

Flow-control Devices for Side-pocket Mandrels

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Introduction

This specification has been developed by users/purchasers and suppliers/manufacturers of subsurface flow-control devices used in side-pocket mandrels (hereafter called flow-control devices) intended for use in the worldwide petroleum and natural gas industry. This specification is intended to provide requirements and information to all parties who are involved in the specification, selection, manufacture, testing, and use of flow-control devices. Further, this specification addresses supplier/manufacture requirements that set the minimum parameters with which suppliers/manufacturers shall comply to claim conformity with this specification.

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

Design validation grades. There are four design validation grades for flow-control devices that provide the user/purchaser with a range of technical and performance requirements. This ensures that the devices supplied according to this specification meet the requirements and that the user/purchaser is able to compare these requirements with their preference or application and determine whether additional requirements will be placed on the supplier/manufacture.

It is important that users of this specification be aware that requirements in addition to those outlined herein might be needed for individual applications. This specification is not intended to inhibit a supplier/manufacture 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/manufacture to identify any variations from this specification and to provide details.

Device functional testing grades. There are four device functional testing grades for flow-control devices that provide the user/purchaser with a range of choices for confirming that individual devices manufactured under this specification meet the design specifications.

Quality levels. There are two quality levels that provide the user/purchaser with the choice of requirements to meet specific preferences or applications. Additional quality upgrades can be specified by the user/purchaser as supplemental requirements.

In addition to this specification, API 19G1 provides requirements for side-pocket mandrels used in the petroleum and natural gas industry. API 19G3, provides requirements for running, pulling and kick-over tools, and latches used in conjunction with side-pocket mandrel flow-control devices.

Flow-control Devices for Side-pocket Mandrels

1 Scope

This specification provides requirements for subsurface flow-control devices used in side-pocket mandrels intended for use in the worldwide petroleum and natural gas industry. This specification addresses injection-pressure-operated (IPO), production-pressure-operated (PPO), pilot, orifice, and dummy flow-control devices. This includes requirements for specifying, selecting, designing, manufacturing, quality control, testing, and preparation for the shipping of flow-control devices. Additionally, it includes information regarding performance testing and calibration requirements.

The installation and retrieval of flow-control devices is outside the scope of this specification. Additionally, this specification is not applicable to flow-control devices used in center-set mandrels or with tubing-retrievable applications.

This specification does not include requirements for side-pocket mandrels, running, pulling, kick-over tools, or latches that may or may not be covered in other API documents. Reconditioning of used flow-control devices is outside the scope of this specification.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their 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 any addenda) applies.

API Q1, *Specification for Quality Management*

API 19G1, *Side-pocket Mandrels*

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

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

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

ANSI/ASQ Z1.4 ², *Sampling Procedures and Tables for Inspection by Attributes*

ANSI/NCSL Z540.3 ³, *Requirements for the Calibration of Measuring and Test Equipment*

ASME Boiler and Pressure Vessel Code ⁴, Section II—Part C: *Specification for Welding Rods, Electrodes and Filler Metal*

ASME Boiler and Pressure Vessel Code, Section IX: *Welding and Brazing Qualification*

ASTM A370 ⁵, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

¹ NACE International, 15835 Park Ten Place, Houston, Texas, 77084, www.nace.org.

² American Society for Quality, 600 North Plankinton Avenue, Milwaukee, Wisconsin 53203, asq.org.

³ NCSL International, 5766 Central Avenue, Suite 150, Boulder, Colorado 80301, www.ncsli.org.

⁴ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016-5990, www.asme.org.

⁵ ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, www.astm.org.

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

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

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

ISO 2859-1⁶, *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 6892-1, *Metallic Materials—Tensile Testing—Part 1: Method of Test at Room Temperature*

ISO 9000, *Quality Management Systems—Fundamentals and Vocabulary*

ISO 15156 (all parts), *Petroleum and Natural Gas Industries—Materials for Use in H₂S-containing Environments in Oil and Gas Production*

SAE AMS-H-6875⁷, *Heat Treatment of Steel Raw Materials*

SAE AS568, *Aerospace Size Standard for O-rings*

SAE AS5752, *Aerospace—Visual Inspection Standard for Elastomeric Sealing Elements Other than O-rings*

3 Terms and Definitions

For the purposes of this specification, the terms and definitions given in ISO 9000 (for quality-system-related terms not given below) and the following apply.

3.1

acceptance

Flow-control device component(s) and/or assembly(s) accepted for use without restriction.

3.2

ager

Pressure device used to apply an external pressure to a flow-control device for a specified period of time and/or number of cycles.

3.3

certificate of conformance

Documentation approved by the supplier/manufacturer identifying that a specific device meets the requirements of this specification and the functional specification.

3.4

coating

Application of a thin film of one material on the surface of another material for different purposes.

⁶ International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

⁷ SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096-0001, www.sae.org.

3.5**critical pressure ratio**

The difference between the upstream and downstream pressure divided by the upstream pressure at which the velocity of fluid exceeds the local speed of sound.

NOTE See 4.2 Symbols and Engineering Terms for additional clarification under critical pressure ratio factor.

3.6**date of manufacture**

Date of manufacturer's final acceptance of finished devices.

NOTE The date is day-month-year in the format DD-MM-YYYY.

3.7**design family**

Group of products whose configurations, sizes, materials, and applications are sufficiently similar that identical design methodologies can be used to establish the design parameters for each device within the family.

3.8**design method**

Practices, procedures, or equations used by the supplier/manufacturer to design a flow-control device.

3.9**design validation**

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

3.10**design verification**

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

3.11**dome**

Chamber that contains an internal pressure that is applied to the responsive element, which can be a bellows or piston.

3.12**dome charge maximum**

Supplier/manufacturer's maximum recommended pressure charge in the dome at recommended operating temperature.

3.13**dynamic flow testing**

Flow testing of an operable flow-control device to determine the fluid flow characteristics as a function of changes in either upstream or downstream pressures at a known temperature.

3.14**end connections**

Thread or other mechanism providing a connection between the flow-control device and other equipment.

3.15**flow coefficient**

A relative measure of a device's efficiency to allow fluid flow. It describes the relationship between the pressure drop across an orifice, valve, or other assembly and the corresponding flow rate.

3.16**flow coefficient testing**

Testing that is performed on a flow-control device to determine the flow capacity and establish the flow coefficient.

3.17**flow-control device**

A device installed in a side-pocket mandrel to control flow of fluids between a well's casing annulus and tubing.

3.18**full life cycle**

Expected period of time over which the device shall function according to the manufacturer's specifications.

3.19**functional test**

Test performed to confirm proper operation of equipment.

3.20**gas passage undercut**

Clearance between the flow-control device and the pocket of the side-pocket mandrel, through which injected media flows.

3.21**heat**

Material originating from a final melt or cast lot.

NOTE For remelted alloys, a heat defined as a raw material originating from a single remelted ingot.

3.22**hold period**

The designated duration of a testing process.

3.23**informative**

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

3.24**job lot**

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

3.25**latch**

Mechanism for installation, retention, or removal of a flow-control device that is landed in a side-pocket mandrel latch profile.

3.26**manufacturing**

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

3.27**model**

Product with unique components and functional characteristics that differentiate it from other products of the same type.

3.28**normative**

Information or procedures that shall be used by the user/purchaser or supplier/manufacturer as they comply with this specification.

3.29**operating environment**

Environmental conditions that the product is exposed to during its service life, such as temperature, pressure, liquid, and gas composition and properties, solids, and others.

3.30**qualified person**

An individual with skills and abilities to perform the required function gained through training or experience or both as measured against established requirements such as standards or tests.

3.31**perceptible leak**

A leak detected or observed during testing.

3.32**qualified design family**

Whereby the design verification of one or more representative design(s) and device(s) permits the entire family to be treated as a design verified and/or validated by association. Validation by association implies the design feature is the same as a previously qualified design feature and is thus qualified by association without additional testing.

3.33**ramp method**

A means to perform a test where the pressure differential is continuously increased or decreased.

3.34**rated pressure**

Maximum differential pressure at the rated temperature the product is designed to function within.

3.35**rated temperature**

Maximum temperature at a specified pressure that the product is designed to operate in.

3.36**side-pocket mandrel**

Tubing-mounted device that accepts a flow-control or other device in a bore that is offset from, and parallel with, the through-bore of the tubing product.

3.37**significant design changes**

Change to the design, identified by the supplier/manufacturer, that can affect the performance of a product and the intended service condition.

3.38**supplier/manufacturer**

Company, organization, or entity that designs, manufactures and/or markets flow-control device devices.

3.39**technical specifications**

Requirements necessary for compliance with the functional specification, which include parameters and limits to ensure the product and component performance.

3.40**test pressure**

Differential pressure between the applied pressure and atmospheric pressure, as specified by the pertinent test procedure which is based upon relevant design criteria.

3.41**test temperature**

Temperature at which the equipment is tested to a specified procedure.

3.42**traceability**

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

3.43**type**

Products with characteristics that differentiate them from other functionally similar products that have unique names or descriptions.

3.44**user/purchaser**

Company, organization, or entity that purchases, installs, and uses flow-control device devices.

3.45**welding**

Method for joining two metallic substances through a process of melting and resolidification.

3.46**wireline**

Equipment and associated technique(s) used to install and retrieve flow-control devices in a side-pocket mandrel using a continuous length of solid line (slick line) or stranded wire, surface spooling and measurement equipment, and specialized tools attached to the downhole end of the wire.

3.47**yield strength**

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

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

4 Symbols and Abbreviated Terms

4.1 Abbreviations

AQL acceptable quality level

CIPT	constant-injection-pressure test
CPPT	constant-production-pressure test
ECV	equalizing control flow-control device
FCD	flow-control device
GST	geometric stem travel for fully opened condition
HAZ	heat-affected zone
ID	inside diameter
IPO	injection-pressure-operated
LST	maximum effective stem travel from the probe test
LVDT	linear variable differential transducer
MSCFD	thousands of standard cubic feet per day
MSCMD	thousands of standard cubic meters per day
NDE	nondestructive examination method
OD	outside diameter
PPO	production-pressure-operated
PQR	procedure qualification record
QC	quality control
SCFD	standard cubic feet per day
SCMD	standard cubic meters per day
SPM	side-pocket mandrel
VST	flow-control device stem travel
WPQ	welder/welding operator performance qualification
WPS	welding procedure specification

4.2 Symbols and Engineering Terms

A_b	area of bellows—based on average diameter, expressed in square centimeters (square inches)
A_p	area of valve port, expressed in square centimeters (square inches)
A_s	area of valve port-ball seat contact, listed in manufacturer catalog as A_p , expressed in square centimeters (square inches)
B_{lr}	bellows assembly load rate, expressed in kilopascals per centimeter (pounds per square inch per inch)
C_1, C_2	empirical constants determined by curve-fitting data, expressed in kilopascals (pounds per square inch)
C_v	flow coefficient
C_t	system time constant, expressed in seconds
C_{t1}	system time constants found by curve-fitting the data, expressed in seconds
C_{t2}	system time constants found by curve-fitting the data, expressed in seconds
dP	differential pressure, expressed in kilopascals (pounds per square inch)
d_{st}	distance stem has moved from seat, expressed in centimeters (inches)
d_{LST}	distance of maximum effective stem travel from probe test, expressed in centimeters (inches)

d_{VST}	distance of flow-control device (FCD) stem travel, expressed in centimeters (inches)
$dP_{\max}$	maximum pressure increase to achieve maximum FCD stem travel for a constant downstream test section pressure, expressed in kilopascals (pounds per square inch)
F_k	ratio of specific heat factor, equal to $k/1.40$; where k = specific heat of lift gas and 1.40 = specific heat of nitrogen test media
F_Y	expansion factor
m_{bf}	slope of the best-fit straight line
P_1	upstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch)
$P_{1,\max}$	maximum upstream system pressure, expressed in gauge kilopascals (pounds per square inch)
P_2	downstream gauge pressure of test section, expressed in gauge kilopascals (pounds per square inch)
$P_2(t)$	downstream system pressure, expressed in gauge kilopascals (pounds per square inch) as a function of time
P_{iod}	operating injection gauge pressure at flow-control device depth, expressed in gauge kilopascals (pounds per square inch)
P_o	FCD opening pressure, expressed in gauge kilopascals (pounds per square inch)
P_{pd}	flowing production gauge pressure at flow-control device depth, expressed in gauge kilopascals (pounds per square inch)
P_{tro}	measured or calculated test rack opening gauge pressure applied over the area of the bellows (A_b) minus the area of the seal (A_s), required to initiate flow through a flow-control device with zero gauge pressure downstream at $15.5\text{ }^{\circ}\text{C}$ ($60\text{ }^{\circ}\text{F}$)

NOTE 1 Referred to as flow-control device opening pressure at standard temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vc}	measured or calculated upstream gauge pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at $15.5\text{ }^{\circ}\text{C}$ ($60\text{ }^{\circ}\text{F}$)
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NOTE 2 Referred to as flow-control device closing pressure at standard temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vcT}	measured or calculated upstream gauge pressure when the downstream pressure is equal to the upstream pressure and near zero gas flow rate at a known temperature
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NOTE 3 Referred to as flow-control device closing pressure at a known temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vo}	FCD opening pressure, expressed in gauge kilopascals (pounds per square inch)
P_{voT}	measured or calculated gauge pressure applied over the area (A_b minus A_s), required to initiate flow through a flow-control device with zero gauge pressure downstream at a known temperature

NOTE 4 Referred to as flow-control device opening pressure at a known temperature, expressed in gauge kilopascals (pounds per square inch).

P_{vsT}	pressure at maximum stem travel, expressed in gauge kilopascals (pounds per square inch)
q_{gi}	measured flow rate at standard conditions, expressed in thousands of standard cubic meters per day (thousands of cubic feet per day)
R	ratio of gas lift valve port area to bellows area (A_p/A_b)

NOTE 5 This relationship is computed based on measured opening and closing pressures using Equation (I.1).

R_p	pressure ratio; the measured differential pressure across the test section divided by the absolute upstream pressure, expressed as $dP/(P_1 + 100)\text{kPa}$ [$dP/(P_1 + 14.7)\text{psi}$]
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$R_{p, crt}$	critical pressure ratio factor; the pressure ratio factor at which the velocity of fluid exceeds the local speed of sound
	NOTE Critical flow occurs when $F_k \times R_{p, crt}$ equals or exceeds the pressure ratio. The value is determined as specified in Clause 5.
s_g	specific gravity of gas (the value for air equals 1.0)
t	time, expressed in seconds
T_1	upstream gas temperature, expressed in either degrees Celsius (Fahrenheit) or units of kelvin (Rankine)
T_v	temperature of flow-control device at depth, expressed in either degrees Celsius (Fahrenheit) or units of kelvin (Rankine)
Z_1	upstream gas compressibility deviation factor

5 Functional Specification

5.1 General

The purpose of the functional specification is to provide guidance, so the user/purchaser can specify and define the functional requirements for flow-control device(s) conforming to this specification.

This section provides the requirements, parameters and operating conditions necessary for specifying flow-control devices. The user/purchaser shall prepare a functional specification for devices that conform to this specification.

The functional specification shall specify the following requirements and operating conditions, as appropriate, and/or identify the supplier/manufacturer's specific device. To comply with this specification, the defined requirements of the specified grades shall be implemented without substitution. Additional requirements (such as user/purchaser requests) shall not invalidate the requirements specified herein.

5.2 Functional Characteristics

A flow-control device is a device that is landed by wireline or other means and secured in a side-pocket mandrel (SPM) bore. The flow-control device acts to control the flow or communication of gas and/or liquid between the pressure-retaining areas of the well (e.g. annulus-to-tubing flow of gas, tubing-to-annulus flow of injection fluid, etc.).

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

- a) functions, which the user/purchaser may define by specifying either a specific flow-control device or functional items such as:
 - flow-control device type: injection-pressure-operated (IPO), production-pressure-operated (PPO), seat material, elastomers, packing type, P_{tro} and P_{vc} ranges, and special coating(s);
 - nominal flow-control device size, e.g. 2.54 cm (1.000 in.), 3.810 cm (1.500 in.), etc.;
 - port size;
 - port type: square-edged, beveled, tapered, venturi, cross-over;
 - maximum bellows pressure;
 - bellows protection;

- maximum spring load rate;
 - maximum flow-control device stem travel;
 - minimum/maximum flow rate when fully open;
 - back-check flow-control device(s);
 - choke size and type, if applicable.
- b) latch, the size and/or type and/or model(s) that is used to install, secure, and retrieve the flow-control device in an SPM;
- c) seal bore, either the nominal size and configuration to accommodate the flow-control device, or the model(s) of the SPM in which the flow-control device is to be installed;
- d) communication ports, either the location and configuration of both inlet and outlet ports on the flow-control device, and/or the model of the flow-control device;
- e) conduit ports, the connection size and configuration for SPM external ports and outlets to which a side-string, control, or injection conduit is to connect. This is for reference to validate that the specified flow-control device communication and internal port sizes are compatible with the SPM.

5.3 Well Parameters

5.3.1 Well Fluid Parameters

The following well fluid parameters, to which the flow-control device is exposed during its full life cycle, shall be provided, as applicable:

- a) fluid composition, chemical composition, and specific gravity of:
- produced fluids (liquid, hydrocarbon gas, CO₂, H₂S, etc.);
 - injection gas (e.g. hydrocarbon gas, CO₂, etc.);
 - injection fluids (e.g. water, steam, CO₂, chemicals, etc.);
 - completion fluids;
 - treatment/stimulation fluids/chemicals;
- b) description of extraneous components (e.g. paraffin, sand, scale, and corrosion products.).

5.3.2 Allowable Well Operations

Expected well intervention(s), including its (their) parameters, shall be stated, as applicable:

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

5.3.3 Corrosion Information

If the user/purchaser has access to corrosion property data of the operating environment based on historical data and/or research, this information shall be made available to the supplier/manufacture. The user/purchaser may indicate to the supplier/manufacture which material(s) has/have the ability to perform as required within the subject well's corrosion environment per the requirements of 5.6, as applicable.

5.4 Operational Parameters

The user/purchaser shall specify the installation, testing, and operational conditions to which the flow-control devices are exposed. These shall include, but are not limited to:

- a) expected hydrostatic head at flow-control device depth;
- b) expected minimum and maximum operating injection pressures;
- c) expected minimum and maximum operating production pressures;
- d) expected minimum and maximum operating temperatures;
- e) expected minimum and maximum gas or liquid injection rates;
- f) expected minimum and maximum fluid production rates;
- g) expected maximum differential pressure across the back-check;
- h) expected maximum internal-to-external differential pressure across the flow-control device;
- i) expected pressure/differential at which a dump/kill or shear orifice opens;
- j) expected installation, testing, and operational procedures;
- k) expected flow-control device deployment and retrieval method(s).

5.5 Compatibility with Well-related Equipment

The user/purchaser, where applicable, shall specify the interface connection designs and material requirements, free-passage requirements, and external/internal dimensional limitations that are needed to ensure that the device conforms to their application. An example list is as follows:

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

The flow-control devices shall be designed to be compatible with polished bore dimensions in accordance with API 19G1. If the design of the flow-control device requires polished bore dimensions other than those listed, an agreement between user/purchaser and supplier/manufacture shall be documented.

5.6 Environmental Compatibility

5.6.1 General

If the user/purchaser has access to the corrosion property data of the operating environment based on historical data and/or research, they shall state to the supplier/manufacturer which material(s) has the ability to perform as required within the corrosion environment per the requirements of 5.6.3 as applicable. Otherwise, material compatibility shall be specified according to 5.6.2.

5.6.2 Well Environment

The user/purchaser shall identify the density, chemical/physical composition, and the condition of the fluid and/or its components, including solid (total suspended solids, sand production, scale, cement, etc.), liquid and/or gas, to which the FCD is exposed during its expected life cycle. Both the minimum and the maximum anticipated values of the production/injection pressures, pressure differentials, temperatures, and flow rates shall be identified. Other operational parameters, as necessary, may be defined.

5.6.3 Material Designation

If the user/purchaser chooses to specify materials for sour service, the requirements for compliance to ANSI NACE MR0175/ISO 15156 shall be stated.

5.7 Design Validation Grades

The user/purchaser shall specify one of the following design validation grades. If no design validation grade is specified, V3 shall be provided as a minimum. The four design validation grade requirements are detailed in Annex C.

- V3: Basic grade of design validation;
- V2: Intermediate grade of design validation;
- V1: High grade of design validation;
- V0: Severe service grade of design validation.

5.8 Device Functional Testing Grades

If applicable to the flow-control device group, the user/purchaser shall specify one of the following device functional testing grades. If no device functional testing grade is specified, grade F3 shall be provided as a minimum. This specification provides the following four device functional testing grades as detailed in Annex C.

- F3: Basic grade of device functional testing;
- F2: Intermediate grade of device functional testing;
- F1: High grade of device functional testing;
- F0: Severe service grade of device functional testing. (The application of F0 shall be limited to flow-control devices validated to the requirements of design validation grade V0.)

5.9 Quality Levels

The user/purchaser shall specify one of the following quality levels. If no quality level is specified, level QL2 shall be provided. This specification provides two quality levels, which are detailed in 7.4.6.

- QL2: Basic level of quality;
- QL1: Highest level of quality.

5.10 Additional Testing

The user/purchaser may specify additional design validation testing, device functional testing, and/or quality controls that are deemed necessary for a specific application, which does not interfere with the defined testing requirements.

6 Technical Specification

6.1 General

The supplier/manufacture shall prepare the technical specification to meet the requirements defined in the user/purchaser's functional specification as defined in Clause 5. The supplier/manufacture shall provide to the user/purchaser the device data as defined in 7.2.7.

There are many possible types and permutations of flow-control devices. For purposes of simplification in flow-control device design validation testing and device functional testing, various flow-control device types are classified into groups as shown in Table 1.

Table 1—Flow-control Device Descriptions

Flow-control Device Group	Flow-control Device Types	Flow-control Device Description
I	IPO	Injection-pressure-operated flow-control device
	Balanced IPO	Injection-pressure-operated flow-control device for which the production pressure does not affect the opening pressure of the flow-control devices and their spreads are equal to zero
	IPO with choke	Injection-pressure-operated flow-control device, with a choke installed downstream of the port
II	PPO	Production-pressure-operated flow-control device
III	Pilot	Injection-pressure-operated flow-control device with a pilot section and a full-opening primary flow section
IV	Orifice	Flow-control device with a designated inside diameter (ID) that cannot be closed
	Venturi nozzle	Flow-control device that creates a constriction within a tubular device (classically an hourglass shape)
	Shear orifice	Flow-control device that is initially closed; once it is opened, it cannot be reclosed
	Dump/kill	Flow-control device that is initially closed; once it is opened, it cannot be reclosed. These flow-control devices have very large ports and no reverse-flow check to allow a high-injection rate to kill the well.
V	Dummy	Blank device that is installed in an SPM to prevent flow or pressure communication

6.2 Technical Characteristics

6.2.1 General

The supplier/manufacturer shall design and manufacture the flow-control device to meet the functional criteria in 6.2.2 through 6.2.6.

6.2.2 Flow-control Device Installation

The flow-control device shall be capable of being positioned and sealed at the specified location and remain so until intervention defines otherwise.

6.2.3 Functional Requirements

While located in the SPM, the flow-control device shall perform in accordance with its specific technical specification.

6.2.4 Tool Passage

The flow-control device shall not interfere with the safe passage of tools through the SPM, as specified in the functional specification.

6.2.5 Corrosion Prevention Notifications

Should the supplier/manufacturer determine that another material can equally or better meet the user/purchaser's specified corrosion-prevention requirements for the application (see 5.3.3), the user/purchaser shall be notified that this material has performance characteristics suitable for all parameters specified in the well (see 5.4). This applies to metallic and nonmetallic components.

Agreement shall be obtained and documented before any change in materials from those indicated by the user/purchaser.

6.2.6 Operating Parameters

The flow-control device shall perform in accordance with the operating parameters and characteristics as stated in the functional specification (see Clause 5).

6.3 Design Criteria

6.3.1 General

The supplier/manufacturer shall use the design criteria in 6.3.2 through 6.3.11 in designing the flow-control device(s).

6.3.2 Materials

The supplier/manufacturer shall meet the requirements as specified by the user/purchaser in Clause 5. If the user/purchaser does not specify materials, the supplier/manufacturer shall select materials suitable for the functional specification and provide a bill of materials with material descriptions. The supplier/manufacturer shall have written specifications for all materials. For sour environments, the materials selected shall be in conformance with the requirements of ANSI/NACE MR0175/ISO 15156.

6.3.3 Performance Rating

The supplier/manufacturer shall state the rated pressure, rated temperature, and other operational characteristics and limits of the flow-control device.

6.3.4 Polished Bore Dimensions

The flow-control device shall be designed to be compatible with seal bore dimensions in accordance with API 19G1. If the design of the flow-control devices requires seal bore dimensions other than those listed, an agreement between user/purchaser and supplier/manufacture shall be documented.

6.3.5 Interchangeability

Components and subassemblies of each type, model, and size of flow-control devices shall be designed, manufactured, and identified to provide interchangeability within the product line of any one manufacturer. Stems and seats lapped to form matched sets are considered a single component for the purposes of this subclause.

6.3.6 Compatibility

The supplier/manufacture shall provide documentation of specific SPMs and latches that are compatible with the flow-control device. The level of documentation depends on the design validation grade and/or device functional test grade selected by the user/purchaser.

6.3.7 Dimensions and Interfaces

Dimensional tolerances of components or subassemblies shall be such that cumulative tolerances do not preclude proper operation as described in the design validation requirements. The assumptions, calculations, and/or other design criteria shall be detailed in the design file for that device or design family, per 6.3.11.

Perform the requirements of Annex D to demonstrate that a specific flow-control device is compatible with the SPM(s), running/pulling tools, kick-over tools, and latches with which it is designed to be used. A statement of compatibility shall be presented in the supplier/manufacture's operating manual or data sheet for this device.

6.3.8 Packing, O-rings, and Seals

6.3.8.1 Allowable Elastomeric Materials

The supplier/manufacture shall provide elastomeric materials that are compatible with the operational environment specified by the user/purchaser, see 5.6. The supplier/manufacture shall document the process used for selecting compatible elastomeric materials and the choices made.

6.3.8.2 Packing Polished Bore Dimensions

The diameters of the external packing on all flow-control devices shall be designed to be compatible with polished bore dimensions, in accordance with API 19G1. If the design of the flow-control device requires polished bore dimensions other than those listed, an agreement between user/purchaser and supplier/manufacture shall be documented.

6.3.8.3 Design Validation Testing

Packing, O-rings, and seal design validation testing shall be conducted as detailed in 6.5.3.3.

6.3.9 Good Design Practices

The following are minimum design practices that shall be used:

- locate the gas passage entry port of the flow-control device in the gas passage undercut of the SPM pocket;
- provide rounded or beveled exterior surfaces to prevent handling difficulties as the flow-control devices are run into or retrieved from an SPM within a well;
- design to prevent inadvertent unseating of the flow-control device from the SPM as other devices are pulled through the mandrel.

6.3.10 Design Methods

Flow-control devices shall be designed using one or more of the following:

- finite element analysis for strength of material issues;
- computational fluid dynamics for flow characteristics;
- proprietary equations;
- standard equations;
- experimental stress analyses;
- experimental flow analyses;
- proof test analysis.

The design method(s) used shall be documented in supplier/manufacturer procedures. All pressure-containing parts shall be designed to satisfy the supplier/manufacturer's test pressures and to meet the conditions defined in the functional specification. The assumptions, calculations, and/or other design criteria utilized shall be detailed in the design file for that device. The supplier/manufacturer shall have on record material specifications and drawings that show all the applicable dimensions and tolerances of parts contained in the validation-tested device.

All flow characteristics pertinent to the design that are calculated by computational fluid dynamics shall be validated through testing, the use of appropriate equations, flow analysis modeling, or other means in accordance with this specification and recognized industry practices for flow validations. All flow evaluations, processes, and results shall be a part of the device design file, per 7.2.2.

6.3.11 Qualified Design Families

Design scaling is allowed only between maximum and minimum port sizes on a specific flow-control device design family. Devices may be grouped into design families if they have interchangeable parts and if their configurations, sizes, and applications are similar to a common methodology for establishing their design limits.

If requested by user/purchaser, the supplier/manufacturer shall provide the following documentation with devices that have been verified by association:

- detailed summary of all records of validated designs and/or devices from the defined family per 7.2.2;
- trend analyses or scatter diagrams, as appropriate, to demonstrate that the performance generated by the design methodology and analysis are consistent to permit validation;

6.4 Allowable Design Changes

6.4.1 General

Any changes in the design of a flow-control device shall be made following the procedures listed in 6.4.2 and 6.4.3. Acceptance criteria and testing results shall be documented and retained per 7.2.2.

6.4.2 Design Changes

Design changes to existing devices within a design family that meet the following requirements do not change their status as part of the design family and do not change their validation by association within a qualified design family. Design changes that are outside of the criteria defined below shall be considered substantive design changes.

- The design changes do not require a change in the common methodology for establishing design performance ratings within the design family.
- The operational parameters for the device(s) changed design shall be consistent with the operational parameters and ratings for the design family.
- A change in seat size is not considered a change in flow-control device design for the purposes of this subclause, unless it also changes the calculated stem travel and bellows position from the initial starting position to the mechanical stop by more than 5 %.

Justifications for design changes identified as nonsubstantive shall be documented and approved by a qualified person. A design that undergoes a substantive change that is no longer associated with previous design family becomes a new design requiring design validation.

6.4.3 Supplemental Features Validation Testing

Flow-control devices with unique or multiple supplemental features that do not change the design of the device are to be tested in accordance with the supplier/manufacturer's documented requirements that validate proper operation of that feature at its rated limits and to the acceptance criteria of the original design.

6.5 Design Verification and Validation Requirements

6.5.1 General

The supplier/manufacturer shall use these design verification and validation procedures to ensure that each flow-control device design family fulfills the applicable functional requirements that it is intended to meet. Flow-control devices of each design, type, and size shall be validation tested before the device may be presented as meeting specific functional requirements of this specification. Documentation shall be retained per 7.2.2.

Testing may be combined to provide results that encompass several of the individual requirements wherein each testing result is unaffected by the other. The supplier/manufacturer shall demonstrate and document that the test results meet the requirements as outlined in Table C.1.

Several of the specified flow-control device design validation tests require more than one flow-control device for evaluation, as detailed in Table C.1. This is to ensure consistency and repeatability across the device design, type, and/or size. The specific devices that are tested shall be manufactured within the nominal manufacturing system and processes; it is not permitted to select special specimens for testing.

During each series of tests, the individual devices shall not be repaired or serviced in any way, unless specifically allowed, see D.2.1.1. If (a) specific component(s) of a flow-control device fails a specific test, the cause of the failure shall be analyzed and documented. The cause of the failure shall be addressed and the design validation test shall be repeated from the beginning.

6.5.2 Design Verification

Design verification shall be performed on each design of flow-control devices to ensure that the device meets the supplier/manufacture's technical specifications. Design verification activities shall include, but are not limited to, design reviews, design calculations, and comparison with similar designs. Supplier/manufacture shall compile a report documenting the design verification processes used.

6.5.3 Design Validation

6.5.3.1 Testing

Design validation testing shall be performed on each design family of flow-control devices to ensure that each device design meets the supplier/manufacture's technical specifications. Design validation test requirements are specified in normative Annexes B through M; requirements for seal designs are specified in 6.5.3.3. Each device design shall successfully complete each of the design validation tests as specified in Table C.1. Devices provided for validation testing shall conform to quality level QL1.

The supplier/manufacture shall compile a report of the successful completion of each applicable annex testing.

Design validation pressure, temperature, and load test results shall be recorded on a continuous, time-based data collection system and the results shall be maintained in the validation test file for that specific device. Validation testing shall be performed in fixtures that are designed to retain the temperatures, pressures, and loads required to perform the defined testing without applying loading that would not be applicable in the device's normal use.

Test pressures shall be a minimum of 1.0 times the rated pressure of the flow-control device. If test temperature is less than rated temperature, the test pressure shall be increased accordingly to ensure that stresses are equivalent to rated pressure at temperature and that the design limits are being tested.

The supplier/manufacture shall meet the validation test requirements of the applicable annex(s) to the selected validation grade. Devices validated to higher grades of design validation may be considered qualified for lower grades of design validation in accordance with Table 2.

Table 2—Design Validation Grade Hierarchy

Validation Grade	Grades Covered
V0	V0, V1, V2
V1	V1, V2
V2	V2
V3	V3

6.5.3.2 Design Validation Grade Table

The design validation grade table specifies the design validation process(es), procedure(s), and test(s) that shall be successfully completed for each design validation grade. See Table C.1.

6.5.3.3 Sealing Device Design Validation Testing

6.5.3.3.1 General

The supplier/manufacture shall have documented procedures, including acceptance criteria, for evaluations or tests of sealing materials or other nonmetals to limits for which the equipment is rated. The supplier/manufacture shall perform and document design validation testing for each size, design, and material of sealing device used in each flow-control device. For O-rings, a single design validation test is required for each series used (i.e. 1xx, 2xx, 3xx, etc.).

Once a sealing device has successfully passed design validation testing, it is qualified for use on multiple devices of similar dimensional requirements within the temperature and pressure differentials tested. Evaluations (or tests) shall verify the material is suitable for use in the specific configuration, environment, and application. The evaluations shall include the combination of pressure, temperature, geometric seal design and its application, and the fluids compatible with the intended application. All sealing devices shall be tested by pressurization in the direction(s) of the seal's intended use and design requirements.

6.5.3.3.2 Required Characteristics for the Apparatus

The testing apparatus shall meet these requirements.

- a) The tested sealing device and the gland, mandrel, and sealing bore surfaces shall be of the identical configuration, dimension, and tolerances as the seal is used in the devices.
- b) When a test fixture is used, it shall be designed to apply the pressures, temperatures, and loads in a manner comparable to that of the production devices.
- c) Testing components/fluids shall be designed to perform the test procedure within the required parameters.
- d) The sealing device design, materials, test results, and all test pressures, test temperatures, and fluid descriptions shall be documented in the test records.

6.5.3.3.3 Test Procedure

The test shall be performed as outlined:

- a) Install the sealing device in the test apparatus following the supplier/manufacturer's procedures. Verify that all equipment and fluids can safely meet the required pressures, temperatures, and accuracy.
- b) Adjust and stabilize the assembled test apparatus to within $^{+10}_0$ % of the sealing device's maximum rated temperature. Adjust and stabilize the differential pressure on the sealing device to $25\% \pm 2\%$ of the maximum rated pressure. Hold and continuously record the temperature and pressure for a minimum of 15 minutes. The pressure and temperature measurement shall remain within the tolerances for a successful test. If there are concerns with low-temperature service, this shall be addressed with a special separate written test procedure.
- c) Repeat Step (b) at $100\% \pm 2\%$ of the maximum rated pressure with all other parameters unchanged.
- d) Release the pressure.
- e) Repeat Step (b) at the maximum rated temperature $^{+10}_0$ % with all other parameters unchanged.
- f) Repeat Step (e) at $100\% \pm 2\%$ of the maximum rated pressure.
- g) Release the pressure.

6.5.3.3.4 Acceptance Criteria

Acceptance criteria are as follows:

- a) The sealing device shall successfully meet the test requirements and remain within the required limits.
- b) A visual inspection of the sealing device following this testing shall confirm that it meets the supplier/manufacturer's written acceptance criteria.

6.5.4 Optional Design Validation Testing

Some applications can require additional design validation testing. These additional design validation tests shall be specified by the user/purchaser in the functional specification (see Clause 5).

7 Supplier/Manufacturer Requirements

7.1 General

Clause 7 contains the detailed requirements to ensure that each device manufactured meets the requirements of the functional specifications in Clause 5 and the technical specifications in Clause 6. As a minimum, each of the topics discussed in 7.2 to 7.10 shall be addressed.

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

7.2 Documentation and Data Control

7.2.1 General

The supplier/manufacturer shall establish and maintain documented procedures to control all documents and data that relate to the requirements, including normative annexes of this specification. These documents and data shall be maintained to demonstrate conformance to specified requirements. All documents and data shall be legible, maintained to prevent damage or loss, and retrievable. 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 and auditable by the user/purchaser.

7.2.2 Documentation Requirements

The supplier/manufacturer shall have available a completed design file containing all the supplier/manufacturer's required design validation testing procedures and design validation grade testing records, with verified acceptance of each. The file shall contain test results and/or calculations that validate the design. The design file and the results of each validation test shall be reviewed and approved by a qualified person other than the originator. This review shall verify that, as a minimum, all of the requirements of this specification have been satisfied.

7.2.3 Documentation Requirements for Specific Device Design Validation Testing

There are four sets of requirements for the documentation of device design validation tests, one for each device design validation grade: V3, V2, V1, and V0. These are identified in Table C.1 and the test requirements. In some cases, the requirements in 7.2 are sufficient. In other cases, special documentation is required and is specified in the appropriate annexes.

Pretest and post-test inspections of critical operational areas as determined by the supplier/manufacturer shall be conducted, documented, and maintained by the supplier/manufacturer.

7.2.4 Devices Tested Prior to Date of Publication of This Specification

The requirements for documentation may be met for flow-control devices that existed before the publication of this specification if the supplier/manufacturer can document that they successfully performed the required tests on these devices to meet the validation testing requirements and that the results of these tests have been approved by a qualified person. If the procedures are not the same as defined in this specification, the supplier/manufacturer shall provide written evidence to ensure that they meet or exceed the requirements of this specification.

7.2.5 Design Documentation

The design validation test results shall be identified with their applicable grade.

All design documents, data, design validation test results, and initial device functional test results in the following list shall be maintained for five years after the date of last manufacture of the device design:

- a) functional and technical specifications;
- b) validation test procedures and results;
- c) supplier/manufacturer's quality manual;
- d) required grade of QC (quality control) documentation as specified in 5.9;
- e) one complete set of drawings, written specifications, and design calculations and standards;
- f) instructions providing methods for the safe installation and use of the flow-control device. This specification shall state the operations that are permitted and those operations that can lead to failure and/or noncompliance with the functional and performance requirements;
- g) material type, yield strength, and connection identification for the actual end connection(s) provided with the flow-control device (where applicable);
- h) welding procedure specification (WPS);
- i) weld procedure qualification record (PQR);
- j) welder/welding operator performance qualification (WPQ).

7.2.6 Device Functional Testing Documentation

7.2.6.1 Test File

The supplier/manufacturer shall have available a complete test file containing all the supplier/manufacturer's required device functional testing procedures and device functional test grade testing records, with verified acceptance of each. The file shall further contain test results and/or calculations that confirm the performance of the device(s) tests.

7.2.6.2 Documentation Requirements for Specific Device Functional Testing

There are four sets of requirements for documentation of device functional tests, one for each device functional testing grade: F3, F2, F1, and F0. These functional testing documentation requirements and the corresponding annexes are identified in Table C.1. The functional test procedures and results shall be traceable to the individual device(s) and shall be maintained for five years after completion of the functional test. (Functional testing to the requirements of F0 shall be performed only on back-check systems that have been validated to V0.)

7.2.7 User/Purchaser Documentation

A device data sheet for each line item on each order shall be supplied upon delivery of the order to the user/purchaser as required in the quality control grade.

Devices with supplemental design features shall be identified as such on the data sheet, in the operator's manual, and in the design documentation.

NOTE The intent of this is to require a separate device data sheet for each unique device or set of devices that is part of a specific design family.

The device sheet shall contain at least the following, as applicable:

- a) name and address of supplier/manufacturer;
- b) supplier/manufacturer assembly number;
- c) supplier/manufacturer device name;
- d) device type;
- e) metallic materials;
- f) nonmetallic materials;
- g) overall length;
- h) temperature range for rated pressure;
- i) rated pressure;
- j) rated temperature;
- k) top connection(s);
- l) conveyance method;
- m) maximum conveyance outside diameter (OD), inclusive of running equipment, as applicable;
- n) retrieval method;
- o) quality control grade;
- p) design validation grade;
- q) device functional testing grade;
- r) technical/operations manual reference number.

7.2.8 Technical/Operations Manual

A technical/operations manual shall be available for devices supplied in accordance with this specification and shall contain:

- a) manual reference number and revision level;
- b) device data sheet;

NOTE An example device data sheet is shown in API 19G4.

- c) operational procedures;

- d) preinstallation inspection procedures;
- e) storage recommendations;
- f) representative drawing showing major dimensions (ODs, IDs, lengths, and SPM seal bore IDs);
- g) special precautions and handling;
- h) list of all devices with which compatibility is claimed for the flow-control device.

7.3 Device Identification Requirements

7.3.1 General

The supplier/manufacturer shall clearly identify and mark each flow-control device according to the requirements of 7.3.2.

7.3.2 Device Identification

Each device furnished to this specification shall be permanently identified using low-stress marking devices, which include interrupted-dot or rounded cold die-stamp, vibratory method, or laser etching. Supplier/manufacturer specifications shall define the method(s) and location of the markings. The following information, as a minimum, shall be marked on each flow-control device:

- a) supplier/manufacturer's name or mark;
- b) date (month and year) of manufacture;
- c) supplier/manufacturer's part number and unique traceable serial number.

7.4 Quality Requirements

7.4.1 General

This specification provides requirements for two quality levels as specified in 7.4.6.

7.4.2 Quality Personnel Qualifications

All personnel performing quality activities shall be qualified in accordance with the supplier/manufacturer's documented requirements.

7.4.3 Manufacturing Nonconformance

The supplier/manufacturer shall establish and maintain documented procedures that comply with API Q1 requirements for control of nonconforming product.

7.4.4 Component Dimensional Examination

Components and assemblies shall be dimensionally inspected to ensure proper function and compliance with design criteria and technical specifications. The frequency of these examinations shall be performed as detailed in the supplier/manufacturer's written requirements.

7.4.5 Traceability

The supplier/manufacturer is responsible for traceability, documentation, and the device condition at time of shipment to the user/purchaser.

All components, weldments, subassemblies, and assemblies of equipment supplied in accordance with this specification shall be traceable to a job lot, for which components and weldments shall also identify the heat(s) or batch lot(s) included. All components and weldments in a multi-heat or batch job lot shall be rejected if any heat or batch does not comply with specified requirements. Individual component identification shall be maintained to facilitate traceability until the supplier/manufacturer's final inspection is completed.

7.4.6 Quality Level Selection

7.4.6.1 General

This specification provides two levels of quality for flow-control devices. The user/purchaser shall specify in the functional specification the level of quality. Each quality level requires appropriate documentation. This specification shall be maintained in manufacturing files or quality files. The documentation of quality shall be presented to the user/purchaser upon request.

Devices shall be supplied to quality level QL2 unless the user/purchaser specifies grade QL1; however, the quality requirements of this specification shall be completed without revision or modification. The user/purchaser may specify additional requirements.

7.4.6.2 Grade QL2—Basic Level of Flow-control Device Quality

The documentation shall include a certificate of conformance for the flow-control devices in the flow-control device job lot.

7.4.6.3 Grade QL1—Highest Level of Flow-control Device Quality

The documentation shall include a certificate of conformance for the flow-control devices in the flow-control device job lot. It shall also contain material test reports (MTRs) for all components, except common hardware items as specified in this subclause. In addition, it shall contain the results of all device functional tests run on this flow-control device job lot.

Examples of common hardware items that may be excluded are:

- roll pins;
- copper gaskets;
- snap rings;
- coating materials;
- valve cores.

7.4.7 Measuring/Testing Equipment

7.4.7.1 General

Measuring and testing equipment shall exceed the measurement accuracy required by the acceptance criteria for that evaluation or test.

7.4.7.2 Calibration

7.4.7.2.1 General

Measuring and testing equipment used for acceptance (including annex acceptance criteria) shall be identified, inspected, calibrated, and adjusted at specific intervals in accordance with documented specifications, ANSI/NCSL Z540.3, and this specification.

7.4.7.2.2 Pressure-measuring Devices

Unless explicitly required, pressure-measuring devices and/or data acquisition systems used for device validation and functional testing shall be calibrated to maintain ± 0.25 % accuracy of full-scale range, or better, as required to perform the specified measurement.

Pressure-measuring devices shall be used only within the calibrated range.

Pressure-measuring devices shall be calibrated with a master pressure-measuring device or a dead weight tester. Calibration intervals for pressure-measuring devices shall be a maximum of three months until a documented calibration history can be established. Calibration intervals shall be established based on repeatability, degree of usage, and documented calibration history.

7.4.8 Elastomeric Materials and Seal Design

7.4.8.1 Inspection Requirements for Packing, O-rings, and Seal Materials

All flow-control device packing, O-rings, and seal materials shall be inspected according to the requirements of 7.4.

7.4.8.2 Elastomeric Materials

Each elastomeric component shall comply with the supplier/manufacturer's written specifications as follows:

- a) Tolerances—The tolerances of O-rings shall be in compliance with SAE AS568 or ISO 3601-1. Other packing elements shall meet the dimensional tolerances of the supplier/manufacturer's written specifications. Minimum sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with ISO 2859-1, General Inspection Level II, at a 2.5 AQL for O-rings and at a 1.5 AQL for other packing elements.

NOTE ISO 2859-1 and ANSI Z1.4 are considered equivalent.

- b) Hardness—The durometer hardness of O-rings shall be measured in accordance with ASTM D2240 or ASTM D1415. The preferred method is to conduct the hardness test on a test specimen from each batch and cure cycle rather than test individual seals. In the event that such tests are conducted on individual seals, sampling procedures for inspection and the basis for acceptance or rejection of a batch lot shall be in accordance with those cited in 7.4 for O-rings or other packing elements.
- c) Visual Inspection—O-rings shall be visually inspected in accordance with SAE-AS-5752 or ISO 3601-3. Other packing elements shall be visually inspected according to the manufacturer's written inspection procedures. The inspection shall include such items as lip damage, flashing, breaks, cracks, or other visible damage.
- d) Handling and Storage—Materials used for sealing devices such as O-rings or other packing elements require written specifications that include handling and storage requirements. These requirements include the shelf life appropriate for each specific material compound.

e) Mechanical Properties—The supplier/manufacturer's documented specifications for each compound shall define those characteristics and limits critical to the performance of the material in the defined application, such as:

- 1) compound type;
- 2) mechanical properties, as a minimum:
 - i) tensile strength (at break);
 - ii) elongation (at break);
 - iii) tensile modulus (at 50 % or 100 %, as applicable).
- 3) compression set;
- 4) specific gravity;
- 5) yield strength (thermoplastics only);
 - i) elongation at yield (thermoplastics only);
 - ii) Young's modulus (thermoplastics only).

7.4.8.3 Other Nonmetallic Materials

Inspection requirements for nonmetals other than elastomers shall comply with the supplier/manufacturer's written specifications.

7.4.8.4 Traceability

Traceability requirements shall be documented by the supplier/manufacturer and shall be sufficient to ensure that all piece parts are manufactured from materials that satisfy the supplier/manufacturer's written specifications. Traceability of piece parts is required until the parts are used in subassemblies or assemblies. The traceability of subassemblies or assemblies is not required for the purposes of this subclause.

7.4.9 Material Certifications

7.4.9.1 Test Certificates

Acceptance of materials shall be indicated in the records traceable to the materials. Raw material used in the manufacture of components shall meet the following requirements:

- a) A certificate of conformance stating that the raw material meets the supplier/manufacturer's documented specifications;
- b) A material test report showing that the supplier/manufacturer can verify that the raw material meets the supplier/manufacturer's documented specifications, including chemistry and physical properties;
- c) A supplier/manufacturer's mill test certificate of the original heat of the metallic material or a supplier/manufacturer's certification of test results are acceptable if the certifications include test results for mechanical properties and chemical composition for that heat of material;