

# Packers and Bridge Plugs

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## Introduction

This specification has been developed by users/purchasers and suppliers/manufacturers of packers and bridge plugs and is intended for use in the petroleum and natural gas industry worldwide. This specification is intended to give requirements and information to both parties in the selection, manufacture, testing, and use of packers and bridge plugs. Further, this specification addresses supplier/matrix requirements that set the minimum requirements with which it is necessary that suppliers/manufacturers comply to claim conformity with this specification.

This specification has been structured to allow for grades of increased requirements both in quality control and design validation. These variations allow the user/purchaser to select the grade required for a specific application.

The three quality grades provide the user/purchaser with a choice of requirements to meet a specific preference or application. Quality grade Q3 is the minimum grade of quality offered by this product standard. Quality grade Q2 provides additional inspection and verification steps, and quality grade Q1 is the highest grade provided. Additional quality requirements can be specified by the user/purchaser as supplemental requirements.

Seven standard design-validation grades (V0 to V6) provide the user/purchaser with a choice of requirements to meet a specific preference or application. Design validation grade V6 is the minimum grade and represents equipment where the validation method has been defined by the supplier/matrix. The complexity and severity of the validation testing increases as the grade number decreases.

This edition now includes annexes with requirements for HPHT environment equipment, HPHT operational tools, and for external flow testing.

It is necessary that users of this specification be aware that requirements above those outlined in this standard can be needed for individual applications. This specification is not intended to inhibit a supplier/matrix from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is necessary that the supplier/matrix identify any variations from this specification.



# Petroleum and natural gas industries—Downhole equipment—Packers and bridge plugs

## 1 Scope

This specification provides requirements and guidelines for packers and bridge plugs as defined herein for use in the petroleum and natural gas industry. This specification provides requirements for the functional specification and technical specification, including design, design verification and validation, materials, documentation and data control, repair, shipment, and storage. In addition, products covered by this specification apply only to applications within a conduit. Installation and maintenance of these products are outside the scope of this specification.

This specification includes the following annexes:

- Annex A: Use of API Monogram by Licensees;
- Annex B: Requirements for HPHT Environment Equipment;
- Annex C: Requirements for HPHT Environment Operational Tools;
- Annex D: External Flow Testing Requirements.

## 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

API Specification 5CT, *Specification for Casing and Tubing*

API Specification 20A, *Carbon Steel, Alloy Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry*, 1st Edition

ANSI/NACE MR0175/ISO 15156 2009<sup>1</sup>, *Petroleum and natural gas industries—Materials for use in H<sub>2</sub>S-containing environments in oil and gas production—Part 3: Cracking-resistant CRAS (corrosion-resistant alloys) and other alloys*

ASME Boiler and Pressure Vessel Code<sup>2</sup>, *Section V: Nondestructive Examination*

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<sup>1</sup> American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, [www.ansi.org](http://www.ansi.org).

<sup>2</sup> ASME International, 2 Park Avenue, New York, New York 10016-5990, [www.asme.org](http://www.asme.org).

ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels; Division 1*, 2013 Edition

ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels; Division 2: Alternative Rules*, 2013 Edition

ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels; Division 3: Alternative Rules for Construction of High Pressure Vessels*, 2013 Edition

ASME *Boiler and Pressure Vessel Code, Section IX, Welding, Brazing, and Fusing Qualifications*

ASTM D297<sup>3</sup>, *Standard Test Methods for Rubber Products—Chemical Analysis*

ASTM D395-03, *Standard Test Methods for Rubber Property—Compression Set*

ASTM D412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension*

ASTM D429, *Standard Test Methods for Rubber Property—Adhesion to Rigid Substrates*

ASTM D624, *Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers*

ASTM D638-10, *Standard Test Method for Tensile Properties of Plastics*

ASTM D1414-94, *Standard Test Methods for Rubber O-Rings*

ASTM D1415, *Standard Test Method for Rubber Property—International Hardness*

ASTM D1708-13, *Standard Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens*

ASTM D2240, *Standard Test Method for Rubber Property—Durometer Hardness*

ASTM E21-09, *Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials*

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E111-04, *Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination for General Industry*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ISO 34-2<sup>4</sup>, *Rubber, vulcanized or thermoplastic—Determination of tear strength—Part 2: Small (Delft) test pieces*

ISO 2859-1, *Sampling procedures for inspection by attributes—Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3601-1, *Fluid power systems—O-rings—Part 1: Inside diameters, cross-sections, tolerances and designation codes*

ISO 3601-3, *Fluid power systems—O-rings—Part 3: Quality acceptance criteria*

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<sup>3</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, [www.astm.org](http://www.astm.org).

<sup>4</sup> International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, [www.iso.org](http://www.iso.org).

ISO 9000, *Quality management systems—Fundamentals and vocabulary*

ISO 9712, *Non-destructive testing—Qualification and certification of NDT personnel*

ISO 10893-5, *Non-destructive testing of steel tubes. Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

ISO 23936-2:2011, *Petroleum, petrochemical and natural gas industries—Non-metallic materials in contact with media related to oil and gas production—Part 2: Elastomers*

### 3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

#### 3.1

##### **assembly**

Product comprised of more than one component.

#### 3.2

##### **bridge plug**

Mechanical device installed in, and used for blocking fluid (liquid or gas) communication in, the conduit and not installed in a designed receptacle.

#### 3.3

##### **casing**

Pipe extending from the surface and intended to line the walls of a drilled well.

#### 3.4

##### **casing size**

Nominal casing outside diameter (OD) as specified in API 5CT.

#### 3.5

##### **component**

Individual part of an assembly.

#### 3.6

##### **conduit**

Casing, tubing, or liner, either metallic or non-metallic.

#### 3.7

##### **design validation**

Process of proving a design by testing to demonstrate conformity of the product to design requirements.

NOTE Seven standard design validation grades (V6 to V0) are specified in 5.5.

[ISO/TS 29001]

#### 3.8

##### **design verification**

Process of examining the result of a given design or development activity to determine conformity with specified requirements.

NOTE These activities are described in 5.4.

[ISO/TS 29001]

**3.9****drift diameter**

Minimum inside diameter (ID) of a packer, expressed as the OD of the drift bar utilized during assembly inspection, as outlined in 6.4.11.

**3.10****end connection**

Thread or other mechanism connecting the packer or bridge plug to the conduit.

**3.11****exposed component**

**Flow-wetted component** (3.13), **internally wetted component** (3.18), and/or component contacted by well fluid below the packing element.

**3.12****extrusion gap**

Radial gap between the maximum rated casing ID and the minimum OD immediately adjacent to the packing element.

**3.13****flow-wetted component**

**Component** (3.5) that comes in direct contact with the dynamic movement of well fluids in the flow stream.

**3.14****gauge OD**

Maximum specified product OD.

**3.15****grade**

Category or rank given to different requirements for quality or design validation.

**3.16****heat-traceable**

Traceable to a unique heat treatment (heat) of material.

**3.17****inflatable packing element**

Packer or bridge plug packing element energized to form a seal by applying fluid pressure directly to the element.

**3.18****internally wetted component**

**Flow-wetted component** (3.13) and any component out of the flow stream, but contacted by well fluids through a port or other passage to the flow-wetted area.

**3.19****job lot**

Batch of material or components that have undergone the same process or series of processes.

**3.20****job-lot traceable**

⟨Parts⟩ identifiable as originating from a job lot that designates the included heat(s).

**3.21****liner**

Pipe that does not extend from the surface and is intended to line the walls of a drilled well.

**3.22****mandrel**

Component(s) of a packer that contain(s) the end connections and provide(s) a conduit through the packer.

**3.23****manufacturing**

Process and actions performed by an equipment supplier/manufacturer that are necessary to provide finished component(s), assemblies, and related documentation that fulfil the requests of the user/purchaser and meet the standards of the supplier/manufacturer.

NOTE Manufacturing begins when the supplier/manufacturer receives the order and is completed at the moment the component(s), assemblies, and related documentation are surrendered to a transportation provider.

**3.24****NACE service**

Packers or bridge plugs whose **type 1 components** (3.41) are manufactured from materials that comply with ISO 15156 (all parts).

**3.25****non-conformance**

Non-fulfilment of a specified requirement.

**3.26****packer**

Mechanical device with a **packing element** (3.27), not installed in a designed receptacle, used for blocking fluid (liquid or gas) communication through the annular space between conduits by sealing off the space between them.

**3.27****packing element**

Seal on a **packer** (3.26) or **bridge plug** (3.2) that blocks fluid communication by sealing on the ID of the conduit.

**3.28****performance envelope**

Graph that illustrates the combined effects of differential pressure and axial loads on a packer or bridge plug at the rated temperature.

**3.29****permanent packer****permanent bridge plug**

**Bridge plug** (3.2) or **packer** (3.26) that has no design feature for intact removal from the conduit, necessitating substantial destruction for its removal.

**3.30****pressure reversal**

Change in the direction of the pressure differential across the packing element from above to below or vice versa.

**3.31****qualified person**

Individual with characteristics or abilities gained through training or experience, or both, as measured against established requirements, such as standards or tests that enable the individual to perform a required function effectively.

**3.32****repositionable packer****repositionable bridge plug**

**Bridge plug** (3.2) or **packer** (3.26) that meets the definition of **retrievable packer (retrievable bridge plug)** (3.33) and has a design feature facilitating its relocation inside the conduit (without removal) while re-establishing its intended function.

**3.33****retrievable packer****retrievable bridge plug**

**Bridge plug** (3.2) or **packer** (3.26) that has a design feature facilitating its removal from the conduit substantially intact.

**3.34****seal**

Device providing a barrier to the passage of liquid and/or gas.

**3.35****shear device**

Component designed to disconnect under a predetermined load.

**3.36****standard service**

**Packer** (3.26) or **bridge plug** (3.2) whose components might or might not be manufactured from materials that comply with ISO 15156 (all parts).

**3.37****substantive design change**

Change to the design, identified by the supplier/manufacturer, that affects the performance of the product in the intended service condition.

**3.38****temperature-cycle range**

Specified range of temperature fluctuation over which the product is designed to operate.

NOTE The temperature-cycle range is applicable anywhere within the product's temperature range.

**3.39****temperature range**

Specified range of temperature over which the product is designed to operate.

**3.40****tubing**

Pipe placed within a well to serve as a production or injection conduit.

**3.41****type 1 component**

⟨Weld⟩ component that isolates pressure and/or may be loaded in tension as the result of axial loads on the packer or bridge plug during run-in, setting, *in situ*, or retrieval.

**3.42****type 2 component**

⟨Weld⟩ component that does not meet the criteria of a **type 1 component** (3.41).

## 4 Acronyms, Abbreviations, and Symbols

|     |                             |
|-----|-----------------------------|
| AQL | acceptance quality limit    |
| COC | certificate of compliance   |
| ID  | inside diameter             |
| MTR | material test report        |
| NDE | non-destructive examination |
| OD  | outside diameter            |
| QC  | quality control             |

## 5 Functional Specification

### 5.1 General

The user/purchaser shall prepare a functional specification for ordering products that conform to this specification and specify the following requirements and operating conditions, as applicable, and/or identify the supplier's/manufacture's specific product. These requirements and operating conditions may be conveyed by means of a dimensional drawing, data sheet, or other suitable documentation.

### 5.2 Type Description

The user/purchaser shall specify, as applicable, the following type:

- packer or bridge plug;
- permanent, retrievable, or repositionable.

### 5.3 Well Parameters

The user/purchaser shall specify, as applicable, the following well parameters:

- dimensions, material, grade of the casing and tubing;
- end connections above/below the packer or bridge plug;
- well angle from the vertical at the setting position of the packer or bridge plug;
- deviations and restrictions through which the packer or bridge plug is required to pass;
- configuration of tubing (single or multiple strings) and other lines (electrical/hydraulic) that are required to pass through or bypass the packer;
- relationship of packer or bridge plug with other well devices/tubing/casing by means of a well schematic drawing, if applicable;
- expected minimum and maximum values of production/injection pressures, pressure differentials, temperatures, changes in temperatures, and flow rates;
- any other relevant well parameter(s).

## 5.4 Operational Parameters

The user/purchaser shall specify, as applicable, any of the following operational parameters:

- installation method, including conveyance method and setting method;
- setting depth;
- retrieving or repositioning method and number of repositionings, if applicable;
- anticipated loading conditions, including combined loading (pressure, tension/compression) and torque, applied to the packer or bridge plug prior to and during setting, during use, and during retrieving;
- expected setting temperature and anticipated temperature cycle during well operations;
- size, type, and configuration of devices that will be run through the packer, if applicable;
- any other relevant operational parameters.

## 5.5 Environmental Compatibility

### 5.5.1 General

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, he/she shall state to the supplier/manufacturer which material(s) has/have the ability to perform as required within the corrosion environment per the requirements of 5.5.3, as applicable. Otherwise, material compatibility shall be specified according to 5.5.2.

### 5.5.2 Well Environment

The user/purchaser shall identify the density, chemical/physical composition, and the condition of the fluid and/or its components, including solid (sand production, scale, etc.), liquid, and/or gaseous, to which the packer or bridge plug is exposed during its expected life cycle.

### 5.5.3 Material Designation

**5.5.3.1** If the user/purchaser chooses to specify materials, the following designations may be used:

- standard service (3.36);
- NACE service (3.24).

**5.5.3.2** Material selection may be made for a group of components using the following designations:

- flow-wetted components (3.13);
- internally wetted components (3.18);
- exposed components (3.11);
- other components.

## 5.6 Compatibility with Related Well Equipment

The user/purchaser, where applicable, shall specify the interface connection designs and material requirements, free-passage requirements, and external/internal dimensional limitations necessary to ensure

that the product will conform to its expected application. The user/purchaser shall identify, as applicable, the following:

- top and bottom tubular connection(s) and the material and dimensions of the connections to the conduit(s);
- internal receptacle profile(s), bore dimensions(s), outside diameter, inside diameter, and the respective locations;
- size, type, and configuration of other products and conduits used in connection with this product.

## **5.7 Design Validation**

The user/purchaser shall specify the required design validation grade. This specification provides seven standard design validation grades (V6 to V0), as defined in 6.5. Additionally, design validation grades V0-H and V3-H are provided in Annex B and may be selected by the user/purchaser.

## **5.8 Quality Control**

The user/purchaser shall specify the required quality grade. This specification provides three quality grades (Q3, Q2, and Q1) of quality control, as defined in 7.4.

# **6 Technical Specification**

## **6.1 General**

The supplier/manufacturer shall prepare a technical specification that conforms to the requirements defined in the functional specification. If the technical specification does not fully meet the functional requirements, the supplier/manufacturer shall identify the differences to the user/purchaser. The supplier/manufacturer shall also provide the user/purchaser with the product data sheet, as detailed in 7.2.3.

## **6.2 Technical Characteristics**

The following criteria shall be met.

- The packer/bridge plug shall locate and seal at the specified location and remain so until intentional intervention defines otherwise. Exceptions to this are the effects of casing failure.
- While located and in service, the packer/bridge plug shall perform in accordance with the functional specification.
- Where applicable, the packer/bridge plug shall not compromise well intervention operations.

## **6.3 Design Requirements**

### **6.3.1 General**

Products conforming to this specification shall be manufactured to drawings and specifications that are substantially the same as those of the same size, type, and model product that was validated.

### **6.3.2 Design Documentation**

Design of products manufactured to this specification shall include documentation of those designs. This documentation shall include, as applicable, design requirements; assumptions; analysis methods; comparison with previous designs or operating history of similar products; calculations; manufacturing

drawings and specifications; design reviews; and/or physical testing results (such as design validation testing).

### **6.3.3 Materials**

#### **6.3.3.1 General**

Materials (both metallic and non-metallic) and/or the service being provided shall be stated by the supplier/manufacturer and shall be suitable for the class of service and the environment specified in the functional specification. The supplier/manufacturer shall have documented specifications for all materials, and all materials used shall comply with the supplier's/manufacturer's documented specifications.

The user/purchaser may specify materials for the specific use and corrosion environment in the functional specification. If the supplier/manufacturer proposes to use another material, the supplier/manufacturer shall state that this material has performance characteristics suitable for all parameters specified in the well and production/injection parameters.

#### **6.3.3.2 Metals**

##### **6.3.3.2.1 Specifications**

The supplier's/manufacturer's specifications shall define the following:

- a) chemical composition limits;
- b) heat treatment conditions;
- c) mechanical property limits:
  - tensile strength;
  - yield strength;
  - elongation;
  - hardness.

##### **6.3.3.2.2 Mechanical Property Verification**

When required by the quality grade, the mechanical properties for type 1 metal components shall be verified by tests conducted on a material sample produced from the same heat of material. The material sample shall experience the same heat treatment process as the component it qualifies. Material subsequently heat-treated from the same heat of material shall be hardness-tested after processing to confirm compliance with the hardness requirements of the supplier's/manufacturer's specifications. The hardness results shall verify through documented correlation that the mechanical properties of the material tested meet the properties specified. The heat treatment process parameters shall be defined in a heat treatment procedure. Hardness testing is the only mechanical property test required after stress relieving. Material test reports provided by the material supplier/manufacturer are acceptable documentation when validated.

##### **6.3.3.3 Non-metals**

The supplier's/manufacturer's documented specifications for non-metallic compounds shall include handling, storage, and labelling requirements, including the cure date, batch number, compound identification, and shelf life, appropriate to each compound, and shall define those characteristics critical to the performance of the material, such as:

- a) compound type;
- b) mechanical properties, as a minimum:
  - tensile strength (at break);
  - elongation (at break);
  - tensile modulus (at 50 % or 100 %, as applicable);
- c) compression set;
- d) durometer hardness.

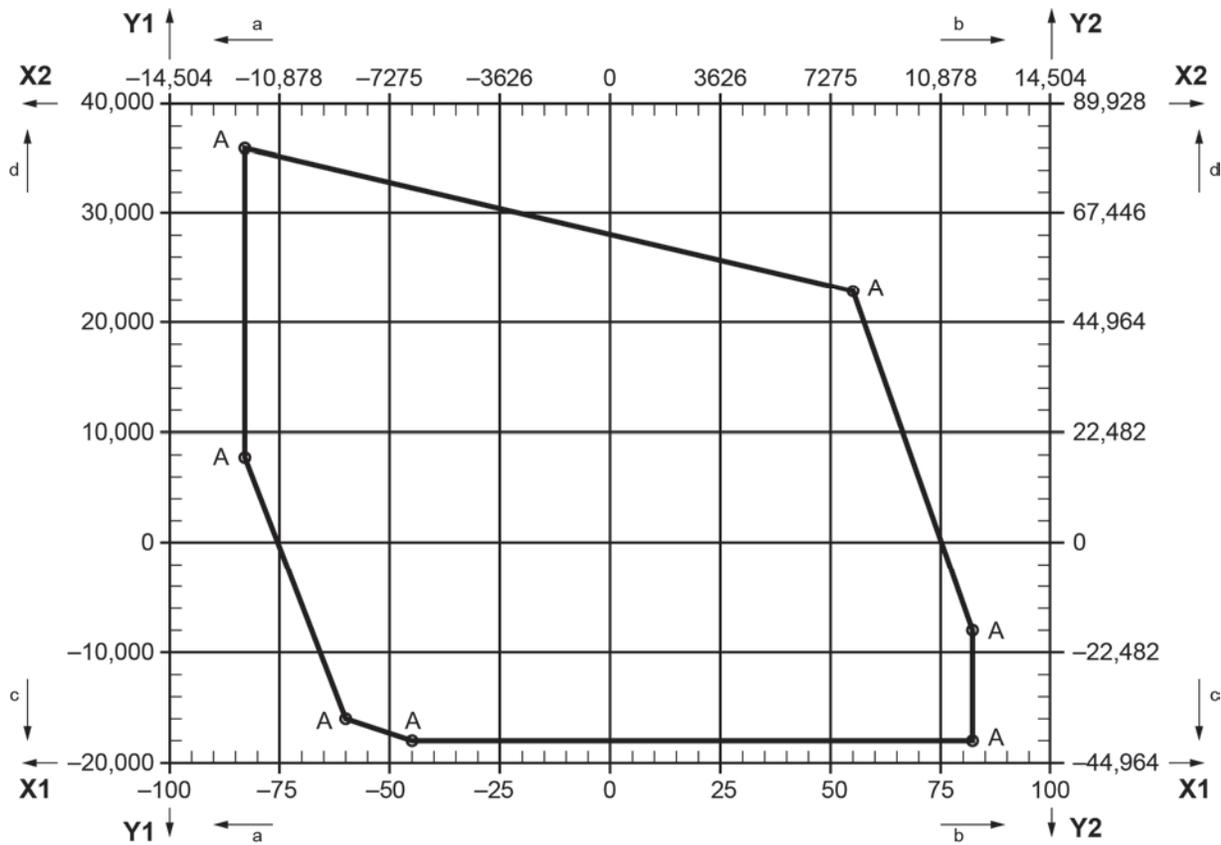
#### **6.3.4 Performance Rating**

The supplier/manufacturer shall state the pressure, temperature, and axial performance ratings, as applicable for the products. For packers and bridge plugs validated to grade V4 through grade V0, a rated performance envelope is required.

An example envelope is illustrated in Figure 1. The area within the boundaries defines the rated performance envelope. The lines forming the boundary of the envelope are defined as the maximum operational limits for the packer or bridge plug. Metal mechanical properties over the temperature range shall be considered when determining performance ratings.

Rated performance envelopes shall meet the following criteria.

- The rated performance envelope shall represent the supplier's/manufacturer's maximum ratings.
- "Above" and "below" on the pressure axis are defined as above and below the product and not internal to the product. If the envelope includes ratings based on pressure internal to the product, this shall be specified with the envelope or handled as an additional graph.
- Products with IDs shall be represented with the ID not plugged unless specified with the envelope.
- Shear devices shall be represented at 100 % of their minimum shear value.
- The ratings of the end connections shall not be included.
- The minimum and maximum casing or tubing IDs shall be specified with the envelope. The envelope shall be applicable over this entire specified ID range.
- Axis and sign convention shall be oriented as shown in Figure 1.
- More than one graph may be displayed with the envelope if a legend is included for explanation. For example, various shear device options can be displayed, as shown in Figure 2.
- The product(s) covered by the envelope shall be specified with the envelope.



### Key

|    |   |   |             |
|----|---|---|-------------|
| X1 | pressure, expressed in megapascals            | a | above       |
| X2 | pressure, expressed in pounds per square inch | b | below       |
| Y1 | force, expressed in decanewtons               | c | compression |
| Y2 | force, expressed in pounds                    | d | tensile     |

NOTE Points labelled "A" are intersection points of two or more operational limits.

**Figure 1—Example of a Rated Performance Envelope**

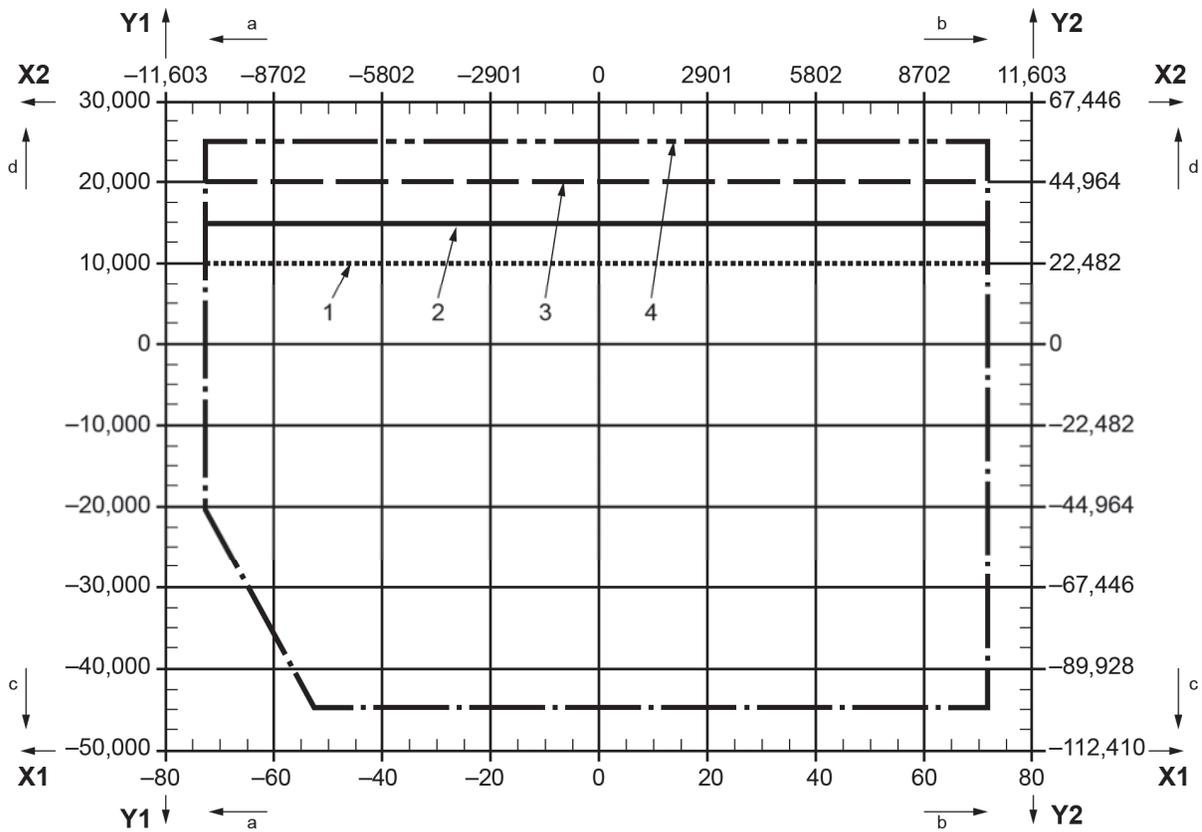
## 6.4 Design Verification

Design verification shall be performed to ensure that each packer and bridge plug design meets the supplier's/manufacture's technical specifications, including conveyance and removal methods/tools. Design verification includes activities such as design reviews, design calculations, comparison with similar designs, and historical records of defined operating conditions. Verification results shall be approved by a qualified person and records of the results shall become a portion of the design documentation.

## 6.5 Design Validation Requirements

### 6.5.1 General

This specification specifies seven grades of design validation for which the product shall be supplied. Products shall be supplied to at least the design validation grade specified.

**Key**

- |    |  |   |             |
|----|--|---|-------------|
| X1 | pressure, expressed in megapascals             | a | above       |
| X2 | pressure, expressed in pounds per square inch  | b | below       |
| Y1 | force, expressed in decanewtons                | c | compression |
| Y2 | force, expressed in pounds                     | d | tensile     |
| 1  | envelope for 10,000 daN (22,482 lb) shear ring |   |             |
| 2  | envelope for 15,000 daN (33,723 lb) shear ring |   |             |
| 3  | envelope for 20,000 daN (44,964 lb) shear ring |   |             |
| 4  | envelope for 25,000 daN (56,205 lb) shear ring |   |             |

**Figure 2—Example of Shear Device Options**

The supplier/manufacturer shall document the validation test procedure and results and shall have on file material specifications and drawings that show all the applicable dimensions and tolerances of parts contained in the validation-tested product. Pre-test and post-test dimensional inspection of critical operational areas, as determined by the supplier/manufacturer, shall be conducted, documented, and maintained by the supplier/manufacturer. Validation test results and dimensional inspection results shall be approved by a qualified person other than the person performing them and records of the results shall become a portion of the design documentation.

The validation grades are the following:

- V6: supplier/manufacturer-defined;
- V5: liquid test;
- V4: liquid test plus axial loads;
- V3: liquid test plus axial loads plus temperature cycling;

- V2: gas test plus axial loads;
- V1: gas test plus axial loads plus temperature cycling;
- V0: gas test plus axial loads plus temperature cycling plus zero bubble acceptance criterion.

Bridge plugs may be run and tested without axial load; however, all validation grades are applicable.

Products qualified to higher grades of design validation may be considered qualified for the lower grades of design validation in accordance with Table 1.

Packers or bridge plugs validated to grade V5 through grade V0 shall not be rated for use in casing or tubing sizes and masses (weights) that can have a maximum ID larger than the ID used in the validation test.

**Table 1—Design Validation Grade Hierarchy**

| Design Validation Grade | Grades Covered                 |
|-------------------------|--------------------------------|
| V0                      | V0, V1, V2, V3, V4, V5, and V6 |
| V1                      | V1, V2, V3, V4, V5, and V6     |
| V2                      | V2, V4, V5, and V6             |
| V3                      | V3, V4, V5, and V6             |
| V4                      | V4, V5, and V6                 |
| V5                      | V5 and V6                      |
| V6                      | V6                             |

## 6.5.2 Validation Test Requirements

### 6.5.2.1 General

The supplier/manufacture shall document all parameters and results of the evaluations that demonstrate conformance to the validation grade. Test data shall identify the leak rate for the duration of the subject test. If no leakage occurred, this shall be clearly stated.

### 6.5.2.2 Grade V6—Supplier/Manufacturer-defined

The supplier/manufacture defines the validation method and acceptance criteria.

### 6.5.2.3 Grade V5—Liquid Test

The supplier/manufacture shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).

- Set and run entire test at or above maximum rated temperature.
- Test at or above maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above maximum rated pressure from above to below or vice versa.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than 1100 kg/m<sup>3</sup> (68.67 lb/ft<sup>3</sup>). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. Time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

#### **6.5.2.4 Grade V4—Liquid Plus Axial Load Test**

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than 1100 kg/m<sup>3</sup> (68.67 lb/ft<sup>3</sup>). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.
- Maintain a minimum hold period of 15 min for pressure tests.

- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

#### **6.5.2.5 Grade V3—Liquid Plus Axial Loads Plus Temperature Cycling Test**

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than  $1100$  kg/m<sup>3</sup> (68.67 lb/ft<sup>3</sup>). Liquid shall be visibly free from particulate matter or other material that can plug a small leak.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

### 6.5.2.6 Grade V2—Gas Plus Axial Load Test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Use a gas test medium of air, nitrogen, or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 20 cm<sup>3</sup> of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. The bubble rate shall not increase during the hold period. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to retrieve the retrievable packers/bridge plugs at the end of the test.

### 6.5.2.7 Grade V1—Gas Plus Axial Loads Plus Temperature Cycling Test

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.

- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.
- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a gas test medium of air, nitrogen, or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: no more than 20 cm<sup>3</sup> of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. The bubble rate shall not increase during the hold period. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

#### **6.5.2.8 Grade V0—Gas Plus Axial Loads Plus Temperature-cycling Test Plus Zero-bubble Acceptance Criterion**

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to this validation grade.

- Set in maximum rated casing or tubing ID  $\pm 0.76$  mm ( $\pm 0.030$  in.) (see 6.5.1).
- Set with the minimum rated setting force or pressure ( $\pm 10$  %).
- Test products with inflatable packing elements horizontally. Centralization at one end of the test fixture is acceptable.
- Products with no anchoring devices or anchoring devices that hold in one direction may be restrained by the test fixture to prevent movement in the un-anchored direction(s).
- Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- Test at or above the maximum rated differential pressure.
- Perform a minimum of two pressure reversals at or above the maximum rated pressure from above to below or vice versa.
- Test to all intersection points of the rated performance envelope.
- Test those packers or bridge plugs having shear-release features at their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load.

- Test a minimum of one temperature cycle. Start the temperature cycle at or above the maximum rated temperature and cool down by at least the maximum rated temperature-cycle range. A pressure hold is required at the low end of the temperature-cycle range and after heating back up to the maximum rated temperature.
- Use a gas test medium of air, nitrogen, or other gas or mixture of gases.
- Maintain a minimum hold period of 15 min for pressure tests.
- Acceptance criterion: zero bubbles of gas accumulated in a graduated cylinder over the hold period after sufficient time has been allowed for stabilization. The time period for stabilization is at the discretion of the supplier/manufacturer. Graduated cylinders for accumulated gas shall be at atmospheric pressure.
- Use the supplier's/manufacturer's specified methods to remove the retrievable-type packers/bridge plugs at the end of the test.

## **6.6 Design Changes**

All design changes shall be documented and reviewed against the design verification and design validation to determine if the change is a substantive change (see 3.37). A design that undergoes a substantive change becomes a new design requiring design verification as specified in 6.4 and design validation as specified in 6.5. Design changes identified as non-substantive shall include documented justification.

The supplier/manufacturer shall, as a minimum, consider the following:

- stress levels of the modified or changed components;
- material changes;
- functional changes.

Changes to a component or series of components may be identified as a substantive change and require design validation. This may be done by testing only the component or series of components rather than the entire assembly. The test shall adequately simulate the loading conditions that would be present if the entire assembly were tested. The supplier/manufacturer shall document the detailed test results and analysis that demonstrate that the component test adequately simulates the required loading conditions. Evaluation results shall be approved by a qualified person (see 3.31) other than the person performing them, and records of the results shall become a portion of the design documentation.

## **6.7 Design Validation by Scaling**

### **6.7.1 General**

Within the same casing size or tubing size, scaling may be used to validate variations in a product family in accordance with the requirements and limitations of 6.7.2 and 6.7.3. This applies to products validated to grade V5 through grade V0 in accordance with 6.5.

### **6.7.2 Product Family for Scaling**

A product family is a group of assemblies that meets the following design requirements:

- configuration: the design principles for the geometry, materials, and functionality are the same;
- design stress levels: the design stress levels in relation to material mechanical properties are based on the same criteria.

### 6.7.3 Limitations of Scaling

Scaling is allowed to validate a product family within a given casing or tubing size with the following limitations.

- A validation test shall be run on the product with the largest extrusion gap (see 3.12).
- A validation test shall be run on the product(s) with the thinnest and thickest cross-section packing element(s).
- Packing elements and anti-extrusion components shall be of the same geometry and materials as the tested product.
- The ID of the packing element(s) and OD of the component under the packing element(s) shall be the same as the tested product.
- Scaling shall not be used to cover products with higher pressure ratings, a higher temperature range, a larger temperature cycle range, higher axial load ratings, or larger rating envelopes than the tested product.

### 6.8 Other Validations

Repositionable packers and bridge plugs shall undergo supplemental validation testing that includes resetting and testing in accordance with the requirements and acceptance criteria of the supplier/manufacturer.

### 6.9 Assembly Verification

Each packer and bridge plug assembly shall be verified in accordance with 7.4.11.

## 7 Supplier's/Manufacturer's Requirements

### 7.1 General

Section 7 contains the detailed requirements necessary to verify that each product manufactured meets the requirements of the functional and technical specifications. These include requirements for documentation and data control, product identification, quality control, functional testing, repair, redress, shipping, and storage.

### 7.2 Documentation and Data Control

#### 7.2.1 General

The supplier/manufacturer shall establish and maintain documented procedures to control all documents and data that relate to the requirements of this standard. These documents and data shall be maintained to demonstrate conformance to specified requirements. All documents and data shall be legible and shall be stored and retained in such a way that they are readily retrievable in facilities that provide a suitable environment to prevent damage or deterioration and to prevent loss. Documents and data may be in any form or type of media, such as hard copy or electronic media. All documents and data shall be available to, and auditable by, the user/purchaser.

All documentation and data associated with design verification, design validation, and design change justification shall be maintained for ten years after the date of last manufacture.

Quality-control documentation includes all documents and data necessary to demonstrate conformance to 7.4.1 through 7.4.15. Quality-control documentation shall be retained by the supplier/manufacturer for a minimum of five years from date of manufacture. These shall be available to and auditable by the user/purchaser.

### 7.2.2 Operating Manual

An operating manual shall be available for all products supplied in accordance with this specification.

Operating manuals shall contain at least the following information:

- manual reference number;
- operational procedures and related tools;
- pre-installation inspection procedures;
- storage recommendations;
- a representative drawing showing major dimensions (ODs, IDs, and lengths);
- special precautions and handling.

### 7.2.3 Product Data Sheet

Product data sheets shall be supplied at delivery to the user/purchaser, as required in 6.1, and shall contain at least the following information, where applicable:

- name and address of supplier/manufacturer;
- manufacturer product number;
- manufacturer product name;
- product type;
- product characteristics;
- service provided;
- metallic materials;
- non-metallic materials;
- drift diameter;
- gauge OD;
- overall length;
- temperature range;
- temperature cycle range for V3, V1, and V0;
- rated performance envelope for V4 through V0;
- pressure rating for V6 and V5;
- top connection(s);
- bottom connection(s);
- casing or tubing range, size and mass and/or minimum and maximum casing or tubing IDs;
- conveyance method;

- maximum conveyance OD, inclusive of running/repositioning equipment, as applicable;
- setting method, including minimum (maximum, as applicable) setting force/pressure;
- retrieval method (if retrievable);
- repositioning method (if repositionable);
- quality grade;
- design validation grade;
- operating manual reference number.

### **7.3 Product Identification**

Each product furnished to this standard shall be permanently identified according to the supplier's/manufacture's specifications. The supplier's/manufacture's specifications shall define the type, method of application, and location of the identifications. The following information shall be included as a minimum:

- manufacturer's identification;
- manufacturer's product number;
- date of manufacture (month/year);
- quality grade;
- design validation grade;
- for quality grade Q1, a unique serial and traceability number.

### **7.4 Quality Control**

#### **7.4.1 General**

This standard specifies three quality grades, Q1, Q2, and Q3, to which the product shall be supplied. Products shall be supplied to at least the quality control grade specified. Quality-control requirements are detailed in 7.4.2 through 7.4.15 and summarized in Table 2. Where there are no requirements listed in 7.4.2 through 7.4.15, the word "None" appears in Table 2.

#### **7.4.2 Material**

Material, metallic or non-metallic, used in the manufacture of components shall meet one of the following requirements:

- COC to the supplier/manufacture stating that the material meets the supplier's/manufacture's documented specifications, or
- MTR to the supplier/manufacture so that the supplier/manufacture can verify that the material meets the supplier's/manufacture's documented specifications.

The supplier/manufacture shall verify, through testing, that the chemical/mechanical properties of metallic materials meet the MTRs as specified for quality grade Q1 for type 1 components. Chemical/mechanical property determination shall be in accordance with a national standard or international standard.

### **7.4.3 Castings**

The casting subcontractor or supplier shall provide a COC to the supplier/major manufacturer stating that the casting meets the supplier's/major manufacturer's documented specifications.

### **7.4.4 Heat Treatment**

#### **7.4.4.1 General**

Heat treatment of components or raw material shall meet the following requirements.

- Heat treating shall be performed with heat-treating equipment that has been calibrated and surveyed.
- If heat treatment is performed by a subcontractor, the subcontractor shall provide a COC to the supplier/major manufacturer stating that the heat treatment meets the supplier's/major manufacturer's documented specifications.
- If heat treatment is performed by the supplier/major manufacturer, heat treatment shall comply with the supplier's/major manufacturer's documented specifications.
- For type 1 components, a heat treatment certificate showing actual times and temperatures is required for quality grade Q1.

#### **7.4.4.2 Heat-treating Equipment Qualification**

##### **7.4.4.2.1 Furnace Calibration**

Furnace calibration shall meet the following requirements.

- a) Each furnace shall be surveyed within one year prior to heat-treating operations. When a furnace is repaired or rebuilt, a new survey shall be required before heat treating.
- b) Batch-type and continuous-type heat-treating furnaces shall be calibrated in accordance with one of the following procedures:
  - procedures specified in an international standard or national standard, such as SAE AMS-H-6875A;
  - procedures specified in an international standard or national standard, such as BS 2M 54;
  - manufacturer's documented specifications, including acceptance criteria that are not less stringent than the procedures identified above.

##### **7.4.4.2.2 Instrumentation**

Instrumentation shall meet the following requirements.

- Automatic controlling and recording instruments shall be used.
- Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmospheres.
- The controlling and recording instruments used for the heat treatment processes shall have an accuracy of  $\pm 1\%$  of their full-scale range.
- Temperature-controlling and -recording instruments shall be calibrated at least once every three months until a documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage and documented calibration history.
- Equipment used to calibrate the production equipment shall have an accuracy of  $\pm 0.25\%$  of the full-scale range.

**Table 2—Summary of Quality Requirements**

| Item   | Quality Grade <sup>a</sup>   |  |   |
|--|--|--|---|
|  | Q3   | Q2   | Q1  |
| Metallic material  | COC or MTR   | COC or MTR   | Verify MTR for type 1 components<br>COC or MTR for type 2 components  |
| Non-metallic material  | COC or MTR   | COC or MTR   | COC or MTR  |
| Castings   | COC  | COC  | COC   |
| Heat treatment   | COC (subcontractor)<br>Job-lot verification<br>(supplier/manufacturer) | COC (subcontractor)<br>Job-lot verification<br>(supplier/manufacturer) | COC (subcontractor)<br>Job-lot verification<br>(supplier/manufacturer)<br>Heat treat certificate for<br>type 1 components |
| Component traceability   | Job-lot traceable for<br>type 1 components                             | Job-lot traceable for type 1<br>components                             | Heat traceable for type 1<br>components   |
| Component dimensions   | Sampling plan  | Sampling plan  | 100 % for type 1 components   |
| <b>Welding</b>   |  |  |   |
| Type 1 welds   | Visual   | Surface NDE per<br>sampling plan and visual                            | Surface NDE 100 %<br>and visual   |
| Type 2 welds   | Visual   | Visual   | Visual  |
| <b>Hardness</b>  |  |  |   |
| Type 1 components  | None   | Sampling plan  | 100 %   |
| Type 2 components  | None   | None   | None  |
| <b>Component NDE</b>   |  |  |   |
| Type 1 components  | None   | Surface NDE per<br>sampling plan                                       | Surface NDE 100 %   |
| Type 2 components  | None   | None   | Visual  |
| Shear devices  | Shear verification   | Shear verification   | Shear verification  |
| Assembly verification  | None   | Functional test<br>ID drift  | Functional test<br>ID drift<br>OD dimensional<br>Torque documentation   |
| Assembly traceability  | None   | None   | Assembly serialization  |
| QC documentation   | Supplier/manufacturere<br>retained                                     | Supplier/manufacturere<br>retained                                     | Supplier/manufacturere<br>retained  |
| <sup>a</sup> "None" indicates that there are no requirements listed in 6.4.2 through 6.4.15. |  |  |   |

#### 7.4.5 Component Traceability

Component traceability shall meet the following requirements.

- Type 1 components shall be job-lot traceable for quality grades Q2 and Q3.
- Type 1 components shall be heat-traceable for quality grade Q1.
- Components that are castings, or are manufactured from castings, shall be excluded from traceability for grades Q3 and Q2.

#### 7.4.6 Component Dimensional Inspection

Component dimensional inspection shall be performed and shall meet the following requirements.

- Thread tolerances, inspection requirements, gauges, gauging practice, gauge calibration and certification shall conform to the specified thread-manufacturer's documented specifications.
- Dimensional tolerances of O-rings shall be in accordance with ISO 3601-1 or equivalent. Other packing elements shall meet dimensional tolerances of the supplier's/manufacturer's documented specifications.
- Type 2 components and all type 1 components for quality grades Q2 and Q3 shall be dimensionally inspected per a sampling plan that meets the requirements of an international standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- Type 1 components shall be 100 % dimensionally inspected for quality grade Q1.

#### 7.4.7 Welds

Welds shall meet the following requirements.

- Type 1 welds (see 3.41) shall meet the requirements of an international standard or national standard such as ASME *Boiler and Pressure Vessel Code*, Section IX.
- Each welded component shall be stress-relieved as specified in the supplier's/manufacturer's documented specifications that include acceptance criteria.

#### 7.4.8 Hardness Inspection of Components

Hardness inspection of components shall meet the following requirements.

- Type 1 components for quality grade Q2 shall be hardness-inspected per a sampling plan that meets the requirements of an international standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- 100 % of type 1 components for quality grade Q1 shall be hardness inspected.
- Type 2 components do not require hardness inspection.
- Hardness inspection of metallic components shall meet the requirements of an international standard or national standard, such as ISO 6506-1, ISO 6507-1, or ISO 6508-1.
- The durometer hardness of O-rings or other elastomeric packing elements shall be determined in accordance with an international standard or national standard, such as ASTM D2240 or ASTM D1415. A test specimen manufactured from each batch may be used.

### 7.4.9 NDE of Components/Welds

NDE of components and welds shall meet the following requirements.

- Welds shall be visually inspected per the requirements of an international standard or national standard, such as the ASME *Boiler and Pressure Vessel Code*, Section V, Article 9.
- NDE for non-metallic components shall be visual inspection per supplier's/manufacture's documented specifications.
- NDE for metallic components shall be magnetic-particle inspection or liquid-penetrant inspection.
- Sampling procedures and the criteria for acceptance or rejection of a batch lot shall be in accordance with ISO 2859-1, general inspection level II, at a 2.5 AQL for O-Rings and a 1.5 AQL for other packing elements, until a documented variation history can be established. Sampling procedures shall then be established based on the documented variation history.
- Visual inspection of O-rings shall be in accordance with ISO 3601-3 or equivalent. Other packing elements shall be visually inspected in accordance with the supplier's/manufacture's documented specifications.
- Magnetic-particle inspection shall meet the requirements of an international standard or national standard, such as ISO 13665 or ASTM E709.
- Liquid-penetrant inspection shall meet the requirements of an international standard or national standard, such as ISO 12095 or ASTM E165.
- NDE acceptance criteria shall be according to the supplier's/manufacture's documented specifications.
- All NDE instructions shall be approved by a level III examiner qualified in accordance with ISO 9712.

NOTE For the purposes of these provisions, ASNT RP SNT-TC-1A is equivalent to ISO 9712.

- Type 1 components and welds for quality grade Q2 shall be NDE-inspected per a sampling plan that meets the requirements of an international standard or national standard, such as ISO 2859-1 or ANSI/ASQC Z1.4.
- Type 1 components and welds for quality grade Q1 shall be 100 % NDE-inspected using liquid-penetrant or magnetic particles.
- Type 2 components for quality grade Q1 shall be visually inspected per the supplier's/manufacture's documented specifications.

### 7.4.10 Shear Device Verification

At least one shear device per heat lot shall be sheared in accordance with the supplier's/manufacture's documented procedure to verify that the shear value meets the supplier's/manufacture's documented specification.

### 7.4.11 Assembly Verification

Assembly verification shall meet the following requirements.

- For quality grades Q2 and Q1, a low-pressure, internal test shall be performed on each packer by plugging the end connection(s) (see 3.10) and pressurizing to a minimum of 350 kPa (approximately 50 psi) using either liquid or gas as the test medium. One-piece mandrels or mandrels with only internal

metal-to-metal sealing connections are excluded from this requirement. Test duration and acceptance criteria shall be defined by the supplier's/manufacture's documented procedures. Functional test data shall be recorded, dated and signed by the qualified person performing the tests.

- For quality grades Q2 and Q1, ID drift each packer per the supplier's/manufacture's documented specifications. ID drift shall apply only to packer IDs not designed as sealing surfaces (sealbores). Drift-bar diameter shall match the rated drift diameter of the packer. Drift-bar dimensions shall meet the requirements specified in API 5CT.
- For quality grade Q1, the OD shall be inspected according to the supplier's/manufacture's documented specifications. OD dimensional inspection shall verify that the entire OD of the assembly is less than, or equal to, the maximum specified OD.
- For quality grade Q1, actual torque values for all metal-to-metal sealing connections shall be recorded and verified to be within the supplier's/manufacture's documented specifications. End connections are specifically excluded from this requirement.

#### **7.4.12 Assembly Traceability**

Assembly serialization shall be used to provide traceability of all type 1 components within each assembly for quality grade Q1.

#### **7.4.13 Manufacturing Non-conformance**

The supplier/manufacture shall establish and maintain documented procedures to ensure that an assembly or component that does not conform to specified requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when applicable), and disposition of non-conforming assemblies or components.

The responsibility for review and authority for the disposition of non-conforming assemblies or components shall be defined by the supplier/manufacture. Non-conforming assemblies or components may be:

- reworked to meet the specified requirements,
- accepted with or without repair by concession; or
- rejected or scrapped.

Repaired and/or reworked assemblies or components shall be inspected in accordance with the requirements of the appropriate quality grade and the documented specifications of the supplier/manufacture.

#### **7.4.14 Calibration Systems**

Measuring and testing equipment used for acceptance shall be identified, controlled, calibrated, and adjusted at specific intervals in accordance with an internationally recognized international standard, such as ISO/IEC 17025.

Technologies for measuring and testing equipment with verifiable accuracies equal to, or better than, those listed in this standard may be applied with appropriate documentation and when approved by a qualified person.

Pressure-measuring devices shall be:

- readable to at least  $\pm 0.5\%$  of the full-scale range or less, as required to perform the specified measurement;

- calibrated to maintain  $\pm 2\%$  accuracy of the full-scale range or less, as required to perform the specified measurement(s);
- used only within the calibrated range;
- calibrated with a master pressure-measuring device or a dead-weight tester.

Calibration intervals for pressure-measuring devices shall be a maximum of three months until a documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage, and documented calibration history.

#### **7.4.15 Personal Qualifications**

Personnel performing NDE shall be qualified in accordance with an international standard or national standard, such as ISO 9712, level 2 minimum, for evaluation and interpretation.

Personnel performing visual examinations shall have an annual eye examination in accordance with an international standard or national standard such as ISO 9712, as applicable to the discipline to be performed.

All other personnel performing inspection for acceptance shall be qualified per the supplier's/manufacture's documented specifications.

## **8 Repair**

Repair activities to packers and bridge plugs shall return the product to a condition meeting all requirements stated in this standard or the edition in effect at the time of original manufacture.

## **9 Shipment/Storage**

Packers and bridge plugs shall be stored per the documented specifications of the supplier/manufacture to prevent deterioration (for example caused by atmospheric conditions, debris, radiation, etc.) prior to transport.

Packers and bridge plugs shall be packaged for transport per the documented specifications of the supplier/manufacture to prevent normal handling loads and contamination from harming the equipment. These specifications shall address the protection of external sealing elements, sealing surfaces, and exposed threaded connections.

# Annex A (informative)

## Use of API Monogram by Licensees

### A.1 Scope

The API Monogram® is a registered certification mark owned by the American Petroleum Institute (API) and authorized for licensing by the API Board of Directors. Through the [API Monogram Program](#), API licenses product manufacturers to apply the API Monogram to new products which comply with product specifications and have been manufactured under a quality management system that meets the requirements of API Q1. API maintains a complete, searchable list of all Monogram licensees on the [API Composite List](#) website ([www.api.org/compositelist](http://www.api.org/compositelist)).

The application of the API Monogram and license number on products constitutes a representation and warranty by the licensee to API and to purchasers of the products that, as of the date indicated, the products were manufactured under a quality management system conforming to the requirements of API Q1 and that the product conforms in every detail with the applicable standard(s) or product specification(s). API Monogram program licenses are issued only after an on-site audit has verified that an organization has implemented and continually maintained a quality management system that meets the requirements of API Q1 and that the resulting products satisfy the requirements of the applicable API product specification(s) and/or standard(s). Although any manufacturer may claim that its products meet API product requirements without monogramming them, only manufacturers with a license from API can apply the API Monogram to their products.

Together with the requirements of the API Monogram license agreement, this annex establishes the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products that satisfy the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program requirements.

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, NW, Washington, DC 20005 or call 202-682-8145 or by email at [certification@api.org](mailto:certification@api.org).

### A.2 Normative References

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

### A.3 Terms and Definitions

For purposes of this annex, the following terms and definitions apply.

#### A.3.1

##### **API monogramable product**

Product that has been newly manufactured by an API licensee utilizing a fully implemented API Q1 compliant quality management system and that meets all the API specified requirements of the applicable API product specification(s) and/or standard(s)

**A.3.2****API specified requirements**

Requirements, including performance and licensee-specified requirements, set forth in API Q1 and the applicable API product specification(s) and or standard(s).

NOTE Licensee-specified requirements include those activities necessary to satisfy API specified requirements.

**A.3.3****API product specification**

Prescribed set of rules, conditions, or requirements attributed to a specified product which address the definition of terms; classification of components; delineation of procedures; specified dimensions; manufacturing criteria; material requirements, performance testing, design of activities; and the measurement of quality and quantity with respect to materials; products, processes, services, and/or practices

**A.3.4****licensee**

Organization that has successfully completed the application and audit process and has been issued a license by API

**A.3.5****design package**

Records and documents required to provide evidence that the applicable product has been designed in accordance with API Q1 and the requirements of the applicable product specification(s) and/or standard(s)

**A.4 Quality Management System Requirements**

An organization applying the API Monogram to products shall develop, maintain, and operate at all times a quality management system conforming to API Q1.

**A.5 Control of the Application and Removal of the API Monogram**

Each licensee shall control the application and removal of the API Monogram in accordance with the following:

- a) Products that do not conform to API specified requirements shall not bear the API Monogram.
- b) Each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:
  - 1) define the authority responsible for application and removal of the API Monogram;
  - 2) define the method(s) used to apply the Monogram;
  - 3) identify the location on the product where the API Monogram is to be applied;
  - 4) require the application of the licensee's license number and date of manufacture of the product in conjunction with the use of the API Monogram;
  - 5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s); and
  - 6) require application of the additional API product specification(s) and/or standard(s) marking requirements.
- c) Only an API licensee may apply the API Monogram and its designated license number to API monogramable products.

- d) The API Monogram license, when issued, is site-specific and subsequently the API Monogram shall only be applied at that site specific licensed facility location.
- e) The API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the licensee's API Monogram marking procedure if the product is subsequently found to be out of conformance with any of the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program.

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the API Policy, *API Monogram Program Alternative Marking of Products License Agreement*, available on the API Monogram Program website at <http://www.api.org/alternative-marking>.

## **A.6 Design Package Requirements**

Each licensee and/or applicant for licensing must maintain a current design package for all of the applicable products that fall under the scope of each Monogram license. The design package information must provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s). The design package(s) must be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in *Advisory # 6*, available on API Monogram Program website at <http://www.api.org/advisories>.

## **A.7 Manufacturing Capability**

The API Monogram Program is designed to identify facilities that have demonstrated the ability to manufacture equipment that conforms to API specifications and/or standards. API may refuse initial licensing or suspend current licensing based on a facility's level of manufacturing capability. If API determines that additional review is warranted, API may perform additional audits (at the organization's expense) of any subcontractors to ensure their compliance with the requirements of the applicable API product specification(s) and/or standard(s).

## **A.8 API Monogram Program: Nonconformance Reporting**

API solicits information on products that are found to be nonconforming with API specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification deficiencies or nonconformities with API specified requirements. Customers are requested to report to API all problems with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at <http://compositelist.api.org/ncr.asp>.

## **Annex B** (informative)

### **Requirements for HPHT Environment Equipment**

#### **B.1 General**

This annex applies to packers and bridge plugs for use in HPHT environments with a pressure rating greater than 103.4 MPa (15,000 psi) or with a temperature rating greater than 177 °C (350 °F). The requirements specified in this annex are in addition to Sections 1 through 9 of this specification. Within this annex the term packer is used to indicate both packers and bridge plugs. This annex was developed considering the guidelines of API TR 1PER15K-1.

This annex may be specified by the user/purchaser for non-HPHT packers. Activities required by this annex shall be performed by a qualified person(s). All results shall conform to the acceptance criteria and be supported by approved documentation.

#### **B.2 Functional Specification for HPHT Equipment**

##### **B.2.1 General**

The user/purchaser shall prepare a functional specification for the HPHT equipment. The functional specification shall include, where applicable:

- the requirements of Section 4;
- internal test pressure requirements;
- industry standards and/or regulatory requirements;
- specified loads, combined loads, temporary test conditions, cyclical loading conditions, thermal gradients, and changes to those parameters.

NOTE Packers under standard operating conditions have very low load cycles over their operational life. For information regarding investigations of load cycling see ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 3, Article KD-3 or Article KD-4.

##### **B.2.2 Operational Parameters**

The following operational parameters shall be specified by the user/purchaser, where applicable:

- well stimulation operations, including its parameters, such as acidizing (composition of the acid and acid returns), the pressure, the temperature, the acid flow rate and the exposure time, and other chemicals used during the stimulation;
- well cementing operations, including its parameters, such as cement types and volumes, spacers, plugs, pressure, and flow rates;
- sand consolidation and fracturing operations, including sand/proppant description and volume, fluid flow rate, proppant/fluid ratio or sand/fluid ratio, chemical composition, pressure, and temperature;
- well-servicing activities and tools interfacing with or passing through the packer;

- size, type, configuration, and operational limitations of the service tools or other devices to be run with or through the packer;
- perforating system induced and applied loads;
- flow rates, exposure time, and chemistry of fluids flowing across or exposed to the packing element;
- anticipated running/pulling speed(s);
- conveyance method, such as; tubing, wireline, tractor, or coil tubing.

### **B.2.3 Non-metals, Functional Specification**

The user/purchaser should provide the following additional functional requirements required for the selection of non-metals, where applicable, as follows:

- a) completion fluid composition, pH, and existence of Bromides (Zn, Ca, Na), Formates (Cs, K, Na), Chlorides (K, Ca, Na), Acetates (Cs);
- b) mud type, mud density, and pH;
- c) aromatic and aliphatic solvents where present (type/amount);
- d) inhibitor treatments (type, concentration, and pH):
  - oxygen scavenger systems,
  - emulsifier systems,
  - continuous or batch treatment,
  - chemical composition,
  - duration and temperature of exposure,
  - details of injected fluids where applicable.

In cases where the user/purchaser has access to historical data and/or research which is applicable to the functional specification, the user/purchaser should state to the supplier/manufacturer which material(s) have the ability to perform as required within a similar environment.

## **B.3 Technical Specification**

### **B.3.1 General**

The supplier/manufacturer shall provide a technical specification to the user/purchaser that conforms to the requirements defined in this annex and the requirements of Section 6.

The user/purchaser should review the technical specification provided by the supplier/manufacturer and confirm that the proposed packer design meets the requirements of the functional specification.

### **B.3.2 Design Requirements**

#### **B.3.2.1 General**

Packers manufactured according to this annex shall be designed and developed in conformance with API Q1.

### **B.3.2.2 Metals**

#### **B.3.2.2.1 General**

The supplier/manufacturer shall conform to the materials requirements defined in Section 6 and the following requirements.

#### **B.3.2.2.2 Temperature Effects**

The supplier/manufacturer shall utilize a temperature de-rated yield strength and modulus of elasticity from test results for each material corresponding to the packer's maximum rated temperature. This testing shall be conducted in accordance with ASTM E21 for yield strength and ASTM E111 for modulus of elasticity. Metal mechanical properties de-rating shall be verified and documented by a qualified person.

#### **B.3.2.2.3 Environmental Effects**

For sour environments, the materials selected shall be in conformance with the requirements of ANSI/NACE MR0175/ISO 15156.

#### **B.3.2.2.4 Castings**

Castings shall not be used for type 1 components that are integral to the tubing string.

NOTE Castings are typically used for slips, cones, and drag blocks, which are components primarily loaded only in compression and drillable bridge plug assemblies and are not integral to the tubing string.

The production of castings shall conform to the same foundry (or hiping) practices and controls as applied to the successfully validation tested component and the qualification casting. The following shall also be completed.

- All castings, with the exception of slips and primarily compression loaded components shall conform to the requirements of API Specification 20A, CSL3.
- Slips and components primarily loaded in compression shall conform to documented requirements defined by the supplier/manufacturer. These requirements shall include: a qualification casting which shall, as a minimum, include requirements for: microstructure, chemistry, volumetric NDE, and 100 % dimensional inspections as described in API Specification 20A, Table 3. Materials not included in Table 1 of API Specification 20A shall be tested to supplier/manufacturer requirements.
- Where a surface hardening process is utilized, a test specimen shall be evaluated for each production job lot to ensure the process conforms to the required acceptance criteria.

#### **B.3.2.2.5 Welding**

Welding, including overlays and brazing shall require the following.

- a) Welding and brazing procedure and personnel qualification shall be in accordance with ASME *Boiler and Pressure Vessel Code*, Section IX or equivalent.
- b) Weld materials not listed in the ASME *Boiler and Pressure Vessel Code*, Section IX shall be applied using weld procedures qualified in accordance with the methods of ASME *Boiler and Pressure Vessel Code*, Section IX or equivalent.
- c) Welding of type 1 components for NACE service shall meet the requirements of ANSI/NACE MR0175/ISO 15156.

- d) Type 1 welds shall be magnetic particle or liquid penetrant inspected for surface defects to verify conformance with the supplier's/manufacturer's written specifications. The applied magnetic particle or liquid penetrant inspections shall conform to the following requirements.
- 1) Wet magnetic particle examinations shall be conducted per ISO 10893-5 or ASTM E709. Indications shall be described as one of the following:
    - a. relevant indication: only those indications with major dimensions greater than 1.6 mm ( $1/16$  in.) shall be considered relevant whereas inherent indications not associated with a surface rupture (i.e., magnetic permeability variations, non-metallic stringers etc.) shall be considered non relevant;
    - b. linear indication: any indication in which the length is equal to or greater than three times its width;
    - c. rounded indication: any indication which is circular or elliptical in which the length is less than three times its width.
    - d. The acceptance criteria shall be:
      - any relevant indication greater than or equal to 4.8 mm ( $3/16$  in.) shall be considered unacceptable;
      - no relevant linear indications shall be allowed for weldments;
      - no more than ten relevant indications shall be present in any 39 cm<sup>2</sup> (6 in.<sup>2</sup>) area;
      - four or more rounded relevant indications in a line separated by less than 1.6 mm ( $1/16$  in.) shall be considered unacceptable.
  - 2) Liquid-penetrant examinations shall be conducted per ASTM E165 with acceptance criteria of:
    - a. no relevant linear indications;
    - b. no relevant rounded indications greater than 5 mm ( $3/16$  in.); or
    - c. no more than four or more relevant rounded indications in a line separated by 1.5 mm ( $1/16$  in.) or less (edge to edge).
- e) All type 1 welds shall be volumetrically inspected by radiographic or ultrasonic techniques to verify conformance with the supplier's/manufacturer's written specifications. Final NDE shall be performed after all welding, post-weld heat treatment and applicable machining operations on welded areas. Where the final geometry is impractical to perform volumetric inspection on, the inspection shall be conducted prior to final machining. The applied radiographic and ultrasonic techniques shall conform to the following requirements:
- 1) Radiographic inspection of weldments shall be performed in accordance with ASTM E94 and to the acceptance criteria of ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1, UW-51, where applicable by supplier/manufacturer requirements.
  - 2) Ultrasonic inspection of weldments shall be performed in accordance with ASME *Boiler and Pressure Vessel Code*, Section V, Article 5 and with the following acceptance criteria, where applicable by supplier/manufacturer requirements.
    - a. Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

- b. Other imperfections are unacceptable if the indications exceed the reference level amplitude and have lengths which exceed:

- $L > 6.4 \text{ mm } (1/4 \text{ in.})$  for  $t \leq 19 \text{ mm } (3/4 \text{ in.})$
- $L > 1/3 t$  for  $19 \text{ mm} < t \leq 57.2 \text{ mm } (3/4 \text{ in.} < t \leq 2 1/4 \text{ in.})$
- $L > 19 \text{ mm } (3/4 \text{ in.})$  for  $t > 57.2 \text{ mm } (2 1/4 \text{ in.})$

where  $t$  is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld,  $t$  is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in  $t$ .

- f) Welding of sub-assemblies (such as rupture disk installations) shall conform to the supplier/manufacturer documented specifications and acceptance criteria.

### **B.3.2.3 Non-metals**

#### **B.3.2.3.1 Compound Selection**

The supplier/manufacturer shall have a documented procedure that provides for the selection of non-metallic material types and the specific compounds as approved to the supplier's/manufacturer's specification(s) for use in packer designs. The documented procedure(s) shall, as a minimum, consider:

- functional requirements;
- technical specifications;
- operational parameters;
- environmental conditions;
- supply chain limitations and compound availability;
- material type and compound use history;
- geometric component design;
- required service life;
- required approvals of material type and compound selection;
- required documentation of material type and compound selection; and
- chemical resistance of elastomeric and polymeric materials to the known well fluids.

The material type and specific compound shall be selected in accordance with the supplier's/manufacturer's procedures and the requirements of the functional specification. Records of material type and compound selection shall become a portion of the design documentation (see 7.2).

#### **B.3.2.3.2 Elastomeric Compound Assessment**

The supplier/manufacturer shall conduct compound assessment testing per documented procedures containing acceptance criteria. These assessments shall include (but may not be limited to) ageing testing, and compression set testing on elastomeric materials.

- a) Ageing testing shall be conducted on an elastomeric compound per ISO 23936-2, Clause 7.2 or the supplier's/manufacturer's documented procedure. The service temperature shall meet or exceed the maximum rated operating temperature of the packer.
- b) Compression set testing shall be conducted on an elastomeric compound per ASTM D395 or ASTM D1414. This evaluation shall determine the retained elastic properties after prolonged action of compressive stresses.

NOTE Ageing testing may require agreement between the user/purchaser and the supplier/manufacturer for test fluid(s), test temperatures, test pressures, test times, and specimen shape.

NOTE Assessment of rapid gas decompression may be a consideration in retrievable service packer applications and wells with gas in the annulus.

### B.3.2.3.3 Material Specifications

In addition to the specification requirements of 6.3.3.3, the supplier/manufacturer shall establish requirements and acceptance criteria for all elastomers and thermoplastic materials. The specification shall detail if the parameters are to be measured on the actual components.

For elastomeric materials, the supplier's/manufacturer's specification shall include requirements and acceptance criteria for the following parameters determined per the applicable specification listed in Table B.1. The specification shall state if the parameters are to be measured on an actual component.

**Table B.1—Parameters for Elastomeric Materials**

| Parameter        | Specification as Applicable |
|------------------|-----------------------------|
| Tensile strength | ASTM D1414, ASTM D412       |
| Tensile modulus  | ASTM D1414, ASTM D412       |
| Elongation       | ASTM D1414, ASTM D412       |
| Compression set  | ASTM D395, ASTM D1414       |
| Tear resistance  | ASTM D624, ISO 34-2         |
| Density          | ASTM D297                   |
| Hardness         | ASTM D2240, ASTM D1415      |

For thermoplastic materials, the supplier's/manufacturer's specification shall include requirements and acceptance criteria for the following parameters, as applicable, determined per the specification listed in Table B.2. The specification shall state if the parameters are measured on an actual component.

### B.3.2.3.4 Bond Strength Validations

Component designs that require that the elastomer or thermoplastic be bonded to a substrate, the adhesive force required for component performance shall be defined and validated with a bond test. The bond test shall conform to the requirements of ASTM D429 or an equivalent supplier/manufacturer referenced testing program that includes measured acceptance criteria. A minimum of three representative sample components shall be evaluated and all tested samples shall perform to the defined acceptance criteria.

Production bonding results shall be evaluated once per production job lot to documented procedures by qualified persons.

**Table B.2—Parameters for Thermoplastic Materials**

| Parameter                   | Specification as Applicable |
|-----------------------------|-----------------------------|
| Yield strength (at break)   | ASTM D638                   |
| Tensile strength (at break) | ASTM D638, ASTM D1708       |
| Elongation (at yield)       | ASTM D638                   |
| Elongation (at break)       | ASTM D638, ASTM D1708       |
| Modulus of elasticity       | ASTM D638                   |

#### **B.3.2.4 Other Materials**

Materials and components that are not manufactured or supplied under the previously specified controls for metals or non-metals materials shall have a documented requirements controlled by the supplier/manufacturer. They shall also have the necessary controls applied to ensure performance to the documented requirements. All components/materials used in tested or delivered products, except common hardware (such as non-traceable nuts, bolts, set screws, and spacers), shall be validated and approved as conforming to documented requirements and design requirements. Each of the properties identified shall have a traceable and supplier/manufacturer approved test report or COC from the component manufacturer for that batch and/or compound of material.

Material and component design validation testing procedures, testing results and compiled/approved testing reports/evaluations shall be documented as part of the component design documentation. Documentation controls shall conform to 7.2.

#### **B.3.2.5 Manufacturing Controls**

In addition to the quality control requirements of 7.4 and the material requirements of 7.4.2 for non-metals, HPHT non-metal components shall be traceable to the manufacturer, production batch (sometimes called a job lot), and production date. Records of traceability shall be maintained per 7.2.1.

#### **B.3.2.6 Design Verification Requirements**

##### **B.3.2.6.1 General**

Design verification shall be performed in conformance with the requirements of 6.3 and 6.4 and the following requirements.

- a) The packer designs shall be analyzed to determine the supplier's/manufacturer's stated performance limits, including the supplier/manufacturer defined rated internal test pressure. The minimum material condition and minimum material yield strength (including the applicable temperature de-rating, see B.3.2.2.2) shall be used in the calculations.
- b) The supplier/manufacturer shall apply a design margin to each component and/or assembly using a documented methodology and practice. The documented design margins shall be utilized in the creation of component or assembly capabilities and/or ratings.
- c) The performance limits of the packer shall be determined on an individual component basis at the maximum rated temperature. The design shall consider all operational loading conditions defined in the functional requirements and by the technical specifications. A stress analysis methodology that considers

the applied loads and combined stresses shall be used to determine the maximum state of stress of each component of the assembly other than that of common hardware.

- d) The supplier/manufacturer shall identify the type 1 components of the product and the mode(s) of stress.
- e) The supplier/manufacturer shall perform and document a combined loading analysis and generate a rated packer performance envelope based upon that analysis (see B.3.4).
- f) If corrosion or corrosion/erosion allowances are included in the design, the design verification and validations shall consider these allowances.
- g) Special features, which are specific components or sub-assemblies that provide additional functional capability not validated in the defined tests, shall be identified and verified through documented procedures and acceptance criteria.

#### **B.3.2.6.2 Design Analysis of Type 1 Components**

Finite Element Analysis (FEA) shall be performed on type 1 components for the maximum operating load cases at the maximum rated temperature to evaluate for plastic collapse, local failure, and buckling using *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 2, Part 5 or *ASME Boiler and Pressure Vessel Code*, Section VIII Division 3, article KD-2 and the supplier/manufacturer documented design margins and load factors (see B.3.2.6.1). Ratcheting analysis shall be performed per *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 3, KD-234 or *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 2, Clause 5.5.7. The material performance data shall be obtained via testing per B.3.2.2.

These requirements do not apply to components which are intended to be plastically deformed for them to perform correctly. Intentionally plastically deformed component designs shall conform to supplier/manufacturer documented design analysis methodology and acceptance criteria.

#### **B.3.2.6.3 Documentation of Component Design Verification**

A summary report of each component's design shall include:

- actual stress,
- stress mode,
- stress factor,
- maximum allowable stress, and
- temperature de-rated minimum yield strength.

Where applicable, documentation of FEA results shall include:

- description of the numerical method used, including name and version of computer software;
- component dimensions which resulted in the highest state of stress;
- loading conditions;
- numerical analysis results, showing the acceptance criteria utilized;
- evidence of verification by a qualified person other than the individual who created the original analysis.

The FEA study shall be electronically archived such that the study is capable of being re-evaluated at a later time.

The design verification summary report shall be approved by a qualified person other than the one who developed and tested the original design and it shall be included in the design documentation.

### **B.3.3 Design Validation Requirements**

#### **B.3.3.1 General**

Packers shall be validated to their rated limits in conformance with the requirements of Section 7 and the requirements of this annex. Packer operational tool designs shall be validated to the requirements of Annex C.

All final design validation activities shall be contained in reports that are a portion of that product's design documentation.

#### **B.3.3.2 Non-metallic Component Validations**

Validation of non-metallic components shall require performance of the following.

- Inspections according to the supplier's/manufacture's specifications, dimensional requirements, documented procedures, and acceptance criteria.
- Component validation testing at packer limits of loading(s) and maximum/minimum operating temperatures. Components successfully tested in the validation testing of the product (see B.3.3) can be considered as validated as a component when all aspects of the components functionality are tested.
- Records of inspections, component validation testing, and final approval shall become a portion of the design documentation of the product (see 7.2).

#### **B.3.3.3 Validation Testing, Failure Mode, and Effects Analysis**

The supplier/manufacture shall conduct an FMEA, fault-tree analysis, or other reliability assessment method to determine if validation testing per this annex sufficiently validates the design for the intended application and further determine the requirements for additional validations.

Reliability assessment methods shall conform to the requirements of an international standard or to the supplier's/manufacture's documented procedures that are based upon an international standard. The approved report of this assessment shall become a part of the tools design documentation.

#### **B.3.3.4 Design Validation Requirements of Packer Assemblies**

##### **B.3.3.4.1 General**

This section contains the requirements for design validation of packers for use in HPHT environments and contains two grades of design validation.

The HPHT validation grades are designated as follows.

- V0-H: gas test plus axial loads plus temperature cycling plus zero bubble acceptance criterion. Packers conforming to these requirements shall additionally be considered qualified for all validation grades specified in Table 1.
- V3-H: liquid test plus axial loads plus temperature cycling. Packers conforming to these requirements shall additionally be considered qualified for validation grade V3, as defined in Table 1.

### B.3.3.4.2 Requirements

The supplier/manufacturer shall adhere to the following test parameters and criteria for conformance to validation grade V0-H or V3-H.

- a) The supplier/manufacturer shall perform an inspection both pre and post testing according to 6.5.1.
- b) The supplier/manufacturer shall document all parameters and results of the evaluations to demonstrate conformance to the validation grade. The test packer shall be manufactured to the requirements of B.5. Any substantive design changes (see 6.6) require all testing phases to be performed on the new design. The supplier/manufacturer shall have documented testing procedures.
- c) Validation testing shall be performed within a test fixture that is designed to have no OD plastic deformation at the planned test or proof test pressures. This fixture simulates supported casing.

NOTE Testing in supported casing is performed to validate the performance of the packer, not the packer-casing system.

- d) The test fixture ID shall dimensionally conform to the criteria specified in the validation testing procedure. Additionally, the following criteria are required.
  - The surface finish of the sealing area shall conform to the design requirements.
  - The fixture's hardness shall be measured and documented as conforming to the design requirements.
  - Supplier/manufacturer shall document the pre-test and post-test dimensional and visual inspection results of critical operational areas of the test fixture, as determined by the supplier/manufacturer. The dimensional and visual inspection results shall be approved by a qualified person other than the person performing them and records of the results shall be documented in the testing report.
- e) The packer shall be set utilizing procedures, methods and tools identified in referenced supplier/manufacturer procedures. Contingency setting methods shall require separate design validation conforming to documented supplier/manufacturer procedures and acceptance criteria.
- f) Test report/data shall identify any measured pressure loss for the duration of the hold period. Where no pressure loss is measured, that shall be documented in the test report.
- g) Validation testing shall be discontinued if the packer fails to perform within the limits specified, except, when such failure (s) are determined to be the result of a failure within the test facility or test fixture, and that failure and its correction do not affect the validity of the testing results.
- h) For validation grade V3-H the test medium shall be water, with or without additives, or hydraulic oil. The density shall be less than 1100 kg/m<sup>3</sup> (68.67 lb/ft<sup>3</sup>). Liquid shall be visibly free from particulate matter and/or other material that have the potential of plugging potential small leaks. Acceptance criteria for pressure testing with liquid shall be no more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.
- i) Validation grade V0-H shall use a test medium of nitrogen, or other gas or mixture of gases. Acceptance criteria for gas testing is a rate of zero bubbles of gas observed over the hold period after stabilization. The test fixture for viewing/measuring gas bubbles shall be at atmospheric pressure.
- j) The minimum time period for pressure stabilization is at the discretion of the supplier/manufacturer.
- k) Maintain a minimum hold period of 30 minutes after stabilization of all temperatures, pressures, and applied loads.
- l) Recorded temperature measurements shall be representative of those of the packer as it is installed within the test fixture.

- m) When performing validation testing, pressure induced loads into the packer from the test fixture configurations shall be considered and compensated for in the product testing.
- n) Axial loads shall be applied to the top of the packer or bridge plug.

NOTE Axial loads are loads applied to the top of the packer or bridge plug by the tubing and are additive to pressure induced loads.

- o) Applied axial loads shall be in addition to the pressure induced loads on the packer.

Pressure induced loads from above shall be calculated using the cross sectional area from the maximum casing ID to the nominal tubing OD for packers that are directly connected to the tubing, and from the maximum casing ID to the minimum sealing ID for packers with internal sealing surfaces (bores).

Pressure induced loads from below shall be calculated using the cross sectional area from the maximum casing ID to the minimum packer ID for packers directly connected to the tubing, and from the maximum casing ID to the minimum sealing ID for packers with internal sealing surfaces (bores).

- p) Special features shall be validated to their rated limits through documented procedures and acceptance criteria. See B.3.2.6.1 g) for verification requirements of special features.
- q) Shear-release packers shall be tested to or above their maximum rated shear load. For safety, the shear device can be replaced with a stronger shear device that can adequately withstand the maximum shear load over the entire performance envelope.

#### **B.3.3.4.3 Retrievable Packer Requirements**

For retrievable packers, a releasing test is required. This validation testing shall be performed a minimum of one time on each packer design at the conclusion of testing of one of the phase 1, phase 2, or phase 3 tests (see B.3.3.4.4). The release loads shall be measured and recorded. The operating manual's specified retrieval methods and required procedures shall be used as the release method for design validation of the releasing features.

NOTE Releasing methods include, but are not limited to; shift to release, cut to release, and shear to release. Operational tools include but are not limited to; chemical cutters, mechanical cutters, and releasing tools. Operational tools are defined in Annex C with the applicable validation requirements.

Acceptance criteria for this testing shall include performance as designed and post testing inspection results conforming to the supplier/manufacturer requirements. An approved test report shall be prepared for the validation of the release feature(s) for each packer design.

#### **B.3.3.4.4 Validation Testing Scope**

Each packer design shall be successfully tested in each of the following test phases (1, 2, and 3). This applies to packers in conformance with validation grades V0-H and V3-H as identified in each phase:

- Phase 1. A maximum casing ID/maximum temperature test. The packer shall be set in the maximum specified casing ID with a tolerance of  $-0.0 \text{ mm}/+0.76 \text{ mm}$  ( $-0.000/+0.030 \text{ in.}$ ). See B.3.3.4.5 for V3-H, and see B.3.3.4.8 for V0-H.
- Phase 2. A maximum casing ID/minimum temperature test. The packer shall be set in the maximum specified casing ID with a tolerance of  $-0.0 \text{ mm}/+0.76 \text{ mm}$  ( $-0.000/+0.030 \text{ in.}$ ). See B.3.3.4.6 for V3-H, and see B.3.3.4.9 for V0-H. This testing is not required if the temperature range (see 3.39) is tested in B.3.3.4.4, Phase 1.
- Phase 3. A minimum casing ID/maximum temperature test. The packer shall be set in minimum specified casing ID with a tolerance of  $-0.76 \text{ mm}/+0.0 \text{ mm}$  ( $-0.030/+0.000 \text{ in.}$ ). In the case where the minimum

casing ID is less than the specified drift, the drift dimension shall be used as the base dimension. See B.3.3.4.7 for V3-H, and see B.3.3.4.10 for V0-H.

NOTE There is only one temperature-cycle range (3.38) of a validated packer design. Where the temperature-cycle range in test phases 1, 2, and 3 are different, the final reported temperature-cycle range of the packer is the smaller temperature-cycle range of the validated temperature-cycle ranges (see B.3.4.2).

Design validations shall be performed with measuring and testing equipment conforming to the requirements of 7.4.14. All measurements for acceptance shall be within the calibrated range(s) of the testing equipment.

The test phases may be completed in any order. The steps within each testing phase shall be performed in the order shown. Repair or redress of a packer during a testing phase requires the testing to re-start at the beginning of that phase.

#### **B.3.3.4.5 Validation Testing Process, Grade V3-H, Phase 1 (Maximum Casing ID/Maximum Temperature)**

The following steps shall be successfully completed to perform the V3-H phase 1 requirements.

- a) Set packer in the maximum rated casing ID  $-0.00 \text{ mm}/+0.76 \text{ mm}$  ( $-0.000/+0.030 \text{ in.}$ ).
- b) For packers with an atmospheric pressure chamber assembly (may include a rupture disc) a pressure integrity test of the test fixture with the packer installed shall be performed to a minimum of 80 % of the minimum rated setting pressure (see step c) for a minimum of 30 minutes at the maximum rated temperature. This pressure is applied to the inside and outside of the packer simultaneously. Acceptance criteria are the ability of the packer to set as designed and to complete the tests of this phase.
- c) Set with the minimum rated setting force or pressure ( $\pm 10 \%$ ).
- d) Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- e) Perform a minimum of three pressure reversals at or above the maximum rated pressure. Testing to begin with the maximum rated pressure from above or below.
- f) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- g) Reduce temperature by a minimum of the temperature-cycle range (see 3.38).
- h) Perform a pressure test at or above the maximum rated pressure from below.
- i) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- j) Increase temperature to or above the maximum rated temperature.
- k) Perform a pressure test at or above the maximum rated pressure from below.
- l) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of the test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- m) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.
- n) Perform a visual inspection according to a documented procedure containing acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.6 Validation Testing Process, Grade V3-H, Phase 2 (Maximum Casing ID/Minimum Temperature)**

The following steps shall be successfully completed to perform the V3-H phase 2 requirements.

- a) Set the packer in the maximum rated casing ID  $-0.00\text{ mm}/+0.76\text{ mm}$  ( $-0.00/+0.030\text{ in.}$ )
- b) For packers with an atmospheric pressure chamber assembly (may include a rupture disc) a pressure integrity test of the test fixture with the packer installed shall be performed to a minimum of 80 % of the minimum rated setting pressure [see step c)] for a minimum of 30 minutes at the minimum rated temperature. This pressure is applied to the inside and outside the packer simultaneously. Acceptance criteria are the ability of the packer to set as designed and to complete the tests of this phase.
- c) Set with the minimum rated setting force or pressure ( $\pm 10\%$ ).
- d) Set the packer at or above the minimum rated temperature plus the temperature-cycle range.
- e) Perform a minimum of three pressure reversals at, or above the maximum rated pressure. Testing to begin with the maximum rated pressure from above or below.
- f) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- g) Reduce temperature to the minimum rated temperature or below.
- h) Perform a pressure test at or above the maximum rated pressure from below.
- i) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- j) Increase temperature to or above the minimum rated temperature plus the temperature-cycle range.
- k) Perform a pressure test at or above the maximum rated pressure from below.
- l) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- m) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.
- n) Perform a visual inspection according to a documented procedure which contains acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.7 Validation Testing Process, Grade V3-H, Phase 3 (Minimum Casing ID/Maximum Temperature)**

The following steps shall be successfully completed to perform the V3-H phase 3 requirements.

- a) Set in minimum rated casing ID  $-0.76\text{ mm}/+0.0\text{ mm}$  ( $-0.030/+0.000\text{ in.}$ ).
- b) Set with the minimum rated setting force or pressure ( $\pm 10\%$ ).
- c) Set the packer at or below the maximum rated temperature minus the temperature-cycle range.
- d) Increase the temperature to or above the maximum rated temperature.
- e) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.

- f) Reduce the temperature by a minimum of the temperature-cycle range.
- g) Perform one pressure reversal from the maximum rated pressure from above to the maximum rated pressure from below.
- h) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of the test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- i) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.
- j) Perform a visual inspection according to a documented procedure containing acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.8 Validation Testing Process, Grade V0-H, Phase 1 (Maximum Casing ID/Maximum Temperature)**

To successfully complete the V0-H phase 1 requirements, complete the following testing steps.

- a) Set in maximum rated casing ID  $-0.00 \text{ mm}/+0.76 \text{ mm}$  ( $-0.000/+0.030 \text{ in.}$ ).
- b) For packers with an atmospheric pressure chamber assembly (may include a rupture disc) a pressure integrity test of the test fixture with the packer installed shall be performed to a minimum of 80 % of the minimum rated setting pressure (see step c) for a minimum of 30 minutes at the maximum rated temperature. This pressure is applied to the inside and outside the packer simultaneously. Acceptance criteria are the ability of the packer to set as designed and to complete the tests of this phase.
- c) Set with the minimum rated setting force or pressure ( $\pm 10 \%$ ).
- d) Set and run the entire test, except temperature cycling, at or above the maximum rated temperature.
- e) Perform a minimum of three pressure reversals at or above the maximum rated pressure. Testing to begin with the maximum rated pressure from above or below.
- f) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- g) Reduce temperature by a minimum of the temperature-cycle range (see 3.38).
- h) Perform a pressure test at or above the maximum rated pressure from below.
- i) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- j) Increase temperature to or above the maximum rated temperature.
- k) Perform a pressure test at or above the maximum rated pressure from below.
- l) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of the test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- m) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.

- n) Perform a visual inspection according to a documented procedure containing acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.9 Validation Testing Process, Grade V0-H, Phase 2 (Maximum Casing ID/Minimum Temperature)**

To successfully complete V0-H phase 2 requirements, all testing steps shall be performed to the defined limits.

- a) Set in maximum rated casing ID  $-0.00\text{ mm}/+0.76\text{ mm}$  ( $-0.000\text{ in.}/+0.030\text{ in.}$ ).
- b) For packers with an atmospheric pressure chamber assembly (may include a rupture disc) a pressure integrity test of the test fixture with the packer installed shall be performed at a minimum of 80 % of the minimum rated setting pressure (see step c) for a minimum of 30 minutes at the minimum rated temperature. This pressure is applied to the inside and outside the packer simultaneously. Acceptance criteria are the ability of the packer to set as designed and to complete the tests of this phase.
- c) Set with the minimum rated setting force or pressure ( $\pm 10\%$ ).
- d) Set the packer at or above the minimum rated temperature plus the temperature-cycle range.
- e) Perform a minimum of three pressure reversals at or above the maximum rated pressure. Testing to begin with the maximum rated pressure from above or below.
- f) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- g) Reduce temperature to or below the minimum rated temperature.
- h) Perform a pressure test at or above the maximum rated pressure from below.
- i) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- j) Increase temperature to at or above the minimum rated temperature plus the temperature-cycle range.
- k) Perform a pressure test at or above the maximum rated pressure from below.
- l) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of the test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- m) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.
- n) Perform a visual inspection according to a documented procedure containing acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.10 Validation Testing Process, Grade V0-H, Phase 3 (Minimum Casing ID/Maximum Temperature)**

To successfully complete V0-H phase 3, complete the following test steps.

- a) Set in minimum rated casing ID  $-0.76\text{ mm}/+0.0\text{ mm}$  ( $-0.030\text{ in.}/+0.000\text{ in.}$ ).

- b) Set with the minimum rated setting force or pressure ( $\pm 10\%$ ).
- c) Set the packer at or below the maximum rated temperature minus the temperature-cycle range.
- d) Increase the temperature to or above the maximum rated temperature.
- e) Test to a minimum of the pressure and load rating intersection points of the rated performance envelope.
- f) Reduce the temperature by a minimum of the temperature-cycle range.
- g) Perform one pressure reversal from the maximum rated pressure from above to the maximum rated pressure from below or above.
- h) Use the method specified in the test procedure to remove the retrievable-type packers/bridge plugs at the end of the test.

NOTE B.3.3.4.3 includes requirements for packer retrieval.

- i) Perform a drift test per 7.4.11. For packers with sealing IDs (sealbores) the drift test shall be conducted per the supplier/manufacturers documented specification and acceptance criteria.
- j) Perform a visual inspection according to a documented procedure containing acceptance criteria and document any evidence of malfunction(s) or anomalies in the test report.

#### **B.3.3.4.11 Validation Test Report**

A final report of the testing shall be prepared and approved by qualified personnel and shall be retained as part of the design documentation for the product (see 6.3.2). The report shall include the following information as a minimum:

- Identification of product manufacturer (company name, location/address);
- date and unique identification of the validation test report;
- identification of the validation test procedures used;
- equipment type, description, and an assembly drawing;
- model designation or other unique product identification by manufacturer;
- product number (if applicable) and bill of materials identifying the components materials and traceability records;
- measured casing ID(s) utilized in the validation test fixture(s);
- representative casing size(s) and weight/mass(s) and the requirements of B.3.3.4.1;
- rated performance envelope;
- validation grade passed, with reference to the applicable industry standard with edition;
- results of specific evaluations and tests such as; visual inspections, pre-test and post-test dimensional inspection of critical operational areas, drift testing and validation test reports;
- remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test, etc.).

### **B.3.3.5 Design Validation Scaling**

#### **B.3.3.5.1 General**

The scaling of validated packer designs shall conform to the requirements of 6.3, 6.6, and 6.7 and the following additional requirements.

- a) The scaled design shall be of the same nominal size, type, and model.
- b) Each scaled product requires design verification, justification, and design documentation of the changes from the validated design.
- c) Scaled designs shall be approved by a qualified person, other than the person who performed the design scaling verifications.
- d) The summary report of the design validation scaling results and the related documentation shall be maintained in the new product's design documentation.
- e) The rated performance envelope shall note whether the packer was validated by testing or by design scaling.

#### **B.3.3.5.2 Design Scaling Parameters**

The supplier/manufacturer shall establish and document the maximum stress factors within the previously validated design's components and in the components of the scaled design. The mode of stress and same method of calculation(s)/verification(s) shall be applied to the identified components of the base design and the scaled design. For each component, the scaled design's stress factors shall not exceed the maximum stress factors of the same components of the validated design. The supplier/manufacturer shall ensure that the scaled design conforms to the applicable validation and functional testing requirements.

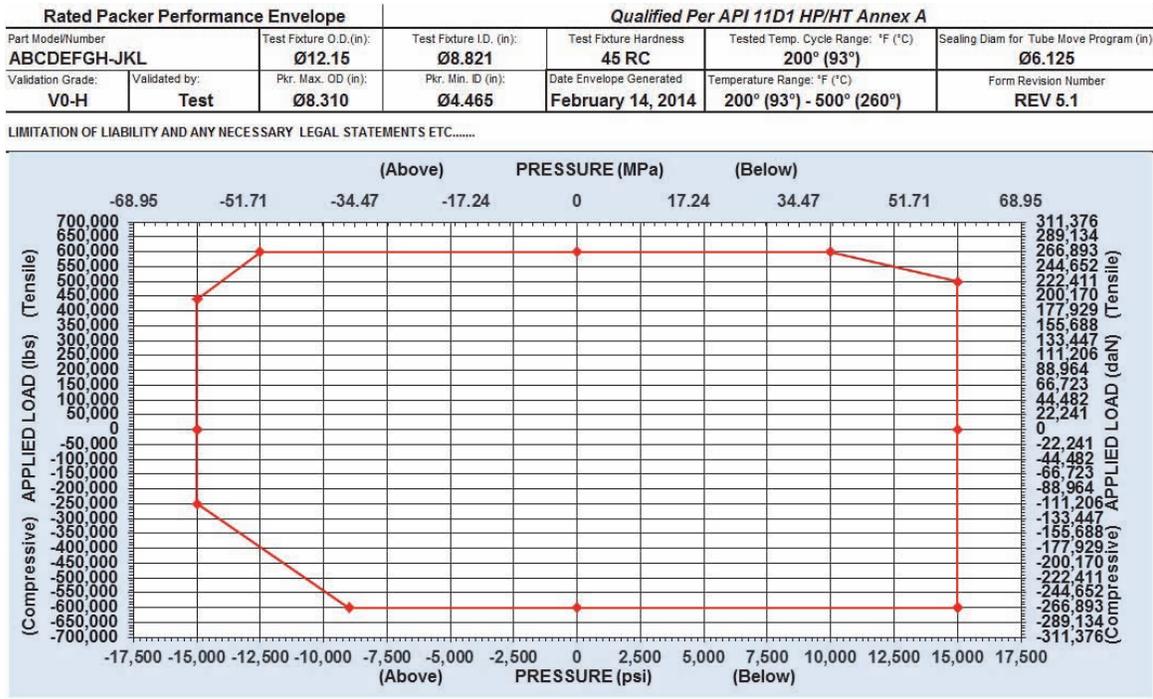
### **B.3.4 Performance Ratings**

#### **B.3.4.1 General**

Each packer design shall have a rated performance envelope that conforms to the specific design limitations defined by the supplier/manufacturer. The ratings illustrated shall be supported by supplier/manufacturer data of the stated capabilities.

Rated performance envelopes for this annex shall meet the criteria of 6.3.4 and contain the data of the following list (an example illustration is provided in Figure B.1):

- product maximum OD and minimum ID;
- measured IDs of test fixtures (maximum ID from phase 1 or 2, and minimum ID from phase 3 testing);
- nominal test fixture OD;
- test fixture hardness;
- validation grade and validation method (test/scaling);
- validated products temperature range and temperature-cycle range (see Figure B.2 for a graphical representation of temperature range and the temperature-cycle range).



- NOTE 1 Envelope values represent the maximum allowable conditions and do not take into account well conditions which might decrease these values.
- NOTE 2 For levels V0 through V4, V3-H, and V0-H, this rated performance envelope represents actual tested points of an unplugged packer. The combined stress loading of threaded end connections is not considered.
- NOTE 3 The performance envelope is calculated at maximum casing ID using minimum material conditions of the unplugged packer at specified temperatures.
- NOTE 4 Axial loads are loads imparted to the top of the packer or bridge plug by the tubing and are additive to pressure induced loads.

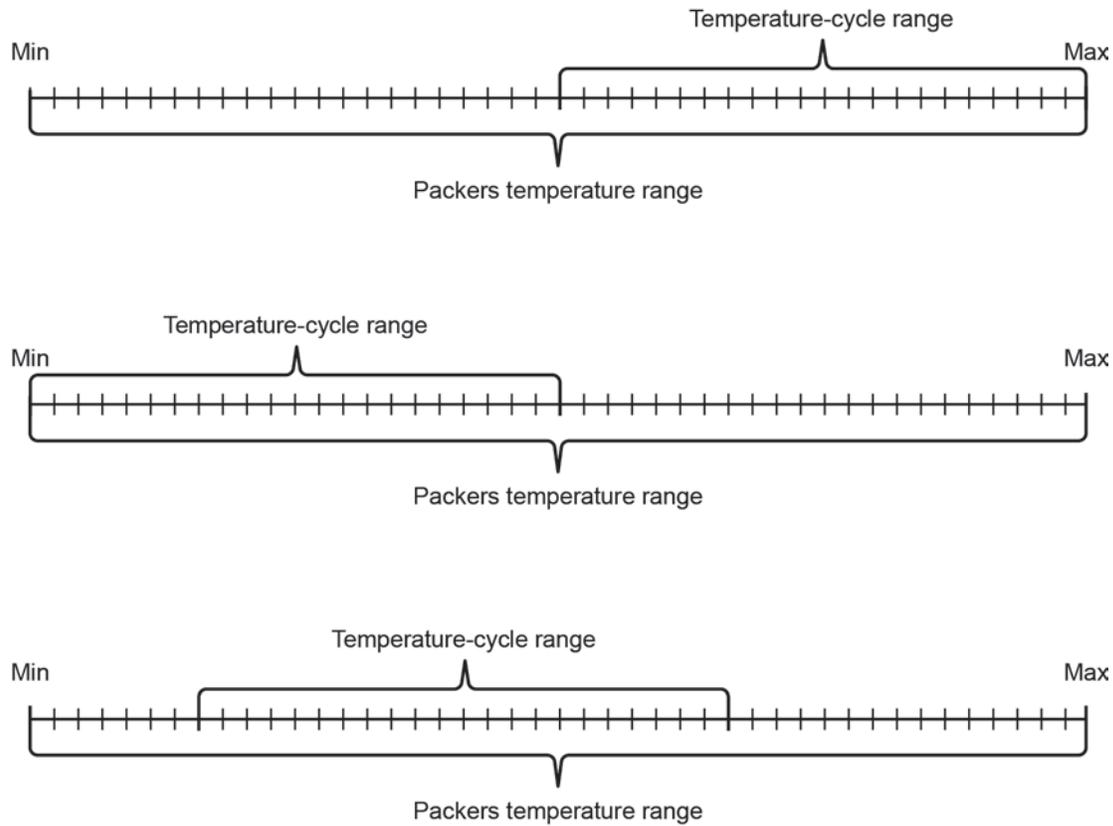
**Figure B.1—Example Rated Performance Envelope**

**B.3.4.2 Temperature-cycle Range and Temperature Range**

Figure B.2 is an illustration of the temperature-cycle range (3.38), which is the temperature fluctuation over which the packer is designed to operate, and the temperature range (3.39), which is the range of temperature over which the packer is designed to operate.

As shown in Figure B.2, the temperature-cycle range is applicable anywhere within the packer’s temperature range.

The information is provided to aid in clarification of the use of these terms and how the design ratings apply. The temperature-cycle range is required because of the behavior of the packer sealing element.



**Figure B.2—Examples of Temperature-cycle Ranges and Temperature Ranges**

### B.3.5 Final Design Approval

The supplier/manufacturer shall conduct a final design review and approve the design for the intended application and functional requirements (see B.3). The final design review shall include the review and approval of the following:

- functional requirements,
- technical specification,
- design verifications,
- design validation records (including any evaluation for scaling, if applicable),
- design outputs and a bill of materials including material specifications.

This review shall be conducted by individuals other than the individual who created the original design. The documentation of the design review shall include the attending member identifications and approval of the results by a qualified person. Records of the final design review, including the completed action items, and approval shall be maintained with the design documentation.

## **B.4 Operational Tool Testing Requirements**

Each operational tool design required for the functionality of the packer shall be verified, validated, and functionally tested in accordance with the requirements of Annex C.

## **B.5 Manufacturing Requirements**

### **B.5.1 General**

Packers produced according to this annex shall be manufactured in conformance to a quality management system which is in conformance to API Q1. The manufacturing of products shall also conform to Section 7.

### **B.5.2 Serialization Requirements**

Type 1 components shall be individually serialized. Prior to product assembly the individual serialization information for type 1 components shall be verified and included on the assembly documentation for that product (see 7.4.12).

### **B.5.3 Non-metallic Material Supplier Qualifications**

The supplier/manufacture shall purchase non-metallic goods and services only from approved suppliers. A documented evaluation procedure and acceptance criteria shall be implemented to ensure that each supplier's products conform to the supplier's/manufacture's material specifications on a repeatable basis.

NOTE See ISO 23936-1 and 2 for effective provisions on qualification of non-metallic sealing material suppliers.

Each non-metallic material supplier shall be evaluated annually to ensure that the applicable controls of all materials, compounds and component processes effectively ensure consistent conformance to the material and technical specifications. These evaluations shall be performed by qualified persons in the applicable technology.

Supplier evaluation records shall identify the materials/components that are approved to be provided by each specific supplier. Supplier documented evaluation records shall include the necessary corrective measures and verification of their implementation. Non-conforming suppliers shall be removed from the approved supplier's registration.

### **B.5.4 Functional Testing Requirements**

#### **B.5.4.1 General**

The supplier/manufacture shall document all parameters and results of functional testing to demonstrate that the packer has been successfully assembled and tested per the supplier's/manufacture's procedures (see 7.4). Functional test results shall be recorded, dated and signed by a qualified person and shall be retained as part of the products manufacturing documentation.

The supplier's/manufacture's functional testing equipment shall conform to the requirements of 7.4.14 and be operated by a qualified person. All pressures are defined as gauge unless otherwise specified and shall be recorded on time-based equipment for the duration of its application.

Unless otherwise specified by the supplier/manufacture, gas pressure-relieving (bleed-down) operations shall be performed at a rate of 6.9 bar (100 psi) per minute or less when the pressures are less than 103.4 bar (1500 psi).

All pressure test holds shall have a minimum duration of 15 minutes after pressure and temperature stabilization.

### **B.5.4.2 Testing Parameters**

Functional testing shall conform to 7.4.11, quality grade Q1, and the requirements defined in this section.

Any sealing plug installed after the completion of the assembly verification testing shall be externally tested to verify full integrity in conformance with the supplier's/manufacture's procedures and acceptance requirements.

Fixtures or clamping devices are allowed to prevent initiation of the setting sequence, provided they do not affect the integrity of the test results.

### **B.5.4.3 Testing Procedures**

An internal pressure test shall be performed on each packer by pressurizing to the rated internal test pressure or the internal test pressure in the functional requirements whichever is greater using either liquid or gas as the test medium.

For packers with sealing IDs (sealbores), the drift test shall be conducted per the supplier's/manufacture's documented specifications.

Fluid charged and atmospheric chamber(s) shall be pressure tested to the chamber's maximum rated pressure. In the event that the design does not allow direct measurement an alternate means of validation shall be documented. Activation devices such as rupture discs are excluded from this requirement.

Acceptance criteria shall include the following.

- a) The loss of applied pressure after stabilization shall be less than 1 % of the applied pressure during the hold period. No leakage shall be visible or observed during testing.
- b) Special features not tested in the defined functional testing shall be tested in accordance with the supplier's/manufacture's procedures and acceptance criteria.
- c) A drift test shall be performed per 7.4.11, including assemblies with internal sealing surfaces (bores). Bridge plugs are exempted from this requirement where applicable.
- d) A visual inspection shall be performed of all accessible surfaces by a qualified person after all testing is successfully completed. Observed damage shall be documented in the test report and the acceptance adjusted as applicable.

### **B.5.4.4 Functional Test Documentation**

A functional test report shall be prepared for each packer tested. The report shall include:

- identification of product manufacturer (company name, location/address, etc.);
- date of functional test and date of report;
- model designation or other identification;
- product number with unique serial number;
- remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test, etc.);
- testing limits applied and testing results compared to the acceptance criteria;

- 
- results of specific evaluations such as visual inspections, drift testing;
  - operational tools used (if any);
  - test fixtures, test fluids, and lubricants;
  - test approval by a qualified person other than the person performing the test.

## **B.6 Repair/Redress**

Packer repair and redress activities shall conform to the requirements and limits of Section 7, Section 8, and B.5.

Repaired packers shall be permanently marked to the requirements of 7.3 and with a “-R” after the design validation grade.

Documentation of the replaced and/or repaired components and all subsequent testing results shall be included in records traceable to the product assembly.

## **Annex C**

### **(normative)**

## **Requirements for HPHT Operational Tools**

### **C.1 General**

This annex includes the requirements for design verification (including interface capabilities), manufacturing, design validation, design evaluation, and reporting requirements for operational tools. These tools are identified in product data sheets or operating manuals for HPHT packers and bridge plugs. End connections of the tools are not included in the requirements of this annex.

These operational tools are required for the packer or bridge plug (primary product) to perform as designed.

Typically, operational tools include setting, running/pulling, and releasing tools. Not included in the requirements of this annex are contingency tools, milling tools, and destructive removal systems. These may be identified or referenced on the data sheet in the operating manual.

Validation grades do not apply to operational tools.

The activities required by this annex shall be performed by competent, qualified person(s). All results shall conform to the acceptance criteria and be supported by documentation.

Post manufacturing operational tool redress, repair, and servicing is not covered by this annex.

### **C.2 Design Verification**

Each operational tool design and its operational/interface capability shall be supported by design verification records/reports to the ratings of the tool. Reports shall be approved by the supplier's/manufacture's qualified person. Each tool's operational capabilities shall conform to the requirements of the functional specification of the primary product.

Design verification by evaluation shall include activities such as design reviews, design calculations, comparison with similar designs, and historical records of defined operating conditions. Verification results shall be approved and records of the results shall become a portion of the tools design documentation.

### **C.3 Design Validation Requirements**

#### **C.3.1 General**

Design validation of all features and capabilities shall be accomplished by evaluation or validation testing to the tools performance ratings and capabilities.

When previously validated tools from the primary product supplier/manufacture are specified, the interface and performance of the tool design may be validated by a review of reports of the tools testing and performance rating. The review shall be documented and approved by a qualified person of the supplier/manufacture.

The supplier/manufacture shall have on file material specifications and drawings that show all the applicable dimensions and tolerances of the components contained in the validation-tested or approved product.

Pre-test and post-test dimensional and visual inspection of critical operational areas, as determined by the supplier/manufacture, shall be conducted, documented, and maintained by the supplier/manufacture. The

assembly results and dimensional inspection results shall be approved by a qualified person other than the person performing them and records of the results shall become a portion of the design documentation.

All testing and evaluations shall be performed to documented procedures and acceptance criteria with approvals. Testing shall conform to the requirements of 7.2, 7.4.4.2.2, and 7.4.14 as applicable to requirements for operational tools.

### **C.3.2 Tools from Alternate Suppliers**

For tools provided by a supplier other than the primary packer or bridge plug supplier/manufacturer, the interface and performance of the tool design shall be validated by a review of reports of the tools successful testing or applicable use and performance validation ratings.

The review shall be documented and approved by a qualified person of the supplier/manufacturer. This report shall be retained in conformance with the requirements of 7.2.

### **C.3.3 Testing During Previous Packer or Bridge Plugs Validations**

An operational tool that has had all of its functional capabilities successfully validated to its ratings in the performance of packer or bridge plug validation testing (design validation of the primary product) shall be considered as meeting the requirements of this annex after the resulting documentation is approved by a qualified person.

Any operational capabilities that have not been validated during the packer or bridge plug validation testing shall be validated separately to the requirements of this annex.

### **C.3.4 Testing Requirements**

Testing equipment, fixtures (where applicable) and procedures shall conform to the requirements of Section 7. Design validations shall be performed with instruments which are calibrated to 7.4.14. All measurements for acceptance shall be within the calibrated range(s) of the testing equipment.

The design and performance of the test fixture shall replicate the interface of the operational tool within its designated packer or bridge plug and shall not influence the testing results. Design validation by testing shall be done with the entire packer or bridge plug or with a fixture with the equivalent fits, clearances and loads as the affected portion of the packer or bridge plug.

Validation testing shall be discontinued if the operational tool or its interface fails to perform within the limits specified, except, when such failures are determined to be a result of a failure within the test facility alone, and that failure and its correction do not affect the validity of the testing and its results.

During validation testing of hydraulically operated tools, fluid metering may be used to provide readable control signals during the testing if necessary to simulate downhole conditions.

### **C.3.5 Final Design Validation Report**

A final report of the design validations shall be prepared by a qualified person and approved by a qualified person other than the person who prepared the report. The report shall as a minimum include:

- testing location(s), date and person performing the testing;
- the tools unique identification, such as part number and serial number;
- procedures used and records required by those procedures;
- detailed results and discussion of results;

- remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test, etc.);
- results of specific evaluations such as; visual inspections, drift testing, scaling, material substitution reports;
- This report shall be retained in conformance with the requirements of 7.2.

## **C.4 Design Changes**

Design changes to a validated operational tool shall conform to 6.6.

## **C.5 Design Validation Scaling**

Design validation scaling shall conform to the requirements of 6.7.2. This scaling shall not be used to cover operational tools with higher pressure ratings, higher temperature ratings, a higher axial load ratings or a larger rating envelope than the validation tested product of the same family.

## **C.6 Manufacturing Requirements**

### **C.6.1 Quality Control**

#### **C.6.1.1 General**

Operational tools shall be manufactured to the requirements of 7.4 (as applicable) with a minimum of quality grade Q3.

#### **C.6.1.2 Assembly Requirements**

The assembly of the operational tool shall follow the supplier's/manufacturer's documented procedures utilizing components that conform to documented specifications. A bill of materials shall be prepared for each assembly.

#### **C.6.1.3 Functional Testing**

Each operational tool manufactured shall be functionally tested prior to shipment.

Operational tool assembly processing and functional testing shall conform to supplier's/manufacturer's documented procedures which shall include the requirements for the fluids, lubricants, methods, and acceptance criteria. A functional testing report shall be prepared for each operational tool successfully tested that includes as a minimum:

- the tools unique identification, such as part number;
- the procedure identification and records required by those procedures;
- results of the successfully completed functional test;
- the date and location of the testing and the testing results approval by a qualified person.

#### **C.6.1.4 Documentation, Data Control, and Operations Manual**

The documentation and data control for the operational tools shall meet the requirements of 7.2.1 and an operations manual per 7.2.2 shall be supplied with each operational tool.

### **C.6.1.5 Product Identification**

Operational tools shall be permanently and uniquely identified according to the supplier's/manufacturer's specifications. The supplier's/manufacturer's specifications shall define the type, method of application, and location of the identifications. The following information shall be included as a minimum:

- manufacturer's identification,
- manufacturer's product number,
- date of manufacture (month/year).

## **Annex D** (informative)

### **Requirements for External Flow Testing**

#### **D.1 Scope**

This annex defines the requirements for packer or bridge plug external flow testing.

NOTE External flow testing (sometimes called swab testing) simulates a condition that exists when an unset packer or bridge plug is moved through casing filled with fluid or when fluid is passed externally around a stationary packer or bridge plug inside a casing.

#### **D.2 General**

##### **D.2.1 Testing Requirements**

Each packer or bridge plug shall be tested within the limits specified in the external flow test procedure. The test results, design documentation and external flow ratings shall be maintained to the requirements of 6.2 as applicable. The supplier's/manufacture's external flow ratings shall be within the testing results recorded. The test procedures, testing results and ratings shall become a portion of the products design documentation.

##### **D.2.2 Personnel**

Preparation, testing, and approval of results shall be conducted by qualified personnel.

##### **D.2.3 Measuring and Monitoring Equipment**

Measuring and monitoring equipment used during the testing shall be calibrated to 7.4.14. All measurements for acceptance shall be within the calibrated range(s) of the testing equipment. All pressures are defined as gauge unless otherwise specified and shall be recorded on time based equipment. Flow rates shall be recorded on time based equipment.

The temperature shall be measured in the flow stream as close as practical to the packing element. The pressure shall be measured above and below the packing element as close as practical to the packing element.

##### **D.2.4 Procedures**

The supplier/manufacture shall develop procedures for conducting the external flow tests which shall be documented and included in the final report of the results. The procedures shall as a minimum include the parameters defined in D.3. The procedures shall include acceptance criteria.

#### **D.3 Test Parameters**

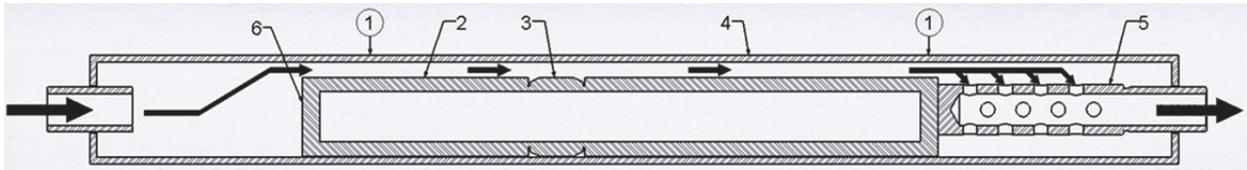
The external flow test shall be conducted with water or other liquid approved by a qualified person to the following test parameters:

- temperature: a minimum of 82.2 °C (180 °F);
- duration: a minimum of 2 hours at the supplier/manufacture defined maximum acceptable flow rate.

The functionally tested packer or bridge plug shall be installed in a section of casing/fixture with an ID equal to a minimum ID of the rated casing range  $\pm 0.762$  mm ( $\pm 0.030$  in.).

The actual ID of the test casing shall be recorded in the test report. The end of the test packer or bridge plug shall be closed to direct all flow entering the fixture to flow around the outside of the product.

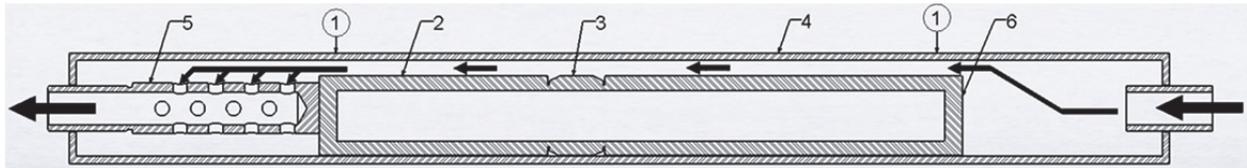
See Figure D.1 and Figure D.2 for an illustration of an example test fixture.



**Key**

- |                         |                                |
|-------------------------|--------------------------------|
| 1 pressure gauge        | 4 test chamber                 |
| 2 packer or bridge plug | 5 ported extension             |
| 3 packing elements      | 6 top of packer or bridge plug |

**Figure D.1—Test Setup for Flow Test from Above**



**Key**

- |                         |                                   |
|-------------------------|-----------------------------------|
| 1 pressure gauge        | 4 test chamber                    |
| 2 packer or bridge plug | 5 ported extension                |
| 3 packing elements      | 6 bottom of packer or bridge plug |

**Figure D.2—Test Setup for Flow Test from Below**

The packer or bridge plug shall be decentralized in the fixture so that one side of the product rests on the ID of the test fixture.

Two or more tests shall be run using a new packing element of the same part number, material specification and construction for each test. Each test shall consist of a flow test from above and below. The test procedure shall define the direction(s) of flow.

Before and after each testing session perform a visual and dimensional inspection according to documented procedures with qualified persons. Document the observations and include the findings in a report.

## D.4 Test Processes

Conduct the external flow testing according to the following steps.

- 1) Place the packer or bridge plug into the test fixture horizontally.
- 2) Secure the test fixture and attach the flow lines to each end of the fixture.
- 3) The water shall be a minimum of 82.2 °C (180 °F).

- 4) Direct the heated water through the fixture starting at 79 L/min (0.5 bpm) or the supplier/manufacture defined starting flow rate, while monitoring pressure drop across the packing element for a minimum of 5 minutes.
- 5) Increase the flow rate by 79 L/ min (0.5 bpm) every 5 minutes until the external flow rate meets or exceeds the supplier/manufacture defined maximum external flow rate.
- 6) Pump the heated water through the test fixture for a minimum of two hours at the defined rate.
- 7) The test is concluded when the pressure or flow rate meets the supplier's/manufacture's stated acceptance criteria.
- 8) Repeat steps 1 through 7 from the opposite direction of flow.

## **D.5 Report**

A test report shall be prepared that includes, as a minimum:

- identification of tool tested including, unique identifier and serial number as applicable;
- date and location of testing;
- procedures utilized and records required;
- identification of personnel performing the test;
- results of testing including comparison to the supplier/manufacture acceptance criteria and discussion of the pertinent results;
- approvals from a qualified person;
- bill of materials and component's traceability records;
- representative casing size(s) and weight/mass(s), measured ID;
- remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test, etc.).

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