

Downhole Chemical Injection Devices and Related Equipment

API SPECIFICATION 19CI
FIRST EDITION, JUNE 2019



AMERICAN PETROLEUM INSTITUTE

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Introduction

This specification has been developed by users/purchasers and suppliers/manufacturers of downhole chemical injection devices/products that are used in side-pocket mandrels and tubing retrievable mandrels/carriers in the worldwide petroleum and natural gas industry. This specification is intended to provide requirements and information to parties who are involved in the specification, selection, manufacture, testing and use of chemical injection devices. Further, this specification contains the minimum supplier/manufacturer requirements to claim conformity to this specification.

This specification has been structured to support a range of requirements in design verification, design validation, functional testing, and quality. These variations allow the user/purchaser to select the grades and levels for a specific application.

There are four design validation grades for chemical injection devices and four for products that provide the user/purchaser with a range of technical requirements and ratings. This ensures that the devices/products supplied according to this specification meet the requirements and that the user/purchaser can compare these requirements with its preference or application and determine whether additional requirements are placed on the supplier/manufacturer.

It is important that users of this specification are aware that requirements in addition to those outlined herein 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 can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the supplier/manufacturer to identify variations from this specification and provide details.

Two quality levels are provided that the user/purchaser may choose to meet specific preferences or applications. Additional quality requirements can be specified by the user/purchaser as supplemental requirements.

In addition to the requirements of this document, related requirements are included in the following:

- API 19G1 provides requirements for side-pocket mandrels;
- API 19G3 provides requirements for running, pulling, kick-over tools and latches used in conjunction with side-pocket mandrel chemical injection devices/products;
- API 19G4 provides requirements for side-pocket mandrels and related equipment;
- API 19AC provides requirements for mandrels or carriers that are used with chemical injection devices/products when installed in a well.

Downhole Chemical Injection Devices and Related Equipment

1 Scope

This specification provides requirements for chemical injection devices intended for use in the worldwide petroleum and natural gas industry. This includes requirements for specifying, selecting, design verification, validation testing, manufacturing, quality-control, testing, and preparation for shipping of chemical injection devices as defined herein. These requirements include in-line debris screen systems, single-use shearable/frangible devices, and performance testing and calibration procedures.

The installation and retrieval of chemical Injection devices and systems is outside the scope of this document (see API 19G2 and API 19G3).

This document does not include requirements for mandrels, carriers, running, pulling, and kick-over tools, handling tools and latches, injection lines, fittings, control line connectors, clamps, chemicals and chemical delivery systems. Service, repair or redress of used chemical Injection devices is outside of the scope of this document.

Validation and functional testing within this specification is performed using water as the testing medium. Design validation in conformance with this specification may not provide assurance that a chemical injection device/product will perform in a specific well, due to the variety and potential contamination of the injected chemicals.

Included in this specification are Annex B through Annex G (normative) and Annex A and Annex H (informative). If a product is supplied bearing the API Monogram and manufactured at a facility licensed by API, the provisions of Annex A apply.

2 Normative References

The following referenced documents are referred to in the text in such a way that some or all the content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including amendments) applies.

API Specification 5B, *Specification for Threading, Gauging and Thread Inspection of Casing, Tubing, and Line Pipe Threads*

API Specification 7-2, *Specification for Threading and Gauging of Rotary Shouldered Thread Connections, Second Edition*

API Specification 19G1, *Side-pocket Mandrels*

API Specification 19G2, *Flow-control Devices for Side Pocket Mandrels*

API Specification 19G3, *Running Tools, Pulling Tools, and Kick-over Tools and Latches for Side-Pocket Mandrels*

API Recommended Practice 19G4, *Practices for Side-pocket Mandrels and Related Equipment*

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

ASME ¹ Boiler and Pressure Vessel Code (BPVC), Section V, *Nondestructive Examination*

¹ American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017-2392, USA, www.asme.org.

ASNT ² Recommended Practice SNT-TC-1A, *Personnel Qualification and Certification in Non-destructive Testing - 2016 Edition*

ASQ ³ Z1.4, *Sampling Procedures and Tables for Inspection by Attributes*

ASTM ⁴ E10, *Standard Test Method for Brinell Hardness of Metallic Materials*

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

ASTM E110, *Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers*

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

ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*

ASTM A388/A388M, *Standard Practice for Ultrasonic Examination of Steel Forging*

ASTM E428, *Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASQ H1331, *Zero Acceptance Number Sampling Plans*

ISO ⁵ 2859-1, *Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

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

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

ISO 6506 (all parts), *Metallic materials—Brinell hardness test*

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 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 13665, *Seamless and Welded Steel Tubes for Pressure Purposes—Magnetic Particle Inspection of the Tube Body for the Detection of Surface Imperfections*

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*

2 American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, OH 43228-0518, USA, www.asnt.org.

3 American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, USA, www.asq.org.

4 ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA, www.astm.org.

5 International Organization for Standardization, Chemin de Blandonnet 8, CP 401-1214 Vernier, Geneva, Switzerland, www.iso.org.

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*

SAE ⁶ AS 568A, *Aerospace Size Standard for O-Rings*

NACE ⁷ MR0175/ISO 15156 (all parts), *Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas devices*

3 Terms, Definitions, Abbreviations, and Acronyms

For the purposes of this document, the terms and definitions given in API Q1 (for quality-system-related terms not given below) and the following apply.

3.1 Terms and Definitions

3.1.1

ambient temperature

Prevailing temperature at the testing facility.

3.1.2

back check test

BCT

Static pressure test conducted where pressure is applied to a non-return (check) valve in the reverse direction to normal forward flow.

3.1.3

back pressure

Pressure opposing forward flow.

3.1.4

back pressure retention

BPR

A device providing back pressure support (U-tube prevention) to prevent hydrostatic-fall-through of fluids while allowing flow to a defined outlet.

3.1.5

certificate of conformance

Document in which the supplier/manufacture certifies that the product or service is in conformance to the referenced standards, specifications, and requirements.

3.1.6

chemical delivery system

A system above the tubing hanger designed to supply the controlled delivery of chemicals into a well.

3.1.7

chemical injection device/product

A downhole, below-the-tubing-hanger device that controls the flow of chemical(s) into a well.

3.1.8

chemicals

Fluids injected into the well via a chemical injection system.

⁶ SAE International, 400 Commonwealth Drive, Warrendale, PA 15096, USA, www.sae.org.

⁷ NACE International, 15835 Park Ten Place, Houston, Texas 77084, USA, www.nace.org.

3.1.9**cleanliness**

A measured value of contaminants within a fluid.

3.1.10**closing pressure**

Pressure at which forward flow through a device stops

3.1.11**completion load**

A load or combination of loads that affects the function or integrity of a chemical injection device/product.

NOTE Loads can include one or more of the following:

- internal and external tubing or casing pressures;
- axial compression or tensile loadings;
- bending loads from dog legs/well deviations.

3.1.12**crack-open pressure**

The pressure at which flow of the fluid is initiated in the flow direction as injection pressure is increased.

3.1.13**design validation**

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

NOTE Design validation can include one or more of the following (this is not an all-inclusive list):

- prototype tests;
- functional or operational tests of production products, or both;
- tests specified by industry standards or regulatory requirements, or both;
- field performance tests and reviews.

3.1.14**design verification**

Process of examining the result of a design and development output to determine conformity with specified requirements.

NOTE Design verification activities can include one or more of the following (this is not an all-inclusive list):

- a) confirming the accuracy of design results through the performance of alternative calculations;
- b) review of design output documents independent of activities of design and development;
- c) comparing new designs to similar proven designs.

3.1.15**device**

Component or subassembly which provides a function defined in Table 6.

3.1.16**end connection**

Thread or other mechanism providing a connection between the chemical injection device/product and other equipment.

3.1.17**external seal assembly**

Sealing mechanism used to seal the exterior of a retrievable chemical injection device/product when installed in its defined mandrel.

3.1.18**external test pressure**

Differential test pressure between the applied external pressure and internal pressure at which a product is tested for collapse resistance.

3.1.19**failure pressure**

The pressure that causes the component or device/product to fail.

3.1.20**flow characterization**

A numerical and/or graphical representation of a device's pressure behavior through a range of flow rates.

3.1.21**forward flow**

The path of movement in which the valve's open position is the non-restrictive conduit point of injection.

3.1.22**forward flowing pressure**

The pressure which results in flow moving in the forward direction through a pressure control device.

3.1.23**free passage**

Ability of a device to pass through a geometric space of a defined size without impact loading.

3.1.24**functional specification**

User/purchaser prepared requirements for chemical injection device/product which include the well parameters, operational parameters and environment, or the identification of the supplier/manufacture's specific device/product.

3.1.25**functional test**

Test performed to confirm proper operation of device/product.

3.1.26**heat**

A particular batch of metal to which a raw material mill assigns a unique identification number called a heat number.

3.1.27**hydrostatic fall-through**

The condition where the applied hydrostatic in a fluid conduit is greater than the pressure present in the fluid in the delivery conduit falling (U-tube effect).

3.1.28**informative**

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

3.1.29**injection line**

Pressure-retaining conduit within a well which can deliver fluid from the tubing hanger to the injection point/device.

3.1.30**screen**

A device in the chemical injection flow path which restricts installation debris flow which may include a bypass and does not function as a flow regulating component.

3.1.31**internal test pressure**

Differential test pressure between the applied internal pressure and external pressure at which a product is tested for burst resistance.

3.1.32**job lot**

A collection or quantity of piece parts, subassemblies or assemblies that are processed together during the manufacturing process.

3.1.33**kickover tool**

Wireline deployed tool used to selectively install and retrieve latch-mounted devices in side-pocket mandrels.

3.1.34**latch**

Retention mechanism for a chemical injection device/product that is installed in a side-pocket mandrel.

3.1.35**legacy device**

A design provided by the supplier/manufacturer before the publication of this specification.

3.1.36**mandrel****carrier**

A well completion component, to which a chemical injection device/product is assembled, at which chemicals may be injected into the well.

3.1.37**manufacturing**

Process(es) performed by an equipment supplier/manufacturer that are necessary to provide a finished component(s) or assembly(ies).

3.1.38**material substitution**

The allowance of materials different than those used when validating a device/product without additional validation testing.

3.1.39**maximum flow rate**

The greatest flow rate at which the injection device/product conforms to the design performance rating.

3.1.40**maximum rated temperature**

The greatest temperature for which the device/product is designed.

3.1.41**mill certificate**

Quality control documentation of a component's raw material, certifying its chemical composition, physical properties, and mechanical properties.

3.1.42**minimum flow rate**

The lowest flow rate at which the injection device/product conforms to the design performance rating.

3.1.43**minimum rated temperature**

The lowest temperature for which the device/product is designed.

3.1.44**model**

Devices/products with unique components and functional characteristics that differentiate them from other devices/products of the same type.

3.1.45**normative**

Information or procedures that are mandatory for use by the user/purchaser or supplier/manufacture.

3.1.46**opening pressure**

Pressure required to open the closure mechanism where the flow dynamics are acceptable.

3.1.47**operating environment**

Set of environmental conditions to which the device is exposed during its service life.

NOTE This includes such environmental variables as temperature, pressure, liquid composition and properties, gas composition and properties, solids, etc.

3.1.48**pocket**

Parallel bore, including sealing surfaces and latching profiles that is offset from and essentially parallel with the through-bore of the side-pocket mandrel.

3.1.49**product**

An assembly of two or more chemical injection devices (as defined in Table 6) which are designed to function as a single unit.

3.1.50**functional testing grade**

Category with a defined range of processes, method(s) and/or test(s) that are used by the supplier/manufacture to demonstrate that a particular device has been manufactured to meet the requirements for that device.

3.1.51**pulling tool**

Device used to retrieve a latch mounted device from a side-pocket mandrel, normally with the use of a kickover tool.

3.1.52**qualified person**

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

3.1.53**rated pressure**

Maximum differential pressure at a defined temperature for which the chemical injection device/product is designed.

3.1.54**rated temperature range**

The range of temperatures from minimum rated temperature to maximum rated temperature.

3.1.55**redress**

Any activity involving the replacement of parts within the limits of the device's operating manual.

3.1.56**repair**

Activity that includes disassembly, reassembly and testing with or without the replacement of qualified parts and can include machining, welding, heat treating or other manufacturing operations that restores the equipment to its original performance.

3.1.57**retrievable chemical injection device**

A chemical injection device that is run, secured in, and retrieved from a side pocket mandrel by wireline or other means.

3.1.58**reverse flow prevention****RFP**

A device (reverse flow check) that allows unidirectional flow from a supply to a defined outlet; the device will affect a seal in the reverse direction by way of an internal actuation mechanism.

3.1.59**running tools**

Device used to deploy latch mounted products into side pocket mandrel, normally combined with the use of a kickover tool.

3.1.60**scaling**

Validating a design by referencing the validation conducted on a device of the same design family.

3.1.61**secondary chemical injection screen****SCIS**

A device in the chemical injection flow path that restricts installation debris flow and may include a bypass and does not function as a flow regulating component.

3.1.62**secondary chemical injection screen (SCIS) element**

Component that prevents the flow of particles of a defined size.

3.1.63**secondary chemical injection screen (SCIS) housing**

The component of the secondary chemical injection screen device that provides the physical structure that retains the element and contains the flowing pressure.

3.1.64**shearable/frangible device**

A device which changes flow dynamics after activation once a differential pressure or other defined load is applied.

3.1.65**shear-out**

Action of a single-use isolation device (SUI) when a defined differential pressure or other defined loading is applied.

3.1.66**side-pocket mandrel**

A well completion component with a bore or pocket that 1) is offset from the through-bore of the production tubing and 2) houses a chemical injection device/product.

NOTE This bore includes sealing surfaces and latching profiles.

3.1.67**single-use isolation****SUI**

A device in the flow path that is initially closed; once it is opened, it cannot be reclosed and does not function as a pressure or flow control component.

3.1.68**sour service**

Exposure to oilfied environments that contain H₂S and can cause cracking of materials by the mechanisms addressed in NACE MR0175.

3.1.69**special feature**

A specific functional capability or subassembly which is not validated in the defined validation testing sequences.

3.1.70**substantive design change**

A design change identified by a qualified person that affects the performance of a device/product in comparison to the other device/product qualified in accordance with this specification.

3.1.71**supplier/manufacturer**

Company, organization, or entity that designs and manufactures chemical injection devices/products.

3.1.72**technical specification**

Requirements of the equipment necessary for compliance with the functional specification.

3.1.73**test pressure**

Pressure applied as specified by the pertinent test procedure.

NOTE Each test pressure has a related test temperature.

3.1.74**test temperature**

Temperature based on relevant design criteria, at which the equipment is tested.

3.1.75**total closure**

The state at which there is no flow through the device.

3.1.76**traceability**

Ability for individual components to be designated as originating from a job lot that identifies the included heat number(s).

3.1.77**tubing reel**

A length of conduit (injection line) of a specified diameter and length typically provided on a cylindrical reel.

3.1.78**type**

Chemical injection device/product with unique characteristics that perform a specific function.

3.1.79**unconventional design**

A chemical injection device or product design that performs one or more functions defined in Table 1 that is not fully compatible with the required validation testing criteria.

3.1.80**user/purchaser**

Company, organization, or entity that purchases, installs and uses chemical injection devices.

3.1.81**U-tube effect**

The hydrodynamic phenomenon of fluid reaching equilibrium and balance in height through their equalization of fluid hydrostatics.

3.1.82**welding**

Method for joining two metallic substances through a process of melting and re-solidification.

NOTE Includes brazing and soldering.

3.1.83**wireline**

A general term referring to oil and gas well intervention operations in which a single-strand or multistrand wire or cable is used to install and retrieve flow control devices.

3.1.84**yield strength**

Stress level measured at test temperature, beyond which material plastically deforms and does not return to its original dimensions.

NOTE Yield strength is expressed in units of force per unit of area.

3.2 Abbreviations and Acronyms

AOQL average outgoing quality limit

BCT	back check test
BPR	back pressure retention
COC	certificate of conformance
ID	internal diameter
ISO	International Organization for Standardization
MTR	material test report
NACE	National Association of Corrosion Engineers
NDE	non-destructive examination
OD	outside diameter
PQR	procedure qualification record
QMS	quality management system
RA	risk assessment
RFP	reverse flow prevention
RIH	run in hole
ROV	remotely operated vehicle
RP	recommended practice
SAE	Society of Automotive Engineers
SCIS	secondary chemical injection screen
SPM	side pocket mandrel
SUI	single-use isolation device
WPQ	welder/welding operator performance qualification
WPS	welding procedure specification

4 Functional Specification

4.1 General

The purpose of the functional specification is to allow the user/purchaser to specify and define the functional requirements for chemical injection devices/products.

The user/purchaser should prepare a functional specification for devices/products that conform to this specification. The specification should contain the requirements of this section and the operating conditions, as appropriate, and/or identify the supplier/manufacturer's specific device. These requirements and operating conditions may be conveyed by means of a dimensional drawing, a data sheet, a functional specification form or other suitable documentation.

4.2 Background

Chemical injection is the process of injecting fluid chemicals into a well to control corrosion and harmful deposits in the tubing and tubing accessories during production. In a typical chemical injection installation, a chemical injection mandrel with a chemical injection valve is installed as part of the tubing string.

A chemical injection line can be run from the chemical injection mandrel to the surface to act as a conduit for the chemicals. In other installations, the chemicals are pumped down the tubing/casing annulus and into a port in the chemical injection mandrel.

Reverse flow prevention (RFP) devices are installed at the point of injection to prevent flow from the production tubing from entering the injection-flow path. A high-pressure pump, capable of overcoming tubing pressure, is installed on the surface to pump the chemicals into the downhole point of injection in the production stream.

Further explanation of chemical injection is in Annex H.

4.3 Functional Characteristics

4.3.1 General

The chemical injection device/product acts to control the flow or communication of gas and/or liquid between the pressure-retaining areas of the well. The user/purchaser shall specify and select the following functional characteristics, as applicable.

4.3.2 Functions

The user/purchaser may specify a specific chemical injection device/product, one device in Table 1, or a combination of the devices in Table 1.

Table 1—Summary of Chemical Injection Device Types

Device Type Abbreviation	Device Type Name	Functional Definition	Applicable Annex
RFP	Reverse flow prevention	A device that allows unidirectional flow from a supply to a defined outlet. The device will affect a seal in the reverse direction by way of an internal actuation mechanism.	B
BPR	Back pressure retention	A device providing back pressure support (U-tube prevention) to prevent hydrostatic-fall-through of fluids while allowing flow to a defined outlet.	C
SUI	Single-use isolation	A pressure activated device in the flow path or a line block that is initially closed; once it is opened, it cannot be reclosed and does not function as a pressure or flow control component.	D
SCIS	Secondary chemical injection screen	A device in the chemical injection flow path which restricts installation debris flow and which may or may not include a bypass, and does not function as a flow regulating component.	E

4.3.3 Retrievable Designs

Retrievable designs shall include the following:

- Nominal chemical injection device/product size, e.g. 25.4 mm (1 in.), or 38.1 mm (1.5 in.), etc.
- Latch (retention mechanism) type for installing, securing, and retrieving the chemical injection device/product in a side-pocket mandrel.
- Seal bore nominal size and configuration to house the chemical injection device/product or the side-pocket mandrel model.
- Either the location and configuration of the inlet and outlet ports of the chemical injection device/product or the model of the chemical injection device/product.
- Conduit ports, connection size, and configuration for side-pocket mandrel external ports and outlets to which a side-string, control line, or injection conduit connects.
- Description of the mandrel; see 5.2.

4.4 Well Parameters

4.4.1 Well Fluid Parameters

The following well fluid parameters to which the chemical injection device/product is exposed should be provided by the user/purchaser.

- a) Fluid composition, specific gravity, etc. of the following:
 - produced fluids (e.g. liquid, hydrocarbon gas, CO₂, H₂S);
 - injection gas (e.g. hydrocarbon gas, CO₂, etc.);
 - injection fluids (e.g. water, steam, CO₂, chemicals, oxygen content, etc.);
 - completion fluids;
 - treatment/stimulation fluids/chemicals.
- b) Description of extraneous components (e.g. paraffin, sand, scale, corrosion products, etc.).

4.4.2 Well Operations

Expected well intervention(s)/operation(s) including the parameters, such as those below, should be provided by the user/purchaser.

- a) acidizing, including acid composition, pressure, temperature, acidizing velocity, exposure time, and other chemicals used during well stimulation;
- b) fracturing, including proppant description, fracture fluid velocity, proppant/fluid ratio;
- c) sand consolidation operations.

4.4.3 Environmental Compatibility

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, this information may be made available to the supplier/manufacturer. The user/purchaser may indicate to the supplier/manufacturer which material(s) have the ability to perform as required within the subject well's corrosion environment.

4.5 Operational Parameters

The user/purchaser should specify installation, testing, and operational parameters as applicable.

- a) chemical injection depth;
- b) topside injection system maximum pressure rating;
- c) chemical properties, e.g. specific gravity, viscosity;
- d) minimum and maximum chemical flow rates;
- e) temperature gradients;
- f) pressure range at the point of injection at the device/product outlet;
- g) operating pressure range of the device/product;

- h) operating temperature range of the device/product;
- i) maximum differential pressure across the chemical injection device/product;
- j) pressure differential at which a SUI opens;
- k) installation; testing and operational procedures;
- l) deployment and retrieval method(s);
- m) injection line length, size, and ratings.

4.6 Fluid Cleanliness

Devices/products from different suppliers/manufacturers and of different functional types may operate with injected fluids of varying cleanliness. It is, therefore, impractical to specify fluid cleanliness. See Annex H for system design guidelines.

4.7 Compatibility with Well Equipment

The user/purchaser, where applicable, shall specify the end connection designs and material requirements, free-passage requirements and external/internal dimensional limitations needed to ensure that the device/product conforms to the application.

An example list follows:

- a) size, type, material, configuration and dimensions of the end connection between the device/product and other well equipment;
- b) internal/external receptacle profile(s)/securing mechanism(s), sealing dimensions and their respective locations.

API 19G1 details the sealing bore dimensions required for side-pocket mandrels specifications. The retrievable chemical injection devices/products should be selected to match the dimensions in accordance with API 19G1. If there are occasions when the design of the side-pocket mandrel requires sealing bore dimensions other than those listed, the agreement between the user/purchaser and supplier/manufacture shall be documented.

4.8 Design Validation Grades

4.8.1 General

The user/purchaser should specify one of the following design validation grades for each chemical injection device or alternately for each product design. If no design validation grade is specified, Grade V2 or CV2 shall be provided.

4.8.2 Device Design Validation Grades

This specification provides four design validation grades as shown in Table 2.

Table 2—Device Design Validation Grade Summary

Grade	Description	Requirements
V4	Minimum grade of device validation	Supplier/manufacture defined requirements with engineering validation documentation of the defined ratings and capabilities.
V3	Reduced grade of device validation	V3 (applicable to BPR/RFP only) requires validation of a single copy of the design with water. Validation includes testing for the designated functions with reduced repetition of the testing steps. See Annex B and Annex C.
V2	Intermediate grade of device validation	V2 requires validation of a single copy of the design with water. Validation includes testing for the designated functions. See Annexes B, C, D, E, and F, as applicable.
V1	Enhanced grade of device validation	V1 requires validation of two copies of the design with water and includes gas testing of some features. Validation includes testing for the designated functions. See Annexes B, C, D, E, and F, as applicable.

4.8.3 Product Design Validation Grades

This specification provides four product design validation grades as shown in Table 3. The devices included within a CV (combined validated) product may have individual device validations.

Table 3—Product Design Validation Grade Summary

Grade	Description	Requirements
CV4	Minimum grade of product validation	Supplier/manufacture defined requirements with engineering validation documentation of the defined ratings and capabilities.
CV3	Reduced grade of product validation	CV3 requires validation of a single copy of the design with water. Validation includes testing for the designated functions with reduced repetition of the testing steps (see Annex G).
CV2	Intermediate grade of product validation	CV2 requires validation of a single copy of the design with water. Validation includes testing for the designated functions (see Annex G).
CV1	Enhanced grade of product validation	CV1 requires validation of two copies of the design with water and gas testing of some features. Validation includes testing for the designated functions (see Annex G).

4.9 Functional Testing Grades

4.9.1 General

The user/purchaser should specify one of the following device/product functional testing grades where applicable, for each device/product manufactured. SCIS devices have one functional test grade, Grade F1. If no functional testing grade is specified, Grades F2 or CF2 shall be provided on devices/products other than SCIS devices.

NOTE The functional testing grade can be different from the design validation grade.

4.9.2 Device Functional Testing Grades

This specification provides three device functional testing grades as shown in Table 4.

Table 4—Device Functional Testing Grade Summary

Grade	Description	Requirements
F3	Minimum grade of functional testing	Supplier/manufacturer defined testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person.
F2	Intermediate grade of functional testing	Testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person as defined in Annexes B, C, D, and E.
F1	Enhanced grade of functional testing	Testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person as defined in Annexes B, C, D, and E.

4.9.3 Product Functional Testing Grades

This specification provides three product combined functional testing grades as shown in Table 5.

Table 5—Product Functional Testing Grade Summary

Grade	Description	Requirements
CF3	Minimum grade of product functional testing	Supplier/manufacturer defined testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person.
CF2	Intermediate grade of product functional testing	Testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person as defined in Annex G.
CF1	Enhanced grade of product functional testing	Testing requirements to documented procedures and acceptance criteria with the results approved by a qualified person as defined in Annex G.

4.10 Quality Levels

The user/purchaser should specify one of the following quality levels, which are summarized in Table 6 and detailed in Table 10. If the user/purchaser does not specify a quality level, the supplier/manufacturer shall provide a device/product that conforms to the QL2 level requirements.

Table 6—Quality Levels Summary

Grade	Description
QL2	Minimum level of quality requirements
QL1	Enhanced level of quality requirements

4.11 Additional Testing/Evaluations

The user/purchaser may specify additional design validation testing, functional testing, or quality requirements, or a combination thereof, that are deemed necessary for a specific application. These requirements shall be in addition to those included herein.

The supplier/manufacturer shall identify the equipment that the retrievable chemical injection device/product is compatible with and can be inserted within. See Annex F for guidance.

For chemical injection products which are covered by this specification, the requirements of Annex G shall apply.

5 Technical Specifications

5.1 General Requirements

The supplier/manufacturer shall prepare the technical specification that conforms to the requirements defined in the functional specification as defined in Section 4 and the requirements of this section. The supplier/manufacturer shall also provide the device/product data as defined in 6.2 to the user/purchaser.

All design verification and validation procedures, test results, and design acceptance shall be included in the design documentation. Each defined requirement shall conform to the specified acceptance criteria. Design verification and validation activities shall be performed and approved by a qualified person. Devices/products conforming to this specification shall be manufactured to drawings and specifications that are substantially the same as those of the same size, type and model that was validated; see 5.9.2.

5.2 Chemical Injection Device Types

5.2.1 General

Chemical injection devices/products covered by this specification are either

- permanently mounted onto or within a tubing mounted mandrel or carrier, which is typically covered by API 19AC, or
- designed as retrievable and use a side-pocket mandrel, which is typically covered by API 19G1.

Chemical injection devices/products which typically connect to an API 19AC mandrel (or carrier) shall incorporate the necessary pressure and load retaining connection(s) of the chemical injection devices/products. The connection shall be verified and validated by the supplier/manufacturer as applicable for the functional specification at the devices' or products' ratings. Retrievable devices/products are secured in and retrieved from side-pocket mandrels (SPM) using wireline or another well intervention mechanism. The chemical injection design shall be positioned and seal at the specified location and remain so until intervention defines otherwise (see API 19G1, API 19G3 or both).

5.2.2 Chemical Injection Device Types

There are many possible configurations of chemical injection devices when they are combined into products. The device types are classified as shown in Table 1. Each device design shall be validation tested to the requirements of the applicable annex as defined by the supplier/manufacturers claimed performance.

Typically, a chemical injection product consists of multiple devices from the types identified in Table 1. The interaction of these devices shall be engineered to perform as the supplier/manufacturer defines to provide the intended performance. Testing of these products is included in Annex G.

5.2.3 Operating Parameters

The chemical injection device/products shall perform in accordance with the operating parameters and characteristics as stated in the functional specification and validated by the validation testing results.

5.3 Design Criteria

5.3.1 General

The supplier/manufacturer shall use the design criteria in 5.3 in designing the device(s)/product(s).

5.3.2 Performance Ratings

The supplier/manufacture shall state the following ratings for each device(s)/product(s) design in the data sheet, as applicable:

- a) internal pressure rating(s);
- b) external pressure rating(s);
- c) rated temperature range;
- d) pressure differential rating(s);
- e) crack-open pressure range(s);
- f) closing pressure (RFP and BPR only);
- g) flow rate; minimum and maximum range;
- h) pressure drop at flowing rates;
- i) leakage acceptance (if any) by direction;
- j) bypass capability (SCIS only);
- k) reverse pressure acceptance (SUI only);
- l) retrievable designs, interface and compatibility with defined mandrels and tools (see Annex F).

5.3.3 Installation and Usage Requirements

The supplier/manufacture shall state any installation, mounting, or other usage requirements to ensure the product will function as intended by the supplier/manufacture (see 5.3.5).

5.3.4 Design Margins

The supplier/manufacture shall apply a design margin to the design of each component used within a device/product 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 that is evaluated. The design margin shall include combined and maximum stresses resulting from operational loads and conditions prescribed by the functional requirements.

The performance of the component shall be established following the design methods defined in 5.7.1.

The rating of a validated design shall be derived from the lowest performance capability of the components used in the device/product after the application of the design margin. Scaled designs, replacement components and design revisions shall conform to the design margin, design assumptions, and design analysis methods that were applied to the validated component or device/product.

5.3.5 Potential Effects of Completion (Mandrel/Carrier) Loading

The supplier/manufacture shall perform a design evaluation to establish if the chemical injection device/product is affected by loads occurring through the installation and use in the well completion at the device's rated limits. The supplier/manufacture shall evaluate if the following completion loading conditions influence the function and/or integrity of the chemical injection device/product:

- internal and external tubing or casing pressures;

- axial compression or tensile loadings;
- the running through, or placement within dog leg areas.

The supplier/manufacturer shall evaluate and document the effect of these loads on the chemical injection device/product.

The process of completion load evaluation shall comply with the requirements of 5.9.5.2. Should this evaluation identify that the device/product may be affected by completion loads, one device/product shall be tested to simulate these loads at their rated limits. If the device/product is not subject to completion loading, completion loading testing is not required.

If a device/product is not subject to completion loading, the supplier/manufacturer shall document installation and usage requirements to prevent the device/product from being subjected to completion loading.

5.4 Materials

5.4.1 General Requirements

Materials, and/or the service, shall be documented by the supplier/manufacturer and shall be suitable for the functional specification. The supplier/manufacturer shall have documented specifications for all materials. All materials used shall comply with the supplier/manufacturer's documented specifications that include chemical and mechanical property limits.

The user/purchaser may specify materials for the specific environment in the functional specification. If the supplier/manufacturer proposes to use another material, the supplier/manufacturer shall confirm the material has performance characteristics suitable for all parameters specified in the well and production/injection parameters. This applies to both metallic and non-metallic components. The supplier/manufacturer shall ensure that the metallic materials designed for use in sour environments shall meet the metallurgical requirements of NACE MR0175.

Each welded component shall be heat treated and stress-relieved if required in the supplier/manufacturer's written specifications, applicable Welding Procedure Qualification (WPQ), and Procedure Qualification Record (PQR). In addition, carbon and low-alloy steel weldments on sour service equipment shall be stress-relieved in accordance with NACE MR0175-2.

5.4.2 Material Substitution in Grade V1, V2 and V3 Devices/Products

Suppliers/manufacturers may make metallic or non-metallic (including seals) material substitutions to a validated device/product without additional validation testing. Material substitutions shall not change the device/product ratings. A qualified person shall verify and document that substitute materials conform to or exceed the specifications of the materials used in the validated device/product. The methods and practices employed to specify the original material shall apply to the substitute material. The functional, environmental, and technical requirements of this specification shall be met.

For non-metallic seal material substitution, the supplier/manufacturer shall verify the substituted material performance in accordance with 5.5.

Material substitutions shall conform to the requirements of 5.4.3, 5.4.4, and 5.8 of this specification. Substitute materials shall be provided by suppliers which have been approved according to a supplier/manufacturer's quality management system (QMS).

5.4.3 Metallic Material Specifications

The supplier/manufacturer's specifications for components having traceability shall define the following where applicable.

- a) Chemical-composition limits.
- b) Heat treatment conditions.
- c) Melt practice (for nickel and titanium-based alloys).
- d) Mechanical-property limits as applicable:
 - tensile strength;
 - yield strength;
 - elongation;
 - hardness;
 - impact toughness.

5.4.4 Metallic Mechanical Property Verifications

When required by the quality level, the mechanical properties for pressure-containing and/or tensile loaded metal components shall be verified by tests conducted on a material sample produced from the same heat of material in accordance with ASTM A370. The material sample shall experience the same heat treatment process as the component it qualifies. Material subsequently heat treated from the same heat of material shall be hardness-tested after processing to confirm compliance with the hardness requirements of the manufacturer's specifications. The hardness results shall verify through documented correlation that the mechanical properties of the material tested meet the properties specified.

Heat treatment process parameters shall be defined in a heat treatment procedure. Hardness testing is the only mechanical-property test required after stress relieving. Material test reports (MTR) provided by the material supplier/manufacturer are acceptable documentation when validated and approved by a qualified person.

5.4.5 Non-metallic Material Specifications

5.4.5.1 General

The supplier/manufacturer shall have documented procedures, including acceptance criteria, for evaluating or testing non-metallic materials to the limits for which the equipment is rated.

The supplier/manufacturer shall provide non-metallic materials that are compatible with the environment specified by the user/purchaser.

The supplier/manufacturer shall have a documented process with acceptance criteria used for selecting compatible non-metallic materials and seals.

5.4.5.2 Non-metallic Components

The supplier/manufacturer shall have written specifications for non-metallic components which shall include handling, packaging, storage and labeling requirements, including the cure date for elastomers, batch number, material identification and shelf life appropriate to each material and shall define those characteristics critical to the performance of the material, such as the following.

- a) Compound unique identification.
- b) The following mechanical properties, as a minimum:
 - tensile strength (at break);

- elongation (at break);
- tensile modulus;
- compression set (elastomers only);
- durometer hardness;
- specific gravity;
- yield strength (thermoplastics only);
- elongation at yield (thermoplastics only).

5.5 Sealing System Requirements

Sealing devices and seal components shall meet the following requirements.

- a) Chemical and environmental effects shall be considered for non-metallic seal components to determine selection of the seal material;
- b) Verification and/or validation shall establish that the non-metallic seal component used is suitable for the specific configuration. The evaluations or tests shall ensure compatibility with the technical and functional requirements and shall include mechanical loads, rated pressure, rated temperature range, design geometry and sealing environment;
- c) Scaling of seal component validation results shall be documented and approved by a qualified person. Limitations on scaling of non-metallic seal components are as follows.
 - Allowable variation in size shall be within ± 5 % of the nominal seal bore diameter and cross section thickness of the validated design.
 - Validation tests conducted on a cross-section size validates seal component sizes of the same cross-section thickness.
 - Seal material shall be identical for the scaled seal component and the validated seal component.
 - Loading mode (including support mechanisms) shall be identical for the scaled seal component and the validated seal component.
 - Critical stress levels of metallic components surrounding the scaled non-metallic seal component stated as a percentage of material yield, shall not exceed those of the validated seal component design at the same conditions.
 - Seal component extrusion gap and tolerances shall not be greater than that allowed by the validated design.
 - Stress calculation method(s) shall be identical for the scaled device and the validated device.
- d) If required by the user/purchaser in the functional specification, an aging evaluation shall be conducted by the supplier/manufacturer to evaluate the cumulative effects of an environment on an elastomeric material in accordance with ISO 23936-1 and/or, ISO 23936-2, or in accordance with the supplier/manufacture's documented testing procedure compliant to an industry specification and agreed to by the user/purchaser.

5.6 Bonding Non-metallic Materials to Substrates

Non-metallic seal components may be bonded to substrates for additional reinforcement or to perform other functions. If the bond of the non-metallic to the substrate is critical to performance, the integrity of the bond shall be evaluated in the same manner as the performance of the seal component itself per the supplier/manufacturer's defined methods and acceptance criteria.

Metallic substrates shall conform to the requirements in 5.4.3. Non-metallic substrates shall conform to the requirements in 5.4.5.

NOTE ASTM D429 provides methods for adhesion testing.

5.7 Design Verification

5.7.1 Design Methods

Documentation of designs shall include, but not be limited to, those criteria for size, test pressure, rated pressure range, materials, operating environment, rated temperature range, validation grade, chemicals and other pertinent requirements upon which the design is based.

The component or device/product ratings shall be established based upon

- a) the minimum material yield strength,
- b) the ultimate tensile strength,
- c) both the minimum material yield strength and ultimate tensile strength, or
- d) the minimum allowable material thickness.

Component or device/product ratings shall include de-rating as appropriate for the maximum rated temperature and shall also include consideration of temperature cycling and any other expected operating stresses when establishing the rated temperature.

Additionally, the ability to quantify the known stresses in components and assemblies with complex geometries shall be considered in establishing a component or device/product rating.

Pressure-containing components shall be designed to satisfy the supplier/manufacturer's test pressures, ratings and to meet the conditions defined in the functional specification. The assumptions, calculations and/or other design criteria shall be detailed in the design file for that device/product. The design method(s) that are used shall be documented in the supplier/manufacturer design records.

Flow characteristics pertinent to the design that are calculated by computational fluid dynamics, documented equations, flow analysis modeling, or other means shall be validated through testing. Final design documentation shall be reviewed and verified by a qualified person other than the individual who created the original design. Design records and documentation shall conform to the requirements of 6.2.

5.7.2 Design Verification Practices

Chemical injection devices/products shall be design verified using one or more of the following methods:

- a) finite element analysis (FEA);
- b) strain gauge testing;
- c) computational fluid dynamics (CFD);

- d) referenced proprietary equations;
- e) standard equations to documented procedures;
- f) experimental stress analyses;
- g) experimental flow analyses;
- h) analysis of testing results assuring conformance to design requirements.

5.8 Design Changes

5.8.1 Design Change Review

Design changes to a validated device/product shall be reviewed by a qualified person to determine if a design change is substantive.

Each design change review shall include the following:

- a) stress shall be compared with minimum material yield strength; the ratio shall not exceed that in the documented criteria of the original device/product;
- b) interchangeability of changed components or devices shall be maintained relative to the validated design;
- c) functional or operational limits and ratings remain unchanged;

The conclusions and justifications of the design change review shall be documented according to 5.8.2 and 5.8.3.

5.8.2 Substantive Design Changes

A device/product that undergoes a substantive design change shall become a new design, thereby requiring verification and validation.

Testing of only the changed component is acceptable, provided the testing includes loading equal to that applied during the validation testing of the device/product.

If the design change affects other components, or the whole device/product, those affected components, or the whole product shall be additionally tested to include loadings equal to those applied during the validation testing of the device/product.

The supplier/manufacture shall document the test results, demonstrating the component was accurately loaded. Test results shall be approved by a qualified person other than the person who performed the testing. The test results shall be part of the design documentation. Design changes shall conform to the design verification requirements of the previously-validated device/product.

5.8.3 Non-substantive Design Changes

Design changes deemed non-substantive by a qualified person shall be documented and justified. The documentation shall be approved by another qualified person. The documentation shall become part of the design documentation (see 6.2).

5.9 Design Validation Requirements

5.9.1 General

The supplier/manufacture shall comply with the design verification and validation requirements to ensure that each chemical injection device/product design fulfills the applicable functional requirements that are

to meet. The annexes applicable to the four device types are identified in Table 1 and products are covered in Annex G. General validation testing requirements are included in 5.10.

Design validation testing shall be performed on each design of chemical injection devices/products to ensure that the device/product meets the supplier/manufacture's technical specifications. Design validation test requirements are specified in the normative Annex B through Annex G. The design validation grade table specifies the design validation process(s), procedure(s) and test(s) that shall be followed for compliance to each design validation grade's requirements.

Where a SUI or a SCIS design, or both, are used, the device/product shall be successfully tested to its rated limits for the selected validation grade according to Annex D and Annex E.

5.9.2 Design Validation Grades

Device design validation grades included are V1, V2, V3 and V4; each grade includes defined criteria for that grade. Grade V1 requires gas and durability testing, V2 requires liquid and durability testing, V3 requires validation testing, and V4 requires supplier/manufacture has documented the validation testing.

Grade V3 validation requirements are included within the V2 requirements with reduced durability testing. Grade V3 is limited to BPR and RFP devices with reduced testing criteria as defined within validation Annex B and Annex C.

Product validation grades included are CV1, CV2, CV3, and CV4; each grade includes defined criteria for that grade. The grade hierarchy is provided in Table 7 and Table 8. See Annex G for the requirements for product validations.

Validation requirements for each grade are included within the applicable annexes.

Table 7—Device Validation Hierarchy

Validation Level	Coverage
V1	V1, V2, V3
V2	V2, V3
V3	V3
V4	V4
NOTE Validation level V4 may be covered by validation levels V1 and V2 or both for specific designs.	

Table 8—Product Validation Hierarchy

Validation Level	Coverage
CV1	CV1, CV2, CV3
CV2	CV2, CV3
CV3	CV3
CV4	CV4
NOTE Validation level CV4 may be covered by validation levels CV1 and CV2 or both for specific designs.	

5.9.3 Legacy Validation for Level V4

Chemical injection devices/products that existed before the publication of this specification may be considered as validated to Level V4 when the supplier/manufacture documents that the design successfully performed the required validation tests, and that these test results have been documented and approved by a qualified person.

The procedures are not required to be as defined in this specification; however, the supplier/manufacturer shall provide written evidence and justification that the test procedure(s) satisfy Annex B through Annex G. Validation of previous testing results shall be compiled and approved by a qualified person of the supplier/manufacturer. These approved validation records shall become a portion of the design file.

5.9.4 Requirements for Validation Level V4

The supplier/manufacturer shall document that the validation testing results and/or documented field history meet the requirements of the device's ratings. Ratings shall be documented and approved by a qualified person other than the qualified person who performed the testing or compiled the data. Testing fluids, auxiliary tubing dimensions and ambient temperatures shall be recorded where they are applied. Validation/verification results and procedures shall be documented. Design changes to V4 devices shall conform to the requirements of 4.8 and 5.9.

Following the effective date of this specification, new designs that conform to this specification shall meet the requirements of V3, V2 or V1. Legacy devices that comply with the V4 requirements of this specification may be validated to comply with V3, V2 or V1, provided requirements of the new validation grade are completed. Validation Level V4 devices manufactured after publication of this specification shall conform to the entirety of this specification's requirements.

Products validated to CV1, CV2, or CV3 may include devices which would separately be considered V4. However, within a CV1, CV2, and CV3 product, they shall have passed the designated product testing. See Annex G for further information.

5.9.5 Body Differential Pressure Rating Verification

5.9.5.1 General

The purpose of this test is to verify the body housing integrity of the chemical injection device/product according to calculated design limitations for the rated pressure and temperature range. The design margin provided by the supplier/manufacturer shall conform to the requirements of 5.3.4.

Suppliers/manufacturers shall perform the test with completed housing components. However, the test may be performed without internal functional components, or with dummy internal components to facilitate a uniform internal test pressure.

The MTR (material test report) yield strength of the components shall be equal to or greater than the minimum yield strength in the design material specification. Where the MTR yield strength of the tested component is greater than the design yield strength, the test pressures and axial loads, if applicable, shall be upwardly adjusted to correlate to the actual yield strength of the tested component.

The yield strength value referenced for the purposes of this test shall be a de-rated yield strength value obtained through material testing at the required test temperatures. Alternatively, it shall be the yield strength at ambient temperature with a temperature de-rating value obtained from the material supplier data or data approved by a supplier/manufacturer qualified person. Lastly, in the absence of other qualified material data, the material may be de-rated using the de-rating factor, (y_r) shown in Table 9. Other temperature de-ratings can be linearly interpolated and documented by a qualified person.

Table 9—Metallic Material De-Rating Factor Examples

Material Types	De-rating Factor, y_r	
	180 °C (350 °F)	345 °C (650 °F)
Carbon and low alloy steels	0.85	0.75
Martensitic, ferritic, and precipitation-hardened stainless steels	0.85	0.75
Austenitic and super duplex steels	0.80	0.73
Corrosion resistant alloys (CRA's)	0.95	0.85
CAUTION This table does not constitute a recommendation of the use of a particular alloy at high temperature. Some materials are embrittled after repeated or prolonged exposure to elevated temperatures. Care should be taken when choosing a material for use at temperatures permitted by temperature de-rating shown. NOTE Table content derived from Table 1 of API 6AF1, Second Edition.		

Before testing commences, a pre-test visual and dimensional inspection shall be performed in accordance with 5.10.3.

Testing and acceptance criteria shall be in accordance with 5.10.2. The applied test pressure shall be equal to or above the supplier/manufacturer's rated pressure.

5.9.5.2 Effect of Completion Loadings

This test may require the application of completion related loadings in accordance with the requirements of 5.3.5. If the supplier/manufacturer can document that the design is independent of completion loadings, the test may be conducted in accordance with 5.9.5.3.

If the supplier/manufacturer cannot document by calculations, analysis, or test results that the body housing is independent from completion loading, the test shall be conducted in accordance with 5.9.5.4.

Where the test is to be conducted with completion loading, testing shall be performed in accordance with 5.9.5.4 using a push/pull unit that will introduce the maximum rated tension and compression loads. Additionally, such test apparatus shall include a test fixture, vessel, housing, or other component that will apply external pressure to the test housing at the maximum rated external pressure of the device/product.

5.9.5.3 Body Differential Pressure Rating Verification without Completion Loading

The supplier/manufacturer shall verify the internal and external pressure ratings of a device/product by performing the following steps that are recorded in a documented test procedure.

- 1) A pre-test visual and dimensional inspection shall be performed per 5.10.3.
- 2) Before performing the internal test, lock the device/product functional mechanism in an open position or disable it to ensure the entire housing under test is exposed to the internal test pressure.
- 3) Apply test fluid at ambient temperature inside the housing using a suitable test fixture.
- 4) Increase the temperature of the device/product to the rated temperature or above and allow it to stabilize.
- 5) Pressurize the device to, or above, the required test pressure for at least a 15-minute hold period.
- 6) Release the pressure applied to the housing.
- 7) Remove and dismantle the device. Perform a post-test visual and dimensional inspection per 5.10.3.
- 8) If the housing does not demonstrate loss of integrity from the pre-test inspection, then the test may be continued to verify external rated pressure.