Openhole Isolation Equipment

API SPECIFICATION 19OH
SECOND EDITION, 2026

Ballot Draft

Introduction

This Specification has been developed by users/purchasers and suppliers/manufacturers of openhole isolation equipment 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 openhole isolation equipment. Further, this Specification addresses supplier/manufacturer requirements that set the minimum requirements with which suppliers/manufacturers 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 for openhole isolation equipment.

This edition has been completely revised. Design validation grades V1 to V4 (removed OH prefix) are new 2nd edition grades. The new V1 grade is not equivalent to V1-OH from 1st edition due to new temperature test cycle requirements. Legacy V1-OH can be validated to V2 if new annex requirements are met. Other changes include cold temperature validation requirements, optional axial load and combined testing, updated quality levels and materials specs, and added further definition to common openhole tests (e.g., ovality, mass loss testing). The new edition also covers chemically reactive packers, expandable packers, cup-style packers, and openhole anchoring devices.

The quality levels have changed to QL2 and QL1. Quality level QL2 is the minimum level of quality offered by this product standard. Quality level QL1 is the highest level provided. Additional materials and quality requirements may be specified by the user/purchaser as supplemental requirements.

Requirements outside those outlined in this Specification may be needed for individual applications. This Specification is not intended to inhibit a supplier/manufacturer from offering, or the user/purchaser from accepting, alternative equipment or engineering solutions. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the supplier/ manufacturer can identify any variations from this Specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process. This Specification was initiated utilizing information provided by the Advanced Well Equipment Standards Group RP 3362.

Openhole Isolation Equipment

1 Scope

This Specification covers requirements and guidelines for openhole isolation equipment: swellable packers, inflatable packers, expandable packers, chemically reactive, openhole bridge plugs, and openhole packers that are designed for use in the petroleum and natural gas industries.

This Specification provides requirements for design verification, design validation, manufacturing, quality, shipping, handling and storage, and related supporting topics.

This specification also covers:

— Validation Test Requirements for Inflatable, Expandable, Openhole Mechanical Packers and Bridge Plugs

— Validation Test Requirements for Swellable and Chemically Reactive Packers

— Combined Load Testing

— Swell Rate and Axial Load Testing for Swellable Packers

— External Flow Testing

— Mass Loss Testing

— Gas Testing

— Minimum Hole Size Testing

The following are not covered in this specification:

— Requirements for the end connections to the well conduit

— Unsupported casing or tubing applications

— Production packers, liner hanger systems, service tools, and test tool packers

2 Normative References

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

ANSI [1]/NACE MR0175 [2]/ISO 15156 [3], *Petroleum and natural gas industries—Materials for use in H2S-containing environments in oil and gas production*

API Spec 5CRA, *Specification for Corrosion Resistant Alloy Seamless Tubes for Use as Casing, Tubing and Coupling*

[1] American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

[2] NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

[3] International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

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

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

ASNT RP SNT-TC-1A[4], *Personnel Qualification and Certification in Non-Destructive Testing*

ASTM D412[5], *Standard Test Methods for Vulcanized and Thermoplastic Elastomers—Tension*

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

D638, *Standard Test Method of Tensile Properties of Plastics*

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

ASTM D1415, *Tentative Method of Testing for International Hardness of Vulcanized Natural and Synthetic Rubbers*

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

ASTM D2140, *Standard Practice for Calculating Carbon-Type Composition of Insulating Oils of Petroleum Origin*

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

ISO 37[6], *Rubber, vulcanized or thermoplastic—Determination of tensile stress–strain properties*

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*

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

SAE AMS-2750, Pyrometry

3 Terms, Definition, Abbreviations and Symbols

3.1 Terms and Definitions

For the purposes of this document, the terms and definitions given in API Q1 and the following apply.

3.1.1
assembly
Product comprised of more than one component.

3.1.2
base elastomer

[4] American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York, 10036.
[5] American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohoken, PA 19427-2959.
[6] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Genevea 20, Switzerland.

An elastomer family of materials with common property limits such as HNBR, FKM, EPDM.

3.1.3
base elastomer formulation
A base elastomer mixed with additives to achieve physical properties that enhance performance.

3.1.4
chemically reactive packer
A packer assembly with non-elastomeric element(s) which chemically react with a setting fluid to form a compound which has substantially higher volume than the original element.

NOTE This type of packer may provide both zonal isolation as well as axial anchoring capabilities

3.1.5
component
An individual part of an assembly.

3.1.6
conduit
Casing, tubing, or liner, either metallic or nonmetallic

3.1.7
design margin
Ratio of the material minimum yield stress divided by the actual design stress in a component at the rated conditions.

3.1.8
design validation
Process of proving a design by testing to demonstrate conformity of the product to design requirements.

3.1.9
design verification
Process of examining the result of design or development output to determine conformity with specified requirements.

3.1.10
element
Single or multiple conformable sealing components

NOTE Element may include spacers and extrusion controlling components that create a sealing unit assembly. It provides isolation of fluid communication through the annular space between the conduit and openhole.

3.1.11
expandable packer
Downhole device designed to isolate fluids in the annular space between a conduit and the openhole that is activated (expanded) by the deformation of an integral structure.

3.1.12
extrusion controls
Device engineered to reduce the extrusion gap between sealing surfaces.

3.1.13
fixed
Prevented from movement in all directions.

3.1.14
functional test (testing)
Post-manufacturing evaluation of a product to defined procedures and acceptance criteria.

3.1.15
heat
Material originating from a final melt or cast lot having the same chemistry.

NOTE For re-melted alloys, the heat is the raw material originating from a single re-melted ingot.

3.1.16
heat traceable
Traceable to a unique heat treatment and heat of material.

3.1.17
heat treatment
heat treating
Heating and cooling a solid metal or alloy in such a way as to obtain desired properties.

NOTE Heating for the sole purpose of hot working is not considered heat treatment.

3.1.18
heat treat lot
Group or quantity of piece parts, sub-assemblies or assemblies that are grouped or processed together during the heat treatment process.

3.1.19
inflatable packer
Downhole device designed to isolate fluids in the annular space between a conduit and the openhole that is activated (expanded) by the selective addition of pressure within a compliant chamber.

3.1.20
job lot
Batch of material or components that have undergone the same process or series of processes as a single production lot.

3.1.21
job-lot traceable
Parts identifiable as originating from specific job lot that designates the included heat(s) and Heat Treat Lots.

3.1.22
material test report
Traceable records of the measured material properties of a component, derived in a defined manner at a defined point in time.

31..23
non-destructive examination
Inspection or review activity applied to a component or assembly that compares the results to a defined requirement without damage to the product or component.

3.1.24
open hole
A wellbore with no casing or liner in place across the formation surfaces.

3.1.25
openhole bridge plug
Mechanical device used for blocking fluid (liquid or gas) communication within the open hole when installed (not installed in a design receptacle or conduit).

3.1.26
openhole mechanical packer
Downhole device designed to isolate fluids in the annular space between a conduit and the open hole that is activated (expanded) by the application of force to an integral mechanism. This includes cup-style packers.

3.1.27
ovality
Defined by the ratio of the major axis hole diameter and the minor axis hole diameter.

EXAMPLE Gauge diameter of an 8.5” open hole with washout in the major axis of 9.5” results in an ovality of 1.12; 9.5 ÷ 8.5 = 1.12 ovality.

NOTE Figure 1 illustrates different openhole conditions with corrresponding major and minor axis used for calculating ovality.

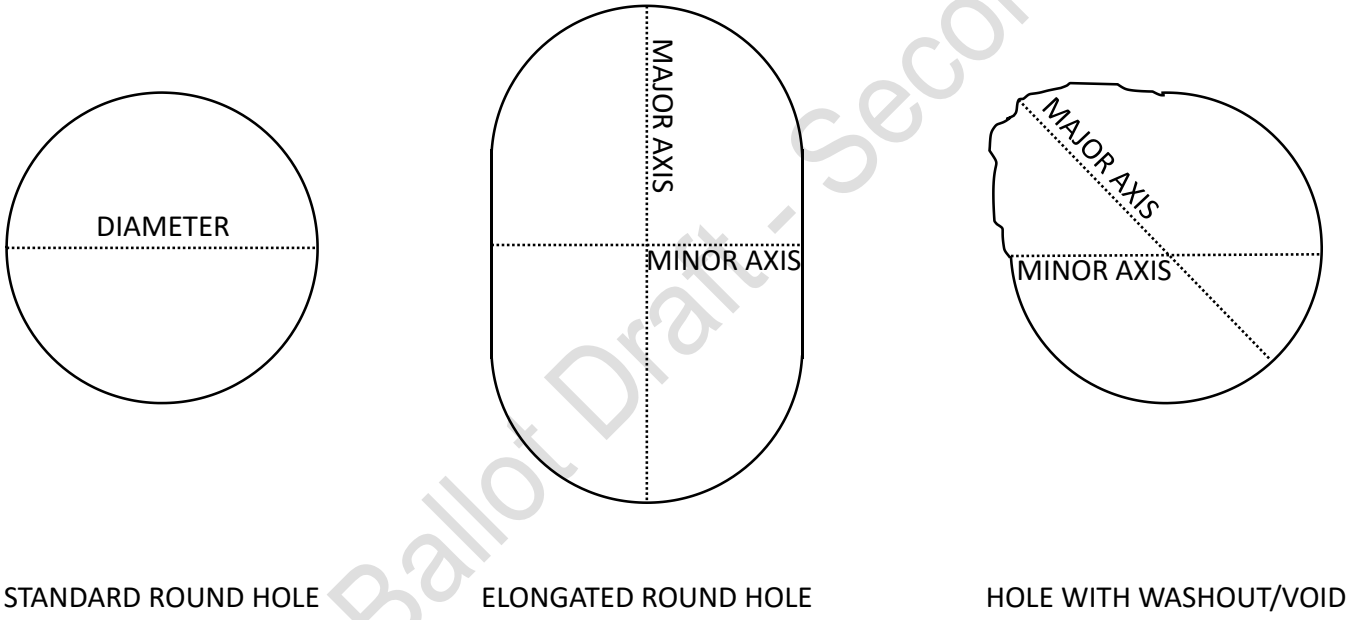


Figure 1—Openhole Ovality Definitions

3.1.28
packer
Device with a element, not installed in a designed receptacle, used for blocking fluid (liquid or gas) communication through the annular space between conduits by sealing the space between them.

3.1.29
packer mandrel
Tubular component(s) within a packer that contain the end connections and provide a conduit through the packer.

3.1.30
performance envelope
Graph that illustrates the combined effects of differential pressure and axial loads on a product at the rated temperature

3.1.31
pressure reversal
Change in the direction of the pressure differential across the element from above to below or vice versa.

EXAMPLE Testing an element from above and subsequently testing from below constitutes one pressure reversal.

3.1.32
product
Within this specification, the term product is used to indicate both packers and bridge plugs

3.1.33
product type
A product where the design principles for the materials and functionality are the same, including sealing and setting mechanism.

EXAMPLE Slip-on swellable packers and bonded swellable packers are two different product types.

3.1.34
product assembly
Group of individual components that create a complete functional product for the various tests described in this specification.

3.1.35
qualified part
Part manufactured under a recognized quality assurance program to meet the design and performance of the original part.

NOTE ISO 9001, API Spec Q1, and ISO TS29001 are examples of a recognized quality assurance program .

3.1.36
qualified person
Individual with characteristics or abilities gained through training, experience, or both, as measured against established requirements that enable the individual to perform a required function effectively.

NOTE Established requirements can include standards or tests

3.1.37
redress
Any activity involving the replacement of qualified parts

3.1.38
repair
Any activity beyond the scope of redress that includes disassembly, reassembly, and testing with or without the replacement of parts.

NOTE Repairs may include machining, welding, heat treating, or other manufacturing operations that restore the equipment to its original performance

3.1.39
restrained
Prevented from movement in all or certain axis directions.

3.1.40
scaling
The ability to validate a design by referencing the design validation conducted on a representative design of the same

product type and family.

3.1.41
setting method
The design methodology and tools necessary to activate the packer to its fully implemented condition.

3.1.42
substantive change
Change to the design or components within the design, identified by the supplier/manufacturer, that may affect the performance of the product in the intended service condition.

3.1.43
swellable packer
Downhole device designed to isolate fluids in the annular space between a conduit and the openhole that is activated (expanded) by the contact of a specified fluid.

3.1.44
temperature-cycle range
Specified amount of temperature change within the product's temperature range over which the product is validated.

NOTE The temperature-cycle range is validated for V1 and V2 per Annex A and Annex B, and is applicable anywhere within the product's temperature range. (Refer to 6.3.3.2).

3.1.45
temperature range
Designates the overall range of minimum and maximum temperatures over which the product is designed to operate.

NOTE The temperature range can be defined by more than one temperature-cycle range; (Refer to 6.3.3.2)

3.1.46
temperature profile
Time-based profile map which shows temperature variation to simulate anticipated downhole conditions during specific well completion operational stages

3.1.47
Type 1 component
Metallic component or weld that isolates pressure and/or may be loaded in tension as the result of axial loads applied during run-in, setting, in use, or retrieval.

3.1.48
Type 2 component
Metallic component or weld that is not classified as Type 1.

3.1.49
volume swell (swell)
The change in cross-sectional area per unit of length of a swellable element in which the inner diameter of the element (mandrel OD) remains unchanged.

3.2 Abbreviations and Symbols

AQL	acceptance quality limit
COC	certificate of compliance
DP	differential pressure
EPDM	ethylene-propylene-diene-monomer
FKM	fluoroelastomers
HNBR	hydrogenated nitrile butadiene rubber
ID	inside diameter
L_1	length of validated packer #1
L_2	length of validated packer #2
L_i	scale packer validated length
MTR	material test report
NDE	non-destructive examination
OD	outside diameter
QC	quality control
UNS	unified numbering system
X_1	validated hole size packer #1
X_2	validated hole size packer #2
X_i	scaled packer validated hole size
Y_1	validated differential pressure rating of packer #1
Y_2	validated differential pressure rating of packer #2
Y_i	scaled packer validation differential pressure rating

4 Functional Requirements

4.1 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/manufacturer's specific product. These requirements and operating conditions may be conveyed by means of a dimensional drawing, data sheet, or other suitable documentation. If not provided, the supplier/manufacturer shall generate a functional specification.

NOTE The supplier/manufacturer can generate internal requirements for products as the user/purchaser.

4.2 Type Description

The functional specification shall specify the following products:

a) inflatable packers,

b) expandable packers,

c) openhole mechanical packers, (e.g., compression-set and cup-style packers)

d) swellable packers (water or oil [hydrocarbon] or both).

e) chemical reactive packers

4.3 Well Parameters

The functional specification shall specify, as applicable, the following well parameters:

a) anticipated openhole size at projected setting depth;

b) dimensions, material, grade of the casing and tubing;

c) end connections above/below the product;

d) well angle from the vertical at the setting position of the product;

e) deviations, dog-leg severity, and restrictions through which the product is required to pass (dog leg, milled window);

f) lines (electrical/hydraulic/other) that are required to pass through or bypass the product;

g) expected minimum and maximum values of production/injection pressures, pressure differentials, temperatures, changes in temperatures, and flow rates;

h) any other relevant well parameter(s), such as expected well ID ovality, washout, expected openhole size range, and allowable setting stress.

NOTE A well schematic can be useful to identify many well parameters and related well equipment.

4.4 Operational Parameters

4.4.1 The user/purchaser should specify, as applicable, the following operational parameters:

a) installation method, including conveyance method, such as tubing, wireline, tractor, or coil tubing;

b) setting method and allowable pressures during setting;

c) anticipated running/pulling speed(s);

d) activation method and/or fluids

e) desired time to set;

f) setting depth, time duration and temperature exposures to reach that depth;

g) retrievable requirement;

h) anticipated loading conditions/ temperature cycles during the life of the well, including combined loading (pressure, tension/compression) and torque, applied prior to and during setting and use;

i) dimensions, type and configuration of devices to be run through (such as internal profile(s)), or over the packer or bridge plug;

j) lost circulation zone(s)

k) flow rates, exposure time, and composition of fluids which are pumped past the element prior to setting

l) 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;

m) well cementing operations, including its parameters, such as cement types and volumes, spacers, plugs, pressure, flow rates, and top of cement;

n) 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;

o) intended removal and/or milling operations;

p) service life;

q) any other relevant operational parameter(s).

NOTE Annex C provides information on combined load testing and axial loading. Annex E provides information on the external flow testing. Annex F provides information on mass loss testing.

4.4.2 If, due to the operational parameters, material qualifications are required outside of or in addition to NACE MR0175/ ISO 15156 or another specified material standard, the user/purchaser shall specify the following:

a) test method(s),

b) design basis/test environment conditions,

c) test acceptance criteria.

4.5 Environmental Compatibility

4.5.1 General

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, the user/purchaser shall state to the supplier/manufacturer which material(s), metals or nonmetals, has/have the ability to perform as required. If the user/purchaser does not provide the material selection to the supplier/manufacturer, the material compatibility shall be determined according to 4.5.2

4.5.2 Well Environment

If the user/purchaser does not provide the material selection, the functional specification shall specify, as applicable, the following well environment parameters:

a) completion and packer fluid composition, pH, and existence of bromides (Zn, Ca, Na), formates (Cs, K, Na), chlorides (K, Ca, Na), and 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):

i. oxygen scavenger systems;

ii. emulsifier systems;

iii. continuous or batch treatment;

iv. chemical composition of fluid exposures;

v. duration and temperature of exposure.

e) produced fluid information;

NOTE Produced fluids such as oil, gas, water, water cut, and concentrations of CO and HS.

f) injected fluid information;

NOTE Injected fluids such as water, pH, inhibitors, and oxygen levels.

g) NACE service environmental and metallurgical limits.

4.5.3 Material Designation

4.5.3.1 If the user/purchaser chooses to specify a service environment for metallic materials, the following designations may be used:

a) standard service;

b) NACE service;

c) NACE service flow-wetted type 1 components;

d) NACE service internally wetted type 1 components;

e) NACE service exposed type 1 components.

NACE MR0175 requirements only apply to metallic materials; consideration should be given to nonmetallic materials separately.

4.5.3.2 Metallic material selection may be made for a group of components using the following designations:

a) flow-wetted components;

b) internally wetted components;

c) exposed components;

d) other components.

4.5.4 Material Evaluation

The user/purchaser may specify material testing on metallic materials (see 5.3.2.2).

The user/purchaser may specify compound evaluation on nonmetallic materials (see 5.3.2.4).

4.6 Design Validation

The user/purchaser shall specify the required design validation grade. This specification provides four validation grades V1, V2, V3, and V4 as defined in 5.5 and covered in Annex A and Annex B.

4.7 Quality Control

The user/purchaser shall specify the required level. This specification provides two quality levels (QL2 and QL1) of quality control. When no quality level is selected by the user/purchaser, see 6.4.2

5 Technical Specification

5.1 General

5.1.1 The supplier/manufacturer shall prepare and provide to the user/purchaser the technical specification that demonstrates that the equipment meets the requirements of the functional specification.

5.1.2 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 that has been validated. Products that are validated by design scaling shall also conform to the scaling requirements in 5.7. 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 ~~to~~ the user/purchaser the product data sheet as defined in 6.2.3.

5.1.3 The 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).

5.2 Technical Characteristics

The product shall be designed to perform in accordance with the functional specification and the defined technical characteristics during installation, activation, and operation.

5.3 Design Requirements

5.3.1 General

5.3.1.1 If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, the user/purchaser shall state to the supplier/manufacturer which material(s), metals or nonmetals, has/have the ability to perform as required. If the user/purchaser does not provide the material selection to the supplier/manufacturer, the material compatibility shall be determined according to 4.5.2

5.3.1.2 Each packer or bridge plug design shall be analyzed and verified to determine the supplier/manufacturer's performance ratings. The minimum material condition and minimum material yield strength shall be used in the calculations. Temperature de-rating of material capabilities shall be utilized where applicable as defined by the supplier/manufacturer procedures. Metal mechanical properties de-rating shall be verified and documented by a qualified person.

5.3.1.3 The following information should be considered when establishing the design requirements for the tool: fluid density, chemical/physical composition, including solids (sand production, scale, salinity), liquid, and/or gaseous, to which the openhole device is exposed during each portion of its expected life cycle. Fluid exposure durations,

temperatures, and pressures should be included along with chemical stimulation and changes in composition over time.

5.3.1.4 The supplier/manufacturer shall apply a design margin to each metallic 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.

5.3.1.5 Elements shall be designed according to the supplier/manufacturers written procedures, which shall address:

a) compatibility with anticipated well fluids;

b) swell fluids for swell rate, if applicable;

c) differential pressure ratings at the defined OH size;

d) temperature ratings.

5.3.1.6 For single component mandrels utilizing material conforming to API 5CT or API 5CRA, the published performance ratings of the product can only be used as the ratings of the openhole isolation device where the validated rating of the element meets or exceeds the ratings of the API 5CT or API 5CRA product. The differential pressure ratings of the openhole isolation device shall not exceed the same differential pressure ratings of the pipe body for single component mandrels.

NOTE The intended applications of openhole devices may consider potential openhole conditions and durations, such as: ovality, straightness, or washouts, that may be encountered in openhole conditions.

5.3.2 Materials

5.3.2.1 General

5.3.2.1.1 Materials and/or the service environment designation (see 4.5.3.1) being provided shall be stated by the supplier/ manufacturer and shall be suitable for the environment specified in the functional specification. The supplier/ manufacturer shall have documented specifications for all materials used. All materials used shall conform to the supplier/manufacturer-documented specifications.

5.3.2.1.2 All components/materials used in tested or delivered equipment, except common hardware that do not affect the performance (such as nuts, bolts, set screws, and spacers), shall be verified as conforming to documented requirements.

5.3.2.1.3 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 material identified shall have performance characteristics for all parameters specified in the well and production/ injection parameters.

5.3.2.1.4 Material substitution is a temporary change to a production bill of material for a validated component which does not change the rating of the product. These temporary material substitutions are allowed without re-validation when they meet the requirements of Sections 4 and 5. The supplier/manufacturer's selection criteria for these substitutions shall be documented and the substituted material shall conform to the design, functional, and technical requirements of the component/equipment.

5.3.2.1.5 Material substitutions require approval by a qualified person from the supplier/manufacturer and the supporting documentation incorporated into the manufacturing records for those units affected. In cases where the user/purchaser specifies material(s) of construction, deviations from such materials shall require user/purchaser notification and approval.

5.3.2.2 Metals

5.3.2.2.1 The supplier/manufacturer's specifications for type 1 components shall define those characteristics critical to the performance of the material, such as the following:

a) chemical-composition limits;

b) melting practice;

c) heat treatment and/or cold work condition;

d) reduction ratio (RR);

e) mechanical-property limits, as applicable:

   i. tensile strength;

   ii. yield strength;

   iii. elongation;

   iv. reduction of area (ROA);

   v. hardness;

   vi. Charpy impact toughness/test temperature.

NOTE Test methods are defined in section 6.

NOTE Materials loaded primarily in compression typically do not have design requirements for yield strength, tensile strength, or elongation.

5.3.2.2.2 Specified mechanical properties shall be determined by tests conducted on a representative sample from the same heat (such as prolongation or sacrificial part). The material test sample shall experience the same thermomechanical processing and be heat treated with the same material it represents. For remelt materials the sample shall be from the same final remelt heat. The mechanical property results shall be documented on a certified material test report (MTR).

5.3.2.2.3 Separate test pieces removed prior to heat treatment may be utilized as representative samples with a documented and validated test procedure, when permitted by applicable specifications or by the equipment user.

5.3.2.2.4 When compliance to NACE MR0175 is specified, the metallic materials and weldments shall conform with the material requirements of NACE MR0175 (as applicable).

NOTE 1 Castings: When pressure-containing castings are employed, the specification of API 20A can provide guidance.

NOTE 2 Fasteners: When load-bearing bolting materials are employed, the specification of API 20E (alloy and carbon steel bolting) or API 20F (corrosion-resistant bolting) can provide guidance.

5.3.2.2.5 The mechanical properties shall be determined by the test methods listed in Section 6.

5.3.2.3 Castings

Castings, when used for type 1 components, shall conform to documented verification and validation requirements defined by the supplier/manufacturer. These requirements shall include the following with acceptance criteria:

a) a qualification casting,

b) microstructure evaluation of the qualification casting,

c) defined chemistry limits,

d) volumetric NDE of the qualification casting,

e) visual and dimensional inspections.

NOTE API 20A provides general guidance for casting process qualification

5.3.2.4 Non-metals

5.3.2.4.1 General

The supplier/manufacturer-documented specifications for nonmetallic compounds shall include:

a) the approved compound(s)

b) characteristics critical to the performance of the product;

c) handling, packaging, and storage requirements;

d) labeling requirements, including:

i. material type;

ii. cure date;

iii. batch number;

iv. material identification;

v. shelf life or expiration date.

The supplier/manufacturer shall have written specifications for nonmetallic components that define those characteristics critical to the performance of the material.

The applicable elastomeric and thermoplastic parameters shall be determined by the specifications listed in Table 7 for elastomers and thermoplastics or by an equivalent international standard. The specification shall state if the parameters are measured on actual components.

The supplier/manufacturer shall have documented procedures, including acceptance criteria, for evaluation or testing non-metal materials (e.g. polymeric seals) to the limits for which the component is rated.

5.3.2.4.2 Elastomeric Compound Assessment

Assessment of elastomeric compounds should take into consideration:

a) If required in the functional specification, an ageing evaluation shall be conducted by the supplier/manufacturer to evaluate the cumulative effects of an environment on an elastomeric material per ISO 23936-2, clause on “requirements for aging tests” or in accordance with the supplier/manufacturer’s documented testing procedure compliant to an industry specification and agreed to by the user/purchaser. This evaluation may include the determination of potential service life. The exposure test temperatures shall

meet or exceed the maximum rated operating temperature of the equipment.

Fluids and other test conditions such as temperature and pressure, as well as boundary condition for material coupons, shall be agreed between the equipment purchaser and the equipment supplier. A standard simulated production fluid for either sweet or sour, either single phase or multiphase are listed in ISO 23936-2 and can be referred for conducting compound qualification test. If not specified, the acceptance criteria for the ageing test shall meet ISO 23936-2 .

The test condition shall not introduce different degradation mechanism at elevated temperatures, it may require longer testing time to reveal or prove long term performance of a compound if testing at elevated temperatures introduces a different degradation mechanism (e.g. thermal degradation) compared to what is expected at the application temperature. Excessively high temperature could introduce thermal degradation deteriorate the material beyond chemical reaction. Exposure to higher temperature could activate chemistry between material and aging medium that would not be present in well condition.

b) If required in the functional specification, a rapid gas decompression evaluation shall be conducted by the supplier/manufacturer on an elastomeric material per ISO 23936-2. The recommended acceptance criteria shall be a rating of 0 or 1 for the seal component cross section if user/purchaser does not specify an acceptance criterion. Fluid composition, test temperatures, test pressures, and depressurization rate shall be specified in the user/purchaser functional specification.

NOTE Specific grades of elastomers and raw materials used to make elastomers can affect their environmental resistance and performance.

Caution should be exercised for the following aspects:

i. Test temperature and duration are sufficient to demonstrate real trends.

ii. Samples are fully saturated in target aging fluid before chemical aging begins.

iii. Samples were properly cured or vulcanized before aging data is used for life prediction.

c) The appropriate mechanical property is used for lifetime prediction. The test condition shall not introduce different or unexpected degradation mechanism at elevated temperatures. It may require longer testing time to reveal or prove the long-term performance.

5.3.2.4.3 Thermoplastic Compound Assessment

Assessment of thermoplastic compounds shall include:

a) If required by the user/purchaser, an aging evaluation shall be conducted by the supplier/manufacturer to evaluate the cumulative effects of an environment on the thermoplastic per the supplier/manufacturer's documented testing procedure compliant to an industry specification and agreed to by the user/purchaser. This evaluation may also include the determination of an effective service life. The service temperature shall meet or exceed the maximum rated operating temperature of the equipment,

b) Fluids and other test conditions including temperature, pressure, and boundary conditions of material coupons, shall be agreed between the equipment purchaser and the equipment supplier. A standard simulated production fluid for either sweet or sour, either single phase or multiphase are listed in ISO 23936-1 and can be referred for conducting compound qualification test. The acceptance criteria for the aging test shall be agreed between the parties.

Caution should be exercised for the following aspects:

i. Test temperature and duration are sufficient to demonstrate real trends

ii. Samples are fully saturated in hydrocarbon fluid before chemical aging begins

iii. Samples are in a stable state of crystallinity before aging data is used for life prediction

c) The appropriate mechanical property is used for lifetime prediction. The test condition shall not introduce different degradation mechanism at elevated temperatures. It may require longer testing time to reveal or prove the long-term performance.

5.3.2.4.4 Substrate Bonding and Strength Validation (Bonded Seals)

Nonmetallic seal components may be bonded to substrates for additional reinforcement or to perform other functions. If the bond of the nonmetallic to the substrate is critical to performance, the integrity of the bond shall be evaluated in the same manner as the performance of the seal component itself per the supplier/manufacturer's defined methods and acceptance criteria. The allowable failure modes, percentage of bonding and/or adhesion strength shall be defined by the equipment supplier/manufacturer. If required by the user/purchaser in the functional specification, a temperature/chemical ageing evaluation on the bond line strength shall be conducted.

NOTE ASTM D429 and ASTM D413 provide methods for adhesion testing.

Substrate metals shall conform to the requirements for metallic components; non-metallic substrates shall conform to the requirements for non-metallic components.

For designs requiring that the elastomers be bonded to a substrate, the adhesive bonding process shall be defined and validated with a bond test. The process validation criteria shall include controls for the elastomer, substrate, adhesives, and any required environmental controls. The bond test shall conform to the requirements of ASTM D429 or an equivalent referenced testing program including surface preparation requirements, with evaluated and documented acceptance criteria. A minimum of three representative bonded samples shall be evaluated and all samples shall conform to the defined acceptance criteria.

Substantive changes, identified by a qualified person, to the elastomer, substrate, adhesive, or environmental limits shall require a new validation.

5.3.3 Design Ratings

5.3.3.1 General

The supplier/manufacturer shall state the pressure, temperature, performance ratings, and hole size as applicable for the isolation device design. V1 designs require the identification of temperature range and temperature-cycle range.

Design ratings for swellable packers shall also include the required time (soak time) to achieve the rated values recorded separately per supplier/manufacturer's documented procedures.

5.3.3.2 Temperature-Cycle Range and Temperature Range

Figure 2 is an illustration of the temperature-cycle range (3.44), which is the temperature change over which the product is validated and the temperature range (3.45), which designates the overall range of minimum and maximum temperatures over which the product is designed to operate. Figure 3 shows an example of validation of tested Temperature Range and Temperature-Cycle Ranges in a product.

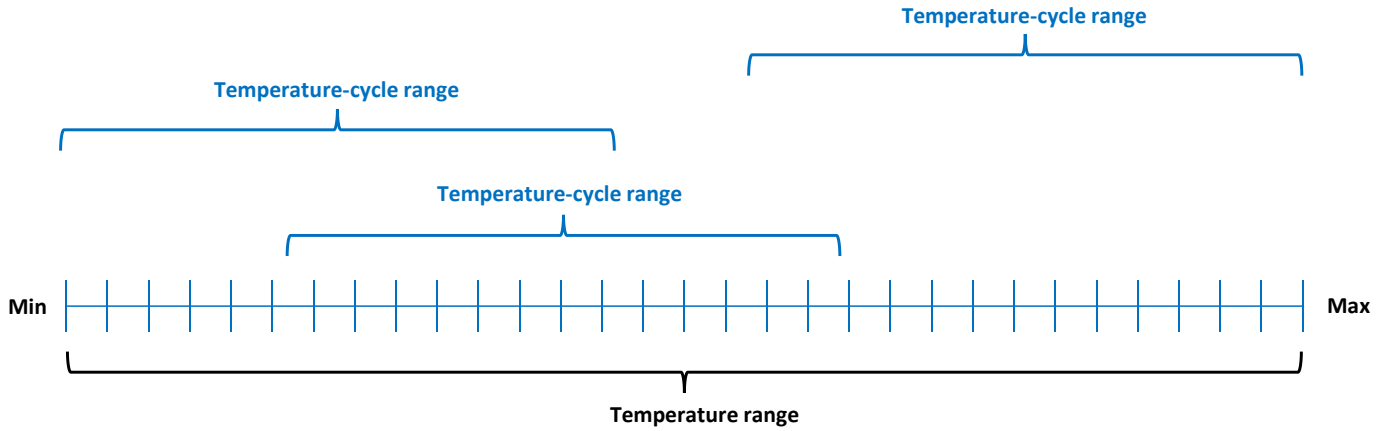


Figure 2—Illustration of use cases of rated Temperature-Cycle Range within the rated Temperature Range of a Product

The following shall apply:

a) There shall be only one rated temperature-cycle range and only one rated temperature range for a validated product.

b) If the product's temperature range cannot be validated using one temperature-cycle range, more than one temperature-cycle range tests shall be performed to cover the full temperature range. The rated temperature-cycle range of the product is the smallest of the temperature-cycle range tests achieved during validation of the specified product.

NOTE: temperature-cycle range may be equal to the temperature range when validated accordingly.

EXAMPLE A product was tested multiple times under the requirements of V1 validation testing with the following temperature-cycle ranges achieved: 50 °F to 200 °F and 250 °F to 350 °F. The rated temperature range of the product is 50 °F to 350 °F, and the rated temperature-cycle range is 100 °F. The product is validated for use in a well completion application where the maximum temperature will not exceed 350 °F, the minimum temperature will not exceed 50 °F, and maximum temperature change of the product in the wellbore will not exceed 100 °F.

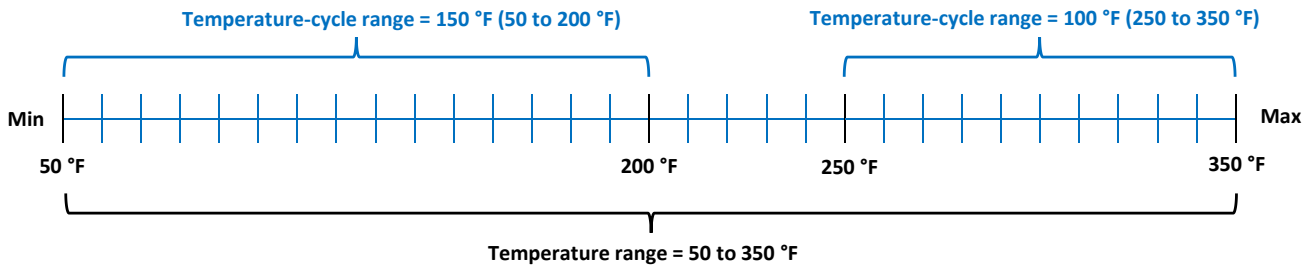


Figure 3—Example of validation of tested Temperature Range and Temperature-Cycle Ranges in a Product.

5.4 Design Verification

5.4.1 Design verification shall be performed to ensure that each product design meets the supplier/manufacturer

technical specifications. Design verification may include activities such as design reviews, design calculations, and comparing the new design with similar proven designs (see API Q1).

5.4.2 The minimum material condition and minimum material yield strength, including the applicable temperature de-rating, shall be used in the calculations.

5.4.3 If corrosion or corrosion/erosion allowances are included in the design, the design verification and validations shall consider these allowances.

5.4.4 Verification results shall be approved by a qualified person, and records of the results shall become a portion of the design documentation.

5.5 Design Validation

5.5.1 General

5.5.1.1 There are four grades of design validation for which the product shall be supplied. Products shall conform to the requirements of the design validation grade. Packers or openhole bridge plugs utilized for design validation shall conform to the requirements of 5.3 and Section 6. Testing shall be performed on calibrated equipment (see 6.13.4) by a qualified person, results shall be documented and approved by a qualified person, and records of all the validation results shall become a portion of the design documentation.

5.5.1.2 The supplier/manufacturer shall document the validation test procedures, testing results, material specifications, drawings, applicable dimensions, and tolerances of parts contained in the validation tested product.

5.5.1.3 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.

5.5.1.4 Validation test results and dimensional inspection results shall be approved by a qualified person other than the person performing the activities and the results shall become a portion of the design documentation.

5.5.1.5 The validation grades listed below are as follows:

— V4: supplier/manufacturer defined testing processes that support the stated ratings;

— V3: liquid test at maximum rated temperature;

— V2: liquid test with temperature range;

— V1: liquid test with temperature cycling.

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

Table 1—Design Validation Grade Hierarchy

Design Validation Grade	Grades Covered
V1	V1 , V2, V3, V4
V2	V2, V3, V4
V3	V3, V4
V4	V4

5.5.1.7 Products that were previously validated in accordance with 1st edition of API 19OH that are being considered to meet the requirements of the 2nd edition validation grades (V1 through V4) shall meet the 2nd edition requirements, with additional validation performed as necessary and results documented and approved by a qualified person. Table 2 lists the validation requirements and corresponding annex per Product family. Table 3 summarizes informative testing.

EXAMPLE If a V1 OH product from API 19OH 1st edition is evaluated against the requirements of API 19OH V2 2nd Edition and found to be in conformance, this evaluation is then documented and approved, and the product is designated as V2 grade from the API 19OH 2nd edition.

5.5.1.8 The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to the validation grade.

Table 2—Annex and Validation Requirements per Product Family

Product Family	Validation	Annex
Inflatable, Expandable, Openhole Mechanical Packers and Bridge Plugs	V1, V2, V3, V4	Annex A (normative)
Swellable and Chemically Reactive Packers	V1, V2, V3, V4	Annex B (normative)

Table 3—Summary of Optional Testing

Test Type	Annex
Combined Load Testing	Annex C (informative)
Additional Testing for Swellable Packers	Annex D (informative)
External Flow Testing	Annex E (informative)
Mass Loss Testing	Annex F (informative)
Gas Testing	Annex G (informative)
Minimum Hole Size Testing	Annex H (informative)

5.5.2 Common Validation Requirements

5.5.2.1 General

The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to the validation grade.

5.5.2.2 Validation Testing

The supplier/manufacturer shall meet the validation test requirements of Annex A or Annex B to the selected validation grade.

5.5.2.3 Validation Test Fixture

The following requirements apply to the test fixture:

a) Validation testing shall be performed within a test fixture that is designed to have no outer diameter (OD) plastic deformation at the planned test or proof test pressures.

NOTE: Unsupported casing or tubing applications are outside the scope of this specification and can require analysis and/or additional testing.

b) The test product maximum openhole rating shall not exceed the test fixture measured ID. The test fixture ID shall be documented.

c) Inflatable packing elements are energized to form a seal by applying fluid pressure directly to the element. Products with inflatable packing elements shall be tested horizontally; centralization at one end of the test fixture is acceptable.

d) Products with no anchoring devices or slips that hold in one direction may be restrained by the test fixture to prevent movement in the unanchored direction(s).

e) The supplier/manufacturer shall document the pre-test and post-test dimensional and visual inspection results of critical operational areas of the test fixture. If a product has an ovality pressure rating, the manufacturer shall have tested in an oval fixture excluding products tested to Annex B.

NOTE Testing in test fixtures is performed to validate the performance of the openhole isolation equipment and does not simulate openhole straightness or washouts. Ovality is covered in Annex A and B.

5.5.2.4 Product Assembly

Table 4 defines the minimum components within the product assembly for the various tests described in this specification.

Table 4—Product Assembly Components

Product Assembly	Validation / Ovality / Mass Loss Test	Flow Test
Open Hole Mechanical Packer	— Element — Anti-extrusion mechanism — Setting mechanism. — Centralizer (if present in the design) — Anchoring device (if assembled on the same part number as the element) — Shunt tube ports and/or control line feedthrough ports, if determined by the supplier to impact the setting process. The ports may be blanked during the test. If the ports are not part of the test device, the supplier shall document in the test report the reason for doing the same.	— Element — Anti-extrusion mechanism — Setting mechanism. — Centralizer (if present in the design) — Anchoring device (if assembled on the same part number as the element) — For all other components, at a minimum their geometry must be replicated including any internal flow opening that can allow annulus flow into or around an external component.
Open Hole Swellable or Chemically Reactive Packer	— Mandrel that follows the rules of scaling — End rings — Sealing element — Conduits that pass through the sealing element if any (blanks may be used to represent the geometry of the conduits).	— Not Applicable

Note: The scaling rules shall always be followed.

5.5.2.5 Measuring and Monitoring Equipment

5.5.2.5.1 Measuring and monitoring equipment used during the validation testing process shall be calibrated in accordance with the quality requirements specified in 6.14

5.5.2.5.2 All applied pressures are defined as gauge unless otherwise specified and shall be recorded on time-based equipment.

5.5.2.5.3 Axial loads and applied temperatures shall be recorded on time-based equipment. Where pressure is used to generate an axial load, it is acceptable to record pressure in lieu of load.

5.5.2.6 Validation Test Report

A final report shall be prepared and approved by qualified personnel and shall be retained as part of the design documentation for the product. The report shall include the following information:

a) identification of product supplier/manufacturer;

b) test facility name, location;

c) date(s) testing was conducted;

d) date and unique identification of the validation test report;

e) validation test performed, grade passed, summary of results, including comparison to supplier/manufacturer acceptance criteria, with reference to the applicable industry standard with edition;

f) identification of the validation test procedures used and records required;

g) equipment type, size, description, model;

h) product identification and serial number, as applicable;

i) reference to validation-tested product supporting information, including:

   i. drawings and/or documents that show applicable dimensions and tolerances of components, and

   ii. material specifications, including revision;

   iii. traceability records for components in the validation-tested product, if applicable;

   iv. pre-test and post-test dimensional and visual inspection results of critical operational areas of the test fixture as determined by the supplier/manufacturer;

   v. pre-test and post-test dimensional and visual inspection results of critical operational areas of the test product as determined by the supplier/manufacturer;

j) list of performance envelope tested points and rated performance envelope, if applicable; results of specific inspections and tests with acceptance criteria evaluation and acceptance justification, such as:

   i. photograph(s) and/or visual inspections including any evidence of malfunction(s), anomalies, or damage;

   ii. pre-test and post-test dimensional inspection of critical operational areas;

   iii. drift testing;

k) remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test).

5.6 Design Changes

5.6.1 Design changes shall be documented and reviewed to determine if the change is substantive. The review shall be made with comparison to a validated design. A design that undergoes a substantive change becomes a new design requiring design verification and design validation as specified in Annex A or Annex B as applicable; however, scaling may be applied in accordance to 5.7 to achieve design validation. Design changes identified as non-substantive shall include documented justification of that designation. The supplier/manufacturer, shall include the following:

a) design margin of the modified or changed components,

b) material changes,

c) functional changes.

5.6.2 Changes to a component or series of components identified as a substantive change require design validation. Component testing may be performed for the design validation on only the component or series of components, rather than the entire assembly. This testing shall adequately simulate the loading conditions that would be present if the entire assembly were tested.

5.6.3 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 of the supplier/manufacturer other than the person performing them, and records of the results shall become a portion of the design documentation.

5.7 Design Validation by Scaling

5.7.1 Openhole isolation equipment designs can be validated by scaling within the defined limits. Scaling is the ability to validate a design by referencing the design validation conducted on a representative design of the same product type and family.

5.7.2 Scaling shall not be used to cover products with higher pressure ratings, higher temperature ratings, or a larger operating temperature range, a larger temperature-cycle range, higher axial load ratings, higher combined loads, or to a higher validation grade than the previously validated product. Additionally scaling for swell packers shall not be used to cover products with different swell compound or material.

5.7.3 Each scaled product requires design verification, evaluation, and justification that the scaled design meets the requirements of section 5.7. The design scaling activities shall be included in the design documentation and shall be approved by a qualified person other than the person who performed the design.

5.7.1 Limitations of Scaling

5.7.1.1 General

Design scaling shall conform to the following requirements:

a) Scaling of validation-tested products is limited to the rated pressure, temperature, and temperature cycle range of the validated product;

b) Scaling is limited to products of the same product type;

c) The supplier/manufacturer shall establish the minimum design margin within the previously validated design type 1 components and in the same components of the scaled design. The mode of stress and same method of calculation(s)/verification(s) shall be applied to the identified type 1 components of the validated design and the scaled design. For the type 1 component with the lowest design margin, the scaled design's design margin shall not be less than the design margin of the same component of the validated design;

d) Base elastomer or compound of the element package cannot be changed. Changes within a base elastomer or compound formulation are allowed when the supplier/manufacturer has performed applicable material evaluations that indicate the base elastomer's or compound's mechanical properties are comparable to that of the validated design's material.

5.7.1.2 Scaling for Inflatable, Expandable, Openhole Mechanical Packers and Bridge Plugs

The following additional scaling requirements apply:

a) ID of the element(s) and OD of the component under the element(s) shall be the same dimensions as those of the validated product.

b) The identical element package design and extrusion controls are used with same setting method.

c) End connections do not limit scaling. Any end connection size and design is acceptable.

d) Anti-extrusion components shall be of the same configuration and materials as those of the validation tested product.

e) The ratio for ovality may only be scaled down, provided the minor axis stays constant. The scaled pressure rating cannot exceed the validated oval pressure rating. Refer to Figure 4.

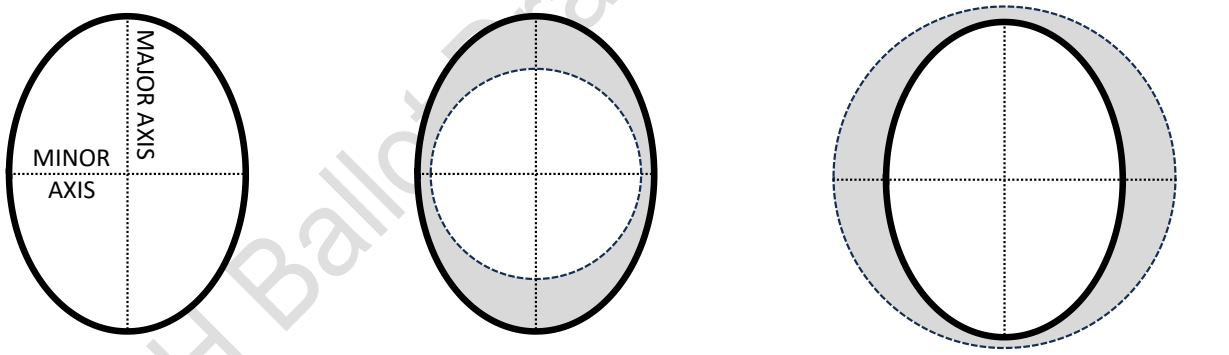


Figure 4—Illustration of Ovality Scaling Limitations for Mechanical Openhole Packer

5.7.1.3 Scaling for Swellable and Chemically Reactive Packers

The following additional scaling considerations apply:

a) Product type (e.g., bonded vs. slip on, shunted vs. un-shunted designs, feedthrough) shall be the same;

b) The same method of adhesion of the element compound shall be used, as applicable;

c) Deformable or expandable anti-extrusion components shall be of the same configuration and materials as those of the validation tested product;

d) The packer length can be increased without limitation while maintaining the pressure rating of longest validation tested product;

e) Scaling can be used to validate a packer design whose volume swell percentage is between the volume swell percentage of two validated designs with the same

   i. nominal sealing element OD, or

   ii. nominal sealing element ID, or

   iii. nominal hole size.

f) The ratio for ovality may only be scaled down, provided the minor axis stays constant. The scaled pressure rating cannot exceed the validated oval pressure rating;

g) Round hole diameter validated products maintain the validated pressure rating for any round or oval hole up to the validated diameter. Refer to Figure 5.

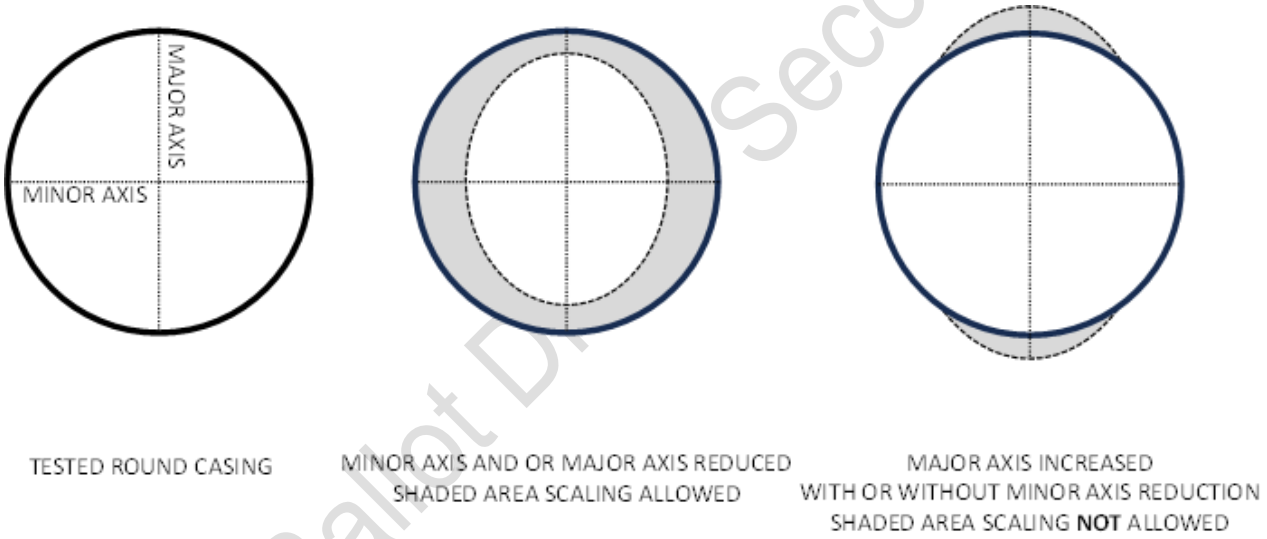


Figure 5—Illustration of Ovality Scaling Limitations for Swellable Packer

5.8 Design Report

The applicable design validation results shall be compiled into a report of that design and shall be approved by a qualified person.

6 Supplier/Manufacturer Requirements

6.1 General

Products shall be manufactured under a quality management system which is in conformance to API Q1.

6.2 Documentation and Data Control

6.2.1 General

6.2.1.1 The supplier/manufacturer shall establish and maintain documented procedures in conformance to API Q1 to control all documents and data that relate to the requirements of this specification. All documentation and data associated with design verification, design validation, and design change justification shall be maintained for 10 years after the date of last manufactured product.

6.2.1.2 Quality control documentation includes all documents and data necessary to demonstrate conformance to Section 6. Quality control documentation shall be retained by the supplier/manufacturer for a minimum of ten years from the date of manufacture.

6.1.1.3 Quality control work shall be controlled by documented instructions that include, or reference, acceptance criteria. All documents and records that show conformance to this document shall be controlled and maintained in accordance with the requirements of API Q1.

6.2.2 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:

a) manual reference number;

b) operational procedures and related operations tools;

c) pre-installation inspection procedures;

d) storage recommendations;

e) a representative drawing identifying major dimensions (ODs, IDs, and lengths);

f) assembly and disassembly instructions, where applicable,

g) special precautions and handling, where applicable.

6.2.3 Product Data Sheet

Product data sheets shall be supplied to the user/purchaser with the product delivery, and shall contain the following information:

a) name of supplier/manufacturer;

b) manufacturer product number;

c) manufacturer product name;

d) product type;

e) product characteristics;

f) service environment (std service, NACE service, flow wet NACE);

g) metallic material identification;

h) nonmetallic material identification;

i) ID drift diameter;

j) gauge OD;

k) overall length;

l) sealing length, as applicable;

m) pressure rating over the hole size range;

n) temperature range, as applicable;

o) temperature-cycle range, as applicable;

p) end connection(s);

q) packer mandrel size and weight, as applicable;

r) nominal open-hole size or range;

s) required setting data, as applicable;

t) quality level;

u) design validation grade;

v) ovality, as applicable;

w) external flow rates, as applicable;

x) torque rating;

y) shunt tube pressure rating, as applicable;

z) operating manual reference number.

6.3 Product Identification

Each product shall be permanently identified according to the supplier/manufacturer's specifications. The supplier/manufacturer's specifications shall define the type, method of application, and location of the identifications. The following information shall be included:

a) supplier/manufacturer identification;

b) supplier/manufacturer's product number;

c) date of manufacture (month/year);

d) quality level;

e) design validation grades;

f) serial number/traceability number for quality grade QL1, where applicable.

6.4 Material and Quality Requirements

6.4.1 General

6.4.1.1 Material, metallic or nonmetallic, used in the manufacture of components shall meet at least one of the following requirements:

a) certificate of compliance (COC) to the supplier/manufacturer stating that the material meets the supplier/manufacturer's documented specifications, or

b) material test report (MTR) to the supplier/manufacturer so that the supplier/manufacturer can verify that the material meets the supplier/manufacturer's documented specifications.

6.4.1.2 The COC and MTR shall also state the revision level and specification it meets.

6.4.1.3 Quality control work shall be controlled by documented instructions that include, or reference, acceptance criteria. All documents and records that show conformance to this document shall be controlled and maintained in accordance with the requirements of API Q1.

6.4.1.4 Rounding in accordance with ASTM E29 may be used unless otherwise restricted by the drawing, material specification, or other controlling document.

6.4.2 Quality Grades / Levels

There are two quality grades or levels that may be specified by the user/purchaser:

Quality Level 1 (QL1) – The highest level of quality verification.

Quality Level 2 (QL2) – Minimum level of quality verification.

If the user/purchaser does not specify the applicable quality level, the minimum of QL2 shall be supplied. Table 5 summarizes the Quality Grade requirements.

Table 5—Quality Grade Requirements Summary

Item	Quality Grade	
	QL2	QL1
Operating manual	Available for each product supplied per 6.2.2	
Data sheet	Supplied with each product per 6.2.3	
Product identification	Per the requirements of 6.3	
Materials: 6.4.1 & 6.4.2		
Type 1 components	MTR and COC	MTR and COC
Type 2 components	MTR or COC	MTR or COC
Castings	Per the requirements of 6.3.3	

Hardness testing, see 7.10 Type 1 components	Per material specification	COC for API 5CT or API 5CRA based components, per material specification for all others
Mechanical properties, non-swelling elastomers	Per material specification and the requirements of 6.4.6	
Mechanical properties, thermoplastics	Per material specification and the requirements of 6.4.6	
Properties of swelling elastomers	Performed per the requirements of 6.4.6.4	
Bond strength	Per the requirements of 6.3.2.4.4	
Heat treat, see 7.5	Per supplier/manufacturer or COC from subcontractor	Type1: Heat treat certificate and per supplier/manufacturer, or COC from subcontractor Type 2: Per supplier/manufacturer or COC from subcontractor
Traceability, see 6.7 Type 1 components Type 2 components Assemblies	 Job-lot traceable Per supplier/manufacturer Per supplier/manufacturer	 Heat-traceable Per supplier/manufacturer Assembly serialization
Component dimensional inspection, see 6.8 Type 1 components Type 2 components	 Per sampling plan Per sampling plan	 100 % inspected Per sampling plan
Welds, see 6.9	Per supplier/manufacturer specifications and 6.9	
Component NDE	Per the requirements of 6.11	
Shear device, see 6.11	Shall conform to the requirements of 6.12	
Functional testing	Per the requirements of 6.13.2	
Calibration systems	Per the requirements of 6.14	
Visual inspections	Per the requirements of 6.15	
Coatings and overlays	Per the requirements of 6.16	

6.4.3 Sampling

Sampling plan inspections, when allowed by Table 5, shall be performed within the following limitations:

a) The supplier/manufacturer shall have a documented sampling plan procedure and the inspections performed shall have the same practices and acceptance criteria as the 100% inspections.

b) Unless specified elsewhere, the lot being sampled shall conform to the limits defined in Table 6. Sampled units shall be randomly selected and shall be inspected according to the supplier/manufacturer's documented specifications. For the purpose of these sampling requirements “Random” is defined as all items having an equal chance of being selected for examination.

c) Alternately an acceptance quality limit (AQL) of 2.5 can be applied, which follows the requirements of a national or international specifications such as ISO 2859-1 or ANSI / ASQ Z1.4 and the supplier/manufacturer's documented variation history. A minimum of four units from each lot shall be inspected, unless the lot includes less than 4 units

where all shall be inspected.

d) Sampling plans of component inspections shall conform to the applicable section(s) of 6.4.2 and the supplier/manufacturer's documented procedures, including the applicable acceptance criteria.

e) In the event that one component of a sampled lot is identified as non-conforming in any of the applied inspections, the entire lot or batch shall be inspected utilizing the identical procedures.

f) Components identified as non-conforming in the inspections shall be dispositioned as defined in the supplier/manufacturer's QMS.

g) Nonmetals - Sampling procedures and the basis for acceptance or rejection of a 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. For other non-metallic components, the requirements for O-rings shall be utilized until:

i. a documented variation history can be established, and
ii. a sampling procedure is determined based on the documented variation history.

NOTE: Table 6 does not apply to 6.4.3 (g)

Table 6—Sampling Plan Unit Count Requirements

Identifier	Total Number of Units in the Lot	Minimum Number of Inspected Units
I	2 to 8	4 units, where available
II	9 to 50	8 units
III	51 to 90	13 units
IV	91 to 150	20 units
V	151 to 280	32 units
VI	281 to 500	50 units
VII	501 to 1200 or more	80 units
Based upon ANSI/ASQ Z1.4 Table 1, General inspection level II information		

6.4.4 Metals

6.4.4.1 The supplier/manufacturer shall conform to the materials requirements in 5.3.2 and the following requirements.

a) For type 1 components supplied to quality levels QL1 and QL2, the supplier/manufacturer shall provide an MTR and COC.

b) For type 2 components supplied to quality levels QL1 and QL2, a COC or MTR shall be provided.

6.4.4.2 Material subsequently heat treated from the same heat of material shall be tested for properties after processing to confirm compliance with the requirements of the manufacturer's specifications. 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.

6.4.4.3 Where a surface hardening process is utilized, the results shall be evaluated to ensure that the process conforms to supplier/manufacturer documented acceptance criteria.

6.4.4.4 Material test reports provided by the material supplier or the supplier/manufacturer are acceptable documentation for conformance with the material specification, when approved by a qualified person.

6.4.4.5 Tensile testing shall be in accordance with ISO 6892-1 or ASTM E8 or A370 for the metallic materials used for traceable components. When testing at elevated temperatures ASTM E21 shall be used.

6.4.4.6 Charpy testing shall be in accordance with ASTM E23, ISO 148-1, or ASTM A370.

6.4.4.7 The tensile and Charpy testing samples shall be taken from material that is from the same heat/heat treat lot for the components it represents.

7.4.4.8 Hardness testing shall be in accordance with:

a) ISO 6506-1 or ASTM E10 for Brinell Test.

b) ISO 6508-1 or ASTM E18 for Rockwell Test.

c) Microhardness testing per ISO 6507-1 or ASTM E384 may be used if ISO 6506-1 or ISO 6508-1 cannot be applied due to size, accessibility, or other limitations.

d) When hardness testing is performed on a finish-machined component and the final surface condition will not permit hardness indentations, the testing may be performed on a separate test coupon that has been heat treated in the same heat treat lot and is of the same heat as the material it represents.

e) Hardness conversion to other measurement units shall be in accordance with ASTM E140, with the stipulations noted in NACE MR0175 for materials that are intended for use in sour service. Supplier/manufacturer may establish documented correlations for individual materials not covered in ASTM E140.

NOTE NACE MR0175 is equivalent to ISO 15156 (all parts).

6.4.5 Castings

Castings shall conform to documented requirements defined by the supplier/manufacturer, which include a COC and MTR to be provided for each casting or casting lot depending on component type designation.

6.4.6 Non-metals

6.4.6.1 The supplier/manufacturer shall conform to the materials requirements in 5.3.2 and provide a CoC showing that all requirements have been met.

6.4.6.2 Mechanical and bonding properties required by the material specification shall be validated by test conducted on a material sample produced from the same batch of material. Properties to be considered are listed in Table 7. When required by the material specification, testing shall be performed as listed in Table 7.

6.4.6.3 Adhesion of bonded seals shall be tested in accordance with ASTM D429, or equivalent standard, utilizing a sample of 1 per job lot.

Table 7—Nonmetallic Material Property Verification

	Material Properties (when specified)	Test Standard
Elastomer	Tensile strength (at break) and tensile modulus (at 50 % or 100 %, as applicable)	ASTM D412, ASTM D1414 (O-ring) or ISO 37
	Elongation (at break)	ASTM D412, ASTM D1414 (O-ring) or ISO 37
	Durometer hardness	ASTM D2240, ASTM D1415 (O-ring) or ISO 48
	Compression set (periodically)	ASTM D395, ASTM D1414 (O-ring) or ISO 815-1
	Optional	
	Density/specific gravity	ASTM D297 or ISO 2781
	Compression relaxation	ASTM D6147 or ISO 3384-1, ISO 6056 (O-ring)
	Tear resistance	ASTM D624 or ISO 34-2
	Tensile or compressive data for FEA analysis	Supplier/manufacturer's procedure
Thermoplastics	**Recommended**	**Test Standard**
	Yield strength or tensile strength	ASTM D638, ASTM D1708 or ISO 527-1
	Elongation at yield or at break	ASTM D638 or ISO 527-1
	Durometer hardness	ASTM D2240 or ISO 48
	Optional	
	Density/specific gravity	ASTM D792 or ISO 1183-1
	Modulus of elasticity	ASTM D638 or ISO 527-1

6.4.6.4 Swellable Elastomers

6.4.6.4.1 Swell Rate Testing

A swell rate test shall be performed according to supplier/manufacturer's procedures and acceptance criteria to verify the elastomer compound's performance at a frequency of no greater than annually. The test procedure shall document the following:

a) test temperature(s);

b) swell test fluids composition, such as salinity and added chemicals that may include retarding or accelerating agents of the swelling process;

c) description of sample and unique material identification;

d) time between measurements, as applicable;

e) pre-and post-test dimensions, and/or specific gravity change (weight) as applicable;

f) visual inspection description of the test sample post-testing.

6.4.6.4.2 Batch Acceptance

6.4.6.5 The supplier/manufacturer shall perform or have performed acceptance testing of each batch of material to ensure the material conforms to the supplier/manufacturer's specifications.

6.5 Heat Treating

6.5.1 General

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

a) Heat treating shall be performed with heat treating equipment that has been calibrated and surveyed.

b) If heat treatment is performed by a subcontractor, the subcontractor shall provide a COC to the supplier/ manufacturer stating that the heat treatment meets the supplier's/manufacturer's documented specifications.

c) If heat treatment is performed by the supplier/manufacturer, heat treatment shall comply with the supplier/ manufacturer's documented specifications.

d) For Type 1 components, a heat treatment certificate showing actual times and temperatures is required for QL1.

6.5.1.2 Samples from each individual heat in each heat treat lot of material shall be tested for conformance to the mechanical properties specified in the supplier/manufacturer’s material specification.

NOTE Heat treatment includes operations such as normalizing, austenitize/quenching, tempering, solution annealing, annealing, or aging.

6.5.2 Stress Relief

Stress relief is heat treatment to release integral material stresses caused by manufacturing. Stress relief may be performed without a furnace (e.g. localized stress relief of a weld), to a documented procedure, and with the temperature measurement and recording instruments calibrated to 6.5.3. A hardness test shall be performed on each stress relieved area, and the results shall be evaluated as within the documented acceptance criteria.

NOTE API 20H provides guidance for the qualification of suppliers of heat treatment services.

6.5.3 Heat Treating Equipment 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 internationally recognized standards such as SAE AMS 2750, API 20H, API 20N or API 6A.

c) Alternately, the supplier/manufacturer's documented specifications, including acceptance criteria that are not less stringent than the procedures identified per (a) and (b), can be used.

d) Temperature-controlling and -recording instruments shall be used for the heat treatment processes shall possess an accuracy of at least ± 1 % of their full-scale range and 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.

e) Equipment used to calibrate the production equipment shall have an accuracy of 0.25 % of the full-scale range.

6.5.4 Instrumentation

Instrumentation shall meet the following requirements:

a) Automatic controlling and recording instruments shall be used.

b) Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmospheres.

c) The controlling and recording instruments used for the heat treatment processes shall have an accuracy of ±1 % of their full-scale range.

6.6 Quality Requirements

7.6.1 This specification defines two quality grades, QL1 and QL2. Products shall be supplied to at least the quality grade specified. When no quality grade is selected by the user/purchaser, a minimum of QL2 shall be supplied. Two grades of quality requirements are included, detailed in the text, and summarized in Table 5.

7.6.2 Where a supplier/manufacturer elects to outsource an activity, they shall ensure that the applicable elements of its quality management system are satisfied and the supplier/manufacturer shall maintain responsibility for conformance of the activity to the specified requirements. Where processes are outsourced, the supplier/manufacturer shall have a COC and where applicable, additional documentation that validates the processes conform to the documented requirements.

6.7 Traceability

6.7.1 Component Traceability

Component traceability shall meet the following requirements.

a) Type 1 components shall be job-lot traceable for quality grade QL2.

b) Type 1 components shall be heat-traceable for quality grade QL1.

c) Components that are castings, or are manufactured from castings, may be excluded from traceability for grade QL2.

6.7.2 Material and Process Certifications

Raw material used in the manufacture of components shall meet these two requirements:

a) COC stating that the raw material meets the supplier/manufacturer's documented specifications. COC's shall note the specifications and revision levels utilized for testing and be traceable to the material or services it represents. The issuer of the COC must have access to the documents, e.g. mill test reports, inspection records, manufacturing records, that show conformance to the requirements. These documents shall be made available to the manufacturer/supplier upon request.

b) MTR so that the supplier/manufacturer can verify that each batch of raw material meets their documented specifications. MTRs shall note the specifications and revision levels utilized for testing.

6.7.3 Assembly Traceability

Assembly serialization shall be used to provide traceability of all Type 1 components within each assembly for quality grade QL1.

6.8 Component Dimensional Inspection

Component dimensional inspection shall be performed to supplier/manufacturer specifications and shall meet the following requirements:

a) Thread tolerances, inspection requirements, gauges, gauging practice, gauge calibration, and certification shall conform to the specified thread manufacturer's documented specifications.

b) Dimensional tolerances of O-rings shall be in accordance with ISO 3601-1, Class A, equivalent international standard, or in accordance to supplier drawings. Other sealing components shall meet supplier/manufacturer dimensional tolerances.

NOTE For the purposes of this provision, SAE AS568B is equivalent to ISO 3601-1, Class A.

c) Type 1 and Type 2 components for quality grades QL2 shall be dimensionally inspected per a sampling plan that meets the requirements of 6.4.3.

d) Type 1 components for quality grade QL1 shall be dimensionally inspected as follows: Inspection shall include 100% of the dimensions specified on a component drawing on 100% of the components.

NOTE Broken edges can be considered under the visual criteria.

6.9 Welds

6.9.1 Type 1 welds shall meet the following requirements.

a) Welding and brazing procedure and personnel qualification shall be in accordance with ASME BPVC, Section IX or equivalent.

b) Weld materials not listed in the ASME BPVC, Section IX shall be applied using weld procedures qualified in accordance with the methods of ASME BPVC, Section IX or equivalent.

6.9.2 Additionally, welding of type 1 components for NACE service products shall meet the requirements of ANSI/NACE MR0175/ISO 15156.

6.9.3 Type 2 welds shall meet the documented requirements of the supplier/manufacturer.

6.9.4 Each welded component shall be stress relieved and non-destructively evaluated where specified in the supplier/ manufacturer's documented specifications that include acceptance criteria.

6.10 Hardness Inspection of Components

Hardness inspection of metallic components shall meet the following requirements:

a) Type 1 components for quality level QL2 shall be hardness inspected per a sampling plan that meets the requirements of Section 6.11.

b) 100% of type 1 components for quality level QL1 shall be hardness inspected.

c) Type 2 components do not require hardness inspection.

d) Hardness inspection of metallic components shall meet the requirements of an international standard or national standard, such as ASTM E10, ASTM E18, ISO 6506-1, ISO 6507-1, or ISO 6508-1.

e) Hardness inspection of API 5CT or API 5CRA components are not required where hardness records are present.

f) The durometer hardness of O-rings or other elastomeric elements shall be determined in accordance with the methods referred to in Table 7. A test specimen manufactured from each batch may be used.

6.11 NDE of Components

6.11.1 NDE – General

6.11.1.1 NDE of metallic and nonmetallic components includes the following general requirements for NDE:

— All NDE procedures shall be approved by a Level III examiner qualified in accordance with ISO 9712 or SNT-TC-1A.

— NDE acceptance criteria shall be according to the supplier/manufacturer's documented specifications.

6.11.1.2 Personnel performing NDE evaluations and interpretations, other than visual or leak tests, shall be qualified in accordance with ISO 9712 or SNT-TC-1A, to at least level II, or equivalent.

6.11.1.3 Personnel performing visual or leak test examinations shall have an annual eye examination, applicable to the discipline to be performed, in accordance with ISO 9712 or SNT-TC-1A.

6.11.1.4 All other personnel performing inspection for acceptance shall be qualified per the supplier/manufacturer-documented requirements.

6.11.2 NDE – Metal Components

6.11.2.1 The supplier/manufacturer shall have documented procedures, including acceptance criteria, for visual inspection of all accessible surfaces for defects and damage before assembly of the equipment. Visual acceptance criteria to be in accordance with the supplier/manufacturer’s documented requirements.

6.11.2.2 The following are requirements when utilizing metal components:

a) For components manufactured from material that is in conformance with API 5CT or API 5CRA, the applicable NDE requirements shall be performed with the material in its final heat treat condition.

b) Components manufactured from material that is in conformance with API 5CT or API 5CRA tubular NDE requirements and that are not heat treated thereafter shall be considered acceptable based upon those records.

c) Quality level QL1, type 1 metallic components and welds shall be 100% NDE inspected utilizing magnetic particle inspection or liquid penetrant inspections to the supplier/manufacturer's procedures, which shall conform to the following:

   i. Magnetic particle inspections shall meet the requirements of an international standard or national standard, such as ISO 10893-5 or ASTM E709. Applicable indications are defined as:
      — indications with major dimensions greater than 1.6 mm (1/16 in.).
      — linear indication is any indication in which the length is equal to or greater than three times its width.
      — rounded indication is any indication which in which the length is less than three times its width.

   ii. Liquid penetrant inspections shall meet the requirements of an international standard or national standard, such as ISO 10893-4 or ASTM E165. Applicable indications are defined as:
      — indications with major dimensions greater than 1.6 mm (1/16 in.),
      — linear indication is any indication in which the length is equal to or greater than three times its width,
      — rounded indication is any indication which in which the length is less than three times its width.

iii. Final NDE shall be performed after all welding, post-weld heat treatment (including stress relief), and applicable machining operations on welded areas.

CAUTION: It is not recommended that liquid penetrant examination be used on braze joints as residual penetrant may negatively impact the ability to perform a rework on the braze joint.

d) Quality level QL2 type 1 components and welds shall be inspected to sampling plan per Section 6.11.

e) Quality levels QL1 and QL2 type 2 components shall conform to the NDE requirements of the supplier/ manufacturer.

f) Welds shall be visually inspected per the requirements of an international standard or national standard, such as the ASME BPVC, Section V, Article 9.

6.11.3 NDE – Nonmetallic Components

The following are requirements for nonmetallic components.

a) Sampling procedures and the criteria for acceptance or rejection of a batch lot shall be in accordance with the sampling plan described in 6.4.3.

b) Visual inspection of O-rings shall be in accordance with ISO 3601-3 Grade S or equivalent.

c) Other sealing elements and nonmetallic components shall be visually inspected in accordance with the supplier/manufacturer's documented specifications at a minimum of 2x magnification.

6.12 Shear Device Verification

At least one Shear Device per Heat/Heat Treat Lot shall be sheared in accordance with the supplier/manufacturer's documented procedure to verify the shear values meet the documented specification.

6.13 Assembly Verification

6.13.1 General

6.13.1.1 The supplier/manufacturer functional testing equipment shall conform to the requirements of 6.13.2 and be conducted by a qualified person.

6.13.1.2 All pressures are defined as gauge unless otherwise specified and shall be recorded on time-based equipment for the duration of its application.

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

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

6.13.2 Functional Testing

Functional testing shall conform to the following:

a) Functional test data shall be recorded, dated, and signed by the qualified person performing the tests.

b) For quality levels QL1 and QL2:

   i. A low-pressure, internal test shall be performed on each product by pressurizing to a minimum of 50 psi using either liquid or gas as the test medium. One-piece mandrels or mandrels with only internal metal-to- metal sealing connections and no pressure ports through them are excluded from this requirement. Test duration and acceptance criteria shall be defined by the supplier/manufacturer's documented procedures.

   ii. ID drift each product per the supplier/manufacturer's documented specifications or a specification applicable to the base pipe such as API 5CT or API 5CRA, with approved drifts.

   iii. ID drift shall apply only to product IDs not designed as sealing surfaces (seal bores).

   iv. For products with sealing IDs (seal bores), the drift test shall be conducted per the supplier/manufacturer-documented specifications and acceptance criteria.

c) For quality level QL1:

   i. The OD shall be inspected according to the supplier/manufacturer'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.

   ii. When required by the supplier/manufacturer-documented specifications, actual torque values for metal-to-metal sealing connections (where applicable) shall be recorded and verified.

   NOTE End connections are excluded from this requirement.

6.13.3 Functional Test Documentation

A functional test record shall be prepared for each product tested and shall include:

a) identification of product manufacturer;

b) date of functional test and date of record;

c) model designation or other identification;

d) product number with unique serial number, as applicable;

e) remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test,);

f) testing limits applied and testing results compared to the acceptance criteria;

g) results of specific evaluations, as defined by the supplier/manufacturer such as:

   i. operational tools used;

   ii. special features;

h) test fixtures, test fluids, and, if applicable, lubricants;

i) test approval by a qualified person other than the person performing the test.

6.14 Calibration Systems

a) Inspection, measuring, and testing equipment shall be used only within its calibrated range and shall be identified,

controlled, calibrated, and adjusted at specific intervals in accordance with written procedures that are based on instrument manufacturer's standards, or internationally recognized standards such as ISO / IEC 17025.

b) Technologies for inspections with verifiable accuracies less than those listed in this standard may be applied with appropriate documentation and when approved by a qualified person(s).

c) Calibration intervals for measuring and testing equipment shall be established based on repeatability, amount of usage, environment and past history for that type of instrument. For standard, adjustable, hand measurement tools the initial calibration interval shall be three months until a recorded calibration history for that instrument can be established. Intervals may then be lengthened or shortened. The calibration interval cannot be increased by more than twice the previous interval and shall not exceed more than one year.

d) Non-standard, or non-adjustable measurement devices including surface plates, threaded plug / ring gauges, co-ordinate measuring machines, optical comparators, shall be calibrated initially and the calibration interval set based on equipment type, usage, and operating environment. Calibration intervals shall not exceed three years for this type of equipment.

e) Calibration standards used to calibrate measuring equipment shall be checked and approved at least once every three years by qualified individuals using qualified equipment with traceability to the applicable national or international standards agency.

f) Instruments and calibration standards that have not been used during the calibration interval and that have been maintained in accordance with defined practice may have their calibration cycle extended for an amount equal to the designated cycle. Pressure measuring devices shall be:

   i. readable to at least ±0.5 % of full-scale range;

   ii. calibrated to maintain ± 2% accuracy of full-scale range

g) Pressure measuring devices shall only be used within the calibrated range and be calibrated with a master pressure measuring device or a dead weight tester. Spring style pressure gauges shall only be used within 25% to 75% of the gauge range. Calibration intervals for pressure measuring devices shall be a maximum of three months until documented calibration history can be established. Calibration intervals shall then be established based on repeatability, degree of usage, environment, and documented history.

h) Temperature measuring devices shall be calibrated in accordance with SAE AMS 2750, Pyrometry, to an accuracy of 0.25% of the full range and be readable to at least 1°. Equipment used to calibrate the production equipment shall possess an accuracy of ±0.25 % of the useable full-scale range.

i) Measuring devices used for the dimensional inspection shall provide sufficient accuracy to minimize the measurement uncertainty. Where practical the measurement uncertainty shall not exceed 25% of the characteristic's tolerance limit. The measurement uncertainty may be determined through measurement studies, equipment manufacturer's accuracy statements, calibration certificates, or other recognized methodologies deemed appropriate by a qualified person.

6.15 Visual Inspections

A visual inspection of all accessible surfaces shall be performed by a qualified person and the results compared to an applicable reference specification, such as ANSI/MSS SP-55-2011, and/or a supplier/manufacturer's set of specific requirements and acceptance criteria. Observed variances from the specification shall be documented and dispositioned according to the supplier/manufacturer's documented process.

6.16 Coatings and Overlays

Coatings and overlays shall be performed in accordance with documented instructions that include acceptance criteria, which are approved by a qualified person.

7 Repair/Redress/Remanufacture Requirements

7.1 Products returned for repair or redress after delivery shall include the return of the product to a condition meeting all requirements agreed upon with user/purchaser.

7.2 Repaired or redressed products shall be permanently marked for traceability back to the repair.

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

8 Shipping, Handling, and Storage

8.1 Products shall be stored per the documented specifications of the supplier/manufacturer to prevent deterioration (for example, caused by atmospheric conditions, debris, radiation, etc.) prior to transport.

8.2 Products shall be packaged for transport per the documented specifications of the supplier/manufacturer 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. Protective packaging may be required for storage of some sealing components to ensure the anticipated shelf life.

8.3 Caution shall be taken to protect components and final products from deterioration and damage during storage and shipment. Additional protection should be provided to prevent the inadvertent contact of corrosion resistant alloys (CRA) materials with alloy/carbon steels where there may be a transfer of free iron to the CRA material.

Annex A
(normative)

Validation Test Requirements for Inflatable, Expandable, Openhole Mechanical Packers, and Bridge Plugs

A.1 General

The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to the selected validation grade. All defined criteria shall be successfully completed to validate the design to the validation grade. The requirements of Sections 4, 5,and 6 are required for the products to be validated.

NOTE: Testing results are documented per 6.5.1

A.2 Common Validation Requirements

The following apply to the product validation testing grade V1 through V3

1) The validation-tested product shall conform to the supplier/manufacturer requirements of Section 6 and a minimum of QL2. For products manufactured for validation testing that were manufactured prior to the publication of this edition, type 1 components do not require a COC.

2) Testing shall be conducted by qualified person(s). The results shall be approved by a qualified person other than the person performing the test. These records shall become part of the design documentation and included in the validation test report (see 5.5.2.6)

3) The product shall be set utilizing procedures and methods identified in the supplier/manufacturer procedures

4) The supplier/manufacturer-specified methods to retrieve the retrievable-type products shall be used at the end of the test. The release loads required to remove the product shall be measured and recorded

5) Time period for stabilization at each test step is at the discretion of the supplier/manufacturer

6) Recorded temperature measurements shall be representative of the product as installed within the test fixture

7) The product may be restrained at one end where the design does not include an anchoring mechanism. The product may be centralized or decentralized in test fixture. The product set up shall be documented in test report.

8) The product shall be set at the orientation (horizontal or vertical) identified by the supplier/ manufacturer procedures and be documented in the test report.

9) Validation testing shall be performed within a test fixture per 6.5.2.3.

NOTE: Unsupported casing or tubing applications are outside the scope of this specification and can require analysis and/or additional testing.

10) The product shall be set in:
    a) a round fixture with the ID equal to or greater than the maximum rated hole size, or
    b) an oval fixture with a major axis equal to maximum rated hole size and minor axis based on the ovality ratio (diameters).

11) If a product has an ovality pressure rating, the manufacturer shall have tested in an oval fixture.

12) Use a liquid test medium of water, with or without additives, or hydraulic oil. The density shall be less than 1100 kg/m3 (68.67 lb/ft3). Liquid shall be visibly free from particulate matter or other material. The particulate matter and other material can conceal a small leak that would otherwise be evident.

13) Where inflate fluids are utilized, that fluid shall be the same as the pressure test fluid, which shall be recorded in the test documentation.

14) Testing data shall be recorded on time-based electronic data acquisition equipment for all measured parameters.

A.3 Grade V4: Supplier/Manufacturer-defined

The supplier/manufacturer shall define the requirements, validation methods, and acceptance criteria.

A.4 Grade V3: Liquid Test at Maximum Rated Temperature

The supplier/manufacturer shall adhere to the following test parameters and acceptance criteria in Table A.1 for conformance to this validation grade. The test media shall be liquid per section A.2.

Table A.1 – Grade V3 Liquid Test at Maximum Rated Temperature

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection	— Validation test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step.	— Actual Temperature — Setting Pressure or Force — Setting Time
c)	Perform a pressure test at or above the maximum rated differential pressure from one direction across the element at or above maximum rated temperature Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
d)	Perform post-test inspection	— Inspection Results

A.5 Grade V2: Liquid Test with Temperature Range

The supplier/manufacturer shall adhere to the following test parameters and criteria in Table A.2 for conformance to this validation grade. The test media shall be liquid per A.2.

Table A.2 – Grade V2 Liquid Test with Temperature Range (Maximum to Minimum Test Temperature)

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection	— Validation test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step. If conducting Low Temperature Validation (A.7 Method A), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Setting Pressure or Force — Setting Time
c)	Perform a test at or above the maximum rated differential pressure from one direction at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
d)	Decrease the temperature by at least the maximum rated temperature-cycle range Allow the temperature and pressure to stabilize.	— Time — Temperature

e)	Perform a test at or above the maximum rated differential pressure from one direction at or below the low end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
f)	Perform post-test inspection	— Inspection Results

A.6 Grade V1: Liquid Test with Temperature Cycling

The supplier/manufacturer shall adhere to the following test parameters and criteria in Table A.3 for conformance to this validation grade. The test media shall be liquid per Section A.2.

Table A.3 – Grade V1 Liquid Test with Temperature Cycling (from Max. to Min. to Max Test Temperature)

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection	— Validation test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step. If conducting Low Temperature Validation (A.7 Method A), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Setting Pressure or Force — Setting Time
c)	Perform a test at or above the maximum rated differential pressure from one direction at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
d)	Decrease the temperature by at least the maximum rated temperature-cycle range. Allow the temperature and pressure to stabilize.	— Time — Temperature

e)	Perform a test at or above the maximum rated differential pressure from one direction at or below the low end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
f)	Increase the temperature to at or above the maximum rated temperature. Allow the temperature and pressure to stabilize. If conducting Low Temperature Validation (A.7 Method A), increase the temperature to at or above the minimum rated temperature plus the temperature cycle range.	— Time — Temperature
g)	Perform a minimum 15-minute pressure hold from one direction (either pressure above or below) at or above maximum rated differential pressure. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
h)	Perform post-test inspection	— Inspection Results

A.7 Low Temperature Rating Validation

For validation grades V1 and V2 where the low temperature rating was not validated during the temperature-cycle range test, the low temperature rating of the product shall be validated using Method A or B. Low temperature validations shall be subject to the requirements for scaling as found in 5.9.

NOTE See 5.3.3.2 for temperature-cycle range and temperature range considerations

A.7.1 Method A – Product validation testing

A.7.1.1 The low temperature rating shall be validated by product testing per the requirements of A.5 (V2) or A.6 (V1). The low temperature rating is the lowest temperature achieved during the temperature-cycle range test.

A.7.1.2 To achieve a lower low temperature rating, additional validation tests shall be conducted. The product shall be set at or above the specified minimum rated temperature plus the temperature-cycle range. Conduct the remaining steps as required by the validation grade.

EXAMPLE A product was tested multiple times under the requirements of V1 validation testing with the following temperature-

cycle ranges achieved: 50 °F to 200 °F and 250 °F to 350 °F. The published temperature range of the product is 50 °F to 350 °F, and the temperature-cycle range is 100 °F.

A.7.2 Method B—Packing element component validation testing

A.7.2.1 Method B is intended to validate the low temperature rating of the packing element component. The low temperature rating shall be validated using supplier/manufacturer-defined component testing of the packing element. Component testing shall adequately simulate the pressure and loading conditions that would be present if the entire assembly were tested. The component shall be set at the minimum rated temperature plus the temperature-cycle range, and the test conducted at the minimum rated temperature. The test medium and acceptance criteria shall match the intended validation grade.

A.7.2.2 The supplier/manufacturer shall have a documented procedure for the component testing, along with supporting test data. A qualified person shall approve the low temperature rating.

Annex B
(normative)

Validation Test Requirements for Swellable and Chemically Reactive Packers

B.1 General

The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to the validation grade. All defined criteria shall be successfully completed to validate the design to the validation grade. The requirements of Sections 4, 5, and 6, are required for the products to be validated.

NOTE Testing results are documented per 5.5.1

B.2 Common Validation Requirements

The following apply to the product validation testing grade V3 through V1.

1) The validation-tested product shall conform to the supplier/manufacturer requirements of Section 6 and a minimum of QL2. For products manufactured for validation testing that were manufactured prior to the publication of this edition, type 1 components do not require a COC.

2) Testing shall be conducted by qualified person(s). The results shall be approved by a qualified person other than the person performing the test. These records shall become part of the design documentation and included in the validation test report (see 5.5.2.6)

3) The product shall be set utilizing procedures and methods identified in the supplier/manufacturer procedures

4) Time period for stabilization at each test step is at the discretion of the supplier/manufacturer

5) Recorded temperature measurements shall be representative of the product as installed within the test fixture

6) The product may be restrained at one end where the design does not include an anchoring mechanism. The product shall be centralized in test fixture. The product set up shall be documented in test report.

7) The product shall be set at the orientation (horizontal or vertical) identified by the supplier/ manufacturer procedures and be documented in the test report.

8) Validation testing shall be performed within a test fixture per 5.5.2.3.

NOTE: Unsupported casing or tubing applications are outside the scope of this specification and can require analysis and/or additional testing.

9) The product shall be set in:
   c) a round fixture with the ID equal to or greater than the maximum rated hole size or a major oval axis (diameter), or
   d) an oval fixture with a major axis equal to maximum rated hole size and minor axis based on the ovality ratio (diameters).

10) Testing data shall be recorded on time-based electronic data acquisition equipment for all measured parameters.

B.3 Validation Test Fluids

B.3.1 A liquid test medium of water, with or without additives, or an oil-based fluid may be used. The characteristics of the fluid(s) shall be documented and reported. The density shall be less than 1,100 kg/m^3 (68.67 lb/ft^3). Test liquid shall be visibly free from particulate matter or other materials that can plug a small leak.

B.3.2 The characteristics of the oil base fluid shall be documented per the defined criteria and reported within final test report and shall include the following:

a) physical appearance,

b) hydrocarbon: visually free of particulates,

c) aromatic content: < 0.5 % according to ASTM D2140,

d) viscosity: documented at a temperature within the packer's published range.

NOTE The time-to-set in the validation testing may not be representative of the packer's time-to-set in the actual well fluids.

B.4 Grade V4: Supplier/Manufacturer-defined

The supplier/manufacturer shall define the requirements, validation methods, and acceptance criteria.

B.5 Grade V3: Liquid Test at Maximum Rated Temperature

The supplier/manufacturer shall adhere to the following test parameters and acceptance criteria in Table B.1 for conformance to this validation grade. The test media shall be liquid per section B.3.

Table B.1 – Grade V3 Liquid Test at Maximum Rated Temperature

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Validation test number — Date — Description of all test media, including setting and test fluids. — Measured fixture ID — Product identification — Inspection test results
b)	Set the product at or above maximum rated temperature utilizing procedures and methods identified in the supplier/manufacturer procedures. Allow the pressure and temperature to stabilize prior to next step.	— Actual Temperature — Time required to contact fixture ID — Time required to reach differential pressure rating (after exposure to defined media)
c)	Perform a pressure test at or above the maximum rated differential pressure from one direction across the element at or above maximum rated temperature	— Start to end of each hold period o Time

	Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	○ Temperature ○ Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
d)	Perform post-test inspection	— Inspection Results

B.6 Grade V2: Liquid Test with Temperature Range

The supplier/manufacturer shall adhere to the following test parameters and acceptance criteria in Table B.2 for conformance to this validation grade. The test media shall be liquid per section B.3.

Table B.2 – Grade V2 Liquid Test with Temperature Range (from Max. to Min. Test Temperature)

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Validation test number — Date — Description of all test media, including setting and test fluids. — Measured fixture ID — Product identification — Inspection test results
b)	Set the product at or above maximum rated temperature utilizing procedures and methods identified in the supplier/manufacturer procedures. Allow the pressure and temperature to stabilize prior to next step. If conducting Low Temperature Validation (B.8), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Time required to contact fixture ID — Time required to reach differential pressure rating (after exposure to defined media)
c)	Perform a test at or above the maximum rated differential pressure from one direction across the element at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period ○ Time ○ Temperature ○ Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
d)	Decrease the temperature by at least the maximum rated temperature-cycle range Allow the temperature and pressure to stabilize.	— Stabilization time — Temperature

e)	Perform a test at or above the maximum rated differential pressure from one direction at or below the low end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
h)	Perform post-test inspection	— Inspection Results

B.7 Grade V1: Liquid Test with Temperature Cycling

The supplier/manufacturer shall adhere to the following test parameters and acceptance criteria in Table B.3 for conformance to this validation grade. The test media shall be liquid per B.3.

Table B.3 – Grade V1 Liquid Test with Temperature Cycling (from Max. to Min. to Max. Test Temperature)

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Validation test number — Date — Description of all test media, including setting and test fluids. — Measured fixture ID — Product identification — Inspection test results
b)	Set the product at or above maximum rated temperature utilizing procedures and methods identified in the supplier/manufacturer procedures. Allow the pressure and temperature to stabilize prior to next step. If conducting Low Temperature Validation (B.8), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Time required to contact fixture ID — Time required to reach differential pressure rating (after exposure to defined media)
c)	Perform a test at or above the maximum rated differential pressure from one direction across the element at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)

	has been allowed for stabilization.	
d)	Decrease the temperature by at least the maximum rated temperature-cycle range. Allow the temperature and pressure to stabilize.	— Stabilization time — Temperature
e)	Perform a test at or above the maximum rated differential pressure from one direction at or below the low end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
f)	Increase the temperature to at or above the maximum rated temperature. Allow the temperature and pressure to stabilize. If conducting Low Temperature Validation (B.8), increase the temperature to at or above the minimum rated temperature plus the temperature cycle range.	— Stabilization time — Temperature
g)	Perform a minimum 15-minute pressure hold from one direction (either pressure above or below) at or above maximum rated differential pressure. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period o Time o Temperature o Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
h)	Perform post-test inspection	— Inspection Results

B.8 Low Temperature Rating Validation

B.8.1 For validation grades V1 and V2 where the low temperature rating was not validated during the temperature-cycle range test, the low temperature rating shall be validated by product testing per the respective validation grade requirements. The low temperature rating is the lowest temperature achieved during the temperature-cycle range test. Low temperature validations shall be subject to the requirements for scaling as found in 5.9.

NOTE See 5.3.3.2 for temperature-cycle range and temperature range considerations

B.8.2 To achieve a lower low temperature rating, additional validation tests shall be conducted. The product shall be set at or above the specified minimum rated temperature plus the temperature-cycle range.

EXAMPLE A product was tested multiple times under the requirements of V1 validation testing with the following temperature-cycle ranges achieved: 50 °F to 200 °F and 250 °F to 350 °F. The published temperature range of the product is 50 °F to 350 °F, and the temperature-cycle range is 100 °F.

B.9 Scaling of Validation-tested Swellable Packer Designs

B.9.1 General

For general scaling rules refer to 6.9 Design Scaling.

B.9.2 Scaling Pressure Rating Vs Hole Size and Length

B.9.2.1 General

B.9.2.1.1 To determine a scaled pressure rating for a defined size of packer design with a specified temperature range in different hole sizes, a straight-line interpolation of pressure capability between two different hole sizes or different lengths of packers validated per this Annex shall be performed. The scaled packer design may be accepted as validated when these processes are completed. The validation of the scaled packer design shall be approved by a qualified person other than the person performing the scaling. The design records of the scaled packer shall include the approved scaling process.

B.9.2.1.2 Extrapolation of pressure capabilities is not acceptable.

B.9.2.2 Pressure Rating vs Hole Size Example

B.9.2.2.1 See Figure B.1. For a specified base pipe size, a graph of pressure rating vs hole size can be created with the pressure rating on the Y axis and the percent volumetric swell on the X axis. A secondary X axis should be included showing the diametric hole size for a given percent of volumetric swell. Linear interpolation between the two test points is allowed. When more than two points are available, non-linear interpolation is allowed.

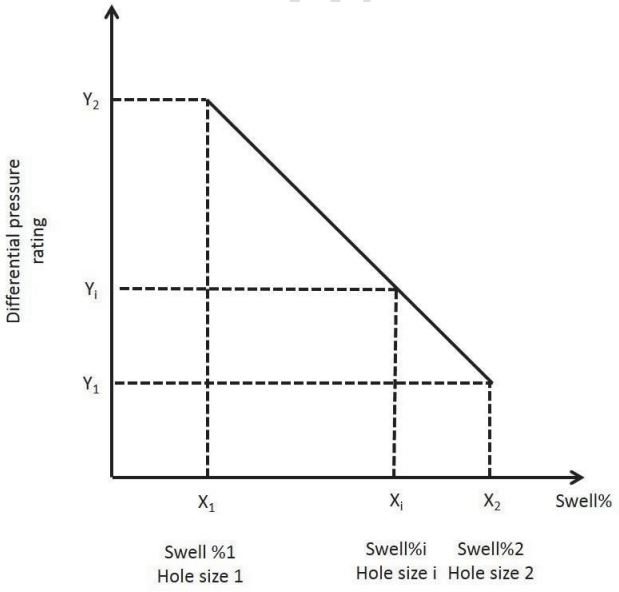


Figure B.1—Pressure Rating Vs Hole Size

B.9.2.3 Pressure Ratings vs Length Changes

B.9.2.3.1 To establish an interpolated validation of a swellable packer design utilizing two different validated packer lengths, create a graphical representation of the two packer designs as shown in Figure B.2.

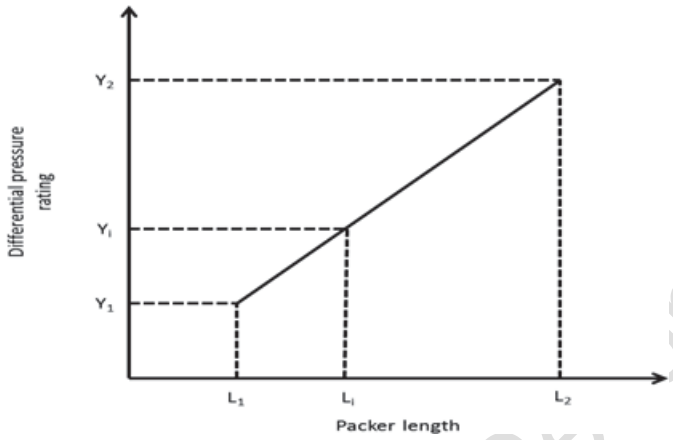


Figure B.2—Pressure Rating vs Length

B.9.2.3.2 For a specified packer size and sealing ID, a plot of seal length can be created by establishing two points representing the two different length packers. Linearly interpolate between the tested packer lengths L_1 and L_2 to calculate the differential pressure rating of L_i.

B.9.2.3.3 Design changes are limited as defined in 5.8.

B.9.2.4 Bilinear Interpolation of Swell Percentage and Length

To establish an interpolated validation of a swellable packer design, perform the following with four data points defined on a graphical representation as shown in Figure B.3.

a) Two performance envelopes created according to Figure B.1 can be overlaid to allow interpolation between volumetric % swell and length.

   i. A straight line between tested points X_1 and X_2 for L_1 create the lower boundary b. A straight line between tested points X_1 and X_2 for L_2 create the upper boundary

   ii. A packer with length Li can be interpolated between the two boundaries to determine the pressure rating for any volumetric % swell X_i.

b) Figure designations:

   i. Specified base pipe size. Packer centralized in hole, i.e. uniform swell %.

   ii. Linearly interpolate between tested swell % X1 and X2 to calculate DP rating of Xi.

   iii. Linearly interpolate between the tested packer lengths L1 and L2 to calculate the differential pressure (DP) rating of Li.

   iv. Hole size calculated based on swell %, base pipe size, and packer.

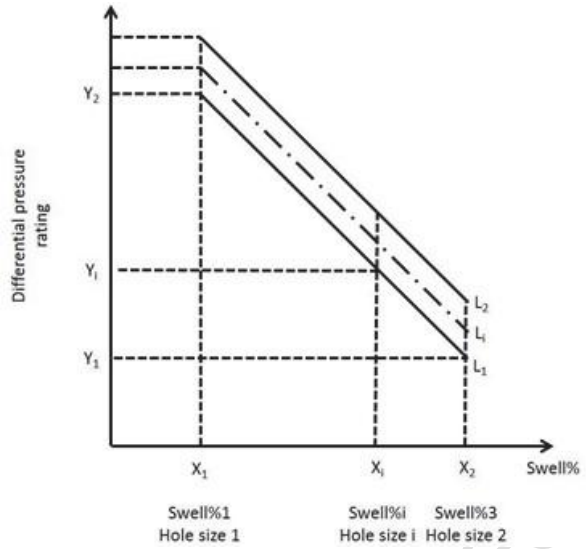


Figure B.3—Combined Performance Interpolation of Swell Percentage and Length

Annex C
(informative)

Combined Load Testing

C.1 General

C.1.1 This annex covers combined load testing for inflatable, expandable, openhole mechanical, and chemically reactive packers. Combined load testing validates a design against the effects of differential pressure and axial loads acting on the product at the maximum rated temperature. **Swellable packers are excluded from this annex**.

C.1.2 Combined load testing for openhole packers shall be in addition to a standard validation grade product, as defined in Annex A. This annex may be completed separately from Annex A, however, documentation for each test including pre-test and post-test dimensional inspection results are required. Alternatively, the requirements of this annex may be completed during the testing performed in Annex A after the completion of the initial pressure reversals and before the temperature cycle test of Annex A.

C.1.3 This annex defines the combined load test procedure and the resulting rated performance envelope requirements.

C.2 Rated Performance Envelope

C.2.1 The combined load rating for a product that has successfully completed the testing requirements of this annex shall be represented by a rated performance envelope. The area within the lines forming the boundaries defines the maximum rated performance envelope of the product when it is set. The performance limits illustrated in the rated performance envelope shall be supported by documented validation testing in accordance with the requirements of this annex. An example envelope is illustrated in Figure C.1. The rated performance envelope shall be approved by a qualified person.

C.2.2 For products that do not have axial load ratings, the rated performance envelope may be a horizontal straight line. For products that are anchoring only, and do not contain pressure, the rated performance envelope may be a vertical straight line.

C.2.3 Rated performance envelopes shall meet the following criteria. Required information that is not on the performance envelope shall be on the product data sheet:

a) The product(s) covered by the envelope;

b) The validation grade;

c) The minimum and maximum rated hole size shall be specified. The envelope shall be applicable over the entire specified hole size range;

d) The seal diameter used to define the envelope and used to separate pressure-induced loads included in the envelope versus pressure-induced loads that must be converted to applied axial loads by the user/purchaser;

e) The rated temperature-cycle range. NOTE: temperature-cycle range validation is defined in 5.3.3.2;

f) The rated temperature limits (maximum and minimum). NOTE: low temperature rating validation is addressed in A.5;

g) The rated performance envelope shall represent the supplier/manufacturer's maximum rating at the maximum rated temperature and be applicable over the entire specified temperature range;

h) The rated performance envelope is based on testing in casing or in a representative fixture. Actual performance in openhole conditions will vary depending on the hole condition and formation competency;

i) Unless otherwise specified, tubing-to-packer loads are applied to the top of the product;

j) Packers with IDs shall be represented with the ID not plugged (unplugged) unless it is otherwise specified on the envelope. Bridge plugs are represented with the ID plugged;

k) "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 on the envelope or illustrated as an additional graphic;

l) Shear devices shall be represented at 100 % of their minimum shear value;

m) The ratings of end connections shall not be included in the rated performance envelope;

n) If more than one graph is displayed with the envelope then a legend shall be included for explanation. For example, various shear device options, plugged, unplugged, location of plug, alternate temperatures, alternate rated IDs, can be displayed;

o) Axis and sign conventions shall be oriented as shown in Figure C.1.

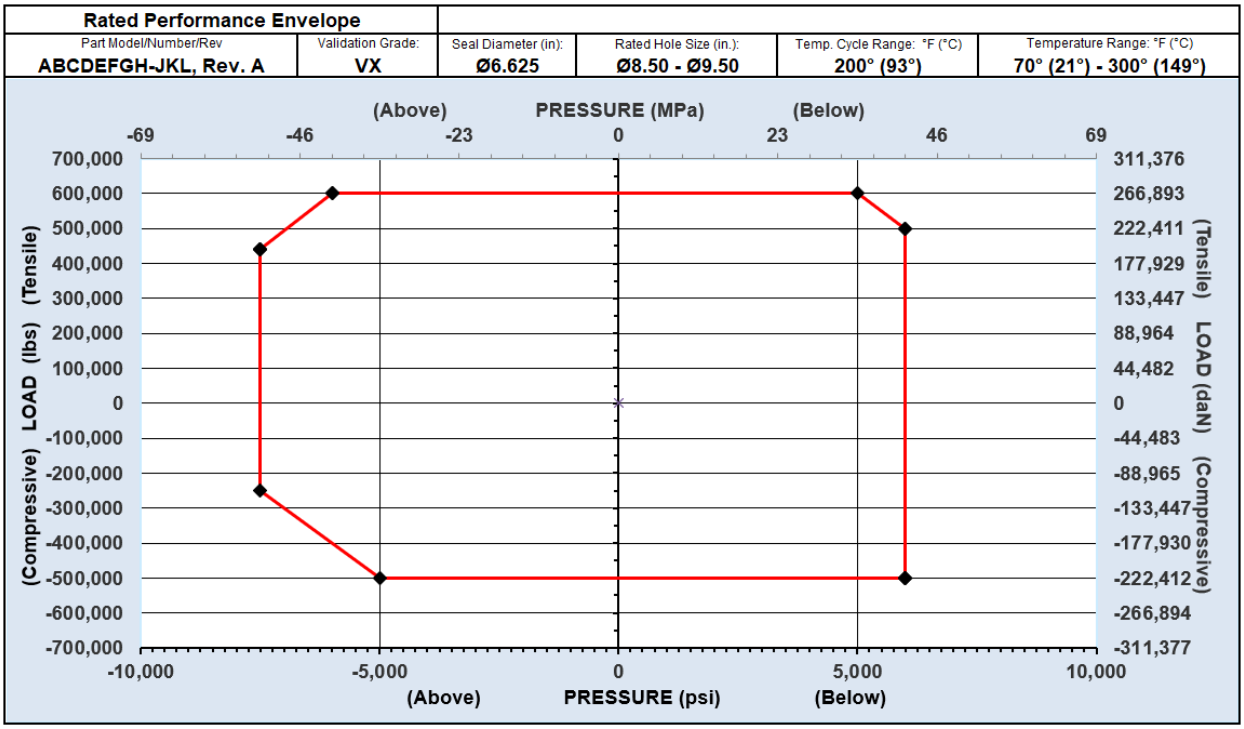


Figure C.1 – Example of a Rated Performance Envelope

C.3 Validation Requirements

C.3.1 Validation testing per this annex is performed when required by the user/purchaser or when the supplier/manufacturer provides a product with a rated performance envelope that includes combined load ratings.

C.3.2 Products that were previously validated to a combined load performance envelope that are being considered to meet the requirements of this edition of 19OH shall be evaluated against the requirements of this annex. Results shall be documented and approved by a qualified person.

C.3.3 Section A.2 Common Validation Requirements apply to this annex with the following additional requirements:

a) Additional test points are at the discretion of the supplier/manufacturer or can be specified by the user/purchaser without invalidating the required test points.

b) Products having shear-release features shall be tested at their maximum rated shear load. For safety, the shear device may be replaced with a stronger shear device that can adequately withstand the maximum shear load.

c) Axial loads shall be applied to the top of the packer. 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 and normalized back to the seal diameter documented in the rated performance envelope.

   Applied axial loads shall be in addition to the pressure-induced loads.

   Pressure-induced loads from above shall be calculated using the cross-sectional area from the fixture ID to the nominal tubing OD or documented seal diameter for products that are directly connected to the tubing.

   Pressure-induced loads from below shall be calculated using the cross-sectional area from the fixture ID to the nominal tubing OD or documented seal diameter for products directly connected to the tubing.

C.4 Validation Test Procedure

C.4.1 The supplier/manufacturer shall develop procedures for validation testing. These procedures shall be documented and referenced with revision level or included in the final report of the results. The procedures shall include pre-test and post-test dimensional inspection activities and identify critical areas to be inspected. The procedure shall at minimum satisfy the requirements in Table C.1.

C.4.2 Failures in the test facility or test fixture and justification for validity of test results shall be included in the final report of the results.

C.5 Measuring and Monitoring Equipment

Measuring and monitoring equipment used during the validation test process shall conform to the requirements of 5.5.2.5 Measuring and Monitoring Equipment.

C.6 Validation Test Requirements

The steps within each test shall be performed in the order shown in Table C.1.

Table C.1 – Combined Load Test at Maximum Rated Hole Size and Maximum Rated Temperature

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Validation test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step. If conducting Low Temperature Validation (A.7 Method A), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Setting Pressure or Force — Setting Time
c)	Perform a test at or above the maximum rated differential pressure from one direction at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria**: No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period ○ Time ○ Temperature ○ Pressure(s) — Direction of each pressure hold (above or below) — Test step passed? (yes or no)
c)	Test to all intersection points of the rated performance envelope. Maintain a minimum hold period of 15 minutes for each envelope point. **Acceptance criteria:** No more than 1 % reduction in the maximum rated differential pressure over the hold period after sufficient time has been allowed for stabilization.	— Start to end of each hold period ○ Time ○ Temperature ○ Pressure(s) ○ Axial/pressure induced load — Direction of each pressure hold (above or below) — Test step passed? (yes or no) — Direction of load
d)	Perform post-test inspection.	— Inspection Results

C.7 Validation Test Report

A final report shall be prepared per 5.5.2.5 Validation Test Report.

C.8 Design Validation by Scaling

The scaling of validated product designs shall conform to the requirements of 5.7 Design Validation by Scaling.

Annex D
(informative)

Swell Rate and Axial Load Testing for Swellable Packers

D.1 General

D.1.1 The volume swell and swell rate are used to determine the swellable packer outside diameter changes over time for information published by the supplier/manufacturer, used by the supplier/manufacturer to determine time to set, or requested by the user/purchaser.

D.1.2 Volume swell is the change in cross-sectional area per unit of length of a swellable element in which the inner diameter of the element (mandrel OD) remains unchanged. The swell rate is the volume swell change over time. Volume swell percentage is the final volume minus the initial volume divided by the initial volume multiplied by 100.

D.1.3 This testing is performed on a material sample to establish volume swell. The supplier/manufacturer shall have procedures and measurement criteria that are performed on using procedures and methods approved by a qualified person and the results documented. Documentation process shall include all material specifications and processes (retarding and/or accelerating agents) applied to the material sample as would be applied to the packer element.

D.2 Swell Percentage and Swell Rate

D.2.1 The selected elastomer's propensity to swell and the rate at which it swells may be determined using small-scale testing. Small-scale testing is separate from the full-scale validation testing. Small-scale samples can be correlated back to full-scale swell percentage and rate when tested in similar wellbore fluids and temperatures.

D.2.2 The supplier/manufacturer shall have a documented procedure to determine the swell rate of an elastomer and document all parameters and results of the evaluations that demonstrate correlation to the swell capabilities of a full- scale packer. Testing, correlations, and procedures shall be performed by a qualified person and checked and approved by a second qualified person.

D.2.3 The test procedure shall document:

a) test temperature,

b) swell test fluid,

c) description of sample,

d) unique material identification,

e) original dimensions of the sample,

f) time between measurements,

g) final dimensions and description.

D.2.4 The correlation/test report will include the testing results as defined in the testing procedures, detailed correlations, and shall be approved by a qualified person.

D.3 Axial Loading for Polymeric Swell packers

D.3.1 General

When selected by the user/purchaser, or as desired by the supplier/manufacturer, an optional axial loading test of the swell packer element can be conducted in an open hole test fixture. This test will not include pressure differential or combined loading and will not require a rating envelope to be generated.

D.3.2 Open Hole Test Fixture

The swellable packer shall be set in a fixture with a formed ID equal to gauge hole size. The ID will require an internal profile on the setting ID with dimensions as described in Figure D.1 that simulate an open hole finish. Figure D.2 illustrates a sample openhole test fixture and internal profile.

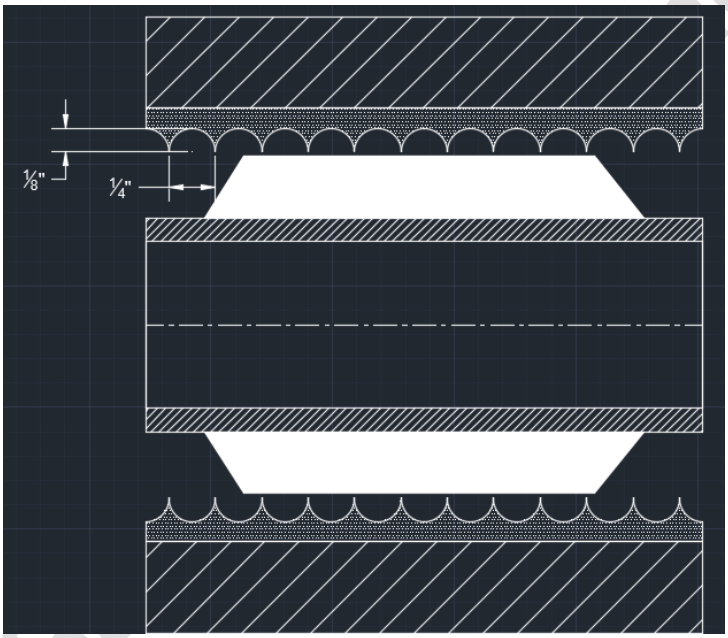


Figure D.1—Illustration of Open Hole Test Fixture Internal Profile

Example method to prepare an open hole finish:

a) Procure a parent casing large enough to allow for sufficient cement sheath
b) Cut to required length(s) and add your choice of connection/test cap
c) Procure Styrofoam core, equal to the hole size
d) Wrap the core with rope.
e) Centralize core in parent casing
f) Fill with concrete & set
g) Remove core by dissolving with toluene

Figure D.2—Illustration of Open Hole Test Fixture and Internal Profile

D.3.3 Axial Load Testing Process

The supplier/manufacturer shall adhere to the following test parameters and criteria in Table D.1 for conformance to the axial load testing. Perform the following steps in the order shown.

Table D.1—Axial Load Testing Process

Step	Procedure and Acceptance Criteria	Data to Be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Validation test number — Date — Description of all test media, including setting and test fluids. — Measured fixture ID — Product identification — Inspection test results
b)	Set the product utilizing procedures and methods identified by supplier/manufacturer. This includes orientation (horizontal or vertical) which shall be documented. If conducting Low Temperature Validation (B.8), set the product at or above the minimum rated temperature plus the temperature cycle range.	— Actual Temperature — Swell test fluid composition — Test orientation (horizontal or vertical) — Time required for swell packer to reach differential pressure rating after exposure to a defined fluid and temperature.

c)	Apply axial load until there is movement of the swell packer	— Load application and direction (tensile or compression) — Time — Temperature — Axial load required to move the swell packer
d)	Perform post-test inspection	— Inspection results

Annex E
(informative)

External Flow Testing

E.1 General

E.1.1 This annex defines the requirement for product external flow testing for all the OH packer except the swellable packer. If a condition exists where the swellable packer seal can swab, then the outlined procedures in this Annex can be used to test the swellable packer.

E.1.2 External flow testing (sometimes called swab testing) simulates a condition that exists

a) when an unset product is moved through the casing or open hole filled with fluid, OR

b) when fluid is passed externally around a stationary product in an open hole.

E.2 Testing Requirement

The following outlines the testing requirements in addition to 6.3 Design Requirements.

a) The product shall be decentralized in the fixture so that one side of the product rests either rest on the ID of the test fixture or have a maximum gap of .05". The fixture setup and engineering analysis showing a max gap between packer OD and casing ID must be properly documented in the test report.

b) Minimum of two tests shall be run using a new packer seal of the same part number and revision, material specification, and construction of each test.

c) Each test shall consist of a flow test from above and below. The test procedure shall define the direction(s) of the flow.

d) The external flow test shall be conducted with water or other liquid approved by a qualified person. If test liquid is not water, then fluid specifications such as viscosity at room temperature and 180 deg F, Density at room temperature and 180F, and solid content (if applicable) must be documented in the test report.

E.2.1 Personnel

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

E.2.2 Measuring and Monitoring Equipment

Measuring and monitoring equipment used during the test process shall conform to the requirements of 5.5.2.5 Measuring and Monitoring Equipment.

E.2.3 Procedures

The supplier/manufacturer shall develop procedures for conducting the external flow tests, which shall be documented and included in the final reports of the results. The procedures shall as minimum include the parameters defined in E.4. The procedures shall include acceptance criteria.

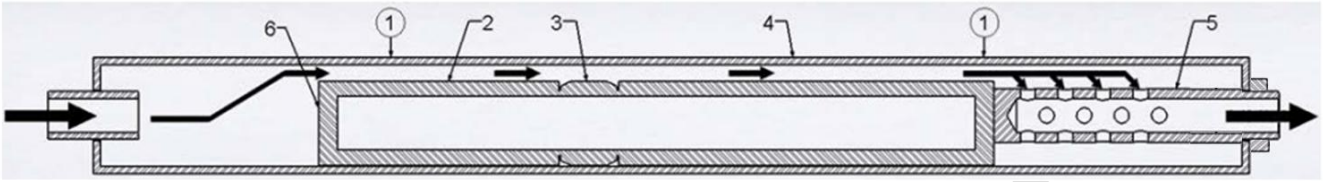
E.3 Test Fixture

a) The functionally tested product shall be installed in a section of the casing/fixture with an ID equal to

minimum ID of the casing or open hole it rated to run through or circulated with a tolerance of ± .762 mm (± .030 in.).

b) In the case where the minimum casing ID or open hole ID is less than the specified drift, the drift dimension shall be used as the fixture ID.

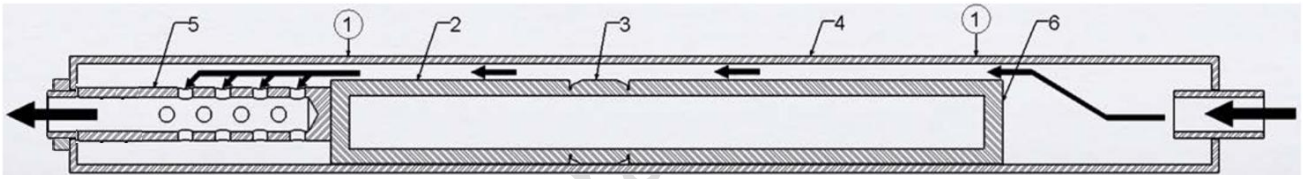
The actual measured ID of the test casing/fixture shall be recorded in the test report. The end of the test product shall be closed to direct all flow entering the fixture to flow around the outside of the product. See figure E.1 and E.2 for an illustration of an example test fixture.



Key

1 pressure gage
2 product
3 packing elements
4 test chamber
5 ported extension
6 top of product

Figure E.1 – Test Setup for Flow Test from Above



Key

1 pressure gage
2 product
3 packing elements
4 test chamber
5 ported extension
6 top of product

Figure E.2 – Test Setup for Flow Test from Below

E.4 Test Procedure

Conduct the external flow testing according to the following steps.

a) Perform a visual and dimensional inspection according to the documented procedures.

b) The test fluid shall be a minimum of 82.2 ºC (180 ºF) throughout the testing.

c) Pump the heated fluid through the fixture starting at the supplier/manufacturer defined starting flow rate for a minimum of 5 minutes while monitoring the pressure drop across the packer.

d) Increase the flow rate stepwise until the flow rate meets or exceeds the supplier/manufacturer defined maximum external flow rate.

e) Pump the heated test fluid through the test fixture for a minimum of 2 hours at the defined maximum external flow rate.

f) The test is concluded when the pressure and/or flow rate meets the supplier/manufacturer stated acceptance criteria.

g) Perform a visual and dimensional inspection according to the documented procedures.

h) Perform steps b) through g) from the opposite direction of flow.

E.5 Report

A test report shall be prepared that include:

a) Identification of the tool tested, including unique identifier and serial number as applicable;

b) Data and location of the testing;

c) Procedures utilized and records required;

d) Results of visual and dimensional inspections;

e) Identification of personnel performing the test;

f) Results of testing including comparison to the supplier/manufacturer acceptance criteria and discussion of the results.

g) Approvals from a qualified person

h) Bills of materials and component's traceability records

i) Measured casing/fixture ID;

j) Test fixture orientation and the gap analysis to ensure that the gap is no more than .05".

k) Remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during the test).

Annex F
(informative)

Mass Loss Testing

F.1 General

This annex defines the requirement for product mass loss testing for chemically reactive openhole packers to be added to the product validation testing per Annex B as a phase set just prior to the setting phase. These requirements are added when the following conditions warrant mass loss considerations as determined by a qualified person:

a) when an unset product is moved through the casing or open hole filled with in-situ reactive fluid, OR

b) when reactive fluid is passed externally around an unset stationary product in an open hole (e.g. during fluid changeover), OR

c) when a well is expected to experience losses or interzonal flow while containing reactive fluids prior to or during the setting of the packer.

F.2 Testing Requirements

The following outlines the testing requirements in addition to section 5.3: Design Requirements.

a) Each product shall be tested within the limits specified in the mass loss test procedure. The test results and design documentation shall be maintained to the requirements of 5.3 Design Requirements as applicable. The test procedures, testing results and ratings shall become a portion of the products design documentation.

b) Mass loss testing is an optional part of the Annex B validation and uses the fixturing as defined in that annex. When required, these tests shall be conducted immediately prior to the setting phase and shall subject the reactive materials to reactive fluid flow simulating expected downhole conditions. This test allows for disassembly of the fixturing to enable measurements of the remaining reactive materials to be completed, or to facilitate assembly to other fixtures (e.g., axial load ram). The transition to the setting phase should begin following this test with interruption only allowed to facilitate said disassembly and/or transportation between flow test facilities and high-pressure testing facilities as applicable.

c) Mass loss test shall be conducted with saltwater brines or other reactive liquid matching the expected well exposure. The reactive fluids shall be heated to the appropriate temperature taking evaporative and boiling conditions into consideration or following a representative simulated temperature profile (which may include heating and/or cooling patterns). Testing may be conducted at ambient pressure or at simulated well pressures in a closed loop flow system.

d) Test duration shall match expected well conditions encountered prior to packer setting phase initiation. Scaling is allowed to any lower exposure time or lower fluid flow rates than tested, but extrapolation is not allowed. Accelerated testing is not permitted.

F.3 Personnel

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

F.4 Measuring and Monitoring Equipment

Measuring and monitoring equipment used during the test process shall conform to the requirements of 5.5.2.5 Measuring and Monitoring Equipment.

F.5 Testing Procedures

The supplier/manufacturer shall develop procedures for conducting the mass loss tests, which shall be documented and included in the final reports of the results. The procedures shall include the parameters defined in F.2.1. The procedures shall include acceptance criteria.

F.5.1 Full Scale Test Fixture

F.5.1.1 The tested product shall be installed in a section of the casing/fixture per Annex B.

F.5.1.2 The actual measured ID of the test casing/fixture shall be recorded in the test report. The fixture will be designed is such a way to allow directed flow to pass through the annular section of the test fixture containing the reactive elements.

F.5.2 Procedure

Conduct the mass loss testing according to the following steps:

a) Perform a visual and dimensional inspection according to the documented procedures.

b) The test fluid shall be at minimum of rated temperature or follow expected temperature profile throughout the testing.

c) Pump the heated fluid through the fixture starting at the supplier/manufacturer defined flow rate or flow rate profile.

d) Pump the heated test fluid through the test fixture per the defined test duration.

e) Proceed to the setting phase as applicable.

F.5.3 Report

Annotation in the Validation Test Report per Annex B shall include:

a) Identification of the tool tested, including unique identifier and serial number as applicable;

b) Data and location of the testing;

c) Procedures utilized and records required;

d) Results of visual and dimensional inspections;

e) Identification of personnel performing the test;

f) Results of testing including comparison to the supplier/manufacturer acceptance criteria and discussion of the

results;

g) Approvals from a qualified person;

h) Bills of materials and component's traceability records;

i) Measured casing/fixture ID;

j) Test fixture orientation and details of packer position within fixture (centralized or decentralized);

k) Remarks (describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during the test).

Annex G
(informative)

Gas Testing

G.1 General

G.1.1 This annex covers the gas testing of openhole packers. Gas testing will validate the ability of the packer to hold differential pressure in a gas. Gas testing for openhole packers shall be in addition to the standard validation in Annex A or Annex B for the specific packer type. The procedures for gas testing shall match the pressure and temperature cycling procedures for corresponding V4, V3, V2 and V1 validation grades in Annex A or Annex B based on packer type.

G.1.2 The tests in this annex should be done separately from Annex A or Annex B due to the complexity of swapping liquid to gas and back to liquid multiple times. Tests can be done using the same setup or using the same packer used for Annex A or Annex B.

G.1.3 The validation level as per Annex A or Annex B will be the validation level of the packer.

G.1.4 This annex defines the procedures for gas testing and gas pressure rating. The results of gas testing, including the differential pressure, temperature range with or without temperature cycle, gas leak rate should be reported as part of the product datasheet.

G.2 Testing Requirements

G.2.1 Gas tests as per this annex are performed when required by the user/purchaser or when the supplier manufacturer provides a product with a rated performance that includes differential pressure with gas.

G.2.2 The following outlines the testing requirements, which are in addition to the main body requirements per 5.3 Design Requirements. The following requirements apply:

a) Testing shall be performed within a test fixture as established in Annex A or Annex B for the specific packer type.

b) The validation-tested product shall conform to the minimum quality requirements specified in the main body.

c) Testing shall be conducted by qualified person(s). The results shall be approved by a qualified person other than the person performing the test. These records shall become part of the design documentation and included in the test report (G.6).

d) The product shall be set utilizing procedures, methods, and tools identified in referenced supplier/manufacturer procedures.

e) Time period for stabilization at each test step is at the discretion of the supplier/manufacturer.

f) Recorded temperature measurements shall be representative of the product as installed within the test fixture

g) The test medium for gas testing in this annex shall be of air, nitrogen, or other gas or mixture of gases.

h) In case liquid is used to set and activate the packer, the liquid from above and below the packer element

should be drained.

i) The pressure and temperature values for the test may be different for Annex G.

j) Graduated cylinders for accumulated gas shall be at atmospheric pressure.

k) The bubble leak rate shall not increase during the hold period.

G.3 Test Procedure

The supplier/manufacturer shall develop procedures for gas testing:

a) The differential pressure and any temperature cycling sequence shall be specified.

b) The procedure shall be documented and referenced with revision level or included in the final report of the results.

c) The procedure shall include pre-test and post-test dimensional inspection activities and identify critical areas to be inspected.

d) The procedures shall satisfy the requirements of Table G.1 or Table G.2.

e) Any failures in the test facility or test fixture and justification for validity of the test results shall be included in the final report of the results.

f) The procedure shall include gas pressure-relieving (bleed-down) operations per supplier/manufacturer. The user/purchaser may provide pressure-relieving guidelines based on specific functional requirements when applicable.

g) The procedure shall record:

   i. The quantity of gas accumulated every 5 minutes in a graduated cylinder over the hold period or minimum 15 minutes after sufficient time has been allowed for stabilization.

   ii. The time period for stabilization. This is at the discretion of the supplier/manufacturer.

   iii. The manufacturer/supplier shall determine the maximum acceptable accumulated gas leak rate over the hold period.

G.4 Measuring and Monitoring Equipment

Measuring and monitoring equipment used during the test process shall conform to the requirements of 5.5.2.5 Measuring and Monitoring Equipment.

G.5 Test Process

The steps within each test shall be performed in the order shown in Table G.1.

Table G.1. Gas Test at Maximum Rated Temperature

Step	Procedure and Acceptance Criteria	Data to be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the test product in fixture as per annex A or Annex B depending on product type: **For Annex A Products:** Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step. **For Annex B Products:** Set the test product at or above maximum rated temperature utilizing procedures and methods identified in the supplier/manufacturer procedures In case liquid is used to set, activate the packer, the liquid shall be drained from above and below packer. If conducting Low Temperature Validation (A.7 for Annex A products, B.8 for Annex B products), set the product at or above the minimum rated temperature plus the temperature cycle range.	**Annex A Products:** — Actual Temperature — Setting Pressure or Force — Setting Time **Annex B Products** — Actual Temperature — Time required to contact fixture ID — Time required to reach differential pressure rating (after exposure to defined media)
c)	Perform a test at or above the maximum rated differential pressure from one direction at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** The bubble rate shall not increase during the hold period.	— Start to end of each hold period o Time o Temperature o Pressure(s) above, below, and tubing o Axial/induced load (pressure) — Record the quantity of gas (cm3) accumulated every 5 minutes in a graduated cylinder over the minimum hold period. — The graduated cylinder for the accumulated gas shall be at atmospheric pressure — Direction of each pressure hold (above or below) of each of the three pressure tests — Test step passed? (yes or no)

h)	For products defined as retrievable, the supplier/manufacturer procedure shall be used to remove the test unit from testing fixture	— Release force, as applicable
i)	Perform post-test inspection	— Inspection Results

Table G.2. Gas Test with Temperature Cycling (from Max. to Min. to Max. Test Temperature)

Step	Procedure and Acceptance Criteria	Data to be Recorded
a)	Record test data as specified and perform pre-test inspection.	— Test number — Date — Description of test media — Measured fixture ID — Product identification — Inspection test results
b)	Set the test product in fixture as per annex A or Annex B depending on product type: **For Annex A Products:** Set the product with both the minimum rated pressure and/or force ±10 % at or above the maximum rated temperature for specified amount of setting time. Allow the pressure and temperature to stabilize prior to next step. **For Annex B Products:** Set the test product at or above maximum rated temperature utilizing procedures and methods identified in the supplier/manufacturer procedures In case liquid is used to set, activate the packer, the liquid shall be drained from above and below packer. If conducting Low Temperature Validation (A.7 for Annex A products, B.8 for Annex B products), set the product at or above the minimum rated temperature plus the temperature cycle range.	**Annex A Products:** — Actual Temperature — Setting Pressure or Force — Setting Time **Annex B Products** — Actual Temperature — Time required to contact fixture ID — Time required to reach differential pressure rating (after exposure to defined media)
c)	Perform a test at or above the maximum rated differential pressure from one direction at or above the high end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** The bubble rate shall not increase during the hold period.	— Start to end of each hold period o Time o Temperature o Pressure(s) above, below, and tubing o Axial/induced load (pressure) — Record the quantity of gas (cm3) accumulated every 5 minutes in a graduated cylinder over the minimum hold period.

		— The graduated cylinder for the accumulated gas shall be at atmospheric pressure — Direction of each pressure hold (above or below) of each of the three pressure tests — Test step passed? (yes or no)
d)	Decrease the temperature by at least the maximum rated temperature-cycle range. Allow the temperature and pressure to stabilize.	— Stabilization time — Temperature
e)	Perform a test at or above the maximum rated differential pressure from one direction at or below the low end of the temperature cycle range. Perform a second test from the opposite direction. Maintain a minimum hold period of 15 minutes after the pressure and temperature are stabilized for each test. **Acceptance criteria:** The bubble rate shall not increase during the hold period.	— Start to end of each hold period o Time o Temperature o Pressure(s) above, below, and tubing o Axial/induced load (pressure) — Record the quantity of gas (cm3) accumulated every 5 minutes in a graduated cylinder over the minimum hold period. — The graduated cylinder for the accumulated gas shall be at atmospheric pressure — Direction of each pressure hold (above or below) of each of the three pressure tests — Test step passed? (yes or no)
f)	Increase the temperature by the amount of the temperature-cycle range. Allow the temperature and pressure to stabilize.	— Stabilization time — Temperature
g)	Perform a minimum 15-minute pressure hold at or above maximum rated differential pressure in any one direction. **Acceptance criteria:** The bubble rate shall not increase during the hold period.	— Start to end of each hold period o Time o Temperature o Pressure(s) above, below, and tubing o Axial/induced load (pressure) — Record the quantity of gas (cm3) accumulated every 5 minutes in a

		graduated cylinder over the minimum hold period. — The graduated cylinder for the accumulated gas shall be at atmospheric pressure — Direction of each pressure hold (above or below) of each of the three pressure tests — Test step passed? (yes or no)
h)	For products defined as retrievable, the supplier/manufacturer procedure shall be used to remove the test unit from testing fixture	— Release force, as applicable
i)	Perform post-test inspection	— Inspection Results

G.6 Test Report

A final report shall be prepared and approved by qualified personnel and shall be retained as part of the design documentation for the product. The report shall include the following information:

a) identification of product supplier/manufacturer;

b) test facility name, location;

c) date(s) testing was conducted;

d) date and unique identification of the test report;

e) test performed, summary of results, including comparison to supplier/manufacturer acceptance criteria, with reference to the applicable industry standard and edition;

f) identification of the test procedures used and records;

g) equipment description, including size, type, model, and description; as applicable;

h) product identification and serial number, as applicable;

i) reference to tested product supporting information, including:

   i. drawings and documents that show applicable dimensions and tolerances of components, including revisions

   ii. material specifications; including revisions;

   iii. trace records

j) for the tested product and test fixture, pre-test and post-test dimensional and visual inspection results of critical operational areas, including measured OD and ID and other critical operational areas, as determined by the supplier/manufacturer;

k) list of gas test pressure, gas test temperature, and gas leak rate as applicable

l) results of specific inspections and tests of the validated product, with acceptance criteria, evaluation, and acceptance justification, such as:

   i. photograph(s) and/or visual inspections including any evidence of malfunction(s), anomalies, or damage;

   ii. drift testing;

m) remarks describing any non-specified equipment or procedures requested by manufacturer, and unusual conditions observed during test.

G.7 Design by Scaling

Scaling of gas tested products shall conform to the requirements of 6.7 Design Scaling

Annex H
(informative)

Minimum Hole Size Testing

H.1 General

This annex defines the requirements for minimum hole size testing when requested by user/purchaser. The requirement specified in the annex are in addition to Annex A. The requirement is valid for a product which employs mechanical means to set the packer and relies on the deformation of the metal or non-metallic components to hold the elastomer from extrusion. This annex does not modify the rated pressure rating established in Annex A.

The following outlines the testing requirements, which are in addition to the main body requirements per 5.3 Design Requirements.

H.2 Testing Requirements

a) The product shall be tested using the same temperature cycle range as in the validation grade test.

b) The product shall be tested at or above the rated pressure for maximum hole size as validated in Annex A

c) Component testing may be performed provided that the test adequately simulates the loading conditions that would be present if the entire assembly were tested. Supplier/manufacturer shall document the detailed test results and analysis that demonstrate justification of component testing.

H.2.2 Procedure

a) The product shall be set in round fixture with ID equal to or less than the minimum rated hole size.

b) Follow the same procedure of validation grade (V4 to V1) used in Annex A

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