

Specification for Downhole Well Test Tools and Related Equipment

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Foreword

This specification has been developed by users/purchasers and suppliers/manufacturers of downhole well test tools 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 the tools named within the scope. Furthermore, this specification addresses the minimum requirements with which the supplier/manufacturer is to comply so as to claim conformity with this specification.

Users of this specification should be aware that requirements above 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 should identify any variations from this specification and provide details.

This first edition of the specification has been authored in an effort to cover the prominent range of well test tools. Additionally included are requirements for service centers to ensure these products perform as designed when maintained as defined therein. It is recognized that these requirements may merit some refinement following their utilization.

Included in this specification are nine annexes (Annexes A through I), all of which are normative except Annexes H and I. Where referenced, these annexes provide mandatory requirements for conformance to this specification.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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Introduction

This specification applies to downhole well test tools that prior to this publication were not addressed by standards or specifications. Additionally, this specification defines requirements for service centers from which these tools are typically provided and maintained.

This specification has been developed by users/purchasers and suppliers/manufacturers of downhole well test tools and related equipment as defined herein and intended for use in the petroleum and natural gas industry worldwide to give requirements and information to both parties in the selection, manufacture, testing, and use of these tools. Furthermore, this specification addresses the minimum requirements with which the supplier/manufacturer is to comply so as to claim conformity with this specification.

This specification has been structured with a single grade of quality control requirements and three grades of design validation. These validation grades provide the user/purchaser the choice of requirements to meet their preference or application. Design validation grades V3 (well test tools) and V3-TP (well test packers) are the minimum grades, and V1 (well test tools) and V1-TP (well test packers) are the most stringent grades.

Annexes A, B, C, D, E, F, and G are normative requirements, whereas Annexes H and I are informative.

Annexes are as follows:

- Annex A—Validation Requirements for Downhole Well Test Tools and Related Equipment;
- Annex B—Factory Acceptance Testing;
- Annex C—Service Center Requirements;
- Annex D—Performance Rating Envelopes;
- Annex E—Well Testing Packer Requirements;
- Annex F—Electronic and Electrical Components, Subcomponents, and Systems Requirements;
- Annex G—Testing Surface Safety Valve Requirements;
- Annex H—Applications Overview;
- Annex I—Operational Recommendations.

The international system of units (SI) is used in this specification; however, U.S. customary units are also shown for reference.

Users of this specification should be aware that requirements above 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 should identify any variations from this specification and provide details.

Specification for Downhole Well Test Tools and Related Equipment

1 Scope

This specification provides the requirements for downhole well test tools and related equipment as they are defined herein for use in the petroleum and natural gas industries. Included are the requirements for design, design validation, manufacturing, functional evaluation, quality, handling, storage, and service centers. Tools utilized in downhole well test operations include tester valves, circulating valves, well testing packers, safety joints, well testing safety valves, testing surface safety valves (TSSVs), slip joints, jars, work string tester valves, sampler carriers, gauge carriers, drain valves, related equipment, and tool end connections.

This specification does not cover open hole well test tools, downhole gauges, samplers, surface equipment, subsea safety equipment, perforating equipment and accessories, pup joints external to well test tool assemblies, work string and its connections, conveyance or intervention systems, installation, control and monitoring conduits, and surface control systems.

A downhole well test is an operation deploying a temporary completion in a well to safely acquire dynamic rates, formation pressure/temperature, and formation fluid data. Downhole well test tools are also used in operations of well perforating, well shut-ins, circulation control of fluids, and stimulation activities. This document covers the downhole tools used to perform these operations; however, the operational requirements of performing these operations are not included.

2 Normative References

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

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

ASME Boiler and Pressure Vessel Code (BPVC)¹, *Section IX: Welding and Brazing Qualifications*

ASNT SNT-TC-1A², *Recommended Practice for Personnel Qualification and Certification in Non-destructive Testing*

ASTM E10³, *Standard Test Methods for Brinell Hardness Testing of Metallic Materials*

ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ISO 3601-1⁴, *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 6506 (all parts), *Metallic materials—Hardness test—Brinell test*

¹ ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

² American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

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

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

ISO 6507 (all parts), *Metallic materials—Vickers hardness test*

ISO 6508 (all parts), *Metallic materials—Rockwell hardness test*

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

ISO 18265, *Metallic materials—Conversion of hardness values*

NACE MR0175 ⁵/ISO 15156 (all parts), *Petroleum, petrochemical, and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

3 Terms and Definitions

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

3.1

absolute pressure

Hydrostatic pressure plus applied pressure.

3.2

absolute pressure dependency

A condition in which a tool has an atmospheric or nonpressure balanced chamber, or seals having multiple sealing elements in a common seal gland, or seal systems having multiple seal glands where an atmospheric space can exist between glands.

3.3

ambient temperature

Prevailing temperature at test site.

3.4

assembly

Product made up of more than one component.

3.5

barrier

Obstacle to prevent flow whose performance can be verified.

3.6

base design

Design of a specified size, type, and model of a downhole well test tool that meets the requirements of this specification.

3.7

batch lot

Material or components that have undergone the same process or series of processes and are traceable to one batch of material.

3.8

bill of materials

Controlled list of components of an assembly.

⁵ NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77084-4906, www.nace.org.

3.9**brazing**

Process of joining metal using a nonferrous filler, the filler having a melting point below that of the metal being joined.

3.10**circulating valve**

Downhole device to provide communication/isolation between annulus and work string.

3.11**closure mechanism**

A system of parts that operate to close the tool, such as to close the inside diameter (ID), or to close on opening to/from the ID to the outside diameter (OD).

3.12**coating**

Permanent deposition of a material onto the surface of a part to enhance its surface properties such as improving corrosion protection, wear resistance, or reducing friction.

3.13**common hardware**

Nontraceable items such as nuts, bolts, set screws, and spacers.

3.14**crossover**

Tubular element with two different threaded connections.

3.15**design validation**

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

3.16**design verification**

Process of examining the result of a given design or development activity to determine conformity with specified requirements. (See 6.6.)

3.17**differential pressure**

Difference between internal and external pressure or the difference in pressure across a closure mechanism or a packer element.

3.18**downhole well test tool**

A device used in combination with other devices to perform a downhole well test.

3.19**drain valve**

Downhole device that manually relieves internally trapped pressure at surface.

3.20**drawdown**

Reduction in borehole pressure below formation pressure.

3.21**drift**

Bar utilized to verify the passage of a specified diameter and length through a well test tool.

3.22**environment**

Set of conditions to which the product is exposed.

3.23**external pressure**

Pressure acting on the outer diameter of a tool.

3.24**fit**

Geometric relationship between parts including the tolerance criteria used during the design of a part and its mating parts.

3.25**functional specification**

Features, characteristics, process conditions, boundaries, and exclusions defining the performance of the tools.

3.26**functional test**

Test process performed to confirm proper operation of a tool.

3.27**gauge carrier**

Tool used to convey gauges downhole.

3.28**gauge, downhole**

A device designed to measure downhole parameters such as pressure and/or temperature.

3.29**hardness**

Material surface property as determined from a test such as Rockwell, Brinell, Vickers, etc.

3.30**heat lot**

Material or components that are traceable to one heat of metallic material.

3.31**heat treatment**

Controlled heating and cooling of materials for the purpose of changing mechanical properties.

3.32**indication**

An identified discontinuity or flaw in a material determined by a nondestructive material inspection technique.

3.33**informative**

Information that is meant to enlighten the user/purchaser or supplier/manufacturer, without containing requirements.

3.34**interchangeability**

Ability to replace one component/subassembly with another component/subassembly without affecting operation or function.

3.35**internal pressure**

Pressure acting on the internal diameter of a tool.

3.36**jar**

A tool used to deliver an axial impact load to the downhole string.

3.37**job**

One deployment of downhole tools to planned depth and retrieval through the rotary table.

3.38**job lot**

Batch of material or components that have undergone the same process or series of processes; this may include more than one heat of metallic components.

3.39**legacy design**

A tool design that was developed and manufactured prior to the publication of this specification.

3.40**load bearing**

Device and/or part that supports or transmits a load.

3.41**manufacturing**

Processes and actions performed that are necessary to provide finished component(s), assembly(ies), and related documentation.

3.42**model**

Tool design with unique components and operating characteristics, which differentiate it from other tool designs of the same type.

3.43**nondestructive examination****NDE**

An inspection technique used to evaluate a part without causing permanent damage. Common techniques include magnetic particle inspection (MPI), dye penetrant inspection (DPI), or X-ray.

3.44**normative**

Information or procedures that shall be used by the user/purchaser or supplier/manufacture to comply with this specification.

3.45**operating manual**

Publication issued by the supplier/manufacture, which contains detailed data and instructions related to the design, installation, operation, and maintenance of a particular tool.

3.46**operating temperature range**

Range defined by the minimum and maximum operating temperatures for tools as specified by the supplier/manufacture.

3.47**operational cycle**

A single complete execution of a tool's operating mechanism, starting and finishing at the same tool state.

3.48**overlay**

Deposition of new material over an existing material.

3.49**packer element sealing system**

Components consisting of elastomeric elements and anti-extrusion devices comprising a sealing system.

3.50**perforating equipment and accessories**

Devices used to create holes in the casing to connect the formation to the casing ID and accessories such as circulating subs, tubing releases, shock absorbers, Y block assemblies, blast joints, gun hanger systems, and swivel subs.

3.51**plating**

Deposition of a thin layer of metal onto a surface by techniques such as electroless or electroplating, vapor deposition, and sputter deposition.

3.52**pressure retaining**

Device or part that is stressed due to the effects of a differential pressure acting on its boundary.

3.53**pressure reversal**

Change from predominant pressure in the annulus to predominant pressure in the work string bore or vice versa.

3.54**pump-through**

Capability of a device/tool with a closure mechanism to be partially opened by the application of differential pressure in the opposite direction of sealing, thus allowing fluid to be pumped through the tool.

3.55**pup joint**

Short tubular element used to join two threaded connections.

3.56**qualified person**

An individual or individuals with competencies gained through training and experience as measured against established requirements, such as standards or tests that enable the individual to perform a required function.

3.57**rated pressure**

Maximum supplier/manufacturer-defined pressure limit; for absolute, external, internal, and barrier differential pressures.

3.58**related equipment**

Any other downhole tool or equipment that would be included or necessary for downhole well test tools operations not included in another standard or specification.

3.59**room temperature**

Temperature typically between 15 °C (60 °F) and 26 °C (80 °F).

3.60**run**

Act of deploying downhole tools below the rotary table after connection to the work string.

3.61**safety joint**

A device to allow an intentional controlled separation of the work string or bottomhole assembly (BHA).

3.62**sampler carriers**

Tool used to convey fluid samplers downhole.

3.63**sealing element**

Device preventing passage (i.e. communication) of liquid and/or gas across the interface in which it is placed.

3.64**service center**

A location where equipment is inspected, repaired, and tested to maintain supplier/manufacture's specifications.

3.65**shear device**

Component designed to part under a predetermined load.

3.66**slip joint**

A tool having a sealed telescoping joint designed to accommodate tubing expansion and contraction.

3.67**special feature**

Specific additional functional capability not specifically described in the validation profile test sequences in Annex A.

3.68**stick-up**

Distance between the rotary table and the lower most part of the surface test tree.

3.69**stress relieving**

Controlled heating of material to a predetermined temperature for the purpose of reducing any residual stresses.

3.70**subassembly**

Subordinate unit consisting of two or more components assembled for incorporation as an integral portion of a tool, which may be independently performance tested before its integration.

3.71**substantive change**

Change that potentially affects the performance or rating of the tool in the intended service as evaluated by a qualified person at the supplier/manufacture.

3.72**surface treatment**

Process designed to alter the surface of a material to achieve a desired property such as hardness or corrosion resistance.

3.73**tester valve**

Downhole device having open and closed positions providing communication/isolation with the formation.

3.74**testing surface safety valve****TSSV**

Fail-closed surface-controlled safety valve placed near surface below the rotary (typically on land and jack-up operations) that performs a barrier function with pump-through and chemical injection capability.

3.75**tool**

Device that is designed to perform specific function(s) within the well testing BHA.

3.76**tool end connection**

Uppermost and lowermost interface/connection of the downhole well test tool.

3.77**type**

A product with unique characteristics or functionality, which differentiates it from other equipment.

3.78**visual inspection**

Visually examining for a variety of surface flaws, such as corrosion, contamination, surface finish, and surface discontinuities.

3.79**welding**

Process of joining metal by bringing abutting surfaces to a molten state with or without the use of a filler material.

3.80**well barrier**

An envelope of one or more well barrier elements that prevents fluids from flowing unintentionally from the formation or well into another formation or to the surface.

3.81**well barrier element**

A pressure and flow containing component that relies on other component(s) to create a well barrier.

3.82**well testing packer**

A sealing and load-bearing device that isolates the formation from annulus fluids and conforms to Annex E.

3.83**well testing safety valve**

A downhole device that is designed to close, typically with annulus overpressure, to isolate the formation from the work string.

3.84**work string**

Tubular conduit used to convey well test tools downhole and provide a flow path for reservoir fluids to surface.

3.85**work string tester valve**

A downhole device that is designed to integrity test the BHA and work string.

4 Abbreviations

AWS	American Welding Society
BHA	bottomhole assembly
BOP	blowout preventer
COC	certificate of compliance (or conformance)
DST	drill stem test
ESD	emergency shutdown
FAT	factory acceptance testing
HPHT	high pressure, high temperature
HPU	hydraulic power unit
HSE	health, safety, and environment
ID	inside diameter
LCM	lost control material
MPI	magnetic particle inspection
MTR	material test report
NDE	nondestructive examination
NORM	naturally occurring radioactive material
NORSOK	Norsk Søkkel Konkuranseposisjon (Norwegian Standards Organization)
NRV	nonreturn valve
OD	outside diameter
OSHA	Occupational Safety and Health Administration
PED	Pressure Equipment Directive
POOH	pulling of out hole
RIH	running in hole
TCP	tubing conveyed perforating

TSSV	testing surface safety valve
TMD	total measured depth
TVD	true vertical depth
WPS	welding procedure specification

5 Functional Specification

5.1 General

The supplier/manufacturer shall establish the functional requirements for tools that conform to this specification. The functional requirements are typically derived from input provided by potential user/purchasers and shall be documented to conform to the applicable requirements of Section 5 herein.

5.2 Functional Characteristics

The functions and characteristics shall include, but not be limited to the following, as applicable (some tools may have multiple functions and characteristics) for each required tool (F = function, C = characteristics).

- a) *Circulating Valve*—(F) Provides communication between annulus and tubing. (C) Number of cycles, flow area, control means and limits, isolation below circulating ports.
- b) *Drain Valve*—(F) Relieves trapped pressure from within the work string at surface. (C) None.
- c) *Gauge Carrier*—(F) Device used to convey downhole gauges. (C) Eccentric/concentric flow bore, porting options, gauge model compatibility/quantity and mounting configuration.
- d) *Jar*—(F) Applies an impact load to the test string. (C) Actuation means, number of cycles.
- e) *Related Equipment*—Other tools that are part of the test tool BHA.
- f) *Safety Joint*—(F) Allows intentional, controlled separation within the test string. (C) Actuation and recovery method.
- g) *Sampler Carrier*—(F) Device used to convey downhole fluid samplers. (C) Actuation means, eccentric/concentric flow bore, sampler model compatibility/quantity and mounting configuration.
- h) *Work String Safety Valve*—(F) Device used to shut in the well should there be a leak in the work string above the safety valve. (C) Actuation means, closure mechanism.
- i) *Testing Surface Safety Valve*—(F) A near-surface emergency safety device that provides isolation in the direction of flow. (C) Chemical injection, pump-through capability, control means, number of cycles, cutting capability.
- j) *Slip Joint*—(F) Telescoping device that allows for axial expansion and contraction of the test string. (C) Pressure balance.
- k) *Tester Valve*—(F) Controls flow (open or closed) and provides downhole communication/isolation with the formation. (C) Number of cycles, option of lock open feature, control means and limits.
- l) *Well Testing Packer*—(F) Isolates the annulus from above and formation from below. (C) Setting, anchoring and retrieval means (including fishing), flow bypass.
- m) *Work String Tester Valve*—(F) Provides a means to pressure test the work string above. (C) Isolation means, control means, number of cycles, filling capability.

5.3 Design Considerations

5.3.1 Well Parameters

The following well parameters shall be considered when establishing the functional characteristics of a tool:

- a) well location and rig type (land, platform, subsea);
- b) air gap, water depth, true vertical depth (TVD), total measured depth (TMD);
- c) blowout preventer (BOP) size, type, configuration;
- d) size, mass (weight), grade, material, connection type of the casing and work string;
- e) casing and/or work string architecture, trajectory, deviations, restrictions, maximum dog leg severity;
- f) casing pressure capability;
- g) general wellbore fluid types and composition.

5.3.2 Operational Parameters

The following anticipated operational parameters shall be considered when establishing the functional characteristics of a tool:

- a) formation fluid composition;
- b) pressure range—for formation and external, internal, and differential pressures of tools;
- c) temperature range;
- d) flow rate and solids content;
- e) underbalance/overbalance annulus;
- f) drawdown;
- g) test duration;
- h) loading conditions for planned test including pressures, temperatures, tension/compression, torque, bending, and intermittent conditions such as pressure testing;
- i) well pumping operations—acid composition, sand/proppant description, fluid flow rate, proppant/fluid ratio or sand/fluid ratio, pressure, temperature and exposure time, and any other chemicals.

5.3.3 Environmental Compatibility

The following parameters shall be considered when establishing the functional characteristics of a tool:

- a) production/injection/annular fluid chemical and physical composition that may affect tool performance such as sand production, scale, water, H₂S, CO₂, waxes, asphaltenes, pH, amines, and others that may be provided by user/purchaser(s);
- b) environmental conditions/changes during transportation, storage, and at surface prior to and during deployment;
- c) applicable regulations and restrictions.

It is the equipment user/purchaser's responsibility to ensure that selected materials in a tool design are suitable for job-specific service environments.

NOTE In the event that the user/purchaser believes a specific well environment requires conformance to NACE MR0175/ISO 15156, the user/purchaser can include that requirement in the individual job contract.

5.3.4 Compatibility with Related Well Equipment

The following information, as applicable, shall be specified to ensure the compatibility of the downhole well test tools with the related well equipment:

- a) downhole well test tool sizes and connections to the work string;
- b) requirement(s) for continuity of flow path and/or through bore access (size, length, etc.), passage of conduits (electrical/hydraulic, etc.) between tool's OD and casing ID, and/or open hole ID restrictions;
- c) details of any devices to be run through the downhole well test tools; provide details such as size, type, configuration, and means of conveyance;
- d) drifting requirements;
- e) internal receptacle profile(s) required in the downhole well test tools for receiving related well equipment, such as sealing bore, dimension(s), eccentricity, and respective locations.

5.4 Design Validation Grade Selection

Three design validation grades are designated for well test tools (V3, V2, V1), and three corresponding grades are designated for well testing packers (V3-TP, V2-TP, V1-TP). The validation grades for packers are uniquely designated with the suffix -TP to differentiate them from packer validation grades in other API specifications that may differ in their definition and requirements.

The design validation grade shall be selected from Table 1 for each design to be provided. These validation grades are proof of design evaluations that are performed on the base design. The detailed requirements for each validation grade are contained in Annex A (well test tools) and Annex E (well test packers). A summary of the validation testing coverage required by tool type and grade is presented in Table 1. For more details on validation grade requirements, see Table A.1 and Table E.1.

Table 1—Design Validation Grade Summary

V1 and V1-TP Design validation with gas test medium	Each design conforms to the validation requirements of V2 as defined in Annex A for well test tools or V2-TP as defined in Annex E for well test packers, in addition to the V1/V1-TP specific requirements, utilizing a gas test media as defined in those annexes.
V2 and V2-TP Design validation with liquid test medium	Each design conforms to the validation requirements, including pressure testing using a liquid test media as defined in Annex A for well test tools (V2) or Annex E for well test packers (V2-TP).
V3 and V3-TP Legacy design validation	To address legacy designs, design verifications are required and are comprised of design calculations and a combination of documented field history performance in an environment similar to that of the functional requirements and/or testing demonstrating that all design limits are verified.

5.5 Quality Grade

A single, common quality grade shall apply to all tools provided under this specification. The detailed quality requirements are contained in Section 7 and summarized in Table 2.

6 Technical Specification

6.1 General

The supplier/manufacturer shall establish a technical specification that conforms to the functional requirements.

6.2 Technical Characteristics

Downhole well test tools and related equipment shall perform in accordance with the functional requirements as stated in Section 5 and within the limitations defined in the product-specific operating manual.

6.3 Design Criteria

6.3.1 General

Downhole well test tools and related tool designs shall perform in a predictable and repeatable manner in accordance with their respective technical specification and meet the design validation requirements of Annex A, Annex E, Annex F, or Annex G, as applicable (see 6.7). Approval of the design shall be performed and documented by a qualified person(s) other than the person(s) who created the design.

6.3.2 Design Requirements

6.3.2.1 General

Design requirements shall include the functional specification and other pertinent requirements upon which the design is based. The following ratings shall be established for each downhole well test tool:

- a) absolute internal (bore) pressure;
- b) absolute external pressure;
- c) maximum differential pressure(s);
- d) other pressure restrictions applicable to the tool, such as differential pressure across a closure mechanism (from below, above, inside, outside);
- e) operational temperature range(s), including temperature drop;
- f) operational cycles per job;
- g) targeted casing size (packers);
- h) nominal tool size, such as OD, ID, and length;
- i) pressure drop at a defined flow rate(s) at ambient temperature with water on ported tools;
- j) tensile rating, including tool end connections;
- k) compressive rating, including tool end connections (straight compression without bending/buckling);

- l) other operational/environmental capabilities and limitations, including storage and transport temperature ranges, as applicable.

Items a) through g) shall be established by validation testing in accordance with the applicable annexes. Items h) through l) shall be established by validation testing and/or verification.

When establishing the rated pressures and load capabilities, material selections shall consider temperature and environment. Where applicable, specialized and/or intermittent conditions, such as pressure testing with temporary test caps, shall also be considered in the design.

Downhole well test tools and components shall be manufactured in accordance with the process, drawings, and specifications of the product that passed the applicable validation test. Any changes shall conform to 6.10.

Electronic and electrical components, subcomponents, and systems shall conform to Annex F.

TSSVs shall conform to Annex G.

If applicable, a table shall be supplied that establishes ratings with the validated design and material variations. The tool's capabilities within those variations shall be stated. A table such as this may contain information on packer element options, gauge ring ODs, and sealing system options.

6.3.2.2 Design Considerations

Downhole well test tool designs shall take into consideration the effects of temperature (range and duration) on all components. The upper temperature limit shall be the lowest high-temperature rating of any component of the downhole test tool. The lower temperature limit shall be the highest low-temperature rating of any component. Derating of metal mechanical properties as a function of temperature shall be accounted for in the design in accordance with the supplier/manufacturer's documented practice and based upon documented material testing.

Downhole well test tools shall be designed to avoid unintended trapped pressure being brought back to surface. Individual downhole well test tools shall be designed with the ability to safely relieve inadvertently trapped pressure during disassembly of the tool.

Downhole well test tool design shall consider the effects of exposure to fluid(s) identified in the functional requirements on all components. These designs shall consider the effects of substances routinely encountered in well testing operations, such as debris, H₂S, CO₂, acids/alkalines, chlorides, and corrosion inhibitors.

The entire operational mission profile of the tool, such as storage, transportation, serviceability, environmental exposure, downhole operation, bending, and transitional environmental conditions (such as low subsea temperature), shall be used to develop design requirements for new tools.

A failure modes risk assessment shall be conducted for each new tool design.

Welding on tension-loaded components is not a preferred joining method. Welding should generally be avoided. When welding is performed, it shall comply with 6.4.2.3.

6.3.2.3 Design Margins

The supplier/manufacturer shall apply a design margin to the design of each component or assembly using a documented methodology and practice that where appropriate has its origins within a national or international standard that is directly applicable to the component or system that is evaluated. The design margin shall consider maximum combined stresses resulting from operational loads and conditions prescribed by the functional requirements.

Design margins establish a level of performance capability to compensate for the rated loading and the intrinsic variations in the mechanical properties such as yield strength, ultimate strength, endurance strength, and modulus of elasticity. The ability to quantify stresses in components and assemblies with complex geometries shall be considered in establishing a design margin. The documented design margins shall be utilized in the creation of component or assembly capabilities or ratings.

The design of the component or tool shall be based upon the minimum material thickness, minimum allowable yield strength at the maximum rated temperatures (including temperature cycles), and operational loads.

The rating of an assembled design shall be determined by the lowest capability or performance potential of any component of the assembly after the application of the design margin. Design extensions, replacement components, and design revisions shall conform to the design margin, design assumptions, and design analysis methods that were applied to the base component or assembly.

The design shall be validated in accordance with Annex A, Annex E, Annex F, and Annex G, as applicable. All design validation results and tool identifications shall be recorded in the tool's design documentation and approved by a qualified person(s). When a sufficient design margin is not verified by calculation, it is acceptable that it be confirmed by validation.

6.3.2.4 Interchangeability of Components

The design, act of tolerancing, and manufacturing of downhole well test tool components shall be conducted so that interchangeability of components and/or subassemblies of separately manufactured tools is possible without affecting the performance of the assembled tool that has met the requirements of design validation.

6.4 Materials

6.4.1 General

Materials for each component shall be stated by the supplier/manufacturer and shall be suitable for the environmental conditions defined in the functional specification. The supplier/manufacturer shall have documented specifications for all materials and materials shall comply with these requirements. Material specification properties shall be reported at room temperature unless specified otherwise.

Nonsubstantive material substitutions from those materials used in the validation of tested tools may be allowed without validation testing, providing the supplier/manufacturer's selection criteria for these substitutions shall be verified and the substituted material shall conform to the validated design, functional specifications, technical specifications, and ratings. Material substitutions require approval by a qualified person(s) and the supporting information incorporated into the design documentation. Substantive material changes (metallic and nonmetallic) shall conform to the provisions of 6.3 and 6.10 and the supporting information shall be incorporated into the design documentation.

Seal materials can be substituted after having passed the requirements of validation testing as specified in A.3.6.6 or E.7 as applicable.

6.4.2 Metals

6.4.2.1 General

The final condition of metallic materials used in the manufacture of downhole well test tools shall comply with the material specifications, which shall include the following items:

- a) chemical composition limits;
- b) heat treatment/conditions;

- c) mechanical property limits, including as a minimum:
 - 1) tensile strength;
 - 2) yield strength (transverse and longitudinal as applicable);
 - 3) elongation;
 - 4) hardness;
 - 5) toughness, where applicable and as defined by the supplier/manufacturer.

For each item, an applicable industry-accepted test standard/method shall be specified.

This provision does not apply to common hardware, nor does it apply to engineered components that are validated independently, such as rupture discs and shearable devices.

6.4.2.2 Cast and Forged Component Requirements

The production of castings and forgings shall conform to the same practices and controls as were applied to the successfully validation tested component and the first article produced. The following shall be completed.

- a) Each cast or forged component shall be surface nondestructive examination (NDE) inspected on 100 % of its visually accessible surfaces after final processing such as final machining or heat treatment.
- b) Each cast or forged component shall be hardness tested at the supplier/manufacturer's defined location(s) on the part conforming to a standard such as ASTM E10, ASTM E18, ASTM E384, or equivalent internationally recognized standard applicable to the material and component. Representative material samples may be utilized if required by the product design.
- c) All castings and forgings require a first article qualification, which shall as a minimum include mechanical properties, heat treat condition and chemistry, volumetric NDE, surface NDE, and 100 % dimensional inspections.

For the requirements of 6.4.2.2, bar and tube stock are not considered to be cast or forged components.

6.4.2.3 Welding and Brazing

Welding and brazing procedures, activities, and personnel qualifications are required in accordance with ASME *BPVC* Section IX. Materials and practices not listed in the ASME *BPVC* Section IX shall be qualified in accordance with the methods of ASME *BPVC* Section IX and approved by a qualified person(s).

Welding shall be governed by a qualified welding procedure specification (WPS). The WPS shall be qualified per Section IX of the ASME *BPVC* or other equivalent industry standard. Weldments for sour service applications shall meet all the requirements of NACE MR0175/ISO 15156. The welding specification shall include requirements for:

- a) postweld heat treatment and/or stress relief;
- b) welding process;
- c) defined nondestructive testing method(s), acceptance criteria, and documentation.

Welding consumables shall conform to American Welding Society (AWS) or supplier/manufacturer's written specifications as specified in the WPS. The supplier/manufacturer shall have a written procedure for selection, storage, control, and use of welding consumables.

6.4.3 Nonmetals

6.4.3.1 General

The supplier/manufacture's documented specifications for nonmetallic materials shall include handling, storage, and labeling requirements and define the quality control limits of characteristics necessary for the performance of the material.

This section does not cover electronic or electrical components. These components are covered in Annex F.

6.4.3.2 Elastomers

The material specifications for elastomers shall include the following, unless not appropriate for the material:

- a) compound identification;
- b) mechanical properties, as a minimum:
 - 1) tensile strength (at break),
 - 2) elongation (at break),
 - 3) durometer hardness;
- c) compression set as applicable and as required;
- d) tensile modulus (as applicable);
- e) documentation of cure date, batch number, and shelf life appropriate to each elastomeric component;
- f) storage, handling, and packaging requirements as required by the material and component;
- g) other requirements necessary for the specific material and application.

6.4.3.3 Plastics

The material specifications for plastics shall include the following:

- a) material identification with sufficient substantive detail to ensure repetitive tool performance within specified limits;
- b) mechanical properties as required such as ultimate tensile strength, flexural modulus and hardness, and glass transition temperature;
- c) requirements for documentation appropriate to each plastic component.

6.4.3.4 Ceramics

The material specifications for ceramics shall include the following:

- a) material identification with sufficient detail to ensure repetitive tool performance within specified limits;
- b) mechanical properties as required;
- c) requirements for documentation appropriate to each ceramic component.

6.4.3.5 Other Materials

The material specifications for other materials such as fluids and lubricants shall include the following:

- a) material identification;
- b) properties as required;
- c) requirements for documentation appropriate to each material.

6.4.4 Coatings, Platings, and Overlays

The suitability of the coatings, plating, and overlays identified for the functional requirements and component materials shall be verified and documented by a qualified person. The coating material and application process shall have a documented specification. The application process shall contain the parameters required to ensure the desired performance of the coating. Coatings, platings, and overlays shall be applied in accordance with documented procedures by qualified personnel. Acceptance tests to ensure repeated quality shall be specified and the results of each batch documented.

6.4.5 Surface Treatments

Surface treatment processes shall have a documented and approved specification by a supplier/manufacturer qualified person, containing the parameters required to ensure the desired surface properties. Surface treatments shall be applied in accordance with documented procedures by a qualified person with acceptance criteria.

Suitability of surface treatments used to achieve the functional requirements shall be verified and documented by a qualified person. The following shall be considered when selecting an appropriate surface treatment process:

- a) effect of the process on the properties of the base metal;
- b) resulting surface finish and the requirements for any post-hardening processes such as grinding, polishing, honing;
- c) case depth;
- d) case hardness;
- e) base metal preparation;
- f) masking (to limit the area treated);
- g) change in corrosion properties.

6.5 Design Documentation

Documentation of designs for each size, type, and model shall include:

- a) functional requirements;
- b) technical specifications;
- c) design verifications, including methods and assumptions;
- d) comparison with previous designs (where applicable);

- e) design calculations;
- f) design reviews;
- g) factory acceptance and validation testing procedures.

Design documentation and validation results shall be retained per 7.2.1 and include the materials as defined in 7.2.2.

6.6 Design Verification

Design verification shall be performed to ensure that each design meets the technical specifications. Design verification shall include design reviews that are approved by a qualified person and may include design calculations, physical tests, comparison with similar designs, and historical records of defined operating conditions of similar tools.

6.7 Design Validation

6.7.1 General

The downhole well test tool designs produced in accordance with this specification shall have passed the validation test at the tool's rating as required in the technical specification and specified in Annex A to qualify each size, type, and model. Successful completion of the validation test and approval by a qualified person shall qualify the design for manufacture of additional tools of the same size, type, and model as the tested design.

Fluids used for pressure testing to validation level V2/V2-TP shall be water, with or without additives, or hydraulic oil/heat transfer fluid. The test fluid shall be visibly free from particulate matter and/or other material that have the potential of plugging small leaks. V1/V1-TP testing is performed with nitrogen or other inert gas. All fluids used in the testing shall be defined and documented in the test report.

Electronic and electrical components, subcomponents, and systems shall conform to Annex F.

Well test packers shall conform to Annex E.

TSSVs shall conform to Annex G.

NOTE The design validation requirements in this specification may not be representative of well conditions.

6.7.2 Supplier/Manufacturer Requirements

The downhole well test tool shall be function/pressure tested prior to validation testing. The supplier/manufacturer shall provide a tool of each size, type, and model to the validation test facility. A detailed validation test procedure that conforms to the requirements of this specification shall also be provided for each tool.

Pre-validation and post-validation testing dimensional inspections of critical dimensions defined by the supplier/manufacturer shall be conducted and documented. For a successful test, all results shall be within the established acceptance criteria, approved by a qualified person(s), and maintained in the design documentation.

6.8 Performance Envelope

A performance rating envelope as defined in Annex D shall be prepared for each validated design.

6.9 Special Feature Validation

Special features shall be validated by testing to their rated limits. Special feature validation testing shall be the responsibility of the supplier/manufacturer.

For a successful test, all results shall be within the established acceptance criteria, approved by a qualified person(s), and maintained in the design documentation.

6.10 Design Changes

6.10.1 General

Design changes shall be documented, reviewed, and approved by a qualified person(s) before implementation. Design changes and changes to design documents shall require the same controls as those applied to the design that has passed the applicable verification and validation requirements of this specification.

Design changes shall be reviewed by a qualified person of the supplier/manufacturer against the design verification and validation documents to determine if the change is a substantive change. Evaluation of design changes may include activities such as subassembly testing, analysis, and design reviews.

A design that undergoes a substantive change becomes a new design requiring design verification and design validation; however, derating is allowed per 6.10.2. All tools containing a substantive change(s) shall continue to meet applicable verification and validation test requirements.

The use of alternate seal compounds and their validation requirements shall conform to A.3.6.6 and E.7, as applicable.

The supplier/manufacturer shall, as a minimum, consider the following for each design change:

- a) stress levels of the modified or changed components compared to those of the base design;
- b) possible functional or operational changes introduced by the design change;
- c) interchangeability with existing components or previously manufactured assemblies.

Design changes shall be communicated to the service center as applicable.

6.10.2 Derating Requirements

6.10.2.1 General

Derating of a successfully validated downhole well test tool (base design) of the same nominal size, type, and model is permitted when the requirements of this subsection and this specification are satisfied. Any increases in validated ratings shall require validation testing in accordance with 6.7.

Tool design or other changes associated with derating are limited to changes in material that result in a decrease in load, pressure, or temperature rating. Any design changes shall conform to 6.10.1.

Derated loads, pressures, or temperatures shall remain within the applicable validated range of the base design.

Each derated tool requires design verification, justification, and design documentation of the changes from the base design. Derated designs shall be approved by a qualified person, other than the person who performed the derating of the design. The documentation shall be maintained per 6.5 and included in the new tool's design records.

6.10.2.2 Derating Process

The supplier/manufacturer shall establish the maximum stresses in the derated design. The same method of calculation(s) and verification(s) shall be applied to the identified components of the base design and the derated design. For each component, the ratio of maximum stress to the yield stress shall not exceed the ratio of maximum stress to yield stress of the base design. The supplier/manufacturer shall ensure that the derated design conforms to the applicable technical specifications.

7 Supplier/Manufacturer Requirements

7.1 General

This section contains the detailed supplier/manufacturer requirements for each tool manufactured under this specification to conform to the technical specifications. These include requirements for documentation, tool identification, quality requirements, traceability, materials, additional processes, assembly and factory acceptance testing (FAT), manufacturing nonconformities, and subsupplier quality controls.

Annex B provides requirements on post-manufacture FAT.

Annex C provides the requirements for the post-manufacture processing of these tools at service centers.

7.2 Documentation

7.2.1 General

The supplier/manufacturer shall establish and maintain documented procedures to control all documents and data that relate to the requirements of this specification. These documents and data shall be legible and maintained to demonstrate conformance to specified requirements. All documents and data shall be retained in facilities that provide an environment that is designed to prevent damage, deterioration, and loss. Documents and data may be in the form of any type of media, such as hard copy or electronic media. All documents and data shall be available for review and/or audit by a user/purchaser within 30 days of the request.

Documentation shall be retained for a minimum of 3 years after a tool has been obsoleted.

Service center documentation requirements are included in Annex C.

7.2.2 Retained Documentation

7.2.2.1 Documentation Requirements for a V1/V1-TP and V2/V2-TP Validated Design

The supplier/manufacturer shall have the following information available to support each design validated for level V1/V1-TP and V2/V2-TP:

- a) technical specifications and design requirements, which include pressures, operational loads, materials, environmental and other pertinent requirements upon which the design is based;
- b) engineering drawings/bills of material/manufacturing specifications/revision history;
- c) material specifications;
- d) assembly drawings;
- e) nonconformance documentation;
- f) design verifications, including methods and assumptions;

- g) comparison with previous designs (where applicable);
- h) design calculations;
- i) design reviews;
- j) validation testing procedures and acceptance criteria;
- k) validation results/report;
- l) performance envelope;
- m) certificates of conformance;
- n) material test reports (MTRs);
- o) heat treat certificates;
- p) material traceability records;
- q) dimensional inspection records;
- r) NDE records;
- s) FAT procedures and records;
- t) shear/burst device testing records (where applicable);
- u) welding procedures/NDE inspections (where applicable);
- v) special feature validation results (where applicable).

7.2.2.2 Documentation Requirements for a V3/V3-TP Validated Design

The documentation requirements for V3/V3-TP validated designs are included in A.3.5 and E.4.

7.2.2.3 Documentation Requirements for Manufactured Tools

The supplier/manufacture shall have the following information (as of the date of manufacture) available to support each manufactured tool:

- a) engineering drawings/bills of material (as built);
- b) assembly drawings;
- c) nonconformance documentation;
- d) operating/maintenance manual;
- e) performance envelope;
- f) certificates of conformance (where applicable);
- g) subcomponent test reports (where applicable);
- h) MTRs;

- i) heat treat certificates;
- j) material traceability records;
- k) dimensional inspection records;
- l) NDE records;
- m) FAT records;
- n) shear/burst device testing records (where applicable);
- o) welding procedures and associated NDE inspections (where applicable).

7.2.2.4 Documentation Requirements for Service Center

The supplier/manufacturer shall have the following information available to support each tool supplied to the service center:

- a) datasheet, technical specifications;
- b) bills of material;
- c) assembly drawings;
- d) operating and maintenance manual;
- e) performance envelope;
- f) certificates of conformance;
- g) MTRs;
- h) heat treat certificates (where applicable);
- i) material traceability records;
- j) NDE records;
- k) supplier/manufacturer's functional testing records;
- l) summary design validation report(s);
- m) shear device testing records (where applicable).

7.2.2.5 Operating and Maintenance Manual(s)

For each manufactured downhole well test tool, the following information, as applicable, shall be available in the appropriate manual(s):

- a) methods for safe assembly and disassembly;
- b) recommended field use and operating instructions for the tool;
- c) tool hazard(s)/safety identifications;
- d) contact information of supplier/manufacturer;

- e) supplier/manufacturer assembly number and tool name;
- f) size, type, and model;
- g) design validation grade;
- h) operational ratings and limits, including:
 - 1) differential pressure (internal and external) at minimum and maximum rated temperatures;
 - 2) absolute pressures (internal and external) at minimum and maximum rated temperatures;
 - 3) other pressure restrictions, static/dynamic;
 - 4) operating temperature range, including any known temperature exposure limitations;
 - 5) tensile and compressive capacity at minimum and maximum rated temperatures (as applicable and including tool end connections);
 - 6) operational cycle limits;
 - 7) rated operating envelope as applicable by validation grade;
 - 8) where applicable, a table shall be supplied that establishes ratings with the validated design and material variations and the tool's capabilities within those variations—examples of contents of these tables include packer element durometer/compound, gauge ring OD, and sealing system variations;
- i) type, size, and weight of tool end connections, where applicable;
- j) tool dimensions, including minimum ID, maximum OD, makeup length, and dimensional data needed for inspection/operations;
- k) operational information, such as pre-charge pressures, activation pressures, shear pressures, and activation loads;
- l) requirements for related tool(s);
- m) drawings and illustrations of the fully assembled tool, including a dimensional drawing for fishing purposes;
- n) bill of material and any special tool requirements;
- o) special feature operational procedures;
- p) troubleshooting procedures;
- q) repair procedures/limitations for Levels 1, 2, and 3 (see C.6.2, C.6.3, and C.6.4);
- r) redress procedures/limitations;
- s) preparations for shipment requirements;
- t) storage requirements.

7.2.2.6 Datasheet Requirements

7.2.2.6.1 General

The supplier/manufacturer shall have available, at the time of tool delivery to the service center, a datasheet that details the tool's operating capabilities. Multiple sizes of the same tool type can be included on the same datasheet. Each rating shall be identified as either validated or verified as required in this specification.