

Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps

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Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps

1 Scope

This standard specifies requirements and gives recommendations for sealing systems for centrifugal and rotary pumps used in the petroleum, natural gas, and chemical industries. See A.1.1 and A.1.2. It is the responsibility of the purchaser or seal vendor to ensure that the selected seal and auxiliaries are suitable for the intended service condition. It is applicable mainly for hazardous, flammable, and/or toxic services where a greater degree of reliability is required for the improvement of equipment availability and the reduction of both emissions to the atmosphere and life-cycle sealing costs. It covers seals for pump shaft diameters from 20 mm (0.75 in.) to 110 mm (4.3 in.).

This standard is also applicable to seal spare parts and can be referred to for the upgrading of existing equipment. A classification system for the seal configurations covered by this standard into categories, types, arrangements, and orientations is provided.

This standard is referenced normatively in API 610. It is applicable to both new and retrofitted pumps and to pumps other than API 610 pumps (e.g. ASME B73.1, ASME B73.2, and API 676 pumps).

This standard might also be referenced by other machinery standards such as other pumps, compressors, and agitators. Users are cautioned that this standard is not specifically written to address all of the potential applications that a purchaser may specify. This is especially true for the size envelope specified for API 682 seals. The purchaser and seal vendor shall mutually agree on the features taken from this standard and used in the application.

2 Normative References

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

API Recommended Practice 520 (all parts), *Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries*

API Standard 526, *Flanged Steel Pressure Relief Valves*

API Standard 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*

API Standard 614 *Lubrication, Shaft-sealing and Control-oil Systems and Auxiliaries for Petroleum, Chemical, and Gas Industry Services*

ASME V¹, *ASME Boiler and Pressure Vessel Code, Section V, Non-destructive Examination*

ASME VIII, *ASME Boiler and Pressure Vessel Code, Section VIII, Rules for the Construction of Pressure vessels*

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

ASME B1.1, *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B1.20.1, *Pipe Threads, General Purpose, Inch*

ASME B16.11, *Forged Fittings, Socket-welding and Threaded*

ASME B16.20, *Metallic Gaskets for Pipe Flanges—Ring Joint, Spiral-wound, and Jacketed*

¹ ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME B31.3, *Process Piping*

ASME B73.1, *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*

ASME B73.2, *Specification for Vertical In-line Centrifugal Pumps for Chemical Process*

ASME PTC 8.2, *Centrifugal Pumps, Performance Test Codes*

AWS D1.1 ², *Structural Welding Code—Steel*

EN 287 (all parts) ³, *Approval testing of welders—fusion welding*

EN 288 (all parts), *Specification and approval of welding procedures for metallic materials*

EN 13445 (all parts), *Unfired pressure vessels*

EPA Method 21 ⁴, Appendix A of Title 40, Part 60 of the U.S. Code of Federal Regulations, *Environmental Protection Agency, United States, Determination of Volatile Organic Compound Leaks*

IEC 60079 (all parts) ⁵, *Electrical apparatus for explosive gas atmospheres*

IEC 60529, *Degrees of protection provided by enclosures (IP code)*

ISO 7 (all parts) ⁶, *Pipe threads where pressure-tight joints are made on the threads*

ISO 261, *ISO general-purpose metric screw threads—General plan*

ISO 262, *ISO general-purpose metric screw threads—Selected sizes for screws, bolts, and nuts*

ISO 286-2, *ISO system of limits and fits—Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

ISO 724, *ISO general-purpose metric screw threads—basic dimensions*

ISO 965 (all parts), *ISO general-purpose metric screw threads—Tolerances*

ISO 7005-1, *Metallic flanges—Part 1: Steel flanges*

ISO 15649, *Petroleum and natural gas industries—Piping*

NEMA 250 ⁷, *Enclosures for Electrical Equipment (1,000 Volts Maximum)*

NFPA 70 ⁸, *National Electrical Code*

Title 1, Part A, Section 112, *U.S. National Emission Standards for Hazardous Air Pollutants (NESHAPs) (Clean Air Act Amendment, Air Pollution Prevention and Control, Air Quality and Emissions Limitations, Hazardous Air Pollutants)*

² American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

³ European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

⁴ U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, Washington, DC 20460, www.epa.gov.

⁵ International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁶ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

⁷ National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.

⁸ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

3 Terms, Definitions, and Symbols

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

3.1 Terms and Definitions

3.1.1

antirotation device

Device used to prevent rotation of one component relative to an adjacent component in a seal assembly.

EXAMPLES Key, pin.

3.1.2

Arrangement 1 seal

See 4.1.4.

3.1.3

Arrangement 2 seal

See 4.1.4.

3.1.4

Arrangement 3 seal

See 4.1.4.

3.1.5

atmospheric leakage collector

External reservoir arranged to capture liquid seal leakage from an Arrangement 1 seal.

3.1.6

auxiliary sleeve

Separate sleeve mounted on the outer diameter of the seal shaft sleeve that facilitates assembly of seal components.

3.1.7

back-to-back configuration

Dual seal in which both of the flexible elements are mounted between the mating rings, the sealed fluid is on the ID of the inner seal, and the barrier or buffer fluid is on the OD of the inner and outer seal.

3.1.8

balanced seal

Mechanical seal in which the fluid closing forces have been modified through seal design.

NOTE In this standard the seal balance ratio is less than 1 (see balance ratio calculation in Annex F).

3.1.9

barrier fluid

Externally supplied fluid at a pressure above the pump seal chamber pressure, introduced into an Arrangement 3 seal to completely isolate the process liquid from the environment.

3.1.10

barrier/buffer seal chamber

Component or aggregate of components that form the cavity into which the outer seal of a pressurized or unpressurized dual seal is installed and in which a barrier or buffer fluid is circulated.

3.1.11**bellows seal**

Type of mechanical seal that uses a flexible metal bellows to provide secondary sealing and spring loading.

3.1.12**buffer fluid**

Externally supplied fluid, at a pressure lower than the pump seal chamber pressure, used as a lubricant and/or to provide a diluent in an Arrangement 2 seal.

3.1.13**cartridge seal**

Completely self-contained unit (including seal/rings, mating ring/s, flexible elements, secondary seal, seal gland plate, and sleeve) that is preassembled and preset before installation.

3.1.14**Category 1 seal**

See 4.1.2.

3.1.15**Category 2 seal**

See 4.1.2.

3.1.16**Category 3 seal**

See 4.1.2.

3.1.17**connection**

Threaded or flanged joint that mates a port to a pipe or to a piece of tubing.

3.1.18**contacting seal**

Seal design in which the mating faces are not designed to intentionally create aerodynamic or hydrodynamic forces to sustain a specific separation gap.

NOTE Contacting seals can actually develop a full fluid film, but this is not typical. Contacting seals do not incorporate geometry (e.g. grooves, pads, face waviness) to ensure that the faces do not touch. The amount of contact is generally very low and permits reliable operation with low leakage.

3.1.19**containment device**

Seal or bushing that is intended to manage leakage from the inner or outer seal and divert it to a location determined by the user.

See Annex F for further description.

3.1.20**containment seal**

Special version of an outer seal used in Arrangement 2 and that normally operates in a vapor (gas buffer or no buffer) but will seal the process fluid for a limited time in the event of an inner seal failure. See 4.1.4.

3.1.21**containment seal chamber**

Component or aggregate of components that form the cavity into which the containment seal is installed.

3.1.22**containment seal chamber leakage collector**

Reservoir connected by pipework to the containment seal chamber for the purpose of collecting condensed leakage from the inner seal of an Arrangement 2.

3.1.23**crystallizing fluid**

Fluid that is in the process of forming solids or that may form solids because of dehydration or chemical reaction and can also be caused by a change of state such as CO₂.

3.1.24**distributed flush system**

Arrangement of holes, passages, baffles, etc. designed to promote an even distribution of flush fluid around the circumference of the seal faces.

NOTE These are normally required when piping plans provide flush into the seal chamber.

3.1.25**drive collar**

External part of the seal cartridge that transmits torque to the seal sleeve and prevents axial movement of the seal sleeve relative to the shaft.

3.1.26**dual mechanical seal**

Arrangement 2 or Arrangement 3 seal of any type.

3.1.27**dynamic sealing pressure rating**

Highest pressure differential that the seal assembly can continuously withstand at the maximum allowable temperature while the shaft is rotating.

NOTE Thereafter, the seal retains its static sealing pressure rating.

3.1.28**dynamic secondary seal**

Secondary seal that is designed to slide or move relative to other components to allow axial movement of the flexible element.

3.1.29**engineered seal**

Mechanical seal for applications with service conditions outside the scope of this standard.

NOTE Engineered seals are not required to meet any of the design or testing requirements of this standard. See 4.1.3 and A.1.2.

3.1.30**external circulating device**

Device located outside of the seal/buffer/barrier chamber to circulate seal chamber fluid through a cooler or through a dual mechanical seal.

3.1.31**face-to-back configuration**

Dual seal in which one mating ring is mounted between the two flexible elements and one flexible element is mounted between the two mating rings and the pump process fluid is on the OD of the inner seal and barrier or buffer fluid is on the ID of the inner seal and OD of the outer seal.

3.1.32**face-to-face configuration**

Dual seal in which both of the mating rings are mounted between the flexible elements.

3.1.33**fixed bushing**

Cylindrical device with a close clearance to the shaft or sleeve that restricts flow between two regions and that does not have a clearance on the outer diameter relative to the housing in which it is mounted.

3.1.34**fixed throttle bushing**

One-piece cylindrical device that is fitted to the stationary part of the containment seal chamber and has a radial clearance to a rotating component; it is used to help isolate one region from another and assist in channeling liquid leakage to an exit port, and the design is intended to maintain a fixed radial clearance over the operating life of the seal, these devices have a low L/D ratio 0.2 or lower.

3.1.35**flashing**

Rapid change in fluid state from liquid to gas.

NOTE In a dynamic seal, this can occur when frictional energy is added to the fluid as it passes between the primary seal faces, or when fluid pressure is reduced below the fluid's vapor pressure because of a pressure drop across the seal faces.

3.1.36**flashing hydrocarbon**

flashing fluid

Liquid hydrocarbon or other fluid with an absolute vapor pressure greater than 0.1 MPa (1 bar) (14.7 psi) at the pumping temperature, or a fluid that will readily boil at ambient conditions.

3.1.37**flexible element**

Combination of elements that accommodate axial movement between rotating and stationary parts.

3.1.38**flexible graphite**

Exfoliated and recompressed graphite material used for static (secondary seal) gaskets in mechanical seal design, from cryogenic to hot service.

3.1.39**floating bushing**

Cylindrical device with a close clearance to the shaft or sleeve that restricts flow between two regions and that has a clearance on the outer diameter relative to the housing in which it is mounted to allow radial motion ("floating") of the bushing should it come in contact with the rotating shaft or sleeve.

3.1.40**fluoroelastomer****FKM**

Saturated polymer in which hydrogen atoms have been replaced with fluorine; it is characterized by excellent hydrocarbon and general chemical resistance.

3.1.41**flush, noun**

Fluid that is introduced into the seal chamber on the process fluid side in close proximity to the seal faces and typically used for cooling and lubricating the seal faces and/or to keep them clean.

3.1.42**gland plate**

gland end plate

Pressure-retaining component(s) similar to a flange, which connects the stationary assembly of a mechanical seal to the seal chamber.

NOTE A gland plate may consist of more than one pressure-containing component, for example the two gland plates often used in a dual seal.

3.1.43**hook sleeve**

Sleeve, with a step or hook at the product end, placed over the shaft to protect it from wear and corrosion.

NOTE The step is usually abutted against the impeller to hold it in place with a gasket between the shaft and the step (hook).

3.1.44**inner seal**

(Arrangement 2 and Arrangement 3) The seal closest to the pump impeller or process fluid.

3.1.45**internal circulating device**

Device located in the seal/buffer/barrier chamber to circulate fluid through a cooler or through a dual mechanical seal.

NOTE There are various designs to achieve radial or axial flow. The internal circulating device can be integral with other seal parts or a separate part. (This device was formerly known as a "pumping ring.")

3.1.46**internally mounted seal**

Seal configuration in which the seal is mounted within the boundaries of the seal chamber or containment seal chamber or gland plate.

3.1.47**leakage concentration**

Measure of the concentration of a volatile organic compound or other regulated emission in the environment immediately surrounding the seal.

3.1.48**leakage rate**

Volume or mass of fluid passing through a seal in a given length of time.

3.1.49**light hydrocarbon**

Hydrocarbon liquid that will readily boil at ambient conditions.

NOTE Typically this definition includes pure and mixed streams of pentane (C₅) and lighter liquids.

3.1.50**mating ring**

Disk- or toroidal-shaped member, mounted either on a sleeve or in a housing such that it does not move axially relative to the sleeve or the housing on or in which it is mounted and that provides the mating seal face for the seal ring face, the mating seal face is perpendicular to the axis of the shaft.

3.1.51**maximum allowable temperature**

Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

NOTE 1 This information is supplied by the seal manufacturer.

NOTE 2 The maximum allowable temperature is usually set by material considerations. This may be the material of the casing or a temperature limit imposed by a gasket or O-ring. The yield strength and ultimate strength are temperature dependent. A component's stress level can depend on operating pressure. Thus, the margin between the strength limit of the material and the operating stress depends on both the material's operating temperature and the component's stress level. If the temperature is lowered, the material's strength increases and the stress level of the component may increase. This is the reason for associating the maximum allowable temperature to the maximum specified operating pressure.

3.1.52

maximum allowable working pressure

MAWP

Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature [cf. **static sealing pressure rating** (3.1.84), **dynamic sealing pressure rating** (3.1.27)].

3.1.53

maximum dynamic sealing pressure

MDSP

Highest pressure expected at the seal (or seals) during any specified operating condition and during start-up and shutdown.

NOTE In determining this pressure, consideration is given to the maximum suction pressure, the flush pressure, and the effect of clearance changes within the pump. This is a process condition and is specified by the purchaser.

3.1.54

maximum operating temperature

Maximum temperature to which the seal (or seals) can be subjected.

NOTE This is a process condition and is specified by the purchaser.

3.1.55

maximum static sealing pressure

MSSP

Highest pressure, excluding pressures encountered during hydrostatic testing, to which the seal (or seals) can be subjected while the pump is shut down.

NOTE This is a process condition and is specified by the purchaser.

3.1.56

noncontacting seal

self-acting seal

Seal design in which the faces are designed to intentionally create aerodynamic or hydrodynamic separating forces to sustain a specific separation gap between the seal ring and the mating ring.

NOTE Noncontacting seals are specifically designed so that there is always an operating gap between the stationary and rotating face.

3.1.57

nonflashing hydrocarbon

nonflashing fluid

Liquid hydrocarbon or other fluid whose vapor pressure at any specified operating temperature is less than an absolute pressure of 0.1 MPa (1 bar) (14.7 psi), or a fluid that will not readily boil at ambient conditions.

3.1.58**nonhydrocarbon service**

Service in which the fluid, such as sour water, boiler feed water, sodium hydroxide, acids, and amines, contains no hydrocarbons or the fluid has relatively small quantities of entrained hydrocarbons.

3.1.59**observed test**

Product test that is observed at the discretion of the purchaser, who has been given notice of the test by the manufacturer, but does not constitute a manufacturing hold point.

3.1.60**orifice nipple**

Pipe nipple made of solid bar stock with an orifice hole drilled through it to restrict leakage in the event of an auxiliary system pipe or component failure.

NOTE Orifice nipples are commonly found on Piping Plan 11 systems.

3.1.61**O-ring**

Elastomeric sealing ring with an O-shaped (circular) cross-section, which may be used as either a static or dynamic secondary seal.

3.1.62**outer seal**

(Arrangement 2 and Arrangement 3) The seal located farthest from the pump impeller or process fluid.

3.1.63**perfluoroelastomer****FFKM**

Fully fluorinated fluorocarbon elastomer commonly used as a secondary seal in high-temperature and/or corrosive service.

3.1.64**piping plan**

Configuration of accessories, instruments, controls, and/or fluids designed to manage or control the environment around the seal.

NOTE Auxiliary piping plans vary with the application, seal type, and arrangement.

3.1.65**polymerizing fluid**

Fluid that is in the process of changing, or is capable of changing, from one chemical composition to another with longer-chain components and different properties, usually becoming significantly more viscous and/or tacky.

3.1.66**port**

Fluid passageway, typically located in the gland plate.

3.1.67**pressure casing**

Composite of all the stationary pressure-containing parts of the seal, including seal chamber barrier or buffer fluid chamber, containment seal chamber, and seal gland plate, and excluding seal ring, mating ring, bellows, sleeves, miscellaneous internal seal parts, and atmospheric side gland connections, which cannot be isolated from atmospheric pressure.

NOTE The MAWP of the auxiliary system is specified in Section 8.

3.1.68**product temperature margin**

Difference between the vaporization temperature of the fluid at the seal chamber pressure and the actual temperature of the fluid.

NOTE For pure fluids, the vaporization temperature is the saturation temperature at seal chamber pressure; for mixed fluids, the vaporization temperature is the bubble point temperature at the seal chamber pressure.

3.1.69**pump manufacturer**

Agency that designs, manufactures, tests, and provides service support for the pump.

NOTE The pump manufacturer may also purchase the sealing system and perform the installation.

3.1.70**pumped fluid**

process fluid

The process stream designated in the datasheet for the pump service.

3.1.71**purchaser**

Agency that issues the order and specifications to the vendor.

3.1.72**pusher seal**

Seal that incorporates a dynamic secondary seal to allow axial movement of the flexible element; the axial movement is driven (pushed) by mechanical and/or hydraulic force.

3.1.73**quench**, noun

Neutral fluid, usually water, steam, or nitrogen, introduced on the atmospheric side of the seal to retard formation of solids that may interfere with seal movement, or for other purposes such as prevention of coking, crystallization, or icing.

3.1.74**seal**

end face mechanical seal

Device that prevents the leakage of fluids between a shaft and housing in relative motion.

NOTE Sealing is accomplished by a stationary seal face bearing against a rotating seal face; the sealing faces are mounted perpendicular to the shaft axis.

3.1.75**seal balance ratio**

Ratio of seal face area exposed to closing force by hydraulic differential pressure across the seal face to the total seal face area (see Annex F).

NOTE It is sometimes expressed as a percentage.

3.1.76**seal chamber**

Component, either integral with or separate from the pump case (housing), which forms the region between the shaft and casing into which the seal is installed.

3.1.77**seal face**

seal faces

The lapped surface of a mating ring or seal ring that comes in contact or close proximity to the other ring and provides the relative rotary motion sealing surface(s).

3.1.78**seal manufacturer**

Agency that designs, manufactures, tests, and provides service support for seals and associated support sealing systems.

3.1.79**seal ring**

Disk- or toroidal-shaped member, mounted either on a sleeve or in a housing such that it is able to move axially relative to the sleeve or the housing on or in which it is mounted and that provides the mating seal face for the mating ring face, the seal ring face is perpendicular to the axis of the shaft.

3.1.80**seal sleeve**

Hollow cylindrical component that fits on the outer diameter of the shaft with a close tolerance fit, incorporates a static secondary seal with the shaft and extends beyond the seal gland plate, it is used in the assembly of the seal components and ensures they rotate with the shaft.

3.1.81**secondary seal**

Device (such as an O-ring, flexible graphite ring, flexible graphite filled spiral wound gasket, or bellows) that prevents leakage of the sealed fluid, barrier fluid, buffer fluid, or quench medium through paths other than the inner or outer seal faces, the containment device, or designated drain.

3.1.82**segmented floating bushing**

Throat or throttle bushing that is composed of circumferential segments retained by a tensioning device.

3.1.83**service condition**

Maximum or minimum temperature or pressure under static or dynamic conditions.

3.1.84**static sealing pressure rating**

Highest pressure that the seal can continuously withstand at the maximum allowable temperature while the shaft is not rotating.

NOTE Thereafter, the seal maintains its dynamic sealing pressure rating.

3.1.85**static secondary seal**

Secondary seal between two surfaces that have no relative motion.

3.1.86**strainer**

A relatively low pressure drop device designed to remove solid particles from the flush or other fluid.

3.1.87**throat bushing**

Device that forms a restrictive close clearance around the sleeve (or shaft) between the seal chamber and the impeller.

**3.1.88
throttle bushing**

Containment device that forms a restrictively close clearance around the sleeve at the atmospheric end of a gland plate.

**3.1.89
total indicator reading**

total indicated runout

TIR

Difference between the maximum and minimum readings of a dial indicator or similar device when monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

NOTE For a perfectly cylindrical surface, the indicator reading implies an eccentricity equal to half the reading. For a perfectly flat face, the indicator reading gives an out-of-squareness equal to the reading. If the diameter in question is not perfectly cylindrical or flat, interpretation of the meaning of TIR is more complex, and may represent ovality or lobing.

**3.1.90
Type A seal**

See 4.1.3.

**3.1.91
Type B seal**

See 4.1.3.

**3.1.92
Type C seal**

See 4.1.3.

**3.1.93
vendor**

Manufacturer of the equipment, or his/her agent, normally responsible for service support.

NOTE This standard addresses the responsibilities between two parties, defined as the purchaser and the vendor. There are many parties that are involved in the purchase and manufacture of the equipment. These parties are given different titles depending on their order in the chain. They may be called buyer, contractor, manufacturer, or subvendor. For example, the party supplying a lubricating oil console may be the console vendor of the compressor manufacturer, the subvendor of the purchaser, and the purchaser of components within the console. All of these terms, however, can be reduced to the purchaser and vendor. It is for this reason that only these two terms are defined. Attempts to define these other terms would only cause confusion.

**3.1.94
volatile hazardous air pollutant
VHAP**

Any compound as defined by Title 1, Part A, Section 112 of the *U.S. National Emission Standards for Hazardous Air Pollutants (NESHAPs) (Clean Air Act Amendment)*.

**3.1.95
witnessed inspection**

witnessed test

Inspection or test for which the purchaser is notified of the timing and a hold is placed on production until the purchaser or his/her representative is in attendance.

3.2 Symbols

For the purposes of this document, the following symbols apply.

A the area of the seal face, expressed in square millimeters

F_O	the opening force, expressed in Newtons
f	the effective coefficient of friction
K	the pressure drop coefficient, dimensionless
$V\%_{AB}$	volume percentage of component A in mixture B
Δp	the differential pressure, expressed in megapascals
ρ_A	density (specific gravity) of fluid A
ρ_B	density (specific gravity) of fluid B
ω_{AB}	mass percentage of component A in mixture B

4 Sealing Systems

4.1 Seal Categories, Types, and Arrangements

4.1.1 General

The seal configurations covered by this standard can be classified into three categories (1, 2, and 3), three types (A, B, and C) and three arrangements (1, 2, and 3). Further, Arrangement 2 and 3 seals can be in three orientations: “face-to-back,” “back-to-back,” and “face-to-face.” These categories, types, arrangements, and orientations are defined below.

See Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, and Figure 9 for typical representations.

4.1.2 Seal Categories

There are three seal categories, as follows.

- *Category 1* seals are intended for use in non-API 610 pump seal chambers, meeting the dimensional requirements of ASME B73.1, and ASME B73.2 seal chamber dimensions and their application is limited to seal chamber temperatures from $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $260\text{ }^{\circ}\text{C}$ ($500\text{ }^{\circ}\text{F}$) and gauge pressures up to 2 MPa (20 bar) (300 psi).
- *Category 2* seals are intended for use in seal chambers meeting the chamber envelope dimensional requirements of API 610. Their application is limited to seal chamber temperatures from $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $400\text{ }^{\circ}\text{C}$ ($750\text{ }^{\circ}\text{F}$) and gauge pressures up to 4 MPa (40 bar) (600 psi).
- *Category 3* provides the most rigorously tested and documented seal design. They meet the seal chamber envelope requirements of API 610 (or equal). Their application is limited to seal chamber temperatures from $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $400\text{ }^{\circ}\text{C}$ ($750\text{ }^{\circ}\text{F}$) and gauge pressures up to 4 MPa (40 bar) (600 psi).

A summary of the main differences in seal categories is given in Annex A.

Temperatures and pressures outside the ranges of these categories, or which involve fluids not included in Annex A, may require engineering and seal selection guidance other than provided in this standard.

4.1.3 Seal Types

There are three seal types, as follows.

- *Type A* seal is a balanced, internally-mounted, cartridge design, pusher seal with multiple springs. Secondary sealing elements are elastomeric O-rings.

Materials are specified in Section 6. Guidance on equivalent materials standards is given in Annex B. Figure 7 depicts a Type A seal.

- *Type B* seal is a balanced, internally-mounted, cartridge design (metal bellows) seal. Secondary sealing elements are elastomeric O-rings.

Materials are specified in Section 6. Guidance on equivalent materials standards is given in Annex B. Figure 8 depicts a Type B seal. A metal bellows seal offers the advantage of having only static secondary seals. It may be specified instead of the default Type A seal for low-temperature service.

- *Type C* seal is a balanced, internally-mounted, cartridge design (metal bellows) seal. Secondary sealing elements are flexible graphite.

Materials are specified in Section 6. Guidance on equivalent materials standards is given in Annex B. Figure 9 depicts a Type C seal. Bellows seals are inherently balanced. Stationary metal bellows seals are the primary choice for high-temperature Arrangement 1 seals.

Type A and Type B seals are suitable for temperatures up to 176 °C (350 °F). Type C seals are for high temperatures up to 400 °C (750 °F). Seals outside the scope of Type A, B, and C are termed engineered seals and referred to as ES.

NOTE For Seal Arrangement 2 and Arrangement 3 the seal types can be mixed across configurations.

4.1.4 Seal Arrangements

4.1.4.1 Arrangement 1, 2, and 3 Seals

There are three seal arrangements, as follows.

- *Arrangement 1*—Seal configurations having one seal per cartridge assembly.
- *Arrangement 2*—Seal configuration having two seals per cartridge assembly, with the space between the seals at a pressure less than the seal chamber pressure.
- *Arrangement 3*—Seal configurations having two seals per cartridge assembly, utilizing an externally supplied barrier fluid at a pressure greater than the seal chamber pressure.

NOTE 1 The principal difference between Arrangement 2 and Arrangement 3 configurations is the concept of containment of leakage versus the elimination of process fluid leakage. Refer to the associated definitions and Annex G piping plan descriptions.

NOTE 2 In Arrangement 2, the outer seal can be a wet seal or a dry-running seal. The inner seal utilizes a piping plan typical of Arrangement 1 seals. If the outer seal is a wet seal design, an unpressurized liquid buffer fluid is supplied to the outer seal chamber. If the outer seal is a dry-running seal it is defined as a containment seal (3.1.20); a gas buffer may be used.

4.1.4.2 Alternate Technology Designs and Sealing Methods

Alternative technology designs and sealing methods are also considered, as follows.

- *Contacting wet (CW) seals*—Seal design where the seal faces are not designed to intentionally create aerodynamic or hydrodynamic forces to sustain a specific separation gap (refer to 3.1.18).
- *Noncontacting (NC) seals (whether wet or dry)*—Seal design where the seal faces are designed to intentionally create aerodynamic or hydrodynamic separating forces to sustain a specific separation gap (refer to 3.1.56).
- *Containment seals (CS), whether contacting or noncontacting*—Seal design with one flexible element, seal ring and mating ring mounted in the containment seal chamber (refer to 3.1.20).

Figure 1 places all these concepts in one diagram, providing a comprehensive way to look at their interrelationships.

4.1.5 Seal Configurations

Arrangement 2 and Arrangement 3 seals can be in the following three configurations:

- face-to-back: refer to 3.1.31;
- back-to-back: refer to 3.1.7;
- face-to-face: refer to 3.1.32;

Refer to Figure 1.

Other configuration such as concentric seals may be agreed by the purchaser and vendor and are considered an engineered seal.

4.2 Objectives

Shaft sealing systems conforming to this standard are intended to meet the following objectives:

- a) all seals should operate continuously for 25,000 h without need for replacement;
- b) Arrangement 2 outer seals should operate for at least 25,000 h without need for replacement (wet or dry seals) at any containment seal chamber or buffer fluid chamber pressure equal to or less than the seal leakage pressure switch setting [not to exceed a gauge pressure of 0.07 MPa (0.7 bar) (10 psi)] and for at least 8 h at the seal chamber conditions;
- c) all seals should operate for 25,000 h without need for replacement while either complying with local emissions regulations, or exhibiting a maximum screening value of 1,000 ml/m³ (1,000 ppm vol) as measured by the EPA Method 21, whichever is more stringent.

4.3 Specifying and/or Purchasing a Sealing System

The datasheet (Annex C) shall be used to convey purchasing requirements. Default requirements are identified therein that allow the purchaser to specify a seal with minimum information. The minimum data required on the datasheet to obtain budgetary pricing on a sealing system is expressed in the seal code. Typical seal codes that can be used are given in Annex D. This assumes all standard defaults (construction features and materials). The minimum information required on the datasheet to purchase a seal with assurance that the selection will satisfy the objectives of 4.2 is the pump data, fluid data, and seal specification.

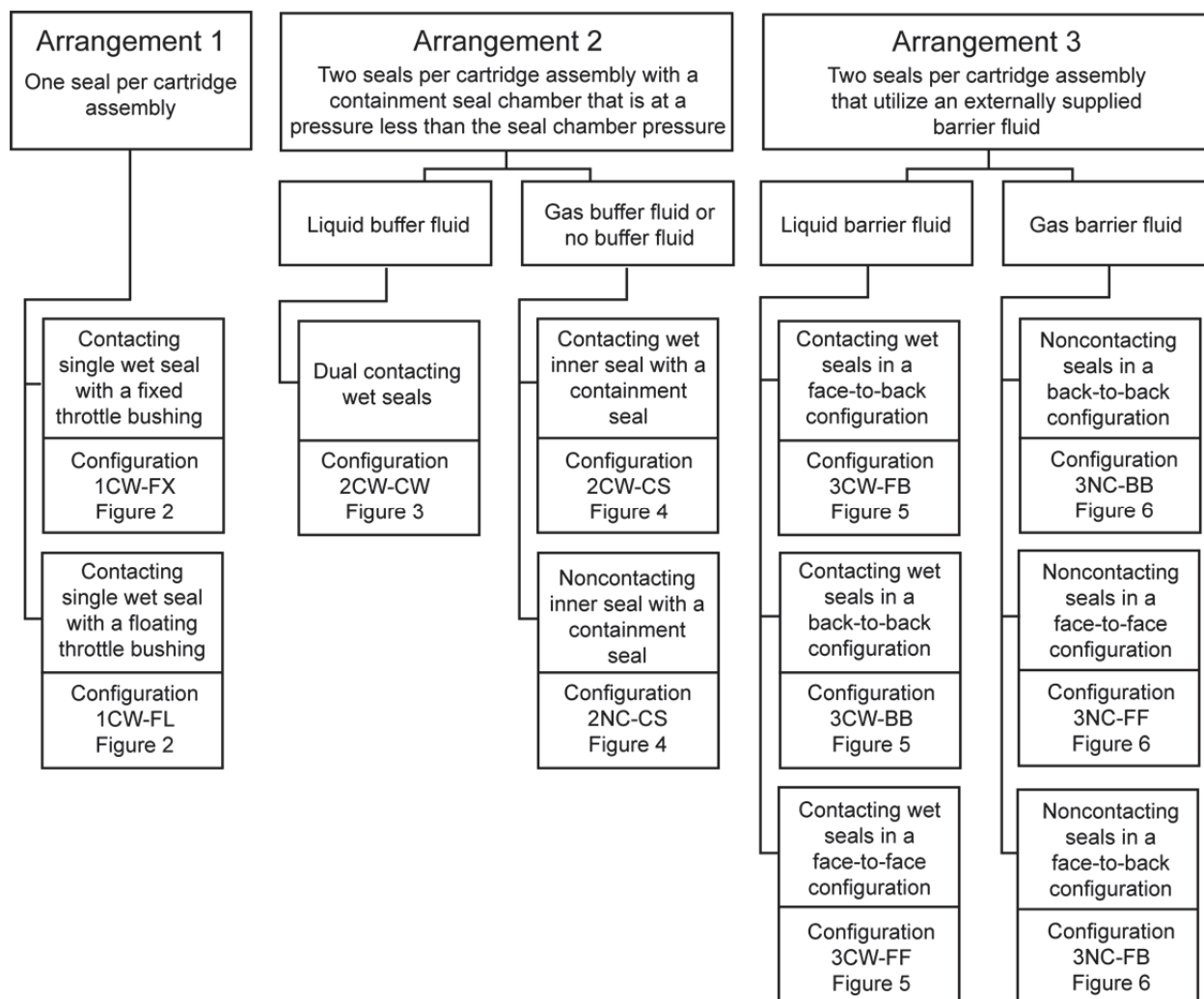
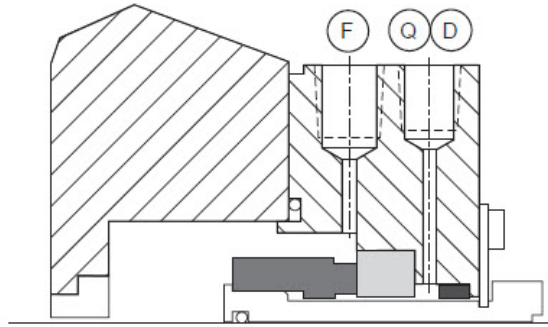
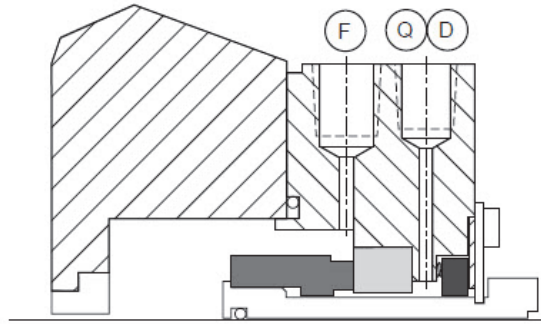


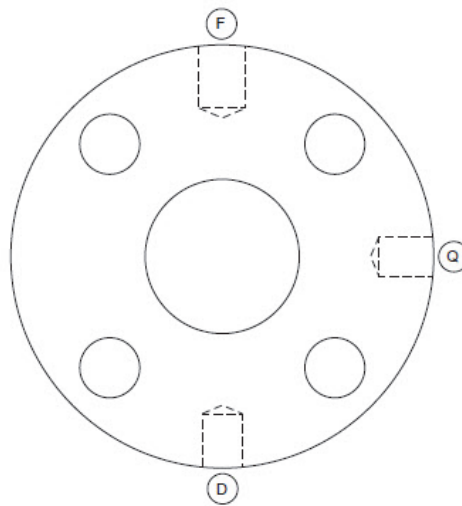
Figure 1—Seal Configurations



a) 1CW-FX, Contacting Single Wet Seal with a Fixed Throttle Bushing



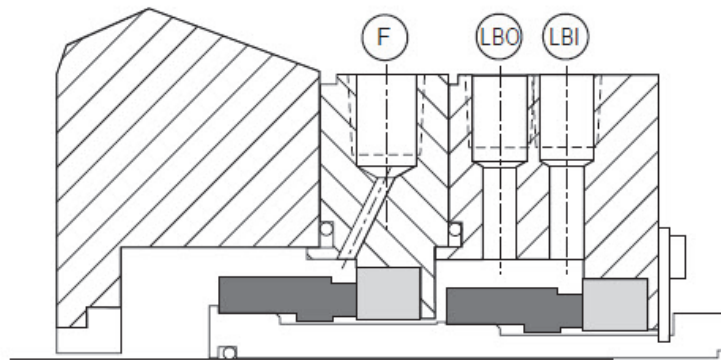
b) 1CW-FL, Contacting Single Wet Seal with a Floating Throttle Bushing



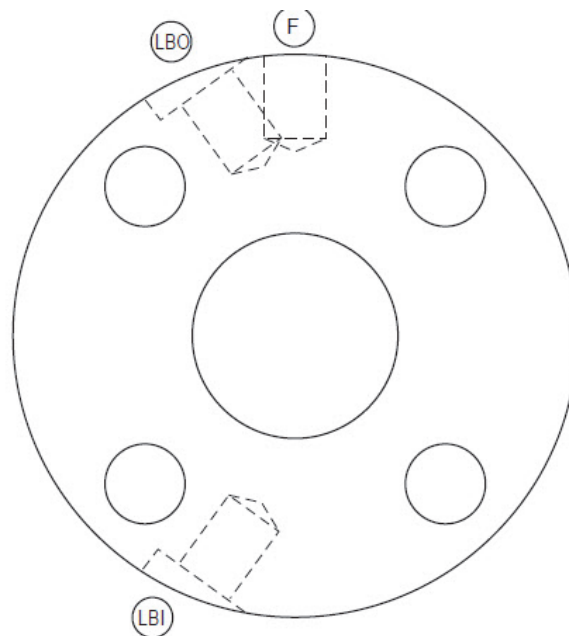
c) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

Figure 2—Arrangement 1: One Seal per Cartridge Assembly



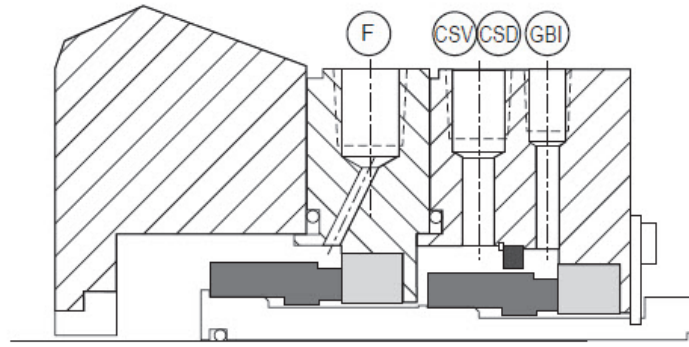
a) 2CW-CW, Dual Contacting Wet Seal



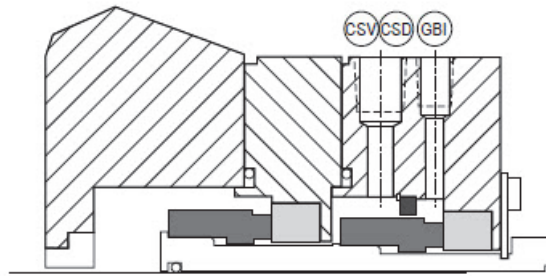
b) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

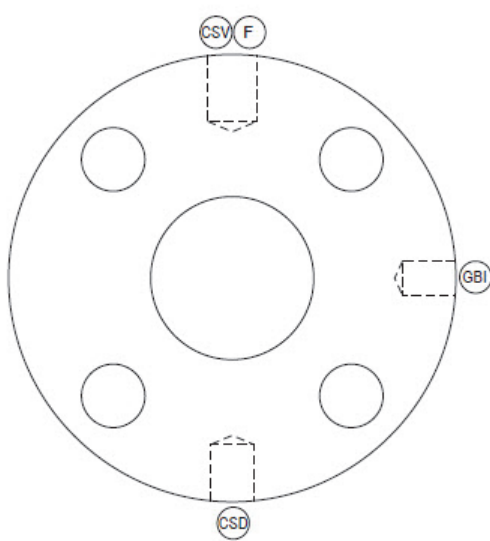
Figure 3—Arrangement 2: Two Seals per Cartridge Assembly with a Liquid Buffer Fluid



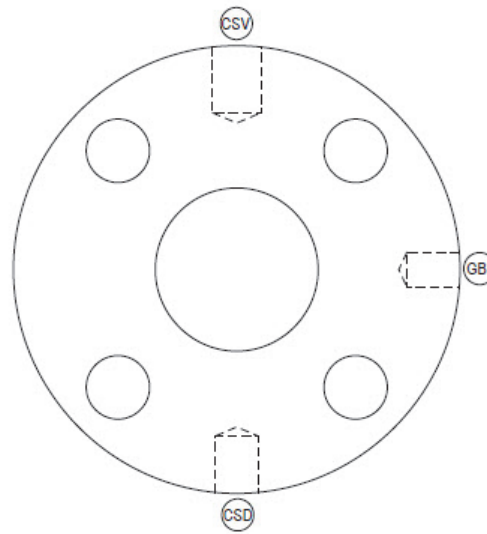
a) 2CW-CS, Contacting Wet Inner Seal with a Containment Seal



b) 2NC-CS, Noncontacting Inner Seal with a Containment Seal



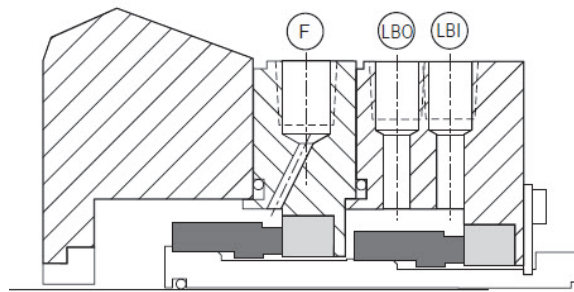
c) Typical Gland Plate Connection Orientation for 2CW-CS



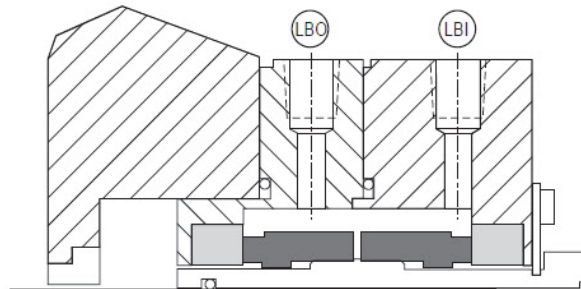
d) Typical Gland Plate Connection Orientation for 2NC-CS

NOTE For connection designations, see Table 2.

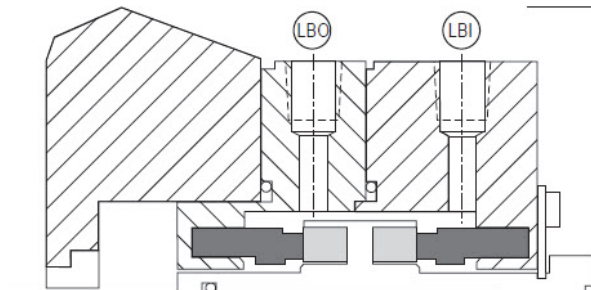
Figure 4—Arrangement 2: Two Seals per Cartridge Assembly with or Without a Gas Buffer Fluid



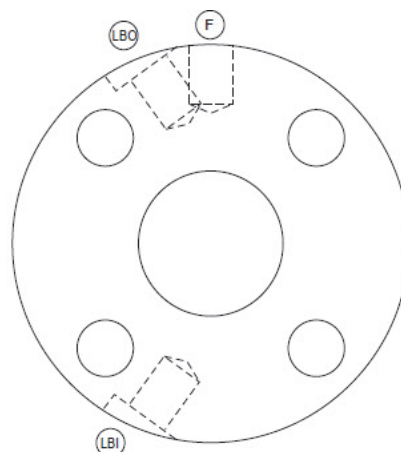
a) 3CW-FB, Contacting Wet Seals in a Face-to-Back Configuration



b) 3CW-BB, Contacting Wet Seals in a Back-to-Back Configuration



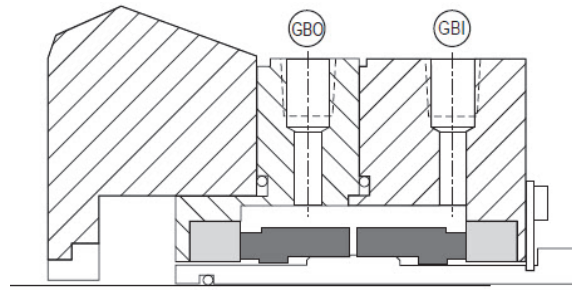
c) 3CW-FF, Contacting Wet Seals in a Face-to-Face Configuration



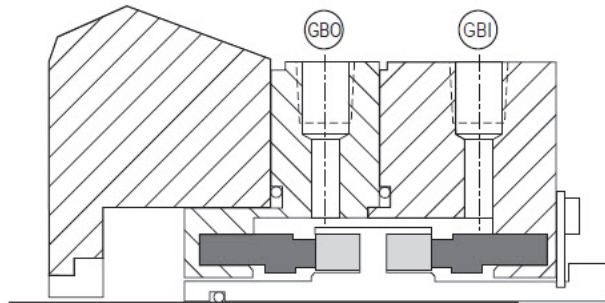
d) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

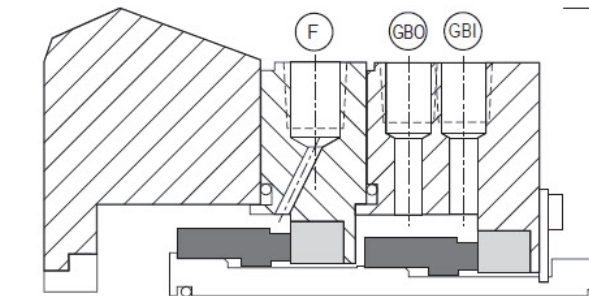
Figure 5—Arrangement 3: Two Seals per Cartridge Assembly with a Liquid Barrier Fluid



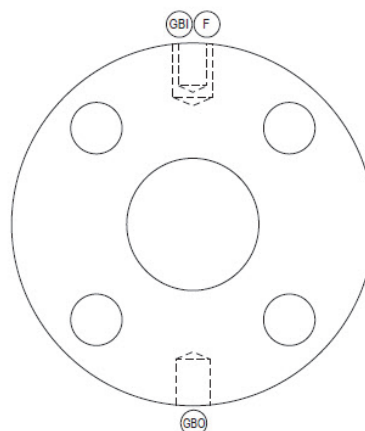
a) 3NC-BB, Noncontacting Seals in a Back-to-Back Configuration



b) 3NC-FF, Noncontacting Seals in a Face-to-Face Configuration



c) 3NC-FB, Noncontacting Seals in a Face-to-Back Configuration



d) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

Figure 6—Arrangement 3: Two Seals per Cartridge Assembly with a Gas Barrier Fluid

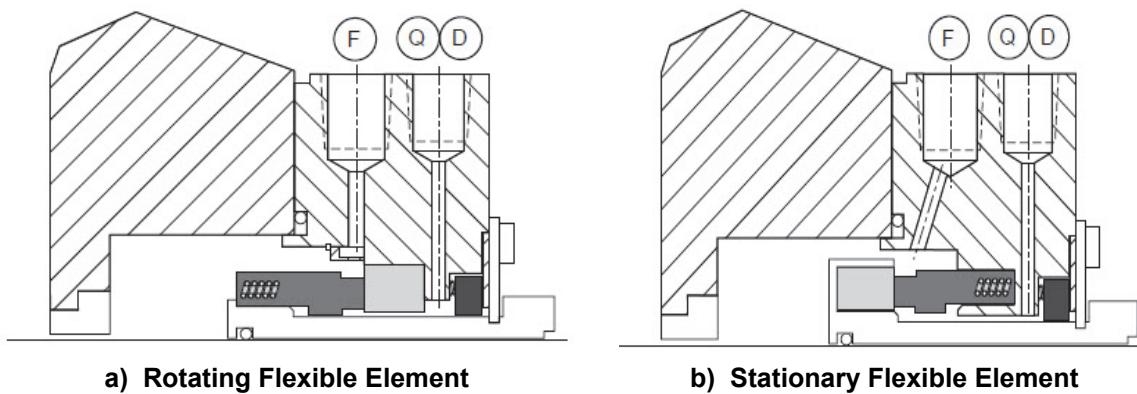


Figure 7—Arrangement 1 Type A Seals

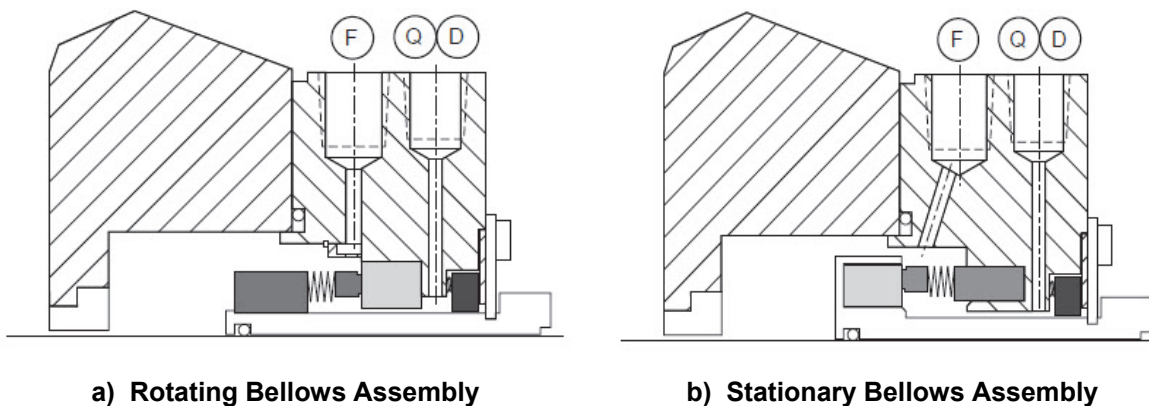


Figure 8—Arrangement 1 Type B Seals

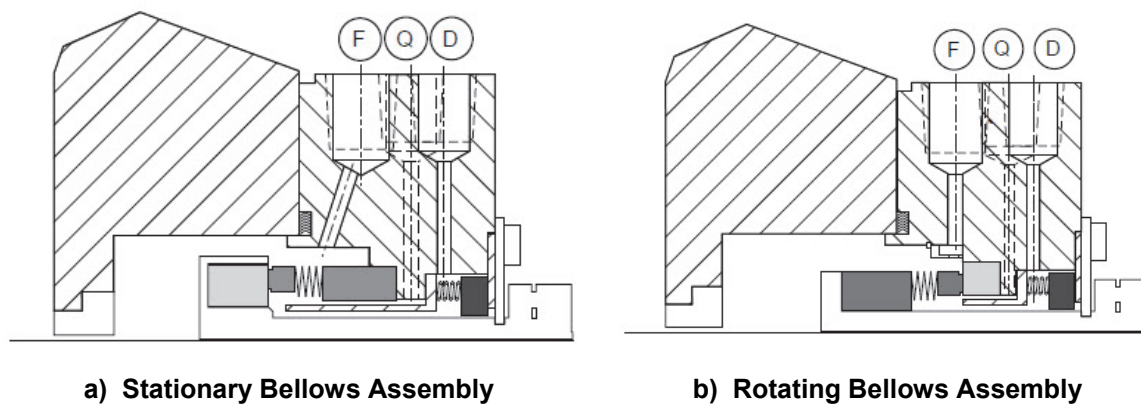


Figure 9—Arrangement 1 Type C Seals

5 General

5.1 Unit Responsibility

Unless otherwise specified, the pump vendor shall have unit responsibility for the seal system if the seal system is purchased as part of a pump system. If not purchased as part of a pump system, the seal vendor shall have unit responsibility for the seal system. The vendor who has unit responsibility shall ensure that all subvendors comply with the requirements of this standard. Annex E specifies the interface responsibilities of the pump and seal vendors.

5.2 Dimensions

- The purchaser shall specify whether data, drawings, hardware (including fasteners), and equipment supplied to this standard shall use SI units (or U.S. Customary units).

6 Design Requirements

6.1 Common Design Requirements (All Categories)

6.1.1 General Information

6.1.1.1 All mechanical seals, regardless of type or arrangement, shall be of the cartridge design, without hook sleeves.

API 610 requires that pumps be designed to enable seal removal without disturbing the driver. If pumps are being retrofitted that are not back-pullout design, it should be verified that adequate shaft end spacing exists by comparing the seal cartridge length to the distance between shaft ends.

- **6.1.1.2** Unless otherwise specified the flexible element shall be rotating for Type A and Type B seals. If specified, or if recommended by the seal manufacturer and agreed by the purchaser, a stationary flexible element shall be supplied for Type A or Type B seals.

NOTE Within the scope of this standard, rotating and stationary flexible elements are considered to be technically equivalent, but the optimum choice is influenced by many different factors. The default for rotating or stationary elements for different seal types and their arrangements have been based on installed population and reliable operation.

There are a number of factors related to the design, manufacture, installation, and repair of the equipment that should be considered when making the selection of a rotating or stationary flexible element. The relative merits of rotary and stationary flexible element seals and the factors influencing the choice are addressed in other subsections in this section and F.5.

- **6.1.1.3** Unless otherwise specified the flexible element shall be stationary for Type C seals. If specified or if recommended by the seal manufacturer and agreed by the purchaser a rotating flexible element shall be used for Type C seals.

NOTE See NOTE in 6.1.1.2.

6.1.1.4 The cartridge seal shall incorporate a setting device (such as setting plates) that is sufficiently robust to enable the assembly to be pushed or pulled during installation, rotor adjustment, or disassembly without transferring radial or axial load to the seal faces.

6.1.1.5 A stationary flexible-element seal shall be provided if seal-face surface speed at the mean diameter of the seal face exceeds 23 m/s (4500 ft/min).

NOTE As speed increases, the flexible element of a rotating seal flexes at a correspondingly faster rate to keep the seal faces closed. At very high speeds (and for large seal sizes), the forces required to keep the faces closed become so large that they negatively affect the seal life.

Consideration should be given for requiring a stationary flexible element if:

- a) balance diameter exceeds 115 mm (4.5 in.) (see 6.1.1.7);
- b) pump case or gland plate distortion and misalignment exist due to pipe loads, thermal distortion, pressure distortion, etc.;
- c) the perpendicularity of the seal chamber mounting surface to the shaft is a problem, aggravated by high rotational speed; or
- d) the seal chamber face runout requirements described in 6.1.2.13 cannot be met (as found in ASME B73.1 and ASME B73.2 pumps and with some slender-shaft, multistage pump designs).

6.1.1.6 This standard does not cover the design of the component parts of mechanical seals; however, the design and materials of the component parts shall be suitable for the specified service conditions. The maximum allowable working pressure (MAWP) shall apply to all parts referred to in the definition of pressure casing.

NOTE It is not normal practice for seals to be rated for the MAWP for the pump in which they are installed.

6.1.1.7 The seal manufacturer shall design the seal faces and seal balance ratio to minimize seal-face-generated heat consistent with optimum life expectations in 4.2 and emissions limit requirements. Balance diameter varies with seal design, but for spring pusher seals it is normally the diameter of the sliding contact surface of the dynamic O-ring. For the inner seal of a dual seal the sliding surface can vary depending on whether the pressure is internal or external. For welded metal bellows-type seals, the balance diameter is normally the mean diameter of the bellows, but this will vary with pressure. Contact the seal vendor for determination of the balance diameter under varying pressure conditions.

NOTE 1 Temperature of the environment around the seal as influenced by seal face generated heat and heat soak will have an impact on seal performance. Refer to F.2.1 and F.2.2 for discussion of seal balance diameter, seal generated heat, and heat soak.

NOTE 2 Starting torque and seal power can be significant issues for small pump drivers, seals at or above the balance diameter and pressure boundaries of this standard, and for Arrangement 3 seals.

6.1.1.8 The seal supplied shall be capable of handling normal and transient differential axial movement between the rotor and stator.

NOTE Maximum axial movement is of particular concern in hot multistage pumps. During start-up conditions, it is not unusual for a large amount of differential thermal growth to occur between the shaft and casing. This differential can exceed the capabilities of some seals. Appropriate warm-up procedures can minimize this problem. Axial movement is also a concern in some vertical pump designs that rely on the motor bearing for thrust positioning (i.e. in-line pumps without pump bearing housings and vertical can pumps). In certain conditions, process pressure can result in an upward thrust. Shaft axial movement is only limited by motor-bearing axial float in these cases.

6.1.1.9 Unless otherwise specified, O-ring sealing surfaces, including all grooves and bores, shall have a maximum surface roughness (Ra) of 1.6 μm (63 $\mu\text{in.}$) for static O-rings. The surface against which dynamic O-ring slide shall have a maximum surface roughness of 0.8 μm (32 $\mu\text{in.}$).

Seal to pump interface sealing diameters shall have a minimum 3 mm (0.12 in.) radius or a minimum 1.5 mm (0.06 in.) chamfered lead-in for static O-rings. Chamfers shall have an angle of between 15° and 30°.

Chamfers or radii internal to the cartridge seal shall be adequate to prevent O-ring damage during assembly and shall be identical to the specification used in the qualification test.

NOTE Lead-in chamfers internal to the cartridge seal can vary from the values specified in this section.

6.1.1.10 O-ring grooves shall be sized to accommodate perfluoroelastomer (FFKM) O-rings.

NOTE 1 Some FFKMs have a greater thermal expansion than most other O-ring materials, such as fluoroelastomer (FKM). Installing a FFKM in a groove designed for FKM can lead to damage to the O-ring. On the other hand, FKM O-rings function properly in the larger FFKM grooves. Choosing the wider groove as a standard eliminates this potential cause of O-ring failure and reduces the number of necessary spares.

NOTE 2 The thermal expansion damage in FFKM O-rings is often confused with damage due to chemical-induced swelling of the O-rings and vice versa.

6.1.1.11 For services where the seal chamber pressure can be below atmospheric or for Arrangement 3 inner seal, all seal components shall be designed with a means of retaining the sealing components to prevent them from being dislodged by atmospheric or barrier pressure (see Figure 10 for examples of such designs). The seal design shall be adequate to seal under vacuum conditions when the pump is not operating (see 6.1.2.14.1 for recommended operating conditions).

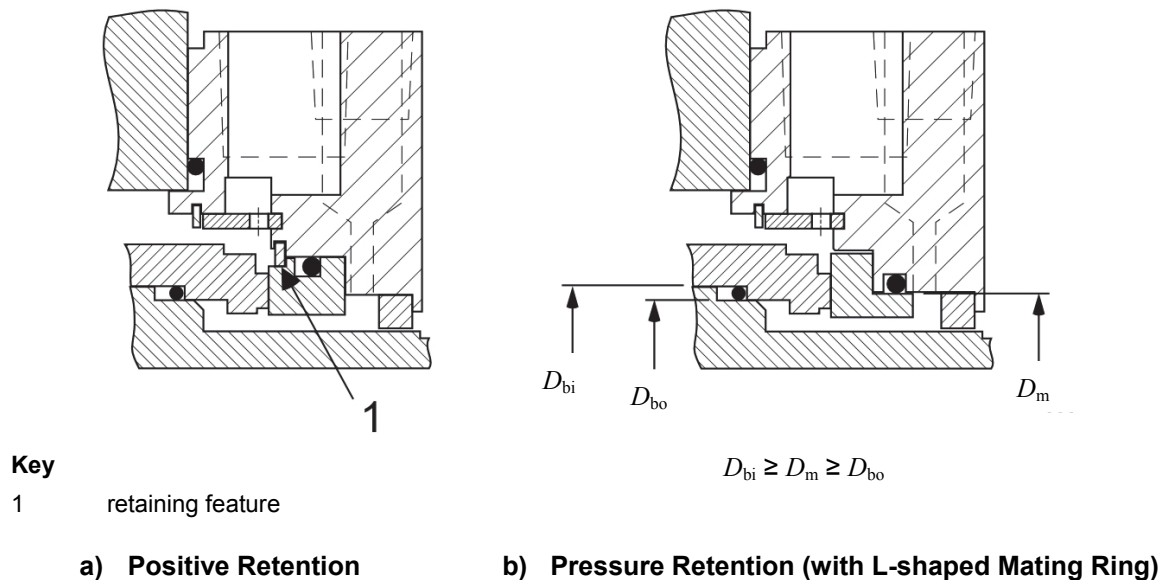


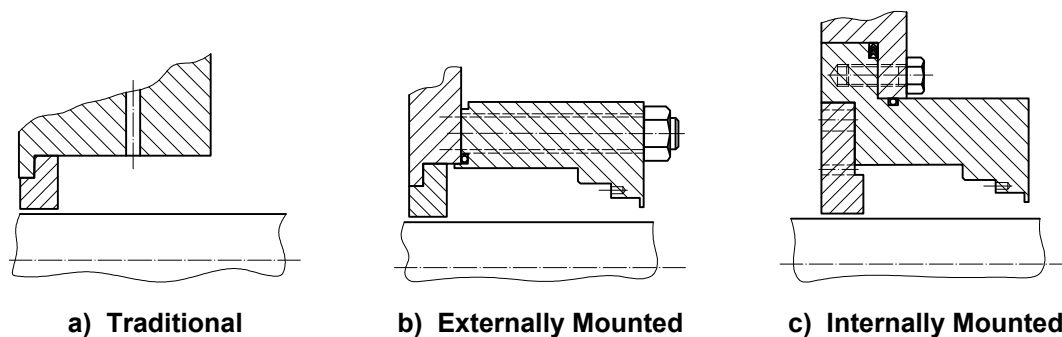
Figure 10—Retention of Seal Components in Vacuum Services and Arrangement 3 Inner Seal

6.1.2 Seal Chamber and Gland Plate

6.1.2.1 Gland plates shall be provided by the seal manufacturer.

6.1.2.2 Unless otherwise specified, seal chambers shall be provided by the pump manufacturer.

6.1.2.3 Seal chambers are one of three types: traditional, externally mounted, or internally mounted. Seal chambers are not required to accommodate packing. Figure 11 shows the three types of seal chamber.



NOTE Type B, the externally mounted seal chamber, offers the most flexibility in terms of its ability to accommodate Arrangement 2 and 3 seals. The seal chamber can be optimized for the axial placement of flush, barrier, and buffer porting facilitating unrestricted flow paths.

Figure 11—Seal Chamber Types

6.1.2.4 The default seal chamber is the traditional type (cylindrical chamber, integral to the casing of the pump) supplied by the pump manufacturer.

Category 1 seals shall be designed to fit into the dimensional envelope defined by ASME B73.1 and ASME B73.2.

Category 2 and Category 3 seals shall be designed to fit into the dimensional envelope of API 610.

Seal chamber designs that utilize all the design features of this standard should result in improved reliability and general standardization of components. Reduced seal radial clearance requires the user to address piping plans and construction requirements for noncompliant seals.

The reliability of a mechanical seal is affected by the radial clearance between its rotating parts and the seal chamber bore. Meeting the minimum radial clearance requirements of this standard is particularly important when sealing difficult services, such as those with significant solids content or those that can result in excessive seal face temperature. Alternative seal chamber designs used in some chemical industry pumps, such as large-bore or tapered seal chambers with flow modifiers, may eliminate the need for a flush or enhance performance based on design of the chamber.

It is expected that the majority of Category 1 seals will be applied to ASME B73.1 and ASME B73.2 pumps, and the majority of Category 2 and Category 3 seals will be installed in API 610 applications. However, there is a recognized possibility that Category 1 seals may be installed in API 610 applications, and Category 2 and Category 3 seals, in certain configurations, may be installed in ASME B73.1 and ASME B73.2 pumps. Careful consideration should be given to correctly applying seal categories into pump types or services for which they are not intended.

- **6.1.2.5** If specified, an internally mounted or externally mounted bolt-on seal chamber shall be provided by the seal manufacturer (Figure 11).

6.1.2.6 The minimum diametral clearance between rotary and stationary components shall be sufficient to prevent contact between parts in relative motion and shall conform to the values in this section and Table 1.

- a) For contacting seals, the minimum diametral clearance between the rotating components of the seal and the stationary surfaces of the seal chamber and gland plate shall be 6 mm ($\frac{1}{4}$ in.) in order to promote fluid circulation and cooling around the seal faces.
- b) For Arrangement 2 or 3 seals where the inner seal is a noncontacting type (2 NC-CS or 3 NC-XX) the minimum diametral clearance between the rotating components of the seal and the stationary surfaces

of the seal chamber and gland plate shall be 3 mm ($1/8$ in.). Non contacting seals generate minimal amount of heat, only that resulting from the viscous shear of the sealed fluid.

- c) The first point of radial contact by a metal component of the seal shall not be at the seal ring or mating ring (see NOTE 2).

NOTE 1 The intent of setting minimal clearances should in no way be construed as implying that any seal component can be used to restrict shaft movement in the event of bearing failure or other machinery or operation problem.

NOTE 2 The requirement in 6.1.2.6 c) is to minimize potential leakage levels and/or a friction generated ignition source in the rare fault event where the relative radial position of the rotating components to the stationary components would be beyond the minimum diametral clearances in Table 1. The importance of having sufficient design clearance to ensure adequate reliability and personal safety in hazardous, toxic and flammable services is paramount. Diametral clearances may be compromised in the event of the following scenarios:

- wear of shaft bearings beyond their design limits;
- operation of the pump beyond its allowable operating range;
- existing pumps that have damaged, corroded, or worn parts that control the radial location of the shaft to the casing.

It is important to ensure pump installation to the appropriate standards on hazardous services. Operational condition monitoring and controlled maintenance and reconditioning procedures are always applied.

NOTE 3 These minimal clearances will be adequate in equipment that is built and/or maintained to the specifications of API 610 and ANSI B73. For other equipment built, repaired, or operated to different specifications these clearances might not be sufficient. Larger clearances should be considered for:

- pump designs unable to conform to the shaft, casing and seal design limits in API 610, API 682, and the shaft/casing limits in ANSI B73.1 and ANSI B73.2. Potentially vulnerable pump designs are discussed in API 610.
- pumps installed with mounting and flange strain, from connecting pipe work, are beyond the recommended limits of API 610 and ANSI B73.1 and ANSI B73.2.

NOTE 4 These minimal clearances are to prevent contact between rotary and stationary parts, but internal clearances in Arrangement 2 and Arrangement 3 CW seals also need to be sufficient to insure proper circulation of the barrier/buffer fluid and cooling of the seal faces. This is particularly important in face-to-back configuration where barrier/buffer fluid circulation to the inner seal is inherently physically remote from the connections. Inadequate cooling of the inner seal can result in reduced seal reliability. Selection of 3CW-BB or 3CW-FF configuration or use of process fluid seal chamber cooling may resolve an inner seal cooling problem.

Table 1—Clearances Between Rotary and Stationary Components

Inside Diameter (ID)	Outside Diameter (OD)		Minimum Diametral Clearance ^a	Reference
ID seal chamber bore and gland plate	OD rotating seal part	CW seal type NC seal type	6 mm (0.25 in.) 3 mm (0.125 in.)	6.1.2.6.a)
ID stationary seal part	OD rotating seal part	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in.) 2 mm (0.079 in.)	6.1.2.6
ID stationary gland part	OD internal circulation device	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in.) 2 mm (0.079 in.)	7.1.2.9
ID containment fixed bushing 2CW-CS, 2NC-CS	OD rotating seal part	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in.) 2 mm (0.079 in.)	7.2.5.1
^a The minimum diametral clearances are calculated by subtracting the maximum outside diameter (of the internal part) from the minimum inside diameter (of the external part).				
Inside Diameter (ID)	Outside Diameter (OD)		Maximum Diametral Clearance ^b	Reference
ID floating carbon bushing	OD rotating sleeve	20 mm to 50 mm 51 mm to 80 mm 81 mm to 125 mm	0.18 mm (0.007 in.) 0.225 mm (0.009 in.) 0.28 mm (0.011 in.)	6.1.2.23
ID fixed throttled bushing	OD rotating sleeve	20 mm to 50 mm 51 mm to 75 mm 76 mm to 100 mm 101 mm to 125 mm	0.635 mm (0.025 in.) 0.762 mm (0.030 in.) 0.889 mm (0.035 in.) 1.016 mm (0.040 in.)	6.1.2.22
^b The maximum diametral clearances are calculated by subtracting the minimum outside diameter (of the internal part) from the maximum inside diameter (of the external part).				

6.1.2.7 All bolt and stud stresses shall be in accordance with the pressure design code at the MAWP. Four studs shall be used. The diameter of the studs shall be in accordance with the seal chamber dimensional references in 6.1.2.4. Larger studs shall be furnished only if required to meet the stress requirements of EN 13445 or ASME VIII or to sufficiently compress spiral-wound gaskets in accordance with ASME B16.20.

6.1.2.8 The MAWP of the seal pressure casing shall be equal to or greater than that of the pump pressure casing on which it is installed. This value shall be provided by the pump manufacturer. The seal pressure casing shall have a corrosion allowance of 3 mm ($\frac{1}{8}$ in.) and shall have sufficient rigidity to avoid any distortion that would impair seal operation, including distortion that may occur during tightening of the bolts to set gasketing. If approved by the purchaser, a smaller corrosion allowance may be acceptable for some higher alloy materials.

The following shall also apply.

- a) Unless otherwise specified, gland plates shall be provided with holes (not slots) for attachment studs.
- b) Provisions shall be made for centering the seal gland plates and/or chamber with either an inside- or an outside-diameter register fit. The register-fit surface shall be concentric to the shaft and shall have a total indicated runout (TIR) of not more than 0.125 mm (0.005 in.), see Figure 12. The rabbet diametrical clearance shall be H7/f7 in accordance with ISO 286-2.

- c) A shoulder at least 3 mm ($1/8$ in.) thick shall be provided in the seal gland plate to support the axial load generated by seal chamber pressure acting on the seal components see Figure 13.

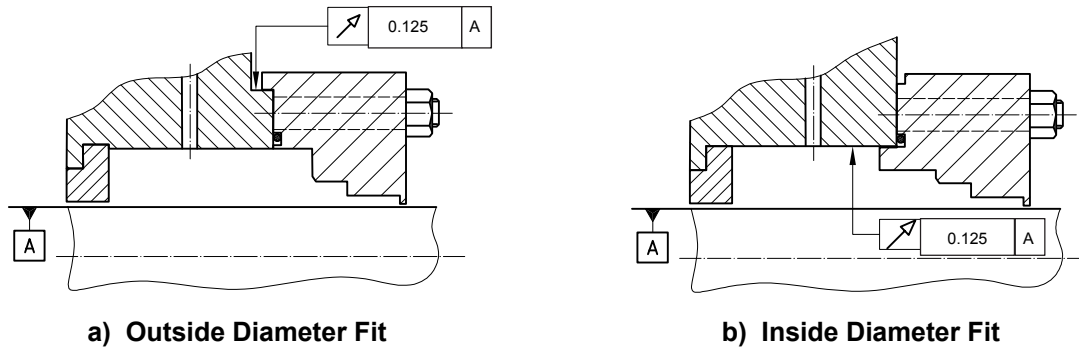
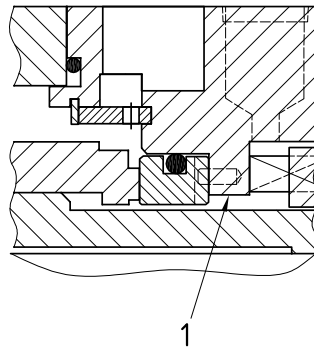


Figure 12—Seal Chamber Register Concentricity



Key

- 1 seal gland plate shoulder

Figure 13—Section Showing Seal Gland Plate Shoulder

6.1.2.9 Stress values used in the design of the pressure casing for any material shall not exceed the values used in the design of the pump casing on which it is installed. Where the original pump design values are not available, the stress values shall be in accordance with API 610.

6.1.2.10 Manufacturing data report forms, third party inspections, and stamping, such as those specified in codes such as ASME VIII, are not required.

6.1.2.11 The use of threaded holes in pressurized parts shall be minimized. To prevent leakage in pressure sections of casing, metal equal in thickness to at least half the nominal bolt diameter, in addition to any corrosion allowance, shall be left around and below the bottom of drilled and tapped holes.

6.1.2.12 Threading details for bolting for pressure casings shall be in accordance with ISO 261, ISO 262, ISO 724, and ISO 965, or with ASME B1.1. Metric fine and UNF threads shall not be used.

Unless otherwise specified, studs in accordance with API 610 Table H.1 shall be used, rather than other fasteners such as cap screws for connection of seal chamber to pump and seal gland plate to pump or seal chamber.

Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches.

Manufacturers marking shall be located on all fasteners 6 mm ($1/4$ in.) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

NOTE 1 A set screw is a headless screw with an internal hex opening on one end.

NOTE 2 Adequate clearance to use socket or box wrenches at gland plate bolting locations might not be feasible on small pumps.

6.1.2.13 The seal manufacturer shall design for seal chamber face runout (TIR) up to $0.5 \mu\text{m/mm}$ (0.0005 in./in.) of seal chamber bore, see Figure 14.

NOTE 1 Some multistage, slender-shaft designs, and some ASME B73 pumps may not be able to meet the requirements of this section (see 6.1.1.5).

NOTE 2 Mechanical seal performance can be adversely affected by excessive runout at the mechanical seal chamber. Seal chamber face runout or seal chamber interface runout is a measure of the squareness of the pump shaft with respect to the face of the seal chamber mounting.

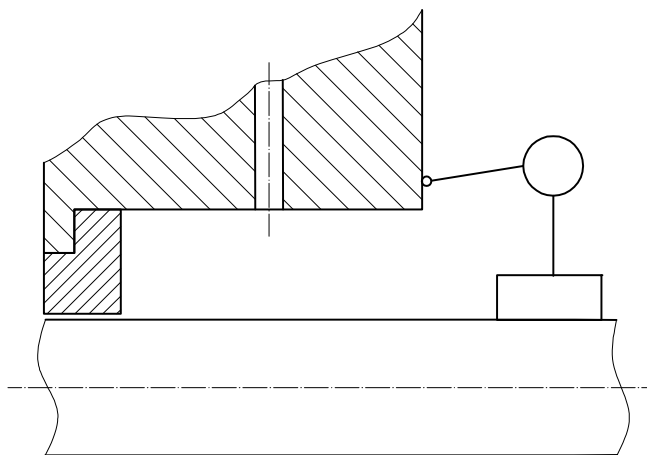


Figure 14—Seal Chamber Face Runout

6.1.2.14 For Arrangement 1 and Arrangement 2, seal chamber pressure and support systems for contacting wet seals (excluding containment seals) shall be designed for proper seal operation. Pumps that develop low differential pressure and pumps that handle high vapor pressure fluids may not achieve the required margins specified in 6.1.2.14.1 and 6.1.2.14.2. If the seal chamber conditions do not meet the specified margins, the seal manufacturer shall:

- confirm the adequacy of the seal selection and piping plan based on the specified fluid;
- recommend the seal chamber operating conditions (minimum pressure and maximum temperature) that will result in a seal installation that has a high probability of achieving three (3) years of uninterrupted service;
- furnish the seal gland plate or seal chamber with a second flush connection to permit measurement of seal chamber pressure directly; and
- furnish a distributed flush system unless space limitations preclude its use.

NOTE Refer to F.1.4 for specific recommendations.

6.1.2.14.1 During operation, the seal chamber pressure shall be at least 0.035 MPa (0.35 bar) (5 psi) above atmospheric pressure. This is particularly important if the inlet pressure to the pump is below atmospheric.

6.1.2.14.2 During operation, a vapor pressure margin (VPM) (i.e. the difference between the seal chamber pressure minus the maximum fluid vapor pressure) shall be maintained as required in 6.1.2.14.2 a). If it is not possible to achieve this margin the criteria in 6.1.2.14.2 b) shall be met.

- a) Not less 0.35 MPa (3.5 bar) (50 psi).
- b) A minimum ratio of 1.3 between the absolute pressure in the seal chamber and the absolute vapor pressure of the pumped fluid at pumping temperature.

NOTE 1 For high vapor pressure fluids, (e.g. NGL's like ethane or olefins like ethylene), it is recommended that the user consult the seal vendor for seal design and appropriate VPM.

NOTE 2 For additional guidance on VPM, the user should consult Annex F.1.4.

6.1.2.15 If supplied, throat bushings shall be renewable and designed so that they cannot be forced out by hydraulic pressure.

- **6.1.2.16** If specified, or if recommended by the seal manufacturer, close-clearance floating throat bushings shall be furnished. Materials and clearances shall be suitable for the service and approved by the purchaser.

NOTE Close-clearance throat bushings can be used for any or all of the following purposes along with the appropriate piping plans:

- to increase or decrease seal chamber pressure;
- to isolate the seal chamber fluid; and/or
- to control the flow into or out of the seal chamber.

See F.5.3 for additional guidance concerning the use of throat bushings.

6.1.2.17 Datasheet-specified gland plate and seal chamber connections shall be identified by symbols permanently marked (e.g. stamped or cast) on the component. The symbol, size, and location in Table 2 shall be used (see Figure 15 for the relative axial position of the process and atmospheric connections). Where appropriate, the letters "I" and "O" (marking In and Out) shall be used in conjunction with these markings. For horizontal pumps, 0° is vertical on top. For vertical pumps, the location of the flush (marked with letter "F") connection defines 0° (see Figure 2 to Figure 6). Where the size of the pump or seal gland precludes the inclusion of the required connection on the seal gland, the seal vendor shall advise the pump vendor to include the necessary connection on the pump or seal chamber. If tangential porting is used, the location of the drilled port into the seal chamber shall comply with Table 2. However, the associated locations for the gland plate tapped connections may differ from those specified in Table 2.

The lack of space for tap and port connections in the seal chamber area may require that these be included within the pump manufacturer's scope of supply. Annex E specifies the interface responsibilities of the pump and seal vendors.

Differential sizing minimizes the possibility of improper assembly, particularly during maintenance in the field. The purchaser should be aware that the specified connection size and location in Table 2 might not be practical on smaller pumps.

6.1.2.18 Connection Points and Plugs

6.1.2.18.1 The seal gland threaded connection points shall be plugged with plastic plugs for shipment. These plugs should be international red in color and have a center tab to be easily pulled and distinguished from metal plugs. (See Figure 16.) A warning tag in international yellow color shall be attached to the plugs or seal indicating that the plugs shall be removed prior to operation. The warning tag shall include the international warning symbol and the following text in English, French, Spanish, German,

Japanese, and Mandarin Chinese: "Remove red plug. Install metal plugs or piping as specified on seal drawing." See Figure 16 for an example of such a tag. Plastic plugs, tags, and seal gland plates shall not be painted over on any equipment. Threaded connections other than on the seal gland shall have metal plugs inserted for shipment.

6.1.2.18.2 Metal plugs of the same material as the gland, or with superior corrosion resistance for the intended service, and sufficient in number to plug all openings in the gland plate shall be furnished and packaged separately in a plastic bag with a warning label that all unused seal connections shall be plugged. The same warning shall be included in the seal drawing and instructions. One copy of the seal drawing is to be included in the plastic bag that contains the metal plugs in addition to the copy of the seal drawing that is included in the box with the seal. The metal plugs shall be solid round or solid hexagonal head plugs furnished in accordance with the dimensional requirements of ASME B16.11. Square head plugs shall not be used because of their tendency to be damaged during installation and removal.

NOTE ASME B16.11 is referenced to prevent the supply of hollow or cored plugs; failures of such plugs have occurred within the industry.

6.1.2.18.3 During installation follow plant practices applying a lubricant/sealant on the threads to ensure the threads are vapor tight. Polytetrafluoroethylene (PTFE) tape, antiseize, or antigalling compounds used on gland plate connections can create the possibility of fouling the seal and should be applied with caution.

Category 1 seal gland plates and seal chambers may not be able to meet this standard plug requirement because of space constraints. In such cases, flush-mount socket head plugs are acceptable.

NOTE The head on a pipe plug interferes with the installation and actual ability to fit on many smaller Category 1 pumps if the bearing bracket inner diameter is close in size to the gland plate outer diameter. Also, a head on the plug utilized on the seal chamber port can interfere with the back side of the gland plate because of the limited axial space.

6.1.2.19 All piping or tubing connections shall be suitable for the hydrostatic test pressure of the seal chamber or gland plate to which they are attached.

6.1.2.20 Gland plates and/or seal chambers for contacting wet seals including the barrier or buffer chamber, and containment seal chambers shall be designed such that the seal chamber and piping system is self-venting during start-up and operation through the piping system. Designs, other than Piping Plan 23, requiring manual seal chamber venting shall be approved by the purchaser. The following shall apply.

- a) On small horizontal pumps where the elevation of the discharge nozzle is not high enough to achieve a continuously rising Piping Plan 11 flush line, then the connection may be located in the process piping upstream of the check valve if approved by the purchaser.
- b) The seal chamber or gland plate shall have a port no less than 3 mm ($1/8$ in.) above the seal faces to allow the removal of trapped gas if contacting wet seal arrangements are vertically oriented. This port shall be uppermost in the chamber (see Figure 17). This applies to ports for both sets of faces in Arrangement 2 (2CW-CW configuration) and the outer seal face of Arrangement 3 contacting wet seals when they are vertically oriented.
- c) Horizontal or vertical pumps having a Piping Plan 23 or vertical pumps having Piping Plans 11, 21, 31, and 41 shall be provided with a separate vent connection in the piping. Vertical pumps having Piping Plan 02 shall have a vent connection in the gland plate. Designs, other than these, requiring manual seal chamber venting require purchaser's approval.
- d) Low-volume seal flush systems that have positive flow due to differential pressures within the pump may not require manual venting (i.e. a short Piping Plan 11 or Piping Plan 13 on a small pump). Entrained gas will quickly purge from the piping and seal chamber upon start-up of the pump.

Table 2—Symbols and Size for Seal Chamber and Gland Plate Connections

Seal Config.	Symbol	Connection	Location	Type	Size ^a		Connection Required ^f
					Cat. 1	Cat. 2 and Cat. 3	
1CW-FX 1CW-FL	F	Flush	0	process	1/2 ^c	1/2	required
	FI	flush in (Plan 14 & 23 only)	180	process	1/2 ^c	1/2	WS
	FO	flush out (Plan 14 & 23 only)	0	process	1/2 ^c	1/2	WS
	D	drain	180	atmospheric	3/8 ^e	3/8	required
	Q	quench	90	atmospheric	3/8 ^e	3/8	required
	H	heating	—	utility	1/2 ^c	1/2	WS
	C	cooling	—	utility	1/2 ^c	1/2	WS
	PIT	pressure sensing port	90	instrumentation	3/8	3/8	WS ^g
2CW-CW	F	flush (inner seal)	0	process	1/2 ^c	1/2	required
	LBI	liquid buffer fluid in	180	process	1/2 ^d	1/2 ^d	required
	LBO	liquid buffer fluid out	0	process	1/2 ^d	1/2 ^d	required
	D	drain (outer seal)	180	atmospheric ^b	3/8 ^e	3/8	WS
	Q	quench (outer seal)	90	atmospheric ^b	3/8 ^e	3/8	WS
2CW-CS	F	flush (inner seal)	0	process	1/2	1/2	required
	FI	flush in (Plan 23 only)	180	process	1/2 ^c	1/2	WS
	FO	flush out (Plan 23 only)	0	process	1/2 ^c	1/2	WS
	GBI	gas buffer fluid in	90	process	1/4	1/4	WS
	CSV	containment seal vent	0	process	1/2	1/2	required
	CSD	containment seal drain	180	process	1/2	1/2	required
	D	drain (outer seal)	180	atmospheric ^b	3/8 ^e	3/8	WS
	Q	quench (outer seal)	90	atmospheric ^b	3/8 ^e	3/8	WS
2NC-CS	GBI	gas buffer fluid in	90	process	1/4	1/4	WS
	CSV	containment seal vent	0	process	1/2	1/2	required
	CSD	containment seal drain	180	process	1/2	1/2	required
	D	drain (outer seal)	180	atmospheric ^b	3/8 ^e	3/8	WS
	Q	quench (outer seal)	90	atmospheric ^b	3/8 ^e	3/8	WS
3CW-FB 3CW-FF 3CW-BB	F	flush (seal chamber)	0	process	1/2	1/2	WS
	LBI	liquid barrier fluid in	180	barrier	1/2 ^d	1/2 ^d	required
	LBO	liquid barrier fluid out	0	barrier	1/2 ^d	1/2 ^d	required
	D	drain (outer seal)	180	atmospheric ^b	3/8 ^e	3/8	WS
	Q	quench (outer seal)	90	atmospheric ^b	3/8 ^e	3/8	WS
3NC-FF 3NC-BB 3NC-FB	F	flush (seal chamber)	0	process	1/2	1/2	WS
	GBI	gas barrier fluid in	0	barrier	1/4	1/4	required
	GBO	gas barrier fluid out	180	barrier	1/2	1/2	WS
	D	drain (outer seal)	180	atmospheric ^b	3/8 ^e	3/8	WS
	Q	quench (outer seal)	90	atmospheric ^b	3/8 ^e	3/8	WS
	V	process vent	0	process	1/2	1/2	WS

^a All sizes listed in this table are NPT tapered thread connections.

^b These connections are rarely provided because they are only required when a throttle bushing is provided. A throttle bushing is not provided with standard Arrangement 2 and 3 configurations.

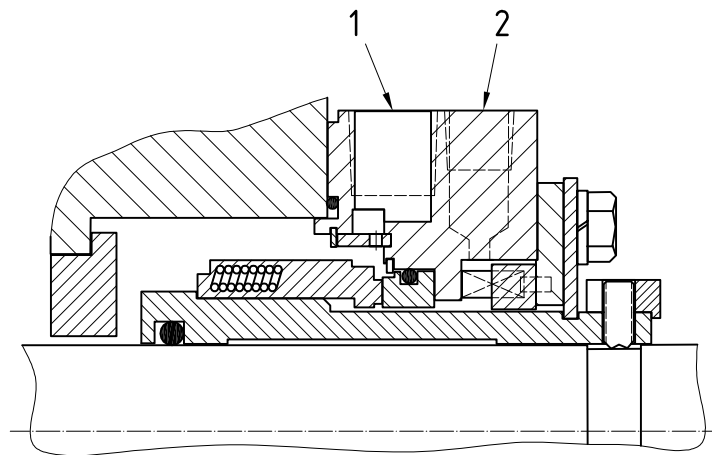
^c A 3/8 NPT connection may be used if 1/2 NPT is not possible because of space constraints.

^d 1/2 NPT required for shaft diameters 60 mm (2.5 in.) or smaller, 3/4 NPT for larger shaft sizes.

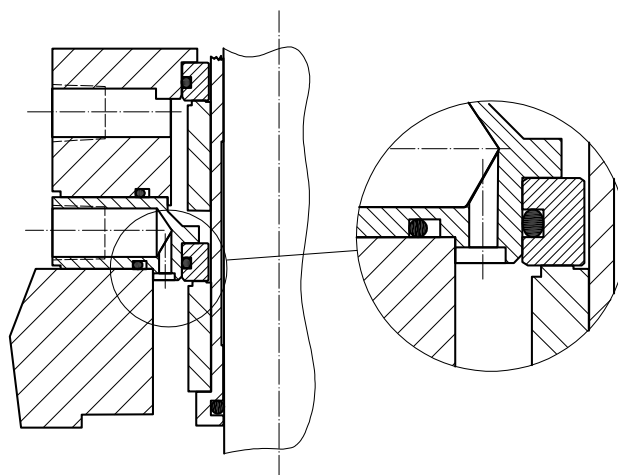
^e A 1/4 NPT connection may be used if 3/8 NPT is not possible because of space constraints.

^f WS = Connection is provided only when the appropriate piping plan is specified.

^g PIT port for indicating pressure transmitter required for Piping Plan 66A and Piping Plan 66B.

**Key**

- 1 process side
- 2 atmospheric side

Figure 15—Mechanical Seal Piping Connections**Figure 16—Plastic Plug with Center Tab and Example of Warning Tag****Figure 17—Seal Chamber/Gland Plate for Vertical Pumps**

- e) Venting of the seal chamber for Arrangement 3 noncontacting seals prior to start-up and during operation may be necessary to avoid the collection of gas in the pump.

NOTE Drilling of throat bushing wall at top dead center, for horizontal shaft pumps, will allow natural venting of the seal chamber inside the pump. This can be a practical alternative when venting through the piping is either impractical or not possible.

6.1.2.21 Drilled passages shall be sized for the application and shall have a minimum diameter of 5 mm ($^3/16$ in.).

6.1.2.22 The diametrical clearance at a fixed throttle bushing bore shall not be more than specified in Table 1.

6.1.2.23 Floating throttle bushings made of carbon shall have a sleeve clearance as shown in Table 1.

NOTE If the bushing is designed to have the maximum diametrical clearance at a given pumping temperature, but the operation is below this temperature, the clearance will be greater than the one indicated in Table 1. If the purchaser wishes to minimize the clearance over a range of operating conditions, and therefore leakage past the bushing, consult the seal manufacturer for recommendation on material or a restriction device such as a segmented floating carbon bushing that can maintain a given clearance over a range of temperatures.

- **6.1.2.24** If specified, heating jackets or inserts shall be provided on seal chambers. Heating requirements shall be agreed between the purchaser, vendor and seal manufacturer.

NOTE The jacket can be used for temperature control, and this includes cooling as well as heating. Use of the jacket for cooling purposes is not recommended because of the relative inefficiency of the method and the tendency of plugging and fouling. Steam has been used effectively for cooling purposes on hot pumps and can prevent solidification of the process medium when idle. When a jacket is used, caution shall be exercised if skim cutting of the seal chamber bore is done, to insure that minimum wall thickness is maintained.

- **6.1.2.25** The supply of connections shall satisfy the requirements in 5.1. The lack of space for tap and port connections off the gland plate may require that these be included within the pump manufacturer's scope of supply, if approved by the purchaser.

6.1.2.26 All mating joints between the seal gland plate, the seal chamber, the containment seal chamber and the pump case shall incorporate a confined gasket to prevent blowout (see Figure 18). Controlled compression of the gasket (e.g. an O-ring or a spiral-wound gasket) shall be accomplished with metal-to-metal contact between the gland plate and the seal chamber face. The design of the joint shall prevent extrusion of the gasket to the interior of the seal chamber where it might interfere with seal cooling. Where space or design limitations make this requirement impractical, an alternative seal gland plate design shall be submitted to the purchaser for approval.

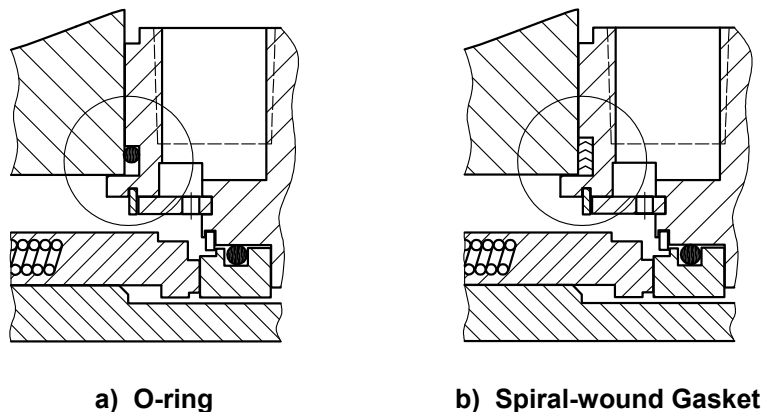


Figure 18—Mating Joint Gasket

NOTE To minimize runout, metal-to-metal contact is needed to keep faces and the shaft perpendicular for seals with rotating flexible elements.

6.1.3 Cartridge Seal Sleeves

6.1.3.1 Seal sleeves shall be furnished by the seal manufacturer. The sleeve shall be made of one piece and sealed at one end. (See 6.1.3.10 concerning auxiliary sleeves.) The seal sleeve assembly shall extend beyond the outer face of the seal gland plate.

NOTE Leakage between the shaft and the sleeve cannot be confused with leakage through the mechanical seal.

6.1.3.2 The seal manufacturer shall obtain the shaft diameter and tolerance from the pump manufacturer and ensure a shaft-to-sleeve fit of F7/h6 in accordance with ISO 286-2. This correlates to a clearance of 0.020 mm (0.0008 in.) to 0.093 mm (0.0037 in.) for the range of seal sizes covered by this standard, and varies as a function of diameter. The intent is to minimize sleeve runout (see Figure 19), while allowing for ease of assembly/disassembly. Shrink disks typically require tighter clearances and should follow the shrink-disk manufacturer's design criteria (see Figure 21).

API 610 requires a shaft diameter tolerance of h6; however, special cases may exist in which pumps are supplied with shaft diameter tolerances outside this. In such cases, the seal manufacturer shall ensure an appropriate fit.

NOTE Other methods to achieve the same level of concentricity are available. The purchaser may wish to discuss these alternatives with the pump and seal vendor.

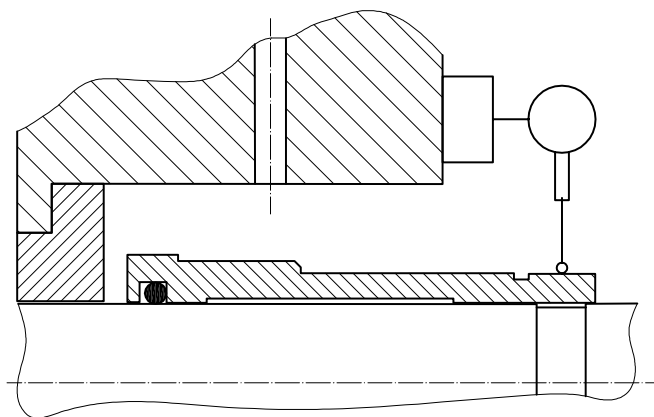


Figure 19—Seal Sleeve Runout

6.1.3.3 A clear means of guidance for setting the proper axial positioning of rotating elements on sleeves shall be provided.

NOTE This provision is intended to help the assembler of the seal properly locate seal components axially so that the correct spring load is attained. Features such as shoulders, or holes to receive dog points or pins, are examples of such clear means. This minimizes the possibility of error during assembly due to imprecise measurements or similar mistake. The intent is not to limit the seal designer to only one method.

6.1.3.4 Unless otherwise specified, shaft-to-sleeve sealing devices shall be elastomeric O-rings or flexible graphite rings. Metallic sealing devices are often unreliable, damage the shaft, and make disassembly difficult. Sealing devices should be softer than the shaft.

6.1.3.5 Shaft-to-sleeve O-ring seals shall be located at the impeller end of the sleeve. For shafts that require the O-ring to pass over the threads, at least 1.6 mm ($\frac{1}{16}$ in.) radial clearance shall be provided

between the threads and the internal diameter of the O-ring, and the diameter transition shall be radiused or chamfered (see 6.1.1.9) to avoid damage to the O-ring.

NOTE This location prevents pumpage from accumulating under the sleeve and making disassembly difficult.

6.1.3.6 Shaft-to-sleeve sealing devices located at the outboard end of the sleeve shall be captured between the sleeve and the shaft.

NOTE Flexible graphite is commonly used on metal bellows seals located on the outboard end of the sleeve.

6.1.3.7 Sleeves shall have a minimum radial thickness of 2.5 mm (0.10 in.) at their thinnest section, excluding a groove on the outer diameter of the sleeve to accommodate a seal-setting plate external to the gland plate.

The sleeve thickness in the area of component drive set screws shall be in accordance with Table 3. Using these dimensions dimples on the outside diameter of the sleeve to accommodate component drive set screws shall be no more than 0.50 mm (0.020 in.) deep.

NOTE 1 The sleeve thickness in the proximity of set-screw locations prevents sleeve distortion due to tightening of the set screws.

NOTE 2 Excessively thin sleeves distort easily.

6.1.3.8 The sleeve shall be machined and finished throughout its length such that the bore and outside diameter are concentric within 25 μ m (0.001 in.) TIR.

Table 3—Minimum Sleeve Thickness in the Area of Component-drive Set Screws

Shaft Diameter		Minimum Sleeve Radial Thickness	
mm	(in.)	mm	(in.)
<57	(<2.250)	2.5	(0.100)
57 to 80	(2.250 to 3.250)	3.8	(0.150)
>80	(>3.250)	5.0	(0.200)

6.1.3.9 Sleeves shall be relieved along their bore, leaving a locating fit at or near each end.

NOTE Relieving the bore makes assembly and disassembly easier with the required close fits.

6.1.3.10 Where possible seal sleeves shall be designed as one piece. Cartridge designs for Arrangement 2 and 3 seals that incorporate an auxiliary sleeve to facilitate the assembly of the inner or outer seal components are acceptable. The auxiliary sleeve shall be axially located on the seal sleeve by positive means as specified in 6.1.3.3. Auxiliary sleeves shall be mounted concentrically to the sleeve and shall not extend beyond the sleeve. (See Figure 20 for an illustration of an auxiliary sleeve.)

6.1.3.11 Drive-collar set screws shall not pass through clearance holes unless the sleeve bore is relieved. For between-bearing pumps, the shaft shall be relieved in this area. This relieved area should be chamfered appropriately to avoid O-ring damage during seal installation.

NOTE If set screws are tightened against the shaft, the holes upset the metal on the shaft surface. If this damage is under the sleeve, it cannot be corrected prior to sleeve removal. For between-bearing pumps, the full length of the sleeve will then need to be pulled over the damaged area. This can cause the sleeve to gall to the shaft or otherwise be damaged. The problem is less severe with overhung pumps where only a small length of the sleeve needs to be pulled over the damaged area.

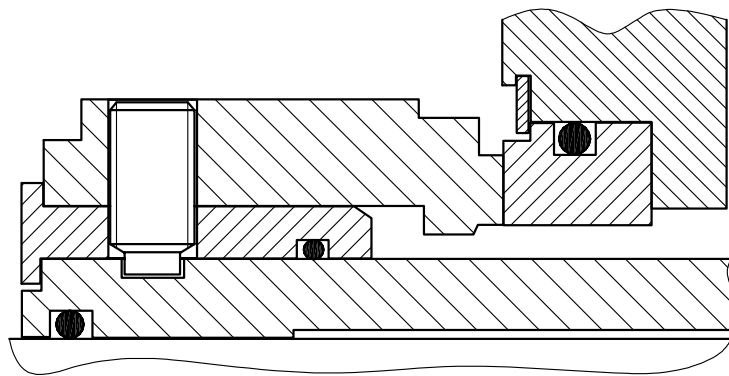


Figure 20—Auxiliary Sleeve Arrangement

6.1.3.12 Drive-collar set screws shall be of sufficient hardness to securely embed in the shaft. Unless otherwise specified the design shall be suitable for a maximum shaft hardness of 38 HRC (353HB). The pump and seal vendor shall ensure that adequate relative hardness exists between the pump shaft and the drive-collar set screws. See F.3.

6.1.3.13 It is the responsibility of the seal vendor to ensure that the drive-collar set screws shall be of sufficient number and size to ensure that rotational drive and axial positioning are adequate for the service conditions. For purposes of determining what is adequate the collar and set screw arrangement shall be able to statically maintain axial positioning under the axial load generated by a minimum of 150 % of the maximum pressure rating of the seal category according to 4.1.2. The axial load is calculated by multiplying the pressure by the annular surface area defined by the shaft and the seal balance diameter. See F.3 for calculation details.

6.1.3.14 Designs using nine or more set screws to drive and/or axially position the sleeve require purchaser approval.

The use of spot drilling on shafts for overhung pumps is not recommended, as this creates a stress riser that can reduce the fatigue life of the shaft.

Spot drilling should be done only after the axial position of the shaft is set. Ensure holes are drilled in line with the set screw holes on the drive collar so that no distortion of the collar or sleeve occurs when the set screws are tightened.

NOTE 1 As shaft size and sealing pressure increase, the axial force on the sleeve (pressure multiplied by area) increases. As the number of set screws increases, the drive collar is weakened and the amount of additional force each set screw will resist decreases.

NOTE 2 Dimples drilled in the pump shaft to accommodate set screws will result in a protruding lip around the drilled hole unless it is chamfered or otherwise eliminated. This lip will damage flexible graphite secondary seals and could damage O-rings.

NOTE 3 It may not be possible to use preexisting spot drilling for replacement seals.

NOTE 4 A shaft recess can aid in maintaining the axial location of the seal while lessening the possibility of shaft seal damage during installation.

- **6.1.3.15** If specified, or if recommended by the seal or pump manufacturer and approved by the purchaser, devices other than set screws may be used for axially positioning and driving the sleeve. Examples include a shrink disk (see Figure 21) or a split ring engaging a groove in the shaft (see Figure 22).

NOTE These designs are expensive and are usually used only on unspared pumps. Use of these designs avoids shaft damage by dimpling the shaft for dog-point set screws when high thrust loads exist on the sleeve.

6.1.4 Mating Rings

6.1.4.1 Antirotation devices shall be designed to minimize distortion of the seal faces. Clamped faces shall not be used unless approved by the purchaser (see Figure 23).

NOTE Flat seal faces are essential for achieving low emissions and good seal performance. Clamped rings are easily distorted.

6.1.4.2 The arrangement of the mating ring and its mounting into the seal gland plate shall be designed to facilitate cooling of the ring and to avoid thermal distortion.

NOTE Mating rings that are mounted deep in the gland plate and have minimal contact with the process fluid tend to not transfer heat away effectively. The resulting temperature gradients can cause distortion of the faces.

6.1.5 Flexible Elements

- **6.1.5.1** If specified by the purchaser and agreed by the vendor, a single-spring Type A seal shall be furnished.

NOTE 1 Multiple coil-spring seals tend to be more axially compact than single coil-spring seals. This gives wider applicability when dual seals are considered. Multiple springs also tend to provide more even loading.

NOTE 2 Single-spring seals generally add 6 mm (0.25 in.) to 13 mm (0.5 in.) to the axial space requirement of a sealing application. For single seal applications, the single spring has advantages and disadvantages. The single spring allows a lower spring rate to achieve the same face loading. This makes the single spring more tolerant of axial misalignment resulting from changes in the relative axial location of the shaft with respect to the seal chamber (such as in case of differential thermal expansion.) The use of cartridge seals has largely eliminated errors in axial setting of the seal.

NOTE 3 For corrosive services, the wire in single springs is significantly greater in cross-section, providing a greater corrosion allowance. Multiple springs can more easily be located outside the process, thus eliminating immersion of the spring in the corrosive media.

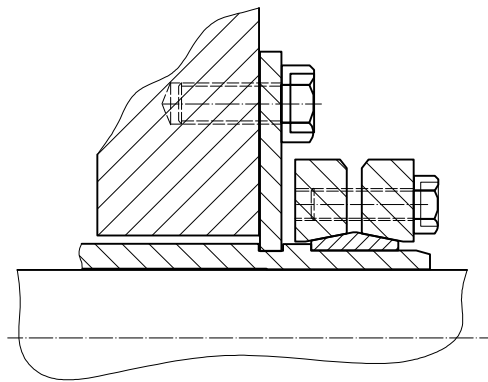


Figure 21—Seal Sleeve Attachment by Shrink Disk

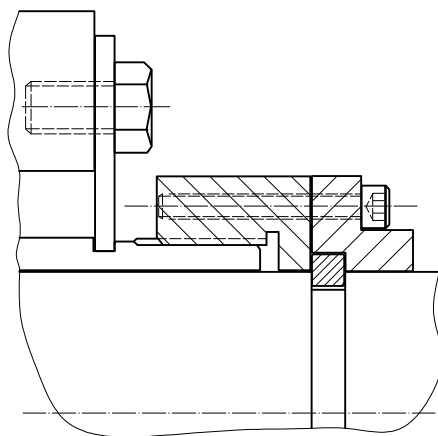


Figure 22—Seal Sleeve Attachment by Split Ring

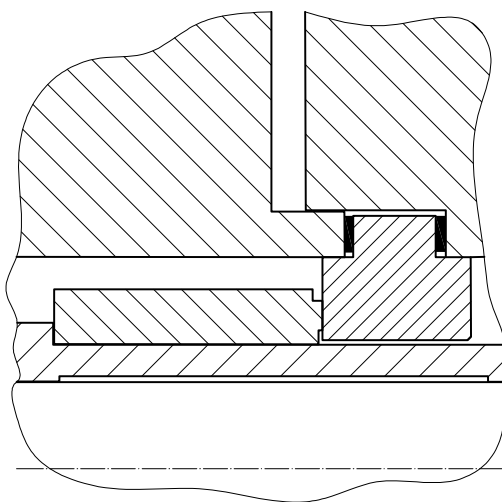


Figure 23—Clamped Faces

6.1.5.2 Flexible elements shall not rely on static lapped joints for sealing.

This requirement means that designs such as lapped-joint rotating seal rings are prohibited, as they employ an unretained slip fit into a flexible element unit. Designs retaining the seal ring with an interference fit and/or gasket are acceptable.

6.1.6 Materials

6.1.6.1 General

6.1.6.1.1 Unless otherwise specified on the datasheets, seal components shall be furnished with the materials referenced in 6.1.6.2 to 6.1.6.9.

NOTE 1 Proper material selection is critical to the reliable operation of a mechanical seal. Selection depends on the characteristics of the contacting fluid. Variables such as operating temperature, pressure, speed, lubricity, and chemical compatibility are key parameters. The purchaser should solicit seal manufacturer input when in doubt about the compatibility of these materials with the intended service. See *NACE Corrosion Engineer's Reference Book* for one source of suitable materials.