Guidance for the Development of Completion Equipment Standards for HPHT Environments

API 19HPHT
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Introduction

This guidance document serves as a repository for suggested text, normative references, definitions, and informative references to be included in a standard for high-pressure high-temperature (HPHT) downhole completion equipment. The document is not intended to be a standalone specification for equipment.

The requirements in this document were written as potential additions to a product specification. The task group has the responsibility to harmonize the content of this document with the product specification and resolve any conflicts.

Requirements which are applicable to the particular downhole completion equipment, or other scenarios not specifically addressed in this guidance document, may be applied as required. This document is not intended to replace sound engineering judgment or knowledge of the specific equipment in the scope of the standard being created or revised. This document was developed considering the guidelines of API TR 1PER15K-1.

Text from this document may be included in standards for non-HPHT equipment at the discretion of the subject matter experts writing those documents.

As used in this document, the terms ‘shall’ and ‘should’ only have meaning when the text from this document is included within a product specification. The task group responsible for developing the HPHT equipment specification requirements should review and consider all instances of ‘shall’ and ‘should’ and make an appropriate determination of requirements and recommendations.

Guidance for the Development of Completion Equipment Standards for HPHT Environments

1 Scope

This document applies to down hole completion equipment for use in HPHT environments with a pressure rating greater than 103.4 MPa (15,000 psi) or with a temperature rating greater than 177 °C (350 °F). This document includes suggested requirements for functional specifications, technical specifications, design verification, design validation, and manufacturing.

2 Normative References

The following referenced documents should be considered for inclusion in the Normative References section of the parent document if used in the text below.

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

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

ANSI/NACE MR0175/ISO 15156, *Petroleum and natural gas industries—Materials for use in H_2S-containing environments in oil and gas production* [1]

ASME *Boiler and Pressure Vessel Code, Section V: Nondestructive Examination* [2]

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

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

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

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

ASTM D297, Standard Test Methods for Rubber Products—Chemical Analysis [3]

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

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

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

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

[2] ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

[3] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

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

ASTM D790, *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

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

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

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

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

ASTM D2990, *Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics*

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

ASTM E23 *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E94, *Standard Guide for Radiographic Examination*

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

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

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ISO 23936-2, *Petroleum, petrochemical and natural gas industries—Non-metallic materials in contact with media related to oil and gas production—Part 2: Elastomers* [4]

3 Terms, Definitions, and Acronyms

3.1 Terms and Definitions

For the purpose of this guidance document, the following terms and definitions should be considered for inclusion in the Terms and Definitions section of the parent document if used in the text below.

3.1.1
compound
combination of constituent elements of the formulation of a nonmetallic material from a particular supplier.

3.1.2
design margin
ratio of the material yield stress divided by the actual design stress in a given component.

NOTE Design margins account for a level of reduced performance capability to compensate for uncertainties in the potential loading (applied stress) and the intrinsic variations in the mechanical properties such as yield strength, ultimate strength, endurance strength, and modulus of elasticity that have distribution about their mean values.

[4] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

3.1.3
stress factor
ratio of the calculated stress to the temperature derated minimum yield strength of the material.

3.1.4
type 1 component
component that isolates pressure and/or may be loaded in tension or compression as the result of axial loads on the equipment.

3.2 Acronyms

The following acronyms should be considered for inclusion in the Acronyms section of the parent document if used in the text below.

COC Certificate of conformance

FEA Finite Element Analysis

FMEA Failure Modes and Effects Analysis

HPHT High Pressure High Temperature

4 General

The text contained in Annex A is recommended to be included as a normative annex for all SC19 documents which contain requirements for products that are intended for use in HPHT conditions. Changes to the text are not recommended but may be required depending on the product or technology being assessed.

Annex A
(informative)

Requirements for HPHT equipment

A.1 General

Activities required by this annex shall be performed by a competent, qualified person. All results shall conform to the acceptance criteria and be supported by approved documentation.

A.2 Functional Specification for HPHT Equipment

A.2.1 General

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

a) well architecture, specified loads, combined loads, temporary test conditions, cyclical loading conditions, thermal gradients, operating temperature range, and changes in those parameters for the life of the well operations

b) industry standards and/or regulatory requirements;

c) additional test requirements;

d) other HPHT requirements as necessary per product standard.

NOTE For information regarding investigations of load cycling see ASME BPVC Section VIII, Div 3, Article KD-3, Article KD-4, or ASME Section VIII, Div. 2, Part 5

A.2.2 Operational Parameters

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

a) well stimulation operations, including its parameters, such as acidizing (composition of the acid and acid returns), pressure, temperature, acid flow rate and exposure time, and other chemicals used during the stimulation;

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

c) sand control and fracturing operations, including sand/proppant description and volume, fluid flow rate, proppant/fluid ratio or sand/fluid ratio, chemical composition, pressure, and temperature;

d) size, type, configuration, and operational limitations of the service tools or other devices to be run with or through the equipment;

e) flow rates, exposure time, any life of well erosion or wall thickness reduction, and chemistry of fluids flowing across or exposed to the equipment;

f) conveyance method, such as; tubing, drill pipe, wireline, tractor, or coil tubing;

g) other operational parameters as necessary per product type.

A.2.3 Materials Compatibility

The user/purchaser should provide the following additional functional requirements as follows for the selection of materials where applicable:

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

b) mud type, mud density, and pH; aromatic and aliphatic solvents where present (type/amount);

c) inhibitor treatments (type, concentration, and pH);

d) oxygen scavenger systems;

e) emulsifier systems;

f) continuous or batch treatment;

g) chemical composition of fluid exposures;

h) duration and temperature of exposure;

i) control line fluid type, density and chemistry.

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

A.3 Technical Specification

A.3.1 General

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

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

A.3.2 Design Requirements

A.3.2.1 General

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

A.3.2.2 Metals

A.3.2.2.1 General

The supplier/manufacturer shall conform to the materials requirements defined in the technical specification and the following requirements.

These requirements apply for all Type 1 components.

The supplier's/manufacturer's material specification shall define mechanical and material properties as applicable to the functional requirements of the equipment:

a) elongation;

b) Charpy impact toughness (ASTM E23);

c) yield strength (ASTM A370);

d) tensile strength (ASTM A370).

A.3.2.2.2 Temperature Effects

The supplier/manufacturer shall utilize temperature de-rated yield strength for Type 1 components for each material corresponding to the maximum rated temperature. The temperature de-rated yield strength testing shall be determined from a documented procedure. Elevated temperature testing shall be conducted in accordance with ASTM E21 for yield strength. Metal mechanical properties de-rating shall be verified and documented. The test material samples shall be taken from heat(s) representative of those to be used for the intended components and shall be removed from midwall or midradius unless the equipment supplier/manufacturer determines that a more appropriate testing location is required. Alternate testing locations may be selected due to a component's highest stress location or, for cold worked material, lowest strength location due to material anisotropy.

Temperature effects for modulus of elasticity, and other relevant properties, should be considered.

A.3.2.2.3 Environmental Effects

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

A.3.2.2.4 Castings

Castings shall not be used for components that isolate pressure and/or are loaded in tension.

All castings shall conform to the requirements of API 20A, CSL3.

A3.2.2.5 Surface Hardening

Where a surface hardening process is utilized, a test specimen shall be evaluated to ensure the process conforms to the written specification and required acceptance criteria. Each equipment specification should determine the frequency for testing requirements.

A3.2.2.6 Coatings

The application of coatings and surface treatments shall be controlled using documented procedures, acceptance criteria, and qualified personnel.

A.3.2.3 Non-metals

A.3.2.3.1 Compound Selection

The supplier/manufacturer shall have a documented procedure that provides for the selection of non-metallic material and compounds that conform to the supplier's/manufacturer's equipment specification. The documented procedure shall consider:

a) functional requirements;

b) technical specifications;

c) operational parameters;

d) environmental conditions;

e) supply chain limitations and compound availability;

f) material type and compound use history;

g) geometric component design;

h) required service life;

i) required approvals for material and compound;

j) required documentation for material and compound; and

k) chemical resistance to known well fluids.

The material type and specific compound shall be selected in accordance with the supplier's /manufacturer's procedures and the requirements of the functional specification. Records of material type and compound selection shall be part of the design documentation.

A.3.2.3.2 Elastomeric Compound Assessment

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

a) Ageing testing shall be conducted on an elastomeric compound per ISO 23936-2 clause 7.2 or the supplier's /manufacturer's documented procedure. The service temperature shall be equal or lower than the maximum rated operating temperature of the equipment.
b) Compression set testing shall be conducted on an elastomeric compound per ASTM D395 or ASTM D1414 when critical to equipment performance. This evaluation shall determine the retained elastic properties after prolonged action of compressive stresses.
c) When required by the functional specification, rapid gas decompression (RGD) testing shall be conducted by the supplier/manufacturer on an elastomeric material per ISO 23936-2, Annex B with acceptance criteria of 0 or 1 for the component cross section. Unless agreed otherwise between the supplier/manufacturer and the user/purchaser, testing parameters shall be
    i. fluid composition;
    ii. test temperature: 100 °C (±2 °C) [212 °F (±5 °F)];
    iii. test pressure: 15 MPa (+1, −0.5 MPa) [2176 psi (+145 psi, −73 psi)];

iv. depressurization rate: 2 MPa/min (±0.2 MPa/min) [290 psi/min (±29 psi/min)].

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

A.3.2.4 Material Specifications

The supplier/manufacturer shall establish requirements and acceptance criteria for all elastomers and thermoplastic materials. The specification shall state if the parameters are to be measured on the actual components.

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

Table A.1—Parameters for Elastomeric Materials

Parameter	Specification as Applicable
Tensile strength	ASTM D1414, ASTM D412
Tensile modulus	ASTM D1414, ASTM D412
Elongation	ASTM D1414, ASTM D412
Compression set	ASTM D395, ASTM D1414
Density	ASTM D297
Hardness	ASTM D2240, ASTM D1415

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

Table A.2—Parameters for Thermoplastic Materials

Parameter	Specification as Applicable
Tensile strength (at either break or yield as applicable)	ASTM D638 or D1708
Elongation (at either break or yield as applicable)	ASTM D638 or D1708
Modulus of elasticity	ASTM D638
Flexural modulus	ASTM D790
Creep failure	ASTM D2990

A.3.2.5 Bond Strength Validations

For designs requiring that the elastomer 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 supplier/manufacturer referenced testing program including surface preparation requirements, with evaluated and documented acceptance criteria.

A.3.2.6 Other Materials

Materials and components that are not manufactured or supplied under the previously specified controls for metals or non-metals materials shall have documented design requirements controlled by the supplier/manufacturer and shall also have the necessary applied controls on material to ensure performance to the documented requirements. All components/materials used in tested or delivered equipment, except common hardware that do not affect DAC [per API Q1], (such as; nuts, bolts, set screws and spacers), shall be verified as conforming to documented requirements. Each of the properties specified shall have a traceable and supplier/manufacturer approved test report or COC from the component manufacturer for that batch and/or compound of material.

The design validation of other materials and components shall conform to the technical specification.

A.4 Design Verification Requirements

A.4.1 General

Design verification shall be performed with the following additional requirements:

a) The designs shall be analyzed to determine the supplier's /manufacturer's stated performance limits, including the supplier/manufacturer defined rated test pressure. The minimum material condition and minimum specified material yield strength including the applicable temperature de-rating (A.3.2.2.2), shall be used in the calculations.

b) The supplier/manufacturer shall apply a design margin to each component and/or assembly using a documented methodology and practice. The documented design margins shall be utilized in the creation of component or assembly capabilities and/or ratings.

c) The performance limits of the product shall be determined on an individual component basis at the maximum rated temperature. The design shall consider all operational loading conditions defined in the functional requirements and by the technical specifications. A stress analysis methodology that considers the applied loads and combined stresses shall be used to determine the maximum state of stress of each component of the assembly other than that of common hardware.

d) If corrosion or corrosion/erosion allowances are included in the design, the design verification shall consider these allowances.

e) Special features, which are components or sub-assemblies that provide additional functional capability not validated in defined tests, shall be identified and verified through documented procedures and acceptance criteria.

A.4.2 Design Analysis

Finite Element Analysis (FEA) shall be performed on Type 1 metallic components.

The FEA shall include the maximum operating load cases at the maximum rated temperature to evaluate for plastic collapse, local failure and buckling using ASME BPVC Section VIII, Division 2, Part 5 or ASME BPVC Section VIII Division 3, article KD-2. The load factors defined by ASME BPVC Section VIII, Division 3 or ASME BPVC Section VIII, Division 2 can be substituted with values as defined by supplier/manufacturer. The design margins defined by the supplier/manufacturer shall be met.

NOTE: a load factor is a value without units multiplied against the design load parameter used in ASME BPVC analyses which is not the same as a stress factor.

When FEA has identified plastic strain in excess of 0.2 %, a ratcheting analysis shall be performed per ASME BPVC Section VIII, Division 3, KD-234 or ASME BPVC Section VIII, Division 2 clause 5.5.7. The material performance data shall be obtained via testing per A.3.2.2.

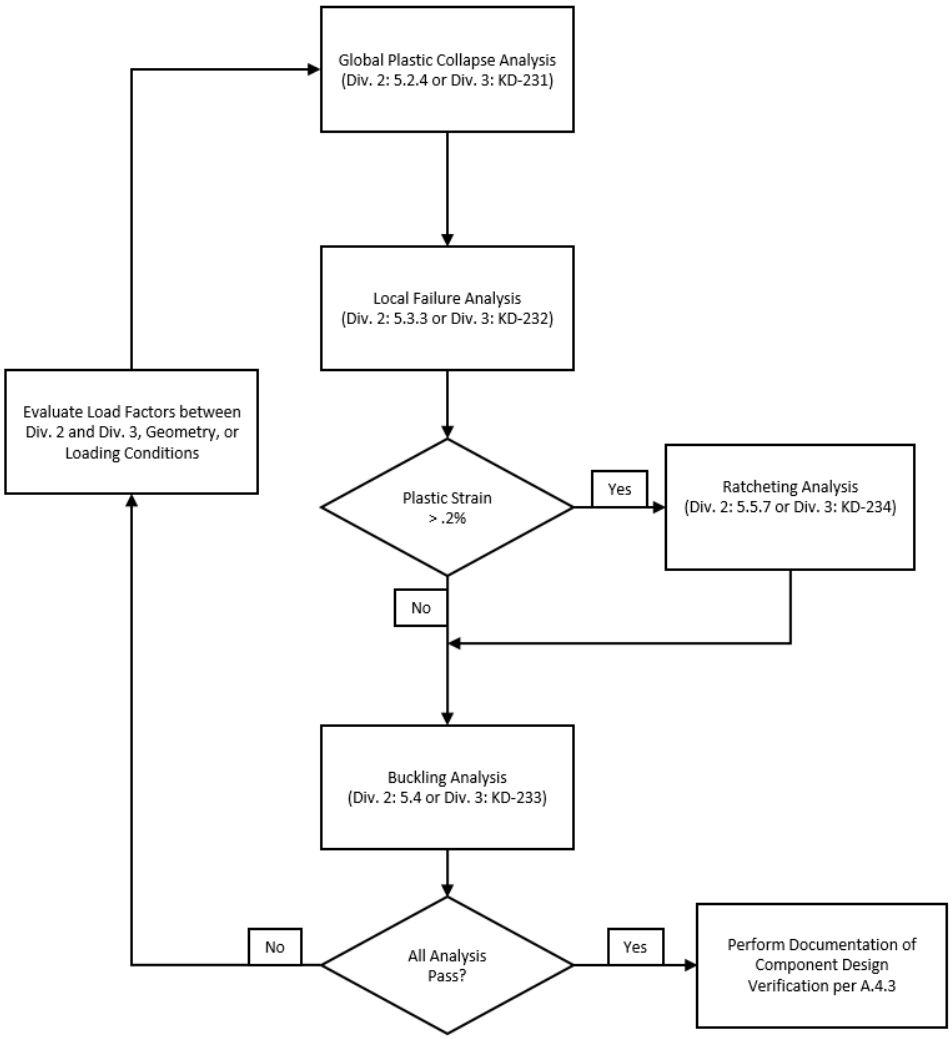

Figure 1—HPHT Design Flow Chart

The product specification should consider cyclic loading and its effect on the applicable equipment.

NOTE A fatigue screening may be performed per ASME BPVC Section VIII, Division 2, Paragraph 5.5.2. If the design exhibits fatigue sensitivity, conduct a fatigue analysis per API 579/ASME FFS-1 using a justified safety factor on anticipated operating life. Load cases to be used in the fatigue screening are provided in the functional specification.

Localized stress discontinuities and localized yielding shall be evaluated by a qualified person to determine if the design is acceptable or if additional analysis is required. These requirements do not apply to components which are intended to be plastically deformed in order for them to perform correctly. Intentionally plastically deformed component designs shall conform to supplier/manufacturer documented design analysis methodology and acceptance criteria.

A.4.3 Documentation of Component Design Verification

A.4.3.1 A summary report of each Type 1 metallic component's design shall include:

a) calculated stress;

b) stress mode;

c) maximum temperature;

d) temperature de-rated minimum yield strength;

e) applied loads; and

f) acceptance criteria.

A.4.3.2 Where applicable, documentation of FEA results shall include:

a) description of the numerical method used, including name and version of computer software;

b) component dimensions which resulted in the highest state of stress;

c) boundary conditions;

d) loading conditions;

e) mesh sensitivity review;

f) maximum allowable stress;

g) analysis results, showing the acceptance criteria utilized;

h) stress-strain curve;

i) mesh parameters; and

j) evidence of verification by a qualified person other than the individual who created the original analysis.

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

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

A.4.4 Design Validation Requirements

A.4.4.1 Validation Testing

Equipment shall be validated to their defined rated limits according to the requirements of this annex.

All design validation activities shall be documented in the product's design documentation. The validation test components shall be constructed to a verifiable and auditable quality plan (A.3.2.1).

The equipment shall be validated per the requirements of technical specification. The HPHT validation grades are to be defined by the specific product standard.

The equipment/system shall have a validated rated performance envelope. The supplier/manufacturer shall perform an inspection, as appropriate, regarding both pre and post testing on all Type 1 components. The supplier/manufacturer shall document all parameters and results of the evaluations that demonstrate conformance to this Annex. If no leakage occurred, this shall be clearly stated.

To meet the requirements of this annex, all test steps within a specific test described shall be completed without any repair or redress of the tested assembly. All results shall conform to the acceptance criteria and be supported by approved documentation.

If corrosion or corrosion/erosion allowances are included in the design, the design validation shall be conducted at minimum material condition.

Validation testing shall be discontinued if the equipment fails to perform within the limits specified for any step, except when such failures are determined and documented by evaluation to be a result of actions by the supplier/manufacturer's personnel or test facility. The basis for discontinuing the test and any unusual conditions observed at or prior to the time of discontinuance shall be documented by the supplier/manufacturer, and corrective actions implemented if the cause of failure is due to the equipment.

A.4.4.2 Failure Mode and Effects Analysis

The supplier/manufacturer shall conduct an FMEA, fault-tree analysis, or other reliability assessment method to determine if validation testing per this annex sufficiently validates the design for the intended application and further determine the requirements for additional validations. The user/purchaser shall be involved in the reliability assessment when required by contract.

Reliability assessment methods shall conform to the requirements of a national or international standard or to the supplier/manufacturers documented procedures that are based upon a national or international standard. The reliability assessment report shall be approved by a qualified person and shall become part of the design documentation.

NOTE: API TR 1PER15K-1 provides guidance and recommended procedures for conducting a FMEA.

A.4.4.3 Non-metallic Component Validations

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

- Pre- and post-inspections according to the supplier's/manufacturer's specifications, dimensional requirements, documented procedures, and acceptance criteria.
- Component validation testing at the limits of rated performance. Components successfully tested in the validation testing of the product can be considered as validated as a component when all aspects of the components functionality are tested.
- Records of inspections, component validation testing, and final approval shall become a portion of the design documentation of the product.

A.5 Validation Test Report

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

- identification of product manufacturer;
- date and unique identification of the validation test report;

— identification of the validation test procedures used;

— equipment type, description, and an assembly drawing;

— model designation or other unique product identification by manufacturer;

— product number (if applicable) and bill of materials identifying the components materials and traceability records;

— results of specific evaluations and tests with acceptance criteria evaluation such as; visual inspections, photographs, pre-test and post-test dimensional inspection of critical operational areas, and validation test reports.

A.5.1 Design Validation Scaling

A.5.1.1 General

The scaling of validated designs shall conform to the requirements within this standard and the following additional requirements.

a) The scaled design shall be of the same nominal size, type, and model as the validated design.

b) Each scaled product requires design verification, justification, and design documentation of the changes from the validated design.

c) Scaled designs shall be approved by a qualified person, other than the person who performed the design scaling verifications.

d) The summary report of the design validation scaling results and the related documentation shall be maintained in the new product's design documentation.

A.5.1.2 Design Scaling Parameters

The supplier/manufacturer shall establish and document the maximum stress factors within the previously validated design's Type 1 metallic components and in the components of the scaled design. The mode of stress and same method of calculation(s)/verification(s) shall be applied to the identified Type 1 metallic components of the base design and the scaled design.

For each Type 1 metallic component, the scaled design's stress factors shall not exceed the maximum stress factors of the same Type 1 metallic components of the validated design. The supplier/manufacturer shall ensure that the scaled design conforms to the applicable validation and functional testing requirements.

A.5.2 Final Design Approval

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

— functional requirements,

— technical specification,

— design verifications,

— design validation records including any evaluation for scaling, if applicable,

— bill of materials,

— drawings,

— material and manufacturing specifications.

This review shall be conducted by qualified individuals. The documentation of the design review shall include the attending member identifications, approval of the results by a qualified person other than the person who created the original design, completed action items shall be included in the equipment's design documentation. Records of the final design review and approval shall be maintained as part of the product's design documentation.

NOTE: Designs developed per this requirement may be part of an additional third party review depending on the specific application of equipment.

A.6 Manufacturing Requirements

A.6.1 General

Equipment produced according to this Annex shall be manufactured according to a quality management system that conforms to API Q1 and supplier/manufacturer requirements.

A.6.2 Serialization

Type 1 metallic components shall be individually serialized and traceable to heat lot.

HPHT non-metal components shall be serialized (as applicable) and traceable to the manufacturer, production batch (sometimes called a job lot), production date, and if applicable, expiration date (or shelf life). Records of traceability shall be maintained.

Prior to product assembly the individual serialization information for these components shall be verified and included on the assembly documentation for that product.

A.6.3 Non-metallic Material Supplier Qualifications

The supplier/manufacturer shall purchase goods and services only from approved suppliers.

The supplier/manufacturer shall develop and/or receive from the subsupplier of nonmetal components a process specification that details the controls necessary for the production of the nonmetal item to meet the supplier/manufacturer's specifications.

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

Supplier evaluation records shall identify the materials/components that are approved to be provided by each specific supplier. Supplier documented evaluation records shall include the necessary corrective measures and verification of their implementation.

A.6.4 Welding

Welding including overlays and brazing shall require the following:

a) Welding and brazing procedure and personnel qualification shall be in accordance with ASME Boiler and Pressure Vessel Code Section IX or equivalent internationally recognized industry standard that is no less stringent than ASME requirements.

b) Weld materials and practices not listed in the ASME *Boiler and Pressure Vessel Code* Section IX shall be applied using weld procedures qualified in accordance with the methods of ASME *Boiler and Pressure Vessel Code* Section IX or equivalent.

c) Welding for sour service shall meet the requirements of ANSI/NACE MR0175/ISO 15156.

A.6.5 Non-Destructive Examination

A.6.5.1 NDE of Type 1 Components

Type 1 metallic components shall be volumetrically inspected by radiographic or ultrasonic techniques after heat treat, and magnetic particle or liquid penetrant inspected for surface defects, after final machining.

A.6.5.2 Pressure Containing Welds

All pressure containing welds shall be magnetic particle or liquid penetrant inspected for surface defects and shall be volumetrically inspected by radiographic or ultrasonic techniques to verify conformance with the supplier's /manufacturer's written specifications. Final NDE shall be performed after all welding, post-weld heat treatment, straightening and applicable machining operations on welded areas.

A.6.5.3 NDE Methods and Acceptance Criteria

a) The following methods for NDE shall be utilized considering the acceptance criteria. If radiographic inspection of components is performed, it shall be in accordance with ASTM E94 and to the acceptance criteria of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UW-51, as a minimum.

b) If wet magnetic particle examination of components is performed, it shall be per ASTM E709.

1) Indications shall be described as one of the following:

i. relevant indication: only those indications with major dimensions greater than 1.6 mm ($^1/_{16}$ in.) shall be considered relevant, whereas inherent indications not associated with a surface rupture (i.e., magnetic permeability variations, non-metallic stringers etc.) shall be considered irrelevant;

ii. linear indication: any indication in which the length is equal to or greater than three times its width;

iii. rounded indication: any indication which is circular or elliptical in which the length is less than three times its width.

2) The acceptance criteria are:

i. any relevant indication greater than or equal to 4.8 mm (3/16 in.) shall be considered unacceptable;

ii. no relevant linear indications shall be allowed for weldments;

iii. no more than ten relevant indications shall be present in any 39 cm^2 (6 $in.^2$) area;

iv. four or more rounded relevant indications in a line separated by less than 1.6 mm (1/16 in.) shall be considered unacceptable.

c) If liquid penetrant of welds is performed, it shall be inspected per ASTM E165 with acceptance criteria of:

1) no relevant linear indications;

2) no relevant rounded indications greater than 4.8 mm (3/16 in.); or

3) no more than four or more relevant rounded indications in a line separated by 1.6 mm (1/16 in.) or less (edge to edge).

d) When performed, ultrasonic inspection of components shall be in accordance with ASME *Boiler and Pressure Vessel Code*, Section V, Article 5 and with the following acceptance criteria.

1) Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

2) Other imperfections are unacceptable if the indications exceed the reference level amplitude and have lengths which exceed:

i. L > 6.4 mm (1/4 in.) for t ≤ 19 mm (3/4 in.)

ii. $L > {}^{1}/_{3}\,t$ for 19 mm < t ≤ 57.2 mm (3/4 in. < t ≤ 2-1/4 in.)

iii. L > 19 mm (3/4 in.) for t > 57.2 mm (2-1/4 in.)

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

A.6.6 Functional Testing Requirements

A.6.6.1 General

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

A pressure test shall be performed on each product by pressurizing to the supplier rated internal test pressure at ambient or minimum rated temperature. In the event that the equipment has design or operational features that does not allow testing to the requirements of this specification, the supplier/manufacturer shall document the incompatibility and shall identify the proposed revised test steps/conditions and technically justify the revision(s). The supplier/manufacturer shall include the justification of any changes to the functional test in the product's design documentation.

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

Unless otherwise specified, all pressure test holds shall have a minimum duration of 15 minutes after pressure stabilization.

A.6.6.2 Functional Testing Parameters

Each assembly shall be functionally tested in accordance with functional testing parameters defined within the documented supplier/manufacturer requirements.

a) The loss of applied pressure after stabilization shall be less than 1% during the hold period. No leakage shall be visible or observed during testing.

b) Special features not tested in the defined functional testing shall be tested in accordance with the supplier's/manufacturer's procedures and acceptance criteria.

c) If applicable, a drift test shall be performed per the requirements of the equipment specification, including assemblies with internal sealing surfaces (bores).

d) A visual inspection shall be performed of all accessible surfaces by a qualified person after all testing is successfully completed. Observed damage shall be documented in the test report and the acceptance adjusted as applicable.

A.6.6.3 Functional Test Documentation

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

- Identification of product manufacturer;
- date of functional test and date of report;
- model designation or other identification;
- product number and revision level with unique serial number;
- remarks describing any non-specified equipment or procedures requested by manufacturer, unusual conditions observed during test, etc.;
- testing limits applied and testing results compared to the acceptance criteria;
- results of specific evaluations such as; visual inspections and drift testing;
- running/pulling tools used (if applicable);
- test fixtures, test fluids, and lubricants;
- test approval by a qualified person other than the person performing the test.

A.6.7 Product Identification

Designs that meet the requirements of this annex shall be permanently marked to the requirements identified in product identification and with the applicable design validation grade.

Bibliography

The following reference documents should be considered for inclusion in the Bibliography of the referenced parent document.

[1] API TR 1PER15K-1, *Protocol for Verification and Validation of High-pressure High-temperature Equipment*

[2] ISO 23936-1, *Petroleum, petrochemical and natural gas industries—Non-metallic materials in contact with media related to oil and gas production—Part 1: Thermoplastics*