revisions)

Signed ______________________________ Date ________________
Owner or Owner's Designee

CERTIFICATE OF INSERVICE INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by ______________________ of ______________________ have inspected the items described in Repair/Replacement Plan number ________________ , and state that, to the best of my knowledge and belief, the Owner has performed all the activities described in the Repair/Replacement Plan in accordance with the requirements of Section XI necessary to place the item in service.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the activitie described in the Repair/Replacement Plan. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or loss of any kind arising from or connected with this inspection.

______________________________ Commission ______________________________
Inspector's Signature (National Board Number and Endorsements)

Date ________________

(06/11)

FORM OAR-1 OWNER'S ACTIVITY REPORT

Report Number ______________________________

Plant ______________________________

Unit No. ____________ (if applicable) Commercial service date ____________ Refueling outage no. ____________

Current inspection interval ______________________________ (1st, 2nd, 3rd, 4th, other)

Current inspection period ______________________________ (1st, 2nd, 3rd)

Edition and Addenda of Section XI applicable to the inspection plans ______________________________

Date and revision of inspection plans ______________________________

Edition and Addenda of Section XI applicable to repair/replacement activities, if different than the inspection plans ____________

____

Code Cases used for inspection and evaluation: ______________________________ (if applicable, including cases modified by Case N-532 and later revisions)

CERTIFICATE OF CONFORMANCE

I certify that (a) the statements made in this report are correct; (b) the examinations and tests meet the Inspection Plan as required by the ASME Code, Section XI; and (c) the repair/replacement activities and evaluations supporting the completion of ____________ (refueling outage number) conform to the requirements of Section XI.

Signed ______________________________ Owner or Owner's Designee, Title Date ______________________________

CERTIFICATE OF INSERVICE INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by ____________ of ____________ have inspected the items described in this Owner's Activity Report, and state that, to the best of my knowledge and belief, the Owner has performed all activities represented by this report in accordance with the requirements of Section XI.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the repair/replacement activities and evaluation described in this report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

______________________________ Inspector's Signature Commission ______________________________ (National Board Number and Endorsement)

Date ______________________________

(06/11)

Table 1
Items with Flaws or Relevant Conditions That Required Evaluation for Continued Service

Examination Category and Item Number	Item Description	Evaluation Description

Table 2
Abstract of Repair/replacement Activities Required for Continued Service

Code Class	Item Description	Description of Work	Date Completed	Repair/Replacement Plan Number

Approval Date: February 26, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-533-1
Alternative Requirements for VT-2 Visual Examination of Class 1, 2, and 3 Insulated Pressure-Retaining Bolted Connections
Section XI, Division 1

Inquiry: What alternative requirements may be used in lieu of those of IWA-5242(a) to remove insulation from Class 1, 2, and 3 pressure-retaining bolted connections to perform a VT-2 visual examination?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWA-5242(a) to remove insulation from Class 1, 2, and 3 pressure-retaining bolted connections to perform a VT-2 visual examination, the following requirements shall be met.

(a) A system pressure test and VT-2 visual examination shall be performed each refueling outage for Class 1 connections and each period for Class 2 and 3 connections without removal of insulation.

(b) The insulation shall be removed from the bolted connection, each refueling outage for Class 1 connections and each period for Classes 2 and 3 connections, and a VT-2 visual examination shall be performed. The connection is not required to be pressurized. Any evidence of leakage shall be evaluated in accordance with IWA-5250.

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Approval Date: March 14, 1995

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-537
Location of Ultrasonic Depth-Sizing Flaws
Section XI, Division 1

Inquiry: What alternative to the requirements of 2.2(b) of Appendix VIII, Supplements 2, 4, and 6, and 2.3 of Supplements 10 and 11, may be used to identify the location of flaws to be sized for depth during a performance demonstration?

Reply: It is the opinion of the Committee that, as an alternative to the requirements for identification of flaw location for depth sizing referenced in the *inquiry*, the region of the specimen containing a flaw to be sized shall be identified to the candidate.

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Approval Date: June 9, 1995

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-539
UNS N08367 in Class 2 and 3 Valves
Section III, Division 1

Inquiry: Under what provisions may solution annealed UNS N08367 be used in Class 2 and 3 valves?

Reply: It is the opinion of the Committee that Class 2 and 3 valves may be constructed from UNS N08367 (cast alloy CN-3MN) provided the following conditions are met:

(a) Pressure retaining materials shall comply with one of the following specifications:

Specifications	Product Form	Grade
SA-351	Castings	CN-3MN (UNS N08367)
SB-564	Forgings	(UNS N08367)
SB-688	Plate	(UNS N08367)

(b) The pressure–temperature ratings of B16.34-1988, Table 2-3.16 shall be used, except that the maximum temperature shall not exceed 650°F. All other applicable requirements of ASME/ANSI B16.34-1988 shall be met as required by NC/ND-3500.

(c) Welding qualifications shall be in accordance with Section IX. The material shall be considered P-No. 45.

(d) Forgings and plate shall be heated to 2025°F – 2150°F and shall be held for a sufficient time to heat the material to temperature, followed by quenching in water or similar rapid cooling by other means. Castings shall be heat treated at 2100°F – 2150°F for at least one hour, followed by quenching in water or similar rapid cooling by other means. Heat treatment after forming or welding is not required. However, if heat treatment is applied, the solution annealing treatment shall be repeated.

(e) All other requirements of Section III, Division 1, as applicable, shall be met.

(f) This Case number shall be identified on the Certificate Holder's Data Report for the valve.

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Approval Date: March 19, 1996

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-548
Air Cooling of SA-182 Grades F304, F304L, F316, F316L Forgings Instead of Liquid Quenching After Solution Heat Treatment, Classes 1, 2, and 3
Section III, Division 1

Inquiry: May austenitic stainless steel forgings, air cooled from the solution heat treatment temperature and otherwise meeting the requirements of SA-182 Grades F304, F304L, F316, and F316L, be used in Section III, Division 1, Construction?

Reply: It is the opinion of the Committee that austenitic stainless steel forgings, air cooled from the solution heat treatment temperature, and otherwise meeting the requirements of SA-182 for Grades F304, F304L, F316, and F316L, may be used in Section III, Division 1 Construction, provided all of the following conditions are met:

(a) Carbon content of the material shall not exceed 0.02%.

(b) Material in the final condition shall pass ASTM A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels.

(c) All other requirements of SA-182 and Section III, Division 1, shall be met.

(d) This Case number shall be shown in the documentation for the material and the Certificate Holders Data Report.

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Approval Date: June 22, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-552-1
Alternative Methods — Qualification for Nozzle Inside Radius Section From the Outside Surface
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, Supplement 5 may be used for qualification of methods for examination of the nozzle inside radius section from the outside surface?

Reply: It is the opinion of the Committee that the following requirements may be used in lieu of the requirements of Appendix VIII, Supplement 5 for qualification of methods for examination of the nozzle inside radius section from the outside surface.

1 PROCEDURE REQUIREMENTS

The examination procedure shall include or provide for the following:

(a) A computational model that calculates misorientation angles and the maximum metal path distance to the required inspection volume. Misorientation angle is shown in Figure 1. These calculations apply to the central ray of the ultrasonic beam.

(b) A scope statement that specifies the maximum acceptable misorientation angle and metal path for the examinations.

(c) Division of the surface of the required examination volume into grids of 1.0 in. or less in the nozzle axis direction and 10 deg or less of azimuth.

(d) Documenting the misorientation angle and metal path distance in each grid cell location for each search unit or scan.

(e) Documenting the search unit or scan that produces the minimum misorientation angle when multiple search units are used.

2 SPECIMEN REQUIREMENTS

Demonstration specimens shall meet the requirements of Appendix VIII, Supplement 4, except as modified by (a) through (d). Flaw depths shall be distributed over the range of depths required by Supplement 4.

(a) One or more full size or sections of full size nozzle mockups shall be used.

(b) Nozzle mockup material and configurations shall be representative of nozzles installed in operating reactor vessels, but may be any thickness, diameter, or radius suitable for demonstration in accordance with 3.

(c) Flaws shall be uniformly distributed in examination zones A and B of Figure 2. At least half of the flaws shall be located within ±45 deg of nozzle azimuth angles 90 or 270.

(d) All flaws shall be located in the required inspection volume and shall be oriented in the radial axial plane of the nozzle inside radius section as shown in Figure IWB-2500-7.

3 CONDUCT OF PERFORMANCE DEMONSTRATIONS

3.1 Procedure Qualification Demonstrations.

(a) The qualification shall demonstrate the following:

(1) Examination surfaces to be used, for example, vessel plate, outer blend radius, nozzle boss, nozzle, extension, and taper.

(2) Maximum metal path length.

(3) Maximum misorientation angles.

(b) The demonstration shall include at least 10 flaws for detection and sizing, in one or more mockups.

(c) The initial demonstration shall be a blind test.

(d) After a successful initial demonstration, the scope of the procedure may be extended by (1) additional demonstrations on additional mockups, or (2) nonblind demonstrations on at least one flaw using scan parameters calculated to provide the desired maximum path length or misorientation angles. Detection shall be demonstrated to specific criteria listed in the examination procedure for any extension of procedure scope.

3.2 Procedure Qualification Documentation. The examination procedure, modeling program and methods, and the qualification results shall be documented to the extent necessary to determine that inservice examinations produce equivalent or smaller misorientation angles than the procedures demonstrated.

Figure 1
Misorientation Angle

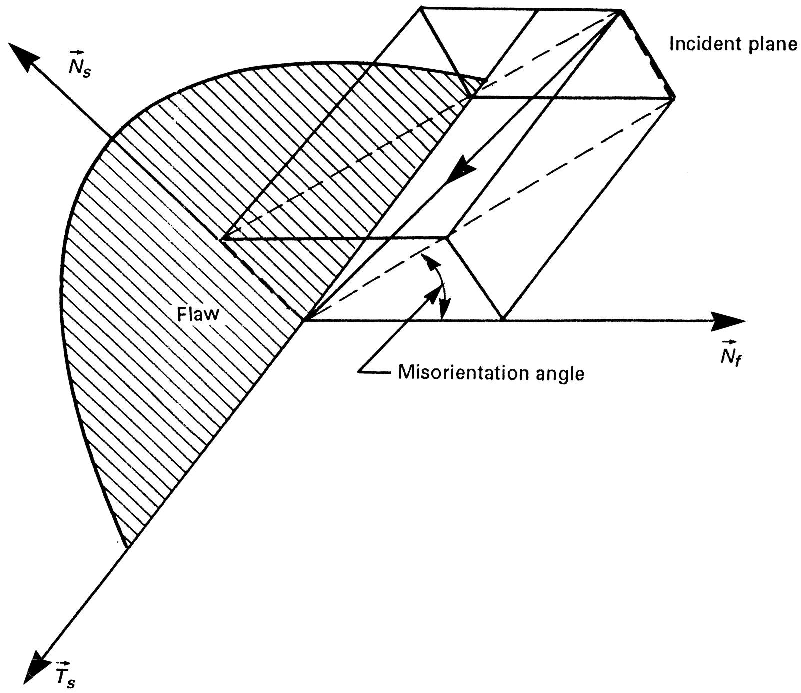
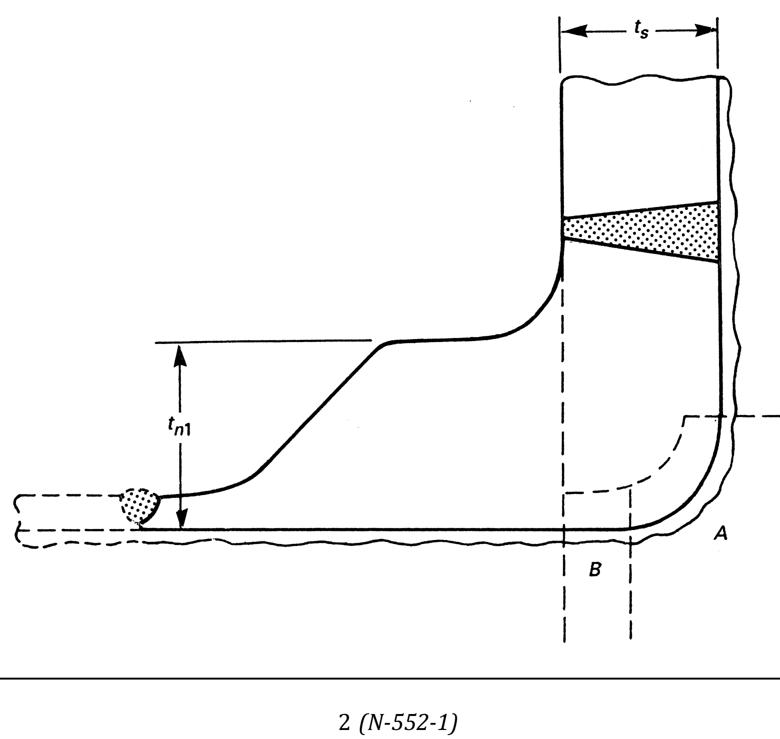


Figure 2
Flaw Distribution Zones



3.3 Personnel Qualification.

(a) Individuals previously qualified in accordance with the requirements of Appendix VIII, Supplement 4, for the same type of procedure (manual or automated), from the outside surface, using the same type of instruments and data recording and analysis equipment, shall be qualified as follows:

(1) Successful demonstration shall include at least three additional flaws.

(2) Examinations shall be demonstrated from a selection of scan surfaces covered by the procedure.

(3) The candidate shall demonstrate a selection of essential variables covered by the procedure, but need not demonstrate the full range.

(b) Individuals not previously qualified in accordance with the requirements of Appendix VIII, Supplement 4, shall be qualified as follows:

(1) The candidate shall demonstrate the procedure on one or more mockups.

(2) The demonstration shall contain at least the minimum number of detection and depth sizing flaws specified in Appendix VIII, Supplement 4.

(3) The demonstration shall include examinations from a selection of scan surfaces described in the procedure.

(4) The demonstration need not cover the full range of all the essential variables.

4 ACCEPTANCE CRITERIA

4.1 Detection Acceptance Criteria.

(a) Examination procedures and equipment are qualified if each flaw is detected and identified. The number of false calls shall not exceed D/10 rounded up to the next whole number, where D is the nominal nozzle inside diameter, in. If only a portion of a nozzle is examined, proportional credit for false calls shall be allowed.

(b) Personnel previously qualified to Appendix VIII, Supplement 4, as described in 3.3(a), are qualified if each of the flaws presented are detected and identified with no false calls.

(c) Personnel not previously qualified to Appendix VIII, Supplement 4, are qualified for detection if the results of the demonstration meet the requirements of Table VIII-S4-1. Additionally, the number of false calls shall not exceed the number specified in (a).

4.2 Depth Sizing Acceptance Criteria.

(a) Examination procedures and equipment are qualified for depth sizing if the results of the sizing demonstration meet the requirements of Appendix VIII, Supplement 4, 3.2.

(b) Personnel previously qualified to Appendix VIII, Supplement 4, as described in 3.3(a), are qualified if the results from the sizing tests, when added to the candidate's results from Appendix VIII, Supplement 4, meet the acceptance criteria of Supplement 4, 3.2.

(c) Personnel not previously qualified to Appendix VIII, Supplement 4, are qualified for depth sizing if the results of the sizing demonstration meet the sizing acceptance criteria of Supplement 4.

5 FIELD EXAMINATIONS

The computational model shall be applied in conjunction with each field examination, to demonstrate that the proposed examination variables are within the bounds of the qualification demonstration.

(a) Documentation showing coverage and misorientation angle shall be provided for each nozzle examination application performed. The documentation shall be used to demonstrate that the inservice examination will achieve misorientation angles that do not exceed the misorientation angles for which the procedure was qualified.

(b) Modeling need not be applied for repeated examination of the same or identical nozzles. Misorientation angles or loss of coverage area need not be calculated when the nozzle geometry changes are bounded by previous calculations.

(c) If the misorientation angle or metal path of the field examination exceeds that of the qualification, additional probe angles and directions may be applied to examine these areas without need for requalification, provided the demonstrated misorientation angle or path length can be achieved.

(d) If an area can be examined by addition of new search unit angles, orientations, or scan areas that produce misorientation angles or path length exceeding the qualified values, a new procedure qualification shall be performed.

(e) If neither (c) nor (d) can be met, the area shall be declared an area of no coverage.

(f) If an area can be examined by addition of new search unit angles, orientations, or scan surfaces that produce misorientation angles and path lengths within or equal to the qualified values, the originally qualified procedure and personnel are qualified to examine the field component. These new search units angles, orientations, or scan areas may be used to obtain examination volume coverage.

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Approval Date: February 14, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-554-3
Alternative Requirements for Reconciliation of Replacement Items and Addition of New Systems
Section XI, Division 1

Inquiry: What alternatives to the reconciliation requirements of IWA-4221 (1995 Edition with the 1995 Addenda through the 1996 Addenda)[1] may be used for reconciliation of replacement items and addition of new systems?

Reply: It is the opinion of the Committee that the following requirements may be used in lieu of the reconciliation requirements of IWA-4221 (1995 Edition with the 1995 Addenda through the 1996 Addenda)[1] for reconciliation of replacement items and the addition of new systems.

1 CODE APPLICABILITY

1.1 CONSTRUCTION CODE AND OWNER'S REQUIREMENTS

(a) An item to be used for repair/replacement activities shall meet the applicable Owner's Requirements. Alternatively, revised Owner's Requirements may be used provided they are reconciled in accordance with 2. A Report of Reconciliation shall be prepared.

(b) An item to be used for repair/replacement activities shall meet the Construction Code specified in accordance with subparagraphs (1), (2), or (3) below.

(1) When replacing an existing item, the new item shall meet the Construction Code to which the original item was constructed.

(2) When adding a new component to an existing system, the Owner shall specify a Construction Code that is no earlier than the earliest Construction Code used for construction of the system or originally installed component in that system.

(3) When adding a new system, the Owner shall specify a Construction Code that is no earlier than the earliest Construction Code used for other systems that perform a similar function.

(c) As an alternative to (b) above the item may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or Section III when the Construction Code was not Section III, provided the requirements of 2 through 6, as applicable, are met. Construction Code Cases may also be used. A Report of Reconciliation, if required, shall be prepared. All or portions of later different Construction Codes may be used as listed below:

(1) Piping, piping subassemblies, and their supports: B31.1 to B31.7 to Section III.

(2) Pumps, valves, and their supports: B31.1 to Draft Code for Pumps and Valves for Nuclear Power to Section III.

(3) Vessels and their supports: Section VIII to Section III.

(4) Atmospheric and 0-15 psig storage tanks and their supports: Section VIII, API 620 or API 650 to Section III.

2 RECONCILIATION OF CODE AND OWNER'S REQUIREMENTS

(a) Code requirements and Owner's Requirements may be technical or administrative.

(1) Only technical requirements that could affect materials, design, fabrication, or examination, and affect the pressure boundary, or core support or component support function, need to be reconciled.

(2) Administrative requirements, i.e., those that do not affect the pressure boundary or core support or component support function, need not be reconciled.[2] Examples of such requirements include quality assurance, certification, Code Symbol Stamping, Data Reports, and Authorized Inspection.

[1] IWA-7210 in the 1977 Edition with the Summer 1978 Addenda through the 1989 Edition with the 1990 Addenda; IWA-4170(c) and (d) in the 1989 Edition with the 1991 Addenda through 1995 Edition.

[2] This provision does not negate the requirement to implement the Owner's QA Program, nor does it affect Owner commitments to regulatory and enforcement authorities.

(b) The administrative requirements of either the Construction Code of the item being replaced or the Construction Code of the item to be used for replacement shall be met.

3 RECONCILIATION OF COMPONENTS

(a) Reconciliation of later Editions or Addenda of the Construction Codes or alternative Codes as permitted by 1.1 is not required. The Owner shall evaluate any changes in weight, configuration, or pressure-temperature rating.

(b) An earlier Edition and Addenda of the same Construction Code may be used, provided all technical requirements of the earlier Construction Code are reconciled.

4 RECONCILIATION OF MATERIAL

4.1 IDENTICAL MATERIAL PROCURED TO A LATER EDITION OR ADDENDA OF THE CONSTRUCTION CODE, SECTION III, OR MATERIAL SPECIFICATION

(a) Materials, including welding materials, may meet the requirements of later dates of issue of the material specification and later Editions and Addenda of the same Construction Code or Section III when the Construction Code was not Section III, provided the materials are the same specification, grade, type, class, or alloy, and heat-treated condition, as applicable.

(b) Differences in the specified material tensile and yield strength shall be compared and evaluated. If the replacement material has a lower strength, a comparison shall be made of the allowable stresses. If the tensile or yield strength is reduced and allowable stresses are reduced, the effect of the reduction on the design shall be reconciled. For welding materials, any reduction in specified tensile strength shall be evaluated to ensure that the strength of the filler metal meets or exceeds the strength of the base materials.

4.2 IDENTICAL MATERIAL PROCURED TO AN EARLIER CONSTRUCTION CODE EDITION OR ADDENDA OR MATERIAL SPECIFICATION

(a) Materials, including welding materials, may meet the requirements of earlier dates of issue of the material specification and earlier Editions and Addenda of the same Construction Code, provided the materials are the same specification, grade, type, class, or alloy, and heat-treated condition, as applicable.

(b) Differences in the specified material tensile and yield strength shall be compared and evaluated. If the replacement material has a lower strength, a comparison shall be made of the allowable stresses. If the tensile or yield strength is reduced and allowable stresses are reduced, the effect of the reduction on the design shall be reconciled. For welding materials, any reduction in specified tensile strength shall be evaluated to ensure that the strength of the filler metal meets or exceeds the strength of the base materials.

(c) Material examination and testing requirements from the Construction Code of the item shall be met.

4.3 USE OF A DIFFERENT MATERIAL

(a) Use of materials of a specification, grade, type, class, or alloy, and heat-treated condition, other than that originally specified, shall be evaluated for suitability for the specified design and operating conditions.

(b) Material examination and testing requirements shall be reconciled to the Construction Code requirements of the item.

4.4 SUBSTITUTION OF MATERIAL SPECIFICATIONS

(a) When an SA or SB Specification is identified as being identical, or identical except for editorial differences, to the corresponding ASTM A or B Specification, either specification may be used.

(b) When an SFA Specification is identified as being identical, or identical except for editorial differences, to the corresponding AWS Specification, either specification may be used.

5 RECONCILIATION OF PARTS, APPURTENANCES, AND PIPING SUBASSEMBLIES

(a) Parts, appurtenances, and piping subassemblies may be fabricated to later Editions and Addenda of the Construction Code and later different Construction Codes, as permitted by 1.1(c), provided materials are reconciled in accordance with 4. The Owner shall evaluate any changes in weight, configuration, or pressure-temperature rating.

(b) An earlier Edition or Addenda of the same Construction Code may be used, provided all technical requirements of the original Construction Code of the component being replaced are met, except as permitted by 4. Failure to meet the technical requirements of the original Construction Code may not be accepted by reconciliation.

6 RECONCILIATION OF DESIGN REQUIREMENTS

6.1 DESIGN TO ALL REQUIREMENTS OF A LATER CONSTRUCTION CODE EDITION OR ADDENDA

(a) When an item is designed to all the requirements of a later Construction Code Edition or Addenda reconciliation beyond those design-related issues defined in 3, 4, and 5 is not required.

6.2 DESIGN TO PORTIONS OF THE REQUIREMENTS OF A LATER CONSTRUCTION CODE EDITION OR ADDENDA

(a) When an item is designed to portions of the requirements of a later Construction Code Edition or Addenda, the following reconciliation beyond those design-related issues defined in 3, 4, and 5 shall be performed.

(1) Material fabrication and examination requirements (e.g., NX-2000, NX-4000, and NX-5000 of Section III) shall be reviewed to reconcile the details applicable to design (e.g., NX-3000 of Section III) against the design of the replacement item. Any differences between the later design provisions and the previous design shall be reconciled.

(2) All design requirements related to the later portions shall be met, or any differences between the later design provisions and the previous design shall be reconciled.

6.3 DESIGN TO ALL OR PORTIONS OF A DIFFERENT CONSTRUCTION CODE

When an item is designed to all or portions of a different Construction Code, the following reconciliations beyond the design-related issues defined in 3, 4, and 5 shall be performed.

(a) Material, fabrication, and examination requirements (e.g., NX-2000, NX-4000, and NX-5000 of Section III) shall be reviewed to reconcile the details applicable to design with the design of the replacement item.

(b) Differences between the new design provisions and the previous design shall be reconciled.

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Approval Date: December 31, 1996

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-557-1
In-Place Dry Annealing of a PWR Nuclear Reactor Vessel
Section XI, Division 1

Inquiry: What requirements may be used for an in-place dry anneal[1] of a PWR reactor vessel?

Reply: It is the opinion of the Committee that an in-place dry anneal of a PWR reactor vessel may be conducted using the following requirements.

(a) The applicable requirements of the 1995 Edition, IWA-4130 through IWA-4170 and IWA-4910 for a repair shall be met.

(b) The vessel temperature shall not exceed 940°F. The vessel temperature shall not exceed 900°F for more than 300 hrs, nor 850°F for more than 1000 hrs.

(c) The region of the vessel to be annealed, the annealing temperature, the hold time at temperature, and the heating and cooling rates shall be defined by the Owner in the Repair/Replacement Plan. The region to be annealed shall be a circumferential band.

(d) The temperature of the reactor vessel extending upward and downward from the edges of the heated region shall be gradually diminished to avoid harmful thermal gradients.

(e) Temperature shall be monitored by thermocouples or equivalent) in direct contact with the vessel wall. Thermocouples (or equivalent) shall be placed to adequately control and monitor temperatures, rates, and gradients as specified in the Repair/Replacement Plan. Time-temperature recordings of the annealing treatment shall be made available for review by the Inspector.

(f) The Owner shall determine and document what mechanical and thermal loadings on the reactor coolant pressure boundary components and their supports are to be evaluated. The purpose of the evaluation is to preclude harmful permanent set and the potential for ductile flaw growth. One way of accomplishing this is by use of the criteria and methodology in (1) and (2), which is only guidance for the evaluation. However, compliance with this guidance will eliminate the need for any futher evaluation. For the upper ranges of time and temperature in (b), Case N-499-1 provides further guidance.

(1) The reactor vessel loadings that require evaluation shall be evaluated using the stress categories and limits of stress intensities in Figure 1. For components other than the reactor vessel, and for supports, evaluation of these loadings shall be performed in accordance with the Construction Code.

(2) Table 1 provides allowable stress intensity values for reactor vessels constructed of any combination of the following materials:

SA-533 Type B, Class 1 plate
[formerly SA-533 Grade B, Class 1 plate or
SA-302 Grade B (Nickel modified) plate with nickel content in the range of 0.40 to 0.70 weight percent]
SA-508 Grade 2, Class 1 forgings
(formerly SA-508 Class 2 forgings)
SA-508 Grade 3, Class 1 forgings
(formerly SA-508 Class 3 forgings)

(g) The Owner shall specify, in the Repair/Replacement Plan, any deformation limits to be satisfied.

(h) Post-anneal volumetric examination, consisting of all of the examinations required during the current inspection interval, shall be performed on that portion of the vessel where the temperature exceeded 700°F. The acceptance criteria, type and number of examinations, qualification requirements, and reporting requirements shall be those of the Owner's Inservice Inspection Program.

(i) Use of this Case shall be documented on an NIS-2 Form.

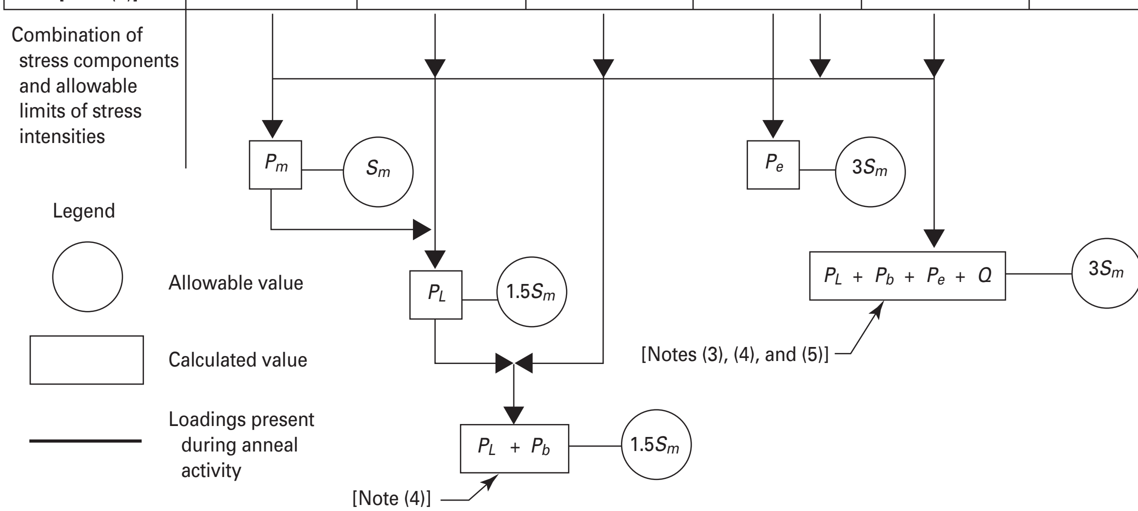
[1] A heat treatment conducted to improve beltline material toughness reduced by neutron irradiation.

Table 1
Design Stress Intensity Values, S_m, For Use in Annealing Activity Evaluations

Temp., F	S_m, ksi
70	26.7
700	26.7
750	26.7
800	26.7
850	25.5
900	24.0
940	22.5

Figure 1
Stress Categories and Limits of Stress Intensity for Annealing Evaluation

Stress Category	Primary			Secondary		Peak and Fatigue
	General Membrane	Local Membrane	Bending	Expansion	Membrane Plus Bending	
Description	Average primary stress across solid section. Excludes effects of discontinuities and concentrations. Produced by mechanical loads.	Average stress across any solid section. Considers effects of discontinuities but not concentrations. Produced by mechanical loads.	Component of primary stress proportional to distance from centroid of solid section. Excludes effects of discontinuities and concentrations. Produced by mechanical loads. [Note (1)]	Stresses which result from the constraint of free end displacement. Considers effects of discontinuities but not local stress concentration (not applicable to vessels).	Self-equilibrating stress necessary to satisfy continuity of structure. Occurs at structural discontinuities. Can be caused by mechanical loads or differential thermal expansion. Excluded local stress concentrations.	Evaluation not required
Symbol [Note (2)]	P_m	P_L	P_b	P_e	Q	F



GENERAL NOTES:
(a) The value of S_m shall be determined from Table 1 using the concurrent temperature at the point being evaluated.
(b) The structural strength of the cladding may be neglected.
(c) When other items are attached to the reactor vessel in the high temperature region (T > 700ºF), these items shall be evaluated for their effect on the pressure boundary.

NOTES:
(1) Bending component of primary stress for piping shall be the stress proportional to the distance from centroid of pipe cross section.
(2) The symbols P_m, P_L, P_b, P_e, Q, and F do not represent single quantities, but sets of six quantities representing the six stress components σ_t, σ_ℓ, σ_r, $\tau_{\ell t}$, $\tau_{\ell r}$, τ_{rt}.
(3) The stresses in category Q are those parts of the total stress that are produced by thermal gradients, structural discontinuities, etc., and they do not include primary stresses that may also exist at the same point. However, it should be noted that a detailed stress analysis frequently gives the combination of primary and secondary stresses directly, and, when appropriate, the calculated value represents the total of P_m + P_b + Q, and not Q alone.
(4) The special stress limits of NB-3227.5, Nozzle Piping Transition, for stresses resulting from the anneal activity, shall be met, except that the $3S_m$ limit applies to the maximum value of the stress intensity rather than the range.
(5) The $3S_m$ limit applies to the maximum value of the stress intensity rather than the range.

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Approval Date: August 9, 1996

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-558
Stamping of Class 2 Vessels Fabricated to Subsection NB
Section III, Division 1

Inquiry: May a vessel, classified in the Design Specification as Class 2, be designed and fabricated to all the requirements of Subsection NB, Class 1, and be stamped Class 2?

Reply: It is the opinion of the Committee that vessels, classified in the Design Specification as Class 2, may be designed and fabricated to all the requirements of Section III, Division 1, Subsection NB, and be stamped Class 2, provided:

(a) All the design and fabrication details of NB-3000 and NB-4000 are complied with.

(b) All materials meet the requirements of NB-2000.

(c) NDE performed prior to the pressure test shall meet the requirements of NB-5000.

(d) The pressure test and post-hydro NDE shall meet the requirements of NC-6221(b) and NC-5400.

(e) This Code Case number shall be listed in the Data Report Form for the vessel.

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Approval Date: March 28, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-560-2
Alternative Examination Requirements for Class 1, Category B-J Piping Welds
Section XI, Division 1

Inquiry: What alternative requirements may be used for examination of Class 1 piping welds, excluding socket welds, in lieu of the requirements for Category B-J welds specified in Table IWB-2500-1?

Reply: It is the opinion of the Committee that the following examination requirements may be used for Class 1 piping welds, excluding socket welds, in lieu of those specified in Table IWB-2500-1 Examination Category B-J.

(a) The examination program shall be based on a total number of elements[1] consisting of not less than 10% of Category B-J piping welds in each system, excluding socket welds, to be inspected during each inspection interval. The selection process shall consist of the following:

(1) Elements shall be selected based on a relative ranking process that identifies the more risk-important segments in the system with regard to probability and consequences of failure. Elements shall be selected from those pipe segments[2] that fall into the highest risk group.

(2) The ranking process shall address relevant degradation mechanisms (e.g., corrosion, stress corrosion, thermal fatigue, thermal stratification, flow-accelerated corrosion) and industry failure experience with the systems and components.

(3) The consequences of failure at various locations in the system shall be based on the break size and operating mode that results in the highest impact on plant safety. Both direct and indirect effects shall be considered.

(4) This process shall be performed in accordance with Mandatory Appendix I. The expertise required to conduct this process shall include knowledge of the function and operation of the system, Probabilistic Risk Assessment (PRA), failure potential, metallurgy, stress analysis and knowledge of the existing preservice and inservice examination results.

(5) Examination volumes for each element shall be defined to include all areas potentially susceptible to the degradation mechanisms, such as ID counterbore discontinuities and high-stress locations in pipes or fittings. Sufficient circumferential length shall be examined to confirm the absence of the identified degradation mechanisms. The appropriate examination method (volumetric, surface, or visual) for detection of the degradation mechanisms shall be determined in accordance with Table 1 and Mandatory Appendix I of this Case.

(6) This Case may be applied to all Class 1 piping systems or to individual systems subject to Category B-J examination requirements. When this Case is applied to more than one system, the selected elements may be distributed to concentrate examinations on higher-risk systems. Class 1 systems that are not evaluated in accordance with this Case shall be examined in accordance with Examination Category B-J.

(7) The selected elements shall be reexamined during subsequent examination intervals. Modifications to the selected elements may be made based on relevant industry experience, changes in plant design or operation, new metallurgical knowledge, or prior examination results.

(b) The element ranking, selection process, examination volumes, examination method, and the basis for each, shall be documented in the ISI program plan. Modifications shall be documented in revisions to the plan. Methods and procedures used for the examinations shall be qualified to reliably detect and size the relevant degradation mechanisms identified for each element. Personnel performing the examinations shall be qualified to use these procedures. Examinations shall be conducted in accordance with IWA-2000. Use of this Case shall be documented on the applicable Data Report Form.

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[1] Elements are structural elements or portions of structural elements of the piping system, such as welds, fittings, or pipe. Each element contains an examination volume determined in accordance with the requirements of this Case.

[2] Segments consist of one or more elements.

(c) If flaws exceeding the acceptance standards of IWB-3400 are detected, they shall be evaluated in accordance with IWB-3132, and additional examinations shall be performed in accordance with IWB-2430. If flaws are accepted by analytical evaluation, the requirements of IWB-2420(b) and (c) for successive examinations shall be applied.

Table 1
Examination Categories

EXAMINATION CATEGORY B-J, CLASS 1 PIPING

Item No.	Parts Examined [Note (1)]	Examination Requirement/ Fig. No. [Note (11)]	Examination Method	Acceptance Standard [Note (11)]	Extent and Frequency 1st	Extent and Frequency Successive (6)]	Defer to End of Interval
B9.11	Elements Subject to Thermal Fatigue	IWB-2500-8(c) [Note (2)] IWB-2500-9, 10, 11	Volumetric	IWB-3514	Element [Note (3)], [Note (4)], [Note (5)]	Same	Not Permissible
B9.12	Elements Subject to High Cycle Mechanical Fatigue	N/A	Visual, VT-2	IWB-3142	Each Refueling Outage	Same	Not Permissible
B9.13	Elements Subject to Erosion Cavitation	IWB-2500-8(c)	Volumetric	IWB-3514	Element [Note (3)], [Note (4)]	Same	Not Permissible
B9.14	Elements Subject to Crevice Corrosion Cracking	[Note (8)]	Volumetric	IWB-3514	Element [Note (3)], [Note (4)]	Same	Not Permissible
B9.15	Elements Subject to Primary Water Stress Corrosion Cracking (PWSCC) [Note (7)]	N/A	Visual, VT-2	IWB-3142	Each Refueling Outage	Same	Not Permissible
B9.16	Elements Subject to Intergranular or Transgranular Stress Corrosion Cracking (IGSCC, TGSCC)	IWB-2500-8(c) IWB-2500-9, 10, 11	Volumetric	IWB-3514	Element [Note (3)], [Note (4)]	Same	Not Permissible
B9.17	Elements Subject to Localized Corrosion [Microbiologically Induced Corrosion (MIC), or Pitting]	IWB-2500-8(c) IWB-2500-9, 10, 11	Visual, VT-3 or Volumetric [Note (9)]	[Note (9)]	Element [Note (3)], [Note (4)]	Same	Not Permissible
B9.18	Elements Subject to Flow Accelerated Corrosion (FAC)	[Note (10)]	[Note (10)]	[Note (10)]	[Note (10)]	[Note	[Note (10)]
B9.19	Elements Subject to External Chloride Stress Corrosion Cracking (ECSCC)	IWB-2500-8(c)	Surface	IWB-3514	Element [Note (3)], [Note (4)]	Same	Not Permissible
B9.20	Elements not Subject to a Damage Mechanism	IWB-2500-8(c) [Note (2)] IWB-2500-9, 10, 11	Volumetric	IWB-3514	Element [Note (3)], [Note (4)], [Note (5)]]	Same	Not Permissible

NOTES:

(1) Piping larger than NPS 1.

(2) The length of the examination volume shall be increased to include $^{1}/_{2}$ in. beyond each side of the base metal thickness transition or counterbore.

(3) Includes elements identified in accordance with the risk-based selection procedures in Mandatory Appendix I.

(4) Includes 100% of the examination location. When the required examination volume or area cannot be examined due to interference by another component or part geometry, limited examinations shall be evaluated for acceptability. Areas with acceptable limited examinations, and their bases, shall be documented.

(5) The examination shall include any longitudinal welds at the locations selected for examination in [Note (3)]. The longitudinal weld examination requirements shall be met for both transverse and parallel flaws within the examination volume defined in [Note (3)].

Table 1
Examination Categories (Cont'd)

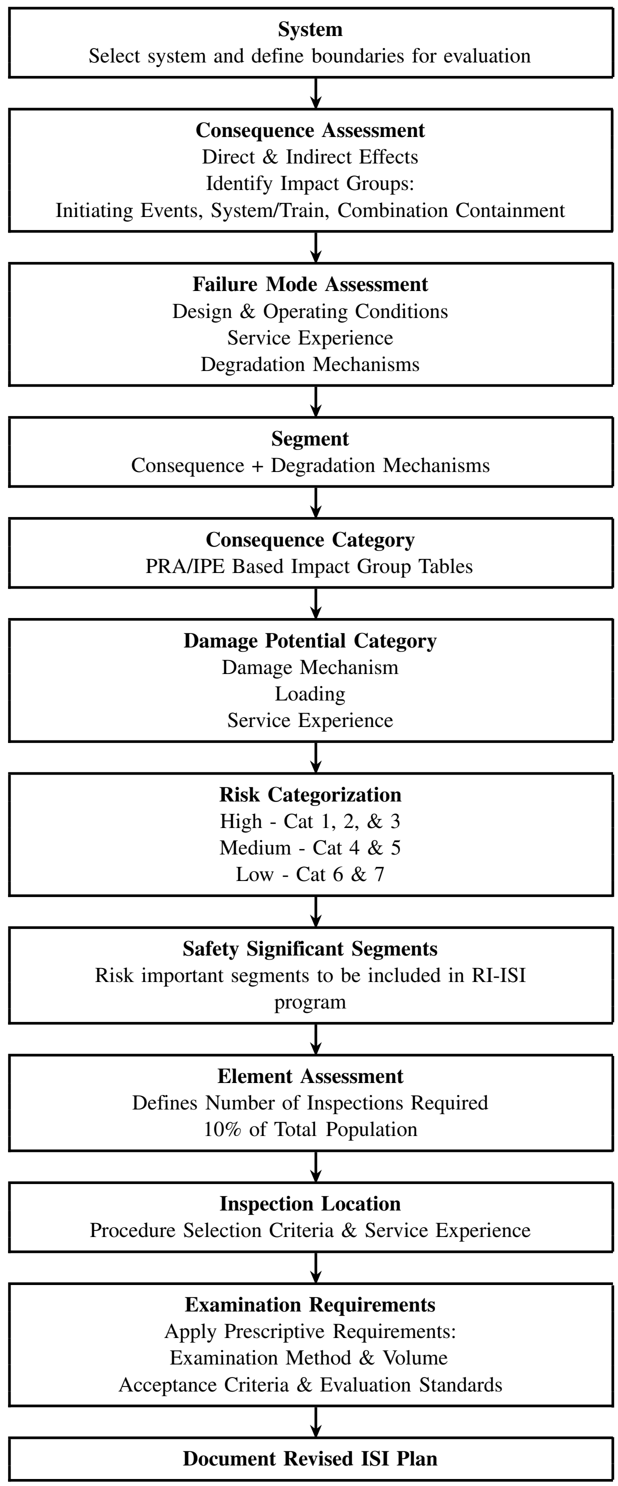
NOTES (CONT'D):
(6) Initially selected elements are to be examined in the same sequence during successive examination intervals, to the extent practical.
(7) Applies to mill annealed Alloy 600 nozzle welds and heat affected zone (HAZ) without stress relief.
(8) The examination volume shall include the volume surrounding the weld, weld heat affected zone, and base metal, where applicable, in the crevice The examination should be concentrated on detection of cracks initiating and propagating from the inner surface.
(9) The examination volume shall include base metal, welds, and weld heat affected zones in the affected regions of carbon and low alloy steel, and with welds and weld heat affected zones of austenitic stainless steel. The examination region shall be sufficient to characterize the extent of the degradation. Examinations shall verify minimum wall thickness required by the Construction Code exists.
(10) In accordance with the Owner's FAC program.
(11) Paragraph and figure numbers refer to the 1989 Edition.

MANDATORY APPENDIX I
REQUIREMENTS FOR RISK-INFORMED SELECTION PROCESS

I-1 INTRODUCTION

This Appendix provides the risk-informed process to be used as an alternative to current selection and inspection requirements for piping that will be scheduled for inservice inspection. This alternative selection process is based on the relative risk-significance of elements within an individual system. Figure I-1 illustrates the evaluation process summarized below.

Figure I-1
Risk Evaluation Process



I-1.1 SYSTEM IDENTIFICATION

Systems shall be selected for analysis, and system boundaries and functions shall be identified.

I-1.2 SEGMENT RISK ASSESSMENT

Each selected system shall be divided into piping segments determined to have similar consequence of failure and potential for failure (common degradation mechanisms, etc.). These segments shall be placed into risk categories based on combinations of consequence and failure potential. Risk-significant segments shall be identified.

I-1.3 ELEMENT ASSESSMENT

Potential locations (elements) within the risk-significant segments shall be selected for inspection based on the specific degradation mechanism identified in the segment.

I-1.4 INSPECTION LOCATION AND EXAMINATION METHODS

The inspection volume and method used for each element shall be determined based on the degradation mechanism associated with the element.

I-1.5 DOCUMENTATION

The results of this procedure alternative selection process shall be documented and reviewed. This process shall include a review incorporating plant-specific and industry experience as well as the results of plant-specific inspections.

I-2 ELEMENT SELECTION PROCESS

I-2.1 SYSTEM IDENTIFICATION

The Owner shall define the Class 1 system boundaries to be addressed in accordance with this Case. This may include all Class 1 piping systems in the Owner's ASME Inservice Inspection program, or individual systems, at the option of the Owner.

I-2.2 RISK ASSESSMENT

Piping within a system shall be grouped into segments of common failure consequence and susceptibility to common degradation mechanisms. To accomplish this grouping for each pipe segment within the system, both the potential for failure (i.e., susceptibility to potential degradation mechanisms) and the direct and indirect consequences of failure, shall be assessed in accordance with I-2.3 and I-2.4.

I-2.3 FAILURE POTENTIAL ASSESSMENT

I-2.3.1 Identification of Degradation Mechanisms. Potentially active degradation mechanisms for each pipe segment within the Class 1 piping systems shall be identified. The following conditions shall be considered.

(a) Design characteristics, including material, pipe size and schedule, component type (e.g., fitting type or ANSI standard), and other attributes related to the system configuration.

(b) Fabrication practices, including welding and heat treatment.

(c) Operating conditions, including temperatures and pressures, fluid conditions (e.g., stagnant, laminar flow, turbulent flow), fluid quality (e.g., primary water, raw water, dry steam, chemical control), and service environment (e.g., humidity, radiation).[3]

(d) Industry-wide service experience with the systems being evaluated.

(e) Results of preservice, inservice, and augmented examinations and the presence of prior repairs in the system.

(f) Degradation mechanisms identified in Table I-1.

I-2.3.2 Degradation Mechanism Categories. Degradation mechanisms shall be categorized as described in Table I-2, in accordance with their probability of causing a large pipe break. Segments susceptible to FAC shall be classified in the high failure potential/large break category. Segments susceptible to any of the other degradation mechanisms shall be classified in the medium failure potential/small leak category. Segments having degradation mechanisms listed in the medium failure potential/small leak category shall be upgraded to the high failure potential/large break category, if the pipe segments also have the potential for water hammer loads.

I-2.4 CONSEQUENCE EVALUATION

I-2.4.1 Failure Modes and Effects Analysis (FMEA). Potential failure modes for each pipe segment shall be identified, and their effects shall be evaluated. The evaluation shall consider the following:

(a) Break Size. The consequence analysis shall be performed assuming a large break for most segments. The exceptions are piping for which a smaller leak is more conservative, or when a small leak can be justified through a leak-before-break analysis in accordance with the criteria specified in NUREG-1061, Volume 3, and 10CFR50, Appendix A, General Design Criteria 4.

(b) Isolability of the Break. A break can be automatically isolated by a check valve, a closed isolation valve, or an isolation valve that closes on a given signal or by operator action.

(c) Indirect Effects. Includes spatial and loss of inventory effects.

(d) Initiating Events. These shall be identified using a plant-specific list of initiating events from the plant Probabilistic Risk Assessment/Individual Plant Examination (PRA/IPE) and the plant design basis.

(e) System Impact/Recovery. The means of detecting a failure, and the technical specifications associated with the system and other impacted systems shall be evaluated. The possible automatic and operator actions to prevent a loss of systems shall also be evaluated.

(f) System Redundancy. The existence of redundant flow paths for accident mitigation purposes shall be considered.

I-2.4.2 Impact Group Assessment. The FMEA impacts for each pipe segment shall be classified into one of three impact groups: initiating event, system, or combination. The consequence category (high, medium, or low) shall then be selected in accordance with (a) through (d).

(a) Initiating Event Impact Group Assessment. When a postulated break in a Class 1 pipe segment results in only an initiating event (e.g., loss of coolant accident, loss of feedwater, reactor trip), the consequence shall be classified into one of four categories: high, medium, low, or none. The initiating event categories shall be assigned according to the following:

(1) The initiating event shall be placed into one of the categories in Table I-3. These shall include all applicable design basis events previously analyzed in the Owner's updated final safety analysis report PRA, or IPE.

(2) Breaks that cause an initiating event classified as routine operation (Category I) are not relevant to this analysis.

(3) For pipe segment breaks that result in Category II (Anticipated Event), Category III (Infrequent Event), or Category IV (Limiting Fault or Accident), the initiating event shall be assigned to the consequence category according to the plant PRA conditional core damage probability (CCDP) criteria specified in Table I-4.

(b) System Impact Group Assessment. The consequence category of a pipe segment failure that does not cause an initiating event, but that degrades or fails a system essential to plant safety, shall be based on the three attributes discussed below:

[3] Systems fabricated to nuclear standards, while resistant to damage mechanisms addressed in the design process, have experienced damage from phenomena unknown at the time of installation.

(1) Frequency of challenge, which determines how often the mitigating function of the system is called upon. This corresponds to the frequency of initiating events that require the system operation.

(2) Number of backup systems available, which determines how many unaffected systems are available to perform the same mitigating function as the degraded or failed system.

(3) Exposure time, which determines the time the system would be unavailable before the plant is changed to a different mode in which the failed system's function is no longer required, the failure is recovered, or other compensatory action is taken. Exposure time is a function of the detection time and allowed outage time.

Consequence Categories shall be assigned in accordance with Table I-5 as High, Medium or Low. As with the initiating event group (Table I-3), frequency of challenge is grouped into design basis event categories (II, III, and IV). Exposure time shall be obtained from Technical Specification limits, and shall be classified as long (> 24 hrs) or short (not to exceed 24 hrs). The Owner or his designee shall ensure that the quantitative basis of Table I-5 (e.g., train unavailability approximately 10^{-2}) is consistent with the pipe failure scenario under evaluation. In lieu of Table I-5, quantitative indices based on conditional core damage frequency may be used on the basis of the plant's PRA/IPE; consequence categories shall be assigned in accordance with Table I-4.

(c) Combination Impact Group Assessment. The consequence category for a pipe segment whose failure results in both an initiating event and the degradation or loss of a system shall be determined from Table I-6. The Owner or his designee shall ensure that the quantitative basis of Table I-6 (e.g., train unavailability approximately 10^{-2}) is consistent with the pipe failure scenario under evaluation. The consequence category is a function of two factors:

(1) Use of the system as a mitigating function for the induced initiating event; and

(2) Number of unaffected backup systems or trains available to perform the same function.

(d) Containment Performance. The above evaluations determine pipe failure importance relative to core damage. Pipe failure shall also be assessed for its impact on containment performance. This shall be accomplished by addressing the following two issues, both of which are based upon an approximate conditional value of ≤ 0.1 between the CCDP and the likelihood of large early release from containment. If there is no margin (i.e., conditional probability of a large early release given core damage is >0.1), the assigned consequence category shall be increased by one level. The two issues are as follows:

(1) CCDP values for initiating events and safety functions shall be evaluated to determine whether the potential for large early containment failure requires the consequence category to be increased.

(2) The impact on containment isolation shall be evaluated. If there is a containment barrier available, the consequence category from the core damage assessment is retained. If there is no containment barrier or the barrier failed in determining the consequence category from the core damage assessment, a margin of at least 0.1 in the core damage consequence category assignment must be present for the consequence category to be retained.

For example, if the CCDP for core damage is less than 10^{-5} (i.e., a “Medium” consequence assignment) and there is no containment barrier, the “Medium” consequence assignment is retained because there is a margin of 0.1 to the “High” consequence category threshold (i.e., 10^{-4}). However, if the CCDP for core damage is 5×10^{-5} (i.e., a “Medium” consequence assignment) and there is no containment barrier, the consequence category is increased to “High” because the margin to the “High” consequence category threshold (i.e., 10^{-4}) is less than 0.1. Table I-7 shall be used to assign consequence categories for those piping failures that can lead to a LOCA outside containment.

I-2.5 SEGMENT RISK CATEGORIZATION

I-2.5.1 Risk Matrix. The risk of pipe segment failure shall be evaluated on the basis of the expected likelihood of the event and the expected consequence. The likelihood of failure is estimated based on the segment exposure to varying degradation mechanisms, and is represented by the degradation mechanism category assigned to the segment in accordance with I-2.3. Consequence is represented by the consequence category assigned to the segment in accordance with I-2.4. The structure used to document the results of this analysis is called a Risk Matrix and is illustrated in Table I-8. Each pipe segment shall be assigned to one of the risk categories in Table I-8, based on its damage mechanism and consequence category.

I-2.5.2 Risk Categories.. The three failure potential (i.e., degradation mechanism) categories and four consequence categories shall be combined into seven risk categories, as follows:

Risk Category	Risk Area
1	High Consequences and High Failure Potential
2	High Consequences and Medium Failure Potential
3	Medium Consequences and High Failure Potential
4	High Consequences and Low Failure Potential
5	Medium Consequences and Medium Failure Potential, or Low Consequences and High Failure Potential
6	Medium Consequences and Low Failure Potential, or Low Consequences and Medium Failure Potential
7	Low Consequences and Low Failure Potential, or None Consequences and Any Failure Potential Category

All pipe segments in the Class 1 systems addressed in accordance with this Case shall be classified, into one of the above seven risk categories, using the risk matrix.

I-2.6 SELECTION OF ELEMENTS FOR INSPECTION

Elements, such as welds, fittings, or pipe sections, shall be identified, within each pipe segment, based on susceptibility to the applicable damage mechanisms identified for that segment. For element selection, each pipe segment shall be classified in accordance with I-2.5 in one of the following risk groups:

Risk Group	Segment Risk Category
High	1, 2, and 3
Medium	4 and 5
Low	6 and 7

Elements shall be selected starting with the elements in the High risk group and working toward the Low risk group, until a total number of elements equal to 10% of the Category B-J piping welds, excluding socket welds, has been selected. Examinations may be concentrated on systems with more high-risk segments, such that a larger percentage of elements in the high-risk Categories 1, 2, and 3 are examined. The elements within each risk category shall be ranked by considering the following:

(a) Elements identified as susceptible to the specific degradation mechanisms in Table I-1.

(b) Plant-specific inservice cracking experience.

(c) Access. There shall be adequate access to the element to ensure that the examination method defined in this section for the relevant damage mechanism can be used effectively for the defined examination volumes.

(d) Radiation Exposure. Elements shall be selected to minimize personnel radiation exposure during examination.

(e) Relative degradation severity for specific degradation mechanisms, when applicable (e.g., wear or erosion rates for flow-accelerated corrosion, Temperature Differential or Richardson number for thermal fatigue, USNRC NUREG-0313, Revision 2 weld categorization for IGSCC). Examinations for elements in Risk Category 4 segments shall be concentrated on any areas of significant stress concentration, geometric discontinuities, or terminal ends.

(f) Elements having break or consequence limiting devices e.g., pipe whip restraints, need not be examined, if these have not been credited in the consequence evaluation.

I-3 EXAMINATION VOLUMES AND METHODS

The selection of examination volumes and methods for each element within a risk category will depend upon the degradation mechanism present, and access, radiation exposure, and cost considerations. Examination methods, volumes, and acceptance and evaluation criteria specifically designed for the active degradation mechanisms in the examination zone shall be used.

Examination programs developed in accordance with this Case shall use NDE techniques that are designed to be effective for specific degradation mechanisms and examination locations. The examination volumes and methods that are appropriate for each degradation mechanism are provided in Table 1. The methods and procedures used for the examinations shall be qualified to reliably detect and size the relevant degradation mechanisms identified for each element. Personnel performing the examinations shall be qualified to use these procedures. Examinations shall be conducted in accordance with IWA-2000.

I-4 CHANGE-IN-RISK EVALUATION

(a) A change-in-risk evaluation shall be performed prior to implementation of the program.

(b) Proposed ISI program changes shall be assessed to determine compliance with the acceptance criteria contained in USNRC Regulatory Guide 1.174, July 1998, Section 2.2.4 and to determine if any adjustments to the proposed ISI program or compensatory measures are needed.

I-5 RE-EVALUATION OF RISK-BASED SELECTIONS

The affected portions of the risk-based inservice examination program shall be re-evaluated as new information affecting the selection and scope of the program becomes available. Examples include piping system design changes, industry-wide failure notifications, and prior examination results.

Table I-1
Degradation Mechanisms

Mechanisms		Attributes	Susceptible Regions
TF	*TASCS*	– piping > NPS 1; and – pipe segment has a slope < 45° from horizontal (includes elbow or tee into a vertical pipe); and – potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or potential exists for two phase (steam/water) flow, or potential exists for turbulent penetration in branch pipe connected to header piping containing hot fluid with high turbulent flow; and – calculated or measured ΔT > 50°F; and – Richardson number > 4.0	nozzles, branch pipe connections, safe ends, welds, heat affected zones (HAZ), base metal, and regions of stress concentration
	TT	– operating temperature > 270°F for stainless steel, or operating temperature > 220°F for carbon steel; and – potential for relatively rapid temperature changes including cold fluid injection into hot pipe segment, or hot fluid injection into cold pipe segment; and – $\mid \Delta T \mid$ > 200°F for stainless steel, or $\mid \Delta T \mid$ > 150°F for carbon steel, or $\mid \Delta T \mid$ > ΔT allowable (applicable to both stainless steel and carbon)	

Table I-1
Degradation Mechanisms (Cont'd)

Mechanisms		Attributes	Susceptible Regions
SCC	*IGSCC (BWR)*	– evaluated in accordance with existing plant IGSCC program per NRC Generic Letter 88-01	austenitic stainless steel welds and HAZ
	IGSCC (PWR)	– operating temperature > 200°F, and – susceptible material (carbon content > 0.035%), and – tensile stress (including residual stress) is present, and – oxygen or oxidizing species are present; OR – operating temperature < 200°F, the attributes above apply, and – initiating contaminants (e.g., thiosulfate, fluoride, chloride) are also required to be present	
	TGSCC	– operating temperature > 150°F, and – tensile stress (including residual stress) is present, and – halides (e.g., fluoride, chloride) are present, and – oxygen or oxidizing species are present	austenitic stainless steel base metal, welds, and HAZ
	ECSCC	– operating temperature > 150°F, and – tensile stress is present, and – an outside piping surface is within five diameters of a probable leak path (e.g., valve stems) and is covered with non-metallic insulation that is not in compliance with USNRC Reg. Guide 1.36; OR – an outside piping surface is exposed to wetting from chloride bearing environments (e.g., seawater, brackish water, brine)	austenitic stainless steel base metal, welds, and HAZ
	PWSCC	– piping material is Inconel (Alloy 600) and – exposed to primary water at T > 560°F, and – the material is mill-annealed and cold worked; or cold worked and welded without stress relief	nozzles, welds, and HAZ without stress relief
LC	*MIC*	– operating temperature < 150°F, and – low or intermittent flow, and – pH < 10, and – presence/intrusion of organic material (e.g., raw water system), or water source is not treated with biocides (e.g., refueling water tank)	fittings, welds, HAZ, base metal, dissimilar metal joints (e.g., welds, flanges), and regions containing crevices
	PIT	– potential exists for low flow, and – oxygen or oxidizing species are present, and – initiating contaminants (e.g., fluoride, chloride) are present	
	CC	– crevice condition exists (e.g., thermal sleeves), and – operating temperature > 150°F, and – oxygen or oxidizing species are present	
FS	*E-C*	– existence of cavitation source (i.e., throttling or pressure reducing valves or orifices), and – operating temperature < 250°F, and – flow present > 100 hrs/yr, and – velocity > 30 ft/s, and – $(P_d - P_v) / \Delta P < 5$	fittings, welds, HAZ, and base metal
	FAC	– evaluated in accordance with existing Owner's FAC program	per Owner's FAC program
Water Hammer [Note (1)]		– potential for fluid voiding and relief valve discharge	

Table I-1
Degradation Mechanisms (Cont'd)

Legend:

- Thermal Fatigue (TF)
  - Thermal Stratification, Cycling, and Striping (TASCS)
  - Thermal Transients (TT)
- Stress Corrosion Cracking (SCC)
  - Intergranular Stress Corrosion Cracking (IGSCC)
  - Transgranular Stress Corrosion Cracking (TGSCC)
  - External Chloride Stress Corrosion Cracking (ECSCC)
  - Primary Water Stress Corrosion Cracking (PWSCC)
- Localized Corrosion (LC)
  - Microbiologically-Induced Corrosion (MIC)
  - Pitting (PIT)
  - Crevice Corrosion (CC)
- Flow Sensitive (FS)
  - Erosion-Cavitation (E-C)
  - Flow Accelerated Corrosion (FAC)

NOTE:
(1) Water Hammer is a rare, severe loading condition, as opposed to a degradation mechanism, but its potential at a location, in conjunction with one or more of the listed mechanisms, could be cause for a higher element ranking.

Table I-2
Degradation Mechanism Category

Failure Potential	Conditions	Degradation Category	Degradation Mechanism
High [Note (1)]	Degradation mechanism likely to cause a large break	Large Break	Flow-Accelerated Corrosion
Medium	Degradation mechanism likely to cause a small leak	Small Leak	Thermal Fatigue, Erosion- Cavitation, Corrosion, Stress Corrosion Cracking
Low	None	None	None

NOTE:
(1) Refer to I-2.3.2.

Table I-3
Consequence Categories for Initiating Event Impact Group

Design Basis Event Category	Initiating Event Type	Representative Initiating Event Frequency Range (1/yr)	Example Initiating Events	Consequence Category
I	Routine Operation	>1		None
II	Anticipated Event	≥1	Reactor Trip, Turbine Trip, Partial Loss of Feedwater	Low [Note (1)]
III	Infrequent Event	10^{-1} to 10^{-2}	Loss of Feedwater, Loss of Off-Site Power Loss of Shutdown Cooling	Low/ Medium/ High [Note (1)]
IV	Limiting Fault or Accident	$<10^{-2}$	Significant Leakage, Very Small LOCA, Small LOCA, Steamline Break, Feedwater Line Break, Large LOCA	Low/ Medium/ High [Note (1)]

NOTE:
(1) Refer to I-2.4.2(a)(3).

Table I-4
Quantitative Indices For Consequence Categories

CCDP	Consequence Category
$\geq 10^{-4}$	High
$10^{-6} \leq \text{CCDP} < 10^{-4}$	Medium
$<10^{-6}$	Low

Table I-5
Consequence Categories for System Impact Group

Frequency of Challenge	Exposure Time	Number of Available Backup Systems			
		0	1	2	≥ 3
Anticipated Event	Long	H	H	M	L
	Short	H	M	L	L
Infrequent Event	Long	H	H	M	L
	Short	H	L	L	L
Limiting Fault or Accident	Long	H	M	L	L
	Short	H	L	L	L

Legend:
H = Consequence Category “High”
M = Consequence Category “Medium”
L = Consequence Category “Low”

Table I-6
Consequence Categories for Combination Impact Group

Event	Consequence Category
Initiating Event and 1 Unaffected Train of Mitigating System Available	High
Initiating Event and 2 Unaffected Trains of Mitigating Systems Available	Medium [Note (1)] (or IE Consequence Category from Table I-3)
Initiating Event and More Than 2 Unaffected Trains of Mitigating Systems Available	Low [Note (1)] (or IE Consequence Category from Table I-3)
Initiating Event and No Mitigating Systems Affected	IE Consequence Category from Table I-3

NOTE:
(1) The higher consequence category from Table I-3 or Table I-6 shall be assigned.

Table I-7
Consequence Categories for Pipe Failures Resulting in Increased Potential for an Unisolated LOCA Outside Containment

Protection Against LOCA Outside Containment	Consequence Category
One active barrier [Note (1)]	High
One passive barrier [Note (2)]	High
Two active barriers	Medium
One active and one passive barrier	Medium
Two passive barriers	Low
More than two passive barriers	None

NOTES:
(1) An active barrier is presented by a valve that needs to close on demand.
(2) An passive barrier is presented by a valve that needs to remain closed.

Table I-8
Risk Matrix for Pipe Segments

RISK GROUPS
HIGH - CAT 1, 2, & 3
MEDIUM - CAT 4 & 5
LOW - CAT 6 & 7

FAILURE POTENTIAL	CONSEQUENCE CATEGORY: NONE	LOW	MEDIUM	HIGH
HIGH	CATEGORY 7	CATEGORY 5	CATEGORY 3	CATEGORY 1
MEDIUM	CATEGORY 7	CATEGORY 6	CATEGORY 5	CATEGORY 2
LOW	CATEGORY 7	CATEGORY 7	CATEGORY 6	CATEGORY 4

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Approval Date: March 22, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-561-2
Alternative Requirements for Wall Thickness Restoration of Class 2 and High Energy Class 3 Carbon Steel Piping
Section XI, Division 1

Inquiry: As an alternative to replacement or internal weld repair, what requirements may be applied for wall thickness restoration of Class 2 and high-energy Class 3 carbon steel piping systems that have experienced internal wall thinning from localized erosion, corrosion, and cavitation or pitting?

Reply: It is the opinion of the Committee that areas of Class 2 and high-energy (i.e., greater than 200°F or 275 psig maximum operating conditions) Class 3 carbon steel piping experiencing internal wall thinning from localized erosion, corrosion, and cavitation or pitting may have the wall thickness restored externally by means of a weld-deposited carbon or low-alloy steel overlay on the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving corrosion-assisted cracking or any other form of cracking.

1 GENERAL REQUIREMENTS

(a) The overlay shall be performed in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.[1]

(b) The overlay shall meet the requirements of IWA-4000,[2] except as stated in this Case.

(c) If the minimum required thickness of deposited weld metal necessary to satisfy the requirements of 3 is greater than the nominal thickness for the size and schedule of the piping, the provisions of this Case shall not apply.

(d) Weld overlay shall not be performed more than once in a single location.

2 INITIAL EVALUATION

The material beneath the surface to which the weld overlay is to be applied shall be evaluated to establish the existing average wall thickness and the rate, extent, and configuration of degradation to be reinforced by the weld overlay. The adjacent area shall be examined to verify that the overlay will encompass the entire unacceptable area. Consideration shall be given to the cause of degradation. The extent of degradation in the piping shall be evaluated to ensure that there are no other unacceptable locations within the surrounding area that could affect the integrity of the overlaid piping. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, considering the type of degradation present. The effect of the overlay on the piping and any remaining degradation shall be evaluated in accordance with IWA-4160.[3]

3 DESIGN

3.1 GENERAL DESIGN REQUIREMENTS

(a) Unless otherwise established by theoretical or experimental analysis, or by proof testing as provided for in 3.3 or 3.4, the full thickness of the weld overlay shall extend a distance of at least s in each direction beyond the area predicted, over the design life of the overlay to infringe upon the required thickness.[4]

where

s = $\geq {}^3\!/_4\sqrt{Rt_{nom}}$
R = outer radius of the component
t_{nom} = nominal wall thickness of the component

[1] IWA-4140 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4130 (Repair Program) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[2] IWA-4000/7000 and IWC/IWD-4000/7000, as applicable, in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[3] IWA-4150 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4130 (Repair Program) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[4] Design thickness as prescribed by the Construction Code.

Edges of the weld overlay shall be tapered to the existing piping surface at a maximum angle ("α" in Figure 1) of 45 deg. Final configuration of the overlay shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of encompassed or adjacent welds.

(b) The thickness shall be sufficient to maintain required thickness for the predicted life of the overlay, and, except for the tapered edges, the overlay shall have a uniform thickness.

(c) The tensile strength of the weld filler metal used for the overlay shall be at least that specified for the base metal to which it is applied.

(d) The predicted maximum degradation of the overlaid piping and the overlay over the design life of the overlay shall be considered in the design. The predicted degradation of the piping shall be based on in-situ inspection and established data for similar base metals. If the weld overlay is predicted to become exposed to the corroding medium, the predicted degradation of the overlay shall be based upon established data for base metals or weld metals with similar chemical composition to that of the filler metal used for the weld overlay.

3.2 Design. The design of weld overlays not prequalified by 3.3, 3.4, or 3.5 shall be in accordance with the applicable requirements of the Construction Code or NC-3100, ND-3100 and NC-3600, ND-3600 (including Appendix II), and shall consider the weld overlay as an integral portion of the piping or component upon which it is applied (not as a weld). The allowable stress values of the base metal shall apply to the design of the deposited weld metal. The following factors shall be considered in the design and application of the overlay:

(a) The shrinkage effects, if any, on the piping.

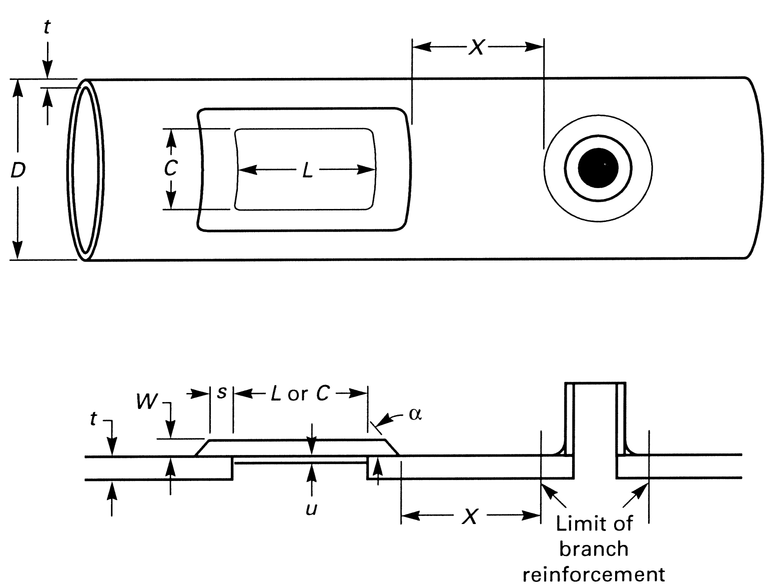
(b) Stress concentrations caused by application of the overly or resulting from existing and predicted piping internal surface configuration.

(c) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled with the original analysis. For rectangular-shaped overlays on piping designed to NC-3650, ND-3650 and aligned parallel or perpendicular to the axis of the piping, unless a lower stress intensification factor (SIF) is established, an SIF (i) of 2.1 shall be applied for overlays on straight pipe and adjacent welds. Also a stress multiplier of 1.7 shall be applied to the SIF for standard elbows; and an SIF of 2.1 shall be applied for tees and branch connections when the toe of the overlay is not less than $2^1/_2\sqrt{Rt_{nom}}$ from any branch reinforcement in Figure 1.

(d) The effects of different coefficients of thermal expansion between the weld overlay filler metal and the base metal.

3.3 Proof Test Qualification as a Piping Product. As an alternative to design, the configuration of weld overlays may be qualified by performance of proof testing of a mockup in accordance with the following requirements:

Figure 1
Overlay Configuration



$X \geq 2^1/_2\sqrt{Rt_{nom}}$

(a) A satisfactory mockup burst test shall qualify the design or configuration for application in the same orientation on the same type of item, and the same location on fittings, when the following conditions are satisfied (see Figure 1):

(1) The base metal is of the same P-No. and Group Number when impact properties are applicable, as the base metal tested.

(2) The specified minimum tensile strength of the item does not exceed that specified for the base metal tested.

(3) The average thickness of the overlay areas is at least the thickness of the mockup plug, u.

(4) The overlap on the full thickness of base metal, *s,* is at least that of the mockup.

(5) The transition angle at the outer edges of the overlay, α, is not greater than that of the mockup.

(6) The overlay surface finish is similar to or smoother than that tested.

(7) The maximum proportionate axial dimension, *L/D,* is not more than that tested.

(8) The maximum proportionate circumferential dimension, *C/D,* is not more than that tested.

(9) The nominal diameter is not less than one-half nor more than two times the diameter tested.

(10) The nominal thickness/diameter ratio, *t/D,* is not less than one-half nor more than three times the *t/D,* ratio tested.

(b) The mockup base shall consist of new base material of similar configuration, or type of item, as the item to be overlaid. A rounded-corner segment of the base material shall be removed to represent the maximum proportionate size (axial dimension of L and circumferential dimension of C) and location of thinning or pitting to be compensated for by the weld overlay. A plug of the same base metal and of uniform thickness u, which shall not exceed the smallest average thickness on which the overlays will be permanently applied, shall be full-penetration welded around the opening and flush with the outside surface of the piping. Alternatively, an equivalent volume of base metal may be removed from the inside surface of the mockup by machining or grinding, without need for welding in a closure plug.

(c) The mockup weld overlay shall be applied in accordance with the design or specified configuration using the specified weld filler metal. Maximum section thickness at the overlaid opening (weld metal plus base metal plug, $u + w$) shall not exceed $87^1/_2$% of the nominal thickness of the piping.

(d) Straight pipe equivalent to a minimum of one pipe diameter, or one-half diameter for piping over NPS 14, shall be provided (butt-welded to the mockup, if necessary) beyond both ends of the overlay. The piping shall be capped and the completed mockup assembly shall be thoroughly vented and hydrostatically pressure tested to bursting. To qualify the design for general application within the limits of (a), burst pressure shall not be less than

$$P = \frac{2tS_{act}}{D_o}$$

where

P = minimum acceptable burst pressure, psi
t = minimum specified thickness (excluding manufacturing tolerances) of the base metal being tested, in
S_{act} = reported actual tensile strength of the base metal being tested, psi
D_o = outside diameter of the pipe, in.

(e) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled in accordance with 3.2(c).

3.4 Proof Test Qualification for Specific Applications. As an alternative to design by analysis or proof test qualification as a piping product, the design or configuration of weld overlays may be qualified for limited service conditions using the provisions of NC-6900 and ND-6900. "Proof Tests to Establish Design Pressure," except that component hydrostatic testing is not required (other than as required by IWA-4000[2]). The mockups shall be fabricated and tested in accordance with the provisions of 3.3(b), 3.3(c), and 3.3(d), and shall be applied in accordance with the provisions and conditions of 3.3(a). The provisions of 3.3(e) shall be met.

3.5 Prequalified Design. Application of weld overlays on straight pipe, portions of tees not less than $2^1/_2\sqrt{Rt_{\text{nom}}}$ from any branch reinforcement in Figure 1, standard elbows, and associated welds to correct limited degradation shall be exempt from the requirements of 3.2 through 3.4 provided all of the following conditions are satisfied in Figure 1:

(a) The requirements of 3.1 apply.

(b) The finished overlay shall be circular, oval, full-circumferential or rectangular in shape.

(c) The distance between toes of adjacent overlays shall not be less than $^3/_4\sqrt{Rt_{\text{nom}}}$ on pipe or tees, nor less than $2\sqrt{Rt_{\text{nom}}}$ on elbows.

(d) The maximum dimension compensated by a circular or oval overlay shall not exceed the lesser of $^1/_2$ the nominal outside diameter of the piping or 8 in.

(e) For rectangular overlays on piping with nominal thickness not less than standard wall nor more than 0.112 D_o, the following shall apply:

(1) The overlays shall be aligned parallel with or perpendicular to the axis of the piping;

[2] IWA-4000/7000 and IWC/IWD-4000/7000, as applicable, in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.

(2) Corners shall be rounded with radii not less than the overlay thickness;

(3) The base metal shall be P-No. 1 material, with impact properties not applicable;

(4) The specified minimum tensile strength of the overlaid item shall not exceed 60,000 psi;

(5) The average thickness of the overlay area (u) shall be at least $\frac{1}{8}$ in.;

(6) The full thickness of the overlay shall extend a distance s beyond the area predicted to infringe upon the base metal required thickness;

where

$$s = \geq 3/4\sqrt{Rt_{nom}}$$

(7) The overlay surface finish may be as-welded or smoother;

(8) For NPS 4 through NPS 16 the maximum axial and circumferential dimensions compensated by the overlay shall not exceed one-half the nominal outside diameter.

(9) For rectangular overlays on piping greater than NPS 16, the maximum angle of taper, α, shall not exceed 30 deg, and the maximum axial dimension and area of base metal predicted to be below the required thickness shall not exceed that defined by

$$L_{max}(\text{in.}) = 0.11D_o + 1.84$$

$$A_{max}(\text{in.}^2) = 0.455D_o - 0.8$$

where

L_{max} = maximum axial dimension of base metal predicted to degrade below the required thickness over the remaining life of the overlay, in.

A_{max} = maximum area of base metal predicted to degrade below the required thickness over the remaining life of the overlay, in.^{2}

(f) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled in accordance with 3.2(c).

4 STEAM- OR WATER-BACKED APPLICATIONS

(a) For overlays applied with water backing, the qualification, application, examination and repair requirements of the temper bead welding technique described in IWA-4650[5] shall apply, except that all references to Subsection NE and Class MC shall be taken as Subsection NC or ND and Class 2 or 3, as applicable.

(b) Steam systems shall be depressurized before welding.

5 INSTALLATION

(a) The entire surface area to which the weld overlay is to be applied shall be examined using the liquid penetrant or magnetic particle method, with acceptance criteria in accordance with NC-2500, ND-2500 and NC-5300, ND-5300 for the product form (base metal or weld) involved.

(b) If through-wall repairs are necessary to satisfy the acceptance criteria, or result from application of the weld overlay,[6] they shall be accomplished by sealing with weld metal using a qualified weld procedure suitable for open-root welding. This weld shall be examined in accordance with (a). In addition, the first layer of overlay over the repaired area shall be examined in accordance with (a). If such repair is performed on a wet surface, the permitted life of the overlay shall be one fuel cycle.

(c) Overlay weld metal shall be deposited using a grove-welding procedure qualified in accordance with Section IX and the Construction Code, Section IX and Section III, or IWA-4610 and either IWA-4620 or IWA-4650.[7] The qualified minimum thickness specified in the weld procedure does not apply to the weld overlay or associated base metal repairs.[8]

(d) The surface of the weld overlay shall be prepared by machining or grinding, as necessary, to permit performance of surface and volumetric examinations required by 6 and any subsequent preservice or inservice examinations. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) The completed weld overlay shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NC-5300 and ND-5300.

(b) The weld overlay, including the existing piping upon which it is applied, shall be examined to verify acceptable wall thickness.

[5] IWA-4540 in the 1989 Edition with the 1991 Addenda through the 1995 Edition. IWE-4200 in the 1986 Edition with the 1988 Addenda through the 1989 Edition with the 1990 Addenda. IWE-4320 in the 1986 Edition with the 1987 Addenda and earlier Editions and Addenda.

[6] Testing has shown that piping with areas of wall thickness less than the diameter of the electrode may burn-through during application of a water-backed weld overlay.

[7] IWA-4500 and either IWA-4510 or IWA-4540 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4510 or IWE-4200 in the 1986 Edition with the 1988 Addenda through 1989 Edition with the 1990 Addenda. IWB-4320 or IWE-4320 in the 1986 Edition with the 1987 Addenda or earlier Editions and Addenda.

[8] Exception to IWA-4000.

(c) Weld overlays shall be volumetrically examined as base metal repairs when required by the Construction Code, except as follows:

(1) Class 3 weld overlays are exempt from volumetric examination when the Construction Code does not require that full-penetration butt welds in the same location be volumetrically examined.

(2) Class 3 weld overlays not exceeding 10 in.^{2} surface area are exempt from volumetric examination.

(3) Other weld overlays shall be exempt from volumetric examination when the finished applied thickness (w in Figure 1) does not exceed:

(-a) $^1/_3t$ for $t \le {}^3/_4$ in.

(-b) $^1/_4$ in. for $^3/_4$ in. $< t \le 2^1/_2$ in.

(-c) The lesser of $^3/_8$ in. or 10% of t for $t > 2^1/_2$ in.

where

t = finished full-section thickness of compensated area (e.g., $w + u$ in Figure 1)

(4) When volumetric examination is required, the full volume of the finished overlay, excluding the tapered edges, but including the volume of base metal required for the service life of the overlay, shall be examined in accordance with the Construction Code or Section III using either the ultrasonic or radiographic method, and shall, to the depth at the surface of the existing piping, satisfy the acceptance criteria for welds of the Construction Code or NC-5300 and ND-5300. Any volume of the existing piping, beneath the weld overlay that is taken credit for in the design, shall satisfy the volumetric acceptance criteria of NC-2500 and ND-2500 or NC-5300 and ND-5300 as applicable.

7 IN-SERVICE EXAMINATION

(a) Examinations shall be performed to characterize the thinning of the underlying pipe wall as a benchmark for subsequent examinations of the overlay.

(b) The Owner shall prepare a plan for additional examinations to verify that minimum wall thickness is not violated over the life of the overlay. The frequency and method of examination shall be determined based on an evaluation of the degradation mechanism.

(c) Except as required by 5(b), the maximum service life of the overlay shall be two fuel cycles unless wall thickness examinations during each of the two fuel cycles are performed to establish the life of the overlay. If the cause of the degradation is not determined, the maximum permitted life of the overlay shall be one fuel cycle.

8 DOCUMENTATION

Use of this Case shall be documented on an NIS-2 Form.

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Approval Date: March 22, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-562-2
Alternative Requirements for Wall Thickness Restoration of Class 3 Moderate Energy Carbon Steel Piping
Section XI, Division 1

Inquiry: As an alternative to replacement or internal weld repair, what requirements may be applied for wall thickness restoration of Class 3 moderate-energy carbon steel piping systems that have experienced internal wall thinning from localized erosion, corrosion, and cavitation or pitting?

Reply: It is the opinion of the Committee that areas of Class 3 moderate energy (i.e., less than or equal to 200°F and less than or equal to 275 psig maximum operating conditions) carbon steel piping experiencing internal wall thinning from localized erosion, corrosion, and cavitation or pitting, may have the wall thickness restored externally by means of a weld-deposited carbon or low-alloy steel overlay on the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving corrosion-assisted cracking or any other form of cracking.

1 GENERAL REQUIREMENTS

(a) The overlay shall be performed in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.[1]

(b) The overlay shall meet the requirements of IWA-4000,[2] except as stated in this Case.

(c) If the minimum required thickness of deposited weld metal necessary to satisfy the requirements of 3 is greater than the nominal thickness for the size and schedule of the piping, the provisions of this Case shall not apply.

(d) Weld overlay shall not be performed more than once in a single location.

2 INITIAL EVALUATION

The material beneath the surface to which the weld overlay is to be applied shall be evaluated to establish the existing average wall thickness and the rate, extent and configuration of degradation to be reinforced by the weld overlay. The adjacent area shall be examined to verify that the overlay will encompass the entire unacceptable area. Consideration shall be given to the cause of degradation. The extent of degradation in the piping shall be evaluated to ensure that there are no other unacceptable locations within the surrounding area that could affect the integrity of the overlaid piping. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, considering the type of degradation present. The effect of the overlay on the piping and any remaining degradation shall be evaluated in accordance with IWA-4160.[3]

3 DESIGN

3.1 GENERAL DESIGN REQUIREMENTS

(a) Unless otherwise established by theoretical or experimental analysis, or by proof testing as provided for in 3.3 or 3.4, the full thickness of the weld overlay shall extend a distance of at least s in each direction beyond the area predicted, over the design life of the overlay to infringe upon the required thickness.[4]

where

s = $\geq {}^3\!/_4\sqrt{Rt_{\text{nom}}}$
R = outer radius of the component
t_{nom} = nominal wall thickness of the component

[1] IWA-4140 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4130 (Repair Progam) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[2] IWA-4000/7000 and IWC/IWD-4000/7000, as applicable, in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[3] IWA-4150 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4130 (Repair Program) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.
[4] Design thickness as prescribed by the Construction Code.

Edges of the weld overlay shall be tapered to the existing piping surface at a maximum angle (α in Figure 1) of 45 deg. Final configuration of the overlay shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of encompassed or adjacent welds.

(b) The thickness shall be sufficient to maintain required thickness for the predicted life of the overlay, and, except for the tapered edges, the overlay shall have a uniform thickness.

(c) The tensile strength of the weld filler metal for the overlay shall be at least that specified for the base metal to which it is applied.

(d) The predicted maximum degradation of the overlaid piping and the overlay over the design life of the overlay shall be considered in the design. The predicted degradation of the piping shall be based upon in-situ inspection and established data for similar base metals. If the weld overlay is predicted to become exposed to the corroding medium, the predicted degradation of the overlay shall be based upon established data for base metals or weld metals with similar chemical composition to that of the filler metal used for the weld overlay.

(e) The effect of weld overlay application on interior coating shall be addressed in the Repair/Replacement Plan (previously Repair Program).

3.2 Design. The design of weld overlays not prequalified by 3.3, 3.4, or 3.5 shall be in accordance with the applicable requirements of the Construction Code or ND-3100 and ND-3600 (including Appendix II), and shall consider the weld overlay as an integral portion of the piping or component upon which it is applied (not as a weld). The allowable stress values of the base metal shall apply to the design of the deposited weld metal. The following factors shall be considered, as applicable, in the design and application of the overlay:

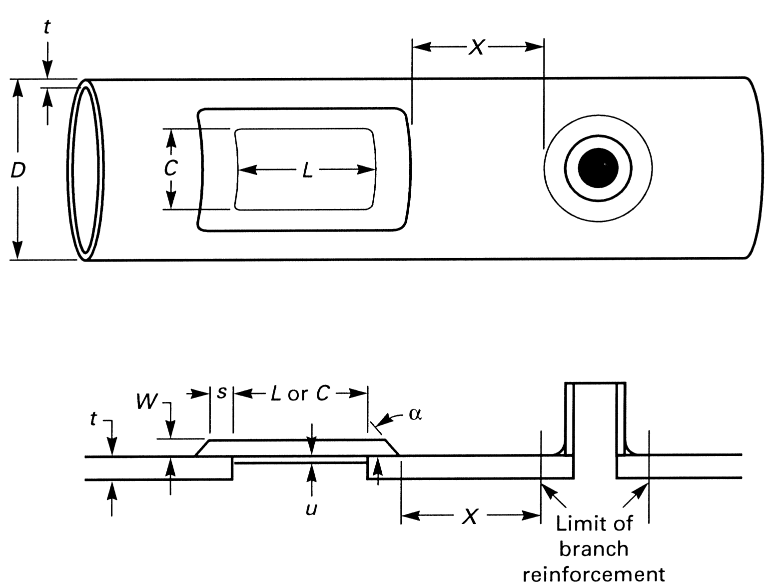
(a) The shrinkage effects, if any, on the piping.

(b) Stress concentrations caused by application of the overlay or resulting from existing and predicted piping internal surface configuration.

(c) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled with the original analysis. For rectangular-shaped overlays on piping designed to ND-3650 and aligned parallel or perpendicular to the axis of the piping, unless a lower stress intensification factor (SIF) is established, an SIF (i) of 2.1 shall be applied for overlays on straight pipe and adjacent welds. Also a stress multiplier of 1.7 shall be applied to the SIF for standard elbows, and an SIF of 2.1 shall be applied for tees and branch connections when the toe of the overlay is not less than $2^1/_2\sqrt{Rt_{nom}}$ from any branch reinforcement in Figure 1.

3.3 Proof Test Qualification as a Piping Product. As an alternative to design, the configuration of weld overlays may be qualified by performance of proof testing of a mockup in accordance with the following requirements:

Figure 1
Overlay Configuration



$X \geq 2^1/_2\sqrt{Rt_{nom}}$

(a) A satisfactory mockup burst test shall qualify the design or configuration for application in the same orientation on the same type of item, and the same location on fittings, when the following conditions are satisfied (see Figure 1):

(1) the base metal is of the same P-No. and Group Number when impact properties are applicable, as the base metal tested;

(2) the specified minimum tensile strength of the item does not exceed that specified for the base metal tested;

(3) the average thickness of the overlay areas is at least the thickness of the mockup plug, u;

(4) the overlap on the full thickness of base metal, s, is at least that of the mockup;

(5) the transition angle at the outer edges of the overlay, α, is not greater than that of the mockup;

(6) the overlay surface finish is similar to or smoother than that tested;

(7) the maximum proportionate axial dimension, L/D, is not more than that tested;

(8) the maximum proportionate circumferential dimension, C/D, is not more than that tested;

(9) the nominal diameter is not less than one-half nor more than two times the diameter tested;

(10) the nominal thickness/diameter ratio, t/D, is not less than one-half nor more than three times the t/D, ratio tested.

(b) The mockup base shall consist of new base material of similar configuration, or type of item, as the item to be overlaid. A rounded-corner segment of the base material shall be removed to represent the maximum proportionate size (axial dimension of L and circumferential dimension of C) and location of thinning or pitting to be compensated for by the weld overlay. A plug of the same base metal and of uniform thickness u, which shall not exceed the smallest average thickness on which the overlays will be permanently applied, shall be full-penetration welded around the opening and flush with the outside surface of the piping. Alternatively, an equivalent volume of base metal may be removed from the inside surface of the mockup by machining or grinding, without need for welding in a closure plug.

(c) The mockup weld overlay shall be applied in accordance with the design or specified configuration using the specified weld filler metal. Maximum section thickness at the overlaid opening (weld metal plus base metal plug, $u + w$) shall not exceed $87^1/_2$% of the nominal thickness of the piping.

(d) Straight pipe equivalent to a minimum of one pipe diameter, or one-half diameter for piping over NPS 14, shall be provided (butt-welded to the mockup, if necessary) beyond both ends of the overlay. The piping shall be capped and the completed mockup assembly shall be thoroughly vented and hydrostatically pressure tested to bursting. To qualify the design for general application within the limits of (a), burst pressure shall not be less than:

$$P = \frac{2tS_{act}}{D_o}$$

where

P = minimum acceptable burst pressure, psi
t = minimum specified thickness (excluding manufacturing tolerance) of the base metal being tested, in.
S_{act} = reported actual tensile strength of the base metal being tested, psi
D_o = outside diameter of the pipe, in.

(e) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled in accordance with 3.2(c).

3.4 Proof Test Qualification for Specific Applications. As an alternative to design by analysis or proof test qualification as a piping product, the design or configuration of weld overlays may be qualified for limited service conditions using the provisions of ND-6900. "Proof Tests to Establish Design Pressure," except that component hydrostatic testing is not required (other than as required by IWA-4000[2]). The mockups shall be fabricated and tested in accordance with the provisions of 3.3(b), 3.3(c), and 3.3(d), and shall be applied in accordance with the provisions and conditions of 3.3(a). The provisions of 3.3(e) shall be met.

3.5 Prequalified Design. Application of weld overlays on straight pipe, portions of tees not less than $2^1/_2\sqrt{Rt_{\text{nom}}}$ from any branch reinforcement in Figure 1, standard elbows, and associated welds to correct limited degradation shall be exempt from the requirements of 3.2 through 3.4, provided all of the following conditions are satisfied:

(a) All of the requirements of 3.1 apply.

(b) The provisions of 3.3(e) shall be met.

(c) The full thickness of weld overlay shall not exceed a maximum axial length of the greater of six in. or the outside diameter of the piping.

(d) The finished overlay shall be circular, oval, full-circumferential, or rectangular in shape.

(1) For each repair, the maximum dimension compensated by a circular overlay shall not exceed $^2/_3$ the nominal outside diameter of the piping.

(2) Rectangular overlays shall be aligned parallel with or perpendicular to the axis of the piping, and corners shall be rounded with radii not less than the overlay thickness.

[2] IWA-4000/7000 and IWC/IWD-4000/7000, as applicable, in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.

(3) For oval overlays, the end radii shall not be less than $\frac{3}{4}\sqrt{Rt_{\text{nom}}}$, and the axis of the overlay shall be aligned parallel with or perpendicular to the axis of the piping.

(e) The distance between toes of adjacent overlays shall not be less than t_{nom}.

4 WATER-BACKED APPLICATIONS

Manual application of overlays on water-backed piping shall be restricted to P-No. 1 base materials. Welding of such overlays shall use the SMAW process and low-hydrogen electrodes. In addition, the surface examination required in 6 shall be performed no sooner than 48 hours after completion of welding.

5 INSTALLATION

(a) The entire surface area to which the weld overlay is to be applied shall be examined using the liquid penetrant or magnetic particle method, with acceptance criteria in accordance with ND-2500/5300 for the product form (base metal or weld) involved.

(b) If through-wall repairs are necessary to satisfy the acceptance criteria, or result from application of the weld overlay,[5] they shall be accomplished by sealing with weld metal using a qualified weld procedure suitable for open-root welding. This weld shall be examined in accordance with (a). In addition, the first layer of overlay over the repaired area shall be examined in accordance with (a). If such repair is performed on a wet surface, the permitted life of the overlay shall be one fuel cycle.

(c) Overlay weld metal shall be deposited using a grove-welding procedure qualified in accordance with Section IX and the Construction Code, Section IX and Section III, or IWA-4610 and either IWA-4620 or IWA-4650.[6] The qualified minimum thickness specified in the weld procedure does not apply to the weld overlay or associated base metal repairs.[7]

(d) The surface of the weld overlay shall be prepared by machining or grinding, as necessary, to permit performance of surface and volumetric examinations required by 6. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) The completed weld overlay shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or ND-5300.

(b) The weld overlay, including the existing piping upon which it is applied, shall be examined to verify acceptable wall thickness.

(c) Weld overlays shall be volumetrically examined as base metal repairs when required by the Construction Code, except as follows:

(1) Weld overlays on piping are exempt from volumetric examination when the Construction Code does not require volumetric examination for full-penetration butt welds at the same location.

(2) Weld overlays not exceeding 10 in.^{2} surface area are exempt from volumetric examination.

(3) Other weld overlays shall be exempt from volumetric examination when the finished applied thickness (w in Figure 1) does not exceed.

(-a) $\frac{1}{3}t$ for $t \leq \frac{3}{4}$ in.

(-b) $\frac{1}{4}$ in. for $\frac{3}{4}$ in. $< t \leq 2\frac{1}{2}$ in.

(-c) The lesser of $\frac{3}{8}$ in. or 10% of t for $t > 2\frac{1}{2}$ in.

where

t = finished full-section thickness of compensated area (e.g., $w + u$, in Figure 1)

(4) When volumetric examination is required, the full volume of the finished overlay, excluding the tapered edges, but including the volume of base metal required for the service life of the overlay, shall be examined in accordance with the Construction Code or Section III, using either the ultrasonic or radiographic method, and shall, to the depth at the surface of the existing piping, satisfy the acceptance criteria for weldments of the Construction Code or ND-5300. Any volume of existing piping beneath the weld overlay that is taken credit for in the design, shall satisfy the volumetric acceptance criteria of ND-2500 or ND-5300 as applicable.

7 IN-SERVICE EXAMINATION

(a) Examinations shall be performed to characterize the thining of the underlying pipe wall as a benchmark for subsequent examinations of the overlay.

[5] Testing has shown that piping with areas of wall thickness less than the diameter of the electrode may burn-through during application of a water-backed weld overlay.

[6] IWA-4500 and either IWA-4510 or IWA-4540 in the 1989 Edition with the 1991 Addenda through 1995 Edition. IWA-4510 or IWE-4200 in the 1986 Edition with the 1988 Addenda through 1989 Edition with the 1990 Addenda. IWB-4320 or IWE-4320 in the 1986 Edition with the 1987 Addenda or earlier Editions and Addenda.

[7] Exception to IWA-4000.

(b) The Owner shall prepare a plan for additional examinations to verify that minimum wall thickness is not violated over the life of the overlay. The frequency and method of examination shall be determined based on an evaluation of the degradation mechanism.

(c) Except as required by 5(b), the maximum permitted life of the overlay shall be two fuel cycles unless wall thickness examinations during each of the two fuel cycles are performed to establish the life of the overlay. If the cause of the degradation is not determined, the maximum permitted life of the overlay shall be one fuel cycle.

8 DOCUMENTATION

Use of this Case shall be documented on an NIS-2 Form.

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Approval Date: January 17, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-564-2
UNS J93380, Alloy CD3MWCuN, Classes 2 and 3 Construction
Section III, Division 1

Inquiry: Under what conditions may solution annealed UNS J93380 casting material, with the chemical composition listed in Table 1 and the tensile properties listed in Table 3, otherwise conforming to the requirements of Specifications SA-995 and ASTM A890/A 890M, as applicable, be used in the construction of vessels and parts under the rules of Section III, Division 1, for Class 2 and 3 construction?

Reply: It is the opinion of the Committee that the material described in the Inquiry may be used under the rules of Section III, Division 1, for Class 2 and 3 construction, provided the following additional requirements are met:

(a) The maximum allowable design stress values in tension shall be those listed in Table 4.

(b) For external pressure design, use Figure 1 and Table 5 of this Case.

(c) Separate welding procedure qualifications and performance qualifications shall be conducted as prescribed in Section IX.

Table 1
Chemical Requirements

Element	Heat Analysis Limit, % Wt
Carbon, max.	0.03
Manganese, max.	1.00
Silicon, max.	1.00
Sulfur, max.	0.025
Phosphorus, max.	0.030
Chromium	24.0–26.0
Nickel	6.5–8.5
Molybdenum	3.0–4.0
Nitrogen	0.20–0.30
Copper	0.5–1.0
Tungsten	0.5–1.0
Iron	Balance

(d) Heat treatment after welding is neither required nor prohibited. However, if heat treatment is applied, the solution annealing treatment shall consist of heating to a minimum temperature of 2010°F and then quenched in water or rapidly cooled by other means.

(e) All other requirements of Section III, Division 1, for Class 2 and 3 construction, as applicable, shall apply.

(f) This Case number shall be identified in the certification for the material.

Table 2
Product Specification

A 890/A 890M	Castings
SA-995	Castings

Table 3
Mechanical Property

Yield Strength min. ksi [Note (1)]	65
Tensile Strength min. ksi	100
Elongation 2 in. or 50 mm [Note (2)]	25.0

NOTES:
(1) Determine by the 0.2% offset method.
(2) When ICI test bars are used in tensile testing as provided for in ASTM A703/A703M, the gage length to reduced section diameter ratio shall be 4 to 1.

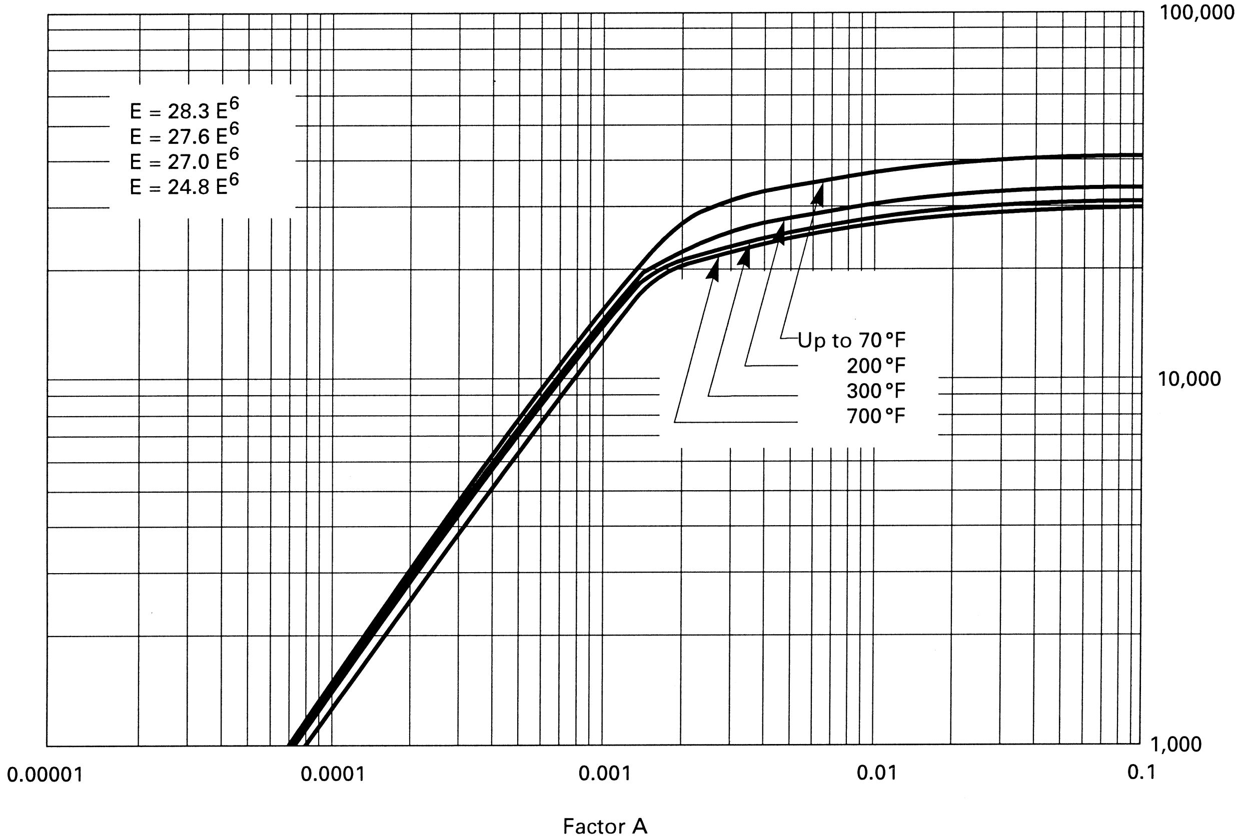
Table 4
Maximum Allowable Design Stress Values in Tension

For Metal Temperature Not Exceeding, °F	ksi
100	25.0
200	25.0
300	23.9
400	23.4
500	23.3
600	23.3

Table 5
Chart for Determining Shell Thickness of Cylindrical and Spherical Shells Under External Pressure When Constructed of High Alloy UNS S32760 and UNS J93380

Temp.	A	B psi.	Temp.	A	B psi.
70°F	7.07E-05	1000	300°F	7.41E-05	1000
	0.0005	7080		0.0005	6750
	0.00075	10600		0.00075	10100
	0.000992	14000		0.000923	12400
	0.00121	17100		0.00109	14400
	0.00143	20100		0.00128	16500
	0.00166	23100		0.00153	18600
	0.00197	26200		0.00198	20400
	0.00284	30100		0.00269	22000
	0.00491	33300		0.00392	23600
	0.00697	34500		0.00721	25700
	0.00849	35700		0.00893	26400
	0.0192	38700		0.019	28700
	0.05	40000		0.05	29600
	0.01	40000		0.1	29600
200°F	7.25E-05	1000	700°F	8.06E-05	1000
	0.0005	6900		0.0005	6200
	0.00075	10300		0.00075	9300
	0.000939	12900		0.000933	11600
	0.00112	15400		0.00108	13400
	0.00133	17800		0.00124	15200
	0.00163	20200		0.00143	17000
	0.00194	21500		0.00171	18800
	0.00272	24200		0.00277	21700
	0.00431	26600		0.00375	22900
	0.00683	27800		0.00701	24900
	0.00872	28800		0.00934	25800
	0.0187	31200		0.0192	27700
	0.05	32200		0.05	28600
	0.01	32200		0.1	28600

Figure 1
Chart for Determining Shell Thickness of Cylindrical and Spherical Shells Under External Pressure When Constructed of High Alloy UNS S32760 and UNS J93380



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Approval Date: December 31, 1996

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-565
Alternative Methods of Nozzle Attachment for Class 1 Vessels
Section III, Division 1

Inquiry: What alternative to the methods of nozzle attachment allowed by NB-3337 may be used in the construction of Class 1 vessels?

Reply: It is the opinion of the Committee that NPS 2 and smaller nozzles may be attached to a vessel by threading, providing the following requirements are met:

(a) All reinforcement required by the opening is integral with the vessel.

(b) NB-3200 stress analysis considers the appropriate details and all nozzle loads.

(c) The threads are not required to provide the primary seal and are not in contact with the contained fluid.

(d) All other applicable requirements of Subsection NB are met.

(e) This Case Number shall be shown in the Data Report.

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Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-566-2
Corrective Action for Leakage Identified at Bolted Connections
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-5250(a)(2) may be used when leakage is detected at bolted connections?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWA-5250(a)(2), the requirements of (a) or (b) below shall be met.

(a) The leakage shall be stopped, and the bolting and component material shall be evaluated for joint integrity as described in (c) below.

(b) If the leakage is not stopped, the Owner shall evaluate the structural integrity and consequences of continuing operation, and the effect on the system operability of continued leakage. This engineering evaluation shall include the considerations listed in (c) below.

(c) The evaluation of (a) and (b) above is to determine the susceptibility of the bolting to corrosion and failure. This evaluation shall include the following:

(1) the number and service age of the bolts;

(2) bolt and component material;

(3) corrosiveness of process fluid;

(4) leakage location and system function;

(5) leakage history at the connection or other system components;

(6) visual evidence of corrosion at the assembled connection.

Approval Date: February 26, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-567-1
Reconciliation Requirements for Class 1, 2, and 3 Replacement Components
Section XI, Division 1

Inquiry: What alternative to the reconciliation requirements of IWA-7210 (IWA-4170 in the 1991 Addenda through the 1995 Edition or IWA-4220 in the 1995 Addenda and later Editions and Addenda) may be used to accept a replacement component constructed to an earlier Edition or Addenda than that of the component being replaced?

Reply: It is the opinion of the Committee that, as an alternative to the reconciliation requirements of IWA-7210 (IWA-4170 in the 1991 Addenda through the 1995 Edition or IWA-4220 in the 1995 Addenda and later Editions and Addenda), a component used for replacement may be constructed to an earlier Edition or Addenda of the original Construction Code of the component being replaced, provided the following requirements are met:

(a) Any deviations from the Owner's Requirements[1] or the original Construction Code[1] of the component being replaced that could affect materials, design, fabrication, or examination, and affect the pressure boundary, or core support or component support function, shall be reconciled. Administrative requirements, i.e., those that do not affect the pressure boundary or core support or component support function, need not be reconciled.[2] Examples of administrative requirements include quality assurance, certification, Code Symbol Stamping, Data Reports, and Authorized Inspection.

(b) The administrative requirements of either the Construction Code of the item being replaced or the Construction Code of the item to be used for replacement shall be met.

(c) The Owner shall evaluate any changes in weight, configuration, or pressure-temperature rating in accordance with IWA-4311.

(d) A report of the reconciliation shall be prepared and made part of the record in accordance with IWA-6340 (IWA-4910 in the 1991 Addenda through the 1995 Edition or IWA-4180 in the 1995 Addenda and later Editions and Addenda).

(e) Use of this Case shall be shown on the NIS-2 Form documenting installation of the component.

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[1] See the 1995 Edition or later IWA-9000 Glossary for definitions of Owner's Requirements and Construction Code.

[2] This provision does not negate the requirement to implement the Owner's QA Program, nor does it affect Owner commitments to regulatory and enforcement authorities.

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Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-569-1
Alternative Rules for Repair by Electrochemical Deposition of Classes 1 and 2 Steam Generator Tubing
Section XI, Division 1

Inquiry: As an alternative to IWA-4000, is it permissible to establish the acceptability of steam generator tubing by electrochemical deposition of material on the inside suface of the tube?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4000, the acceptability of steam generator tubing may be established by electrochemical deposition of material on the inside surface of the tube.

1 GENERAL REQUIREMENTS

(a) The repair shall be performed in accordance with a Repair/Replacement Program and Plan (Repair Program)[1] satisfying the requirements of IWA-4000 in the Edition and Addenda of Section XI applicable to the plant in-service inspection program, or later Edition and Addenda.

(b) Electrochemical deposition shall be performed in accordance with a procedure qualified in accordance with this case and in accordance with the Repair/ Replacement Program and Plan (Repair Program).

(c) The suitability evaluation required by the Owner shall document the probable cause of the flaw and shall ascertain that the electrochemically deposited material is resistant to the failure mechanism.

(d) The requirements of NB-3222 through NB-3229,[2] as applicable, shall be met for the pressure boundary and the tube material adjacent to the electrochemical deposit. The Owner shall establish the material properties of the electrochemically deposited materials necessary for this analysis.

2 MATERIAL REQUIREMENTS

(a) All chemicals used in the process shall be certified by the manufacturer to be within the range of purity levels specified in the Electrodeposition Procedure Specification (EPS).

3 PROCEDURE QUALIFICATION REQUIREMENTS

(a) The repair organization shall complete a procedure qualification test to demonstrate process acceptability.

(b) Essential variables for procedure qualification testing are as follows:

(1) A change in tubing specification, grade, type, or class.

(2) A change of more than 10% in the nominal tube diameter.

(3) Addition or deletion of tube cleaning prior to electrodeposition.

(4) A change in deposit position (e.g., horizontal to vertical, etc.).

(5) A decrease in deposit thickness.

(6) A change of more than 10% in the distance between the anode O.D. and the tube I.D.

(7) A decrease in deposit length, or an increase of more than 10% in deposit length.

(8) A change in the type of current (i.e., DC, Pulsating).

(9) A change of more than 10% in electrical current, frequency, or pulse width.

(10) A decrease of more than 10% in the electrolyte flow velocity at the anode O.D.

(11) Addition or deletion of an electrolyte constituent. A change in the concentration of any electrolyte constituent.

(12) A change of more than 10% in electrolyte temperature, °F.

(13) Addition or deletion of post-installation heat treatment.

[1] When applying this Case to Editions and Addenda later than the 1989 Edition, references to "Repair Plan" shall be read as "Repair Plan" or "Repair/Replacement Plan."

[2] All references to Section III are applicable to the 1986 Edition with the 1986 Addenda through the 1995 Edition with the 1995 Addenda. Use of later Section III Editions or Addenda is permitted, provided they are reconciled with these requirements.

(c) The number of coupons required for procedure qualification testing is dependent on the number and length of deposit samples needed to satisfy the testing requirements specified below. A minimum of six separate coupons is required.

(d) Testing of Procedure Qualification Coupons:

(1) The entire length of each deposit shall be examined by the ultrasonic method in accordance with ASME Section III, NB-2552, as modified by (-a) through (-c):

(-a) Replace NB-2552.1(c) with: Deposits with defects that produce indications in excess of the indications produced by the standard defects in the reference specimen are unacceptable and shall be a basis of rejection for the procedure qualification coupon. Flaws in underlying tube base material may be considered nonrelevant.

(-b) Amend NB-2552.1(a) to include: The examination shall be conducted with single axial and circumferential beam directions, provided meaningful indications are obtained from the standard defects in the reference specimen.

(-c) Amend NB-2552.3 to include: The location of the standard defects shall be within the area of the deposit. To determine bond acceptability, the ultrasonic method shall demonstrate that there are no nonbonded areas greater than 0.125 in. in length or width within the minimum required reinforcement length.

(2) Two coupons shall be cut longitudinally. One specimen from each coupon shall be subjected to a 180 deg bend test in accordance with ASTM B489-85.

(-a) Specimen width shall be equal to or greater than one-fourth (90 deg) of tube circumference.

(-b) Maximum mandrel diameter shall be 0.250 in. Minimum elongation shall be 15% when calculated as follows:

$$E = 100T/(D + T)$$

where

E = percent elongation
T = total thickness of the base metal and the deposit
D = mandrel diameter (0.250 in.)

(-c) The specimens shall be bent such that the apex of the bend is in the center of the deposit and the specimen's I.D. (inside diameter) surface is located on the convex surface of the bend.

(-d) No visible cracks or lack of bonding exceeding 0.062 in. are permitted.

(3) A chemical analysis shall be performed on a minimum of two separate procedure qualification test specimens. This analysis shall be performed in accordance with ASTM E39, E76, and E354, except that ASTM E38 shall be used for elements not covered by E354. Chemical composition shall comply with the following requirements:

Nickel[3]	99.0% minumum
Phosphorous	0.06% minimum to 0.8% maximum
Silicon	0.01% maximum
Sulfur	0.01% maximum

(4) Burst testing shall be performed on a minimum of two separate procedure qualification test specimens.

(-a) Burst test specimens shall be prepared by mechanically removing tubing material from the deposit exterior (360 deg) leaving only deposit material for testing.

(-b) The minimum longitudinal dimension of the exposed deposit shall be the lesser of 50% of the deposit length or 1 in.

(-c) The minimum length of the burst test specimen shall be 8 in., with the deposit located midway along the tube length.

(-d) Coupon ends shall be sealed, and the coupon shall be pressurized until bursting occurs.

(-e) Burst test results are considered acceptable when:

(-1) burst occurs in the tube base material, outside the electochemical deposit area at a burst pressure >95% of the computed test pressure, or

(-2) the test assembly withstands, without rupture, 105% of the computed proof test pressure defined by the equation

$$P = 2\,St/D$$

where

P = computed proof test pressure
S = minimum tensile strength of tube base material
t = nominal tube wall thickness
D = tube outside diameter

(-3) Burst testing shall demonstrate a minimum deposit ultimate tensile strength of 90 ksi.

(5) Failure of any one test shall constitute failure of the entire procedure qualification.

(e) The results of completed tests shall be documented on a Procedure Qualification Record. All essential variables shall be documented on this record. The repair oganization responsible for the procedure qualification shall sign the Procedure Qualification Record, certifying its accuracy.

[3] Cobalt shall be counted as nickel, but shall not exceed 0.025% maximum.

4 OPERATOR QUALIFICATION REQUIREMENTS

(a) Operator qualification shall be documented on an Operator Qualification Record. Essential variables (as defined herein) shall be documented on this record, as well as the results of tests performed on the operator qualification samples.

(b) The operator shall prepare a minimum of two coupons, and shall install electrochemical deposits in these coupons using a qualified Electrochemical Procedure Specification (EPS).

(1) The two deposits shall be subjected to 180 deg bend tests. Bend specimens, testing, and acceptance criteria shall be as specified in 3(d)(2).

(2) Any operator who fails the qualification test shall receive additional training prior to requalification.

(3) An operator who prepares the electrochemical deposits for the procedure qualification coupons required by 3 is also qualified within the limits of performance qualification established in (e).

(c) Operator qualification in accordance with (b) using any qualified EPS shall qualify an operator for electrodeposition using any other qualified EPS.

(d) The repair organization responsible for operator qualification shall sign the Operator Qualification Record, certifying its accuracy.

(e) Renewal of qualification is required when the operator has not performed an electrochemical deposit within 6 months, or when there is specific reason to question his ability to make electrochemical deposits. Renewal of qualification shall be in accordance with (b), except that only one coupon is required.

5 PROCEDURE REQUIREMENTS

(a) Each electrodeposition operation shall be accomplished in accordance with an Electrodeposition Procedure Specification (EPS).

(1) The EPS shall identify all essential variables.

(2) The EPS shall reference one or more supporting PQRs. Supporting PQRs shall document testing and acceptance of the essential variable ranges referenced in the EPS.

(3) The essential variable ranges referenced in the EPS shall be within the ranges qualified by the supporting PQR(s). Changes beyond those qualified on supporting PQRs require requalification.

(4) The EPS shall specify each of the chemicals to be used in the process, and shall specify minimum purity levels for each of the chemicals listed.

(5) The repair organization responsible for the electrodeposition process shall sign each EPS, certifying accuracy.

(b) The deposited material shall be applied to the inside tube surface, 360 deg around the circumference of the tube.

(c) For axial flaws, the bonded reinforcement length shall extend at least $2\sqrt{rt}$ in. on either end of the flaw (where r or the nominal outside radius and t is the nominal thickness of the tube, in.). For circumferential flaws, the bonded reinforcement length shall extend at least $2\sqrt{rt}$ in. on either side of the flaw. The required bond area may start at any location along the length of the deposit.

(d) The transition at the ends of the deposit shall have a slope not exceeding 1:3 (i.e., 1 in. thickness per 3 in. length). Transition areas on deposit ends shall not be credited toward overall bonding area.

(e) The surface of each deposit shall be suitably smooth to facilitate nondestructive examination.

6 EXAMINATION REQUIREMENTS

(a) Following installation of a deposit, ultrasonic examination shall be performed on the entire volume of the deposit.

(1) Deposit thickness and length shall be within the range qualified. Deposit length shall comply with 5(c).

(2) Testing shall demonstrate that there are no nonbonded areas greater than 0.125 in. in width or length within the minimum required reinforcement length. Nonbonded areas greater than 0.125 in. and less than 0.250 in. may be evaluated by the Owner for acceptability. Nonbonded areas greater than 0.250 in. in any dimension are unacceptable.

(3) Flaw detection ultrasonic examination acceptance criteria and method shall be in accordance with 3(d). Examinations need only address:

(-a) flaws in the deposited material, and

(-b) flaws in the original tube which were not considered in the evaluation of minimum bond reinforcement length 5(c).

(b) A performance demonstration of the ultrasonic examination system shall be conducted to demonstrate the examination system's capability for distinguishing thickness, nonbonded locations, and flaws identified in (a)(3). The following shall be demonstrated:

(1) The equipment is capable of identifying the standard defects in the reference specimen 3(d)(1).

(2) The equipment is capable of identifying tube wall thickness and deposit thickness with a minimum accuracy of ±0.002 in.

(3) The equipment is capable of identifying nonbonded areas with width or length dimensions exceeding 0.125 in.

(c) The Owner shall prepare a plan for monitoring the condition of the deposit and the underlying tube material.

7 PRESSURE TESTING

Pressure testing is not required.

8 DOCUMENTATION REQUIREMENT

(a) Records shall be maintained by the Owner in accordance with IWA-6000 and shall include the following:

(1) Electrodeposition Procedure Specification (EPS);

(2) Procedure Qualification Record (PQR);

(3) Certification of Operator Qualification;

(4) Material certifications in accordance with 2(a);

(5) Locations of repaired areas and repaired tubes;

(6) Results of examinations required by 6.

(b) Use of this Case shall be documented on Form NIS-2.

Approval Date: September 9, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-570-2
Alternative Rules for Linear Piping and Linear Standard Supports for Classes 1, 2, 3, and MC
Section III, Division 1

Inquiry: What alternative rules to Section III, Subsection NCA and NF may be used for the construction of Class 1, 2, 3, and MC Linear Piping and Linear Standard Supports?

Reply: It is the opinion of the Committee that as an alternative to the requirements of NCA and NF, Class 1, 2, 3, and MC Linear Piping and Linear Standard Supports may be constructed to ANSI/AISC N690-1994 "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2, ANSI/AISC N690-1994(R2004) S2.[1]

1 GENERAL

1.1 The Owner or his designee shall provide a Design Specification that shall identify the loadings and combinations of loadings for which the supports are to be designed.

1.2 The Owner or his designee shall review and approve each support calculation to determine that all the appropriate Design and Service Loadings have been evaluated and that the acceptance criteria provided in this Code Case and in ANSI/AISC N690 have been considered.

1.3 The supports shall be constructed under a Quality Assurance Program which meets the requirements of the Owner.

1.4 The use of this Code Case shall be in accordance with NCA-1140 and shall be listed on the applicable Data Report for the component which utilizes the Linear Piping or Linear Standard Support.

2 MATERIAL

2.1 In those instances where material may be subject to lamellar tearing, such as through-thickness transmission of tensile loads in thick plates, the Design Specification shall include the requirement that the material be ultrasonically examined. Acceptance criteria shall be as stated in ANSI/AISC N690, Section Q1.4.

2.2 Copies of Certified Mill Test Reports, certified reports of tests made by the fabricator or a qualified testing laboratory, or Certificates of Compliance as required by ANSI/AISC N690 shall be furnished to the Owner for all supports provided under these requirements.

2.3 The requirements of Section Q1.4 or Q2.2 do not apply to items such as gaskets, seals, bushings, springs, wire rope used as a spring, compression spring end plates, bearings, retaining rings, washers, wear shoes, shims, slide plates, hydraulic fluids, etc., or to material used for stops for seismic and other dynamic loads that are designed primarily for compressive loading and are not connected to the support of the pressure boundary. Requirements, if any, for these materials shall be stated in the Design Specification.

3 DESIGN

3.1 The design requirements which shall be satisfied in elastic analysis for any Design and Level A through D Service Loadings stated in the Design Specification are those given in Table Q1.5.7.1 of ANSI/AISC N690 and the additional requirements of 3.2 through 3.11 below.

3.2 The *Normal, Severe, Extreme, Abnormal, Abnormal Severe,* and *Abnormal Extreme* load categories of ANSI/AISC N690 shall be correlated to the appropriate Design and Service Loadings identified in the Design Specification as shown in Table 3.2.

3.3 The rules and stress limits which shall be satisfied for any Test Loading stated in the Design Specification shall be those given for *Load Combination 1* in Table Q1.5.7.1 of ANSI/AISC N690 with the test fluid weight included in the *Loading 1,* multiplied by a stress limit coefficient of 1.33.

[1] As used in this document ANSI/AISC N690 refers to ANSI/AISC N690-1994(R2004), including Supplement No. 2.

3.4 The Stress Limit Coefficients in ANSI/AISC N690 shall be modified as shown in Table 3.2.

3.5 For the design of supports, the stresses caused by the restraint of free-end displacements of components and piping, such as thermal expansion and relative anchor displacements, shall be considered as primary stresses.

Table 3.2
Correlation of Service Loadings and Stress Limit Coefficients

Loading Category	Stress Limit Coefficient	Level of Services
Normal	1.0	Design and Level A
Severe	1.33	Level B
Extreme	1.5	Level C
Abnormal	1.5	Level C
Abnormal Severe	1.5	Level C
Abnormal Extreme	1.7	Level D

3.6 Thermal stresses within the support as defined by NF-3121.11 need not be evaluated. For component supports designed as Linear Standard Supports, the range of primary plus secondary stresses resulting from level A and B loading shall be limited to $2S_y$ or S_u at temperature, whichever is less.

3.7 Shear stress limit shall not exceed $0.42S_u$, at temperature.

3.8 To avoid column buckling, the allowable stresses shall be limited to two-third of the critical buckling stresses.

3.9 The stress limit coefficients in Table 3.2 are not intended for control of deformations. When required by the Design Specification, deformation control must be considered separately.

3.10 As an alternative to design by analysis, Design by Load Rating as defined in NF-3380 and NF-3480 may be used.

3.11 Plastic design per Part 2 of ANSI/AISC N690 shall not be used.

4 FABRICATION

4.1 The requirements for welding qualifications given in NF-4300 may be used for any portion of the fabrication and installation in lieu of those specified in ANSI/AISC N690 provided all such welding is performed by an NPT Certificate Holder.

4.2 Thermal cutting is prohibited on quenched and tempered steels.

5 EXAMINATION

5.1 All full penetration butt welded joints in Class 1 supports shall be nondestructively examined by radiographic or ultrasonic methods in accordance with ANSI/AISC N690.

5.2 All other welded joints in Class 1 supports shall be nondestructively examined by liquid penetrant or magnetic particle methods in accordance with ANSI/ AISC N690.

5.3 All NDE personnel shall be qualified to the requirements of ANSI/AISC N690, and all nondestructive examinations shall be supervised or performed by an AWS Certified Welding Inspector.

5.4 As an alternative to 5.3, NPT Certificate Holders may use NF-5500 for NDE personnel qualification.

6 STAMPING

6.1 The requirements of NF-8000 for nameplates, stamping and Data Reports are not required for Linear Piping and Linear Standard Supports designed and constructed to the requirements of ANSI/AISC N690.

Approval Date: March 12, 1997

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-573
Transfer of Procedure Qualification Records Between Owners
Section XI, Division 1

Inquiry: What alternatives to the welding and brazing procedure qualification requirements of IWA-4000 may be used?

Reply: It is the opinion of the Committee that as an alternative to the welding and brazing procedure qualification requirements of IWA-4000, a procedure qualification record (PQR) qualified by one Owner may be used by another Owner. When this alternative is used, the following requirements shall be met:

(a) The Owner that performed the procedure qualification test shall certify, by signing the PQR, that testing was performed in accordance with Section IX.

(b) The Owner that performed the procedure qualification test shall certify, in writing, that the procedure qualification was conducted in accordance with a Quality Assurance Program that satisfies the requirements of IWA-1400.

(c) The Owner accepting the completed PQR shall accept responsibility for obtaining any additional supporting information needed for WPS development.

(d) The Owner accepting the completed PQR shall document, on each resulting WPS, the parameters applicable to welding. Each WPS shall be supported by all necessary PQRs.

(e) The Owner accepting the completed PQR shall accept responsibility for the PQR. Acceptance shall be documented by the Owner's approval of each WPS that references the PQR.

(f) The Owner accepting the completed PQR shall demonstrate technical competence in application of the received PQR by completing a performance qualification test using the parameters of a resulting WPS.

(g) The Owner may accept and use a PQR only when it is received directly from the Owner that certified the PQR.

(h) Use of this Case shall be shown on the NIS-2 form documenting welding or brazing.

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Approval Date: August 14, 1997

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-575
Alternative Examination Requirements for Full Penetration Nozzle-to-Vessel Welds in Reactor Vessels With Set-On Type Nozzles
Section XI, Division 1

Inquiry: When performing volumetric examinations in accordance with Table IWB-2500-1, Examination Category B-D, Item No. B3.90, what alternative requirements may be applied in lieu of volumetrically examining volume A-B-C-D-E-F-G-H as shown in Fig. IWB-2500-7(c)?

Reply: It is the opinion of the Committee that, for the configuration shown in Figure 1, volumetric examinations may be performed on the alternative examination volume shown in Figure 2, provided the following conditions are met:

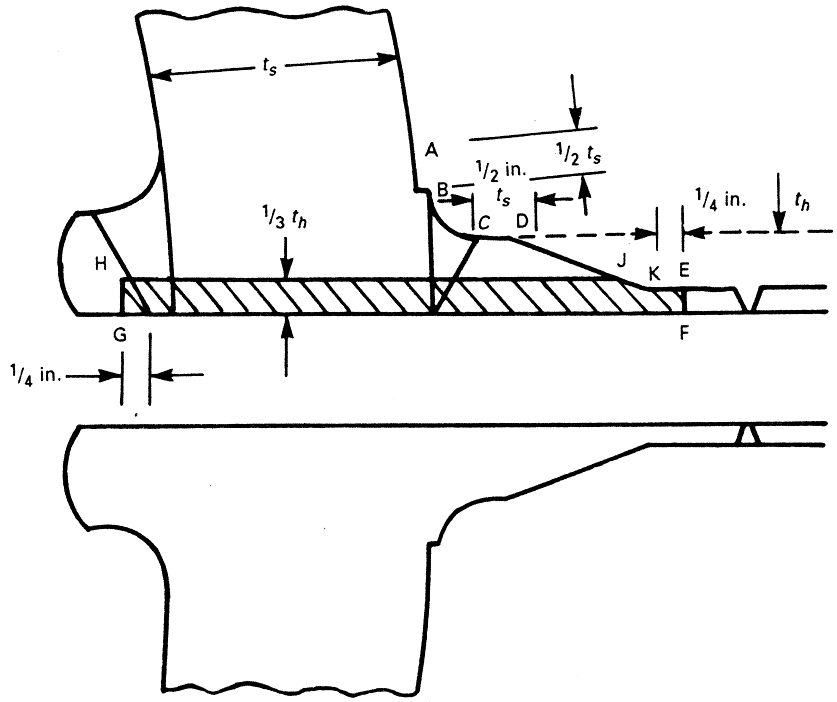
(a) The inside diameter of the nozzle shall be 4 in. or less;

(b) The thickness of the vessel shall be 4 in. or greater;

(c) A surface examination in accordance with the requirements of Section XI, Division 1, shall be performed on area A-B-C-D as shown in Figure 2;

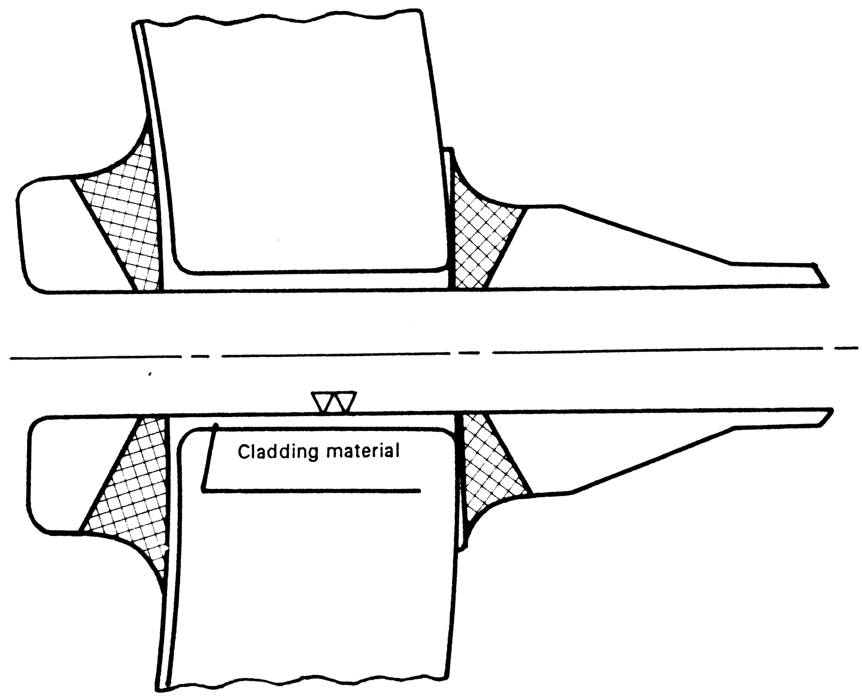
(d) This Case number shall be shown on the Data Report.

Figure 1
Nozzle-to-vessel Configuration



Examination Region	Exam. Volume	Exam. Surface
Attachment weld inside control	E-F-G-H-J-K	A-B, C-D

Figure 2
Alternative Examination Volume



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Approval Date: March 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-576-2
Repair of Classes 1 and 2 SB-163, UNS N06600 Steam Generator Tubing
Section XI, Division 1

Inquiry: In lieu of meeting the requirements of the Construction Code, as required by IWA-4411,[1] may SB-163, UNS N06600, steam generator tubing be repaired by applying a laser beam weld (LBW) deposit on the inside surface of the steam generator tubing?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4411[1] SB-163, UNS N06600, steam generator tubing may be repaired by means of partial penetration, with filler metal, laser beam welding (LBW) on the inside surface of the tube in accordance with the following requirements.

1 GENERAL REQUIREMENTS

(a) The repair shall be performed in accordance with a Repair/Replacement Program and Plan satisfying the requirements of IWA-4000 in the Edition and Addenda of Section XI applicable to the plant inservice inspection program, or later Edition and Addenda.

(b) Laser beam welding shall be performed in accordance with a procedure qualified in accordance with this Case and in accordance with the Repair/Replacement Program and Plan.

(c) Welding operator performance qualification tests shall be performed in accordance with the requirements of this Case.

(d) The suitability evaluation required by the Owner shall document the probable cause of the original flaw and potential flaws in adjacent location and shall ascertain that the LBW deposit and adjacent base material are more resistant to the failure mechanism than the parent material. The maximum permissible LBW deposit length shall be determined by this evaluation.

(e) The Owner shall perform in accordance with IWB-3630, evaluation of an assumed flaw within the LBW deposit with a depth of 20% of the minimum qualified LBW deposit thickness.

(f) The requirements of NB-3222 through NB-3229,[2] as applicable, shall be met for the pressure boundary and the tube material adjacent to the LBW deposit. The Owner shall establish the material properties of the LBW deposited materials necessary for this analysis.

(g) Each LBW deposit, and adjacent tube base material extending a minimum of $^1/_{16}$ in. from each end of the LBW deposit, shall receive a postweld heat treatment (PWHT).

(h) The LBW deposit shall be applied over 360 deg of the I.D. circumference of the tube.

(i) Weld repair of an LBW deposit requires requalification of the weld procedure if any essential variable is changed.

(j) The LBW deposit is defined as the recast material consisting of a combination of the remelted tube base material and the added weld filler material.

2 MATERIAL REQUIREMENTS

The weld filler material used in the LBW process shall be certified by the manufacturer to meet the requirements of Table 1.

3 PROCEDURE QUALIFICATION REQUIREMENTS

(a) The repair organization shall complete a weld procedure qualification in accordance with the latest mandatory Edition and Addenda of Section IX, and the additional requirements and exemptions to Section IX, as specified in this Case.

(b) The procedure qualification shall also meet the requirements of IWA-4721 and IWA-4723 of the 1995 Addenda of Section XI, with the following changes and additions:

[1] The references in this Case are based on the 2010 Edition with the 2011 Addenda, except where references have specific Edition or Addenda specified. For use with other Editions or Addenda, refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

[2] All references to Section III are applicable to the 1986 Edition with the 1986 Addenda through the 1995 Edition with the 1995 Addenda. Use of later Section III Editions or Addenda is permitted, provided they are reconciled with these requirements.

Table 1
Chemical Requirements

Element	Composition, %
Carbon	0.01–0.10
Chromium	42.0–46.0
Copper, max.	0.50
Iron, max.	0.50
Manganese, max.	0.20
Nickel	Balance
Phosphorus	0.020
Silicon, max.	0.20
Sulfur, max.	0.015
Titanium	0.30–1.00
Other elements, max.	0.50

(1) Reference to "sleeve" or "sleeving" shall be replaced by "weld repair."

(2) The following essential variables are added:

(-a) a change in welding position from horizontal (vertical tubes) to any other position.

(-b) a change in the length of the LBW deposit beyond the upper and lower bounds of the range qualified.

(-c) a change in the PWHT temperature beyond the upper and lower bounds of the range qualified. The procedure shall be qualified using both the upper and lower PWHT temperatures.

(-d) a change in weld location, i.e., tube support plate, tube sheet, free span, or in the sludge pile.

(-e) a change from welding with water, on the outer surface of the tube to welding without water on the outer surface of the tube, and vice versa.

(-f) the burst test coupon material for the qualification test shall be made from SB-163, UNS N06600.

(-g) the LBW deposit and adjacent base material (HAZ) shall be demonstrated to be more resistant to the failure mechanism than the parent material.

(c) The chromium composition at the I.D. surface of the LBW deposit shall be measured on at least two separate procedure qualification test specimens. This analysis shall be performed in accordance with ASTM E354-93. The minimum chromium level for the LBW deposit shall be 20%. If multiple layers are used, the first layer shall be evaluated.

(d) Testing of Procedure Qualification Specimens:

(1) Examination of the five test specimens in accordance with IWA-4723.2(d) of the 1995 Addenda of Section XI shall include the full length of the LBW deposit.

(2) Burst testing shall be performed on at least two additional, separate procedure qualification test specimens as a substitute verification test method in lieu of the mechanical test requirements in Section IX.

(-a) Burst test specimens shall be prepared by mechanically removing the remaining, unmelted original tube base material from the LBW deposit exterior (360 deg) leaving only LBW deposit material for testing.

(-b) The minimum axial dimension of the exposed LBW deposit shall be equal to $5\sqrt{rt}$ where r is the inner radius of the parent tube and t is the nominal thickness of the parent tube.

(-c) The maximum exposed LBW deposit length and maximum total thickness (remaining, unmelted original tube wall plus LBW deposit) for the burst test specimens shall be equal to the minimum production repair length, excluding the transition region, and minimum total thickness. The minimum total thickness shall be within the length defined by 5(b).

(-d) The minimum length of the burst test specimen shall be 8 in., with the LBW deposit located midway along the tube length.

(-e) Specimen ends shall be sealed, and the specimen shall be pressurized until bursting occurs.

(-f) The burst test results shall meet one of the following requirements:

(-1) Bursting occurs in the tube base material, outside the LBW deposit area, at a burst pressure of at least 95% of the computed proof test pressure, as identified below, or

(-2) The test assembly withstands, without rupture, 105% of the computed proof test pressure defined by the following equation:

$$P = 2St/D$$

where

D = tube outside diameter
P = computed proof test pressure
S = minimum specified tensile strength of tube base material
t = nominal tube wall thickness

(3) Burst testing shall demonstrate a minimum LBW deposit ultimate tensile strength of 80 ksi.

(e) The entire length of each LBW deposit and adjacent tube base material extending a minimum of $^1/_{16}$ in. from each end of the LBW deposit transition region shall be examined in accordance with the requirements of (1), (2), (3), and (f).

(1) The ultrasonic method, in accordance with Section V, Article 5, shall be used to measure the following:

(-a) The minimum total thickness (remaining, unmelted original tube wall plus LBW deposit).

(-b) The axial length of the LBW deposit.

(-c) The size of lack of fusion to the base metal within the reinforcement length. No lack of fusion to the base metal greater than $^1/_8$ in. in length or width shall be allowed.

(2) Ultrasonic examination shall be performed in accordance with NB-2552, as modified by (-a), (-b), (-c), and (-d).

(-a) Replace NB-2552.1(c) with the following: Deposits with defects that produce indications in excess of the indications produced by the standard defects in the

reference specimen are unacceptable and shall be a basis of rejection of the procedure qualification specimen. Flaws in the underlying tube base material may be considered nonrelevant.

(-b) Amend NB-2552.1(a) to include the following: The examination shall be conducted with single axial and circumferential beam directions, provided meaningful indications are obtained from the standard defects in the reference specimen.

(-c) Amend NB-2552.3 to include the following: The location of the standard defects shall be within the area of the LBW deposit excluding the transition region.

(-d) Amend NB-2552.3 to include the following: The reference notches shall have a depth not exceeding 20% of the qualified LBW deposit thickness.

(3) The eddy current method, in accordance with IWA-2233 of the 1995 Addenda of Section XI, shall be used to examine the LBW deposit.

(-a) The acceptance criteria shall be in accordance with IWB-3521.1 of the 1995 Addenda of Section XI.

(-b) Amend IWB-3521.1 of the 1995 Addenda of Section XI to the following: **Allowable Flaws for U-Tube Steam Generators.** For single or multiple flaws of cracks, wastage, or intergranular corrosion in tubing meeting the requirements of NB-2550 and having an r/t ratio of less than 8.70, where r is the inside radius and t is the nominal wall thickness of the parent tube, the depth of an allowable O.D. flaw shall not exceed 20% of the qualified LBW deposit thickness, unless acceptance in accordance with IWB-3132 of the 1995 Edition of Section XI can be established. All linear indications within the LBW deposit shall be rejected. Flaws in the underlying tube base material may be considered nonrelevant.

(f) A demonstration of each examination system shall be conducted to demonstrate to the ANII the examination system's capability.

(1) The ultrasonic examination system shall be capable of the following:

(-a) Identifying the total thickness with a minimum accuracy of ±10%.

(-b) Identifying lack of fusion to the base metal with length or width dimensions of $^1/_8$ in., or less.

(-c) Identifying pre-existing flaws in the base tube and determining if the length of the LBW deposit on each side of the pre-existing flaws is in accordance with 5(b).

(2) The eddy current system shall be capable of the following:

(-a) detecting flaws in the LBW deposit of at least 20% of the qualified LBW deposit thickness.

(-b) the eddy current examination capability tests shall be demonstrated on samples welded to the requirements of this Case and containing representative flaws in the LBW deposit.

(-c) detecting the existing parent tube defect or tube support plate to verify that the LBW deposit is at the correct location.

(g) Failure of any one test shall constitute failure of the entire procedure qualification.

(h) The results of completed tests and examinations shall be documented on a Procedure Qualification Record. All essential variables shall be documented on this record. The repair organization responsible for the procedure qualification shall sign the Procedure Qualification Record, certifying its accuracy.

4 WELDING OPERATOR PERFORMANCE QUALIFICATION REQUIREMENTS

Welding operator performance qualification shall be as follows:

(a) Essential variable. A change in laser type (e.g., a change from CO_2 to YAG) shall require requalification of the welding operator.

(b) The test assembly for the performance qualification of welding operators shall be the same as for a welding procedure qualification.

(c) The performance qualification shall be made in accordance with a qualified WPS.

(d) One test assembly is required.

(e) The welded test assembly shall be sectioned axially through its center. The two faces of one of the half-sections shall be polished and etched with a suitable etchant to give a clear definition of the weld metal and heat affected zone and shall be visually examined at 10X. The weld shall be free of cracks and lack of fusion. If the test assembly fails, the welding operator may be immediately retested by welding two consecutive test assemblies, both of which must be acceptable when examined. Alternatively, the operator may receive additional training with the laser welding equipment, and may be retested by welding only one test assembly.

(f) Renewal of performance qualification is required when the welding operator has not welded using the laser process for more than 6 mo, or when there is any reason to question his ability to make acceptable welds. Renewal of qualification shall be identical to the initial qualification.

5 PRODUCTION PROCEDURE REQUIREMENTS

(a) Each LBW operation shall be performed in accordance with a WPS containing the variables required by Section IX and the additional variables of this Case.

(b) Each LBW deposit shall be of sufficient length to equal the length of the pre-existing defect, (based upon prerepair nondestructive examination) plus a length added to either side of the defect equal to the sum of the uncertainty of the axial positioning of the LBW tooling in the steam generator tubing and the greater of (1) or (2):

(1) the uncertainty of the defect length based upon the prior examination method and procedure

(2) a length equal to $\sqrt{rt}$, where r is the tube inside radius and t is the nominal tube wall thickness

(c) The transitions at the ends of the LBW deposit shall permit volumetric inspection and flaw detection in the transition zones.

(d) The surface of each LBW deposit shall be suitably smooth to permit nondestructive examination of the LBW deposit, base tube, and transition regions.

6 EXAMINATION REQUIREMENTS

Following installation of an LBW deposit, nondestructive examination shall be performed on the entire length of the LBW deposit and adjacent tube base material extending a minimum of $^1/_{16}$ in., from each end of the LBW deposit transition region. The flaw detection methods and acceptance criteria shall be in accordance with 3(e) and 3(f).

(a) The ultrasonic method shall be used for the following:

(1) To measure the total thickness (remaining, unmelted original tube wall plus weld buildup) and LBW deposit length, and to verify that the dimensions are within the range qualified. For each LBW deposit, the minimum thickness shall comply with 3(e)(1)(-a) within the length defined by 5(b) and the minimum length shall comply with 5(b).

(2) To identify and size areas of lack of fusion to the base metal within the LBW deposit length. Lack of fusion to the base metal greater than $^1/_8$ in. in any dimension is unacceptable.

(3) To verify that the LBW deposit extends beyond either end of the remnants of the pre-existing axial defects in accordance with 5(b).

(b) The eddy current method shall be used for the following:

(1) To detect the existing parent tube defect or tube support plate extent and verify that the LBW deposit is located at the correct location.

(2) To detect flaws within the LBW deposit. The inspection parameters shall be established to maximize sensitivity within the LBW deposit. All linear indications within the LBW deposit shall be rejected.

(3) The examination requirements of this Case satisfy the preservice examination requirements of Section XI for the repair.

(4) The Owner shall prepare a plan for monitoring the condition of the LBW deposit.

7 DOCUMENTATION REQUIREMENTS

Use of this Case shall be documented on Form NIS-2.

Approval Date: March 28, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-577-1
Risk-Informed Requirements for Class 1, 2, or 3 Piping, Method A
Section XI, Division 1

Inquiry: What alternative to the requirements of Subsections IWB or IWC or additional requirements for Subsection IWD may be used for inservice inspection of Class 1, 2, or 3 piping?

Reply: It is the opinion of the Committee that the following requirements may be used as an alternative to the requirements of Subsections IWB or IWC or as additional requirements of Subsection IWD for inservice inspection of Class 1, 2, or 3 piping.

TABLE OF CONTENTS

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

This Case provides risk-informed requirements for inservice inspection of Class 1, 2, or 3 piping. For Class 1 or 2 piping, these requirements are an alternative to the requirements of Categories B-F, B-J, C-F-1, or C-F-2. For Class 3 piping, the requirements in this Case are new. Each selected Class of piping shall include all systems and portions of systems in that Class. Application of this Case to Class 3 piping may result in a requirement for additional examinations.

-1200 PIPING SUBJECT TO EXAMINATION

The examination requirements of this Case shall be used for Class 1, 2, or 3 piping evaluated by the risk-informed process. Piping in systems evaluated as part of the plant Probabilistic Risk Assessment (PRA), but outside the current Section XI examination boundaries may be included.

-2000 EXAMINATION AND INSPECTION

-2110 Duties of the Inspector

Duties of the Inspector shall be in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

-2400 INSPECTION SCHEDULE

-2410 Inspection Program

The examinations of Examination Category R-A shall be completed during each inspection interval in accordance with Table IWB-2411-1 or Table IWB-2412-1, with the following exceptions.

(a) If, during the interval, a reevaluation using the risk-informed process of this Case is conducted and scheduled items are no longer required to be examined, these items may be eliminated regardless of the percentage requirements of Table IWB-2411-1 or Table IWB-2412-1.

(b) If during the interval, a reevaluation using the risk-informed process of this Case is conducted and items are required to be added to the examination program, those items shall be added in accordance with IWB-2412 of the 1994 Addenda.

-2420 Successive Inspections

(a) The sequence of piping examinations established during the first inspection interval using the risk-informed process shall be repeated during each successive inspection interval; however, the examination sequence may be revised to satisfy the requirements of Table IWB-2411-1 or Table IWB-2412-1.

(b) If piping structural elements are accepted for continued service by analytical evaluation in accordance with -3200, the areas containing the flaws or relevant conditions shall be reexamined during the next three inspection periods referenced in the schedule of the inspection program of -2400.

(c) If the reexaminations required by (b) reveal that the flaws or relevant conditions remain essentially unchanged for three successive inspection periods, the piping examination schedule may revert to the original schedule of successive inspections.

-2430 Additional Examinations

(a) Examinations performed in accordance with -2500 that reveal flaws or relevant conditions exceeding the acceptance standards of -3000 shall be extended to include additional examinations. The additional examinations shall include piping structural elements described in Table 1 with the same postulated failure mode and the same or higher failure potential.

(1) The number of additional elements shall be the number of piping structural elements with the same postulated failure mode originally scheduled for that fuel cycle.

(2) The scope of the additional examinations may be limited to those High-Safety-Significant (HSS) piping structural elements within systems whose materials and service conditions are determined by an evaluation to have the same postulated failure mode as the piping structural element that contained the original flaw or relevant condition.

(b) If the additional examinations required by (a) reveal flaws or relevant conditions exceeding the acceptance standards of -3000, the examination shall be further extended to include additional examinations.

(1) These examinations shall include all remaining piping elements within Table 1 whose postulated failure modes are the same as the piping structural elements originally examined in (a).

(2) An evaluation shall be performed to establish when those examinations are to be conducted. The evaluation must consider failure mode and potential.

(c) For the inspection period following the period in which the examinations of (a) or (b) were completed, the examinations shall be performed as originally scheduled in accordance with -2400.

-2500 EXAMINATION AND PRESSURE TEST REQUIREMENTS

(a) Piping structural elements determined to be HSS in accordance with Mandatory Appendix I shall be examined as required by Table 1.

(b) Pressure testing and VT-2 visual examinations shall be performed on Class 1, 2, and 3 piping systems in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

(c) Examination qualification and methods and personnel qualification shall be in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

Table 1
Examination Categories

EXAMINATION CATEGORY R-A, RISK-INFORMED PIPING EXAMINATIONS

					Extent and Frequency		
Item No.	Parts Examined	Examination Requirement/ Fig. No. [Note (2)], [Note (10)]	Examination Method [Note (12)]	Acceptance Standard [Note (10)]	1st Interval		Defer to End of Interval
R1.10	High-Safety-Significant Piping Structural Elements						
R1.11	Elements Subject to Thermal Fatigue	IWB-2500-8(c) [Note (1)], IWB-2500-9, IWB-2500-10, IWB-2500-11, IWC-2500-7(a) [Note (1)]	Volumetric	IWB-3514	Element [Note (2)], [Note (4)]		Not Permissible
R1.12	Elements Subject to High Cycle Mechanical Fatigue	N/A	Visual, VT-2 [Note (11)]	IWB-3142	Each Refueling		Not Permissible
R1.13	Elements Subject to Erosion Cavitation	IWB-2500-8(c)	Volumetric [Note (9)]	IWB-3514 [Note (8)]	Element [Note (2)]		Not Permissible
R1.14	Elements Subject to Crevice Corrosion Cracking	[Note (7)]	Volumetric	IWB-3514	Element [Note (2)]		Not Permissible
R1.15	Elements Subject to Primary Water Stress Corrosion Cracking (PWSCC) [Note (6)]	N/A	Visual, VT-2 [Note (11)]	IWB-3142	Each Refueling		Not Permissible
R1.16	Elements Subject to Intergranular or Transgranular Stress Corrosion Cracking (IGSCC or TGSCC)	IWB-2500-8(c), IWB-2500-9, IWB-2500-10, IWB-2500-11	Volumetric	IWB-3514	Element [Note (2)]		Not Permissible
R1.17	Elements Subject to localized [Microbiologically-Induced Corrosion (MIC) or Pitting]	IWB-2500-8(c) IWB-2500-9, IWB-2500-10, IWB-2500-11	Visual, VT-3 Internal Surfaces or Volumetric [Note (8)]	[Note (8)]	Element [Note (2)]		Not Permissible
R1.18	Elements Subject to Flow Accelerated Corrosion (FAC)	[Note (9)]	[Note (9)]	[Note (9)]	[Note (9)]		[Note (9)]
R1.19	Elements Subject to External Chloride Stress Corrosion Cracking (ECSCC)	IWB-2500-8(c)	Surface	IWB-3514	Element [Note (2)]		Not Permissible
R1.20	Elements not Subject to a Damage Mechanism	IWB-2500-8(c) [Note (1)], IWB-2500-9, IWB-2500-10, IWB-2500-11, IWC-2500-7(a) [Note (1)]	Volumetric	IWB-3514	Element [Note (2)], [Note (4)]		Not Permissible

NOTES:
(1) The length for the examination volume shall be increased to include $\frac{1}{2}$ in., beyond each side of the base metal thickness transition or counterbore.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(2) Includes all examination locations identified in accordance with the risk-informed selection process in Mandatory Appendix I.

(3) Includes 100% of the examination location. When the required examination volume or area cannot be examined due to interference by another component or part geometry, limited examinations shall be evaluated for acceptability by the Expert Panel. Acceptance of limited examinations or volumes shall not invalidate the resul risk-informed evaluation. Areas with acceptable limited examinations, and their bases, shall be documented.

(4) The examination shall include any longitudinal weld at the location selected for examination in [Note (2)]. The longitudinal weld examination requirements shall be met for both transverse and parallel flaws examination volume defined in [Note (2)].

(5) Initially-selected examination locations are to be examined in the same sequence during successive inspection intervals, to the extent practical.

(6) Applies to mill annealed Alloy 600 nozzle welds and heat affected zone (HAZ) without stress relief.

(7) The examination volume shall include the volume surrounding the weld, weld heat affected zone, and base metal, where applicable, in the crevice Examination should focus on detection of cracks initiating and propagating from the inner surface.

(8) The examination volume shall include base metal, welds, and weld HAZ in the affected regions of carbon and low alloy steel, and the welds and HAZ of austenitic steel. Examinations shall verify the minimum wall thickness required. Acceptance criteria for localized thinning is in the course of preparation. The examin method and examination region shall be sufficient to characterize the extent of the element degradation.

(9) In accordance with the Owner's existing FAC program.

(10) Paragraph and figure numbers refer to the 1989 Edition.

(11) VT-2 examinations may be conducted during a system pressure test or a pressure test specific to that element.

(12) Socket welds require only a VT-2 examination each refueling outage.

-3000 ACCEPTANCE STANDARDS

-3100 STANDARDS

-3110 Characterization

When a volumetric or surface examination method is used, each flaw or group of flaws shall be characterized in accordance with IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of -3200.

-3120 Acceptability

Flaws, areas of degradation, or relevant conditions that do not exceed the allowable acceptance standards of -3200 are acceptable.

-3200 ACCEPTANCE STANDARDS

For component configurations or examination methods not addressed by Table 1, the Owner shall develop acceptance criteria consistent with the requirements of IWA-3000. The referenced paragraphs below and in Table 1 shall be applied in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

(a) Flaws that exceed the acceptance standards listed in Table 1 found during surface or volumetric examinations may be accepted by repair/replacement activities or analytical evaluation, as specified in IWB-3130 (IWB-3120 prior to the Winter 1983 Addenda).

(b) Flaws or relevant conditions that exceed the acceptance standards listed in Table 1 found during visual examinations may be accepted by supplemental examination, corrective measures, repair/replacement activities, or analytical evaluation, as specified in IWB-3140 (IWB-3130 prior to the Winter 1983 Addenda).

(c) Other unacceptable conditions not addressed by (a) or (b) may be accepted by repair/replacement activities in accordance with -4000, or by analytical evaluation in accordance with IWA-3000.

-4000 REPAIR/REPLACEMENT PROCEDURES

Repair/replacement activities shall be performed in accordance with the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program.

-5000 SYSTEM PRESSURE TESTS

IWA-5000, IWB-5000, IWC-5000, and IWD-5000 of the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program apply for the piping under evaluation.

-6000 RECORDS AND REPORTS

IWA-6000 of the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program applies.

-9000 GLOSSARY

accident sequence: a combination of events leading from an initiating event that challenges safety systems to an undesired consequence, such as core damage or a breach of containment integrity.

core damage: prolonged oxidation and severe fuel damage due to uncovering and heatup of the reactor core.

core damage frequency (CDF): an estimate of the likelihood of a severe accident associated with core damage.

event tree: a quantifiable logical network that begins with an initiating event or condition and progresses through a series of branches (usually binary) that represent expected system or operator performance that either succeeds or fails and arrives at either a success or failed condition (e.g., core damage) at the end of the tree.

failure: events involving leakage, rupture, or conditions that would disable a component's ability to perform its intended safety function.

failure mode: a condition or degradation mechanism that can cause a failure.

failure modes and effects analysis: an analysis intended to identify the conceivable failure modes of a component and the impact of the failure on operations, the system, and surrounding components along with the likelihood of the failure and consequences.

initiating event: any event that perturbs the steady state operation of the plant, if operating, or the steady state operation of the decay heat removal systems during shutdown operations such that a transient is initiated in the plant that leads to the need for reactor subcriticality and decay heat removal.

large early release: a radioactivity release from the containment involving the rapid unscrubbed release of airborne fission products to the environment occuring before the effective implementation of off-site emergency response and protective actions.

large early release frequency (LERF): an estimate of the likelihood of a severe accident associated with a radioactive release from containment.

piping segment: a portion of piping for which a failure at any point in the segment results in the same consequence (e.g., loss of the system, loss of a pump train) as a failure at any other point in the segment and includes piping structural elements between major discontinuities, such as pumps and valves.

piping structural element: an item within a specified piping segment, such as a straight length of pipe, a pipe elbow, a coupling, a fitting, a flanged joint, or a weld.

piping system: an assembly of piping segments, piping supports, and other components that may consist of one or more Code classes with a defined function as described within the Owner's Inservice Inspection Program.

probabilistic risk assessment (PRA): a quantitative assessment of the risk associated with plant operation and maintenance and measured in terms of frequency of occurrence of different events, including severe core damage or a breach of containment integrity.

recovery action: a human action performed to recover from a specific failure in order to mitigate or reduce the consequences of the failure.

spatial effects: a failure consequence affecting other systems or components, such as failures due to pipe whip, jet impingement, or flooding.

MANDATORY APPENDIX I
RISK-INFORMED PROCESS

I-1 INTRODUCTION AND SCOPE

This Appendix provides the risk-informed selection process to be used for the selection of piping segments and piping structural elements (including connections) in systems that will be scheduled for inservice inspection.

I-2 EXPERT PANEL REQUIREMENTS

I-2.1 GENERAL

Each Owner shall establish an expert panel to implement the risk-informed selection process described in this Appendix. The expert panel shall be indoctrinated in the specific requirements to be used under this risk-informed selection process. Risk analysis techniques shall include the use of applicable risk-importance measures, threshold values, failure probability models, failure mode assessments, and the use of expert judgment. Each of these techniques shall be covered in the indoctrination to the extent necessary to provide the expert panel with a level of knowledge needed to adequately evaluate and approve the scope of the risk-informed selections.

I-2.2 EXPERT PANEL FORMATION

Panel members selected for this risk-informed selection process shall include members of the expert panel established to implement other Probabilistic Risk Assessment (PRA) applications such as those associated with maintenance, quality assurance, or inservice testing activities, if such a panel were used. The panel for this risk-informed selection process shall include individuals having expertise in the following fields:

(a) Probabilistic risk assessment;

(b) Inservice examination;

(c) Nondestructive examination;

(d) Stress and material considerations;

(e) Plant operations;

(f) Plant and industry maintenance, repair and failure history;

(g) System design and operation.

The Owner shall define and document quorum requirements. Members may be experts in more than one field, but the Owner shall consider the diversity of the panel make-up, avoiding heavy reliance on any one member's judgment. The Owner is responsible for ensuring adequate experience levels for each expert panel member. This experience shall be documented and maintained by the Owner.

I-2.3 EXPERT PANEL LEADER SELECTION

The Owner shall select a panel leader who is familiar with the requirements of this risk-informed selection process. The panel leader shall facilitate the panel activities and shall be responsible to ensuring accomplishment of this risk-informed selection process.

I-2.4 EXPERT PANEL RESPONSIBILITIES

The expert panel shall be responsible for evaluation and approval of all risk-informed selection results (i.e., system, segment, structural elements, and inspection selections) by utilizing their expertise (including knowledge of plant operation, prior inspection results, industry data, and any available stress and fracture mechanics results) and PRA insights to make the final decision on the HSS structural elements to be included for inservice inspection. Selections made in accordance with this process, or any other required input where the judgment of the expert panel is needed, shall be reached by consensus.

I-2.5 MAINTENANCE OF THE EXPERT PANEL

The Owner shall maintain the expert panel to allow changes as necessary to the risk-informed selections when new information is applied, as directed by the requirements of this Appendix. Members may be added or removed as needed as long as the requirements of I-2.2 are satisfied.

I-3 BOUNDARY REQUIREMENTS

I-3.1 BOUNDARY IDENTIFICATION

Boundaries for the scope of piping systems, or portions thereof, to be considered for evaluation in accordance with this risk-informed selection process must be clearly defined. They shall be determined according to the following requirements:

(a) Identify the piping boundaries of the applicable plant PRA and the current Section XI inservice inspection program Class 1, 2, or 3, examination boundaries. Examination boundaries are determined in accordance with the requirements of IWA-1320, and limited by exemptions under IWB-1220, IWC-1220, and IWD-1220. Examination Category C-F-1 and C-F-2 piping that is exempt from NDE under the requirements of Table IWC-2500-1 due to nominal wall thickness limitations shall be considered for selection in accordance with this process.

(b) PRA boundaries shall then be compared to the Section XI inservice inspection program Class 1, 2, or 3, examination boundaries.

(1) Piping items, or portions thereof included in both the plant PRA boundaries and the Section XI examination boundaries shall be included.

(2) Piping items, or portions thereof, that are included under the plant PRA boundaries, but are outside the current Section XI examination boundaries may be included.

(c) Piping items, or portions thereof within the Class 1, 2, or 3 boundaries (including exempt piping in (a) above) and known from PRA insights to have a high consequence contribution, shall be included.

I-3.2 USE OF THE APPLICABLE (2) PRA

The boundary requirements of I-3.1 shall be used to identify the piping systems, or portions thereof, to be considered for risk-informed selections of HSS and Low/Safety-Significant (LSS) piping segments and piping structural elements in accordance with this process. The Owner's Level 1 PRA and its evaluated safety function that consists of core damage protection and the risk measure associated with that safety function (core damage frequency), provides the necessary information for the piping system PRA boundaries to be used in this process. If a piping system, or portions thereof, provides an additional safety function such as containment integrity, then insights from the Owner's Level 2 PRA may be used, as it relates to its associated risk measure and safety function (large early release frequency). Use of PRA insights beyond the Level 1 PRA for the determination of system boundaries to be considered in this process shall be documented, reviewed, and approved by the expert panel. The expert panel must clearly define how the safety function of the piping has been addressed, and whether the risk-informed selection process used is still applicable to this piping.

I-3.3 ADEQUACY OF THE APPLICABLE (2) PRA

The PRA shall meet the guidelines of the "PSA Applications Guide," EPRI TR — 105396, Tables 3-1, 3-2, and Appendix B: Checklist for Technical Consistency in a PSA Model, dated August 1995.[1] Alternatively, the PRA may meet the requirements of a document approved by the regulatory authority having jurisdiction at the plant site that provides requirements for PRA adequacy.

I-4 RISK-INFORMED PROCESS

I-4.1 GENERAL

The risk-informed selection of nuclear power plant piping segments and piping structural elements shall be performed by an Owner using the process described in this Appendix. The final result of this process is to identify those HSS piping structural elements that will be examined in accordance with Table 1. The basic overview of this process is provided in Figure I-1.

I-4.2 QUANTITATIVE APPROACH

I-4.2.1 General. The process for this quantitative approach uses risk-based ranking calculational methods, with established threshold values, and risk-informed considerations of operational and deterministic insights to select a final list of HSS piping structural elements to be included in an inservice inspection program. This approach is divided into four major tasks:

(a) identify and define the piping system boundaries, and portions thereof, that will be considered in this risk-informed selection process in accordance with the boundary requirements of I-3;

(b) define, calculate, rank, and then select the HSS piping segments within these identified systems using the failure modes and effects analysis (FMEA) technique and relevant plant information, including the plant PRA results;

(c) assess or calculate, rank, and then select the HSS piping structural elements, such as welds, elbows, and tees, within the HSS piping segments that will form the risk-informed inservice inspection program for piping; and

(d) determine the areas or volumes of the selected piping structural elements to be scheduled for examination, and the appropriate examination methods or monitoring techniques to be used, in accordance with Table 1.

I-4.2.2 Risk Importance Measures. Risk Reduction Worth (RRW) shall be used as the primary risk importance measure in this risk-informed selection process. In addition, the Risk Achievement Worth (RAW) importance measure shall be considered in accordance with I-4.2.6(b)(1). RRW and RAW are used in failure consequence calculations, as discussed below:

(a) Risk Reduction Worth. RRW indicates the reduction factor in risk if the piping is assumed perfectly reliable for all failure modes. The RRW is calculated by reevaluating the PRA model and substituting a value of zero for the component unavailability for each piping segment of interest. Thus, RRW is represented as follows:

$$RRW = R_o/R_{\bar{i}}$$

where

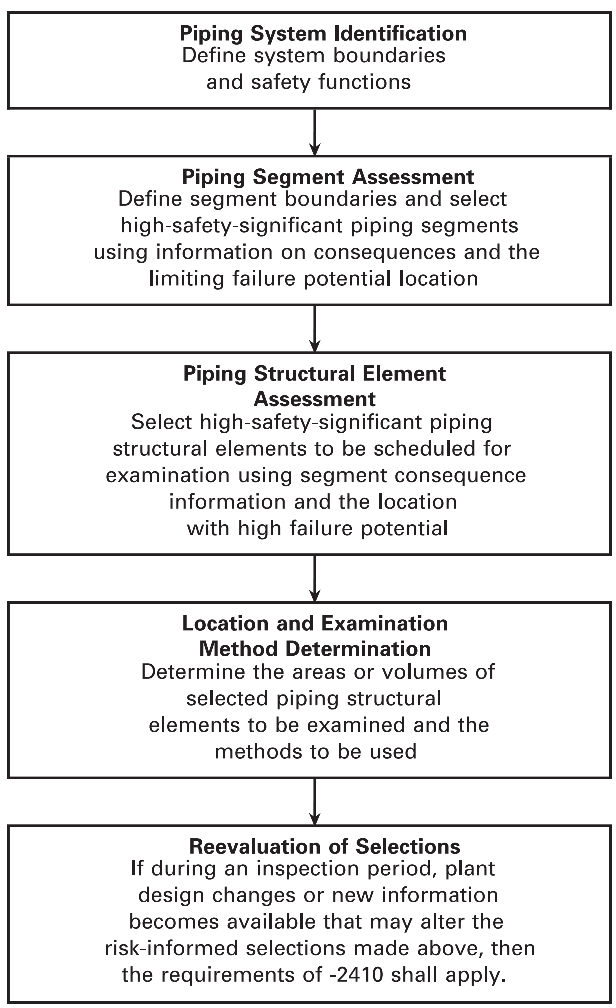
$R_{\bar{i}}$ = decreased risk level (total core damage frequency or large early release frequency from piping pressure boundary failures) with the component assumed to be perfectly reliable

[1] Copies of this report may be obtained from the Electric Power Research Institute, Palo Alto, California.

Table I-1
Definition of Failure Probability Estimates for Pipe Segments

Definition	Failure Probability (per year)
An event that individually may be expected to occur more than once during the lifetime of the pipe segment.	10^{-1}
An event that individually may be expected to occur during the lifetime of the pipe segment.	10^{-2}
An event that individually is not expected to occur during the lifetime of the pipe segment; however, when considering all piping systems, an event in this category has the credibility of happening once.	10^{-4}
An event of such low probability that an event in this category is rarely expected to occur.	10^{-6}
An event of such extremely low probability that an event in this category is considered to be incredible.	10^{-8}

Figure I-1
Overview Risk-informed Selection Process



R_o = base risk level (total core damage frequency or large early release frequency from piping pressure boundary failures only)

(1) Fussell-Vesely. Fussell-Vesely (F-V) importance may be used in lieu of RRW because of the mathematical relationship between the measures. The following relationship allows translation of F-V results to RRW if the F-V is less than 0.1:

$$RRW = \frac{1}{[1 - (\mathrm{F} - \mathrm{V})]}$$

(b) Risk Achievement Worth. RAW indicates the increased factor in risk if the piping is assumed failed for all failure modes. The RAW is calculated by reevaluating the PRA model and substituting a value of unity for the component unavailability belonging to the piping segment of interest. Thus, RAW is represented as follows:

$$RAW = R_i^+ / R_o$$

where

R_i^+ = increased risk level (core damage frequency or large early release frequency from piping pressure boundary failures) without component i, or with component i assumed failed

R_o = base risk level (core damage frequency or large early release frequency from piping pressure boundary failures only)

I-4.2.3 Selection of Systems. The expert panel shall determine from the boundary requirements of I-3 the systems and portions thereof that will be considered in this risk-informed selection process. The final system list along with the rationale for any decisions, including those affected by other PRA application considerations such as risk significance determinations, shall be documented.

I-4.2.4 Piping Segments Risk Ranking and Selection. The selected systems (as identified in I-4.2.3) shall be divided into piping segment. The ranking process is found in I-4.2.5 and I-4.2.6.

I-4.2.5 Calculation of Piping Segment Risk Importances. The FMEA technique, or a similar approach, shall be used to rank piping segments within the selected systems on the basis of core damage frequency and, if possible, large early release frequency. Relevant plant information that is used for initial formulation of the FMEA shall be realistic as possible and reflect current plant operational practices. The FMEA technique should include at least the following information.

(a) Piping Segment. A location and boundary description of the segment that includes consideration of the number of structural elements, such as elbows, flow reducers, welds, and fittings, within the segment, and their nominal pipe size.

(b) Failure Mode. Identification of the full range of potential failure modes, such as mechanical fatigue, thermal fatigue, stress corrosion cracking, and flow accelerated corrosion (FAC), that may occur within the piping segment, and the identification of the particular structural elements where these failures are most likely to occur.

(c) Failure Probability. Estimates of the failure probability of a piping segment under consideration assuming no inservice inspection. Failure rates (on demand, per hour, or per year) are required inputs to the consequence calculations. The piping segment failure rate is analogous to the active component failure rates that are used in the PRA, where the rate is the number of observed failures divided by the number of years.

Historical or service data, expert judgment, or Structural Reliability Risk Assessment (SRRA) calculations shall be used to estimate the limiting piping segment failure probabilities. The selected experts shall have sufficient structural reliability knowledge to estimate the failure probability. The process shall integrate information from utility engineers and technical staff from relevant disciplines. Table I-1 provides definitions that have been found useful in having the selected experts relate their knowledge of piping failures to a failure probability. SSRA models that are used to estimate piping failure probabilities shall contain the following fundamental parameters:

(1) an appropriate geometric characterization of the piping segment of interest;

(2) flaw density and a size distribution after preservice inspection;

(3) a characterization of the loading conditions, including mean stress, cyclic stress, number of cycles for both expected and postulated events; a probabilistic treatment of the frequency and loading uncertainty of these events shall also be considered;

(4) the failure modes and degradation mechanism(s) that are identified to potentially occur within the piping segment of interest shall be characterized over the lifetime of the piping system, including a probabilistic treatment of the uncertainties in these potential failure modes and degradation mechanism, particularly those associated with aging effects;

(5) failure criteria shall be included, such as a limited loss of pipe wall, leaks, and rupture; the uncertainties in these parameters should also be probabilistically treated, as appropriate;

(6) the probabilistic calculations shall be performed using accepted mathematical processes, such as Monte-Carlo simulation, that are verified by appropriate means.

The above noted fundamental parameters for the SSRA calculations should also be considered if historical or service data, or expert judgment processes are used to estimate piping failure probabilities. Only estimates of limiting failure probabilities for the pipe segments are needed. The estimates should be based on the scope of structural elements within the piping segment, and consideration of particular structural elements that will dominate the overall failure probability for the piping segment.

(d) Failure Consequence. Failure consequences are:

(1) those pressure boundary failures affecting the function of the system in question often referred to as direct effects. The direct effects to be considered include

(-a) failures that cause an initiating event such as LOCA or reactor trip;

(-b) failures that disable a single train or system;

(-c) failures that disable multiple trains or systems; and

(-d) failures that cause any combination of the failures above.

(2) those pressure boundary failures affecting other systems, components or piping segments, often referred to as spatial or indirect effects, such as failures that cause pipe whip, jet impingement, or flooding.

The total effect on core damage and, if possible, large early release, given the failure of the piping segment under consideration, shall be assessed. Consideration shall be given to the failure mode postulated for the piping segment. The consequences must then be measured in the correct terms to ensure proper calculations of the risk measures.

The spatial effects of piping segment failure on other systems, components, or piping segments shall be approximated. Previous plant hazard evaluations are useful in this process, along with a plant walkdown. Any assessment, which when performed to determine that the effect on impacted targets would not cause any additional effects, interfere with the system operation, or prevent plant shutdown, shall be documented.

(e) Recovery Action. Consideration shall be given to evaluating the consequence of piping failure with and without operator recovery action.

(f) Core Damage Frequency. This value provides the risk, in terms of core damage frequency, in units of events per year, associated with the failure of the piping segment under consideration. The conditional core damage frequency/probability per failure is multiplied by the segment failure probability/rate to obtain a core damage frequency due to failures for each segment. If a quantitative level 2 PRA is available, the large early release frequency shall also be evaluated.

(g) Piping Segment Importances. The risk-importance measures defined in I-4.2.2 shall be used to assist in the piping segment risk selection.

(h) Remarks. Any other information, including the evaluation of other plant operating modes other than at-power and external events, that is appropriate to establish the importance of the piping segment shall be considered by the expert panel.

I-4.2.6 Select High-Safety-Significant Piping Segments. The expert panel shall:

(a) Apply the risk-importance measure RRW as described in I-4.2.2. Any piping segment exceeding the following screening criteria shall initially be considered HSS:

(1) RRW > 1.005

(b) Ideally, the screening criteria established by this quantitative approach should capture the HSS piping segments, but the following condition shall also be considered by the expert panel.

(1) All piping segments not exceeding the screening criteria shall be evaluated by the expert panel to determine whether any piping segment was inappropriately ranked below these threshold values. RAW insights may be considered. Considerations should be given to the limitations of the PRA implementation approach resulting from the PRA structure and to limitations in the meanings and uncertainty associated with the importance measures. The expert panel should also consider defense-in-depth, aging, deterministic and operational insights from inspection results, industry data, available pipe failure data, and other PRA application impacts. The expert panel shall then determine if additional piping segments should be considered HSS.

(c) The final HSS and LSS piping segments list, along with the rationale for any adjustments and decisions, shall be documented. The selection of structural elements for the final list of HSS piping segments, as described in I-4.2.8, shall be performed.

I-4.2.7 Process for Selecting Piping Structural Elements. The HSS piping segments, as identified in I-4.2.6 shall be selected for further evaluation at the piping structural elements level. The selection process is found in I-4.2.8.

I-4.2.8 Piping Structural Element Selection. A set of inspection locations shall be identified for which (1) failures will have greatest potential impact on safety, and (2) there is a greater likelihood of detectable degradation and consequently a greater potential for identifying, through NDE, piping degradation prior to failure. The following criteria shall be used:

(a) All high failure importance locations in each HSS piping segment identified as likely to be affected by a known or postulated degradation mechanism, must be examined. Portions of the pipe segment that have high failure potential should be selected for inspection. Exceptions include those locations already being examined under existing augmented programs.

(b) Other portions of the piping segment not affected by a known degradation mechanism should be evaluated using a statistical evaluation such as the process described in (c) below.

(c) For HSS piping segments with low failure potential, a statistical evaluation should be used to define the number of random locations to be examined. A sampling plan shall be selected for each segment that achieves at least

95% confidence (no more than 5% risk) of exceeding a target leak frequency defined from industry operating experience based upon the best estimate failure probability.

(d) To account for uncertainty and the possibility of unknown degradation mechanisms in the segment at least one element in each HSS piping segment shall be examined. The final list of structural elements and rationale for any decisions made in establishing this list shall be documented.

I-4.2.9 Change-In-Risk Evaluation

(a) A change-in-risk evaluation shall be performed prior to implementation of the program using the piping segment risk evaluation.

(b) Proprosed ISI program changes shall be assessed to determine compliance with the acceptance criteria contained in USNRC Regulatory Guide 1.174, July 1998, Section 2.2.4, and to quantitatively determine if any adjustments to the proposed ISI program or compensatory measures are needed. These acceptance criteria are intended to provide assurance that the effect of the proposed change in the ISI program is risk-neutral or that the increases in CDF and LERF due to the change are small.

(1) Types of attributes that should be considered in the quantitative evaluation include changes in:

(-a) inspection frequency,

(-b) inspection accuracy,

(-c) failure rates: verifiable values of failure rates shall be used in the quantification process for ISI components,

(-d) failure modes, and

(-e) compensatory measures: include those specifically incorporated into plant programs and those developed for specific situations. Management-directed compensatory measures should also be included in the quantitative assessment, as appropriate.

(c) The change-in-risk effects shall be qualitatively evaluated (i.e., risk decreases, as well as risk increases) for ISI program changes (e.g., inspection effectiveness).

I-4.2.10 Location and Examination Method Determinations. Once the piping structural elements list is completed in accordance with I-4.2.8, the areas or volumes of concern for each of the HSS piping structural elements shall be determined and documented. This determination is based on the postulated failure modes identified in I-4.2.5 and the configuration of each piping structural element. The examination methods or monitoring techniques that are to be used for these identified areas or volumes of concern shall be determined and documented.

I-5 REEVALUATION OF RISK-INFORMED SELECTIONS

I-5.1 GENERAL

Risk-informed selections made to the inservice inspection program for piping in accordance with -2410 shall be reevaluated as follows:

(a) New information may become available that could alter the risk-informed selections for piping. Such information may result from changes to the PRA, from inspection results, from new failure modes experienced by the industry, from replacement activities, from repair activities, or operational changes. The Owner must verify that the effect of the new information on the piping segments and piping structural elements would not alter the previous risk-informed selections. This verification shall be performed at least once each inspection period.

(b) When it is determined that the new information would affect the piping selections, the Owner shall reevaluate the previous selections made using the same risk-informed selection process approach that originally established the risk-informed inservice inspection program for piping.

(c) This reevaluation of the selections shall be performed by inserting the new information at the appropriate level of the analysis, e.g., piping segment or piping structural element. It may not be necessary to reperform the entire risk-informed selection process, but the evaluation of the changes to the piping selections that do occur shall be documented.

I-6 USE OF OTHER PIPING INSPECTION PROGRAMS

I-6.1 GENERAL

The Owner may have other piping inspection programs not covered by Section XI, Division 1. Each of these programs may address concerns associated with postulated failure modes for selected piping structural elements such as intergranular stress corrosion cracking, FAC, high energy line break conditions, or the identification of leakage by general operational walkdowns. When a piping structural element has been selected for inclusion into the risk-informed inservice inspection program, and the postulated failure modes for that piping structural elements are already being addressed by one of these other piping inspection programs, the Owner may use these programs to satisfy the examination requirements of Table 1, subject to the following conditions:

(a) the other inspection program shall use examination methods and techniques that would meet the requirements of IWA-2000 or be acceptable under IWA-2240;

(b) the examination methods or techniques shall cover the HSS areas or volumes of concern for selected piping structural elements; and

(c) use of these examination methods and techniques shall be documented, and then reviewed and approved by the expert panel.

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Approval Date: March 28, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-578-1
Risk-Informed Requirements for Class 1, 2, or 3 Piping, Method B
Section XI, Division 1

Inquiry: What alternative to the requirements of Subsections IWB or IWC or as additional requirements for Subsection IWD may be used for inservice inspection of Class 1, 2, or 3 piping?

Reply: It is the opinion of the Committee that, the following requirements may be used in lieu of the requirements of Subsections IWB or IWC or as additional requirements for Subsection IWD for inservice inspection of Class 1, 2, or 3 piping.

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-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

This Case provides risk-informed requirements for inservice inspection of Class 1, 2, or 3 piping. For Class 1 or 2 piping, these requirements are an alternative to the requirements of Categories B-F, B-J, C-F-1, or C-F-2. For Class 3 piping, the requirements in this Case are new. Application of this Case to Class 3 piping may result in a requirement for additional examinations.

This Case may be applied to all Class 1, 2, and 3 piping system, an individual Class of piping (e.g. Class 1 piping), or to individual systems. Systems that are not evaluated in accordance with this Case shall be examined in accordance with Examination Category B-F, B-J, C-F-1, or C-F-2, as applicable.

-1200 PIPING SUBJECT TO EXAMINATION

The examination requirements of this Case shall be used for Class 1, 2, or 3 piping evaluated by the risk-informed process. Piping in systems evaluated as part of the plant Probabilistic Risk Assessment (PRA), but outside the current Section XI examination boundaries may be included.

-2000 EXAMINATION AND INSPECTION

-2110 DUTIES OF THE INSPECTOR

Duties of the Inspector shall be in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

-2400 INSPECTION SCHEDULE

-2410 Inspection Program

The examinations of Examination Category R-A shall be completed during each inspection interval in accordance with Table IWB-2411-1 or Table IWB-2412-1, with the following exceptions.

(a) If, during the interval, a reevaluation using the risk-informed process of this Case is conducted and scheduled items are no longer required to be examined, these items may be eliminated regardless of the percentage requirements of Table IWB-2411-1 or Table IWB-2412-1.

(b) If during the interval, a reevaluation using the risk-informed process of this Case is conducted and items are required to be added to the examination program, those items shall be added in accordance with IWB-2412 of the 1994 Addenda.

-2420 Successive Inspections

(a) The sequence of piping examinations established during the first inspection interval using the risk-informed process shall be repeated during each successive inspection interval; however, the examination sequence may be revised to satisfy the requirements of Table IWB-2411-1 or Table IWB-2412-1.

(b) If piping structural elements are accepted for continued service by analytical evaluation in accordance with -3200, the areas containing the flaws or relevant conditions shall be reexamined during the next three inspection periods referenced in the schedule of the inspection program of -2400.

(c) If the reexaminations required by (b) reveal that the flaws or relevant conditions remain essentially unchanged for three successive inspection periods, the piping examination schedule may revert to the original schedule of successive inspections.

-2430 Additional Examinations

(a) Examinations performed in accordance with-2500 that reveal flaws or relevant conditions exceeding the acceptance standards of -3000 shall be extended to include additional examinations. The additional examinations shall include piping structural elements described in Table 1 with the same postulated failure mode and the same or higher failure potential.

(1) The number of additional elements shall be the number of piping structural elements with the same postulated failure mode originally scheduled for that fuel cycle.

(2) The scope of the additional examinations may be limited to those High-Safety-Significant (HSS) piping structural elements within systems, whose materials and service conditions are determined by an evaluation to have the same postulated failure mode as the piping structural element that contained the original flaw or relevant condition.

(b) If the additional examinations required by-2430(a) reveal flaws or relevant conditions exceeding the acceptance standards of -3000, the examination shall be further extended to include additional examinations.

(1) These examinations shall include all remaining piping elements within Table 1 whose postulated failure modes are the same as the piping structural elements originally examined in (a)

(c) For the inspection period following the period in which the examinations of (a) or (b) were completed, the examinations shall be performed as originally scheduled in accordance with -2400.

-2500 EXAMINATION AND PRESSURE TEST REQUIREMENTS

(a) Piping structural elements determined to be high-safety-significant in accordance with Mandatory Appendix I shall be examined as required by Table 1.

(b) Pressure testing and VT-2 visual examinations shall be performed on Class 1, 2, and 3 piping systems in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

(c) Examination qualification and methods and personnel qualification shall be in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

-3000 ACCEPTANCE STANDARDS

-3100 STANDARDS

-3110 Characterization

When a volumetric or surface examination method is used, each flaw or group of flaws shall be characterized in accordance with IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of -3200.

-3120 Acceptability

Flaws, areas of degradation, or relevant conditions that do not exceed the allowable acceptance standards of -3200 are acceptable.

-3200 ACCEPTANCE STANDARDS

For component configurations or examination methods not addressed by Table 1, the Owner shall develop acceptance criteria consistent with the requirements of IWA-3000. The referenced paragraphs below and in Table 1 shall be applied in accordance with the Edition and Addenda of Section XI specified in the Owner's Inservice Inspection Program.

(a) Flaws that exceed the acceptance standards listed in Table 1 found during surface or volumetric examinations may be accepted by repair/replacement activities or analytical evaluation, as specified in IWB-3130 (IWB-3120 prior to the Winter 1983 Addenda).

(b) Flaws or relevant conditions that exceed the acceptance standards listed in Table 1 found during visual examinations may be accepted by supplemental examination, corrective measures, repair/replacement activities, or analytical evaluation, as specified in IWB-3140 (IWB-3130 prior to the Winter 1983 Addenda).

(c) Other unacceptable conditions not addressed by (a) or (b) may be accepted by repair/replacement activities in accordance with -4000, or by analytical evaluation in accordance with IWA-3000.

-4000 REPAIR/REPLACEMENT PROCEDURES

Repair/replacement activities shall be performed in accordance with the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program.

-5000 SYSTEM PRESSURE TESTS

IWA-5000, IWB-5000, IWC-5000, and IWD-5000 of the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program apply.

-6000 RECORDS AND REPORTS

IWA-6000 of the Section XI Edition and Addenda specified in the Owner's Inservice Inspection Program applies.

-9000 GLOSSARY

accident sequence: a combination of events leading from an initiating event that challenges safety systems to an undesired consequence, such as core damage or a breach of containment integrity.

core damage: prolonged oxidation and severe fuel damage due to uncovering and heatup of the reactor core.

core damage frequency: an estimate of the likelihood of a severe accident associated with core damage.

event tree: a quantifiable logical network that begins with an initiating event or condition and progresses through a series of branches (usually binary) that represent expected system or operator performance that either succeeds or fails and arrives at either a success or failed condition (e.g., core damage) at the end of the tree.

failure: events involving leakage, rupture, or conditions that would disable a component's ability to perform its intended safety function.

failure mode: a condition or degradation mechanism that can cause a failure.

failure modes and effects analysis: an analysis intended to identify the conceivable failure modes of a component and the impact of the failure on operations, the system, and surrounding components along with the likelihood of the failure and consequences.

initiating event: any event that perturbs the steady state operation of the plant, if operating, or the steady state operation of the decay heat removal systems during shutdown operations such that a transient is initiated in the plant that leads to the need for reactor subcriticality and decay heat removal.

large early release: a radioactivity release from the containment involving the rapid unscrubbed release of airborne fission products to the environment occuring before the effective implementation of off-site emergency response and protective actions.

large early release frequency (LERF): an estimate of the likelihood of a severe accident associated with a radioactive release from containment.

Table 1
Examination Categories

EXAMINATION CATEGORY R-A, RISK-INFORMED PIPING EXAMINATIONS							
					Extent and Frequency		
Item No.	Parts Examined	Examination Requirement/ Fig. No. [Note (2)], [Note (10)]	Examination Method [Note (12)]	Acceptance Standard [Note (10)]	1st Interval		Defer to End of Interval
R1.10	High-Safety-Significant Piping Structural Elements						
R1.11	Elements Subject to Thermal Fatigue	IWB-2500-8(c) [Note (1)] IWB-2500-9, 10, 11 IWC-2500-7(a) [Note (1)]	Volumetric	IWB-3514	Element [Note (2)], [Note (4)]		Not Permissible
R1.12	Elements Subject to High Cycle Mechanical Fatigue	N/A	Visual, VT-2 [Note (11)]	IWB-3142	Each Refueling		Not Permissible
R1.13	Elements Subject to Erosion Cavitation	IWB-2500-8(c)	Volumetric [Note (9)]	IWB-3514 [Note (8)]	Element [Note (2)]		Not Permissible
R1.14	Elements Subject to Crevice Corrosion Cracking	[Note (7)]	Volumetric	IWB-3514	Element [Note (2)]		Not Permissible
R1.15	Elements Subject to Primary Water Stress Corrosion Cracking (PWSCC) [Note (6)]	N/A	Visual, VT-2 [Note (11)]	IWB-3142	Each Refueling		Not Permissible
R1.16	Elements Subject to Intergranular or Transgranular Stress Corrosion Cracking (IGSCC, TGSCC)	IWB-2500-8(c), IWB-2500-9, IWB-2500-10, IWB-2500-11	Volumetric	IWB-3514	Element [Note (2)]		Not Permissible
R1.17	Elements Subject to localized Microbiologically-Corrosion (MIC), or Pitting]	IWB-2500-8(c), IWB-2500-9, IWB-2500-10, IWB-2500-11	Visual, VT-3 Internal Surfaces or Volumetric [Note (8)]	[Note (8)]	Element [Note (2)]		Not Permissible
R1.18	Elements Subject to Flow Accelerated Corrosion (FAC)	[Note (9)]	[Note (9)]	[Note (9)]	[Note (9)]		[Note (9)]
R1.19	Elements Subject to External Chloride Stress Corrosion Cracking (ECSCC)	IWB-2500-8(c)	Surface	IWB-3514	Element [Note (2)]		Not Permissible
R1.20	Elements not Subject to a Damage Mechanism	IWB-2500-8(c) [Note (1)], IWB-2500-9, IWB-2500-10, IWB-2500-11, IWC-2500-7(a) [Note (1)]	Volumetric	IWB-3514	Element [Note (2)], [Note (4)]		Not Permissible

NOTES:
(1) The length for the examination volume shall be increased to include $\frac{1}{2}$ in., beyond each side of the base metal thickness transition or counterbore.
(2) Includes all elements identified in accordance with the risk-informed selection process in Mandatory Appendix I.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(3) Includes 100% of the examination location. When the required examination volume or area cannot be examined due to interference by another component or part geometry, limited examinations shall be evaluated for acceptability. Acceptance of limited examinations or volumes shall not invalidate the results of the risk-informed evaluation. Areas with acceptable limited examinations, and their bases, shall be documented.

(4) The examination shall include any longitudinal weld at the location selected for examination in [Note (2)]. The longitudinal weld examination requirements shall be met for both transverse and parallel flaws examination volume defined in [Note (2)].

(5) Initially-selected elements are to be examined in the same sequence during successive inspection intervals, to the extent practical.

(6) Applies to mill annealed Alloy 600 nozzle welds and heat affected zone (HAZ) without stress relief.

(7) The examination volume shall include the volume surrounding the weld, weld heat affected zone, and base metal, where applicable, in the crevice Examination should focus on detection of cracks initiating and propagating from the inner surface.

(8) The examination volume shall include base metal, welds, and weld HAZ in the affected regions of carbon and low alloy steel, and the welds and of austenitic steel. Examinations shall verify the minimum wall thickness required. Acceptance criteria for localized thinning is in the course of preparation. The examination and examination region shall be sufficient to characterize the extent of the element degradation.

(9) In accordance with the Owner's FAC program.

(10) Paragraph and figure numbers refer to the 1989 Edition.

(11) VT-2 examinations may be conducted during a system pressure test or a pressure test specific to that element.

(12) Socket welds require only a VT-2 examination each refueling outage.

piping segment: a portion of piping for which a failure at any point in the segment results in the same consequence (e.g., loss of the system, loss of a pump train) as a failure at any other point in the segment and includes piping structural elements between major discontinuities, such as pumps and valves.

piping structural element: an item within a specified piping segment, such as a straight length of pipe, a pipe elbow, a coupling, a fitting, a flanged joint, or a weld.

piping system: an assembly of piping segments, piping supports, and other components that may consist of one or more Code classes with a defined function as described within the Owner's Inservice Inspection Program.

probabilistic risk assessment (PRA): a quantitative assessment of the risk associated with plant operation and maintenance and measured in terms of frequency of occurrence of different events, including severe core damage or a breach of containment integrity.

recovery action: a human action performed to recover from a specific failure in order to mitigate or reduce the consequences of the failure.

spatial effects: a failure consequence affecting other systems or components, such as failures due to pipe whip, jet impingement, or flooding.

MANDATORY APPENDIX I
REQUIREMENTS FOR RISK-INFORMED SELECTION PROCESS

I-1 INTRODUCTION

This Appendix provides the risk-informed process to be used as an alternative to current selection and inspection requirements for piping that will be scheduled for inservice inspection. This alternative selection process is based on the relative risk-significance of locations within an individual system. Figure I-1 illustrates the evaluation process summarized below.

I-1.1 SYSTEM IDENTIFICATION

Systems shall be selected for analysis, and system boundaries and functions shall be identified.

I-1.2 SEGMENT RISK ASSESSMENT

Each selected system shall be divided into piping segments determined to have similar consequence of failure and potential for failure (common degradation mechanisms, etc.). These segments shall be placed into risk categories based on combinations of consequence and failure potential. Risk-significant segments shall be identified.

I-1.3 ELEMENT ASSESSMENT

Potential locations (elements) within the risk-significant segments shall be selected for inspection based on the specific degradation mechanism identified in the segment.

I-1.4 INSPECTION LOCATION AND EXAMINATION METHODS

The inspection volume and method used for each element shall be determined based on the degradation mechanism associated with the element.

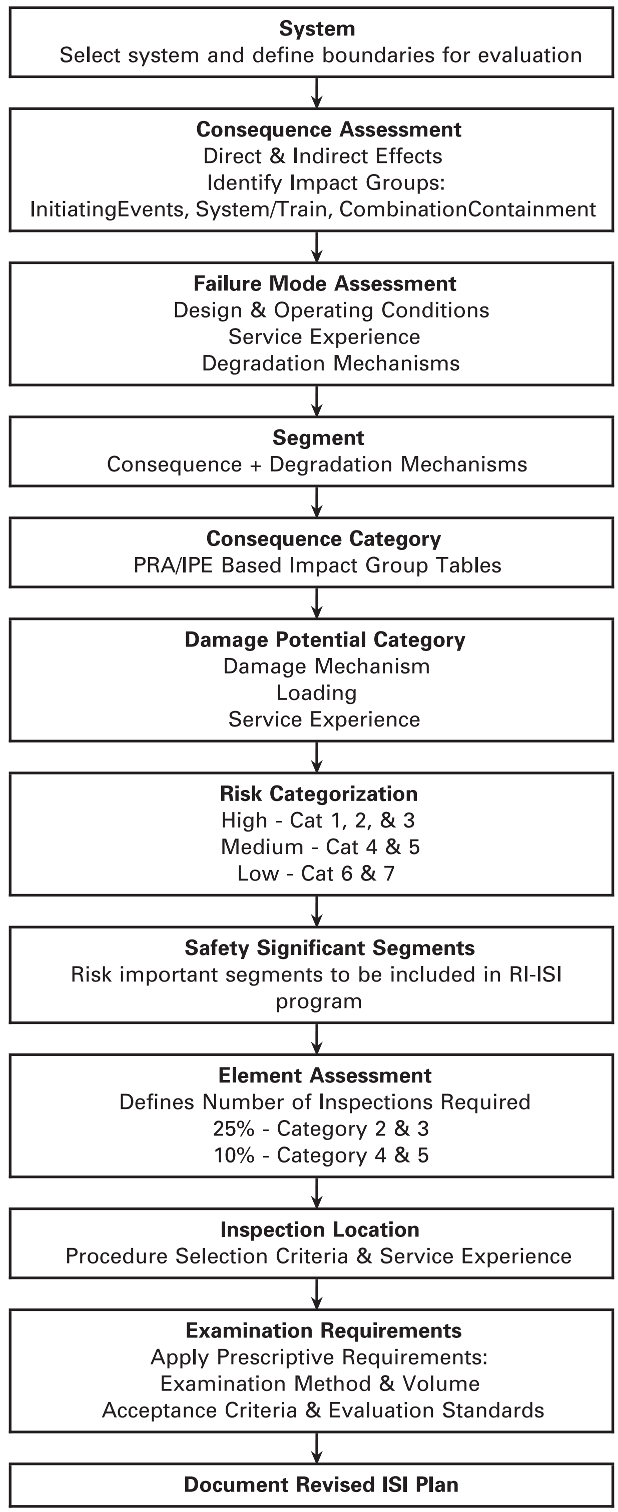
I-1.5 DOCUMENTATION

The results of this alternative selection process shall be fully documented and reviewed. This process shall include a review incorporating plant-specific and industry experience as well as the results of plant-specific inspections.

I-2 SYSTEM IDENTIFICATION

The Owner may define the system boundaries included in the scope of the risk-informed inservice inspection evaluation. Within each system boundary, the risk-informed evaluation may include Class 1, 2, and 3 piping in the Owner's ASME Section XI program and piping outside the current Section XI examination boundaries.

Figure I-1
Risk Evaluation Process



I-3 SEGMENT RISK ASSESSMENT

Piping within a system shall be grouped into segments of common failure consequence and susceptibility to common degradation mechanisms. To accomplish this grouping for each pipe segment within a system, both the potential for failure (i.e., susceptibility to potential degradation mechanisms) and the direct and indirect consequences of failure, shall be assessed in accordance with I-3.1 and I-3.2.

I-3.1 FAILURE POTENTIAL ASSESSMENT

I-3.1.1 Identification of Degradation Mechanisms. Potential active degradation mechanisms for each pipe segment within the selected system boundaries shall be identified. The following conditions shall be considered.

(a) Design characteristics, including material, pipe size and schedule, component type (e.g., fitting type or ANSI standard) and other attributes related to the system configuration.

(b) Fabrication practices, including welding and heat treatment.

(c) Operating conditions, including temperatures and pressures, fluid conditions (e.g., stagnant, laminar flow, and turbulent flow), fluid quality (e.g., primary water, raw water, dry steam, and chemical control), and service environment (e.g., humidity and radiation).[1]

(d) Industry-wide service experience with the systems being evaluated.

(e) Results of preservice, inservice, and augmented examinations, and the presence of prior repairs in the system.

(f) Degradation mechanisms identified in Table I-1.

I-3.1.2 Degradation Mechanism Categories. Degradation mechanisms shall be categorized as described in Table I-2 in accordance with their probability of causing a large pipe break. Segments susceptible to FAC shall be classified in the high failure potential/large break category. Segments susceptible to any of the other degradation mechanisms shall be classified in the medium failure potential/small leak category. Segments having degradation mechanisms listed in the small leak category shall be upgraded to the high failure potential/large break category, if the pipe segments also have the potential for water hammer loads.

I-3.2 CONSEQUENCE EVALUATION

I-3.2.1 Failure Modes and Effects Analysis (FMEA). Potential failure modes for each pipe segment shall be identified, and their effects shall be evaluated. This evaluation shall consider the following:

(a) Break Size. The consequence analysis shall be performed assuming a large break for most segments. The exceptions are piping for which a smaller leak is more conservative, or when a small leak can be justified through a leak before break analysis in accordance with the criteria specified in NUREG-1061, Volume 3, and 10CFR50, Appendix A, General Design Criterion 4.

(b) Isolability of the Break. A break can be automatically isolated by a check valve, a closed isolation valve, or an isolation valve that closes on a given signal or by operator action.

(c) Indirect Effects. Includes spatial and loss of inventory effects.

(d) Initiating Events. These shall be identified using a plant-specific list of initiating events from the plant Probabilistic Risk Assessment/Individual Plant Examination (PRA/IPE) and the plant design basis.

(e) System Impact/Recovery. The means of detecting a failure, and the Technical Specifications associated with the system and other impacted systems. Possible automatic and operator actions to prevent a loss of systems shall also be evaluated.

(f) System Redundancy. The existence of redundant flowpaths for accident mitigation purposes shall be considered.

I-3.2.2 Impact Group Assessment. The FMEA impacts for each pipe segment shall be classified into one of three impact groups: initiating event, system, or combination. The consequence category (high medium, low, none) shall then be selected in accordance with (a) through (d) below.

(a) Initiating Events (IE) Impact Group Assessment. When a postulated break results in only an initiating event (e.g., loss of coolant accident, loss of feedwater, reactor trip), the consequence shall be classified into one of four categories: high, medium, low, or none. The initiating event categories shall be assigned according to the following:

(1) The initiating event shall be placed into one of the categories in Table I-3. These shall include all applicable design basis events previously analyzed in the Owner's updated final safety analysis report, PRA, or IPE.

(2) Breaks that cause an initiating event classified as routine operation (Category I) are not relevant to this analysis.

(3) For pipe segment breaks that result in Category II (Anticipated Event), Category III (Infrequent Event), or Category IV (Limiting Fault or Accident), the initiating event shall be assigned to the consequence category according to the plant PRA conditional core damage probability (CCDP) criteria specified in Table I-4.

[1] Systems fabricated to nuclear standards, while resistant to degradation mechanisms addressed in the design process, have experienced damage from phenomena unknown at the time of installation.

Table I-1
Degradation Mechanisms

Mechanisms		Attributes	Susceptible Regions
TF	*TASCS*	– piping > NPS 1; and – pipe segment has a slope < 45° from horizontal (includes elbow or tee into a vertical pipe); and – potential exists for low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or – potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or potential exists for two phase (steam/water) flow, or potential exists for turbulent penetration in branch pipe connected to header piping containing hot fluid with high turbulent flow; and – calculated or measured ΔT > 50°F; and – Richardson number > 4.0	nozzles, branch pipe connections, safe ends, welds, heat affected zones (HAZ), base metal, and regions of stress concentration
	TT	– operating temperature > 270°F for stainless steel, or operating temperature > 220°F for carbon steel; and – potential for relatively rapid temperature changes including cold fluid injection into hot pipe segment, or hot fluid injection into cold pipe segment; and – $\vert \Delta T \vert$ > 200°F for stainless steel, or $\vert \Delta T \vert$ > 150°F for carbon steel, or $\vert \Delta T \vert$ > ΔT allowable (applicable to both stainless steel and carbon)	

Table I-1
Degradation Mechanisms (Cont'd)

Mechanisms		Attributes	Susceptible Regions
SCC	*IGSCC (BWR)*	– evaluated in accordance with existing plant IGSCC program per NRC Generic Letter 88-01	austenitic stainless steel welds and HAZ
	IGSCC (PWR)	– operating temperature > 200°F, and – susceptible material (carbon content ≥ 0.035%), and – tensile stress (including residual stress) is present, and – oxygen or oxidizing species are present; OR – operating temperature < 200°F, the attributes above apply, and – initiating contaminants (e.g., thiosulfate, fluoride, chloride) are also required to be present	
	TGSCC	– operating temperature > 150°F, and – tensile stress (including residual stress) is present, and – halides (e.g., fluoride, chloride) are present, or caustic (NaOH) is present, and – oxygen or oxidizing species are present (only required to be present in conjunction with halides, not required with caustic)	austenitic stainless steel base metal, welds, and HAZ
	ECSCC	– operating temperature > 150°F, and – tensile stress is present, and – an outside piping surface is within five diameters of a probable leak path (e.g., valve stems) and is covered with non-metallic insulation that is not in compliance with Reg. Guide 1.36; OR – an outside piping surface is exposed to wetting from chloride bearing environments (e.g., seawater, brackish water, brine)	austenitic stainless steel base metal, welds, and HAZ
	PWSCC	– piping material is Inconel (Alloy 600) and – exposed to primary water at T > 560°F, and – the material is mill-annealed and cold worked; or cold worked and welded without stress relief	nozzles, welds, and HAZ without stress relief
LC	*MIC*	– operating temperature < 150°F, and – low or intermittent flow, and – pH < 10, and – presence/intrusion of organic material (e.g., raw water system), or water source is not treated with biocides (e.g., refueling water tank)	fittings, welds, HAZ, base metal, dissimilar metal joints (e.g., welds, flanges), and regions containing crevices
	PIT	– potential exists for low flow, and – oxygen or oxidizing species are present, and – initiating contaminants (e.g., fluoride, chloride) are present	
	CC	– crevice condition exists (e.g., thermal sleeves), and – operating temperature > 150°F, and – oxygen or oxidizing species are present	

Table I-1
Degradation Mechanisms (Cont'd)

Mechanisms		Attributes	Susceptible Regions
FS	*E-C*	– existence of cavitation source (i.e., throttling or pressure reducing valves or orifices), and – operating temperature < 250°F, and – flow present > 100 hrs/yr, and – velocity > 30 ft/s, and – $(P_d - P_v)/\Delta P < 5$	fittings, welds, HAZ, and base metal
	FAC	– evaluated in accordance with existing Owner's FAC program	per Owner's FAC program
Water Hammer [Note (1)]		– potential for fluid voiding and relief valve discharge	

Legend:
Thermal Fatigue (TF)
Thermal Stratification, Cycling, and Striping (TASCS)
Thermal Transients (TT)
Stress Corrosion Cracking (SCC)
Intergranular Stress Corrosion Cracking (IGSCC)
Transgranular Stress Corrosion Cracking (TGSCC)
External Chloride Stress Corrosion Cracking (ECSCC)
Primary Water Stress Corrosion Cracking (PWSCC)
Localized Corrosion (LC)
Microbiologically-Induced Corrosion (MIC)
Pitting (PIT)
Crevice Corrosion (CC)
Flow Sensitive (FS)
Erosion-Cavitation (E-C)
Flow Accelerated Corrosion (FAC)

NOTE:
(1) Water Hammer is a rare, severe loading condition, as opposed to a degradation mechanism, but its potential at a location, in conjunction with one or more of the listed mechanisms, could be cause for a higher element ranking.

(b) System Impact Group Assessment. The consequence category of a pipe segment failure that does not cause an initiating event, but that degrades or fails an essential system to plant safety, shall be based on the three attributes discussed below:

(1) Frequency of challenge, which determines how often the mitigating function of the system is called upon. This corresponds to the frequency of initiating events that require the system operation.

(2) Number of backup systems available, which determines how many unaffected systems are available to perform the same mitigating function as the degraded or failed system.

(3) Exposure time, which determines the time the system would be unavailable before the plant is changed to a different mode in which the failed system's function is no longer required, the failure is recovered, or other compensatory action is taken. Exposure time is a function of the detection time and Allowed Outage Time, as defined in the plant Technical Specification.

Table I-2
Degradation Mechanism Category

Failure Potential	Conditions	Degradation Category	Degradation Mechanism
High [Note (1)]	Degradation mechanism likely to cause a large break	Large Break	Flow-Accelerated Corrosion
Medium	Degradation mechanism likely to cause a small leak	Small Leak	Thermal Fatigue, Erosion-Cavitation, Corrosion, Stress Corrosion Cracking
Low	None	None	None

NOTE:
(1) Refer to I-3.1.2.

Table I-3
Consequence Categories for Initiating Event Impact Group

Design Basis Event Category	Initiating Event Type	Representative Initiating Event Frequency Range (1/yr)	Example Initiating Events	Consequence Category
I	Routine Operation	>1		None
II	Anticipated Event	≥1	Reactor Trip, Turbine Trip, Partial Loss of Feedwater	Low [Note (1)]
III	Infrequent Event	10^{-1} to 10^{-2}	Loss of Feedwater, Loss of Off-Site Power Loss of Shutdown Cooling	Low/ Medium/ High [Note (1)]
IV	Limiting Fault or Accident	$<10^{-2}$	Significant Leakage, Very Small LOCA, Small LOCA, Steamline Break, Feedwater Line Break, Large LOCA	Low/ Medium/ High [Note (1)]

NOTE:
(1) Refer to I-3.2.2(a)(3).

Consequence categories shall be assigned in accordance with Table I-5 as High, Medium, or Low. As with the initiating event group (Table I-3), frequency of challenge is grouped into design basis event categories (II, III, and IV). Exposure time shall be obtained from Technical Specification limits, and shall be classified as long (>24 hrs) or short (not to exceed 24 hrs). The Owner or his designee shall ensure that the quantitative basis of Table I-5 (e.g., train unavailability approximately 10^{-2}) is consistent with the pipe failure scenario under evaluation. In lieu of Table I-5, quantitative indices based on conditional core damage probability may be used to assign consequence categories on the basis of the plant's PRA/IPE in accordance with Table I-4.

(c) Combination Impact Group Assessment. The consequence category for a pipe segment whose failure results in both an initiating event and the degradation or loss of a system shall be determined using Table I-6. The Owner or his designee shall ensure that the quantitative basis of Table I-5 (e.g., train unavailability approximately 10^{-2}) is consistent with the pipe failure scenario under evaluation. The consequence category is a function of two factors:

(1) Use of the system as a mitigating function for the induced initiating;

(2) Number of unaffected backup systems or trains available to perform the same function.

(d) Containment Performance. The above evaluations determine pipe failure importance relative to core damage. Pipe failure shall also be assessed for its impact on containment performance. This shall be accomplished by addressing the following two issues, both of which are based upon an approximate conditional value of $\leq 10^{-1}$ between the CCDP and the likelihood of large early release from containment. If there is no margin (i.e., conditional probability of a large early release given core damage is $> 10^{-1}$), the assigned consequence category shall be increased by one level. The two issues are as follows:

(1) CCDP values for initiating events and safety functions shall be evaluated to determine whether the potential for large early containment failure requires the consequence category to be increased.

Table I-4
Quantitative Indices for Consequence Categories

CCDP	Consequence Category
$\geq 10^{-4}$	High
$10^{-6} \leq$ CCDP $< 10^{-4}$	Medium
$<10^{-6}$	Low

Table I-5
Consequence Categories for System Impact Group

Frequency of Challenge	Exposure Time	Number of Available Backup Systems			
		0	1	2	≥3
Anticipated Event	Long	H	H	M	L
	Short	H	M	L	L
Infrequent Event	Long	H	H	M	L
	Short	H	L	L	L
Limiting Fault or Accident	Long	H	M	L	L
	Short	H	L	L	L

Legend:
H = Consequence Category "High"
M = Consequence Category "Medium"
L = Consequence Category "Low"

(2) The impact on containment isolation shall be evaluated. If there is a containment barrier available, the consequence category from the core damage assessment is retained. If there is no containment barrier or the barrier failed in determining the consequence category from the core damage assessment, a margin of at least 10^{-1} in the core damage consequence category assignment must be present for the consequence category to be retained.

For example, if the CCDP for core damage is less than 10^{-5} (i.e., a "Medium" consequence assignment) and there is no containment barrier, the "Medium" consequence assignment is retained because there is a margin of 0.1 to the "High" consequence category threshold (i.e., 10^{-4}). However, if the CCDP for core damage is 5×10^{-5} (i.e., a "Medium" consequence assignment) and there is no containment barrier, the consequence category is increased to "High" because the margin to the "High" consequence category threshold (i.e., 10^{-4}) is less than 10^{-1}. Table I-7 shall be used to assign consequence categories for those piping failures that can lead to a LOCA outside containment.

I-3.3 SEGMENT RISK CATEGORIZATION

I-3.3.1 Risk Matrix. The risk of pipe segment failure shall be evaluated on the basis of the expected likelihood of the event and the expected consequence. The likelihood of failure is estimated based on the segment exposure to varying degradation mechanisms, and is represented by the degradation category assigned to the segment in accordance with I-3.1. Consequence is

Table I-6
Consequence Categories for Combination Impact Group

Event	Consequence Category
Initiating Event and 1 Unaffected Train of Mitigating System Available	High
Initiating Event and 2 Unaffected Trains of Mitigating Systems Available	Medium [Note (1)] (or IE Consequence Category from Table I-3)
Initiating Event and More Than 2 Unaffected Trains of Mitigating Systems Available	Low [Note (1)] (or IE Consequence Category from Table I-3)
Initiating Event and No Mitigating Systems Affected	IE Consequence Category from Table I-3

NOTE:
(1) The higher consequence category from Table I-3 or Table I-6 shall be assigned.

Table I-7
Consequence Categories for Pipe Failures Resulting in Increased Potential for an Unisolated LOCA Outside Containment

Protection Against LOCA Outside Containment	Consequence Category
One active barrier [Note (1)]	High
One passive barrier [Note (2)]	High
Two active barriers	Medium
One active and one passive barrier	Medium
Two passive barriers	Low
More than two passive barriers	None

NOTES:
(1) An active barrier is presented by a valve that needs to close on demand.
(2) An passive barrier is presented by a valve that needs to remain closed.

represented by the consequence category assigned to the segment in accordance with I-3.2. The structure used to document the results of this analysis is called a Risk Matrix and is shown in Table I-8. Each pipe segment shall be assigned to one of the risk categories in Table I-8 based on its degradation and consequence categories.

I-3.3.2 Risk Categories. The three failure potential (i.e., degradation mechanism) categories and four consequence categories shall be combined into seven risk categories, as follows:

Risk Category	Risk Area
1	High Consequence and High Failure Potential Category
2	High Consequence and Medium Failure Potential Category
3	Medium Consequence and High Failure Potential Category
4	High Consequence and Low Failure Potential Category
5	Medium Consequence and Medium Failure Potential Category, or Low Consequence and High Failure Potential Category
6	Medium Consequence and Low Failure Potential Category, or Low Consequence and Medium Failure Potential Category
7	Low Consequence and Low Failure Potential Category, or No Consequence and Any Failure Potential Category

I-4 ELEMENT ASSESSMENT

The number of elements to be examined in each risk category shall be as follows:

(a) For those segments that are in Risk Category 1, 3, or 5 and are included in the existing plant FAC Inspection Program, the number of inspection locations shall be the same as the existing plant FAC Inspection Program.[2]

(b) For those segments that are Risk Category 1, 2, 3, or 5 and are included in the existing plant IGSCC Inspection Program, the number of inspection locations shall be the same as the existing plant IGSCC (i.e., Generic Letter 88-01) Inspection Program.[2]

(c) For segments determined to have degradation mechanisms other than those included in the existing plant FAC and IGSCC Inspection Programs, the following number of locations shall be examined as part of the risk-based program.

(1) For Risk Categories 1, 2, and 3 the number of inspection locations in each category shall be at least 25% of the total number of elements in each risk category.

(2) For Risk Category 4 or 5, the number of inspection locations in each category shall be at least 10% of the total number of elements in each risk category.

(d) For those segments in Risk Category 6 or 7, volumetric and surface element examinations are not required.

[2] Use of piping inspection programs not covered by this Division may be used to satisfy the examination requirements of Table 1, subject to the following conditions:
(a) the other inspection programs must use examination methods and techniques that would meet the requirements of IWA-2000 or be acceptable under IWA-2240;
(b) the examination methods or techniques must cover the more-safety-significant areas or volumes of concern for selected structural elements; and
(c) use of these examinations and methods shall be documented in accordance with the Owner's Quality Assurance program and shall include a multi-discipline review incorporating plant specific and industry experience as well as the results of the current inspection practices. This shall be made available to the Inspector.

Table I-8
Risk Matrix

RISK GROUPS HIGH - CAT 1, 2, & 3 MEDIUM - CAT 4 & 5 LOW - CAT 6 & 7		CONSEQUENCE CATEGORY			
		NONE	LOW	MEDIUM	HIGH
FAILURE POTENTIAL	HIGH	CATEGORY 7	CATEGORY 5	CATEGORY 3	CATEGORY 1
	MEDIUM	CATEGORY 7	CATEGORY 6	CATEGORY 5	CATEGORY 2
	LOW	CATEGORY 7	CATEGORY 7	CATEGORY 6	CATEGORY 4

(e) All elements, regardless of risk category, shall be pressure and leak tested.

I-5 INSPECTION LOCATIONS AND EXAMINATION METHODS

I-5.1 SELECTION OF ELEMENTS FOR INSPECTION

Examination programs developed in accordance with this Case shall use NDE techniques suitable for specific degradation mechanisms and examination locations. The examination volumes and methods that are appropriate for each degradation mechanism are provided in Table 1 of this Case. The methods and procedures used for the examinations shall be qualified to reliably detect and size the relevant degradation mechanisms identified for each element. Personnel performing the examinations shall be qualified to use these procedures. Examinations shall be conducted and documented in accordance with IWA-2000. The elements within each risk category shall be ranked by considering the following:

(a) Elements identified as susceptible to the specific degradation mechanisms in Table I-1.

(b) Plant-specific inservice cracking experience.

(c) Relative degradation severity for specific degradation mechanisms, when applicable (e.g., wear or erosion rates for flow accelerated corrosion ΔT or Richardson number for thermal fatigue, USNRC NUREG-0313, Revision 2 weld categorization for IGSCC). Examination for elements in Risk Category 4 segments shall be concentrated on any areas of significant stress concentration, geometric discontinuities, or terminal ends.

(d) Access. There shall be adequate access to the element to ensure the examination method for the relevant degradation mechanism can be used effectively for the defined examination volumes.

(e) Radiation Exposure. Elements shall be selected to minimize personnel radiation exposure during inspection.

(f) Elements having break or consequence limiting devices, e.g., pipe whip restraints, need not be examined, if these have not been credited in the consequence evaluation.

I-5.2 EXAMINATION VOLUMES AND METHODS

Examination programs developed in accordance with this Case shall use NDE techniques suitable for specific degradation mechanisms and examination locations. The examination volumes and methods that are appropriate for each degradation mechanism are provided in Table 1 of this Case. The methods and procedures used for the examinations shall be qualified to reliably detect and size the relevant degradation mechanisms identified for each elements. Personnel performing the examinations shall be qualified to use these procedures. Examinations shall be conducted and documented in accordance with IWA-2000.

I-6 REEVALUATION OF RISK-INFORMED SELECTIONS

The affected portions of the risk-informed inservice inspection program shall be reevaluated as new information affecting implementation of the program becomes available. Examples include piping system design changes, industry-wide failure notifications, and prior examination results.

I-7 CHANGE-IN-RISK EVALUATION

(a) A change-in-risk evaluation shall be performed prior to implementation of the program.

(b) Proposed ISI program changes shall be assessed to determine compliance with the acceptance criteria of USNRC Regulatory Guide 1.174, July 1998, Section 2.2.4 and to determine if any adjustments to the proposed ISI program or compensatory measures are needed.

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Approval Date: August 14, 1997

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-579
Use of Nonstandard Nuts, Class 1, 2, and 3, MC, CS Components and Supports Construction Section III, Division 1

Inquiry: May nonstandard nuts be used in construction of Section III, Division 1, Class 1, 2, and 3, MC, CS Components and Supports?

Reply: It is the opinion of the Committee that nonstandard nuts conforming to the requirements of SA-194, except 9.1, may be used in construction of Section III, Division 1, Subsection NB, NC, ND, NE, NG components and NF supports provided the following requirements are met.

(a) When parts of the nonstandard nuts are not load bearing, the materials used in construction of these parts need not conform to SA-194, but shall be compatible with the material used in the load bearing part of the nut and shall be compatible with the service conditions specified for the stud or bolt.

(b) The screw threads of the nonstandard nuts shall be manufactured to meet the requirements for threads in ASME B1.1. Demonstration that this requirement is met shall be in accordance with the requirements of 9.2 of SA-194. The gauging of the threads may be performed immediately after the final formation of the threads, provided any remaining manufacturing processes do not change the profile of the thread form.

(c) The requirements of NCA-3800 for control of material and any assembly associated with the nonstandard nut shall apply. The size exemptions of NB-2610, NC-2610, ND-2610, NE-2610, NG-2610, and NF-2610 shall apply.

(d) The requirements for bolting materials of NB-2000, NC-2000, ND-2000, NE-2000, NG-2000, and NF-2000 shall apply to the load bearing parts of nonstandard nuts.

(e) The Certificate Holder assuming overall responsibility for the components or supports using the nonstandard nut shall ensure that, for the design and service loadings in the Design Specification, the design using nonstandard nuts, meets the requirements of NB-3000, NC-3000, ND-3000, NE-3000, NG-3000, and NF-3000 as applicable.

(f) The nonstandard nut shall meet the proof load requirements of SA-194. If the design of the nonstandard nut includes moveable parts in the load bearing path, and a vibration environment is specified, the nut design shall be tested to demonstrate that it has the vibration resistance necessary to meet the design and service loadings specified. Test reports shall be made available to the Certificate Holder and the Authorized Nuclear Inspector upon request.

(g) It shall be demonstrated by the Certificate Holder that the specified preload has been achieved in accordance with the manufacturer's requirements for installation.[1] When devices are used to preload the bolt, this action shall not degrade the load bearing capacity of the nonstandard nut.

(h) Bolts using these nonstandard nuts for NF construction shall meet the requirements of NF-4725.

(i) Locking nuts shall not be used with nonstandard nut designs using moveable interior parts, if the lock nut interferes with the function of the first nut.

(j) Welding on nuts with moveable interior parts is not permitted.

(k) Use of this Case shall be identified on the documentation for the material.

[1] If cleanliness of load bearing surfaces and/or moveable parts is important to the load bearing capability of the nonstandard nut, the manufacturer shall establish the cleanliness requirements.

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Approval Date: January 4, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-580-2
Use of Alloy 600 With Columbium Added
Section III, Division 1

Inquiry: May Ni-Cr-Fe Alloy 600 with columbium, added during melting, for improved stress corrosion resistance, and otherwise meeting chemical analysis per Table 1, minimum mechanical properties per Table 2, and conforming to other requirements of specifications listed in Table 3, be used for Section III, Division 1, Class 1, 2, 3, and CS construction?

Reply: It is the opinion of the Committee that the material described in the above Inquiry may be used for Section III, Division 1, Class 1, 2, 3, and CS construction; provided these additional requirements are met:

(a) Columbium content of base metal and weld filler metal shall be in the range of 1-3%;

(b) The maximum allowable stress values shall be those given in Table 4;

(c) The design stress intensity values, and yield and tensile strength values shall be per Table 5;

(d) Heat treatment of the alloy shall be at a temperature in the range of 1875°F – 2000°F (1025°C – 1095°C), followed by rapid cooling;

(e) All applicable requirements of Section III shall be met;

(f) The material shall be considered as P-43;

(g) This Case number shall be shown in documentation for and on the material.

Table 1
Chemical Requirements

Element	Composition, %
Carbon, max.	0.050
Chromium	14.0-17.0
Columbium	1.0-3.0
Copper, max.	0.5
Iron	6.0-10.0
Manganese, max.	1.0
Nickel, min.	72.0
Silicon, max.	0.5
Sulfur, max.	0.015

Table 2
Mechanical Properties

Condition and Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, min. ksi	Yield Strength (0.2% offset) min. ksi	Elongation in 2 in., or 4*D*, min., %
Bar (SB-166)	85	35	30
Hot worked (as worked):			
Rounds:			
All Sizes			
Square, hexagons and rectangles:			
All sizes	85	35	20
Rings and disks [Note (1)]	...	...	...
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	80	35	30
Rings and disks [Note (2)]	...	...	...
Forging Quality:			
All sizes	[Note (3)]	[Note (3)]	[Note (3)]

Table 2
Mechanical Properties (Cont'd)

Condition and Size	Tensile Strength, min. ksi	Yield Strength (0.2% offset) min. ksi	Elongation in 2 in., or 4*D*, min., %
Pipe (SB-167)			
Hot worked or hot worked (annealed):			
Rounds:			
5 in., O.D. and under	80	30	35
Over 5 in., in O.D.	75	25	35
Cold-worked (annealed):			
5 in., O.D. and under	80	35	30
Over 5 in., in O.D.	80	30	35
Condition and Temper	**Tensile Strength, min. ksi**	**Yield Strength [Note (4)] (0.2% offset) min. ksi**	**Elongation in 2 in., or 4*D*, min., %**
Plate (SB-168)			
Hot-rolled Plate:			
Annealed	80	35	30
Hot-rolled Plate:			
As-rolled [Notes (5) (6)]	85	35	30
Hot-rolled Sheet:			
Annealed	80	35	30
Cold-rolled Sheet:			
Annealed	80	35	30
Material Condition	**Tensile Strength, min. ksi**	**Yield Strength (0.2% offset) min. ksi**	**Elongation in 2 in., or 4*D*, min., %**
Forging (SB-564)			
Annealed	80	35	30

NOTES:
(1) Hardness B 75 to B 100, or equivalent.
(2) Hardness B 75 to B 95, or equivalent.
(3) Forging quality is furnished to chemical requirements and surface inspection only. No mechanical properties are required.
(4) Yield strength requirements do not apply to material under 0.020 in., in thickness.
(5) As-rolled plate may be given a stress relieving heat treatment subsequent to final rolling.
(6) As-rolled plate specified suitable for hot forming shall be furnished from heats of know good hot-malleability (see para. X1.2.2). There are no applicable tensile or hardness requirements for such material.

Table 3
Material Specifications

SB-166	Bar
SB-167	Pipe
SB-168	Plate
SB-564	Forging

Table 4
Allowable Stresses for Section III, Class 2 and 3

Temp °F	SB-167 25/75 Low ksi	SB-167 25/75 High ksi [Note (1)]	SB-167 30/80 Low ksi	SB-167 30/80 High ksi [Note (1)]	SB-166 SB-167 SB-168 SB-564 35/80 Low ksi	SB-166 SB-167 SB-168 SB-564 35/80 High ksi [Note (1)]	SB-166 SB-168 35/85 Low ksi	SB-166 SB-168 35/85 High ksi [Note (1)]
−20 to 100	16.7	16.7	20.0	20.0	20.0	20.0	21.3	21.3
200	13.6	16.7	16.3	20.0	19.1	20.0	19.1	21.3
300	12.8	16.7	15.4	20.0	18.0	20.0	18.0	21.3
400	12.8	16.7	15.3	20.0	17.9	20.0	17.9	21.3
500	12.8	16.7	15.3	20.0	17.9	20.0	17.9	21.3
600	12.8	16.7	15.3	20.0	17.9	20.0	17.9	21.3

NOTE:

(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66$^2/_3$% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage of malfunction. Section II, Part D, Table Y-2 lists multiplying factors which, when applied to the yield strength values shown in Section II, Part D, Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

Table 5
Design Stress Intensity, Yield and Tensile Strength Values for Section III, Class 1

Temp °F	SB-167 25/75 S Intens S_m, ksi [Note (1)]	SB-167 25/75 Y.S. ksi	SB-167 25/75 UTS ksi	SB-167 30/80 S Intens S_m, ksi [Note (1)]	SB-167 30/80 Y.S. ksi	SB-167 30/80 UTS ksi	SB-166 SB-167 SB-168 SB-564 35/80 S Intens S_m, ksi [Note (1)]	SB-166 SB-167 SB-168 SB-564 35/80 Y.S. ksi	SB-166 SB-167 SB-168 SB-564 35/80 UTS ksi
−20 to 100	16.7	25.0	75	20.0	30.0	80	23.3	35.0	80
200	16.7	20.4	75	20.0	24.5	80	23.3	28.6	80
300	16.7	19.2	75	20.0	23.1	80	23.3	26.9	80
400	16.7	19.1	75	20.0	23.0	80	23.3	26.8	80
500	16.7	19.1	75	20.0	23.0	80	23.3	26.8	80
600	16.7	19.1	75	20.0	23.0	80	23.3	26.8	80

NOTE:

(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66$^2/_3$% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage of malfunction. Section II, Part D, Table Y-2 lists multiplying factors which, when applied to the yield strength values shown in Section II, Part D, Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

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Approval Date: August 14, 1997

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-583
Annual Training Alternative
Section XI, Division 1

Inquiry: What alternative to the annual training requirements of Appendix VII-4240 may be used?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of Appendix VII-4240, supplemental practice may be used to maintain UT personnel examination skills. Personnel shall practice UT techniques by examining or by analyzing prerecorded data from material or welds containing flaws similar to those that may be encountered during inservice examinations. This practice shall be at least 8 hr per year and shall be administered by an NDE Instructor or Level III; no examination is required.

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Approval Date: May 4, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-586-1
Alternative Additional Examination Requirements for Classes 1, 2, and 3 Piping, Components, and Supports Section XI, Division 1

Inquiry: What alternative requirements to IWB-2430 (a), IWC-2430(a), IWD-2430(a) (starting with 1991 Addenda), and IWF-2430(a) (starting with Winter 1981 Addenda) may be used for additional examinations?

Reply: It is the opinion of the Committee that the following alternative requirements may be used:

(a) When the applicable Section XI acceptance criteria are exceeded, an engineering evaluation shall be performed. Topics to be addressed in the engineering evaluation shall include the following:

(1) A determination of the root cause of the flaws or relevant conditions.

(2) An evaluation of applicable service conditions and degradation mechanisms to establish that the affected welds, areas, or supports will perform their intended safety functions during subsequent operation.

(3) A determination of which additional welds, areas, or supports could be subject to the same root cause conditions and degradation mechanisms. This may require the inclusion of piping systems other than the one containing the original flaws or relevant conditions.

(b) Additional examinations shall be performed on those welds, areas, or supports subject to the same root cause conditions and degradation mechanisms. No additional examinations are required if the engineering evaluation concludes that either:

(1) there are no additional welds, areas, or supports subject to the same root cause conditions, or;

(2) no degradation mechanism exists.

(c) Any required additional examinations shall be performed during the current outage.

(d) The engineering evaluation shall be retained in accordance with IWA-6000.

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Approval Date: July 23, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-589-1
Class 3 Nonmetallic Cured-In-Place Piping
Section XI, Division 1

Inquiry: What requirements shall be applied when performing a repair/replacement activity on buried pressure piping using thermosetting resin Cured-In-Place Piping (CIPP)?

Reply: It is the opinion of the Committee that in lieu of the requirements of IWA-4000 or IWA-7000, as applicable, repair/replacement activities may be performed on buried pressure piping using thermosetting resin CIPP in accordance with the following requirements.

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TABLES

1 GENERAL REQUIREMENTS

1.1 APPLICABILITY

1.1.1 This Case applies only when the host pipe or surrounding material can serve as an initial form.

1.1.2 This Case applies only to Class 3 continuously supported buried piping systems with single-phase flow and no lateral branch connections in the area of application.

1.1.3 The provisions of this Case do not apply to pumps, valves, or pressure vessels.

1.2 INSERTED FORM OR SPRAYED FORM

The inserted form or sprayed form may be selected, typically based on inside diameter and number and radius of bends of host pipe.

1.2.1 Inserted Form.

1.2.1.1 This Case applies only to thermosetting resin CIPP with reinforcing fillers.

1.2.1.2 This Case applies only to host pipes with a value for ovality, q, of 10% or less, as determined in accordance with 2.3.2.

1.2.2 Sprayed Form. This Case applies only to epoxies, with or without reinforcing fiber (e.g., fiberglass, carbon). When CIPP is used with a fully deteriorated host pipe, reinforcing fibers shall be used.

1.3 REFERENCED STANDARDS AND SPECIFICATIONS

When standards and specifications are referenced in this Case, their revision date or indicator shall be as shown in Mandatory Appendix I.

1.4 PROGRAM REQUIREMENTS

The requirements of IWA-4000 Subsubarticles titled Responsibility, Repair/Replacement Program and Plan, Verification of Acceptability, and Inspection and Documentation shall be met. Use of this Case shall be documented on Form NIS-2.

2 DESIGN

2.1 MATERIAL PROPERTY DETERMINATION

2.1.1 The Owner shall specify a design life and the maximum temperature to which CIPP will be exposed over its design life for all anticipated loading conditions.

2.1.2 A time-temperature corrected flexural modulus of elasticity (E_F) shall be determined in accordance with ASTM D790 and ASTM D2990 using the maximum temperature and design life from 2.1.1.

2.1.3 A time-temperature corrected ultimate tensile strength (S_T) shall be determined in accordance with ASTM D638 and ASTM D2990 using the maximum temperature and design life from 2.1.1.

2.1.4 The coefficient of thermal expansion for the maximum temperature from 2.1.1 shall be determined in accordance with ASTM D696.

2.2 DESIGN REQUIREMENTS

2.2.1 The Owner shall evaluate the condition of the host pipe to determine whether it should be considered partially or fully deteriorated.

2.2.2 The Owner shall specify anticipated or postulated loads in the Design Specification for the modifications or piping system.

2.2.3 For a partially deteriorated host pipe, the Owner shall specify minimum pipe wall thickness and allowable localized areas of pipe wall thinning, to ensure that the host pipe will support soil and surcharge loads throughout its design life.

2.2.4 The required CIPP design wall thickness, t_r, for a partially deteriorated host pipe shall be at least the greater of the thickness determined by eqs. 2.3.1(1) and 2.3.3(3). This minimum thickness shall be increased to provide for all applicable manufacturing-specific installation or carrier tube constructability tolerances and shall be referred to as the nominal CIPP wall thickness, t_n, and shall be used in the analysis required by 2.4.[1]

2.2.5 The t_r for a fully deteriorated host pipe shall be at least the greater of the thickness determined by eqs. 2.3.1(1) and 2.3.2(2). This minimum thickness shall be increased to provide for all applicable manufacturing-specific installation or carrier tube constructability tolerances and shall be referred to as t_n and shall be used in the analysis required by 2.4.[1]

2.3 DESIGN EQUATIONS

2.3.1 Equation (1) shall be used to determine the t_r required due to internal pressure on CIPP contained in a partially or fully deteriorated host pipe.

$$t_r = \frac{D_O}{\left[\left(\frac{2S_T}{P_D N_S}\right) + 1\right]} \tag{1}$$

where

t_r = required CIPP design wall thickness, in. (for sprayed form, the top coat shall not be credited for t_r when reinforcement is used in the design)
P_D = internal design pressure, psig
D_O = outside diameter of CIPP (inside diameter of host pipe), in.

[1] Although the partially deteriorated host pipe assumption could result in a thinner wall thickness than a fully deteriorated host pipe, it will require future monitoring of the host pipe (5.1) whereas the fully deteriorated pipe will not.

S_T = time-temperature corrected ultimate tensile strength of CIPP, psi
N_S = 4 (Design Factor)

2.3.2 Equation (2) shall be used to determine the t_r required due to applicable external pressures on CIPP contained in a fully deteriorated host pipe.

$$t_r = 0.721\, D_o \left[\frac{(N_E q_t / C)^2}{E_F R w B' E'_s} \right]^{1/3} \tag{2}$$

where

q_t = total external pressure on CIPP, psi
Rw = water buoyancy factor (0.67 minimum) $= 1 - \left[0.33\left(H_w/H\right)\right]$
H_w = height of groundwater above top of host pipe, ft.
H = height of soil above top of host pipe, ft.
B' = coefficient of elastic support $= 1/\left(1 + 4_e{}^{-0.065\text{H}}\right)$.
C = ovality reduction factor

$$= \left[\left(1 - \frac{q}{100}\right) / \left(1 + \frac{q}{100}\right)^2\right]^3$$

q = ovality (%) of host pipe

$$= 100 \times \frac{\left(\text{Maximum measured diameter - Minimum measured diameer}\right)}{\textit{Average}\ \text{measured diameter}}$$

N_E = 2 (Design Factor)
E'_s = modulus of soil reaction, psi
E_F = time-temperature corrected flexural modulus of elasticity for CIPP, psi

2.3.3 Equation (3) shall be used to determine the t_r required due to applicable external pressures on CIPP contained in a partially deteriorated host pipe.

$$t_r = \frac{D_o}{\left[\dfrac{2K\, E_F C}{q_t N_E (1 - \nu^2)}\right]^{1/3} + 1} \tag{3}$$

where

K = buckling enhancement factor of the soil and host pipe adjacent to CIPP. A value of 7.0 shall be used.
ν = Poisson's ratio = 0.30; or Poisson's ratio may be determined using the test method of ASTM D2105

2.4 ANALYSIS EQUATIONS

To validate CIPP design, the analysis shall consider the effects due to applicable thermal expansion, weight, other sustained loads, and other occasional loads specified in the Owner's Requirements.

2.4.1 Stresses due to sustained and occasional loads shall meet the requirements of eq. (4).

$$\frac{P_{mo} D_o}{4 t_n} + 0.75 i \left[\frac{M_A + M_B}{Z}\right] + \frac{S_\alpha}{A} \leq \frac{k S_T}{4} \tag{4}$$

where

D_O = outside diameter of CIPP, in.
M_A = resultant moment loading on cross section due to weight and other applicable sustained loads, in-lb. Because CIPP is continuously supported by the existing soil system or the partially deteriorated host pipe, the MA term can usually be neglected.
Z = section modulus of CIPP, in.^{3} = $\pi\, r_m{}^2\, t_n$
r_m = mean radius of CIPP, in.
t_n = nominal CIPP wall thickness, in.
P_{mo} = maximum operating pressure, psig
M_B = resultant moment loading on cross section due to applicable occasional loads, such as thrusts from relief and safety valve loads, from pressure and flow transients, and seismic inertia, in-lb. For seismic inertia, use only one-half of the range. The effects of seismic displacements shall be included in eq. (4).
S_α = axial loading on cross section due to seismic displacements or other applicable occasional loads, lb.
A = cross-sectional area of CIPP, in.^{2}
k = occasional load factor = 1.2
i = stress intensification factor (SIF). The product 0.75 i shall never be taken as less than 1. The SIF for CIPP in a straight host pipe shall be taken as 1. Refer to 2.6 for SIF's applicable to CIPP in a curved host pipe.
S_T = time-temperature corrected ultimate tensile strength of CIPP, psi

2.4.2 Stresses due to thermal expansion loads shall meet the requirements of eq. (5).

The allowable stress range in ND-3672.6(a) and ND-3611.2 do not apply to thermosetting-resin CIPP.

$$\frac{i M_C}{Z} + \frac{S}{A} \leq \frac{S_T}{2} \tag{5}$$

where

M_C = resultant moment loading on cross section due to thermal expansion, in-lb.
S = axial loading on cross section due to seismic displacements, if included, and thermal expansion, lb.

2.4.3 Determination of Resultant Moment. For eqs. 2.4.1(4) and 2.4.2(5), the resultant moment shall be calculated by using the square root of the sum of the squares method. All directional moment components in the same direction shall be combined before determining the resultant moment.

2.5 TERMINUS REQUIREMENTS

2.5.1 For inserted form, end seals shall be installed at all terminus locations of each CIPP section to anchor and seal CIPP to the host pipe.

2.5.2 For sprayed form, all terminus locations shall be tapered as required to prevent damage due to fluid flow.

2.5.3 The terminus design shall be qualified by testing to withstand all piping system loads with a minimum design factor of four (4).

2.5.4 The requirements of IWA-4000, subarticle titled "Welding and Welder Qualification (Including Welding Operator)," shall be met for structural supports.

2.6 CURVED PIPING COMPONENTS FOR INSERTED FORM

The process of installing CIPP is such that, as the carrier tube is inserted around curved sections of the host pipe, i.e., bends and elbows, wrinkling at the intrados of these items may occur. These wrinkles can be areas of stress concentration, and therefore an SIF shall be established. The Owner is required to determine, through testing in accordance with Mandatory Appendix II, the value of the applicable SIF. This SIF shall be used in 2.4, Analysis Equations.

2.6.1 Minimum CIPP Design Wall Thickness Determination. The t_r for curved piping members shall be determined as for CIPP contained in a straight host pipe described in 2.2 and 2.3.

3 INSTALLATION REQUIREMENTS

3.1 HOST PIPE PREPARATION AND EXAMINATION

The Owner shall perform an examination to determine the design condition of the host pipe, i.e., partially or fully deteriorated.

3.1.1 The host pipe interior shall be cleaned of loose rust, scale, and biofouling. For sprayed form, the inside pipe surface shall be prepared to SSPC-SP-10/NACE 2 near-white-blast cleaning condition. The Owner shall perform examinations to verify proper surface preparation.

3.1.2 The host pipe interior shall be free of sharp protrusions to the extent required for the modification.

3.2 CARRIER TUBE DELAMINATION REQUIREMENTS FOR INSERTED FORM

If a permanently installed impermeable plastic membrane is to be used to contain the resins during installation, the Owner shall ensure that delamination of the protective membrane will not occur. This shall be done by testing conducted in accordance with ASTM D903 with test criteria specified by the Owner.

3.3 CARRIER TUBE WET-OUT FOR INSERTED FORM

3.3.1 All host pipe preinstallation requirements shall be completed prior to the wet-out of the carrier tube.

3.3.2 Resin and curing agent batches and mixture proportion shall be verified to meet the Owner's requirements. The manufacturer's recommended temperature limit for the mix shall not be exceeded.

3.3.3 The thickness and general physical condition of the carrier tube shall be verified.

3.3.4 Inspection shall be performed to ensure that no air voids are present in the wet-out carrier tube.

3.3.5 Proper precautions shall be taken to ensure that premature curing of the wet-out carrier tube does not occur before insertion into the host pipe.

3.4 CARRIER TUBE INSERTION FOR INSERTED FORM

3.4.1 The time-temperature curing cycle profile for the resin system shall be established prior to insertion of the carrier tube.

3.4.2 Manufacturer's instructions shall be followed for the carrier tube insertion.

3.5 EPOXY MIXING FOR SPRAYED FORM

3.5.1 Mixing shall be performed in accordance with the material manufacturer's instructions.

3.5.2 The installation procedure shall include the tolerance for mixture control.

3.6 EPOXY APPLICATION FOR SPRAYED FORM

The manufacturer's instructions shall be followed for application of epoxy resin.

4 POST-INSTALLATION REQUIREMENTS

4.1 TEST SAMPLE RETRIEVAL

For each CIPP length installed, samples shall be taken in accordance with the following:

4.1.1 For inserted form, samples shall be taken from either end of CIPP inserted through the host pipe or from a similar size run-out piece, similarly cured, located immediately beyond the terminus points.

4.1.2 For sprayed form, create test coupons from the epoxy resin at the beginning and end of the installed CIPP and whenever an epoxy resin batch is remixed or reapportioned.

4.1.3 The samples shall be large enough to provide ten specimens for each of the test procedures required in 4.2.

4.1.4 For sprayed form, three adhesion test coupons shall be prepared, and tested in accordance with ASTM D3983, using test criteria specified by the Owner.

4.1.5 Test samples shall be identified to provide traceability between the resin, curing agent, and resin filler, and the pipe section they represent.

4.2 MATERIAL TESTING

The samples obtained in accordance with the requirements of 4.1 shall be tested to confirm the design basis material property values, i.e., E_F, S_T, and the coefficient of thermal expansion used in the analysis required by 2.

4.3 INSTALLED GEOMETRY VERIFICATION

4.3.1 The Owner shall verify that the minimum wall thickness of the installed CIPP meets the requirements of 2.2, 2.3, and 2.4. CIPP wall thickness shall be measured in accordance with Section V, Article 23, SE-797, "Standard Practice for Thickness Measurement by Manual Contact Ultrasonic Method." Measurement personnel shall be qualified in accordance with Owner-approved procedures.

4.3.2 For inserted form, a set of four measurements, equally spaced around the circumference of the CIPP, shall be taken at each terminus and at one or more intermediate points specified by the Owner.

4.3.3 For each manual application of the sprayed form, five separate spot measurements spaced evenly over each 100 square-foot section of the pipe shall be taken.

(a) For CIPP piping not exceeding 300 square feet in area, each 100 square-foot area shall be measured.

(b) For CIPP piping not exceeding 1000 square feet, three 100 square-foot area shall be randomly selected and measured.

(c) For CIPP piping exceeding 1000 square feet, the first 1000 square feet shall be measured as specified in (b), and for each additional 1000 square feet or increment thereof, one 100 square-foot area shall be randomly selected and measured.

(d) If the measured wall thickness for any 100 square-foot area (b) and (c) does not meet the minimum wall thickness requirements of 2.2, 2.3, and 2.4, each 100 square-foot area shall be measured in the targeted 1000 square-foot area.

4.3.4 For sprayed form with reinforcement, the thickness measurements shall not credit unreinforced layers of the CIPP. If the UT technique can not determine the difference between the final thickness of the reinforced layers and the thickness of the top coat, the final thickness measurements shall be taken before the top coat is applied.

4.3.5 For inserted form, the owner shall verify that the ovality requirements of 2.3.2 are enveloped by the CIPP as-installed condition. The sampling requirements shall be the same as 4.3.2 and 4.3.3.

4.3.6 For inserted form and sprayed form, additional sets of measurements shall be taken in areas of significant host pipe degradation specified by the Owner.

4.4 SYSTEM PRESSURE TEST

A system pressure test shall be performed on the CIPP in accordance with IWA-5244. If practicable, a pressure loss test shall be conducted, at a test pressure determined by the Owner.

4.5 DOCUMENTATION OF CIPP AS-INSTALLED CONDITION

4.5.1 A visual examination shall be performed. Voids, surface flaws, and areas of improper curing shall be evaluated, as required, by the Owner. Corrective action requirements shall be in accordance with Mandatory Appendix III.

4.5.2 Through-wall flaws are unacceptable.

4.5.3 Flaws in the CIPP (Tables III-1 and III-2) shall be corrected in accordance with Mandatory Appendix III.

4.5.4 For sprayed form, discontinuity testing (Holiday) on all accessible surfaces in accordance with ASTM D4748, D 5162, or NACE Standard RP0188 shall be performed to identify pinholes and thin spots in the CIPP.

4.5.5 For sprayed form, hardness of the CIPP shall be measured in accordance with ASTM D2583 to verify proper mix ratio. Hardness measurement points shall be randomly determined at four radial points every three feet of applied length.

4.6 CONFIRMATION OF WRINKLE GEOMETRY USED IN SIF DETERMINATION FOR INSERTED FORM

If Mandatory Appendix II is used to determine an SIF, the Owner shall verify that the geometry of wrinkles at the intrados of curved piping components is enveloped by those previously tested in accordance with Mandatory Appendix II.

4.7 EXAMINATION AND TESTING OF REPAIRS TO THE CIPP

Examination and testing of repairs to the CIPP shall conform to the requirements of 4.

5 MONITORING PLANS

5.1 HOST PIPE MONITORING PLAN

A plan for monitoring a partially deteriorated host pipe's corrosion rates shall be prepared by the Owner to ensure that the criteria established in 2.2.3 are satisfied. No monitoring plan is required for a fully deteriorated host pipe.

5.2 CIPP MONITORING PLAN

A plan for monitoring CIPP for degradation due to environmental conditions, erosion, or thermal expansion and contraction shall be prepared by the Owner.

6 GLOSSARY

carrier tube: one or more layers of materials or a combination of materials capable of carrying resin, withstanding installation pressure and curing temperatures.

Cured-In-Place Pipe (CIPP): nonmetallic pipe formed within the host pipe using cured thermosetting resins.

curing: the changing of properties of a polymeric system by the application of heat or other means into a more stable and usable condition.

epoxy: a two-component system composed of epichlorohydrin and bisphenol A, combined with an amine-based curing agent.

fully deteriorated host pipe: a host pipe that is not relied upon to support soil, surcharge, or groundwater loads.

glass transition temperature: the temperature at which a change in a plastic to a viscous or rubbery condition occurs, accompanied by a rapid change in mechanical and physical properties.

host pipe: the old or existing pipe to be modified.

intrados: the interior curve of an elbow.

partially deteriorated host pipe: a host pipe which is relied upon to support soil and surcharge loads throughout its design life.

reinforcement: a high strength filler imbedded in the plastic, resulting in mechanical properties superior to those of the base resin.

resin filler: a relatively inert material added to a plastic to modify its strength, permanence or working properties.

surcharge: loading on a buried pipe produced by ground transportation traffic, e.g., truck or railway.

terminus: the begining and end of the CIPP.

thermoset resin: plastics that cannot be resoftened following polymerization, e.g., Bakelite, epoxy, polyurethane, polyesters, vinyl esters.

top coat: layer of epoxy or other nonmetallic coating applied to improve appearance, flow coefficient, or chemical resistance, or to provide UV protection or barrier to abrasion and impact conditions.

wet-out: full coating and saturation of the matrix of reinforcing fibers by thermoset resin.

MANDATORY APPENDIX I
REFERENCED STANDARDS AND SPECIFICATIONS

The following standards and specifications are referenced in the text of this Case.

Standard or Specification	Title	Revision Date or Indicator
ASTM D638	Standard Test Method for Tensile Properties of Plastics	1998
ASTM D696	Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C With Vitreous Silica Dilatometer	1991
ASTM D790	Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Insulating Materials	1998
ASTM D903	Standard Test Method for Peel or Stripping Strength of Adhesive Bonds	1998
ASTM D2105	Standard Test Method of Longitudinal Tensile Properties of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube	1997
ASTM D2583	Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor	1995
ASTM D2990	Standard Test Method for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics	1995
ASTM D3983	Standard Test Method for Measuring Strength and Shear Modulus of Non-Rigid Adhesives by the Thick-Adhered Tensile-Lap Specimen	1998
ASTM D4787	Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates	1993
ASTM D5162	Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coatings on Metallic Substrates	1991
NACE Standard RP0188	Discontinuity (Holiday) Testing of Protective Coating	1988

MANDATORY APPENDIX II
TEST PROCEDURE FOR DETERMINATION OF STRESS INTENSIFICATION FACTOR DUE TO WRINKLES IN CURVED PIPING COMPONENTS FOR INSERTED FORM

II-1 GENERAL

The test procedure described in *Fatigue Tests of Piping Components,* by A.R.C. Markl,[2] and summarized in this Appendix, shall be used to determine the Stress Intensification Factor (SIF) caused by the wrinkles that may form at the intrados of CIPP inserted through a curved host piping component.

II-1.1 SELECTION OF COMPONENT TYPES FOR TESTING

The component types selected for testing shall be consistent with the design condition of the host pipe, i.e., partially or fully deteriorated, and used in 2.3.

II-2 TEST SAMPLE FABRICATION

(a) The component types, as determined in accordance with II-1.1, shall be inserted and cured into radii and diameter steel pipe sections similar to the proposed host-pipe. Split elbows, bends, and straight pipe sections shall be used to provide a suitable form for CIPP installation that can be easily removed to expose stand-alone sections of CIPP as required for test sample fabrication.

(b) Adequate length at the test sample ends shall be left to accommodate attachment of any required anchor flange. All anchor flange material shall be compatible with the material of the attaching pipe section, either fiberglass or steel.

II-3 TEST EQUIPMENT REQUIREMENTS

The test equipment used to perform the testing described in this Appendix shall be capable of testing full-size samples and incorporating the loading orientation and test sample anchoring methods contained in Markl's paper.

II-4 NUMBER OF TEST SAMPLES

Thirty (30) test samples shall be fabricated in accordance with II-2 to provide data to be used in determination of the Stress Intensification Factor (SIF).

II-5 TEST PROCEDURE SUMMARY

The following test procedure summary shall be followed in experimentally determining the Stress Intensification Factor (SIF).

II-5.1 Determine a force deflection curve based on testing of straight pipe samples with fatigue test equipment.

II-5.2 Based on a series of deflection-controlled fatigue tests on straight pipe, plot the results on a single log-log curve.

II-5.3 Determine a force deflection curve based on testing of curved piping components with fatigue test equipment.

II-5.4 Based on a series of deflection-controlled fatigue tests on curved piping components, plot the results superimposed on the straight pipe log-log curve from II-5.2.

II-5.5 Calculate the Stress Intensification Factor (SIF), as outlined in Markl's paper, for each curved piping component.

[2] *Fatigue Tests of Piping Components,* by A.R.C. Markl, ASME Transaction 1952, Paper No. 51-PET-21.

MANDATORY APPENDIX III CORRECTIVE ACTION REQUIREMENTS FOR CIPP PRESSURE BOUNDARY

III-1 GENERAL

All required corrective actions to the pressure boundary of CIPP due to voids, surface flaws, and areas of improper curing shall be in accordance with this Appendix and Tables III-1 and III-2.

III-1.1 SURFACE FLAW CORRECTIVE ACTIONS

III-1.1.1 Grind away the thermoset resin around the surface flaw to create adhesive bonding sites.

III-1.1.2 Mix the components of the resin system in accordance with manufacturer's recommended proportions.

III-1.1.3 Trowel or spray the mix over the surface flaw.

III-1.1.4 The resin system applied to the surface flaw shall be completely cured. Inspection in accordance with the CIPP resin manufacturer's recommendations shall be the determining factor in judging cure completion.

III-1.1.5 Grind away, as required, the excess resin so that the corrective action follows the contour of the existing CIPP.

III-1.2 VOID CORRECTIVE ACTIONS

III-1.2.1 The injection of resin into a void shall be done by drilling small ports (approximately $\frac{1}{4}$ in. in diameter) in CIPP. The axial and circumferential spacing of the injection ports shall be based on the viscosity of the resin system being used.

III-1.2.2 The host pipe shall not be damaged while drilling the ports in CIPP.

III-1.2.3 The injection method shall use gravity to expel air in the void.

III-1.2.4 Each port shall have a means whereby either a permanent or semi-permanent plug can be obtained during the injection process.

III-1.2.5 Reinforcement of the repair area shall be not less than that of the original CIPP. The components of the resin system being injected shall be mixed in accordance with the manufacturer's recommended proportions.

III-1.2.6 The resin system injected into the void shall be completely cured. Inspection in accordance with the CIPP resin manufacturer's recommendations shall be the determining factor in judging cure completion.

III-1.3 CORRECTIVE ACTION FOR AREAS OF IMPROPER CURING

Areas of improper curing shall be completely cured. Inspection in accordance with the CIPP resin manufacturer's recommendations shall be the determining factor in judging cure completion.

Table III-1
Corrective Action Requirements for Inserted Form CIPP Pressure Boundary

Flaw	Unacceptable Conditions	Corrective Actions
Air Bubble (Void)	Air entrapment greater than $^1/_2$ in. diameter within and between reinforcement and inside surface	III-1.2
Dry Spot	Area where reinforcement has not been thoroughly wetted with resin	III-1.1
Improper Curing	As defined by manufacturer's instructions	III-1.3
Lack of Fill-Out	Area where the resin has drained from the reinforcement	III-1.1
Pits or Pinholes	Small crater in surface, not affecting the reinforcement and exceeding 10% of the wall thickness. No corrective action is required for pits less than or equal to 10% of the wall thickness.	Coat with resin
Surface Cracking	Cracks allowing fluids to reach and wick into the reinforcing fibers	III-1.1

Table III-2
Corrective Action Requirements for Sprayed Form CIPP Pressure Boundary

Flaw	Unacceptable Conditions	Corrective Actions
Air Bubble (Void)	Air entrapment within the thermoset resin	III-1.2
Dry Spot	Area where reinforcement has not been thoroughly wetted with resin	III-1.1
Improper Curing	As defined by manufacturer's instructions	III-1.3
Pinholes (thin spots)	Discontinuity (Holiday) test results exceeding the criteria specified in 4.5.4	Coat with resin
Pits	Small crater in surface, not affecting the reinforcement and exceeding 10% of the wall thickness. No corrective action is required for pits less than or equal to 10% of the wall thickness	Coat with resin
Surface Cracking	Cracks allowing fluids to reach and wick into the reinforcing fibers	III-1.1

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Approval Date: November 8, 2011

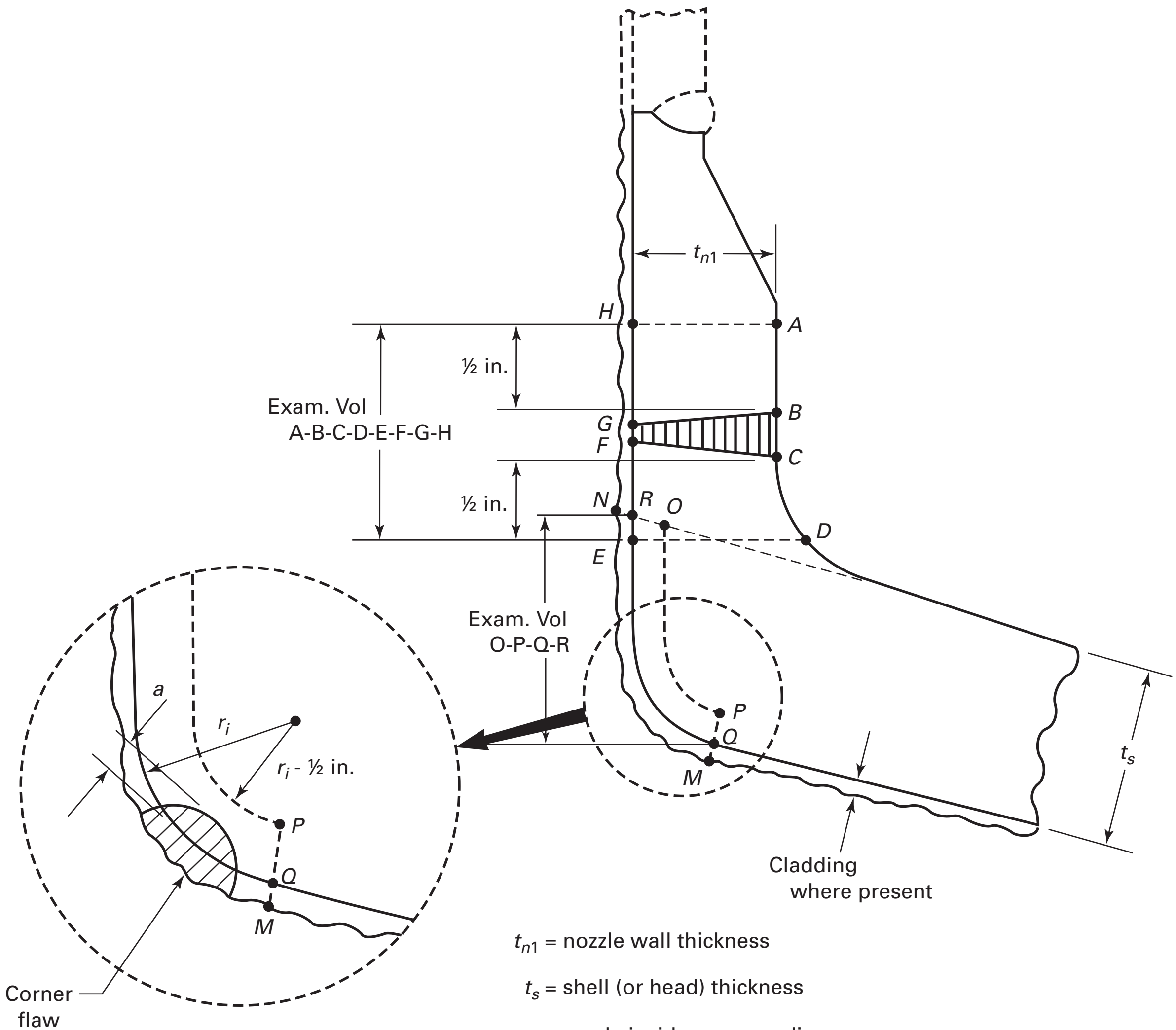
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-593-2
Examination Requirements for Steam Generator Nozzle-to-Vessel Welds
Section XI, Division 1

Inquiry: When conducting examinations of steam generator nozzle-to-vessel welds, what volume may be examined in lieu of the examination volume specified in Table IWB-2500-1, Examination Category B-D when the nozzle-to-vessel weld design is as shown in Figure 1?

Reply: It is the opinion of the Committee that the examination volume A-B-C-D-E-F-G-H, and O-P-Q-R in Figure 1 shall be used in lieu of the examination volume specified in Table IWB-2500-1, Examination Category B-D.

Figure 1
Nozzle in Shell or Head
[Examination Zones in Cylindrical Nozzles Joined by Full Penetration Butt Welds (½ in. = 13 mm).]



Examination Region [Note (1)]	Examination Volume [Note (2)]
Shell (or head) adjoining region	C-D-E-F
Attatchment weld region	B-C-F-G
Nozzle cylinder region	A-B-G-H
Nozzle inside corner region	O-P-Q-R

NOTES:
(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.
(2) Examination volumes shall be determnined either by direct measurements on the component or by measurements based on design drawings.

Approval Date: October 14, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-594-1
Repairs to P-4 and P-5A Castings Without Postweld Heat Treatment Class 1, 2, and 3 Construction Section III, Division 1

Inquiry: Under what conditions may repair welds be made to P-4 and P-5A castings for Class 1, 2, and 3 construction without postweld heat treatment of the repair when rejectable indications are found in the base material by examination in accordance with NB-2571, NC-2571, or ND-2571 after machining?

Reply: It is the opinion of the Committee that repair welds may be made to P-4 and P-5A castings for Class 1, 2, and 3 construction without postweld heat treatment of the repair when rejectable indications are found in the base material by examination in accordance with NB-2571, NC-2571, or ND-2571 after machining, provided the following requirements are met:

(a) The depth of the repair cavity shall not exceed a depth of $^3/_8$ in. or 10% of the nominal thickness, whichever is less, and the surface area shall not exceed 10 in.^{2}

(b) The repair cavity shall be examined by the magnetic particle or liquid penetrant method when a flaw has been removed from the material. Acceptance criteria shall be in accordance with NB-5340, NC-5340 or ND-5340 or NB-5350, NC-5350, or ND-5350, as applicable.

(c) The welding process shall be either SMAW with low-hydrogen electrodes or GTAW. SMAW electrodes shall be of the moisture-resistant designation and shall have a diffusible hydrogen indicator of H8 or H4 (e.g. E9018R-B3-H8). Electrodes shall have been stored at a temperature of 250°F minimum from the time that their shipping container is opened until they are consumed. SMAW electrode size shall be limited to $^5/_{32}$ in. diameter maximum.

(d) A minimum preheat of 250°F for P-4 materials and 300°F for P-5A materials shall be maintained at the repair cavity for at least 15 min prior to starting welding. Preheat shall be measured on the surface of the component on opposite sides of the cavity no closer than 3 in. from the edge of the cavity. After welding has been completed, the weld area shall be heated to 500°F minimum and held for a minimum of 2 hr.

(e) Welds shall be made using at least two layers of weld metal. A final layer of weld metal shall be applied after the weld metal has reached the anticipated final surface level. This final layer shall be applied without touching the base metal, but close enough to it so that the toe of the underlying heat-affected zone is tempered by the heat from the final layer of weld metal. The final layer of weld metal shall be mechanically removed after cooling to ambient temperature.

(f) In addition to the welding procedure qualification requirements of Section IX, an additional test coupon shall be prepared and tested using base metal of the same P-number as that to be used in the repair, and the additional testing described in either (1) or (2) below shall be performed on that test coupon. That test coupon shall be welded using the proposed preheat temperature, interpass temperature, welding electrode or filler metal classification and size and heat input (measured in accordance with Section IX, QW-409.1) for each weld layer. If the qualification is acceptable, the procedure is qualified using the preheat temperature, interpass temperature, welding electrode or filler metal classification and size and heat input for each weld layer that were used during qualification, except that heat input may vary ±10% from that qualified. If thermal methods are used to create the repair cavity, that method shall be used to prepare the test coupon cavity unless the repair procedure requires that at least $^1/_{16}$ in. of metal is removed from the cavity after using a thermal metal-removal method.

(1) The test coupon shall be at least 12 in.^{2} and $1^1/_2$ in. thick. A cavity that is approximately $^3/_8$ in. deep and 2 in.^{2} shall be created in the coupon. After the cavity has been welded following the proposed WPS, the specimen shall be metallographically examined, and the weld cross section shall reveal that at least 85% of the coarse-grain region of each weld layer in the heat-affected zone has been converted to fine-grain or microstructure other than martensite by heat from subsequent weld layers, and that any coarse-grained regions are discontinuous. In addition, the weld metal and heat-affected zone hardness shall not exceed 225 and 241 Brinell for P-4 and P-5A respectively. This test coupon shall qualify the WPS for repairs to all thicknesses of material.

(2) The test coupon shall be at least $1^1/_2$ in. thick. A groove weld shall be made following the proposed WPS, and the weld metal and heat-affected zone shall be impact tested in accordance with NB-2320, NC-2320, or ND-2320, as applicable. The impact tests shall meet the requirements of NB-2330 for Class 1, Table NC-2330 for Class 2, or Table ND-2330 for Class 3, at or below the lowest metal service temperature. Dropweight testing is not required. This test coupon shall qualify the WPS for repairs to thicknesses of material based on the values achieved during impact testing in accordance with Table NB-2332(a)-1 for Class 1; Table NC-2332.1-1 or NC-2332.1-2 for Class 2; or Table ND-2331(a)-1 or ND-2331(a)-2 for Class 3.

(g) The final repaired surface shall be examined by magnetic particle or liquid penetrant method. Acceptance criteria shall be in accordance with NB-5340, NC-5340, or ND-5340 or NB-5350, NC-5350, or ND-5350, as applicable.

(h) Use of this Case number shall be identified on the Data Report.

Approval Date: May 7, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-597-3
Evaluation of Pipe Wall Thinning
Section XI, Division 1

Inquiry: What methods may be used for evaluation of Class 2 and 3 piping items subjected to internal or external wall thinning?

Reply: It is the opinion of the Committee that the following methods may be used for evaluation of Class 2 and 3 piping items subjected to internal or external wall thinning.

-1000 SCOPE

(a) This Case provides requirements for evaluation of Class 2 and 3 piping items (e.g., pipe and fittings) with internal or external wall thinning.

(b) This Case is applicable to wall thinning due to flow-accelerated corrosion and other corrosion mechanisms.

(c) The provisions of this Case apply to Class 2 and 3 butt-welded pipe, pipe bend, elbow, tee, branch connection, or reducer piping items.

(d) This Case shall not be applied to planar flaws.

(e) This Case shall not be applied to wall thinning locations in piping items that are not accessible for either volumetric examination or direct physical measurement.

-3000 ACCEPTANCE STANDARDS

-3100 PRESERVICE EXAMINATION

Piping items examined prior to commercial service are acceptable for service when the measured wall thickness meets the requirements of the Construction Code.

-3200 INSERVICE EXAMINATION

-3210 General

(a) The current wall thickness of the metal loss region, t_c, shall be determined in accordance with -3220.

(b) The predicted wall thickness in the metal loss region, t_p, shall be determined at the end of the evaluation period τ, in accordance with -3220.

(c) If the minimum predicted wall thickness at the end of the evaluation period, $t_{p,\ \mathrm{min}}$, is less than $0.25t_{\mathrm{nom}}$, further use of this Case is not permitted. Alternatively, the Owner may select a shorter evaluation period and determine a new t_p and $t_{p,\ \mathrm{min}}$.

(d) The metal loss region shall be evaluated in accordance with the requirements of the Construction Code or the acceptance criteria in either -3500 or -3600 of this Case.

(e) The metal loss region of the piping item shall be subjected to volumetric re-examination or direct physical measurement in accordance with -3220 at intervals that do not exceed the length of the evaluation period.

(f) If the metal loss region of the piping item does not meet the acceptance criteria of this Case, a repair/replacement activity shall be performed.

-3220 Characterization of Metal Loss

Current wall thickness of the metal loss region, t_c, shall be characterized by volumetric thickness measurement or by physical measurement. The condition of the full pipe circumference shall be assessed, and the metal loss region shall be inspected to characterize the extent of degradation.

(a) The rate of metal loss during the evaluation period shall be determined. The rate of metal loss shall account for concurrent internal and external metal loss, as applicable, at the affected location.

(b) For each position along the profile of the metal loss region, the local predicted remaining wall thickness at the end of the evaluation period, t_p, shall be calculated as follows:

$$t_p = t_c - R \times \tau$$

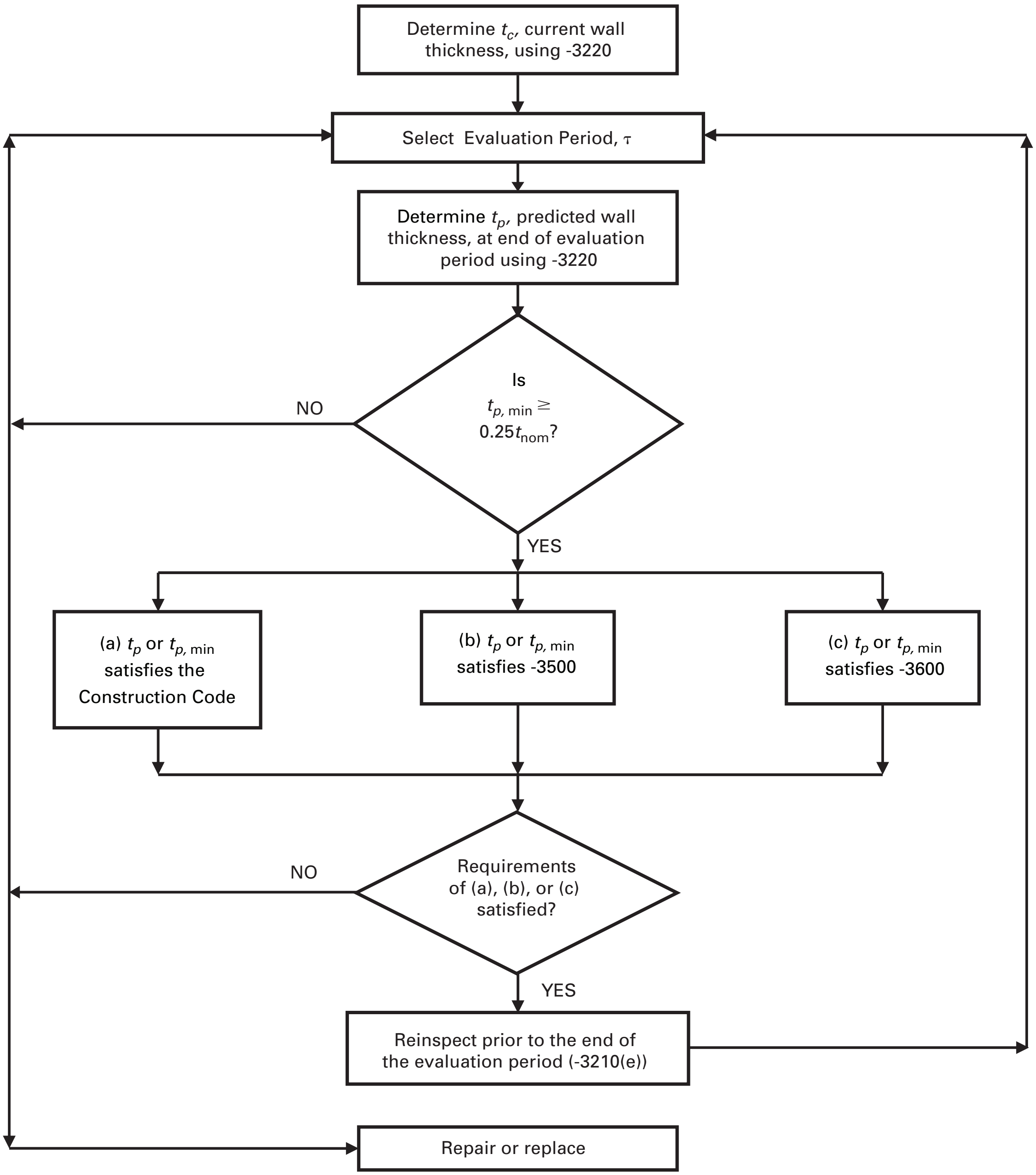
where

R = predicted rate of metal loss during the evaluation period, and which includes a factor for uncertainty in metal loss rate, in./yr (mm/yr)

t_c = current local wall thickness at the position along the profile of the metal loss region corresponding to t_p, in. (mm)

τ = length of the evaluation period, yr

Figure -3210-1
General Flow Chart



The Owner shall be responsible for determining the rate of future metal loss, R, and factors to account for uncertainties in the metal loss rate. The known rate of metal loss for the specific degradation mechanism based on operating experience or laboratory tests shall be used if available. For metal loss caused by flow-accelerated corrosion, a future wall thinning rate calculated using the average actual rate over the service or inspection history, including an appropriate uncertainty factor, is acceptable. If the wall thinning rate is calculated based on the total time in service, the Owner shall not assume an initial pipe wall thickness less than t_{nom} unless initial wall thickness measurements are available.

(c) The minimum value of t_p in the metal loss region is $t_{p,\mathrm{min}}$, as illustrated in Figure -3622-3.

-3500 WALL THICKNESS ACCEPTANCE STANDARDS

(a) A Class 2 or 3 butt welded pipe, pipe bend, elbow, branch connection, or reducer piping item is acceptable for continued service without further evaluation when t_p at all locations on the piping item meets the following requirements.

(E) *(1)* For straight pipe, pipe bends, and elbows purchased to a nominal pipe specification with an allowable wall thickness under tolerance of 12.5%, t_p shall be not less than $0.875t_{\mathrm{nom}}$.

(2) For the small end of concentric and eccentric reducers, t_p shall be not less than $0.875t_{\mathrm{nom}}$ for the pipe size at the small end. For the large end, the large end transition and the conical portion, t_p shall not be less than $0.875t_{\mathrm{nom}}$ for the pipe size at the large end. For the small end transition, the required thickness shall be gradually reduced from that required at the large end to that required at the small end (see Figure -3622-2).

(3) For tees and branch connections, t_p shall be not less than $0.875t_{\mathrm{nom}}$ for the same size pipe for regions outside the limits of reinforcement required by the Construction Code used in the evaluation. For regions within the limits of reinforcement, t_p shall be not less than the thickness required to meet the branch reinforcement requirements of the Construction Code.

(4) For regions of piping items designed to specific wall thickness requirements, including designed weld counterbores and regions with integral reinforcement, t_p shall be not less than the minimum design thickness, including tolerances and excluding any corrosion allowances, specified in the original design analysis for the piping item.

(5) As an alternative to the requirements of (2) and (3), for reducers, tees, or branch connections purchased to fitting standards allowed in NB-3132 and for which baseline as-installed thickness measurements exist, t_p shall be not less than 0.875 times the as-installed thickness measurements, except that the thickness shall be not less than $0.875t_{\mathrm{nom}}$.

-3600 ANALYTICAL EVALUATION

-3610 General Requirements

(a) Analytical evaluations shall be conducted using the predicted wall thickness profile, t_p, at the end of the evaluation period for the piping item.

(b) Analytical evaluation shall be conducted in accordance with the Construction Code. Later Construction Code Editions and Addenda may be used.

(c) A piping item is acceptable for continued service if the minimum pipe wall thickness, branch reinforcement requirements, and piping stress criteria of the Construction Code used in the analytical evaluation are met for all specified loading conditions.

(d) As an alternative to (b) and (c), butt welded pipe, pipe bend, elbow, branch connection, and reducer piping items may be evaluated in accordance with -3620.

-3620 Analytical Evaluation of Pipe, Pipe Bends, Elbows, Branch Connections, and Reducers

-3621 General Requirements

(a) Analytical evaluations shall be conducted using the appropriate piping equations, loadings, load combinations, allowable stresses, material properties, and other acceptance standards from the Construction Code used in the analytical evaluation, except as specifically modified by this Case. Any linear elastic analysis method allowed by NB-3200 and the Owner's Requirements may be used.

(b) Whenever a new t_p is determined in accordance with -3210(b), the associated value of L_m used in -3622 shall also be recalculated.

(c) An analytical evaluation shall be conducted in accordance with -3622 to determine the acceptability of the thinned region for hoop stress due to internal pressure.

(d) An analytical evaluation shall be conducted in accordance with -3623 to determine the acceptability of the thinned region for longitudinal stress due to internal pressure and moments.

(e) For a branch connection or tee, the region within the limits of reinforcement defined in the Construction Code shall also meet the requirements of -3624.

(f) Requirements for the analytical evaluation of cyclic operation are given in -3625.

(g) If the ratio R_o/t_p is greater than 50, the potential for buckling of the thinned region shall be evaluated. Analytical evaluation methods and acceptance criteria shall be specified by the Owner.

(E)

Figure -3621-1
Flow Chart for Analytical Evaluation of Pipe, Pipe Bends, Elbows, Branch Connections, and Reducers

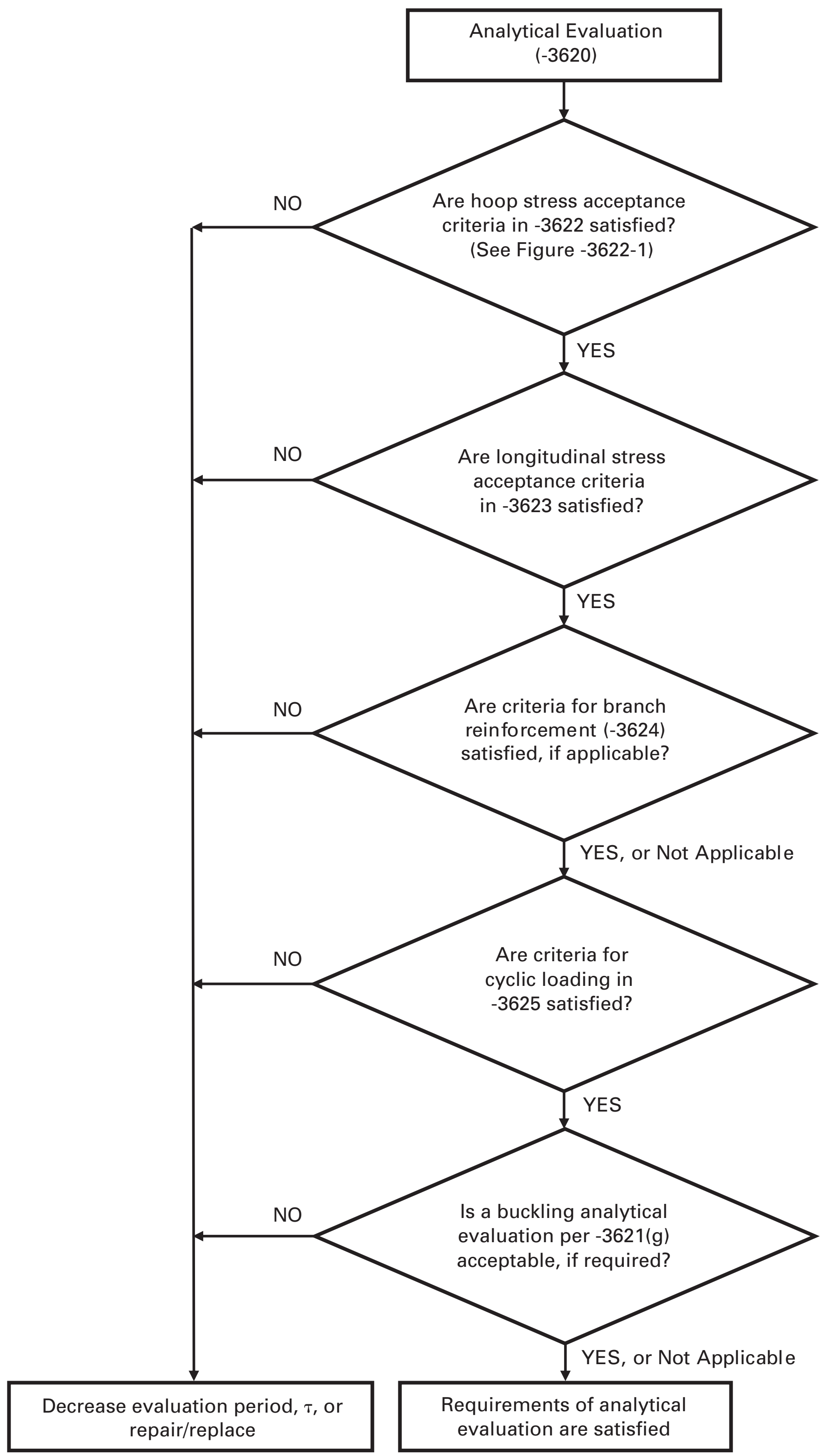
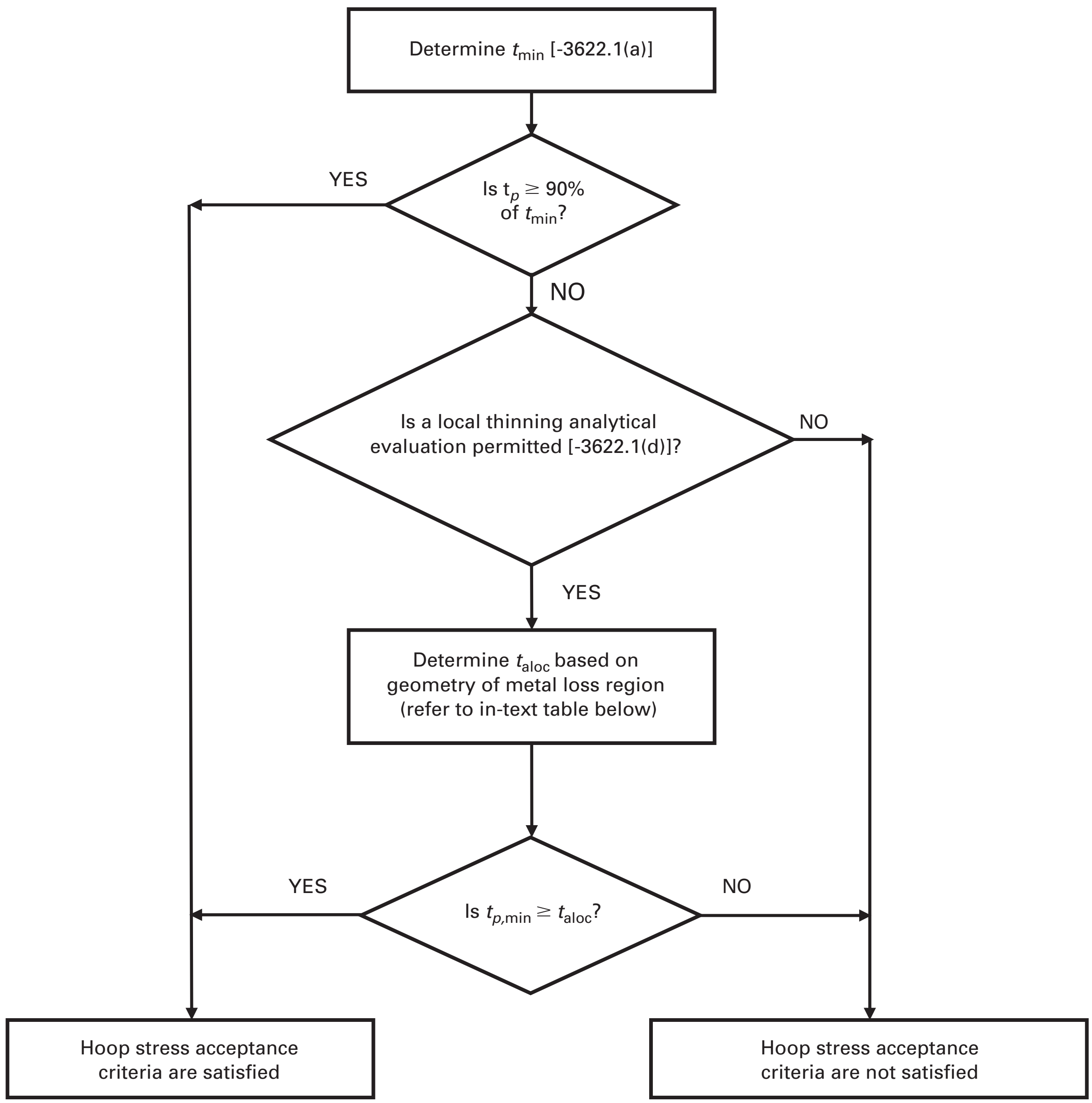


Figure -3622-1
Flow Chart for Thickness Analytical Evaluation for Hoop Stress Due to Internal Pressure (-3622) to Be Used With Figure -3621-1



Condition	Governing Paragraph
Thinned Areas are of Limited Circumferential Extent	-3622.2
Thinned Areas are of Limited Axial and Circumferential Extent	-3622.3
Thinned Areas are of Unlimited Circumferential Extent	-3622.4
Minimum Allowable Local Thickness for Elbows and Pipe Bends	-3622.5
Conical Portions of Concentric Reducers	-3622.6

-3622 Thickness Analytical Evaluation for Hoop Stress Due to Internal Pressure

-3622.1 Analytical Evaluation for Minimum Wall Thickness for Hoop Stress Due to Internal Pressure

(a) Except as provided in (b), the value of t_p at any location shall be not less than 90% of the minimum wall thickness of the piping item, t_{min}, required for design pressure, defined in the Construction Code used in the analytical evaluation, exclusive of any additional corrosion allowance.

(1) For straight pipe, bends, and elbows, t_{min} shall be determined by the following equation:

$$t_{\min} = \frac{PD_o}{2(S + yP)}$$

(2) For concentric and eccentric reducers, t_{min} at each end shall be equal to t_{min} of straight pipe of the same nominal size as the reducer end. For the conical portion of the reducer and the transition at the large diameter end, t_{min} shall be that of the large diameter end. A gradual transition in t_{min} shall be assumed for the transition at the small end (see Figure -3622-2).

(3) For branch connections and tees, except at regions providing reinforcement of the opening required by the Construction Code used in the analytical evaluation, t_{min} shall be as required for straight pipe.

(E) *(b)* When t_p is less than $0.9t_{min}$ at any location, additional analytical evaluations may be conducted to determine the allowable local thickness, t_{aloc}, subject to the limitations in (d). The thinned region and the parameters that define the depth and extent of thinning are illustrated in Figure -3622-3. The allowable local thickness shall be determined in accordance with the applicable methods of -3622.2, -3622.3, -3622.4, -3622.5, or -3622.6, depending on the extent of the locally thinned area and the piping component. The value of $t_{p,\ min}$ shall be not less than t_{aloc}.

(c) For a region at a distance greater than $1.5\sqrt{R_{nom}t_{nom}}$ from the butt weld at the inner portion of elbows or pipe bends (Figure -3622-4), the t_{min} in the analytical evaluation of -3622.2, -3622.3, or -3622.4 shall be replaced by t'_{min}, defined by the following:

$$t'_{\min} = \left(0.5 + \frac{0.5}{1 + \dfrac{\cos\theta}{(R_b/R_o)}} \right) t_{\min,\ \text{pipe}}$$

(d) Local thinning analytical evaluation shall not be allowed for the following:

(1) Any thinned area in the run piping with a location at which the wall thickness is less than t_{min} and is closer to the center of the branch connection than $D_i + 0.5\ L_m$. The dimension D_i is the nominal inside diameter of the branch connection and L_m is the maximum extent of the thinned region that is less than t_{min}.

(2) At the small end transition of a reducer.

-3622.2 Minimum Allowable Local Thickness of Thinned Areas of Limited Circumferential Extent (E)

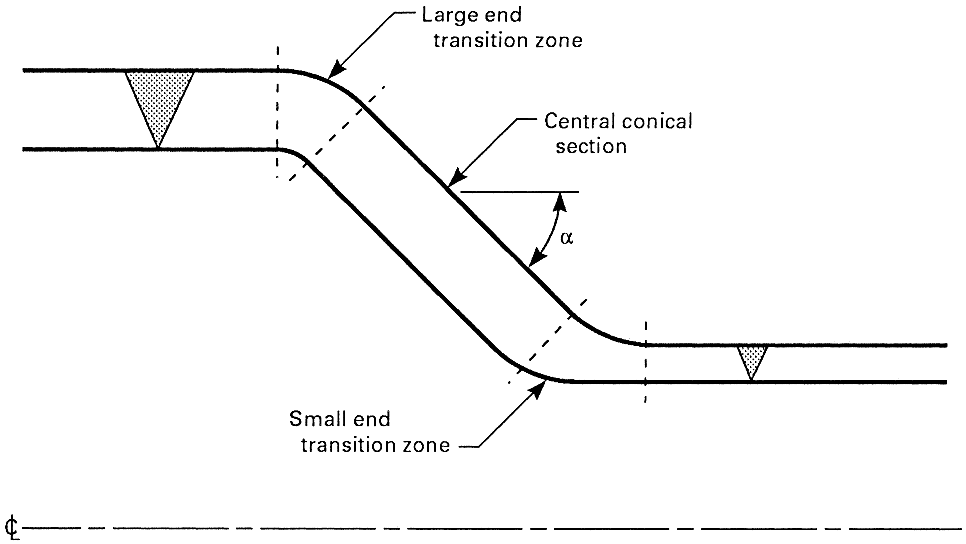
(a) The analytical evaluation procedure shall consider the depth and extent of the affected area and require that the wall thickness exceed t_{min} for a distance that is the greater of $2.5\sqrt{R_{nom}t_{nom}}$ or $2L_{m,\ avg}$ between adjacent thinned regions, where R_{nom} is the mean radius of the piping item based on nominal wall thickness and $L_{m,\ avg}$ is the average of the extent of L_m below t_{min} for the adjacent areas (see Figure -3622-5). Alternatively, the adjacent thinned regions shall be considered a single

Table -3622-1
Minimum Allowable Local Thickness (Based on Hoop Stress)

$\dfrac{L_{m(a)}}{\sqrt{R_{\min}t_{\min}}}$	t_{aloc}/t_{min}: -3622.2, Limited Circumferential Extent	t_{aloc}/t_{min}: -3622.4, Unlimited Circumferential Extent
0	0.100	0.100
0.20	0.100	0.261
0.23	0.100	0.300
0.26	0.100	0.375
0.32	0.100	0.477
0.38	0.100	0.551
0.45	0.100	0.616
0.50	0.100	0.651
0.60	0.100	0.703
0.70	0.182	0.742
0.83	0.300	0.778
0.85	0.315	0.782
0.90	0.349	0.794
1.00	0.410	0.813
1.20	0.505	0.841
1.40	0.572	0.860
1.60	0.622	0.873
1.80	0.659	0.883
2.00	0.687	0.891
2.25	0.714	0.897
2.50	0.734	0.900
2.75	0.750	0.900
3.00	0.763	0.900
3.50	0.787	0.900
4.00	0.811	0.900
4.50	0.834	0.900
5.00	0.858	0.900
5.50	0.882	0.900
6.00	0.900	0.900
>6.00	0.900	0.900

GENERAL NOTE: Interpolation may be used for intermediate values.

Figure -3622-2
Zones of Reducer or Expander



GENERAL NOTE: Transition zones extend from the point on the ends where the diameter begins to change to the point on the central cone where the cone angle is constant.

thinned region in the analytical evaluation. Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to combination.

(b) Determine the allowable local thickness t_{aloc}, from Table -3622-1, provided that the circumferential extent of wall thinning predicted to be less than t_{min}, $L_{m(c)}$, is less than or equal to $\sqrt{R_{min}t_{min}}$. R_{min} is the mean radius of the piping item based on the minimum wall thickness t_{min}. For straight pipe, Table -3622-1 may be used when $L_{m(c)}$ exceeds $\sqrt{R_{min}t_{min}}$, except that an additional thickness t_b (the Construction Code required thickness to withstand the piping sustained and occasional primary moment loads) shall be added to the value determined from Table -3622-1.

(c) This approach shall not be used to evaluate a reducer.

-3622.3 Minimum Allowable Local Thickness of Thinned Areas of Limited Axial and Circumferential Extent

(**E**) *(a)* The value of t_{aloc} shall be determined by satisfying (b) and (c) or (d) below when the maximum extent of wall thinning, L_m, for which thickness is predicted to be less than t_{min} is less than or equal to $2.65\sqrt{R_{min}t_{min}}$, and t_{nom} is greater than $1.13t_{min}$. This approach requires that adequate reinforcement be available surrounding the thinned area in accordance with (c) or (d) below. This analytical evaluation approach is not applicable for the following conditions:

(1) Thinned areas adjacent to branch connections, when the reinforcement zone for the thinned area would overlap the required reinforcement of the branch connection.

(2) Thinned areas for which any portion of the reinforcement zone would lie on the conical or small diameter transition zone of a reducer.

(3) Adjacent thinned areas qualified by this approach when the reinforcement zones associated with each area would overlap.

(b) The thickness of the remaining pipe wall at the thinned section is adequate if the following equation is satisfied.

$$\frac{t_{aloc}}{t_{min}} \geq \frac{0.353L_m}{\sqrt{R_{min}t_{min}}}$$

(c) If there is a surrounding reinforcement zone with predicted thickness of at least t_{nom} for a minimum dimension of $L/2$ in all directions, reinforcement for the thinned area shall satisfy the following equation.

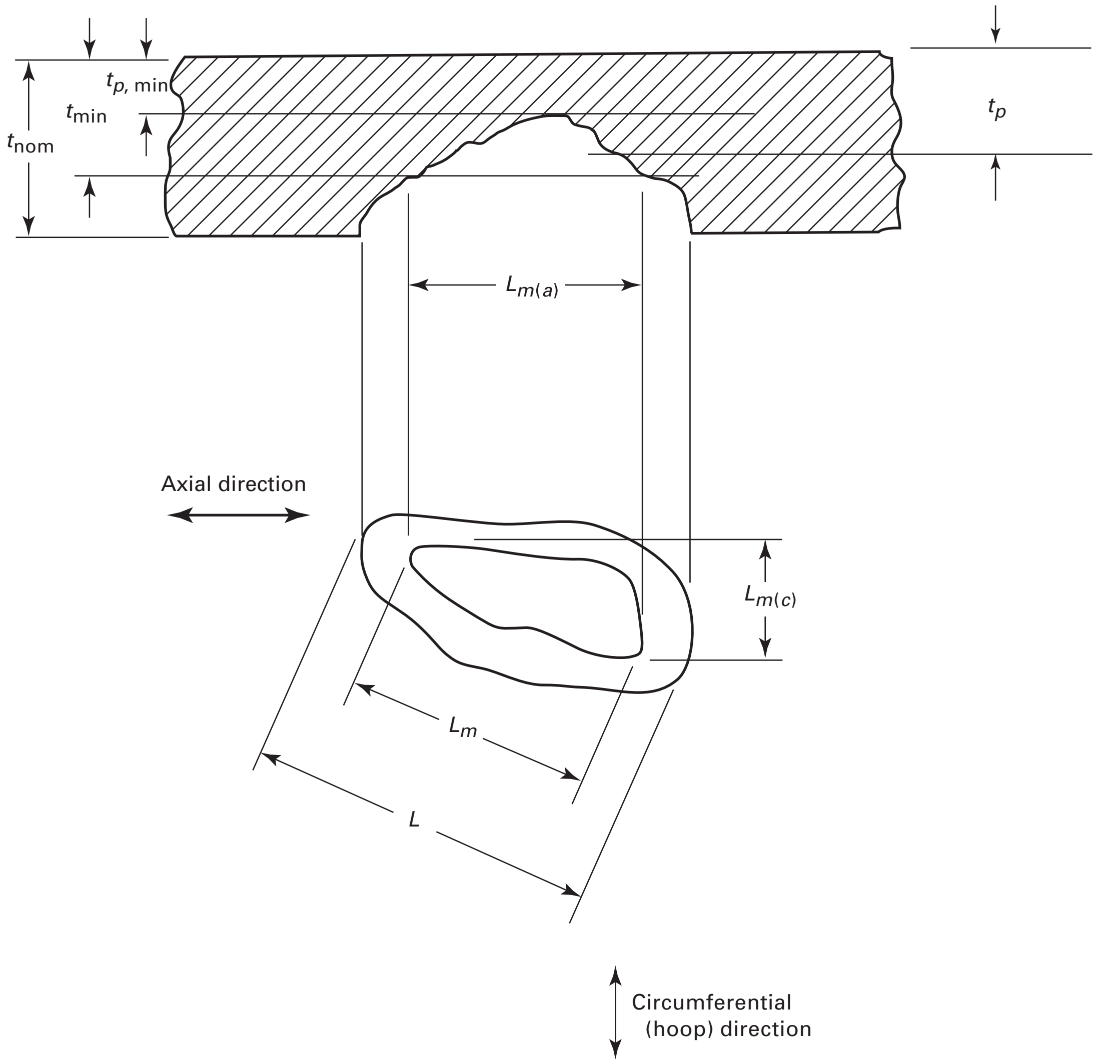
$$\frac{t_{aloc}}{t_{min}} \geq 1 - \left(\frac{1.5\sqrt{R_{min}t_{min}}}{L}\right)\left(\frac{t_{nom}}{t_{min}} - 1\right)$$

(d) As an alternative to (c) above, the reinforcement adjacent to the thinned area shall satisfy the following equation.

$$\frac{t_{aloc}}{t_{min}} \geq 1 - \left(\frac{0.935A_{rein}}{L_m t_{min}}\right)$$

(E)

Figure -3622-3
Illustration of Wall Thinning



-3622.4 Minimum Allowable Local Thickness of Thinned Areas of Unlimited Circumferential Extent

(a) A thinned region with unlimited circumferential extent is defined as one that may extend up to the entire circumference of the piping item.

(b) The analytical evaluation shall include consideration of the depth and extent of the affected area less than t_{min}. The wall thickness shall exceed t_{min} for an axial distance the greater of $2.5\sqrt{R_{nom}t_{nom}}$ or $2L_{m(a)}$,max between adjacent thinned regions at each circumferential location on the piping item (see Figure -3622-6). Alternatively, the adjacent thinned regions shall be considered a single thinned region in the analytical evaluation. Areas need not be combined into single areas based on separation in the circumferential (hoop) direction provided that circumferential extents of individual adjacent thinned areas do not overlap.

(c) Thickness t_{aloc} shall be determined from Table -3622-1.

(d) This approach shall not be used to evaluate a reducer.

-3622.5 Minimum Allowable Local Thickness for Elbows and Pipe Bends (E)

(a) For locations at a distance greater than $\sqrt{R_{min}t_{min}}$ from welds to adjacent piping items, the predicted thickness on the outer portion of an elbow or bend may be less than t_{min} for straight pipe. The local allowable thickness at each location shall be determined by

(E)

Figure -3622-4
Elbow or Pipe Bend

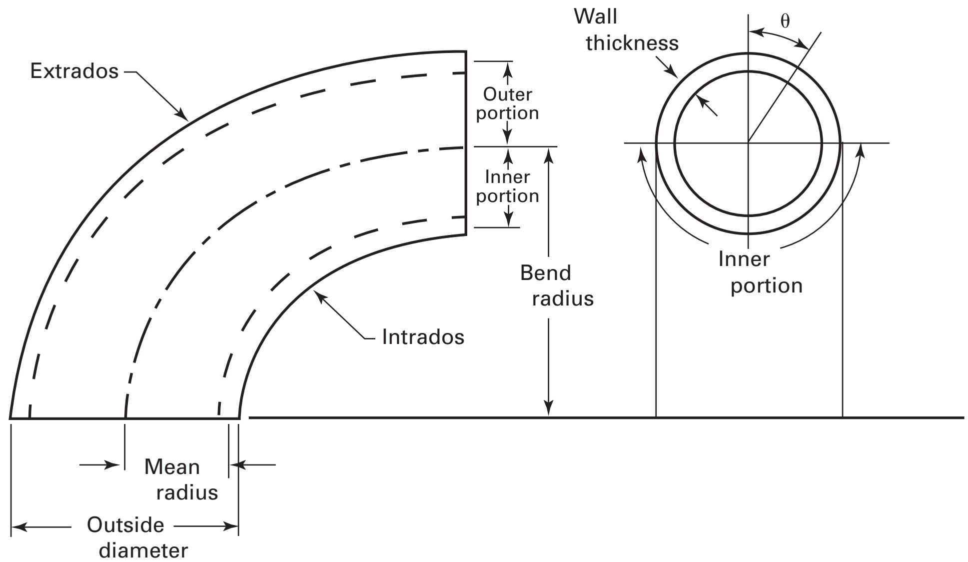
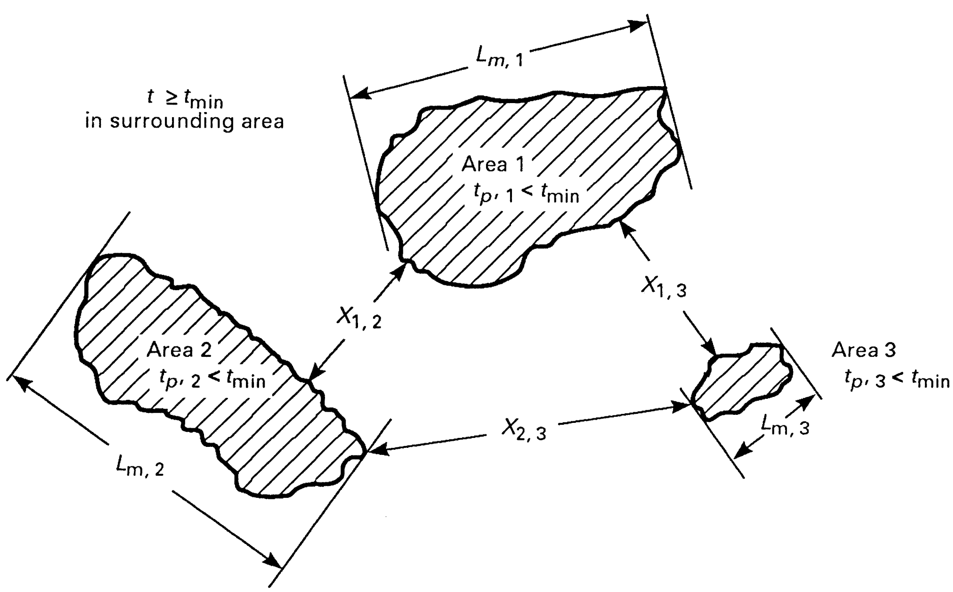


Figure -3622-5
Separation Requirements for Adjacent Thinned Areas With Limited Circumferential Extent (Hoop Stress Check)



Legend:

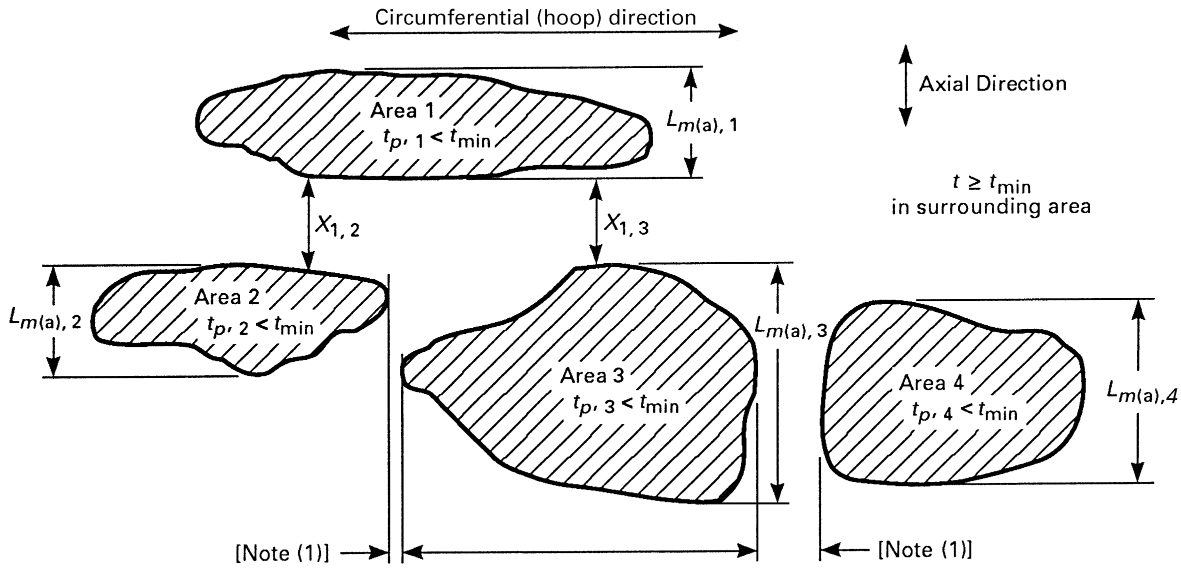
$X_{i,\ j}$ = minimum distance between areas i and j

$L_{m,\ I}$ = maximum extent of thinned area i

$L_{m,\ \mathrm{avg}} = 0.5\ (L_{m,\ i} + L_{m,\ j})$

GENERAL NOTE: Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to combination.

Figure -3622-6
Axial Separation Requirements for Adjacent Thinned Areas With Unlimited Circumferential Extent (Hoop Stress Check)



Legend:

$X_{i,\,j}$ = minimum distance between areas i and j at any circumferential location on pipe

$L_{\max}$ = maximum of the extents $L_{m(a),\,i}$ and $L_{m(a),\,j}$ of two adjacent areas

$L_{m(a),\,I}$ = maximum extent of thinned area i in axial direction

GENERAL NOTE: Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to any combination of adjacent areas.

NOTE:
(1) Areas need not be combined into single areas based on separation in the circumferential (hoop) direction, provided that circumferential extents of individual adjacent thinned areas do not overlap.

$$\frac{t_{aloc}}{t_{\min,\text{pipe}}} \geq 0.5 + \frac{0.5}{1 + \frac{\cos\theta}{\left(\frac{R_b}{R_{\min}}\right)}}$$

where

$R_b/R_{\min}$ = ratio of elbow bend radius to mean pipe radius, based on $t_{\min}$ for the same size pipe

-3622.6 Minimum Allowable Local Thickness for Conical Portions of Concentric Reducers

(a) For the conical portion of concentric reducers, the local allowable thickness less than $t_{\min}$ shall satisfy the following equation:

$$\frac{t_{\text{aloc}}}{t_{\min,1}} \geq \frac{d_o/D_1}{\cos\alpha}$$

(b) For the flared transition at the small end of a concentric reducer, the local allowable thickness shall be gradually reduced from the value determined at the conical end of the flare to $t_{\min}$ for the small end of the reducer.

(c) This approach shall not be used to evaluate eccentric reducers.

-3623 Piping Stress Analytical Evaluation for Longitudinal Stresses

-3623.1 Analytical Evaluation Requirements

(a) The effects of piping stresses shall be evaluated in accordance with the equations of the Construction Code used in the evaluation. If the piping design analysis is based on nominal piping thickness, the allowable stresses used in a stress analysis based on the predicted thickness profile, t_p, may be multiplied by 1.143. Consideration shall be given to changes in the pipe metal area, pipe inside area, section modulus, and stress indices or stress intensification factors, as described in -3623.2, -3623.3, and -3623.4. The effects of cyclic operating conditions shall be addressed in accordance with -3625.

(b) The piping stress analytical evaluation shall be based on the predicted thickness at each cross section of the piping item that exhibits significant thinning or is affected by a change in stress index or stress intensification factor. Alternatively, the analytical evaluation may use the limiting cross section that is based on combinations of wall thinning and loadings.

-3623.2 Nominal Longitudinal Pressure Stresses

(a) The pipe metal area and the pipe inside area, for the thinned cross section might result in stresses different from those of the piping stress analysis of record.

(b) For simplified analysis, the piping item may be assumed to be uniformly thinned with a thickness of $t_{p,\ \min}$. For this approach, the nominal longitudinal pressure stress shall be determined by:

$$S_p = \frac{PD_o}{4t_{p,\min}}$$

When evaluating reducers, the large and small ends shall be evaluated separately. For the large end, $t_{p,\ \min}$ shall be determined from all locations for the large end and conical section. For the small end, $t_{p,\ \min}$ for the entire reducer shall be used.

(c) Detailed stress analysis may be conducted based on the complete set of measurements around the thinned cross section of the piping item. The nominal longitudinal pressure stress, S_p, shall be determined by

$$S_P = \frac{PA_i}{A_P}$$

(1) To evaluate piping at a branch connection beyond the limits of reinforcement, it shall be assumed that the entire region within limits of reinforcement is at thickness $t_{\min}$ for the unreinforced pipe section, with the outside surface at the pipe nominal outside radius. If excess reinforcement is available within the limits of reinforcement, the excess metal area may be included in A_p.

(2) When evaluating the longitudinal pressure stress in the central cone of a reducer, the stress shall be determined based on the local radius at the cross section and the local t_p at and adjacent to the cross section of interest, except that the resulting stress shall be multiplied by a factor of $1/\cos\alpha$.

(d) When using Code Editions and Addenda that require use of stress indices, the nominal longitudinal stress determined in accordance with (b) and (c) shall be doubled.

-3623.3 Nominal Longitudinal Bending Stresses

(a) Thinning of the piping item cross-sectional area might result in bending stresses different from those of the piping stress analysis of record. The nominal longitudinal bending stress, S_b, for the various loading conditions and load combinations shall be determined by

$$S_b = \frac{M_b + PA_o\delta}{Z_{\min}}$$

(b) For simplified analysis, the piping item section modulus may be based on a uniformly thinned section with thickness $t_{p,\ \min}$. When evaluating reducers, the large and small ends shall be evaluated separately. For the large end, $t_{p,\ \min}$ shall be determined from all locations for the large end and conical section. For the small end, $t_{p,\ \min}$ for the entire reducer shall be used.

(c) Detailed stress analysis may be conducted based on a complete set of measurements around the thinned cross section of the piping item.

(d) When evaluating thinning at the cross section of a branch connection, the requirements of -3623.2(c)(1) shall be met.

-3623.4 Stress Intensification Factors and Stress Indices. The local piping item wall thickness could affect the stress indices or stress intensification factors used in determination of the effective piping stress at a branch connection. When reduced wall thickness could increase these factors, the effect shall be considered by using a reduced piping item thickness determined in accordance with (a), (b), or (c).

(a) Except as allowed in (b) or (c) below, stress intensification factors or stress indices for a piping item shall be based on the assumption of uniform wall thickness, using a value of $t_{p,\ \min}$ and an associated mean pipe radius in the formula for these factors.

(b) As an alternative to (a) above, the factors may be based on the average t_p of the thinned region excluding branch reinforcement zones, except that predicted thickness at locations within a distance of twice the pipe nominal wall thickness from butt welds to adjacent components need not be considered. For reducers, the average t_p of the small end shall be used with the small end diameter to determine the factor.

(c) As an alternative to (a) or (b) above, detailed stress analysis of thinned piping items may be conducted to calculate stress intensification factors or stress indices.

-3624 Analytical Evaluation of Branch Connections

-3624.1 Branch Connections Not Requiring Reinforcement.

(a) The region on the piping run shall be evaluated in accordance with the requirements of -3622 and -3623, without consideration of the branch connection, except that t_p within a region of radius of D_i of the branch pipe from the center of the branch connection shall not be less than $t_{\min}$ for the pipe run.

(b) The branch piping shall be evaluated in accordance with the requirements of -3622 and -3623.

-3624.2 Branch Connections Requiring Reinforcement.

(a) Branch reinforcement requirements shall be determined in accordance with the Construction Code used in the analytical evaluation.

(b) For the region of the piping run that provides branch reinforcement, the value of t_p at any location shall be not less than $t_{\min}$ for the nominal pipe run plus any required reinforcement at that location.

(c) For the region of the branch pipe that provides branch reinforcement, t_p shall be not less than $t_{\min}$ for the branch pipe plus any required reinforcement.

Table -3625-1
Modified Stress Range Reduction Factors

Number of Equivalent Full Temperature Cycles [Note (1)], *N*	Stress Range Reduction Factor [Note (2)], *f*
650 or less	1.0
>650 to 1100	0.9
>1100 to 2000	0.8
>2000 to 3900	0.7
>3900 to 8500	0.6
>8500 to 21,000	0.5
over 21,000	0.4

NOTES:
(1) Cycles to the end of the evaluation period or repair/replacement activity.
(2) The modified stress range reduction factors are based on an increase in the stress intensification factor, i, by a factor of 2 over the life of the component.

-3625 Analytical Evaluation for Cyclic Operation

(a) For piping items with $t_{p,\ \min}$ not less than $0.75t_{\text{nom}}$ and subject to no more than 150 equivalent full temperature cycles at the end of the evaluation period, in accordance with the Construction Code used in the analytical evaluation, piping stress equations that include thermal expansion and anchor movement stresses need not be evaluated.

(b) For piping items not meeting the provisions of (a) above, when the design includes consideration of thermal expansion stresses, the allowable stress range for expansion stress shall be determined in accordance with the Construction Code used in the analytical evaluation, except that the stress intensification factor, i, shall be revised to take into account the geometry of the thinned region. As an alternative to establishing a revised stress intensification factor, the stress range reduction factors of Table -3625-1, which are based on an increase in the stress intensification factor by a factor of 2 over the life of the component, may be used.

(c) The potential for local overstrain in the thinned region for the combination of maximum sustained plus thermal expansion stresses shall be evaluated. Sustained loads include pressure, weight, and other sustained mechanical loads. Local overstrain is defined in NC-3672.6(b). Analytical evaluation methods and acceptance criteria shall be specified by the Owner.

-3626 Nomenclature

A_i = predicted inside cross-sectional area for a pipe that has experienced wall thinning
A_m = predicted metal cross-sectional area for a pipe that has experienced wall thinning
A_o = total cross-sectional area of pipe based on nominal outside diameter, $\frac{\pi D_o^2}{4}$
A_p = predicted metal cross-sectional area of pipe
A_{rein} = the reinforcement area available in the pipe wall based on the predicted thickness distribution in excess of $t_{\min}$ and within the limits of reinforcement of the Construction Code for an opening with diameter L_m at the region of local thinning
D_1 = outside diameter at the large end of the reducer
D_i = nominal inside diameter of a branch connection
D_o = nominal outside diameter of piping item
d_o = maximum outside diameter of a reducer at the thinned location
f = stress range reduction factor
$I_{\min}$ = predicted minimum moment of inertia of the thinned pipe about the neutral axis of the pipe section, considering all orientations of the section neutral axis
i = stress intensification factor of the Construction Code (not less than 1.0)
L = maximum extent of a local thinned area with wall thickness less than t_{nom}
L_m = maximum extent of a local thinned area with wall thickness less than $t_{\min}$
$L_{m(a)}$ = maximum axial extent of a local thinned area with wall thickness less than $t_{\min}$
$L_{m(a),\ \max}$ = maximum of the axial extents of two adjacent local thinned areas with wall thickness less than $t_{\min}$
$L_{m(c)}$ = maximum circumferential extent of a local thinned area with wall thickness less than $t_{\min}$
$L_{m,\ \text{avg}}$ = average of the extents of thickness less than $t_{\min}$ for two adjacent thinned areas
M_b = resultant bending moment from the design analysis of record for each loading condition under consideration
P = design pressure
R = rate of metal loss
R_b = bend radius of an elbow to the elbow center line

R_{max} = radius to the nominal outside surface of the pipe plus the nominal distance between the center of the pipe and the neutral axis
R_{min} = mean radius of piping item based on the nominal outside radius and the minimum wall thickness
R_{nom} = mean radius of piping item based on the nominal radius and thickness
R_o = nominal outside radius
S = allowable stress at design temperature for piping items, including joint efficiency factor, *E,* if applicable
S_b = maximum nominal bending stress at the thinned section without stress intensification factors or stress indices
S_p = nominal longitudinal pressure stress
t_{aloc} = allowable local thickness
t_b = uniform thickness of piping item, required by the Construction Code, to withstand sustained and occasional bending loadings in the absence of pressure, thermal expansion, and anchor movement loadings
t_c = current wall thickness at location of t_p
t_{min} = minimum wall thickness required by the Construction Code to sustain pressure, exclusive of tolerances and any allowances for corrosion
$t_{min,\, l}$ = t_{min} for large end of a reducer
$t_{min,\, pipe}$ = t_{min} for straight pipe
t_{nom} = nominal thickness of pipe or fitting specified in the applicable industry standard for the piping item. For items designed to specified minimum thickness, the nominal thickness is the design thickness, including corrosion allowance and excluding tolerances
t_p = predicted local thickness profile in a piping item at the end of the evaluation period
$t_{p,\, min}$ = minimum predicted local thickness of a piping item at the end of the evaluation period
t'_{min} = adjusted minimum thickness for inner portion of an elbow
y = factor required by the Construction Code used in the analytical evaluation
Z_{min} = predicted minimum section modulus for the thinned section, including consideration of the shift of the neutral axis of the thinned pipe section, I_{min}/R_{max}
α = maximum cone angle at the center of a reducer
δ = nominal distance between the center of the pipe and the neutral axis of the thinned piping section
θ = maximum angle from the center of the outer one-half of the elbow to the location of the thinned area being evaluated, as measured in the pipe cross section
τ = length of evaluation period

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Approval Date: September 18, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-600
Transfer of Welder, Welding Operator, Brazer, and Brazing Operator Qualifications Between Owners
Section XI, Division 1

Inquiry: What alternative to the welding and brazing performance qualification requirements of IWA-4000 may be used?

Reply: It is the opinion of the Committee that as an alternative to the welding and brazing performance qualification requirements of IWA-4000, a welder, welding operator, brazer, or brazing operator qualified by one Owner may be used by another Owner. The following requirements shall be met.

(a) The Owner who performed the qualification test shall certify that testing was performed in accordance with Section IX by signing the record of Welder/Welding Operator/Brazer/Brazing Operator Performance Qualification (WPQ/BPQ).

(b) The Owner who performed the qualification test shall certify, in writing, that qualification was conducted in accordance with a Quality Assurance Program that satisfies the requirements of IWA-1400.

(c) The Owner accepting the WPQ/BPQ shall obtain any necessary supporting information to satisfy QW-301.4 (e.g., Welding Procedure Specification, type of tests).

(d) The Owner accepting the WPQ/BPQ shall require each welder, welding operator, brazer, or brazing operator to demonstrate proficiency by completing a renewal qualification test in accordance with QW-322.2(a) or QB-322(b).

(1) When WPQ transfer involves prior groove tests, the renewal test shall use a groove configuration.

(2) When WPQ transfer involves prior fillet tests, the renewal tests may use either a groove or a fillet configuration.

(e) The Owner accepting the WPQ/BPQ shall accept responsibility for the Performance Qualification Test, and shall document acceptance on the WPQ/BPQ for the renewal test. This WPQ/BPQ shall reference the WPQ/BPQ supplied by the Owner that performed the qualification.

(f) The Owner accepting the WPQ/BPQ shall accept responsibility for compliance with QW-322.

(g) The Owner may accept and use a WPQ/BPQ only when it is received directly from the Owner who performed the qualification.

(h) The Owner accepting the WPQ/BPQ shall comply with the Quality Assurance requirements of IWA-4142(a).

(i) Use of this Case shall be documented on the WPQ/BPQ for the renewal test in lieu of on the Repair/Replacement Plan and the NIS-2 Form.

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Approval Date: June 21, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-606-2
Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique for BWR CRD Housing/Stub Tube Repairs
Section XI, Division 1

Inquiry: May the automatic or machine GTAW temper bead technique be used without use of preheat or postweld heat treatment on Class 1, BWR CRD housing or stub tube repairs?

Reply: It is the opinion of the Committee that BWR CRD housing or stub tube repair/replacement activities on P-No. 1, 3, 12A, 12B, and 12C material and their associated welds and P-No. 8 or P-No. 43 material to P-Nos. 1, 3, 12A, 12B, and 12C[1] material and their associated welds, may be made by the automatic or machine GTAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code, when it is impractical to do so, and without the nondestructive examination requirements of the Construction Code, provided the requirements of 1 through 5, and all other requirements of IWA-4000,[2] are met.

1 GENERAL REQUIREMENTS

(a) The maximum area of an individual weld based on the finished surface shall be 100 sq. in., and the depth of the weld shall not be greater than one-half of the ferritic base metal thickness.

(b) Repair/replacement activities on a dissimilar-metal weld in accordance with this Case are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in., or less of nonferritic weld deposit exists above the original fusion line.

(c) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Case, provided the depth of repair in the base material does not exceed $^3/_8$ in.

(d) Prior to welding the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in., whichever is less, shall be at least 50°F.

(e) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(f) Weld metal and heat affected zones may be peened to control distortion. Peening shall not be used on the final (face) layer, except as permitted in (g), below.

(g) Peening intended only to reduce residual surface tensile stresses is permitted on the final (face) layer, after any surface examinations otherwise required by this Case are completed. A VT-1 visual examination shall be performed after this peening.

2 WELDING QUALIFICATIONS

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of 2.1 and 2.2.

2.1 PROCEDURE QUALIFICATION

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number, as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded.

(b) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be duplicated in the test assembly.

(c) Consideration shall be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

(d) The root width and included angle of the cavity in the test assembly shall be no greater than the minimum specified for the repair.

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified as P-No.3 material in a later Edition of Section IX.

[2] IWA-4000 or IWA-7000, as applicable, in the 1989 Edition, with the 1990 Addenda, and earlier Editions and Addenda.

(e) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F.

(f) The test assembly cavity depth shall be at least one-half the depth of the weld to be installed during the repair/replacement activity and at least 1 in. The test assembly thickness shall be at least twice the test assembly cavity depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions surrounding the cavity shall be at least the test assembly thickness and at least 6 in. The qualification test plate shall be prepared in accordance with Figure 1.

(g) Ferritic base material for the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (i) below, but shall be in the base metal.

(h) Charpy V-notch tests of the ferritic weld metal of the procedure qualification shall meet the requirements as determined in (g) above.

(i) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (g) above. Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(2) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(3) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens shall be reported in the Procedure Qualification Record.

(j) The average values of the three HAZ impact tests shall be equal to or greater than the average values of the three unaffected base metal tests.

2.2 PERFORMANCE QUALIFICATION

Welding operators shall be qualified in accordance with Section IX.

3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements.

(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (QW-422) for P-No. 8 to P-No. 1, 3, or 12 (A, B, or C) weld joints or F-No. 43 weld metal (QW-432) for P-No. 8 or 43 to P-No. 1, 3, or 12 (A, B, or C) weld joints.

(c) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least $^1\!/_8$ in., overlay thickness as shown in Figure 2, Steps 1 through 3, with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. Particular care shall be taken in placement of the weld layers at the weld toe area of the ferritic material to ensure that the HAZ and ferritic weld metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification. For similar-metal welding, the completed weld shall have at least one layer of weld reinforcement deposited. This reinforcement shall be removed by mechanical means, so that the finished surface is essentially flush with the surface surrounding the weld (Figure 3).

(d) The maximum interpass temperature for field applications shall be 350°F regardless of the interpass temperature during qualification.

(e) Particular care shall be given to ensure that the weld region is free of all potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4 EXAMINATION

(a) The final weld surface and the band around the area defined in 1(d) shall be examined using a surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hr. The ultrasonic examination shall be in accordance with Appendix I.[3]

(b) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(c) NDE personnel shall be qualified in accordance with IWA-2300.

(d) Surface examination acceptance criteria shall be in accordance with NB-5340 or NB-5350, as applicable. Ultrasonic examination acceptance criteria shall be in

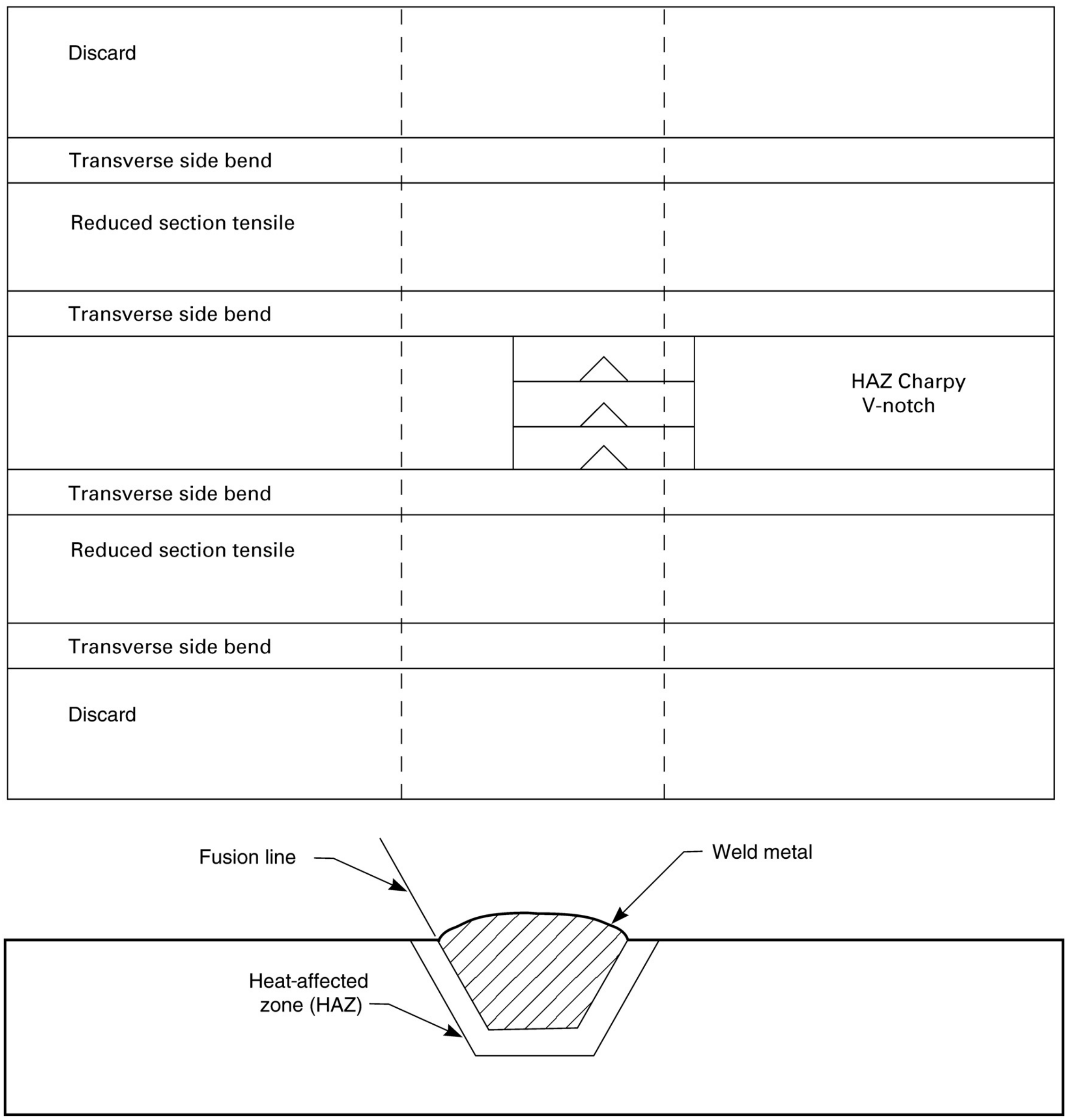
[3] 1989 Edition with 1989 Addenda and later Editions and Addenda.

accordance with IWB-3000. Additional acceptance criteria may be specified by the Owner to account for differences in weld configurations.

5 DOCUMENTATION

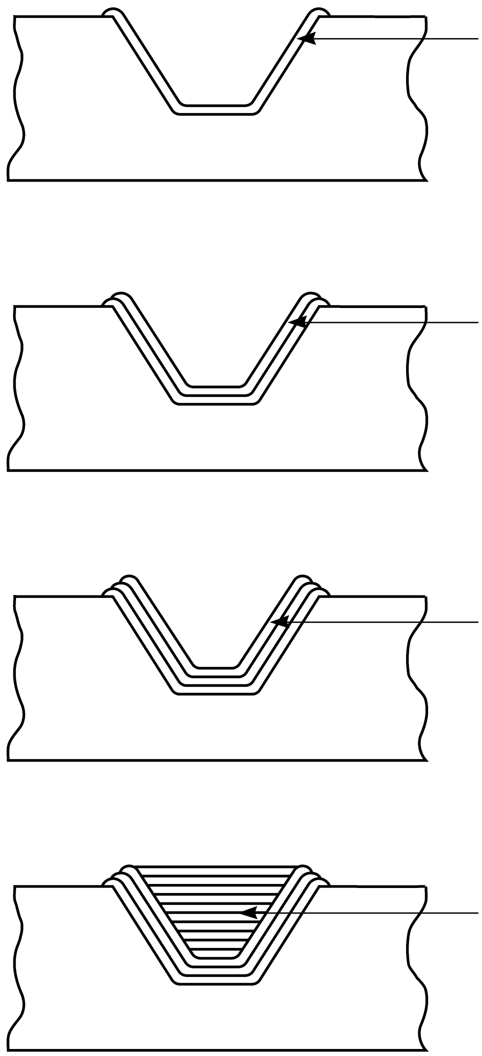
Use of this Case shall be documented on Form NIS-2.

Figure 1
Qualification Test Plate



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

Figure 2
Automatic or Machine (GTAW) Temper Bead Welding



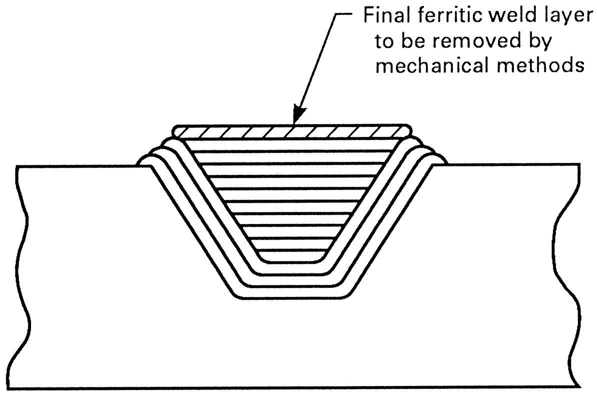
Step 1: Deposit layer one with first layer weld parameters used in qualification.

Step 2: Deposit layer two with second layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the second layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.

Step 3: Deposit layer three with third layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the third layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.

Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly. NOTE: Particular care shall be taken in application of the fill layers to preserve the temper of the weld metal and HAZ.

Figure 3
Final Ferritic Weld Layer



GENERAL NOTE: For ferritic filler metals the completed weld shall have at least one layer of weld reinforcement deposited. This reinforcement shall be removed by mechanical means, so that the finished surface of the weld is essentially flush with the surface of the component surrounding the repair.

Approval Date: February 26, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-607
Guidance on Implementation of NS Certificate of Accreditation
Section III, Division 1

Inquiry: The 1999 Addenda to Section III Subsection NCA introduced the NS Certificate for the construction of "Supports". Are current NPT or QSC Certificate Holders required to obtain an NS Certificate to construct "Supports" to these requirements?

Reply: It is the opinion of the Committee that organizations currently holding an NPT Certificate or a Quality Systems Certificate whose scopes include "Supports" may continue to construct "Supports" as so stipulated in the scope of their Certificates without applying for the NS Certificate until the expiration of their existing certificate. N Certificate Holders may construct "Supports" when so stipulated in the scope of their certificates. An NS Certificate Holder may supply supports constructed to previous Code Editions and Addenda without stamping and ANI inspection.

The use of this Case shall be recorded on the NS-1 Certificate of Conformance.

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Approval Date: September 17, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-609-1
Alternative Requirements to Stress-Based Selection Criteria for Category B-J Welds
Section XI, Division 1

Inquiry: What alternatives to the requirements of Table IWB-2500-1, Category B-J, Note 1 from the 1977 Edition through the 2004 Edition with the 2005 Addenda or Note 2 in the 2004 Edition with the 2006 Addenda through the 2010 Edition, may be used to select the weld population requiring examination during an interval?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of Table IWB-2500-1, Category B-J, Note 1 from the 1977 Edition through the 2004 Edition with the 2005 Addenda or Note 2 in the 2004 Edition with the 2006 Addenda through the 2010 Edition, the following requirements may be used to select the weld population requiring examination during an interval. Category B-J welds shall be selected for examination, such that 25% of the total nonexempt welds (IWB-1220) are examined during the interval. The welds selected for examination shall include the following:

(a) All terminal ends in each pipe or branch run connected to vessels.

(b) All terminal ends in each pipe or branch run connected to other components.

(c) All dissimilar metal welds not covered under Category B-F, between one of the following combinations:

(1) carbon or low alloy steels and high alloy steels;

(2) carbon or low alloy steels and high nickel alloys;

(3) high alloy steels and high nickel alloys.

(d) Additional piping welds, such that the total number of circumferential butt welds (or branch connection or socket welds) selected for examination equals 25% of the total number of nonexempt circumferential butt welds (or branch connection or socket welds) in the reactor coolant piping system. These additional piping welds shall be distributed as follows:

(1) The examinations shall be distributed among the Class 1 systems prorated, to the degree practicable, on the number of nonexempt welds in each system (e.g., if a system contains 30% of the nonexempt welds, 30% of the nondestructive examinations required by Category B-J should be performed on that system).

(2) Within each system, examinations shall be distributed between line sizes prorated, to the degree practicable, on the number of nonexempt welds in each line size.

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Approval Date: July 30, 1998

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-610
Alternative Reference Stress Intensity Factor (K_{IR}) Curve for Class Components
Section III, Division 1

Inquiry: May alternative reference stress intensity factor (K_{IR}) curve of Fig. A be used in lieu of Fig. G-2210-1 in Appendix G for the evaluation of nonductile failure for Class 1 components?

Reply: It is the opinion of the Committee that for Section III, Division 1 Class 1 components, the reference stress intensity factor (K_{IR}) curve of Fig. A may be used in lieu of Fig. G-2210-1 in Appendix G provided the following additional requirements are met:

(a) Materials shall meet the requirements of SA-533 Type B Class 1, SA-508 Grade 2 Class 1, SA-508 Grade 3 Class 1.

(b) The base materials shall meet the requirements of NB-2331 and weld metals shall meet the requirements of NB-2430.

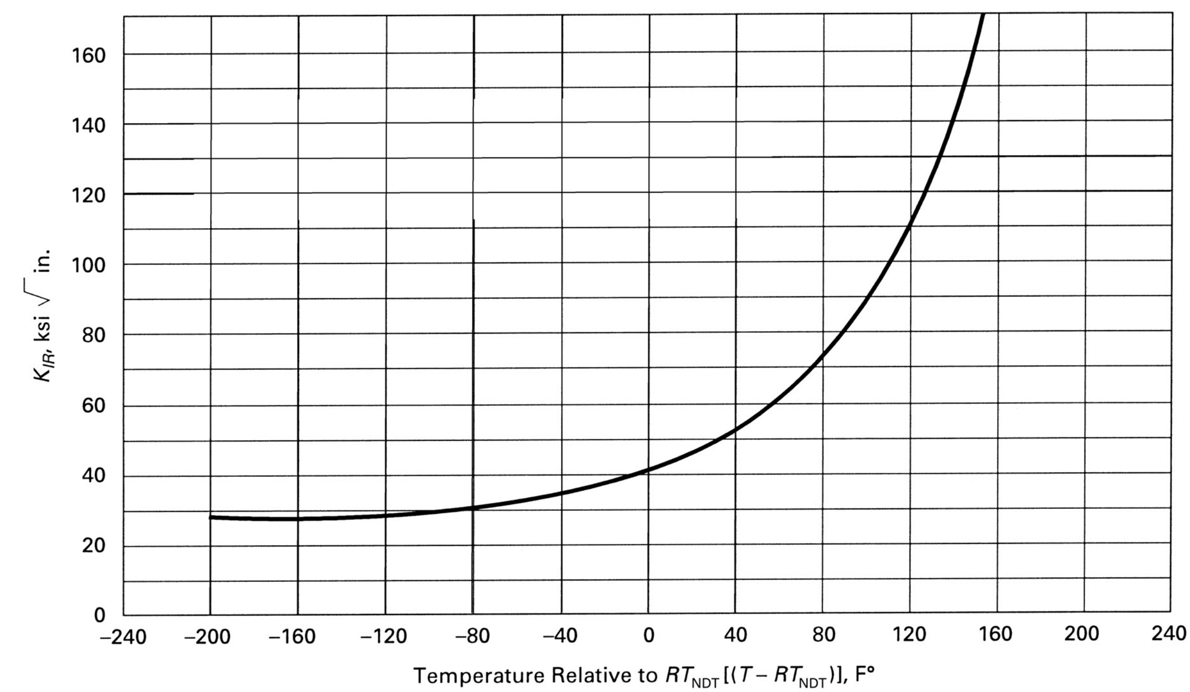
(c) The Charpy 30 ft-lb transition temperature (Tr30) of the material shall not be higher than 43°F.

(d) The Charpy Upper Shelf Energy (USE) of the material shall not be lower than 54 ft-lb.

(e) One pass welded specimens shall be used for the determination of T_{NDT}.

(f) This Case number shall be shown on the Manufacturer's Data Report.

Figure A
K_{IR} Curve



GENERAL NOTE:

$$K_{IR} - 26.81 = 13.79 \exp\left[0.0152\left(T - RT_{NDT}\right)\right]$$

where

K_{IR} = reference stress intensity factor, ksi $\sqrt{\text{in.}}$
RT_{NDT} = reference nil ductility temperature, F°
T = temperature at which K_{IR} is permitted, F°

Approval Date: December 20, 2010

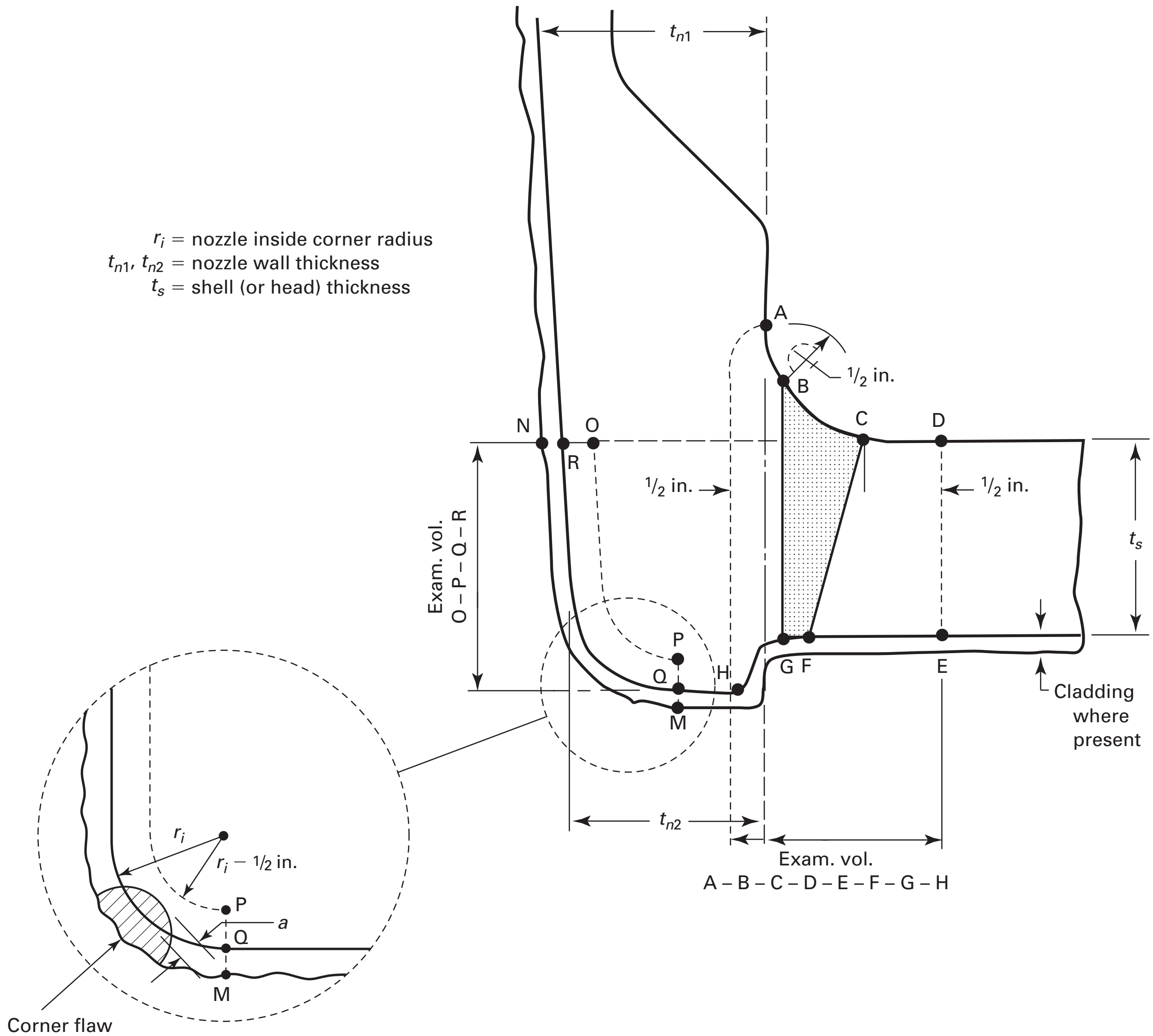
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-613-2
Ultrasonic Examination of Full Penetration Nozzles in Vessels, Examination Category B-D, Reactor Nozzle-To-Vessel Welds and Nozzle Inside Radius Section, Figs. IWB-2500-7(a), (b), (c), and (d)
Section XI, Division 1

Inquiry: What alternatives to the examination volume requirements of Figs. IWB-2500-7(a), (b), (c), and (d) are permissible for ultrasonic examination of reactor-nozzle-to-vessel welds and nozzle inside radius section?

Reply: It is the opinion of the Committee that Category B-D nozzle-to-vessel welds and nozzle inside radius section previously ultrasonically examined using the examination volumes of Figs. IWB-2500-7(a), (b), (c), and (d) may be examined using the reduced examination volume (A-B-C-D-E-F-G-H and O-P-Q-R) of Figures 1, 2, 3, and 4 as applicable.

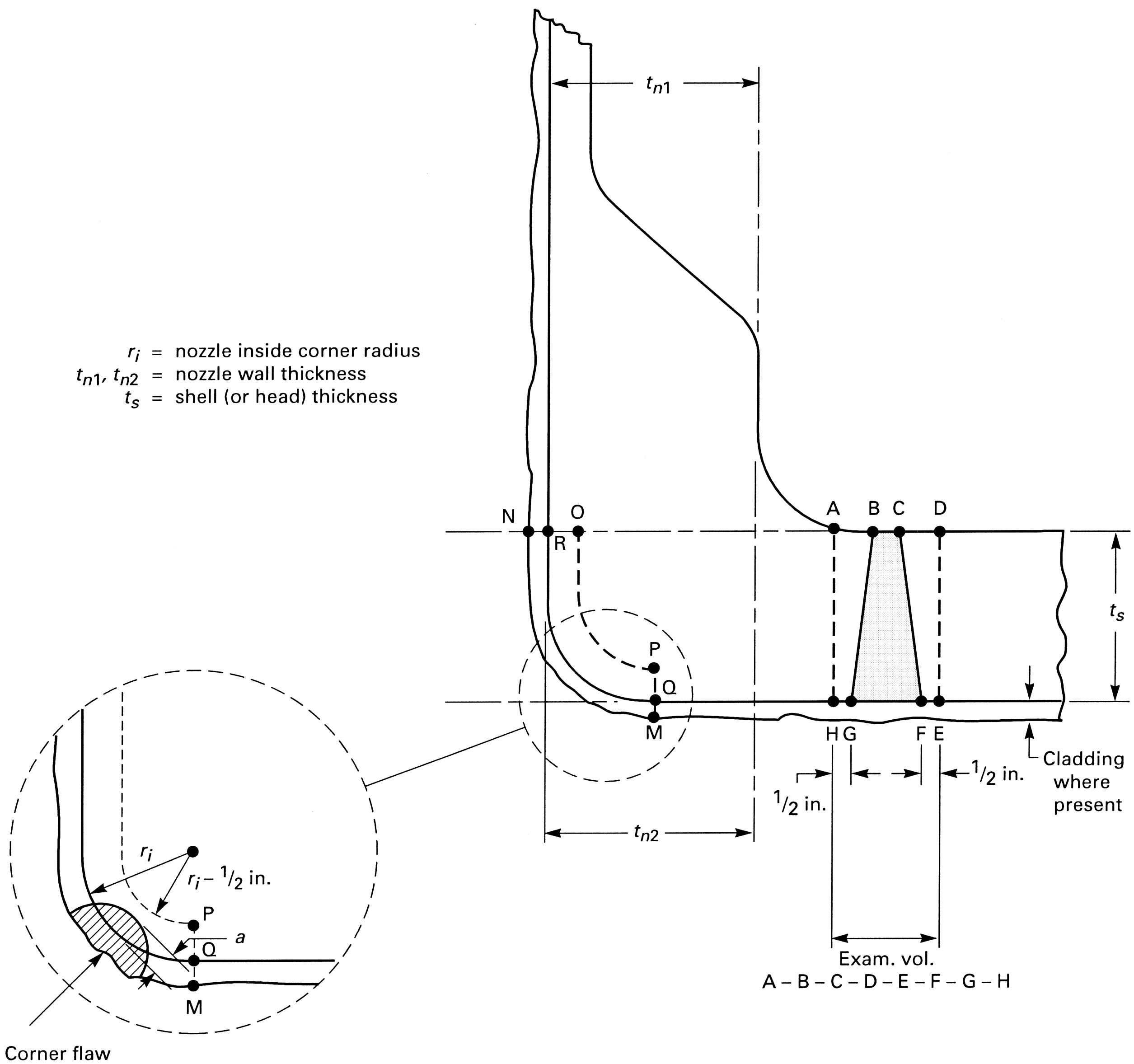
Figure 1
Nozzle in Shell or Head
(Examination Zones in Barrel Type Nozzles Joined by Full Penetration Corner Welds) (½ in. = 13 mm)



EXAMINATION REGION [Note (1)]	EXAMINATION VOLUME [Note (2)]
Shell (or head) adjoining region	C – D – E – F
Attachment weld region	B – C – F – G
Nozzle cylinder region	A – B – G – H
Nozzle inside corner region	O – P – Q – R

NOTES:
(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.
(2) Examination volumes may be determined either by direct measurements on the component or by measurements based on design drawings.

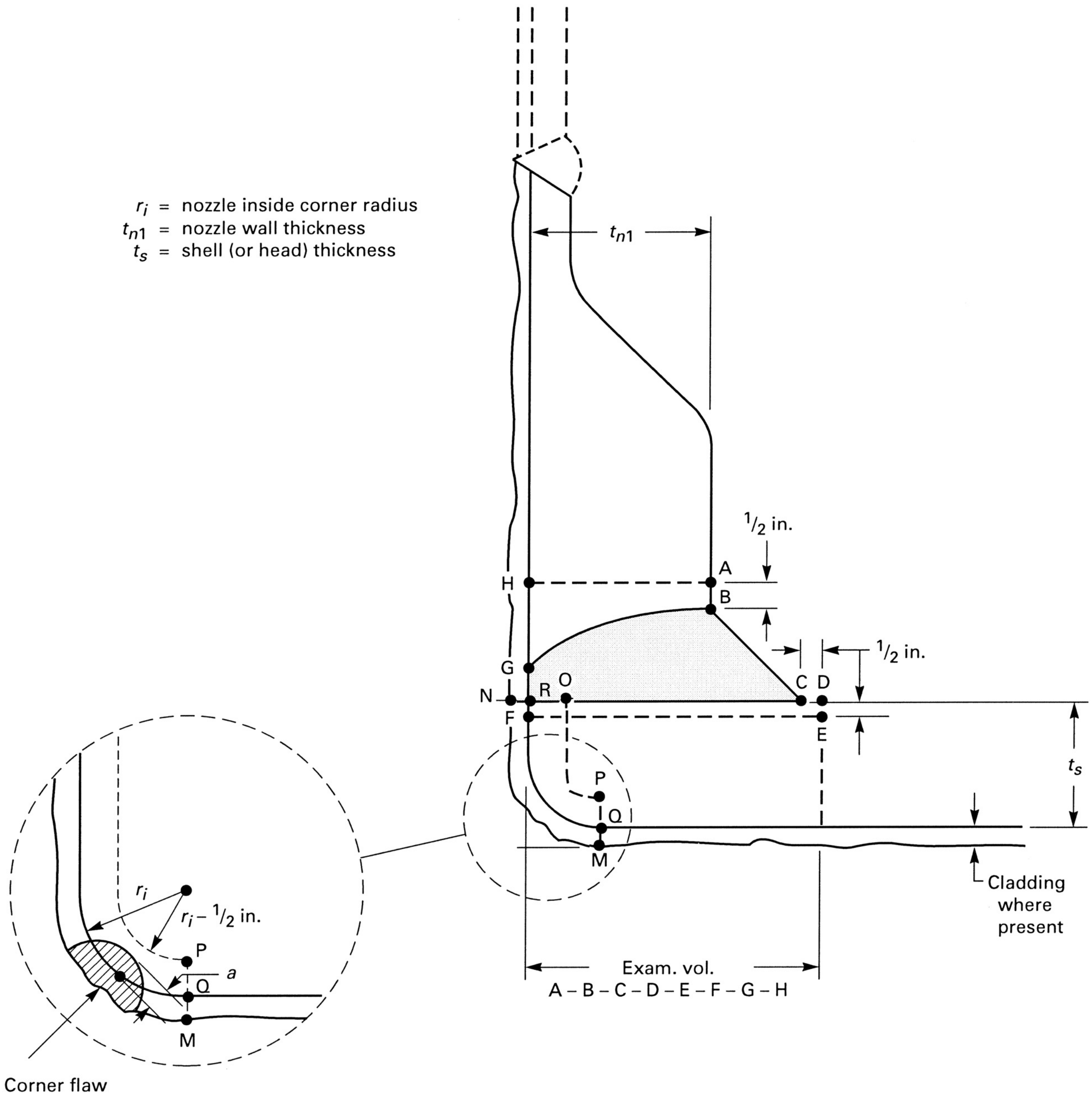
Figure 2
Nozzle in Shell or Head
(Examination Zones in Flange Type Nozzles Joined by Full Penetration Butt Welds) (½ in. = 13 mm)



EXAMINATION REGION [Note (1)]	EXAMINATION VOLUME [Note (2)]
Shell (or head) adjoining region	C – D – E – F
Attachment weld region	B – C – F – G
Nozzle cylinder region	A – B – G – H
Nozzle inside corner region	O – P – Q – R

NOTES:
(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.
(2) Examination volumes may be determined either by direct measurements on the component or by measurements based on design drawings.

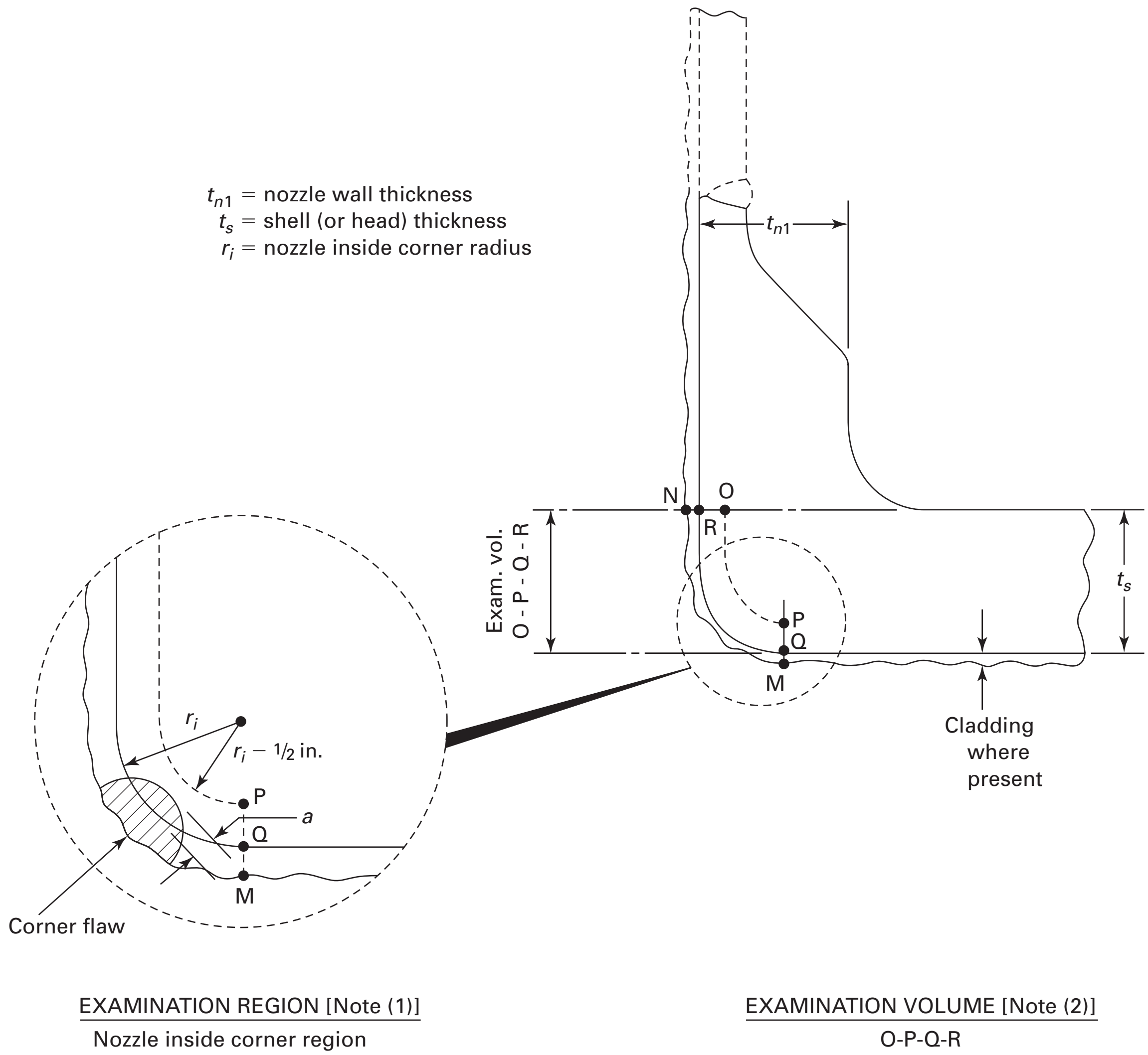
Figure 3
Nozzle in Shell or Head
(Examination Zones in Set-on Type Nozzles Joined by Full Penetration Corner Welds) (½ in. = 13 mm)



EXAMINATION REGION [Note (1)]	EXAMINATION VOLUME [Note (2)]
Shell (or head) adjoining region	C – D – E – F – G
Attachment weld region	B – C – R – G
Nozzle cylinder region	A – B – G – H
Nozzle inside corner region	O – P – Q – R

NOTES:
(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.
(2) Examination volumes may be determined either by direct measurements on the component or by measurements based on design drawings.

Figure 4
Nozzle in Shell or Head
(Examination Zone in Nozzles Integrally Cast or Formed in Shell or Head) (1/2 in. = 13 mm)



NOTES:
(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.
(2) Examination volumes may be determined either by direct measurements on the component or by measurements based on design drawings.

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Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-615
Ultrasonic Examination as a Surface Examination Method for Category B-F and B-J Piping Welds
Section XI, Division 1

Inquiry: May ultrasonic examination from the inside surface be used as a surface examination method for Category B-F and B-J piping welds NPS 4 and larger?

Reply: It is the opinion of the Committee that ultrasonic examination from the inside surface may be used as a surface examination method for Category B-F and B-J piping welds NPS 4 and larger, when the following requirements are met:

(a) Any flaw recorded by ultrasonic examination shall be compared to the volumetric acceptance standards of Table IWB-3514-1 or Table IWB-3514-2 for a surface planar flaw.

(b) The ultrasonic examination technique used shall be demonstrated capable of detecting the largest acceptable flaw having the greatest a/t ratio for a 0.50 aspect ratio at the surface to be examined.

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Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-616
Alternative Requirements for VT-2 Visual Examination of Classes 1, 2, and 3 Insulated Pressure Retaining Bolted Connections
Section XI, Division 1

Inquiry: What alternative requirements may be used in lieu of those of IWA-5242(a) for removal of the insulation from Classes 1, 2, and 3 pressure retaining bolted connections to perform a VT-2 visual examination, when the bolting material is resistant to boric acid degradation?

Reply: It is the opinion of the Committee that when corrosive resistant bolting material that is used has a chromium content greater than or equal to 10%, such as SA-564 Grade 630 H1100, SA-453 Grade 660, SB-637 UNS N07718 or SB-637 UNS N07750, it is permissible to perform the VT-2 examination without insulation removal.

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Approval Date: June 17, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-618
Use of a Reactor Pressure Vessel as a Transportation Containment System
Section XI, Division 1

Inquiry: What requirements may be used for one-time use of a reactor pressure vessel as a containment system[1] for transportation of the vessel and internals, excluding the fuel, to a disposal site?

Reply: It is the opinion of the Committee that a reactor pressure vessel may be used as a transportation containment system for one-time transportation of the vessel and internals, excluding the fuel, to a disposal site, provided that the following requirements are met.

-1000 GENERAL REQUIREMENTS

(a) All references to Section XI in this Case are limited to the 1995 Edition with the 1996 Addenda or later Editions and Addenda.

(b) The requirements of IWA-4000 apply, except as specified in this Case.

(c) A modified Design Specification that includes all anticipated normal and abnormal loads and all postulated handling and transport conditions[2] shall be prepared.

(d) The modified Design Specification shall define the jurisdictional boundaries between the containment system and any nonstructural attachments or impact-limiting devices.[3] Impact-limiting devices are exempt from the requirements of this Case.

(e) The modified Design Specification shall categorize all loads into Service Levels A, B, C, or D.

-2000 MATERIALS

(a) For containment system materials that have been subjected to fast neutron fluence, degradation of the material fracture toughness due to irradiation shall be considered.

(b) Materials added to the reactor vessel shall meet the following requirements.

(1) Containment system materials shall meet the requirements of IWA-4200.

(2) Nonstructural attachments are exempt from the rules of this Case, except that the materials shall be identified and compatible with the materials to which they are attached.

(3) Materials for structural attachment shall meet the requirements of the Construction Code or the requirements of NF-2000,[4] except that the requirements of NA-3700, NCA-3800 need not be met.

-3000 DESIGN

(a) An amendment or revision to the reactor pressure vessel Design Report or analysis shall be prepared in accordance with IWA-4300.

(b) Service Level A and B Limits apply for expected normal handling and transport loading conditions.

(c) Service Level C Limits apply for unexpected handling and transport loading conditions that may cause localized damage not requiring repair and not affecting the vessel's ability to continue to perform the containment system function.

(d) Service Level D Limits apply for unexpected handling and transport loading conditions that may cause damage to the containment system requiring repair and not affecting the vessel's ability to perform the containment system function.

(e) Analysis for cyclic service is not required.

(f) The potential for brittle fracture shall be evaluated in accordance with (1) or (2) below.

[1] The term containment system is as used in the Code of Federal Regulations. Title 10, Part 71 (10 CFR 71) and Section III, Division 1.

[2] Guidance for specification of postulated normal and abnormal handling and transport conditions is provided in 10 CFR 71.

[3] An impact-limiting device provides controlled energy absorption and reduces deceleration loads on the containment system; these deceleration loads shall be determined to define the applied mechanical loads from impact events.

[4] Section III, 1977 Edition or later.

(1) The $LST — RT_{NDT}$ or fracture toughness requirements of Table 1 or Table 2, respectively, as applicable, shall be met.

(2) The following criteria shall be met.

(-a) For Service Levels A and B loading conditions:

$$K_I < K_{Ia}/\sqrt{10}$$

(-b) For Service Levels C and D loading conditions:

$$K_I < K_{Ia}/\sqrt{2}$$

where

K_I = the maximum applied crack tip stress intensity factor
K_{Ia} = the available dynamic fracture toughness for the corresponding crack tip temperature
RT_{NDT} = from A-4000

Table 1
***LST* — *Rt*$_{NDT}$ Values for Ferritic Steel Materials for Containment Systems**

Nominal Wall Thickness, in.	$LST — RT_{NDT}$, F [Note (1)], [Note (2)], min.
$^5/_8$	25
1	45
2	75
3	90
4	103
8	115
12	120

GENERAL NOTE: LST, lowest service temperature, is the minimum volumetric average metal temperature of the vessel expected during handling and transport.

NOTES:
(1) RT_{NDT} may be determined in accordance with Reg. Guide 1.99, Rev. 2.
(2) The values in Tables 1 and 2 may be linearly interpolated.

(-c) For vessels with recorded flaws that exceed the acceptance criteria of IWB-3500, the flaw dimensions and characterization shall be evaluated in accordance with Appendix A.

(-d) For vessels containing flaws that meet the acceptance criteria of IWB-3500 or not containing any recorded flaws, an assumed surface flaw shall be evaluated using a depth a/t=0.019 with an aspect ratio a/l=0. For welds, the assumed flaw shall be oriented in the plane of the weld. For base metal, the assumed flaw shall be oriented perpendicular to the direction of the maximum principal stress.

(-e) For areas of the vessel outside the region of inspection, semi-elliptical surface flaws with a depth a/t=0.1 with an aspect ratio a/l=1/6 shall be assumed at the inside and outside surface locations having significant tensile stress. For welds, the assumed flaws shall be oriented in the weld plane; for base metal, they shall be oriented perpendicular to the direction of maximum principal stress.

Table 2
Fracture Toughness Values for Containment System Material at the *LST*

Nominal Wall Thickness, in.	Rapid-Load Fracture Toughness, ksi$\sqrt{\text{in.}}$ [Note (1)], [Note (2)], min.
$^5/_8$	50
1	64
2	94
3	113
4	130

GENERAL NOTE: LST, lowest service temperature, is the minimum volumetric average metal temperature of the vessel expected during handling and transport.

NOTES:
(1) The values in Tables 1 and 2 may be linearly interpolated.
(2) Rapid-load fracture toughness is defined in ASTM E399 and ASTM E813.

-4000 FABRICATION

Attachment welds to the containment system, including closure attachment welds, shall meet the requirements of the Construction Code or NB-4000, with the following exceptions:

(a) Exemption from PWHT is permitted in accordance with the alternative requirements of IWA-4621.

(b) Fillet-welded and partial-penetration corner joints are permissible.

(c) As an alternative to (b) above, fitting alignment, surface shape, and size of nonstructural attachments to the containment system shall meet the requirements of NF-4000.[4]

(d) Impact testing of the weld metal and heat-affected zone is not required for welding procedure qualification when the weld joint does not exceed $^5/_8$ in., nominal thickness, regardless of impact test requirements for the base metal.

-5000 EXAMINATION

(a) The preservice inspection and testing requirements of IWA-4530 do not apply.

(b) As an alternative to surface examination requirements of the Construction Code, all welded attachment joints and repairs of such welds may be examined by the visual method of NF-5000,[4] except that structural attachment welds and nozzle closure device attachments, and any other weld(s) applied for the purpose of serving as a seal weld, shall be examined by the magnetic particle or liquid penetrant method, in accordance with ND-5000.

-6000 TESTING

(a) The pump and valve testing requirements of IWA-4530 do not apply.

(b) The pressure testing requirements of IWA-4540 do not apply.

(c) Construction Code pressure testing and overperssure protection do not apply.

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Approval Date: February 15, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-619
Alternative Requirements for Nozzle Inner Radius Inspections for Class 1 Pressurizer and Steam Generator Nozzles
Section XI, Division 1

Inquiry: What alternative to the inspection requirements of Table IWB-2500-1, Examination Category B-D, for pressurizers and steam generators may be used?

Reply: It is the opinion of the Committee that the inspections required by Table IWB-2500-1, Examination Category B-D, Item Numbers B3.40 and B3.60 (Inspection Program A) and Item Numbers B3.120 and B3.140 (Inspection Program B) need not be performed.

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Approval Date: February 26, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-620
Rules for Class 1 Type M Pumps
Section III, Division 1

Inquiry: What rules may be used for design and construction of Class 1 Type M Pumps (depicted in Figure 1A and 1B) under Section III, Division 1?

Reply: It is the opinion of the Committee that the rules described below be applied for design and construction of Section III, Division 1, Class 1 Type M pumps.

1 DESCRIPTION OF TYPE M PUMPS

Type M pumps typify gland-less type of pumps. With gland-less pumps the enclosure of the driver (motors or turbines) are integral or bolted to the pump casing (Figure 1B) or welded to a vessel that contains the pump impeller and diffuser (Figure 1A). In both cases the driver enclosure is at the same pressure as the pump enclosure and is to be designed as a pressure boundary item. In Figure 1A installations, the pumps do not have a separate and distinct pump casing with inlet/outlet nozzles, volute casing, or barrel. The pump impeller and diffuser may be located within the larger pressure vessel, which supports the driver enclosure. The pump shaft exits an opening in the pump casing or the pressure vessel and couples the impeller to the driver. In Figure 1B installations there is a regular pump casing that is to be designed to the rules of this Article (NB-3400). In addition to the motor casing, a heat exchanger may be required to cool the motor. The heat exchanger is connected to the motor casing by piping. The motor casing, piping, and heat exchanger are exposed to the same pressure as the pump casing or the vessel that contains the impeller, and their design is subject to appropriate Articles of Subsection NB.

2 THE TYPE M PUMP PRESSURE BOUNDARY

The pressure boundary of the Type M pumps in Figure 1A begins at the attachment point of the driver casing to the main vessel (such as reactor pressure vessel or steam generator), the pressure retaining parts of the electrical and instrument penetrations, the piping, and the driver heat exchanger. In Figure 1B, the Type M pump pressure boundary includes the pump casing, the driver casing, the driver covers, pressure retaining parts of the electrical and instrument penetrations, piping, and the driver heat exchanger. The design of the functional part of the pump and motor such as impeller, shaft, coupling, rotor, stator, and instruments are not governed by ASME rules. The Class 1 Type M pump pressure boundaries shall be designed and constructed according to the rules of NB-3400.

3 THE CLASS 1 TYPE M PUMP PRESSURE BOUNDARY DESIGN RULES

Since the Type M pumps pressure boundary parts do not introduce new and unique configurations and shapes, the design rules for cylinders, covers, bolts, nozzles, penetrations, piping, tube sheets, etc., from various Articles of Subsection NB-3000 may be used.

3.1 All other pertinent requirements of Section III, Division 1 shall apply.

3.2 This Case number shall be shown in documentation for pumps meeting these requirements.

Figure 1A

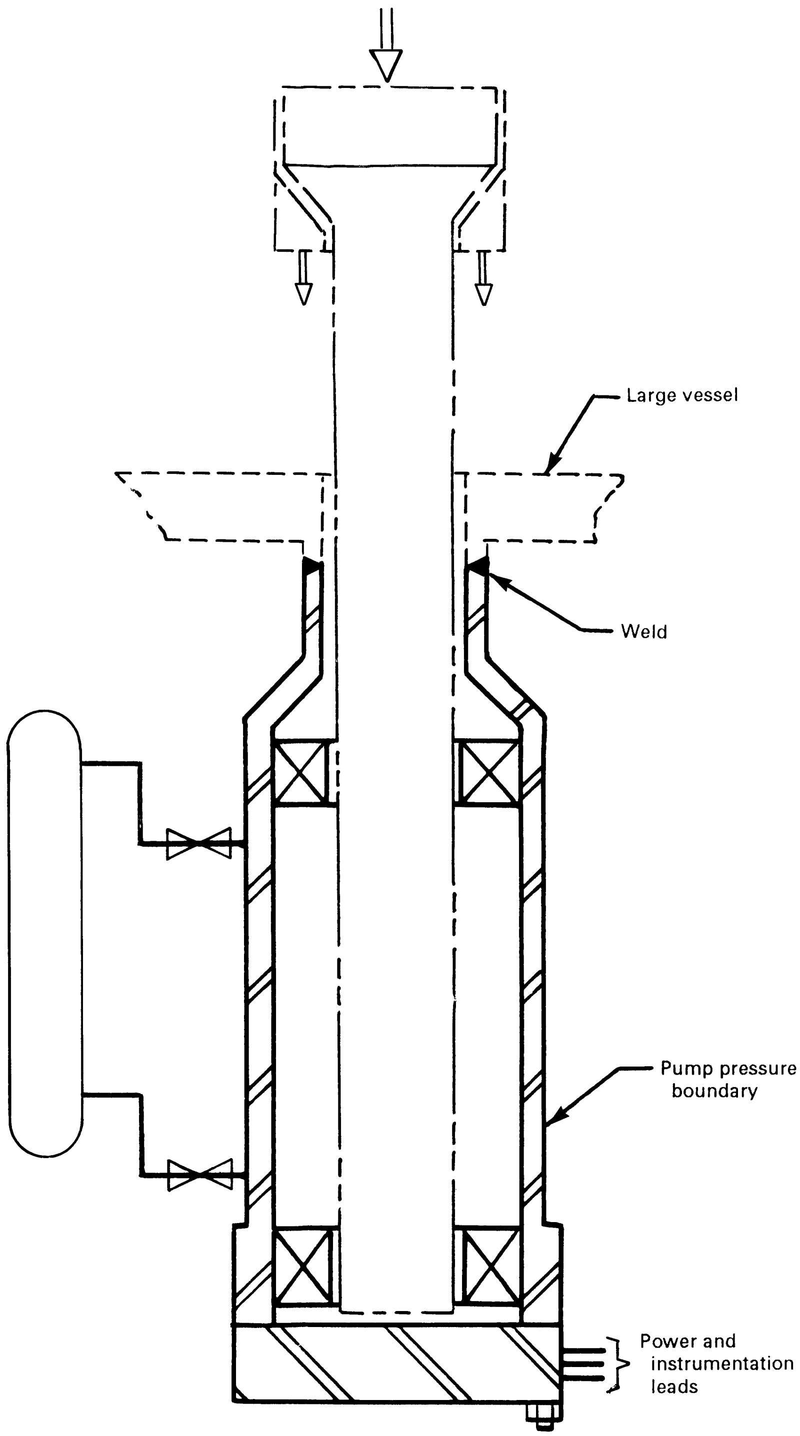
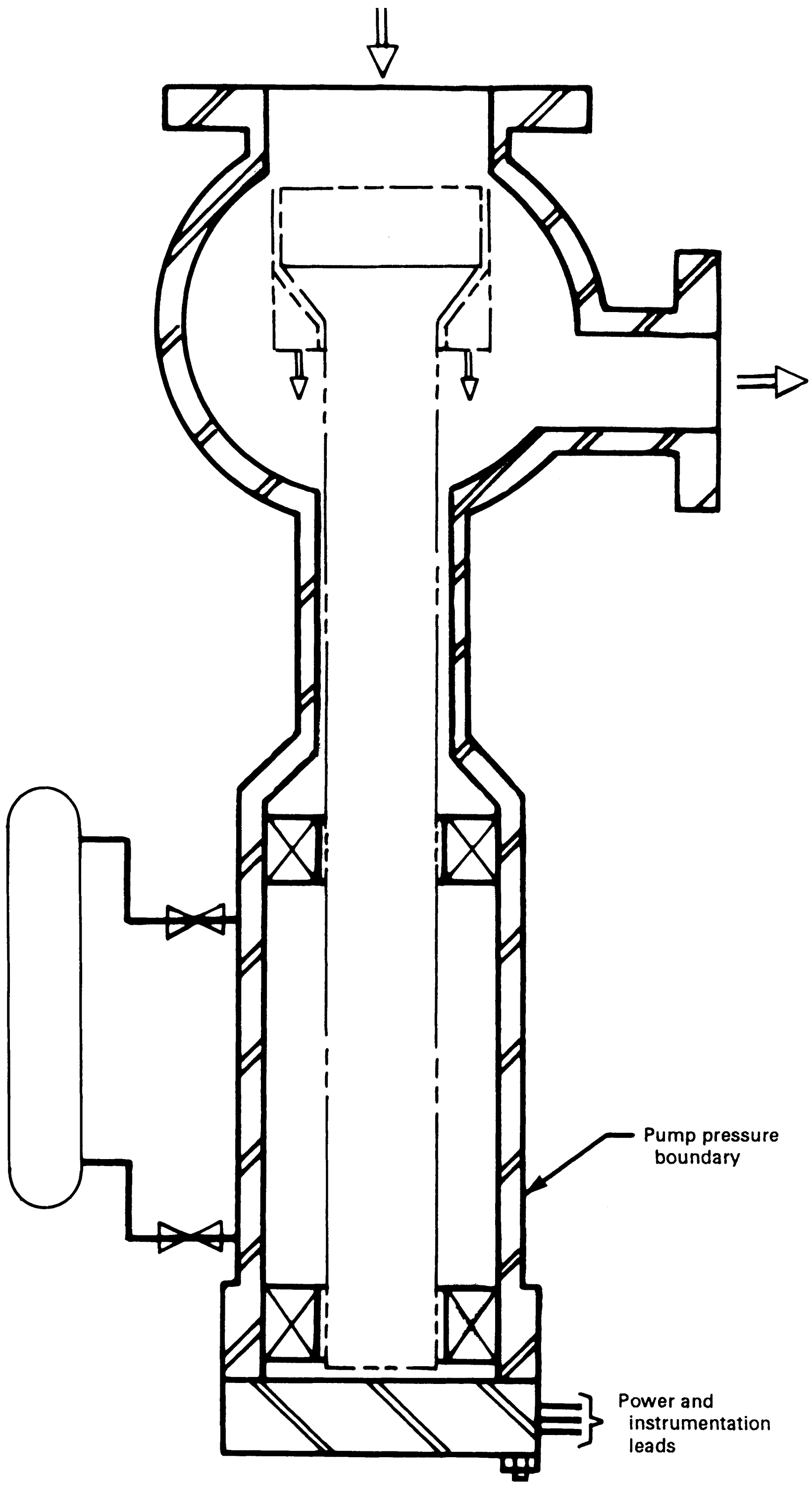

Large vessel
Weld
Pump pressure boundary
Power and instrumentation leads

Figure 1B



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Approval Date: October 8, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-621-1
Ni-Cr-Mo Alloy (UNS N06022) Welded Construction to 800°F
Section III, Division 1

Inquiry: Under what conditions may Ni-Cr-Mo alloy (N06022) solution annealed plates, sheet, strip, rod, fittings, forgings, seamless and welded tubing according to the specifications listed in Table 1 be used for components for Section III, Division 1, Class 1 construction?

Reply: It is the opinion of the Committee that the material described in the Inquiry may be used under the rules of Section III, Division 1, in the construction of Class 1 components provided the following additional requirements are met:

(a) The maximum design stress intensity, the yield strength, and the ultimate tensile strength values shall be those shown in Table 2. For pipe, tube, and fitting products welded without filler metal, a joint efficiency factor of 0.85 shall be used.

(b) For external pressure design, Fig. NFN-10 of Section II, Part D shall be used.

(c) Welding procedures and performance qualification shall be in accordance with Section IX and Section III.

(d) All other applicable requirements of Section III, Division 1, Class 1 shall be met.

(e) This Case number shall be shown in the documentation and marking of the material and on the Manufacturer's Data Report.

Table 1
Product Specifications

Bar	SB-574
Fittings	SB-366
Forgings	SB-564
Plate, sheet, and strip	SB-575
Seamless pipe and tube	SB-622
Welded pipe	SB-619
Welded tube	SB-626

Table 2
Design Stress Intensity Values, S_m, ksi

For Metal Temperature Not Exceeding, °F	S_m, max. ksi [Note (1)]	Ultimate Tensile Strength, S_u ksi	Yield Strength S_y, ksi
−20 to 100	30.0	100.0	45.0
200	30.0	100.0	40.1
300	30.0	98.5	36.9
400	30.0	95.3	34.3
500	29.0	92.9	32.2
600	27.6	91.1	30.6
650	27.0	90.4	30.0
700	26.5	89.7	29.4
750	26.1	89.1	29.0
800	25.7	88.4	28.6

NOTE:
(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed $66\frac{2}{3}\%$ but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. Table Y-2 of Section II, Part D, lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-624
Successive Inspections
Section XI, Division 1

Inquiry: What alternative to the requirements of IWB-2420(a), IWC-2420(a), IWD-2420(a) (starting with the 1991 Addenda), IWE-2420(a) (starting with the Winter 1981 Addenda), and IWF-2420(a) (starting with the Winter 1978 Addenda) may be used to modify the sequence of examinations established during the first inspection interval, in a manner that optimizes scaffolding, radiological, insulation removal, or other considerations?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWB-2420(a), IWC-2420 (a), IWD-2420(a), IWE-2420(a), and IWF-2420(a), the sequence of examinations may be modified, provided the percentage requirements of Tables IWB-2411-1, IWC-2411-1, IWD-2411-1, and IWE-2411-1, Tables IWB-2412-1, IWC-2412-1, IWD-2412-1, and IWE-2412-1, Table IWF-2410-1, or Table IWF-2410-2 are satisfied.

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Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-625-1
Ni-Cr-Mo Alloy (UNS N06059) Welded Construction to 800°F
Section III, Division 1

Inquiry: Under what conditions may Ni-Cr-Mo Alloy (N06059) solution annealed plates, sheet, strip, rod, fittings, forgings, seamless and welded tubing according to the ASTM specifications listed in Table 1 be used for Class 1 components under the rules of Section III, Division 1, up to and including 800°F?

Reply: It is the opinion of the Committee that the material described in the Inquiry may be used under the rules of Section III, Division 1, in the construction of Class 1 components up to and including 800°F provided the following additional requirements are met:

(a) The maximum design stress intensity, the yield strength and the ultimate strength values shall be those shown in Table 2.

(b) For external pressure design, Fig. NFN-14 of -Section II, Part D shall be used.

(c) Welding procedures and performance Qualification shall be in accordance with Section III. The P-number for this alloy is 44.

(d) All other applicable requirements of Section III, Division 1, shall be met.

(e) This Case number shall be shown on the Manufacturer's Data Report.

Table 1
Product Specifications

SB-366	Fittings
SB-564	Forgings
SB-574	Bar
SB-575	Plate, sheet, and strip
SB-619	Welded pipe
SB-622	Seamless pipe/tube
SB-626	Welded tube

Table 2
Design Stress Intensity Values

For Metal Temperatures Not Exceeding, °F	Design Stress Intensity Values, S_m, ksi	Ultimate Strength, S_u, ksi	Yield Strength, S_y, ksi
−20 to 100	30.0	100.0	45.0
200	30.0	100.0	40.4
300	30.0	100.0	37.8
400	30.0	97.9	35.8
500	30.0	94.4	33.9
600	28.9	91.2	32.1
650	28.1	89.7	31.2
700	27.3	88.3	30.3
750	26.5	87.1	29.4
800	25.7	86.1	28.6

Approval Date: May 7, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-629
Use of Fracture Toughness Test Data to Establish Reference Temperature for Pressure Retaining Materials
Section XI, Division 1

Inquiry: Is it permissible to use fracture toughness test data as an alternative to the methods specified in Appendix A, A-4200, and Appendix G, G-2110 to establish a fracture-toughness-based reference temperature, RT_{T_0}, for pressure retaining materials, other than bolting?

Reply: It is the opinion of the Committee that fracture toughness test data may be used as an alternative to the methods specified in Appendix A, A-4200, and Appendix G, G-2110 to establish a fracture-toughness-based reference temperature, RT_{T_0}, for pressure retaining materials other than bolting, in accordance with the following additional requirements.

(a) Fracture toughness testing for specific base metal or weld materials shall be performed in accordance with ASTM E1921-97, "Standard Test Method for the Determination of Reference Temperature, T_0, for Ferritic Steels in the Transition Range." The minimum test requirements of the test method shall be satisfied for the specific material being evaluated. Test data shall satisfy the validity requirements specified in the test method.

(b) Test specimen location and orientation shall be in accordance with the requirements of NB-2300 for Charpy V-notch specimens. Different specimen geometries may be used in accordance with ASTM E1921-97.

(c) The value of T_0 for the test data shall be determined in accordance with (a) above.

(d) The value of T_0 shall be used to calculate the reference temperature RT_{T0} in the following equation:

$$RT_{T_0} = T_0 + 35$$

(e) The reference temperature RT_{T_0} may be used as an alternative indexing reference temperature to RT_{NDT} for the K_{Ic} and K_{Ia} toughness curves, as applicable, in Appendix A and Appendix G.

(f) Use of this Case shall be identified in the applicable documentation.

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Approval Date: September 24, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-631
Use of Fracture Toughness Test Data to Establish Reference Temperature for Pressure Retaining Materials Other Than Bolting for Class 1 Vessels Section III, Division 1

Inquiry: Is it permissible to use fracture toughness test data as an alternative to the testing requirements of NB-2300 to establish a fracture toughness based reference temperature, RT_{To}, for Section III, Division 1, Class 1 pressure retaining materials, other than bolting?

Reply: It is the opinion of the Committee that fracture toughness test data may be used as an alternative to the specimen and testing requirements of NB-2300 to establish a fracture toughness based reference temperature, RT_{To} for Section III, Division 1, Class 1 pressure retaining materials, other than bolting, in accordance with the following additional requirements.

(a) Fracture toughness testing for specific base metal or weld materials shall be performed in accordance with ASTM E1921-97, *Standard Test Method for the Determination of Reference Temperature, T_o, for Ferritic Steels in the Transition Range.* The minimum test requirements of the test method shall be satisfied for the specific material being evaluated. Test data must satisfy all of the validity requirements specified in the test method.

(b) Test specimen location and orientation shall be in accordance with the requirements of NB-2322 for Charpy V-Notch specimens. Different specimen geometries which are in accordance with ASTM E1921-97, *Standard Test Method for the Determination of Reference Temperature, T_o, for Ferritic Steels in the Transition Range,* may be used.

(c) Determine the value of T_o for the test data obtained in (a).

(d) Use the value of T_o to calculate the reference temperature RT_{To} from the following equation:

$$RT_{To}\,(°\mathrm{F}) = [T_o + 35](°\mathrm{F})$$

(e) This reference temperature may be used as an alternative indexing reference temperature for the K_{IR} toughness curves in Appendix G of Section III.

(f) All other applicable rules of Section III, Division 1, Class 1, shall be met.

(g) This Case number shall be identified in the applicable documentation.

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Approval Date: December 3, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-632
Use of ASTM A572, Grades 50 and 65 for Structural Attachments to Class CC Containment Liners
Section III, Division 2

Inquiry: Is it permissible to use ASTM A572, Grades 50 and 65 plate and shapes for structural attachments to Class CC containment liner plates?

Reply: It is the opinion of the Committee that as an alternative to the provisions of CC-2511, ASTM A572 plate and shapes, Grades 50 and 65 may be used as welded structural attachments to Class CC containment liners. In addition, the rules of NF-2000 shall be met. Grade 50 shall be considered S-1, Group 1 material for welding and Grade 65 shall be considered S-1, Group 3. The provisions of Subsection CC shall be met for attachment welds, including nondestructive examination.

The use of this Case shall be identified in the Data Report.

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Approval Date: June 14, 2002
(ACI) Approval Date: June 14, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-633
Use of SA-533/SA-533M, Type B, Class 2, Plate for Structural Attachments to Class CC Containment Liners Section III, Division 2

Inquiry: Is it permissible to use SA-533/SA-533M, Type B, Class 2, plate for structural attachments to Class CC containment liner plates?

Reply: It is the opinion of the Committee that as an alternative to the provisions of CC-2511, SA-533/SA-533M, Type B, Class 2 plate, may be used as welded structural attachments to Class CC containment liners. In addition, the rules of NF-2000 shall be met. The provisions of Subsection CC shall be met for attachment welds, including nondestructive examination.

The use of this Case shall be identified in the Data Report.

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Approval Date: February 14, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-635-1
Use of 22Cr-5Ni-3Mo-N (Alloy UNS S31803) Forgings, Plate, Bar, Welded and Seamless Pipe, and/or Tube, Fittings, and Fusion Welded Pipe With Addition of Filler Metal, Classes 1, 2, and 3
Section III, Division 1

Inquiry: Under what rules may 22Cr-5Ni-3Mo-N (Alloy UNS S31803) forgings, plate, bar, welded and seamless pipe and/or tube, fittings, and fusion welded pipe with addition of filler metal be used for Section III, Division 1, Classes 1, 2, and 3 construction?

Reply: It is the opinion of the Committee that 22Cr-5Ni-3Mo-N (Alloy UNS S31803) forgings, plate, bar, welded and seamless pipe and/or tube, fittings, and fusion welded pipe with addition of filler metal may be used for Section III, Division 1, Classes 1, 2, and 3 construction, provided the requirements of (a) through (f) are met:

(a) Material shall conform to the requirements of the applicable product specification listed in Table 2.

(b) This material shall be treated as P-No. 10H Group 1.

(c) The design stress intensity maximum allowable stress and yield strength values shall be those shown in Table 1 of this Case.

(d) For external pressure, design, use Fig. HA-5 of Section II, Part D.

(e) All other requirements of Section III, Division 1, for Classes 1, 2, and 3 materials shall be met.

(f) This Case number shall be identified on the material manufacturer's certification for the material.

Table 1
Design Stress Intensity Maximum Allowable Stress and Yield Strength Values

For Metal Temperature Not Exceeding, °F	Design Stress Intensity, ksi	Maximum Allowable Stress, ksi [Note (1)] and [Note (2)]	Yield Strength, ksi
100	30.0	25.7	65.0
200	30.0	25.7	57.8
300	28.9	24.8	53.7
400	27.8	23.9	51.2
500	27.2	23.3	49.6
600	26.9	23.1	47.9

NOTES:
(1) The allowable stress values are based on the revised criterion of tensile strength divided by 3.5.
(2) For Class 3 Construction, a factor of 0.85 shall be applied for welded pipe, welded fittings, and welded tube.

Table 2
Product Specifications

Bar	SA-479
Fittings	SA-815
Forgings	SA-182
Plate	SA-240
Welded and seamless pipe	SA-790
Welded and seamless tubing	SA-789
Welded pipe with addition of filler metal	SA-928

Approval Date: September 24, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-636
Use of 18Cr-13Ni-3Mo (Alloy UNS S31703), 19Cr-15Ni-4Mo (Alloy UNS S31725), and 18.5Cr-15.5Ni-4.5Mo-N (Alloy UNS S31726) Forgings, Seamless Tubing, Plate, Welded Tubing, Welded and Seamless Pipe, Welded Pipe With Addition of Filler Metal and Fittings, Classes 2 and 3
Section III, Division 1

Inquiry: Under what rules may 18Cr-13Ni-3Mo (Alloy UNS S31703); 19Cr-15Ni-4Mo (Alloy UNS S31725); 18.5Cr-15.5Ni-4.5Mo-N (Alloy UNS S31726) forgings, seamless tubing, plate, welded tubing, welded and seamless pipe, welded pipe with addition of filler metal and fittings be used for Section III, Division 1, Classes 2 and 3?

Reply: It is the opinion of the Committee that 18Cr-13Ni-3Mo (Alloy UNS S31703); 19Cr-15Ni-4Mo (Alloy UNS S31725); 18.5Cr-15.5Ni-4.5Mo-N (Alloy S31726) forgings, seamless tubing, plate, welded tubing, welded and seamless pipe, welded pipe with addition of filler metal and fittings may be used for Section III, Division 1, Classes 2 and 3 construction, provided the requirements of (a) through (f) are met:

(a) Material shall conform to the requirements of the applicable product specification listed in Table 2.

(b) This material shall be treated as P-No. 8 Group 1 for UNS S31703, P-No 8 Group 4 for both UNS S31725 and UNS S31726.

(c) The maximum allowable stress values shall be those shown in Table 1 of this Case.

(d) For external pressure design, use Fig. HA-4 of Section II, Part D for UNS S31703 and UNS S31725. Fig. HA-1 applies to UNS S31726.

(e) All other requirements of Section III, Division 1, for Classes 2 and 3 materials shall be met.

(f) This Case number shall be identified on the certification for the material.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress, ksi [Note (1)]							
	25/65		25/70		30/75		35/80	
100	16.7	16.7	16.7	16.7	20.0	20.0	22.9	22.9
200	16.7 [Note (2)]	14.2	16.7 [Note (2)]	14.2	20.0 [Note (2)]	17.0	22.9 [Note (2)]	18.8
300	16.7 [Note (2)]	12.7	16.7 [Note (2)]	12.7	19.6 [Note (2)]	15.2	22.6 [Note (2)]	16.8
400	15.7 [Note (2)]	11.7	15.7 [Note (2)]	11.7	18.9 [Note (2)]	14.0	21.0 [Note (2)]	15.6
500	14.8 [Note (2)]	10.9	14.8 [Note (2)]	10.9	17.7 [Note (2)]	13.1	20.3 [Note (2)]	15.0
600	14.0 [Note (2)]	10.4	14.0 [Note (2)]	10.4	16.9 [Note (2)]	12.5	...	...

GENERAL NOTE: The allowable stress values are based on the revised criterion of tensile strength divided by 3.5.

NOTES:
(1) For welded pipe, welded tubing, and welded fittings, a factor of 0.85 shall be applied.
(2) Due to the relatively low yield strength of this material, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These higher stress values exceed $66^2/_3\%$, but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

Table 2
Product Specifications

	UNS S31703	UNS S31725	UNS S31726
Bar	...	SA-479	SA-479
Fittings	SA-403	SA-403	SA-403
Fittings	SA-813	...	...
Forgings	SA-182	SA-182	SA-182
Plate	SA-240	SA-240	SA-240
Seamless tubing	SA-212	SA-213	SA-312
Welded and seamless pipe	SA-312	SA-312	SA-312
Welded and seamless pipe	...	SA-376	SA-376
Welded pipe with addition of filler metal	SA-358	SA-358	SA-358
Welded tubing	SA-249	SA-249	SA-249

Approval Date: September 20, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-637-1
Use of 44Fe-25Ni-21Cr-Mo (Alloy UNS N08904) Plate, Bar, Fittings, Welded Pipe, and Welded Tube, Classes 2 and 3
Section III, Division 1

Inquiry: Under what rules may 44Fe-25Ni-21Cr-Mo (Alloy UNS N08904) plate, bar, fittings, welded pipe, and welded tube be used for Section III, Division 1, Classes 2 and 3 construction?

Reply: It is the opinion of the Committee that 44Fe-25Ni-21Cr-Mo (Alloy UNS N08904) plate, bar, fittings, welded pipe, and welded tube may be used for Section III, Division 1, Classes 2 and 3 construction, provided the requirements of (a) through (f) are met:

(a) Material shall conform to the requirements of the applicable product specification listed in Table 2.

(b) This material shall be treated as P-No 45.

(c) The maximum allowable stress values shall be those shown in Table 1 of this Case.

(d) For external pressure design, use Fig. NFN-9 of Section II, Part D.

(e) All other requirements of Section III, Division 1, for Classes 2 and 3 materials shall be met.

(f) This Case number shall be identified on the certification for the material.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress, ksi 31Y.S./71U.T.S [Note (1)] and [Note (2)]
100	20.3
200	16.7
300	15.1
400	13.8
500	12.7
600	11.9

NOTES:
(1) For welded pipe, welded tube and welded fittings, a factor of 0.85 shall be applied to listed allowable stress values.
(2) The allowable stress values are based on the revised criterion of tensile strength divided by 3.5, where applicable.

Table 2
Product Specifications

Bar	SB-649
Fittings	SB-366
Plate	SB-625
Welded pipe	SB-673
Welded tube	SA-249

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(15) **Approval Date: November 5, 2014**

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-638-8
Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique
Section XI, Division 1

Inquiry: In lieu of the preheat and PWHT requirements of IWA-4400, may the automatic or machine GTAW temper bead technique be used without use of preheat or postweld heat treatment?

Reply: It is the opinion of the Committee that, in lieu of the preheat and postweld heat treatment requirements of IWA-4411, the materials and welds specified in 1(a) may be repaired using the automatic or machine GTAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code All other requirements of IWA-4000[1] shall be met, except as modified by this Case.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair to P-No. 1, 3, 12A, 12B, and 12C[2] materials, and their associated welds and welds joining P-No. 8 or 43 materials to P-No. 1, 3, 12A, 12B, and 12C[2] materials, with the following limitations. This Case shall not be used to repair SA-302, Grade B material, unless the material has been modified to include 0.4% to 1.0% nickel, quenching and tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld based on the finished surface over the ferritic material shall be 500 in.^{2} (325,000 mm^2), and except as permitted in (1), the depth of the weld shall not be greater than one-half of the ferritic base metal thickness.

(1) Through-wall circumferential welds are permitted if the following restrictions are met:

(-a) For repair/replacement activities associated with existing welds, the existing weld (including any associated buttering) shall be removed in its entirety.

(-b) Temper bead buttering shall be applied across the entire face of the weld preparation area on the base materials requiring tempering, and shall extend around the full circumference of the joint.

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Case are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm), or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Case, provided the depth of repair in the base material does not exceed $^3/_8$ in. (10 mm).

(e) Prior to welding the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less shall be at least 50°F (10°C).

(f) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Weld metal and heat-affected zones may be peened to control distortion. Peening shall not be used on the final (face) layer, except as permitted in (h) below.

(h) Penning demonstrated to reduce residual surface tensile stresses is permitted on the final (face) layer after any surface examinations otherwise required by this Case are completed. A VT-1 visual examination in accordance with 4(b) shall be performed after this peening.

2 WELDING QUALIFICATIONS

(a) The welding procedures and the welding operators shall be qualified in accordance with QW-290 and the requirements of 2.1 and 2.2.

[1] The references in this Case are based on the 2010 Edition with the 2011 Addenda. For use with other Edition or Addenda refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

[2] P-No. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later Edition of Section IX.

(b) Existing welding procedure and welding operator qualifications performed in accordance with previous revisions of this Case may be used with this revision without requalification.

2.1 PROCEDURE QUALIFICATION

(a) Prior simulated postweld heat treatment on the procedure qualification test assembly is neither required nor prohibited. However, if used, the simulated postweld heat treatment shall not exceed the time or temperature already applied to the base material to be welded.

(b) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be bounded in the test assembly within the limits of Table IWA-4662.1-1.

(c) Consideration shall be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

(d) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(e) The following are procedure qualification requirements:

(1) The test assembly base material for the welding procedure qualification shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be as specified in (4) below, but shall be in the base metal. Impact testing of austenitic (nickel-based P-No. 4X and stainless steel P-No. 8) materials is not required.

(2) As an alternative to the test temperature requirements of (1), the Charpy V-notch test temperature for procedure qualification may be determined in accordance with (-a), (-b), or (-c) below. The Charpy V-notch test temperature shall be in the transition temperature range for the test assembly ferritic base metal.

(-a) The test temperature for the test assembly base metal shall be derived from the full transition temperature curve in the Certified Material Test Report.

(-b) A full transition temperature curve for the test assembly base metal shall be developed using Charpy V-notch testing.

(-c) The test temperature shall be in the range where one or more Charpy V-notch tests in the test assembly base metal exhibit 35 mils to 50 mils (0.89 mm to 1.3 mm) lateral expansion.

(3) Charpy V-notch tests of weld metal of the procedure qualification shall meet the requirements as determined in (1).

(4) Charpy V-notch tests of the heat-affected zone (HAZ) shall be performed at the same temperature as the base metal. Number, location, and orientation of test specimens shall meet the requirements of (5) through (7).

(5) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(6) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(7) The Charpy V-notch test shall be performed on the weld metal, the heat affected zone and unaffected base metal in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens shall be reported in the Procedure Qualification Record.

(8) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be not less than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Case, either of the following shall be performed:

(-a) The welding procedure shall be requalified.

(-b) An *Adjustment Temperature* for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of the 2001 Edition with the 2002 Addenda or later. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the *Adjustment Temperature*.

2.2 PERFORMANCE QUALIFICATION

Welding operators shall be qualified in accordance with Section IX.

3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements.

(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers, regardless of the interpass temperature used during qualification. The interpass temperature limitations of QW-406.3 and QW-406.8 need not be applied.

(c) The interpass temperature shall be determined by direct measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding. If direct measurement is impractical, e.g., because of geometric limitations or radiological reasons, interpass temperature shall be determined in accordance with (1) or (2).

(1) heat flow calculations using the variables listed below as a minimum:

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

(-e) time per weld pass and delay time between each pass

(-f) time to complete the weld

(2) measurement of the actual interpass temperature on a test coupon that is equal to or less than the thickness of the item to be welded. The maximum heat input of the welding procedure shall be used in the welding of the test coupon.

(d) Particular care shall be given to ensure that the weld region is free of potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4 EXAMINATION

(a) Except as permitted in (1), the following examinations shall be performed in accordance with the Construction Code or Section III.

(1) Prior to repair welding, surface examination shall be performed on the area to be welded. Alternatively, if surface examination materials cannot be cleaned from crevices in the area to be welded (e.g., trapped in crevices remaining after removal of the full thickness of a partial penetration or fillet weld), VT-1 visual examination may be performed, provided the requirements of (b) are met.

(2) When ferritic materials are used, the weld shall be nondestructively examined after the completed weld has been at ambient temperature for at least 48 hr. When austenitic materials are used, the weld shall be nondestructively examined after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. Examination of the welded region shall include both volumetric and surface examination methods.

(3) Demonstration for ultrasonic examination of the repaired volume is required using representative samples that contain construction-type flaws.

(4) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(5) Acceptance criteria for surface and volumetric examination shall be in accordance with the Construction Code or Section III.

(b) VT-1 visual examinations performed in accordance with 1(h) or (a)(1) shall meet the following requirements:

(1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving text with lower case characters without an ascender or descender (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (610 mm).

(2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

(3) Visual examination acceptance standards shall comply with the following:

(-a) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width.

(-b) Only indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) shall be considered relevant. The following relevant indications are unacceptable.

(-1) any cracks or linear indications

(-2) rounded indications with major dimensions greater than $^3/_{16}$ in. (5 mm)

(-3) four or more rounded indications in a line separated by $^1/_{16}$ in. (1.5 mm) or less edge to edge

(-4) ten or more rounded indications in any 6 in.^{2} (4 000 mm^2) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated

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Approval Date: September 24, 1999

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-639
Alternative Calibration Block Material
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix I, Supplement 1 and Section V, Article 4 for calibration block material may be used when blocks of the same material specification, product form, and heat treatment condition as the material to be examined are not available?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of Appendix I, Supplement 1 and Section V, Article 4, when calibration blocks of the same material specification, product form, and heat treatment condition as the material to be examined are not available, calibration blocks fabricated from material of similar chemical analysis, tensile properties, and metallurgical structure may be used.

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Approval Date: January 17, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-641
Alternative Pressure-Temperature Relationship and Low Temperature Overpressure Protection System Requirements
Section XI, Division 1

Inquiry: What alternatives to Appendix G-2215 may be used for determination of pressure-temperature relationships and low temperature overpressure protection system effective temperatures and allowable pressures?

Reply: It is the opinion of the Committee that, as an alternative to Appendix G-2215, the following may be used.

-1000 INTRODUCTION

-1100 SCOPE

This Case presents alternative procedures for calculating pressure-temperature relationships and low temperature overpressure protection (LTOP) system effective temperatures and allowable pressures. These procedures take into account alternative fracture toughness properties, circumferential and axial reference flaws, and plant-specific LTOP effective temperature calculations.

-2215 Allowable Pressure

-2215.1 Pressure-Temperature Relationship. The equations below provide the basis for determination of the allowable pressure at any temperature at the depth of the postulated defect during Service Conditions for which Level A and Level B Service Limits are specified. In addition to the conservatism of these assumptions, it is recommended that a factor of 2 be applied to the calculated K_I values produced by primary stresses. In shell and head regions remote from discontinuities, the only significant loadings are: (1) general primary membrane stress due to pressure; and (2) thermal stress due to thermal gradient through the thickness during startup and shutdown. Therefore, the requirement to be satisfied and from which the allowable pressure for any assumed rate of temperature change can be determined is as follows:

$$2K_{Im} + K_{It} < K_{Ic} \quad (1)$$

throughout the life of the component at each temperature with K_{Im} from G-2214.1, K_{It} from G-2214.3, and K_{Ic} from Figure G-2210-1.

The allowable pressure at any temperature shall be determined as follows:

(a) For the startup condition

(1) consider postulated defects in accordance with G-2120

(2) perform calculations for thermal stress intensity factors due to the specified range of heat-up rates from G-2214.3

(3) calculate the K_{Ic} toughness for all vessel beltline materials from G-2212 using temperatures and RT_{NDT} values for the corresponding locations of interest

(4) calculate the pressure as a function of coolant inlet temperature for each material and location. The allowable pressure-temperature relationship is the minimum pressure at any temperature determined from

(-a) the calculated steady-state (K_{It} = 0) results for the $^1/_4$ thickness inside surface postulated defects using the following equation:

$$P = \frac{K_{Ic}}{2M_m}\left(t/R_i\right)$$

(-b) the calculated results from all vessel beltline materials for the heatup stress intensity factors using the corresponding $^1/_4$ thickness outside-surface postulated defects and the following equation:

$$P = \frac{K_{Ic} - K_{It}}{2M_m}\left(t/R_i\right)$$

(b) For the cooldown condition

(1) consider postulated defects in accordance with G-2120

(2) perform calculations for thermal stress intensity factors due to the specified range of cooldown rates from G-2214.3

(3) calculate the K_{Ic} toughness for all vessel beltline materials from G-2212 using temperatures and RT_{NDT} values for the corresponding location of interest

(4) calculate the pressure as a function of coolant inlet temperature for each material and location using the following equation:

$$P = \frac{K_{Ic} - K_{It}}{2M_m}\left(t/R_i\right)$$

The allowable pressure-temperature relationship is the minimum pressure at any temperature, determined from all vessel beltline materials for the cooldown stress intensity factors using the corresponding $^1/_4$ thickness inside-surface postulated defects.

-2215.2 Low Temperature Overpressure Protection System. Plants having LTOP systems may use the following temperature and pressure conditions to provide protection against failure during reactor startup and shutdown operation due to low temperature overpressure events that have been classified Service Level A or B.

(a) LTOP System Effective Temperature. The LTOP system effective temperature T_e is the temperature at or above which the safety relief valves provide adequate protection against nonductile failure. LTOP systems shall be effective below the higher temperature determined in accordance with (1) and (2) below. Alternatively, LTOP systems shall be effective below the higher temperature determined in accordance with (1) and (3) below.

(1) a coolant temperature[1] of 200°F

(2) a coolant temperature[1] corresponding to a reactor vessel metal temperature[2], for all vessel beltline materials, where T_e is defined for inside axial surface flaws as RT_{NDT} + 40°F, and T_e is defined for inside circumferential surface flaws as RT_{NDT} − 85°F

(3) a coolant temperature[1] corresponding to a reactor vessel metal temperature,[2] for all vessel beltline materials, where T_e is calculated on a plant specific basis for the axial and circumferential reference flaws using the following equation:

$$T_e = RT_{NDT} + 50\ln[((F \cdot M_m(pR_i/t)) - 33.2)/20.734]$$

where

F = 1.1, accumulation factor for safety relief valves
M_m = the value of M_m determined in accordance with G-2214.1
p = = vessel design pressure, ksi
R_i = vessel inner radius, in.
t = vessel wall thickness, in.

(b) LTOP System Allowable Pressure. LTOP systems shall limit the maximum pressure in the vessel to 100% of the pressure determined to satisfy eq. -2215.1(1) if K_{Ic} is used for determination of allowable pressure, or 110% of the pressure determined to satisfy eq. -2215.1(1) if K_{Ia} is used (as an alternative to K_{Ic}) for determination of allowable pressure.

[1] The coolant temperature is the reactor coolant inlet temperature.

[2] The vessel metal temperature is the temperature at a distance one-fourth of the vessel section thickness from the clad-base-metal interface in the vessel beltline region. RT_{NDT} is the highest adjusted reference temperature, for weld or base metal in the beltline region, at a distance one-fourth of the vessel section thickness from the clad-base-metal interface as determined in accordance with Regulatory Guide 1.99, Rev. 2.

Approval Date: March 28, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-642
Alternative Rules for Progressive Liquid Penetrant Examination of Groove Welds in P-No. 8 Materials $^{3}/_{16}$ in. (5 mm) Thick and Less Made by Autogenous Machine or Automatic Welding
Section III, Division 1

Inquiry: What alternative rules to those of NG-5231 for progressive examination may be applied to Table NG-3352-1 for autogenous longitudinal groove welds made from both sides by machine or automatic welding in P-No. 8 materials nominally $^{3}/_{16}$ in. (5 mm) thick or less. The first pass of weld is made using plasma arc welding (PAW) in the keyhole mode followed by additional weld passes that are used primarily to control surface appearance?

Reply: It is the opinion of the Committee that the quality factor associated with progressive liquid penetrant examination in Table NG-3352-1 may be applied to P-No. 8 material that is nominally $^{3}/_{16}$ in. (5 mm) thick or less provided:

(a) The weld shall be an autogenous longitudinal seam groove weld made from two sides by machine or automatic welding. The first pass shall be made using plasma arc welding (PAW) in the keyhole mode followed by additional passes that are used primarily to control surface appearance on each side of the groove using the same or a different welding process. Tolerances on welding parameters such as the voltage, amperage, travel speed, gas flow rate, and standoff distance shall be established for the first pass to ensure full penetration.

(b) Welding shall be done using automatic joint tracking, or the PAW process shall be visually monitored by the operator for alignment with the groove.

(c) Liquid penetrant examination shall be performed on the external weld surface and adjacent base material for $^{1}/_{2}$ in. (13 mm) on each side of the weld.

(d) Liquid penetrant examination shall be performed on all accessible internal weld surfaces and adjacent base material for $^{1}/_{2}$ in. (13 mm) on each side of the weld and shall include a minimum of 6 in. (300 mm) of weld length on each end of each seam.

(e) The liquid penetrant examination shall be in accordance with NG-5111 following a written procedure.

(f) This Case number shall be shown on the Data Report Form.

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Approval Date: May 4, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-643-2
Fatigue Crack Growth Rate Curves for Ferritic Steels in PWR Water Environment
Section XI, Division 1

Inquiry: As an alternative to the fatigue crack growth rate da/dN characterized in A-4300, what crack growth behavior characterization may be used for ferritic material in PWR primary water environments when information on the susceptibility of the material to environmentally assisted cracking is available?

Reply: It is the opinion of the Committee that as an alternative to the fatigue crack growth rate behavior characterized in A-4300, the following characterization may be used for ferritic material in PWR primary water environments when information on the susceptibility of the material to environmentally assisted cracking is available.

1 INTRODUCTION

The fatigue crack growth behavior of ferritic materials can be greatly affected by exposure to light-water reactor environments. Some combinations of material and environment are susceptible to enhanced crack growth rates, referred to herein as Environmentally Assisted Cracking (EAC). Susceptibility to EAC during fatigue cycling is controlled by (1) metallurgical factors such as material chemistry, particularly sulfur content and morphology, (2) environmental factors such as water chemistry and temperature, and (3) factors affecting crack-tip properties such as Electrochemical Corrosion Potential (ECP), water flow rate as it flushes the crack-tip region, and crack-face surface conditions as they affect mass transport of particles into and out of the crack-tip region. This Case provides criteria for determining the susceptibility of ferritic materials to EAC, reference fatigue crack growth rate behavior for material susceptible to EAC, and reference fatigue crack growth rate behavior for material not susceptible to EAC.

2 NOMENCLATURE

The symbols used in this Case are defined as follows:

a = flaw depth, in.
Δa = increment of flaw growth in depth direction, in.
Δa_i = increment of flaw growth in depth direction in time increment Δt_i, in.
Δa_{cr} = flaw growth increment required for EAC initiation, in.
C_o = fatigue crack growth rate scaling constant, $(\text{in./cycle})\cdot(\text{ksi}\sqrt{\text{in.}})^{-n}$
da/dN = fatigue crack growth rate, in./cycle
i = time increment index, I = 1, ..., N
$K_{\max}$ = maximum stress intensity factor during cycle, $\text{ksi}\sqrt{\text{in.}}$
$K_{\min}$ = minimum stress intensity factor during cycle, $\text{ksi}\sqrt{\text{in.}}$
ΔK = $K_{\max} - K_{\min}$ = range of applied stress intensity factor, $\text{ksi}\sqrt{\text{in.}}$
ΔK_b, ΔK_c = ΔK values defining regions of enhanced crack growth, $\text{ksi}\sqrt{\text{in.}}$
ΔK_{th} = mechanical threshold ΔK value, $\text{ksi}\sqrt{\text{in.}}$
ℓ = flaw length, in.
$\Delta\ell$ = increment of flaw growth in length direction, in.
n = fatigue crack growth rate exponent
N = number of increments in evaluation period
R = $K_{\min}/K_{\max}$ = R ratio
S = bulk sulfur content in weight percent
Δt_i = time increment, yr.
V_i = crack-tip velocity adjusted for calculational uncertainty, in./sec
V_{in} = crack-tip velocity required for EAC initiation, in./sec
α = crack-tip velocity calculational uncertainty factor
θ = load rise time, sec

3 EAC SUSCEPTIBILITY CRITERIA

For steels with bulk sulfur content (as determined by material certification) $S < 0.004$ wt-percent exposed to water the crack growth law of 4.2 may be used, because the material is not susceptible to EAC.

For steels with sulfur content $S \geq 0.004$ wt-percent exposed to water, the following procedure based on a calculation of the average crack-tip velocity over a prescribed time period shall be used to determine EAC susceptibility for that time period. The flow chart in Figure 1 summarizes the procedure.

(a) Divide the evaluation period into N increments of no longer than one year. The time increment Δt_i is associated with the ith increment, i=1,2,3, ..., N.

(b) During the first time increment, evaluate flaw growth Δa and $\Delta \ell$ at the depth and surface locations of the flaw in accordance with the calculational procedure of A-5200 and the reference fatigue crack growth behavior of this Case. Flaw growth for a subsurface flaw that need not be evaluated as a surface flaw may be determined using the fatigue crack growth rate da/dN for material exposed to air environments given in A-4300. Use the proximity rules of IWA-3310 or IWB-3610 for subsequent time increments to determine if breakthrough to a surface flaw occurs during the evaluation period.

(1) For clad components, flaw growth shall be evaluated using one of the following:

(-a) If the flaw is determined to be a Category 3, Category 4, or Category 5 subsurface flaw in accordance with IWB-3610 and the proximity rules of Fig. IWB-3610-1 require the flaw to be evaluated as a surface flaw, the crack growth law of 4.1 shall be used.

(-b) If the flaw is determined to be a Category 2 surface flaw, the crack growth law of 4.2 shall be used.

(2) For unclad components, flaw growth shall be evaluated using one of the following:

(-a) If a subsurface indication is considered a surface flaw in accordance with IWA-3310 and the proximity rules of Fig. IWA-3310-1, the crack growth law of 4.1 shall be used.

(-b) If the flaw is a surface flaw, the crack growth law of 4.2 shall be used.

(c) For surface flaws exposed to water, calculate the average crack-tip velocity at the deepest location of the flaw as the flaw growth Δa_i, in increment i=1 divided by the time increment Δt_i. Convert this velocity to units of in./sec., and multiply by α=1.5 to obtain the adjusted crack-tip velocity V_i for increment i=1.

(d) Define the crack-tip velocity, in units of in./sec., at which EAC can initiate by:

(1) For a ≤ 0.1 in.

$$V_{in} = 2.0 \times 10^{-8}$$

(2) For a > 0.1 in.

$$V_{in} = 2.0 \times 10^{-8} \times (0.1/a)$$

where

a = the flaw depth at the beginning of the time increment

(e) Determine the mode of crack growth behavior for the increment as follows:

Δa_{cr} = 0.013 in., is the increment of flaw growth for which V_i must exceed V_{in} for EAC to occur

(1) If $V_i < V_{in}$, EAC has not occurred and flaw growth for the next time increment may be evaluated using the crack growth law of 4.2.

(2) If $V_i \geq V_{in}$ and $\Delta a_i < \Delta a_{cr}$, EAC has not occurred and flaw growth for the next time increment may be evaluated using the crack growth law of 4.2.

(3) If $V_i \geq V_{in}$ and $\Delta a_i \geq \Delta a_{cr}$, EAC is assumed to have occurred and flaw growth for both the present time increment Δt_i, and the next time increment Δt_{i+1}, shall be evaluated using the crack growth law of 4.1.

(f) Evaluate flaw growth Δa and $\Delta \ell$ for the next time increment and repeat (c) through (e). The determination of Δa_i in (e)(2) and (e)(3) for which $V_i \geq V_{in}$ shall include the flaw growth during all previous increments in which $V_i \geq V_{in}$. Continue to the end of the evaluation period.

4 FATIGUE CRACK GROWTH RATE

The fatigue crack growth rate *da/dN* of the material is characterized in terms of the range of the applied stress intensity factor, ΔK. This characterization is generally in the form of eq. (1).

$$da/dN = C_o \Delta K^n \qquad (1)$$

where

n = the slope of the log (da/dN) versus log (ΔK) curve
C_o = a scaling constant

The fatigue crack growth behavior of the material is affected by R. Reference fatigue crack growth rates below apply to $0 \leq R < 1$ and $K_{\min} \geq 0$. If $K_{\min} < 0$, use $R = 0$. The scaling constants below produce fatigue crack growth rates in the units of in./cycle. Reference fatigue crack growth rate curves of materials exposed to light-water reactor environments are shown in Figures 2 and 3

4.1 MATERIAL SUSCEPTIBLE TO EAC

The fatigue crack growth rate for material susceptible to EAC depends on bulk sulfur content and rise time.

For bulk sulfur content $S \leq 0.013$ wt-percent and rise time $\theta \leq 1$ second, the crack growth parameters of 4.2 shall be used.

For bulk sulfur content $S \leq 0.013$ wt-percent and rise time $\theta > 1$ sec the fatigue crack growth rate is given by eq. 4(1), with C_o and n given by (see Figure 2):

for $\Delta K < \Delta K_{th}$

Figure 1
Flow Chart of Calculational Procedure to Determine EAC Susceptibility

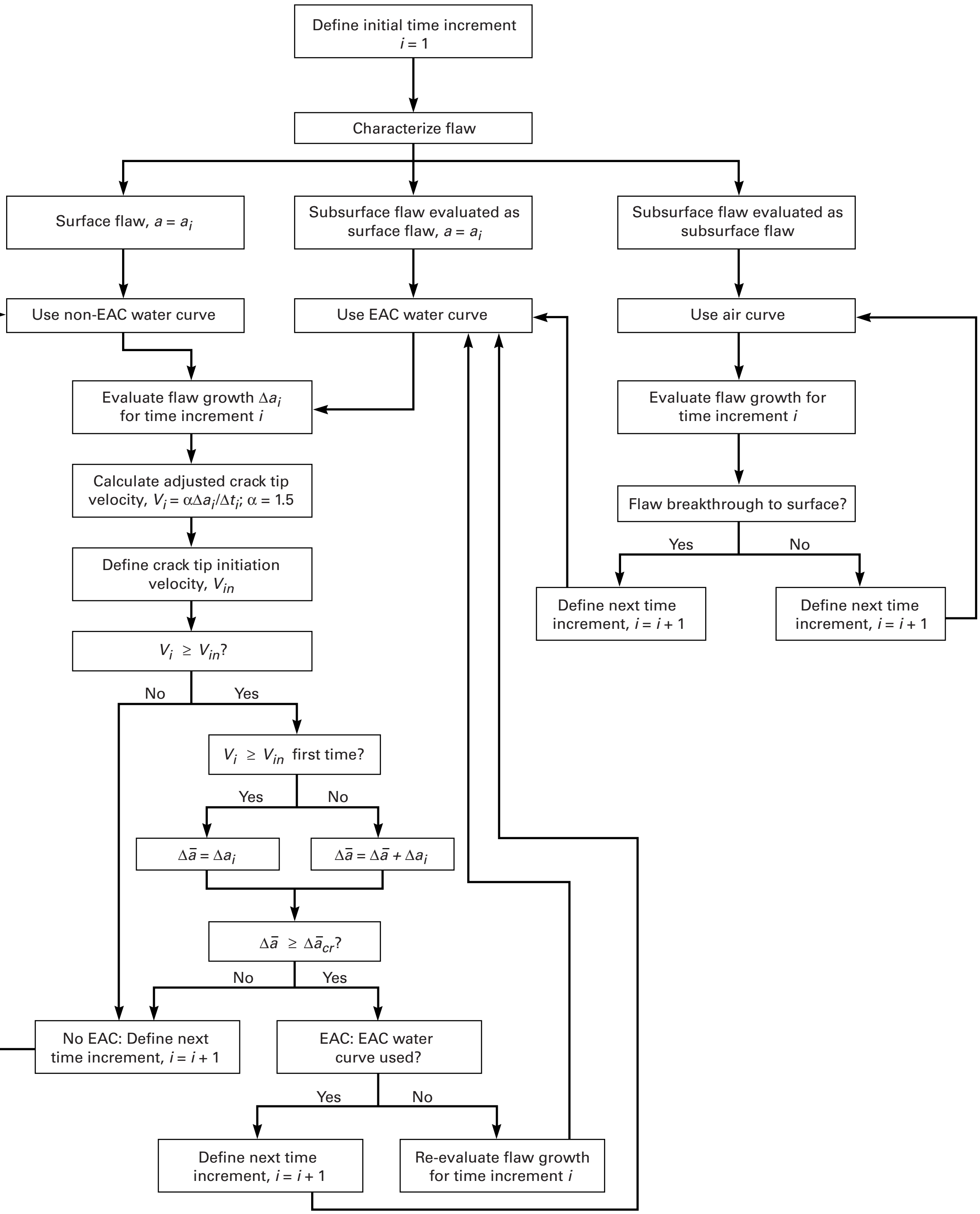
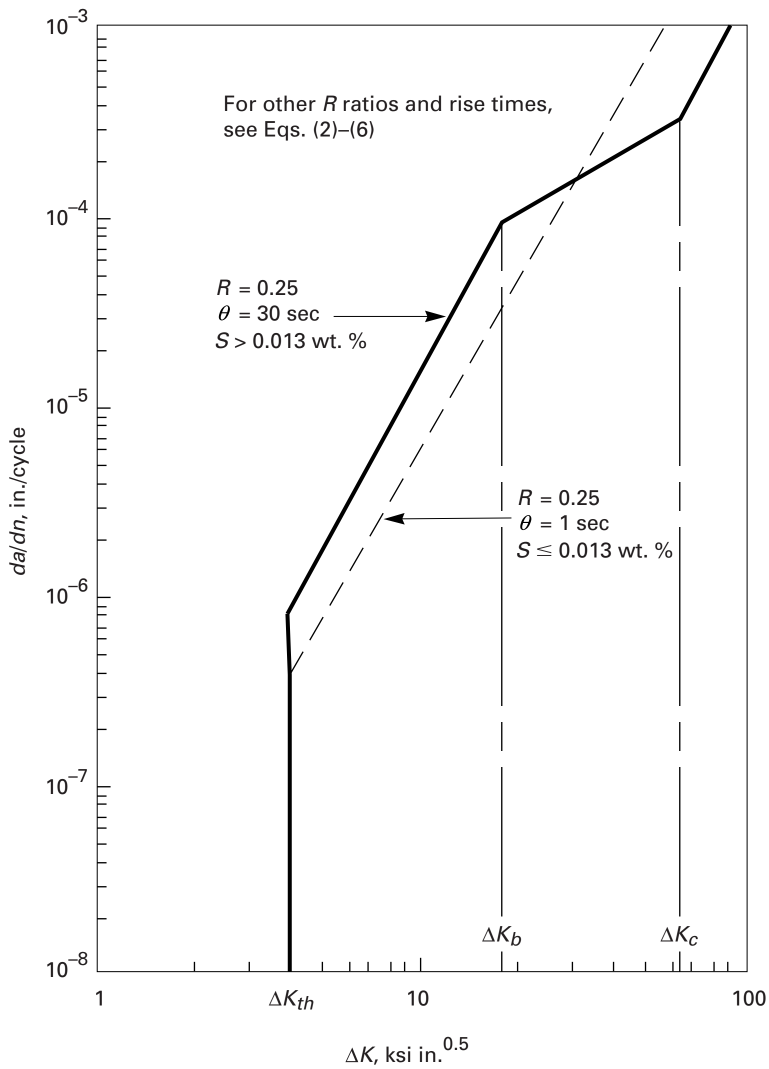


Figure 2
Reference Fatigue Crack Growth Curves for Low Alloy Ferritic Material Susceptible to EAC in Water Environments



$$C_o = 0 \tag{2a}$$

for $\Delta K \geq \Delta K_{th}$

$$C_o = 6.13 \times 10^{-8}/(2.88 - R)^{3.07} \quad n = 3.07 \tag{2b}$$

For bulk content S > 0.013 wt-percent, the fatigue crack growth rate is given by eq. 4(1), with C_o and n given by (see Figure 2):

for $\Delta K < \Delta K_{th}$

$$C_o = 0 \tag{3a}$$

for $\Delta K_{th} \leq \Delta K \leq K_b$

$$C_o = 7.47 \times 10^{-6}/(2.88 - R)^{6.65} \quad n = 3.07 \tag{3b}$$

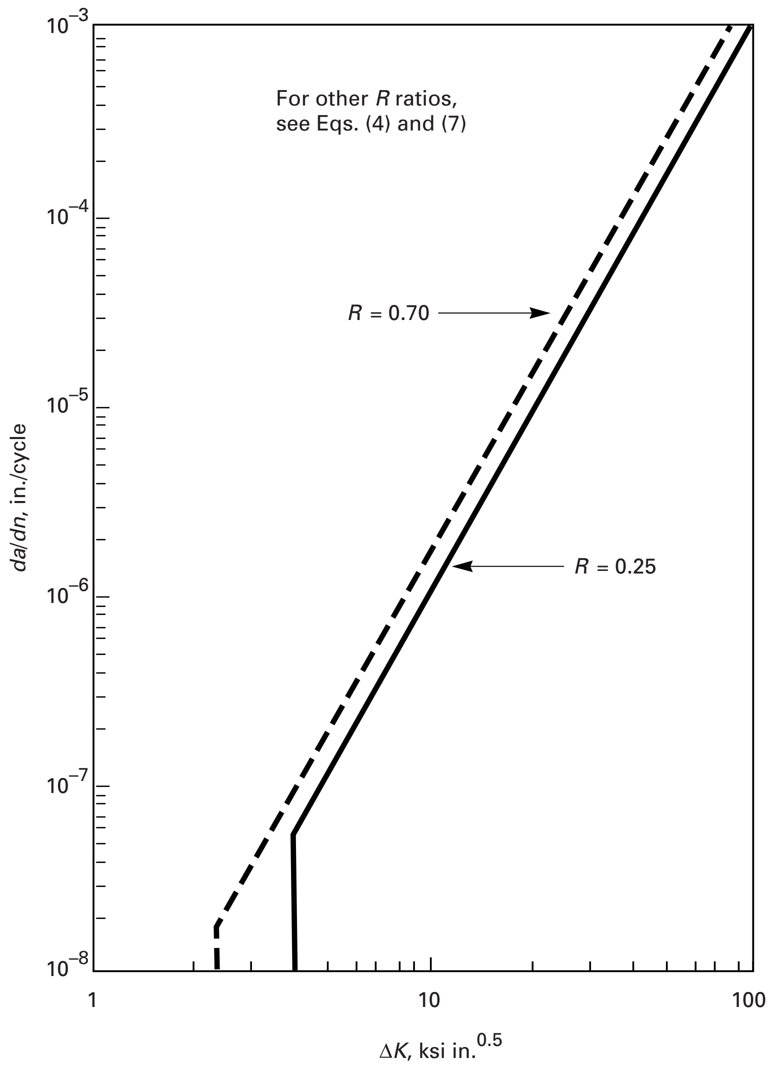
for $\Delta K_b < \Delta K \leq K_c$

$$C_o = 1.39 \times 10^{-6}\, \theta^{0.691}/(2.88 - R)^{0.948} \quad n = 0.948 \tag{3c}$$

for $\Delta K > \Delta K_c$

$$C_o = 1.45 \times 10^{-8}/(2.88 - R)^{3.07} \quad n = 3.07 \tag{3d}$$

Figure 3
Reference Fatigue Crack Growth Curves for Low Alloy Ferritic Material Not Susceptible to EAC in Water Environments



The mechanical threshold ΔK value, below which the fatigue crack growth rate is negligible, is given by the following:

for $0 \le R < 1.0$

$$\Delta K_{th} = 5.0(1 - 0.8R) \quad (4)$$

The values of ΔK_b and ΔK_c that delineate the regions of enchanced fatigue crack growth for $S > 0.013$ wt-percent as shown in Figure 2 are given by the following:

$$\Delta K_b = 0.453\,\theta^{0.326}(2.88 - R)^{2.69} \quad (5)$$

$$\Delta K_c = 8.57\,\theta^{0.326}\,(2.88 - R) \quad (6)$$

The load rise time, θ, is the period of time in seconds for which the stress is increasing during a stress cycle. The rise time, which excludes hold times and time periods for which the stress is decreasing during the cycle, includes the time periods from minimum stress to steady state and from steady state to maximum stress. Hold times include periods in which the change in stress does not exceed 1000 psi/hr. For material susceptible to EAC with $S > 0.013$ wt-percent and for transients for which θ is not available, reference fatigue crack growth behavior is given by eq. 4(1), with C_o and n given by Eqs. (3a) and (3b) for the entire range of ΔK. For $\Delta K > \Delta K_b$, the lower of the curves corresponding to $S > 0.013$ wt-percent [eq. (3c) , (3d), and (6)] or $S \le 0.013$ wt-percent eq. (2b) may be used for $S \le 0.013$ wt-percent material.

4.2 MATERIAL NOT SUSCEPTIBLE TO EAC

Reference fatigue crack growth behavior for material not susceptible to EAC is given by eq. 4(1), with C_o and n given by (see Figure 3):

(a) for $\Delta K < \Delta K_{th}$

$$C_o = 0 \tag{7a}$$

(b) for $\Delta K \geq \Delta K_{th}$

$$C_o = 1.45 \times 10^{-8}/(2.88 - R)^{3.07}$$
$$n = 3.07 \tag{7b}$$

5 SI UNITS

It is recommended that the flaw growth evaluation using the procedures of this Case be performed in U.S. Customary units, since the equations and figures contained in this Case were developed in these units. Conversion from U.S. Customary units to SI units can be performed employing the following conversions:

1 in.	=	25.4 mm
1 ksi in.$^{0.5}$	=	1.0988 MPa m$^{0.5}$
T [°F]	=	1.8T [°C] + 32

where T is temperature.

Approval Date: February 14, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-644-1
Weld Procedure Qualification for Procedures Exempt From PWHT in Classes 1, 2, and 3 Construction
Section III, Division 1

Inquiry: For weld procedures that are exempt from PWHT in Table NB-4622.7(b)-1, Table NC-4622.7(b)-1, and Table ND-4622.7(b)-1, which require weld procedure qualification using base metal thickness equal to or greater than the production weld, may the maximum required coupon qualification thickness be 1.5 in.?

Reply: It is the opinion of the Committee that for weld procedures that are exempt from PWHT in Table NB-4622.7(b)-1, Table NC-4622.7(b)-1, and Table ND-4622.7(b)-1, which require weld procedure qualification using base metal thickness equal to or greater than the production weld, the maximum required coupon qualification thickness is 1.5 in.

(a) This requirement applies to welds of $^5/_8$ in. nominal thickness or less for the following materials:

(1) All welds of P-No. 1 materials in vessels (except repair welds and fillet welds).

(2) All welds of P-No. 3 material (except Group 3 and repair welds in vessels).

(3) All welds of P-No. 9A, Group 1 and P-No. 9B, Group 1 materials.

(b) All other requirements of Table NB-4622.7(b)-1 shall be met.

(c) Use of this Case shall be documented in the Data Report Form.

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Case N-645-1
Use of Rupture Disk Devices on Nuclear Fuel Storage Cannisters, Class 1
Section III, Division 1

ANNULLED

Annulment Date: February 9, 2015

Reason: No longer needed.

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Case N-646
Alternative Stress Intensification Factors for Circumferential Fillet Welded or Socket Welded Joints for Class 2 or 3 Piping
Section III, Division 1

ANNULLED

Annulment Date: November 10, 2014

Reason: Has been incorporated.

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Approval Date: December 8, 2000

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-647
Alternative to Augmented Examination Requirements of IWE-2500
Section XI, Division 1

Inquiry: What alternative to the requirements of IWE-2500 may be used for augmented examination of Class MC components and metallic liners of Class CC components?

Reply: It is the opinion of the Committee that the following may be used as an alternative to the requirements of IWE-2500(c) (1989 Edition through the 1995 Edition with the 1997 Addenda) or IWE-2500(b) and Table IWE-2500-1, Examination Category E-C (1998 Edition through the 1998 Edition with the 2000 Addenda).

Augmented examination of surface areas identified in IWE-1242 shall comply with the following criteria:

(a) Surface areas requiring augmented examination that are accessible for visual examination shall be examined using a VT-1 (1989 Edition through the 1995 Edition with the 1997 Addenda) or a detailed (1998 Edition with the 2000 Addenda) visual examination method.

(b) Surface areas requiring augmented examination that are not accessible for visual examination of the side requiring augmented examination shall be examined for wall thinning using an ultrasonic thickness measurement method in accordance with Section V, T-544.

(1) When ultrasonic thickness measurements are performed, grids not exceeding one foot square shall be used. The number and location of the grids shall be determined by the Owner.

(2) Ultrasonic thickness measurements shall be used to determine the minimum wall thickness within each grid. The location of the minimum wall thickness within each grid shall be marked or recorded such that periodic reexamination can be performed in accordance with the requirements of Table IWE-2500-1, Examination Category E-C (1989 Edition through the 1995 Edition with the 1997 Addenda) or Table 1, Examination Category E-C (1998 Edition through the 1998 Edition with the 2000 Addenda). A sampling plan may be used to determine the number and location of ultrasonic thickness measurement grids within each contiguous examination area, provided

(-a) acceptance of the examination area is based on a statistical confidence level of at least 95% that 95% of all grids within the examination area meet the acceptance standards of IWE-3500;

(-b) grid locations are selected at random from within each examination area.

Table 1
Examination Categories

EXAMINATION CATEGORY E-C, CONTAINMENT SURFACES REQUIRING AUGMENTED EXAMINATION

Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method	Acceptance Standard	Extent and Frequency of Examination: 1st Inspection Interval	Extent and Frequency of Examination: Successive Inspection Interval	Deferral of Inspection to End of Interval
E4.10	Containment Surface Areas [Note (1)]						
E4.11	Visible Surfaces	IWE-2310(c) Reply (a)	Detailed Visual	IWE-3511	100% of surface areas identified by IWE-1242 [Note (1)]	100% of surface identified by [Note (2)]	Not Permissible
E4.12	Surface Area Grid Minimum Wall Thickness Locations	Reply (b)	Ultrasonic Thickness	IWE-3511	100% of minimum wall thickness locations during each inspection period, established in accordance with Reply (b)(1) [Note (2)] and Reply (b)(2) [Note (2)]	100% of minimum thickness locations during each inspection period, established accordance with (b)(1) [Note Reply (b)(2)	Not Permissible

NOTES:
(1) Containment surface areas requiring augmented examination are those identified in IWE-1240.
(2) The extent of examination shall be 100% for each inspection period until the areas remain essentially unchanged for the next inspection period. Such longer require augmented examination in accordance with IWE-2420(c).

Approval Date: September 4, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-648-2
Alternative Requirements for Inner Radius Examinations of Class 1 Reactor Vessel Nozzles
Section XI, Division 1

Inquiry: What alternative to the preservice examination requirements of IWB-2200(a) and inservice examination requirements of Table IWB-2500-1, Examination Category B-D may be used for reactor vessels?

Reply: It is the opinion of the Committee that in lieu of the preservice examination requirements of IWB-2200(a) and inservice examination requirements of Table IWB-2500-1, Examination Category B-D the requirements specified in 1 and 2 below shall be met.

1 PRESERVICE EXAMINATION

For reactor vessel nozzles other than BWR feedwater nozzles and operational control rod drive return line nozzles, a VT-1 visual examination of the surface M-N shown in Figure IWB-2500-7, sketches (a) through (d) may be performed in lieu of the volumetric examination required by Table IWB-2500-1, Examination Category B-D, Item No. B3.100, provided the following requirements are met:

(a) The surface M-N shown in Figure IWB-2500-7, sketches (a) through (d) shall have been examined using a surface examination method and shall have met the Section III fabrication acceptance standards at least once after the Construction Code hydrostatic test. The surface examination shall have been performed prior to the preservice VT-1 visual examination.

(b) The appropriate surfaces shall have been prepared in accordance with IWA-2200(b) for application of a future volumetric examination in accordance with Table IWB-2500-1, Examination Category B-D.

(c) An evaluation that includes the following shall have been performed:

(1) review of the fabrication examination history for the nozzle inner radius region

(2) verification that the nozzle of interest meets the requirements of Section III, Nonmandatory Appendix G

For the preservice VT-1 visual examination, crack-like surface flaws exceeding the acceptance criteria of Table IWB-3510-3 are unacceptable for service, unless the reactor vessel meets the requirements of IWB-3122.2 or IWB-3122.3. The component thickness, t, to be applied in calculating the allowable surface-flaw-length-to-component-thickness ratio, l/t, in Table IWB-3510-3, shall be selected as specified in Table IWB-3512-2.

2 INSERVICE EXAMINATION

For reactor vessel nozzles other than BWR feedwater nozzles and operational control rod drive return line nozzles, a VT-1 visual examination of the surface M-N shown in Figure IWB-2500-7, sketches (a) through (d) may be performed in lieu of the volumetric examination required by Table IWB-2500-1, Examination Category B-D, Item No. B3.100. For the inservice VT-1 visual examination, crack-like surface flaws exceeding the criteria of Table IWB-3510-3 are unacceptable for continued service, unless the reactor vessel meets the requirements of IWB-3142.2, IWB-3142.3, or IWB-3142.4. The component thickness, t, to be applied in calculating the allowable surface-flaw-length-to-component-thickness ratio, l/t, in Table IWB-3510-3 shall be selected as specified in Table IWB-3512-2.

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Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-649
Alternative Requirements for IWE-5240 Visual Examination
Section XI, Division 1

Inquiry: What alternative to the requirements of IWE-5240 may be used for visual examination of the pressure retaining boundary following a repair/replacement activity?

Reply: It is the opinion of the Committee that the following requirements may be used in lieu of those in IWE-5240 for visual examination following a repair/replacement activity.

(a) Following a repair/replacement activity affecting the containment pressure boundary, when a pressure test (Type A, Type B, or Type C) is performed to verify the leak-tight integrity of the affected pressure boundary, VT-3 visual examination (1989 Edition through the 1995 Edition with the 1997 Addenda) or general visual examination (1998 Edition through the 1998 Edition with the 2000 Addenda) shall be performed during or after the pressure test on the areas affected by the repair/replacement activity.

(b) Alternatively, following a repair/replacement activity affecting the containment pressure boundary, when a pressure test (Type A, Type B, or Type C) is deferred, VT-1 visual examination (1989 Edition through the 1995 Edition with the 1997 Addenda) or detailed visual examination (1998 Edition through the 1998 Edition with the 2000 Addenda) shall be performed on the areas affected by the repair/replacement activity. When the pressure test is performed, the requirements of the above paragraph shall be met.

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Approval Date: March 28, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-650
Use of SA-537, Class 2 Plate Material in Non-pressure Boundary Application Service 700°F to 850°F, Class 1 or CS
Section III, Division 1

Inquiry: May plate material requirements of SA-537, Class 2, < 2½ in. thickness be used at temperatures over 700°F but not exceeding 850°F in non-pressure boundary application for no more than 3 cycles of 100 hr duration each during the component life?

Reply: It is the opinion of the Committee that material conforming to SA-537, Class 2, < 2½ in. thickness may be used at temperatures over 700°F but, not exceeding 850°F in non-pressure boundary applications, for no more than 3 cycles of 100 hr duration each during the service life of the component, provided that the design stress intensity, yield strength, and ultimate tensile strength shall be as listed in Table 1, and the following restrictions apply:

(a) The primary local membrane plus bending plus secondary stress intensity $\left(P_L + P_B + Q\right)$ shall not exceed 7.5 ksi.

(b) No welding is permitted.

(c) All other applicable requirements of Section III, Division 1, Class 1 or CS are met.

(d) The Data Report Form, Design Specifications and Design Report shall reference this Case number.

Table 1
Maximum Allowable Stress and Strength Values

For Metal Temperature Not Exceeding °F	Ultimate Tensile Strength S_u, ksi	Yield Strength S_y, ksi	Design Stress Intensity S_m, ksi
750	77.4	37.7	25.1
800	74.8	36.6	24.4
850	69.8	35.1	23.2

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Approval Date: August 14, 2001

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-651
Ferritic and Dissimilar Metal Welding Using SMAW Temper Bead Technique Without Removing the Weld Bead Crown for the First Layer
Section XI, Division 1

Inquiry: Under what conditions may the SMAW temper bead technique be used without removing the weld bead crown of the first layer on Classes 1, 2, and 3 components?

Reply: It is the opinion of the Committee that repair to P-Nos. 1, 3, 12A, 12B, and 12C[1] materials and their associated welds and P-No. 8 or P-No. 43 materials and their associated welds to P-Nos. 1, 3, 12A, 12B, and 12C[1] material may be made by the following SMAW temper bead technique. This technique does not require removal of the weld bead crown of the first layer nor the specified postweld heat treatment of the Construction Code, provided the following requirements and all other requirements of IWA-4000,[2] are met.

1 GENERAL REQUIREMENTS

(a) The maximum area of an individual weld based on the finished surface shall be 100 in.^{2}, and the depth of the weld shall not be greater than one-half of the base metal thickness.

(b) Repair/replacement activities on a dissimilar-metal weld are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in., or less of nonferritic weld deposit exists above the original fusion line.

(c) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed, provided the depth of repair in the base material does not exceed $^3/_8$ in.

(d) Prior to welding the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in., whichever is less, shall be at least 350°F.

(e) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(f) Peening may be used, except on the initial and final layers.

2 WELDING QUALIFICATIONS

The welding procedures and the welders shall be qualified in accordance with Section IX and the requirements of 2.1 and 2.2.

2.1 PROCEDURE QUALIFICATION

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number, as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded.

(b) Consideration shall be given to the effects of irradiation on the properties of material, including weld material, for applications in the beltline region of the reactor vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

(c) The included angle of the cavity in the test assembly shall be no greater than the minimum specified for the repair.

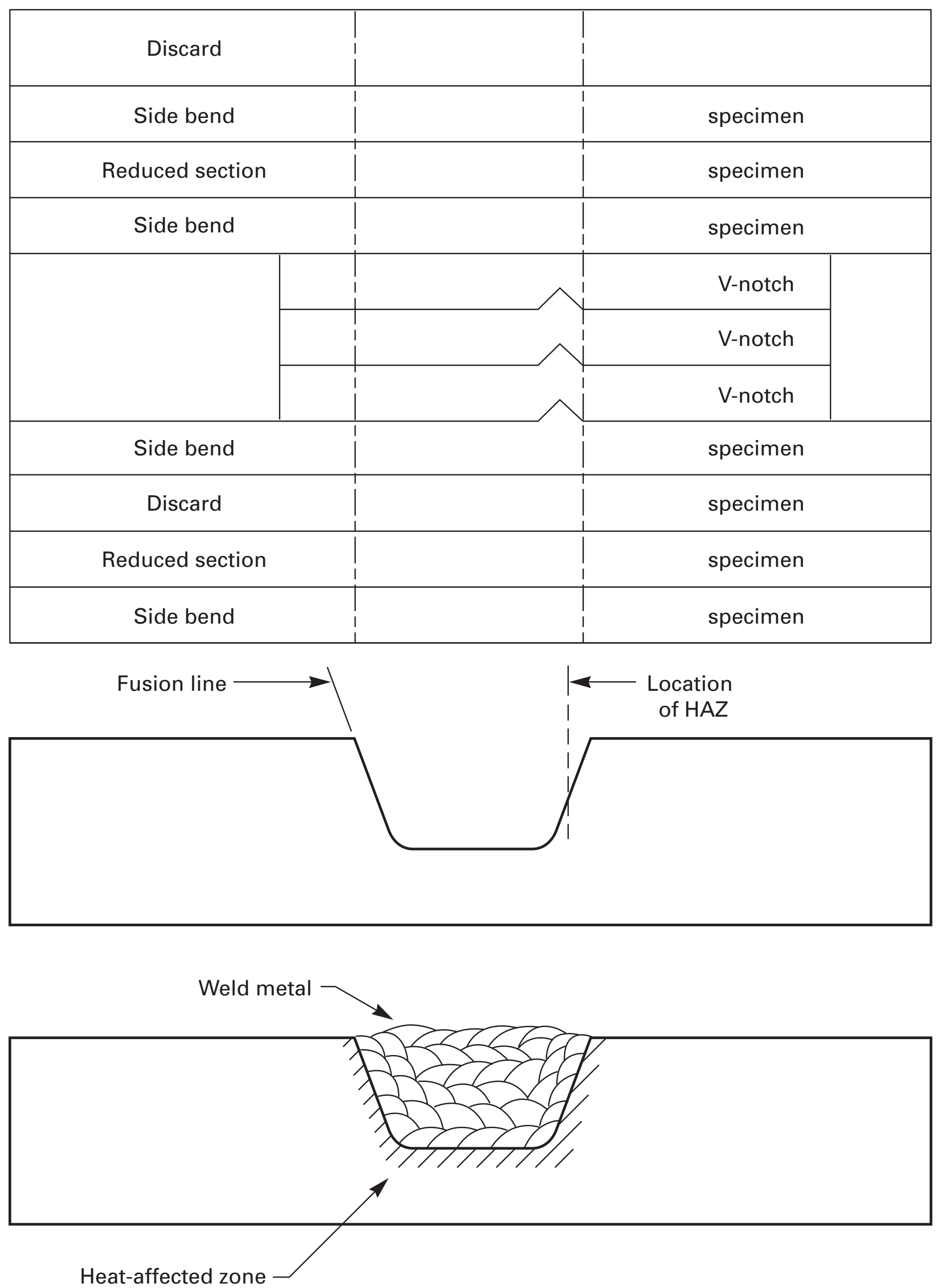
(d) The maximum interpass temperature for the first two layers of the test assembly shall be 450°F.

(e) The test assembly cavity depth shall be at least one-half the depth of the weld to be installed during the repair/replacement activity and at least 1 in. The test assembly thickness shall be at least twice the test assembly cavity depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions surrounding the cavity shall be at least the test assembly thickness and at least 6 in. The qualification test plate shall be prepared in accordance with Figure 1.

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified as P-No.3 material in a later Edition of Section IX.

[2] IWA-4000 or IWA-7000, as applicable, in the 1989 Edition, with the 1990 Addenda, and earlier Editions and Addenda.

Figure 1
Qualification Test Plate



GENERAL NOTE: Base metal and weld metal Charpy impact specimens are not shown. This figure illustrates a similar metal weld.

(f) For ferritic base materials the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service metal temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (h), but shall be in the base metal.

(g) Charpy V-notch tests of the weld metal of the procedure qualification shall meet the requirements as determined in accordance with (f).

(h) Charpy V-notch tests of the heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (f). Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(2) If the test material is in the form of a plate or a forging, the axis of the weld shall be aligned parallel to the principal direction of rolling or forging.

(3) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens shall be reported in the Procedure Qualification Record.

(i) The average value of lateral expansion of the three HAZ impact tests shall be equal to or greater than the average value of the three unaffected base metal tests.

2.2 PERFORMANCE QUALIFICATION

(a) Welders shall be qualified in accordance with Section IX.

(b) If the weld is to be performed where physical obstructions impair the welder's ability to perform, the welder shall also demonstrate the ability to deposit sound weld metal in the positions required, using the parameters and simulated physical obstructions that are involved in the repair/replacement activities.

3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements.

(a) The weld metal shall be deposited by the SMAW process.

(b) Ferritic electrodes shall be low hydrogen electrodes meeting the coating moisture content requirements of SFA-5.5.

(c) For dissimilar materials, the weld metal shall be A-No. 8 (QW-422) for P-No. 8 to P-No. 1, or P-No. 3 joints, or F-No. 43 (QW-432) for P-No. 8 or P-No. 43 to P-No. 1, or P-No. 3 joints. The maximum bead width shall be four times the electrode core diameter.

(d) Covered electrodes shall be handled and controlled as follows:

(1) For ferritic materials covered electrodes from hermetically sealed containers shall immediately be used or placed into holding or drying ovens operating between 225°F and 300°F. Covered electrodes from other than hermetically sealed containers shall be baked and maintained in accordance with the manufacturer's recommendations. After baking and before the electrodes are allowed to cool below 225°F, they shall be transferred to holding or drying ovens operating between 225°F and 350°F. Electrodes exposed to atmosphere for a period of 8 hr, for E70XX electrodes or 4 hr, for E80XX and E90XX electrodes shall be baked and reprocessed as described above. Electrodes shall not be rebaked more than once.

(2) For dissimilar materials, nonferritic covered electrodes shall be maintained in heated ovens. The oven temperature shall be maintained between 225°F and 350°F. Electrodes exposed to the atmosphere for more than 8 hr shall be discarded, or baked in accordance with the manufacturer's recommendations and placed immediately back into the holding ovens. Electrodes shall not be baked more than once.

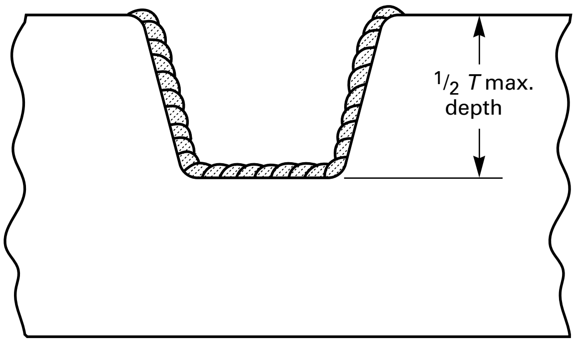
(e) The cavity shall be welded as follows:

(1) For ferritic materials, the cavity shall be buttered using a $^3/_{32}$ in., diameter electrodes as shown in Figure 2, Step 1. The second layer shall be deposited using $^1/_8$ in., diameter electrodes. Subsequent layers shall be deposited using electrodes no larger than $^5/_{32}$ in. diameter. Bead deposition shall be as shown in Figure 2, Step 2. When the weld metal conforms to SFA-5.1 or SFA-5.5, the completed weld shall have at least one layer of weld reinforcement deposited and this reinforcement shall be removed by mechanical means.

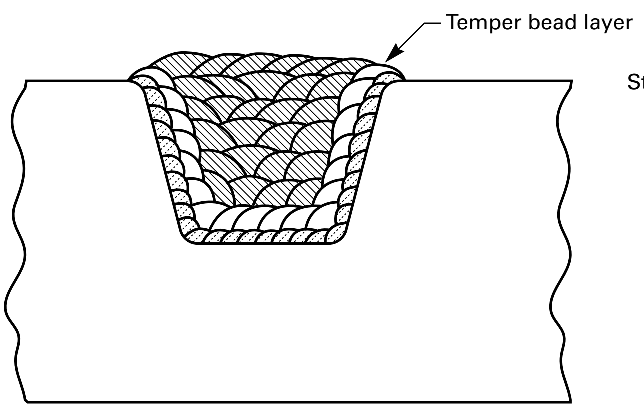
(2) For dissimilar metal welds, areas of the ferritic material, exposed or not, on which weld metal is to be deposited, shall be covered with a single layer of weld deposit using $^3/_{32}$ in., diameter electrodes as shown in Figure 3, Step 2. The second layer shall be deposited using $^1/_8$ in. diameter electrodes. Subsequent layers shall be deposited using welding electrodes no larger than $^5/_{32}$ in., diameter as shown in Figure 3, Step 3.

(3) Particular care shall be taken in the application of the temper bead weld layers at the weld toe area of the ferritic base material to ensure that the HAZ is tempered.

Figure 2
Temper Bead Welding for Ferritic Base Metals



Step 1: Butter cavity with one layer of weld metal using $^3/_{32}$ in. diameter coated electrode. Each weld bead overlaps 50% ± 25% of previous weld bead.



Step 2: The second layer shall be deposited using a $^1/_8$ in. diameter electrode. Each weld bead overlaps 50% ± 25% of the previous weld bead. Subsequent layers shall be deposited using electrodes no larger than $^5/_{32}$ in. diameter. Particular care shall be taken in the application of the temper bead weld layers at the weld toe area of the ferritic base material to ensure that the HAZ is tempered.

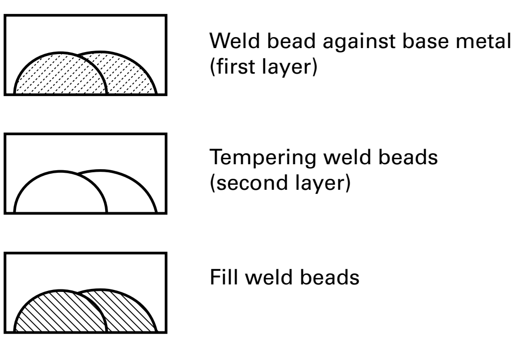
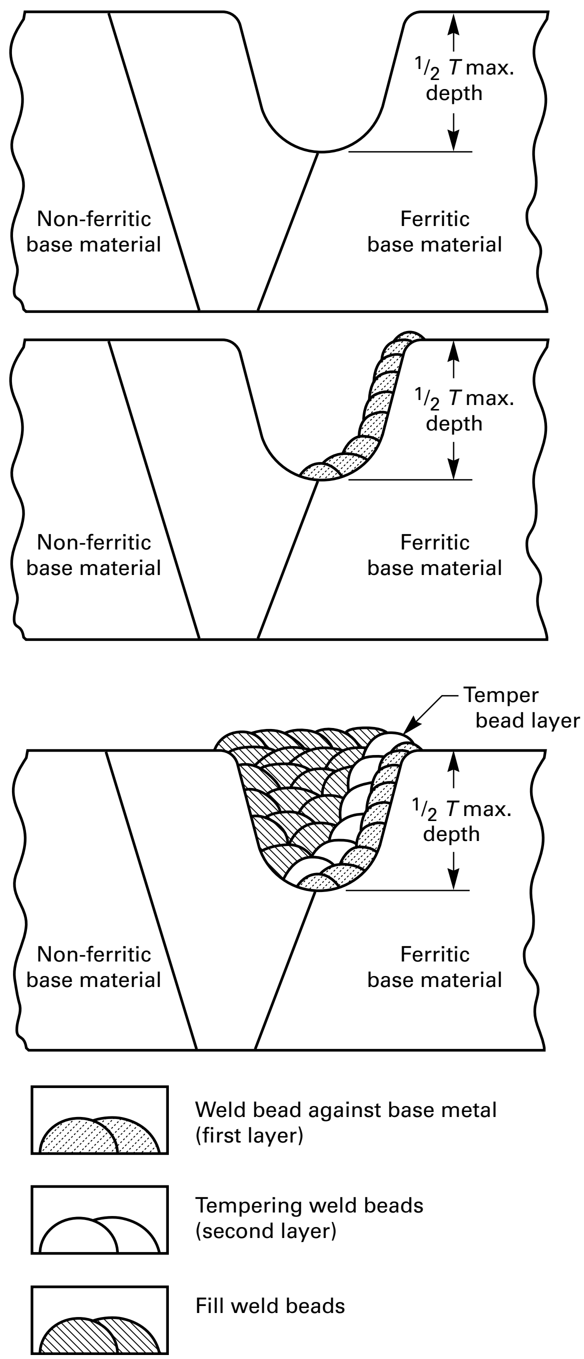


Figure 3
Temper Bead Welding of Dissimilar Materials



Step 1: Prepare cavity and determine axial depth into ferritic base material.

Step 2: Butter ferritic base material with one layer of weld metal using $^3/_{32}$ in. diameter coated electrode. Each weld bead overlaps 50% ± 25% of previous weld bead.

Step 3: The second layer shall be deposited using a $^1/_8$ in. diameter electrode. Each weld bead overlaps 50% ± 25% of the previous weld bead. Subsequent layers shall be deposited using electrodes no larger than $^5/_{32}$ in. diameter. Particular care shall be taken in the application of the temper bead weld layers at the weld toe area of the ferritic base material to ensure that the HAZ is tempered.

(f) In depositing weld metal in the first and second layers each weld bead shall overlap 50% ± 25% of the previous weld bead.

(g) The weld area shall be maintained at a temperature of 450°F to 550°F for at least 2 hr, after completion of the weld in P-No. 1 materials. For P-No. 3 materials, the holding time shall be at least 4 hr.

4 EXAMINATION

(a) Prior to welding, a surface examination shall be performed on the area to be welded.

(b) The weld and the preheated band shall be examined using the magnetic particle or liquid penetrant method for ferritic materials, or the liquid penetrant method for dissimilar materials. The deposited weld metal and HAZ shall be examined using the ultrasonic method. Ultrasonic examination shall be shall be in accordance with Appendix I.[3] Nondestructive Examination (NDE) shall be performed after the completed weld has been at ambient temperature for at least 48 hr.

(c) Areas from which weld-attached thermocouples have been removed shall be ground and shall be examined using a surface examination method.

(d) NDE personnel shall be qualified in accordance with IWA-2300.

(e) Surface examination acceptance criteria shall be in accordance with NB-5340 or NB-5350, as applicable. Ultrasonic examination acceptance criteria shall be in accordance with IWB-3000.

5 DOCUMENTATION

Use of this Case shall be documented on Form NIS-2.

[3] Appendix I in Section XI, 1986 Edition with 1986 Addenda, or later Editions or Addenda.

Approval Date: September 3, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-652-2
Alternative Requirements to Categories B-G-1, B-G-2, and C-D Bolting Examination Methods and Selection Criteria
Section XI, Division 1

Inquiry: What alternative requirements may be used in lieu of the examination methods and selection criteria of Table IWB-2500-1, Examination Categories B-G-1 and B-G-2, and Table IWC-2500-1, Examination Category C-D?

Reply: It is the opinion of the Committee that, as an alternative to the examination methods and selection criteria of, Table IWB-2500-1, Examination Categories B-G-1 and B-G-2, and Table IWC-2500-1, Examination Category C-D, Table 1, 2 and 3, respectively, may be used.

Table 1
Examination Categories

EXAMINATION CATEGORY B-G-1, ALTERNATIVE RULES FOR PRESSURE RETAINING BOLTING, GREATER THAN 2 in. IN DIAMETER

Item No.	Parts Examined [Note (1)]	Examination Requirements/Figure No.	Examination Method [Note (2)]	Acceptance Standard	Extent and Frequency of Examinations: 1st Inspection Interval [Note (3)],[Note (6)]	Extent and Frequency of Examinations: Successive Inspection Intervals	(3)],[Note	Deferral of Examination to End of Interval
	Reactor Vessel							
B6.10	Closure Head Nuts	Surfaces	Visual, VT-1	IWB-3517	All bolts, studs, nuts, bushings, threads in flange stud holes	Same as	interval	Permissible
B6.20	Closure Studs	IWB-2500-12	Volumetric	IWB-3515				
B6.40	Threads in Flange	IWB-2500-12	Volumetric	IWB-3515				
B6.50	Closure Washers, Bushings	Surfaces	Visual, VT-1	IWB-3517				
	Pressurizer							
B6.60	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs, nuts, bushings and flange surfaces	Same as	interval	Permissible
B6.70	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.80	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				
	Steam Generators							
B6.90	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs, nuts, bushings and flange surfaces	Same as	interval	Permissible
B6.100	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.110	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				
	Heat Exchangers							
B6.120	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs,[Note (4)], [Note (5)] nuts, bushings, and flange surfaces	Same as [Note	[Note (4)],	Permissible
B6.130	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.140	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				
	Piping							
B6.150	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs, nuts, bushings and flange surfaces	Same as	interval	Permissible
B6.160	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.170	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				
	Pumps							
B6.180	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs,[Note (4)], [Note (5)] nuts, bushings, and flange surfaces	Same as [Note	[Note (4)],	Permissible
B6.190	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.200	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				

Table 1
Examination Categories (Cont'd)

EXAMINATION CATEGORY B-G-1, ALTERNATIVE RULES FOR PRESSURE RETAINING BOLTING, GREATER THAN 2 in. IN DIAMETER

					Extent and Frequency of Examinations			
Item No.	**Parts Examined [Note (1)]**	**Examination Requirements/Figure No.**	**Examination Method [Note (2)]**	**Acceptance Standard**	**1st Inspection Interval [Note (3)],[Note (6)]**	**Successive Inspection Intervals**	**(3)],[Note**	**Deferral of Examination to End of Interval**
	Valves							
B6.210	Bolts and Studs	IWB-2500-12	Volumetric	IWB-3515	All bolts, studs,[Note (4)], [Note (5)] nuts, bushings, and flange surfaces	Same as [Note	[Note (4)],	Permissible
B6.220	Flange Surface,[Note (7)] when connection disassembled	Surfaces	Visual, VT-1	IWB-3517				
B6.230	Nuts, Bushings, and Washers	Surfaces	Visual, VT-1	IWB-3517				

NOTES:

(1) Bolting may be examined:

(a) in place under tension;

(b) when the connection is disassembled;

(c) when the bolting is removed.

(2) When bolts or studs are removed for examination, surface examination meeting the acceptance standards of IWB-3515 may be substituted for volumet examination.

(3) Bushings and threads in base material of flanges are required to be examined only when the connections are disassembled. Bushings may be inspected place.

(4) Volumetric examination of bolting for heat exchangers, pumps, or valves may be conducted on one heat exchanger, one pump, or one valve among a heat exchangers, pumps, or valves that are similar in design, type, and function. In addition, when the component to be examined contains a group of bolted connections of similar design and size, such as flanged connections, the examination may be conducted on one bolted connection among the group.

(5) Visual examination of bolting for heat exchangers, pumps, or valves is required only when the component is examined under Examination Category B- or B-M-2. Examination of a bolted connection is required only once during the interval.

(6) The examination of flange bolting in piping systems may be limited to one bolted connection among a group of bolted connections that are similar size, function, and service.

(7) Examination includes 1 in. annular surface of flange surrounding each stud.

Table 2
Examination Categories

EXAMINATION CATEGORY B-G-2, ALTERNATIVE RULES FOR PRESSURE RETAINING BOLTING, 2 in. AND LESS IN DIAMETER

					Extent and Frequency of Examinations		
Item No.	**Parts Examined [Note (1)]**	**Examination Requirements/Figure No.**	**Examination Method**	**Acceptance Standard**	**1st Inspection Interval [Note (2)], [Note (3)]**	**Successive Inspection Intervals (2)], [Note**	**Deferral of Examination to End of Interval**
	Reactor Vessel						
B7.10	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Pressurizer						
B7.20	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Steam Generators						
B7.30	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Heat Exchangers						
B7.40	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Piping						
B7.50	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Pumps						
B7.60	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible
	Valves						
B7.70	Bolts, Studs, and Nuts	Surface	Visual, VT-1	IWB-3517	All bolts, studs, and nuts	Same interval	Not permissible

NOTES:
(1) Bolting is required to be examined only when a connection is disassembled or bolting is removed.
(2) For components other than piping, examination of bolting is required only when the component is examined under Examination Category B-A, B-B, or B-M-2. Examination of a bolted connection is required only once during the interval.
(3) The examination of flange bolting in piping systems may be limited to one bolted connection among a group of bolted connections that are similar size, function, and service. Examination is required only when the flange is disassembled. Examination of a bolted connection is required only once during the interval.

Table 3
Examination Categories

EXAMINATION CATEGORY C-D, ALTERNATIVE RULES FOR PRESSURE RETAINING BOLTING GREATER THAN 2 in. IN DIAMETER

Item No.	Parts Examined [Note (1)]	Examination Requirements/ Figure No.	Examination Method [Note (2)]	Acceptance Standard	Extent and Frequency Examinations [Note (1)], (4)]	[Note	Frequency of Examination [Note (5)]
	Pressure Vessels						
C4.10	Bolts and Studs	IWC-2500-6	Volumetric	IWC-3513	100% bolts and studs at each connection of components inspected	to be	Each inspection interval
	Piping						
C4.20	Bolts and Studs	IWC-2500-6	Volumetric	IWC-3513	100% bolts and studs at each connection of components inspected	to be	Each inspection interval
	Pumps						
C4.30	Bolts and Studs	IWC-2500-6	Volumetric	IWC-3513	100% bolts and studs at each connection of components inspected	to be	Each inspection interval
	Valves						
C4.40	Bolts and Studs	IWC-2500-6	Volumetric	IWC-3513	100% bolts and studs at each connection of components inspected	to be	Each inspection interval

NOTES:

(1) The examination may be performed on bolting in place under load or upon disassembly of the connection.

(2) When bolts or studs are removed for examination, surface examination meeting the acceptance standards of IWB-3515 may be substituted for volumet examination.

(3) The examination of bolting for vessels, pumps, or valves may be conducted on one vessel, one pump, or one valve among a group of vessels, pumps, or are similar in design, size, function, and service. In addition, when the component to be examined contains a group of bolted connections of similar design and size such as flange onnections, or manway covers, the examination may be conducted on one bolted connection among the group.

(4) The examination of flange bolting in piping systems may be limited to one bolted connection among a group of bolted connections that are similar size, function, and service.

(5) The areas selected for the initial examination shall be reexamined in the same sequence over the service lifetime of the component, to the extent

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Approval Date: April 4, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-653-1
Qualification Requirements for Full Structural Overlaid Wrought Austenitic Piping Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, Supplement 11 may be used?

Reply: It is the opinion of the Committee that, in lieu of the requirements of Appendix VIII, Supplement 11, the following requirements may be used.

1 SCOPE

This Case provides qualification requirements for detection and length and depth sizing for both service-induced and fabrication-induced flaws. It is applicable for wrought austenitic, ferritic, or dissimilar metal welds, overlaid with austenitic weld material.

2 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, weld joint configuration, and access limitations). The same specimens may be used to demonstrate both detection and sizing qualification.

2.1 General. The specimen set shall conform to the following requirements.

(a) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(b) The specimen set shall consist of at least three specimens having different nominal pipe diameters and overlay thicknesses. They shall include the minimum and maximum nominal pipe diameters for which the examination procedure is applicable. Pipe diameters within a range of 0.9 to 1.5 times the nominal diameter shall be considered equivalent. If the procedure is applicable to pipe diameters of 24 in. (600 mm) or larger, the specimen set must include at least one specimen 24 in. (600 mm) or larger but need not include the maximum diameter. The specimen set must include at least one specimen with overlay not thicker than 0.1 in. (2.5 mm) more than the minimum thickness, and at least one specimen with overlay not thinner than 0.25 in. (6 mm) less than the maximum thickness for which the examination procedure is applicable.

(c) The surface condition of at least two specimens shall approximate the roughest surface condition for which the examination procedure is applicable.

(d) Specimens shall be divided into inservice inspection (ISI) and preservice inspection (PSI) grading units.

(1) ISI Grading Unit. A grading unit designed to include a portion of the original weld and base material and the weld overlay material above it and designed to contain service-induced flaws (cracks).

(2) PSI Grading Unit. A grading unit designed to include a portion of the weld overlay, including the interface between the weld overlay and the original weld and base material, and designed to contain fabrication-induced flaw types (e.g., interbead lack of fusion, laminar lack of bond, cracks).

2.2 Service-Induced Flaws. Service-induced flaws shall be in or near the weld, buttering, or heat-affected zone, and open to the inside surface. The examination procedure shall specify the examination volume. If the examination procedure specifies an examination volume greater than the outer 25% of the base metal wall thickness, the detection and sizing test sets shall include at least five representative flaws suitable to demonstrate the procedure capability in this extended volume. Intentional fabrication-induced flaws shall not interfere with ultrasonic detection or characterization of service-induced flaws. At least 70% of the flaws in the detection and sizing tests shall be cracks. Specimens containing stress corrosion cracking (SCC) shall be used when available. If implantation of actual cracks produces spurious reflectors not characteristic of actual flaws, alternative flaws may be used but shall comprise not more than 30% of the total service-induced flaws. Alternative flaw mechanisms, if used, shall provide crack-like reflective characteristics. The shape of the alternative flaw is intended to simulate the growth pattern of actual flaws and may be semi-elliptical. The tip width of the alternative flaws shall not exceed 0.002 in. (0.05 mm).

2.3 Fabrication-Induced Flaws. At least 40% of the flaws shall be noncrack fabrication flaws (e.g., interbead lack of fusion or laminar lack of bond) in the overlay or the pipe-to-overlay interface. At least 20% of the flaws shall be cracks wholly contained in the overlay.

2.4 Detections Specimens.

(a) At least 20% but less than 40% of the service-induced flaws shall be oriented within 20 deg of the pipe axial direction. The remainder shall be oriented circumferentially. Flaws shall not be open to any surface to which the candidate has physical or visual access.

(b) ISI grading units include the overlay material and the examination volume specified in the examination procedure. ISI grading units shall extend circumferentially for at least 1 in. (25 mm) and shall start at the weld centerline and shall be wide enough in the axial direction to encompass one-half of the original weld crown and at least $^1/_2$ in. (13 mm) of the adjacent base material. The grading units shall be of various sizes. For an axially-oriented discontinuity, the axial dimension of the ISI grading unit may encompass the original weld crown and at least $^1/_2$ in. (13 mm) of both adjacent base materials.

(1) If service-induced flaws penetrate into the overlay material, the ISI grading unit shall not be used as part of any PSI grading unit.

(2) Sufficient unflawed area shall exist on all sides of the grading unit to preclude interfering reflections from adjacent flaws.

(c) PSI grading units shall include the overlay material and the overlay-to-component interface for a length of at least 1 in. (25 mm).

(d) PSI grading units designed to be unflawed shall be separated by unflawed overlay material and unflawed overlay-to-component interface for at least 1 in. (25 mm) at both ends. Sufficient unflawed overlaid weld and base metal shall exist on both sides of the PSI grading unit to preclude interfering reflections from adjacent flaws. The specific area used in one PSI grading unit shall not be used in another PSI grading unit. PSI grading units need not be spaced uniformly about the specimen.

(e) Detection sets shall be selected from Table VIII-S2-1. The detection sample sets shall contain at least ten flawed ISI grading units and five flawed PSI grading units. Additionally, for each type of grading unit, the sets shall contain at least twice as many unflawed as flawed grading units.

2.5 Sizing Specimens.

(a) Sizing sample sets shall contain at least ten flaws. At least 30% of the flaws shall be fabrication-induced flaws. At least 40% of the flaws shall be service-induced flaws and shall be open to the inside surface. Sizing sets shall contain a representative distribution of flaw dimensions that cover the examination volume specified in the examination procedure.

(b) At least 20% but less than 40% of the flaws shall be oriented axially. The remainder shall be oriented circumferentially. Flaws shall not be open to any surface to which the candidate has physical or visual access.

(c) Service-induced flaws used for length sizing demonstrations shall be oriented circumferentially.

(d) Depth sizing specimen sets shall include at least two distinct locations where a service-induced flaw extends into the overlay material by at least 0.1 in. (2.5 mm) in the through-wall direction.

3 PERFORMANCE DEMONSTRATION

The specimen inside surface and identification shall be concealed from the candidate. All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited. The PSI test and the ISI test may be performed separately. The criteria in 3.1, 3.2, and 3.3 shall be satisfied separately by the demonstration results for ISI grading units and by those for PSI grading units.

3.1 Detection Test.

(a) Flawed and unflawed grading units shall be randomly mixed. Although the boundaries of specific grading units shall not be revealed to the candidate, the candidate shall be made aware of the types of grading units (ISI or PSI) in each specimen.

(b) Examination equipment and personnel shall be considered qualified for detection if the results of the performance demonstration satisfy the acceptance criteria of Table VIII-S2-1 for both detection and false calls.

(c) If the procedure is intended to be used to examine greater than the upper 25% of the original pipe volume, a candidate for personnel qualification shall not fail to detect more than one of the flaws located in the extended volume.

3.2 Length Sizing Test.

(a) The length sizing test may be conducted separately or in conjunction with the detection test.

(b) If the length sizing test is conducted in conjunction with the detection test, and the detected flaws do not satisfy the requirements of 2.5, additional specimens shall be provided to the candidate. The regions of the additional specimens containing flaws to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(c) For a separate length sizing test, the regions of each specimen containing flaws to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(d) For flaws in ISI grading units, the candidate shall estimate the length of that part of the flaw that is in the examination volume specified in the examination procedure.

(e) Examination procedures, equipment, and personnel are qualified for length sizing if the RMS error of the circumferential flaw length measurements, as compared to the true circumferential flaw lengths, is not more than 0.75 in. (19 mm). The length of a service-induced flaw is measured in accordance with (d).

(f) Examination procedures, equipment, and personnel qualified for length sizing in accordance with (a) through (e) are considered qualified for both length and width sizing of laminar flaws.

3.3 Depth Sizing Test.

(a) Depth sizing consists of measuring the metal thickness above the flaw (i.e., remaining ligament) and may be conducted separately or in conjunction with the detection test.

(b) If the depth sizing test is conducted in conjunction with the detection test, and the detected flaws do not satisfy the requirements of 2.5, additional specimens shall be provided to the candidate. The regions of the additional specimens containing flaws to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

(c) For a separate depth sizing test, the regions of each specimen containing flaws to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

(d) Examination procedures, equipment, and personnel are qualified for depth sizing if the RMS error of the flaw depth measurements, as compared to the true flaw depths, is not more than 0.125 in. (3.2 mm).

4 PROCEDURE QUALIFICATION

In addition to the requirements of 2 and 3, procedure qualification shall satisfy the following:

(a) The specimen set shall include the equivalent of at least three personnel performance demonstration test sets. Successful personnel performance demonstrations may be combined to satisfy these requirements.

(b) Detectability of all flaws in the procedure qualification test set within the scope of the procedure shall be demonstrated. Length and depth sizing shall meet the requirements of 3.2 and 3.3.

(c) At least one successful personnel demonstration shall be performed.

(d) To qualify new values of essential variables, the test set shall include the equivalent of one personnel test set. The acceptance criteria of (b) shall be met.

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Approval Date: April 17, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-654
Acceptance Criteria for Flaws in Ferritic Steel Components 4 in. and Greater in Thickness
Section XI, Division 1

Inquiry: What alternative to the acceptance criteria of IWB-3611 or IWB-3612 may be used?

Reply: It is the opinion of the Committee that as an alternative to the acceptance criteria of IWB-3611 or IWB-3612, the following acceptance criteria may be used.

1 NOMENCLATURE

The following nomenclature is used in this Case.

a_f = end-of-evaluation-period flaw depth for surface flaw, in.
$2a_f$ = end-of-evaluation-period flaw depth for subsurface flaw, in.
ℓ_f = end-of-evaluation-period flaw length, in.
PSF_a = partial safety factor on flaw depth and length
PSF_s = partial safety factor on applied stress
PSF_k = partial safety factor on reference static initiation fracture toughness
PSF_R = partial safety factor on residual stress
σ = applied stress at the flaw location due to pressure, thermal, and mechanical loads, ksi
σ_R = residual stress at the flaw location due to fabrication and cladding effects, ksi
K_{Ic} = reference static initiation fracture toughness,ksi $\sqrt{\text{in.}}$
K_{Ia} = reference dynamic and arrest fracture toughness, ksi $\sqrt{\text{in.}}$

2 APPLICATION OF PARTIAL SAFETY FACTORS

A flaw shall be shown to be acceptable based on crack initiation using the partial safety factors on stress (PSF_s), flaw size (PSF_a), and material fracture toughness (PSF_k), given in Table 2.1 and Table 2.2.

Table 2.1
Partial Safety Factors for Measured Flaw Depths of at Least 0.2 in.

Service Level	PSF_s	PSF_k	PSF_a
A & B	2.60	1.07	1.25
C & D	1.40	1.00	1.15

Table 2.2
Partial Safety Factors for Measured Flaw Depths Less Than 0.2 in.

Service Level	PSF_s	PSF_k	PSF_a
A & B	2.13	1.18	1.43
C & D	1.40	1.00	1.20

2.1 The partial safety factors in Table 2.1 and Table 2.2 shall be used on the applied stresses as eq. (1).

$$\sigma' = \sigma PSF_s \tag{1}$$

where

σ' = the stress after application of PSF_s

The applied stress shall include all forms of loading, including pressure, thermal, and mechanical loads. For residual stress, σ_R, the partial safety factors are applied in eq. (2).

$$\sigma' = \sigma_R PSF_R \tag{2}$$

2.2 The value of PSF_R shall equal PSF_s. The fracture toughness determine in accordance with A-4200(b) shall be modified as follows in eqs. (3) and (4):

$$K_{Ia}' = K_{Ia}/PSF_k \tag{3}$$

$$K_{Ic}' = K_{Ic}/PSF_k \tag{4}$$

2.3 The end-of-evaluation-period flaw dimensions shall be modified as follows in (5), (6), and (7).

$$a' = a_f\ PSF_a \quad \text{(for a surface flaw)} \tag{5}$$

$$2a' = 2a_f\ PSF_a \quad \text{(for a subsurface flaw)} \tag{6}$$

$$\ell' = \ell_f\ PSF_a \tag{7}$$

3 ACCEPTANCE CRITERIA

Flaw acceptance shall be demonstrated by satisfying the following criteria in eqs. (8) and (9).

$$K'_I \leq K_{Ia}' \text{ for Levels A and B} \tag{8}$$

$$K'_I \leq K_{Ic}' \text{for Levels C and D} \tag{9}$$

where

$K_I{}'$ = the stress intensity factor calculated in accordance with A-3000 using the stresses σ' and $\sigma_R{}'$, and flaw dimensions a' (or $2a'$), and ℓ'

Approval Date: September 27, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-655-2
Use of SA-738, Grade B, for Metal Containment Vessels, Class MC
Section III, Division 1

Inquiry: May steel plate conforming to SA-738, Grade B, be used for the construction of metal containment conforming to the rules of Section III, Subsection NE?

Reply: It is the opinion of the Committee that SA-738, Grade B, may be used for the construction of metal containments conforming to the rules of Section III, Subsection NE, provided the following requirements are met:

(a) The maximum temperature shall not exceed 650°F (343°C).

(b) The allowable stress S, and the allowable stress intensity S_{mc} shall be 1.1 times the S values given for SA-738, Grade B in Section II, Part D, Subpart 1, Table 1A. The yield stress values S_y shall be given in Section II, Part D, Subpart 1, Table Y-1. For external pressure design, use the chart referenced for SA-738, Grade B, in Table 1A of Section II, Part D, Subpart 1.

(c) Exception to postweld heat treatment is permitted up through a nominal thickness of 1.75 in. (44 mm) under the conditions given in Table NE-4622.7(b)-1 including Note (3).

(d) SA-20/SA-20M Supplementary Requirement S1, "Vacuum Treatment" shall be mandatory for this material.

(e) SA-20/SA-20M Supplementary Requirement S20, "Maximum Carbon Equivalent for Weldability" shall be mandatory for this material.

(f) The exception from heat treatment of material test coupons below 2 in. (50 mm) given in NE-2211 shall not apply to this material.

(g) The Case number shall be shown on the Certificate Holder's Data Report.

(h) The allowable stress intensity S_{m1} shall be the values listed in Tables 1 and 1M.

Table 1
Design Stress Intensity Values for SA-738 Grade B

Temperature (°F)	S_{m1} (ksi)
−20 to 100	28.3
150	28.3
200	28.3
250	28.3
300	28.3
400	28.3
500	28.3
600	28.1
650	27.7

Table 1M
Design Stress Intensity Values for SA-738 Grade B

Temperature (°C)	S_{m1} (MPa)
−30 to 40	195
100	195
125	195
150	195
175	195
200	195
225	195
250	195
275	195
300	195
325	193
350	190

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Case N-657
Use of the N-1A Data Report Form for Spent Fuel Canisters
Section III, Division 1

ANNULLED

Annulment Date: February 9, 2015

Reason: No longer needed.

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Approval Date: April 4, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-658
Qualification Requirements for Ultrasonic Examination of Wrought Austenitic Piping Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, Supplement 2 may be used?

Reply: It is the opinion of the Committee that, in lieu of the requirements of Appendix VIII, Supplement 2, the following requirements may be used.

1 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, access limitations). The same specimens may be used to demonstrate both detection and sizing qualification.

1.1 General. This Case is applicable to austenitic piping welds examined from either the inside (I.D.) or outside (O.D.) surface. The applicable qualification criteria shall be satisfied separately. This Case is not applicable to piping welds containing supplemental corrosion resistant cladding applied to mitigate IGSCC. The specimen set shall conform to the following requirements.

(a) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(b) The specimen set shall consist of at least four specimens having different nominal pipe diameters and thicknesses. The set shall include pipe specimens not thicker than 0.1 in., more than the minimum thickness, nor thinner than 0.5 in., less than the maximum thickness for which the examination procedure is applicable. It shall include the minimum within NPS $^1/_2$ in., and maximum pipe diameters for which the examination procedure is applicable. If the procedure is applicable to pipe O.D. of 24 in., or larger, the specimen set must include at least one specimen 24 in., O.D. or larger but need not include the maximum diameter.

(c) Taking into consideration the accessible scanning surface, the O.D. or I.D. specimen set shall include applicable examples of the following fabrication conditions:

(1) unground weld reinforcement (crowns);

(2) wide crowns, such that the total crown width is $1^1/_2$ to 2 times the nominal pipe wall thickness;

(3) geometric conditions that normally require discrimination from flaws (e.g., counterbore, weld root conditions such as excessive I.D. reinforcement for O.D. scans, or O.D. reinforcement for I.D. scans, as applicable);

(4) typical limited scanning surface conditions (e.g., diametrical shrink, single-side access due to safe ends or fittings, clad surfaces, or counterbore within the scanning area, as applicable).

(d) All flaws in the specimen set shall be cracks.

(1) Mechanical fatigue cracks and either IGSCC or thermal fatigue cracks shall be used. At least 75% of the cracks shall be either IGSCC or thermal fatigue cracks.

(2) At least 50% of the cracks shall be coincident with fabricated conditions described in (c).

1.2 Detection Specimens. The specimen set shall include detection specimens that meet the following requirements.

(a) Specimens shall be divided into grading units. Each grading unit shall include at least 3 in. of weld length. If a grading unit is designed to be unflawed, at least 1 in. of unflawed material shall exist on either side of the grading unit. The segment of weld length used in one grading unit shall not be used in another grading unit. Grading units need not be uniformly spaced around the pipe specimen.

(b) Detection sets for personnel qualification shall be selected from Table VIII-S2-1. The number of unflawed grading units shall be at least twice the number of flawed grading units. For initial procedure qualification, detection sets shall include the equivalent of three personnel qualification sets. To qualify new values of essential variables, at least one personnel qualification set is required.

(c) Flawed grading units shall meet the following criteria for flaw depth, orientation, and type.

(1) A minimum of $^1/_3$ of the flaws, rounded to the next higher whole number, shall have depths between 5% and 30% of the nominal pipe wall thickness. At least $^1/_3$ of the

flaws, rounded to the next higher whole number, shall have depths greater than 30% of the nominal pipe wall thickness.

(2) At least one and a maximum of 10% of the flaws, rounded to the next higher whole number, shall be oriented axially. The remainder of the flaws shall be oriented circumferentially.

(3) Service-induced flaws shall be included when available. When the procedure is intended to detect IGSCC, at least four field-removed IGSCC-flawed grading units shall be included in the detection test set.

1.3 Sizing Specimens. The specimen set shall contain sizing specimens that meet the following requirements.

(a) The minimum number of flaws shall be 10. For initial procedure qualification, sizing sets shall include the equivalent of three personnel qualification sets. To qualify new values of essential variables, at least one personnel qualification set is required.

(b) Flaws in length sizing sample sets shall meet the requirements of 1.2(c)(1), when given in conjunction with a detection test. When the length sizing test is administered independently, the flaw depth requirements do not apply.

(c) Flaws in the depth sizing sample set shall be distributed as follows:

Flaw Depth (% Wall Thickness)	Minimum Percentage of Flaws
5–30%	20%
31–60%	20%
61–100%	20%

The remaining flaws shall be in any of the above categories.

2 CONDUCT OF PERFORMANCE DEMONSTRATIONS

When scanning from the O.D., the specimen inside surface and identification shall be concealed from the candidate. When scanning from the I.D., flaw location and specimen identification shall be obscured to maintain a "blind test." All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.

2.1 Detection Test. Flawed and unflawed grading units shall be randomly mixed.

2.2 Length and Depth Sizing Test.

(a) Each reported flaw in the detection test shall be length sized. When only length sizing is being tested, the regions of each specimen containing a flaw to be sized may be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(b) The depth sizing test may be performed in conjunction with or separate from the detection test. When only depth sizing is being tested, the regions of each specimen containing a flaw to be sized may be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region.

3 ACCEPTANCE CRITERIA

3.1 Detection Acceptance Criteria.

(a) Personnel demonstration shall meet the requirements of Table VIII-S2-1 for both detection and false calls. If the procedure is intended to detect IGSCC, failure to detect more than one of the IGSCC flaws is unacceptable for personnel qualification.

(b) Procedure qualification shall demonstrate detectability of each flaw within the scope of the procedure. Successful personnel demonstrations may be combined to satisfy the requirements for procedure qualification.

3.2 Sizing Acceptance Criteria. Examination procedures, equipment, and personnel are qualified for sizing if the results of the performance demonstration satisfy the following criteria:

(a) The RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths, shall not exceed 0.75 in.;

(b) The RMS error of the flaw depths estimated by ultrasonics, as compared with the true depths, shall not exceed 0.125 in.

Approval Date: June 9, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-659-2
Use of Ultrasonic Examination in Lieu of Radiography for Weld Examination
Section III, Division 1; Section III, Division 3

Inquiry: Under what conditions and limitations may an ultrasonic examination be used in lieu of radiography where radiography is required by NB-5200, NC-5200, ND-5200, WB-5200 or WC-5200, and substitution of ultrasonic examination would not otherwise be permitted?

Reply: It is the opinion of the Committee that all welds may be examined using the ultrasonic (UT) method in lieu of the radiographic (RT) method, provided that all of the following requirements are met:

(a) The ultrasonic examination area shall include 100% of the volume of the entire weld, plus $^1/_2$ in. (13 mm) of each side of the welds. The ultrasonic examination area shall be accessible and scanned by angle beam examination in four directions, two directions perpendicular to the weld axis and two directions parallel to the weld axis. Where perpendicular scanning is limited on one side of the weld, a technique using the second leg of the V-path may be credited as access for the second perpendicular examination direction provided that the detection capability of that technique is included in the procedure demonstration described in (c) and (d).

(b) In accordance with (a) above the ultrasonic examination shall be performed in accordance with Section V, Article 5 up to and including the 2001 Edition or Article 4 for later Edition and Addenda. A straight beam and two angle beams having nominal angles of 45 and 60 deg should generally be used; however, other pairs of angle beams may be used provided the measured difference between the angles is at least 10 deg. Alternatively, ultrasonic examination that includes a straight beam may be performed by a procedure qualified in accordance with the performance demonstration methodology of Section XI, Appendix VIII provided the entire volume of the weld examination is included in the demonstration.

(c) A written procedure shall be followed. The procedure shall be demonstrated to perform acceptably on a qualification block or specimen with both surface and subsurface flaws as described in (d).

(d) The qualification block material shall conform to the requirements applicable to the calibration block. The material from which blocks are fabricated shall be one of the following: a nozzle dropout from the component; a component prolongation; or material of the same material specification, product form, and heat treatment condition as one of the materials joined. For piping, if material of the same product form and specification is not available, material of similar chemical analysis, tensile properties, and metallurgical structure may be used. Where two or more base material thicknesses are involved, the calibration block thickness shall be of a size sufficient to contain the entire examination path. The qualification block configuration shall contain a weld representative of the joint to be examined, including thickness and for austenitic materials, the same welding process. The qualification blocks shall include at least two planar flaws in the weld, one surface and one subsurface oriented parallel to the fusion line, no larger in the through-wall direction than the diameter of the applicable side-drilled hole in the calibration block shown in Fig. T-542.2.1 of Section V, Article 5, for Editions and Addenda through the 2001 Edition and T-434.2.1 of Article 4 for later Editions and Addenda and no longer than the shortest unacceptable elongated discontinuity length listed in NB-5330, NC-5330, ND-5330, WB-5330 or WC-5330 for the thickness of the weld being examined. Where a Section XI, Appendix VIII, performance demonstration methodology is used, supplemental qualification to a previously approved procedure may be demonstrated through the use of a blind test with appropriate specimens that contain a minimum of three different construction-type and fabrication-type flaws distributed throughout the thickness of the specimen.

(e) This Case shall not be applied to weld examination volumes that include cast products forms or corrosion-resistant-clad austenitic piping butt welds.

(f) A documented examination plan shall be provided showing the transducer placement, movement and component coverage that provides a standardized and repeatable methodology for weld acceptance. The examination plan shall also include ultrasonic beam angle used, beam directions with respect to weld centerline, and volume examined for each weld.

(g) The evaluation and acceptance criteria shall be in accordance with NB-5330, NC-5330, ND-5330, WB-5330 or WC-5330, as acceptable. Any flaws characterized as surface-connected cracks, lack of fusion, or lack of penetration may be evaluated by a supplemental surface examination (MT or PT) performed in accordance with NB-5000, NC-5000, ND-5000, WB-5000 or WC-5000, as applicable.

(h) For welds subject to inservice ultrasonic examination, the examination and evaluation shall also meet the requirements of the applicable Edition of Section XI for preservice examination.

(i) The ultrasonic examination shall be performed using a device with an automated computer data acquisition system.

(j) Data shall be recorded in unprocessed form. A complete data set with no gating, filtering, or thresholding for response from examination volume in (a) shall be included in the data record.

(k) Personnel who acquire and analyze UT data shall be qualified and trained using the same type of equipment as in (i), and demonstrate their capability to detect and characterize the flaws using the procedure as described in (c).

(l) Review and acceptance of the procedure by the Authorized Nuclear Inspector is required.

(m) All other related requirements of the applicable subsection shall be met.

(n) Flaws exceeding the acceptance criteria referenced in this Case shall be repaired, and the weld subsequently reexamined using the same ultrasonic examination procedure that detected the flaw.

(o) This Case number shall be recorded on the Data Report.

Approval Date: July 23, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-660
Risk-Informed Safety Classification for Use in Risk-Informed Repair/Replacement Activities
Section XI, Division 1

Inquiry: What additional classification criteria may be used as a supplement to the group classification criteria of IWA-1320 to determine Risk-Informed Safety Classification (RISC) for use in risk-informed repair/replacement activities?

Reply: It is the opinion of the Committee that as a supplement to the group classification criteria of IWA-1320, the following requirements may be used to determine the Risk-Informed Safety Classification (RISC) for risk-informed repair/replacement activities.

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

This Case provides a process for determining the Risk-Informed Safety Classification (RISC) for use in risk-informed repair/replacement activities. The RISC process of this Case may be applied to any of Classes 1, 2, and 3, or non-class[1] pressure-retaining items or their associated supports, except core supports, in accordance with the risk-informed safety classification criteria established by the regulatory authority having jurisdiction at the plant site.

-1200 CLASSIFICATIONS

(a) The RISC process is described in Mandatory Appendix I of this Case. Pressure retaining and component support items shall be classified High Safety Significant (HSS) or Low Safety Significant (LSS). However, because this classification is to be used only for repair/replacement activities, failure potential is conservatively assumed to be 1.0 in determining a consequence category in Mandatory Appendix I. These classifications might not be directly related to other risk-informed applications.

(b) Class 1 items that are part of the reactor coolant pressure boundary except as provided in (c)(2)(i) and (c)(2)(ii) of Title 10 of the U.S. Code of Federal Regulations (10 CFR), Part 50.55a shall be classified High Safety Significant (HSS). For items that are connected to the reactor coolant pressure boundary, as defined in 10 CFR 50.55a (c)(2)(i) and (c)(2)(ii), the RISC process of (a) should be applied.

-1300 OWNER'S RESPONSIBILITY

-1310 Determination of Classification

The responsibilities of the Owner shall include determination of the appropriate classification for the items identified for each risk-informed repair/replacement activity, in accordance with Mandatory Appendix I of this Case. The Owner shall ensure that core damage frequency (CDF) and large early release frequency (LERF) are included as risk metrics in the RISC process.

-1320 Required Disciplines

Personnel with expertise in the following disciplines shall be included in the classification process.

(a) probabilistic risk assessment (PRA)

(b) plant operations

(c) system design

(d) safety or accident analysis

Personnel may be experts in more than one discipline, but are not required to be experts in all disciplines.

-1330 Adequacy of the Pra

The Owner is responsible for demonstrating adequacy of any PRA used as the basis for this process. All deficiencies identified shall be reconciled during the analysis to support the RISC process. The resolution of all PRA issues shall be documented.

[1] Non-class items are items not classified in accordance with IWA-1320.

-9000 GLOSSARY

conditional consequence: an estimate of an undesired consequence, such as core damage or a breach of containment, assuming failure of an item, e.g., conditional core damage probability (CCDP).

core damage: uncovering and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage is anticipated and involving enough of the core to cause a significant release.

failure: an event involving leakage, rupture, or a condition that would disable the ability of an item to perform its intended safety function.

failure modes and effects analysis (FMEA): a process for identifying failure modes of specific items and evaluating their effects on other components, subsystems, and systems.

high-safety-significant function: a function that has been determined to be safety significant from traditional plant risk-assessment evaluations of core damage or large early release events (e.g., evaluations performed to support the Maintenance Rule 10 CFR 50.65).

initiating event (IE): any event either internal or external to the plant that perturbs the steady state operation of the plant, if operating, thereby initiating an abnormal event, such as a transient or Loss of Coolant Accident (LOCA) within the plant. Initiating events trigger sequences of events that challenge plant control and safety systems whose failure could potentially lead to core damage or large early release.

large early release: the rapid unmitigated release of airborne fission products from the containment to the environment occuring before the effective implementation of off-site emergency response and protective actions.

piping segment: a portion of piping component, or a combination thereof, and their supports, in which a failure at any location results in the same consequence (e.g., loss of the system, loss of a pump train).

probabilistic risk assessment (PRA): a qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public (also referred to as a probabilistic safety assessment, PSA).

recovery action: a human action performed to regain equipment or system operability from a specific failure or human error in order to mitigate or reduce the consequences of the failure.

risk metrics: a determination of what activity or conditions produce the risk, and what individual, group, or property is affected by the risk.

spatial effects: a failure consequence affecting other systems or components, such as failures due to pipe whip, jet impingement, or flooding.

success criteria: criteria for establishing the minimum number or combination of systems or components required to operate, or minimum levels of performance per component during a specific period of time (mission time), to ensure that the safety functions are satisfied.

MANDATORY APPENDIX I
RISK-INFORMED SAFETY CLASSIFICATION (RISC) PROCESS

I-1 INTRODUCTION

This Appendix provides the risk-informed process used to determine Risk-Informed Safety Classification (RISC) for use in risk-informed repair/replacement activities. This RISC process is based on conditional consequence of failure. The process provides a conservative assesment of the importance of an item. This process divides each selected system into piping segments that are determined to have similar consequence of failure. These piping segments are categorized based on the conditional consequence. Once categorized, the safety significance of each piping segment is identified.

I-2 SCOPE IDENTIFICATION

The Owner shall define the boundaries included in the scope of the RISC evaluation process.

I-3 CONSEQUENCE ASSESSMENT

Piping segments can be grouped based on common conditional consequence (i.e., given failure of the piping segment). To accomplish this grouping, the direct effects, and indirect effects shall be assessed for each piping segment. Additionally, information shall be collected for each piping segment that is not modeled in the PRA, but considered relevant to the classification (e.g., information regarding design basis accidents, shutdown risk, containment isolation, flooding, fires, seismic conditions).

I-3.1 CONSEQUENCE EVALUATION

I-3.1.1 Failure Modes and Effects Analysis (FMEA). Potential failure modes for each piping segment shall be identified, and their effects shall be evaluated. This evaluation shall consider the following:

(a) Pressure Boundary Failure Size. The consequence analysis shall be performed assuming a large pressure boundary failure for piping segments. Alternatively, the consequence analysis can be performed assuming a smaller leak, when;

(1) a smaller leak is more conservative; or

(2) when a small leak can be justified through a leak-before-break analysis in accordance with the criteria specified in NUREG-1061, Volume 3; 10CFR50, Appendix A, General Design Criterion 4; or

(3) it can be documented that plant configuration precludes the possibility of a large pressure boundary failure.

(b) Isolability of the Break. A break can be automatically isolated by a check valve, a closed isolation valve, or an isolation valve that closes on a given signal or by operator action.

(c) Indirect Effects. These include spatial interactions such as pipe whip, jet spray, and loss-of-inventory effects (e.g., draining of a tank).

(d) Initiating Events. These are identified using a list of initiating events from any existing plant-specific Probabilistic Risk Assessment (PRA) or Individual Plant Examination (IPE) and the Owner's Requirements.

(e) System Impact or Recovery. The means of detecting a failure, and the Technical Specifications associated with the system and other affected systems. Possible automatic and operator actions to prevent a loss of systems function.

(f) System Redundancy. The existence of redundancy for accident mitigation purposes.

I-3.1.2 Impact Group Assessment. The results of the FMEA evaluation for each piping system, or a portion thereof, shall be classified into one of three impact groups: initiating event, system, or combination. Each piping system, or a portion thereof, shall be partitioned into postulated piping failures that cause an initiating event, disable a system without causing an initiating event, or cause an initiating event and disable a system. The consequence category assignment (high, medium, and low) for each piping segment within each impact group shall be selected in accordance with (a) through (d) below.

(a) Initiating Events (IE) Impact Group Assessment. When the postulated failure results in only an initiating event (e.g., loss of feedwater, reactor trip), the consequence shall be classified into one of four categories: high, medium, low, or none. The initiating event categories shall be assigned according to the following:

(1) The initiating event shall be placed in one of the categories in Table I-1. All applicable design basis events previously analyzed in the Owner's updated final safety analysis report, PRA, or IPE shall be included.

(2) Breaks that cause an initiating event classified as Category I (routine operation) need not be considered in this analysis.

(3) For piping segment breaks that result in Category II (Anticipated Event), Category III (Infrequent Event), or Category IV (Limiting Fault or Accident), the consequence category shall be assigned to the initiating event according to the conditional core damage probability (CCDP) criteria specified in Table I-5. The quantitative index for the

Table I-1
Consequence Categories for Initiating Event Impact Group

Design Basis Event Category	Initiating Event Type	Representative Initiating Event Frequency Range (1/yr)	Example Initiating Events	Consequence Category [Note (1)]
I	Routine Operation	>1		N/A
II	Anticipated Event	$\geq 10^{-1}$	Reactor Trip, Turbine Trip, Partial Loss of Feedwater	Low/Medium
III	Infrequent Event	10^{-1} to 10^{-2}	Excessive Feedwater or Steam Removal	Low/Medium
			Loss of Off-Site Power	Medium/High
IV	Limiting Fault or Accident	$<10^{-2}$	Small LOCA, Steam Line Break, Feedwater Line Break, Large LOCA	Medium/High

NOTE:
(1) Refer to I-3.1.2(a)(3).

initiating event impact group (CCDP) is the ratio of the core damage frequency due to the initiating event to the initiating event frequency.

(b) System Impact Group Assessment. The consequence category of a failure that does not cause an initiating event, but degrades or fails a system essential to prevention to core damage, shall be based on the following:

(1) Frequency of challenge, which determines how often the mitigating function of the system is called upon. This corresponds to the frequency of initiating events that require the system operation.

(2) Number of backup systems (portions of systems, trains, or portion of trains) available, which determines how many unaffected systems (portions of systems, trains, or portions of trains) are available to perform the same mitigating function as the degraded or failed systems.

(3) Exposure time, which determines the time the system would be unavailable before the plant is changed to a different mode in which the failed system's function is no longer required, the failure is recovered, or other compensatory action is taken. Exposure time is a function of the detection time and Allowed Outage Time, as defined in the plant Technical Specification. Consequence categories shall be assigned in accordance with Table I-2 as High, Medium, or Low. Frequency of challenge is grouped into design basis event categories (II, III, and IV). Exposure time shall be obtained from Technical Specification limits. The Owner or his designee shall ensure that the quantitative basis of Table I-2 (e.g., one full train unavailability approximately 10^{-2}) is consistent with the failure scenario being evaluated. In lieu of Table I-2, quantitative indices may be used to assign consequence categories in accordance with Table I-5. The quantitative index for the system impact group is the product of the change in conditional core damage frequencey (CDF) and the exposure time.

(c) Combination Impact Group Assessment. The consequence category for a piping segment whose failure results in both an initiating event and the degradation or loss of a system shall be determined using Table I-3. The Owner or his designee shall ensure that the quantitative basis of Table I-3 (e.g., one full train unavailability approximately 10^{-2}) is consistent with the pipe failure scenario being evaluated. The consequence category is a function of two factors:

(1) Use of the system to mitigate the induced initiating event;

(2) Number of unaffected backup systems or trains available to perform the same function.

In lieu of Table I-3 quantitative indices may be used to assign consequence categories in accordance with Table I-5.

(d) Containment Performance. The above evaluations determine failure importance relative to core damage. Failure shall also be evaluated for its effect on containment performance. This shall be accomplished by addressing two issues, both of which are based on an approximate conditional probability value of not greater than 0.1 between the CCDP and the likelihood of large early release from containment. If there is no margin i.e., conditional probability of a large early release due to core damage is greater than 0.1, the assigned consequence category shall be increased by one level. The two issues are described as follows:

(1) CCDP values for initiating events and safety functions are evaluated to determine if the potential for large early release due to containment failure requires the consequence category to be increased.

Table I-2
Guidelines for Assigning Consequence Categories to Failures Resulting in System or Train

Affected Systems		Number of Unaffected Backup Trains							
Frequency of Challenge	Exposure Time to Challenge	0.0	0.5	1.0	1.5	2.0	2.5	3.0	≥ 3.5
Anticipated (DB Cat. II)	All year	HIGH	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	LOW*	LOW
	Between test (1–3 months)	HIGH	HIGH	HIGH	MEDIUM*	MEDIUM	LOW*	LOW	LOW
	Long AOT (≤ 1 week)	HIGH	HIGH	MEDIUM*	MEDIUM	LOW*	LOW	LOW	LOW
	Short AOT (≤ 1 day)	HIGH	MEDIUM*	MEDIUM	LOW*	LOW	LOW	LOW	LOW
Infrequent (DB Cat. III)	All year	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	LOW*	LOW	LOW
	Between test (1–3 months)	HIGH	HIGH	MEDIUM*	MEDIUM	LOW*	LOW	LOW	LOW
	Long AOT (≤ 1 week)	HIGH	MEDIUM*	MEDIUM	LOW*	LOW	LOW	LOW	LOW
	Short AOT (≤ 1 day)	HIGH	MEDIUM	LOW*	LOW	LOW	LOW	LOW	LOW
Unexpected (DB Cat. IV)	All year	HIGH	HIGH	MEDIUM	MEDIUM	LOW*	LOW	LOW	LOW
	Between test (1–3 months)	HIGH	MEDIUM	MEDIUM	LOW*	LOW	LOW	LOW	LOW
	Long AOT (≤ 1 week)	HIGH	MEDIUM	LOW*	LOW	LOW	LOW	LOW	LOW
	Short AOT (≤ 1 day)	HIGH	LOW*	LOW	LOW	LOW	LOW	LOW	LOW

GENERAL NOTE: If there is no containment barrier and the consequence category is marked by an *, the consequence category should be increased (medium) to high or low to medium.

Table I-3
Consequence Categories for Combination Impact Group

Event	Consequence Category
Initiating Event and 1 Unaffected Train of Mitigating System Available	High
Initiating Event and 2 Medium Unaffected Trains of Mitigating Systems Available	Medium [Note (1)] (or IE Consequence Category from Table I-1)
Initiating Event and More Than 2 Unaffected Trains of Mitigating Systems Available	Low [Note (1)] (or IE Consequence Category from Table I-1)
Initiating Event and No Mitigating System Affected	N/A

NOTE:
(1) The higher classification of this table or Table I-1 shall be used.

(2) The effect on containment isolation is evaluated. If there is a containment barrier available, the consequence category from the core damage assessment is retained. If there is no containment barrier or the barrier failed in determining the consequence category from the core damage assessment, some margin in the core damage consequence category assignment must be present for it to be retained. For example, if the CCDP for core damage is less than 10^{-5} (i.e., a "Medium" consequence assignment) and there is no containment barrier, the "Medium" consequence assignment is retained because there is a 0.1 margin to the "High" consequence category threshold (i.e., 10^{-4}). However, if the CCDP for core damage is 5×10^{-5} (i.e., a "Medium" consequence assignment) and there is no containment barrier, the consequence category is increased to "High" because the margin to the "High" consequence category threshold (i.e., 10^{-4}) is less than 0.1. Table I-4 shall be used to assign consequence categories for those piping failures that can lead to a LOCA outside containment. In lieu of using Table I-4, quantitative indices may be used to assign consequence categories in accordance with Table I-5 with each range lowered one order of magnitude (e.g., not less that 10^{-5}) is High.

I-3.1.3 Piping Segments, Functions, and Design, Operational, or Risk Considerations Not Modeled in PRA. If any of the conditions in (a) or (b) below are true, the piping shall be classified HSS.

(a) For piping segments, functions, and design, operational, or risk considerations that are not explicitly modeled in the PRA, the effects of the following shall be evaluated.

(1) Failure of the piping segment will significantly increase the frequency of an initiating event, including those initiating events originally screened out in the PRA, such that the CDF or large early release frequency (LERF) would be estimated to increase by more than 10^{-4}/yr or 10^{-7}/yr, respectively.

(2) Failure of the piping segment will compromise the integrity of the reactor coolant pressure boundary as defined in -1200(b).

(3) Even when considering operator actions used to mitigate an accident, failure of the piping segment will fail a high-safety-significant function.

(4) Failure of the piping segment will result in failure of other safety-significant piping segments, e.g., through indirect effects.

(5) Failure of the piping segment will prevent or adversely affect the plant's capability to reach or maintain safe shutdown conditions.

(b) In addition to being HSS in terms of their contribution to CDF or LERF, piping segments might also be HSS in terms of other risk metrics or conditions. Therefore, the following conditions shall be evaluated.

(1) The piping segment is a part of a system that acts as a barrier to fission product release during severe accidents.

(2) The piping segment supports a significant mitigating or diagnostic function addressed in the Emergency Operating Procedures or the Severe Accident Management Guidelines.

(3) Failure of the piping segment will result in unintentional release of radioactive material in excess of plant offsite dose limits specified in 10 CFR Part 100.

I-3.1.4 Maintain Defense-in-Depth. When categorizing piping segments LSS, the RISC process shall demonstrate that the defense-in-depth philosophy is maintained. Defense-in-depth may be demonstrated by following the guidelines of U.S. NRC Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," dated July 1998.

I-3.1.5 Maintenance of Adequate Safety Margins. When categorizing piping segments LSS, the RISC process shall verify that there are sufficient safety margins to account for uncertainty in the engineering analysis and in the supporting data. Safety margin shall be incorporated when determining performance characteristics and

Table I-4
Consequence Categories for Failures Resulting in Increased Potential for an Unisolated LOCA outside of Containment

Protection Against LOCA Outside Containment	Consequence Category
One Active [Note (1)]	High
One Passive [Note (2)]	High
Two Active	Medium
One Active and One Passive	Medium
Two Passive	Low
More than Two	None

NOTES:
(1) An example of Active Protection is a valve that needs to close on demand.
(2) An example of Passive Protection is a valve that needs to remain closed.

parameters, e.g., piping segment, system, and plant capability or success criteria. The amount of margin should depend on the uncertainty associated with the performance parameters in question, the availability of alternatives to compensate for adverse performance, and the consequences of failure to meet the performance goals. Sufficient safety margins are maintained by ensuring that safety analysis acceptance criteria in the plant licensing basis are met, or proposed revisions account for analysis and data uncertainty.

I-3.2 CLASSIFICATION

I-3.2.1 Final Risk-Informed Safety Classification. Piping segments may be grouped together within a system, if the consequence evaluation (I-3.1) determines the effect of the postulated failures to be the same. The Risk-Informed Safety Classification shall be as follows:

I-3.2.1.1 Classification Definitions.

HSS : piping segment considered high-safety-significant.
LSS : piping segment considered low-safety-significant.

Classification Considerations.

(a) Piping segments determined to be a "High" consequence category in any table by the consequence evaluation (I-3.1.1) and (I-3.1.2) shall be considered HSS. The Owner may further refine the classification ranking by more extensive application of the process defined in these requirements. These analyses shall be documented.

(b) Piping segments determined to be a "Medium" consequence category in any table by the consequence evaluation (I-3.1.1) and (I-3.1.2) shall be determined HSS or LSS by considering the RISC evaluation and the other relevant information (I-3.1.3, I-3.1.4, and I-3.1.5) provided for determining classification. Any piping segment initially determined to be a "Medium" consequence category and that is subject to a known active degradation mechanism shall be classified HSS.

(c) Piping segments and their associated supports determined to be consequence category "Low" or "None" (no change to base case) by the consequence evaluation (I-3.1.1) and (I-3.1.2) and not meeting (a) or (b) above in any table, or not modeled, shall be determined HSS or LSS using the other relevant information (I-3.1.3, I-3.1.4, and I-3.1.5).

(d) A component support or snubber shall have the same classification as the highest-ranked piping segment within the piping analytical model in which the support is included. The Owner may further refine the classification ranking by more extensive application of the process defined in these requirements. These analyses shall be documented.

Table I-5
Quantitative Indices for Consequence Categories

CCDP or Quantitative Index, no Units	Consequence Category
$\geq 10^{-4}$	High
$10^{-6} \leq$ value $< 10^{-4}$	Medium
$< 10^{-6}$	Low
No change to base case	None

I-4 REEVALUATION OF RISK-INFORMED SAFETY CLASSIFICATION

New information may become available that alters the RISC for a piping segment. Such information may result from changes to the PRA, plant operation, or design of items. The Owner shall identify and verify the effect of the new information on the RISC assigned to the piping segment. When it is determined that the new information affects the RISC, the Owner shall reevaluate the classification, using the same approach originally used to establish the RISC.

Approval Date: March 22, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-661-2
Alternative Requirements for Wall Thickness Restoration of Class 2 and 3 Carbon Steel Piping for Raw Water Service
Section XI, Division 1

Inquiry: As an alternative to replacement or internal weld repair, what requirements may be applied for wall thickness restoration of Class 2 and 3 carbon steel raw water[1] piping systems that have experienced internal wall thinning from localized errosion, corrosion, cavitation, or pitting?

Reply: It is the opinion of the Committee that areas of Class 2 and 3 carbon steel raw water piping experiencing internal wall thinning from localized erosion, corrosion, cavitation, or pitting may have the wall thickness restored externally by means of a weld-deposited carbon or low-alloy steel overlay on the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving corrosion-assisted cracking or any other form of cracking.

1 GENERAL REQUIREMENTS

(a) The wall thickness overlay shall be performed in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.[2]

(b) The wall thickness overlay shall meet the requirements of IWA-4000,[3] except as stated in this Case.

(c) If the minimum required thickness of deposited weld metal necessary to satisfy the requirements of 3 is greater than the nominal thickness for the size and schedule of the piping, the provisions of this Case shall not apply.

(d) Weld overlay shall only be performed once in the same location.

2 INITIAL EVALUATION

The material beneath the surface to which the weld overlay is to be applied shall be evaluated to establish the existing average wall thickness and the rate, extent and configuration of degradation to be reinforced by the weld overlay. The adjacent area shall be examined to verify that the overlay will encompass the entire unacceptable area. Consideration shall be given to the cause of degradation. The extent of degradation in the piping, shall be evaluated to ensure that there are no other unacceptable locations within the surrounding area that could affect the integrity of the overlaid piping. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, considering the type of degradation present. The effect of the overlay on the piping, and any remaining degradation shall be evaluated in accordance with IWA-4160.[4]

3 DESIGN

3.1 GENERAL DESIGN REQUIREMENTS

(a) Unless otherwise established by theoretical or experimental analysis, or by proof testing as provided for in 3.3 or 3.4, the full thickness of the weld overlay shall extend a distance of at least s in each direction beyond the area predicted, over the design life of the overlay to infringe upon the required thickness.[5]

where

R = outer radius of the component

$s = \geq ¾ \sqrt{Rt_{nom}}$

[1] Raw water is defined as water such as from a river, lake, or well or brackish/salt water used in plant equipment, area coolers, and heat exchangers. In many plants it is referred to as "Service Water."

[2] IWA-4140 in the 1989 Edition with the 1991 Addenda through the 1995 Edition. IWA-4130 (Repair Program) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.

[3] IWA-4000/7000 and IWC/IWD-4000/7000, as applicable, in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.

[4] IWA-4150 in the 1989 Edition with the 1991 Addenda through the 1995 Edition. IWA-4130 (Repair Program) in the 1989 Edition with the 1990 Addenda and earlier Editions and Addenda.

[5] Design thickness as prescribed by the Construction Code.

t_{nom} = nominal wall thickness of the component

Edges of the weld overlay shall be tapered to the existing piping surface at a maximum angle ("α" in Figure 1) of 45 deg. Final configuration of the overlay shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of encompassed or adjacent welds.

(b) The thickness shall be sufficient to maintain required thickness for the predicted life of the overlay, and, except for the tapered edges, the overlay shall have a uniform thickness.

(c) The tensile strength of the weld filler metal for the overlay shall be at least that specified for the base metal to which it is applied.

(d) The predicted maximum degradation of the overlaid piping and the overlay over the design life of the overlay shall be considered in the design. The predicted degradation of the piping shall be based on in situ inspection and established data for similar base metals. If the weld overlay is predicted to become exposed to the corroding medium, the predicted degradation of the overlay shall be based upon established data for base metals or weld metals with similar chemical composition to that of the filler metal used for the weld overlay.

(e) The effect of weld overlay application on interior coatings shall be addressed in the Repair/Replacement Plan (previously Repair Program).

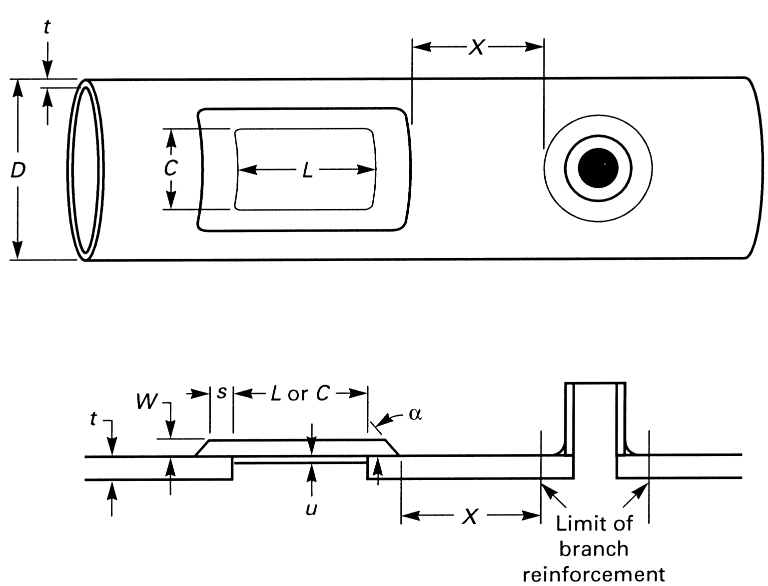
3.2 Design. The design of weld overlays not prequalified by 3.3, 3.4, or 3.5 shall be in accordance with the applicable requirements of the Construction Code or NC-3100, ND-3100 and NC-3600, ND-3600 (including Appendix II), and shall consider the weld overlay as an integral portion of the piping or component upon which it is applied (not as a weld). The allowable stress values of the base metal shall apply to the design of the deposited weld metal. The following factors shall be considered, as applicable, in the design and application of the overlay:

(a) The shrinkage effects, if any, on the piping;

(b) Stress concentrations caused by application of the overlay or resulting from existing and predicted piping internal surface configuration;

(c) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled with the original analysis. For rectangular-shaped overlays on piping designed to NC-3650, ND-3650 and aligned parallel or perpendicular to the axis of the piping, unless a lower stress intensification factor (SIF or i) is established, an SIF (i) of 2.1 shall be applied for overlays on straight pipe and adjacent welds. Also, a stress *multiplier* of 1.7 shall be applied to the SIF (i) for standard elbows; and an SIF (i) of 2.1 shall be applied for tees and branch connections when the toe of the overlay is not less than $2\frac{1}{2}\sqrt{Rt_{nom}}$ from any branch reinforcement in Figure 1.

Figure 1
Overlay Configuration



$$X \geq 2^1/_2 \sqrt{Rt_{nom}}$$

3.3 Proof Test Qualification as a Piping Product. As an alternative to design, the configuration of weld overlays may be qualified by performance of proof testing of a mockup in accordance with the following requirements:

(a) A satisfactory mockup burst test shall qualify the design or configuration for application in the same orientation on the same type of item, and the same location on fittings, when the following conditions are satisfied (see Figure 1).

(1) The base metal is of the same P-No. and Group Number when impact properties are applicable, as the base metal tested.

(2) The specified minimum tensile strength of the item does not exceed that specified for the base metal tested.

(3) The average thickness of the overlay areas is at least the thickness of the mockup plug, *u.*

(4) The overlap on the full thickness of base metal, *s,* is at least that of the mockup.

(5) The transition angle at the outer edges of the overlay, α, is not greater than that of the mockup.

(6) The overlay surface finish is similar to or smoother than that tested.

(7) The maximum proportionate axial dimension, *L/D,* is not more than that tested.

(8) The maximum proportionate circumferential dimension, *C/D,* is not more than that tested.

(9) The nominal diameter is not less than one-half nor more than two times the diameter tested.

(10) The nominal thickness/diameter ratio, *t/D,* is not less than one-half nor more than three times the *t/D,* ratio tested.

(b) The mockup base shall consist of new base material of similar configuration, or type of item, as the item to be overlaid. A rounded-corner segment of the base material shall be removed to represent the maximum proportionate size (axial dimension of L and circumferential dimension of C) and location of thinning or pitting to be compensated for by the weld overlay. A plug of the same base metal and of uniform thickness, *u,* which shall not exceed the smallest average thickness on which the overlays will be permanently applied, shall be full-penetration welded around the opening and flush with the outside surface of the piping. Alternatively, an equivalent volume of base metal may be removed from the inside surface of the mockup by machining or grinding, without need for welding in a closure plug.

(c) The mockup weld overlay shall be applied in accordance with the design or specified configuration using the specified weld filler metal. Maximum section thickness at the overlaid opening (weld metal plus base metal plug, or $u + w$) shall not exceed $87^1/_2$% of the nominal thickness of the piping.

(d) Straight pipe equivalent to a minimum of one pipe diameter, or one-half diameter for piping over NPS 14 (DN 350), shall be provided (butt-welded to the mockup, if necessary) beyond both ends of the overlay. The piping shall be capped, and the completed mockup assembly shall be thoroughly vented and hydrostatically pressure tested to bursting. To qualify the design for general application within the limits of (a), burst pressure shall not be less than:

$$P = \frac{2tS_{act}}{D_o}$$

where

D_o = outside diameter of the pipe
P = minimum acceptable burst pressure
S_{act} = reported actual tensile strength of the base metal being tested
t = minimum specified thickness (excluding manufacturing tolerances) of the base metal being tested

(e) If flexibility analysis was required by the original Construction Code, the effect of the weld overlay shall be reconciled in accordance with 3.2(c).

3.4 Proof Test Qualification for Specific Applications. As an alternative to design by analysis or proof test qualification as a piping product, the design or configuration of weld overlays may be qualified for limited service conditions using the provisions of NC-6900 and ND-6900, "Proof Tests to Establish Design Pressure," except that component hydrostatic testing is not required (other than as required by IWA-4000[3]). The mockups shall be fabricated and tested in accordance with the provisions of 3.3(b), 3.3(c), and 3.3(d), and shall be applied in accordance with the provisions and conditions of 3.3(a). The provisions of 3.3(e) shall be met.

3.5 Prequalified Design. Application of weld overlays on straight pipe, portions of tees not less than $2\frac{1}{2}\sqrt{Rt_{nom}}$ from any branch reinforcement in Figure 1, standard elbows, and associated welds to correct limited degradation shall be exempt from the requirements of 3.2 through 3.4 provided all of the following conditions are satisfied.

(a) All the requirements of 3.1 apply.

(b) The provisions of 3.3(e) shall be met.

(c) The full thickness of weld overlay shall not exceed a maximum axial length of the greater of 6 in. (150 mm) or the outside diameter of the piping.

(d) The finished overlay shall be circular, oval, full-circumferential or rectangular in shape.

(1) For each repair, the maximum dimension compensated by a circular overlay shall not exceed $^2/_3$ the nominal outside diameter of the piping.

(2) Rectangular overlays shall be aligned parallel with or perpendicular to the axis of the piping, and corners shall be rounded with radii not less than the ovelay thickness.

(3) For oval overlays, the end radii shall not be less than $\frac{3}{4}\sqrt{Rt_{nom}}$, and the axis of the overlay shall be aligned parallel with or perpendicular to the axis of the piping.

(e) The distance between toes of adjacent overlays shall not be less than t_{nom}.

4 WATER-BACKED APPLICATIONS

(a) Manual application of overlays on water-backed piping shall be restricted to P-No. 1 base materials. Welding of such overlays shall use the SMAW process and low-hydrogen electrodes. In addition, the surface examination required in 6 shall be performed no sooner than 48 hr after completion of welding.

(b) If a weld overlay is made in accordance with 5(b) on a wet surface, the permitted life of the overlay shall be one fuel cycle.

5 INSTALLATION

(a) The entire surface area to which the weld overlay is to be applied shall be examined using the liquid penetrant or magnetic particle method, with acceptance criteria in accordance with NC-2500, ND-2500 or NC-5300, ND-5300 for the product form (base metal or weld) involved.

(b) If through-wall repairs are necessary to satisfy the acceptance criteria, or result from application of the weld overlay,[6] they shall be accomplished by sealing with weld metal using a qualified weld procedure suitable for open-root welding. This weld shall be examined in accordance with (a). In addition, the first layer of overlay over the repaired area shall be examined in accordance with (a).

(c) Overlay weld metal shall be deposited using a groove-welding procedure qualified in accordance with Section IX and the Construction Code, or Section IX and Section XI, IWA-4610 and either IWA-4620 or IWA-4650.[7] The qualified minimum thickness specified in the weld procedure does not apply to the weld overlay or associated base metal repairs.[8]

(d) The surface of the weld overlay shall be prepared by machining or grinding, as necessary, to permit performance of surface and volumetric examinations required by 6. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) The completed weld overlay shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NC-5300 and ND-5300.

(b) The weld overlay, including the existing piping upon which it is applied, shall be examined to verify acceptable wall thickness.

(c) Weld overlays shall be volumetrically examined as base metal repairs when required by the Construction Code, except as follows:

(1) Class 3 weld overlays are exempt from volumetric examination when the Construction Code does not require that full-penetration butt welds in the same location be volumetrically examined.

(2) Weld overlays not exceeding 10 in.^{2} (6 500 mm^2) surface area are exempt from volumetric examination.

(3) Other weld overlays shall be exempt from volumetric examination when the finished applied thickness (w in Figure 1) does not exceed:

(-a) $\frac{1}{3}t$ for $t \leq \frac{3}{4}$ in. (19 mm)

(-b) $\frac{1}{4}$ in. (6.4 mm) for $\frac{3}{4}$ in. (19 mm) < $t \leq 2\frac{1}{2}$ in. (64 mm)

(-c) The lesser of $\frac{3}{8}$ in. (9.5 mm) or 10% of t for $t > 2\frac{1}{2}$ in. (64 mm)

where

t = finished full-section thickness of compensated area (e.g., $w + u$ in Figure 1)

(4) When volumetric examination is required, the full volume of the finished overlay, excluding the tapered edges, but including the volume of base metal required for the service life of the overlay, shall be examined in accordance with the Construction Code or Section III, using either the ultrasonic or radiographic method, and shall, to the depth at the surface of the existing piping, satisfy the acceptance criteria for weldments of the Construction Code or NC-5300, ND-5300. Any volume of existing piping beneath the weld overlay that is taken credit for in the design, shall satisfy the volumetric acceptance criteria of NC-2500, ND-2500 or NC-5300, ND-5300, as applicable.

7 IN-SERVICE EXAMINATION

(a) Examinations shall be performed to characterize the thinning of the underlying pipe wall as a benchmark for subsequent examinations of the overlay.

[6] Testing has shown that piping with areas of wall thickness less than the diameter of the electrode may burn-through during application of a water-backed weld overlay.

[7] IWA-4500 and either IWA-4510 or IWA-4540 in the 1989 Edition with the 1991 Addenda through the 1995 Edition. IWA-4510 or IWE-4200 in the 1986 Edition with the 1988 Addenda through the 1989 Edition with the 1990 Addenda. IWB-4320 or IWE-4320 in the 1986 Edition with the 1987 Addenda or earlier Editions and Addenda.

[8] Exception to IWA-4000.

(b) The Owner shall prepare a plan for additional examination to verify that minimum wall thickness is not violated over the life of the overlay. The frequency and method of examination shall be determined based on an evaluation of the degradation mechanism.

(c) Except as required by 4(b), the maximum permitted life of the overlay shall be two fuel cycles, unless examinations during each of the two fuel cycles are performed to establish the permitted life of the overlay. If the cause of the degradation is not determined, the maximum permitted life of the overlay shall be one fuel cycle.

8 DOCUMENTATION

Use of this Case shall be documented on an NIS-2 Form.

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Approval Date: June 25, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-662-1
Alternative Repair/Replacement Requirements for Items Classified in Accordance With Risk-Informed Processes
Section XI, Division 1

Inquiry: What alternative requirements may be used in lieu of IWA-1320, IWA-1400(n), IWA-4000, and IWA-6210(e), for repair/replacement activities on items and their associated supports (exclusive of core support structures, and Class CC and MC items), when using risk-informed classification criteria?

Reply: It is the opinion of the Committee that as an alternative to IWA-1320, IWA-1400(n), IWA-4000, and IWA-6210(e), repair/replacement activities may be performed in accordance with the following requirements, when the item (exclusive of core support structures, and Class CC and MC items) has been classified in accordance with risk-informed classification criteria.

1 GENERAL REPAIR/REPLACEMENT ACTIVITY REQUIREMENTS

(a) Requirements for the risk-informed classification process are outside the scope of this Case.

(b) Repair/replacement activities shall meet the following requirements, in accordance with the Edition and Addenda of Section XI specified in the Repair/Replacement Program, or in accordance with later Editions and Addenda of Section XI as provided by IWA-4150(b). The references used in this Case refer to the 2010 Edition of Section XI. For use with other Editions and Addenda of Section XI, refer to Table 2.

(c) The risk informed safety classification (RISC) (i.e., High Safety Significant (HSS) or Low Safety Significant (LSS)), the safety-related (SR) or nonsafety-related (NSR) classification,[1] and the Code classification of the item (i.e., Class 1, 2, or 3 in accordance with IWA-1320 or nonclass)[2] shall be used to determine the treatment requirements of this Case as specified in Table 1.

(d) The scope of this Case is limited to Class 1, 2, or 3 and nonclass HSS items, and Class 1, 2, or 3 LSS items. LSS nonclass items are outside the scope of Section XI, and not addressed by this Case.

2 FULL REQUIREMENTS

All requirements of IWA-1400(n), IWA-4000, and IWA-6210(e), shall be met.

3 STRUCTURAL INTEGRITY REQUIREMENTS

The following requirements shall be met.

(a) IWA-4110 Scope.

(b) IWA-4120 Applicability, except the provisions of IWA-4120(a) are not applicable.

(c) For repair/replacement activities involving piping, tubing (except heat exchanger tubing, and sleeves and welded plugs used for heat exchanger tubing), valves, and fittings, NPS 1 and smaller, and associated supports, either (1) or (2) shall be met.

(1) For LSS items, repair/replacement activities are exempt from all requirements, except that the item shall meet the technical requirements of the Construction Code selected for use in accordance with this Case.

(2) For HSS items, repair/replacement activities shall meet the requirements of 3, except the requirements to use the services of an Authorized Inspection Agency and

[1] Safety-related is defined as those structures, systems, and components that are relied upon to remain functional during and following design basis events to assure that (1) the integrity of the reactor coolant pressure boundary; (2) the capability to shut down the reactor and maintain it in a safe shutdown condition; or (3) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to applicable guideline exposures.

[2] Nonclass items or their associated supports are items not classified Classes 1, 2, 3, and MC, or CC in accordance with IWA-1320.

Table 1
RISC and Code Classifications

	Classification	Treatment	Paragraph
RISC–1	Class 1, 2, or 3	Full requirements	2
HSS–SR	Nonclass	Structural integrity requirements	3
RISC–2	Class 1, 2, or 3	Structural integrity requirements	3
HSS–NSR	Nonclass	Structural integrity requirements	3
RISC–3	Class 1, 2, or 3	Structural integrity requirements	3
LSS–SR	Nonclass	Not applicable	1(d)
RISC–4	Class 1, 2, or 3	Structural integrity requirements	3
LSS–NSR	Nonclass	Not applicable	1(d)

the administrative requirements[3] of the Construction Code of the item used in a repair/replacement activity need not be met.

(d) As an alternative to IWA-4142, the Repair/Replacement organization shall implement administrative controls for repair/replacement activities to ensure that the requirements of this Case are met. The administrative controls shall meet IWA-4142 or shall be consistent with those required by the construction codes and standards, or an alternative construction code and standard, applicable to that activity.

(e) As an alternative to IWA-4141 Owner's Responsibilities and IWA-4150 Repair/Replacemet Program and Plan, a plan shall be developed for each repair/replacement activity. This plan may be contained in the normal work control documents for the site, as long as the following are specified.

(1) Owner's Requirements, including a Construction Code Edition and Addenda, if specified, used for the following:

(-a) construction of the item to be affected by the repair/replacement activity;

(-b) construction of the item to be installed by the repair/replacement activity;

(-c) performance of the repair/replacement activity.

(2) The following items, when applicable to the specific repair/replacement activity, shall be documented.

(-a) a description of any defects and nondestructive examination methods used to detect those defects;

(-b) the defect removal method;

(-c) the applicable weld procedure, heat treatment, nondestructive examination, tests, and material requirements;

(-d) the applicable examination, test, and acceptance criteria to be used to verify acceptability.

(f) If the repair/replacement activity is being performed due to the item failing to satisfy structural integrity requirements, an evaluation shall be performed as follow.

(1) Prior to returning the item to service, the suitability of the item shall be determined. This evaluation shall include an assessment of the effect of this failure mechanism on the risk categorization of the item. If the requirements for the original item are determined to be deficient (e.g., improper material for the service, inadequate provisions for erosion, inadequate fatigue provisions), appropriate corrective provisions shall be included in the Owner's Requirements. Owner's Requirements shall be revised or updated in accordance with IWA-4180.

(2) An evaluation shall be performed to determine if other items susceptible to the same failure mechanism require corrective actions performed to preclude a similar failure.

(3) The evaluations in (1) and (2) shall be documented and retained by the Owner.

(g) IWA-4170 Inspection. The ANII shall document acceptance of the repair/replacement activity. The specific documentation to be used shall be designated by the Owner and shall be accepted by the Authorized Inspection Agency.

(h) Completion of Form NIS-2 is not required.

(i) Items used for repair/replacement activities shall meet (1), (2), or (3), and (4), and (5).

[3] Administrative requirements are those requirements that do not affect the pressure boundary or component support function. Examples include quality assurance, certification, Code Symbol Stamping, Data Reports, and Authorized Inspection. Technical requirements are distinguished from administrative requirements and are those requirements related to materials, design, fabrication, examination, or testing that affect the pressure boundary or component support function.

Table 2
Paragraph Number Cross Reference for Use with Earlier Editions and Addenda

1995 Edition With 1996 Addenda Through 2010 Edition	1991 Addenda Through 1995 Edition	1988 Addenda Through 1990 Addenda	1983 Winter Addenda Through Addenda	1981 Winter Addenda Through 1983 Summer Addenda
IWA-4110 Scope	IWA-4110	IWA-4110, IWA-7110	IWA-4110, IWA-7110	IWA-4110, IWA-7110
IWA-4120 Applicability	IWA-4120 [91A to 92E], or IWA-4111 [92A to 95E]	IWA-7400	IWA-7400	IWA-7400
IWA-4140 Responsibility	IWA-4130, IWA-4920	IWA-4130, IWA-7120	IWA-4130, IWA-7120	IWA-4130, IWA-7120
IWA-4150 Repair/Replacement Program and Plan	IWA-4140, IWA-4170	IWA-4120, IWA-4130, IWA-7130	IWA-4130, IWA-7120, and IWA-7130 in the [W85A]	IWA-4130
IWA-4160 Verification of Acceptability	IWA-4150	IWA-7220, IWA-4130	IWA-7220, IWA-4130	IWA-7220, IWA-4130
IWA-4170 Inspection	IWA-4160	IWA-4140, IWA-7140	IWA-4140, IWA-7140 added in [W85A]	IWA-4140
IWA-4180 Documentation [96A through 02A] IWA-4311(e) and IWA-6350 [03A through 09A] IWA-4180(d) and IWA-6350 [11A]	IWA-4910	IWA-4800, IWA-7520	IWA-4700, IWA-7520	IWA-4700, IWA-7520
IWA-4220 Code Applicability	IWA-4170	IWA-4120, IWA-7210	IWA-4120, IWA-7210	IWA-4120, IWA-7210
IWA-4300 Design	IWA-4300 was added in the [95A]	Not applicable	Not applicable	Not applicable
IWA-4400 Welding, Brazing, Metal Removal, and Installation	IWA-4200, IWA-4300 through [93A], and IWA-4170	IWA-4120, IWA-4200, IWA-4300, IWA-4400, and IWB-4200 [88A to 89A]	IWA-4120, IWA-4200, IWA-4300, IWA-4400, and IWB-4200	IWA-4120, IWA-4200, IWA-4300, and IWB-4200
IWA-4411 (2001 Edition through 2010 Edition IWA-4421 [97A to 00A] IWA-4410 [96A]	IWA-4170	IWA-4120	IWA-4120	IWA-4120
IWA-4500 Examination and Testing	IWA-4700, IWA-4800	IWA-4600, IWA-4700	IWA-4400, IWA-4500	IWA-4400, IWA-4500
IWA-4530 Preservice Inspection and Testing	IWA-4820	IWA-4600, IWA-7530	IWA-4500, IWA-7530	IWA-4500, IWA-7530
IWA-4540 Pressure Testing	IWA-4700	IWA-4700	IWA-4400	IWA-4400
IWA-4600 Alternative Welding Methods	IWA-4500	IWA-4500	IWB-4300	IWB-4300
IWA-4700 Heat Exchanger Tubing	IWA-4400	IWB-4200, IWB-4300 [90A]	IWB-4400	IWB-4400

GENERAL NOTE: All subarticle and subsubarticle references are to IWA, unless otherwise noted.

(1) The requirements of the Construction Code and Owner's Requirements shall be met as required by IWA-4220.

(2) In lieu of the Construction Code requirements of IWA-4220, the item shall meet the requirements (i.e., administrative and technical) of one of the following alternative construction codes or standards applicable to that item: ASME, ANSI, AWS, AISC, AWWA, API-650, API-620, MSS-SPs, TEMA, and those standards referenced within these documents. Except for components, the material, fabrication, and examination requirements of the Construction Code used for the replacement item shall be reconciled against the design of the item on which the repair/replacement activity is being performed. When installing a piping subassembly to alternative codes or standards, the reconciliation shall be performed from piping anchor to piping anchor, encompassing the subassembly.

(3) In lieu of the requirements of IWA-4220, when the Construction Code is Section III, material, parts, piping subassemblies, and component supports used or repair/replacement activities may be fabricated or manufactured and supplied in accordance with the technical requirements of Section III and the administrative requirements of an applicable alternative construction code or standard in (c)(1) and (c)(2). These provisions shall not be used for construction of components.

(4) Regardless of the above selected option, the fracture toughness requirements of the original Construction Code, or later Edition or Addenda of the Construction Code, of the item being replaced shall be met.

(5) Owner's Requirements may be revised by reconciliation in accordance with IWA-4220; however, the justification cannot be based solely on the item being classified LSS.

(j) IWA-4300 Design, except that the evaluation or reanalysis, review, and certification shall be performed to the requirements of the Construction Code selected for the item in accordance with this Case.

(k) IWA-4400 Welding, Brazing, Metal Removal, and Installation. As an alternative to meeting the Construction Code of the item as required in IWA-4411, (1) or (2) shall be met:

(1) The requirements of an alternative construction code or standard in (c)(1), (c)(2) applicable to that item. If an alternative construction code or standard is used, welds shall meet the design requirements (e.g., joint efficiency factors, examination) of that construction code or standard. When installing an item constructed to an alternative construction code or standard into an existing component, the installation requirements shall be those of the Construction Code for the item on which the repair/replacement activity is being performed, or the Construction Code of the item being installed.

(2) Alternative design and materials may be used for repair/replacement activities performed on RISC-2 nonclass items as long as the as-left (i.e., returned-to-service) configuration provides reasonable assurance that the affected item will perform its intended function and is accepted by analysis, evaluation or testing, and documented in accordance with IWA-4300, except for the requirements to meet the Construction Code or Owner's Requirements. Use of this option is subject to the following limitations:

(-a) The repair/replacement activity may remove and install material, parts, components, and piping subassemblies, subject to the following limitations.

(-1) The repair/replacement activity may not install a component (i.e., vessel, pump, valve, storage tank, or piping system), unless the component meets the requirements of (i);

(-2) The repair/replacement activity may not install a piping subassembly (i.e., a section of piping system consisting of fittings and pipes or tubes fabricated as subassemblies in a shop or in the field before being installed in a nuclear power system), unless the piping subassembly meets the requirements of (i).

(-b) It is not practical to perform the repair/replacement activity in accordance with IWA-4400 or an alternative construction code or standard in (i)(2) due to the fact that the repair/replacement activity would result in one of the following:

(-1) the unit being shut down;

(-2) significantly increasing daily or cumulative plant risk, as determined and documented by the Owner, based on analysis of the maintenance to be performed during the repair/replacement activity (e.g., 10CFR 50.65(a)(4)).

(-c) The item shall meet its original Construction Code or (1), prior to returning the item to service following the next refueling outage or system outage of sufficient duration to allow the repair/replacement activity to be performed.

(l) IWA-4500 Examination and Testing, except as follows:

(1) Examination and testing shall be performed in accordance with the Construction Code selected in accordance with this Case and the Owner's Requirements.

(2) Preservice examinations shall be performed in accordance with the requirements applicable to inservice inspection of the item selected for examination (e.g., use of risk-informed inservice inspection Cases). Preservice examinations shall be performed prior to return of the system to service and may be performed prior to or following any required pressure tests.

(3) Unless exempted by IWA-4540, a system leakage test shall be performed in accordance with IWA-5000 (1991 Addenda or later) prior to, or as part of, returning the item to service.

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Approval Date: September 17, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-663
Alternative Requirements for Classes 1 and 2 Surface Examinations
Section XI, Division 1

Inquiry: What alternative to the surface examination requirements for piping welds of Examination Categories B-F, B-J, C-F-1, and C-F-2 may be used?

Reply: It is the opinion of the Committee that in lieu of the surface examination requirements for piping welds of Examination Category B-F (NPS 4 and larger), B-J (NPS 4 and larger), C-F-1, and C-F-2, surface examinations may be limited to areas identified by the Owner as susceptible to outside surface attack.

Susceptibility to outside surface attack shall be determined in accordance with Table 1.

Examination Category B-F less than NPS 4 and Examination Category B-J less than NPS 4 shall be examined in accordance with IWB-2500.

All areas identified as susceptible to outside surface attack shall be examined during each interval. The requirements of IWB-2411, IWB-2412, IWC-2411, and IWC-2412, as applicable, shall be met. Acceptance standards shall be in accordance with IWB-3514 or IWC-3514, as applicable. The areas shall be reexamined in the same sequence, during subsequent inspection intervals over the service lifetime of the piping item, to the extent practical.

Table 1
Susceptibility Criteria

Mechanism	Criteria
External chloride stress corrosion cracking	• austenitic stainless steel base metal, welds, or heat affected zone (HAZ), and • operating temperature > 150°F, and • a piping outside surface is within five pipe diameters of a probable leak path (e.g., valve stem) and is covered with nonmetallic insulation that is not in compliance with U.S. NRC Regulatory Guide 1.36 (e.g., chloride content) or equivalent requirements or • austenitic stainless steel base metal, welds, or HAZ, and • a piping outside surface is exposed to wetting from a concentrated chloride-bearing environment (e.g., seawater, brackish water, brine)
Other outside surface initiated mechanisms	Items identified as susceptible to outside surface attack by a plant-specific service history review. This review should include plant-specific processes and programs that minimize chlorides and other contaminants.

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Approval Date: August 20, 2002

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-664
Performance Demonstration Requirements for Examination of Unclad Reactor Pressure Vessel Welds, Excluding Flange Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, Supplement 6 may be used for performance demonstration for examination of the inner 10% of unclad RPV welds excluding flange welds?

Reply: It is the opinion of the Committee that, for performance demonstration for examination of the inner 10% of unclad RPV welds, excluding flange welds, the requirements of Appendix VIII, Supplement 4 may be used in lieu of the requirements of Appendix VIII, Supplement 6.

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Approval Date: February 28, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-665
Alternative Requirements for Beam Angle Measurements Using Refracted Longitudinal Wave Search Units
Section XI, Division 1

Inquiry: When conducting ultrasonic examinations using refracted longitudinal waves, what alternative to the requirements of Appendix III-4520(g)(1)(c), and Supplement 4(b)(1) of the 1983 Edition with the Winter 1985 Addenda through the 1995 Edition with the 1997 Addenda, and Supplement 1(b)(1) of the 1998 Edition through the 2001 Edition with the 2002 Addenda, to measure the beam angle on the part being examined, may be used?

Reply: It is the opinion of the Committee that, when using refracted longitudinal wave search units, the basic calibration block may be used to measure the beam angle. The beam angle at the opposite surface of the basic calibration block shall be at least 35 deg.

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Approval Date: March 13, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-666-1
Weld Overlay of Class 1, 2, and 3 Socket Welded Connections
Section XI, Division 1

Inquiry: As an alternative to the defect removal provisions of IWA-4420,[1] may the structural integrity of a cracked or leaking socket weld, if the failure is a result of vibration fatigue, be restored by installation of weld overlay on the outside surface of the pipe, weld, fitting, or flange?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4420, as described in the Inquiry, the structural integrity of a cracked or leaking socket weld in Class 1, 2, and 3, NPS 2 (DN 50) and smaller piping, resulting from vibration fatigue, may be restored by deposition of weld overlay on the outside surface of the pipe, weld, fitting, or flange, provided the following requirements are met. This Case is not applicable to the full or partial penetration weld joining a pipe or fitting of a branch to the run pipe nor is it applicable to systems containing petroleum products such as lubricating oil or fuel or other substances that create a fire or explosion hazard.

1 GENERAL REQUIREMENTS

(a) The weld overlay shall be performed in accordance with a Repair/Replacement Program satisfying the requirements of IWA-4150 in the Edition and Addenda of Section XI applicable to the plant inservice inspection program, or later Edition and Addenda. The references used in this Case refer to the 2004 Edition. For use with other Editions and Addenda, refer to Table 1 for applicable references.

(b) Use of this Case is limited to Class 1, 2, or 3, NPS 2 (DN 50) and smaller socket welded connections with base material of P-No. 1 Group 1 and P-No. 1 Group 2, or P-No. 8. For water backed welding, the carbon content of P-No. 1 Group 2 materials shall be limited to 0.30% maximum.

(c) The structural portion of the overlay and seal layers shall be deposited in accordance with a Shielded Metal Arc or Gas Tungsten Arc Welding Procedure Specification (WPS) qualified in accordance with IWA-4440.

(d) The structural overlay shall be performed when the system is at a temperature equal to or less than 200°F (93°C). The Owner shall implement measures to prevent separation of the pipe from the fittings or flange when repairs are made with system pressure greater than 275 psig (1900 kPa). Prior to performing a repair, the Owner shall verify that the pipe base material adjacent to the socket weld requiring overlay meets the required minimum wall thickness.

(e) A socket weld may not be overlaid more than one time.

(f) The weld overlay shall meet all applicable requirements of IWA-4000, except as stated in this Case.

2 EVALUATION

(a) The Owner shall verify that the socket weld failure is a result of vibration fatigue. This determination shall include review of the design, operating history, including changes in the piping system, and visual inspection of the failed socket weld. Metallurgical analysis of the flaw surface for failure determination is not required.

(b) If review of the design, operating history, and changes to the piping system indicates that the current system configuration has not been changed for one or more fuel cycles, the weld overlay shall be acceptable until the next refueling outage, if no action is taken to reduce the vibration to acceptable levels. If corrective action is taken that reduces the vibration to acceptable levels, the weld overlay shall be acceptable for the remaining life of the piping system. If the time to failure of the original socket weld was less than one fuel cycle, corrective action that reduces the vibration to acceptable levels must be taken. Vibration acceptance standards shall be in accordance with ASME-OMb-S/G-2002, Part 3.

(c) The evaluations required by this Case shall be documented and maintained in accordance with IWA-6300.

[1] The references in this Case are based on the 2004 Edition, except where references have specific Edition or Addenda specified. For use with other Editions or Addenda, refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

3 DESIGN

(a) The Owner shall consider, in the suitability evaluation required by IWA-4160, the source of the vibration that caused the original socket weld failure. The completed weld overlay shall meet the dimensional requirements of Figure 1. The minimum throat dimension shall be 0.77 t_n for fittings and 0.98 t_n for flanges. This dimension shall be maintained from the seal weld surface and the original socket weld face as shown in Figure 1. When the fatigue crack is located in the base metal adjacent to the toe of the socket weld, the minimum throat dimensions shall be measured from the location of the crack farthest from the weld toe.

(b) The filler metal for the structural portion of the overlay of P-No. 1 material shall be AWS Classification E70XX-X, or ER70S-X. Filler metal for the structural portion of the overlay of P-No. 8 materials shall be AWS Classification E3XX-XX or ER3XX. The filler metal for the seal weld layers may be any filler metal permitted by a qualified WPS.

(c) If the weld overlay is applied to a socket weld, without any other modification to the piping system, stress analysis of the effect of the overlay is not required. If other physical modifications are made to the piping system, the effect of the other physical modifications on the piping stress analysis shall be evaluated. Stress indices and stress intensification factors for the overlaid socket weld shall be the same as the minimum value that would be calculated for a standard socket weld in accordance with the Construction Code selected in accordance with IWA-4220.

4 PROCEDURE

(a) Prior to welding, the location and approximate extent of cracking shall be determined visually.

(b) The crack shall be sealed by depositing one or more weld beads. Seal welds may be deposited on wet surfaces. Peening may be used in combination with welding to seal the crack.

(c) The seal weld, remaining socket weld, and adjacent base material that will be overlaid shall be examined using VT-1 visual examination.

(1) The procedure and personnel performing this visual examination shall meet the requirements of 5(a)(2) and 5(a)(3).

(2) The examination surfaces shall be acceptable when no cracks or evidence of leakage are detected and the surfaces are suitable for overlay.

(d) At least two structural overlay layers shall be deposited around the entire circumference of the fitting, weld, and pipe. The weld sequence shall be from the fitting to the pipe for the overlay of toe cracks and shall be from the pipe to fitting for the overlay of root cracks. The completed weld overlay shall meet the dimensional requirements of Figure 1. The throat dimensions shall not include the seal layers deposited in accordance with (b).

(e) As-welded surfaces are permitted; however they shall be sufficiently free of coarse ripples, grooves, overlaps, and abrupt ridges and valleys to permit interpretation of the required nondestructive examinations.

5 FINAL EXAMINATION AND TESTING

(a) Visual and nondestructive examination of the final structural overlay weld shall be performed in accordance with (1) through (3):

(1) VT-1 visual examination shall be performed on the completed weld overlay. In addition, the weld overlay shall be nondestructively examined in accordance with the Construction Code identified in the Repair/Replacement Plan. The method and extent of nondestructive examination shall be as specified for a socket weld.

(2) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving text with lower case characters (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (600 mm).

(3) Personnel performing VT-1 visual examinations shall be qualified in accordance with IWA-2300 and shall have received additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

(4) Visual indications shall be evaluated using the acceptance standards in (-a) through (-e).

(-a) Cracks and incomplete fusion are unacceptable.

(-b) Concavity and convexity of the surface of the overlay and craters are acceptable provided the criteria for weld size can be satisfied.

(-c) Undercut at the toe of the weld on the pipe side is unacceptable. Undercut at the toe of the weld on the fitting side shall not exceed a depth of $^1/_{32}$ in. (0.8 mm).

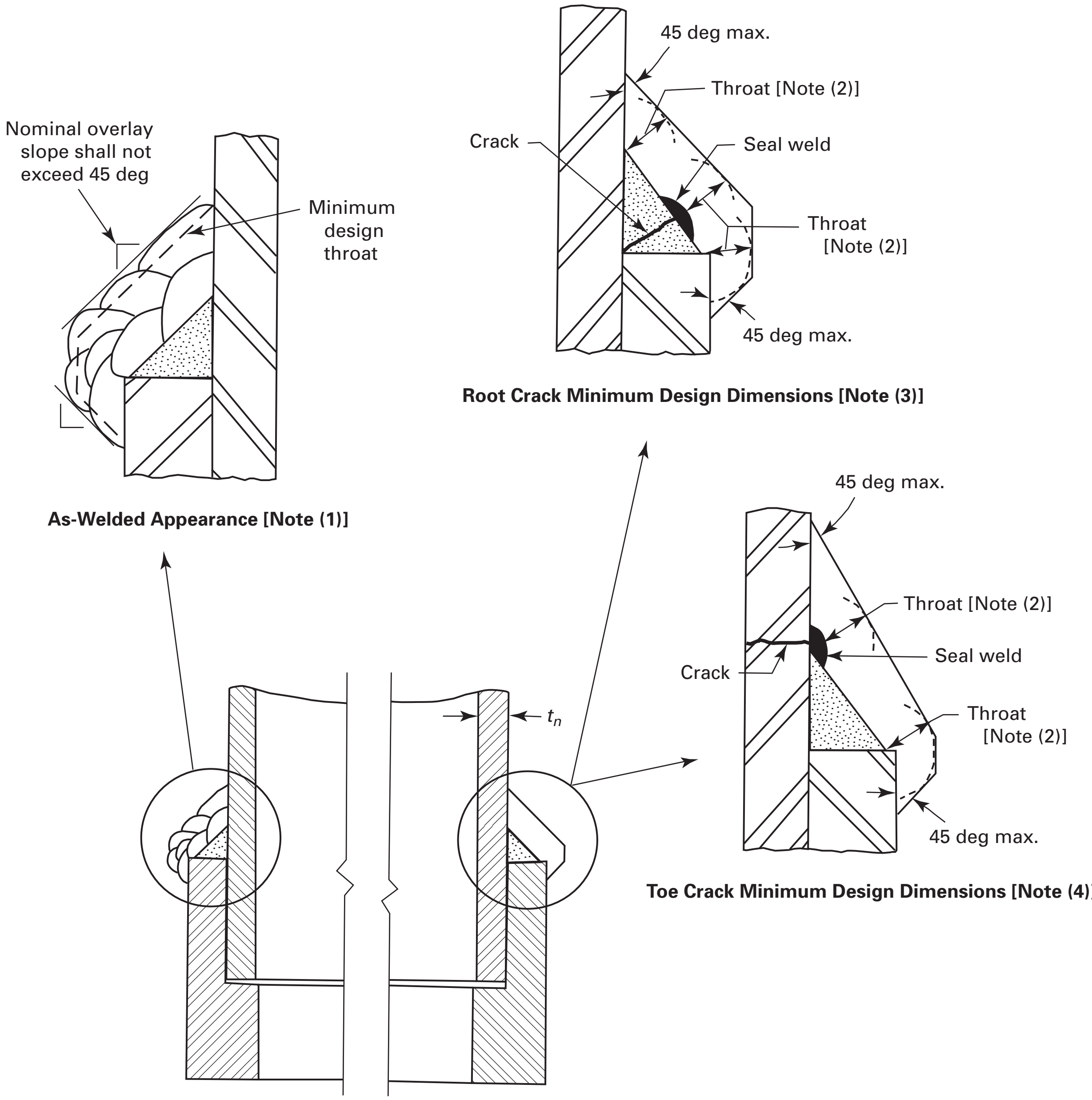
(-d) Only surface porosity whose major dimension exceeds $^1/_{16}$ in. (1.5 mm) shall be considered relevant. Overlay welds that contain surface porosity are unacceptable if a pore diameter exceeds $^1/_8$ in. (3 mm) or the sum of diameters of random porosity exceeds $^3/_8$ in. (10 mm), or if four or more pores are aligned and the pores are separated by $^1/_{16}$ in. (1.5 mm) or less, edge to edge.

(-e) Arc strikes on the weld overlay or in the adjacent pipe are unacceptable.

(b) The completed weld overlay shall be dimensionally inspected to verify compliance with the criteria of 4(d).

(c) A system leakage test shall be performed in accordance with IWA-4540.

Figure 1
Minimum Weld Overlay Dimensions



GENERAL NOTE: The details on the right show the minimum design dimensions while the detail on the left shows an acceptable as-welded appearance.

NOTES:

(1) Final surfaces may be as welded or ground, provided the minimum throat dimensions are met and the nominal overlay slope does not exceed 45 deg.

(2) The minimum throat dimension shall be 0.77 t_n for fittings and 0.98 t_n for flanges. The minimum throat dimension shall be maintained from the seal weld and from the toe of the original socket weld at the pipe and at the fitting shoulder. The minimum throat dimensions and 45 deg maximum overlay slope shall both be satisfied.

(3) A root crack initiates from the root of the socket weld and propagates through to the face of the fillet weld.

(4) A toe crack initiates at the outside surface of the pipe at or near the toe of the fillet weld and propagates through to the inside surface of the pipe.

6 DOCUMENTATION

Use of this Case shall be documented on an NIS-2 Form.

Approval Date: January 4, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-670-1
Use of Ductile Cast Iron Conforming to ASTM A874/A 874M-98 or JIS G5504-2005 for Transport and Storage Containments
Section III, Division 3

Inquiry: May ductile cast iron with a wall thickness greater than 12 in. (300 mm) but less than 21 in. (530 mm) conforming to ASTM A874/A874M-98 or JIS G5504-2005 be used in the construction of transport and storage containments in accordance with Subsection WB Class TC and WC Class SC Containment, Section III, Division 3?

Reply: It is the opinion of the Committee that ductile cast iron with a wall thickness greater than 12 in. (300 mm) but less than 21 in. (530 mm) conforming to ASTM A874/A874M-98 or JIS G5504-2005 may be used for the construction of transport and storage containments in Subsection WB Class TC and WC Class SC Containments, Section III, Division 3, provided that the following additional requirements are met:

(a) The containment body shall be cast by a single pouring controlled by a casting plan to ensure reproducibility. The casting plan shall be agreed upon between the manufacturer and purchaser and shall become a lifetime quality assurance record in accordance with WA-4134.

(b) The material properties and design allowables in Tables 1, 1M, 2, 2M and 3, also Figures 1, 1M, 2 and 2M shall be used.

(c) Tensile specimens shall be taken from each containment casting or its excess length part that has the same or equivalent solidification property. The location shall be near the center of the thickness and shall be at a distance from the end of the excess length part that is not less than one-half of the maximum casting thickness. The excess length part shall be at least the same thickness as the maximum casting thickness.

(d) For fracture toughness requirements, toughness test specimens shall be taken from each containment casting or its excess length part. The location shall be the same as that for the tensile specimens. The fracture toughness specimen orientation shall be L-R, as identified in ASTM E399-90 (Reapproved 1997), Fig. 3 (Crack Plane Orientation Code for Bar and Hollow Cylinder).

(e) Rapid-load fracture toughness test shall be performed in accordance with WB-2321.3, except that ASTM E1820-01 shall be used. A test shall consist of at least four test specimens. The test shall be performed at −40°F [−40°C]. The rapid-load fracture toughness value shall satisfy the following inequality at −40°F [−40°C].

$$\text{(average)}K_{IC,\,R} - 3\sigma_{SD} \geq 46\ \text{ksi-in.}^{1/2}\ (50\ \text{MPa-m}^{1/2})$$

where

$K_{IC,\,R}$ = rapid load fracture toughness ksi-in.$^{1/2}$ (MPa-m$^{1/2}$)
σ_{SD} = standard deviation ksi-in.$^{1/2}$ (MPa-m$^{1/2}$)

The average value and standard deviation shall be established assuming Weibull distribution of the measurements.

(f) For examination of the containment casting, the following shall apply: All cast products shall be examined by the ultrasonic method as specified in (g). All external and accessible internal surfaces, except threaded surface, shall be either liquid penetrant or magnetic particle examined. All examinations shall be performed after final machining except that ultrasonic testing shall be performed at the time when the configuration is best suited for scanning and most meaningful results can be obtained.

(g) Ultrasonic examination shall be performed in accordance with T-571.4 of Article 5 of Section V. Each manufacturer shall certify that the procedure is in accordance with the following requirements and shall make the procedure available for approval upon request.

The following acceptance standards shall be applied:

(1) The Quality Levels of SA-609 as shown in Section V shall apply for the casting thicknesses indicated.

(-a) Quality Level 1 for thicknesses up to 2 in. (50 mm)

(-b) Quality Level 3 for thicknesses 2 in. (50 mm) to 4 in. (100 mm)

(-c) Quality Level 4 for thicknesses greater than 4 in. (100 mm)

(2) In addition to the Quality Level requirements stated in (-a) above, the requirements in (-a) through (-e) below shall apply for both straight beam and angle beam examination.

(-a) Areas giving indications exceeding the Amplitude Reference Line with any dimension longer than those specified in the following tabulation are unacceptable:

UT Quality Level	Longest Dimension of Area, in. (mm)[Note (1)], [Note (2)], [Note (3)]
1	1.5 (38)
2	2.0 (50)
3	2.5 (64)
4	3.0 (75)

NOTES:
(1) The areas for the Ultrasonic Quality Levels in SA-609 refer to the surface area on the casting over which continuous indication, exceeding the transfer corrected distance amplitude curve, is maintained.
(2) Areas are to be measured from dimensions of the movement of the search unit, using the center of the search unit as the reference point.
(3) In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria which incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

(-b) Quality Level 1 shall apply for the volume of castings within 1 in. (25 mm) of the surface regardless of the overall thickness.

(-c) Discontinuities indicated to have a change in depth equal to or greater than one-half the wall thickness or 1 in. (25 mm) (whichever is less) are unacceptable.

(-d) Two or more indications in the same plane with amplitudes exceeding the Amplitude Reference Line and separated by a distance less than the longest dimension of the larger of the adjacent indications are unacceptable if they cannot be encompassed within an area less than that of the Quality Level specified in (-a).

(-e) Two or more indications greater than permitted for Quality Level 1 for castings less than 2 in. (50 mm) in thickness, greater than permitted for Quality Level 2 for thicknesses 2 in. (50 mm) through 4 in. (100 mm), and greater than permitted for Level 3 for thicknesses greater than 4 in. (100 mm), separated by a distance less than the longest dimension of the larger of the adjacent indications are unacceptable, if they cannot be encompassed in an area less than that of the Quality Level requirements stated in (1).

(h) Castings shall not be repaired by plugging, welding, brazing, impregnation, or any other means.

(i) This Case number shall be listed in the Design Specification and the Data Report Form for this material.

Table 1
Yield Strength, Tensile Strength and Design Stress Intensity Values

Temperature, °F	S_Y, min., ksi	S_U min., ksi	Design Stress Intensity, S_m, ksi [Note (1)]
−20 to 100 [Note (2)]	29.0	43.5	10.9
200	25.4	43.4	10.8
300	24.1	41.3	10.3
400	23.5	39.9	10.0
500	23.1	39.1	9.8
600	22.5	38.4	9.6
650	22.1	37.6	9.4

NOTES:
(1) A criterion of 4 on tensile strength was used in establishing these values.
(2) For lower temperature than −20°F, use the values at −20 to 100°F.

Table 1M
Yield Strength, Tensile Strength and Design Stress Intensity Values

Temperature, °C	S_Y, min., MPa	S_U min., MPa	Design Stress Intensity, S_m, MPa [Note (1)]
−30 to 40 [Note (2)]	200	300	75.0
65	182	300	75.0
100	174	297	74.3
150	166	285	71.2
200	162	276	68.9
250	160	270	67.6
300	157	267	66.7
325	154	263	65.8
350[Note (3)]	151	257	64.2

NOTES:
(1) A criterion of 4 on tensile strength was used in establishing these values.
(2) For lower temperature than −30°C, use the values at −30 to 40°C.
(3) The maximum design temperature is 343°C, the value at 350°C is provided for interpolation purpose, only.

Table 2
Tabulated Values From Figure 1

	Values of S_a, ksi	
Number of Cycles	Zero Mean Stress	Maximum Mean Stress
1.0E1	112	112
2.0E1	94	94
5.0E1	76	76
1.0E2	65	65
2.0E2	56	56
5.0E2	45	45
1.0E3	38	38
2.0E3	32	32
5.0E3	27	27
1.0E4	24	24
2.0E4	21	21
5.0E4	18	18
1.0E5	17	17
2.0E5	15	15
3.0E5	15	15
5.0E5	14	13
1.0E6	13	11
2.0E6	12	10
5.0E6	12	9
1.0E7	11	8
2.0E7	11	8
5.0E7	11	7
1.0E8	11	7

Table 2M
Tabulated Values From Figure 1M

	Values of S_a, MPa	
Number of Cycles	Zero Mean Stress	Maximum Mean Stress
1.0E1	772	772
2.0E1	649	649
5.0E1	522	522
1.0E2	447	447
2.0E2	386	386
5.0E2	307	307
1.0E3	261	261
2.0E3	223	223
5.0E3	185	185
1.0E4	162	162
2.0E4	144	144
5.0E4	125	125
1.0E5	114	114
2.0E5	105	105
3.0E5	101	101
5.0E5	96	88
1.0E6	90	76
2.0E6	86	67
5.0E6	82	60
1.0E7	79	55
2.0E7	77	52
5.0E7	75	49
1.0E8	73	48

Table 3
Tabular Values for B Value Chart for Determining Shell Thickness Under External Pressure

Temp. °F	A	B psi	Temp. °C	A	B MPa
105	1.00E−05	1.16E+02	40	1.00E−05	8.00E−01
	8.66E−05	1.00E+03		1.26E−04	1.00E+01
	6.28E−04	7.25E+03		6.28E−04	5.00E+01
	1.00E−03	8.81E+03		1.00E−03	6.07E+01
	2.00E−03	1.06E+04		2.00E−03	7.31E+01
	7.00E−03	1.30E+04		7.00E−03	8.96E+01
	3.50E−02	1.45E+04		3.50E−02	1.00E+02
	1.00E−01	1.45E+04		1.00E−01	1.00E+02
212	1.00E−05	1.12E+02	100	1.00E−05	7.72E−01
	8.93E−05	1.00E+03		1.30E−04	1.00E+01
	5.62E−04	6.30E+03		5.62E−04	4.34E+01
	1.00E−03	8.00E+03		1.00E−03	5.52E+01
	2.50E−03	9.74E+03		2.50E−03	6.72E+01
	7.00E−03	1.12E+04		7.00E−03	7.72E+01
	3.00E−02	1.26E+04		3.00E−02	8.69E+01
	1.00E−01	1.26E+04		1.00E−01	8.69E+01
390	1.00E−05	1.06E+02	200	1.00E−05	7.31E−01
	9.43E−05	1.00E+03		1.37E−04	1.00E+01
	5.57E−04	5.90E+03		5.57E−04	4.07E+01
	1.00E−03	7.40E+03		1.00E−03	5.10E+01
	2.50E−03	9.10E+03		2.50E−03	6.27E+01
	7.00E−03	1.04E+04		7.00E−03	7.17E+01
	3.00E−02	1.18E+04		3.00E−02	8.14E+01
	1.00E−01	1.18E+04		1.00E−01	8.14E+01

Figure 1
Design Fatigue Curve (ksi)

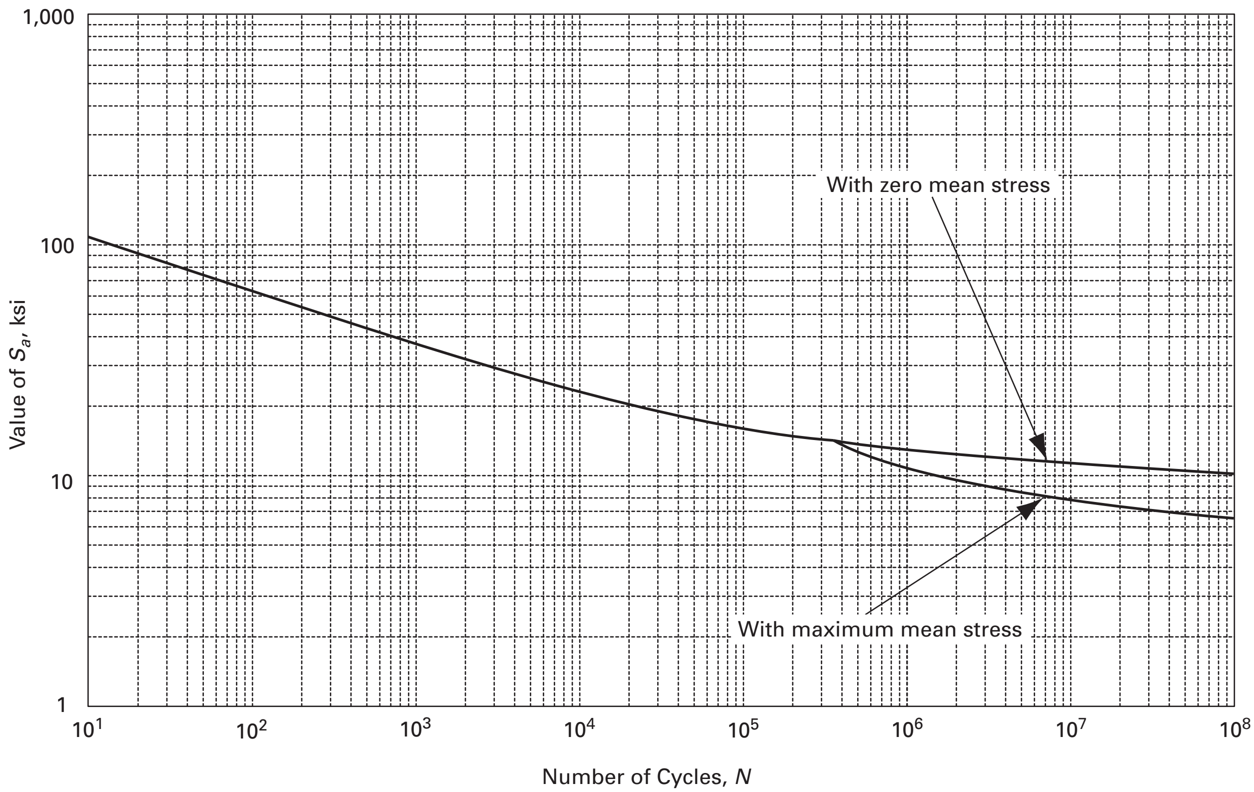


Figure 1M
Design Fatigue Curve (MPa)

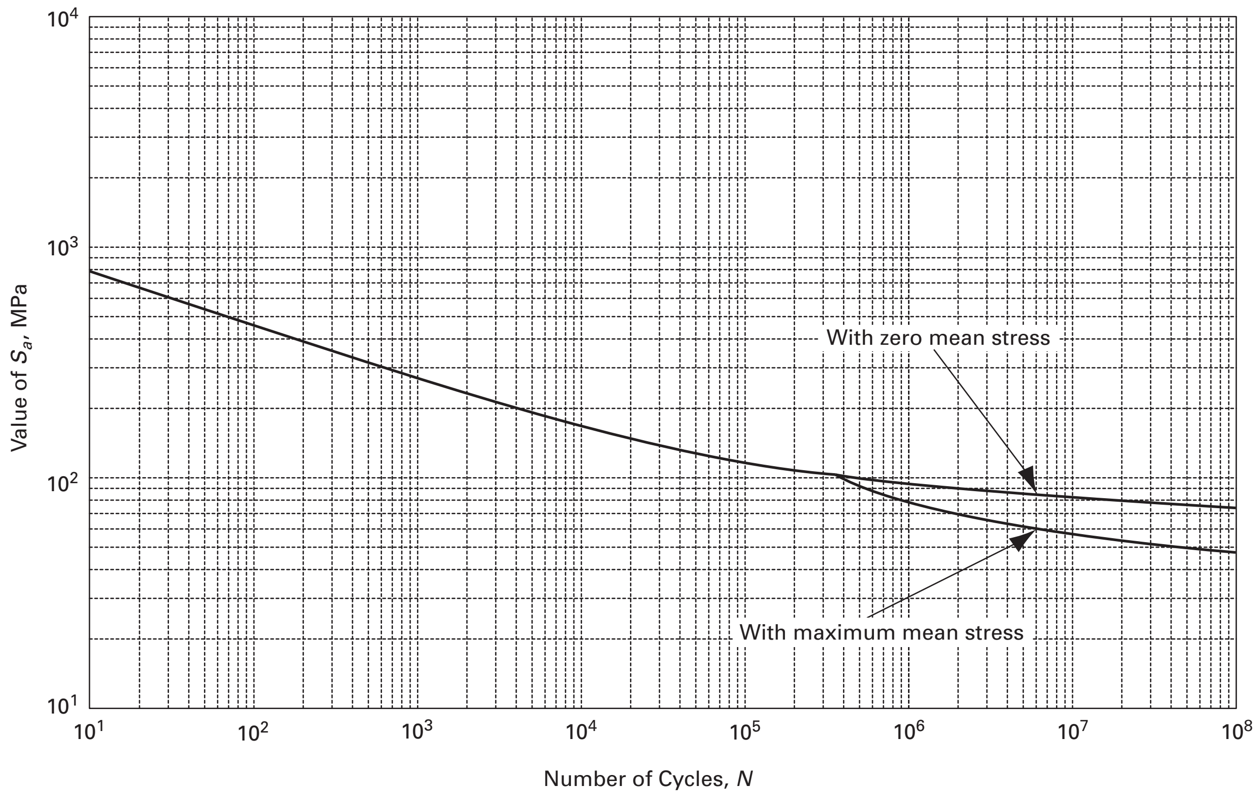


Figure 2
B Value (Chart for Determining Shell Thickness Under External Pressure)

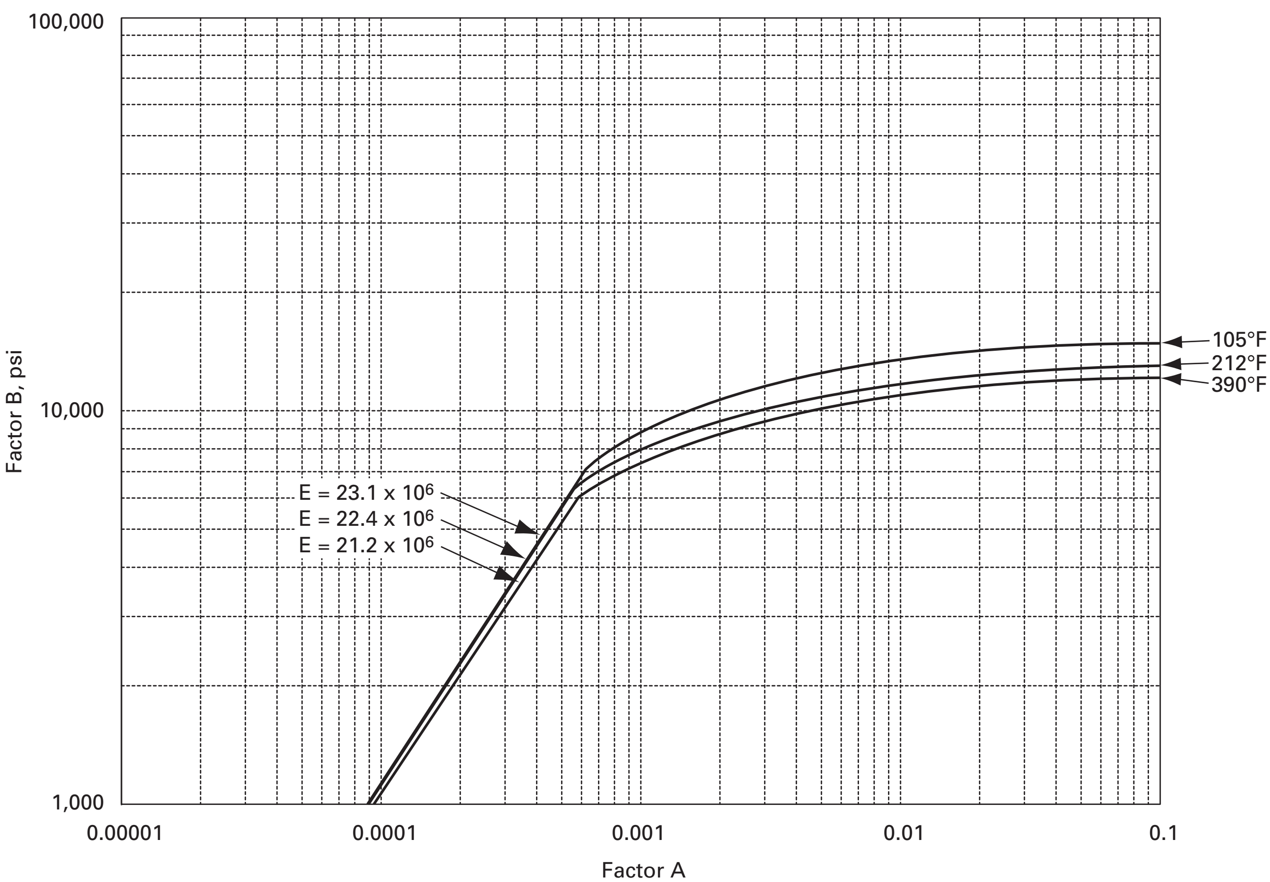
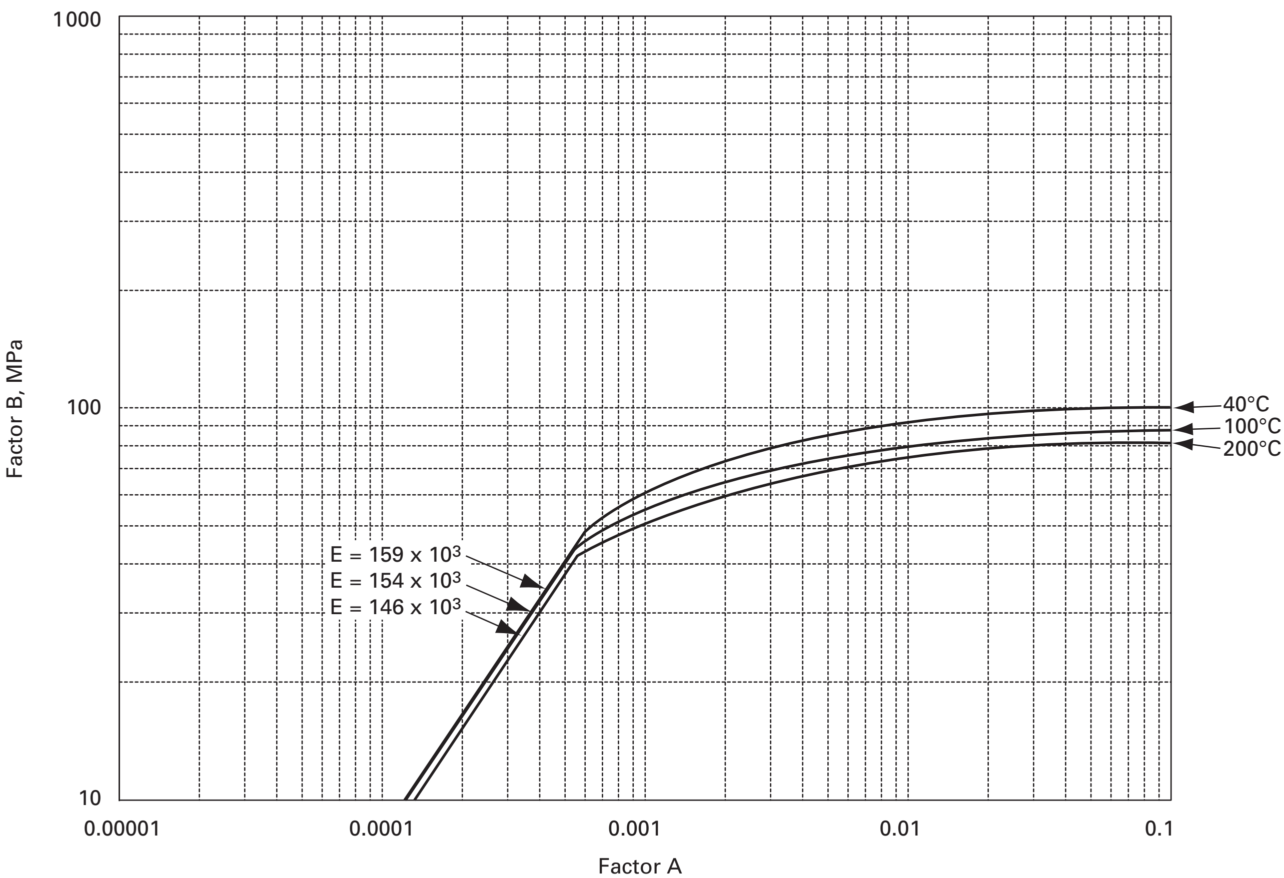


Figure 2M
B Value (Chart for Determining Shell Thickness Under External Pressure)



Approval Date: August 7, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-673
Boron Containing Powder Metallurgy Aluminum Alloy for Storage and Transportation of Spent Nuclear Fuel Section III, Division 1

Inquiry: May boron containing powder metallurgy aluminum alloy in the T1 temper meeting the chemical composition and mechanical properties given in Table 1 and Table 2 and otherwise conforming to the requirements of SB-221, ASTM B243 and B 311 be used in the construction of Section III, Subsection NF, Class 1 supports and Subsection NG, Class CS core support structures for storage and transportation of spent nuclear fuel in Section III, Division 1?

Reply: It is the opinion of the Committee that aluminum alloys as described in the above Inquiry may be used in the construction of Section III, Subsection NF, Class 1 supports, and Subsection NG, Class CS core support structures for storage and transportation of spent nuclear fuel in Section III, Division 1 under the following conditions:

(a) Yield strength values, S_y, and tensile strength values, S_u, shall be those listed in Tables 3 and 3M.

(b) The maximum allowable stress values and design stress intensities for the material shall be those in Tables 4 and 4M.

(c) Welding is not permitted.

(d) Pressure retaining applications are not permitted.

(e) The maximum application temperature for the material shall be 500°F (260°C).

(f) Structural components shall be made by cold pressing and sintering prealloyed powder consisting of the elements listed in Table 1 including Boron Carbide nominally composed of B_4C.

(g) The sintered density shall be 2.0 g/cm^3 minimum.

(h) This Case number shall be shown on the Data Report and in the certification and marking of the material.

Table 1
Chemical Requirements

Elements	Composition, % (by Weight)
Silicon	0.4–0.9
Iron	0.35 max.
Copper	0.35 max.
Manganese	0.5 max.
Magnesium	0.4–0.8
Chromium	0.30 max.
Zinc	0.25 max.
Titanium	0.10 max.
Boron + Carbon (as Boron Carbide)	1.5–9
Aluminum	Remainder

Table 2
Mechanical Property Requirements

Property	Values
Tensile strength, min., ksi (MPa)	21.0 (144)
Yield strength, min., ksi (MPa)	11.0 (75)
Elongation in 2 in. (50 mm), min. (%)	20

Table 3
Yield Strength S_y, and Tensile Strength S_u, ksi

Temperature °F	S_y	S_u
−20/100	11.0	21.0
150	10.6	21.0
200	10.3	19.7
250	10.0	17.8
300	9.5	15.8
350	8.8	13.8
400	7.8	11.4
450	6.7	9.4
500	5.5	7.7

Table 3M
Yield Strength S_y, and Tensile Strength S_u, MPa

Temperature °C	S_y	S_u
−30/40	75.0	144
65	72.3	144
100	70.0	132
125	67.8	120
150	64.7	106
175	60.3	93.9
200	54.5	80.3
225	47.5	67.7
250	40.1	58.8
275	33.5 [Note (1)]	48.2 [Note (1)]

NOTE:
(1) The values of 275°C are provided for interpolataion only. See para. (e) of the Reply for maximum use temperature.

Table 4
Maximum Allowable Stress and Design Stress Intensity Values

For Metal Temperature Not Exceeding, °F	Allowable Stress or Design Stress Intensity Values max., ksi [Note (1)]
−20/100	6.0
150	6.0
200	5.6
250	5.1
300	3.9
350	3.1
400	2.5
450	2.2
500	1.9

NOTE:
(1) The revised criterion of 3.5 on tensile strength was used in establishing these values.

Table 4M
Maximum Allowable Stress and Design Stress Intensity Values

For Metal Temperature Not Exceeding, °C	Allowable Stress or Design Stress Intensity Values max., MPa [Note (1)]
−30/40	41.1
65	41.1
100	37.7
125	34.4
150	26.9
175	21.5
200	17.9
225	14.6
250	13.9
275	12.6 [Note (2)]

NOTES:
(1) The revised criterion of 3.5 on tensile strength was used in establishing these values.
(2) The value at 275°C is provided for interpolation only. See para. (e) of the Reply for maximum use temperature.

Approval Date: February 14, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-683
Method for Determining Maximum Allowable False Calls When Performing Single-Sided Access Performance Demonstration in Accordance With, Appendix VIII, Supplements 4 and 6
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, Supplements 4 and 6 may be used for determining the maximum allowable number of false calls when performing single-sided access performance demonstration?

Reply: It is the opinion of the Committee that the maximum number of allowable false calls permitted for implementing Supplements 4 and 6 when performing single-sided access performance demonstration shall be based on the total scan area that would be scanned when scanning from all four directions.

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Approval Date: May 9, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-685
Lighting Requirements for Surface Examination
Section XI, Division 1

Inquiry: What alternative to the surface examination lighting requirements invoked by IWA-2221 and IWA-2222 may be used?

Reply: It is the opinion of the Committee that, for nonfluorescent magnetic particles and visible dye liquid penetrant examination, a light intensity of 50 fc may be used. In lieu of measuring the light intensity with a light meter, lighting may be considered sufficient if the examiner can resolve standard test chart characters as described for VT-1 in IWA-2210.

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Approval Date: January 10, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-686-1
Alternative Requirements for Visual Examinations, VT-1, VT-2, and VT-3
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-2210, visual examinations, and Table IWA-2210-1, visual examinations, may be used when performing visual examinations in accordance with IWA-2211, VT-1, IWA-2212, VT-2, and IWA-2213, VT-3.

Reply: It is the opinion of the Committee that as an alternative to the requirements of IWA-2210 and Table IWA-2210-1, the following requirements may be used for performing VT-1, VT-2, and VT-3 examinations.

(a) Visual examinations shall be conducted in accordance with the 2001 Edition of Section V, Article 9, T-941 for the written procedure and T-990 for reporting of the examination results.

(b) VT-1 Examination:

(1) VT-1 examination is conducted to detect discontinuities and imperfections on the surfaces of components, including such conditions as cracks, wear, corrosion, or erosion.

(2) The VT-1 examination procedure shall be demonstrated capable of resolving characters in accordance with Table 1.

(3) Direct visual examination distance requirements shall be as specified in Table 1.

(4) Illumination for examination shall meet the requirements specified in Table 1.

(5) It is not necessary to measure the illumination level on each examination surface when the same portable non-battery-powered light source (e.g., drop light) or similar installed lighting equipment is demonstrated to provide the illumination specified in Table 1 at the maximum examination distance.

(6) When a battery-powered light is used, the adequacy of the illumination level shall be checked before and after each examination or series of examinations, not to exceed 4 hr between checks.

(7) Remote visual examination may be substituted for direct examination. The remote examination procedure shall be demonstrated capable of resolving characters in accordance with Table 1. Additionally, the remote visual examination system shall be capable of distinguishing the colors applicable to the component examinations being conducted.

(c) VT-2 Examination:

(1) VT-2 examination is conducted to detect evidence of leakage from pressure retaining components, with or without leakage collection systems, as required during the system pressure test.

Table 1
Visual Examinations

Visual Examination	Minimum Illumination, fc (lx) [Note (1)]	Maximum Direct Examination Distance, ft (mm)	Maximum Height, in. (mm) for Procedure Demonstration Characters [Note (2)]
VT-1	50 (550)	2 (600)	0.044 (1.0)
VT-3	50 (550)	N/A	0.105 (3.0)

NOTES:
(1) Resolution of the specified characters can be used in lieu of illumination measurement to verify illumination adequacy.
(2) For procedure demonstration, a test chart or card containing text with some lower case characters, without an ascender or descender (e.g., a, c, e, o), that meet the specified height requirements is required. Measurement of the test chart or card shall be made once before its initial use with an optical comparator (10X or greater) or other suitable instrument to verity that the height of the lower case characters without an ascender or descender meets the specified requirements.

(2) VT-2 examination shall be conducted in accordance with IWA-5000.

(d) VT-3 Examination:

(1) VT-3 examination is conducted to determine the general mechanical and structural condition of components and their supports by verifying parameters such as clearances, settings, and physical displacements; to detect discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion; and to detect conditions that could effect operability or functional adequacy of snubbers and constant load and spring type supports.

(2) The VT-3 examination procedure shall be demonstrated capable of resolving characters in accordance with Table 1.

(3) There are no direct visual examination distance requirements, provided the examiner can resolve the characters in accordance with Table 1.

(4) Illumination for examination shall meet the requirements specified in Table 1.

(5) It is not necessary to measure illumination levels on each examination surface when the same portable non-battery-powered light source (e.g., drop light) or similar installed lighting equipment is demonstrated to provide the illumination specified in Table 1 at the maximum examination distance.

(6) When a battery-powered light is used, the adequacy of the illumination level shall be checked before and after each examination or series of examinations, not to exceed 4 hr between checks.

(7) Remote visual examination may be substituted for direct examination. The remote examination procedure shall be demonstrated capable of resolving characters in accordance with Table 1. Additionally, the remote visual examination system shall be capable of distinguishing the colors applicable to the component examinations being conducted.

Approval Date: November 18, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-691
Application of Risk-Informed Insights to Increase the Inspection Interval for Pressurized Water Reactor Vessels
Section XI, Division 1

Inquiry: IWB-2412, Inspection Program B, requires an Inspection Interval of 10 yr. Under what conditions may this interval be increased to 20 yr for the examination of Examination Category B-A and B-D welds in pressurized water reactor vessels and Category B-J welds to the reactor vessel nozzles?

Reply: It is the opinion of the Committee that the following requirements for application of risk-informed insights from probabilistic fracture mechanics (PFM) and risk analyses may be used to justify an increase from 10 yr to 20 yr in the requirements of IWB-2412 for Inspection Interval for examination of Examination Category B-A and B-D welds in pressurized water reactor vessels and Category B-J welds to the reactor vessel nozzles. The length of the Inspection Periods may also be doubled.

(a) The frequency of the postulated events shall be integrated with the conditional vessel failure probabilities for the accident transients. The following two criteria for acceptable changes shall be satisfied:

(1) Change in core-damage frequency (CDF) shall be less than 1×10^{-6} per reactor year.

(2) Change in large early release frequency (LERF) shall be less than 1×10^{-7} per reactor year.

(b) As the basis for determining the change in risk, the inputs to a reactor vessel PFM and risk analyses shall include the following:

(1) Accident transients and frequencies;
(2) Operational transients;
(3) Initial flaw distribution;
(4) Fluence distribution;
(5) Material fracture toughness;
(6) Crack growth rate correlation;
(7) Cladding and residual stress;
(8) Effectiveness of inservice inspection.

(c) Mandatory Appendix I includes inputs to PFM and risk analyses that have been used to demonstrate feasibility of the methodology. Requirements for demonstrating that plant specific data for the PFM and risk analysis inputs are bounded are included in Mandatory Appendix I. Integration of the results of the PFM and risk analyses with the frequency of postulated events shall demonstrate that the above two acceptance criteria are met. The Inspection Interval may be increased from 10 to 20 yr based on the analysis that satisfies these criteria. Alternatively, the Inspection Interval increase from 10 to 20 yr may be justified using plant specific data to demonstrate.

(d) Use of this Case shall be documented on Form NIS-1.

MANDATORY APPENDIX I
PROBABILISTIC FRACTURE MECHANICS (PFM)

I-1 BASIC PFM CONSIDERATIONS

The PFM methodology shall include the following considerations:

(a) Vessel failure is more likely with increasing time of operation due to the growth of preexisting flaws by fatigue in combination with a decrease in vessel flaw resistance due to irradiation. Credible, postulated accident loads that potentially lead to vessel failure shall be considered to occur at a given time in the life of the plant (e.g., after 40 yr of operation).

(b) The applied stress intensity factor, K_I, due to an accident loading on a given crack, shall be calculated and compared to the material fracture toughness, K_{IC}, to determine if the accident loading would cause vessel failure. The condition in which the applied K_I due to accident loading exceeds the material K_{IC} represents failure. The PFM methodology shall include consideration of distributions and uncertainties in flaw number and size, fluence, material properties, crack growth rate, residual stresses, and effectiveness of inspections. A Monte Carlo approach shall be used to determine a conditional vessel failure probability due to a given accident loading condition and a prescribed inspection interval. All locations of interest in the vessel shall be addressed in a similar way, unless a bounding approach is used to exclude some areas from consideration.

(c) Reliability of the vessel is defined as the number of non-failed simulated vessels divided by the total number of simulated vessels in the Monte Carlo simulations.

(d) The change in the probability of vessel failure due to a change in inspection interval shall be used to evaluate acceptability of such an inspection interval change.

(e) If the Category B-J piping welds to the reactor pressure vessel nozzles are included in a piping risk-informed inspection program, the two criteria for acceptable change (item 1 of the Reply) shall also be applied for all piping inspections in the risk-informed program, including the increased inspection interval of the Category B-J piping welds to vessel nozzles. If the Category B-J piping welds to the reactor pressure vessel are not included in a piping risk-informed inspection program, an analysis that uses approved piping risk-informed inspection methods shall be applied to those welds, to demonstrate that the criteria (item 1 of the Reply) are met, including the increased inspection interval.

I-2 RISK ACCEPTANCE CRITERIA

When the frequency of postulated events is integrated with the conditional vessel failure probabilities for the respective events, the two criteria for acceptable changes are:

(a) Change in core-damage frequency (CDF) < 1×10^{-6} per reactor year and;

(b) Change in large early release frequency (LERF) < 1×10^{-7} per reactor year.

These criteria will also satisfy the regulatory guidance provided by U.S. NRC Regulatory Guide 1.174.[1] A conservative approach to simplify these acceptance criteria is to pressume that flaw initiation (i.e., a situation where the applied K_I exceeds the material K_{IC}) is equivalent to vessel failure, and vessel failure causes a large early release. Therefore, an alternative acceptance criterion to demonstrate that the available risk analysis (feasibility demonstration) is bounding is change in vessel failure frequency < 1×10^{-7} per reactor year.

I-3 OPERATIONAL AND ACCIDENT LOADINGS

A Monte Carlo analysis shall be used to simulate the entire expected operating life of the vessel. Over that expected lifetime, normal operating transients are considered to cause the growth by fatigue of any flaws that exist in the vessel. Postulated accident loads shall be applied at a given time, e.g., after 40 yr of operation, to determine if failure could occur at that time.

Pressurized thermal shock (PTS) shall be assumed to define the most significant loading imposed on the vessel in the PFM and risk analyses.

I-4 REQUIRED PLANT-SPECIFIC INPUTS

This section provides an overview of the data input required for the Monte Carlo analysis.

I-4.1 ACCIDENT TRANSIENTS AND FREQUENCY

A set of accident transients and their frequencies of occurence that can be postulated to realistically result in reactor vessel failure shall be defined. Plant probabilistic risk assessment (PRA) models shall be used to define these events. For each postulated transient event, the

[1] Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," U.S. Nuclear Regulatory Commission, 1998.

pressure, temperature, and heat transfer coefficient versus time for the wetted surface of a given region shall be determined.

To demonstrate that the risk analysis is bounding, the severity of the plant-specific transient that is the major contributor to PTS risk shall be equal to or less than a small-break LOCA with low decay heat and late repressurization. The severity of the postulated PTS transient is determined by the maximum cool-down rate early in the transient and the maximum pressure and minimum temperature late in the transient. The frequency of this plant-specific PTS transient shall also be less than or equal to 5×10^{-6} per year.

I-4.2 OPERATIONAL TRANSIENTS

The operational transients and the number of cycles occuring each year that contribute to fatigue crack growth shall be identified. Each transient shall represent a full heat-up/cool-down cycle between atmospheric pressure at room temperature and full system pressure at maximum operating temperature.

To demonstrate that the PFM analyses bound the plant-specific vessel conditions, the number of equivalent transients shall be less than or equal to 720 and the embrittlement index temperature, which is described in I-4.5, shall be less than or equal to 178°F (80°C) as shown in Figure I-1.

I-4.3 INITIAL FLAW DISTRIBUTION

To demonstrate that the PFM and risk analyses are bounding, it shall be shown that not more than 3 axial flaws (surface breaking or embedded in inner $^1/_8$ of the wall) were found during either a preservice or inservice inspection and not repaired.

I-4.4 FLUENCE DISTRIBUTION

The fluence distribution versus operating time, both axial and azimuthal, shall be based on plant-specific or bounding data for the current operating time and shall be extrapolated to the end of expected lifetime of the vessel.

Demonstration that the PFM and risk analyses bound the plant-specific fluence conditions shall be made through use of the embrittlement index temperature, in accordance with I-4.5 and illustrated in Figure I-1.

I-4.5 MATERIAL FRACTURE TOUGHNESS

Vessel material fracture toughness of the limiting belt line plates and weld materials used in the PFM shall be bounding or based on plant-specific data, including the following:

(a) Physical and mechanical properties of base metal, clad, and welds (e.g., copper and nickel content), and their uncertainties;

(b) Initial RT_{NDT}, including uncertainty;

(c) ΔRT_{NDT} versus time and depth, including uncertainty;

(d) Fracture toughness with fluence and depth, including uncertainty.

In PFM and risk analyses, initial belt line RT_{NDT} data is used with neutron fluence to calculate the shift and adjusted reference temperature (ART) as a function of operating time. The basis given in Regulatory Guide 1.99 Revision 2, Position 1.1[2] shall be used to determine the shift. Two example values [123°F (50°C) and 178°F (80°C)] of embrittlement index tempreature, which is the highest value of ART after 60 years of operation, are shown in Figure I-1. The fracture toughness is then determined by using the ART in the Section XI, Appendix A, K_{IC} curve. To demonstrate that the available analyses bound the plant-specific vessel toughness, the following two conditions shall be satisfied:

(1) The Section XI, K_{IC} curve shall apply to the plant-specific vessel material.

(2) The plant-specific embrittlement index temperature shall be not more than the values shown in Figure I-1.

I-4.6 CRACK GROWTH RATE CORRELATION

The basic physical models for fatigue crack growth due to normal plant operation, including the effect of uncertainties, shall be used for input into the probabilistic fracture mechanics analysis.

The PFM and risk analyses shall include a probabilistic representation of the fatigue crack growth correlation for ferritic materials in water that is consistent with models contained in Section XI, Appendix A.

I-4.7 CLADDING AND RESIDUAL STRESS

The residual stress distribution in welds and the cladding stress and its temperature dependence due to differential thermal expansion shall be considered.

To document that these estimates bound the plant-specific stresses, it shall be shown that there are no unexpected conditions that would violate the assumptions upon which they are based. Unexpected conditions include the vessel wall or cladding thickness being out of tolerance or a significant amount of rework being required during initial fabrication.

[2] Regulatory Guide 1.99, Revision 2, “Radiation Embrittlement of Reactor Vessel Materials,” U.S. Nuclear Regulatory Commission, 1988.

I-4.8 EFFECTIVENESS OF INSERVICE INSPECTION

Volumetric examination shall be conducted in accordance with Section XI, Appendix VIII, or when applicable, Regulatory Guide 1.150.[3] The following effects shall be considered along with the change in ISI interval:

(a) Extent of inspection (percent coverage);

(b) Probability of detection (POD) with flaw size;

(c) Repair criterion for removing flaws from service.

The following plant-specific conditions shall be used to demonstrate that the available analyses are bounding:

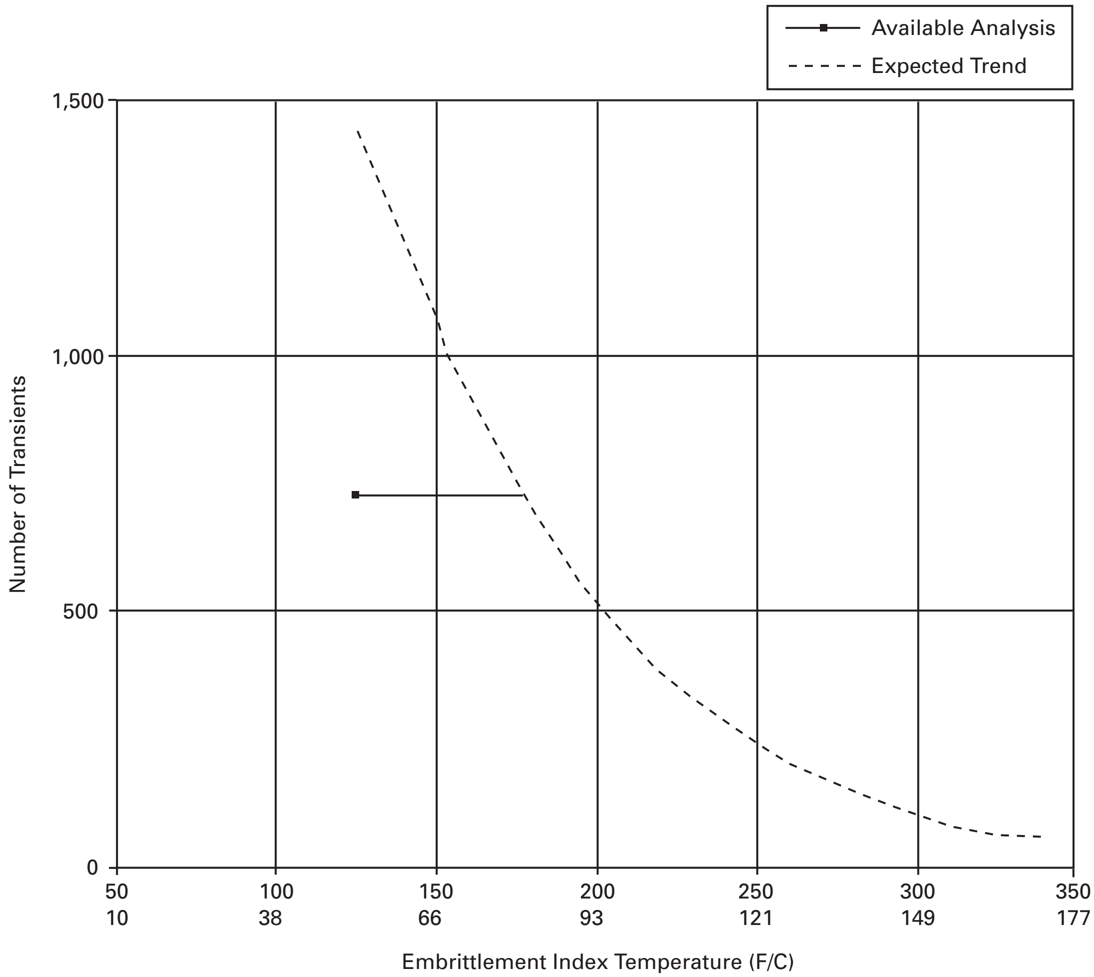
(1) Extent of inspection of all vessel belt line welds is 100% or less.

(2) Inspection practices are as required per Appendix VIII, or when applicable, Regulatory Guide 1.150.[3]

(3) All detectable flaws have been accepted as-is, repaired, or removed from service.

[3] Regulatory Guide 1.150, Revision 1, "Ultrasonic Testing of Reactor Vessel Welds During Preservice Examinations," U.S. Nuclear Regulatory Commission, 1983.

Figure I-1
Allowable Number of Transients



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Approval Date: June 17, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-692
Use of Standard Welding Procedures
Section III, Division 1; Section III, Division 3

Inquiry: Is the groove weld test demonstration specified in Section IX, Article V, QW-510(d) required in order to adopt Standard Welding Procedure Specifications (SWPS) for use in Section III, Divisions 1 and 3 construction?

Reply: It is the opinion of the Committee that the groove weld test demonstration specified in Section IX, Article V, QW-510(d) is not required in order to adopt Standard Welding Procedure Specifications (SWPS) listed in Section IX, Appendix E, for use in Section III, Divisions 1 and 3 construction, provided:

(a) All other requirements of Section IX are met.

(b) This Case shall be shown on the Data Report Form.

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Approval Date: January 16, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-694-2
Evaluation Procedure and Acceptance Criteria for PWR Reactor Vessel Head Penetration Nozzles
Section XI, Division 1

Inquiry: What evaluation procedure may be used to justify continued operation without repair of flawed PWR reactor vessel head penetration nozzles?

Reply: It is the opinion of the Committee that the following evaluation procedure may be used to justify continued operation without repair.

1 SCOPE

Upper and lower head penetration nozzles containing indications may be evaluated to determine acceptability for continued service in accordance with the evaluation procedures and acceptance criteria of this Case. The evaluation procedures and acceptance criteria shall be the responsibility of the Owner. Note that the acceptance standards of IWB-3500 cannot be used to accept indications in this region.

2 EVALUATION PROCEDURES

This evaluation procedure is applicable to head penetration nozzles with 8 in. (200 mm) nominal outside diameter and less. This procedure shall not be used for partial penetration nozzle to vessel (J-groove) welds.

2.1 METHODOLOGY FOR EVALUATION

(a) A flaw growth analysis shall be performed on each detected flaw to determine its maximum growth due to fatigue, stress corrosion cracking or both mechanisms, when applicable, during a specified evaluation period. The minimum time interval for the flaw growth evaluation shall be until the next inspection.

(b) All applicable loadings shall be considered, including weld residual stress, in calculating the crack growth.

(c) The flaw shall be characterized in accordance with the requirements of IWA-3400, including the proximity rules of Fig. IWA-3400-1 for surface flaws.

(d) The flaw shall be projected into both axial and circumferential orientations, and each orientation shall be evaluated. The axial orientation is the same for each nozzle, but the circumferential orientation will vary depending on the angle of intersection of the penetration nozzle with the head. The circumferential orientation is defined in Figure 2-1.

(e) The location of the flaw, relative to the J-groove attachment weld, shall be determined.

(f) The flaw shall be evaluated using analytical procedures, such as those described in Nonmandatory Appendix A, to calculate the following critical flaw parameters:

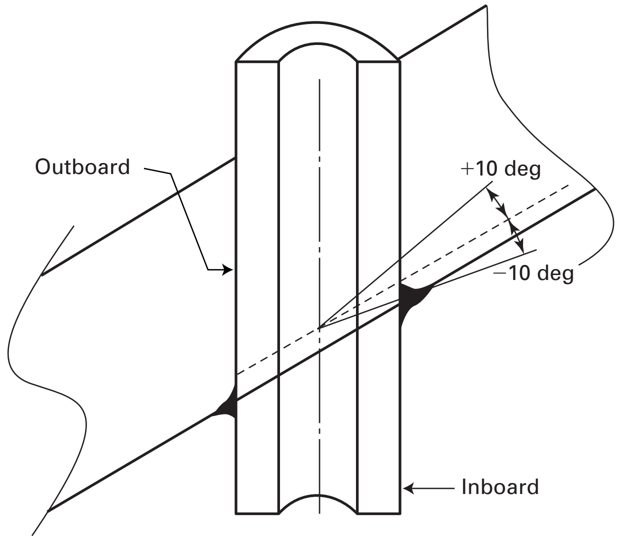
a_f = the maximum depth to which the detected flaw is calculated to grow at the end of the evaluation period

ℓ_f = the maximum length to which the detected flaw is calculated to grow at the end of the evaluation period

3 ACCEPTANCE CRITERIA

The calculated maximum flaw dimensions at the end of the evaluation period shall be compared with the maximum allowable flaw dimensions in Table 3-1.

Figure 2-1
Definition of Circumferential Orientation for Flaw Characterization



GENERAL NOTE: Planar flaws within 10 deg of the plane formed by the J-groove weld root, shown as the dashed line, shall be considered circumferential flaws.

Table 3-1
Reactor Vessel Head Penetration Nozzle Acceptance Criteria

Location	Axial		Circumferential	
	a_f	ℓ_f	a_f	ℓ_f
Inboard of Weld (I.D.) [Note (1)]	t	No Limit	t	0.75 Circ.
At and Outboard of Weld (I.D.)	$0.75t$	No Limit	[Note (2)]	[Note (2)]
Inboard of Weld (O.D.) [Note (1)]	t	No Limit	t	0.75 Circ.
At and Outboard of Weld (O.D.)	[Note (2)]	[Note (2)]	[Note (2)]	[Note (2)]

GENERAL NOTES:
(a) Linear surface flaws of any size in the partial penetration nozzle to vessel (J-groove) welds are not acceptable.
(b) t = wall thickness of head penetration nozzle.
(c) Inboard of the weld is not part of the pressure boundary.
(d) At and outboard of the weld is part of the pressure boundary.

NOTES:
(1) Intersecting axial and circumferential flaws in the nozzle are not acceptable.
(2) Requires case-by-case evaluation. Acceptance criteria shall be justified by the Owner.

NONMANDATORY APPENDIX A EVALUATION OF FLAWS IN PWR REACTOR VESSEL HEAD PENETRATION NOZZLES

A-1000 INTRODUCTION

A-1100 SCOPE

(a) This Appendix provides a method for determining the acceptability for continued service of pressurized water reactor vessel head penetration nozzles. The evaluation methodology is based on the conclusion that head penetration nozzles are ductile materials, where the ability to reach limit load is assured. Flaws shall be evaluated by comparing the maximum flaw dimensions determined by flaw growth analysis with the maximum allowable flaw dimensions at the end of a selected evaluation period.

(b) This Appendix provides rules for flaw modeling and evaluation. Flaw growth analysis is based on growth due to fatigue, stress corrosion cracking (SCC), or both, as appropriate to the flaw under evaluation. The flaw acceptance criteria of 3 provide a structural margin on failure for plastic limit load. The criteria may be used to determine the acceptability of flawed head penetration nozzles for continued service until the next inspection, or conversely, to determine the time interval until a subsequent inspection.

A-1200 PROCEDURE

The following is a summary of the analytical procedure.

(a) Determine the actual flaw configuration from the measured flaw in accordance with Article IWA-3000.

(b) Using A-2000, resolve the actual flaw into circumferential and axial flaw components.

(c) Determine the stresses at the location of the detected flaw for Service Levels A and B conditions including weld residual stresses. For weld residual stresses, the reported yield strength of the head penetration nozzle at room temperature shall be used, if known. If not known, a yield strength of 64 ksi (441 MPa) shall be used. Specified minimum values for the nozzle material shall not be used when determining the weld residual stress.

(d) Using the analytical procedures described in A-3000, determine the flaw parameters a_f and ℓ_f.

(e) Using the flaw parameters a_f and ℓ_f apply the flaw evaluation criteria of 3 to determine the acceptability of the flawed nozzle for continued service.

A-2000 FLAW MODEL FOR ANALYSIS

A-2100 SCOPE

This Appendix provides criteria for flaw shape, consideration of multiple flaws, flaw orientation, and flaw location, which are used in the comparison with the allowable flaw size.

A-2200 FLAW SHAPE

The flaw shall be completely bounded by a rectangular or circumferential planar area in accordance with the methods described in IWA-3300. Figure A-2200-1 and Figure A-2200-2 illustrate flaw characterization for circumferential and axial flaws.

A-2300 PROXIMITY TO CLOSEST FLAW

For multiple neighboring flaws, if the shortest distance between the boundaries of two neighboring flaws is within the proximity limits specified in IWA-3300, the neighboring flaws shall be bounded by a single rectangular or circumferential planar area in accordance with IWA-3300.

A-2400 FLAW ORIENTATION

Flaws that do not lie in either and axial[1] or a circumferential[2] plane shall be projected into these planes in accordance with the provisions of IWA-3340. The axial and circumferential flaws obtained by these projections shall be evaluated separately in accordance with A-3000.

A-2500 FLAW LOCATION

For the purpose of analysis, the flaw shall be considered in its actual location. The applicable stress, including weld residual stress, shall be determined at this location. Surface or subsurface flaw characterizations shall be used, depending on the type of flaw. If the flaw is subsurface but within the proximity limit of IWA-3340 of the surface of the component, the flaw shall be considered a surface flaw and bounded by a rectangular or circumferential planar area with the base on the surface.

[1] A plane parallel to the nozzle axis.

[2] A plane parallel, within ±10 deg, of the plane of the attachment weld, as illustrated in Figure 2-1.

A-3000 ANALYSIS

A-3100 SCOPE

This Appendix provides the methodology for flaw evaluation and describes the procedures to determine the flaw size at the end of the evaluation period.

A-3200 FLAW GROWTH ANALYSIS

(a) The maximum depth a_f and the maximum length ℓ_f to which the detected flaw will grow in the plane of the flaw by the end of the evaluation period shall be determined. This Appendix describes the procedures for the flaw growth analysis.

(b) Crack growth in austenitic head penetration nozzles can be due to cyclic fatigue flaw growth, SCC under sustained load, or a combination of both. Flaw growth analysis shall be performed for normal operating conditions, as defined in Section XI, Nonmandatory Appendix A, A-5200. Flaw growth is governed by the applied stress intensity factor.

A-3210 Stress Intensity Factor Determination

(a) Because the total stresses in this region are typically non-linear, it is recommended that the distribution be fit to a polynomial, as shown in eq. (1).

$$\sigma(x) = A_0 + A_1 x + A_2 x^2 + A_3 x^3 + \ldots + A_m X^m \tag{1}$$

where

A_i = coefficients of the polynomial fit
x = the coordinate distance into the nozzle wall
σ = stress perpendicular to the plane of the crack that produces the maximum K_I along the crack front

The following general expression is used to determine the stress intensity factor, K_I, along the crack front for a surface flaw with the m th order polynomial stress distribution. This general expression uses the influence coefficients, G_j, and shape factor, Q, which may be determined using the procedure defined in Section XI, Nonmandatory Appendix A, A-3000. Alternative procedures may be used to determine the influence coefficients and shape factor. The technical basis for the influence coefficients and shape factor used to calculate the stress intensity factor shall be documented.

$$K_I = \left[\frac{\pi a}{Q}\right]^{0.5} \sum_{j=0}^{m} G_j(a/c, a/t, t/R) A_j a_j \tag{2}$$

where

a = crack depth
c = half-crack length
G_j = influence coefficients
m = polynomial order for defined stress distribution
Q = shape factor
R = inside radius of the nozzle
t = wall thickness

(b) Other methods may be used to calculate the stress intensity factor[3] when technically justified and documented.

A-3220 Flaw Growth Due to Fatigue

(a) The fatigue crack growth rate of Alloy 600 material in PWR water environments can be characterized in terms of the range of the applied stress intensity factor, K_I. This characterization is of the form:

$$da/dN = C_o\,(\Delta K)^n \tag{3}$$

where n and C_o are constants dependent on the material and environmental conditions. These parameters are based on crack growth data obtained from specimens of the same material specification and product form, or suitable alternative. Material variability, environment, test frequency, mean stress, and other variables that affect the data shall be considered.

(b) The fatigue crack growth behavior of Alloy 600 materials is affected by temperature, R ratio ($K_{\min}/K_{\max}$), and environment. Reference fatigue crack growth rates for PWR water environments are given in Section XI, C-8411.

(c) To determine the maximum potential for fatigue flaw growth of the detected flaw during normal operating conditions, a cumulative fatigue flaw growth study of the nozzle shall be performed. The design transients prescribed in the system Design Specification that apply during the evaluation period shall be included. Each transient shall be considered in approximate chronological order as follows:

(1) Determine ΔK, the maximum range of K_I fluctuation associated with the transient.

(2) Find the incremental flaw growth corresponding to ΔK from the fatigue flaw growth rate data.

(3) Update the flaw size and proceed to the next transient.

(d) The above procedure, after all transients have been considered, yields the final flaw size, a_f and ℓ_f at the end of the evaluation period, considering fatigue crack growth alone.

A-3230 Flaw Growth Due to Stress Corrosion Cracking

(a) Flaw growth due to SCC is a function of the material condition, environment, the stress intensity factor due to sustained loading, and the total time that the flaw is exposed to the environment under sustained loading. The procedure for computing SCC flaw growth is based on experimental data relating the flaw growth rate (da/dt) to the sustained load stress intensity factor K_I. Sustained loads resulting from pressure and steady state thermal stresses, as well as weld residual stresses, shall be included. The procedure used for determining the cumulative flaw growth is as follows:

(1) Determine the stress intensity factor K_I for a given steady state stress condition. For an axially-oriented flaw, use the hoop stress through-thickness distribution along the flaw length that produces the maximum K_I at the deepest point.

(2) Calculate the incremental growth of the flaw depth and length corresponding to the period for which the steady state stress is applied. This can be obtained from the relationship between da/dt and K_I. A sufficiently small time interval shall be selected to ensure that the flaw size and the associated K_I value do not change significantly during this interval. Alternatively, the flaw length may be determined by maintaining a fixed flaw aspect ratio, a/ℓ, equal to the original flaw aspect ratio, and all of the length change shall be added at the flaw end with the highest stress.

(3) Update the flaw size.

(4) Continue the flaw growth analysis for the period during which the stress exists until the end of the evaluation period.

(b) The above procedure yields the final flaw size, a_f and ℓ_f, at the end of the evaluation period, considering SCC flaw growth alone.

(c) Reference SCC growth rates for Alloy 600 material in PWR water environments are given in Section XI, Nonmandatory Appendix C, C-8511.

For calculation of crack growth from the outside surface of the nozzle, in the annulus region between the nozzle and the head, a factor of two shall be applied to the crack growth rate above.

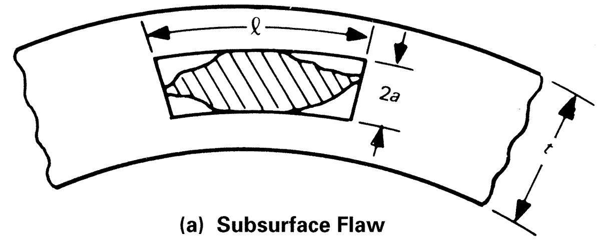
A-3240 Flaw Growth Due to a Combination of Fatigue and SCC

When the service loading and the material and environmental conditions are such that the flaw is subjected to both fatigue and SCC growth, the final flaw size a_f and ℓ_f are obtained by adding the increments in flaw size due to fatigue and SCC computed in accordance with the procedures described above. The cyclic loads shall be considered in approximately chronological order.

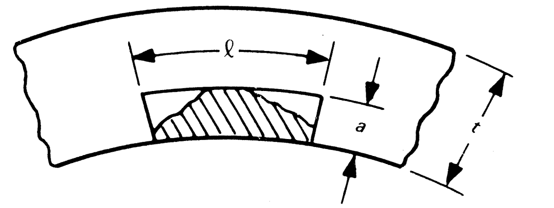
A-3300 FLAW EVALUATION

The allowable end-of-evaluation period flaw sizes are provided in Table 3-1. The allowable flaw sizes specified in these tables are independent of the applied stress level.

Figure A-2200-1
Flaw Characterization—Circumferential Flaws

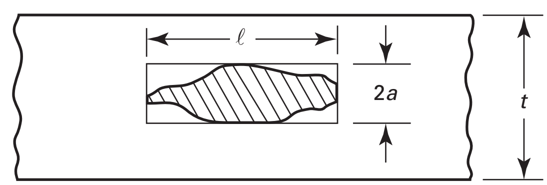


(a) Subsurface Flaw

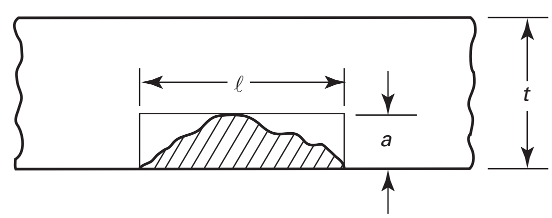


(b) Surface Flaw

Figure A-2200-2
Flaw Characterization—Axial Flaws



(a) Subsurface Flaw



(b) Surface Flaw

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(15) **Approval Date: December 31, 2014**

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-695-1
Qualification Requirements for Dissimilar Metal Piping Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of Mandatory Appendix VIII, Supplement 10, may be used for qualification requirements for dissimilar metal piping welds?

Reply: It is the opinion of the Committee that as an alternative to the requirements of Mandatory Appendix VIII, Supplement 10, the following requirements may be used.

1 SCOPE

This Case is applicable to dissimilar metal piping welds examined from either the inside or outside surface. This Case is not applicable to piping welds containing supplemental corrosion resistant clad (CRC) applied to mitigate intergranular stress corrosion cracking (IGSCC).

2 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accomodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, weld joint configuration, access limitations). The same specimens may be used to demonstrate both detection and sizing qualification.

2.1 GENERAL

The specimen set shall conform to the following requirements.

(a) The minimum number of flaws in a specimen set shall be ten.

(b) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(c) The specimen set shall include the minimum and maximum pipe diameters and thicknesses for which the examination procedure is applicable. Pipe diameters within $^1/_2$ in. (13 mm) of the nominal diameter shall be considered equivalent. Pipe diameters larger than 24 in. (600 mm) shall be considered to be flat. When a range of thicknesses is to be examined, a thickness tolerance of ± 25% is acceptable.

(d) The specimen set shall include examples of the following fabrication conditions:

(1) geometric and material conditions that normally require discrimination from flaws (e.g., counterbore or weld root conditions, cladding, weld buttering, remnants of previous welds, adjacent welds in close proximity, weld repair areas)

(2) typical limited scanning surface conditions shall be included as follows:

(-a) for outside-surface examination, weld crowns, diametrical shrink, single-side access due to nozzle and safe end external tapers

(-b) for inside-surface examination, internal tapers, exposed weld roots, and cladding conditions

(e) Qualification requirements shall be satisfied separately for outside-surface and inside-surface examinations.

2.2 FLAW LOCATION

(a) At least 80% of the flaws shall be contained wholly in the weld or buttering material.

(b) If the specimens in the test set have both austenitic and ferritic sides, at least one flaw and no more than 10% of the total flaws shall be located in ferritic material, and at least one flaw and no more than 10% of the total flaws shall be in austenitic base material.

(c) For single-side qualifications, flaws located on the far side of the weld shall be included in the test set.

2.3 FLAW TYPE

(a) At least 60% of the flaws shall be cracks, and the remainder shall be alternative flaws. Specimens with IGSCC shall be used when available. Alternative flaws shall meet the following requirements:

(1) Alternative flaws shall provide crack-like reflective characteristics and shall only be used when implantation of cracks would produce spurious reflectors that are uncharacteristic of service-induced flaws.

(2) Alternative flaws shall have a tip width no more than 0.002 in. (0.05 mm).

(b) At least 50% of the flaws shall be coincident with areas described in 2.1(d).

2.4 FLAW DEPTH

All flaw depths shall be greater than 10% of the nominal pipe wall thickness. Flaw depths shall exceed the nominal clad thickness when placed in cladding. Flaws in the specimen set shall be distributed as follows:

Flaw Depth (% Wall Thickness)	Minimum Number of Flaws
10–30%	20%
31–60%	20%
61–100%	20%

At least 75% of the flaws shall be in the range of 10 to 60% of wall thickness.

2.5 FLAW ORIENTATION

(a) For other than sizing specimens at least 30% and no more than 70% of the flaws, rounded to the next higher whole number, shall be oriented axially. The remainder of the flaws shall be oriented circumferentially.

(b) Sizing specimens shall meet the following requirements.

(1) Length-sizing flaws shall be oriented circumferentially.

(2) Depth-sizing flaws shall be oriented as in (a).

3 PERFORMANCE DEMONSTRATION

Personnel and procedure performance demonstration tests shall be conducted according to the following requirements.

(a) For qualifications from the outside surface, the specimen inside surface and specimen identification shall be concealed from the candidate. When qualifications are performed from the inside surface, the flaw location and specimen identification shall be obscured to maintain a "blind test." All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.

(b) For single-side qualifications, the specimen set shall contain a range of access restrictions.

(1) For components that have scan access from both the ferritic and austenitic sides, qualification shall be performed from the austenitic side of the weld only.

(2) For components with no austenitic side, or for which scan access is limited to the ferritic side only, qualification may be performed from the ferritic side.

3.1 DETECTION TEST

(a) The specimen set shall include detection specimens that meet the following requirements:

(1) Specimens shall be divided into grading units.

(-a) Each grading unit shall include at least 3 in. (76 mm) of weld length.

(-b) The end of each flaw shall be separated from an unflawed grading unit by at least 1 in. (25 mm) of unflawed material. A flaw may be less than 3 in. (76 mm) in length.

(-c) The segment of weld length used in one grading unit shall not be used in another grading unit.

(-d) Grading units need not be uniformly spaced around the pipe specimen.

Table 1
Personnel Performance Demonstration Detection Test Acceptance Criteria

Detection Test Acceptance Criteria		False Call Acceptance Criteria	
No. of Flawed Grading Units	Minimum Detection Criteria	No. of Unflawed Grading Units	Maximum No. of False Calls
10	8	15	2
11	9	17	3
12	9	18	3
13	10	20	3
14	10	21	3
15	11	23	3
16	12	24	4
17	12	26	4
18	13	27	4
19	13	29	4
20	14	30	5

(2) Personnel performance demonstration detection test sets shall be selected from Table 1. The number of unflawed grading units shall be at least $1^1/_2$ times the number of flawed grading units.

(3) Flawed and unflawed grading units shall be randomly mixed.

(b) Examination equipment and personnel are qualified for detection when personnel performance demonstrations satisfy the acceptance criteria of Table 1 for both detection and false calls.

3.2 LENGTH-SIZING TEST

(a) Each reported circumferential flaw in the detection test shall be length-sized.

(b) When the length-sizing test is conducted in conjunction with the detection test, and less than ten circumferential flaws are detected, additional specimens shall be provided to the candidate such that at least ten flaws are sized. The regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region, provided it does not compromise the sample or data set confidentiality.

(c) For a separate length-sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the length of the flaw in each region, provided it does not compromise the sample or data set confidentiality.

(d) Examination procedures, equipment, and personnel are qualified for length-sizing when the RMS error of the flaw length measurements, as compared to the true flaw lengths, do not exceed 0.75 in. (19 mm).

3.3 DEPTH-SIZING TEST

(a) The depth-sizing test may be conducted separately or in conjunction with the detection test. For a separate depth-sizing test, the regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region, provided it does not compromise the sample or data set confidentiality.

(b) When the depth-sizing test is conducted in conjunction with the detection test, and less than ten flaws are detected, additional specimens shall be provided to the candidate such that at least ten flaws are sized. The regions of each specimen containing a flaw to be sized shall be identified to the candidate. The candidate shall determine the maximum depth of the flaw in each region, provided it does not compromise the sample or data set confidentiality.

(c) For qualifications from the outside-surface, examination procedures, equipment, and personnel are qualified for depth sizing if the RMS error of the flaw depth measurements, as compared to the true flaw depths, does not exceed 0.125 in. (3 mm).

(d) For qualifications from the inside-surface, examination procedures, equipment, and personnel are qualified for depth sizing if the RMS error of the flaw depth measurements, as compared to the true flaw depths, does not exceed 0.125 in. (3 mm) for piping less than 2.1 in. (54 mm) in thickness, or 0.250 in. (6 mm) for piping 2.1 in. (54 mm) or greater in thickness.

4 PROCEDURE QUALIFICATION

Procedure qualification shall include the following additional requirements.

(a) The specimen set shall include the equivalent of at least three personnel performance demonstration test sets. Successful personnel performance demonstrations may be combined to satisfy these requirements.

(b) Detectability of all flaws in the procedure qualification test set that are within the scope of the procedure shall be demonstrated. Length and depth sizing shall meet the requirements of 3.1, 3.2, and 3.3.

(c) At least one successful personnel performance demonstration shall be performed.

(d) To qualify new values of essential variables, at least one personnel performance demonstration test set is required. The acceptance criteria of (b) shall be met.

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Approval Date: May 7,2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-696-1
Qualification Requirements for Mandatory Appendix VIII Piping Examinations Conducted From the Inside Surface
Section XI, Division 1

Inquiry: What alternatives to the requirements of Mandatory Appendix VIII, may be used to complete Supplements 2, 3, and 10 qualifications for piping examinations that are conducted from the inside surface?

Reply: It is the opinion of the Committee that as an alternative to the requirements of Mandatory Appendix VIII, Supplements 2, 3, and 10, performed from the inside surface the following requirements may be used to expand successful Supplement 10 qualifications in conjunction with selected aspects of Supplements 2 and 3.

1 SCOPE

This Case is applicable to wrought austenitic, ferritic and dissimilar metal piping welds examined from the inside surface. This Case provides for expansion of Supplement 10 qualifications to permit coordinated qualification for Supplements 2 and 3.

2 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, access limitations). The same specimens may be used to demonstrate both detection and sizing qualification.

2.1 GENERAL

The specimen set shall conform to the following requirements.

(a) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(b) The specimen set shall include the minimum and maximum pipe diameters and thicknesses for which the examination procedure is applicable. Applicable tolerances are provided in Supplements 2, 3, and 10.

(c) The specimen set shall include examples of the following fabrication conditions:

(1) geometric and material conditions that normally require discrimination from flaws (e.g., counterbore or weld root conditions, cladding, weld buttering, remnants of previous welds, adjacent welds in close proximity, and weld repair areas);

(2) typical limited scanning surface conditions (e.g., internal tapers, exposed weld roots, and cladding conditions).

2.2 SUPPLEMENT 2 FLAWS

(a) At least 70% of the flaws shall be cracks, and the remainder shall be alternative flaws.

(b) Specimens with IGSCC shall be used when available.

(c) Alternative flaws, if used, shall provide crack-like reflective characteristics and shall comply with the following:

(1) Alternative flaws shall be used only when implantation of cracks produces spurious reflectors that are uncharacteristic of service-induced flaws.

(2) Alternative flaws shall have a tip width of no more than 0.002 in. (0.05 mm).

2.3 SUPPLEMENT 3 FLAWS

Supplement 3 flaws shall be mechanical or thermal fatigue cracks.

2.4 DISTRIBUTION

The specimen set shall contain a representative distribution of flaws. Flawed and unflawed grading units shall be randomly mixed.

3 PERFORMANCE DEMONSTRATION

Personnel and procedure performance demonstration tests shall be conducted according to the following requirements.

(a) The same essential variable values, or, when appropriate, the same criteria for selecting values as demonstrated in Supplement 10 shall be used.

(b) The flaw location and specimen identification shall be obscured to maintain a "blind test."

(c) All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.

3.1 DETECTION TEST

(a) The specimen set for Supplement 2 qualification shall include at least five flawed grading units and ten unflawed grading units in austenitic piping. A maximum of one flaw shall be oriented axially.

(b) The specimen set for Supplement 3 qualification shall include at least three flawed grading units and six unflawed grading units in ferritic piping. A maximum of one flaw shall be oriented axially.

(c) Specimens shall be divided into grading units.

(1) Each grading unit shall include at least 3 in. (76 mm) of weld length.

(2) The end of each flaw shall be separated from an unflawed grading unit by at least 1 in. (25 mm) of unflawed material. A flaw may be less than 3 in. (76 mm) in length.

(3) The segment of weld length used in one grading unit shall not be used in another grading unit.

(4) Grading units need not be uniformly spaced around the pipe specimen.

(d) All grading units shall be correctly identified as being either flawed or unflawed.

3.2 LENGTH-SIZING TEST

(a) The coordinated implementation shall include the following requirements for personnel length-sizing qualification.

(b) The specimen set for Supplement 2 qualification shall include at least four flaws in austenitic material.

(c) The specimen set for Supplement 3 qualification shall include at least three flaws in ferritic material.

(d) Each reported circumferential flaw in the detection test shall be length sized. If only length-sizing is being tested, the regions of each specimen containing a flaw to be sized may be identified to the candidate. The candidate shall determine the length of the flaw in each region.

(e) Supplement 2 or Supplement 3 examination procedures, equipment, and personnel are qualified for length-sizing if the flaw lengths estimated by ultrasonics, as compared with the true lengths, do not exceed 0.75 in. (19 mm) RMS, when they are combined with a successful Supplement 10 qualification.

3.3 DEPTH-SIZING TEST

The coordinated implementation of Supplements 2 and 10 shall include the following requirements for personnel depth sizing qualification. Depth sizing qualification for ferritic piping shall be performed in accordance with Supplement 3.

(a) The specimen set for Supplement 2 qualification shall include at least four circumferentially oriented flaws in austenitic material.

(b) For a separate depth-sizing test, the regions of each specimen containing a flaw to be sized may be identified to the candidate. The candidate shall determine the depth of the flaw in each region.

(c) Supplement 2 examination procedures, equipment, and personnel are qualified for depth-sizing if the RMS error of the flaw depth measurements as compared to the true flaw depths, does not exceed 0.125 in. (3 mm) for piping less than 2.1 in. (54 mm) in thickness, or 0.250 in. (6 mm) for piping 2.1 in. (54 m) or greater in thickness, when they are combined with a successful Supplement 10 qualification.

4 PROCEDURE QUALIFICATION

Procedure qualification shall include the following additional requirements.

(a) The specimen set shall include the equivalent of at least three personnel performance demonstration test sets. Successful personnel performance demonstration may be combined to satisfy these requirements.

(b) Detectability of all flaws in the procedure qualification test set that are within the scope of the procedure shall be demonstrated. Length and depth sizing shall meet the requirements of 3.1, 3.2, and 3.3.

(c) At least one successful personnel performance demonstration shall be performed.

(d) To qualify new values of essential variables, at least one personnel performance demonstration is required. The acceptance criteria of (b) shall be met.

Approval Date: November 18, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-697
Pressurized Water Reactor (PWR) Examination and Alternative Examination Requirements for Pressure Retaining Welds in Control Rod Drive and Instrument Nozzle Housings
Section XI, Division 1

Inquiry: What examination requirements may be used for PWR pressure retaining welds in In-Core Instrumentation (ICI) housings > NPS 2 (DN 50) and alternative examination requirements for pressure retaining welds in Control Rod Drive (CRD) housings contained in Table IWB-2500-1, Examination Category B-O?

Reply: It is the opinion of the Committee that for PWR pressure retaining welds in ICI housings > NPS 2 (DN 50) the following examination requirements may be applied and as an alternative to the examination requirements for pressure retaining welds in CRD housings contained in Table IWB-2500-1, Examination Category B-O, the following examination requirements may be applied:

(a) A volumetric or inside surface examination;

(b) Welds in 10% of the ICI housings shall be selected for examination each inspection interval and it is permissible to defer these examinations to the end of the interval;

(c) The surface examination area on the inside surface of each ICI or CRD housing weld shall cover the area from B-C depicted in Fig. IWB-2500-18 from the 1977 Edition up to and including the 1992 Edition with the 1992 Addenda and C-D from the 1993 Addenda up to and including the 2001 Edition with the 2003 Addenda; and

(d) All other requirements of Table IWB-2500-1, Examination Category B-O, shall apply.

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Approval Date: November 18, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-698
Design Stress Intensities and Yield Strength Values for UNS N06690 With a Minimum Specified Yield Strength of 35 ksi (240 MPa), Class 1 Components
Section III, Division 1

Inquiry: Is it permissible in the construction of Class 1 components conforming to the requirements of Section III, Division 1, to use a nickel-chromium-iron UNS N06690 hot-worked and annealed condition with minimum yield strength of 35 ksi (240 MPa) otherwise conforming to material Specification SB-167?

Reply: It is the opinion of the Committee that the material specified in the Inquiry may be used in the construction of Class 1 components under the rules of Section III, Division 1, provided the following additional requirements are met.

(a) The design stress intensity and yield strength values shall be as shown in Table 1.

(b) The outer diameter is equal to or less than NPS 5 (DN 125).

Table 1
Design Stress Intensity and Yield Strength Values

Temperature °F	Design Stress Intensity Values, S_m, ksi (MPa)	Yield Strength, ksi (MPa)
100	23.3 (161.5)	35.0 (240.0)
200	23.3 (161.5)	31.6 (216.2)
300	23.3 (161.5)	29.8 (204.0)
400	23.3 (161.5)	28.7 (198.5)
500	23.3 (161.5)	27.8 (193.0)
600	23.3 (161.5)	27.6 (191.0)
700	23.3 (161.5)	27.6 (191.0)
800	23.3 (161.5)	27.6 (191.0)

(c) For external pressure the required thickness shall be determined in accordance with NB-3133 using Fig. NFN-4 in Section II, Part D, Subpart 3.

(d) Welding procedures and performance qualification shall be in accordance with Section IX and this Code Case. The material shall be considered to be P-No. 43.

(e) This Case number shall be shown on the Data Report for the component and the marking and certification of the material.

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Approval Date: January 5, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-699
Use of Titanium Grade 2 (UNS R50400) Tube and Bar, and Grade 1 (UNS R50250) Plate and Sheet for Class 1 Construction
Section III, Division 1

Inquiry: What design fatigue curve is appropriate for the design of SB-338 Grade 2 (UNS R50400) titanium tubing, SB-348 Grade 2 titanium bar and SB-265 Grade 1 (UNS R50250) titanium plate in the construction of Section III, Division 1, Class 1 components?

Reply: It is the opinion of the Committee that for Section III, Division 1, Class 1 construction that the following fatigue design curves shall be used for fatigue analysis of the materials defined in the Inquiry:

(a) Fatigue analysis shall be performed using the fatigue design curve in Figure 1 for Grade 1 (UNS R50250) materials. Tabulated values for fatigue design curve for titanium Grade 1 are given in Table 1.

(b) Fatigue analysis shall be performed using the fatigue design curve in Figure 2 for Grade 2 (UNS R50400) materials. Tabulated values for fatigue design curve for titanium Grade 2 are given in Table 2.

(c) The use of this Case number shall appear on the Data Report.

Figure 1
Fatigue Design Curve Titanium Grade 1 For Temperatures Not Exceeding 600°F (316°C)

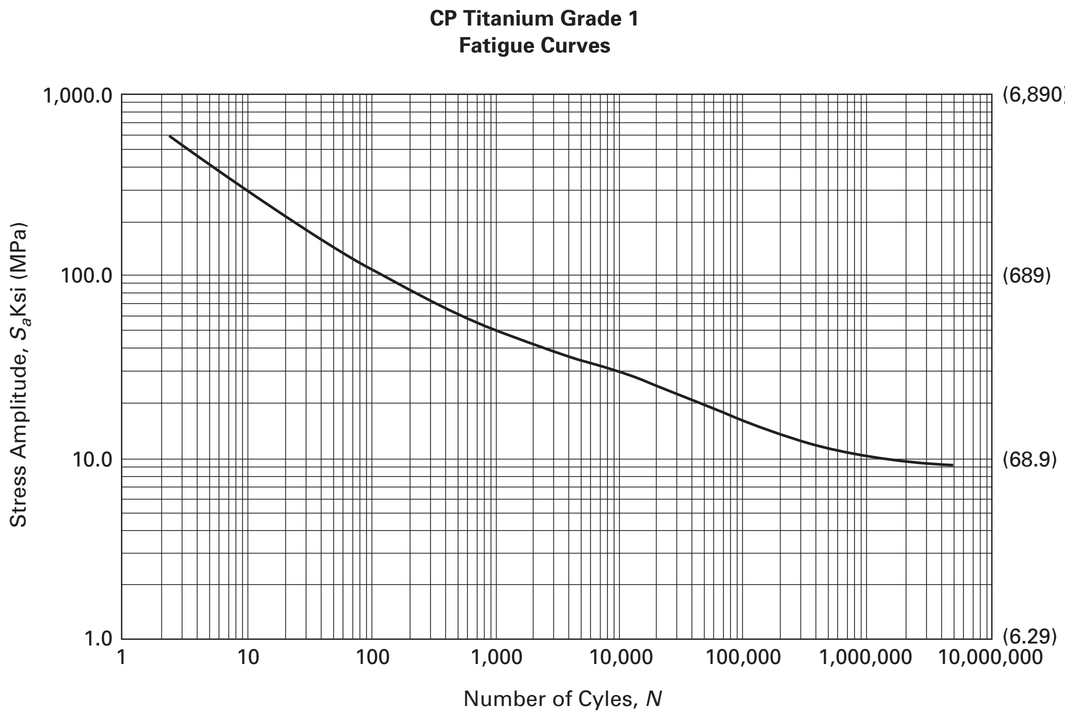

Figure 2
Fatigue Design Curve Titanium Grade 2 For Temperatures Not Exceeding 600°F (316°C)

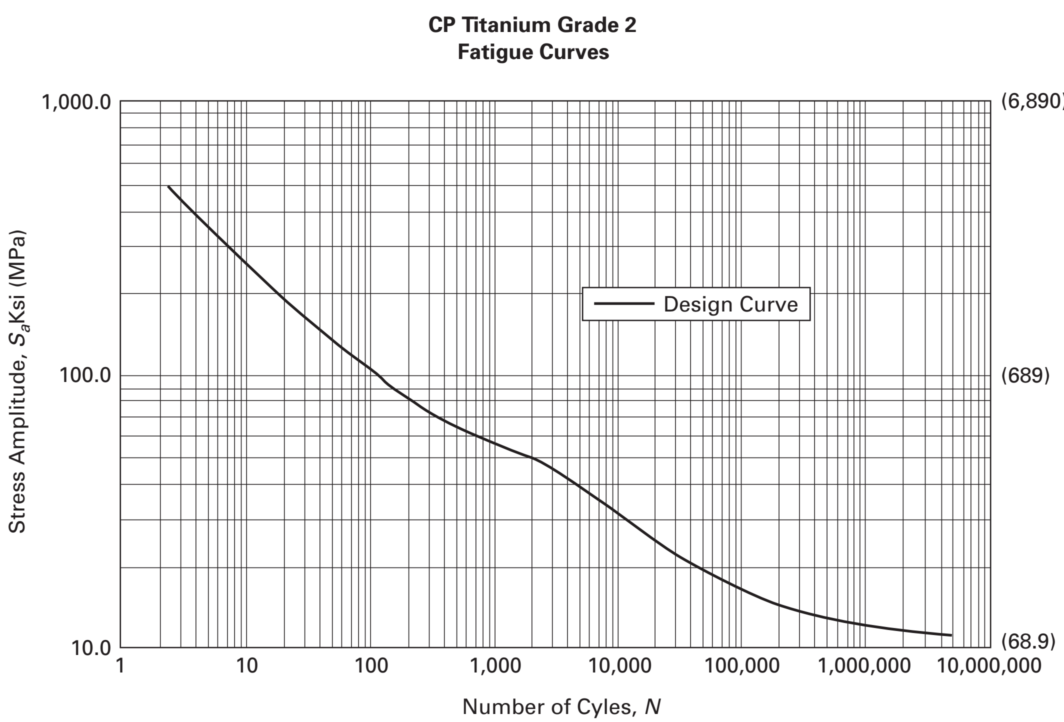

Table 1
Tabulated Values of Fatigue Design Allowable for CP Titanium Grade 1

Cycles (N)	Design (S_a) (ksi)	Design (S_a) (MPa)
10	295	2 034
20	215	1 482
50	144.4	995
100	109.0	751
200	83.7	577
500	61.4	423
1,000	50.2	346
2,000	42.2	291
5,000	35.1	242
10,000	30.7	212
20,000	25.0	172.4
50,000	20.1	138.6
100,000	16.15	111.3
200,000	13.60	93.8
500,000	11.50	79.3
1,000,000	10.50	72.4
2,000,000	9.80	67.6
5,000,000	9.20	63.4

Table 2
Tabulated Values of Fatigue Design Allowable for CP Titanium Grade 2

Cycles (N)	Design (S_a) (ksi)	Design (S_a) (MPa)
10	258	1 779
20	192.0	1 324
50	133.2	918
100	103.6	714
200	82.6	569
500	64.0	441
1,000	54.6	376
2,000	48.0	331
5,000	38.6	266
10,000	32.0	221
20,000	25.5	175.8
50,000	19.34	133.3
100,000	16.52	113.9
200,000	14.66	101.1
500,000	13.10	90.3
1,000,000	12.34	85.1
2,000,000	11.82	81.5
5,000,000	11.36	78.3

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Approval Date: November 18, 2003

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-700
Alternative Rules for Selection of Classes 1, 2, and 3 Vessel Welded Attachments for Examination
Section XI, Division 1

Inquiry: What alternative rules may be used in lieu of those required by Table IWB-2500-1, Table IWC-2500-1, and Table IWD-2500-1, Examination Categories B-K and C-C, footnote 4, and Examination Category D-A, footnote 3, for selection of vessel welded attachments for examination?

Reply: It is the opinion of the Committee that for multiple vessels of similar design, function and service, only one welded attachment of only one of the multiple vessels shall be selected for examination. For single vessels, only one welded attachment shall be selected for examination. The attachment selected for examination on one of the multiple vessels or the single vessel, as applicable, shall be an attachment under continuous load during normal system operation, or an attachment subject to a potential intermittent load (seismic, water hammer, etc.) during normal system operation if an attachment under continuous load does not exist.

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Approval Date: February 20, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-702
Alternative Requirements for Boiling Water Reactor (BWR) Nozzle Inner Radius and Nozzle-to-Shell Welds
Section XI, Division 1

Inquiry: What alternative to the inservice inspection requirements of Table IWB-2500-1, Examination Category B-D may be used for BWR nozzle inner radii and nozzle-to-shell welds?

Reply: It is the opinion of the Committee that for BWR's examination of a minimum of 25% of nozzle inner radii and nozzle-to-shell welds, including at least one nozzle from each system and nominal pipe size, may be performed for Table IWB-2500-1, Examination Category B-D Item Nos. B3.10, B3.20, B3.90, and B3.100. VT-1 visual examination may be used in lieu of volumetric examination for Item Nos. B3.20 and B3.100. This Case excludes BWR feedwater nozzles and control rod drive return line nozzles. It is a requirement of this Case that the provisions of Appendix VIII in the 1989 Addenda or later Editions and Addenda be used for examinations.

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Approval Date: May 4, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-703
Use of Strain Hardened Austenitic Material at Lower Design Stress Values for Class 1 Valves
Section III, Division 1

Inquiry: Under what rules may materials for instrument line valves NPS 1 (DN 25) and smaller made to a specification other than those listed in Section II, Part D, Subpart 1, Table 2A, namely SA-479 Type 316 (UNS S31600), solution annealed condition and strain hardened to Level 2, be used for these products, for Section III, Division 1, Class 1 construction?

Reply: It is the opinion of the Committee that material for instrument line valves NPS 1 (DN 25) and smaller, made to SA-479 Type 316 (UNS S31600), solution annealed condition and strain hardened to Level 2, which is not listed in Section II, Part D, Subpart 1, Table 2A, can be used for these products, for Section III, Division 1, Class 1 construction, provided the requirements of (a) through (e) are met:

(a) The material meets all the mechanical property requirements, including minimum elongation in 2 in. (50 mm) of Table 2, SA-479, for Type 316 (UNS S31600), annealed condition, except that strain hardening after solution annealing is required to Level 2

(b) The design stress intensity, tensile strength, and yield strength values of the annealed condition shown in Tables 1 and 1M shall be used in their design to satisfy the requirements of NB-3200.

(c) The minimum tensile strength for welding procedure qualification tests in accordance with Section IX shall meet the requirements for SA-479 Type 316 (UNS S31600), annealed condition.

(d) All other requirements of Section III, Division 1, Class 1 materials shall be met.

(e) This Case number shall be identified on the Material Organization's certification for the material and on the valve Data Report Form.

Table 1
Design Stress Intensity, Tensile and Yield Strength Values, U.S. Customary Units

For Metal Temperature Not Exceeding °F	Design Stress Intensity Values, S_m, ksi	Tensile Strength, S_u, ksi	Yield Strength, S_y, ksi
−20 to 100	20.0	75.0	30.0
200	20.0	75.0	25.9
300	20.0	72.9	23.4
400	19.3	71.9	21.4
500	18.0	71.8	20.0
600	17.0	71.8	18.9
650	16.6	71.8	18.5
700	16.3	71.8	18.2
750	16.1	71.5	17.9
800	15.9	70.8	17.7

Table 1M
Design Stress Intensity, Tensile and Yield Strength Values, SI

For Metal Temperature Not Exceeding °C	Design Stress Intensity Values, S_m, MPa	Tensile Strength, S_u, MPa	Yield Strength, S_y, MPa
−30 to 40	138	517	207
65	138	...	189
100	138	516	176
150	138	502	161
200	134	496	148
250	126	495	139
300	119	495	132
325	116	495	129
350	114	495	127
375	112	495	125
400	111	493	123
425	110	489	122
450[Note (1)]	108	482	121

NOTE:
(1) These values are provided for interpolation purposes only. The maximum design temperature for this material is 800°F (427°C)

Approval Date: October 12, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-705
Evaluation Criteria for Temporary Acceptance of Degradation in Moderate Energy Class 2 or 3 Vessels and Tanks
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-3000, IWC-3120, and IWD-3120 may be used for temporary acceptance of degradation, including through-wall degradation, in moderate energy Class 2 or 3 vessels and tanks, including heat exchangers?

Reply: It is the opinion of the Committee that the following alternate requirements to IWA-3000, IWC-3120, and IWD-3120 may be used to accept degradation, including through-wall degradation, in moderate energy Class 2 or 3 vessels and tanks, including heat exchangers, for a limited time not exceeding the evaluation period as defined in this Case.

1 SCOPE

(a) The provisions of this Case apply to vessels and tanks, including heat exchangers, classified by the Owner as Class 2 or 3, and whose maximum operating temperature does not exceed 200°F (93°C) and whose maximum operating pressure does not exceed 275 psig (1.9 MPa).

(b) The provisions of this Case define the requirements to demonstrate the structural integrity of the vessel or tank but not the consequences of leakage. The Owner shall determine what constitutes acceptable leakage, evaluate the consequences of leakage, and determine system operability.

(c) The provisions of this Case provide procedures and criteria for evaluating failure conditions for fracture and overpressure (blowout). The Owner shall verify that other potential failure modes are not relevant for the observed degradation (e.g., buckling).

(d) The evaluation period is the operational time for which the temporary acceptance criteria are satisfied (i.e., evaluation period ≤ τ_{allow}), but not greater than 26 months from the initial discovery of the condition.

(e) The following conversion factors from U.S. Customary to SI units shall be used:

$$1 \text{ in./hr} = 7.056 \times 10^{-3} \text{ mm/sec}$$
$$1 \text{ ksi}\sqrt{\text{in.}} = 1.099 \text{ MPa}\sqrt{\text{m}}$$
$$°\text{F} = 1.8\ (°\text{C}) + 32$$

2 PROCEDURE

The procedures for use of this Case are provided in this Section, and a flowchart of the overall methodology is provided as Figure 1.

2.1 DISCOVERY OF DEGRADATION OR LEAKAGE

(a) Evaluations and examination results shall be documented in accordance with IWA-6300.

(b) Leakage shall meet the applicable leakage limits for the vessel or tank. The Owner shall determine acceptable leakage limits and evaluate the consequences of leakage and system operability.

2.2 DEGRADATION CHARACTERIZATION

(a) The vessel or tank shall be examined to characterize degradation in the affected section in accordance with IWA-3300, unless the alternative methods of (e) or 2.4(a) are implemented. The Owner shall develop the scope and methods of examination to characterize the degradation for the structural evaluation procedures of this Case.

(b) If multiple degradation locations, including irregular (compound) shapes are detected, their interaction in a given cross section shall be accounted for in the structural integrity evaluation in accordance with IWA-3330.

(c) For degradation that intersects openings in the vessel or tank (e.g., nozzle penetrations), the effect of the opening discontinuity shall be included in the fracture evaluation.

(d) Nonplanar degradation shall be projected into equivalent planar flaws in accordance with IWA-3340 for fracture evaluation purposes and characterized in terms of extent of degradation in accordance with Figure 2 or Figure 4 for part-through-wall or through-wall degradation, respectively.

(e) The Owner shall determine methods for estimating the geometry of degradation in inaccessible or uninspectable regions, e.g., size correlated to leakage rate. If using

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.

Figure 1
Overall Methodology

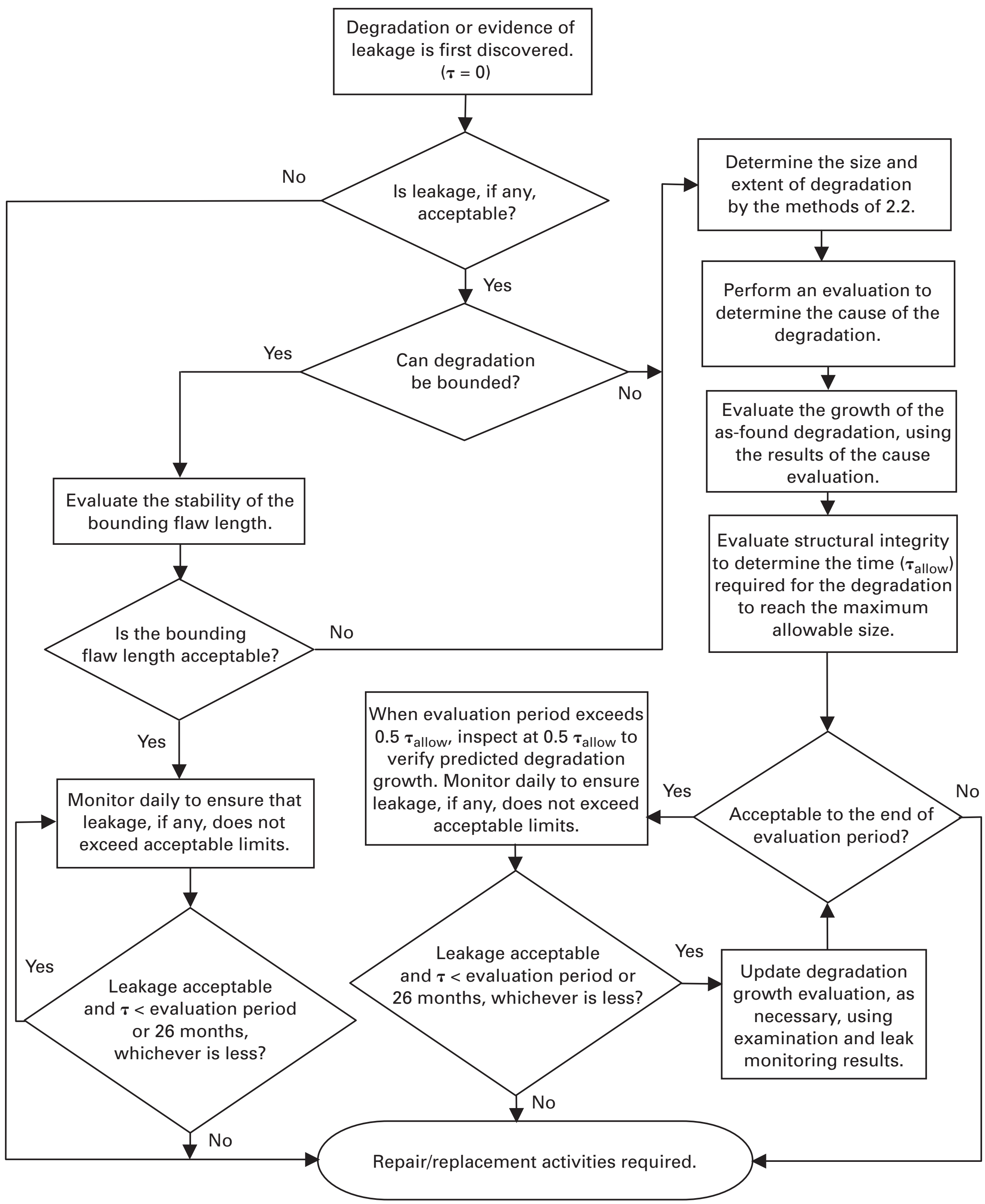
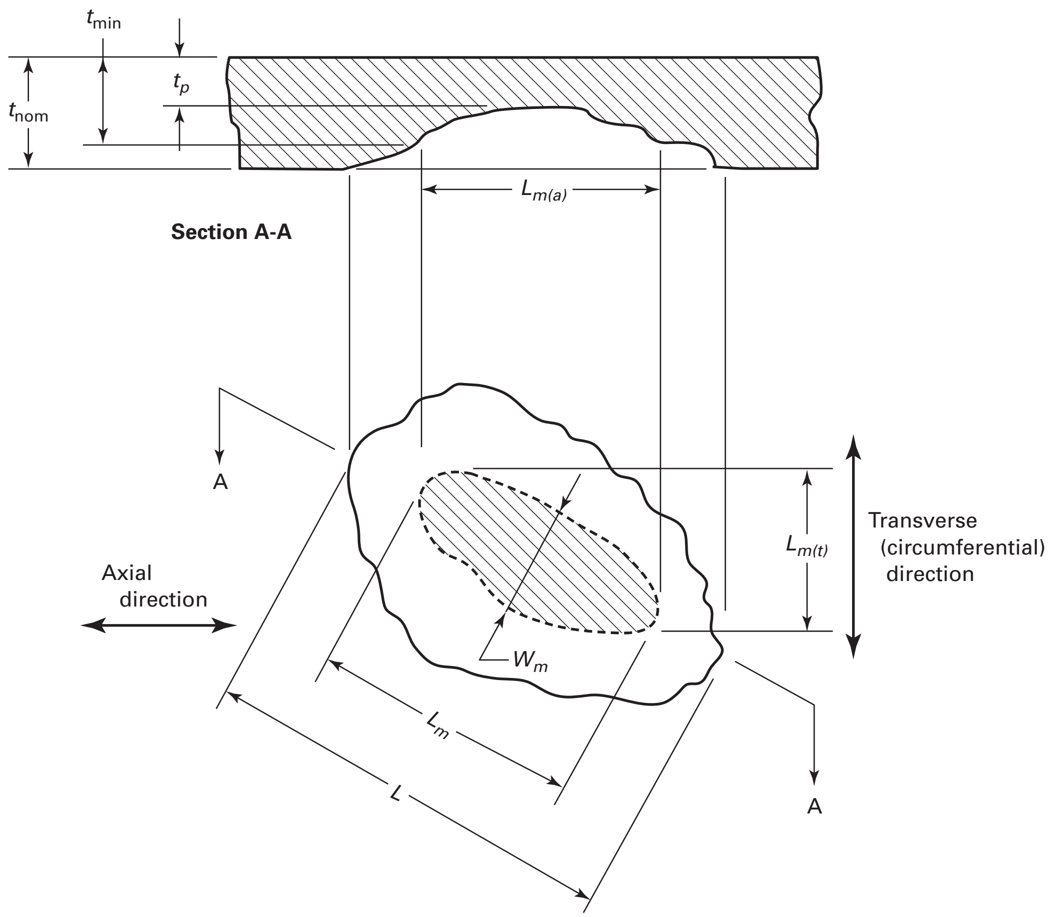


Figure 2
Illustration of Nonplanar Part-Through-Wall Degradation Due to Wall Thinning



this approach to determine a maximum flaw size, such as a size correlated to an observed leak rate, a factor of 2 shall be applied to the flaw dimensions.

2.3 EVALUATION METHODOLOGY

Degradation shall be evaluated as planar in accordance with the requirements of 2.4 or 2.5. To prevent bursting, nonplanar part-through-wall degradation shall also be evaluated in accordance with the requirements of 2.6.

2.4 BOUNDING FLAW EVALUATION

(a) A bounding flaw length shall be assumed for structural evaluation purposes, based on one or more of the following limiting factors:

(1) geometric limitations (e.g., overlapping welded plates in tanks which could limit degradation propagation or the ability to detect the degradation beyond a specified length)

(2) stress limitations (e.g., degradation growing into a decreasing stress field such that growth is terminated)

(3) environmental limitations (e.g., degradation growing into a nonaggressive environment)

(b) The bounding flaw shall be assumed to be a planar through-wall flaw over its entire length.

(c) A structural integrity evaluation shall be performed to determine acceptance of the bounding flaw. Acceptable methods for the required evaluation are provided in 3.1, and acceptance criteria are provided in 5. For bounding flaws that do not meet the acceptance criteria, the provisions of 2.5 shall be met.

(d) Bounding flaws that meet the acceptance criteria of 5 shall be monitored daily to ensure that leakage does not exceed leakage limits in accordance with 2.1(b) and for trending purposes. If leakage limits are exceeded within the evaluation period, structural integrity shall be reconfirmed and leakage limiting measures applied, or repair/replacement activities shall be performed.

(e) Repair/replacement activities shall be performed no later than the end of the evaluation period. Repair/replacement activities shall be in accordance with

IWA-4000 or IWA-7000, respectively, in editions and addenda prior to the 1991 Addenda or in accordance with IWA-4000 in the 1991 Addenda or later.

2.5 EVALUATION OF MEASURED FLAWS

(a) For degradation that cannot be bounded or for bounding flaws that do not meet the acceptance criteria of 5, the size and extent of degradation shall be determined by methods of 2.2.

(b) An evaluation shall be performed to determine the cause of the degradation (e.g., stress corrosion, fatigue, fabrication defects, etc.).

(c) A degradation-growth evaluation shall be performed to predict the time (τ_{allow}) at which the detected degradation will grow to the maximum structurally allowable size in accordance with the acceptance criteria of 5. The growth evaluation shall account for the results of the evaluation in accordance with (b) and the relevant growth mechanisms, in accordance with 4.

(d) For degradation evaluated to be structurally acceptable for the evaluation period in accordance with 3, examination at 0.5 τ_{allow} shall be performed to verify the predicted growth. If τ_{allow} exceeds twice the time to the end of the evaluation period, examination is not required.

(e) Daily leakage monitoring (e.g., vessel or tank level indications, sump measurements, etc.) shall be performed to ensure that leakage, if any, does not exceed the acceptance limits, in accordance with 2.1(b), and for trending purposes. If acceptance limits are exceeded, repair/replacement activities shall be performed.

(f) The degradation growth evaluation of (c) shall be updated when new leakage monitoring or examination results become available, considering all previous examination and leakage monitoring results. If the updated flaw size from examination or the predicted flaw size from the flaw growth analysis exceeds the acceptance criteria of 5, repair/replacement activities shall be performed no later than the end of the updated evaluation period.

(g) Repair/replacement activities shall be performed no later than the end of the evaluation period. Repair/replacement activities shall be in accordance with IWA-4000 or IWA-7000, respectively, in editions and addenda prior to the 1991 Addenda or in accordance with IWA-4000 in the 1991 Addenda or later.

2.6 NONPLANAR PART-THROUGH-WALL DEGRADATION CONSIDERING DEGRADATION GROWTH

In addition to the requirements of 2.4 or 2.5 above, nonplanar part-through-wall degradation shall be evaluated in accordance with the requirements of 3.3.

3 STRUCTURAL INTEGRITY EVALUATION

The structural integrity of the degraded vessel or tank shall be evaluated as specified below. The Owner shall also verify that other potential failure modes are not relevant for the observed degradation.

3.1 BOUNDING AND MEASURED FLAW EVALUATIONS

(a) The stresses at the degradation location shall include the appropriate combination of applied loadings for Levels A, B, C, and D and test conditions from the Design Specification for the vessel or tank being evaluated. These shall include, as appropriate, deadweight, pressure, hydrostatic, thermal, and safe shutdown earthquake (SSE), including seismic sloshing. Stresses from external loadings, such as piping reactions for degradation near nozzle penetrations and wind loading, shall also be included.

(b) Residual stresses resulting from original welding and any rework, bolt-up stresses, and cladding-induced stresses shall be evaluated in accordance with the methods of A-3200.[1]

(c) If there is no stress analysis for the degradation location, the applied stress shall be assumed to be the yield stress.

(d) Inaccessible degradation shall be assumed to be located in the region of highest principal tensile stress within that portion of the vessel or tank. If it can be determined that the degradation is confined to a specific region, other regions may be disregarded.

(e) The stress intensity factor for the stresses determined in (a) through (d) shall be calculated using the methods of A-3000[1] and meet the acceptance criteria of 5.

3.2 FLAW EVALUATIONS CONSIDERING DEGRADATION GROWTH

(a) For degradation considering growth in accordance with 2.5, the time for growth to the allowable size (τ_{allow}) shall be calculated in accordance with the acceptance criteria of 5 based on the stress intensity factor determined in 3.1(e) for planar flaws.

(b) For nonplanar through-wall degradation along a portion of the thinned wall, as illustrated in Figure 4, the degradation, including growth through the end of the evaluation period, shall be evaluated as two independent planar through-wall flaws, one oriented in the axial direction and the other oriented in the circumferential direction. The minimum wall thickness, t_{min}, shall be determined using eq. 3.3(a)(1). The through-wall lengths for each flaw are the lengths, L_{axial} and L_{circ}, where the local wall thickness is equal to t_{min} as projected along the axial and circumferential planes, as shown in Figure 4.

[1] Reference to Appendices A and C shall apply to Appendices A and C of the 2004 Edition with the 2005 Addenda.

3.3 NONPLANAR PART-THROUGH-WALL DEGRADATION CONSIDERING DEGRADATION GROWTH

(a) For nonplanar part-through-wall degradation (Figure 2) in cylindrical portions of vessels or tanks, including degradation growth through the evaluation period, the vessel or tank is acceptable when the remaining wall thickness (t_p) is greater than or equal to the minimum wall thickness (t_{min}).

$$t_{min} = \frac{pD_o}{2(S + 0.5p)} \tag{1}$$

where

p = maximum operating pressure at the degradation location
D_o = vessel or tank outside diameter
S = allowable stress at operating temperature

(b) Alternatively, an evaluation for nonplanar part-through-wall degradation in cylindrical portions of vessels or tanks may be performed as specified below. The evaluation procedure used is dependent upon the depth and extent of the affected area, as illustrated in Figure 2, and includes degradation growth through the end of the evaluation period.

(1) When the width of the wall thinning that exceeds t_{min}, W_m, is less than or equal to $0.5\sqrt{R_o t}$, where R_o is the outside radius, and W_m is defined in Figure 2, the degradation can be classified as a planar flaw, and further analysis as a nonplanar flaw is not required. When the above requirement is not satisfied, the requirement in (2) shall be met.

(2) When the length of the wall thinning that exceeds t_{min}, $L_{m(t)}$, is not greater than $\sqrt{R_o t_{min}}$, t_{aloc} is determined from Figure 3,

where $L_{m(t)}$ is defined in Figure 2. When the above requirement is not satisfied, the requirement in (3) shall be met.

(3) When the maximum extent of wall thinning that exceeds t_{min}, L_m, is less than or equal to $2.65\sqrt{R_o t_{min}}$, and t_{nom} is greater than $1.13 t_{min}$, t_{aloc} is determined by satisfying both of the following equations:

$$\frac{t_{aloc}}{t_{min}} \geq \frac{1.5\sqrt{R_o t_{min}}}{L}\left[1 - \frac{t_{nom}}{t_{min}}\right] + 1.0 \tag{2}$$

$$\frac{t_{aloc}}{t_{min}} \geq \frac{0.353 L_m}{\sqrt{R_o t_{min}}} \tag{3}$$

(4) When the requirements of (1) through (3) are not satisfied, repair/replacement activities shall be performed.

(c) The Owner shall determine evaluation methods for nonplanar part-through-wall degradation in noncylindrical portions of vessels or tanks. The evaluation shall include analysis conditions specified in 3.1 and 3.2. Degradation is acceptable when the criteria of 5(d) are satisfied. The Owner shall also verify that other potential failure modes (e.g., buckling) are not relevant for the observed degradation.

4 DEGRADATION GROWTH EVALUATION

If degradation growth is evaluated, the analysis shall include the relevant growth mechanisms determined in the cause evaluation. Predicted degradation growth shall be updated based on examination and leakage monitoring results, when new results become available. The following describes some of the potential degradation growth -mechanisms.

(a) Fatigue Crack Growth. Fatigue crack growth shall be calculated. Methods of Appendix C1 shall be used for austenitic steels, and those of Appendix A1 shall be used for ferritic steels.

(b) Stress Corrosion Cracking in Austenitic Steels. If stress corrosion cracking (SCC) is active in austenitic steels, the following growth rate equation shall be used:

$$da/dt = S_T C \, K_{max}{}^n \tag{4}$$

where

C = material constant
da/dt = flaw growth rate (in./hr)
K_{max} = maximum stress intensity factor under long-term, steady-state conditions (ksi $\sqrt{\text{in.}}$)
n = material constant
S_T = temperature correction factor

For intergranular stress corrosion cracking (IGSCC) in austenitic steels, $T \leq 200°F$ (93°C)

C = 1.79×10^{-8}
n = 2.161
S_T = 1

See Figure 5 for flaw growth rate versus stress intensity factor for IGSCC in austenitic steels.

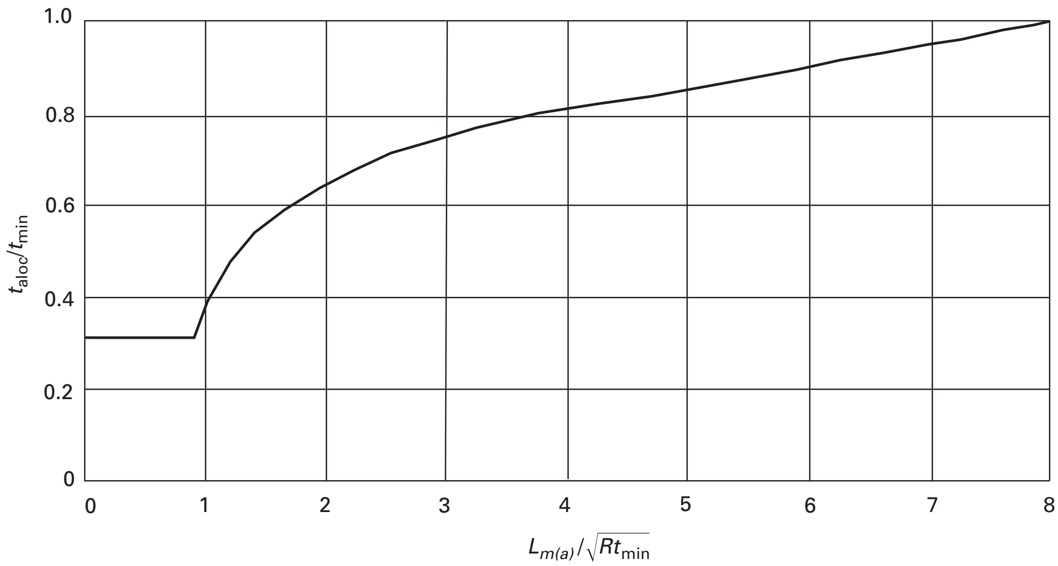
For transgranular stress corrosion cracking (TGSCC) in austenitic steels, $T \leq 200°F$ (93°C)

C = 1.79×10^{-7}
n = 2.161
S_T = $3.71 \times 10^8 \, [10^{(0.01842\,T - 12.25)}]$
T = metal temperature in °F

See Figure 6 for flaw growth rate versus stress intensity factor for TGSCC in austenitic steels.

(c) Other Degradation Growth Mechanisms. When other degradation growth mechanisms, such as microbiologically induced corrosion (MIC), are present, as determined by the cause evaluation, the contribution to degradation growth shall be included in the degradation growth evaluation.

Figure 3
Allowable Wall Thickness and Length of Locally Thinned Area



5 ACCEPTANCE CRITERIA

(a) For bounding flaws or for end-of-evaluation-period flaw sizes based on flaw growth analysis, the applied stress intensity factor, K_I, shall satisfy the following limits:

$K_I < K_{Ic}/3.0$ (Levels A and B and test conditions)

$K_I < K_{Ic}/1.4$ (Levels C and D)

(b) If the applicable material fracture toughness values are not known, the following fracture toughness values shall be used:

(1) for austenitic stainless steels, $135\ \text{ksi}\sqrt{\text{in.}}$ $(148\ \text{MPa}\sqrt{\text{m}})$

(2) for ferritic steels, $35\ \text{ksi}\sqrt{\text{in.}}$ $(38\ \text{MPa}\sqrt{\text{m}})$

(c) For nonplanar part-through-wall degradation in cylindrical portions of vessels or tanks, including degradation growth through the end of the evaluation period, the vessel or tank is acceptable when the minimum remaining wall thickness (t_p) is greater than or equal to the minimum wall thickness required for pressure loading (t_{min}), where t_{min} is determined in accordance with 3.3(a). Alternatively, the degradation is acceptable if $t_p \geq t_{aloc}$, where t_{aloc} is determined in accordance with 3.3(b).

(d) For nonplanar part-through-wall degradation in noncylindrical portions of vessels or tanks, including degradation growth through the evaluation period, the vessel or tank is acceptable if the following structural factors (SF) based on load are maintained:

$SF \geq 3.0$ (Levels A and B and test conditions)

$SF \geq 1.4$ (Levels C and D)

(e) For through-wall penetration, the potential leakage flow area of the degradation, or the total of the potential leakage flow areas of multiple degradation locations that are combined into a single, degradation location for the purpose of evaluation, shall not exceed 20 in.^{2} (130 cm^2).

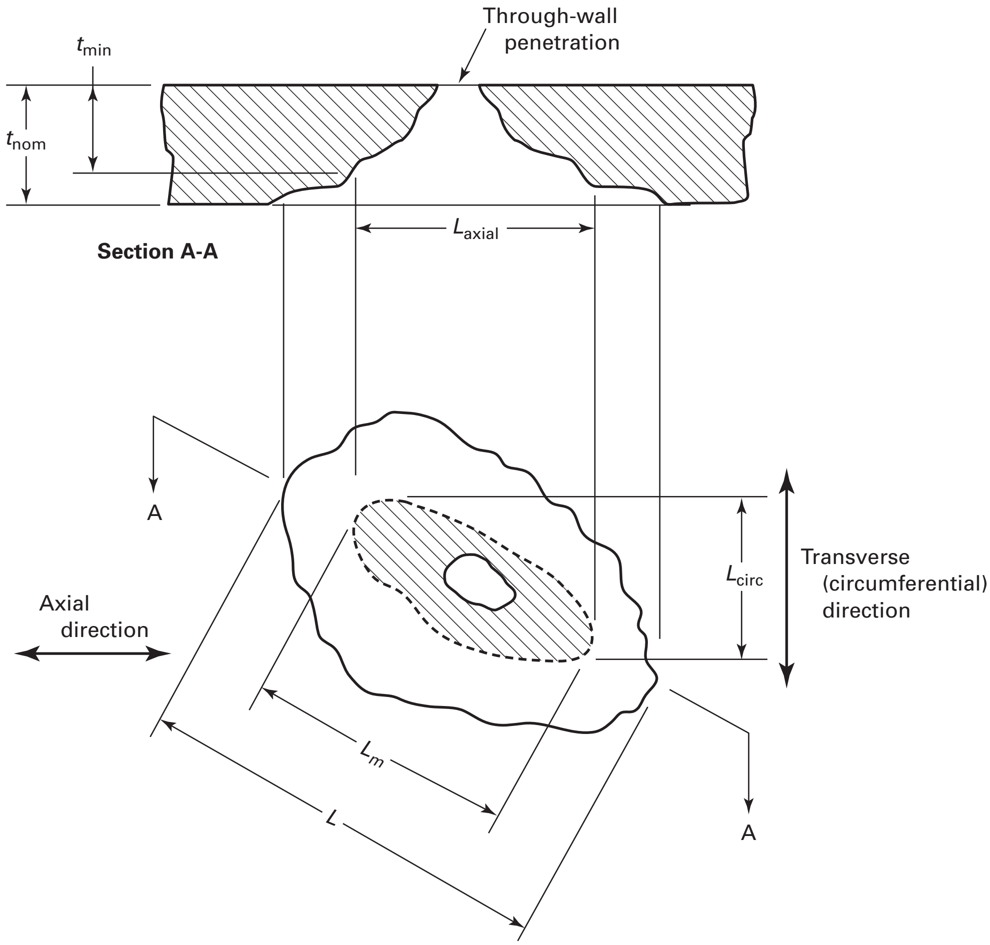
6 SUBSEQUENT EXAMINATIONS AND SURVEILLANCE

The following actions shall be implemented for degradation determined to be structurally acceptable at the end of the evaluation period:

(a) Daily leakage monitoring (e.g., vessel or tank level indications, sump measurements, etc.) shall be performed to ensure that leakage, if any, does not exceed acceptable limits.

(b) Degradation, including growth, that meets the acceptance criteria of this Case shall be determined by examination at one-half of the allowable operating time (i.e., $0.5\ \tau_{allow}$), to verify the growth predictions, unless τ_{allow} exceeds twice the time to the end of the evaluation period, as allowed by 2.5(d).

Figure 4
Illustration of Nonplanar Through-Wall Degradation Due to Wall Thinning



7 NOMENCLATURE

C = material constant in austenitic steel stress corrosion cracking equation
D_o = vessel or tank outer diameter (for cylindrical portions of vessels and tanks)
da/dt = flaw growth rate for stress corrosion cracking in austenitic steel
K_I = applied stress intensity factor
K_{Ic} = fracture toughness
$K_{\max}$ = maximum stress intensity factor under long-term, steady-state conditions used in the stress corrosion cracking equation for austenitic steel
L = maximum extent of a local thinned area with $t < t_{\text{nom}}$
L_{axial} = crack length for through-wall nonplanar degradation in axial direction
L_{circ} = crack length for through-wall nonplanar degradation in circumferential direction
L_m = maximum extent of a local thinned area with $t < t_{\min}$
$L_{m(a)}$ = axial extent of wall thinning below $t_{\min}$
$L_{m(t)}$ = circumferential extent of wall thinning below $t_{\min}$
n = material constant in austenitic steel stress corrosion cracking equation
p = maximum operating pressure at the degradation location
R = vessel or tank mean radius (for cylindrical portions of vessels and tanks)
R_o = vessel or tank outer radius (for cylindrical portions of vessels and tanks)
S = allowable stress at the operating temperature
S_T = temperature correction factor in austenitic steel stress corrosion cracking equation
T = metal temperature at the degradation location
t = wall thickness
t_{aloc} = allowable local thickness for a nonplanar flaw that exceeds $t_{\min}$

Figure 5
Flaw Growth Rate for IGSCC in Austenitic Steels

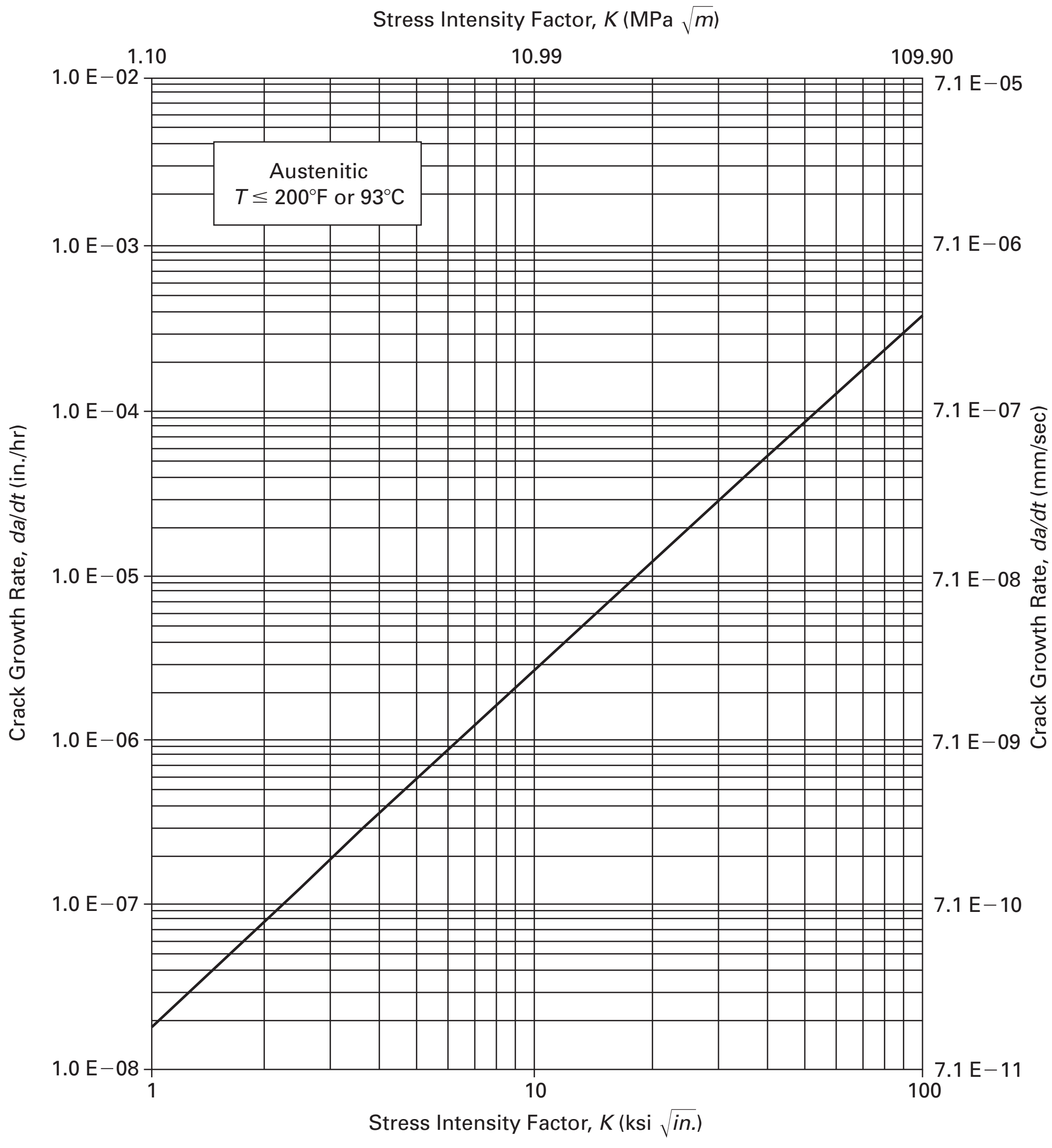
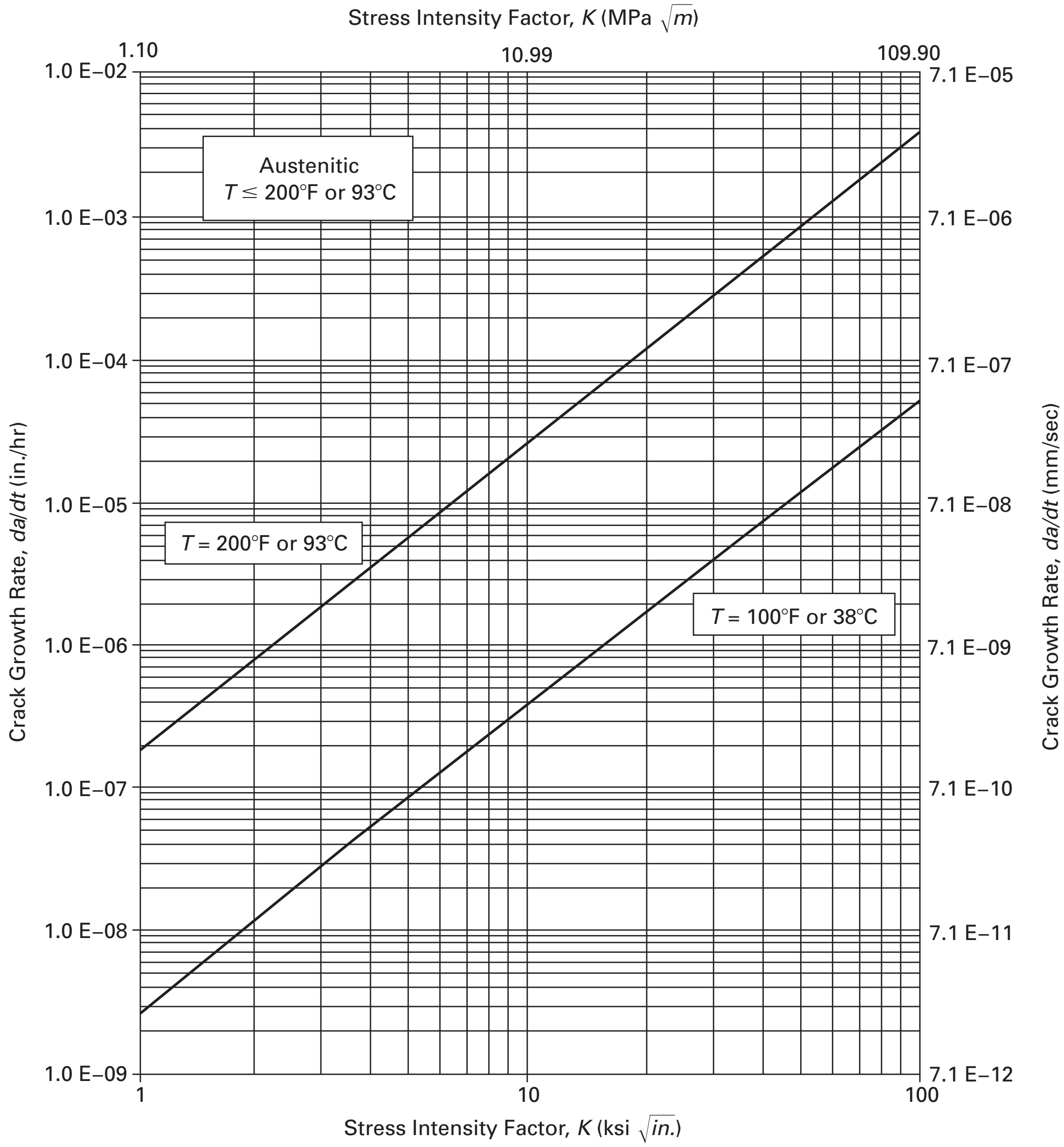


Figure 6
Flaw Growth Rate for TGSCC in Austenitic Steels



t_{min} = minimum wall thickness required for pressure loading
t_{nom} = nominal wall thickness
t_p = minimum remaining wall thickness
W_m = maximum extent of a local thinned area perpendicular to L_m with $t < t_{min}$
τ = operational time after first discovery of degradation
τ_{allow} = operational time required for the detected degradation to grow to the maximum structurally allowable size, based on the acceptance criteria of 5

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Approval Date: January 10, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-706-1
Alternative Examination Requirements of Table IWB-2500-1 and Table IWC-2500-1 for PWR Stainless Steel Residual and Regenerative Heat Exchangers
Section XI, Division 1

Inquiry: What alternative to the requirements of Table IWB-2500-1, Examination Categories B-B, B-D, and B-J, and Table IWC-2500-1, Examination Categories C-A, C-B, and C-F-1, may be used for PWR stainless steel regenerative and residual heat exchangers?

Reply: It is the opinion of the Committee that the requirements of Table 1 may be used for PWR stainless steel regenerative and residual heat exchangers, in lieu of the requirements of Table IWB-2500-1, Examination Categories B-B, B-D, and B-J, and Table IWC-2500-1, Examination Categories C-A, C-B, and C-F-1.

This Case may not be applied to any heat exchanger nor to any heat exchanger design or configuration that has experienced a through-wall leak, such as heat exchangers with an inner shell (inner barrel). The Owner shall evaluate industry experience to determine which heat exchanger designs or configurations have leaked. If any leakage is detected, it shall be corrected in accordance with IWA-4000 or (IWA-7000 prior to the 1991 Addenda). Use of this Case shall be discontinued for that heat exchanger design or configuration. The affected heat exchanger and others of the same design or configuration shall be examined in accordance with IWB-2500 or IWC-2500, as applicable.

Table 1
Pressure Retaining Welds Nozzle Inside-Radius Sections, and Reinforcing Plate Welds in PWR Stainless Steel Residual and Regenerative Heat Exchangers

Item No.	Parts Examined [Note (1)], [Note (2)]	Examination Method	Acceptance Standard	Extent and Frequency Examination		
				First Inspection Interval	Successive Inspection	Deferral of Examination to End of Interval
1.10	Residual and regenerative heat exchangers	...	...	...	...	...
1.11	Category B-B welds [Note (3)]	VT-2	IWB-3522	All welds	Same as interval	Not permissible
1.12	Category B-D welds and nozzle inside-radius sections [Note (3)]	VT-2	IWB-3522	All welds	Same as interval	Not permissible
1.13	Category B-J welds [Note (3)]	VT-2	IWB-3522	All welds	Same as interval	Not permissible
1.14	Category C-A welds [Note (4)]	VT-2	IWC-3516	All welds	Same as interval	Not permissible
1.15	Category C-B welds and nozzle inside-radius sections [Note (4)]	VT-2	IWC-3516	All welds	Same as interval	Not permissible
1.16	Category C-F-1 welds [Note (4)]	VT-2	IWC-3516	All welds	Same as interval	Not permissible

NOTES:

(1) Application of the requirements of this table is limited to those welds that are part of the as-received heat exchanger assembly. The regenerative heat exchanger assembly may be formed from multiple smaller heat exchanger subcomponents connected by sections of piping. All of the smaller heat exchanger subcomponents and the connect piping are within the boundary of the heat exchanger assembly.

(2) All welds, other than reinforcing plate welds, shall have received at least one volumetric examination; the preservice or Construction Code volumetric examination may be used to meet this requirement. Reinforcing plate welds shall have received at least one surface examination. This does not apply to nozzle inside-radius section

(3) The component shall be examined for evidence of leakage while undergoing the system leakage test (IWB-5220) as required by Examination Category performed every refueling outage.

(4) The component shall be examined for evidence of leakage while undergoing the system leakage test (IWC-5220) as required by Examination Category be performed every inspection period.

Approval Date: November 2, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-707
Use of SA-537, Class 1 Plate Material for Spent-Fuel Containment Internals in Non-Pressure Retaining Applications Above 700°F (370°C)
Section III, Division 3

Inquiry: Until such time as Section III, Division 3, incorporates rules for internals, may plate material conforming to the requirements of SA-537, Class 1, ≤ 1 in. (25 mm) thickness, normalized condition, be used at temperatures above 700° (370°C), but not exceeding 850°F (455°C), for spent-fuel containment internals in non-presssure retaining applications?

Reply: It is the opinion of the Committee that, until such time as Section III, Division 3, incorporates rules for internals, plate material conforming to the requirements of SA-537, Class 1, ≤ 1 in. (25 mm) thickness, normalized condition, may be used at temperatures above 700°F (370°C), but not exceeding 850°F (455°C), for spent-fuel containment internals in non-pressure retaining applications, provided that the ultimate tensile strength, yield strength, and design stress intensity values shall be as listed in Tables 1 and 1M, creep is determined to be negligible, and the following requirements are met:

(a) Methods for evaluation of negligible creep are described in Subsection NH, para. T-1324.

(b) Welding procedure and performance qualifications shall be conducted as prescribed in Section IX.

(c) The design documentation shall reference this Case number.

Table 1
Tensile, Yield Strength, and Design Stress Intensity Values (U.S. Customary Units)

For Metal Temperature Not Exceeding °F	Tensile Strength, S_u, ksi	Yield Strength, S_y, ksi	Design Stress Intensity, S_m, ksi [Note (1)]
750	67.7	31.5	21.0
800 [Note (2)]	65.4	30.5	20.3
850 [Note (2)]	61.1	29.2	19.5

NOTES:
(1) The values of S_m do not exceed the lesser of $S_u/3$ or $^2/_3\ S_y$ at temperature.
(2) Upon prolonged exposure to temperatures above 800°F (425°C), the carbide phase of carbon steel may be converted to graphite.

Table 1M
Tensile, Yield Strength, and Design Stress Intensity Values (SI Units)

For Metal Temperature Not Exceeding °C	Tensile Strength, S_u, MPa	Yield Strength, S_y, MPa	Design Stress Intensity, S_m, MPa [Note (1)]
400	466	217	145
425 [Note (2)]	452	211	141
450 [Note (2)]	437	204	136
475 [Note (3)]	395	199	133

NOTES:
(1) The values of S_m do not exceed the lesser of $S_u/3$ or $^2/_3\ S_y$ at temperature.
(2) Upon prolonged exposure to temperatures above 800°F (425°C), the carbide phase of carbon steel may be converted to graphite.
(3) These values are provided for interpolation purposes only. The temperature limit is 455°C (850°F).

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Approval Date: September 21, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-708
Use of JIS G4303, Grades SUS304, SUS304L, SUS316, and SUS316L
Section III, Division 1

Inquiry: May austenitic stainless steel bar material, manufactured in accordance with JIS G4303, Grades SUS304, SUS304L, SUS316, and SUS316L be used in Section III construction?

Reply: It is the opinion of the Committee that austenitic stainless steel bar material, manufactured in accordance with JIS G4303, Grades SUS304, SUS304L, SUS316, and SUS316L may be used in Section III construction provided the following requirements are met:

(a) The design values in Section II, Part D, Tables 1A, 2A, U, Y-1, and Y-2 that are used for JIS G4303, Grades SUS304, SUS304L, SUS316, and SUS316L shall correspond to those of SA-479/SA-479M, Types 304, 304L, 316, and 316L, respectively.

(b) The base metal shall be considered P-Number 8, Group 1, for the purposes of welding procedure and performance qualification in accordance with Section IX.

(c) When JIS G4303, Grades SUS304, SUS304L, SUS316, or SUS316L are used, this Case number shall be shown on the Certificate Holder's Data Report.

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Approval Date: May 5, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-710
Use of Zirconium Alloy UNS R60702, Bars, Forgings, Plate, Seamless and Welded Fittings, Seamless and Welded Tubing, and Seamless and Welded Pipe, for Class 3 Construction
Section III, Division 1

Inquiry: May zirconium alloy UNS R60702, bars, forgings, plate, seamless and welded fittings, seamless and welded tubing, and seamless and welded pipe, be used for Section III, Division 1, Class 3 construction?

Reply: It is the opinion of the Committee that zirconium alloys UNS R60702, bars, forgings, plate, seamless and welded fittings, seamless and welded tubing, and seamless and welded pipe, may be used for Section III, Division 1, Class 3 construction, provided the requirements of (a) through (f) are met:

(a) Material shall conform to the requirements of the applicable product specification listed in Table 1.

(b) Alloy R60702 shall be considered as P-No. 61.

(c) The maximum allowable stress values shall be those shown in Table 2 of this Case.

(d) For external pressure design, use Fig. NFZ-1 of Section II, Part D.

(e) All other requirements of Section III, Division 1, for Class 3 materials shall be met.

(f) This Case number shall be identified on the marking of the material, the certification for the material and on the manufacturer's Data Report.

Table 1
Product Specifications

	UNS R60702
Bar	SB-550
Forgings	SB-493
Plate	SB-551
Seamless and Welded Fittings	B 653
Seamless and Welded Pipe	SB-658
Seamless and Welded Tube	SB-523

Table 2
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding °F	Maximum Allowable Stress, ksi [Note (1)], UNS R60702 (30/55)
−20 to 100	15.7
200	13.7
300	11.2
400	9.1

GENERAL NOTE: The allowable stress values are based on the revised criteria of tensile strength divided by 3.5.

NOTE:
(1) For welded pipe, welded tubing, and welded fittings, a factor of 0.85 shall be applied.

Table 3
Yield Strength Values

Temperature, °F	Yield Strength, ksi UNS R60702 (30/55)
100	30.0
150	25.8
200	23.1
250	20.4
300	18.0
350	15.9
400	14.0

Approval Date: January 5, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-711
Alternative Examination Coverage Requirements for Examination Category B-F, B-J, C-F-1, C-F-2, and R-A Piping Welds
Section XI, Division 1

Inquiry: What alternative to the examination coverage requirements of Table IWB-2500-1, Examination Categories B-F and B-J, Table IWC-2500-1, Examination Categories C-F-1 and C-F-2, Case N-560 Examination Category B-J1 and Examination Category R-A[1] piping welds may be used when the required examination volume cannot be examined due to interference by a permanent item (e.g., non-bolted component support) or part geometry?

Reply: It is the opinion of the Committee that, when the examination has been completed and the required examination volume on Table IWB-2500-1, Examination Categories B-F and B-J, Table IWC-2500-1, Examination Categories C-F-1 and C-F-2, Case N-560 Examination Category B-J and Examination Category R-A piping welds, cannot be examined due to interference by a permanent item (e.g., non-bolted component support) or part geometry, and 1 or 2 is met, the alternative examination volume defined by the evaluation process of 3 may be used to determine acceptable examination coverage.

1 GENERAL

The examination coverage does not meet Case N-560, N-577, N-578 or Appendix R requirements, as applicable, and one of the following conditions is met.

(a) The inspection location of concern is risk Region 1A per Risk-informed Method A.[2]

(b) An inspection location selected for examination is based on the most limiting predicted severity of the postulated degradation mechanism. Examples of locations considered to be the most limiting are ones that experience the highest ΔT due to thermal transients and highest temperature for locations in PWR's susceptible to IGSCC.

(c) Selection of an alternative inspection location within the same risk region or category will not improve examination coverage of the volume of primary interest (e.g., other locations have similar structural discontinuities).

2 EXAMINATION COVERAGE

The examination coverage does not meet the requirements of Table IWB-2500-1 or Table IWC-2500-1, and selection of an alternative inspection location meeting the same original selection criteria (e.g., Category C-F-1 structural discontinuity weld) will not improve examination coverage of the volume of primary interest.

3 EVALUATION PROCESS

(a) The Owner shall determine the degradation mechanisms associated with the weld. If the weld is Examination Category R-A, the Owner may use the degradation mechanism assessments developed to support the risk-informed inservice inspection examination requirements. If the Examination Category is B-F, B-J, C-F-1, or C-F-2, the Owner shall perform an assessment to determine the potential degradation mechanisms. This assessment shall use Table 1 to determine all applicable degradation mechanisms.

(b) Based upon the results of (a), Table 2 is entered at the corresponding Degradation Mechanism and associated Process Decision Point. The alternative examination coverage, based on the potential degradation mechanisms and associated configuration, is defined in Table 2. The acceptable coverage is 100% of the volume of primary interest as defined in Table 2. Examples of

[1] Examination Category B-J, in this instance, applies to implementing risk-informed inservice inspection programs through the use of Case N-560 and Examination Category R-A applies to plant implementing risk-informed inservice inspection programs through the use of Case N-577 and Case N-578 and associated revisions or Appendix R.

[2] Method A applies to plants implementing risk-informed inservice inspection programs through the use of Case N-577 and associated revisions or Supplement 1 of Appendix R.

the results of this process for components identified as susceptible to thermal fatigue and IGSCC (PWR's) are provided in Figure 2.

(c) The use of this Case, the alternative required examination volume, documentation of examination limitations, and examination coverage achieved shall be part of the documentation required for the examination record associated with the weld. Additionally, if the weld is not Case N-560 Examination Category B-J or Examination Category R-A, the assessment documenting the potential degradation mechanisms shall be part of the documentation record.

(d) Inspection locations that require the use of Table 2 to determine partial examination coverage acceptability shall be listed on Form N-711-A and included with Form NIS-1 or Form OAR-1.

Table 1
Degradation Mechanisms Criteria

Degradation Mechanisms		Criteria	Susceptible Regions
TF	TASCS	– piping > NPS 1 (DN 25); and – pipe segment has a slope < 45 deg from horizontal (includes elbow or tee into a vertical pipe); and – potential exists for a low flow in a pipe section connected to a component allowing mixing of hot and cold fluids, or potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or potential exists for two phase (steam/water) flow, or potential exists for turbulent penetration into a relatively colder branch pipe connected to header piping containing hot fluid with high turbulent flow; and – calculated or measured ΔT > 50°F (10°C); and – Richardson number > 4.0	nozzles, branch pipe connections, safe ends, welds, heat affected zones (HAZ), base metal; and regions of stress concentration
	TT	– operating temperature > 270°F (130°C) for stainless steel, or operating temperature > 220°F (105°C) for carbon steel, and – potential for relatively rapid temperature changes including cold fluid injection into hot pipe segment, or hot fluid injection into cold pipe segment, and – $\lvert \Delta T \rvert$ > 200°F for stainless steel, or $\lvert \Delta T \rvert$ > 150°F for carbon steel, or $\lvert \Delta T \rvert$ > ΔT allowable (applicable to both stainless steel and carbon)	
SCC	IGSCC (BWR)	– evaluated in accordance with existing plant IGSCC program per NRC Generic Letter 88-01, or alternative (e.g., BWRVIP-075)	austenitic stainless steel welds and HAZ
	IGSCC (PWR)	– operating temperature > 200°F (93°C); and – susceptible material (carbon content ≥ 0.035%); and – tensile stress (including residual stress) is present; and – oxygen or oxidizing species are present [Note (1)] OR – operating temperature < 200°F (93°C), the attributes above apply; and – initiating contaminants (e.g., thiosulfate, fluoride or chloride) are also required to be present	
	TGSCC	– operating temperature > 150°F (65°C), and – tensile stress (including residual stress) is present, and – halides (e.g., fluoride or chloride) are present, or caustic (NaOH) is present, and – oxygen or oxidizing species are present (only required to be present in conjunction w/halides, not required w/caustic)	austenitic stainless steel base metal, welds, and HAZ
	PWSCC	– UNS N06600, UNS N06082, or UNS W86182 and – exposed to primary water at T > 570°F (300°C); and – the material is mill-annealed and cold worked, or cold worked and welded without stress relief	nozzles, welds, and HAZ without stress relief

Table 1
Degradation Mechanisms Criteria (Cont'd)

Degradation Mechanisms		Criteria	Susceptible Regions
LC	MIC	– operating temperature < 150°F (65°C), and – low or intermittent flow; and – pH < 10; and – presence/intrusion of organic material (e.g., raw water system), or water source is not treated w/biocides (e.g., refueling water tank)	fittings, welds, HAZ, base metal, dissimilar metal joints (e.g., welds and flanges), and regions containing crevices
	PIT	– potential exists for low flow; and – oxygen or oxidizing species are present; and – initiating contaminants (e.g., fluoride or chloride) are present	
	CC	– crevice condition exists (e.g., thermal sleeves); and – operating temperature > 150°F (65°C); and – oxygen or oxidizing species are present	
FS	E-C	– existence of cavitation source (i.e., throttling or pressure reducing valves or orifices); and – operating temperature < 250°F (120°C); and – flow present > 100 hr/yr; and – velocity > 30 ft/s (9.1 m/s); and – $(P_d - P_v)/\Delta P < 5$ where, P_d = static pressure downstream of the cavitation source, P_v = vapor pressure, and ΔP = pressure difference across the cavitation source	fittings, welds, HAZ, and base metal
	FAC	– evaluated in accordance with existing plant FAC program	per plant FAC program

Legend:

Degradation Mechanism (DM)
Thermal Fatigue (TF)
Thermal Stratification, Cycling, and Striping (TASCS)
Thermal Transients (TT)
Stress Corrosion Cracking (SCC)
Intergranular Stress Corrosion Cracking (IGSCC)
Boiling Water Reactor (BWR)
Pressurized Water Reactor (PWR)
Transgranular Stress Corrosion Cracking (TGSCC)
Primary Water Stress Corrosion Cracking (PWSCC)
Localized Corrosion (LC)
Microbiologically-Influenced Corrosion (MIC)
Pitting (PIT)
Crevice Corrosion (CC)
Flow Sensitive (FS)
Erosion-Cavitation (E-C)
Flow-Accelerated Corrosion (FAC)
Heat Affected Zone (HAZ)
Nominal Pipe Size (NPS)
Nuclear Regulatory Commission (NRC)
BWR Vessel and Internals Project (BWRVIP)

NOTE:
(1) The EPRI PWR Primary Water Chemistry Guidelines, EPRI 1002884, September 2003, provide a threshold value of > 100 ppb with respect to defining an oxidizing environment.

Table 2
Partial Examination Coverage Evaluation Process

Degradation Mechanisms	Process Decision Point [Note (1)]	If Decision Point is "Yes"	If Decision Point is "No"	Risk Characterization [Note (2)], [Note (3)] Method A	Risk Characterization [Note (2)], [Note (3)] Method B
FAC	Requirements governed by plant FAC program.			Region 1A Region 1B Region 2 Non RI-ISI Examination	Category 1 Category 3 Category 5 Non RI-ISI Examination
WH + other DM VF (assumed)	(a) Is water hammer or vibratory fatigue still applicable?	– correct design deficiency – re-risk-rank system without water hammer or vibratory fatigue	– re-risk-rank system without water hammer or vibratory fatigue		
	(b) Is the examination still required?	– partition by applicable degradation mechanism as shown below	– no further action required		
TASCS TT	(c) Is the inspection location on a horizontal run to a steam generator or BWR vessel, including feedwater nozzle?	– see decision point (d)	– see decision point (e)	Region 1A Region 1B Region 2 Non RI-ISI Examination	Category 2 Category 5 Non RI-ISI Examination
	(d) Was the weld, pipe side heat affected zone and pipe side counterbore transition region captured?	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable	– volume of primary interest not sufficiently examined – coverage requirement not met		
	(e) Is the inspection location a pipe component weld? Included pipe to pumps, valves, nozzles and branch connections.	– see decision point (f)	– see decision point (g) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(f) Was the weld, pipe side heat affected zone and pipe side counterbore transition region captured?	– document examination limitation and coverage achieve and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable	– see decision point (h) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		

Table 2
Partial Examination Coverage Evaluation Process (Cont'd)

Degradation Mechanisms	Process Decision Point [Note (1)]	If Decision Point is "Yes"	If Decision Point is "No"	Risk Characterization [Note (2)], [Note (3)] Method A	Method B
TASCS TT	(g) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable	Region 1A Region 1B Region 2 Non RI-ISI Examination	Category 2 Category 5 Non RI-ISI Examination
	(h) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable		
IGSCC (BWR)	Requirements governed by Owner controlled program.				
IGSCC (PWR) PWSCC	(i) Is the inspection location a pipe or safe end to nozzle weld?	– see decision point (j)	– see decision point (m)		
	(j) Is Alloy UNS N06600, UNS N06082 or UNS W86182 present? Includes fitting, weld, or buttering.	– partial coverage (i.e., ≤ 90%) is not acceptable – coverage requirement not met	– see decision point (k)		
	(k) Was the weld, pipe side heat affected zone and pipe side counterbore transition region captured? if corrosion resistant cladding exists on the inner surface, the weld is not a concern.	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable	– see decision point (l) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(l) Is the oounterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable		

Table 2
Partial Examination Coverage Evaluation Process (Cont'd)

Degradation Mechanisms	Process Decision Point [Note (1)]	If Decision Point is "Yes"	If Decision Point is "No"	Risk Characterization [Note (2)], [Note (3)] Method A	Method B
IGSCC (PWR) PWSCC	(m) Is the inspection location a pipe to cast component weld? Includes pipe to pumps and valves.	– see decision point (n)	– see decision point (q) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met	Region 1A Region 1B Region 2 Non RI-ISI Examination	Category 2 Category 5 Non RI-ISI Examination
	(n) Is the carbon and ferrite content combination within the resistant region as shown on Figure 1?	– see decision point (o)	– see decision point (r) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(o) Was the weld, pipe side heat affected zone and pipe side counterbore transition region captured?	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable	– see decision point (p) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(p) Is the counterbore transition region located within $^1/_2$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable		
	(q) Is the counterbore transition region located within $^1/_2$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable		

Table 2
Partial Examination Coverage Evaluation Process (Cont'd)

Degradation Mechanisms	Process Decision Point [Note (1)]	If Decision Point is "Yes"	If Decision Point is "No"	Risk Characterization [Note (2)], [Note (3)]	
				Method A	Method B
IGSCC (PWR) PWSCC	(r) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2, or R-A, as applicable	Region 1A Region 1B Region 2 Non RI-ISI Examination	Category 2 Category 5 Non RI-ISI Examination
TGSCC	(s) Was the weld, pipe/component side heat affected zone and pipe/component side counterbore transition region captured?	– volume of primary interest examined	– see decision point (t) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(t) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-l, C-F-2 or R-A, as applicable		
MIC PIT	Requirements governed by Owner controlled program.				
CC	(u) In course of preparation				
E-C	(v) Is the coverage adequate to identify wastage at the inspection location?	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable	– insufficient coverage – coverage requirement not met		

Table 2
Partial Examination Coverage Evaluation Process (Cont'd)

Degradation Mechanisms	Process Decision Point [Note (1)]	If Decision Point is "Yes"	If Decision Point is "No"	Risk Characterization [Note (2)], [Note (3)] Method A	Method B
No DM Identified	(w) Is the inspection location a pipe to component weld? Includes pipe to pumps, valves, nozzles and branch connections.	– see decision point (x)	– see decision point (y) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met	Region 1B Region 2 Non RI-ISI Examination	Category 4 Non RI-ISI Examination
	(x) Was the weld, pipe side heat affected zone and pipe side counterbore transition region captured?	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable	– see decision point (z) if the examination limitation is a counterbore issue – if the examination limitation is a weld or heat affected zone issue, then the volume of primary interest was not sufficiently examined and the coverage requirement was not met		
	(y) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable		
	(z) Is the counterbore transition region located within $\frac{1}{2}$ in. (13 mm) of the weld fusion line?	– volume of primary interest not sufficiently examined – coverage requirement not met	– document examination limitation and coverage achieved and verify examination performed to the examination requirements of B-F, B-J, C-F-1, C-F-2 or R-A, as applicable		

Legend:

Thermal Fatigue (TF)
Thermal Stratification, Cycling, and Striping (TASCS)
Thermal Transient (TT)
Stress Corrosion Cracking (SCO
Intergranular Stress Corrosion Cracking (IGSCC)
Boiling Water Reactor (BWR)
Pressurized Water Reactor (PWR)
Transgranular Stress Corrosion Cracking (TGSCC)
Primary Water Stress Corrosion Cracking (PWSCC)
Localized Corrosion (LC)
Microbiologically-Influenced Corrosion (MIC)
Pitting (PIT)
Crevice Corrosion (CC)
Flow Sensitive (FS)
Erosion-Cavitation (E-C)
Flow Accelerated Corrosion (FAC)
Vibratory Fatigue (VF)
Degradation Mechanism (DM)
Water Hammer (WH)

NOTES:
(1) The term “counterbore transition region” is depicted in Figure 3.
(2) As determined by the risk-informed inservice inspection (RI-ISI) process, if applicable.

Table 2
Partial Examination Coverage Evaluation Process (Cont'd)

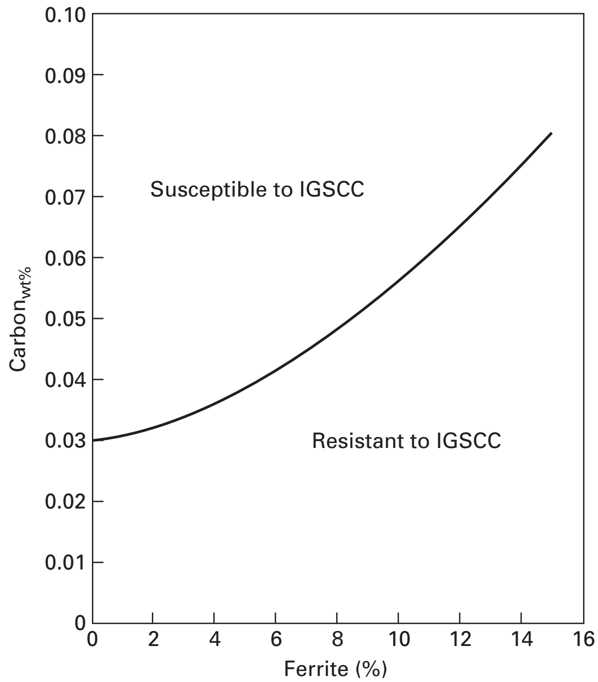
NOTES (CONT'D):

(3) Method A applies to plants implementing risk-informed inservice inspection programs through the use of Case N-577 and associated revisions or Appendix R Supplement 1 of Section XI. Method B applies to plants implementing risk-informed inservice inspection programs through the use of Case N-578 and associated revisions or Appendix R Supplement 2 of Section XI. Applicable terms (e.g., Region 1A) are define therein. The risk characterization of Method B also applies to Case N-560.

Form N-711-A Abstract of Welds Satisfying Alternate Examination Coverage Requirements of Case N-711

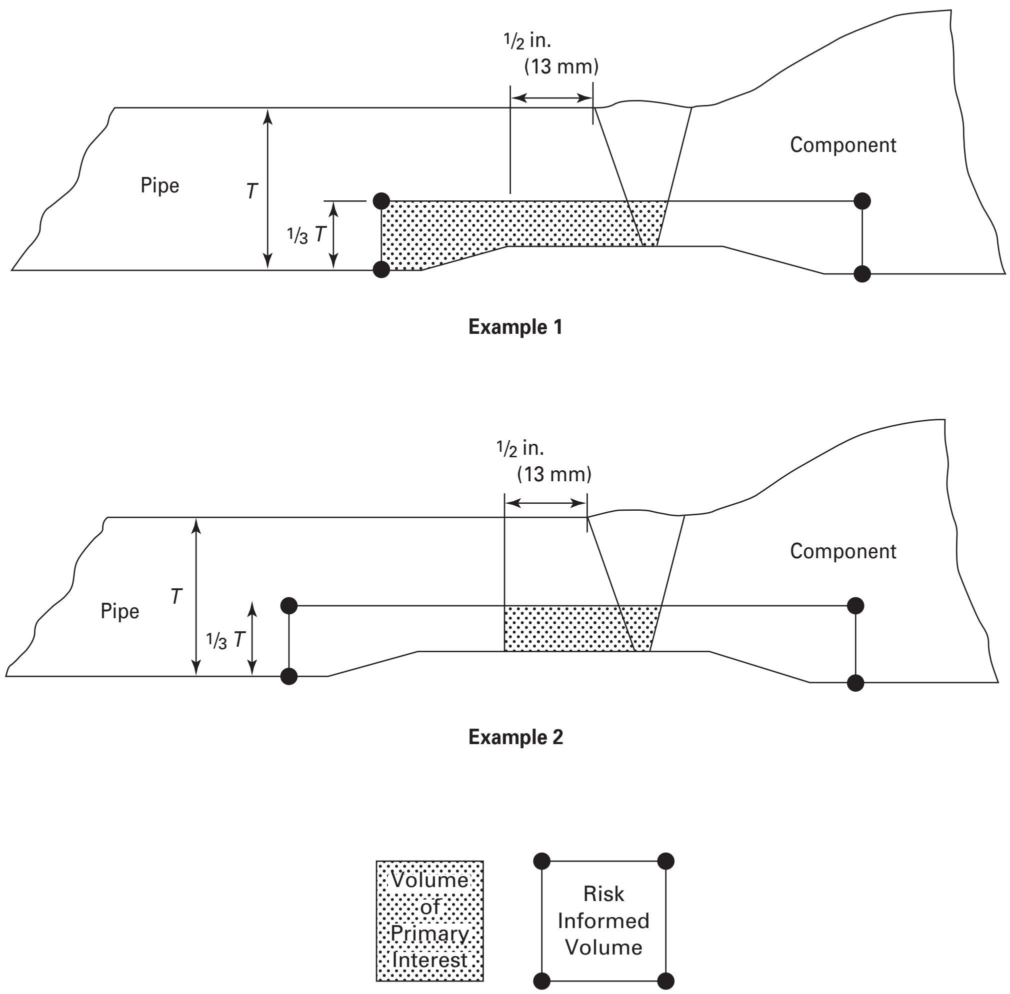
Examination Category	Weld Number	Weld Description	Percent Coverage	Description of Limitation

Figure 1
Carbon Content and Ferrite Content Combination for Cast Stainless Steels — IGSCC Resistance



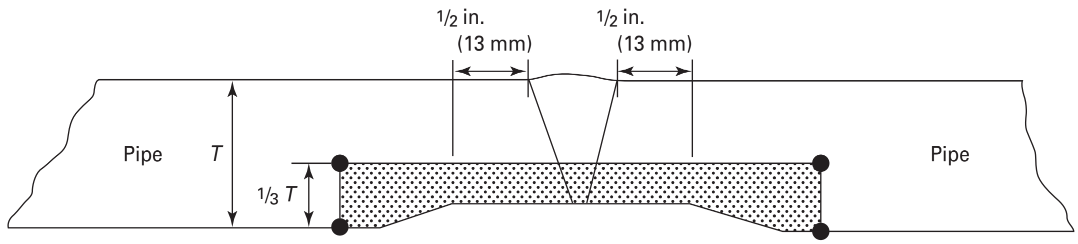
GENERAL NOTES:
(a) Applicable to oxidizing environments only.
(b) Does not apply to castings that have been furnace sensitized.
(c) Ferrite carbon content NOT within resistant region of Figure 1.

Figure 2
Degradation Mechanisms

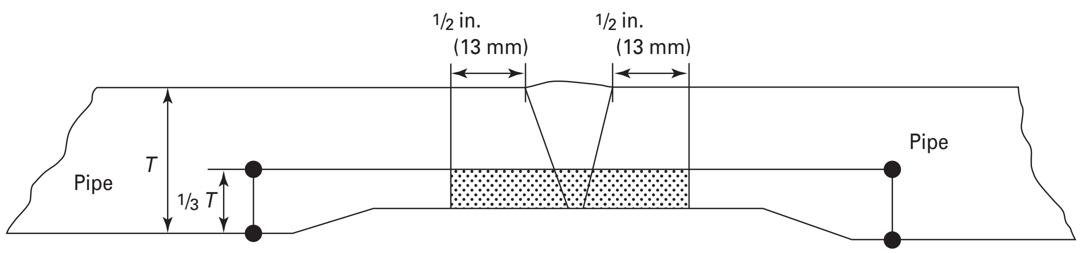


TASCS, TT; Component Configuration, Pipe-to-Component

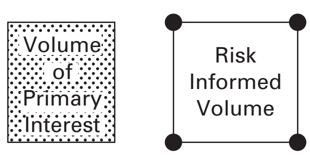
Figure 2
Degradation Mechanisms (Cont'd)



Example 3

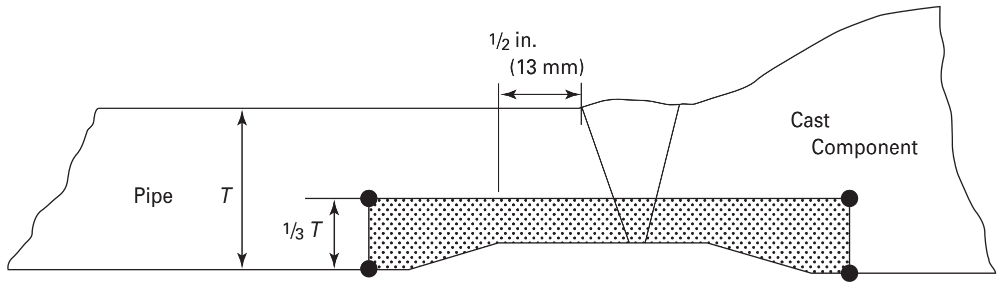


Example 4

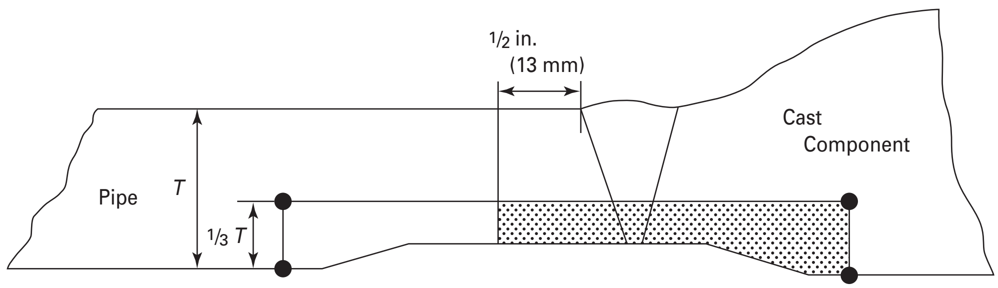


TASCS, TT; Component Configuration, Pipe-to-Pipe

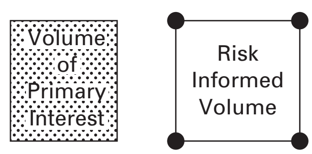
Figure 2
Degradation Mechanisms (Cont'd)



Example 5



Example 6



TASCS, TT; Component Configuration, Pipe-to-Cast Component

GENERAL NOTES:

(a) Figure 2 provides six examples that illustrate the volume of primary interest for combinations of different degradation mechanisms and component configurations. An overview of how the evaluation process defined in Table 2 of this Case is used to determine the volume of primary interest for these six examples is presented below.

Example	DMs	Configuration	Location of Counterbore Transition Region	Other Information Relevant to the Evaluation Process	Associated Process Decision Points
1	TASCS, TT	Pipe to Component	Any portion within $\frac{1}{2}$ in. (13 mm) of the weld fusion line	N/A	(c)→ (e)→ (f)→ (h)
2	TASCS, TT	Pipe to Component	Entire region beyond $\frac{1}{2}$ in. (13 mm) of the weld fusion line	N/A	(c)→ (e)→ (f)→ (h)
3	TASCS, TT	Pipe to Pipe	Any portion within $\frac{1}{2}$ in. (13 mm) of the weld fusion line	N/A	(c)→ (e)→ (g)

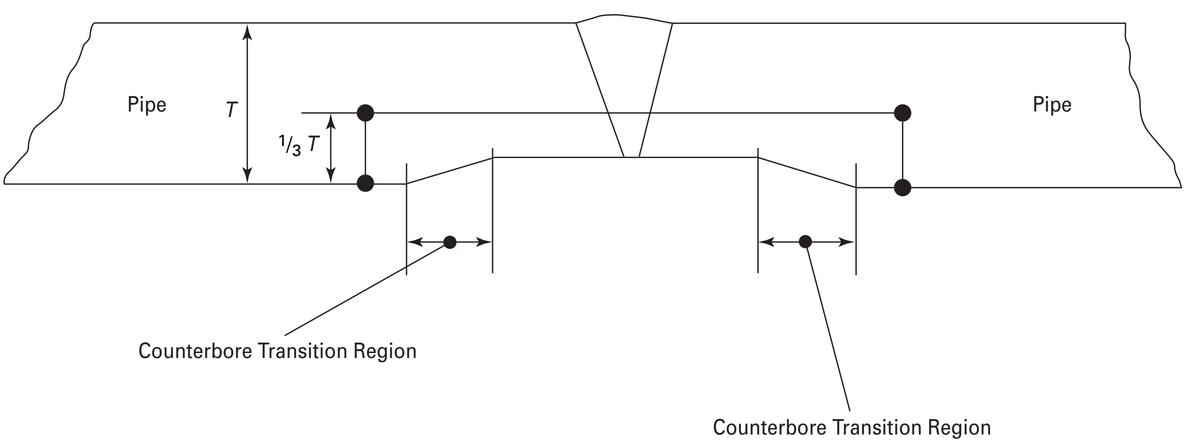
Figure 2
Degradation Mechanisms (Cont'd)

GENERAL NOTES (CONT'D):
Table continued

Example	DMs	Configuration	Location of Counterbore Transition Region	Other Information Relevant to the Evaluation Process	Associated Process Decision Points
4	TASCS, TT	Pipe to Pipe	Entire region beyond $\frac{1}{2}$ in. (13 mm) of the weld fusion line	N/A	(c)→ (e)→ (g)
5	IGSCC	Pipe to Component	Any portion within $\frac{1}{2}$ in. (13 mm) of the weld fusion line	Cast component whose carbon and ferrite content are not within the resistant region shown in Figure 1 of this Case	(i)→ (m)→ (n)→ (r)
6	IGSCC	Pipe to Component	Entire region beyond $\frac{1}{2}$ in. (13 mm) of the weld fusion line	Cast component whose carbon and ferrite content are not within the resistant region shown in Figure 1 of this Case	(i)→ (m)→ (n)→ (r)

(b) An explanation of the terms used in Figure 2 is provided as follows:
(1) risk-informed volume: this represents the volume typically defined by implementing a Risk-informed ISI Program.
(2) volume of primary interest: this represents the volume defined by application of Table 2 of this Case.

Figure 3
Counterbore Transition Region



Approval Date: May 12, 2004

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-712
Class 1 Socket Weld Examinations
Section XI, Division 1

Inquiry: What alternative to the surface examination requirements for socket welds of Examination Categories B-F and B-J may be used?

Reply: It is the opinion of the Committee that, in lieu of the surface examination requirements for socket welds of Examination Categories B-F and B-J, examinations may be limited to areas identified by the Owner as susceptible to outside surface attack or thermal fatigue. Susceptibility to outside surface attack shall be determined in accordance with Table 1.

A surface examination shall be performed for areas identified as susceptible to outside surface attack. Areas identified as susceptible to thermal fatigue, a VT-2 visual examination shall be performed at operating pressure during each refueling outage.

Table 1
Susceptibility Criteria

Mechanism	Criteria
External chloride stress corrosion cracking	• austenitic stainless steel base metal, welds, or heat affected zone (HAZ), and • operating temperature > 150°F, and • a piping outside surface is within five pipe diameters of a probable leak path (e.g., valve stem) and is covered with nonmetallic insulation that is not in compliance with U.S. NRC Regulatory Guide 1.36 (e.g., chloride content) or equivalent requirements or • austenitic stainless steel base metal, welds, or HAZ, and • a piping outside surface is exposed to wetting from a concentrated chloride-bearing environment (e.g., seawater, brackish water, brine)
Other outside surface initiated mechanisms	Items identified as susceptible to outside surface attack by a plant-specific service history review. This review should include plant-specific processes and programs that minimize chlorides and other contaminants.

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Approval Date: November 10, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-713
Ultrasonic Examination in Lieu of Radiography
Section XI, Division 1

Inquiry: Under what conditions may ultrasonic examination be used in lieu of radiography required by the Construction Code?

Reply: It is the opinion of the Committee that, in lieu of the requirement of IWA-4000 to examine welding and brazing in accordance with the requirements of the Construction Code, when the Construction Code requires radiographic examination, welds may be examined using the ultrasonic (UT) method in lieu of the radiographic (RT) method provided the following requirements are met:

(a) The nominal material thickness shall be 0.237 in. (6 mm) or greater.

(b) The ultrasonic examination shall not be applied to weld joints that include austenitic castings, austenitic welds with single side access, or components with structural austenitic weld inlay.

(c) The ultrasonic examination shall include 100% of the wall thickness in the weld area and shall include $\frac{1}{2}T$ on all sides of the weld volume for Class 1 pressure vessel welds, and $\frac{1}{2}$ in. (13 mm) on all sides of the weld volume for all other welds. A supplemental straight beam examination shall also be used to identify laminations that could limit angle beam examinations.

(d) Ultrasonic examination shall be performed in accordance with the requirements of Appendix I and the following requirements:

(1) Where Appendix I requires the use of Appendix VIII procedures, equipment, and personnel, a supplemental performance demonstration as described in (e) shall be performed. The examination volume, as defined in (c), shall be included in the supplemental performance demonstration.

(2) Where Appendix I requires the use of Article 4 of Section V, as supplemented by Table I-2000-1, a supplemental performance demonstration as described in (e) shall be conducted as a blind test. Two angle beams having nominal angles of 45 and 60 deg should generally be used; however, other pairs of angle beams may be used provided the measured difference between the angles is at least 10 deg. In addition to these two angles, a 70 deg angle beam shall be used if the examination is conducted from a clad surface, or if the examination is conducted from an unclad surface and there is no accompanying surface examination. Examination scans shall be in four directions; two beam path directions perpendicular to the weld axis and two beam path directions parallel to the weld axis. Where the examination scan perpendicular to the weld is limited on one side, the second leg of the V-path may be used to achieve the two beam path directions. The flaws in (g)(2) must be located on the far side of the weld during demonstration of the single sided examination.

(e) A written procedure shall be followed. The procedure shall be demonstrated to detect all flaws in the qualification block or specimen as described in (g). Where Section V Article 4 is used, the ranges of essential variables requiring procedure requalification shall be identified.

(f) The qualification block shall conform to all of the following requirements:

(1) The block shall be fabricated from material of the same material specification, product form, and material heat treatment condition as one of the materials joined. Alternatively, for piping, if material of the same product form and specification is not available, material of similar chemical composition,[1] tensile properties, and metallurgical structure[2] may be used.

(2) If two or more base material thicknesses are involved, the qualification block thickness shall be of a size sufficient to contain the entire examination path.

(3) For austenitic materials, the qualification block configuration shall contain a weld representative of the joint to be ultrasonically examined, including the same welding process.

(4) Production weld surface condition shall be similar to that used in the qualification (e.g., smooth, flush, as welded).

[1] Chemical composition is within the same ranges as required in the original material specification.

[2] Same phase and similar grain shape as produced by the heat treatment required by the applicable material specification.

(g) The qualification block shall include flaws in accordance with one of the following:

(1) If an Appendix VIII performance demonstration methodology is used, supplemental qualification to a previously approved procedure shall be demonstrated through the use of a blind test with appropriate specimens that contain at least three different construction-type flaws (e.g., slag, lack of fusion, incomplete penetration) distributed throughout the thickness of the specimens, unless such flaws were included in the Appendix VIII qualification.

(2) If a Section V methodology is used, at least three planar flaws shall be included in the qualification block weld, including at least one subsurface flaw oriented parallel to the fusion line, one inner surface flaw, and one outer surface flaw. The flaws shall be no larger in the through-wall direction than the diameter of the applicable side-drilled hole in the calibration block of Section V, Article 4, and no larger than the smallest permitted flaw size of the applicable acceptance standard specified in (l).

(h) An examination procedure shall be provided showing the transducer placement, movement and component coverage that provides a repeatable methodology for weld acceptance. The examination procedure shall also include the ultrasonic beam angle used, beam directions with respect to weld centerline, and volume examined for each weld.

(i) Where Section V methodology is used, the ultrasonic examination shall be performed using a computer acquisition system that records the UT data and search unit position. Manual examination methods and techniques qualified in accordance with this Case may be used to supplement the automated data for evaluation and characterization of indications.

(j) Examination data shall be recorded at the same settings used during procedure demonstration. Data from the examination volume in (c) shall be recorded.

(k) Ultrasonic examination personnel shall be qualified in accordance with IWA-2300. Examination personnel shall be qualified and trained using the same type of equipment described in the examination procedure. Data analysis personnel shall demonstrate their ability to characterize flaws using the procedure as described in (e).

(l) The acceptance standards for volumetric examination shall be in accordance with IWB-3400, IWC-3400, or IWD-3000 (as applicable). Preservice acceptance standards shall be applied when provided. For components or configurations for which acceptance standards are not specified, the acceptance standards of the Construction Code shall apply. Analytical evaluation for acceptance of flaws within the repair volume in accordance with IWB-3600 or IWC-3600 is not permitted. Flaws within the inspection volume but outside the repair volume, which existed prior to the repair/replacement activity, may be evaluated under IWB-3600 or IWC-3600.

(m) Flaws exceeding the applicable acceptance standards referenced in (l) shall be repaired, and the weld subsequently reexamined using the same ultrasonic examination procedure that detected the flaw.

(n) Where Section V is referenced, the 2004 Edition or later Editions and Addenda shall be used. Where Section XI Editions and Addenda prior to the 1989 Edition with the 1989 Addenda are referenced in the repair/replacement program, the 1989 Edition with the 1989 Addenda of Appendices I and VIII, or later Editions or Addenda, shall be used.

(o) Use of this Case shall be documented on an NIS-2 Data Report Form.

(p) Use of this Case is limited to welds made at the Owner's facilities as part of a repair/replacement activity.

Approval Date: January 27, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-716-1
Alternative Classification and Examination Requirements
Section XI, Division 1

Inquiry: What alternative may be used in lieu of the requirements of IWB-2420, IWB-2430, Table IWB-2500, Examination Categories B-F and B-J, IWC-2420, IWC-2430, and Table IWC-2500 (excluding Examination Categories C-C and C-H), for inservice inspection of Class 1 piping welds or Class 2 components, IWB-2200 and IWC-2200 for preservice inspection of Class 1 piping welds or Class 2 components, or as additional requirements for Class 3 or Non-Class components?

Reply: It is the opinion of the Committee that the following requirements may be used in lieu of the requirements of IWB-2420, IWB-2430, Table IWB-2500-1 Examination Categories B-F and B-J, IWC-2420, IWC-2430, and Table IWC-2500-1 (excluding Examination Categories C-C and C-H), for inservice inspection of Class 1 piping welds or Class 2 components, IWB-2200 and IWC-2200 for preservice inspection of Class 1 piping welds or Class 2 components, or as additional requirements for Class 3 or Non-Class components.

1 SCOPE

The scope shall include Class 1 piping welds and Class 2 components, excluding attachment welds and supports, as identified in IWB-1200 and IWC-1200, Components Subject to Examination, limited by the exemptions of IWB-1220 and IWC-1220, and depending upon the results of 2(a)(5), might include Class 1 or 2 components exempt from volumetric and surface examination by Section XI, or Class 3 or Non-Class components.[1] Plants issued a combined operating license after January 1, 2012 shall submit the results of the application of this Case to the regulatory authority having jurisdiction at the plant site for review and approval.

2 GENERAL REQUIREMENTS

Components shall be assigned a category that shall be used to determine the treatment requirements of this Case.

(a) High safety significant (HSS) components shall include the following:

(1) Class 1 portions of the reactor coolant pressure boundary (RCPB), with the exception of components described as follows in (-a) or (-b):

(-a) In the event of postulated failure of the component during normal reactor operation, the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system.

(-b) The component is or can be isolated from the reactor coolant system by two valves in series (both closed, both open, or one closed and the other open). Each open valve must be capable of automatic actuation and, assuming the other valve is open, its closure time must be such that, in the event of postulated failure of the component during normal reactor operation, each valve remains operable and the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system only.

(2) Applicable portions of the shutdown cooling pressure boundary function. That is, Class 1 and 2 components of systems or portions of systems needed to utilize the normal shutdown cooling flowpath either

(-a) as part of the RCPB from the reactor pressure vessel (RPV) to the second isolation valve (i.e., farthest from the RPV) capable of remote closure, or to the containment penetration, whichever encompasses the larger number of welds, or

(-b) other systems or portions of systems from the RPV to the second isolation valve (i.e., farthest from the RPV) capable of remote closure or to the containment penetration, whichever encompasses the larger number of welds.

(3) Class 2 portions of steam generators and Class 2 feedwater system components greater than NPS 4 (DN 100) of pressurized water reactors (PWRs) from the steam generator to the outer containment isolation valve,

[1] Requirements for Class 3 and Non-Class HSS components, excluding piping, are in course of preparation.

(4) components larger than NPS 4 (DN 100) within the break exclusion region for high energy piping systems[2] as defined by the Owner

(5) any piping or component (including piping segments or components grouped or subsumed within existing plant initiating event groups) whose contributions to core damage frequency (CDF) is greater than 1E-06, or whose contribution to large early release frequency (LERF) is greater than 1E-07, based upon a plant-specific probabilistic risk assessment (PRA) of pressure boundary failures (e.g., pipe whip, jet impingement, spray, and inventory losses). This may include Class 1 and 2 components exempt from volumetric and surface examination by Section XI, or Class 3, or Non-Class components.

(b) Low safety significant (LSS) components shall include all other Class 1, 2, 3, or Non-Class components not classified as HSS in accordance with (a) above.

3 PRESERVICE INSPECTION REQUIREMENTS

Prior to initial plant startup or prior to startup following a repair/replacement activity, the following examinations shall be performed on HSS components. For plants implementing this Case after initial startup, the PSI requirements apply only to the HSS components affected by a repair/replacement activity.

(a) Vessels, pumps, valves, and pressure-retaining bolting require preservice inspection at least once prior to initial service. The examination volumes, areas, techniques, and procedures shall be in accordance with the applicable requirements of Section XI.

(b) Piping weld examinations, with the exception of VT-2 visual examinations listed in Table 1, shall be performed in accordance with the requirements defined in Table 1 at least once prior to initial service. Examinations shall include all piping welds, with the exception of VT-2 visual examinations listed in Table 1, classified as HSS in accordance with this Case.

4 INSERVICE INSPECTION REQUIREMENTS

(a) HSS vessels, pumps, valves, and pressure-retaining bolting shall be selected and examined in accordance with Section XI.

(b) Ten percent of the HSS piping welds shall be selected for examination. The examination requirements for these locations are defined in Table 1. The existing plant IGSCC (Generic Letter 88-01, Categories B through G) inspection program may be credited toward the 10% requirement, provided the requirements of this Case are met. Selection of piping welds for examination shall be as follows:

(1) The susceptibility of each HSS piping weld to the degradation mechanisms listed in Table 2 shall be determined. HSS piping welds shall be assigned an item number in Table 1 based upon the results of the degradation mechanism evaluation. HSS piping welds identified as not susceptible shall be assigned to Item No. R1.20 of Table 1.

(2) Examinations shall be prorated equally among systems to the extent practical, and each system shall individually meet the following requirements. At least 25% of the piping welds in each item number and item number combination (e.g., R1.11 and R1.16) shall be selected, excluding Item Numbers R1.15 and R1.20.

(3) For the RCPB;

(-a) Ten percent of the piping welds shall be selected.

(-b) At least two-thirds of the examinations shall be located between the first isolation valve (i.e., isolation valve closest to the RPV) and the RPV. If this cannot be accomplished due to a limited number of available welds between the first isolation valve and the RPV, 25% of the piping welds between the RPV and the first isolation valve shall be selected, not to exceed 10% of the RCPB piping welds.

(4) At least 10% of the piping welds in that portion of the RCPB outside containment (e.g., portions of the main feedwater system in BWRs) shall be selected.

(5) For each system within the break exclusion region, at least 10% of the piping welds shall be selected.

(6) If the examinations selected above exceed 10% of the total number of HSS piping welds, the examinations may be reduced by prorating among the requirements of (2), (3), (4), and (5) above, to the extent practical, such that at least 10% of the HSS piping welds are examined.

(7) If the examinations selected above are not at least 10% of the HSS piping welds, additional welds shall be selected so that the total number selected for examination is at least 10% of the HSS piping welds. The additional piping welds may be selected using the criteria of (2), (3), (4), and (5) above.

(8) When selecting welds for examination, the following shall be considered:

(-a) plant-specific cracking experience

(-b) weld repairs

(-c) random selection

(-d) minimization of worker exposure

[2] NUREG-0800, 3.6.2 provides a method for defining this scope of piping.

(9) For raw water systems[3] identified as susceptible to localized corrosion, excluding crevice corrosion, in lieu of the above 10% sample, areas to be examined may be determined in accordance with section 3.6.7.1 or section 3.6.7.2 of EPRI TR-112657, Revision B-A.[4] As discussed in TR-112657,[4] if representative segments are defined, inspections shall include HSS segments.

(10) For combinations of material type and service condition with less than 10 yr of operating experience, the sample shall be at least 25% of the locations (e.g. welds) containing the material.

(c) LSS components are exempt from the volumetric, surface, and VT-1 and VT-3 visual examination requirements of Section XI.

5 CHANGE-IN-RISK EVALUATION

A change-in-risk evaluation shall be performed prior to the initial implementation of this Case.

(a) Bounding Failure Frequency. The failure frequencies of 2E-06 per weld-year for welds in the high failure potential category, 2E-07 per weld-year for welds in the medium failure potential category, and 1E-08 per weld-year in the low failure potential category may be used as bounding failure frequencies for piping welds as defined in Table 3. Failure frequencies for welds in components other than piping may be obtained from industry sources such as NUREG/CR-6928[5] and EPRI TR-111472.[6] Additionally, probabilistic fracture mechanics (PFM) models may be used. If PFM models are used, the requirements of Mandatory Appendix I shall be met.

(b) Conditional Risk Estimates. The estimated conditional core damage probability (CCDP) and conditional large early release probability (CLERP) may be used if available. Bounding values of the highest estimated CCDP and CLERP may be used if specific estimates are not available.

(c) The following general equations shall be used to estimate the change-in-risk. One estimate shall be made for the change in core damage frequency (CDF) and one for large early release frequency (LERF). The equations only illustrate the change in CDF. The change in LERF due to application of the process shall be estimated by substituting the CLERP for CCDP in the equations.

$$\Delta R_{\mathrm{CDF}} = \Sigma_j (I_{rj} - I_{ej})^* PF_j^* \mathrm{CCDP}_j$$

where

Σ_j = summation of locations selected for examination

ΔR_{CDF} = change in CDF due to replacing the prior deterministic ISI program with the ISI program developed in accordance with this Case

I_{rj} = factor of reduction in pipe rupture frequency at location j associated with the ISI program developed by this Case

I_{ej} = factor of reduction in pipe rupture frequency at location j associated with the prior deterministic ISI program

PF_j = piping failure frequency at location j without examination

$CCDP_j$ = conditional core damage probability at location j

In terms of probability of detection

$[POD_j = (1 - I_j)]$, the equation becomes

$$\Delta R_{\mathrm{CDF}} = \textstyle\sum_j (POD_{ej} - POD_{rj})^* PF_j^* \mathrm{CCDP}_j$$

where

POD_{ej} = probability of detection at location j associated with the prior deterministic ISI program

POD_{rj} = probability of detection at location j associated with the ISI program developed in accordance with this Case

It is acceptable to use bounding estimates for pipe failure frequency, conditional core damage probability, and conditional large early release probability, to simplify the calculations. If these bounding estimates are used, the equation becomes:

$$\Delta R_{\mathrm{CDF}} = [(POD_e{}^* N_{efc} - POD_r{}^* N_{rfc})]^* PF_f{}^* \mathrm{CCDP}_c$$

where

POD_e = probability of detection in the existing ISI program (may be degradation mechanism specific)

N_{efc} = number of examination locations in the consequence f and failure frequency c categories associated with the prior deterministic ISI program (need not include locations with a

[3] The term Raw Water System is a general term to define a secondary or tertiary cooling water system that does not contain nuclear grade water (e.g., primary or secondary). Plant-specific identifiers for these types of systems include normal service water, emergency service water, nuclear service water, RHR service water, and circulating water. These systems might be subject to water treatment (e.g., use of chlorine, biocides).

[4] EPRI TR-112657, Revision B-A, Revised Risk-informed Inservice Inspection Evaluation Procedure, December 1999. USNRC ADAMS, Ascension Number ML993190460.

[5] NUREG/CR-6928, Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants, dated February 2007.

[6] Assembling Bolted Connections Using Spiral-Wound Gaskets: Sealing Technology & Plant Leakage Reduction Series, EPRI, Palo Alto, CA: 1999. TR-111472.

surface only examination and identified as not susceptible to outside diameter attack in accordance with the criteria of Table 2)

POD_r = probability of detection in the ISI program developed by this Case (may be degradation mechanism specific)

N_{rfc} = number of examination locations in the consequence f and failure frequency c categories associated with the ISI program developed using this Case

PF_f = piping failure frequency for the high, medium, and low failure frequency estimates

$CCDP_c$ = conditional core damage probability consequence estimates

(d) Acceptance Criteria. Any increase in CDF and LERF for each system shall be less than 1E-07 per year and 1E-08 per year, respectively, and the total increase in CDF and LERF should be less than 1E-06 per year and 1E-07 per year respectively. If necessary, additional examinations shall be selected to meet this acceptance criteria.

6 SUCCESSIVE INSPECTIONS AND ADDITIONAL EXAMINATIONS

Examination Category R-A welds shall meet the successive inspection and additional examination requirements of (a) and (b) below. For raw water systems[3] identified as susceptible to localized corrosion, excluding crevice corrosion, successive inspections and additional examinations may be determined in accordance with section 3.6.7.1 or section 3.6.7.2 of EPRI TR-112657, Revision B-A.[4] All other examination categories shall meet the applicable successive inspection and additional examination requirements of Section XI.

(a) Successive Inspections. As an alternative to the successive inspection requirements of IWB-2420, IWC-2420, or IWD-2420, the following requirements shall be met.

(1) The sequence of piping examinations established during the first inspection interval using this Case shall be repeated during each successive inspection interval to the extent practical. The examination sequence may be modified to optimize scaffolding, radiological, insulation removal, or other considerations, provided the percentage requirements of IWB-2410 are met.

(2) If Examination Category R-A Piping Welds are accepted for continued service by analytical evaluation in accordance with IWB-3132.3 or IWB-3142.4, the areas containing flaws or relevant conditions shall be reexamined during the next three inspection periods.

(3) If Class 2, 3, or non Class vessels, pumps, valves, and pressure-retaining bolting are accepted for continued service by analytical evaluation in accordance with IWC-3122.3, or IWC-3132.3, as applicable, the areas containing flaws or relevant conditions shall be reexamined during the next inspection period.

(4) If the reexaminations required by 6(a)(2) reveal that the flaws or relevant conditions remain essentially unchanged, the examination schedule shall revert to the original schedule of successive inspections.

(5) If the reexaminations required by 6(a)(3) reveal that the flaws or relevant conditions remain essentially unchanged during the successive inspection period, the examination schedule shall revert to the original schedule of successive inspections.

(b) Additional Examinations. As an alternative to the additional examination requirements of IWB-2430, IWC-2430, or IWD-2430, the following requirements shall be met.

(1) Examinations performed, excluding Examination Categories B-P and C-H, that reveal flaws or relevant conditions exceeding the acceptance standards of Table IWB-3410-1, Table IWC-3410-1, or IWD-3000, as applicable, shall be extended to include a first sample of additional examinations during the current outage.

(-a) The inspection item to be examined in the first sample of additional examinations shall include HSS inspection items with the same postulated degradation mechanism in systems whose materials and service conditions are similar to the element that exceeded the acceptance standards.

(-b) The number of examinations required is the number of HSS inspection items with the same postulated degradation mechanism scheduled for the current inspection period. If there are not enough HSS inspection items to equal this number, the Owner shall include remaining HSS inspection items and LSS inspection items within the Class 1, 2, and 3 systems subject to examination in accordance with Section XI, up to and including this number that are subject to the same degradation mechanism. This might require additional analysis of LSS components (e.g., degradation mechanism evaluation).

(2) If the additional examinations required by 6(b)(1) reveal flaws or relevant conditions exceeding the acceptance standards of Table IWB-3410-1, Table IWC-

[3] The term Raw Water System is a general term to define a secondary or tertiary cooling water system that does not contain nuclear grade water (e.g., primary or secondary). Plant-specific identifiers for these types of systems include normal service water, emergency service water, nuclear service water, RHR service water, and circulating water. These systems might be subject to water treatment (e.g., use of chlorine, biocides).

[4] EPRI TR-112657, Revision B-A, Revised Risk-informed Inservice Inspection Evaluation Procedure, December 1999. USNRC ADAMS, Ascension Number ML993190460.

3410-1, or IWD-3000 as applicable, the examinations shall be extended to include a second sample of additional examinations during the current outage.

(-a) The second sample of additional inspection items to be examined shall include all remaining HSS inspection items subject to the same degradation mechanism.

(-b) The Owner shall also examine LSS inspection items identified with the same postulated damage mechanism within the Class 1, 2, and 3 systems subject to examination in accordance with Section XI or document the basis for their exclusion. This might require additional analysis of LSS components (e.g., degradation mechanism evaluation).

(3) For the inspection period following the period in which the examination of 6(b)(1) and (2) were completed, the examinations shall be performed as originally scheduled in accordance with IWB-2400.

7 PROGRAM UPDATES

Programs developed in accordance with this Case shall be reevaluated on the basis of inspection periods that coincide with the inspection program requirements for Inspection Program A or B of IWA-2431 or IWA-2432 (1989 Edition through 2004 Edition with 2006 Addenda), as applicable. For Inspection Program B, the third period reevaluation will serve as the subsequent inspection interval reevaluation. As of the 2007 Edition of Section XI, Inspection Program A was eliminated and Inspection Program B was addressed under IWA-2431. For the 2007 Edition through the latest Edition and Addenda, examination selections made in accordance with this Case shall be reevaluated on the basis of inspection periods that coincide with the inspection program requirements of IWA-2431. For the inspection program, the third period reevaluation will serve as the subsequent inspection interval reevaluation. The performance of each inspection period reevaluation may be accelerated or delayed by as much as one year. Each reevaluation shall consider the cumulative effects of previous reevaluations. The reevaluation shall determine if any changes to the HSS/LSS categorization (i.e. (a) or (e) below) or examination selections need to be made, by evaluation of the following:

(a) plant design changes (e.g., physical: new piping or equipment installation; programmatic: power uprating/ 18 to 24 month fuel cycle; and procedural: operating procedure changes)

(b) changes in postulated conditions or assumptions (e.g., check valve seat leakage is greater than previously assumed)

(c) examination results (e.g., discovery of leakage or flaws)

(d) Failures in HSS or LSS components (e.g., plant-specific or industry occurrences of through-wall or through-weld leakage, failure due to a new degradation mechanism, or a nonpostulated mechanism)[7]

(e) PRA updates that would increase the scope of 2(a)(5) (e.g., new initiating events, new system functions, more detailed model used, and initiating event and failure data changes)

(f) the impact of 7(a) through 7(e) on the change-in-risk evaluation in 5

8 OWNER'S RESPONSIBILITY

(a) The Owner shall determine the appropriate classification for components in accordance with the provisions of this Case.

(b) The Owner shall ensure that the technical adequacy of the PRA is reviewed to confirm that it meets the requirements of Mandatory Appendix II of this Case, or that the Owner has met PRA technical adequacy requirements for RI-ISI applications accepted by the regulatory authority having jurisdiction at the plant site.

(c) The results of the application of this Case (e.g., determination of HSS components, change-in-risk evaluation) shall be documented and reviewed.

[7] NUREG-0737 (Clarification of TMI Action Plan Requirements) provides an acceptable method for review of industry operating experience.

Table 1
Examination Categories

EXAMINATION CATEGORY R-A							
Item No.	Parts Examined	Examination Requirement/ Fig. No. [Note (2)]	Examination Method	Acceptance Standard	Extent and Frequency 1st Interval	Extent and Frequency Successive Intervals	Defer to End of Interval
R1.10	HSS Piping Welds						
R1.11	Welds Subject to Thermal Fatigue	IWB-2500-8(c) [Note (1)] IWB-2500-9, 10, 11	Volumetric [Note (8)], [Note (10)]	IWB-3514	Weld [Note (2)], [Note (4)]	Same	Not Permissible
R1.12	Not Used						
R1.13	Welds Subject to Erosion-Cavitation	[Note (6)]	Volumetric [Note (7)]	IWB-3514 [Note (6)]	Weld [Note (2)]	Same	Not Permissible
R1.14	Welds Subject to Crevice Corrosion Cracking	[Note (5)]	Volumetric [Note (9)], [Note (10)]	IWB-3514	Weld [Note (2)]	Same	Not Permissible
R1.15	Welds Subject to Primary Water Stress Corrosion Cracking (PWSCC)	IWB-2500-8(c) [Note (1)] IWB-2500-9, 10, 11	Volumetric [Note (7)], [Note (9)], [Note (10)]]	IWB-3514	Weld [Note (2)], [Note (4)]	Same	Not Permissible
R1.16	Welds Subject to Intergranular or Transgranular Stress Corrosion Cracking (IGSCC or TGSCC)	IWB-2500-8(c) [Note (1)] IWB-2500-9, 10, 11 [Note (7)] for IGSCC	Volumetric [Note (7)] for IGSCC, [Note (9)], [Note (10)]]	IWB-3514	Weld [Note (2)], [Note (4)]	Same	Not Permissible [Note (7)] for IGSCC
R1.17	Welds Subject to Localized Corrosion [Microbiologically-Influenced Corrosion (MIC) or Pitting]	IWB-2500-8(a) IWB-2500-8 (b) IWB-2500-8(c) IWB-2500-9, 10, 11	Visual, VT-3 Internal Surfaces or Volumetric [Note (6)] or [Note (7)]]	[Note (6)]	Weld [Note (2)]	Same	Not Permissible
R1.18	Welds Subject to Flow Accelerated Corrosion (FAC)	[Note (7)]	[Note (7)]	[Note (7)]	[Note (7)]	[Note	[Note (7)]
R1.19	Welds Subject to External Chloride Stress Corrosion Cracking (ECSCC)	IWB-2500-8(a), IWB-2500-8 (b), IWB-2500-8(c), IWB-2500-9, 10, 11	Surface	IWB-3514	Weld [Note (2)]	Same	Not Permissible
R1.20	Welds Not Subject to a Degradation Mechanism	IWB-2500-8(c) IWB-2500-9, 10, 11	Volumetric [Note (9)], [Note (10)]	IWB-3514	Weld [Note (2)], [Note (4)]	Same	Not Permissible

NOTES:

(1) The length of the examination volume shown in Fig. IWB-2500-8(c) shall be increased by enough distance [approximately $\frac{1}{2}$ in. (13 mm)] to each side of the base metal thickness transition or counterbore transition.

(2) Includes examination locations and Class 1 weld examination requirement figures that typically apply to Class 1, 2, 3, or Non-Class welds identif accordance with 4 Inservice Inspection Requirements.

(3) Includes essentially 100% of the examination location. When the required examination volume or area cannot be examined due to interference component or part geometry, limited examinations shall be evaluated for acceptability. Acceptance of limited examinations or volumes shall not invalidate the results o change-in-risk evaluation (see (5)). Areas with acceptable limited examinations and their bases, shall be documented.

(4) The examination shall include any longitudinal welds at the location selected for examination in (2). The longitudinal weld examination requirements be met for both transverse and parallel flaws within the examination volume defined in (2) for the intersecting circumferential welds.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(5) The examination volume shall include the volume surrounding the weld, weld HAZ, and base metal, where applicable, in the crevice region. Examinat should focus on detection of cracks initiating and propagating from the inner surface.

(6) The examination volume shall include base metal, welds, and weld HAZ in the affected regions of carbon and low alloy steel, and the welds and of austenitic steel. Examinations shall verify the minimum wall thickness required. Acceptance criteria for localized thinning is in the course of preparation. The examinat method and examination region shall be sufficient to characterize the extent of the element degradation.

(7) In accordance with the Owner's existing programs, such as PWSCC, IGSCC, MIC, or FAC inspection programs, for degradation mechanisms as described Table 2.

(8) Socket welds of any size and branch pipe connection welds NPS 2 (DN 50)and smaller selected for examination require a volumetric examination of piping base metal within $^1/_2$ in. (13 mm) of the toe of the weld, and the fitting itself shall receive a VT-2 visual examination.

(9) Socket welds of any size and branch pipe connection welds NPS 2 (DN 50) and smaller require only a VT-2 visual examination. For PWSCC susceptible ations, the insulation shall be removed.

(10) The VT-2 visual examinations shall be conducted during a system pressure test or a pressure test specific to that weld, in accordance with Examina Categories B-P, C-H, or D-B, as applicable.

Table 2
Degradation Mechanisms

Mechanisms		Attributes	Susceptible Regions
TF	TASCS	– piping > NPS 1 (DN 25) – piping segment has a slope < 45 deg from horizontal (includes elbow or tee into a vertical pipe) – potential exists for a low flow in a piping section connected to a component allowing mixing of hot and cold fluids, or potential exists for leakage flow past a valve (i.e., in-leakage, out-leakage, cross-leakage) allowing mixing of hot and cold fluids, or potential exists for convection heating in dead-ended pipe sections connected to a source of hot fluid, or potential exists for two phase (steam/water) flow, or potential exists for turbulent penetration in branch piping connected to header piping containing hot fluid with high turbulent flow – calculated or measured ΔT > 50°F (28°C) – Richardson number > 4.0	nozzles, branch pipe connections, safe ends, welds, heat affected zones (HAZ), base metal, and regions of stress concentration
	TT	– operating temperature > 270°F (130°C) for stainless steel, or operating temperature > 220°F (105°C) for carbon steel – potential for relatively rapid temperature changes including cold fluid injection into hot pipe segment, or hot fluid injection into cold pipe segment – $\lvert\Delta T\rvert$ > 200°F (110°C) for stainless steel, or $\lvert\Delta T\rvert$ > 150°F (83°C) for carbon steel, or $\lvert\Delta T\rvert$ > ΔT allowable (applicable to stainless and carbon)	
SCC	IGSCC (BWR)	– evaluated in accordance with the Owner's existing IGSCC inspection program following NRC Generic Letter 88-01, or alternative (e.g., BWRVIP-075)	base metal, welds, and HAZ
	IGSCC (PWR)	– operating temperature > 200°F (93°C) – susceptible material (carbon content ≥ 0.035%) – tensile stress (including residual stress) is present – oxygen or oxidizing species are present – operating temperature < 200°F (93°C), the attributes above apply – initiating contaminants (e.g., thiosulfate, fluoride, chloride) are also required to be present	
	TGSCC	– operating temperature > 150°F (65°C) – tensile stress (including residual stress) is present – halides (e.g., fluoride or chloride) are present, or caustic (NaOH) is present – oxygen or oxidizing species are present (only required to be present in conjunction with halides, not required with caustic)	austenitic stainless steel base metal, welds, and HAZ
	ECSCC	– operating temperature > 150°F (65°C) – an outside piping surface is within five diameters of a probable leak path (e.g., valve stems) and is covered with nonmetalic insulation that is not in compliance with Reg. Guide 1.36, or an outside piping surface is exposed to wetting from concentrated chloride-bearing environments (e.g., seawater, brackish water, brine)	
	PWSCC	– evaluated in accordance with the Owner's existing PWSCC inspection program and, as applicable, the requirements endorsed by the regulatory authority having jurisdiction at the plant site (e.g., 10CFR50.55a(g)(6)(ii)(F) dated June 21, 2011)	base metal, welds, and HAZ

Table 2
Degradation Mechanisms (Cont'd)

Mechanisms		Attributes	Susceptible Regions
LC	MIC	– operating temperature < 150°F (65°C) – low or intermittent flow – pH < 10 – presence/intrusion of organic material (e.g., raw water system), or water source is not treated with biocides (e.g., refueling water tank)	fittings, welds, HAZ, base metal, dissimilar metal joints (e.g., welds, flanges), and regions containing crevices
	PIT	– potential exists for low flow – oxygen or oxidizing species are present – initiating contaminants (e.g., fluoride, chloride) are present	
	CC	– crevice condition exists (e.g., thermal sleeves) – operating temperature > 150°F (65°C) – oxygen or oxidizing species are present	
FS	E-C	– existence of cavitation source (i.e., throttling or pressure reducing valves or orifices) – operating temperature < 250°F (120°C) – flow present > 100 hr/yr – velocity > 30 ft/s (9.1 m/s) – $(P_d - P_v)/\Delta P < 5$ where, P_d = static pressure downstream of the cavitation source, P_v = vapor pressure, and ΔP = pressure difference across the cavitation source	fittings, welds, HAZ, and base metal
	FAC	– evaluated in accordance with the Owner's existing FAC inspection program	per FAC program

Legend:
Thermal Fatigue (TF)
Thermal Stratification, Cycling, and Striping (TASCS)
Thermal Transients (TT)
Stress Corrosion Cracking (SCC)
Intergranular Stress Corrosion Cracking (IGSCC)
Transgranular Stress Corrosion Cracking (TGSCC)
External Chloride Stress Corrosion Cracking (ECSCC)
Localized Corrosion (LC)
Microbiologically-Influenced Corrosion (MIC)
Primary Water Stress Corrosion Cracking (PWSCC)
Pitting (PIT)
Crevice Corrosion (CC)
Flow Sensitive (FS)
Erosion-Cavitation (E-C)
Flow-Accelerated Corrosion (FAC)

Table 3
Degradation Mechanism Category

Failure Potential	Conditions	Degradation Category	Degradation Mechanism
High [Note (1)]	Degradation mechanism likely to cause a large break	Large Break	Flow-Accelerated Corrosion
Medium	Degradation mechanism likely to cause a small leak	Small Leak	Thermal Fatigue, Erosion-Cavitation, Corrosion, Stress Corrosion Cracking
Low	None	None	None

NOTE:
(1) Segments having degradation mechanism listed in the small leak category shall be upgraded to the high failure potential large/break category if the pipe segments also have the potential for water hammer loads.

MANDATORY APPENDIX 1
PFM USER TRAINING AND QUALIFICATION

To ensure that the input parameters are consistently assigned and the Probabilistic Fracture Mechanics (PFM) model used in this Case is properly executed, the users of the PFM model shall be trained and qualified. Acceptable qualification and the scope of training are to be determined by the Owner, based on the background and experience of the individuals using the model. Training should consist of the following topics:

(a) overall risk-informed ISI process

(b) how PFM calculated probabilities are used in this Case

(c) capabilities and limitations of PFM model

(d) expertise and type of information required, including applicable sources

(e) how potential degradation mechanisms are considered and combined

(f) the importance of each input parameter on each degradation mechanism and failure mode

(g) examples of PFM tool use for different degradation mechanisms and failure modes

(h) how detailed PFM input (e.g., uncertainties) is developed and used

MANDATORY APPENDIX 2
PRA TECHNICAL ADEQUACY REQUIREMENTS

The Owner shall ensure that the technical adequacy of the PRA is reviewed to confirm that it meets the requirements of Table II-1 or that the Owner has met PRA technical adequacy requirements for RI-ISI applications accepted by the regulatory authority having jurisdiction at the plant site.

Table II-1
Supporting Requirement as Defined in U.S. NRC Regulatory Guide 1.200, r1

Index No.	Capability Category Required
IF-D5A	III & II
IE-A3a, IE-C11, IE-C12	II & I
AS-A7	
SY-A7, SY-A15, SY-B2	
HR-D7, HR-F1	
DA-B2, DA-C9	
IF-D3a, IF-E3a	
IE-A4	II
IF-C3, IF-C6, IF-C8	
AS-9	
SC-B2	
IE-E4a, IE-A6, IE-A7, IE-B3	I
AS-A10	
SC-A2, SC-A5, SC-B1	
SY-A4, SY-A20, SY-B1, SY-B7, SY-B11	
HR-B1, HR-C2, HR-D2, HR-D3, HR-E3, HR-E4, HR-F2, HR-G1, HR-G3, HR-G4, HR-G5, HR-H1	
DA-B1, DA-C7, DA-C8, DA-C10, DA-C12, DA-D1, DA-D3, DA-D4, DA-D5, DA-D6, DA-D7	
IF-A1a, IF-C3b, IF-D3	
QU-A2b, QU-D3, QU-D5a, QU-E3, QU-F3	
LE-B1, LE-B2, LE-C1, LE-C2a, LE-C2b, LE-C3, LE-C4, LE-C8a, LE-C8b, LE-C9a, LE-C9b, LE-C10, LE-D1a, LE-D1b, LE-D2, LE-D3, LE-D4, LE-D5, LE-D6, LE-E2, LE-E3, LE-F1a, LE-G3	
IE-A10, IE-B5, IE-C1, IE-C1a, IE-C2, IE-C3, IE-C4, IE-C5, IE-C13, IE-D3	Need not be met
AS-C3, SC-C3, SY-C3, HR-I3, DA-E3, IF-D6	
QU-E1, QU-E2, QU-E4, QU-F4	
LE-F2, LE-F3, LE-G4	

Table II-1
Supporting Requirement as Defined in U.S. NRC Regulatory Guide 1.200, r1 (Cont'd)

Index No.	Capability Category Required
IE-A1, IE-A2, IE-A3, IE-A5, IE-B1, IE-B2, IE-B4, IE-C1b, IE-C6, IE-C7, IE-C8, IE-C9, IE-C10, IE-D1, IE-D2	Spans all three categories and needs to be met
AS-A1, AS-A2, AS-A3, AS-A4, AS-A5, AS-A6, AS-A8, AS-A11, AS-B1, AS-B2, AS-B3, AS-B4, AS-B5, AS-B5a, AS-B6, AS-C1, AS-C2	
SC-A1, SC-A4, SC-A4a, SC-A6, SC-B3, SC-B4, SC-B5, SC-C1, SC-C2	
SY-A1, SY-A2, SY-A3, SY-A5, SY-A6, SY-A8, SY-A10, SY-A11, SY-A12, SY-A12a, SY-A12b, SY-A13, SY-A14, SY-A16, SY-A17, SY-A18, SY-A18a, SY-A19, SY-A21, SY-A22, SY-B3, SY-B4, SY-B5, SY-B6, SY-B8, SY-B10, SY-B12, SY-B13, SY-B14, SY-B15, SY-B16, SY-C1, SY-C2	
HR-A1, HR-A2, HR-A3, HR-B2, HR-C1, HR-C3, HR-D1, HR-D4, HR-D5, HR-D6, HR-E1, HR-E2, HR-G2, HR-G6, HR-G7, HR-G9, HR-H2, HR-H3, HR-I1, HR-I2	
DA-A1, DA-A1a, DA-A2, DA-A3, DA-C1, DA-C2, DA-C3, DA-C4, DA-C5, DA-C6, DA-C11, DA-C11a, DA-C13, DA-C14, DA-C15, DA-D2, DA-D6a, DA-D8, DA-E1, DA-E2	
IF-A1, IF-A1b, IF-A3, IF-A4, IF-B1, IF-B1a, IF-B1b, IF-B2, IF-B3, IF-B3a, IF-C1, IF-C2, IF-C2a, IF-C2b, IF-C2c, IF-C3A, IF-C3c, IF-C4, IF-C4a, IF-C5, IF-C5a, IF-C7, IF-C9, IF-D1, IF-D4, IF-D5, IF-D7, IF-E1, IF-E3, IF-E4, IF-E5, IF-E5a, IF-E6, IF-E6a, IF-E6b, IF-E7, IF-E8, IF-F1, IF-F2, IF-F3	
QU-A1, QU-A2a, QU-A3, QU-A4, QU-B1, QU-B2, QU-B3, QU-B4, QU-B5, QU-B6, QU-B7a, QU-B7b, QU-B8, QU-B9, QU-C1, QU-C2, QU-C3, QU-D1a, QU-D1B, QU-D1C, QU-D4, QU-D5b, QU-F1, QU-F2, QU-F5, QU-F6	
LE-A1, LE-A2, LE-A3, LE-A4, LE-A5, LE-B3, LE-C5, LE-C6, LE-C7, LE-E1, LE-E4, LE-F1b, LE-G1, LE-G2, LE-G5, LE-G6	

GENERAL NOTES:
(a) For a supporting requirement to be met, all relevant peer review and other independent findings shall have been addressed and necessary changes made to PRA models, methods, and documentation.
(b) There may be some supporting requirements that are not achievable due to plant operational status (e.g., after fuel load but prior to commercial operation). These supporting requirements shall be met to the extent practical and the program updated in accordance with 7.

Approval Date: September 9, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-721
Alternative Rules for Linear Piping Supports
Section III, Division 1

Inquiry: What alternative rules to Section III, Subsection NCA and NF may be used for the construction of linear piping supports?

Reply: It is the opinion of the Committee that as an alternative to the requirements of NCA and NF, linear piping supports may be constructed to ANSI/AISC N690L-03, "Load and Resistance Factor Design Specification for Safety Related Steel Structures for Nuclear Facilities" with the following additional requirements.

1 GENERAL

1.1 The Owner or his designee shall provide a Design Specification (NCA-3252, NCA-3255) that shall identify the loadings for which the supports are to be designed in accordance with NA4 of ANSI/AISC N690L-03. The Design Specification shall contain sufficient detail to provide a complete basis for construction of the supports.

1.2 The Owner or his designee shall review and approve each support calculation to determine that all the specified loadings and combinations of loadings have been evaluated and that the acceptance criteria provided in this Code Case and in ANSI/AISC N690L-03 have been considered.

1.3 The supports shall be constructed under a Quality Assurance Program that meets the requirements of the Owner.

1.4 The use of this Code Case shall be in accordance with NCA-1140 and shall be listed on the applicable Data Report for the piping system which utilizes the linear piping support.

2 MATERIAL

2.1 The requirements of Section NA3 of ANSI/AISC N690L-03 do not apply to items listed in NF-1110(e). Requirements, if any, for these materials shall be stated in the Design Specification.

3 DESIGN

3.1 The design shall be by elastic analysis and shall meet the requirements of ANSI/AISC N690L-03 and the additional requirements of 3.2 through 3.5 below.

3.2 The rules that shall be satisfied for any Test Loading stated in the Design Specification shall be those given for "Severe Environmental Loads" in Section NA4-2 of ANSI/AISC N690L-03 with the test fluid weight included.

3.3 All loads on the support resulting from restraint of free end displacement and anchor motions of piping shall be considered as R_o or R_a loads.

3.4 In applying T_o and T_a the following shall apply in lieu of the requirements of ANSI/AISC N690L-03:

(a) Thermal stresses within the support as defined in NF-3121.11 need not be evaluated.

(b) Loads resulting from restraint of free end displacement and anchor motions of the support shall be considered as T_o or T_a loads. The value of the T_o or T_a load used in the support evaluation shall be one-half of the full range of the load.

3.5 When required by the Design Specification, deformation control shall be considered separately.

4 FABRICATION

4.1 The requirements for welding qualifications given in NF-4300 may be used for any portion of the fabrication and installation in lieu of those specified in ANSI/AISC N690L-03 provided all such welding is performed by an N-Type Certificate Holder and the qualification is performed under the QA Program applicable to the certificate.

5 EXAMINATION

5.1 All full penetration butt welded joints in supports for Class 1 piping shall be nondestructively examined by radiographic methods in accordance with ANSI/AISC N690L-03.

5.2 All other welded joints in supports for Class 1 piping shall be nondestructively examined by liquid penetrant or magnetic particle methods in accordance with ANSI/AISC N690L-03.

5.3 All NDE personnel shall be qualified to the requirements of ANSI/AISC N690L-03.

5.4 As an alternative to 5.3 N-Type Certificate Holders may use NF-5500 for NDE personnel qualification provided the qualification is performed under the QA Program applicable to the certificate.

6 CERTIFICATION

6.1 The requirements of NF-8000 for Certificates of Accreditation and Certification Documents are not required for linear piping supports designed and constructed to the requirements of ANSI/AISC N690L-03.

Approval Date: September 8, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-722-2
Visual Examinations for PWR Pressure Retaining Welds in Class 1 Components Fabricated With Alloy 600/82/182 Materials
Section XI, Division 1

Inquiry: What examinations, in addition to those of Table IWB-2500-1, may be performed to provide additional detection capability for pressure boundary leakage in pressurized water reactor plants having pressure retaining partial or full penetration welds in Class 1 components fabricated with Alloy 600/82/182 material?

Reply: It is the opinion of the Committee that in addition to the examination requirements of Table IWB-2500-1 examinations of Table 1 shall be performed for pressurized water reactor plants having pressure-retaining partial- or full-penetration welds in Class 1 components fabricated with Alloy 600/82/182 material.

Table 1
Examination Categories

CLASS 1 PWR COMPONENTS CONTAINING ALLOY 600/82/182[Note (1)]

Item No.	Parts Examined [Note (2)], [Note (9)], [Note (10)], [Note (11)]	Examination Requirements	Examination Method [Note (3)], [Note (4)]	Acceptance Standard	Extent and Frequency of Examination: First Inspection Interval	Extent and Frequency of Examination: Successive Inspection	Deferral of Inspection to End of Interval
Reactor Vessel [Note (2)]							
B15.80	RPV bottom-mounted instrument penetrations	All penetrations	Visual, VE	IWB-3522	Every other refueling outage	Same interval	Not permissible
B15.100	Instrument connections [Note (8)]	All connections	Visual, VE	IWB-3522	Once per interval [Note (6)], [Note (7)]	Same interval	Not permissible
Steam Generators							
B15.120	Bottom channel head drain tube penetration	All penetrations	Visual, VE	IWB-3522	Once per interval [Note (6)], [Note (7)]	Same interval	Not permissible
B15.130	Primary side hot leg instrument connections	All connections	Visual, VE	IWB-3522	Each refueling outage	Same interval	Not permissible
B15.135	Primary side cold leg instrument connections	All connections	Visual, VE	IWB-3522	Once per interval [Note (6)], [Note (7)]	Same interval	Not permissible
Pressurizer							
B15.140	Heater penetrations	All penetrations	Visual, VE	IWB-3522	Each refueling outage	Same interval	Not permissible
B15.180	Instrument connections	All connections	Visual, VE	IWB-3522	Each refueling outage	Same interval	Not permissible
Piping							
B15.200	Hot leg instrument connections	All connections	Visual, VE	IWB-3522	Each refueling outage	Same interval	Not permissible
B15.205	Cold leg instrument connections	All connections	Visual, VE	IWB-3522	Once per interval [Note (6)], [Note (7)]	Same interval	Not permissible

NOTES:

(1) Alloy 600/82/182 are equivalent to UNS N06600 (SB-163, SB-166, SB-167, and SB-168), UNS N06082 and W86182.

(2) The reactor vessel closure head and butt welds larger than NPS 1 (DN 25) or having an operating temperature less than 525°F (274°C) are not in this Case.

(3) The Visual Examination (VE) performed on Alloy 600/82/182 items for evidence of pressure boundary leakage and corrosion on adjacent ferritic ste components shall be in accordance with (a) or (b). The VE may be performed when the system or component is depressurized.

(a) A direct VE of the bare-metal surface shall be performed with the insulation removed.

(b) Alternatively, the VE may be performed with insulation in place, or removed, using remote visual inspection equipment that provides resolution item metal surface equivalent to a bare-metal direct VE.

(c) The direct VE shall be performed at a distance not greater than 4 ft (1.2 m) from the component and with a demonstrated illumination level allow resolution of lower case characters having a height of not greater than 0.105 in (2.7 mm).

(4) Personnel performing the VE shall be qualified as VT-2 visual examiners and shall have completed a minimum of 4 hr of additional training in detecti borated water leakage from Alloy 600/82/182 items and the resulting boric acid corrosion of adjacent ferritic steel components.

(5) Reserved.

(6) VE shall be performed in accordance with the schedule in IWB-2400.

(7) The detection of evidence of pressure leakage at a VE location shall require the VE of all items within the Item No. prior to reactor startup. These additional shall not affect the original VE schedule of the items within the Item No.

(8) This Case does not require visual examination of Alloy 600/82/182 materials in flange seal leak-off lines.

(9) The examinations required by this Case do not apply to items that have been mitigated by weld overlay or stress improvement.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(10) If evidence of leakage is detected and determined to have originated from the items being examined, supplemental surface or volumetric examinations be performed on the items. The supplemental examination shall determine whether flaws exist in the items and shall characterize the location, orientation, and length of the fl which the evidence of leakage originates. If the orientation of the flaws is determined to be circumferential and potentially a result of PWSCC, additional items under the same shall be examined using the same surface or volumetric methods. The examinations of additional items shall be performed in the same locations and provide coverage of an area lume equal to that required to characterize the initially-identified flaw. If the flaws cannot be characterized, the flaw orientation shall be assumed to be circumferential. The number additional items examined shall be equal to the number of items under this Item No. found to have evidence of leakage. If any of the additional items are found to have circumferentially-oriented flaws, all remaining items under this Item No. shall be examined using the same surface or volumetric methods. Alternatively, all items under this Item No. may be replaced without the requirement for supplemental or additional examinations.

(11) Alloy 600/82/182 welds never exposed to the reactor water environment are not included in this Case.

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Approval Date: January 12, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-725
Design Stress Values for UNS N06690 With a Minimum Specified Yield Strength of 35 ksi (240 MPa), Classes 2 and 3 Components
Section III, Division 1

Inquiry: Is it permissible to use nickel-chromium-iron UNS N06690 material that has a minimum yield strength of 35 ksi (240 MPa) and that otherwise conforms to Material Specification SB-167 (hot or cold worked, annealed) or SB-564 (annealed) in the construction of Classes 2 and 3 components that conform to the requirements of Section III, Division 1?

Reply: It is the opinion of the Committee that nickel-chromium-iron UNS N06690 material that has a minimum yield strength of 35 ksi (240 MPa) and that otherwise conforms to Material Specification SB-167 (hot or cold worked, annealed) or SB-564 (annealed) may be used in the construction of Classes 2 and 3 components that conform to the requirements of Section III, Division 1, provided the following additional requirements are met.

(a) The maximum allowable stress values shall be those shown in Table 1 of this Case.

(b) This Case number shall be listed on the Data Report Form for the component.

Table 1
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding (°F)	Maximum Allowable Stress (ksi)
−20 to 100	23.3
200	23.3 [Note (1)]
300	23.3 [Note (1)]
400	23.3 [Note (1)]
500	23.1 [Note (1)]
600	22.9 [Note (1)]
650	22.9 [Note (1)]
700	22.8 [Note (1)]
750	22.7 [Note (1)]
800	22.6 [Note (1)]

Table 1
Maximum Allowable Stress Values (Cont'd)

NOTE:
(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed $66^2/_3$% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. Table Y-2 in Section II, Part D, Subpart 2 lists multiplying factors which, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

Table 1M
Maximum Allowable Stress Values

For Metal Temperature Not Exceeding (°C)	Maximum Allowable Stress (MPa)
−30 to 40	161
65	161 [Note (1)]
100	161 [Note (1)]
125	161 [Note (1)]
150	161 [Note (1)]
175	161 [Note (1)]
200	161 [Note (1)]
225	160 [Note (1)]
250	160 [Note (1)]
275	159 [Note (1)]
300	158 [Note (1)]
325	158 [Note (1)]
350	158 [Note (1)]
375	157 [Note (1)]
400	156 [Note (1)]
425	156 [Note (1)]

NOTE:
(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater

Table 1M
Maximum Allowable Stress Values (Cont'd)

NOTE (CONT'D):

deformation is acceptable. The stress values in this range exceed $66^2/_3\%$ but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion

Table 1M
Maximum Allowable Stress Values (Cont'd)

NOTE (CONT'D):

can cause leakage or malfunction. Table Y-2 in Section II, Part D, Subpart 2 lists multiplying factors which, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

Approval Date: February 24, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-727
Dissimilar Welding Using Continuous Drive Friction Welding for Reactor Vessel CRDM/CEDM Nozzle to Flange/Adapter Welds, Class 1
Section III, Division 1

Inquiry: May the continuous drive friction welding process be used on Class 1 vessels, as an alternative to NB-4311.4(a), for reactor vessel CRDM/CEDM nozzle to flange/adapter dissimilar metal welds?

Reply: It is the opinion of the Commitee that as an alternative to NB-4311.4(a), the continuous drive friction welding process may be used on Class 1 vessels for reactor vessel CRDM/CEDM nozzle to flange/adapter dissimilar metal welds provided the requirements specified in the paragraphs below and the additional requirements specified in NB-4000, NB-5000, and Section IX are met, except as specified herein.

1 GENERAL REQUIREMENTS

The welds between the two members shall be a square butt weld.

2 WELDING PROCEDURE QUALIFICATION

(a) The nominal configuration of the base materials shall be the same as that to be welded in production. The coupon length shall be such that the heat flow is comparable to that of the items to be welded in production.

(b) The base materials alignment and tilt angle shall be the same as that to be welded in production.

(c) The welding equipment and controls shall be the same as is to be used in production.

(d) The welding procedure shall be qualified at the same facility as the production welding location.

(e) A minimum of four cross sections, approximately 90 deg apart, shall be taken from the test assembly. Each cross section shall be examined at a minimum of 10 times magnification. All test surfaces shall be free of cracks, incomplete penetration, and lack of fusion. Only a single rounded indication with maximum dimensions not to exceed $^1/_{32}$ in. (0.8 mm) or 10% of the thickness, whichever is less, shall be permitted on each test surface.

(f) The welding procedure shall be requalified after every 300 welds or less when a continuous production run is performed (where no tooling or machine setting is changed), and any time the welding equipment has not been used for a time period of three months or more.

(g) The welding procedure shall be requalified after maintenance is performed on welding system components that may affect the weld characteristics or quality.

(h) QW-410.29 as specified in QW-262 shall not be considered an essential or nonessential variable.

3 WELDING OPERATOR PERFORMANCE QUALIFICATION

(a) The base materials shall be of the same Material Specification and Alloy Classification (UNS Number) as that to be welded in production.

(b) The nominal configuration of the base materials shall be the same as that to be welded in production.

(c) The base materials alignment and tilt angle shall be the same as that to be welded in production.

(d) The welding equipment and controls shall be the same as is to be used in production.

(e) The welding operator shall be qualified at the same facility as the production welding location.

(f) A minimum of four cross sections, approximately 90 deg apart, shall be taken from the test assembly. Each cross section shall be examined at a minimum of 10 times magnification. All test surfaces shall be free of cracks, incomplete penetration, and lack of fusion. Only a single rounded indication with maximum dimensions not to exceed $^1/_{32}$ in. (0.8 mm) or 10% of the thickness, whichever is less, shall be permitted on each test surface.

4 WELDING

(a) The rotational speed shall be within ±5% of that used during welding procedure qualification.

(b) The applied butting (axial) force duration shall be within 1 sec of that used during welding procedure qualification.

(c) The applied friction (rotational) force duration shall be within +2/−1 sec of that used during welding procedure qualification.

(d) The braking time between the removal of the rotational (friction) force and the application of the forging (axial) force shall be within ±1 sec of that used during welding procedure qualification.

(e) The applied forging (axial) force duration shall be within ±2 sec of that used during welding procedure qualification.

(f) Weld joint preparation and cleaning shall be equivalent to joint preparation and cleaning performed during procedure qualification.

(g) Weld repair shall be prohibited.

5 EXAMINATION

(a) Ultrasonic examination shall be used in lieu of radiography. Ultrasonic examination shall be performed in accordance with NB-5000.

(b) The ultrasonic calibration standard shall use a weldment with the same base Material Specification and Alloy Classification (UNS Number) and the same configuration as the production weldment.

6 DOCUMENTATION

Use of this Case shall be documented on the applicable Data Report Form.

Approval Date: October 11, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-728
Use of ASTM B932-04 Plate Material for Nonpressure Retaining Spent Fuel Containment Internals to 650°F (343°C)
Section III, Division 3

Inquiry: Until such time as Section III, Division 3 incorporates rules for internals, may plate material conforming to the requirements of ASTM B932-04 be used at temperatures to 650°F (343°C) for nonpressure retaining spent fuel containment internals?

Reply: It is the opinion of the Committee that until such time as Section III, Division 3 incorporates rules for internals, plate material conforming to the requirements of ASTM B932-04 may be used at temperatures to 650°F (343°C) for nonpressure retaining spent fuel containment internals, provided that the ultimate tensile strength, yield strength, and design stress intensity values shall be as listed in Table 1 and Table 1M and the following are met.

(a) Welding of this material is not permitted for this application.

(b) The Data Report Form, Design Specification, and Design Report shall reference Case N-728.

Table 1
Maximum Design Stress Intensity, Tensile Strength, and Yield Strength Values

Temperature °F	Tensile Strength, S_u ksi	Yield Strength, S_y ksi	Design Stress Intensity, S_m ksi
−20 to 100	100	45.0	30.0
200	100	40.7	27.1
300	100	38.2	25.4

Table 1
Maximum Design Stress Intensity, Tensile Strength, and Yield Strength Values (Cont'd)

Temperature °F	Tensile Strength, S_u ksi	Yield Strength, S_y ksi	Design Stress Intensity, S_m ksi
400	100	36.3	24.2
500	100	34.9	23.3
600	100	33.9	22.6
650	100	33.3	22.2
700	100	32.6	...
750	100	31.6	...

Table 1M
Maximum Design Stress Intensity, Tensile Strength, and Yield Strength Values

Temperature °C	Tensile Strength, S_u MPa	Yield Strength, S_y MPa	Design Stress Intensity, S_m MPa
−30 to 40	690	310	207
100	690	278	185
150	690	263	175
200	690	251	167
250	690	242	161
300	690	236	157
350	690 [Note (1)]	229 [Note (1)]	153 [Note (1)]
400	690	217	...

NOTE:
(1) The 350°C value is provided for interpolation only. The maximum use temperature is 343°C.

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Approval Date: June 22, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-729-4
Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds
Section XI, Division 1

Inquiry: What alternative examination requirements to those of Table IWB-2500-1, Examination Category B-P, IWB-2200, IWB-2400, and IWB-3000, may be used for PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds?

Reply: It is the opinion of the Committee that the following alternatives to the requirements of Table IWB-2500-1, Examination Category B-P, IWB-2200, IWB-2400, and IWB-3000, may be used for PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds.

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

This Case provides alternative requirements for examination of PWR reactor vessel upper heads with nozzles having pressure-retaining partial-penetration welds.

-1200 COMPONENTS SUBJECT TO EXAMINATION

-1210 Examination Requirements

The examination requirements shall apply to the following:

(a) Heads having nozzles fabricated from UNS N06600 material with UNS N06082 or UNS W86182 partial-penetration welds.

(b) Heads having nozzles fabricated from Primary Water Stress Corrosion Cracking (PWSCC) resistant materials, such as UNS N06690 base metal with UNS N06052 or UNS W86152 partial-penetration welds.

-2000 EXAMINATION AND INSPECTION

-2200 PRESERVICE EXAMINATION

-2210 Baseline Examination

The examinations listed in Table 1 shall be performed completely, once, as a baseline examination. These examinations shall include all nozzles. Examinations performed prior to implementation of this Case that meet the requirements of Table 1, with the exception of the 4 hr of additional training required for VE personnel, may be credited.

-2220 Preservice Examination after Repair/replacement Activities

Prior to return to service, the applicable volumetric and surface examinations listed in Table 1 shall be performed on items affected by the repair/replacement activity.

-2400 INSPECTION SCHEDULE

-2410 Inspection Program

Inservice examination methods and frequency, as required by Table 1, shall be determined using the following parameters to characterize the susceptibility to crack initiation and the potential for crack propagation:

(a) Susceptibility to crack initiation is represented by the EDY parameter, calculated as follows:

$$EDY = \sum_{j=1}^{n}\left\{\Delta EFPY_j \exp\left[-\frac{Q_i}{R}\left(\frac{1}{T_{\text{head}j}} - \frac{1}{T_{\text{ref}}}\right)\right]\right\}$$

(b) Potential for crack propagation is represented by the RIY parameter, calculated as follows:

$$RIY = \sum_{j=n1}^{n2}\left\{\Delta EFPY_j \exp\left[-\frac{Q_g}{R}\left(\frac{1}{T_{\text{head}j}} - \frac{1}{T_{\text{ref}}}\right)\right]\right\}$$

where

EDY = total effective degradation years, normalized to a reference temperature of 1059.67R (588.71K)

$\Delta EFPY_j$ = effective full power years accumulated during time period j

Table 1
Examination Categories

CLASS 1 PWR REACTOR VESSEL UPPER HEAD						
Item No.	**Parts Examined**	**Examination Requirements/Fig. No.**	**Examination Method**	**Acceptance Standard**	**Extent and Frequency of Examination**	**Deferral of Examination to End of Interval**
B4.10	Head with UNS N06600 nozzles and UNS N06082 or UNS W86182 partial penetration welds	Figure 1	Visual, VE [Note (1)],[Note (2)]	-3140	Each refueling outage [Note (3)] (4)]	Not permissible
B4.20	UNS N06600 nozzles and UNS N06082 or UNS W86182 partial-penetration welds in head	Figure 2 [Note (5)]	Volumetric ([Note (6)]Surface [Note (6)]	-3130	All nozzles, every 8 calendar years before RIY=2.25, whichever is less [Note (8)], [Note (9)]	Not permissible
B4.30	Head with nozzles and partial-penetration welds of PWSCC-resistant materials	Figure 1	Visual, VE [Note (1)], [Note (2)]	-3140	Every third refueling outage or years, whichever is less [Note	Not permissible
B4.40	Nozzles and partial-penetration welds of PWSCC- resistant materials in head	Figure 2 [Note (5)]	Volumetric [Note (6)]Surface [Note (6)]	-3130	All nozzles, not to exceed one interval (nominally 10 calendar [Note (8)], [Note (9)]	Not permissible

NOTES:

(1) The VE shall consist of the following:

(a) A direct examination of the bare-metal surface of the entire outer surface of the head, including essentially 100% of the intersection of each with the head. If welded or bolted obstructions are present (i.e., mirror insulation, insulation support feet, shroud support ring/lug), the examination shall include ≥95% area in the region of the nozzles as defined in Figure 1 and the head surface uphill and downhill of any such obstructions. The examination may be performed with insulation place using remote equipment that provides resolution of the component metal surface equivalent to a bare-metal direct examination.

(b) The examination may be performed with the system depressurized.

(c) The examination shall be performed with an illumination level and a sufficient distance to allow resolution of lower case characters not greater 0.105 in. (2.7 mm) in height.

(2) Personnel performing the VE shall be qualified as a VT-2 visual examiner and shall have completed at least 4 hr of additional training in detection borated water leakage from UNS N06600, UNS N06082 or UNS W86182 components and the resulting boric acid corrosion of adjacent ferritic steel components.

(3) Examination may be performed with the system depressurized.

(4) If EDY < 8 and no flaws unacceptable for continued service under -3130 or -3140 have been detected, the reexamination frequency may be extended every third refueling outage or 5 calendar years, whichever is less, provided an IWA-2212 VT-2 visual examination of the head is performed under the insulation multiple access points in outages that the VE is not completed. This IWA-2212 VT-2 visual examination may be performed with the reactor vessel depressurized.

(5) If the examination area or volume requirements of Figure 2 cannot be met, the alternative requirements of Mandatory Appendix I shall be used evaluation shall be submitted to the regulatory authority having jurisdiction at the plant site.

(6) Volumetric or surface examinations shall be performed on essentially 100% of the required volume or equivalent surfaces of the nozzle tube, as by Figure 2. A demonstrated volumetric or surface leak path assessment through all J-groove welds shall be performed. For leaking penetrations, the meandering fluid pattern of the ultrasonic data display represents the leak path of the primary coolant from the pressure vessel to the atmosphere. If a surface examination is being substituted volumetric examination on a portion of a penetration nozzle that is below the toe of the J-groove weld (Point E in Figure 2) the surface examination shall be on the penetration nozzle inside and outside wetted surface.

(7) If not previously performed, baseline volumetric and surface examinations shall be performed.

(a) for plants with EDY > 12, at the next refueling outage,

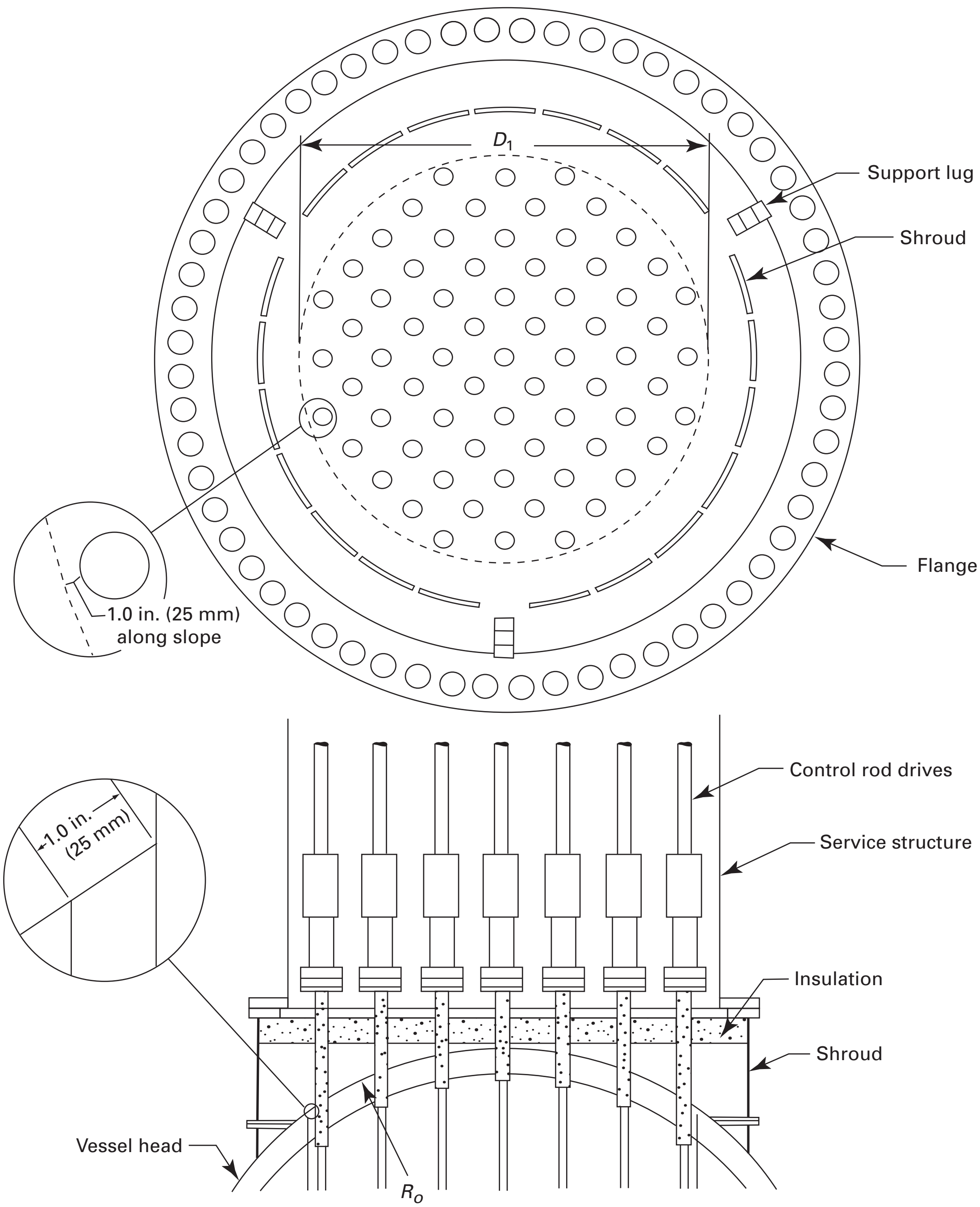
(b) for plants with EDY ≥ 8 and EDY ≤ 12, no later than the second refueling outage, or,

(c) for plants with EDY < 8, no later than February 10, 2008.

(8) If flaws are attributed to PWSCC, whether or not acceptable for continued service in accordance with -3130 or -3140, the reinspection interval each refueling outage. Additionally, repaired areas shall be examined during the next refueling outage following the repair.

(9) Includes essentially 100% of surface or volume.

Figure 1
PWR Reactor Vessel Upper Head Extent of Visual Examination

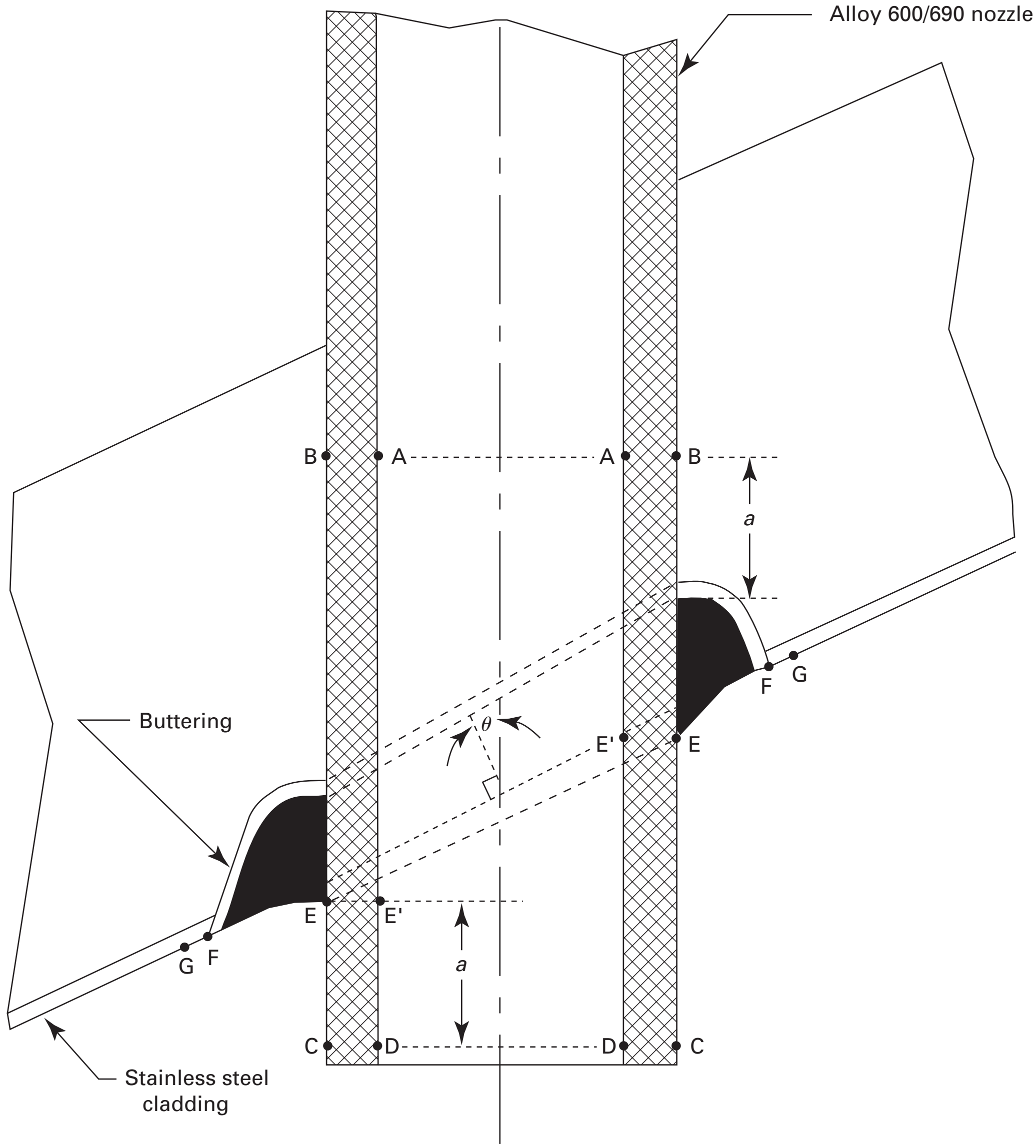


$$A = 2\pi R_o\left[R_o - \sqrt{R_0^2 - (D_1/2)^2}\right]$$

$A_{obstruct}$ = area on head outer surface obstructed within D_1

$$\frac{A - A_{obstruct}}{A} \geq 0.95$$

Figure 2
Examination Volume for Nozzle Base Metal and Examination Area for Weld and Nozzle Base Metal



Legend:

a = 1.5 in. (38 mm) for Incidence Angle, θ, ≤ 30 deg and for all nozzles ≥ 4.5 in. (115 mm) OD or 1 in. (25 mm) for Incidence Angle, θ, > 30 deg; or to the end of the tube, whichever is less

A-B-C-D = extent of volumetric examination for the tube (base metal)

A-D = extent of surface examination for the tube inside surface

G-F = $^1/_4$ in. (6 mm) from the theoretical point "F" in accordance with the design drawings, including tolerances, unless the point "F" can be physically determined.

G-F-E-C = extent of surface examination for the J-groove weld (filler metal and buttering) and tube outside surface below the weld

G-F-E = extent of surface examination zone for the J-groove weld (filler metal and buttering)

n = number of time periods with distinct 100% power head temperature[1] since initial head operation

$n1$ = number of the first time period with distinct 100% power head temperature[1] since time of most recent volumetric or surface NDE

$n2$ = number of the most recent time period with distinct 100% power head temperature[1]

Q_g = activation energy for crack growth
= 31 kcal/mol (130 kJ/mol)

Q_i = activation energy for crack initiation
= 50 kcal/mol (209 kJ/mol)

R = universal gas constant
= 1.103×10^{-3} kcal/mol-R (8.314 J/mol K)

RIY = reinspection years, normalized to a reference temperature of 1059.67R (588.71K)

$T_{head\ j}$ = 100% power head temperature during time period j

T_{ref} = reference temperature
= 1059.67R (588.71K)

-2420 Successive Examinations

(a) If a component is accepted by evaluation for continued service in accordance with -3132.3, the areas containing the flaws shall be reexamined prior to the end of the evaluation period used in the flaw evaluation. If the provisions of Table 1 do not require reexamination of the areas containing the flaws at least once per inspection period, a reexamination shall be performed during the next three inspection periods listed in the schedule of the inspection program of IWA-2400.

(b) If the reexaminations required by -2420*(a)* reveal that the flaws remain essentially unchanged for three successive examinations, the component examination schedule may revert to the schedule of examinations identified in Table 1.

-2430 Additional Examinations

If an examination performed in accordance with Table 1 or -2420 reveals a leak or a flaw not acceptable for continued service in accordance with the provisions of -3132.3, an examination in accordance with Table 1 [Note (6)] shall be performed on all items of that Item Number prior to return to service. Additionally, a visual examination in accordance with Table 1 [Note (1)] (VE throughout this Case), if not already completed during the current outage, shall be performed prior to return to service.

-2500 EXAMINATION REQUIREMENTS

Components shall be examined as specified in Table 1. Surface examinations shall be qualified in accordance with the low rigor requirements of Article 14 of Section V. Volumetric examinations shall be qualified in accordance with (a) through (j). If obstructions or limitations prevent examination of the volume or surface required by Figure 2 for one or more nozzles, the analysis procedure of Mandatory Appendix I shall be used to demonstrate the adequacy of the examination volume or surface for each such nozzle. If Mandatory Appendix I is used, the evaluation shall be submitted to the regulatory authority having jurisdiction at the plant site.

(a) Demonstration Specimen Set

(1) At least 20% of the flaws shall be in the depth range 10% to 30% through-wall.

(2) At least 20% of the flaws shall be in the depth range 30% to 50% through-wall.

(3) At least 20% of the flaws shall be connected to the nozzle inside surface.

(4) At least 20% of the flaws shall be connected to the nozzle outside surface.

(5) At least 20% and no more than 60% of the total number of flaws shall be axially-oriented.

(6) The demonstration specimen set shall include geometric and material conditions that normally require discrimination from primary stress corrosion cracking. Unflawed area is considered to be the entire surface area within the examination volume that is susceptible to crack initiation, minus the combine area of all the demonstration flaws and their associated location tolerances (defined below). The demonstration specimen set contains a minimum number of unflawed grading units that are typically at least 1.5 times the number of flawed grading units.

(b) Procedure Demonstration. Procedure qualification shall include the equivalent of at least three personnel performance demonstration test sets (30 flaws). Successful personnel performance demonstrations may be combined to satisfy these requirements. All flaws shall be detected and the number of false calls shall be less than or equal to 20% of the number of flaws in the demonstration test sets. At least one successful personnel performance demonstration shall be performed. Procedures are qualified with appropriate flaws to the applicable thickness qualification ranges of +25% to −40%. Procedures are qualified to examine nozzles within the minimum and maximum nominal inside diameters of the demonstration mockups. The procedure to perform the volumetric or surface examination for leak path assessment shall be qualified in accordance with the low rigor requirements of Section V, Article 14, without the requirements of Mandatory Appendix II.

(c) Personnel Demonstration. Personnel demonstration test sets shall include at least 10 flaws in the tube material. The demonstration test shall meet the detection test acceptance criteria of Table VIII-S10-1 of Section XI,

[1] Head temperature at 100% power may have been changed during the life of the plant due to design changes, power uprates, etc., and the summation is over the number of distinct periods, either since initial head operation for EDY or since the last volumetric or surface NDE for RIY.

Appendix VIII, Supplement 10. At least two areas of leak paths will be included in the personnel detection demonstration set to evaluate the leak path assessment ability. All leak path indications shall be detected with no false calls. In any part of a reported leak path area falls within the location of a demonstration flaw, the leak path area shall be considered detected. Any part of the reported leak path area that falls outside the location of the demonstrated flaw shall be considered a false call. Sizing is not required. To effectively evaluate the leak path assessment capabilities, for example, 2.0 in. (50 mm) above the weld, scanning access above the weld shall be restricted to the minimum limitations identified in the examination procedure.

(d) Detection and False Calls. In any part of a reported flaw indication falls within the location tolerance of a demonstration flaw shall be considered detected. However, any portion of the flaw that is reported outside the location tolerance shall be considered a false call as well. If a reported indication does not intersect any of the demonstration flaw's location tolerances, the reported flaw indication shall be considered a false call.

(e) Location Tolerance. For the purpose of determining a detection, each demonstration flaw has a location tolerance of ±0.5 in. (±13 mm) in the axial direction and ±25 deg in the circumferential direction for control rod drive mechanisms (CRDMs) and control element drive mechanisms (CEDMs), and ±18 deg for in core instrumentation nozzles in the circumferential direction. For a CRDM example, an axial flaw 0.75 in. (19 mm) long has a location tolerance of 1.75 in. (44 mm) in the axial direction with a circumferential tolerance of 50 deg. A circumferential flaw 30 deg long has a location tolerance area of 1 in. (25 mm) in the axial direction with a circumferential tolerance of 25 deg in either circumferential direction.

(f) Length Sizing. The RMS value of length sizing errors from ultrasonic data shall be less than or equal to 0.375 in. (10 mm). At least 10 flaws shall be included in the test set. RMS error shall be calculated as follows:

$$\mathrm{RMS} = \left[\frac{\sum_{i=1}^{n}(m_i - t_i)^2}{n}\right]^{1/2}$$

where

m_i = measured flaw size
n = number of flaws measured
t_i = true flaw size

(g) Depth Sizing. In an acceptable demonstration, the RMS value of depth sizing errors from ultrasonic data shall be less than or equal to 0.125 in. (3 mm). At least 10 flaws shall be included in the test set. RMS error shall be calculated as follows:

$$\mathrm{RMS} = \left[\frac{\sum_{i=1}^{n}(m_i - t_i)^2}{n}\right]^{1/2}$$

(h) Orientation Limitations. The reported orientation of a recorded flaw is not considered essential when determining flaw detection capabilities.

(i) Essential Variable Changes. Qualification of new values of essential variables requires at least one successful personnel qualification in accordance with the applicable requirements of -2500*(c)* through *(g)*. Procedures shall include clearly identified essential variables. The examination procedure shall identify parameters for the essential variables listed in VIII-3130 and meet the minimum requirements outlined in Appendix VIII. An essential variable describes parameters that directly affect the capability of the system to detect and size flaws. Any changes outside the established range of an essential variable shall meet the requirements of VIII-4000, or the procedure shall be requalified.

(j) Retest. Retesting for procedure qualification may be done as many times as necessary to qualify the procedure. Before any retesting, the procedure shall be reviewed to determine changes needed to improve the procedure performance. Retesting test sets shall contain at least 50% flaws different from those used in the previous test set. Any candidate that is unsuccessful in passing the initial personnel qualification test may immediately take one retest. They shall have been given feedback from the performance demonstration administrator (PDA) before retesting. After two consecutive unsuccessful personnel qualification attempts, within 12 months, a waiting period of at least 48 hr is required prior to a third test being attempted. The intent of this waiting period is to allow the candidate time to practice or receive additional training on the procedure for which performance demonstration qualification is being sought. This practice or retraining is suggested, but is not mandatory. The candidate shall be eligible for one additional attempt, the failure of which shall result in the candidate's ineligibility to retest for 12 months. Retesting test sets shall contain at least 50% flaws different from those used in the previous test set.

-3000 ACCEPTANCE STANDARDS

-3100 EVALUATION OF EXAMINATION RESULTS

-3130 Inservice Volumetric and Surface Examinations

-3131 General

(a) The volumetric and surface examinations required by -2500 and performed in accordance with IWA-2200 shall be evaluated by comparing the examination results with the acceptance standards in -3132.1, except where (b) is applicable.

(b) When flaws are detected by a required volumetric or surface examination, the component is acceptable for continued service provided the requirements of IWB-3112(b) are met.

(c) Volumetric and surface examination results shall be compared with recorded results of the preservice examination and prior inservice examinations. Acceptance of components for continued service shall be in accordance with -3132.

-3132 Acceptance

-3132.1 Acceptance by Volumetric or Surface Examination.

(a) A component whose volumetric or surface examination confirms the absence of flaws shall be acceptable for continued service.

(b) A component whose surface examination detects linear indications of any size, or rounded indications if other relevant conditions indicate nozzle leakage exists on the partial-penetration weld shall be corrected in accordance with the provisions of -3132.2.

(c) A component with planar flaws in the nozzle base metal shall be corrected in accordance with the provisions of -3132.2 or -3132.3. Linear indications detected by surface examination of the nozzle base material shall be considered planar. Prior to evaluation, the depth of linear indications shall be further characterized by volumetric examination. If volumetric examination cannot be performed, the linear indication shall be assumed to be planar and through-wall.

-3132.2 Acceptance by Repair/Replacement Activity. A component whose volumetric or surface examination reveals a leak or flaw not acceptable for continued service in accordance with the provisions of -3132.3 is unacceptable for continued service until the additional exams of -2430 are satisfied and the component is corrected by a repair/replacement activity to the extent necessary to meet the acceptance standards of -3000.

-3132.3 Acceptance by Analytical Evaluation. A component whose volumetric examination detects planar flaws or whose surface examination detects linear indications which are assumed to be planar, is acceptable for continued service without repair/replacement activity if an analytical evaluation meets the requirements of IWB-3660 of the 2004 Edition. The area containing the flaw shall be reexamined in accordance with -2420(a) and -2420(b).

-3140 Inservice Visual Examinations (VE)

-3141 General

(a) The VE required by -2500 and performed in accordance with IWA-2200 and the additional requirements of this Case shall be evaluated by comparing the examination results with the acceptance standards specified in -3142.1.

(b) Acceptance of components for continued service shall be in accordance with -3142.

(c) Relevant conditions for the purposes of the VE shall include evidence of reactor coolant leakage, such as corrosion, boric acid deposits, and discoloration.

-3142 Acceptance

-3142.1 Acceptance by VE.

(a) A component whose VE confirms the absence of relevant conditions shall be acceptable for continued service.

(b) A component whose VE detects a relevant condition shall be unacceptable for continued service until the requirements of (1),(2), and (c) below are met.

(1) Components with relevant conditions require further evaluation. This evaluation shall include determination of the source of the leakage and correction of the source of leakage in accordance with -3142.3.

(2) All relevant conditions shall be evaluated to determine the extent, if any, of degradation. The boric acid crystals and residue shall be removed to the extent necessary to allow adequate examinations and evaluation of degradation, and a subsequent VE of the previously obscured surfaces shall be performed, prior to return to service, and again in the subsequent refueling outage. Any degradation detected shall be evaluated to determine if any corrosion has impacted the structural integrity of the component. Corrosion that has reduced component wall thickness below design limits shall be resolved through repair/replacement activity in accordance with IWA-4000.

(c) A nozzle whose VE indicates relevant conditions indicative of possible nozzle leakage shall be unacceptable for continued service unless it meets the requirements of -3142.2 or -3142.3.

-3142.2 Acceptance by Supplemental Examination. A nozzle with relevant conditions indicative of possible nozzle leakage shall be acceptable for continued service if the results of supplemental examinations [-3200(b)] meet the requirements of -3130.

-3142.3 Acceptance by Corrective Measures or Repair/Replacement Activity.

(a) A component with relevant conditions not indicative of possible nozzle leakage is acceptable for continued service if the source of the relevant condition is corrected by a repair/replacement activity or by corrective measures necessary to preclude degradation.

(b) A component with relevant conditions indicative of possible nozzle leakage shall be acceptable for continued service if a repair/replacement activity corrects the defect in accordance with IWA-4000.

-3200 SUPPLEMENTAL EXAMINATIONS

(a) Volumetric or surface examinations that detect flaws which require evaluation in accordance with -3130 may be supplemented by other techniques to characterize the flaw (i.e., size, shape, and orientation).

(b) The supplemental examination performed to satisfy -3142.2 shall include volumetric examination of the nozzle tube and surface examination of the partial-penetration weld, or surface examination of the nozzle tube inside surface, the partial penetration weld, and nozzle tube outside surface below the weld, in acccordance with Figure 2, or the alternative examination area or volume shall be analyzed to be acceptable in accordance with Mandatory Appendix I. The supplemental examinations shall be used to determine the extent of the unacceptable conditions and the need for corrective measures, analytical evaluation, or repair/replacement activity.

-9000 GLOSSARY

bounding loss of coolant accident conditional core damage probability (CCDP): the plant-specific conditional core damage probability for the loss of coolant accident (e.g., medium, small, or small-small break) that bounds the consequences of the head nozzle-ejection event.

effective degradation years (EDY): the lifetime accumulated effective time at temperature, normalized to 1059.67R (588.71K), with an activation energy characteristic of initiation of Primary Water Stress Corrosion Cracking in UNS N06600, 50 kcal/mol (209 kJ/mol).

reinspection years (RIY): the accumulated effective time at temperature between examinations normalized to 1059.67R (588.71K), with an activation energy characteristic of growth of Primary Water Stress Corrosion Cracking in UNS N06600, 31 kcal/mol (130 kJ/mol).

MANDATORY APPENDIX I
ANALYSIS PROCEDURE FOR ALTERNATIVE EXAMINATION AREA OR VOLUME DEFINITION

I-1000 SCOPE

This Mandatory Appendix provides an analysis procedure that shall be used to define an alternative examination area or volume (zone) to that defined in Figure 2 if impediments (such as physical obstructions, threads on the nozzle end, or an ultrasonic examination corner shadow zone) prevent examination of the complete zone. In such cases, analyses shall be performed to demonstrate that there is an extremely low probability of PWSCC existing wholly in the unexamined zones, and that the potential undetected PWSCC will not lead to a safety concern or an unacceptable probability of leakage in the time interval until the next examination.

For alternative examination zones that eliminate portions of Figure 2 examination zone above the J-groove weld (Figure I-1), the analyses shall be performed using at least two of the three techniques below to demonstrate that the applicable criteria are satisfied. For alternative examination zones that eliminate portions of Figure 2 examination zone below the J-groove weld (Figure I-2), the analyses shall be performed using at least the stress analysis method (I-2000) or the deterministic fracture mechanics analysis method (I-3000) to demonstrate that the applicable criteria are satisfied.

All other examination requirements of Table 1 shall be met.

I-2000 STRESS ANALYSIS

This analysis shall be used to determine a reduced examination zone. Plant-specific analysis shall demonstrate that the hoop and axial stresses on the nozzle inside and outside surfaces remain below 20 ksi (140 MPa) (tensile) over the entire region outside the alternative examination zone but within the examination zone defined in Figure 2. The analysis shall be performed using either design or as-built weld dimensions for the specific nozzles for which a portion of Figure 2 examination zone is being eliminated, or for nozzles shown to bound the stresses in those specific nozzles.

I-3000 DETERMINISTIC FRACTURE MECHANICS ANALYSES

The analyses described in I-3100 or I-3200 shall be used to determine a reduced examination zone.

I-3100 ZONES ABOVE THE J-GROOVE WELD

For alternative examination zones above the J-groove weld, the analysis shall demonstrate that a potential circumferential crack in the unexamined zone will not grow to a size that exceeds the acceptance criteria for austenitic piping in IWB-3640 prior to the next scheduled examination.

The crack growth calculation shall be performed based on the following:

(a) The assumed initial flaw size shall be a through-wall, circumferentially-oriented crack equal to 30 deg of the nozzle circumference, at the outermost edge of the alternative examination zone (Figure I-1).

(b) Alternatively, the flaw shall be assumed to exist in a plane closer to the J-groove weld (i.e., within the inspected region), if such location can be shown to conservatively bound flaws at the outermost edge of the alternative examinaton zone.

(c) The flaw shall be assumed to be at either the uphill or the downhill location of the nozzle, whichever results in the higher applied stress intensity factor (Figure I-1).

(d) The average of inside and outside surface axial stress shall be applied along the entire length of the assumed through-wall crack.

(e) The stress intensity factor for a circumferential, through-wall crack in a cylinder shall be used.

(f) Crack growth rate determination shall be in accordance with Appendix O of Section XI, in the 2004 Edition.

I-3200 ZONES BELOW THE J-GROOVE WELD

For alternative examination zones below the J-groove weld, the analysis shall demonstrate that a potential axial crack in the unexamined zone will not grow to the toe of the J-groove weld prior to the next scheduled examination.

(a) Method 1. Using stress analysis results for the as-designed J-groove weld configuration, demonstrate that the upper extremity of an axial through-wall crack would not propagate to the toe of the J-groove weld prior to the next scheduled examination.

The crack growth calculation shall be performed based on the following:

(1) The initial axial through-wall crack size shall be determined by assuming its upper extremity to be initially located at the bottom edge of the alternative examination zone and the lower extremity to be located where either the inside or the outside surface hoop stress becomes compressive (Figure I-2).

(2) If the hoop stress remains tensile for the entire portion of the nozzle below the weld, an axial through-wall crack shall be postulated from the bottom edge of the alternative examination zone to the bottom of the nozzle (Figure I-3).

(3) The average of inside and outside surface hoop stresses shall be applied along the entire length of the assumed through-wall crack.

(4) The postulated axial flaw shall be located in the unexamined zone at the azimuthal location that results in the shortest time to reexamination.

(5) The stress intensity factor for an axial through-wall crack in a cylinder shall be used.

(6) Crack growth rate determination shall be in accordance with Appendix O of Section XI, in the 2004 Edition.

(b) Method 2. If acceptability cannot be demonstrated using Method 1, the following shall be performed.

(1) Review the available UT examination data and demonstrate that the as-built J-groove weld depth is larger than the as-designed weld depth.

(2) Determine the hoop stress distribution in the portion of the nozzle below the weld by performing a stress analysis based on the as-built J-groove weld configuration.

(3) Perform the crack growth calculation of Method 1, using the hoop stress distribution for the as-built configuration.

I-4000 PROBABILISTIC FRACTURE MECHANICS ANALYSIS

These provisions shall not be applied to heads having prior PWSCC in nozzles or J-groove welds that required repair/replacement activity. Calculate the percentage of the total required examination zone defined in Figure 2, for all nozzles in the head, that will be eliminated. Demonstrate, using a probabilistic fracture mechanics method, that the total eliminated examination zone in all nozzles does not lead to unacceptable probabilities of leakage and nozzle ejection prior to the next required examination. A probability of leakage no greater than 5% per vessel per year and a probability of core damage associated with the potential for nozzle ejection no greater than 1×10^{-6} per vessel per year are acceptable.

Figure I-1
Circumferential Flaw Assumption for Elimination of Portions of the Required Examination Zone Above J-Groove Weld

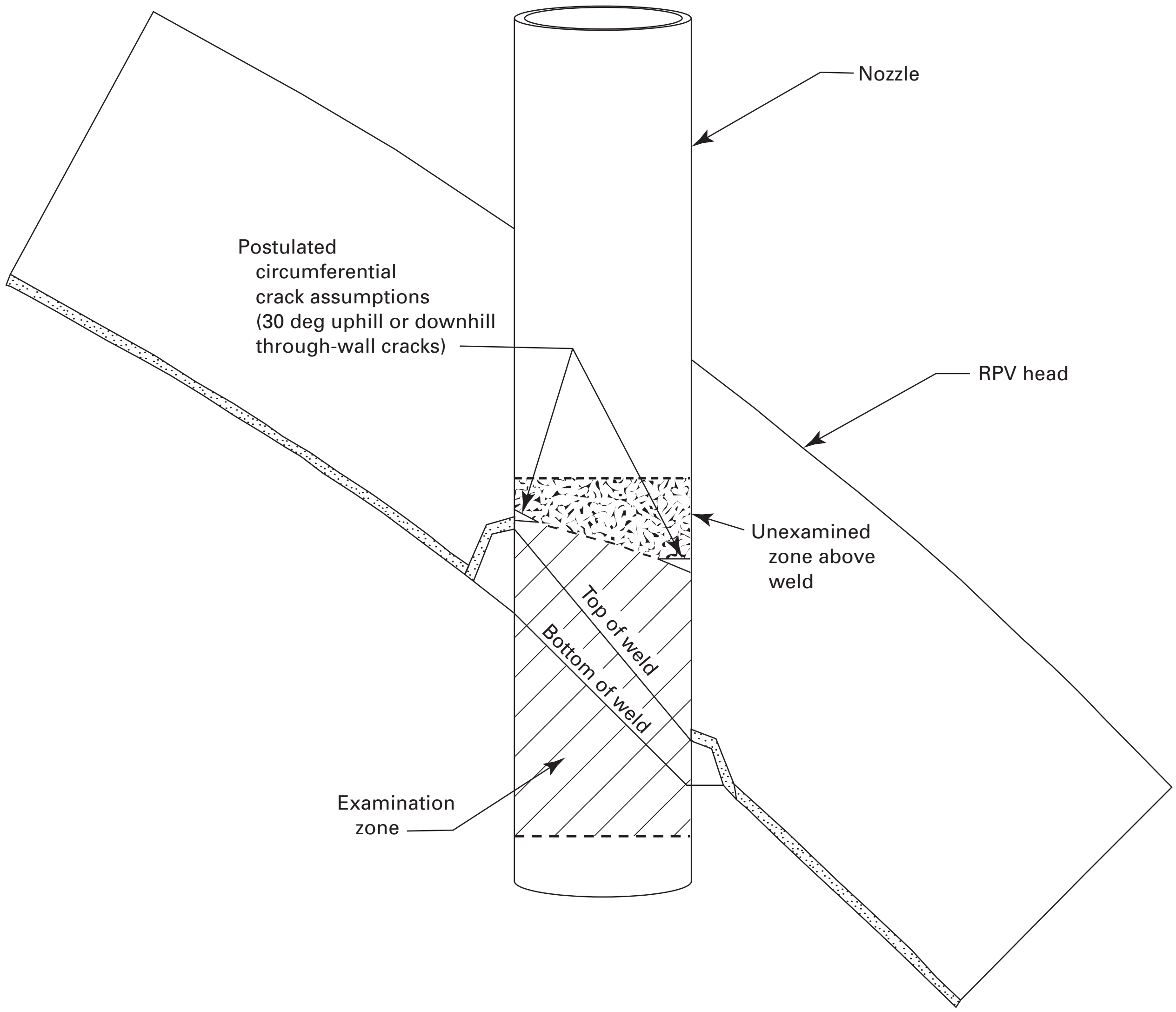


Figure I-2
Axial Flaw Assumption for Elimination of Portions of the Required Examination Zone Below J-Groove Weld

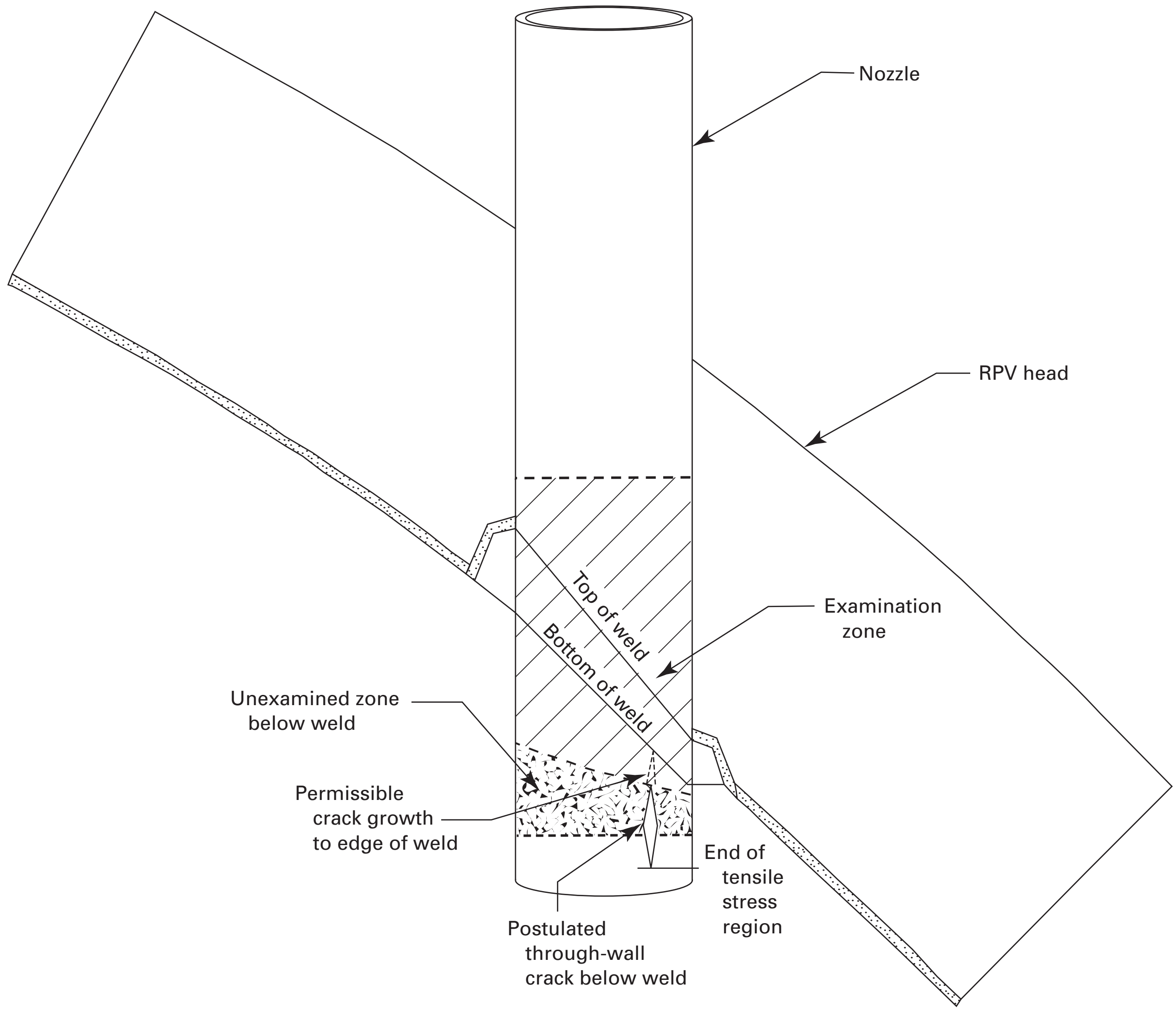
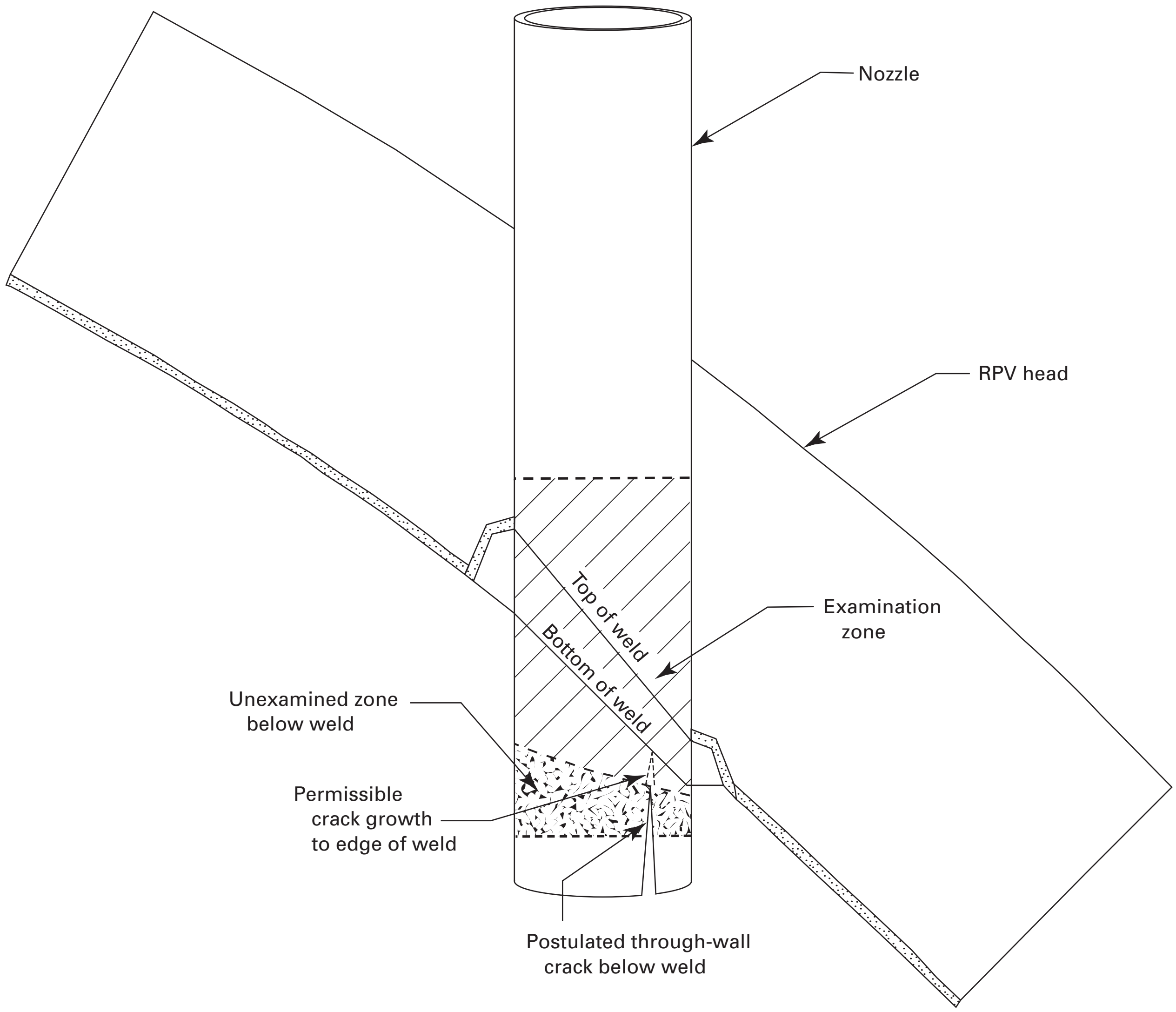


Figure I-3
Axial Flaw Assumption for Elimination of Portions of the Required Examination Zone Below J-Groove Weld (Tensile Stress to Bottom of Nozzle)



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Approval Date: July 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-730-1
Roll Expansion of Class 1 Control Rod Drive Bottom Head Penetrations in BWRs
Section XI, Division 1

Inquiry: May the mechanical roll expansion technique be used as a repair/replacement activity to eliminate leakage from Class 1 Control Rod Drive (CRD) bottom head penetrations in Boiling Water Reactors (BWRs)?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWB-3140, the mechanical roll expansion technique may be used as a repair/replacement activity to eliminate leakage from Class 1 CRD bottom head penetrations in BWRs, provided the following requirements are met.

1 SCOPE

1.1 This Case applies to use of mechanical roll expansion for the purpose of sealing leakage from cracks detected in the following locations:

(a) CRD stub tube base metal
(b) CRD stub-tube-to-housing J-groove weld
(c) CRD stub-tube-to-vessel attachment weld
(d) CRD housing-to-vessel attachment weld (BWR/6)

1.2 This Case shall not be used when leakage is due to through-wall cracking in the housing.

1.3 The following conditions shall apply to this Case:

(a) Housing material: Any P-No. 8 or P-No. 43.
(b) Vessel material: Any P-No. 3.
(c) Measured percent wall thinning: 3.5% – 6.5%.
(d) Roll-band length shall not exceed 6 in. (150 mm).
(e) Minimum roller top/bottom end radius $^3/_4$ in. (19 mm).
(f) Ratio of housing specified minimum yield strength to vessel head specified minimum yield strength < 1.0.
(g) If more than one roll is required to achieve the required roll-band length, the minimum overlap for each roll shall be at least 0.5 in. (13 mm).
(h) Rollers shall be lubricated.

1.4 The provisions of IWA-4140, IWA-4150, IWA-4170, and IWA-4310 shall be met.

2 GENERAL REQUIREMENTS

2.1 When a CRD housing is roll expanded against the vessel, creating a mechanical seal to eliminate leakage and to prevent upward displacement of the housing, the following requirements shall be met:

(a) Values for wall thinning and roll-band length shall be specified. The target value for wall thinning for the rolling shall be 4% to 6%. Because of variations in the gap between the housing outside surface and the vessel bore inside surface, the actual amount of wall thinning may vary from 3.5% to 6.5%. In no case shall the total wall thinning exceed 6.5%. The required wall thinning may be achieved using any number of intermediate partial rolls.

(b) The roll-band length (L) is defined as the flat portion of the roll, excluding the rounded transition region at each end. The minimum roll-band length shall not be less than in the prequalified procedure or the length qualified by a procedure qualification. In addition, the length shall not be less than the roll-band length required to resist end-of-scram loads, as determined by the following equation:

$$L = (\mathrm{SF})F/[0.4\pi(1-p) \times T \times S_y]$$

where

F = maximum upward end-of-scram force, Kips (MN)
p = nominal wall-thinning fraction (e.g., 0.04 for 4% thinning)
SF = Structural Factor = 2
S_y = yield strength of the housing material at room temperature, ksi (MPa)
T = thickness of housing, in. (m)

(c) As an alternative to the criteria in (b), testing may be used to establish the minimum roll-band length required to resist end-of-scram loads. The testing shall use mockups that meet the acceptance criteria for the essential variables listed in Table 1. A mechanical roll-expansion tool using a tapered shaft to effect expansion and a hard stop to limit expansion shall be used. The load and deflection during a pull test on the housing shall be recorded. The load capability corresponding to initial slipping of the housing shall be determined at room temperature. The load at initial slippage, corresponding to the

maximum load before the intersection of the line with slope equal to 95% of the slope of the load deflection curve, shall exceed twice the maximum upward end-of-scram load.

(d) When multiple roll passes are required to achieve the desired roll-band length the direction of the rolling shall be initiated from the top and progress downward toward the free end of the CRD housing.

(e) Rolling shall not be performed on portions of the housing extending above or below the vessel bottom head.

2.2 A Roll-Expansion Procedure Specification (REPS) shall be prepared. The REPS shall define the requirements for roll expansion for procedure qualification (if required), for performance demonstration, and for the plant-specific rolling. The REPS shall define the target values for wall thinning and roll-band length as well as the procedure to be used to achieve these target values.

2.3 No plant-specific procedure qualification is required (i.e., the procedure is prequalified) if the plant-specific rolling parameters are within the tolerances specified in Table 2. A mechanical roll-expansion tool using a tapered shaft to effect expansion and a hard stop to limit expansion shall be used.

3 PLANT-SPECIFIC PROCEDURE QUALIFICATION

If the design of the roll does not meet the conditions of Table 2, a plant-specific procedure qualification is required. A REPS for the procedure qualification and for the plant-specific application shall be developed. The procedure qualification shall be demonstrated on a mockup meeting the acceptance criteria of Table 1 and the requirements listed in section 1. The vessel may be simulated in the mockup by a flat plate with thickness at least 1.5 in. (38 mm) greater than the target roll-band length, but in no case less than 4 in. (100 mm).

3.1 The roll-band length and percent wall thinning achieved in the procedure qualification shall be determined by measurement. The measured wall-thinning shall define the minimum qualified wall-thinning for use in the plant-specific application. The measured roll-band length shall define the minimum qualified roll-band length for use in the plant-specific application.

3.2 The mockup shall be rolled at ambient temperature, heated to 550°F (290°C), held at temperature for one hour, cooled to ambient temperature, and subjected to a leakage test at 1875 psig (13 MPa) for at least one hour. Successful roll expansion requires VT-2 visual examination and verification of no leakage.

3.3 A REPS qualified for one plant may be used at another plant, provided the acceptance criteria listed in Table 1 and all other provisions of this Case are met.

3.4 Transfer of a procedure qualification between Owners shall be subject to the following requirements:

(a) The Owner that performed the procedure qualification shall certify in writing that the procedure qualification was developed in accordance with a Quality Assurance Program that satisfies the requirements of IWA-1400(n).

(b) The Owner that performed the procedure qualification shall certify in writing that the procedure qualification meets the provisions of this Case.

4 PERFORMANCE DEMONSTRATION

(a) Prior to implementing a roll expansion in a plant, the Owner shall conduct a performance demonstration to verify personnel capabilities. The performance demonstration shall be conducted on a mockup meeting the

Table 1
Plant-specific Procedure Qualification or Alternative Testing Mockup Requirements

Essential Variable	Acceptance Criteria
Percent wall thinning	Greater than or equal to target value not to exceed 6.5%.
Roll-band length	Greater than or equal to the value used, not to exceed 6 in. (150 mm) (backed by vessel material).
Housing outside diameter	Housing outside diameter ± 0.25 in. (6.0 mm) used for the mockup.
Housing inside diameter	Housing inside diameter ± 0.25 in. (6.0 mm) used for the mockup.
Housing material	The P-Number used in the mockup qualifies any material in that P-Number, e.g., any P-No. 8 material qualifies any other P-No. 8 material or any P-No. 43 material qualifies any other P-No. 43 material.
Vessel head material	Any P-No. 3 material used in the mockup qualifies any other P-No. 3 material.

Table 2
Prequalified Rolling Parameters

Essential Variable	Acceptance Criteria
Percent wall thinning	3.5% to 6.5%
Roll-band length, L	3 in. ≤ L, ≤ 6 in. (76 mm ≤ L, ≤ 150 mm) (backed by vessel material)
Housing outside diameter	5.975 ± 0.250 in. (150.0 ± 6.00 mm)
Housing inside diameter	4.86 ± 0.25 in. (123 ± 6.0 mm)
Housing material	Any P-No. 8 material
Vessel head material	Any P-No. 3 material

requirements of Table 3. The vessel may be simulated in the mockup by a flat plate with thickness at least 1.5 in. (38 mm) greater than the target roll-band length, but in no case less than 4 in. (100 mm). Tooling shall be of the identical design and nominal dimensions as tooling to be used for the plant-specific roll.

(b) Personnel performing tasks required to meet the acceptance criteria for the essential variables of the REPS in the plant-specific application shall perform the same tasks in the performance demonstration. Performance of a task in the performance demonstration qualifies a person to perform that task in the plant-specific application for a period of 12 months from that demonstration. Personnel qualification shall be documented in the plant records of the roll-expansion.

(c) The REPS for the performance demonstration shall define the target values for wall thinning and roll-band length as well as the location of the roll-band to be achieved. These target values need not be identical to those specified for the plant specific application.

(d) Acceptance criteria for the performance demonstration are as follows:

(1) measured wall thinning equal to the target value ± 0.5%

(2) measured roll-band length equal to the target value plus 0.25 in. (6.0 mm) or minus 0 in. (0 mm)

(3) roll-band position equal to the target value ± 0.25 in. (6.0 mm)

5 EVALUATION

Each proposed roll expansion shall be evaluated as follows.

5.1 Analysis shall be performed to show that the thickness of the CRD housing after rolling is sufficient to meet the primary stress limits of the Construction Code.

5.2 The expanded penetration shall satisfy all plant-specific design criteria related to structural integrity. All specified load combinations and design-basis events shall be addressed.

5.3 Crack growth shall be predicted, considering stress corrosion cracking and fatigue. The analytical evaluation of the predicted crack shall satisfy the requirements of IWB-3600.

5.4 If the source of the leakage is a crack in the vessel attachment weld, a postulated axial crack in the vessel attachment weld shall be evaluated. The analytical evaluation shall include an assumption that the entire weld is cracked radially and shall satisfy the requirements of IWB-3600.

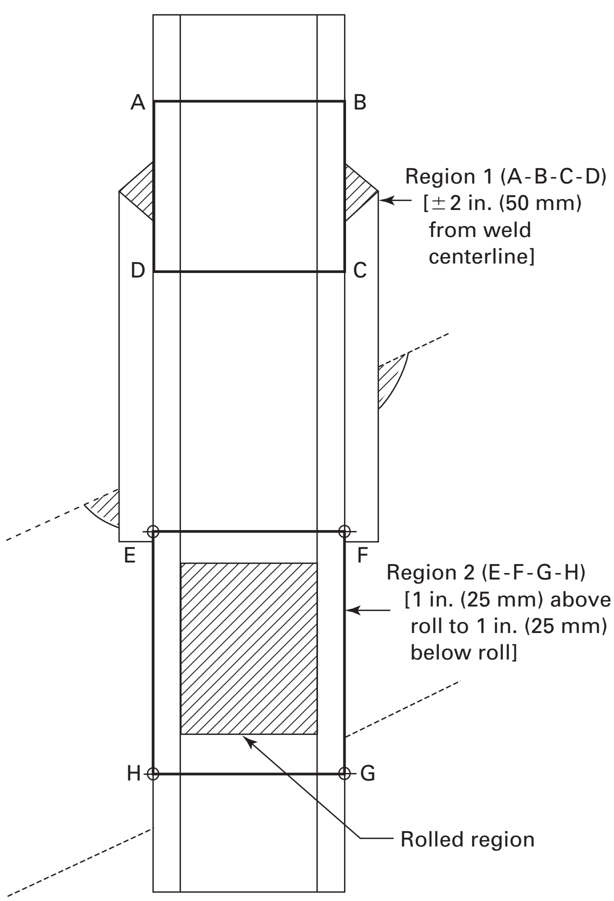
Table 3
Performance Demonstration Essential Variables

Variable	Acceptance Criteria
Percent wall thinning	Target wall thinning ± 0.5%.
Roll-band length	Any value, provided the roll-band length is no more than 6.0 in. (150 mm). However, if multiple rolls are required to achieve the required plant-specific roll-band length, the performance demonstration requires multiple rolls (backed by vessel material).
Housing outside diameter	Actual housing outside diameter ± 0.25 in. (6.0 mm).
Housing inside diameter	Actual housing inside diameter ± 0.25 in. (6.0 mm).
Housing material	Same type as application (e.g., any P-No. 8 or any P-No. 43 material).
Vessel head material	Any P-No. 3 material

6 EXAMINATIONS AND TESTS

6.1 Prior to roll expansion, ultrasonic (UT) examination of the regions specified in Figure 1 or Figure 2 shall be performed. For stub-tube configurations (Figure 1), Region 2 and the stub-tube-to-housing J-groove-weld region (Region 1) shall be examined. For the BWR/6 CRD configuration (Figure 2), Region 2 and the housing-to-vessel-weld region (Region 1) shall be examined. If the leakage is due to through-wall cracking of the housing or if planar flaws are detected in Region 2, this Case shall not be used. For housing indications in the area of the stub tube-to-housing J-groove-weld region or the housing-to-vessel-weld region (Region 1) the housing including weld region shall be evaluated as a housing weld for the purpose of determining flaw acceptance. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. This Case may not be used if the requirements of IWB-3640 are not met.

Figure 1
Examination Volume for Stub-Tube-Type CRD Housings



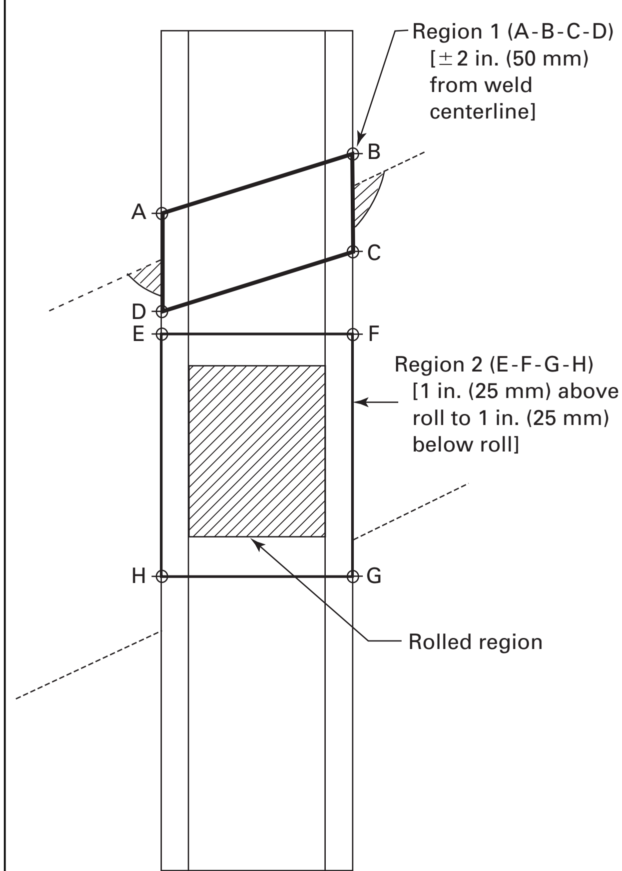
6.2 After completion of the roll expansion, UT examination of the stub-tube-to-housing J-groove-weld region or housing-to-vessel-weld region (Region 1) shall be performed. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. This Case may not be used if the requirements of IWB-3640 are not met.

6.3 After completion of the roll expansion, UT examination of the rolled region (Region 2) shall be performed to establish that no planar flaws exist in the rolled region.

6.4 The UT procedure used in the examinations shall be demonstrated on a plant-specific mockup, with flaws located in the area of interest, in accordance with Appendix I of this Case.

6.5 If the location of the leakage has not been determined, an in-vessel VT-1 visual examination of the leaking CRD penetration shall be made before the end of the next scheduled refueling outage, to attempt to locate the leakage source and to determine the general condition of the

Figure 2
Examination Volume for BWR/6 CRD Housings



housing. Cracks, wear, or localized accumulation of corrosion products shall require corrective action. Roll expansion satisfies the corrective action requirement.

6.6 After completion of the post-roll-expansion UT examination, the CRD housing penetration shall be subjected to VT-2 visual examination in conjunction with a system leakage test in accordance with IWB-5000. For CRD housings subjected to roll expansion, the acceptance criterion is no leakage.

7 INSERVICE INSPECTIONS

The following examinations shall be added to the inservice inspection plan:

7.1 A UT examination of roll-expanded CRD housings shall be performed in accordance with Figure 1 or Figure 2 on at least 10% of previously-rolled housings, during each inspection interval. If planar flaws are discovered in the roll region (Region 2), this Case shall not be used. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. If the requirements of IWB-3640 are not met, the defect shall be corrected by a repair/replacement activity.

7.2 If flaws are detected that fail to meet the acceptance standards of IWB-3523, the additional examination requirements of IWB-2430 shall be met.

7.3 The UT procedure used in the examinations of 7.1 and 7.2 shall be demonstrated on a plant-specific mockup with flaws located in the area of interest, in accordance with Appendix I of this Case.

7.4 At subsequent system leakage tests in accordance with IWB-5000, CRD housings having roll expansion shall meet the requirements of 6.6.

8 RECORDS

8.1 The Owner shall retain the following records for the life of the vessel.

(a) Roll-Expansion Procedure Specification (REPS)
(b) record of procedure qualification
(c) locations all roll-expanded CRD housings
(d) results of post-expansion examinations and evaluations
(e) evaluations performed in accordance with 5
(f) records of performance demonstration, including documentation of personnel qualifications
(g) records of nondestructive examinations

8.2 Use of this Case shall be documented on Form NIS-2.

MANDATORY APPENDIX I
USE OF MOCKUP FOR UT PROCEDURE DEMONSTRATION

I-1 The UT procedure shall be demonstrated on a mockup. Personnel who perform flaw detection and evaluation using the procedure shall be qualified in accordance with Appendix VIII, Supplement 2.

I-2 The UT shall be performed using automated, digital, data acquisition methods.

I-3 Mockups shall be manufactured with inside and outside diameters in accordance with Table 3. P-No. 8 material shall be used for the mockups unless Alloy 600, Alloy 690, or equivalent nominal chemistry is used for the installed component, in which case the mockups shall be manufactured using Alloy 600 or Alloy 690 wrought material. The mockup length shall be sufficient to accommodate the required flaws and to provide adequate access to examine the flaw areas.

I-4 The mockup shall contain at least 10 surface-breaking flaws, distributed such that at least 40% and no more than 6% of the flaws shall be on the outside surface. The mockup shall contain flaws oriented axially and circumferentially. Flaws shall be located in the mockup such that no flaw ultrasonic response shall interfere with any other flaw response. At least 30% and no more than 5% of the flaws shall be oriented axially. The flaws shall range in depth from 5% to 70% through-wall from either surface. The flaw length-to-depth ratios shall be distributed in a range from 2 to 6. Flaws may be actual cracks (thermal or mechanical fatigue, or IGSCC) or notches compressed so that the faces of each notch are in contact. If compressed notches are used, the notch tip width shall have a radius no greater than 0.002 in. (0.05 mm).

I-5 The UT procedure shall be considered acceptable if it can be demonstrated that the flaws are detected and discernible using specific criteria identified in the examination procedure (e.g., a signal-to-noise ratio of at least 2 to 1 can be obtained from the flaws). The data from the procedure demonstration shall be evaluated to determine the length-sizing and depth-sizing error values associated with the procedure. These error values shall be included in any flaw acceptance evaluations.

Approval Date: February 22, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-731
Alternative Class 1 System Leakage Test Pressure Requirements
Section XI, Division 1

Inquiry: What alternative Class 1 system leakage test pressure requirements may be used for portions of Class 1 systems that are continuously pressurized during an operating cycle by a statically-pressurized passive safety injection system of a pressurized water reactor, in lieu of the requirements of IWB-5221(a)?

Reply: It is the opinion of the Committee that, for portions of Class 1 safety injection systems that are continuously pressurized during an operating cycle, the pressure associated with a statically-pressurized passive safety injection system of a pressurized water reactor may be used.

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Approval Date: July 1, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-733
Mitigation of Flaws in NPS 2 (DN 50) and Smaller Nozzles and Nozzle Partial Penetration Welds in Vessels and Piping by Use of a Mechanical Connection Modification
Section XI, Division 1

Inquiry: May flaws in NPS 2 (DN 50) and smaller nozzles and nozzle partial penetration welds in vessels and piping originally constructed to Section III, Class 1 or Class A or to B31.7 Class 1 be mitigated by use of a mechanical connection modification that replaces the structural integrity of the Category D or branch connection partial penetration weld and provides the primary pressure sealing function of the existing nozzle?

Reply: It is the opinion of the Committee that a mechanical connection modification that replaces the Category D or branch connection partial penetration weld and provides the primary pressure sealing function of the existing nozzle may be used to mitigate flaws in NPS 2 (DN 50) and smaller nozzles and nozzle partial penetration welds in vessels and piping originally constructed in Section III, Class 1 or Class A or B31.7 Class 1, provided the following requirements are met:

(a) Mechanical connection assemblies are permitted only for nozzles on which there are substantially no piping reactions, such as pressurizer heater penetrations and openings for instrumentation. The mechanical connection assembly and the vessel or piping location where the mechanical connection assembly is installed shall be designed taking no structural credit for the existing Category D or branch connection partial penetration weld and shall be based on the stress and fatigue requirements of NB-3200.[1] The structural integrity of the vessel or piping with the mechanical connection assembly installed shall be reevaluated for the connection loads and design basis loads using the requirements of NB-3300 for vessels and NB-3600 for piping, and the stress and fatigue requirements of NB-3200. All reinforcement required by the opening shall be in accordance with NB-3300 for vessel and NB-3600 for piping, and shall be integral with the vessel or piping to which the nozzle is attached. The NB-3200 stress analysis shall evaluate all nozzle loads. The design shall include provisions to prevent separation of the mechanical connection under all design and service loading conditions. NB-3200 analysis of a mechanical connection assembly installed on a piping branch connection shall include, in accordance with NB-3622.3, consideration of vibration loading as addressed in the original piping design. A Design Report Addendum certified in accordance with NCA-3555 shall be provided for the vessel or piping with the mechanical connection modification installed.

(b) For the evaluation, a maximum postulated planar flaw size that bounds the original partial penetration weld configuration, including the partial penetration weld and weld deposited buttering or overlay applied to the weld preparation in the vessel or piping base material, shall be assumed. The assumed flaw size is shown schematically in Figure 1. The flaw shall be postulated at the plane of highest stress (minimum expected service life). The total expected service life of the mechanical connection assembly, and the vessel or piping to which it is attached, shall be calculated. Crack growth into the ferritic vessel or piping shall be calculated. This calculation shall include the effects of fatigue and stress corrosion cracking mechanisms. The applicable acceptance criteria of IWB-3600 shall apply. When the mechanical connection assembly installation potentially results in the exposure of the annulus between the nozzle and the vessel to primary coolant environment, the evaluation shall also include an assessment of potential corrosion of material in the annulus between the vessel or piping and the nozzle. The predicted corrosion loss shall be included in the reinforcement calculations required in (a) and shall meet the stress limits of NB-3300.

(c) A prototype joint shall be fabricated that is representative of the component and nozzle geometry and materials with the mechanical connection assembly installed. Leak tightness of the mechanical connection asembly shall be demonstrated by testing of the prototype joint at 1.25 times the design pressure. Evidence of leakage is unacceptable. The prototype joint shall be subjected to performance tests to demonstrate that structural integrity and leak tightness of the joint are maintained

[1] All references to Section III shall be taken as any Edition and Addenda from the 1989 Edition through the 2004 Edition.

under simulated service conditions, including thermal cycling and seismic loading. Thermal cycle testing shall consist of at least three simulated plant heatup and cooldown cycles. Seismic qualification shall follow the guidelines of IEEE 344-1987 or QME 1-1997, including at least five operating basis earthquake events and one safe shutdown earthquake event. Evidence of leakage at conclusion of these tests is unacceptable. Records of the prototype joint testing shall be maintained by the Owner.

(d) Bolting of the mechanical connection assembly shall not be in contact with the contained fluid. Threaded nozzles in which the threads provide the primary seal shall not be used. Materials chosen for the mechanical connection, including threaded fasteners and bolting, shall not be subject to degradation due to exposure to primary coolant. If used as part of the mechanical connection assembly, prestress level for SA-453 Grade 660 bolting or fasteners shall be less than 100 ksi (690 MPa).

(e) The machined sealing surfaces shall be inspected to verify that no foreign material is present that could interfere with the sealing capability of the connection. Bolting shall be torqued into the vessel or piping material at temperatures at or above the RT_{NDT} of the material.

(f) As part of returning the system to service following initial installation and each reinstallation of the mechanical connection assembly, a VT-2 visual examination with insulation removed in conjunction with a system leakage test as described in IWA-5211(a) shall be performed in accordance with IWA-5000 on the portion of the system containing the mechanical connection assembly. The test pressure shall be maintained a minimum of 10 min prior to examination for leakage. The examination procedure shall identify any special requirements for examining parts of the mechanical connection assembly designed to divert or collect any seal leakage. If leakage is detected during the test, correction by retorquing may be attempted. If retorquing would be to values above those used in the analysis described in (a), perform a revised analysis using the torque values used to eliminate the leakage. If leakage is not corrected, the entire mechanical connection assembly shall be disassembled and the assembly and surrounding base metal shall be VT-3 examined. The following relevant conditions shall require corrective action:

(1) structural distortion or displacement of parts to the extent that component function may be impaired;

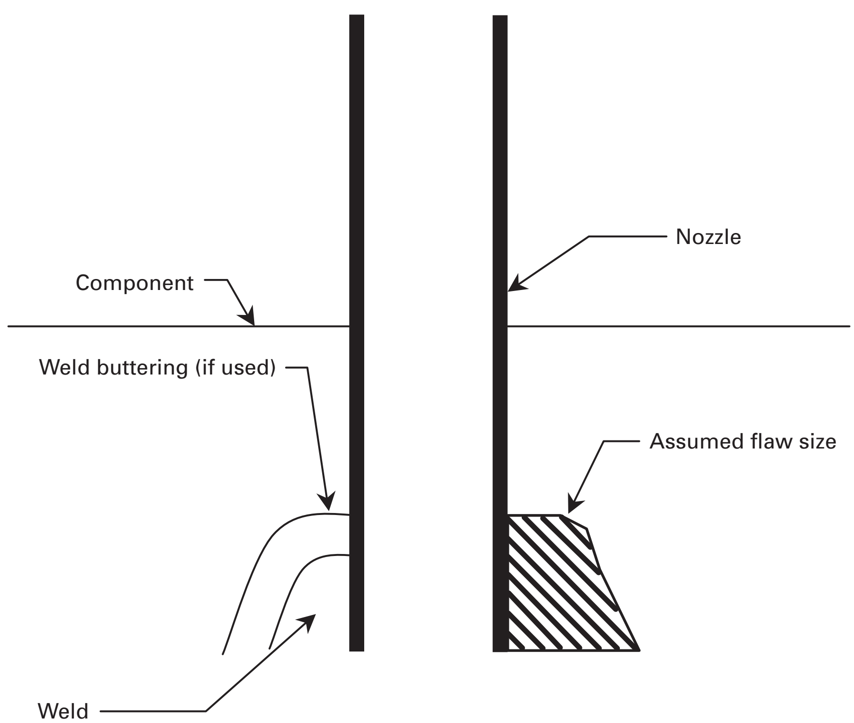
(2) loose, missing, cracked, or fractured parts, bolting, or fasteners;

(3) foreign materials or accumulation of corrosion products;

(4) corrosion or erosion that reduces the section thickness by more than 5%; or

(5) wear of mating surfaces that may lead to loss of function.

Figure 1
Mechanical Connection Assembly



Upon reinstallation, the above requirements shall be repeated. There shall be no evidence of leakage upon startup.

(g) Preservice inspection of the mechanical connection assembly shall be performed as follows:

(1) A VT-1 visual examination shall be performed for all pressure retaining bolting prior to assembly. Acceptance standards of IWB-3517 apply.

(2) A VT-3 visual examination shall be performed with insulation removed. The following relevant conditions shall require corrective action:

(-a) structural distortion or displacement of parts to the extent that component function may be impaired;

(-b) loose, missing, cracked, or fractured parts, bolting, or fasteners;

(-c) foreign materials or accumulation of corrosion products;

(-d) corrosion or erosion that reduces the section thickness by more than 5%; or

(-e) wear of mating surfaces that may lead to loss of function.

(h) Inservice inspection of the mechanical connection assembly shall be performed as follows:

(1) The mechanical connection assembly shall be added to the inspection plan.

(2) The following examinations are required each refueling outage. Examinations required by (-a) and (-b) shall be performed with the insulation removed.

(-a) A VT-3 visual examination of each mechanical connection assembly shall be performed. The following relevant conditions shall require corrective action:

(-1) structural distortion or displacement of parts to the extent that component function may be impaired;

(-2) loose, missing, cracked, or fractured parts, bolting, or fasteners;

(-3) foreign materials or accumulation of corrosion products;

(-4) corrosion or erosion that reduces the section thickness by more than 5%; or

(-5) wear or corrosion of mating surfaces that may lead to loss of function.

(-b) VT-2 visual examination shall be performed in accordance with IWA-5240 on each mechanical connection assembly location. For pressurized water reactors, visual examination may be conducted when the system is depressurized.

(-c) If the mechanical connection assembly includes a leakage detection/diversion fitting, it shall be subject to a VT-2 visual examination for evidence of seal leakage in addition to the examination required by (-b). If leakage or evidence of leakage is identified the entire mechanical connection shall be disassembled and examined as required by (4).

(-d) The mechanical connection assembly shall be included in the System Pressure Test conducted in accordance with Table IWB-2500-1, Category B-P. Removal of insulation as stated in IWA-5242(a) is not required.

(-e) For the examinations of (-b), (-c), and (-d), above, if leakage or evidence of leakage since the prior examination is identified the entire mechanical connection assembly shall be disassembled and examined as required by (4).

(3) The following examinations shall be required at each interval:

(-a) A VT-1 visual examination shall be performed for all pressure retaining bolting with the bolting in-place. Acceptance standards of IWB-3517 apply. The examination shall be performed with the insulation removed.

(-b) A 10% sample of mechanical connection assemblies shall be disassembled. The mechanical connection assemblies to be disassembled shall be selected based on the longest installed service life, with preference given to the presence of known through-wall flaws in the original pressure boundary, if any, and locations identified for high susceptibility to primary water stress corrosion cracking. Each mechanical connection assembly selected for disassembly shall be examined as required by (4).

(4) A VT-1 visual examination of the mechanical connection assembly shall be performed when it is disassembled for any reason after the initial installation. the VT-1 visual examination shall also include the surfaces of the component on which the mechanical connection assembly is installed, including bore, counterbore if any, bolt holes, and bolting, following disassembly. The following relevant conditions shall require corrective action:

(-a) structural distortion or displacement of parts to the extent that component function may be impaired;

(-b) loose, missing, cracked, or fractured parts, bolting, or fasteners;

(-c) foreign materials or accumulation of corrosion products;

(-d) corrosion or erosion that reduces the section thickness by more than 5%; or

(-e) corrosion of mating surfaces that may lead to loss of function.

Upon reinstallation, (f) applies.

(i) All applicable requirements of Section XI shall be met except for IWB-2420(b) and IWA-4340 (for the 1998 Edition with the 2000 Addenda or later).

(j) Inspection requirements included in this Case shall be incorporated in the ISI program requirements for the component on which the mechanical connection assembly is installed. Alternative inspection requirements permitted by other Cases shall not be substituted for the requirements defined by this Case. Use of this Case for installation of a mechanical connection modification shall be documented on Form NIS-2 or Form NIS-2A.

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Approval Date: October 12, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-735
Successive Inspections of Class 1 and 2 Piping Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of IWB-2420 or IWC-2420 may be used to determine the need for successive inspections for piping welds found by volumetric examination to contain subsurface flaws?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWB-2420 or IWC-2420 for successive inspections of piping weld examination, volumes containing subsurface flaws are not required, provided the following requirements are met:

(a) The flaw shall be characterized as subsurface in accordance with Figure 1. Interpolation for all a/ℓ values between the curves in Figure 1 may be performed using the values in Table 1.

(b) The NDE technique and evaluation that detected and characterized the flaw shall be documented in the flaw evaluation report.

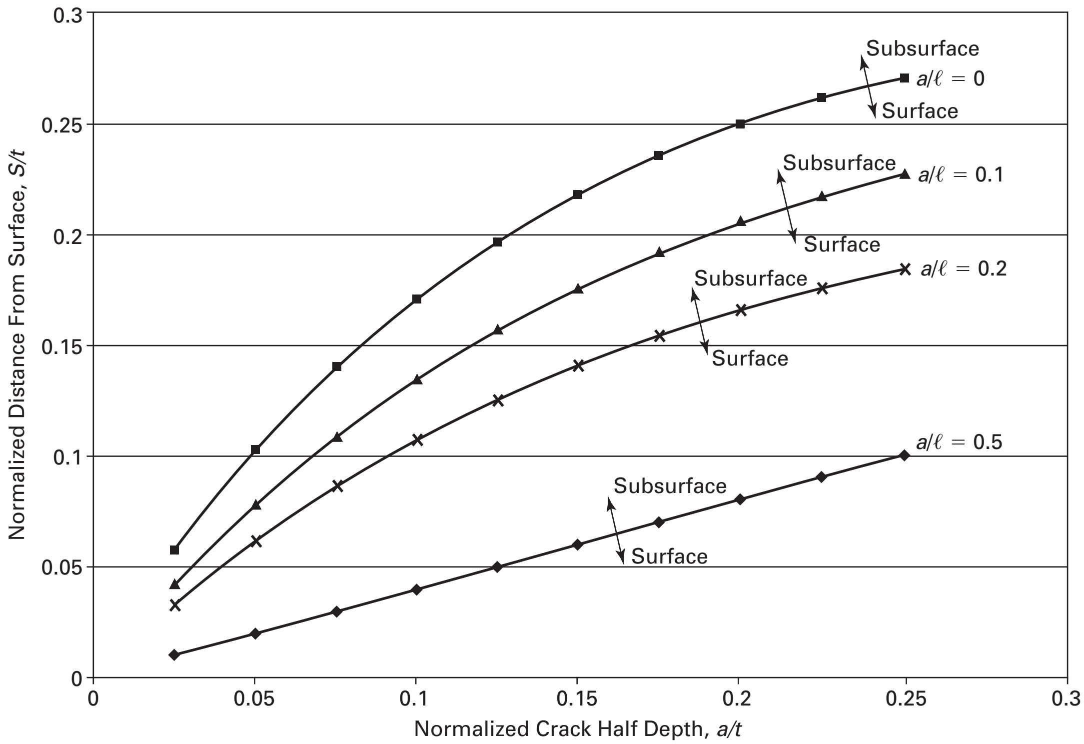
(c) The flaw shall be acceptable for continued service in accordance with IWB-3600 or IWC-3600 for the intended service life of the component.

(d) The flaw shall not be detected in a weld in austenitic stainless steel in Boiling Water Reactors (BWRs), in UNS N06600 or W86182 in Pressurized Water Reactors (PWRs) and BWRs, or in UNS W86082 in PWRs.

Table 1
Surface Proximity Rules for Successive Examinations of Piping Components

	S/t			
a/t	a/ℓ=0	a/ℓ=0.1	a/ℓ=0.2	a/ℓ=0.5
0.025	0.058	0.042	0.033	0.010
0.050	0.104	0.078	0.061	0.020
0.075	0.141	0.108	0.085	0.030
0.100	0.172	0.134	0.107	0.040
0.125	0.197	0.157	0.125	0.050
0.150	0.218	0.176	0.141	0.060
0.175	0.236	0.192	0.155	0.070
0.200	0.250	0.206	0.166	0.080
0.225	0.261	0.217	0.176	0.090
0.250	0.270	0.227	0.184	0.100

Figure 1
Successive Examination Surface Proximity Rule for Piping Components



Approval Date: January 5, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-736
Use of UNS S32050 Welded and Seamless Pipe and Tubing, Forgings, and Plates Conforming to SA-249/SA-249M, SA-479/SA-479M, and SA-240/SA-240M, and Grade CK35MN Castings Conforming to ASTM A743-03 for Construction of Class 1, 2, and 3 Components Section III, Division 1

Inquiry: May UNS S32050 in the form of welded and seamless pipe and tubing, forging, and plate conforming to SA-249/SA-249M, SA-479/SA-479M, and SA-240/SA-240M, and Grade CK35MN castings conforming to ASTM A743-03, be used in the construction of Class 1, 2, and 3 components under the rules of Section III, Division 1?

Reply: It is the opinion of the Committee that material described in the Inquiry may be used in the construction of Class 1, 2, and 3 components under the rules of Section III, Division 1, providing the following additional requirements are met.

(a) The design temperature shall not exceed 650°F (343°C).

(b) The maximum allowable stress values, design stress intensity, tensile strength, and yield strength shall be those listed in Tables 1 through 4.

(c) Separate welding procedure and performance qualifications shall be conducted in accordance with Section IX. Post-weld heat treatment is neither required or prohibited.

(d) The Case number shall be identified on the Material Organization's Certification and the Manufacturer's Data Report.

Table 1
Maximum Allowable Stress Values

Temperature °F	UNS S32050 ksi	Grade CK35MN (Casting) ksi
−20/100	28.0	23.7
200	28.0	23.3
300	27.1	21.5
400	25.3	19.9
500	24.4	18.8
600	23.9	18.1
650	23.7	18.0

Table 1M
Maximum Allowable Stress Values

Temperature °C	UNS S32050 MPa	Grade CK35MN (Casting) MPa
−30/40	193	168
65	193	168
100	193	159
125	193	153
150	186	148
175	178	143
200	175	138
225	172	134
250	169	131
275	167	128
300	165	126
325	164	124
350	163 [Note (1)]	124 [Note (1)]

NOTE:
(1) These values are provided for interpolation use only. The temperature limit is 343°C.

Table 2
Design Stress Intensity

Temperature °F	UNS S32050 ksi	Grade CK35MN (Casting) ksi
−20/100	32.0	27.3
200	29.5	22.7
300	27.1	20.4
400	24.5	19.1
500	22.1	18.4
600	20.3	18.1
650	19.7	18.0

Table 2M
Design Stress Intensity

Temperature °C	UNS S32050 MPa	Grade CK35MN (Casting) MPa
−30/40	221	188
65	211	168
100	202	154
125	194	147
150	186	141
175	178	136
200	170	132
225	163	129
250	155	127
275	149	126
300	143	125
325	138	124
350	135 [Note (1)]	124 [Note (1)]

NOTE:
(1) These values are provided for interpolation use only. The temperature limit is 343°C.

Table 3
Tensile Strength

Temperature °F	UNS S32050 ksi	Grade CK35MN (Casting) ksi
−20/100	98.0	83.0
200	98.0	81.6
300	92.8	75.1
400	88.5	69.8
500	85.4	65.8
600	83.6	63.4
650	83.0	62.8
700	82.7	62.7
750	82.7	63.0

Table 3M
Tensile Strength

Temperature °C	UNS S32050 MPa	Grade CK35MN (Casting) MPa
−30/40	676	572
65	676	572
100	674	557
125	655	536
150	639	517
175	625	500
200	612	484
225	601	470

Table 3M
Tensile Strength (Cont'd)

Temperature °C	UNS S32050 MPa	Grade CK35MN (Casting) MPa
250	592	458
275	585	448
300	579	441
325	575	435
350	572	433
375	570	432
400	570	432

Table 4
Yield Strength

Temperature °F	UNS S32050 ksi	Grade CK35MN (Casting) ksi
−20/100	48.0	41.0
200	44.3	34.1
300	40.6	30.7
400	36.7	28.6
500	33.2	27.5
600	30.4	27.1
650	29.5	27.0
700	28.9	26.9
750	28.7	26.7

Table 4M
Yield Strength

Temperature °C	UNS S32050 MPa	Grade CK35MN (Casting) MPa
−30/40	331	283
65	317	252
100	303	232
125	291	220
150	279	211
175	267	204
200	255	198
225	244	194
250	233	191
275	223	189
300	215	187
325	207	186
350	202	186
375	199	185
400	198	184

Approval Date: July 1, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-738
NDE of Full Penetration Butt Welds in Class 2 Supports
Section III, Division 1

Inquiry: What examinations may be applied to primary members of Class 2 support welds in lieu of the magnetic particle or liquid penetrant examinations required by NF-5221?

Reply: It is the opinion of the Committee that the examination requirements of NF-5212 for Class 1 support welds may be used in lieu of the requirements of NF-5221 for Class 2 support welds.

The Case number shall be included in the Code Data Report or NS-1 Certificate of Conformance.

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Approval Date: January 21, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-739-1
Alternative Qualification Requirements for Personnel Performing Class CC Concrete and Post-Tensioning System Visual Examinations
Section XI, Division 1

Inquiry: What alternative to the requirements of IWL-2310 may be used for qualification of personnel performing Class CC concrete and post-tensioning system visual examinations?

Reply: It is the opinion of the Committee that the following alternative to the requirements of IWL-2310 may be used for qualification of personnel performing Class CC concrete and post-tensioning system visual examinations:

(a) Personnel performing general or detailed visual examinations (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-3C, VT-1C, or Limited VT-1 (i.e., wires, strands, anchorage hardware, and reinforcing steel) visual examinations (1992 Edition with the 1992 Addenda through the 1995 Edition with the 1996 Addenda) shall be approved by the Responsible Engineer and shall be qualified by satisfying the following requirements:

(1) at least 10 hr plant experience, such as that gained by plant personnel involved in inspection, maintenance, or repair/replacement activities in each of the following:

(-a) structural concrete and reinforcing steel

(-b) post-tensioning system components (for plants with post-tensioning systems only)

(2) at least 4 hr of training in Section XI, Subsection IWL requirements and at least 2 hr of training in plant-specific procedures for IWL visual examinations. Training shall include requirements for in-service and preservice examinations and reporting criteria for the following:

(-a) concrete (applicable conditions such as those described in ACI 201.1R should be included)

(-b) reinforcing steel

(-c) post-tensioning system items (e.g., wires, strands, anchorage hardware, corrosion protection medium, and free water) [for plants with post-tensioning systems only]

(3) training proficiency shall be demonstrated by administering a qualification examination consisting of the following:

(-a) A written examination covering Section XI, Subsection IWL requirements and plant-specific procedure requirements for visual examinations, containing at least 15 questions in each of the following:

(-1) concrete and reinforcing steel

(-2) post-tensioning system components (i.e., wires, strands, anchorage hardware, corrosion protection medium, and free water) [for plants with post-tensioning systems only]

(-b) A practical examination using test specimens with flaws or indications to be detected by the following visual examination techniques:

(-1) general and detailed visual examination of concrete (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-3C and VT-1C visual examination of concrete (1992 Edition with the 1992 Addenda through the 1995 Edition with the 1996 Addenda)

(-2) detailed visual examination of reinforcing steel (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-1 visual examination of reinforcing steel (1992 Edition with the 1992 Addenda through the 1995 Edition with the 1996 Addenda)

(-3) detailed visual examination (1995 Edition with the 1997 Addenda through the 2004 Edition with the 2006 Addenda) or VT-1 visual examination (1992 Edition with the 1992 Addenda through the 1995 Edition with the 1996 Addenda) of post-tensioning system components (i.e., wires, stands, and anchorage hardware) [for plants with post-tensioning systems only]

(-c) Passing grades for examinations shall be as follows:

(-1) an average combined grade of 80% for written and practical examinations

(-2) a minimum grade of 70% for each written and practical examination

(-d) Individuals failing to attain the required passing grades shall receive additional training as determined by the Responsible Engineer before reexamination. The written reexamination questions shall be selected at random from a bank of questions

containing at least twice the number of examination questions, or the written examination shall contain at least 30% different or reworded questions. The practical reexamination test shall contain at least 50% different test specimens or shall contain specimens with at least 50% different flaws or indications from those used during the most recent practical examination that was not passed by the candidate. No individual shall be reexamined more than twice within any consecutive 12-month period.

(4) training proficiency shall be demonstrated by administering subsequent examinations at a frequency not exceeding 5 years

(5) the vision test requirements of IWA-2321 of the 2004 Edition with the 2006 Addenda

(b) The qualification requirements of this Case shall be described in the Employer's written practice.

Approval Date: November 10, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-740-2
Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items
Section XI, Division 1

Inquiry: As an alternative to the provisions of IWA-4410 and IWA-4611 for reducing a defect to an acceptable size in accordance with the provisions of the Construction Code or Section XI, is it permissible to increase the wall thickness, or to apply a mitigation to a specified location, by deposition of weld overlay on the outside surface of the piping, component, or associated weld?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4410 and IWA-4611, a defect in austenitic stainless steel or austenitic nickel alloy piping, components, or associated welds may be reduced to a flaw of acceptable size in accordance with IWB-3640 by addition of a repair weld overlay. In addition, for these materials, in lieu of IWA-4410, a mitigative weld overlay may be applied. All Section XI references are to the 2007 Edition with the 2008 Addenda. For the use of this Case with other editions and addenda, refer to Table 1. The weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of the piping, component, or associated weld, including ferritic materials when necessary, provided the following requirements are met:

1 GENERAL REQUIREMENTS

1.1 DEFINITION

(a) Full Structural Weld Overlay. Deposition of weld reinforcement on the outside diameter of the piping, component, or associated weld, such that the weld reinforcement is capable of supporting the design loads, without consideration of the piping, component, or associated weld beneath the weld reinforcement. Full structural weld overlay can be either mitigative or repair weld overlay as defined in (b) and (c).

(b) Mitigative Weld Overlay. Weld overlay that is applied over material with no inside surface connected flaws found during an examination performed in accordance with 2(a)(3), prior to the weld overlay being applied.

(c) Repair Weld Overlay. Weld overlay that is applied over material with an inside surface connected flaw or subsurface defect, or where a pre-weld overlay examination is not performed.

(d) SCC Susceptible Materials. For this Case, the stress-corrosion-cracking (SCC) susceptible materials are UNS N06600, N06082, or W86182 in PWR environment; or UNS N06600, W86182, or austenitic stainless steels and associated welds in BWR environments.

1.2 GENERAL OVERLAY REQUIREMENTS

(a) A full-structural weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of circumferential welds. This Case applies to austenitic nickel alloy and austenitic stainless steel welds between the following:

(1) P-No. 8 or P-No. 43 and P-Nos. 1, 3, 12A, 12B, or 12C[1]

(2) P-No. 8 and P-No. 43

(3) Between P-Nos. 1, 3, 12A, 12B, and 12C materials

(b) If a weld overlay on any of the material combinations in (a) obstructs a required examination of an adjacent P-No. 8 to P-No. 8 weld, the overlay may be extended to include overlaying the adjacent weld.

(c) Weld overlay filler metal shall be austenitic nickel alloy (28% Cr min., ERNiCrFe-7/7A) meeting the requirements of (e)(1) or (e)(2), as applicable, applied 360 deg around the circumference of the item and deposited using a Welding Procedure Specification (WPS) for groove welding, qualified in accordance with the Construction Code and Owner's Requirements identified in the Repair/Replacement Plan. As an alternative to the post weld heat treatment (PWHT) requirements of the Construction Code and Owner's requirements, the provisions of Mandatory Appendix I may be used for ambient-temperature temper bead welding.

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

(1) For P-No. 1 base materials, the Construction Code PWHT exemptions permitted for circumferential butt welds may be applied to exempt the weld ovelay from PWHT, with the following clarifications:

(-a) The nominal weld thickness is defined as the maximum overlay thickness applied over the ferritic base material.

(-b) The base material thickness is defined as the maximum thickness of the ferritic material where the overlay is applied.

(2) If ambient-temperature temper bead welding is used, Mandatory Appendix I shall be used.

(d) Prior to deposition of the weld overlay, the surface to be weld overlaid shall be examined using the liquid penetrant method. Indications with major dimensions greater than $^{1}/_{16}$ in. (1.5 mm) shall be removed, reduced in size, or weld repaired in accordance with the following requirements:

(1) One or more layers of weld metal shall be applied to seal unacceptable indications in the area to be repaired with or without excavation. The thickness of these layers shall not be used in meeting weld reinforcement design thickness requirements. Peening the unacceptable indication prior to welding is permitted.

(2) If weld repair of indications identified in (d) is required, the area where the weld overlay is to be deposited, including any local weld repairs or initial weld overlay layer, shall be examined by the liquid penetrant method. The area shall contain no indications with major dimensions greater than $^{1}/_{16}$ in. (1.5 mm) prior to application of the structural layers of the weld overlay.

(3) To reduce the potential of hot cracking when applying an austenitic nickel alloy over P-No. 8 base metal, it is permissible to apply a layer or multiple layers of austenitic stainless steel filler material over the austenitic stainless steel base metal. The thickness of these layers shall not be used in meeting weld reinforcement design thickness requirements. The filler material used shall meet the minimum requirements for delta ferrite.

(e) Weld overlay deposits shall meet the following requirements:

(1) The austenitic stainless steel weld overlay shall consist of at least two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The first layer of weld metal with delta ferrite content of at least 7.5 FN shall constitute the first layer of the weld reinforcement that may be credited toward the required thickness. Alternatively, layers of at least 5 FN are acceptable, provided the carbon content of the deposited weld metal is determined by chemical analysis to be less than 0.02%.

(2) The austenitic nickel alloy weld overlay shall consist of at least two weld layers deposited using a filler material with a Cr content of at least 28%. The first layer of weld metal deposited may not be credited toward the required thickness. Alternatively, for PWR applications, a first diluted layer may be credited toward the required thickness, provided the portion of the layer over the austenitic base material, austenitic filler material weld, and the associated dilution zone from an adjacent ferritic base material contain at least 24% Cr, and the Cr content of the deposited weld metal is determined by chemical analysis of the production weld or of a representative coupon taken from a mockup prepared in accordance with the WPS for the production weld. Alternatively, for BWR applications, a diluted layer may be credited toward the required thickness, provided the portion of the layer over the austenitic base material, austenitic filler material weld, and the associated dilution zone from an adjacent ferritic base material contain at least 20% Cr, and the Cr content of the deposited weld metal is determined by chemical analysis of the production weld or of a representative coupon taken from a mockup prepared in accordance with the WPS for the production weld.

(f) This Case is only for welding in applications predicted not to have exceeded thermal neutron ($E < 0.5$ eV) fluence of 1×10^{17} neutrons per cm^2 prior to welding.

(g) A new weld overlay shall not be installed over the top of an existing weld overlay that has been in service.

2 CRACK GROWTH AND DESIGN

(a) Crack Growth Calculation of Flaws in the Original Weld or Base Metal. The size of all flaws detected or postulated in the original weld or base metal shall be used to define the life of the overlay. The inspection interval shall be longer than the shorter of the life of the overlay or the period specified in 3(c). Crack growth due to both stress corrosion and fatigue shall be evaluated. Flaw characterization and evaluation shall be based on the examination results or postulated flaw, as described below. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required.

(1) For repair overlays, the initial flaw size for crack growth in the original weld or base metal shall be based on the as-found flaw or postulated flaw, if no pre-overlay examination is performed.

(2) For postulated flaws, the axial flaw length shall be 1.5 in. (38 mm) or the combined width of the weld plus buttering plus any adjacent SCC susceptible material, whichever is greater. The circumferential flaw length shall be assumed to be 360 deg. The depths associated with these lengths are specified in (3) and (4).

(3) If in Appendix VIII, Supplement 10, or Supplement 2, as applicable, ultrasonic examination is performed prior to application of the overlay, and no inside-surface-connected planar flaws are discovered, initial flaws originated from the inside surface of the weldment equal to 10% of the original wall thickness shall be assumed in both the axial and circumferential directions, and the overlay shall be considered mitigative.

(4) If in Appendix VIII, Supplement 10, or Supplement 2, as applicable, ultrasonic examination is not performed prior to application of the overlay, initial inside-surface-connected planar flaws equal to at least 75%

through the original wall thickness shall be assumed, in both the axial and circumferential directions, and the overlay shall be considered a repair. For cast austenitic stainless steel (CASS) items, a 100% through-wall flaw shall be assumed unless the subsequent inservice inspection schedule is modified as discussed in 3(c)(8).

(5) There may be circumstances in which an overlay examination is performed using an ultrasonic examination procedure qualified in accordance with Appendix VIII, Supplement 11 for depths greater than the outer 25% of the original wall thickness (Figure 2). For such cases, the initial flaw depths shall be assumed shall be the detected depth found by the Appendix VIII, Supplement 11 qualified examination, plus the postulated worst-case flaw in the region not covered by the Appendix VIII ultrasonic examination.

(6) In determining the life of the overlay, any inside-surface-connected planar flaw found by the overlay preservice inspection of 3(b) that exceeds the depth of (3), (4) or (5) above shall be used as part of the initial flaw depth. The initial flaw depth assumed is the detected flaw depth plus the postulated worst-case flaw depth in the region of the pipe wall thickness that was not examined using an ultrasonic examination procedure meeting Appendix VIII for that region. An overlay meeting this condition shall be considered a repair, rather than mitigation.

(b) Structural Design and Sizing of the Overlay. The design of the weld overlay shall satisfy the following, using the assumptions and flaw characterization requirements in (a). The following design analysis shall be completed in accordance with IWA-4311:

(1) The axial length and end slope of the weld overlay shall cover the weld and heat-affected zones on each side of the weld, as well as any SCC-susceptible base material adjacent to the weld, and provide for load redistribution from the item into the weld overlay and back into the item without violating applicable stress limits of NB-3200. Any laminar flaws in the weld overlay shall be evaluated in the analysis to ensure that load redistribution complies with the above. These requirements will usually be satisfied if the weld overlay full thickness length extends axially beyond the SCC-susceptible material or projected flaw by at least $0.75\sqrt{Rt}$, where R is the outer radius of the item and t is the nominal wall thickness of the item at the applicable side of the overlay (i.e., R and t of the nozzle on the nozzle side and R and t of the safe-end on the safe-end side).

(2) Unless specifically analyzed in accordance with (1), the end transition slope of the overlay shall not exceed 30 deg.

(3) The assumed flaw in the underlying base material or weld shall be based on the limiting case of (-a) and (-b) that results in the larger required overlay thickness.

(-a) 100% through-wall circumferential flaw for the entire circumference

(-b) 100% through-wall flaw with length of 1.5 in. (38 mm) or the combined width of the weld plus buttering plus any SCC-susceptible material, whichever is greater, in the axial direction

(4) The overlay design thickness shall be verified, using only the weld overlay thickness conforming to the deposit analysis requirements of 1.2(e). The combined wall thickness at the weld overlay, any postulated worst-case planar flaws under the laminar flaws in the weld overlay, and the effects of any discontinuity (e.g., another weld overlay or reinforcement for a branch connection) within a distance of $2.5\sqrt{Rt}$ from the toes of the weld overlay, including the flaw size assumptions defined in (3), above, shall be evaluated and shall meet the requirements of IWB-3640, IWC-3640, or IWD-3640, as applicable.

(5) The effects of any changes in applied loads, as a result of weld shrinkage from the entire overlay, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the weld overlay) shall be evaluated. Existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640, IWC-3640, or IWD-3640, as applicable.

3 EXAMINATION

In lieu of all other examination requirements, the examination requirements of this Case shall be met for the life of the overlay. Nondestructive examination methods shall be in accordance with IWA-2200, except as specified herein. Nondestructive examination personnel shall be qualified in accordance with IWA-2300. Ultrasonic examination procedures and personnel shall be qualified in accordance with Appendix VIII, Supplement 11. The examination shall be performed to the maximum extent practicable, for axial and circumferential flaws. If 100% coverage of the required volume for axial flaws cannot be achieved, but essentially 100% coverage for circumferential flaws (100% of the susceptible volume) can be achieved, the examination for axial flaws shall be performed to achieve the maximum coverage practicable, with limitations noted in the examination report. The examination coverage requirements shall be considered to be met. For cast stainless steel components for which no supplement is available in Appendix VIII, the weld volume shall be examined using Appendix VIII procedures to the maximum extent practicable.

(a) Acceptance Examination

(1) The weld overlay shall have a surface finish of 250 μin. (6.3 μm) RMS or better and contour that permits ultrasonic examination in accordance with procedures qualified in accordance with Appendix VIII. The weld overlay shall be inspected to verify acceptable configuration.

(2) The weld overlay and the adjacent base material for at least $^1/_2$ in. (13 mm) from each side of the overlay shall be examined using the liquid penetrant method. The weld overlay shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300. The adjacent base material shall satisfy the surface examination acceptance criteria for base material of the Construction Code or NB-2500. If ambient temperature temper bead welding is performed, the liquid penetrant examination of the completed weld overlay shall be conducted no sooner than 48 hr following completion of the three tempering layers over the ferritic steel.

(3) The examination volume A-B-C-D in Figure 1(a) shall be ultrasonically examined to assure adequate fusion (i.e., adequate bond) with the base material and to detect welding flaws, such as interbead lack of fusion, inclusions, or cracks. The interface C-D shown between the overlay and weld includes the bond and heat-affected zone from the overlay. If ambient temperature temper bead welding is performed, the ultrasonic examination shall be conducted no sooner than 48 hr following completion of the three tempering layers over the ferritic steel. Planar flaws detected in the weld overlay acceptance examination shall meet the preservice examination standards of IWB-3514. In applying the acceptance standards to planar indications, the thickness, t_1, or t_2 defined in Figure 1(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to SCC. For susceptible material, t_1 shall be used. If a flaw in the overlay crosses the boundary between the two regions, the more conservative of the two dimensions (t_1 or t_2) shall be used. Laminar flaws in the weld overlay shall meet the following requirements:

(-a) The acceptance standards of IWB-3514 shall be met, with the additional limitation that the total laminar flaw area shall not exceed 10% of the weld surface area and that no linear dimension of the laminar flaw area shall exceed the greater of 3 in. (76 mm) or 10% of the pipe circumference.

(-b) For examination volume A-B-C-D in Figure 1 (a), the reduction in coverage due to laminar flaws shall be less than 10%. The uninspectable volume is the volume in the weld overlay underneath the laminar flaws for which coverage cannot be achieved with the angle beam examination method.

(-c) Any uninspectable volume in the weld overlay shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed flaw shall meet the preservice examination acceptance standards of IWB-3514, with nominal wall thickness as defined above the planar flaws. Alternatively, the assumed flaw shall be evaluated and meet the requirements of IWB-3640, IWC-3640, and IWD-3640, as applicable. Both axial and circumferential planar flaws shall be assumed.

(4) After completion of all welding activities, VT-3 visual examination shall be performed on all affected restraints, supports, and snubbers, to verify that design tolerances are met.

(b) Preservice Inspection

(1) The examination volume in Figure 2 shall be ultrasonically examined. The angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions, to locate and size any planar flaw that have propagated into the outer 25% of the base metal thickness or into the weld overlay. For weld overlays on cast austenitic stainless steel base materials, if a 100% through-wall flaw is used for crack growth, only planar flaws that have propagated into the weld overlay, or are in the overlay, are required to be located and sized.

(2) The preservice examination acceptance standards of IWB-3514 shall be met for the weld overlay. In applying the acceptance standards to planar indications, the thickness, t_1 or t_2, defined in Figure 1(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to SCC. For susceptible material, t_1 shall be used. Planar flaws in the outer 25% of the base metal thickness shall meet the design analysis requirements of 2(b).

(3) The flaw evaluation requirements of IWB-3640, IWC-3640, or IWD-3640 shall not be applied to planar flaws, identified during preservice examination, that exceed the preservice examination acceptance standards of IWB-3514.

(c) Inservice Inspection

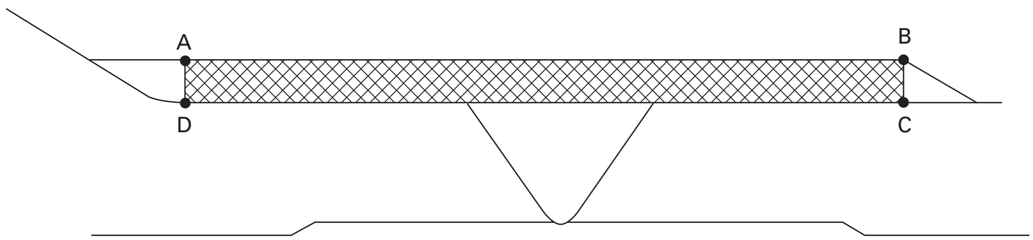
(1) The weld overlay examination shall be added to the inspection plan. The weld overlay inspection interval shall not be greater than the life of the overlay as determined in 2(a) above. All weld overlays shall be examined prior to the end of their design life.

(2) The weld overlay examination volume in Figure 2 shall be ultrasonically examined during the first or second refueling outage following application. Alternatively, for mitigative weld overlays, in which pre-overlay examinations are performed in accordance with 2(a)(3), post-overlay examinations are performed in accordance with (a) and (b), and no inside-surface-connected planar flaws are discovered, the overlay may be placed immediately into the population to be examined in accordance with (5).

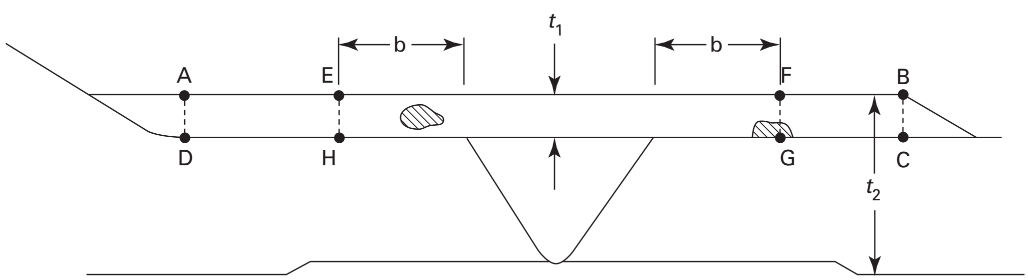
(3) The weld overlay examination volume in Figure 2 shall be ultrasonically examined to determine if any new or existing planar flaws have propagated into the outer 25% of the base material thickness or into the overlay. The angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions.

(4) The weld overlay shall meet the inservice examination acceptance standards of IWB-3514. In applying the acceptance standards to planar indications, the thickness,

Figure 1
Acceptance Examination Volume and Thickness Definitions



(a) Examination Volume A–B–C–D



(b) Thickness (t_1 and t_2) for Table IWB-3514-2

GENERAL NOTES:
(a) Dimension b is equivalent to the nominal thickness of the nozzle or pipe being overlaid, as appropriate.
(b) The nominal wall thickness is t_1 for flaws in E-F-G-H, and t_2 for flaws in A-E-H-D or F-B-C-G.
(c) For flaws that scan two examination volumes (such as illustrated in F-G) the t, thickness shall be used.
(d) The weld includes the nozzle or safe end butter, where applied, plus any SCC-susceptible base material in the nozzle.

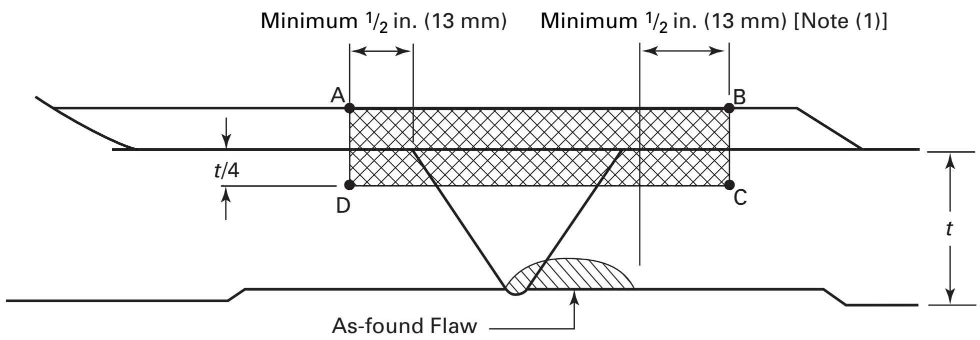
t_1 or t_2, defined in Figure 1(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to SCC. For susceptible material, t_1 shall be used. If the acceptance standards of IWB-3514 cannot be met, the weld overlay shall meet the acceptance standards of IWB-3600, IWC-3600, or IWD-3600, as applicable. If a planar flaws is detected in the outer 25% of the base material thickness shall meet the design analysis requirements of 2. Any indication characterized as stress corrosion cracking in the weld overlay material is unacceptable.

(5) Weld overlay examination volumes in Figure 2 that show no indication of planar flaw growth or new planar flaws shall be placed into a population to be examined on a sample basis, except as required by (1). Twenty-five percent of this population shall be examined once during each inspection interval.

(6) If inservice examinations reveal planar flaw growth, or new planar flaws, meeting the acceptance standards of IWB-3514, IWB-3600, IWC-3600, or IWB-3600, the weld overlay examination volume shall be reexamined during the first or second refueling outage following discovery of the growth or new flaws.

(7) For weld overlay examination volumes with unacceptable indications in accordance with (4), the weld overlay and original defective weld shall be removed. A repair/replacement activity shall be performed in accordance with IWA-4000.

Figure 2
Preservice and Inservice Examination Volume



Examination Volume A–B–C–D

GENERAL NOTE: The weld includes the nozzle or safe end butter, where applied.

NOTE:
(1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least 1/2 in. (13 mm) beyond the as-found flaw and at least 1/2 in. (13 mm) beyond the toes of the original weld, including weld end butter, where applied.

(8) If preservice and inservice examinations in accordance with ASME Section XI, Appendix VIII, Supplement 11 cannot be performed for the entire weld overlay examination volume in Figure 2 because of cast austenitic stainless steel items, and a 100% initial flaw assumption is not used in the crack growth evaluation of 2(a), a 75% through- wall depth may be assumed in the crack growth calculation, provided that the required examination volume is examined at a higher frequency than the requirements in (c). The subject weld shall be ultrasonically examined during the first or second refueling outage following the weld overlay installation. If ultrasonic examination is performed prior to weld overlay installation and after installation without detecting any planar flaws in the original weld or the weld overlay, then the ultrasonic examination during the first or second refueling outage is not required. After the first inservice examination, the required examination volume shall be ultrasonically examined every 10 years from the date of the installation until such time when ultrasonic examination is qualified to examine the cast austenitic stainless steel portion of the required inspection volume in accordance with the performance demonstration requirements of ASME Code, Section XI, Appendix VIII. The inspection of the overlaid weld shall not be credited to satisfy the requirement of the 25% inspection sample every ten years of overlaid welds without cast stainless steel materials. After the required examination volume is examined by qualified ultrasonic examination for the cast austenitic stainless steel material and no planar flaws are detected, the weld may be placed in the 25% inspection sample population in accordance with (5).

(d) Additional Examinations. If inservice examinations reveal a defect, in accordance with (c)(4), planar flaw growth into the weld overlay design thickness, or axial flaw growth beyond the specified examination volume, additional weld overlay examination volumes, equal to the number scheduled for the current inspection period, shall be examined prior to return to service. If additional defects are found in the second sample, 50% of the total population of weld overlay examination volumes shall be examined prior to return to service. If additional defects are found, the entire remaining population of weld overlay examination volumes shall be examined prior to return to service.

4 PRESSURE TESTING

A system leakage test shall be performed in accordance with IWA-5000.

5 DOCUMENTATION

Use of this Case shall be documented on Form NIS-2.

MANDATORY APPENDIX I
AMBIENT-TEMPERATURE TEMPER BEAD WELDING

I-1 GENERAL REQUIREMENTS

(a) This Appendix applies to dissimilar austenitic filler metal welds between P-Nos. 1, 3, 12A, 12B, and 12C[1] materials and their associated welds and welds joining P-No. 8 or 43 materials to P-Nos. 1, 3, 12A, 12B, and 12C[1] materials with the following limitation. This Appendix shall not be used to repair SA-302 Grade B material unless the material has been modified to include from 0.4% to 1.0% nickel, quenching, tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld overlay based on the finished surface over the ferritic base material shall be 500 in.^{2} (325 000 mm^2).

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Appendix are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm) or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Appendix, provided the depth of repair in the base material does not exceed $^3/_8$ in. (10 mm).

(e) Prior to welding, the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

(f) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Peening may be used, except on the initial and final layers.

I-2 WELDING QUALIFICATIONS

The welding procedures and operators shall be qualified in accordance with Section IX and the requirements of I-2.1 and I-2.2.

I-2.1 Procedure Qualification.

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded. The materials shall be post-weld heat treated to at least the time and temperature that was applied to the materials being welded.

(b) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(c) The weld overlay shall be qualified using groove weld coupon. The test assembly groove depth shall be at least 1 in. (25 mm). The test assembly thickness shall be at least twice the test assembly groove depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Figure I-1.

(d) Ferritic base material for the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (e) but shall be in the base metal.

(e) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (d). Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

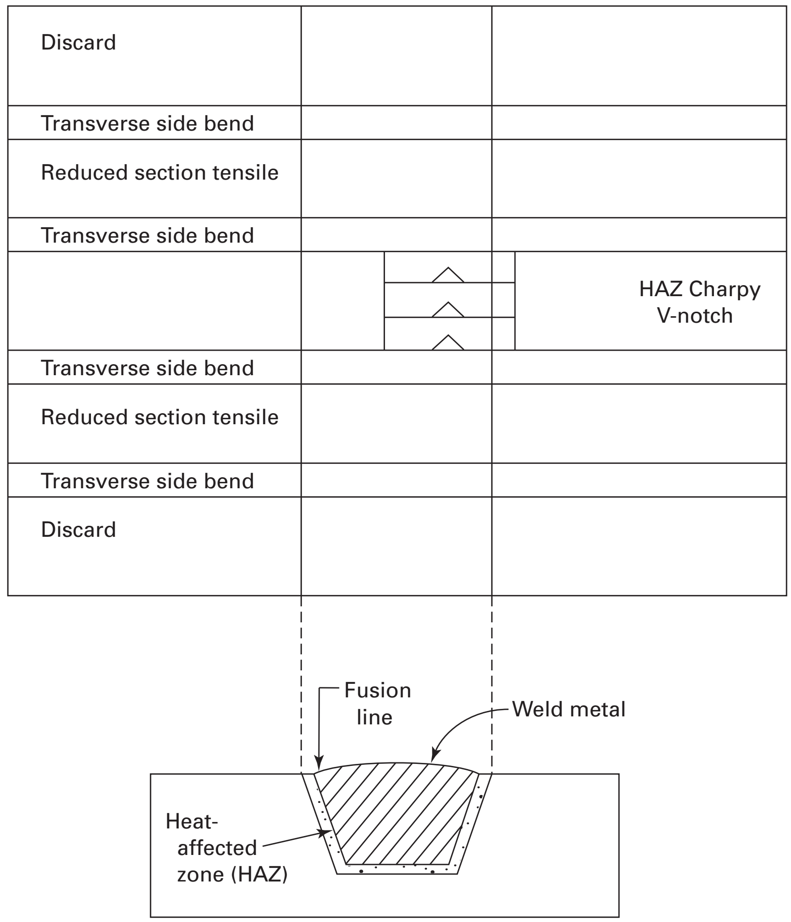
(2) If the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(3) If the test material is in the form of a plate or forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(4) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation, and location of all test specimens shall be reported in the Procedure Qualification Record.

(f) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average

Figure I-1
Qualification Test Plate



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Appendix, either of the following shall be performed:

(1) The welding procedure shall be requalified.

(2) An Adjustment Temperature for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with the 2002 Addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

I-2.2 Performance Qualification. Welding operators shall be qualified in accordance with Section IX.

I-3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements:

(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (QW-442) for P-No. 8 to P-No. 1, 3, or 12 (A, B, or C) weld joints or F-No. 43 weld metal (QW-432) for P-No. 8 or 43 to P-No. 1, 3, or 12 (A, B, or C) weld joints.

Table 1
References for Alternative Editions and Addenda of Section XI

2001 Edition with 2003 Addenda through 2007 Edition with 2008 Addenda	1995 Edition with 1996 Addenda through 2001 Edition with 2002 Addenda	1995 Edition with 1995 Addenda	1989 Edition with 1991 Addenda through 1995 Edition	1986 Edition with 1988 Addenda through 1989 Edition with 1990 Addenda
IWA-4000 Repair/ Replacement Activities	IWA-4000	IWA-4000	IWA-4000	IWA-4000 & IWA-7000
IWA-4410 Welding, Brazing, Metal Removal, and Installation – General Requirements	IWA-4410	IWA-4410	IWA-4170	IWA-4120
IWA-3300 Flaw Characterization	IWA-3300	IWA-3300	IWA-3300	IWA-3300
IWA-4611 Defect Removal	IWA-4611	IWA-4421 & IWA-4424	IWA-4170(b)	IWA-4120
IWB-3514 Standards for Category B-F	IWB-3514	IWB-3514	IWB-3514	IWB-3514
IWB/C/D-3600 Analytical Evaluation	IWB/C-3600	IWB/C-3600	IWB/C-3600	IWB/C-3600
IWB/C/D-3640 Evaluation Procedures	IWB/C-3640 or IWB/C-3650	IWB/C-3640 or IWB/ C-3650	IWB/C-3640 or IWB/ C-3650	IWB/C-3640 or IWB/C-3650

(c) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least $^1/_8$ in. (3 mm) overlay thickness with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45 kJ/in. (1.8 kJ/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic overlay filler material at the toe of the overlay to ensure that the HAZ and ferritic base metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers regardless of the interpass temperature used during qualification. The interpass temperature limitation of QW-406.3 need not be applied.

(e) The interpass temperature shall be determined as follows:

(1) temperature measurement (e.g., pyrometers, temperature-indicating crayons, and thermocouples) during welding. If direct measurement is impractical, interpass temperature shall be determined in accordance with (2) or (3).

(2) heat-flow calculations using at least the variables listed below.

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

(-e) arc time per weld pass and delay time between each pass

(-f) arc time to complete the weld

(3) measurement of the maximum interpass temperature on a test coupon that is no thicker than the item to be welded. The maximum heat input of the welding procedure shall be used in welding the test coupon.

(f) Particular care shall be given to ensure that the weld region is free of all potential sources of hydrogen. The surfaces to be welded, filler metals, and shielding gas shall be suitably controlled.

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Approval Date: October 11, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-741
Use of 22Cr-5Ni-3Mo-N (Alloy UNS S32205 Austenitic/Ferritic Duplex Stainless Steel) Forgings, Plate, Welded and Seamless Pipe and Tubing, and Fittings to SA-182, SA-240, SA-789, A 790-04a, SA-815, Classes 2 and 3 Section III, Division 1

Inquiry: May solution annealed UNS S32205 wrought material conforming to SA-182, SA-240, SA-789, SA-815, and wrought material conforming to A 790-04a and otherwise conforming to the requirements of specification, SA-790, be used in the construction of vessels under the rules of Section III, Division 1 Classes 2 and 3?

Reply: It is the opinion of the Committee that the material described in the *Inquiry* may be used under the rules of Section III, Division 1 Classes 2 and 3, providing the requirements of (a) through (f) are met:

(a) The maximum allowable design stress values in tension shall be those listed in Table 1, Table 1M, Table 2, and Table 2M for the different tensile strengths of 90 ksi (621 MPa) and 95 ksi (655 MPa), respectively. The maximum applicable use temperature shall be 600°F (316°C).

(b) For external pressure design, figure and Table HA-5 of Section II, Part D shall be used.

(c) Separate welding procedure qualifications and performance qualifications shall be conducted as prescribed in Section IX.

(d) The solution annealing treatment shall be as in the applicable specification.

(e) If heat treatment is performed after welding, the solution heat treatment shall be as noted in (d) above.

(f) This Case number shall be identified on the Material Organization's certification and the Manufacturer's Data Report.

Table 1
Maximum Allowable Design Stress Values in Tension U.S. Customary Values for Material with 90 ksi Tensile Strength

Temperature	SA-182, SA-240, and SA-815	
(°F)	Nonwelded, ksi	Welded, ksi
100	25.7	21.8
200	25.7	21.8
300	24.8	21.1
400	23.9	20.3
500	23.3	19.8
600	23.1	19.6

GENERAL NOTES:
(a) **CAUTION**: This material may be expected to develop embrittlement after exposure at moderately elevated temperatures. See A-340 and A-360 in Appendix A of Section II, Part D.
(b) The revised criterion of 3.5 on tensile strength was used in establishing these values.
(c) The maximum design temperature for this material is as stated in (a).

Table 1M
Maximum Allowable Design Stress Values in Tension Metric Values for Material with 621 MPa Tensile Strength

	SA-182, SA-240, and SA-815	
Temperature (°C)	Nonwelded, MPa	Welded, MPa
40	177	150
65	177	150
100	177	150
150	171	145
200	165	140
250	161	137
300	159	135
325	159	135 [Note (1)]

GENERAL NOTES:
(a) **CAUTION**: This material may be expected to develop embrittlement after exposure at moderately elevated temperatures. See A-340 and A-360 in Appendix A of Section II, Part D.
(b) The revised criterion of 3.5 on tensile strength was used in establishing these values.

Table 1M
Maximum Allowable Design Stress Values in Tension Metric Values for Material with 621 MPa Tensile Strength (Cont'd)

NOTE:
(1) The value at 325°C is provided for interpolation only. The maximum design temperature for this material is as stated in (a).

Table 2
Maximum Allowable Design Stress Values in Tension U.S. Customary Values for Material with 95 ksi Tensile Strength

	SA-789 and A 790-04a	
Temperature (°F)	**Nonwelded, ksi**	**Welded, ksi**
100	27.1	23.0
200	27.1	23.0
300	26.2	22.3
400	25.2	21.4
500	24.6	20.9
600	24.3	20.7

GENERAL NOTES:
(a) **CAUTION**: This material may be expected to develop embrittlement after exposure at moderately elevated temperatures. See A-340 and A-360 in Appendix A of Section II, Part D.
(b) The revised criterion of 3.5 on tensile strength was used in establishing these values.
(c) The maximum design temperature for this material is as stated in (a).

Table 2M
Maximum Allowable Design Stress Values in Tension Metric Values for Material with 655 MPa Tensile Strength

	SA-789 and A 790-04a	
Temperature (°C)	**Nonwelded, MPa**	**Welded, MPa**
40	187	159
65	187	159
100	187	159
150	180	153
200	174	148
250	170	145
300	168	143
325	168	143 [Note (1)]

GENERAL NOTES:
(a) **CAUTION**: This material may be expected to develop embrittlement after exposure at moderately elevated temperatures. See A-340 and A-360 in Appendix A of Section II, Part D.
(b) The revised criterion of 3.5 on tensile strength was used in establishing these values.

NOTE:
(1) The value at 325°C is provided for interpolation only. The maximum design temperature for this material is as stated in (a).

Approval Date: October 11, 2005

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-744
Use of Metric Units Boiler and Pressure Vessel Code Section III, Division 1; Section III, Division 3; Section V; Section IX

Inquiry: Under what conditions may a Manufacturer use a mixed system of units (e.g., a combination of U.S. Customary units, SI units, and/or local customary units) to demonstrate compliance with all of the requirements of Section III, Divisions 1 and 3 of the Boiler and Pressure Vessel Code?

Reply: It is the opinion of the Committee that a Manufacturer may use a mixed system of units (e.g., a combination of U.S. Customary units, SI units, and/or local customary units) to demonstrate compliance with all of the requirements of Section III, Divisions 1 and 3 of the Boiler and Pressure Vessel Code under the following conditions:

(a) For any single equation, all variables must be expressed in a single system of units. In general, it is expected that a single system of units shall be used for all aspects of design except where infeasible or impractical. When components are manufactured at different locations, where local customary units are different than those used for the general design, the local units may be used for the design and documentation of that component. Similarly, for proprietary components or those uniquely associated with a system of units different than that used for the general design, the alternate units may be used for the design and documentation of that component.

(b) When separate equations are provided for U.S. Customary and SI units, those equations must be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary or SI units for use in these equations. The result obtained from execution of these equations may be converted to other units.

(c) Production, measurement and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other fabrication documents may be in U.S. Customary, SI, or local customary units in accordance with the fabricator's practice. When values shown in calculations and analysis, fabrication documents, or measurement and test equipment are in different units, any conversions necessary for verification of Code compliance shall be in accordance with (g) and (h).

(d) Material that has been manufactured and certified to either the U.S. Customary or SI material specification (e.g., SA-516/SA-156M) may be used regardless of the unit system used in design.

(e) Standard fittings (e.g., flanges, elbows, etc.) that have been certified to either U.S. Customary units or SI units may be used regardless of the units system used in design.

(f) Conversion of units using the precision specified in (g) and (h) shall be performed to ensure that dimensional consistency is maintained. Conversion factors between U.S. Customary and SI units may be found in the Nonmandatory Appendix, Guidance for the Use of U.S. Customary and SI Units in the ASME Boiler and Pressure Vessel Code. Whenever local customary units are used the Manufacturer shall provide the source of the conversion factors, which shall be subject to verification and acceptance by the Authorized Inspector or Certified Individual.

(g) Conversion factors shall be accurate to at least four significant figures.

(h) The results of conversions of units shall be expressed to a minimum of three significant figures.

(i) All entries on a Manufacturer's Data Report shall be in units consistent with the fabrication drawings for the component using U.S. Customary, SI, or local customary units. It is acceptable to show alternate units parenthetically. Users of this Case are cautioned that the receiving Jurisdiction should be contacted to ensure the units are acceptable.

(j) U.S. Customary, SI, or local customary units may be used for the Code required nameplate marking consistent with the units used on the Manufacturer's Data Report. It is acceptable to show alternate units parenthetically. Users of this Case are cautioned that the receiving Jurisdiction should be contacted to ensure the units are acceptable.

(k) This Case shall be shown on the Manufacturer's Data Report.

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Approval Date: January 5, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-746
Use of 46Fe-24Ni-21Cr-6Mo-Cu-N (UNS N08367) Bolting Materials for Class 2 and 3 Components Section III, Division 1

Inquiry: Under what conditions may 46Fe-24Ni-21Cr-6Mo-Cu-N (UNS N08367) rod and bar material, conforming to the requirements of SB-691, be used as bolting material in the construction of Section III, Division 1, Class 2 and 3 components?

Reply: It is the opinion of the Committee that SB-691, 46Fe-24Ni-21Cr-6Mo-Cu-N (UNS N08367) rod and bar material, may be used as bolting material for the construction of Section III, Division 1, Class 2 and 3 components, provided the following requirements are met:

Table 1
Maximum Allowable Stresses

For Metal Temperature Not Exceeding, °F	ksi
−20/100	23.8
200	23.8
300	22.4
400	21.5
500	20.5
600	19.4
650	19.0
700	18.6
750	18.3
800	18.0

(a) The design temperature shall not exceed 800°F (427°C).

(b) The maximum allowable stress values shall be those listed in Tables 1 and 1M.

(c) Welding is not permitted.

(d) This Case number shall be identified in the documentation for the material and shown on the appropriate Data Report Form.

Table 1M
Maximum Allowable Stresses

For Metal Temperature Not Exceeding, °C	MPa
−30/40	164
65	164
100	163
125	158
150	155
175	151
200	149
225	147
250	143
275	139
300	136
325	133
350	128
375	127
400	126
425	124
450 [Note (1)]	122 [Note (1)]

NOTE:
(1) These values are provided for interpolation use only. The temperature limit is 427°C.

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Approval Date: January 13, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-747
Reactor Vessel Head-to-Flange Weld Examinations
Section XI, Division 1

Inquiry: What alternative to the volumetric and surface examination requirements for the reactor vessel head-to-flange weld of Table IWB-2500-1, Examination Category B-A, Item No. B1.40 may be used?

Reply: It is the opinion of the Committee that, in lieu of the requirement of Table IWB-2500-1, Examination Category B-A, Item No. B1.40, for volumetric and surface examinations of the reactor vessel head-to-flange weld, the following may be used. After a preservice or in-service ultrasonic examination has been performed with no defect found, only the surface examination requirements of B1.40 need to be met.

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Approval Date: September 9, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-748
Use of Eddy Current Examination in Lieu of Liquid Penetrant Examination
Section III, Division 3

Inquiry: Under what conditions and limitations may eddy current examination be used in lieu of liquid penetrant examination (PT), when liquid penetrant examination is required for containment closure welds?

Reply: It is the opinion of the Committee that containment closure welds may be examined using the eddy current method as an alternate to PT provided the following requirements are met:

1 SCOPE

This Case provides (or references) requirements for eddy current examination of weld surfaces that are to be used in lieu of liquid penetrant examination when performing containment closure welds. Containment closure welds are welds that are made after spent fuel or other radioactive materials have been added to the containment vessel.

2 GENERAL

(a) Personnel Qualification. Nondestructive examination personnel shall be qualified in accordance with the requirements of WB-5500 or WC-5500, as applicable.

(b) Written Procedure. Eddy current examinations shall be performed in accordance with a qualified written procedure. The written procedure (procedure) shall contain a statement of scope that specifically defines the limits of procedure applicability (e.g., geometry, material specification, grade, type, or class). It shall also establish a single value, or range of values, for each requirement. The procedure shall contain a technique, delineating the essential and nonessential variables, which shall, as a minimum contain the requirements listed in Tables 1 and 2. The procedure must address both data acquisition and data analysis (and can be two separate procedures, provided they reference each other.)

(c) Procedure Qualification. Procedure qualification is required using essential variables listed in Tables 1 and 2. When a change in an acquisition or analysis technique causes a requirement identified as an essential variable to change from the specified value, or range of values, the procedure shall be requalified. A change of a requirement identified as a nonessential variable from a specified value, or a range of values, does not require requalification of the procedure.

(d) Procedure Demonstration. Qualification of the procedure shall be demonstrated to the satisfaction of the Authorized Nuclear Inspector (ANI) in accordance with the requirements of WA-5255.

3 EQUIPMENT

Equipment shall consist of electronic apparatus capable of energizing the test coil or probes with alternating currents of suitable frequencies and shall be capable of sensing the changes in the electromagnetic properties of the material. Output produced by this equipment shall be collected for analysis by automated data acquisition equipment.

Reference specimen material shall be processed in the same manner as the product being examined. It shall be the same material type (chemical composition and product form) as the material being examined.

4 TECHNIQUE

Specific techniques may include special probe or coil designs, electronics, calibration standards, analytical algorithms, and/or display software. Techniques, such as channel mixing, may be used as necessary to suppress signals due to surface variability.

5 CALIBRATION

The procedure shall address requirements for system calibration. Calibration requirements include those actions required to ensure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system, whether displayed, recorded, or automatically processed, are repeatable and correct. A description of the calibration process shall be included in the procedure. Furthermore, the calibration standard shall contain linear and rounded defects equal to or less than $^{1}/_{16}$ in. (1.5 mm) In length or diameter. These calibration defects shall be located in the weld, at the toe of the weld, and in the weld heat affected zone.

6 DOCUMENTATION

(a) Record of Qualification. A record of qualification shall be maintained and shall include the following information:

(1) Identification of the procedure or procedures qualified and a summary of the essential variables (a copy of the procedure is sufficient);

(2) Personnel performing and witnessing the qualifications (including the ANI);

(3) Description and drawings of the qualification specimens and the calibration blocks, as applicable;

(4) Qualification results.

(b) Written Report of Examination. A written report of the examination shall be developed and contain the following information:

(1) Material specifications and thickness

(2) Coil or probe manufacturer, size and type

(3) Mode of operation (absolute, differential, etc.)

(4) Examination frequency or frequencies

(5) Manufacturer, model, and serial number of eddy current equipment

(6) Minimum digitizing rate or maximum scanning speed

(7) Examination procedure number and revision

(8) Calibration standard and serial number

(9) Identity of examination personnel and qualification level

(10) Date of inspection

(11) Date and time of qualification results or requalification (as applicable)

(12) Results of examination and related sketches or maps of rejectable indications

7 RECORDS ACCESS AND REPORTING

(a) All records including qualification and requalification records shall be made available to the ANI in accordance with the requirements of WA-5000, as applicable.

(b) This Case shall be referenced on the Data Report for the item.

8 ACCEPTANCE STANDARDS

(a) All indications must be detected with a minimum 2:1 signal-to-noise ratio at the minimum digitization rate (for digital systems) or maximum scanning speed (for analog systems) permitted by the procedure.

(b) Only imperfections producing indications with major dimensions greater than $^{1}/_{16}$ in. (1.5 mm) shall be considered relevant imperfections. Imperfections producing the following indications are unacceptable:

(1) Any cracks or linear indications;

(2) Rounded indications with dimensions greater than $^{3}/_{32}$ in. (2.5 mm);

(3) Four or more rounded indications in a line separated by $^{1}/_{16}$ in. (1.5 mm) or less edge to edge;

Table 1
Requirements for Data Acquisition

Requirements (As Applicable)	Essential Variable	Non-Essential Variable
Instrument or system, including manufacturer's name and model	X	...
Size and type of probe, including manufacturer's name and part number	X	...
Analog cable type and length including the following:	X	...
(a) probe cable type and length		
(b) extension cable type and length		
Examination frequencies, or minimum and maximum range, as applicable	X	...
Coil excitation mode, e.g., absolute or differential	X	...
Minimum data to be recorded	X	...
Method of data recording	...	X
Minimum digitizing rate (samples per inch) or maximum scanning speed (for analog systems) as applicable	X	...
Scan pattern, when applicable (e.g., helical pitch and direction, rectilinear rotation, length, scan index, or overlap)	X	...
Material type	X	...
Magnetic bias method, when applicable	...	X
Scanning equipment/fixtures	...	X
Scanning technique (automatic/manual)	X	...
Manufacturer, title and version of data acquisition software, as applicable	X	...

Table 2
Requirements for Data Analysis

Requirements (As Applicable)	Essential Variable	Non-Essential Variable
Method of calibration, e.g., phase angle or amplitude adjustments	X	...
Channels and frequencies used for analysis	X	...
Extent or area of the component evaluated	...	X
Data review requirements, e.g., secondary data review, computer data screening, as applicable	...	X
Reporting requirements, i.e., signal-to-noise threshold, voltage threshold	X	...
Methods of identifying indications and distinguishing them from non-relevant indications, such as indications from probe lift-off or conductivity and permeability changes in weld material	X	...
Manufacturer and model of eddy current data analysis equipment	X	...
Manufacturer, title and version of data analysis software, as applicable	X	...

(4) Ten or more rounded indications in any 6 in.^{2} (4 000 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated.

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Approval Date: March 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-749
Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range
Section XI, Division 1

Inquiry: IWB-3610 and IWB-3620 provide acceptance criteria for flaws in ferritic steel components. What alternative acceptance criteria may be used to evaluate flaws in ferritic steel components operating in the upper shelf temperature range?

Reply: It is the opinion of the Committee that, in lieu of IWB-3610 and IWB-3620, flaws in ferritic steel components operating in the upper shelf temperature range may be evaluated using the following acceptance criteria.

1 SCOPE

This Case provides acceptance criteria for determining acceptability of flaws in a ferritic steel component when the component metal temperature is in the upper shelf temperature range. The methodology is based on principles of elastic-plastic fracture mechanics (EPFM).

2 EVALUATION

The applied J-integral for the flaw shall be calculated and compared with the J-integral fracture resistance of the material to determine acceptability. All specified design transients for normal operating and upset, and emergency and faulted conditions for the vessel shall be evaluated. The evaluation shall be the responsibility of the Owner and shall be subject to the review and approval by the regulatory and enforcement authorities having jurisdiction at the plant site. The following evaluation shall be performed:

(a) Applicability of these acceptance criteria is limited to ferritic steel components on the upper shelf of the Charpy energy curve when the metal temperature exceeds the upper shelf transition temperature, T_c. T_c is defined as follows:

(U.S Customary Units)

$$T_c = RT_{NDT} + 105°\text{F}$$

(*SI Units*)

$$T_c = RT_{NDT} + 58.3°\text{C}$$

The effect of radiation embrittlement shall be included in determining RT_{NDT}.

(b) The flaws shall be characterized in accordance with Appendix A, A-2000.

(c) All applicable loading (primary and secondary) shall be evaluated in determining flaw acceptability. Residual stresses do not need to be included in the calculation of allowable flaw size.

(d) The J-integral analysis shall be performed at the location of the flaw in accordance with 4.

3 ACCEPTANCE CRITERIA

The end-of-evaluation-period flaw(s) (a_f, ℓ_f) is acceptable for continued operation if the J-integral (J) satisfies the criteria of 3.1 for ductile crack initiation. If the criteria of 3.1 are not satisfied, the criteria of 3.2 on crack extension and flaw stability shall be met.

3.1 ACCEPTANCE CRITERIA BASED SOLELY ON LIMITED DUCTILE CRACK EXTENSION

(a) For normal and upset conditions, J shall be evaluated at loads equal to 2.0 times the primary loads and 1.0 times the secondary loads, including thermal stresses. The applied J shall be less than or equal to the J-integral of the material at a ductile crack extension of 0.10 in. (2.5 mm).

(b) For emergency and faulted conditions, J shall be evaluated at loads equal to 1.5 times the primary loads and 1.0 times the secondary loads, including thermal. The applied J shall be less than or equal to the J-integral of the material at a ductile crack extension of 0.10 in. (2.5 mm).

(c) The primary stress limits of NB-3000 shall be satisfied, assuming a local area reduction of the pressure retaining membrane equal to the area of the end-of-evaluation-period flaw, as determined using the flaw characterization rules of IWA-3000.

3.2 ACCEPTANCE CRITERIA BASED ON LIMITED DUCTILE CRACK EXTENSION AND STABILITY

(a) For normal and upset conditions, the following requirements shall be satisfied:

(1) For ductile crack extension, J shall be evaluated at loads equal to 1.5 times the primary loads and 1.0 times the secondary loads, including thermal stresses. The applied J shall be less than or equal to the J-integral of the material at a ductile crack extension of 0.10 in. (2.5 mm).

(2) The flaw shall be stable at loads equal to 2.14 times the primary loads and 1.0 times the secondary loads, including thermal stresses. Flaw stability shall be determined in accordance with 4.3.

(3) The primary stress limits of NB-3000 shall be satisfied after stable ductile crack extension.

(b) For emergency and faulted conditions, the following requirements shall be satisfied.

(1) For ductile crack extension, J shall be evaluated at loads equal to 1.25 times the primary loads and 1.0 times the secondary loads, including thermal stresses. The applied J shall be less than or equal to the J-integral of the material at a ductile crack extension of 0.10 in. (2.5 mm).

(2) The flaw shall be stable at loads equal to 1.2 times the primary loads and 1.0 times the secondary loads, including thermal stresses. Flaw stability shall be determined in accordance with 4.3.

(c) For faulted conditions, the total end-of-evaluation-period flaw depth, including stable ductile crack extension, shall be less than or equal to 75% of the wall thickness, and the remaining ligament shall not be subject to tensile instability. For ligament tensile stability, the internal pressure shall be less than P_I, where P_I is the internal pressure to cause tensile instability of the remaining ligament. For the case of the reactor pressure vessel, the methods given in Appendix K, K-5300(b)(1) for axial flaws, and K-5300(b)(2) for circumferential flaws may be used.

4 ANALYSIS

This section contains requirements for determining applied fracture mechanics parameters (applied J-integral), the J-integral resistance curve for the material (J-R curve), and flaw stability.

4.1 Applied J-Integral. Calculation of the J-integral due to applied loads shall account for elastic-plastic behavior of the stress-strain curve for the material. When linear elastic fracture mechanics with small scale yielding applies, the J-integral may be calculated using crack-tip stress intensity factor formulae with a plastic-zone correction. The plastic-zone correction shall be calculated prior to application of any structural factors on applied loads. The methodology and calculations shall be documented.

4.2 Selection of the J-Integral Resistance Curve.. The J-integral resistance versus crack-extension curve (J-R curve) shall be a conservative representation of the toughness of the controlling material at upper shelf temperatures in the operating range at the location of the flaw. One of the following shall be used to determine the J-R curve.

(a) A J-R curve may be generated for the material by following accepted test procedures. The J-R curve shall be based on the proper combination of flaw orientation, temperature, and fluence level. Crack extension shall be ductile tearing with no cleavage.

(b) A J-R curve may be generated from a J-integral database obtained from the same class of material with the same orientation, using correlations for effects of temperature, chemical composition, and fluence level. Crack extension shall be ductile tearing with no cleavage.

(c) As an alternative to (a) or (b), an indirect method of estimating the J-R curve may be used, provided the method is justified for the material.

4.3 FLAW STABILITY

A flaw under ductile crack extension is stable when the requirements of (a) and (b) are satisfied.

(a) The equilibrium requirement for stable flaw extension is

$$J = J_R$$

where

J = the J-integral due to applied loads for the flaw
J_R = the J-integral resistance to ductile tearing for the material

(b) The requirement for flaw stability under ductile tearing is

$$\frac{\partial J}{\partial a} < \frac{d J_R}{da} \quad \text{at } J = J_R$$

where

$\partial J/\partial a$ = the partial derivative of the applied J-integral with respect to flaw depth, a, with constant load
dJ_R/da = the slope of the J-R curve

Under increasing load, stable flaw extension will continue as long as $\partial J/\partial a$ remains less than dJ_R/da.

Approval Date: August 3, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-751
Pressure Testing of Containment Penetration Piping
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-4540 (IWA-4700 in the 1989 Edition through the 1995 Edition) may be used for pressure testing piping that penetrates a containment vessel when the piping and isolation valves that are part of the containment system are Class 2 but the balance of the piping system is outside the scope of Section XI?

Reply: It is the opinion of the Committee that a 10CFR50, Appendix J, Type C test may be used as an alternative to the requirements of IWA-4540 (IWA-4700 in the 1989 Edition through the 1995 Edition) for pressure testing piping that penetrates a containment vessel, if the piping and isolation valves that are part of the containment system are Class 2 and the balance of the piping system is outside the scope of Section XI. There shall be no leakage through welds or brazed joints made as part of the repair/replacement activity. If there is leakage through the isolation valves, the brazed joints or welds shall be examined by a method that confirms that the leakage is not through the brazed joints or welds.

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Approval Date: July 14, 2006

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-753
Vision Tests
Section XI, Division 1

Inquiry: What alternatives to the visual acuity demonstration requirements of IWA-2321(a) may be used for performance of vision tests administered to NDE personnel by Optometrists, Ophthalmologists, or other health care professionals?

Reply: It is the opinion of the Committee that, as an alternative to the visual acuity demonstration requirements of IWA-2321(a), any vision test administered by an Optometrist, Ophthalmologist, or other health care professional who administers vision tests and documents compliance with the acuity requirements of IWA-2321 (a) is acceptable.

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Approval Date: February 28, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-754-1
Optimized Structural Dissimilar Metal Weld Overlay for Mitigation of PWR Class 1 Items
Section XI, Division 1

Inquiry: As an alternative to the provisions of IWA-4410, IWA-4611, and IWA-4540[1] for reducing a defect to an acceptable size in accordance with the provisions of the Construction Code or Section XI, is it permissible to increase the wall thickness, or to apply a preemptive overlay to a specified location, by deposition of an optimized structural weld overlay on the outside surface of the piping, component, or associated weld?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4410, IWA-4611, and IWA-4540,[1] a defect in austenitic stainless steel or austenitic nickel alloy piping, components, or associated welds may be reduced to a flaw of acceptable size in accordance with IWB-3640 by the addition of a repair-optimized structural weld overlay. This Case is limited to mitigation repair of as-found inside surface and subsurface flaws that measure not more than 50% in depth from the inside surface. In addition, for these materials, in lieu of IWA-4410, a pre-emptive optimized weld overlay may be applied to welds in which no flaws have been found. The weld overlay shall be applied by deposition of weld reinforcement (weld overlay) around the entire circumference on the outside surface of the piping, component, or associated weld, including ferritic materials when necessary, provided the following requirements are met.

1 GENERAL REQUIREMENTS

1.1 DEFINITIONS

(a) mitigation: as used in this Case, mitigation is an activity performed to reduce or eliminate the susceptibility of materials specified in (e) to crack initiation or crack propagation. Mitigation can be preemptive, i.e., taken before crack initiation, or repair, i.e., taken after crack initiation is discovered.

(b) optimized structural weld overlay (OWOL): deposition of weld reinforcement around the entire circumference on the outside surface of the piping, component, or associated weld, such that the weld reinforcement is capable of compliance with the requirements of this Case with consideration of the outer 25% of the wall thickness of the piping, component, or associated weld beneath the weld reinforcement in the design. An optimized structural weld overlay can be either a preemptive or repair optimized structural weld overlay as defined in (c) and (d).

(c) pre-emptive optimized structural weld overlay: OWOL that is applied around the entire circumference on the outside surface over material with no inside-surface-connected flaws found during an examination performed in accordance with 2(a)(3), prior to the weld overlay being applied.

(d) repair optimized structural weld overlay: OWOL that is applied over material with inside surface or sub-surface flaws not greater than 50% of the wall thickness from the inside surface found during an examination performed in accordance with 2(a)(3) prior to the weld overlay being applied.

(e) SCC-susceptible materials: for PWRs, UNS N06600, N06082, or W86182 surfaces with a nominal operating temperature greater than or equal to 525°F (275°C) and in contact with the reactor coolant environment.

(f) life of the overlay: the amount of time for a flaw or postulated flaw to grow to the flaw depth assumed in the design of the OWOL.

1.2 GENERAL OWOL REQUIREMENTS

(a) This Case applies to OWOLs on austenitic nickel alloy and austenitic stainless steel welds between the following:

(1) P-No. 8 or P-No. 43 and P-Nos. 1, 3, 12A, 12B, or 12C[2]

[1] The references in this Case are based on the 2010 Edition with the 2011 Addenda, except where references have specific Edition or Addenda specified. For use with other Editions or Addenda, refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

[2] P-Nos. 12A, 12B, and 12C designations refer to P-Numbers assigned by Section IX between 1967 and the Summer 1973 Addenda. In the Winter 1973 Addenda of Section IX, P-No.12A materials were reclassified P-No. 1, Gr. 1; P-No. 1, Gr. 3; P-No. 3, Gr. 1; P-No. 9A, Gr. 1; or P-No. 9B, Gr. 1; and P-No. 12B and 12C materials were reclassified P-No. 3, Gr. 3.

(2) P-No. 8 and P-No. 43

(3) P-No. 8 to P-No. 8

(4) Any combination of P-Nos. 1, 3, 12A, 12B, and 12C materials

(b) If a weld overlay on any of the material combinations in (a) obstructs a required examination of an adjacent P-No. 8 to P-No. 8 weld, the overlay may be extended to include overlaying the adjacent weld.

(c) Weld overlay filler metal shall be austenitic stainless steel or austenitic nickel alloy (28% Cr min., ERNiCrFe-7/7A) meeting the requirements of (f)(1) or (f)(2), as applicable. They shall be applied around the entire circumference of the item and deposited using a Welding Procedure Specification (WPS) for groove welding, qualified in accordance with the Construction Code and Owner's Requirements identified in the Repair/Replacement Plan. As an alternative to the postweld heat treatment (PWHT) requirements of the Construction Code and Owner's requirements, the provisions of Appendix I may be used for ambient-temperature temper bead welding.

(1) For ferritic base materials, the Construction Code PWHT exemptions permitted for circumferential butt welds may be applied to exempt the weld overlay from PWHT, with the following clarifications:

(-a) The nominal weld thickness is defined as the maximum overlay thickness applied over the ferritic base material.

(-b) The base material thickness is defined as the maximum thickness of the ferritic material where the overlay is applied.

(2) If ambient-temperature temper bead welding is used, Appendix I shall be used.

(d) Prior to deposition of the OWOL, the surface to be weld overlaid shall be examined using the liquid penetrant method in accordance with IWA-2222 using personnel qualified in accordance with IWA-2300. Indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) shall be removed or reduced in size, or repaired in accordance with the following requirements:

(1) One or more layers of weld metal shall be applied to repair surface indications only after their excavation to an acceptable size.

(2) If weld repair of indications identified in (d) is required, the area where the weld overlay is to be deposited, including any local weld repairs or initial weld overlay layer, shall be examined by the liquid penetrant method in accordance with (d). The area shall contain no indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) prior to application of the structural layers of the OWOL.

(e) To reduce the potential of hot cracking when applying an austenitic nickel alloy over P-No. 8 base metal, it is permissible to apply a layer or multiple layers of austenitic stainless steel filler material over the austenitic stainless steel base metal or austenitic stainless steel weld metal. The thickness shall be considered in the design analysis required by 2(b). These filler materials shall meet the requirements (f)(1) if considered in contributing to the weld reinforcement design thickness.

(f) OWOL deposits shall meet the following requirements:

(1) The austenitic stainless steel OWOL shall consist of at least two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The carbon content of the stainless steel weld OWOL shall not exceed 0.035% C. The first layer of weld metal with delta ferrite content of at least 7.5 FN shall constitute the first layer of the weld reinforcement that may be credited toward the required thickness. Alternatively, layers of at least 5 FN are acceptable, provided the carbon content of the deposited weld metal is determined by prior chemical analysis of a representative sample to be less than 0.02%.

(2) The austenitic nickel alloy OWOL shall consist of at least two weld layers deposited using ERNiCrFE-7/7A filler material with a Cr content of at least 28%. The first layer of weld metal deposited may not be credited toward the required thickness, but the presence of this layer shall be considered in the design analysis requirements in 2(b). Alternatively, a first diluted layer may be credited toward the required thickness, provided the layer and the associated dilution zone contain at least 24% Cr, and the Cr content of the deposited weld metal is determined by chemical analysis of the production weld or of a representative coupon taken from a mockup prepared in accordance with the WPS for the production weld.

(3) A new weld overlay shall not be installed over the top of an existing weld overlay that has been in service.

2 CRACK GROWTH AND DESIGN

(a) Crack Growth Calculation of Flaws in the Original Weld or Base Metal. The size of all flaws detected or postulated in the original weld or base metal shall be used to define the life of the OWOL. Crack growth due to both stress corrosion cracking and fatigue, shall be evaluated. The fatigue crack growth law for Alloy 600 shall be addressed for the PWR reactor coolant environment. The fatigue crack growth shall be addressed using the guidance from NUREG/CR-6721 and CR-6907 for PWR applications. Flaw characterization and evaluation shall be based on the examination results or an inside-surface-connected postulated flaw, as described below. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required.

(1) For repair OWOLs, the initial flaw size for crack growth in the original weld or base metal shall be based on the as-found flaw from the results of the N-770-2 (or later in accordance with 5), ultrasonic examination.

(2) For inside-surface-connected postulated flaws, the axial flaw length shall be 1.5 in. (38 mm) or the combined width of the susceptible weld plus buttering, when applicable plus any adjacent SCC susceptible material, whichever is greater. The circumferential flaw length

shall be assumed to extend around the entire circumference. The depths associated with these lengths are specified in (a), (3), and (4).

(3) If no inside-surface-connected planar flaws are discovered in the N-770-2 (or later in accordance with 5) ultrasonic examination performed prior to application of the overlay, initial flaws originated from the inside surface of the weldment equal to 10% of the original wall thickness shall be assumed in both the axial and circumferential directions, and the OWOL shall be considered preemptive.

(4) For cast austenitic stainless steel (CASS) items, a 75% through-wall flaw shall be assumed in the susceptible weld material in the limiting direction. The adjacent susceptible weld material and cast material shall be examined in accordance with N-770-2 (or later in accordance with 5).

(5) Any inside-surface-connected planar flaw found during the N-770-2 (or later in accordance with 5) preservice inspection shall be used to update the life of the OWOL. The detected flaw depth shall include the postulated worst-case flaw depth in the region of the pipe wall thickness that was not examined using an ultrasonic examination meeting Appendix VIII for that region. An OWOL meeting this condition shall be considered a repair.

(6) A bounding assessment of the OWOL effects on the SCC susceptible location shall be performed to satisfy (b)(8). The residual stress assessment must include the residual stresses that exist prior to application of the OWOL. Thus, the OWOL analysis includes residual stress assumed to be present due to the as-welded condition plus any machining or subsequent weld repairs that may have previously occurred. An as-welded stress distribution for a repair that is 50% through-wall in depth and extends around the entire circumference shall be assumed in the analysis. If construction records show more severe weld repairs, they shall be assumed in the analysis. Inside surface weld repairs are known to develop severe residual stress fields and provide flaw initiation sites due to grinding and weld defects and, therefore, must be accounted for in the analysis. In cases where construction records document that PWHT was performed on the susceptible weld or weld repairs, the residual stress distribution may be modified considering the effects of the PWHT.

(b) Structural Design and Sizing of the Overlay. The effects of the OWOL on the validity of the component design shall be evaluated as required by IWA-4311. In addition, the design of the OWOL shall satisfy the following requirements using the assumptions and flaw characterization requirements in (a). In addition the following requirements shall be met.

(1) The optimized structural weld overlay shall be designed such that the weld reinforcement is capable of supporting the design and service loads with consideration of the outer 25% of the wall thickness of the piping, component, or associated weld beneath the weld reinforcement in the design. An optimized structural weld overlay can be either preemptive or repair weld overlay.

(2) The axial length and end slope of the OWOL shall cover the susceptible weld including buttering where applicable and heat-affected zones on each side of the weld and the heat-affected zone on the ferritic nozzle or branch connection side of the buttering as well as any SCC-susceptible base material adjacent to the weld, and provide for load redistribution from the item into the OWOL and back into the item without violating applicable stress limits of NB-3200 or NB-3600. Any laminar flaws in the OWOL shall be evaluated in the analysis to ensure that load redistribution complies with the above. These requirements will usually be satisfied if the OWOL full thickness length extends axially beyond the SCC-susceptible material or projected flaw by at least $0.75\sqrt{Rt}$ on both side(s) of the susceptible material, where R is the outer radius of the item and t is the nominal wall thickness of the item at the applicable side of the OWOL (i.e., R and t of the nozzle on the nozzle side and R and t of the safe-end on the safe-end side).

(3) Unless specifically analyzed in accordance with (2), the end transition slope of the overlay shall not exceed 30 degrees.

(4) The assumed flaw in the underlying base material or original weld shall be based on the limiting case of (-a) and (-b) that results in the larger required OWOL thickness.

(-a) 75% through-wall circumferential inside surface flaw for the entire circumference.

(-b) 75% through-wall axial inside surface flaw with length of 1.5 in. (38 mm), or the combined width of the weld plus buttering plus any SCC-susceptible material, whichever is greater, in the axial direction or the alternative in 3(c).

(-c) In applying IWB-3641 allowable flaw size criteria to structural sizing of the OWOLs, the following shall be considered.

(-1) The design shall account for potential lower toughness of the underlying weld material (particularly at the fusion line with the low-alloy or carbon steel nozzle or branch connection).

(-2) The limit load solution for net section collapse should use the flow stress of the lower-strength stainless steel material rather than that of the Alloy 82/182 weldment to address potential for SCC located near the stainless steel fusion line.

(-3) In the design of OWOLs, the specific strength and fracture toughness properties of the underlying weldment, base material, weld layers not credited toward the OWOL in accordance with 1.2(e) and 1.2(f), and OWOL shall be used, as appropriate. Alternatively, the lower of the strength and fracture toughness properties of the underlying weldment, base material, weld

layers not credited toward the weld overlay in accordance with 1.2(e) and 1.2(f), and the weld overlay shall be used for the entire OWOL assembly.

(5) The combined wall thickness at the weld overlay, including the requirements of (4), any postulated worst-case planar flaws under the laminar flaws in the OWOL, and the effects of any discontinuity (e.g., another weld overlay or reinforcement for a branch connection) within a distance of $2.5\sqrt{Rt}$ from the toes of the OWOL shall be evaluated and shall meet the requirements of IWB-3640.

(6) The effects of any changes in applied loads, as a result of weld shrinkage from the entire OWOL, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the OWOL) shall be evaluated. Existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640.

(7) The usage factor at the location (beyond the OWOL and adjacent to the ends of the OWOL) shall be assessed. The fatigue analysis shall be conducted using the applicable requirements of Section III for Class 1 components (NB-3600 for piping and NB-3200 for vessel nozzles).

(8) The minimum thickness of the OWOL shall be sufficient to reduce residual stresses to less than 10 ksi (69 MPa) tensile at operating temperature and pressure on the internal wetted surface of all SCC-susceptible materials defined in 1.1(e).

(c) Evaluation of the Margins Beyond the Design Basis Flaw. OWOLs shall satisfy the additional structural requirement that the location exhibits Structural Factors (SFs) greater than or equal to those listed in Table 1 for an assumed limiting flaw consisting of circumferential cracking extending around the entire circumference of the item and 100% through the susceptible material of the nozzle, piping or associated weld, under the applicable design loads and service conditions.

3 EXAMINATIONS

(a) Prior Volumetric Examinations. Prior Vvolumetric examinations (including examination deferrals) shall be, prior to application of the overlay OWOL shall be performed in accordance with in accordance with N-770-2 (or later in accordance with 5).

(b) Acceptance Examination. Nondestructive examination (NDE) methods shall be in accordance with IWA-2200, except as specified herein. NDE personnel shall be qualified in accordance with IWA-2300.

(1) Surface Finish. The weld overlay shall have a surface finish of 250 μin. (6.3 μm) RMS or better and contour that permits ultrasonic examination in accordance with procedures qualified in accordance with Mandatory Appendix VIII and Appendix VIII, Supplement 11. The OWOL shall be inspected to verify acceptable configuration.

(2) Surface Examination. The OWOL and the adjacent base material for at least $^1/_2$ in. (13 mm) from each side of the OWOL shall be examined using the liquid penetrant method. The OWOL shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300. The adjacent base material shall satisfy the surface examination acceptance criteria for base material of the Construction Code or NB-2500. If ambient temperature temper bead welding is performed, the liquid penetrant examination of the completed OWOL shall be conducted no sooner than 48 hr following completion of the three tempering layers over the ferritic steel.

(3) Volumetric Examination. Examination procedures, personnel and equipment shall be qualified in accordance with Appendix VIII and Appendix VIII, Supplement 11. The examination volume A-B-C-D in Figure 1, sketch (a), which includes the overlay and welds made in accordance with 1.2(d), 1.2(e), and 1.2(f), shall be ultrasonically examined to assure adequate fusion (i.e., adequate bond) with the base material and to detect welding flaws, such as interbead lack of fusion, inclusions, or cracks. The examination volume shall include the bond and heat-affected zone. If ambient temperature temper bead welding is performed, the ultrasonic examination shall be conducted no sooner than 48 hrs following completion of the three tempering layers over the ferritic steel. Planar flaws detected in the OWOL acceptance examination shall meet the preservice examination standards of IWB-3514. In applying the acceptance standards to planar indications, the thickness, t_1 or t_2 defined in Figure 1, sketch (b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to SCC. For susceptible material, t_1 shall be used. If a flaw in the OWOL crosses the boundary between the two regions, the more conservative of the two dimensions (t_1 or t_2) shall be used. Laminar flaws in the OWOL shall meet the following requirements:

(-a) The acceptance standards of IWB-3514 shall be met, with the additional limitation that the total laminar flaw area shall not exceed 10% of the weld surface area and that no linear dimension of the laminar flaw area shall exceed the greater of 3 in. (76 mm) or 10% of the component outer circumference.

(-b) For examination volume A-B-C-D in Figure 1, sketch (a), the reduction in coverage due to laminar flaws shall be less than 10%. The unexamined volume is the volume in the OWOL underneath the laminar flaws for which coverage cannot be achieved with the angle beam examination method.

(-c) Any unexamined volume in the OWOL shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed flaw shall meet the preservice examination acceptance standards of IWB-3514, with nominal wall thickness as defined above in (3) for the planar flaws. Alternatively, the

assumed flaw shall be evaluated and meet the requirements of IWB-3640. Both axial and circumferential planar flaws shall be assumed.

(4) After completion of all welding activities, VT-3 visual examination shall be performed on all affected restraints, supports, and snubbers, to verify that design tolerances are met.

(c) Preservice and Inservice Examinations. In lieu of all other Preservice and Inservice inspection requirements, the examination requirements in accordance with N-770-2 (or later in accordance with 5) shall be met. Alternately, the requirements of (1) through (3) below may be used to modify the provisions of N-770-2 (or later in accordance with 5).

(1) NDE qualification for procedures, equipment, and personnel shall be in accordance with Appendix VIII and Appendix VIII, Supplement 11, except that for OWOLs the qualified through-wall flaw examination depth shall be extended to the outer 50% of the base material for circumferential flaws. The qualified examination depth for axial flaws shall remain at the outer 25% of the base material.[3]

(2) A design requirement is added to show that Section XI, Appendix C, C-5410, eqs. (7) and (8) are met for a 100% through-wall axial flaw in the underlying material, but excluding the 75% upper bound limit of applicability of that equation.

(3) An analysis of fatigue and SCC crack growth must demonstrate that an assumed initial 75% through-wall axial flaw in the underlying material would not violate Section XI, Appendix C, C-5410, eqs. (7) and (8) during the life of the overlay

4 PRESSURE TESTING

In lieu of meeting the requirements of IWA-4540, a system leakage test of the area affected by the repair/replacement activity shall be performed in accordance with IWA-5000, prior to or as a part of returning to service.

5 USE OF CASE N-770-2 OR LATER

(a) The revision of Case N-770 used shall be applicable, as indicated in the Applicability Index for Section XI Cases found in the Code Cases: Nuclear Components book, to the Edition and Addenda specified for the repair/replacement activity.

(b) The revision of Case N-770 used is subject to acceptance by the regulatory and enforcement authorities having jurisdiction at the plant site.

(c) The revision of Case N-770 used shall be in effect at the time of the repair/replacement activity, except as provided in (d).

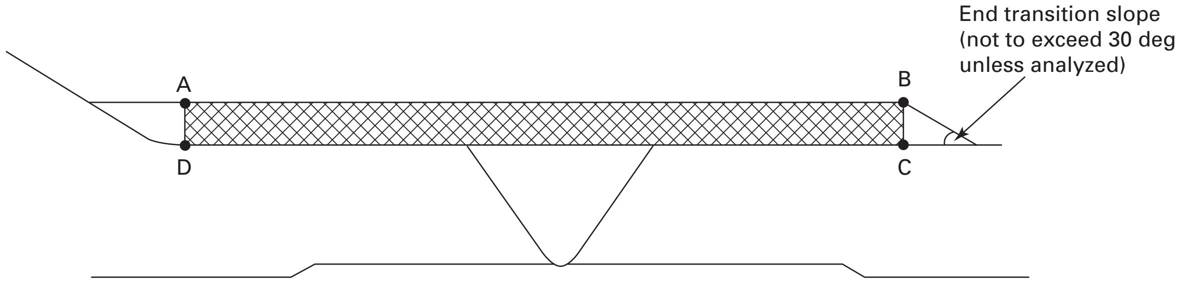
(d) A revision of Case N-770 that is superseded at the time of the repair/ replacement activity, but acceptable to the regulatory and enforcement authorities having jurisdiction at the plant site may be used.

Table 1
Structural Factors for OWOL Limiting Flaw Assumption

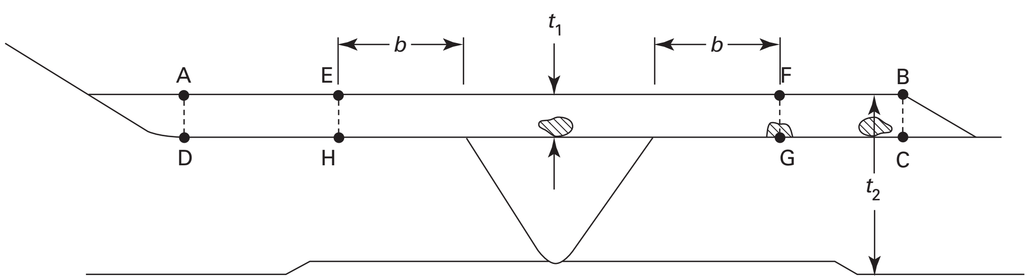
Service Level	Membrane Stress	Bending Stress
Level A (normal)	2.4	2.0
Level B (upset)	1.8	1.6
Level C (emergency)	1.3	1.4
Level D (faulted)	N/A	N/A

[3] Additional details, including appropriate flaw size distribution, flaw location distribution, or grading unit requirements, and the demonstration acceptance criteria, may be found in a letter dated July 13, 2009 from FENOC for the Davis Besse Plant to the NRC (ML091950627).

Figure 1
Examination Volume and Thickness Definitions



(a) Examination Volume A–B–C–D



(b) Thickness (t_1 and t_2) for Table IWB-3514-2

GENERAL NOTES:
(a) Dimension b is equivalent to the nominal thickness of the nozzle or pipe being overlaid, as appropriate.
(b) The nominal wall thickness is t_1 for flaws in E-F-G-H, and t_2 for flaws in A-E-H-D or F-B-C-G.
(c) For flaws that span two examination volumes (such as illustrated in F-G) the t, thickness shall be used.
(d) The weld includes the nozzle or safe end butter, where applied, plus any SCC-susceptible base material.

MANDATORY APPENDIX I
AMBIENT-TEMPERATURE TEMPER BEAD WELDING

I-1 GENERAL REQUIREMENTS

(a) This Mandatory Appendix applies to dissimilar austenitic filler metal welds between P-Nos. 1, 3, 12A, 12B, and 12C[2] materials and their associated welds and welds joining P-No. 8 or 43 materials to P-Nos. 1, 3, 12A, 12B, and 12C[2] materials with the following limitation. This Mandatory Appendix shall not be used to repair SA-302 Grade B material unless the material has been modified to include from 0.4% to 1.0% nickel, quenching, tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld overlay based on the finished surface over the ferritic base material shall be 1,000 in.^{2} (65 0000 mm^2).

(c) Repair/replacement activities on a dissimilar metal weld in accordance with this Mandatory Appendix are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm) or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Mandatory Appendix, provided the depth of repair in the base material does not exceed $^3/_8$ in. (10 mm).

(e) Prior to welding, the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

(f) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Peening may be used, except on the initial and final layers.

I-2 WELDING QUALIFICATIONS

The welding procedures and operators shall be qualified in accordance with Section IX and the requirements of I-2.1 and I-2.2.

I-2.1 Procedure Qualification.

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded.

(b) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(c) The weld overlay shall be qualified using groove weld coupon. The test assembly groove depth shall be at least 1 in. (25 mm). The test assembly thickness shall be at least twice the test assembly groove depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Figure I-1.

(d) Ferritic base material for the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (e), but shall be in the base metal.

(e) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (d). Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture.

(2) If the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(3) If the test material is in the form of a plate or forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(4) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation, and location of all test specimens shall be reported in the Procedure Qualification Record.

(f) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected

base metal specimens and the procedure qualification meets all other requirements of this Mandatory Appendix, either of the following shall be performed:

(1) The welding procedure shall be requalified.

(2) An Adjustment Temperature for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with the 2002 Addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

I-2.2 Performance Qualification. Welding operators shall be qualified in accordance with Section IX.

I-3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements:

(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (QW-442) for P-No. 8 to P-No. 1, 3, or 12 (A, B, or C) weld joints or F-No. 43 weld metal (QW-432) for P-No. 8 or 43 to P-No. 1, 3, or 12 (A, B, or C) weld joints.

(c) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least $^1/_8$ in. (3 mm) overlay thickness with the heat input for each layer controlled to within &ff184;10% of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45 kJ/in. (1.8k J/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic overlay filler material at the toe of the overlay to ensure that the HAZ and ferritic base metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers regardless of the interpass temperature used during qualification. The interpass temperature limitation of QW-406.3 need not be applied.

(e) The interpass temperature shall be determined as follows:

(1) Temperature measurement (e.g., pyrometers, temperature-indicating crayons, and thermocouples) during welding. If direct measurement is impractical, interpass temperature shall be determined in accordance with (2) or (3).

(2) heat-flow calculations, using at least the variables listed below

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

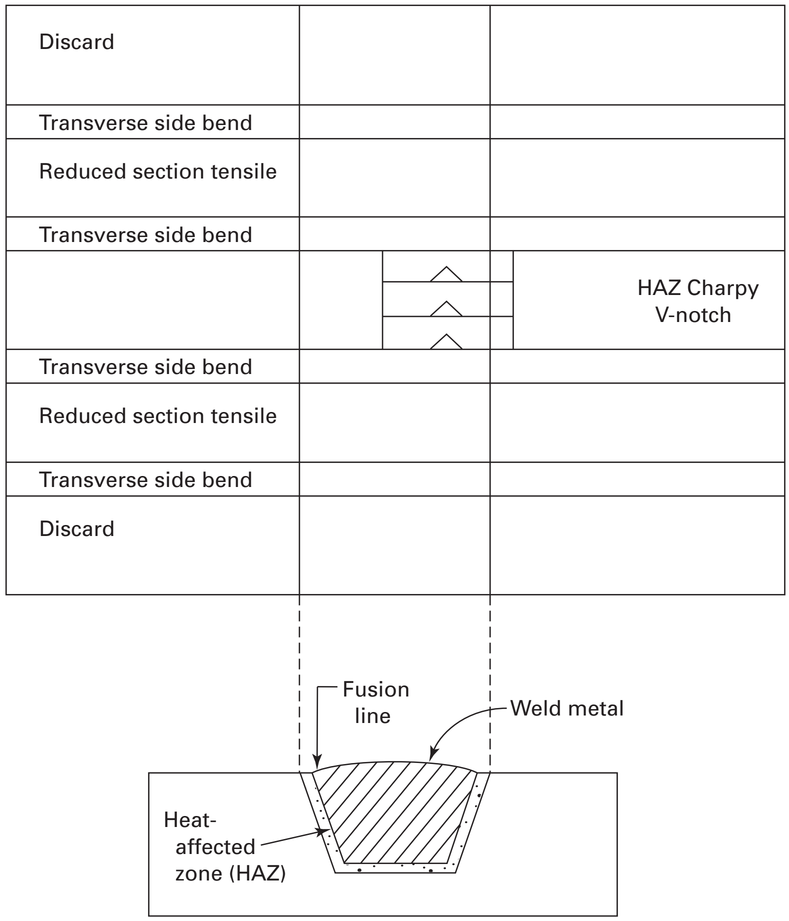
(-e) arc time per weld pass and delay time between each pass

(-f) arc time to complete the weld

(3) Measurement of the maximum interpass temperature on a test coupon that is no thicker than the item to be welded. The maximum heat input of the welding procedure shall be used in welding the test coupon.

(f) Particular care shall be given to ensure that the weld region is free of all potential sources of hydrogen. The surfaces to be welded, filler metals, and shielding gas shall be suitably controlled.

Figure I-1
Qualification Test Plate



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a dissimilar metal weld.

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Approval Date: August 13, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-755-2
Use of Polyethylene (PE) Class 3 Plastic Pipe
Section III, Division 1

Inquiry: Under what conditions may polyethylene (PE) pipe be used for the construction of Section III, Division 1, Class 3, buried piping systems?

Reply: It is the opinion of the Committee that buried PE piping systems may be constructed to the rules of Section III, Division 1, Class 3 provided the following requirements for PE piping are met.

(a) For the construction of a buried polyethylene piping system, only the following are permitted:

(1) straight polyethylene pipe

(2) three segment and five segment mitered elbows (made from polyethylene pipe)

(3) polyethylene to metallic flanges

(4) butt fusion joints

(b) All metallic components that interface with the polyethylene material shall meet the requirements of Subsection ND, Class 3 construction.

(c) This Case provides the requirements for the materials, design, procurement, fabrication, installation, examination, and testing of PE material.

(d) All applicable requirements of Section III shall be met unless modified by this Case.

(e) Use of this Case shall be identified on the N-5 Data Report.

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FIGURES

TABLES

-1000 GENERAL REQUIREMENTS

-1100 SCOPE

(a) This Case contains rules for the construction of Class 3 polyethylene pressure piping components at design temperatures not exceeding 140°F (60°C), and for maximum Service Levels B, C, or D temperatures not exceeding those for which allowable stresses are provided in this Case. Use of these materials is permitted only for buried Class 3 service water or buried Class 3 cooling water systems.

(b) Terms relating to polyethylene as used in this Case are defined in -9000.

-1200 POLYETHYLENE MATERIAL SUPPLY

The polyethylene material shall be procured in accordance with the requirements of NCA-3970 (2010 Edition or later).

-1300 CERTIFICATE HOLDER RESPONSIBILITY

(a) The Certificate Holder shall comply with the requirements of NCA-3970 (2010 Edition or later).

(b) The Certificate Holder responsible for the installation of the polyethylene pipe shall assure that the material meets the requirements of the Design Specification.

(c) The Certificate Holder shall perform any of the functions required by their respective Quality Assurance Program that are not performed by the Polyethylene Material Organization. He may elect to perform any other quality program functions, which would normally be the responsibility of the Polyethylene Material Organization. These functions shall be clearly defined in the Certificate Holder's Quality Assurance Program.

(d) The Certificate Holder shall make all necessary provisions so that his Authorized Inspection Agency can perform the inspections necessary to comply with this Case.

(e) In accordance with NCA-8120(b), a Certificate of Authorization may be issued by the Society to an organization certifying joining by fusing in accordance with this Case.

-2000 MATERIALS

-2100 GENERAL REQUIREMENTS FOR MATERIALS

-2110 Scope

All PE material and components shall be procured using the requirements of this Case and the following additional requirements.

(a) PE material shall be selected from approved specifications listed in Mandatory Appendix III, and shall have material properties as specified in Mandatory Appendix IV.

(b) All metallic materials and components shall be procured using the requirements of Subsection ND.

-2200 ADDITIONAL PRODUCT FORM REQUIREMENTS

-2210 Mitered Elbows

The mitered elbow fabricator shall ensure the following requirements are met:

(a) The configuration of the mitered elbow shall meet the requirements of -3132(d).

(b) All fabrication processes used in the fabrication of the mitered elbow shall meet the requirements of -4000 and Mandatory Appendix I.

(c) Mitered elbows shall have the fused joints inspected and accepted in accordance with -5000.

(d) The Code Case Data Report Form NM(PE)-2 shall be used for this product form (see Mandatory Appendix II).

-2220 Flange Adapter

The flange adapter fabricator shall ensure the pressure rating of the polyethylene flange adapter is equal to or greater than the attached pipe. The flange adapter shall meet all the necessary geometric, dimensioning, and tolerance requirements of the specified design and shall be certified by the fabricator as void free.

-2300 EXAMINATION AND REPAIR OF MATERIAL

-2310 Receipt Examination

(a) All PE material external surfaces shall be given a visual examination prior to installation. Any indentation more than 10% of $t_{\text{fab min}}$, shall be unacceptable.

(b) Personnel performing the examination shall be qualified in accordance with -5000 of this Case.

-2320 Repair of Material

(a) Pipe surface gouges or cuts less than or equal to 10% of $t_{\text{fab min}}$ may be removed by grinding or machining in accordance with the following requirements:

(1) the removed area has a minimum taper of 3:1 (half width of the overall area to depth) without any sharp edges

(2) the remaining wall thickness is in excess of t_{design} required by this Case

(b) If the gouge or cut is in excess of 10% of $t_{\text{fab min}}$ the damaged section shall be removed and discarded.

(c) For flange adapters, the following requirements shall apply:

(1) if the damaged area is other than in the pipe section, the entire flange adapter section shall be replaced

(2) if the damaged area is the pipe section the receipt examination requirements of -2310(a) and -2310(b) shall apply

-2400 POLYETHYLENE MATERIAL FUSING QUALIFICATION TESTING

-2410 General

(a) The polyethylene materials used in accordance with this Case shall be tested for compliance with Mandatory Appendix I, I-220 fusion procedure specification (FPS).

(b) The polyethylene materials tested shall be from the same Polyethylene Material Manufacturer's facility that supplies the polyethylene materials used in accordance with this Case.

(c) Joint testing shall include each different polyethylene source material supplied by the same or different Polyethylene Material Manufacturers in all combinations.

(d) Joint testing shall include the same polyethylene source material supplied by different Polyethylene Material Manufacturers in all combinations.

-2420 Fusing Essential Variable for Testing

One joint shall be made of each of the following conditions:

(a) Interfacial pressure of 90 psi (620 kPa) and the heater temperature of 450°F (232°C).

(b) Interfacial pressure of 60 psi (410 kPa) and the heater temperature of 450°F (232°C).

(c) Interfacial pressure of 90 psi (620 kPa) and heater temperature of 400°F (204°C).

(d) Interfacial pressure of 60 psi (410 kPa) and heater temperature of 400°F (204°C).

-2430 Testing

Testing of the joints shall be in accordance with Mandatory Appendix I, I-131.

-3000 DESIGN

-3100 SCOPE

The design rules of this Article are limited to buried, polyethylene piping systems constructed of straight pipe, three and five-segment mitered elbows, fusion joints, and flanged connections.

-3110 Nomenclature

A = cross-sectional area of pipe at the pipe section where the evaluation is conducted, in.^{2} (mm^2)
a = difference in thickness between pipe walls at a tapered transition joint, in. (mm)
B_d = trench width, ft (m)
B_1 = stress index, Table -3223-1
B_2 = stress index, Table -3223-1
B' = burial factor
b = total length of taper at a tapered transition joint, in. (mm)
c = the sum of mechanical allowances, erosion allowance and other degradation allowance, in. (mm)
c' = length of counter bore at a tapered transition joint, in. (mm)
D = average outside diameter of pipe in accordance with ASTM F714 or ASTM D3035, in. (mm)
DR = dimension ratio of pipe = average outside diameter of the pipe divided by the minimum fabricated wall thickness = $D/t_{\text{fab min}}$
E_{pipe} = modulus of elasticity of pipe per Tables -3210-3(a) and -3210-3(b), psi (MPa)
E' = modulus of soil reaction, psi (MPa) (data is site specific)
E'_N = modulus of soil reaction of native soil around trench, psi (MPa) (data is site specific)
F_a = axial force due to the specified Design, Service Level A, B, C, or D applied mechanical loads, lb (N)
F_{aC} = axial force range due thermal expansion and/or contraction and/or the restraint of free end displacement, lb (N)
F_{aD} = axial force due to the nonrepeated anchor motion, lb (N)
F_{aE} = axial force range due to the combined effects of seismic wave passage, seismic soil movement, and building seismic anchor motion effects, lb (N)
F_S = soil support factor, per Tables -3210-2(a) and -3210-3(b)
f_o = ovality correction factor, per Table -3221.2-1
g = acceleration due to gravity, ft/s^2 (m/s^2)
H = height of ground cover, ft (m)
H_{gw} = height of ground water above top of the pipe, ft (m)
i = stress intensification factor, per Table -3311.2-1
K = bedding factor
k = factor from Table -3223-2
L = deflection lag factor
M = resultant bending moment due to the specified design, Service Level A, B, C, or D applied mechanical loads, in.-lb (N-mm)
M_C = resultant moment range due thermal expansion and/or contraction and/or the restraint of free end displacement, in.-lb (N-mm)
M_D = resultant moment due to the nonrepeated anchor motion, in.-lb (N-mm)

M_E = resultant moment range due to the combined effects of seismic wave passage, seismic soil movement, and building seismic anchor motion effects, in.-lb (N-mm)
P = internal design gage pressure, plus pressure spikes due to transient events, psi (MPa)
P_a = design or Service Level A, B, C, or D pressure, psi (MPa)
P_D = piping system internal design gage pressure at the specified design temperature T_D, both being specified in the piping Design Specification, not including the consideration of pressure spikes due to transients, psi (MPa)
P_E = vertical soil pressure due to earth loads, lb/ft^2 (MPa)
P_{gw} = pressure due to ground water above the top of the pipe, lb/ft^2 (MPa)
P_{hydro} = external hydrostatic pressure, equal to earth plus groundwater pressure plus surcharge load, psi (MPa)
P_L = vertical soil pressure due to surcharge loads, lb/ft^2 (MPa)
R = buoyancy reduction factor
$r_1{}'$ = radius of curvature at the beginning of a tapered transition joint, in. (mm)
$r_2{}'$ = radius of curvature at the end of a tapered transition joint, in. (mm)
S = allowable stress, per Tables -3131-1(a) and -3131-1(b) or Table -3223-3, psi (MPa)
S_{comp} = allowable side wall compression stress per Tables -3220(a) and -3220(b), psi (MPa)
T = temperature, °F (°C)
T_D = design temperature, °F (°C)
T_{ground} = temperature of soil around pipe, °F (°C)
T_{water} = temperature of water running through pipe, °F (°C)
t = $t_{\text{fab min}}$, in. (mm)
t_{Design} = minimum required wall thickness, in. (mm)
$t_{\text{fab min}}$ = minimum fabricated wall thickness in accordance with ASTM D3035 or F714 (called minimum wall thickness in Table 9 of ASTM F714), in. (mm)
$t_{\min}$ = minimum wall thickness for pressure, in. (mm)
W_P = weight of empty pipe per unit length, lb/ft (kg/m)
W_w = weight of water displaced by pipe, per unit length, lb/ft (kg/m)
Z = section modulus of pipe cross section at the pipe section where the moment is calculated, in.^{3} (mm^3)
α = coefficient of thermal expansion of pipe, 1/°F (1/°C)
ΔP = differential pressure due to negative internal pressure of pipe, psi (MPa)
ΔT = $T_{\text{water}} - T_{\text{ground}}$, °F (°C)
ΔT_{eq} = equivalent temperature rise, °F (°C)
$(\varepsilon_a)_{\text{Earthquake}}$ = strain in the pipe from earthquake wave computer analysis
$\varepsilon_{\text{soil}}$ = maximum soil strain due to seismic wave passage
ν = Poisson's ratio (0.35 for short duration loads to 0.45 for long duration loads)
Ω = change in diameter as a percentage of the original diameter, commonly called the change in ring diameter
$\Omega_{\max}$ = maximum allowable change in diameter as a percentage of the original diameter, commonly called the change in ring diameter, per Table -3210-1
ρ_{dry} = density of dry soil, lb/ft^3 (kg/m^3)
$\rho_{\text{saturated}}$ = density of saturated soil, lb/ft^3 (kg/m^3)
σ_E = tensile stress in the pipe due to an earthquake, psi (MPa)
σ_{sw} = circumferential compressive stress in the sidewalls of pipe, psi (MPa)
σ_τ = tensile stress in the pipe, psi (MPa)

-3120 Design Life

(a) The Design Specification shall specify the design life of the system.

(b) The duration of load shall be specified for each load case, and the PE pipe physical and mechanical properties shall be based on the duration of load.

-3130 Design and Service Loading

Design loads shall be as defined in ND-3112.1 through ND-3112.3. Loads applied to buried PE pipe shall be defined in the Design Specification, and shall include, as a minimum, the following:

(a) Maximum internal design gage pressure P_D, for pressure design in accordance with -3131 and -3132, and, if applicable, maximum negative internal gage pressure for evaluation in accordance with -3221.2.

(b) Maximum and minimum temperature T, for the selection of allowable stress (Tables -3131-1(a) through -3131-1(d) and -3223-3) and design for temperature effects in accordance with -3300. The maximum Service Level A temperature shall be the design temperature, T_D.

(c) The loads resulting from the maximum transient pressures.

(d) Vertical soil pressure P_E, due to saturated soil, surcharge, buoyancy, and flotation, for the designs in accordance with -3200.

(e) Vertical pressure due to surcharge loads P_L for the design in accordance with -3200.

(f) Permanent ground movement, soil settlement, for design as nonrepeated anchor movements in accordance with -3200.

(g) Seismic wave passage and, seismic soil movement and building anchor motions, for seismic design in accordance with -3400.

(h) Ground movement caused by frost heave for design for expansion and contraction in accordance with -3311.

-3131 Pressure Design of Pipe

-3131.1 Minimum Required Wall Thickness. The minimum required wall thickness of straight sections of pipe for pressure design shall be determined by the following:

$$t_{design} = t_{min} + c$$

$$t_{min} = \frac{P_D D}{(2S + P_D)}$$

-3131.2 Allowable Service Level Spikes Due to Transient Pressures. The sum of the maximum anticipated operating pressure plus the maximum anticipated Level B pressure spikes due to transients shall be no greater than 1.5 times the piping system Design Pressure, P_D, (see -3131.1). The sum of the maximum anticipated operating pressure plus the maximum anticipated Level C and D pressure spikes due to transients shall be no greater than 2 times the piping system design pressure, P_D, (see -3131.1).

-3132 Pressure Design of Joints and Fittings

(a) Polyethylene pipe shall be joined using the butt fusion process. All connections to metallic piping shall be flanged joints.

(b) The design of flange adapters shall ensure the flange adapter has the capacity to withstand a pressure greater than or equal to the design pressure, P_D, of the attached pipe.

(c) Flanged connections shall include a metallic backup ring and shall provide a leak tight joint up to and including the piping hydrostatic test pressure. In addition, the maximum surge pressure per -3131.2 shall not cause permanent deformation of the pipe.

(d) Mitered elbows shall comply with the requirements of ND-3644, excluding ND-3644(a) and (b). In place of ND-3644(e), butt fusion joints shall be used in accordance with this Case. The maximum DR permitted for mitered elbow segments is 13.5. The minimum wall thickness of the mitered elbow segments shall be at least 1.22 $t_{fab\ min}$.

-3200 SOIL AND SURCHARGE LOADS

-3210 Ring Deflection

The soil and surcharge loads on a buried polyethylene pipe shall not result in a pipe diameter ring deflection, ; Ω, beyond the limit of ; Ω_{max} per Table -3210-1.

(U.S. Customary Units)

$$\Omega = \frac{100}{144} \times \frac{K \times L \times P_E + K \times P_L}{\frac{2E_{pipe}}{3} \times \left(\frac{1}{DR - 1}\right)^3 + 0.061 \times F_S \times E'} \leq \Omega_{max}$$

(SI Units)

$$\Omega = 100 \times \frac{K \times L \times P_E + K \times P_L}{\frac{2E_{pipe}}{3} \times \left(\frac{1}{DR - 1}\right)^3 + 0.061 \times F_S \times E'} \leq \Omega_{max}$$

(U.S. Customary Units)

$$P_E = [\rho_{saturated} \times H_{gw} + \rho_{dry} \times (H - H_{gw})]$$

(SI Units)

$$P_E = [\rho_{saturated} \times H_{gw} + \rho_{dry} \times (H - H_{gw})]g/1.0E + 06$$

E_{pipe} must be taken at the maximum life specified in the Design Specification.

where

$$K = 0.1$$

L = 1.25 to 1.5, or 1.0 if using soil prism pressure

-3220 Compression of Sidewalls

The circumferential compressive stress in the sidewalls σ_{sw} due to soil and surcharge loads shall not exceed S_{comp} per Tables -3220(a) and -3220(b).

(U.S. Customary Units)

$$\sigma_{sw} = \frac{(P_E + P_L) \times DR}{2 \times 144} \leq S_{comp}$$

(SI Units)

$$\sigma_{sw} = \frac{(P_E + P_L) \times DR}{2} \leq S_{comp}$$

-3221 External Pressure

-3221.1 Buckling Due to External Pressure. External pressure from ground water, earth loads, and surcharge loads on a buried PE pipe shall not cause the pipe to buckle.

(U.S. Customary Units)

$$P_{\text{hydro}} = \frac{P_E + P_L + P_{gw}}{144} \leq 2.8\sqrt{\frac{R \times B' \times E' \times E_{\text{pipe}}}{12(DR - 1)^3}}$$

(SI Units)

$$P_{\text{hydro}} = (P_E + P_L + P_{gw}) \leq 2.8\sqrt{\frac{R \times B' \times E' \times E_{\text{pipe}}}{12(DR - 1)^3}}$$

and the buoyancy reduction, R, and burial, B', factors are

$$R = 1 - 0.33 \times \frac{H_{gw}}{H}$$

(U.S. Customary Units)

$$B' = \frac{1}{1 + 4 \times \exp(-0.065 \times H)}$$

(SI Units)

$$B' = \frac{1}{1 + 4 \times \exp(-0.213 \times H)}$$

-3221.2 Effects of Negative Internal Pressure. When the pipe is subject to a negative internal pressure, it shall withstand the differential pressure without credit for the surrounding soil.

$$\Delta P \leq \frac{f_0}{2} \times \frac{2E_{\text{pipe}}}{1 - \upsilon^2} \times \left(\frac{1}{DR - 1}\right)^3$$

-3222 Flotation

Buried PE pipe shall have sufficient cover or be anchored to the ground to prevent flotation by groundwater. To ensure this occurs, the following relationship shall be satisfied:

(U.S. Customary Units)

$$W_W < W_P + P_E \times D/12$$

(SI Units)

$$W_W < W_P + (1000 \times P_E \times D/g)$$

-3223 Longitudinal Stress Design

-3223.1 Longitudinal Applied Mechanical Loads. Longitudinal stresses due to axial forces and bending moments resulting from applied mechanical loads shall not exceed $k \times S$.

where

$$B_1 \times \frac{P_a \times D}{2 \times t} + 2 \times B_1 \times \frac{F_a}{A} + B_2 \times \frac{M}{Z} \leq k \times S$$

-3223.2 Short Duration Longitudinal Applied Mechanical Loads. For the assessment of short duration loads (less than five minutes) the allowable stress, S, may be replaced by one of the following two alternatives:

(a) 40% of the material tensile strength at yield or

(b) the values in Table -3223-3

-3300 TEMPERATURE DESIGN

-3310 Minimum Temperature

The polyethylene material shall not be used at a temperature below the manufacturer's limit, but in no case shall the temperature be less than minus 50°F (minus 45°C).

-3311 Design for Expansion and Contraction

-3311.1 Fully Constrained Thermal Contraction. The stress resulting from the assumption of fully constrained thermal contraction of the buried pipe when $T_{\text{water}} < T_{\text{ground}}$, increased by the stress due to axial contraction from Poisson's effect, shall not exceed the allowable stress S.

$$\sigma_\tau = \left| E_{\text{pipe}} \times \alpha \times \Delta T - \upsilon \times \frac{P \times D}{2 \times t} \right| \leq S$$

-3311.2 Fully Constrained Thermal Expansion. The stress resulting from the assumption of fully constrained thermal expansion of the buried pipe when $T_{\text{water}} > T_{\text{ground}}$, shall not exceed the allowable stress S.

$$\sigma_\tau = E_{\text{pipe}} \times \alpha \times \Delta T \leq S$$

-3311.3 Alternative Thermal Expansion or Contraction Evaluation. As an alternative to -3311.1 and -3311.2, the soil stiffness may be accounted for to calculate pipe expansion and contraction stresses. The stresses shall satisfy the following equation:

$$\frac{iM_C}{Z} + \frac{F_{aC}}{A} \leq 1,100\,\text{psi}\,(7.6\ \text{MPa})$$

-3312 Nonrepeated Anchor Movements

The effects of any single nonrepeated anchor movements shall meet the requirements of the following equation:

$$\frac{iM_D}{Z} + \frac{F_{aD}}{A} < 2S$$

-3400 SEISMIC DESIGN

-3410 Seismic Induced Stresses

The stresses in the buried PE piping system due to soil strains caused by seismic wave passage, seismic soil movement, and building seismic anchor motion effects, where applicable, shall be evaluated. The stresses shall satisfy the following equation:

$$\frac{iM_E}{Z} + \frac{F_{aE}}{A} \leq 1,100 \text{ psi } (7.6 \text{ MPa})$$

Seismic wave passage, seismic soil movement, and building seismic anchor motion loads shall be combined by square root sum of the squares.

Appendix D provides a nonmandatory method for the analysis of seismic wave passage, seismic soil movement, and building seismic anchor motion effects.

-4000 FABRICATION AND INSTALLATION

-4100 GENERAL REQUIREMENTS

-4110 Scope

This Case provides the requirements for the installation of PE piping and fittings. Methods of fabrication and installation shall be by thermal fusion and flanged joints. Use of threaded or adhesive joints with PE material is not permitted. All metallic interface components will be installed following the requirements of Subsection ND.

-4120 Examinations

Examination activities that are not referenced for examination by specific Case paragraphs, and are performed solely to verify compliance with requirements of -4000, may be performed by the persons who perform or supervise the work. These visual examinations are not required to be performed by personnel and procedures qualified to -5100 and -5500, respectively, unless so specified.

-4130 Repair of Material

PE material originally accepted on delivery in which defects exceeding the limits of -2310 are known or discovered during the process of fabrication or installation is unacceptable. The PE material may be used provided the defective area can be physically removed from the material in accordance with -2320.

-4200 CUTTING, FORMING, AND BENDING

-4210 Cutting

Materials may be cut to shape and size by mechanical means such as machining or cutting.

-4220 Forming and Bending Processes

The following requirements shall apply to the forming and bending processes used in the fabrication and installation of polyethylene pipe:

(a) The PE material shall not be cold or hot formed or bent except as permitted in (b).

(b) During installation, a pipe radius of curvature greater than or equal to thirty times the outside diameter is permitted except within two outside diameters of a flange connection or mitered elbow (measured from the pipe to component fusion joint), where the pipe radius of curvature shall be at least one hundred times the pipe outside diameter.

-4300 FUSING QUALIFICATIONS

-4310 General Requirements

(a) Fusing procedure and machine operator performance qualification shall comply with the requirements of Mandatory Appendix I of this Case.

(b) The thermal fusion butt joint is the only thermal fusion joint allowed in this Case, see Figure -4310-1.

-4320 Qualifications

-4321 Required Qualifications

(a) Each Certificate Holder shall be responsible for the fusing done by his organization and shall establish the procedure and conduct the tests required by this Case and Mandatory Appendix I in order to qualify both the fusing procedures and the performance of fusion machine operators who apply these procedures.

(b) Procedures, and fusion machine operators used to join permanent pressure parts shall also meet the qualification requirements of Mandatory Appendix I.

-4322 Maintenance and Certification of Records

The Certificate Holder shall maintain records of qualified fusing procedures and the fusion machine operators qualified by them, showing the date and results of tests and the identification mark assigned to each fusing operator. These records shall be reviewed, verified, and signed by any authorized individual assigned by the Certificate Holder and they shall be accessible to the Authorized Nuclear Inspector.

-4323 Fusing Prior to Qualification

The fusing procedure specification (FPS) shall be qualified as required by Mandatory Appendix I prior to their use. Only fusing operators who are qualified in accordance with -4320 and Mandatory Appendix I of this Case shall be used.

-4324 Transferring Qualifications

The FPS qualifications and performance qualification tests for fusion machine operators conducted by one Certificate Holder shall not transfer qualified fusing procedures or fusion machine operators records to another Certificate Holder.

-4330 Requirements for Fusing Procedure Qualification Tests

-4331 Conformance to Mandatory Appendix I Requirements

All fusing procedure qualification tests shall be in accordance with the requirements of Mandatory Appendix I as supplemented or modified by the requirements of this Case.

-4332 Preparations of Test Coupons and Specimens

Removal of test coupons from the fusion test coupon and the dimensions of specimens made from them shall conform to the requirements of Mandatory Appendix I.

-4400 RULES GOVERNING MAKING FUSED JOINTS

-4410 General Requirements

-4411 Identification, Storage, and Handling of PE Materials

Each Certificate Holder is responsible for control of the PE materials that are used in the fabrication and installation of components. Suitable identification, storage, and handling of PE material shall be maintained.

-4412 Cleanliness and Protection of Surfaces to Be Fused

The surfaces of the heater used for fusing shall be free of scale, rust, oil, grease, and other deleterious material. The work shall be protected from deleterious contamination and from rain, snow, and wind during fusing operations. Fusing shall not be performed on wet surfaces.

-4420 Rules for Making Fused Joints

-4421 Fused Joint Fit-up Requirements

(a) Components of different outside diameters shall not be fused together.

(b) The alignment of components for open butt fusion joints will be held in position by the fusing machine; the allowable surface mismatch shall be less than 10% $t_{fab\ min}$ of the components being fused.

(c) To fuse components with differing DR's, the component with the smaller DR shall be countered-bored and tapered to equal the wall thickness, or the O.D. shall be machined and tapered to equal the wall thickness of the component with the larger DR and shall comply with Figure -4421.3-1.

-4422 Identification of Joints by Fusing Operator

Each fusing operator shall apply the identification mark assigned to him by the Certificate Holder adjacent to all permanent fused joints or series of joints on which the fuses. The marking shall be 1 ft (0.3 m) or less from the fusion bead and shall be done with permanent metallic paint marker or stenciling marker.

-4423 Repairs

Repair of a fused joint is not allowed. All unacceptable joints shall be cut out and replaced.

-4430 Fusing Data Acquisition Recorder

The fusion machine shall have a data acquisition recorder attached to it. The data acquisition record produced by the device shall include the information of the fusion process [Mandatory Appendix I, I-222, except I-222(d)].

(a) Failure to run the recorder during the fusion process shall cause rejection of the fusion joint.

(b) The data acquisition records shall be compared to the FPS to ensure that the proper butt fusion parameters and procedures were followed. If any parameter is out of the approved range, the fused joint shall be cut out and remade in compliance with the FPS.

-4500 FABRICATION, ASSEMBLY, AND ERECTION

-4510 General

This section provides the requirements for flanged joints and pipe supports.

-4520 Flanged Joints Using PE Material

(a) Flanged connections are only permitted for the joining of polyethylene pipe to metallic pipe or piping components. The polyethylene flange connection shall be constructed using a polyethylene flange adapter having a DR ratio equal to the attached PE pipe and be joined by fusion to the attached piping.

(b) The polyethylene flange adapter shall be connected to the metal flange using a metallic backing ring. The backing ring shall have a pressure rating equal to or greater than the metal flange.

(c) Before bolting up, flange faces shall be aligned to the design plane within $^1/_{16}$ in./ft (5.3 mm/m) measured across any diameter; flange bolt holes shall be aligned within $^1/_8$ in. (3.2 mm) maximum offset. Damage to the gasket seating surface on the PE flange that would prevent the gasket sealing shall be evaluated per -2320. Use of a gasket is optional.

(d) The flange shall be joined using bolts of a size and strength that conforms to the requirements of ASME B16.5 or ASME B16.47 Series A as applicable. Bolts or studs should extend completely through their nuts. Any bolts or studs which fail to do so are considered

acceptably engaged if the lack of complete engagement is not more than one thread. Flat washers shall be used under bolt heads and nuts.

(e) In assembling flanged joints, the gasket, if used shall be uniformly compressed to the proper design loading. Special care shall be used in assembling flanged joints in which the flanges have widely differing mechanical properties. Tightening to a predetermined torque is recommended. If used, no more than one gasket shall be used between contact faces in assembling a flanged joint. The gasket material shall be selected to be consistent and compatible with the service requirements of the piping system. See Figure -4520-1 for a typical flange configuration.

-4530 Pipe Supports

All installed PE pipe supports shall meet the requirements of Subsection NF and the following:

(a) Piping shall be supported, guided, and anchored in such a manner as to prevent damage to the piping. Point loads and narrow areas of contact between piping and supports shall be avoided. Suitable padding shall be placed between piping and supports where damage to piping may occur.

(b) Valves and equipment that would transmit excessive loads to the piping shall be independently supported to prevent such loads.

-5000 EXAMINATION

-5100 GENERAL REQUIREMENTS

(a) Visual examinations shall be conducted in accordance with the examination method of Section V, Article 9.

(b) All personnel qualified to perform visual examinations required by this Case, excluding the hydrostatic pressure test, shall receive the same training as required for the fusion machine operator in Mandatory Appendix I. This training shall include the use of a fusion machine to make a fused joint. This joint is not required to be tested for qualification. This training shall be documented on a training record.

-5110 Procedures

-5111 Examination Procedures

All examinations performed under this Case shall be executed in accordance with detailed written procedures which have been proven by actual demonstration, to the satisfaction of the Authorized Nuclear Inspector. Written procedures, records of demonstration of procedure capability, and personnel qualification shall be made available to the Authorized Nuclear Inspector on request.

-5120 Time of Examination of Completed Fused Joints

Visual examination of all fused joints shall be conducted:

(a) upon the completion of cooling period

(b) after the review required by -4430 has been completed and accepted

(c) shall be completed before piping is placed in the burial trench

-5200 REQUIRED EXAMINATIONS

Visual examinations are required on the following material and components.

(a) During receipt inspection of the external surface for indentations.

(b) Fusion joints after the fusion process includes review and verification of fusion data for the joint, and external surfaces.

(c) All pipe fusion joints during the hydrostatic test.

-5210 General Requirements

The following visual examination and inspections shall be conducted:

(a) inspection of the general surface for indentations.

(b) fusion joints, including review and verification of fusion data for the joint.

(c) all fusion joints during the hydrostatic test [-6100(c)]. Any fusion joint leakage shall cause rejection of the joint.

(1) The visual examination shall be conducted by examining the accessible external exposed surfaces of pressure retaining components for evidence of leakage.

(2) For components whose external surfaces are inaccessible for direct visual examination, only the examination of the surrounding area (including areas or surfaces located underneath the components) for evidence of leakage shall be required.

(3) Flange gasket leakage is excluded from this requirement.

-5300 ACCEPTANCE STANDARDS

-5310 General Requirements

Unacceptable joints shall be removed. Repair of unacceptable joints is not permitted.

-5320 Visual Examination Acceptance Criteria of External Surfaces

-5321 Thermal Fusion Butt Joints

Thermal fusion butt joints shall meet the following:

(a) Joints shall exhibit proper fusion bead configuration, see Nonmandatory Appendix C.

(b) There shall be no evidence of cracks or incomplete fusion.

(c) Joints shall not be visually angled or offset. The ovality offset shall be less than 10% $t_{\text{fab min}}$ of the fused components.

(d) The cleavage between fusion beads shall not extend to or below the outside diameter pipe surface (see Figure 5321-1).

(e) Review the data acquisition record for the joint and compare it to the Fusion Procedure Specification (FPS) to ensure the proper parameters and procedures were followed in making the fused joint.

-5500 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL

-5510 General Requirements

Organizations performing Code required nondestructive examinations shall use personnel qualified in accordance with ND-5520 as applicable. When these services are subcontracted by the Certificate Holder, he shall verify the qualification of personnel to the requirements of ND-5520 as applicable. All nondestructive examinations required by this Case shall be performed by and the results evaluated by qualified nondestructive examination personnel.

-5520 Personnel Qualification Requirements

(a) Personnel performing visual examinations required for this Case shall be qualified in accordance with ND-5520 and the Certificate Holder's NDE Program. This training shall be documented on a training record.

(b) Personnel performing visual examinations on material receipt and completed fused joints shall receive the required training in -5100(b). Personnel performing only the hydrostatic test visual examination are not required to complete the training in -5100(b), but are required to complete 4 hr of training in PE piping and joining practices. This training shall be documented on a training record.

-6000 TESTING

-6100 GENERAL REQUIREMENTS

(a) Prior to initial operation, the installed system shall be hydrostatically tested in the presence of the Authorized Nuclear Inspector.

(b) All joints, including fused joints, shall be left exposed for examination during the test. For long sections of piping the hydrostatic testing may be accomplished by testing in small subsections of the longer section. Upon a satisfactory test of each small section the piping may be buried. This process shall be documented in the Certificate Holder's Quality Assurance Program found acceptable to the Authorized Nuclear Inspection Agency.

(c) The pressure in the test section shall be gradually [minimum rate of 5 psi/min (34.5 kPa/min) not to exceed a maximum rate of 20 psi/min (138 kPa/min)] increased to the specified test pressure and held for 4 hr. Make up water may be added to maintain test pressure during this time to allow for initial expansion. Following the 4 hr initial pressurization period, the test pressure shall be reduced by 10 psig (70 kPa) and the system monitored for another 1 hr. Make up water may no longer be added to maintain pressure. Each joint shall be examined. If no visual leakage is observed and the pressure remains within 5% of the test pressure for the 1 hr, the pipe section under test is considered acceptable.

(d) The temperature of the piping under test shall be maintained within the temperature limits of the system design.

(e) The total test time including initial pressurization, initial expansion, and time at test pressure, must not exceed 8 hr. If the pressure test is not completed the test section shall be depressurized. The test section shall not be repressurized for at least 8 hr.

(f) A pneumatic test is not permitted.

-6200 HYDROSTATIC TEST REQUIREMENTS

(a) The piping system shall be tested by hydrostatic test in accordance with ND-6200.

(b) The minimum test pressure shall be 1.5 times the design pressure, P_D, of the PE piping system plus 10 psi (70 kPa).

(c) Qualified visual examination personnel shall conduct the examination for leakage.

-8000 NAMEPLATES, STAMPING AND REPORTS

-8100 GENERAL REQUIREMENTS

-8110 Scope

The requirements for nameplates, stamping and reports for components constructed in accordance with this Case shall be as given in NCA-8000 with the following exceptions:

(a) The attachment of name plates shall be performed using an adhesive or corrosion resistance wire that is compatible with and will not degrade PE.

(b) No indentation stamping is allowed on the polyethylene pipe surface, and all marking shall be performed with a metallic paint marker or stenciling marker.

(c) The polyethylene material manufacturer is permitted to apply the standard print line identifier to his piping product.

-9000 GLOSSARY

butt fusion cycle: pressure/time diagram for a defined fusion temperature, representing the butt fusion operation.

Certified Certificate of Analysis for Batch (CCAB): a document attesting that material is in accordance with specified requirements, including batch analysis of all chemical analysis, test, and examinations.

control specimen: the specimen from the base material tested to determine the tensile strength for the purpose of determining an acceptable tensile strength.

cool time under pressure: in the fusion process, the theoretical fusion pressure plus drag pressure is applied between the pipe ends. This pressure must be maintained until the fusion joint is cool to the touch. This time is approximately 30 to 90 in./sec of pipe diameter.

data acquisition record: a detailed record of the times and pressures used in the fusion process along with the heater surface temperature, employee information, fusion machine information, pipe information, date and time for a permanent record of each joint made.

drag pressure: the pressure required by the fusion machine to overcome the drag resistance and frictional resistance and keep the carriage moving at its slowest speed.

drag resistance: frictional resistance due to the weight of the length of pipe fixed in the movable clamp at the point at which movement of the movable clamp is initiated (peak drag) or the friction occurring during movement (dynamic drag).

frictional resistance in the butt fusion machine: force necessary to overcome friction in the whole mechanism of the butt fusion machine.

fusion machine operator: person trained to carry out fusion joining between polyethylene (PE) pipes and/or fittings based on the Fusion Procedure Specification (FPS).

fusion operator certificate: approval certificate issued by the examiner/assessor stating the knowledge and the skill of the fusion operator to produce fusion joints following a given fusion procedure.

fusion procedure specification: a document providing in detail the required variables for the butt fusion process to assure repeatability in the butt fusion procedure (FPS).

heater bead-up size: in the heating cycle, the pipe is brought against the heater and the force is dropped to the soak cycle. During this cycle, a bead of polyethylene is formed between the pipe end and the heater surface on both sides. When the bead-up size reaches the size established in the FPS, it is time to open the carriage and remove the heater.

heater surface temperature: the temperature, in degrees F, of the surface of the coated heater is critical to the butt fusion process. It is usually expressed as a range [example: 400°F to 450°F (200°C to 230°C)] and the common practice is to set the average surface temperature at the midrange [example: 425°F (215°C)].

Hydrostatic Design Basis (HDB): one of a series of established stress values for a compound.

Hydrostatic Design Stress (HDS): the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

interfacial pressure: the amount of force in pounds (lbs) per square inch of pipe area required to calculate the fusion machine gauge pressure. The interfacial pressure is multiplied by the pipe area in square inches to determine the amount of fusion force (lbs) required to fuse the pipe. This force is divided by the total effective piston area of the hydraulic fusion machine to determine the theoretical gauge pressure to set on the fusion machine. The drag pressure must be added to this pressure to determine the actual gauge pressure required for fusion. The interfacial pressure usually has a range [example: 60 psi to 90 psi (0.41 MPa to 0.62 MPa)] and the common practice is to use the mid-range [example: 75 psi (0.5 MPa)] when making these calculations.

long-term hydrostatic pressure – strength (LTHS): the estimated tensile stress in the wall of the pipe in the circumferential orientation that when applied continuously will cause failure of the pipe at 100,000 hours.

lot: the quantity of:

(a) Polyethylene Source Material documented on the Certificate of Analysis (COA) and related traceability documentation.

(b) Polyethylene Material documented on the Certified Product Test Report (CPTR).

modulus of soil reaction, E′: the soil reaction modulus is a proportionality constant that represents the embedment soil's resistance to ring deflection of pipe due to earth pressure. E′ has been determined empirically from field deflection measurements by substituting site parameters (i.e., depth of cover, soil weight) into Spangler's equation and "backcalculating" E′.

polyethylene (PE): a polyolefin composed of polymers of ethylene. It is normally a translucent, tough, waxy solid which is unaffected by water and by a large range of chemicals. There are three general classifications: low-density, medium-density, and high-density.

Product Quality Certification (PQC): a document attesting that material is in accordance with specified requirements, including batch analysis of all chemical analysis, test, and examinations.

test coupon: a fusion assembly for procedure or performance qualification testing. The coupon may be any product from sheet plate, pipe, or tube material.

test joint: work pieces joined by fusing to qualify fusing procedures, or fusing operators.

test specimen: section of test coupon used for mechanical testing of the joint.

thermoplastic resin: a resin material which does not react or polymerize and which flows with the application of heat and solidifies when cooled. A material which can be reformed.

Figure -4310-1
Thermal Fusion Butt Joint

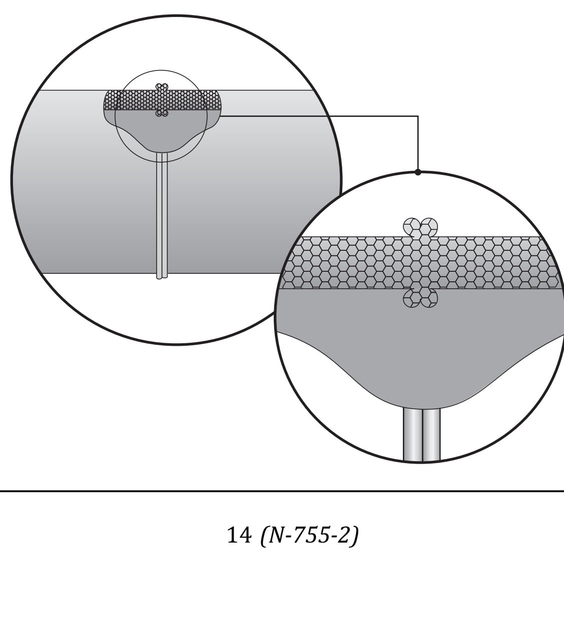
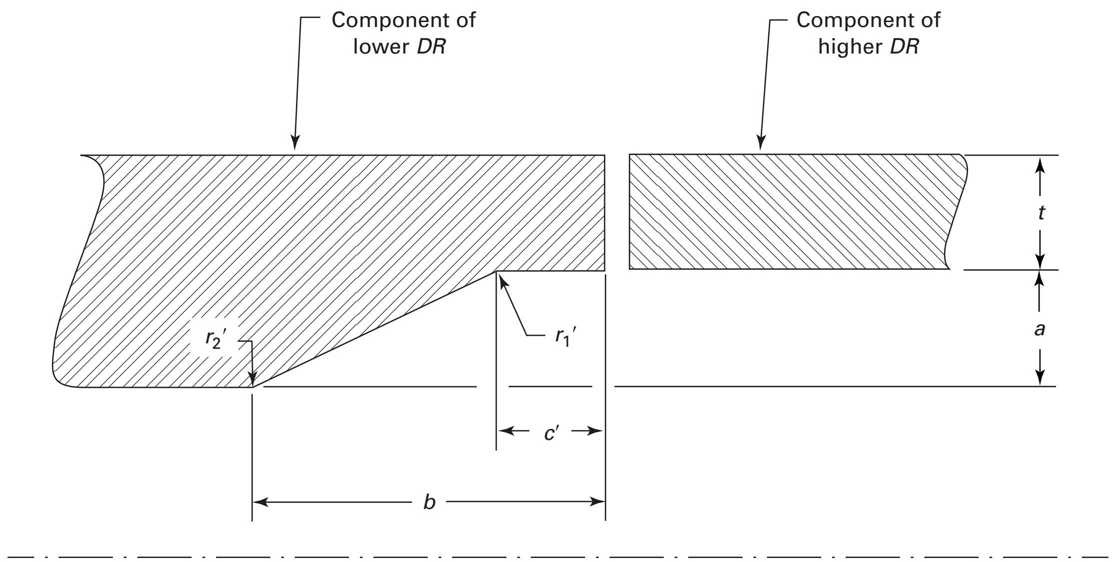


Figure -4421.3-1
Tapered Transition Joint



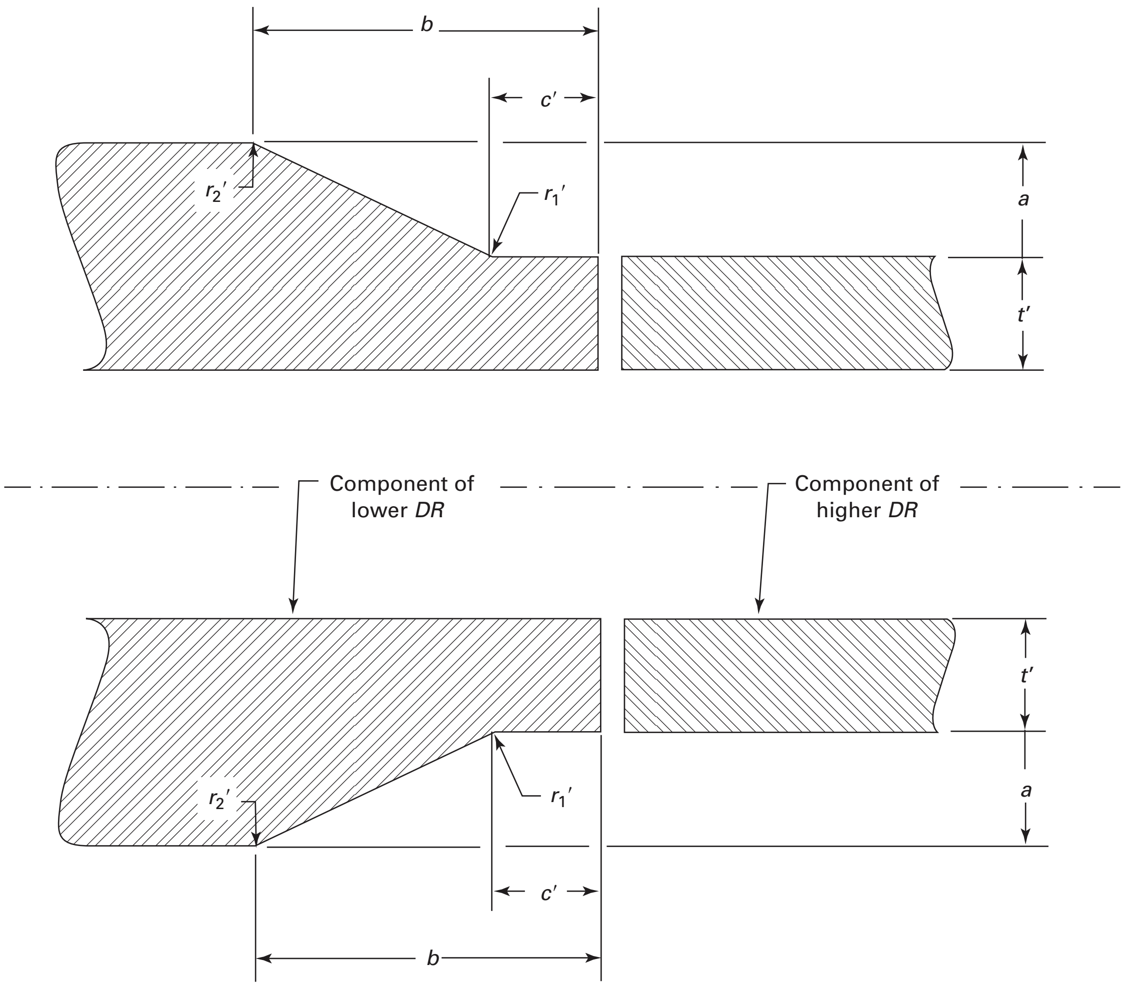
$t' = t_{\text{fab min}}$ of thinner component
c' min $= 2.5t'$
c' values are after facing

$$0.35 < \left[\frac{a}{(b - c')}\right] < 0.60$$

$r_1'{}_{\text{min}} = 0.05t'$
$r_2'{}_{\text{min}} = 0.05t'$

(a) Reinforcement on Inside Diameter

Figure -4421.3-1
Tapered Transition Joint (Cont'd)



$t' = t_{\text{fab min}}$ of thinner component
c' min = $2.5t'$
c' values are after facing

$$0.35 < \left[\frac{a}{(b - c')}\right] < 0.60$$

$r_1'{}_{\min} = 0.05t'$
$r_2'{}_{\min} = 0.05t'$

(b) Reinforcement on Outside Diameter

Figure -4520-1
Transition Flange Arrangement

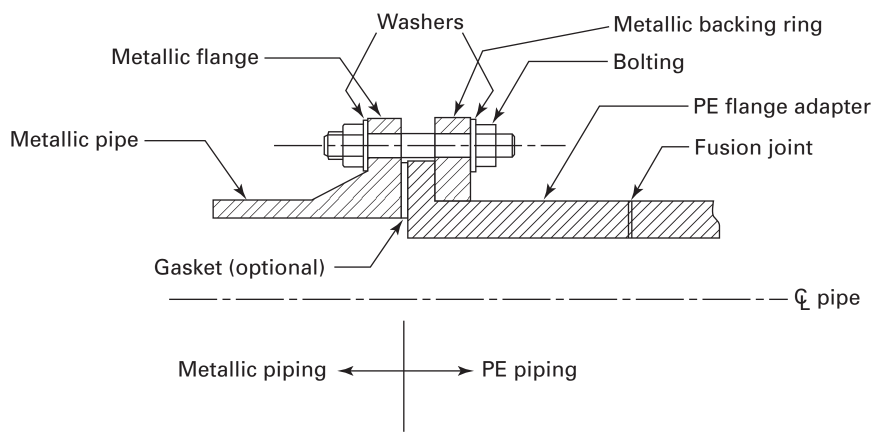


Figure 5321-1
Polyethylene Pipe Butt Fusion Joint O.D. Bead (Cross Section View)

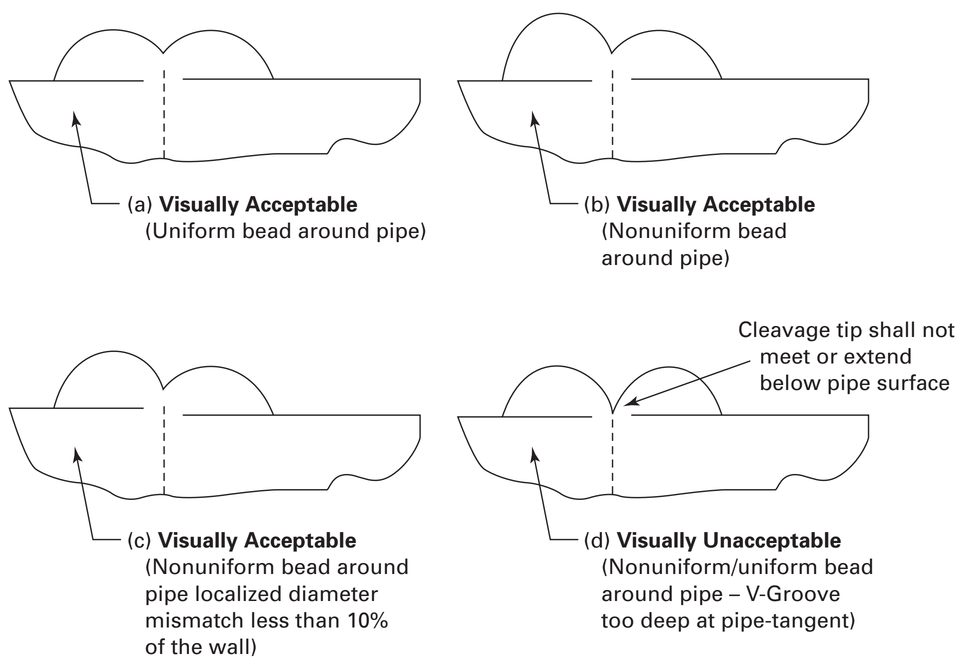


Table -3131-1(a)
Long-Term Allowable Stress, *S*, for Polyethylene (psi)

Temperature (°F)	≤ 50 yr	Temperature (°F)	≤ 50 yr	Temperature (°F)	≤ 50 yr
≤ 73	800	96	689	119	587
74	795	97	684	120	582
75	790	98	680	121	578
76	785	99	675	122	574
77	780	100	670	123	570
78	775	101	666	124	565
79	770	102	661	125	561
80	765	103	657	126	557
81	760	104	652	127	553
82	755	105	648	128	549
83	751	106	643	129	545
84	746	107	639	130	540
85	741	108	634	131	536
86	736	109	630	132	532
87	731	110	626	133	528
88	726	111	621	134	524
89	722	112	617	135	520
90	717	113	612	136	516
91	712	114	608	137	512
92	708	115	604	138	508
93	703	116	599	139	504
94	698	117	595	140	500
95	694	118	591	…	…

GENERAL NOTE: The stresses listed in Tables -3131-1(a) and -3131-1(b) support a 50 yr operating life; stresses for operating lives longer than 50 yr are under development.

Table -3131-1(b)
Long-term Allowable Stress, *S*, for Polyethylene (MPa)

Temperature (°C)	≤ 50 yr	Temperature (°C)	≤ 50 yr	Temperature (°C)	≤ 50 yr
≤ 23	5.52	36	4.73	49	4.01
24	5.45	37	4.68	50	3.96
25	5.39	38	4.62	51	3.91
26	5.33	39	4.56	52	3.85
27	5.27	40	4.50	53	3.80
28	5.21	41	4.45	54	3.75
29	5.15	42	4.39	55	3.70
30	5.09	43	4.34	56	3.65
31	5.03	44	4.28	57	3.60
32	4.97	45	4.23	58	3.55
33	4.91	46	4.17	59	3.50
34	4.85	47	4.12	60	3.45
35	4.79	48	4.07	…	…

GENERAL NOTE: The stresses listed in Tables -3131-1(a) and -3131-1(b) support a 50 yr operating life; stresses for operating lives longer than 50 yr are under development.

Table -3131-1(c)
Elevated Temperature Allowable Stress, *S*, for Polyethylene (psi)

Temperature (°F)	≤ 0.3 yr
≤ 176	341

Table -3131-1(d)
Elevated Temperature Allowable Stress, S, for Polyethylene (MPa)

Temperature (°C)	≤ 0.3 yr
≤ 80	2.35

Table -3210-1
Maximum Allowable Ring Deflection, Ω_{max}

DR	Ω_{max} (%)
13.5	6.0
11	5.0
9	4.0
7.3	3.0

Table -3210-2(a)
Soil Support Factor, F_S (in.)

	$(12 \times B_d) / D$, in./in.					
E'_N/E'	1.5	2.0	2.5	3.0	4.0	5.0
0.1	0.15	0.30	0.60	0.80	0.90	1.00
0.2	0.30	0.45	0.70	0.85	0.92	1.00
0.4	0.50	0.60	0.80	0.90	0.95	1.00
0.6	0.70	0.80	0.90	0.95	1.00	1.00
0.8	0.85	0.90	0.95	0.98	1.00	1.00
1.0	1.00	1.00	1.00	1.00	1.00	1.00
1.5	1.30	1.15	1.10	1.05	1.00	1.00
2.0	1.50	1.30	1.15	1.10	1.05	1.00
3.0	1.75	1.45	1.30	1.20	1.08	1.00
5.0	2.00	1.60	1.40	1.25	1.10	1.00

Table -3210-2(b)
Soil Support Factor, F_S (mm)

	$(1000 \times B_d) / D$, mm/mm					
E'_N/E'	1.5	2.0	2.5	3.0	4.0	5.0
0.1	0.15	0.30	0.60	0.80	0.90	1.00
0.2	0.30	0.45	0.70	0.85	0.92	1.00
0.4	0.50	0.60	0.80	0.90	0.95	1.00
0.6	0.70	0.80	0.90	0.95	1.00	1.00
0.8	0.85	0.90	0.95	0.98	1.00	1.00
1.0	1.00	1.00	1.00	1.00	1.00	1.00
1.5	1.30	1.15	1.10	1.05	1.00	1.00
2.0	1.50	1.30	1.15	1.10	1.05	1.00
3.0	1.75	1.45	1.30	1.20	1.08	1.00
5.0	2.00	1.60	1.40	1.25	1.10	1.00

Table -3210-3(a)
Modulus of Elasticity of Polyethylene Pipe, E_{pipe} (psi)

Load Duration	Temperature (°F) ≤ 73	80	90	100	110	120	130	140	176
0.5 hr	82,000	76,300	67,200	59,900	52,500	47,600	41,000	35,300	18,000
1 hr	78,000	72,500	64,000	56,900	49,900	45,200	39,000	33,500	17,200
10 hr	65,000	60,500	53,300	47,500	41,600	37,700	32,500	28,000	14,200
24 hr	60,000	55,800	49,200	43,800	38,400	34,800	30,000	25,800	13,200
100 hr	55,000	51,200	45,100	40,200	35,200	31,900	27,500	23,700	12,100
1,000 hr	46,000	42,800	37,700	33,600	29,400	26,700	23,000	19,800	10,100
1 yr	40,000	37,200	32,800	29,200	25,600	23,200	20,000	17,200	8,800
10 yr	34,000	31,600	27,900	24,800	21,800	19,700	17,000	14,600	N/A
50 yr	29,000	27,000	23,800	21,200	18,600	16,800	14,500	12,500	N/A

Table -3210-3(b)
Modulus of Elasticity of Polyethylene Pipe, E_{pipe} (MPa)

Load Duration	Temperature (°C) ≤ 23	27	32	38	43	49	54	60	80
0.5 hr	566	526	463	413	362	328	283	243	124
1 hr	538	519	441	392	344	312	269	231	118
10 hr	449	417	368	328	287	260	224	193	99
24 hr	414	385	339	302	265	240	207	178	91
100 hr	379	353	311	277	243	220	190	163	83
1,000 hr	317	295	260	232	203	184	159	137	70
1 yr	276	257	226	201	177	160	138	117	61
10 yr	234	218	192	171	150	136	117	101	N/A
50 yr	200	186	164	146	128	116	100	86	N/A

Table -3220(a)
Allowable Side Wall Compression Stress, S_{comp} (psi)

Temperature (°F)	S_{comp}
≤ 50	1,180
73	1,015
140	520
160	400
180	325

Table -3220(b)
Allowable Side Wall Compression Stress, S_{comp} (MPa)

Temperature (°C)	S_{comp}
≤ 10	8.14
23	7.00
60	3.59
71	2.76
82	2.24

Table -3221.2-1
Ovality Correction Factor, f_o

Percent-Ovality	Ovality Correction Factor
1%	0.91
2%	0.84
3%	0.76
5%	0.64
6%	0.59

Table -3223-1
Stress Indices, B_1 and B_2

	DR 7	*DR* 9	*DR* 11	*DR* 13.5
B_1 Straight and butt fused joint	0.5	0.5	0.5	0.5
B_2 Straight and butt fused joint	1.0	1.0	1.0	1.0
B_1 Miter [Note (1)]	0.69	0.69	0.69	0.69
B_2 Miter [Note (1)]	1.38	1.64	1.91	2.21

NOTE:
(1) Mitered elbows shall not exceed 22.5 deg (±3 deg) angle of change in direction at mitered joint.

Table -3223-2
Design and Service Level Longitudinal Stress Factors, *K*

Service Level	Design	*A*	*B*	*C*	*D*
k	1.0	1.0	1.1	1.33	1.33

Table -3223-3
Short Duration (< 5 min) Allowable Longitudinal Tensile Stress Values

Temp (°F)	(°C)	*S* (psi)	*S* (MPa)
≤ 70	≤ 21	1,200	8.3
100	38	940	6.5
120	49	770	5.3
140	60	630	4.3
176	80	400	2.7

Table -3311.2-1
Stress Intensification Factor, *i*

Fitting or Joint	*i*
Straight pipe	1.0
Butt fusion	1.0
Mitered elbows	2.2

MANDATORY APPENDIX I
POLYETHYLENE PIPE FUSING

I-100 FUSION GENERAL REQUIREMENTS

Mandatory Appendix I of this Case relates to the qualification of fusion machine operators and the procedures that they employ in fusing polyethylene (PE) piping. Due to the major differences between metallic welding and plastic fusing, the fusion procedure specification (FPS) and the Procedure Qualification Record (PQR) have been combined for this Mandatory Appendix.

I-101 SCOPE

The requirements in this Mandatory Appendix apply to the preparation of the fusion procedure specification (FPS), and the qualification of fusion machine operators for thermal butt fusion joining.

I-102 TERMS AND DEFINITIONS

Some of the more common terms relating to fusion are defined in -9000, and ASTM F412, Standard Terminology Relating to Plastic Piping Systems.

I-103 RESPONSIBILITY

I-103.1 Fusion. Each manufacturer or contractor is responsible for the fusing done by his organization and shall conduct the tests required in this Mandatory Appendix to qualify the procedures he uses in the production of the fused joints made for this Case (I-200), and the performance of fusion machine operators who use these procedures (I-300).

I-103.2 Records. Each manufacturer or contractor shall maintain a record of the results obtained in the fusing procedure and fusion machine operator performance qualifications. These records shall be certified by the manufacturer or contractor and shall be accessible to the Authorized Nuclear Inspector.

I-104 DOCUMENTS

I-104.1 A FPS is a written document that provides direction to the fusion machine operator for making fused joints in accordance with the requirements of this Case. Any manufacturer or contractor that will have responsible operational control of production fusing shall have a FPS that has been qualified by that manufacturer or contractor in accordance with I-200 of this Mandatory Appendix.

(a) The FPS specifies the conditions under which the fusing must be performed. These conditions include the PE materials that are permitted. Such conditions are referred to in this Mandatory Appendix as fusing "essential variables." When a FPS is to be prepared by the manufacturer or contractor, it shall address these essential variables.

(b) The purpose for the qualification of a FPS is to determine that the fused joint proposed for construction is capable of providing the required properties for its intended application. FPS qualification establishes the properties of the fused joint, not the skill of the fusion machine operator.

I-104.2 In performance qualification, the basic criterion established for fusion machine operator qualification is to determine the operator's ability to operate the fusing equipment to produce a sound fused joint.

I-105 JOINT ORIENTATION

The orientation of all fused butt joints produced for tests or production shall be made within ±45 deg of the horizontal axis position illustrated in Figure I-105.

I-106 TRAINING

(a) Thermal Butt Joint. Each fusion machine operator will receive a minimum of 24 hr of training, covering the principles of the fusion process and the operation of the fusion equipment. There will be a two part test at the end of this training; Part 1 Theoretical Knowledge and Part 2 Performance Qualification.

(1) The theoretical knowledge test shall cover as a minimum: safety, fundamentals of the fusing process, and recognition of typical joint imperfections.

(2) Performance qualification test using an approved FPS.

(b) Nonmandatory Appendix A to this Case provides guidance for a training program.

I-120 EXAMINATIONS

I-121 VISUAL EXAMINATION

All fused joints shall receive a visual examination. The examination shall include all accessible surfaces of the fused joint and shall meet the following criteria:

(a) Joints shall exhibit proper fusion bead configuration, see Nonmandatory Appendix C.

(b) There shall be no evidence of cracks or incomplete fusion.

(c) Joints shall not be visually mitered (angled, offset). The ovality offset shall be less than 10% of the minimum wall thickness of the fused components.

(d) The cleavage between fusion beads shall not extend to or below the outside diameter pipe surface (see Figure I-121-1).

(e) Review the data acquisition record for the joint and compare it to the Fusion Procedure Specification (FPS) to ensure the proper parameters and procedures were followed in making the fused joint, see I-122.

I-122 Data Acquisition Record Evaluation

I-122.1 Data Acquisition Device.

(a) The data acquisition device shall be capable of recording the following butt fusion essential variables on each joint:

(1) heater surface temperature immediately prior to insertion of the heater plate

(2) gauge pressure during the heat cycle

(3) gauge pressure during the fusion and cool cycle

(4) amount of time during the heat cycle

(5) the amount of time to open the fusion machine, remove the heater, and bring the pipe ends together at fusion pressure

(6) amount of time during the fusion and cool cycle

(b) All job information related to the joints such as job number, joint number, employee number, time, date, fusion machine identification, pipe manufacturer, interfacial pressure, and pipe material shall be recorded.

(c) The data acquisition device must be capable of storing at least one day of butt fusion joint information and capable of downloading this information as a permanent record.

I-122.2 Data Acquisition Log Evaluation. The butt fusion joint record should be compared to the FPS to ensure that the proper butt fusion parameters and procedures were followed. If they were not, the joint shall be cut out and a new joint fused using the correct parameters and procedures per the FPS. An example of a data acquisition log review is provided in Nonmandatory Appendix B of this Case.

(a) Verify that all job related data was entered in the record.

(b) Verify that the recorded "Fuse" interfacial pressure was within the range of qualification.

(c) Verify that the heater surface temperature recorded was within the range of qualification.

(d) Verify that the drag pressure was recorded.

(e) The examiner shall calculate the fusion pressure for the fusion machine and add the drag pressure to confirm the machine's hydraulic fusion gauge pressure. This fusion gauge pressure must be shown in the recorded pressure/time diagram at the initial heater contact and during the fusion/cool cycle.

(f) Verify that the fusion gauge pressure dropped quickly to a value less than or equal to the drag pressure at the beginning of the heat soak cycle.

(g) At the end of the heat soak cycle, review that the machine was opened, the heater removed and the pipe ends brought together at the fusion gauge pressure as quickly as possible (not to exceed allowance in procedure).

(h) Verify that the machine fusion gauge pressure was within the range of qualification for the pipe diameter being fused. Observe that the data recording device stopped logging at the end of the fusion/cool cycle.

I-130 TESTS

I-131 HIGH SPEED TENSILE IMPACT TEST

I-131.1 Significance and Use. This test method is designed to impart tensile impact energy to a butt fused plastic pipe specimen. The failure mode is used as criterion in the evaluation of the butt fusion joint.

I-131.2 Test Specimens.

(a) The test specimen shall conform to the dimensions shown in Figure I-131.2. Except as permitted in I-131.3*(c)*, test specimens of butt fused pipe shall use the full wall thickness.

(b) Preparation. Test specimens shall be prepared by machining operations on butt fused sections of pipe and on the pipe itself. The machining operations shall result in a smooth surface on both sides of the reduced area with no notches or gouges.

(c) All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Marks left by coarse machining operations shall be carefully removed with a fine file or abrasive, and the filed surfaces shall then be smoothed with abrasive paper (600 grit or finer). The finishing sanding strokes shall be made in a direction parallel to the longitudinal axis of the test specimen. In machining a specimen, undercuts that would exceed the dimensional tolerances shall be avoided.

(d) When marking the specimens, use a permanent marker of a color that will be easily read or etch the specimen number in the area outside the hole.

I-131.3 Number of Test Specimens. The following specifies the number of required test specimens:

(a) four test specimens shall be cut 90 deg apart from a pipe coupon made from pipe sizes larger than 4 in. (100 mm)

(b) two test specimens shall be cut 180 deg apart from a pipe coupon made from 2 in. to 4 in. pipe sizes (50 mm to 100 mm), inclusive

(c) for pipes with a wall thickness greater than 2.5 in. (62 mm), the test specimens shall be cut into equal thicknesses to fit the testing machine

I-131.4 Speed of Testing. The speed of testing shall be in accordance with Table I-131.4.

I-131.5 Conditioning.

(a) Conditioning. Condition the test specimens at 73.4°F ± 4°F [23°C ± 2°C] for not less than 1 hr prior to test.

(b) Test Conditions. Conduct the tests at 73.4°F ± 4°F [23°C ± 2°C] unless otherwise specified by contract or the relevant ASTM material specification.

I-131.6 Test Procedure.

(a) Set up the machine and set the speed of testing to the proper rate as required in I-131.4.

(b) Pin each specimen in the clevis tooling of the testing machine. This will align the long axis of the specimen and the tooling with the direction of pull of the machine.

(c) Determine the mode of failure and note in the report.

I-131.7 Acceptance Criteria. The failure mode shall not be brittle in the fusion interface per Figure I-131.7. For further guidance see ASTM F2634, Fig. X1.3.

I-132 ELEVATED TEMPERATURE SUSTAINED PRESSURE TESTS

I-132.1 Specimens. The following provides the requirements for the test specimens:

(a) Test specimens shall be made from a minimum of two pieces of pipe with the completed specimens having at least 1.5 times the pipe O.D. or 12 in. (305 mm), whichever is greater, from the end of the test specimen. The minimum nominal pipe size used shall be IPS 8 (DN 200) DR 11.

(b) Fusing shall be in accordance with the FPS under test.

I-132.2 Test Performance. Test performance shall be in accordance with ASTM D3035 or ASTM F714.

I-133 FREE BEND TESTS

I-133.1 Specimens. Two bend specimens as shown in Figure I-133.1 shall be removed from the joint approximately 180 deg apart.

I-133.2 Testing Procedure. One test specimen shall be bent so that the inside surface of the joint is in tension and the other shall be bent so that the outside surface of the joint is in tension. The ends of each specimen shall be brought together until the ends of the specimens touch.

I-133.3 Acceptance Criteria. The specimens shall not crack or fracture in the fused joint.

I-200 FUSION PROCEDURE QUALIFICATIONS

I-201 GENERAL

Each manufacturer or contractor shall prepare written fusion procedure specifications that are defined as follows:

(a) Fusion Procedure Specification (FPS). A FPS is a written qualified fusing procedure prepared to provide direction for making production fused joints to the requirements of this Code Case. The FPS shall be used to provide direction to the fusion machine operator to assure compliance with the requirements of this Code Case.

(b) Contents of the FPS. The completed FPS shall describe all of the essential variables for each fusion process used in the FPS. These essential variables are listed and defined in I-222. The manufacturer or contractor may include any other information in the FPS that may be helpful in making a fused joint.

(c) Changes in essential variables require requalification of the FPS.

(d) Format of the FPS. The information required to be in the FPS may be in any format, written or tabular, to fit the needs of each manufacturer or contractor, as long as every essential variable outlined in I-222 is included or referenced. I-220 provides the parameters that need to be addressed in the FPS. Form II-200 has been provided as a guide for the FPS. This Form includes the required data for the fusing, it is only a guide and is located in Mandatory Appendix II.

(e) Availability of the FPS. A FPS used for production fusing shall be available for reference and review by the Authorized Nuclear Inspector at the fabrication or installation site.

I-210 MANUFACTURER'S OR CONTRACTOR'S RESPONSIBILITY

(a) Each manufacturer or contractor shall list the parameters applicable to fusing that he performs in construction of fusion joints made in accordance with this Case. These parameters shall be listed in a document known as a fusion procedure specification (FPS).

(b) Each manufacturer or contractor shall qualify the FPS by the fusing of test coupons, testing of specimens cut from the test coupons, and recording fusing data and test results in the FPS. The fusion machine operators used to produce the fused joints to be tested for qualification of procedures shall be under the full supervision and control of the manufacturer or contractor during the production of these test fused joints. The fused joints to be tested for qualification of procedures shall be fused either by direct employees or by individuals engaged by contract for their services as fusion machine operators under the full supervision and control of the manufacturer or contractor. It is not permissible for the manufacturer or contractor to have the supervision and control of fusing of the test fused joints performed by another organization. It is permissible, however to subcontract any or all of the work of preparation of test material for fusing and subsequent work on preparation of test specimens from the completed fused jointment, performance of nondestructive examination, and mechanical tests, provided the manufacturer or contractor accepts the responsibility for any such work.

(c) This Case recognizes a manufacturer or contractor as the organization which has responsible operational control of the production of the fusion joints to be made

in accordance with this Case. If in an organization effective operational control of fusing procedure qualification for two or more companies of different names exists, the companies involved shall describe in their quality control system/quality assurance program, the operational control of procedure qualifications. In this situation, separate fusion procedure qualifications are not required, provided all other requirements of this Mandatory Appendix are met.

(d) The manufacturer or contractor shall certify that he has qualified each fusion procedure specification.

I-220 FUSION PROCEDURE SPECIFICATION (FPS)

I-221 Standard Fusion Procedure Specification

(a) The standard fusion procedure specification is based on standard industry practice and testing as reported in the Plastic Pipe Institute (PPI), report TR-33.

(b) When the FPS is limited to the following parameters, qualification testing is not required. If the manufacturer or contractor deviates from the conditions listed below, procedure qualification testing in I-223 shall be performed.

(1) The pipe is limited to the horizontal position ±45 deg (see Figure I-105).

(2) The pipe ends shall be faced to establish clean, parallel mating surfaces that are perpendicular to the pipe centerline on each pipe end. When the ends are brought together, there shall be no visible gap.

(3) The external surfaces of the pipe are aligned to within 10% of the pipe wall thickness.

(4) The drag pressure shall be measured and recorded. The fusion pressure shall be calculated so that an interfacial pressure of 60 psi to 90 psi (0.41 MPa to 0.62 MPa) is applied to the pipe ends.

(5) The heater plate surface temperature shall be 400°F to 450°F (204°C) to 232°C measured at four locations approximately 90 deg apart, on both sides immediately prior to insertion of the heater plate in the fusion machine.

(6) The heater plate shall be inserted into the gap between the pipe ends and fusion pressure shall be applied and maintained until an indication of melt is observed around the circumference of the pipe. The pressure shall be reduced to drag pressure and the fixture shall be locked in position so that no outside force is applied to the joint during the soak time.

(7) The ends shall be held in place until the bead size shown in Figure I-221(b)-1 and Table I-221(b)-1 is formed in the heat soak cycle between the heater faces and the pipe ends.

(8) After the proper bead size is formed, machine shall be opened and the heater removed. The pipe ends shall be brought together and the fusion pressure reapplied.

(9) The maximum time from removal of the heating plate until the pipe ends are pushed together shall not exceed the time given in Table I-221(b)-1 and Table I-221(b)-2

(10) The fusion pressure shall be maintained until the joint has cooled, after which the pipe can be removed from the fusion machine. The cooling time under pressure shall be 30 in./sec to 90 in./sec (25.4 mm) of pipe diameter. When the wall thickness is greater than 2 in. (51 mm), a minimum of 90 in./sec (25.4 mm) of pipe diameter shall be used for the cooling time.

I-222 Essential Variables for Fusion Procedure Specifications (FPS)

Any change in the essential variables listed below and I-221, requires requalification of the FPS per I-223. The following are the essential variables:

(a) pipe material
(b) heater surface temperature range
(c) butt fusion interfacial pressure range
(d) melt bead width in heat soak cycle
(e) maximum heater removal time
(f) minimum cool time under fusion pressure

I-223 Testing Procedure to Qualify the FPS

(a) Use IPS 8 (DN 200) DR 11 pipe size as a minimum in qualification testing of butt fusion joints.

(b) Make the following butt fusion joints using the following combinations of heater temperature ranges and interfacial pressure ranges and the FPS:

(1) High heater surface temperature and high interfacial pressure, five joints.

(2) High heater surface temperature and low interfacial pressure, five joints.

(3) Low heater surface temperature and high interfacial pressure, five joints.

(4) Low heater surface temperature and low interfacial pressure, five joints.

(c) Evaluate three joints of each combination using the high speed tensile impact tests per I-131. All joints must fail in a ductile mode.

(d) Evaluate two joints of each combination using the sustained pressure testing per I-132. All joints must pass this test.

I-230 MECHANICAL TESTS

I-231 General Requirements

(a) The type and number of test specimens that shall be tested to qualify a butt FPS are given in I-223, and shall be removed in a manner similar to that shown in I-130. If any test specimen required by I-223 fails to meet the applicable acceptance criteria, the test coupon shall be considered as failed.

(b) When it can be determined that the cause of failure is not related to fusing parameters, another test coupon may be fused using identical fusing parameters.

(c) Alternatively, if adequate material of the original test coupon exists, additional test specimens may be removed as close as practicable to the original specimen location to replace the failed test specimens.

(d) When it has been determined that the test failure was caused by an essential variable, a new test coupon may be fused with appropriate changes to the variable (s) that was determined to cause the test failure.

(e) When it is determined that the test failure was caused by one or more fusing conditions other than essential variables, a new set of test coupons may be fused with the appropriate changes to the fusing conditions that were determined to cause the test failure. If the new test passes, the fusing conditions that were determined to cause the previous test failure shall be addressed by the manufacturer to ensure that the required properties are achieved in the production fused joint.

I-232 Preparation of Test Coupon

The base materials shall consist of pipe. The dimensions of the test coupon shall be sufficient to provide the required test specimens.

I-300 FUSION PERFORMANCE QUALIFICATION

I-300.1 General. This Article lists the essential variables that apply to fusion machine operator performance qualifications.

The fusion machine operator qualification is limited by the essential variables.

I-300.2 SCOPE

(a) The basic premises of responsibility in regard to fusion are contained within I-103 and I-301.2. These paragraphs require that each manufacturer or contractor (an assembler or an installer is to be included within this premise) shall be responsible for conducting tests to qualify the performance of fusion machine operators in accordance with qualified fusion procedure specifications, which his organization employs in the construction of fused joints built in accordance with this Mandatory Appendix. The purpose of this requirement is to ensure that the manufacturer or contractor has determined that his fusion machine operators using his procedures are capable of developing the minimum requirements specified for an acceptable fused joint. This responsibility cannot be delegated to another organization.

(b) The fusion machine operators used to produce such fused joints shall be tested under the full supervision and control of the manufacturer or contractor during the production of these test fused joints. It is not permissible for the manufacturer or contractor to have the fusing performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test materials for fusing and subsequent work on the preparation of test specimens from the completed fused joints, performance of nondestructive examination and mechanical tests, provided the manufacturer, contractor, assembler, or installer accepts full responsibility for any such work.

(c) This Mandatory Appendix recognizes a manufacturer or contractor as the organization which has responsible operational control of the production of the fused joints to be made in accordance with this Mandatory Appendix. If in an organization effective operational control of the fusion machine operator performance qualification for two or more companies of different names exists, the companies involved shall describe in the quality control system, the operational control of performance qualifications. In this Mandatory Appendix requalification of fusion machine operators within the companies of such an organization will not be required, provided all other requirements of this Mandatory Appendix are met.

(d) The Mandatory Appendix recognizes that manufacturers or contractors may maintain effective operational control of fusion machine operator performance qualification (FPQ) records under different ownership than existed during the original fusion machine operator qualification. When a manufacturer or contractor or part of a manufacturer or contractor is acquired by a new owner(s), the FPQ may be used by the new owner(s) without requalification, provided all of the following are met:

(1) new owner(s) takes responsibility for the FPQ

(2) FPQ reflect the name of the new owner(s)

(3) Quality Control System/Quality Assurance Program reflects the source of the FPQ as being from the former manufacturer or contractor

I-300.3 More than one manufacturer or contractor may simultaneously qualify one or more fusion machine operators. When simultaneous qualifications are conducted, each participating organization shall be represented during fusing of test coupons by an employee who is responsible for fusion machine operator performance qualification.

(a) The fusion procedure specifications (FPS) that are followed during simultaneous qualifications shall be compared by the participating organizations. The FPS's shall be identical for all the essential variables. The qualified thickness ranges for base material need not be identical, but these thicknesses shall be adequate to permit fusing of the test coupons. Alternatively, the participating organizations shall agree upon the use of a single FPS provided each participating organization has a FPS covering the range of essential variables to be followed in the performance qualification. When a single FPS is to be followed, each participating organization shall review and accept that FPS.

(b) Each participating organization's representative shall positively identify each fusion machine operator who is being tested. Each organizational representative shall also verify marking of the test coupon with the fusion machine operator's identification.

(c) Each organization's representative shall perform a visual examination of each completed test coupon and shall examine each test specimen to determine its acceptability. Alternatively, after visual examination, when the test coupon(s) are prepared and tested by an independent laboratory, that laboratory's report may be used as the basis for accepting the test results.

(d) Each organizational representative shall complete and sign a fusion machine operator performance qualification (FPQ) record for each fusion machine operator. Data Report Form II-200 has been provided as a guide for the FPS.

(e) When a fusion machine operator changes employers between participating organizations, the employing organization shall verify that the fusion machine operator's continuity of qualifications has been maintained as required by I-322 by previous employers since his qualification date. If the fusion machine operator has had his qualification withdrawn for specific reasons, the employing organization shall notify all other participating organizations that the fusion machine operator's qualification(s) has been revoked in accordance with I-322.1(b). The remaining participating organizations shall determine that the fusion machine operator can perform satisfactory work in accordance with this Mandatory Appendix.

(f) When a fusion machine operator's qualifications are renewed in accordance with the provisions of I-322.2, each renewing organization shall be represented by an employee who is responsible for fusion machine operator performance qualification. The testing procedures shall follow the rules of this paragraph.

I-301 TESTS

I-301.1 Intent of Tests. The performance qualification tests are intended to determine the ability of fusion machine operators to make sound fused joints.

I-301.2 Qualification Tests. Each manufacturer or contractor shall qualify each fusion machine operator for the fusing process to be used in production. The performance qualification test shall be fused in accordance with qualified fusion procedure specifications (FPS). Changes beyond which requalification is required are given in I-322. Allowable visual and mechanical examination requirements are described in I-303. Retests and renewal of qualification are given in I-320.

The fusion machine operator who prepares the FPS qualification test coupons meeting the requirements of I-200 is also qualified within the limits of the performance qualifications, listed in I-303 for fusion machine operators.

The performance test may be terminated at any stage of the testing procedure, whenever it becomes apparent to the supervisor conducting the tests that the fusion machine operator does not have the required skill to produce satisfactory results.

I-301.3 Identification of Fusion Machine Operators. Each qualified fusion machine operator shall be assigned an identifying number, letter, or symbol by the manufacturer, contractor or manufacturer or contractor, which shall be used to identify the work of that fusion machine operator.

I-301.4 Record of Tests. The record of fusion machine operator performance qualification (FPQ) tests shall include the essential variables, the type of test and test results, and the ranges qualified in accordance with Data Report Form II-300 for each fusion machine operator.

I-302 TYPE OF TEST REQUIRED

I-302.1 Mechanical Tests. All mechanical tests shall meet the requirements prescribed in I-131 (High Speed Tensile Impact Test) or I-133 (Free Bend Test).

I-302.2 Test Coupons in Pipe. For test coupons made on pipe in the horizontal axis position of Figure I-105. The coupons shall be removed from the test piece in accordance with Figure I-133.1.

I-302.3 Visual Examination. For pipe coupons all surfaces shall be examined visually per I-121 before cutting of bend specimens. Pipe coupons shall be visually examined per I-121 over the entire circumference, inside and outside.

I-303 Fusion Machine Operators

Each fusion machine operator who fuses under the rules of this Mandatory Appendix shall have passed the mechanical and visual examinations prescribed in I-302.1 and I-302.3 respectively.

I-303.1 Examination. Fused joints made in test coupons for performance qualification shall be examined by mechanical and visual examinations (I-302.1, I-302.3).

I-310 QUALIFICATION TEST COUPONS

I-310.1 Test Coupons. The test coupons shall be pipe. Qualifications for pipe are accomplished by fusing one pipe assembly in the horizontal axis position (Figure I-105). The minimum pipe size shall be IPS 8 (DN 200) DR 11.

I-320 RETESTS AND RENEWAL OF QUALIFICATION

I-321 Retests

A fusion machine operator who fails one or more of the tests prescribed in I-303, as applicable, may be retested under the following conditions.

I-321.1 Immediate Retest Using Visual Examination. When the qualification coupon has failed the visual examination of I-302.3, retesting shall be by visual examination before conducting the mechanical testing.

When an immediate retest is made, the fusion machine operator shall make two consecutive test coupons all of which shall pass the visual examination requirements.

The examiner may select one of the successful test coupons from each set of retest coupons which pass the visual examination for conducting the mechanical testing.

I-321.2 Immediate Retest Using Mechanical Testing. When the qualification coupon has failed the mechanical testing of I-302.1, the retesting shall be mechanical testing.

When an immediate retest is made, the fusion machine operator shall make two consecutive test coupons which shall pass the test requirements.

I-321.4 Further Training. When the fusion machine operator has had further training or practice, a new test shall be made.

I-322 EXPIRATION AND RENEWAL OF QUALIFICATION

I-322.1 Expiration of Qualification. The performance qualification of a fusion machine operator shall be affected when one of the following conditions occurs:

(a) When he has not fused with a process during a period of 6 mo or more, his qualification, for that process shall expire.

(b) When there is a specific reason to question his ability to make fused joints that meet the specification, the qualifications that support the fusing he is doing shall be revoked.

I-322.2 Renewal of Qualification

(a) Renewal of qualification expired under I-322.1(a) may be made by fusing a single test coupon and by testing of that coupon as required by I-301. A successful test renews the fusion machine operator previous qualifications for the process for which he was previously qualified.

(b) Fusion machine operators whose qualifications have been revoked under I-322.1(b) above shall requalify. Qualification shall utilize a test coupon appropriate to the planned production work. The coupon shall be fused and tested as required by I-301 and I-302. A successful test restores the qualification.

I-330 ESSENTIAL VARIABLES FOR FUSION MACHINE OPERATORS

I-331 General

A fusion machine operator shall be requalified whenever a change is made in one or more of the essential variables listed below.

(a) A change in pipe diameter from one range to another.

(1) less than IPS 8 (DN 200)
(2) IPS 8 (DN 200) to IPS 20 (DN 500), inclusive
(3) IPS over 20 (DN 500)

(b) A change in name of the manufacturer of equipment.

(c) The axis of the pipe is limited beyond the horizontal position ±45 deg. Qualification in any position other than horizontal qualifies the orientation tested ± 20 deg.

I-340 FUSION MACHINE OPERATOR QUALIFICATION TESTING

(a) A data acquisition device shall be attached to the fusion machine and the data concerning the joint entered. The data acquisition recorder shall be used to record data required by I-122.

(b) The supervisor conducting the test shall observe making of the butt fusion joint and note if the fusion procedure specification (FPS) was followed.

(c) The completed joint shall be visually examined and meet the acceptance criteria of I-121.

(d) After the joint is complete, the data acquisition record shall be reviewed by the assessor and compared to the FPS to ensure the proper procedures were followed.

(e) The test specimens shall be removed, tested and meet the acceptance criteria in accordance with I-131 or I-133.

Figure I-105
Horizontal Axis Position

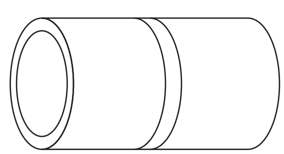


Figure I-121-1
Polyethylene Pipe Butt Fusion Joint O.D. Bead (Cross-Section View)

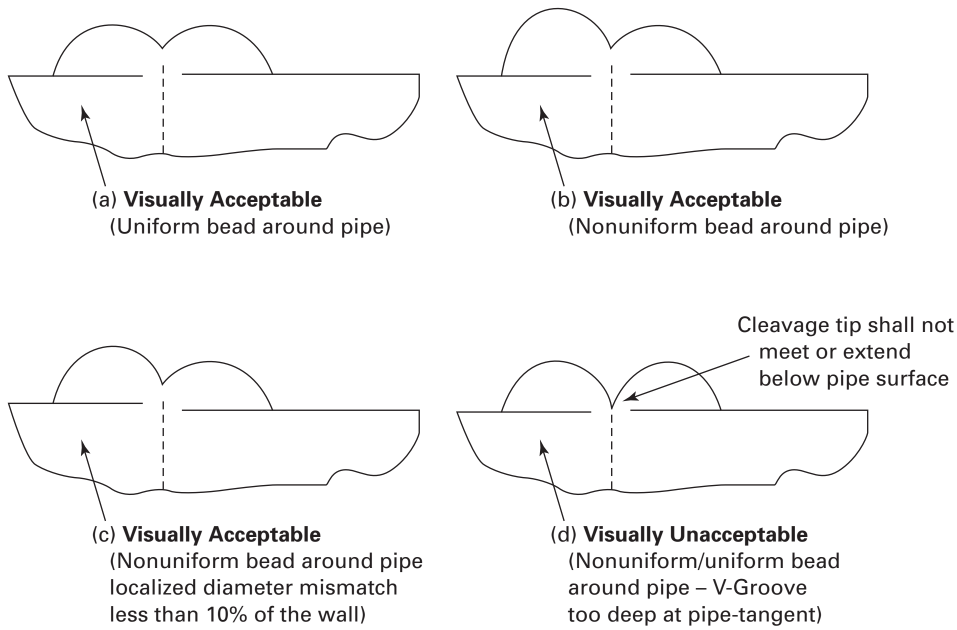
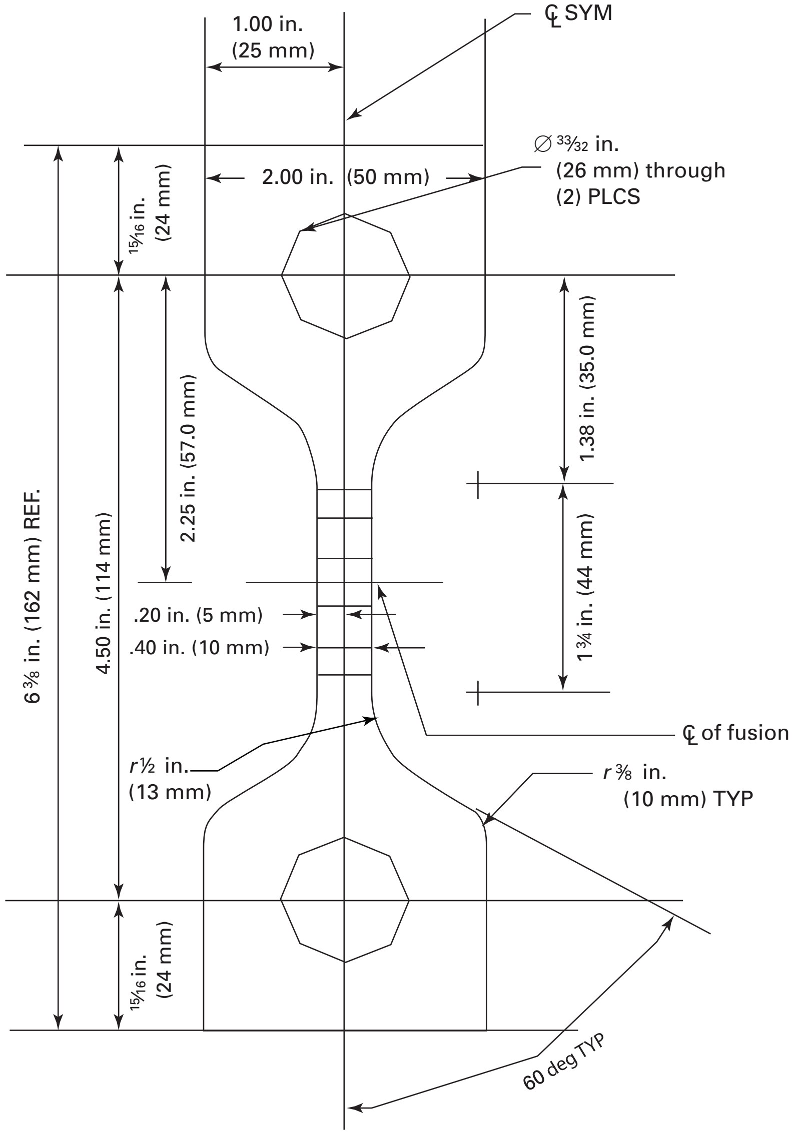
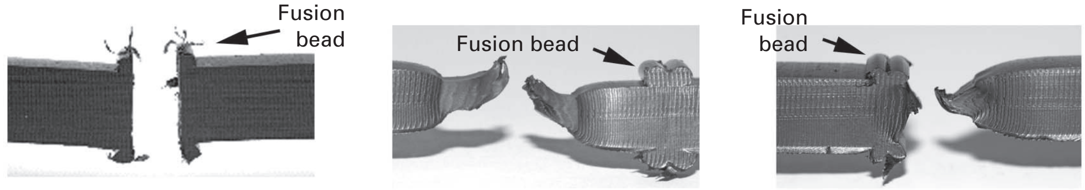


Figure I-131.2
Tensile Full Thickness Impact Test Coupon Configuration



GENERAL NOTE: All machined surfaces 125 RMS or better.

Figure I-131.7
Tensile Test Sample Evaluation Sample



(a) Brittle Failure

(b) Ductile Failure
Outside Fusion Interface

(c) Ductile Failure
Adjacent to Fusion Interface

Figure I-133.1
Bend Specimen

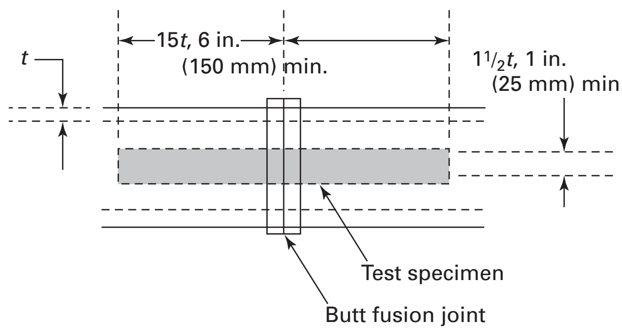
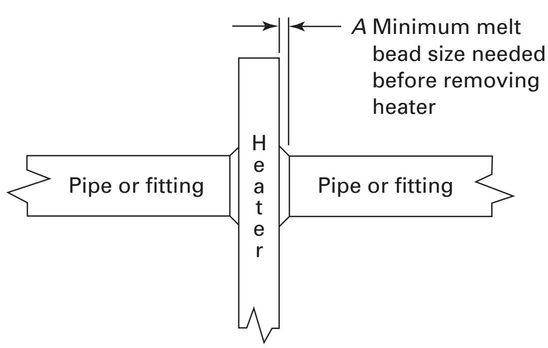


Figure I-221(b)-1
Minimum Melt Bead Size



GENERAL NOTE: The value of A is given in Table I-221(b)-1.

Table I-131.4
Testing Speed

Wall Thickness	Testing Speed
≤ 1.25 in. (32 mm)	6 in./sec (152 mm/s)
> 1.25 in. (32 mm)	4 in./sec (102 mm/s)

GENERAL NOTE: Testing speed tolerance: $+0.5$ in./s to -1 in./s $(+12.7$ mm/s to -25.4 mm / s$)$.

Table I-221(b)-1
Minimum Melt

IPS Pipe Size (DN)	Outside Diameter, in. (mm)	*A* Bead Size, in. (mm)
< 3 IPS (DN 80)	3.5 (89)	$^1/_{16}$ (1.5)
≥ 3 IPS (DN 80) to ≤ 8 IPS (DN 200)	3.5 (89) to ≤ 8.625 (219)	$^3/_{16}$ (5)
> 8 IPS (DN 200) to ≤ 12 IPS (DN 300)	8.625 (219) to ≤ 12.75 (324)	$^1/_4$ (6)
> 12 IPS (DN 300) to ≤ 24 IPS (DN 600)	12.75 (324) to ≤ 24 (610)	$^3/_8$ (10)
> 24 IPS (DN 600) to ≤ 36 IPS (DN 900)	24 (610) to ≤ 36 (900)	$^7/_{16}$ (11)
> 36 IPS (DN 900) to ≤ 65 IPS (DN 1625)	36 (900) to ≤ 65 (1625)	$^9/_{16}$ (14)

Table I-221(b)-2
Maximum Heater Plate Removal Time for Pipe-to-Pipe Fusing

Pipe Wall Thickness, in. (mm)	Max. Heater Plate Removal Time Seconds
Field Applications	
0.20 to 0.36 (5 to 9)	8
> 0.36 to 0.55 (9 to 14)	10
> 0.55 to 1.18 (14 to 30)	15
> 1.18 to 2.5 (30 to 64)	20
> 2.5 to 4.5 (64 to 114)	25
> 4.5 (114)	30
Material Manufacturer Facility	
1.18 to 2.5 (30 to 64)	40
> 2.5 to 4.5 (64 to 114)	50
> 4.5 (114)	60

MANDATORY APPENDIX II
DATA REPORT FORMS

FORM NM(PE)-2 DATA REPORT FOR NONMETALLIC BATCH PRODUCED PRODUCTS REQUIRING FUSING
As Required by the Provisions of the ASME Section III, Division I, Code and Code Case N-755

1. Manufactured by ______________________________
(name and address of manufacturer of nonmetallic products)
2. Manufactured for ______________________________
(name and address of purchaser)
3. (a) Identification–Certificate Holder's Serial No ______________________________
(Lot No., Batch No., etc.) (print string)
______________________ ____________
(National Bd. No.) (year of manufacturing)

(b) Owner ______________________________

4. Manufactured according to Material Spec. ____________ Purchase Order No. ____________
(ASTM)
5. Remarks ______________________________
(brief description of fabrication)
____
____

CERTIFICATE OF COMPLIANCE

We certify that the statements made in this report are correct and that the products defined in this report conform to the requirements of the ASME Material specification listed above on line 4. The Certified Material Batch Reports provided for the material covered by this report.

Certificate of Authorization (NA if Owner) No. __________ to use the __________ Symbol expires __________
(Date)

Date __________ Name ______________________ Signed ______________________
(Certificate Holder) (authorized representative)

CERTIFICATE OF INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors employed by______________________________
of ______________________ have inspected the products described in this Partial Data Report product in accordance with the ASME Section III, Division 1, Code and Code Case N-755. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the products described in this Partial Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______________ Signed ______________________________
(Authorized Nuclear Inspector)

GENERAL NOTE: Supplemental sheets in form of lists, sletches or drawings may be used provided (1) size is $8^{1}/_{2} \times 11$ in. (2) information on items 1 – 4 on this Data Report is included on each sheet, and (3) each sheet is numbered and number of sheets is recorded at the top of this form.

(08/11)

FORM II-200 FUSION PROCEDURE SPECIFICATION

Prepared by __________ Date ______ Approved by __________ Date ______

Material __________

Fusion Machine Info __________

Data Acquisition MFGR __________

Data Acquisition Attached __________

Fusion Interfacial Pressure __________

Heater Surface Temperature __________

Fusion Drag Pressure __________

Fusion Pressure __________

Bead-up Size __________

Heater Removal Time __________

Cool Time and Fusion Pressure __________

Technique __________

(08/07)

FORM II-300 FUSION MACHINE OPERATOR PERFORMANCE QUALIFICATION (FPQ) TEST FORM

Operator's Name ______________________ Payroll No. __________ Stamp I.D. __________

Lab Test No. ______________________ Test: Qualification __________ Requalification __________

Fusion Machine Manufacturer ______________________

Fusion Machine Pipe Size Range ______________________

Test Position ______________________

Material Specification ______________________ to ______________________

Fusion Specification Procedure ______________________

Pipe Size ______________________ Pipe *DR* ______________________

NDE Requirements: Visual ______________________ Visual Results ______________________

Free Bend Test ______________________ Bend Test Results ______________________

Data Acquisition Record Review Results ______________________

Test Conducted By ______________________

We certify that the statements in this record are correct and that the fused joints are prepared, fused and tested in accordance with the requirements of Mandatory Appendix I, of CC N-755.

Date ______________ Signed By ______________________

(Title)

____

(08/07)

MANDATORY APPENDIX III
POLYETHYLENE STANDARDS AND SPECIFICATIONS

The acceptable PE material standards are listed in Table III-1 of this Case.

Table III-1
PE Standards and Specifications Referenced in Text

Standard ID	Published Title	Referenced Edition
American Society for Testing and Materials (ASTM)		
ASTM D638	Standard Test Method for Tensile Properties of Plastics	2010
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement	2008
ASTM D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer	2010
ASTM D1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique	2010
ASTM D1598	Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure	2002 (R2009)
ASTM D1599	Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings	1999 (R2005)
ASTM D1603	Standard Test Method for Carbon Black Content in Olefin Plastics	2006
ASTM D2122	Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings	1998 (R2010)
ASTM D2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading	2010
ASTM D2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products	2008
ASTM D3035	Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter	2008
ASTM D3261	Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing	2010a
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials	2010
ASTM D4218	Standard Test Method for Determination of Carbon Black Content in PE Compounds by the Muffle-Furnace Technique	2008
ASTM D4883	Standard Test Method for Density of Polyethylene by the Ultrasound Technique	2009
ASTM F412	Standard Terminology Relating to Plastic Piping Systems	2009
ASTM F714	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter	2008
ASTM F1473	Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of PE Pipes and Resins	2007
ASTM F2620	Standard Practice for Heat Fusion Joining of PE Pipe and Fittings	2009
ASTM F2634	Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints Using Tensile-Impact Method	2007
Plastic Pipe Institute (PPI)		
PPI TR-3	Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe	2010
PPI TR-4	PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe	2010a

MANDATORY APPENDIX IV POLYETHYLENE COMPOUND AND POLYETHYLENE MATERIAL

IV-100 POLYETHYLENE COMPOUND AND POLYETHYLENE MATERIAL REQUIREMENTS

IV-110 General Requirements

(a) Natural compound, pigment concentrate compound, polyethylene compound and polyethylene material shall be procured using the requirements of this Mandatory Appendix.

(b) Conformance with ASTM Standards referenced in Mandatory Appendix III and herein shall be limited as specified in this Mandatory Appendix. In the event of conflict between a referenced standard and this Mandatory Appendix, the requirements of this Mandatory Appendix shall prevail.

(c) Natural compound, pigment concentrate compound, polyethylene compound, and polyethylene material shall be marked in accordance with the marking requirements in this Mandatory Appendix and the applicable ASTM standard.

IV-120 REQUIREMENTS FOR POLYETHYLENE COMPOUND, NATURAL COMPOUND, PIGMENT CONCENTRATE COMPOUND, AND POLYETHYLENE SOURCE MATERIAL

IV-121 Requirements for Certification of Polyethylene Compound

(a) General

(1) To provide polyethylene material that is in accordance with the design requirements of this case, certification of polyethylene compound shall be in accordance with Mandatory Appendix IV and Table IV-121.

(2) The required value for each physical property shall be as specified in Table IV-121.

(3) The requirement standard for determining the required value for physical properties shall be as specified in Table IV-121.

(4) The test method for determination of the required value for the physical property shall be as specified in Table IV-121.

(b) Polyethylene compound used for the manufacture of polyethylene material shall meet the requirements of the polyethylene compound manufacturer and Table IV-121.

(c) Polyethylene compound shall be black except as provided in IV-131*(b)*.

(d) Polyethylene compound is the combination of natural compound and pigment concentrate compound as follows:

(1) When polyethylene compound is combined by the Polyethylene Compound Manufacturer, polyethylene compound is the polyethylene source material.

(2) When polyethylene compound is combined by the Polyethylene Material Manufacturer, natural compound and pigment concentrate compound are the polyethylene source materials.

(3) When polyethylene compound is combined by the Polyethylene Material Manufacturer, the Natural Compound Manufacturer shall provide the Polyethylene Material Manufacturer with a formulation that specifies the weight ratio (proportions) of natural compound and pigment concentrate compound, and with processing equipment setting recommendations that produce polyethylene compound in accordance with Table IV-121.

(e) Polyethylene compound shall have an independent listing that is published in PPI TR-4, Table I.A.13. The independent listing shall identify the following:

(1) A standard grade hydrostatic design basis (HDB) rating of at least 1,600 psi (11.03 MPa) at 73°F (23°C).

(2) A standard grade HDB rating of at least 1,000 psi (6.90 MPa) at 140°F (60°C).

(3) A hydrostatic design stress (HDS) rating of at least 1,000 psi (6.90 MPa) for water at 73°F (23°C).

(4) Standard grade HDB ratings and HDS ratings shall be determined in accordance with PPI TR-3, Parts A, D, and F.

(5) The polyethylene compound shall have a material designation of PE4710 in accordance with PPI TR-4, Table-I.A.13.

(6) The unique trade name or designation for the polyethylene compound.

(7) The Polyethylene Natural Compound Manufacturer.

(f) The Polyethylene Material Manufacturer of polyethylene pipe shall have a dependent listing for black polyethylene compound that is published in PPI TR-4, Table I.A.13. The dependent listing shall identify the following:

(1) A standard grade hydrostatic design basis (HDB) rating of at least 1,600 psi (11.03 MPa) at 73°F (23°C).

(2) A standard grade HDB rating of at least 1,000 psi (6.90 MPa) at 140°F (60°C).

(3) A hydrostatic design stress (HDS) rating of at least 1,000 psi (6.90 MPa) for water at 73°F (23°C).

(4) Standard grade HDB and HDS ratings shall be determined in accordance with PPI TR-3, Parts A, D and F.

(5) The Polyethylene Material Manufacturer shall assign a unique trade name or designation to the polyethylene compound that is published in PPI TR-4, Table I.A.13.

(g) The Certificate of Analysis shall identify the trade name or designation assigned to the polyethylene compound by the Polyethylene Compound Manufacturer that is published in PPI TR-4.

(h) The Certified Polyethylene Test Report shall identify the trade name for the polyethylene compound assigned by the Polyethylene Material Manufacturer that is published in PPI TR-4, Table I.A.13, and shall identify the following:

(1) the Certificate of Analysis trade names for the natural compound and the pigment concentrate compound, or

(2) the Certificate of Analysis trade name for the polyethylene compound

(i) If specified, color polyethylene compound shall contain color and ultraviolet (UV) stabilization in accordance with ASTM D3350 Code E. Color polyethylene compound color and ultraviolet (UV) stabilization duration requirements shall be specified in the Design Specification. Per IV-131(b), color polyethylene compound shall be used only for optional color stripes on polyethylene material in the form of pipe.

IV-122 Natural Compound

(a) Natural compound shall meet requirements specified by the Natural Compound Manufacturer.

(b) Natural compound shall be combined with pigment concentrate compound in accordance with IV-121(d).

(c) The Natural Compound Manufacturer shall assign a unique trade name or designation to the natural compound.

IV-123 Pigment Concentrate Compound

(a) Black pigment concentrate compound shall meet requirements specified by the Natural Compound Manufacturer.

(b) Black pigment concentrate compound shall be combined with natural compound in accordance IV-121(d)(3).

(c) The Pigment Concentrate Compound Manufacturer shall assign a unique trade name or designation to the pigment concentrate compound.

(d) Color pigment concentrate compound shall be in accordance with IV-131(b) and IV-131(b)(2).

IV-130 POLYETHYLENE MATERIAL

IV-131 Polyethylene Material — Pipe

(a) Polyethylene material in the form of pipe shall be manufactured in accordance with this Case and ASTM D3035 for sizes below 3 in. (76 mm) nominal outside diameter or ASTM F714 for sizes 3 in. (76 mm) nominal outside diameter and larger. Elevated temperature sustained pressure test per ASTM D3035 or ASTM F714 shall be successfully completed twice annually.

(b) Pipe shall be black and shall be manufactured by extrusion. With the exception of optional color stripes per this subarticle, black pipe shall contain 2% to 3% carbon black that is well dispersed through the pipe wall when samples taken from pipe are tested per ASTM D1603 or ASTM D4218.

(1) Optional color stripes that are coextruded into the pipe outside surface during extrusion are acceptable. The depth of optional color stripes into the pipe outside surface shall not exceed 10% of the $t_{\text{fab min}}$ wall thickness required for the pipe design stress. Color stripes shall not project above the pipe outside surface and shall not be covered in whole or in part by black pipe material.

(2) Where natural compound and pigment concentrate compound are combined by the Polyethylene Material Manufacturer, the Polyethylene Material Manufacturer shall use the same natural compound with black pigment concentrate compound and with color pigment concentrate compound if optional color stripes are coextruded into the pipe outside surface.

(3) Where black polyethylene compound and color polyethylene compound are used to extrude pipe with optional color stripes, coextruded into the outside surface, the black polyethylene compound and color polyethylene compound shall have been combined using the same natural compound.

(c) Pipe print line marking shall be applied during extrusion using heated indentation.

(d) Prior to shipment of the pipe, the purchaser may specify any testing requirements for the fusibility of the material per -2400 of this Case.

IV-132 Polyethylene Material — Flange Adapter

This section provides requirements for polyethylene material — flange adapters. Prior to shipment of the flange adapter, the purchaser may specify any testing requirements for the fusibility of the material per -2400 of this Case.

IV-132.1 Polyethylene Material — Machined Flange Adapter. The polyethylene material used to fabricate flange adapters that are machined from pipe shall meet the requirements of IV-131.

IV-132.2 Polyethylene Material — Molded Flange Adapter. This section provides requirements for molded-to-size flange adapters and molded flange adapters that are machined-to-size. The polyethylene compound used to manufacture molded flange adapters shall meet the requirements of IV-121 and shall be manufactured in accordance with this Case.

IV-140 GENERAL REQUIREMENTS FOR QUALITY TESTING AND DOCUMENTATION

(a) Through its Quality Assurance Program, the Polyethylene Source Material Manufacturer shall ensure that polyethylene compound is certified in accordance with IV-121.

(b) The requirements of this Mandatory Appendix provide for polyethylene material that is in accordance with the design requirements of this Case.

(c) Acceptance of individual lots of polyethylene source material shall be in accordance with IV-141.

IV-141 Certificate of Analysis

The following contains requirements for Certificate of Analysis and related traceability documentation.

IV-141.1 Polyethylene Compound.

(a) Polyethylene compound shall be qualified per IV-121.

(b) The Polyethylene Compound Manufacturer shall test polyethylene compound in accordance with Table IV-141.1 and shall provide a Certificate of Analysis (C of A) and related traceability documentation to the purchaser of the lot.

(c) The Certificate of Analysis Report shall provide the certified test results in accordance with Table IV-141.1

(d) The Certificate of Analysis Report or related traceability documentation shall provide the following information:

(1) the name of the Polyethylene Compound Manufacturer

(2) the manufacturing location

(3) a code or number that is unique and specific to the lot

(4) the Polyethylene Compound Manufacturer's trade name for the polyethylene compound as published in PPI TR-4

(5) the shipping method or type of container*(s)* for the lot such as railcar or boxes and additional information such as a railcar number if shipped by rail or the name of the commercial carrier and number of boxes if shipped by commercial carrier

(6) the lot quantity of polyethylene compound in pounds or kilograms

(7) the date of shipment

(8) other information that identifies the purchaser (customer), purchaser order, purchaser contact, purchaser delivery location, and contact information for the Polyethylene Compound Manufacturer

(9) if applicable, the Quality System Program statement information per NCA-3974.4

IV-141.2 Natural Compound.

(a) The Natural Compound Manufacturer shall test natural compound in accordance with Table IV-141.2. The Natural Compound Manufacturer shall provide a Certificate of Analysis and related traceability documentation to the purchaser of the lot.

(b) The Certificate of Analysis report shall provide the certified test results in accordance with Table IV-141.2.

(c) The Certificate of Analysis report or related traceability documentation shall provide the following information:

(1) the name of the Natural Compound Manufacturer

(2) the manufacturing location

(3) a code or number that is unique and specific to the lot

(4) the Natural Compound Manufacturer's trade name for the natural compound

(5) the shipping method or type of container(s) for the lot such as railcar or boxes and additional information such as a railcar number if shipped by rail or the name of the commercial carrier and number of boxes if shipped by commercial carrier

(6) the lot quantity of natural compound in pounds or kilograms

(7) the date of shipment

(8) other information that identifies the purchaser (customer), purchaser order, purchaser contact, delivery location, and contact information for the Natural Compound Manufacturer

(9) if applicable, the Quality System Program statement information per NCA-3974.4

IV-141.3 Pigment Concentrate Compound.

(a) The Pigment Concentrate Compound Manufacturer shall test pigment concentrate compound in accordance with Table IV-141.3. The Pigment Concentrate Compound Manufacturer shall provide a Certificate of Analysis report and related traceability documentation to the purchaser of the lot.

(b) The Certificate of Analysis report shall provide the certified test results for the lot in accordance with Table IV-141.3.

(c) The Certificate of Analysis report or related traceability documentation shall provide the following information:

(1) the name of the Pigment Concentrate Compound Manufacturer

(2) the manufacturing location

(3) a code or number that is unique and specific to the lot

(4) the Pigment Concentrate Compound Manufacturer's trade name for the pigment concentrate compound

(5) the shipping method or type of container(s) for the lot such as railcar or boxes and additional information such as a railcar number if shipped by rail or the name of the commercial carrier and number of boxes if shipped by commercial carrier

(6) the lot quantity of pigment concentrate compound in pounds or kilograms

(7) the date of shipment

(8) other information that identifies the purchaser (customer), purchaser order, purchaser contact, delivery location, and contact information for the Pigment Concentrate Compound Manufacturer

(9) if applicable, the Quality System Program statement information per NCA-3974.4

IV-142 Certified Polyethylene Test Report for Polyethylene Material — Pipe

(a) The Polyethylene Material Manufacturer — Pipe shall certify the Certificate of Analysis report values by testing a sample from the polyethylene source material lot in accordance with Table IV-142.1. The polyethylene source material lot shall not be used when certification testing does not verify Certificate of Analysis report values.

(b) The Polyethylene Material Manufacturer — Pipe shall test pipe in accordance with Table IV-142.2 and shall provide a Certified Polyethylene Test Report (CPTR) to the purchaser.

(c) The Certified Polyethylene Test Report (CPTR) shall provide the following per lot:

(1) certified test results for the lot in accordance with IV-142(a) and IV-142(b)

(2) the name of the Polyethylene Material Manufacturer

(3) the manufacturing location

(4) a code or number that is unique and specific to the lot

(5) the ASTM standard for pipe manufacture

(6) the specification for the polyethylene compound, e.g., Code Case N-755, Mandatory Appendix IV

(7) the shipping method and the name of the commercial carrier

(8) the lot quantity in feet or meters

(9) the date of shipment

(10) other information that identifies the purchaser (customer), purchaser order, purchaser contact, delivery location, and contact information for the Polyethylene Material Manufacturer

(11) a certification that the polyethylene material was made from only virgin polyethylene source material, and that no scrap or regrind polyethylene material was used (see NCA-3974.3)

(12) slow crack growth resistance greater than 2000 hr per ASTM F1473 completed on a compression molded plaque at 2.4 MPa and 80°C per Table IV-121 for the polyethylene compound

(13) if applicable, the Quality System Program statement information per NCA-3974.4

IV-143 Minimum Quality Testing Requirements for Polyethylene Material — Molded Flange Adapters

(a) The Polyethylene Material Manufacturer — Molded flange adapters shall certify the Certificate of Analysis report values by testing a sample from the polyethylene source material lot in accordance with Table IV-142.1. The polyethylene source material lot shall not be used when certification testing does not verify the Certificate of Analysis report values.

(b) The Certified Polyethylene Test Report (CPTR) shall provide the following per lot:

(1) certified test results for the lot in accordance with IV-143*(a)*

(2) the name of the Polyethylene Material Manufacturer

(3) the manufacturing location

(4) a code or number that is unique and specific to the lot

(5) the specification for the polyethylene compound, e.g., Code Case N-755, Mandatory Appendix IV

(6) the shipping method and the name of the commercial carrier

(7) the lot quantity in pieces

(8) the date of shipment

(9) other information that identifies the purchaser (customer), purchaser order, purchaser contact delivery location, and contact information for the polyethylene material manufacturer

(10) a certification that the polyethylene material was made from only virgin polyethylene material, and that no scrap or regrind polyethylene material was used (see NCA-3974.3)

(11) a certification that the flange adapter is void free (see -2220)

(12) slow crack growth resistance greater than 2000 hr per ASTM F1473 completed on a compression molded plaque at 2.4 MPa and 80°C in Table IV-121 for the polyethylene compound

(13) if applicable, the Quality System Program statement information per NCA-3974.4

Table IV-121
Certification Requirements for Polyethylene Compound

No.	Property, Units	Required Value	Requirement Standard	Test Method
1	Density, g/cm^3	(a) 0.956 to 0.968 w/2 to 3% carbon black (b) 0.947 to 0.955 w/o carbon black or pigment	ASTM D3350	ASTM D1505 or ASTM D792 or ASTM D4883
2	High load melt flow rate, g/10 min.	4 to 20	Polyethylene Compound Manufacturer Quality Program	ASTM D1238, Condition 190/21.6
3	Carbon black, %	2 to 3	ASTM D3350 and Table IV-121	ASTM D4218 or ASTM D1603

Table IV-121
Certification Requirements for Polyethylene Compound (Cont'd)

No.	Property, Units	Required Value	Requirement Standard	Test Method
4	Slow Crack growth resistance, hr	> 2,000	ASTM D3350	ASTM F1473 at 2.4 MPa and 80°C in air
5	Thermal stability, °F (°C)	> 428 (> 220)	ASTM D3350	ASTM D3350
6	Tensile strength at yield, psi (MPa)	≥ 3,500 (≥ 24.14)	ASTM D3350	ASTM D638, Type IV at 50 mm/min (2 in./min)
7	Tensile elongation at break, %	≥ 500	ASTM D3350	ASTM D638, Type IV at 50 mm/min (2 in./min)
8	HDB at 73°F (23°C), psi (MPa)	1,600 (11.03)	ASTM D2837, PPI TR-3 and PPI TR-4	ASTM D2837, PPI TR-3 and PPI TR-4
9	HDB at 140°F (60°C), psi (MPa)	1,000 (6.90)	ASTM D2837, PPI TR-3 and PPI TR-4	ASTM D837, PPI TR-3 and PPI TR-4
10	HDS for water at 73°F (23°C), psi (MPa)	1,000 (6.90)	ASTM D2837, PPI TR-3 and PPI TR-4	ASTM D837, PPI TR- 3 and PPI TR-4
11	Thermoplastic pipe materials designation code	PE4710	Listed in PPI TR-4	NA

GENERAL NOTE: Only SI units are provided in Tables IV-121, IV-141.1, IV-141.2, and IV-141.3, since the applicable ASTM standards do not provide U.S. Customary units.

Table IV-141.1
Minimum Quality Testing Requirements for Polyethylene Compound Lots

No.	Test	Test Standard	Test Frequency	Test Timing	*C* of *A* Reports Test Result
1	High load melt flow rate, Condition 190/21.6, g/10 min.	ASTM D1238 and Table IV-121	Once per lot	NA	Yes
2	Density	ASTM D792 or ASTM D1505 or ASTM D4883 and Table IV-121	Once per lot	Before lot shipment	Yes
3	Tensile strength at yield and tensile elongation	ASTM D638 and Table IV-121	Once per lot	Before lot shipment	Yes
4	Thermal stability	ASTM D3350 and Table IV-121	Once per lot	Before lot shipment	Yes
5	Carbon black content	ASTM D1603 or ASTM D4218 and Table IV-121	Once per lot	Before lot shipment	Yes

Table IV-141.2
Minimum Quality Testing Requirements for Natural Compound Lots

No.	Test	Test Standard	Test Frequency	Test Timing	*C* of *A* Reports Test Result
1	High load melt flow rate, Condition 190/21.6, g/10 min.	ASTM D1238	Once per lot	NA	Yes
2	Density	ASTM D792 or ASTM D1505 or ASTM D4883 and Table IV-121	Once per lot	Before lot shipment	Yes
3	Tensile strength at yield and tensile elongation	ASTM D638	Once per lot	Before lot shipment	Yes
4	Thermal stability	ASTM D3350	Once per lot	Before lot shipment	Yes

Table IV-141.3
Minimum Quality Testing Requirements for Pigment Concentrate Compound Lots

No.	Test	Test Standard	Test Frequency	Test Timing	*C* of *A* Reports Test Result
1	Carbon black content (black only)	ASTM D1603 or ASTM D4218	Every 24 hr during lot production	Every 24 hr after acceptable product has been produced for given production lot.	Yes
2	Color and UV stabilizer (color only)	ASTM D3350	Every 24 hr during lot production	Every 24 hr after acceptable product has been produced for given production lot.	Yes

Table IV-142.1
Minimum Quality Testing Requirements for Polyethylene Source Material

No.	Test	Test Standard	Test Frequency	CPTR Reports Test Results
1	High load melt flow rate, Condition 190/21.6, g/10 min.	ASTM D1238 [Ref: IV-142 (a)]	Once per lot upon receipt at the processing facility	Yes
2	Density	ASTM D792 or ASTM D1505; [Ref: IV-142 (a)] and Table IV-121	Once per lot upon receipt at the processing facility	Yes
3	Carbon black concentration percentage for black polyethylene compound or black pigment concentrate compound	ASTM D1603 or ASTM D4218 [Ref: IV-142 (a)]	Once per lot upon receipt at the processing facility	Yes
4	Slow crack growth resistance, hr [Note (1)]	Greater than 2,000 hr per ASTM F1473 completed on a compression molded plaque at 2.4 MPa and 80°C in Table IV-120	Once per lot prior to shipment of polyethylene material	Yes
5	Thermal stability [Note (1)]	Greater than 428°F (220°C) ASTM D3350 and Table IV-121	Once per lot prior to shipment of polyethylene material	Yes

NOTE:
(1) In no case shall any individual test result, used to establish this value in accordance with the reference industry standards be less than the minimum required value listed in this table.

Table IV-142(b)
Minimum Quality Testing Requirements for Polyethylene Material — Pipe

No.	Test/Requirement	Manufacturing Standard/ Acceptance Criteria	Test Method	Test Frequency	CPTR Reports Test Results
1	Workmanship	< 3 in. IPS (DN 80) — ASTM D3035; ≥3 in. IPS (DN 80) — ASTM F714	N/A	Hourly or once per length, whichever is less frequent during ongoing production	Yes
2	Outside diameter	< 3 in. IPS (DN 80) — ASTM D3035; ≥ 3 in. IPS (DN 80) — ASTM F714	ASTM D2122 [Note (1)]	Hourly or once per length, whichever is less frequent during ongoing production	Yes
3	Toe-In	< 3 in. IPS (DN 80) — ASTM D3035; ≥ 3 in. IPS (DN 80) — ASTM F714	ASTM D2122 [Note (1)]	Once per shift during ongoing production	Yes
4	Wall thickness	< 3 in. IPS (DN 80) — ASTM D3035; ≥ 3 in. IPS (DN 80) — ASTM F714	ASTM D2122 [Note (1)]	Hourly or once per length, whichever is less frequent during ongoing production	Yes
5	Short term strength	< 3 in. IPS (DN 80) — ASTM D3035; ≥ 3 in. IPS (DN 80) — ASTM F714	ASTM D1599 or ASTM D2290	At the beginning of production and weekly thereafter during ongoing production	Yes
6	Carbon black content	IV-131(b)	ASTM D1603 or ASTM D4218	At the beginning of production and weekly thereafter during ongoing production	Yes

NOTE:
(1) Sample conditioning shall be as specified in ASTM D3035 or ASTM F714, as applicable.

NONMANDATORY APPENDIX A
FUSION MACHINE OPERATOR QUALIFICATION TRAINING

A-100 SCOPE

(a) The major portion of the quality of PE piping systems is determined by the skills of the fusion machine operators. When installing polyethylene (PE) piping, the quality of the fusion joints is essential for the piping system.

(b) It is important that the fusion machine operators are trained and competent in the fusion technology employed in constructing PE piping systems. Continued competence of the fusion operator is covered by periodic retraining and reassessment.

(c) This document gives guidance for the training, assessment and approval of fusion operators in order to establish and maintain competency in construction of polyethylene piping systems for pressure applications. The fusion joining technique covered by this Nonmandatory Appendix is butt fusion. This Nonmandatory Appendix covers both the theoretical and practical knowledge necessary to ensure high quality fusion joints.

A-110 REFERENCES

The fusion standards in this Nonmandatory Appendix are listed Table A-110-1.

A-200 TRAINING

A-210 TRAINING COURSE

(a) A trainee fusion operator for PE systems should follow a training course in order to obtain a fusion operator certificate for PE pipes. The course should cover all aspects of the butt fusion process including safety, machine evaluation and maintenance, machine operation, FPS guidelines, pressure and temperature setting, data log device operation and set-up, in-ditch fusion techniques, visual examination guidance, and data log record evaluation. The minimum course duration is 24 hr.

(b) The course will be delivered by a competent qualified trainer with a minimum of 3 yr of experience in the butt fusion processes and who has mastered the techniques involved.

(c) The trainer should have a range of fusion machines representative of the equipment encountered on worksites for installing pipes, in order for the trainee fusion operator to become acquainted with the fusion equipment commonly used. The trainee fusion operator may be trained on one of these fusion machines or on a machine from his own company if accepted by the training center. The fusion equipment must comply with the fusion machine manufacturer's specifications and/or ISO 12176-1, see Table A-110-1.

A-220 OPERATOR ASSESSMENT

The trainee fusion operator who has followed a training course as described above should then pass a theoretical and practical assessment in order to be qualified as a fusion operator for PE systems. The assessor should not be the trainer but should have the same assessment qualifications as the trainer shown above.

A-230 TRAINING CURRICULUM

(a) The training course should comprise of any combination of fusion packages based on the requirements of utility or pipeline operators. These packages may be given as individual modules or combined to suit requirements. The course shall include safety training related to the fusion process and equipment.

(b) All consumables and tools necessary for the training package should be available during the training session. The pipes and fittings to be used shall conform to the ASTM product forms permitted by this Nonmandatory Appendix.

(c) The lessons should be designed so that the trainee fusion operator learns to master the fusion technique and attains a good working knowledge of the piping system materials and practical problems encountered when fusing pipe in the field. The fusion operator should receive a written manual covering all the elements dealt with in the training.

(d) The theoretical course should deal with general information in connection with raw materials, pipes and fittings, and also with theoretical knowledge about preparation, tools, and devices, joining components, different materials, different diameter ratios and correct and incorrect parameters. The safety course should include information concerning the fusion process, such as protective clothing, general safety, regulations for electrical equipment, handling heater plates, etc. Areas of study should include but not be limited to the following:

(1) Butt fusion joining.

(-a) Principles of fusion.

(-b) Straight/coiled pipes, service lines, main lines, etc.

(-c) Components: pipes, flange adapters saddle fittings, other fittings.

(-d) Butt fusion equipment: manual, semi-automatic and automatic machines.

Table A-110-1
Fusion Standards and Specifications Referenced in Text

Standard ID	Published Title	Referenced Edition
American Society for Testing and Materials (ASTM)		
ASTM F2620	Standard Practice for Heat Fusion Joining of PE Pipe and Fittings	2009
International Organization for Standardization (ISO)		
ISO 1276-1	Plastic Pipes and Fittings — Equipment for Fusion Jointing Polyethylene Systems — Part 1: Butt Fusion	2006
ISO TR 19480	Thermoplastics Pipes and Fittings for the Supply of Gaseous Fuels or Water — Guidance for Training and Assessment of Fusion Operators	2005
Plastic Pipe Institute (PPI)		
PPI TR-33	Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe	2005

(-e) Joint preparation: cleaning, rounding, alignment, facing, etc.

(-f) Butt fusion cycle: pressure, time and temperature relationships, diagram.

(-g) Failure modes: understanding and avoiding possible screwups.

(-h) Test methods: visual examination, high speed tensile-impact test, bending test, hydrostatic test, data log recording/evaluation, etc.

(2) The trainee fusion operator should be familiar with the butt fusion joining technique and procedure (FPS) by making a sufficient number of butt fusion joints. In some cases, the fusion technique may vary slightly according to diameter, material or other factors. In such cases, the trainee fusion operator should also be made familiar with the various techniques.

(3) The trainee should start by making a butt joint between two pipes, and should then learn to make butt fusion joints with pipes and fittings such as tees, reducers, etc.

(4) The trainee should learn how to detect and avoid typical fusion defects.

(5) The trainee should learn how to assess the quality of a butt fusion joint by doing a visual examination of the butt fusion joint and comparing it to the visual guidelines published in the pipe manufacturer's heat fusion joining procedure booklet. The trainee should also compare the data log record to the FPS to ensure the proper parameters and procedures were followed in the butt fusion process.

A-300 ASSESSMENT AND TESTING

(a) Training program should end with a theoretical and practical examination (test piece).

(b) The content of the theoretical examination shall consist of not less than 20 multiple choice questions about the butt fusion process, fusion machine operation, pipe, quality examination, safety, etc. within a set period of time. A score of 80% or better is considered passing on this examination. Questions to be included but not limited to are:

- How do you calculate the fusion machine gauge pressure?
- What is the proper heater surface temperature range from the FPS?
- What is the proper butt fusion interfacial pressure range from the FPS?
- How do you calculate the drag pressure?
- How do you know when to remove the heater in the heating cycle?
- How long do you leave the pipe ends together under pressure in the cooling cycle?
- What is the difference between IPS pipe and DIPS pipe?
- How do I determine the hydraulic fusion machines total effective piston area?
- How is the total effective piston area of the fusion machine used to determine the fusion machines gauge pressure for a specific pipe?
- How do you adjust the machine to improve the alignment of the pipe after facing?
- How much material should be removed from the pipe ends in the facing operation?
- How do you determine if the fusion machine conforms to the equipment manufacturer's specifications?
- How do you align the pipe in the butt fusion machine?
- Can you butt fuse pipe in a ditch?
- What is interfacial pressure?

(c) The practical examination will require the trainee fusion operator to make a fusion joint with a hydraulic butt fusion machine with a minimum pipe size of 6 in. IPS DR 11. A data acquisition device must be attached to the fusion machine and the data concerning the joint entered. The data log device shall be used to record the joint made by the trainee. The assessor shall observe

the butt fusion joint and note if the proper procedure (FPS) was followed. After the joint is complete, the data log record shall be reviewed by the assessor and compared to the FPS to ensure the proper procedures were followed. The assessor will then conduct a visual examination of the joint to make sure it satisfies the pipe manufacturers recommended visual guidance criteria per I-121 of this Nonmandatory Appendix.

(d) If a data log device is not available, the assessor will manually record the butt fusion parameters used in the butt fusion process. This should be compared with the FPS to ensure they agree.

(e) Trainee fusion operators who pass the theoretical and practical examination would receive a fusion operator certificate bearing the logo of the assessment center awarding the approval. The fusion operator certificate should state the technique or techniques and fusion machines for which the operator is qualified.

A-400 REASSESSMENT

If the trainee fails one of the examinations, he should retake it after a period not shorter than one week. If the trainee fails the examination for the second time, the trainee should repeat the training course before taking the test again.

NONMANDATORY APPENDIX B
DATA ACQUISITION LOG REVIEW

Review both the recorded log information and the pressure/time graph to evaluate if the proper procedure was followed. The following examples are shown to assist in this evaluation:

(a) Recorded Data Log Information Correct Procedure. (No Errors) all job information entered. Fuse interfacial pressure in range (between 60 psi to 90 psi) heater surface temperature in range (between 400°F to 450°F).

Job Information		
1.	Date and Time:	01/11/05 03:15:06 PM
2.	Joint Number:	4
3.	Job Number:	XYZ
4.	Employee No:	56
5.	Machine I.D.:	28
6.	Machine Model:	MMI 28 Combo
7.	Piston Area:	4.71 in 2
8.	Pipe Material:	Perf. Pipe PE 3408
9.	Pipe Size:	8 in. IPS DR 17
Interfacial Pressures		
12.	Heat:	0 psi
13.	Soak:	...
14.	Fuse:	75 psi
15.	Cool:	...
Recommended Gauge Pressures		
18.	Heat:	30 psi
19.	Soak:	...
20.	Fuse:	236 psi
21.	Cool:	...
Recorded Data		
24.	Drag Pressure:	30 psi
25.	Data Logger Probe:	426°F
26.	External Probe:	

(b) Incorrect Procedure. The following are in error:

(1) Fuse interfacial pressure out of range (60 psi to 90 psi).

(2) Heater surface temperature out of range(400°F to 450°F).

Job Information		
1.	Date and Time:	01/11/05 03:15:06 PM
2.	Joint Number:	4
3.	Job Number:	XYZ
4.	Employee No:	56
5.	Machine I.D.:	28
6.	Machine Model:	MMI 28 Combo
7.	Piston Area:	4.71 in 2
8.	Pipe Material:	PolyPipe PE 3408
9.	Pipe Size:	8 in. IPS DR 17
Table continued		
Job Information		
Interfacial Pressures		
12.	Heat:	0 psi
13.	Soak:	...
14.	Fuse:	50 psi
15.	Cool:	...
Recommended Gauge Pressures		
18.	Heat:	30 psi
19.	Soak:	...
20.	Fuse:	195 psi
21.	Cool:	...
Recorded Data		
24.	Drag Pressure:	30 psi
25.	Data Logger Probe:	475°F
26.	External Probe:	

(c) Incorrect Procedure. (Errors) parameters in the proper range but important job information missing: joint number, employee number, and piston area (see Fig. B-3).

Job Information		
1.	Date and Time:	01/11/05 03:15:06 PM
2.	Joint Number:	
3.	Job Number:	XYZ
4.	Employee No:	
5.	Machine I.D.:	28
6.	Machine Model:	MMI 28 Combo
7.	Piston Area:	
8.	Pipe Material:	PolyPipe PE 3408
9.	Pipe Size:	8 in. IPS DR 17
Interfacial Pressures		
12.	Heat:	0 psi
13.	Soak:	...
14.	Fuse:	90 psi
15.	Cool:	...
Recommended Gauge Pressures		
18.	Heat:	30 psi
19.	Soak:	...
20.	Fuse:	195 psi
21.	Cool:	...
Recorded Data		
24.	Drag Pressure:	30 psi
25.	Data Logger Probe:	400°F
26.	External Probe:	

(d) Pressure/Time Graph Evaluation. No Errors (see Fig. B-1).

(1) P1: *Drag Pressure.* Fusion machine mechanical drag plus pipe drag. Pressure may drop to (0) psi during soak cycle (psi gauge).

(2) P2: *Fusing Pressure.* Calculated machine fusion gauge pressure plus drag pressure.

(3) T1: *Initial Heater Contact Time at Fusion Pressure.* Time required to observe an indication of melt around the pipe circumference.

(4) T2: *Heat Soak Time.* Time required to develop the size of melt bead against the heater specified in the procedure.

(5) T3: *Heater Removal Time.* Time required to open the fusion machine, remove the heater and bring the pipe ends together at fusion pressure. The time must not exceed the time in the specification.

(6) T4: *Cool Time.* Time required to cool the joint at fusion gauge pressure. This must be 30 in./s to 90 in./s of pipe diameter. Use 90 in./s of pipe diameter for any pipe diameter with a wall thickness greater than 1.50 in.

(e) Correct Procedure. The following requirements apply (see Fig. B-2):

(1) Review if P1 and P2 recorded gauge pressures agree with the specified fusion procedure. P2 can drop to zero during the heat soak cycle.

(2) Review if P2 is maintained for 30 in./s to 90 in./s of pipe diameter during the fuse/cool cycle.

(3) On large diameter, heavy wall pipe, it sometimes takes several minutes to see an indication of melt around the cirfumference of the pipe, so the initial contact time against the heater at fusion gauge pressure is usually longer than normal. Make sure the heat soak time is longer than the initial contact time.

Figure B-1
Typical Time/Pressure Diagram of a Butt Fusion Joint

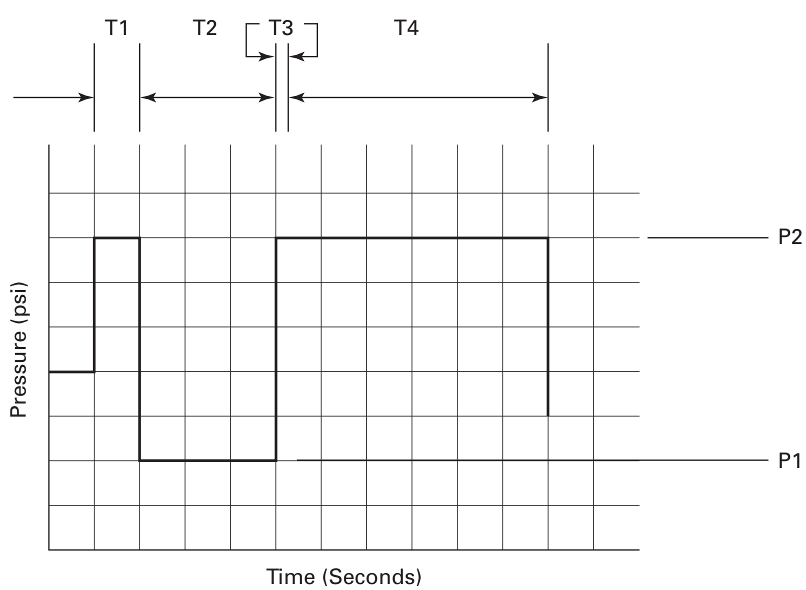


Figure B-2
Correct Procedure

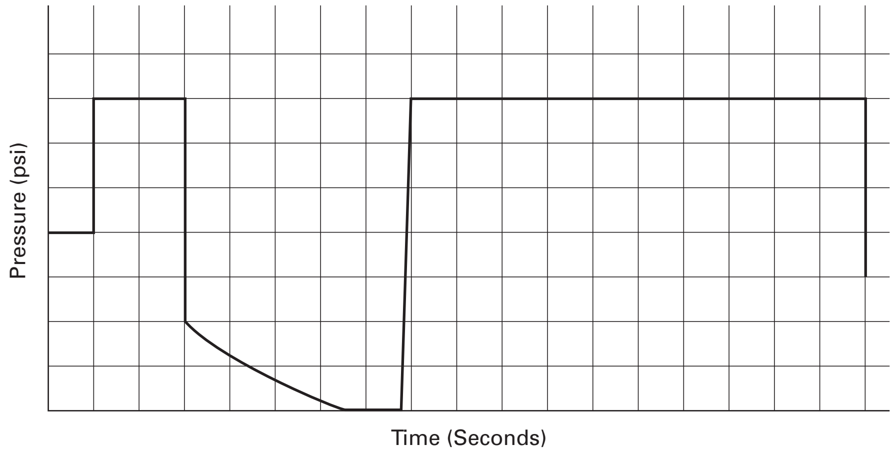
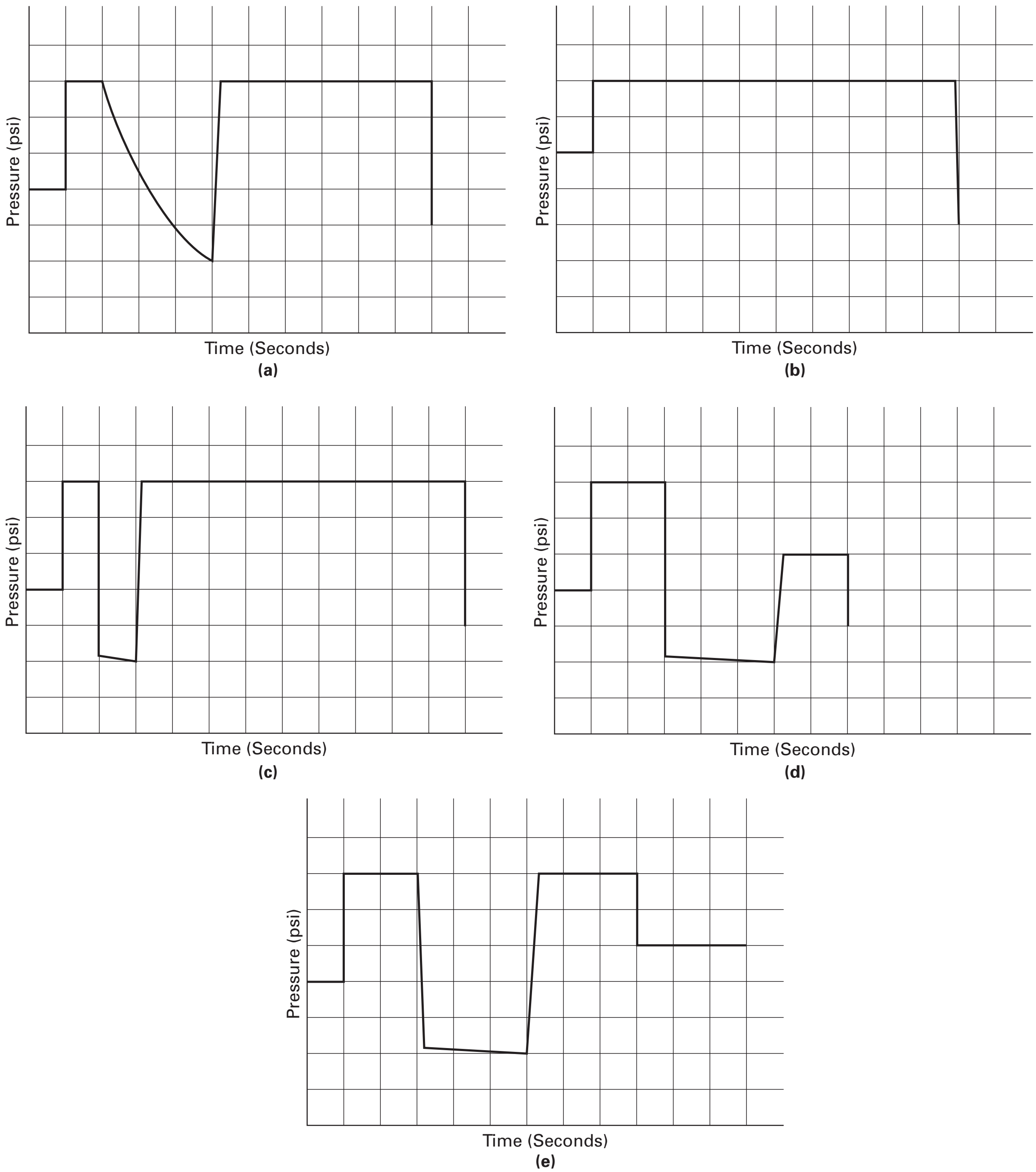


Figure B-3
Incorrect Procedures

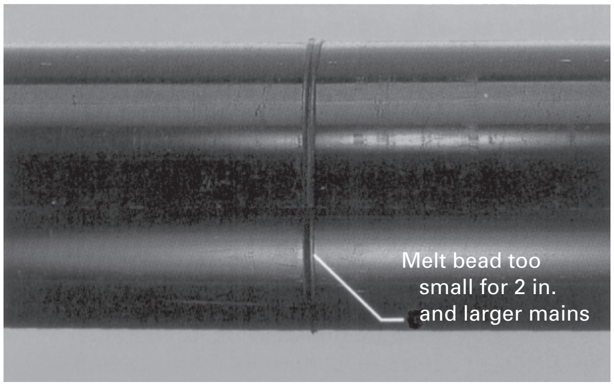


GENERAL NOTES:
(a) No Heat Soak Time: Pressure not reduced at start of Heat Cycle.
(b) No Heat Soak Time: Pressure maintained during Heat Soak Cycle.
(c) Heat soak time is very short. Do a visual examination of the bead size to make sure it is within the butt fusion specifications.
(d) The specified fusion gauge pressure was not applied during the Fuse/Cool cyle. The Fuse/Cool Times does not appear long enough. Review specification.
(e) Fusion gauge pressure not maintained in the Fuse/Cool cycle for the time in the specification.

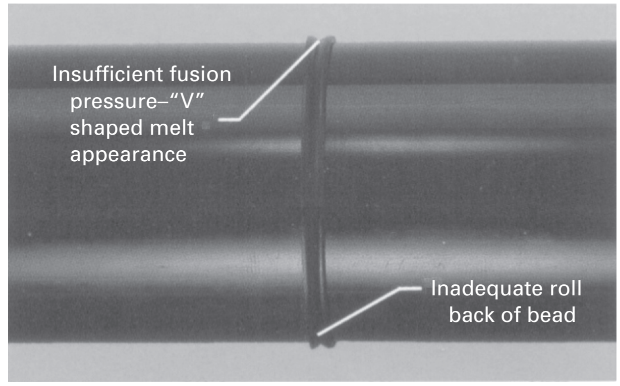
NONMANDATORY APPENDIX C
FUSION BEAD CONFIGURATION

This Nonmandatory Appendix contains pictures of critical attributes of the completed thermal fusion butt joints. These pictures may be used by personnel performing a visual examination on fusion beads. This figure (Figure C-1) is only to be used as a guide.

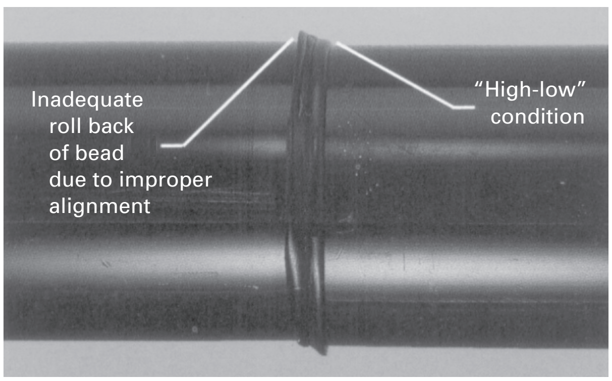
Figure C-1
Fusion Bead Configuration



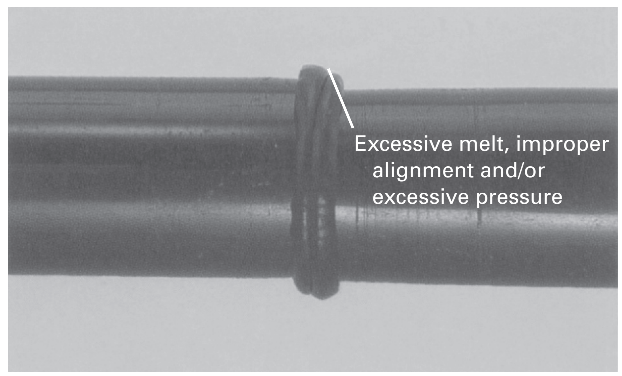
(a) Butt Fusion of Pipe
(Unacceptable appearance–insufficient melt)



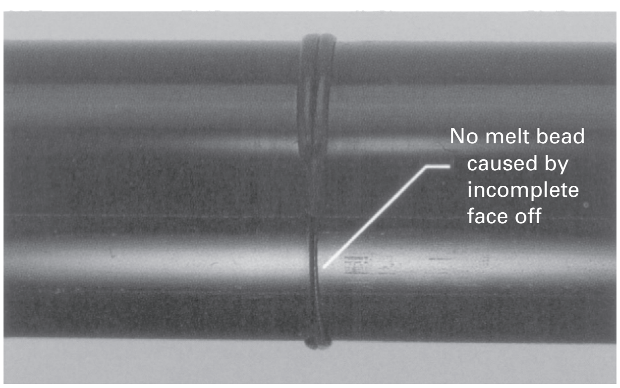
(b) Butt Fusion of Pipe
(Unacceptable appearance–inadequate roll back)



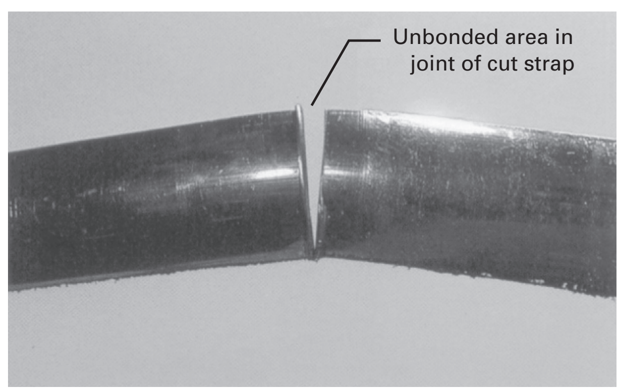
(c) Butt Fusion of Pipe
(Unacceptable appearance–improper alignment)



(d) Butt Fusion of Pipe
(Unacceptable appearance)



(e) Butt Fusion of Pipe
(Unacceptable appearance–incomplete face off)



(f) Butt Fusion of Pipe
(Unacceptable appearance–incomplete face off)

NONMANDATORY APPENDIX D
NONMANDATORY SEISMIC ANALYSIS METHOD

The buried pipe may be qualified by analysis for the effects of seismic wave passage, following the method provided in this Appendix.

Step 1. The strains from seismic wave passage, and seismically-induced permanent or temporary movements if any, shall be obtained by a plant-specific geotechnical civil investigation.

Step 2. The soil strains (see -3410) shall be converted into an equivalent temperature rise of the buried pipe, as follows:

$$\Delta T_{eq} = \frac{\epsilon_{\text{soil}}}{\alpha}$$

Step 3. The pipe soil system shall be modeled as a piping system constrained by soil springs.

(a) The pipe model shall consider two cases: short-term modulus (< 10 hr, Tables -3210-3(a) and -3210-3(b)) for wave passage and long term modulus for permanent soil movement (permanent seismic anchor motion).

(b) The soil model shall have at least a bi-linear stiffness, and shall consider two cases: upper and lower bound of soil stiffness.

For guidance on modeling soil pipe interaction, refer to ASCE and ASCE 4, see Table D-1

Step 4. The equivalent change of temperature ΔT_{eq} shall be applied to the pipe soil model, to obtain forces and moments throughout the system.

Step 5. The anticipated building seismic anchor movements, if any, shall be applied to the pipe soil model to obtain forces and moments throughout the system.

Step 6. The anticipated seismic movements, if any, shall be applied to the pipe soil model to obtain forces and moments throughout the system.

Step 7. The results of Steps 4, 5, and 6 shall be combined by SRSS, at each point along the piping system to obtain resultant forces and moments.

Step 8. The resultant forces and moments shall be evaluated as follows:

(a) The axial stresses in pipe, fittings, and fused joints shall comply with the requirements of -3410.

(b) Alternatively, the seismic induced strain shall be determined as follows:

$$(\epsilon_a)_{\text{Earthquake}} = \left[\left|\left[\sigma_E\right| + \left|v(PD/2t)\right|\right]/E$$

This strain, $(\varepsilon_a)_{\text{Earthquake}}$ shall be limited to the values listed in Table D-2, where k is defined in Table -3223-2.

Table D-1
Standards and Specifications Referenced in Text

Standard ID	Published Title	Referenced Edition
American Society of Civil Engineers (ASCE)		
ASCE	Guidelines for the Seismic Design of Oil and Gas Pipeline Systems,	1984
ASCE 4	Seismic Analysis of Safety-Related Nuclear Structures and Commentary, or American Lifelines Alliance, Guidelines for the Design of Buried Steel Pipes	2001 with the 2005 Addenda

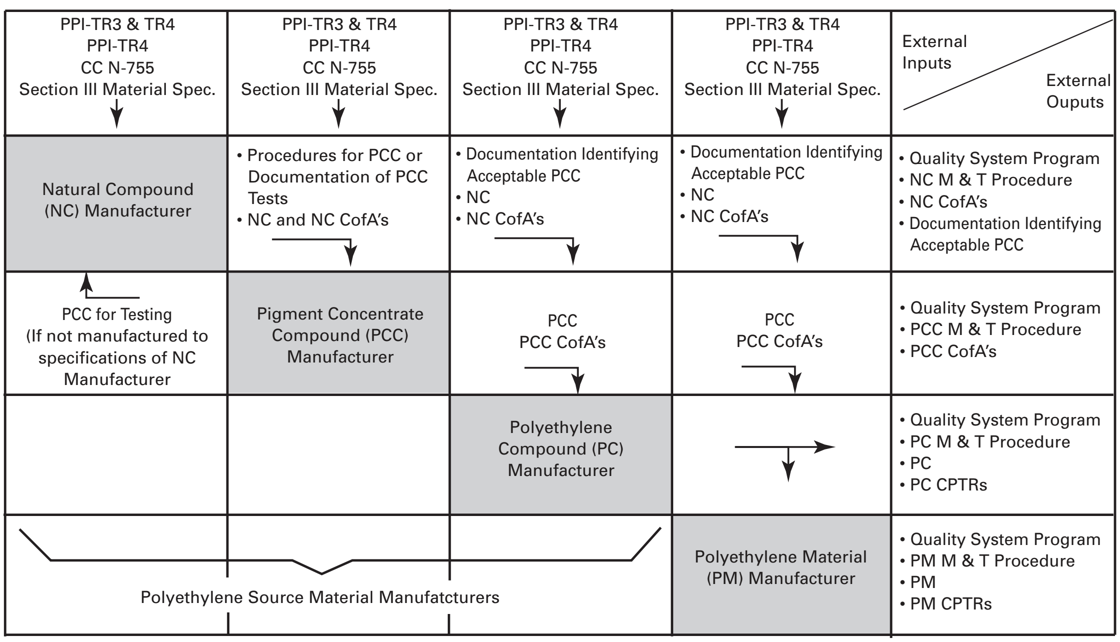
Table D-2
Seismic Strain Limits

DR	Allowable Strain
$DR \leq 13.5$	0.025 × k
$13.5 < DR \leq 21$	0.020 × k
$DR > 21$	0.017 × k

NONMANDATORY APPENDIX E
POLYETHYLENE MATERIAL ORGANIZATION RESPONSIBILITIES DIAGRAM

This Nommandatory Appendix contains Figure E-1 depicting inputs and outputs that govern activities of Polyethylene Material Organization.

Figure E-1
Polyethylene Material Organization Responsibilities per NCA-3970



GENERAL NOTES:
(a) This figure depicts the following:
   (1) external inputs (top row) that govern activities of Polyethylene Material Organizations.
   (2) outputs from one Polyethylene Material Organization that are as follows:
      (a) either inputs to other Polyethylene Material Organizations
      (b) or are external outputs in the form of products or quality documentation
(b) The definitions are as follows:
   (1) C of A = Certificate of Analysis
   (2) CPTR = Certified Polyethylene Test Report
   (3) M & T = Manufacturing & Testing
   (4) Polyethylene Source Material Manufacturer = Natural Compound Manufacturer, Pigment Concentrate Compound Manufacturer, or Polyethylene Compound Manufacturer
(c) Polyethylene material supplier and polyethylene service suppliers are not shown.

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Approval Date: January 21, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-756
Alternative Rules for Acceptability for Class 1 Valves, NPS 1 (DN 25) and Smaller With Nonwelded End Connections Other Than Flanges
Section III, Division 1

Inquiry: Under what rules may instrument, control, and sampling line valves, NPS 1 (DN 25) and smaller, with nonwelded piping end connections other than flanges, be designed in accordance with the alternative provisions of NB-3513.2?

Reply: It is the opinion of the Committee that instrument, control, and sampling line valves, NSP 1 (DN 25) and smaller, with nonwelded piping end connections other than flanges, may also be designed in accordance with the alternative provisions of NB-3512.2(d) for weld end valves, provided the following requirements are met:

(a) The end connections shall meet the requirements of NB-3671.3 or NB-3671.4.

(b) The design shall be qualified in accordance with the requirements of MSS-SP-105-2005, Section 5.

(c) Valve bonnets threaded directly into valve bodies shall have a lock weld or locking device that assures the assembly does not disengage either through stem operation or vibration.

(d) This Case number shall be identified on the NPV-1 Data Report Form.

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Approval Date: September 21, 2007

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-757-1
Alternative Rules for Acceptability for Class 2 and 3 Valves, NPS 1 (DN 25) and Smaller With Welded and Nonwelded End Connections Other Than Flanges
Section III, Division 1

Inquiry: Under what rules may instrument, control and sampling line valves, NPS 1 (DN 25) and smaller, with welded and nonwelded end connections other than flanges, meet the design requirements of Section III, Division 1, Class 2 and 3 rules of NC-3512 and ND-3512, when the valve minimum wall thickness does not meet the requirements of ASME B16.34?

Reply: It is the opinion of the Committee that instrument, control, and sampling line valves, NPS 1 (DN 25) and smaller, having valve minimum wall thickness not in accordance with ASME B16.34, with welded and nonwelded end connections other than flanges, may meet the design requirements of Section III, Division 1, Class 2 and 3 rules of NC-3512 and ND-3512, provided the following additional requirements are met:

(a) Valves not meeting the wall thickness requirements of ASME B16.34, shall meet the pressure design rules of NC-3324 and ND-3324; an experimental stress analysis (Section III, Division 1, Appendix II); or Design Based on Stress Analysis (Section III, Division 1, Appendix XIII); and the design shall be qualified in accordance with the requirements of MSS-SP-105-2005, Section 5.

(b) The end connections shall meet the requirements of NC-3661 and ND-3661, NC-3671.3 or ND-3671.4, for welded, threaded, and flared, flareless and compression type fittings tube ends.

(c) Valve loadings including, but not limited to operation, closure, and assembly, shall be accounted for by one of the following methods: experimental stress analysis (Appendix II) or Design Based on Stress Analysis (Appendix XIII).

(d) All valves shall meet the requirements of NC-3521, ND-3521.

(e) Valve bonnets threaded directly into valve bodies shall have a lock weld or locking device to assure that the assembly does not disengage either through stem operation or vibration.

(f) This Case number shall be identified on the NPV-1 Data Report Form.

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Approval Date: January 4, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-759-2
Alternative Rules for Determining Allowable External Pressure and Compressive Stresses for Cylinders, Cones, Spheres, and Formed Heads, Class 1, 2, and 3 Section III, Division 1

Inquiry: May alternative rules for determining allowable external pressure and compressive stresses for cylinders, cones, spheres, and formed heads be used for the design of these components in lieu of the rules of Section III, Division 1, NB-3133, NC-3133, ND-3133, and Appendix XXII?

Reply:

(a) It is the opinion of the Committee that cylinders, cones, spheres, and formed heads for pressure vessels otherwise designed and constructed in accordance with the rules of Section III, Division 1, NB-3133, NC-3133, ND-3133, and Appendix XXII, may be designed using the following rules for calculation of allowable external pressure and compressive stresses in lieu of the rules stated in the Inquiry above.

(b) When used, this Case shall be made applicable to the entire vessel.

(c) This Case number shall be shown on the Manufacturer's Data Report.

1 SCOPE, DESIGN, METHOD, AND NOMENCLATURE

1.1 Scope. This Case provides alternative rules to those given in Section III, Division 1, NB-3133, NC-3133, ND-3133, and Appendix XXII, for determining allowable compressive stresses for unstiffened and ring stiffened circular cylinders and cones, and for unstiffened spherical, ellipsoidal, and torispherical heads. The allowable stress equations are based upon theoretical buckling equations that have been reduced by knockdown factors and by plasticity reduction factors that were determined from tests on fabricated shells. (Nomenclature is provided in 1.4.)

This Case expands the coverage of load conditions and shell geometries, and includes equations for combinations of loads not considered in the Code paragraphs referenced above. These alternative rules are applicable to D_o/t ratios not exceeding 2,000, compared to the D_o/t = 1,000 limit in Fig. G in Subpart 3 of Section II, Part D. The slenderness limit for these rules is $KL_u/r \le 200$. Use of these alternative rules assumes the shell section to be axisymmetric with uniform thickness for unstiffened cylinders and formed heads. Stiffened cylinders and cones are also assumed to be of uniform thickness between stiffeners. Where nozzles with reinforcing plates or locally thickened shell sections exist, use the thinnest uniform thickness in the applicable unstiffened or stiffened shell section for calculation of allowable compressive stress.

The maximum temperature permitted for use of this Case cannot exceed the maximum temperature permitted in Section III, Subsection NB, NC, and ND, or Table 1. In Class 1 applications, all references to Subsections NC and ND should be ignored. In Class 2 applications, all references to Subsections NB and ND should be ignored. In Class 3 applications, all references to Subsections NB and NC should be ignored.

1.2 Buckling Design Method. The buckling strength formulations presented in this Case are based on classical linear theory with simple support boundary conditions and Poisson's ratio of 0.3. The differences between elastic stresses obtained for buckling tests on fabricated shells and the theoretical buckling stresses are accounted for by knockdown factors. These factors are equivalent to the ratio of strain in a fabricated shell at buckling stress and the strain corresponding to the theoretical buckling stress. The design equations apply to shells with initial imperfections within the specified fabrication tolerances of 7 and 8.3.

The design of cylinders and cones for compressive loads is an iterative procedure. The first step in the design process is to assume a shell geometry and thickness and calculate the resulting stresses from dead and live (including pressure) loads. The next step is to calculate the allowable stresses for individual load cases and substitute these values into interaction equations for combined load cases. The shell thickness or geometry can be adjusted to give the desired agreement between applied and allowable stresses.

Table 1
Material Specifications

Material	Maximum Temperature
Aluminum and Aluminum Alloys	300°F (149°C)
Copper and Copper Alloys	150°F (66°C)

The next step is to determine the stiffener sizes if rings are used. The stiffener elements must satisfy the requirements of 6.4 to prevent local buckling of the stiffener.

Special consideration shall be given to ends of members (shell sections) or areas of load application where stress distribution may be in the inelastic range and localized stresses may exceed those predicted by linear theory. When the localized stresses extend over a distance equal to one half the length of a buckle node (approximately $1.2\sqrt{D_0 t}$), the localized stresses should be considered as a uniform stress around the full circumference. Additional stiffening may be required.

1.3 Geometry. Allowable stress equations are given for the following geometries:

(a) Unstiffened cylindrical, conical, and spherical shells

(b) Ring stiffened cylindrical and conical shells

(c) Unstiffened spherical, ellipsoidal, and torispherical heads

The cylinder and cone geometries are illustrated in Figures 1.4.1 and 1.4.3 and the stiffener geometries in Figure 1.4.4. The effective sections for ring stiffeners are shown in Figure 1.4.2. The maximum cone angle α shall not exceed 60 deg.

1.4 Nomenclature.

NOTE: The terms not defined here are uniquely defined in the sections in which they are first used. The word “hoop” used in this Case is synonymous with the term “circumferential.”

A = cross-sectional area of cylinder
= $\pi(D_o - t)t$, in.^{2} (mm^2)

A_F = cross-sectional area of a large ring stiffener that acts as a bulkhead, in.^{2} (mm^2)

A_S = cross-sectional area of a ring stiffener, in.^{2} (mm^2)

c = distance from neutral axis of cross-section to point under consideration, in. (mm)

D_e = outside diameter of assumed equivalent cylinder for design of cones or conical sections, in. (mm)

D_i = inside diameter of cylinder, in. (mm)

D_L = outside diameter at large end of cone, or conical section between lines of support, in. (mm)

D_o = outside diameter of cylinder, in. (mm)

D_S = outside diameter at small end of cone, or conical section between lines of support, in. (mm)

E = modulus of elasticity of material at design temperature, determined from the applicable material chart in Subpart 2 of Section II, Part D, ksi (MPa). The applicable material chart is given in Tables 1A and 1B, or Tables 2A and 2B, Subpart 1, Section II, Part D. Use linear interpolation for intermediate temperatures.

E_t = tangent modulus, ksi (MPa)

f_a = axial (longitudinal) compressive membrane stress resulting from applied axial load, Q, ksi (MPa)

F_{aha} = allowable axial compressive membrane stress of a cylinder due to axial compression load in the presence of hoop compression with $\lambda_c > 0.15$, ksi (MPa)

f_b = axial (longitudinal) compressive membrane stress resulting from applied bending moment, M, ksi (MPa)

F_{ba} = allowable axial compressive membrane stress of a cylinder due to bending moment, M, in the absence of other loads, ksi (MPa)

F_{bha} = allowable axial compressive membrane stress of a cylinder due to bending in the presence of hoop compression, ksi (MPa)

F_{ca} = allowable compressive membrane stress of a cylinder due to axial compression load with $\lambda_c > 0.15$, ksi (MPa)

F_{cha} = allowable axial compressive membrane stress of a cylinder due to axial compression load in the presence of hoop compression for $0.15 < \lambda_c < 1.2$, ksi (MPa). $F_{cha} = F_{aha}$ when $f_q = 0$.

f_h = hoop compressive membrane stress resulting from applied external pressure, P, ksi (MPa)

F_{ha} = allowable hoop compressive membrane stress of a cylinder or formed head under external pressure alone, ksi (MPa)

F_{hba} = allowable hoop compressive membrane stress of a cylinder in the presence of longitudinal compression due to a bending moment, ksi (MPa)

F_{he} = elastic hoop compressive membrane failure stress of a cylinder or formed head under external pressure alone, ksi (MPa)

F_{hva} = allowable hoop compressive membrane stress in the presence of shear stress, ksi (MPa)

F_{hxa} = allowable hoop compressive membrane stress of a cylinder in the presence of axial compression, for $\lambda_c \leq 0.15$, ksi (MPa)

f_q = axial (longitudinal) compressive membrane stress resulting from pressure load, Q_p, on end of cylinder, ksi (MPa)

F_{ta} = allowable stress in tension, from applicable table in Subpart 1 of Section II, Part D, ksi (MPa)

f_v = shear stress from applied loads, ksi (MPa)

F_{va} = allowable shear stress of a cylinder subjected only to shear stress, ksi (MPa)

F_{ve} = elastic shear buckling stress of a cylinder subjected only to shear stress, ksi (MPa)

F_{vha} = allowable shear stress of a cylinder subjected to shear stress in the presence of hoop compression, ksi (MPa)

f_x = $f_a + f_q$, ksi (MPa)

F_{xa} = allowable compressive membrane stress of a cylinder due to axial compression load with $\lambda_c \leq 0.15$, ksi (MPa)

F_{xe} = elastic axial compressive membrane failure (local buckling) stress of a cylinder in the absence of other loads, ksi (MPa)

F_{xha} = allowable axial compressive membrane stress of a cylinder in the presence of hoop compression for $\lambda_c \leq 0.15$, ksi (MPa)

F_y = yield strength of material at design metal temperature from applicable table in Subpart 1 of Section II, Part D, ksi (MPa)

FS = stress reduction factor or design factor

I = moment of inertia of full cross-section,

= $\pi R^3 t$, in.^{4}(mm^4)

I_s = moment of inertia of ring stiffener about its centroidal axis, in.^{4} (mm^4)

I_s' = moment of inertia of ring stiffener plus effective length of shell about centroidal axis of combined section, in.^{4} (mm^4)

$$= I_s + A_s Z_s^2 \frac{L_e t}{A_s + L_e t} + \frac{L_e t^3}{12}$$

K = effective length factor for column buckling; refer to 3.2 for further definition

$L_B, L_{B1}, L_{B2}, L_{B...}$ = length of cylinder between bulkheads or large rings designed to act as bulkheads, in. (mm)

L_c = axial length of cone or conical section, in. (mm) (see Figure 1.4.3)

L_e = effective length of shell, in. (mm) (see Figure 1.4.2)

L_F = one-half of the sum of the distances, L_B, from the centerline of a large ring to the next large ring or head line of support on either side of the large ring, in. (mm) (see Figure 1.4.1)

L_s = one-half of the sum of the distances from the center line of a stiffening ring to the next line of support on either side of the ring, measured parallel to the axis of the cylinder, in. (mm). A line of support is described in the definition for L (see Figure 1.4.1), in. (mm)

L_u = laterally unbraced (laterally unsupported) length of a cylindrical member that is subject to column buckling, in. (mm). This applies to supports for pressure vessels or pedestal type vessels. Stiffening rings are not points of support unless they are externally supported. (Refer also to additional explanation at the end of this nomenclature section.)

$L, L_1, L_2, L...$ = design length of unstiffened vessel section between lines of support or the total length of tube between tube sheets, in. (mm). A line of support is:

(a) a circumferential line on a head (excluding conical heads) at one-third the depth of the head from the head tangent line as shown on Figure 1.4.1

(b) a stiffening ring that meets the requirements of eq. 6.1(a)(6-1)

(c) a tubesheet

Lt = overall length of vessel as shown in Figure 1.4.1, in. (mm)

M = applied bending moment across the vessel cross-section, in.-kips (N-mm)

M_s = $L_s / \sqrt{R_o t}$

M_x = $L / \sqrt{R_o t}$

P = applied external pressure, ksi (MPa)

P_a = allowable external pressure in the absence of other loads, ksi (MPa)

Q = applied axial compression load, kips (N)

Q_p = axial compression load on end of cylinder resulting from applied external pressure, kips (N)

R = radius to centerline of shell, in. (mm)

R_c = radius to centroid of combined ring stiffener and effective length of shell, in. (mm)

= $R + Z_c$

R_o = radius to outside of shell, in. (mm)

r = radius of gyration of cylinder, in. (mm)

$$= \frac{\left(D_o^2 + D_i^2\right)^{1/2}}{4}$$

S = elastic section modulus of full shell cross-section, in.^{3} (mm^3)

$$= \frac{\pi\left(D_o^4 - D_i^4\right)}{32 D_o}$$

t = thickness of shell, less corrosion allowance, in. (mm)

t_c = thickness of cone, less corrosion allowance, in. (mm)

V = shear force from applied loads at cross-section under consideration, kips (N)

Z_c = radial distance from centerline of shell to centroid of combined section of ring and effective length of shell, in. (mm)

$= \dfrac{A_s Z_s}{A_s + L_e t}$

Z_s = radial distance from centerline of shell to centroid of ring stiffener (positive for outside rings), in. (mm)

ϕ = angle measured around the circumference from the direction of applied shear force to the point under consideration

α = one-half of the apex angle of a conical section

β = capacity reduction factor to account for shape imperfections

λ_c = slenderness factor for column buckling

$= \dfrac{K L_u}{\pi r}\sqrt{\dfrac{F_{xa} FS}{E}}$

In the equation for λ_c above, a laterally unsupported length, L_u, for a free-standing pressure vessel without guide wires or other bracing should be measured from the top head tangent line to the base of the vessel support skirt. For λ_c values ≤ 0.15, consideration for column instability (column buckling) is not required for either the vessel shell or the vessel skirt for any of the load combinations in 5. For $\lambda_c > 0.15$, consideration for column buckling is required, see 5 and specifically 5.1.2.

For load combinations including external pressure, the load on the end of a cylinder due to external pressure does not contribute to instability of the pressure vessel as a free standing column (column buckling). The axial compressive stress due to external pressure load does, however, lower the effective yield stress of the pressure shell [see eq. 5.1.2(5-3)], and the quantity in the parentheses ($1\text{-}f_q/F_y$) accounts for this reduction. The reduced effective yield stress does not apply to parts that are not part of the pressure shell.

2 GENERAL DESIGN INFORMATION

2.1 Materials. The allowable stress equations apply directly to shells fabricated from carbon and low alloy steel materials. These equations can also be applied to other materials for which a chart or table is provided in Subpart 3 of Section II, Part D. The method for calculating the allowable stresses for shells constructed from these materials is determined by the following procedure.

Step 1. Calculate the value of factor A using the following equations. The terms F_{xe}, F_{he}, and F_{ve} are defined in the Nomenclature (1.4).

$$A = \frac{F_{xe}}{E} \quad A = \frac{F_{he}}{E} \quad A = \frac{F_{ve}}{E}$$

Step 2. Using the value of A calculated in Step 1, enter the applicable material chart in Subpart 3 of Section II, Part D for the material under consideration. Move vertically to an intersection with the material temperature line for the design temperature. Use interpolation for intermediate temperature values.

Step 3. From the intersection obtained in Step 2, move horizontally to the right to obtain the value of B. E_t is given by the following equation:

$$E_t = \frac{2B}{A}$$

When values of A fall to the left of the applicable material/temperature line in Step 2, $E_t = E$.

Step 4. Calculate the allowable stresses from the following equations:

$$F_{xa} = \frac{F_{xe}}{FS}\frac{E_t}{E} \quad F_{ba} = F_{xa} \quad F_{ha} = \frac{F_{he}}{FS}\frac{E_t}{E} \quad F_{va} = \frac{F_{ve}}{FS}\frac{E_t}{E}$$

2.2 Stress Reduction Factors. Allowable stresses in this Case for design and test conditions are determined by applying a stress reduction factor, FS, to predicted buckling stresses calculated in this Case. The required values of FS are 2.0 when the buckling stress is elastic and $^5/_3$ (1.67) when the buckling stress equals yield stress at design temperature. A linear variation shall be used between these limits. The equations for FS are given below.

$$\begin{aligned} &FS = 2.0 && \text{if} \quad F_{ic} \leq 0.55F_y \\ &FS = 2.407 - 0.741F_{ic}/F_y && \text{if} \quad 0.55 \quad F_y < F_{ic} < F_y \\ &FS = 1.667 && \text{if} \quad F_{ic} \geq F_y \end{aligned}$$

F_{ic} is the predicted buckling stress, which is determined by letting $FS = 1$ in the allowable stress equations. For service loading, the allowable stresses may be increased as permitted by the appropriate service limit:

Service Level A 1.0

Service Level B 1.1

Service Level C 1.2

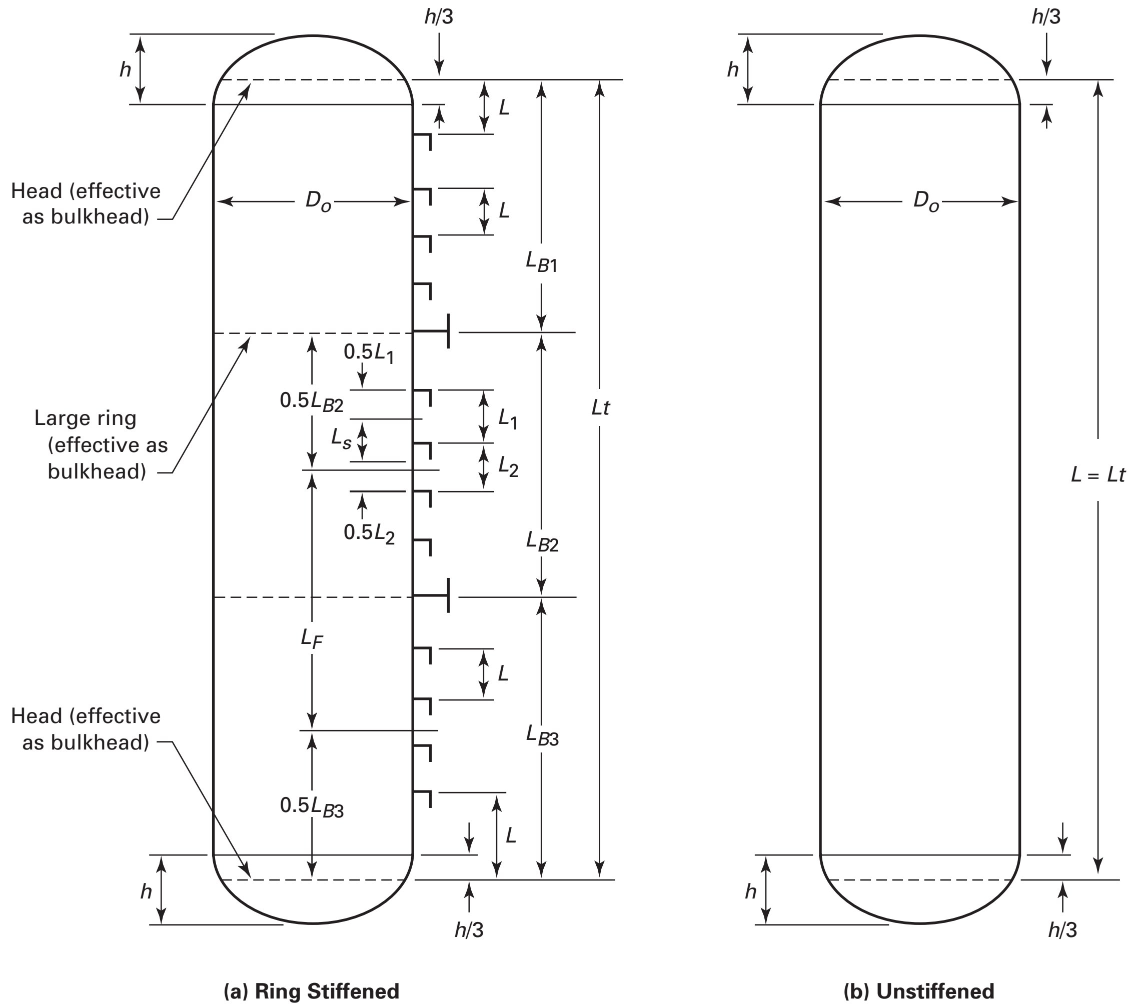
2.3 Capacity Reduction Factors (β). Capacity reduction factors that account for shape imperfections are built into the allowable stress equations in this Case. These factors are in addition to the stress reduction factors in 2.2.

(a) For unstiffened or ring stiffened cylinders under axial compression:

$$\beta = 0.207 \qquad \text{for} \frac{D_o}{t} \geq 1,247$$

$$\beta = \frac{338}{389 + \frac{D_o}{t}} \qquad \text{for} \frac{D_o}{t} < 1,247$$

Figure 1.4.1
Geometry of Cylinders



(b) Unstiffened and ring stiffened cylinders and cones under external pressure: β = 0.8

(c) Spherical, torispherical, and ellipsoidal heads under external pressure: β = 0.124

2.4 Stress Components for Stability Analysis and Design. Stress components that control the buckling of a cylindrical shell consist of longitudinal, circumferential, and in-plane shear membrane stresses.

3 ALLOWABLE COMPRESSIVE STRESSES FOR CYLINDRICAL SHELLS

The maximum allowable stresses for cylindrical shells subjected to loads that produce compressive stresses are given by the following equations. For stress components acting alone, the maximum values shall be used. For combined stress components, the concurrent (coexisting) stress values shall be used.

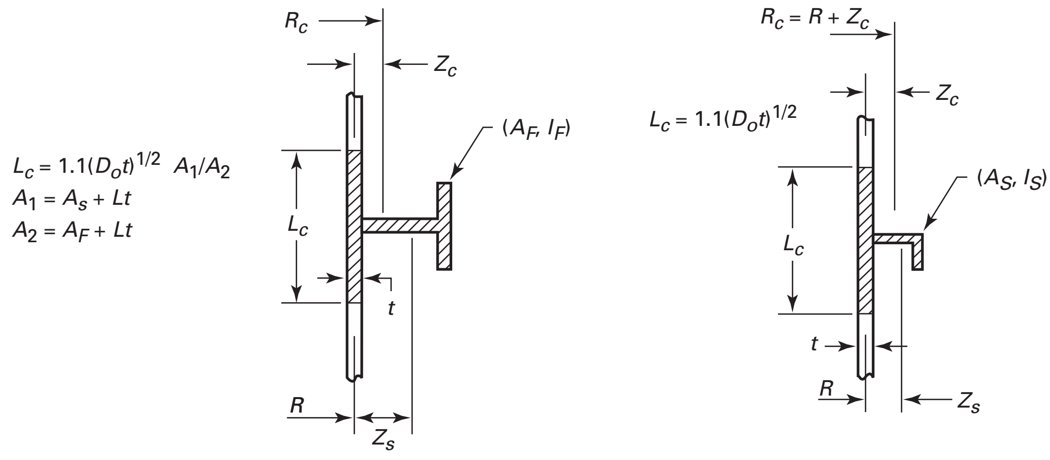
In no case shall the allowable primary membrane compressive stresses exceed the maximum allowable tensile stress listed in Section II, Part D.

3.1 External Pressure. The allowable circumferential compressive stress for a cylinder under external pressure is given by F_{ha} and the allowable external pressure is given by the following equation.

$$P_a = 2F_{ha}\frac{t}{D_o}$$

$$F_{ha} = \frac{F_y}{FS} \quad \text{for} \frac{F_{he}}{F_y} \geq 2.439 \tag{3-1a}$$

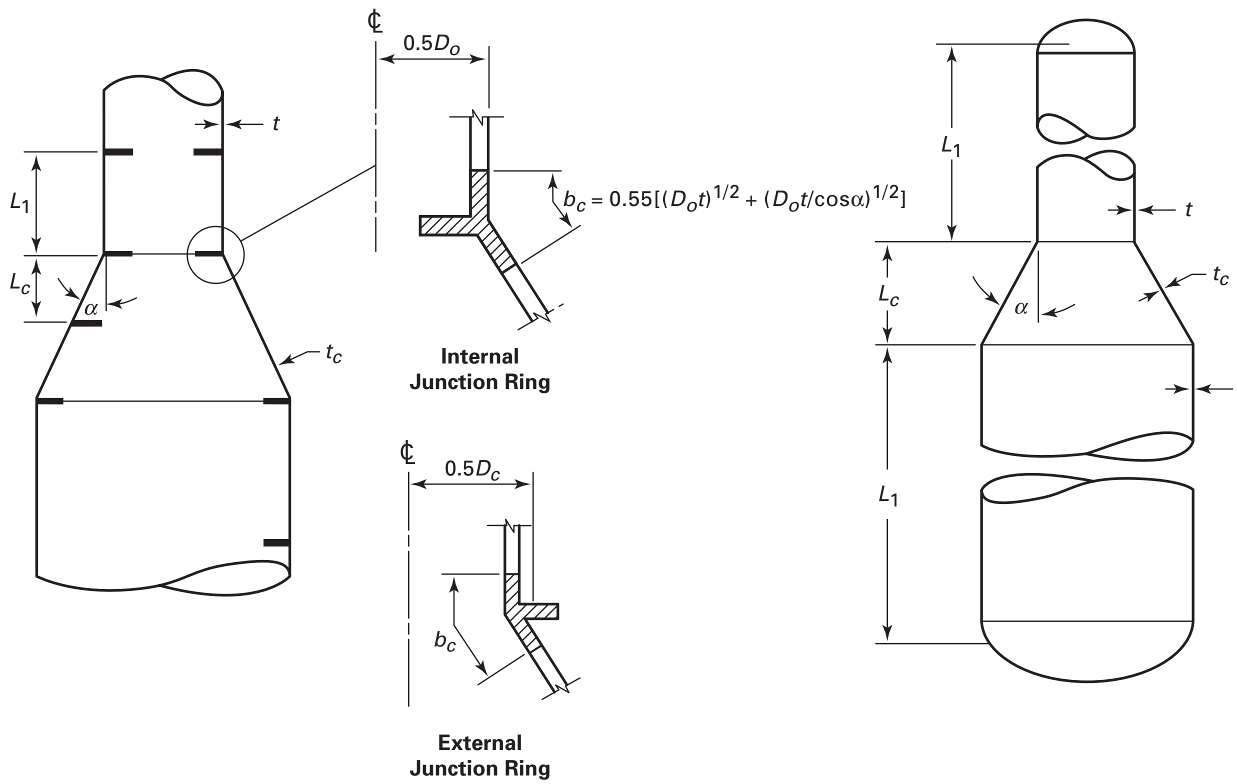
Figure 1.4.2
Sections Through Rings



(a) Large Ring That Acts as a Bulkhead

(b) Small Ring

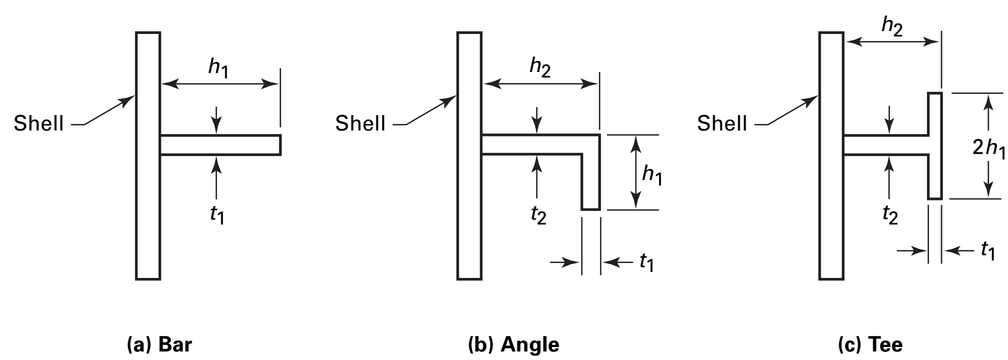
Figure 1.4.3
Geometry of Conical Sections



(a) Stiffened

(b) Unstiffened

Figure 1.4.4
Stiffener Geometry for Eqs. 6.4(a)(6-6) and 6.4(b)(6-7)



$$F_{ha} = \frac{0.7F_y}{FS}\left(\frac{F_{he}}{F_y}\right)^{0.4} \quad \text{for } 0.552 < \frac{F_{he}}{F_y} < 2.439 \tag{3-1b}$$

$$F_{ha} = \frac{F_{he}}{FS} \quad \text{for } \frac{F_{he}}{F_y} \le 0.552 \tag{3-1c}$$

where

$$F_{he} = 1.6C_h E\frac{t}{D_o} \tag{3-2}$$

$$C_h = 0.55\frac{t}{D_o} \quad \text{for } M_x \ge 2\left(\frac{D_o}{t}\right)^{0.94} \tag{3-2a}$$

$$C_h = 1.12M_x^{-1.058} \quad \text{for } 13 < M_x < 2\left(\frac{D_o}{t}\right)^{0.94} \tag{3-2b}$$

$$C_h = \frac{0.92}{M_x - 0.579} \quad \text{for } 1.5 < M_x \le 13 \tag{3-2c}$$

$$C_h = 1.0 \quad \text{for } M_x \le 1.5 \tag{3-2d}$$

3.2 Uniform Axial Compression. Allowable longitudinal stress for a cylindrical shell under uniform axial compression is given by F_{xa} for values of $\lambda_c \le 0.15$ and by F_{ca} for values of $\lambda_c > 0.15$.

$$\lambda_c = \frac{KL_u}{\pi r}\sqrt{\frac{F_{xa}FS}{E}}$$

where KL_u is the effective length. L_u is the unbraced length. Minimum values for K are:

(a) 2.1 for members with one end free and the other end fixed (i.e., “free standing” pressure vessels supported at grade)

(b) 1.0 for members with both ends pinned

(c) 0.8 for members with one end pinned and the other end fixed

(d) 0.65 for members with both ends fixed

In this case, “member” is the unbraced cylindrical shell or cylindrical shell section as defined in the Nomenclature, 1.4.

3.2.1 Local Buckling (for $\lambda_c \le 0.15$). F_{xa} is the smaller of the values given by eqs. (3-3a) through (3-3c). (E)

$$F_{xa} = \frac{F_y}{FS} \quad \text{for } \frac{D_o}{t} < 135 \tag{3-3a}$$

$$F_{xa} = \frac{466F_y}{\left(331 + \frac{D_o}{t}\right)FS} \quad \text{for } 135 < \frac{D_o}{t} < 600 \tag{3-3b}$$

$$F_{xa} = \frac{0.5F_y}{FS} \quad \text{for } \frac{D_o}{t} \ge 600 \tag{3-3c}$$

or

$$F_{xa} = \frac{F_{xe}}{FS} \tag{3-4}$$

where

$$F_{xe} = \frac{C_x Et}{D_o} \tag{3-5}$$

$$C_x = \frac{409\bar{c}}{389 + \frac{D_o}{t}} \text{ not to exceed } 0.9 \quad \text{for } \frac{D_o}{t} < 1247$$

$$C_x = 0.25\bar{c} \quad \text{for } \frac{D_o}{t} \ge 1247$$

$$\bar{c} = 2.64 \quad \text{for } M_x \le 1.5$$

$$\bar{c} = \frac{3.13}{M_x^{0.42}} \quad \text{for } 1.5 < M_x < 15$$

$$\bar{c} = 1.0 \quad \text{for } M_x \ge 1.5$$

$$M_x = \frac{L}{(R_o t)^{1/2}} \tag{3-6}$$

3.2.2 Column Buckling ($\lambda_c > 0.15$ and $Kl_u/r < 200$).

$$F_{ca} = F_{xa}[1 - 0.74(\lambda_c - 0.15)]^{0.3} \quad \text{for } 0.15 < \lambda_c < 1.147 \tag{3-7a}$$

$$F_{ca} = \frac{0.88F_{xa}}{\lambda_c^2} \text{ for } \lambda_c \geq 1.147 \tag{3-7b}$$

3.3 Axial Compression Due to Bending Moment. Allowable longitudinal stress for a cylinder subjected to a bending moment acting across the full circular cross-section is given by F_{ba}.

$$F_{ba} = F_{xa}(\text{see para. 3.2.1}) \quad \text{for } \frac{D_o}{t} \geq 135 \tag{3-8a}$$

$$F_{ba} = \frac{466F_y}{FS\left(331 + \frac{D_o}{t}\right)} \quad \text{for } 100\frac{D_o}{t} < 135 \tag{3-8b}$$

$$F_{ba} = \frac{1.081F_y}{FS} \quad \text{for } \frac{D_o}{t} < 100 \text{ and } \gamma \geq 0.11 \tag{3-8c}$$

$$F_{ba} = \frac{(1.4 - 2.9\gamma)F_y}{FS} \quad \text{for } \frac{D_o}{t} < 100 \text{ and } \gamma < 0.11 \tag{3-8d}$$

where

$$\gamma = \frac{F_y D_o}{E\,t} \tag{3-8e}$$

3.4 Shear. Allowable in-plane shear stress for a cylindrical shell is given by F_{va}.

$$F_{va} = \frac{\eta_v F_{ve}}{FS} \tag{3-9}$$

where

$$F_{ve} = \alpha_v C_v E \frac{t}{D_o} \tag{3-10}$$

$$C_v = 4.454 \quad \text{for} \quad M_x \leq 1.5 \tag{3-11a}$$

$$C_v = \left(\frac{9.64}{M_x^2}\right)\left(1 + 0.0239M_x^3\right)^{1/2} \quad \text{for} \quad 1.5 < M_x < 26 \tag{3-11b}$$

$$C_v = \frac{1.492}{M_x^{1/2}} \quad \text{for} \quad 26 \leq M_x < 4.347\frac{D_o}{t} \tag{3-11c}$$

$$C_v = 0.716\left(\frac{t}{D_o}\right)^{1/2} \quad \text{for } M_x \geq 4.347\frac{D_o}{t} \tag{3-11d}$$

$$\alpha_v = 0.8 \quad \text{for } \frac{D_o}{t} \leq 500 \tag{3-11e}$$

$$\alpha_v = 1.389 - 0.218\log_{10}\left(\frac{D_o}{t}\right) \quad \text{for } \frac{D_o}{t} > 500 \tag{3-11f}$$

$$\eta_v = 1.0 \quad \text{for } \frac{F_{ve}}{F_y} \leq 0.48 \tag{3-11g}$$

$$\eta_v = 0.43\frac{F_y}{F_{ve}} + 0.1 \quad \text{for } 0.48 < \frac{F_{ve}}{F_y} < 1.7 \tag{3-11h}$$

$$\eta_v = 0.6\frac{F_y}{F_{ve}} \quad \text{for } \frac{F_{ve}}{F_y} \geq 1.7 \tag{3-11i}$$

4 ALLOWABLE COMPRESSIVE STRESSES FOR CONES

Unstiffened conical transitions or cone sections between rings of stiffened cones with an angle $\alpha \leq 60$ deg shall be designed for local buckling as an equivalent cylinder according to the following procedure. See Figure 1.4.3 for cone geometry.

4.1 EXTERNAL PRESSURE

4.1.1 Allowable Circumferential Compression Stresses. Assume an equivalent cylinder with diameter, D_e, equal to $0.5\left(D_L + D_S\right)/\cos\alpha$, $L_{ce} = L_c/\cos\alpha$. The value D_e is substituted for D_o, L_{ce} for L, and $D_e/2$ for R_o in the equations given in 3.1 to determine F_{ha}. The allowable stress must be satisfied at all cross-sections along the length of the cone.

4.1.2 Intermediate Stiffening Rings. If required, circumferential stiffening rings within cone transitions shall be sized using eq. 6.1(a)(6-1).

4.1.3 Cone-Cylinder Junction Rings. A junction ring is not required for buckling due to external pressure If $f_h < F_{ha}$ where F_{ha} is determined from eqs. 3.1(3-1a) through 3.1(3-1c) with F_{he} computed using C_h equal to 0.55 $(\cos\alpha)$ (t/D_o) in eq. 3.1(3-2). D_o is the cylinder diameter at the junction. The hoop stress may be calculated from the following equation. (E)

$$f_h = \frac{P\,D_o}{2\,t_c\cos\alpha}$$

If $t_c \cos\alpha$ is less than t, then substitute t for t_c to determine C_h and f_h.

Circumferential stiffening rings required at the cone-cylinder junctions shall be sized such that the moment of inertia of the composite ring section satisfies the following equation:

$$I_c \geq \frac{D^2}{16E}\left\{tL_1F_{he} + \frac{t_cL_cF_{hec}}{\cos^2\alpha}\right\} \tag{4-1}$$

where

D = cylinder outside diameter at junction
L_c = distance to first stiffening ring in cone section along cone axis as shown in Figure 1.4.3
L_1 = distance to first stiffening ring in cylinder section or line of support
F_{he} = elastic hoop buckling stress for cylinder [see eq. 3.1(3-2)]
F_{hec} = F_{he} for cone section treated as an equivalent cylinder
t = cylinder thickness
t_c = cone thickness

4.2 UNIFORM AXIAL COMPRESSION AND BENDING

4.2.1 Allowable Longitudinal and Bending Stresses. Assume an equivalent cylinder with diameter D_e equal to $D/\cos\alpha$, where D is the outside diameter at the cross-section under consideration and length equal to L_c. D_e is substituted for D_o in the equations given in 3.2 and 3.3 to find F_{xa} and F_{ba} and L_c for L in eq. 3.2.1(3-6). The radius R_o is equal to $D_e/2$ at the large end of the cone. The allowable stress must be satisfied at all cross-sections along the length of the cone.

4.2.2 Unstiffened Cone-Cylinder Junctions. Cone-cylinder junctions are subject to unbalanced radial forces (due to axial load and bending moment) and to localized bending stresses caused by the angle change. The longitudinal and hoop stresses at the junction may be evaluated as follows:

(a) Longitudinal Stress. In lieu of detailed analysis, the localized bending stress at an unstiffened cone-cylinder junction may be estimated by the following equation.

$$f_b' = \frac{0.6t\sqrt{D(t+t_c)}}{t_e^2}(f_x + f_b)\tan\alpha \tag{4-2}$$

where

D = outside diameter of cylinder at junction to cone
t = thickness of cylinder
t_c = thickness of cone
t_e = t to find stress in cylinder section
t_e = t_c to find stress in cone section
f_x = uniform longitudinal stress in cylinder section at the cone-cylinder junction resulting from pressure and/or applied axial loads, see Nomenclature, 1.4
f_b = longitudinal stress in cylinder section at the cone-cylinder junction resulting from bending moment
α = cone angle as defined in Figure 1.4.3

For strength requirements, the total stress $f_x + f_b + f_b'$ in the cone and cylinder sections shall be limited to 3 times the allowable stress at temperature listed in Section II, Part D, Tables 1A and 1B (Subsection NC and ND or Tables 2A and 2B (Subsection NB) . The combined stress $(f_x + f_b)$ shall not exceed the allowable stress at temperature listed in Section II, Part D, Tables 1A and 1B (Subsection NC and ND or Tables 2A and 2B (Subsection NB)

(b) Hoop Stress. The hoop stress caused by the unbalanced radial line load may be estimated from: (E)

$$f_h' = 0.45\sqrt{D/t}\,(f_x + f_b)\tan\alpha \tag{4-3}$$

For hoop tension, f_h' shall be limited to 1.5 times the tensile allowable per (a) above. For Class 3 applications, the applicable joint efficiency shall be included when determining the allowable tensile stress. For hoop compression, f_h' shall be limited to F_{ha} where F_{ha} is computed from eqs. 3.1(3-1a) through 3.1(3-1c) with

$$F_{he} = 0.4\,E(t/D)$$

A cone-cylinder junction that does not satisfy the above criteria may be strengthened either by increasing the cylinder and cone wall thickness at the junction, or by providing a stiffening ring at the junction.

4.2.3 Cone-Cylinder Junction Rings. If stiffening rings are required, the section properties shall satisfy the following requirements:

$$A_c \geq \frac{tD}{F_y}(f_x + f_b)\tan\alpha \tag{4-4}$$

$$I_c \geq \frac{tD(D_c)^2}{8E}(f_x + f_b)\tan\alpha \tag{4-5}$$

where

A_c = cross-sectional area of composite ring section
D = cylinder outside diameter at junction
D_c = diameter to centroid of composite ring section for external rings
D_c = D_i for internal rings
I_c = moment of inertia of composite ring section

In computing A_c and I_c, the effective length of shell wall acting as a flange for the composite ring section shall be computed from:

$$b_e = 0.55\left(\sqrt{Dt} + \sqrt{Dt_c/\cos\alpha}\right) \tag{4-6}$$

The nearest surface of the stiffening ring shall be located within a distance of t_r or 1 in. (25 mm), whichever is greater, from the cone junction. The thickness of the ring, t_r, is defined by t_1 or t_2 in Figure 1.4.4.

4.3 SHEAR

4.3.1 Allowable In-Plane Shear Stress. Assume an equivalent cylinder with a length equal to the slant length between rings (L_c/cos α) and a diameter D_e equal to D/cos α, where D is the outside diameter of the cone at the cross-section under consideration. This length and diameter shall be substituted into the equations given in 3.4 to determine F_{va}.

4.3.2 Intermediate Stiffening Rings. If required, circumferential stiffening rings within cone transition shall be sized using eq. 6.4(a)(6-6) where L_s is the average distance to adjacent rings along the cone axis.

4.4 Local Stiffener Geometry Requirements. To preclude local buckling of a stiffener, the requirements of 6.4 must be met.

4.5 Tolerances. The tolerances specified in 7 shall be met.

5 ALLOWABLE STRESS EQUATIONS FOR UNSTIFFENED AND RING-STIFFENED CYLINDERS AND CONES UNDER COMBINED LOADS

The following rules do not apply to cylinders and cones under load combinations that include external pressure for values of $\lambda_c \geq 1.2$. For $\lambda_c \geq 1.2$, this Case is not applicable.

For load combinations that include uniform axial compression, the longitudinal stress to use in the interaction equations is f_x for local buckling equations ($\lambda_c \leq 0.15$) and f_a for column buckling equations ($\lambda_c > 0.15$). The stress component, f_q, which results from pressure on the ends of the cylinder, does not contribute to column buckling.

5.1 FOR COMBINATION OF UNIFORM AXIAL COMPRESSION AND HOOP COMPRESSION

(E) **5.1.1** For $\lambda_c \leq 0.15$ the allowable stress in the longitudinal direction is given by F_{xha} and the allowable stress in the circumferential direction is given by F_{hxa}.

$$f_x \leq F_{xha}$$

$$F_{xha} = \left(\frac{1}{F_{xa}{}^2} - \frac{C_1}{C_2 F_{xa} F_{ha}} + \frac{1}{C_2{}^2 F_{ha}{}^2} \right)^{-0.5} \tag{5-1}$$

where

$$C_1 = \frac{\left(F_{xa}FS + F_{ha}FS\right)}{F_y} - 1.0 \tag{5-1a}$$

$$\text{and} \quad C_2 = \frac{f_x}{f_h} \tag{5-1b}$$

$$f_x = f_a + f_q = \frac{Q}{A} + \frac{Qp}{A} \quad \text{and} \quad f_h = \frac{PD_o}{2t}$$

Eq. (5-1) should not be used (does not apply) if either f_h is not present (or not being considered), or $f_x = 0$. F_{xa} FS is given by the smaller of eqs. 3.2.1(3-3a) through 3.2.1(3-3c) or 3.2.1(3-4), and F_{ha} FS is given by eqs. 3.1(3-1a) through 3.1(3-1c). To determine F_{xa} and F_{ha} the values of FS are obtained from 2.2.

$$F_{hxa} = \frac{F_{xha}}{C_2} \tag{5-2}$$

The values of FS are to be determined independently for the axial and hoop directions.

5.1.2 For $0.15 < \lambda_c < 1.2$, the allowable stress in the longitudinal direction is given by F_{aha}, and is determined from column buckling considerations. (The rules do not apply to values of $\lambda_c \geq 1.2$ for shells under combined axial compression and external pressure.) (E)

$$f_a \leq F_{aha} \quad \text{where} \quad F_{aha} = F_{cha}\left(1 - \frac{f_q}{F_y}\right) \tag{5-3}$$

The load on the end of a cylinder due to external pressure does not contribute to column buckling and therefore F_{aha} is compared with f_a rather than f_x. The stress due to the pressure load does, however, lower the effective yield stress and the quantity in parentheses $(1 - f_q/F_y)$ accounts for this reduction. F_{cha} is obtained from eq. 3.2.2(3-7a) or eq. 3.2.2(3-7b) by substituting F_{xha}, determined from eq. 5.1.1(5-1) for F_{xa}. The resulting equations are:

(a) for $\lambda_c \leq 0.15$

$$F_{cha} = F_{xha} \tag{5-3a}$$

(b) for $0.15 < \lambda_c < 1.2$

$$F_{cha} = F_{xha}[1 - 0.74(\lambda - 0.15)]^{0.3} \tag{5-3b}$$

5.2 For Combination of Axial Compression Due to Bending Moment, *M*, and Hoop Compression. The allowable stress in the longitudinal direction is given by F_{bha}, and the allowable stress in the circumferential direction is given by F_{hba}. (E)

$$F_b \leq F_{bha}$$
$$F_{bha} = C_3 C_4 F_{ba} \tag{5-4}$$

where C_3 and C_4 are given by the following equations and F_{ba} is given by eqs. 3.3(3-8a) through 3.3(3-8d).

$$C_4 = \frac{f_b}{f_h}\frac{F_{ha}}{F_{ba}} \tag{5-4a}$$

$$C_3^{\,2}(C_4^{\,2} + 0.6C_4) + C_3^{\,2n} - 1 = 0 \qquad (5\text{-}5)$$

$$f_b = \frac{Mc}{I} \quad f_h = \frac{PD_o}{2t} \quad n = 5 - 4\frac{F_{ha}\cdot FS}{F_y}$$

Solve for C_3 from eq. (5-5) by iteration. F_{ha} is given by eqs. 3.1(3-1a) through 3.1(3-1c).

$$F_{hba} = F_{bha}\frac{f_h}{f_b} \qquad (5\text{-}6)$$

(E) **5.3 For Combination of Hoop Compression and Shear.** The allowable shear stress is given by F_{vha} and the allowable circumferential stress is given by F_{hva}.

$$F_{vha} = \left[\left(\frac{F_{va}^{\,2}}{2C_5F_{ha}}\right)^2 + F_{va}^{\,2}\right]^{1/2} - \frac{F_{va}^{\,2}}{2C_5F_{ha}} \qquad (5\text{-}7)$$

where

$$C_5 = \frac{f_v}{f_h} \quad \text{and} \; f_v = V\sin\phi/\pi Rt$$

F_{va} is given by eq. 3.4(3-9) and F_{ha} is given by eqs. 3.1(3-1a) through 3.1(3-1c).

$$F_{hva} = \frac{F_{vha}}{C_5} \qquad (5\text{-}8)$$

5.4 For Combination of Uniform Axial Compression, Axial Compression Due to Bending Moment, *M*, and Shear, in the Presence of Hoop Compression ($f_h \neq 0$).

$$\text{Let} \quad K_s = 1 - \left(\frac{f_v}{F_{va}}\right)^2 \qquad (5\text{-}9)$$

5.4.1 For $\lambda_c \leq 0.15$

$$\left(\frac{f_a}{K_sF_{xha}}\right)^{1.7} + \frac{f_b}{K_sF_{bha}} \leq 1.0 \qquad (5\text{-}10)$$

F_{xha} is given by eq. 5.1.1(5-1), F_{bha} is given by eq. 5.2(5-4) and F_{va} is given by eq. 3.4(3-9).

(E) **5.4.2** For $0.15 < \lambda_c < 1.2$

$$\frac{f_a}{K_sF_{aha}} + \frac{8}{9}\frac{\Delta f_b}{K_sF_{bha}} \leq 1.0 \quad \text{for} \quad \frac{f_a}{K_sF_{aha}} \geq 0.2 \qquad (5\text{-}11)$$

$$\frac{f_a}{2K_sF_{aha}} + \frac{\Delta f_b}{K_sF_{bha}} \leq 1.0 \quad \text{for} \quad \frac{f_a}{K_sF_{aha}} < 0.2 \qquad (5\text{-}12)$$

where

$$\Delta = \frac{C_m}{1 - \dfrac{f_aFS}{F_e}} \qquad (5\text{-}12a)$$

$$F_e = \frac{\pi^2E}{(KL_u/r)^2} \qquad (5\text{-}12b)$$

See 5.1 for F_{xha}. F_{bha} is given by eq. 5.2(5-4). K is the effective length factor (see 3.2). FS is determined from equations in 2.2, where $F_{ic} = F_{xa}\ FS$ [See eqs. 3.2.1(3-3a) through 3.2.1(3-3c) and eq. 3.2.1(3-4)].

C_m = coefficient whose value shall be taken as follows:

(a) For compression members in frames subject to joint translation (side sway),

$$C_m = 0.85$$

(b) For rotationally restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending,

$$C_m = 0.6 - 0.4(M_1/M_2)$$

where M_1/M_2 is the ratio of the smaller to larger moments at the ends of that portion of the member unbraced in the plane of bending under consideration. M_1/M_2 is positive when the member is bent in reverse curvature and negative when bent in single curvature.

(c) For compression members in frames braced against joint translation and subjected to transverse loading between their supports:

(1) for members whose ends are restrained against rotation in the plane of bending,

$$C_m = 0.85$$

(2) for members whose ends are unrestrained against rotation in the plane of bending, for example, an unbraced skirt supported vessel,

$$C_m = 1.0$$

5.5 FOR COMBINATION OF UNIFORM AXIAL COMPRESSION, AXIAL COMPRESSION DUE TO BENDING MOMENT, *M*, AND SHEAR, IN THE ABSENCE OF HOOP COMPRESSION ($f_h = 0$)

5.5.1 For $\lambda_c \leq 0.15$ (E)

$$\left(\frac{f_a}{K_sF_{xa}}\right)^{1.7} + \frac{f_b}{K_sF_{ba}} \leq 1.0 \qquad (5\text{-}13)$$

F_{xa} is given by the smaller of eqs. 3.2.1(3-3a) through 3.2.1(3-3c) or eq. 3.2.1(3-4), F_{ba} is given by eqs. 3.3(3-8a) through 3.3(3-8d) and K_s is given by eq. 5.4(5-9).

5.5.2 For $0.15 < \lambda_c < 1.2$ (E)

$$\frac{f_a}{K_s F_{ca}} + \frac{8}{9}\frac{\Delta f_b}{K_s F_{ba}} \leq 1.0 \quad \text{for} \quad \frac{f_a}{K_s F_{ca}} \geq 0.2 \tag{5-14}$$

$$\frac{f_a}{2K_s F_{ca}} + \frac{\Delta f_b}{K_s F_{ba}} \leq 1.0 \quad \text{for} \quad \frac{f_a}{K_s F_{ca}} < 0.2 \tag{5-15}$$

F_{ca} is given by eq. 3.2.2(3-7a) or eq. 3.2.2(3-7b), F_{ba} is given by eqs. 3.3(3-8a) through 3.3(3-8d), and K_s is given by eq. 5.4(5-9). See 5.4.2 for definition of Δ.

6 SIZING OF RINGS (GENERAL INSTABILITY)

6.1 External Pressure.

(a) Small rings

$$I_s' \geq \frac{1.5 F_{he} L_s R_c^2 t}{E(n^2 - 1)} \tag{6-1}$$

F_{he} = stress determined from eq. 3.1(3-2) with $M_x = M_s$.

$$n^2 = \frac{2D_o^{3/2}}{3L_B t^{1/2}} \quad \text{use} \quad n = 2 \text{ for } n^2 \leq 4,$$

$$\text{and } n = 10 \text{ for } n^2 > 100$$

(b) Large rings that act as bulkheads

$$I_s' \geq I_F \tag{6-2}$$

where

$$I_F = \frac{F_{heF} L_F R_c^2 t}{2E} \tag{6-2a}$$

A_1 = cross-sectional area of small ring plus shell area equal to $L_s t$, in. (mm^2)

A_2 = cross-sectional area of large ring plus shell area equal to $L_s t$, in.^{2} (mm^2)

F_{heF} = average value of the hoop buckling stresses, F_{he}, over length L_F where F_{he} is determined from eq. 3.1(3-2), ksi (MPa)

I_F = the value of I_s', which makes a large stiffener act as a bulkhead. The effective length of shell is $L_e = 1.1\sqrt{D_o t}\left(A_1/A_2\right)$

R_c = radius to centroid of combined large ring and effective width of shell, in. (mm)

6.2 Uniform Axial Compression and Axial Compression Due to Bending. When ring stiffeners are used to increase the allowable longitudinal compressive stress, the following equations must be satisfied. For a stiffener to be considered, M_x shall be less than 15.

$$A_s \geq \left[\frac{0.334}{M_s^{0.6}} - 0.063\right] L_s t \text{ and } \quad A_s \geq 0.06 L_s t \tag{6-3}$$

$$\text{also} \quad I_s' \geq \frac{5.53 L_s t^3}{M_s^{1.8}} \tag{6-4}$$

6.3 Shear. (**E**)

$$I_s' \geq 0.184 C_v M_s^{0.8} t^3 L_s \tag{6-5}$$

C_v = value determined from eqs. 3.4(3-11a) through 3.4(3-11d) with $M_x = M_s$

6.4 Local Stiffener Geometry Requirements.. Stiffener geometry requirements are as follows. See Figure 1.4.4 for stiffener geometry and definition of terms.

(a) Flat bar stiffener, flange of a tee stiffener, and outstanding leg of an angle stiffener

$$\frac{h_1}{t_1} \leq 0.375\left(\frac{E}{F_y}\right)^{1/2} \tag{6-6}$$

where h_1 is the full width of a flat bar stiffener or outstanding leg of an angle stiffener and one-half of the full width of the flange of a tee stiffener and t_1 is the thickness of the bar, leg of angle, or flange of tee.

(b) Web of tee stiffener or leg of angle stiffener attached to shell

$$\frac{h_2}{t_2} \leq 1.0\left(\frac{E}{F_y}\right)^{1/2} \tag{6-7}$$

where h_2 is the full depth of a tee section or full width of an angle leg and t_2 is the thickness of the web or angle leg.

7 TOLERANCES FOR CYLINDRICAL AND CONICAL SHELLS

7.1 Shells Subjected to External Pressure. Cylindrical and conical shells shall meet the tolerances as specified herein. These tolerance requirements replace some portions of those specified in NB-4221.2, NC-4221.2, and ND-4221.2. All requirements of NB-4221.2, NC-4221.2, and ND-4221.2 are applicable. In place of the maximum deviation requirements specified in NB-4221.2(a), NC-4221.2(a), and ND-4221.2(a) the following requirements apply.

The maximum deviation from a true circular form, *e*, shall not exceed the value given by the following equations.

$$e = 0.0165t(M_x + 3.25)^{1.069} \tag{7-1}$$

e need not be less than 0.2 t, and shall not exceed the smaller of $0.0242R$ or $2t$.

7.2 Shells Subjected to Uniform Axial Compression and Axial Compression Due to Bending Moment. Cylindrical and conical shells shall meet the out-of-roundness limitations specified in NB-4221.1, NC-4221.1, and

ND-4221.1. Additionally, the local deviation from a straight line, e, measured along a meridian over a gauge length L_x shall not exceed the maximum permissible deviation e_x given below.

e_x = 0.002R
$L_x = 4\sqrt{Rt}$ but not greater than L for cylinders
$L_x = 4\sqrt{Rt/\cos\alpha}$ but not greater than $L_c/\cos\alpha$ for cones
$L_x = 25t$ across circumferential welds

Also L_x is not greater than 95% of the meridional distance between circumferential welds.

(E) **7.3 If Tolerances Are Exceeded, Allowable Buckling Stress Adjustment.** The maximum deviation, e, can exceed e_x if the maximum axial stress is less than F_{xa} for shells designed for axial compression only or less than F_{xha} for shells designed for combinations of axial compression and external pressure. The change in buckling stress is given in eq. (7-2), and the reduced allowable buckling stress, $F_{xa(reduced)}$, is determined as shown by eq. (7-3a) using the values for F_{xa} and FS_{xa} from eqs. 3.2.1(3-3a) through 3.2.1(3-3c) and 3.2.1(3-4).

$$F'_{xe} = \left[0.944 - 0.286\log\left(\frac{e}{e_x}0.0005\right)\right]E\frac{t}{R} \tag{7-2}$$

where e is the new maximum deviation. The quantity

$$0.286\log\left(\frac{e}{e_x}0.0005\right)$$

is an absolute number (i.e., the log of a very small number is negative). See example for $e = 2e_x$ below.

For example, when $e = 2e_x$, the reduction in allowable buckling stress can be calculated by the following formula:

$$F'_{xe} = 0.086E\frac{t}{R} \tag{7-3}$$

$$\text{The}\quad F_{xa(reduced)} = \frac{F_{xa}{*}FS_{xa} - F'_{xe}}{FS_{xa}} \tag{7-3a}$$

7.4 Measurements for Deviations. Measurements to determine e shall be made from a segmental circular template having the design outside radius, and placed on outside of the shell. The chord length L_c is given by the following equation.

$$L_c = 2R\sin(\pi/2n) \tag{7-4}$$

$$n = c\left(\frac{\sqrt{R/t}}{L/R}\right)^d \quad 2 \le n \le 1.41(R/t)^{0.5} \tag{7-5}$$

where

$c = 2.28(R/t)^{0.54} \le 2.80$
$d = 0.38(R/t)^{0.044} \le 0.485$

The requirements of NB-4221.2(b),(c), NC-4221.2(b),(c), ND-4221.2(b),(c), NB-4221.1, NC-4221.1, ND-4221.1, and NB-4221.4, NC-4221.4, ND-4221.4 remain applicable.

7.5 Shells Subjected to Shear. Cylindrical and conical shells shall meet the tolerances specified in NB-4221.1, NC-4221.1, ND-4221.1.

8 ALLOWABLE COMPRESSIVE STRESSES FOR SPHERICAL SHELLS AND FORMED HEADS, WITH PRESSURE ON CONVEX SIDE

8.1 Spherical Shells.

8.1.1 With Equal Biaxial Stresses. The allowable compressive stress for a spherical shell under uniform external pressure is given by F_{ha} and the allowable external pressure is given by P_a. (E)

$$F_{ha} = \frac{F_y}{FS} \quad \text{for} \frac{F_{he}}{F_y} \ge 6.25 \tag{8-1a}$$

$$F_{ha} = \frac{1.31F_y}{FS\left(1.15 + \frac{F_{he}}{F_y}\right)} \quad \text{for} \quad 1.6 < \frac{F_{he}}{F_y} < 6.25 \tag{8-1b}$$

$$F_{ha} = \frac{0.18F_{he} + 0.45F_y}{FS} \quad \text{for } 0.55 < \frac{F_{he}}{F_y} \le 1.6 \tag{8-1c}$$

$$F_{ha} = \frac{F_{he}}{FS} \quad \text{for} \frac{F_{he}}{F_y} \le 0.55 \tag{8-1d}$$

$$F_{he} = 0.075E\frac{t}{R_o} \tag{8-2}$$

$$P_a = 2F_{ha}\frac{t}{R_o} \tag{8-3}$$

where R_o is the radius to the outside of the spherical shell and F_{ha} is given by eqs. (8-1a) through (8-1d).

8.1.2 With Unequal Biaxial Stresses — Both Stresses Are Compressive. The allowable compressive stresses for a spherical shell subjected to unequal biaxial stresses, σ_1 and σ_2, where both σ_1 and σ_2 are compression stresses resulting from applied loads, are given by the following equations. (E)

$$F_{1a} = \frac{0.6}{1 - 0.4k}F_{ha} \tag{8-4}$$

Table 2
Factor K_o

Use Interpolation for Intermediate Values						
$D_o/2h_o$	...	3.0	2.8	2.6	2.4	2.2
K_o	...	1.36	1.27	1.18	1.08	0.99
$D_o/2h_o$	2.0	1.8	1.6	1.4	1.2	1.0
K_o	0.90	0.81	0.73	0.65	0.57	0.50

$$F_{2a} = kF_{1a} \tag{8-5}$$

where $k = \sigma_2/\sigma_1$ and F_{ha} is given by eqs. 8.1.1(8-1a) through 8.1.1(8-1d). F_{1a} is the allowable stress in the direction of σ_1 and F_{2a} is the allowable stress in the direction of σ_2. σ_1 is the larger of the compression stresses.

(E) **8.1.3 With Unequal Biaxial Stresses — One Stress Is Compressive and the Other Is Tensile.** The allowable compressive stress for a spherical shell subjected to unequal biaxial stresses σ_1 and σ_2, where σ_1 is a compression stress and σ_2 is a tensile stress, is given by F_{1a}.

F_{1a} is the value of F_{ha} determined from eqs. 8.1.1(8-1a) through 8.1.1(8-1d) with F_{he} given by eq. (8-6).

$$F_{he} = (C_o + C_p)E\frac{t}{R_o} \tag{8-6}$$

$$C_o = \frac{102.2}{195 + R_o/t} \quad \text{for}\frac{R_o}{t} < 622 \tag{8-6a}$$

$$C_o = 0.125 \quad \text{for}\frac{R_o}{t} \geq 622 \tag{8-6b}$$

$$C_p = \frac{1.06}{3.24 + \dfrac{1}{\bar{p}}} \quad \bar{p} = \frac{\sigma_2}{E}\frac{R_o}{t} \tag{8-6c}$$

8.1.4 Shear. When shear is present, the principal stresses shall be calculated and used for σ_1 and σ_2.

8.2 Toroidal and Ellipsoidal Heads. The allowable compressive stresses for formed heads is determined by the equations given for spherical shells where R_o is defined below.

h_o = outside height of the ellipsoidal head measured from the tangent line (head-bend line), in. (mm)
K_o = factor depending on the ellipsoidal head proportions $D_o/2h_o$ (see Table 2)
R_o = for torispherical heads, the outside radius of the crown portion of the head, in. (mm)
R_o = for ellipsoidal heads, the equivalent outside spherical radius taken as K_oD_o, in. (mm)

8.3 Tolerances for Formed Heads. Formed heads shall meet the tolerances specified in NB-4222, NC-4222, ND-4222. Additionally, the maximum local deviation from true circular form, e, for spherical shells and any spherical portion of a formed head designed for external pressure shall not exceed the shell thickness. Measurements to determine e shall be made with a gage or template with the chord length L_e given by the following equation:

$$L_e = 3.72\sqrt{Rt} \tag{8-7}$$

9 REINFORCEMENT FOR OPENINGS (E)

The reinforcement for openings in vessels that do not exceed 25% of the cylinder diameter or 80% of the ring spacing into which the opening is placed may be designed in accordance with the following rules. Openings in shells that exceed these limitations require a special design that considers a critical buckling analysis in addition to the rules provided in this Case. Small nozzles that do not exceed the size limitations in NB-3332.1, NC-3332.1, and ND-3332.1 are exempt from reinforcement calculations.

9.1 Reinforcement for nozzle openings in vessels designed for external pressure alone shall be in accordance with the requirements of NB-3330, NC-3330, and ND-3330 as applicable. The required thickness shall be determined in accordance with 3.1 or 4.1. Factor F used in NB-3330, NC-3330, and ND-3330 shall be 1.0.

Openings shall meet the requirements of NC-3331(c) and ND-3331(c), respectively.

9.2 For cylinders designed for axial compression (which includes axial load and/or bending moment) without external pressure, the reinforcement of openings shall be in accordance with the following:

where

$$\gamma_n = \left(\frac{d}{2\sqrt{Rt}}\right)$$

For $d \leq 0.4\sqrt{Rt}$

$$A_r = 0 \tag{9-1}$$

For $d > 0.4\sqrt{Rt}$ and $\gamma_n \leq \left(\frac{R/t}{291} + 0.22\right)^2$

$$A_r = 0.5dt_r \tag{9-2}$$

For $d > 0.4\sqrt{Rt}$ and $\gamma_n > \left(\frac{R/t}{291} + 0.22\right)^2$

$$A_r = 1.0dt_r \tag{9-3}$$

and A_r is the area of reinforcement required, d is the inside diameter of the opening and t_r is the thickness of shell required for the axial compression loads without external pressure. The reinforcement shall be placed within a distance of $0.75\sqrt{Rt}$ from the edge of the opening. Reinforcement available from the nozzle neck shall be limited to a thickness not exceeding the shell plate thickness at the nozzle attachment, and be placed within a limit measured normal to the outside surface of the vessel shell of $0.5\sqrt{(d/2)t_n}$ (but not exceeding $2.5 \times t_n$), where t_n is the nozzle wall thickness.

9.3 For cylinders designed for axial compression in combination with external pressure, the reinforcement shall be the larger of that required for external pressure alone (9.1) or axial compression alone (9.2). Required reinforcement shall be placed within the limits described in 9.2 above.

10 REFERENCES

API 2U (1987), API Bulletin 2U (BUL 2U), "Bulletin on Stability Design of Cylindrical Shells," prepared under the jurisdiction of the API Committee on Standardization of Offshore Structures, First Edition, May 1987.

"ASME Code Case N-284: Metal Containment Shell Buckling Design Methods," Revision 1, May 1991.

Welding Research Council Bulletin 406, "Proposed Rules for Determining Allowable Compressive Stresses for Cylinders, Cones, Spheres, and Formed Heads," C.D. Miller and K. Mokhtarian, November 1995, ISSN 0043-2326.

Miller, C.D. and Mokhtarian, K., (1996), "A Comparison of Proposed Alternative Rules with ASME Code Rules for Determining Allowable Compressive Stresses," The Eighth International Conference on Pressure Vessel Technology, Montreal, Canada, July 25, 1996.

Miller, C.D. and Saliklis, E.P. (1993), "Analysis of Cylindrical Shell Database and Validation of Design Formulations," API Project 90-56, October 1993.

Miller, C.D., "Experimental Study of the Buckling of Cylindrical Shells With Reinforced Openings," ASME/ANS Nuclear Engineering Conference, Portland, Oregon, July 1982.

Miller, C.D., "The Effect of Initial Imperfections on the Buckling of Cylinders Subjected to External Pressure," PVRC Grant 94-28. Welding Research Council Bulletin 443, Report No. 1, July 1999.

"Commentary on the Alternative Rules for Determining Allowable Compressive Stresses for Cylinders, Cones, Spheres, and Formed Heads for Section VIII, Divisions 1 and 2," PVRC Grant 99-07, Welding Research Council Bulletin 462, June 2001.

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Approval Date: October 10, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-760-2
Welding of Globe Valve Disks to Valve Stem Retainers, Classes 1, 2, and 3
Section III, Division 1

Inquiry: Under what alternative rules for welding procedure qualification may Section III, Division 1 globe valve disks made from AMS 5387 in addition to other materials already permitted by Section III, be welded to a loose stem retainer when the electron beam welding process is used?

Reply: It is the opinion of the Committee that, in lieu of qualifying a WPS in accordance with NB-4330, NC-4330 or ND-4330 and welding in accordance with NB-4400, NC-4400, and ND-4400, globe valve disks made from AMS 5387 and other materials permitted by Section III may be welded to loose stem retainers for globe valves NPS 4 (DN 100) and smaller, when attached using the electron beam welding process under the conditions given below.

1 WELDING PROCEDURE QUALIFICATION

(a) Joint design shall be a partial penetration square groove weld in which one part is inserted into the other so as to provide integral backing.

(b) Welding procedure qualification requirements of Section IX shall apply except for the following:

(1) The use of filler metal, buttering or supplementary deoxidation material is prohibited.

(2) Requalification is required if the groove preparation differs more than 10% from the depth of the groove in the welded assembly used for qualification.

(3) In lieu of the testing that is required by QW-215.2, for each valve size, a welded assembly consisting of production parts shall be sectioned into four quadrants. For each quadrant:

(-a) One face shall be smoothed, polished and etched to give a clear definition of the weld and heat-affected zone. The weld and heat-affected zone shall be examined at 10 × magnification and shall confirm the following:

(-1) No cracks.

(-2) Complete fusion of the weld metal into both members to the depth of penetration required by the engineering design.

(-3) Porosity shall not reduce the weld throat below the minimum required to achieve the required depth of penetration.

(4) The manufacturer shall establish the maximum permissible tolerance of the weld location relative to the joint centerline for each valve size. This shall be done by machining a scribe line into each member parallel to the joint at a distance from the edge to be determined by the manufacturer. The manufacturer shall establish the offset of the weld bead from the joint centerline that can be tolerated while still achieving the required depth of penetration utilizing the scribe lines as references. This shall be done by welding and examining multiple coupons with varying weld offsets until the range has been established. Where the part geometry is such that a scribe line cannot be placed on one member, any machined surface that is parallel to the weld and suitably located to serve as a reference for the weld location may be used in lieu of a scribe line.

2 PRODUCTION WELDING

(a) A scribe line shall be machined into the outer surface of each member parallel to the joint at a distance from the edge of the joint such that, after welding, the scribe lines can be used to verify that the weld was properly located over the joint within the tolerance limits established during procedure qualification. Where the part geometry is such that a scribe line cannot be placed on one member, any machined surface that is parallel to the weld and suitably located to serve as a reference for the weld location may be used in lieu of a scribe line.

(b) The welding operator shall align the weld joint visually using the crosshairs of the alignment microscope. The assembly shall be rotated 360 deg and alignment verified around the circumference before welding is started.

(c) The weld shall be visually examined at 10 × magnification and shall be free of cracks or lack of fusion. The weld bead shall be located between the scribe lines within the tolerance established by the manufacturer.

3 ALLOWABLE STRESS

For AMS 5387, the allowable stress shall be one-fourth of the room-temperature specified minimum tensile strength, and the S_m value shall be one-third of the room-temperature specified minimum tensile strength, up to 650°F (343°C).

This Case number shall be listed in the NPV-1 Data Report Form for the valves.

Approval Date: September 20, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-761
Fatigue Design Curves for Light Water Reactor (LWR) Environments
Section III, Division 1

Inquiry: What fatigue curves may be utilized in combination with the Class 1 fatigue design rules to account for the effects of light water reactor (LWR) coolant environment on exposed surfaces of LWR materials?

Reply: It is the opinion of the Committee that for Class 1 components the following curves may be used to evaluate metal fatigue on surfaces exposed to LWR coolant.

1 SCOPE

Curves and the associated tabular data values are provided for carbon and low alloy steel for temperatures not exceeding 700°F (370°C) in Tables 1 and 1M and for austenitic stainless steel temperatures not exceeding 800°F (425°C) in Tables 2 and 2M. These curves include maximum mean stress corrections where applicable.

2 GENERAL

When the thermal cycle under consideration occurs at a *mean* temperature below 662°F (350°C) for carbon and low alloy steels and below 617°F (325°C) for austenitic stainless steels, environmental effects are reduced. This temperature correction is given in eqs. 3(a)(1a) and 3(b)(1b) for carbon and low alloy steels, and eqs. 4(a)(2a) and 4(b)(2b) for austenitic stainless steels. These temperature correction equations are based on the average temperature during the cycle. They provide the proper continuous transition from the maximum environmental effects at elevated temperatures given by the curves, to 300°F (150°C) below which the fatigue design curves for air apply.

3 CARBON AND LOW ALLOY STEELS

(a) Equation (1a) in terms of °F is as follows:

For 300°F ≤ T ≤ 662°F:

$$\ln N_D = \ln N_a + (\ln \overline{N}_e - \ln N_a)\frac{(T - 300°\text{F})}{362°\text{F}} \qquad (1a)$$

where

N_a = allowable design cycles in air
N_D = allowable design cycles including temperature correction and environmental effects
$\overline{N}_e$ = N_e or N_{eu} – allowable design cycles for the strain rate dependent environmental fatigue curves, N_e; or optionally using Curve B, which covers unrestricted strain rates, N_{eu}
T = mean metal temperature in cycle

(b) Equation (1b) in terms of °C is as follows:

For 150°C <T ≤ 350°C:

$$\ln N_D = \ln N_a + (\ln \overline{N}_e - \ln N_a)\frac{(T - 150°\text{C})}{200°\text{C}} \qquad (1b)$$

4 AUSTENITIC STAINLESS STEELS

(a) Equation (2a) in terms of °F is as follows:

For 300°F ≤ T ≤ 617°F:

$$\ln N_D = \ln N_a + (\ln \overline{N}_e - \ln N_a)\frac{(T - 300°\text{F})}{317°\text{F}} \qquad (2a)$$

(b) Equation (2b) in terms of °C is as follows:

For 150°C ≤ T ≤ 325°C:

$$\ln N_D = \ln N_a + (\ln \overline{N}_e - \ln N_a)\frac{(T - 150°\text{C})}{175°\text{C}} \qquad (2b)$$

5 CRITERIA

Note that the lowest of the environmental fatigue design curves (Curve B) covers unrestricted strain rates, and is necessarily the most conservative fatigue design curve. Other design curves are provided, each covering the entire range of strain rates faster than the minimum value specified for that curve. Of course, when taking credit for faster strain rates to reduce environmental effects, the higher stress amplitudes that may occur must be considered.

6 STRAIN RATE

The strain rate to be used is the local strain rate corresponding to the strain amplitude being used to perform the fatigue evaluation, including strain concentration effects. Faster strain rates reduce environmental degradation effects. The rate should include only positive strain rates. Under load cycles that involve variable strain rates, use of the average strain rate (total strain divided by total time for the transient) and average temperature provides conservative fatigue lives. Use of values consistent with the modified rate approach is also permitted, see Figure 1.

7 EXAMPLE APPLICATION FOR CARBON/LOW ALLOY STEEL

(a) local stress amplitude = 180 ksi

(b) strain rate = 0.004%/sec

(c) mean metal temperature in cycle = 288°C (550°F)

(d) from Figure 2 the following nomenclature applies

where

N_a = allowable design cycles in air = 150 cycles

N_e = allowable design cycles in reactor water at a minimum strain rate of 0.004%/sec = 36 cycles before mean temperature correction

N_{eu} = allowable design cycles in reactor water at an *unrestricted* strain rate from Curve B of Figure 2 before mean temperature correction = 10 cycles

(e) applying temperature correction of eq. 3(b)(1b) at T = 288°C

(1) at a strain rate of 0.004%/sec

$$\ln N_D = \ln 150 + (\ln 36 - \ln 150)\frac{(288 - 150)}{200°\text{C}} \tag{3}$$

where

N_D = 56 cycles at 288°C (550°F)

(2) at unrestricted strain rates:

$$\ln N_D = \ln 150 + (\ln 10 - \ln 150)\frac{(288 - 150)}{200°\text{C}} \tag{4}$$

where

N_D = 23 cycles at 288°C (550°F)

(f) for temperatures not exceeding 800°F (427°C), see Figure 3

Table 1
Reactor Water Environmental Fatigue Design Curves for Carbon and Low Alloy Steels for Temperatures Not Exceeding 700°F (371°C) and $N \leq 10^6$ Cycles

N (cycles)	S (ksi) Curve A, [Note (1)] $\dot{\varepsilon} \geq 1.0$	$\dot{\varepsilon}$ in. % / sec $\dot{\varepsilon} \geq 0.1$	$\dot{\varepsilon} \geq 0.014$	$\dot{\varepsilon} \geq 0.004$	Curve B [Note (2)]
1.0E+01	580	500	351	295	180
2.0E+01	410	368	262	223	134
5.0E+01	275	245	185	150	91.0
1.0E+02	205	183	137	114	70.0
2.0E+02	155	138	104	87.0	55.0
5.0E+02	105	96.0	74.0	63.0	41.0
1.0E+03	83.0	75.0	58.0	50.0	33.0
2.0E+03	64.0	59.0	46.0	40.0	27.5
5.0E+03	48.0	44.0	35.0	30.0	21.5
1.0E+04	38.0	35.0	28.5	24.8	18.5
2.0E+04	31.0	28.5	23.3	20.5	16.5
5.0E+04	23.0	22.0	18.5	17.3	15.0
1.0E+05	20.0	18.5	16.3	15.7	14.1
2.0E+05	16.5	16.0	14.8	14.5	13.5
5.0E+05	13.5	13.5	13.5	13.3	12.9
1.0E+06	12.5	12.5	12.5	12.5	12.5

GENERAL NOTE: Interpolation between tabular values is permissible based on data representation by straight lines on a log-log plot.

NOTES:
(1) Curve A may also be used for any strain rates under restricted conditions: Low temperatures ≤ 300°F (150°C) or low dissolved oxygen (≤ 0.04 ppm).
(2) Curve B covers all strain rates in reactor water.

Table 1M
Reactor Water Environmental Fatigue Design Curves for Carbon and Low Alloy Steels for Temperatures Not Exceeding 700°F (371°C) and $N \leq 10^6$ Cycles

N (cycles)	S (MPa) Curve A, [Note (1)] $\dot{\varepsilon} \geq 1.0$	$\dot{\varepsilon}$ in. % / sec $\dot{\varepsilon} \geq 0.1$	$\dot{\varepsilon} \geq 0.014$	$\dot{\varepsilon} \geq 0.004$	Curve B [Note (2)]
1.E+01	3,999	3,445	2,418	2,033	1,240
2.E+01	2,827	2,536	1,805	1,536	923
5.E+01	1,896	1,688	1,275	1,034	627
1.E+02	1,413	1,261	944	785	482
2.E+02	1,069	951	717	599	379
5.E+02	724	661	510	434	282
1.E+03	572	517	400	345	227
2.E+03	441	407	317	276	189
5.E+03	331	303	241	207	148
1.E+04	262	241	196	171	127
2.E+04	214	196	161	141	114
5.E+04	159	152	127	119	103
1.E+05	138	127	112	108	97.1

Table 1M Reactor Water Environmental Fatigue Design Curves for Carbon and Low Alloy Steels for Temperatures Not Exceeding 700°F (371°C) and $N \leq 10^6$ Cycles (Cont'd)

	S (MPa)	$\dot{\varepsilon}$ in. % / sec			
	Curve A, [Note (1)]				Curve B [Note (2)]
N (cycles)	$\dot{\varepsilon} \geq 1.0$	$\dot{\varepsilon} \geq 0.1$	$\dot{\varepsilon} \geq 0.014$	$\dot{\varepsilon} \geq 0.004$	
2.E+05	114	110	102	100	93.0
5.E+05	93.0	93.0	93.0	91.6	88.9
1.E+06	86.0	86.0	86.0	86.0	86.0

GENERAL NOTE: Interpolation between tabular values is permissible based on data representation by straight lines on a log-log plot.

NOTES:
(1) Curve A may also be used for any strain rates under restricted conditions: Low temperatures ≤ 300°F (150°C) or low dissolved oxygen (≤ 0.04 ppm).
(2) Curve B covers all strain rates in reactor water.

Table 2 Environmental Fatigue Design Curves for Types 304, 310, 316, and 348 Austenitic Stainless Steels for Temperatures Not Exceeding 800°F (427°C)

	S_a (ksi)	$\dot{\varepsilon}$ in. % / sec			
	Curve A, [Note (1)]				Curve B [Note (2)]
N (cycles)	$\dot{\varepsilon} \geq 1.0$	$\dot{\varepsilon} \geq 0.1$	$\dot{\varepsilon} \geq 0.01$	$\dot{\varepsilon} \geq 0.0014$	
1.E+01	870	750	600	460	280
2.E+01	624	537	445	334	202
5.E+01	399	343	292	217	131.0
1.E+02	287	243	208	161.0	94.9
2.E+02	209	178.0	158.0	123.0	73.2
5.E+02	141.0	124.0	109.0	87.0	52.7
1.E+03	108.0	95.5	86.0	70.3	42.6
2.E+03	85.6	76.9	69.6	56.8	36.0
5.E+03	65.3	59.4	53.4	43.2	29.9
1.E+04	53.4	48.2	43.5	35.7	26.6
2.E+04	43.5	39.6	35.9	30.0	24.3
5.E+04	34.1	31.1	28.7	25.4	21.6
1.E+05	28.4	26.7	25.0	22.6	20.0
2.E+05	24.4	23.2	21.9	20.2	18.80
5.E+05	20.6	19.70	18.90	18.10	17.10
1.E+06	18.30	17.50	17.20	16.70	16.20
2.E+06	16.40	16.00	15.90	15.70	15.50
5.E+06	14.80	14.80	14.80	14.80	14.80
1.E+07	14.40	...	...	...	...
1.E+08	14.10	...	...	...	...
1.E+09	13.90	...	...	...	...
1.E+10	13.70	...	...	...	...
1.E+11	13.60	...	...	...	...

Table 2 Environmental Fatigue Design Curves for Types 304, 310, 316, and 348 Austenitic Stainless Steels for Temperatures Not Exceeding 800°F (427°C) (Cont'd)

GENERAL NOTE: Interpolation between tabular values is permissible based on data representation by straight lines on a log-log plot.

NOTES:
(1) Curve A may also be used for any strain rates under restricted conditions: Low temperatures ≤ 300°F (150°C).
(2) Curve B covers all strain rates in reactor water.

Table 2M Environmental Fatigue Design Curves for Types 304, 310, 316, and 348 Austenitic Stainless Steels for Temperatures Not Exceeding 800°F (427°C)

	S_a (MPa)	$\dot{\varepsilon}$ in. % / sec			
	Curve A, [Note (1)]				Curve B [Note (2)]
N (cycles)	$\dot{\varepsilon} \geq 1.0$	$\dot{\varepsilon} \geq 0.1$	$\dot{\varepsilon} \geq 0.01$	$\dot{\varepsilon} \geq 0.0014$	
1.E+01	6000	5171	4137	3172	1931
2.E+01	4300	3703	3068	2303	1393
5.E+01	2748	2365	2013	1496	903
1.E+02	1978	1675	1434	1110	654
2.E+02	1440	1227	1089	848	505
5.E+02	974	855	752	600	363
1.E+03	745	658	593	485	294
2.E+03	590	530	480	392	248
5.E+03	450	410	368	298	206
1.E+04	368	332	300	246	183
2.E+04	300	273	248	207	168
5.E+04	235	214	197.9	175.1	148.9
1.E+05	196.0	184.1	172.4	155.8	137.9
2.E+05	168.0	160.0	151.0	139.6	129.6
5.E+05	142.0	135.8	130.3	124.8	117.9
1.E+06	126.0	120.7	118.6	115.1	111.7
2.E+06	113.0	110.3	109.6	108.3	106.9
5.E+06	102.0	102.0	102.0	102.0	102.0
1.E+07	99.0	...	...	...	...
1.E+08	97.1	...	...	...	...
1.E+09	95.8	...	...	...	...
1.E+10	94.4	...	...	...	...
1.E+11	93.7	...	...	...	...

GENERAL NOTE: Interpolation between tabular values is permissible based on data representation by straight lines on a log-log plot.

NOTES:
(1) Curve A may also be used for any strain rates under restricted conditions: Low temperatures ≤ 300°F (150°C).
(2) Curve B covers all strain rates in reactor water.

Figure 1
Application of the Modified Rate Approach

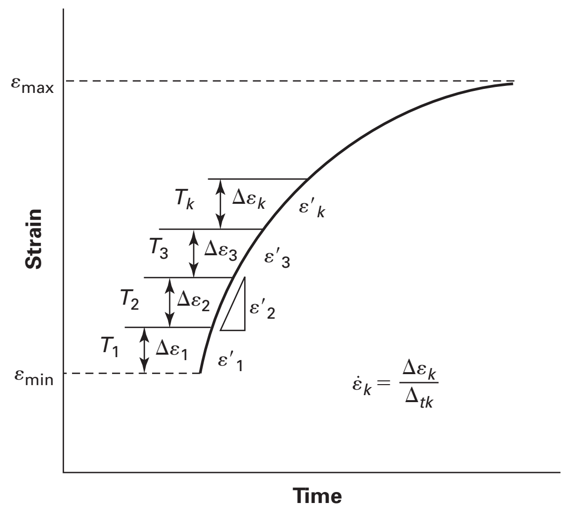
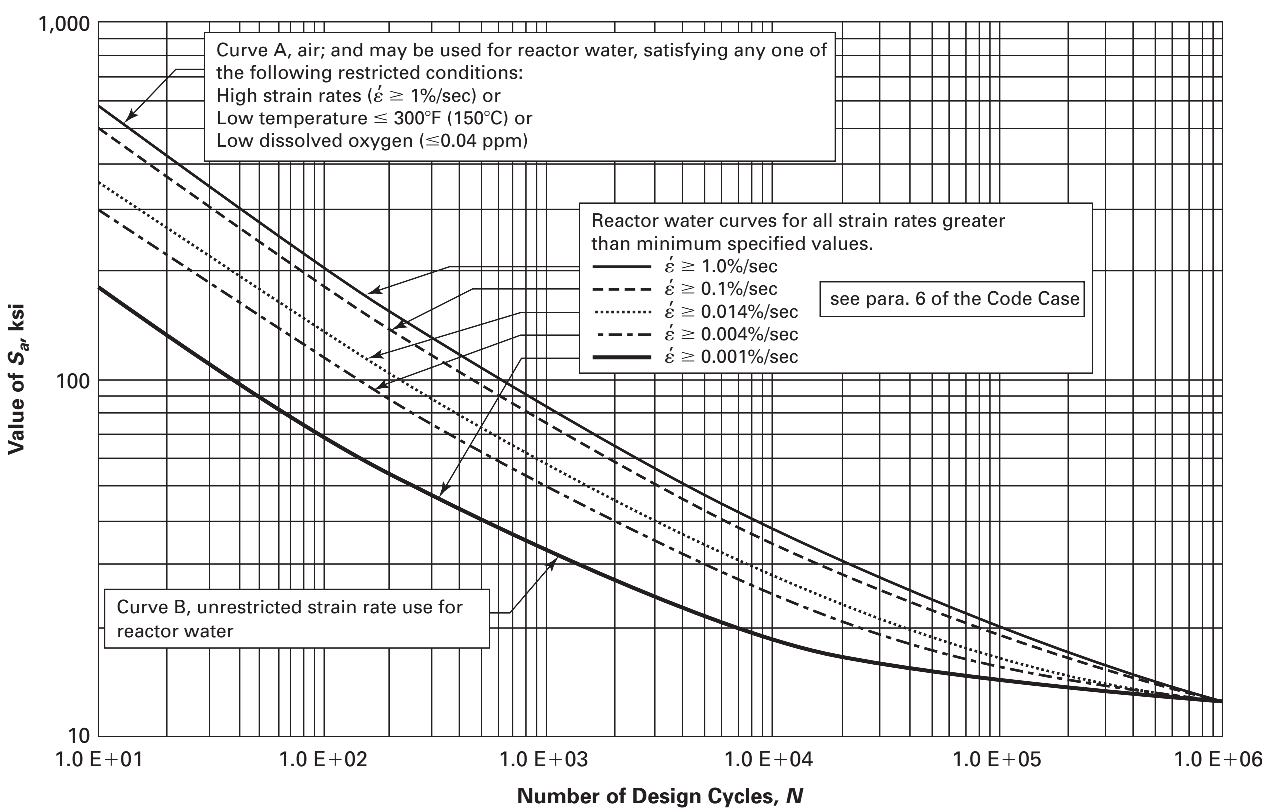
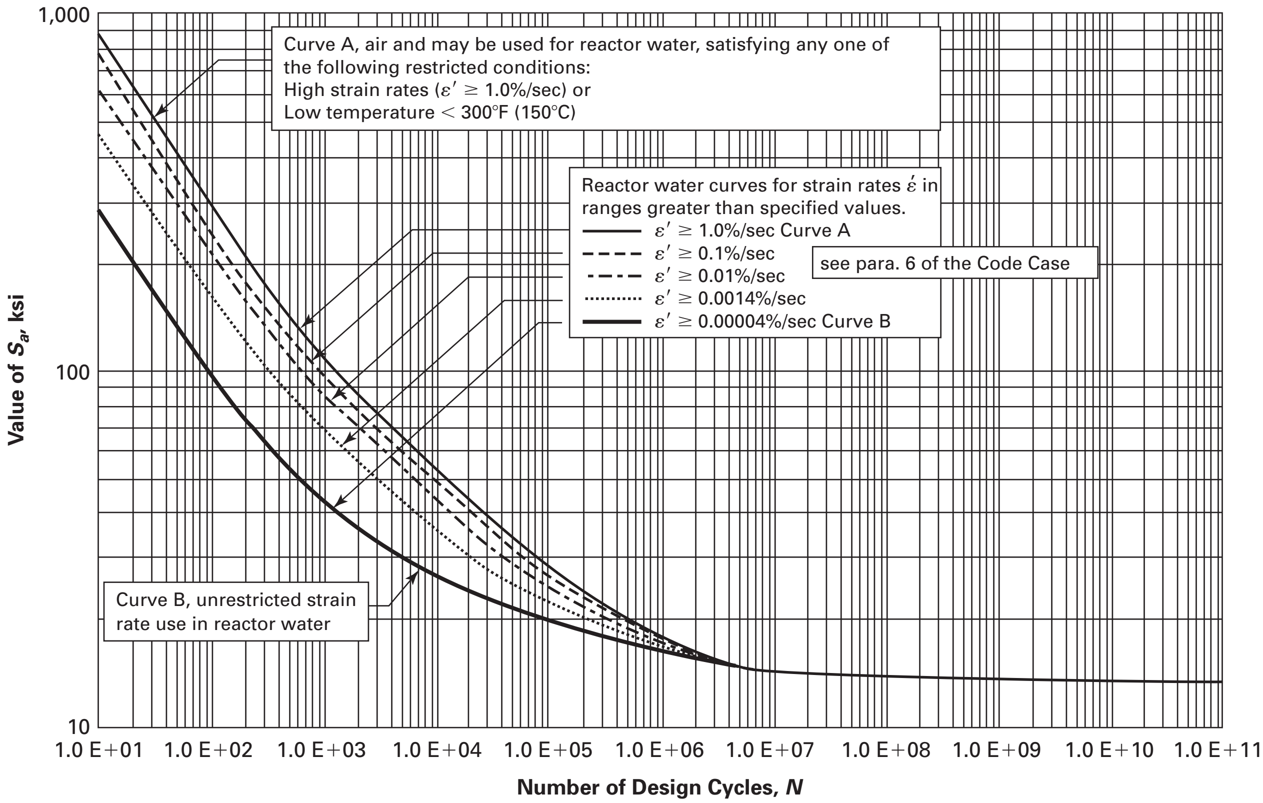


Figure 2
Reactor Water Environmental Fatigue Design Curves for Carbon and Low Alloy Steels for Temperature Not Exceeding 700°F (371°C) and $N \leq 10_6$ Cycles Above 10^6 Cycles the Air Curve Can Be Used for Reactor Water



GENERAL NOTE: $E = 30 \times 10^6$ psi (2.07×10^5 MPa)

Figure 3
Environmental Fatigue Design Curves for Types 304, 310, 316, and 348 Austenitic Stainless Steels for Temperatures Not Exceeding 800°F (427°C)



GENERAL NOTE: E = 28.3 × 10^3 ksi (1.95 x 10^5 MPa)

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Approval Date: October 21, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-762-1
Temper Bead Procedure Qualification Requirements for Repair/Replacement Activities Without Postweld Heat Treatment
Section XI, Division 1

Inquiry: Under what conditions may the provisions for procedure qualification of temper bead welding of QW-290 be used in lieu of the procedure qualification requirements of IWA-4600, when postweld heat treatment will not be performed?

Reply: It is the opinion of the Committee that the provisions for procedure qualification of temper bead welding QW-290 may be used under the following conditions when postweld heat treatment will not be performed:

(a) This Case shall be used with the 2004 Edition with the 2006 Addenda of ASME BPV Code Section IX, or later editions or addenda.

(b) This Case is for repair/replacement activities of P-Nos. 1, 3, 12A, 12B, and 12C materials and associated welds that join these materials to P-No. 8, or P-No. 4X materials.[1]

(c) The welding processes shall be gas-tungsten arc welding, shielded metal arc welding, or a combination of these processes.

(d) The material that is used for procedure qualification testing shall receive a heat treatment that is at least equivalent to the time and temperature already applied to the material being welded.

(e) If welding will be performed in a pressurized environment, the pressures shall be bounded in the test assembly by pressures associated with the depth limits of Table IWA-4662.1-1.

(f) Consideration shall be given to the effects of irradiation on the properties of material, including weld material for applications in the core beltline region of the reactor vessel. Special material requirements in the Design Specification shall apply to the test assembly materials for these applications.

(g) Procedure qualification impact testing requirements:

(1) The test assembly base material for the welding procedure qualification shall meet the impact test requirements of the Construction Code and Owner's requirements. If such requirements are not in the Construction Code and Owner's requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be as specified in (3) below, but shall be in the base metal. Impact testing of austenitic (nickel-based P-No. 4X and stainless steel P-No. 8) materials is not required.

(2) Charpy V-notch tests of weld metal of the procedure qualification shall meet the requirements as determined in (1).

(3) Charpy V-notch tests of the heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (1). Number, location, and orientation of test specimens shall meet the requirements of (4).

(4) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to align parallel to the fusion line.

(5) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(6) Charpy V-notch tests shall be performed on the weld metal, the heat-affected zone and unaffected base metal in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy,

[1] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later edition of Section IX.

test temperature, orientation, and location of all test specimens shall be reported in the Procedure Qualification Record.

(7) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Case, then either of the following shall be performed:

(-a) The welding procedure shall be requalified.

(-b) An *Adjustment Temperature* for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with 2002 Addenda or later editions or addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

(h) Use of this Case shall be documented on Form NIS-2.

Approval Date: August 28, 2008
(ACI) Approval Date: March 19, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-763
ASTM A709-06, Grade HPS 70W (HPS 485W) Plate Material Without Postweld Heat Treatment as Containment Liner Material or Structural Attachments to the Containment Liner, Subsection CC
Section III, Division 2

Inquiry: As an alternative to the provisions of Section III, Division 2, CC-2121(a), CC-2511, CC-2533.4.5, CC-4552, and CC-4554, may ASTM A709-06, Grade HPS 70W (HPS 485W) plate material be used as containment liner material, or structural attachments welded to the containment liner, without postweld heat treatment?

Reply: It is the opinion of the Committee that, as an alternative to the provisions of CC-2121(a), CC-2511, CC-2533.4.5, CC-4552, and CC-4554, ASTM A709-06, Grade HPS 70W (HPS 485W) plate up to 4 in. (100 mm) thick may be used as containment liner material, or structural attachments welded to the containment liner, without postweld heat treatment, provided the following requirements are met:

(a) Charpy V-notch impact tests shall be made of the base material in accordance with CC-2520, except as provided in (1).

(1) The test temperature shall be no higher than −10°F (−23°C). The minimum absorbed energy of each of the three specimens shall be at least 28 ft-lbf (38 J). The average absorbed energy of the three specimens shall be at least 35 ft-lbf (47 J). The exemptions of CC-2521 shall not be used.

(b) Charpy V-notch impact tests shall be made of the welding material in accordance with CC-2611 and CC-2612.1.1, and shall meet the test temperature and acceptance criteria of (a) above.

(c) For containment liner material, the WPS shall be qualified for notch toughness using Charpy V-notch impact tests in accordance with CC-4533, and shall meet the test temperature and acceptance criteria of (a)(1). For structural attachments, the WPS shall be qualified for notch toughness using Charpy V-notch impact tests in accordance with CC-4533 and shall meet the test temperature and acceptance criteria of (a)(1).

(d) To minimize introduction of hydrogen in the arc atmosphere, base metal and electrodes, filler metals, fluxes, and gases shall be protected from contamination. Welding consumables shall be supplied with a maximum diffusible hydrogen content of 4 ml of hydrogen per 100 g of weld metal measured in accordance with AWS A4.3, "Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding." Coated electrodes shall be supplied in hermetically sealed containers. Immediately after opening a hermetically sealed container, electrodes shall be stored in ovens held at a temperature of at least 250°F (120°C).

(e) For material up to $^3/_4$ in. (19 mm) thick, the minimum preheat temperature shall be at least 50°F (10°C). For material over $^3/_4$ in. (19 mm) and up to $1^1/_2$ in. (38 mm) thick, the minimum preheat temperature shall be at least 70°F (20°C). For material over $1^1/_2$ in. (38 mm) and up to $2^1/_2$ in. (64 mm) thick, the minimum preheat temperature shall be at least 150°F (65°C). For material over $2^1/_2$ in. (64 mm) thick, the minimum preheat temperature shall be at least 225°F (110°C). The maximum interpass temperature shall not exceed 450°F (230°C).

(f) Atmospheric Corrosion Resistance of ASTM A709-06. The provisions of ASTM A709-06 related to atmospheric corrosion resistance are not applicable to this Case.

(g) Separate welding procedure and performance qualifications shall be performed in accordance with Section IX.

(h) No postweld heat treatment is permitted.

(i) The nondestructive examination of CC-5521 [for liner welds, CC-5521(a) through (f), as applicable, or, for attachment welds, CC-5521(g)] shall be performed at least 48 hr after completion of welding.

(j) Welds between ASTM A709-06, Grade HPS 70W (HPS 485W) and other materials are permitted only if those materials are exempted from PWHT by Table CC-4552-2.

(k) This Case number shall be identified in the Data Report for the containment liner.

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Approval Date: January 26, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-765
Alternative to Inspection Interval Scheduling Requirements of IWA-2430
Section XI, Division 1

Inquiry: What alternative to the requirement of IWA-2430(d) [1989 Edition through the 2004 Edition with the 2006 Addenda] or IWA-2430(c) [2007 Edition through the 2007 Edition with the 2008 Addenda] may be used to modify the schedule for inspection intervals for Inspection Program B [1989 Edition through the 2004 Edition with the 2006 Addenda] and the Inspection Program of IWA-2431 [2007 Edition through the 2007 Edition with the 2008 Addenda]?

Reply: It is the opinion of the Committee that the following may be used as an alternative to the requirement of IWA-2430(d) for Inspection Program B [1989 Edition through the 2004 Edition with the 2006 Addenda] and IWA-2430(c) for the Inspection Program of IWA-2431 [2007 Edition through the 2007 Edition with the 2008 Addenda].

Inspection intervals shall conform to the requirements of Inspection Program B (1989 Edition through the 2004 Edition with the 2006 Addenda) or the Inspection Program of IWA-2431 (2007 Edition through the 2007 Edition with the 2008 Addenda) and the following:

(a) Each inspection interval may be extended by as much as one year, and may be reduced without restriction, provided the examinations required for the interval have been completed. Successive intervals shall not extend more than one year beyond the original pattern of ten-year intervals, and shall not exceed eleven years in length. For extended intervals, neither the start and end dates nor the inservice inspection program for the successive interval need be revised.

(b) Examinations may be performed to satisfy the requirements of an extended interval in conjunction with examinations performed to satisfy the requirements of the successive interval. However, an examination performed to satisfy requirements of either the extended interval or the successive interval shall not be credited to both intervals.

(c) That portion of an inspection interval described as an inspection period may be extended by as much as one year, and may be reduced without restriction, provided the examinations required for that period have been completed. This adjustment shall not alter the requirements for scheduling inspection intervals.

(d) The inspection interval for which an examination was performed shall be identified on examination records.

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Approval Date: April 7, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-766-1
Nickel Alloy Reactor Coolant Inlay and Onlay for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Dissimilar Metal Welds in Class 1 Items Section XI, Division 1

Inquiry: As an alternative to the provisions of IWA-2200, IWA-4400, and IWA-4530, is it permissible to mitigate flaws or the potential for flaws, by application of a corrosion resistant inlay or onlay on the inside surface of full penetration circumferential austenitic nickel alloy dissimilar metal welds (DMW) in Class 1 vessel nozzles and piping in PWRs?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-2200, IWA-4400, and IWA-4530, an austenitic nickel alloy inlay or onlay may be deposited to mitigate flaws or the potential for flaws on the inside surface of Class 1 full penetration circumferential austenitic nickel alloy DMW in PWR vessel nozzles and piping in accordance with the provisions of this Case.

1 GENERAL

(a) Definitions of Terms

(1) inlay. a corrosion resistant barrier applied on the inside surface of the component between the stress-corrosion-cracking (SCC) susceptible material and the reactor coolant, requiring excavation of some portion of the SCC susceptible material. See Figure 1.

(2) onlay. a corrosion-resistant barrier applied on the inside surface between the SCC susceptible material and the reactor coolant, not requiring (nor prohibiting) excavation of some portion of the SCC susceptible material. See Figure 2.

(3) mitigation. an activity performed to reduce or eliminate the susceptibility of Alloy 82/182[1] weld filler material or Alloy 600[2] materials to crack initiation or crack propagation. Mitigation can be preemptive, i.e., performed before crack initiation, or repair, i.e., performed after crack initiation is discovered.

(b) This Case shall apply to inlay or onlay for DMW and adjacent vessel nozzles, cladding, piping, and associated austenitic stainless steel welds, if applicable, consisting of the following base materials or combinations thereof:

(1) P-No. 8 and P-No. 43

(2) P-No.8 or 43 and P-No.1, 3, 12A, 12B, or 12C[3]

(c) Prior to installation of the inlay or onlay, the DMW and area to be welded shall be examined in accordance with 3*(b)*. Any detected flaws shall meet the following requirements.

(1) Indications detected in the examination of 3(b)(1) that exceed the acceptance standards of IWB-3514 shall be corrected in accordance with the defect removal requirements of IWA-4000. Alternatively, indications that do not meet the acceptance standards of IWB-3514 may be accepted by analytical evaluation in accordance with IWB-3600.

(2) Surface indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) shall be removed or reduced in size, or shall be weld repaired in accordance with the following requirements.

(-a) One or more layers of weld metal shall be applied to seal unacceptable indications, with or without excavation. The thickness of the layers shall not be credited to the thickness of the inlay or onlay as specified in 2. However, the thickness of the layers shall be included in the analysis of 2(b).

(3) If weld repair of indications identified in (c) is required, the area where the weld inlay or onlay is to be deposited, including any local weld repairs, shall be examined using the liquid penetrant or eddy current method. The area shall be free of surface indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) prior to installation of the inlay or onlay.

[1] Alloy 82 and Alloy 182 are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06082 (SFA-5.14, ERNiCr-3) and UNS W86182 (SFA-5.11, ENiCrFe-3), respectively.

[2] Alloy 600 is a common abbreviation used by industry, the regulatory authority, and research organizations for UNS N06600.

[3] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

(d) To reduce the potential for hot cracking when applying an austenitic nickel alloy over P-No. 8 base metal, cladding, or adjacent weld, it is permissible to apply austenitic filler material over the austenitic stainless steel or ferritic steel materials. The thickness of these layers shall be included in the analysis in 2(b).

(e) The location of the DMW fusion zones shall be identified. The accuracy of the locating technique shall be demonstrated on representative mockups and documented.

(f) Inlays or onlays shall be deposited using a Welding Procedure Specification (WPS) qualified for groove welding in accordance with the Construction Code and Owner's Requirements identified in the Repair/Replacement Plan.

(g) Welders and welding operators shall be qualified in accordance with the Construction Code and Owner's Requirements identified in the Repair/Replacement Plan.

(h) The preheat and postweld heat treatment requirements of the Construction Code and Owner's Requirements identified in the Repair/Replacement Plan shall be met if welding on ferritic base materials or if $^1/_8$ in. (3 mm) or less of nonferritic weld deposit exists above the fusion line of the ferritic steel base material. As an alternative, ambient temperature temper bead welding may be performed in accordance with Mandatory Appendix I.

(i) Weld filler metal for the inlay or onlay shall be nickel alloy with chromium content of at least 28%. Repairs to the DMW may be made with nickel alloy weld filler material having a chromium content of at least 28% or ERNiCr-3.

(j) The inlay or onlay shall consist of at least two layers after final surface preparation and shall comply with the thickness requirements of 2(a). All inlay or onlay layers credited toward the minimum thickness shall contain at least 24% chromium.

(k) The chromium content of the deposited weld metal shall be determined by chemical analysis of a coupon from a mockup representative of the materials on which the inlay or onlay will be deposited using the applicable production weld parameters and the same production weld metal classification. The weld filler metal used for the mockup shall have chromium content no greater than that to be used for the inlay or onlay. Alternatively, if the chromium content of the mockup filler metal is greater than that used for the inlay or onlay, the mockup coupon may be accepted provided the following criteria are met.

$$Cr_1 - (Cr_2 - Cr_m) \geq 24\%$$

where

Cr_1 = Cr content (%) of filler metal to be used for inlay or onlay as reported on the CMTR

Cr_2 = Cr content (%) of filler metal used in the mockup coupon as reported on the CMTR

Cr_m = Cr content (%) of the mockup coupon weld deposit as determined by chemical analysis

(l) For onlays, metal removal associated with surface preparation for welding is permitted, provided it does not encroach on the minimum design thickness.

2 DESIGN AND ANALYSIS REQUIREMENTS

(a) The thickness of the inlay or onlay shall comply with the following:

(1) The thickness shall be at least $^1/_8$ in. (3 mm).

(2) The minimum thickness shall cover the DMW and extend beyond the DMW and butter fusion zones by at least twice the demonstrated accuracy of the locating technique of 1(e) or $^1/_4$ in. (6 mm), whichever is greater.

(b) For the final configuration, the applicable stress limits of the Construction Code shall be met. If the combined thickness of the inlay or onlay and any remaining portion of the original cladding is 10% or less of the total wall thickness, the inlay or onlay design may be considered exempt from evaluation of the primary plus secondary stress intensity (NB-3222.2) and analysis for cyclic operation (NB-3222.4).

(c) A crack growth evaluation shall be performed to demonstrate that a planar flaw in the DMW or butter at the interface between the DMW or butter and the inlay or onlay will not grow by fatigue through the full thickness of the inlay or onlay. The fatigue crack growth evaluation shall be performed in accordance with IWB-3640,[4] for the applicable service life, considering all loads subject to Level A and B Service Limits. Both axial and circumferential planar flaws shall be evaluated using the following criteria as applicable.

(1) Flaws With Depths of 10% or Less of DMW Thickness. Axial and circumferential flaw depths shall be assumed to be 10% of the original DMW thickness if the embedded flaw depths do not exceed 10% of the original DMW thickness, or if there are no embedded flaws. The length of the assumed axial flaw shall be the entire width of the DMW and butter plus any adjacent SCC-susceptible material.

(2) Flaws With Depths Greater Than 10% of DMW Thickness

(-a) For axial and circumferential flaws whose depths exceed 10% of the original DMW thickness, the actual flaw depths and lengths shall be used in the IWB-3640 evaluation.

(-b) In addition to the evaluation of 2(c)(2)(-a), postulated axial and circumferential flaws with depths equal to 10% of the DMW thickness shall be evaluated. The length of the assumed circumferential flaw shall be 360 deg. The length of the assumed axial flaw shall be the entire width of the DMW and butter plus any adjacent SCC-susceptible material.

[4] IWB-3640 or IWB-3650 in 2001 Edition or earlier.

(d) Postulated planar flaws in the inlay or onlay shall be evaluated for fatigue crack growth through the inlay or onlay in accordance with IWB-3640 for the service life. Both circumferential and axial surface connected flaws of $^1/_{16}$ in. (1.5 mm) depth shall be postulated. A postulated circumferential flaw shall be 360 deg around the circumference. A postulated axial flaw shall be the entire width of the DMW and butter plus any adjacent SCC susceptible material. The fatigue crack growth evaluation shall demonstrate that a surface-connected flaw will not grow through the full thickness of the inlay or onlay, considering all applicable loads subject to Level A and B Service Limits.

(e) If the inlay or onlay deposited in accordance with this Case is thicker than $^1/_8\,t$, where t is the original nominal DMW thickness, the effects of any change in applied loads, as a result of weld shrinkage from the entire inlay or onlay, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the inlay or onlay) shall be evaluated. Existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640.

3 EXAMINATION

(a) General

(1) The examination requirements of this Case shall be met in lieu of all other examination requirements.

(2) Nondestructive examination methods shall meet the requirement of IWA-2200, except as specified in (-a) and (-b) below.

(-a) Eddy current examination shall be performed in accordance with IWA-2223, except that the length of the Appendix IV, Supplement 2 qualification cracks or notches shall not exceed $^1/_{16}$ in. (1.5 mm).

(-b) Volumetric acceptance examinations shall comply with (c)(2) and (d).

(3) Nondestructive examination personnel shall be qualified in accordance with IWA-2300.

(b) Examination Prior to Application of the Inlay or Onlay

(1) Volumetric examination of the applicable DMW and butter shall be performed in accordance with Case N-770-1 or later, as specified in 4, during the same outage as the repair/replacement activity.

(2) Surface examination shall be performed using the liquid penetrant or eddy current method on the area to be welded.

(3) Prior to installation of the inlay or onlay, all indications shall meet the requirements of 1(c).

(c) Acceptance Examination of the Inlay or Onlay

(1) The inlay or onlay surface, including at least $^1/_2$ in. (13 mm) of adjacent material, shall be examined using eddy current examination method. Indications with major dimension greater than $^1/_{16}$ in. (1.5 mm) are not permitted. The adjacent material, including existing cladding, may alternatively be examined using the liquid-penetrant method and evaluated using the surface examination acceptance criteria for base material of Section III, NB-2500.

(2) The inlay or onlay volume, including the fusion zone, and ferritic steel heat-affected zone, when temper bead welding is used, shall be ultrasonically examined in accordance with Section V, Article 4, using Cladding Technique One.[5] Calibration blocks shall be in accordance with Fig. T-434.4.2.2.[5] Imperfections producing a response greater than 20% of the reference level are unacceptable regardless of length. If temper bead welding is used, the examination shall be conducted no sooner than 48 hr after the completion of the third temper bead layer over the ferritic steel base material.

(d) Acceptance Examination of the Weld Repair (if applicable)

(1) If weld repair is required for indications identified in 1(c)(1), the weld repair volume shall be examined ultrasonically in accordance with Section V, Article 4. The acceptance criteria of Section III, NB-5330 shall be met. If temper bead welding is used, the examination shall be conducted no sooner than 48 hr after the completion of the third temper bead layer over the ferritic steel base material.

(e) Preservice and Inservice Examination

(1) Preservice and inservice examinations shall be performed in accordance with Case N-770-1 or later, as specified in 4.

4 USE OF CASE N-770-1 OR LATER

(a) The revision of Case N-770 used shall be applicable, as indicated in the Applicability Index for Section XI Cases found in the Code Cases: Nuclear Components book, to the Edition and Addenda specified for the repair/replacement activity.

(b) The revision of Case N-770 used is subject to acceptance by the regulatory and enforcement authorities having jurisdiction at the plant site.

(c) The revision of Case N-770 used shall be in effect at the time of the repair/replacement activity, except as provided in (d).

(d) A revision of Case N-770 that is superseded at the time of the repair/replacement activity, but acceptable to the regulatory and enforcement authorities having jurisdiction at the plant site, may be used.

[5] All Section V references are to the 2001 Edition with the 2002 Addenda through 2010 Edition with the 2011 Addenda.

Figure 1
Typical Inlay

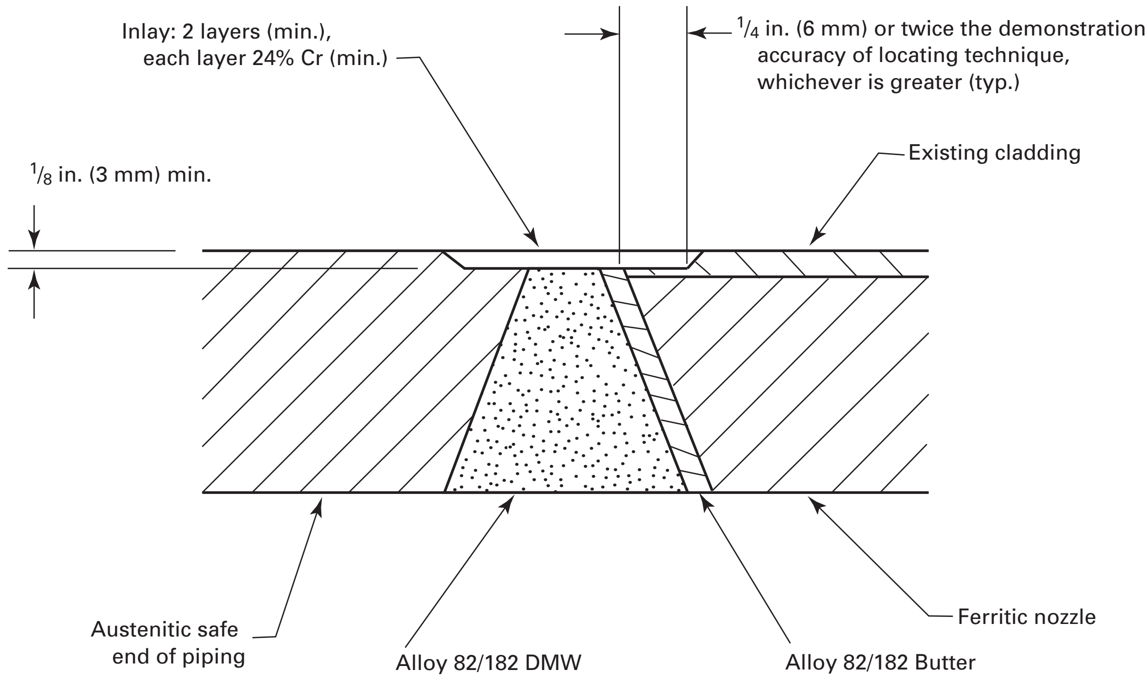
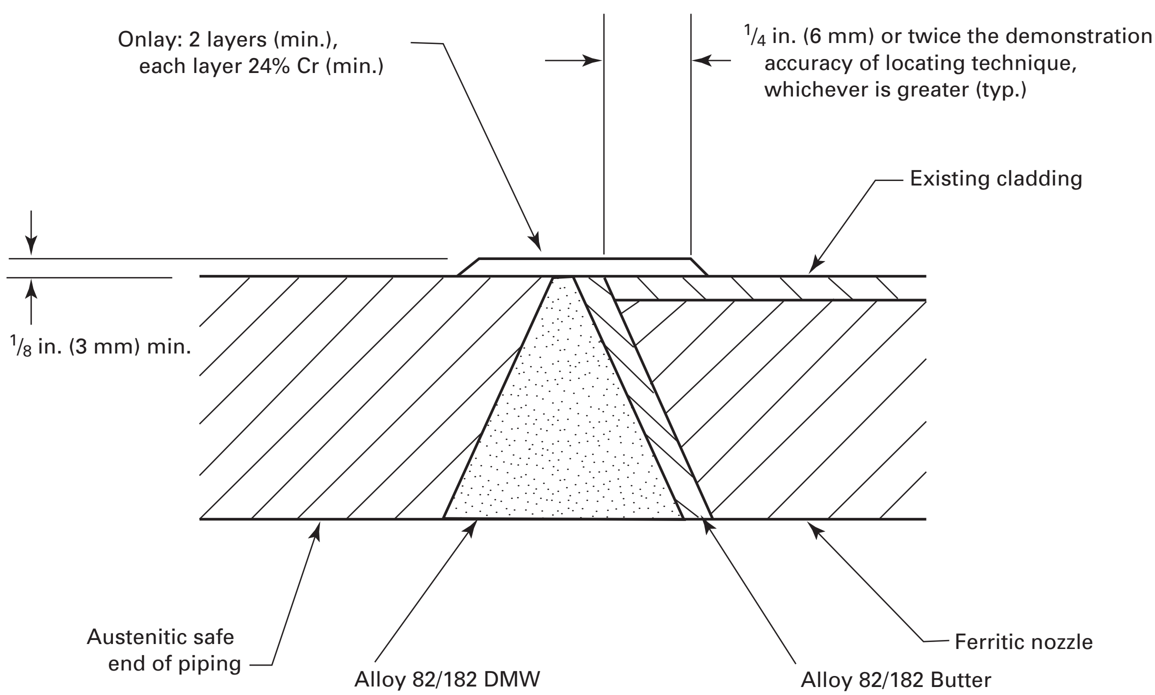


Figure 2
Typical Onlay



MANDATORY APPENDIX I
AMBIENT-TEMPERATURE TEMPER BEAD WELDING

I-1 GENERAL REQUIREMENTS

(a) The maximum area of an individual inlay or onlay based on the finished surface over the ferritic base material shall be 500 in.^{2} (325 000 mm^2).

(b) Repair/replacement activities on a DMW in accordance with this Appendix shall be limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm) or less of nonferritic weld deposit exists above the original fusion line.

(c) Prior to welding, the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

I-2 WELDING QUALIFICATIONS

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of I-2.1 and I-2.2.

I-2.1 Procedure Qualification.

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials to be welded.

(b) The root width and included angle of the cavity in the test assembly shall be no greater than the minimum specified for the weld.

(c) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(d) The weld procedure shall be qualified using a groove weld coupon. The test assembly cavity depth shall be at least 1 in. (25 mm). The test assembly thickness shall be at least twice the test assembly cavity groove depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the cavity groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Figure I-1.

(e) Ferritic base material for the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (f), but shall be in the base metal.

(f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (e). Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(2) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(3) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation, and location of all test specimens shall be reported in the Procedure Qualification Record.

(g) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Appendix, either of the following shall be performed.

(1) The welding procedure shall be requalified.

(2) An Adjustment Temperature for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with the 2002 Addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

I-2.2 Performance Qualification. Welding operators shall be qualified in accordance with Section IX.

I-3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements.

(a) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least $^1/_8$ in. (3 mm) weld thickness with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45 kJ/in. (1.8 kJ/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic weld filler material at the toe of the weld to ensure that the HAZ and ferritic base metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(b) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers regardless of the interpass temperature used during qualification. The interpass temperature limitation of QW-406.3 need not be applied.

(c) The interpass temperature shall be determined by one of the following methods:

(1) heat flow calculations using at least the variables listed below:

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

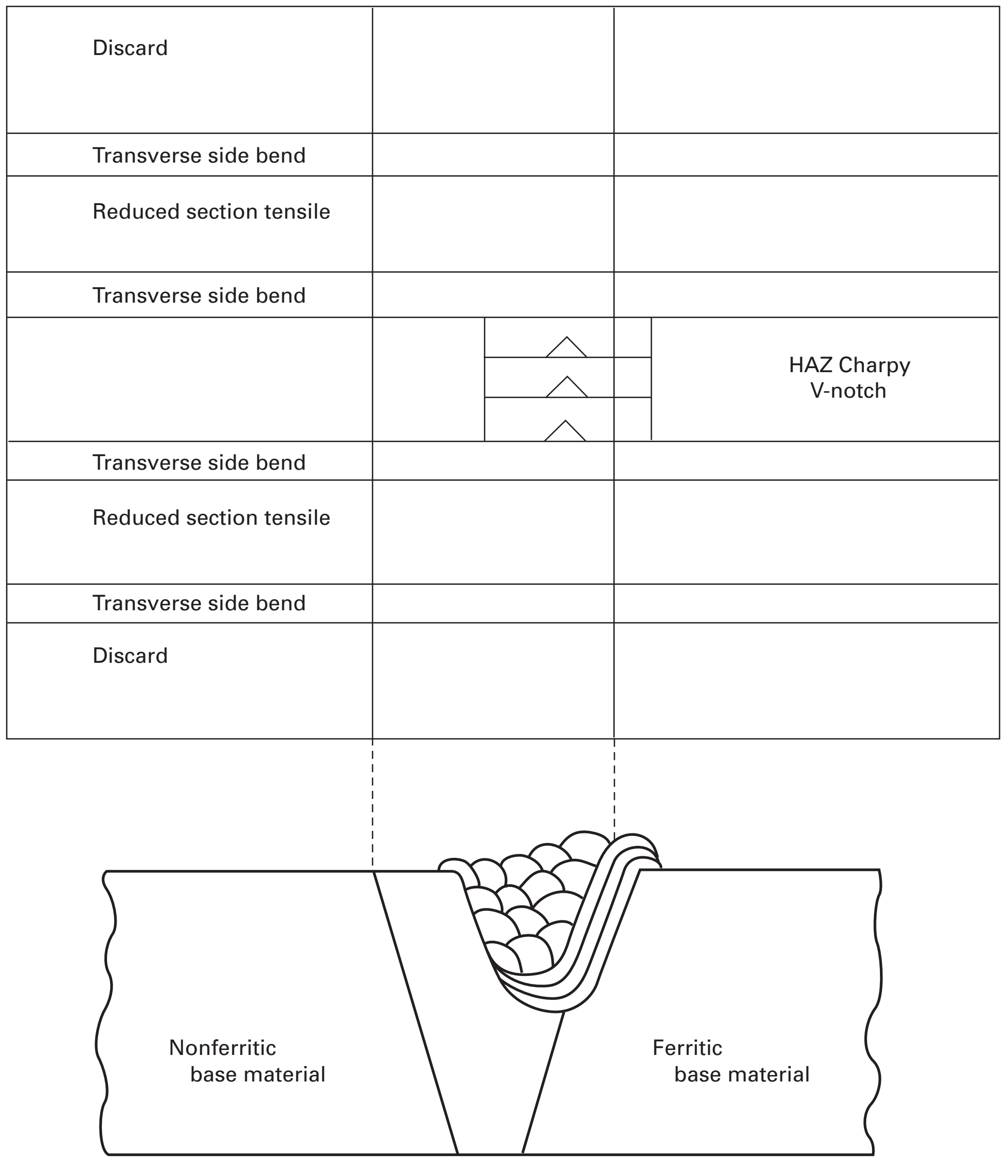
(-e) arc time per weld pass and delay time between each pass

(-f) arc time to complete the weld

(2) Measurement of the maximum interpass temperature on a test coupon that is no thicker than the item to be welded. The maximum heat input of the welding procedure shall be used in the welding of the test coupon.

(d) Particular care shall be given to ensure that the weld region is free from all potential sources of hydrogen. The surfaces to be welded, filler metals, and shielding gas shall be suitably controlled.

Figure I-1
Qualification Test Plate



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a dissimilar-metal weld,

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Approval Date: January 4, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-767
Use of 21Cr-6Ni-9Mn (Alloy UNS S21904) Grade FXM-11 (Conforming to SA-182/SA-182M and SA-336/SA-336M), Grade TPXM-11 (Conforming to SA-312/SA-312M) and Type XM-11 (Conforming to SA-666) Material, for Class 1 Construction
Section III, Division 1

Inquiry: Is it permissible to use 21Cr-6Ni-9Mn (Alloy UNS S21904) conforming to SA-182/SA-182M, SA-312/SA-312M, SA-336/SA-336M, and SA-666 in the construction of Class 1 components to the rules of Section III, Division 1 (up to the 2004 Edition with the 2006 Addenda)?

Reply: It is the opinion of the Committee that 21Cr-6Ni-9Mn (Alloy UNS S21904) conforming to SA-182/SA-182M, SA-312/SA-312M, SA-336/SA-336M, and SA-666 may be used for Section III, Division 1, Class 1 construction (up to the 2004 Edition with the 2006 Addenda) provided the following additional requirements are met:

(a) The design stress intensity values shall be those shown in Tables 1 and 1M for applications with a maximum use temperature of less than or equal to 600°F (316°C).

(b) External pressure chart HA-6 shall be used.

(c) This Case number shall be identified on the Certificate Holders Data Report Form.

Table 1
U.S. Customary Design Stress Intensity Values, S_m, ksi

For Metal Temperature Not Exceeding, °F	S_m
−20 to 100	30.0
200	30.0
300	28.0
400	26.4
500	24.4
600	23.1

GENERAL NOTE: Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66⅔% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stess values that will result in lower levels of permanent strain.

Table 1M
Metric Design Stress Intensity Values, S_m, MPa

For Metal Temperature Not Exceeding, °C	S_m
−30 to 40	207
65	207
100	206
125	200
150	193
200	183
250	171
300	162
325	158

GENERAL NOTES:

(a) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66⅔% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stess values that will result in lower levels of permanent strain.

(b) The values of 325°C is for interpolation, the maximum use temperature is 316°C.

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Approval Date: July 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-769-2
Roll Expansion of Class 1 In-Core Housing Bottom Head Penetrations in BWRs
Section XI, Division 1

Inquiry: May the mechanical roll expansion technique be used as a repair/replacement activity to eliminate leakage from Class 1 In-Core Housing (ICH) bottom head penetrations in Boiling Water Reactors (BWRs)?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWB-3140, the mechanical roll expansion technique may be used as a repair/replacement activity to eliminate leakage from Class 1, ICH bottom head penetrations in BWRs, provided the following requirements are met.

1 SCOPE

1.1 This Case applies to use of mechanical roll expansion for the purpose of sealing leakage from cracks detected in the following locations:

(a) In-core housing-to-vessel attachment weld (BWR/2-6)

(b) ICH stub tube base metal (ABWR)

(c) ICH stub-tube-to-housing J-groove weld (ABWR)

(d) ICH stub-tube-to-vessel attachment weld (ABWR)

1.2 This Case shall not be used when leakage is due to through-wall cracking in the housing.

1.3 The following conditions shall apply to this Case:

(a) Housing material: any P-No. 8 or P-No. 43.

(b) Vessel material: any P-No. 3.

(c) Measured percent wall thinning: 2% – 5%.

(d) Roll-band length shall not exceed 6 in. (150 mm).

(e) Roller top and bottom end radius shall be at least $^1/_4$ in. (6 mm).

(f) Ratio of housing specified minimum yield strength to vessel head specified minimum yield strength shall be less than 1.0.

(g) If more than one roll is required to achieve the required roll-band length, the minimum overlap for each roll shall be at least 0.5 in. (13 mm).

(h) Rollers shall be lubricated.

1.4 The provisions of IWA-4140, IWA-4150, IWA-4170, and IWA-4310 shall be met.

2 GENERAL REQUIREMENTS

2.1 If the ICH is roll expanded against the vessel, creating a mechanical seal to eliminate leakage, the following requirements shall be met:

(a) Values for wall thinning and roll-band length shall be specified. The target value for wall thinning for the rolling shall be 2.5% to 4.5%. Because of variations in the gap between the housing outside surface and the vessel bore inside surface, the actual amount of wall thinning may vary from 2% to 5%. In no case shall the total wall thinning exceed 5%. The required wall thinning may be achieved using any number of intermediate partial rolls.

(b) The roll-band length, L, is defined as the flat portion of the roll, excluding the rounded transition region at each end. The minimum roll-band length shall not be less than in the prequalified procedure or the length qualified by a procedure qualification. In addition, the length shall not be less than the value given by the following equation.

$$L = [SF\ P\ (R^2)] / \left\{0.4[(1-p)T\ S_y]\right\},$$
but not less than 2 in. (50 mm)

where

P = design pressure
p = nominal wall-thinning fraction (e.g., 0.04 for 4% thinning)
R = nominal outside radius of housing
SF = Structural Factor = 2
S_y = yield strength of the housing material at room temperature
T = thickness of housing

(c) If multiple roll passes are required to achieve the desired roll-band length the direction of the rolling shall be initiated from the top and progress downward toward the free end of the ICH housing.

(d) Rolling shall not be performed on portions of the housing extending above or below the vessel bottom head.

2.2 A Roll-Expansion Procedure Specification (REPS) shall be prepared. The REPS shall define the requirements for roll expansion for procedure qualification (if required), for performance demonstration, and for the plant-specific rolling. The REPS shall define the target values for wall thinning and roll-band length, as well as the procedure to be used to achieve these target values.

2.3 No plant-specific procedure qualification is required (i.e., the procedure is prequalified) if the plant specific rolling parameters are within the tolerances specified in Table 1. A mechanical roll-expansion tool using a tapered shaft to effect expansion and a hard stop to limit expansion shall be used.

3 PLANT-SPECIFIC PROCEDURE QUALIFICATION

If the design of the roll does not meet the conditions of Table 1, a plant-specific procedure qualification is required. A REPS for the procedure qualification and for the plant-specific application shall be developed. The procedure qualification shall be demonstrated on a mockup meeting the acceptance criteria of Table 2 and the requirements listed in 1. The vessel may be simulated in the mockup by a flat plate with thickness at least 1.5 in. (38 mm) greater than the target roll-band length, but in no case less than 4 in. (100 mm).

3.1 The roll-band length and percent wall thinning achieved in the procedure qualification shall be determined by measurement. The measured wall-thinning shall define the minimum qualified wall-thinning for use in the plant-specific application. The measured roll-band length shall define the minimum qualified roll-band length for use in the plant-specific application.

3.2 The mockup shall be rolled at ambient temperature, heated to 550°F (290°C), held at temperature for one hour, cooled to ambient temperature, and subjected to a leakage test at 1875 psig (13 MPa) for at least one hour. Successful roll expansion requires VT-2 visual examination and verification of no leakage.

3.3 A REPS qualified for one plant may be used at another plant, provided the acceptance criteria listed in Table 2 and all other provisions of this Case are met.

3.4 Transfer of a procedure qualification between Owners shall be subject to the following requirements:

(a) The Owner that performed the procedure qualification shall certify in writing that the procedure qualification was developed in accordance with a Quality Assurance Program that satisfies the requirements of IWA-1400(n).

(b) The Owner that performed the procedure qualification shall certify in writing that the procedure qualification meets the provisions of this Case.

4 PERFORMANCE DEMONSTRATION

(a) Prior to implementing a roll expansion in a plant, the Owner shall conduct a performance demonstration to verify personnel capabilities. The performance demonstration shall be conducted on a mockup meeting the requirements of Table 3. The vessel may be simulated in the mockup by a flat plate with thickness at least 1.5 in. (38 mm) greater than the target roll-band length, but in no case less than 4 in. (100 mm). Tooling shall be of the identical design and nominal dimensions as tooling to be used for the plant-specific roll.

(b) Personnel performing tasks required to meet the acceptance criteria for the essential variables of the REPS in the plant-specific application shall perform the same tasks in the performance demonstration. Performance of a task in the performance demonstration qualifies a person to perform that task in the plant-specific application for a period of 12 mo from that demonstration. Personnel qualification shall be documented in the plant records of the roll-expansion.

(c) The REPS for the performance demonstration shall define the target values for wall thinning and roll-band length as well as the location of the roll-band to be achieved. These target values need not be identical to those specified for the plant specific application.

(d) Acceptance criteria for the performance demonstration are as follows:

(1) measured wall thinning equal to the target value ±0.5%

(2) measured roll-band length equal to the target value +0.25 in. (6.0 mm) or −0 in. (0 mm)

(3) roll-band position equal to the target value ±0.25 in. (6.0 mm)

5 EVALUATION

Each proposed roll expansion shall be evaluated as follows.

5.1 Analysis shall be performed to show that the thickness of the ICH after rolling is sufficient to meet the primary stress limits of the Construction Code.

5.2 The expanded penetration shall satisfy all plant specific design criteria related to structural integrity. All specified load combinations and design-basis events shall be addressed.

5.3 Crack growth shall be predicted, considering stress corrosion cracking and fatigue. The analytical evaluation of the predicted crack shall satisfy the requirements of IWB-3600.

5.4 If the source of the leakage is a crack in the vessel attachment weld, a postulated axial crack in the vessel attachment weld shall be evaluated. The analytical evaluation shall include an assumption that the entire weld thickness is cracked radially and shall satisfy the requirements of IWB-3600.

Table 1
Prequalified Rolling Parameters

Essential Variable	Acceptance Criteria
Percent wall thinning	2% to 5%
Roll-band length, L	2 in. ≤ L ≤ 6 in. (50 mm ≤ L ≤ 150 mm)(backed by vessel material)
Housing outside diameter	2 ± 0.0625 in. (50 ± 1.5 mm)
Housing inside diameter	1.5 ± 0.0625 in. (38 ± 1.5 mm)
Housing material	Any P-No. 8 material
Vessel head material	Any P-No. 3 material

6 EXAMINATIONS AND TESTS

6.1 Prior to roll expansion, ultrasonic (UT) examination of the regions specified in Figure 1 or Figure 2 shall be performed. For the BWR/ 2-6 ICH configuration (Figure 1), Region 2 and the housing-to-vessel-weld region (Region 1) shall be examined. For ABWR stub-tube configurations (Figure 2), Region 2 and the stub-tube-to-housing J-groove-weld region (Region 1) shall be examined. If the leakage is due to through-wall cracking of the housing or if planar flaws are detected in Region 2, this Case shall not be used. For housing indications in the area of the stub tube-to-housing J-groove-weld region or the housing-to-vessel-weld region (Region 1), the housing including weld region shall be evaluated as a housing weld for the purpose of determining flaw acceptance. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. This Case may not be used if the requirements of IWB-3640 are not met.

6.2 After completion of the roll expansion, UT examination of the stub-tube-to-housing J-groove-weld region or housing-to-vessel-weld region (Region 1) shall be performed. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. This Case may not be used if the requirements of IWB-3640 are not met.

6.3 After completion of the roll expansion, UT examination of the rolled region (Region 2) shall be performed to establish that no planar flaws exist in the rolled region.

6.4 The UT procedure used in the examinations shall be demonstrated on a plant-specific mockup, with flaws located in the area of interest, in accordance with Mandatory Appendix I of this Case.

6.5 If the location of the leakage has not been determined, an in-vessel VT-1 visual examination of the leaking ICH penetration shall be made before the end of the next scheduled refueling outage, to attempt to locate the leakage source and to determine the general condition of the housing. Cracks, wear, or localized accumulation of corrosion shall requires corrective action. Roll expansion satisfies the corrective action requirement.

6.6 After completion of the post-roll-expansion UT examination, the ICH penetration shall be subjected to VT-2 visual examination in conjunction with a system leakage test in accordance with IWB-5000. For ICH housings subjected to roll expansion, the acceptance criterion is no leakage.

Table 2
Plant Specific Procedure Qualification Requirements

Essential Variable	Acceptance Criteria
Percent wall thinning	Greater than or equal to target value not to exceed 5%
Roll-band length	Greater than or equal to the value used, not to exceed 6 in. (150 mm) (backed by vessel material)
Housing outside diameter	Housing outside diameter ±0.0625 in. (1.5 mm) used for the mockup
Housing inside diameter	Housing inside diameter ±0.0625 in. (1.5 mm) used for the mockup
Housing material	The P-Number used in the mockup qualifies any material in that P-Number, i.e., any P-No. 8 material qualifies any other P-No. 8 material or any P-No. 43 qualifies any other P-No. 43 material
Vessel head material	Any P-No. 3 material used in the mockup qualifies any other P-No. 3 material

Table 3
Performance Demonstration Essential Variables

Variable	Acceptance Criteria
Percent wall thinning	Target wall thinning ± 0.5%
Roll-band length	Any value provided the roll-band length is no more than 6 in. (150 mm). However, if multiple rolls will be required to achieve the required in-plant roll-band length, the performance demonstration shall require multiple rolls (backed by vessel material).
Housing outside diameter	Actual housing outside diameter ±0.0625 in. (1.5 mm)
Housing inside diameter	Actual housing inside diameter ±0.0625 in. (1.5 mm)
Housing material	Same type as application (e.g., any P-No. 8 or any P-No. 43 material)
Vessel head material	Any P-No. 3 material

7 INSERVICE INSPECTIONS

The following examinations shall be added to the inservice inspection plan.

7.1 A UT examination of roll-expanded ICH shall be performed before the end of the next scheduled refueling outage, to attempt to locate the leakage source and to determine the general condition of the housing. Cracks, wear, or localized accumulation of corrosion products requires corrective action. Roll expansion satisfies the corrective action requirement performed in accordance with Figure 1 or Figure 2 on at least 10% of previously-rolled housings, during each inspection interval. If planar flaws are discovered in the roll region

Figure 1
Examination Volume for In-Core Housings (BWR/2-6)

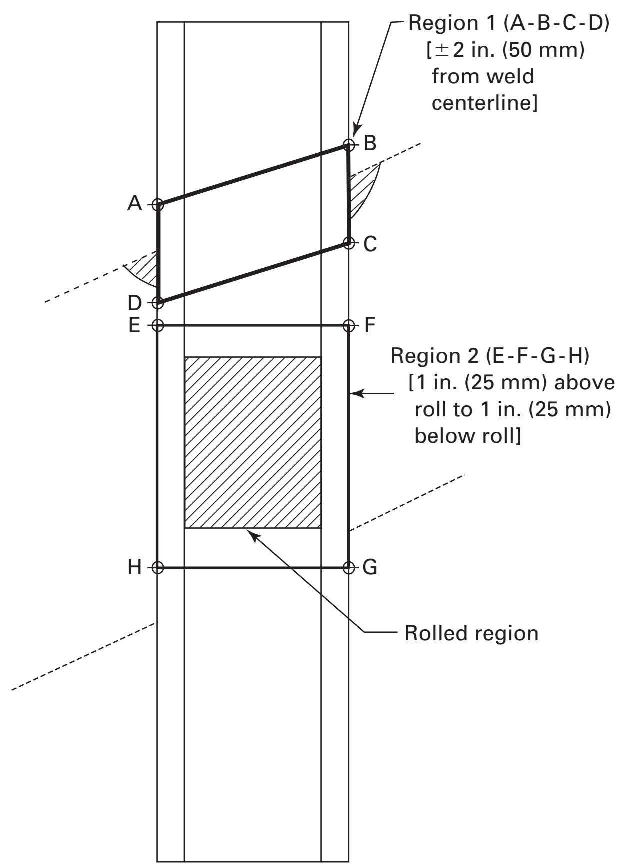
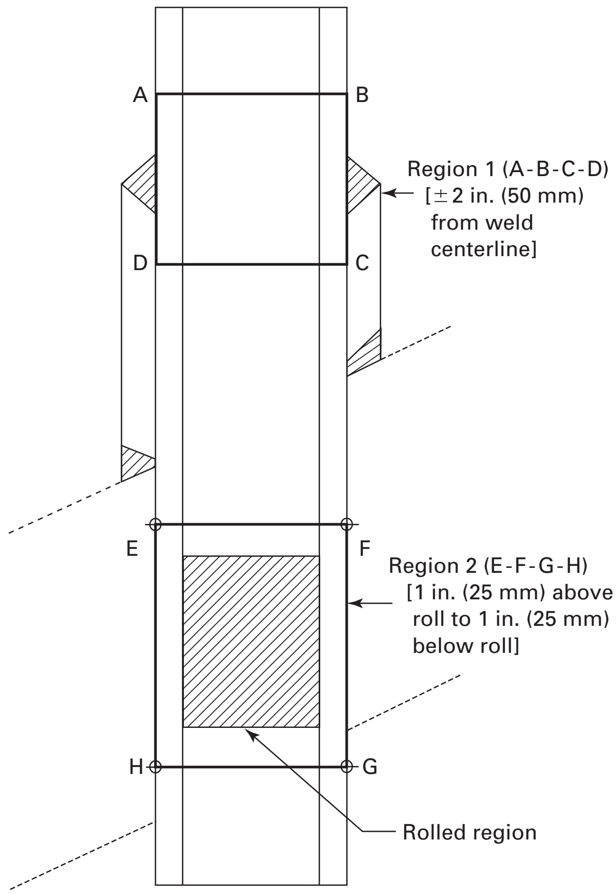


Figure 2
Examination Volume for In-core Housings (ABWR)



(Region 2), this Case shall not be used. The examination results shall be evaluated in accordance with IWB-3523. If flaws exceed the acceptance standards of IWB-3523, they shall be evaluated to show that the requirements of IWB-3640 are satisfied. If the requirements of IWB-3640 are not met, the defect shall be corrected by a repair/replacement activity.

7.2 If flaws are detected that fail to meet the acceptance standards of IWB-3523, the additional examination requirements of IWB-2430 shall be met.

7.3 The UT procedure used in the examinations of 7.1 and 7.2 shall be demonstrated on a plant-specific mockup with flaws located in the area of interest, in accordance with Mandatory Appendix I of this Case.

7.4 At subsequent system leakage tests in accordance with IWB-5000, ICH having roll expansion shall meet the requirements of 6.6.

8 RECORDS

8.1 The Owner shall retain the following records for the life of the vessel.

(a) Roll-Expansion Procedure Specification (REPS)
(b) record of procedure qualification
(c) locations all roll-expanded ICH
(d) results of post-expansion examinations and evaluations
(e) evaluations performed in accordance with 5
(f) records of performance demonstration, including documentation of personnel qualifications
(g) records of nondestructive examinations

8.2 Use of this Case shall be documented on Form NIS-2.

MANDATORY APPENDIX I
USE OF MOCKUP FOR UT PROCEDURE DEMONSTRATION

I-1 The UT procedure shall be demonstrated on a mockup. Personnel who perform flaw detection and evaluation using the procedure shall have current automated data analysis qualification for IGSCC in piping components in accordance with Appendix VIII, Supplement 2.

I-2 The UT shall be performed using automated, digital, data acquisition methods.

I-3 Mockups shall be manufactured with inside and outside diameters in accordance with Table 3. P-No. 8 material shall be used for the mockups unless Alloy 600, Alloy 690, or equivalent nominal chemistry is used for the installed component, in which case the mockups shall be manufactured using Alloy 600 or Alloy 690 wrought material. The mockup length shall be sufficient to accommodate the required flaws and to provide adequate access to examine the flaw areas.

I-4 The mockup shall contain at least 10 surface breaking flaws, distributed such that at least 40% of the total flaws shall initiate from the inside surface and at least 40% from the outside surface. The mockup shall contain flaws oriented axially and circumferentially. Flaws shall be located in the mockup such that no flaw ultrasonic response shall interfere with any other flaw response. At least 30% and no more than 50% of the flaws shall be oriented axially. Flaws in the depth sizing sample shall be distributed as follows:

Flaw Depth (% of Wall Thickness)	Minimum Percent of Flaws
20–40	20
41–60	20
61–80	20

The flaw length-to-depth ratios shall be distributed in a range from 2 to 6. Flaws may be actual cracks (thermal or mechanical fatigue, or IGSCC) or notches compressed so that the faces of each notch are in contact. If notches are used, and their depth is 0.08 in. (2 mm) or greater, they shall be compressed so that the faces are in contact and the notch tip shall have a radius no greater than 0.002 in. (0.05 mm). Notches less than 0.08 in. (2 mm) in depth need not be compressed as long as the width of the notch (between faces) is no greater than 0.004 in. (0.1 mm).

I-5 The UT procedure shall be considered acceptable if it can be demonstrated that the flaws are detected and discernible using specific criteria identified in the examination procedure (e.g., a signal-to-noise ratio of at least 2 to 1 can be obtained from the flaws). The data from the procedure demonstration shall be evaluated to determine the length-sizing and depth-sizing error values associated with the procedure. These error values shall be included in any flaw acceptance evaluations.

Approval Date: May 7, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-770-4
Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities
Section XI, Division 1

Inquiry: What alternative examination requirements and acceptance standards to those of Section XI, Table IWB-2500-1, Examination Category B-F and Examination Category B-J; or Nonmandatory Appendix R, Table R-2500-1, Examination Category R-A, Item No. R1.15; and IWA-4530, IWB-2200, IWB-2400, and IWB-3000, may be used for Class 1 PWR piping and vessel nozzle butt welds fabricated with Alloy 82/182[1] material with or without the application of mitigation activities?

Reply: It is the opinion of the Committee that the following alternatives to the examination requirements and acceptance standards of Section XI, Table IWB-2500-1, Examination Category B-F, and Examination Category B-J; or Nonmandatory Appendix R, Table R-2500-1, Examination Category R-A, Item No. R1.15; and IWA-4530, IWB-2200, IWB-2400, and IWB-3000, may be used for Class 1 PWR piping and vessel nozzle butt welds fabricated with weld filler material UNS N06082 (SFA-5.14, ERNiCr-3) or UNS W86182 (SFA-5.11, ENiCrFe-3), or a combination of both, with or without the types of mitigation listed in -2410(a). These individual filler materials or a combination of both will be hereinafter referred to as Alloy 82/182[1] material.

-1000 SCOPE AND RESPONSIBILITY

-1100 SCOPE

(a) Except as stated in (c) through (f), this Case provides alternative examination requirements and acceptance standards for volumetric examination, and surface examination, where applicable, of NPS 2 (DN 50) and greater and visual examination of greater than NPS 1 (DN 25) pressure retaining Class 1 PWR piping and vessel nozzle butt welds fabricated with Alloy 82/182 materials, with or without application of mitigation activities. Pressurizer nozzle butt welds are considered part of the hot leg welds.

(b) This Case shall not be used to perform mitigation activities. For the types of mitigation activities identified in -2410(a), this Case provides pre-mitigation examination requirements, configuration requirements, peening, and stress improvement performance criteria, and pre-service examination requirements.

(c) Butt welds described in (a) with normal operating temperatures of less than 525°F (274°C) are not included in this Case.

(d) Pressure retaining welds in control rod drive and instrument nozzle housings of reactor vessel heads are not included in this Case.

(e) Alloy 82/182 welds never exposed to the reactor water environment are not included in this Case.

(f) If a mitigated or unmitigated butt weld initially included in (a) is subsequently completely removed and replaced with primary water stress corrosion cracking (PWSCC) resistant materials, the weld shall no longer be included in the scope of this Case. The weld shall be added to the ISI Program as a new weld in accordance with IWB-2412(b) in editions and addenda up to and including the 2006 Addenda and in accordance with IWB-2411(b) in the 2007 Edition or later editions and addenda.

-1200 COMPONENTS SUBJECT TO EXAMINATION

-1210 Examination Requirements

The examination requirements shall apply to the following:

(a) Class 1 piping and vessel nozzle butt welds fabricated with Alloy 82/182 material without or mitigated by either stress improvement or peening..

(b) Class 1 piping and vessel nozzle butt welds fabricated with Alloy 82/182 material and mitigated with full structural weld overlay, optimized weld overlay, inlay or onlay with either, or any combination of weld filler materials UNS N06052 (SFA-5.14, ERNiCrFe-7), UNS W86152

[1] Alloy 82 and Alloy 182 are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06082 (SFA-5.14, ERNiCr-3) and UNS W86182 (SFA-5.11, ENiCrFe-3), respectively.

(SFA-5.11, ENiCrFe-7), or UNS N06054 (SFA-5.14, ERNiCrFe-7A). These individual filler materials or any combination thereof will be hereinafter referred to as Alloy 52/152.[2]

-2000 EXAMINATION

-2200 BASELINE EXAMINATION

The examinations listed in Table 1 applicable to the configurations of welds within the scope of -1100 shall be performed in accordance with -2500 completely, once, as a baseline examination and shall be evaluated by comparing the examination results with the acceptance standards in -3132. Inspection Items A-1, A-2, B-1, and B-2 of Table 1 describe butt welds which have not been mitigated while Inspection Items C through L describe butt welds which have been mitigated using one of the following techniques: full structural weld overlay, optimized weld overlay, stress improvement, inlay, onlay, or peening. For Inspection Items C through L, the preservice examination (-2220) establishes the baseline examination. These examinations shall include all piping and vessel nozzle butt welds within the scope of -1100. Examinations performed prior to implementation of this Case that meet the requirements of Table 1 and Section XI, Mandatory Appendix VIII may be credited. Welds in Table 1 Inspection Item A-1, A-2, B-1, and B-2 that have not been examined using Section XI, Mandatory Appendix VIII requirements shall be examined within the next two refueling outages from adoption of this Case. Welds in all other categories shall be scheduled in accordance with Table 1.

-2220 Preservice Examination After Repair/Replacement Activities or Stress Improvement or Peening

Prior to return to service, the applicable examinations listed in Table 1 shall be performed on items affected by a repair/replacement activity (mitigation by full structural weld overlay, optimized weld overlay, inlay, or onlay), or by mitigation using stress improvement or peening methods. Preservice examinations shall meet the acceptance standards of Table 1. Preservice examination acceptance in accordance with -3132.3 shall not be permitted for flaws in new weld material applied with the mitigation techniques defined in Table 1. Previously evaluated flaws in the dissimilar metal weld that were mitigated by the techniques identified in Table 1 need not be reevaluated unless the previously evaluated flaws have grown or new planar flaws have been identified.

-2400 EXAMINATION SCHEDULE

-2410 Examination Program

(a) Inservice examination methods and frequencies as required by Table 1 shall be determined using the following parameters to characterize the susceptibility to crack initiation, the potential for crack propagation, and the mitigation technique.

(1) Susceptibility to crack initiation shall be categorized by the operating temperature of the component, as follows:

(-a) Hot leg temperatures [defined as temperatures ≥ 580°F (304°C)]

(-1) The hot leg shall be further divided into items at operating temperatures > 625°F (329°C) (Item A-1) and items at operating temperature ≤ 625°F (329°C) (Item A-2)

(-b) Cold leg temperatures [defined as temperatures ≥ 525°F (274°C) and < 580°F (304°C)]

(2) The potential for crack propagation shall be categorized by the status of the weld as follows:

(-a) cracked

(-b) uncracked

(3) The following mitigation techniques are included in this Case:

(-a) Full Structural Weld Overlay

(-b) Optimized Weld Overlay

(-c) Stress Improvement. Stress improvement techniques shall meet the Performance Criteria and Measurement or Quantification Criteria of Mandatory Appendix I

(-d) Inlay

(-e) Onlay

(-f) Peening. Peening techniques shall meet the Performance Criteria and Measurement or Qualification Criteria of Mandatory Appendix I.

(b) Welds included in -1100 shall be identified as unique populations within the ISI Program, categorized by Table 1 Inspection Items, and examined in accordance with Table 1.

(c) The mitigated welds in Table 1, Inspection Items C through L, shall be added to the ISI Program as new welds in accordance with IWB-2412(b) in editions and addenda up to and including the 2006 Addenda and in accordance with IWB-2411(b) in the 2007 Edition and later editions or addenda.

(d) If more than one mitigation technique is used, a population of welds mitigated using each technique shall be established in accordance with Table 1. Each Inspection Item population, or a sample of each Inspection Item population as required by Table 1, shall be added to the ISI Program in accordance with (c) and shall be examined in accordance with Table 1.

[2] Alloy 52, Alloy 152, and other similar designations are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06052 (SFA-5.14, ERNiCrFe-7), UNS W86152 (SFA-5.11, ENiCrFe-7), and UNS N06054 (SFA-5.14, ERNiCrFe-7A), respectively. For the purposes of this Case, these materials are considered equivalent.

Table 1
Examination Categories

CLASS 1 PWR PRESSURE RETAINING DISSIMILAR METAL PIPING AND VESSEL NOZZLE BUTT WELDS CONTAINING ALLOY						
Inspection Item	**Parts Examined**	**Examination Requirements/ Fig. No.**	**Examination Method [Note (1)]**	**Acceptance Standard**	**Extent and Frequency of Examination**	**Deferral of Examination to End of Interval**
A-1	Unmitigated butt weld at Hot Leg operating temperature (-2410) > 625°F (329°C)	Weld Surface Figure 1	Visual [Note (2)], [Note (3)] Volumetric [Note (4)]	-3140 -3130	Each refueling outage Every second refueling outage [Note (5)]	Not permissible
A-2	Unmitigated butt weld at Hot Leg operating temperature (-2410) ≤ 625°F (329°C)	Weld Surface Figure 1	Visual [Note (2)], [Note (3)] Volumetric [Note (4)]	-3140 -3130	Each refueling outage Every 5 yr [Note (5)]	Not permissible
B-1	Unmitigated butt weld at Cold Leg operating temperature (-2410) ≥ 525°F (274°C) and < 580°F (304°C), less than NPS 14 (DN 350)	Weld Surface Figure 1	Visual [Note (2)], [Note (3)] Volumetric [Note (4)]	-3140 -3130	Once per interval Every second inspection period not to exceed [Note (5)]	Not permissible
B-2	Unmitigated butt weld at Cold Leg operating temperature (-2410) ≥ 525°F (274°C) and < 580°F (304°C), NPS 14 or larger (DN 350)	Weld Surface Figure 1	Visual [Note (2)], [Note (3)] Volumetric [Note (4)]	-3140 -3130	Once per interval Once per interval	[Note (11)]
C-1	Uncracked [Note (6)] butt weld reinforced by full structural weld overlay of Alloy 52/152 [Note (7)] material	Figures 2(a) and 2(b)	Volumetric [Note (4)], [Note (8)], [Note (9)]	-3130	These welds shall be placed into a population examined on a sample basis. Twenty-five this population shall be added to the ISI Program accordance with -2410 and shall be examined each inspection interval [Note (10)]. For each the 25% sample that has an analyzed life of less yr, at least one inservice examination shall be prior to exceeding the life of the overlay.	[Note (11)]
C-2	Uncracked [Note (6)] butt weld reinforced by optimized weld overlay of Alloy 52/152 [Note (7)] material	Figures 5(a) and 5(b)	Volumetric [Note (4)], [Note (14)], [Note (18)]	-3130	100% of these welds shall be examined once inspection interval. For any overlays that analyzed life of less than 10 yr, the inspection interval shall be less than or equal to the analyzed	[Note (11)]
D	Uncracked butt weld mitigated with stress improvement [Note (12)]	Figure 1	Volumetric [Note (4)], [Note (13)]	-3130	Examine all welds no sooner than the third outage and no later than 10 yr following stress improvement. Examination volumes that show no indication cracking shall be placed into a population to be examined a sample basis. Twenty-five percent of this shall be added to the ISI Program in accordance -2410 and shall be examined once each inspection [Note (10)]. If more than one type of stress improvement the population of each type of stress improved shall be established and 25% of each type shall be the ISI Program in accordance with -2410 and shall examined once each inspection interval [Note (10)]	[Note (11)]

Table 1
Examination Categories (Cont'd)

CLASS 1 PWR PRESSURE RETAINING DISSIMILAR METAL PIPING AND VESSEL NOZZLE BUTT WELDS CONTAINING ALLOY

Inspection Item	Parts Examined	Examination Requirements/ Fig. No.	Examination Method [Note (1)]	Acceptance Standard	Extent and Frequency of Examination	Deferral of Examination to End of Interval
E	Cracked butt weld mitigated with stress improvement [Note (12)]	Figure 1	Volumetric [Note (4)], [Note (13)]	-3130	Once during the first or second refueling outage following application of stress improvement. Examination volumes that show no indication of crack growth cracking shall be placed into a population to be examined a sample basis. Twenty-five percent of this shall be added to the ISI Program in accordance -2410 and shall be examined once each inspection [Note (10)]. If more than one type of stress improvement the population of each type of stress improved shall be established and 25% of each type shall be the ISI Program in accordance with -2410 and shall examined once each inspection interval [Note (10)]	[Note (11)]
F-1	Cracked [Note (6)] butt weld reinforced by full structural weld overlay of Alloy 52/152 material [Note (7)]	Figures 2(a) and 2(b)	Volumetric [Note (4)], [Note (8)], [Note (9)]	-3130	Once during the first or second refueling outage following overlay. Weld overlay examination volumes show no indication of crack growth or new cracking placed into a population to be examined on a sample Twenty-five percent of this population shall added to the ISI Program in accordance with -2410 be examined once each inspection interval For each overlay in the 25% sample that has analyzed life of less than 10 yr, at least one inservice examination shall be performed prior to exceeding the life overlay.	[Note (11)]
F-2	Cracked [Note (6)] butt weld reinforced by optimized weld overlay of Alloy 52/152 [Note (7)] material	Figures 5(a) and 5(b)	Volumetric [Note (4)], [Note (14)], [Note (18)]	-3130	Once during the first or second refueling outage following overlay. Examination volumes that show indication of crack growth or new cracking shall be examined once each inspection interval. For any overlays an analyzed life of less than 10 yr, the inspecion interval shall be less than or equal to the analyzed	[Note (11)]

Table 1
Examination Categories (Cont'd)

CLASS 1 PWR PRESSURE RETAINING DISSIMILAR METAL PIPING AND VESSEL NOZZLE BUTT WELDS CONTAINING ALLOY						
Inspection Item	**Parts Examined**	**Examination Requirements/ Fig. No.**	**Examination Method [Note (1)]**	**Acceptance Standard**	**Extent and Frequency of Examination**	**Deferral of Examination to End of Interval**
G	Uncracked butt weld mitigated with an inlay of Alloy 52/152 material [Note (7)], [Note (15)]	Figure 3	Volumetric [Note (4)], [Note (16)] Surface [Note (17)]	-3130	Perform a volumetric examination [Note (16)] surface examination [Note (17)] of all welds no the third refueling outage and no later than of 10 yr following inlay or the analyzed life inlay. Examination volumes that show no indications cracking shall be placed into a population to be examined a sample basis. Twenty-five percent of this shall receive a surface examination [Note (17)] performed from the weld inside surface and a volumetric examination [Note (16)] performed from inside or outside surface. The 25% sample added to the ISI Program in accordance with -2410 shall be examined once each inspection interval	[Note (11)]
H	Uncracked butt weld mitigated with an onlay of Alloy 52/152 material [Note (7)], [Note (15)]	Figure 4	Volumetric [Note (4)], [Note (16)] Surface [Note (17)]	-3130	Perform a volumetric examination [Note (16)] surface examination [Note (17)] of all welds no the third refueling outage and no later than of 10 yr following onlay or the analyzed life onlay. Examination volumes that show no indications cracking shall be placed into a population to be examined a sample basis. Twenty-five percent of this shall receive a surface examination [Note (17)] performed from the weld inside surface and a volumetric examination [Note (16)] performed from inside or outside surface. The 25% sample added to the ISI Program in accordance with -2410 shall be examined once each inspection interval	[Note (11)]

Table 1
Examination Categories (Cont'd)

CLASS 1 PWR PRESSURE RETAINING DISSIMILAR METAL PIPING AND VESSEL NOZZLE BUTT WELDS CONTAINING ALLOY						
Inspec-tion Item	**Parts Examined**	**Examination Requirements/ Fig. No.**	**Examination Method [Note (1)]**	**Acceptance Standard**	**Extent and Frequency of Examination**	**Deferral of Examination to End of Interval**
J	Cracked butt weld mitigated with an inlay of Alloy 52/152 material [Note (7)], [Note (15)]	Figure 3	Volumetric [Note (4)], [Note (16)] Surface [Note (17)]	-3130	Once during the first or second refueling outage following application of inlay. This examination shall a volumetric examination [Note (16)] and examination [Note (17)]. Examination volumes that show no indications cracking or crack growth shall be placed population to be examined on a sample basis. Twenty-five percent of this population shall receive a surface examination [Note (17)] performed from the weld inside surface volumetric examination [Note (16)] performed from either the inside or outside surface. The 25% shall be added to the ISI Program in accordance -2410 and shall be examined once each inspection [Note (10)].	[Note (11)]
K	Cracked butt weld mitigated with an onlay of Alloy 52/152 material [Note (7)], [Note (15)]	Figure 4	Volumetric [Note (4)], [Note (16)] Surface [Note (17)]	-3130	Once during the first or second refueling outage following application of onlay. This examination shall a volumetric examination [Note (16)] and examination [Note (17)]. Examination volumes that show no indications cracking or crack growth shall be placed population to be examined on a sample basis. Twenty-five percent of this population shall receive a surface examination [Note (17)] performed from the weld inside surface volumetric examination [Note (16)] performed from either the inside or outside surface.The 25% shall be added to the ISI Program in accordance -2410 and shall be examined once each inspection [Note (10)].	[Note (11)]

Table 1
Examination Categories (Cont'd)

CLASS 1 PWR PRESSURE RETAINING DISSIMILAR METAL PIPING AND VESSEL NOZZLE BUTT WELDS CONTAINING ALLOY						
Inspec-tion Item	**Parts Examined**	**Examination Requirements/ Fig. No.**	**Examination Method [Note (1)]**	**Acceptance Standard**	**Extent and Frequency of Examination**	**Deferral of Examination to End of Interval**
L	Uncracked butt weld mitigated by peening [Note (19)]	Figure 1	Volumetric [Note (4)], [Note (19)], [Note (21)], Surface [Note (19)], [Note (20)]	-3130	Perform a volumetric examination [Note (21)] surface examination [Note (20)] of all hot leg welds 2nd refueling outage following the application peening and a second examination within 10 yr following application of peening. Examinations that indications of cracking shall be placed into population to be examined on a sample basis. Twenty-five percent of this population shall receive a surface examination [Note (20)] performed from the weld inside surface volumetric examination [Note (21)] performed from either the inside or outside surface. The 25% shall be added to the ISI Program in accordance -2410 and shall be examined once each inspection [Note (10)]. Perform a volumetric examination [Note (21)] surface examination [Note (20)] of all cold leg welds within 10 yr following application of peening. Examinations that show no indications of cracking shall be a population to be examined on a sample basis. Twenty-five percent of this population shall receive examination [Note (20)] performed from inside surface and a volumetric examination [Note performed from either the inside or outside The 25% sample shall be added to the ISI Program accordance with -2410 and shall be examined each inspection interval [Note (10)].	[Note (11)]

NOTES:

(1) Volumetric examination requirements, methods, acceptance standards and frequencies are applicable to Class 1 PWR piping and vessel nozzle butt NPS 2 (DN 50) or greater.

(2) A VE shall consist of the following:

(a) A direct examination of the bare metal surface of the entire outer surface of the weld with the insulation removed or lifted to allow access VE.

(b) The direct VE shall be performed at a distance not greater than 4 ft (1.2 m) from the weld and with a demonstrated illumination level sufficient allow resolution of lower case characters having a height of not greater than 0.105 in. (2.7 mm).

(c) Alternatively, the VE may be performed with insulation in place or removed using remote visual equipment that provides resolution of the weld surface equivalent to a bare metal direct VE as defined in (a) and (b), above.

(d) Personnel performing the VE shall be qualified as a VT-2 visual examiner and shall have completed at least 4 hr of additional training in detection borated water leakage from Alloy 600/82/182 components and the resulting boric acid corrosion of adjacent ferritic steel components.

(e) Examination may be performed with the system depressurized.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(3) A VE may be performed during an outage when a volumetric examination is performed from the weld outer surface. An ultrasonic examination performed from the component inside or outside surface in accordance with the requirements of Table 1 and Mandatory Appendix VIII (1995 Edition with the 1996 Addenda or later) shall acceptable in lieu of the VE requirement of this table.

(4) Ultrasonic volumetric examination shall be used and shall meet the applicable requirements of Mandatory Appendix VIII.

(5) Subsequent Inservice Inspection of Unmitigated Welds With Inside Surface Connected Planar Flaws

(a) If planar surface flaws are detected in the butt weld/base metal inside surface, this weld shall be reexamined at the shorter frequency of every refueling outage or the frequency determined by the crack growth analysis of -3132.3.

(b) This weld shall be subsequently examined at the frequency required by (a) unless mitigated.

(6) Preweld Overlay Examination for Full Structural and Optimized Weld Overlays

(a) Except as provided in (b) and (c), volumetric examination shall be performed prior to full structural or optimized weld overlay and shall include examination volume of Figure 1.

(b) As an alternative to (a), if the volumetric examination prior to the full structural weld overlay is not performed, it shall be assumed to be and shall be classified F-1.

(c) For reactor vessel nozzle welds at cold leg temperatures requiring the core internals to be removed to perform the examination, the volumetric ations are not required prior to application of the weld overlay. If the preweld overlay volumetric examination is not performed, a postweld overlay preservice examination consi surface examination and a volumetric examination shall be performed after removal of the core internals. If these examinations do not detect cracks, the weld shall be consider be uncracked and shall be subject to the examination requirements of Inspection Item: C-1 or C-2. This postweld overlay volumetric examination shall include the examination in Figure 1 and the examination volume in Figure 2(a) or Figure 5(a). The postweld overlay preservice surface examination shall be performed on the weld inside surface, extent Figure 1, and shall consist of an eddy current examination in accordance with IWA-2223. If either of these examinations reveal a crack or cracks, crack depth shall be determined sing techniques that meet the applicable requirements of Mandatory Appendix VIII, prior to evaluation in accordance with -3132.3.

(d) If the crack is completely removed by a repair/replacement activity in accordance with IWA-4000 and the weld overlay is then applied, the be reclassified Inspection Item C-1 or C-2.

(7) Alloy 52, Alloy 152, and other similar designations are common abbreviations used by industry, the regulatory authority, and research organi r UNS N06052 (SFA-5.14, ERNiCrFe-7), UNS W86152 (SFA-5.11, ENiCrFe-7), and UNS N06054 (SFA-5.14, ERNiCrFe-7A), respectively. These individual filler materials or any mbination thereof are referred to as Alloy 52/152.

(8) Inservice Inspection of Full Structural Weld Overlay

(a) The weld overlay examination volume in Figure 2(a) shall be ultrasonically examined to determine the acceptability of the mitigated weld. angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions.

(b) The weld overlay shall meet the requirements of -3132. In applying the acceptance standards to planar indications, the thickness t_1 or t_2, defined Figure 2(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to For susceptible material, t_1 shall be used.

(c) As an alternative to (a), for inservice inspection, the weld examination volume in Figure 1 may be ultrasonically examined. If cracking is detected extending beyond the weld examination volume, the weld examination of (a) and (b) above shall be performed to determine the acceptability of the weld overlay.

(d) If inservice examinations of (a), (b), or (c) reveal crack growth, or new cracking in the weld overlay or outer 25% of original weld/base material the acceptance standards, the weld overlay examination volume shall be reexamined during the first or second refueling outage following detection of the crack growth or cking. The weld overlay examination volume shall be subsequently examined two additional times at the period of one or two refueling outages, i.e., a total of three examination within six refueling outages of detection of the crack growth or new cracking.

(e) If the examinations required by (d) reveal that the flaws remain essentially unchanged for three successive examinations, the weld examination schedule may revert to the sample and schedule of examinations identified in Table 1. This weld shall be included in the 25% sample.

(9) Preservice Inspection for a Full Structural Weld Overlay

(a) The examination volume in Figure 2(a) shall be ultrasonically examined. The angle beam shall be directed perpendicular and parallel to the with scanning performed in four directions, to locate and size any planar flaws that have propagated into the outer 25% of the original weld or base metal thickness or into the overlay. For weld overlays on cast austenitic stainless steel base materials, if a 100% through-wall flaw is used for the crack growth analysis, only planar flaws that have propagated weld overlay or are in the overlay shall be located and sized.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(b) The preservice examination acceptance standards of IWB-3514 shall be met for flaws in the weld overlay material. In applying the acceptance s to planar indications, the thickness, t_1 or t_2, defined in Figure 2(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., nozzle, or piping material) is not susceptible to PWSCC. For susceptible material, t_1 shall be used. Planar flaws in the outer 25% of the original weld or base material thickn meet the design analysis requirements of -3132.3(d).

(c) The flaw evaluation requirements of IWB-3640 shall not be applied to planar flaws in the weld overlay material, identified during preservice examination, that exceed the preservice examination acceptance standards of IWB-3514.

(10) The 25% sample shall consist of the same welds in the same sequence during successive intervals to the extent practical provided the 25% sample con welds that experience the highest operating temperature in the Inspection Item. If hot leg and cold leg welds are included in the same Inspection Item, the initial 25% sample need to include the cold leg welds. Those welds not included in the 25% sample shall be examined prior to the end of the mitigation evaluation period if the plant is to be operated beyond that time.

(11) Deferral of Examinations

(a) Examinations of welds originally classified Table IWB-2500-1, Category B-J welds prior to mitigation are not permitted to be deferred to the interval.

(b) Examinations of welds originally classified Table IWB-2500-1, Category B-F welds, Item Numbers B5.10, and B5.20 prior to mitigation, may be following weld inlay, onlay, overlay, peening, or stress improvement, as follows:

(1) Examination for Inspection Item C-1 and C-2 may be deferred to the end of the interval and performed coincident with the vessel nozzle examinations required by Category B-D.

(2) The first examinations following weld inlay, onlay, overlay, peening,, or stress improvement for Inspection Items D through L shall be performed specified. The second examination of hot leg welds of Inspection Item L shall be performed as specified.. Subsequent examinations for Inspection Items D through L may be coincident with the vessel nozzle examinations required by Category B-D.

(3) For successive inspection intervals following weld inlay, onlay, overlay, peening, or stress improvement, subsequent examinations may be to the end of the interval, provided no additional repair/replacement activities have been performed on the examination item, and no flaws or relevant conditions requiring examination in accordance with Table 1 are contained in the mitigated weld.

(c) Welds that were classified in accordance with Nonmandatory Appendix R, prior to mitigation shall be reclassified based on the configuration iping structural element and the postulated degradation mechanisms if any remaining after the mitigation. Deferral of examinations shall be according to (a) and (b), above.

(d) Examinations for Inspection Item B-2 may be deferred to the end of the interval and performed coincident with the reactor vessel nozzle examinations required by Examination Category B-D, as provided by IWA-2430. The time between examinations shall not exceed 13 yr.

(12) If stress improvement techniques are used, the following shall be met:

(a) Except as provided in (e) below, volumetric examinations shall be performed on these welds before the stress improvement techniques are The prestress improvement examination shall be conducted in the same outage as the application of stress improvement or, for non-cracked welds, no more than one cycle o the application of stress improvement. The examination volume of Figure 1 applies.

(b) Post-stress improvement examinations are required and shall be considered the preservice baseline examination. The examination volume 1 and the following acceptance standards apply:

(1) For uncracked welds, no new planar surface flaws are permitted in the butt weld or base metal inside surface.

(2) For cracked welds, any growth or change in crack size of previously detected planar surface flaws shall be re-evaluated in accordance with -3132.3.

(3) Flaws other than planar surface flaws detected in the butt weld or base metal inside surface, shall meet the acceptance standards of IWB-3514.

(c) If the crack is completely removed by repair/replacement activity in accordance with IWA-4000 and the stress improvement is then applied, shall be restored to Inspection Item D.

(d) A documented evaluation shall be completed demonstrating that the stress improvement technique meets the performance criteria in Mandatory Appendix I.

(e) For reactor vessel nozzle welds at cold leg temperatures requiring the core internals to be removed to perform the examination, the volumetric ations are not required prior to application of the stress improvement technique. If the prestress improvement volumetric examination is not performed, a post stress improvemen preservice surface examination and volumetric examination shall be performed after removal of the core internals. If these examinations do not detect cracks, the weld shall be consi uncracked and be subject to the examination requirements of Inspection Item D. This post stress improvement preservice volumetric examination shall include the examination shown in Figure 1. The post stress improved preservice surface examination shall be performed on the butt weld inside surface, extent E-F of Figure 1, and shall consist of an eddy examination in accordance with IWA 2223. If either of these examinations reveal a crack or cracks, crack depth shall be determined using techniques that meet the applicable requirements of Section XI, Mandatory Appendix VIII, prior to evaluation in accordance with -3132.3.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(13) Inservice Inspection for Stress Improvement

(a) The required examination volume of Figure 1 shall be ultrasonically examined to determine the acceptability of the mitigated weld.

(b) If inservice examinations of (a) reveal crack growth or new cracking, the weld examination volume of Figure 1 shall be examined during each next three refueling outages.

(c) If the examinations required by (b) reveal that the flaws remain essentially unchanged for three successive examinations, the weld examination schedule may revert to the sample and schedule of examinations identified in Table 1. This weld shall be included in the 25% sample.

(14) Preservice Inspection for Optimized Weld Overlays

(a) The examination volume in Figure 5(a) shall be ultrasonically examined. The angle beam shall be directed perpendicular and parallel to the with scanning performed in four directions, to locate and size any planar flaws that have propagated into the outer 50% of the original weld or base metal thickness or into the overlay. For weld overlays on cast austenitic stainless steel base materials only planar flaws that have propagated into the weld overlay or are in the overlay are required to and sized.

(b) As an alternative to (a), for weld overlays that can be shown to meet the requirements for full structural weld overlays with respect to axial flaws, required examination volume of Figure 2(a) may be used for scans in which the angle beam is directed perpendicular to the pipe axis. The examination volume of Figure 5(a) shall for scans in which the angle beam is directed parallel to the pipe axis.

(c) The preservice examination acceptance standards of IWB-3514 shall be met for flaws in the weld overlay material and the outer 25% of the original weld/base material. In applying the acceptance standards to planar indications, the thickness, t_1 or t_2, defined in Figure 5(b), shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to PWSCC. For susceptible material, t_1 shall be used. Planar flaws in 25% to 50% of the original weld or base material thickness shall meet the design analysis requirements of -3132.3(d).

(d) The flaw evaluation requirements of IWB-3640 shall not be applied to planar flaws in the weld overlay material, identified during preservice examination, that exceed the preservice examination acceptance standards of IWB-3514.

(15) If Alloy 52/152 weld inlay or onlay techniques are applied, the following shall be met:

(a) Volumetric examinations shall be performed on these welds both immediately before application of inlay or onlay and after application as preservice baseline examination.

(b) If the configuration of the inlay or onlay does not permit coverage in accordance with -2500(c) of the required preservice and inservice examination volume for each modified dissimilar metal weld, the weld shall be examined in accordance with Inspection Item A or B.

(c) If the capabilities of the volumetric examination for detection, length sizing, and through-wall sizing for the dissimilar metal weld are adversely affected by the inlay or onlay, the weld shall be examined in accordance with Inspection Item A or B.

(d) Preservice surface examinations shall be performed using the eddy current method. The eddy current examination shall be performed in accordance with IWA-2223, except that the length of Mandatory Appendix IV, Supplement 2 qualification cracks or notches shall not exceed $^1/_{16}$ in. (1.5 mm). Linear indications exceeding (1.5 mm) in length shall be unacceptable.

(e) Preservice volumetric examination shall be performed on the modified dissimilar metal weld. All flaws that were detected in (a), above, extending beyond the examination volume, shall be reexamined and sized, if they remain in the original weld. Planar flaws in the inlay or onlay shall meet the preservice examination standards IWB-3514. Laminar flaws shall meet the acceptance standards of IWB-3514. Planar flaws in the balance of the dissimilar metal weld examination volume shall comply with the inservic examination acceptance standards of IWB-3514 or the requirements of IWB-3600.

(f) If the crack detected prior to weld inlay or onlay is completely removed by a repair/replacement activity in accordance with IWA-4000 and the inlay or onlay is then applied, the weld shall be reclassified as Inspection Item G or H, respectively.

(16) Inservice Inspection Volumetric Examination for Weld Inlay or Weld Onlay

(a) If inservice examinations reveal crack growth, or new cracking, meeting the acceptance standards of -3132.3, the weld examination volume reexamined during the first refueling outage following discovery of the growth or new cracking. The weld examination volume shall be subsequently examined during each two refueling outages.

(b) Any volumetric examinations that reveal crack growth or new cracking, meeting the acceptance standards shall also be subject to a surfac examination, see [Note (17)]. This surface examination shall also be required in any subsequent examinations required by (a).

(c) If the examinations required by (a) reveal that the flaws remain essentially unchanged for three successive examinations, the weld examination schedule may revert to the sample and schedule of examinations identified in Table 1. This weld shall be included in the 25% sample population. If cracking penetrates beyond the thickness the inlay or onlay, the weld shall be reclassified as Inspection Items A-1, A-2, or B, as appropriate, until corrected by repair/replacement activity in accordance with IWA-4000 corrective measures beyond the scope of this Case (e.g., stress improvement).

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(17) *Inservice Inspection Surface Examination for Weld Inlay or Weld Onlay*. Surface examinations shall be performed using the eddy current method. The current examination shall be performed in accordance with IWA-2223, except that the length of Mandatory Appendix IV, Supplement 2 qualification cracks or notches shall not /16 in. (1.5 mm). Linear indications exceeding $^{1}/_{16}$ in. (1.5 mm) in length shall be unacceptable.

(18) Inservice Inspection of Optimized Weld Overlays

(a) The weld overlay examination volume of Figure 5(a) shall be ultrasonically examined to determine the acceptability of the mitigated weld angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions.

(b) As an alternative to (a), for weld overlays that can be shown to meet the requirements for full structural overlays with respect to axial flaws, required examination volume of Figure 2(a) may be used for scans in which the angle beam is directed perpendicular to the pipe axis. The examination volume of Figure 5(a) shall for scans in which the angle beam is directed parallel to the pipe axis. Scanning shall be performed in four directions.

(c) The weld overlay shall meet the requirements of -3132. In applying the acceptance standards to planar indications, the thickness t_1 or t_2, defined Figure 5(b) shall be used as the nominal wall thickness, provided the base material beneath the flaw is not susceptible. For susceptible base materials, t_1 shall be used.

(d) As an alternative to (a), for inservice inspection, the examination volume in Figure 1 may be ultrasonically examined. If cracking is detected beyond the Figure 1 weld examination volume, the examination volume of (a) or (b) shall be examined in accordance with (c) to determine the acceptability of the optimized overlay.

(e) If the inservice examinations of (a), (b), (c), or (d) reveal crack growth or new cracking in the applied weld overlay or volume of original weld material as described in (a) or (b) meeting the acceptance standards, the weld overlay examination volume shall be reexamined during the next three refueling outages following detection of the crack growth or new cracking.

(f) If the examinations required by (e) reveal that flaws remain essentially unchanged for three successive examinations, the weld examination may revert to schedule of examinations identified in Table 1.

(19) If peening techniques are used, the following shall be met:

(a) Volumetric [Note (21)] examination from either the inside or outside surface and surface [Note (20)] examinations from the inside surface performed on these welds prior to the application of peening techniques and as a preservice examination in accordance with -2220. The prepeening examination shall be in the same outage as the application of peening. The examination volume and surface of Figure 1 apply. Eddy current examination in accordance with IWA-2223 is required.

(b) The prepeening examination shall be considered the preservice baseline examination. The following acceptance standards apply:

(1) No planar surface flaws are acceptable for Inspection Item L welds. If any planar surface flaws are detected, the requirements of (c) shall

(2) Flaws other than planar surface flaws detected in the butt weld or base metal inside surface shall be acceptable for continued service in with the requirements of -3132.1(b).

(c) A weld with a planar surface flaw shall be acceptable for continued service in accordance with -3132.2(a) or -3132.3(a) and be categorized by on Item in accordance with Table 1 as follows:

(1) If the flaw is removed by repair/replacement activity in accordance with IWA-4000 prior to the application of peening, the weld may be be placed into Inspection Item L.

(2) If the flaw is not removed, the weld may be peened while acceptability for continued service in accordance with -3132.3(a) is determined. If is acceptable for continued service in accordance with -3132.3(a), the weld shall be placed into Inspection Items A-1, A-2, B-1, or B-2, and shall be re-examined in accordance 1 [Note (5)]. The flaw may subsequently be made acceptable for continued service in a subsequent outage in accordance with (3).

(3) If the flaw will be made acceptable for continued service in accordance with -3132.2(a) and Table 1, peening may be performed over the to or following the repair/replacement activity or corrective measure. The weld shall be placed in the Table 1 Inspection Item category for the repair/replacement activity or orrective measure used for acceptance of the flaw.

(20) Inservice Surface Examination for Peening

(a) Surface examinations shall be performed on the examination area of Figure 1. Surface examinations shall be performed using eddy cur mination in accordance with IWA-2223.

(b) If new surface flaws are detected, the weld shall be reclassified as Inspection Items A-1, A-2, B-1, or B-2, as applicable, and shall be re-examined accordance with [Note (5)]. Alternatively, the flaw may be made acceptable by a repair/replacement activity or other mitigation techniques in accordance with -3132.2(e).

(21) Inservice Volumetric Examination for Peening

(a) The examination volume of Figure 1 shall be ultrasonically examined.

Table 1
Examination Categories (Cont'd)

NOTES (CONT'D):

(b) The acceptance standards of -3000 apply for the peened dissimilar metal weld.

(c) If inservice examinations of (a) reveal new cracking, the surface examination [Note (20)] shall be performed to confirm that the flaw is not surface-connected. If the flaw is not surface-connected, the weld shall be re-examined during each of the next three refueling outages.

(d) If the examinations required by (c) reveal that the flaw remains essentially unchanged for three successive examinations, the weld schedule revert to the schedule of examinations identified in Table 1.

(e) If an indication is found to be surface-connected, the weld shall be reclassified as Inspection Items A-1, A-2, B-1, or B-2, as applicable, and shall re-examined in accordance with [Note (5)]. Alternatively, the flaw may be made acceptable by a repair/replacement activity or other mitigation techniques in accordance with -3132.2(e).

-2420 Successive Examinations

Successive examinations are specified in Table 1.

-2430 Additional Examinations

(a) Examinations performed in accordance with Table 1 that reveal unacceptable flaws as defined in (1), (2), (3), (4), (5), (6), and (7), shall be extended to include examinations of additional welds during the current outage. The use of IWB-3514 is for the purpose of determination of scope expansion and not for the purposes of determining acceptability of the flaws. Acceptability of flaws shall be determined in accordance with -3132.

The number of additional weld examinations shall be equal to the number of welds for that Inspection Item of Table 1 originally scheduled to be performed during the present inspection period. The additional examinations shall be selected from the same Inspection Item and if applicable, from welds of similar materials, construction, and the same or higher operating temperatures. However, if the original examination was for Inspection Item B of Table 1, the additional examinations shall include first, additional welds from Inspection Item A, if any remain, and second, additional welds from Inspection Item B to reach the required number of additional examinations.

(1) For Table 1 Inspection Items A-1, A-2, B-1, and B-2 and the examination volume of Figure 1, examinations of additional unmitigated welds during the current outage are required if planar surface flaws in the butt weld or base metal inside surface exceeding the surface flaw sizes of IWB-3514 are revealed.

(2) For Table 1 Inspection Items D and E and the examination volume of Figure 1, additional mitigated welds from the same Inspection Item and using the same stress improvement method shall be examined during the current outage if planar surface flaws in the butt weld or base metal inside surface exceeding the surface flaw sizes of IWB-3514 are revealed.

(3) For Table 1 Inspection Items C-1, C-2, F-1, and F-2 and the examination volumes Figures 2(a) and 5(a), examinations of additional weld overlays from the same Inspection Item during the current outage are required if unacceptable planar flaws are detected in the weld overlay thickness, or if this examination reveals crack growth into the examination volume larger than predicted by the previous -3132.3 evaluation.

(4) For Table 1 Inspection Items G through K and the examination volumes of Figures 3 and 4, examinations of additional mitigated welds from the same Inspection Item during the current outage are required if planar flaws exceeding the surface flaw sizes of IWB-3514 are revealed which are connected to the inlay or onlay interface, if new flaws or growth of previously identified flaws are detected in the inlay or onlay, or if the acceptance standards of the surface examination are not met.

(5) For Table 1 Inspection Item L and the examination volume of Figure 1, additional mitigated welds from the same Inspection Item and using the same peening method shall be examined during the current outage, if planar surface flaws are revealed in the butt weld or base metal inside surface.

(6) Examination volumes that reveal axial crack growth beyond the specified examination volume.

(7) For other than the flaws in (1), (2), (3), (4), (5), or (6), the additional examination requirements of IWB-2430 apply.

(b) If the additional examinations required by (a) reveal flaws exceeding the requirements of (a)(1), (a)(2), (a)(3), (a)(4), (a)(5), or (a)(6) the examinations shall be further extended to include additional examinations during the current outage. These additional examinations shall include the remaining number of welds for that Inspection Item in Table 1, at the same or higher operating temperature conditions. In addition a 25% sample of welds of that Inspection Item at lower operating temperatures shall be sampled. If the examinations of this sample of welds at lower operating temperature reveal flaws exceeding the requirements of (a)(1), (a)(2), (a)(3), (a)(4), (a)(5), or (a)(6), the examinations shall be further extended to include all welds of that Inspection Item, regardless of operating temperature, within the scope of -1100.

-2500 EXAMINATION REQUIREMENTS

(a) Welds shall be examined as specified in Table 1. Volumetric examinations shall meet the requirements of Mandatory Appendix VIII.

(b) For cast stainless steel items for which no supplement is available in Mandatory Appendix VIII, the required examination volume shall be examined by Mandatory Appendix VIII procedures to the maximum extent practical including 100% of the susceptible material volume (non-stainless-steel volume). If 100% of the susceptible material within the required exam volume is examined both before and after mitigation plus the weld overlay, inlay, or onlay volume, if applicable, and no inside surface connected planar flaws are detected, the inspection frequency of Table 1 for uncracked items is applicable. If 100% of the susceptible material within the required exam volume is not examined in the pre- and post-mitigation volumetric examinations, the inspection frequency of Table 1 for cracked items shall be applied with the following exceptions:

(1) The examination of the mitigated weld shall not be credited to satisfy the requirement of the 25% inspection sample every inspection interval. The mitigated weld shall be inspected each inspection interval.

(2) If the required examination volume, including 100% of the susceptible material within the required exam volume, is subsequently examined using a qualified

ultrasonic examination and no planar flaws are detected, the weld may be placed in the 25% inspection sample population in accordance with Table 1.

(c) For axial and circumferential flaws, examination shall be performed to the maximum extent practical using qualified personnel and procedures. If 100% coverage of the susceptible material within the required volume for axial and circumferential flaws cannot be met, but essentially 100% coverage for circumferential flaws (100% of the susceptible material within the required exam volume) can be achieved, the examination for axial flaws shall be completed to achieve the maximum coverage practical, with any limitations noted in the examination report. The examination coverage requirements shall be considered to be satisfied.

(d) For piping or nozzles with inside diameter not less than 14 in. (360 mm), in locations with operating temperature less than 570°F (300°C), and where examination coverage is limited by permanent obstructions, the examination coverage requirements of this Case may be modified as follows:

(1) For circumferentially-oriented flaws, the maximum possible coverage shall be achieved and any limitations shall be documented. If the coverage is less than 90%, the following flaw tolerance evaluations shall be performed and shall be submitted to the regulatory authority having jurisdiction at the plant site:

(-a) A straight-sided through-wall flaw shall be postulated in the region where examination coverage is obstructed, with a length equal to the obstructed length. The critical length for a through-wall flaw in this region shall be calculated, using the principles of IWB-3640. The time to the next volumetric examination of this weld shall be shorter than the time for the postulated flaw to reach the critical length.

(-b) A part-through-wall surface flaw shall be postulated in the region where examination coverage is obstructed, with length equal to the length of the obstructed region. The allowable flaw depth shall be calculated using IWB-3640. The time for the postulated flaw to reach that allowable flaw depth shall be longer than the time to the next volumetric examination of this weld.

(-c) The effects of the potential boric acid leakage and corrosion on the structural integrity of the carbon or low-alloy steel adjacent to the dissimilar weld shall be evaluated using the criteria of -3142.

(2) If 90% coverage is not achieved for circumferential flaws, VE of the region shall be performed during each inspection period.

-3000 ACCEPTANCE STANDARDS

-3100 EVALUATION OF EXAMINATION RESULTS

-3130 Inservice Volumetric Examinations

-3131 General

(a) The volumetric examinations required by -2500 and performed in accordance with IWA-2200 shall be evaluated by comparing the examination results with the acceptance standards in -3132.

(b) Volumetric examination results shall be compared with recorded results of the preservice examination and prior inservice examinations. Acceptance of welds for continued service shall be in accordance with -3132.

-3132 Acceptance

-3132.1 Acceptance by Volumetric Examination

(a) A weld whose volumetric examination confirms the absence of flaws shall be acceptable for continued service.

(b) A weld with planar surface flaws in the butt weld or base metal inside surface shall be accepted for continued service in accordance with the provisions of -3132.2 or -3132.3. Other flaws shall meet the acceptance standards of IWB-3514 or be accepted for continued service in accordance with -3132.2 or -3132.3.

(c) A weld previously mitigated by the techniques identified in Table 1 with new planar surface flaws in the butt weld or base metal inside surface or unexpected or unacceptable growth of existing flaws shall be accepted for continued service in accordance with the provisions of -3132.2 or -3132.3.

-3132.2 Acceptance by Repair/Replacement Activity or Corrective Measures

(a) A weld whose volumetric examination reveals a flaw not acceptable for continued service in accordance with the provisions of -3132.3 is unacceptable for continued service until the additional exams of -2430 are satisfied and the weld is corrected by repair/replacement activity in accordance with IWA-4000 or by corrective measures beyond the scope of this Case (e.g., stress improvement) that may result in a weld being classified as Table 1, Inspection Item E.

(b) For weld overlay examination volumes [Figures 2(a) and 5(a)] with unacceptable flaws in accordance with -3132.3(d), the weld overlay shall be removed, including the original defective weld, and the weld shall be corrected by repair/replacement activity in accordance with IWA-4000.

(c) For weld examination volumes whose inside surface has been previously mitigated by weld inlay or onlay (Figure 3 or 4, respectively), or by stress improvement Figure 1, with unacceptable flaws in accordance with -3132.3(c), the original defective weld shall be corrected by repair/replacement activity in accordance with IWA-4000.

(d) If examinations of weld volumes or areas (Figure 1) reveal unacceptable flaws in accordance with -3132.3(e) in a weld that has been previously mitigated by peening, the weld is unacceptable for continued service until corrected in accordance with (a). If corrected by a mitigation technique in Table 1, the weld shall be placed in the Inspection Item for the repair/replacement activity or corrective measure used for acceptance of the flaw.

(e) As an alternative to the -3132.3(e) reclassification of a weld previously mitigated by peening containing acceptable flaws, the weld shall be corrected by repair/replacement activity in accordance with IWA-4000 or by other mitigation techniques in accordance with the requirements of Table 1 during the outage in which the flaw was identified. If corrected by a mitigation technique in Table 1, the weld shall be placed in the Inspection Item for the repair/replacement activity or corrective measure used for acceptance in the flaw.

-3132.3 Acceptance by Evaluation

(a) A weld whose volumetric examination detects planar surface flaws in the butt weld or base metal inside surface, or other flaws [-3132.1(b)] in the required examination volume that exceed the acceptance standards of IWB-3514, is acceptable for continued service if an analytical evaluation meets the requirements of IWB-3600 and the additional examinations of -2430 are performed during the current outage. The weld containing the flaw shall be reexamined in accordance with Table 1.

(b) Previously-evaluated flaws that were mitigated by the techniques identified in Table 1 need not be reevaluated nor have additional successive or additional examinations performed if new planar flaws have not been identified or the previously evaluated flaws have remained essentially unchanged.

(c) A weld previously mitigated by stress improvement or weld inlay or onlay, whose volumetric or surface examinations detect crack growth or new planar surface flaws in the butt weld or base metal inside surface or in the inlay or onlay, or new planar flaws or growth of previously identified planar flaws that are connected to the inlay or onlay interface, is acceptable for continued service without additional repair/replacement activity if an analytical evaluation meets the requirements of IWB-3600 and the additional exams of -2430 are performed in the current outage. The mitigated weld containing the flaw shall be reexamined in accordance with Table 1.

(d) A weld overlay whose volumetric examination (Figures 2(a) and 2(b) or Figures 5(a) and 5(b)) detects planar flaw growth or new planar flaws that exceed the acceptance standards of IWB-3514 is acceptable for continued service without repair/replacement activity if the weld overlay meets the acceptance criteria of IWB-3600, the additional exams of -2430 are performed, and the weld overlay is reexamined in accordance with Table 1. If a planar flaw is detected in the outer 25% of the original weld/base metal thickness for the examination volume of Figure 2(a), or the outer 25% to 50% of the original weld or base metal thickness for the examination volume of Figure 5(a), it is acceptable for continued service if the crack growth calculations and structural design and sizing calculations required for original weld overlay acceptance show or are revised to show acceptability of the detected flaw. Any indication in the weld overlay material characterized as stress corrosion cracking is unacceptable.

(e) If volumetric or surface examination of the weld previously mitigated by peening detects new planar surface flaws in the butt weld or base metal inside surface, the weld is acceptable for continued service without additional repair/replacement activity or corrective measures, provided an analytical evaluation meets the requirements of IWB-3600, and the additional examinations of -2430 are performed in the current outage. In this analytical evaluation, the beneficial effects of peening shall not be considered, the weld shall not be considered mitigated; and the weld shall be reclassified as Inspection Items A-1, A-2, B-1, or B-2, as applicable, and re-examined in accordance with Table 1, Note (5).

-3140 Inservice Bare Metal Visual Examinations (VE)

-3141 General

(a) The bare metal visual examination (VE) required by Table 1 and performed in accordance with IWA-2200 as revised by the additional requirements of this Case shall be evaluated by comparing the examination results with the acceptance standards specified in -3142.1.

(b) Acceptance of welds for continued service shall be in accordance with -3142.

(c) Relevant conditions for the purposes of the VE shall include areas of corrosion, boric acid deposits, discoloration, and other evidence of pressure boundary leakage.

(d) In lieu of other visual examination requirements, requirements of this Case govern.

-3142 Acceptance

-3142.1 Acceptance by Bare Metal Visual Examination.

(a) A weld whose VE confirms the absence of relevant conditions shall be acceptable for continued service.

(b) A weld whose VE detects a relevant condition shall be unacceptable for continued service unless the requirements of (1), (2), and (3) below are met.

(1) Welds with relevant conditions require further evaluation. This evaluation shall include determination of the source of the leakage and correction of the source of leakage in accordance with -3142.3.

(2) All relevant conditions shall be evaluated to determine the extent, if any, of pressure boundary degradation. The boric acid crystals and residue shall be removed to the extent necessary to allow adequate examinations and evaluation of pressure boundary degradation, and a

subsequent VE of the previously obscured surfaces shall be performed prior to return to service. Any pressure boundary degradation detected shall be evaluated to determine if any corrosion has affected the structural integrity of the component. Corrosion that has reduced component wall thickness below the thickness required by the Construction Code shall be resolved through repair/replacement activity in accordance with IWA-4000.

(3) A weld whose VE indicates relevant conditions indicative of possible through-wall leakage shall be unacceptable for continued service unless it meets the requirements of -3142.2 or -3142.3.

-3142.2 Acceptance by Supplemental Examination. A weld with relevant conditions indicative of possible through-wall leakage shall be acceptable for continued service if the results of supplemental examinations [-3200(a)] meet the requirements of -3130.

-3142.3 Acceptance by Corrective Measures or Repair/Replacement Activity.

(a) A weld with relevant conditions indicative of possible through-wall leakage shall be acceptable for continued service if a repair/replacement activity corrects the condition in accordance with IWA-4000.

(b) A weld with relevant conditions not indicative of possible through-wall leakage is acceptable for continued service if the source of the relevant condition is corrected by repair/replacement activity or by corrective measures necessary to preclude pressure boundary degradation.

-3200 SUPPLEMENTAL EXAMINATIONS

(a) Any visual examination that detects a relevant condition (-3141) indicative of possible through-wall leakage shall also receive a volumetric examination in accordance with -2500. The extent of the volumetric examination shall be in accordance with Figures 1, 2(a), 2(b), 3, 4, 5(a) or 5(b), as applicable.

(b) A surface examination may also be performed to help further characterize the extent of the unacceptable condition and the need for corrective measures, analytical evaluation, or repair/replacement activity.

-9000 GLOSSARY

cracked: containing planar surface-connected flaws in contact with the reactor coolant environment during normal operation. A weld that is mitigated before it is examined shall be considered cracked. Reactor vessel nozzle welds at cold leg temperature requiring the core internals to be removed to perform the pre-mitigation examination may be considered uncracked if the requirements of Table 1, [Note 6(c)] or [Note 12(e)], as appropriate, are met. (See uncracked.)

full structural weld overlay: deposition of weld reinforcement on the outside surface of the piping, component, or associated weld such that the weld reinforcement is capable of supporting the design loads without the piping, component, or associated weld beneath the weld reinforcement.

inlay: a corrosion resistant barrier applied on the inside surface of the component between the Alloy 82/182 weld and the reactor coolant, requiring excavation of some portion of the Alloy 82/182 weld.

mitigation: an activity to reduce or eliminate the susceptibility of Alloy 82/182 weld filler material or Alloy 600[3] materials to crack initiation or crack propagation. Mitigation can be preemptive, i.e., before crack initiation, or repair, i.e., after crack initiation is discovered.

onlay: a corrosion resistant barrier applied on the inside surface of the component between the Alloy 82/182 weld and the reactor coolant, not requiring excavation of some portion of the Alloy 82/182 weld.

optimized weld overlay: deposition of weld reinforcement on the outside surface of the piping, component, or associated weld, such that the weld reinforcement is capable of supporting the design and service loads with consideration of the outer 25% of the wall thickness of the piping, component, or associated weld beneath the weld reinforcement in the design.

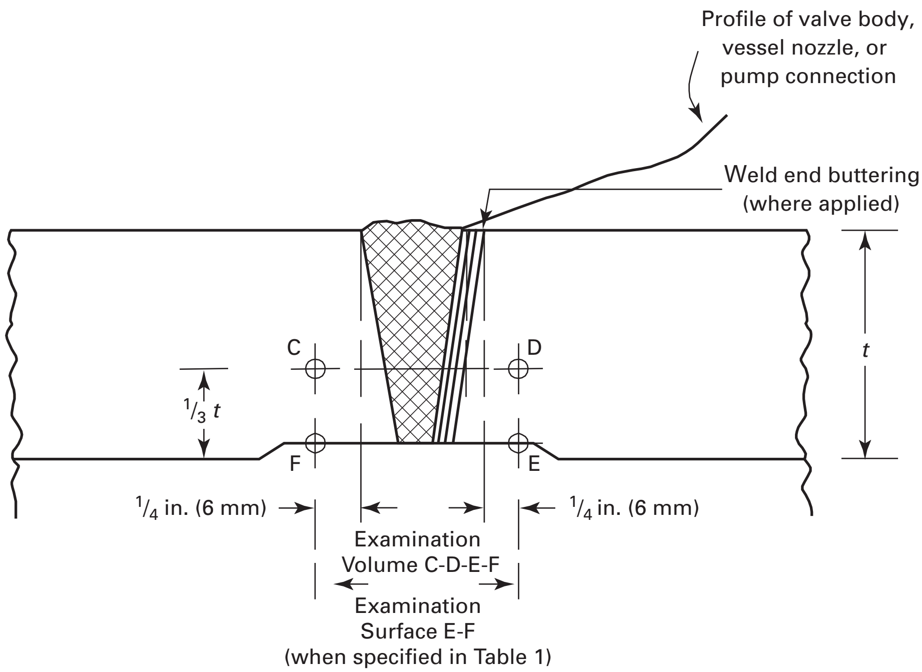
peening: a process that produces sufficient stress conditions on the surface of interest, to inhibit initiation and propagation of primary water stress corrosion cracking through application of a compressive stress layer. Mitigation by peening is not included in IWA-4000 and is not a repair/replacement activity.

stress improvement: a process that produces sufficient stress conditions on the inside wetted surface to inhibit initiation and propagation of primary water stress corrosion cracking. Stress improvement techniques without welding are not included in IWA-4000 and are not repair/replacement activities.

uncracked: examined in accordance with the requirements of -2500 with no planar surface-connected flaws in contact with the reactor coolant environment during normal operation.

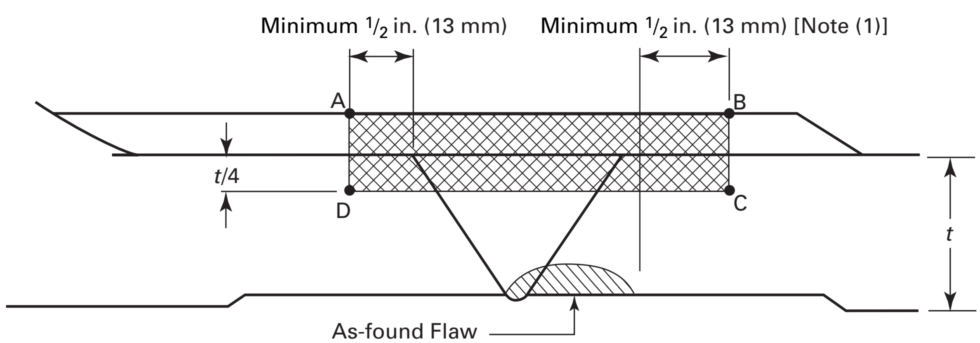
[3] Alloy 600 is a common abbreviation used by industry, the regulatory authority, and research organizations for UNS N06600.

Figure 1
Examination Surface and Volume for Welds NPS 2 (DN 50) or Larger



GENERAL NOTE: When weld end buttering is present, on both sides, the examination surface and volume shall be measured from the end of both butterings. It may include remnants of replaced welds, and may appear artificially deep on exposed surfaces due to fabrication processes. Buttering thickness may be determined from manufacturer's drawings or assumed to be $\frac{1}{2}$ in. (13 mm) if the true dimension is unknown.

Figure 2(a)
Examination Volume for Full Structural Weld Overlays

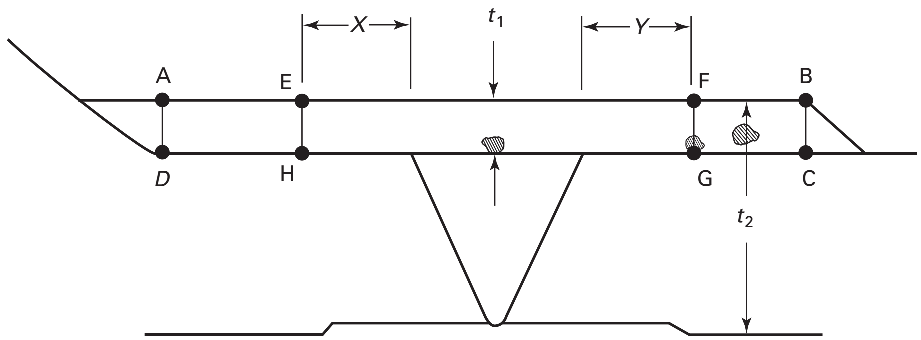


Examination Volume A–B–C–D

GENERAL NOTE: The weld includes the nozzle or safe end butter, where applied.

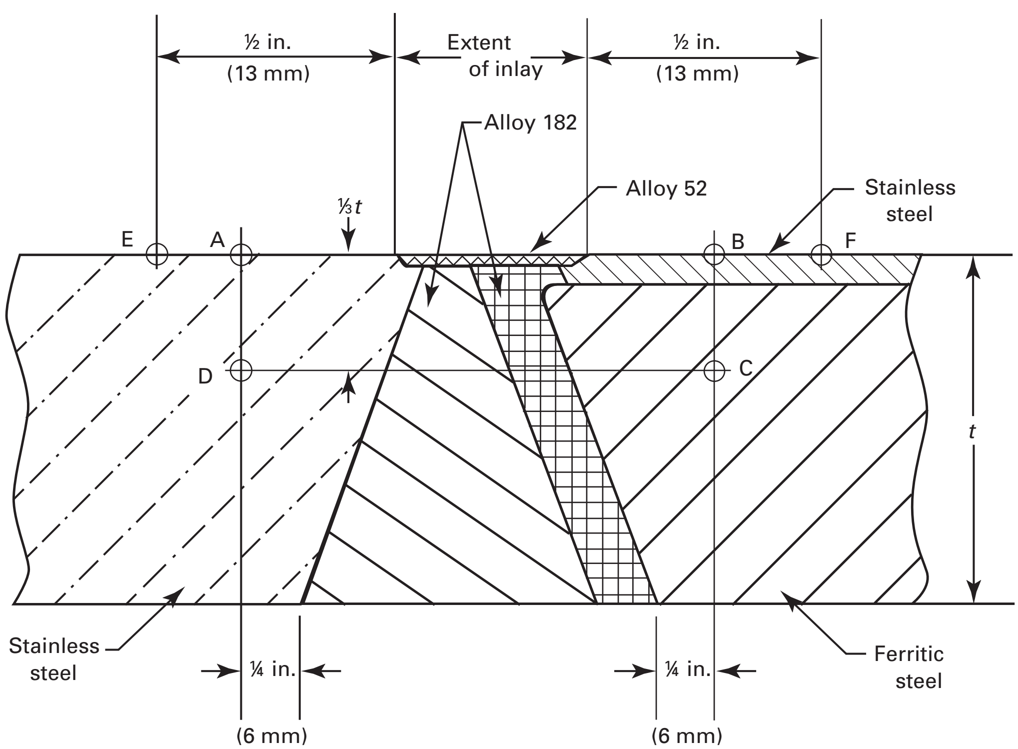
NOTE:
(1) For axial and circumferential flaws, the axial extent of the examination volume shall extend at least $\frac{1}{2}$ in. (13 mm) beyond the as-found flaw and at least $\frac{1}{2}$ in. (13 mm) beyond the toes of the original weld, including weld end butter, where applied, plus any PWSCC-susceptible base material in the nozzle and safe-end.

Figure 2(b)
Definition of Thickness t_1 and t_2 for Application of IWB-3514 Acceptance Standards



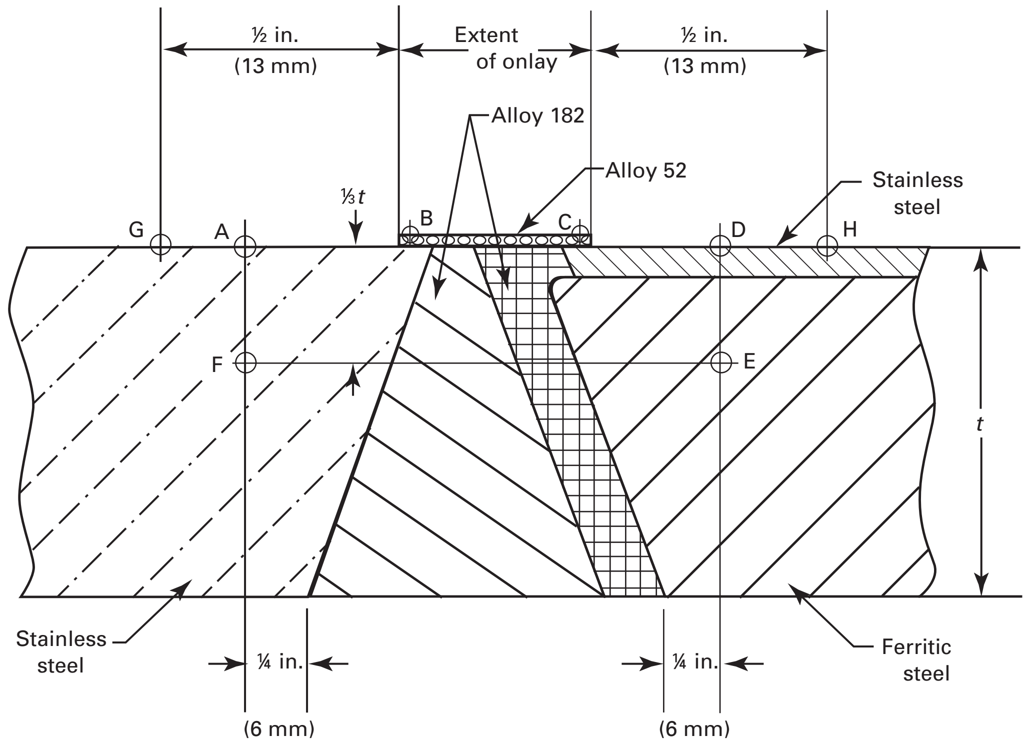
GENERAL NOTES:
(a) Dimension X or Y is equivalent to the nominal thickness of the nozzle end preparation or the pipe, respectively, being overlaid.
(b) The nominal wall thickness is t_1 for flaws in E-F-G-H and t_2 for flaws outside E-F-G-H.
(c) For flaws that are in E-F-G-H and extend outside this volume, the thickness t_1 shall be used.
(d) The weld includes the nozzle or safe end butter, where applied, plus any PWSCC-susceptible base material in the nozzle and safe-end.

Figure 3
Examination Surface and Volume for Weld Inlay



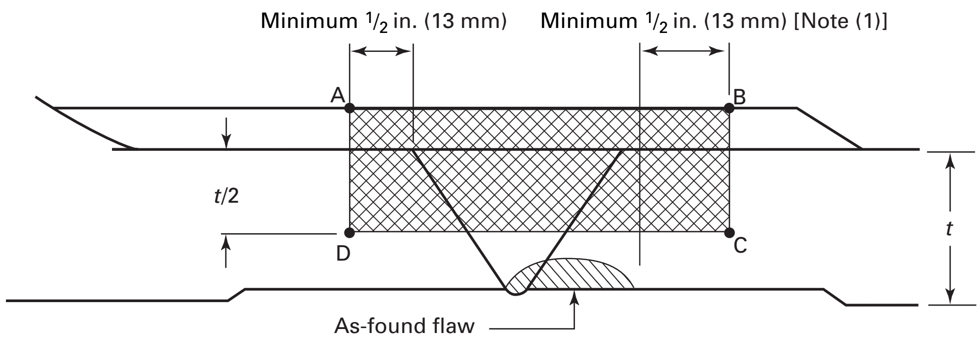
Volumetric Examination Volume A-B-C-D
Surface Examination Extent E-F

Figure 4
Examination Surface and Volume for Weld Inside Surface Onlay



Volumetric Examination Volume A-B-C-D-E-F
Surface Examination Extent G-H

Figure 5(a)
Examination Volume for Optimized Weld Overlays

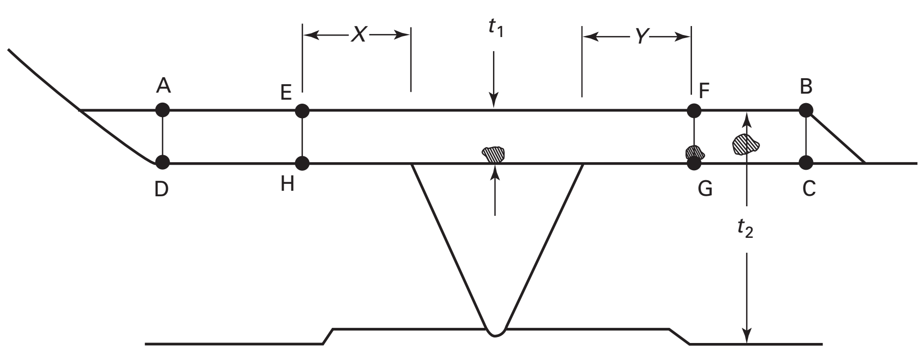


Examination Volume A–B–C–D

GENERAL NOTES:
(a) The weld includes the nozzle or safe end butter, where applied, plus any PWSCC-susceptible base material in the nozzle and safe-end.
(b) As an alternative to Examination Volume A-B-C-D for weld overlays that can be shown to meet the requirements for full structural overlays with respect to axial flaws, the required examination volume of Figure 2(a) may be used for scans in which the angle beam is directed perpendicular to the pipe axis. The Examination Volume A-B-C-D in Figure 5(a) shall be used for scans in which the angle beam is directed parallel to the pipe axis.

NOTE:
(1) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least 1/2 in. (13 mm) beyond the as-found flaw and at least 1/2 in. (13 mm) beyond the toes of the original weld, including any weld end butter, where applied.

Figure 5(b)
Definition of Thickness t_1 and t_2 for Application of IWB-3514 Acceptance Standards



GENERAL NOTES:
(a) Dimension X or Y is equivalent to the nominal thickness of the nozzle end preparation or the pipe, respectively, being overlaid.
(b) The nominal wall thickness is t_1 for flaws in E-F-G-H and t_2 for flaws outside E-F-G-H.
(c) For flaws that are in E-F-G-H and extend outside this volume, the thickness t_1 shall be used.
(d) The weld includes the nozzle or safe end butter, where applied, plus any PWSCC-susceptible base material in the nozzle and safe-end.

MANDATORY APPENDIX I PERFORMANCE CRITERIA AND MEASUREMENT OR QUANTIFICATION CRITERIA FOR MITIGATION BY STRESS IMPROVEMENT OR PEENING

I-1 PERFORMANCE CRITERIA

To minimize the likelihood of crack initiation, the process shall have resulted in a compressive stress in the susceptible material along the entire wetted surface under steady state operation. Susceptible material includes the weld, butter, and base material, as applicable. The residual stress plus normal operating stress shall be included in the evaluation.

I-1.1 Measurement or Quantification Criteria. A properly bench-marked analysis or demonstration test shall be performed to confirm the postmitigation stress state. The analysis or testing shall show that the steady-state operating axial and hoop direction stresses combined with residual stresses are compressive at the inside surface. A prestress improvement residual stress condition resulting from a construction weld repair from the inside surface to a depth of 50% of the weld thickness and extending for 360 deg shall be assumed. The analysis or testing shall identify the critical process parameters and define acceptable ranges of the parameters needed to ensure that the compressive stress field has been developed.

I-1.1.1 For peening, demonstration testing shall confirm the nominal depth of the compressive residual stress produced by the peening technique is at least 0.04 in. (1.0 mm), unless the alternative of I-1.1.2 is used.

I-1.1.2 For peening techniques where the nominal compressive surface stress field applied is less than 0.04 in. (1.0 mm), the following shall apply:

(a) Testing shall establish the nominal depth of compressive residual stress.

(b) Prepeening surface examinations required by Table 1 shall be qualified in accordance with Mandatory Appendix IV Supplement 2 except that the flawed grading unit specimens shall use crack or compressed notch depths no greater than the nominal peening depth or machined notches with a maximum depth of one-half the nominal peening depth.

I-2 PERFORMANCE CRITERIA

The effect produced by the mitigation process shall be permanent.

I-2.1 Measurement or Quantification Criteria. An analysis or demonstration test shall be performed to confirm that the mitigation process is permanent. The analysis and demonstration test plan shall include startup and shutdown stresses, normal operating pressure stress, thermal cyclic stresses, transient stresses, and residual stresses. The analysis or demonstration test shall account for

(a) load combinations that could relieve stress due to shakedown

(b) any material properties related to stress relaxation over time

I-2.1.1 Testing shall be performed to verify that the peening process maintains the compressive surface stress condition for the remaining service life of the component and growth of a postulated PWSCC flaw that is at or below the demonstrated detection limit of the surface examination technique applied.

I-3 PERFORMANCE CRITERIA

The capability to perform ultrasonic examinations of the relevant volume of the component shall not have been adversely affected.

I-3.1 Measurement or Quantification Criteria. Mock-up testing and nondestructive examination qualified to Section XI, Mandatory Appendix VIII, performance demonstration requirements shall have been performed to demonstrate that a qualified examination of the relevant volume of the mitigated component can be accomplished subsequent to the mitigation including changes to component geometry, material properties, or other factors.

I-4 PERFORMANCE CRITERIA

The mitigation process shall not have degraded the component or adversely affected other components in the system.

I-4.1 Measurement or Quantification Criteria for Mitigation by Stress Improvement. An analysis shall have been performed to verify that the mitigation process does not result in changes to the piping system geometry that exceed Section III or original Construction Code design criteria. A walk down of the piping system shall be performed to verify support integrity and satisfaction of design tolerances. An analysis or evaluation shall be performed to verify that the properties specified in the material specification are met after the stress improvement.

I-4.2 Measurement or Quantification Criteria for Mitigation by Peening.

I-4.2.1 Analysis or testing shall have been performed to verify that peening does not cause undesirable hardness at the peened surface, erosion of surfaces, undesirable surface roughening, or detrimental effects in the transition regions adjacent to the peened regions.

I-5 PERFORMANCE CRITERIA

The mitigated weld shall be inspectable by a qualified process.

I-5.1 Measurement or Quantification Criteria. An evaluation shall be performed to confirm that the required examination volume of the mitigated configuration is within the scope of an Mandatory Appendix VIII supplement or supplements and that the examination procedures to be used have been qualified in accordance with Mandatory Appendix VIII. The evaluation shall confirm that the geometric limitations (e.g., weld crown, nozzle contour) of an Mandatory Appendix VIII qualification are not exceeded for the mitigated weld.

I-6 PERFORMANCE CRITERIA

Existing flaws, if any, shall be addressed as part of the mitigation.

I-6.1 Measurement or Quantification Criteria for Mitigation by Stress Improvement. An examination qualified to Section XI, Mandatory Appendix VIII performance demonstration requirements shall have been performed in accordance with Table 1 of this Case before the application of the mitigation process to identify and size any existing flaws. Any flaws identified shall be specifically considered in satisfying performance criterion 7.

I-6.2 Measurement or Quantification Criteria for Mitigation by Peening.

I-6.2.1 A volumetric examination qualified to Section XI Mandatory Appendix VIII, performance demonstration requirements and a surface examination in accordance with IWA-2223 shall have been performed in accordance with Table 1 of this Case to assure the absence of planar surface flaws before the application of the peening mitigation.

I-6.2.2 An analysis meeting the requirements of IWB-3640 shall be performed to assess growth by fatigue of a shallow postulated planar surface flaw [either half the nominal compressive depth or 0.02 in. (0.5 mm)] in the peened compressive residual stress zone. The fatigue assessment shall include the applied stress cycles that occur at the specific location, in combination with the levels of compressive stress expected from the applied peening method, adjusted for temperature and load-cycling-induced relaxation.

I-7 PERFORMANCE CRITERIA

The effect of mitigation by stress improvement on the presence of existing flaws shall be analyzed. The stress intensity factor at the depth of the flaw shall be determined using combined residual and steady state operating stresses, and shall not be greater than zero.

I-7.1 Measurement or Quantification Criteria for Mitigation by Stress Improvement. An analysis shall be performed using IWB-3600 evaluation methods and acceptance criteria to verify that the mitigation process will not result in any existing flaws to become unacceptable over the life of the weld, or before the next scheduled examination.

Approval Date: September 8, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-771
Alternative Requirements for Additional Examinations of Class 2 or 3 Items
Section XI, Division 1

Inquiry: What alternatives to the additional examination requirements of IWC-2430(a) or IWD-2430(a) may be used for inspection items when the inservice examinations are performed during power operation?

Reply: It is the opinion of the Committee that the following alternatives to IWC-2430(a) or IWD-2430(a) may be used for additional examinations of Class 2 or 3 inspection items when the examinations are performed during power operation.

(a) The additional examinations required by IWC-2430 (a) or IWD-2430(a) shall be preferentially selected from accessible welds, areas, or parts of similar material and service subject to the same degradation mechanisms and shall be performed within 30 days after initial detection of the flaw. If another flaw exceeding the acceptance standards of IWC-3400 or IWD-3400 is detected during these additional examinations, the additional examinations required by IWC-2430(b) or IWD-2430(b) shall be implemented without delay, and the provisions of (b) through (d) shall not be used. To perform these examinations, a system or plant outage might be required.

(b) If the number of additional examinations required by IWC-2430(a) or IWD-2430(a) of welds, areas, or parts of similar material and service subject to the same degradation mechanisms cannot be satisfied from the population of accessible welds, areas, or parts, provided the requirements of (c) and (d) are satisfied, the remaining additional examinations of these locations may be deferred until the next refueling outage or the next outage of sufficient duration to perform the examinations. If the cause of the flaw is determined to be stress corrosion cracking, deferral of the additional examinations is not permissible.

(c) An analytical evaluation of the initially-detected flaw shall be performed in accordance with IWC-3600 or IWD-3600, as appropriate. Flaw growth rates in Appendix C or flaw growth rates acceptable to the regulatory authority shall be used in the analytical evaluation. The analytical evaluation shall satisfy the requirements of either (1) or (2).

(1) The flaw shall be acceptable for continued service, and the flaw depth shall not exceed 50% of the allowable flaw depth until after the end of the next scheduled refueling outage. In addition, a through-wall flaw with a length equal to the end-of-evaluation-period part-through-wall flaw length shall be stable with a structural factor on load of 1.0.

(2) As an alternative to (1), the flaw shall be acceptable for continued service until the end of the next scheduled refueling outage. In addition, a through-wall flaw with a length equal to the end-of-evaluation-period part-through-wall flaw length shall be stable with a structural factor on load of 1.0. The affected inaccessible locations shall be monitored for leakage at least monthly.

(d) If the service conditions at an inaccessible location are more severe in terms of the degradation mechanism than the service conditions for the initially-detected flaw, a flaw shall be postulated at the inaccessible location. The postulated flaw shall have the same ratio of depth to wall thickness, the same ratio of length to depth, and the same orientation as the initially-detected flaw. An analytical evaluation of the postulated flaw shall be performed in accordance with IWC-3600 or IWD-3600, as appropriate. Flaw growth rates in Appendix C or flaw growth rates acceptable to the regulatory authority shall be used in the analytical evaluation. The analytical evaluation shall satisfy the requirements of either (c)(1) or (c)(2).

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Approval Date: January 26, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-773
Alternative Qualification Criteria for Eddy Current Examinations of Piping Inside Surfaces
Section XI, Division 1

Inquiry: What alternative to the qualification requirements of Appendix IV, Supplement 2 may be used when eddy current examination is used to complement ultrasonic examination performed on the inside surfaces of austenitic, dissimilar metal and clad piping welds, to assist in interpretation of flaws as being surface connected, and to provide surface flaw detection in specific areas of insufficient ultrasonic probe contact?

Reply: It is the opinion of the Committee that if eddy current examination is used to complement ultrasonic examination performed on the inside surfaces of austenitic, dissimilar metal and clad piping welds to assist in the interpretation of flaws as being surface connected, and to provide surface flaw detection in specific areas of insufficient probe contact, the following qualification requirements may be used as an alternative to the qualification requirements of Appendix IV, Supplement 2.

1 SCOPE

Personnel and procedures qualified in accordance with this Case are qualified for detection and length-sizing of inside surface flaws in volume C-D-E-F as defined in Fig. IWB-2500-8(c). Examination results may be used as complementary surface examination data in conjunction with ultrasonic examinations only under the supervision of an examiner qualified in accordance with the applicable Appendix VIII supplement for which the data is being used.

2 SPECIMEN REQUIREMENTS

2.1 General. The test specimen set shall conform to the following requirements:

(a) Specimens may be curved or flat and shall be of sufficient thickness to preclude eddy current signals from the opposite surface or surface distortion due to welding or cladding.

(b) The specimen set shall comply with the following fabrication conditions and material content:

(1) Specimens shall be fabricated from the same base material nominal composition (UNS Number) and heat treatment (e.g., solution annealed, precipitation hardened, solution heat treated and aged) as those to be examined.

(2) Welding shall be performed with the same filler metal AWS classification, and postweld heat treatment (e.g., as welded, solution annealed, stress relieved) as the welds to be examined. Welding, cladding, and buttering may be applied manually or by automated methods.

(3) Normal geometric conditions causing surface irregularities, such as counter-bore and weld-root conditions, shall be represented in the test specimen set.

(4) The test specimen set shall include metallurgical and surface variations causing nonrelevant eddy current indications.

(5) An example of weld or cladding repair shall be included in the test specimen set.

(c) The examination specimen scanning surface shall maintain a relationship of two unflawed areas for every flaw area. The flaw area shall be defined as a bounding area of at least 1 in. (25 mm) surrounding each flaw.

2.2 Flaw Location. At least two flaws shall be located on the surfaces of each material type in the specimen, including welds, buttering, and cladding, where present.

2.3 Flaw Type. Flaws shall be cracks or EDM notches.

2.4 Flaw Opening Dimension. The demonstration flaws shall have a maximum opening dimension of 0.0019 in. (50 μm). The maximum opening dimension may be exceeded by 0.0006 in. (15 μm) at discreet areas along the flaw length provided the aggregate length of those areas does not exceed 10% of the length of the flaw. The PDA shall verify that demonstration flaw responses are free from additional signals caused by the implantation process.

2.5 Flaw Orientation. The specimens shall contain flaws oriented parallel and perpendicular to the weld axis ±15 deg. The procedure qualification test set shall include at least 30% of each orientation type. In addition, for procedure qualification, at least one and not more than 20% of the flaws shall be oriented 45 ± 15 deg to the weld axis.

Table 3.2.2-1
Detection Performance Criteria for Open (Non-blind) Procedure Demonstration

Flaws	Detections Required	Maximum False Calls
10	10	2
11	11	2
12	12	2
13	13	3
14	14	4
15	15	4
16	16	5
17	17	5
18	18	6

2.6 Flaw Length. At least 33% of the flaws comprising the procedure test set (Table 3.2.2-1), shall have a length of 0.4 in. (10 mm) or less.

3 PERFORMANCE DEMONSTRATION

3.1 Performance Demonstration Administrator. Performance demonstration conduct, including procedure demonstration, testing of personnel, validation and control of test specimens and documentation of qualification results are the responsibility of the Performance Demonstration Administrator (PDA). For this activity, the PDA shall be certified to at least Level II in the eddy current examination method. The PDA shall be employed by an independent company or a functionally independent organization within the same company demonstrating the procedure.

3.1.1 Procedure Demonstration. For procedure demonstration, the PDA shall verify the procedure content requirements of 3.2.1, including examination equipment, and acquisition and analysis of examination data according to the procedure instructions. The PDA shall grade the procedure demonstration in accordance with the criteria specified in 3.2.2 and shall document the results.

3.1.2 Personnel Examinations. For personnel examinations, the PDA shall select the flaws to be included in the sample set, administer and grade the examination in accordance with the criteria in 3.3, and document the results.

3.2 Procedure Demonstration Requirements. The procedure shall be subject to a non-blind open demonstration, in which personnel may have specific knowledge of defect locations in the test specimens. The following procedure parameters shall be explained and physically demonstrated by the qualification candidates. Personnel whose function is only to acquire data or operate scanners are not qualification candidates.

3.2.1 Procedure Content. The procedure shall comply with the requirements of Appendix IV, IV-2100 and 2200. In addition, the procedure shall capture or illustrate acquisition software input displays, so that all essential input values and operational parameters are identified. The following procedure equipment descriptions and operations shall be verified by the PDA.

3.2.1.1 Examination Equipment. The procedure shall define examination equipment essential and nonessential variables. Equipment essential variables shall be described in the procedure by function, manufacturer, model, or type. Procedure descriptions of the system shall include at least the requirements of 3.2.1, including the following additional information:

(a) calibration standard and secondary standard documentation

(b) a diagram of the essential analog system (probes, cabling, interconnects, and instruments)

(c) a diagram of nonessential cabling and equipment (digital transfer cabling, component interconnects, data storage computers and data display computers)

(d) essential acquisition and analysis software

3.2.1.2 Calibration and Acquisition Parameters. The following calibration and acquisition parameters shall be demonstrated:

(a) examination sensitivity calibration

(b) system characterization if applicable

(c) probe rate of movement

(d) probe index size

(e) minimum sample rate in procedure

(f) scanning of test areas as a verification of the intended versus actual scan boundary

3.2.1.3 Analysis Parameters. The procedure shall have specific criteria for indication assessment including amplitude response, phase, screening criteria (if applicable), and length measurement. The following indication assessment parameters shall be demonstrated:

(a) instructions for confirming data quality (i.e., minimum signal-to-noise ratio) with corrective measures if data quality is not satisfied

(b) instructions for characterizing indications as nonrelevant

(c) instructions for the recognition and recording of relevant eddy current indications

3.2.2 Procedure Demonstration Detection and Characterization Acceptance Criteria.

(a) Detection and false call criteria for procedure demonstration shall be in accordance with Table 3.2.2-1. At least 10 flaws shall be used in the demonstration for each Appendix VIII supplement for which this technique is to be used as a complementary method. The procedure shall be considered qualified for examination of the clad inside surface of ferritic piping (Appendix VIII,

Supplement 3), provided that stainless steel cladding is included as one of the materials used for demonstrating this technique for Supplement 3 or Supplement 10 welds.

(b) In the processed data, all relevant flaws in the test set shall be resolved according to the procedure requirements for image quality.

(c) The equipment shall be capable of producing responses from the specimen flaws that are consistent with the procedure definition of relevant flaws. For indications from material boundaries, surface geometry, weld repairs, or other nonrelevant sources, the equipment shall produce responses that are consistent with procedure definitions of nonrelevant indications.

(d) If there is insufficient procedure instruction or raw data to properly characterize a known flaw, the PDA shall identify a missed detection. If a nonrelevant indication or condition is interpreted as a flaw, the PDA shall identify a false call.

(e) The reported flaw location shall be within 1.0 in. (25 mm) of the true location.

3.2.3 Length Measurement Acceptance Criteria. Length shall be measured in a manner consistent with the procedure instructions. Measured versus true length shall be ≤ 0.5 in. (13 mm) RMS error for all flaws.

3.2.4 Procedure Qualification. The procedure shall be qualified if the equivalent of two personnel examinations are successfully performed in accordance with 3.3.

3.3 Personnel Qualification. Personnel qualifications shall be conducted as blind tests, in which the candidate has no knowledge of the contents of the specimen set. The test set may be composed of flaws used for the procedure qualification or from other specimens fabricated in conformance with 2 at the discretion of the PDA. The performance demonstration detection and false call criteria shall be in accordance with Table 3.3.1-1.

Table 3.3.1-1
Eddy Current Blind Test Detection and False Call Criteria

Flaws	Detections Required	Maximum False Calls
5	5	0
6	6	1
7	6	1
8	7	2
9	7	2
10	8	3
11	9	3
12	9	3
13	10	4
14	11	5
15	11	5

4 ESSENTIAL VARIABLE CHANGES AND REQUALIFICATION

Hardware, equipment settings, and operational input values that directly affect the calibration, acquisition, and image quality requirements of the procedure are considered essential variables. Changes in essential variables of a demonstrated procedure shall not be allowed without requalification of the procedure in accordance with IV-3120(b) and IV-3130.

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Approval Date: September 3, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-774
Use of 13Cr-4Ni (Alloy UNS S41500) Grade F6NM Forgings Weighing in Excess of 10,000 lb (4 540 kg) and Otherwise Conforming to the Requirements of SA-336/SA-336M for Class 1, 2 and 3 Construction
Section III, Division 1

Inquiry: Is it permissible to use 13Cr-4Ni (Alloy UNS S41500) Grade F6NM forgings weighing in excess of 10,000 lb (4 540 kg) and otherwise conforming to the requirements of SA-336/SA-336M for Section III, Class 1, 2 and 3 Construction?

Reply: It is the opinion of the Committee that 13Cr-4Ni (Alloy UNS S41500) Grade F6NM forgings weighing in excess of 10,000 lb (4 540 kg) and otherwise conforming to the requirements of SA-336/SA-336M may be used for Section III, Class 1, 2, and 3 Construction provided the following additional requirements are met:

(a) The chemical composition shall conform to the requirements shown in Table 1.

(b) After hot working, forgings shall be cooled to a temperature below 1000°F [538°C] prior to heat treating in accordance with the following requirements. Forgings shall be normalized at 1850°F [1010°C] minimum, followed by air cooling to below 200°F [95°C] and then tempered in the range of 1040°F to 1120°F [560°C to 600°C]. When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures defined above are used. Forgings shall conform to the mechanical property requirements listed in Table 2.

(c) Design stress intensity values shall be those shown in Tables 3 and 3M for applications with a maximum design temperature less than or equal to 700°F (371°C).

(d) Allowable stress values shall be those shown in Tables 4 and 4M for applications with a maximum design temperature less than or equal to 700°F (371°C).

(e) S_y and S_u values shall be those shown in Tables 5, 5M, 6, and 6M.

(f) External Pressure Chart CS-3 shall be used.

(g) The material shall be considered as P-No. 6, Group No. 4.

(h) This Case number shall be identified on the Design Specification, the Design Report, the Certified Material Test Report (CMTR) for the material and on the Certificate Holders Data Report Form.

Table 1
Chemical Composition Requirements

Element	Composition, %
Carbon	0.05 max.
Manganese	0.50–1.00
Phosphorus	0.030 max.
Sulfur	0.030 max.
Silicon	0.60 max.
Nickel	3.5–5.5
Chromium	11.5–14.0
Molybdenum	0.50–1.00

GENERAL NOTE: Nominal composition for this table is 13% chromium, 4% nickel, with Grade F6NM and UNS designation S41500.

Table 2
Tensile and Hardness Requirements

Grade	Tensile Strength, Min., ksi [MPa]	Yield Strength, Min., ksi [MPa]	Elongation in 2 in. [50 mm] or 4*D*, Min., %	Reduction of Area, Min., %	Brinell Hardness Number
F6NM	115 [790]	90 [620]	15	45	295 max.

Table 3
U.S. Customary: (Class 1) Design Stress Intensity Values, S_m (ksi)

°F	S_m
−20 to 100	38.3
200	38.3
300	38.3
400	37.9
500	36.5
600	35.0
650	34.3
700	33.4

Table 3M
Metric: (Class 1) Design Stress Intensity Values, S_m (MPa)

°C	S_m
−30 to 40	264
65	264
100	264
125	264
150	264
200	262
250	254
300	244
325	240
350	235
375 [Note (1)]	229

NOTE:
(1) The value of 375°C is for interpolation, the maximum design temperature is 371°C.

Table 4
U.S. Customary: (Class 2 and 3) Allowable Stress Values, S_m (ksi)

°F	S_m
−20 to 100	32.9
200	32.9
300	32.9
400	32.5
500	31.3
600	30.0
650	29.4
700	28.7

Table 4M
Metric: (Class 2 and 3) Allowable Stress Values, S_m (MPa)

°C	S_m
−30 to 40	227
65	227
100	227
125	227
150	227
200	225
250	217
300	209

Table 4M
Metric: (Class 2 and 3) Allowable Stress Values, S_m (MPa) (Cont'd)

°C	S_m
325	205
350	202
375 [Note (1)]	197

NOTE:
(1) The value of 375°C is for interpolation, the maximum design temperature is 371°C.

Table 5
U.S. Customary: Y-1 Yield Strength Values, S_y (ksi)

°F	S_y
−20 to 100	90.0
150	87.7
200	86.5
250	85.5
300	84.6
400	82.8
500	80.8
600	78.5
650	77.2
700	75.7

Table 5M
Metric: Y-1 Yield Strength Values, S_y (MPa)

°C	S_y
−30 to 40	621
65	605
100	595
125	589
150	583
175	578
200	572
225	566
250	560
275	553
300	546
325	538
350	530
375 [Note (1)]	520

NOTE:
(1) The value of 375°C is for interpolation, the maximum design temperature is 371°C.

Table 6
U.S. Customary: Tensile Strength Values, S_u (ksi)

°F	S_u
−20 to 100	115.0
200	115.0
300	115.0
400	113.7
500	109.5
600	105.1
650	102.8
700	100.3

Table 6M
Metric: Tensile Strength Values, S_u (MPa)

°C	S_u
−30 to 40	793
100	793
150	793
200	785
250	761
300	733
325	719
350	705
375 [Note (1)]	689

NOTE:
(1) The value of 375°C is for interpolation, the maximum design temperature is 371°C.

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Approval Date: June 24, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-775
Alternative Requirements for Bolting Affected by Borated Water Leakage
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-5250(a)(2) may be used if leakage is detected at bolted connections, and the Owner elects to replace all of the bolting, rather than examine the removed bolting?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of IWA-5250(a)(2), the requirements of (a) and (b) shall be met.

(a) Corrective action shall be taken to stop the leak. The cause of the leakage shall be addressed in accordance with the Owner's corrective action program.

(b) All pressure retaining bolting at the leaking connection shall be replaced in accordance with IWA-4000 (IWA-7000 in the 1989 Edition with the 1990 Addenda and earlier editions and addenda). VT-3 visual examination of the removed bolting is not required.

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Approval Date: April 9, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-776
Alternative to IWA-5244 Requirements for Buried Piping Section XI, Division 1

Inquiry: What alternative to the requirement of IWA-5244 may be used for examination of buried components?

Reply: It is the opinion of the Committee that the following may be used as an alternative to the requirements of IWA-5244 for examination of buried components.

(a) For buried components surrounded by an annulus, the VT-2 visual examination shall consist of an examination for evidence of leakage at each end of the annulus and at low point drains.

(b) For buried components without an annulus, the following examination requirements shall be met:

(1) A VT-2 visual examination shall be performed to identify evidence of leakage on ground surfaces in the vicinity of the buried components and in areas where leakage might be channeled or accumulated. The examination shall be performed after the component has been pressurized to system leakage test pressure for at least 24 hr. Portions of buried components where a VT-2 examination is impractical (e.g., component is buried beneath impermeable material or encased in concrete) are exempt from VT-2 examination.

(2) A test that determines the rate of pressure loss, a test that determines the change in flow between the ends of the buried components, or a test that confirms that flow during operation is not impaired shall be performed. Personnel performing these tests need not be qualified for VT-2 visual examination.

(3) The Owner shall specify criteria for the examinations and tests of (1) and (2).

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Approval Date: October 10, 2008

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-777
Calibration of C_v Impact Test Machines
Section III, Division 1; Section III, Division 2; Section III, Division 3

Inquiry: Under what conditions may sources of standard specimens be used other than currently specified National Institute of Standards and Technology in NB/NC/ND/NE/NF/NG-2360(b) in Division 1, CC-2528(b) in Division 2, and WB/WC-2360(b) in Division 3?

Reply: It is the opinion of the Committee that, as an alternative to the requirements of the paragraphs listed in the Inquiry, which stipulate that only standard specimens obtained from the National Institute of Standards and Technology shall be used for calibration of C_v impact test machines, standard specimens may be obtained from other suppliers, provided the following additional requirements are met:

(a) For Divisions 1 and 2, the supplier of subcontracted calibration services shall be accredited in accordance with the requirements of NCA-3126 and NCA-3855.3(c).

(b) For Division 3, the supplier of subcontracted calibration services shall be accredited in accordance with the requirements of WA-3123 and NCA-3855.3(c).

(c) This Case number shall be listed in the documentation records for material impact tested on machines calibrated using standard specimens obtained in accordance with (a) and (b).

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Approval Date: December 25, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-778
Alternative Requirements for Preparation and Submittal of Plans, Schedules, and Preservice and Inservice Inspection Summary Reports
Section XI, Division 1

Inquiry: What alternative to the requirements of IWA-1400(c) and IWA-6240 may be used for preparation and submittal of plans, schedules, and preservice and inservice inspection summary reports?

Reply: It is the opinion of the Committee that the following may be used as an alternative to the requirements of IWA-1400(c) and IWA-6240 for preparation and submittal of inservice inspection plans, schedules, and preservice and inservice inspection summary reports.

(a) The Owner shall be responsible for preparation of plans, schedules, and preservice and inservice inspection summary reports.

(b) The preservice inspection summary report shall be completed prior to the date of placement of the unit into commercial service.

(c) The inservice inspection summary report shall be completed within 90 calendar days of the completion of each refueling outage.

(d) Plans, schedules, and preservice and inservice inspection summary reports shall be submitted to the enforcement and regulatory authorities having jurisdiction at the plant site, if required by these authorities.

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Approval Date: January 26, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-779
Alternative Rules for Simplified Elastic-Plastic Analysis Class 1
Section III, Division 1

Inquiry: What alternative rules may be used to satisfy the requirements of NB-3228.5, NE-3228.3, NG-3228.3, or NB-3653.6, Simplified Elastic-Plastic Analysis?

Reply: It is the opinion of the Committee that when the range of primary plus secondary stress intensity exceeds $3S_m$, the following alternative rules may be used to meet the requirements of NB-3228.5, NE-3228.3, NG-3228.3, or NB-3653.6.

(a) The $3S_m$ limit on the range of primary plus secondary stress intensity (NB-3222.2, NE-3221.4, or NG-3222.2) may be exceeded provided that the following rules are met:

(1) The component meets the requirements of subparagraphs (a), (c), (d), (e), and (f) of NB-3228.5, NE-3228.3, or NG-3228.3.

(2) The value of S_a used for entering the design fatigue curve is one-half of the stress intensity range calculated by the combination of the terms in (3), (4), and (5) below.

(3) The total stress intensity range, excluding both thermal bending stresses caused by linear through-wall thermal gradients and local thermal stresses, shall be multiplied by the factor K_e given in NB-3228.5(b), NE-3228.3(b), or NG-3228.3(b).

(4) The local thermal stress range [NB-3213.13(b), NE-3213.13(b), NG-3213.12(b)] is multiplied by a factor K_v for Poisson's ratio effects:

$$K_v = 1.4, \text{ for } S_p > 3S_m \text{ and } S_{p\text{-}tb\text{-}lt} \geq 3S_m$$
$$= 1.0 + 0.4\ (S_p - 3S_m)\ /\ (S_{tb+lt}), \text{ for } S_p > 3S_m \text{ and } S_{p\text{-}tb\text{-}lt} < 3S_m$$
$$= 1.0, \text{ for } S_p \leq 3S_m$$

and $K_v \leq K_e$

S_p = total stress intensity range
S_{tb+lt} = thermal bending plus local thermal stress intensity range
$S_{p\text{-}tb\text{-}lt}$ = total stress intensity range excluding thermal bending and local thermal stresses

(5) The thermal bending stress range caused by linear through-wall thermal gradients is multiplied by a factor K_v as defined in (4) for Poisson's ratio effects, and a factor K_n as defined below for plastic strain redistribution at local discontinuities (such as notches):

$$K_n = 1.0 + \left[\left(\frac{S_{p-lt}}{S_n}\right)^{\left[\frac{1-n}{1+n}\right]} - 1\right]\left[\frac{(S_{p-lt}) - 3S_m}{S_{p-lt}}\right], \text{ for } (S_{p-lt}) > 3S_m$$

$$= 1.0 \text{ for } (S_{p-lt}) \leq 3S_m$$

and $K_nK_v \leq K_e$

$S_{p\text{-}lt}$ = total stress intensity range excluding local thermal stresses
S_n = primary plus secondary stress intensity range. For piping, the linear radial thermal gradient stress intensity, classified as a peak stress, is added to S_n in this procedure to determine K_n.
n = strain hardening exponent (Table NB-3228.5(b)-1, Table NE-3228.3(b)-1, or Table NG-3228.3(b)-1)

(6) As an alternative to (2) through (5) above, an overall elastic-plastic strain concentration factor K'_e can be determined directly from an elastic-plastic analysis of the component and the load case under consideration. K'_e is defined as the ratio of the numerically maximum principal strain range from the plastic analysis to that from the elastic analysis. The resulting K'_e can be applied to other load cases with an elastically predicted stress range less than or equal to the elastic stress range of the load case used to derive K'_e. The value of S_a used for entering the design fatigue curve is multiplied by K'_e.

(b) When performing the simplified elastic-plastic analysis for pairs of load sets that do not satisfy eq. (10) of NB-3653.1, the following alternative rules may be used to meet the requirements of NB-3653.6:

(1) The requirements of NB-3653.6 (a) and (b) shall be met.

(2) The requirements of NB-3653.6 (c) shall be met, except that eq. (14) shall be replaced by eq. (14a), as defined below.

$$S_{alt} = 0.5\left[K_e\left(K_1 C_1 \frac{P_o D_o}{2t} + K_2 C_2 \frac{D_o}{2I} M_i + K_3 C_3 E_{ab}\left|\alpha_a T_a - \alpha_b T_b\right|\right) + K_v K_n\left(\frac{1}{2(1-v)} K_3 E\alpha\left|\Delta T_1\right|\right) + K_v\left(\frac{1}{1-v} E\alpha\left|\Delta T_2\right|\right)\right] \quad (14a)$$

where

K_v = the lesser of 1.4 or K_e

$$K_n = 1.0 + \left[\left(\frac{S_p - \frac{1}{1-v}E\alpha\left|\Delta T_2\right|}{S_n + \frac{1}{2(1-v)}E\alpha\left|\Delta T_1\right|}\right)^{\left[\frac{1-n}{1+n}\right]} - 1\right] \times \left[\frac{\left(S_p - \frac{1}{1-v}E\alpha\left|\Delta T_2\right|\right) - 3S_m}{S_p - \frac{1}{1-v}E\alpha\left|\Delta T_2\right|}\right]$$

and $K_n K_v \leq K_e$

(3) All other terms are defined in NB-3650.

(c) The use of this Case number shall be identified in the Data Report.

Approval Date: April 9, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-780
Alternative Requirements for Upgrade, Substitution, or Reconfiguration of Examination Equipment When Using Appendix VIII Qualified Ultrasonic Examination Systems
Section XI, Division 1

Inquiry: What alternatives to the requirements of Appendix VIII, VIII-3000, VIII-40000, and Supplement 1 may be used to verify the performance of previously qualified examination systems if essential ultrasonic system components are upgraded, substituted, or otherwise reconfigured?

Reply: It is the opinion of the Committee that the following alternative to the requirements of Appendix VIII, VIII-3000, VIII-4000, and Supplement 1 may be used if essential ultrasonic system components are upgraded, substituted, or otherwise reconfigured.

1 SCOPE

(a) Ultrasonic systems consist of equipment, procedures, and personnel. As an alternative to full system requalification, the equivalency evaluation defined by 2, 3, and 4 may be used to justify the acceptability of ultrasonic system component replacement subject to the stated limitations and conditions.

(b) An ultrasonic system component is defined as a piece of equipment or hardware (and the controlling software if applicable for digital components) that constitutes part of the examination equipment. Components include probes or transducers, interconnecting cables, and ultrasonic instrumentation (either a commercially packaged instrument or the individual parts of a custom instrument or data acquisition system, as applicable) that can be easily separated or isolated by cable connections or plug-in connections.

(c) Use of this equivalency evaluation is limited to replacement ultrasonic system components that are designed and intended to perform the same function as the component that is to be replaced. If the component to be substituted is a digital component, and new or different software is needed to control or operate the replacement component, equivalency of the new component shall be evaluated with the new software installed. If the equivalency evaluation is successful, the new software shall be controlled in the same manner as for the original component.

(d) This equivalency evaluation shall not be used to modify any processes in the procedure, such as the system calibration or verification processes, scan or data collection processes, or the flaw discrimination or sizing processes. If the function of the replacement ultrasonic system component is different from that of the original component (e.g., longitudinal-wave transducer versus shear-wave transducer) such that it requires changes to the processes in the procedure, VIII-3140 applies.

2 TECHNICAL JUSTIFICATION

(a) Prior to initiating the practical demonstration, the implementing examination organization shall prepare a Technical Justification documenting the following:

(1) the need or reason for the ultrasonic system component substitution

(2) a description of how the ultrasonic system component is used within the qualified procedures and the effect, if any, that the substitution is expected to have

(3) an assessment of the significance of the procedure changes that are needed (if any) to use the substituted ultrasonic system component, including a list of any required equipment-related essential variable changes (such as instrument settings, cable length, number of connectors)

(4) an evaluation of the design differences between the ultrasonic system components

(5) a technical assessment of the expected acceptability of the substitution, including laboratory or modeling studies covering the entire ranges of all essential variables

(6) recommendations for an appropriate set of reflectors for the practical demonstration

(b) The Technical Justification shall be reviewed and approved by a Performance Demonstration Administrator (PDA). The PDA shall be an independent company

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.

and shall be the same PDA that was involved in the original blind performance demonstration, or a PDA that has access to the original qualification documentation.

3 PRACTICAL DEMONSTRATION

In addition to development of the technical justification described above, a Practical Demonstration shall be performed to provide evidence that the substituted ultrasonic system component will not have an adverse affect on the performance of the procedure. The Practical Demonstration need not be monitored by the PDA, however the PDA shall evaluate and approve results.

3.1 A set of at least three reflectors or signals shall be selected that will demonstrate the performance of the examination system over the normal sound path distance (near, far, and mid-range) within the scope of the procedure. These reflectors may be flaws, artificial flaws (e.g., machined holes or notches), or artificially-generated electronic signals. If physical test specimens are used, they may be blind or open specimens.

3.2 The examination system shall be configured as specified in the originally-qualified procedure and shall be used to record a signal presentation from each of the selected reflectors or signals. If flaws or artificial flaws are used, signal presentations shall be collected with each model of transducer qualified for use with the procedure. If electronic signals are used, the signals shall be generated using the lowest and highest transducer frequencies qualified for use with the procedure. The results shall be documented in a manner that will allow independent evaluation, such as a rectified waveform (A-scan) or side-view image (B-scan) and shall be of the same form as the signals that are used for flaw discrimination or sizing in the original procedure.

3.3 The examination system shall be modified to include the upgraded, substituted, or reconfigured ultrasonic system component and shall be used to record signal presentations from the same reflectors or electronic signals. The results shall be documented as specified in 3.2.

3.4 The demonstration results obtained using the original ultrasonic system component and the substituted component shall be evaluated for equivalency by the PDA using the discrimination criteria [i.e., VIII-2100(d)(9)] of the original procedure. If the data presentations recorded using the substituted component are equivalent to or better than those recorded using the original component, the substitution of the replacement component is acceptable.

4 DOCUMENTATION

The acceptance document for the original procedure shall be amended to reflect the acceptability of the equipment substitution in accordance with this Case and shall be issued to the user by the PDA. A copy of the documentation (Technical Justification, Practical Demonstration results, and the amended acceptance document for the procedure) shall be retained by the examination organization and the PDA as long as the procedure remains in use.

Approval Date: January 30, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-782
Use of Code Editions, Addenda, and Cases
Section III, Division 1

Inquiry: What Code Editions, Addenda, and Cases may be used as an alternative to NCA-1140(a)(2)(a) and NCA-1140(a)(2)(b)?

Reply: It is the opinion of the Committee that as an alternative to NCA-1140(a)(2)(a) and NCA-1140(a)(2)(b), the following requirements may be used:

(a) The Edition and Addenda endorsed for a design certified or licensed by the regulatory authority.

(b) This Case number shall be recorded on the documentation for the item.

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Approval Date: April 9, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-784
Experience Credit for Ultrasonic Examiner Certification
Section XI, Division 1

Inquiry: What alternatives to the experience requirements of VII-4110 and the personnel requirements of VIII-2200 may be used to acquire experience hours toward initial certification for Level I and Level II ultrasonic examiners?

Reply: It is the opinion of the Committee that as an alternative to the number of experience hours in VII-4110 (i.e., work experience), laboratory practice hours beyond those required for training in accordance with VII-4220 may be credited as Level I experience, provided those practice hours are dedicated to the Level I or II skill areas as described in CP-189. The 800 hr of Level II experience time in Table VII-4110-1, may be reduced to 400 hr, which shall include a minimum of 80 hr of field experience and a minimum of 320 hr of laboratory practice, provided that the practice is dedicated to scanning specimens containing flaws in materials representative of those in actual power plant components and the candidate passes an Appendix VIII, Supplement 2 performance demonstration for detection and length sizing. Also, as an alternative to the requirement of VIII-2200, prior Level II qualification in accordance with Appendix VII is not a prerequisite for the Appendix VIII performance demonstration.

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Approval Date: October 12, 2009

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-785
Use of SA-479/SA-479M, UNS S41500 for Class 1, Welded Construction
Section III, Division 1

Inquiry: May SA-479/SA-479M UNS S41500 wrought bar material, meeting the chemical analysis requirements of Table 1, the S_m design stress intensity values of Table 2, the S_u tensile strength values of Table 3, and the S_y yield strength values of Table 4, in accordance with SA-182/SA-182M, Grade F6NM (UNS S41500), be used for the construction of Section III, Division 1, Class 1 pressure boundary components?

Reply: It is the opinion of the Committee that the material described in the *Inquiry* may be used for Section III, Division 1, Class 1 construction, provided the following requirements are met:

(a) The chemical composition complies with that specified in Table 2 of SA-182/SA-182M, for Grade F6NM and Table 1 of SA-479/SA-479M for UNS S41500 (Table 1 of this Case).

(b) The design stress intensity values S_m used are the same as those provided in Table 2 of Section II, Part D for SA-182/SA-182M Grade F6NM (Table 2 of this Case).

(c) The tensile strength values S_u used are the same as those provided in Table U of Section II, Part D for SA-182/SA-182M Grade F6NM (Table 3 of this Case).

(d) The yield strength values S_y used are the same as those provided in Table Y-1 of Section II, Part D for SA-182/SA-182M Grade F6NM (Table 4 of this Case).

Table 1
Chemical Requirements

Element	Composition, %
Carbon	0.05 max.
Manganese	0.50–1.00
Phosphorus	0.030 max.
Sulfur	0.030 max.
Silicon	0.60 max.
Nickel	3.5–5.5
Chromium	11.5–14.0
Molybdenum	0.50–1.00

Table 2
Section III, Class 1 Design Stress Intensity Values S_m, for Ferrous Materials (Customary)

Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Designation/UNS No.	Class/ Condition/ Temper	Size/Thickness, in.	P-No.	Group No.
13Cr-4Ni	Bar	SA-479	...	S41500	...	...	6	4

Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Max. Temp. Limit (STP = Supports Only)	External Pressure Chart No.	Notes
115	90	700	CS-3	...

Design Stress Intensity, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding

−20 to 100	150	200	250	300	400	500	600	650	700	750	800	850	900
38.3	...	38.3	...	38.3	37.9	36.5	35.0	34.3	33.4	...	...	...	...

Table 2
Section III, Class 1 Design Stress Intensity Values S_m, for Ferrous Materials (Metric)

Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Designation/UNS No.	Class/ Condition/ Temper	Size/Thickness, mm	P-No.	Group No.
13Cr-4Ni	Bar	SA-479	...	S41500	...	...	6	4

Min. Tensile Strength, MPa	Min. Yield Strength, MPa	Max. Temp. Limit (STP = Supports Only)	External Pressure Chart No.	Notes
795	620	371	CS-3	...

Design Stress Intensity, MPa (Multiply by 1000 to Obtain kPa), for Metal Temperature, °C, Not Exceeding

−30 to 40	65	100	125	150	200	250	300	325	350	375	400	425	450	475	500
264	264	264	264	264	262	254	244	240	235	229	...	...	...	...	...

Table 3
Tensile Strength Values S_u, for Ferrous Materials (Customary)

Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Designation/ UNS No.	Class/Condition/ Temper	Size/Thickness, in.	Min. Tensile Strength, ksi
13Cr-4Ni	Bar	SA-479	...	S41500	...	...	115

Tensile Strength, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding													
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000
115.0	115.0	115.0	113.7	109.5	105.1	102.8	100.3	97.6	94.7	91.4	...	...	...

Table 3
Tensile Strength Values S_u, for Ferrous Materials (Metric)

Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Designation/ UNS No.	Class/Condition/ Temper	Size/Thickness, mm	Min. Tensile Strength, MPa
13Cr-4Ni	Bar	SA-479	...	S41500	...	...	795

Tensile Strength, MPa (Multiply by 1000 to Obtain kPa), for Metal Temperature, °C, Not Exceeding														
−30 to 40	100	150	200	250	300	325	350	375	400	425	450	475	500	525
793	793	793	785	761	733	719	705	689	672	654	634	613	...	...

Table 4
Yield Strength Values S_y, for Ferrous Materials (Customary)

Nominal Composition	Product Form	Spec. No.	Type/ Grade	Alloy Designation/UNS No.	Class/Condition/Temper
13Cr-4Ni	Bar	SA-479	...	S41500	...

Size/Thickness, in.	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes
...	115	90	...

Yield Strength, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								
−20 to 100	150	200	250	300	350	400	450	500
90.0	87.7	86.5	85.5	84.6	...	82.8	...	80.8

Yield Strength, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding									
550	600	650	700	750	800	850	900	950	1000
...	78.5	77.2	75.7	...	...	...	...	...	...

Table 4
Yield Strength Values S_y, For Ferrous Materials (Metric)

Nominal Composition	Product Form	Spec. No.	Type/Grade	AlloyDesignation/ UNS No.	Class/Condition/ Temper
13Cr-4Ni	Bar	SA-479	...	S41500	...

Size/Thickness, mm	Min. Tensile Strength, MPa	Min. Yield Strength, MPa	Notes
...	795	620	...

Yield Strength, MPa (Multiply by 1000 to Obtain kPa), for Metal Temperature, °C, Not Exceeding									
−30 to 40	65	100	125	150	175	200	225	250	275
621	605	595	589	583	578	572	566	560	553

Yield Strength, MPa (Multiply by 1000 to Obtain kPa), for Metal Temperature, °C, Not Exceeding									
300	325	350	375	400	425	450	475	500	525
546	538	530	520	...	...	...	...	...	...

(15) **Approval Date: December 31, 2014**

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-786-1
Alternative Requirements for Sleeve Reinforcement of Class 2 and 3 Moderate-Energy Carbon Steel Piping Section XI, Division 1

Inquiry: As an alternative to replacement or internal weld repair in accordance with IWA-4400,[1] what requirements may be applied for wall reinforcement of Class 2 and 3 moderate-energy carbon steel piping systems that have experienced internal wall thinning from localized erosion, corrosion, and cavitation or pitting?

Reply: It is the opinion of the Committee that, in lieu of IWA-4400, Class 2 and 3 moderate-energy [i.e., less than or equal to 200°F (93°C) and less than or equal to 275 psig (1.9 MPa) maximum operating conditions] carbon steel piping experiencing internal wall thinning from localized erosion, corrosion, and cavitation or pitting may have the wall thickness reinforced by applying full-circumferential reinforcing sleeves to the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving any form of cracking.

1 GENERAL REQUIREMENTS

(a) Installation of the reinforcing sleeve shall be in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.

(b) The design, materials, and installation shall meet the requirements of the Construction Code and IWA-4000, except as stated in this Case.

(c) If the minimum required thickness of reinforcing sleeve necessary to satisfy the requirements of 3 is greater than 1.4 times the nominal thickness for the size and schedule of the piping, this Case may not be used.

(d) Additional reinforcement or repair is not permitted on top of an existing reinforcing sleeve.

(e) This Case may be applied only to piping not required to be ultrasonically examined for inservice inspection.

(f) This Case may not be applied to pumps, valves, expansion joints, vessels, heat exchangers, tubing, flanges, flanged joints, socket welded or threaded joints, or branch connection welds.

2 INITIAL EVALUATION

(a) The material beneath the surface to which the reinforcing sleeve is to be applied shall be ultrasonically measured to establish the existing wall thickness and the extent and configuration of degradation to be reinforced. The adjacent area shall be examined to verify that the repair will encompass the entire unacceptable area, and that the adjacent base material, including at least $0.75\sqrt{Rt_{\text{nom}}}$ base metal beyond the toe of the attachment welds, is of sufficient thickness to accommodate the attachment welds.

(b) The cause and rate of degradation shall be determined. The extent and rate of degradation in the piping shall be evaluated to ensure that there will be no other unacceptable locations within the surrounding area that could affect the integrity of the reinforced areas for the life of the repair. Surrounding areas showing signs of degradation shall be identified and included in the Owner's plan for thickness-monitoring inspections of full-structural reinforcing sleeves [see 8(c)]. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, based on the type and rate of degradation present.

(c) The effects of the reinforcing sleeve and attachment welds on the piping and any remaining degradation shall be evaluated in accordance with IWA-4311.

3 DESIGN

3.1 Types of Reinforcing Sleeves.

(a) Type A reinforcing sleeves as shown in Figure 1 may be used for structural reinforcement of thinned areas which are not expected to penetrate the wall and cause leakage. The piping longitudinal stresses shall meet the

[1] The references to Section XI in this Case refer to the 2013 Edition. For use with other Editions and Addenda, refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

requirements of the Construction Code. Type A reinforcing sleeves shall have a maximum service life of the time until the next refueling outage.[2]

(b) Type B reinforcing sleeves as shown in Figure 2 may be used for pressure plus full- or partial-structural reinforcement of thinned areas that penetrate, or are expected to penetrate the wall and cause leakage.

(1) Full-structural reinforcement is designed to accommodate pressure plus axial and circumferential design loadings at the location for the design life of the repair without taking credit for any portion of the degraded segment. Full-structural reinforcement sleeves shall be removed and the piping repaired or replaced in accordance with IWA-4000 no later than the end of the design life of the repair.

(2) Partial-structural reinforcement is designed to accommodate design loadings at the segment being reinforced, taking partial credit for the degraded segment after factoring in predicted degradation over the life of the repair. Partial credit is considered taken if the design relies on any portion of the segment of piping beneath the sleeve, other than the base metal beneath the attachment welds, to provide structural or pressure integrity. Partial-structural reinforcing sleeves shall have a maximum service life of the time until the next refueling outage.

3.2 General Design Requirements — Type A and B Sleeves.

(a) The design of reinforcing sleeves shall be in accordance with the requirements of NC-3100 and NC-3600 or ND-3100 and ND-3600, and Section III Appendices, Mandatory Appendix II.

(b) Material for reinforcing sleeves shall be ferritic, with welds of compatible weld filler metal.

(c) The minimum width of reinforcing sleeves shall be 4 in. (100 mm).

(d) The thickness of the reinforcing sleeve shall be sufficient to maintain required thickness for the predicted life of the repair.

(e) The following factors shall be considered, as applicable, in the design and application of the sleeves:

(1) all loading the sleeve is expected to encounter

(2) shrinkage effects, if any, on the piping

(3) stress concentrations caused by installation of the reinforcing sleeve or resulting from existing and predicted piping internal surface configuration

(4) effects of welding on any interior coating

(5) differential thermal expansion between reinforcing sleeve, the attachment welds, and the pipe

(6) potential for loose debris in the system from continued degradation of the reinforced area of the piping

(f) Longitudinal seam welds shall be full penetration. Backing may be applied to prevent burn-through of the pipe. If full contact between sleeve and pipe is required, any backing shall be recessed into the underside of the sleeve, or hardenable filler shall be used to fill the void, as indicated in Figure 3.

(g) Longitudinal seam joint efficiency of 0.8 shall be used, except that 100% joint efficiency is permitted if the longitudinal seam is volumetrically examined.

(h) Fatigue evaluation shall be performed if required for the original pipe, or if thermal gradients exceed 100°F (56°C), or if lesser thermal gradients will occur during more than 200 heatup and cool-down cycles over the life of the repair.

(i) If flexibility analysis was required by the original Construction Code, the effect of the reinforcement shall be reconciled with the original analysis.

(j) Final configuration of the attachment welds shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of attachment or adjacent welds.

(k) The predicted maximum degradation of the carrier base metal and reinforcing sleeve over the design life of the reinforcement shall be based on in-situ inspection and established data for similar base metals.

The initial degradation rate selected for design of the sleeve shall be at least 2 times the maximum rate observed at that location; or if unknown, 4 times the estimated maximum degradation rate for that system or a similar system at the same plant site for the same degradation mechanism. If the degradation rate for that location and the cause of the degradation are not determined, 4 times the maximum degradation rate observed for all degradation mechanisms for that system or a similar system at the same plant site shall be applied.

(l) Weld seams encompassed by the sleeve shall be ground flush. Alternatively, bulges may be rolled or formed in the sleeves to accommodate such obstructions. Refer to Figure 4.

(m) Sleeves shall closely match the outside surface of the carrier piping. If required by design, gaps shall be filled with hardenable filler.

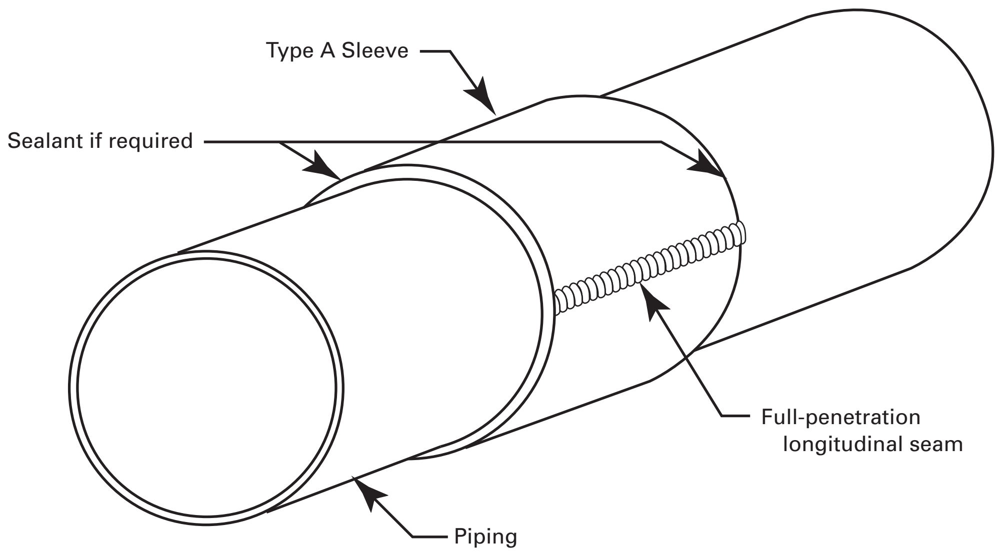
(n) Hardenable filler shall be suitable for the system operating conditions, and shall be compatible with the sleeve, weld metal, piping, and any exterior coating that is not removed from the piping.

(o) Branch connections may be installed on reinforcing sleeves only for the purpose of filling or venting during installation, or for leak testing of the sleeve, and shall be limited to NPS 1 (DN 25) or smaller.

3.3 Specific Requirements — Type A Sleeves. Type A sleeves in moist environments shall have edges sealed, but not seal welded, to prevent moisture intrusion and corrosion.

[2] If a Type A or partial-structural Type B reinforcing sleeve is installed during a refueling outage, the maximum permitted service life is one fuel cycle, until the next refueling outage.

Figure 1
Type A Reinforcing Sleeve



3.4 Specific Requirements — Type B Sleeves.

(a) If permitted by the design, suitable gasket material may be applied inside the sleeve to prevent moisture during welding (see Figure 2).

(b) Hardenable filler and gasket material shall be compatible with the system fluid.

(c) Partial-structural sleeves shall be designed to withstand the design pressure.

(d) Partial-structural sleeves may be attached by fillet welds in accordance with the requirements of 3.2(a).

(e) Full-structural sleeves shall be attached by partial-penetration welds (see Figure 5) that, unless otherwise established by analysis in accordance with the requirements of 3.2(a), extend for a distance of at least s in each axial direction beyond the area predicted, over the design life of the repair, to fall below the required thickness,[3] where

$$s \geq 0.75\sqrt{Rt_{\text{nom}}}$$

and

$$s \geq 1 \text{ in. } (25\,\text{mm})$$

where

R = $D/2$ = outer radius of the piping
t_{nom} = nominal wall thickness of the piping

The thickness of the partial-penetration attachment welds shall equal the thickness of the sleeve, and the outer edges of the welds shall be tapered to the piping surface at a maximum angle ("α" in Figure 5) of 45 deg.

(f) If flexibility analysis was required by the original Construction Code, and unless a lower stress intensification factor (SIF or i) is established, an SIF (i) of 2.1 shall be applied for attachment fillet welds and tapered edges of partial-penetration attachment welds on straight pipe and at adjacent welds. Also, a stress multiplier of 1.7 shall be applied to the SIF (i) for sleeves enclosing standard elbows, and an SIF (i) of 2.1 shall be applied for sleeve attachments on tees and branch connections provided the toe of the fillet or tapered edge is not less than $2.5\sqrt{Rt_{\text{nom}}}$ from any branch reinforcement. (See Figure 5.)

4 WATER-BACKED APPLICATIONS

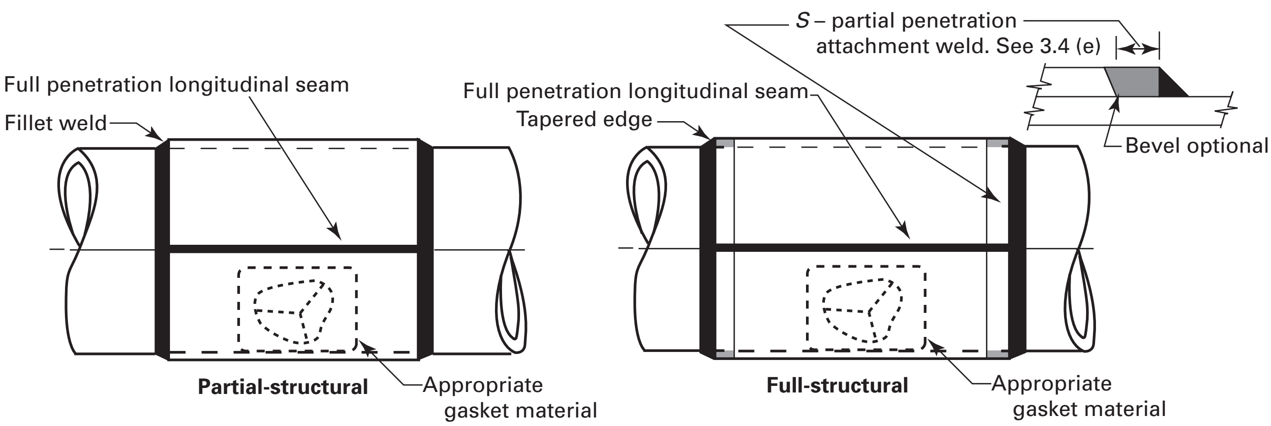
(a) Manual welding of reinforcing sleeves on water-backed piping shall use the SMAW process and low-hydrogen electrodes.[4]

(b) When welding a reinforcing sleeve to a leaking area, precautions, such as installation of a gasket or sealant beneath the sleeve, shall be taken to prevent welding on wet surfaces.

(c) For piping materials other than P-No. 1 Group 1, the surface examination of welds required in 6 shall be performed no sooner than 48 hr after completion of welding.

[3] Design thickness as prescribed by the Construction Code.
[4] Testing has shown that piping with areas of wall thickness less than the diameter of the electrode may burn through during welding on water-backed piping.

Figure 2
Type B Reinforcing Sleeves



5 INSTALLATION

(a) The circumference of the base material in the area to be welded or to provide backing for welding shall be cleaned to bare metal. The entire area shall be cleaned, if required for application of hardenable filler.

(b) The sleeve shall be fitted tightly around the pipe. Preheating the sleeve to achieve a shrink fit, or use of mechanical or hydraulic clamping, draw bolts, or other devices may be used to ensure fit.

(c) If hardenable filler is used, it may be applied prior to sleeve installation or pumped into the annulus between the sleeve and base metal after the sleeve is in place. If pumped into the annulus, provisions shall be made to prevent over-pressurization and intrusion of the hardenable filler into the system.

(d) Means shall be provided to isolate or divert leakage to eliminate moisture during welding. If welding is performed on a wet surface, the maximum permitted life of the reinforcing sleeve shall be the time until the next refueling outage.

(e) Weld metal shall be deposited using a groove-welding procedure qualified in accordance with Section IX and the Construction Code.

(f) Fillet weld leg length shall be increased by the amount of fit-up gap. Care shall be exercised to avoid sharp discontinuities that could cause stress risers at the toes of fillet welds or tapered edges of partial-penetration attachment welds.

(g) Provision for venting during the final closure weld or pressure testing shall be made if necessary.

(h) The surfaces of all welds shall be prepared, if necessary, by machining or grinding, to permit performance of surface and volumetric examinations required by 6. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) All welds shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or Section III (NC-5300 or ND-5300).

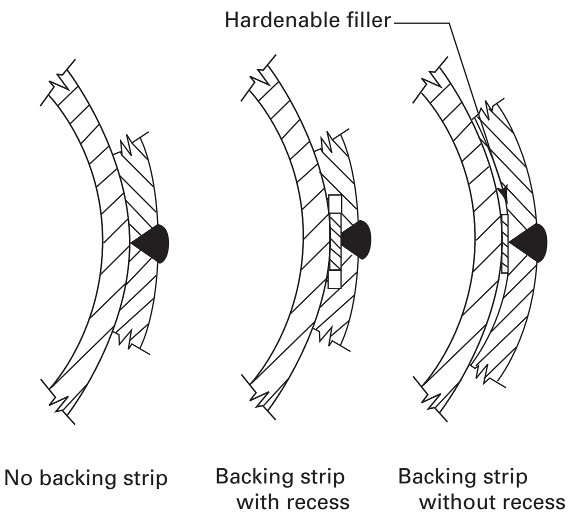
(b) Except for the tapered edges, partial-penetration attachment welds, including the piping base metal upon which they are applied, shall be examined ultrasonically to verify and record baseline wall thickness.

(c) Longitudinal seam welds in the sleeve shall be ultrasonically or radiographically examined in accordance with the Construction Code or Section III if longitudinal seam welds in the piping require volumetric examination. If the design does not permit a joint efficiency of 0.8, Class 3 longitudinal seam welds may be examined in accordance with (d), in lieu of volumetric examination.

(d) Partial-penetration attachment welds (Figure 2) shall be volumetrically examined when full-penetration girth welds in the carrier piping are required by the Construction Code to be volumetrically examined. Where configuration does not permit meaningful volumetric examination, and for Class 3 longitudinal seam welds requiring volumetric examination [see (c)], the first layer, each $^{1}/_{2}$ in. thickness of weld deposit, and final surface shall be examined in accordance with (a), in lieu of volumetric examination.

(e) When volumetric examination is required, the full volume of the attachment weld, excluding the tapered edges but including the volume of base metal required for the service life of the reinforcing sleeve, shall be examined in accordance with the Construction Code or Section III using either the ultrasonic or radiographic method, and shall, to the depth at the surface of the piping, satisfy the acceptance criteria for weldments of the Construction Code or Section III (NC-5300 or ND-5300). Any volume of the piping beneath the reinforcing sleeve that is credited

Figure 3
Type A and Type B Sleeve Longitudinal Seams



in the design shall satisfy the volumetric acceptance criteria of NC-5320 and NC-5330, or ND-5320 and ND-5330, as applicable.

7 PRESSURE TESTING

In lieu of IWA-4540, a system leakage test of the repair/replacement activity shall be performed in accordance with IWA-5000 prior to, or as part of, returning to service. Type B reinforcing sleeves attached to piping that has not been breached shall be equipped with pressure taps for performance of pressure testing.

8 INSERVICE EXAMINATION

(a) Preservice and inservice examination of Type B full-structural reinforcing sleeve welds shall be performed in accordance with IWC-2000 or IWD-2000, if required. [See 1(e).]

(b) The Owner shall perform a base-line inspection of full-structural reinforcing sleeves, their attachment welds, adjacent base metal for a length of at least $0.75\sqrt{Rt_{\text{nom}}}$, and the surrounding areas showing signs of degradation [see 2(b)], using ultrasonic or direct thickness measurement.

(c) The Owner shall prepare a plan to repeat the thickness monitoring inspections at least every refueling outage, to verify that minimum design thicknesses required by the Construction Code or Section III are not violated in the sleeve or at the attachment welds, including the underlying base metal.

(1) More frequent thickness monitoring inspections shall be scheduled when warranted by the degradation rates observed during these inspections, such that the required design thicknesses will be maintained at least until the subsequently scheduled thickness monitoring inspection.

(2) Provisions shall be made for access to full-structural reinforcing sleeves on buried piping in order to accomplish these inspections.

(d) Type A and partial-structural Type B reinforcing sleeves shall be visually monitored for evidence of leakage at least monthly. If the areas containing these sleeves are not accessible for direct observation, monitoring shall be accomplished by visual assessment of surrounding areas or ground surface areas above pressure pads on buried piping, or by monitoring of leakage collection systems, if available.

(e) For Type A and partial-structural Type B reinforcing sleeves, regardless of when during a cycle or inspection interval they are installed, the repair shall be considered to have a maximum service life of the time until the end of the next refueling outage.

(f) If the cause of the degradation is not determined, the maximum permitted service life of any reinforcing sleeve shall be the time until the end of the next refueling outage.

Figure 4
Bulge to Accommodate Girth Weld

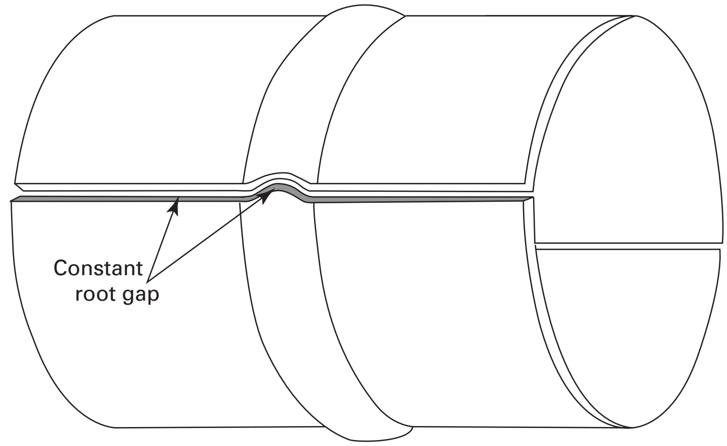
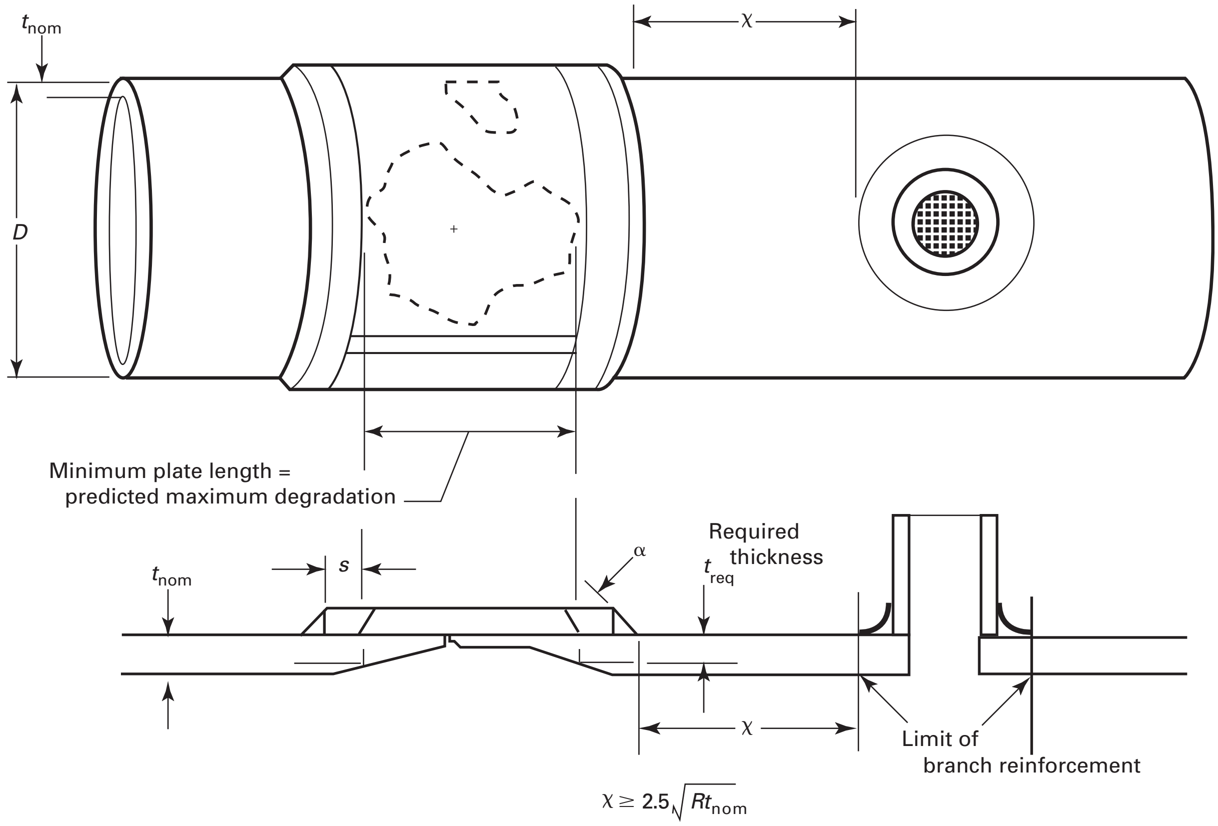


Figure 5
Design Details — Type B Full-Structural Sleeves



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Approval Date: April 9, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-788
Third Party NDE Certification Organizations
Section XI, Division 1

Inquiry: What alternatives to the requirements of IWA-2300 may be used for qualification and certification of NDE personnel?

Reply: It is the opinion of the Committee that Third Party NDE Certification Organizations may be used in lieu of employer-based certification of Level II and III NDE personnel as follows:

1 GENERAL REQUIREMENTS FOR THIRD PARTY NDE CERTIFICATION

(a) The Third Party NDE Certification Organization is an independent body, such as a technical society, research organization, or government agency, separate from the organizations that use the NDE personnel that it certifies and not owned by any organization that uses such certified NDE personnel. The Third Party NDE Certification Organization shall have demonstrated experience in administration of programs for certification of personnel based on factors including training and examination, for NDE, inspection, quality, or other power industry service.

(b) The Third Party NDE Certification Organization's Quality Assurance Program is documented and complies with the applicable quality assurance program criteria of 10CFR50 Appendix B or the 1994 Edition of ASME NQA-1, Part 1, Basic Requirements and Supplementary Requirements for Nuclear Facilities, except that in lieu of Supplement 2S-2, the qualification of nondestructive examination personnel shall be as required by this Case.

(c) The Organization is qualified in accordance with the provisions of Section 2 of this Case.

(d) The Organization makes available to the Inspector the examination results for certified NDE personnel and other documents requested by the Inspector to assure compliance with the requirements of this Case.

(e) Certification in surface and volumetric methods shall be based on the experience, training, and examination requirements of CP-189 and additional initial training and experience requirements of Appendix VII for ultrasonic examination; however, for the Specific Examination, standards, specifications, and procedures typical of those used for inservice inspection of nuclear power plant components may be used in lieu of those from a specific employer. Level III examination requirements of IWA-2323 shall be applied.

(f) Certification for VT-1, VT-2, and VT-3 visual examination shall be based on the experience, training, and examination requirements of Appendix VI; however, for the Specific Examination, standards, specifications, and procedures typical of those used for inservice inspection of nuclear power plant components may be used in lieu of those from a specific employer.

(g) To maintain certification, the vision tests of IWA-2321 are required.

(h) It is the duty of the Inspector to verify that Third Party NDE Certification Organizations used to certify NDE personnel satisfy the applicable requirements described in (a) through (h).

2 QUALIFICATION OF THIRD PARTY NDE CERTIFICATION ORGANIZATIONS

(a) The qualification of a Third Party NDE Certification Organization requires evaluation of the Organization's Quality Assurance Program in accordance with the requirements of (1) through (9).

(1) The Quality Assurance Program of the Third Party NDE Certification Organization shall be surveyed, accepted, and audited by the party performing the evaluation on the basis of its compliance with 1(a) through 1(h). The party performing the evaluation may be the Owner, the Owner's designee, or other organizations, such as those supplying NDE services to the Owner.

(2) The Third Party NDE Certification Organization's Quality Assurance Manual shall be the guide for surveying and auditing the Third Party NDE Certification Organization's continued compliance with the accepted Quality Assurance Program.

(3) The Third Party NDE Certification Organization shall make available, for on-site review by the party performing the evaluation, any procedures, process sheets, or drawings necessary to understand the Program. The Third Party NDE Certification Organization shall keep a

controlled copy of the Manual on file and in a place and manner readily available to the party performing the audit.

(4) The Third Party NDE Certification Organization shall notify the parties who have accepted its Program of proposed revisions to the Quality Assurance Manual. The party accepting the Program shall evaluate and accept such revisions prior to implementation of the revisions.

(5) If the Third Party NDE Certification Organization's scope of activities includes approval and control of suppliers, such as operators of remote examination facilities, this activity shall be included in the Third Party NDE Certification Organization's Quality Assurance Manual and shall be reviewed by the party accepting the Program. During surveys or audits of Third Party NDE Certification Organizations, the party performing the evaluation shall review objective evidence that the Organization's control of suppliers is adequate to assure compliance with the applicable requirements of this Case.

(6) If the Third Party NDE Certification Organization's scope includes shipment of examination materials to others, such as remote examination facilities, control of this activity shall be included in the Quality Assurance Manual and shall be reviewed by the party accepting the Program. During surveys or audits of Third Party NDE Certification Organizations, the party performing the evaluation shall review objective evidence that the qualified Organization's control of shipments is adequate to assure that the examination materials are not compromised.

(7) Audits by parties performing evaluations of Third Party NDE Certification Organizations shall meet the following requirements:

(-a) The party performing the evaluations shall include the audit frequency in its Quality Assurance Manual.

(-b) The audit frequency shall be at least once triennially during the interval in which NDE personnel certified by the Third Party NDE Certification Organization are used.

(-c) Audits shall be performed in accordance with written procedures or checklists by personnel not having direct responsibility in the areas being audited.

(-d) Audit results shall be documented by auditing personnel for review by management having responsibility in the area being audited.

(-e) Procedures shall include provisions for documentation of corrective action taken in response to deficiencies. Follow-up action, including re-audit of deficient areas where indicated, shall be taken to verify implementation of such corrective actions.

(8) The party performing the evaluation shall supplement triennial audits with performance assessments documenting the effectiveness of the Third Party NDE Certification Organization's Quality Assurance Program. Performance assessments shall meet the following requirements.

(-a) Assessment schedules shall be commensurate with the schedule of utilization of NDE personnel certified by the Third Party NDE Certification Organization, but assessment need not occur more frequently than once annually.

(-b) Assessments shall include a documented review of a Third Party NDE Certification Organization's history of conditions adverse to quality, nonconformances, and corrective actions.

(9) The party performing the evaluation shall verify that the Third Party NDE Certification Organization has a mechanism to provide documents to the Inspector in accordance with 1(d).

(b) If a Third Party NDE Certification Organization has been qualified by an Owner, it is not necessary for another party to requalify that Organization for use of NDE personnel certified by that Organization if those NDE personnel will be providing services to an Owner who qualified the Third Party NDE Certification Organization. A vendor is not required to qualify a Third Party NDE Certification Organization when using personnel qualified by that Organization for services provided to an Owner who has previously qualified that Organization.

Approval Date: November 13, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-789-1
Alternative Requirements for Pad Reinforcement of Class 2 and 3 Moderate-Energy Carbon Steel Piping for Raw Water Service
Section XI, Division 1

Inquiry: As an alternative to replacement or internal weld repair in accordance with IWA-4400, what requirements may be applied for wall reinforcement of Class 2 and 3 moderate-energy carbon steel raw water[1] piping systems that have experienced internal wall thinning from localized erosion, corrosion, and cavitation or pitting?

Reply: It is the opinion of the Committee that, in lieu of meeting IWA-4400, areas of Class 2 and 3 moderate-energy [i.e., less than or equal to 200°F (93°C) and less than or equal to 275 psig (1.9 MPa) maximum operating conditions] carbon steel raw water piping experiencing internal wall thinning from localized erosion, corrosion, and cavitation or pitting may have the wall reinforced by applying reinforcing pads to the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving flow-accelerated corrosion (FAC), corrosion-assisted cracking, or any other form of cracking.

1 GENERAL REQUIREMENTS

(a) Application of the reinforcing pad shall be performed in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.

(b) The design, materials, and installation shall meet the requirements of the Construction Code and IWA-4000, except as stated in this Case.

(c) If the minimum required thickness of reinforcing pad necessary to satisfy the requirements of 3 is greater than the nominal thickness for the size and schedule of the piping, this Case shall not be used.

(d) Additional reinforcement or repair is not permitted on top of an existing reinforcing pad.

(e) Reinforcing pads, including those installed during a refueling outage, shall not remain in service beyond the end of the next refueling outage.

(f) This Case may only be applied to piping not required to be ultrasonically examined for inservice inspection.

2 INITIAL EVALUATION

(a) The material beneath the surface to which the reinforcing pad is to be applied and the adjacent area shall be ultrasonically measured to establish the existing wall thickness and the extent and configuration of degradation to be corrected by the reinforcing pad.

(b) The cause and rate of degradation shall be determined. If the cause is determined to be flow-accelerated corrosion (FAC), corrosion-assisted cracking, or any other form of cracking, this Case shall not apply. The extent and rate of degradation in the piping shall be evaluated to ensure that there are no other unacceptable locations within the surrounding area that could affect the integrity of the repaired piping. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, considering the type of degradation present.

(c) The effects of the repair on the piping and any remaining degradation shall be evaluated in accordance with IWA-4311.

3 DESIGN

3.1 TYPES OF REINFORCING PADS

(a) Reinforcing pads may be used for leak prevention only (pressure pad), or for leak prevention plus structural reinforcement of thinned areas including areas that do, or are expected to, penetrate the piping wall (structural pad).

(1) Pressure pads are designed to retain pressure, and may be used only where the piping is predicted to retain full structural integrity until the next refueling outage

[1] Raw water is defined as water such as from a river, lake, or well or brackish/salt water; used in plant equipment, area coolers, and heat exchangers. In many plants it is referred to as "Service Water."

assuming a corrosion rate of either 2 times the actual measured corrosion rate in that location, or 4 times the estimated maximum corrosion rate for the system.

(2) Structural pads are designed for pressure plus structural reinforcement and may be used where the piping is predicted not to retain full structural integrity until the next refueling outage.

3.2 GENERAL DESIGN REQUIREMENTS — PRESSURE AND STRUCTURAL PADS

(a) The design of reinforcing pads shall be in accordance with the applicable requirements of the Construction Code or Section III (NC-3100, ND-3100 and NC-3600, ND-3600 including Appendix II).

(b) The reinforcing pad shall be sized to encompass the unacceptable area with the attachment welds located on adjacent base material of sufficient thickness to accommodate the design stresses.

(c) The plate for the reinforcing pad shall be rolled or otherwise formed to fit the contour of the piping to achieve proper weld fit-up.

(d) The thickness of the reinforcing pad shall be sufficient to maintain required thickness until the next refueling outage.

(e) The tensile strengths of the plate and weld filler metal for the reinforcing pad shall be at least that specified for the base metal to which it is applied.

(f) The predicted maximum degradation of the reinforced piping until the next refueling outage shall be included in the design. The predicted degradation of the piping shall be based on in-situ inspection of, and established data for, similar base metals in similar environments. If the reinforcing pad is predicted to become exposed to the raw water, the predicted degradation of the reinforcing pad shall be based upon established data for base metals or weld metals with similar chemical composition to that used for the reinforcing pad.

(g) Material for reinforcing pads shall be ferritic, with welds of compatible weld filler metal.

(h) The following factors shall be included, as applicable, in the design and application of the pad:

(1) shrinkage effects, if any, on the piping

(2) stress concentrations caused by installation of the reinforcing pad or resulting from existing and predicted piping internal surface configuration

(3) effects of welding on any interior coating

(4) added weight of the pad with respect to any design analyses that could be affected

(i) If flexibility analysis was required by the original Construction Code, the effect of the reinforcing pad shall be reconciled with the original analysis. For rectangular-shaped reinforcing pads on piping designed to NC-2650, ND-3650 and aligned parallel or perpendicular to the axis of the piping, unless a lower stress intensification factor [SIF or (i)] is established, an SIF (i) of 2.1 shall be applied for reinforcing pads on straight pipe and adjacent welds. Also, a stress multiplier of 1.7 shall be applied to the SIF (i) for standard elbows, and an SIF (i) of 2.1 shall be applied for tees and branch connections when the toe of the attachment weld is not less than $2.5\sqrt{Rt_{\text{nom}}}$ from any branch reinforcement in Figure 1.

(j) Corners of reinforcing pad plates shall be rounded with radii not less than the reinforcing pad thickness, and the toes of attachment welds at the corners shall have 1 in. (25 mm) minimum radius.

(k) The distance between toes of attachment welds and other attachments or branch reinforcement (Figure 1 and 2) shall not be less than the following equation:

$$d = 2.5\sqrt{Rt_{\text{nom}}}$$

where

d = minimum distance between toes of fillet welds of adjacent fillet welded attachments
R = the outer radius of the piping
t_{nom} = nominal thickness of the piping

(l) When permitted by the design, suitable gasket material may be applied inside the pad to prevent moisture during welding (see Figures 1 and 2).

3.3 SPECIFIC DESIGN REQUIREMENTS — PRESSURE PADS

Pressure pads shall meet the requirements of 3.2, Figure 2, and the following:

(a) Fillet-welded pressure pads shall be designed to withstand the membrane strain of the piping in accordance with the requirements of the Code specified in 3.2(a) such that the following criteria are satisfied:

(1) The allowable membrane stress is not exceeded in the piping or the pad.

(2) The strain in the pad does not result in fillet weld stresses exceeding allowable stresses for such welds.

(b) Design as a reinforced opening in accordance with the Construction Code shall satisfy (a).

(c) As an alternative to (a), pressure pads may be designed as structural pads in accordance with 3.4 or as prequalified designs in accordance with 3.5.

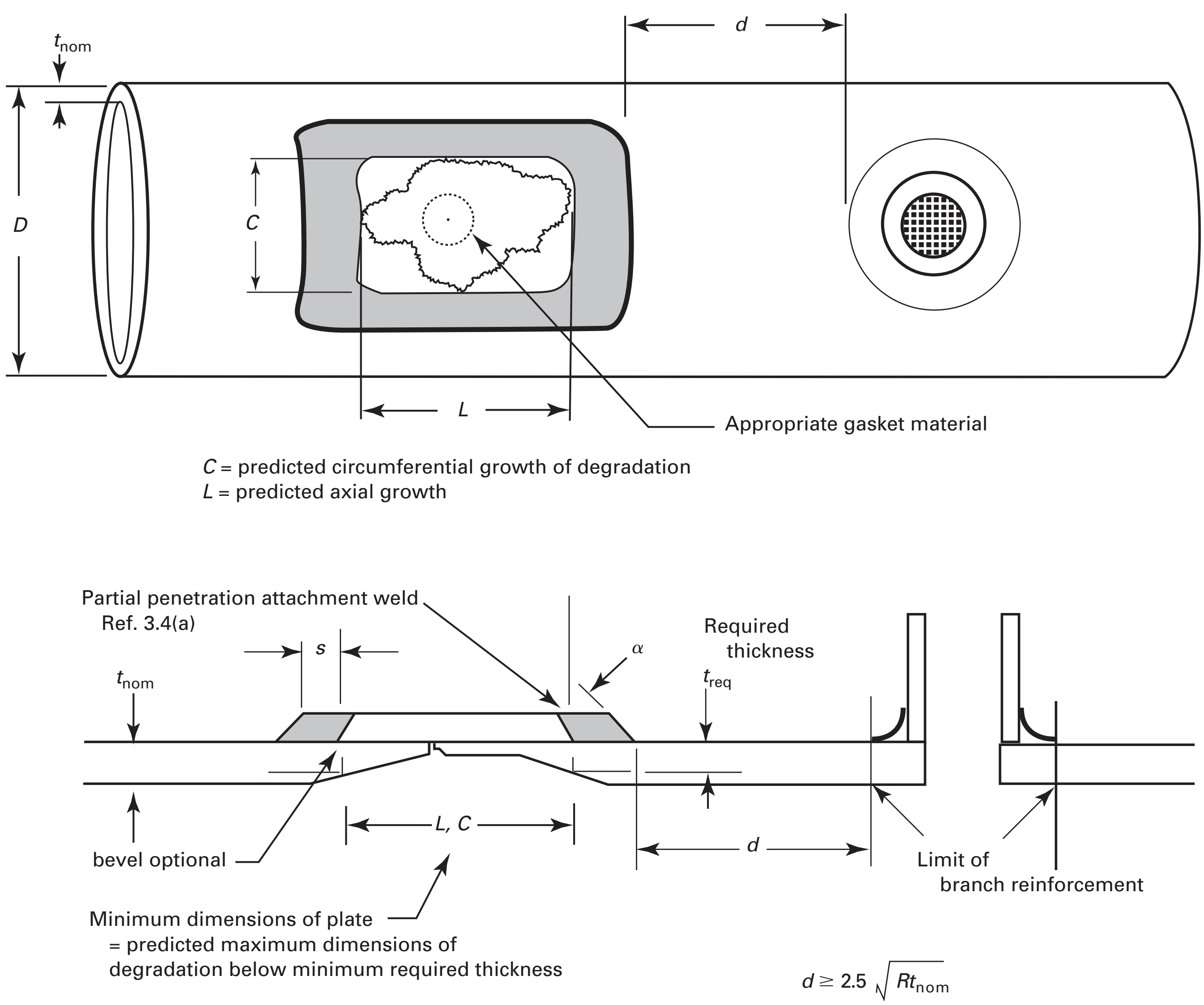
3.4 SPECIFIC DESIGN REQUIREMENTS — STRUCTURAL PADS

Structural pads shall meet the requirements of 3.2, Figure 1, and the following:

(a) Unless otherwise established by analysis in accordance with the requirements of 3.2(a), structural pads shall be attached by partial penetration attachment welds (see Figure 1) that extend for a distance of at least s in each direction beyond the area predicted, by the next refueling outage, to infringe upon the required thickness.[2]

[2] Design thickness as prescribed by the Construction Code.

Figure 1
Structural Pad



$$s \geq 0.75\sqrt{Rt_{nom}}$$

where

R = outer radius of the component
s = 1 in. (25 mm) minimum
t_{nom} = nominal wall thickness of the component

(b) The thickness of the partial penetration attachment welds shall equal the thickness of the pad and the edges of the welds shall be tapered to the piping surface at a maximum angle ("α" in Figure 1) of 45 deg.

(c) Final configuration of the structural pad including attachment welds shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of encompassed or adjacent welds.

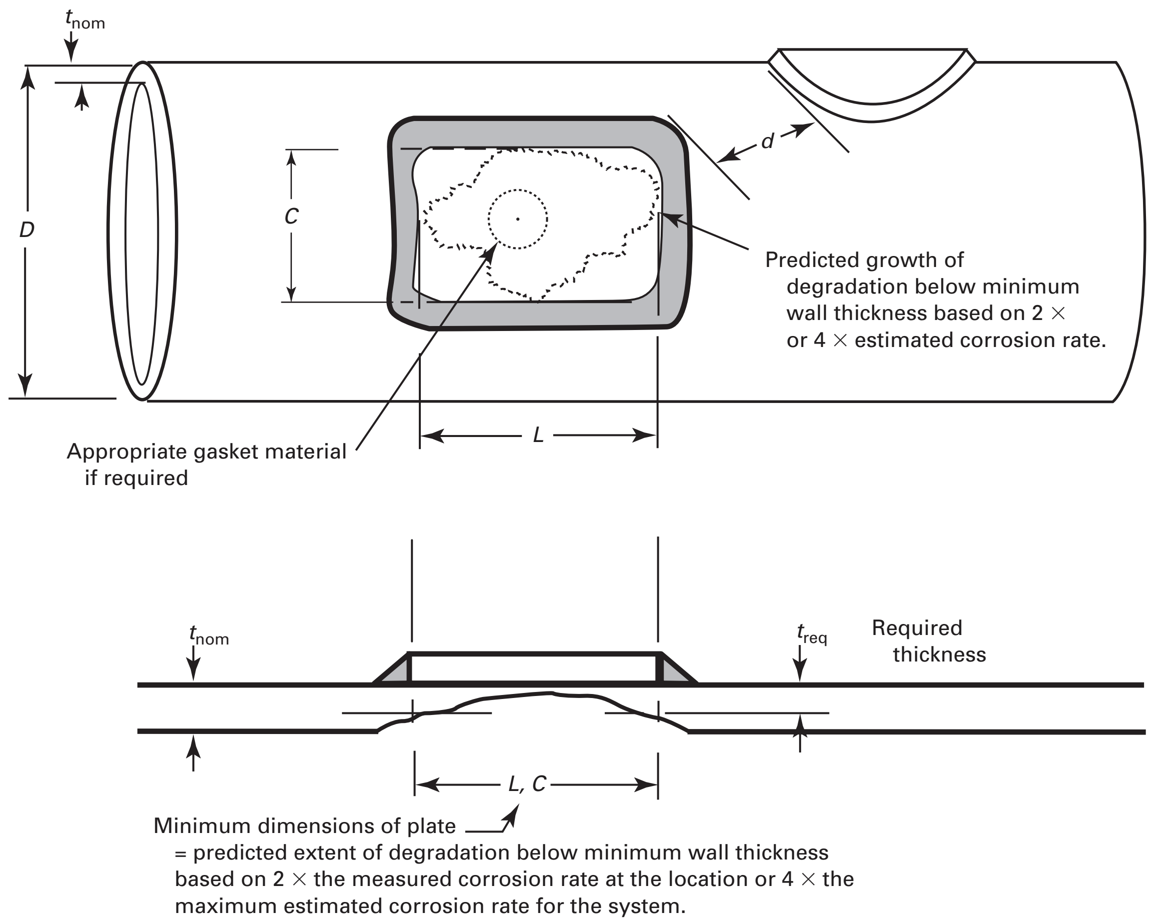
(d) Except for the tapered edges, the structural pad plate and attachment welds shall have a uniform thickness.

3.5 PREQUALIFIED DESIGN

Application of structural pads on straight pipe, standard elbows, and associated welds shall be exempt from the requirements of 3.2(a), provided all of the following conditions are satisfied.

(a) All other requirements of 3.1, 3.2, and 3.4 are satisfied.

Figure 2
Pressure Pad



(b) The axial length of structural pad plus width of partial penetration attachment welds shall not exceed the greater of 6 in. (150 mm) or the outside diameter of the piping.

(c) The finished structural pad shall be circular, oval, or rectangular in shape.

(1) The maximum dimension compensated by a circular structural pad shall not exceed two-thirds of the nominal outside diameter of the piping.

(2) Rectangular structural pads shall be aligned parallel with or perpendicular to the axis of the piping.

(3) For oval structural pads, the end radii shall not be less than $0.75\sqrt{Rt_{nom}}$, and the axis of the structural pad shall be aligned parallel with or perpendicular to the axis of the piping.

4 WATER-BACKED APPLICATIONS

(a) Attachment welds on water backed piping shall be applied using the SMAW process with low-hydrogen electrodes.

(b) When welding a reinforcing pad to a leaking area, precautions shall be taken to prevent welding on wet surfaces, such as installation of a gasket or sealant beneath the pad.

(c) For piping materials other than P-No. 1, Group 1, the surface examination required in 6 shall be performed no sooner than 48 hr after completion of welding.

5 INSTALLATION

(a) The base material in the area to be welded shall be cleaned to bare metal.

(b) Weld metal shall be deposited using a groove – welding procedure qualified in accordance with Section IX and the Construction Code.

(c) Provisions for venting during the final closure weld, or for pressurizing for leak-testing, shall be included, if necessary.

(d) The surface of the attachment weld shall be prepared, if necessary, by machining or grinding to permit performance of surface and volumetric examinations required by 6. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) The completed attachment weld shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or Section III (NC-5300, ND-5300).

(b) Except for the tapered edges, partial penetration attachment welds, including the piping base metal upon which they are applied, shall be ultrasonically measured to verify acceptable wall thickness.

(c) Partial penetration attachment welds shall be volumetrically examined when full penetration girth welds in the piping are required by the Construction Code to be volumetrically examined. Where configuration does not permit meaningful volumetric examination, the first layer, each $^1/_2$ in. (13 mm) thickness of weld deposit, and the final surface shall be examined in accordance with (a) in lieu of volumetric examination.

(d) If volumetric examination is required, the full volume of the attachment weld, excluding the tapered edges, but including the volume of base metal required for the intended life of the reinforcing pad, shall be examined in accordance with the Construction Code or Section III, using either the ultrasonic or radiographic method, and shall, to the depth at the surface of the piping, satisfy the acceptance criteria for weldments of the Construction Code or Section III (NC-5320, ND-5320 or NC-5330, ND-5330). Any volume of the piping beneath the reinforcing pad that is credited in the design shall satisfy the volumetric acceptance criteria of Section III (NC-5320, ND-5320 or NC-5330, ND-5330), as applicable.

7 PRESSURE TESTING

In lieu of IWA-4540, a system leakage test of the repair/replacement activity shall be performed in accordance with IWA-5000 prior to, or as part of, returning to service.

Reinforcing pads attached to piping that has not been breached shall be equipped with pressure taps for performance of pressure testing.

8 INSERVICE MONITORING

(a) Upon completion of the repair, inspections shall be performed for structural pads, using ultrasonic or direct thickness measurement, to record the thickness of the plate, the thickness at the attachment welds, including the underlying base metal, and to the extent examinable in a 3 in. (75 mm) wide band, surrounding the repair, as a baseline for subsequent monitoring of the repair.

(b) The Owner shall prepare a plan for additional thickness monitoring for structural pads using ultrasonic or direct thickness measurement to verify that minimum design thicknesses, as required by the Construction Code or Section III, are maintained until the next refueling outage. The monitoring shall be monthly for the first quarter and the subsequent frequency shall be based on the results of the monitoring activities, but at least quarterly.

Provisions shall be made for access to structural pads on buried piping during operation to accomplish these examinations.

(c) Areas containing pressure pads shall be monitored monthly for evidence of leakage. If the areas containing pressure pads are not accessible for direct observation, monitoring shall be accomplished by observation of surrounding areas or ground surface areas above pressure pads on buried piping; or leakage collection systems, if available, shall be monitored.

(d) If the results of the monitoring program identify leakage or indicate that the structural margins required by 3 will not be maintained until the next refueling outage, additional repair/replacement activities not prohibited by 1(d) shall be performed prior to encroaching upon the design limits.

(e) All reinforcing pads, regardless of when installed, shall be removed no later than the end of the next refueling outage.

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Approval Date: September 20, 2010
(ACI) Approval Date: October 23, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-791
Shear Screw and Sleeve Splice
Section III, Division 2

Inquiry: What requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when a shear screw and sleeve splice, as described in Section 3.3.11 of ACI 439.3R-07, is used?

Reply: It is the opinion of the Committee that the following requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when a shear screw and sleeve splice[1] is used.

The type of splice listed below is permitted within the limitations described in the following paragraphs:

1 QUALIFICATIONS, RECORDS, AND IDENTIFYING STAMPS

1.1 Required Qualifications. Each Constructor or Fabricator is responsible for the splicing made by their organization and they shall conduct the tests required by this Case in order to qualify the splicing procedure and the splicers.

1.2 Maintenance and Certification of Records. The Constructor or Fabricator shall maintain a record of the splicing procedure and the splicers qualified and employed by them, showing the date and results of tests, and the identification mark or marks assigned to each splicer. These records shall be reviewed, verified, and signed by an authorized individual assigned by the Constructor. The records shall be accessible to the Owner and to the Authorized Inspector.

1.3 Splicing Prior to Qualification. No splicing shall be undertaken until a splicer has been qualified. Only splicers who are qualified in accordance with 4 shall be used.

2 SPLICE SYSTEM QUALIFICATION REQUIREMENTS FOR SHEAR SCREW AND SLEEVE SPLICE SYSTEMS

2.1 General Requirements. Each shear screw and sleeve splice system manufacturer shall conduct a series of performance tests on each type of coupler in order to qualify their splice system for use. Potential changes in splice performance due to relaxation, if any, of screw clamping force with time shall be addressed.

2.2 Materials to Be Used for Performance Tests. The types of materials to be used for the performance test splices shall be the same as those intended for use in production splices. The actual materials used and the necessary dimensions of all test specimens shall be documented.

2.3 Type and Number of Performance Tests.

(a) Static Tensile Tests. Six splice specimens for each reinforcing bar size, bar grade, and splice type to be used in construction shall be tensile tested to failure using the loading rate set forth in SA-370. A tensile test on an unspliced specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The average tensile strength of the splices shall not be less than 90% of the actual tensile strength of the reinforcing bar being tested, nor less than 100% of the specified minimum tensile strength of the bar. The tensile strength of an individual splice specimen shall not be less than 125% of the specified minimum yield strength of the spliced bar. Each individual test report of both the spliced and unspliced specimens shall include at least the following information:

(1) tensile strength

(2) total elongation

[1] For the purpose of this Case, the term *shear screw* and *sleeve splice* is defined as a shaped steel sleeve placed over the butted ends of two reinforcing bars, then a series of cone-pointed shear screws are tightened down that indent into the surface of the bars and push the bars into the wedge of two converging sides of the sleeve whereupon the heads shear off at a prescribed tightening force.

(3) load-extension curve to the smaller of 2% strain or the strain at 125% of the specified minimum yield strength of the reinforcing bar

The gage length for each pair of spliced and unspliced specimens shall be the same, and equal to the length of the splice sleeve, plus not less than 1 bar diameter nor more than 3 bar diameters at each end.

(b) Cyclic Tensile Tests. Three specimens of the bar-to-bar splice for each reinforcing bar size, bar grade and splice type to be used in construction shall be subjected to a low cycle tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load and return.

2.4 Essential Variables. The performance tests shall be completely reconducted when any of the following applicable changes listed below are made. Changes other than those listed may be made without the necessity for repeating the performance tests:

(a) a change in splice sleeve or shear screw material or grade

(b) a reduction in the cross-sectional area of the splice sleeve

(c) a reduction in the bar engagement length

(d) an increase in reinforcing bar grade

(e) a reduction in the number of shear screws

(f) a change in geometry of the splice sleeve at the contact point between sleeve and reinforcing bar

(g) a change in load transfer mechanism of the splice sleeve

(h) a change in shear screw geometry

(i) a change in shear screw torque limits

(j) a change in shear screw hardness properties

(k) a change in shear screw spacing

(l) a change in edge distance from end of coupler to first shear screw

3 REQUIREMENTS FOR PRODUCTION SPLICING PROCEDURES

All production splicing shall be performed in accordance with a written procedure which shall include, as a minimum, the procedures used for the performance tests in 2.3, with the following additional information:

(a) bar end preparation

(b) cleanliness requirements

(c) permissible gap between reinforcing bar ends

(d) method used to verify proper insertion length of both bars within the coupler

(e) method used to measure shear screw torque limits

(f) method used to torque the shear screws

4 INITIAL QUALIFICATION TESTS

Each splicer shall prepare two qualification splices on the largest bar size for each type of coupler to be used. The qualification splices shall be made using reinforcing bar identical to that to be used in the structure. The completed qualification splices shall be tensile tested using the loading rates set forth in SA-370 and the tensile results shall meet those specified in Table CC-4333-1.

5 CONTINUING SPLICE PERFORMANCE TESTS

5.1 Introduction. A continuing series of tests shall be made to ensure that production splices meet the tensile requirements. Examination of installed splices is specified in 9.

5.2 Splice Samples. Splice samples shall be assembled in accordance with the splicing procedure required by 3. Splice samples may be production splices (cut directly from in-place reinforcement) or straight sister splices (removable splices made in place next to production splices and under the same conditions), in accordance with the schedule established in 5.3.

5.3 Testing Frequency. Splice samples shall be tensile tested in accordance with the following schedule. Separate test cycles shall be established for each bar size, grade, and coupler type as follows:

(a) If only production splices are tested, the sample frequency shall be as follows:

(1) one of the first ten production splices

(2) one of the next 90 production splices

(3) two of the next units and each subsequent unit of 100 production splices

(b) If production and sister splices are tested, the sample frequency shall be as follows:

(1) one production splice of the first ten production splices.

(2) one production and three sister splices for the next 90 production splices.

(3) three splices, either production or sister splices, for the next and each subsequent unit of 100 production splices. At least one-fourth of the total number of splices tested shall be production splices.

Straight sister splices may be substituted for production test samples on radius bent bars and for splicing sleeves arc welded to structural steel elements or the liner.

5.4 Tensile Testing Requirements. Splice samples shall be tensile tested using the loading rates set forth in SA-370. The following shall constitute the acceptance standards.

(a) The tensile strength of each sample shall equal or exceed 125% of the specified minimum yield strength as shown in Table CC-4333-1.

(b) The average tensile strength of each group of 15 consecutive samples shall equal or exceed the specified minimum tensile strength as shown in Table CC-4333-1.

If any sample tested fails to meet the provisions of (a) or (b), the requirements of 5.5 shall be followed.

5.5 Substandard Tensile Test Results.

(a) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor or Fabricator. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing frequency of 5.3.

(b) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure does not occur in the bar, two additional splices shall be tested. If either of these retests fails to meet the strength requirement of Table CC-4333-1, splicing shall be halted. Splicing shall not be resumed until the cause of failures has been corrected and resolved.

(c) If the running average tensile strength of 15 consecutive samples fails to meet the tensile requirement of Table CC-4333-1, splicing shall be halted. The Constructor or Fabricator shall investigate the cause and make the necessary corrective action.

(d) When splicing is resumed, the testing frequency shall be started anew.

6 RECORDING OF TENSILE TEST RESULTS

The results of all tensile tests obtained from the tests prescribed by 4 and 5, along with all other pertinent data, shall be recorded.

7 WELDING

Welding of splice sleeves to parts shall be performed using welding procedures and welders qualified in accordance with AWS D1.1 or Section IX. Welding material requirements are specified in CC-2600.

8 IMPACT REQUIREMENTS

When reinforcing bar or mechanical splices are to be welded to material that requires impact testing, the following shall apply.

(a) The weld filler metal shall be impact tested in accordance with the requirements of the material that the reinforcing bar is attached to.

(b) The acceptance criteria of the material requiring impact testing shall be met.

9 EXAMINATION OF SPLICES

(a) Bar ends and splice sleeves shall be visually examined prior to assembly for cleanliness in accordance with CC-5320.

(b) Bars shall be marked with a suitable marker to indicate depth of insertion into splice. After assembly, the actual depth of insertion shall be checked by means of this mark.

(c) Proper assembly, including verification that all shear screw heads have sheared off, shall be checked for compliance with the installation procedure described in the Construction Specification.

10 SPLICE MATERIAL

10.1 Bar-to-Bar Splice Material. The material to be used for sleeves in shear screw and sleeve bar-to-bar splices shall conform to CC-2310(b).

10.2 Welding Material. The material to be used for sleeves in shear screw and sleeve splices attached by welding to the liner or structural steel elements shall be carbon steel conforming to CC-2310(c).

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Approval Date: August 12, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-792-1
Fatigue Evaluations Including Environmental Effects
Section III, Division 1

Inquiry: Section III, NCA-1130, states that the rules do not cover deterioration, which may occur in service as a result of environmental effects such as radiation, corrosion, or erosion. It further states that these effects shall be taken into account with a view to realizing the design or specified life of the components and supports. What alternative rules may be used for Section III, Class 1 components subject to both cyclic loading and environmental effects in light water reactor environments?

Reply: It is the opinion of the Committee that the thermal and mechanical fatigue concerns from the light water reactor environment may be evaluated in accordance with the following requirements for carbon and low-alloy steels, austenitic stainless steels, and nickel-chrome-iron materials.

-1000 INTRODUCTION

-1100 SCOPE

This Case provides a method for performing fatigue usage factor evaluations of Class 1, light water reactor coolant system and primary pressure boundary components when the effects of light water reactor coolant on fatigue life are judged to be significant. The fatigue usage factor evaluation procedures and acceptance criteria are provided in -2000. This Case is limited to carbon and low-alloy steels, austenitic stainless steels, and nickel-chrome-iron materials.

The evaluations shall be documented in accordance with the provisions of -3000.

-1200 NOMENCLATURE

The symbols adopted in this Case are defined as follows:

DO = effective dissolved oxygen content of water (ppm)
E = Young's Modulus, psi (MPa)
$F_{en,i}$ = effective environmental correction factor for the i_{th} stress cycle or load set pair
O^* = transformed oxygen content
S = sulfur content of carbon and low-alloy steels, weight %
S^* = transformed sulfur content
S_{range} = range of stress intensity associated with a transient cycle, psi (MPa)
T = temperature, °F (°C)
T^* = transformed temperature
T_a = average temperature on side a during a temperature transient
T_b = average temperature on side b during a temperature transient
ΔT_1 = linear temperature gradient through a component wall during a temperature transient
ΔT_2 = nonlinear temperature gradient through a component wall during a temperature transient
U_{en} = cumulative fatigue usage factor including the environmental effects
U_i = partial fatigue usage factor for load set pair i obtained by using Code fatigue curves
ε_i = strain range for load set pair i, %
ε' = strain rate, %/sec
ε'^* = transformed strain rate

-2000 ENVIRONMENTAL FATIGUE CORRECTION EVALUATION

-2100 SCOPE

The evaluation method uses as input the partial fatigue usage factors U_1, U_2, U_3,..., U_n, determined in the Class 1 component fatigue evaluation. For components evaluated using the design by analysis procedure in NB-3200, the partial fatigue usage factors are determined using the provisions in NB-3222.4(e)(5). For Class 1 piping systems designed using NB-3600 procedures, NB-3653 provides the procedure for the calculation of partial fatigue usage factors for each of the load set pairs.

The cumulative fatigue usage factor, U_{en}, considering the environmental effects is calculated as the following:

$$U_{en} = U_1 \cdot F_{en,1} + U_2 \cdot F_{en,2} + U_3 \cdot F_{en,3} \dots U_i \cdot F_{en,i} \dots + U_n \cdot F_{en,n}$$

where

$F_{en,i}$ = the effective environmental fatigue correction factor for the i_{th} stress cycle (NB-3200) or load set pair (NB-3600)

U_i = the partial fatigue usage factor for the i_{th} stress cycle or load set pair using the fatigue curve defined in Table -2100-1 or Table -2100-2 and shown in Figures -2100-1 or -2100-2

Figures -2100-1 and -2100-2 are the same as Figs. I-9.1 and I-9.2 in Section III, Division 1, Mandatory Appendix I, 2009b Addenda.

The cumulative fatigue usage factor, U_{en}, shall not exceed 1.0.

-2110 Environmental Factor Definition

The values of the environmental fatigue correction factor for each load pair, i, are to be calculated using the expressions below:

(a) Carbon and Low Alloy Steels

$$F_{en,i} = \left[\exp\left(0.121 - 0.101 S^* T^* O^* \varepsilon'^*\right)\right] \qquad (1)$$

(b) Austenitic Stainless Steels (wrought and cast)

$$F_{en,i} = \left[\exp\left(0.734 - T^* \varepsilon'^* O^*\right)\right] \qquad (2)$$

(c) Ni-Cr-Fe Alloys

$$F_{en,i} = \left[\exp\left(-T^* \varepsilon'^* O^*\right)\right] \qquad (3)$$

-2120 Evaluation Procedures

Three evaluation procedures are provided. Paragraph -2400 provides a simplified procedure for components that are evaluated using the analysis for cyclic operation procedure in NB-3222.4. A simplified procedure for piping systems designed for cyclic operation using NB-3653 is provided in -2500. An alternate method for determining strain rate is provided in -2600. This alternate method may be used to reduce conservatisms in the simplified methods when detailed transient analysis results are available.

-2200 Consideration of Strain Rate Due to Dynamic Loads

A stress cycle or load set pair involving only reversing or nonreversing dynamic loads satisfies the threshold for high strain rate and the transformed strain rate value of $\varepsilon'^* = 0$ may be used. A stress cycle or load set pair that involves reversing or nonreversing dynamic loads and other loads (e.g., pressure change, temperature change) does not satisfy this criterion. The transformed strain rate value of $\varepsilon'^* = 0$ may be used for the dynamic load portion of the stress cycle or load set pair when using the modified strain rate approach in -2600.

-2300 Environmental Factor Evaluation

Each of the three evaluation procedures defined in -2120 requires the use of key parameters such as strain rate, metal surface temperature, dissolved oxygen content, and for carbon and low-alloy steels, metal sulfur content to calculate $F_{en,i}$ for each stress cycle or load set pair. Because environmental effects on fatigue life occur primarily during the loading portion of the cycle (i.e., up-ramp with increasing strain or stress), the calculation of these key parameters is performed only for the stress up-ramp portion of the cycle. This concept is illustrated in Figure -2600-1.

Table -2100-1
Tabulated Values of S_a, ksi (MPa), for Figures -2100-1 and -2100-1M

Number of Cycles [Note (1)]	UTS ≤ 80 ksi (UTS ≤ 552 MPa) S_a	
1E1	580	(3999)
2E1	410	(2827)
5E1	275	(1896)
1E2	205	(1413)
2E2	155	(1069)
5E2	105	(724)
1E3	83	(572)
2E3	64	(441)
5E3	48	(331)
1E4	38	(262)
2E4	31	(214)
5E4	23	(159)
1E5	20	(138)
2E5	16.5	(114)
5E5	13.5	(93)
1E6	12.5	(86)
1E7	11.1	(77)
1E8	9.9	(68)
1E9	8.8	(61)
1E10	7.9	(54)
1E11	7.0	(48)

GENERAL NOTES:

(a) $E = 30 \times 10^6$ psi (207×10^3 MPa).

(b) Interpolation between tabular values is permissible based upon data representation by straight lines on log-log plot. See Section III, Division 1, Mandatory Appendix I, Table I-9.0, General Note (b).

NOTE:

(1) The number of cycles indicated shall be read as follows:
$IEJ = I \times 10^J$, e.g., 5E6 = 5×10^6 or 5,000,000

Table -2100-2
Tabulated Values of S_a, ksi (MPa), for Figures -2100-2 and -2100-2M

Number of Cycles [Note (1)]	S_a	
1E1	870	(6000)
2E1	624	(4300)
5E1	399	(2748)
1E2	287	(1978)
2E2	209	(1440)
5E2	141	(974)
1E3	108	(745)
2E3	85.6	(590)
5E3	65.3	(450)
1E4	53.4	(368)
2E4	43.5	(300)
5E4	34.1	(235)
1E5	28.4	(196)
2E5	24.4	(168)
5E5	20.6	(142)
1E6	18.3	(126)
2E6	16.4	(113)
5E6	14.8	(102)
1E7	14.4	(99.0)
1E8	14.1	(97.1)
1E9	13.9	(95.8)
1E10	13.7	(94.4)
1E11	13.6	(93.7)

GENERAL NOTES:
(a) $E = 28.3 \times 10^6$ psi (195×10^3 MPa).
(b) Interpolation between tabular values is permissible based upon data representation by straight lines on log-log plot. See Section III, Division 1, Mandatory Appendix I, Table I-9.0, General Note (b).

NOTE:
(1) The number of cycles indicated shall be read as follows:
$IEJ = I \times 10^J$, e.g., 5E6 = 5×10^6 or 5,000,000

-2400 EVALUATION PROCEDURE FOR DESIGN BY ANALYSIS

-2410 Determination of Transformed Strain Rate

The following provides rules for determining transformed strain rate for components. Guidelines for determination of strain rate are in the course of preparation. In the interim, the rules of -2410 herein may be used.

-2411 The strain rate, ε' (%/sec), for a stress cycle is determined as follows:

$$\varepsilon' = S_{\text{range}\,i} \cdot 100/\left(E \cdot t_{\max}\right)$$

$S_{\text{range i}}$ = the stress intensity based on the stress difference range for cycle i as determined in NB-3222.4(e)(5) (including K_e in NB-3228.5)

$t_{\max}$ = the time in seconds when the stress difference reaches a maximum from the start of the transient

This calculation is performed only for the wetted surface and up-ramp portion of the transients constituting the stress cycle or load set pair.

-2412 The transformed strain rate, ε'^*, for carbon and low alloy steels is obtained as follows:

$\varepsilon'^* = 0$	$(\varepsilon' > 1\%/\text{sec})$
$\varepsilon'^* = \ln(\varepsilon')$	$(0.001\%/\text{sec} \le \varepsilon' \le 1\%/\text{sec})$
$\varepsilon'^* = \ln(0.001)$	$(\varepsilon' < 0.001\%/\text{sec})$

-2413 The transformed strain rate, ε'^*, for wrought and cast austenitic stainless steels is obtained as follows:

$\varepsilon'^* = 0$	$(\varepsilon' > 0.4\%/\text{sec})$
$\varepsilon'^* = \ln(\varepsilon'/0.4)$	$(0.0004\%/\text{sec} \le \varepsilon' \le 0.4\%/\text{sec})$
$\varepsilon'^* = \ln(0.0004/0.4)$	$(\varepsilon' < 0.0004\%/\text{sec})$

-2414 The transformed strain rate, ε'^*, for Ni-Cr-Fe alloys is obtained as follows:

$\varepsilon'^* = 0$	$(\varepsilon' > 5.0\%/\text{sec})$
$\varepsilon'^* = \ln(\varepsilon'/5.0)$	$(0.0004\%/\text{sec} \le \varepsilon' \le 5.0\%/\text{sec})$
$\varepsilon'^* = \ln(0.0004/5.0)$	$(\varepsilon' < 0.0004\%/\text{sec})$

-2420 Determination of Transformed Temperature

-2421 The temperature, T, associated with a stress cycle i is equal to the average of the highest and lowest metal temperatures of the surface in contact with the fluid in the transients constituting the stress cycle or load set pair.

-2422 The transformed temperature, T^*, for carbon and low alloy steels is obtained as follows:

$T^* = 0.0$	$(T < 300°\text{F})$
$T^* = (T - 300)/1.8$	$(660°\text{F} > T > 300°\text{F})$

$T^* = 0.0$	$(T < 150°\text{C})$
$T^* = T - 150$	$(350°\text{C} > T > 150°\text{C})$

-2423 The transformed temperatures, T^*, for wrought and cast austenitic stainless steels is obtained as follows:

$T^* = 0.0$	$(T < 300°\text{F})$
$T^* = (T - 300)/315$	$(300 \le T < 615°\text{F})$
$T^* = 1$	$(T \ge 615°\text{F})$

$T^* = 0.0$	$(T < 150°\text{C})$
$T^* = (T - 150)/175$	$(150 \le T < 325°\text{C})$
$T^* = 1$	$(T \ge 325°\text{C})$

-2424 The transformed temperatures, T^*, for Ni-Cr-Fe alloys is obtained as follows:

$T^* = T/615$	$(T < 615°\text{F})$
$T^* = 1$	$(T \ge 615°\text{F})$

Table continued

$T^* = T/325$	$(T < 325°C)$
$T^* = 1$	$(T \geq 325°C)$

-2430 Determination of Transformed *DO*

-2431 For carbon and low alloy steels, the effective dissolved oxygen content, DO, associated with the transients constituting the stress cycle or load set pair i equal to the higher of the oxygen levels in the transients constituting the stress cycle or load set. The transformed DO, O^* is obtained as follows:

$O^* = 0$	$(DO \leq 0.04$ ppm)
$O^* = \ln(DO/0.04)$	(0.04 ppm $< DO \leq 0.5$ ppm)
$O^* = \ln(12.5)$	$(DO > 0.5$ ppm)

-2432 For wrought and cast austenitic stainless steels, the transformed DO, O^* is obtained as follows:

$O^* = 0.281$	(all DO levels)

-2433 For Ni-Cr-Fe alloys, the transformed DO, O^* is obtained as follows:

$O^* = 0.09$	(for BWR normal water chemistry)
$O^* = 0.16$	(for PWR and BWR hydrogen water chemistry)

-2440 Determination of Transformed Sulfur

Transformed sulfur is applicable only to carbon and low alloy steels.

The sulfur content, S in terms of weight percent may be obtained from the material procurement specification, the certified material test report or an equivalent source. If the sulfur content is unknown, then its value shall be assumed as 0.015%. The transformed sulfur, S^* is obtained as follows:

$S^* = 0.015$	$(DO > 1.0$ ppm)
$S^* = 0.001$	$(DO \leq 1.0$ ppm and $S \leq 0.001$ wt%)
$S^* = S$	$(DO \leq 1.0$ ppm and $0.001 < S \leq 0.015$ wt%)
$S^* = 0.015$	$(DO \leq 1.0$ ppm and $S > 0.015$ wt%)

-2450 Determination of $F_{en,\ i}$

The environmental correction factor $F_{en,\ i}$ shall be calculated using equations given in -2100.

-2460 Alternate Determination of $F_{en,\ i}$ Based on Modified Strain Rate Approach

A procedure similar to that described in -2600 may be used to remove some of the conservatism built into the $F_{en,\ i}$ determined in -2450.

-2500 EVALUATION PROCEDURE FOR PIPING

The procedures in this section use the input information and the partial fatigue usage results from the NB-3650 fatigue evaluation. The example of specific load set information needed is: internal pressure, the three moment components, $|T_a - T_b|$, ΔT_1 and ΔT_2. When the detailed results of one-dimensional transient heat transfer analyses are available in the form of time history of $|T_a - T_b|$, ΔT_1 and ΔT_2, such results may be used to reduce conservatisms in the calculated values of environmental correction factor.

-2510 Determination of Strain Rate

The rules for determination of strain rate for piping are in the course of preparation. In the interim, the rules of -2410 may be used.

-2520 Determination of Transformed Temperatures

The transformed temperatures shall be obtained as described in -2420.

-2530 Determination of Transformed *DO*

The transformed DO shall be obtained as described in -2430.

-2540 Determination of Transformed Sulfur

The transformed sulfur shall be obtained as described in -2440.

-2550 Determination of $F_{en,\ i}$

The environmental correction factor $F_{en,\ i}$ shall be calculated using equations given in -2100.

-2560 Alternate Determination of $F_{en,\ i}$ Based on Modified Strain Rate Approach

A procedure similar to that described in -2600 may be used to remove some of the conservatism built into the $F_{en,\ i}$ determined in -2550.

-2600 MODIFIED STRAIN RATE APPROACH

When the results of detailed transient analyses are available to predict strain rate, such results may be used to reduce conservatisms in the calculated values of $F_{en,\ i}$. The following expression or equivalent shall be used:

$$F_{en,i} = \frac{\Sigma F_{en,k} \Delta\varepsilon_k}{\Sigma \Delta\varepsilon_k}$$

where (refer to Figure -2600-1)

$F_{en,\ k}$ = F_{en} computed for segment k of the cycle, based on the transformed parameters ε'^*, S^*, T^*, and O^* applicable to that segment

$\Delta\ \varepsilon_k$ = strain range for segment k of the cycle, in./in. (mm/mm)

ε'_k = $100\Delta\varepsilon_k/\Delta t_k$ the strain rate for segment k, %/sec

$\Delta\ t_k$ = the time duration for segment k, sec

-3000 RECORDS AND REPORTS

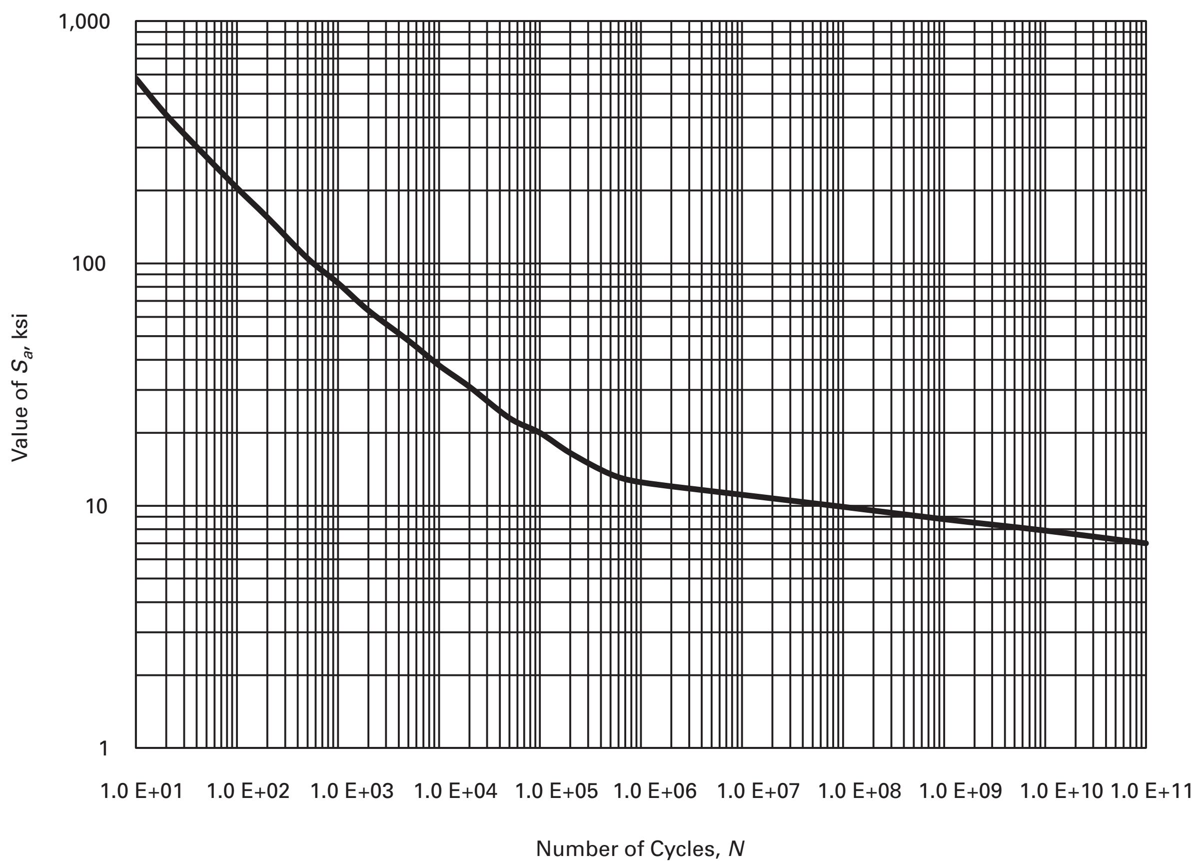
-3100 SCOPE

This section contains records and report provisions for evaluations specified in -2000.

-3200 EVALUATION RECORDS AND REPORTS

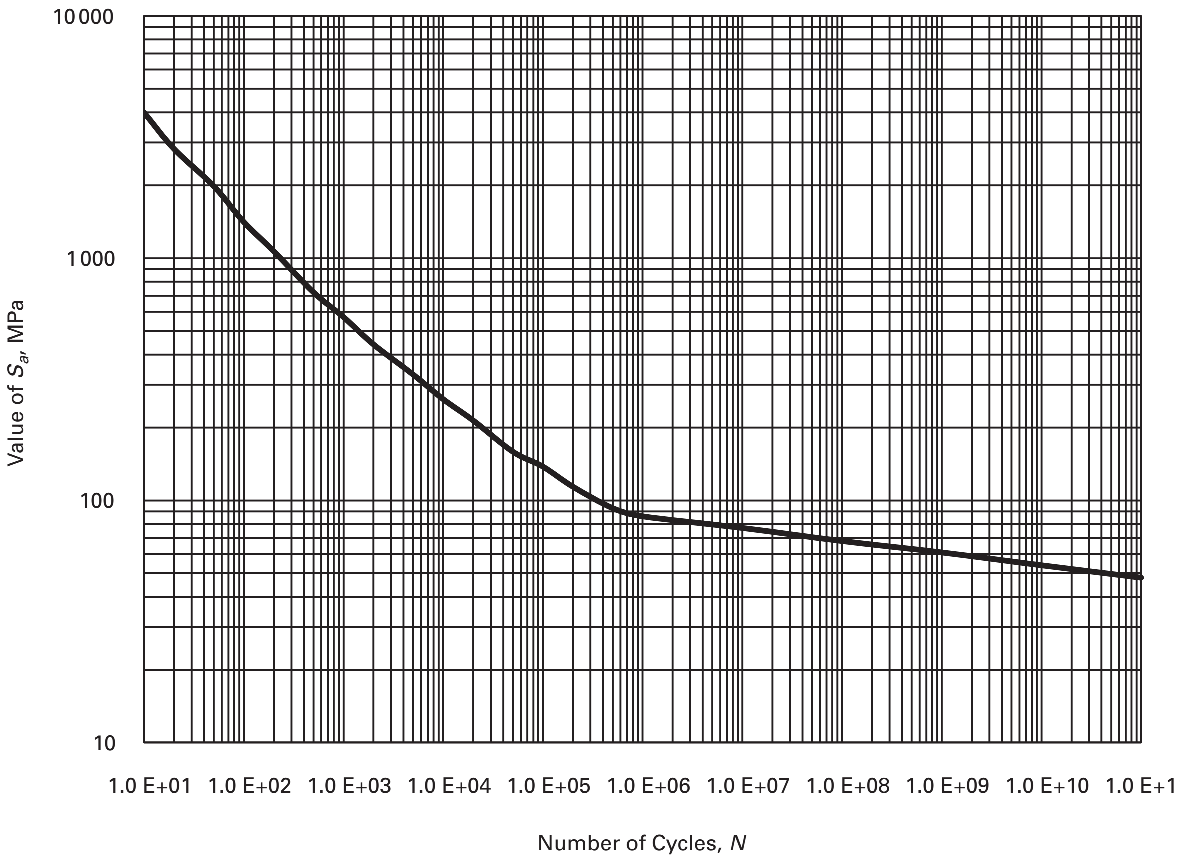
The evaluations specified in -2000 shall be documented in the Design Reports.

Figure -2100-1
Design Fatigue Curve for Carbon and Low Alloy Steels With UTS ≤ 80 ksi and Metal Temperatures Not Exceeding 700°F



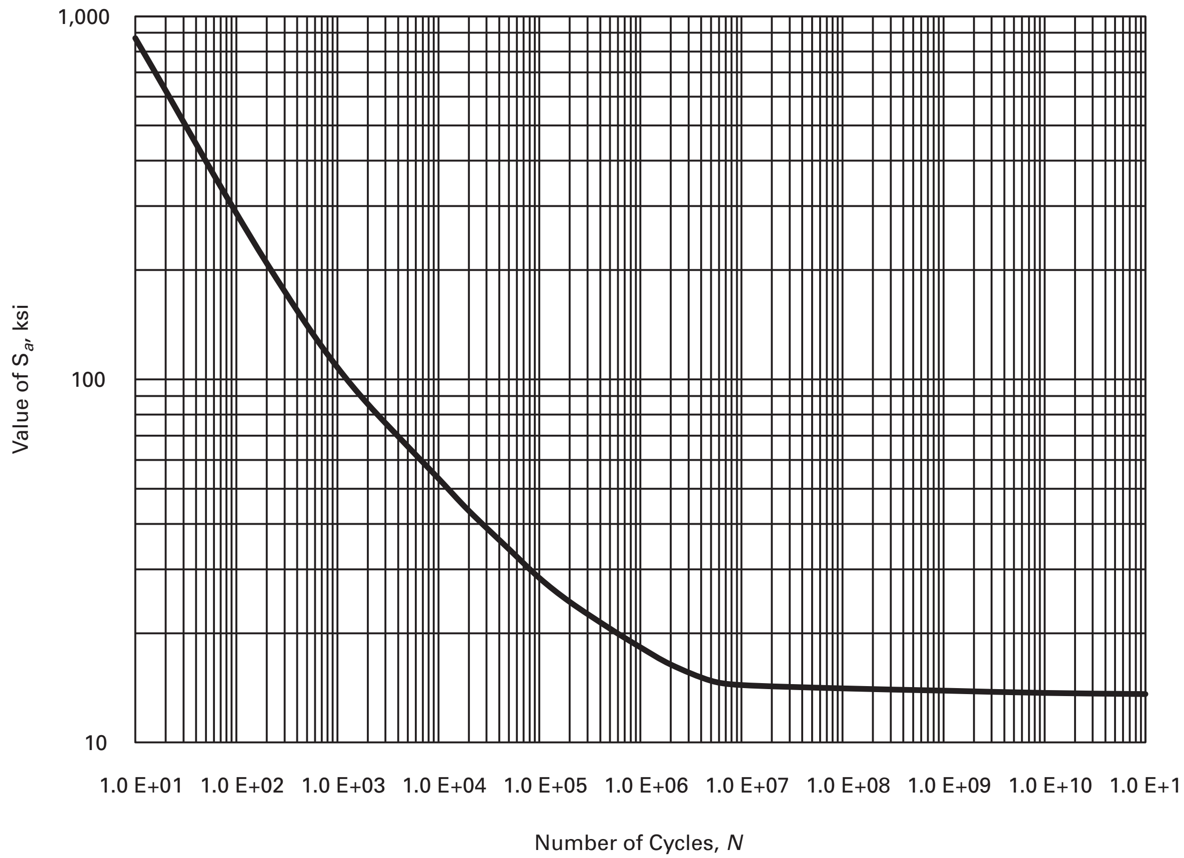
GENERAL NOTE: $E = 30 \times 10^6$ psi.

Figure -2100-1M
Design Fatigue Curve for Carbon and Low Alloy Steels With UTS ≤ 552 MPa and Metal Temperatures Not Exceeding 370°C



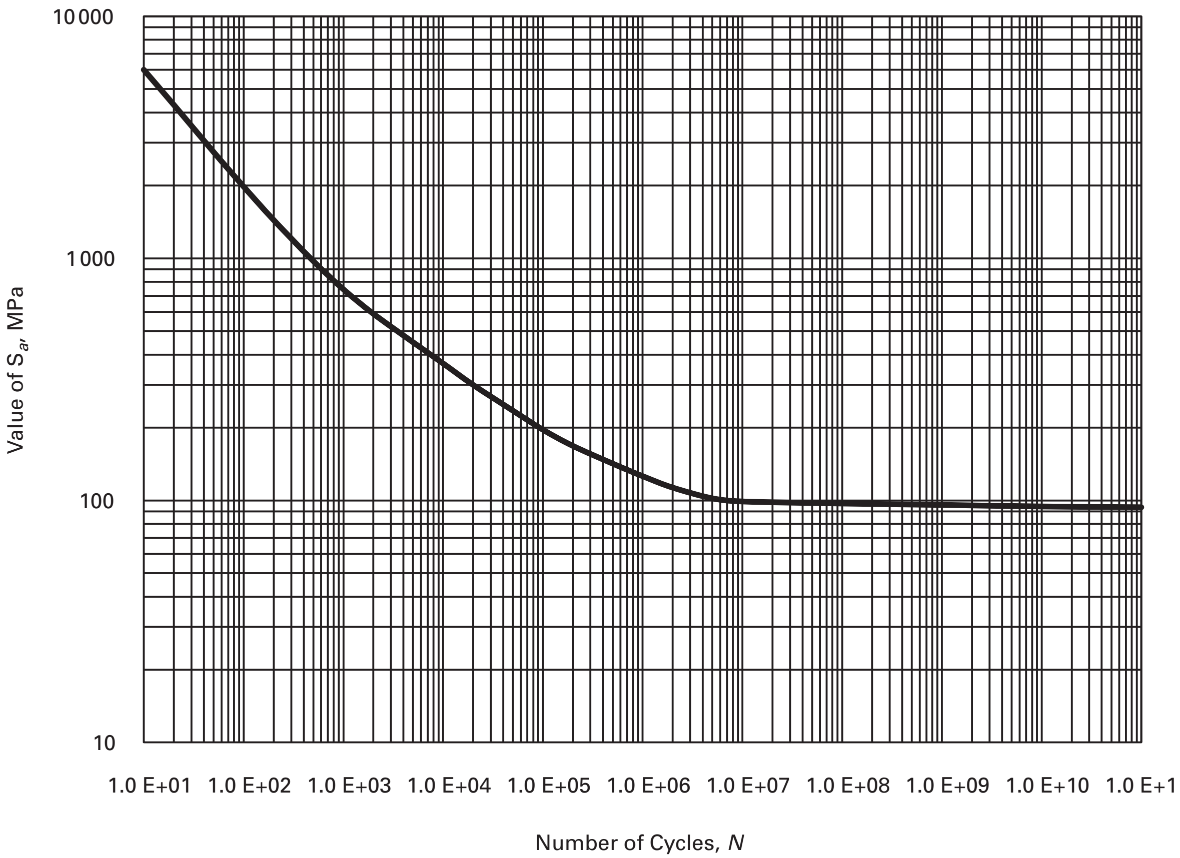
GENERAL NOTE: E= 207 x 10^3 MPa.

Figure -2100-2
Design Fatigue Curve for Austenitic Steels and Nickel-Chromium-Iron Alloy for Temperatures Not Exceeding 800°F



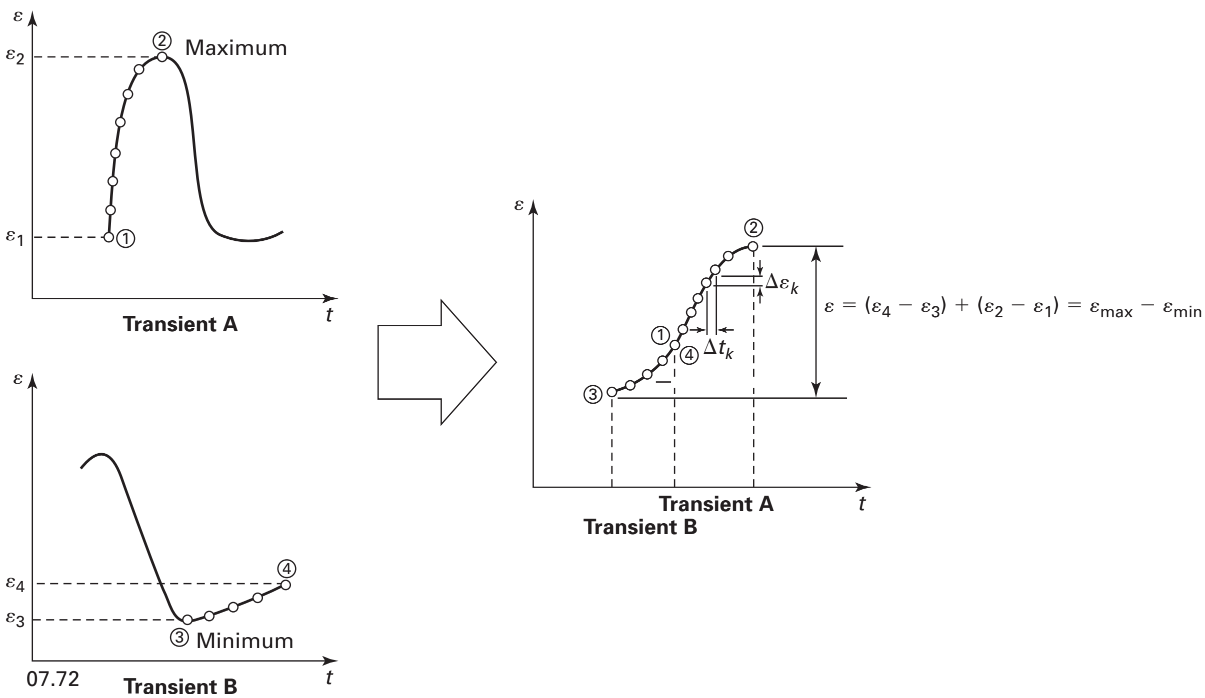
GENERAL NOTE: $E = 28.3 \times 10^6$ psi.

Figure -2100-2M
Design Fatigue Curve for Austenitic Steels and Nickel-Chromium-Iron Alloy for Temperatures Not Exceeding 425°C



GENERAL NOTE: E= 195 x 10^3 MPa.

Figure -2600-1
Modified Strain Rate Calculation



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Approval Date: September 20, 2010
(ACI) Approval Date: October 23, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-793
Extruded Steel Sleeves With Parallel Threaded Ends
Section III, Division 2

Inquiry: What requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems, when an extruded steel sleeve[1] with parallel threaded ends, as described in Section 3.3.4 of ACI 439.3R-07, is used?

Reply: It is the opinion of the Committee that the following requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when an extruded steel sleeve with parallel threaded ends[1] are used.

The type of splice listed below is permitted within the limitations described in the following paragraphs:

1 QUALIFICATIONS, RECORDS AND IDENTIFYING STAMPS

1.1 Required Qualifications. Each constructor or fabricator is responsible for the splicing made by their organization and they shall conduct the tests required by this Case in order to qualify the splicing procedure and the splicers.

1.2 Maintenance and Certification of Records. The constructor or fabricator shall maintain a record of the splicing procedure and the splicers qualified and employed by them, showing the date and results of tests, and the identification mark or marks assigned to each splicer. These records shall be reviewed, verified, and signed by an authorized individual assigned by the constructor. The records shall be accessible to the owner and to the authorized inspector.

1.3 Splicing Prior to Qualification. No splicing shall be undertaken until a splicer has been qualified. Only splicers who are qualified in accordance with 4 shall be used.

2 SPLICE SYSTEM QUALIFICATION REQUIREMENTS FOR EXTRUDED STEEL SLEEVES WITH PARALLEL THREADED ENDS

2.1 General Requirements. Each splice system manufacturer shall conduct a series of performance tests on each type of coupler in order to qualify the system for use.

2.2 Materials to Be Used for Performance Tests. The types of materials to be used for the performance test splices shall be the same as those intended for use in production splices. The actual materials used and the necessary dimensions of the test specimens shall be documented.

2.3 Type and Number of Performance Tests.

(a) Static Tensile Tests. Six splice specimens for each reinforcing bar size and splice type to be used in construction shall be tensile tested to failure using the loading rate set forth in SA-370. All deformation patterns used in construction, per bar size, shall be tested. The static tensile tests shall be repeated for each bar grade to be used in construction. A tensile test on an unspliced specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The average tensile strength of the splices shall not be less than 90% of the actual tensile strength of the reinforcing bars being tested, nor less than 100% of the specified minimum tensile strength of the bar. The tensile strength of an individual splice specimen shall not be less than 125% of the specified minimum yield strength of the spliced bar. Each individual test report of both the spliced and unspliced specimens shall include at least the following information:

(1) tensile strength

(2) total elongation

[1] For the purpose of this Case, the term *extruded steel sleeve with parallel threaded ends* is defined as a mechanical splice comprising of steel sleeves that are axially deformed onto the ends of reinforcing bars by an hydraulic extrusion press, and subsequently connected by directly engaging internal and external threads on opposing couplers or by means of an interconnecting threaded stud.

(3) load-extension curve to the smaller of 2% strain or the strain at 125% of the specified minimum yield strength of the reinforcing bar

The gage length for each pair of spliced and unspliced specimens shall be the same, and equal to the length of the splice assembly plus not less than one bar diameter nor more than three bar diameters at each end.

(b) Cyclic Tensile Tests. Three specimens of the bar-to-bar splice for each reinforcing bar size, bar grade, and splice type to be used in construction shall be subjected to a low cycle tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load and return.

2.4 Essential Variables. The performance tests shall be completely reconducted when any of the following applicable changes listed below are made. Changes other than those listed may be made without the necessity for repeating the performance tests:

(a) a change in splice sleeve material or grade

(b) a change in the stud material or grade

(c) a reduction in the cross-sectional area of the splice sleeve or of the stud

(d) a reduction in the bar engagement length

(e) an increase in reinforcing bar grade

(f) a change in thread geometry

(g) a change in torque

(h) a change in prescribed extrusion pressure

(i) a change in extrusion die geometry

(j) a reduction in the minimum required length of lock nuts used

3 REQUIREMENTS FOR PRODUCTION SPLICING PROCEDURES

All production splicing shall be performed in accordance with a written procedure, that shall include, as a minimum, the procedures used for the performance tests in 2.3, with the following additional information:

(a) cleanliness requirements

(b) type of equipment and methods used for extrusion

(c) required extrusion pressure, method of measurement, tolerance on pressure, and frequency of calibration of the hydraulic system

(d) method used to verify final alignment and engagement of the coupler on both bars

(e) bar end preparation

(f) method of mechanically locking the position splices

(g) limits of extrusion die wear and frequency of checking

(h) type of equipment and methods used for torquing

(i) required force and method of measurement for torquing

4 INITIAL QUALIFICATION TESTS

Each splicer shall prepare two qualification splices on the largest bar size for each type of coupler and each of the splice position to be used. The qualification splices shall be made using reinforcing bar identical to that to be used in the structure. The completed qualification splices shall be tensile tested using the loading rates set forth in SA-370 and the tensile results shall meet those specified in Table CC-4333-1.

5 CONTINUING SPLICE PERFORMANCE TESTS

5.1 Introduction. A continuing series of tests shall be made to ensure that production splices meet the tensile requirements. Nondestructive examination requirements are specified in 10.

5.2 Splice Samples. Splice samples may be production splices (cut directly from in-place reinforcement) or straight sister splices (removable splices made in place next to production splices and under the same conditions), in accordance with the schedule established in 5.3.

5.3 Testing Frequency. Splice samples shall be tensile tested in accordance with the following schedule. Separate test cycles shall be established for each bar size, bar grade, coupler type, and splice position (horizontal, vertical and diagonal). Straight sister splices may be substituted for production test samples on radius bent bars and for splicing sleeves arc welded to structural elements or the liner.

(a) If only production splices are tested, the sample frequency shall be as follows:

(1) one of the first ten production splices

(2) one of the next 90 production splices

(3) two of the next units and each subsequent unit of 100 production splices

(b) If production and sister splices are tested, the sample frequency shall be as follows:

(1) one production splice of the first ten production splices.

(2) one production and three sister splices for the next 90 production splices.

(3) three splices, either production or sister splices, for the next and each subsequent unit of 100 production splices. At least one-fourth of the total number of splices tested shall be production splices.

5.4 Tensile Testing Requirements. Samples shall be tensile tested using the loading rates set forth in SA-370. The following shall constitute the acceptance standards:

(a) The tensile strength of each sample shall equal or exceed 125% of the specified minimum yield strength as shown in Table CC-4333-1.

(b) The average tensile strength of each group of 15 consecutive samples shall equal or exceed the specified minimum tensile strength as shown in Table CC-4333-1.

If any tested sample fails to meet the provisions of (a) or (b) above, the requirements of 5.5 shall be followed.

5.5 Substandard Tensile Test Results.

(a) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor or Fabricator. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing frequency required by 5.3.

(b) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure does not occur in the bar, two additional splices shall be tested. If either of these retests fails to meet the strength requirement of Table CC-4333-1, splicing shall be halted. Splicing shall not be resumed until the cause of failures has been corrected and resolved.

(c) If the running average tensile strength of 15 consecutive samples fails to meet the tensile requirements of Table CC-4333-1, splicing shall be halted. The Constructor or Fabricator shall investigate the cause and make the necessary corrective action.

(d) When splicing is resumed, the testing frequency shall be started anew.

6 RECORDING OF TENSILE TEST RESULTS

The results of all tensile tests obtained from the tests prescribed by 4 and 5, along with all other pertinent data, shall be recorded.

7 WELDING

Welding of splice sleeves to parts shall be performed using welding procedures and welders qualified in accordance with AWS D1.1 or Section IX. Welding material requirements are specified in CC-2600.

8 IMPACT REQUIREMENTS

When reinforcing bar or mechanical splices are to be welded to material that requires impact testing, the following shall apply:

(a) The weld filler metal shall be impact tested in accordance with the requirements of the material that the reinforcing bar is attached to.

(b) The acceptance criteria of the material requiring impact testing shall be met.

9 SPLICE MATERIAL

9.1 The materials to be used for extruded steel sleeves with parallel threaded ends shall conform to ASTM A513, A 519 or A 576.

9.2 The materials to be used for extruded steel sleeves with parallel threaded ends attached to liner plates or structural steel shapes shall be carbon steel conforming to ASTM A513, A 519 or A 576 Grades 1008 through 1030.

9.3 The materials to be used for the threaded studs shall conform to ASTM A322 Grades 4130 through 4145, or to ASTM A108 Grades 1030 through 1045.

10 EXAMINATION OF SPLICES

(a) Bar ends and splice sleeves shall be visually examined prior to assembly for cleanliness in accordance with CC-5320.

(b) Threads shall be checked with a manufacturer's thread gage.

(c) Bars shall be marked with a suitable marker to indicate depth of insertion into the splice. After completion, the actual depth of insertion shall be checked for compliance with 3 by means of this mark.

(d) Proper assembly and torque shall be checked for compliance with the installation procedure described in the Construction Specification.

(e) One splice of each 100 production splices shall be disassembled, inspected for compliance with CC-4333.3 and all threads rechecked with the Manufacturer's thread gage.

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Approval Date: September 20, 2010
(ACI) Approval Date: October 23, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-794
Swaged Splice With Threaded Ends
Section III, Division 2

Inquiry: What requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when a swaged splice with threaded ends, as described in Section 3.3.2 of ACI 439.3R-07, is used?

Reply: It is the opinion of the Committee that the following requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when a swaged splice with threaded ends[1] is used.

The type of splice listed below is permitted within the limitations described in the following paragraphs:

1 QUALIFICATIONS, RECORDS, AND IDENTIFYING STAMPS

1.1 Required Qualifications. Each Constructor or Fabricator is responsible for the splicing made by their organization and they shall conduct the tests required by this Case in order to qualify the splicing procedure and the splicers.

1.2 Maintenance and Certification of Records. The Constructor or Fabricator shall maintain a record of the splicing procedure and the splicers qualified and employed by them, showing the date and results of tests, and the identification mark or marks assigned to each splicer. These records shall be reviewed, verified, and signed by an authorized individual assigned by the Constructor. The records shall be accessible to the Owner and to the Authorized Inspector.

1.3 Splicing Prior to Qualification. No splicing shall be undertaken until a splicer has been qualified. Only splicers who are qualified in accordance with 4 shall be used.

2 SPLICE SYSTEM QUALIFICATION REQUIREMENTS FOR SWAGED SPLICE WITH THREADED ENDS

2.1 General Requirements. Each splice system manufacturer shall conduct a series of performance tests on each type of coupler in order to qualify their splice system for use.

2.2 Materials to Be Used for Performance Tests. The types of materials to be used for the performance test splices shall be the same as those intended for use in production splices. The actual materials used and the necessary dimensions of all test specimens shall be documented.

2.3 Type and Number of Performance Tests.

(a) Static Tensile Tests. Six splice specimens for each reinforcing bar size, bar grade, deformation pattern, and splice type to be used in construction shall be tensile tested to failure using the loading rate set forth in SA-370. One of the six specimens shall be tested at 20°F (−7°C) or less. A tensile test on an unspliced specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The average tensile strength of the splices shall not be less than 90% of the actual tensile strength of the reinforcing bar being tested, nor less than 100% of the specified minimum tensile strength of the bar. The tensile strength of an individual splice specimen shall not be less than 125% of the specified minimum yield strength of the spliced bar. Each individual test report of both the spliced and unspliced specimens shall include at least the following information:

(1) tensile strength

(2) total elongation

[1] For the purpose of this Case, a *swaged splice with threaded ends* is defined as a mechanical splice comprising of steel couplers hydraulically pressed onto reinforcing bars by cold-swaging dies and subsequently connected by directly engaging internal and external threads on opposing couplers or by means of an interconnecting threaded stud.

(3) load-extension curve to the smaller of 2% strain or the strain at 125% of the specified minimum yield strength of the reinforcing bar

The gage length for each pair of spliced and unspliced specimens shall be the same, and equal to the length of the splice assembly, plus not less than 1 bar diameter nor more than 3 bar diameters at each end.

(b) Cyclic Tensile Tests. Three specimens of the bar-to-bar splice for each reinforcing bar size, bar grade, and splice type to be used in construction shall be subjected to a low cycle tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load and return.

2.4 Essential Variables. The performance tests shall be completely reconducted when any of the applicable changes listed below are made. Changes other than those listed may be made without the necessity for repeating the performance tests:

(a) a change in splice sleeve material or grade

(b) a change in stud material or grade

(c) a reduction in the cross-sectional area of the splice sleeve or stud

(d) a reduction in the bar engagement length

(e) an increase in reinforcing bar grade

(f) a change in prescribed swaging pressure

(g) a change in die profile geometry

(h) a change in thread geometry

(i) a change in torque

(j) a change in outside or inside diameter of splice sleeve

3 REQUIREMENTS FOR PRODUCTION SPLICING PROCEDURES

All production splicing shall be performed in accordance with a written procedure which shall include, as a minimum, the procedures used for the performance tests in 2.3, with the following additional information:

(a) bar end preparation

(b) cleanliness requirements

(c) type of equipment and methods used for swaging

(d) required swaging pressure, method of measurement, pressure tolerance, and frequency of calibration of the hydraulic system

(e) method used to verify final engagement of the threads and engagement tolerance

(f) method used to verify each sleeve is swaged along the prescribed length

(g) method used to verify final alignment

(h) limits of die wear and frequency of checking

(i) minimum and maximum number of swaging operations per sleeve

(j) method used to ensure that stud is locked to swaged sleeve

4 INITIAL QUALIFICATION TESTS

Each splicer shall prepare two qualification splices on the largest bar size for each type of coupler and each splice position to be used. The qualification splices shall be made using reinforcing bar identical to that to be used in the structure. The completed qualification splices shall be tensile tested using the loading rates set forth in SA-370 and the tensile results shall meet those specified in Table CC-4333-1.

5 CONTINUING SPLICE PERFORMANCE TESTS

5.1 Introduction. A continuing series of tests shall be made to ensure that production splices meet the tensile requirements. Examination of installed splices is specified in 9.

5.2 Splice Samples. Splice samples shall be assembled in accordance with the splicing procedure required by 3. Splice samples may be production splices (cut directly from in-place reinforcement) or straight sister splices (removable splices made in place next to production splices and under the same conditions), in accordance with the schedule established in 5.3.

5.3 Testing Frequency. Splice samples shall be tensile tested in accordance with the following schedule. Separate test cycles shall be established for each bar size, grade, coupler type and splice position (horizontal, vertical, and diagonal bars) as follows:

(a) If only production splices are tested, the sample frequency shall be as follows:

(1) one of the first ten production splices

(2) one of the next 90 production splices

(3) two of the next units and each subsequent unit of 100 production splices

(b) If production and sister splices are tested, the sample frequency shall be as follows:

(1) one production splice of the first ten production splices.

(2) one production and three sister splices for the next 90 production splices.

(3) three splices, either production or sister splices, for the next and each subsequent unit of 100 production splices. At least one-fourth of the total number of splices tested shall be production splices.

Straight sister splices may be substituted for production test samples on radius bent bars and for splicing sleeves arc welded to structural steel elements or the liner.

5.4 Tensile Testing Requirements. Splice samples shall be tensile tested at 20°F (−7°C) or less using the loading rates set forth in SA-370. The following criteria shall constitute the acceptance standards.

(a) The tensile strength of each sample shall equal or exceed 125% of the specified minimum yield strength as shown in Table CC-4333-1.

(b) The average tensile strength of each group of 15 consecutive samples shall equal or exceed the specified minimum tensile strength as shown in Table CC-4333-1.

If any sample tested fails to meet the provisions of (a) or (b), the requirements of 5.5 shall be followed.

5.5 Substandard Tensile Test Results.

(a) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor or Fabricator. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing frequency of 5.3.

(b) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure does not occur in the bar, two additional splices shall be tested. If either of these retests fails to meet the strength requirement of Table CC-4333-1, splicing shall be halted. Splicing shall not be resumed until the cause of failures has been corrected and resolved.

(c) If the running average tensile strength of 15 consecutive samples fails to meet the tensile requirement of Table CC-4333-1, splicing shall be halted. The Constructor or Fabricator shall investigate the cause and make the necessary corrective action.

(d) When splicing is resumed, the testing frequency shall be started anew.

6 RECORDING OF TENSILE TEST RESULTS

The results of all tensile tests obtained from the tests prescribed by 4 and 5, along with all other pertinent data, shall be recorded.

7 WELDING

Welding of structural connectors to parts shall be performed using welding procedures and welders qualified in accordance with AWS D1.1 or Section IX. Welding material requirements are specified in CC-2600.

8 IMPACT REQUIREMENTS

When reinforcing bar or mechanical splices are to be welded to material that requires impact testing, the following requirements shall apply.

(a) The weld filler metal shall be impact tested in accordance with the requirements of the material that the reinforcing bar is attached to.

(b) The acceptance criteria of the material requiring impact testing shall be met.

9 EXAMINATION OF SPLICES

(a) Bar ends and splice sleeves shall be visually examined prior to assembly for cleanliness and proper end preparation in accordance with CC-5320.

(b) Bars shall be marked with a suitable marker to indicate depth of insertion into splice. After completion, the actual depth of insertion shall be checked for compliance with 3 by means of this mark.

(c) Proper assembly, torque and swaging pressure shall be checked for compliance with the installation procedure described in the Construction Specification.

(d) One splice of each 100 production splices shall be disassembled, inspected for compliance with 3, and all threads rechecked with the manufacturer's thread gage.

10 SPLICE MATERIAL

10.1 Bar-to-Bar Splice Material. The material to be used for sleeves in swaged splice with threaded ends bar-to-bar splices shall conform to CC-2310(b).

10.2 Welding Material. The material to be used for sleeves in swaged splice with threaded ends attached by welding to the liner or structural steel elements shall be carbon steel conforming to CC-2310(c).

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Approval Date: September 17, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-795
Alternative Requirements for BWR Class 1 System Leakage Test Pressure Following Repair/Replacement Activities
Section XI, Division 1

Inquiry: What alternative to the pressure corresponding to 100% rated reactor power, of IWB-5221(a), may be used during a BWR Class 1 system leakage test following repair/replacement activities?

Reply: It is the opinion of the Committee that as an alternative to the pressure corresponding to 100% rated reactor pressure required by IWB-5221(a), the following requirements shall be met for a BWR Class 1 system leakage test, following repair/replacement activities.

(a) A system leakage test (IWB-5220) shall be conducted at a test pressure of at least 87% of the pressure required by IWB-5221(a).

(b) The system shall be maintained at this pressure during the required hold time and the performance of the VT-2 visual examination, except as provided by IWA-5245.

(c) This alternative test pressure may not be used to satisfy the requirements of Table IWB-2500-1, Category B-P.

(d) This alternative test pressure may not be used to satisfy pressure test requirements following repair/replacement activities on the reactor vessel.

(e) A test condition holding time, after pressurization to test conditions, before the visual examinations commence, shall be as follows:

(1) 15 min holding time for noninsulated components

(2) 6 hr holding time for insulated components

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Approval Date: October 18, 2010
(ACI) Approval Date: October 23, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-796
Threaded Sleeves With Parallel Threads Cut on Upsized Bar Ends
Section III, Division 2

Inquiry: What requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems, when threaded sleeves with parallel threads[1] cut on upsized bar ends, as described in Section 3.3.15 of ACI 439.3R-07, are used?

Reply: It is the opinion of the Committee that the following requirements may be used in the construction of concrete containments complying with the rules of Section III, Division 2, for the materials used for reinforcing bar splices, and the qualification and performance testing of reinforcing bar splice systems when a threaded sleeve with parallel threads cut on upsized bar ends is used.

The type of splice listed below is permitted within the limitations described in the following:

1 QUALIFICATIONS, RECORDS AND IDENTIFYING STAMPS

1.1 Required Qualifications. Each constructor or fabricator is responsible for the splicing made by their organization and they shall conduct the tests required by this Case in order to qualify the splicing procedure and the splicers.

1.2 Maintenance and Certification of Records. The constructor or fabricator shall maintain a record of the splicing procedure and the splicers qualified and employed by them, showing the date and results of tests, and the identification mark or marks assigned to each splicer. These records shall be reviewed, verified, and signed by an authorized individual assigned by the constructor. The records shall be accessible to the owner and to the authorized inspector.

1.3 Splicing Prior to Qualification. No splicing shall be undertaken until a splicer has been qualified. Only splicers who are qualified in accordance with para. 4 shall be used.

2 SPLICE SYSTEM QUALIFICATION REQUIREMENTS FOR THREADED SLEEVES WITH PARALLEL THREADS CUT ON UPSIZED BAR ENDS

2.1 General Requirements. Each splice system manufacturer shall conduct a series of performance tests on each type of coupler in order to qualify the system for use.

2.2 Materials to Be Used for Performance Tests. The types of materials to be used for the performance test splices shall be the same as those intended for use in production splices. The actual materials used and the necessary dimensions of the test specimens shall be documented.

2.3 Type and Number of Performance Tests.

(a) Static Tensile Tests. Six splice specimens for each reinforcing bar size and splice type to be used in construction shall be tensile tested to failure using the loading rate set forth in SA-370. The static tensile tests shall be repeated for each bar grade to be used in construction. One of the six specimens shall be tested at 20°F (−7°C) or less. A tensile test on an unspliced specimen from the same bar used for the spliced specimens shall be performed to establish actual tensile strength. The average tensile strength of the splices shall not be less than 90% of the actual tensile strength of the reinforcing bars being tested, nor less than 100% of the specified minimum tensile strength of the bar. The tensile strength of an individual splice specimen shall not be less than 125% of the specified minimum yield strength of the spliced bar. Each

[1] The term *threaded sleeves with parallel threads cut on upsized bar ends* is defined as a mechanical splice comprised of a steel coupler with parallel internal threads that is used to connect the threaded ends of reinforcing bars, those bar ends having been enlarged by cold forging prior to threading.

individual test report of both the spliced and unspliced specimens shall include at least the following information:

(1) tensile strength

(2) total elongation

(3) load-extension curve to the smaller of 2% strain or the strain at 125% of the specified minimum yield strength of the reinforcing bar

The gage length for each pair of spliced and unspliced specimens shall be the same, and equal to the length of the splice assembly plus not less than one bar diameter nor more than three bar diameters at each end. One of the splice specimens shall be cold soaked for a minimum of 24 hr prior to testing at a temperature equal to or less than the temperature required for this test. The test temperature at the root of the critical thread shall be 20°F (−7°C) or less and maintained until the specimen reaches yield load level.

(b) Cyclic Tensile Tests. Three specimens of the bar-to-bar splice for each reinforcing bar size, grade and splice type to be used in construction shall be subjected to a low cycle tensile test. Each specimen shall withstand 100 cycles of stress variation from 5% to 90% of the specified minimum yield strength of the reinforcing bar. One cycle is defined as an increase from the lower load to the higher load and return.

2.4 Essential Variables. The performance tests shall be completely reconducted when any of the following applicable changes listed below are made. Changes other than those listed may be made without the necessity for repeating the performance tests:

(a) a change in splice sleeve material or grade

(b) a reduction in the cross-sectional area of the coupler

(c) a reduction in the bar engagement length

(d) an increase in reinforcing bar grade

(e) a change in thread geometry

(f) a change in torque

(g) a change in the cold forging die geometry

(h) a reduction in the minimum required length of lock nuts used

3 REQUIREMENTS FOR PRODUCTION SPLICING PROCEDURES

All production splicing shall be performed in accordance with a written procedure, which shall include, as a minimum, the procedures used for the performance tests in 2.3, with the following additional information:

(a) type of equipment and methods used to verify bar thread acceptability

(b) cleanliness requirements

(c) type of equipment and methods used for torquing

(d) required force and method of measurement

(e) method of mechanically locking the position splices

(f) method used to verify the final alignment and engagement of the coupler on both bars

4 INITIAL QUALIFICATION TESTS

Each splicer shall prepare two qualification splices on the largest bar size for each type of coupler to be used. The qualification splices shall be made using reinforcing bar identical to that to be used in the structure. The completed qualification splices shall be tensile tested using the loading rates set forth in SA-370 and the tensile results shall meet those specified in Table CC-4333-1.

5 CONTINUING SPLICE PERFORMANCE TESTS

5.1 Introduction. A continuing series of tests shall be made to ensure that production splices meet the tensile requirements. Nondestructive examination requirements are specified in 10.

5.2 Splice Samples. Samples shall be assembled in accordance with the splicing procedure required by 3. Splice samples shall be straight sister splices (removable splices made in place next to production splices and under the same conditions), in accordance with the schedule established in 5.3.

5.3 Testing Frequency. Splice samples shall be tensile tested in accordance with the following schedule. Separate test cycles shall be established for each bar size, bar grade, and coupler type, using straight sister splices as follows:

(a) one of the first ten splices

(b) one of the next 90 splices

(c) two of the next and subsequent units of 100 splices

In addition, a minimum of three tests shall be made for each bar heat.

5.4 Tensile Testing Requirements. Samples shall be tensile tested at 20°F (−7°C) or less using the loading rates set forth in SA-370. The following shall constitute the acceptance standards:

(a) The tensile strength of each sample shall equal or exceed 125% of the specified minimum yield strength as shown in Table CC-4333-1.

(b) The average tensile strength of each group of 15 consecutive samples shall equal or exceed the specified minimum tensile strength as shown in Table CC-4333-1.

If any tested sample fails to meet the provisions of (a) or (b), the requirements of 5.5 shall be followed.

5.5 Substandard Tensile Test Results.

(a) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor or Fabricator. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing frequency required by 5.3.

(b) If any splice used for testing fails to meet the strength requirement of Table CC-4333-1 and failure does not occur in the bar, two additional splices shall be tested. If either of these retests fails to meet the tensile requirement of Table CC-4333-1, splicing shall be halted. Splicing shall not be resumed until the cause of failures has been corrected and resolved.

(c) If the running average tensile strength of 15 consecutive samples fails to meet the tensile requirements of Table CC-4333-1, splicing shall be halted. The Constructor or Fabricator shall investigate the cause and make the necessary corrective action.

(d) When splicing is resumed, the testing frequency shall be started anew.

6 RECORDING OF TENSILE TEST RESULTS

The results of all tensile tests obtained from the tests prescribed by 4 and 5, along with all other pertinent data, shall be recorded.

7 WELDING

Welding of splice sleeves to parts shall be performed using welding procedures and welders qualified in accordance with AWS D1.1 or Section IX. Welding material requirements are specified in CC-2600.

8 IMPACT REQUIREMENTS

When reinforcing bar or mechanical splices are to be welded to material that requires impact testing, the following shall apply:

(a) The weld filler metal shall be impact tested in accordance with the requirements of the material that the reinforcing bar is attached to.

(b) The acceptance criteria of the material requiring impact testing shall be met.

9 SPLICE MATERIAL

The material to be used for threaded sleeves with parallel threads shall conform to ASTM A513, A519 or A576.

The material to be used for threaded sleeves with parallel threads attached to liner plates or structural steel shapes shall be carbon steel conforming to ASTM A513, A519 or A576 Grades 1008 through 1030.

10 EXAMINATION OF SPLICES

(a) Bar ends and splice sleeves shall be visually examined prior to assembly for cleanliness.

(b) Threads shall be checked with a manufacturer's thread gage.

(c) Bars shall be marked with a suitable marker to indicate depth of insertion into the splice. After assembly, the actual depth of insertion shall be checked for compliance with 3 by means of this mark.

(d) Proper assembly and torque shall be checked for compliance with the installation procedure described in the Construction Specification.

(e) One splice of each 100 production splices shall be disassembled, inspected for compliance with CC-4333.3 and all threads rechecked with the Manufacturer's thread gage.

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Approval Date: December 20, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-798
Alternative Pressure Testing Requirements for Class 1 Piping Between the First and Second Vent, Drain, and Test Isolation Devices
Section XI, Division 1

Inquiry: What alternative to the extended pressure test boundaries of IWB-5222(b) may be used for the portion of Class 1, vent, drain, and test piping between the first and second isolation devices that normally remain closed during plant operation?

Reply: It is the opinion of the Committee that, for portions of Class 1 vent, drain, and test piping between the first and second isolation devices that normally remain closed during plant operation, only the boundaries of IWB-5222(a) shall apply.

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Approval Date: December 20, 2010

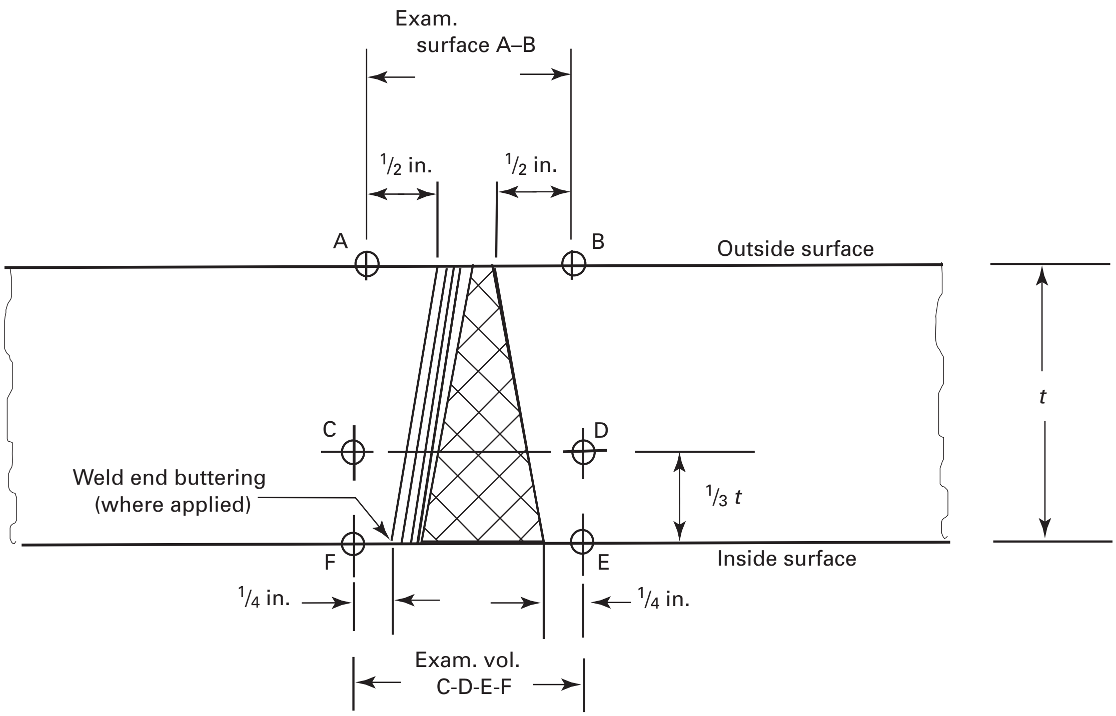
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-799
Dissimilar Metal Welds Joining Vessel Nozzles to Components
Section XI, Division 1

Inquiry: What requirements may be used for examination of dissimilar metal welds between reactor vessel nozzles and pumps and between steam generator nozzles and pumps?

Reply: It is the opinion of the Committee that the requirements of Examination Category B-F may be applied to dissimilar metal welds between reactor vessel nozzles and pumps and between steam generator nozzles and pumps. Where an alternative joint configuration is used (with the weld crown on the inside surface), the examination requirements shall be as shown in Figure 1.

Figure 1
Alternative Configuration for NPS 4 (DN 100) or Larger
($\frac{1}{2}$ in. = 13 mm, $\frac{1}{4}$ in. = 6 mm)



GENERAL NOTE: When weld end buttering is present on both sides, the examination surface and volume shall be measured from the end of both butterings. It may include remnants of replaced welds, and may appear artificially deep on exposed surfaces due to fabrication processes. Buttering thickness may be determined from manufacturer's drawings or assumed to be $\frac{1}{2}$ in. if the true dimension is unknown.

Approval Date: December 20, 2010

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-800
Alternative Pressure Testing Requirements for Class 1 Piping Between the First and Second Injection Valves Section XI, Division 1

Inquiry: What alternative to the extended pressure test boundaries of IWB-5222(b) may be used for that portion of the Class 1 boundary between the first and second isolation valves in the injection and return path of Class 2 safety systems?

Reply: It is the opinion of the Committee that for portions of the Class 1 boundary between the first and second isolation valves in the injection and return path of standby safety systems, the system leakage test may be conducted by pressurization of the Class 1 volume using the Class 2 safety system to pressurize the volume. Such alternative tests shall be performed each inspection interval. The system leakage test shall be conducted using the pressure associated with the Class 2 system function that provides the highest pressure between the Class 1 isolation valves.

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Approval Date: August 12, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-801-1
Rules for Repair of N-Stamped Class 1, 2, and 3 Components by Organization Other Than the N Certificate Holder That Originally Stamped the Component Being Repaired
Section III, Division 1

Inquiry: For the period of time between component N-stamping[1] and the Owner's filing of the N-3 Data Report, what rules may be used for repairs to N-stamped components?

Reply: It is the opinion of the Committee that for the period of time between Component stamping and the Owner's filing of the N-3 Data Report, the rules of this Case may be used for repairs to N-Stamped Class 1, 2, or 3 components.

An N Certificate Holder may perform repairs to the component in accordance with Section III under the following conditions:

(a) The scope of the Certificate of Authorization for the organization performing the repair shall include construction of the type and Code class of the component to be repaired.

(b) The N Certificate Holder performing the repair shall review the component Design Specification and Design Report, stress analysis, or applicable design rules to determine the required repair parameters. This review shall be documented and certified by a Registered Professional Engineer (RPE). If this review results in a need to revise the Design Specification or Design Report,[2] these documents shall be revised prior to completion of the Code Data Report described in this Case. When required, these revisions shall also be certified by an RPE. RPEs shall be qualified in accordance with the edition of Section III referenced in the Design Specification. Alternatively, the RPE may be qualified in accordance with Appendix XXIII of the 2007 or later Edition of Section III, Division 1. The revision of any design documents shall be reconciled with the Design Report.

(c) The N Certificate Holder performing the repair shall complete the repair under the provisions of the Section III Edition and Addenda required by the Design Specification.

(d) The N Certificate Holder performing the repair shall document the repair on Code Data Report Form N-10 and attach or reference supporting documentation to describe the repair. The certification of Data Report N-10 indicates that the N Certificate Holder performing the repair assumes responsibility for Code compliance of the repair as described in the Data Report.

(e) Unless otherwise stated herein, the component shall be subjected to pressure testing as required by NB-6000, NC-6000, or ND-6000 as applicable following the repair. Where the component has already been installed, the hydrostatic test pressure would exceed the test pressure requirements of the piping system in which the component is installed, and the component cannot be isolated for testing, the repair shall be tested to the piping system pressure test requirements. The test pressure shall be documented on the Code Data Report completed by the N Certificate Holder performing the repair.

(f) The N Certificate Holder's QA program (including the Quality Assurance Manual) shall describe the controls for performing repair of N-stamped components. These controls shall include the requirements for materials, fabrication, examination, inspection, testing, certification and documentation of the repairs.

(g) All of the requirements of the Design Specification and the Code Edition and Addenda applicable to the construction of the component shall be met except for pressure testing which may be performed as described in (e).

(h) The use of this Case shall be documented on the Code Data Report completed by the N Certificate Holder performing the repair. In addition, the Code Data Report completed by the N Certificate Holder performing the repair shall be attached to, or referenced on the Data Report of the N Certificate Holder who originally stamped the component, or shall be referenced on an attachment to the original Data Report.

[1] The term "N-Stamp" is intended to include the "Certification Mark and appropriate certification mark designator."

[2] The term *Design Report* shall be taken to mean Stress Report or Stress Analysis as appropriate to the edition of Section III for the component being repaired.

(i) Stamping of the repaired component by the N Certificate Holder performing the repair shall not be required.

(j) The Authorized Nuclear Inspector shall review plans for repairs conducted under this Case and perform required in-process inspections and a final review of the completed repair prior to signing the Code Data Report.

FORM N-10 REPORT FOR REPAIRS TO STAMPED COMPONENTS*
As Required by the Provisions of Section III, Division 1, Code and Code Case N-801

Pg. 1 of 2

1. Owner ______ 1 ______ Date ______ 2 ______
(Name)
______ Sheet __3__ of ______
(Address)

2. Plant ______ 4 ______ Unit ______ 5 ______
(Name)
______ ______ 6 ______
(Address) (Repair Organization P.O. No., Job No., etc.)

3. Work Performed by ______ 7 ______ N Symbol Stamp No. ______ 8 ______
______ Expiration Date ______ 9 ______
(Address)

4. (a) Section III Edition/Addenda and Class of component being repaired ______ 10 ______
(b) Section III Cases used in construction of component being repaired ______ 11 ______
(c) Section III Edition/Addenda and Class used for repair ______ 12 ______
(d) Section III Cases used for repair ______ 13 ______

5. Identification of Components Repaired

Name of Component Repaired	Name of Manufacturer	Manufacturer's Serial Number	National Board Number	Other Information	Year Built
14	15	16	17	18	19

6. Description of Work: ______ 20 ______

7. Tests Conducted: Hydrostatic ☐ Pneumatic ☐ System Leakage ☐ Exempt ☐ Other ☐ Test Pressure ______ 21 ______

Attach supplemental pages as required.

*Supplemental information in the form of lists, sketches, or drawings may be used, provided: (1) size is $8^1/_2$ in. X 11 in.; (2) information in items 1 through 6 on this Data Report is included on each sheet; and (3) each sheet is numbered and the number of sheets is recorded at the top of this form.

FORM N-10 (Back — Pg. 2 of 2)

8. Original Design Specification
   Certified by ________ 22 ________ P.E. State ________ Reg. No. ________
   Original Design Report
   Certified by ________ 23 ________ P.E. State ________ Reg. No. ________

9. Revised Design Specification
   Certified by ________ 24 ________ P.E. State ________ Reg. No. ________
   Revised Design Report
   Certified by ________ 25 ________ P.E. State ________ Reg. No. ________

10. Remarks ________ 26 ________

Upon completion, this Data Report Form and all attachment sheets shall be attached to the original Data Report for the component receiving the described repair.

CERTIFICATE OF COMPLIANCE

I certify that the statements made in this report are correct and that this repair conforms to the requirements of Case N-801 and the Case required provisions of ASME Section III, Division 1. Further, I certify that the repair described in this Data Report remains in compliance with the Design Specification and Design Report described above, or, if necessary, the Design Specification and Design Report have been revised in accordance with the requirements of ASME Section III, Division 1.

N-Type Symbol Stamp ____ N ________ 27 ________

Certificate Of Authorization No. ________ 28 ________ Expiration Date ________

Signed ________ 29 ________ Date ________
(Representative of Organization Performing Repair)

CERTIFICATE OF INSPECTION

I certify that the statements made in this report are correct and that this repair conforms to the requirements of Case N-801 of ASME Section III, Division 1.

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by ________ 30 ________ of ________ 31 ________, and state to the best of my knowledge and belief, the Certificate Holder has performed the repair on this component in accordance with Case N-801 and the Case required provisions of the ASME Code, Section III, Division 1.

By signing this certificate neither the inspector nor his employer makes any warranty, expressed or implied, concerning the component described in this Data Report. Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ____ 32 ____ Signed ________ 33 ________ Commission ________ 34 ________
(ANI's Signature) {National Board Number and Endorsement]

Table N-10-1
Guide for Completing Form N-10

References to Circled Numbers in the Form	Description
(1)	The name and address of the Owner of the nuclear power plant.
(2)	The date this form was prepared.
(3)	Enter sheet number and total number of sheets comprising this Data Report package.
(4)	The name and address of the nuclear power plant where the work documented on this Data Report was performed.
(5)	The Owner's designated unit identification number.
(6)	A unique identification of the documentation authorizing the work (i.e., repair package no., work order no., NCR disposition work authorization no., etc.).
(7)	The name and address of the Certificate Holder performing the work (should be as indicated on the organization's Certificate of Authorization).
(8)	N-Symbol Stamp number (as indicated on the organization's Certificate of Authorization).
(9)	The expiration date of the Certificate of Authorization (as indicated on the organization's Certificate of Authorization).
(10)	The Code year and addenda applicable to the edition of Section III for the item receiving the work. Include Code Class of construction, as appropriate.
(11)	Record any Code Cases (including revision) used in the original construction of this item.
(12)	The Code year and addenda applicable to the repair of the item. Include Code Class of construction, as appropriate.
(13)	Record any Code Cases (including revision) used in the repair of this item.
(14)	The name of the item as described on the Data Report provided by the manufacturer who originally stamped the item.
(15)	Name of the manufacturer as described on the Data Report provided by the manufacturer who originally stamped the item.
(16)	The serial number of the item as described on the Data Report provided by the manufacturer who originally stamped the item.
(17)	National Board Number assigned to the item as described on the Data Report provided by the manufacturer who originally stamped the item.
(18)	Other appropriate identification (e.g., State or Province number, plant assigned designator) taken from drawings or other records.
(19)	Year the item was manufactured as described on the Data Report provided by the manufacturer who originally stamped the item.
(20)	A brief narrative of the work performed.
(21)	Indicate the appropriate pressure test performed following the repair. Include the test pressure.
(22)	Name, State of registration and registration number of the Registered Professional Engineer (RPE) who certified the original Design Specification.
(23)	Name, State of registration and registration number of the Registered Professional Engineer (RPE) who certified the original Design Report (or Stress Report or Stress Analysis as appropriate).
(24)	Name, State of registration and registration number of the Registered Professional Engineer (RPE) who certified the revised Design Specification, if applicable.
(25)	Name, State of registration and registration number of the Registered Professional Engineer (RPE) who certified the revised Design Report (or Stress Report or Stress Analysis as appropriate), if applicable.
(26)	Additional information necessary to describe the work performed. Describe any change from the original construction requirements.
(27)	Information pre-entered since only N Certificate Holders are allowed to perform this work.
(28)	Enter the N-Symbol Stamp number and expiration date of the organization performing the work.
(29)	Signature and title of the individual representing the organization performing the work and that is certifying the accuracy of the contents of the Data Report and its attachments. Include date of signature.
(30)	The name of the Inspector's employer, the Authorized Inspection Agency.
(31)	The address of the Authorized Inspection Agency (City/Town and State or Province).
(32)	The date (month, day, year) that the Authorized Nuclear Inspector signed the Data Report.
(33)	The Authorized Nuclear Inspector's signature.
(34)	The Inspector's National Board commission number and endorsement must be shown.

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Approval Date: February 25, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-803
Similar and Dissimilar Metal Welding Using Ambient Temperature Automatic or Machine Dry Underwater Laser Beam Welding (ULBW) Temper Bead Technique
Section XI, Division 1

Inquiry: In lieu of the preheat and postweld heat treatment requirements of IWA-4400, may the automatic or machine dry ULBW temper bead technique be used without use of preheat or postweld heat treatment on Class 1, 2, or 3 components?

Reply: It is the opinion of the Committee that, in lieu of the preheat and postweld heat treatment requirements of IWA-4400, the materials and welds specified in 1(a) may be repaired using the automatic or machine dry ULBW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code, when it is impractical to drain the component or is impractical for radiological reasons. All other requirements of IWA-4000[1] shall be met, except as modified by this Case.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair of P-Nos. 1, 3, 12A, 12B, and 12C[2] materials, and their associated welds and welds joining P-No. 8 or 43 materials to P-Nos. 1, 3, 12A, 12B, and 12C materials, with the following limitations. Use of this Case is restricted to welding that employs A-No. 8 or F-No. 43 filler materials. This Case shall not be used to repair SA-302, Grade B material, unless the material has been modified to include 0.4% to 1.0% nickel, quenching and tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld based on the finished surface over the ferritic material shall be 500 in.^{2} (325 000 mm^2), and the depth of the weld shall not be greater than one-half of the ferritic base metal thickness.

(c) Repair/replacement activities on a dissimilar metal weld in accordance with this Case are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm), or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Case, provided the depth of repair in the base material does not exceed $^3/_8$ in. (10 mm).

(e) Prior to welding the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

(f) Welding materials shall meet the Owner's Requirements and the Construction Code specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Except on the initial and final layers, peening may be used.

(h) The terms and definitions of AWS D3.6M-99, "Specification for Underwater Welding," shall be used.

(i) This Case applies only to Dry ULBW.

(j) Use of waterproof or supplemental coatings for the filler metal is prohibited.

(k) Consideration shall be given to the effects of irradiation on the properties of material, including weld material, for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

2 WELDING QUALIFICATIONS

The welding procedures and welding operators shall be qualified in accordance with Section IX, except as modified by the requirements of 2.1 and 2.2.

[1] The references to Section XI in this Case refer to the 2010 Edition. For use of this Case with other Editions and Addenda, refer to Table 2.
[2] P-No. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later Edition of Section IX.

2.1 PROCEDURE QUALIFICATION

2.1.1 Essential Variables.

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number, as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded.

(b) Welding qualifications shall address the effects of welding in a pressurized environment in accordance with Table 1.

(c) A change in the method for underwater transport and storage of filler material (e.g., from sealed packages to exposed).

(d) A change in the nominal background gas composition.[3]

(e) For P-Nos. 1, 3, 12A, 12B, and 12C materials, a decrease in the minimum distance from the point of welding to the wetted surface in any direction, when the minimum distance is less than 6 in. (150 mm).

2.1.2 Nonessential Variables.

(a) A change in the method of protecting, removing moisture from, or otherwise conditioning bare filler metal in the underwater environment.

2.1.3 Additional Qualification Test Requirements.

(a) The root width and included angle of the cavity in the test assembly shall be no greater than the minimum specified for the repair.

(b) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(c) The test assembly cavity depth shall be at least one-half the depth of the weld to be installed during the repair/replacement activity. The test assembly thickness shall be at least twice the test assembly cavity depth, and shall be at least 1 in. (25 mm). The minimum qualified base metal thickness shall be equal to the test assembly thickness, and the maximum qualified base metal thickness shall be unlimited. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Figure 1.

(d) Ferritic base material for the procedure qualification test shall meet the impact test requirements of the Construction Code and Owner's requirements. If such requirements are not in the Construction Code and Owner's requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in (f), but shall be in the base metal.

(e) Charpy V-notch testing of A-No. 8 and F-No. 43 weld metal of the procedure qualification is not required.

(f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (d). Number, location, and orientation of test specimens shall be as follows:

(1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(2) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(3) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation, and location of all test specimens shall be reported in the Procedure Qualification Record.

(g) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be no less than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Case, either of the following shall be performed.

(1) The welding procedure shall be requalified.

(2) An *Adjustment Temperature* for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of the 2001 Edition with the 2002 Addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the *Adjustment Temperature*.

2.2 PERFORMANCE QUALIFICATION

Welding operators shall be qualified in accordance with Section IX and the following additional essential variables:

(a) a change in depth beyond that qualified in accordance with Table 1.

(b) a change in welding mode (i.e., dry chamber, dry spot, or habitat).

[3] Background gas is gas that displaces water and is not necessarily intended to shield the arc. The gas might or might not be breathable.

Table 1
Depth Limitations for Underwater Welding Qualification

Type of Welding	Maximum Depth Qualified [Note (1)]	Minimum Depth Qualified [Note (2)]
Dry ULBW	*D* plus 33 ft (10 m)	*D* minus 33 ft (10 m)

GENERAL NOTES:
(a) *D* is qualification test depth.
(b) A change in depth beyond the range qualified in accordance with Table 1 requires requalification.

NOTES:
(1) For the maximum depth qualified, depth shall be measured from the lower extremity of the test weldment with a tolerance of plus or minus 9 in. (230 mm).
(2) For the minimum depth qualified, depth shall be measured from the upper extremity of the test weldment with a tolerance of plus or minus 9 in. (230 mm).

3 WELDING PROCEDURE REQUIREMENTS

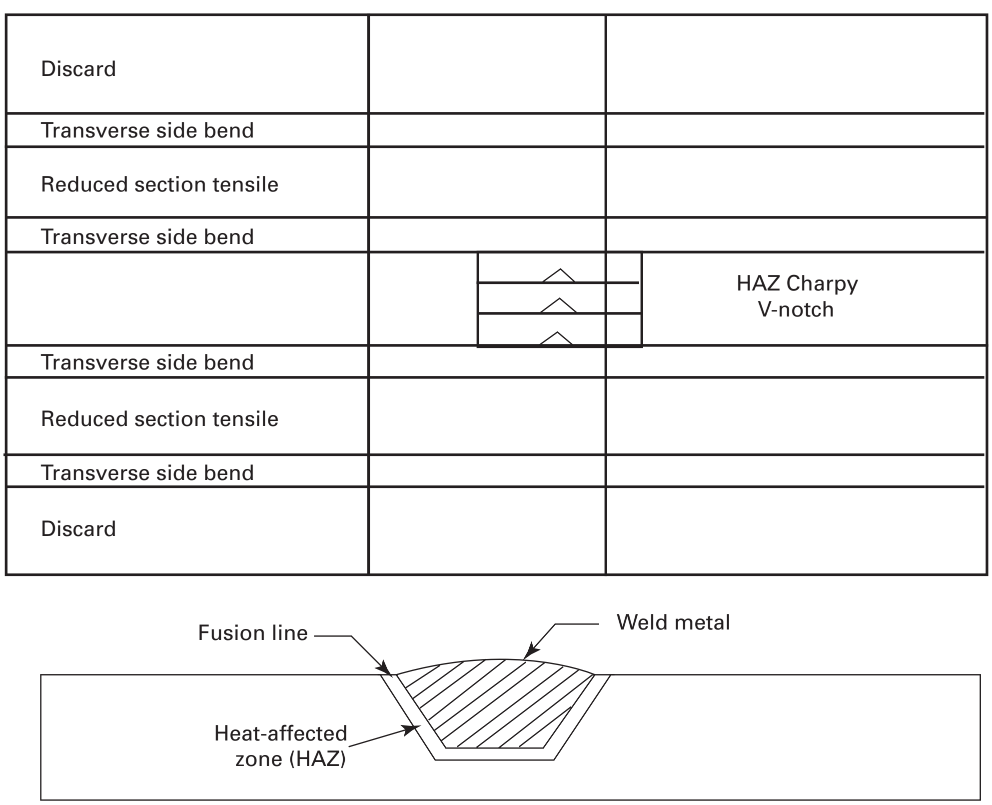
The Welding Procedure Shall Include the Following Requirements:

(a) The weld metal shall be deposited by the automatic or machine, dry ULBW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (QW-442) for P-No. 8 to P-Nos. 1, 3, or 12A, 12B, or 12C weld joints or F-No. 43 weld metal (QW-432) for P-No. 8 or 43 to P-Nos. 1, 3, or 12A, 12B, or 12C weld joints. Only A-No. 8 and F-No. 43 filler materials are permitted by this Case.

(c) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least $^1/_8$ in. (2 mm), overlay thickness, as shown in Figure 2, Steps 1 through 3, with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. The heat input of the first three layers shall not

Figure 1
Qualification Test Plate



GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

Table 2
References for Alternative Editions and Addenda of Section XI

2001 Edition Through 2010 Edition	1995 Edition With the 1997 Addenda Through the 1998 Edition With the 2000 Addenda	1995 Edition With the 1995 Addenda Through 1995 Edition With 1996 Addenda	1989 Edition With the 1991 Addenda Through the 1995 Edition	1983 Edition With the Winter Addenda Through 1989 Edition With the Addenda	1980 Edition With the 1981 Winter Addenda Through the 1983 Edition With the 1983 Summer Addenda
IWA-2210 Visual Examination	IWA-2210	IWA-2210	IWA-2210	IWA-2210	IWA-2210
IWA 2300 Qualifications of Nondestructive Examination Personnel	IWA-2300	IWA-2300	IWA-2300	IWA-2300	IWA-2300
IWA 4000 Repair/Replacement Activities	IWA-4000	IWA-4000	IWA-4000	IWA-4000 and IWA-7000	IWA-4000 and IWA-7000
IWA-4411 Welding, Brazing, Fabrication and Installation	IWA-4421(a)	IWA-4410(a)	IWA-4170(b)	IWA-4210(a)	IWA-4120

exceed 45,000 J/in. under any conditions. Particular care shall be taken in placement of the weld layers at the weld toe area of the ferritic material to ensure that the HAZ is tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers, regardless of the interpass temperature used during qualification.

(e) The interpass temperature shall be determined by direct measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding. If direct measurement is impractical (e.g., because of geometric limitations or radiological reasons), interpass temperature shall be determined in accordance with (1) or (2).

(1) heat flow calculations using the following variables as a minimum:

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

(-e) time per weld pass and delay time between each pass

(-f) time to complete the weld

(2) measurement of the maximum interpass temperature on a test coupon that is equal to or less than the thickness of the item to be welded. The maximum heat input of the welding procedure shall be used in the welding of the test coupon.

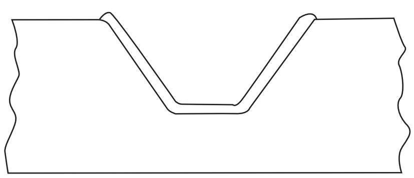
(f) The dry underwater laser welding process entails welding in close proximity to water. The essential variables imposed by this Case ensure acceptable moisture levels within the mechanical barrier that isolates the weld pool from the surrounding water. In addition to these essential variables, particular care shall be taken to ensure that the weld region is cleaned to bright metal, to ensure it is free of deleterious material that could constitute a potential hydrogen source. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4 EXAMINATION

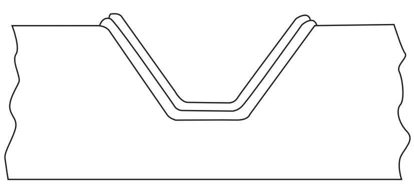
(a) Except as permitted in (1), the following examinations shall be performed in accordance with the Construction Code or Section III.

(1) Prior to repair welding, surface examination shall be performed on the area to be welded. When surface examination is impractical, VT-1 visual examination may be performed, provided the requirements of (b) are met.

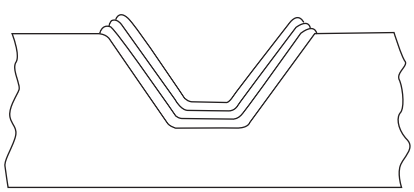
Figure 2
Dry ULBW



Step 1: Deposit layer one with first layer parameters used in qualification.



Step 2: Deposit layer two with second layer weld parameters used in qualification [Note (1)].



Step 3: Deposit layer three with third layer weld parameters used in qualification [Note (2)].

NOTES:
(1) Particular care shall be taken in application of the second layer at the weld toe to ensure that the HAZ of the base metal is tempered.
(2) Particular care shall be taken in application of the third layer at the weld toe to ensure that the HAZ of the base metal is tempered.

(2) The weld shall be nondestructively examined after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. Examination of the welded region shall include volumetric and surface examination methods.

(3) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(4) Acceptance criteria for surface and volumetric examination shall be in accordance with the Construction Code or Section III.

(b) VT-1 visual examinations performed in accordance with (a)(1) shall meet the following:

(1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving text with lower case characters (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (600 mm).

(2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

(3) Visual examination acceptance standards shall comply with the following:

(-a) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width.

(-b) Only indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) shall be considered relevant. The following relevant indications are unacceptable:

(-1) any cracks or linear indications

(-2) rounded indications with major dimensions greater than $^3/_{16}$ in. (5 mm)

(-3) four or more rounded indications in a line separated by $^1/_{16}$ in. (1.5 mm) or less edge to edge.

(-4) ten or more rounded indications in any 6 in.^{2} (4 000 mm^2) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated.

Approval Date: October 14, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-804
Alternative Preheat Temperature for Austenitic Welds in P-No. 1 Material Without PWHT
Section III, Division 1

Inquiry: Under what conditions may austenitic welds in P-No. 1, Group 1 or 2 materials be made using lower preheat temperatures than those specified in Tables NB-4622.7(b)-1, NC-4622.7(b)-1, ND-4622.7(b)-1, NE-4622.7(b)-1, NF-4622.7(b)-1, and NG-4622.7(b)-1?

Reply: It is the opinion of the Committee that, as an alternative to the minimum preheat temperature specified in Tables NB-4622.7(b)-1, NC-4622.7(b)-1, ND-4622.7(b)-1, NE-4622.7(b)-1, NF-4622.7(b)-1, and NG-4622.7(b)-1, preheat is not required for fillet or partial-penetration welds of nominal thickness $^3/_4$ in. (19 mm) or less in P-No. 1, Gr. 1 or 2 material over $1^1/_2$ in. (38 mm) thick, under the following conditions.

(a) Maximum reported carbon content of carbon steel base material shall be 0.30 or less.

(b) Weld filler material shall be austenitic.

(c) The provisions of this Case shall not be applied to vessels or tanks.

(d) Use of this Case shall be documented in the applicable Certificate Holder's Data Report.

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Approval Date: February 25, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-805
Alternative to Class 1 Extended Boundary End of Interval or Class 2 System Leakage Testing of the Reactor Vessel Head Flange O-Ring Leak-Detection System
Section XI, Division 1

Inquiry: What alternative to the requirements of IWB-5222(b) or IWC-5220 may be used when performing system leakage tests of the reactor vessel head flange O-ring leak-detection system?

Reply: It is the opinion of the Committee, that the following alternative to IWB-5222(b) or IWC-5220 may be applied for testing of the reactor vessel head flange O-ring leak detection system. The Class 1 or 2 portions of the leak-detection system shall be examined using the VT-2 visual examination method. The test shall be conducted at ambient conditions after the refueling cavity has been filled to its normal refueling water level for at least 4 hr.

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Approval Date: June 22, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-806
Evaluation of Metal Loss in Class 2 and 3 Metallic Piping Buried in a Back-Filled Trench
Section XI, Division 1

Inquiry: What methods may be used to evaluate Class 2 and 3 metallic piping items (e.g., pipe and fittings) buried in a back-filled trench with metal loss on the internal or external surfaces?

Reply: It is the opinion of the Committee that the following methods may be used to evaluate Class 2 and 3 metallic piping items buried in a back-filled trench with metal loss on the internal or external surfaces.

1 SCOPE

(a) These requirements apply to Section III, B31.1, and B31.7 metallic piping classified by the Owner as Class 2 or 3 and buried in a back-filled trench. The provisions of this Case do not apply to the following:

(1) cast iron piping items

(2) leakage through a piping item or piping joint

(3) a cracked piping item or piping joint

(b) The *Level 1* evaluation criteria apply to any piping item within the scope of (a).

(c) The *Level 2* evaluation criteria apply to pipe, elbows, and bends, including welded joints. The *Level 2* evaluation criteria also apply to adjoining fittings and flanges to a distance of $(R_o t_{\mathrm{nom}})^{1/2}$ from the weld centerline, where R_o is the outside radius of the piping item and t_{nom} is the nominal wall thickness of the piping item specified in the applicable industry standard.

(d) The evaluation criteria apply to lined, unlined, coated, and uncoated piping items. Credit for strength of the lining or coating is not permitted.

2 PROCEDURE

(a) The geometry of the metal loss region shall be characterized in accordance with 3.

(b) The length of the evaluation period, τ_{ev}, during which the evaluation remains valid shall be established.

(c) The rate of metal loss during the evaluation period shall be determined in accordance with 3. The rate of metal loss analysis shall consider the relevant mechanisms, such as general corrosion or wastage. The analysis shall project the metal loss region to the end of the evaluation period.

(d) If multiple metal loss regions are detected, the interaction and combined area of metal loss in a given pipe section shall be accounted for in the evaluation. Concurrent metal loss on both the inside and outside surfaces, as applicable, in a given pipe section shall be accounted for in the evaluation.

(e) The projected metal loss region at the end of the evaluation period shall be evaluated using the acceptance standards of 4. One of two levels of analytical evaluation of the metal loss region shall be used, as follows.

(1) Level 1 evaluation of 5 requires that the piping item meets the design requirements.

(2) Level 2 evaluation of 6 is based on use of engineering equations to demonstrate that requirements based on internal pressure loading, soil and surcharge loads, bending moments, axial forces, and transverse forces are met.

(f) Subsequent examination of the metal loss region shall be performed no later than the end of the evaluation period. If examinations reveal the metal loss does not meet the acceptance criteria of this Case, a repair/replacement activity shall be performed.

(g) Examination or repair/replacement activity of the affected piping item shall be performed no later than when the metal loss region is projected to no longer meet the acceptance criteria of 4.

3 CHARACTERIZATION OF METAL LOSS

(a) Current wall thickness of the metal loss region, t_c, shall be characterized by volumetric thickness measurement or by physical measurement. The condition of the full pipe circumference shall be assessed and the metal loss region shall be inspected to characterize the extent of degradation.

(b) An evaluation shall be performed to determine the cause of metal loss. The rate of metal loss during the evaluation period shall be determined, and shall include the

relevant metal loss mechanisms determined in the cause evaluation. The rate of metal loss shall account for concurrent internal and external corrosion, as applicable, at the affected location, based on the conditions on the internal and external surfaces. Metal loss regions due to concurrent internal and external corrosion are illustrated in Figure 1.

(c) The projected future metal loss during the evaluation period, Δt_{ml}, shall be calculated as follows:

$$\Delta t_{ml} = (F_{ml,\text{I.D.}} R_{ml,\text{I.D.}} + F_{ml,\text{O.D.}} R_{ml,\text{O.D.}})\,\tau_{ev} \tag{1}$$

where

$F_{ml,\text{I.D.}}$ = factor to account for uncertainty in predicted rate of metal loss on the internal surface, dimensionless
$F_{ml,\text{O.D.}}$ = factor to account for uncertainty in predicted rate of metal loss on the external surface, dimensionless
$R_{ml,\text{I.D.}}$ = predicted rate of metal loss during the evaluation period on the internal surface, in./yr (mm/yr)
$R_{ml,\text{O.D.}}$ = predicted rate of metal loss during the evaluation period on the external surface, in./yr (mm/yr)
Δt_{ml} = projected future metal loss during the evaluation period, in. (mm)
τ_{ev} = length of the evaluation period, yr

Determination of predicted rates of metal loss and factors to account for uncertainties in predicted metal loss shall be the responsibility of the Owner.

(d) The projected distribution of wall thickness of the metal loss region at the end of the evaluation period, t_p, shall be determined. The projected wall thickness of the metal loss region may have a different value at any given location within the metal loss region.

$$t_p = t_c - \Delta t_{ml} \tag{2}$$

where

t_c = current wall thickness of the metal loss region, in. (mm)
t_p = projected wall thickness of the metal loss region at the end of the evaluation period, in. (mm)

The minimum value of t_p anywhere in the metal loss region is $t_{p,\min}$.

(e) The projected wall thickness of the material surrounding the metal loss region at the end of the evaluation period, $t_{p,\text{pipe}}$, shall be determined.

(f) If there is evidence that the rate of metal loss is greater than projected, the metal loss evaluation shall be updated. The metal loss evaluation may also be updated if the rate of metal loss is less than projected.

4 ACCEPTANCE STANDARDS

(a) Analytical evaluation of the metal loss region shall be performed in accordance with either 5 or 6.

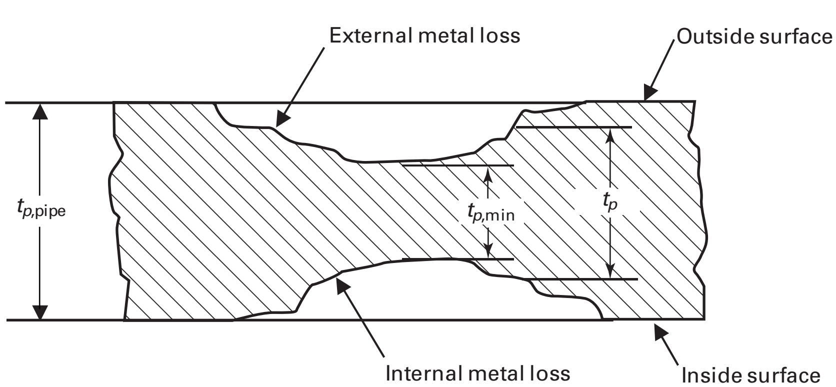
(b) The minimum value of projected wall thickness at the end of the evaluation period, $t_{p,\min}$, shall be at least 0.1 in. (2.5 mm).

(c) For axial or circumferential extent of wall loss greater than the allowable diameter of an unreinforced opening in accordance with the Construction Code, the minimum value of projected wall thickness at the end of the evaluation period, $t_{p,\min}$, shall be at least 20% of the nominal wall thickness specified in the applicable industry standard for the piping item.

5 LEVEL 1 ANALYTICAL EVALUATION

The piping item shall meet the design requirements of the Construction Code, assuming uniform wall thickness equal to $t_{p,\min}$.

Figure 1
Illustration of Metal Loss Regions Due to Concurrent Internal and External Corrosion



6 LEVEL 2 ANALYTICAL EVALUATION

The metal loss region shall be evaluated in accordance with 6.1, 6.2, 6.3, and 6.4. The interaction and combined area of concurrent metal loss on both the inside and outside surfaces, as applicable, in a given pipe section shall be accounted for in the evaluation.

6.1 EVALUATION FOR INTERNAL PRESSURE

(a) The minimum wall thickness of a straight section of pipe, elbow, or bend, exclusive of tolerances and any allowances for corrosion, for pressure shall be calculated using

$$t_{\min} = \frac{P_D D_o}{2(SE + 0.4P_D)} \tag{3}$$

where

D_o = nominal outside diameter of the piping item, in. (mm)
E = longitudinal weld joint efficiency factor for Class 3 piping items, 1.0 for other piping items, dimensionless
P_D = Design Pressure, psi (MPa)
S = allowable stress for Class 2 and 3 components at the Design Temperature, psi (MPa)

(b) The requirements of either 6.1.1 or 6.1.2 shall be met.

6.1.1 Evaluation of General Metal Loss

(a) Evaluation of general metal loss, for any axial or circumferential extent, shall be based on both an average, and a minimum, wall thickness of the metal loss region at the end of the evaluation period.

(b) The metal loss region shall be at a distance that is greater than or equal to $(Rt_{\min})^{1/2}$ from a structural discontinuity, such as a welded component, flange, branch connection or tee, where R is the mean radius of the piping item at the end of the evaluation period.

(c) An average current wall thickness of the metal loss region, $t_{c,\text{avg}}$, shall be calculated. The procedures of Nonmandatory Nonmandatory Appendix A of this Case may be used to calculate $t_{c,\text{avg}}$. An average wall thickness of the metal loss region at the end of the evaluation period, $t_{p,\text{avg}}$, shall be calculated by substitution of $t_{c,\text{avg}}$ for t_c in eq. 3(d)(2). Alternatively, $t_{p,\text{avg}}$ may be assumed to be equal to $t_{p,\min}$.

(d) The values of $t_{p,\text{avg}}$ and $t_{p,\min}$ shall satisfy the following:

$$t_{p,\text{avg}} \geq t_{\min} \tag{4}$$

$$t_{p,\min} \geq 0.5t_{\min} \tag{5}$$

6.1.2 Evaluation of Local Metal Loss Region

(a) A local metal loss region is illustrated in Figure 2. With the exception of $t_{\min}$, the dimensions in Figure 2 correspond to the end of the evaluation period, and are defined as follows:

L = maximum extent of local metal loss region with wall thickness less than $t_{p,\text{pipe}}$ at the end of the evaluation period, in. (mm)
L_m = maximum extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
$L_{m(a)}$ = maximum axial extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
$L_{m(t)}$ = maximum circumferential extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
$t_{p,\text{pipe}}$ = wall thickness of the material surrounding the local metal loss region at the end of the evaluation period, in. (mm)
t_p = projected wall thickness of the local metal loss region at the end of the evaluation period, and which may vary along the local metal loss region, in. (mm)

(b) The minimum projected wall thickness of the metal loss region at the end of the evaluation period shall satisfy

$$t_{p,\min} \geq t_{\text{aloc}} \tag{6}$$

where

t_{aloc} = pressure-based minimum allowable local wall thickness of the metal loss region, in. (mm)

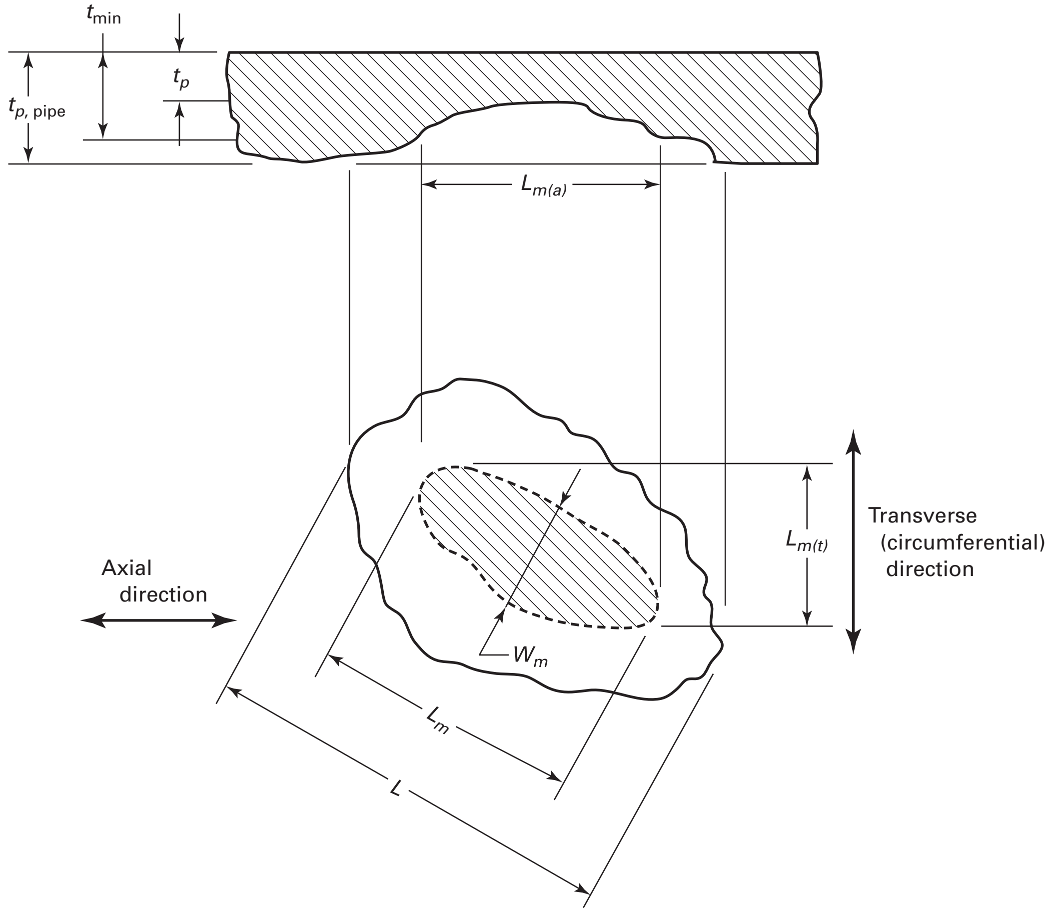
(c) The procedures of 6.1.2.1, 6.1.2.2, 6.1.2.3, or 6.1.2.4 shall be used to determine the allowable local wall thickness, t_{aloc}, depending on the circumferential and axial extents of the local metal loss region, as well as the location of the local metal loss region in the case of metal loss in an elbow or bend. The classification of circumferential and axial extent is relative to the characteristic dimension $(R_{\min}t_{\min})^{1/2}$, where $R_{\min}$ is the mean radius of the piping item based on outside radius, R_o, and $t_{\min}$.

$$R_{\min} = R_o - \frac{t_{\min}}{2} \tag{7}$$

(1) Limited Circumferential Extent. With reference to Figure 2, the allowable local wall thickness may be calculated in accordance with 6.1.2.1 if the circumferential extent, $L_{m(t)}$, of the local metal loss region projected to be less than $t_{\min}$ does not exceed $(R_{\min}t_{\min})^{1/2}$.

(2) Limited Axial and Circumferential Extent. The allowable local wall thickness may be calculated in accordance with 6.1.2.2 if the maximum extent, L_m, of local

Figure 2
Illustration of Local Metal Loss Region



wall thickness projected to be less than t_{min} is less than or equal to 2.65 $(R_{min}t_{min})^{1/2}$ and $t_{p,\text{pipe}}$ is greater than $1.13t_{min}$.

(3) Unlimited Circumferential Extent. The allowable local wall thickness may be calculated in accordance with 6.1.2.3 if the circumferential extent, $L_{m(t)}$, of the local metal loss region projected to be less than t_{min} exceeds $(R_{min}t_{min})^{1/2}$.

(4) Local Metal Loss Region on Outer Portion of Elbow or Bend. The geometry of an elbow or bend is illustrated in Figure 3. For a local metal loss region on the outer portion of an elbow or bend and farther than $(R_{min}t_{min})^{1/2}$ from an adjacent piping item, the allowable local wall thickness may be calculated in accordance with 6.1.2.4.

(d) If any portion of a local metal loss region is on the inner portion of an elbow or bend, and is farther than 1.5 $(Rt_{p,\text{pipe}})^{1/2}$ from an adjacent piping item, the pressure-based evaluation wall thickness for the inner portion of an elbow or bend, exclusive of tolerances and any allowances for corrosion, shall be calculated using

$$t_{\min,eb} = t_{\min}\left[0.5 + \frac{0.5}{1 + \frac{\cos\phi}{(R_b/R_o)}}\right] \tag{8}$$

where

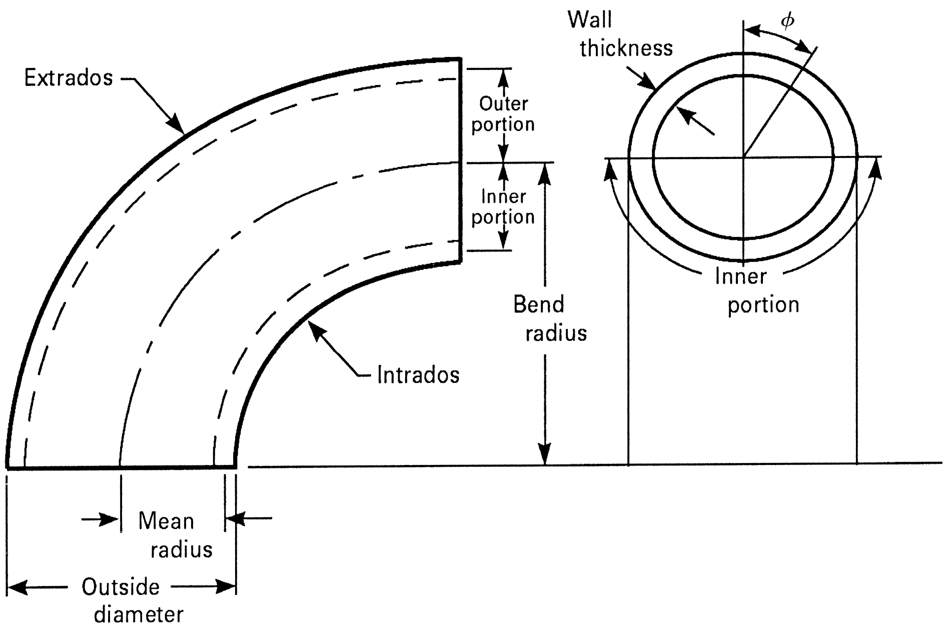
R_b = bend radius of the elbow or bend to the elbow or bend centerline, in. (mm)

R_o = outside radius of the piping item adjacent to the metal loss region, in. (mm)

ϕ = angle from the extrados of the elbow or bend to the boundary of the local metal loss region that is closest to the intrados, as measured in the pipe circumferential cross-section, see Figure 3, radians

The value of $t_{\min,eb}$ shall be no less than t_{min} from eq. 6.1(a)(3). In the evaluations of 6.1.2.1, 6.1.2.2, and 6.1.2.3, $t_{\min,eb}$ shall be used in place of t_{min} unless otherwise specified.

Figure 3
Geometry and Nomenclature for an Elbow and Bend



6.1.2.1 Local Metal Loss Region with Limited Circumferential Extent. With reference to Figure 2, if the circumferential extent, $L_{m(t)}$, of the local metal loss region projected to be less than t_{min} does not exceed $(R_{min}t_{min})^{1/2}$, the allowable local wall thickness shall be calculated in accordance with (a) and (b).

(a) With reference to Figure 4, the wall thickness between adjacent local metal loss regions shall exceed t_{min} for a length that is the greater of $2.5(Rt_{p,\text{pipe}})^{1/2}$ or $2L_{m,\text{avg}}$ of the adjacent local metal loss regions. The parameter $L_{m,\text{avg}}$ is the average of the maximum extents of wall thickness less than t_{min} for the adjacent local metal loss regions.

$$L_{m,\text{avg}} = \frac{L_{m,i} + L_{m,j}}{2} \tag{9}$$

where

$L_{m,i}$ = Lm for local metal loss region i, in. (mm)
$L_{m,j}$ = Lm for local metal loss region j, in. (mm)

Alternatively, the adjacent local metal loss regions shall be combined and evaluated as one metal loss region. Combination of adjacent local metal loss regions into an equivalent single local metal loss region shall be based on dimensions and extents prior to any combination of adjacent local metal loss regions. These requirements for adjacent local metal loss regions shall apply to any two adjacent local metal loss regions on the inside surface, on the outside surface, or to one local metal loss region on the inside surface and the other local metal loss region on the outside surface.

(b) The pressure-based minimum allowable local wall thickness of the metal loss region, t_{aloc}, shall be determined from the ratio of t_{aloc}/t_{min} that is given as a function of $L_{m(a)}/(Rt_{min})^{1/2}$ by Curve 1 of Figure 5, where $L_{m(a)}$ is the axial extent of the local metal loss region with wall thickness projected to be less than t_{min}.

6.1.2.2 Local Metal Loss Region with Limited Axial and Circumferential Extent. With reference to Figure 2, if the maximum extent, L_m, of local wall thickness projected to be less than t_{min} is less than or equal to $2.65(R_{min}t_{min})^{1/2}$, and $t_{p,\text{pipe}}$ is greater than $1.13t_{min}$, the allowable local wall thickness shall be calculated in accordance with (a) and (b).

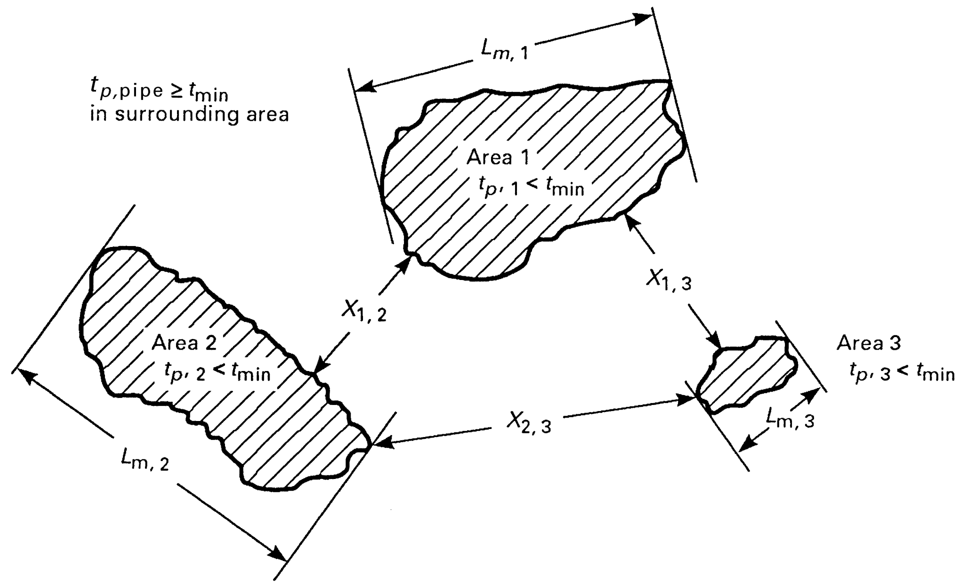
(a) The proximity requirements for adjacent local metal loss regions for *Limited Circumferential Extent* in 6.1.2.1(a) shall be applied to *Limited Axial and Circumferential Extent* of the local metal loss region.

(b) The value of pressure-based minimum allowable local wall thickness of the metal loss region, t_{aloc}, shall be equal to the greater of t_{aloc1} of (1) and t_{aloc2} of (2).

(1) The value of t_{aloc1} is given by eq. (10)

$$t_{\text{aloc1}} = 0.353\,L_m\left(\frac{t_{\min}}{R_{\min}}\right)^{1/2} \tag{10}$$

Figure 4
Separation Requirements for Adjacent Local Metal Loss Regions with Limited Circumferential Extent

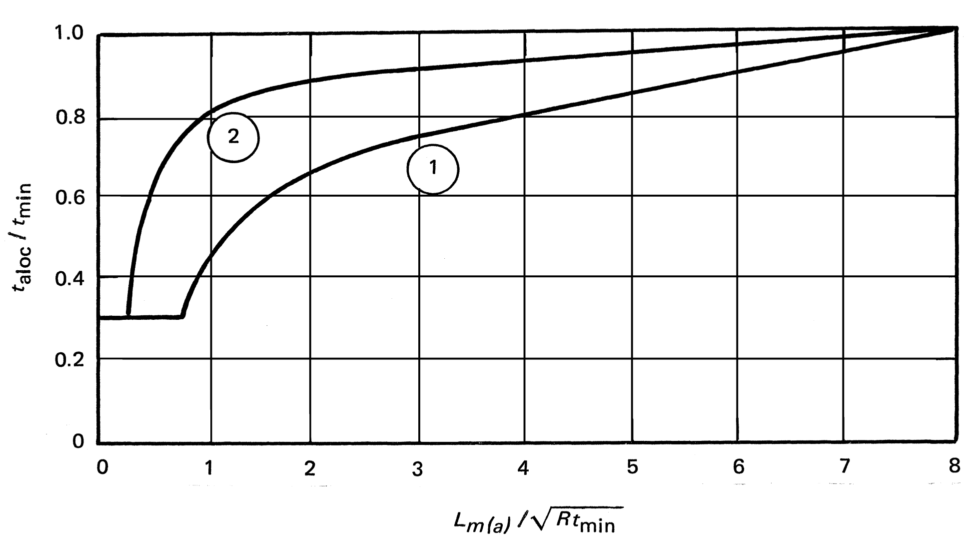


$X_{i,j}$ = minimum distance between areas i and j
$L_{m,i}$ = maximum extent of thinned area i
$L_{m,\text{avg}}$ = 0.5 $(L_{m,i} + L_{m,j})$
GENERAL NOTE: Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to combination.

For a local metal loss region on any portion of an elbow of bend, t_{min} in eq. (10) is given by eq. 6.1(a)(3).

(2) With reference to Figure 2, a surrounding reinforcement zone with projected wall thickness of at least $t_{p,\text{pipe}}$ is required for a distance no less than the larger of $L/2$ or $0.75(R_{min}t_{min})^{1/2}$ in all directions. If these

Figure 5
Allowable Wall Thickness and Length of Local Metal Loss Region



requirements are satisfied, the value of t_{aloc2} that provides adequate area reinforcement of the local metal loss region is given by

$$t_{\text{aloc2}} = t_{\min} - 1.5\frac{(R_{\min}t_{\min})^{1/2}}{L}(t_{p,\text{pipe}} - t_{\min}) \tag{11}$$

This procedure shall not be applied to adjacent local metal loss regions where the reinforcement zones for each local metal loss region overlap. As an alternative, area reinforcement may be evaluated in accordance with the Construction Code.

6.1.2.3 Local Metal Loss Region with Unlimited Circumferential Extent. With reference to Figure 2, if the circumferential extent, $L_{m(t)}$, of the local metal loss region projected to be less than t_{min} exceeds $(R_{min}t_{min})^{1/2}$, the allowable local wall thickness shall be calculated in accordance with (a) and (b).

(a) With reference to Figure 6, the wall thickness between adjacent local metal loss regions shall exceed t_{min} for an axial distance that is the greater of $2.5(Rt_{p,\text{pipe}})^{1/2}$ or $2L_{m(a),\max}$ of the adjacent local metal loss regions. The parameter $L_{m(a),\max}$ is the maximum of the axial extents, $L_{m(a)}$, of wall thickness less than t_{min} for the adjacent local metal loss regions. Alternatively, the adjacent local metal loss regions shall be combined and evaluated as one metal loss region. Combination of adjacent local metal loss regions into an equivalent single local metal loss region shall be based on dimensions and extents prior to any combination of adjacent local metal loss regions. Local metal loss regions need not be combined into a single local metal loss region based on separation in the circumferential direction, provided the circumferential extents of individual adjacent local metal loss regions do not overlap. These requirements for adjacent local metal loss regions shall apply to any two adjacent local metal loss regions on the inside surface, on the outside surface, or to one local metal loss region on the inside surface and the other local metal loss region on the outside surface.

(b) The pressure-based minimum allowable local wall thickness of the metal loss region, t_{aloc}, shall be determined from the ratio of t_{aloc}/t_{min} that is given as a function of $L_{m(a)}/(Rt_{min})^{1/2}$ by Curve 2 of Figure 5, where $L_{m(a)}$ is the axial extent of the local metal loss region with wall thickness projected to be less than t_{min}.

6.1.2.4 Local Metal Loss Region in Outer Portion of Elbow or Bend. With reference to Figure 3, for a local metal loss region on the outer portion of an elbow or bend and farther than $(R_{min}t_{min})^{1/2}$ from an adjacent piping item, the allowable local wall thickness shall be calculated using

$$t_{\text{aloc}} = t_{\min}\left[0.5 + \frac{0.5}{1 + \frac{\cos\phi}{(R_b/R_{\min})}}\right] \tag{12}$$

6.2 EVALUATION FOR SOIL AND SURCHARGE LOADS

Evaluations of the metal loss region for soil and surcharge loads shall be performed for the following:

(a) Pipe ovality under soil and surcharge loads

(b) Compression of buried pipe walls

(1) circumferential through-wall ovality stress

(2) crushing compressive stress in side walls

(3) buckling due to external pressure

(4) effects of negative internal pressure

(c) Procedures for evaluation of the metal loss region for soil and surcharge loads are provided in Nonmandatory Appendix B of this Case.

6.3 EVALUATION OF LONGITUDINAL STRESSES

(a) The longitudinal stresses in the piping item at the location of the metal loss region shall be evaluated in accordance with the equations of the Construction Code used in the evaluation, and shall meet the requirements of the Construction Code. Stresses due to axial forces shall be added to the stresses due to internal pressure and bending moments in the equations of the Construction Code.

(b) The potential for shell buckling of the metal loss region due to compressive longitudinal stresses shall be evaluated.

(c) Changes in the piping item metal area, piping item inside area, section modulus, and stress indices or stress intensification factors, shall be evaluated in accordance with 6.3.1 and 6.3.2.

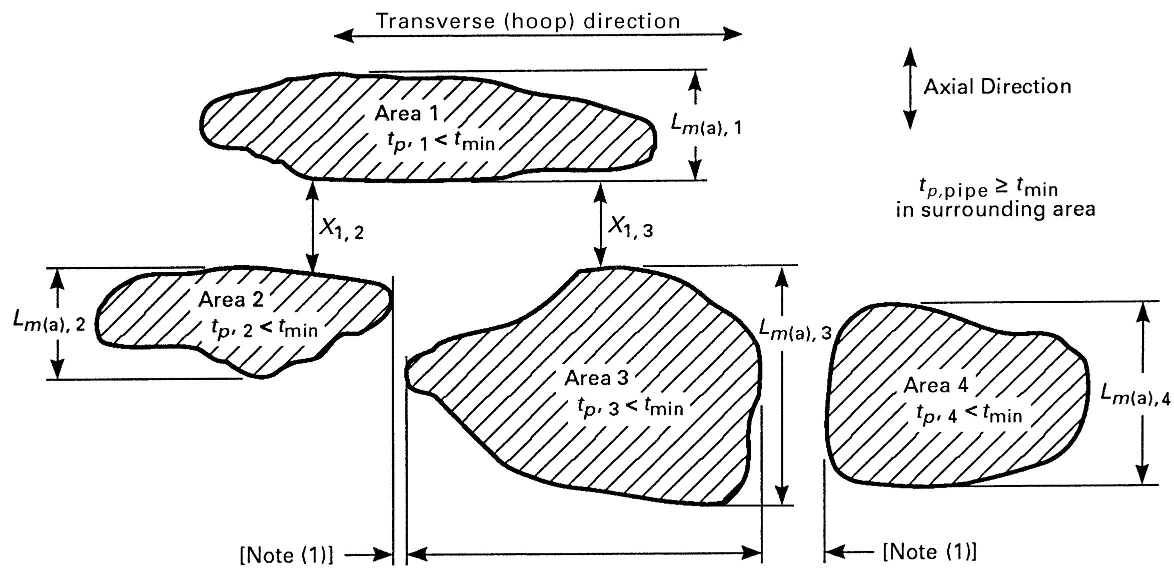
(d) The piping stress evaluation shall be based on the projected wall thickness at each cross-section of the piping item that contains a metal loss region or is affected by a change in stress index or stress intensification factor. Alternatively, the evaluation may be based on the limiting cross-section.

6.3.1 Properties of Circumferential Cross-Section of Piping Item

(a) The piping item may be assumed to have uniform metal loss with a wall thickness of $t_{p,\min}$, with the section properties of the cross-section of the piping item based on a uniformly thinned cross-section with wall thickness $t_{p,\min}$.

(b) As an alternative to (a), stress analysis may be performed for a piping item cross-section with a uniform wall thickness outside of the local metal loss region, as illustrated in Figure 7 for a local metal loss region on the inside surface. A conservative value for the wall thickness outside of the local metal loss region at the end of the evaluation period, $t_{p,\text{pipe}}$, shall be used. Section properties for this idealization of the cross-section of the piping item are provided in Nonmandatory Appendix C of this Case.

Figure 6
Separation Requirements for Adjacent Local Metal Loss Regions with Unlimited Circumferential Extent



$X_{i,j}$ = minimum distance between areas i and j at any circumferential location on pipe
$L_{m(a),i}$ = maximum extent of thinned area i in axial direction
L_{max} = maximum of the extents $L_{m(a),i}$ and $L_{m(a),j}$ of two adjacent areas

GENERAL NOTE: Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to any combination of adjacent areas.

NOTE:
(1) Areas need not be combined into single areas based on separation in the transverse (hoop) direction, provided that transverse extents of individual adjacent thinned areas do not overlap.

(c) When either (a) or (b) is applied, the minimum section modulus of the cross-section of the piping item containing the metal loss region, including consideration of the shift of the neutral axis of the cross-section containing the metal loss region, shall be calculated usings

$$Z_{\min} = \frac{I_{\min}}{R_o} \tag{13}$$

where

$I_{\min}$ = projected minimum moment of inertia of the cross-section of the piping item containing the metal loss region about the neutral axis, considering all orientations of the cross-section of the neutral axis, in.^{4} (mm^4)

(d) As an alternative to (a) and (b), detailed analysis may be performed based on the variation of wall thickness around the cross-section of the piping item containing the metal loss region.

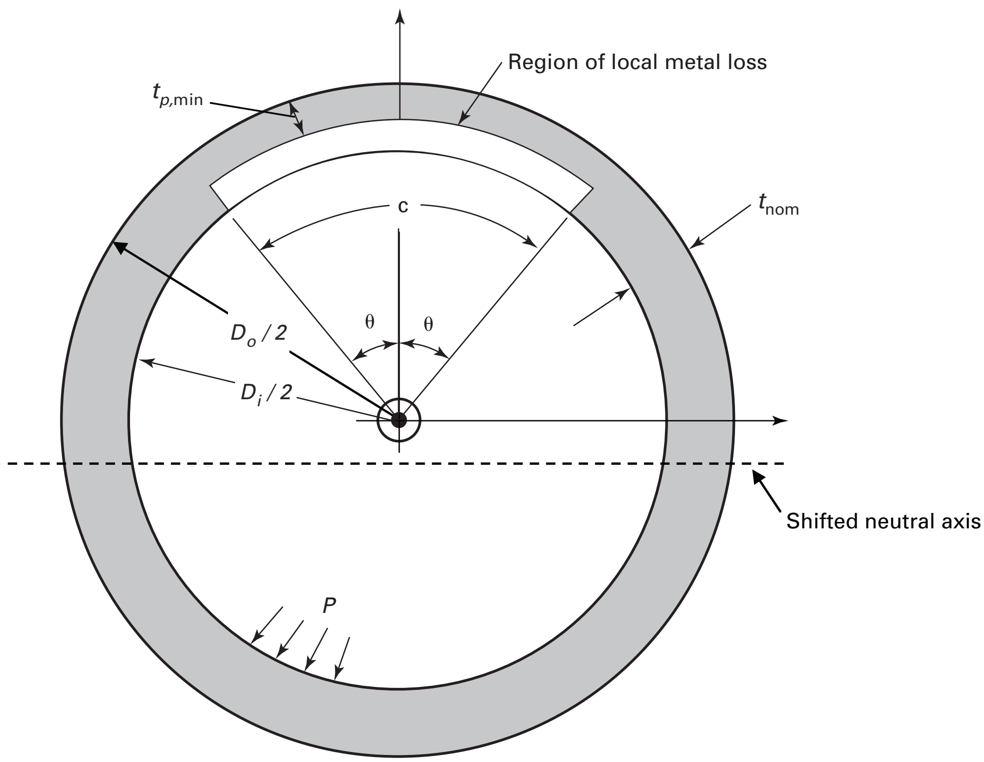
6.3.2 Stress Intensification Factors and Stress Indices

(a) Except as permitted in (b) or (c), stress intensification factors or stress indices for a piping item shall be based on the assumption of uniform metal loss using a wall thickness of $t_{p,\min}$ and an associated pipe mean radius in the equations for the stress intensification factors or stress indices.

(b) As an alternative (a), the stress intensification factors or stress indices may be based on the average value of the projected wall thickness of the metal loss region at the end of the evaluation period, t_p, excluding branch reinforcement zones, except that projected wall thickness at locations within a distance of twice the pipe wall thickness, $t_{p,\text{pipe}}$, from butt welds to adjacent components need not be considered.

(c) As an alternative to (a) and (b), detailed stress analysis of the piping item containing the metal loss region may be performed to evaluate the effects of metal loss on the stress distributions in the affected piping item.

Figure 7
Illustration of Local Metal Loss Region on the Inside Surface of a Pipe With a Shifted Neutral Axis



6.4 EVALUATION OF SHEAR STRESSES

(a) Shear loads and shear stresses in the piping item containing a metal loss region shall be calculated using a pipe-soil interaction model to represent the confining effect of the soil, and the interaction between buried pipe and its extension above the ground, if applicable. The modeling method of the 2010 Edition of B31.1, Appendix VII, "Procedures for the Design of Restrained Underground Piping," may be used.

(b) Shear loads shall be included in the evaluation. Shear loads that might be applicable to an evaluation include the following:

(1) differential seismic anchor motion

(2) frost heave

(3) non-seismic natural ground settlement and building settlement

(4) buoyancy and flotation

(c) The following equations shall be satisfied for the maximum shear loads for each service level.

$$\frac{V}{A_p} \le 0.6S_h \quad \text{for service Levels A, B, and C} \tag{14}$$

$$\frac{V}{A_p} \le 0.42S_u \quad \text{for Service Level D} \tag{15}$$

where

A_p = projected metal cross-sectional area of the piping item at the end of the evaluation period, in.^{2} (mm^2)
S_h = allowable stress at the temperature consistent with the loading under consideration, psi (MPa)
S_u = ultimate tensile strength of the material at the temperature consistent with the loading under consideration, psi (MPa)
V = shear load, lb (N)

7 ACRONYMS AND NOMENCLATURE

7.1 ACRONYMS

AWWA American Water Works Association
ASTM American Society for Testing and Materials

7.2 NOMENCLATURE

A_{cyl} = metal cross-sectional area of the piping item at the end of the evaluation period and as calculated in the absence of the local metal loss region, in.^{2} (mm^2)

A_f = cross-sectional area of the local metal loss region at the end of the evaluation period, in.^{2} (mm^2)
A_p = projected metal cross-sectional area of the piping item at the end of the evaluation period, in.^{2} (mm^2)
a = maximum depth of the local metal loss region at the end of the evaluation period, in. (mm)
B = length over which the wall thickness is averaged in the metal loss region, in. (mm)
B' = coefficient of elastic support of the piping item by surrounding soil, and may be obtained from AWWA M11, "Steel Water Pipe: A Guide for Design and Installation," dimensionless
b_L = surface length of the area over which the surface load is uniformly spread, in. (mm)
b_W = surface width of the area over which the surface load is uniformly spread, in. (mm)
c = length of the metal loss region in the circumferential direction, in. (mm)
D_f = diameter at the base of the local metal loss region at the end of the evaluation period, in. (mm)
D_i = inside diameter of the piping item at the end of the evaluation period, in. (mm)
D_L = deflection lag factor, and may be obtained from AWWA M11, dimensionless
D_o = nominal outside diameter of the piping item, in. (mm)
d = offset of concentrated surface load from the vertical centerline of the piping item, in. (mm)
E = longitudinal weld joint efficiency factor for Class 3 piping items, 1.0 for other piping items, dimensionless
E' = modulus of soil reaction, and may be obtained from AWWA M11, psi (MPa)
E_{pipe} = modulus of elasticity of the piping item, psi (MPa)
F' = impact factor applied to the surface load that accounts for the dynamic effect of the surface load, dimensionless
F_{surf} = concentrated or distributed load at the soil surface, lb (N)
$F_{ml,\mathrm{I.D.}}$ = factor to account for uncertainty in predicted rate of metal loss on the internal surface, dimensionless
$F_{ml,\mathrm{O.D.}}$ = factor to account for uncertainty in predicted rate of metal loss on the external surface, dimensionless
H_{BD} = burial depth of the piping item, from the soil surface to the top of the piping item, in. (mm)
h_W = height of water table above top of piping item, in. (mm)
I_{Lx} = moment of inertia of the area of the local metal loss region, A_{f}, about the local axis that is parallel to the x-x axis and intersects the centroid of the local metal loss region, at the end of the evaluation period, in.^{4} (mm^4)
$I_{\min}$ = projected minimum moment of inertia of the cross-section of the piping item containing the metal loss region about the neutral axis, considering all orientations of the cross-section of the neutral axis, in.^{4} (mm^4)
I_{TWP} = through-wall bending moment of inertia of the piping item per unit length at the end of the evaluation period, in.^{3} (mm^3)
I_x = moment of inertia of the cross-section of the piping item about the x-x axis at the end of the evaluation period and as calculated in the absence of the local metal loss region, in.^{4} (mm^4)
K = bedding constant, and may be obtained from AWWA M11, dimensionless
K_b = bending moment coefficient, may be obtained from AWWA C150, "Thickness Design of Ductile-Iron Pipe"
K_x = deflection coefficient, and may be obtained from AWWA C150
L = maximum extent of local metal loss region with wall thickness less than $t_{p,\mathrm{pipe}}$ at the end of the evaluation period, in. (mm)
L_m = maximum extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
$L_{m,\mathrm{avg}}$ = average of the maximum extents of wall thickness less than $t_{\min}$, L_m, for adjacent local metal loss regions at the end of the evaluation period, in. (mm)
$L_{m(a)}$ = maximum axial extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
$L_{m(a),\max}$ = maximum of the axial extents of wall thickness less than $t_{\min}$, $L_{m(a)}$, for adjacent local metal loss regions at the end of the evaluation period, in. (mm)
$L_{m(t)}$ = maximum circumferential extent of local metal loss region with wall thickness less than $t_{\min}$ at the end of the evaluation period, in. (mm)
M_s = constrained soil modulus, psi (MPa)
N = number of point measurements of wall thickness in the metal loss region, dimensionless
P_{cr} = critical buckling pressure for the piping item, psi (*MPa)*
P_D = Design Pressure, psi (MPa)
P_{gw} = hydrostatic pressure around the piping item due to groundwater, psi (MPa)
P_{neg} = negative internal pressure, where the numerical value is negative, psi (MPa)

P_{soil} = pressure at the top of the piping item due to weight of the trench fill, psi (MPa)
P_{SS} = pressure at the top of the piping item due to soil and surface loads, psi (MPa)
$P_{SS}{}'$ = total external pressure plus negative internal pressure, psi (MPa)
P_{surf} = pressure at the top of the piping item due to surface loads, psi (MPa)
Q = parameter used in the calculation of the length over which the wall thickness is averaged, dimensionless
R = pipe mean radius at the end of the evaluation period, in. (mm)
R_a = outside radius of the local metal loss region at the end of the evaluation period, in. (mm)
R_b = bend radius of the elbow or bend to the elbow or bend centerline, in. (mm)
R_{min} = mean radius of the piping item based on outside radius and t_{min}, in. (mm)
$R_{ml,\mathrm{I.D.}}$ = predicted rate of metal loss during the evaluation period on the internal surface, in./yr (mm/yr)
$R_{ml,\mathrm{O.D.}}$ = predicted rate of metal loss during the evaluation period on the external surface, in./yr (mm/yr)
R_o = outside radius of the piping item adjacent to the metal loss region, in. (mm)
R_W = buoyancy factor, dimensionless
S = allowable stress for Class 2 and 3 components, at the Design Temperature, psi (MPa)
S_h = allowable stress at the design temperature or the temperature consistent with the loading under consideration, psi (MPa)
S_y = specified yield strength of the material at the temperature consistent with the loading under consideration, psi (MPa)
S_u = specified ultimate tensile strength of the material at the temperature consistent with the loading under consideration, psi (MPa)
s = length of the metal loss region in the longitudinal direction in. (mm)
t_{aloc} = pressure-based minimum allowable local wall thickness of the local metal loss region, in. (mm)
t_{aloc1} = a value of t_{aloc} for protection against pressure blowout of a local metal loss region with limited axial and circumferential extent, in. (mm)
t_{aloc2} = a value of t_{aloc} for area reinforcement of a local metal loss region with limited axial and circumferential extent, in. (mm)
t_c = current wall thickness of the metal loss region, in. (mm)
$t_{c,\mathrm{avg}}$ = current average wall thickness of the metal loss region, in. (mm)
$t_{c,i}$ = current point measurements of wall thickness in the metal loss region, in. (mm)
$t_{c,\mathrm{min}}$ = minimum measured wall thickness of the metal loss region, in. (mm)
$t_{c,\mathrm{pipe}}$ = current wall thickness of the material surrounding the metal loss region, in. (mm)
t_{ev} = evaluation wall thickness of the piping item at the end of the evaluation period, in. (mm)
t_{min} = pressure-based minimum wall thickness of a straight section of pipe, elbow or bend, exclusive of tolerances and any allowances for corrosion, in. (mm)
$t_{\mathrm{min},eb}$ = pressure-based evaluation wall thickness for the inner portion of an elbow or bend, exclusive of tolerances and any allowances for corrosion, in. (mm)
t_{nom} = nominal wall thickness of the piping item specified in the applicable industry standard
t_p = projected wall thickness of the local metal loss region at the end of the evaluation period, and which may vary along the local metal loss region, in. (mm)
$t_{p,\mathrm{avg}}$ = average wall thickness of the metal loss region at the end of the evaluation period, in. (mm)
t_{pipe} = wall thickness of the material surrounding the metal loss region, in. (mm)
$t_{p,\mathrm{min}}$ = minimum value of projected wall thickness of the metal loss region at the end of the evaluation period, in. (mm)
$t_{p,\mathrm{pipe}}$ = wall thickness of the material surrounding the metal loss region at the end of the evaluation period, in. (mm)
Δt_{ml} = projected future metal loss during the evaluation period, in. (mm)
V = shear load, lb (N)
V_{AF} = vertical arching factor, dimensionless
W_{CL} = linear weight of coating and lining of the piping item per unit length, lb/in. (N/mm)
W_{pipe} = linear weight of piping item per unit length excluding the linear weight of fluid inside the piping item, lb/in. (N/mm)
W_w = linear weight of water displaced by the piping item, lb/in (N/mm)
X = surface width of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless
$\overline{y}$ = distance between the neutral axis of the cross-section of the piping item containing the metal loss region at the end of the evaluation period, $\overline{x} - \overline{x}$, and the axis *x-x*, *in. (mm)*
$\overline{y}_{Lx}$ = distance between the centroid of the metal loss region and the *x-x* axis at the end of the evaluation period, in. (mm)
Δy = out-of-round deflection of the cross-section of the piping item causing ovality, in. (mm)

Y = surface length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless

Z = parameter dependent on surface width and length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless

Z_1 = surface area over which the surface load is uniformly spread as normalized by the square of burial depth of the piping item, dimensionless

$Z_{\min}$ = minimum section modulus of the cross-section of the piping item containing the metal loss region, including consideration of the shift of the neutral axis of the cross-section containing the metal loss region, in.^{3} (mm^3)

α = parameter used to calculate the Coefficient of Variation (COV) of the wall thickness measurements, in.^{2} (mm^2)

ϕ = angle from the extrados of the elbow or bend to the boundary of the local metal loss region that is closest to the intrados, as measured in the pipe circumferential cross-section, see Figure 3, radians

Φ_H = hoop stiffness parameter, dimensionless

γ_S = unit weight of dry soil or trench fill, lb/in.^{3} (N/mm^3)

γ_W = unit weight of water above the top of the piping item, lb/in.^{3} (N/mm^3)

θ = one-half of the circumferential angular extent of the metal loss region, radians

η_t = wall thickness ratio used in the calculation of the length over which the wall thickness is averaged

σ_{TW} = through-wall bending stress due to ovalization of the piping item, psi (MPa)

τ_{ev} = length of the evaluation period, yr

Ω = ovality of the piping item cross-section, dimensionless

$\Omega_{\max}$ = maximum allowable ovality of the piping item cross-section, dimensionless

NONMANDATORY APPENDIX A
CALCULATION OF AVERAGE WALL THICKNESS IN METAL LOSS REGION

A-1 SCOPE

This Appendix may be used for calculation of average wall thickness in a metal loss region. Two procedures are provided:

(a) The first procedure is based on averaging point measurements of wall thickness in the metal loss region.

(b) The second procedure is based on determining average wall thickness based on Critical Thickness Profiles in the metal loss region.

A-2 PROCEDURE

(a) Current wall thickness, t_c, at a minimum of 15 grid points in the metal loss region shall be measured. A grid spacing of $2t_{nom}$ or less is acceptable, where t_{nom} is the nominal thickness of the piping item specified in the applicable industry standard.

(b) Average wall thickness may be calculated based on averaging point measurements of wall thickness in the metal loss region in accordance with A-3. The Coefficient of Variation (COV) of the wall thickness measurements shall be calculated. If the COV is no greater than 10%, the calculated average wall thickness may be used in the evaluation. If the COV is greater than 10%, additional wall thickness measurements shall be performed with smaller grid spacing to achieve a COV no greater than 10%.

(c) As an alternative to (b), average wall thickness may be calculated based on Critical Thickness Profiles in the metal loss region in accordance with A-4.

(d) If there are multiple metal loss regions under evaluation, the smallest average wall thickness from all of the metal loss regions shall be used in the evaluation.

A-3 AVERAGE WALL THICKNESS FROM POINT MEASUREMENTS OF WALL THICKNESS

(a) The current average wall thickness of the metal loss region based on point measurements of wall thickness shall be calculated using

$$t_{c,\text{avg}} = \frac{1}{N}\sum_{i=1}^{N} t_{c,i} \qquad \text{(A-1)}$$

where

N = number of point measurements of wall thickness in the metal loss region, dimensionless

$t_{c,i}$ = current point measurements of wall thickness in the metal loss region, in. (mm)

(b) The COV of the wall thickness measurements is defined as the standard deviation divided by the average, and shall be calculated using

$$COV = \frac{1}{t_{c,\text{avg}}}\left(\frac{\alpha}{N-1}\right)^{1/2} \qquad \text{(A-2)}$$

where

$$\alpha = \sum_{i=1}^{N}\left(t_{c,i} - t_{c,\text{avg}}\right)^2 \qquad \text{(A-3)}$$

A-4 AVERAGE WALL THICKNESS FROM CRITICAL THICKNESS PROFILES

A-4.1 CRITICAL THICKNESS PROFILES

(a) The location and length of the inspection planes and paths in both the longitudinal and circumferential directions shall be determined. Examples of longitudinal inspection planes M1, M2, and M3, and circumferential inspection planes C1, C2, and C3, for a straight section of pipe are illustrated in Figure A-1. Examples of longitudinal inspection paths M1, M2, and M3, and circumferential inspection planes C1, C2, and C3, for an elbow or bend are illustrated in Figure A-2

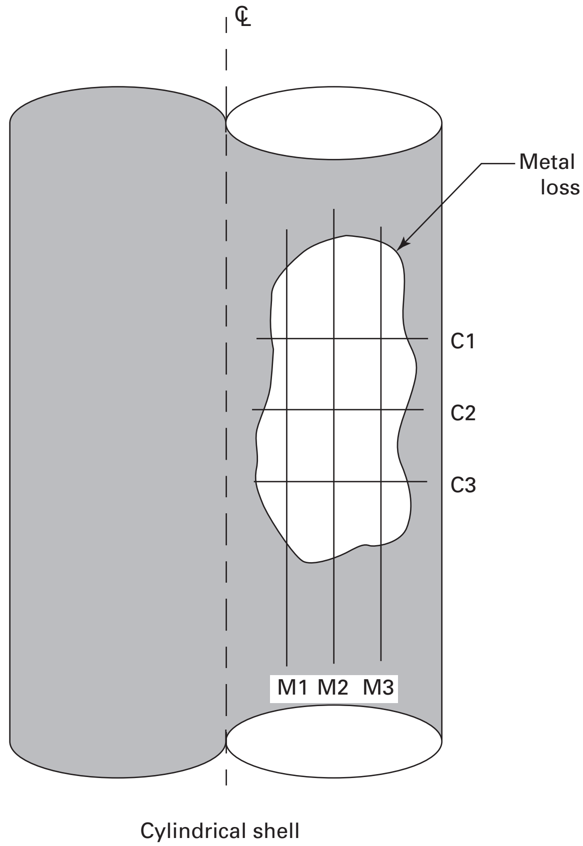
(b) The current wall thickness profile of the material surrounding the metal loss region, $t_{c,\text{pipe}}$, shall be determined.

(c) Wall thickness measurements in the metal loss region along each longitudinal and circumferential inspection plane or path shall be determined.

(d) The minimum measured wall thickness of the metal loss region, $t_{c,\min}$, shall be determined.

(e) The Critical Thickness Profiles in both the longitudinal and circumferential directions shall be determined by projecting the minimum wall thickness for each position along all parallel inspection planes or paths onto a common plane or path as illustrated by the example in Figure A-3. The length of the Critical Thickness Profile is given by the end point locations where the wall thickness is greater than or equal to $t_{c,\text{pipe}}$. With reference to Figure A-3, the Critical Thickness Profile in the longitudinal direction is given by projecting the minimum wall thickness at each

Figure A-1
Inspection Planes for Straight Sections of Pipe



GENERAL NOTE: M1, M2, and M3 are longitudinal inspection planes, and C1, C2, and C3 are circumferential inspection planes.

interval along the M1 through M5 inspection planes onto a common plane. The length of the metal loss region in the longitudinal direction, s, is determined using the Critical Thickness Profile and $t_{c,\text{pipe}}$ as shown in Figure A-3. The Critical Thickness Profile in the circumferential direction is given by projecting the minimum wall thickness at each interval along the C1 through C7 inspection planes onto a common plane. The length of the metal loss region in the circumferential direction, c, is determined using the Critical Thickness Profile and $t_{c,\text{pipe}}$ as shown in Figure A-3.

A-4.2 AVERAGE WALL THICKNESS

(a) The pressure-based minimum wall thickness, exclusive of tolerances and any allowances for corrosion, $t_{\min}$, shall be calculated in accordance with 6.1 of this Case.

(b) The projected minimum wall thickness of the metal loss region at the end of the evaluation period, $t_{p,\min}$, shall be determined in accordance with 3 of this Case.

(c) The wall thickness of the material surrounding the metal loss region at the end of the evaluation period, $t_{p,\text{pipe}}$, shall be determined.

(d) The wall thickness ratio, η_t, shall be calculated using

$$\eta_t = \frac{t_{p,\min}}{t_{p,\text{pipe}}} \tag{A-4}$$

(e) The length over which the wall thickness shall be averaged shall be calculated using

$$B = Q(D_i t_{p,\text{pipe}})^{1/2} \tag{A-5}$$

where

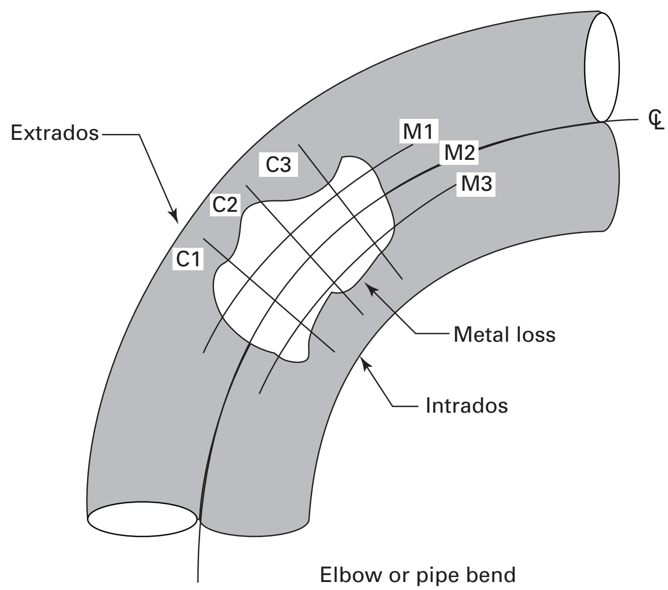
$$Q = 1.123\left[\left(\frac{1-\eta_t}{1-\dfrac{\eta_t}{0.9}}\right)^2 - 1\right]^{1/2} \quad \text{for } \eta_t < 0.9$$

$$Q = 50 \text{ for } \eta_t \geq 0.9 \tag{A-6}$$

and

B = length over which the wall thickness is averaged in the metal loss region, in. (mm)

Figure A-2
Inspection Planes and Paths for Elbows and Bends



GENERAL NOTE: M1, M2, and M3 are longitudinal inspection paths, and C1, C2, and C3 are circumferential inspection planes.

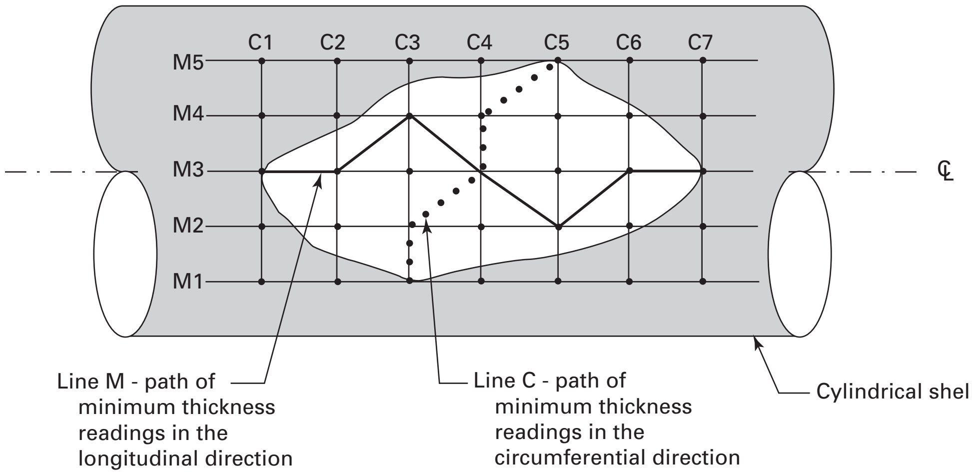
D_i = inside diameter of the piping item at the end of the evaluation period, in. (mm)

Q = parameter used in the calculation of the length over which the wall thickness is averaged, dimensionless

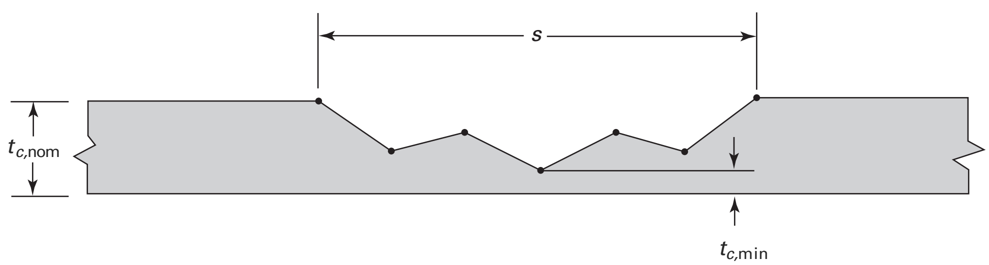
(f) The current average wall thickness of the Critical Thickness Profile in the longitudinal direction shall be calculated over the averaging length B. The current average wall thickness of the Critical Thickness Profile in the circumferential direction shall also be calculated over the averaging length B. The length B shall be located on each Critical Thickness Profile such that the calculated average wall thickness for the Critical Thickness Profile is a minimum.

(g) The current average wall thickness of the metal loss region, $t_{c,\text{avg}}$, shall be equal to the smaller of the average wall thickness values for the longitudinal and circumferential Critical Thickness Profiles.

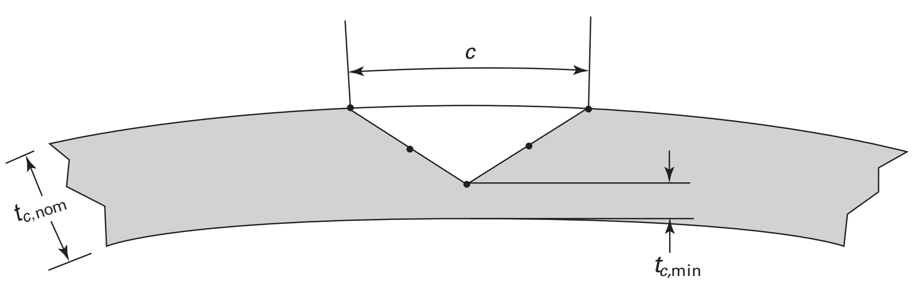
Figure A-3
Illustration of Method of Determining Critical Thickness Profiles



(a) Inspection Planes and the Critical Thickness Profile



(b) Critical Thickness Profile – in the Longitudinal Plane (Projection of Line M)



(c) Critical Thickness Profile – in the Circumferential Plane (Projection of Line C)

GENERAL NOTE: M1 through M5 are longitudinal inspection planes, and C1 through C7 are circumferential inspection planes.

NONMANDATORY APPENDIX B
EVALUATION FOR SOIL AND SURCHARGE LOADS

B-1 SCOPE

This Appendix may be used for evaluation of the metal loss region for soil and surcharge loads.

B-2 PROCEDURE

(a) Internal pressure, soil loads, and surcharge loads that are required for the evaluations in this Appendix shall be determined.

(b) Pipe ovality shall be evaluated in accordance with B-3.

(c) Compression of buried pipe walls shall be evaluated in accordance with B-4 and shall include the following:

(1) circumferential through-wall ovality stress

(2) crushing compressive stress in side walls

(3) buckling due to external pressure

(4) effects of negative internal pressure

(d) Buoyancy and flotation shall be evaluated in accordance with B-5.

(e) The evaluation wall thickness used in this Appendix, t_{ev}, shall be equal to the minimum value of projected wall thickness of the metal loss region at the end of the evaluation period, $t_{p,\min}$, unless a larger value of t_{ev} is justified. If there is a local metal loss region in the piping item, as illustrated in Figure B-1, a value of t_{ev} that is larger than $t_{p,\min}$ may be justified for evaluations of local stresses in the piping item wall due to directional loads. For example, with reference to Figure B-1, local stresses may be evaluated at the top of the piping item cross-section using $t_{p,\min}$, as well as at the 3 o'clock position using $t_{p,\text{pipe}}$.

B-3 PIPE OVALITY

(a) Pipe ovality is defined as the linear deflection of the piping item cross-section divided by piping item diameter, as illustrated in Figure B-2. Ovality of the piping item under soil and surcharge loads shall satisfy the following equation.

$$\Omega \le \Omega_{\max} \tag{B-1}$$

where

Ω = ovality of the piping item cross-section, dimensionless

$\Omega_{\max}$ = maximum allowable ovality of the piping item cross-section, dimensionless

The value of $\Omega_{\max}$ shall be the applicable piping item ovality limit in the Design Specification or Construction Code, but shall not exceed 0.05. If the piping item ovality limit in the Design Specification or Construction Code is not available, $\Omega_{\max}$ shall be equal to 0.05.

(b) The piping item ovality shall be calculated using

$$\Omega = \frac{K P_{SS}}{\frac{E_{\text{pipe}} I_{TWP}}{R^3} + 0.061\,E'} \tag{B-2}$$

where

E' = modulus of soil reaction, and may be obtained from AWWA M11, "Steel Water Pipe: A Guide for Design and Installation," psi (MPa)

E_{pipe} = modulus of elasticity of the piping item, psi (MPa)

I_{TWP} = through-wall bending moment of inertia of the piping item per unit length at the end of the evaluation period, in.^{3} (mm^3)

K = bedding constant, and may be obtained from AWWA M11, dimensionless

P_{SS} = pressure at the top of the piping item due to soil and surface loads, psi (MPa)

R = pipe mean radius at the end of the evaluation period, in. (mm)

(c) The through-wall bending moment of inertia of the piping item per unit length shall be calculated using

$$I_{TWP} = \frac{{t_{ev}}^3}{12} \tag{B-3}$$

where

t_{ev} = evaluation wall thickness of the piping item at the end of the evaluation period, in. (mm)

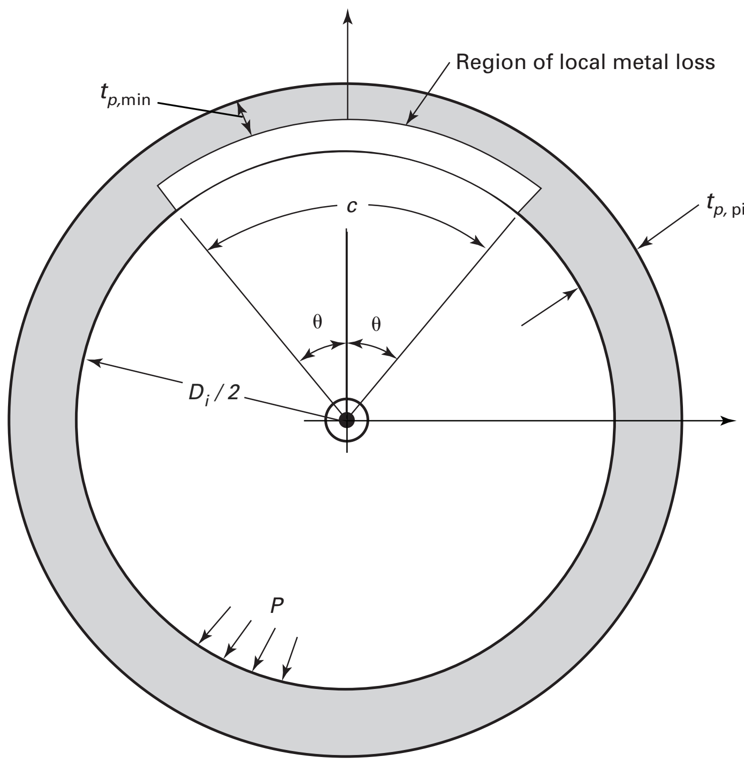
(d) The soil and surface pressure, P_{SS}, at the top of the piping item, as illustrated in Figure B-3, shall be the sum of the pressure P_{soil} from the fill in the trench and the surface pressure P_{surf}. If P_{surf} is due to a sustained load such as a permanent structure

$$P_{SS} = D_L(P_{\text{soil}} + P_{\text{surf}}) \tag{B-4}$$

If P_{surf} is due to an occasional load such as a moving vehicle

$$P_{SS} = D_L P_{\text{soil}} + P_{\text{surf}} \tag{B-5}$$

Figure B-1
Illustration of Local Metal Loss Region on the inside Surface of a Pipe



where

D_L = deflection lag factor, and may be obtained from AWWA M11, dimensionless

P_{soil} = pressure at the top of the piping item due to weight of the trench fill, psi (MPa)

P_{surf} = pressure at the top of the piping item due to surface loads, psi (MPa)

(e) If the top of the piping item is above the upper elevation of the water table, the soil pressure at the top of the piping item shall be calculated using

Figure B-2
Ovality of Pipe Cross-section (Not to Scale)

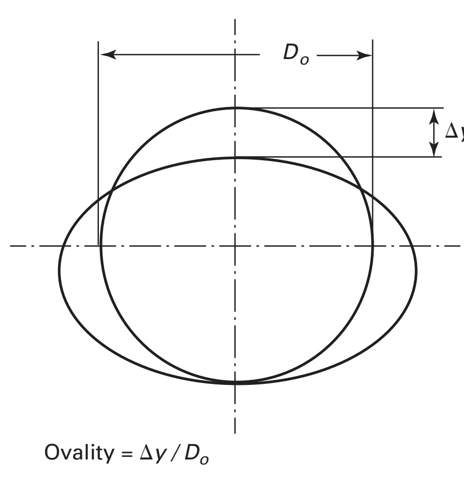
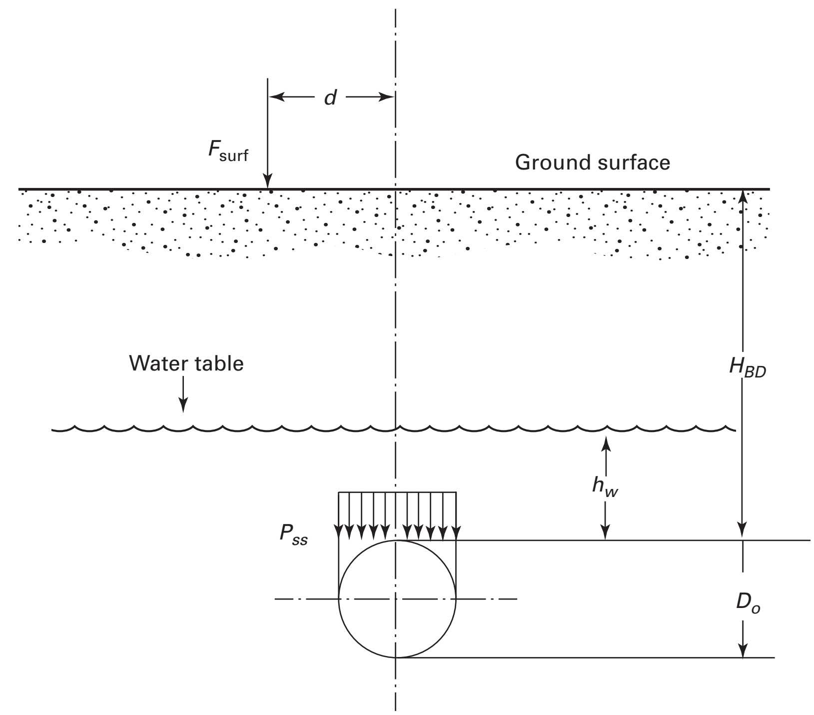


Figure B-3
Illustration of Soil and Surface Load Parameters



$$P_{soil} = V_{AF}\gamma_s H_{BD} \quad \text{(B-6)}$$

where

$$V_{AF} = 0.76 - 0.71\left(\frac{\Phi_H - 0.7}{\Phi_H + 1.75}\right) \quad \text{(B-7)}$$

$$\Phi_H = \frac{M_S R}{\pi E_{pipe} D_0} \quad \text{(B-8)}$$

D_o = nominal outside diameter of the piping item, in. (mm)
H_{BD} = burial depth of the piping item, from the soil surface to the top of the piping item, in. (mm)
M_s = constrained soil modulus, psi (MPa)
Φ_H = hoop stiffness parameter, dimensionless
V_{AF} = vertical arching factor, dimensionless
γ_S = unit weight of dry soil or trench fill, lb/in.^{3} (N/mm^3)

A relation for V_{AF} that is an alternative to eqs. (B-7) and (B-8) may be used if justified. The value of V_{AF} may be conservatively assumed to be equal to 1.0. If the top of the piping item is below the upper elevation of the water table, the soil pressure at the top of the piping item shall be calculated using

$$P_{soil} = \gamma_W h_W + R_W \gamma_S H_{BD} \quad \text{(B-9)}$$

where

$$R_W = 1 - \frac{h_W}{3H_{BD}} \quad \text{(B-10)}$$

h_W = height of the water table above the top of piping item, in. (mm)
R_W = buoyancy factor, dimensionless
γ_W = unit weight of water above the top of the piping item, lb/in.^{3} (N/mm^3)

(f) The pressure at the top of the piping item due to a concentrated load at the soil surface, F_{surf}, as illustrated in Figure B-3, shall be calculated using

$$P_{surf} = \frac{3F_{surf}F'}{2\pi H_{BD}^2\left[1 + \left(\frac{d}{H_{BD}}\right)^2\right]^{2.5}} \quad \text{(B-11)}$$

where

d = offset of concentrated surface load from the vertical centerline of the piping item, in. (mm)
F' = impact factor applied to the surface load that accounts for the dynamic effect of the surface load

F_{surf} = load at the soil surface, lb (N)

A load F_{surf} that is uniformly distributed at the soil surface may be conservatively assumed to be a concentrated load, and the pressure at the top the piping item may be calculated using eq. (B-11). Alternatively, the pressure at the top of the piping item due to a uniformly distributed load at the soil surface may be calculated using

$$P_{\text{surf}} = \frac{1}{4\pi}\frac{F_{\text{surf}}F'}{b_W b_L}\left[\left(\frac{2XY\sqrt{Z}}{Z + Z_1}\right)\left(\frac{Z+1}{Z}\right) + \tan^{-1}\left(\frac{2XY\sqrt{Z}}{Z - Z_1}\right)\right] \tag{B-12}$$

where

$$X = \frac{b_W}{H_{BD}} \tag{B-13}$$

$$Y = \frac{b_L}{H_{BD}} \tag{B-14}$$

$$Z = X^2 + Y^2 + 1 \tag{B-15}$$

$$Z_1 = (XY)^2 \tag{B-16}$$

b_L = surface length of the area over which the surface load is uniformly spread, in. (mm)
b_W = surface width of the area over which the surface load is uniformly spread, in. (mm)
X = surface width of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless
Y = surface length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless
Z = parameter dependent on surface width and length of the area over which the surface load is uniformly spread as normalized by the burial depth of the piping item, dimensionless
Z_1 = surface area over which the surface load is uniformly spread as normalized by the square of burial depth of the piping item, dimensionless

For truck and rail car loads, standard values of loads provided in ASTM A796/A796M-10, "Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications," may be used as an alternative to loads given by eqs. (B-11) through (B-16).

B-4 COMPRESSION OF BURIED PIPE WALLS

B-4.1 CIRCUMFERENTIAL THROUGH-WALL OVALITY STRESS

The membrane stress due to internal pressure, plus the circumferential through-wall ovality stress in the sidewalls of the piping item, σ_{TW}, shall satisfy the following equation.

$$\frac{P_D D_o}{2t_{ev}} + \sigma_{TW} \le 1.5S_h \tag{B-17}$$

where

$$\sigma_{TW} = 3P_{SS}\frac{D_o}{t_{ev}}\left(\frac{D_o}{t_{ev}} - 1\right)\left[K_b - \frac{K_x}{\dfrac{8\,E_{\text{pipe}}}{E'\left(\dfrac{D_o}{t_{ev}} - 1\right)^3} + 0.732}\right] \tag{B-18}$$

D_o = nominal outside diameter of the piping item, in. (mm)
K_b = bending moment coefficient, and may be obtained from AWWA C150, Thickness Design of Ductile-Iron Pipe
K_x = deflection coefficient, and may be obtained from AWWA C150
P_D = Design Pressure, psi (MPa)
S_h = allowable stress at the temperature consistent with the loading under consideration, psi (MPa)
σ_{TW} = through-wall bending stress due to ovalization of the piping item, psi (MPa)

where P_{SS} is given by eq. B-3(d)(B-4) or B-3(d)(B-5).

B-4.2 CRUSHING COMPRESSIVE STRESS IN SIDE WALLS

The compressive stress in the piping item due soil and surface pressures, and any negative internal pressure, shall satisfy the following equation.

$$\frac{(P_{SS} - P_{\text{neg}})D_o}{2\,t_{ev}} \le S_h \tag{B-19}$$

where

P_{neg} = negative internal pressure, where the numerical value is negative, psi (MPa)

B-4.3 BUCKLING DUE TO EXTERNAL PRESSURE

The total pressure, P_{SS}', from soil and surcharge loads plus the external pressure from ground water, P_{gw}, plus any negative internal pressure, shall satisfy the following equation for prevention of buckling.

$$P_{SS}' \le \frac{P_{cr}}{2} \tag{B-20}$$

where

$$P_{SS}' = P_{SS} + P_{gw} - P_{neg} \tag{B-21}$$

$$P_{cr} = \left[32 R_W B' E' \frac{E_{pipe} I_{TWP}}{D_o^{\ 3}} \right]^{1/2} \tag{B-22}$$

(U.S. Customary Units)

$$B' = \frac{1}{1 + 4 \exp\left[-0.065 \left(\frac{H_{BD}}{12} \right) \right]} \tag{B-23}$$

(SI Units)

$$B' = \frac{1}{1 + 4 \exp\left[-0.213 \left(\frac{H_{BD}}{1{,}000} \right) \right]} \tag{B-24}$$

B' = coefficient of elastic support of the piping item by surrounding soil, and may be obtained from AWWA M11, dimensionless
P_{cr} = critical buckling pressure for the piping item, psi (MPa)
P_{gw} = hydrostatic pressure around the piping item due to groundwater, psi (MPa)
P_{SS}' = total external pressure plus negative internal pressure, psi (MPa)

where I_{TWP} is given by eq. B-3(c)(B-3), and R_W is given by eq. B-3(e)(B-10).

B-4.4 EFFECTS OF NEGATIVE INTERNAL PRESSURE

If the piping item is subject to a negative internal pressure, the requirements of the Construction Code for negative internal pressure shall be met with no credit for the support of the surrounding soil.

B-5 BUOYANCY AND FLOTATION

The piping item shall have sufficient cover, or be anchored to the ground, to prevent flotation by groundwater, in accordance with the following. The linear weight of water displaced by the piping item, excluding the linear weight of fluid inside the piping item, shall satisfy the following equation.

$$W_w \leq \frac{2}{3} \left(W_{pipe} + W_{CL} + P_{soil} D_o \right) \tag{B-25}$$

where

P_{Soil} = pressure at the top of the piping item due to weight of the trench fill, psi (MPa)
W_{CL} = linear weight of coating and lining of the piping item per unit length, lb/in. (N/mm)
W_{pipe} = linear weight of the piping item per unit length excluding the linear weight of fluid inside the piping item, lb/in. (N/mm)
W_w = linear weight of water displaced by the piping item, lb/in (N/mm)

NONMANDATORY APPENDIX C SECTION PROPERTIES OF PIPING ITEM CONTAINING METAL LOSS REGION

C-1 SCOPE

This Appendix may be used to calculate properties in the radial-circumferential plane of the cross-section of the piping item containing a local metal loss region on either the inside or outside surface. Section properties for metal loss on both the inside and outside surfaces of a piping item are beyond the scope of this Appendix. Alternatively, for metal loss on both the inside and outside surfaces, metal loss on the inside surface may be projected to be on the outside surface, and the provisions of this Appendix may be used.

C-2 PROCEDURE

(a) The geometry of the cross-section of the piping item in the radial-circumferential plane that includes the local metal loss region shall be determined in accordance with C-3.

(b) The section properties in the radial-circumferential plane of the cross-section of the piping item that includes the metal loss region shall be determined in accordance with C-4.

C-3 GEOMETRY OF CROSS-SECTION OF PIPING ITEM CONTAINING METAL LOSS REGION

(a) The cross-section of the piping item shall be characterized as having a uniform wall thickness outside of the local metal loss region equal to the wall thickness at the end of the evaluation period, $t_{p,\mathrm{pipe}}$.

(b) The local metal loss region shall be idealized as having a uniform depth, a, around the circumference of the piping item with a remaining wall thickness in the metal loss region equal to the minimum value of projected wall thickness of the metal loss region at the end of the evaluation period, $t_{p,\min}$. The circumferential angular extent of the local metal loss region shall be characterized as 2θ.

(c) The cross-section of a piping item with a local metal loss region on the inside surface is illustrated in Figure C-1, and on the outside surface in Figure C-2. In Figures C-1 and C-2, the *x*-*x* axis is the neutral axis of the cross-section of the piping item as calculated in the absence of the local metal loss region, and the $\bar{x} - \bar{x}$ axis is the neutral axis of the cross-section of the piping item including the local metal loss region.

C-4 SECTION PROPERTIES OF PIPING ITEM CONTAINING METAL LOSS REGION

(a) For an applied bending moment acting about the *x*-*x* axis in Figures C-1 and C-2, the maximum bending stress will occur at point A in these figures. The corresponding moment of inertia is the minimum moment of inertia of the cross-section of the piping item, and is given by

$$I_{\min} = I_x + A_{cyl}\bar{y}^2 - \left[I_{Lx} + A_f\left(\bar{y}_{Lx} + \bar{y}\right)^2\right] \tag{C-1}$$

where

$$I_x = \frac{\pi}{64}\left(D_0^4 - D_i^4\right) \tag{C-2}$$

$$A_{cyl} = \frac{\pi}{4}\left(D_0^2 - D_i^2\right) \tag{C-3}$$

$$I_{Lx} = R_a{}^3 a \begin{bmatrix} \left(1 - \dfrac{3}{2}\dfrac{a}{R_a} + \left(\dfrac{a}{R_a}\right)^2 - \dfrac{1}{4}\left(\dfrac{a}{R_a}\right)^3\right) \\ \left(\theta + \sin\theta\cos\theta - \dfrac{2\sin^2\theta}{\theta}\right) \\ +\dfrac{1}{3}\left(\dfrac{a}{R_a}\right)^2 \dfrac{\sin^2\theta}{\theta}\dfrac{1}{2 - \dfrac{a}{R_a}} \\ \left(1 - \dfrac{a}{R_a} + \dfrac{1}{6}\left(\dfrac{a}{R_a}\right)^2\right) \end{bmatrix} \tag{C-4}$$

$$\bar{y}_{Lx} = \frac{2}{3}\frac{R_a\sin\theta}{\theta}\left(1 - \frac{a}{R_a} + \frac{1}{2 - \frac{a}{R_a}}\right) \tag{C-5}$$

A_{cyl} = metal cross-sectional area of the piping item at the end of the evaluation period and as calculated in the absence of the local metal loss region, in.^{2} (mm^2)

A_f = cross-sectional area of the local metal loss region at the end of the evaluation period, in.^{2} (mm^2)

a = maximum depth of the local metal loss region at the end of the evaluation period, in. (mm)

D_i = inside diameter of the piping item at the end of the evaluation period, in. (mm)

D_o = nominal outside diameter of the piping item, in. (mm)

I_{Lx} = moment of inertia of the area of the local metal loss region, A_f, about the local axis that is parallel to the x-x axis and intersects the centroid of the local metal loss region, at the end of the evaluation period, in.^{4} (mm^4)

I_x = moment of inertia of the cross-section of the piping item about the x-x axis at the end of the evaluation period and as calculated in the absence of the local metal loss region, in.^{4} (mm^4)

R_a = outside radius of the local metal loss region at the end of the evaluation period, in. (mm)

$\overline{y}$ = distance between the neutral axis of the cross-section of the piping item containing the metal loss region at the end of the evaluation period, $\overline{x} - \overline{x}$, and the axis x-x, in. (mm)

$\overline{y}_{Lx}$ = distance between the centroid of the metal loss region and the x-x axis at the end of the evaluation period, in. (mm)

θ = one-half of the circumferential angular extent of the local metal loss region at the end of the evaluation period, radians

(b) If the local metal loss region is on the inside surface of the piping item, as illustrated in Figure C-1

$$A_f = \frac{\theta}{4}\left(D_f^2 - D_i^2\right) \tag{C-6}$$

$$\overline{y} = \frac{1}{12}\frac{\sin\theta\left(D_f^3 - D_i^3\right)}{A_{cyl} - A_f} \tag{C-7}$$

$$R_a = \frac{D_f}{2} \tag{C-8}$$

where

D_f = diameter at the base of the local metal loss region on the inside surface of the piping item at the end of the evaluation period, as illustrated in Figure C-1, in. (mm)

(c) If the local metal loss region is on the outside surface of the piping item, as illustrated in Figure C-2

$$A_f = \frac{\theta}{4}\left(D_o^2 - D_f^2\right) \tag{C-9}$$

$$\overline{y} = \frac{1}{12}\frac{\sin\theta\left(D_o^3 - D_f^3\right)}{A_{cyl} - A_f} \tag{C-10}$$

$$R_a = \frac{D_o}{2} \tag{C-11}$$

where

D_f = diameter at the base of the local metal loss region on the outside surface of the piping item at the end of the evaluation period, as illustrated in Figure C-2, in. (mm)

Figure C-1
Cross-Section of Piping Item With Local Metal Loss Region on the Inside Surface

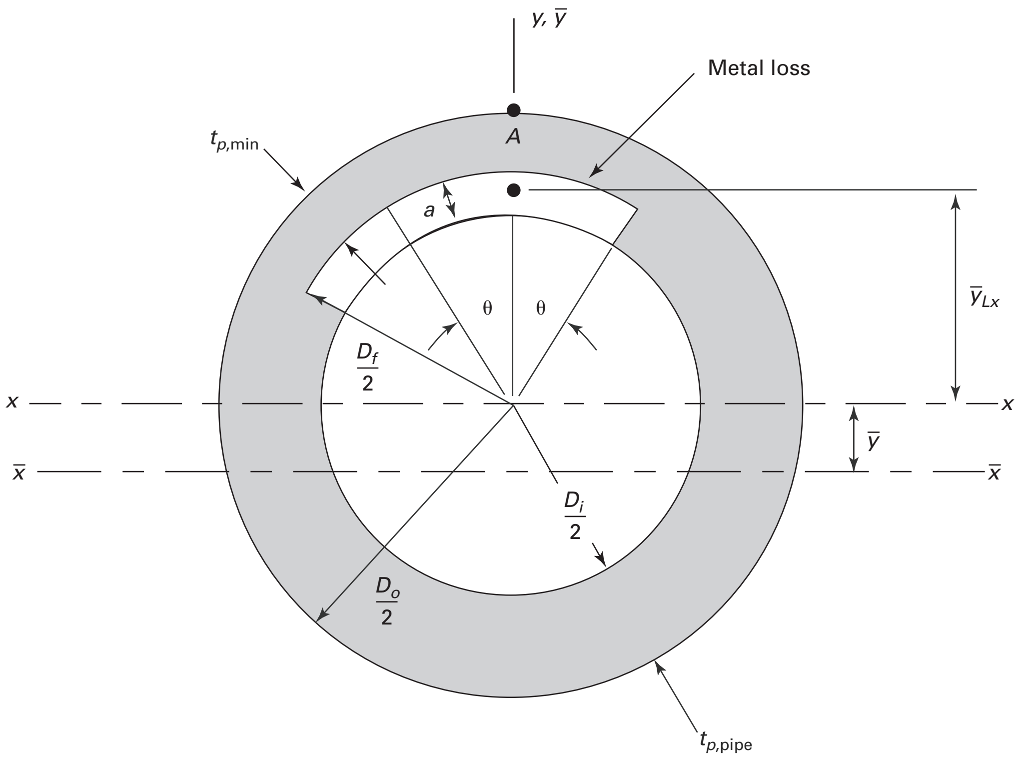
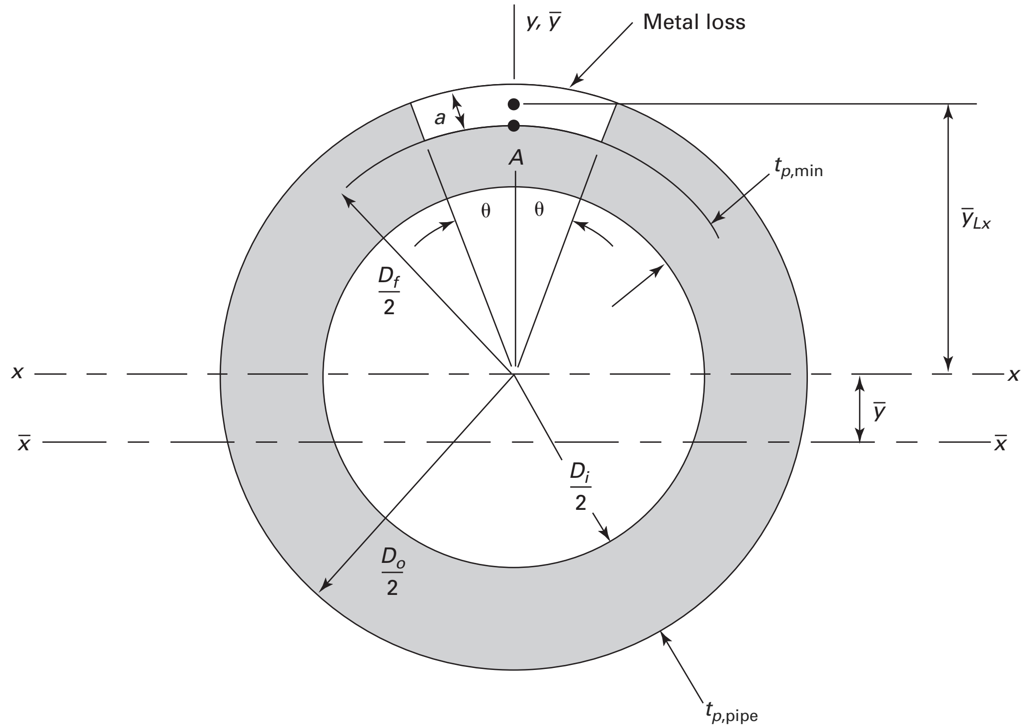


Figure C-2
Cross-Section of Piping Item With Local Metal Loss Region on the Outside Surface



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Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-807
Use of Grades 75 and 80 Reinforcement in Concrete Containments
Section III, Division 2

Inquiry: Under what conditions may ASTM A615 Grades 75, 80, and ASTM A706 Grade 80 reinforcement be used to meet the requirements of Subarticles CC-2310, CC-3422.1, CC-3520, CC-3532.1.2, and Table CC-4333-1, and Table VIII-1410-1 for containment construction?

Reply: It is the opinion of the Committee that ASTM A615 Grades 75, 80, and ASTM A706 Grade 80 reinforcement may be used for containment construction meeting all of the requirements of Division 2, Subarticles CC-2310, CC-3422.1, CC-3520, CC-3532.1.2, Table CC-4333-1, and Mandatory Appendix VIII, as modified by the following alternative requirements:

(a) The material to be used for reinforcing bars for containments shall conform to ASTM A615 or A706 and the special requirements described in CC-2330. ASTM A615 shall be further subject to the following conditions:

(1) The actual yield strength based on mill tests shall not exceed f_y by more than 18,000 psi (125 MPa).

(2) The ratio of the actual tensile strength to the actual yield strength shall not be less than 1.25.

(b) The specified yield strength of reinforcement shall be that used in construction and shall not exceed 80,000 psi (550 MPa).

(c) For the purpose of calculating the required radial, peripheral and torsional shear, for hoop and meridional reinforcement required for combined tangential shear and membrane force, the yield strength of reinforcement shall be limited to 60 ksi (420 MPa).

(d) Development length of Grades 75 and 80 reinforcement calculated using CC-3532.1.2(i) shall be multiplied by a factor of 1.2.

(e) The completed qualification splices shall be tensile tested using the loading rates set forth in SA-370 and the tensile results shall meet those specified in Table 1 (revised Table CC-4333-1). The tensile strength of each sample shall equal or exceed 125% of the specified yield strength as shown in Table 1. The average tensile strength of each group of fifteen consecutive samples shall equal or exceed the specified minimum tensile strength as shown in Table 1. If any splice used for testing fails to meet the strength requirement of Table 1 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor or Fabricator. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing frequency of CC-4333.5.3.

(f) If any splice used for testing fails to meet the strength requirement of Table 1 and failure does not occur in the bar, two additional splices shall be tested. If either of these retests fails to meet the strength requirement of Table 1, splicing shall be halted. Splicing shall not be resumed until the cause of failures has been corrected and resolved.

(g) If the running average tensile strength of fifteen consecutive samples fails to meet the tensile requirement of Table 1, splicing shall be halted. The Constructor or Fabricator shall investigate the cause and make the necessary corrective action. When splicing is resumed, the testing frequency shall be started anew.

(h) The electrode, electrode-gas combination, or grade of weld metal shall be in accordance with Table 2. Welding consumables shall be purchased with the following diffusible hydrogen supplemental designators:

(1) SMAW, H4

(2) FCAW, H8

(3) SAW, H4

(i) See Table 3 for references.

Table 1
Tensile Requirements for Mechanical Reinforcing Bar Splices and Welded Joints (Revised Table CC-4333-1)

		Reinforcing Bar Properties				Splice or Joint Strength Requirement			
		Minimum Yield Strength		Minimum Tensile Strength		Minimum Average Mechanical Splice or Welded Joint Tensile Strength [Note (1)]		Minimum Single Mechanical Splice or Welded Joint Tensile Strength [Note (2)]	
Specifications	Bar Grade	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)
A615	40	40,000	(280)	70,000	(480)	70,000	(480)	50,000	(350)
A615	60	60,000	(420)	90,000	(620)	90,000	(620)	75,000	(520)
A706	60	60,000	(420)	80,000	(550)	80,000	(550)	75,000	(520)
A615	75	75,000	(520)	100,000	(690)	100,000	(690)	93,750	(646)
A615	80	80,000	(550)	105,000	(725)	105,000	(725)	100,000	(690)
A706	80	80,000	(550)	100,000	(690)	100,000	(690)	100,000	(690)

NOTES:
(1) See CC-4333 and Appendix VIII.
(2) These values are equivalent to 125% of the yield strength of each bar grade.

Table 2
Filler Metal Requirements (Revised Table VIII-1410-1)

	Electrode Classification for Welding		
Base Metal (ASTM Specifications)	Shielded Metal Arc Welding (Low Hydrogen Electrode) (VIII-1411) (AWS Specifications)	Gas Metal Arc Welding (VIII-1412) (AWS Specifications)	Flux Cored Arc Welding (VIII-1412) (AWS Specifications)
A615 Gr. 40	A5.1 or A5.5 E70XX	A5.18 ER70S-X, E70C-3, ER70C-6	A5.20 or A5.29 E7XT-X, E7XTX-X (multiple pass only)
A706 Gr. 60	A5.5 E80XX	A5.28 ER80S-X, E80C-X	A5.29 E8XTX-X
A615 Gr. 60	A5.5 E90XX	A5.28 ER90S-X	A5.29 E9XTX-X
A615 Gr. 75	A5.5 E100XX	A5.28 ER100S-X, E100C-X	A5.29 E10XTX-X
A615 Gr. 80	A5.5 E110XX	A5.28 ER110S-X, E110C-X	A5.29 E11XTX-X
A706 Gr. 80	A5.5 E100XX	A5.28 ER100S-X, E100C-X	A5.29 E10XTX-X

Table 3
Standards and Specifications Referenced in Text

Standard ID	Published Title	Referenced Edition
American Society for Testing and Materials (ASTM)		
A615/A615M	Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement	2009b
A706/A706M	Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement	2009b
American Welding Society (AWS)		
A5.1	Procurement Guidelines for Consumables — Welding and Allied Processes — Fluxed and Gas Shielded Electrical Welding Processes	2002
A5.5/A5.5M	Low-Alloy Steel Electrodes for Shielded Metal Arc Welding	2006
A5.18/A5.18M	Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding	2005
A5.20/A5.20M	Carbon Steel Electrodes for Flux Cored Arc Welding	2005
A5.28/A5.28M	Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding	2005
A5.29/A5.29M	Low-Alloy Steel Electrodes for Flux Cored Arc Welding	2010

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Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-811
Alternative Qualification Requirements for Concrete Level III Inspection Personnel
Section III, Division 2

Inquiry: What alternative to the ACI Level III examination requirements of Section III, Division 2, 2004 Edition with the 2005 Addenda and earlier Editions and Addenda, Mandatory Appendix VII, VII-2220, VII-2230, and VII-3213 may be used when qualifying a Concrete Level III Inspector?

Reply: It is the opinion of the Committee that as an alternative to the ACI Level III examination requirements of the 2004 Edition with the 2005 Addenda and earlier Editions and Addenda, Mandatory Appendix VII, VII-2220, VII-2230, and VII-3213, the ACI Concrete Construction Special Inspector examination may be used in accordance with the 2004 Edition with the 2006 Addenda and later Editions and Addenda, Mandatory Appendix V, V-2220, V-2230, and V-3213, provided all other requirements of Mandatory Appendix VII from the original Code used are met.

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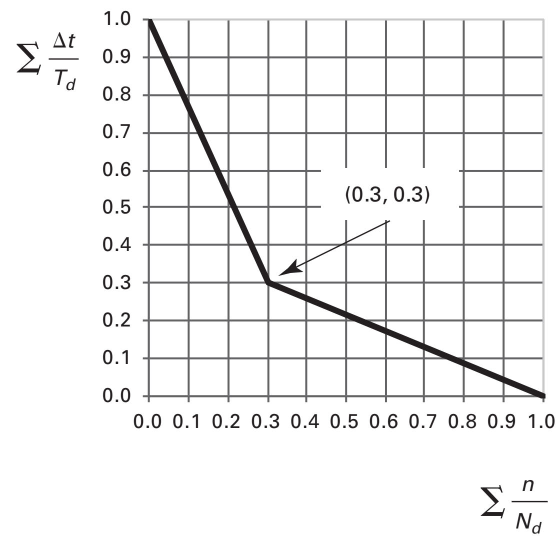
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-812-1
Alternate Creep-Fatigue Damage Envelope for 9Cr-1Mo-V Steel
Section III, Division 1; Section III, Division 5

Inquiry: Is there an alternate creep-fatigue damage envelope for 9Cr-1Mo-V steel when evaluating creep damage in accordance with Section III, Division 1, Subsection NH, T-1431(d) using the procedures of T-1433(a) Step 5(b)?

Reply: It is the opinion of the Committee that the creep-fatigue damage envelope shown in Figure 1 of this Case may be used as an alternate to the damage envelope shown in Fig. T-1420.2 of Section III, Subsection NH when evaluating creep damage in accordance with T-1433(a) Step 5(b) to satisfy the requirements of T-1431(d).

Figure 1
Alternate Creep-fatigue Damage Envelope for 9Cr-1Mo-V For Use with T-1433(a) Step 5 (b)



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Approval Date: October 24, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-813
Alternative Requirements for Preservice Volumetric and Surface Examination
Section XI, Division 1

Inquiry: What alternative requirements may be used to evaluate preservice volumetric and surface examination results in lieu of the provisions for Class 1 and 2 components of IWB-3110 and IWC-3110?

Reply: It is the opinion of the Committee that the following provisions may be used in lieu of IWB-3111 and IWB-3112 for Class 1 components or IWC-3111 and IWC-3112 for Class 2 components.

B-3110 CLASS 1

B-3111 GENERAL

(a) The preservice volumetric and surface examinations required by IWB-2200 and performed in accordance with IWA-2200 shall be evaluated by comparing the examination results with the acceptance standards specified in B-3112.

(b) Acceptance of components for service shall be in accordance with B-3112, IWB-3113, and IWB-3114.

B-3112 ACCEPTANCE

(a) A component whose volumetric or surface examination in accordance with IWB-2200 meets (1), (2), or (3) shall be acceptable for service, provided the verified flaws are recorded in accordance with the requirements of IWA-1400, IWA-2220(b), and IWA-6230 in terms of location, size, shape, orientation, and distribution within the component

(1) confirms the absence of flaws or identifies only flaws that have already been shown to meet the nondestructive examination standards of NB-2500 or NB-5300, as documented in Quality Assurance Records (NCA-4134.17).

(2) detects flaws by volumetric examination that are confirmed by surface or volumetric examination to be non-surface-connected and that do not exceed the standards of Table IWB-3410-1.

(3) detects flaws by volumetric examination that are confirmed by surface or volumetric examination to be non-surface-connected and that are accepted by analytical evaluation in accordance with the provisions of IWB-3132.3 to the end of the service lifetime of the component, and reexamined in accordance with the requirements of IWB-2420(b) and IWB-2420(c). The use of Appendix A for preservice inspection results is acceptable.

(b) A component whose volumetric or surface examination detects flaws that do not meet the criteria established in (a) shall be unacceptable for service, unless the component is corrected by a repair/replacement activity in accordance with IWB-3113 to the extent necessary to meet the provisions of (a) prior to placement of the component in service.

C-3110 CLASS 2

C-3111 GENERAL

(a) The preservice volumetric and surface examinations required by IWC-2200 and performed in accordance with IWA-2200 shall be evaluated by comparing the examination results with the acceptance standards specified in C-3112.

(b) Acceptance of components for service shall be in accordance with C-3112, IWC-3113, and IWC-3114.

C-3112 ACCEPTANCE

(a) A component whose volumetric or surface examination in accordance with IWC-2200 meets (1), (2), or (3) shall be acceptable for service, provided the verified flaws are recorded in accordance with the requirements of IWA-1400, IWA-2220(b), and IWA-6230 in terms of location, size, shape, orientation, and distribution within the component

(1) confirms the absence of flaws or identifies only flaws that have already been shown to meet the nondestructive examination standards of NC-2500 or NC-5300, as documented in Quality Assurance Records (NCA-4134.17).

(2) detects flaws by volumetric examination that are confirmed by surface or volumetric examination to be non-surface-connected and that do not exceed the standards of Table IWC-3410-1.

(3) detects flaws by volumetric examination that are confirmed by surface or volumetric examination to be nonsurface-connected, that are accepted by analytical evaluation in accordance with the provisions of IWC-3132.3 to be acceptable to the end of the service lifetime of the component, and reexamined in accordance with the requirements of IWB-2420(b) and IWB-2420 (c), in lieu of IWC-2420(b) and IWC-2420(c).

(b) A component whose volumetric or surface examination detects flaws that do not meet the criteria established in (a) shall be unacceptable for service, unless the component is corrected by a repair/replacement activity in accordance with IWC-3113 to the extent necessary to meet the provisions of (a) prior to placement of the component in service.

Approval Date: December 6, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-815
Use of SA-358/SA-358M Grades Fabricated as Class 3 or Class 4 Welded Pipe, Class CS Core Support Construction
Section III, Division 1

Inquiry: Is it permissible to use SA-358/SA-358M grades fabricated as Class 3 or Class 4 welded pipe for core support structures in accordance with Section III, Division 1, Subsection NG for Class CS construction?

Reply: It is the opinion of the Committee that SA-358/SA-358M grades fabricated as Class 3 or Class 4 welded pipe may be used for core support structures in accordance with Section III, Division 1, Subsection NG for Class CS construction, provided the following additional requirements are satisfied.

(a) The maximum design stress intensity, S_m, values for Class 3 and Class 4 shall be the values listed in Section II, Part D, Subpart 1, Table 2A for the corresponding grade of SA-358/SA-358M. The maximum design temperature shall be 800°F (427°C).

(b) The S_y and S_u values for Class 3 and Class 4 shall be the values listed in Section II, Part D, Subpart 1, Tables Y-1 and U for the corresponding grade of SA-358/SA-358M.

(c) This Case shall be identified on the Data Report form for core support structure.

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Approval Date: December 6, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-816
Use of Temper Bead Weld Repair Rules Adopted in 2010 Edition and Earlier Editions
Section III, Division 1

Inquiry: What alternative to the temper bead welding requirements of NB-4622.9 through NB-4622.11 for Code Editions up to and including the 2007 Edition through the 2009 Addenda, may be used for temper bead weld repairs to base metals, weld metal, cladding, and dissimilar metal welds for Section III, Division 1, Class 1 construction?

Reply: It is the opinion of the Committee that, as an alternative to the temper bead welding requirements of NB-4622.9 through NB-4622.11, temper bead weld repairs to base metals, weld metal, cladding, and dissimilar metal welds, for construction of Section III, Division 1, Class 1 components to Code Editions and Addenda up to and including the 2007 Edition with the 2009 Addenda, may be made provided the following additional requirements are satisfied:

-4622.9 Temper Bead Weld Repair. Repairs may be made without PWHT or after the final PWHT under the conditions listed below, provided it is impractical to postweld heat treat the area after repair. References in the following paragraphs to "P-No." are to Section IX, QW/QB-422; to "F-No." are to Section IX, QW-432; and to "A-No." are to Section IX, QW-442.

(a) General Requirements

(1) Repair Welding Procedure. The WPS shall be prepared and qualified in accordance with Section IX, QW-290 following the impact testing option with the testing performed in accordance with the requirements of NB-4334 and NB-4335.

(2) Welding Procedure Qualification Test Plate. The test assembly materials for the welding procedure qualification shall be subjected to heat treatment that is at least equivalent to the time and temperature applied to the material being repaired.

(3) Neutron Fluence. If the repair area is to be subjected to a significant fast neutron fluence greater than 10^{19} nvt E ≥ 1 MeV, the weld metal Cu content shall not exceed 0.10%.

(4) Nondestructive Examination Methods. All nondestructive examination shall be in accordance with NB-5000. Final nondestructive examination of completed weld repairs shall be performed after the weld has been at ambient temperature for a minimum period of 48 hr.

(5) Preparation of Repair Cavity. The maximum area of an individual repair based on the finished surface shall be 500 in.^{2} (3 230 cm^2) and the depth of repair shall not be greater than one-third of the base material thickness. The area to be repaired shall be suitably prepared for welding in accordance with a written procedure. Before repair, the surface to be repaired shall be examined by either the magnetic particle or liquid penetrant method.

(6) Documentation of Weld Repairs. The Certificate Holder shall prepare a chart that shows the location and size of the prepared cavity, the welding material identification, the welding procedure identification, and the results of nondestructive examination.

(7) Performance Qualifications. If the repair weld is to be performed where physical obstructions impair the welder's ability to perform, the welder shall also demonstrate the ability to deposit sound metal in the positions required, using the same parameters and simulated physical obstructions as are involved in the repair.

(8) FCAW and GMAW Welding Electrodes. The following shall apply except for nickel alloy F-No. 43 or A-No. 8 electrodes:

(-a) FCAW electrodes shall meet the requirements for supplemental designator *H4* indicating that they are very low in diffusible hydrogen as defined in the applicable specifications in Section II, Part C.

(-b) Welding shall begin using a previously unopened container of electrode. When the electrode is not used for more than 4 hr, it shall be removed from the wire feeder and stored in accordance with NQA-1, Subpart 2.2, Level C.

(9) SMAW Welding Electrodes. The following shall apply for SMAW welding electrodes:

(-a) Welding electrodes shall be supplied in hermetically sealed containers. After being removed from containers, electrodes shall be stored in a rod oven between 225°F to 350°F (105°C to 175°C).

(-b) Except for nickel alloy F-No. 43 electrodes

(-1) electrodes shall meet the requirements for supplemental designators *R* indicating a moisture-resistant coating and *H4* indicating that they are very low in diffusible hydrogen as defined in the specifications in Section II, Part C

(-2) when electrodes are removed from elevated temperature storage, they may be exposed to the atmosphere in accordance with the following schedule:

(+a) E70XX: 9 hr

(+b) E80XX: 4 hr

(+c) E90XX and higher strength: 2 hr

Electrodes that are exposed to the atmosphere for more than the above time shall be discarded or baked to remove any absorbed moisture for the time and temperature recommended by the electrode manufacturer or the applicable filler metal specification. After baking and before the electrodes are allowed to cool below 225°F (105°C), they shall be transferred into holding ovens at 225°F to 350°F (105°C to 175°C).

(10) Postweld Hydrogen Bakeout. For repairs made using SMAW or FCAW, the weld area shall be maintained at a temperature of 450°F to 550°F (230°C to 290°C) for a minimum time of 2 hr after welding is completed for P-No. 1 materials and 4 hr for P-No. 3 materials.

(b) Repairs to Base Metals and Weld Metal. Weld repairs to P-No. 1 and P-No. 3 material and A-Nos. 1, 2, 10, or 11 weld metal may be made provided the following additional requirements are met:

(1) The second (temper bead) layer shall be examined by the magnetic particle or liquid penetrant method.

(2) The completed weld shall have the weld reinforcement, including the final layer, removed substantially flush with the surface prior to performing the required nondestructive examination.

(3) The nondestructive examination of the repair weld and base metal for a minimum of 4 in. (100 mm) around the repair shall be in accordance with NB-4453.4. In addition, all repairs shall be ultrasonically examined.

(c) Repair Welds to Cladding. Weld repairs may be made to P-No. 8 or P-No. 43 cladding on P-No. 1 and P-No. 3 material after final PWHT. If the defect is removed and there is greater than $^1/_8$ in. (3 mm) of A-No. 8 or F-No. 43 weld metal thickness remaining above the cladding weld metal/base metal interface, repair may be made without postweld heat treatment provided the welding process is SMAW or GTAW; where $^1/_8$ in. (3 mm) or less of A-8 or F-43 weld metal thickness remains or a process other than SMAW or GTAW is to be used, (a) and the following additional requirements apply:

(1) The depth of the repair cavity into the ferritic base metal shall not be greater than $^1/_4$ in. (6 mm) or 10% of the base metal thickness, whichever is less. Areas with cavity depth greater than this shall be repaired in accordance with (b) to within the limit before implementing the cladding repair.

(2) The repairs shall be made using A-No. 8 weld metal for P-No. 8 cladding or F-No. 43 weld metal for either P-No. 8 or P-No. 43 cladding.

(3) The repair weld and base metal for a minimum of 4 in. (100 mm) around the repair shall be examined by the liquid penetrant method.

(d) Temper Bead Weld Repair to Dissimilar Metal Welds Made With Buttering. This paragraph applies to welds between P-No. 1 or P-No. 3 and austenitic stainless or nickel base metals where the P-No. 1 or P- No. 3 weld ends have been buttered with A-No. 8 or F-No. 43 filler metal, then heat treated. If the defect is removed and there is greater than $^1/_8$ in. (3 mm) of A-No. 8 or F-No. 43 weld metal thickness remaining above the buttering weld metal/base metal interface, repair may be made without postweld heat treatment provided the welding process is SMAW or GTAW; if $^1/_8$ in. (3 mm) or less of A-No. 8 or F-No. 43 weld metal thickness remains or a process other than SMAW or GTAW is to be used, NB-4622.9(a) and the following additional requirements apply:

(1) If the defect penetrates into P-No. 1 or P-No. 3 base material, repair of that base material may be performed in accordance with this paragraph provided the depth of repair measured in the axial direction does not exceed $^3/_8$ in. (10 mm). See Figure -4622.9(d)(1)-1. The depth of the repair cavity shall not exceed one-half the joint thickness. In the event that the extent of the repair into the ferritic material in the axial direction exceeds $^3/_8$ in. (10 mm), repair shall be made in accordance with (b) prior to replacing the A-No. 8 or F-No. 43 weld metal.

(2) After at least $^3/_{16}$ in. (5 mm) of A-No. 8 or F-No. 43 weld metal has been deposited against the P-No. 1 or P-No. 3 base metal, the repair area shall be given a postweld hydrogen bakeout as described in (a)(10), after which the weld may be completed without further postweld hydrogen baking.

(3) The repair weld and base metal for a minimum of 4 in. (100 mm) around the repair shall be examined by the liquid penetrant method.

(4) The repair shall be examined by the radiographic method and, if practical, by the ultrasonic method.

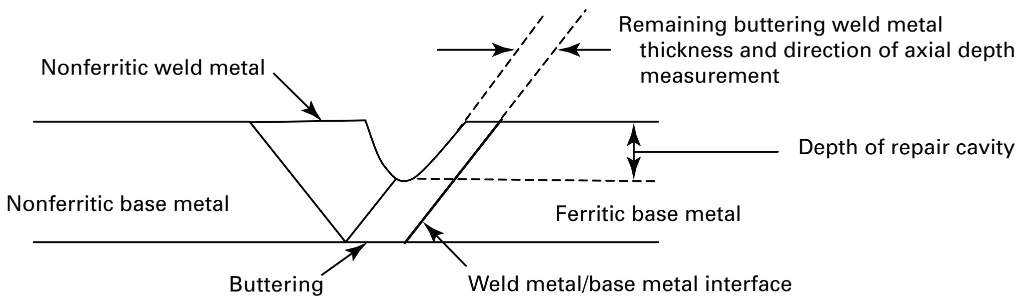
(5) For repairs to partial penetration welds, the radiographic and ultrasonic examinations specified above need not be performed if meaningful results cannot be obtained. For those cases, liquid penetrant examination shall be performed in accordance with the following:

(-a) For repairs where the depth of the cavity did not exceed $^3/_{16}$ in. (5 mm), liquid penetrant examination shall be performed after the weld is completed.

(-b) For repairs where the depth of the cavity exceeded $^3/_{16}$ in. (5 mm), liquid penetrant examination shall be performed after approximately $^3/_{16}$ in. (5 mm) of weld metal has been deposited and the postweld hydrogen bakeout specified in (a)(10) has been completed. Additional similar incremental deposit thicknesses shall be liquid penetrant examined, but additional postweld hydrogen bakeouts are not required.

(e) This Case number shall be shown on the welding procedure specification and listed on the Data Report.

Figure -4622.9(d)(1)-1
Dissimilar Metal Repair Cavity Measurement



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Approval Date: December 6, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-817
Use of Die Forgings, SB-247, UNS A96061, Class T6, With Thickness ≤ 4.000 in. Material, Class 2 Construction (1992 Edition or Later)
Section III, Division 1

Inquiry: Is it permissible to use die forgings, SB-247, UNS A96061, Class T6, with thickness ≤ 4.000 in. material in Class 2 construction in accordance with Section III, Division 1, Subsection NC (1992 Edition or later)?

Reply: It is the opinion of the Committee that the die forgings, SB-247, UNS A96061, Class T6, with thickness ≤ 4.000 in. material may be used in Class 2 construction in accordance with Section III, Division 1, Subsection NC, provided the following additional requirements are satisfied:

(a) The maximum allowable stress values, S, shall be those listed in Table 1B of Section II, Part D, Subpart 1, in accordance with the Code Edition and Addenda identified in the Design Specification, when the1992 Edition or later Edition and Addenda is specified for construction. The maximum temperature limit is 300°F (149°C).

(b) This Case shall be identified in the Data Report.

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Approval Date: August 20, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-818-1
Use of NDE and Fracture Mechanics for Acceptance of Full Penetration Butt Welds in Lieu of Weld Repair, Class 1 and 2
Section III, Division 1

Inquiry: Under what conditions may use of NDE with acceptance criteria based on fracture mechanics be applied for acceptance of full penetration butt welds in ferritic vessels and in austenitic and ferritic piping in lieu of weld repair[1] when the radiography required by NB-5200 and NC-5200 indicates that the acceptance standards of Article NB-5000 or Article NC-5000 are not satisfied?

Reply: It is the opinion of the Committee that full penetration butt welds in ferritic vessels and in austenitic and ferritic piping may be accepted using NDE with acceptance criteria based on fracture mechanics in lieu of weld repair when the radiography required by NC-5200 and NC-5200 indicates that the acceptance standards of Article NB-5000 or Article NC-5000 are not satisfied, provided the following requirements are met:

(a) Materials shall meet Article NB-2000 or Article NC-2000, as applicable, and shall be limited to the following:

(1) P-No. 1 and P-No. 3 ferritic steel meeting NB-2330 or NC-2330, and for vessels, Nonmandatory Appendix G, G-2110[2] toughness requirements

(2) P-No. 8 and P-No. 43 material

(3) weld filler metal associated with the materials listed in (1) and (2)

(b) The ultrasonic (UT) method specified in this Case shall be applied in lieu of the radiographic (RT) method specified in NB-5200 or NC-5200 to examine welds in vessels and piping to characterize flaw indications. The UT method shall be qualified in accordance with Mandatory Appendix I. Acceptance of flaws shall be in accordance with Mandatory Appendix II.

(c) The UT examination shall include 100% of the volume of the entire weld, plus $^1/_2$ in. (13 mm) of base material on each side of the weld. The complete weld volume and base material for a distance of $^1/_4$ in. (6 mm) from each weld toe shall additionally be interrogated to identify indications from mid-wall to far side where reduced far surface UT responses may be obtained. The UT examination volume shall be accessible and scanned by angle beam in four directions: two directions perpendicular to the weld axis, except as provided in (1) below, and two directions parallel to the weld axis. A supplemental straight beam examination shall be used to measure component thickness, to provide far side profile information, and to detect laminations that could limit angle beam examination.

(1) Single-side access examination is permitted only for ferritic welds, provided the UT technique applied passes acceptable performance demonstration qualification using fabrication flaws of interest as described in Mandatory Appendix I, I-2. Where perpendicular scanning is limited on one side of such ferritic weld, a technique using the second leg of the V-path may be credited as access for the second perpendicular examination direction provided that the detection capability of that technique is included in the procedure demonstration described in (f) and (g).

(d) Weld surfaces shall be prepared in accordance with the qualified UT examination procedure. The surfaces shall be conditioned (smooth) such that transducers may properly couple with the scanning surface with no more than a $^1/_{32}$-in. gap between the search unit and the scanning surface. For dissimilar metal and austenitic welds, and for single-side access examinations for ferritic welds, the weld crown shall be ground flush.

(e) Requirements of Section V, Article 4 shall not apply except as stated in (f).

1 The basis for these requirements is provided in EPRI report 3002000643 and in ASME 2011 Addenda, Pressure Vessels and Piping Conference paper PVP2011-57675.

2 Compliance with the requirements of Nonmandatory Appendix G is a condition of the flaw acceptance criteria that is included in this Code Case.

(f) A written UT procedure containing, as a minimum, the requirements listed in Section V, Article 4, Table T-421, shall be followed. The procedure shall be demonstrated on qualification blocks or specimens as described in Mandatory Appendix I.

(g) The qualification block material shall be of the same material specification, product form, and heat treatment condition as one of the materials joined. If material as specified above is not available, material of similar chemical analysis, tensile properties, and metallurgical structure may be used. Where two or more base material thicknesses are involved, the qualification block thickness shall be of a size sufficient to contain the entire examination beam path. The qualification block configuration shall contain a weld representative of the joint to be examined, including thickness and for austenitic and dissimilar materials, the same welding process. The scanning and weld surfaces shall be representative of production surfaces.

(h) A documented examination plan shall be provided showing the transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld UT examination. The examination plan shall also include UT beam angle or angles used, beam directions with respect to the weld centerline, and volume examined for each weld.

(i) When UT examination shows a near-surface flaw indication, its status may be verified by surface examination or by UT observation of the flaw depth and proximity to the surface.

(j) For welds subject to inservice UT examination, the examination and evaluation shall also meet the requirements of the applicable Edition and Addenda of Section XI for preservice examination.

(k) The UT examination shall be performed using an encoded (amplitude and position) system.

(l) Data shall be recorded to allow for subsequent second or third party analysis. A complete data set shall be included in the data record.

(m) Review and acceptance of the procedure by the Inspector is required.

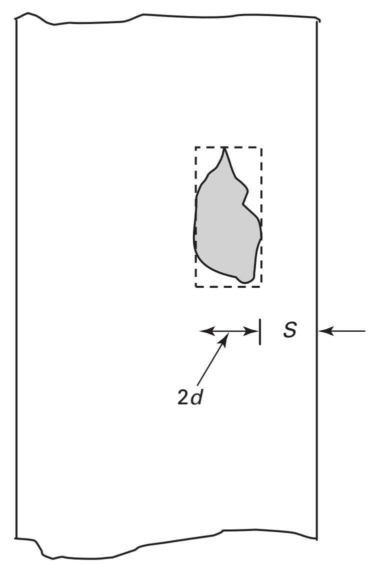
(n) All other requirements of Section III, Division 1 for Class 1 and 2 construction, as applicable, shall be met.

(o) Flaws exceeding the acceptance criteria referenced in this Case shall be repaired, removed, or reduced to an acceptable size, and the weld subsequently reexamined using the same examination procedure that detected the flaw. The rules of NB-4450 or NC-4450 shall be met. Flaws characterized as surface flaws shall be removed and reexamined and shall meet the requirements of NB-5340 or NB-5350 for Class 1 construction and NC-5340 or NC-5350 for Class 2 construction. Surface flaws shall be as defined by Figure 1.

(p) Use of this Case for acceptance of flaws that exceed NB-5200 or NC-5200 requires evaluation of weld process control parameters. This evaluation is required for consideration of process changes to minimize, to the extent practical, weld process-induced flaws.

(q) This Case number shall be recorded on the Data Report.

Figure 1
Flaw Configuration



GENERAL NOTE: Flaw considered as a surface flaw if $S < 0.4d$.

MANDATORY APPENDIX I
ULTRASONIC EXAMINATION PROCEDURE AND PERSONNEL QUALIFICATION

I-1 SCOPE

This Mandatory Appendix provides requirements for qualification of ultrasonic (UT) personnel and procedures when NDE with acceptance criteria based on fracture mechanics is used in lieu of weld repair of full penetration welds in vessels and piping.

I-2 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., pipe size, weld joint configurations, surface from which the examination is conducted, access limitations). The same specimens may be used to demonstrate qualification of both detection (I-3.1) and flaw evaluation (I-3.2) capability.

I-2.1 GENERAL

(a) The minimum number of flaws in a specimen set shall be ten.

(b) Specimens shall have sufficient volume to minimize spurious reflectors that may interfere with the interpretation process.

(c) The specimen set shall include the minimum and maximum vessel and pipe diameters and thickness for which the examination procedure is applicable. Pipe diameters within a range of $\frac{1}{2}$ in. (13 mm) of the nominal diameter shall be considered equivalent. Vessel and pipe diameters larger than 24 in. (600 mm) shall be considered to be flat.

(d) The specimen set shall meet the following requirements:

(1) For piping and dissimilar metal welds in vessel nozzles, the set shall include the following:

(-a) specimens not thicker than 0.1 in. (2.5 mm) above the minimum thickness for which the examination procedure is applicable

(-b) specimens not thinner than 0.5 in. (13 mm) [1 in. (25 mm) for ferritic welds] below the maximum thickness for which the examination procedure is applicable

(2) For vessels, the specimens shall be at least 90% of the maximum thickness to be examined.

(e) The specimen set shall include simulations of the following fabrication conditions:

(1) geometric and material conditions that require discrimination from flaws (e.g., counterbore or weld root conditions, cladding, weld buttering, remnants of previous welds, welds in close proximity).

(2) typical limited scanning surface conditions shall be included as follows when applicable:

(-a) weld crowns

(-b) diametral shrinkage

(-c) single-side access due to nozzles

(-d) safe-ends and other adjacent configurations

(-e) transducer contact surface limitations

I-2.2 FLAW LOCATION

(a) Flaws shall be located in the butt weld joint and its heat affected zone.

(b) At least 10% of flaws shall be distributed in the outer third and middle third of the through wall thickness respectively, and at least 50% of flaws shall be located within the inner third of the test specimens.

(c) Multiple flaws may overlap each other in the circumferential direction.

(d) For ferritic weld single-side access demonstrations, flaws shall be distributed approximately equally on both sides of the weld centerline.

I-2.3 FLAW CLASSIFICATION

(a) At least 25% of flaws shall meet the criteria for surface flaws, and at least two of these shall be embedded surface flaws (where $0 < S < 0.4d$). At least 40% of flaws shall be subsurface flaws.

(b) A flaw shall be considered a surface flaw if the nearest distance from the surface, S, is less than $0.4d$ where $2d$ is the depth (through-wall height) of the flaw (see Figure 1).

I-2.4 FLAW TYPE

At least 50% of flaws shall be planar flaws, such as lack-of-fusion, incomplete penetration or cracks. At least 30% of flaws shall be volumetric flaws, such as slag inclusions, or porosity.

I-2.5 FLAW DEPTH

(a) For piping and dissimilar metal welds in vessel nozzles, flaw depths (through-wall height) shall be less than 50% of nominal wall thickness. At least 20% of flaws located in the inner third of the test specimens shall be approximately the height of a weld pass.

(b) For ferritic vessels, flaw depths shall be within 1% [but not less than 0.075 in. (1.9 mm)] to 50% of nominal wall thickness. At least 20% of flaws located in inner third of the test specimens shall be approximately the height of a weld pass.

I-2.6 FLAW ORIENTATION

At least 10% but no more than 20% of flaws shall be axially oriented and the remaining flaws shall be circumferentially oriented.

I-3 PERFORMANCE DEMONSTRATION

Personnel and procedure performance demonstration tests shall be conducted as blind tests. The surface opposite the surface from which the examination is conducted shall be concealed from the candidates. Identification of the test specimens shall be concealed from the candidates. All examinations shall be completed prior to grading the results and presenting the results to the candidate. Divulgence of particular specimen results or candidate viewing of unmasked specimens after the performance demonstration is prohibited.

I-3.1 DETECTION TEST

(a) The specimen set shall include detection specimens that meet the following requirements:

(1) Specimens shall be divided into grading units.

(-a) Each grading unit shall include at least 3 in. (75 mm) of weld length.

(-b) The end of each flaw shall be separated from an unflawed grading unit by at least 1 in. (25 mm) of unflawed material. A flaw may be less than 3 in. (75 mm) in length.

(-c) The segment of weld length used in one grading unit shall not be used in another grading unit.

(-d) Grading units need not be uniformly spaced around the specimen.

(-e) More than one flaw may be located in one grading unit.

(2) Personnel performance demonstration detection test sets shall be selected from Table I-1. The number of unflawed grading units shall be at least $1\frac{1}{2}$ times the number of flawed grading units.

(3) Flawed and unflawed grading units shall be randomly mixed.

(b) Examination equipment and personnel are qualified for detection when personnel performance demonstrations satisfy the acceptance criteria of Table I-1 for both detection and false calls.

I-3.2 FLAW EVALUATION TEST

The candidate shall size the flaw depth, and each flaw shall be classified as either surface flaw or subsurface flaw. A flaw shall be considered as a surface flaw if the nearest distance from the surface, S, is less than $0.4d$ where $2d$ is the depth of the flaw (see Figure 1). The minimum through-wall dimension used for evaluation of nonplanar flaws shall not be less than 0.08 in. (2 mm). The candidate shall then evaluate whether the flaw is acceptable or unacceptable in accordance with Mandatory Appendix II.

(a) When the flaw classification and evaluation test is conducted in conjunction with a successful detection test, where less than ten flaws are detected, additional specimens shall be provided to the candidate such that at least ten flaws are sized. The additional regions of each specimen containing a flaw to be sized may be identified to the candidate. The candidate shall determine the length and maximum depth of the flaw in each region.

(b) Personnel performance demonstration flaw evaluation test sets shall be selected from Table I-2. The number of acceptable flaws shall be at least $1\frac{1}{2}$ times the number of rejectable flaws.

(c) Examination equipment and personnel are qualified for flaw evaluation when personnel performance demonstrations satisfy the acceptance criteria of Table I-2 for both rejectable flaws and acceptable flaws.

(d) Examination procedures, equipment, and personnel are qualified for depth-sizing when the RMS error of the flaw depth measurements, as compared to the true flaw depths, does not exceed 0.125 in. (3 mm).

I-4 PROCEDURE QUALIFICATION

Procedure qualification shall include the following additional requirements.

(a) The specimen set shall include the equivalent of at least three personnel performance demonstration test sets. Successful personnel performance demonstrations may be combined to satisfy these requirements.

(b) Detectability of all flaws in the procedure qualification test set that are within the scope of the procedure shall be demonstrated. Flaw classification and evaluation test shall meet the requirements of I-3.2.

(c) At least one successful personnel performance demonstration shall be performed.

(d) To qualify new values of essential variables, at least one personnel performance demonstration set shall be required. The acceptance test criteria of (b) shall be met.

Table I-1
Personnel Performance Demonstration Detection Test Acceptance Criteria

Detection Test Acceptance Criteria		False Call Acceptance Criteria	
No. of Flawed Grading Units	Minimum Detection Criteria	No. of Unflawed Grading Units	Maximum No. of False Calls
10	8	15	2
11	9	17	3
12	9	18	3
13	10	20	3
14	10	21	3
15	11	23	3
16	12	24	4
17	12	26	4
18	13	27	4
19	13	29	4
20	14	30	5

Table I-2
Personnel Performance Demonstration Flaw Evaluation Acceptance Criteria

Rejectable Flaw Acceptance Criteria		Incorrect Evaluation Acceptance Criteria	
No. of Rejectable Flaws	Minimum to Call Correctly	No. of Acceptable Flaws	Maximum No. to Call Rejectable
5	5	8	2
6	5	9	2
7	6	11	2
8	7	12	3
9	8	14	3
10	8	15	3

MANDATORY APPENDIX II
UT FLAW ACCEPTANCE STANDARDS

II-1 SCOPE

This Mandatory Appendix provides standards for acceptance of subsurface flaws. Flaws exceeding these acceptance standards shall be repaired, and the weld subsequently reexamined using the same UT procedure that detected the flaw.

II-2 FLAW ACCEPTANCE STANDARDS FOR FULL PENETRATION BUTT WELDS IN FERRITIC AND AUSTENITIC PIPING, DISSIMILAR METAL WELDS IN VESSEL NOZZLES, AND VESSEL NOZZLES-TO-PIPING

(a) The acceptance standards shall apply for materials that meet the requirements of NB-2330 or NC-2330 as applicable, and the specified minimum yield strength of 50 ksi (345 MPa) or less for ferritic materials and 35 ksi (240 MPa) or less for austenitic materials at 100°F (40°C).

(b) A fabrication subsurface flaw depth shall not exceed the following regardless of length (see Figure 1 and Table II-1):

(1) For $0.4 \le S/d < 1.0$, maximum allowable flaw depth $2d = (S/d)^{0.96} \times 0.2t$

(2) For $S/d \ge 1.0$, maximum allowable flaw depth $2d = 0.2t$

(c) Surface flaws ($S < 0.4d$, Figure 1) shall comply with Section III, Subsection NB or NC surface examination acceptance standards, as applicable.

II-3 FLAW ACCEPTANCE STANDARDS FOR FULL PENETRATION FERRITIC WELDS IN VESSEL AND NOZZLE-TO-VESSEL JOINTS

(a) The acceptance standards shall apply for materials that meet the requirements of NB-2330 or NC-2330 and Nonmandatory Appendix G-2110.

(b) For vessels equal to or less than 12 in. (300 mm) thickness, a fabrication subsurface flaw shall not exceed the following regardless of length (see Figure 1 and Table II-1):

(1) For $0.4 \le S/d < 1.0$, maximum allowable flaw depth $2d = (S/d)^{0.96} \times 0.4t$

(2) For $S/d \ge 1.0$, maximum allowable flaw depth $2d = 0.4t$

(c) For vessels equal to or greater than 16 in. (400 mm) thickness, a fabrication subsurface flaw shall not exceed the following regardless of length (see Figure 1 and Table II-1):

(1) For $0.4 \le S/d < 1.0$, maximum allowable flaw depth $2d = (S/d)^{0.96} \times 0.03t$

(2) For $S/d \ge 1.0$, maximum allowable flaw depth $2d = 0.03t$

(d) For vessels greater than 12 in. (300 mm) and less than 16 in. (400 mm) thickness, the maximum subsurface flaw depth ($2d$) shall be linearly interpolated between the values determined in (b) and (c).

(e) Surface flaws ($S < 0.4d$, Figure 1) shall comply with Section III, Subsection NB or NC surface examination acceptance standards, as applicable.

Table II-1
Subsurface Flaw Acceptance Criteria

Item	Reference	2d/t						
S/d =	Figure 1	0.4	0.5	0.6	0.7	0.8	0.9	≥ 1.0
Pipe/nozzle buttweld	II-2(b)	0.083	0.103	0.122	0.142	0.161	0.181	0.200
Vessel t ≤ 12 in. (300 mm)	II-3(b)	0.016	0.020	0.024	0.028	0.032	0.036	0.040
Vessel t ≥ 16 in. (400 mm)	II-3(c)	0.012	0.015	0.018	0.021	0.024	0.027	0.030

GENERAL NOTE: For vessels 12 in. (300 mm) < 16 in. (400 mm), 2d/t values are to be determined by linear interpolation between II-3(b) and II-3(c)

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Approval Date: December 6, 2011

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-819
Use of Die Forgings, SB-247, UNS A96061, Class T6, With Thickness ≤ 4.000 in. Material, Class 2 Construction (1989 Edition With the 1991 Addenda or Earlier)
Section III, Division 1

Inquiry: Is it permissible to use die forgings, SB-247, UNS A96061, Class T6, with thickness ≤ 4.000 in. material in Class 2 construction in accordance with Section III, Division 1, Subsection NC (1989 Edition with the 1991 Addenda or earlier)?

Reply: It is the opinion of the Committee that the die forgings, SB-247, UNS A96061, Class T6, with thickness ≤ 4.000 in. material may be used in Class 2 construction in accordance with Section III, Division 1, Subsection NC, provided the following additional requirements are satisfied:

(a) The maximum allowable stress values, S, shall be those listed in Table I-8.4 of Section III, Appendix I, in accordance with the Code Edition and Addenda identified in the Design Specification, when the 1989 Edition with the 1991 Addenda or earlier Edition and Addenda is specified for construction. The maximum temperature limit is 300°F (149°C).

(b) This Case shall be identified in the Data Report.

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Approval Date: December 29, 2011
(ACI) Approval Date: January 25, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-820
Twisting of Horizontal Prestressing Tendons
Section III, Division 2

Inquiry: Under what conditions may the provisions of CC-4432.5 regarding intentional twisting for nominal 0.6 in. strand (ASTM A416) horizontal circumferential tendons comprised of multiple elements stressed simultaneously as a group be waived?

Reply: It is the opinion of the Committee that intentional twisting of tendons comprised of multiple elements stressed simultaneously as a group may be waived for horizontal circumferential tendons as well as other configurations of tendons meeting all other requirements of CC-4430, provided the following additional conditions are met:

(a) Tendons shall be maximum of 0.6 in. (nominal diameter) strand (ASTM A416), which are prefabricated and pulled into the duct at one time (complete tendon). All strands shall be the same hand lay.

(b) Provisions shall be made to keep strand in the tendon bundle parallel as the tendon is pulled into the duct.

(c) The uncoiler shall allow individual strands to move against each other as the tendon is pulled in. The tendon shall be pulled from a cage versus being pretied and pulled in from a rotating table (lazy susan).

(d) The use of this Case shall be identified in the Data Report.

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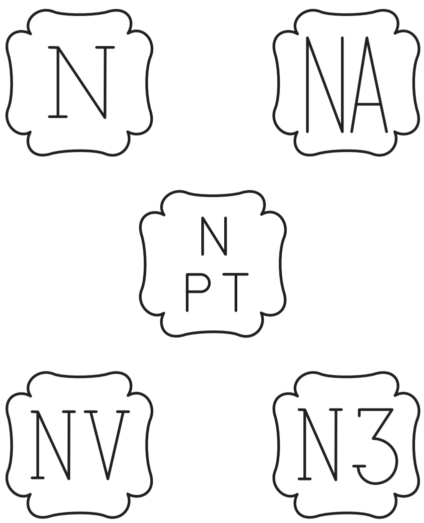
Approval Date: October 28, 2014

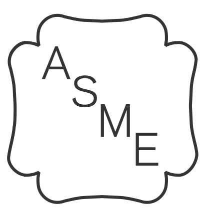
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-822-2
Application of the ASME Certification Mark
Section III, Division 1; Section III, Division 2; Section III, Division 3; Section III, Division 5

Inquiry: In the 2011 Addenda to the 2010 Edition of Section III, the ASME Code Symbols shown below:



were replaced by the single ASME Certification Mark shown below, accompanied by the appropriate Nuclear Designator required by NCA-8000 or WA-8000.



For construction to Section III Editions and Addenda prior to the 2011 Addenda, in lieu of the Code Symbol Stamps required by NCA-8000 or WA-8000 in the Section III Edition and Addenda used for construction, may a N, NA, NPT, NV, or N3 Certificate Holder use the new ASME Certification Mark with the appropriate Nuclear Designator specified in the 2011 Addenda or the 2013 Edition?

Reply: It is the opinion of the Committee that the ASME Certification Mark with the appropriate Nuclear Designator in the 2011 Addenda or the 2013 Edition may be used for construction to Section III Editions and Addenda prior to the 2011 Addenda. In addition, it is the opinion of the Committee that the N, NA, NPT, NV, and N3 Code Symbols may be used for construction to the 2011 Addenda or the 2013 Edition of Section III.

Use of this Case is not required for use of the N, NA, NPT, NV, and N3 Code Symbols for construction to Section III Editions and Addenda prior to the 2011 Addenda.

The N, NA, NPT, NV, and N3 Code Symbols may be used only through December 31, 2015.

Because the ASME Certification Mark with the appropriate Nuclear Designator is equivalent to the corresponding N, NA, NPT, NV, and N3 Code Symbols, use of this Case is not required to be documented in the Design Specification, Design Report, or Data Report, and the provisions of NA/NCA/WA-1140 related to use of Cases need not be met for use of this Case.

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Approval Date: January 23, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-823-1
Visual Examination
Section XI, Division 1

Inquiry: What alternatives to the requirements of IWA-2210 may be used when applying the requirements of Section V for visual examination?

Reply: It is the opinion of the Committee that visual examination shall be conducted in accordance with the requirements of Section V, Article 9, except that the angle of view requirements for direct visual only apply to VT-1 and the requirements for illumination, distance, and resolution demonstration shall be in accordance with Table 1.

Table 1
Visual Examinations

Visual Examination	Minimum Illunmination fc (lux) [Note (1)]	Maximum Direct Examination Distance, ft (mm)	Maximum Height for Procedure Demonstration Characters, in. (mm) [Note (2)]
VT-1	50 (550)	2 (600)	0.044 (1.1)
VT-2	n/a	n/a	n/a
VT-3	50 (550)	n/a	0.105 (2.7)

NOTES:
(1) Resolution of the specified characters can be used in lieu of illumination measurement to verify illumination adequacy.
(2) For procedure demonstration, a test chart or card containing text with some lowercase characters, without an ascender or descender (e.g., a, c, e, o), that meet the specified height requirements is required. Measurements on the test chart or card shall be made once before its initial use with an optical comparator (10X or greater) or other suitable instrument. At least one character of each specified character size shall be measured, to ensure that the card meets the applicable requirements. Alternatively, a production lot of cards may be verified by measurements on the first and last cards produced and at least one card in the approximate middle of the production run. A production lot shall not exceed 50 cards.

Approval Date: October 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-824
Ultrasonic Examination of Cast Austenitic Piping Welds From the Outside Surface
Section XI, Division 1

Inquiry: What alternative to the requirements of Appendix VIII, VIII-3110(c) may be used when performing ultrasonic examinations of centrifugally-cast and statically-cast austenitic piping welds from the outside surface?

Reply: It is the opinion of the Committee that the following requirements may be used in lieu of the requirements of Appendix VIII, VIII-3110(c), when ultrasonically examining cast austenitic piping welds from the outside surface.

1 ULTRASONIC EXAMINATION OF CAST AUSTENITIC PIPING WELDS

(a) In addition to variations in attenuation, velocity, reflection, and refraction at grain boundaries, the following welds are associated with beam splitting, beam distortion, and beam skewing, due to the coarse-grained and anisotropic nature of the cast austenitic base materials:

(1) centrifugally-cast or statically-cast austenitic steel to wrought carbon or low alloy steel

(2) statically-cast austenitic steel to centrifugally-cast austenitic steel

(3) centrifugally-cast austenitic steel to centrifugally-cast austenitic steel

(4) statically-cast austenitic steel to statically-cast austenitic steel

(5) statically-cast austenitic steel to wrought austenitic steel

(b) Examination of the welds for, which the ultrasonic beam must pass through the wrought carbon, low alloy steel, or wrought austenitic steel materials of the welds in (a) shall meet the requirements of Appendix I, I-2220.

(c) The requirements of Appendix III, as supplemented by Table I-2000-1, shall be met for examination of the welds for, which the ultrasonic beam must pass through the cast austenitic base materials listed in 1(a), with the following modifications. Examinations in accordance with this Case shall be performed from the outside surface only.

(1) In lieu of the requirements of III-2120, the following requirements shall be met:

(-a) All search units shall be dual, transmit-receive, refracted longitudinal wave probes, consisting of monolithic elements (conventional search unit) or multi-element phased arrays (phased-array search unit).

(-b) Wedges, whether integral or replaceable, shall allow for no more than a $^1/_{32}$ in. (0.8 mm) gap between the search unit and the component surface along the scan length.

(-c) Two ranges of inspection frequencies are required.

(-1) For piping less than or equal to 1.6 in. (41 mm) thick, up to 1.5 MHz probes shall be used; however, higher frequency probes (up to and including 2 MHz) may be useful for flaw characterization.

(-2) For piping greater than 1.6 in. (41 mm) thick, 0.5 MHz to 1.0 MHz probes shall be used.

(-d) At least one inside-surface-impingement beam angle (calculated) shall be within the range of 30 deg to 50 deg for examination volume coverage. At least one beam angle greater than or equal to 55 deg is required for detection of deeper flaws.

(-e) Search unit size is dependent on frequency, and focal length or sound path. For detection of inner-surface-initiated flaws, the search unit shall have a sufficiently large active aperture to enable appropriate beam focusing within 80% to 110% of the nominal wall thickness of the piping material. The following relationship shall be used to determine if the appropriate aperture has been chosen:

$$D\sqrt{N4c/f}$$

where

c = longitudinal wave velocity in material
D = minimum probe diameter or aperture
f = nominal probe frequency
N = required focal length

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.

For phased array search units, the focal sound path shall be verified using sound-beam modeling, to ensure that focal laws producing a beam focusing within 80% to 110% of the nominal wall thickness of the piping material are selected for the examination.

(2) In addition to III-2200(a) and (b), personnel shall receive 4 hr of training and 4 hr of hands-on laboratory examination of cast austenitic steel welds related to discriminating between flaw indications and indications of geometric or metallurgical origin. This training shall include descriptions of coarse grain structures, their effect on the ultrasonic beam, and the expected ultrasonic response characteristics of metallurgical and flaw reflectors.

(3) In lieu of the requirements of III-2430, scanning shall be conducted such that an average material noise level of 5% to 20% full screen height is observed.

(4) In lieu of the requirements of Table III-3430-1, a notch depth, d, of $0.1t$ shall be used, with the corresponding tolerances in the table for all material thicknesses.

(5) In addition to the requirements of III-4200, to allow adequate ultrasonic coupling with the examination surface and to accommodate the relatively large search units required, the scanning surface condition shall be flush. Flush is defined as no more than a $^1/_{32}$ in. (0.8 mm) gap between the search unit and the examination surface for the entire length of the scan.

(6) In lieu of the requirements of III-4430, the angle beam examination for reflectors transverse to the weld shall be performed in two directions covering at least $^1/_2$ in. (13 mm) on the cast austenitic steel base materials and the entire weld crown.

(7) In lieu of III-4520(g)(1)(-b), the search unit positions parallel to the reflector at the end points where the reflector response is reduced to the noise level shall be recorded (estimated length).

(8) In lieu of the requirements of III-4530, tip-diffraction methods shall be used for flaw depth sizing when a tip-diffracted signal can be resolved. Flaw length sizing should be performed using the full-amplitude drop technique.

(9) In addition to the requirements of Appendix III, ultrasonic coupling between the contoured search units and the examination surface must be over the entire contact face of the search unit. Continuous noise level on the ultrasonic display should not be used as the sole indicator of sufficient coupling. The examination procedure shall address adequate coupling, by requiring use of liberal amounts of couplant material, requiring recognition of material reflectors at or near the inside surface, requiring couplant monitoring beam angles, or a combination thereof.

(10) In addition to the requirements of Appendix III, encoded scans with off-line analysis shall be used. If encoded scanning and off-line analysis are not feasible, manual scans are allowed.

Approval Date: October 2, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-825
Alternative Requirements for Examination of Control Rod Drive Housing Welds
Section XI, Division 1

Inquiry: What alternative to the requirements of Table IWB-2500-1, Examination Category B-O, may be used for the extent and frequency of examination for welds in Control Rod Drive (CRD) housings?

Reply: It is the opinion of the Committee that, in lieu of the extent and frequency of examination requirements of Table IWB-2500-1, Examination Category B-O, for welds in Control Rod Drive (CRD) housings, 10% of the combined length of each weld configuration (e.g., housing-to-housing and housing-to-flange) of the peripheral CRD housing welds may be examined, provided each weld selected for examination is examined to the maximum extent practicable.

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Approval Date: July 16, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-826
Ultrasonic Examination of Full Penetration Vessel Weld Joints in Figures IWB-2500-1 Through IWB-2500-6 Section XI, Division 1

Inquiry: What alternatives to the examination volume requirements of Figures IWB-2500-1 through IWB-2500-6 are permissible?

Reply: It is the opinion of the Committee that the examination volume requirements of Figures IWB-2500-1 through IWB-2500-6 may be reduced from the original $\frac{1}{2}\,t$ dimension (e.g., $\frac{1}{2}\,t_{1,}$ $\frac{1}{2}\,t_s$) to $\frac{1}{2}$ in. (13 mm), as shown in Figures 1 through 6, provided the original $\frac{1}{2}\,t$ volume received a preservice or prior inservice ultrasonic examination in accordance with the applicable requirements of Appendix VIII, I-3000, and IWA-2200(c). This Case shall not apply to examinations conducted to meet the successive inspection requirements of IWB-2420(b).

Figure 1
Vessel Shell Circumferential Weld Joints (½ in. = 13 mm)

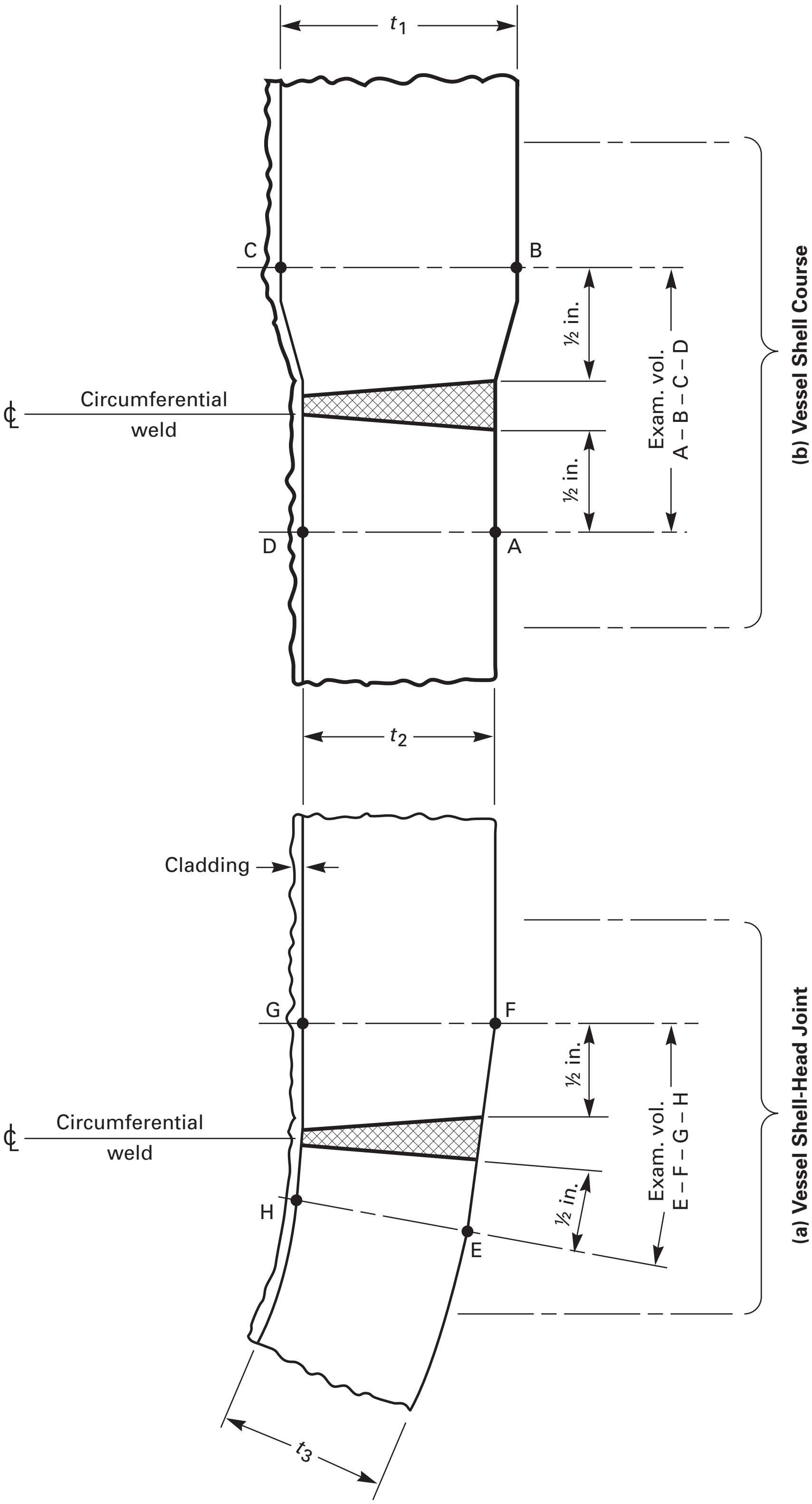


Figure 2
Vessel Shell Longitudinal Weld Joints (½ in. = 13 mm)

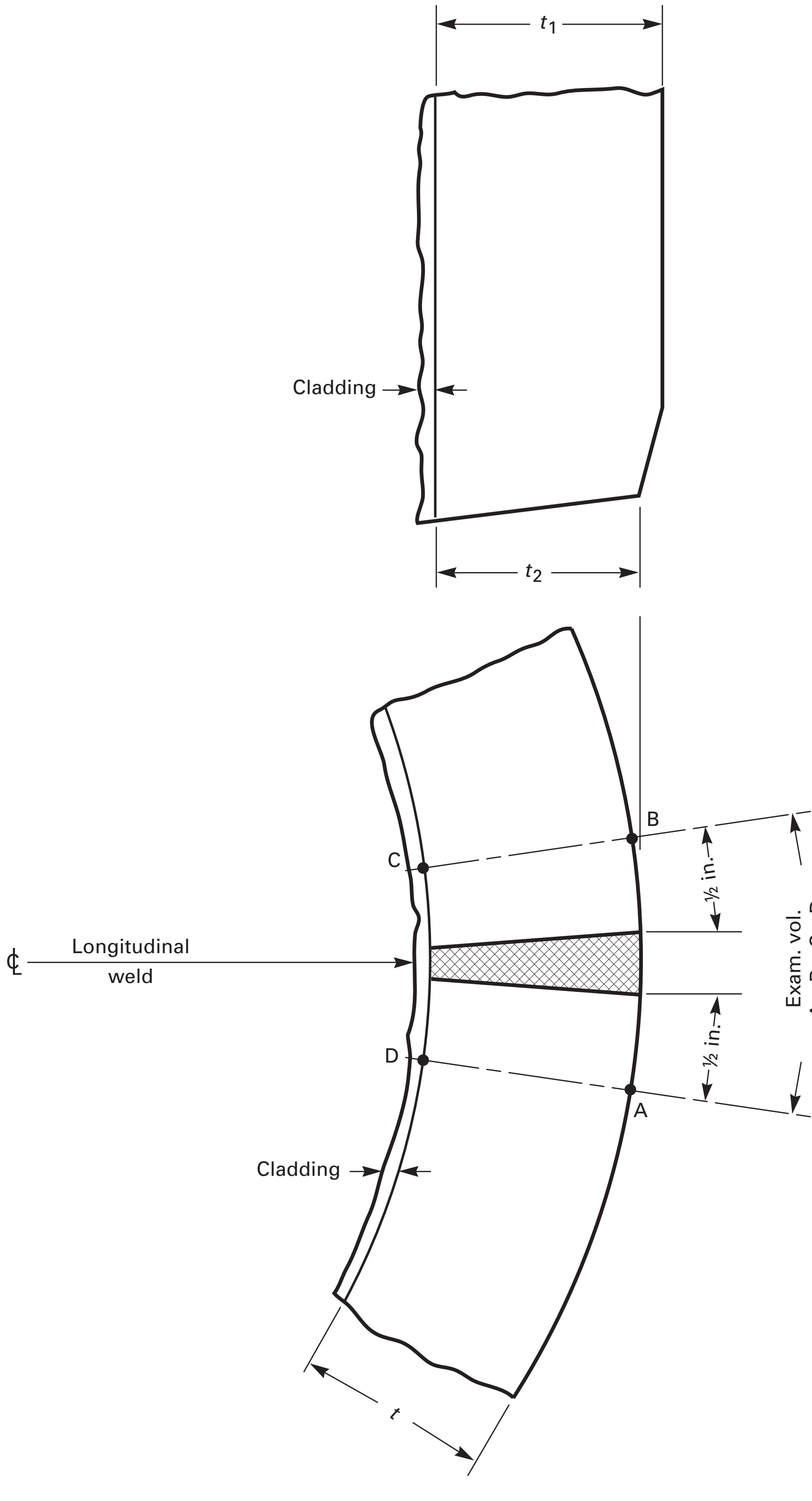
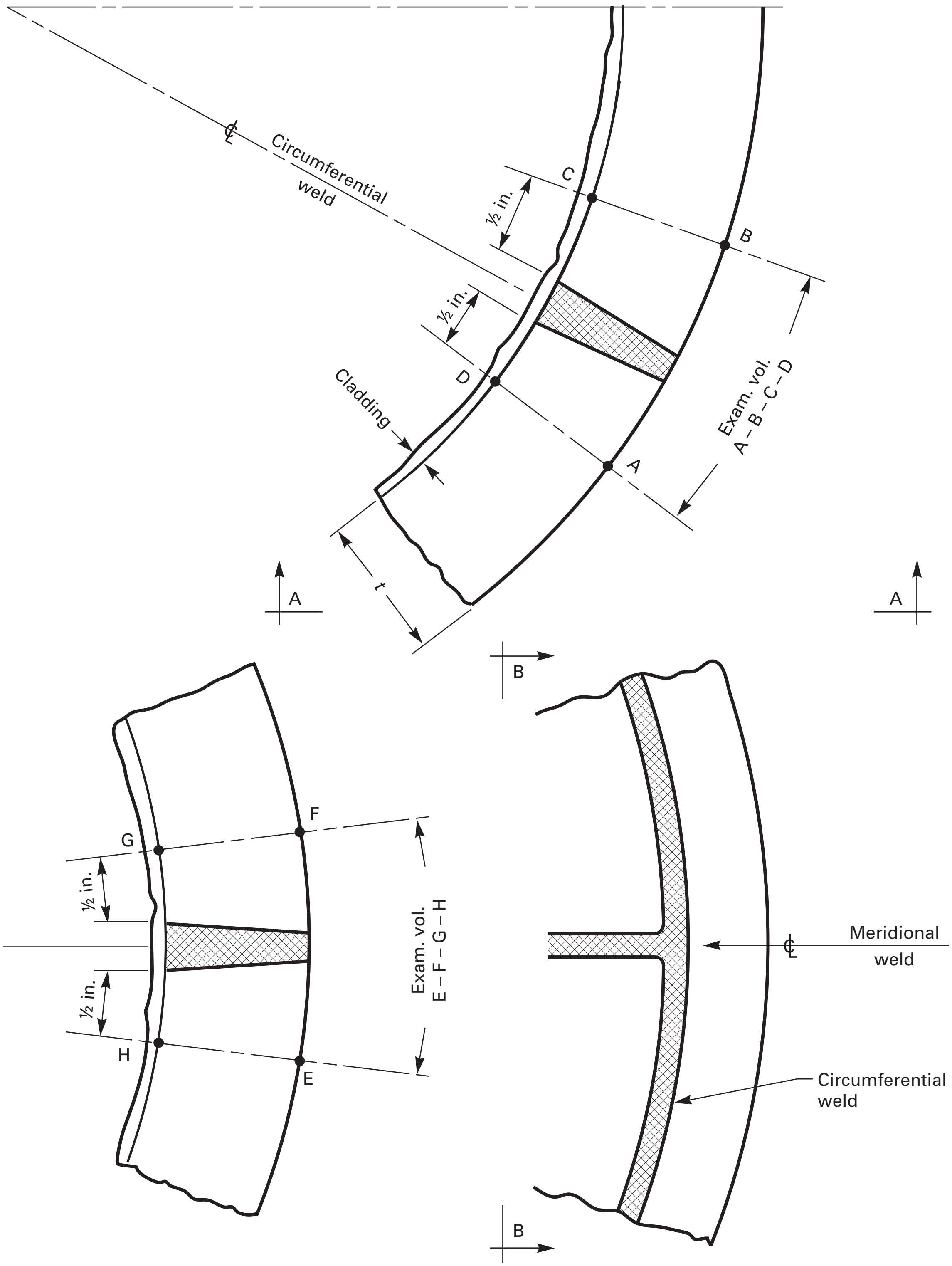


Figure 3
Spherical Vessel Head Circumferential and Meridional Weld Joints ($\frac{1}{2}$ in. = 13 mm)



Section B – B

View A – A

Figure 4
Shell-to-Flange Weld Joint (½ in. = 13 mm)

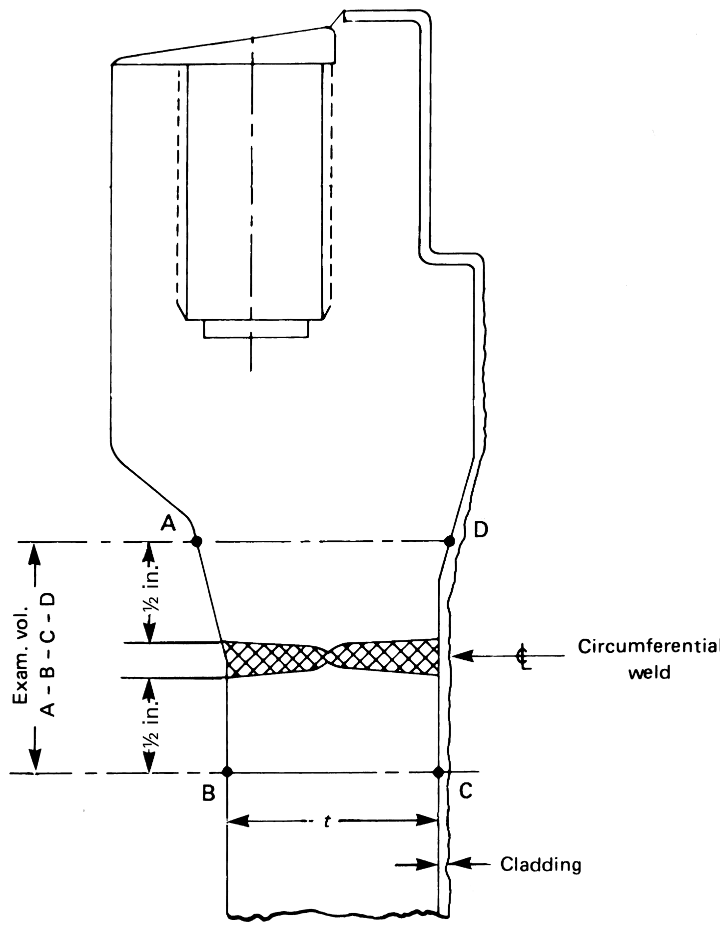


Figure 5
Head-to-Flange Weld Joint (½ in. = 13 mm)

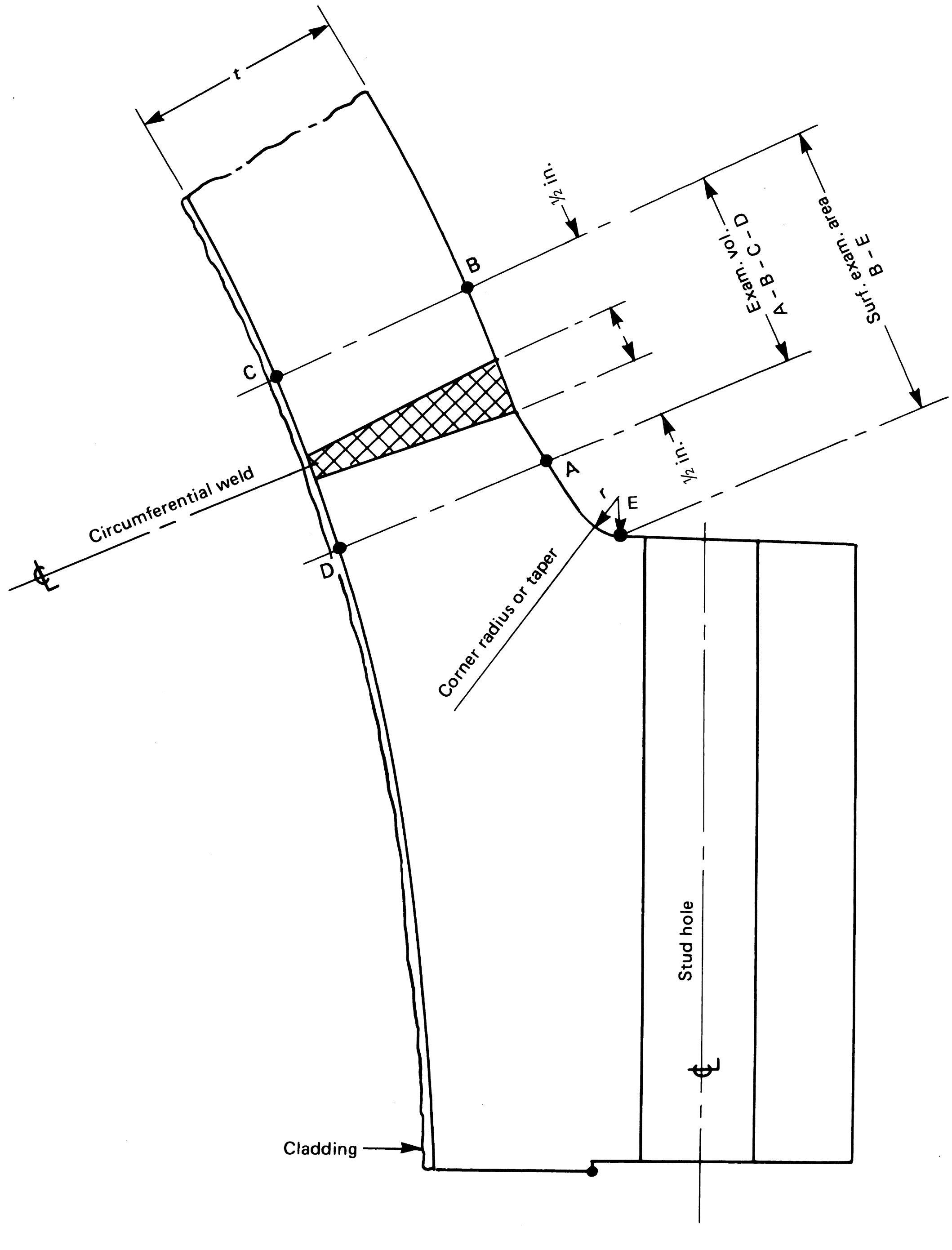
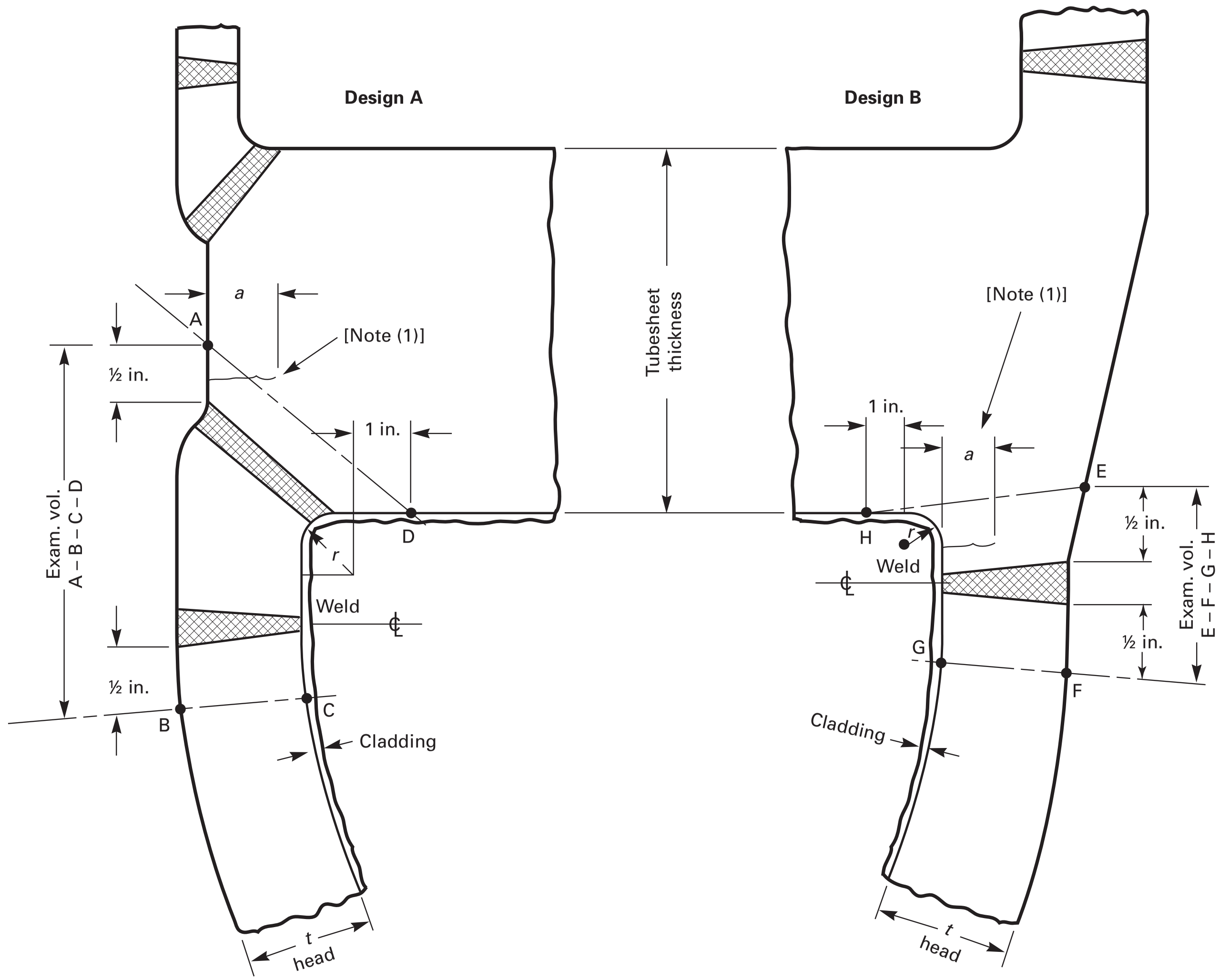


Figure 6
Typical Tubesheet-to-Head Weld Joints (½ in. = 13 mm)



GENERAL NOTE: All flaws are exaggerated in size and scale.

NOTE:
(1) Laminar flaws within examined volume of tubesheet are considered planar flaws.

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Approval Date: April 27, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-828
Alternative Nonmetallic Material Manufacturer's and Constituent Supplier's Quality System Program Requirements, Section III, NCA-3900, 2010 Edition, and Earlier Editions and Addenda
Section III, Division 1; Section III, Division 2

Inquiry: What alternative to the Section III,2010 Edition, and earlier Editions and Addenda, NCA-3920 through NCA-3960 Quality System Program requirements may be used by a Nonmetallic Material Manufacturer or Constituent Supplier?

Reply: It is the opinion of the Committee that in lieu of the Section III, 2010 Edition, and earlier Editions and Addenda, NCA-3920 through NCA-3960 Quality System Program requirements, a Nonmetallic Material Manufacturer or Constituent Supplier may use the following alternative for use with the 2010 Edition, and earlier Editions and Addenda, provided sections 1 through 4 of this Case and all other applicable requirements of NCA-3900, as applicable, are met. Use of this Case shall be documented on the Data Report.

1 QUALITY SYSTEM CERTIFICATE (NONMETALLIC MATERIALS)

(a) Nonmetallic Material Manufacturer may obtain a Quality System Certificate (Materials) issued by the Society verifying the adequacy of the Nonmetallic Material Manufacturer's Quality System Program. Alternatively, the Nonmetallic Material Manufacturer shall have his Quality System Program surveyed and qualified by the Constructor or Fabricator of the concrete components.

(b) A Nonmetallic Material Constituent Supplier may obtain a Quality System Certificate (Materials) issued by the Society verifying the adequacy of the Nonmetallic Material Constituent Supplier's Quality System Program. Alternatively, the Nonmetallic Material Constituent Supplier shall have his Quality System Program surveyed and qualified by the Nonmetallic Material Manufacturer of the concrete. Additionally, both the Constructor or Fabricator and the Nonmetallic Material Manufacturer shall be responsible for assuring that the constituents supplied meet the applicable requirements of CC-2100 and CC-2200.

2 EVALUATION FOR QUALITY SYSTEM CERTIFICATES

(a) The Society, when requested by the Nonmetallic Material Manufacturer on forms issued by the Society, will arrange for an evaluation of the applicant's Quality System Program. The Program will be evaluated on the basis of its compliance with the applicable material requirements of this Case. The certificate that is issued for a 3-year period will describe and specify the scope and limits of work for which the applicant is qualified and will be subjected to a planned audit program by the Society. No later than 6 months prior to the expiration of the certificate, the Nonmetallic Material Manufacturer shall apply for a renewal evaluation and for the issuance of a new certificate.

(b) The Society, when requested by the Nonmetallic Material Constituent Supplier on forms issued by the Society, will arrange for an evaluation of the applicant's Quality System Program. The Program will be evaluated on the basis of its compliance with the applicable requirements of this Case. The certificate that is issued for a 3-year period will describe and specify the material constituent that the applicant is qualified to supply and will be subject to a planned audit program by the Society. No later than 6 months prior to the expiration of the certificate, the Nonmetallic Material Constituent Supplier shall apply for a renewal evaluation and for the issuance of a new certificate.

3 QUALITY SYSTEM PROGRAM REQUIREMENTS

3.1 GENERAL

(a) A Nonmetallic Material Manufacturer or a Nonmetallic Material Constituent Supplier, hereafter referred to as the Material Organization, need not be a Certificate Holder, but their Quality System Program shall conform to the requirements of this Case, as applicable to the scope of their work.

(b) Material supplied by a Nonmetallic Material Constituent Supplier shall meet all applicable requirements of CC-2100 and CC-2200.

(c) The Material Organization shall establish a written Quality System Program for the control of quality during manufacture or during other work it proposes to perform, and for the traceability of material or source material under its control. The Program shall be planned, documented, implemented, and maintained in accordance with the requirements of this Subarticle.

(d) The Quality System Program shall include consideration of the technical aspects and provide for planning and accomplishment of activities affecting quality. The Program shall provide for any special controls, processes, test equipment, tools, and skills to attain the required quality and verification of quality.

3.1.1 Scope.

(a) The Quality System Program shall define the specific activities included in the scope of the work the Material Organization proposes to perform, including any of the following:

(1) Testing, examination, repair, or treatments required by the material specification or the specific applicable material requirements of this Case and certification of the results of such tests, examinations, repairs, or treatments.

(2) Receipt, identification, verification, handling, storage, and shipment of material or source material.

(3) Approval and control of supplier and source material or subcontracted services.

(b) The Program shall include measures to comply with all requirements of this Subarticle, to the extent necessary to ensure compliance with the requirements of this Case.

3.1.2 Organization.

(a) The organizational structure for executing the Program may take various forms, provided the persons and organizations assigned the quality assurance functions have the required authority and organizational freedom.

(b) Persons or organizations responsible for defining and measuring the overall effectiveness of the Program shall

(1) be designated

(2) be sufficiently independent from the pressures of production

(3) have direct access to responsible management at a level where appropriate action can be initiated, and

(4) report regularly on the effectiveness of the Program

(c) The organizational structure, functional responsibilities, level of authority, and lines of communication for activities affecting quality shall be documented. Persons or organizations responsible for assuring that an appropriate Quality System Program has been established and verifying that activities affecting quality have been correctly performed shall have sufficient authority, access to work areas, and organizational freedom to

(1) identify quality problems

(2) initiate, recommend, or provide solutions to quality problems through designated channels

(3) verify implementation of solutions

(4) ensure that further processing, delivery, or use is controlled until proper distribution of a nonconformance, deficiency, or unsatisfactory condition has occurred

(d) Individuals or groups assigned the responsibility of checking, auditing, or otherwise verifying that production and quality control activities have been correctly performed shall be independent of the individual or group directly responsible for performing the specific activity. Such persons shall not report directly to the supervisor with immediate responsibility for the work being verified.

(e) Management shall regularly review the status and adequacy of the Program.

3.2 PERSONNEL

3.2.1 Indoctrination, Training, and Qualification of Personnel.

(a) Measures shall be established to ensure that all personnel performing or managing activities affecting quality are indoctrinated and trained. The assignment of personnel shall be at the discretion of the organization's management. Indoctrination and training measures shall reflect the following requirements:

(1) Personnel to be indoctrinated or trained shall be identified.

(2) The extent of indoctrination and training shall be commensurate with the scope, complexity, and nature of the activity as well as the education, experience, and proficiency of the person.

(3) Personnel shall be indoctrinated in the general criteria, applicable codes, standards, company procedures, Quality System Program requirements, job responsibilities, and authority as they relate to a particular function.

(4) Training shall be provided, as needed, to achieve initial proficiency, maintain proficiency, and to adapt to changes in technology, methods, and job responsibilities.

(b) Personnel who lead audits shall be qualified on the basis of education, experience, training, audit participation, and examination in accordance with the organization's Quality System Program.

3.2.2 Personnel Records.

(a) Records shall be maintained of the implementation of indoctrination and training of personnel. Records of indoctrination and training may take the form of attendance sheets, training logs, or personnel training records.

(b) Qualification records of personnel who lead audits shall be documented and maintained and shall include education, experience, audit training and examination, and audit participation used as the basis of qualification.

3.3 PROGRAM DOCUMENTATION

3.3.1 Quality System Manual.

(a) The Quality System Program shall be described and summarized in a Quality System Manual that shall be a major basis for demonstration of compliance with the rules of this Case.

(b) The Program documented in the Manual shall be implemented by written procedures that are maintained either separately or in the Quality System Manual.

(c) Detailed technical procedures and processes are not considered part of the Manual; however, the controls of such procedures and processes shall be covered by the Manual.

3.3.2 Procedures, Instructions, and Drawings.

(a) Activities affecting quality shall be prescribed by and performed in accordance with documented instructions, procedures, or drawings of a type appropriate to the circumstances.

(b) These documents shall include or reference appropriate criteria for determining that the prescribed activities have been satisfactorily completed.

3.3.3 Document Control. The preparation, issue, and change of documents that specify quality requirements or prescribe activities affecting quality, such as Quality System program Manuals, purchase specifications, instructions, procedures, and drawings shall be controlled to ensure that the correct documents are being used at the location where the activity is performed. Such documents, including changes thereto, shall be reviewed for adequacy and approved for release by authorized personnel.

3.3.4 Quality Records. Records that furnish documentary evidence of quality shall be specified, prepared, controlled, and maintained. Records shall be legible, identifiable, and retrievable. Records shall be protected against damage, deterioration, or loss. Requirements and responsibilities for record transmittal, distributions, retention, maintenance, and disposition shall be established and documented.

3.3.5 Records of Examinations and Tests. All characteristics required to be reported by the material specification and this Case shall be verified and the results recorded. Records shall be traceable to the document and revision to which an inspection, examination, or test was performed. Certified Material Test Reports shall be prepared by manufacturers, or obtained from material suppliers, as appropriate.

3.4 CONTROL OF PURCHASED MATERIALS, SOURCE MATERIALS, AND SERVICES

3.4.1 General.

(a) Measures shall be established to ensure that all purchased material, source material, and subcontracted services conform to the requirements of this Case.

(b) These measures shall be designed to prevent the use of incorrect or defective material or source material, or materials that have not received the required examinations or tests.

3.4.2 Sources of Material, Source Material, and Services.

(a) Services including performance and certification of operations, processes, the results of tests, examinations, repairs, or treatments required by the material specification or by this Case shall be furnished by an approved supplier.

(b) Source materials shall be tested for conformance to applicable requirements either

(1) prior to shipment

(2) upon receipt, prior to use

3.4.3 Approval and Control of Suppliers of Source Material and Services.

(a) The Material Organization shall be responsible for the approval of and control of activities performed by suppliers of source materials and subcontracted services. Such control shall provide for source evaluation and selection, evaluation of objective evidence of quality, audit, and examination of items and services upon delivery, in accordance with requirements documented in the Material Organization's program.

(b) The Material Organization shall be responsible for establishing and verifying that the supplier's controls applicable to the activities performed are adequate by surveying and auditing the supplier's established quality system that is consistent with the requirements of this Subarticle.

(c) As an alternative to survey and audit of suppliers of subcontracted calibration services, a Material Organization may accept accreditation by National Voluntary Laboratory Accreditation Program (NVLAP), American Association for Laboratory Accreditation (A2LA), or other accrediting body recognized by NVLAP through the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA), provided the following requirements are met:

(1) The accreditation is to ANSI/ISO/IEC 17025, "General Requirements for the Competence of Testing and Calibration Laboratories."

(2) The published scope of accreditation for the calibration laboratory covers the needed measurement parameters, ranges, and uncertainties.

(3) The Material Organization shall specify through procurement documents that the calibration certificate/report shall include identification of the laboratory equipment/standards used and shall include as found and as-left data.

(4) The Material Organization shall be responsible for reviewing objective evidence for conformance to the procurement documents.

(5) This activity shall be documented in the Material Organization's Quality System Manual.

(d) The Material Organization shall be responsible for assuring that all material and activities conform to all applicable requirements of this Case.

3.4.4 Procurement Document Control.

(a) Procurement documents shall include requirements necessary to ensure compliance with the requirements of this Case.

(b) Procurement documents shall require material, source material, or subcontracted services to be furnished in accordance with the applicable requirements of this Subarticle.

(c) Procurement documents shall require approved suppliers to reference the accepted quality system or controls established by the Material Organization on documentation that accompanies the source material or services furnished.

(d) Procurement documents that specify quality requirements or prescribe activities affecting quality shall be reviewed for adequacy and approved for release by authorized personnel.

3.5 IDENTIFICATION, MARKING, AND MATERIAL CONTROL

3.5.1 General.

(a) Control shall be established to ensure that only correct and accepted material or source material is used. Identification shall be maintained on these materials or on documents traceable to these materials, or in a manner that ensures that the identification is established and maintained.

(b) Measures shall be established for controlling and identifying material or source material, including that which is partially processed, throughout the manufacturing process, during the performance of tests, examinations, repairs, and treatments, and during receipt, storage, handling, and shipment.

3.5.2 Marking Method. Materials and source materials shall be marked by any method acceptable to the purchaser that will not result in harmful contamination and will identify these materials in accordance with the material specification.

3.6 PROCESS CONTROL

3.6.1 General. Processes affecting quality of materials, source materials, or services shall be controlled. Special processes that control or verify quality shall be performed by qualified personnel using qualified procedures in accordance with specific requirements.

3.6.2 Manufacturing Process Control. Operations shall be performed under a controlled system such as process sheets, shop procedures, checklists, travelers, or equivalent procedures. Measures shall be established to ensure that processes are controlled in accordance with the material specification and the rules of this Case.

3.6.3 Handling, Storage, Shipping, and Preservation. Instructions shall be established for handling, storage, shipping, and preservation of material or source material to prevent damage or deterioration.

3.7 CONTROL EXAMINATIONS, TESTS, AND NONCONFORMING MATERIAL

3.7.1 Inspection, Examination, and Test Control.

(a) Inspections, examinations, and tests shall be established to assure conformance with the requirements of the material specification and this Case.

(b) Inspections or examinations required to verify conformance of material, source material, or an activity to specified requirements shall be planned. Characteristics to be inspected or examined, and inspection or examination methods to be employed, shall be specified. Inspection or examination results shall be documented.

(c) Tests required to verify conformance to specified requirements shall be planned. Characteristics to be tested and test methods to be employed shall be specified. Test results shall be documented and their conformance with acceptance criteria shall be evaluated.

3.7.2 Control of Measuring and Test Equipment.

(a) Procedures shall be in effect to ensure those tools, gages, instruments, and other measuring and test devices used to verify compliance with the material specification and this Case are calibrated and properly adjusted at specific periods or use intervals to maintain accuracy within necessary limits. Periodic checks on equipment may be performed to determine that calibration is maintained.

(b) Calibration shall be against certified equipment having known valid relationships and documented traceability to nationally recognized standards, where such standards exist. If no known nationally recognized standards exist, the basis for calibration shall be documented.

(c) Control measures shall include provisions for measuring and test equipment identification and for determining calibration status by equipment marking or on records traceable to the equipment.

3.7.3 Discrepancies in Measuring or Test Equipment.

(a) When discrepancies in excess of tolerances for measuring or test equipment are found at calibration, appropriate corrective action shall be taken, and material measured or tested since the previous calibration shall be reviewed to determine that all applicable requirements have been met.

(b) When periodic checks on equipment are performed to determine that calibration is maintained, potential material or source material discrepancies need only be resolved to the previous check, provided

(1) the methods used and the frequency of periodic checking are described in calibration procedures

(2) the calibration discrepancy was found by periodic check

3.7.4 Inspection and Test Status. Measures shall be established so that the status and results of any required inspections, examinations, or tests can be determined at any time. Status shall be maintained through indicators such as physical location and tags, marking, shop travelers, stamps, inspection records, or other suitable means. The authority for application and removal of such indicators shall be specified.

3.7.5 Control of Nonconforming Material.

(a) Adequate control measures shall be established to prevent the use of material that does not conform to the requirements of the material specification and this Case.

(b) Material or source material with nonconformances shall be identified, segregated when practical, and reviewed for acceptance, rejection, or repair in accordance with documented procedures. The responsibility and authority for the disposition of nonconformances in these materials shall be defined.

(c) Repaired material or source material shall be reexamined in accordance with applicable procedures.

(d) Measures that control further processing of nonconforming or defective material or source material, pending a decision on its disposition, shall be established and maintained. These control measures shall extend to notification of other affected organizations, as appropriate.

3.8 AUDITS AND CORRECTIVE ACTION

3.8.1 Audits.

(a) Audits shall be performed in accordance with written procedures or checklists by personnel not having direct responsibility in the areas being audited.

(b) Audit results shall be documented by auditing personnel for review by management having responsibility in the area being audited.

(c) Procedures shall include provisions for documentation of corrective action taken in response to deficiencies. Follow-up action, including re-audit of deficient areas where indicated, shall be taken to verify implementation of such corrective actions.

(d) In addition to audits of Material Organizations and suppliers, a comprehensive system of planned and periodic internal audits shall be carried out to ensure compliance with all aspects of the Quality System Program and to determine the effectiveness of the Program.

(e) Internal audits shall be performed in accordance with the requirements of (a) through (c) above.

3.8.2 Corrective Action.

(a) Measures shall be established to ensure that conditions adverse to quality such as failures, malfunctions, deviations, defective material and equipment, nonconformances, and quality system deficiencies, are promptly identified and reported to appropriate levels of management. The measures shall also ensure that the cause of conditions adverse to established quality levels be determined and corrected.

(b) The identification of significant or recurring conditions adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.

(c) These requirements shall also extend to the performance of the approved supplier's corrective action measures.

4 RESPONSIBILITY

4.1 CONSTRUCTOR OR FABRICATOR

(a) The Constructor or Fabricator responsible for the placement of nonmetallic materials (plastic concrete) shall ensure that the plastic concrete meets the requirements of the Construction Specification, and that tests performed by the manufacturer and supplier of the nonmetallic materials and constituents meet the requirements of Section III, Division 2.

(b) The Constructor or Fabricator shall survey and qualify the Quality System Program of the Nonmetallic Material Manufacturer if they do not obtain a Quality System Certificate (NCA-3923).

(c) The Constructor or Fabricator shall perform any of the functions required by NCA-3950 that are not performed and he may elect to perform any other Quality Program functions that would normally be the responsibility of the Nonmetallic Material Manufacturer or the Nonmetallic Material Constituent Supplier. He shall ensure that nonmetallic material constituents have met applicable requirements of CC-2100 and CC-2200.

(d) The Constructor or Fabricator shall make all necessary provisions so that the Authorized Inspector and his Authorized Inspection Agency can make the inspections necessary to comply with this Code.

(e) The functions performed by the Constructor or Fabricator shall be clearly defined and included in his Quality System Program.

4.2 NONMETALLIC MATERIAL MANUFACTURER

(a) The Nonmetallic Material Manufacturer shall have his Quality System Program surveyed and qualified by the Constructor or Fabricator if he does not obtain a Quality System Certificate.

(b) The Nonmetallic Material Manufacturer, using the constituents, shall survey and qualify the Quality System Program(s) of Nonmetallic Material Constituent Suppliers if they do not obtain a Quality System Certificate (NCA-3923) and shall ensure that the constituent materials have been tested and have met applicable requirements of CC-2100 and CC-2200.

(c) The functions performed by the Nonmetallic Material Manufacturer shall be clearly defined and included in his Quality System program.

4.3 NONMETALLIC MATERIAL CONSTITUENT SUPPLIER

(a) The Nonmetallic Material Constituent Supplier shall have his Quality System Program surveyed and qualified by the Nonmetallic Material Manufacturer if he does not obtain a Quality System Certificate.

(b) The Nonmetallic Material Constituent Supplier shall ensure that constituent materials have been tested and have met applicable requirements of CC-2100 and CC-2200.

Approval Date: December 28, 2012

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-829
Austenitic Stainless Steel Cladding and Nickel Base Cladding Using Ambient Temperature Machine GTAW Temper Bead Technique
Section XI, Division 1

Inquiry: In lieu of the preheat and PWHT requirements of IWA-4400, may the automatic or machine GTAW temper bead technique be used to repair austenitic stainless steel cladding and nickel-base cladding without use of preheat or postweld heat treatment?

Reply: It is the opinion of the Committee that, in lieu of the preheat and postweld heat treatment requirements of IWA-4411, austenitic stainless steel cladding and nickel-base cladding may be repaired using the automatic or machine GTAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code. All other requirements of IWA-4000[1] shall be met, except as modified by this Case.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair of austenitic stainless steel cladding and nickel base cladding on P-Nos. 1, 3, 12A, 12B, and 12C[2] materials when the ferritic material is within ⅛ in. (3 mm) of being exposed.

(b) The maximum area of an individual cladding repair based on the finished surface shall be 500 in.^{2} (325 000 mm^2), and the depth of the weld into the ferritic base metal shall not be greater than $^1/_4$ in. (6 mm) or 10% of the base metal thickness, whichever is less.

(c) Prior to welding, the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

(d) Welding materials shall meet the Owner's Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(e) Peening may be used, except on the initial and final layers.

2 WELDING QUALIFICATIONS

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of 2.1 and 2.2 of this Case. Section IX, QW-290, including the impact test essential variables of QW-290, shall apply, except that cladding is exempt from the impact testing and hardness testing requirements of QW-290.

2.1 PROCEDURE QUALIFICATION

(a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded. The materials shall be postweld heat treated, to at least the time and temperature that was applied to the materials being welded. If the repair involves two different P-Number or Group Number materials, the test assembly shall duplicate the combination. Cladding representative of the production cladding material shall be deposited on one face of this coupon, as follows: A-No. 8 filler metal shall be used to represent austenitic stainless steel cladding; F-No. 43 filler metal shall be used to represent nickel base cladding. After cladding, the repair cavity of 2.1(d) shall be prepared in this clad deposit (see Figure. 1).

(b) Consideration shall be given to the effects of irradiation on the properties of materials, including weld material, for applications in the core beltline region of the reactor vessel. Special material requirements in the Design Specification also apply to the test assembly materials for these applications.

[1] The references to Section XI in this Case refer to the 2010 Edition with the 2011 Addenda. For use of this Case with other Editions and Addenda, refer to the Guideline for Cross–Referencing Section XI Cases, Table 1.

[2] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later Edition of Section IX.

(c) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (65°C).

(d) The qualification test plate shall be prepared in accordance with Figure 1, and the cavity prepared for welding. The test assembly base material shall be at least 6 in. x 6 in. x 2 in. (150 mm x 150 mm x 50 mm) thick. The excavation prepared for temper bead cladding shall be at least 6 in. x 1.5 in. (150 mm x 40 mm), and shall be in the area from, which the bend test specimens will be removed.

(e) The side bend test shall consist of four samples oriented transverse to the direction of welding. The guided bend test requirements and acceptance standards described in Section IX for cladding shall be applicable to the clad deposit, the clad-to-clad fusion zone, and the HAZ of the base material. Bend specimens shall include at least one fusion zone between the original cladding and the temper bead cladding repair weld (i.e., the clad-to-clad fusion zone).

2.2 PERFORMANCE QUALIFICATION

Welding operators shall be qualified in accordance with IWA-4400.

3 WELDING PROCEDURE REQUIREMENTS

(a) The weld metal shall be deposited by the automatic or machine gas tungsten-arc weld process using cold-wire feed.

(b) The welds shall be made using A-No. 8 weld metal (QW-442) for austenitic stainless steel cladding or F-No. 43 weld metal (QW-432) for either austenitic stainless steel or nickel base cladding.

(c) The cavity shall be buttered with a deposit of at least three layers, to achieve at least ⅛ in. (3 mm) deposit thickness as shown in Figure 1, Steps 1 through 3.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers, regardless of the interpass temperature used during qualification. The interpass temperature limitations of QW-406.3 and QW-406.8 need not be applied.

(e) The interpass temperature shall be determined by one of the following methods:

(1) temperature measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding.

(2) heat flow calculations using the variables listed below as a minimum:

(-a) welding heat input

(-b) initial base material temperature

(-c) configuration, thickness, and mass of the item being welded

(-d) thermal conductivity and diffusivity of the materials being welded

(-e) time per weld pass and delay time between each pass

(-f) time to complete the weld

(3) measurement of the maximum interpass temperature on a test coupon that is equal to or less than the thickness of the item to be welded. The maximum heat input of the welding procedure shall be used in the welding of the test coupon.

(f) Particular care shall be given to ensure that the weld region is free of potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

EXAMINATION

(a) The following examinations shall be performed in accordance with the Construction Code or Section III.

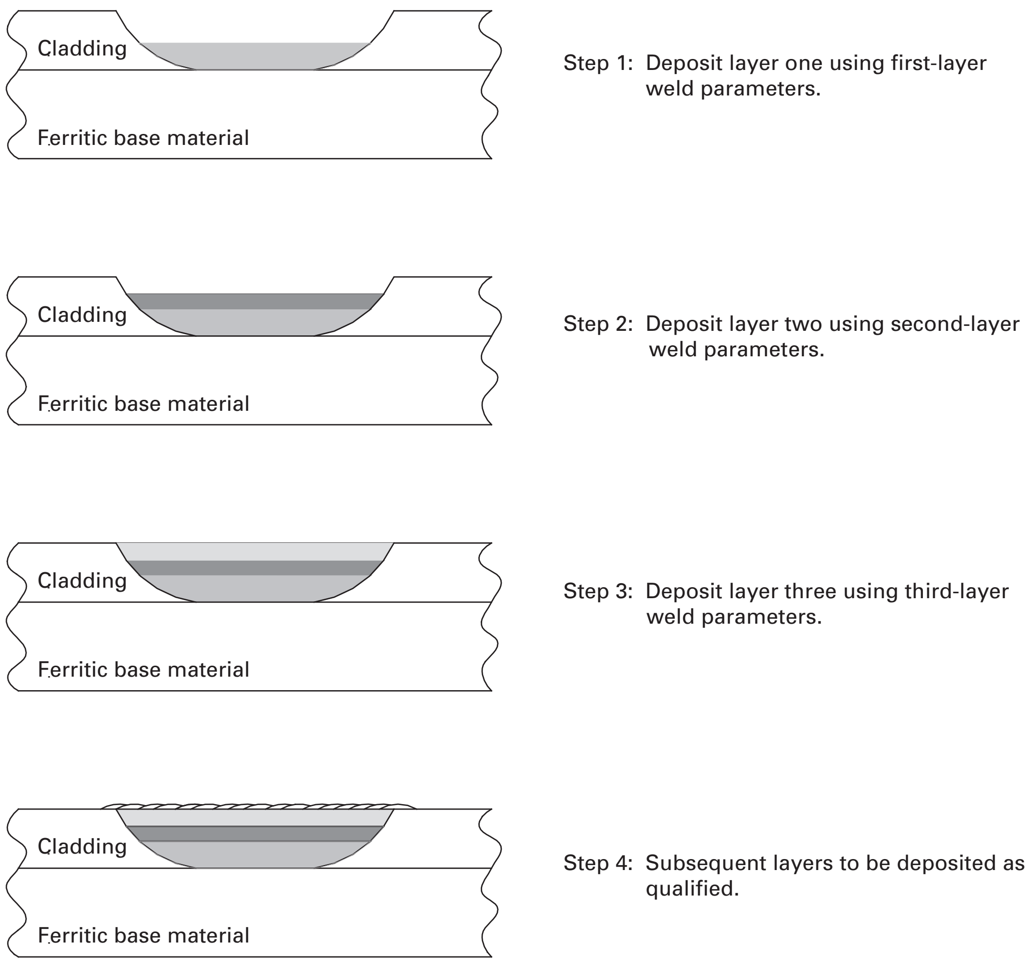
(1) Prior to repair welding, surface examination shall be performed on the area to be welded.

(2) The weld shall be nondestructively examined after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. The repair weld and base metal for a minimum of 4 in. (100 mm) around the repair shall be examined by the liquid penetrant method.

(3) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(4) Acceptance criteria for surface examinations shall be in accordance with the Construction Code or Section III.

Figure 1
Qualification Test Plate and Automatic or Machine (GTAW) Temper Bead Cladding Repair



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Approval Date: September 4, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-830
Direct Use of Master Fracture Toughness Curve for Pressure-Retaining Materials of Class 1 Vessels Section XI, Division 1

Inquiry: Is it permissible to use a material-specific Master Curve as an alternative fracture toughness curve for crack initiation, K_{Ic}, in Section XI, Division 1, Nonmandatory Appendices A and G, for Class 1 pressure-retaining materials, other than bolting?

Reply: It is the opinion of the Committee that a material-specific Master Curve fracture toughness curve generated in accordance with ASTM E1921 may be used as an alternative fracture toughness curve, K_{Ic}, in Section XI, Division 1, Nonmandatory Appendices A and G, for Class 1 pressure-retaining materials, other than bolting, with the following additional requirements:

(a) Fracture toughness testing for specific base metal or weld materials in the irradiated or nonirradiated condition shall be performed in accordance with ASTM E1921, "Standard Test Method for the Determination of Reference Temperature, T_o, for Ferritic Steels in the Transition Range." The minimum test requirements of the test method shall be satisfied for the specific material being evaluated. Test data shall satisfy all of the validity requirements specified in the test method.

(**E**) *(b)* Test specimen location and orientation shall meet the requirements of NB-2322 for Charpy V-notch specimens. Any of the specimen geometries in accordance with ASTM E1921 may be used.

(c) The value of T_o for the test data shall be obtained by the method in (a) above.

(d) Using the value of T_o, a 95% lower tolerance bound Master Curve toughness (ksi-in.$^{0.5}$ or MPa-m$^{0.5}$) is calculated from the following equations:[1]

(U.S. Customary Units)

$$K_{Jc\,-\,\text{lower }95\%} = 22.9 + 33.3 \exp\left[0.0106\,(T - T_o)\right]$$

(SI Units)

$$K_{Jc\,-\,\text{lower }95\%} = 25.2 + 36.6 \exp\left[0.019\,(T - T_o)\right]$$

The Master Curve K_{Ic} curve is defined as this 95% lower tolerance bound curve.

(e) The Master Curve K_{Ic} curve ($K_{Jc\text{-lower }95\%}$) as a function of $(T - T_o)$ may be used as an alternative to the K_{Ic} curve defined in Section XI, Division 1, Nonmandatory Appendix A, A-4200 or Nonmandatory Appendix G, G-2210 as related to $(T - RT_{NDT})$.

(f) Plant-specific applications are subject to review and approval by the regulatory authority having jurisdiction at the plant site. For highly irradiated reactor pressure vessel steel exhibiting large fracture toughness shifts, consideration may be given to limiting the lower shelf of $K_{Jc\text{-lower }95\%}$, to a value consistent with the current K_{Ic} curve.

[1] These equations may also be expressed in terms of RT_{To}:

(a) (U.S. Customary Units) — $K_{Jc\,-\,\text{lower }95\%} = 22.9 + 33.3 \exp\left[0.0106\left(T - RT_{To} + 35\right)\right]$, ksi-in.$^{0.5}$ and °F

(b) (SI Units) — $K_{Jc\,-\,\text{lower }95\%} = 25.2 + 36.6 \exp\left[0.019\left(T - RT_{To} + 19.4\right)\right]$, MPa-m$^{0.5}$ and °C

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Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-833
Minimum Nonprestressed Reinforcement in the Containment Base Mat or Slab Required for Concrete Crack Control
Section III, Division 2

Inquiry: What alternatives to the requirements of CC-3535 may be used for the minimum nonprestressed reinforcement in the containment base mat or slab required for concrete crack control?

Reply: It is the opinion of the Committee that the following requirements may be used as an alternative to the requirements of CC-3535 for minimum nonprestressed reinforcement in the containment base mat or slab for concrete crack control.

(a) When an expected crack formation is so located that critical elements of the containment, such as anchor zone concrete, buttresses, ring girders, and large opening edges, may be weakened, bonded nonprestressed reinforcement shall be provided to carry the total tensile force in the concrete. Nonprestressed reinforcement for crack control shall not be spaced farther apart than 3 times the total section thickness, or farther apart than 18 in. (450 mm).

(b) Nonprestressed reinforcement shall be provided in the containment shell to control surface and membrane cracking from the effects of shrinkage, temperature, and membrane tension. The area of such reinforcement in each direction at each face of the concrete shall be a minimum of 0.0020 times the gross cross-sectional area of the section. This reinforcement may be met in whole or in part by reinforcement otherwise required to resist calculated loads. An integral steel liner, if provided, may be included to satisfy the requirement for inside face reinforcement. Reinforcing bars considered as face reinforcement shall be not more than one-fifth of the total section thickness from the concrete face.

(c) For slabs and base mat structures, the ratio of nonprestressed reinforcement area to gross concrete area shall be not less than 0.0018 in. each direction unless the area of reinforcement provided at each face is at least one-third greater than that required by analysis.

This Case number shall be identified on the Certificate Holder's Data Report Form.

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Approval Date: October 22, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-834
ASTM A988/A988M-11 UNS S31603, Subsection NB, Class 1 Components
Section III, Division 1

Inquiry: May ASTM A988/A988M-11 UNS S31603 be used for Section III, Division 1, Subsection NB, Class 1 Components construction?

Reply: It is the opinion of the Committee that, ASTM A988/A988M-11 UNS S31603 may be used for Section III, Division 1, Subsection NB, Class 1 Components in construction provided the following additional requirements are met:

(a) For purposes of welding procedure and performance qualification, this material shall be considered P-No. 8.

(b) The design stress intensity values and the maximum allowable stress values, fatigue design curves, tensile strength and yield strength values, thermal expansion and other properties shall be the same as for SA-240 UNS S31603.

(c) The maximum allowable powder particle size shall be 0.020 in. (0.5 mm) or less.

(d) Following atomization, powders shall be stored under a positive nitrogen or argon atmosphere.

(e) An 8 in. (200 mm) or longer protrusion (extension) shall be added to one end of each item that equals or exceeds the thickest section of that item. The protrusion shall be removed upon completion of isostatic pressing and heat treatment of the item and shall be used for microstructural characterization, density measurements, chemical testing, mechanical testing, and intergranular corrosion testing as required below:

(1) Density measurements and microstructural examination shall be performed at the midsection of coupons removed from the protrusion in accordance with ASTM A988/A988M-11 paras. 8.1.1 and 8.1.2.

(2) In addition to a chemical composition analysis of the final blend powder, an analysis of a sample from each component shall be required.

(3) Intergranular corrosion tests shall be performed using test coupons removed from the protrusion in accordance with ASTM A262 Practice E.

(4) Mechanical property tests, including tension tests and hardness tests, shall be performed using test coupons removed from the protrusion in accordance with ASTM A988/A988M-11, Section 9, Mechanical Properties.

(f) The material shall be examined using the ultrasonic examination method in accordance with NB-2540 over 100% of its entire volume using both straight and angle beam methods. Items that are produced in the form of tubular products shall be examined in accordance with NB-2550.

(g) The material shall not be used for components where the neutron irradiation fluence levels will exceed 1×10^{17} n/cm^2 (E > 1 Mev) within the design life of the component.

(h) Following final hot isostatic-pressing, all surfaces exposed to the process fluid shall be removed by machining or grinding to a depth of 0.008 in. (0.2 mm) or greater. Final accessible surfaces shall be examined by the liquid penetrant method in accordance with NB-2576.

(i) All other requirements of NB-2000 for austenitic materials shall apply.

(j) This Case number shall be marked on the material and listed on the Certified Material Test Report and on the Component Data Report.

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Approval Date: October 22, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-836
Heat Exchanger Tube Mechanical Plugging, Class 1
Section III, Division 1

Inquiry: For heat exchangers that have been in storage for more than 25 yr, prior to completion of construction, may mechanical plugs be used to plug tubes?

Reply: It is the opinion of the Committee that mechanical plugs may be used by an N Certificate Holder to plug tubes of such heat exchangers prior to completion of construction, provided the following requirements are met:

(a) The provisions of Section XI, 2007 Edition with the 2008 Addenda and 2013 Edition, IWA-4713 shall be met, except for IWA-4713.1(a) and IWA-4713.5. All other provisions of Section XI are not applicable.

(b) The mechanical plug's pressure-retaining material shall comply with the requirements of Subsection NB. This material shall meet the requirements of SB-166, UNS N06690.

(c) The following records, in addition to those required by NCA-4134.17, shall be maintained by the Certificate Holder and transferred to the Owner as required by Section III:

(1) plugging procedure specification (PPS)

(2) records of procedure qualification for the plugging method, including the essential variables and results of all tests required by IWA-4713.3

(3) records of performance qualification for each operator, including the PPS, identification, such as number and revision

(4) certified material test reports for the pressure-retaining portion of the installed plugs

(5) identification of all plugged tubes as shown in final drawings for the heat exchanger

(6) results of postinstallation examinations and evaluations

(7) evaluations performed in accordance with IWA-4713.3(a)(4)

(d) The mechanical plugs shall not be removed after the pressure test.

(e) This Case shall be identified in the Design Specification and on the applicable Data Report Form.

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Approval Date: October 22, 2013

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-837
Alternative to the Registered Professional Engineer Requirements
Section III, Division 1; Section III, Division 2; Section III, Division 3; Section III, Division 5

Inquiry: What alternative to the Professional Engineer registration required in Section III may be used for Code activities performed for nuclear facilities located outside the United States of America and its territories and the provinces and territories of Canada?

Reply: It is the opinion of the Committee that, in lieu of registration in the United States of America or its territories or the provinces or territories of Canada, the Professional Engineer registration required in Section III may be in the International Register of Professional Engineers by an Authorized Member of the International Professional Engineers Agreement (IPEA), under the following conditions:

(a) The Code activity is performed for nuclear facilities located outside the United States of America and its territories and the provinces and territories of Canada.

(b) All other qualifications and requirements described in Mandatory Appendix XXIII of Section III Appendices, XXIII-1200 shall be met.

(c) This Case number shall be identified in the Data Report for the component or system and in the document being certified.

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Approval Date: September 4, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-839
Similar and Dissimilar Metal Welding Using Ambient Temperature SMAW Temper Bead Technique
Section XI, Division 1

Inquiry: In lieu of the preheat and PWHT requirements of IWA-4400, may the manual SMAW temper bead technique be used without use of preheat or postweld heat treatment?

Reply: It is the opinion of the Committee that, in lieu of the preheat and postweld heat treatment requirements of IWA-4411, the materials and welds specified in 1(a) may be repaired using the manual SMAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code. All other requirements of IWA-4400[1] shall be met, except as modified by this Case.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair to P-Nos. 1, 3, 12A, 12B, and 12C[2] materials, and their associated welds and welds joining P-No. 8 or P-No. 43 materials to P-Nos. 1, 3, 12A, 12B, and 12C[2] materials, with the following limitations. This Case shall not be used to repair SA-302, Grade B material, unless the material has been modified to include 0.4% to 1.0% nickel, quenching and tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld based on the finished surface over the ferritic material shall be 500 in.^{2} (325 000 mm^2), and except as permitted in (1), the depth of the weld shall not be greater than one-half of the ferritic base metal thickness. Through-wall circumferential welds are permitted if the following restrictions are met:

(1) For repair replacement activities associated with existing welds, the existing weld (including any associated buttering) shall be removed in its entirety.

(2) Temper bead buttering shall be applied across the entire face of the weld preparation area on the base materials requiring tempering, and shall extend around the full circumference of the joint.

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Case are limited to those along the fusion line of a nonferritic weld to ferritic base material on which $^1/_8$ in. (3 mm), or less of nonferritic weld deposit exist above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material may be performed in accordance with this Case, provided the depth of repair in the base material does not exceed $^3/_8$ in. (10 mm).

(e) Prior to welding the area to be welded and a band around the area of at least $1^1/_2$ times the component thickness or 5 in. (130 mm), whichever is less shall be at least 50°F (10°C).

(f) Peening may be used except on the initial and final layers.

2 WELDING QUALIFICATIONS

The welding procedures and the welding operators shall be qualified in accordance with QW-290 and the requirements of 2.1 and 2.2.

2.1 PROCEDURE QUALIFICATION

(a) Prior simulated postweld heat treatment on the procedure qualification test assembly is neither required nor prohibited. However, if used, the simulated postweld heat treatment shall not exceed the time or temperature already applied to the base material to be welded.

(b) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be bounded in the test assembly within the limits of Table IWA-4662.1-1.

(c) Consideration shall be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor

[1] The references in this Case are based on the 2013 Edition. For use with other Edition or Addenda refer to the Guideline for Cross-Referencing Section XI Cases, Table 1.

[2] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later Edition of Section IX.

vessel. Special material requirements in the Design Specification shall also apply to the test assembly materials for these applications.

(d) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(e) The following are procedure qualification requirements:

(1) The test assembly base material for the welding procedure qualification shall meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be as specified in (4) below, but shall be in the base metal. Impact testing of austenitic (nickel-based P-No. 4X and stainless steel P-No. 8) material is not required.

(2) As an alternative to the test temperature requirements of (1), the Charpy V-notch test temperature for procedure qualification may be determined in accordance with (-a), (-b), or (-c) below. The Charpy V-notch test temperature shall be in the transition temperature range for the test assembly ferritic base metal.

(-a) The test temperature for the test assembly base metal shall be derived from the full transition temperature curve in the Certified Material Test Report.

(-b) A full transition temperature curve for the test assembly base metal shall be developed using Charpy V-notch testing.

(-c) The test temperature shall be in the range where one or more Charpy V-notch tests in the test assembly base metal exhibit 35 mils to 50 mils (0.89 mm to 1.3 mm) lateral expansion.

(3) Charpy V-notch tests of the weld metal of the procedure qualification shall meet the requirements as determined in (1).

(4) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal. Number, location, and orientation of test specimens shall meet the requirements of (5) through (7).

(5) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.

(6) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.

(7) The Charpy V-notch test shall be performed on the ferritic weld metal, heat affected zone and unaffected base metal in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A test shall consist of a set of three full-size 0.394 in. × 0.394 in. (10 mm × 10 mm) specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens shall be reported in the Procedure Qualification Record.

(8) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be no less than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this Case, either of the following shall be performed.

(-a) The welding procedure shall be requalified.

(-b) An *Adjustment Temperature* for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with the 2002 Addenda or later. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the *Adjustment Temperature*.

2.2 PERFORMANCE QUALIFICATION

Welders shall be qualified in accordance with Section IX.

3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements:

(a) The weld metal shall be deposited by the manual SMAW process.

(b) Ferritic weld metal used shall have the following additional requirements applied:

(1) Welding electrodes shall meet the requirements for supplemental designators, *R*, indicating a moisture-resistant coating and, *H*4, indicating that they are low in diffusible hydrogen (<4 mL/100g) as defined in the applicable specifications in Section II, Part C. Welding electrodes shall be supplied in unopened hermetically sealed containers or vacuum sealed packages.

(2) Electrodes shall be used directly from vacuum sealed packages, hermetically sealed containers, or shall be placed in storage at 225°F to 350°F (110°C to 180°C) prior to use.

(3) Electrodes not consumed within 8 hr for E70XX electrodes or 4 hr for E80XX and E90XX after removal from vacuum sealed packages, hermetically sealed

containers, or storage at 225°F to 350°F (110°C to 180°C) shall not be used for temper bead welding. The use of reheated or rebaked electrodes is not permitted.

(c) Austenitic or nickel based weld metal used shall have the following additional requirements applied:

(1) Welding electrodes shall be supplied in unopened hermetically sealed containers or vacuum sealed packages.

(2) Electrodes shall be used directly from vacuum sealed packages, hermetically sealed containers, or shall be placed in storage at 225°F to 350°F (110°C to 180°C) prior to use.

(3) Electrodes not consumed within 8hr after removal from vacuum sealed packages, hermetically sealed containers, or storage at 225°F to 350°F (110°C to 180°C) shall not be used for temper bead welding. The use of reheated or rebaked electrodes is not permitted.

(d) The maximum interpass temperature for field applications shall be 350°F (180°C) for all weld layers, regardless of the interpass temperature used during qualification. The interpass temperature limitations of QW-406.3 and QW-406.8 need not be applied.

(e) The interpass temperature shall be determined by direct measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding.

(f) Particular care shall be given to ensure that the weld region is free of potential sources of hydrogen (i.e., the surface to be welded and filler metal shall be suitably controlled).

4 EXAMINATION

(a) Except as permitted in (1), the following examinations shall be performed in accordance with the Construction Code or Section III.

(1) Prior to repair welding, surface examination shall be performed on the area to be welded. If surface examination materials cannot be cleaned from crevices in the area to be welded (e.g., trapped in crevices remaining after removal of the full thickness of a partial penetration or filler weld), VT-1 visual examination may be performed, provided the requirements of (b) are met.

(2) When ferritic filler materials are used, the weld shall be nondestructively examined after the completed weld has been at ambient temperature for at least 48 hr. When austenitic filler materials are used, the completed weld shall be nondestructively examined after the initial three temper bead layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. Examination of the welded region shall include both volumetric and surface examination methods. Demonstration for ultrasonic examination of the repaired volume is required using representative samples which contain construction type flaws.

(3) Areas from which any weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(4) Acceptance criteria for surface and volumetric examination shall be in accordance with the Construction Code or Section III.

(b) VT-1 visual examinations performed in accordance with the (a)(1) shall meet the following:

(1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving lower case text characters without ascenders or descenders (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (610 mm).

(2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

(3) Visual examination acceptance standards shall comply with the following:

(-a) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width.

(-b) Only indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm) shall be considered relevant. The following relevant indications are unacceptable:

(-1) any cracks or linear indications

(-2) rounded indications with major dimensions greater than $^3/_{16}$ in. (1.5 mm)

(-3) four or more rounded indications in a line separated by $^1/_{16}$ in. (1.5 mm) or less edge to edge

(-4) ten or more rounded indications in any 6 in.^{2} (4 000 mm^2) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated

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Approval Date: January 23, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-840
Cladding Repair by Underwater Electrochemical Deposition in Class 1 and 2 Applications
Section XI, Division 1

Inquiry: As an alternative to Article IWA-4000 under what conditions may cladding be repaired by the application of material using underwater electrochemical deposition?

Reply: It is the opinion of the Committee that, as an alternative to Article IWA-4000, cladding may be repaired by application of material using underwater electrochemical deposition under the following conditions.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair of austenitic stainless steel cladding and nickel base cladding on P-Nos. 1, 3, 12A, 12B, and 12C materials when the ferritic material is exposed.

(b) The maximum area of an individual electrodeposition repair based on the finished surface shall be 100 in.^{2} (65 000 mm^2), and the depth of the repair into the ferritic base metal shall be no greater than $^1/_4$ in. (6 mm) or 10% of the base metal thickness, whichever is less.

(c) The repair shall be performed in accordance with a Repair/Replacement Program and Plan, satisfying the requirements of Article IWA-4000 in the edition and addenda of Section XI applicable to the plant inservice inspection program, or later editions and addenda.

(d) Electrochemical deposition shall be performed in accordance with an Electrodeposition Procedure Specification (EPS) qualified in accordance with this Case and in accordance with the Repair/Replacement Program and Plan.

(e) The suitability evaluation shall document the probable cause of the flaw and shall ascertain that the electrochemically deposited material will provide acceptable corrosion resistance for the intended application.

(f) Underwater electrochemical deposition uses chemicals that are introduced into an enclosure that is in direct contact with Reactor Coolant System (RCS) water. Prior to the electrochemical deposition process, an assessment shall be performed to address the following:

(1) the electrochemical constituents to be used

(2) the maximum volume of these chemicals that could be released into the RCS during electrodeposition, and the resulting effect on RCS chemistry

(g) Consideration shall be given to the effects of irradiation on the properties of material, including electrodeposition material, for applications in the core beltline region of the reactor vessel. Special material requirements in the Design Specification shall apply to the test assembly materials for these applications.

(h) Minimum permissible electrochemical deposit thickness shall be specified. Specified minimum deposit thickness shall be sufficient to accommodate any anticipated deposit wear or erosion during operation.

2 MATERIAL REQUIREMENTS

All chemicals used in the process shall be certified by the manufacturer to be within the range of purity levels specified in the EPS.

3 PROCEDURE QUALIFICATION REQUIREMENTS

(a) The Repair/Replacement Organization shall complete procedure qualification testing to demonstrate process acceptability.

(b) Procedure qualification consists of two distinct qualification activities.

(1) Process Qualification. Testing wherein the process itself (irrespective of the actual production application) is qualified. Process testing must be acceptably completed prior to Process Demonstration.

(2) Process Demonstration. Testing of the qualified process, using equipment and conditions that simulate the production application. Process Demonstration testing includes all essential variables from the Process Qualification test and the additional essential variables governing the Process Demonstration test.

(c) Process Qualification Requirements

(1) Essential variables for Process Qualification testing are as follows:

(-a) a change from a base metal listed under one P-Number in Table QW/QB-422 to a metal listed under another P-Number or to any other base metal

(-b) a reduction in base material thickness to less than the thickness used in qualification, except that qualification on a coupon not less than 0.5 in. (13 mm) thick qualifies the thickness range of 0.5 in. (13 mm) minimum to unlimited maximum

(-c) a change in the nominal composition of the cladding adjacent to the repair (e.g., a change from A-No. 8 cladding to F-No. 43 cladding, or vice versa)

(-d) a change in deposit position (e.g., horizontal to vertical)

(-e) a change in anode material classification

(-f) a change in the type of current (i.e., DC, pulsing)

(-g) a change of more than 10% in electrical current, frequency, or pulse width

(-h) addition or deletion of an electrolyte constituent

(-i) a change in the nominal concentration of any electrolyte constituent

(-j) a change of more than 10% in the pH value of the electrolyte mixture

(-k) a change of more than 10% in electrolyte temperature

(-l) a change of more than 10% in the electrolyte flow velocity between the workpiece and the anode surface

(-m) a change of more than 10% in the distance between

(-1) the anode and the substrate

(-2) the anode and the deposit

(-n) use or omission of cleaning prior to electrodeposition and, where cleaning is used, a change in the type or method of cleaning

(-o) use or omission of chemical activation of the repair surface prior to electrodeposition and, where chemical activation is used, a change in the type or method of chemical activation

(-p) use or omission of a strike layer (i.e., a transition layer between the substrate and the nickel deposit) or an increase in strike layer thickness

(-q) a decrease in deposit thickness

(-r) addition or deletion of postinstallation heat treatment

(2) Process qualification coupon requirements are as follows:

(-a) Coupons may be plate, pipe, or other product forms.

(-b) The number of coupons required for process qualification testing is dependent on the number and length of deposit samples needed to satisfy the testing requirements specified herein.

(-c) Coupons shall be at least of 6 in. (150 mm) long by 2 in. (50 mm) wide.

(-d) Cladding representative of the production cladding material shall be deposited on one face of each coupon, as follows:

(-1) A-No. 8 filler metal shall be used to represent austenitic stainless steel cladding

(-2) F-No. 43 filler metal shall be used to represent nickel-based cladding

(-e) After cladding, a repair cavity shall be prepared by excavating into the clad deposit to expose base material. The size of the exposed base material shall be a minimum of 2 in. (50 mm) long by 1.5 in. (38 mm) wide.

(3) Testing of Process Qualification Coupons

(-a) The entire face of each deposit, including the adjacent cladding, shall be examined using the liquid penetrant method in accordance with Section IX requirements for corrosion resistant overlay, and shall meet the acceptance standards in QW-195. Surface conditioning prior to liquid penetrant examination is not permitted.

(-b) Side-bend testing shall be performed on at least four samples oriented parallel with the 6 in. (150 mm) coupon length. Guided-bend testing shall be performed in accordance with Section IX requirements for corrosion-resistant overlay deposits. The corrosion-resistant overlay acceptance criteria of Section IX shall apply to the electrochemical deposit, the base metal-to-electrochemical deposit interface, and the clad-to-electrochemical deposit interface. Bend specimens shall include at least one bond zone between the cladding and the electrochemical deposit.

(-c) A chemical analysis shall be performed on a minimum of two separate procedure qualification test specimens. This analysis shall be performed in accordance with ASTM E39, ASTM E76, and ASTM E354, except that ASTM E38 shall be used for elements not covered by ASTM E354. Chemical composition shall comply with the following requirements:

Nickel[1]	99.0% minimum
Silicon	0.01% maximum
Sulfur	0.01% maximum

(4) The results of completed process qualification tests shall be documented on a Process Qualification Record (PQR). All essential variables shall be documented on this record. The Repair/Replacement Organization responsible for the procedure qualification shall sign the PQR, certifying its accuracy.

[1] Cobalt shall be counted as nickel, but shall not exceed 0.025% maximum.

(5) After PQR approval, process demonstration is required.

(d) Process Demonstration Requirements

(1) Essential variables for Process Demonstration testing are as follows:

(-a) a change in the enclosure to a shape, size, or configuration different than the shape, size, and configuration used in the demonstration coupon test

(-b) an increase in water depth (i.e., an increase in the distance between the deepest portion of the repair and the surface of the water) beyond the depth used for the demonstration coupon test

(-c) a change in the anode to a shape, size, or configuration different than that used in the demonstration test

(-d) a change in the method of enclosure sealing to a method different than that used in the demonstration test

(-e) a change of more than 10% in electrolyte volume (flow) between the chamber inlet and the chamber outlet

(-f) the addition of a repair process (i.e., a process that serves to remove any portion of an existing electrochemical deposit) see 4

(-g) an increase in deposit surface area to a size larger than that used for the demonstration coupon test

(-h) the deletion of surface conditioning of the electrochemical deposit

(-i) where surface conditioning is performed, the tooling, method, and extent of surface conditioning

(-j) a decrease in the smoothness of the cladding surfaces adjacent to the repair (i.e., as-welded, rough-ground, machined, or polished)

(-k) use or omission of hydrogen venting from the enclosure or a change in the size or configuration of hydrogen venting devices on the enclosure

(2) Process Demonstration Coupon Requirements are as follows:

(-a) Coupon shape, size, and orientation (i.e., position) shall accurately simulate the production application, except that coupon thickness need not exceed the minimum qualified thickness.

(-b) Coupons shall consist of a base material of the same P-Number as the production material, and cladding representative of the production cladding material shall be deposited on one face of each coupon, as follows:

(-1) A-No. 8 filler metal shall be used to represent austenitic stainless steel cladding.

(-2) F-No. 43 filler metal shall be used to represent nickel-based cladding.

(-c) Coupons shall be prepared by excavation into the deposited cladding. The excavation shall simulate the length, width, depth, and shape of the actual production cavity.

(-d) Electrochemical deposition shall be accomplished within the essential variable ranges qualified by an approved PQR.

(3) Testing of demonstration coupons shall be as follows:

(-a) VT-1 visual examination shall be performed on the electrochemical deposit for each demonstration coupon. VT-1 shall comply with the requirements of this Case, see 7.

(-b) The entire face of each deposit, including a minimum of 0.5 in. (13 mm) of the adjacent cladding, shall be examined using the liquid penetrant method in accordance with Section IX requirements for corrosion resistant overlay, and shall meet the acceptance standards in QW-195.

(-c) The demonstration coupon shall be sectioned at or near the center of the deposit, with the cut line oriented to include the deposit length and the deposit-to-cladding interface. The two deposit faces exposed by sectioning shall be polished and etched with a suitable etchant and shall be visually examined with 5X magnification for imperfections in the deposit. The deposit shall be free of cracks, porosity, disbond, and inclusions.

(-d) Two consecutive acceptable demonstration test results are required for acceptance.

(4) The results of completed process demonstration tests shall be documented on a Process Demonstration Record (PDR). The PDR shall reference the applicable PQRs. All process demonstration essential variables shall be documented on this record.

4 QUALIFICATION OF REPAIRS

(a) Repair of electrochemical deposits is not permitted unless such repair is qualified in accordance with this Case.

(b) Repair qualification shall comply with the following requirements:

(1) Repair Process Qualification

(-a) Coupons for repair process qualification shall comply with 3(c)(2) of this Case, with the additional requirement that, following excavation into the cladding deposit, an initial acceptable electrochemical deposit shall be installed in the excavated area. This deposit shall be installed in accordance with an approved EPS.

(-b) The repair process shall be used to completely remove the existing electrochemical deposit from each test coupon.

(-c) Upon deposit removal, the repair cavity shall be visually examined to ensure it is smooth, uniform, free of contaminants or oxides, and to ensure that the original deposit has been removed.

(-d) Upon visual acceptance, an approved EPS shall be used to restore an acceptable deposit in the repair region.

(-e) After the electrochemical deposit is restored, coupons shall be tested. Testing and acceptance requirements shall be as specified in 3(c)(3), except that the chemical analysis of 3(c)(3)(-c) is not required.

(-f) Two acceptable coupons are required for repair process qualification.

(-g) The results of the completed repair process qualification shall be documented on a PQR. All essential variables shall be documented on this record. The Repair/Replacement Organization responsible for the procedure qualification shall sign the PQR, certifying its accuracy.

(-h) After PQR approval, a repair process demonstration is required.

(2) Repair Process Demonstration

(-a) The repair process demonstration shall comply with 3(d) of this Case, with the additional requirement that the repair shall be implemented on a completed, acceptable electrochemical deposit.

(-b) Upon deposit removal, the prepared cavity shall be visually examined to ensure it is smooth, uniform, free of contaminants or oxides, and to ensure that the original deposit has been removed.

(-c) Upon visual acceptance, the approved EPS shall be used to restore an acceptable deposit in the repair region.

(-d) Testing and examination of the restored repair shall comply with the testing of demonstration coupon requirements of 3(d)(3).

(-e) The results of completed repair process demonstration tests shall be documented on a PDR. The PDR shall reference the applicable repair PQRs. All repair process demonstration essential variables shall be documented on this record.

(3) A separate EPS shall be prepared for the repair process.

5 OPERATOR QUALIFICATION REQUIREMENTS

(a) Operator qualification shall be documented on an Operator Qualification Record. Essential variables (as defined herein) shall be documented on this record, as well as the results of tests performed on the operator qualification samples.

(b) The operator shall prepare a demonstration coupon, and shall install an electrochemical deposit in this coupon using an approved EPS.

(1) Deposit testing shall be as specified in 3(d)(3) for process demonstration test coupons.

(2) An operator is qualified only for the approved EPS used in operator qualification.

(3) For deposit repairs, a separate operator qualification is required. Repair testing shall be as specified in 4(b)(2) for repair process demonstration test coupons. An operator is qualified for repairs using only the approved EPS used in operator qualification.

(4) Any operator who fails the qualification test shall receive additional training prior to requalification.

(5) Operator qualification may be performed concurrently with the process demonstration testing of 3(d).

(c) The Repair/Replacement Organization responsible for operator qualification shall sign the Operator Qualification Record, certifying its accuracy.

(d) Renewal of qualification is required when an operator has not performed an electrochemical deposit in accordance with this Case within 6 mo, or when there is specific reason to question an operator's ability to make electrochemical deposits. Renewal of qualification shall be in accordance with 5(b). Renewal of expired repair qualifications may be accomplished by renewal of deposit qualification.

6 PROCEDURE REQUIREMENTS

(a) Each electrodeposition operation shall be accomplished in accordance with an EPS.

(1) The EPS shall identify all essential variables.

(2) The EPS shall reference one or more supporting PQRs and one or more supporting PDRs. Supporting PQRs and PDRs shall document testing and acceptance of the essential variable ranges referenced in the EPS.

(3) The essential variable ranges referenced in the EPS shall be within the ranges qualified by the supporting PQRs and PDRs. Changes beyond those qualified on supporting PQRs and PDRs require requalification.

(4) The EPS shall specify each of the chemicals to be used in the process, and shall specify minimum purity levels for each of the chemicals listed.

(5) The Repair/Replacement Organization responsible for the electrodeposition process shall sign each EPS, certifying accuracy.

(b) Prior to electrodeposition, the surfaces to be repaired shall be visually examined to ensure they are smooth, uniform, and free of contaminants or oxides.

(c) The deposited material shall be applied to the repair region, covering all exposed base material and at least 0.2 in. (5 mm) of the adjacent cladding. Deposited material shall bond uniformly with base material and adjacent cladding.

(d) Transitions at the edges of the deposit shall have a slope not exceeding 1:3.

(e) The surface of each deposit shall be suitably smooth to facilitate nondestructive examination.

7 EXAMINATION REQUIREMENTS

(a) Prior to electrodeposition, the surfaces to be repaired shall be visually examined to ensure they are smooth, uniform, and free of contaminants or oxides.

(b) Following electrodeposition, VT-1 visual examination shall be performed on the completed deposit.

(c) VT-1 visual examination shall meet the following:

(1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving lower case text characters without ascenders or descenders (e.g., a, c, e, o) not

exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (600 mm).

(2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of electrochemical deposits for fabrication conditions, including dimensional requirements and fabrication flaws.

(3) Visual examination acceptance standards shall comply with the following:

(-a) Deposits shall be smooth and uniform in appearance, showing visual evidence of full coverage of the repair region and showing no evidence of disbonding at exposed edges. Transitions at the edges of the deposit shall have a slope not exceeding 1:3. The deposit shall be free of pores, surface discontinuities, visible thinning, and other visible discontinuities, except as permitted in (-b) below.

(-b) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width. Only indications with major dimensions greater than 0.044 in. (1.1 mm) shall be considered relevant. The following relevant indications are unacceptable:

(-1) any cracks or linear indications

(-2) rounded indications with major dimensions greater than $^1/_{16}$ in. (1.5 mm)

(-3) four or more rounded indications in a line separated by $^1/_{16}$ in. (1.5 mm) or less edge to edge

(-4) ten or more rounded indications in any 6 in.^{2} (4 000 mm^2) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated

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Approval Date: January 6, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-841
Exemptions to Mandatory PWHT of SA-738 Grade B for Class MC Applications
Section III, Division 1

Inquiry: May the exemption thickness to mandatory PWHT allowed by Table NE-4622.7(b)-1 for SA-738, Grade B, be increased to $2^3/_8$ (60 mm)?

Reply: It is the opinion of the Committee that, the exemption thickness to PWHT for SA-738, Grade B, may be increased from $1^3/_4$ in. (44 mm) given in Table NE-4622.7(b)-1 to $2^3/_8$ in. (60 mm), provided the following requirements are met:

(a) Exemption to PWHT is permitted for a nominal thickness greater than $1^3/_4$ in. (44 mm) but equal to or less than $2^3/_8$ in. (60mm) under the conditions given in Table 1.

(b) When using the SMAW process, the welding electrodes shall be identified with a diffusible hydrogen designator of H-8 or lower and the heat input shall be 66,000 J/in. (26 000 J/cm) minimum.

(c) All other requirements of Section III, Division 1, for Class MC shall be met.

(d) The Case number shall be shown on the Data Report Form.

Table 1
Exemptions to Mandatory PWHT

P-Number (See Section IX, QW-420)	Type of Weld [Note (1)]	Normal Thickness, in. (mm) (NE-4622.3)	Max. Required Carbon, % [Note (2)]	Min. Preheat Required, °F (°C)
1	All welds, including repair welds in material greater than $1^3/_4$ in. (44 mm), but equal to or less than $2^3/_8$ in. (60 mm) exclusive of welds joining nozzles or penetrations to the vessel shell [Note (3)]	Over $1^3/_4$ to $2^3/_8$ (44 to 60)	0.24	200 (95) [Note (4)]

NOTES:
(1) Where the thickness of material is identified in the Type of Weld column, it is the thickness of the base material at the welded joint.
(2) Carbon level of the pressure-retaining materials being joined.
(3) This exemption is limited to SA-738 Grade B materials, under the following conditions:
(a) For Charpy V-Notch Testing per NE-2331(a)(1), the testing criteria are as described in either of the following:
(1) The testing temperature is 10°F (5.6°C) below the Lowest Service Metal Temperature, and the C_v energy values are as shown in Table NE-2332.1-2.
(2) The testing temperature is the Lowest Service Metal Temperature, and the C_v energy values are increased by 5ft-lb (7J) over those shown in Table NE-2332.1-2.
(b) For Drop Weight Testing permitted by NE-2331(a)(2), the difference between Lowest Service Metal Temperature and the nil ductility transition temperature, (LSMT − T_{NDT}), is equal to or greater than 10°F + A (5.6°C + A), in which the value of A is determined in accordance with Section III Appendices, Nonmandatory Appendix R.
(4) For the SMAW process, a minimum preheat temperature shall be 250°F (120°C).

Approval Date: January 28, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-842
Alternative Inspection Program for Longer Fuel Cycles
Section XI, Division 1

Inquiry: What alternatives to the scheduling requirements of Section XI, Division 1 may be used for the Inspection Program for nuclear power plants with fuel cycles longer than 40 mo?

Reply: It is the opinion of the Committee that, as an alternative to the scheduling requirements of IWA-2431, and IWB-2411, IWC-2411, IWD-2411, IWE-2411, and IWF-2410, for the Inspection Program for nuclear power plants with fuel cycles longer than 40 mo, the following requirements shall be met:

(a) The requirements of IWA-2430 shall be met, except that the length of the inspection intervals shall be 8 yr, and the maximum interval shall not extend more than 1 yr beyond the original pattern of 8-yr intervals and shall not exceed 9 yr in length.

(b) In lieu of the scheduling requirements of IWB-2411, IWC-2411, IWD-2411, and IWF-2410, the following requirements apply. The length of each inspection period shall be 4 yr, with the tolerances of IWA-2430. With the exceptions provided in IWB-2411, IWC-2411, and IWD-2411, and in (c) below, at least 25% of the required number of examinations for the interval shall be completed in each inspection period, and the maximum percentage of the required number of examination credited to each inspection period shall be 75%. If there is only one item or weld to be examined in an Examination Category, the item or weld may be examined in either period. The scheduling requirements of Article IWE-2000 shall be met, using 4-yr inspection periods, except as described in (c) below.

(c) In lieu of the requirements of IWB-2411(b), IWC-2411(b), IWD-2411(b), IWE-2411(b), or IWF-2410(c), if items or welds care added to the Inspection Program during the service lifetime of a plant, examination shall be scheduled as follows:

(1) If items or welds are added during the first period of an interval, at least 30% of the examinations required by the applicable Examination Category and Item Number for the added items or welds shall be performed during the second period of that interval.

(2) If items or welds are added during the second period of an interval, examinations shall be scheduled for successive intervals in accordance with (b) above.

(d) Table IWB-2500-1 (B-N-1, B-N-2, B-N-3), Table Note 3 (Table Note 42 in 2011 Addenda) need not be applied.

(e) All other applicable requirements of Section XI, Division 1 shall be met.

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Approval Date: January 23, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-843
Alternative Pressure Testing Requirements Following Repairs or Replacements for Class 1 Piping Between the First and Second Inspection Isolation Valves
Section XI, Division 1

Inquiry: What alternative rules to the test pressure required by IWB-5221 may be applied following repair or replacement activities for that portion of Class 1 boundary between the first and second isolation valves in the injection path of Class 2 safety systems?

Reply: It is the opinion of the Committee that for the portions of the Class 1 boundary between the first and second isolation valves in the injection path of standby safety systems, the system leakage test following repair or replacement activities may be conducted at the test pressure required for the plant for the periodic leakage test.

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Approval Date: February 9, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-844
Alternatives to the Requirements of NB-4250(c)
Section III, Division 1

Inquiry: NB-4250(c) states that "if the weld is subject to preservice inspection, the length of the counterbore shall be $2t_{min}$ for pipe and t_{min} for components and fittings, as shown in Figure NB-4250-2 or Figure NB-4250-3." May alternative configurations to those shown in Figure NB-4250-2 or Figure NB-4250-3 be used for weld joints subject to preservice inspection?

Reply: It is the opinion of the Committee that alternative configurations to those shown in Figure NB-4250-2 or Figure NB-4250-3 may be used for weld joint configurations subject to preservice inspection under the following conditions:

(a) The requirements of Figure NB-4250-1 shall be met.

(b) The Owner's Design Specification shall describe the weld joint configuration required for preservice inspection in lieu of the weld joint configuration shown in Figure NB-4250-2 or Figure NB-4250-3.

(c) The Certificate Holder shall verify that the required preservice inspection can be performed with the proposed weld joint configuration.

(d) Use of this Case shall be documented in the appropriate Data Report Form.

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Approval Date: May 7, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-845
Qualification Requirements for Bolts and Studs
Section XI, Division 1

Inquiry: What alternative to the requirements of Mandatory Appendix VIII, Supplement 8, may be used for qualification requirements for bolts and studs?

Reply: It is the opinion of the Committee that as an alternative to the requirements of Mandatory Appendix VIII, Supplement 8, the following requirements may be used.

1 SCOPE

This Case is applicable to bolts or studs examined from either end or from the bore hole.

2 SPECIMEN REQUIREMENTS

Qualification test specimens shall meet the requirements listed herein, unless a set of specimens is designed to accommodate specific limitations stated in the scope of the examination procedure.

2.1 GENERAL

(a) Specimens shall have sufficient volume to minimize spurious reflections that may interfere with the interpretation process.

(b) For examinations performed from the end of a bolt or stud, the specimens shall be full-scale sections that are sufficient to demonstrate the technique. For examinations from the bore, a segment may be used, provided it has sufficient length to demonstrate the technique.

(c) For each examination technique (e.g., bore hole, straight beam), the specimen set shall consist of at least three specimens having different diameters and lengths, as applicable.

(d) The specimen set shall contain typical geometric conditions that normally require discrimination from flaws (e.g., shank-to-thread transitions, head-to-shank transitions, bore hole geometry, or threads).

(e) The specimen set shall include typical scanning surface conditions (e.g., bore holes, grooves, transitions).

(f) The qualification specimens shall be ferritic forged material. Variations in materials shall be addressed by the process described in 5.

(g) The specimen set shall contain at least five circumferentially-oriented notches.

(h) The notch size shall not exceed the maximum depth and reflective area specified in Table 1.

(i) For examinations performed from the end of a bolt or stud, the specimen set shall contain notches at the minimum and maximum required metal paths representative of the examination volume.

(1) For examinations performed from the head surface of bolts with integral heads, the minimum metal path distance shall be demonstrated on a notch located in the head-to-shank region. When the examination is performed from the opposite surface, this notch can also be used to demonstrate the maximum metal path distance.

(2) Notches located within one diameter of the start of the examination volume are suitable for demonstrating the minimum metal path distances.

(3) Notches located within one diameter of the end of the examination volume are suitable for demonstrating the maximum metal path distances.

(j) For bore hole examinations, the specimen set shall contain a range of bore hole sizes and stud diameters sufficient to demonstrate the minimum and maximum metal paths.

(k) The specimen sets shall contain notches located on the outside-surface of the bolt or stud. The notch locations shall be within the required examination volume and coincident with geometric features that would challenge the discrimination capabilities of the technique (e.g., threaded surface, thread-to-shank transitions, head-to-shank transitions, or other geometric features).

(l) Additional notches may be included, provided they do not interfere with detection of required notches.

Table 1
Maximum Notch Dimensions

Bolt or Stud Size	Depth, in. (mm) [Note (1)]	Reflective Area, in.^{2} (mm^2)
Greater than 4 in. (100 mm) diameter	0.157 (4)	0.059 (38)
2 in. (50 mm) diameter and greater, but not over 4 in. (100 mm) diameter	0.107 (2.7)	0.027 (17)

NOTE:
(1) For threaded surfaces, notch depth is measured from the bottom of the thread root to the bottom of the notch.

3 CONDUCT OF PERFORMANCE DEMONSTRATIONS

3.1 PERSONNEL QUALIFICATIONS

Specimen identification and notch locations shall be obscured, so as to maintain a "blind test." A flaw shall be considered detected when the notch, as defined in 2.1, is found. To receive credit for detection, the following criteria must be satisfied:

(a) The notch response shall have a minimum peak-signal-to-peak-noise ratio of 2:1.

(b) The notch responses shall equal or exceed the reporting criteria specified in the procedure.

(c) The reported notch axial location correlation shall be within ±$^1/_2$ in. (±13 mm) or ±5% of the bolt or stud length, whichever is greater.

(d) A false call is any call made by the candidate where a flaw is not present or the flaw is positioned outside the limits specified in (c) above.

3.2 BLIND PROCEDURE QUALIFICATIONS

Procedure qualifications shall include the following requirements:

(a) The specimen set shall include the equivalent of at least three personnel performance demonstration test sets. Successful personnel performance demonstrations may be combined to satisfy this requirement.

(b) Detectability of all flaws in the procedure qualification test set that are within the scope of the procedure shall be demonstrated.

(c) At least one successful personnel demonstration shall be performed.

(d) With the exception of the variables defined in 5.3, at least one personnel performance demonstration set is required for qualification of new essential variables. The acceptance criteria of 3.2 shall be met.

4 ACCEPTANCE CRITERIA

(a) Personnel are considered qualified if they detect a minimum of 80% of the flaws within the test set and have no more than one false call.

(b) Procedure and equipment qualification shall demonstrate detectability of each flaw within the scope of the procedure. Successful personnel demonstrations may be combined to satisfy the requirements for procedure qualification.

5 PROCEDURE DEMONSTRATION PRIOR TO EXAMINATION

Prior to examination, a procedure demonstration shall be performed that includes the following requirements:

5.1 CALIBRATION STANDARD REQUIREMENTS

(a) A calibration standard shall be used that has a similar material specification and product form to the bolt or stud to be examined.

(b) The calibration standard shall have similar geometrical features and scan surface to the bolt or stud to be examined.

(c) The calibration standard shall contain circumferential notches that do not exceed the maximum depth and reflective area requirements defined in Table 1.

(d) For examination performed from the end of the bolt or stud, the notch locations shall satisfy the requirements defined in 2.1(i) and 2.1(k).

(e) For bore-hole examinations, the calibration standard shall have the same outside diameter as the bolt or stud to be examined. The calibration standard shall have a bore hole with the same diameter as the bolt or stud to be examined.

The calibration standard shall contain at least one notch at the maximum metal path that satisfies the location requirements of 2.1(k).

5.2 DEMONSTRATION REQUIREMENTS

(a) Personnel performing the demonstration shall have satisfied the blind qualification requirements of this Case.

(b) The qualified examiner shall demonstrate that the entire examination system (i.e., procedure, equipment, and settings) is effective for the specific bolt or stud to be examined.

(c) The examiner shall demonstrate to a UT Level III, familiar with the examination techniques and procedure requirements, the examination system's ability to detect and locate all of the required notches as defined in 5.1 (e.g., minimum and maximum metal paths for examinations performed from the end and maximum metal paths for examinations performed from the bore) within the accuracy and sensitivity limits defined in 3.2(a) through 3.2(c).

(d) Results of the demonstration shall be documented.

(e) The demonstration shall be performed prior to the start of any examination or series of examinations.

(f) The examiner shall demonstrate the same examination process that will be used on the bolt or stud (i.e., examination from the same surface or surfaces from which the examination will be performed).

5.3 PROCEDURE OPTIMIZATION

The following parameters of the demonstrated examination system may be modified to optimize the examination techniques for the bolt or stud configuration to be examined. If these modifications are required, the demonstration requirements defined in 5.2 shall be applied:

(a) search unit size and frequency to address material attenuation

(b) instrument settings to address changes in frequency (e.g., filtering, pulse width for instruments with square wave pulsers)

(c) bore-hole probe (e.g., fixture size, element size) to address variations in bore-hole diameters

5.4 PROCEDURE EXPANSION FOR QUALIFIED METAL PATHS

The following demonstration shall be performed when a bolt or stud to be examined requires metal paths that exceed the minimum or maximum demonstrated in 2 through 4. Demonstrations defined in 5 shall be performed to ensure the effectiveness of the examination system prior to use. If the extended metal path demonstration fails to satisfy the requirements of 5.2(c), the qualification process defined in 2 through 4 shall be performed for the new metal path.

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Approval Date: July 25, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-846
Certificate Holder Ability to Supply Polyethylene Material
Section III, Division 1

Inquiry: Under what conditions may a Certificate Holder supply polyethylene material per NCA-3970?

Reply: It is the opinion of the Committee that a Certificate Holder may furnish polyethylene material when stated in the scope of its certificate. In this case, a Quality System Certificate is not required, nor is the user of the polyethylene material required to survey, qualify, or audit such a Certificate holder.

The use of this Case shall be documented on the required certification supplied with the polyethylene material.

This Case may be used in the 2010 Edition and later.

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Approval Date: September 4, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-849
In Situ VT-3 Examination of Removable Core Support Structure Without Removal
Section XI, Division 1

Inquiry: In lieu of meeting the requirements of Table IWB-2500-1, Item B13.70, to remove the core support structure to perform a VT-3 preservice or inservice visual examination, may the examination be performed with the core support structure in situ using a remote examination system?

Reply: It is the opinion of the Committee that, in lieu of removing the core support structure, a VT-3 preservice or inservice visual examination may be performed in situ, provided the following requirements are met:

(a) All surfaces accessible for examination when the structure is removed shall be accessible when the structure is in situ, except for load bearing or contact surfaces.

(b) Gaps between contact surfaces shall be measured and recorded for each examination.

Examination of bearing and contact surfaces and any bolts needing removal is required only when the core barrel is removed from the reactor vessel.

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Approval Date: October 20, 2014
(ACI) Approval Date: August 1, 2014

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-850
Equivalent Rectangular Compressive Stress Block for Concrete Containment
Section III, Division 2

Inquiry: Under what conditions may an equivalent rectangular concrete stress distribution be used to satisfy the requirements of CC-3511.1(e) for calculating flexure and membrane strengths in factored load design?

Reply: It is the opinion of the Committee that an equivalent rectangular compressive stress distribution may be used to satisfy the requirements of CC-3511.1(e) provided the following conditions are met:

(a) The requirements of CC-3511.1(e) are satisfied by an equivalent rectangular concrete stress distribution defined below:

(1) Concrete stress of $\alpha_1 f'_c$ shall be assumed uniformly distributed over an equivalent compressive zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance $a = \beta_{1c}$ from the fiber of maximum compressive strain.

(2) Distance from the fiber of maximum strain to the neutral axis, c, shall be measured in a direction perpendicular to the neutral axis.

(3) For factored primary loads, α_1 shall be taken as 0.06 and β_1 shall be taken as 0.70. Maximum allowable strain at extreme concrete compression fiber shall be assumed equal to or less than 0.0013.

When the concrete strain at extreme concrete compression fiber is smaller than 0.0013, α_1 shall be adjusted as

$$\alpha_1\left(\frac{\varepsilon_c}{0.0013}\right)$$

(4) For factored primary plus secondary loads, α_1 shall be taken as 0.75 and β_1 shall be taken as 0.70. Maximum allowable strain at extreme concrete compression fiber shall be assumed equal to 0.0020.

(5) The stresses determined shall be compared to the stress limits of CC-3420 to ensure design adequacy.

(6) The following definitions shall be used:

α_1 = factor relating width of equivalent rectangular compressive stress block

β_1 = factor relating depth of equivalent rectangular compressive stress block to neutral axis depth

ε_c = concrete strain at extreme concrete compression fiber

(b) All requirements of CC-3511.1(a) through (d) shall be met.

(c) Use of this Case shall be noted on the C-1 Data Report Form.

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(15) **Approval Date: November 5, 2014**

Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-851
Alternative Method for Establishing the Reference Temperature for Pressure Retaining Materials
Section XI, Division 1

Inquiry: Is it permissible to use fracture toughness test data as an alternative to the methods specified in Nonmandatory Appendix A, A-4200, based on RT_{NDT}, and Nonmandatory Appendix G, G-2110 to establish a fracture-toughness-based reference temperature, RT_{T_0}, for pressure retaining materials, other than bolting?

Reply: It is the opinion of the Committee that fracture toughness test data may be used as an alternative to the methods specified in Nonmandatory Appendix A, A-4200, based on RT_{NDT}, and Nonmandatory Appendix G, G-2110 to establish a fracture-toughness-based reference temperature, RT_{T_0}, for pressure retaining materials other than bolting, in accordance with the following additional requirements.

(a) Fracture toughness testing for specific base metal or weld materials shall be performed in accordance with ASTM E1921-97, "Standard Test Method for the Determination of Reference Temperature, T_0, for Ferritic Steels in the Transition Range." The minimum test requirements of the test method shall be satisfied for the specific material being evaluated. Test data shall satisfy the validity requirements specified in the test method.

(b) Test specimen location and orientation shall be in accordance with the requirements of NB-2300 for Charpy V-notch specimens. Different specimen geometries may be used in accordance with ASTM E1921-97.

(c) The value of T_0 for the test data shall be determined in accordance with (a) above.

(d) The value of T_0 shall be used to calculate the reference temperature RT_{T_0} in the following equation:

(U.S. Customary Units)

$$RT_{T_0} = T_0 + 35°\mathrm{F}$$

(SI Units)

$$RT_{T_0} = T_0 + 19.4°\mathrm{C}$$

(e) The reference temperature RT_{T_0} may be used as an alternative indexing reference temperature to RT_{NDT} for the K_{Ic} toughness curve, as applicable in Nonmandatory Appendices A and G. For the K_{Ia} curve in Nonmandatory Appendix A, the reference temperature, $RT_{K_{Ia}}$, may be used in place of RT_{NDT}, where $RT_{K_{Ia}}$ is related to T_0 and RT_{T_0} as follows:

(U.S. Customary Units)

$$RT_{K_{Ia}} = T_0 + 80.95\exp\left[-0.00613\,T_0\right] = RT_{T_0} - 35°\mathrm{F} + 80.95\exp\left[-0.00613\left(RT_{T_0} - 35°\mathrm{F}\right)\right]$$

(SI Units)

$$RT_{K_{Ia}} = T_0 + 44.97\exp\left[-0.00613\,T_0\right] = RT_{T_0} - 19.4°\mathrm{C} + 44.97\exp\left[-0.00613\left(RT_{T_0} - 19.4°\mathrm{C}\right)\right]$$

(f) Use of this Case shall be identified in the applicable documentation.

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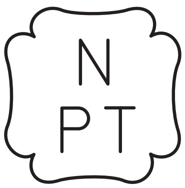
(15) **Approval Date: February 9, 2015**

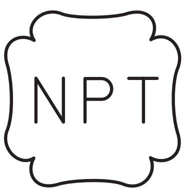
Code Cases will remain available for use until annulled by the applicable Standards Committee.

Case N-852
Application of the ASME NPT Stamp
Section III, Division 1; Section III, Division 2; Section III, Division 3; Section III, Division 5

Inquiry: In the 2010 Edition and earlier editions and addenda of Section III, the ASME NPT Code Symbol Stamp is as shown below:

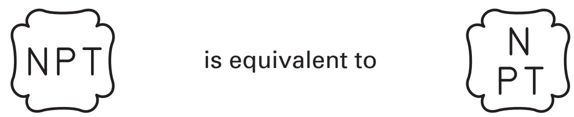


ASME has issued some NPT Code Symbol Stamps to NPT Certificate Holders with the NPT letters arranged horizontally as shown below:



For construction to Section III, 2010 Edition and earlier editions and addenda, may an NPT Certificate Holder use the NPT Code Symbol Stamp with the NPT letters arranged horizontally as shown above in lieu of the NPT Code Symbol Stamp as depicted and required by Article NCA-8000 or Article WA-8000?

Reply: It is the opinion of the Committee that the ASME NPT Code Symbol Stamp with the NPT letters arranged horizontally may be used for construction to the 2010 Edition and earlier editions and addenda of Section III. In addition, it is the opinion of the Committee that the NPT Code Symbol Stamp with the NPT letters arranged horizontally is equivalent to the NPT Code Symbol Stamp as depicted and required by Article NCA-8000 or Article WA-8000.



Use of this Case is not required for use of the NPT Code Symbol Stamp with the NPT letters arranged horizontally for construction to the 2010 Edition and earlier editions and addenda of Section III. Because the NPT Code Symbol Stamp with the NPT letters arranged horizontally is equivalent to the NPT Code Symbol Stamp as depicted by Article NCA-8000 or Article WA-8000, use of this Case is not required to be documented in the Design Specification, Design Report, or Data Report, and the provisions of NA/NCA/WA-1140 related to use of Code Cases need not be met for the use of this Case.

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