ASME B31T-2015
(Revision of ASME B31T-2010)

Standard Toughness Requirements for Piping

ASME Code for Pressure Piping, B31

AN INTERNATIONAL PIPING CODE®

The American Society of Mechanical Engineers

ASME B31T-2015
(Revision of ASME B31T-2010)

Standard Toughness Requirements for Piping

ASME Code for Pressure Piping, B31

AN INTERNATIONAL PIPING CODE®

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: August 12, 2016

This Code will be revised when the Society approves the issuance of a new edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Code. Interpretations are published under http://go.asme.org/Interpretations. Periodically certain actions of the ASME B31 Committees may be published as Cases. Cases are published on the ASME Web site under the Committee Pages at http://go.asme.org/B31committee as they are issued.

Errata to codes and standards may be posted on the ASME Web site under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The B31 Committee Pages can be found at http://go.asme.org/B31committee. The associated B31 Committee Pages for each code and standard can be accessed from this main page. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

CONTENTS

FOREWORD

In 2000, the B31 Code for Pressure Piping, Materials Technical Committee (MTC), determined that there was a need to develop a standard set of toughness requirements for piping components that can be adopted by reference by the various piping codes and other codes and standards. At the time, the requirements of the B31 Code books varied, with some having no requirements at all.

This Code is intended to provide requirements for evaluating the suitability of materials used in piping systems for piping that may be subject to brittle failure due to low-temperature service conditions.

Under direction of ASME Standards and Certification, both SI and U.S. Customary units are provided. The 2010 edition of this Code was approved by the American National Standards Institute (ANSI) on April 20, 2010.

This edition of the Code was approved by ANSI on October 21, 2015.

ASME B31 COMMITTEE
Code for Pressure Piping

(The following is the roster of the Committee at the time of the approval of this Code.)

STANDARDS COMMITTEE OFFICERS

J. E. Meyer, *Chair*
J. W. Frey, *Vice Chair*
A. P. Maslowski, *Secretary*

STANDARDS COMMITTEE PERSONNEL

R. J. T. Appleby, ExxonMobil Pipeline Co.
C. Becht IV, Becht Engineering Co., Inc.
K. C. Bodenhamer, TRC Pipeline Services
R. Bojarczuk, ExxonMobil Research and Engineering Co.
C. J. Campbell, Consultant
J. S. Chin, TransCanada Pipeline US
D. D. Christian, Victaulic
R. P. Deubler, Fronek Power Systems, LLC
C. Eskridge, Jr., Jacobs Engineering
D. J. Fetzner, BP Exploration Alaska, Inc.
P. D. Flenner, Flenner Engineering Services
J. W. Frey, Stress Engineering Services, Inc.
D. R. Frikken, Becht Engineering Co., Inc.
R. A. Grichuk, Fluor Enterprises, Inc.
R. W. Haupt, Pressure Piping Engineering Associates, Inc.
G. A. Jolly, Flowserve/Gestra, USA
A. P. Maslowski, The American Society of Mechanical Engineers
W. J. Mauro, American Electric Power
J. E. Meyer, Louis Perry Group
T. Monday, Team Industries, Inc.
M. L. Nayyar, NICE
G. R. Petru, Acapella Engineering Services, LLC
E. H. Rinaca, Retired
M. J. Rosenfeld, Kiefner/Applus—RTD
J. T. Schmitz, Southwest Gas Corp.
S. K. Sinha, Lucius Pitkin, Inc.
W. J. Sperko, Sperko Engineering Services, Inc.
J. Swezy, Jr., Boiler Code Tech, LLC
F. W. Tatar, FM Global
K. A. Vilminot, Black & Veatch
G. Antaki, *Ex-Officio Member,* Becht Engineering Co., Inc.
L. E. Hayden, Jr., *Ex-Officio Member,* Consultant
A. Livingston, *Ex-Officio Member,* Kinder Morgan
J. S. Willis, *Ex-Officio Member,* Page Southerland Page, Inc.

B31 MATERIALS TECHNICAL COMMITTEE

R. A. Grichuk, *Chair,* Fluor Enterprises, Inc.
C. E. O'Brien, *Secretary,* The American Society of Mechanical Engineers
W. P. Collins, WPC Solutions, LLC
R. P. Deubler, Fronek Power Systems, LLC
C. Eskridge, Jr., Jacobs Engineering
A. A. Hassan, Power Generation Engineering and Services Co.
G. A. Jolly, Flowserve/Gestra, USA
C. J. Melo, Technip USA, Inc.
M. L. Nayyar, NICE
M. B. Pickell, Retired
D. W. Rahoi, Consultant
R. A. Schmidt, Canadoil
H. R. Simpson, PM&C Engineering
J. L. Smith, Consultant
Z. Djilali, *Contributing Member,* Sonatrach

CORRESPONDENCE WITH THE B31 COMMITTEE

General. ASME Codes are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Code may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B31 Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

Proposing Revisions. Revisions are made periodically to the Code to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Code. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Code. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the B31 Materials Technical Committee will render an interpretation of any requirement of the Code. Interpretations can only be rendered in response to a written request sent to the Secretary of the B31 Standards Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Code for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The B31 Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the Secretary of the B31 Standards Committee.

ASME B31T-2015
SUMMARY OF CHANGES

Following approval by the B31 Committee and ASME, and after public review, ASME B31T-2015 was approved by the American National Standards Institute on October 21, 2015.

ASME B31T-2015 contains editorial changes, revisions, and corrections identified by a margin note, **(15),** placed next to the affected areas.

Page	*Location*	*Change*
1	1	(1) Footnote added (2) References to "this Standard" changed to "this Code"
2	3.3	Reference to "this Standard" changed to "this Code"
	3.4	Reference to "this Standard" changed to "this Code"
	3.5	First paragraph revised
	3.6	Title revised
	3.6.1	First paragraph revised
3	3.6.2	Last two paragraphs moved to end of 3.6.1
	3.7.1	Second paragraph revised
	3.7.2.2	Reference to "this Standard" changed to "this Code" in second paragraph
4	3.7.2.3	References to "this Standard" changed to "this Code" in first paragraph and paras. (a) and (c)
7	4.4.2	Revised
10, 15	Table 3.1-1	(1) Columns 4, 6, 8, and 10–14 revised for CS B ≤ 11.9 mm (2) Columns 4, 6, 8, and 10–14 revised for CS B ≤ 14.5 mm (3) Columns 4, 6, 8, and 10–15 revised for CS B ≤ 17.3 mm (4) Columns 4, 6, 8, and 10–14 revised for CS B ≤ 0.47 in. (5) Columns 4, 6, 8, and 10–14 revised for CS B ≤ 0.57 in. (6) Columns 4, 6, 8, and 10–15 revised for CS B ≤ 0.68 in.
22, 23–25	Table 3.2-1	(1) First two A351 entries updated, last three added (2) New Note (8) added, and remaining Notes renumbered accordingly (3) Second A671 entry revised, fourth and fifth added (4) First A672 entry revised, fourth and fifth added

Page	*Location*	*Change*
26	Table 4.4.2-1	General Note added
28, 30	Mandatory Appendix I	(1) Figure I-1, Group B curve revised (2) Table I-1, Curve B values revised for rows 4–8 and 10–19
36–38	Mandatory Appendix III	(1) Twelfth and 14th CS B entries revised, 13th and 15th added (2) Third and fifth CS D entries added (3) Seventh SS −425 entry added (4) Sixteenth and 17th SS −325 entries added (5) Third SS −60 entry added (6) Twenty-second SS −20 entry deleted, 23rd revised
41	Nonmandatory Appendix A	References to “this Standard” changed to “this Code”
43	Nonmandatory Appendix B	References to “this Standard” changed to “this Code”

STANDARD TOUGHNESS REQUIREMENTS FOR PIPING

(15) 1 INTRODUCTION

This Code provides requirements for evaluating the suitability of materials used in piping systems for piping that may be subject to brittle failure due to low-temperature service conditions. While low-temperature service is usually considered to be below ambient temperature, brittle failure can occur at temperatures above ambient temperature for certain combinations of materials, thicknesses, and stress levels. The definition of "low-temperature service" as used in this Code, therefore, varies widely across the many applications for which piping systems are used. For a building service air line, low temperature may be 0°C (32°F), whereas for a cryogenic piping system, it could easily be −185°C (−300°F).[1] However, the principles used to evaluate the suitability of a piping system as related to service temperature by evaluating the toughness of the material can be applied across a wide temperature range, and this Code has been established to provide uniform guidance in this area. This Code may be invoked in whole or in part by various piping codes and/or specifications and is only mandatory when so invoked.

Suitability of piping systems for low-temperature service is a function of several variables, including material properties, design loadings, and fabrication procedures. The three primary factors that generally control the susceptibility for brittle fracture are material toughness, crack size, and tensile stress level. There are a wide variety of services where low-temperature suitability need not even be considered; however, a screening criterion is necessary to determine this.

One objective of this Code is to provide a simple approach to evaluate whether additional consideration is necessary to evaluate suitability for low-temperature service. This is done by establishing a low-temperature service limit for various materials. Services at or warmer than this limit are not considered low temperature, and additional considerations relative to suitability are not required.

For services colder than this limit, various requirements are provided that, when met, qualify the material for low-temperature services. These requirements include impact testing, qualification of welding and other fabrication procedures, and limiting the design loadings.

[1] For guidance on cryogenic valves, refer to MSS SP-134, *Valves for Cryogenic Service Including Requirements for Body/Bonnet Extensions.*

The low-temperature service limit established herein is based on a reasonable degree of assurance that at this temperature the material will have a ductile failure mode. The actual ductile-to-brittle transition temperature for a given material specification will vary based on actual heat chemistry of the material and subsequent processing. For critical applications, the design engineer can select materials with a lower low-temperature service limit, or require impact testing. On less-critical applications, material with a higher low-temperature service limit may be acceptable. The final selection is left to the referring code and the design engineer (when permitted by the referring code).

To keep the number of sets of requirements to a minimum, material groupings have been established, and a unique set of requirements have been provided for each group. These groups are assigned "T-numbers" for easy reference. Although most materials used in piping systems are listed, some are not, and these unlisted materials are not addressed in this Code. Where permitted by code or specification invoking this Code, these requirements may be used for unlisted materials. The invoking code or specification may establish the correct T-number group for the material or may invoke the testing and other requirements of this Code using the worst-case assumption that the design minimum temperature is colder than the temperatures that would allow exemption from any of the requirements of this Code. The guidelines for establishing the correct T-number group are provided in Nonmandatory Appendix B.

2 GLOSSARY

CVN: abbreviation for Charpy V-notch.

design minimum temperature: the lowest component temperature expected in service.

fully deoxidized steel: steel that has been deoxidized either by the addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between the carbon and oxygen during solidification. Also known as killed steel. Steels that are not fully deoxidized include rimmed, semi-killed, and capped steels. Limitations on the use of steels that are not fully deoxidized may be imposed by the applicable piping code or specification.

lower critical temperature: the temperature at which the first phase change occurs when heating a metal.

low-temperature service limit: the design minimum temperature where additional requirements for low-temperature service do not apply.

NDT temperature: the nil ductility transition temperature.

stress ratio: the ratio of the design stress to an allowable stress. (See para. 3.6.2.)

T-number: a number assigned to a group of similar materials with similar low-temperature requirements. The number consists of the material type, a temperature characteristic, and possibly a suffix.

3 LOW-TEMPERATURE RANGES AND REQUIREMENTS

3.1 Low-Temperature Service Requirements

Low-temperature service requirements are contained in Table 3.1-1. These requirements are established for T-number groups of materials with similar requirements. In addition to T-number group, in some cases requirements are dependent on thickness and/or other characteristics as listed in Table 3.1-1.

3.2 Material Groupings (Column 1 of Table 3.1-1)

Material T-number groups for each covered material specification are provided in Table 3.2-1. (In addition, a table sorted by material type and T-number group that lists all materials in each T-number group is provided in Mandatory Appendix III.) In determining the applicable T-number group for a material from the table, consideration shall be given to the material specification, grade, and any other variables as established in the notes. The table separates the materials into types (carbon steel, low-alloy steel, etc.), and the group number is representative of the low-temperature service limit for the material; however, the low-temperature service limit may vary based on the design and fabrication requirements. Low-temperature service limits shall be determined from Table 3.1-1. An "(A)" in the T-number group [e.g., CS −20(A)] indicates that materials of that group may not be used at temperatures colder than the group number [e.g., −29°C (−20°F)].

(15) 3.3 Nominal Thickness and Notes (Columns 2 and 3 of Table 3.1-1)

For material T-number groups where the low-temperature suitability varies significantly according to the thickness, a thickness is listed in column 2 of Table 3.1-1. Note that the thickness is the nominal thickness as defined in the code or specification referencing this Code. The variation based on thickness applies to carbon steel T-number groups CS A, CS B, CS C, and CS D where Table 3.1-1 lists thickness at each 10°F increment. When it is desired to refine the influence of the thickness, Mandatory Appendix I provides the continuous curves and tables that can be used at intermediate values or greater thickness. Since the nominal thicknesses in Table I-1 of Mandatory Appendix I are generally derived based on uniform increments of temperature, the table does not contain uniform increments of thickness. Again, the continuous curves in Mandatory Appendix I should be consulted for the precise values.

For material T-number groups where the low-temperature suitability is dependent on some other factor, those factors are given in the notes listed in column 3 of Table 3.1-1.

3.4 Low-Temperature Service Limit (Column 4 of Table 3.1-1) (15)

Column 4, the first temperature column in Table 3.1-1, is the low-temperature service limit. If the design minimum temperature is equal to or warmer than this value, then low-temperature requirements do not apply. Materials within a group may be used at this temperature or temperatures warmer than this limit without imposing any of the requirements of this Code. This limit considers material properties and the influence of fabrication processes on the material properties.

3.5 Material Requirements for Low-Temperature Service (Columns 5 and 6 of Table 3.1-1) (15)

Column 5 lists the minimum permitted temperature of the material. When a temperature is listed, this is the design minimum temperature permitted for the material group regardless of impact testing or any other requirements except as permitted by column 18, where the applied stress is limited to 30% of the allowable.

Column 6 is the minimum temperature without impact testing for the material. If the design minimum temperature is equal to or warmer than this value, the material does not require impact testing. If the design minimum temperature is colder than this value, impact testing of the material in accordance with section 3 is required. For carbon steels, this limit might vary with material thickness (T-number groups CS A, CS B, CS C, and CS D) or with stress levels. Additional rows are provided in the table for thickness variations. Interpolation between thicknesses is permitted. Figures and a table for the curves of the variation of temperature with thickness are provided in Mandatory Appendix I and these may be used as an alternative to the values in Table 3.1-1. Permitted temperatures with stress limits are provided for by using columns 10 through 18 instead of column 6 as discussed in para. 3.6 below.

3.6 Design Requirements for Low-Temperature Service (Columns 10–18 of Table 3.1-1) (15)

3.6.1 Minimum Material Temperature Without Impact Testing. (15) Columns 10 through 17 list the minimum material temperature without impact testing based on

design stresses and may be used for carbon steels provided

(a) the piping system is subjected to a hydrostatic test at no less than 1.5 times the design pressure

(b) the piping system is not subjected to unevaluated external loads such as maintenance loads, impact loads, and thermal shock

The curve used to generate columns 10 through 17 is provided in Mandatory Appendix II and may be used as an alternative to columns 10 through 17.

Column 18 lists the minimum low-temperature service limit achievable by limiting stresses to less than 10% of the tensile strength (i.e., SR ≤ 0.3) and may be used without any additional low-temperature service requirements. At these stress levels, the design margin is considered adequate to prevent a brittle fracture failure mode. The low-temperature service limit listed in column 18 may be used in lieu of that listed in column 4 when the stress ratio ≤ 0.3.

(15) **3.6.2 Stress Ratio.** The stress ratio is defined as the maximum of the following:

(a) nominal pressure stress (based on minimum pipe wall thickness less allowances) divided by the allowable stress at the design minimum temperature.

(b) for piping components with pressure ratings, the pressure for the condition under consideration divided by the pressure rating at the design minimum temperature.

(c) combined longitudinal stress due to pressure, dead weight, and displacement strain (stress intensification factors are not included in this calculation) divided by the allowable stress at the design minimum temperature. In calculating longitudinal stress, the forces and moments in the piping system shall be calculated using nominal dimensions, and the stresses shall be calculated using section properties based on the nominal dimensions less corrosion, erosion, and mechanical allowances.

In determining the stress ratio, the loadings coincident with the metal temperature under consideration may be used in lieu of maximum design values. Where there are several low-temperature design conditions, each shall be evaluated to determine the stress ratio.

3.7 Fabrication Requirements for Low-Temperature Service (Columns 7, 8, and 9 of Table 3.1-1)

(15) **3.7.1 Temperature Limits.** Column 7 lists the minimum weld permitted temperature. When a temperature is listed, this is the design minimum temperature permitted for welded construction for this material group, thickness, and notes regardless of impact testing or any other requirements. Use of the material is prohibited at temperatures colder than this temperature unless permitted by column 9.

Column 8 of Table 3.1-1 lists the design minimum temperature permitted for each material group without additional fabrication requirements. Alternatively, when stresses are limited to 30% of allowable, the temperatures in column 9 may be used instead of the values in column 8.

When materials are used at temperatures colder than those listed in column 8 or 9 as applicable, the welding and bending and forming procedures shall be qualified to verify that they do not result in significant loss of material toughness. In addition, weld filler metal shall meet the impact test requirements of para. 3.7.4.

3.7.2 Welding Procedure Specifications

3.7.2.1 General. When welding procedures are required to be qualified with impact testing per para. 3.7.1, the supplementary essential variables of ASME Boiler and Pressure Vessel Code (BPVC) Section IX are applicable. Impact tests of the weld metal and heat-affected zone (HAZ) shall be performed in accordance with the following paragraphs except that impact tests of the heat-affected zone are not required for

(a) the qualification for welds in P-Nos. 1 and 3 materials that are postweld heat treated and are made by any process other than electroslag, electrogas, or thermit

(b) the qualification for weld deposit cladding or hard-facing on any base material

(c) that portion of the heat-affected zone associated with GTAW root deposits with a maximum of two layers or 5 mm ($^3/_{16}$ in.) thickness, whichever is less

(15) **3.7.2.2 Test Specimens.** The weld procedure qualification impact test specimens shall be Charpy V-notch specimens prepared and tested in accordance with the requirements in ASME BPVC Section IX. A test shall consist of five specimens, all of which shall be tested at or below the design minimum temperature. The highest and lowest values of these specimens shall be disregarded, and the average value of the three remaining specimens shall equal or exceed the impact value required for the base metal to be welded in production.

The impact specimen representing the weld deposit shall be located so that the longitudinal axis of the specimen is at least 0.25t from a surface, where t is the thickness of the test weld and, where the thickness of the test assembly permits, not less than 10 mm ($^3/_8$ in.) from the weld surface of the test assembly. In addition, when the postweld heat treatment temperature exceeds the maximum temperature specified by the code referencing this Code, and the test assembly is cooled at an accelerated rate, the longitudinal axis of the specimen shall be a minimum of t from the edge of the test assembly. The specimen shall be transverse to the longitudinal axis of the weld with the area of the notch located in the weld. The length of the notch of the Charpy V-notch specimen shall be normal to the surface of the weld.

Specimens representing the heat-affected zone shall be taken from the welding procedure qualification test assemblies in accordance with (a) through (c) below.

(a) If the qualification test material is in the form of a plate or a forging, the axis of the weld shall be oriented

in the direction parallel to the principal direction of rolling or forging.

(b) The specimens shall be removed from a location as near as practical to a depth midway between the surface and center thickness. The coupons for heat-affected zone impact specimens shall be taken transverse to the axis of the weld and etched to define the heat-affected zone. The notch of the CVN specimen shall be cut approximately normal to the material surface in such a manner as to include as much heat-affected zone as possible in the resulting fracture. Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line. When a grain-refining heat treatment is not performed on welds made by the electroslag or electrogas welding process, the notch for the impact specimens shall be located in the grain-coarsened region.

(c) For the comparison of heat-affected zone values with base material values, CVN specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.

(15) **3.7.2.3 Test Requirements.** The impact test requirements and acceptance standards for the weld metal used for welding procedure qualification shall be the same as specified in section 4 for the base material to be welded or repaired. Retests in accordance with the provisions of para. 4.5.4 are permitted. Where two materials are to be joined by welding and have different fracture toughness requirements, the test requirements and acceptance standards of either material may be used for the weld metal unless otherwise specified by the code referencing this Code.

For Charpy V-notch tests of the heat-affected zone, three Charpy V-notch specimens representing the heat-affected zone material and three representing the unaffected base material shall be tested at the design minimum temperature of the base material. Test acceptance criteria are as follows:

(a) The Charpy V-notch impact tests of the unaffected base material shall meet the requirements of this Code. If the average lateral expansion values of the three HAZ specimens are equal to or greater than the average value for the unaffected base material CVN specimens, the qualification test shall be considered acceptable, and the values and testing temperature shall be recorded on the Welding Procedure Qualification Record (PQR).

(b) If the average Charpy V-notch lateral expansion for the heat-affected zone of (a) above is less than that for the unaffected base material, and the qualification test meets the other criteria of acceptance, the Charpy V-notch test results may be recorded on the Welding PQR. Data shall then be obtained as specified in (c) below to provide an additive temperature for the adjustment to compensate for the heat-affected zone toughness decrease as described in (d) below. Alternatively, the welding procedure qualification may be rewelded and retested.

(c) The data for development of the temperature adjustment (T_{ADJ}) shall be developed by performing additional Charpy V-notch tests on either the welding procedure qualification heat-affected zone or the unaffected base material, or both, at temperatures that provide toughness values that meet or exceed those required for the thickness of material to be welded in production. The average toughness data for the heat-affected zone and the unaffected base material shall be plotted on a property–temperature chart. The temperatures at which these two sets of data exhibit a common acceptable value of toughness for the production thickness involved shall be determined. The determined temperature for the unaffected base material shall be subtracted from the similarly determined temperature for the heat-affected zone. This difference shall be used in (d) below as T_{ADJ}. If the temperature difference is zero or is a negative number, no adjustment is required for the base material to be welded in production, and the minimum temperature established by this Code will still apply as stated in (a) above. The Charpy V-notch testing results shall be recorded on the Welding PQR, and any offsetting T_{ADJ} or increased toughness requirements shall be noted on the Welding PQR and on the Welding Procedure Specification (WPS).

(d) At least one of the following methods shall be used to compensate for the heat-affected zone toughness decrease due to the welding procedure. More than one compensation method may be used on a par basis.

(1) The low-temperature service limit for all of the material to be welded in production WPSs supported by this PQR shall be increased by the adjustment temperature T_{ADJ}.

(2) The specified testing temperature for the production material may be reduced by T_{ADJ}.

(3) The materials to be welded may be welded using the WPS provided they exhibit Charpy V-notch values that are no less than the minimum required lateral expansion value required for the material plus the difference in average lateral expansion values between the unaffected base metal and the HAZ.

3.7.3 Forming and Bending Processes. Any process may be used to hot form, cold form, or bend material, including weld metal, provided the impact properties of the material, when required, are not reduced below the minimum specified values, or they are effectively restored by heat treatment following the forming operation. Hot forming is defined as forming with the material temperature warmer than 56°C (100°F) below the lower critical temperature of the material.

When required, the hot- or cold-forming process shall be qualified for impact properties as follows.

A procedure qualification test shall be conducted using specimens taken from material of the same specification, grade or class, and heat treatment, and with similar impact properties, as required for the material to be used in production. These specimens shall be subjected to the equivalent forming or bending process and heat treatment as the material to be used in production. Applicable tests shall be conducted to determine that the required impact properties of section 4 are met after straining.

3.7.3.1 Materials Not Requiring Procedure Qualification Tests. Procedure qualification tests are not required for materials listed in (a) through (e) below.

(a) hot-formed material, such as forgings, in which the hot forming is completed prior to removal of the impact test specimens

(b) hot-formed material represented by test coupons that have been subjected to heat treatment representing the hot-forming procedure and the heat treatments to be applied to the parts

(c) material that has a final strain less than 0.5%

(d) material where the final strain is less than that of a previously qualified procedure for that material

(e) material from which the impact testing in accordance with section 4 is performed on each heat and lot, as applicable, after forming

3.7.3.2 Performance of Procedure Qualification Test. The procedure qualification test shall be performed in the manner stipulated in (a) through (f) below.

(a) The tests shall be performed on three different heats of material both before straining and after straining and heat treatment to establish the effects of the forming and subsequent heat treatment operations.

(b) Specimens shall be taken in accordance with the requirements of section 4 and shall be taken from the tension side of the strained material.

(c) The percent strain shall be established by the following formulas:

For cylinders:

$$\% \text{ strain} = 50t/R_f\left[1 - \left(R_f/R_o\right)\right]$$

For spherical or dished surfaces:

$$\% \text{ strain} = 75t/R_f\left[1 - \left(R_f/R_o\right)\right]$$

For pipe:

$$\% \text{ strain} = 100r/R$$

where

R = nominal bending radius to the centerline of the pipe, mm (in.)

r = nominal radius of the pipe, mm (in.)

R_f = final radius to centerline of shell, mm (in.)

R_o = original radius (equal to infinity for a flat part), mm (in.)

t = nominal thickness, mm (in.)

(d) The procedure qualification shall simulate the maximum percent surface strain, employing a bending process similar to that used in the fabrication of the material or by direct tension on the specimen.

(e) Sufficient CVN test specimens shall be taken from each of the three heats of material to establish a transition curve showing both the upper and lower shelves. On each of the three heats, tests consisting of three impact specimens shall be conducted at a minimum of five different temperatures distributed throughout the transition region. The upper and lower shelves may be established by the use of one test specimen for each shelf. Depending on the product form, it may be necessary to plot the transition curves using both lateral expansion and energy level data.

(f) Using the results of the impact test data from each of three heats, taken both before and after straining, determine either of the following:

(1) the maximum change in NDT temperature along with

(-a) the maximum change of lateral expansion and energy at the temperature under consideration, or

(-b) the maximum change of temperature at the lateral expansion and energy levels under consideration

(2) when lateral expansion is the acceptance criterion, either the maximum change in temperature or the maximum change in lateral expansion

3.7.3.3 Acceptance Criteria. To be acceptable, the formed material used in production shall have impact properties before forming sufficient to compensate for the maximum loss of impact properties due to the qualified forming processes used. A new procedure qualification test is required when any of the changes in (a), (b), or (c) below are made.

(a) The actual postweld heat treatment time at temperature is warmer than previously qualified unless the material is P-No. 1 and the thickness is less than 50 mm (2 in.). If the material is not postweld heat treated, the procedure shall be qualified without postweld heat treatment.

(b) The maximum calculated strain of the material exceeds the previously qualified strain by more than 0.5%.

(c) Preheat over 120°C (250°F) is used in the forming or bending operation but not followed by a subsequent postweld heat treatment.

3.7.4 Weld Filler Metal

3.7.4.1 General. Weld filler metal for applications where the design minimum temperature is colder than the temperature listed in column 8 or 9 of Table 3.1-1,

as applicable, shall be impact tested. The impact tests shall be conducted for each lot of covered, flux cored, metal cored, or fabricated electrodes; for each heat of bare electrodes, rod, or wire for use with the OFW, GMAW, GTAW, PAW, and EGW (electro-gas welding) processes (ASME BPVC Section IX, QW/QB-492); for each heat of consumable inserts; for each combination of heat of bare electrodes and lot of submerged arc flux; for each combination of lot of fabricated electrodes and lot of submerged arc flux; for each combination of heat of bare electrodes or lot of fabricated electrodes and dry blend of supplementary powdered filler metal and lot of submerged arc flux; or for each combination of heat of bare electrodes and lot of electroslag flux. Where the specification for welding consumables specifies impact testing at a temperature equal to or colder than the design minimum temperature, testing of each heat/lot combination is not required, provided the filler metal will be used in the same heat treatment condition as is specified in the filler metal specification. Tests performed on the welding material in the qualification of weld procedures may satisfy the testing requirements for the lot, heat, or combination of heat and batch of welding material used.

3.7.4.2 Test Coupons. The welding test coupon shall be made using the welding process, filler metal specification and classification, minimum tensile strength, preheat and interpass temperatures, and postweld heat treatment to be used in the production welding using each process to be used in the production welding. The test coupon shall be of sufficient size and thickness that the required test specimens can be removed.

The weld metal to be tested for all processes except electroslag welding shall be deposited in such a manner as to eliminate substantially the influence of the base material on the results of the tests. Weld metal to be used with the electroslag process shall be deposited in such a manner as to conform to one of the applicable WPS for production welding, ASME BPVC Section IX, QW-201.1.

The welding of the test coupon shall be performed within the range of preheat and interpass temperatures that will be used in production welding. Coupons shall be tested in the as-welded condition or they shall be tested in the applicable postweld heat-treated condition when the production welds are to be postweld heat treated. The postweld heat treatment holding time shall be at least 80% of the maximum time to be applied to the weld metal in production application. The total time for postweld heat treatment of the test specimen may be applied in one heating cycle. The cooling rate from the postweld heat treatment temperature shall be of the same order as that applicable to the weld metal in the production welds. In addition, weld coupons for weld metal to be used with the electroslag process that are tested in the as-welded condition, or following a postweld heat treatment within the holding temperature ranges of the applicable code for the material being tested, shall have a thickness within the range of 0.5 times to 1.1 times the thickness of the welds to be made in production. Electroslag weld coupons to be tested following a postweld heat treatment, which will include heating the coupon to a temperature warmer than the holding temperature ranges of the applicable code for the material being tested, shall have a thickness within the range of 0.9 times to 1.1 times the thickness of the welds to be made in production.

3.7.4.3 Test Specimens. Regardless of the welding process or welding material being tested, the impact test specimens shall be located and prepared in accordance with the requirements of SFA-5.1, Carbon Steel Electrodes for Shielded Metal Arc Welding.

3.7.4.4 Test Requirements. Impact testing of the weld metal shall meet the requirements applicable to the base metal. Where different requirements exist for the two base metals, the weld metal may conform to either of the two requirements unless the requirement of para. 4.5.3 applies.

4 IMPACT TESTING METHODS AND ACCEPTANCE CRITERIA

4.1 General

When impact testing is required by section 3, provisions in the applicable code, or the engineering design, it shall be done in accordance with this section unless otherwise required by the applicable code.

4.2 Procedure

Impact testing of each product form of material for any specification (including welds in the components) shall be done using procedures and apparatus in accordance with ASTM A370, and in conformance with the impact testing requirements of the following specifications:

Product Form	Specification
Pipe	ASTM A333 or API 5L
Tube	ASTM A334
Fittings	ASTM A420
Forgings	ASTM A350
Castings	ASTM A352
Bolting	ASTM A320
Plate	ASTM A20

The specific requirements of this section 4 or the applicable code shall also be met.

If a conflict exists between the requirements, the order of precedence shall be as follows:

(a) the applicable code

(b) this Code

(c) the product form specification
(d) ASTM A370

4.3 Test Specimens

Each set of impact test specimens shall consist of three specimen bars. All impact tests shall be made using standard 10-mm (0.394-in.) square-cross-section Charpy V-notch specimen bars, except when the material shape or thickness does not permit. Charpy impact tests may be performed on specimens of full material thickness, which may be machined to remove surface irregularities. Alternatively, such material may be reduced in thickness to produce the largest possible Charpy subsize specimen. If subsize specimens are used, the test temperature shall be adjusted in accordance with para. 4.4.2. Toughness tests are not required when the maximum obtainable Charpy specimen has a width along the notch less than 2.5 mm (0.098 in.).

4.4 Test Temperatures

For all Charpy impact tests, the test temperature criteria in para. 4.4.1 or 4.4.2 shall be observed. The test specimens, as well as the handling tongs, shall be cooled for a sufficient length of time to reach the test temperature.

4.4.1 For Materials With Thickness Equal to or Greater Than 10 mm (0.394 in.). Where the largest attainable CVN specimen has a width along the notch of at least 8 mm (0.315 in.), the Charpy test using such a specimen shall be conducted at a temperature not warmer than the design minimum temperature. Where the largest possible test specimen has a width along the notch less than 8 mm (0.315 in.), the test shall be conducted at a temperature colder than the design minimum temperature in accordance with para. 4.4.2.

(15) **4.4.2 For Materials With Thickness Less Than 10 mm (0.394 in.).** Where the largest attainable CVN specimen has a width along the notch of at least 80% of the material thickness, the Charpy test of such a specimen shall be conducted at a temperature not warmer than the design minimum temperature. Where the largest possible test specimen has a width along the notch of less than 80% of the material thickness, the test shall be conducted at a temperature colder than the design minimum temperature by an amount equal to the difference (referring to Table 4.4.2-1) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. These temperature reduction criteria do not apply when Table 4.5.1-1 specifies lateral expansion for minimum required values.

Test Temperature = (Design Minimum Temperature) + (Temperature Reduction Based on Actual Material Thickness) − (Temperature Reduction Based on Charpy Impact Specimen Width)

For example, if the design minimum temperature is −20°C, the actual material thickness is 6 mm, and the specimen is 4 mm, the test temperature is (−20) + 8.3 − 16.7 = −28.4°C.

4.5 Acceptance Criteria

4.5.1 Minimum Energy Requirements. Except for bolting materials and high-alloy steels (P-Nos. 6, 7, and 8), the applicable minimum energy requirement for carbon, low-alloy steels, and other materials with specified minimum tensile strengths less than 656 MPa (95 ksi) shall be those shown in Table 4.5.1-1. If subsize specimens are used, the minimum energy acceptance criteria may be reduced by the ratio of the test specimen width to the standard size width [10 mm (0.394 in.)].

4.5.2 Lateral Expansion Requirements. Carbon, low-alloy steels and other materials having specified minimum tensile strengths equal to or greater than 656 MPa (95 ksi), all bolting materials, and all high-alloy steels (P-Nos. 6, 7, and 8) shall have a lateral expansion opposite the notch of not less than 0.38 mm (0.015 in.) for all specimen sizes. The lateral expansion is the increase in width of the broken impact specimen over that of the unbroken specimen measured on the compression side, parallel to the line constituting the bottom of the V-notch (see ASTM A370). For bolting materials with specified minimum tensile strength greater than 656 MPa (95 ksi) and size less than or equal to M50 (2 in.), the impact requirements of ASTM A320 may be applied.

4.5.3 Weld Impact Test Requirements. Where two base metals having different required impact energy values are joined by welding, the impact test energy requirements shall conform to the requirements of the base material having a specified minimum tensile strength most closely matching the specified minimum tensile strength of the weld metal.

4.5.4 Retests

4.5.4.1 For Absorbed Energy Criteria. When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

4.5.4.2 For Lateral Expansion Criterion. If the value of lateral expansion for one specimen in a group of three is below 0.38 mm (0.015 in.) but not below 0.25 mm (0.010 in.), and if the average value for three specimens equals or exceeds 0.38 mm (0.015 in.), a retest of three additional specimens may be made, each of which shall

equal or exceed the specified minimum value of 0.38 mm (0.015 in.). In the case of heat-treated materials, if the required values are not obtained in the retest or if the values in the initial test are below the minimum allowed for retest, the material may be re–heat treated and retested. After re–heat treatment, a set of three specimens shall be made. For acceptance, the lateral expansion of each of the specimens shall equal or exceed the specified minimum value of 0.38 mm (0.015 in.).

4.5.4.3 For Erratic Test Results. When an erratic result is caused by a defective specimen or there is uncertainty in the test procedure, a retest will be allowed.

(15)

Table 3.1-1 Low-Temperature Service Requirements by Material Group

SI Units [Note (1)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, mm	Notes	Low-Temp., °C, Service Limit	Minimum Material Permitted Temp., °C	Minimum Temp., °C, Without Impacts	Minimum Weld Permitted Temp., °C	Temp., °C, Without Impacts SR > 0.3	Temp., °C, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °C, Without Impacts for Stress Ratios								Low-Temp., °C, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels																	
CS −55	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−29	−48	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS −55	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS −50	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−29	−48	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS −50	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−46	...	−29	−104	−46	−48	−48	−48	−48	−48	−48	−48	−104
CS −20	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−29	−48	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS −20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−29	...	−29	−104	−29	−34	−40	−46	−48	−48	−48	−48	−104
CS −20(A)	...	...	−29	−29	−29	...	−29	−29	N/A	...	...	...	...	...	...	...	...
CS 0	...	...	−18	−18	−18	...	−29	−29	−18	−23	−29	−34	−40	−48	−48	−48	−104
CS +20(A)	...	...	−7	−7	−7	...	−7	−7	N/A	...	...	...	...	...	...	...	...
CS A	≤ 10.0	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−7	−48	−48	...	−7	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS A	≤ 10.0	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−7	...	−7	...	−7	−104	−7	−12	−18	−23	−29	−40	−48	−48	−104
CS A	≤ 11.1	...	−4	...	−4	...	−4	−104	−4	−9	−15	−21	−26	−37	−48	−48	−104
CS A	≤ 12.7	...	−1	...	−1	...	−1	−104	−1	−7	−12	−18	−23	−34	−48	−48	−104
CS A	≤ 15.2	...	4	...	4	...	4	−104	4	−1	−7	−12	−18	−29	−48	−48	−104
CS A	≤ 17.7	...	10	...	10	...	10	−104	10	4	−1	−7	−12	−23	−43	−48	−104
CS A	≤ 21.6	...	16	...	16	...	16	−104	16	10	4	−1	−7	−18	−37	−48	−104
CS A	≤ 26.2	...	21	...	21	...	21	−104	21	16	10	4	−1	−12	−32	−48	−104
CS A	≤ 31.1	...	27	...	27	...	27	−104	27	21	16	10	4	−7	−26	−48	−104
CS A	≤ 39.7	...	32	...	32	...	32	−104	32	27	21	16	10	−1	−21	−48	−104
CS A	≤ 51.6	...	38	...	38	...	38	−104	38	32	27	21	16	4	−15	−48	−104
CS A	≤ 76.2	...	43	...	43	...	43	−104	43	38	32	27	21	10	−9	−48	−104
CS A	≤ 93.7	...	46	...	46	...	46	−104	46	41	35	29	24	13	−7	−48	−104
CS A	> 93.7	...	49	...	49	...	49	−104	49	43	38	32	27	16	−4	−48	−104

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

SI Units [Note (1)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, mm	Notes	Low-Temp., °C, Service Limit	Minimum Material Permitted Temp., °C	Minimum Temp., °C, Without Impacts	Minimum Weld Permitted Temp., °C	Temp., °C, Without Impacts SR > 0.3	Temp., °C,, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °C, Without Impacts for Stress Ratios								Low-Temp., °C, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels (Cont'd)																	
CS B	≤ 10.0	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−29	−48	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS B	≤ 10.0	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−29	...	−29	−104	−29	−34	−40	−46	−48	−48	−48	−48	−104
CS B	≤ 11.9	...	−29	...	−29	...	−29	−104	−29	−35	−40	−46	−48	−48	−48	−48	−104
CS B	≤ 14.5	...	−22	...	−22	...	−22	−104	−22	−27	−33	−38	−44	−48	−48	−48	−104
CS B	≤ 17.3	...	−13	...	−13	...	−13	−104	−13	−19	−24	−30	−35	−47	−48	−48	−104
CS B	≤ 21.1	...	−7	...	−7	...	−7	−104	−7	−12	−18	−23	−29	−40	−48	−48	−104
CS B	≤ 24.9	...	−1	...	−1	...	−1	−104	−1	−7	−12	−18	−23	−34	−48	−48	−104
CS B	≤ 30.2	...	4	...	4	...	4	−104	4	−1	−7	−12	−18	−29	−48	−48	−104
CS B	≤ 37.3	...	10	...	10	...	10	−104	10	4	−1	−7	−12	−23	−43	−48	−104
CS B	≤ 47.0	...	16	...	16	...	16	−104	16	10	4	−1	−7	−18	−37	−48	−104
CS B	≤ 61.9	...	21	...	21	...	21	−104	21	16	10	4	−1	−12	−32	−48	−104
CS B	≤ 82.6	...	27	...	27	...	27	−104	27	21	16	10	4	−7	−26	−48	−104
CS B	≤ 101.6	...	32	...	32	...	32	−104	32	27	21	16	10	−1	−21	−48	−104
CS B	> 101.6	...	49	...	49	...	49	−104	49	43	38	32	27	16	−4	−48	−104
CS C	≤ 10.0	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS C	≤ 10.0	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS C	≤ 10.4	...	−29	...	−46	...	−29	−104	−46	−48	−48	−48	−48	−48	−48	−48	−104
CS C	≤ 11.2	...	−29	...	−40	...	−29	−104	−40	−46	−48	−48	−48	−48	−48	−48	−104
CS C	≤ 13.5	...	−29	...	−34	...	−29	−104	−34	−40	−46	−48	−48	−48	−48	−48	−104
CS C	≤ 16.5	...	−29	...	−29	...	−29	−104	−29	−34	−40	−46	−48	−48	−48	−48	−104
CS C	≤ 21.6	...	−23	...	−23	...	−23	−104	−23	−29	−34	−40	−46	−48	−48	−48	−104
CS C	≤ 27.4	...	−18	...	−18	...	−18	−104	−18	−23	−29	−34	−40	−48	−48	−48	−104
CS C	≤ 35.1	...	−12	...	−12	...	−12	−104	−12	−18	−23	−29	−34	−46	−48	−48	−104
CS C	≤ 44.5	...	−7	...	−7	...	−7	−104	−7	−12	−18	−23	−29	−40	−48	−48	−104
CS C	≤ 57.2	...	−1	...	−1	...	−1	−104	−1	−7	−12	−18	−23	−34	−48	−48	−104
CS C	≤ 74.7	...	4	...	4	...	4	−104	4	−1	−7	−12	−18	−29	−48	−48	−104
CS C	≤ 95.3	...	10	...	10	...	10	−104	10	4	−1	−7	−12	−23	−43	−48	−104
CS C	≤ 101.6	...	11	...	11	...	11	−104	11	6	0	−6	−11	−22	−42	−48	−104
CS C	> 101.6	...	49	...	49	...	49	−104	49	43	38	32	27	16	−4	−48	−104

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

SI Units [Note (1)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, mm	Notes	Low-Temp., °C, Service Limit	Minimum Material Permitted Temp., °C	Minimum Temp., °C, Without Impacts	Minimum Weld Permitted Temp., °C	Temp., °C, Without Impacts SR > 0.3	Temp., °C, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °C, Without Impacts for Stress Ratios								Low-Temp., °C, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels (Cont'd)																	
CS D	≤ 12.7	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS D	≤ 12.7	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−48	...	−29	−104	−48	−48	−48	−48	−48	−48	−48	−48	−104
CS D	≤ 14.7	...	−29	...	−46	...	−29	−104	−46	−48	−48	−48	−48	−48	−48	−48	−104
CS D	≤ 19.8	...	−29	...	−40	...	−29	−104	−40	−46	−48	−48	−48	−48	−48	−48	−104
CS D	≤ 25.4	...	−29	...	−34	...	−29	−104	−34	−40	−46	−48	−48	−48	−48	−48	−104
CS D	≤ 33.0	...	−29	...	−29	...	−29	−104	−29	−34	−40	−46	−48	−48	−48	−48	−104
CS D	≤ 42.9	...	−23	...	−23	...	−23	−104	−23	−29	−34	−40	−46	−48	−48	−48	−104
CS D	≤ 57.2	...	−18	...	−18	...	−18	−104	−18	−23	−29	−34	−40	−48	−48	−48	−104
CS D	≤ 74.6	...	−12	...	−12	...	−12	−104	−12	−18	−23	−29	−34	−46	−48	−48	−104
CS D	≤ 95.3	...	−7	...	−7	...	−7	−104	−7	−12	−18	−23	−29	−40	−48	−48	−104
CS D	≤ 101.6	...	−5	...	−5	...	−5	−104	−5	−11	−16	−22	−27	−38	−48	−48	−104
CS D	> 101.6	...	49	...	49	...	49	−104	49	43	38	32	27	16	−4	−48	−104
Low-Alloy Steels																	
LA −320	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−196	−196	−48	−48	−104	N/A	...	...	...	...	...	...	...	N/A
LA −320	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−196	...	−29	−104	N/A	...	...	...	...	...	...	...	N/A
LA −275	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−171	−171	−48	−48	−104	N/A	...	...	...	...	...	...	...	N/A
LA −275	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−171	...	−29	−104	N/A	...	...	...	...	...	...	...	N/A
LA −150	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−101	−101	−48	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −150	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−101	...	−29	−104	N/A	...	...	...	...	...	...	...	−104

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

SI Units [Note (1)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, mm	Notes	Low-Temp., °C, Service Limit	Minimum Material Permitted Temp., °C	Minimum Temp., °C, Without Impacts	Minimum Weld Permitted Temp., °C	Temp., °C, Without Impacts SR > 0.3	Temp., °C, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °C, Without Impacts for Stress Ratios								Low-Temp., °C, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Low-Alloy Steels (Cont'd)																	
LA −100	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−73	−73	−48	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −100	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−73	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA −75	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−59	−59	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −75	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−59	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA −55	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −55	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−48	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA −40	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −40	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−40	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA −20	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA −20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−29	...	−29	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA 0	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA 0	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−18	...	−18	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
LA +20	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−48	−48	−48	...	−48	−104	N/A	...	...	...	...	...	...	...	−104
LA +20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (3)]	−7	...	−7	...	−29	−104	N/A	...	...	...	...	...	...	...	−104

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

SI Units [Note (1)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, mm	Notes	Low-Temp., °C, Service Limit	Minimum Material Permitted Temp., °C	Minimum Temp., °C, Without Impacts	Minimum Weld Permitted Temp., °C	Temp., °C, Without Impacts SR > 0.3	Temp., °C, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °C, Without Impacts for Stress Ratios								Low-Temp., °C, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Stainless Steels																	
SS −425	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−254	...	−254	...	−254	−254	N/A	...	...	...	...	...	...	...	...
SS −425	...	Carbon ≤ 0.1% and solution heat treated	−101	...	−254	...	−101	−104	N/A	...	...	...	...	...	...	...	−104
SS −425	...	Carbon > 0.1% or not solution heat treated	−29	...	−29	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
SS −325	...	Max. possible Charpy $t < 2.5$ mm [Note (2)]	−198	...	−198	...	−254	−254	N/A	...	...	...	...	...	...	...	...
SS −325	...	Carbon ≤ 0.1% and solution heat treated	−101	...	−198	...	−101	−104	N/A	...	...	...	...	...	...	...	−104
SS −325	...	Carbon > 0.1% or not solution heat treated	−29	...	−29	...	−29	−104	N/A	...	...	...	...	...	...	...	−104
SS −60	...	...	−29	...	−51	...	−29	−29	N/A	...	...	...	...	...	...	...	−104
SS −20	...	...	−29	...	−29	...	−29	−29	N/A	...	...	...	...	...	...	...	−104
Nickel Alloys																	
NI −325	...	...	−198	...	−198	...	−198	−198	N/A	...	...	...	...	...	...	...	...
Cast Irons																	
CI −20	...	...	−29	...	...	N/P	N/P	N/P	N/A	...	...	...	...	...	...	...	...
CI −20(A)	...	...	−29	−29	N/A	N/P	N/P	N/P	N/A	...	...	...	...	...	...	...	...
Copper Alloys																	
CU −452	...	...	−269	...	−269	...	−269	−269	N/A	...	...	...	...	...	...	...	...
CU −325	...	...	−198	...	−198	...	−198	−198	N/A	...	...	...	...	...	...	...	...
Aluminum Alloys																	
AL −452	...	...	−269	...	−269	...	−269	−269	N/A	...	...	...	...	...	...	...	...
Titanium and Titanium Alloys																	
TI −75	...	...	−59	...	−59	...	−59	−59	N/A	...	...	...	...	...	...	...	...
Zirconium and Zirconium Alloys																	
ZI −75	...	...	−59	...	−59	...	−59	−59	N/A	...	...	...	...	...	...	...	...

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels																	
CS −55	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−20	−55	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS −55	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS −50	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−20	−55	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS −50	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−50	...	−20	−155	−50	−55	−55	−55	−55	−55	−55	−55	−155
CS −20	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−20	−55	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS −20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−20	...	−20	−155	−20	−30	−40	−50	−55	−55	−55	−55	−155
CS −20(A)	...	...	−20	−20	−20	...	−20	−20	N/A	...	...	...	...	...	...	...	...
CS 0	...	...	0	0	0	...	−20	−20	0	−10	−20	−30	−40	−55	−55	−55	−155
CS +20(A)	...	...	20	20	20	...	20	20	N/A	...	...	...	...	...	...	...	...
CS A	≤ 0.394	Max. possible Charpy $t < 2.5$ mm [Note (5)]	20	−55	−55	...	20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS A	≤ 0.394	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	20	...	20	...	20	−155	20	10	0	−10	−20	−40	−55	−55	−155
CS A	≤ 0.4375	...	25	...	25	...	25	−155	25	15	5	−5	−15	−35	−55	−55	−155
CS A	≤ 0.5	...	30	...	30	...	30	−155	30	20	10	0	−10	−30	−55	−55	−155
CS A	≤ 0.6	...	40	...	40	...	40	−155	40	30	20	10	0	−20	−55	−55	−155
CS A	≤ 0.7	...	50	...	50	...	50	−155	50	40	30	20	10	−10	−45	−55	−155
CS A	≤ 0.85	...	60	...	60	...	60	−155	60	50	40	30	20	0	−35	−55	−155
CS A	≤ 1.03	...	70	...	70	...	70	−155	70	60	50	40	30	10	−25	−55	−155
CS A	≤ 1.25	...	80	...	80	...	80	−155	80	70	60	50	40	20	−15	−55	−155
CS A	≤ 1.5625	...	90	...	90	...	90	−155	90	80	70	60	50	30	−5	−55	−155
CS A	≤ 2.0325	...	100	...	100	...	100	−155	100	90	80	70	60	40	5	−55	−155
CS A	≤ 3		110	...	110	...	110	−155	110	100	90	80	70	50	15	−55	−155
CS A	≤ 3.6875	...	115	...	115	...	115	−155	115	105	95	85	75	55	20	−55	−155
CS A	> 3.6875	...	120	...	120	...	120	−155	120	110	100	90	80	60	25	−55	−155

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels (Cont'd)																	
CS B	≤ 0.394	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−20	−55	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS B	≤ 0.394	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−20	...	−20	−155	−20	−30	−40	−50	−55	−55	−55	−55	−155
CS B	≤ 0.47	...	−20	...	−20	...	−20	−155	−20	−30	−40	−50	−55	−55	−55	−55	−155
CS B	≤ 0.57	...	−7	...	−7	...	−7	−155	−7	−17	−27	−37	−47	−55	−55	−55	−155
CS B	≤ 0.68	...	9	...	9	...	9	−155	9	−1	−11	−21	−31	−51	−55	−55	−155
CS B	≤ 0.83	...	20	...	20	...	20	−155	20	10	0	−10	−20	−40	−55	−55	−155
CS B	≤ 0.98	...	30	...	30	...	30	−155	30	20	10	0	−10	−30	−55	−55	−155
CS B	≤ 1.19	...	40	...	40	...	40	−155	40	30	20	10	0	−20	−55	−55	−155
CS B	≤ 1.47	...	50	...	50	...	50	−155	50	40	30	20	10	−10	−45	−55	−155
CS B	≤ 1.85	...	60	...	60	...	60	−155	60	50	40	30	20	0	−35	−55	−155
CS B	≤ 2.4385	...	70	...	70	...	70	−155	70	60	50	40	30	10	−25	−55	−155
CS B	≤ 3.25	...	80	...	80	...	80	−155	80	70	60	50	40	20	−15	−55	−155
CS B	≤ 4.00	...	90	...	90	...	90	−155	90	80	70	60	50	30	−5	−55	−155
CS B	> 4.00	...	120	...	120	...	120	−155	120	110	100	90	80	60	25	−55	−155
CS C	≤ 0.394	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS C	≤ 0.394	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS C	≤ 0.41	...	−20	...	−50	...	−20	−155	−50	−55	−55	−55	−55	−55	−55	−55	−155
CS C	≤ 0.44	...	−20	...	−40	...	−20	−155	−40	−50	−55	−55	−55	−55	−55	−55	−155
CS C	≤ 0.53	...	−20	...	−30	...	−20	−155	−30	−40	−50	−55	−55	−55	−55	−55	−155
CS C	≤ 0.65	...	−20	...	−20	...	−20	−155	−20	−30	−40	−50	−55	−55	−55	−55	−155
CS C	≤ 0.85	...	−10	...	−10	...	−10	−155	−10	−20	−30	−40	−50	−55	−55	−55	−155
CS C	≤ 1.08	...	0	...	0	...	0	−155	0	−10	−20	−30	−40	−55	−55	−55	−155
CS C	≤ 1.38	...	10	...	10	...	10	−155	10	0	−10	−20	−30	−50	−55	−55	−155
CS C	≤ 1.75	...	20	...	20	...	20	−155	20	10	0	−10	−20	−40	−55	−55	−155
CS C	≤ 2.25	...	30	...	30	...	30	−155	30	20	10	0	−10	−30	−55	−55	−155
CS C	≤ 2.94	...	40	...	40	...	40	−155	40	30	20	10	0	−20	−55	−55	−155
CS C	≤ 3.75	...	50	...	50	...	50	−155	50	40	30	20	10	−10	−45	−55	−155
CS C	≤ 4.00	...	52	...	52	...	52	−155	52	42	32	22	12	−8	−43	−55	−155
CS C	> 4.00	...	120	...	120	...	120	−155	120	110	100	90	80	60	25	−55	−155

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Carbon Steels (Cont'd)																	
CS D	≤ 0.5	Max possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS D	≤ 0.5	Max possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−55	...	−20	−155	−55	−55	−55	−55	−55	−55	−55	−55	−155
CS D	≤ 0.58	...	−20	...	−50	...	−20	−155	−50	−55	−55	−55	−55	−55	−55	−55	−155
CS D	≤ 0.78	...	−20	...	−40	...	−20	−155	−40	−50	−55	−55	−55	−55	−55	−55	−155
CS D	≤ 1.0	...	−20	...	−30	...	−20	−155	−30	−40	−50	−55	−55	−55	−55	−55	−155
CS D	≤ 1.3	...	−20	...	−20	...	−20	−155	−20	−30	−40	−50	−55	−55	−55	−55	−155
CS D	≤ 1.6875	...	−10	...	−10	...	−10	−155	−10	−20	−30	−40	−50	−55	−55	−55	−155
CS D	≤ 2.25	...	0	...	0	...	0	−155	0	−10	−20	−30	−40	−55	−55	−55	−155
CS D	≤ 2.9375	...	10	...	10	...	10	−155	10	0	−10	−20	−30	−50	−55	−55	−155
CS D	≤ 3.75	...	20	...	20	...	20	−155	20	10	0	−10	−20	−40	−55	−55	−155
CS D	≤ 4.00	...	23	...	23	...	23	−155	23	13	3	−7	−17	−37	−55	−55	−155
CS D	> 4.00	...	120	...	120	...	120	−155	120	110	100	90	80	60	25	−55	−155
Low-Alloy Steels																	
LA −320	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−320	−320	−55	−55	−155	N/A	...	...	...	...	...	...	...	N/A
LA −320	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−320	...	−20	−155	N/A	...	...	...	...	...	...	...	N/A
LA −275	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−275	−275	−55	−55	−155	N/A	...	...	...	...	...	...	...	N/A
LA −275	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−275	...	−20	−155	N/A	...	...	...	...	...	...	...	N/A
LA −150	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−150	−150	−55	−55	−155	N/A	...	...	...	...	...	...	...	−155

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Low-Alloy Steels (Cont'd)																	
LA −150	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−150	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA −100	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−100	−100	−55	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA −100	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−100	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA −75	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−75	−75	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA −75	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−75	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA −55	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA −55	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−55	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA −40	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA −40	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−40	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA −20	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA −20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	−20	...	−20	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
LA 0	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA 0	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	0	...	0	...	−20	−155	N/A	...	...	...	...	...	...	...	−155

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	SR ≤ 0.3
Low-Alloy Steels (Cont'd)																	
LA +20	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−55	−55	−55	...	−55	−155	N/A	...	...	...	...	...	...	...	−155
LA +20	...	Max. possible Charpy $t \geq 2.5$ mm [Note (6)]	20	...	20	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
Stainless Steels																	
SS −425	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−425	...	−425	...	−425	−425	N/A	...	...	...	...	...	...	...	...
SS −425	...	Carbon ≤ 0.1% and solution heat treated	−150	...	−425	...	−150	−155	N/A	...	...	...	...	...	...	...	−155
SS −425		Carbon > 0.1% or not solution heat treated	−20	...	−20	...	−20	−155	N/A	...	...	...	...	...	...	...	−155
SS −325	...	Max. possible Charpy $t < 2.5$ mm [Note (5)]	−325	...	−325	...	−425	−425	N/A	...	...	...	...	...	...	...	...
SS −325		Carbon ≤ 0.1% and solution heat treated	−150	...	−325	...	−150	−155	N/A	...	...	...	...	...	...	...	−155
SS −325	...	Carbon > 0.1% or not solution heat treated	−20	...	−20	...	−20	−155	N/A	...		...	...	...	...	...	−155
SS −60	...	...	−20	...	−60	...	−20	−20	N/A	...	...	...	...	...	...	...	−155
SS −20	...	...	−20	...	−20	...	−20	−20	N/A	...	...	...	...	...	...	...	−155
Nickel Alloys																	
NI −325	...	...	−325	...	−325	...	−325	−325	N/A	...	...	...	...	...	...	...	...
Cast Irons																	
CI −20	...	...	−20	...	...	N/P	N/P	N/P	N/A	...	...	...	...	...	...	...	...
CI −20(A)	...	...	−20	−20	N/A	N/P	N/P	N/P	N/A	...	...	...	...	...	...	...	...

Table 3.1-1 Low-Temperature Service Requirements by Material Group (Cont'd)

U.S. Customary Units [Note (4)]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				Material		Weld											
T-Number Group	Nominal Thickness, in.	Notes	Low-Temp., °F, Service Limit	Minimum Material Permitted Temp., °F	Minimum Temp., °F, Without Impacts	Minimum Weld Permitted Temp., °F	Temp., °F, Without Impacts SR > 0.3	Temp., °F, Without Impacts SR ≤ 0.3	Minimum Material Temperature, °F, Without Impacts for Stress Ratios								Low-Temp., °F, Service Limit SR ≤ 0.3
									1	0.9	0.8	0.7	0.6	0.5	0.4	> 0.3	
Copper Alloys																	
CU −452	...	...	−452	...	−452	...	−452	−452	N/A	...	...	...	...	...	...	...	...
CU −325	...	...	−325	...	−325	...	−325	−325	N/A	...	...	...	...	...	...	...	...
Aluminum Alloys																	
AL −452	...	...	−452	...	−452	...	−452	−452	N/A	...	...	...	...	...	...	...	...
Titanium and Titanium Alloys																	
TI −75	...	...	−75	...	−75	...	−75	−75	N/A	...	...	...	...	...	...	...	...
Zirconium and Zirconium Alloys																	
ZI −75	...	...	−75	...	−75	...	−75	−75	N/A	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) N/A: not applicable.

(b) N/P: not permitted.

(c) SR: stress ratio per para. 3.6.2.

NOTES:

(1) All temperatures are in degrees Celsius.

(2) This line is applicable if the maximum Charpy specimen obtainable from the product is less than 2.5 mm.

(3) This line is applicable if the maximum Charpy specimen obtainable from the product is equal to or greater than 2.5 mm.

(4) All temperatures are in degrees Fahrenheit.

(5) This line is applicable if the maximum Charpy specimen obtainable from the product is less than 2.5 mm (0.98 in.).

(6) This line is applicable if the maximum Charpy specimen obtainable from the product is equal to or greater than 2.5 mm (0.98 in.).

(15)

Table 3.2-1 Material Groupings by Material Specification

Specification	Type/Grade/Class/ Condition/Temper/UNS		T-Number Group	Material Type	Product Form	Notes
A36	...	...	CS A	Carbon steels	PL	...
A47	Grade	32510	CI −20(A)	Cast irons	C	...
A48	Grade	20, 25, 30, 35, 40, 45, 50, 55, 60	CI −20	Cast irons	C	...
A53	Grade	A (Type F)	CS +20(A)	Carbon steels	P	...
A53	Grade	A (except Type F), B	CS B	Carbon steels	P	...
A105	...	...	CS −20	Carbon steels	Fl & FO	...
A106	Grade	A, B, C	CS B	Carbon steels	P	...
A126	Class	A, B, C	CI −20	Cast irons	C	...
A134	Grade	A283 Gr A, A283 Gr B	CS B	Carbon steels	P	...
A134	Grade	A283 Gr C, D	CS A	Carbon steels	P	...
A134	Grade	A285 Gr A, A285 Gr B	CS B	Carbon steels	P	...
A134	Grade	A285 Gr C	CS A	Carbon steels	P	...
A134	Grade	A36	CS A	Carbon steels	P	...
A134	Grade	A570 Gr 30, 33, 36, 40, 45, 50	CS A	Carbon steels	P	...
A135	Grade	A, B	CS B	Carbon steels	P	...
A139	Grade	A, B, C, D, E	CS A	Carbon steels	P	...
A167	Type	347, 348	SS −325	Stainless steels	PL	1
A167	Type	347, 348	SS −20	Stainless steels	PL	2
A167	Type	302B, 308	SS −325	Stainless steels	PL	3
A167	Type	302B, 308	SS −20	Stainless steels	PL	4
A167	Type	309, 310	SS −325	Stainless steels	PL	1, 3, 5
A167	Type	309, 310	SS −20	Stainless steels	PL	2 or 4, 5
A178	Grade	A, C	CS −20	Carbon steels	T	...
A179	...	...	CS −20	Carbon steels	T	...
A181	Class	60, 70	CS A	Carbon steels	Fl & FO	...
A182	Grade	F1, F2, F5, F5a, F9, F11, F12, F21, F22, F91	LA −20	Low-alloy steels	Fl & FO	...
A182	Grade	F10	SS −325	Stainless steels	Fl & FO	3
A182	Grade	F10	SS −20	Stainless steels	Fl & FO	4
A182	Grade	F304, F304L, F316, F316L	SS −425	Stainless steels	Fl & FO	...
A182	Grade	F304H, F316H, F317L, F321, F321H, F347, F347H, F348, F348H	SS −325	Stainless steels	Fl & FO	...
A182	Grade	F310	SS −325	Stainless steels	Fl & FO	3, 5
A182	Grade	F310	SS −20	Stainless steels	Fl & FO	4, 5
A182	Grade	F6a	SS −20	Stainless steels	Fl & FO	5
A182	Grade	F60 (S32205)	SS −20	Stainless steels	Fl & FO	5
A182	Grade	S32760	SS −60	Stainless steels	Fl & FO	...
A192	...	...	CS −20	Carbon steels	T	...
A193	Grade	B5 ≤ 4 in., B16 ≤ 4 in.	LA −20	Low-alloy steels	B	...
A193	Grade	B6	SS −20	Stainless steels	B	...
A193	Grade	B7 (≤ 2½ in.)	LA −55	Low-alloy steels	B	...
A193	Grade	B7 (> 2½ in., ≤ 4 in.)	LA −40	Low-alloy steels	B	...
A193	Grade	B7M (≤ 4 in.)	LA −55	Low-alloy steels	B	...
A193	Grade	B8 Class 2, B8C Class 1, B8C Class 2, B8M, B8T	SS −325	Stainless steels	B	6
A194	Grade	1	CS −20	Carbon steels	N	...
A194	Grade	3	LA −20	Low alloy steels	N	...
A194	Grade	6	SS −20	Stainless steels	N	...
A194	Grade	2, 2H, 2HM	CS −55	Carbon steels	N	...
A194	Grade	4, 7, 7M	LA −150	Low-alloy steels	N	...
A194	Grade	8, 8CA, 8FA, 8MA, 8TA	SS −325	Stainless steels	N	...
A194	Grade	8A	SS −425	Stainless steels	N	...
A197	...	...	CI −20(A)	Cast irons	C	...

Table 3.2-1 Material Groupings by Material Specification (Cont'd)

Specification		Type/Grade/Class/ Condition/Temper/UNS	T-Number Group	Material Type	Product Form	Notes
A202	Grade	A, B	LA –20	Low-alloy steels	PL	...
A203	Grade	A, B, D, E	LA –20	Low-alloy steels	PL	...
A204	Grade	A, B, C	LA –20	Low-alloy steels	PL	...
A210	Grade	A-1	CS –20	Carbon steels	T	...
A214	...	...	CS –20	Carbon steels	T	...
A216	Grade	WCA, WCB, WCC	CS –20	Carbon steels	C	...
A217	Grade	C5, C12, WC1, WC4, WC5, WC6, WC9	LA –20	Low-alloy steels	C	...
A217	Grade	CA–15	SS –20	Stainless steels	C	5
A226	...	...	CS –20	Carbon steels	T	...
A234	Grade	WP1, WP5, WP9, WP11, WP12, WP22, WP91	LA –20	Low-alloy steels	FI	...
A234	Grade	WPB, WPC	CS B	Carbon steels	FI	...
A240	Type	305	SS –325	Stainless steels	PL	1, 3
A240	Type	305	SS –20	Stainless steels	PL	2 or 4
A240	Type	302, 317, 317L, 321, 321H, 347, 348	SS –325	Stainless steels	PL	1
A240	Type	302, 317, 317L, 321H, 348	SS –20	Stainless steels	PL	2
A240	Type	304, 304L, 316, 316L	SS –425	Stainless steels	PL	1
A240	Type	304, 304L, 316, 316L, 321, 347	SS –20	Stainless steels	PL	2
A240	Type	309S, 310S	SS –325	Stainless steels	PL	1, 5
A240	Type	309S, 310S	SS –20	Stainless steels	PL	2, 5
A240	Type	405, 410, 410S, 420, 429, X8M	SS –20	Stainless steels	PL	5
A240	UNS	S32205	SS –20	Stainless steels	PL	5
A240	UNS	S32760	SS –60	Stainless steels	PL	...
A268	Grade	TP405, TP409, TP410, TP430, TP430Ti, TP433, TP436	SS –20	Stainless steels	T	5
A269	Grade	TP304, TP304L, TP316, TP316L	SS –425	Stainless steels	P	1
A269	Grade	TP304, TP304L, TP316, TP316L	SS –20	Stainless steels	P	2
A278	Class	20, 25, 30, 35, 40, 45, 50, 60	CI –20	Cast irons	C	...
A283	Grade	A, B, C, D	CS A	Carbon steels	PL	...
A285	Grade	A, B	CS B	Carbon steels	PL	...
A285	Grade	C	CS A	Carbon steels	PL	...
A299	...	...	CS A	Carbon steels	PL	...
A302	Grade	A, B, C, D	LA –20	Low-alloy steels	PL	...
A307	Grade	B	CS –20	Carbon steels	B	...
A312	Grade	TP304, TP304L, TP316, TP316L	SS –425	Stainless steels	P	1
A312	Grade	TP304, TP304L, TP316, TP316L	SS –20	Stainless steels	P	2
A312	Grade	TP304H, TP316H, TP321H, TP347H, TP348H	SS –325	Stainless steels	P	...
A312	Grade	TP309, TP310	SS –325	Stainless steels	P	1, 3, 5
A312	Grade	TP309, TP310	SS –20	Stainless steels	P	2 or 4, 5
A312	Grade	TP317, TP317L, TP321, TP347, TP348	SS –325	Stainless steels	P	1
A312	Grade	TP317, TP317L, TP321, TP347, TP348	SS –20	Stainless steels	P	2
A320	Grade	B8 Class 1	SS –425	Stainless steels	B	...
A320	Grade	B8 Class 2, B8C Class 1, B8C Class 2, B8F, B8M, B8T	SS –325	Stainless steels	N	...
A320	Grade	L7, L43	LA –150	Low-alloy steels	B	7
A320	Grade	L7A, L7B, L7C	LA –150	Low-alloy steels	B	7
A320	Grade	L7M	LA –100	Low-alloy steels	B	7
A325	...	...	CS –20	Carbon steels	B	
A333	Grade	8	LA –320	Low-alloy steels	P	7
A333	Grade	1, 6	CS –50	Carbon steels	P	7
A333	Grade	3, 4	LA –150	Low-alloy steels	P	7
A333	Grade	7, 9	LA –100	Low-alloy steels	P	7
A334	Grade	3	LA –150	Low-alloy steels	T	7

Table 3.2-1 Material Groupings by Material Specification (Cont'd)

Specification	Type/Grade/Class/ Condition/Temper/UNS		T-Number Group	Material Type	Product Form	Notes
A334	Grade	8	LA –320	Low-alloy steels	T	7
A334	Grade	1, 6	CS –50	Carbon steels	T	7
A334	Grade	7, 9	LA –100	Low-alloy steels	T	7
A335	Grade	P1, P2, P5, P5b, P5c, P9, P11, P12, P15, P21, P22, P91	LA –20	Low-alloy steels	P	. . .
A350	Grade	LF-1	CS –20	Carbon steels	Fl & FO	7
A350	Grade	LF-2 Class 1	CS –50	Carbon steels	Fl & FO	7
A350	Grade	LF-2 Class 2	CS 0	Carbon steels	Fl & FO	7
A350	Grade	LF3	LA –150	Low-alloy steels	Fl & FO	7
A351	Grade	CE20N, CH20, CK20, HK30, HK40	SS –20	Stainless steels	C	5
A351	Grade	CD3M–W–Cu–N, CE8MN	SS –60	Stainless steels	C	. . .
A351	Grade	CF8C, CF10MC, CH8, CH10, CN7M	SS –325	Stainless steels	C	. . .
A351	Grade	HT30	SS –325	Stainless steels	C	1
A351	Grade	CF3, CF3A, CF3M, CF8, CF8A, CF8M	SS –425	Stainless steels	C	. . .
A352	Grade	LC1	LA –75	Low alloy steels	C	7
A352	Grade	LC2	LA –100	Low-alloy steels	C	7
A352	Grade	LC3	LA –150	Low-alloy steels	C	7
A352	Grade	LCB	CS –50	Carbon steels	C	7
A353	. . .	. . .	LA –320	Low-alloy steels	PL	7
A354	Grade	BC	LA 0	Low-alloy steels	B	. . .
A354	Grade	BD	LA +20	Low-alloy steels	B	. . .
A358	Grade	304, 304L, 316, 316L	SS –425	Stainless steels	P	1
A358	Grade	304, 304L, 316, 316L	SS –20	Stainless steels	P	2
A358	Grade	309S, 310S	SS –325	Stainless steels	P	1, 5
A358	Grade	309S, 310S	SS –20	Stainless steels	P	2, 5
A358	Grade	321, 347, 348, S34565	SS –325	Stainless steels	P	1
A358	Grade	321, 347, 348, S34565	SS –20	Stainless steels	P	2
A369	Grade	FP1, FP2, FP3b, FP5, FP9, FP11, FP12, FP21, FP22	LA –20	Low-alloy steels	P	. . .
A369	Grade	FPA	CS B	Carbon steels	P	. . .
A369	Grade	FPB	CS –20	Carbon steels	P	. . .
A376	Grade	16–8–2H	SS –325	Stainless steels	P	1, 5
A376	Grade	16–8–2H	SS –20	Stainless steels	P	2, 5
A376	Grade	TP304, TP316	SS –425	Stainless steels	P	1
A376	Grade	TP304, TP316, TP321, TP347, TP348	SS –20	Stainless steels	P	2
A376	Grade	TP304H, TP316H, TP321, TP321H, TP347, TP347H, TP348	SS –325	Stainless steels	P	1
A376	Grade	TP304H, TP316H, TP321H, TP347H	SS –20	Stainless steels	P	2
A381	Class	Y35, Y42, Y46, Y48, Y50, Y52, Y56, Y60	CS A	Carbon steels	P	. . .
A387	Grade	2, 5, 9, 11, 12, 21, 22, 91	LA –20	Low-alloy steels	PL	. . .
A395	. . .	. . .	CI –20(A)	Cast irons	C	. . .
A403	Grade	WP304, WP304L, WP316, WP316L	SS –425	Stainless steels	Fl	. . .
A403	Grade	WP304H, WP316H, WP317, WP317L, WP321, WP321H, WP347H, WP347, WP348	SS –325	Stainless steels	Fl	. . .
A403	Grade	WP309, WP310	SS –325	Stainless steels	Fl	3, 5
A403	Grade	WP309, WP310	SS –20	Stainless steels	Fl	4, 5
A409	Grade	TP304, TP316	SS –425	Stainless steels	P	1

Table 3.2-1 Material Groupings by Material Specification (Cont'd)

Specification		Type/Grade/Class/ Condition/Temper/UNS	T-Number Group	Material Type	Product Form	Notes
A409	Grade	TP304, TP316	SS –20	Stainless steels	P	2
A409	Grade	TP309, TP310	SS –20	Stainless steels	P	2 or 4, 5
A409	Grade	TP309, TP310	SS –325	Stainless steels	P	1, 3, 5
A409	Grade	TP317, TP321, TP347, TP348	SS –325	Stainless steels	P	1
A409	Grade	TP317, TP321, TP347, TP348	SS –20	Stainless steels	P	2
A414	Grade	A	CS B	Carbon steels	PL	. . .
A414	Grade	B, C, D, E, F, G	CS A	Carbon steels	PL	. . .
A420	Grade	WPL3	LA –150	Low-alloy steels	FI	7
A420	Grade	WPL–6	CS –50	Carbon steels	FI	7
A420	Grade	WPL8	LA –320	Low-alloy steels	FI	7
A426	Grade	CP1, CP2, CP5, CP5b, CP9, CP11, CP12, CP15, CP21, CP22	LA –20	Low-alloy steels	P	. . .
A426	Grade	CPCA–15	SS –20	Stainless steels	P	5
A437	Grade	B4B, B4C	SS –20	Stainless steels	B	. . .
A451	Grade	CPE20N, CPH8, CPH10, CPH20, CPK20	SS –20	Stainless steels	P	5
A451	Grade	CPF8, CPF8C, CPF8M, CPF10MC	SS –20	Stainless steels	P	. . .
A453	Grade	651 Class A, 651 Class B	SS –20	Stainless steels	B	. . .
A479	Type	304H, 316, 316H	SS –325	Stainless steels	PL	8
A479	Type	304, 304L, 316L	SS –425	Stainless steels	PL	8
A487	Grade	CA6NM	SS –20	Stainless steels	C	5
A515	Grade	60	CS B	Carbon steels	PL	. . .
A515	Grade	65, 70	CS A	Carbon steels	PL	. . .
A516	Grade	55, 60 not normalized	CS C	Carbon steels	PL	9
A516	Grade	55, 60, 65, 70 normalized	CS D	Carbon steels	PL	9
A516	Grade	65, 70 not normalized	CS B	Carbon steels	PL	9
A524	Grade	I, II	CS –20	Carbon steels	P	. . .
A536	Grade	65–45–12, 60–40–18	CI –20	Cast irons	C	. . .
A537	Class	1	CS D	Carbon steels	PL	. . .
A553	Type	2	LA –275	Low-alloy steels	PL	7
A553	Type	1	LA –320	Low-alloy steels	PL	7
A563	Grade	A	CS –20(A)	Carbon steels	N	. . .
A570	Grade	30, 36, 40, 45, 50	CS A	Carbon steels	PL	. . .
A571	Type	D–2M, Class 1	CI –20	Cast irons	C	10
A587	. . .	. . .	CS –20	Carbon steels	P	. . .
A645	. . .	. . .	LA –275	Low-alloy steels	PL	7
A671	Grade	CA55 (A285 Gr C), CB70 (A515 Gr 70), CK75 (A299), CMS75 (A299)	CS A	Carbon steels	P	. . .
A671	Grade	CB60 (A515 Gr 60)	CS B	Carbon steels	P	. . .
A671	Grade	CC60 (A516 Gr 60)	CS C	Carbon steels	P	9
A671	Grade	CC65 (A516 Gr 65), CC70 (A516 Gr 70) not normalized	CS B	Carbon steels	P	9
A671	Grade	CC60 (A516 Gr 60), CC65 (A516 Gr 65), CC70 (A516 Gr 70) normalized	CS D	Carbon steels	P	9
A671	Grade	CD70 (A537 Cl 1)	CS D	Carbon steels	P	. . .
A671	Grade	CF70, CF71	LA –20	Low-alloy steels	P	. . .
A672	Grade	A45 (A285 Gr A), A50 (A285 Gr B), B60 (A515 Gr 60)	CS B	Carbon steels	P	. . .
A672	Grade	A55 (A285 Gr C), B65 (A515 Gr 65), B70 (A515 Gr 70), N75 (A299)	CS A	Carbon steels	P	. . .
A672	Grade	C55 (A516 Gr 55), C60 (A516 Gr 60)	CS C	Carbon steels	P	. . .
A672	Grade	C65 (A516 Gr 65), C70 (A516 Gr 70) not normalized	CS B	Carbon steels	P	9
A672	Grade	C55 (A516 Gr 55), C60 (A516 Gr 60), C65 (A516 Gr 65), C70 (A516 Gr 70) normalized	CS D	Carbon steels	P	9
A672	Grade	D70 (A537 Cl 1)	CS D	Carbon steels	P	. . .
A672	Grade	L65, L70, L75	LA –20	Low-alloy steels	P	. . .
A675	Grade	45, 50, 55, 60, 65, 70, 80	CS –20	Carbon steels	B	11

Table 3.2-1 Material Groupings by Material Specification (Cont'd)

Specification		Type/Grade/Class/ Condition/Temper/UNS	T-Number Group	Material Type	Product Form	Notes
A691	Grade	½CR, 1CR, 1¼CR, 2¼CR, 3CR, 5CR, 9CR, CM65, CM70, CM75, P91	LA –20	Low-alloy steels	P	...
A691	Grade	CMS75 (A299)	CS A	Carbon steels	P	...
A691	Grade	CMSH70 (A537 Cl 1)	CS D	Carbon steels	P	...
A789	UNS	S31803, S32304, S32750, S32760	SS –60	Stainless steels	T	...
A789	UNS	S32205	SS –20	Stainless steels	P	5
A789	UNS	S32900	SS –20	Stainless steels	T	...
A790	UNS	S31803, S32304, S32750, S32760	SS –60	Stainless steels	P	...
A790	UNS	S32205	SS –20	Stainless steels	P	5
A790	UNS	S32900	SS –20	Stainless steels	P	...
A815	UNS	S32205	SS –20	Stainless steels	Fl & FO	5
A815	UNS	S32760	SS –60	Stainless steels	Fl & FO	...
API 5L	Grade	A, A25 (Smls & ERW), B	CS B	Carbon steels	P	...
API 5L	Grade	A25 (Butt weld)	CS –20(A)	Carbon steels	P	...
API 5L	Grade	X42, X46, X52, X56, X60, X65, X70, X80	CS A	Carbon steels	P	...
API 5L	Grade	X42, X46, X52, X56, X60, X65, X70, X80	CS B	Carbon steels	P	12
B21	UNS	C46400, C48200, C48500	CU –325	Copper alloys	B	11
B42	UNS	C10200, C12000, C12200	CU –452	Copper alloys	P	...
B43	UNS	C23000	CU –452	Copper alloys	P	...
B61	UNS	C92200	CU –325	Copper alloys	C	...
B62	UNS	C83600	CU –325	Copper alloys	C	...
B68	UNS	C12200	CU –452	Copper alloys	T	...
B75	UNS	C10200, C12000, C12200	CU –452	Copper alloys	T	...
B88	UNS	C12200	CU –452	Copper alloys	T	...
B96	UNS	C65500	CU –452	Copper alloys	PL	...
B98	UNS	C65100, C65500, C66100	CU –325	Copper alloys	B	11
B148	UNS	C95200, C95300, C95500	CU –452	Copper alloys	C	...
B148	UNS	C95400, C95600	CU –325	Copper alloys	C	...
B150	UNS	C61400, C63000, C64200	CU –325	Copper alloys	B	11
B152	UNS	C10200, C10400, C10500, C10700, C12200, C12300	CU –452	Copper alloys	PL	...
B169	UNS	C61400	CU –452	Copper alloys	PL	...
B171	UNS	C70600, C71500	CU –452	Copper alloys	PL	...
B187	UNS	C10200, C11000, C12000, C12200	CU –325	Copper alloys	B	11
B280	UNS	C12200	CU –452	Copper alloys	T	...
B283	UNS	C11000, C46400, C65500	CU –452	Copper alloys	FO	...
B283	UNS	C37700, C48500, C67500	CU –325	Copper alloys	FO	...
B466	UNS	C70600, C71000	CU –452	Copper alloys	P & T	...
B467	UNS	C70600, C71500	CU –452	Copper alloys	P	...
B493	Grade	R60702, R60705	ZI –75	Zirconium	FO	...
B523	Grade	R60702, R60705	ZI –75	Zirconium	T	...
B550	Grade	R60702, R60705	ZI –75	Zirconium	PL	...

Table 3.2-1 Material Groupings by Material Specification (Cont'd)

Specification		Type/Grade/Class/ Condition/Temper/UNS	T-Number Group	Material Type	Product Form	Notes
B551	Grade	R60702, R60705	ZI –75	Zirconium	PL	...
B584	UNS	C86200, C86300, C86400, C86500, C86700, C90300, C90500, C92200, C92300, C97300, C97600, C97800	CU –325	Copper alloys	C	...
B658	Grade	R60702, R60705	ZI –75	Zirconium	P	...
Various	...	Various	NI –325	Nickel alloys	Various	...
Various	...	Various	AL –452	Aluminum	...	...
Various	...	Various	TI –75	Titanium	...	...

GENERAL NOTE: Product form abbreviations are
B = Bolts
C = Castings
FI = Fittings
FO = Forgings
N = Nuts
P = Pipe
PL = Plates, sheets, and bars
T = Tube

NOTES:
(1) Solution heat treated after forming.
(2) Not solution heat treated after forming.
(3) Carbon content ≤ 0.10%.
(4) Carbon content > 0.10%.
(5) This material may have low impact properties at room temperature after being exposed to high service temperatures.
(6) Strain-hardened varieties of this carbide solution–treated bolting material can also be used at the low temperatures indicated.
(7) Material specification requires impact testing.
(8) Strain-hardened varieties of this material can also be used at the low temperatures indicated.
(9) This materials group depends on if they are normalized or not.
(10) Minimum temperature –195°C (–320°F) with impact testing.
(11) Bar specification used for making bolting material.
(12) T-number group CS B may only be used when normalized or quenched and tempered.

(15)

Table 4.4.2-1 Charpy Impact Test (Absorbed Energy) Temperature Reduction for Material or Specimens < 10 mm (0.394 in.)

Actual Material Thickness or Charpy Impact Specimen Width [Note (1)]		Temperature Reduction Below Design Minimum Temperature	
mm	in.	°C	°F
10 (full-size standard bar)	0.394	0	0
9	0.354	0	0
8	0.315	0	0
7.5 (3/4-size bar)	0.295	2.8	5
7	0.276	4.4	8
6.67 (2/3-size bar)	0.262	5.6	10
6	0.236	8.3	15
5 (1/2-size bar)	0.197	11.1	20
4	0.157	16.7	30
3.33 (1/3-size bar)	0.131	19.4	35
3	0.118	22.2	40
2.5 (1/4-size bar)	0.098	27.8	50

GENERAL NOTE: These temperature reduction criteria do not apply when Table 4.5.1-1 specifies lateral expansion for minimum required values.

NOTE:

(1) Straight-line interpolation for intermediate values is permitted.

Table 4.5.1-1 Minimum Required Charpy V-Notch Impact Values

Specified Minimum Tensile Strength	Number of Specimens (See Para. 4.5.4 for Retests)	Energy (Standard Size Specimens)			
		Fully Deoxidized Steels		Other Than Fully Deoxidized Steels	
		J	ft-lbf	J	ft-lbf
Carbon, Low-Alloy Steels, and Other Materials (Other Than Steels in P-Numbers 6, 7, and 8)					
65 ksi (448 MPa) and less	Average for three specimens	18	13	14	10
	Minimum for one specimen	14	10	10	7
Over 65 ksi (448 MPa) to 75 ksi (517 MPa)	Average for three specimens	20	15	18	13
	Minimum for one specimen	16	12	14	10
Over 75 ksi (517 MPa) to 95 ksi (656 MPa)	Average for three specimens	27	20	. . .	. . .
	Minimum for one specimen	20	15	. . .	. . .
		Lateral Expansion			
Over 95 ksi (656 MPa)	Minimum for three specimens	0.38 mm (0.015 in.)			
Steels in P-Numbers 6, 7, and 8					
All	Minimum for three specimens	0.38 mm (0.015 in.)			

MANDATORY APPENDIX I
TEMPERATURE THICKNESS CURVES

See Figs. I-1 and I-1M and Table I-1.

(15) **Fig. I-1 Temperature Thickness Curves for Groups A, B, C, and D (Customary Units)**

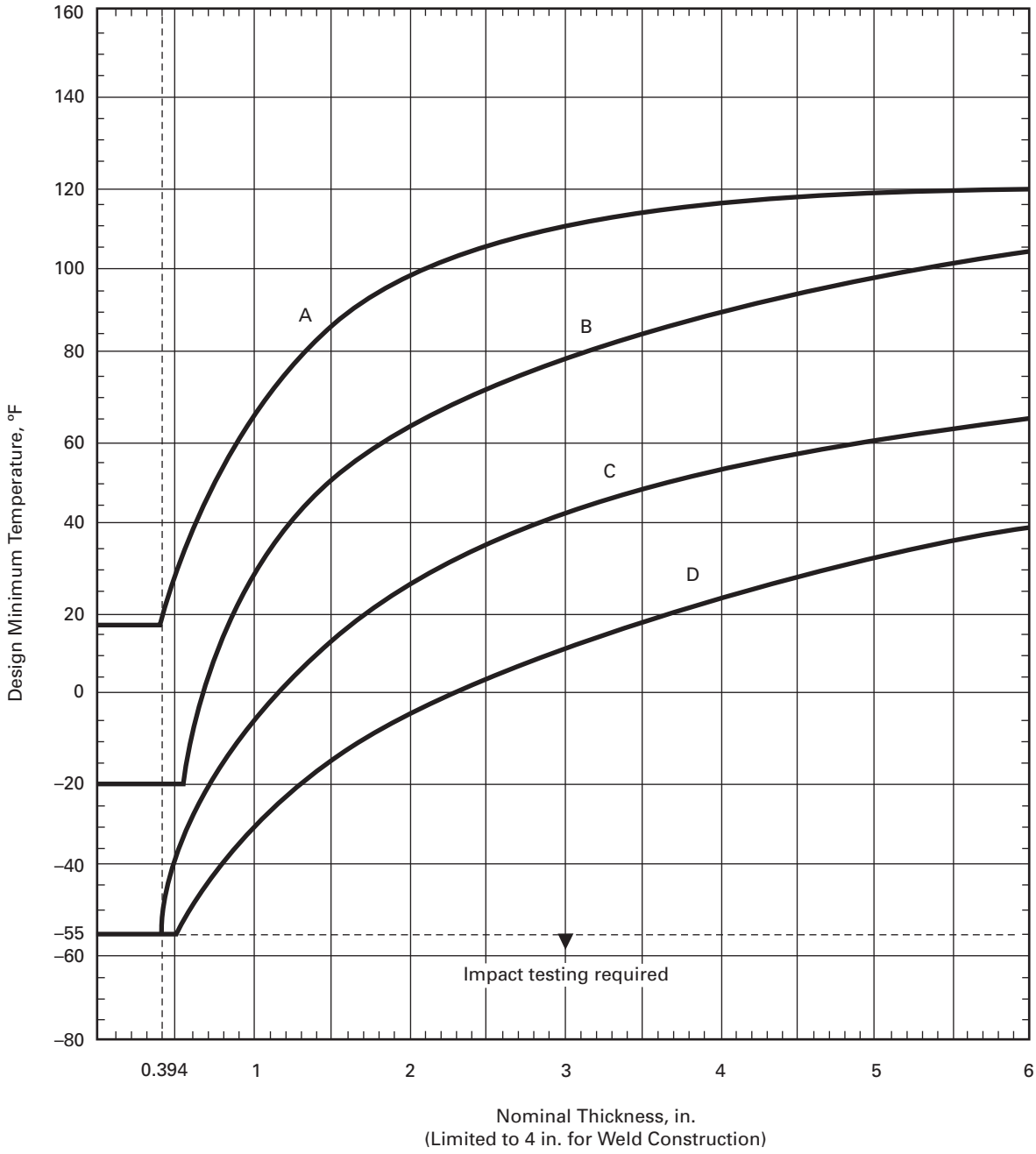
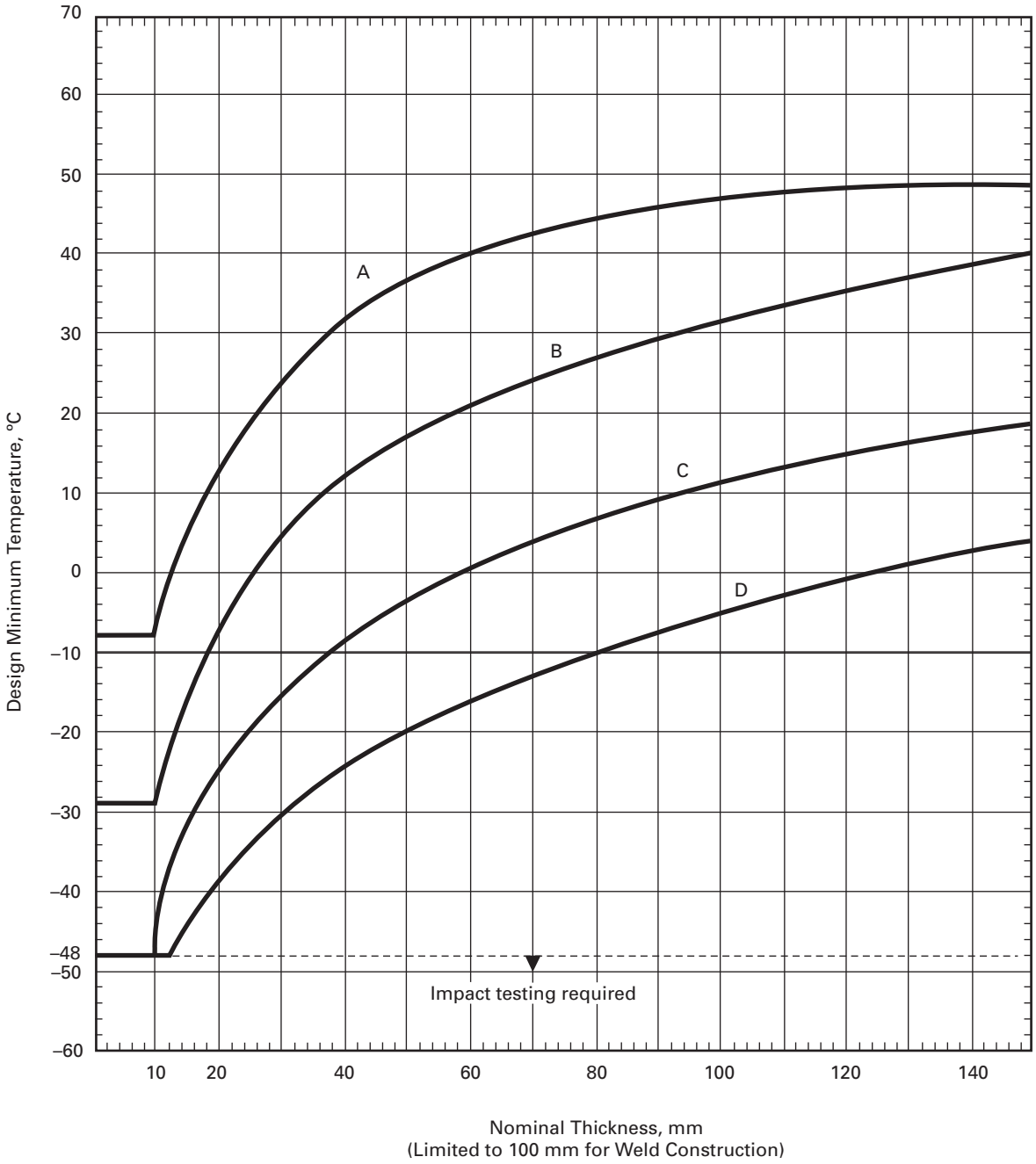


Fig. I-1M Temperature Thickness Curves for Groups A, B, C, and D (SI Units)



(15)

Table I-1 Tabular Values for Figs. I-1 and I-1M

U.S. Customary Units					SI Units				
Thickness, in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F	Thickness, mm	Curve A, °C	Curve B, °C	Curve C, °C	Curve D, °C
0.25	18	−20	−55	−55	6.4	−8	−29	−48	−48
0.3125	18	−20	−55	−55	7.9	−8	−29	−48	−48
0.375	18	−20	−55	−55	9.5	−8	−29	−48	−48
0.4375	25	−20	−40	−55	11.1	−4	−29	−40	−48
0.5	32	−20	−34	−55	12.7	0	−29	−37	−48
0.5625	37	−7	−26	−51	14.3	3	−22	−32	−46
0.625	43	2	−22	−48	15.9	6	−17	−30	−44
0.6875	48	9	−18	−45	17.5	9	−13	−28	−43
0.75	53	15	−15	−42	19.1	12	−9	−26	−41
0.8125	57	20	−12	−38	20.6	14	−7	−24	−39
0.875	61	25	−9	−36	22.2	16	−4	−23	−38
0.9375	65	29	−6	−33	23.8	18	−2	−21	−36
1	68	33	−3	−30	25.4	20	1	−19	−34
1.0625	72	36	−1	−28	27.0	22	2	−18	−33
1.125	75	39	2	−26	28.6	24	4	−17	−32
1.1875	77	42	4	−23	30.2	25	6	−16	−31
1.25	80	44	6	−21	31.8	27	7	−14	−29
1.3125	82	46	8	−19	33.3	28	8	−13	−28
1.375	84	48	10	−18	34.9	29	9	−12	−28
1.4375	86	49	12	−16	36.5	30	9	−11	−27
1.5	88	51	14	−14	38.1	31	11	−10	−26
1.5625	90	53	16	−13	39.7	32	12	−9	−25
1.625	92	55	17	−11	41.3	33	13	−8	−24
1.6875	93	57	19	−10	42.9	34	14	−7	−23
1.75	94	58	20	−8	44.5	34	14	−7	−22
1.8125	96	59	22	−7	46.0	36	15	−6	−22
1.875	97	61	23	−6	47.6	36	16	−5	−21
1.9375	98	62	24	−5	49.2	37	17	−4	−21
2	99	63	26	−4	50.8	37	17	−3	−20
2.0625	100	64	27	−3	52.4	38	18	−3	−19
2.125	101	65	28	−2	54.0	38	18	−2	−19
2.1875	102	66	29	−1	55.6	39	19	−2	−18
2.25	102	67	30	0	57.2	39	19	−1	−18
2.3125	103	68	31	1	58.7	39	20	−1	−17
2.375	104	69	32	2	60.3	40	21	0	−17
2.4375	105	70	33	3	61.9	41	21	1	−16
2.5	105	71	34	4	63.5	41	22	1	−16
2.5625	106	71	35	5	65.1	41	22	2	−15
2.625	107	73	36	6	66.7	42	23	2	−14
2.6875	107	73	37	7	68.3	42	23	3	−14
2.75	108	74	38	8	69.9	42	23	3	−13
2.8125	108	75	39	8	71.4	42	24	4	−13
2.875	109	76	40	9	73.0	43	24	4	−13
2.9375	109	77	40	10	74.6	43	25	4	−12
3	110	77	41	11	76.2	43	25	5	−12

Table I-1 Tabular Values for Figs. I-1 and I-1M (Cont'd)

U.S. Customary Units					SI Units				
Thickness, in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F	Thickness, mm	Curve A, °C	Curve B, °C	Curve C, °C	Curve D, °C
3.0625	111	78	42	12	77.8	44	26	6	−11
3.125	111	79	43	12	79.4	44	26	6	−11
3.1875	112	80	44	13	81.0	44	27	7	−11
3.25	112	80	44	14	82.6	44	27	7	−10
3.3125	113	81	45	15	84.1	45	27	7	−9
3.375	113	82	46	15	85.7	45	28	8	−9
3.4375	114	83	46	16	87.3	46	28	8	−9
3.5	114	83	47	17	88.9	46	28	8	−8
3.5625	114	84	48	17	90.5	46	29	9	−8
3.625	115	85	49	18	92.1	46	29	9	−8
3.6875	115	85	49	19	93.7	46	29	9	−7
3.75	116	86	50	20	95.3	47	30	10	−7
3.8125	116	87	51	21	96.8	47	31	11	−6
3.875	116	88	51	21	98.4	47	31	11	−6
3.9375	117	88	52	22	100.0	47	32	11	−6
4	117	89	52	23	101.6	47	32	11	−5
4.0625	117	90	53	23	103.2	47	32	12	−5
4.125	118	90	54	24	104.8	48	32	12	−4
4.1875	118	91	54	25	106.4	48	33	12	−4
4.25	118	91	55	25	108.0	48	33	13	−4
4.3125	118	92	55	26	109.5	48	33	13	−3
4.375	119	93	56	27	111.1	49	34	13	−3
4.4375	119	93	56	27	112.7	48	34	13	−3
4.5	119	94	57	28	114.3	48	34	14	−2
4.5625	119	94	57	29	115.9	48	34	14	−2
4.625	119	95	58	29	117.5	48	35	14	−2
4.6875	119	95	58	30	119.1	48	35	14	−1
4.75	119	96	59	30	120.7	48	36	15	−1
4.8125	119	96	59	31	122.2	48	36	15	−1
4.875	119	97	60	31	123.8	48	36	16	−1
4.9375	119	97	60	32	125.4	48	36	16	0
5	119	97	60	32	127.0	48	36	16	0
5.0625	119	98	61	33	128.6	48	37	16	1
5.125	119	98	61	33	130.2	48	37	16	1
5.1875	119	98	62	34	131.8	48	37	17	1
5.25	119	99	62	34	133.4	48	37	17	1
5.3125	119	99	62	35	134.9	48	37	17	2
5.375	119	100	63	35	136.5	48	38	17	2
5.4375	119	100	63	36	138.1	48	38	17	2
5.5	119	100	63	36	139.7	48	38	17	2
5.5625	119	101	64	36	141.3	48	38	18	2
5.625	119	101	64	37	142.9	48	38	18	3
5.6875	119	102	64	37	144.5	48	39	18	3
5.75	120	102	65	38	146.1	49	39	18	3
5.8125	120	103	65	38	147.6	49	39	18	3
5.875	120	103	66	38	149.2	49	39	19	3
5.9375	120	104	66	39	150.8	49	40	19	4
6	120	104	66	39	152.4	49	40	19	4

MANDATORY APPENDIX II
STRESS RATIO CURVES

See Figs. II-1 and II-1M.

Fig. II-1 Stress Ratio Curve (Customary Units)

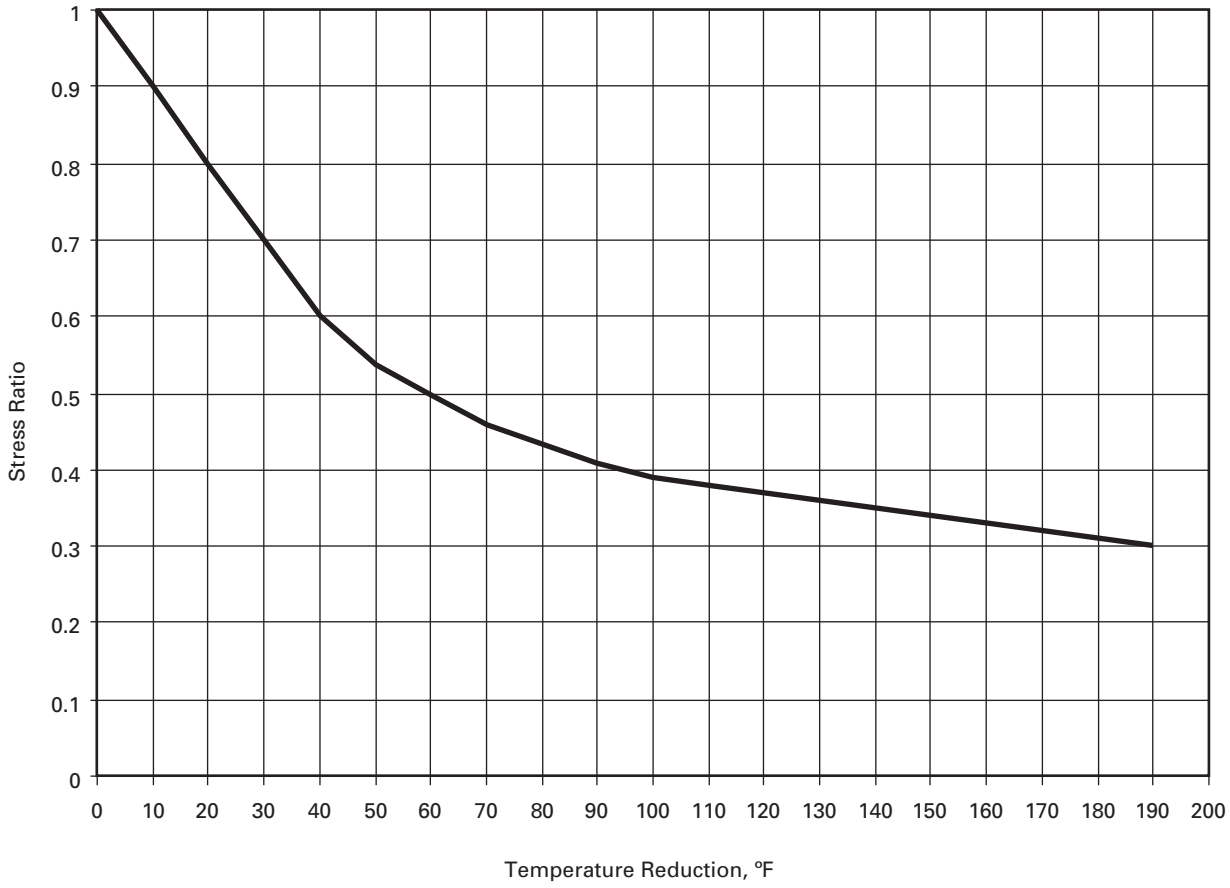
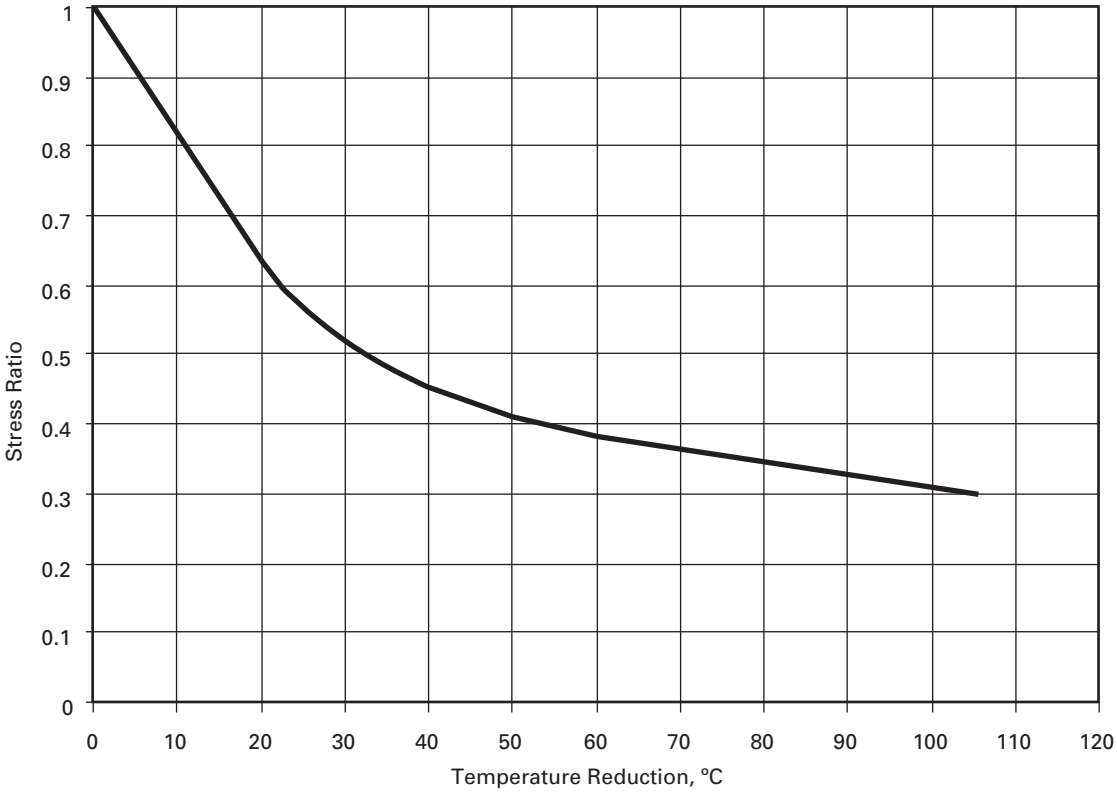


Fig. II-1M Stress Ratio Curve (SI Units)



MANDATORY APPENDIX III
MATERIAL GROUPINGS BY T-NUMBER

See Table III-1.

Table III-1 Material Groupings by T-Number (15)

T-Number Group	Specification	Type/Grade/Class/Condition/Temper/UNS	Product Form	Notes
Carbon Steels				
CS −55	A194	Grade 2, 2H, 2HM	N	. . .
CS −50	A333	Grade 1, 6	P	1
CS −50	A334	Grade 1, 6	T	1
CS −50	A350	Grade LF-2 Class 1	Fl & FO	1
CS −50	A352	Grade LCB	C	1
CS −50	A420	Grade WPL-6	Fl	1
CS −20	A105	. . .	Fl & FO	. . .
CS −20	A178	Grade A, C	T	. . .
CS −20	A179	. . .	T	. . .
CS −20	A192	. . .	T	. . .
CS −20	A194	Grade 1	N	. . .
CS −20	A210	Grade A-1	T	. . .
CS −20	A214	. . .	T	. . .
CS −20	A216	Grade WCA, WCB, WCC	C	. . .
CS −20	A226	. . .	T	. . .
CS −20	A307	Grade B	B	. . .
CS −20	A325	. . .	B	. . .
CS −20	A350	Grade LF-1	Fl & FO	1
CS −20	A369	Grade FPB	P	. . .
CS −20	A524	Grade I, II	P	. . .
CS −20	A587	. . .	P	. . .
CS −20	A675	Grade 45, 50, 55, 60, 65, 70, 80	B	2
CS −20(A)	A563	Grade A	N	. . .
	API 5L	Grade A25 (Butt weld)	P	. . .
CS 0	A350	Grade LF-2 Class 2	Fl & FO	1
CS +20(A)	A53	Grade A (Type F)	P	. . .
CS A	A36	. . .	PL	. . .
CS A	A134	Grade A36	P	. . .
CS A	A134	Grade A283 Gr C, D	P	. . .
CS A	A134	Grade A285 Gr C	P	. . .
CS A	A134	Grade A570 Gr 30, 33, 36, 40, 45, 50	P	. . .
CS A	A139	Grade A, B, C, D, E	P	. . .
CS A	A181	Class 60, 70	Fl & FO	. . .
CS A	A283	Grade A, B, C, D	PL	. . .
CS A	A285	Grade C	PL	. . .
CS A	A299	. . .	PL	
CS A	A381	Class Y35, Y42, Y46, Y48, Y50, Y52, Y56, Y60	P	. . .
CS A	A414	Grade B, C, D, E, F, G	PL	. . .
CS A	A515	Grade 65, 70	PL	. . .
CS A	A570	Grade 30, 36, 40, 45, 50	PL	. . .
CS A	A671	Grade CA55 (A285 Gr C), CB70 (A515 Gr 70), CK75 (A299), CMS75 (A299)	P	. . .
CS A	A672	Grade A55 (A285 Gr C), B65 (A515 Gr 65), B70 (A515 Gr 70), N75 (A299)	P	. . .
CS A	A691	Grade CMS75 (A299)	P	. . .
CS A	API 5L	Grade X42, X46, X52, X56, X60, X65, X70, X80	P	. . .
CS B	A53	Grade A (except Type F), B	P	. . .
CS B	A106	Grade A, B, C	P	. . .
CS B	A134	Grade A283 Gr A, A283 Gr B	P	. . .
CS B	A134	Grade A285 Gr A, A285 Gr B	P	. . .
CS B	A135	Grade A, B	P	. . .

Table III-1 Material Groupings by T-Number (Cont'd)

T-Number Group	Specification	Type/Grade/Class/Condition/Temper/UNS	Product Form	Notes
Carbon Steels (Cont'd)				
CS B	A234	Grade WPB, WPC	FI	...
CS B	A285	Grade A, B	PL	...
CS B	A369	Grade FPA	P	...
CS B	A414	Grade A	PL	...
CS B	A515	Grade 60	PL	...
CS B	A516	Grade 65, 70 not normalized	PL	3
CS B	A671	Grade CB60 (A515 Gr 60)	P	...
CS B	A671	Grade CC65 (A516 Gr 65), CC70 (A516 Gr 70)	P	3
CS B	A672	Grade A45 (A285 Gr A), A50 (A285 Gr B), B60 (A515 Gr 60)	P	...
CS B	A672	Grade C65 (A516 Gr 65), C70 (A516 Gr 70)	P	3
CS B	API 5L	Grade A, A25 (Smls & ERW), B	P	...
CS B	API 5L	Grade X42, X46, X52, X56, X60, X65, X70, X80	P	4
CS C	A516	Grade 55, 60 not normalized	PL	3
CS C	A671	Grade CC60 (A516 Gr 60)	P	...
CS C	A672	Grade C55 (A516 Gr 55), C60 (A516 Gr 60)	P	...
CS D	A516	Grade 55, 60, 65, 70 normalized	PL	3
CS D	A537	Class 1	PL	...
CS D	A671	Grade CC60 (A516 Gr 60), CC65 (A516 Gr 65), CC 70 (A516 Gr 70)	P	3
CS D	A671	Grade CD70 (A537 Cl 1)	P	...
CS D	A672	Grade C55 (A516 Gr 55), C60 (A516 Gr 60), C65 (A516 Gr 65), C70 (A516 Gr 70)	P	3
CS D	A672	Grade D70 (A537 Cl 1)	P	...
CS D	A691	Grade CMSH70 (A537 Cl 1)	P	...
Low-Alloy Steels				
LA −320	A333	Grade 8	P	1
LA −320	A334	Grade 8	T	1
LA −320	A353	...	PL	1
LA −320	A420	Grade WPL8	FI	1
LA −320	A553	Type 1	PL	1
LA −275	A553	Type 2	PL	1
LA −275	A645	...	PL	1
LA −150	A194	Grade 4, 7, 7M	N	...
LA −150	A320	Grade L7, L43	B	1
LA −150	A320	Grade L7A, L7B, L7C	B	1
LA −150	A333	Grade 3, 4	P	1
LA −150	A334	Grade 3	T	1
LA −150	A350	Grade LF3	FI & FO	1
LA −150	A352	Grade LC3	C	1
LA −150	A420	Grade WPL3	FI	1
LA −100	A320	Grade L7M	B	1
LA −100	A333	Grade 7, 9	P	1
LA −100	A334	Grade 7, 9	T	1
LA −100	A352	Grade LC2	C	1
LA −75	A352	Grade LC1	C	1
LA −55	A193	Grade B7 (≤ $2\frac{1}{2}$ in.)	B	...
LA −55	A193	Grade B7M (≤ 4 in.)	B	...
LA −40	A193	Grade B7 (>$2\frac{1}{2}$ in., ≤ 4 in.)	B	...
LA −20	A182	Grade F1, F2, F5, F5a, F9, F11, F12, F21, F22, F91	FI & FO	...
LA −20	A193	Grade B5 ≤ 4 in., B16 ≤ 4 in.	B	...
LA −20	A194	Grade 3	N	...
LA −20	A202	Grade A, B	PL	...
LA −20	A203	Grade A, B, D, E	PL	...

Table III-1 Material Groupings by T-Number (Cont'd)

T-Number Group	Specification	Type/Grade/Class/Condition/Temper/UNS	Product Form	Notes
Low-Alloy Steels (Cont'd)				
LA −20	A204	Grade A, B, C	PL	. . .
LA −20	A217	Grade C5, C12, WC1, WC4, WC5, WC6, WC9	C	. . .
LA −20	A234	Grade WP1, WP5, WP9, WP11, WP12, WP22, WP91	FI	. . .
LA −20	A302	Grade A, B, C, D	PL	. . .
LA −20	A335	Grade P1, P2, P5, P5b, P5c, P9, P11, P12, P15, P21, P22, P91	P	. . .
LA −20	A369	Grade FP1, FP2, FP3b, FP5, FP9, FP11, FP12, FP21, FP22	P	. . .
LA −20	A387	Grade 2, 5, 9, 11, 12, 21, 22, 91	PL	. . .
LA −20	A426	Grade CP1, CP2, CP5, CP5b, CP9, CP11, CP12, CP15, CP21, CP22	P	. . .
LA −20	A671	Grade CF70, CF71	P	. . .
LA −20	A672	Grade L65, L70, L75	P	. . .
LA −20	A691	Grade ½CR, 1CR, 1¼CR, 2¼CR, 3CR, 5CR, 9CR, CM65, CM70, CM75, P91	P	. . .
LA 0	A354	Grade BC	B	. . .
LA +20	A354	Grade BD	B	. . .
Stainless Steels				
SS −425	A182	Grade F304, F304L, F316, F316L	FI & FO	. . .
SS −425	A194	Grade 8A	N	. . .
SS −425	A240	Type 304, 304L, 316, 316L	PL	5
SS −425	A269	Grade TP304, TP304L, TP316, TP316L	P	5
SS −425	A312	Grade TP304, TP304L, TP316, TP316L	P	5
SS −425	A320	Grade B8 Cl 1	B	. . .
SS −425	A351	Grade CF3, CF3A, CF3M, CF8, CF8A, CF8M	C	. . .
SS −425	A358	Grade 304, 304L, 316, 316L	P	5
SS −425	A376	Grade TP304, TP316	P	5
SS −425	A403	Grade WP304, WP304L, WP316, WP316L	FI	. . .
SS −425	A409	Grade TP304, TP316	P	5
SS −425	A479	Type 304, 304L, 316L	PL	. . .
SS −325	A167	Type 302B, 308	PL	6
SS −325	A167	Type 347, 348	PL	5
SS −325	A167	Type 309, 310	PL	5, 6, 7
SS −325	A182	Grade F304H, F316H, F317L, F321, F321H, F347, F347H, F348, F348H	FI & FO	. . .
SS −325	A182	Grade F10	FI & FO	6
SS −325	A182	Grade F310	FI & FO	6, 7
SS −325	A193	Grade B8 Cl 2, B8C Cl 1, B8C Cl 2, B8M, B8T	B	8
SS −325	A194	Grade 8, 8CA , 8FA, 8MA, 8TA	N	. . .
SS −325	A240	Type 302, 317, 317L, 321, 321H, 347, 348	PL	5
SS −325	A240	Type 305	PL	5, 6
SS −325	A240	Type 309S, 310S	PL	5, 7
SS −325	A312	Grade TP304H, TP316H, TP321H, TP347H, TP348H	P	. . .
SS −325	A312	Grade TP317, TP317L, TP321, TP347, TP348	P	5
SS −325	A312	Grade TP309, TP310	P	5, 6, 7
SS −325	A320	Grade B8 Cl 2, B8C Cl 1, B8C Cl 2, B8F, B8M, B8T	N	. . .
SS −325	A351	Grade CF8C, CF10MC, CH8, CH10, CN7M	C	. . .
SS −325	A351	Grade HT30	C	1
SS −325	A358	Grade 321, 347, 348, S34565	P	5
SS −325	A358	Grade 309S, 310S	P	5, 7
SS −325	A376	Grade TP304H, TP316H, TP321, TP321H, TP347, TP347H, TP348	P	5
SS −325	A376	Grade 16-8-2H	P	5, 7
SS −325	A403	Grade WP304H, WP316H, WP317, WP317L, WP321, WP321H, WP347, WP347H, WP348	FI	. . .

Table III-1 Material Groupings by T-Number (Cont'd)

T-Number Group	Specification	Type/Grade/Class/Condition/Temper/UNS	Product Form	Notes
Stainless Steels (Cont'd)				
SS −325	A403	Grade WP309, WP310	FI	6, 7
SS −325	A409	Grade TP317, TP321, TP347, TP348	P	5
SS −325	A409	Grade TP309, TP310	P	5, 6, 7
SS −325	A479	Type 304H, 316, 316H	PL	. . .
SS −60	A182	Grade S32760	FI & FO	. . .
SS −60	A240	UNS S32760	PL	. . .
SS −60	A351	Grade CD3M-W-Cu-N, CE8MN	C	. . .
SS −60	A789	UNS S31803, S32304, S32750, S32760	T	. . .
SS −60	A790	UNS S31803, S32304, S32750, S32760	P	. . .
SS −60	A815	UNS S32760	FI & FO	. . .
SS −20	A167	Type 302B, 308	PL	9
SS −20	A167	Type 347, 348	PL	10
SS −20	A167	Type 309, 310	PL	10 or 7, 9
SS −20	A182	Grade F10	FI & FO	9
SS −20	A182	Grade F310	FI & FO	7, 9
SS −20	A182	Grade F6a	FI & FO	7
SS −20	A182	Grade F60 (S32205)	FI & FO	7
SS −20	A193	Grade B6	−20	. . .
SS −20	A194	Grade 6	−20	. . .
SS −20	A217	Grade CA-15	C	7
SS −20	A240	Type 304, 304L, 316, 316L, 321, 347	PL	10
SS −20	A240	Type 302, 317, 317L, 321H, 348	PL	10
SS −20	A240	Type 305	PL	9 or 10
SS −20	A240	Type 309S, 310S	PL	7, 10
SS −20	A240	Type 405, 410, 410S, 420, 429, X8M	PL	7
SS −20	A240	UNS S32205	PL	7
SS −20	A268	Grade TP405, TP409, TP410, TP430, TP430Ti, TP433, TP436	T	7
SS −20	A269	Grade TP304, TP304L, TP316, TP316L	P	10
SS −20	A312	Grade TP304, TP304L, TP316, TP316L	P	10
SS −20	A312	Grade TP317, TP317L, TP321, TP347, TP348	P	10
SS −20	A312	Grade TP309, TP310	P	10 or 7, 9
SS −20	A351	Grade CE20N, CH20, CK20, HK30, HK40	C	7
SS −20	A358	Grade 304, 304L, 316, 316L	P	10
SS −20	A358	Grade 321, 347, 348, S34565	P	10
SS −20	A358	Grade 309S, 310S	P	7, 10
SS −20	A376	Grade TP304, TP316, TP321, TP347, TP348	P	10
SS −20	A376	Grade TP304H, TP316H, TP321H, TP347H	P	10
SS −20	A376	Grade 16-8-2H	P	7, 10
SS −20	A403	Grade WP309, WP310	FI	7, 9
SS −20	A409	Grade TP304, TP316	P	10
SS −20	A409	Grade TP317, TP321, TP347, TP348	P	10
SS −20	A409	Grade TP309, TP310	P	10 or 7, 9
SS −20	A426	Grade CPCA-15	P	7
SS −20	A437	Grade B4B, B4C	B	. . .
SS −20	A451	Grade CPF8, CPF8C, CPF8M, CPF10MC	P	. . .
SS −20	A451	Grade CPE20N, CPH8, CPH10, CPH20, CPK20	P	7
SS −20	A453	Grade 651A, 651B	B	. . .
SS −20	A487	Grade CA6NM	C	7
SS −20	A789	UNS S32205	T	7
SS −20	A789	UNS S32900	T	. . .
SS −20	A790	UNS S32205	P	7
SS −20	A790	UNS S32900	P	. . .
SS −20	A815	UNS S32205	FI & FO	7

Table III-1 Material Groupings by T-Number (Cont'd)

T-Number Group	Specification	Type/Grade/Class/Condition/Temper/UNS	Product Form	Notes
Nickel Alloys				
NI –325	Various		Various	...
Cast Irons				
CI –20	A48	Grade 20, 25, 30, 35, 40, 45, 50, 55, 60	C	...
CI –20	A126	Class A, B, C	C	...
CI –20	A278	Class 20, 25, 30, 35, 40, 45, 50, 60	C	...
CI –20	A536	Grade 65-45-12, 60-40-18	C	...
CI –20	A571	Type D-2M, Class 1	C	11
CI –20(A)	A47	Grade 32510	C	...
CI –20(A)	A197	...	C	...
CI –20(A)	A395	...	C	...
Copper Alloys				
CU –452	B42	UNS C10200, C12000, C12200	P	...
CU –452	B43	UNS C23000	P	...
CU –452	B68	UNS C12200	T	...
CU –452	B75	UNS C10200, C12000, C12200	T	...
CU –452	B88	UNS C12200	T	...
CU –452	B96	UNS C65500	PL	...
CU –452	B148	UNS C95200, C95300, C95500	C	...
CU –452	B152	UNS C10200, C10400, C10500, C10700, C12200, C12300	PL	...
CU –452	B169	UNS C61400	PL	...
CU –452	B171	UNS C70600, C71500	PL	...
CU –452	B280	UNS C12200	T	...
CU –452	B283	UNS C11000, C46400, C65500	FO	...
CU –452	B466	UNS C70600, C71000	P & T	...
CU –452	B467	UNS C70600, C71500	P	...
CU –325	B21	UNS C46400, C48200, C48500	B	2
CU –325	B61	UNS C92200	C	...
CU –325	B62	UNS C83600	C	...
CU –325	B98	UNS C65100, C65500, C66100	B	2
CU –325	B148	UNS C95400, C95600,	C	...
CU –325	B150	UNS C61400, C63000, C64200	B	2
CU –325	B187	UNS C10200, C11000, C12000, C12200	B	2
CU –325	B283	UNS C37700, C48500, C67500	FO	...
CU –325	B584	UNS C86200, C86300, C86400, C86500, C86700, C90300, C90500, C92200, C92300, C97300, C97600, C97800	C	...
Aluminum Alloys				
AL –452	Various	Various	...	...
Titanium and Titanium Alloys				
TI –75	Various	Various	...	...
Zirconium and Zirconium Alloys				
ZI –75	B493	Grade R60702, R60705	FO	...
ZI –75	B523	Grade R60702, R60705	T	...
ZI –75	B550	Grade R60702, R60705	PL	...
ZI –75	B551	Grade R60702, R60705	PL	...
ZI –75	B658	Grade R60702, R60705	P	...

Table III-1 Material Groupings by T-Number (Cont'd)

GENERAL NOTE: Product form abbreviations are
B = Bolts
C = Castings
FI = Fittings
FO = Forgings
N = Nuts
P = Pipe
PL = Plates, sheets, and bars
T = Tube

NOTES:
(1) Material specification requires impact testing.
(2) Bar specification used for making bolting material.
(3) This materials group depends on if they are normalized or not.
(4) T-number group CS B may only be used when normalized or quenched and tempered.
(5) Solution heat treated after forming.
(6) Carbon content ≤ 0.10%.
(7) This material may have low impact properties at room temperature after being exposed to high service temperatures.
(8) Strain-hardened varieties of this carbide solution–treated bolting material can also be used at the low temperatures indicated.
(9) Carbon content > 0.10%.
(10) Not solution heat treated after forming.
(11) Minimum temperature –195°C (–320°F) with impact testing.

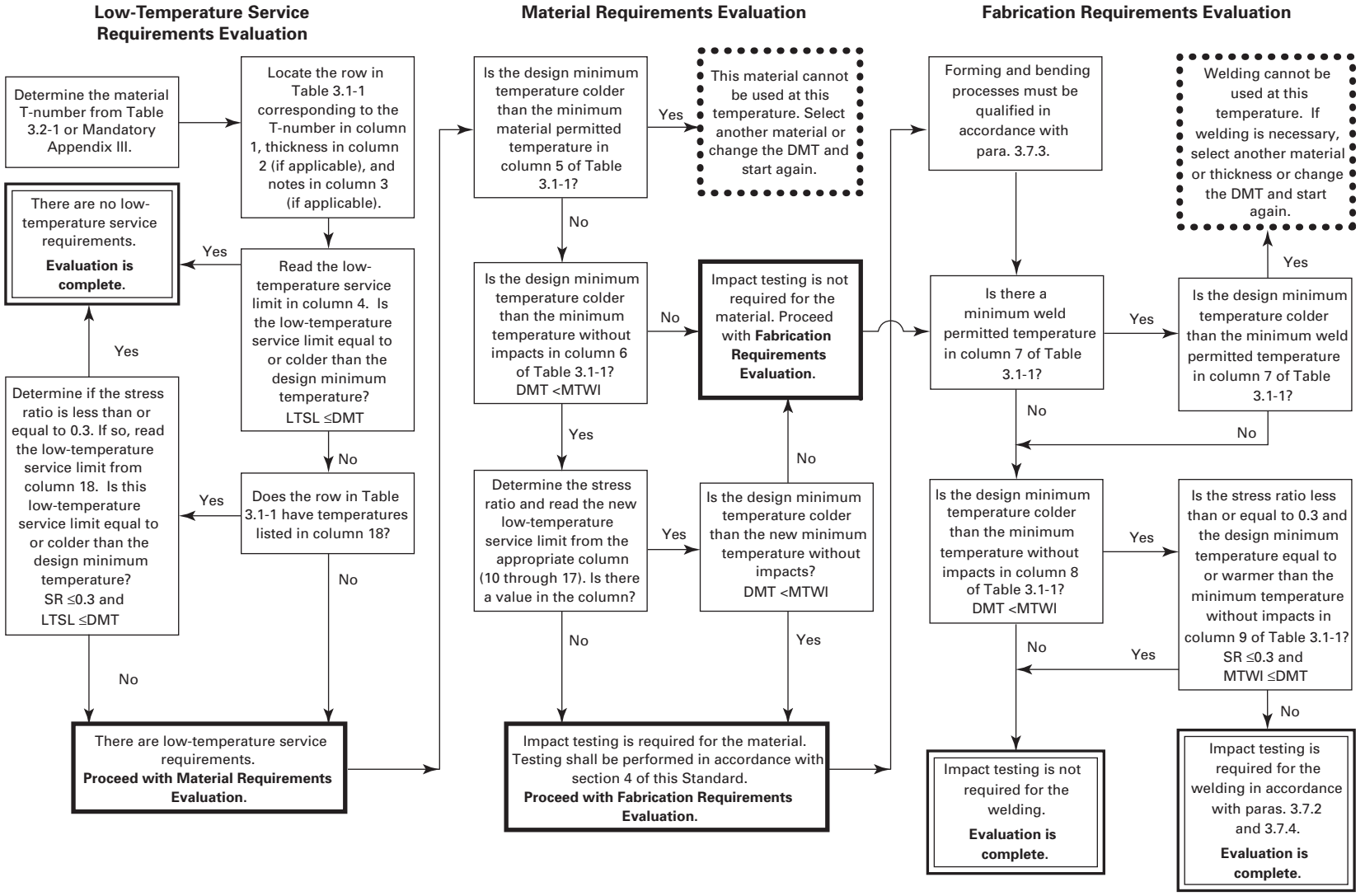
NONMANDATORY APPENDIX A
FLOWCHART OF REQUIREMENTS

(15)

Figure A-1 provides guidance in the implementation of this Code. It is intended to reflect the important items but does not necessarily reflect all of the requirements of this Code.

Given a material specification (including grade, class, etc.), a material thickness, and a design minimum temperature, the low-temperature service requirements would be determined as presented in Fig. A-1.

Fig. A-1 Flowchart of Requirements



GENERAL NOTES:

(a) The double line indicates a step that completes the evaluation.

(b) The bold line indicates a step that completes the phase of the evaluation.

(c) The dotted line indicates the evaluation resulted in an unacceptable condition and needs to be performed again with a new set of parameters.

NONMANDATORY APPENDIX B
GUIDELINES FOR ESTABLISHING T-NUMBER GROUP

(15)

This Nonmandatory Appendix provides guidelines for establishing the T-number group for materials not currently listed in this Code. T-numbers may be assigned to materials listed in any of the B31 piping codes. In establishing the T-number group the committee evaluates the material and the rules governing its use in the Code and gives special consideration to rules governing its use in low-temperature services. If a T-number is being requested for a material, the request should identify the code(s) that list the material and any factors that would influence its toughness or use at low temperatures. Notch toughness data should be provided including test results for the intended design minimum temperature and the range of material thicknesses desired. For welded construction, the notch toughness data shall include the results of the toughness tests required by this Code for weld metal and heat-affected zone for weldments made by the intended welding process.

Based on the material properties and data, a T-number is developed by

(a) establishing the correct material type (CS, LA, SS, NI, CI, CU, AL, TI, ZI) following the material type category used for the allowable stress listing for the material

(b) establishing the material minimum temperature without impact testing based on the material type, chemistry, product form, heat treatment, and the material notch toughness data

(c) determining if use of the material should be prohibited at temperatures below the temperature associated with the group number

The additional material T-number listing will be included in the next revision of this Code. In addition, a Code Case may be issued to provide for interim use of the T-number.

INTENTIONALLY LEFT BLANK

ASME B31T-2015

ISBN 978-0-7918-7068-6