Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps

API Standard 682

FIFTH EDITION, XXXXXXXX 202X

Introduction

This Standard is based on the accumulated knowledge and experience of manufacturers and users of equipment in the petroleum, natural gas and chemical industries but its use is not restricted to these industries.

Users of this Standard should be aware that further or differing requirements may be needed for individual applications. This Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this Standard and provide details.

The purpose of this Standard is to assist purchasers with the selection and operation of mechanical seals. This Standard is a stand-alone seal standard, which can be referenced by the current edition of API 610 (ISO 13709), ASME B73.1, ASME B73.2, and API 676 for new pumps and can also be used to retrofit existing pumps. The seals in this Standard may also be used in non-API 610 (ISO 13709) pumps.

In this Standard, where practical, US Customary units are included in brackets for information.

A bullet (●) at the beginning of a sub-clause or paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information or decision should be indicated on suitable data sheets: otherwise it should be stated in the quotation request (enquiry) or in the order.

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 0.75 in. (20 mm) to 6.0 in. (150 mm).

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 can be applicable to 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 should mutually agree on the features taken from this standard and used in the application.

The seals used in the figures are also intended to show the generic location of the seals relative to the piping plans. Other seal designs detailed in this standard (e.g. types, configurations, categories, rotating vs stationary options) as well as designs from different manufacturers may have a different appearance than the generic seals used in the figures. The seals illustrated are not an endorsement of a specific design or configuration.

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 Standard 520 (Part 1 and Part 2), *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 V [1], *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*

ASME B18.18.2M, Inspection and Quality Assurance for High-Volume Machine Assembly Fasteners

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*

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[1] ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.
[2] American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

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)*

3 Terms, Definitions, Abbreviations and Symbols

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

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[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.

3.1 Terms and Definitions

3.1.1
Anti-rotation 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 4.2.4.

3.1.3
Arrangement 2 seal
See 4.2.4.

3.1.4
Arrangement 3 seal
See 4.2.4.

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 and the barrier fluid is on the OD of both the inner seal and outer seal.

3.1.8
balanced seal
Mechanical seal in which the net hydraulic closing forces have been modified through seal design as detailed 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. The cartridge may be mounted within the boundaries of the seal chamber or containment seal chamber or gland plate.

3.1.14
Category 1 seal
See 4.2.2.

3.1.15
Category 2 seal
See 4.2.2.

3.1.16
Category 3 seal
See 4.2.2.

3.1.17
Category 4 seal
See 4.2.2.

3.1.18
connection
Threaded or flanged joint that mates a port to a pipe or to a piece of tubing.

3.1.19
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.

3.1.20
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.

3.1.21
containment seal
Version of an outer seal used in Arrangement 2 and that normally operates in a vapor (gas buffer or no buffer) but will contain the process fluid while operating at seal chamber conditions to enable safe shutdown in the event of an inner seal failure. See 4.2.4.

3.1.22
containment seal chamber
Component or aggregate of components that form the cavity into which the containment seal is installed.

3.1.23
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.

3.1.24
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.

3.1.25
dead-leg
A length of piping with no flow

3.1.26
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.

3.1.27
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.

3.1.28
dual mechanical seal
Arrangement 2 or Arrangement 3 seal of any type.

3.1.29
dynamic sealing pressure rating
Highest pressure differential the seal assembly can continuously withstand at the minimum and maximum allowable working temperature while the shaft is rotating.

NOTE This is the highest differential pressure the seal assembly can be exposed to while the shaft is rotating (through start-up and normal operating conditions) and still retain its static sealing pressure rating. Any shaft rotation at pressures above this rating could lead to major seal damage and/or failure.

3.1.30
dynamic secondary seal
Secondary seal that is designed to slide or move relative to other components to allow axial movement of the flexible element.

3.1.31
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.

3.1.32
face-to-back configuration
Dual seal in which one mating ring between the two flexible elements and one flexible element is mounted between the two mating rings and the barrier or buffer fluid is on the ID of the inner seal and OD of the outer seal.

3.1.33
face-to-face configuration
Dual seal in which both mating rings are mounted between the flexible elements and the barrier fluid is on the OD of both the inner seal and outer seal.

3.1.34
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.

3.1.35
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.

3.1.36
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.

3.1.37
flashing hydrocarbon
flashing fluid
Liquid hydrocarbon or other fluid with an absolute vapor pressure greater than 14.7 psi (0.1 MPa) (1 bar) at the pumping temperature, or a fluid that will readily boil at ambient conditions.

3.1.38
flexible element
Combination of elements that accommodate axial movement between rotating and stationary parts.

3.1.39
flexible graphite
Exfoliated and recompressed graphite material used for static (secondary seal) gaskets in mechanical seal design, from cryogenic to hot service.

3.1.40
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.

3.1.41
fluoroelastomer
FKM
Saturated polymer in which hydrogen atoms have been replaced with fluorine; it is characterized by excellent hydrocarbon and general chemical resistance.

3.1.42
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.

3.1.43
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 components, for example the two gland plates often used in a dual seal.

3.1.44
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).

3.1.45
inner seal
(Arrangement 2 and Arrangement 3) The seal closest to the pump impeller or process fluid.

3.1.46
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.”)

3.1.47
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 (C_5) 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 working temperature
MAWT
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

NOTE 1 This information is supplied by the seal manufacturer.

NOTE 2 The maximum allowable working 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 working 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 allowable temperature [cf. **static sealing pressure rating** (3.1.90), **dynamic sealing pressure rating** (3.1.29)].

3.1.53
maximum barrier fluid pressure
Highest expected barrier fluid pressure between the inner and outer seal of Arrangement 3 seals.

3.1.54
maximum dynamic sealing pressure
MDSP
Highest pressure expected at the seal (or seals) during any specified operating condition while the shaft is rotating. This includes transient conditions while starting and stopping of the pump.

NOTE Both static and dynamic sealing pressures play an important part in the selection of a mechanical seal. They are dependent on the pump system design, suction pressure, suction temperature, operating point, and pump clearances. They are also directly affected by the mechanical seal piping plan.

3.1.55
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.

3.1.56
maximum static sealing pressure
MSSP
Highest pressure, excluding pressures encountered during hydrostatic testing to which the seal (or seals) can be subjected while the shaft is not rotating.

NOTE Both static and dynamic sealing pressures play an important part in the selection of a mechanical seal. They are dependent on the pump system design, suction pressure, suction temperature, operating point, and pump clearances. They are also directly affected by the mechanical seal piping arrangement.

3.1.57
Non-contacting 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.

3.1.58
Non-flashing hydrocarbon
Non-flashing fluid
Liquid hydrocarbon or other fluid whose vapor pressure at any specified operating temperature is less than an absolute pressure of 14.7 psi (0.1 MPa) (1 bar), or a fluid that will not readily boil at ambient conditions.

3.1.59
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.

3.1.60
NPS
Value approximately equal to a diameter in inches.

EXAMPLE: NPS 3/4

NOTE 1 Refer to ASME B31.3

NOTE 2 The letters NPS are followed by a value which is related to an approximate diameter of the bore, in inches, for piping up to and including 12 in. diameter. For piping over 12 in. (NPS 12), the NPS value is the nominal OD.

3.1.61
NPT
American National Standard Pipe Taper
Thread form designation for pipe threads.

EXAMPLE: 3/4-14 NPT

NOTE Proper designation is comprised of a number representing nominal pipe size followed by the number of threads per inch and the letters NPT representing the thread series.

3.1.62
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.

3.1.63
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.

3.1.64
O-ring
Elastomeric sealing ring with an O-shaped (circular) cross-section, which may be used as either a static or dynamic secondary seal.

3.1.65
outer seal
(Arrangement 2 and Arrangement 3) The seal located farthest from the pump impeller or process fluid. Arrangement 2 outer seals will contain the process fluid while operating at seal chamber conditions to enable safe shutdown in the event of an inner seal failure.

3.1.66
perfluoroelastomer
FFKM
Fully fluorinated fluorocarbon elastomer commonly used as a secondary seal in high-temperature and/or corrosive service.

3.1.67
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.

3.1.68
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.

3.1.69
port
Fluid passageway, typically located in the gland plate.

3.1.70
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 1 The MAWP of the auxiliary system is specified in Section 8.

NOTE 2 The atmospheric side of the seal gland, the seal flush (piping) plan, auxiliary piping, and valves are not part of the pressure casing.

3.1.71
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.

3.1.72
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.

3.1.73
pumped fluid
process fluid
The process stream designated in the datasheet for the pump service.

3.1.74
purchaser
Agency that issues the order and specifications to the vendor.

3.1.75
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.

3.1.76
quench
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.

3.1.77
reservoir
A storage vessel that can contain pressurized or non-pressurized fluids.

3.1.78
seal
end face mechanical seal
Device that controls 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.

3.1.79
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 1 Seal balance ratio is sometimes expressed as a percentage.

NOTE 2 In this standard the seal balance ratio is less than 1 (see balance ratio calculation in Annex F).

3.1.80
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.

3.1.81
seal face
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).

3.1.82
seal manufacturer
Agency that designs, manufactures, tests, and provides service support for seals and associated support sealing systems.

3.1.83
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.

3.1.84
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.

3.1.85
sealing system
Pump seal that includes the seal cartridge, seal chamber and accessories.

3.1.86
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.

3.1.87
segmented floating bushing
Throat or throttle bushing that is composed of circumferential segments retained by a tensioning device.

3.1.88
service condition
Maximum or minimum temperature or pressure under static or dynamic conditions.

3.1.89
spark resistant material
A material that is not prone to generate impact sparks under conditions of an application.

3.1.90
static sealing pressure rating
Highest pressure differential the seal assembly can continuously withstand at the minimum and maximum allowable working temperature while the shaft is not rotating and still retain its dynamic sealing pressure rating without disassembly and repair.

3.1.91
static secondary seal
Secondary seal between two surfaces that have no relative motion.

3.1.92
throat bushing
Device that forms a restrictive close clearance around the sleeve (or shaft) between the seal chamber and the impeller.

3.1.93
throttle bushing
Containment device that forms a restrictively close clearance around the sleeve at the atmospheric end of a gland plate.

3.1.94
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.

3.1.95
Type A seal
See 4.2.3.

3.1.96
Type B seal
See 4.2.3.

3.1.97
Type C seal
See 4.2.3.

3.1.98
vapor pressure margin
VPM
The seal chamber pressure minus the fluid vapor pressure.

3.1.99
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 sub-vendor. For example, the party supplying a lubricating oil console may be the console vendor of the compressor manufacturer, the sub-vendor 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.

3.1.100
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)*.

3.1.101
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 General

4.1 Unit Responsibility

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 sub-vendors comply with the requirements of this standard. Annex E specifies the interface responsibilities of the pump and seal vendors.

4.2 Seal Categories, Types and Arrangements

4.2.1 **General**

The seal configurations covered by this standard can be classified into four categories (1, 2, 3, and 4), three types (A, B, and C) and three arrangements (1, 2, and 3).

See Figure 2 through Figure 10 for typical representations.

NOTE The seals used in the figures are intended to be generic representations of seal configurations. The appearance of a seal may differ between manufacturers. These figures are not an endorsement of a specific design.

4.2.2 **Seal Categories**

4.2.2.1 There are four 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. Their application is limited to seal chamber temperatures from –40 °F (–40 °C) to 500 °F (260 °C) and dynamic sealing gauge pressures up to 300 psi (20 bar).

— *Category 2* seals are intended for use in seal chambers meeting the seal chamber envelope dimensional requirements of API 610. Their application is limited to seal chamber temperatures from –40 °F (–40 °C) to 750 °F (400 °C) and dynamic sealing gauge pressures up to 600 psi (40 bar).

— *Category 3* seals require additional documentation and may require additional design and testing requirements when compared to a Category 2 seal. They meet the seal chamber envelope requirements of API 610 (or equal). Their application is limited to seal chamber temperatures from –40 °F (–40 °C) to 750 °F (400 °C) and dynamic sealing gauge pressures up to 600 psi (40 bar).

— *Category 4* 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 °F (-40 °C) to 350 °F (176 °C) and dynamic sealing gauge pressures up to 1480 psi (102 bar).

Further differences in the details of seal categories are given in Annex A and Annex E.

4.2.2.2 For applications with temperatures and pressures outside the specified range of these categories, or for fluids not covered in Annex A, the seal manufacturer shall provide a list of exceptions to this standard (a deviation list) for a proposed seal.

NOTE For applications that fall outside the scope of this standard, the purchaser and seal vendor can apply guidance from this standard on a best effort basis while aligning on additional features, testing and qualification requirements.

4.2.3 **Seal Types**

There are three seal types, as follows.

— *Type A* seal is a balanced, cartridge design, pusher seal with multiple springs. Secondary sealing elements are elastomeric O-rings. Figure 8 depicts a Type A seal.

— *Type B* seal is a balanced, cartridge design (metal bellows) seal. Secondary sealing elements are elastomeric O-rings. Figure 9 depicts a Type B seal.

— *Type C* seal is a balanced, cartridge design (metal bellows) seal. Secondary sealing elements are flexible graphite. Figure 10 depicts a Type C seal.

NOTE 1 Further difference in the detail of seal types is given in Annex A.

NOTE 2 Materials are specified in Section 6. Guidance on equivalent material standards is in Annex B.

4.2.4 **Seal Arrangements**

4.2.4.1 **Arrangement 1, 2, and 3 Seals**

There are three seal arrangements, as follows.

— *Arrangement 1*—Seal configurations having one seal per cartridge assembly with process fluid on the outside diameter (OD) of the seal faces.

— *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, using 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 uses 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 (3.1.21); it may use a gas buffer.

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

4.2.4.2 **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 3.1.19).

— *Non-contacting (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 3.1.57).

— *Containment seals (CS), whether contacting or non-contacting*—Seal design with one flexible element, seal ring and mating ring mounted in the containment seal chamber (refer to 3.1.21).

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

4.2.5 **Seal Configurations**

Dual seals can be in the following three configurations:

— face-to-back: refer to 3.1.32;

— back-to-back: refer to 3.1.7;

— face-to-face: refer to 3.1.33;

Refer to Figure 2.

Other configurations such as concentric seals may be agreed by the purchaser and vendor.

5 Requirements

5.1 Units

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

5.2 Seal Qualification

5.2.1 Seal series not previously qualified per API 682 (4th Edition) shall be qualified per seal qualification testing requirements documented in Annex I prior to market availability.

NOTE API 682 (5th Edition) introduced Category 4 seals and expanded seal sizes from API 682 (4th Edition) resulting in additional seal qualification testing requirements. These additional requirements are not intended to be retroactively applied to seal series previously qualified to API 682 (4th Edition) requirements.

5.2.2 **[●]** Purchaser and seal vendor may agree on alternative qualification methods documented in Section I.6.

NOTE An overview of seal qualification and job testing requirements is illustrated in Figure 1.

Seal Manufacturer

Standardized Mechanical Seal Series

Default
Annex I.1 to I.5
* Seal Qualification Test (SQT)
  specific to seal configurations & seal types
  two test sizes
  representative test fluids & test procedures
  seal qualification criteria
  test form
  seal quallification test certificate

Job Seal

Option
Annex I.6
complementary or alternative to SQT
for standardized and customized designs
if approved by purchaser:
* Seal Manufacturer Specific Tests
* Validated Computational Models
* Field Reference Data

Pressure-casing components of Job Seal
Clause 8.3.2.1
except gland plates machined from a single piece of wrought material or bar stock
* Hydrostatic Test

Assembled Job Seal
Clause 8.3.2.2
* Assembly Integrity Test

Assembled Job Seal
Clause 8.3.2.3
* Additional Job Seal Testing
  as agreed between purchaser and seal vendor
  (Not within scope of API 682)

Accessories for Job Seal

Pressure-casing components of Accessories
Clause 8.3.4
* Hydrostatic Test

Pump OEM

Pump Performance Test
Clause 8.3.3
* Installed Job Seal or
* Installed Job Seal with modified Seal Faces or
* Job Seal not installed (test with Shop Seal)

Figure 1—Seal Qualification and Job Testing Overview

5.3 Sealing System Specification and/or Purchase

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 is the pump data, fluid data, and seal specification.

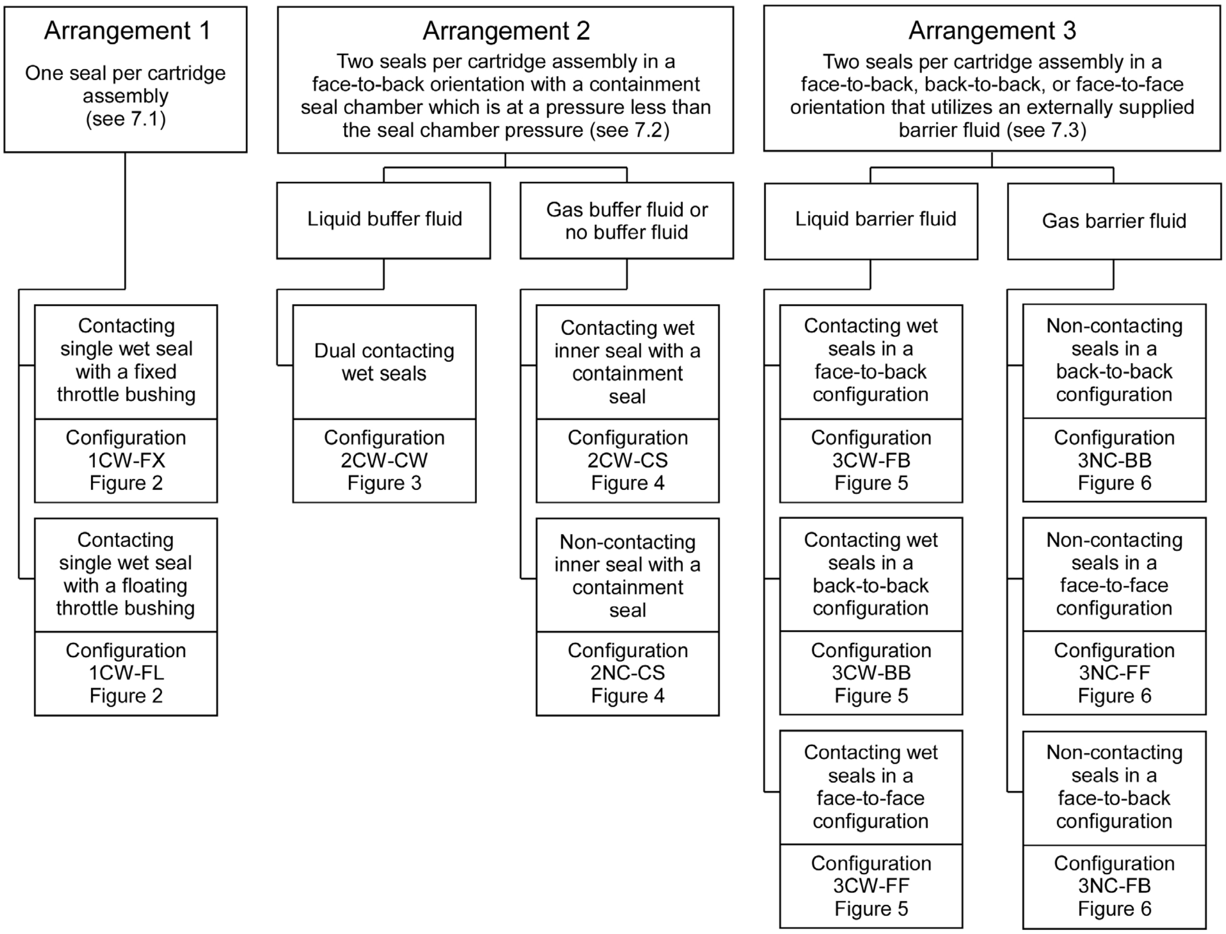
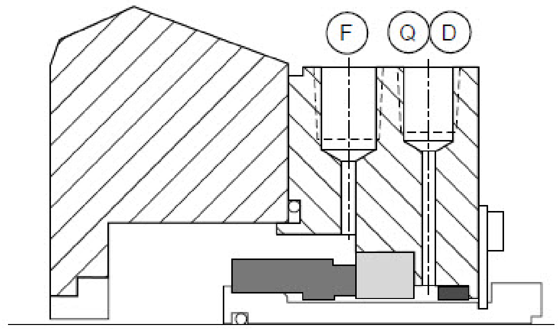
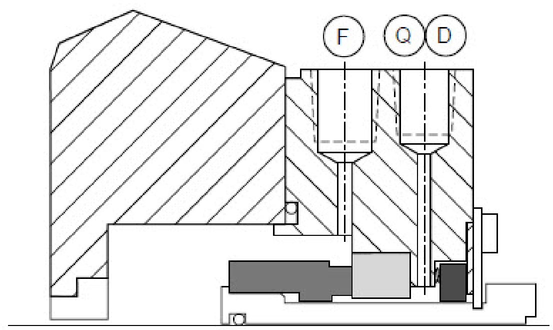


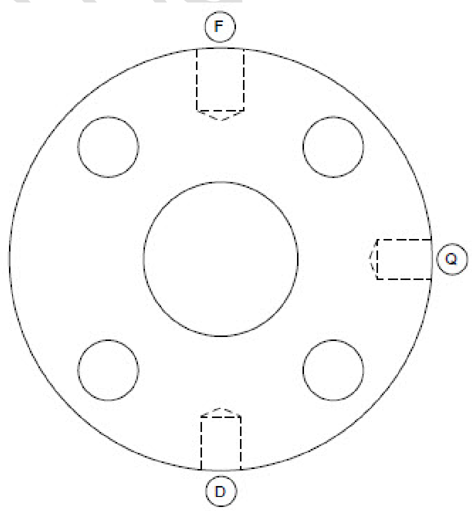
Figure 2—Seal Configurations



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



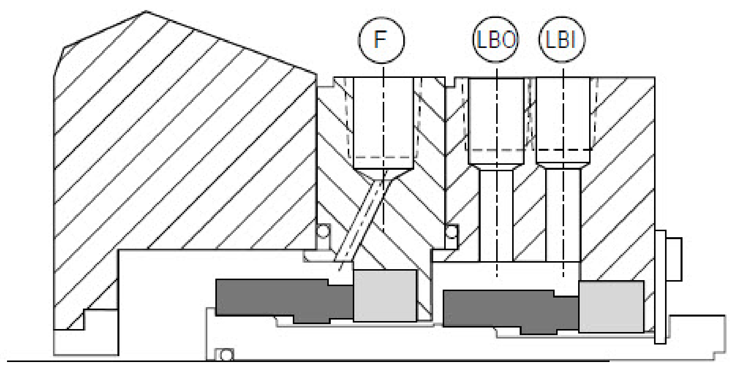
b) 1CW-FL, Contacting Single Wet Seal with a Floating Throttle Bushing



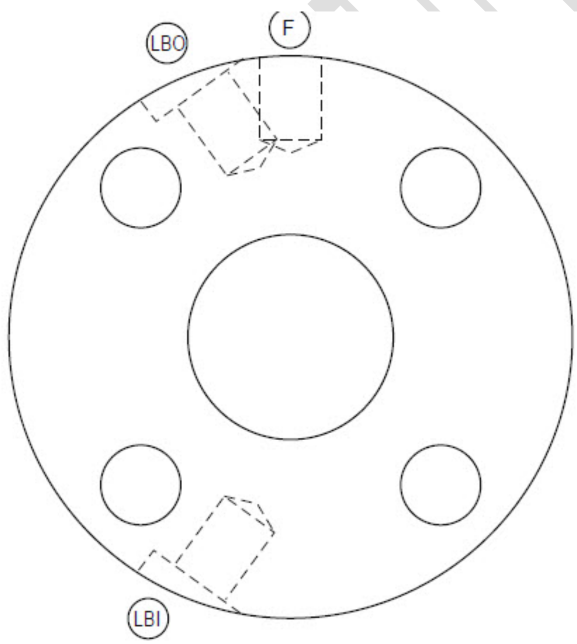
c) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

Figure 3—Arrangement 1: One Seal per Cartridge Assembly



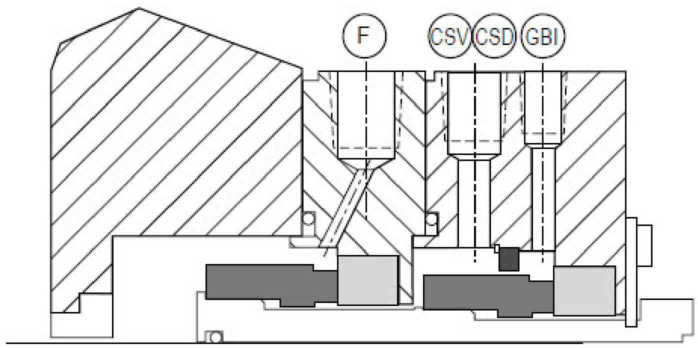
a) 2CW-CW, Dual Contacting Wet Seal



b) Typical Gland Plate Connection Orientation

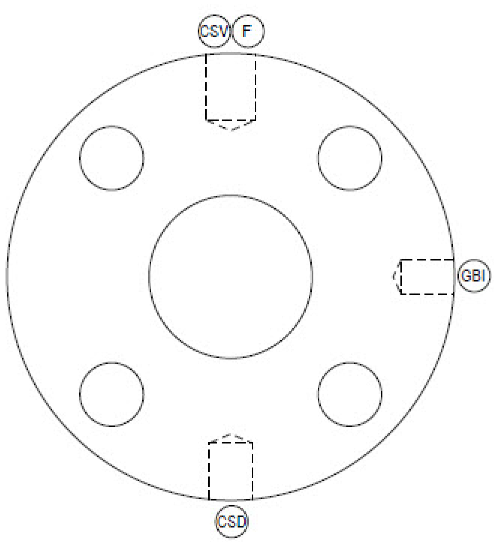
NOTE For connection designations, see Table 2.

Figure 4—Arrangement 2: Two Seals per Cartridge Assembly with a Liquid Buffer Fluid

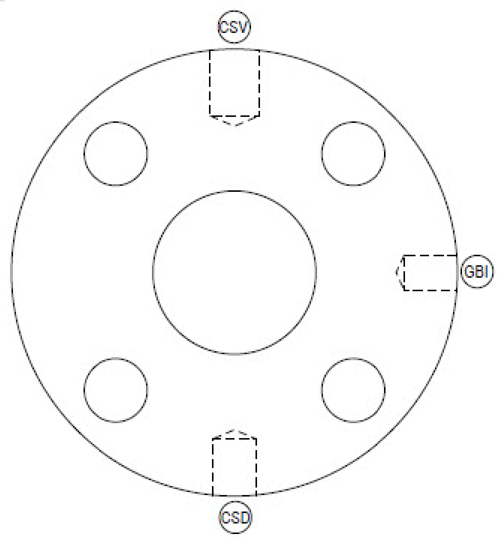


a) 2CW-CS, Contacting Wet Inner Seal with a Containment Seal

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



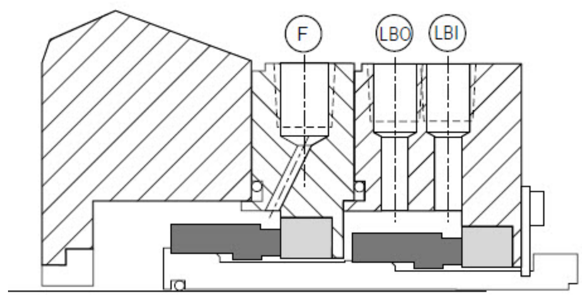
c) Typical Gland Plate Connection Orientation for 2CW-CS



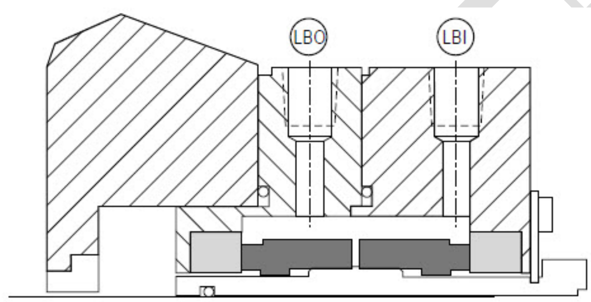
d) Typical Gland Plate Connection Orientation for 2NC-CS

NOTE For connection designations, see Table 2.

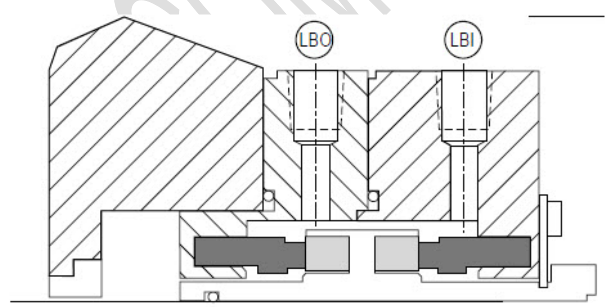
Figure 5—Arrangement 2: Two Seals per Cartridge Assembly with or Without a Gas Buffer Fluid



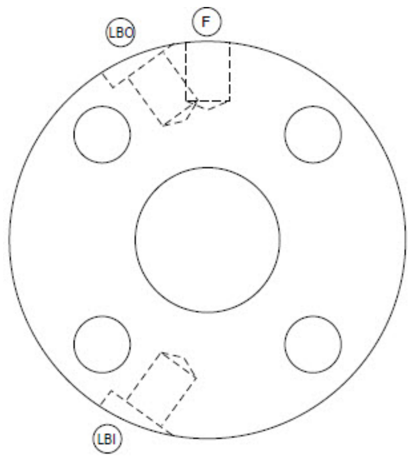
a) 3CW-FB, Contacting Wet Seals in a Face-to-Back Configuration



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



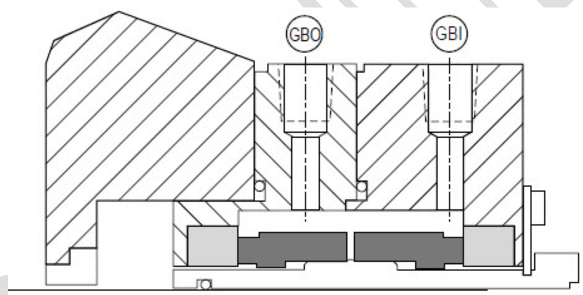
c) 3CW-FF, Contacting Wet Seals in a Face-to-Face Configuration



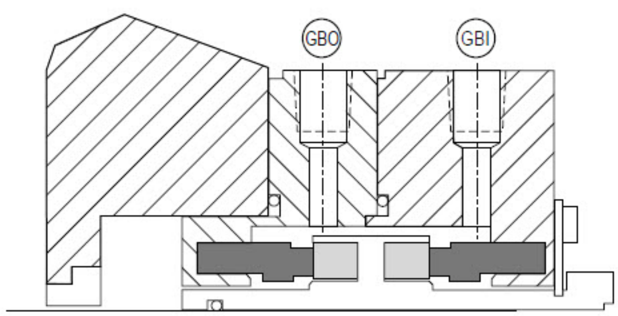
d) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

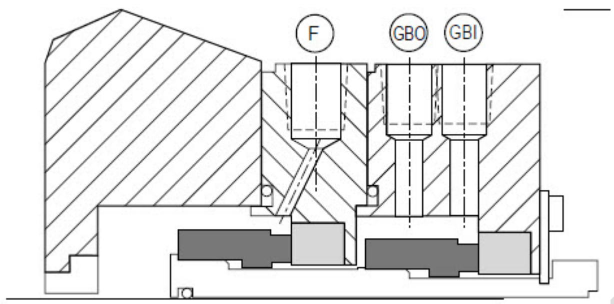
Figure 6—Arrangement 3: Two Seals per Cartridge Assembly with a Liquid Barrier Fluid



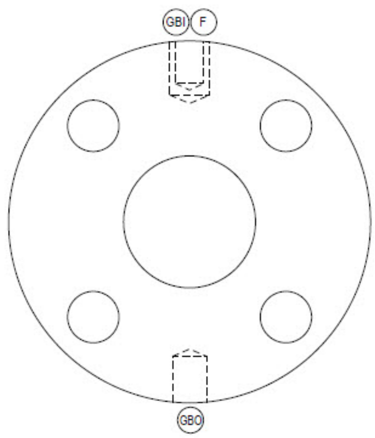
a) 3NC-BB, Non-contacting Seals in a Back-to-Back Configuration



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



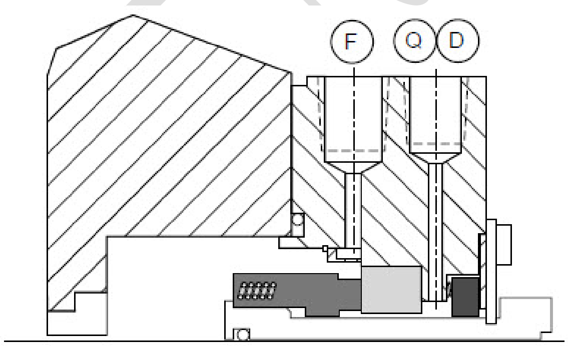
c) 3NC-FB, Non-contacting Seals in a Face-to-Back Configuration



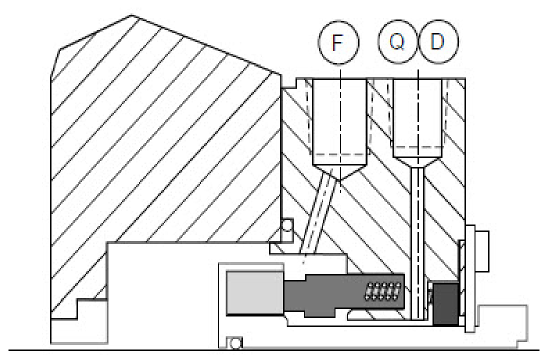
d) Typical Gland Plate Connection Orientation

NOTE For connection designations, see Table 2.

Figure 7—Arrangement 3: Two Seals per Cartridge Assembly with a Gas Barrier Fluid

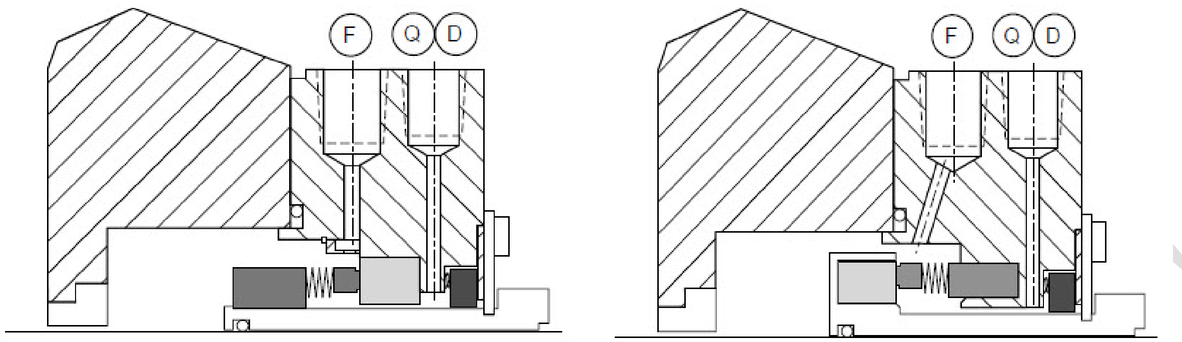


a) Rotating Flexible Element



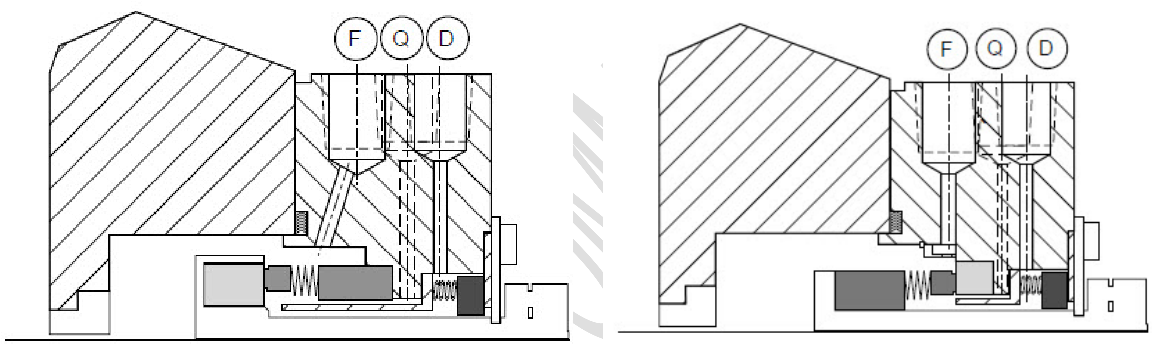
b) Stationary Flexible Element

Figure 8—Arrangement 1 Type A Seals



a) Rotating Bellows Assembly **b) Stationary Bellows Assembly**

Figure 9—Arrangement 1 Type B Seals



a) Stationary Bellows Assembly **b) Rotating Bellows Assembly**

Figure 10—Arrangement 1 Type C Seals

6 Basic Design

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.

NOTE API 610 requires that pumps be designed to enable seal removal without disturbing the driver.

6.1.1.2 Rotating or stationary flexible elements are acceptable for Type A, Type B and Type C seals.

NOTE There are several factors related to the design, manufacture, installation, and repair of the equipment that are 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, Annex A and Annex F.

6.1.1.3 Cartridge seals weighing more than 50 lb (25 kg) shall include lifting points and jacking tap provisions to aid installation and removal.

6.1.1.4 The cartridge seal shall incorporate a setting device 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 should be provided if seal-face surface speed at the mean diameter of the seal face exceeds 4500 ft/min (23 m/s).

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

a) nominal balance diameter exceeds 4.5 in. (115 mm);

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 6.1.3.9 cannot be met

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.

6.1.1.6 The pump and seal manufacturer shall jointly confirm that the seal is capable of handling normal and transient differential axial movement between the rotor and stator seal components.

NOTE 1 For pumps above 330F (165C), during start-up conditions, it is not unusual for a large amount of differential thermal growth to occur between the shaft and casing. Pump Temperature Equalization guidance is available in API RP 697 Pump Repairs.

NOTE 2 Axial movement is also a concern in some vertical pump designs that rely on the motor bearing for thrust positioning (i.e. OH4, OH5 and VS6 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.

6.1.1.7 The seal manufacturer shall design the seal faces such that normal operating wear at the seal faces will not change the seal balance ratio.

6.1.1.8 Split mechanical seals with segmented seal faces shall not be used.

6.1.1.9 O-ring sealing surfaces, including all grooves and bores, shall have a maximum surface roughness (Ra) of 63 µin. (1.6 µm) for static O-rings. The surface against which dynamic O-ring slide shall have a maximum surface roughness of 32 µin. (0.8 µm).

Seal to pump interface sealing diameters shall have a minimum 0.12 in. (3 mm) radius or a minimum 0.06 in. (1.5 mm) 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.

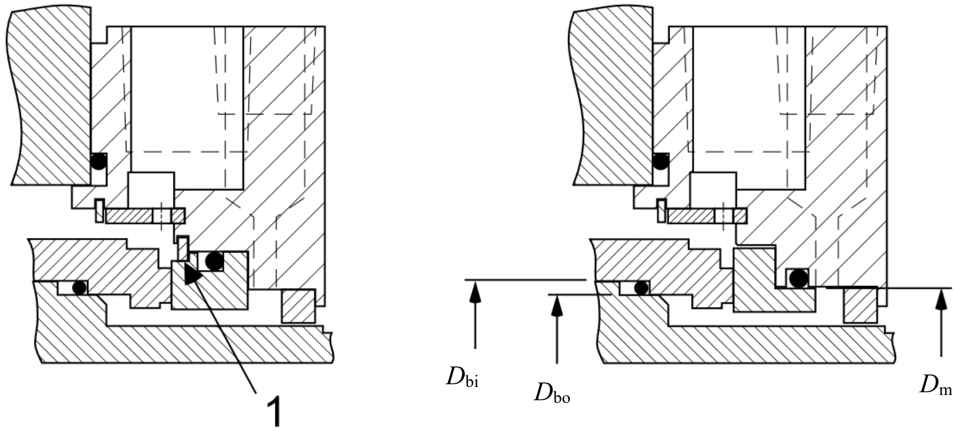
NOTE Lead-in chamfers internal to the cartridge seal can vary from the values specified in this section.

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 11 for examples of such designs). The seal design shall be adequate to seal under vacuum conditions when the pump is not operating (see 6.1.3.14.1 for recommended operating conditions).



Key

1 retaining feature

$D_{bi} \geq D_m \geq D_{bo}$

a) Positive Retention **b) Pressure Retention (with L-shaped Mating Ring)**

Figure 11—Examples of Seal Retention Components in Vacuum Services and Arrangement 3 Inner Seal

6.1.2 Pressure and Temperature Ratings

6.1.2.1 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 MAWP and MAWT 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 and MAWT of the pressure casing in which they are installed.

6.1.2.2 [●] The purchaser shall specify all process conditions on the seal datasheet.

6.1.2.3 Seal selection shall be based on the seal chamber conditions observed at pump normal conditions and function across all pressure and temperature ranges specified on the pump or seal datasheet.

NOTE Optimal mechanical seal selection entails designing the seal for normal process conditions, while ensuring the seal will survive when exposed to the MSSP and MDSP requirements. Good alignment between pump vendor, seal manufacturer and purchaser is important to prevent a compromised seal selection. This does acknowledge that although the seal will function at specified extreme pressure and temperature conditions, leakage rates may be higher and service hours may be lower than those at normal conditions.

6.1.2.4 Pump vendor shall define the minimum and maximum expected seal chamber pressure and temperature conditions when the pump shaft is rotating (through start-up and normal operating conditions). These pressures shall consider pump type / arrangement, pump internal clearances, and pump minimum / maximum suction and discharge pressures.

6.1.2.5 Seal manufacturer shall define the minimum and maximum pressure and temperature conditions at the seal faces when the pump shaft is rotating (through start-up and normal operating conditions). These pressures shall consider expected piping plans, flushing rates, and seal chamber pressure and temperature.

6.1.2.6 The static seal pressure rating shall be equal to or greater than the MSSP.

6.1.2.6.1 For Arrangement 1 seals, the MSSP shall be the highest discharge pressure for any of the respective operating case (normal, rated or alternate) on the pump or seal data sheet.

6.1.2.6.2 For Arrangement 2 seals, the inner seal MSSP shall be the highest discharge pressure for any of the respective operating case (normal, rated or alternate) on the pump or seal data sheet.

6.1.2.6.3 For Arrangement 2 seals, the outer seal MSSP shall be the maximum expected seal chamber pressure for any process condition specified on the pump data sheet.

6.1.2.6.4 For Arrangement 3 seals, the inner seal MSSP shall be the differential between maximum barrier fluid pressure and minimum static seal chamber pressure.

NOTE The maximum differential pressure the inner seal is exposed to is typically the differential between maximum barrier fluid pressure and atmospheric pressure for positive pressure pump applications. For sub-atmospheric pump applications it is important to consider the sub-atmospheric pressure conditions when defining the maximum differential pressure the inner seal will be exposed to.

6.1.2.6.5 For Arrangement 3 seals, the outer seal MSSP shall be the greater of maximum barrier fluid pressure or the highest discharge pressure for any of the respective operating case (normal, rated or alternate) on the pump or seal data sheet.

NOTE Depending on the inner and outer seal arrangements, it may be acceptable to have the inner and outer seal ratings equivalent.

6.1.2.6.6 [●] If specified by purchaser, vendor shall use alternative maximum static sealing pressure (MSSP) requirements specified for the specific application.

NOTE 1 The primary premise for the default MSSP requirements are parallel pump configurations where one of the pumps is a stand-by pump. If the suction valve on the stand-by pump is closed, the pump casing can be pressurized up to discharge header pressure due to discharge check-valve leakage or bypass.

NOTE 2 For stand-alone pump configurations, high discharge pressure pump applications or in applications where specific pressure and temperature conditions may limit the use of available seal designs, it may be advantageous for the purchaser to consider specifying a lower MSSP by leveraging alternative engineering solutions or administrative controls.

NOTE 3 For applications where the seals will normally operate at discharge pressure, the purchaser may default to an MSSP that is greater than the pump normal/rated discharge pressure. This may also be the case for applications where maximum suction pressure and pump shut-off pressure can occur from a single initiating event.

6.1.2.7 The dynamic seal pressure rating shall be equal to or greater than the MDSP.

6.1.2.7.1 For Arrangement 1 seals, the MDSP shall be as specified in Paragraphs 6.1.2.4 and 6.1.2.5.

6.1.2.7.2 For Arrangement 2 seals, the inner and outer seal MDSP shall be as specified in Paragraphs 6.1.2.4 and 6.1.2.5.

NOTE In the case of Arrangement 2 seals (wet or dry), the outer seal will normally be exposed to different fluid, pressure and temperature conditions than the inner seal. When exposed to the inner seal conditions, it is acknowledged the outer seal leakage rates may be higher and service hours may be lower than those at the outer seal normal sealing conditions.

6.1.2.7.3 For Arrangement 3 seals, the inner seal MDSP shall be the differential between the maximum barrier fluid pressure and minimum dynamic seal chamber pressure (through start-up and normal operating conditions).

6.1.2.7.4 For Arrangement 3 seals, the outer seal MDSP shall be the maximum expected barrier fluid pressure.

6.1.2.8 The seal manufacturer shall advise if it would be advantageous for Purchaser to consider alternative engineering / administrative controls to reduce the required sealing pressure.

NOTE: In certain pump applications, selecting the seal to meet the maximum static and dynamic sealing pressure requirements may result in compromised seal operation at normal operating conditions. In such cases it may be advantageous to leverage alternative administrative or engineering controls to lower the maximum required sealing pressure. Such alternatives may include suction pressure relief valves, suction and discharge valve permissives, administratively locking suction valves open, etc.

6.1.2.9 The MSSP and MDSP, along with the static and dynamic seal pressure ratings, shall be stated on the API-682 mechanical seal drawing.

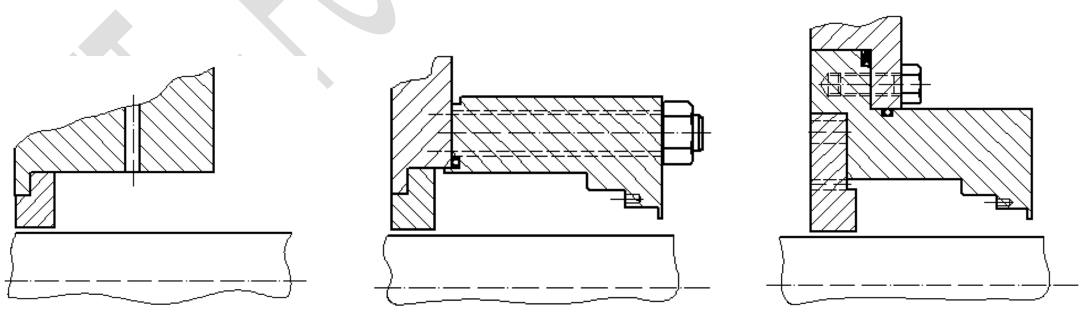
6.1.2.10 The static and dynamic reverse pressure rating shall be documented on the seal drawing for seal arrangements 3CW-FF and 3CW-BB seals.

6.1.3 **Seal Chambers and Gland Plates**

6.1.3.1 Gland plates shall be provided by the seal manufacturer.

6.1.3.2 Seal chambers shall be provided by the pump manufacturer.

6.1.3.3 Seal chambers are one of three types: traditional (cylindrical or taper), externally mounted, or internally mounted. Seal chambers are not required to accommodate packing. Figure 12 shows the three types of seal chamber.



a) Traditional **b) Externally Mounted** **c) Internally Mounted**

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 12—Seal Chamber Types

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

6.1.3.5 [●] If specified, a traditional (taper), internally mounted or externally mounted bolt-on seal chamber shall be provided by the seal manufacturer (Figure 12).

6.1.3.5.1 Category 1 seal chambers shall be designed to the dimensional envelope defined by ASME B73.1 and ASME B73.2.

6.1.3.5.2 Other than Category 1 seal chambers shall be designed to the dimensional envelope of API 610.

NOTE 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.

6.1.3.6 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 (CW), the minimum diametral clearance between the rotating components of the seal and the stationary surfaces of the seal chamber and gland plate shall be 0.25 in. (6 mm) 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 non-contacting 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 0.125 in. (3 mm). 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 6.1.3.6 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 ASME 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 ASME B73.1 and ASME 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 ASME B73.1 and ASME 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	6 mm (0.25 in.)	6.1.3.6.a)
		NC seal type	3 mm (0.125 in.)	6.1.3.6 b)
ID stationary seal part	OD rotating seal part	shaft ≤ 60 mm 60 mm < shaft ≤ 110 mm shaft > 110 mm	1 mm (0.039 in.) 2 mm (0.079 in.) 3 mm (0.125 in.)	6.1.3.6 c)
ID stationary gland part	OD internal circulation device	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in.) 2 mm (0.079 in.)	6.3.1.2.7
ID containment fixed bushing 2CW-CS, 2NC-CS	OD rotating seal part	shaft ≤ 60 mm	1 mm (0.039 in.)	6.3.2.4.1
		shaft > 60 mm	2 mm (0.079 in.)	6.3.2.5.1
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 126 mm to 150 mm 151 mm to 175 mm	0.18 mm (0.007 in.) 0.225 mm (0.009 in.) 0.28 mm (0.011 in.) 0.33 mm (0.013 in.) 0.38 mm (0.015 in.)	6.1.3.23
ID fixed throttle bushing	OD rotating sleeve	20 mm to 50 mm 51 mm to 75 mm 76 mm to 100 mm 101 mm to 125 mm 126 mm to 150 mm 151 mm to 175 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.) 1.143 mm (0.045 in.) 1.270 mm (0.050 in.)	6.1.3.22
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).				

6.1.3.7 For Category 1 seals, all bolt and stud stresses shall be in accordance with ASME B73.1 or 73.2. For Category 2, Category 3 and Category 4 seals, all bolting and stud stresses shall be in accordance with API 610 clause on mechanical shaft seals.

6.1.3.8 The MAWP and MAWT of the seal chamber and gland plates 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.

6.1.3.8.1 The seal chamber and gland plates shall be manufactured from a corrosion resistant material that matches or exceeds the corrosion resistance of the pump casing material.

6.1.3.8.2 The seal chamber and gland plates shall have sufficient rigidity to avoid any distortion that would impair seal operation, including distortion that may occur during tightening of the bolts.

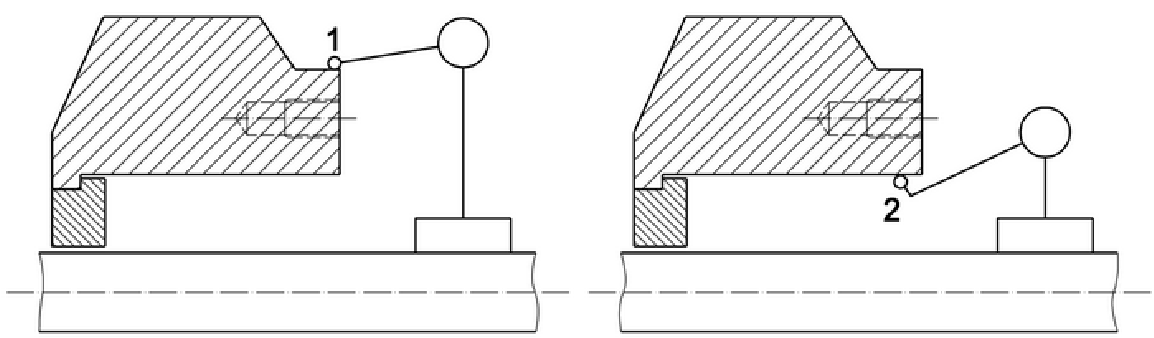
6.1.3.8.3 Seal gland plates shall be provided with holes (not slots) for attachment studs.

6.1.3.8.4 [●] If seal gland plate slots are specified, hardened washers shall be supplied for the seal gland plate.

NOTE In some applications, seal gland plates are provided with vertical slots.

6.1.3.8.5 Seal gland plate stud holes shall be sized according to ASME B18.2.8 LOOSE fit class or ISO 273 COARSE fit class.

6.1.3.8.6 The seal gland plate and/or chamber shall be centered with either an inside- or an outside-diameter register fit. The register fit shall be concentric to the shaft and shall have a total indicated runout (TIR) of not more than 0.005 in. (0.125 mm), see Figure 13. The fit shall be H7/f7 in accordance with ISO 286-2.



Key

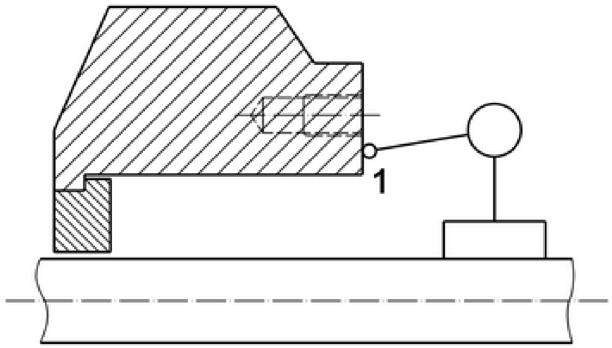
1 location of outside diameter measurement

2 location of inside diameter measurement

Figure 13—Seal Chamber Register Concentricity

6.1.3.9 The seal manufacturer shall design for seal chamber face runout (TIR) as defined by the applicable pump standard, see Figure 14.

NOTE 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.



Key

1 location of face runout measurement

Figure 14—Seal Chamber Face Runout

6.1.3.9.1 A shoulder shall be provided integral to the seal gland plate to support the axial load generated by the seal chamber pressure.

6.1.3.10 Stress values used in the design of the seal gland shall be in accordance with the design factors for pressure casings as stated in API 610.

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

6.1.3.12 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.

6.1.3.13 Threading details for bolting pressure casing components 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.

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

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

6.1.3.13.2 A manufacturer's marking shall be located on all fasteners 0.25 in. (6 mm) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

6.1.3.14 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 6.1.3.1.1 and 6.1.3.14.2. If the seal chamber conditions do not meet the specified margins, the seal manufacturer shall:

a) confirm the adequacy of the seal selection and piping plan based on the specified fluid;

b) recommend the seal chamber operating conditions (minimum pressure and maximum temperature)

c) consider furnishing the seal gland plate or seal chamber with a second flush connection to permit measurement of seal chamber pressure directly; and

d) consider furnishing a distributed flush system unless space limitations preclude its use.

e) consider using hydrodynamic seal face features to allow for operation with lower vapor pressure margins.

NOTE Refer to F.1.4 for specific recommendations.

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

6.1.3.14.2 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 6.1.3.14.2 a). If it is not possible to achieve this margin the criteria in 6.1.3.14.2 b) shall be met.

a) Not less 50 psi (0.35 MPa) (3.5 bar).

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.

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

6.1.3.16 [●] If specified, or if recommended by the seal manufacturer, close-clearance floating throat bushings shall be used to improve seal performance. The bushing materials, configuration and clearances shall be suitable for the service and approved by the purchaser.

NOTE 1 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 Section F.5.3 for additional guidance concerning the use of throat bushings.

NOTE 2 The effectiveness of the close-clearance floating bushing may be compromised by existing internal vents and drains in the seal chamber. The effectiveness of the bushing may be improved by plugging these holes.

6.1.3.17 Datasheet-specified gland plate and seal chamber connections shall be identified by symbols permanently marked (e.g. stamped or cast) on the component.

6.1.3.18 The symbol, size, and location in Table 2 shall be used to locate ports and tapped holes in the seal chamber and gland plate. (See Figure 2 through Figure 10 for the relative axial position of the process and atmospheric connections)

6.1.3.18.1 Where appropriate, the letters “I” and “O” (marking In and Out) shall be used in conjunction with these markings.

6.1.3.18.2 For horizontal pumps, 0° is vertical on top.

6.1.3.18.3 For vertical pumps, the location of the flush (marked with letter “F”) connection defines 0° (see Figure 3 to Figure 7).

6.1.3.18.4 If tangential porting is used, the location of the drilled port into the seal chamber shall comply with Table 2. Tapped connections can be located at a different angle than the seal gland ports.

6.1.3.18.5 If the specified connection size or location cannot comply with Table 2, the seal supplier and purchaser shall agree on tapped connections, porting sizes and locations. These connections could be on the pump and in the pump manufacturer’s scope of supply. The dimension from the face of the seal chamber to the port centerline will be noted on the seal drawing.

NOTE Annex E specifies the interface responsibilities of the pump and seal vendors.

6.1.3.19 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.

6.1.3.20 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 0.125 in. (3 mm) 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 15). 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.

e) Venting of the seal chamber for Arrangement 3 non-contacting 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.

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

Seal Config.	Symbol	Connection	Port Location [h]	Type	Minimum Size [a]		Connection Required [f]
					Cat. 1	Cat. 2, 3 & 4 [i]	
1CW-FX	F	flush	0	process	1/2 [c]	1/2	required
1CW-FL	FI	flush in (Plan 14 & 23 only)	180	process	1/2 [c]	1/2 [d]	WS
	FO	flush out (Plan 14 & 23 only)	0	process	1/2 [c]	1/2 [d]	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 [d]	WS
	FO	flush out (Plan 23 only)	0	process	1/2 [c]	1/2 [d]	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	F	flush (seal chamber)	0	process	1/2	1/2	WS
3CW-FF	LBI	liquid barrier fluid in	180	barrier	1/2 [d]	1/2 [d]	required
3CW-BB	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	F	flush (seal chamber)	0	process	1/2	1/2	WS
3NC-BB	GBI	gas barrier fluid in	0	barrier	1/4	1/4	required
3NC-FB	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 0.375 NPT connection may be used if 0.5 NPT is not possible because of space constraints.
d. 0.5 NPT required for shaft diameters 2.5 in. (60 mm) or smaller, 0.75 NPT for larger shaft sizes.
e. A 0.25 NPT connection may be used if 0.375 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.
h. With purchaser approval, the port location may be relocated to a different angle when necessitated by restriction in the pump or piping plan. (reference 6.1.3.18.5)
i. Ports may be larger than noted in this table on some Category 4 applications. These require engineering assessment.

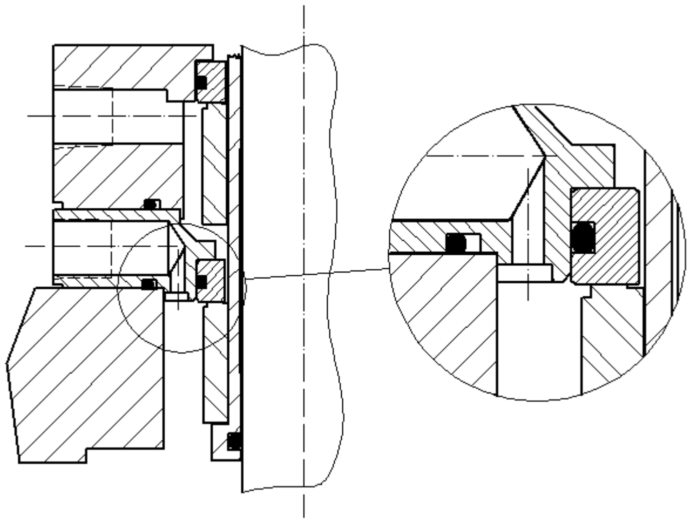


Figure 15—Seal Chamber/Gland Plate for Vertical Pumps

6.1.3.21 Drilled passages shall be sized for the application and shall have a minimum diameter of 0.188 in. (5 mm).

6.1.3.22 The diametral clearance at a fixed throttle bushing (see 3.1.35) bore shall not be more than specified in Table 1.

6.1.3.23 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 diametral 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.

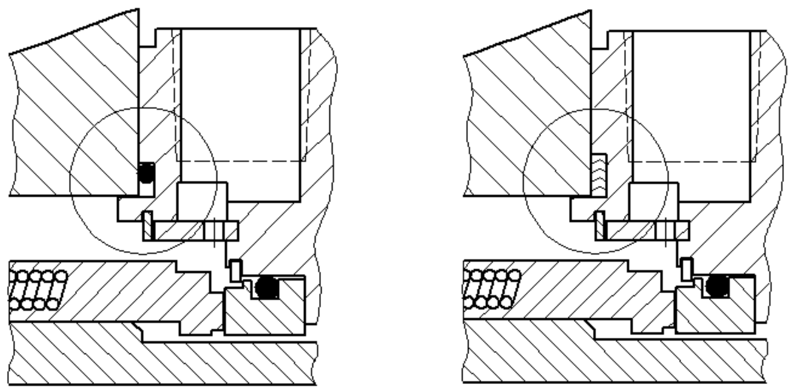
6.1.3.24 [●] If specified, heating jackets or inserts shall be provided on seal chambers. Heating requirements shall be agreed between the purchaser, vendor and seal manufacturer.

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.

6.1.3.25 Gaskets for the gland plate or plates shall be designed for the maximum operating pressure and temperature and the following requirements.

6.1.3.25.1 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 16).

6.1.3.25.2 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.



a) O-ring **b) Spiral-wound Gasket**

Figure 16—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.

6.1.3.25.3 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.

6.1.3.25.4 Where space or design limitations make this requirement impractical, an alternative seal gland plate design shall be submitted to the purchaser for approval.

6.1.3.25.5 The pump manufacturer shall provide gland bolt torque specification to the user.

NOTE API RP 697 Pump Repairs Annexes include recommended torque values for metal-to-metal joints.

6.1.4 **Cartridge Seal Sleeves**

6.1.4.1 Seal sleeves shall be furnished by the seal manufacturer. The sleeve shall be made of one piece. (See 6.1.4.10 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.

6.1.4.2 The pump manufacturer shall provide the shaft diameter and tolerance to the seal manufacturer. If not provided, the seal manufacturer shall ask for it.

6.1.4.2.1 The seal manufacturer shall ensure a shaft-to-sleeve fit in accordance with ISO 286-2 as detailed Table 3. The intent of this requirement is to minimize sleeve runout (see Figure 17), while allowing for ease of installation and removal.

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

Table 3: Shaft to Seal Sleeve Fits

Shaft Diameter		Sleeve
mm	in.	
20 to 110	0.750 to 4.312	F7
>110 to 150	>4.312 to 6.000	F8

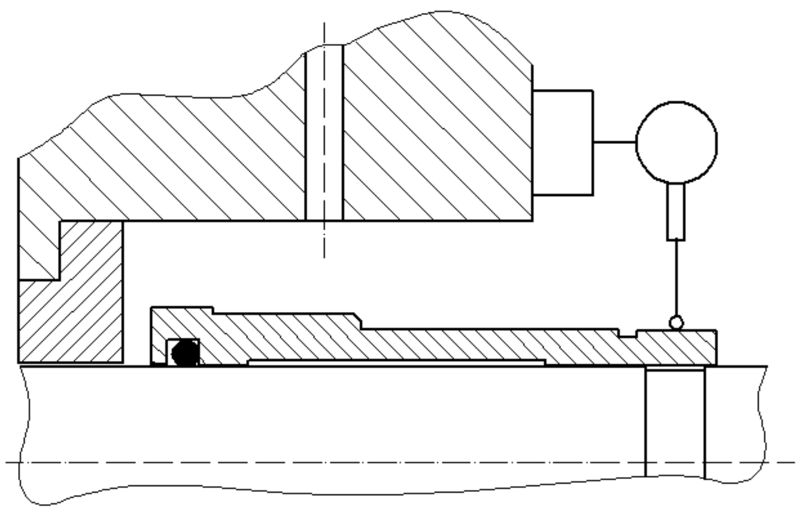


Figure 17—Seal Sleeve Runout

6.1.4.2.2 If the shaft diametral tolerance differs from h6, the seal manufacturer shall agree to the shaft to seal sleeve fit tolerance with the purchaser.

NOTE API 682 standard shaft to sleeve fit is based on a shaft diameter tolerance of h6; however, special cases may exist in which pumps are supplied with different shaft diameter tolerances.

6.1.4.2.3 Shrink disks typically require tighter clearances for seal face surface speeds greater than 4500 ft/min (23 m/s). Shrink-disk fits shall be per the shrink disk manufacturer's design criteria (see paragraph 6.1.4.16).

6.1.4.3 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.

6.1.4.4 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.

6.1.4.5 Shaft-to-sleeve O-ring seals shall be located as close as practicable to the impeller end of the sleeve.

6.1.4.5.1 For shafts that require the O-ring to pass over the threads, at least 0.063 in. (1.6 mm) radial clearance shall be provided between the threads and the internal diameter of the O-ring.

6.1.4.5.2 The diameter transition shall be radiused or chamfered (see 6.1.1.9) to avoid damage to the O-ring.

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

6.1.4.6 Non-elastomeric 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.

6.1.4.7 Sleeves shall have a minimum radial thickness of 0.10 in. (2.5 mm) at their thinnest section, excluding a local feature such as a setting device groove or a hole which does not compromise the dimensional integrity of the sleeve. The sleeve thickness in the area of component drive set screws shall be in accordance with Table 4.

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

Table 4—Minimum Sleeve Thickness in the Area of Component-drive Set Screws

Shaft Diameter		**Minimum Sleeve Radial Thickness**	
mm	in.	mm	in.
20 to 60	0.750 - 2.375	2.5	0.100
> 60 to 80	> 2.375 to 3.250	3.8	0.150
> 80 to 110	> 3.250 to 4.312	5.0	0.200
> 110 to 150	> 4.312 to 6.000	6.0	0.250

6.1.4.8 The seal sleeve shall be machined and finished throughout its length such that the total runout between the bore and outside diameter does not exceed 0.001 in. (25 µm) TIR.

6.1.4.9 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.

6.1.4.10 Where possible seal sleeves shall be designed as one piece.

6.1.4.10.1 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.

6.1.4.10.2 The auxiliary sleeve shall be axially located on the seal sleeve by positive means as specified in 6.1.4.3.

6.1.4.10.3 Auxiliary sleeves shall not extend beyond the seal sleeve. See Figure 18 for an illustration of an auxiliary sleeve.

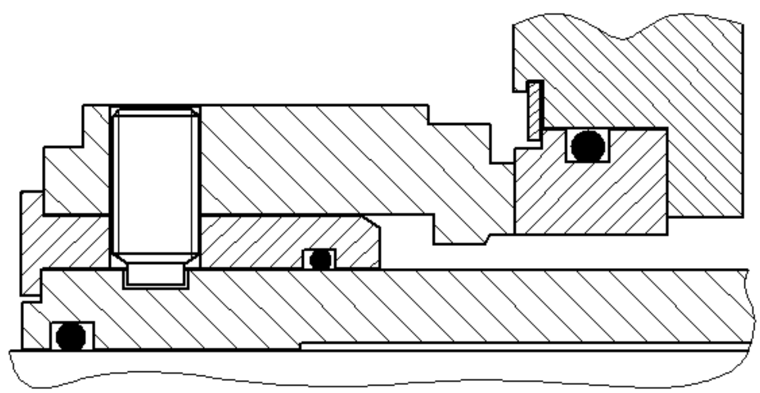


Figure 18—Example Auxiliary Sleeve Arrangement

6.1.4.11 Drive-collar set screws shall not pass through clearance holes unless the sleeve bore has a relief groove. For between-bearing pumps, the shaft shall be relieved in the set screw 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.

6.1.4.12 Drive-collar set screws shall be harder than the shaft.

NOTE Reference Table F.2 and Table F.3 for typical hardness ranges for pump shafts and set screws.

6.1.4.13 For all Categories, the drive collar and set screw arrangement shall be able to maintain position under the loads generated by a minimum of 150% of the greater of MSSP or MDSP according to 6.1.2.6 and 6.1.2.7.

6.1.4.14 For Category 1, 2 and 3 seals the drive collar and set screw arrangement shall also be able to maintain position under the loads generated by a minimum of 150% of the maximum pressure rating of the seal category according to 4.1.2.

NOTE 1 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.4 for calculation details.

NOTE 2 A seal could have internal clearances that may result in some minor deflection under loads.

6.1.4.15 Designs using more than 12 set screws to drive and/or axially position the sleeve require purchaser approval.

6.1.4.16 [●] 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 19) or a split ring engaging a groove in the shaft (see Figure 20).

NOTE Use of these designs avoids shaft damage by dimpling the shaft for set screws when high thrust loads exist on the sleeve.

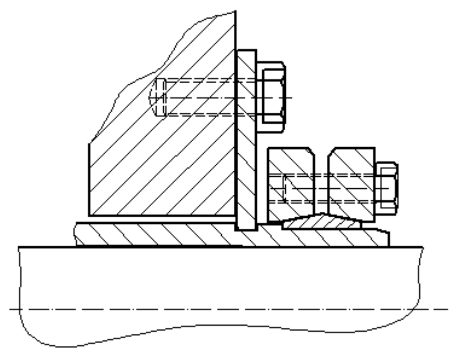


Figure 19—Seal Sleeve Attachment by Shrink Disk

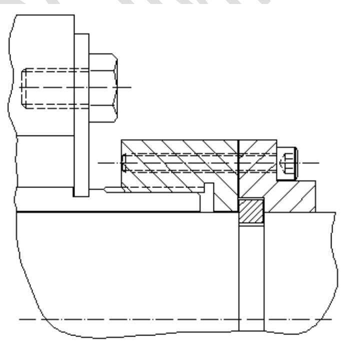


Figure 20—Seal Sleeve Attachment by Split Ring

6.1.5 **Mating Rings**

6.1.5.1 Anti-rotation devices shall be designed to minimize distortion of the seal faces. Clamped faces shall not be used unless approved by the purchaser (see Figure 21).

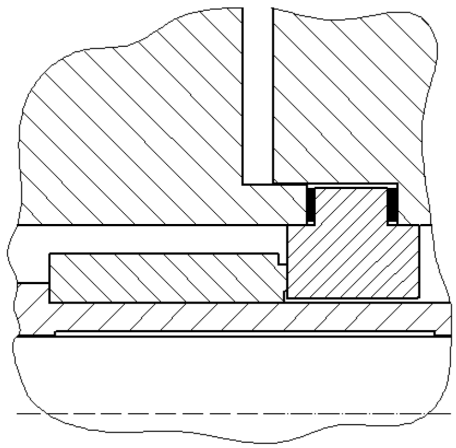


Figure 21—Clamped Faces

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

6.1.5.2 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.

6.1.6 **Flexible Elements**

6.1.6.1 [●] The flexible element of a Type A seal shall be a multiple spring design. If specified, a single-spring Type A seal can be furnished by the seal manufacturer.

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 0.25 in. (6 mm) to 0.5 in. (13 mm) 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 Single spring designs are more resistant to clogging when compared to multiple spring designs.

NOTE 4 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.

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

NOTE 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.

6.1.7 **Materials**

6.1.7.1 **General**

6.1.7.1.1 Seal components shall be furnished with the materials referenced in 6.1.7.2 to 6.1.7.9.

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. See *NACE Corrosion Engineer's Reference Book* for one source of suitable materials.

NOTE 2 Material selection can vary depending on the function of the part and its proximity to, or contact with, the process fluid. Thus, it is not uncommon in corrosive services for dual seals to have different material used for components in the outer part of the seal that are not wetted by the process fluid.

6.1.7.1.2 Superior or alternative materials recommended for the service by the seal manufacturer shall be stated in the proposal.

6.1.7.1.3 Materials identified in the proposal other than those specified in this standard shall be identified with their applicable specification numbers (e.g. ISO, EN, ASTM, etc.) and the material grade. If no such designation exists, the manufacturer's material specification, giving physical properties, chemical composition, and test requirements, shall be made available upon request.

6.1.7.2 **Seal Faces**

6.1.7.2.1 Seal face materials shall be in accordance with 6.1.7.2.2 through 6.1.7.2.6.

NOTE There are many face materials available, each having relative benefits and disadvantages. No material or material combination is excluded simply from the fact that it is not specifically mentioned, consult the seal manufacturer for the best face combination in a specific service.

6.1.7.2.2 Except as required by 6.1.7.2.4, one of the rings shall be resin or antimony impregnated carbon graphite. The manufacturer shall state the type of carbon graphite offered for each service.

6.1.7.2.3 [●] For all seal categories the material for one of the rings shall be reaction-bonded silicon carbide (RBSiC) or self-sintered silicon carbide (SSSiC), depending on the chemical compatibility and recommendation by the seal vendor. The manufacturer shall state the type of silicon carbide offered for each service.

NOTE See Section B.2.3 for guidance related to manufacture and use of RBSiC versus SSSiC.

6.1.7.2.4 Abrasive, viscous, and high-pressure services may require two hard materials. For such services, the default material for both the seal ring and the mating rings shall be silicon carbide. Other hard face combinations of SSSiC, RBSiC, and graphite loaded SSSiC, graphite loaded RBSiC, or tungsten carbide are widely used and are acceptable with purchaser approval.

NOTE See Section B.2.4 for guidance regarding the selection of optimum hard face-material combinations.

6.1.7.2.5 Seal and mating rings shall be of homogeneous material, except that inherently wear-resistant materials such as silicon carbide or tungsten carbide may be enhanced by applying a coating (e.g., diamond coatings). Overlays or coatings shall not be used as the sole means of providing wear resistance.

NOTE Temperature limitations for seal-face materials are listed in Section B.2.1.

6.1.7.2.6 The seal manufacturer shall advise if the specified face material combination may not be suitable for performance testing of the pump on water. If so, the seal manufacturer shall recommend alternative materials for use during pump performance testing.

6.1.7.3 **Seal Sleeves**

Seal sleeves shall be stainless steel [Austenitic Stainless Steel Type 316, 316L, or 316Ti, or equivalent (see B.1)]. Sleeves for alloy pumps in corrosive services shall be of the same alloy as the casing, or one with superior corrosion resistance.

6.1.7.4 **Springs**

Seals with multiple coil-springs shall have Alloy C-276 or Alloy C4 spring material or springs with superior corrosion resistance or mechanical strength for the specified application (see Table B.2). Single coil-springs shall have Austenitic stainless-steel Type 316 stainless steel spring material or one with superior corrosion resistance or mechanical strength for the specified application (see Table B.2).

NOTE Cross-section thickness of the spring is taken into consideration when selecting spring materials. Heavier cross-section springs, such as those found in single-spring seals, are not as prone to stress corrosion cracking as the thinner cross-section type found in multiple-spring seals. For example, Alloy C-276 is the material most suited to multiple-spring seals, whereas Austenitic stainless steel Type 316 stainless steel may be just as suitable in the same service using a single spring.

6.1.7.5 **Secondary Seals**

6.1.7.5.1 The default O-ring material shall be FKM.

NOTE Temperature limitations, chemical and mechanical compatibility for elastomers is discussed in Annex B.

6.1.7.5.2 If operating temperatures or chemical compatibility preclude the use of FKMs, the purchaser and vendor shall agree on secondary seal material selections for the specified process conditions.

NOTE See Annex B for additional details.

6.1.7.5.3 Seal manufacturers shall use elastomer material type and grade selections based on successful prior use in the refining, chemical, or pipeline industry. Similar grades and types as used in qualification testing, with the same nominal durometer in the dynamic secondary seal location may be substituted without additional qualification testing as specified in Annex I.

6.1.7.5.4 If the temperature, chemical or mechanical limitations of elastomers have been exceeded, secondary seals shall be flexible graphite.

6.1.7.5.5 If used as a core component per Annex I, a mechanically energized polymeric secondary seal can be provided if agreed to by the vendor and purchaser.

6.1.7.6 **Metal Bellows**

Metal bellows shall be Alloy C-276 for Type B seals and Alloy 718 for Type C seals. If recommended by the seal vendor and agreed to by the purchaser, Alloy 718 may also be used for Type B seals.

NOTE This requirement only applies to the bellows core (the flexible diaphragms).

6.1.7.7 **Gland Plates**

6.1.7.7.1 Gland plates shall be stainless steel [Austenitic Stainless Steel Type 316, 316L, or 316Ti, or equivalent (see Section B.1)]. Gland plates for alloy pumps in corrosive services shall be of the same alloy as the casing, or one with superior corrosion resistance.

6.1.7.7.2 [●] The gland plate to seal chamber gasket shall be an O-ring for services below 350 °F (175 °C) of the same material required by 6.1.7.5.1 and 6.1.7.5.2. For temperatures over 350 °F (175 °C) or if specified, graphite-filled type Austenitic Stainless Steel Type 304 or Austenitic Stainless Steel Type 316 stainless steel spiral-wound gaskets shall be used.

NOTE Spiral-wound gaskets have bolt torque requirements for full compression. See 6.1.3.7 for bolting requirements for spiral-wound gaskets.

6.1.7.7.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (UNS N04400) alloy. Stamp top of seal gland with rotation arrow for between bearing pumps that have unidirectional seals. Attachment pins shall be of the same material. Welding shall not be permitted.

6.1.7.8 **Bolt-on Seal Chambers**

6.1.7.8.1 Bolt-on seal chambers for alloy pumps shall be of the same alloy as the casing, or one with superior corrosion resistance and mechanical properties. Seal chambers for other pumps shall be stainless steel [Austenitic Stainless Steel Type 316, 316L, or 316Ti, or equivalent (see Section B.1)].

NOTE 1 Bolting is typically included in the pump vendor scope of supply.

NOTE 2 The user should consider thermal expansion properties of the materials to avoid stress or gasket-related problems if bolt-on chambers are supplied for high-temperature services in material dissimilar to that of the pump or attachment stud.

6.1.7.8.2 Chamber-to-casing gasket material requirements shall conform to 6.1.7.7.2.

6.1.7.9 **Miscellaneous Parts**

6.1.7.9.1 Spring-retaining components, drive pins, anti-rotation pins, and internal set screws shall have strength and corrosion resistance equal to or better than AISI Type 316 stainless steel (see Section B.1).

6.1.7.9.2 The pump and seal vendors shall ensure that outside drive components have suitable corrosion resistance for the service (see Section F.3). See also 6.1.4.12 thru 6.1.4.14.

6.1.7.10 **Welding**

6.1.7.10.1 If required, welding shall comply with the Welding Section requirements of API 610.

6.1.7.10.2 Metal bellows used are exempted from welding requirements because they are manufactured using a proprietary welding process that is not covered by general welding codes or industry standards.

6.1.7.11 **Low Temperature Service**

6.1.7.11.1 For operating temperatures below –20 °F (–29 °C) or, if specified, for other low ambient temperatures, steels shall comply with the Low Temperature Service Section of API 610.

6.1.7.11.2 Refer to Section B.3 Table B.4, which covers temperature limits for elastomers.

6.2 Design Requirements (Category-specific)

6.2.1 **Seals for Category 1**

6.2.1.1 **General Information (Category 1)**

This subsection provides design details for Category 1 seals, as described in Section 4.2. Specific information provided here is in addition to the common seal design features listed in 6.1.

6.2.1.2 **Seal Chamber and Gland Plate (Category 1)**

6.2.1.2.1 [●] If specified, or if required by 6.1.3.14, a distributed seal flush system such as a circumferential or multiport arrangement shall be provided for Arrangement 1 and Arrangement 2 seals. The seal flush arrangement shall be located to maximize the uniformity and degree of cooling of the seal faces. For multiport systems, ports having a minimum diameter of 0.125 in. (3 mm) shall be used.

6.2.1.2.2 The seal flush passages shall be designed so that they can be cleaned (see Figure 22).

NOTE In many cases, effective seal operation is dependent on distributed flush systems that maximize heat removal from the seal faces to ensure effective film formation and prevent asymmetrical thermal distortions in sealing components. There are other methods for distributing the flush in addition to those illustrated in Figure 22. Depending on face orientation and space available on some seal designs a distributed flush system as shown in Figure 22 may not be required for Arrangement 2 seals because this may become unnecessarily complex and expensive. In these circumstances, consult the seal manufacturer for detailed information on the features and benefits of variations to the flush distribution systems to achieve even cooling around the circumference of the face components.

6.2.2 **Seals for Category 2**

6.2.2.1 **General Information (Category 2)**

This subsection provides design details for Category 2 seals, as described in Section 4.2. Specific information provided here is in addition to the common seal design features listed in 6.1.

6.2.2.2 **Seal Chamber and Gland Plate (Category 2)**

6.2.2.2.1 A distributed flush system shall be provided for Category 2, Arrangement 1 and Arrangement 2 seals except when Piping Plan 13 or Piping Plan 23 are specified or when specified by the purchaser. The seal flush arrangement shall be located to maximize the uniformity and degree of cooling of the seal faces. For multiport systems, ports having a minimum diameter of 0.125 in. (3 mm) shall be used.

6.2.2.2.2 The seal flush passages shall be designed so that they can be cleaned (see Figure 22).

NOTE See NOTE in 6.2.1.2.2.

6.2.3 **Seals for Category 3**

6.2.3.1 **General Information (Category 3)**

This subsection provides design details for Category 3 seals, as described in Section 4.2. Specific information provided here is in addition to the common seal design features listed in 6.1. Category 2 information from 6.2.2 applies to Category 3 seals, except as amended in this subsection.

6.2.3.2 **Seal Chamber and Gland Plate (Category 3)**

6.2.3.2.1 A distributed flush system shall be provided for Category 3, Arrangement 1 and Arrangement 2 seals except when Piping Plan 13 and Piping Plan 23 are specified. The seal piping arrangement shall be located to maximize the uniformity and degree of cooling of the seal faces. For multiport systems, ports having a minimum diameter of 0.125 in. (3 mm) shall be used.

6.2.3.2.2 The seal flush passages shall be designed so that they can be cleaned (see Figure 22).

NOTE See NOTE in 6.2.1.2.2.

6.2.4 **Seals for Category 4**

6.2.4.1 **General Information (Category 4)**

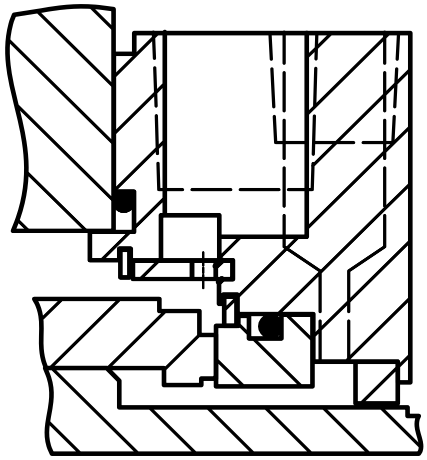
This subsection provides design details for Category 4 seals, as described in Section 4.2. Specific information provided here is in addition to and supersedes the common seal design features listed in 6.1.

6.2.4.2 **Seal Chamber and Gland Plate (Category 4)**

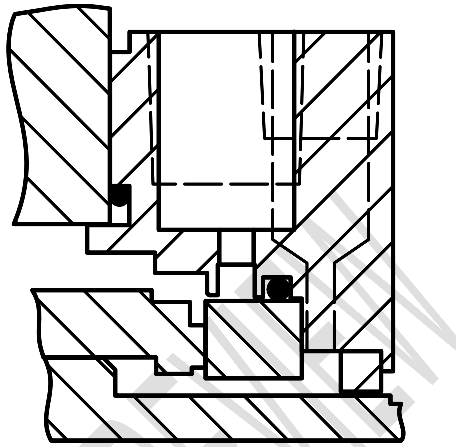
6.2.4.2.1 A distributed flush system shall be provided for Category 4, Arrangement 1 and Arrangement 2 seals except when Piping Plan 13 and Piping Plan 23 are specified. The seal flush arrangement shall be located to maximize the uniformity and degree of cooling of the seal faces. For multiport systems, ports having a minimum diameter of 0.125 in. (3 mm) shall be used.

6.2.4.2.2 The seal flush passages shall be designed so that they can be cleaned (see Figure 22).

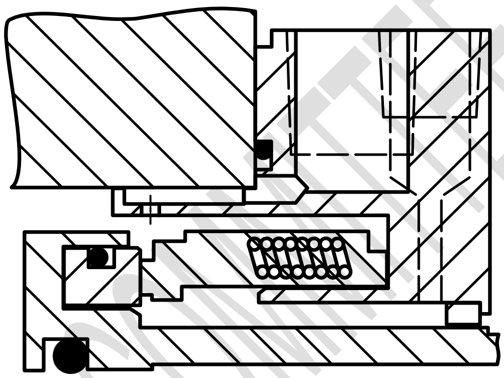
NOTE See NOTE in 6.2.1.2.2.



a) Rotating Flexible Element



b) Rotating Flexible Element



c) Stationary Flexible Element

These are only examples—other configurations may be used.

Figure 22—Distributed Flush Systems

6.3 Seal Configuration Requirements

6.3.1 Arrangement 1 Seals

6.3.1.1 Seal Sleeves

Seal sleeves shall be in one piece.

6.3.1.2 Seal Chamber and Gland Plate

6.3.1.2.1 Throttle bushings shall be per Table 5. The default bushing type shall be applied unless an optional bushing type is specified by the purchaser.

Table 5—Recommended Throttle Bushing Type

Seal Category	Fixed	Floating	Segmented
Category 1	Default	Optional	Optional
Category 2	Optional	Default	Optional
Category 3	Optional	Default	Optional
Category 4	Optional	Default	Optional

6.3.1.2.1.1 Throttle bushings shall be positively retained against pressure blowout to minimize leakage if the seal fails.

6.3.1.2.1.2 Bushing clearance shall be selected to allow for thermal growth.

NOTE Refer to B.4 and F.6.

6.3.1.2.2 Piping Plan 66A and 66B shall use floating carbon bushings.

NOTE When space permits floating segmented carbon bushings can achieve better performance.

6.3.1.2.3 [●] If specified, or if required by the seal manufacturer, an external quench (see Figure G.27) shall be provided to the seal gland plate in accordance with the following:

a) the design shall direct the quench to the seal face area and secondary seals;

b) seals equipped with a water quench shall be designed to allow quench water to exit via the drain connection;

c) if a steam quench is specified and if space allows, the seal gland plate shall be equipped with a quench baffle; and

d) the baffle shall be a spark resistant material designed with adequate clearance to prevent contact with adjacent moving components due to distortion or heating. (Reference Table 1)

NOTE 1 Quenching involves the introduction of a medium, usually water, nitrogen or steam, on the atmospheric side of a mechanical seal assembly. Quenching is normally applied if the material being sealed is noxious, flammable, oxidizes, polymerizes, or will crystallize when dry. Quenching can also be used for heating or cooling. The gland plate is equipped with a throttle bushing to prevent moisture or steam leakage from a quenched seal from entering the bearing housing and contaminating the lubricating oil, and to maximize containment of the quench fluid.

NOTE 2 This baffle directs the steam to the area where coke would tend to collect and routes the steam to carry material away from the seal and seal faces. By cooling the leakage on the atmospheric side of the seal faces, a steam quench prevents coke formation and subsequent seal hang-up in hot [above 300 °F (150 °C)] services. It also keeps viscous product thin when the pump is not running. If stocks thicken at the faces, seals can be damaged at start-up. Condensation collecting at the seal faces can vaporize and damage the seal faces.

6.3.1.2.4 Type C, Arrangement 1 seals shall include a quench baffle. The quench baffle shall meet the requirements of 6.3.1.2.3 d).

6.3.1.2.5 Seal systems that use internal circulating devices, such as a pumping device, and rely on the rotation of the mechanical seal to maintain circulation shall be designed with the inlet at the bottom of the seal and the outlet at the top of the seal as space allows.

NOTE This requirement enhances venting when the pump shaft is not rotating.

6.3.1.2.6 The internal circulating device shall provide adequate flow that considers all operating and transient conditions. For example, this can include consideration for varying pump speeds, temperatures and fluid properties (refer to Annex F).

6.3.1.2.7 [●] For Category 3 or if specified, the seal manufacturer shall provide the performance curve for head versus flow for the internal circulating device based on actual qualification test results.

NOTE For conditions other than those encountered in the qualification test, calculated performance curves are based on modeling and/or additional tests as needed.

6.3.1.2.8 The minimum diametral clearance between the rotating element of a circulation device and stationary component, seal chamber bore or containment chamber bore shall be in accordance with the values listed in Table 1.

NOTE For axial flow circulation devices, the minimum clearance could impact circulation device performance.

6.3.1.2.9 Designs of mechanical seals using internal circulating devices shall ensure that the device inlet and outlet ports properly align with the seal flush supply and return connections when installed in the seal chamber.

6.3.2 Arrangement 2 Seals

6.3.2.1 General

6.3.2.1.1 The inner seal shall be a contacting wet seal (2CW-CW, see Figure 4, or 2CW-CS, see Figure 5a) with a face to back configuration. The inner seal shall have an internal (reverse) balance feature designed and constructed to withstand reverse pressure differentials up to 40 psi (0.275 MPa) (2.75 bar) without opening or dislodging components. Refer to Figure 11.

NOTE The containment seal chamber pressure is normally less than the inner seal chamber pressure. The containment seal chamber is usually connected through an orifice to a vapor recovery system, in which case it will operate at the pressure of the system to which it is connected. It is unusual for a vapor recovery system to reach a gauge pressure of 40 psi (0.275 MPa) (2.75 bar) even under upset conditions.

6.3.2.1.2 [●] If specified, a non-contacting inner seal (2NC-CS, see Figure 5b) shall be provided.

NOTE Non-contacting inner seal designs use a lift-off face pattern, such as grooves or waves, which can provide reliable operation in liquid or gas service. Often it is difficult to provide adequate vapor suppression margin when sealing clean high vapor pressure or mixed vapor pressure fluids with contacting wet-face designs. A non-contacting inner seal can give the option of sealing a liquid/gas mixture by allowing the product to flash into a gas across the seal faces, effectively using the non-contacting design inner seal as a gas seal. The leakage rate from a non-contacting design is normally higher than a contacting wet design.

6.3.2.1.3 A contacting wet outer seal shall be used with liquid buffer systems.

6.3.2.1.4 A non-contacting containment seal shall be used for gas buffer systems.

6.3.2.1.5 [●] If specified, a contacting containment seal face design may be provided for containment seals.

NOTE 1 Non-contacting containment seals use a face pattern (grooves, waves, etc.) to provide lift-off of the seal faces. Relative to contacting “dry-running” containment seals, non-contacting face designs:

a) have a lower wear rate in operation,

b) are more tolerant to a buffer gas environment with dew points below −40 °F (−40 °C),

c) are designed for higher surface speeds and pressure differentials and

d) may experience higher leakage rates.

NOTE 2 Contacting containment seal designs normally provide the lowest leakage of vapors and liquids. Manufacturer’s standard dry contacting seal designs are pressure limited for continuous service, usually below a gauge pressure of 10 psi (0.07 MPa) (0.7 bar). Refer to Annex F.

6.3.2.1.6 [●] The buffer fluid type shall be specified on the datasheet.

NOTE If a buffer gas is not used, the containment seal chamber is typically filled with vaporized process fluid.

6.3.2.2 **Buffer Seal Chamber and Gland Plates**

6.3.2.2.1 [●] If specified and if additional length for the seal arrangement is available, a fixed throttle bushing made of carbon shall be installed in the gland plate and positively retained against pressure blowout.

NOTE 1 A throttle bushing is rarely required with a dual seal but may be used in cold services where a quench is used to avoid icing.

NOTE 2 Limited axial space between the seal chamber face and the bearing housing often makes the use of a throttle bushing with an Arrangement 2 seal impractical.

6.3.2.2.2 Seal systems that use internal circulating devices shall comply with the provisions of 6.1.2.4 through 6.1.2.8.

6.3.2.3 **Contacting Wet Seals with a Liquid Buffer Fluid (2CW-CW)**

6.3.2.3.1 Liquid buffer systems shall be designed such that the maximum temperature differential between the buffer fluid inlet and outlet immediately adjacent to the seal chamber is:

— 15 °F (8 °C) for glycol/water or buffer fluids with viscosity close to that of water and

— 30 °F (16 °C) for oil buffer fluids.

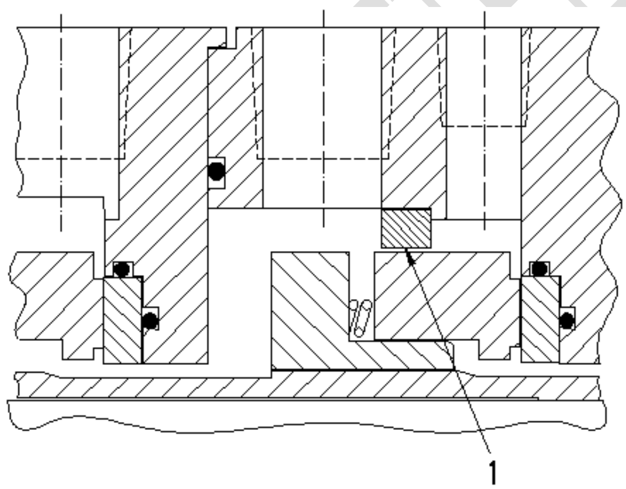
NOTE The allowable temperature differential includes the effects of both “heat soak” and seal-face-generated heat. The allowable temperature differential across the seal should not be confused with the bulk temperature rise of the buffer fluid during steady-state operation or with the differential temperature between the process fluid and steady-state buffer fluid temperature.

6.3.2.3.2 There are various ways to achieve enhanced flow in and out of the buffer seal chamber such as tangential ports, internal dams or cut-waters, radial and axial flow rings, and modified buffer seal chamber designs. The seal shall meet the temperature rise criteria, and the vendor qualification testing of Annex I. See 6.1.2.4 through 6.1.2.8 for requirements on internal circulating devices.

6.3.2.4 **Buffer Seal Chamber and Gland Plates for Contacting Wet Inner Seal with a Dry-running Containment Seal (2CW-CS)**

6.3.2.4.1 A fixed spark resistant bushing, or equivalent device approved by the purchaser, shall be installed to separate the containment-seal faces from the containment seal vent and drain connection ports. The bushing shall be positively retained to prevent axial movement and damage to seal components. The clearance for a fixed bushing shall be in accordance with Table 1 (see Figure 23).

NOTE The bushing helps isolate the containment-seal faces from normal inner-seal leakage by directing it toward the containment-seal vent or drain connection. Space limitations might require the seal supplier to propose an alternative containment-seal chamber layout.



Key
1 containment-seal chamber bushing

Figure 23—Section Showing Containment-Seal Chamber Bushing for 2CW-CS and 2NC-CS Configurations

6.3.2.4.2 The use of the containment-seal vent or drain connections for buffer gas injection is permitted only with the purchaser’s approval.

6.3.2.5 **Seal Chamber and Gland Plates for Non-contacting Inner Seal with a Dry-running Containment Seal (2NC-CS)**

6.3.2.5.1 A fixed spark resistant bushing, or equivalent device approved by the purchaser, shall be installed to separate the containment-seal faces from the containment vent and drain connection ports. The bushing shall be positively retained to prevent axial movement and damage to seal components. The minimum diametral clearance between the bushing and rotating parts in the seal chamber shall in accordance with Table 1 (see Figure 5b).

Purchaser's approval is required for any alternative seal chamber layout that deviates from the standard layout described above.

NOTE The bushing helps isolate the containment-seal faces from normal inner-seal leakage by directing it toward the containment-seal vent or drain connection. Space limitations might require the seal supplier to propose an alternative containment-seal chamber layout.

6.3.3 **Arrangement 3 Seals**

6.3.3.1 **General**

6.3.3.1.1 [●] The barrier fluid shall be agreed to by the seal vendor and purchaser. It can be a liquid or gas.

NOTE Refer to Annex F for guidance on setting barrier fluid pressures.

6.3.3.1.2 The inner seal shall be designed and constructed to operate in conditions per a – d. Refer to 6.1.1.11 and Figure 11.

a) In static operation, the seal shall be able to contain the rated seal chamber pressure if barrier fluid pressure is lost. (reverse pressure scenario)

b) In static operation, the seal shall be able to contain the rated barrier pressure if seal chamber pressure is atmospheric. (This is a seal qualification test point.)

c) In dynamic operation, the seal shall be capable of operation for a time period agreed between the purchaser and the seal vendor to allow orderly pump shutdown upon loss of gas or liquid barrier fluid pressure.

d) In continuous dynamic operation, the purchaser shall inform the seal vendor if the seal shall be required to operate continuously under abnormal conditions such as at rated barrier pressure with atmospheric pressure in the pump (gas or liquid barrier) or at rated seal chamber pressure if barrier pressure is lost for gas barrier seals. The purchaser shall advise the vendor of these abnormal conditions.

NOTE The internal or reverse balance feature requires that the mating ring and the secondary seal be designed to stay in place and contain pressure if either the barrier fluid or the process pressure is lost. Continuous, dynamic operation under these special conditions may have an impact on the selection of the seal design and configuration as well as the selection of the seal cooling system.

6.3.3.1.3 Standard Arrangement 3 configurations shall use two seal rings and two mating rings. If recommended by the vendor and approved by the purchaser, a common mating ring (mono-block design) may be provided.

6.3.3.2 **Seal Chamber and Gland Plates**

6.3.3.2.1 [●] If specified as a result of the process conditions and if additional length for the seal arrangement is available, a fixed throttle bushing made of carbon shall be installed in the gland plate and positively retained against pressure blowout.

NOTE The specification of a throttle bushing for a dual seal is rarely required but, for example, can be used in services where a quench is used to avoid icing. Limited axial space between the seal-chamber face and the bearing housing often makes the use of a throttle bushing with an Arrangement 3 seal impractical.

6.3.3.2.2 [●] If specified or recommended by the seal supplier and approved by the purchaser, a flush connection to the process side of the seal chamber shall be provided with Arrangement 3 configurations.

NOTE Some Arrangement 3 configurations may require a flush on the process fluid side of the seal chamber to isolate the process fluid from the seal parts or to assist in heat removal from the inner seal. Toxic and/or difficult-to-seal applications may use a flush in the seal chamber in addition to an Arrangement 3 seal.

6.3.3.3 **Contacting Wet Seal Configurations with a Liquid Barrier Fluid (3CW-FB, 3CW-FF, 3CW-BB)**

6.3.3.3.1 **General**

6.3.3.3.1.1 Liquid-barrier systems shall be designed such that the maximum temperature differential between the barrier fluid inlet and outlet immediately adjacent to the seal chamber is:

— 15 °F (8 °C) for glycol/water or barrier fluids with viscosity close to that of water and

— 30 °F (16 °C) for oil barrier fluids.

NOTE The allowable temperature differential includes the effects of both “heat soak” and seal-face-generated heat. The allowable temperature differential across the seal should not be confused with the rise in bulk temperature of the barrier fluid during steady-state operation or with the differential temperature between the pump fluid and steady-state barrier fluid temperature.

6.3.3.3.1.2 Seal systems that use internal circulating devices shall comply with 6.1.2.4 through 6.1.2.8.

6.3.3.3.2 **Default Seal Types and Arrangements**

6.3.3.3.2.1 The default configuration for Category 1, 2 and 3 shall have the inner and outer seals arranged in a face-to-back (3CW-FB) configuration (see Figure 6a).

6.3.3.3.2.2 The default configuration for Category 4 shall have the inner and outer seals arranged in a face-to-face (3CW-FF) configuration (see Figure 6c).

6.3.3.3.2.3 [●] If specified or recommended by the seal vendor, a face-to-face (3CW-FF) or a back-to-back (3CW-BB) configuration shall be provided (Figure 6b and Figure 6c).

NOTE See Annex A for information to select the preferred seal configuration.

6.3.3.4 **Default Seal Types and Arrangements for Non-contacting Seal Configurations with a Gas Barrier Fluid (3NC-FB, 3NC-FF, 3NC-BB)**

6.3.3.4.1 The default configuration for Category 1, 2, and 3 shall be a back-to-back (3NC-BB) configuration (Figure 7a).

6.3.3.4.2 The default configuration for Category 4 shall be a face-to-face (3NC-FF) configuration (Figure 7b).

6.3.3.4.3 [●] If specified or recommended by the seal vendor, a face-to-face (3NC-FF) or a face-to-back (3NC-FB) configuration shall be provided (Figure 7b and Figure 7c).

6.3.3.4.4 The purchaser should verify that any special pump casing vent needs are satisfied.

NOTE If the pump seal chamber and casing is a not a self-venting design, then gas from inner seal leakage may accumulate in the pump during long idle periods and may require the pump to be vented prior to operation.

7 Accessories

7.1 General

7.1.1 Sealing systems consist of a seal arrangement and external accessories to operate the seal arrangement according to specified piping plans. The selection of the piping plans depends on the application and is described in Annex A sheets 7 to 9.

7.1.2 The purchaser and the mechanical seal manufacturer shall mutually agree which piping plan or plans (refer to Annex G) shall be realized to meet the seal chamber pressure and temperature requirements of 6.1.3.14.

7.1.3 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

7.1.4 Components and appurtenances within the pressure boundary shall have a pressure-temperature rating at least equal to the MAWP and MAWT of the pressure casing to which the system will be attached, but in no case shall they be designed for gauge pressures less than:

— Category 1: 275 psi (20 bar) at 100F (38C)

— Category 2 and Category 3: 720 psi (50 bar) at 100F (38C)

— Category 4: 1440 psi (100 bar) @ 100F (38C)

Note: The above requirements are aligned with ASME B16.5 flange ratings for stainless steel flanges not Seal Category ranges as defined in Section 4.

7.1.4.1 Components or equipment fitted of a piping plan that are located in a dead-leg may have a lower MAT.

NOTE Accumulators or other components may be installed in a dead-leg of the system. The dead-leg will never be exposed to high temperatures due to lack of circulation.

7.1.4.2 For Piping Plans 32, 35, 72 or 74 supplied as assembled panels or modules, the maximum allowable working pressure and temperature for the regions shown in Figures G.16, G.17, G.33 and G.34 respectively shall be specified by the purchaser.

7.1.4.3 The check valve pressure and temperature rating at the Piping Plan 32, 72 or 74 panel outlet shall comply with 8.1.4.

NOTE 1 Piping plans 32, 35, 72 and 74 supply external fluids at a pressure often much lower than the MAWP of the pressure casing and are not exposed to the MAWT of the casing. See also NOTE to 7.4.1.7.

NOTE 2 Refer to Annex G for Piping Plan specific details.

NOTE 3 For high-discharge pressure pumps, where the seal chamber pressure can get higher than the static or dynamic sealing pressure rating of the seal, purchasers could consider the installation of a pressure relief valve in the suction piping of the pump, downstream of the suction block valve, instead of building the seal auxiliary system to the MAWP of the pump casing. The relief valve can be arranged to exit on the upstream side of the suction block valve. For further information about relief valves refer to 7.4.8.

7.1.5 For pressurized piping plans, the pressure source shall be designed to not exceed the dynamic pressure rating of the seal, the MAWP of the pump pressure casing and the MAWP of the seal auxiliary system.

NOTE For Piping Plan 53A and Piping Plan 53B the liquid barrier fluid can be pressurized by an external gas system. If necessary, to reduce the pressure differences within the seal, the same can be done for Piping Plan 52. The pressurization system for Piping Plan 54 can be part of the seal auxiliary system or also be external. The seal auxiliary systems for the Piping Plan 72 and Piping Plan 74 are connected to external gas systems that provide pressurized gas.

7.1.6 **[●]** Accessories (including reservoirs) are part of the pump piping system. Accessories shall be designed, fabricated, and inspected in accordance with ASME B31.3, or if specified ISO 15649, using piping components. It is the user's responsibility to ensure that local codes do not require that accessories be built in accordance with a pressure vessel code such as EN 13445 or ASME VIII, Division 1.

7.1.7 Filling/refilling systems for liquid buffer and barrier fluids can also be attached to some closed seal auxiliary systems. These filling/refilling systems shall not be operated to exceed the dynamic pressure rating of the seal and the MAWP of the seal auxiliary system.

NOTE Filling/refilling systems for buffer and barrier systems are normally used for the Piping Plans 52, 53A, 53B, and 53C. Users often consider the effect of filling on the system pressure. While the standard does not allow the pressure to exceed the seal or system MAWP, the pressure will rise when closed systems are refilled and may exceed the pressure of the gas supply system. See Annex F for examples.

7.1.8 Components for piping plans shall comply with the requirements in Table 5, Table 6, and Table 7. For further information about suitable metals, refer to Table B.1.

NOTE When using specialized alloys for the flush piping and barrier/buffer systems, purchasers can consider whether these materials are required for services such as Piping Plans 32, 53, 54, 72, and 74 as the components do not normally see the process fluid.

7.1.9 Local operation, venting, filling, and draining should not require the use of a portable ladder or climbing on piping or equipment.

NOTE Some users request connections to be extended to the edge of the baseplate.

7.1.10 Liquid seal auxiliary systems shall be self-venting or shall incorporate vents to remove vapor.

7.1.11 Closed systems (Piping Plan 52, 53, 23, etc.) shall be designed with adequate fill and vent connections to allow initial and top up filling without trapping air or other vapor in the system.

7.1.12 Closed systems (Piping Plan 52, 53, 23, etc.) shall have drains to allow safe removal of liquids.

7.1.13 When designing the vent piping to a vapor recovery system, the purchaser should take into account the potential for condensation of hydrocarbon vapors from other sources connected to that system.

Additional condensation-collection vessels and/or heat tracing of the vent lines may be required to avoid buildup of a static liquid head in the vent piping and the possible contamination of the barrier/buffer fluid.

7.1.14 The method of filling the seal auxiliary system shall be considered during the engineering phase of a project. The closed-fill system shall enable the operator to fill the reservoir without exposure to the barrier/buffer fluid.

NOTE 1 Some systems will require adding fluids while the system is pressurized to prevent a pressure reversal in barrier fluid applications.

NOTE 2 Some examples of acceptable refill systems include:

— a centrally located tank that is permanently connected by piping to various reservoirs and/or day tanks using a transfer pump or inert gas pressure to transfer the barrier/buffer fluid;

— a hand pump that can be connected to a day tank or drum with a hose or removable spool piece;

— a small vessel, located adjacent to the reservoir, which can be pressurized with an inert gas to force the barrier/buffer fluid into the reservoir.

7.2 Piping for Seal Auxiliary Systems

7.2.1 Seal auxiliary systems are part of the seal piping system and shall comply with the requirements of Table 5, Table 6, and Table 7.

7.2.2 Seal auxiliary systems shall include all components as defined by figures and tables in Annex G.

7.2.3 The supplier specified on the datasheet shall furnish all seal auxiliary piping systems, including mounted components that are located within the confines of the associated pump's baseplate, any barrier/buffer fluid reservoir baseplate area or any auxiliary baseplate area.

7.2.3.1 If piping is furnished, it shall terminate with flanged connections at the edge of the baseplate.

7.2.3.2 The purchaser shall furnish interconnecting piping or tubing between sealed equipment and auxiliaries that are mounted separate from the baseplate.

7.2.4 The length of piping or tubing and the use of fittings between equipment and auxiliaries should be minimized. In lieu of fittings, it’s preferable to use long radius bends (3R or greater).

7.2.5 Piping or tubing shall have a slope of not less than 1:24 (0.5 in/ft or 40 mm/m), using long radius bends.

7.2.6 For systems using an internal circulation device, the total length of connecting piping or tubing between the mechanical seal and the seal auxiliary system should not exceed 16.4ft (5m) in length. Systems greater than 16.4ft (5m) shall have an engineering review to ensure acceptable flow rate. For piping diameters, refer to 7.2.9 and for further general information to Annex F.

7.2.7 The mechanical design of auxiliary piping or tubing systems shall achieve the following:

a) support and protection to prevent damage from vibration or from shipment, operation, and maintenance;

b) flexibility and accessibility for operation, maintenance and cleaning;

c) installation in an arrangement adapted to the contour of the machine without obstructing access to pump coupling from at least one side or other access openings required for maintenance;

d) elimination of air pockets by the use of vents with valves or properly sloped piping arrangements;

e) complete drainage through low points without disassembly of piping, seal, or gland plate components;

f) reduction of the number of potential emission sources and pressure drop by minimizing the use of threaded connections, flanges, fittings and valves;

g) the system should be suitable for any special cleaning/decontamination procedures identified by the purchaser (i.e. steam cleaning, solvent wash, etc.).

7.2.8 Seamless pipe or tubing shall be furnished in accordance with Table 5, Table 6, and Table 7 for all auxiliary systems.

7.2.9 Piping and tubing between equipment and auxiliaries for Piping Plan 23, Plan 52 and Plan 53A/B/C shall be in accordance with 7.1.8, Table 5, and the following:

— 0.5 in. (12 mm) minimum, for shaft diameter 2.5 in. (60 mm) and smaller;

— 0.75 in. (20 mm) minimum, for shaft diameter greater than 2.5 in. (60 mm) or if flow rate exceeds 2 U.S. gal/min (8 L/min) or if the total length of connection pipework between seal and auxiliary system exceeds 16.4 ft (5 m) in length.

NOTE Refer to Annex F.

Table 5—Minimum Requirements for Auxiliary Components and Assemblies

<table>
<tr><th rowspan="6">Component</th><th colspan="8">Fluids and Piping Plans</th></tr>
<tr><td colspan="4">Process-Flush-Buffer-Barrier</td><td colspan="2">Quench</td><td colspan="2">Cooling Water</td></tr>
<tr><td>inner seal</td><td colspan="2">between seals</td><td>leakage recovery</td><td colspan="2">to/from atmospheric seal area</td><td colspan="2">to/from heat exchanger/cooling coil</td></tr>
<tr><td>11,12,13,14,21,22,23,31,32,41</td><td colspan="2">52,53A,53B,53C,54,55,72,74</td><td>65,66A,66B,75,76</td><td colspan="2">62</td><td colspan="2">21,22,23,41,52,53A,53B,53C,54,55</td></tr>
<tr><td colspan="4">Fluid Characteristics</td><td colspan="2">Gauge Pressure</td><td colspan="2">Nominal Size</td></tr>
<tr><td colspan="2">nonflammable, nonhazardous</td><td colspan="2">flammable, hazardous</td><td>≤0.5 MPa (5 bar) (75 psi)</td><td>>0.5 MPa (5 bar) (75 psi)</td><td>Standard ≤DN 25 (NPS 1)</td><td>Optional ≥DN 40 (NPS 1 1/2)</td></tr>
<tr><td>Fabricated Joints ≤DN 25 (NPS 1)</td><td colspan="2">threaded</td><td colspan="2">welded</td><td>threaded</td><td>welded</td><td>threaded</td><td>welded</td></tr>
<tr><td>Fabricated Joints ≥DN 40 (NPS 1 ½)</td><td colspan="8">Purchaser to specify</td></tr>
</table>

<table>
<tr><td>Pipe [a]</td><td colspan="2">seamless</td><td colspan="2">seamless</td><td>Carbon steel (ASTM A120 Schedule 40 painted to purchaser specification s)</td><td>stainless steel (ASTM A269 seamless Type 316)</td></tr>
<tr><td>Tubing</td><td colspan="2">Seamless ASTM A269 Type 316/L; or ASTM A213 Type 316Ti</td><td colspan="2">Seamless ASTM A269 Type 316/L; or ASTM A213 Type 316Ti</td><td>Seamless ASTM A269 Type 316/L; or ASTM A213 Type 316Ti</td><td></td></tr>
<tr><td>All Valves</td><td colspan="2">Class 800</td><td colspan="2">Class 800</td><td colspan="2">Class 200 bronze</td></tr>
<tr><td>Gate and Globe Valve</td><td colspan="2">bolted bonnet and gland</td><td colspan="2">bolted bonnet and gland</td><td colspan="2"></td></tr>
<tr><td>Pipe Fittings</td><td colspan="2">forged
Class 3000</td><td colspan="2">forged
Class 3000</td><td colspan="2">malleable iron (ASTM A338 and A197Class 150) galvanized to ASTM A153</td></tr>
<tr><td>Tube Compression Fittings</td><td colspan="2">manufacturer’s standard</td><td colspan="2">manufacturer’s standard</td><td colspan="2">manufacturer’s standard</td></tr>
<tr><td>Flange Gaskets</td><td></td><td>Type 304 or 316 stainless steel spiral wound</td><td></td><td>Type 304 or 316 stainless steel spiral wound</td><td></td><td></td></tr>
<tr><td>Flange Bolting</td><td></td><td>Low alloy steel (ASTM A193 Grade B7 ASTM A194 Grade 2H)</td><td></td><td>Low alloy steel (ASTM A193 Grade B7 ASTM A194 Grade 2H)</td><td></td><td></td></tr>
<tr><td>Plugs</td><td colspan="6">metallic solid round or solid hexagonal head plugs in accordance with the dimensional requirements of ASME B16.</td></tr>
<tr><td colspan="7">The ASTM standards listed are examples of acceptable materials for each type. Alternate materials may be used if approved by the purchaser (Annex B may be used for guidance). Examples of acceptable materials are:
— carbon steel pipe: ASTM A53 Grade B, ASTM A106 Grade B, ASTM A524 or API Spec 5L Grade A or B;
— carbon steel fittings, valves and flanged components: ASTM A105 and ATMS A181;
— stainless steel piping ASTM A312 Type 316L;
— stainless steel fittings, valves and flanged components: ASTM A403 Type 316L.</td></tr>
<tr><td colspan="7">[a] The design requirements for seal coolers and cooling coils are specified in 8.3.2 and 8.3.6.2.13.</td></tr>
</table>

Table 6—Minimum Pipe Wall Thickness

<table>
<tr><th rowspan="2">Materials</th><th colspan="3">Nominal Pipe Size Minimum</th></tr>
<tr><th>DN</th><th>NPS</th><th>Schedule</th></tr>
<tr><td>Carbon steel</td><td>DN 15 to DN 40</td><td>$^{1}/_{2}$ to 1 $^{1}/_{2}$</td><td>80</td></tr>
</table>

	DN 50 to DN 200	2 to 8	40
	>= DN 250	>= 10	20
Stainless steel	DN 15 to DN 25	1/2 to 1	80S
	DN 40 to DN 75	1 1/2 to 3	40S
	>= DN 100	>= 4	10S
Note: Schedule 40 piping and flanges are permissible for cooling water piping.			

Table 7—Minimum Tubing Wall Thickness

Nominal Tubing Size (mm)	Minimum Wall Thickness (mm)	Nominal Tubing Size (in)	Minimum Wall Thickness (in)
12	1.5	1/2	0.065
20	2.0	3/4	0.095
25	2.6	1	0.109
[a] The tubing size is the outside diameter.			

7.2.10 Piping design and joint fabrication, examination and inspection shall comply with ASME B31.3, or other international standard as approved by the purchaser. Welding shall be performed by operators and procedures qualified in accordance with the appropriate part of EN 287 and EN 288, or ASME IX.

7.2.11 Piping systems shall be fabricated by bending and welding to minimize the use of flanges and fittings where practical.

7.2.11.1 Welded flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance.

7.2.11.2 The use of flanges at other points is permitted only with the purchaser's approval.

7.2.11.3 Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas.

7.2.11.4 The number of threaded connections shall be minimized.

7.2.11.5 Pipe bushings shall only be used with approval by purchaser.

7.2.11.6 Pipe unions shall not be used.

7.2.12 Tubing shall be fabricated by bending and the use of compression fittings.

NOTE Combining different components of compression fittings from differing manufacturers could cause a fitting to leak.

7.2.12.1 Piping or tubing shall not be welded if the wall thickness is less than 0.1 in. (2.5 mm). This includes fixation of external fins or other surface area extension devices on the OD of the pipe or tube.

7.2.12.2 Connections that are internal to auxiliary devices are not permitted including coolers and seal reservoirs. This includes but is not limited to welding, brazing, and compression fittings.

NOTE Leaky internal connections are difficult to discover and can cause contamination, vaporization and excessive pressurization of the cooling water.

7.2.12.3 Connection methods for fins on pipe or tube shall be suitable for the maximum specified operating temperature of the pump.

7.2.12.4 Fabricated joints for Piping Plan 72 and Piping Plan 74 auxiliary systems shall be butt welded instead of socket welded.

NOTE Socket welding creates a cavity for debris accumulation that can subsequently damage a gas seal.

7.2.13 **[●]** Pipe shall have tapered threads in accordance with ASME B1.20.1 or ISO 7.

7.2.13.1 Flanges shall be in accordance with ASME B16.5.

NOTE For the purpose of these provisions, ISO 7005-1 is equivalent to ASME B16.5.

7.2.13.2 Lap joint flanges may be used with the purchaser's approval.

7.2.13.3 For socket-welded construction a 0.063 in. (1.5 mm) gap shall be left between the pipe end and the bottom of the socket.

7.2.14 The following nominal sizes of connections, piping, valves and fittings shall not be used: NPS 1.25 (DN 30), NPS 2.5 (DN 65), NPS 3.5 (DN 90), NPS 5 (DN 125), NPS 7 (DN 175), or NPS 9 (DN 225), excluding piping used to manufacture reservoirs and seal coolers.

7.2.15 **[●]** The purchaser shall specify hazardous and/or flammable services to determine if special requirements are necessary for piping, flanges, gaskets and o-rings, valves and other appurtenances.

7.2.16 **[●]** The purchaser shall specify if chlorides in a concentration above 10 PPM (10 mg/kg) are present in the environment, process or barrier fluid.

NOTE Chlorides can lead to stress-corrosion cracking in stainless steel.

7.2.17 The minimum nominal size of any connection—other than the gland plate and piping to the gland plate shall be NPS 0.5 (DN 15). Gland plate connections shall be in accordance with 6.1.3.18 and 6.1.3.19.

7.2.18 The sizing of the internal tubing and connections in an auxiliary system for Piping Plan 72 and Piping Plan 74 shall be according to the vendor standards.

7.2.19 Flanged or tapped openings not designed to be connected to piping or tubing shall be blanked or plugged with fittings rated for the specified pressure rating per the design drawings.

7.2.19.1 Solid hexagonal head or solid round plugs shall be furnished in accordance with the dimensional requirements of ASME B16.11.

7.2.19.2 All plugs shall be of the same material as the gland plate.

7.2.19.3 A sealant with lubricant properties shall be used on the threads to ensure the threads are vapor tight per ASME B1.20.1.

7.2.20 **[●]** If specified, sight flow indicators (open or closed as specified) shall be furnished in each cooling water outlet line.

7.2.21 **[●]** If specified, each utility, such as air and inert gas supplies, cooling water supply and return lines, and others as specified, shall be manifolded to a common connection. The manifold shall be of sufficient dimensions to handle the maximum flow-through of all components that may require simultaneous use of the specified utility.

7.3 Components of Seal Auxiliary Systems (if Specified in Annex G)

7.3.1 **General**

If a piping plan in Annex G includes a component described in this section, that component shall meet the requirements of this section. Not all piping plans will have all of the components described in this section.

7.3.2 **Coolers**

7.3.2.1 **General**

7.3.2.1.1 If furnished, external-seal flush coolers shall be in accordance with 7.3.2.1.2 to 7.3.2.1.13. Requirements for coolers mounted within or integral to barrier/buffer fluid reservoirs are given in 7.3.6.2.13.

NOTE External-seal flush coolers mounted in the seal flush piping may be considered as a viable means of creating the required product temperature margin (see 6.1.3.14).

7.3.2.1.2 [●] Seal flush coolers shall be designed, fabricated, and inspected in accordance with ASME B31.3, ISO 15649, ASME VIII, or EN 13445 as specified or agreed.

7.3.2.1.3 A separate external seal flush cooler shall be provided for each mechanical seal.

7.3.2.1.4 An austenitic stainless steel tag shall be securely fastened to all coolers. In letters a minimum of 6 mm (0.25 in.) high, this tag shall read: “IMPORTANT: ALL TRAPPED GAS SHALL BE VENTED FROM THIS SYSTEM PRIOR TO OPERATION TO PREVENT DAMAGE TO THE MECHANICAL SEAL.”

7.3.2.1.5 For separate coolers mounted in Piping Plan 23 flush loops and for external coolers in buffer/barrier systems see Figure G.40 and Figure G.41 for recommendations.

NOTE When the pump shaft is stationary and in a standby mode, localized cooling to improve the seal life can be achieved within the auxiliary system by use of a thermosyphon principle. This mechanism requires a minimum difference in height between the heat exchanger and the seal.

7.3.2.1.6 [●] If Piping Plan 23 is specified, a positive circulating device shall be provided. The circulation device shall be in accordance with 6.3.1.2.5 to 6.3.1.2.9. The purchaser shall specify if an external circulating pump or a flow-through system from an external source is required.

7.3.2.1.7 The tubes shall be of austenitic stainless steel in accordance with Table 7.

7.3.2.1.8 Tubing connectors, fittings, or seams shall not be internal to the cooler.

7.3.2.1.9 The criteria for thermal sizing of the cooler and internal cooling coils of reservoirs shall be provided by the seal manufacturer. The seal manufacturer shall confirm that the selected cooler will meet the expected thermal duty requirements at the site utility conditions specified on the datasheets.

NOTE The performance of air coolers is impacted by environmental conditions (e.g. ambient temperature, solar radiation, confined spaces, hot adjacent equipment, etc.)

7.3.2.1.10 For buffer/barrier systems the performance of the internal or external pumping device, combined with the total resistance of the flow circuit shall provide sufficient flow rate to achieve the limits defined in 6.3.2.3.1 and 6.3.2.3.2 (see also Annex F).

7.3.2.1.11 At low ambient temperature or high wind chill locations the selection of water coolers and air coolers should be reviewed because of possible freezing inside the cooler or connection piping.

7.3.2.1.12 The user shall design the cooling water system to avoid shell over-pressurization resulting from blocking-in of the water side while high-temperature process fluid is passing through the tubes. This can be accomplished through adequate pressure rating of the shell, the addition of pressure-relief protection, or operating procedures.

7.3.2.1.13 The cooling-water system shall be designed for the conditions specified in Table 8.

7.3.2.2 **Water Coolers**

7.3.2.2.1 Water coolers shall be arranged with the seal flush fluid on the tube side and the cooling water on the shell side.

7.3.2.2.2 [●] If specified, water coolers shall be arranged with the seal flush fluid on the shell side and cooling water on the tube side. When this option is specified the purchaser shall provide material selections.

7.3.2.2.3 Water Coolers shall have 316/L or equivalent tubes and at a minimum the shell shall be carbon steel. Cast Iron shall not be used.

7.3.2.2.4 [●] If specified, other material selections shall be per 7.1.8 and 7.2.16.

7.3.2.2.5 The seal flush cooler shall be arranged for complete draining and venting of both the water and process sides. A drain valve (not just a plug) shall be mounted at the lowest point on the shell side.

Table 8—Conditions Affecting Cooling Water System Design

Condition	Value
Velocity over heat exchange surfaces	5 ft/s to 8 ft/s (1.5 m/s to 2.5 m/s)
Maximum allowable working pressure, gauge	100 psi (0.7 MPa) (7 bar)
Test pressure, gauge	See 10.3.3
Maximum pressure drop	15 psi (0.1 MPa) (1 bar)
Maximum inlet temperature	90 °F (32 °C)
Maximum outlet temperature	120 °F (49 °C)
Fouling factor on water side	0.002 hr-ft^2-°F/Btu (0.35 m^2·K/kW)

Shell corrosion allowance [a]	0.125 in. (3 mm)
[a] Not applicable for piping and other, non-shell components	

7.3.2.2.6 Welding of tubes or fillet welds at tube sheets with a tube wall thickness less than 0.1 in. (2.5 mm) is not allowed inside the cooler.

7.3.2.3 **Air Coolers**

7.3.2.3.1 The air cooler shall be constructed with finned tubing components in accordance with Table 5 and Table 7.

7.3.2.3.2 [●] If specified, the air cooler shall be constructed using finned austenitic stainless steel piping components in accordance with Table 5 and Table 6.

7.3.2.3.3 The default cooler shall be a natural draft air cooler.

7.3.2.3.4 [●] If specified or if required by application, forced draft air coolers are acceptable.

7.3.2.3.5 [●] If specified, the purchaser may consider the inclusion of a high-temperature alarm to warn of loss or limited air flow rate.

7.3.2.3.6 If finned tubing or piping is used the fins shall be aluminum or stainless steel.

7.3.2.3.7 Welded connections shall be according to 7.2.12.

7.3.2.3.8 The air cooler design shall be arranged for complete draining and venting.

7.3.2.3.9 The design of the air cooler shall include a fouling factor 0.0006 hr-ft^2-°F/Btu to 0.0023 hr-ft^2-°F/Btu (0.1 m^{2}K/kW to 0.4 m^{2}K/kW) on the air side.

7.3.3 **Strainers and Filters**

7.3.3.1 **General**

7.3.3.1.1 Housing and elements shall be made of Type 304/L or Type 316/L Stainless Steel.

7.3.3.1.2 Requirements in this section refer to wet seal piping plans.

NOTE See section 7.3.10.4 for gas seal system requirements.

7.3.3.1.3 A drain shall be provided at the bottom of the housing to allow for particulate isolation and removal.

7.3.3.2 **Strainers**

NOTE Strainers are used in Piping Plan 12, Piping Plan 22, and Piping Plan 32 to remove large particles from normally clean fluids.

7.3.3.2.1 Strainers shall have a size no finer than 120 mesh (125 µm). (See Figure G.7, G.11 and G.14.)

7.3.3.3 **Filters**

NOTE Filters are used in Piping Plan 15, 25, 35, 54 and 55 systems to condition product, barrier or buffer fluids. They remove particulates that may be harmful to mechanical seal internal components.

7.3.3.3.1 The default filter element shall be designed to remove particles 10 micron and larger.

NOTE Seals in volatile services can use special patterns, recesses, and grooves for enhanced face lubrication, having tighter requirements for particulate removal.

7.3.3.3.2 [●] Filters shall have provisions for on-line filter element monitoring and change out. The default arrangement shall be duplex (parallel) filter arrangement. If specified, simplex and bypass is another option.

NOTE Provisions can include a filter bypass, equalization lines, cross-over valves, double block and isolation valves, and other appurtenances (See Figures in Annex G).

7.3.4 **Cyclone Separator**

7.3.4.1 Cyclone separators shall not be used unless the solids have a density of at least twice the density of the flushing fluid.

NOTE Common materials frequently found in refinery process streams and their approximate densities are listed in Table 9.

7.3.4.2 Cyclone separators shall not be used with a pressure differential less than 25 psi (1.7 bar).

7.3.4.3 Cyclone separators shall be selected to maximize the removal of solids for a specific pump stage differential.

7.3.4.4 The default for Piping Plan 31 and 41 shall be designed so that the cyclone separator is the flow-limiting device.

7.3.4.4.1 If the pressure differential exceeds the cyclone separator design differential or if required to balance flows, flow orifices can be used.

7.3.4.4.2 The orifice shall have a minimum diameter greater than the separator inlet hole.

NOTE 1 See Figure G.15 and Figure G.18 in Annex G.

NOTE 2 The efficiency of separation (percentage of solids carried over) of a cyclone also depends on differential pressure and particle size. As the differential pressure across the cyclone varies (increases or decreases) from the design differential, the separation efficiency usually is reduced. As the particle size decreases, separation efficiency also decreases.

7.3.4.5 A separate cyclone separator shall be provided for each mechanical seal.

7.3.4.6 Unless required by 7.1.8, cyclone separators shall be austenitic stainless steel type 316/L, or 316Ti per Annex B.

7.3.5 **Flow Control Orifice**

7.3.5.1 The number and location of flow control orifices needed shall be determined by the vendor specified to furnish the auxiliary piping system. An orifice may be required in the seal flush system solely or in conjunction with a throat bushing to:

— limit the seal flush circulation rate to the seal;

— control the seal chamber pressure.

NOTE Frequently, buffer fluid reservoirs for Piping Plan 52 are continuously vented to a vapor recovery system. A flow control orifice, sized specifically for the system, is normally installed in the vent line to restrict the flow from the reservoir and to provide a back pressure on it.

7.3.5.2 The pump vendor and the seal auxiliary system vendor shall clarify which orifices belong to their scope of supply.

Table 9—Approximate Densities of Materials Found in Process Streams

Substance Material	**Density**	
	kg/m^3	lb/ft^3
Cement, sand, stone	2307	144
Clay	1762	110
Coke	513	32
Earth (mud)	1538	96
Gasoline (relative density 0.7)	721	45
Glass	2595	162
Kerosene	801	50
Limestone	2355	147
Paraffin	897	569
Sand	2018	126
Steel	7801	487
Sulfur	2002	125
Tar	1201	75
Water	993	62
Wood (pine)	432	27

7.3.5.3 [●] When piping is supplied a plate orifice or orifices shall be furnished and mounted in the auxiliary piping between a pair of flanges. If tubing is specified, the same design shall be used with the flanges connected by tubing fittings to the tube.

7.3.5.3.1 [●] If specified, a bar-stock orifice (also called an orifice fitting or orifice nipple) shall be supplied.

7.3.5.3.2 Pipe unions with an orifice shall not be used.

7.3.5.3.3 To prevent leakage, orifice fittings relying on a threaded connection shall not be used unless approved by the owner.

7.3.5.3.4 Orifices in liquid or fouling fluids shall have a minimum bore of 0.125 in. (3 mm).

NOTE Orifice bores smaller than 0.125 in. (3 mm) become blocked more easily and can cause a seal failure.

7.3.5.3.5 Orifices shall have a visible tang that extends beyond the outside diameter of the flange and be stamped with the bore diameter, line size, and material.

7.3.5.3.6 When bar stock orifices or orifice fittings are specified, they shall be stamped with the bore diameter, line size and material. If insulated, there shall be a visible tag with this information.

7.3.5.4 Multiple orifices, installed in series, may be used if more pressure drop is required than can be accomplished with a single 0.125 in. (3 mm) orifice.

7.3.5.5 [●] If specified, an orifice nipple (not an orifice union) shall be furnished at the pump discharge and/or suction nozzle to restrict leakage in the event of an auxiliary system pipe or component failure.

7.3.5.6 The material for flow control orifices shall be in accordance with 7.1.8.

7.3.5.7 For Piping Plan 66B, the drain connection of the gland plate shall be plugged with a socket or hex-head plug of austenitic stainless-steel type 316 with a drilled hole.

7.3.5.7.1 For clean fluids with a viscosity at operating temperature less than or equal to 5 cSt (5 mm^2/s), the hole shall have a diameter of 0.0625 in. (1.5 mm).

7.3.5.7.2 For fluids with a viscosity at operating temperature above 5 cSt (5 mm^2/s) or that contain solids that may cause plugging, the hole shall have a diameter of 0.125 in. (3 mm).

7.3.5.8 The effects of auto refrigeration of leakage across an orifice in a vent system shall be reviewed to determine if the design temperature of the components is acceptable for low temperature service.

7.3.6 **Barrier/Buffer Fluid Reservoirs and Accumulators**

7.3.6.1 **General**

7.3.6.1.1 [●] If a barrier/buffer fluid reservoir or an accumulator is specified, the purchaser and the mechanical seal manufacturer shall mutually agree on the sizing, instrumentation requirements, fluid selection, and general arrangement.

7.3.6.1.2 A separate reservoir or accumulator shall be furnished for each mechanical seal.

7.3.6.1.3 The barrier/buffer fluid reservoir or accumulator shall be mounted on a rigid support and should not be affected by pump vibration.

7.3.6.1.4 Reservoirs and accumulators should be located leaving room for operation and maintenance. They should not be located directly above the pump. Typical configuration details for barrier/buffer fluid reservoirs can be found in Figure G.41.

7.3.6.1.5 The thermal effects of solar radiation or other ambient conditions on reservoirs and bladder accumulators shall be mitigated. (see Annex F).

7.3.6.1.6 For Category 1, 2, and 3 seals, the Piping Plan 53A reservoir and Piping Plan 53B/C accumulator designs shall achieve a refill frequency of greater than 28 days.

7.3.6.1.6.1 The refill frequency shall be calculated by the vendor using 2 times the actual qualification test leakage rate adjusted linearly for the job seal size and barrier pressure versus the qualification test barrier pressure.

7.3.6.1.6.2 The vendor and purchaser shall mutually agree to a solution for systems that do not meet the 28 day minimum refill frequency requirement.

NOTE Piping Plan 53B may not be suitable for use with Category 4 seals without additional considerations. Due to the higher pressures and higher leak rates associated with Category 4 seals, it is commonly impractical to design Plan 53B systems that can achieve the 28 day refill requirement. If an Arrangement 3 seal is preferred, alternatives include automatic refill systems or Plan 54. See Appendix F for further discussion.

7.3.6.1.7 [●] If Piping Plans 52, 53A, 53B, or 53C are specified, a positive-circulating device shall be provided.

7.3.6.1.7.1 The circulation device shall be in accordance with 6.3.1.2.5 to 6.3.1.2.9.

7.3.6.1.7.2 The purchaser shall specify if an external circulating pump or a flow-through system from an external source is required.

7.3.6.1.7.3 Systems that rely only on a thermosyphon to maintain circulation during normal operation shall not be used.

7.3.6.1.8 [●] The purchaser shall specify on the datasheets the characteristics of the barrier/buffer fluid (see Annex A, Sheet 10 of the recommended selection procedure).

7.3.6.1.9 The seal manufacturer shall use the purchaser's selection of barrier/buffer fluid properties for all design calculations. If properties are not acceptable for the application, the manufacturer shall discuss alternative options with the purchaser.

7.3.6.1.10 The minimum barrier pressure shall ensure a pressure of 20 psi (0.14 MPa) (1.4 bar) above the maximum seal chamber pressure.

7.3.6.1.11 Auxiliaries, including reservoirs and accumulators, shall be designed for outdoor installation and site environmental conditions specified by the purchaser. The purchaser and equipment vendors shall agree to supplied equipment protection for the jobsite location. (i.e., winterization for low ambient temperatures, sun shields for radiant heat, heat tracing, insulation, etc.).

NOTE 1 See API Project Design Datasheet Figure N.4 in API 610 as an example for specifying site environmental conditions.

NOTE 2 Annex F contains application guidance on the need for protection features and methods for evaluating their effects on sealing system performance.

7.3.6.2 **Barrier/Buffer Fluid Reservoirs**

7.3.6.2.1 The barrier/buffer fluid reservoir shall be constructed as shown in Annex G (Figure G.38 and Figure G.39).

7.3.6.2.2 The connections on reservoirs for Category 1 shall be threaded and for Categories 2, 3, and 4 shall be flanged.

7.3.6.2.3 [●] If specified by the purchaser, other connections may be provided for reservoirs.

7.3.6.2.4 The height of the normal liquid level (NLL) in the barrier/buffer fluid reservoir above the gland plate of the associated pump shall be established by the seal manufacturer.

7.3.6.2.4.1 The height shall be greater than 3 ft (1 m).

7.3.6.2.4.2 The height shall be based on required flow rate, barrier/buffer fluid ambient conditions, reservoir location, system hydraulic resistance, and the positive circulating device's head versus flow performance characteristics and net positive suction head requirements.

7.3.6.2.5 The reservoir for 52 and 53A shall be equipped with an indicating pressure transmitter PIT sensing the vapor space above the high liquid level (HLL) in the reservoir.

NOTE Arrangement 2 seals equipped with a buffer fluid reservoir normally use a high-pressure alarm to indicate if the primary seal has failed. Arrangement 3 seals equipped with a barrier fluid reservoir normally use a low-pressure alarm to indicate a drop or loss of barrier fluid pressure.

7.3.6.2.6 [●] The reservoir shall be equipped with a level transmitter and low-level alarm (LLA). When specified, a high-level alarm (HLA) shall be provided.

7.3.6.2.7 The reservoir shall be designed to meet the sizing criteria as follows (see Figure G.38 and Figure G.39).

a) The volume of liquid in the reservoir, at NLL, shall be a minimum of

   1) 3 U.S. gal (12 L) for shaft diameters 2.5 in. (60 mm) and smaller,

   2) 5 U.S. gal (20 L) for shaft diameters larger than 2.5 in. (60 mm).

b) Sizing reservoirs larger than clause 7.3.6.2.7.a shall be based on maintenance intervals and cooling requirements.

c) The NLL shall be at least 6 in. (150 mm) above the LLA point.

NOTE A distance of 6 in. (150 mm) allows a convenient visual reference.

d) The volume of the vapor space in the reservoir above the NLL shall be equal to or greater than the liquid volume between the NLL and the LLA point.

NOTE The requirements in Items c) and d) allow for fluctuations in liquid level while ensuring adequate vapor space above the liquid.

e) The HLA, if furnished, shall be at least 2 in. (50 mm) above the NLL.

NOTE A distance of 2 in. (50 mm) minimizes the amount of leaked product entering the reservoir while providing sufficient volume to prevent spurious alarms due to normal fluctuations in level.

f) The LLA shall be at least 2 in. (50 mm) above the top of the return connection.

NOTE The distance specified in Item f) allows the level to fluctuate but still cover the return nozzle.

g) The barrier/buffer return (inlet) to the reservoir shall be at least 10 in. (250 mm) above the barrier/ buffer supply (outlet) connection.

h) The barrier/buffer supply (outlet) from the reservoir shall be at least 2 in. (50 mm) above the bottom of the reservoir. In addition, a valved drain connection, orientated to allow complete draining, shall be provided at the bottom of the reservoir. An internal stand-pipe may be installed in the reservoir.

NOTE Having the supply line exit the reservoir above the bottom prevents any particulate that may have settled out in the reservoir from being carried into the mechanical seal.

i) The type and size of the reservoir connections shall be in accordance with Table 5 and 7.2.9 or 7.2.10.

7.3.6.2.8 The barrier/buffer fluid reservoir shall be fabricated in accordance with 7.3.6.2.9 to 7.3.6.2.15.

7.3.6.2.9 [●] The standard reservoir shall be in accordance with Figure G.38. If specified, the reservoir shall be in accordance with Figure G.39.

7.3.6.2.10 The reservoir is part of the pump piping system. The reservoir shall be designed, fabricated and inspected in accordance with ASME B31.3, or if specified ISO 15649 using piping components. However, local regulations or certifications may require the reservoir to comply with a pressure vessel code like ASME VIII or EN 13445. This shall be clearly called out on the drawing and the datasheet. It is the user's responsibility to make sure local regulations are met and indicated on the datasheet.

7.3.6.2.11 As a minimum, reservoirs shall be fabricated as follows:

— 3 U.S. gal (12 L) reservoirs shall be fabricated from NPS 6 (DN 150) Schedule 40 pipe;

— 5 U.S. gal (20 L) reservoirs shall be fabricated from NPS 8 (DN 200) Schedule 40 pipe.

7.3.6.2.12 A nameplate, stamped with the MAWP, hydrostatic test pressure, and the minimum and maximum allowable working temperatures, shall be permanently attached to the reservoir.

7.3.6.2.13 The barrier/buffer fluid reservoir level gauge shall be a reflex weld pad with a visible range extending from 1 in. (25 mm) below the low-level alarm point to at least 3 in. (75 mm) above the NLL or, if furnished, 1 in. (25 mm) above the high-level alarm point, whichever is greater. Permanent marking to indicate normal level shall be provided.

7.3.6.2.14 The barrier/buffer fluid reservoir and any piping or components welded directly to the reservoir shall be austenitic stainless steel type 316L.

7.3.6.2.15 The barrier/buffer fluid reservoir shall be equipped with a cooling coil as follows.

a) The design of the cooling coil shall comply with 7.3.2.1.7, 7.3.2.1.8, 7.3.2.1.10, 7.3.2.1.11, and 7.3.2.1.13.

b) The coil shall be mounted internally to the reservoir such that the top of the coil is below the bottom of the return (inlet) connection. The cooling liquid shall be on the tube side.

c) Reservoirs equipped with cooling coils that will not be used in the field installation shall have the cooling water inlet and outlet connection plugged with metal plugs.

d) The cooling coil shall be arranged so that it can be completely drained.

7.3.6.3 **Bladder Accumulator**

7.3.6.3.1 [●] The bladder accumulator shall be designed, fabricated, and inspected in accordance with a pressure vessel code such as ASME VIII, EN 13455, or equivalent.

NOTE Bladder accumulators do not typically comply with piping codes such as ASME B31.3 due to their fabrication method.

7.3.6.3.2 Bladder accumulators shall have threaded connections.

NOTE Bladder accumulators are typically only available with threaded connections.

7.3.6.3.3 The minimum size of the bladder accumulator for Plan 53B shall be in accordance with Table 11.

Table 11—Sizing of Bladder Accumulators for Plan 53B

Shaft Size	Seal Category	Seal Chamber Gauge Pressure	Accumulator Nominal Size, Minimum
Less than or equal to 60 mm (2.5 in.)	Category 1	Less than 1.2 MPa (12 bar) (175 psi)	20 L (5 U.S. gal)
	Category 2 and 3	Less than 2.5 MPa (25 bar) (360 psi)	
Greater than 60 mm (2.5 in.) to 110 mm (4.375 in.)	Category 1	Less than 1.2 MPa (12 bar) (175 psi)	35 L (9 U.S. gal)
	Category 2 and 3	Less than 2.5 MPa (25 bar) (360 psi)	
Greater than 110 to 150 mm (6 in.) or All Category 4 Seals	Any	Any	Designed

Note 1. The accumulator working liquid volume is the difference between maximum and minimum barrier liquid volumes. A typical working liquid volume is 15 % to 25 % of the accumulator volume.

Note 2. There are a number of variables that impact the design of Plan 53B accumulator auxiliary seal systems. The accumulator sizes detailed in Table 11 are minimum sizes. Refer to Section F.3.3.3. for more detail.

Note 3 The accumulator alarm and refill pressures can be affected by ambient temperature changes. Two alarm strategies have been developed to address this: fixed alarm strategy (default) and floating alarm strategy (if specified). Refer to Section F.3.3.3.3 for more detail.

7.3.6.3.4 The size of the accumulator shall ensure that barrier fluid pressure at maximum ambient temperature does not exceed the MAWP of the auxiliary system and the dynamic seal pressure rating of the seal cartridge.

7.3.6.3.5 There should always be a minimum liquid volume retained in the accumulator to prevent loss of barrier pressure at the accumulator minimum barrier pressure condition. This should be enough to prevent any contact between the bladder and the fluid port that may either damage the bladder or close the valve.

NOTE A typical accumulator supplier recommendation is 10% of the total accumulator volume.

7.3.6.3.6 The precharge gas pressure and the refill barrier fluid pressure shall be provided by the seal vendor based on minimum ambient temperature and every 10 °F (5 °C) temperature increment to the maximum ambient temperature.

7.3.6.3.7 The maximum and minimum barrier pressure shall be calculated by the seal vendor at minimum ambient temperature and maximum ambient temperature. These values together with a method of estimating the maximum operating barrier pressure at intermediate temperature conditions shall be provided to the purchaser for the initial setting and subsequent replenishment of barrier fluid.

NOTE 1 The maximum operating barrier pressure is dependent on the temperature of the gas in the bladder at the time of filling or refilling. See Annex F for more detail on precharge gas and barrier pressure calculations.

NOTE 2 The bladder accumulator is normally piped and situated such that its bladder gas volume is not affected by the barrier liquid temperature changes but is primarily influenced by local ambient temperature conditions. The corresponding barrier pressure fluctuations will assume the high and low ambient conditions apply to the gas in the bladder. Refer to Annex F for details regarding barrier pressure calculations.

7.3.6.3.8 [●] If specified, an isolation valve shall be installed at the inlet of the accumulator to enable bladder integrity testing.

NOTE 1 Reference Annex G.22 and Annex F for further guidance on bladder integrity testing.

NOTE 2 If valve is left closed during operation it could lead to potential for thermal overpressure of the seal and seal system.

7.3.6.3.9 Plan 53B systems shall be equipped with a pressure transmitter on the liquid side to provide a refill alarm.

7.3.6.3.10 With the fixed pressure alarm strategy the alarm set point shall not be less than the accumulator minimum barrier pressure calculated at the maximum ambient temperature.

7.3.6.3.11 [●] If specified, a temperature transmitter shall be supplied on the gas side of the accumulator in addition to the pressure transmitter on the liquid side.

NOTE 1 The use of a temperature and pressure transmitter provide a temperature compensated alarm floating alarm. See Section F.3.3.3.3.

NOTE 2 A local or plant wide (ambient) temperature measurement can be sufficient.

7.3.6.3.11.1 The output signal from these transmitters shall be available for connection to the plant distributed control system (DCS) for alarm calculation and function.

7.3.6.3.11.2 Specific input for programming the DCS to establish the floating pressure alarm algorithm shall be provided by the vendor.

NOTE 1 Specific input required for the alarm algorithm will typically include the minimum and maximum barrier liquid volume, the accumulator volume, and the minimum barrier system pressure at minimum ambient temperature. The vendor will use this data and the site ambient temperature data to optimize system design, minimize the frequency of refilling, and verify that the system design is suitable for the local installation. Refer to Annex F for more detail.

NOTE 2 The temperature transmitter on the gas side itself is not intended to provide alarm point or trip point. The purpose of this transmitter is to measure the gas temperature of the accumulator and to provide information for the DCS to calculate the pressure related alarm point with temperature compensation – hence floating alarm points depending on gas temperature of the accumulator.

7.3.6.3.11.3 [●] If specified, a locally mounted single loop controller shall be provided for each accumulator. Parameters used by the controller to establish the floating pressure alarm algorithm shall be provided by the vendor.

NOTE This option would be most applicable for locations that do not have DCS systems available.

7.3.6.3.12 Bladder accumulator shells shall be minimum of carbon steel or higher corrosion resistance as the application requires and rated to the MAWP of the casing.

NOTE Internal cladding or coating may be supplied for barrier fluid compatibility or to lower the chance of rupture of the bladder

7.3.6.3.12.1 The rated MAWT of the bladder accumulator shell shall be according to manufacturer's standard, but not less than 175°F (80°C).

7.3.6.3.12.2 Bladder materials shall be according to manufacturer's standard and compatible with the barrier liquid.

7.3.6.3.12.3 The bladder must be rated for at least the minimum ambient temperature unless the accumulator is heat traced and insulated to maintain the temperature greater than the minimum accumulator temperature rating.

7.3.6.3.12.4 Provided that a failure of the elastomeric bladder does not represent a loss of containment, its temperature rating may be lower than the maximum allowable working temperature to which the system will be attached but not lower than the maximum ambient temperature plus solar heating effects.

NOTE Bladder materials are often not suitable for elevated temperatures

7.3.6.3.13 Vendor shall provide an austenitic stainless-steel nameplate, prominently attached. It shall be stamped with at least the information described below. See an example nameplate in Section F.3.3.3.3.

a) Pump Item Number
b) Auxiliary piping system design pressure
c) Minimum and maximum design temperature
d) Barrier liquid
e) Nitrogen precharge pressure at the minimum ambient temperature and every 10 °F (5 °C) temperature increment to the maximum ambient temperature
f) Barrier fluid refill pressure at the minimum ambient temperature and every 10 °F (5 °C) temperature increment to the maximum ambient temperature
g) Low pressure alarm value which is either fixed (per fixed alarm strategy) or temperature compensated (per floating alarm strategy)
h) Lettering shall be easily readable from grade

NOTE The design conditions listed above may appear on a separate nameplate

7.3.6.3.14 The MAWP of the bladder accumulator shell shall exceed the maximum possible supply pressure of the nitrogen precharge system used.

7.3.6.3.15 The barrier fluid cooling circuit should be arranged in accordance with Figure G.37. If a water cooler is selected the height of the cooler in the barrier fluid circuit above the seal gland plate shall be established by the seal vendor. The height of the cooler shall not be less than 18 in. (450 mm).

7.3.6.4 **Piston Accumulator**

7.3.6.4.1 [●] The piston accumulator shall be designed, fabricated, and inspected in accordance with a pressure vessel code such as ASME VIII, EN 13455, or equivalent.

NOTE Fabrication methods of piston accumulators do not typically comply with piping codes such as ASME B31.3.

7.3.6.4.2 Piston accumulators shall have threaded connections.

7.3.6.4.3 [●] If specified, the connections on a piston accumulator shall be flanged.

7.3.6.4.4 The barrier system shall contain an accumulator with a mechanism to provide the barrier fluid with a positive differential pressure above the seal chamber pressure. The differential pressure shall be a minimum 20 psi (0.14 MPa) (1.4 bar).

NOTE This ensures the inner seal operates with a minimal differential pressure and a positive barrier pressure is provided with unplanned excursions in the seal chamber pressure.

7.3.6.4.5 For shaft diameters equal or smaller than 60 mm the barrier minimum liquid volume in accumulator shall be 0.05 U.S. gal (0.2 L) and a maximum liquid volume of at least 0.7 U.S. gal (2.8 L). For shaft diameters above 60 mm the barrier minimum liquid volume in accumulator shall be of 0.09 U.S. gal (0.35 L) and a maximum liquid volume of at least 1.28 U.S. gal (5.1 L).

NOTE These working volumes are similar to the working volume of the two barrier reservoirs in 7.3.6.2.

7.3.6.4.6 Piston accumulators shall be equipped with a:

— differential pressure transmitter with a low-level alarm;

— level indicator and level transmitter with a low- and high-level alarm to warn if piston reaches minimum or maximum end position.

7.3.6.4.7 Piston accumulators and any piping or components welded directly to the accumulator shall be of the same material as the process wetted gland plate or one of a superior corrosion resistance (see 7.1.8).

7.3.6.4.8 The secondary seals of the accumulator shall conform to 6.1.7.5.1 and 6.1.7.5.2 and be of a material compatible with both the process liquid and barrier liquid.

7.3.6.4.9 Provided that a failure of the elastomeric components does not represent a loss of containment, the component temperature rating may be lower than the maximum allowable working temperature to which the system will be attached.

NOTE Elastomeric materials are often not suitable for elevated temperatures

7.3.6.4.10 A nameplate, stamped with at least the Pump Item Number, seal auxiliary system MAWP, and the barrier liquid, shall be permanently attached to the system.

7.3.6.4.11 The barrier fluid cooling circuit should be arranged in accordance with Figure G.40. If a water cooler is selected, the height of the cooler in the barrier fluid circuit above the seal gland plate shall be established by the seal vendor but shall not be less than 18 in. (450 mm).

7.3.6.4.12 [●] If specified a temperature indicator shall be supplied.

7.3.7 **External Circulating Pump**

7.3.7.1 [●] If specified, or if an internal circulating device cannot be provided to meet desired flow rates, an external forced-circulation pump is required. The circulating pump selection shall be agreed upon by the purchaser and the seal manufacturer.

NOTE: Where a failure of the external circulating pump could potentially result in a failure of the mechanical seal in the main pump, an interlock between the circulating pump and the main pump should be considered.

7.3.7.2 Electrical equipment shall comply with IEC 60079 or NFPA 70 Articles 500-502 for the hazardous area classification specified by the purchaser.

7.3.8 **Components for External Seal Flush Systems**

7.3.8.1 [●] If Piping Plan 32, Piping Plan 54, or Piping Plan 55 is selected (Figure G.16, Figure G.24, Figure G.25), the purchaser shall specify the fluid characteristics. The seal manufacturer shall specify the minimum flow rate, minimum pressure and temperature required, where these are factors.

7.3.8.2 [●] If specified, the seal and/or pump manufacturer shall review the purchaser's selection of external flush.

NOTE Inappropriate selection of flush or excessive flush flow rates can affect pump performance.

7.3.9 **Collection Reservoir for Liquid Leakage**

7.3.9.1 **General**

7.3.9.1.1 [●] If leakage can solidify at ambient temperatures, the collector lines shall be heat-traced and insulated. If specified, the purchaser shall identify type and specification for heat tracing.

7.3.9.1.2 The purchaser shall provide any additional requirements for drain disposition.

7.3.9.1.3 The pipe from the gland plate to the collector shall have a minimum slope of 0.5 in./ft (40 mm/m) towards the collector. The minimum pipe size shall be NPS 0.5 (DN 15).

7.3.9.1.4 All components supplied within the scope of Piping Plan 65 and Piping Plan 75, together with interconnecting pipework shall be considered part of the pump casing and meet the requirements of 7.1.4.

7.3.9.1.5 Each seal assembly shall have an independent collection reservoir with instrumentation as specified in Figure G.28, Figure G.29, and Figure G.35.

7.3.9.2 **Reservoir for Atmospheric Leakage (Piping Plan 65A and Piping Plan 65B)**

7.3.9.2.1 The system shall comply with 7.3.9.2.2 to 7.3.9.2.7 and Figure G.28 or Figure G.29.

7.3.9.2.2 The reservoir shall include a level transmitter with a local indicator.

7.3.9.2.3 The reservoir shall have a volume of at least 0.75 U.S. gal (3 L).

7.3.9.2.4 The orifice for Piping Plan 65A shall have a bore diameter of at least 0.2 in. (5 mm).

7.3.9.2.5 The reservoir shall be in accordance with 7.3.6.2.10, 7.3.6.2.12 and Table 5.

7.3.9.2.6 The components of the reservoir shall be fabricated from appropriate size, Schedule 40 pipe.

7.3.9.2.7 The upper drain connection of the reservoir shall be positioned below the drain connection of the gland plate.

7.3.9.3 **Reservoir for Containment Seal Chamber Leakage (Piping Plan 75)**

7.3.9.3.1 If a condensate collection system is provided, the system shall comply with 7.3.9.3.2 to 7.3.9.3.5 (see Figure G.35).

7.3.9.3.2 The condensate collection reservoir:

a) shall be at least 8 in. (200 mm) diameter carbon steel, Schedule 40, and 3 U.S. gal (12 L) minimum capacity in accordance with 7.3.6.2.10, 7.3.6.2.12 and Table 5;

b) shall have at least one flanged end cover for internal maintenance access;

c) shall be fitted with a level gauge mounted on the flanged end cover;

d) shall have a NPS 0.75 in. (DN 20) minimum drain connection that terminates with a valve; and

e) shall have a connection for pressure indicating transmitter with a high-pressure alarm to detect primary seal leakage. This can be on the vessel or in the vent pipe as long as it is upstream of the orifice for which it is measuring pressure.

f) shall have NPS 0.5 in. (DN 15) minimum vent to vapor collection system with a restriction orifice.

7.3.9.3.3 [●] A transmitter with a high-level alarm shall be provided, if specified.

7.3.9.3.4 [●] A test connection shall be installed for injection of nitrogen to test containment seal and/or purge collector, if specified.

7.3.9.3.5 The vent restriction orifice of the leakage collection reservoir shall be below the drain connection of the seal gland plate.

7.3.10 **Barrier/Buffer Gas Supply Systems**

7.3.10.1 If a barrier/buffer gas system is specified, the purchaser and the mechanical seal manufacturer shall mutually agree on the instrumentation requirements and general arrangement.

7.3.10.2 Barrier/buffer gas supply systems shall be provided by the seal supplier and include components and instrumentation as specified in Figure G.33 and Figure G.34.

7.3.10.3 The minimum and maximum operating pressures shall also be within the range of the instrument. If possible, the pressure regulator, indicator, and transmitters shall be selected such that the normal operating pressure is in the middle third of the range.

7.3.10.4 A coalescing filter with a replaceable element or cartridge design shall be supplied and include a drain valve.

7.3.10.4.1 Filter housing shall be stainless steel. Cast aluminum, if approved by the purchaser, is permitted only in air or nitrogen service.

7.3.10.4.2 The coalescing filter shall have an efficiency of 98.8 % on particles of diameter equal or greater than 4 μm with a beta ratio β4 ≤ 85.

7.3.10.4.3 [●] If specified, the filter shall have a liquid-level indicator.

NOTE It is critical that the supply of gas be filtered effectively. Seal face grooves can easily become blocked, where seal face separation decreases and rapid face wear can occur.

7.3.10.5 [●] An indicating pressure transmitter and indicating flow transmitter shall be provided upstream of the check valve. High pressure, high flow, and low flow shall be remotely alarmed from the transmitters. If specified a high-flow switch shall be provided and installed between the flow meter and the check valve (see Figure G.33 and Figure G.34).

7.3.10.6 Each seal arrangement shall have an independent barrier/buffer gas supply system.

7.3.10.7 All external connections of the system shall be NPS 0.5 (DN 15) minimum and in accordance with Table 5.

7.3.10.8 Gas supply systems shall be mounted on a metallic panel that has a minimum thickness of 0.25 in. (6 mm). All components shall be suitably supported to avoid damage to the components and internal piping/tubing.

7.4 Instrumentation

7.4.1 General

7.4.1.1 Instrumentation and installation shall conform to this standard.

7.4.1.2 Controls and instrumentation shall be designed for outdoor installation and shall comply with IEC 60529 designation IP 56 or with NEMA 250 enclosure Type 4.

7.4.1.3 Controls and instrumentation shall be made of materials compatible with the environment and fluids to which they will be exposed. Special consideration shall be given to all controls and instrumentation, such as level gauges and switches, exposed to the pumped fluid and barrier/buffer fluid (if any).

7.4.1.4 Instrumentation and controls shall be designed and manufactured for use in the specified area classification (class, group, and division or zone) stated in the datasheet.

7.4.1.5 All controls and instruments shall be located and arranged to permit easy visibility by the operators, as well as accessibility for tests, adjustments, and maintenance.

7.4.1.6 The MAWP and MAWT of the instruments shall be equal to the MAWP and MAWT of the pump pressure casing except for the following:

7.4.1.6.1 Plan 32, 62, 72 and 74, shall be specified by the purchaser as defined in Annex G.

7.4.1.6.2 Instruments that are in a dead-leg may have a lower MAT.

NOTE Accumulators or other components may be installed in a dead-leg of the system. The dead-leg will never be exposed to high temperatures due to lack of circulation.

7.4.1.7 Instruments in contact with auxiliary system fluids shall be suitable for the normal operating temperatures of those fluids but their temperature limit shall not be below 212 °F (100 °C). If a failure of the instruments in an auxiliary circuit does not represent a loss of containment, the temperature limit of an instrument may be lower than the MAWT of the pressure casing.

NOTE The temperature limit of some common instruments can be below the possible MAWT of a pressure casing. Many bourdon tube pressure gauges with liquid filling, for example, do normally have a temperature limit of about 212 °F (100 °C). The operation temperature of a buffer/barrier medium is often much lower than the MAWT of the pump.

7.4.1.8 [●] If specified by the purchaser, instrumentation in buffer/barrier circuits shall be suitable for the MAWT of the pump. When instruments need to be suitable for the MAWT of the pump, special design features for the instrumentation have to be considered by the seal vendor.

7.4.2 Temperature-indicating Gauges

7.4.2.1 Dial temperature gauges shall be heavy duty and corrosion resistant. The gauges shall be bimetallic or liquid filled with a rigid stem suitable for mounting as needed. Mercury-filled thermometers shall not be acceptable. Black printing on a white background is standard style for gauge faces.

7.4.2.2 Dial temperature gauges shall be installed in pipe sections or in tubing runs as specified. Auxiliary equipment may be either piping or tubing. The owner shall specify whether gauges shall be placed in tubing or piping.

7.4.2.3 The sensing elements of temperature gauges shall be in the flowing fluid to the depth specified by the gauge manufacturer.

7.4.2.4 Temperature gauges installed in tubing shall be a minimum of 1.5 in. (38 mm) in diameter, and the stem shall have a minimum length of 2 in. (50 mm). All other gauges shall be a minimum of 3.5 in. (90 mm) in diameter, and the stem shall have a minimum length of 3 in. (75 mm).

NOTE The use of 3.5 in. (90 mm) gauge diameter instead of standard 5 in. (125 mm) is due to the normally small size of piping used in seal systems.

7.4.3 Thermowells

7.4.3.1 Temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with thermowells made of austenitic stainless steel or another material more compatible with the liquid as defined by the manufacturer. Thermowells installed in piping shall be NPS 0.5 (DN 15) minimum. Thermowells for use in tubing shall be approved by the purchaser. Thermowell designs and installation should not restrict liquid flow.

7.4.3.2 The thermowell connection into the piping, tubing, or accessories shall be consistent with other connections in the piping system.

7.4.4 **Pressure Indicators**

7.4.4.1 Pressure indicators shall be in accordance with API 614.

7.4.4.2 Pressure indicators shall have block-bleed valves.

7.4.4.3 [●] If specified, oil-filled pressure indicators shall be furnished.

7.4.5 **Transmitters and Switches**

7.4.5.1 **General**

7.4.5.1.1 Transmitters and switches shall be per API 614.

7.4.5.1.2 [●] If specified, switches shall be provided in place of transmitters.

7.4.5.1.3 If switches are specified instead of transmitters these devices should be substituted at locations shown for transmitters in Annex G. Depending on the function of the transmitter, a local indicator could also be required in addition to the switch.

7.4.5.2 **Pressure Transmitters**

7.4.5.2.1 Pressure transmitter shall be designed for the maximum pressure to which the transmitter may be exposed. Transmitters exposed to vacuum shall be suitable for full vacuum.

7.4.5.2.2 The measuring element and all pressure-containing parts shall be austenitic stainless steel type 316 unless the pumped fluid requires the use of alternative materials.

7.4.5.2.3 Connections for pressure input shall be NPT 0.5 minimum.

7.4.5.2.4 Pressure transmitters shall have block-bleed valves.

7.4.5.2.5 [●] If specified, connections for pressure input shall be flanged.

7.4.6 **Level Indicators**

7.4.6.1 The standard level indicator shall be the weld pad reflex design.

7.4.6.2 [●] If specified, an externally mounted, removable, reflex indicator shall be furnished instead of the standard weld pad design.

7.4.7 **Flow Instruments**

7.4.7.1 **Flow Indicators**

Flow indicators shall be of the nonrestrictive bull’s-eye type and shall have a body that matches or exceeds the line material specification. To facilitate viewing of the flow through the line, each flow indicator shall be installed in accordance with the manufacturer's instructions. The diameter of the bull's eye shall be at least one-half the inside diameter of the line and shall clearly show the minimum flow.

7.4.7.2 **Flow Meters**

Flow meters shall be armored rotameter or internal magnetic float design in accordance with the following.

a) Rotameters shall be installed in the vertical position and piped in accordance with the vendor's recommendations.

b) The capacity of the rotameter selected shall be such that normal flow rate falls in the middle one-third of the scale.

c) A check valve shall be installed on the outlet of the meter to prevent back flow.

d) Glass tube flow meters, if approved by purchaser, may only be used on air or inert gas at temperatures of 140 °F (60 °C) or less, and gauge pressures of 100 psi (0.7 MPa) (7 bar) or less.

7.4.8 **Relief Valves**

7.4.8.1 The seal system supplier shall furnish the relief valves that are to be installed on the seal support system.

7.4.8.1.1 The system supplier shall determine the size and set pressure of supplied relief valves.

7.4.8.1.2 Relief valves for all operating equipment shall meet the relief-valve requirements defined in API 520, Part I and Part II, and if applicable in API 526 (diameter ≥ 1 in.).

7.4.8.1.3 The seal support system suppliers' quotation shall list all relief valves they supply.

7.4.8.2 [●] If specified, thermal relief valves shall be provided for components that may be blocked in by isolation valves.

7.4.9 **Pressure Control Valves**

Pressure control valves for gas buffer and barrier systems shall be supplied in accordance with the following.

a) Pressure control valves shall be self-contained, spring-loaded with an internal pressure-sensing connection.

b) The pressure control valve shall be designed such that the regulated pressure is applied directly to the diaphragm through the valve body.

c) An adjusting device shall be provided with a locking mechanism to ensure that the control point cannot shift or be changed inadvertently.

d) The pressure control valve body shall be rated for the maximum upstream and downstream pressure and temperature to which it may be subjected.

e) Cast-iron valve bodies are not permitted. Cast aluminum, if approved by the purchaser, is permitted only in air or nitrogen service; spring and diaphragm housings shall be steel or stainless steel.

f) Pressure control valves shall not be self-venting.

7.4.10 **Pressure Amplifiers**

A gas-pressure booster shall be provided if necessary to increase utility gas supply pressure.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

8.1.1 The purchaser's representative shall have entry to all vendor and sub-vendor plants where manufacturing, testing, or inspection of the equipment is in progress.

8.1.2 The vendor shall notify sub-vendors of the purchaser's inspection and testing requirements.

8.1.3 The vendor shall provide a minimum of five working days notice to the purchaser before conducting any inspection or test that the purchaser has specified should be a witnessed test or an observed test.

8.1.4 **[●]** The purchaser shall specify the extent of his/her participation in the inspection and testing.

8.1.5 The purchaser's representative shall have access to the manufacturer's quality control program for review.

8.1.6 Equipment for the specified inspection and tests shall be provided by the vendor.

8.1.7 **[●]** If specified, the purchaser, the vendor, or both, shall verify compliance with this standard and initial and date a completed checklist. An example of an inspector's checklist is given in Annex H.

8.2 Inspection

8.2.1 Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

8.2.2 **[●]** In addition to the requirements of 6.1.7.10, the purchaser may specify the following:

— parts that shall be subjected to surface and subsurface examination and

— the type of examination required, such as magnetic-particle, liquid-penetrant, radiographic, or ultrasonic examination.

8.2.3 The nondestructive examination (NDE) shall be performed as required by the material specification. If additional radiographic, ultrasonic, magnetic particle, or liquid penetrant examinations of the welds or materials are specified by the purchaser, the methods and acceptance criteria shall be as follows. Alternative standards may be proposed by the vendor or specified by the purchaser.

a) Radiography shall be in accordance with Section V, Article 2 and Article 22 of the ASME *Code*.

b) The radiographic acceptance standard used for welded fabrications shall be ASME VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography). The acceptance standard used for castings shall be ASME VIII, Division 1, Appendix 7.

c) Ultrasonic inspection shall be in accordance with ASME V, Articles 4, 5 and 23.

d) The ultrasonic acceptance standard used for welded fabrications shall be ASME VIII, Division 1, Appendix 12. The acceptance standard used for castings shall be ASME VIII, Division 1, Appendix 7.

e) Magnetic particle inspection shall be in accordance with ASME V, Article 7 and Article 25.

f) The magnetic particle acceptance standard used for welded fabrications shall be ASME VIII, Division 1, Appendix 6. The acceptance standard used for castings shall be ASME VIII, Division 1, Appendix 7.

g) Liquid penetrant inspection shall be in accordance with ASME V, Article 6 and Article 24.

h) The liquid penetrant acceptance standard used for welded fabrications shall be ASME VIII, Division 1, Appendix 8. The acceptance standard used for castings shall be ASME VIII, Division 1, Appendix 7.

i) Regardless of the acceptance criteria in Items b), d), f), and h), it shall be the manufacturer's responsibility to review the design limits of the equipment if more stringent requirements are necessary. Defects that do not meet the acceptance criteria imposed in Items b), d), f), and h) above shall be removed to meet the quality standards cited, as determined by the inspection method specified.

j) During assembly of the system and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another appropriate method to remove foreign materials, corrosion products, and mill scale.

k) [●] If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the manufacturer.

8.3 Testing

8.3.1 General

8.3.1.1 Job seal testing sequence shall be as shown in Figure 24.

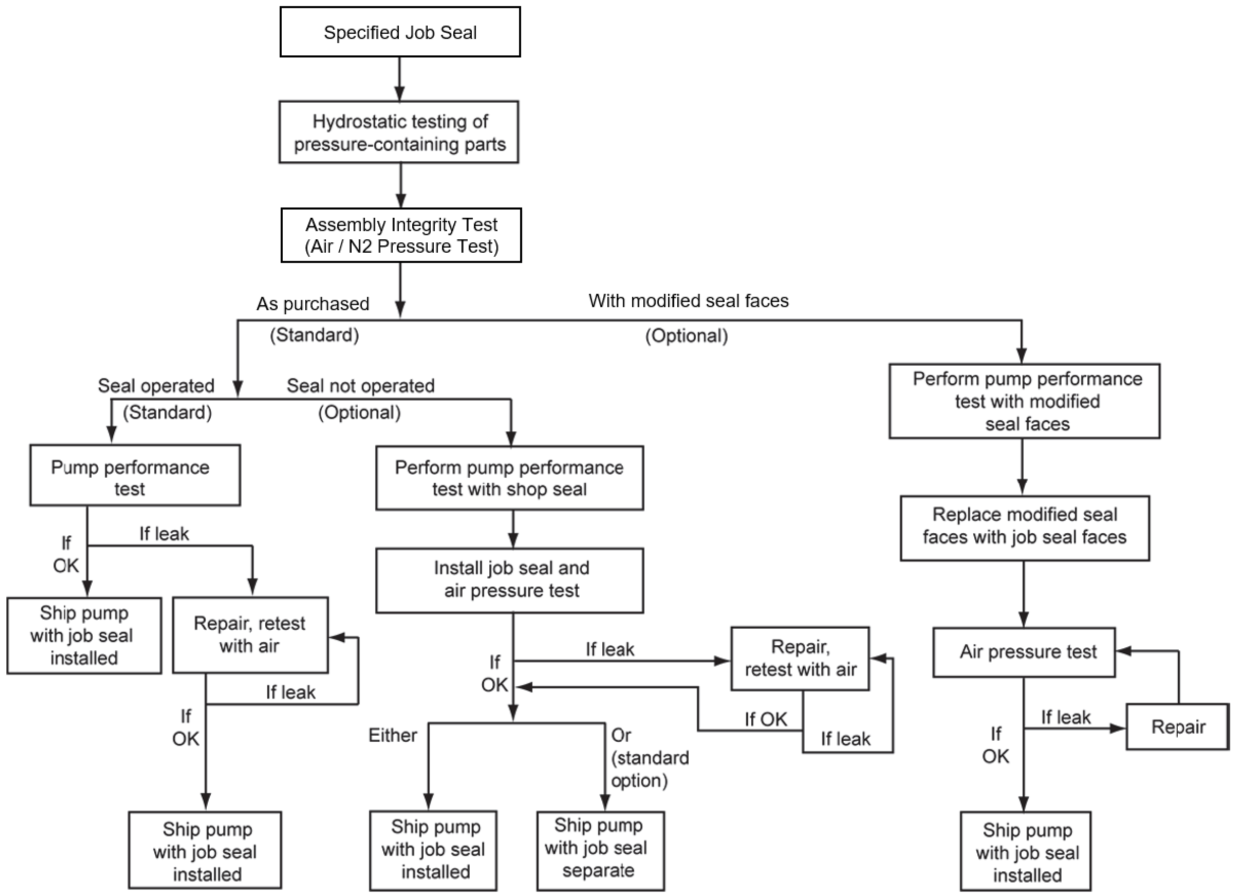


Figure 24—Job Seal Testing Sequence

8.3.2 Job Seal Testing by Seal Vendor

8.3.2.1 Hydrostatic Test for Pressure-Containing Mechanical Seal Parts

8.3.2.1.1 Pressure-casing seal components, except gland plates machined from a single piece of wrought material or bar stock, shall be tested hydrostatically with liquid at a minimum of 1.5 times the MAWP of the pump casing to which the component is connected but not less than a gauge pressure of 20 psi (0.14 MPa) (1.4 bar).

8.3.2.1.2 The test liquid shall be at a higher temperature than the nil ductility transition temperature of the material being tested.

8.3.2.1.3 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at the operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or in EN 13445 or ASME VIII, Division 1 for vessels. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The datasheets shall list actual hydrostatic test pressures.

8.3.2.1.4 Where applicable, tests shall be in accordance with the EN 13445 or ASME VIII. If a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

8.3.2.1.5 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 ppm wt (50 mg/kg). To prevent deposition of chlorides because of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

8.3.2.2 **Assembly Integrity Test**

8.3.2.2.1 Each mechanical seal assembly shall be tested with pressurized air (or nitrogen) by the seal manufacturer in accordance with 8.3.2.2 prior to shipment.

NOTE The assembly integrity test is an acceptance test intended to confirm the seal cartridge was assembled correctly. The seals are not expected to be leak-free, and the results of this test are not intended to be representative of seal performance on liquid. Reference Section A.1.3 and F.1.1 for further information on seal leakage.

8.3.2.2.2 [●] If specified, optional air or nitrogen testing at test conditions that differ from the standard assembly integrity test shall be completed

8.3.2.2.3 Provisions for assembly integrity testing shall include requirements 8.3.2.2.3.1 to 8.3.2.2.3.4.

8.3.2.2.3.1 Seals shall be thoroughly inspected, cleaned, and faces verified to be free of lubricants and grease as they are assembled.

8.3.2.2.3.2 The job type, size, material, and part number gasketing specified shall be used.

8.3.2.2.3.3 The test fixture shall be capable of accommodating the entire seal without modification to the seal cartridge, seal chamber if provided by the seal manufacturer, or the gland plate.

8.3.2.2.3.4 Arrangement 2 seals shall have provisions to test each sealing section independently.

8.3.2.2.4 Integrity tests shall be conducted using an appropriate test rig by the seal manufacturer in accordance with 8.3.2.2.4.1 to 8.3.2.2.4.4.

NOTE Typically a test rig simulates a large seal chamber using a canister having various connections, bolting, valves, and instrumentation. Adapters are used to accommodate a range of seal sizes.

8.3.2.2.4.1 The test rig shall have connections to test the simulated seal chamber, the buffer chamber, the barrier chamber, or the containment chamber independently in accordance with 8.3.2.2.5 and 8.3.2.2.6.

8.3.2.2.4.2 The test rig shall have a fill and pressurizing system capable of being isolated from the simulated seal chamber, the buffer chamber, the barrier chamber or the containment chamber that is being tested.

8.3.2.2.4.3 The volume of gas to be pressurized and tested in any of the chambers shall be a maximum of 1 ft3 (28 L).

8.3.2.2.4.4 The pressure gauge used for the test shall have a range so that the gauge pressure of 25 psi (0.17 MPa) (1.7 bar) is close to the midpoint.

8.3.2.2.5 Each simulated seal chamber, buffer chamber, barrier chamber, or containment chamber being tested shall be independently pressurized with clean gas to a gauge pressure of 25 psi (0.17 MPa) (1.7 bar).

8.3.2.2.6 After pressurizing according to 8.3.2.2.5, isolate each simulated seal chamber, buffer chamber, barrier chamber, or containment chamber from the pressurizing source for five minutes.

8.3.2.2.7 The maximum pressure decrease during the test shall be 2 psi (0.014 MPa) (0.14 bar).

NOTE 1 Pressure drop is inversely proportional to the volume being tested. This is an important consideration if the test chamber contains only a small volume of gas. When testing non-contacting seals, two sets of core seal components simultaneously, or field testing dual seals having a small volume of gas, special test conditions and/or acceptance criteria may apply.

NOTE 2 Because of variations in volume, installation, and alignment, the results of the assembly integrity test may not be repeatable after installation.

8.3.2.2.8 Following successful completion of the assembly integrity test, the tested seal cartridge shall not be disassembled. The cartridge assembly shall be tagged with the words "certified seal manufacturer assembly integrity test acceptable," giving the test date and the inspector's name.

8.3.2.2.9 In the event that the seal assembly does not pass the assembly integrity test, the entire test shall be repeated until a successful test has been accomplished.

8.3.2.3 **Additional Job Seal Testing**

8.3.2.3.1 [●] If specified, testing at test conditions that differ from the standard qualification testing conditions shall be completed.

NOTE The standard qualification testing conditions aims to provide end users with the highest degree of confidence that a commercial product seal will perform as required. If additional certainty is demanded for a specific application additional testing of the job seal will need to be mutually agreed between the purchaser and seal vendor.

8.3.3 Job Seal Testing by Pump Vendor

8.3.3.1 [●] If specified, the air-tested seal shall be supplied to the pump manufacturer with modified seal faces for operation during the pump performance test. Following the pump performance test, the job seal faces shall be installed in the seal and air tested in accordance with 8.3.2.2.

8.3.3.2 [●] If specified, the seal being supplied shall not be operated in the pump during the pump performance test, to prevent damage. During the pump performance test, the pump shall use a seal supplied by the pump manufacturer. The seal being supplied, and the seal chamber (if applicable), shall be installed after the pump performance test and air tested in accordance with 8.3.2.2. It shall be specified if the seal is to be shipped uninstalled.

8.3.4 Hydrostatic Test of Pressure-Containing Seal Accessories

8.3.4.1 Pressure-containing seal accessories shall be hydrostatically tested with liquid at a minimum of 1.5 times the MAWP of the pump casing to which the component is connected but not less than a gauge pressure of 20 psi (0.14 MPa) (1.4 bar).

8.3.4.2 Requirements listed in 10.3.2.1.2 to 10.3.2.1.5 shall also be applied to hydrostatic testing of pressure-containing seal accessories.

8.4 Preparation for Shipment

8.4.1 The equipment shall be prepared for the type of shipment as described in 8.4.3.

8.4.2 The manufacturer shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

8.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include the following.

a) Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates. Stainless steel parts need not be painted.

b) Carbon steel exterior machined surfaces shall be coated with a suitable rust preventive.

c) The interior of the equipment shall be clean and free from scale, welding spatter, and foreign objects.

d) Internal steel areas of carbon steel systems of any auxiliary equipment, such as reservoirs, shall be coated with a suitable oil-soluble rust preventive.

e) Flanged openings shall be provided with metal closures at least 0.1875 in. (4.8 mm) thick, with elastomer gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be installed.

f) Seal gland plate threaded openings shall be plugged in accordance with 8.4.6.

g) Threaded connections other than on the seal gland shall have metal plugs inserted for shipment in accordance with 8.2.19.

h) Shipping units shall be marked with industry standard cautionary symbols indicating center of gravity, sling or lifting points, top heavy packages, fragile and liquid contents, moisture sensitive contents, etc. per ASTM D5445-05.

i) For Category 3 seals, the equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment, and shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

8.4.4 Auxiliary piping connections shall be die stamped or permanently tagged to agree with the manufacturer's connection table or general arrangement drawing. Service and connection designations shall be indicated.

8.4.5 One copy of the seal manufacturer's installation instructions shall be packed and shipped with the equipment.

8.4.6 The seal gland threaded connection points shall be plugged with plastic plugs for shipment.

8.4.6.1 These plugs shall be red in color and have a center tab to be easily pulled and distinguished from metal plugs. (See Figure 25)

8.4.6.2 A yellow warning tag 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 25 for an example of such a tag.

8.4.6.3 Plastic plugs, tags, and seal gland plates shall not be painted over on any equipment.

8.4.6.4 Metal plugs shall be of the same material as the gland, or with superior corrosion resistance for the intended service.

8.4.6.4.1 Metal plugs shall be furnished and packaged separately from the seal with a warning label that all unused seal connections shall be plugged. The same warning shall be included in the seal drawing and instructions. The seal drawing is to be included with the metal plugs in addition to the copy of the seal drawing that is included in the box with the seal.

8.4.6.4.2 The metal plugs shall be solid round or solid hexagonal head plugs furnished in accordance with the dimensional requirements of ASME B16.11.

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

8.4.6.4.3 Category 1 seals provided with flush-mount socket head plugs are acceptable.

NOTE The head on a pipe plug interferes with the installation and 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 used on the seal chamber port can interfere with the back side of the gland plate because of the limited axial space.

Figure 25—Plastic Plug with Center Tab and Example of Warning Tag

9 Vendors Data

9.1 General

9.1.1 The transfer of the required data and documents is the joint responsibility of the purchaser and vendor. The following checklists and forms shall be used to facilitate the transfer of data for inquiries, proposals, and contracts. The purchaser may submit the required data to the vendor in a form other than that indicated herein. However, the alternative forms shall include at least all the information specified in Annex C and Annex E.

9.1.2 **[●]** Other or additional documentation requirements for proposals and contracts shall be specified in the inquiry of the purchaser.

9.1.3 The minimum information to be furnished by the seal vendor is specified in the Data Requirement Forms and shall be sent to the address or addresses noted on the enquiry or order.

9.1.4 The following information shall be identified on proposal letters, contract cover sheets, and on mechanical seal datasheets for Category 1, Category 2 and Category 4 installations. Category 3 installations shall have the information on cover letters, mechanical seal datasheets, arrangement drawings, and on installation, operation, and maintenance manuals:

a) the purchaser or user's corporate name;

b) the job or project reference;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order; and

f) the manufacturer’s identifying proposal reference, shop order number, serial number, or other reference required to uniquely identify return correspondence.

9.1.5 At the inquiry stage, the installation, operation, and maintenance manuals shall be in English. A copy shall be included with the supplied seal and auxiliary system. It shall provide sufficient instructions and a cross-referenced list of all drawings and bills of materials to enable the purchaser to correctly install, operate, and maintain all of the equipment covered by the purchase order.

9.1.6 A copy of the seal drawing shall be put into the box in which the seal is shipped and another copy shall be put into the bag that also contains the metal plugs for the gland plate.

9.2 Data Requirement Forms

The information to be furnished for inquiries, proposals and contracts is described in the Data Requirements Forms (see Annex E). These forms specify the required data. The Data Requirement Forms also specify which party is responsible for supplying the data.

9.3 Datasheet

Completion of the datasheets (Annex C) is the joint responsibility of the purchaser and the vendor. The purchaser may submit the datasheets to the vendor in a form other than that indicated herein. However, the alternative datasheets shall include at least all the information provided in Annex C. Mechanical seals can be described in a general manner by using mechanical seal codes such as those given in Annex D.

NOTE This information is the basis for the selection, the specification and the purchasing agreement.

9.4 Inspector Checklist

This list can be used to check the compliance and completeness of the delivered seals and seal auxiliary systems according to this standard.

Annex A
(informative)

Recommended Seal Selection Procedure

A.1 Assumptions and Instructions

A.1.1 Application Range

This seal selection procedure provides a recommended seal type, arrangement, piping plan and barrier/buffer fluid given the intended service condition, provided the conditions meet the seal operating envelope of Category 1 seals, Category 2 seals, Category 3 or Category 4 seals.

The fluids covered by this selection process include:

a) water;

b) sour water (containing hydrogen sulfide H_2S);

c) caustics;

d) amines;

e) some acids; and

f) most hydrocarbons.

A.1.2 Additional Engineering Required

This is a recommended procedure only. It is the responsibility of the purchaser or seal vendor using this procedure to ensure that the selected seal and auxiliaries are suitable for the intended service condition. The use of other selection criteria and more detailed engineering review is specifically recommended for the following service conditions:

a) pressures or temperatures outside the ranges defined in Section 4.2 of this standard;

b) installations into seal chambers not included in Section 6 of this standard;

c) seal types and arrangements not listed in this standard, e.g. coaxial seals;

d) surface speed above 4500 ft/min (23 m/s);

e) highly corrosive fluids for which the materials specified in this standard are not suitable;

f) fluids with absolute vapor pressures in excess of 493 psi (3.4 MPa) (34 bar);

g) unstable liquid properties, for example multiphase or non-Newtonian fluids, etc.;

h) high solids concentration;

i) shaft diameters above 5.9 in. (150 mm) or below 0.75 in. (20 mm);

j) high viscosity or pour point above or within 36 °F (20 °C) of minimum ambient temperature; and

k) fluids with special and/or unusual properties such as pharmaceuticals, liquid oxygen, hydrofluoric acid, food grade materials, and other specialty liquids.

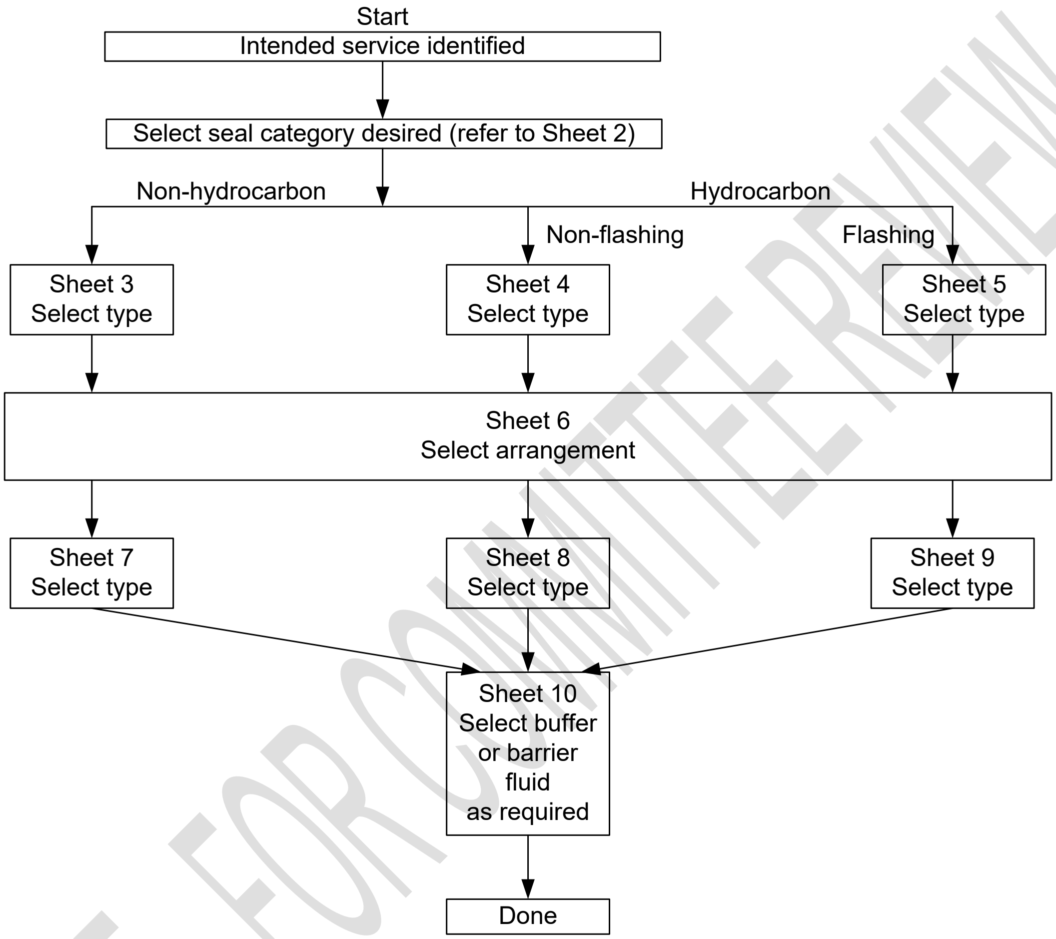
A.1.3 Seal Leakage

There is always a mass flow rate across the face of a mechanical seal, so all seals “leak” to some extent. Leakage can occur regardless of seal category, type or arrangement; however, with Arrangement 2 and Arrangement 3 seals, the leaked fluid could be buffer or barrier fluid instead of process fluid. See F.1.1 for more detail.

A.1.4 Instructions and Seal Selection Sheets

To use these seal selection sheets, begin on Table A.1 (Sheet 1) and consult the appropriate sheet according to the relevant service condition and fluid. Where alternative seal types are listed, they should be considered an acceptable equivalent to the default seal shown.

RECOMMENDED SEAL SELECTION PROCEDURE
SHEET 1 OF 10



RECOMMENDED SEAL SELECTION PROCEDURE
SEAL CATEGORY, TYPE, AND ARRANGEMENT SUMMARY
SHEET 2 OF 10

Seal category shall be Category 1, Category 2, Category 3 or Category 4 as specified.

The major features of each category are summarized below. Options, where they exist for each feature, are listed in the text as “if specified.” Subsection numbers in parentheses indicate where the requirements are specified.

	Category 1	**Category 2**	**Category 3**	**Category 4**
Seal chamber size (4.2.2)	ASME B73.1 or ASME B73.2	API 610	API 610	API 610
Seal chamber temperature range (4.2.2)	–40 °F to 500 °F (–40 °C to 260 °C)	–40 °F to 750 °F (–40 °C to 400 °C)		–40 °F to 350 °F (–40 °C to 176 °C)
Maximum dynamic sealing pressure, gauge (4.2.2)	300 psi (2.0 MPa) (20 Bar)	600 psi (4.0 MPa) (40 Bar)		1480 psi (10.2 MPa) (102 Bar)
Face materials (6.1.7.2)	carbon vs silicon carbide			
Distributed inlet flush requirements, Arrangements 1 and 2 with rotating flexible elements	If required by 6.1.3.14 or if specified (6.2.1.2.1)	Required. (6.2.2.2.1)	Required (6.2.3.2)	Required (6.2.4.2)
Cartridge seal shaft size increments required	None	10 mm increments.		
Throttle bushing design requirement for Arrangement 1 seals (6.3.1.2.1)	Default is fixed carbon; optional floating or segmented carbon (6.3.1.2.1)	Default is floating carbon; optional fixed or segmented carbon (6.3.1.2.1)	Default is floating carbon; optional fixed or segmented carbon (6.3.1.2.1)	Default is floating carbon; optional fixed or segmented carbon (6.3.1.2.1)
Dual-seal circulation device head flow curve provided	If specified (6.3.1.2.6)		Required (6.3.1.2.6)	If specified (6.3.1.2.6)
Scope of vendor qualification test	Test as Category 1 unless all the following have been tested to Category 2 or 3: a) core seal components b) adaptive hardware c) seal type d) configuration faces (I.3.5)	Test as Category 2 unless all the following have been tested to Category 3: a) core seal components b) adaptive hardware c) seal type d) configuration faces (I.3.5)	Test as Category 3, entire seal assembly as a unit (I.3.5)	Test as Category 4, entire seal assembly as a unit (I.3.5)

Proposal data requirements	Minimal (Annex E)	Rigorous, including qualification test results (Annex E)
Contract data requirements	Minimal (Annex E)	Rigorous (Annex E)

SHEET 2 OF 10 (*continued*)

Seal type shall be Type A, Type B, or Type C as specified.

The major features of each type are summarized below. Options, where they exist for each feature, are listed in the text as "if specified." Subsection numbers in parentheses indicate where the requirements are specified.

Feature	Type A	Type B	Type C
Standard temperature application range (4.2.3)	–40 °F to 350 °F (–40 °C to 176 °C)		–40 °F to 750 °F (–40 °C to 400 °C)
Hydraulic balance requirement (4.2.3)	Balanced (e.g. hydraulic balance less than 1)		
Mounting requirement (4.2.3)	Inside the seal chamber		
Cartridge requirement (4.2.3 and 6.1.1.1)	Cartridge design		
Flexible element style (4.2.3)	Pusher (e.g. sliding elastomer)	Non-pusher (e.g. bellows)	
Flexible element orientation (4.2.3)	Rotating or stationary options are acceptable (6.1.1.2) Stationary element required if seal-face surface speed at the mean diameter of the seal face exceeds 4500 ft/min (23 m/s) (6.1.1.5)		
Bellows material (6.1.7.6)	Not applicable	Alloy C-276	Alloy 718
Spring type (4.2.3)	Multiple-coil springs Single-spring option (6.1.6.1)	Single bellows	
Maximum surface speed for rotating element application (6.1.1.5)	Stationary element required if seal-face surface speed at the mean diameter of the seal face exceeds 4500 ft/min (23 m/s) (6.1.1.5)		
Secondary sealing element material (4.2.3)	Elastomer		Flexible graphite

SHEET 2 OF 10 (*continued*)

Seal arrangement shall be Arrangement 1, Arrangement 2, or Arrangement 3 as specified.

The major features of each arrangement are summarized below. Options, where they exist for each feature, are listed in the text as "if specified." Section numbers in parentheses indicate where the requirements are specified.

Feature	Arrangement 1	Arrangement 2	Arrangement 3
Number of core seal components per cartridge, see Annex I	One (4.2.4)	Two (4.2.4)	Two (4.2.4)
Uses a barrier or buffer fluid (4.2.4)	No	Sometimes, but not required. Liquid or gas buffer permitted.	Yes, barrier fluid required, liquid or gas permitted
Allows noncontacting (wet or dry) seals (4.2.4)	No	Yes, Figure 4 and Figure 5	Yes, Figure 6 and Figure 7
Throttle bushing requirement. (6.3.1.2.1)	Category 1: Fixed carbon Category 2: Floating carbon Category 3: Floating carbon Category 4: Floating carbon	If specified	
Arrangement 2 containment seal chamber bushing requirement	Not applicable	Required with dry-running containment seal regardless of inner seal design (6.3.2.4.1 and 6.3.2.5.1)	Not applicable
Maximum buffer/barrier fluid temperature rise	Not applicable	15 °F (8 °C) aqueous or diesel, 30 °F (16 °C) mineral oils (6.3.2.3.1)	15 °F (8 °C) aqueous or diesel, 30 °F (16 °C) mineral oils (6.3.3.3.1)
Seal chamber pressure/flush design requirement (6.1.3.14)	Seal chamber pressure 50 psi (0.35 MPa) (3.5 bar) above fluid vapor pressure		None
Minimum operating seal chamber pressure requirement (6.1.3.14)	5 psi (0.035 MPa) (0.35 bar) above atmospheric pressure		None
Minimum gland plate connection sizes and orientation	See Table 2		
Minimum barrier/buffer fluid liquid reservoir	Not applicable	3 U.S. gal (12 liters) for shaft diameter 2.5 in. (60 mm) and smaller barrier; otherwise 5 U.S. gal (20 liters) (7.3.6.2.5)	
Test requirements	(8.3) Annex I		

RECOMMENDED SEAL TYPE SELECTION PROCEDURE
SHEET 3 OF 10
Nonhydrocarbon services

Fluids		**Operating Conditions, Recommended Seal Types, and Special Features**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		Water			Sour water		Caustic, amines crystallize		Acids [a] H_2SO_4, H_3PO_4
Pumping temperature.	°F (°C)	<180 (<80)		>180 (>80)	<180 (<80)				
Seal chamber gauge pressure, Category 1 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)		Not applicable	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)
Seal chamber gauge pressure, Category 2 and 3 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)		<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)
Seal chamber gauge pressure, Category 4 seals	psi (MPa) (bar)	Not applica ble	600 to 1480 (4.0 to 10.2 MPa) (40 to 102 Bar)		Not applicable				
Default seal type		Type A							
Options if specified		Type B Type C	Type B [b] Type C [b]		Type B Type C	Type B [b] Type C [b]	Type B Type C	Type B [b] Type C [b]	Type B Type C
Required special features		Not applicable		Circulating device	Perfluoroelastomer		Amine-resistant perfluoroelastomer		Perfluoro-elastomer and single spring for Type A seals
Special features for contaminants [c]									
Abrasive particulates		Hardface versus hardface							
This selection procedure chooses seal designs consistent with the default positions throughout this standard. Listed options meeting the requirements of this standard might perform equally well.									

[a] Up to 20 % H_2SO_4 at 25 °C (77° F) only. Up to 20 % H_3PO_4 at 80 °C (176 °F) only. All other acids, including hydrofluoric, fuming nitric, and hydrochloric acids, require special engineering agreed between purchaser and vendor.

[b] Consult vendor to understand available options for Type B and Type C seals along with review of qualification per applicable seal category.

[c] Special features listed apply only in mixtures having pH between 4 and 11.

[d] NaOH applications require self-sintered SiC.

RECOMMENDED SEAL TYPE SELECTION PROCEDURE
SHEET 4 OF 10
Nonflashing hydrocarbons

Fluids		**Operating Conditions, Recommended Seal Types, and Special Features**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Pumping temp	°F (°C)	−40 to 23 (−40 to −5)		23 to 348.8 (−5 to 176)		348.8 to 500 (176 to 260)		500 to 700 (260 to 400)	
Seal chamber gauge pressure, Category 1 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)	Not applicable		
Seal chamber gauge pressure, Category 2 and 3 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<2.0 (<20) (<300)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)
Seal chamber gauge pressure, Category 4 seals	psi (MPa) (bar)	600 to 1480 (4.0 to 10.2 MPa) (40 to 102 Bar)				Not applicable			
Standard seal type		Type A				Type C	ES [a]	Type C	ES [a]
Option if specified		Type B Type C	Type B [a] Type C [a]	Type B Type C	Type B [a] Type C [a]	Type B [a] Type C [a]	Not applicable	Type B [a] Type C [a]	Not applicable
Required special features		Consult Vendor for O-ring material		Not applicable					
Special features for contaminants [b]									
Caustic		Not applicable		Perfluoroelastomer		Not applicable			
Abrasive particles		Hardface versus hardface							
Aromatics and/or H_2S		Not applicable		Perfluoroelastomer		Not applicable			
Amines		Not applicable		Amine-resistant Perfluoroelastomer		Not applicable			
This selection procedure chooses seal designs consistent with the default positions throughout this standard. Listed options meeting this standard might perform equally well.									

[a] Consult vendor to understand available options for Type B and Type C seals along with review of qualification per applicable seal category.

[b] Special features listed apply only in mixtures having pH between 4 and 11.

RECOMMENDED SEAL TYPE SELECTION PROCEDURE
SHEET 5 OF 10
Flashing hydrocarbons

Fluids		Operating Conditions, Recommended Seal Types, and Special Features							
		1	2	3	4	5	6	7	8
Pumping temp	°F (°C)	−40 to 23 (−40 to −5)		23 to 348.8 (−5 to 176)		348.8 to 500 (176 to 260)		500 to 700 (260 to 400)	
Seal chamber gauge pressure, Category 1 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)	Not applicable	<300 (<2.0) (<20)	Not applicable		
Seal chamber gauge pressure, Category 2 and 3 seals	psi (MPa) (bar)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)	<2.0 (<20) (<300)	300 to 600 (2.0 to 4.0) (20 to 40)	<300 (<2.0) (<20)	300 to 600 (2.0 to 4.0) (20 to 40)
Seal chamber gauge pressure, Category 4 seals	psi (MPa) (bar)	600 to 1480 (4.0 to 10.2 MPa) (40 to 102 Bar)				Not applicable			
Standard seal type		Type A		Type A [d]		Type C	Type C [a]	Type C	Type C [a]
Option if specified		Type B [a, b] Type C [a, b]		Type B [a] Type C [a]		Type A Type B [a]	Type A	Not applicable	Not applicable
Required special features		Consult Vendor for O-ring material		Not applicable					
Special features for contaminants [c]									
Caustic		Not applicable		Perfluoroelastomer		Not applicable			
Abrasive particles		Hardface versus hardface							
Aromatics and/or H_2S		Not applicable		Perfluoroelastomer		Not applicable			
Amines		Not applicable		Amine-resistant Perfluoroelastomer		Not applicable			
Ammonia		NH_3 resistant carbon graphite							

This selection procedure chooses seal designs consistent with the default positions throughout this standard. Listed options meeting this standard might perform equally well.

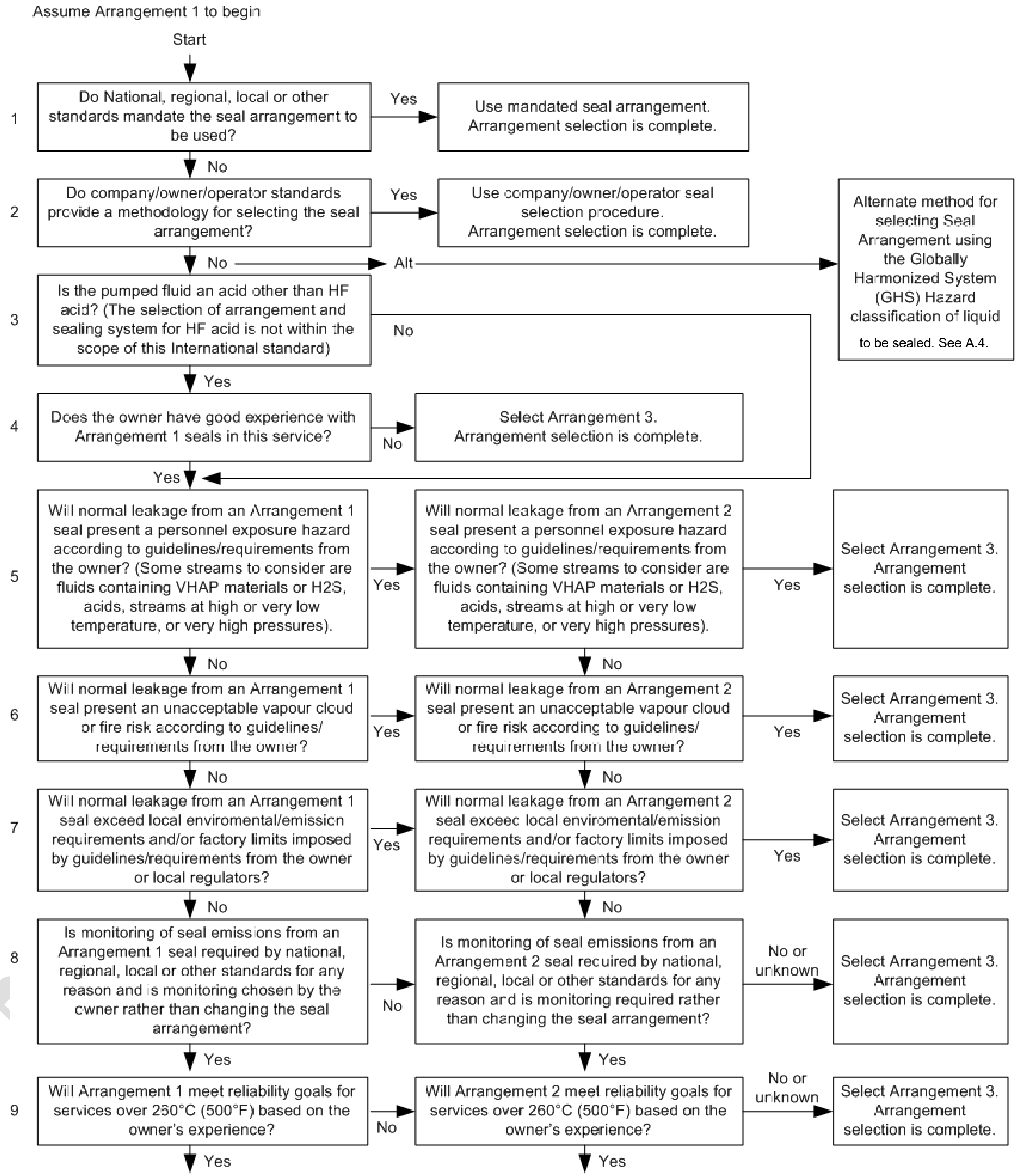
[a] Consult vendor to understand available options for Type B and Type C seals along with review of qualification per applicable seal category.

[b] For operating temperatures below 23 deg F (-5 deg C) special design considerations for bellow seal designs needs to be considered. See note A.2.1.4 for more details.

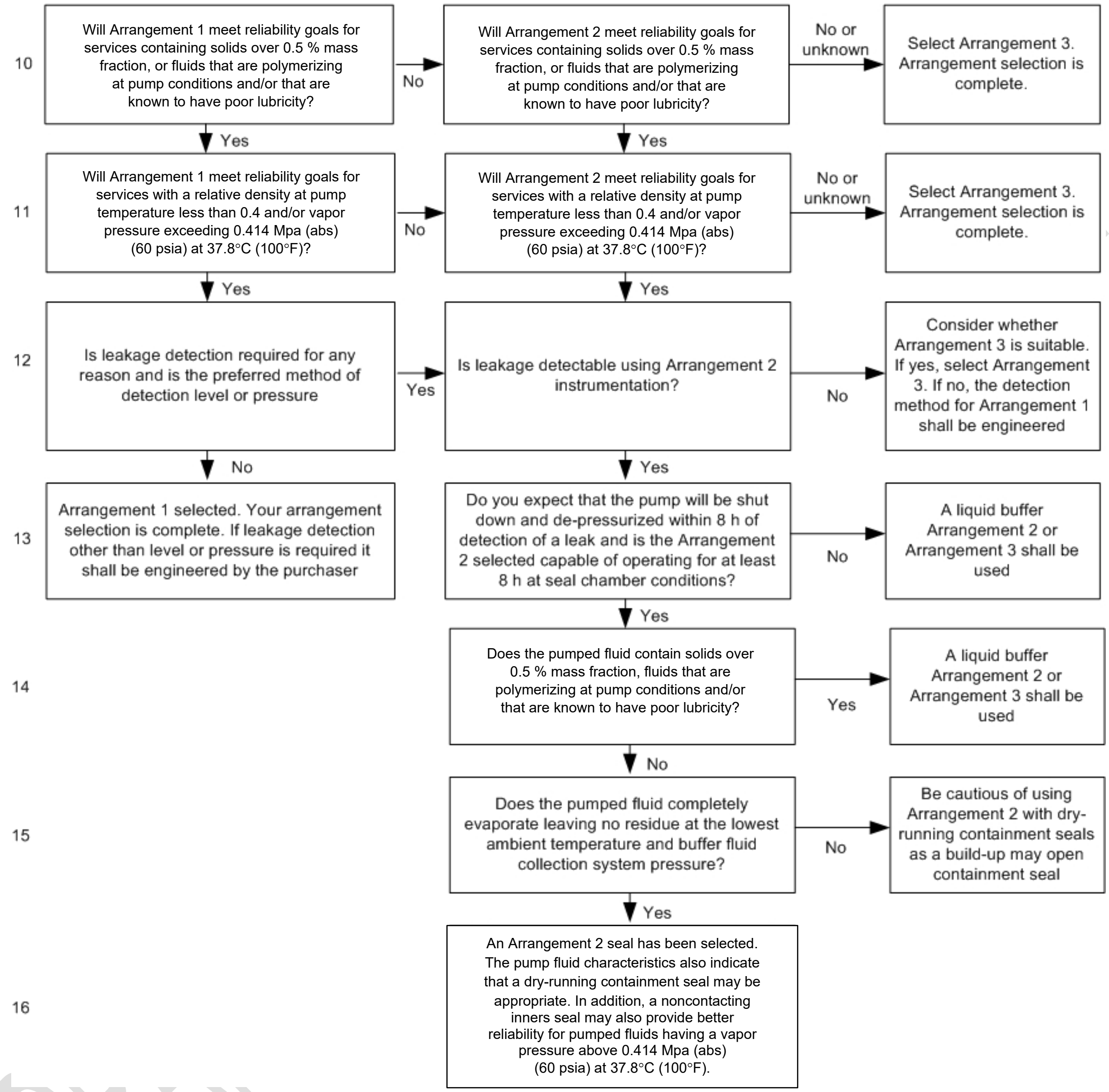
[c] Special features listed apply only in mixtures having pH between 4 and 11.

[d] Requires special feature (circulating device) above 60 °C (140 °F), and special feature (perfluoroelastomer) if pumping temperature is above 176 °C (350 °F)

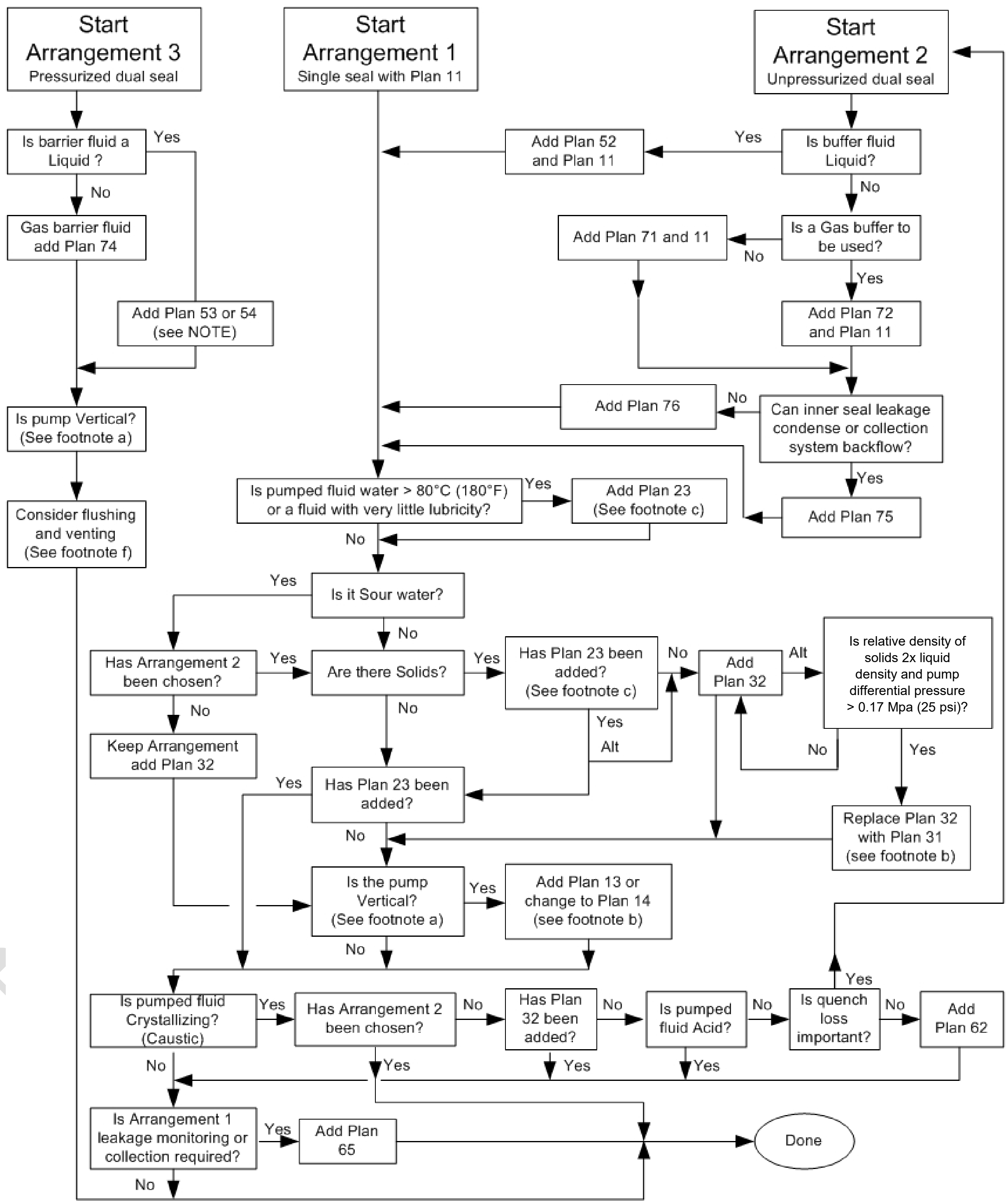
RECOMMENDED SEAL ARRANGEMENT SELECTION PROCEDURE
SHEET 6 OF 10
Considerations in the selection of a seal arrangement



SHEET 6 OF 10 (continued)



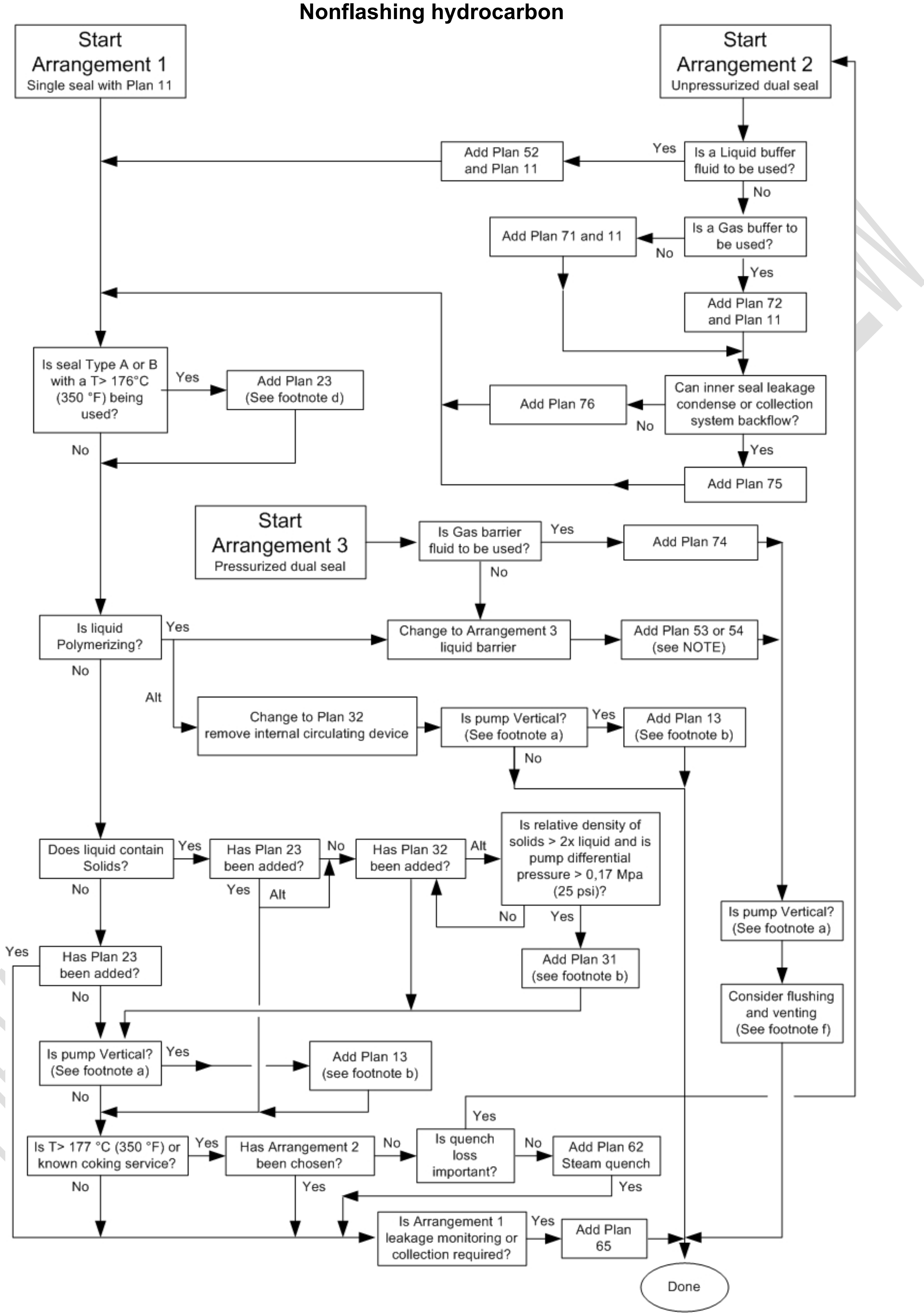
RECOMMENDED SEAL PIPING PLAN SELECTION PROCEDURE
SHEET 7 OF 10
Nonhydrocarbon



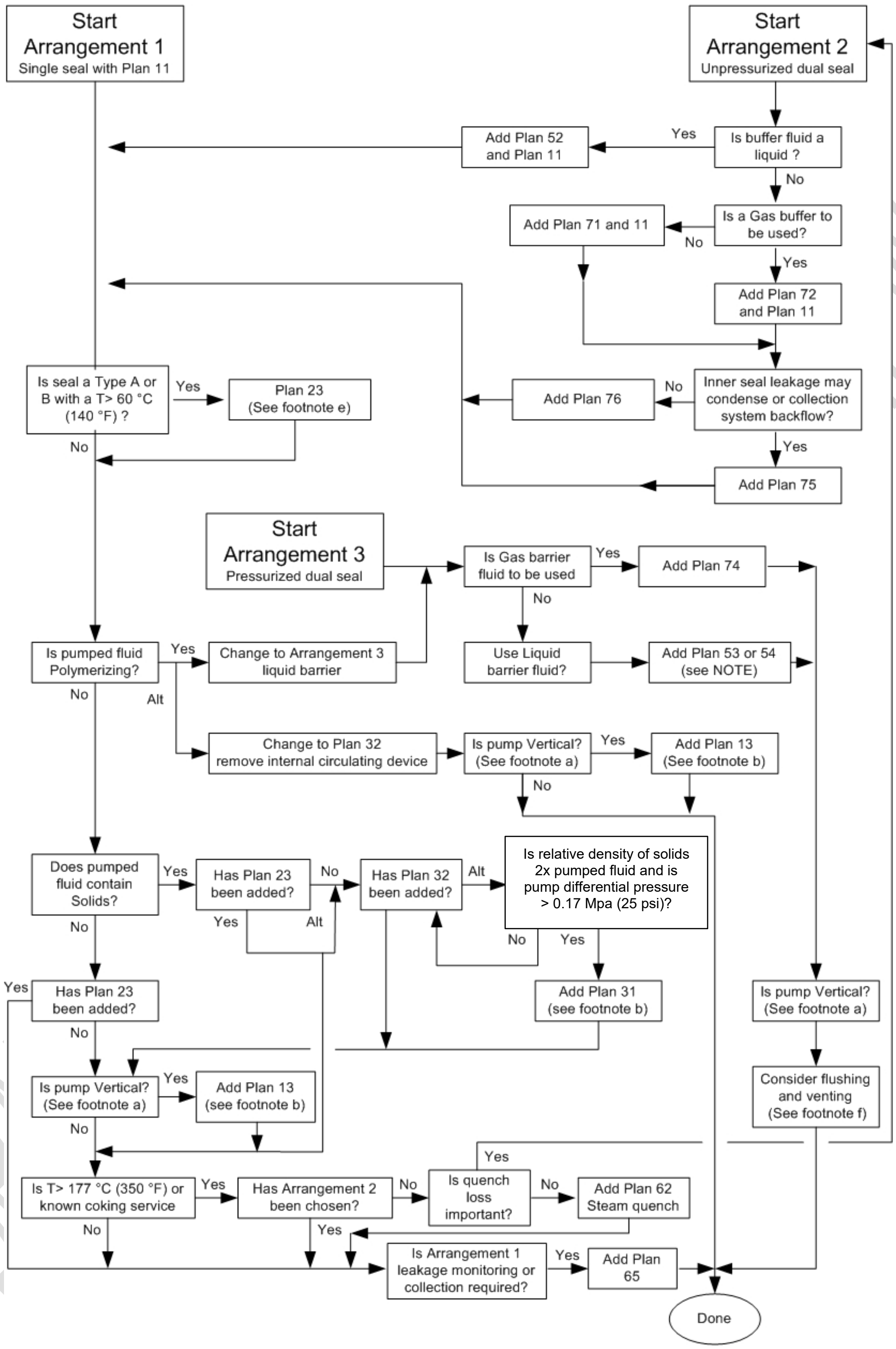
RECOMMENDED SEAL PIPING PLAN SELECTION PROCEDURE
SHEET 8 OF 10

Is relative density of solids > 2x liquid and is pump differential pressure > 0.17 Mpa (25 psi)?

Nonflashing hydrocarbon



RECOMMENDED SEAL PIPING PLAN SELECTION PROCEDURE
SHEET 9 OF 10
Flashing hydrocarbon


Start
Arrangement 1
Single seal with Plan 11
Start
Arrangement 2
Unpressurized dual seal
Add Plan 52 and Plan 11
Yes
Is buffer fluid a liquid ?
No
Add Plan 71 and 11
No
Is a Gas buffer to be used?
Yes
Add Plan 72 and Plan 11
Is seal a Type A or B with a T> 60 °C (140 °F) ?
Yes
Plan 23 (See footnote e)
No
Add Plan 76
No
Inner seal leakage may condense or collection system backflow?
Yes
Add Plan 75
Start
Arrangement 3
Pressurized dual seal
Is Gas barrier fluid to be used
Yes
Add Plan 74
No
Is pumped fluid Polymerizing?
Yes
Change to Arrangement 3 liquid barrier
Use Liquid barrier fluid?
Add Plan 53 or 54 (see NOTE)
No
Alt
Change to Plan 32 remove internal circulating device
Is pump Vertical? (See footnote a)
Yes
Add Plan 13 (See footnote b)
No
Does pumped fluid contain Solids?
Yes
Has Plan 23 been added?
No
Has Plan 32 been added?
Alt
Is relative density of solids 2x pumped fluid and is pump differential pressure > 0.17 Mpa (25 psi)?
Yes
Alt
No
Yes
No
Add Plan 31 (see footnote b)
Is pump Vertical? (See footnote a)
Yes
Has Plan 23 been added?
No
Is pump Vertical? (See footnote a)
Yes
Add Plan 13 (see footnote b)
Consider flushing and venting (See footnote f)
No
Yes
Is T> 177 °C (350 °F) or known coking service
Yes
Has Arrangement 2 been chosen?
No
Is quench loss important?
No
Add Plan 62 Steam quench
No
Yes
Is Arrangement 1 leakage monitoring or collection required?
Yes
Add Plan 65
Done

NOTE See F.2.7 and Annex G for guidance on selecting Piping Plan 53A, 53B, or 53C.

Footnotes for Sheets 7, 8, and 9

[a] The user should evaluate whether to add Piping Plan 13 or not, considering such factors as the inclusion of a bleed bushing, contamination of the seal chamber with pumped fluid, the need for venting of the seal chamber, and the need to reduce seal chamber pressure due to static or dynamic pressure rating of the seal versus the expected static and dynamic seal chamber pressure.

[b] When a Piping Plan 13 alone is selected, if there is insufficient pressure difference between the seal chamber and the pump suction to ensure the required flush flow, then select a Piping Plan 14. For services with suspended solids where Piping Plan 31, 32, or 41 is required and vertical pumps are selected, then a bleed bushing should be provided instead of a Piping Plan 13. The objective is to avoid excessive head bushing wear and the unnecessary introduction of suspended solids into the seal chamber.

Discussion: An example is charge service in a Gas Oil Separation Plant: Piping Plan 32 is used because of suspended solids and it makes little sense to apply Piping Plan 13 (or 14) that requires the process flow with suspended solids to pass the head bushing below the seal chamber. Suspended solids in the process fluid passing the head bushing will increase the bushing wear and clearance reducing the effectiveness of the bushing. Solids introduced into the seal chamber can collect on seal parts causing premature failure.

[c] Cooling is needed because of low lubricity at elevated temperature. The recommended piping plan is Piping Plan 23 because field experience has shown that this plan is much less prone to plugging than Piping Plan 21 because of recirculation of cooler fluid from the seal chamber. However, the user may wish to reconsider using Piping Plan 21 because of the added seal complexity imposed by Piping Plan 23 (size and cost), and other factors such as the use of an air cooler for Piping Plan 21 in areas where water cannot be used or is not available. (An air cooler works better on Piping Plan 21 because of the higher temperature difference between the pumped fluid and the cooling medium.) The user may also wish to consider the use of Piping Plan 32 if a suitable fluid is available, especially if the fluid is normally injected into the process anyway (such as make-up water). See the flush descriptions later in this annex for additional detail.

[d] Cooling is needed because of temperature limits of the standard secondary elastomers for Arrangement 1 and possibly for Arrangement 2 (consult the seal vendor). Consideration may be given to changing to perfluoroelastomer if cooling is not possible. The recommended piping plan is Piping Plan 23 because field experience has shown that this plan is much less prone to plugging than Piping Plan 21 because of recirculation of cooler fluid from the seal chamber. However, the user may wish to reconsider using Piping Plan 21 because of the added seal complexity imposed by Piping Plan 23 (size and cost) and other factors such as the use of an air cooler for Piping Plan 21 in areas where water cannot be used or is not available. (An air cooler works better on Piping Plan 21 because of the higher temperature difference between the pumped fluid and the cooling medium.) The user may also wish to consider the use of Plan 32 if a suitable fluid is available, especially if the fluid is normally injected into the process anyway (such as make-up water). See the flush descriptions later in this annex for additional detail.

[e] Cooling is recommended to suppress flashing within the seal faces. Because of cooling-water temperatures, this is usually only effective above the temperature shown. Below this temperature, or as an alternative to adding cooling, the user may wish to use experience at their site or other alternatives such as high flushing rates, distributed flush systems, increased seal chamber pressure, or combinations thereof, to obtain satisfactory seal life. There may also be the opportunity to use Piping Plan 32 if suitable flush fluid is available or, if experience is available, a change to Arrangement 3 may be appropriate.

[f] Consider the need to add additional flushing to the process side of the inner seal. Flushing is sometimes needed for Arrangement 3 FB orientation to provide additional cooling, and Piping Plan 11 or Piping Plan 13 may be a suitable choice. Other services may require a Piping Plan 32 flush if the pumped fluid is extremely corrosive, aggressive, or solids laden. Consider the need for venting on vertical pumps. Special attention may be needed on Arrangement 3 NC configurations to ensure effective pump operation. Consult the pump vendor if the pump is vented through the seal chamber, and consider the effects listed in footnote a above.

RECOMMENDED SEAL ARRANGEMENT SELECTION PROCEDURE
SHEET 10 OF 10
Buffer/barrier fluid selection

The following should be considered when selecting a barrier/buffer fluid:

a) compatibility of the fluid with the process fluid being sealed, so as not to react with or form gels or sludge if leaked into the process fluid or the process fluid into the barrier/buffer fluid;

b) compatibility of the fluid with the metallurgy, elastomers, and other materials of the seal/flush system construction;

c) compatibility of the fluid assuming it reaches the process fluid temperature (high or low).

On pressurized barrier fluid systems where the method of pressurization is a gas barrier, special attention should be given to the application conditions and barrier fluid selection. Gas solubility in a barrier fluid increases with increasing pressure and decreases with increasing barrier fluid temperature. As pressure is relieved or temperatures rise, gas is released from solution and can result in foaming and loss of circulation of the barrier fluid. This problem is normally seen where higher viscosity barrier fluids, such as lubricating oils, are used at pressures above 150 psi (1 MPa) (10 bar).

The viscosity of the barrier/buffer fluid should be checked over the entire operating-temperature range, with special attention being given to start-up conditions. The viscosity should be less than 500 cSt (500 mm^2/s) at the minimum temperature to which it is exposed.

The following barrier fluid performance facts should be considered.

a) The most desirable viscosity for barrier/buffer fluids is between 2 cSt (2 mm^2/s) and 10 cSt (10 mm^2/s) at operating temperature.

NOTE To prevent seal face blistering, barrier / buffer fluid viscosities are typically kept low (generally less than 20 cP). Barrier/buffer fluids having a viscosity up to 100 mm^2/s (100 cSt) at operating temperature may be acceptable but may require seal face material changes (i.e. hard versus hard) and external fluid circulation to accommodate. Reference Annex B for further details on carbon material thresholds.

b) For aqueous streams, mixtures of water and ethylene glycol or propylene glycol are usually adequate. Commercially available automotive antifreeze should never be used. The additives in antifreeze tend to plate out on seal parts and cause failure as a result of gel formation.

c) The fluid should not freeze at the minimum ambient temperature at the site.

Fluid volatility and toxicity of the fluid shall be such that leakage to the atmosphere or disposal does not impose an environmental problem. The barrier/buffer fluid can be classified as hazardous, depending upon the local regulations at the pump site. A verification of the barrier/buffer fluid safety datasheet should be carried out to ensure that the leakage across the outer seal does not infringe local personnel occupational exposure limits. In addition:

a) the fluid should have an initial boiling point at least 50 °F (28 °C) above the temperature to which it will be exposed;

b) if oxygen is present the fluid should have a flash point higher than the operating temperature of the barrier fluid;

c) ethylene glycol can be considered a hazardous material and/or hazardous waste when used as a barrier fluid.

The fluid should be able to meet the minimum three-year (3-yr) continuous seal operation criteria without adverse deterioration. It should not form sludge, polymerize, or coke after extended use.

For hydrocarbon streams, mineral oil is known to degrade at temperatures greater than 70 °C (158 °F), however, paraffin-based high purity oils having little or no additive for wear/oxidation resistance, or synthetic-based oils have been used successfully.

Antiwear or oxidation-resistance additives in commercial turbine oils have been known to plate out on seal faces.

A.2 Tutorial Section

A.2.1 Seal Selection Justification

A.2.1.1 All seal selections by service were made with the following considerations in mind:

a) to produce a reliable sealing system that has a high probability of operating for three (3) years of uninterrupted service, meeting or exceeding environmental emission regulations;

b) to ensure personnel and plant safety in hazardous services; and

c) to minimize spare parts inventory required for insurance stock.

A.2.1.2 All selections were made using experience gained in engineering, purchasing, operating, retrofitting, and maintaining mechanical seals in various services and locations. The selections were made to ensure that the best seal for the service will be installed. This standard does not attempt to prevent the selection of other seals. However, if a seal not specified by this standard is chosen, special engineering is recommended for successful operation.

Any seal operating with a dynamic sealing pressure above gauge pressures of 300 psi (2 MPa) (20 bar) for Category 1 seals, or 600 psi (4 MPa) (40 bar) for Category 2 and Category 3 seals or 1480 psi (10.2 MPa) (102 bar) for Category 4 seals requires special engineering. Any product temperature above 500 °F (260 °C) for Category 1 seals or above 750 °F (400 °C) for Category 2 and Category 3 seals or above 350 °F (176 °C) for Category 4 seals also requires special engineering design considerations. Therefore, the selection categories are limited to the above pressures and temperatures for this standard.

A.2.1.3 The seal references in this standard are:

a) Type A, pusher seal;

b) Type B, bellows seal with elastomeric secondary seals; and

c) Type C, bellows seal with flexible graphite secondary seal elements.

See Section 3, Section 4, and sheet 2 of this annex for further description.

NOTE Pressure levels listed apply to Category 1, Category 2, Category 3, or Category 4 as noted on the applicable sheet.

A.2.2 Nonhydrocarbon Services—Sheet 3

A.2.2.1 Clean Water Below 180 °F (80 °C) and Below a Gauge Pressure of 300 psi (2 MPa) (20 bar)

The recommended seal is a Type A pusher with no special features required.

The recommended option is either a Type B or Type C metal bellows with no special features required.

A.2.2.2 Clean Water Below 180 °F (80 °C) and a Gauge Pressure of Between 300 psi (2 MPa) (20 bar) and 600 psi (4 MPa) (40 bar)

The recommended seal is a Type A pusher with no special features required.

Any seal other than a Type A should be specially engineered for high pressure. Seal manufacturers normally rate their metal bellows designs for gauge pressures of less than 300 psi (2 MPa) (20 bar). The seal manufacturer should be consulted for specific performance data above this pressure.

A.2.2.3 Water Above 180 °F (80 °C) and at a Gauge Pressure Below 600 psi (4 MPa) (40 bar)

The recommended seal is a Type A pusher with special features. The special features are a single-spring seal with an internal circulating device to circulate through a Piping Plan 23 closed-loop system. As shown on sheet 7, a Piping Plan 21 can also be used, especially if an air cooler is used. The alternative seal is a Type A recommended pusher with special features to include an internal circulating device to circulate through a Piping Plan 23 closed-loop system, and a close-clearance bushing in the bottom of the sealing chamber.

A Piping Plan 23 flushing arrangement is the most efficient way of providing a cool flush to the seal faces. Use of an internal circulating device to circulate the fluid through a closed-loop cooler allows the cooler to continuously cool a recirculated stream rather than a continuous (hot) stream from the discharge of the pump (Piping Plan 21). The cooler now has to cool only that fluid in the loop, and the duty cycle is much less severe than a Piping Plan 21.

A survey in one facility revealed that the average temperature of the inlet flush to the sealing chamber was 122 °F (50 °C). The average pumping temperature of the product was 426 °F (219 °C). The idle pump's average inlet temperature was 100 °F (38 °C). The idle pump relied only on the thermosyphon through the cooler to cool the fluid. The cooler should be mounted in accordance with this standard to ensure proper thermosyphoning.

A.2.2.4 Sour Water Below 180 °F (80 °C) Up to a Gauge Pressure of 600 psi (4 MPa) (40 bar)

The recommended seal is a Type A pusher with special features. The elastomers should be changed to FFKM to resist the H_2S, as H_2S is generally the agent that sours water.

The recommended option up to a gauge pressure of 300 psi (2 MPa) (20 bar) is either a Type B or Type C seal with the special feature of FFKM for the Type B.

The use of a Type B or Type C seal above a gauge pressure of 300 psi (2 MPa) (20 bar) requires special engineering for the high pressure.

This selection is made to maximize the standardization process, as the Type A seal is recommended for all pressure ranges. Sour water can become flashing as the temperature and H_2S content increase.

A.2.2.5 Caustic, Amines, and Other Crystallizing Fluids Below 80 °C (180 °F) and Below a Gauge Pressure of 600 psi (4.0 MPa) (40 bar)

The recommended seal is a Type A pusher with the special features of FFKM.

The recommended alternative, up to a gauge pressure of 300 psi (2.0 MPa) (20 bar) is a Type B metal bellows seal with FFKM.

The use of Type C seals up to a gauge pressure of 300 psi (2.0 MPa) (20 bar) with flexible graphite secondary seals should be specially engineered, as graphite is not recommended for some caustic applications.

For gauge pressures above 300 psi (2.0 MPa) (20 bar) but below 600 psi (4.0 MPa) (40 bar), the use of Type B and Type C metal bellows seals require special engineering for the high pressure.

Any application in a crystallizing fluid requires the use of a Piping Plan 62 quench or a Piping Plan 32 flush to keep crystals from forming on the atmospheric side of the seal. Most facilities prohibit a quench from seals unless totally contained. A Piping Plan 32 flush arrangement is generally not acceptable, as it dilutes the product and is sometimes expensive to operate. In these conditions an Arrangement 2 dual seal (un-pressurized buffer) should be considered, using clean water (or other compatible fluid) as a buffer to keep the crystals in solution. The same special features apply to both the dual seal and the single seals.

A.2.2.6 Acids: Sulphuric, Hydrochloric, Phosphoric Acids at Less Than 180 °F (80 °C) and Below a Gauge Pressure of 300 psi (2.0 MPa) (20 bar)

The recommended seal is a Type A pusher with the special features of a single coil-spring.

The recommended option is a Type B or Type C seal using flexible graphite as a secondary in the Type C seal.

Because of the thin cross-section of multiple-coil springs and bellows plates, the most corrosion-resistant material for the application should be selected.

Hydrofluoric, fuming nitric, and other acids are not covered in this selection. Specially engineered designs agreed between the owner and the seal manufacturer should be used.

Seals for use with acids at temperatures over 180 °F (80 °C) require special engineering.

Seals for use with acids at a gauge pressure above 300 psi (2.0 MPa) (20 bar) require special engineering.

A.2.3 Nonflashing Hydrocarbons [Absolute Vapor Pressure Less Than 14.7 psi (0.1 MPa) (1 bar) at Pumping Temperature]—Sheet 4

A.2.3.1 From (–40 °F to 20 °F (–40 °C to –5 °C) and Below a Gauge Pressure of 600 psi (4.0 MPa) (40 bar)

The recommended seal is a Type A pusher. The recommended alternative up to a gauge pressure of 300 psi (2.0 MPa) (20 bar) is either a Type B or a Type C seal with flexible graphite secondary seals.

For gauge pressures over 300 psi (2.0 MPa) (20 bar), seal Type B and Type C require engineered bellows designed for the high pressure.

At temperatures below 20 °F (–5 °C) special elastomer compounds are required. Consult seal vendor regarding available options.

A.2.3.2 From 20 °F to 350 °F (–5 °C to 176 °C) and Gauge Pressures Below 600 psi (4.0 MPa) (40 bar)

The recommended seal is a Type A pusher with no special features required. (Check elastomer compatibility charts for pumped fluid.)

The recommended option for gauge pressures up to 300 psi (2.0 MPa) (20 bar) is a Type B or Type C non-pusher. The Type C seal should be used with flexible graphite secondary seals.

The recommended alternative for gauge pressures above 300 psi (2.0 MPa) (20 bar) is a Type B or Type C with engineered bellows for the high pressure.

The recommended pusher seal elastomer is FKM, which is rated at 400 °F (204 °C). A pumping temperature of 350 °F (176 °C) is realistic for FKM, as the face friction will generate additional heat and raise the temperature the elastomer shall endure.

A.2.3.3 From 350 °F to 500 °F (176 °C to 260 °C) and Below a Gauge Pressure of 300 psi (2.0 MPa) (20 bar)

The recommended seal is a Type C stationary non-pusher metal bellows seal using flexible graphite for secondary seals.

The Type C seal is recommended because of the temperature range, which is the range where coking generally occurs. The stationary bellows design easily accepts a steam baffle for anticoking protection, whereas a rotating bellows does not.

The recommended alternative is a Type A pusher with special features including an internal circulating device and FFKM, circulating through a Piping Plan 23 closed-loop system in accordance with the piping plan selection diagram.

A Type A seal with an internal circulating device and a Piping Plan 23 closed-loop system maintains the product temperature below the range where coking occurs.

A.2.3.4 From 350 °F to 500 °F (176 °C to 260 °C) and from a Gauge Pressure of 300 psi (2.0 MPa) (20 bar) to 600 psi (4.0 MPa) (40 bar)

A totally engineered sealing system is required for hot high-pressure services.

A.2.3.5 From 500 °F to 750 °F (260 °C to 400 °C) and Below a Gauge Pressure of 300 psi (2.0 MPa) (20 bar)

The Type C seal is recommended because of the temperature range, which is the range where coking generally occurs. The stationary bellows design easily accepts a steam baffle for anticoking protection, whereas a rotating bellows does not.

The recommended alternative is a totally engineered sealing system.

A.2.3.6 From 500 °F to 750 °F (260 °C to 400 °C) and from a Gauge Pressure of 300 psi (2.0 MPa) (20 bar) to 600 psi (4.0 MPa) (40 bar)

The only acceptable option is a totally engineered sealing system.

A.2.4 Flashing Hydrocarbons (Vapor Pressure Above 14.7 psi (0.1 MPa) (1 bar) at Pumping Temperature)—Sheet 5

A.2.4.1 From (–40 °F to 20 °F (–40 °C to –5 °C) and a Gauge Pressure Below 600 psi (4.0 MPa) (40 bar)

The recommended seal is a Type A pusher with the special feature of an NBR elastomer. It should be ensured that NBR is compatible with the pumped fluid.

The recommended alternative is an engineered sealing system with an engineered metal bellows for the flashing service.

Metal bellows seals in flashing service are prone to fatigue failure, induced by "stick-slip" if marginal vapor suppression occurs. If metal bellows are desired, the seal should be a totally engineered sealing system with special attention to vapor suppression under all operating conditions of the pump, including, but not limited to, start-up, shutdown and plant upsets.

A.2.4.2 From 20 °F to 350 °F (–5 °C to 176 °C) and a Gauge Pressure Below 600 psi (4.0 MPa) (40 bar)

The recommended seal is a Type A pusher with special features to maintain adequate vapor suppression. If the temperature is above 140 °F (60 °C), an internal circulating device and a Piping Plan 23 closed-loop system should be considered as an alternative to help reduce flashing at the seal face. If the temperature is above 350 °F (176 °C), FFKM should be used.

The recommended alternative is a totally engineered sealing system with an engineered metal bellows.

Vapor suppression by cooling is always preferred over pressurization. Therefore, a Type A seal with internal circulating device and a Piping Plan 23 closed-loop system is selected if the temperature is above 140 °F (60 °C). The 140 °F (60 °C) limit is based on the cooling-water temperature in the hot months, where little cooling of a product below 140 °F (60 °C) will occur. Various locations can require a higher or lower limit based on the maximum cooling-water temperature in that specific location.

A.2.4.3 From 350 °F to 750 °F (176 °C to 400 °C) and Below a Gauge Pressure of 300 psi (2.0 MPa) (20 bar)

The recommended seal is a Type C seal. The recommended alternative is a totally engineered sealing system.

A.2.4.4 Above 350 °F (176 °C) and a Gauge Pressure from 300 psi (2.0 MPa) (20 bar) to 600 psi (4.0 MPa) (40 bar)

The seal should be a totally engineered sealing system.

A.3 Tutorial Seal Selection—Sheet 6

A.3.1 Sheet 6 is intended as a guide to some of the aspects that might be considered in the selection of a seal arrangement. The user should evaluate the cost benefits and risk associated with any selection.

A.3.2 Question 1 is whether there are any regulations effective at the site of the equipment that require specific hardware. This hardware could include low-emission single seal or dual seals. The question is intended to alert the user so that he/she can investigate the possibility that specific designs might be required.

A.3.3 Question 2 alerts the user to examine the pumped stream to determine if any owner or operator standards exist that would dictate or help define the required arrangement from the owner or operator. These standards might deem the stream hazardous and require specific methods of control or limits of exposure on emissions, even if local regulations do not. Seal designs should then employ the required hardware or be designed to meet the required emission limit.

A.3.4 Question 3 addresses selection of arrangement for acids. If the stream is not acid, the user can skip from question 3 to question 5.

A.3.5 Question 4 selects the arrangement for an acid stream as either a single seal or a pressurized dual seal. Unpressurised dual seals are not recommended because of the potential for buildup of acid in the buffer system or containment seal chamber.

A.3.6 Question 5 addresses materials that can pose a personnel hazard, such as rich (in H_2S) amine streams, to highlight the need for control beyond a single seal without external flush. The highlight is needed because specifications often overlook the need for added control measures on this type of stream.

A.3.7 Question 6 is similar to question 5, except it addresses streams for which an Arrangement 1 seal will not meet safety requirements of the owner concerning a potential vapor cloud or fire risk.

A.3.8 Question 7 addresses the need for additional sealing control on those streams that will not meet local emission requirements with an Arrangement 1 seal. Arrangement 2 or Arrangement 3 is chosen as needed instead.

A.3.9 Question 8 alerts the user to the fact that in certain countries, Arrangement 1 seals in specific services are required to be monitored (or “sniffed”) for emissions. If the user wishes to perform this monitoring then Arrangement 1 is suitable. However, the option is given to change the arrangement and possibly avoid monitoring.

A.3.10 Question 9 addresses reliability considerations for hot services. Experience has shown that Arrangement 2 or Arrangement 3 can provide better reliability.

A.3.11 Question 10 addresses reliability considerations for polymerizing agents, solids, and low-lubricity fluids out of the seal faces in order to help meet the goal of three-year (3-yr) uninterrupted service life.

A.3.12 Experience has shown Arrangement 1 and Arrangement 2 used in very light fluids often cannot meet the goal of a three-year (3-yr) service. Special sealing arrangements involving the use of noncontacting inner seals in an Arrangement 2 have been known to provide very reliable service in fluids such as methane, ammonia, propane, and other hydrocarbon mixtures of high vapor pressure.

A.3.13 Question 12 is intended to alert the user to the possible need for provision of an alarm for leakage. An arrangement other than Arrangement 1 is generally needed if leakage shall be detected.

A.3.14 Question 13 determines how the user intends to use the containment feature of an unpressurized dual seal. Because of heat generation and face load, dry containment seals can have limited life at full seal chamber conditions.

A.3.15 This step changes to an Arrangement 3 or recommends a liquid buffer if the pumpage contains solids or polymerizing agents. These contaminants can reduce the reliability of dry containment seals.

A.3.16 An Arrangement 2 seal has been selected and further guidance is provided on the possible use of noncontacting inner seals.

A.4 Alternative Seal Arrangement Selection Method Using Material Safety Datasheet Information

A.4.1 The selection procedure proposed below selects the applicable seal arrangement, based on the sealed fluid hazard code according to the 2007 second revised edition of the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS) and the European Union Regulation (EC) 1272/2008 on the classification, labeling and packaging of substances and mixtures. This procedure may also be applicable using the Dangerous Substances Directive 67/548/EEC risk phrase classification of the pumped fluid to be sealed.

A.4.2 The seal type should be selected according to the selection logic included in Annex A sheets 3, 4, and 5 and the applicable sections of this standard.

A.4.3 The piping plan should be selected according to the selection logic included in Annex A sheets 7, 8, and 9 and the applicable sections of this standard.

A.4.4 To use this selection method the purchaser shall generate and supply the vendor with the Safety Datasheet (SDS) for the pumped fluid and any buffer or barrier fluid. There can be more than one SDS for variations in pumped fluid. For this procedure, the areas of most interest in the SDS are as follows.

— *Chapter 3*—Composition/component data, especially constituent components contributing to hazards.

— *Chapter 8*—Exposure controls/personal protection, especially occupational exposure limits.

— *Chapter 15*—Regulatory data especially the applicable H statement codes or R phrases.

A.4.5 All possible combinations of R-phrases or H-statements have been grouped into four groups and are listed in Table A.1 and Table A.2.

A.4.6 Using the data from Chapter 15 of the SDS, the pumped fluid R phrases or H statements should be examined individually to establish the applicable group and the most severe (lowest group number) should be used for the selection procedure.

A.4.7 If the applicable R-phrases or H-statement codes lead to a selection of Group III or Group IV but Chapter 8 of the SDS recommends or imposes exposure limits then the pumped liquid should be considered Group II.

A.4.8 Entering the Seal Selection logic chart (Figure A.1) at the top left-hand corner the seal arrangement selection can be simply established. The Group II seal arrangement selection chart (Figure A.2) should be used for all Group II liquids and should be applied for each of the constituent components contributing to the hazard that are listed in Chapter 3 of the SDS.

The *x*-axis of this chart represents the mass fraction (as a percentage) of the component that contributes to the hazard (e.g. 1 % benzene in gasoline). This data can be found in Chapter 3 of the SDS. The sloping lines represent the threshold limit value for an eight hour (8 h) time weighted average (TLV-TWA) exposure limit for that component (e.g. 3.25 mg/m^3 for benzene). The intersection of the mass fraction component line and the TLV-TWA exposure limit line can be read on the *y*-axis as the seal arrangement required.

A.4.9 The Group II seal arrangement selection chart (Figure A.2) is primarily intended to be used for Category 1, 2 and 3 seals. For Category 4 seals it is recommended to consult with the seal vendor to confirm applicability.

NOTE Given the larger diameters and higher pressure for Category 4 seals, it is possible for seal leakage rates to exceed the allowable limit of 5.6 grams / hour (1,000 ppmv) inherent to the Group II seal arrangement selection chart (Figure A.2).

A.4.10 An Arrangement 2 (Category 1, 2, 3, and 4) selection from the Group II seal arrangement selection chart (Figure A.2) assumes application of a Plan 75 (or Plan 76) used in conjunction with a Plan 72 or a Plan 52 used with uncontaminated buffer fluid.

A.4.11 If the fraction percentage of the component is given as volume percent instead of mass percent the conversion is as follows.

$$\omega_{AB} = V\%_{AB}\left(\frac{\rho_A}{\rho_B}\right) \qquad \text{(A.1)}$$

where

ω_{AB}	is the mass percentage of component A in mixture B;
$V\%_{AB}$	is the volume percentage of component A in mixture B;
ρ_A	is the density (specific gravity) of fluid A;
ρ_B	is the density (specific gravity) of fluid B.

A.4.12 If required, conversions from parts per million (volume) (ppmv) to milligrams per cubic meter (mg/m$^{3)}$ at different temperatures can be made using the conversion charts in Figure A.3 and Figure A.4.

A.4.13 Buffer or barrier fluids should also be tested using this procedure to ensure that they satisfy the requirements for an Arrangement 1 or 1+ seal.

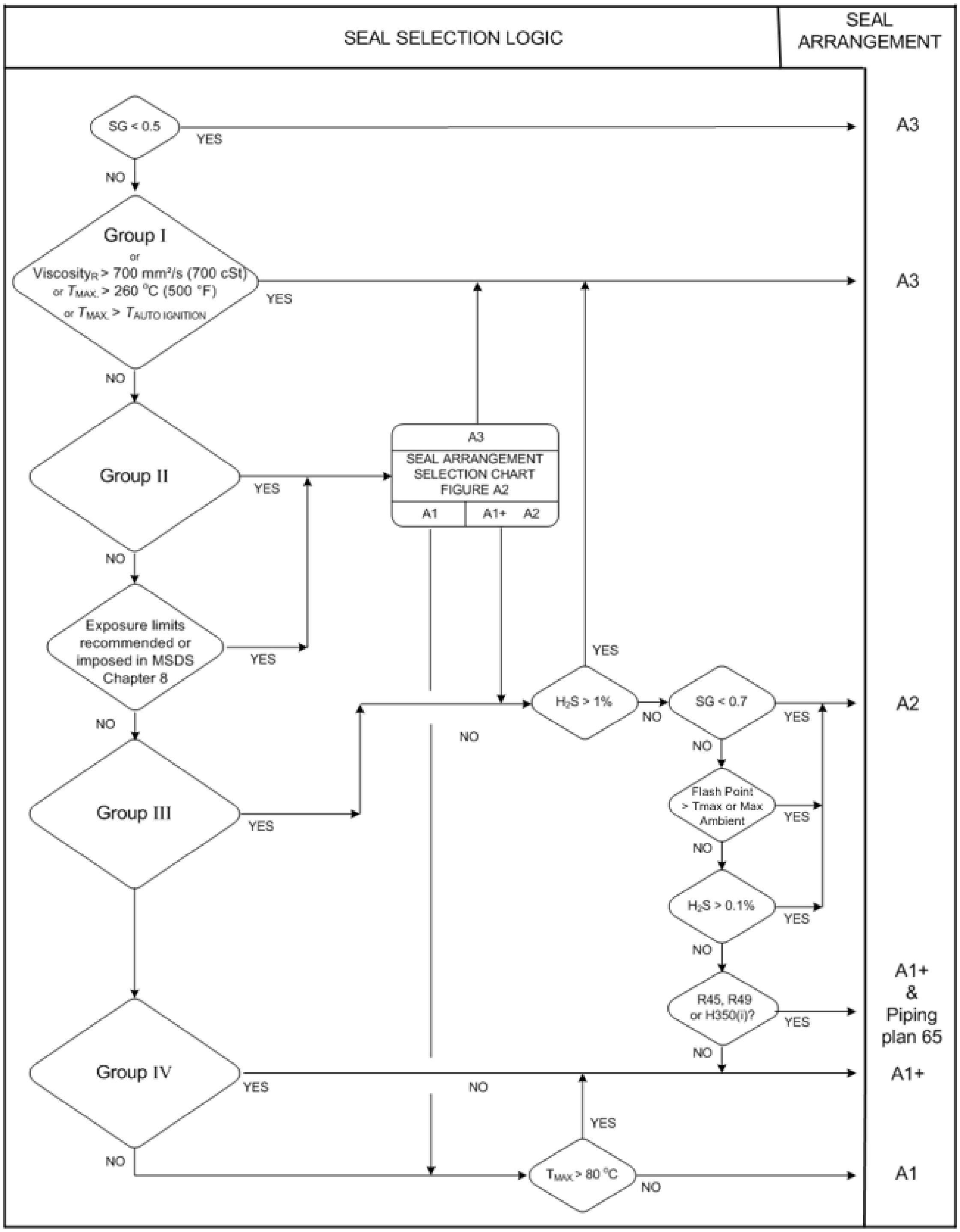
Table A.1—R-phrase Grouping Table

R-phrase	Group	R-phrase	Group	R-phrase	Group
R 1	I	R 30	III	R 48/20/22	III
R 2	III	R 31	III	R 48/21	III
R 3	I	R 32	II	R 48/21/22	III
R 4	I	R 33	III	R 48/22	III
R 5	III	R 34	III	R 48/23	II
R 6	I	R 35	III	R 48/23/24	II
R 7	III	R 36	IV	R 48/23/24/25	II
R 8	III	R 36/37	IV	R 48/23/25	II
R 9	III	R 36/37/38	IV	R 48/24	III
R 10	IV	R 36/38	IV	R 48/24/25	III
R 11	III	R 37	IV	R 48/25	III
R 12	III	R 37/38	IV	R 49 Cat 1	II
R 13	n/a	R 38	IV	R 49 Cat 2	III
R 14	I	R 39	III	R 49 Cat 3	III
R 14/15	I	R 39/23	II	R 50	IV
R 15	III	R 39/23/24	II	R 50/53	IV
R 15/29	II	R 39/23/24/25	II	R 51	IV
R 16	III	R 39/23/25	II	R 51/53	IV
R 17	I	R 39/24	III	R 52	IV
R 18	III	R 39/24/25	III	R 52/53	IV
R 19	III	R 39/25	III	R 53	IV
R 20	IV	R 39/26	II	R 54	IV
R 20/21	IV	R 39/26/27	II	R 55	IV
R 20/21/22	IV	R 39/26/27/28	II	R 56	IV
R 20/22	IV	R 39/26/28	II	R 57	IV
R 21	IV	R 39/27	III	R 58	IV
R 21/22	IV	R 39/27/28	III	R 59	IV
R 22	IV	R 39/28	III	R 60	II
R 23	III	R 40	III	R 61	II
R 23/24	III	R 41	III	R 62	III
R 23/24/25	III	R 42	III	R 63	III
R 23/25	III	R 42/43	III	R 64	III
R 24	IV	R 43	IV	R 65	IV
R 24/25	IV	R 44	III	R 66	IV
R 25	IV	R 45 Cat1	II	R 67	IV
R 26	II	R 45 Cat 2	III	R 68	IV
R 26/27	II	R 45 Cat 3	III	R 68/20	III
R 26/27/28	II	R 46	II	R 68/20/21	III
R 26/28	II	R 47	II	R 68/20/21/22	III
R 27	III	R 48	III	R 68/20/22	III
R 27/28	III	R 48/20	III	R 68/21	IV
R 28	III	R 48/20/21	III	R 68/21/22	IV
R 29	III	R 48/20/21/22	III	R 68/22	IV

Table A.2—H Statement Grouping Table

H Statement	Group	H Statement	Group	H Statement	Group
EUH001	I	H242[a]	III	H332	IV
EUH006	I	H250	I	H333	IV
EUH014	I	H251	I	H334	III
EUH018	III	H252	I	H335	IV
EUH019	III	H260	III	H336	IV
EUH029	III	H261	III	H340	II
EUH031	III	H270	III	H341	II
EUH032	II	H271	III	H350	II
EUH044	III	H272	III	H350i	II
EUH059	IV	H280	n/a [b]	H351	II
EUH066	IV	H281	n/a [b]	H360D	II
EUH070	IV	H290	n/a [b]	H360Df	II
EUH071	II	H300	III	H360F	II
H200	I	H301	IV	H360FD	II
H201	I	H302	IV	H360Fd	II
H202	I	H303	IV	H361d	III
H203	I	H304	IV	H361f	III
H204	III	H305	IV	H361fd	III
H205	III	H310	II	H362	III
H220	III	H311	IV	H370	II
H221	III	H312	IV	H371	III
H222	III	H313	IV	H372	II
H223	III	H314	III	H373	III
H224	III	H315	IV	H400	IV
H225	III	H316	IV	H401	IV
H226	IV	H317	IV	H402	IV
H227	IV	H318	III	H410	IV
H228	n/a [b]	H319	IV	H411	IV
H240	I	H320	IV	H412	IV
H241	I	H330	II	H413	IV
H242	III	H331	III		

[a] Self-reacting liquid.
[b] Not applicable, refers to solids and gases.



Seal type (A, B, or C) should be in accordance with Annex A Sheets 3, 4, and 5.

Piping Plan should be in accordance with Annex A Sheets 7, 8, and 9.

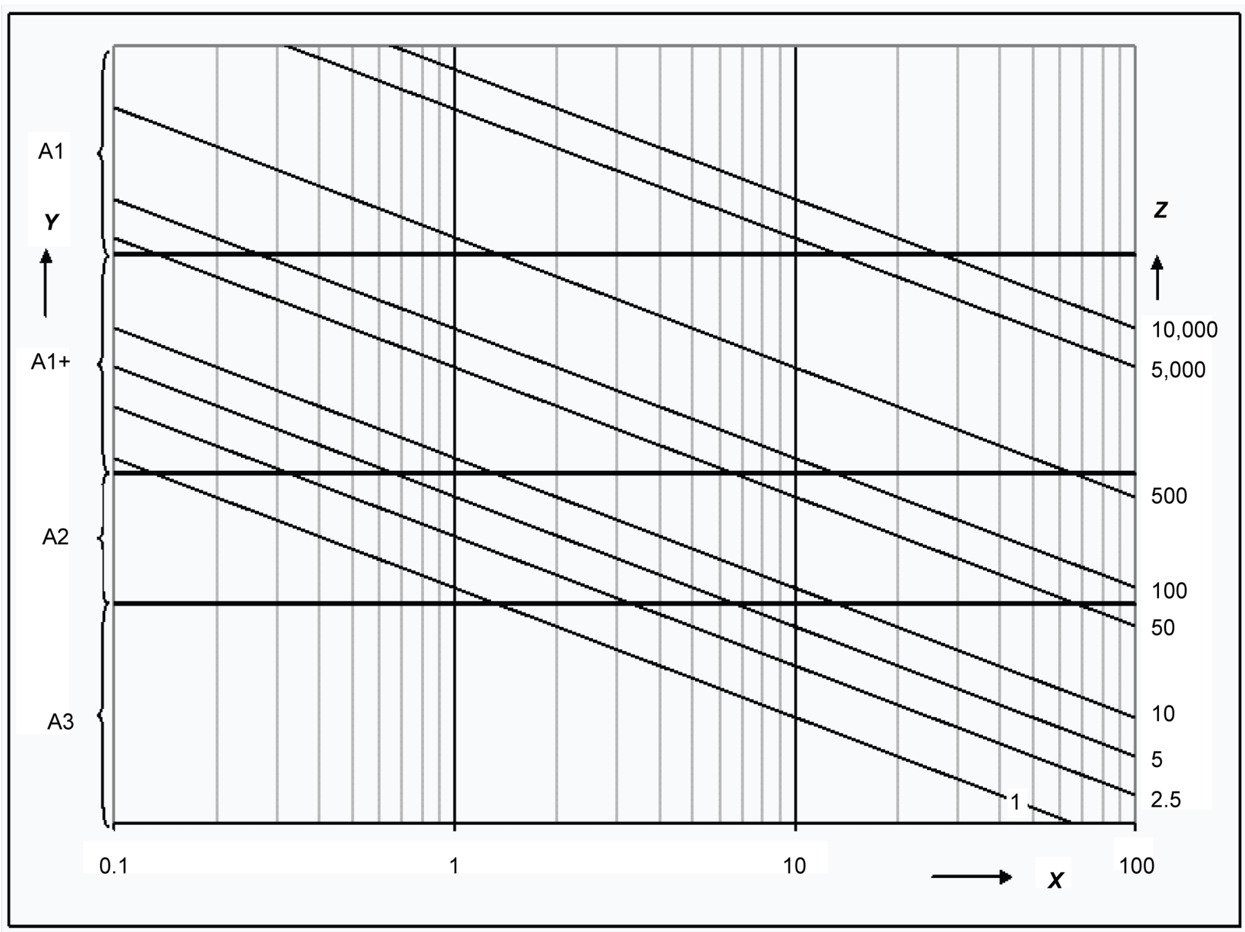
Key

A1+ Arrangement 1 seal with floating carbon bushing in accordance with 7.1.2.2

T temperature of pumped fluid, expressed in Celsius (°C) [Fahrenheit (°F)]

V_R rated viscosity, expressed in (millimeters per square millimeter) per second m/mm$^{2/}$s [centistokes (cSt)]

Figure A.1—Seal Selection Logic



Key

X mass fraction (as a percentage) of component contributing to hazard

Y selected seal arrangement

Z threshold limit value for an 8 h time weighted average (TLV-TWA) of the component in mg/m^3

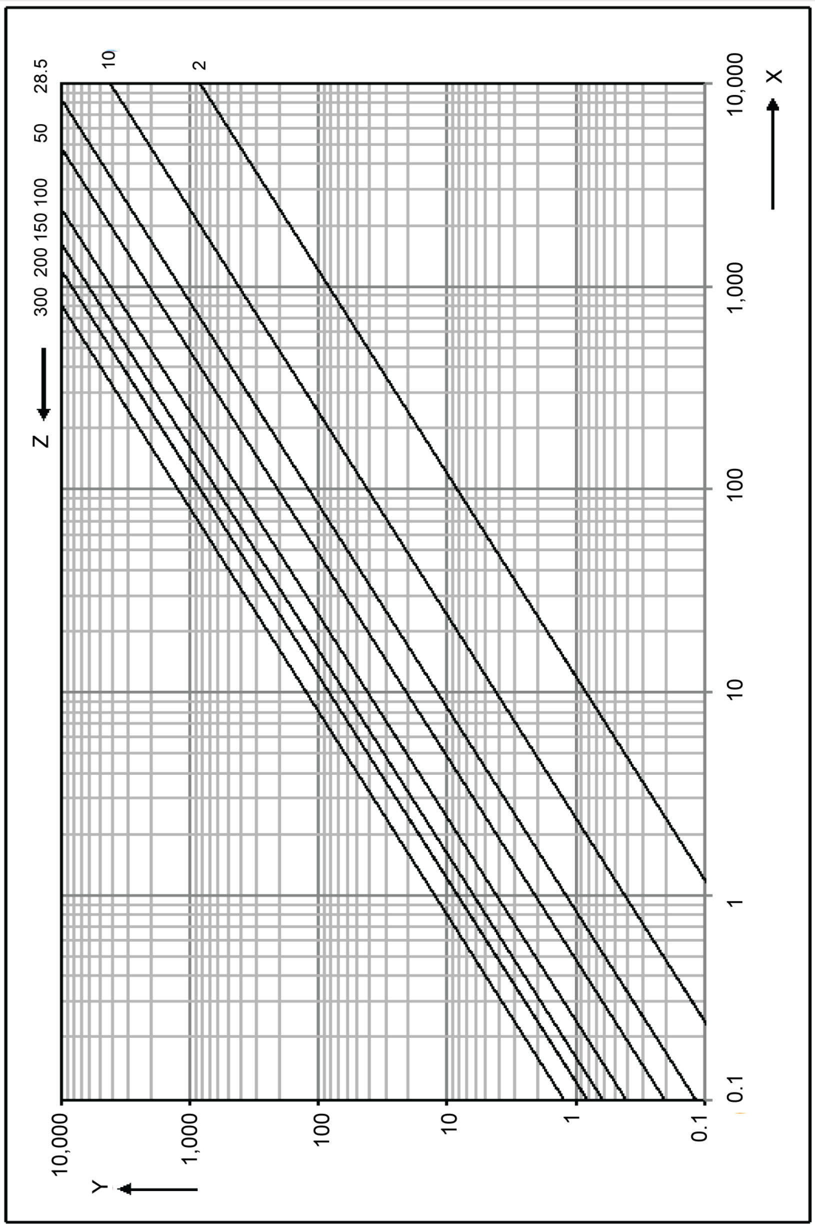
NOTE 1 If (Z/(14,965 × X) < 0.05, “A3.” If (Z/(14,965 × X) < 0.5, “A2.” If (Z/(14,965 × X) < 25, “A1+,” “A1.”

NOTE 2 Figure A.2 is primarily applicable for Arrangement 1 (Category 1, 2 and 3) seals.

NOTE 3 Arrangement 1 (Category 4) seals may exceed exceed leakage rates assumed by Figure A.2. For such applications it is recommended to consult the seal vendor to confirm suitability.

NOTE 4 For Arrangement 2 seals (Category 1, 2, 3, and 4) Figure A.2 guidance assumes application of a Plan 75 or 76 used in conjunction with a Plan 72 or a Plan 52 used with uncontaminated buffer fluid.

Figure A.2—Group II Seal Arrangement Selection Chart



Key

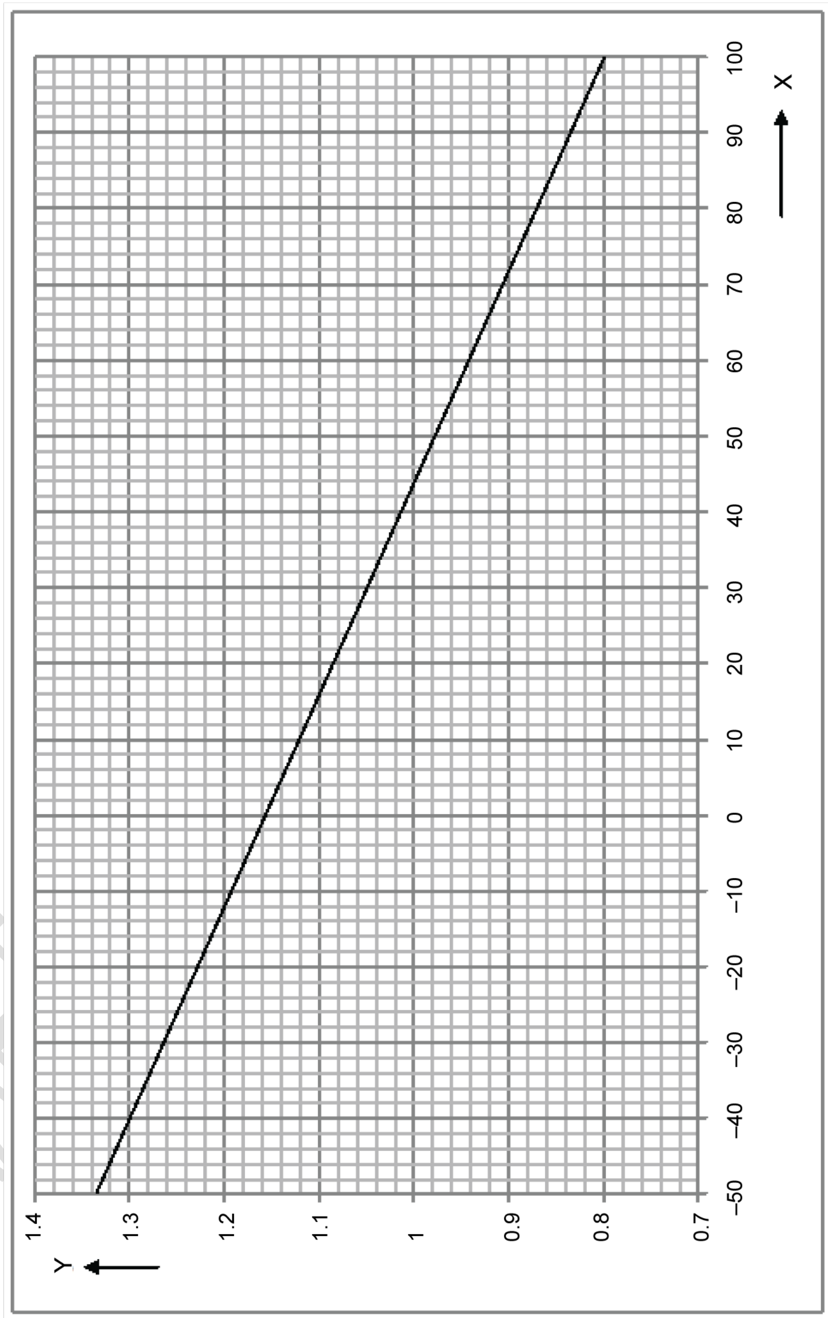
X ppm exposure limit for contributing component (TLV-TWA)

Y mg/m^3 exposure limit for contributing component (TLV-TWA)

Z molecular weight of component contributing to hazard

Y $X \times Z/24.45$

Figure A.3—Conversion of mg/m³ to ppmv at 25 °C (77 °F) and Atmospheric Pressure



Key

X ambient temperature, °C

Y correction factor (multiply result of Figure A.3 by)

Y 298.15/273.15 + X

Figure A.4—Temperature Correction Factor for Figure A.3

Annex B
(informative)

Typical Materials and Material Specifications for Seal Chamber and Mechanical Seal Components

B.1 Materials Standards

Table B.1 and Table B.2 may be used for guidance regarding materials specifications. If this table is used, it should not be assumed that the material specifications are acceptable without taking full account of the service in which they will be applied. Table B.1 lists corresponding international materials, which may be acceptable. These materials represent family/type and grade only. The final required condition or hardness level (where appropriate) is not specified. These materials might not be interchangeable for all applications.

Table B.1—Materials Standards

Material Class	Applic-ations	Inter-national	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Grade	Material No.	JIS
Cast iron	Pressure castings	185/Gr. 250	A278/A278M Class 30	F12401	EN 1561	EN-GJL-250	JL 1040	G 5501, FC 250
	General castings	185/Gr. 300	A48/A48M Class 25/30/40	F11701/ F12101	EN 1561	EN-GJL-250 EN-GJL-300	JL 1040 JL 1050	G 5501, FC 250/300
Carbon steel	Pressure castings	4991 C23 45 AH	A216/A216M Gr WCB	J03002	EN 10213	GP 240 GH	1.0619	G 5151, Cl SCPH 2
	Wrought/ forgings	683-18-C25	A266 Class 4	K03506	EN 10222-2	P 280 GH	1.0426	G 3202, Cl SFVC 2A
	Bar stock: pressure	683-18-C25	A696 Gr B40	G10200	EN 10273	P 295 GH	1.0481	G 4051, Cl S25C
	Bar stock: general	683-18-C45e	A576 Gr 1045	G10450	EN 10083-2	C 45	1.0503	G 4051, Cl S45C
	Bolts and studs	2604-2-F31	A193/A193M Gr B7	G41400	EN 10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts	683-1-C45	A194/A194M Gr 2H	K04002	EN 10269	C 35 E	1.1181	G 4051, Cl S45C
	Plate	9328-4, P 355 TN/ PL 355 TN	A516/A516M Gr 65/70	K02403/ K02700	EN 10028-3	P 355 N P 355 NL1	1.0562 1.0566	G 3106, Gr SM400B
	Pipe	9329-2 PH26	A106/A106M Gr B	K03006	EN 10208-1	L 245 GA	1.0459	G 3456, Gr. STPT 370 / 410
	Fittings	—	A105/A105M	K03504	—	—	—	G 4051, Cl S25C G 3202, Cl SFVC 2A, SFVC2B
4140 alloy steel	Bar stock	—	A434 Class BB A434 Class BC	G41400 [c]	EN 10083-1	42 Cr Mo 4	1.7225	G 4105, Cl SCM 440
	Bolts and studs	2604-2-F31	A193/A193M Gr B7	G41400	EN 10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts	683-1C45	A194/A194M Gr 2H	K04002	EN 10269	C 45 E	1.1191	G 4051, Cl S45C

Table B.1—Materials Standards (continued)

Material Class	Applic-ations	Inter-national	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Grade	Material No.	JIS
12 % Chrome steel	Pressure castings	—	A487/A487M Gr CA6NM	J91540	EN 10213	GX 4 Cr Ni 13-4	1.4317	G 5121, C1 SCS 6, SCS 6X
	General castings	—	A743/A743M Gr CA 15	J91150	EN 10283	GX 12 Cr 12	1.4011	G 5121,Cl SCS 1, SCS 1X1
		—	A743/A743M Gr CA6NM	J91540	EN 10283	GX 4 Cr Ni 13-4	1.4317	G 5121, Cl SCS 6, SCS 1X1
	Wrought/ forgings: pressure	683-13-3	A182/A182M Gr F6a Cl 1 A182/A182M Gr F 6 NM	S41000 S41500	EN 10250-4 EN 10222-5	X12 Cr13 X 3 Cr Ni Mo 13-4-1	1.4006 1.4313	G 3214, Gr. SUS 410-A G 3214, Cl SUS F6 NM
	Wrought/ forgings: general	683-13-2	A473 Type 410	S41000	EN 10088-3	X 12 Cr 13	1.4006	G 3214, Gr. SUS 410-A
	Bar stock: pressure	683-13-3	A479/A479M Type 410	S41000	EN 10272	X 12 Cr 13	1.4006	G 4303, Gr. SUS 410 or 403
	Bar stock: general	683-13-3	A276 Type 410	S41400	EN 10088-3	X 12 Cr 13	1.4006	G 4303, Gr. SUS 410 or 403
	Bar stock: forgings [c]	683-13-4	A276 Type 420 A473 Type 416 A582/A582M Type 416	S42000 S41600 S41600	EN 10088-3	X 20 Cr 13 X 20 Cr S 13 X 20 Cr S 13	1.4021 1.4005 1.4005	G 4303, Gr. SUS 420J1 or 420J2
	Bolts and studs [d]	3506-1, C4-70	A193/A193M Gr B6	S41000	EN 10269	X22CrMoV 12-1	1.4923	G 4303, Gr. SUS 410 or 403
	Nuts [d]	3506-2, C4-70	A194/A194M Gr 6	S41000	EN 10269	X22CrMoV 12-1	1.4923	G 4303, Gr. SUS 410 or 403
	Plate	683-13-3	A240/A240M Type 410	S41000	EN 10088-2	X 12 Cr 13	1.4006	G 4304/4305 Gr. SUS 403 or 410

Table B.1—Materials Standards (continued)

Material Class	Applic-ations	International	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Grade	Material No.	JIS
Austenitic stainless steel	Pressure castings	683-13-10	A351/A351M Gr CF3	J92500	BSI/BS/ EN 10213-4	GX2 Cr Ni 19-11	1.4309	G 5121, Cl SCS 19A
		683-13-19	A351/A351M Gr CF3M	J92800	BSI/BS/ EN 10213-4	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 16A, SCS 16AX
	General castings	—	A743/A743M Gr CF3	J92500	EN 10283	GX2 Cr Ni 19-11	1.4309	G 5121, Cl SCS 19A
		—	A743/A743M Gr CF3M	J92800	EN 10283	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 16A, SCS 16AX
	Wrought/ forgings	9327-5, XCrNi18-10	A182/A182M Gr F 304L	S30403	EN 10222-5	X2 Cr Ni 19-11	1.4306	G 3214, Gr. SUS F 304L
		9327-5, XCrNiMo17-12	A182/A182M Gr F 316L	S31603	EN 10222-5 EN 10250-4	X2 Cr Ni Mo 17-12-2	1.4404	G 4304/4305, Gr. SUS 304L/316L
	Bar stock [e]	9327-5 X2CrNi18-10 683-13-19	A479A/479M Type 304L A479/A479M Type 316L A276, grade 316 A276, grade 316L A276, grade 316 Ti	S30403 S31603 S31635	EN 10088-3 EN 10088-3 EN 10088-3	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2 X2 Cr Ni Mo Ti 17-12-2	1.4306 1.4404 1.4571	G 4303, Gr. SUS 304L G 4303, Gr. SUS 316 L G 4303, Gr. SUS 316 Ti
		9327-5 X2CrNiMo17-12	A479/A479M Type XM19	S20910	—	—	—	—
	Plate	9328-5 X2CrNiMo17-12-2	A240/A240M Gr 304L / 316L	S30403 S31603	EN 10028-7 EN 10028-7	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 4304/4305, Gr. SUS 304L/ 316L
	Pipe	683-13-10 683-13-19	A312/A312M Type 304L 316L	S30403 S31603	—	—	—	G 3459, Gr. SUS 304 LTP/316 LTP
	Fittings	9327-5, X2CrNi18-10 9327-5, X2CrNiMo17-12	A182/A182M Gr F304L, Gr 316L	S30403 S31603	EN 10222-5	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 3214, Gr. SUS F304L/F316L
	Bolts and studs	3506-1, A4-70	A193/A193M Gr B 8M	S31600	EN 10250-4	X5 Cr Ni Mo 17-12-2	1.4401	G 4303, Gr. SUS 316
	Nuts	3506-2, A4-70	A194/A194M Gr B 8M	S31600	EN 10250-4	X5 Cr Ni Mo 17-12-2	1.4401	G 4303, Gr. SUS 316

Table B.1—Materials Standards (continued)

Material Class	Applic-ations	Inter-national	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Grade	Material No.	JIS
Duplex stainless steel	Pressure castings	—	A890/A890M Gr 1 B A995/A995M Gr 1 B	J93372	BSI/BS/ EN 10213-4	GX2 CrNiMoCuN-25-6-3-3	1.4517	—
		—	A890/A890M Gr 3 A A995/A995M Gr 3 A	J93371 J93371	—	—	—	G 5121, Gr. SCS 11
		—	A890/A890M Gr 4 A A995/A995M Gr 4 A	J92205 J92205	BSI/BS/ EN 10213-4	GX2 CrNiMoCuN-25-6-3-3	1.4517	G 5121, Gr. SCS 10
	Wrought / forgings	9327-5, X2CrNiMoN 22-5-3	A182/A182M Gr F 51	S31803	EN 10250-4 EN 10222-5	X2CrNiMoN-22-5-3	1.4462	—
		—	A479/A479M	S32550	EN 10088-3	X2CrNiMoCuN-25-6-3	1.4507	—
	Bar stock	9327-5, X2CrNiMo N22-5-3	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	B 2312/B 2316 Gr. SUS 329 J3L
	Plate	—	A240/A240M-S31803	S31803	EN 10028-7	X2CrNiMoN-22-5-3	1.4462	G 4304/G 4305, Gr. SUS 329 J3L
	Pipe	—	A790/A790M-S31803	S31803	—	—	—	G 3459, Gr. SUS 329 J3LTP
	Fittings	9327-5, X2CrNiMo N22-5-3	A182/A182M Gr F 51	S31803	EN 10250-4 EN 10222-5	X2CrNiMoN-22-5-3	1.4462	B 2312/B 2316 Gr. SUS 329 J3L
	Bolts and studs	—	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	G 4303, Gr. SUS 329J3L
	Nuts	—	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	G 4303, Gr. SUS 329 J3L

Table B.1—Materials Standards (continued)

Material Class	Applic-ations	International	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Grade	Material No.	JIS
Super duplex stainless steel [f]	Pressure castings	—						
		—	A890/A890M Gr 5A	J93404	BSI/BS/ EN 10213-4	GX2CrNiMoN26-7-4	1.4469	—
		—	A890/A890M Gr 6A	J93380	—	—	—	—
	Wrought/ forgings	—	A182/A182M Gr 55	S32750 S32760	EN 10250-4 EN 10088-3	X2CrNiMoCu-WN 25-7-4	1.4501	G 4303, Gr. SUS 329 J4L
	Bar stock	—	A276-S32760 A479/A479M-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCu WN 25-7-4	1.4501	G 4304/G 4305, Gr. SUS 329 J4L
	Plate	—	A240/A240M-S32760	S32750 S32760	EN 10028-7	X2CrNiMoCu WN 25-7-4	1.4501	—
	Pipe	—	A790/A790M-S32760	S32750 S32760	—	—	—	G 3459, Gr. SUS 329 J4LTP
	Fittings	—	A182/A182M Gr F55	S32750 S32760	EN 10250-4 EN 10088-3	X2CrNiMoCu-WN 25-7-4	1.4501	B 2312/B 2316 Gr. SUS 329 J4L
	Bolts and studs	—	A276-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCu-WN 25-7-4	1.4501	G 4303, Gr. SUS 329 J4L
	Nuts	—	A276-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCu-WN 25-7-4	1.4501	G 4303, Gr. SUS 329 J4L

a UNS (unified numbering system) designation for chemistry only.

b Where EN standards do not yet exist, European national standards are available, e.g. AFNOR, BS, DIN, etc.

c Do not use for shafts in the hardened condition (over 302 HB).

d Special, normally use AISI 4140.

e For shafts, standard grades of austenitic stainless steel may be substituted in place of low carbon (L) grades.

f Super Duplex stainless steel classified with pitting resistance equivalent (PRE) number greater than or equal to 40.
$\mathrm{PRE} = w\mathrm{Cr} + 3.3[w\mathrm{Mo} + (0.5w\mathrm{W})] + 16w\mathrm{N}$, where w is the percentage mass fraction of the element indicated by the subscript.

Table B.2—Miscellaneous Materials Specifications

Common Name	Composition Specification
Bronze	UNS C87200 (silicon-bronze), C90700 or C92200 (tin-bronze), C95200 (aluminium bronze) or C95800 (nickel- aluminium-bronze)
Low-carbon nickel-molybdenum-chromium alloy (Super Alloy, e.g. Alloy C276, C4.)	ASTM B564, UNS N10276 (forgings) ASTM B574, UNS N10276 (bar and rod) ASTM B575, UNS N10276 (plate, sheet and strip) ASTM A494, Grade CW-2M (weldable cast) ASTM F1058, UNS R30003 (wire)
Nickel-copper alloy (Alloy 400)	ASTM B564, UNS N04400 (forgings) ASTM B164, Class A, UNS N04400 (bar and rod) ASTM B127, UNS N04400 (plate, sheet and strip) ASTM A494, Grade M30C (weldable cast)
Ni-resist	ASTM A436, Type 1, 2, or 3, UNS F41000, F41002, and F41004 respectively (austenitic cast iron), ASTM A439, Type D2, UNS F43000 (austenitic ductile iron)
Precipitation hardening nickel alloy (Alloy 718)	ASTM B637, UNS N07718 (forgings and bar) ASTM B670, UNS N07718 (plate, sheet and strip)
Alloy 20	ASTM A744 Grade CN7M, UNS N08007 (casting) ASTM B473, UNS N08020 (bar)
Alloy 42	ASTM F30, UNS K94100 (bar)
Precipitation-hardening stainless steel	ASTM A564, Grade 630, UNS S 17400 or Grade 631, UNS 17700 (wrought) ASTM A747, Grade CB7Cu-1, UNS J92180 (cast)

Elastomer	ASTM Standard Practice D1418 NBR, ISO 1629, Acrylonitrile butadiene
	ASTM Standard Practice D1418 EPDM, ISO 1629, Ethylene-propylene-diene
	ASTM Standard Practice D1418 FKM, ISO 1629, Fluoroelastomer
	ASTM Standard Practice D1418 FFKM, ISO 1629, Perfluoroelastomer
Flexible graphite	ASTM F104 Type 51, exfoliated and recompressed graphite material used as static secondary seals.
Carbon graphite	Self-lubricating composite of carbon and graphite impregnated with metallic or nonmetallic materials depending on the application need.
Thermoplastic resin	Chemically resistant material such as polyetheretherketone (PEEK) with continuous carbon fiber wound (API 610 Composite 1), or chopped carbon fiber filled (API 610 Composite 2).

B.2 Seal Rings and Mating Rings

B.2.1 Typical Temperature Limits

Typical temperature limits for seal face materials are given in Table B.3

Table B.3—Typical Temperature Limits for Seal Face Materials

Face Material	Maximum Temperature [a] °C (°F)
Tungsten carbide	1100 (2012) [b]
Silicon carbide (sintered, SSiC)	1650 (3002) [b]
Silicon carbide (reaction bonded, RBSiC)	1400 (2552) [b]
Silicon carbide—Graphite loaded (sintered, SSiCG)	550 (1022) [b]
Silicon carbide—Graphite loaded (reaction bonded, RBSiCG)	550 (1022) [b]
Carbon-graphite:	
Resin impregnated	285 (550)
Antimony impregnated	500 (932) [b]

[a] With the exception of SSiC, chemical compatibility of face materials can vary with temperature and environment.

[b] The temperature limit and scope of this standard is 400 °C (750 °F). Application of this material at a higher temperature would be considered out of scope..

B.2.2 Carbon-graphite

B.2.2.1 General

Carbon-graphite is one of the most widely used seal face materials. It is typically prepared from a mixture of non-crystalline carbon and highly crystalline graphite with a pitch binder that is carbonized at high temperatures. The resulting structure is then impregnated with a resin or metal to reduce the porosity, minimize permeability, and enhance mechanical and wear properties.

Carbon-graphite has excellent tribological qualities and good mechanical properties. Many grades, i.e. compositions, are available that are compatible with a wide range of temperatures and aggressive environments. Because of its low modulus of elasticity, compared with the metal carbides, carbon-graphite is more susceptible to bending or distortion under pressure. Although broadly chemically inert, carbon-graphite can be attacked by strong oxidizing fluids, such as nitric or sulphuric acids, particularly at high temperature. Special grades have been developed that stand up to these more corrosive environments. In addition, there are grades designed for dry-running applications, such as contacting containment seals that normally run at low differential pressure.

B.2.2.2 Resin Impregnated

While resin impregnated grades have the lower modulus of elasticity, they are generally more corrosion resistant than the metal impregnated grades. Maximum temperature limits also are lower. Because of their wear resistance, compatibility with metal carbides, and general utility resin impregnated carbon-graphite is the most widely used material.

B.2.2.3 Metal Impregnated

Metal-filled carbons have a higher modulus of elasticity and temperature limits than resin-filled grades but have less corrosion resistance. These metal-filled carbons are often used in high-pressure applications and, depending on the metal, are useful in limited lubrication applications like flashing hydrocarbons. Antimony impregnated grades are one of the most widely applied metal impregnated carbon-graphite because of its superior blister resistance and temperature range.

B.2.2.4 Blister Resistance

Mechanically induced shear forces can produce blistering of the seal face. Blisters are irregularities on the seal surface that degrade performance resulting in higher leak rates and eventually failure of the seal. So it is essential that the carbon-graphite is resistant to blistering. While antimony impregnated grades have shown to be less susceptible to blistering, both resin and metal impregnated grades are available that offer improved blister resistance. Blistering potential is largely viscosity dependent. As a general guideline, when considering fluid viscosity:

- Up thru 32 cP; carbon grades are acceptable in all oils and most other fluids.
- 33 thru 68 cP; carbon grades are likely to regenerate blisters.
- 69 cP and above; carbon grades should be avoided to minimize blister formation.

B.2.3 Silicon Carbide

B.2.3.1 General

Silicon carbide is widely used as a material for seal rings. Its primary advantages are high hardness, excellent corrosion resistance, high thermal conductivity, and low coefficient of friction against carbon-graphite. Silicon carbides can be classified according to composition and manufacturing process. In addition, within these classifications, there are various grades, grain structures, etc. As a result, the two classifications of silicon carbide have some variation in performance when used as a seal face material.

Although there are differences within the classifications of silicon carbide, there are general characteristics as well. Reaction-bonded silicon carbide is regarded as having a marginally lower coefficient of friction against carbon-graphite under certain conditions. It is less brittle and is not as hard as sintered silicon carbide. Although real, these differences are small. One substantial difference is in corrosion resistance. As a rough rule of thumb, reaction-bonded silicon carbide is recommended for service where the pH is between 4 and 11; outside this range, sintered silicon carbide should be used.

For mechanical seals, reaction-bonded silicon carbide and sintered silicon carbide are widely used. New compositions of silicon carbide are also used called silicon carbide graphite-loaded because they contain both silicon carbide and free graphite.

B.2.3.2 Reaction Bonded Silicon Carbide (RBSiC)

Reaction-bonded silicon carbide is manufactured by reacting silicon metal with carbon-graphite in a silicon carbide matrix. The resulting material contains free silicon metal usually in the range of 8 % to 12 %. The wear and lubricating characteristics of reaction bonded silicon carbide are the best of all hard face materials; therefore it is the preferred material for high pressures and speeds. It also has good chemical resistance; however, some chemicals will attack the free silicon within the structure. Examples include sodium hydroxide and other caustics, amines, hydrofluoric acid and phosphoric acid containing small amounts of hydrofluoric acid.

B.2.3.3 Sintered Silicon Carbide (SSiC)

Sintered silicon carbide, on the other hand, consists strictly of silicon carbide. It is produced from pure silicon carbide powder with non-oxide sintering aids and is a homogeneous form of silicon carbide that does not contain any free silicon. The absence of the free silicon makes sintered silicon carbide chemically inert in virtually all corrosive environments. It is the most resistant to chemically aggressive fluids and can be used in virtually any fluid. However, it does not have the pressure velocity (PV) capabilities of the other type of silicon carbide, and being the most brittle material it tends to chip more easily.

B.2.3.4 Silicon Carbide–Graphite Loaded

Reaction bonded silicon carbide–graphite (RBSiCG) and sintered silicon carbide–graphite (SSiCG) are available. Methods to improve the dry running capability and PV limits of hard-versus-hard face combinations, such as silicon carbide against silicon carbide, have gained considerable attention. New composites of silicon carbide and graphite and modified face surface designs have been introduced to reduce face lubrication sensitivity and improve PV limits. These composites contain both silicon carbide and free graphite ranging from a few percent up to fifty percent (50 %) graphite. The addition of graphite to the silicon carbide base reduces strength but improves tribological behavior. The ability to handle abrasives with these composites is not as good as that of pure silicon carbide but is significantly better than carbon-graphite. Users should review experience with this material for the specific service prior to selecting it for use.

B.2.3.5 Crystalline Diamond Face Treatment

A relatively new face treatment in the sealing industry, diamond treated hard face materials are available. There are various versions of diamond face treatments available depending on the seal manufacturer. Diamond face treatment may help with intermittent dry running and times of reduced face lubrication as well as dealing with abrasive particulate. It may help extend the seal life in certain applications due to the hardness of the face treatment and the low coefficient of friction which is less than carbon. It may be applied to one or both seal faces depending on the manufacture's requirements. Diamond treated faces cannot be repaired and must be replaced after use.

B.2.4 Seal Ring and Mating Ring Combinations

B.2.4.1 General

Most materials exhibit poor wear behavior when in sliding contact with a surface fabricated from the same material. This is why two dissimilar materials, carbon-graphite versus silicon carbide is the standard selection in this standard. This is illustrated in Figure B.1, which compares the PV (pressure × velocity) relationship of different material combinations.

However, in some services it is usually preferable to use two hard faces because a soft face material wear rate might be high. Typical hard face materials are sintered silicon carbide, reaction bonded silicon carbide, and tungsten carbide. Factors that may justify the use of two hard faces include:

a) the presence of abrasive particles in the sealed fluid;

b) the viscosity of the fluid;

c) crystallization of the fluid;

d) products that polymerize;

e) presence of high vibration and shock;

f) high internal (ID) pressured seal faces requiring a higher face tensile strength.

B.2.4.2 Hard Face Combinations

As a general rule, two hard faces will work satisfactorily if there is sufficient liquid lubrication. However, hard face combinations will experience irreversible damage if run under dry conditions so two hard faces are not recommended for services where there will be marginal lubricating conditions. Face material development and industry experience has shown a trend toward the use of silicon carbide hard face combinations because of its greater versatility with respect to corrosion, abrasion/erosion resistance, and a lower sensitivity to face damage. There are some general rules to consider, as follows.

a) Sintered silicon carbide vs itself can give excellent results in corrosive service and is the preferred combination of two hard faces for many chemical uses.

b) Reaction-bonded silicon carbide vs itself has also been used extensively in hydrocarbon processing. It provides good performance for services such as crude oil where abrasive particles are present.

c) Tungsten carbide versus silicon carbide has shown good performance where the medium sealed is oil. Even in less viscous liquid services, such as water with abrasives, tungsten carbide vs silicon carbide is the most common selection if two hard faces are required.

d) Tungsten carbide versus tungsten carbide has been used successfully in heavy oils, tars, and asphalts. It gives poor performance in water but can be used successfully in caustic service. Special attention should be given to the PV (pressure × velocity) conditions, as the limits for this materials combination are lower than other hard face combinations.

e) As a general rule, the science of tribology frowns on using two like materials in frictional contact. For this reason reaction-bonded silicon carbide, narrow face, has been used against a sintered silicon carbide, wide face. Practical concerns, such as corrosion resistance and increased inventory costs, make this a less popular combination.

Promising new materials are being developed for seal faces where hard-face combinations are required. An example is reaction bonded or sintered silicon carbide graphite loaded. RBSiCG or SSiCG versus SiC have been used successfully in some pipeline services where a variety of fluids are pumped, but detailed application guidelines are currently beyond the scope of this standard. Figure B.1 shows PV comparisons for typical face material combinations.

Crystalline diamond coated seal faces show promise in abrasive applications with marginal lubrication because of its lower coefficient of friction and improved surface hardness. Batch processes, intermittent dry running conditions are some typical ideal applications. A potential drawback with crystalline diamond coated seal faces is the potential for leakage. This is inherent as the substrate material is generally a rough treated silicon carbide, so the combined roughness of diamond faces is typically on the order of most traditional hard vs hard face combinations.

B.3 Secondary Seals

B.3.1 General

Secondary seals can be subdivided into three main groups: elastomers, energized seals, flexible graphite rings and flexible graphite filled spiral wound gaskets. The selection of these seals is important to the function and life of the mechanical seal.

B.3.2 Typical Temperature Limits for Secondary Seals

General temperature limitations can vary depending on polymeric family and composition of the elastomer, but typical values are given in Table B.4.

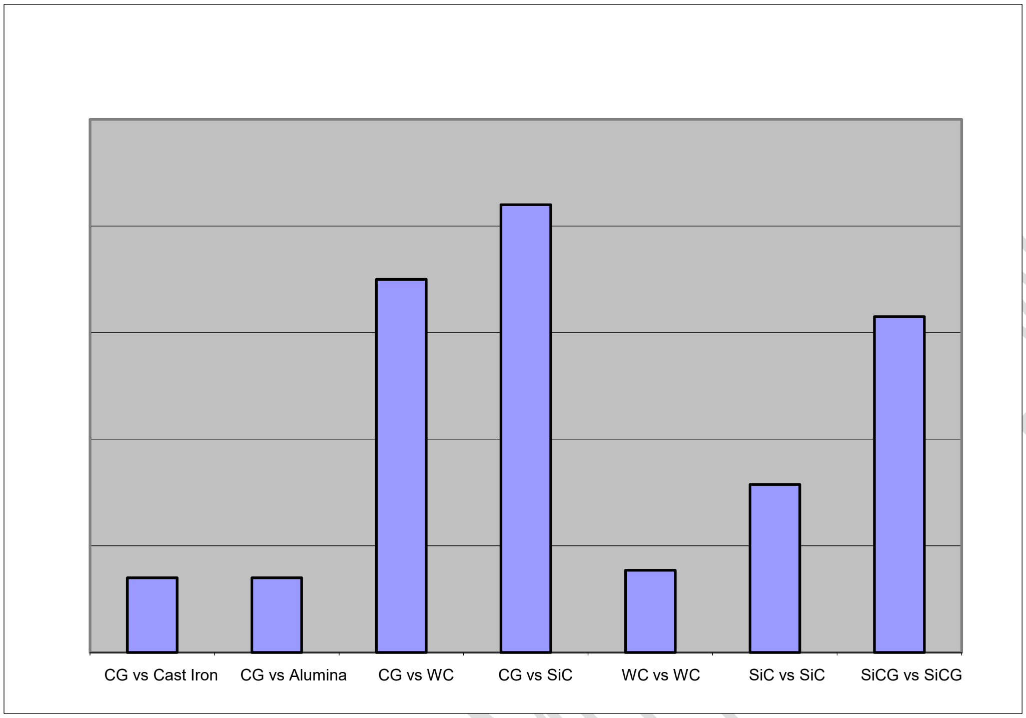


Figure B.1—Relative PV Comparisons for Seal Face Combinations

Table B.4—Typical Temperature Limits for Secondary Seals

Material	ISO/DIN 1629	ASTM D1418	Minimum Temperature °C (°F) [a]	Maximum Temperature °C (°F) [a]
Fluoroelastomer				
Hydrocarbon service	FKM	FKM	–7 (20)	176 (350)
Water-based service			–7 (20)	121 (250)
Perfluoroelastomer (high temperature)	FFKM	FFKM	0 (32)	290 (554)
Perfluoroelastomer (chemically resistant)	FFKM	FFKM	–7 (20) [b]	260 (500)
Nitrile	NBR	NBR	–40 (–40)	121 (250)
Ethylene propylene diene	EPDM	EPDM	–50 (–58)	150 (302)
Tetrafluoroethylene propylene	FEPM/ TFE	FEPM/TFE	–7 (20)	210 (410)
Fluorosilicone	FVMQ	FVMQ	-60 (-80)	205 (400)
Polytetrafluoroethylene	PTFE	PTFE	–270 (–454)	315 (599)
Flexible graphite	—	—	–240 (–400)	480 (896)

[a] The temperature ranges listed can be affected by the fluid environment.

[b] Some FFKM grades are not suitable below 20 °C (68 °F).

NOTE Refer to Annex A, above and below application temperature limits of this standard that are –40 °C to 400 °C (–40 °F to 750 °F) with a 176 °C (350 °F) limit for elastomers. PTFE is not recommended secondary seal material, refer to Annex A.

B.3.3 Elastomers

B.3.3.1 General

Elastomers are a complex integration of polymer architecture, fillers, cure chemistries and design considerations. While O-rings are not the sole elastomer configuration, they are the standard selection for secondary seals in this standard. The general characteristics discussed in this tutorial apply to all elastomer designs.

Properly selected, compounded, cured and designed elastomeric seals perform predictably in a defined service (i.e. medium, time, temperature, pressure, and static/dynamic duty). However, if compromises are made, the elastomeric seal may perform inconsistently with shortened service life.

Writing and/or applying a specification for elastomers is difficult because of the proprietary nature of elastomers, the variety of polymer architectures available and differing compound ingredients used. This standard provides only limited, general guidance for selection of elastomers and provides no specifics for selection of a particular compound, cure, and filler. It should be noted that new compounds are continuously formulated that change the possible working parameters of elastomer types and prescribing one solution for general applications/medias could exclude viable options.

B.3.3.2 Elastomer Characteristics

B.3.3.2.1 General

Elastomers are grouped into families by virtue of their base polymer. It is the base polymer that dictates the majority of the elastomer properties. Different mixtures of copolymers, fillers, compounds, and curing cycles affect the physical and chemical properties of the elastomers, which in turn effect how well the elastomer seals the media. Examples of how these mixtures affect the elastomer properties are given in B.3.3.2.2 through B.3.3.2.5.

B.3.3.2.2 FKM (Fluoroelastomer)

FKM has a vinylidene fluoride polymer base. This makes the elastomer suitable for use with hydrocarbons, silicone fluids, and water and the temperature range matches the temperature envelope of this standard for Type A and Type B seals. FKM is subdivided into three main types depending on the monomer(s) included with the base polymer in accordance with ASTM D1418. Each FKM type has different physical and chemical properties.

— *Type I*—The addition of hexafluoropropylene (HFP) increases chemical resistance.

— *Type II*—The combination of HFP and tetrafluoroethylene (TFE) increases the chemical resistance but reduces its compression set resistance and low temperature capability.

— *Type III*—The combination of HFP, TFE plus the addition of perfluoromethylvinylester (PVME) increases the chemical resistance and low temperature capabilities.

B.3.3.2.3 FFKM (Perfluoroelastomer)

FFKM has a PTFE polymer base and is not typed like FKM. The chemical inertness of the full fluorinated backbone allows excellent resistance to acids and bases, oxidizers, water and hydrocarbons. Special FFKM compounds are required for amine and steam service (see Annex A) that use unique crosslink and/or cure systems.

While performance variances may be minor, there is a differentiation made between chemically resistant and high-temperature FFKM. High-temperature FFKM typically has very similar chemical resistance, but because of the added high temperature range the low temperature capability is reduced. The higher temperature range and increased chemical resistance is the reason FFKM is the standard O-ring selection in this standard when FKM is not suitable.

B.3.3.2.4 NBR (Nitrile)

NBR has a base polymer of butadiene. This offers resistance to hydrocarbon applications, silicone greases, and water, but is less resistant to normal atmospheric exposure (i.e. sunlight, oxygen). The amount of the copolymer acrylonitrile within the base resin permits use in low-temperature applications, but increases susceptibility to swell in oil. NBR application temperature limit [120 °C (248 °F)] and sensitivity to some common hydrocarbon fluids (gasoline, naphtha, etc.), limit its application in some refining and chemical services. Therefore, FKM (not NBR) is the standard O-ring selection in this standard.

B.3.3.2.5 EPDM (Ethylene Propylene)

EPDM has an ethylene propylene (EP) polymer base. This offers resistance to water, steam, weak acids, phosphate ester and atmospheric exposure. The addition of ethylene propylene terpolymer (EPT) increases its resistance to oxidation and radiation. Peroxide curing increases the crosslink density and compression set resistance. However, a significant limitation for this material is its incompatibility with vegetable or mineral oils, silicone, hydrocarbons, and greases. Special handling is required to avoid contact with these fluids and lubricants and is the reason this material is reluctantly used in many refining and chemical plants.

B.3.3.2.6 FVMQ (Fluorosilicone)

Silicone is an elastomer made from silicon, oxygen, hydrogen, and carbon. Fluorosilicone is a fluorinated silicone that shares the same stability and compression set resistance as silicone, usable across a wide temperature range. Unlike silicone, fluorosilicone has additional chemical resistance to non-polar solvents, fuels, oils, acids, and alkaline chemicals. It would have limitations in hot air, ketones, aliphatic and aromatic hydrocarbons, toluene, benzene, ozone, and oxidative environments. Fluorosilicone is advantageous because of it's low temperature capability [-60 °C (-80 °F)], making it a preferable option in low temperature light hydrocarbon applications.

B.3.3.3 Chemical and Mechanical Compatibility

When selecting the proper elastomer, it is important to choose an elastomer that will be compatible with the sealing fluid and lubricants used with the associated equipment. It may also be prudent to consider liquids or gases that are used to purge the pump and associated piping prior to start-up or associated with maintenance activity. Understanding and communicating the service requirements with the vendor can avoid potential media incompatibility issues such as swelling, polymerization, softening, compression set. Elastomer compatibility can vary considerably with time, temperature, concentration, and mixture of different fluids.

The seal selection guide in Annex A recommends families (FKM and FFKM) based on successful user experience. Elastomer selection should not be bound to only the recommended selection if field experience with the specific seal configuration and application has been successful. Specific elastomer application guidelines outside of those covered in Annex A are available from the following sources:

— FSA *Mechanical Seal Handbook* [55];

— HI "Mechanical Seals for Pumps: Application Guidelines" [56];

— Pruitt, Kenneth M., *Chemical Resistance for Elastomers III* [61];

— mechanical seal and elastomer manufacturers.

Subsection 6.1.1.10 requires O-ring grooves to be sized to accommodate FFKM O-rings. Some FFKMs have a greater thermal expansion than most other O-ring materials, such as FKM. Installing a FFKM in a groove designed for FKM will 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 that thermal expansion damage in FFKM O-rings is often confused with damage due to chemical-induced swelling of the O-rings and vice versa. The O-ring groove should be designed such that at ambient and operating temperatures the O-ring will seal. A standard O-ring size reference is ISO 3601-2:2008.

Physical properties of the O-rings such as thermal expansion, elongation, hardness, and modulus vary because of the elastomer composition. The composition can alter the amount of stretch, squeeze and volume fill the O-ring can achieve. Also, extreme temperatures can vary the predicted characteristics and physical properties of the elastomer. Proper O-ring groove design helps to avoid secondary sealing problems associated with these variables.

B.3.3.4 Hardness

Elastomer hardness is measured in International Rubber *Hardness* Degrees (IRHD) or Shore A Durometer hardness points. Standard elastomer hardness is typically specified in 5-point increments with a ± 5 point tolerance. Density of the elastomer is directly related to the hardness. To decrease the amount of media permeation a higher hardness O-ring may be selected. Typically high-hardness O-rings have more plastic properties and will be less permeable reducing potential for rapid gas decompression and extrusion, but elastic properties may be compromised.

Attention should be given to fillers used when increasing the density to avoid material incompatibility problems. Although most elastomers use carbon black as fillers, other fillers can be used. Chemical compatibility of the base polymer and the fillers used should be confirmed.

Table B.5 shows a typical hardness range for selected elastomers. It is important to note that the hardness ranges shown can exceed a specific elastomer durometer manufacturing tolerance. Use of elastomers with hardness outside the range successfully qualification tested may impact the ability of the seal assembly to meet the performance expectations of this standard.

Table B.5—Typical Hardness Range for Elastomeric Secondary Seals

Material	ISO/DIN 1629	ASTM D1418	Minimum Hardness Shore A [a]	Maximum Hardness Shore A [a]
Fluoroelastomer	FKM	FKM	70	90

Perfluoroelastomer	FFKM	FFKM	70	90
Nitrile	NBR	NBR	65	75
Ethylene propylene diene	EPDM	EPDM	75	80
Tetrafluoroethylene propylene	FEPM/TFE	FEPM/TFE	75	90
Fluorosilicone	FVMQ	FVMQ	70	90
[a] Unique compound formulation leads to varying hardness ranges. Some compounds may have hardnesses outside the above ranges.				

B.3.3.5 Other Secondary Seal Considerations

Users may wish to consider alternatives in cases where the standard elastomer O-ring materials, FKM and FFKM, do not meet all performance requirements. These alternatives normally include O-ring materials other than FKM and FFKM. Flexible graphite, while not O-ring material, is a standard secondary seal and may be a reasonable alternative. Elastomer shapes other than O-rings are rarely used. The primary factor in selecting an appropriate alternative should be proven experience and lower cost.

a) Alternative secondary seal O-ring material may include elastomers such as nitrile rubber (NBR), hydrogenated nitrile rubber (HNBR), ethylene propylene/diene (EPM/EPDM), tetrafluoroethylene/propylene (FEPM/TFE), and FFKM alternatives/substitutes. Flexible graphite is an alternative worth considering although it is not suitable for use as a dynamic secondary seal. Tetrafluoroethylene (TFE) coated elastomer O-rings provide low friction and chemical resistance at the contact surface with a self-energizing elastomeric core; however, failure of the thin coating can result in O-ring failure so they are less often used.

b) Bellows designs and other non-pusher secondary seals provide specific advantages. Problems with hang-up of dynamic O-rings caused by sludge or debris can be eliminated by substitution of bellows seals, as an example.

c) While seldom used, spring energized polymer rings are a specific type of energized secondary seals comprised of a two part assembly; a jacket and an energizer spring retained in the jacket cavity. The inner cavity can also be energized by an elastomer. The energizer provides the positive force against the jacket lips needed to seal since the polymer lacks the resilience of an elastomer. They are used in high-pressure, polymerizing and/or low-friction applications, and only in engineered seals. The jacket material is typically PTFE because of its chemical resistance and low friction. It is important that chemical and physical suitability of all the materials used in these seals be verified.

d) Wedge, u-cup, or v-ring shaped elastomer or PTFE material also has to be energized by external means, such as a spring, but reliability concerns associated with fretting and increased friction eliminate these as suitable alternatives within this standard.

Other considerations for selection of particular elastomeric compounds include the following:

a) critical properties (such as compression set, swell, hardness, etc.) may be more important for some mechanical seal types than for others. As an example, higher durometer elastomers may be required as a preventative measure to avoid Rapid Gas Decompression (RGD) damage in high pressure, light hydrocarbon services;

b) dynamic secondary seals can have reduced temperature ratings;

c) the elastomer should be identified by ISO 1629 or ASTM D1418 designation, and should not use reprocessed materials;

d) processing aids used in the manufacture of the secondary sealing elements not containing per and polyfluoroalkyl (PFAS) materials may be regulated depending on local or federal requirements.

B.3.4 Flexible Graphite Filled Spiral Wound Gaskets and Rings

Flexible graphite is a highly conformable material that is chemically inert, naturally lubricous, and has excellent thermal conductivity. It is mechanically bonded pure graphite that enables use within the entire temperature range of this standard. It is not as robust a material as an elastomer or polymer so shall be handled more carefully or mechanically reinforced. It is less resilient than an elastomer and shall be fully contained under compression when not reinforced.

Forms of the material are fabricated from sheet. The most common use of flexible graphite is as a ring shaped static secondary seal for high-temperature bellows seals and mating rings and as filler for a spiral wound gasket. It has also been used to a lesser extent in a spring energized wedge design. Use in strong oxidizing acids is the principal limitation.

B.4 Throat and Throttle Bushings

Throat and throttle bushings can be provided by the seal vendor and the material required by this standard is carbon. Other materials have been used for pump bushings include bronze and nonmetallic materials such as polyetheretherketone (PEEK), PTFE compounds, and carbon graphite compounds.

A fixed throat bushing is normally provided by the pump vendor as part of most overhung, one and two stage pumps. Pump vendor supplied bushings for pumps with three or more stages change name and function, but there is almost always a fixed pump bushing located at the bottom of the seal chamber. If specified, the seal vendor can supply an additional throat bushing of a fixed or floating design.

Throttle bushing(s) supplied by the seal vendor are always mounted in the gland plate. Like throat bushings, some multistage pump designs are provided with bushings that they call throttle bushings. Inside the pump they are usually used to minimize the leakage between high-pressure pump areas to lower pressure areas.

The operating diametral clearance of solid floating carbon throat or throttle bushing will be smaller than that of a fixed bushing (in accordance with 6.1.2.23 and Table 2). The operating diametral clearance of a floating segmented bushing can be smaller than that of a solid floating bushing. The inner diameter of a solid ring floating bushing shall consider the differential thermal expansion between the rotor (shaft and sleeve) and the bushing to avoid bushing failure. If the desired clearance for the solid floating bushing cannot be achieved or maintained because of thermal related dimensional changes, then use of a segmented floating bushing may be a good choice.

Carbon bushing material is suitable for chemical plant and refining services but can be more sensitive to impact damage than other materials. PEEK material, some graphite compounds, and PTFE (and TFE composites) may be suitable for some pump bushing applications, but they may not be the best choice for throat and throttle bushing material because of thermal expansion properties and lack of memory and are not the recommended material in this standard.

Annex C
(informative)

Data sheets to be populated during next ballot.

Annex D
(informative)

Seal Codes

D.1 Introduction

The mechanical seals code provides a concise way of referring to a design and features commonly supplied with the seal.

D.2 Mechanical Seal Coding Construction

D.2.1 General

In accordance with this standard, mechanical seals can be described in a general manner by using the following simplified coding system. Table D.1 indicates the construction of a finished seal code. It is the intention of this seal code to accurately describe the seal and seal system being implemented in a given application.

Table D.1—Example of an Arrangement 1 Mechanical Seal Code

Seal				**Design Options**				**Size**		**Plans**
Category	Arrangement	Type		Containment device	Gasket material	Face material		Shaft Size mm		Piping Plan
1	**1**	**A**	**-**	**P**	**F**	**O**	**-**	**050**	**-**	**11**

D.2.2 First Position: Seal Category (1, 2, 3, 4)

The first position designates the seal category. These categories are defined in 4.2.2.

D.2.3 Second Position: Seal Arrangement (1, 2, 3)

The seal arrangement code identifies the use of single or dual seal arrangement and also whether the dual seal arrangement is pressurized or nonpressurized. Seal arrangements are defined in 4.2.4.

D.2.4 Third Position: Seal Type (A, B, C)

This position designates the seal type (A, B, or C) as defined in 4.2.3. For dual seal assemblies with different seal types in the inner and outer position, the seal types will be designated as inner seal/outer seal (e.g. B/A).

D.2.5 Fourth Position: Containment Device (P, L, F, C, S, X)

The fourth position describes the containment device found on the atmospheric side of the mechanical seal. This device will help provide isolation of the seal from the atmosphere. The available options are shown below:

— P—plain gland with no bushing: this design can be used in Arrangement 2 or Arrangement 3 seals;

— L—floating throttle bushing: this design can be used on single Category 1, Category 2, or Category 3 seals;

— F—fixed throttle bushing: this design can be used on Category 1, Arrangement 1 seals;

— C—containment seal: a containment seal can be used in Arrangement 2 (2CW-CS or 2NC-CS) seals;

— S—floating, segmented carbon bushing: a segmented carbon bushing may be specified in Category 1, Category 2, or Category 3 seals;

— X—unspecified: the option for the containment device is unknown or not covered by the standard options. This will be specified separately.

D.2.6 Fifth Position: Secondary Sealing Element (Gasket) Material (F, G, H, I, R, X)

The fifth position describes the materials used in the secondary sealing element (gaskets) in the mechanical seal assembly. Unless otherwise specified, the material is the same for all gaskets in the assembly. For dual seal assemblies with different secondary sealing materials in the inner and outer position, the seal materials will be designated as inner seal/outer seal (e.g. G/F).

See Annex B for tutorial on secondary sealing elements. The available options are shown below:

— F—FKM gaskets;

— G—polytetraflouroethylene (PTFE) spring energized gaskets;

— H—nitrile gaskets;

— I—FFKM gaskets;

— R—flexible graphite (with spiral wound flexible graphite gaskets for gland gasket);

— X—unspecified: the option for the secondary sealing element is unknown or not covered by the standard options. This will be specified separately.

D.2.7 Sixth Position: Seal Face Material Combination (M, N, O, P, Q, R, S, T, X)

The sixth position describes the material combination used in the seal assembly. Unless otherwise specified for dual seals, the face combination is the same for all seals in the assembly. For dual seal assemblies with different seal face materials in the inner and outer position, the seal face materials will be designated as inner seal/outer seal (e.g. P/N).

See Annex B for a tutorial on seal face materials. The available options are shown below:

— M—carbon vs nickel bound tungsten carbide;

— N—carbon vs reaction bonded silicon carbide;

— O—reaction bonded silicon carbide vs nickel bound tungsten carbide;

— P—reaction bonded silicon carbide vs reaction bonded silicon carbide;

— Q— sintered silicon carbide vs sintered silicon carbide;

— R—carbon vs sintered silicon carbide;

— S—graphite loaded, reaction bonded silicon carbide vs reaction bonded silicon carbide;

— T—graphite loaded, sintered silicon carbide vs sintered silicon carbide;

— X—unspecified: the option for the seal face material combination is unknown or not covered by the standard options. This will be specified separately.

D.2.8 Seventh Position: Shaft Size in mm

The seventh position is the shaft size onto which the seal cartridge will be installed. This size will be expressed in whole millimeters and displayed as three digits. For millimeters that are not whole or when converting inch dimensions to millimeters, the dimension should be rounded up to the next whole millimeter. This dimension is intended for seal sizing only and is not intended for detailed seal design. For an unknown or unspecified shaft size, the position will be described as XXX.

Example 1: 25 mm is described as 025.

Example 2: 37.25 mm is described as 038.

Example 3: 34.9 mm (1.375 in.) is described as 035.

Example 4: an unspecified or unknown shaft size will be described as XXX.

D.2.9 Eighth Position: Piping Plans

The eighth position defines the piping plans that will be used in the seal installation. The description of the piping plans can be found in Annex G. If more than one piping plan is used in the seal installation, the piping plans should be listed in numerical order separated by a forward slash “/”.

Example: A seal using a Plan 11 and a Plan 53A would be described as 11/53A.

D.2.10 Examples of Finished Seal Codes

Example 1: 33B-LIN-075-53A

3—Category 3

3—Arrangement 3

B—Type B seal

L—Floating bushing

I—FFKM secondary seals

N—Carbon vs reaction bonded silicon carbide

075—Installed on a 75 mm shaft

53A—Piping Plan 53A

Example 2: 12B/A-PFQ/O-050-11/52

1—Category 1

2—Arrangement 2

B/A—Type B inner seal with Type A outer seal

P—Plain gland with no bushing

F—FKM secondary seals in both inner and outer seals

Q/O—Sintered silicon carbide versus sintered silicon carbide in the inner seal with carbon vs sintered silicon carbide in the outer seal

050—Installed on a 50 mm shaft

11/52—Piping Plan 11 and Piping Plan 52

D.3 Historical Mechanical Seal Codes

For many years API 610 contained a mechanical seal coding system that was widely used in industry. This coding method provided a reference to the nomenclature and features used with mechanical seals that were current during that time period. While this coding method is obsolete and does not address the requirements of this standard, it still is still being used in some areas of industry today. It is reviewed here as a historical reference only. Table D.2 shows how the seal code was constructed.

Table D.2—API 610 Mechanical Seal Code (Obsolete)

First Digit	Second Digit	Third Digit	Fourth Digit	Fifth Digit
Design	Arrangement	Gland Plate Type	Gaskets	Seal Faces

First digit—Design

- B—balanced
- U—unbalanced

Second digit —Arrangement

- S—single
- D—double
- T—tandem

Gland plate type

- P—plain
- T—throttle bushing
- A—auxiliary sealing device

Gasket material

- E—FKM/TFE
- F—FKM
- G—TFE
- H—nitrile
- I—FFKM
- R—graphite foil
- X —as specified

Seal face materials

- J—carbon versus stellite
- K—carbon versus Ni-resist (Type 1, 2, or 3)
- L—carbon versus tungsten carbide-1 (cobalt binder)
- M—carbon versus tungsten carbide-2 (nickel binder)
- N—carbon versus silicon carbide (reaction bonded)
- O—tungsten carbide-2 (nickel binder) versus silicon carbide (reaction bonded)
- P—silicon carbide (reaction bonded) versus silicon carbide (reaction bonded)
- X—as specified

Example: BSTFN

Balanced (B) single (S) seal with a throttle bushing (T), FKM gaskets (F), and carbon versus silicon carbide faces (N).

Annex E
(normative)

Mechanical Seals Data Requirement Forms

Annex E (normative) - Data Requirements Form for Inquiries and Proposals

Reference			
Corporate Name and Site:	…		
Job or Project Reference:	…		
Item No. / Service Name:	…	…	
Inquiry No. / By:	…	…	
Other Identification for Inquiry:	…		
Revision No. / Date:	…	…	

Details	Category 1	2	3	4	**DOCUMENT** x: mandatory o: optional	No.	**DATA**	user	pump vendor	seal vendor	quantity	date
Inquiry	x	x	x	x	**Inquiry Letter** *(with above Reference)*	1	define if seal chamber shall be delivered by seal or pump vendor	x	x			
						2	pump casing alloy, if better than SS 316 (corrosion, erosion)	x	x			
						3	define if ext. circulating pumps are an option (plan 23, 52, 53A/B/C)	x	x			
						4	special design f. continuous op. @ abnormal barrier press. condititons	x	x			
						5	design temperature of instruments > 100 °C required	x	x			
						6	additional documents (e.g. special material or test certificates)	x	x			
						7	additional job testing requirements	x	x			
						8	language(s) other than English for all or specific documents	x	x			
						9	further details / specified options	x	x			
	x	x	x	x	**Data Sheet** - *acc. to Annex C or alternative purchaser layout*	10	to be completed by purchaser:	x	x			
						11	to be completed by purchaser or seal vendor:	x	x			
Proposal	x	x	x	x	**Proposal Letter** (with above Reference)	12	proposed seals & auxiliary systems (type,size,material,piping plan)			x		
						13	alternatives proposed			x		
						14	deviating features & any test data of offered API-682 (5th Ed.) seals			x		
						15	estimated seal leakage of 2NC-CS (if applicable)			x		
						16	advise if drive collar requires more than twelve screws			x		
						17	specify device for seal sleeve attachement, if not set screws			x		
						18	exceptions to this standard (deviation list)			x		
						19	clarification of any design or specification differences between the			x		
						20	tested and the proposed seal					
						21	any conditions observed that would jeopardize the ability of the seal			x		
						22	to meet the relibility and performance requirements					
						23	dynamic & static seal pressure rating			x		
						24	max. reverse pressure (where applicable)			x		
						25	max. & min. operating temperatures			x		
						26	required connections on the pump seal chamber			x		
						27	specify if pump vendor shall provide flash tap & port connections			x		
						28	define heating or cooling requirements for pump			x		
	x	x	x	x	**Data Sheet** - *acc. to Annex C or alternative purchaser layout*	29	to be completed by seal vendor:			x		
						30	to be completed by purchaser or seal vendor:			x		
						31	modified faces for pump performance test			x		
						32	alternative seal for pump performance test			x		
						33	seal axial thrust force on shaft			x		
	x	x	x	x	**Cross-Sectional Seal Drawing** ***typical*** *modified typcial drawing is acceptable* *(with above Reference)*	34	dimensional information to check the fit of the installation			x		
						35	in the equipment, including the seal chamber bore and depth, gland					
						36	plate connections, and the distance to the nearest obstruction					
						37	external to the seal chamber					
						38	overall seal dimensions & any relevant seal setting dimensions			x		
						39	seal axial tolerance to differential shaft/casing movement			x		
						40	key drive requirements (if applicable)			x		
						41	material specifications			x		
			x		**Detailed BOM of Seal**	42	may be on Cross-Sectional Seal Drawing			x		
	o	o	o	o	**Separate Seal Chamber Drawing**	43	clarifying any pump modifications required to fit the proposed seal,			x		
						44	showing either the seal assembly or include a cross-reference to it					
			x		**Seal Qualification Test Certificate**	45	properly conducted test & fulfilled requirements			x		
			x		**Seal Qualification Test Form**	46	test data & any other relevant information (see Annex I)			x		
			x		**Auxiliary System Drawing** *schematic* *(with above Reference)*	47	piping & instrumentation diagram			x		
						48	all external utility requirements & positions					
						49	appropriate labelling & reference to the bill of materials					
						50	barrier- or buffer-fluid specification					
						51	hydrostatic test pressure, if applicable					
						52	maximum design pressure & temperature					
						53	size & set pressure of relief valves					
			x			54	may be on Auxiliary System Drawing			x		
	x	x	x	x		55	type, quantity, size, set pressure			x		

Annex E (normative) - Data Requirements Form for Contracts

Reference			
	Corporate Name and Site:	…	
	Job or Project Reference:	…	
	Item No. / Service Name:	…	…
	Purchase Order No. / Date:	…	…
	Other Identification for Purchase Order:	…	
	Revision No. / Date:	…	…

Details	Category 1	Category 2	Category 3	Category 4	DOCUMENT (x: mandatory, o: optional)	No.	DATA	user	pump vendor	seal vendor	quantity	date
Contract	x	x	x	x	**Purchase Order Letter**	1	relevant details / specified options	x	x			
	x	x	x	x	**Seal Chamber Drawing** *(dimensions & locations)*	2	bolting, tapped connections, ports, bore, impeller end of shaft,	x	x			
						3	advise if register fit is outside or inside, shaft hardness					
	x	x		x	**Data Sheet** - *acc. to Annex C or alternative purchaser layout*	4	to be completed by purchaser: ◯	x	x			
						5	to be completed by purchaser or seal vendor: ▢◯	x	x	x		
			x			6	to be completed by seal vendor: ▢			x		
						7	seal axial thrust on shaft			x		
						8	seal energy & heat-soak calculations			x		
			x		**Cover Sheet**	9	reference data (see above)			x		
			x		**Index Sheet / Drawing List**	10	list of all drawings respect. BOMs by drawing number & title			x		
	x	x		x	**Cross-Sectional Seal Drawing** ***to scale*** *(with above Reference)*	11	dimensional information to check fit of the installation			x		
						12	overall seal dimensions & any relevant seal setting dimensions					
						13	seal axial tolerance to differential shaft/casing movement					
						14	material specifications					
						15	process flush rates (plan 01,11,12,13,14,21,22,23,31,32,41)					
						16	rec. fastener torques, note about gland plugs (8.4.6)					
			x		**Cross-Sectional Seal Drawing** ***specific*** *(with above Reference)*	17	all seal components related to the order as well as pump components			x		
						18	related to the seals					
						19	dimensions to properly verify the seal setting position					
						20	pump dimensions interfacing with the seal					
						21	seal boundry dimensions, end view, port locations & symbols					
						22	seal chamber & gland plate connection dimensions					
						23	auxiliary system & utility specifications					
						24	connecting dimensions for auxiliary system & utilities					
						25	pump process & seal operating conditions					
						26	seal allowable exial movement from set point					
						27	seal category, type & arrangement as designated					
						28	appropriate labelling & reference to BOM,					
						29	including materials of construction and item description					
						30	process flush rates (plan 01,11,12,13,14,21,22,23,31,32,41)					
						31	rec. fastener torques, note about gland plugs (8.4.6)					
	x	x	x	x	**Detailed BOM of Seal**	32	may be on drawing, recommended spare parts			x		
	x	x		x	**Seal Instruction** ***typical***	33	installation (includes description of seal chamber venting),			x		
			x		*(with above Reference)* ***specific***	34	operation, maintenance					
			x		**Circulation Device Perform. Curve**	35	head versus flow based on test results			x		
	x	x		x	**Auxiliary System Drawing** ***schematic*** *(with above Reference)*	36	piping & instrumentation diagram			x		
						37	all external utility requirements & positions					
						38	appropriate labelling & reference to BOM,					
						39	barrier/buffer-fluid specification					
						40	hydrotest pressure (if applicable)					
						41	maximum design pressure & temperature					
						42	rec. fastener torques (reservoir flange, level gauge)					
						43	size & set pressure of relief valves					
			x		**Auxiliary System Drawing** ***detailed*** *(with above Reference)*	44	all mounting and overall boundry dimensions			x		
						45	all external utility requirements & positions					
						46	all connecting pipework locations, type and size					
						47	appropriate labelling & reference to BOM,					
						48	barrier/buffer-fluid specification					
						49	equipment & alarm set points					
						50	hydrotest pressure (if applicable)					
						51	maximum design pressure & temperature					
						52	orifice sizes & req. Fastener torques (reservoir, flange, level gauge)					
						53	size & set pressure of relief valves					
	x	x	x	x	**Detailed BOM of Auxiliary System**	54	may be on drawing, recommended spare parts			x		
	x	x	x	x	**Relief valve list**	55	type, quantity, size, set-pressure			x		
	x	x		x	**Aux. System Instruction** ***typical***	56	installation, operation, maintenance			x		
			x		*(with above Reference)* ***specific***	57						
			x		**Hydro Static Test Certification**	58	for pressure containing seal parts & accessories			x		
			x		**Material Safety Data Sheet(s)**	59	e.g. for paints, preservatives, coatings, chemicals etc.			x		
	o	o	o	o	**Inspector Checklist** *(see Annex H)*	60	items & dates of inspection, inspector name, status	x	x			

Annex F
(informative)

Technical Tutorials and Illustrative Calculations

F.1 Seal Leakage and Leakage Management

F.1.1 Seal Leakage

There is always a mass flow rate across the face of a mechanical seal, so all seals “leak” to some extent. Seal leakage depends on seal size, fluid sealed, pressure, speed and face technology. Some seals, particularly non-contacting seals, are designed to have a certain flow between the faces. Nevertheless, for most pumps, there is no visible seal leakage depending on the state of the fluid being sealed. Leakage can occur regardless of seal category, type, or arrangement; however, with Arrangement 2 and Arrangement 3 dual seals, the leaked fluid may be buffer or barrier fluid instead of process fluid. Buffer and barrier fluids are often lubricating oils, which are not volatile, and wetting of the gland plate may occur leading to occasional visible droplets. However, visible leakage in the order of drops per minute is normally an indication of a seal problem. Sometimes visible leakage is apparent only over time, as the non-volatile components of the process stream or buffer/barrier fluids accumulate.

Conventional plain face contacting wet seals provide the lowest levels of leakage however there is a tribology limit for various face materials and fluid in contact with seal faces (B2.4 and figure B1). Higher pressure velocity application may require face modification features such as variable or low seal balance ratio or face enhancing features such as hydrodynamic lift design, scallops, matte lapping, or preferential lapping to reduce wear and extend the design envelope; however, leakage can be slightly higher than similar seals using plain faces. Seals designed for high pressures but actually used at low pressures may have unacceptable leakage. A single contacting wet seal (1CW) sealing water at a vendor pump test ordinarily leaks a fluid that is volatile and is not visible. The aforementioned design features, necessary for specific process reliability, can in a water-sealing environment alter leakage levels such that a slight visible leakage can occur at the vendor pump test.

Factors other than design features can result in increased leakage as well; however, these may be the result of aberrant system conditions. In particular, after a contacting seal has worn in to match a certain set of operating conditions, changing those conditions can result in increased leakage until the faces have worn to match the new conditions. Such changes include fluid type, viscosity, or density in either the process or buffer/barrier fluid. Operating conditions such as temperature or pressure outside its design envelope can damage the seal and result in greater leakage rates. Other system factors that affect seal leakage rates, besides condition of the seal parts, include pump operation at off-design conditions, pipe strain, bearing problems, fitting leaks at the seal gland (often mistaken as seal leakage), impeller or sleeve gasket damage, etc.

F.1.2 Leakage Management

End face mechanical seals and devices used on the atmospheric side of these seals are a subset of the larger topic of leakage management. Depending on local laws and fluid properties different levels of leakage of the process fluid to the atmosphere or drain may be acceptable. Leakage management might include the selection of a sealless pump, or a pump with additional containment using a bushing, packing or another end face seal of either contacting or noncontacting design. Refer to Annex A for examples of end face seal selection methodology.

For example, when containment of the process fluid and zero leakage to the atmosphere is required a sealless pump or an Arrangement 3 seal may be the right choice. At the other extreme, the use of a bleed bushing in a vertical cooling water pump instead of an end face seal may be appropriate since water leaking past the bleed bushing could be directed back to the sump.

Leakage management auxiliary systems can also be attached in series with mechanical seals. With these systems, leakage can be diverted to a location determined by the plant operator. Some examples of auxiliary systems include a separate buffer liquid lubricated outer seal and the associated support auxiliary system or a containment chamber and a sealing device for the containment chamber with its auxiliary support system. While there are many types of containment devices, three types are recommended by the standard:

1) simple fixed bushings;

2) floating bushings; and

3) special purpose mechanical seals that are called "containment seals."

Selection of the appropriate containment sealing device and auxiliary system depends on the requirements for leakage control as well as expectations during normal operation and upsets.

A containment sealing device does not necessarily have the performance or rating of a mechanical seal. There are many types of containment devices, but fixed bushings have the highest release rates. Floating bushings leak significantly less than fixed bushings. Containment seals have considerably lower leakage than segmented bushings. (Figure F.1) Containment devices may also be used to manage quench fluids such as steam or water.

Containment devices may also be used to manage quench fluids such as steam or water.
Mechanical seals used as dry running containment seals may be similar in appearance to conventional face type seals, but they include special features and materials. Although there are many variations, containment seals are designed to operate without the presence of a lubricating liquid. This ability to operate dry is possible because face material pairs have been specially developed and heat generation is very low. Containment seals may be further classified as having either contacting or noncontacting seal faces. Whereas contacting seals usually have a plain, flat face, a noncontacting seal face includes features to create aerodynamic lift that separates the faces. Noncontacting containment seals leak more than the contacting type; however, contacting containment seals have a finite wear life. Whether contacting or noncontacting, containment seals can have low leakage and long life.

Auxiliary systems used to contain process leakage from emission to the atmosphere are usually supplied with equipment that can enable the plant operator to monitor the process seal leakage rate and alarm when levels are considered excessive. Arrangement 1 seals are fitted with either a fixed or floating bushing as the containment device. Optional leakage management systems for Arrangement 1 seals are Piping Plan 62 and Piping Plan 65.
Arrangement 2 seals use two mechanical seals; the outer seal can be either a conventional wet mechanical seal or a dry-running containment seal. Optional leakage management systems for
Arrangement 2 are Piping Plan 52, 71, 72, 75 and 76.

F.1.3 Predicted Leakage Rates

All mechanical seals require face lubrication to achieve reliability; this results in a minimal level of leakage. On a water pump test of a contacting wet seal (1CW), the leakage typically evaporates and is not visible. Pressurized dual contacting wet seals (3CW), when used with a nonevaporative, lubricating oil barrier fluid, can also produce visible leakage in the form of droplets but typically at a rate less than 5.6 g/h (grams per

hour) (two drops per minute) for Category 1,2,3. Seals, Operating conditions for Category 4 seals will typically produce higher leakage rates.
The seal vendor should be consulted about predicted leakage rates.
Noncontacting inner seal designs use a lift-off face pattern, such as grooves or waves, which can provide reliable operation in liquid or gas service. Often it is difficult to provide an adequate vapor pressure margin when sealing clean high vapor pressure or mixed vapor pressure fluids with contacting wet face designs. A noncontacting inner seal can give the option of sealing a liquid/gas mixture by allowing the product to flash into a gas across the seal faces, effectively using the noncontacting design inner seal as a gas lubricated seal. The leakage rate from a noncontacting design is normally higher than a contacting wet design.

Noncontacting containment seals use a face pattern (grooves, waves, etc.) to provide an aerodynamic lift of the seal faces. Contacting containment seals use the face material properties and often specific molecules in the gas such as humidity to manage the wear rate and achieve reliability objectives.

Noncontacting face designs have the following benefits:
a) lower wear rate in operation;
b) more tolerant to higher pressures and pressure spikes created by the downstream leakage management system such as a flare or relief system;
c) more tolerant to a Piping Plan 72 that may use a low-humidity gas.

Contacting containment seals have different benefits as follows.

—The leakage rate to atmosphere, in normal and alarm conditions, is much lower. This is particularly significant when sealing a process with a high liquid content at atmospheric conditions in the inner seal leakage (see Figure F.2).

— The plain face design is more reliable when there is a significant liquid content in the inner seal leakage.

Figure F.1 shows expected relative gas leakage rates for different containment devices typically used in Arrangement 1 and Arrangement 2 configurations, assuming a differential pressure across the device of 10psi (0.7bar). This pressure is a common containment seal chamber alarm pressure setting and would be a gauge pressure assuming the leakage across the device is to atmosphere.

Figure F.2 shows expected relative water leakage rates for the same devices shown in Figure F.1 but at a differential pressure of 40psi (10 bar)

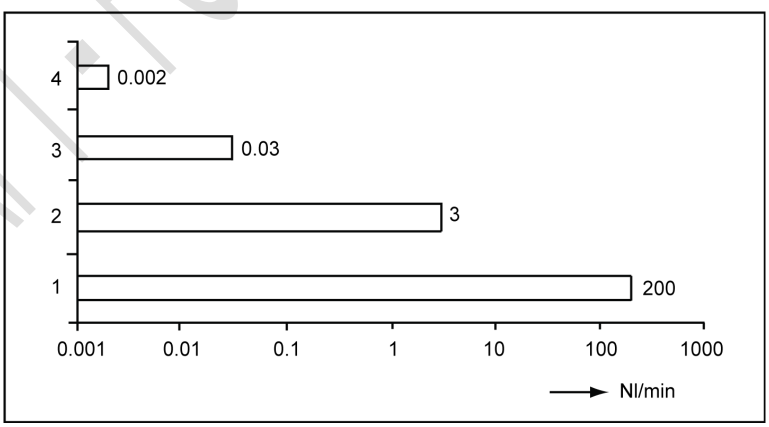


Figure F.1—Estimated Gas Leakage for 2.000” (50 mm) Shaft at 10psi (0.7 bar), Expressed in Normal Liters per Minute

Key

1 solid floating bushing
2 segmented floating bushing
3 noncontacting containment seal
4 contacting containment seal

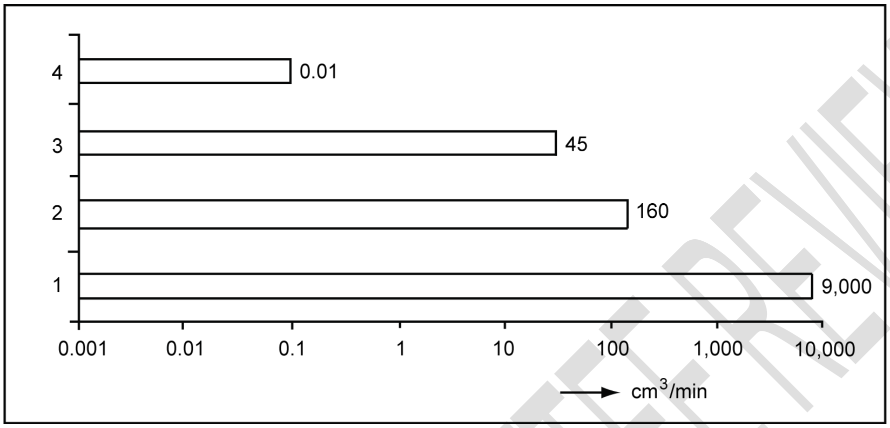


Figure F.2—Estimated Liquid (Water) Leakage for (50 mm) Shaft at 10psi (0.7 bar), Expressed in Cubic Centimeters per Minute

Key
1 solid floating bushing
2 segmented floating bushing
3 noncontacting containment seal
4 contacting containment seal

F.1.4 Vapor Pressure Margin and Product Temperature Margin

F.1.4.1 Lubrication Between Seal Faces

It is assumed that reliable seal performance requires liquid between the faces for lubrication. Since most seals have no visible leakage, it is accepted that the liquid between the faces vaporizes at some point as it travels across the face to the atmospheric side of the seal. The amount of gas between the seal faces of an idealized seal depends on the fluid properties, sealing pressure, and sealing temperature. For example, high vapor pressure fluids like propane will have a large percentage of the seal face width operating with gas between the faces. The Hydrocarbon Processing Industries use this ratio of liquid/gas as the basis for criteria used to predict seal face performance. It is reinterpreted as a vapor pressure margin (see below). Most seal vendors have modeling programs to estimate the fluid state transition point. However, when dealing with fluid mixtures or pump systems designed to handle more than one fluid, optimizing seal selection and piping plans can be more involved.

F.1.4.2 Vapor Pressure Margin and Product Temperature Margin

A pressure margin between seal chamber pressure and the maximum liquid vapor pressure is included in 6.1.2.14.2 because it has proved to be easy to administer and it correlates well with other methods of evaluating seal suitability for given service conditions as measured by seal life at an acceptable seal leakage rate.

The pressure margin between seal chamber pressure and the maximum liquid vapor pressure applies to contacting wet Arrangement 1 seals and the inner seal of an Arrangement 2 configuration. This margin is considered a threshold below which seal vendors shall more closely consider the seal piping plan, seal selection, and configuration of adaptive hardware to achieve an acceptable service life.

The standard recognizes some pumps that develop low differential pressure and pumps that handle high vapor pressure fluids may not achieve the required margins. For contacting wet seal designs, maintaining an adequate vapor pressure margin helps protect the seal faces against excessive levels of localized boiling of the process fluid at the seal faces. Boiling of the process fluid at the seal faces can cause loss of seal face lubrication and subsequent seal failure. Low-density fluids that are pumped with low vapor pressure margins are some of the most troublesome fluids to seal and account for a high percentage of seal repairs.

Methods for achieving the required pressure margin may use one or a combination of the following options. The selection and application of these solutions is usually the result of mutual agreement between the purchaser and the seal and pump vendors.

a) Lowering the seal chamber fluid temperature by cooling the flush fluid.

b) Raising the seal chamber pressure by removing the back wear ring and plugging impeller balance holes.

c) Utilizing an external flush fluid.

d) Raising the seal chamber pressure through the use of a close clearance (floating) throat bushing.

Lowering the flush fluid temperature (seal-chamber fluid temperature) is always preferable to pressurizing the seal chamber by using a close clearance throat bushing. Bushing wear over a period of operating time inevitably results in a decreased seal chamber pressure and margin over vapor pressure.

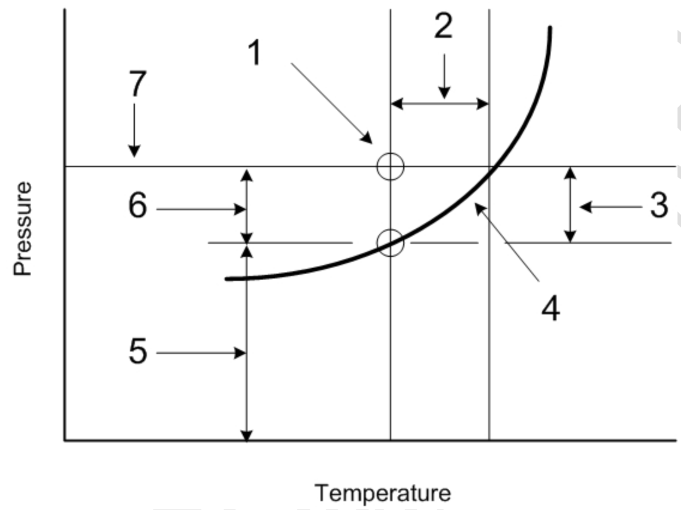
If the pump is vertical and a Piping Plan 13 is required to assist in vapor removal from the seal face environment, a Piping Plan 14 with a distributed flush injection is a possible solution combining both features.

Some applications may not need complicated seal flush systems or the 0.35 MPa (3.5 bar) (50 psi) margin between seal chamber pressure and vapor pressure. A generic example of this is cooling water service. Assuming the water is a 38 °C (100 °F) with an atmospheric pump suction and seal chamber pressure, the vapor pressure would be an absolute pressure of 0.0065 MPa (0.065 bar) (0.94 psia). The absolute vapor pressure at 58 °C (136 °F), a 20 °C product temperature margin (PTM), would be about 0.018 MPa (0.18 bar) (2.7 psia). Ample PTM would be present in the seal chamber to achieve the expected three-year seal life without seal flush fluid cooling or pressurizing the seal chamber to provide a 0.35 MPa (3.5 bar) (50 psi) margin over vapor pressure.

The idea of a vapor pressure margin requirement dates to the Fifth Edition (1971) of API 610 pump specification (if not earlier) requiring seal chamber pressure to be 0.172 MPa (1.72 bar) (25 psi) above suction pressure (assumed to be roughly equal to seal chamber pressure). API 610, Sixth Edition contained the same requirement. API 610, Seventh Edition called for conditions leading to a stable film at the seal faces to be jointly established by pump and seal vendors. The Eighth Edition of API 610 referred to API 682, First Edition, which required a margin of at least 0.35 MPa (3.5 bar) (50 psi) above the maximum vapor pressure.

Figure F.3 graphically represents the different methods of calculating the actual operating margins and the vapor pressure ratio for a specific process and operating point. The minimum operating margins stated above and the values discussed in the next subsection are performance recommendations for each method to achieve reliable seal face function. Figure F.4 uses the value(s) discussed in the next subsection and it illustrates how the pressure and temperature margins between process liquid vapor pressure and minimum recommended seal chamber pressure vary between the three calculating methods for a propane service.

The vapor pressure margin recommended in API standards and subsequently ISO standards is primarily aimed at hydrocarbon services where the process liquid is often pumped close to its saturated vapor pressure. Sealing of water-based liquids becomes more sensitive to vapor pressure margin and they are typically rated to operate reliably with a temperature margin below their atmospheric boiling point.



Key

1 operating point

2 product temperature margin (PTM)

3 vapor pressure margin

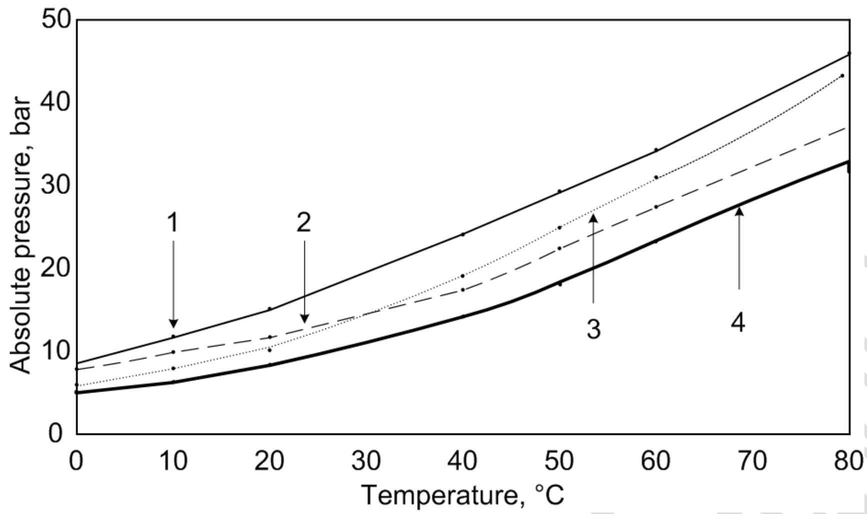
4 liquid vapor pressure curve

5 vapor pressure at process temperature (VP)

6 vapor pressure ratio (SP/VP)

7 seal chamber pressure (-SP)

Figure F.3—Illustration of Alternative Vapor Pressure Margin Calculation Options



Key

1 20 °C (68 °F) product temperature margin

2 3.5 bar (50 psi) margin

3 1.3 ratio over vapor pressure

4 vapor pressure curve

Figure F.4—Illustration of Vapor Pressure Margin Calculation Methods as Applied to Propane

F.1.4.3 Fixed Ratio or Product Temperature Margin in API 682, Second and Third Editions

Although temperature and vaporization are probably better indicators of reliability, pressure has become the parameter of choice. The pressure margin in API 682 First Edition of 0.35 MPa (3.5 bar) (50 psi) can be viewed as a “pressure interpretation of a temperature requirement.” For example, the previous edition of this standard required a “product temperature margin” (PTM) of not less than 20 °C (36 °F) or a ratio of seal chamber pressure to maximum vapor pressure of 1.3 (130 %). PTM is the difference between the process temperature in the seal chamber and the saturation temperature of the process liquid at the seal chamber pressure. As an example, the API 682 qualification tests on propane are at 32 °C (90 °F) and a pressure of 1.8 MPa (18 bar) (261 psia). The saturation temperature of propane at 1.8 MPa (18 bar) (261 psia) is 52 °C (126 °F). Therefore, the API 682 tests are based on a PTM of 52 °C − 32 °C = 20 °C (126 °F − 90 °F = 36 °F). Although PTM is a single component concept, for mixtures it can be based on the bubble point, but this can be a complex calculation.

Seals with good heat transfer designs (wetted area, thermal conductivity, convection heat transfer) and reduced heat generation (low speed, low pressure, low balance ratio, hydropads, narrow faces, low spring loads, good tribological mating faces) can operate with a smaller PTM than seals without these good characteristics. The fixed minimum margins stated in API 682 are values that general field experience has proven to give reliable operation. Some seal vendors may claim success at lower margins and this is possible but shall be judged in the context of the specific fluid characteristics and pump service conditions.

A fixed ratio (at least 1.3) between the seal chamber pressure and maximum fluid vapor pressure is a criterion appropriate for hydrocarbons with a steep saturation pressure versus temperature curve and lower pressure applications, but reaches a practical limit at very high pressures. Ratios around 1.3 are usually acceptable for seals using premium materials, having good heat transfer characteristics and having good flush designs with adequate flush rates, like API 682 Type A seals.

The standard reverts back to the 0.35 MPa (3.5 bar) (50 psi) vapor pressure margin in API 682, First Edition. This simpler performance evaluation strategy is adequate for most hydrocarbon services, but may be inadequate on high vapor pressure services. The use of product temperature margin or a 30 % pressure margin between seal chamber pressure and maximum vapor pressure are reasonable alternate methods for determining that a seal will achieve three years of uninterrupted service, but specific fluid characteristics required with this method may not be readily available.

F.2 Seal Chamber Temperature Rise and Flush

F.2.1 General

The steady-state temperature of the fluid in the seal chamber is a function of a simple thermodynamic balance. The heat flow into the seal chamber fluid minus the heat flow out of the seal chamber yields a zero net heat flow. This is deceptively simple. In actual applications, the heat flows into and out of the seal chamber fluids are extremely complex.

There are several sources of heat flow into the fluid. These include heat generated because of friction and fluid shear at the seal faces, heat generated because of turbulence caused by the rotating seal components, and heat conducted from the pump through the seal chamber and shaft (or positive heat soak). There are also several sources of heat flow out of the seal chamber. These include heat conducted back into the pump through the seal chamber or shaft (or negative heat soak) and heat lost to the atmosphere through convection and radiation.

When seal face generated heat, heat soak, balance ratio, fluid properties and other factors are combined, required flush flow rates or temperature rise in the seal chamber can be calculated. While operating margin between fluid vapor pressure and flush fluid temperature can determine the correct piping plan and flow rate, a flush flow rate that results in the recommended temperature rise are generally considered adequate to meet seal life expectations. Achieving the required buffer and barrier liquid flow rates with seal Piping Plan 52 or Piping Plan 53 A/B/C that use an internal circulating device requires special attention to the piping system curves for these systems (see F.3.1 and 3.2). Starting torque, seal power and seal generated heat 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. Certain seal chamber arrangements such as dead-ended and taper bore boxes have other considerations.

F.2.2 Seal Face Generated Heat

F.2.2.1 General

While the calculation of the heat generated by a mechanical seal appears to be a simple matter, several assumptions shall be made that introduce potentially large variations in the results. Two variables that are particularly influential are K, the pressure drop coefficient, and f, the effective coefficient of friction.

K is a number between 0.0 and 1.0 that represents the pressure drop as the sealed fluid migrates across the seal faces. For flat seal faces (parallel fluid film) and a nonflashing fluid, K is approximately equal to 0.5. For convex seal faces (converging fluid film) or flashing fluids, K is greater than 0.5. For concave seal faces (diverging fluid film), K is less than 0.5. Physically, K is the coefficient that is used to quantify the amount of differential pressure across the seal faces that is transmitted into the hydraulic component of the fluid film support forces, referred to as the opening forces. The opening force is expressed by the following equation:

$$F_{\mathrm{O}} = A \times \Delta p \times K \tag{F.1}$$

where

F_O	is the opening force, expressed in Newtons;
A	is the area of the seal face, expressed in square millimeters;
Δp	is the differential pressure, expressed in megapascals;
K	is the pressure drop coefficient, dimensionless.

For practical purposes, K varies between 0.5 and 0.8. As a standard practice for nonflashing fluids though, a value of 0.5 is selected for K. Although K is known to vary depending upon seal fluid properties (including multiphase properties) and film characteristics (including thickness and coning), this value is selected as a benchmark for consistent calculation; nevertheless, the engineer shall be made aware that this assumption has been made.

The effective coefficient of dynamic friction, f, is a number that is similar to the standard coefficient term that most engineers are familiar with. The standard coefficient of friction term is used to represent the ratio of parallel forces to normal forces. This is normally applied to the interaction between two surfaces moving relatively. These surfaces may be of the same material or different materials.

In a mechanical seal, the two relatively-moving surfaces are the seal faces. If the seal faces were operating dry, it would be a simple matter to determine the coefficient of friction. In actual operation, the seal faces operate under various lubrication regimes, and various types of friction are present.

If there is significant asperity contact, f is highly dependent on the materials and less dependent on the fluid viscosity. If there is a very thin fluid film (only a few molecules thick), friction may depend upon interaction between the fluid and the seal faces. With a full fluid film, there is no mechanical contact between the faces and f is solely a function of viscous shear in the fluid film. All of these types of friction can be present at the same time on the same seal face.

An effective coefficient of friction is used to represent the gross effects of the interaction between the two sliding faces and the fluid film. Actual testing has shown that normal seals operate with f between about 0.01 and 0.18. For normal seal applications, this standard has selected a value of 0.07 for f. This is reasonably accurate for most water and medium hydrocarbon applications. Viscous fluids (such as oils) will have a higher value, while less viscous fluids (such as LPG or light hydrocarbons) can have a lower value.

The combination of the assumption of K and the assumption of f can lead to a significant deviation between calculated heat generation results and actual results. Therefore, the engineer shall keep in mind that these calculations are useful only as an order-of-magnitude approximation of the expected results. These results shall never be stated as a guarantee of performance.

Calculation of the effective frictional face generated heat first requires an evaluation of the normal forces on the seal face. The opening force has already been discussed but the opposing closing force (normally the higher value) is a sum of the seal spring force and a hydraulic force determined by the seal ring design (see F.2.2.2). The seal face generated heat is the normal force (difference between the closing and opening forces) multiplied by the effective coefficient of friction and translated into a heat rate by adjusting for diameter and shaft speed (see F.2.2.4.8).

F.2.2.2 Balance Ratio

F.2.2.2.1 General

Seal vendors design seal faces with a balance ratio to minimize seal face generated heat consistent with optimum seal life expectations and emission limits. The balance ratio impacts the face loading, heat generated and the pressure rating of the seal. A balanced seal design will have a balance ratio less than 1, typically in the range of 0.6 to 0.9. The balance ratio can be interpreted as the proportion of the seal chamber pressure that is helping to create the closing force on the seal face. For example, the typical range of 0.6 to 0.9 balance ratio means that there is a 10 % to 40 % reduction in the hydraulic pressure load on the faces. Type A pusher seal designs will often require a step in the shaft sleeve as shown in Figure F.5. The step in the shaft sleeve increases the area of the seal face on which seal chamber pressure is offset or balanced resulting in a reduction in face load and face generated heat.

Balance diameter varies with seal design, but for Type A seals it is normally the diameter of the sliding contact surface of the dynamic O-ring. For the inner Type A seal of a dual seal configuration the sliding surface can vary depending on whether the pressure is internal or external. For Type B and Type C seals, the balance diameter is normally the mean diameter of the bellows, but this will vary with the pressure. Contact the seal vendor for determination of the balance diameter under varying pressure conditions.

An example of the seal balance ratio measurement points shall be as shown in Figure F.5. There are other methods of achieving pressure balance under pressure reversals. Contact the seal vendor if the sliding contact surface of the dynamic O-ring is not readily apparent.

F.2.2.2.2 Calculation Inputs

D_o is the seal face outside diameter;

D_i is the seal face inside diameter;

D_b is the balance diameter of the seal.

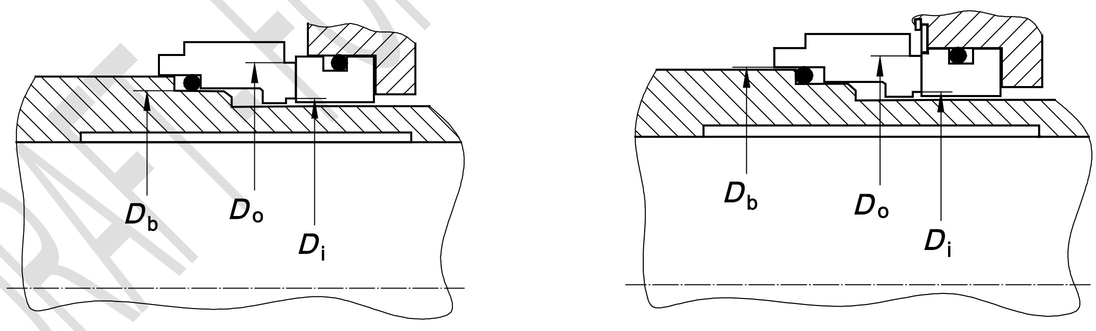
F.2.2.2.3 Formula

For seals externally pressurized, the seal balance ratio, B, is defined by the equation:

$$B = (D_o^2 - D_b^2) / (D_o^2 - D_i^2) \quad \text{(F.2)}$$

For seals internally pressurized, the seal balance ratio, B, is defined by the equation:

$$B = (D_b^2 - D_i^2) / (D_o^2 - D_i^2) \quad \text{(F.3)}$$



a) Seal with Higher Pressure at Outer Diameter b) Seal with Higher Pressure at Inner Diameter

Figure F.5—Illustration of Balance Ratio Measurement Points

F.2.2.3 Seal Face Generated Heat Calculation Inputs

Required inputs:

D_o is the seal face contact outer diameter, expressed in millimeters;

D_i is the seal face contact inner diameter, expressed in millimeters;

D_b is the effective seal balance diameter, expressed in millimeters;

F_{sp} is the spring force at working length, expressed in Newtons;

Δp is the pressure differential across the seal face, expressed in megapascals;

n is the face rotational speed, expressed in revolutions per minute;

f is the coefficient of friction (assume 0.07);

K is the pressure drop coefficient (assume 0.5).

F.2.2.4 Seal Face Generated Heat Calculation Formula

F.2.2.4.1 Face Area, A (mm²)

$$A = \frac{\pi(D_o^2 - D_i^2)}{4} \qquad \text{(F.4)}$$

F.2.2.4.2 Seal Balance Ratio, B

$$B = \left(\frac{D_o^2 - D_b^2}{D_o^2 - D_i^2}\right) \qquad \text{(F.5)}$$

F.2.2.4.3 Spring Pressure, p_{sp} (MPa)

$$p_{sp} = \frac{F_{sp}}{A} \qquad \text{(F.6)}$$

F.2.2.4.4 Total Face Pressure, p_{tot} (MPa)

$$p_{tot} = \Delta p(B - K) + p_{sp} \qquad \text{(F.7)}$$

F.2.2.4.5 Mean Face Diameter, D_m (mm)

$$D_m = \frac{(D_o + D_i)}{2} \qquad \text{(F.8)}$$

F.2.2.4.6 Running Torque, T_r (N m)

$$T_r = p_{tot} \times A \times f\left(\frac{D_m}{2000}\right) \qquad \text{(F.9)}$$

F.2.2.4.7 Starting Torque, T_s (N m) Estimated at 3 to 5 Times Running Torque

$$T_s = T_r \times 4 \tag{F.10}$$

F.2.2.4.8 Seal Face Generated Heat Power, *P* (kW)

$$P = (T_r \times N) / (9548) \tag{F.11}$$

F.2.2.5 Example Calculation

Fluid: Water

Pressure: 2 MPa (20 bar) (290 psi)

Speed: 3000 r/min

Inputs:

D_o = 61.6 mm (2.425 in.)

D_i = 48.9 mm (1.925 in.)

D_b = 52.4 mm (2.063 in.)

F_{sp} = 190 N (42.71 lb force)

Δp = 2 MPa (20 bar) (290 psi)

n = 3000 r/min

f = 0.07

K = 0.5

Equation (F.4) gives:

$$A = \left(\frac{\pi}{4}\right) \times (61.6^2 - 49.9^2) = 1102 \text{ mm}^2 \ (1.708 \text{ in.}^2)$$

Equation (F.5) gives:

$$B = \frac{\left(61.6^2 - 52.4^2\right)}{\left(61.6^2 - 48.9^2\right)} = 0.746$$

Equation (F.6) gives:

$$p_{sp} = \left(\frac{190}{1102}\right) = 0.172 \text{ N/mm}^2 \ (0.172 \text{ MPa}) \ (24.946 \text{ psi})$$

Equation (F.7) gives:

$$P_{\text{tot}} = 2\,(0.746 - 0.5) + 0.172 = 0.664 \text{ N/mm}^2 \text{ (0.664 MPa) (96.305 psi)}$$

Equation (F.8) gives:

$$D_{\text{m}} = \frac{(6.16 + 48.9)}{2} = 55.25 \text{ mm (2.175 in.)}$$

Equation (F.9) gives:

$$T_{\text{r}} = 0.664 \times 1102 \times 0.07\left(\frac{55.25}{2000}\right) = 1.42 \text{ N·m (1.047 ft-lb)}$$

Equation (F.10) gives:

$$T_{\text{s}} = 1.42 \times 4 = 5.68 \text{ N·m (4.189 ft-lb)}$$

Equation (F.11) gives:

$$P = (1.42 \times 3000)/9548 = 0.446 \text{ kW (0.6 HP)}$$

F.2.3 Heat Soak

F.2.3.1 General

Heat soak is the heat transferred from the pump and pumped fluid to fluid in the seal chamber. The pump and pumped fluid heat is transferred into and out of the seal chamber in amounts dependent of service conditions and pump design.

In some cases, assumptions can be made that simplify the model. For example, consider a single seal with Piping Plan 11, 12, 13, or 31. With these piping plans, the fluid injected into the seal chamber will be at pump temperature so heat soak and heat loss to the atmosphere can be ignored. Except in the case of large seals at high speeds, heat generation due to liquid turbulence is usually insignificant and can also be ignored.

In applications that use a Piping Plan 21, 22, 23, 32, or 41, the fluid injected into the seal chamber may be at a significantly lower temperature than the pump temperature. If this is the case, there can be a significant heat flow or heat soak into the seal chamber from the pump. The calculation of heat soak is a complex matter, requiring detailed analysis or testing and a thorough knowledge of the specific pump construction and pumped product properties.

Experience has shown in the hydrocarbon processing industries that efforts to minimize heat soak with the use of cooling water in seal chamber jackets have been largely unsuccessful because of fouling and the cross sectional thickness of the pump parts.

It is necessary for the seal vendor to make an estimation of the rate of heat soak and the empirical formula below can be used to provide an estimation of the level. It is unable to consider all the differences in equipment design and hence the prediction is usually greater than may be experienced in the field.

F.2.3.2 Heat Soak Calculation Inputs

U is the material property coefficient;

A is the effective heat transfer area;

D_b is the seal balance diameter, expressed in millimeters;

ΔT is the difference between pump temperature and desired seal chamber temperature, expressed in Kelvin.

A typical value for ($U \times A$) that can be used for estimating purposes with stainless steel sleeve and gland construction and steel pump construction is 0.00025. This value will generally provide a conservative estimate of heat soak.

F.2.3.3 Heat Soak Formula

If specific knowledge of the pump construction and pumped product properties is not available, the heat soak [Q_{hs} (kW)] can be estimated by the equation:

$$Q_{hs} = U \times A \times D_b \times \Delta T \quad \text{(F.12)}$$

F.2.3.4 Example Calculation

$U \times A$ = 0.00025

D_b = 55 mm (seal balance diameter)

pump temperature = 175 °C (347 °F)

desired seal chamber temperature = (65 °C) (149 °F)

ΔT = 175 – 65 = 110 K (110 °C) (198 °F)

Q_{hs} = 0.00025 × 55 × 110 = 1.5 kW (2.01 HP)

Seal Flush Fluid Temperature Rise

F.2.4.1 General

Temperature rise of the flush fluid as it travels through the seal chamber is a function of a thermodynamic balance applied to a liquid flow rate. The seal face generated heat is added to the heat soak, if relevant to the piping plan, and applying this to a known flow rate using a thermodynamic formula, a temperature rise can be predicted. The choice of whether the heat soak is included is discussed in F.2.2.

The temperature rise calculated using the following formulas results in the average temperature rise of the flush fluid in the seal chamber. However, within the seal chamber, there are areas that are hotter and cooler than the mean fluid temperature. An effective flush design and flow rate is required to ensure that the area around the seal face is effectively cooled.

F.2.4.2 Calculation Inputs

Q is the heat generation at the seal faces, expressed in kilowatts;

$Q_{heatsoak}$ is the heat transferred from the pump and pumped fluid to fluid in the seal chamber, expressed in kilowatts;

q_{inj} is the injection flow rate, expressed in liters per minute;

d is the relative density (specific gravity) of the injected fluid at pump temperature;

c_p is the specific heat capacity of the injected fluid at pump temperature, expressed in joules per kilogram Kelvin.

F.2.4.3 Formula—Without Heat Soak

The differential temperature, ΔT (in Kelvin), can be calculated by the following equation:

$$\Delta T = \frac{(60,000 \times Q)}{(d \times q_{inj} \times c_p)} \quad \text{(F.13)}$$

F.2.4.4 Formula—with Heat Soak

The differential temperature, ΔT (in Kelvin), including the effects of heat soak can be calculated using the inputs described above and the following equation:

$$\Delta T = 60,000 \times \frac{(Q + Q_{heatsoak})}{(d \times q_{inj} \times c_p)} \quad \text{(F.14)}$$

F.2.4.5 Example Calculation (Without Heat Soak)

Q = 0.9 kW (1.2 HP)

q_{inj} = 11 L/min (2.905 GPM)

d = 0.75

c_p = 2300 J/kg·K (0.549 BTU/lb- °F)

Equation (F.13) gives:

$$\Delta T = \frac{(60,000 \times 0.9)}{(0.75 \times 11 \times 2300)} = 2.8 \text{ K } (2.8\ ^\circ\text{C})\ (5\ ^\circ\text{F})$$

F.2.5 Seal Flush Flow Rate

F.2.5.1 General

In some applications, it is necessary to specify the flush rate required to maintain the seal chamber temperature below a certain level. In this case, the maximum allowable temperature rise would be calculated by subtracting the maximum allowable temperature in the seal chamber (or buffer/barrier seal chamber) from the flush liquid temperature. For good seal performance, the maximum temperature rise should be limited to 5.6 °C (10 °F) (5.6 K) for Arrangement 1 and Arrangement 2 inner seal flush flow rates and 16 °C

(30 °F) (16 K) for Piping Plan 23 and buffer/barrier flow rates (see 7.2.3.1 and 7.3.3.1). It is then a simple matter of rearranging Equations (F.10), (F.11), and (F.12) to solve for the required flush flow rate.

The temperature rise used in these calculations is the sealing chamber temperature rise. The temperature rise at the seal faces will be greater than the chamber temperature rise. If Equations (F.13) and (F.14) are used to calculate a minimum flow rate based on sealing chamber temperature, the seal faces can overheat and perform poorly. Depending on the service a design factor of at least two may need to be applied to the calculated required minimum flow rate. The injection shall also be directed at the seal interface to ensure proper cooling.

F.2.5.2 Seal Flush Flow Rate Calculation Inputs for Arrangement 1 and Arrangement 2

Q is the heat generation at the seal faces, expressed in kilowatts;

Q_{heatsoak} is the heat transferred from the pump and pumped process fluid to the fluid in the seal chamber, expressed in kilowatts;

ΔT is the desired differential temperature, typically a minimum of 5.6 K (5.6 °C) (10 °F), expressed in (in degrees Kelvin);

d is the relative density (specific gravity) of the injected fluid at the temperature of the seal chamber inlet;

c_p is the specific heat capacity of the injected fluid at the temperature of the seal chamber inlet, expressed in joules per kilogram Kelvin.

F.2.5.3 Seal Flush Flow Rate Formula

F.2.5.3.1 General

For flush flow in liters per minute without heat soak typical for seals with Piping Plan 11, 12, 13, or 31, the equation would be:

$$q_{\text{inj}} = \frac{(60,000 \times Q)}{(d \times \Delta T \times c_p)} \tag{F.15}$$

For flush flow in liters per minute with heat soak typical for seals with Piping Plan 21, 22, 23, 32, or 41, the equation would be:

$$Q_{\text{inj}} = 60,000 \times \frac{(Q + Q_{\text{heatsoak}})}{(d \times \Delta T \times c_p)} \tag{F.16}$$

F.2.5.3.2 Seal Flush Flow Rate Example Calculation (Arrangement 1 Without Heat Soak)

Q = 0.9 kW (1.2 HP)

ΔT_{max} = 5.6 K (5.6 °C) (10 °F)

d = 0.90

c_p = 2593 J/kg·K (0.619 BTU/lb-°F)

Equation (F.15) gives:

q_{inj} = (60,000 × 0.9)/(0.9 × 5.6 × 2593) = 4.1 L/min (1.083 gal/min)

F.2.5.3.3 Seal Flush Flow Rate Example Calculation (Arrangement 1 Without Heat Soak)

Q = 0.9 kW (1.2 HP)

ΔT_{max} = 5.6 °K (5.6 °C) (10 °F)

d = 0.90

c_p = 2593 J/kg·K (0.619 BTU/lb-°F)

Equation (F.15) gives:

q_{inj} = (60,000 × 0.9)/(0.9 × 5.6 × 2593) = 4.1 L/min (1.083 gal/min)

F.3 Piping Plan 52, 53A, and 53B Systems

F.3.1 Auxiliary System Design and Friction Curves

F.3.1.1 General

Buffer/barrier seal chamber generated heat and appropriate flush flow for Piping Plan 52 and Plan 53A seal systems are particularly unique because they usually use an internal circulating device, the buffer/barrier fluid circulates through the reservoir, and the exchanger would be internal to the reservoir. Estimated system friction curves are included in this section for Piping Plan 52 and Plan 53A. These system curves represent piping losses and do not include losses through porting in the gland plate or other components.

Unlike Piping Plan 52 and Piping Plan 53A, Piping Plan 53B and Piping Plan 53C may use an external exchanger and the circulating flow does not pass through the accumulator. There would be a significant increase in system friction if losses through an external exchanger are added to the interconnecting piping losses.

Performance curves for the internal circulating devices used with any Piping Plan 52 or Piping Plan 53 will vary depending on the type and design of device, the operating clearance, the gland plate design, fluid properties, and the peripheral velocity. As a result, the specific device performance curve should be overlaid on the Piping Plan 52 or Piping Plan 53 A/B/C system curve to determine the appropriate interconnecting pipe/tube size so the desired flow will be achieved. Refer to Section 8 for recommended tube and pipe sizes. When there is any doubt about these parameters, 20 mm (0.75 in.) pipe or tubing should be used because, as can be seen in the systems curves below, friction losses are minimized. An analysis of the parameters would determine that an increase to a 25 mm (1 in.) pipe offered little benefit. While not modeled, whenever possible the purchaser should consider tangential oriented buffer/barrier fluid gland plate connections to improve flush flow rates.

While selected less frequently than internal circulating devices, seal vendors can also offer an external circulating pump to ensure that the desired flush flow is achieved.

This subsection provides the background behind the pipe size recommendations in this standard and describes how a seal vendor might analyze and check the performance of a Piping Plan 52 or 53A system. Illustrative diagrams are shown.

Piping Plan 52 and 53 A seal systems have been modeled with standardized stub pipe with lap joints . The length of the stub pipe has been assumed at 150 mm (6 in.), as shown in Figure F.6. The stub pipe material has been assumed as 1/2 in. Schedule 80 pipe irrespective of whether the main circuit is constructed of pipe or tube.

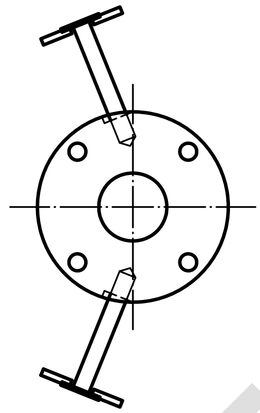


Figure F.6—Gland Plate Model

Fluid properties used to generate the system curves are:

— water with a specific gravity of 0.9983 at 20 °C (68 °F) and viscosity of 0.1 MPa·s (1 cP);

— oil with a specific gravity of 0.85 at 20 °C (68 °F) and viscosity of 10 MPa·s (10 cP);

— maximum flush flow rate is assumed to be 1.2 m^3/h (5 U.S. gal/min).

The general model used for the barrier fluid system is as shown in Figure F.7. The interconnecting piping to and from the reservoir has been assumed to be of equal length, and this has been set at 2.5 m per leg. The inlet to the gland plate is assumed to be from the lower pipe leg with an exit from the gland plate as the upper pipe leg (see Figure F.6).

The piping materials are either Schedule 80 pipe or tube. The diameter and bore used to calculate the system losses are shown in Table F.1.

Estimated system curves for the pipe work sizes shown in Table F.1 are illustrated in Figure F.8 and Figure F.9 for mineral oil and water. Tubing sizes and wall thickness can vary and the layout and length of piping will also vary between installations, so the curves in Figure F.8 and Figure F.9 should be used as a guideline rather than an exact reflection of a specific field installation.

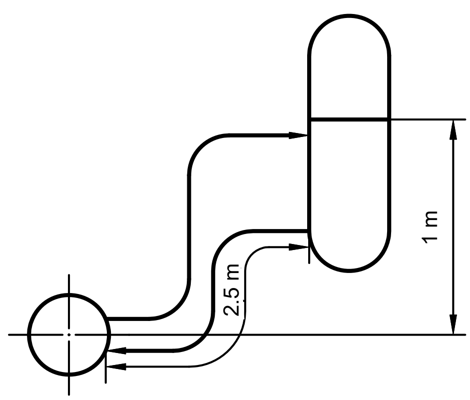


Figure F.7—System Model

Table F.1—Pipe and Tube Dimensions for System Loss Calculations

Diameter	**Bore** Mm	**Bore** (in.)
15 mm (0.5 in.) pipe	13.84	(0.546)
20 mm (0.75 in.) pipe	18.88	(0.742)
12 mm (0.5 in.) tube	9 [a]	(0.37) [b]
20 mm (0.75 in.) tube	16 [c]	(0.543) [d]

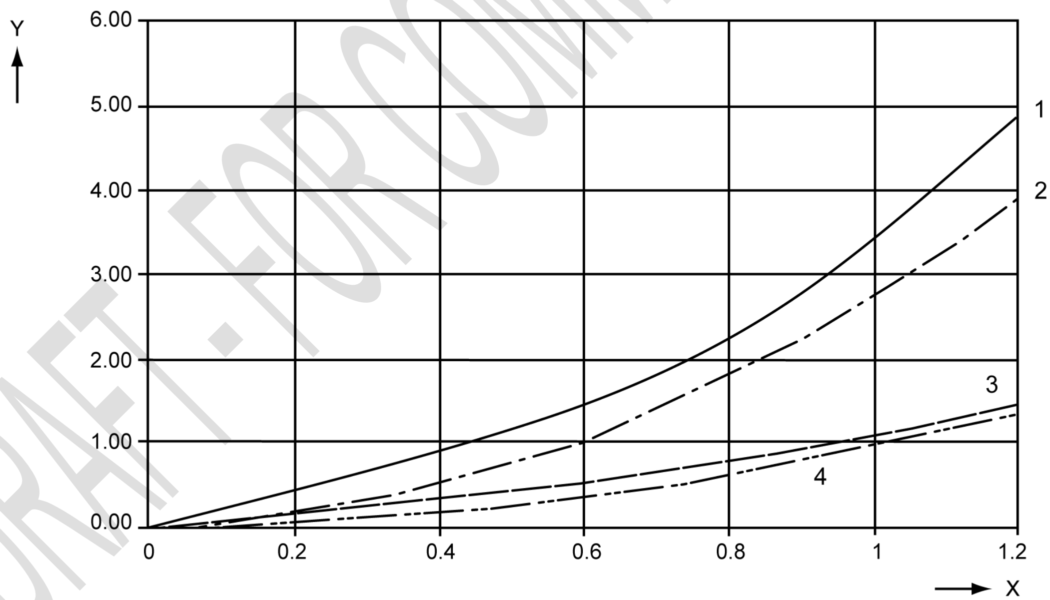
[a] OD = 12 mm; wall thickness = 1.5 mm.

[b] OD = 0.5 in.; wall thickness = 0.65 in.

[c] OD = 20 mm; wall thickness = 2 mm.

[d] OD = 0.75 in.; wall thickness = 0.095 in.

F.3.1.2 Pipe System Friction Curves



Key

X flow, m³/h

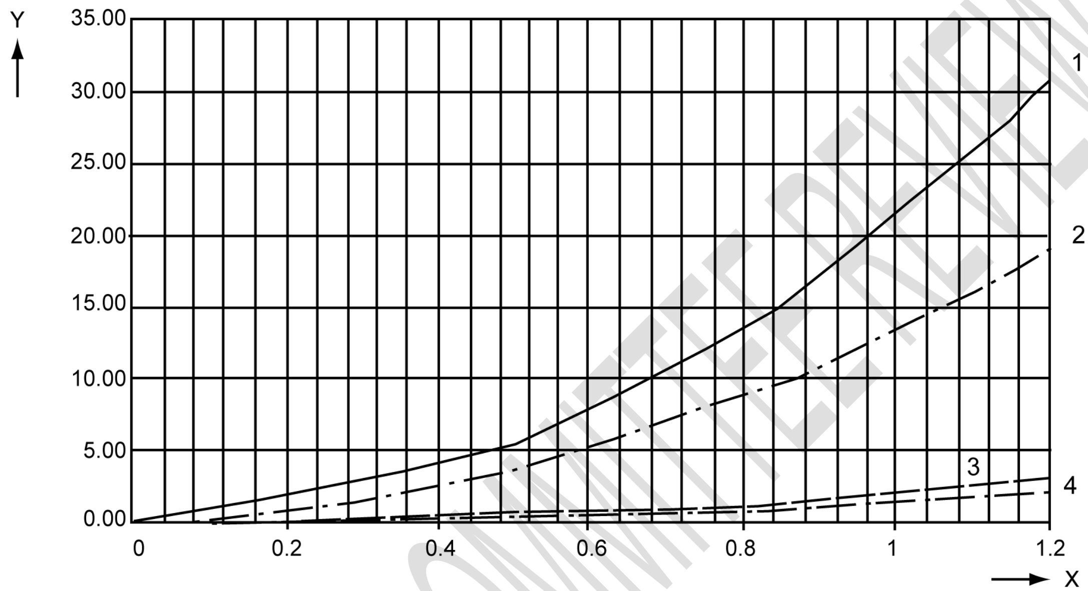
Y friction, m

1 15 mm mineral oil

2 15 mm water
3 20 mm mineral oil
4 20 mm water

Figure F.8—Pipe System Friction Curves

F.3.1.3 Tubing System Friction Curves



Key

X flow, m³/h
Y friction, m

1 12 mm mineral oil
2 12 mm water
3 20 mm mineral oil
4 20 mm water

Figure F.9—Tubing System Friction Curves

F.3.1.4 Internal Circulating Device Performance Verification

When an internal circulating device is used the seal vendor should evaluate its performance curve. The curve should illustrate head versus capacity and the vendor should also confirm that the NPSH(r) is satisfied over the entire flow range of the device. The device NPSH(r) may be represented by a curve or data. Users should carefully review applications using an internal circulating device, but especially when:

a) the process fluid temperature exceeds 176 °C (350 °F);

b) the shaft rotating speed is equal to or less than 1800 r/min;

c) variable speed drives are used;

d) shaft diameter is less than 50 mm (2 in.);

e) the total length of interconnecting pipework exceeds 5 m (16.4 ft);

f) a radial clearance smaller than that specified in 6.1.3.6. and table 1 is proposed to achieve the required flush flow rate.

g) the viscosity of the circulating fluid varies significantly because of start-up, ambient, or process related temperature changes.

Performance of the internal circulating device should exceed the required flush flow using the specified buffer/barrier fluid at all operating and start up conditions. The system resistance curve (based on the auxiliary components supplied, the specific buffer/barrier fluid, its mean settlement temperature, and the specific seal system layout) should be plotted over the circulating device performance curve. Typical system resistance curves are provided in F.3.1.2 and F.3.1.3 for Piping Plan 52 and Piping Plan 53 tube and pipe systems approximating construction in accordance with G.41.

Piping Plans 23 53B 53C seal systems will likely have steeper system resistance curves compared to Piping Plan 52 or Piping Plan 53 systems because of the additional system resistance of the heat exchanger. Piping Plan 23 systems typically use heat exchangers with the process fluid inside the exchanger tubing.

Depending on the seal ring orientation and space available on some seal designs with a Piping Plan 23 use of a distributed flush may not be advisable if the added resistance of the flush geometry detrimentally impacts the flush flow velocity. In these circumstances consult the seal manufacturer for detailed information on the evidence for achieving reliable operation without a distributed flush.

For Plans 23 53B and 53C to improve flush flow circulation rates, inlet and outlet connections for the internal circulating device should oriented to facilitate thermosyphon as illustrated in Figure G.40. In addition, the seal chamber or gland plate inlet and outlet ports should properly align with the internal circulating device and their drill-through diameters designed as large as is practical.

Figure F.10 and Figure F.11 illustrate the intersection points between a hypothetical circulating device performance curve(s) and the system curves. These intersection points indicate the estimated comparative flow that can be achieved with each combination of pipe and tube size and mineral oil or water buffer/barrier systems. Please note:

a) performance data for the circulating device is identical for the tubing and pipe plots;

b) the values for the flow axis are identical;

c) the values for the head axis are identical;

d) variations in the resulting intersection points are solely the result of differences in the system curves created by combinations of fluid with different size pipe or tubing.

Figure F.10 and Figure F.11 also show the system resistance in tubing systems is normally significantly higher than pipe systems for the same fluid, nominal size, and flow rate producing steeper tube system curves. As a result, the performance curves intersect the tubing system curves at a lower flow compared to the same nominal size pipe. The user should be aware that the highest flush rate is achieved with an interconnecting pipework selection of pipe and with a size selection of 20 mm.

F.3.2 Typical Barrier Fluid Flow Rates for Arrangement 3CW Seals

Figure F.12, Figure F.13, Figure F.14, and Figure F.15 are typical required flush flow rates for Arrangement 3CW seal, pressurized dual contacting wet seals, graphically illustrated. The curves are based on:

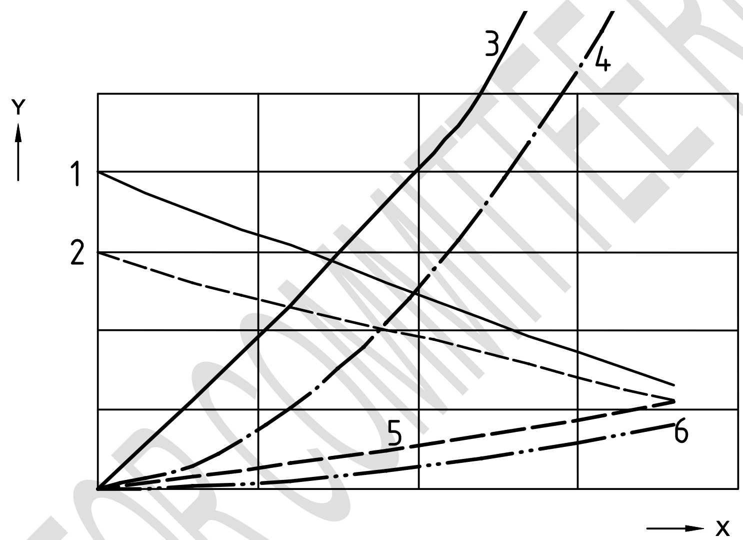
a) a barrier fluid specific heat C_p of 2093 J/Kg·°K (0.5 BTU/lb °F);

b) shaft speed 3600 r/min;

c) balance ratio of 0.75;

d) a flush flow temperature rise of 8 °C (15 °F);

e) seal chamber pressure of 1.034 MPa (10.034 bar) (150 psig);

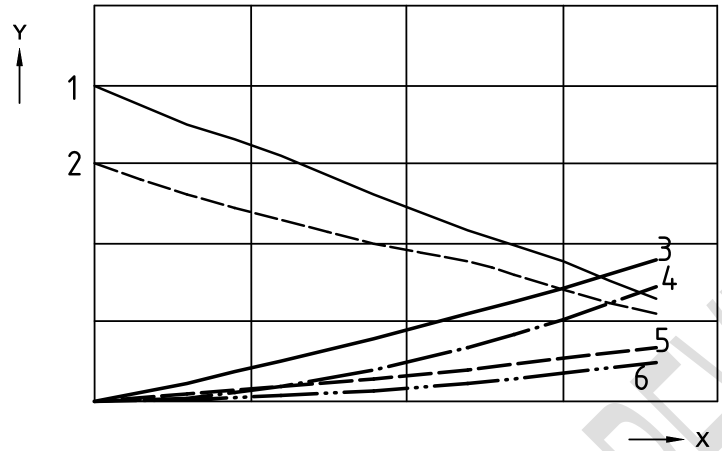


Key

X flow
Y head

1 performance curve on water
2 performance curve on mineral oil
3 12 mm system curve with mineral oil
4 12 mm system curve with water
5 20 mm system curve with mineral oil
6 20 mm system curve with water

Figure F.10—Circulating Device Performance and System Resistance in Tubing System Curves

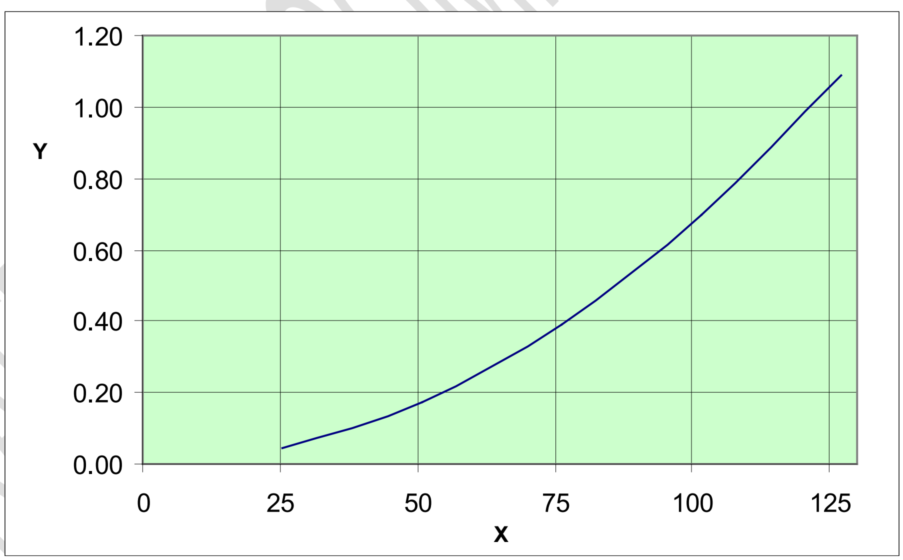


Key

X flow
Y head

1 performance curve on water
2 performance curve on mineral oil
3 15 mm system curve with mineral oil
4 15 mm system curve with water
5 20 mm system curve with mineral oil
6 20 mm system curve with water

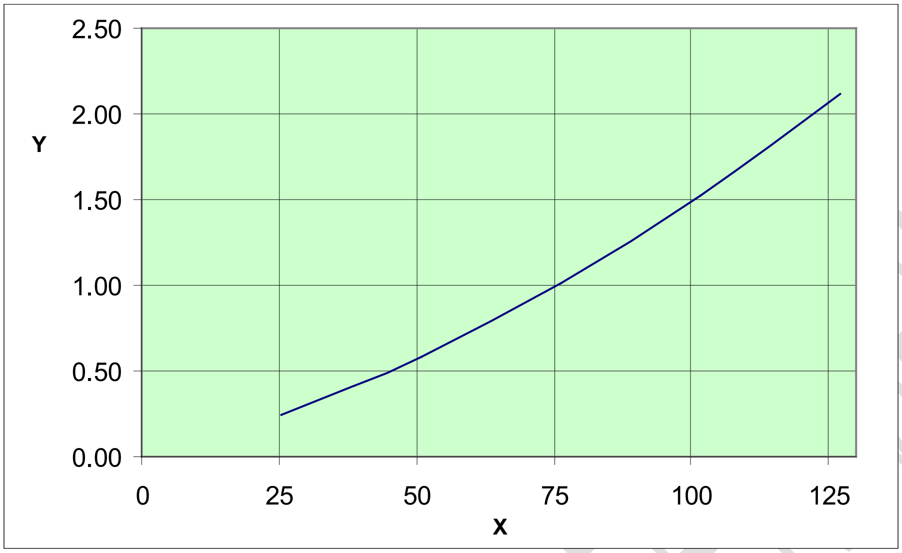
Figure F.11—Circulating Device Performance and System Resistance in Pipe System Curves



Key

X seal mean diameter, mm
Y flow, m^3/h

Figure F.12—Typical Required Flush Flow for Arrangement 3 CW Seals Without Heat Soak Considered and a Pumped Fluid Temperature of 54 °C (130 °F)

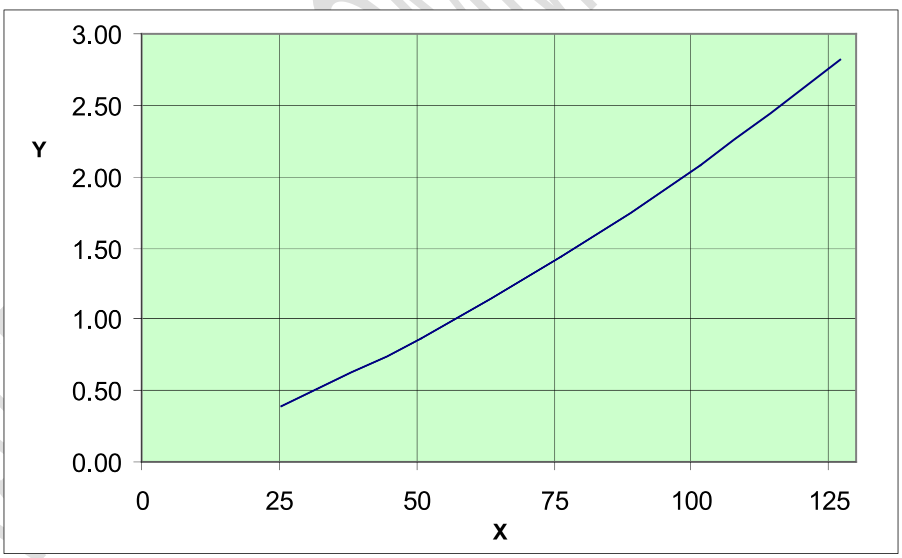


Key

X seal mean diameter, mm

Y flow, m^3/h

Figure F.13—Typical Required Flush Flow for Arrangement 3 CW Seals with Heat Soak Considered and a Pumped Fluid Temperature of 176 °C (350 °F)

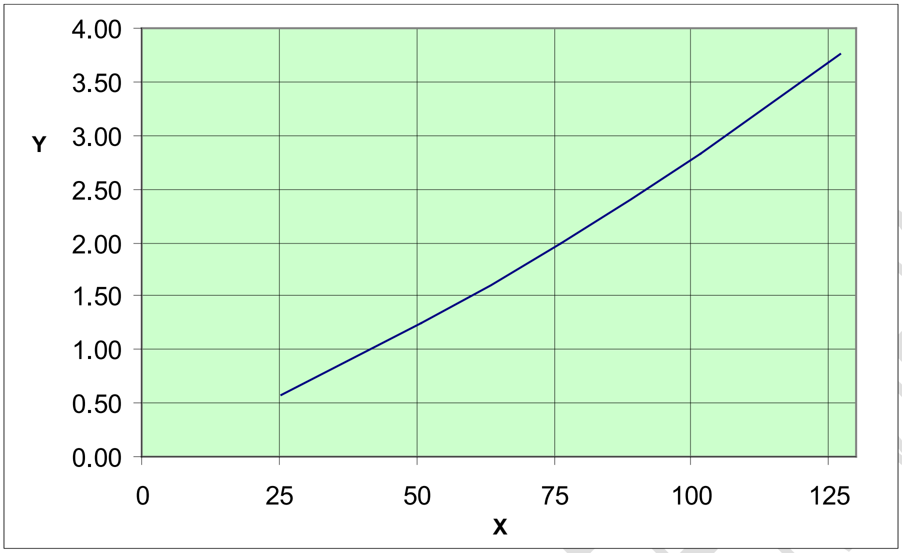


Key

X seal mean diameter, mm

Y flow, m^3/h

Figure F.14—Typical Required Flush Flow for Arrangement 3 CW Seals with Heat Soak Considered and a Pumped Fluid Temperature of 260 °C (500 °F)



Key

X seal mean diameter, mm

Y flow, m³/h

Figure F.15—Typical Required Flush Flow for Arrangement 3CW Seals with Heat Soak Considered and a Pumped Fluid Temperature of 371 °C (700 °F)

f) barrier fluid pressure of 1.379 MPa (13.79 bar) (200 psig);

g) a safety factor for flush flow of 1.0.

NOTE 1 7.2.3.1 and 7.3.3.1.1 requires a maximum barrier / buffer flow temperature rise of 8 °C (15 °F) or 16 °C (30 °F) depending on the barrier fluid type.

NOTE 2 For barrier fluids with a different specific heat, divide the predicted graph flow rate by the C_p ratio [actual barrier C_p divided by 2093 J/Kg·K (0.5 BTU/lb °F)].

While curves are provided for pumped fluid temperatures above 176 °C (350 °F), achieving an adequate flow using an internal circulating device for higher temperature applications becomes increasingly difficult and a Piping Plan 54 or external circulating device may be required for these services.

F.3.3 Piping Plan 53A and 53B Barrier Pressure and Operation

F.3.3.1 General

Piping Plans 53A and 53B provide barrier liquid to Arrangement 3 dual seals at a pressure above the maximum (process pumped fluid) seal chamber pressure by using a gas charged 53A reservoir or 53B accumulator. Piping Plan 53C also provides a pressure margin above the maximum seal chamber pressure, but it is achieved by using a reference line from the seal chamber and a piston accumulator rather than a gas charged reservoir or accumulator.

The barrier pressure in a Plan 53B can be influenced by changes in ambient temperatures changes and solar radiation. These extremes should be considered at the design stage and how it can impact the seals and sealing system. F.3.3.3.2 discuss methods of mitigating the effects of these temperature changes. Piping Plan 53A and 53C pressure fluctuations due to ambient temperature changes are minimal and are not covered in this standard.

It is important to verify the pressure rating of seals and associatedplan 53B system components and confirm that pressure fluctuations do not exceed these ratings. For example, Type B or Type C seals typically have lower differential pressure rating than Type A seals.

With Piping Plans 53B, as barrier fluid pressure increases seal face related friction also increases. Users should be aware that it may become difficult or impossible to rotate some pumps prior to start-up when the seal is pressurized. In small pumps, seal face friction may also contribute significantly to the motor load and it is possible to experience an overload condition (high amps) causing shutdown of a marginally sized motor.

F.3.3.2 Piping Plan 53A Operation

F.3.3.2.1 General

Figure G.21 illustrates Piping Plan 53A system. The barrier liquid reservoir is pressurized by an outside source, typically the plant nitrogen system, another plant gas source or bottled gas. It is essential that the gas supply is uninterrupted and stable. A pressure regulator to control the barrier fluid pressure should be installed upstream of the gas supply isolation valve which should normally be open. Closing this isolation valve may result in a loss of barrier pressure across the inner seal. Figure G.21 shows this valve as normally open to avoid this scenario.
The pressure regulator is not normally in the scope of supply of the pump or seal vendor and hence is not shown in Figure G.21.

The standard does not allow the use of self-venting regulators per 9.9(f). This eliminates the potential for barrier fluid contaminated by hazardous fluid to be vented to the atmosphere. Some users have successfully used self-venting regulators. Routing the vent port to a collection system avoids release of potentially hazardous fluid to atmosphere

If a non-self-venting regulator is used the pressure in the 53A system can vary due to influences of a number of factors such as; barrier fluid temperature, cooling water flow and temperature, ambient temperature, solar radiation etc. In such circumstances user should monitor the pressure and may adjust by manually venting.

Venting may also be required during refilling the system with barrier fluid. A provision for venting excess gas pressure should be included, either via a bleed valve between the regulator and the barrier fluid reservoir or via a bleed valve adjacent to the PIT. The vent port should be routed to a safe place

53A normally operates at or below a gauge pressure of 1 MPa (10 bar) (150 psi). It is unlikely that barrier liquid pressure change due to temperature fluctuation will exceed the rated pressure of the seal. There may be a concern on standby service, use of cooling water to help stabilize the temperature.

Barrier liquid level will drop because of seal leakage. The need to add barrier liquid to the reservoir occurs when the operating volume of barrier liquid is consumed due to normal seal leakage.

A level indicator and level transmitter with a low-level alarm are provided on Piping Plan 53A systems to indicate the need to add barrier liquid. In addition to a level transmitter, Piping Plan 53A systems are also provided with a pressure transmitter. Normally a low alarm set point is used for level and pressure. A high alarm set point for each is optional.

Refills are typically managed by operations and maintenance personnel based on a low-level alarm. Seal pots are typically equipped with a quick connect fitting and the barrier fluid is refilled with an auxiliary seal cart and pump. Barrier fluid is added until the proper point in the sight glass and the low-level alarm is satisfied. (refer to 8.1.14)

F.3.3.3 Piping Plan 53B Operation

F.3.3.3.1 General

Figure G.19 illustrates a typical Piping Plan 53B system. The barrier liquid is pressurized using a gas charge inside a bladder within the accumulator. Unlike a typical Piping Plan 53A system, after a Piping Plan 53B accumulator bladder is pre-charged to the required gas pressure, the accumulator is then disconnected from the gas source during operation.

Barrier fluid is then introduced to the system via the barrier fluid fill connection (see G.19) until the desired barrier pressure is achieved. Accumulator pressure will drop because of normal seal leakage and reduced barrier liquid volume. When the pressure drops to the refill alarm point barrier fluid will then need to be replenished.

The refilling frequency of barrier liquid should be at least of twenty-eight days (28 d) as per 8.3.6.1.6. For this purpose, the expected seal leakage rate provided by the seal vendor is considered to select a suitable working volume of the accumulator in combination with an appropriate alarm strategy.

F.3.3.3.2 Temperature impact on accumulator pressure

Accumulator pressure will also be affected by the gas temperature in the bladder. The barrier liquid does not flow through the accumulator, so the bladder gas temperature will change with ambient temperature (and solar exposure). Accumulator pressure variations can be significant.

A manufacturers name plate (table F.2) is attached to the system that provides nitrogen precharge and refill pressures that are adjusted for ambient temperature. Alarm pressure will be fixed for the default fixed alarm strategy, (8.3.6.3.8) or adjusted for temperature for an optional floating alarm strategy (8.3.6.3.10)

Accumulator gas precharge pressure should consider the extremes of ambient temperature (and solar) at the time of precharge. Failure to do so may result in an over pressurizing the seal or seal support system components.

While most accumulators are exposed to atmospheric conditions, the effect of solar radiation can be mitigated by the use of a sunscreen, shade or reflective insulation. The impact of ambient temperature variations may be reduced if the accumulator is insulated or temperature controlled (i.e. heat traced). The user should verify that the seal and seal support system is suitable for all system pressures by following the calculation sequence illustrated in this annex.

The use of a larger accumulator or automatic refill unit can reduce the amount of pressure variation experienced during normal operation. This becomes advantageous at higher barrier pressures and in cases where longer duration between refills is desired

In some cases, the use of small accumulators or long durations between refills will result in higher refill pressures.

- This may require the use of seals and systems with higher pressure ratings.
- The higher barrier pressures also result in more seal face heat generation and requirements for heat removal.
- Large variations in barrier pressure can negatively impact seal reliability.

Pump Item No				
Barrier Liquid				
Temperature		Pressure		
		Precharge	Refill	Alarm
		Comissioning	Operating	Fixed
	°C	barg	barg	barg
min.	-15	14.3	20.0	
	-10	14.6	20.4	
	-5	14.9	20.8	
	0	15.2	21.2	
	5	15.5	21.6	
	10	15.8	22.0	18.2
	15	16.1	22.4	
	20	16.4	22.8	
	25	16.7	23.2	
	30	17.0	23.6	
	35	17.3	24.0	
max	40	17.6	24.4	
Caution	Do not adjust gas precharge pressure with liquid barrier fluid in the accumulator			

Table F.2

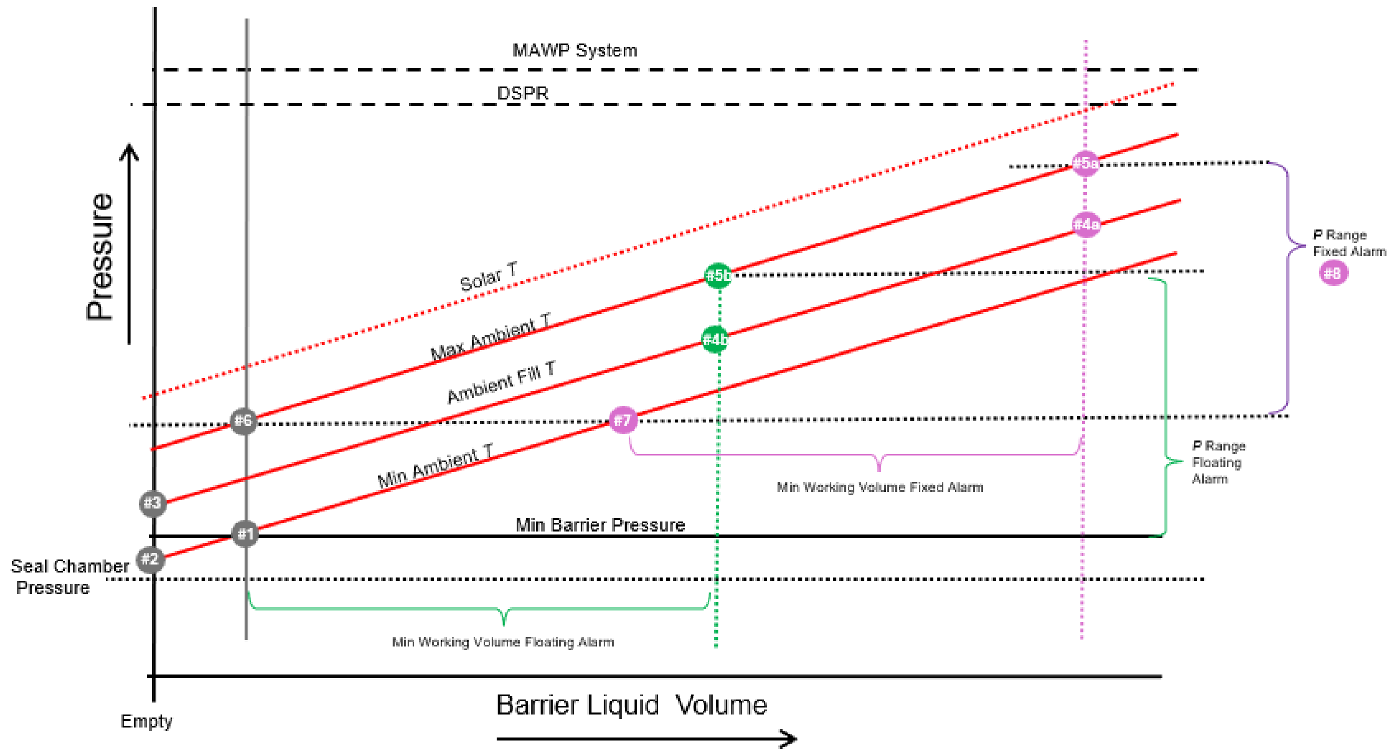
The following definitions are used to identify illustrated points in Figure F.16:

a) Accumulator minimum barrier pressure—This is the lowest operating barrier pressure and is equal to the sum of the maximum seal chamber pressure and a pressure margin, which is recommended to be a minimum of 0.14 MPa (1.4 bar) (20 psi). This establishes Point #1 in Figure F.16. The value is used as a starting point for the example calculations in this annex.

b) Low Pressure Alarm This is the pressure where an operator would need to be notified for refill and considers ambient temperature. This is calculated as a fixed value for the fixed alarm strategy Point #6 in figure F16 and will be a variable value for a floating alarm strategy between point #1 and #6 Figure F16.

c) Accumulator pressure range—This is the pressure range between the maximum and minimum barrier pressure and is specific to a temperature value. It is illustrated between Point #6 and Point #5a when a fixed pressure alarm strategy is used and Point #1 and Point #5b if a floating pressure alarm is used.

d) Accumulator working liquid volume—This is the liquid volume in the accumulator between the maximum barrier pressure and the alarm pressure. Refer to Figure F.16. The selection of the accumulator sizes in this standard have been made to optimize the working liquid volume to be roughly equal to the working liquid volume for reservoir systems provided with Piping Plan 52 and 53A systems.



Point #1 Min barrier pressure at minimum barrier liquid volume at min ambient *T*
Point #2 Gas precharged at Min Ambient *T*
Point #3 Gas precharge pressure based on actual ambient *T* at the time of charging
Point #4a Refill pressure at ambient *T* at the time of barrier liquid filling fixed alarm
Point #4b Refill pressure at ambient *T* at the time of barrier liquid filling floating alarm
Point #5a Refill pressure at max ambient *T* fixed alarm
Point #5b Refill pressure at max ambient *T* floating alarm
Point #6 Alarm pressure set point fixed alarm or upper alarm point for floating
Point #7 Min barrier pressure fixed alarm

Figure F.16

F.3.3.3.3 Alarm Strategy and Accumulator Working Liquid Volume

The accumulator working liquid volume is dependent on many variables but should be optimized by the vendor to balance the accumulator working pressure range with the performance limits of the seal system, the desired minimum frequency of filling and the alarm strategy. The accumulator working liquid volume is typically 15 % to 25 % of the total accumulator volume. The charts (Figure F.16,) illustrate important calculation points for Piping Plan 53B systems. volume.

F.3.3.3.4 Fixed and Floating Alarm Strategies

The fixed pressure alarm (without a temperature bias; see 8.3.6.3.8) uses a pressure transmitter or pressure switch with a low pressure setting at Point #6. Figure F.16 illustrates a fixed alarm strategy. This alarm strategy does work and is commonly applied. However, in the case of large fluctuations in ambient temperatures, can result in the need to use higher pressure to achieve the minimum working volume

Unlike a fixed alarm set point, a floating alarm set point can use the full potential liquid volume between minimum and maximum in the accumulator. The accumulator pressure range is also maximized, between Points #1 and Point #5 depending on the local ambient temperature change over the barrier pressure drop.

It follows that if temperature fluctuations of the gas in the accumulator were substantially reduced or eliminated then working liquid volume associated with a fixed alarm system will approach that of a floating alarm system.

The choice of a lower fixed pressure value may risk the accumulator minimum liquid volume being reached at high ambient temperature without a warning alarm. When the barrier pressure value at maximum ambient temperature (Point #6) is considered at lower ambient (gas bladder) temperatures, the result is a reduced accumulator working barrier liquid volume. By Increasing the refill pressure point #5 full working volume can be achieved.

If specified or recommended by the seal vendor the pressure alarm for refilling Piping Plan 53B may require the use of a floating alarm value (a pressure alarm with a temperature bias) . If the floating alarm strategy is used the alarm value is calculated continuously by the plant distributed control system (DCS) to indicate when barrier liquid volume reaches minimum liquid volume based on the temperature of the gas in the bladder (see 8.3.6.3.10). See Figure F.16, the alarm pressure can vary between points #1 and #6 at minimum liquid volume.

A pressure alarm with a temperature bias provides a temperature compensated set point that will maximize the working liquid volume at all local ambient temperatures. It is accomplished by the use of a pressure and temperature transmitter (refer to Figure G.16) in the auxiliary seal system. These signals would be integrated into a plant DCS system to provide an accurate temperature adjusted pressure alarm value. In case a plant DGS system is not available, a local programmable logic controller (PLC) or a loop controller could be considered alternatively (see 8.3.6.3.10.2).

Specific DCS input required for a floating alarm algorithm will include the minimum and maximum barrier liquid volume, the accumulator volume, and the accumulator minimum barrier pressure calculated at minimum ambient temperature. The vendor will use this data and the site ambient temperature data to optimize system design, minimize the frequency of refilling, and verify that the system design is suitable for the local installation.

If the accumulator is properly insulated or fully shaded the solar temperature need not be considered, The illustrated accumulator working pressure range (#8 in Figure F.16) represents the minimum pressure range, but may rise to the difference in pressure between Point #1 and Point #5b with a maximum ambient temperature change when a floating alarm strategy is used.

F.3.3.3.5 Piping Plan 53B Calculation Tutorial and Formula

The following discussion refers to the illustrated “numbered” points in Figure F.16. It assumes the accumulator bladder gas temperature corresponds to the local ambient temperature. To simplify the explanation the calculation, including the scenario for floating alarm, also assumes the bladder pre-charge pressure is applied at the same ambient temperature prevailing when the system is initially filled with barrier liquid.

Point #1— Minimum barrier pressure at minimum barrier liquid volume and minimum ambient temperature. This pressure is the basis for all subsequent calculations and is the sum of the maximum seal chamber pressure and a pressure margin to avoid pressure reversals across the inner seal.

Point #2— Piping Plan 53B accumulator bladders are pre-charged with gas (usually nitrogen) when completely empty; Point #2 uses the value of Point #1 to determine the equivalent gas pre-charge pressure with an empty accumulator (zero liquid volume) if the local ambient temperature is also at a minimum.

Point #2 Pressure = Pressure at Point #1 × (gas volume at minimum liquid volume / total empty accumulator volume)

Point #3— Calculates the gas pre-charge pressure based on actual ambient temperature at the time of charging the accumulator bladder. Point #3 uses the value of Point #2, but applies a ratio of temperatures, ambient at the time of filling and minimum ambient temperature.

Point #3 pressure = Pressure at Point #2 × (ambient temp (°C + 273) (or; °F + 460) at time of filling / minimum ambient temp (°C + 273) [or; °F + 460)]

NOTE The pressure at Point #3 is the value used to pre-charge the accumulator. When the gas charge reaches the prescribed pressure, it should be isolated and then the system should be prepared for adding barrier liquid. When the barrier liquid reaches the maximum liquid volume the pressure in the accumulator would reach the pressure at Point #4.

Point #4a and 4b— Calculates the maximum barrier accumulator pressure with the maximum barrier liquid volume in the accumulator at the prevailing ambient temperature at the time of barrier liquid filling [assumes the same temperature as that used when pre-charging the bladder (refer to Point #3)]. Point #4 uses the value of Point #3, but applies a ratio of volumes; empty accumulator and gas volume with barrier liquid at the maximum volume.

Point #4a represent the pressure at the maximum liquid volume require for a fixed alarm strategy.

Point #4b represent the pressure at the maximum liquid volume require for a floating alarm strategy.

NOTE The bladder gas volume at maximum barrier liquid volume is a result of removing the volume between maximum and minimum barrier liquid volume values plus the minimum liquid volume (see 8.3.6.3.2) from the empty accumulator volume. The volume between maximum and minimum barrier liquid volume is normally estimated by the system design engineer and is an iterative value resulting from optimizing a balance between the maximum barrier pressure and accumulator working liquid volume necessary to meet the 28 day refill frequency. An initial value needs to be assumed and subsequently adjusted as appropriate.

Point #5a and 5b— Calculates the maximum barrier pressure at maximum barrier liquid volume, but at the maximum ambient temperature. Point #5 uses the value of Point #4, but applies a ratio of temperatures, maximum ambient and ambient temperature at the time of filling.

Point #5a represent the pressure at the maximum temperature for a fixed alarm strategy.

Point #5b represent the pressure at the maximum temperature for a floating alarm strategy.

Point #5 Pressure = Pressure at Point #4 × maximum ambient temp (°C + 273) (or; °F + 460) / ambient temp (°C + 273) [or; (F + 460)] at time of filling

NOTE It is important the maximum barrier pressure at maximum ambient temperature does not exceed the dynamic sealing pressure rating (DSPR) of the seal or the MAWP of the system.

Points #6—This represents an alarm pressure set point for a fixed alarm strategy. It corresponds to the barrier pressure at minimum liquid volume, but at maximum ambient temperature. The alarm pressure will vary between point #6 and #1 with the ambient temperature for a floating alarm strategy.

Point #6 uses the value of Point #1, but applies a ratio of temperatures; maximum ambient and minimum ambient temperature.

Alarm pressure at Point #6 = Pressure at Point #1 × [maximum ambient temp (°C + 273) (or; °F + 460)] / [minimum ambient temp (°C + 273) (or; °F + 460)]

NOTE 1 If a fixed alarm strategy is chosen, the value calculated for Point #6 will be the recommended alarm pressure. If a floating alarm strategy is chosen then the value calculated for Point #6 represents the highest alarm pressure based on a calculated algorithm (see 8.3.6.3.4), but the alarm pressure will vary between Point #1 and Point #6 depending on the bladder gas temperature.

F3.4 Automatic 53B Barrier Fluid Make Up Systems

F.3.4.1. General

Plan 53B systems require that the accumulator be refilled with barrier fluid when the barrier pressure reaches the alarm setting. The 53B system is designed such that the accumulator size, alarm pressure, and refill pressure provide at least 28 days between refills, based on expected barrier fluid consumption (seal leakage). In applications that experience large variations in accumulator temperature, have high barrier fluids consumption, or elevated barrier pressure (as with Category 4), the system design may require multiple accumulators or excessive refill pressure to achieve 28 days between refills. It is common to apply automatic refill unit in these cases so that alarm and refill pressures can be reduced while eliminating the need for the operator to manually refill the Plan 53 system.

F.3.4.2 Traditional 53B Manual Refilling

The refilling or topping-up of Plan 53 barrier systems has traditionally been carried out manually. This is often accomplished using a hand pump barrier fluid reserve tank mounted and on the 53B system stand or use of mobile top up carts with quick connect fittings via a flexible hose, to isolation barrier liquid refill valves 1 figure G22. Refilling 53B systems with barrier fluid is normally carried out with the pump online.

F.3.4.3 Manual Barrier Refill Using Pressurized Manifold (Header) Systems

Barrier fluid refill using pressurized manifold (header) system have become common in plants with large populations of 53B systems. With this method, each 53B barrier system is permanently connected to the header of this make-up system by a normally closed isolation valve (see Figure G.22, Item 1). This valve is manually opened for refilling each individual 53B.

F.3.4.4 Automatic Barrier RefillSystems

Automatic refill systems eliminate the need for a 28 day period between refilling Plan 53B systems. This, in turn, eliminates the requirement for very large or multiple accumulators for seals with higher leakage rate typically associated with Category 4 pressures or larger shaft diameters. It is common to reduce the refill frequency to less than 5 days with an automatic refill system. Nevertheless, in the event of failure of the automatic refill unit, the accumulator would need to be of sufficient volume to maintain barrier pressure for at least one day.

A 53B accumulator supplied by automatic refill unit can operate at lower barrier pressure and in a narrower pressure range, which can reduce seal leakage, seal wear, and seal generated heat.. Additionally, the impact of diurnal variation in ambient temperature on the 53B accumulator pressure is mitigated as the refill system automatically compensates for any loss of pressure due to reduction in ambient temperature.

A system solution consisting of a 53B piping plan combined with an automatic refill unit should be considered in the following situations:

a) For standard Plan 53B systems as an addition to eliminate the need to manually refill the unit
b) When minimum barrier pressure exceeds 30 bar (450 psi).
c) When ambient temperature varies more than 20 °C (40 °F)
d) When maximum barrier pressure exceeds the MAWP of the system or DSPR
e) As an alternative to very large or multiple accumulators in the Plan 53B system
f) As a method of reducing barrier pressure and barrier pressure variation by increasing the refill frequency.
g) As a viable alternative to a traditional plan 54 system

F. 3.4.4.1 General Description

Automatic refill units are normally comprised of an atmospheric tank with a pump unit to pressurize a manifold (header) that is permanently connected to the 53B refill connection (see Figure G.22, Item 1) which would be normally open when used in conjunction with an automatic refill unit

Centrifugal, positive displacement (both rotary and reciprocating) and diaphragm pumps have all been used successfully to pressurize the refill line. Electrically driven pumps require a control system to turn on and off while pneumatically driven pumps can be self regulated without the need for a controller. The supply refill system may also use a secondary accumulator with PCV to reduce stop start frequence of the pressurizing pump.

F. 3.4.4.2 Auto Fill System Used on Multiple 53B Systems.

Multiple Plan 53B system can be connected to a single automatic refill unit by individual valve connections in combination with appropriate pressure settings. Between Bearing pumps where seal chambers are at similar pressures or duty stand by pumps do not require any additional pressure control.

However, when connected to multiple 53Bs operating at different pressures the system would require additional engineering and components. The volume of the barrier fluid reservoir shall be sized to provide the specified refill time of the reservoir at least 28 days according to 8.3.6.1.6, taking into account all connected 53B system.

F. 3.4.4.3 Automatic Refill Alarm and condition monitoring strategies

Barrier fluid consumption provides an indication of seal health.

The automatic refill unit normally includes a valve between it and the Plan 53B system that is used to control the refill process. It is important to understand the function of the refill unit and how this valve will be used because it affects how the barrier fluid consumption is monitored. With certain systems, this will be a solenoid valve that opens to allow refill. In other cases, this is a pressure regulating valve that maintains a constant pressure on the Plan 53B system. When the pressure regulating valve is used, barrier fluid consumption is monitored by use of a liquid level transmitter in the atmospheric tank.

With Auto refill units supplying multiple 53Bs, detection of increased leakage of any individual seal requires either manual intervention or the use of additional components to identify the individual faulty seal. Examples of these additional components could be solenoid valves or flow instruments.

F.4 Cartridge Sleeve Drive Collar Set Screw Loading

A cartridge sleeve drive collar and set screws are required to manage the torque occurring at the seal face and the axial force derived from the seal chamber pressure acting across the process end of the seal sleeve. For most seal sizes and seal chamber pressures, the axial force is the critical design criteria, not the torque load on the set screws. The effective area at the sleeve end over which the seal chamber pressure acts for most seal arrangements is the area difference between the shaft and seal balance diameter.

The number, size, and type of set screw used to a drive mechanical seal sleeves will vary with sleeve and pump design, maximum seal chamber pressure, materials of construction, and seal configuration. This annex considers cup point set screw driven cartridge seal assemblies, not designs that use a key drive and split-ring location or shrink disk design sleeve drives.

This annex assumes that the set screws are evenly spaced in the drive collar and that the total axial load is evenly distributed to each set screw. If the drive collar were mounted such that the set screws offset the collar so it contacted the shaft on one side, then there will be added friction associated with contact between the drive collar and the shaft potentially increasing the axial load capability. As this is not the normal mounting practice, it is assumed that the radial distance between the shaft and drive collar is evenly distributed.

The axial holding capability is primarily a function of screw size, number of set screws and applied torque. However, many other factors such as presence of oil, process fluid temperature (thermal expansion), the finish and hardness of the shaft and set screws, the length of the threaded engagement and safety factors applied will impact the axial holding capability.

For example, load capability is reduced with lower hardness steel screws because of lower seating torque. Load capability of a drive collar will increase by adding additional set screws. To reduce the chance of slipping and to increase load capacity, a dimple can be drilled in the shaft into which the set screw's point enters. The downside of a dimpled shaft is the drive collar set screws may not align with the dimples after a maintenance event. Experience has shown that drive collars for seals that fall within the pressure and size limits of API 682 have conservative axial load capabilities.

The set screw need only be slightly harder than the shaft for to make a good impingement on the shaft and therefore deliver full holding power. However, if the set screw is softer than or only as hard as the shaft the holding power will be reduced.

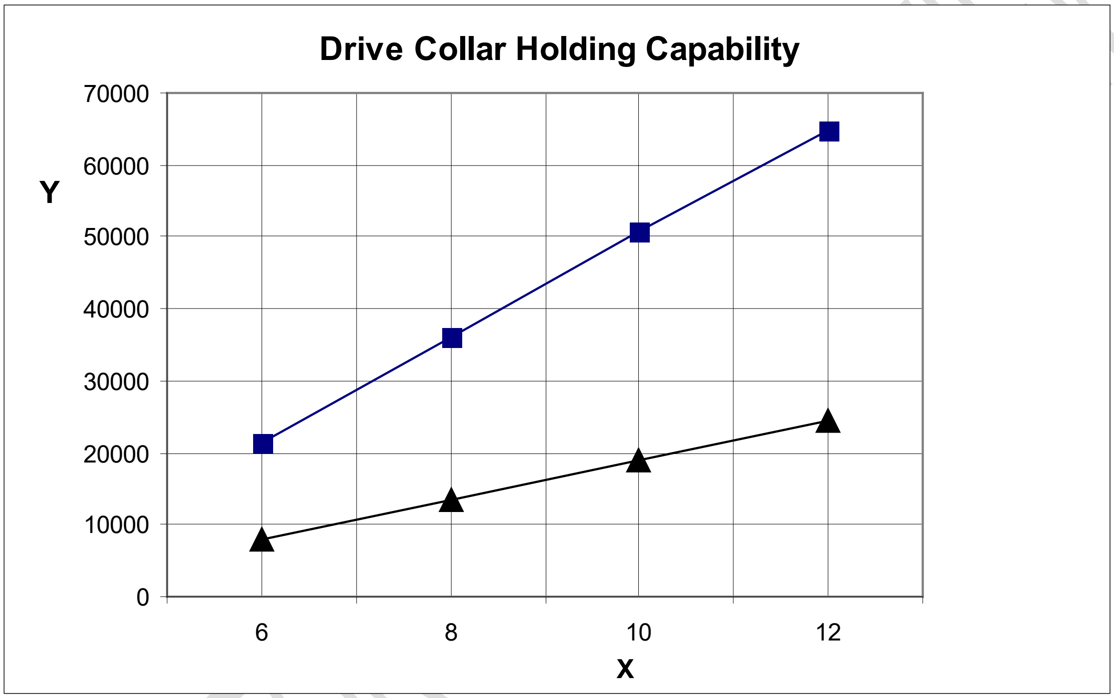
To determine if the set screw is harder than the shaft, tighten the set-screw onto the shaft and then remove and examine the rim around the cup point. If the set-screw is harder, the rim itself will retain its sharp profile. If the set screw is softer than or only as hard as the shaft, the rim will be flattened indicating no impingement and, therefore, reduced holding power.

The ability of the drive collar to maintain the axial position of the assembled components is a significant safety issue. Since the axial holding capability of a drive collar is a function of many variables, it is difficult to provide a value for all conditions. As mentioned earlier, many factors will impact the axial holding capability of a drive collar and the values illustrated in Figure F.17 represent an average based on several methods of calculation.

The user should consult with the seal vendor to verify the drive collar axial load capability in high-pressure or large shaft diameter applications (applications exceeding the pressure rating or size of seals covered by this standard).

The nominal torsional holding power of a drive collar can be estimated by the product of the drive collar axial holding power and the shaft radius.

Typically cartridge drive collar set screws are tightened against the shaft. Table F.3 and Table F.4 give typical hardness values for shaft and set screw materials.



Key

X set screw diameter, mm

Y axial holding capability, N

1 drive collar with 8 set screws

2 drive collar with 3 set screws

Figure F.17—Drive Collar Holding Capability

Table F.3—Typical Hardness Ranges for Set Screw Materials

Material	Hardness (HRC)	
	min	max
316 SS	15	
C276	22	
410 SS (hardened)	41	43
416 SS	25	30
440C	58	
4140	37	45
4340	42	

Table F.4—Typical Hardness Ranges for Pump Shaft Materials

Material	Hardness (HRC)	
	min	max
Carbon steel	15	20
4140	30	38
316SS	15	20
12 % Chrome	20	32
4340 reduced hardness		22
17-4PH	22	35
Monel	18	

Table F.5 gives the estimated sleeve for various seal sizes based on 0.689 MPa (6.89 bar) (100 psi) seal chamber pressure. The product of axial load for a given shaft diameter and the ratio of the field or application seal chamber pressure to 0.689 MPa (6.89 bar) (100 psi) will provide the user with an estimate of the total axial load for a specific application.

Table F.5—Estimated Sleeve Axial Loads

Shaft Diameter		Axial Load	
Mm	(in.)	N	(lbf)
25	1.0	1048	236
38	1.5	1397	314
51	2.0	1747	393
64	2.5	2096	471
76	3.0	2446	550
89	3.5	2795	628

102	4.0	3144	707
114	4.5	3494	785

F.5 Rotating or Stationary Flexible Element Selection

F.5.1 General

Within the scope of API 682, configurations with either a rotating or stationary flexible element are considered to be technically equivalent. The optimum choice in using a rotating or stationary flexible element in a standardized cartridge assembly is not a simple decision and is influenced by many factors. This standard has default configurations, but it also recognizes, through included options, that the default selection may not always be the best choice. Some of factors that may influence the selection of a rotating or stationary flexible element are discussed below.

F.5.2 Perpendicularity

Perpendicularity of the mating ring to the shaft axis is important for both stationary and rotating flexible element designs.

The perpendicularity of a mating ring mounted in the gland plate (where a rotating flexible element is used) is controlled by the combination of the seal chamber face and support surface on the gland plate. The flexible element is required to flex with each rotation to accommodate any lack of perpendicularity, but for reliable seal performance there are limits to this function. A rotating flexible element seal is the standard default for Type A and Type B seals based on installed population.

Perpendicularity for a rotating mating ring mounted on the sleeve (where a stationary flexible element is used) is controlled by the seal sleeve run out and perpendicularity of support surface on the sleeve. It is independent of the seal chamber face run out. An advantage of a stationary flexible element is that it will deflect to a fixed position to align with the rotating face. A stationary flexible element seal is the standard default for Type C seals.

Both rotating and stationary flexible elements can provide reliable service when pump and seal construction complies with the perpendicularity, fits, clearances and runout limits in pump and seal standards such as API 682, API 610, and ASME B73.1. However, the use of a stationary flexible element is recommended when circumstances exist where these values can be exceeded. Some of the circumstances where a stationary flexible element may be the best choice are discussed below.

F.5.3 Stationary Flexible Element Selection

Stationary flexible elements are the default selection for Category 4 seals and may be the preferred choice to provide more reliable seal operation when:

a) seals are installed in high-temperature pumps where thermal distortion of the casing and/or gland plate will affect the alignment of the shaft to the seal chamber face. This is one reason stationary flexible elements are the default selection above 176 °C;

b) seals are installed in ASME B73.1 and B73.2 pumps or multistage pumps with high levels of shaft flexure may affect the alignment of the shaft and seal chamber face;

c) seals are installed in high-pressure pumps where the pressure results in excessive distortion of the seal chamber face and its alignment to the shaft axis;

d) seals are installed in pumps with excessive pipe loads causing casing distortion affecting the alignment of the shaft and seal chamber face;

e) the seal balance diameter exceeds 115 mm (4.5 in.);

f) the peripheral face velocity exceeds 23 m/s (4500 ft/min).

F.5.4 Seal Flush

Use of a rotating flexible element may enable an improved flush location to the inner seal of a dual seal installation where long flexible elements (such as bellows, single spring and some multispring designs) are used. This is due to restricted seal chamber dimensions and the resulting adaptive hardware construction.

F.5.5 Shaft r/min and Peripheral Seal Velocity

As the rotating shaft speed increases, a rotating flexible element flexes at a correspondingly faster rate to keep the faces closed. At very high velocities (and for large seal sizes), the forces required to keep the faces closed become so large that they can negatively affect seal life. Stationary flexible elements are recommended if the face velocity exceeds 23 m/s or if the seal balance diameter exceeds 115 mm.

F.5.6 Suspended Solids

Several seal configurations have proved to be somewhat resistant to problems associated with sealing process fluids that contain suspended solids are listed below.

- Suspended solids in the seal chamber may be centrifuged away from important functional parts of a rotating flexible element when the process is on the outer surface.
- Seals using a stationary flexible element with springs external to the process liquid are also a proven design in process fluids with high particulate concentrations.
- Rotating metal bellows with the process liquid on the outer surface tend to throw out particulates from between the bellows in some services.

F.5.7 Bellows Vibration

Some bellows seals vibrate during operation and are sometimes equipped with dampening tabs or other devices to control vibration. The use of a stationary bellows seal can help to avoid this problem.

F.6 Throat and Throttle Bushings

F.6.1 General

Refer to Annex B for a discussion of throat and throttle bushing materials. The following subsections differentiate the application uses for these bushings.

F.6.2 Throat Bushings

Normally a throat bushing is provided by the pump vendor as part of the pump. Defined by API 610 and this standard, it is a device that forms a restrictive close clearance around the sleeve (or shaft) between the seal and the impeller. Throat bushing material supplied by the pump vendor as part of the pump back cover or seal chamber will comply with the applicable pump standards (such as Annex H of API 610). Typically this material can range from bronze to super duplex stainless steel and is selected based on compatibility with the process fluid and material of parts in close proximity.

A floating bushing as defined by this standard fits around the shaft or sleeve and has sufficient outer diameter clearance so it can move or "float" radially with movement or contact with the rotating part. A fixed or a floating throat bushing may be provided by the seal vendor and installed at the bottom of the seal chamber for several reasons. Examples include the following.

a) *Improved isolation of the seal chamber*—A throat bushing will help decrease the communication of fluid between the pump casing and the seal chamber that can improve the product temperature margin. The application of a floating throat bushing may be used in conjunction with seal Piping Plan 23.

b) *Decrease external flush fluid flow*—The close clearance created by the use of a floating throat bushing along with Piping Plan 32 can decrease the consumption of external flush fluid. The throat bushing is not intended to be used as a flow control device.

c) *Increase seal chamber pressure*—The close clearance created by the use of a floating throat bushing can, at least temporarily, increase the seal chamber pressure when used with Piping Plans 11, 21, 31, and 41 improving the product temperature margin.

Lowering the flush fluid temperature and seal chamber fluid temperature is always preferable to pressurizing the seal chamber by using a floating throat bushing. Wear on a throat bushing installed primarily used to restrict flow and pressurize the seal chamber inevitably results in a decreased seal chamber pressure and possibly a lower product temperature margin. Since a fixed throat bushing is provided by the pump vendor, when a throat bushing is provided by the seal vendor it is often a floating design.

F.6.3 Throttle Bushings

A throttle bushing, defined by this standard, is a device mounted in the gland plate on the atmospheric side of the mechanical seal that forms a restrictively close clearance around the sleeve (or shaft). It is always mounted in the gland plate and is therefore supplied by the seal vendor. The standard throttle bushing material is carbon, but a spark resistant metallic material (i.e. bronze) and other nonmetallic materials have been used. Throttle bushings are fundamentally part of the seal leakage management system. Refer to F.1.1 and F.1.2 for more discussion of leakage management.

Category 1 seals are supplied with a fixed, solid carbon throttle bushings as standard and a floating carbon bushing is an option. Category 2, Category 3 and Category 4 seals are supplied with a floating, solid carbon throttle bushing as standard. Floating carbon bushings can be a solid material or segmented design. A throttle bushing is supplied for all compliant Arrangement 1 seals; however they are rarely provided or needed when Arrangement 2 and Arrangement 3 seals are provided.

As shown in Figure F.1 and Figure F.2, leakage past a floating throttle bushing is greater than a containment seal, but is small enough to contain or redirect excessive seal leakage. It is suitable for restricting leakage to work effectively with quench (Piping Plan 62) or leakage detection systems (i.e. Piping Plan 65A, 65B, 66A, and 66B).

F.7 Containment Seal Field Testing

F.7.1 General

Containment seals (3.1.21) are the outer seals used in Arrangement 2 configuration 2CW-CS and 2NC-CS are designed to operate at vapour recovery system back pressure during normal operation and in the event of inner seal failure contain the process fluid for a period of time long enough to enable activation of an alarm and safe shut down of the equipment. The functionality of a containment seal is not monitored by piping plans 72, 76 and 75.

One way to verify containment seal performance in the field is to implement periodically a pressure test. This can be used to ascertain the condition of the faces and functionality of the containment seal flexible element. Users and seal vendors have developed methods of field testing containment seals.

F.7.2 Test Preperation

The containment seal chamber must first be isolated, valves connecting the plan 75 or 76 to the vapour recovery system (see 1 Figure G.33 and FigureG.35) should be blocked in prior to the test. This retains the functionality of the pressure indicator and transmitter within the test volume. If a plan 72 gas purge system is installed this is also isolated. The test volume is a combination of the containment seal chamber attached piping plan(s) and associated pipework. If there is any liquid retained this should be drained safely.

Check for any pressure rise which would indicate inner seals leakage. Any increase in pressure over 5 mins should be noted and an adjustment made from the allowable pressure drop in F.7.3

F.7.3 Pressure Test

A pressure test can then be applied using a test gas from potable test equipment. A test pressure of 25 psig (1.72 bar) is applied through the test connections of a plan 75 and the drain connection of a plan 76 pressurising the test volume. If a gas purge plan 72 system is connected this can alternatively be used to provide test gas.

The test volume is then isolated from the test gas and the pressure drop measured over a 5 min period. The pressure loss should not exceed 3 psi (0.21 bar) if the test volume is in the 0.5 to 1.0 cubic foot range (14 to 28 litres). Should the pressure loss exceed the above stated values it is advisable to replace the seal. After the test blocked in valves to the vent / gas purge system should be reopened.

The high pressure alarm function can also be checked during the same test.

The test volume in the containment seal cavity alone or containment seal plus the associated plan 76 piping may be less than 0.5 cubic foot (14 litres). The test will then be more sensitive and could result in a greater pressure drop. In such circumstances a larger volume in the mobile test equipment can be introduced. Alternatively, a reduction in the test time period or an increase in allowable pressure drop can be considered. User should consult seal vendor for additional guidance.

Note API 682 arrangement 2 inner seals are designed seals to have an internal (reverse) balance feature to withstand reverse pressure differentials (7.2.1.1) up to 40 psi (0.275 MPa) (2.75 bar) For Non API-682 seals consult seal vendor for a suitable test pressure.

This test protocol would be performed with equipment static. Some users have adapted for a dynamic or online test of a containment seal, but isolation of the containment seal in a dynamic state can result in accelerated wear of the faces. User should consult seal vendor for suitability.

F.8. Piping Plan 15, 25, and 35

F.8.1 General

Since the publication of API 682 4th edition the use of filtered flush systems has increased. Accordingly, piping plans 15, 25 and 35 have been added to Annex G. Plan 15 is commonly applied to 2NC-CS arrangements in natural gas liquids (NGL) pipeline applications. Mechanical seals of this type require a very clean flush at all times. The dual filter configuration recommended for Plan 15 in these services, where the condition of the active filter element is monitored by a differential pressure transmitter with a local indicator.

Single filter alternate option may be specified by a user. See F.8.2.1d), below.

F.8.2 Single and Dual Filter Strategies

As solids accumulate in a filter element, the flush flow rate to the mechanical seal will decrease, and seal generated heat removal will decline. This will reduce the life of the seal or even cause a sudden failure. Purchasers can elect the default dual filter arrangement or specify a single filter arrangement. A dual filter arrangement allows the end user to isolate and change one filter element while the flush fluid continues to be filtered by the second filter. A single filter can be changed while the pump is in operation, but the flush is routed through a bypass line with no filter installed. The choice between a dual and single filter depends on the following factors:

a) Percent and frequency of solids in the process. Some processes are known to be clean during certain phases of plant operation during which the flush can be bypassed without filtration. A single filter may be sufficient if the new filter element is on hand and ready to be installed.
b) Replacing filters with higher pressure ratings may take more experience. Filter housing bolting and gasketing may require more specialized knowledge. An unanticipated delay or damage to the filter housing may require the user to run for a long period of time with the flush unfiltered. In these cases, the default dual filter arrangement is a better solution.
c) A filter element may have become severely fouled. If the filter housing requires extensive time to clean out before the new element can be installed, a dual filter arrangement allows this to be done thoroughly without allowing an unfiltered flush to enter the seal chamber for a long period of time.
d) Mechanical seal type. High performance seals such as 2NC-CS usually need to have a very clean flush at all times. The default dual filter is the best choice in this case. Applications with flashing hydrocarbons may be compromised by face damage caused by a very low percentage of solids. 2CW-CS and 2CW-CW designs may use a multiport flush baffle with small holes that can plug. A dual filter limits the risk of these situations.

Annex G
(normative)

Standard Piping Plans and Auxiliary Hardware

G.1 General

This annex contains drawings, descriptions, and tutorials of standard piping plans and auxiliary hardware that have regularly been used in industry. While not all of these piping plans are referenced in this standard, they may have applications in special cases with purchaser approval.

Seals shall be shipped with plastic shipping plugs installed in the ports. All plastic plugs shall be removed from the seal at installation. All ports shall be either connected to piping or tubing to support the appropriate piping plan or plugged with a metal plug as described in 6.1.2.18.

The pumps, seal chambers, and seal designs used in these figures are intended to illustrate the required principles and design features of the piping plans. Although all piping plans are illustrated with a generic single-stage, overhung horizontal centrifugal pump, the piping plans are equally applicable to other pump designs (e.g. vertical and between bearing pumps.) The seals used in the figures are also intended to show the generic location of the seals relative to the piping plans. Other seal designs detailed in this standard (e.g. types, configurations, categories, rotating vs stationary options) as well as designs from different manufacturers may have a different appearance than the generic seals used in the figures. The seals illustrated are not an endorsement of a specific design or configuration.

In piping plans using seal coolers, the figures show a generic cooler. The actual design of the cooler, port locations, and mounting requirements will be specified by the cooler supplier. Any piping plan using a seal cooler may interchangeably use either a water-cooled or air-cooled seal cooler (in accordance with the cooler requirements of this standard) and still retain the same piping plan designation.

The details for each of the piping plans represent the minimum requirements for the piping plans. It is not uncommon, however, for users of this standard to specify slight variations to these piping plans. An example may be that the user specifies a level switch rather than a level transmitter. Substitutions for the instrumentation requirements in these piping plans are allowed (with purchaser's approval) while still retaining the piping plan designations described in this standard. To accommodate piping plans not shown in this annex, a Piping Plan 99 should be selected that allows the purchaser to fully specify the requirements of the piping plan.

The piping plan figures are intended to only be a graphical illustration of the piping plan and not a complete P&ID of the system or an installation drawing. Some features such as fitting, flanges, etc. are not shown. Other items such as block and bleed valves on instrumentation or other components are omitted for clarity. The purchaser is responsible for ensuring the final installed system complies with the purchasing and end user specifications.

Unless otherwise specified, the scope of supply for the piping plans in this annex will be mutually agreed upon between the purchaser and the vendor.

G.2 Symbol Library

flow indicator	FI
flow orifice	FO
flow transmitter with local indicator	FIT
level indicator	LI
level transmitter	LT
level transmitter with local indicator	LIT
pressure differential transmitter with local indicator	PDIT
pressure indicator	PI
pressure transmitter with local indicator	PIT
temperature indicator	TI
temperature transmitter with local transmitter	TIT
high level alarm set point	**HLA**
low level alarm set point	**LLA**
normal liquid level	**NLL**

Figure GE..1—Instrument Symbols

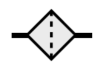
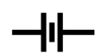
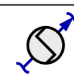
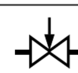
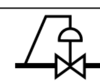
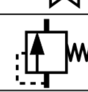
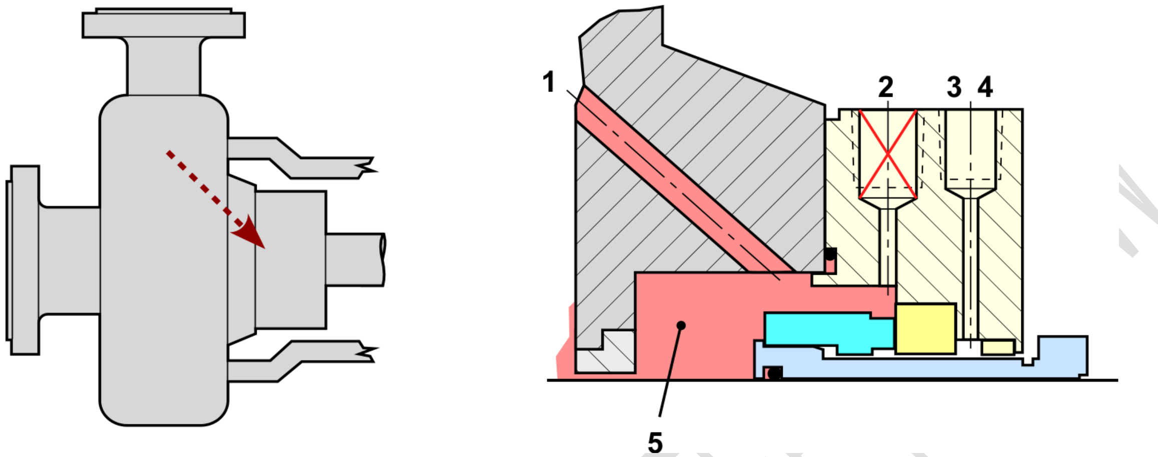
process fluid piping	
process fluid in equipment	
external liquid piping	
external liquid in equipment	
external gas piping	
external gas in equipment	
cooling water piping	
cyclone separator	
filter	
flow orifice	
seal cooler	
strainer, Y	
valve, normally open	
valve, normally closed	
valve, three-way	
valve, check	
valve, needle	
valve, pressure control	
valve, pressure relief	

Figure G.2—Color Legend and Equipment Symbols

G.3 Piping Plan 01



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 inlet

2 flush (F), plugged (for possible future circulating fluid or for venting on vertical pumps)

3 quench (Q)

4 drain (D)

5 seal chamber

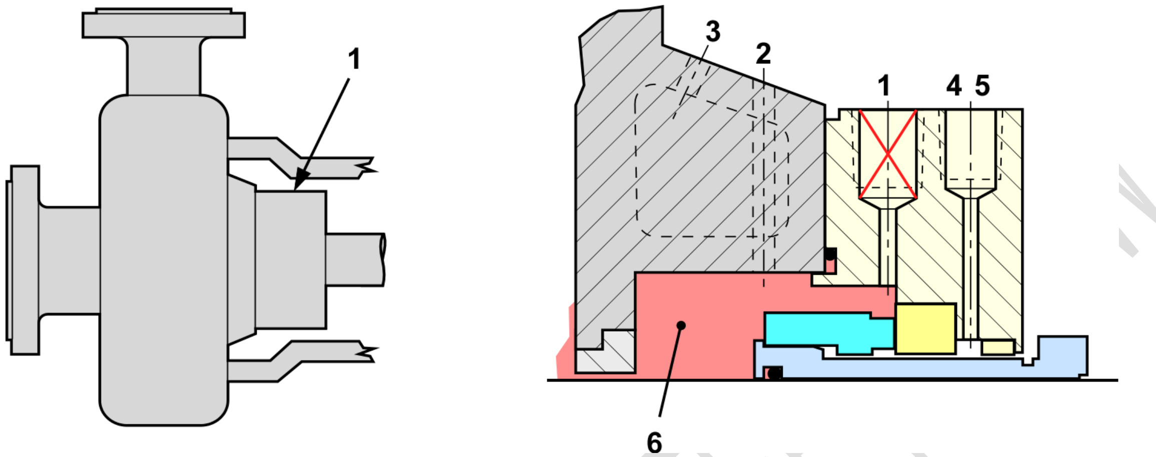
Figure G.3—Standard Seal Piping Plan 01

In Piping Plan 01, integral (internal) recirculation is from a high-pressure region of the pump to the seal chamber.

NOTE Piping Plan 01 is similar to a Piping Plan 11 except that internal porting is used to direct flow to the seal chamber from an area behind the impeller near the discharge. This porting also serves to vent the chamber during commissioning of the pump. This plan is recommended for clean fluids only. Piping Plan 01 may be useful with liquids that thicken or solidify at normal ambient temperatures to minimize the risk of freezing the fluid in flush piping. Special attention is needed to ensure that the recirculation supplied is sufficient for the seal operating requirements.

Piping Plan 01 is not recommended for vertical pumps because of difficulty in venting the seal chamber.

G.4 Piping Plan 02



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 flush (F), plugged (for possible future circulating fluid or for venting on vertical pumps)

2 vent (V), if required

3 heating/cooling inlet (HI or CI), heating /cooling outlet (HO or CO), if required

4 quench (Q)

5 drain (D)

6 seal chamber

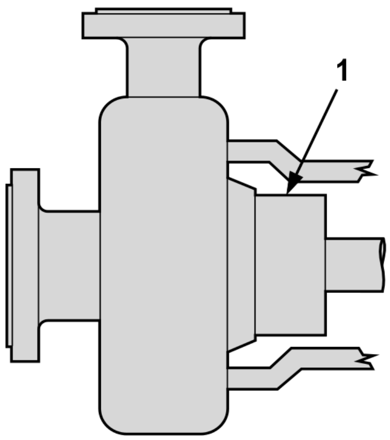
Figure G.4—Standard Seal Piping Plan 02

Piping Plan 02 has a dead-ended seal chamber with no recirculation of flushed fluid.

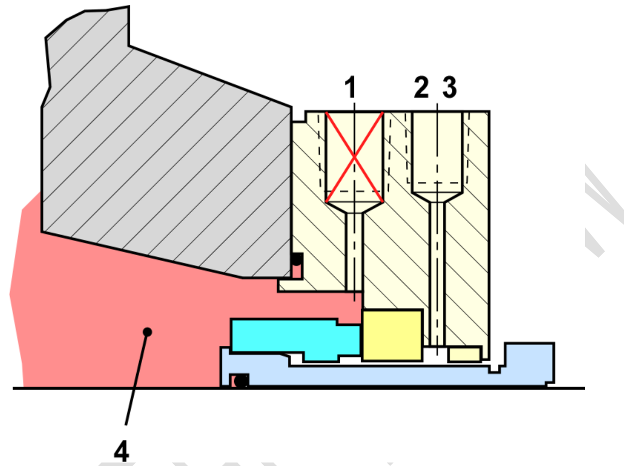
Piping Plan 02 is more common in the chemical industry in applications with low seal chamber pressures and process temperatures. The process fluid should be relatively clean to avoid excessive erosion of the seal gland, seal chamber, or seal parts created by the swirling flow pattern. The vapor pressure sensitivity of the process fluid should also be taken into consideration to avoid flashing conditions in the seal chamber or at the seal faces. Piping Plan 02 can be used with cool clean fluids with high specific heats, such as water, in relatively low-speed pumps. The product temperature margin should be carefully reviewed for any application where the selection of Piping Plan 02 is being considered.

Pumps may optionally be provided with cooling or heating jackets to assist in controlling the temperature in the seal chamber. Cooling jackets are prone to fouling in high-temperature applications and shall be used only with great care.

G.5 Piping Plan 03



a) Piping and Instrumentation Schematic



b) Seal Chamber Details

Key

1 flush (F), plugged (for possible future circulating fluid or for venting on vertical pumps)

2 quench (Q)

3 drain (D)

4 seal chamber

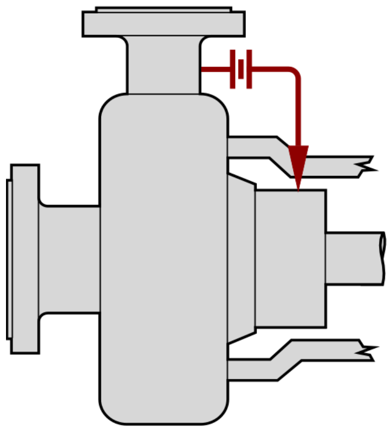
Figure G.5—Standard Seal Piping Plan 03

In Piping Plan 03 there is circulation between the seal chamber and the pump created by the design of the seal chamber.

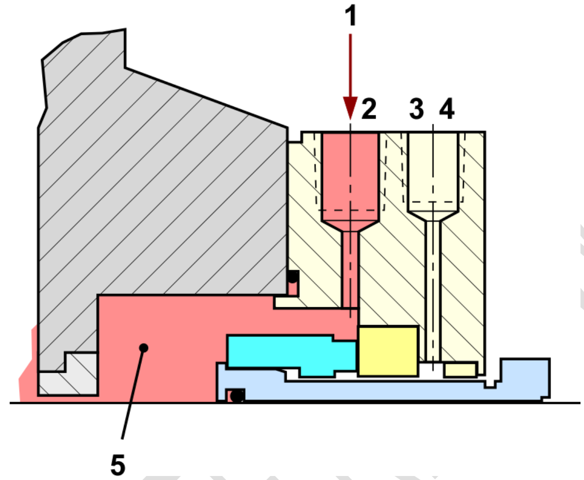
Piping Plan 03 is commonly used in pump designs where the seal chamber has a tapered bore and no throat bushing. This seal chamber geometry or flow enhancement features in the seal chamber create circulation that provides cooling for the seal and vent air or vapors from the seal chamber. This piping plan is most often used in applications where there is not significant seal generated heat. It is also used in applications where there may be solids that could collect in a traditional seal chamber.

NOTE This piping plan is most commonly used with Category 1 seals.

G.6 Piping Plan 11



a) Piping and Instrumentation Schematic



b) Seal Chamber Details

Key

1 from high-pressure region of pump (pump discharge or pump discharge piping)

2 flush (F)

3 quench (Q)

4 drain (D)

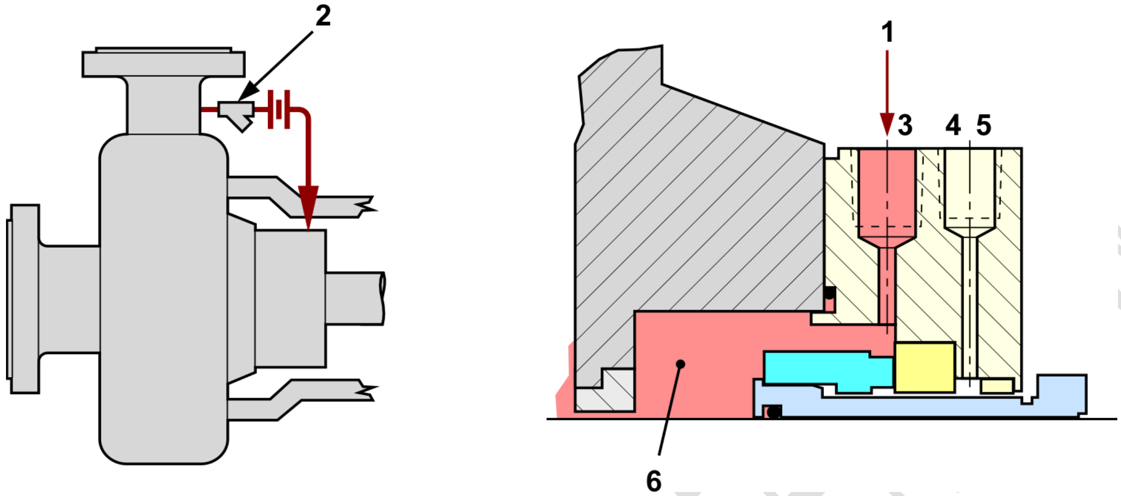
5 seal chamber

Figure G.6—Standard Seal Piping Plan 11

In Piping Plan 11 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a flow control orifice to the seal. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

Piping Plan 11 is the default seal flush piping plan for all Arrangement 1 and 2 seals. In Piping Plan 11, product is routed from the pump discharge to the seal chamber to provide cooling for the seal and to vent air or vapors from the seal chamber. Fluid then flows from the seal chamber back into the process stream. It is the most commonly used piping plan for clean general service equipment. For high-head applications, careful consideration should be given to calculation of the required flush flow rate. Calculations are required to determine the proper orifice and throat bushing dimensions to assure adequate seal flush flow. In pumps with low differential head or pumping high-viscosity fluids, the required flow rate for the piping plan may be achieved without the flow control orifice. Care shall be taken when using this piping plan with polymerizing fluid that may plug the orifice and connecting piping.

G.7 Piping Plan 12



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 from strainer

2 strainer

3 flush (F)

4 quench (Q)

5 drain (D)

6 seal chamber

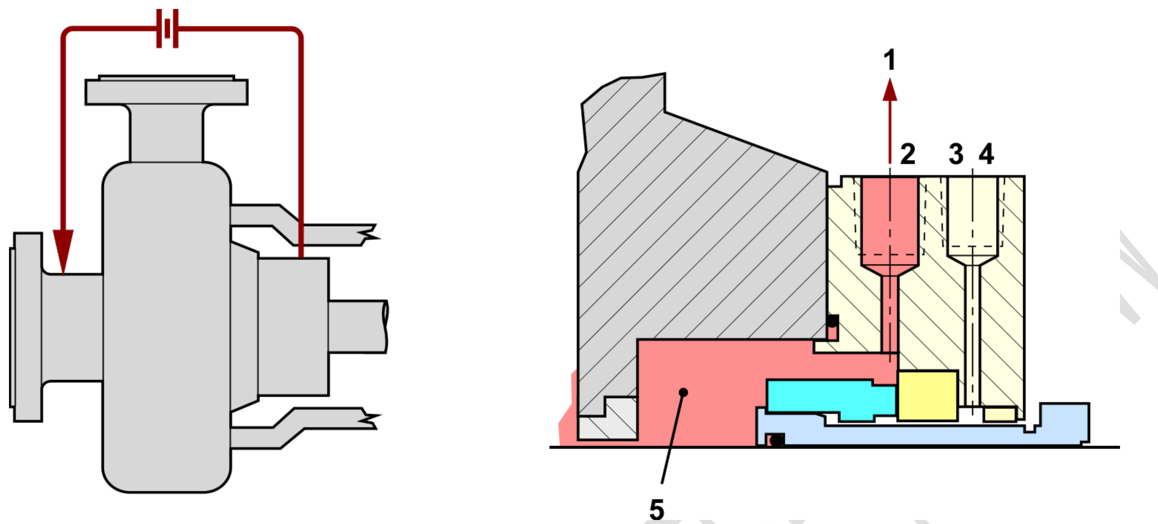
Figure G.7—Standard Seal Piping Plan 12

In Piping Plan 12 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a strainer and a flow control orifice into the seal. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

This plan is similar to a Piping Plan 11, with the addition of a strainer to remove occasional particles. Strainers are not commonly recommended in piping plans because blockage of the strainer will cause a seal failure.

This piping plan has not proven to achieve a three year (3-yr) operating life.

G.8 Piping Plan 13



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 to pump suction

2 flush (F)

3 quench (Q)

4 drain (D)

5 seal chamber

Figure G.8—Standard Seal Piping Plan 13

In Piping Plan 13 there is recirculation from the seal chamber through a flow control orifice and back to the pump suction or pump suction piping. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

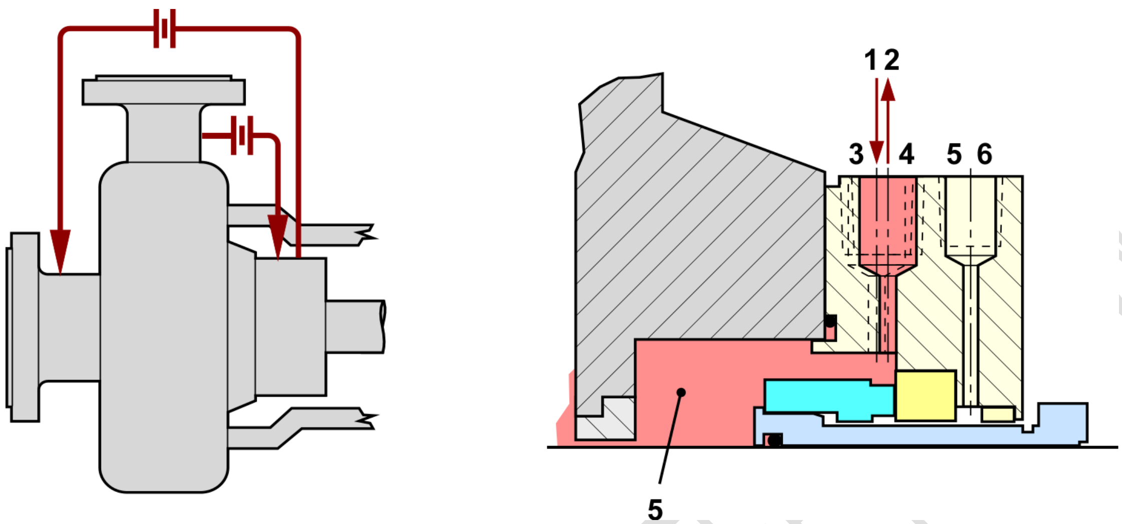
NOTE Piping Plan 13 is the standard pipng plan selection for vertical pumps that are not provided with a bleed bushing below the seal chamber. The seal chamber pressure on some vertical pumps (most VS pumps) supplied without a bleed bushing would normally operate at full discharge pressure. Because of this arrangement there is no pressure differential to allow a Piping Plan 11 to work. In Piping Plan 13, product is routed from the seal chamber back to the pump suction to provide cooling for the seal and to vent air or vapors from the seal chamber.

Piping Plan 13 provides self-venting on vertical in-line pumps provided differential pressure is sufficient to ensure circulation and seal chamber pressure is sufficient to prevent vaporization.

Piping Plan 13 is also used in high-head pumps where the use of Piping Plan 11 would require too small of an orifice or would produce too high a flush flow rate. This piping plan will generally not work well in low-head pumps because of the low-pressure differential between the seal chamber and the pump suction. The suitability of the service for Piping Plan 13 can be determined by calculating the required flush flow rate and then calculating the required orifice size.

A distributed flush injection is not recommended with a Piping Plan 13.

G.9 Piping Plan 14



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from pump discharge
2	to pump suction
3	flush inlet (FI)
4	flush outlet (FO)
5	quench (Q)
6	drain (D)
7	seal chamber

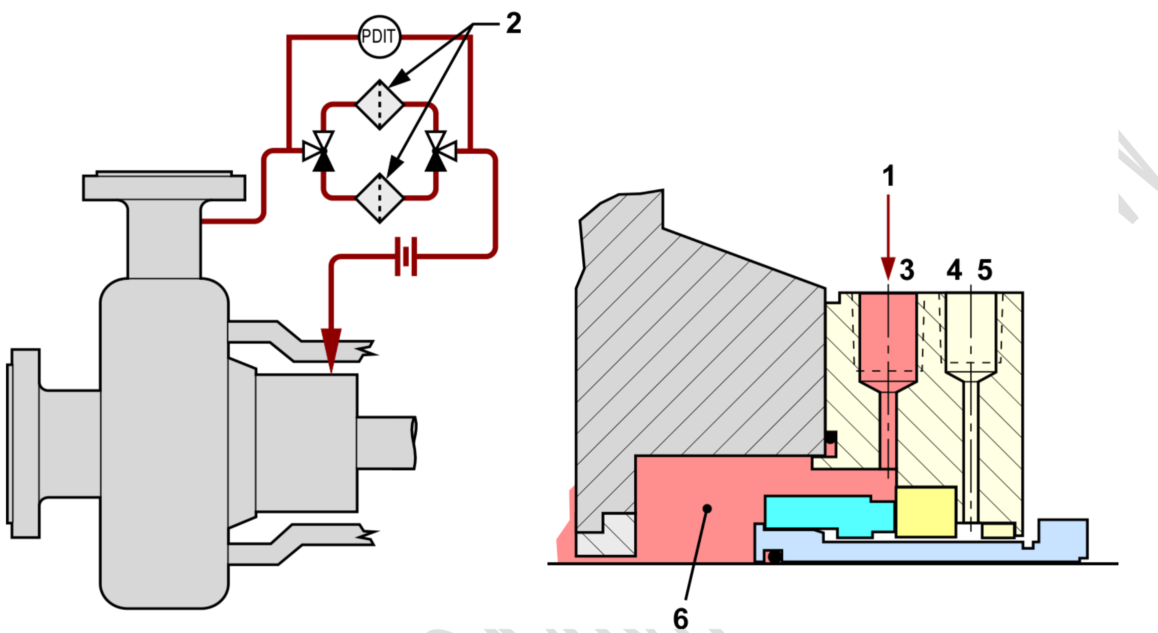
Figure G.9—Standard Seal Piping Plan 14

In Piping Plan 14 there is recirculation from pump discharge through a flow control orifice to the seal and simultaneously from the seal chamber through a flow control orifice (if required) to pump suction. This allows fluid to enter the seal chamber and provide cooling while continuously venting the pressure in the seal chamber. Piping Plan 14 is a combination of Piping Plan 11 and Piping Plan 13.

NOTE Piping Plan 14 is most commonly used on vertical pumps.

A distributed flush injection is not recommended with a Piping Plan 14.

G.10 Piping Plan 15



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from filter
2	filter
3	flush (F)
4	quench (Q)
5	drain (D)
6	seal chamber
PDIT	differential pressure transmitter with local indicator

Figure G.10—Standard Seal Piping Plan 15

In Piping Plan 15 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a filter and a flow control orifice to the seal. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

Piping Plan 15 is intended for applications where the process fluid contains solids which may negatively impact seal performance. In Piping Plan 15, product is routed from the pump discharge through the filter to the seal chamber to provide cooling for the seal and to vent air or vapors from the seal chamber. Fluid then flows from the seal chamber back into the process stream. It is most commonly used in applications with a very low concentration of fine solid contaminants. For high-head applications, careful consideration should be given to calculation of the required flush flow rate. Calculations are required to determine the proper orifice and throat bushing dimensions to assure adequate seal flush flow. In pumps with low differential head or pumping high-viscosity fluids, the required flow rate for the piping plan may be achieved without the flow control orifice. Care shall be taken when using this piping plan with polymerizing fluid that may plug the filter, orifice or connecting piping.

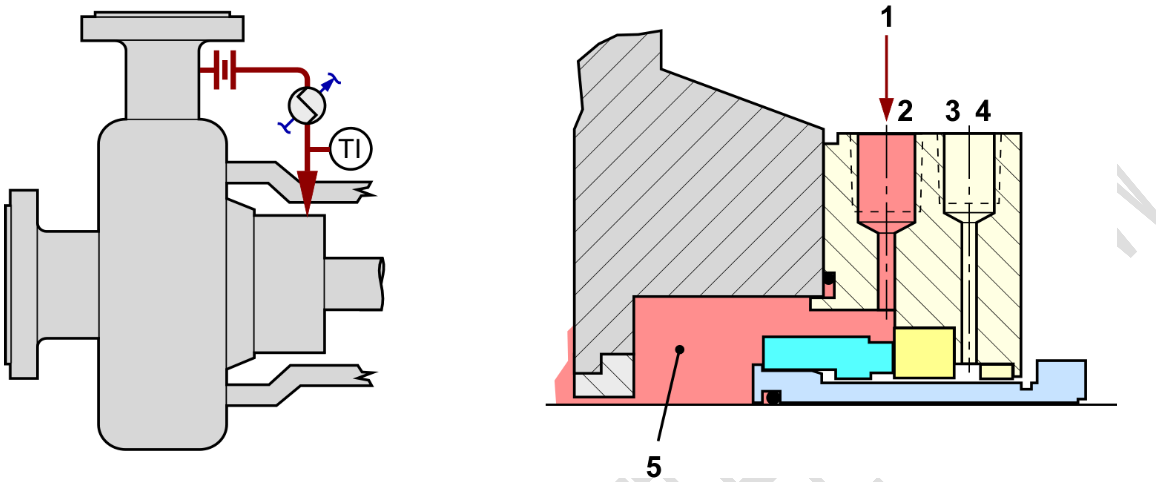
The recommended filter configuration for this piping plan is a dual filter configuration where the condition of the active filter element is monitored by a differential pressure transmitter with a local indicator. A high differential pressure indicates that the filter element is becoming plugged. The dual filter arrangement allows the operator to switch over to a clean filter while performing maintenance on the plugged filter. The filter arrangement shown in Figure G.10 is intended to represent this capability. Each filter volume and capacity shall be sized to accommodate the required flush flow rate.

The actual piping arrangement (piping, PDIT, filters, and valves) will vary depending upon the specific components selected for the filter on this piping plan. Other components such as a filter drain, vent, and equalization line and not shown in this figure. The actual procedure for performing maintenance on the filter element is the responsibility of the end user.

As an alternate, an end user may specify a single filter element with a PDIT or single filter element with a bypass line and a PDIT.

For additional information on single or dual filter strategies in Annex F for Piping Plans 15, 25, and 35.

G.11 Piping Plan 21



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from high-pressure region of pump (pump discharge or pump discharge piping)
2	flush (F)
3	quench (Q)
4	drain (D)
5	seal chamber
TI	temperature indicator

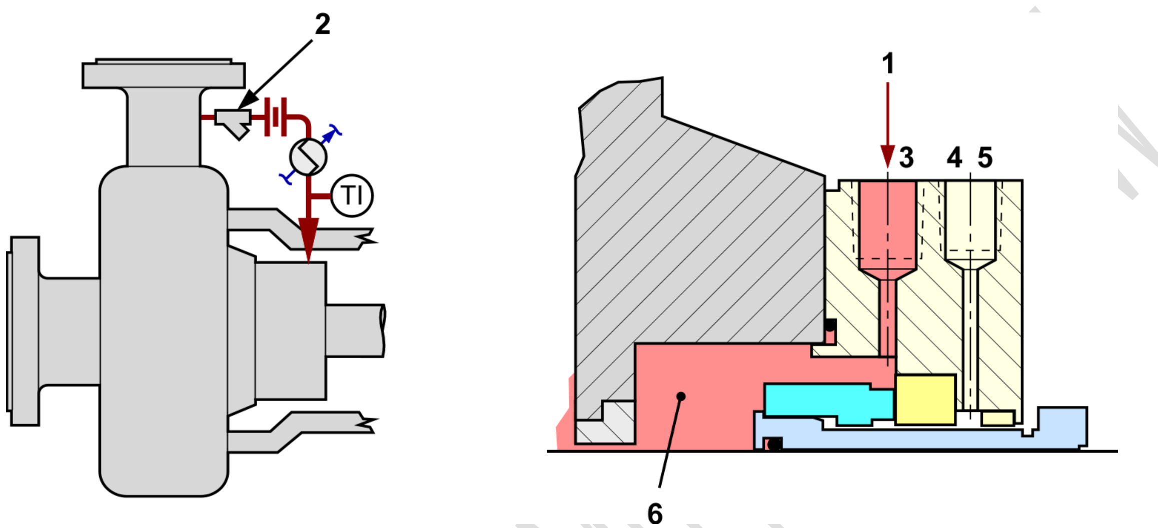
Figure G.E.11—Standard Seal Piping Plan 21

In Piping Plan 21 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a flow control orifice and cooler, then into the seal chamber. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

In Piping Plan 21, product in the seal chamber is isolated from that in the impeller area of the pump by a throat bushing. Piping Plan 21 provides a cool flush to the seal. This may be needed to improve the margin to vapor formation, to meet secondary sealing element temperature limits, to reduce coking or polymerizing, or to improve lubricity (as in hot water). The benefit of Piping Plan 21 is that it not only provides a cool flush but also has sufficient pressure differential to allow good flow rates. The drawback is that the cooler duty is high, leading to fouling and plugging on the water side and potential plugging on the process side if the fluid becomes too viscous. Piping Plan 21 works best in dry climates where a vertically oriented, finned air cooler is used instead of a water cooler. Piping Plan 21 also uses more energy than Piping Plan 23, because the pumped fluid that is used for the flush is repumped from suction back to the discharge. A close clearance throat bushing is recommended to isolate the cooled process fluid from the pump fluid.

In pumps with low differential head or pumping high-viscosity fluids, the required flow rate for the piping plan may be achieved without the flow control orifice. Care shall be taken when using this piping plan with polymerizing fluid that may plug the orifice and connecting piping.

G.12 Piping Plan 22



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from high-pressure region of pump (pump discharge or pump discharge piping)
2	strainer
3	flush (F)
4	quench (Q)
5	drain (D)
6	seal chamber
TI	temperature indicator

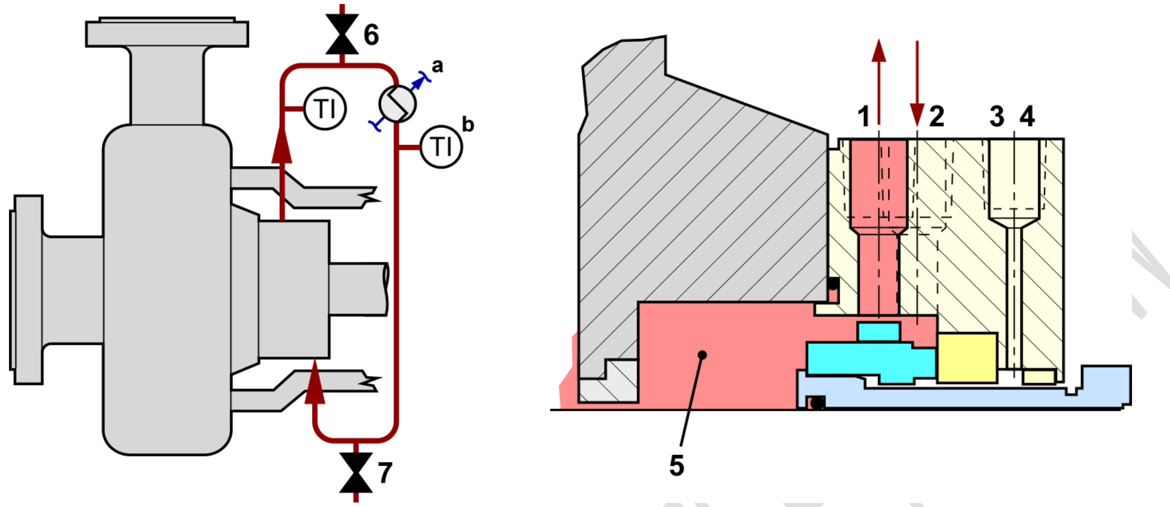
Figure G.12—Standard Seal Piping Plan 22

In Piping Plan 22 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a strainer, a flow control orifice, a cooler, and into the seal chamber.

This piping plan is similar to a Piping Plan 21, with the addition of a strainer to remove occasional particles. Strainers are not commonly recommended in piping plans because blockage of the strainer will cause a seal failure.

This piping plan has not proven to achieve a three-year (3-yr) operating life.

G.13 Piping Plan 23



a) Piping and Instrumentation Schematic

b) Seal Chamber Details

Key

1 flush outlet (FO)

2 flush inlet (FI)

3 quench (Q)

4 drain (D)

5 seal chamber

6 vent (normally closed)

7 drain (normally closed)

TI temperature indicator

[a] Vertically oriented finned air cooler shall be installed if specified.

[b] Optional

Figure G.E.13—Standard Seal Piping Plan 23

In Piping Plan 23 there is recirculation from a circulation device in the seal chamber through a cooler and back into the seal chamber.

NOTE In Piping Plan 23, product in the seal chamber is isolated from that in the impeller area of the pump by a throat bushing. The seal is equipped with an internal circulating device that circulates seal chamber fluid through a cooler and back to the seal chamber. To maximize circulation, the piping losses should be minimized through the proper selection of pipe size, elimination of fittings, use of large radius bends, and reduction in the length of piping runs. See Figure G.37 for recommended piping practices.

In Piping Plan 23, the cooler cools only that fluid in which the seal operates, and this cool fluid does not enter the process. This results in high energy efficiency. Lessening the duty is very desirable because it extends the life of the cooler. The industry has considerable negative experience with Piping Plan 21 and Piping Plan 22 because of cooler plugging.

A throat bushing is required to improve isolation between the process fluid and the seal chamber fluid. In pumps with no throat bushing or an installed bushing with an excessive clearance, a dedicated throat bushing may be required.

Effective flow of the Piping Plan 23 system is only achieved with proper exclusion of all gas and air bubbles from the seal cooler and piping. Venting of the system during commissioning is critical to proper operation (as referenced in 6.1.2.20). The process fluid vented through the vent valve should be routed to a safe location or connected to a drain or recovery system. This is necessary to prevent exposing the operator to process fluid during venting and to comply with local process disposal requirements.

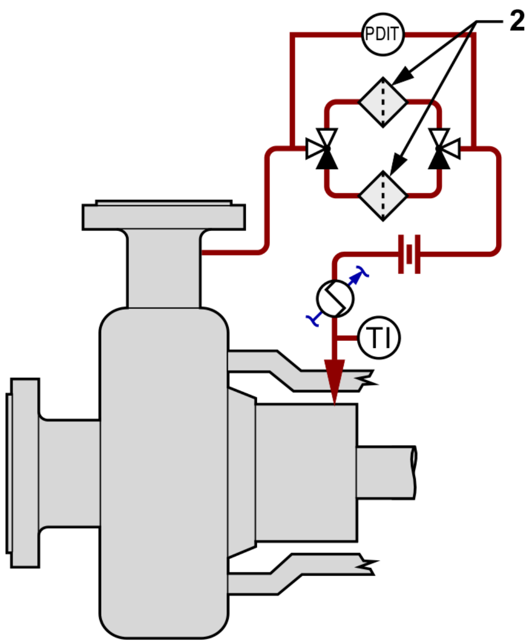
The drain valve is used to drain process fluid from the piping plan during decommissioning of the pump and during seal or piping plan maintenance. The process fluid from the drain valve should be routed to a safe location or connected to a drain or recovery system. This is necessary to prevent exposing the operator to process fluid during draining and to comply with local process disposal requirements.

Piping Plan 23 is the piping plan of choice for all hot water services, particularly boiler feed water, and many hydrocarbon services. This piping plan is the standard selection for hot water at 80 °C (180 °F) and above, and boiler feed water. Hot water has very low lubricity above 80 °C (180 °F), resulting in high seal face wear. This piping plan is also desirable in many hydrocarbon and chemical services where it is necessary to cool the fluid to establish the required margin between fluid vapor pressure (at the seal chamber temperature) and seal chamber pressure. In a Piping Plan 23, the cooler only removes seal face-generated heat plus heat soak from the process. This duty is usually much less severe than that in Piping Plan 21 or Piping Plan 22.

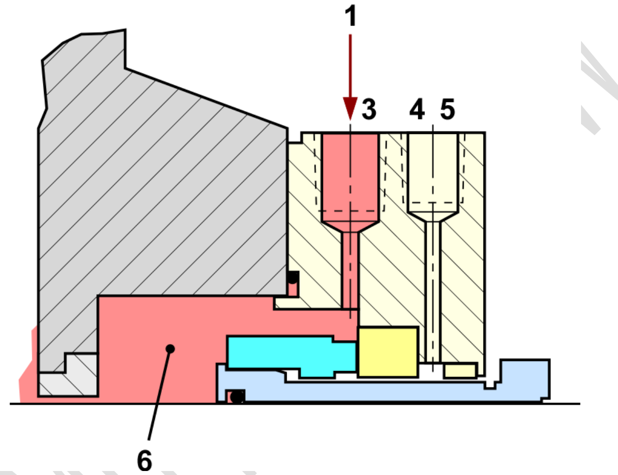
High-freezing-point and viscous products should be considered when selecting a Piping Plan 23 flush system. The cooler might cool the fluid below the point of circulation. In these applications, consider using steam as a cooling medium, or use a Piping Plan 21 system.

A distributed flush injection is not recommended with a Piping Plan 23.

G.14 Piping Plan 25



a) Piping and Instrumentation Schematic



b) Seal Chamber Details

Key

1	from cooler
2	filter
3	flush (F)
4	quench (Q)
5	drain (D)
6	seal chamber
PDIT	differential pressure transmitter with local indicator
TI	temperature indicator

Figure G.E.14—Standard Seal Piping Plan 25

In Piping Plan 25 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a filter, a flow control orifice and a cooler, then into the seal chamber. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

In Piping Plan 25, product in the seal chamber is isolated from that in the impeller area of the pump by a throat bushing. Piping Plan 25 provides a cool, clean flush to the seal. This may be needed to improve the margin to vapor formation, to meet secondary sealing element temperature limits, to reduce coking or polymerizing, or to improve lubricity (as in hot water) while filtering contamination from the process fluid. The benefit of Piping Plan 25 is that it not only provides a cool, clean flush but also has sufficient pressure differential to allow good flow rates. One drawback is that the cooler duty is high, leading to fouling and plugging on the water side and potential plugging on the process side if the fluid becomes too viscous.

Another drawback is the fluids with higher concentrations of contaminants can lead to rapid filter plugging and increased maintenance. Piping Plan 25 works best in dry climates where a vertically oriented, finned air cooler is used instead of a water cooler. Piping Plan 25 also uses more energy than Piping Plan 23, because the pumped fluid that is used for the flush is repumped from suction back to the discharge. A close clearance throat bushing is recommended to isolate the cooled process fluid from the pump fluid.

In pumps with low differential head or pumping high-viscosity fluids, the required flow rate for the piping plan may be achieved without the flow control orifice. Care shall be taken when using this piping plan with polymerizing fluid that may plug the orifice, filter, or connecting piping.

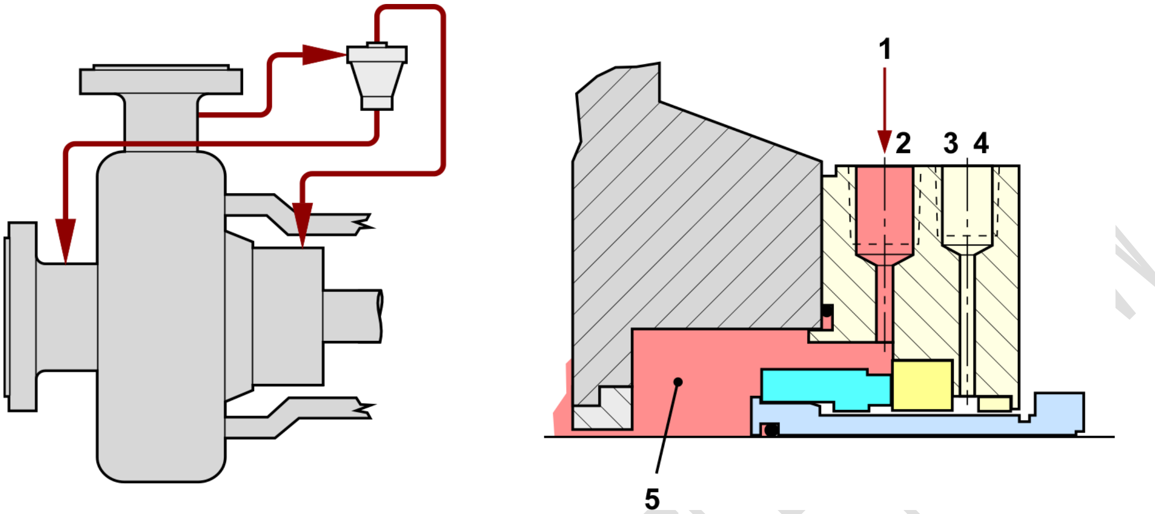
The recommended filter configuration for this piping plan is a dual filter configuration where the condition of the active filter element is monitored by a differential pressure transmitter with a local indicator. A high differential pressure indicates that the filter element is becoming plugged. The dual filter arrangement allows the operator to switch over to a clean filter while performing maintenance on the plugged filter. The filter arrangement shown in Figure G.10 is intended to represent this capability. Each filter volume and capacity shall be sized to accommodate the required flush flow rate.

The actual piping arrangement (piping, PDIT, filters, and valves) will vary depending upon the specific components selected for the filter on this piping plan. Other components such as a filter drain, vent, and equalization line and not shown in this figure. The actual procedure for performing maintenance on the filter element is the responsibility of the end user.

As an alternate, an end user may specify a single filter element with a PDIT or single filter element with a bypass line and a PDIT.

For additional information on single or dual filter strategies in Annex F for Piping Plans 15, 25, and 35.

G.15 Piping Plan 31



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 from clean discharge connection of cyclone separator

2 flush (F)

3 quench (Q)

4 drain (D)

5 seal chamber

Figure G.15E.—Standard Seal Piping Plan 31

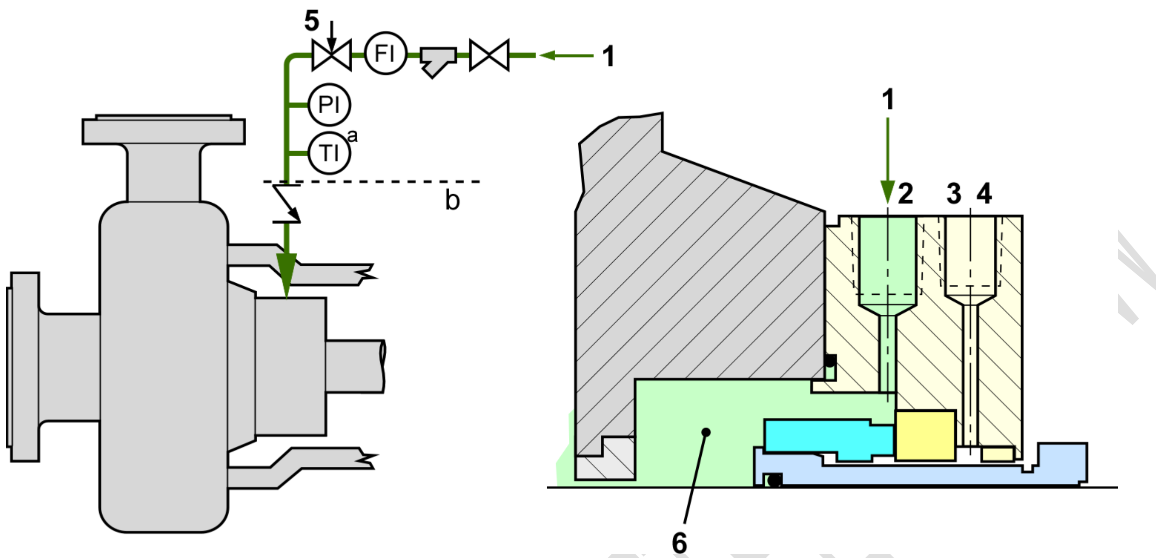
In Piping Plan 31 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a cyclone separator delivering the clean fluid to the seal chamber. The solids are delivered to the pump suction line.

Piping Plan 31 is specified only for services containing solids with a specific gravity at least twice that of the process fluid. A typical use of this piping plan is water service to remove sand or pipe slag. In Piping Plan 31, product is routed from the discharge of the pump into a cyclone separator. Solid particles are centrifuged from the stream and routed back to suction. The seal flush is routed from the cyclone separator into the flush connection on the seal gland plate. If the process stream is very dirty or is a slurry, Piping Plan 31 typically is inadequate and is not recommended. The use of a pump throat bushing is recommended when specifying a Piping Plan 31.

Cyclone separators are not generally recommended for process fluids that contain gases.

Field experience has shown that abrasive wear on the inside of the cyclone may result in reduced reliability. Reliability can be improved by inspecting the cyclone separators at regular intervals. This piping plan has not proven to consistently achieve a three-year (3-yr) operating life.

G.16 Piping Plan 32



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from external source	6	seal chamber
2	flush (F)	FI	flow indicator
3	quench (Q)	PI	pressure indicator
4	drain (D)	TI	temperature indicator
5	needle or globe valve		

a Optional

b Pressure and temperature boundary for seal flush supply system

Figure E.G.16—Standard Seal Piping Plan 32

In Piping Plan 32, flush is injected into the seal chamber from an external source.

The check valve and all components downstream from the check valve must be rated to the MAWP and MAWT of the pressure casing. All components located upstream of the check valve must be rated to a minimum of the MAWP and MAWT of the supply system or as defined by the purchaser.

NOTE Piping Plan 32 is used in services containing solids or contaminants, in which a suitable cleaner or cooler external flush will improve the seal environment. It is also used to reduce flashing or air intrusion (in vacuum services) across the seal faces by providing a flush that has a lower vapor pressure or that will raise the seal chamber pressure to an acceptable level.

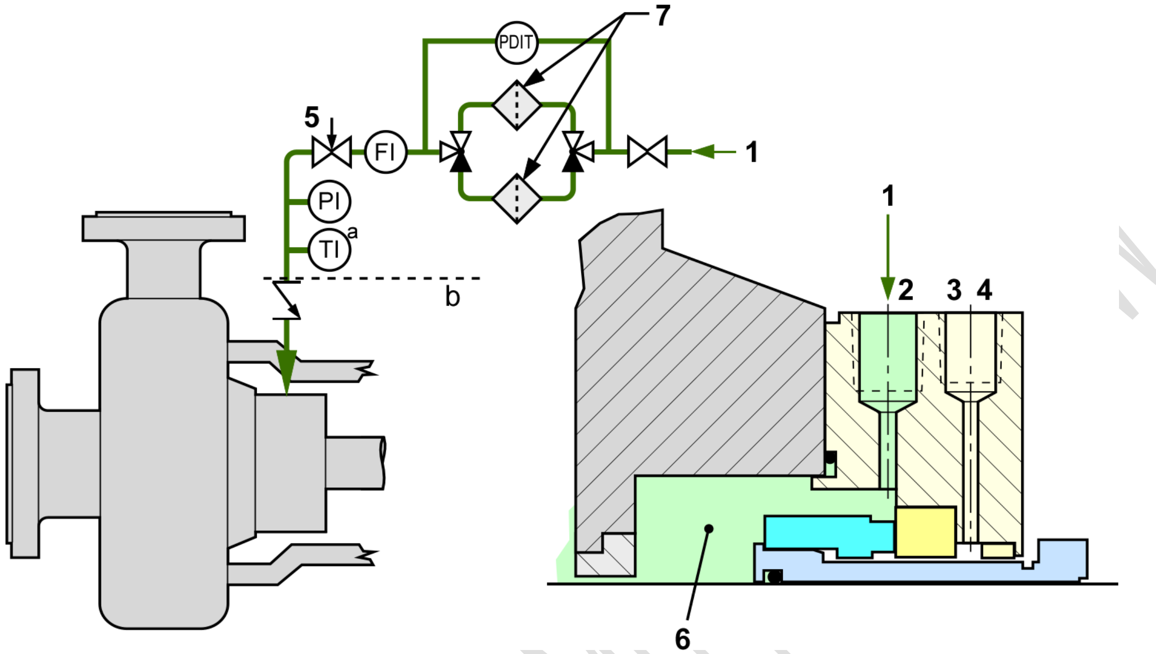
In Piping Plan 32, the flushing product is brought from an external source to the seal. The external flush should be continuous and reliable even during nonstandard situations such as start-up or shutdown.

Care shall be exercised in choosing a Piping Plan 32 flush fluid. Since the fluid will flow into the process, it shall be chemically compatible with the process and not degrade the quality of the process fluid. In high-temperature applications, the user should consider the effects of the potential for the Piping Plan 32 flush fluid to flash under pump conditions and degrade pump performance.

This piping plan is almost always used in conjunction with a close-clearance throat bushing. The bushing can function as a throttling device to maintain an elevated pressure in the stuffing box or as a barrier to isolate the pumped product from the seal chamber.

Piping Plan 32 is not recommended for cooling only, as the energy costs can be very high. Product degradation costs should also be considered when using a Piping Plan 32.

G.17 Piping Plan 35



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from external source	7	filter, mesh
2	flush (F)	FI	flow indicator
3	quench (Q)	PI	pressure indicator
4	drain (D)	TI	temperature indicator
5	needle valve or globe valve	PDIT	differential pressure transmitter with local indicator
6	seal chamber		

a Optional

b Pressure and temperature boundary for seal flush supply system

Figure E.G.16—Standard Seal Piping Plan 35

In Piping Plan 35, flush is injected into the seal chamber from an external source.

The check valve and all components downstream from the check valve must be rated to the MAWP and MAWT of the pressure casing. All components located upstream of the check valve must be rated to a minimum of the MAWP and MAWT of the supply system or as defined by the purchaser.

NOTE Piping Plan 35 is used in services containing solids or contaminants, in which a suitable cleaner or cooler external flush will improve the seal environment. In a Piping Plan 35, the external flush is further cleaned by passing the external flush through a filter in the supply line. It is also used to reduce flashing or air intrusion (in vacuum services) across the seal faces by providing a flush that has a lower vapor pressure or that will raise the seal chamber pressure to an acceptable level.

In Piping Plan 35, the flushing product is brought from an external source to the seal. The external flush should be continuous and reliable even during nonstandard situations such as start-up or shutdown.

Care shall be exercised in choosing a Piping Plan 35 flush fluid. Since the fluid will flow into the process, it shall be chemically compatible with the process and not degrade the quality of the process fluid. In high-temperature applications, the user should consider the effects of the potential for the Piping Plan 35 flush fluid to flash under pump conditions and degrade pump performance.

This piping plan is almost always used in conjunction with a close-clearance throat bushing. The bushing can function as a throttling device to maintain an elevated pressure in the stuffing box or as a barrier to isolate the pumped product from the seal chamber.

Piping Plan 35 is not recommended for cooling only, as the energy costs can be very high. Product degradation costs should also be considered when using a Piping Plan 35.

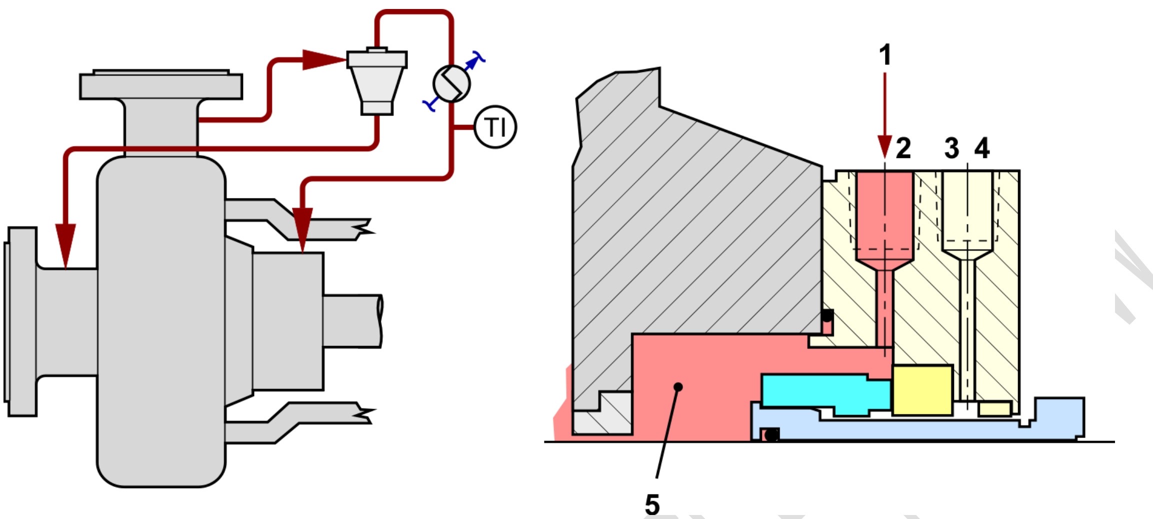
The recommended filter configuration for this piping plan is a dual filter configuration where the condition of the active filter element is monitored by a differential pressure transmitter with a local indicator. A high differential pressure indicates that the filter element is becoming plugged. The dual filter arrangement allows the operator to switch over to a clean filter while performing maintenance on the plugged filter. The filter arrangement shown in Figure G.10 is intended to represent this capability. Each filter volume and capacity shall be sized to accommodate the required flush flow rate.

The actual piping arrangement (piping, PDIT, filters, and valves) will vary depending upon the specific components selected for the filter on this piping plan. Other components such as a filter drain, vent, and equalization line and not shown in this figure. The actual procedure for performing maintenance on the filter element is the responsibility of the end user.

As an alternate, an end user may specify a single filter element with a PDIT or single filter element with a bypass line and a PDIT.

For additional information on single or dual filter strategies in Annex F for Piping Plans 15, 25, and 35.

G.18 Piping Plan 41



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from cooler
2	flush (F)
3	quench (Q)
4	drain (D)
5	seal chamber
TI	temperature indicator

Figure E.G.18—Standard Seal Piping Plan 41

In Piping Plan 41 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a cyclone separator delivering the clean fluid to a cooler and then to the seal chamber. The solids are delivered to the pump suction line.

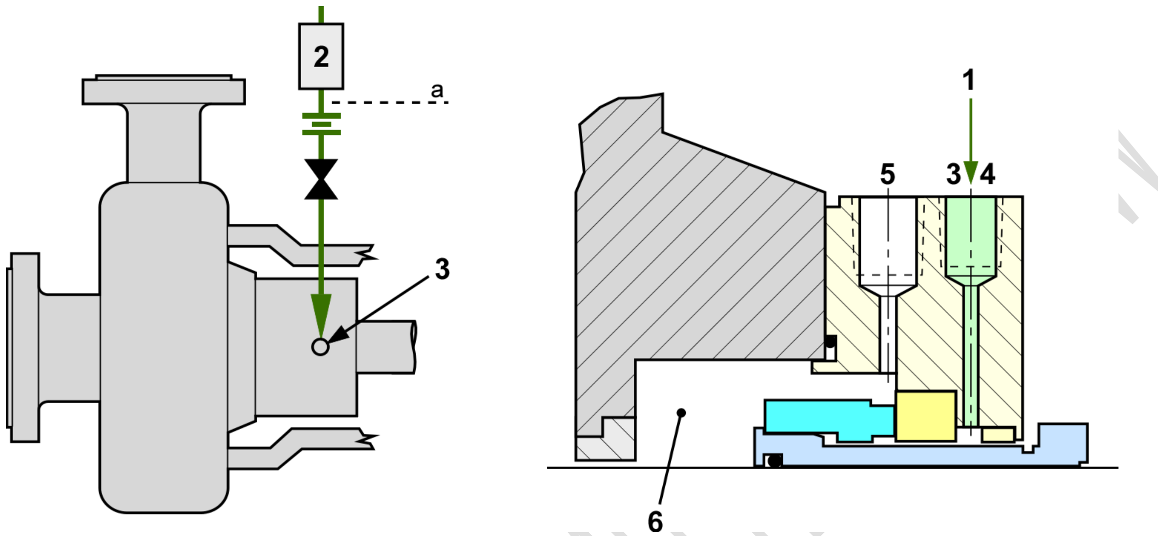
Piping Plan 41 is a combination of Piping Plan 21 and Piping Plan 31 and is specified only for hot services containing solids. Contained solids should have a specific gravity of at least twice that of the process fluid. For this seal piping plan to be used, the seal should require a cool flush. This cool flush may be needed to improve the temperature margin over the fluid vapor pressure, or to meet secondary sealing element temperature limits, or to reduce coking or polymerizing, or to improve lubricity (as in hot water). A typical use of this piping plan is in a hot water service to remove sand or pipe slag.

In Piping Plan 41, product is routed from the discharge of the pump into a cyclone separator. Solid particles are centrifuged from the stream and routed back to suction. The seal flush is then routed from the cyclone separator through a cooler and into the flush connection on the seal plate.

If the process stream is very dirty or is a slurry, Piping Plan 41 typically is inadequate and is not recommended. The benefits, detriments, and the best conditions for the use of the cooler in the flush stream can be found in the write-up on Piping Plan 21. The use of a pump throat bushing is recommended when a Piping Plan 41 is specified.

Field experience has shown that abrasive wear on the inside of the cyclone may result in reduced reliability. This piping plan has not proven to consistently achieve a three-year (3-yr) operating life.

G.19 Piping Plan 51



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 from reservoir

2 reservoir

3 quench (Q)

4 drain (D), plugged

5 flush (F)

6 seal chamber

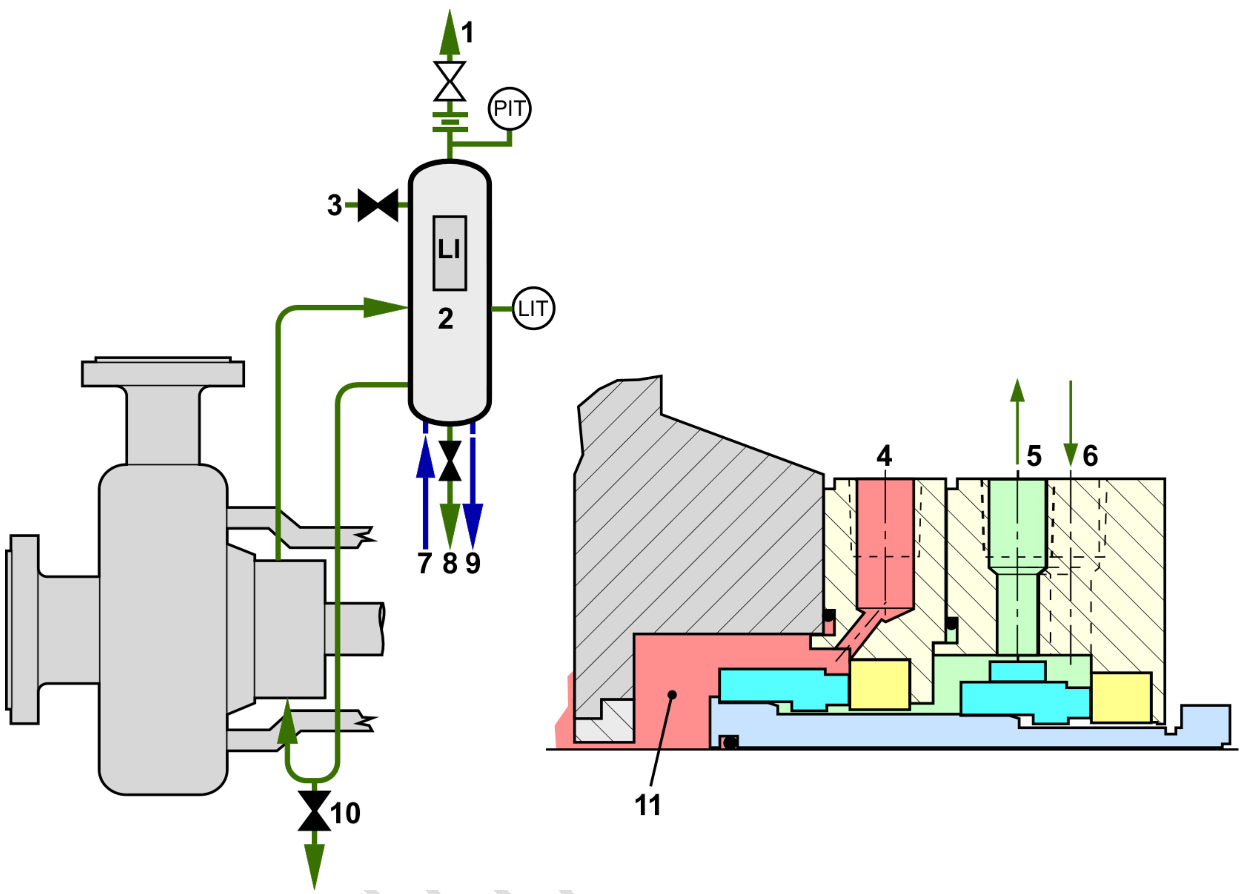
[a] Items below this line shall be provided by the vendor. Items above this line are the responsibility of the purchaser

Figure G.E.19—Standard Seal Piping Plan 51

In Piping Plan 51 there is an external reservoir providing a dead-ended blanket for fluid to the quench connection of the gland plate on an Arrangement 1 seal. A Piping Plan 51 is typically used when a dead-ended atmospheric quench is needed. One example where this might be used is to provide a means to prevent or remove any ice formation on the atmospheric side of the seal of a pump operating with a fluid below 0 °C (32 °F).

One method of operation is to fill the quench reservoir with a suitable liquid. While preparing the pump for startup the block valve below the reservoir is opened and the quench liquid is allowed to sit in the area between the seal and throttle bushing. Just prior to pump startup the block valve is closed to ensure the pot is only exposed to atmospheric pressure. This piping plan is only recommended for vertical applications.

G.20 Piping Plan 52



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	to collection system
2	reservoir
3	buffer liquid refill
4	flush (F)
5	liquid buffer out (LBO)
6	liquid buffer in (LBI)
7	cooling water in
8	reservoir buffer fluid drain
9	cooling water out
10	buffer fluid drain
11	seal chamber
LI	level indicator
LIT	level transmitter with local indicator
PIT	pressure transmitter with local indicator

Figure E.G.20—Standard Seal Piping Plan 52

In Piping Plan 52 there is an external reservoir providing buffer liquid for the outer seal of an Arrangement 2 seal. The buffer liquid shall be maintained at a pressure less than seal chamber pressure and less than 0.28 MPa (2.8 bar) (40 psi).

Buffer liquid is circulated to and from the reservoir by means of an internal circulating device. To maximize buffer liquid circulation, the piping losses should be minimized through the proper selection of pipe size, elimination of fittings, use of large radius bends, and reduction in the length of piping runs.

Piping Plan 52 is used with Arrangement 2 seals, with a contacting wet containment seal (configuration 2CW-CW) using a liquid buffer system. It is normally used in services where process fluid leakage to atmosphere should be minimized and contained. It is also used in applications where the process may solidify in contact with atmosphere or in applications where additional heat removal from the inner seal is required. The buffer liquid is contained in a seal reservoir that is vented to a collection system, thus maintaining the buffer system pressure close to atmospheric.

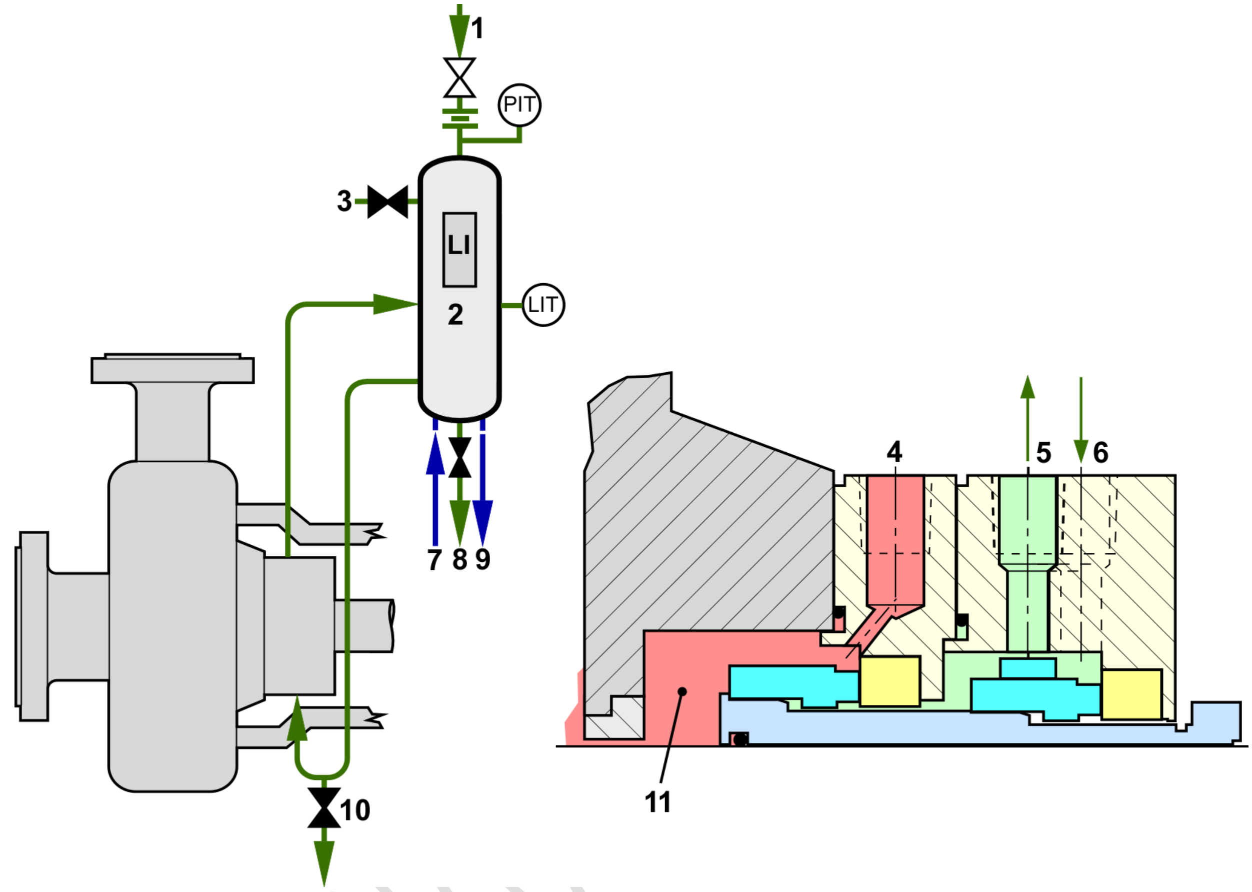
Piping Plan 52 works best with clean, nonpolymerizing, pure products that have a vapor pressure higher than the buffer system pressure. Leakage of higher vapor pressure process liquids into the buffer system will flash in the seal reservoir and the vapor can escape to the collection system.

Inner seal process liquid leakage will normally mix with the buffer fluid and contaminate the buffer liquid over time. Maintenance associated with seal repairs, refilling, draining, and flushing a contaminated buffer system can be considerable.

The drain valves are used to drain buffer fluid from the piping plan during seal or piping plan maintenance. The process fluid from the drain valve should be routed to a safe location or connected to a drain or recovery system. This is necessary to prevent exposing the operator to process fluid during draining and to comply with local process disposal requirements.

For general recommendations on piping practices and reservoir details, see Figure G.35, Figure G.36, and Figure G.38.

G.21 Piping Plan 53A



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from external pressure source
2	reservoir
3	barrier liquid refill
4	flush (F)
5	liquid barrier out (LBO)
6	liquid barrier in (LBI)
7	cooling water in
8	reservoir barrier fluid drain
9	cooling water out
10	barrier fluid drain
11	seal chamber
LI	level indicator
LIT	level transmitter with local indicator
PIT	pressure transmitter with local indicator

Figure E.G.21—Standard Seal Piping Plan 53A

In Piping Plan 53A there is a pressurized external barrier fluid reservoir supplying clean fluid to the barrier fluid seal chamber. The barrier liquid is maintained at a pressure greater than seal chamber pressure.

Barrier liquid is circulated to and from the reservoir by means of an internal circulating device. To maximize barrier liquid circulation, the piping losses should be minimized through the proper selection of pipe size, elimination of fittings, use of large radius bends, and reduction in the length of piping runs.

Piping Plan 53A is used with an Arrangement 3 seal and used in services where no leakage to atmosphere can be tolerated. It may also be selected for applications where the pump may be operated dry or the pump process fluid may be damaging to the seal faces.

A Piping Plan 53A system consists of dual mechanical seals with a barrier liquid between them. The barrier liquid is contained in a reservoir that is pressurized above the seal chamber pressure. Inner seal leakage will be barrier liquid leakage into the product. There will always be some leakage. If seal chamber gauge pressures vary significantly, the inner and outer seal stresses can be reduced by the application of a controlled differential pressure regulator. For specific recommendations on barrier liquid pressurization, see Annex F.

A 3 mm (0.125 in.) orifice is provided in the pressurization gas supply line to limit gas flow into the process in the event of an inner seal failure.

The following comments compare the differences and considerations between all dual pressurized piping plans (Piping Plan 53A, 53B and 53C) and dual unpressurized piping plans (Piping Plan 52). Piping Plan 53 is usually chosen over Piping Plan 52 for dirty, abrasive, or polymerizing products that would either damage the seal faces or cause problems with the buffer liquid system if Piping Plan 52 were used. There are two operational features of a Piping Plan 53 that are noteworthy, as follows.

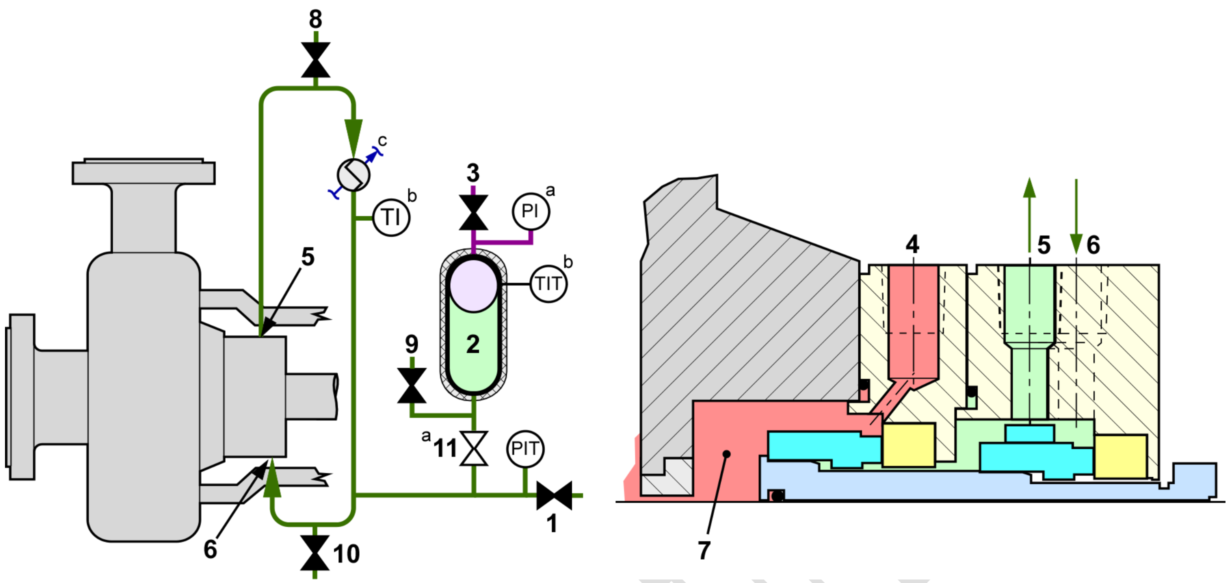
e) The clean barrier liquid provides lubrication to the seal faces, but the barrier liquid that passes across the inner seal faces will enter the pumped process stream. Therefore, the process liquid shall be compatible with the barrier liquid and be able to tolerate a small amount of contamination from the barrier liquid.

The reservoir pressure should always exceed the maximum seal chamber pressure by a minimum of 0.14 MPa (1.4 bar) (20 psi) (as referenced in 8.3.6.1.10). If the reservoir pressure is less than the seal chamber pressure, then the normal leakage flow direction across the inner seal will be reversed and the seal system will begin to operate like a Piping Plan 52. The barrier liquid may become contaminated with the pumped process liquid possibly creating a hazardous barrier liquid and increase the possibility of seal failure.

The addition of an external barrier fluid circulation pump will change the designation to a Plan 54 or Plan 99.

For general recommendations on piping practices and reservoir details, see Figure G.35, Figure G.36, and Figure G.38.

G.22 Piping Plan 53B



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	barrier liquid refill	8	vent
2	bladder accumulator	9	vent
3	bladder charge connection	10	barrier fluid drain
4	flush (F)	11	valve (for checking accumulator bladder integrity)
5	liquid barrier out (LBO)	PI	pressure indicator
6	liquid barrier in (LBI)	PIT	pressure transmitter with local indicator
7	seal chamber	TI	temperature indicator
		TIT	temperature transmitter local indicator

[a] If specified, both the PI and valve 11 shall be installed for checking bladder integrity.

[b] If specified.

[c] Vertically oriented, finned air cooler shall be installed if specified.

Figure G.E.22—Standard Seal Piping Plan 53B

In Piping Plan 53B, there is an external barrier fluid system pressurized by a bladder accumulator supplying clean liquid to the barrier fluid seal chamber. The accumulator and barrier liquid are maintained at a pressure greater than seal chamber pressure.

Barrier liquid is circulated through the system by means of an internal circulating device. To maximize barrier liquid circulation, the piping losses should be minimized through the proper selection of pipe size, elimination of fittings, use of large radius bends, and reduction in the length of piping runs.

Piping Plan 53B is used with an Arrangement 3 liquid seal and differs from Piping Plan 53A in that pressure is maintained in the barrier liquid system through the use of a bladder-type accumulator. The use of an accumulator prevents contact between the pressurization gas and the barrier liquid. This prevents gas absorption into the barrier liquid and allows for high-pressure operation. The accumulator is precharged prior to filling the system with barrier liquid and is brought to operating pressure by compressing the bladder in the accumulator as the system is filled with barrier liquid. Leakage past the inner and outer seals results in a decrease in the barrier system pressure. This requires that the barrier system be pressurized to a higher initial pressure and allowed to “leak” down to the minimum allowable system pressure. At this time, the system would be refilled to restore the maximum working barrier liquid volume. Seal performance is therefore monitored by pressure decrease and not by barrier liquid level as in Piping Plan 53A. For specific recommendations on pressurization, operation, and monitoring of Piping Plan 53B systems, refer to Annex F.

Barrier fluid will be added through the barrier fluid refill connection (1). In operation, barrier fluid refill is most commonly performed by the operator manually adding barrier fluid until the barrier pressure reaches the correct refill pressure. Optionally, automatic refill systems can be designed which maintain the barrier pressure in the correct operating range. Refer to Annex F for additional details.

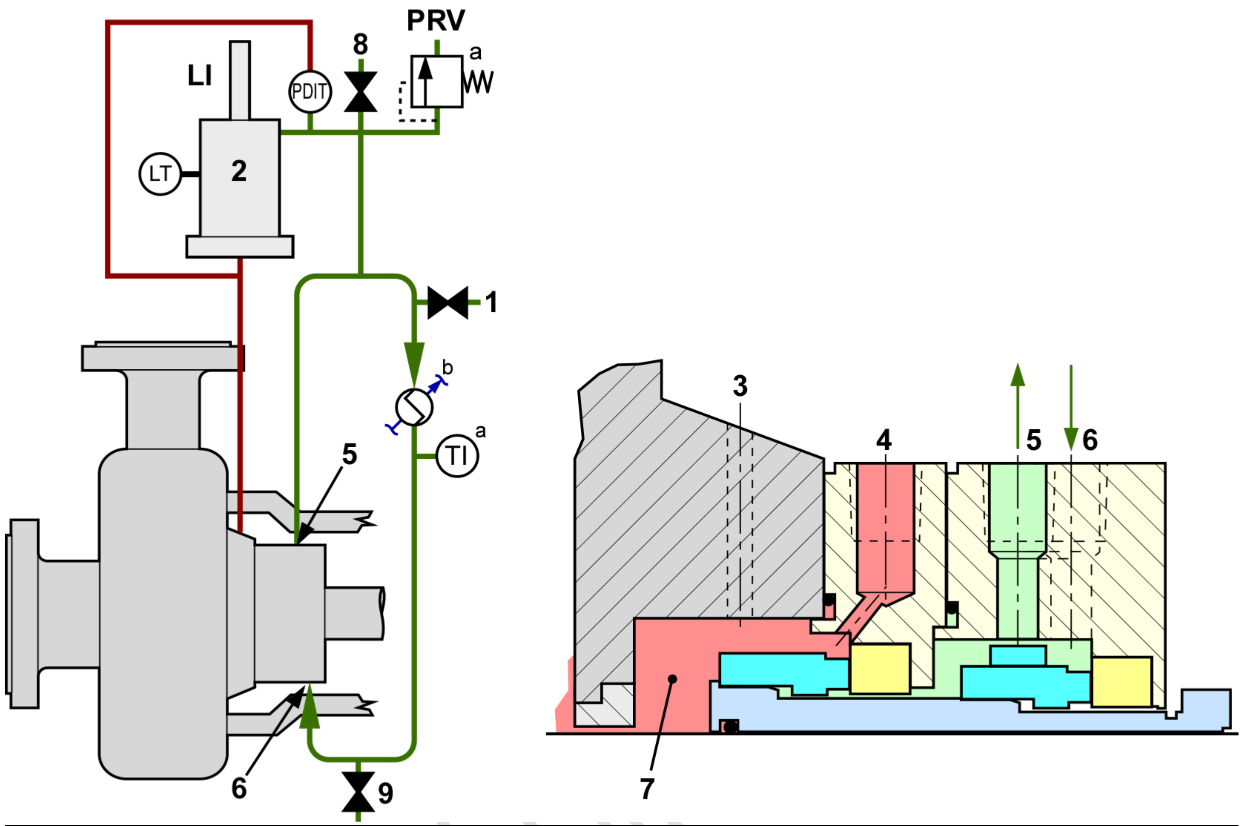
Effective flow of the Piping Plan 53B system is only achieved with proper exclusion of all gas and air bubbles from the seal cooler and piping. Venting of the system during commissioning is critical to proper operation. The vent line should be routed to a safe location or connected to a drain or recovery system to prevent exposing the operator to process during venting.

The temperature of the gas in the bladder accumulator will have a direct impact on the pressure of the barrier fluid in the piping plan. The bladder accumulator shall be insulated to minimize the impact of varying ambient temperatures on the temperature of the gas in the bladder accumulator. If specified, temperature measurements from the TIT shall be taken on the external surface of the accumulator under the insulation. This has proven to provide an accurate estimate of the gas temperature in the bladder and can be used for temperature compensated refill pressures and floating alarm strategies. Refer to Annex F for additional details.

The addition of an external barrier fluid circulation pump will change the designation to a Plan 54 or Plan 99.

For additional considerations between using a Piping Plan 53 and a Piping Plan 52, see G.18 Piping Plan 53A.

G.23 Piping Plan 53C



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	barrier liquid refill	LI	level indicator
2	piston accumulator	LT	level transmitter
3	pressure reference	PRV	pressure relief valve
4	flush (F)	PDIT	differential pressure transmitter with local indicator
5	liquid barrier out (LBO)	TI	temperature indicator
6	liquid barrier in (LBI)		
7	seal chamber		
8	vent		
9	barrier fluid drain		

[a] If specified.

[b] Vertically oriented, finned air cooler may be provided if specified.

Figure G.E.23—Standard Seal Piping Plan 53C

In Piping Plan 53C, there is an external barrier fluid system pressurized by a piston accumulator supplying clean liquid to the barrier fluid seal chamber. The barrier liquid is maintained at a pressure greater than seal chamber pressure.

Barrier liquid is circulated through the system by means of an internal circulating device. To maximize barrier liquid circulation, the piping losses should be minimized through the proper selection of pipe size, elimination of fittings, use of large radius bends, and reduction in the length of piping runs.

Piping Plan 53C is used with an Arrangement 3 liquid seal and differs from Piping Plan 53A in that pressure is maintained in the barrier liquid through the use of a piston accumulator. The piston accumulator senses pressure from a reference source (normally a line connected to the seal chamber) and creates a higher pressure through differential areas in the piston. This high pressure creates the required pressure differential necessary for an Arrangement 3 seal. Since the barrier pressure is generated from the seal chamber pressure, the system is self-energizing and reacts to fluctuations in the seal chamber fluid pressure.

The piston accumulator will have a level indicator to indicate the position of the piston within the accumulator. This should indicate both a maximum and minimum barrier fluid level in the accumulator. When the accumulator is initially filled, or subsequently refilled during operation, the user must not overfill the system since this may lead to bottoming out the piston and an overpressurization of the barrier fluid. The piston must also not be allowed to operate beyond the minimum barrier fluid level since this may result in depressurization of the barrier fluid.

The piston accumulator will require a minimum seal chamber pressure to overcome friction losses due to the sliding between the piston and accumulator seals. Operation of the system below this minimum pressure may result in an inconsistent barrier fluid pressure or a loss of barrier fluid pressure. The user should consult with the supplier to obtain the required operating pressure range for the system.

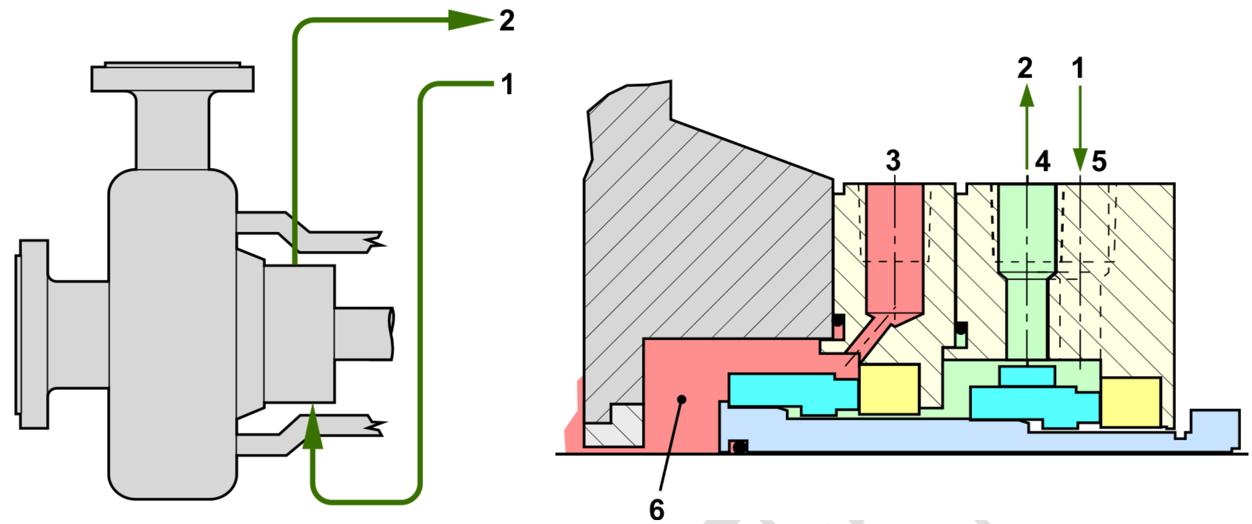
To create the reference pressure in the piston transmitter, process fluid is introduced into the piston. This requires that the materials used in the piston transmitter are compatible with the process fluid. Process fluids that contains solids, tend to plate out on metal surfaces, or solidify under atmospheric temperatures are not suitable for a Piping Plan 53C.

Effective flow of the Piping Plan 53C system is only achieved with proper exclusion of all gas and air bubbles from the seal cooler and piping. Venting of the system during commissioning is critical to proper operation. The vent line should be routed to a safe location or connected to a drain or recovery system to prevent exposing the operator to process during venting. For specific recommendations on piping practices for Piping Plan 53C systems, refer to Annex F.

The addition of an external barrier fluid circulation pump will change the designation to a Piping Plan 54 or Piping Plan 99.

For additional considerations between using a Piping Plan 53 and a Piping Plan 52, see G.18 Piping Plan 53A.

G.24 Piping Plan 54



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	from external source
2	to external source
3	flush (F)
4	liquid barrier out (LBO)
5	liquid barrier in (LBI)
6	seal chamber

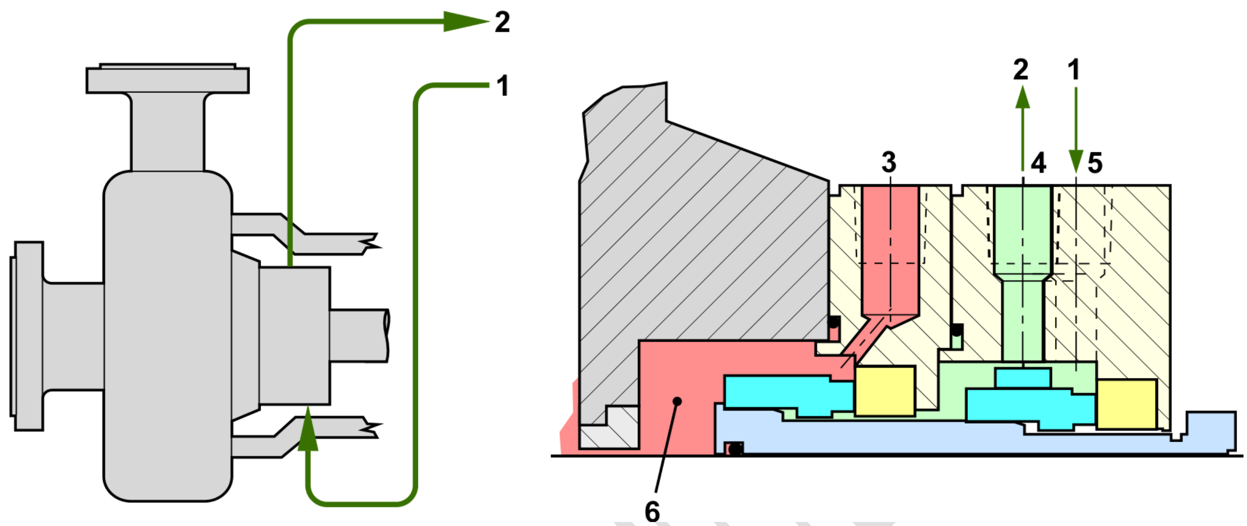
Figure E.G.24—Standard Seal Piping Plan 54

In Piping Plan 54, there is a pressurized external barrier fluid system supplying clean liquid to the barrier fluid seal chamber. Piping Plan 54 is used with Arrangement 3 liquid seals and the barrier liquid is maintained at a pressure greater than seal chamber pressure. Barrier liquid is circulated by an external pump or pressure system. The design of the system including instrumentation, coolers, filters, and other components is outside the scope of this standard.

Piping Plan 54 systems are also pressurized dual-seal systems with inner seal leakage into the pumped product. In a Piping Plan 54, a cool clean product from an external source is supplied to the seal as a barrier liquid. The supply pressure of this product is at least 0.14 MPa (1.4 bar) (20 psi) greater than the pressure the inner seal is sealing against. This results in a small leakage of barrier fluid into the process. This plan with an Arrangement 3 seal should never be used where the barrier liquid pressure is less than the sealed pressure. If it were, the failure of one inner seal could contaminate the entire barrier liquid system and cause additional seal failures.

Piping Plan 54 is often used in services where the pumped fluid is hot, contaminated with solids, or the internal flow inducer is unable to supply a sufficient flow rate. If Piping Plan 54 is specified, carefully consider the reliability of the barrier liquid source. If the source is interrupted or contaminated, the resulting seal failures are very expensive to rectify. A properly engineered barrier liquid system is typically complex and often expensive. Where these systems are properly engineered, they provide among the most reliable systems.

G.25 Piping Plan 55



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 from external source

2 to external source

3 flush (F)

4 liquid buffer out (LBO)

5 liquid buffer in (LBI)

6 seal chamber

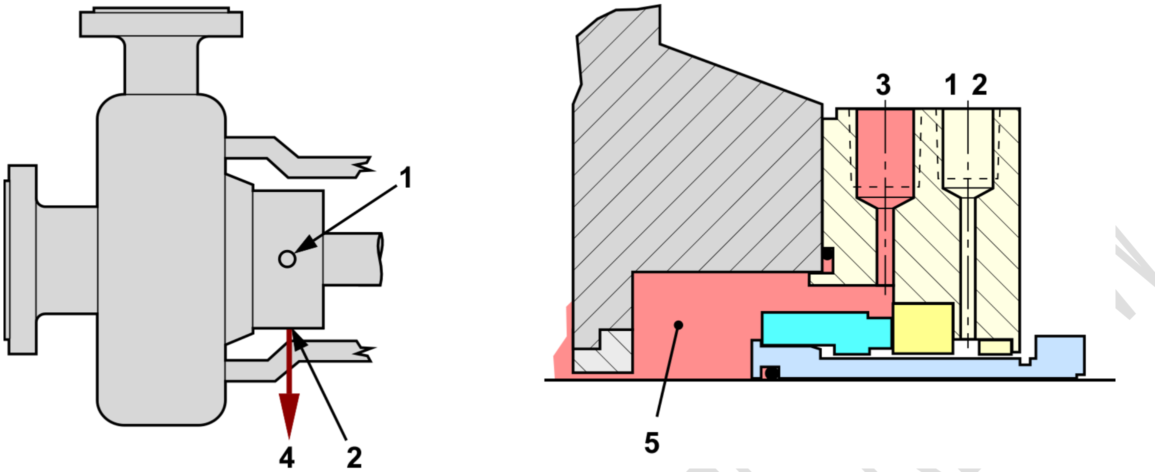
Figure G.25E.—Standard Seal Piping Plan 55

In Piping Plan 55, there is an unpressurized external buffer fluid system supplying clean liquid to the buffer fluid seal chamber. Piping Plan 55 is used with Arrangement 2 liquid seals. The buffer liquid shall be maintained at a pressure less than seal chamber pressure and less than 0.28 MPa (2.8 bar) (40 psi). Buffer liquid is circulated by an external pump or pressure system.

Piping Plan 55 is similar to Piping Plan 54 except the buffer liquid is unpressurized. Piping Plan 55 is used with Arrangement 2 seals, with a contacting wet containment seal (configuration 2CW-CW) using a liquid buffer system. It is normally used in services where process fluid leakage to atmosphere should be minimized and contained. It is also used in applications where the process may solidify in contact with atmosphere or in applications where additional heat removal from the inner seal is required.

Piping Plan 55 differs from a Piping Plan 52 in that the buffer liquid is not self-contained and the buffer liquid circulation is created by an external pump or pressure system. If Piping Plan 55 is specified, carefully consider the reliability of the buffer liquid source and the possible contamination of the buffer flow with process liquid or vapor.

G.26 Piping Plan 61



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 quench (Q), plugged, metal

2 drain (D), open connected to metal tubing

3 flush (F)

4 to collection point

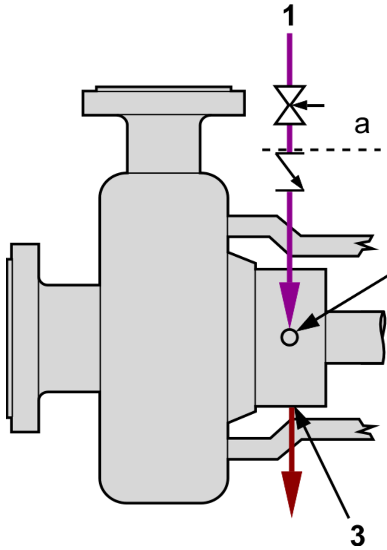
5 seal chamber

Figure E.G.26—Standard Seal Piping Plan 61

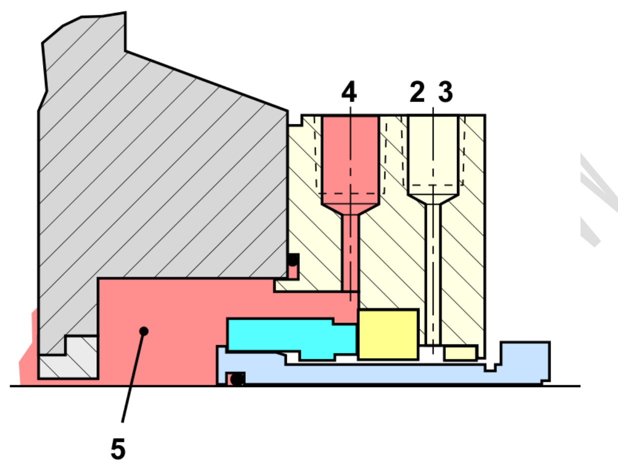
In Piping Plan 61 there are tapped and plugged atmospheric-side connections for purchaser's use.

In Piping Plan 61, all ports are plugged with plastic plugs at the time of shipment. At installation, the user shall connect tubing to the drain port and direct leakage to a collection point. This piping plan may also be specified if the purchaser may use these ports in the future.

G.27 Piping Plan 62



a) Piping and Instrumentation Schematic



b) Seal Chamber Details

Key

1 from seal quench supply system

2 quench (Q)

3 drain (D)

4 flush (F)

5 seal chamber

a Pressure and temperature boundary for seal quench supply system

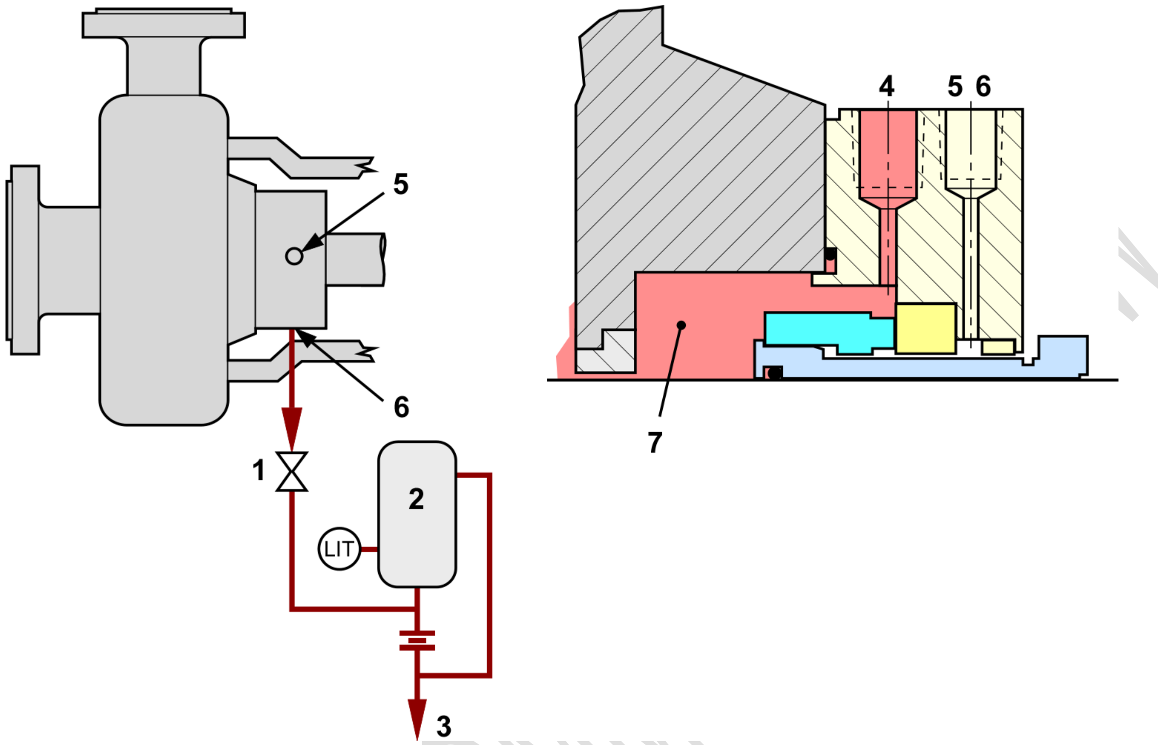
Figure E.G.27—Standard Seal Piping Plan 62

In Piping Plan 62, a quench stream is brought from an external source to the atmospheric side of the seal faces. The quench stream can be low-pressure steam, nitrogen, or clean water. It is used in selected single seal applications to exclude the presence of oxygen to prevent coke formation (for example, hot hydrocarbon services) and to flush away undesirable material buildup around the dynamic seal components (for example, caustic and salt services).

The check valve and all components downstream from the check valve must be rated to the MAWP and MAWT of the pressure casing. All components located upstream of the check valve must be rated to a minimum of the MAWP and MAWT of the supply system or as defined by the purchaser.

Piping Plan 62 is most effective when used with a close clearance bushing or containment device in the seal gland. This bushing not only contains the quench in the seal gland but also provides protection for the operator if a high-temperature quench is used. The drain port outlet should be larger than the quench port inlet. The drain port shall be sized to allow drainage of the quench medium.

G.28 Piping Plan 65A



a) Piping and Instrumentation Schematic

b) Seal Chamber Details

Key

1	valve (locked open)
2	leakage collection reservoir
3	to liquid collection system
4	flush (F)
5	quench (Q)
6	drain (D)
7	seal chamber
LIT	level transmitter with local indicator

Figure E.G.28—Standard Seal Piping Plan 65A

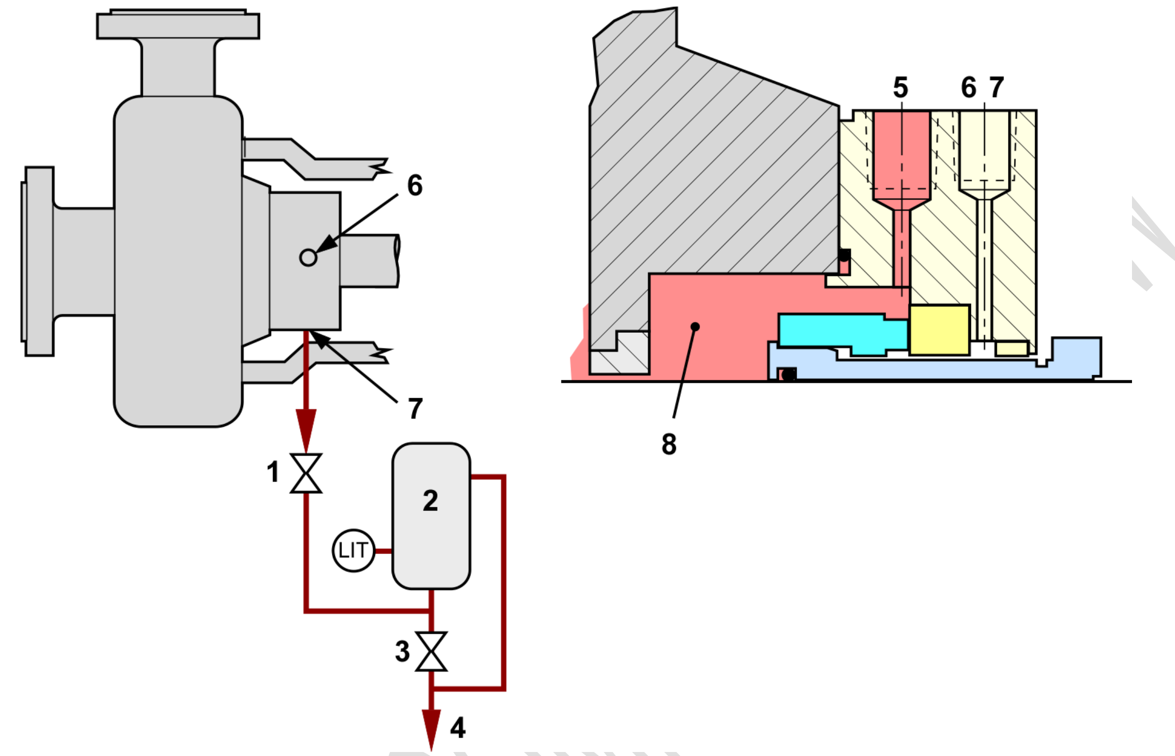
In Piping Plan 65A there is an atmospheric leakage collection and detection system for condensing leakage. Failure of the seal will be detected by an excessive flow rate into the leakage collection system. This piping plan is used when pumped fluid condenses at ambient temperatures.

Piping Plan 65A is a seal leakage detection piping plan normally used with Arrangement 1 seals in services where seal leakage is expected to be mostly liquid (not gas). Piping is connected to the drain connection in the gland plate and directs any seal leakage past or through a reservoir and then through an orifice, exiting into an oil and water sewer or liquid collection system. Excessive flow rates would be restricted by the orifice located downstream of the reservoir and are redirected to it, causing the level transmitter to activate an alarm. The orifice, typically 5 mm (0.25 in.), should be located in a vertical piping leg to avoid accumulation of fluid in the drain piping. A connection on the reservoir above the level transmitter is connected to a pipe by-passing the orifice allowing excessive leakage to be effectively drained. A pressure transmitter can be provided as an option to allow for monitoring pressure increase in the system.

Piping Plan 65A is most effective when used with a floating or segmented bushing or containment device in the seal gland. The reservoir shall be mounted below the seal gland to allow leakage to flow to the reservoir. On small pumps, there may be insufficient vertical height to install the orifice in a vertical leg if the reservoir is installed on the base plate. If required, the reservoir should be located off of the baseplate at ground level or the orifice may in located in a horizontal piping leg.

Valve 1 shall be left open during operation and may be closed only for maintenance of the piping plan.

G.29 Piping Plan 65B



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	valve (locked open)
2	leakage collection reservoir
3	drain valve
4	to liquid collection system
5	flush (F)
6	quench (Q)
7	drain (D)
8	seal chamber
LIT	level transmitter with local indicator

Figure E.G.29—Standard Seal Piping Plan 65B

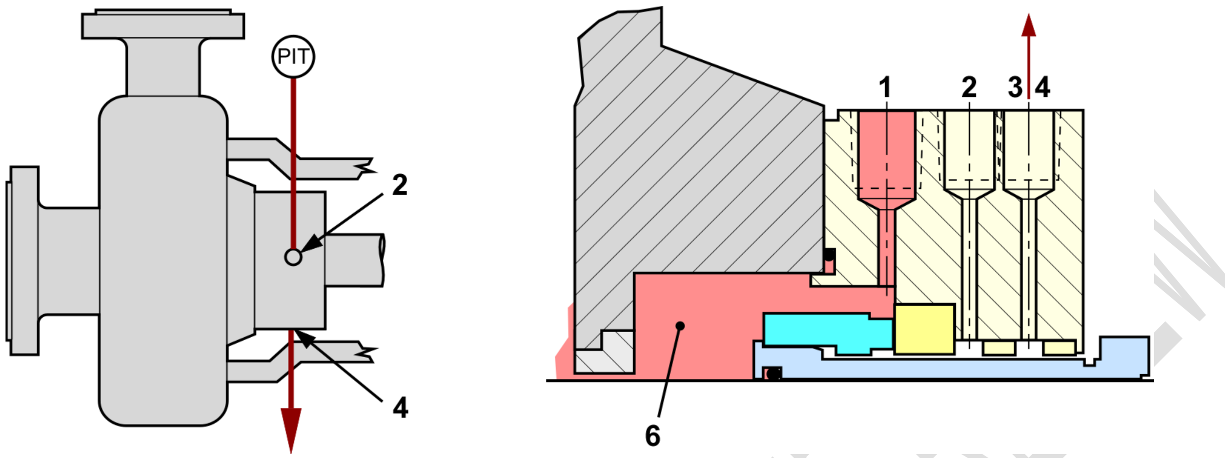
In Piping Plan 65B there is an atmospheric leakage collection and detection system for condensing leakage. Failure of the seal will be detected by a cumulative leakage into the system. This piping plan is used when pumped fluid condenses at ambient temperatures.

Piping Plan 65B is a seal leakage detection piping plan normally used with Arrangement 1 seals in services where seal leakage is expected to be mostly liquid (not gas). Piping is connected to the drain connection in the gland plate and directs any seal leakage into a reservoir resulting in an increase in level of process fluid in the reservoir. The level increases will be monitored by the level transmitter and will activate an alarm. A connection on the reservoir above the transmitter is connected to a pipe bypassing the valve allowing excessive leakage to be effectively drained.

Piping Plan 65B is most effective when used with a floating or segmented bushing or containment device in the seal gland. The reservoir shall be mounted below the seal gland to allow leakage to flow to the reservoir.

Valve 1 shall be left open during operation and may be closed only for maintenance of the piping plan. Valve 2 shall normally be closed during operation although it may be opened periodically to allow collected leakage to be drained.

G.30 Piping Plan 66A



a) Piping and Instrumentation Schematic

b) Seal Chamber Details

Key

1 flush (F)

2 pressure transmitter sensing port (PIT)

3 quench (Q)

4 drain (D)

5 seal chamber

PIT pressure transmitter with local indicator

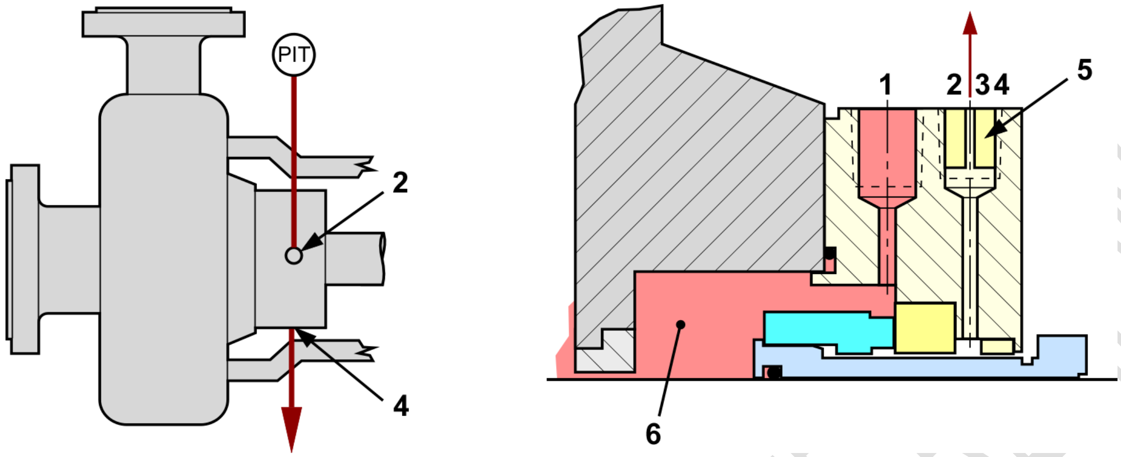
Figure E.G.30—Standard Seal Piping Plan 66A

In Piping Plan 66A, the throttle bushings in the seal gland minimize the seal leakage leaving the seal gland and allow for detection of a seal failure.

Piping Plan 66A is intended for use in Arrangement 1 applications where it is required to limit leakage in case of a seal failure or it is required to monitor excessive leakage. In this piping plan, normal seal leakage can flow freely to the drain port. If the seal leakage is excessive however, the inner bushing will restrict the flow to the drain and limit the amount of leakage leaving the seal gland. As the leakage rate increases, the pressure will increase on the upstream side of the inner bushing. This pressure will be monitored by the pressure transmitter and can be used to monitor seal performance and trigger an alarm indicating a seal failure. Leakage out of the drain port is collected and piped to a liquid recovery system or sump. See 7.1.2.3 for additional details.

NOTE This piping plan is most commonly used on pipeline applications.

G.31 Piping Plan 66B



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 flush (F)

2 pressure transmitter sensing port (PIT)

3 quench (Q)

4 drain (D), with orifice plug installed

5 orifice plug

6 seal chamber

PIT pressure transmitter with local indicator

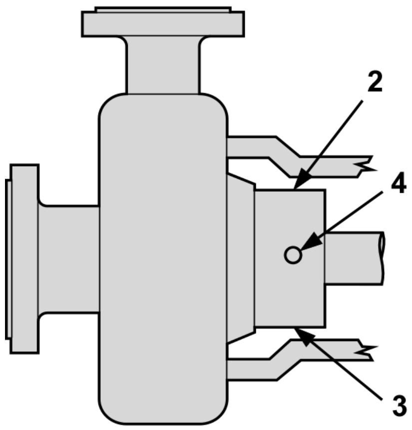
Figure G.E.31—Standard Seal Piping Plan 66B

In Piping Plan 66B, an orifice plug in the drain port minimizes the seal leakage leaving the seal gland and allows for detection of a seal failure.

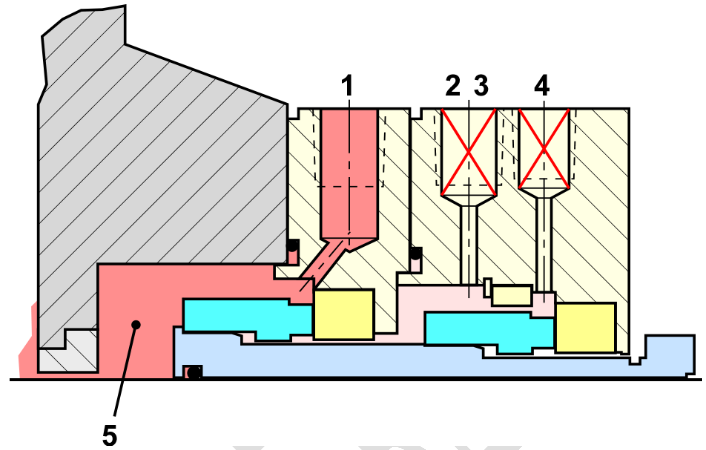
Piping Plan 66B is intended for use in Arrangement 1 applications where it is required to limit leakage in case of a seal failure or it is required to monitor excessive leakage. In this piping plan, normal seal leakage can flow freely out the drain port. If the seal leakage is excessive however, the orifice plug in the drain limits the amount of leakage leaving the seal gland. As the leakage rate increases, the pressure will increase on the upstream side of the orifice plug. This pressure will be monitored by the pressure transmitter and can be used to monitor seal performance and trigger an alarm indicating a seal failure. Since the drain cavity will become pressurized, a floating throttle bushing should be used to limit leakage past the bushing. Leakage out of the drain port is collected and piped to a liquid recovery system or sump. See 7.1.2.3 for additional details.

NOTE This piping plan is most commonly used on pipeline applications.

G.32 Piping Plan 71



a) Piping and Instrumentation Schematic



b) Seal Chamber Details

Key

1 flush (F)

2 containment seal vent (CSV), plugged

3 containment seal drain (CSD), plugged

4 gas buffer inlet (GBI), plugged

5 seal chamber

Figure E.G.32—Standard Seal Piping Plan 71

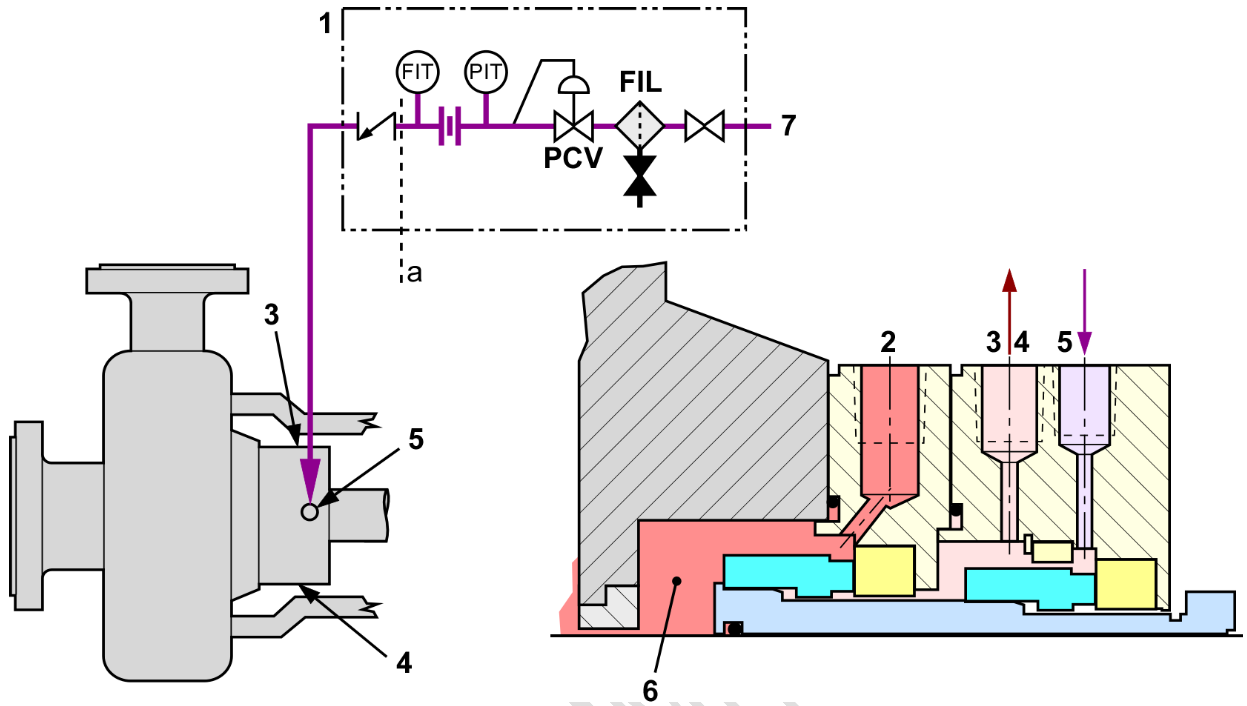
In Piping Plan 71 there are tapped connections for the purchaser's use. All ports shall be plugged with plastic plugs at the time of shipment. At installation, the user shall remove all plastic plugs and all ports shall either be connected to tubing or plugged with metal plugs as described in 8.2.19. Typically, this piping plan is used if the purchaser might use buffer gas in the future.

Piping Plan 71 is used on Arrangement 2, unpressurized dual seals, which use a dry containment seal and where no buffer gas is supplied but the provision to supply a buffer gas is desired.

This piping plan should only be used in applications where the process leakage past the inner seal is vapor phase and non-polymerizing. Condensing, mixed phase or liquid phase leakage will collect in the containment seal chamber which can impact the performance of the containment seal. These applications may require the use of Piping Plan 75 or 76 to remove the inner seal leakage from the containment seal cavity. A buffer gas (Piping Plan 72) may also be needed to sweep inner seal leakage away from the outer seal into a collection system or to dilute the leakage but this is not specified.

The gland ports (2, 3 and 4) may be used for monitoring the containment seal cavity or for testing the integrity of the outer seal.

G.33 Piping Plan 72



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1 buffer gas panel
2 flush (F)
3 containment seal vent (CSV)
4 containment seal drain (CSD)
5 gas buffer inlet (GBI)
6 seal chamber
7 from buffer gas supply
a pressure and temperature boundary for buffer gas supply system

FIL coalescing filter
FIT flow transmitter with local indicator
PCV pressure control valve
PIT pressure transmitter with local indicator

Figure G.33E.—Standard Seal Piping Plan 72

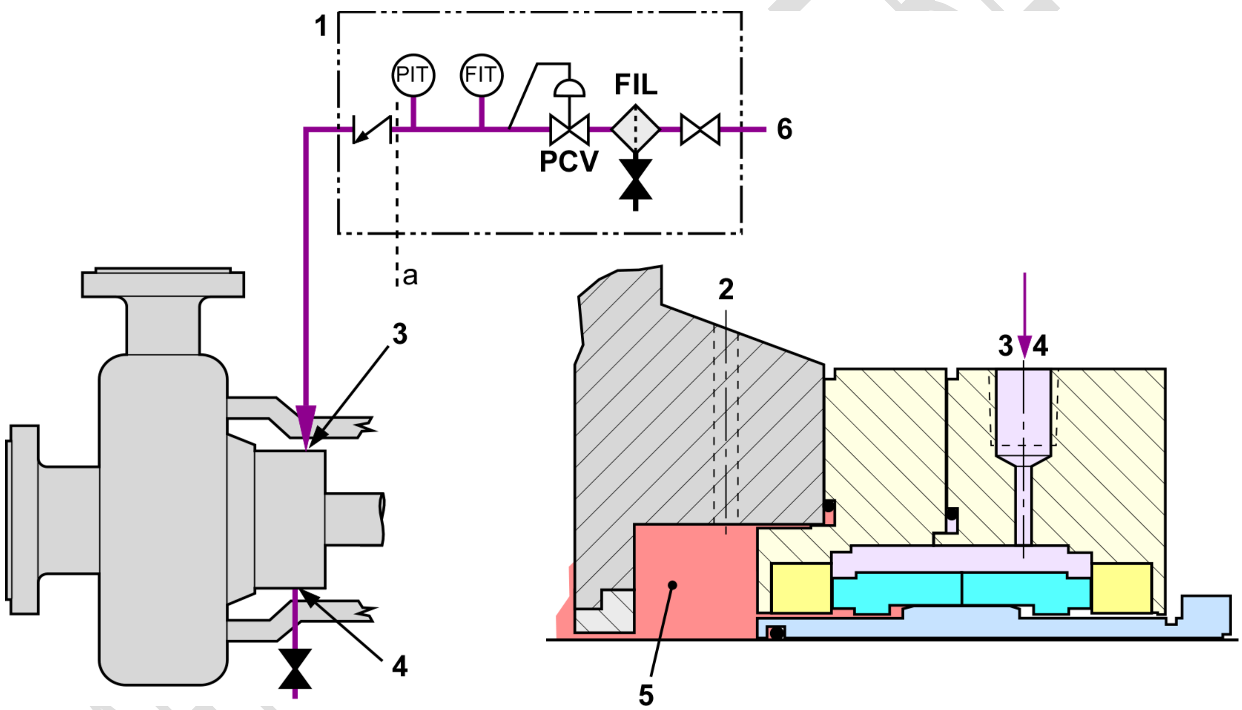
In Piping Plan 72 there is externally supplied buffer gas for Arrangement 2 seals. Buffer gas is maintained at a pressure less than seal chamber pressure. In normal operation, the buffer gas pressure should not exceed 0.07 MPa (0.7 bar) (10 psi).

The check valve and all components downstream from the check valve must be rated to the MAWP and MAWT of the pressure casing. All components located upstream of the check valve must be rated to a minimum of the MAWP and MAWT of the supply system or as defined by the purchaser.

Piping Plan 72 can be used on Arrangement 2 unpressurized dual seals that use a dry-running containment seal. This plan may be used alone or in conjunction either a Piping Plan 75 or Piping Plan 76. The buffer gas can be used to sweep inner-seal leakage away from the outer seal to a collection system and/or dilute the leakage so the emissions from the containment seal are reduced.

The Piping Plan 72 system is intended to function as follows: from the source supply provided by the plant operator, the buffer gas enters the system, mounted on a plate or panel, provided by the seal vendor. A coalescing filter to remove any particles and liquid that might be present follows an inlet block valve on the panel. The gas then flows through a forward-pressure regulator that is set at the Piping Plan 75 or Piping Plan 76 alarm point, or at least 0.04 MPa (0.4 bar) (5 psi) above the normal flare pressure. Next comes a pressure transmitter with a local indicator ahead of an orifice; these are used to set the regulator. They also ensure the source pressure always maintains a flush flow over the operating range of the combined systems (when used with Piping Plan 75 or Piping Plan 76) and does not pressurize the seal chamber or affect the alarm settings of the exit flush piping plan. The orifice provides flow regulation and is followed by a flow transmitter to measure flow. The orifice also serves to control buffer gas loss in the event of an outer seal failure. (The use of a needle or globe valve for the orifice to allow flow regulation is optional.) The flow transmitter with a local indicator will display buffer gas flow rate and alarm on high flow. The last element on the panel is a check valve. Buffer gas is then routed through tubing to the seal.

G.34 Piping Plan 74



a) Piping and Instrumentation Schematic **b) Seal Chamber Details**

Key

1	barrier gas panel	FIL	coalescing filter
2	vent (if required)	FIT	flow transmitter with local indicator
3	gas barrier inlet (GBI)	PCV	pressure control valve
4	gas barrier outlet (GBO) (normally closed), used only to depressurize barrier	PIT	pressure transmitter with local indicator
5	seal chamber		
6	from barrier gas supply		

a pressure and temperature boundary for seal quench supply system

Figure E.G.34—Standard Seal Piping Plan 74

In Piping Plan 74 there is externally supplied barrier gas for Arrangement 3 seals. Barrier gas is maintained at a pressure greater than seal chamber pressure.

The check valve and all components downstream from the check valve must be rated to the MAWP and MAWT of the pressure casing. All components located upstream of the check valve must be rated to a minimum of the MAWP and MAWT of the supply system or as defined by the purchaser.

Piping Plan 74 systems are used on Arrangement 3, dual pressurized seals, where the barrier medium is a gas. They are the gas barrier equivalent to the traditional Piping Plan 54 liquid barrier system. The most common barrier gas is plant nitrogen. The supply pressure to the seal is typically at least 0.17 MPa (1.7 bar) (25 psi) greater than the seal chamber pressure. This results in a small amount of gas leakage into the pump, with most of the gas barrier leaking to atmosphere. This arrangement should never be used where the barrier-gas pressure can be less than the sealed pressure. If this were to happen, the entire barrier gas system could become contaminated with the pumped fluid.

Piping Plan 74 systems are typically used in services that are not too hot (within elastomer property limits) but that may contain toxic or hazardous materials whose leakage cannot be tolerated. Because they are pressurized dual seal systems, leakage to the atmosphere is eliminated under normal conditions. Piping Plan 74 may also be used to obtain very high reliability, since solids or other materials that can lead to premature seal failure cannot enter the seal faces. For services containing sticky or polymerizing agents or where dehydration of the pumpage causes solids buildup, Piping Plan 74 systems are not generally recommended.

The Piping Plan 74 system is intended to function as follows:

— from the source supply provided by the plant operator;

— the buffer gas enters the system;

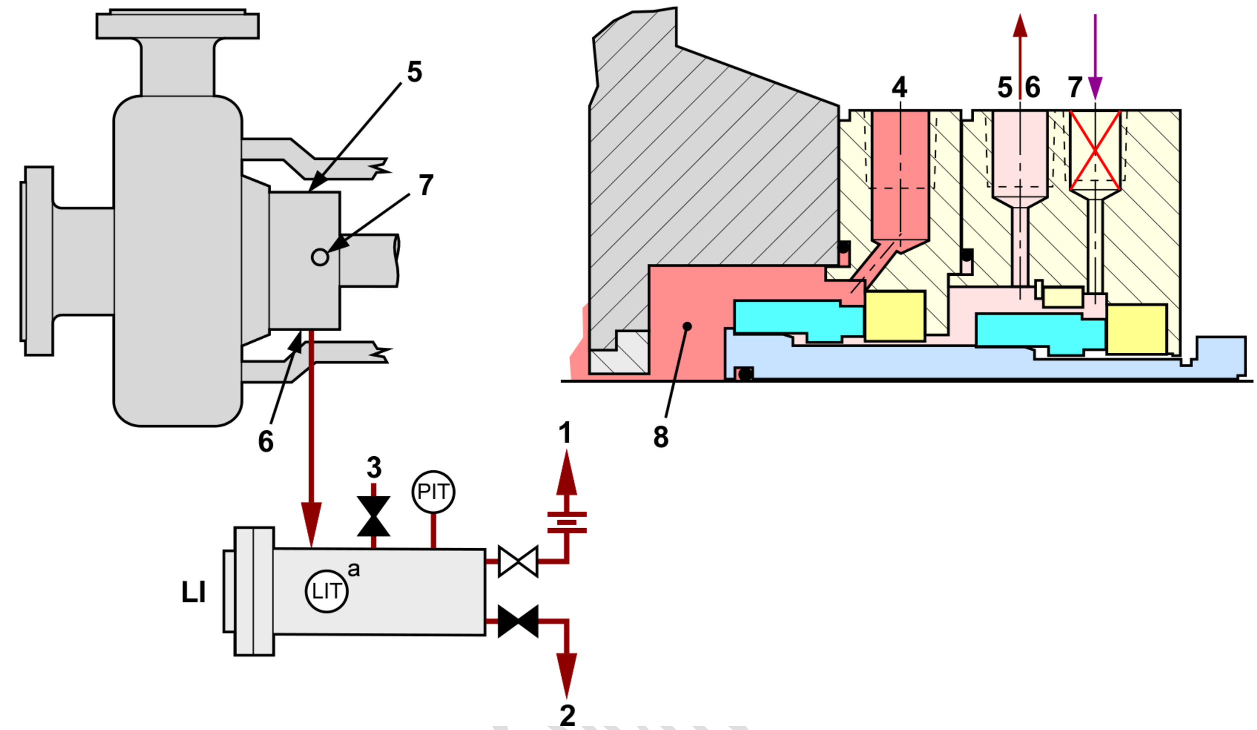
— mounted on a plate or panel, provided by the seal vendor.

An inlet block valve on the panel is followed by a 2 μm to 3 μm filter coalescing filter to remove any particles and liquid that might be present. The gas then flows through a pressure regulator that is set at least 0.17 MPa (1.7 bar) (25 psi) greater than the seal chamber pressure. The flow transmitter with a local indicator follows the regulator and is used to measure the flow and alarm at excessive flow. The next element is a pressure transmitter with a local indicator that is used to confirm adequate pressure. The pressure transmitter is used to raise an alarm upon loss of barrier gas pressure. The last elements on the panel is a check valve. Barrier gas is then routed to the seal using tubing.

No orifice is used in the barrier gas panel to help ensure barrier pressure is maintained during high flow rates. For pumps requiring more than one seal assembly (e.g. between bearing pumps), each seal shall be provided with a separate barrier gas panel so failure of one seal assembly will not compromise the performance of the other seal.

The barrier gas shall be pressurized prior to filling the pump and maintained at all times including standby operation. During standby, small amounts of leakage will continue to leak past the inner seal and collect in the pump. This may require venting the pump prior to starting the pump.

G.35 Piping Plan 75



a) **Piping and Instrumentation Schematic**

b) **Seal Chamber Details**

Key

1 to vapor collection system

2 to liquid collection system

3 test connection (if specified)

4 flush (F)

5 containment seal vent (CSV), plugged

6 containment seal drain (CSD)

7 gas buffer inlet (GBI), plugged unless used with a Piping Plan 72

8 seal chamber

LI level indicator

LIT level transmitter with local indicator

PIT pressure transmitter with local indicator

[a] If specified.

Figure G.35E.—Standard Seal Piping Plan 75

In Piping Plan 75 there is a containment seal chamber leakage collection system for condensing or mixed phase leakage on Arrangement 2 seals. This piping plan is used when pumped fluid condenses at ambient temperatures. This system is supplied by vendor.

Piping Plan 75 systems are typically used on Arrangement 2, unpressurized dual seals, which also use a dry containment seal and where the leakage from the inner seal may condense. They may be used with a buffer gas (Piping Plan 72) or without a buffer gas (Piping Plan 71).

If an unpressurized dual seal is installed, usually it is because leakage of the pumped fluid to the atmosphere should be restricted more than can be achieved with an Arrangement 1 seal. Therefore, a means is needed to collect the leakage and route it to a collection point. The Piping Plan 75 system is intended to perform this collection function for pumped fluids that may form some liquid (condense) at ambient temperature.

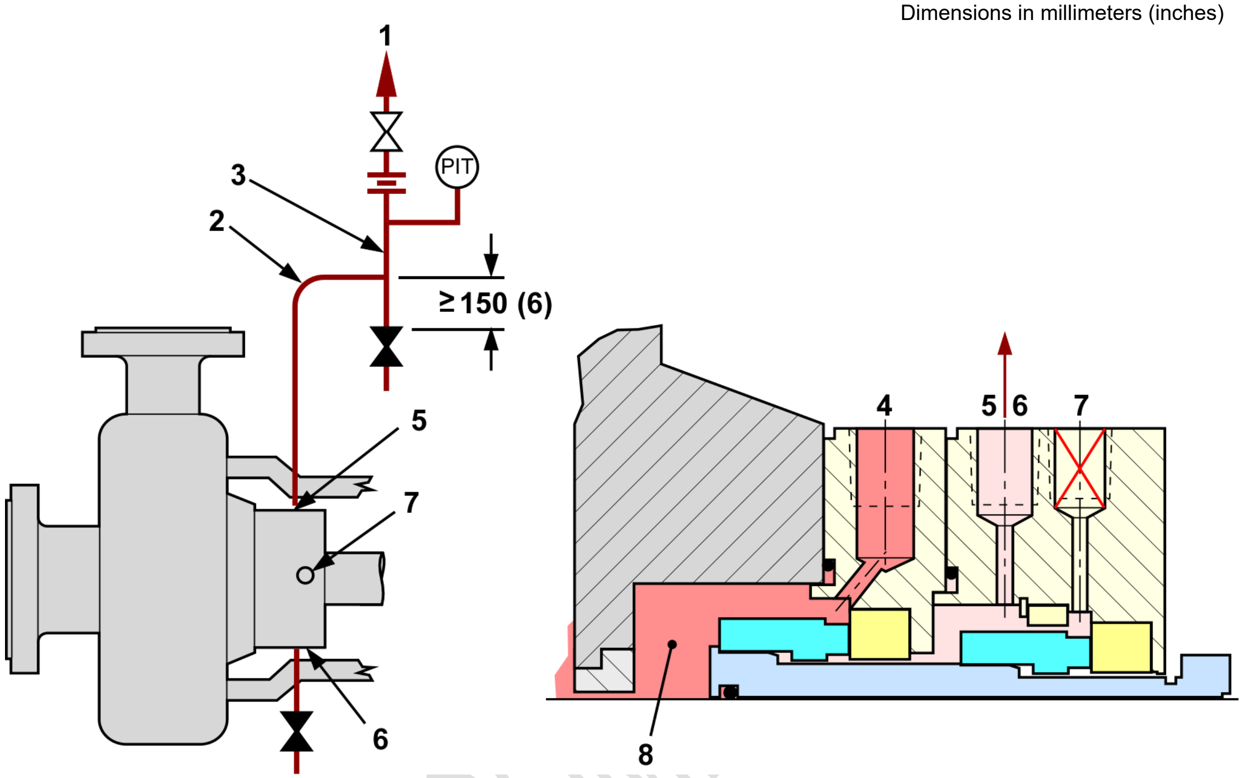
NOTE Even if the pumped liquid does not condense, users may wish to install this system because of the risk of back-flow of condensation from the collection system.

Piping Plan 75 is intended to work as follows. Leakage from the inner seal is restricted from escape by the containment seal and routed into the drain line. The collector accumulates any liquid, while vapor passes through into the collection system. A level indicator on the collector is used to determine when the collector needs to be drained and the level transmitter will enable the user to monitor the liquid leakage rate. An orifice in the outlet line of the collector restricts flow such that high leakage of the inner seal will cause a pressure increase and trigger the pressure transmitter to alarm at a gauge pressure of 0.07 MPa (0.7 bar) (10 psi). The block valve in the outlet of the collector serves to isolate the collector for maintenance. It may also be used to test the inner seal by closing while the pump is in operation and noting the time/pressure buildup relationship in the collector. If specified, a connection on the collector may be used to inject nitrogen or other gas for the purpose of testing the containment seal. Refer to Annex F for additional details on Ping Plan 75 test strategies.

The pressure transmitter in Piping Plan 75 will track the pressure in the vapor collection system. In normal operation, the pressure in the containment seal chamber can be as high as the vapor collection system pressure plus the check valve cracking pressure (if present). Pressures greater than this may indicate excessive leakage past the inner seal.

G.36 Piping Plan 76

Dimensions in millimeters (inches)



a) Piping and Instrumentation Schematic

b) Seal Chamber Details

Key

1 to vapor collection system
2 tube
3 pipe
4 flush (F)
5 containment seal vent (CSV)
6 containment seal drain (CSD), closed
7 gas buffer inlet (GBI), plugged unless used with a Piping Plan 72
8 seal chamber
PIT pressure transmitter with local indicator

Figure G.E.36—Standard Seal Piping Plan 76

In Piping Plan 76 there is a containment seal chamber drain for noncondensing leakage on Arrangement 2 seals. This piping plan is used if the pumped fluid does not condense at ambient temperatures. This system is supplied by the vendor.

Tubing shall be 13 mm (1/2 in.) minimum diameter and shall rise continuously upward from the CSV connection to the piping/instrumentation harness.

The harness shall be pipe of minimum size DN 15 (NPS $^1/_2$). Harness shall be supported from overhead structure or side stand such that no strain is put on the tubing connection to the seal gland plate.

Piping Plan 76 systems are typically used on Arrangement 2, unpressurized dual seals, which also use a dry containment seal and where leakage from the inner seal will not condense. They may be used with a buffer gas (Piping Plan 72) or without a buffer gas (Piping Plan 71).

If an unpressurized dual seal is installed, usually it is because leakage of the pumped fluid to the atmosphere should be restricted more than can be achieved with an Arrangement 1 seal. Therefore, a means is needed to route the leakage to a collection point. The Piping Plan 76 system is intended for services where no condensation of the inner seal leakage or from the collection system will occur. Should liquid accumulate in the containment seal chamber, excessive heat could be generated, leading to hydrocarbon coking and possible seal failure.

Piping Plan 76 is intended to work as follows: leakage from the inner seal is restricted from escape by the containment seal and goes out the containment-seal vent. An orifice in the outlet line of the collector restricts flow such that high leakage of the inner seal will cause a pressure increase and trigger the pressure transmitter to alarm at a gauge pressure of 0.07 MPa (0.7 bar) (10 psi). The block valve in the outlet serves to isolate the system for maintenance. It may also be used to test the inner seal by closing while the pump is in operation and noting the time/pressure buildup relationship in the collector. A drain connection on the piping harness may be used to inject nitrogen or other gas for the purpose of testing the containment seal as well as for checking for any liquid buildup. Refer to Annex F for additional details on Ping Plan 76 test strategies.

The pressure transmitter in Piping Plan 76 will track the pressure in the vapor collection system. In normal operation, the pressure in the containment seal chamber can be as high as the vapor collection system pressure plus the check valve cracking pressure (if present). Pressures greater than this may indicate excessive leakage past the inner seal.

G.37 Piping Plan 99

Engineered piping plan not defined by other existing piping plans.

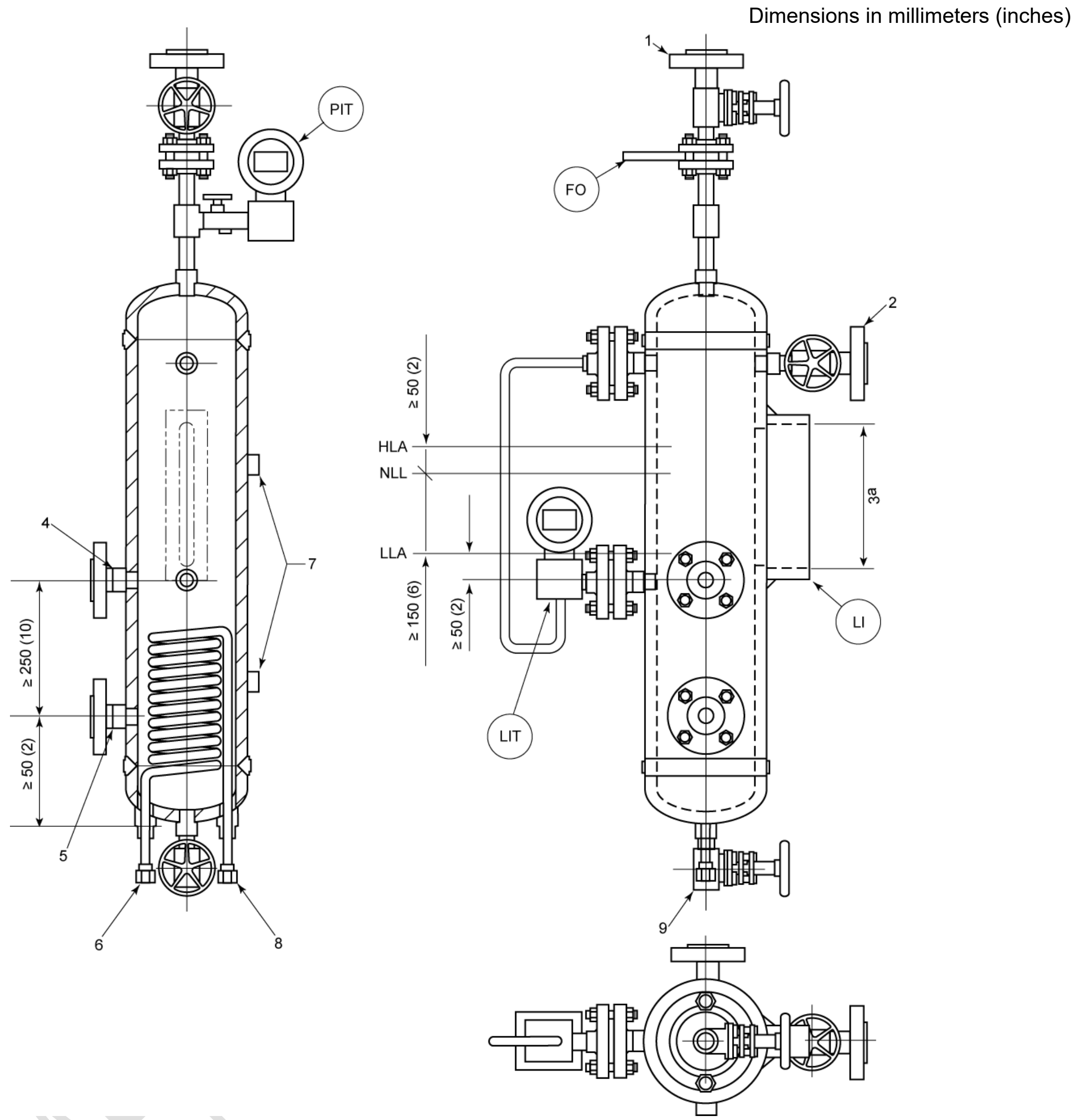
In some challenging seal applications, it is necessary to design a piping plan for the specific characteristics of the seal, arrangement, process conditions or operating practices. The requirements for these applications may require modifications to existing piping plans or the creation of a new and unique plan.

Piping Plan 99 defines an engineered piping plan. The description and requirements for this piping plan shall be clearly defined in specifications outside of this standard. Wherever possible though applicable requirements within this standard should be applied to the new piping plan.

The decision to use a Piping Plan 99 may be made by either the purchaser or the supplier with purchaser's approval.

G.38 External Barrier/Buffer Fluid Reservoir

Figure G.38 shows the standard configuration of an external barrier/buffer fluid reservoir.



Key

1	vent	FO	flow orifice
2	pressure fill	LI	level indicator
3	visible length	LIT	level transmitter with local indicator
4	return from seal	PIT	pressure transmitter with local indicator
5	supply to seal	HLA	high-level alarm set point
6	cooling liquid inlet	NLL	normal liquid level
7	mounting lugs	LLA	low level alarm set point
8	cooling liquid outlet		
9	drain		

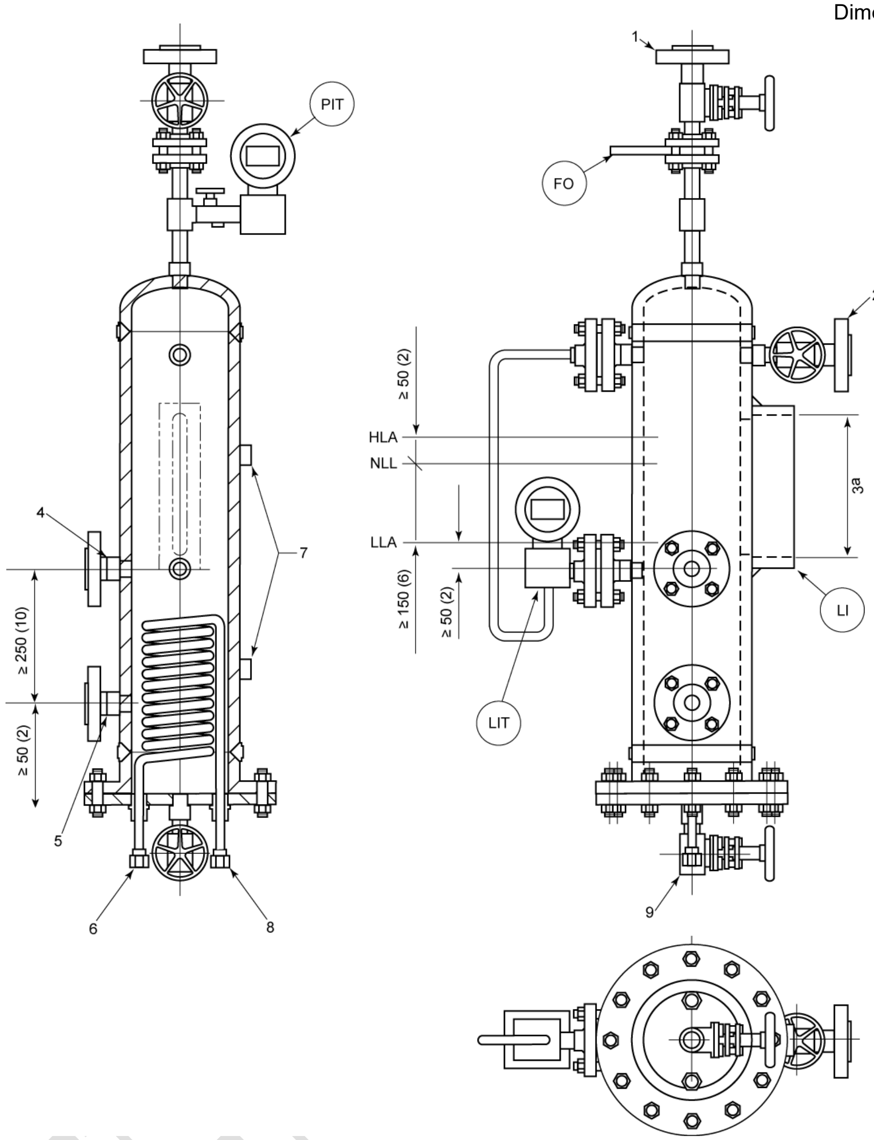
[a] Visible length shall extend from below LLA to 75 mm (3.0 in.) above NLL or 25 mm (1.0 in.) above HLA, whichever is greater.

Figure E.G.38—Standard External Barrier/Buffer Fluid Reservoir

G.39 Alternate External Barrier/Buffer Fluid Reservoir

Figure G.39 shows an alternative configuration.

Dimensions in millimeters (inches)



Key

1	vent	FO	flow orifice
2	pressure fill	LI	level indicator
3	visible length	LIT	level transmitter with local indicator
4	return from seal	PIT	pressure transmitter with local indicator
5	supply to seal	HLA	high-level alarm set point
6	cooling liquid inlet	NLL	normal liquid level
7	mounting lugs	LLA	low level alarm set point
8	cooling liquid outlet		
9	drain		

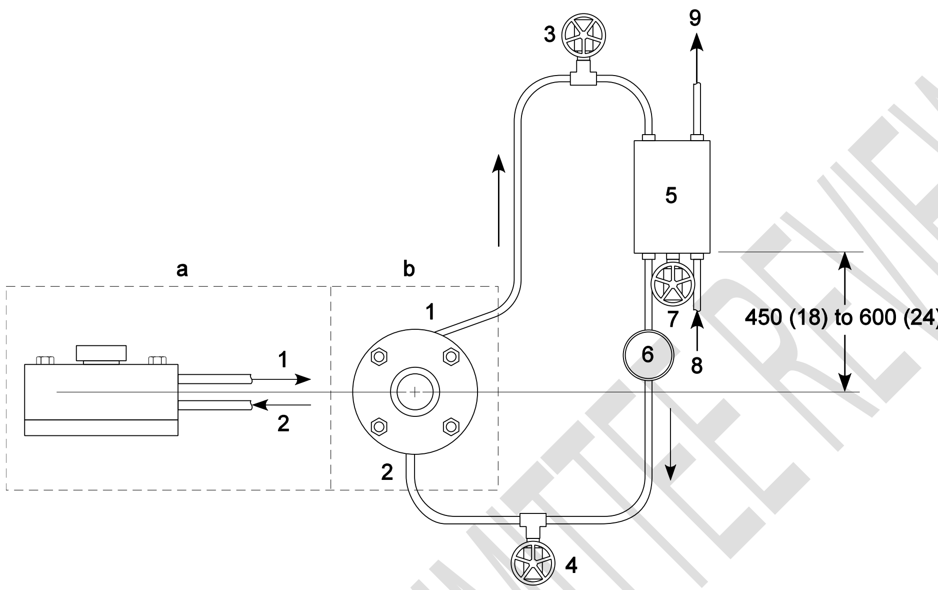
[a] Visible length shall extend from below LLA to 75 mm (3 in.) above NLL or 25 mm (1 in.) above HLA, whichever is greater.

Figure G.E.39—Alternative External Barrier/Buffer Fluid Reservoir

G.40 Piping Plan 23 Circulation System

Figure G.40 shows a typical configuration for the installation of a Piping Plan 23 circulation system.

Dimensions in millimeters (inches)



Key

1 to seal cooler
2 from seal cooler
3 high point vent in connecting tubing
4 low point drain in connecting tubing
5 seal flush cooler
6 temperature indicator
7 cooling water service drain
8 cooling water inlet (CWI)
9 cooling water outlet (CWO)

[a] For vertical applications.

[b] For horizontal applications.

Figure E.G.40—Typical Installation of a Piping Plan 23 Circulation System

The seal flush cooler shall have the cooling liquid on the shell side and the process fluid on the tube side. The cooler design and arrangement shall provide complete venting and draining of both the cooling liquid and process fluids. The cooler shall be mounted in accordance with the manufacturer’s instructions to achieve this.

The seal cooler shall be located as close to the pump as possible while leaving sufficient room for operation and maintenance. It should not be located directly above the pump. To promote thermosyphoning, the seal cooler shall be located 450 mm to 600 mm (18 in. to 24 in.) above the centerline of the gland plate. Hot lines should be insulated as necessary for safety.

To reduce friction losses in tubing, smooth, long radius bends shall be used. For piping, the number of 90° elbows shall be minimized, although 45° elbows may be used.

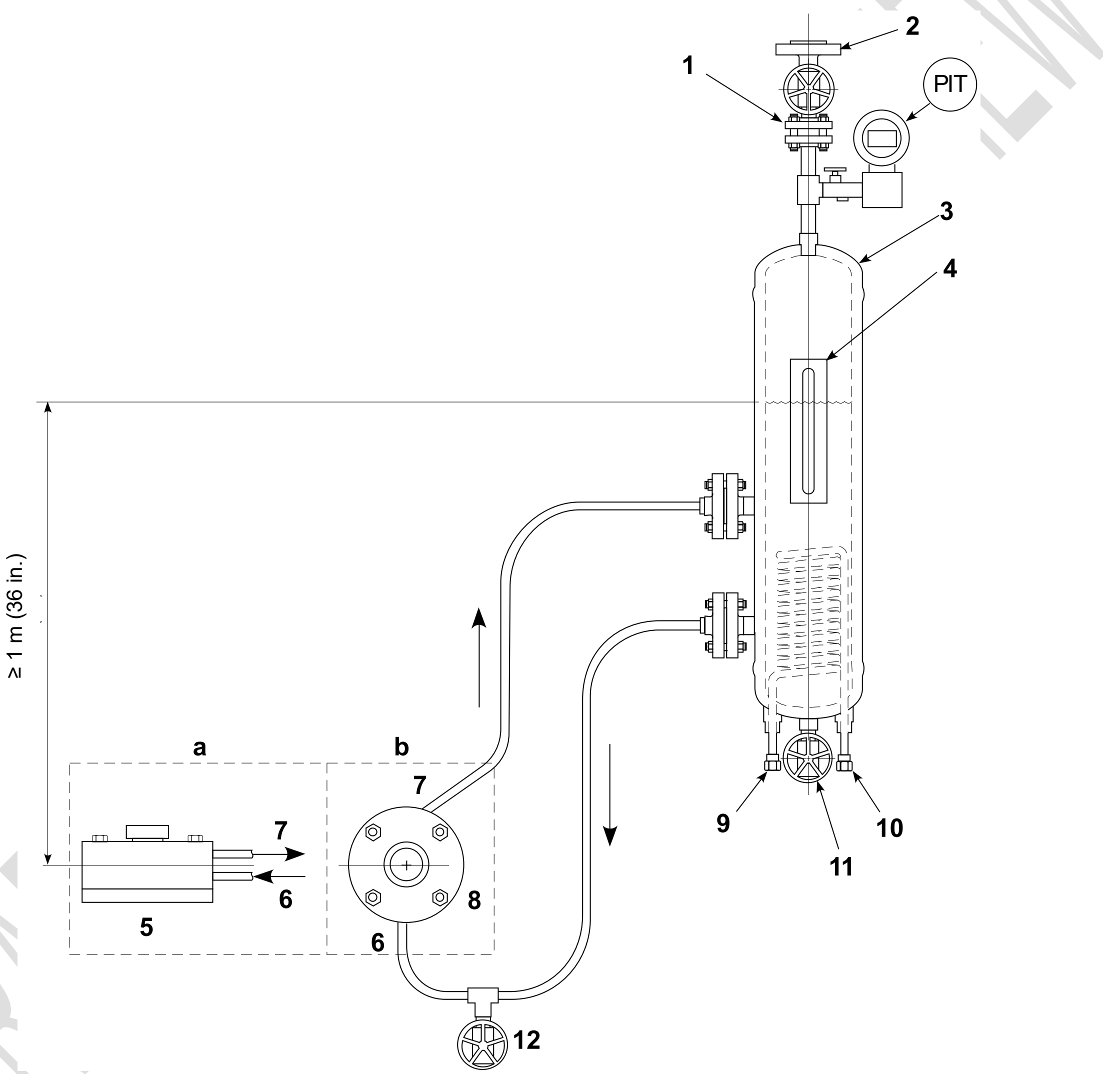
All lines shall slope up from the gland to the high point vent; the slope shall be a minimum of 40 mm/m (0.5 in./ft). The seal cooler and all connecting tubing and piping shall be completely vented and free from air before the seal is put into operation.

NOTE Other piping plans using seal coolers, especially Piping Plan 53B and Piping Plan 53C, will benefit from using the same system design requirements as the Piping Plan 23 (e.g. sloping tubing, venting, and cooler location) except specific components in the system will differ.

G.41 Barrier/Buffer Fluid Reservoir

Figure G.41 shows a typical configuration for the installation of a barrier/buffer fluid reservoir.

Dimensions in millimeters (inches)



Key

1	flanged orifice	7	to reservoir
2	vent	8	gland, horizontal 9 cooling liquid inlet
3	reservoir	10	cooling liquid outlet
4	level indicator	11	reservoir barrier/buffer fluid drain
5	gland, vertical	12	barrier/buffer fluid drain
6	from reservoir		

[a] For vertical applications.

[b] For horizontal applications.

Figure E.G.41—Typical Installation of a Barrier/Buffer Fluid Reservoir

The seal reservoir shall be located as close to the pump as possible while leaving sufficient room for operation and maintenance. It should not be located directly above the pump. Hot lines shall be insulated as necessary for safety.

For tubing, smooth, long radius bends shall be used. For piping, the number of 90° elbows shall be minimized, although 45° elbows may be used.

All lines shall slope up from the gland to the high point vent; the slope shall be 40 mm/m (0.5 in./ft).

Figure G.41 indicates the vertical distance between the pump shaft and the barrier fluid level should be a minimum of 1 m (36”). This distance is intended to ensure the interconnecting piping can meet the requirements for venting and thermosyphoning while minimizing the tubing length. While there is no specified maximum reservoir mounting height, the height should be as low as practical to minimize tubing friction losses and maximize barrier fluid circulation flow rates.

Annex H
(informative)

Inspectors' Checklist for All Seals

Item	Subsection Reference	Date Inspected	Inspected by	Status
Gland connections marked	6.1.3.17 6.1.3.18			
Plugs and tagging	8.4.6			
Weld procedures approved	6.1.7.10			
Repair procedures approved	6.1.7.10			
Impact test results	6.1.7.11			
Adequate clearance and safe access	7.1.3			
Piping, fabrication, examination, and inspection meet standards and weld procedures approved.	7.2.10 7.2.11			
Tags attached to coolers	7.3.2.1.4			
Orifice data	7.3.5.3.5			
Buffer/barrier-fluid reservoir tag	7.3.6.2.12			
Reservoir sizing criteria	7.3.6.2.7			
Relief valve list	7.4.8.1.3			
Compliance with inspector's checklist	8.1.7			
NDE inspection results	8.2.3			
Cleanliness inspection	8.2.3 j) 8.4.3 c)			
Hardness test results	8.2.3 k)			
Qualification test results	Annex I			
Test certificate	Annex I			
Certified hydrostatic test results	8.3.2.1.1 8.3.4.1			
Seal supplied air test tag	8.3.2.2.8			
Seal leakage acceptance criteria	Annex I			
Site storage procedures	8.4.2			
Preparation for shipment	8.4.3			
Auxiliary piping connections tagged or marked	8.4.4			
Installation instructions	8.4.5			
Contract data	9.1.1 and Annex E			

Annex I
(normative)

Seal Qualification Testing Protocol

I.1 General (Informative)

I.1.1 Purpose

I.1.1.1 In order to provide the end user with a high degree of confidence that a manufacturer's commercial product seal will perform as required by this standard, each seal configuration in combination with other seal system attributes as noted in Annex I shall be suitably qualified by the seal manufacturer prior to its market availability.

I.1.1.2 The seal qualification test is the default qualification method. It does not constitute an acceptance test. The intent is not to perform the qualification test for every individual seal cartridge or seal size in every qualification test fluid, but to qualify specific seal configurations and attributes in specific qualification test fluids to simulate various process fluids and typical industry applications.

NOTE 1 To give a comprehensive overview about the qualification requirements the relevant information has been enhanced and reorganized. The qualification requirements for the new Category 4 have also been integrated.

NOTE 2 Category 4 seals are a small subset of the total seal population within the petroleum, natural gas, and chemical industries with a broad application base. Many manufacturers already have existing seal models that have been through extensive manufacturers development testing and have now been successfully operating in the field for many years. These would have historically been sold as 'Engineered' seals due to application conditions out of scope of the standard

NOTE 3 API-682 (5th Edition) has also extended the size range for all categories to shaft diameters up to 150 mm (5.000"). This is also a small subset of the total seal population within the petroleum, natural gas, and chemical industries with a broad application base. Many manufacturers already have existing qualified seal model offerings that extend to these larger sizes that have been successfully operating in the field for many years. These would have historically also been sold as 'Engineered' seals due to application conditions out of scope of the standard.

I.1.2 Seal Qualification Overview

I.1.2.1 The qualification of mechanical seal series or specific job seal designs shall be completed in accordance with Figure I.1.

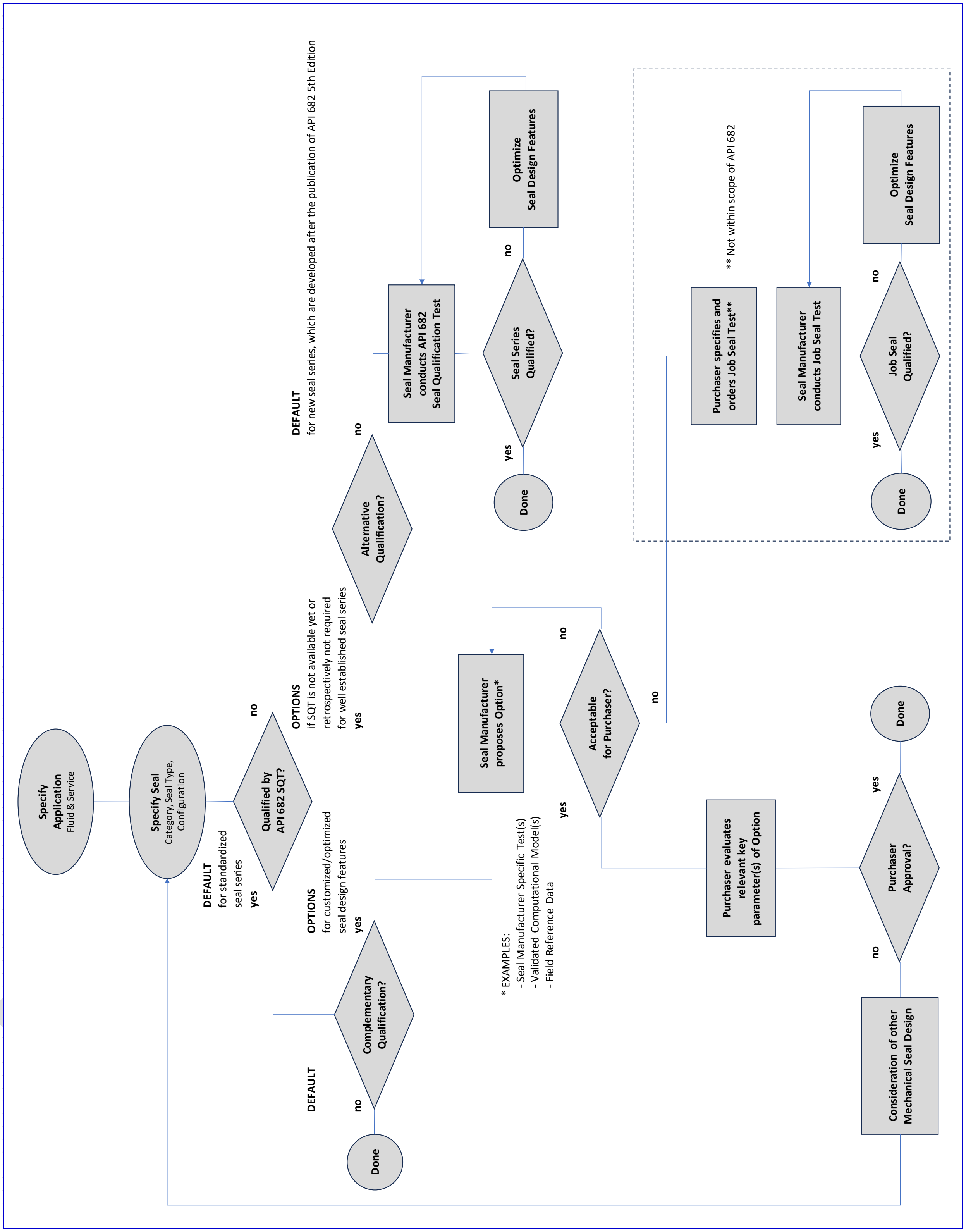

Specify Application
Fluid & Service
Specify Seal
Category, Seal Type, Configuration
Qualified by API 682 SQT?
DEFAULT
for standardized seal series
yes
no
OPTIONS
for customized/optimized seal design features
yes
Complementary Qualification?
DEFAULT
no
Done
OPTIONS
if SQT is not available yet or retrospectively not required for well established seal series
yes
Alternative Qualification?
no
DEFAULT
for new seal series, which are developed after the publication of API 682 5th Edition
Seal Manufacturer conducts API 682 Seal Qualification Test
Seal Series Qualified?
no
Optimize Seal Design Features
yes
Done
Seal Manufacturer proposes Option*
* EXAMPLES:
- Seal Manufacturer Specific Test(s)
- Validated Computational Model(s)
- Field Reference Data
Acceptable for Purchaser?
no
yes
no
Purchaser evaluates relevant key parameter(s) of Option
Purchaser Approval?
yes
Done
no
Consideration of other Mechanical Seal Design
** Not within scope of API 682
Purchaser specifies and orders Job Seal Test**
Seal Manufacturer conducts Job Seal Test
Job Seal Qualified?
no
Optimize Seal Design Features
yes
Done

Figure I.1—Seal Qualification Overview

I.2 Hierarch and Attribute of Sealing Systems

The specification and qualification of a sealing system is not possible without an understanding of the terminology, attributes and hierarchy used to describe it. Although there are many variations and much overlapping within the industry, this standard has adopted the terms and definitions of Section 3 to describe the attributes of a sealing system. In addition, the hierarchy of a typical sealing system is illustrated below. The numbers prior to each attribute indicate the level within the hierarchy.

The references shown below are for general reference only and are not an all-inclusive index.

1. Seal cartridge
  2. Core seal components
    3. Seal ring assembly
      4. Seal ring geometry (see 6.1.5)
      4. Seal ring material (see 6.1.7.2.2)
      4. Seal ring drive mechanism(s)
      4. Secondary seal material and hardness (see 6.1.7.5)
      4. Spring(s)
        5. Single spring
        5. Multiple springs
        5. Metal bellows
      4. Spring force control mechanism
    3. Mating ring assembly
      4. Mating ring geometry (see 6.1.5)
      4. Mating ring material and hardness (see 6.1.7.2.2)
      4. Mating ring drive mechanism(s) (see 6.1.5.1)
      4. Secondary seal material (see 6.1.7.5)
  2. Adaptive hardware
    3. Sleeve (see 6.1.4)
      4. Sleeve drive mechanism
        5. Drive collar (see 6.1.1.4)
        5. Set screws (see 6.1.4.12)
        5. Alternative drive mechanisms
    3. Gland plate (see 6.1.3)
      4. Connection orientation (see Table 2)
      4. Flush geometry
        5. Single point flush
        5. Distributed flush
    3. Positive circulation device
      4. None
      4. Internal
      4. External pump
      4. External flush
  2. Seal category (see 4.2.2)
    3. Category 1
    3. Category 2
    3. Category 3
  2. Seal type (see 4.2.3)
    3. Type A
    3. Type B

3. Type C

2. Seal configuration (see Figure 2)

3. Seal arrangement (see 4.2.4)
4. Arrangement 1 (see 6.3.1)
4. Arrangement 2 (see 6.3.2)
4. Arrangement 3 (see 6.3.3)

3. Rotating component (see 6.1.1.2 and 6.1.1.5)
4. Seal ring rotates
4. Mating ring rotates

3. Sealing interface (see 4.2.4)
4. Contacting wet
4. Contacting dry
4. Noncontacting wet
4. Noncontacting dry

3. Seal ring orientation (see Figure 2 and 4.2.5)
4. Single seal: not applicable
4. Dual seal: back-to-back
4. Dual seal: face-to-face
4. Dual seal: face-to-back

3. Containment device
4. Fixed bushing (see 6.3.1.2.1)
4. Floating carbon bushing (see 6.3.1.2.1)
4. Segmented, floating carbon bushing (see 6.3.1.2.1)
4. Containment seal (see 6.3.2.4 and 6.3.2.5)

1. **Seal chamber** (see 6.1.3)
2. **Traditional**
2. **Externally mounted**
2. **Internally mounted**

1. Accessories (see Section 7)

2. Interconnecting piping for seal auxiliary systems (see 7.2)

2. Seal auxiliary system (see 7.3)

3. Seal auxiliary system components

I.3 Seal Qualification Testing

I.3.1 History

I.3.1.1 The detailed protocol for qualification testing of seals was originally incorporated in the body of API-682 (1st, 2nd and 3rd Editions). The protocol was moved to this annex part of API-682 (4th Edition). This reorganization simplifies the standard for users while providing the necessary details required by seal manufacturers to accurately and consistently execute qualification testing.

I.3.1.2 Seal manufacturers provide specialized products for many industries. Most of the designs available have a long history of proven success in the application for which the seal is designed. A subset of the total seal population is for the petroleum, petrochemical, and natural gas industries that are covered by this standard; therefore, it is normal to expect special services and applications to be outside its scope and associated qualification tests. Even within the petroleum, petrochemical, and natural gas industries there is a vast array of temperatures, pressures, and liquids sealed with mechanical seals. End users as well as manufacturers recognized the need to increase the design and testing focus of sealing products intended for petroleum, petrochemical, and natural gas industries to address the need for increased standardization, improved reliability, and lower leakage.

I.3.1.3 API-682 (1st Edition) published in 1994 introduced a standardized cartridge seal specifically designed to fit a new seal chamber dimensional envelop. Historically the industry had generally used component (non-cartridge) type seals mounted directly on pump sleeves. Given the industry had to design a new suite of cartridge seals to meet API-682 (1st Edition), the API-682 task force at the time introduced the requirement of qualification testing of seals. This entailed API-682 compliant seals would be qualified if two sizes of a specific seal design and material were tested in one or more of the four qualification test fluids. At the time of API-682 (1st Edition), there were no pass/fail criteria. API-682 (2nd Edition) published in 2002 introduced criteria for wear and leakage. Seal Categories 1 and 2 were also added part of API-682 (2nd Edition) with API-682 (1st Edition) qualification tested seals essentially being defined as Category 3 seals. As of API-682 (4th Edition), the intent of qualification testing is to provide the end user with a high degree of confidence that the commercial seal product being offered will perform successfully in the intended service by virtue of passing tests on the appropriate test fluid for the representative pumped fluid and service condition as shown in Annex I.4 and I.5.

I.3.1.4 Users and manufacturers recognize that seals are designed for specific applications and a single design will not be suitable for all applications. Typically, users want cost efficient seals for less arduous services and manufacturers will qualify those seals for only those services. For example, there is little need to qualify a high-temperature metal bellows seal with flexible graphite secondary seals for use in a cold water service. Likewise, simple cold water seals will not be used in high-temperature services and obviously would not pass the hot oil qualification test. At the same time, through continuous improvement efforts by all, numerous design variations - including materials, geometry, loading, and seal auxiliary support systems - are implemented, tested and qualified. The population of qualified seal designs, materials, and auxiliary components is substantial and increasing.

I.3.1.5 Manufacturers keep qualification test records of all complying seal designs and sizes and can provide them on request. The various seal configurations are shown in Figure 2; many of these have been newly introduced since API 682:1994 (First Edition). Many of the new configurations used seals that had been previously qualified; however, additional qualification testing parameters were required for the untested designs and components. For example, noncontacting seal face designs were introduced in API 682:2002 (Second Edition) and testing in a gas environment was required as part of the qualification tests for those products.

I.3.2 Scope of Test

I.3.2.1 General

I.3.2.1.1 All relevant details for the proper execution of the seal qualification tests (SQT) are now documented with seal qualification test charts in Annex I.4 and I.5. Each SQT chart summarizes all relevant testing details for a specific seal configuration and seal category. These charts replace all former tables and clauses previously documented in API 682 (4th Edition).

I.3.2.1.2 Due to the broad range of seal chamber pressures now covered by API-682 (5th Edition) for Category 4 seals, an alternative seal qualification test is required for Category 4 seals versus Category 1, 2 and 3 seals. Specific seal qualification test details for Category 4 seals are therefore documented separately in Annex I.5, while the testing details for Category 1, 2 and 3 seals are documented in Annex I.4.

I.3.2.1.3 For dual seals, qualification testing shall be done using an internal circulation device only and this test with the internal circulation device shall serve as qualification for external circulation devices.

I.3.2.1.4 Commercially available products shall be tested by configuration and in accordance with the relevant seal qualification test charts in Annex I4. or I.5. However, the following attributes, features or components shall not be considered as part of the test:

a) throttle bushings (whether fixed, floating, or multiple)
b) dynamic secondary seal material except for durometer, see 6.1.7.5 and I.3.2.1.10; see Annex B for tutorial discussion of elastomer properties
c) static secondary seal material

I.3.2.1.5 Seal types are qualified only for the configuration used during that test; however, a configuration may have mixed seal types. The requirements for qualification may be transferred among combinations of seal types and configurations that share the same adaptive hardware provided each seal type has been tested in that configuration.

NOTE As an example, if configuration 3CW-BB has been qualified in propane using Type A seals as both the inner and outer seal and a similar 3CW-BB has also been qualified in propane using Type B seals as both the inner and outer seal then those seal types may be mixed in that configuration (3CW-BB) for light hydrocarbon services. That is, the configuration is also qualified with Type A as the inner seal and Type B as the outer seal as well as Type B as the inner seal and Type A as the outer seal. For purposes of transferring qualification, dry-running containment seals may be considered to be a seal type.

I.3.2.1.6 Core seal components are qualified only for the adaptive hardware and configuration used during that test.

NOTE Adaptive hardware of the commercially available product should be essentially identical to the qualified seal in terms of functionality and internal geometry. However, the manufacturer's commercially available product may deviate from the test design to fit into a specific seal chamber or to realize enhanced performance. The manufacturer should be able to adequately demonstrate the enhanced performance of a modified design.

I.3.2.1.7 To be qualified for use in a particular pumped fluid and service condition, a manufacturer's commercial product shall be successfully tested using the appropriate qualification test fluid as specified in the seal qualification test charts in Annex I.4 and I.5. A qualified seal, for the service represented by the qualification test fluid, requires the product shall meet all the seal qualification criteria documented in the relevant seal qualification test chart.

NOTE 1 A seal manufacturer's commercial product need be tested only in the representative qualification test fluid to its required service. It is not necessary to test a commercial product in all qualification test fluids.

NOTE 2 The qualification test fluids were selected to model the behavior of the fluids described in the recommended seal selection procedure (Annex A). The properties of the qualification test fluids are representative of the properties of the pumped fluid and service conditions (for example, viscosity, corrosiveness, crystallization, vapor pressure, hydrocarbon, or nonhydrocarbon). The qualification test fluids selected were considered to be readily available and safe for testing in a laboratory environment.

NOTE 3 All mechanical seals require face lubrication to achieve reliability; this results in a minimal level of leakage, see F.1.1. On a water pump test of a contacting wet seal, the leakage typically evaporates and is not visible. Face design features, however, can increase leakage levels and visible droplets may occur.

Pressurized dual contacting wet seals, when used with a non-evaporative, lubricating-oil barrier fluid, can also produce visible leakage in the form of droplets.

NOTE 4 The owner or purchaser determines the applicable emission/leakage limits at the intended point of application and compares these limits to the maximum permitted leakage rates given in the relevant seal qualification test chart. This maximum permitted leakage rate is the qualification criteria for a defined seal size range and standardized test conditions. It is not the maximum allowable leakage value for all possible service conditions within the application scope of a category and all possible fluids of a specific fluid medium group. Local limits may be lower than the stated values. If an Arrangement 1 seal does not comply with local emission or leakage requirements, then Arrangement 2 or Arrangement 3 may be required to meet the applicable limits.

I.3.2.1.8 The nominal balance diameters of the test seals shall be within the diameter ranges specified in the relevant seal qualification test charts in Annex I.4 and I.5.

NOTE Many seal applications are covered by this standard. The testing of these sizes is considered representative of the range of sizes identified. The performance of sizes between the test sizes is considered to be similar to the test sizes.

I.3.2.1.9 After one face material pair (a specific combination of seal ring material and mating ring material including vendor, grade, surface finish and profile) has been successfully qualified, additional face material pairs may be qualified for the same service represented by the qualification test fluid used in that test as follows:

- Using the same seal ring material as tested in I.3.2.1.9, additional mating ring materials (vendor, grade, surface finish, and profile) may be qualified for use with that same seal ring material by testing only the larger test size for that category in the qualification test fluid.
- Using the same mating ring material as tested in I.3.2.1.9, additional seal ring materials (vendor, grade, surface finish, and profile) may be qualified for use with that same mating ring material by testing only the larger test size for that category in the representative qualification test fluid.

NOTE This reduces the number of tests and promotes testing of additional face materials.

I.3.2.1.10 After one secondary seal elastomer material (vendor, grade, and durometer) has been successfully qualified, additional secondary seal elastomeric materials are qualified for the same service represented by the qualification test fluid used in that test as follows:

- shall comply with 6.1.7.5
- shall be the same nominal durometer hardness as used during previous qualification testing within ±5 points.

I.3.2.1.11 The temperature and pressure measurements are values taken to be representative of the majority of the seal chamber volume of fluid.

NOTE The seal chamber fluid temperature is the average of the measured inlet and outlet temperature.

I.3.2.1.12 Instrumentation used to measure leakage concentration of VOCs shall be capable of identifying:

a) the maximum emission concentration from the seal at the most likely leak point. The instrument shall sample at a maximum of 1 cm from the maximum emission source;
b) the local ambient VOC concentration within a 1 m to 2 m radius from the probable source of a leak. This may involve a 360° sweep of the installation.

NOTE The requirements of I.3.2.1.12 are essentially the same as EPA Method 21; however, EPA Method 21 is a manual method for measuring leakage concentration whereas qualification testing may involve seal test rigs and automated data acquisition.

I.3.2.1.13 All instrumentation shall be selected to be appropriate for the value being measured.

I.3.2.1.14 All instrumentation shall be calibrated and traceable to an appropriate standard.

I.3.2.1.15 Seal-face wear shall be computed based on the average change in length of the faces as measured before and after testing. Measurements shall be taken at four places approximately equally spaced around the circumference of the seal faces.

I.3.2.1.16 Seal leakage shall be based on the total leakage measured during the test divided by the total duration of dynamic operation during the test.

I.3.2.1.17 Liquid leakage from the inner seal of a 2CW-CW or 2CW-CS seal configuration is not allowed to collect in the buffer or containment chamber.

I.4 Seal Qualification Test for Category 1, 2 and 3 Seals

I.4.1 Table I.1 illustrates how qualification testing for different seal configurations has generally been organized by seal manufacturers. While category, size, face material, type, and flexible element orientation may vary, the basic seal configuration largely dictates the qualification test scope, procedure, and fluid. Because of the large number of possible combinations of these parameters (approximately 4000) it is unlikely that seal manufacturers have tested or will test all possible combinations in all possible qualification test fluids. Seal manufacturers often first focus their testing efforts on the defaults of this standard, their own most popular products and the most representative test conditions for specific service applications. Users should verify that the required seal qualification tests have been performed for their intended application. It is possible that the qualification test for a special design or a new product has not yet been conducted. If the required tests have not yet been conducted, the user and the manufacturer shall mutually agree on the necessary steps to qualify that commercially available product according to Figure I.1.

Table I.1 – Organization of qualification testing for Category 1, 2 and 3

<table>
<tr><th colspan="6">Seal Design Parameters[a]</th><th colspan="3">Test Parameters[b]</th></tr>
<tr><th>Category</th><th>Seal Balance Diameter
mm</th><th>Face Material Pair</th><th>Type</th><th>Flexible Element</th><th>Configuration</th><th>Scope</th><th>Procedure</th><th>Fluid</th></tr>
<tr><td rowspan="11">1
2
3</td><td rowspan="11">Category 1:
38 to 75
and
>75 to < 127

Category 2/3:
50 to 75
and
125[c] to 190[d]</td><td rowspan="11">Carbon/SS-SiC

Carbon/RB-SiC

SS-SiC/SS-SiC

RB-SiC/RB-SiC</td><td rowspan="11">A

B

C</td><td rowspan="11">Rotating

Stationary</td><td>1CW-FX
1CW-FL[e]</td><td>Inner seal</td><td rowspan="7">Static
Dynamic
Cyclic</td><td rowspan="6">Water
propane
NaOH
oil cold
oil hot</td></tr>
<tr><td>2CW-CW[e]</td><td rowspan="3">Inner seal and arrangement</td></tr>
<tr><td>2CW-CS</td></tr>
<tr><td>3CW-FB[e]</td></tr>
<tr><td>3CW-BB
3CW-FF</td><td rowspan="3">Arrangement</td></tr>
<tr><td>3NC-BB[e]
3NC-FB
3NC-FF</td></tr>
<tr><td rowspan="2">2NC-CS</td><td>Propane</td></tr>
<tr><td rowspan="2">Focus on containment seal</td><td rowspan="2">Static
Dynamic</td><td>Propane leakage</td></tr>
<tr><td>2CW-CS</td><td>Glycol/water, mineral oil, diesel or synthetic oil
and
Nitrogen, steam or propane leakage</td></tr>
<tr><td>3CW-BB
3CW-FF</td><td rowspan="2">Arrangement</td><td>Variable barrier liquid pressure</td><td>Glycol/water, mineral oil, diesel or synthetic oil</td></tr>
<tr><td>3NC-BB[e]
3NC-FB
3NC-FF</td><td>Variable barrier gas pressure</td><td>Nitrogen</td></tr>
<tr><td colspan="9">a: As test seal cartridge is specified by the parameters in this column and the representative materials and geometry of its core seal components. In dual seal combinations of face materials pairs, types and flexible element positions are possible.
b: For a specific service a seal vendor's commercial product only needs to be tested in the representative test fluid.
c: 100 mm if seal was tested before publishing date of 5th edition
d: 127 mm if seal was tested before publishing date of 5th edition
e: Default Configuration</td></tr>
</table>

NOTE As an example, consider the seal configuration 2CW-CS from Table I.1. This is an Arrangement 2 seal cartridge fitted with a contacting, wet inner seal and dry-running containment seal as the outer seal. A manufacturer might make 2CW-CS using Type A, rotary flexible element components but another manufacturer might use Type A, stationary flexible element components. Other manufacturers might choose Type B, Type C, or even mix seal types. There are four face material pairs that might be considered for testing and any, or all, such pairs might be tested. Whatever is to be offered to the purchaser shall be tested. Examples of combinations include:

— Type A, carbon/SSiC, rotary flexible element;
— Type A, SSiC/SSiC, stationary flexible element;
— Type B, carbon/SSiC, stationary flexible element, etc.

Again, it is not required to test all possible combinations but the combination that is to be offered to the purchaser shall be tested.

It is also required to test two sizes within a range of balance diameters; for example, a manufacturer might choose to test 50 mm and 125 mm balance diameter seal cartridges.

If the manufacturer wishes to offer the 2CW-CS for service in a vaporizing liquid then the qualification tests shall be accomplished in propane as the process liquid, the vaporized propane leakage from the inner seal, which collects in the containment chamber and a commercially available petroleum based diesel fuel or synthetic oil as buffer liquid.

I.4.2 Category 1, 2 and 3 qualification tests shall be conducted using the core seal components, adaptive hardware, seal types and seal configurations as proposed for commercially available seals.

I.4.3 The requirements to become a qualified seal may be transferred across Category 1, 2 and 3 for commercial products that share the following features and attributes:

a) core seal components
b) adaptive hardware
c) seal type
d) configuration

Category 3 qualification may be transferred to Category 2 or Category 1. Category 2 qualification may be transferred to Category 1.

NOTE This potentially reduces the number of tests and provides incentives for reducing inventory of spare parts; however, Category 3 can be qualified only through specific testing.

I.4.4 Leakage concentration of volatile organic compound (VOC) qualification test fluids shall be measured with an organic vapor analyzer based on Appendix A of Title 40, Part 60 of the U.S. Code of Federal Regulations, or equivalent. The results of the measurements shall be recorded at the points shown in Figure I.2, Figure I.3, and Figure I.4 as a minimum requirement.

NOTE Site measurements of VOC emissions are undertaken using EPA Method 21, which is a manual method intended to identify sources giving rise to emissions of more than 1000 ppm. These measurements are intended to predict the on-site results using EPA Method 21 from the qualification test results.

I.4.5 Each qualification test for each qualification test fluid shall consist of a dynamic, static and cyclic phase.

NOTE 1 These phases were selected to qualify the seal type for the operating ranges (temperatures and pressures) defined for the pumped fluid and process conditions as shown in the upper section of the seal qualification test charts (Table I.4.2 to I.4.8). Figure I.2 to Figure I.4 show a graphical representation of the test procedures. The test phases were selected to model actual pump operating conditions such as normal running, upset, standby, and start-up/shutdown.

NOTE 2 Arrangement 3 seals are tested to simulate an unusual combination of pump operating conditions or an upset or failure condition that can realistically occur during operation.

Different configurations can offer varying operational benefits. The FB configuration has a greater tolerance to operation with a loss of barrier liquid or pressure but may have a limited performance with higher pressure differentials across the inner seal than FF or BB configurations. The FF and BB configurations, however, have greater potential to manage an unusual range of chamber conditions which produce high inner seal pressure differentials but are less tolerant to a loss of barrier liquid and pressure. The qualification tests have been devised to recognize the different configuration benefits.

There are two potential conditions which could occur:

— Loss of barrier fluid and pressure is simulated only for the FB configuration but not to the BB or FF orientation which are less tolerant to this condition. The qualification test plan for BB and FF configurations includes a much shorter dynamic period of barrier fluid pressure loss but with an extended static check to ensure containment is still maintained.
— Loss of pump pressure is also simulated. This condition simulates operation of the pump when there are pump suction upsets or wide swings in suction pressure. It would also simulate operation of the pump when the barrier fluid is fully pressurized prior to pressurizing the pump. The longer test applies only to FF and BB configurations to test their greater tolerance to this condition whereas FB configurations are tested for the shorter period in the cyclic phase.

I.4.6 The test phases shall be run consecutively, without disassembly of the seal. All further required testing details are documented in the seal qualification test charts according to Table I.2 to Table I.8.

I.4.7 Category 1, 2 and 3 qualification test details in accordance with API-682 (4th Edition) remain valid except for the following amendments:

a) With the publication of API-682 (5th Edition), for new mechanical seal series the seal balance diameter of the large test seal shall be between 125 mm and 190 mm. For mechanical seals, which have been developed and tested before API-682 (5th Edition), additional retroactive seal qualification testing with these larger diameters is not required.
b) With the publication of API-682 (5th Edition) the buffer and barrier fluid for the seal qualification testing of 2CW-CW and 3CW-FF, 3CW-BB and 3CW-FB configurations can also be done with a synthetic oil instead of diesel or mineral oil.
c) With the publication of API-682 (5th Edition) the test fluid for the seal qualification testing of containment seals in 2CW-CS configurations (PART 3) and 2NC-CS configurations (PART 2) can also be done with a synthetic oil instead of diesel.

I.4.8 Minimum test data that shall be recorded during seal qualification testing is presented in the forms illustrated by Figure I.5 and Figure I.6.

Table I.2 – SQT Chart for seal configuration 1CW-FL and 1CW-FX

PUMPED FLUIDS & SERVICE CONDITIONS					
Acid	≤ 80 °C	-	-	-	-
Sour Water					
Water					
Caustic	-	≤ 80 °C	-	-	-
Non-Flashing Hydrocarbons	-	-	-40 °C to -5 °C	-5 °C to < 176 °C	176 °C to 400 °C
Flashing Hydrocarbons	-	-	-40 °C to < 176 °C	-	

SEAL QUALIFICATION TEST Single Seal Arrangement		**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition		**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
		Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C		**r/min**	**duration**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Base Point:	**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
	drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
	raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
	raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
h)	repeat steps b) to g)	3x													
i)	repeat steps b) to e)	1x													
j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260

Seal Qualification Criteria							
Leakage:	Core Seal	Maximum permitted SQT leakage at seal faces					
		5.6 g/h	5.6 g/h	EPA Method 21 1000 ppm	5.6 g/h	5.6 g/h	
	Adaptive Hardware	No measurable secondary seal leakage					
Face Wear:		After completion of the qualification test, the total wear of the seal faces shall be less than 1 % of the available seal-face wear					
Seal Integrity:		No obvious damage of seal parts after test					

Table I.3 – SQT Chart for seal configuration 2CW-CW

PUMPED FLUIDS & SERVICE CONDITIONS						
	Acid Sour Water Water	≤ 80 °C	-	-	-	-
	Caustic	-	≤ 80 °C	-	-	-
	Non-Flashing Hydrocarbons	-	-	-40 °C to -5 °C	-5 °C to < 176 °C	176 °C to 400 °C
	Flashing Hydrocarbons	-	-	-40 °C to < 176 °C	-	
SEAL QUALIFICATION TEST - PART 1 **Only Inner Seal of Dual Seal Arrangement**	**Test Fluid:**	**Water**	**NaOH (20%)**	**Propane**	**Mineral Oil**	
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition	**Category:**	**1 / 2 / 3**			**1** (A/B) / **2 / 3** (A, B / C, A / B / C, C)	
	Seal Type:	**A / B / C**			**A/B** | **A** | **B / C** | **A / B / C** | **C**	
Test Procedure - see also Figure I.2	Same dynamic, static and cyclic phase as in PART 2					
Seal Qualification Criteria	**Leakage:** Core Seal	Maximum permitted SQT leakage at seal faces				
		5.6 g/h	5.6 g/h	-	5.6 g/h	
	Adaptive Hardware	No measurable secondary seal leakage				

SEAL QUALIFICATION TEST - PART 2 **Dual Seal Arrangement**															
		Test Fluid:		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
		Buffer Fluid:		**Glycol/Water**		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**					**Mineral Oil or Synthetic Oil**
Test Seal		**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
		Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C		**r/min**	**duration**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Buffer Fluid - Pressure / Temperature		-	-	**≤ 0.1**	**< 80**	**≤ 0.1**	**< 80**	**≤ 0.1**	**< 80**	**≤ 0.1**	**< 80**	**≤ 0.1**		**< 80**	
Base Point:	**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
	drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
	raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
	raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
h)	repeat steps b) to g)	3x													
i)	repeat steps b) to e)	1x													
j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260

Seal Qualification Criteria									
Leakage: Core Seal	Maximum permitted SQT leakage at seal faces								
	Inner Seal*	**Outer Seal**	**Inner Seal***	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal***	**Outer Seal**
	Water	Buffer Fluid	NaOH (20%)	Buffer Fluid	Propane	Buffer Fluid & Propane Leakage	Mineral Oil	Buffer Fluid
	5.6 g/h		5.6 g/h		-	5.6 g/h 1000 ppm	5.6 g/h	
Adaptive Hardware	No measurable secondary seal leakage								
Face Wear:	After completion of the qualification test, the total wear of the seal faces shall be less than 1 % of the available seal-face wear								
Seal Integrity:	No obvious damage of seal parts after test								

Table I.4 – SQT Chart for seal configuration 2CW-CS

PUMPED FLUIDS & SERVICE CONDITIONS			**Acid** **Sour Water** **Water**		≤ 80 °C		-		-		-					-
			Caustic		-		≤ 80 °C		-		-					-
			Non-Flashing Hydrocarbons		-		-		-40 °C to -5 °C		-5 °C to < 176 °C					176 °C to 400 °C
			Flashing Hydrocarbons		-		-		-40 °C to < 176 °C		-					
SEAL QUALIFICATION TEST - PART 1 **Only Inner Seal of Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
			Buffer Fluid:		**none**		**none**		**none**		**none**					**gas purge**
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2			Same dynamic, static and cyclic phase as in PART 2													
Seal Qualification Criteria			**Leakage:**	Core Seal	Maximum permitted SQT leakage at seal faces											
					5.6 g/h		5.6 g/h		-		5.6 g/h					
				Adaptive Hardware	No secondary leakage											
SEAL QUALIFICATION TEST - PART 2 **Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
			Buffer Fluid:		**none**		**none**		**none**		**none**					**gas purge**
Test Seal			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**						**A / B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C			**r/min**	**time**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Base Point:		**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase	a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
	c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
		drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
	d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
		raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
		raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
	e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	h)	repeat steps b) to g)	3x													
	i)	repeat steps b) to e)	1x													
	j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Seal Qualification Criteria			**Leakage:**	Core Seal	Maximum permitted SQT leakage at seal faces											
					Inner Seal*	**Outer Seal**	**Inner Seal***	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal***				**Outer Seal**	
					Water	-	NaOH (20%)	-	Propane	Propane Leakage	Mineral Oil				-	
					5.6 g/h	-	5.6 g/h	-	-	1000 ppm	5.6 g/h				-	
				Adaptive Hardware	No measurable secondary seal leakage											
SEAL QUALIFICATION TEST - PART 3 **Focus on Containment Seal**			**Test Fluid:**		**Water***		**NaOH (20%)***		**Propane**		**Mineral Oil**					
Test Fluid (@ Base Point)			-	-	0.4	80	0.8	20	01. Aug	30	0.8	20	0.8		20	260
Test Seal			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**											**C**
Test Procedure - See also Figure I.3 * : only 24 hours if Containment Seal is already qualified for Propane **: assumed maximum flare header pressure			**r/min**	**duration**	MPA (gauge)	°C	MPA (gauge)	°C	MPA (gauge)	°C	MPA (gauge)	°C low*	MPA (gauge)		°C low*	high
Buffer Fluid	a)	**Buffer Gas**	3600	100 h (24 h)*	**Nitrogen**		**Nitrogen**		**Propane Leakage from Inner Seal**		**Nitrogen**					**Nitrogen or Steam**
		normal operation			0.07	20 - 80	0.07	20 - 80	0.07	30	0.07	20 - 90	0.07		20 - 90	150 - 260
		maximum permitted SQT leakage rate per pair of seal faces			-		-		1000 ppm EPA Method 21		-					-
	b)	**Buffer Gas**	0	5 min.	**Nitrogen or Air**											
		upset condition			0.17	T(amb.)	0.17	T(amb.)	0.17	T(amb.)	0.17	T(amb.)	0.17		T(amb.)	T(amb.)
		documentation			report pressure decay after each minute (may exceed maximum pressure drop of 0.014 MPA											
	c)	**Buffer Liquid**	3600	100 h (24 h)*	**Glycol/Water**				**Diesel or Synthetic Oil**							**Mineral Oil**
		upset condition			0.28**	20 - 80	0.28**	20 - 80	0.28**	30	0.28**	20 - 90	0.28**		20 - 90	150 - 260
		documentation			record leakage											
	d)	**Buffer Liquid**	0	≥ 4 h	**Glycol/Water**				**Diesel or Synthetic Oil**							**Mineral Oil**
		upset condition			1.7	T(amb.)	1.7	T(amb.)	1.7	T(amb.)	1.7	T(amb.)	1.7		T(amb.)	T(amb.)
		documentation			record leakage											
Seal Qualification Criteria			**Face Wear:**		After all tests (PART 1 to 3) the sum of the seal face wear shall be less than 1% of the available seal face wear											
			Seal Integrity:		No obvious damage of seal parts after test											

Table I.5 – SQT Chart for seal configuration 2NC-CS

PUMPED FLUIDS & SERVICE CONDITIONS			**Non-Flashing Hydrocarbons**		-40 °C to -5 °C	
			Flashing Hydrocarbons		-40 °C to < 176 °C	
SEAL QUALIFICATION TEST - PART 1 **Dual Seal Arrangement**			**Test Fluid:**		**Propane**	
			Buffer Fluid:		**none**	
Test Seal - Dual Seal Arrangement Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition			**Category:**		**1 / 2 / 3**	
			Seal Type:		**A / B / C**	
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C			**r/min**	**duration**	MPA (abs.)	°C
Base Point:		**Dynamic Phase**	3600	≥ 100 h	1.8	30
		Static Phase	0	≥ 4 h	1.8	30
Cyclic Phase	a)	establish equilibrium @ base point	3600	5 min.	1.8	30
	b)	drop & raise pressure	3600	5 min.	1.8 1.1 1.8	30
	e)	turn off flush if applicable	3600	≥ 1 min.	1.8	30
	f)	shut down test	0	≥ 10 min.	1.8	30
	g)	establish basepoint conditions	3600	5 min.	1.8	30
	h)	repeat steps b) to g)	3x			
	i)	repeat steps b) to e)	1x			
	j)	reestablish flush & reach equilibrium	3600	5 min.	1.8	30
	k)	shut down the test	0	-	1.8	30
		maintain basepoint conditions	0	≥ 10 min.	1.8	30
Seal Qualification Criteria			Leakage:	Core Seal	Maximum permitted SQT leakage at seal faces	
					Inner Seal	**Outer Seal**
					Propane	Propane Leakage of Inner Seal
					-	1000 ppm EPA Method 21
				Adaptive Hardware	No measurable secondary seal leakage	
SEAL QUALIFICATION TEST - PART 2 **Focus on Containment Seal**			**Test Fluid:**		**Propane**	
Test Fluid (@ Base Point):			-	-	1.8	30
Test Seal			**Category:**		**1 / 2 / 3**	
			Seal Type:		**A / B / C**	
Test Procedure - see also Figure I.3 *: assumed maximum flare header pressure			**r/min**	**time**	MPA (gauge)	°C
Buffer Fluid	a)	**Buffer Gas**	3600	100 h	**Propane Leakage** of Inner Seal	
		normal operation			0.07	30
		maximum permitted SQT leakage rate per pair of seal faces			1000 ppm EPA Method 21	
	b)	**Buffer Gas**	0	5 min.	**Nitrogen or Air**	
		upset condition			0.17	T(amb.)
		documentation	report pressure decay after each minute (may exceed maximum pressure drop of 0.014 MPA)			
	c)	**Buffer Liquid**	3600	100 h	**Diesel or Synthetic Oil**	
		upset condition			0.28*	30
		documentation	record leakage			
	d)	**Buffer Liquid**	0	≥ 4 h	**Diesel or Synthetic Oil**	
		upset condition			1.7	T(amb.)
		documentation	record leakage			
Seal Qualification Criteria						
Seal Integrity			No obvious damage of seal parts after test			
Face Wear			After completion of the qualification test there can be no measurable wear of the inner seal faces and the total wear of the containment seal faces after all tests (PART 1 & 2) shall be less than 1 % of the available seal face wear.			

Table I.6 – SQT Chart for seal configuration 3CW-FB

PUMPED FLUIDS & SERVICE CONDITIONS	**Acid**			≤ 80 °C		-		-		-					-
	Sour Water														
	Water														
	Caustic			-		≤ 80 °C		-		-					-
	Non-Flashing Hydrocarbons			-		-		-40 °C to -5 °C		-5 °C to < 176 °C					176 °C to 400 °C
	Flashing Hydrocarbons			-		-		-40 °C to < 176 °C		-					
SEAL QUALIFICATION TEST - PART 1 **Only Inner Seal of Dual Seal Arrangement**	**Test Fluid:**			**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition	**Category:**			**1 / 2 / 3**						**1**		**2 / 3**			
	Seal Type:			**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2	Same dynamic, static and cyclic phase as in PART 2														
Seal Qualification Criteria	**Leakage:**	Core Seal		Maximum permitted SQT leakage at seal faces											
				5.6 g/h		5.6 g/h		-		5.6 g/h					
		Adaptive Hardware		No measurable secondary seal leakage											
SEAL QUALIFICATION TEST - PART 2 **Dual Seal Arrangement**	**Test Fluid:**			**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
	Barrier Fluid:			**Glycol/Water**		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**					**Mineral Oil or Synthetic Oil**
Test Seal	**Category:**			**1 / 2 / 3**						**1**		**2 / 3**			
	Seal Type:			**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C		**r/min**	**duration**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Barrier Fluid - Pressure / Temperature		-	-	**0.6**	**< 80**	**1.0**	**< 80**	**2.0**	**< 80**	**1.0** **1.9**	**< 80**	**1.0** **3.7**	**1.0** **1.9**	**< 80**	**< 80**
Base Point:	**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
	drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
	raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
	raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
h)	repeat steps b) to g)	3x													
i)	repeat steps b) to e)	1x													
j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Seal Qualification Criteria	**Leakage:**	Core Seal		Maximum permitted SQT leakage at seal faces											
				Inner Seal	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**				**Outer Seal**	
				5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)					
		Adaptive Hardware		No measurable secondary seal leakage											
	Face Wear:			After completion of the qualification test, the total wear of the seal faces shall be less than 1 % of the available seal-face wear											
	Seal Integrity:			No obvious damage of seal parts after test											

Table I.7 – SQT Chart for seal configuration 3CW-FF and 3CW-BB

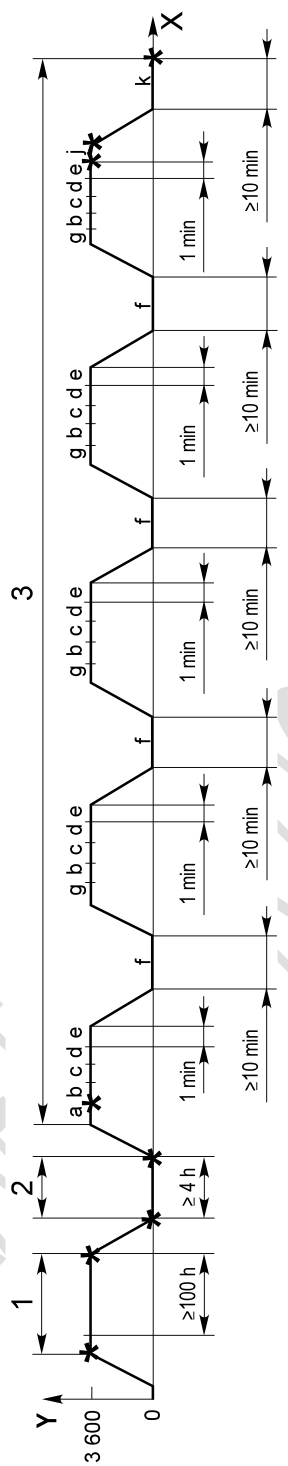
PUMPED FLUIDS & SERVICE CONDITIONS			**Acid** **Sour Water** **Water**		≤ 80 °C		-		-		-					-
			Caustic		-		≤ 80 °C		-		-					-
			Non-Flashing Hydrocarbons		-		-		-40 °C to -5 °C		-5 °C to < 176 °C					176 °C to 400 °C
			Flashing Hydrocarbons		-		-		-40 °C to < 176 °C		-					
SEAL QUALIFICATION TEST - PART 1 **Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
			Barrier Fluid:		**Glycol/Water**		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**					**Mineral Oil**
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C			**r/min**	**time**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Barrier Fluid - Pressure / Temperature			-	-	**0.6**	**< 80**	**1.0**	**< 80**	**2.0**	**< 80**	**1.0** **1.9**	**< 80**	**1.0** **3.7**	**1.0** **1.9**	**< 80**	**< 80**
Base Point:		**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase	a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
	c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
		drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
	d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
		raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
		raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
	e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	h)	repeat steps b) to g)	3x													
	i)	repeat steps b) to e)	1x													
	j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Seal Qualification Criteria			**Leakage:**	Core Seal	Maximum permitted SQT leakage at seal faces											
					Inner Seal	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**				**Outer Seal**	
					5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)		5.6 g/h (Barrier Fluid)					
				Adaptive Hardware	No measurable secondary seal leakage											
SEAL QUALIFICATION TEST - PART 2 **Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
			Barrier Fluid:		**Glycol/Water**		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**					**Mineral Oil or Synthetic Oil**
Test Seal			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - Variable Barrier Fluid Pressure			**r/min**	**duration**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Barrier Fluid - Pressure / Temperature			-	-	**0.6** **0.1 **** **0.0 *****	**< 80**	**1.0** **0.1 **** **0.0 *****	**< 80**	**2.0** **0.1 **** **0.0 *****	**< 80**	**1.0** **0.1 **** **0.0 *****	**< 80**	**1.0** **0.1 **** **0.0 *****		**< 80**	**< 80**
	a)	**dynamic test** without product fluid	3600	100 h	-	-	-	-	-	-	-	-	-		-	-
with product fluid	b)	flood the seal chamber with product fluid at base point conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	c)	reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	d)	reduce barrier fluid pressure (see **)	3600	1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	e)	repressurize barrier fluid and reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
static test	f)	stop rotation	0	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	g)	depressurize & drain the barrier fluid, inner seal statically at full base point pressure (see ***)	0	4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Seal Qualification Criteria			**Face Wear:**		After completion of the qualification test, the total wear of the seal faces shall be less than 1 % of the available seal face wear											
			Seal Integrity:		No obvious damage of seal parts after test											

Table I.8 – SQT Chart for seal configuration 3NC-BB, 3NC-FF and 3NC-FB

PUMPED FLUIDS & SERVICE CONDITIONS						
	Acid Sour Water Water	≤ 80 °C	-	-	-	-
	Caustic	-	≤ 80 °C	-	-	-
	Non-Flashing Hydrocarbons	-	-	-40 °C to -5 °C	-5 °C to < 176 °C	176 °C to 400 °C
	Flashing Hydrocarbons	-	-	-40 °C to < 176 °C	-	176 °C to 400 °C

SEAL QUALIFICATION TEST - PART 1 **Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
			Barrier Fluid:		**Nitrogen**											
Test Seal Balance diameter range - small & large test seal Category 1: 38 to 75 mm & >75* to <127* mm Category 2/3: 50 to 75 mm & 100* to 127* mm *: 125 to 190 mm if tested after publication of API 682 5th edition			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.2 Tolerance Range for p: ±5 % / T: ±5 °C			**r/min**	**duration**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
Barrier Fluid - Minimum Pressure / Temperature			-	-	**0.6**	**amb.**	**1.0**	**amb.**	**2.0**	**amb.**	**1.0** **1.9**	**amb.**	**1.0** **3.7**	**1.0** **1.9**	**amb.**	**amb.**
Base Point:		**Dynamic Phase**	3600	≥ 100 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		Static Phase	0	≥ 4 h	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Cyclic Phase	a)	establish equilibrium @ base point	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	b)	drop & raise pressure	3600	5 min.	0.4 0.1 0.4	-	0.8 0.1 0.8	20	1.8 1.1 1.8	30	0.8 0.1 0.8	20	0.8 0.1 0.8		20	260
	c)	drop temperature	3600	5 min.	0.4	80 20	-	-	-	-	-	-	-		-	-
		drop & raise temperature			-	-	-	-	-	-	-	-	0.8		-	260 150 260
	d)	raise temperature	3600	5 min.	0.4	20 80	-	-	-	-	-	-	-		-	-
		raise & drop temperature			-	-	0.8	20 80 20	-	-	0.8	20 90 20	0.8		20 90 20	-
		raise & drop pressure			-	-	-	-	-	-	0.8 1.7 0.8	20	0.8 3.5 0.8	0.8 1.7 0.8	20	260
	e)	turn off flush if applicable	3600	≥ 1 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	f)	shut down test	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	g)	establish basepoint conditions	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	h)	repeat steps b) to g)	3x													
	i)	repeat steps b) to e)	1x													
	j)	reestablish flush & reach equilibrium	3600	5 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
	k)	shut down the test	0	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
		maintain basepoint conditions	0	≥ 10 min.	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
Seal Qualification Criteria			**Leakage:**	Core Seal	No maximum permitted values - Just documentation of SQT leakage at seal faces											
					Inner Seal	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**	**Outer Seal**	**Inner Seal**			**Outer Seal**		
					Nl/min (Barrier Fluid)		Nl/min (Barrier Fluid)		Nl/min (Barrier Fluid)		Nl/min (Barrier Fluid)					
				Adaptive Hardware	No measurable secondary seal leakage											
SEAL QUALIFICATION TEST - PART 2 **Dual Seal Arrangement**			**Test Fluid:**		**Water**		**NaOH (20%)**		**Propane**		**Mineral Oil**					
Test Seal			**Category:**		**1 / 2 / 3**						**1**		**2 / 3**			
			Seal Type:		**A / B / C**						**A/B**		**A**	**B / C**	**A / B / C**	**C**
Test Procedure - see also Figure I.4 Tolerance Range for p: ±5 % / T: ±5 °C			**r/min**	**time**	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)	°C	MPA (abs.)		°C	
product side @ base point conditions			-	-	0.4	80	0.8	20	1.8	30	0.8	20	0.8		20	260
barrier gas side			**Barrier Fluid:**		**Nitrogen**											
variable barrier gas pressure	a)	static test	0	≥ 1h	0.0	-	0.0	-	0.0	-	0.0	-	0.0		-	-
	b)	restore barrier pressure, restart	3600	until equilibrium	0.6	-	1.0	-	2.0	-	1.0	-	1.0		-	-
		documentation			record any process leakage and barrier gas consumption											
	c)	isolate barrier gas supply immediately adjacent to the seal	3600	1 min	(0.6)	-	(0.6)	-	(2.0)	-	(1.0)	-	(1.0)		-	-
	d)	restore barrier pressure	3600	until equilibrium	0.6	-	0.6	-	2.0	-	1.0	-	1.0		-	-
		documentation			record any process leakage and barrier gas consumption											
	e)	shut down, gas control panel blocked in, maintain base point conditions for the inner seal	0	10 min.	*	-	*	-	*	-	*	-	*		-	-
		documentation			* record any pressure rise in the barrier system											
Seal Qualification Criteria			**Face Wear**		After completion of the qualification test there can be no measurable wear of the seal faces											
			Seal Integrity:		No obvious damage of seal parts after test											

Figure I.2 – Seal Manufacturer Qualification Test Procedure



Key

X time

Y speed, r/min

1 dynamic test phase

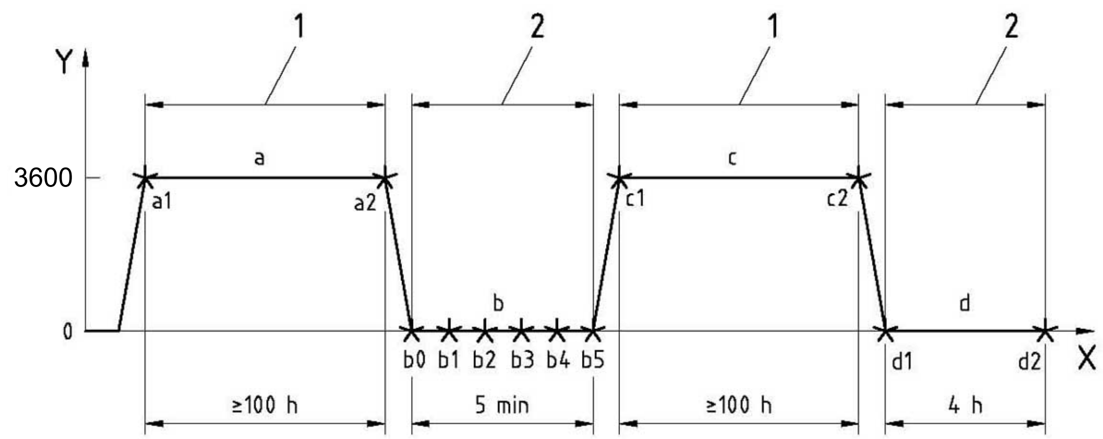
2 static test phase

3 cyclic test phase

* indicates the timing that measurements are to be taken and recorded on the qualification test results form (Figure I.5)

NOTE The points a, b, c, d, e, f, g, j, and k relate to the cyclic phase in the seal qualification test charts.

Figure I.3 – Seal Manufacturer Qualification Test Procedure for Containment Seals



Key

X time

Y speed, r/min

1 dynamic test phase

2 static test phase

⋆ indicates the timing that measurements are to be taken and recorded on the qualification test results form (Figure I.6).

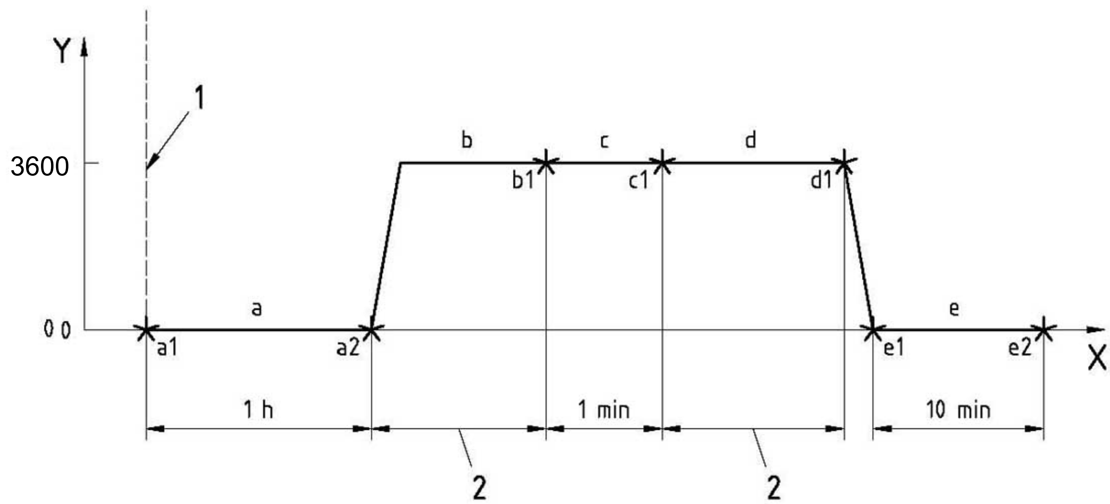
[a] A gauge pressure of 0.07 MPa (0.7 bar) (10 psi) of the buffer gas

[b] A gauge pressure of 0.17 MPa (1.7 bar) (25 psi) nitrogen.

[c] A gauge pressure of 0.28 MPa (2.8 bar) (40 psi) of the buffer liquid.

[d] A gauge pressure of 1.7 MPa (17 bar) (250 psi) of the buffer liquid

Figure I.4 – Seal Manufacturer Qualification Test Procedure for Gas Barrier Seals



Key

X time

Y speed, r/min

1 commences at end point of Figure I.2

2 equilibrium

[a] Barrier at a gauge pressure of 0 MPa (0 bar) (0 psi), inner seal at base point test pressure.

[b] Barrier at normal barrier gas pressure, inner seal at base point test pressure.

[c] Isolate barrier pressure from supply pressure, inner seal at base point test pressure.

[d] Barrier at normal barrier gas pressure, inner seal at base point test pressure.

[e] Barrier blocked in, inner seal at base point test pressure.

⋆ indicates the timing that measurements are to be taken and recorded on the qualification test results form

Figure I.5 – Mechanical Seal Qualification Test Form (1CW-FL, 2CW-CW, 3CW-FB,3CW-FF,3CW-BB)

Mechanical Seal Qualification Test Form for CATEGORY 1, 2 and 3

1CW-FL, 1CW-FX, 2CW-CW, 3W-FB, 3CW-FF, 3CW-BB

Date: ________________

Revision: ________________

For dual seals report information as inner/outer

Manufacturer: ____________________

Seal Model & Size: ____________________

API 682 Seal Code: ____________________

Balance Diameter (in/mm): ____________________

Materials of construction

Rotating face(s): ____________________

Stationary face(s): ____________________

Static secondary seals: ____________________

Dynamic secondary seal(s): ____________________

Durometer: ____________________

Metal hardware: ____________________

Test Conditions

Test Fluid: ____________________

Shaft speed: ____________________

Barrier/Buffer Fluid: ____________________

Base Point temperature (°F/°C): ____________________

Base Point pressure (psi/bar): ____________________

Piping Plan(s): ____________________

			Seal Chamber		**Flush**			**Barrier/Buffer Fluid**				**Seal Operation Leakage**		
Units	☐ **US**		psi	°F	°F		gal/min	psi	°F		gal/min	g/h or ppm	g/h	g/h and/or ppm
	☐ **Metric**		bar	°C	°C		l/min	bar	°C		l/min			
Date	**Time** **Start**	**Stop**	**Pressure**	**Temperature**	**Temperature IN**	**Temperature OUT**	**Flow Rate**	**Pressure**	**Temperature IN**	**Temperature OUT**	**Flow Rate**	**Test Fluid** @ Inner Seal 1CW, 2CW	**Barrier Fluid** @ Inner Seal 3CW	**Buffer/Barrier Fluid** @ Outer Seal 2CW, 3CW
DYNAMIC														
STATIC														
CYCLIC														
											Total:			

Face Wear (in/mm)

Inner Seal - Rotating Face: ____________________

Inner Seal - Stationary Face: ____________________

Outer Seal - Rotating Face: ____________________

Outer Seal - Stationary Face: ____________________

Alignment

Shaft runout: ____________________

Sleeve runout: ____________________

Seal chamber concentricity: ____________________

Seal chamber face runout: ____________________

Figure I.6 – Mechanical Seal Qualification Test Form (2CW-CS, 2NC-CS, 3NC-FF, 3NC-BB, 3NC-FB)

Mechanical Seal Qualification Test Form for CATEGORY 1, 2 and 3

2CW-CS, 2NC-CS, 3NC-FB, 3NC-FF, 3NC-BB

Date: ________________

Revision: ________________

For dual seals report information as inner/outer

Manufacturer: ________________

Seal Model & Size: ________________

API 682 Seal Code: ________________

Balance Diameter (in/mm): ________________

Materials of construction

Rotating face(s): ________________

Stationary face(s): ________________

Static secondary seals: ________________

Dynamic secondary seal(s): ________________

Durometer: ________________

Metal hardware: ________________

Test Conditions

Test Fluid: ________________

Shaft speed: ________________

Barrier/Buffer Fluid: ________________

Base Point temperature (°F/°C): ________________

Base Point pressure (psi/bar): ________________

Piping Plan(s): ________________

			Inner Seal		Barrier/Buffer Fluid			Speed	Seal Operation Leakage			
Units	☐ US		psi	°F	Name	psi	°F	r/min	g/h	SCFH	ppm	SCFH
	☐ Metric		bar	°C		bar	°C			NL/min		NL/min
Date	Time Start	Time Stop	Pressure	Temp.		Pressure	Temp.		Inner Seal		Outer Seal	
									Total:			

Face Wear (in/mm)

Inner Seal - Rotating Face: ________________

Inner Seal - Stationary Face: ________________

Outer Seal - Rotating Face: ________________

Outer Seal - Stationary Face: ________________

Alignment

Shaft runout: ________________

Sleeve runout: ________________

Seal chamber concentricity: ________________

Seal chamber face runout: ________________

I.5 Seal Qualification Test for Category 4 Seals

I.5.1 Table I.9 illustrates how qualification testing for different seal configurations shall be organized by seal manufacturers. While category, size, face material, type, and flexible element orientation may vary, the basic seal configuration largely dictates the qualification test scope, procedure, and fluid. Because of the large number of possible combinations of these parameters it is unlikely that seal manufacturers have tested or will test all possible combinations in all possible qualification test fluids. Seal manufacturers often first focus their testing efforts on the defaults of this standard, their own most popular products and the most representative test conditions for specific service applications. Users should verify that the required seal qualification tests have been performed for their intended application. It is possible that the qualification test for a special design or a new product has not yet been conducted. If the required tests have not yet been conducted, the user and the manufacturer shall mutually agree on the necessary steps to qualify that commercially available product according to Figure I.1.

Table I.9 – Organization of qualification testing for Category 4

<table>
<tr><th colspan="6">Seal Design Parameters[a]</th><th colspan="3">Test Parameters[b]</th></tr>
<tr><th>category</th><th>seal balance diameter
mm</th><th>face
material pair</th><th>type</th><th>flexible element</th><th>configuration</th><th>scope</th><th>procedure</th><th>test fuid</th></tr>
<tr><td rowspan="5">4</td><td rowspan="5">50 to 75
and
125 to 190</td><td rowspan="5">Carbon/SS-SiC
Carbon/RB-SiC
SS-SiC/SS-SiC
RB-SiC/RB-SiC</td><td rowspan="5">A
B</td><td rowspan="5">rotating
stationary</td><td>1CW-FL[c]
2CW-CW[c]
2CW-CS[c]
3CW-FF[c]
3CW-BB
3NC-FF[c]
3NC-BB</td><td rowspan="2">arrangement</td><td rowspan="2">static
dynamic
cyclic</td><td>water
propane
oil cold</td></tr>
<tr><td rowspan="2">2NC-CS[c]</td><td>propane</td></tr>
<tr><td rowspan="2">focus on containment seal</td><td rowspan="2">static
dynamic</td><td>nitrogen</td></tr>
<tr><td>2CW-CS[c]</td><td>nitrogen
water</td></tr>
<tr><td>3CW-FF[c]
3CW-BB</td><td>arrangement</td><td>variable barrier liquid pressure</td><td>glycol/water, mineral oil, diesel or synthetic oil</td></tr>
<tr><td colspan="9">a: As test seal cartridge is specified by the parameters in this column and the representative materials and geometry of its core seal components. In dual seal combinations of face materials pairs, types and flexible element positions are possible.
b: For a specific service a seal vendor's commercial product only needs to be tested in the representative test fluid.
c: Default</td></tr>
</table>

I.5.2 Category 4 qualification tests shall be conducted using the core seal components, adaptive hardware, seal types, and seal configurations as proposed for commercially available seals excluding the seal ring and the mating ring, which may be modified to meet qualification test requirements.

I.5.3 Category 4 qualification may not be transferred to any other seal Category.

I.5.4 If the design, materials and size of the inner test seal for a 1CW-FL configuration and a 2CW-CS configuration are the same, the test of one configuration can also be used for the qualification of the other seal configuration and the same test fluid.

I.5.5 Leakage concentration of volatile organic compound (VOC) qualification test fluids shall be measured with an organic vapor analyzer based on Appendix A of Title 40, Part 60 of the U.S. Code of Federal Regulations, or equivalent.

NOTE Site measurements of VOC emissions are undertaken using EPA Method 21, which is a manual method intended to identify sources giving rise to emissions of more than 1000 ppm. These measurements are intended to predict the on-site results using EPA Method 21 from the qualification test results.

I.5.6 For the seal qualification test with mineral oil, the seal manufacturer must choose a fluid with viscosity between 5 cSt and 32 cSt (@ 40 °C).

NOTE This decision is mainly based on the intended operation scope for the tested seal series. The viscosity of the test fluid has an impact on the measured leakage rate during the seal qualification test.

I.5.7 Each qualification test for each qualification test fluid shall consist of a dynamic, static and cyclic phase.

NOTE These phases were selected to qualify the seal type for the operating ranges (temperatures and pressures) defined for the pumped fluid and process conditions as shown in the upper section of the seal qualification test charts.

I.5.8 The test phases shall be run consecutively, without disassembly of the seal. All further required testing details are documented in the seal qualification test charts (Table I.10 to Table I.15).

I.5.9 The seal qualification test charts for Category 4 seals do not specify absolute values for test pressures, rather they specify percentages of the Dynamic Seal Pressure Rating (100 %).

Category 4 covers seal chamber pressures up to 1480 psi (102 bar). Given the wide range of allowable seal chamber pressures, many applications may require different seal features to achieve acceptable results. Based on this, it is not feasible for all Category 4 seals to have a Dynamic Seal Pressure Rating (DSPR) of 102 bar.

Mechanical seal series with lower dynamic seal pressure ratings than the Category 4 rating can be qualified as a Category 4 seal based on their specific DSPR. Therefore, the required test pressures are specified as percentages of this value.

I.5.10 The maximum dynamic test pressure for propane is limited to 870 psi (60 bar).

NOTE For the propane test the 100% reference pressure for a mechanical seal series with a DSPR of 50 bar is also 50 bar, while it is 60 bar for a mechanical seal series with a DSPR of 90 bar. For a DSPR of 90 bar a 50% test pressure would be 30 bar, as its 100% reference pressure is 60 bar. For the water or mineral oil test the 100 % reference pressure is the DSPR of 90 bar.

I.5.11 The static test (125 %) may be performed with propane or water and conducted with a separate test setup.

I.5.12 The DSPR of a qualified mechanical seal series shall be documented on the seal qualification test certificate.

I.5.12 Minimum test data that shall be recorded during seal qualification testing is presented in the forms illustrated by Figure I.8 and Figure I.9.

Table I.10 - SQT Chart for seal configuration 1CW-FL

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Hydrocarbons**		< 80 °C		-		-	
		Non-Flashing Hydrocarbons		-		-40 °C to -5 °C		-5 °C to < 176 °C	
		Flashing Hydrocarbons		-		-40 °C to < 176 °C			
SEAL QUALIFICATION TEST		**Test Fluid:**		**Water**		**Propane**		**Mineral Oil** **5 cSt to 32 cSt @ 40 °C** (choice of seal manufacturer)	
Test Seal - Single Seal Arrangement		**Category:**		**4**					
Balance diameter range for test seal		**Seal Type:**		**A, B**					
Small test seal: 50 to 90 mm Big test seal: 125 to 190 mm		**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar					
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**	**p**	**T**	**p**	**T**
Static Phase		0	4 h	125 %	ambient	125 % *	ambient	125 %	ambient
Dynamic Phase	Pressure Step 1	3600	75 h	75 %	50 °C	75 % **	30 °C	75 %	40 °C
	Pressure Step 2	3600	25 h	50 %		50 % **		50 %	
	Pressure Step 3	3600	8 h	100 %		100 % **		100 %	
	Pressure Step 4	3600	4 h	75 %		75 % **		75 %	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C	25 % **	30 °C	25 %	30 °C
	b) Stop	0	min. 1 minute						
	Repeat a) to b)	50 x							
Seal Qualifiction Criteria		**Leakage:**	Core Seal	Maximum permitted SQT leakage at seal faces according to **Figure I.7a**					
			Adaptive Hardware	No measurable secondary seal leakage					
		Face Wear:		After completion of the qualification test the total wear of the seal faces shall be less than 1 % of the available seal-face wear					
		Seal Integrity:		No obvious damage of seal parts after test					

Table I.11 - SQT Chart for seal configuration 2CW-CW

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Hydrocarbons**		< 80 °C		-		-	
		Non-Flashing Hydrocarbons		-		-40 °C to -5 °C		-5 °C to < 176 °C	
		Flashing Hydrocarbons		-		-40 °C to < 176 °C			
SEAL QUALIFICATION TEST		**Test Fluid:**		**Water**		**Propane**		**Mineral Oil** **5 cSt to 32 cSt @ 40 °C** (choice of seal manufacturer)	
		Buffer Fluid:		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**	
Test Seal - Dual Seal Arrangement		**Category:**		**4**					
Balance diameter range for test seal		**Seal Type:**		**A, B**					
Small test seal: 50 to 90 mm Big test seal: 125 to 190 mm		**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar					
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**	**p**	**T**	**p**	**T**
Buffer Fluid	Static Phase Dynamic Phase Cyclic Phase	-	-	≤ 2 bar	≤ 60 °C	≤ 2 bar	≤ 60 °C	≤ 2 bar	≤ 60 °C
Test Fluid									
Static Phase		0	4 h	125 %	ambient	125 % *	ambient	125 %	ambient
Dynamic Phase	Pressure Step 1	3600	75 h	75 %	50 °C	75 % **	30 °C	75 %	40 °C
	Pressure Step 2	3600	25 h	50 %		50 % **		50 %	
	Pressure Step 3	3600	8 h	100 %		100 % **		100 %	
	Pressure Step 4	3600	4 h	75 %		75 % **		75 %	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C	25 % **	30 °C	25 %	30 °C
	b) Stop	0	min. 1 minute						
	Repeat a) to b)	50 x							
Seal Qualifiction Criteria		**Leakage:**	Core Seals	Maximum permitted SQT leakage at seal faces					
				Inner Seal	Outer Seal	Inner Seal	Outer Seal	Inner Seal	Outer Seal
				acc. to **Figure I.7a**	acc .to **Figure I.7b**	acc. to **Figure I.7a**	acc. to **Figure I.7b**	acc. to **Figure I.7a**	acc. to **Figure I.7b**
			Adaptive Hardware	No measurable secondary seal leakage					
		Face Wear:		After completion of the qualification test the total wear of the seal faces shall be less than 1 % of the available seal-face wear					
		Seal Integrity:		No obvious damage of seal parts after test					

Table I.12 - SQT Chart for seal configuration 2CW-CS

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Hydrocarbons**		< 80 °C		-		-	
		Non-Flashing Hydrocarbons		-		-40 °C to -5 °C		-5 °C to < 176 °C	
		Flashing Hydrocarbons		-		-40 °C to < 176 °C			
SEAL QUALIFICATION TEST		**Test Fluid:**		**Water**		**Propane**		**Mineral Oil** **5 cSt to 32 cSt @ 40 °C** (choice of seal manufacturer)	
		Buffer Fluid:		**none**		**none**		**none**	
Test Seal - Dual Seal Arrangement		**Category:**		**4**					
Balance diameter range for test seal		**Seal Type:**		**A, B**					
Small test seal: 50 to 90 mm Big test seal: 125 to 190 mm		**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar					
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**	**p**	**T**	**p**	**T**
Test Fluid									
Static Phase		0	4 h	125 %	ambient	125 % *	ambient	125 %	ambient
Dynamic Phase	Pressure Step 1	3600	75 h	75 %	50 °C	75 % **	30 °C	75 %	40 °C
	Pressure Step 2	3600	25 h	50 %		50 % **		50 %	
	Pressure Step 3	3600	8 h	100 %		100 % **		100 %	
	Pressure Step 4	3600	4 h	75 %		75 % **		75 %	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C	25 % **	30 °C	25 %	30 °C
	b) Stop	0	min. 1 minute						
	Repeat a) to b)	50 x							
Seal Qualifiction Criteria		**Leakage**	Core Seals	Maximum permitted SQT leakage at seal faces					
				Inner Seal	Outer Seal	Inner Seal	Outer Seal	Inner Seal	Outer Seal
				acc. to **Figure I.7a**	Not requested	acc. to **Figure I.7a**	acc to **Figure I.7b**	acc. to **Figure I.7a**	Not requested
			Adaptive Hardware	No measurable secondary seal leakage					
Focus on Containment Seal (CS)		**Test Fluid:**		75 %	30 °C	75% **	30 °C	75 %	30 °C
		Buffer Fluid:		**Nitrogen**		**Nitrogen**		**Nitrogen**	
Dynamic phase	Normal Operation	3600	60 min	p(Buffer) = 0,7 bar	ambient	p(Buffer) = 0,7 bar	ambient	p(Buffer) = 0,7 bar	ambient
Focus on Containment Seal (CS)		**Test Fluid:**		75 %	30 °C	75 % **	30 °C	75 %	30 °C
		Buffer Fluid:		**Water**		**Nitrogen**		**Water**	
Static phase	Upset Condition	0	60 min	p(Buffer) = p(50 %)	ambient	p(Buffer) = p(50 %) **	ambient	p(Buffer) = p(50 %)	ambient
Seal Qualification Criteria		**Leakage (g/h):**		To be documented		-		To be documented	
		Pressure Decay (bar/minute):		To be documented		To be documented		To be documented	
		Face Wear:		After completion of the qualification test the total wear of the seal faces shall be less than 1 % of the available seal-face wear					
		Seal Integrity:		No obvious damage of seal parts after test					

Table I.13 - SQT Chart for seal configuration 2NC-CS

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Flashing Hydrocarbons**		-40 °C to -5 °C	
		Flashing Hydrocarbons		-40 °C to < 176 °C	
SEAL QUALIFICATION TEST		**Test Fluid:**		**Propane**	
		Buffer Fluid:		**none**	
Test Seal - Dual Seal Arrangement		**Category:**		**4**	
Balance diameter range for test seal		**Seal Type:**		**A, B**	
Small test seal:	50 to 90 mm	**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar	
Big test seal:	125 to 190 mm				
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**
Test Fluid					
Static Phase		0	2 h	125 % *	ambient
Dynamic Phase	Pressure Step 1	3600	35 h	75 % **	30 °C
	Pressure Step 2	3600	15 h	50 % **	
	Pressure Step 3	3600	4 h	100 % **	
	Pressure Step 4	3600	2 h	75 % **	
	Low VP margin	3600	10 minutes	11 bar	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C
	b) Stop	0	min. 1 minute		
	Repeat a) to b)	50 x			
Seal Qualifiction Criteria		**Leakage**	Core Seals	Maximum permitted SQT leakage at seal faces	
				inner seal	outer seal
				acc. to **Figure I.7a**	acc. to **Figure I.7b**
			Adaptive Hardware	No measurable secondary seal leakage	
Focus on Containment Seal (CS)		**Test Fluid:**		75 % **	30 °C
		Buffer Fluid:		**Nitrogen**	
Dynamic Phase	Normal Operation	3600	60 min	p(Buffer) = 0,7 bar	ambient
Static Phase	Upset Condition	0	5 min	p(Buffer) = p(50 %) **	
Seal Qualification Criteria		**Pressure Decay (bar/minute)**		To be documented	
		Face Wear:		After completion of the qualification test there can be no measurable wear of the inner seal faces and the total wear of the containment seal faces shall be less than 1 % of the available seal-face wear	
		Seal Integrity:		No obvious damage of seal parts after test	

Table I.14 - SQT Chart for seal configuration 3CW-FF and 3CW-BB

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Hydrocarbons**		< 80 °C		-		-	
		Non-Flashing Hydrocarbons		-		-40 °C to -5 °C		-5 °C to < 176 °C	
		Flashing Hydrocarbons		-		-40 °C to < 176 °C			
SEAL QUALIFICATION TEST		**Test Fluid:**		**Water**		**Propane**		**Mineral Oil** **5 cSt to 32 cSt @ 40 °C** (choice of seal manufacturer)	
		Barrier Fluid:		**Glycol/Water**		**Diesel or Synthetic Oil**		**Diesel or Synthetic Oil**	
Test Seal - Dual Seal Arrangement		**Category:**		**4**					
Balance diameter range for test seal		**Seal Type:**		**A, B**					
Small test seal: 50 to 90 mm Big test seal: 125 to 190 mm		**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar					
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**	**p**	**T**	**p**	**T**
Barrier Fluid	Static phase Dynamic phase Cyclic phase	-	-	5 bar above p(Test Fluid)	≤ 60 °C	5 bar above p(Test Fluid)	≤ 60 °C	5 bar above p(Test Fluid)	≤ 60 °C
Static Phase		0	4 h	125 %	ambient	125 % *	ambient	125 %	ambient
Dynamic Phase	Pressure Step 1	3600	75 h	75 %	50 °C	75 % **	30 °C	75 %	40 °C
	Pressure Step 2	3600	25 h	50 %		50 % **		50 %	
	Pressure Step 3	3600	8 h	100 %		100 % **		100 %	
	Pressure Step 4	3600	4 h	75 %		75 % **		75 %	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C	25 % **	30 °C	25 %	30 °C
	b) Stop	0	min. 1 minute						
	Repeat a) to b)	50 x							
Barrier Fluid	Reverse Pressure	-	-	0 bar	30 °C	0 bar	30 °C	0 bar	30 °C
Static Phase		0	30 minutes	75 %		75 % **		75 %	
Seal Qualifiction Criteria		**Leakage:**	Core Seals	Maximum permitted SQT leakage at seal faces					
				Inner Seal	Outer Seal	Inner Seal	Outer Seal	Inner Seal	Outer Seal
				acc. to **Figure I.7c**	acc .to **Figure I.7d**	acc. to **Figure I.7c**	acc. to **Figure I.7d**	acc. to **Figure I.7c**	acc. to **Figure I.7d**
			Adaptive Hardware	No measurable secondary seal leakage					
		Face Wear:		After completion of the qualification test the total wear of the seal faces shall be less than 1 % of the available seal-face wear					
		Seal Integrity:		No obvious damage of seal parts after test					

Table I.15 - SQT Chart for seal configuration 3NC-FF and 3NC-BB

PUMPED FLUIDS & SERVICE CONDITIONS		**Non-Hydrocarbons**		< 80 °C		-		-	
		Non-Flashing Hydrocarbons		-		-40 °C to -5 °C		-5 °C to < 176 °C	
		Flashing Hydrocarbons		-		-40 °C to < 176 °C			
SEAL QUALIFICATION TEST		**Test Fluid:**		**Water**		**Propane**		**Mineral Oil** **5 cSt to 32 cSt @ 40 °C** (choice of seal manufacturer)	
		Barrier Fluid:		**Nitrogen**		**Nitrogen**		**Nitrogen**	
Test Seal - Dual Seal Arrangement		**Category:**		**4**					
Balance diameter range for test seal		**Seal Type:**		**A, B**					
Small test seal: 50 to 90 mm Big test seal: 125 to 190 mm		**Reference Pressure (100 %):**		**Dynamic Sealing Pressure Rating (DSPR)** **of manufacturer specific mechanical seal series** The rating has to be documented on the SQT Certificate and TEST FORM. * Can be conducted with test fluid water @ 125 % of DSPR and T(ambient). ** For the Propane Test 100% refers to a max. test pressure of 60 bar or a DSPR ≤ 60 bar e.g. if DSPR = 50 bar, then p(100%) = 50 bar, if DPSR = 90 bar, then p(100%) = 60 bar					
Test Procedure	Tolerance Range p: ±5 %, T: ±5 °C	**r/min**	**duration** (minimum)	**p**	**T**	**p**	**T**	**p**	**T**
Barrier Fluid	Static phase Dynamic phase Cyclic phase	-	-	5 bar above p(Test Fluid)	≤ 60 °C	5 bar above p(Test Fluid)	≤ 60 °C	5 bar above p(Test Fluid)	≤ 60 °C
Static Phase		0	2 h	125 %	ambient	125 % *	ambient	125 %	ambient
Dynamic Phase	Pressure Step 1	3600	35 h	75 %	50 °C	75 % **	30 °C	75 %	40 °C
	Pressure Step 2	3600	15 h	50 %		50 % **		50 %	
	Pressure Step 3	3600	4 h	100 %		100 % **		100 %	
	Pressure Step 4	3600	2 h	75 %		75 % **		75 %	
Cyclic Phase	a) Start	3600	min. 1 minute	25 %	30 °C	25 % **	30 °C	25 %	30 °C
	b) Stop	0	min. 1 minute						
	Repeat a) to b)	50 x							
Seal Qualification Criteria		**Leakage:** Measured values have to be documented in TEST FORM	Core Seals	Maximum permitted SQT leakage at seal faces					
				Inner Seal	Outer Seal	Inner Seal	Outer Seal	Inner Seal	Outer Seal
				acc. to **Figure I.7c**	acc .to **Figure I.7d**	acc. to **Figure I.7c**	acc. to **Figure I.7d**	acc. to **Figure I.7c**	acc. to **Figure I.7d**
			Adaptive Hardware	No measurable secondary seal leakage					
		Face Wear:		After completion of the qualification test there can be no measurable wear of the seal faces					
		Seal Integrity:		No obvious damage of seal parts after test					

Figure I.7a - Maximum Permitted SQT Leakage Rate for Category 4 at Inner Seal

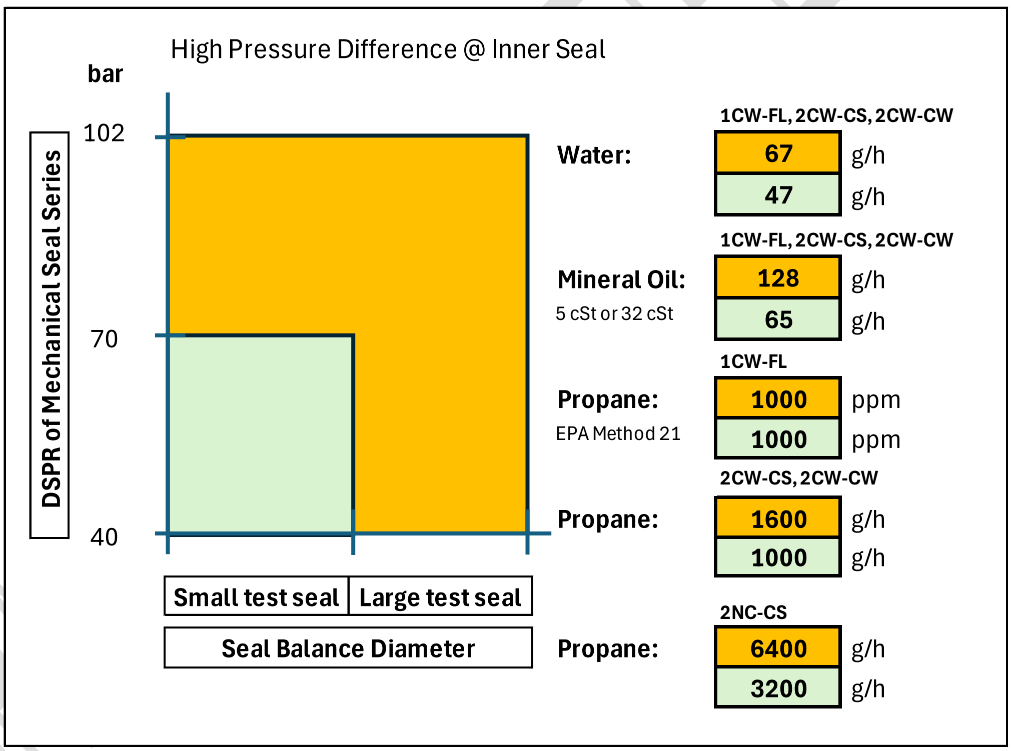


Figure I.7b - Maximum Permitted SQT Leakage Rate for Category 4 at Outer Seal

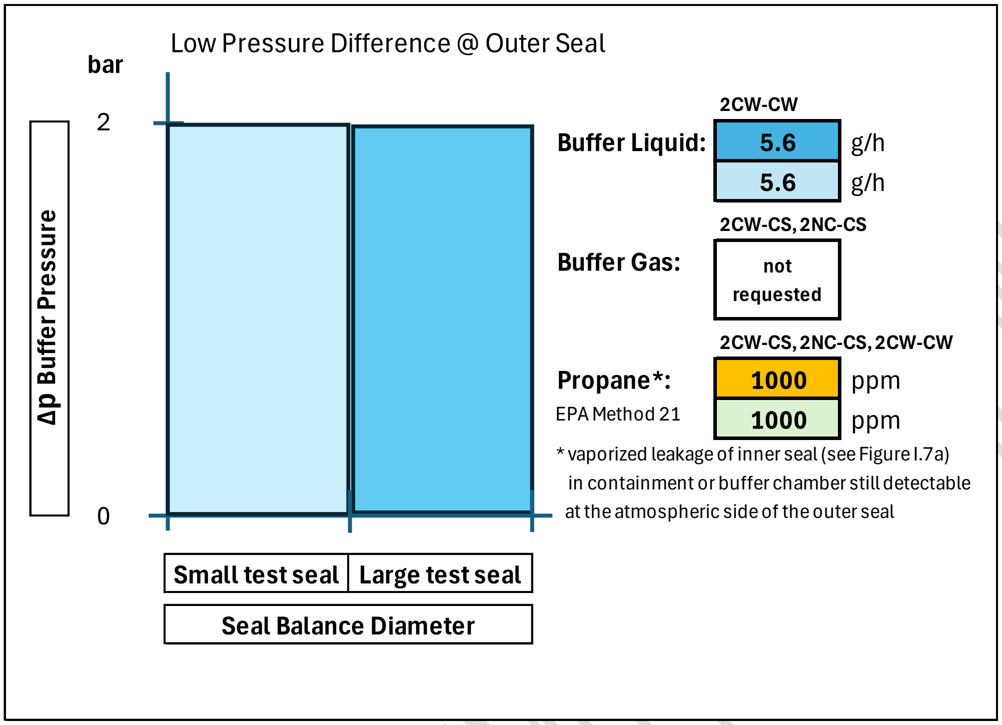


Figure I.7c - Maximum Permitted SQT Leakage Rate for Category 4 at Inner Seal

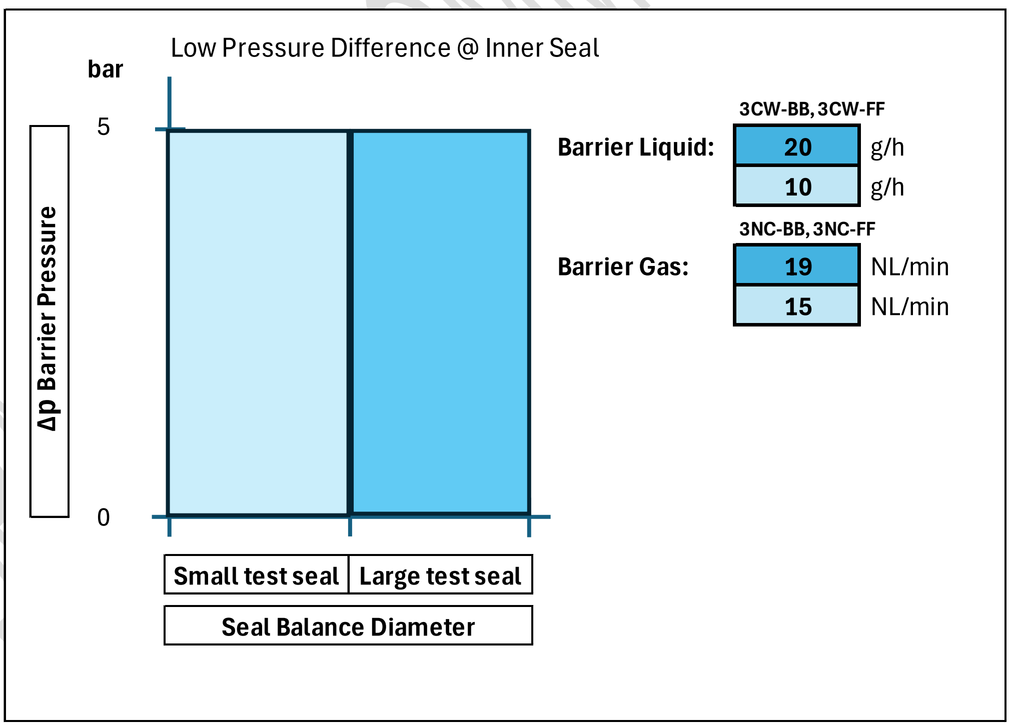


Figure I.7d - Maximum Permitted SQT Leakage Rate for Category 4 at Outer Seal

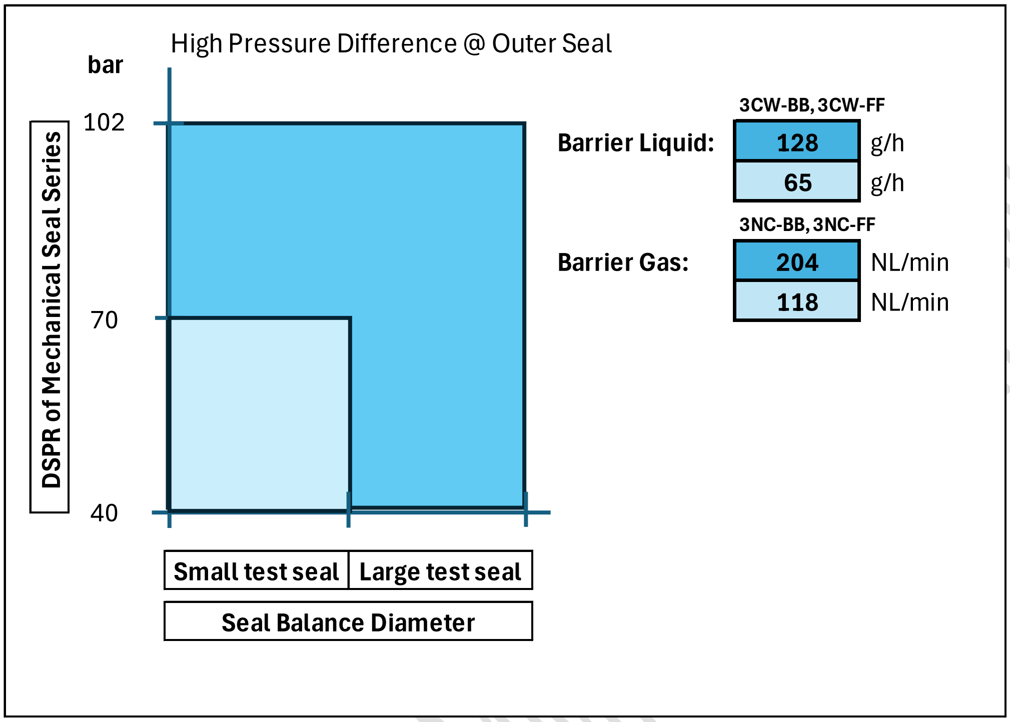


Figure I.8 – Mechanical Seal Qualification Test Form (1CW-FL, 2CW-CW, 3CW-BB,3CW-FF)

Mechanical Seal Qualification Test Form for CATEGORY 4

1CW-FL, 2CW-CW, 3CW-FF, 3CW-BB

Date: ____________

Revision: ____________

For dual seals report information as inner/outer

Manufacturer: ____________

Seal Model & Size: ____________

API 682 Seal Code: ____________

Balance Diameter (mm/in): ____________

Dynamic Seal Pressure Rating (psi/bar) ____________

Materials of construction

Rotating face(s): ____________

Stationary faces(s): ____________

Static secondary seals: ____________

Dynamic secondary seal(s): ____________

Durometer: ____________

Metal hardware: ____________

Test Conditions

Test Fluid: ____________

Shaft speed: ____________

Viscosity (cSt), only if Mineral Oil: ____________

Barrier/Buffer Fluid: ____________

Piping Plan(s): ____________

			Seal Chamber		Flush			Barrier/Buffer Fluid				Seal Operation Leakage		
Units	☐ **US**		psi	°F	°F		gal/min	psi	°F		gal/min	g/h or ppm	g/h	g/h or/and ppm
	☐ **Metric**		bar	°C	°C		l/min	bar	°C		l/min			
Date	**Time** **Start**	**Time** **Stop**	**Pressure**	**Temperature**	**Temperature IN**	**Temperature OUT**	**Flow Rate**	**Pressure**	**Temperature IN**	**Temperature OUT**	**Flow Rate**	**Test Fluid** @ Inner Seal 1CW, 2CW	**Barrier Fluid** @ Inner Seal 3CW	**Buffer/Barrier Fluid** @ Outer Seal 2CW, 3CW
DYNAMIC														
STATIC														
CYCLIC														
											Total:			

Face Wear (in/mm)

Inner Seal - Rotating Face: ____________

Inner Seal - Stationary Face: ____________

Outer Seal - Rotating Face: ____________

Outer Seal - Stationary Face: ____________

Alignment

Shaft runout: ____________

Sleeve runout: ____________

Seal chamber concentricity: ____________

Seal chamber face runout: ____________

Figure I.9 – Mechanical Seal Qualification Test Form (2CW-CS, 2NC-CS, 3NC-FF, 3NC-BB)

Mechanical Seal Qualification Test Form for CATEGORY 4

2CW-CS, 2NC-CS, 3NC-FF, 3NC-BB

Date: ____________

Revision: ____________

For dual seals report information as inner/outer

Manufacturer: ____________

Seal Model & Size: ____________

API 682 Seal Code: ____________

Balance Diameter (in/mm): ____________

Dynamic Seal Pressure Rating (psi/bar) ____________

Materials of construction

Rotating face(s): ____________

Stationary face(s): ____________

Static secondary seals: ____________

Dynamic secondary seal(s): ____________

Durometer: ____________

Metal hardware: ____________

Test Conditions

Test Fluid: ____________

Shaft speed: ____________

Viscosity (cSt), only if Mineral Oil: ____________

Barrier/Buffer Fluid: ____________

Piping Plan(s): ____________

			Inner Seal		**Barrier/Buffer Fluid**			**Speed**	**Seal Operation Leakage**			
Units	☐ **US**		psi	°F	**Name**	psi	°F	r/min	g/h	SCFH	ppm	SCFH
	☐ **Metric**		bar	°C		bar	°C			NL/min		NL/min
Date	**Time** **Start**	**Stop**	**Pressure**	**Temp.**		**Pressure**	**Temp.**		**Inner Seal**		**Outer Seal**	
								Total:				

Face Wear (in/mm)

Inner Seal - Rotating Face: ____________

Inner Seal - Stationary Face: ____________

Outer Seal - Rotating Face: ____________

Outer Seal - Stationary Face: ____________

Alignment

Shaft runout: ____________

Sleeve runout: ____________

Seal chamber concentricity: ____________

Seal chamber face runout: ____________

I.6 Alternative Seal Qualification Approaches

I.6.1 If agreed by purchaser, seal qualification may be per seal vendor specific testing in lieu of API-682 (5th Edition) default Seal Qualification Testing.

NOTE Seal vendors have continuously evolved their internal testing processes and procedures to align with industry requirements since the initial development of API-682 and the seal qualification test. The seal manufacturer may have already completed a specific internal test protocol for a product that follows a structured new product development (NPD) process with gated requirements to satisfy technology readiness levels (TRLs). Such internal testing may include, but is not limited to, dynamic testing at steady-state, start-up, and shut-down, static testing (overpressure), offset bias (underloading and overloading of faces), torsional analysis of drive and anti-rotation mechanisms, and material validation. The purpose of manufacturer specific testing provides validation of seal component performance beyond computational models, in the desired configuration after the materials have been subject to manufacturing processes. Documentation of a seal manufacturer specific internal product test plan following an NPD process would augment 682 Seal Qualification Testing protocols by demonstrating basic technology principles, component performance, and subsequent validation in laboratory and operational environments.

I.6.2 Validated Computational Models (Option)

I.6.2.1 If agreed by purchaser, seal qualification may be per Validated Computational Models in lieu of API-682 (5th Edition) default Seal Qualification Testing.

NOTE There a several established computational methods used in the sealing industry to predict seal leakage rates. Typical examples include numerical methods (e.g. finite element analysis, finite volume method) and uncertainty quantification (e.g. statistical methods, design Of experiment). These methods result in computational models intended to understand seal performance. The models must be validated to ascertain their reliable predictive capability. Based on this validation they can then be used to predict the performance of a specific job seal with representative design features for a defined range of conditions.

I.6.2.2 If agreed by purchaser, seal vendor shall submit written explanation of the principals applied to validate the computational model.

NOTE 1 The basis for the validation is the comparison of the calculated and measured values of key performance parameters. Based on suitable criteria it must be proven that the computational model can predict the relevant effects for the relevant seal design features and operation range. The validated model can then be used for specific mechanical seal series and mechanical seal series with comparable design features. The validation of the applied computational model must be documented by the seal manufacturer.

NOTE 2 Seal manufacturers decide which computational methods they want to apply. The following effects have an impact on the leakage rate and may be considered by the used computational model: heat transfer, deformation of seal parts, seal face friction, seal gap fluid flow, fluid-structure-interaction and uncertainties due to relevant tolerances.

I.6.3 Vendor Field Experience (Option)

I.6.2.1 If agreed by purchaser, seal qualification may be per seal vendor field experience in lieu of API 682 (5th Edition) default seal qualification testing.

NOTE This requirement entails the seal vendor submitting a list of previously supplied installations that have similar operating conditions for purchaser review.

Bibliography

[1] ISO 683-13:1986 9, Heat-treatable steels, alloy steels and free-cutting steels—Part 13: Wrought stainless steels (withdrawn)

[2] ISO 629, *Rubber and lattices—Nomenclature*

[3] ISO 2858, *End-suction centrifugal pumps (rating 16 bar)—Designation, nominal duty point and dimensions*

[4] ISO 2892, *Austenitic cast iron*

[5] ISO 3506-1, *Mechanical properties of corrosion-resistant stainless-steel fasteners—Part 1: Bolts, screws and studs*

[6] ISO 3506-2, *Mechanical properties of corrosion-resistant stainless-steel fasteners—Part 2: Nuts*

[7] ISO 6208, *Nickel and nickel alloy plate, sheet and strip*

[8] ISO 9327-5, *Steel forgings and rolled or forged bars for pressure purposes—Technical delivery conditions—Part 5: Stainless steels*

[9] ISO 9723, *Nickel and nickel alloy bars*

[10] ISO 9725, *Nickel and nickel alloy forgings*

[11] ISO 12725, *Nickel and nickel alloy castings*

[12] API 5L, *Specification for Line Pipe*

[13] API Standard 614, *Lubrication, Shaft Sealing and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and as Industry Services*

[14] API Standard 676, *Positive Displacement Pumps—Rotary*

[15] ASME B16.5 10, *Pipe flanges and flange fittings, steel, nickel alloy and other special alloys*

[16] ASME B31.3, *Process piping*

[17] ASTM A53 11, *Zinc-coated welded and seamless black and hot-dipped steel pipe*

[18] ASTM A105, *Carbon steel forgings for piping components*

[19] ASTM A106, *Seamless carbon steel pipe for high temperature service*

[20] ASTM A120, *Black and hot-dipped zinc-coated (galvanized) welded and seamless steel pipe for ordinary uses*

[21] ASTM A181, *Carbon steel forgings for general purpose piping*

[22] ASTM A182, *Forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts for high-temperature service*

[23] ASTM A193, *Alloy-steel and stainless steel bolting materials for high-temperature service*

[24] ASTM A194, *Carbon and alloy steel nuts for bolts for high-pressure and high-temperature service*

[25] ASTM A197, *Cupola malleable iron*

[26] ASTM A269, *Seamless and welded austenitic stainless steel tubing for general service*

[27] ASTM A312, *Seamless and welded austenitic stainless steel pipe*

[28] ASTM A338, *Malleable iron flanges, pipe fittings, and valve parts for railroad, marine, and other heavy duty service at temperatures up to 650 °F (345 °C)*

[29] ASTM A524, *Seamless carbon steel pipe for atmospheric and lower temperatures*

[30] ASTM A217, *Martensitic stainless and alloy steel castings for pressure-containing parts suitable for high temperature service*

[31] ASTM A276, *Stainless and heat-resisting steel bars and shapes*

[32] ASTM A351, *Austenitic steel castings for high-temperature service*

[33] ASTM A436, *Austenitic gray iron castings*

[34] ASTM A439, *Austenitic ductile iron castings*

[35] ASTM A487, *Standard specification for steel castings suitable for pressure service*

[36] ASTM A494, *Nickel and nickel alloy castings*

[37] ASTM A582, *Standard specification for free-machining stainless steel bars*

[38] ASTM A744, *Iron-chromium-nickel and nickel-base corrosion resistant castings for severe service*

[39] ASTM B127, *Specification for nickel-copper alloy (UNS No4400) plate sheet and strip*

[40] ASTM B164, *Specification for nickel-copper alloy rod, bar and wire*

[41] ASTM B473, *Chromium-nickel-iron-molybdenum-copper-columbium stabilized alloy (UNS N08020) bar and wire*

[42] ASTM B564, *Specification for nickel alloy forgings*

[43] ASTM B574, *Specification for low-carbon and nickel-molybdenum-chromium and low-carbon nickel-chromium-molybdenum alloy rod*

[44] ASTM B575, *Specification for low-carbon and nickel-molybdenum-chromium and low-carbon nickel-chromium-molybdenum alloy plate, sheet and strip*

[45] ASTM B637, *Specification for precipitation hardening nickel alloy bars, forgings, and forging stock for high-temperature service*

[46] ASTM A670, *Specification for precipitation hardening nickel alloy (UNS N07718) plate, sheet, and strip for high-temperature service*

[47] ASTM D1418, *Practice for rubber and rubber lattices—Nomenclature*

[48] EN 10088-3 12, *Stainless steels—Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes*

[49] EN 10213-2, *Technical delivery conditions for steel castings for pressure purposes—Part 2: Steel grades for use at room temperature and elevated temperatures*

[50] EN 10213-4, *Technical delivery conditions for steel castings for pressure purposes—Part 4: Austenitic and austenitic-ferritic steel grades*

[51] EN 10222-5, *Steel forgings for pressure purposes—Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels*

[52] EN 10250-4, *Open die steel forgings for general engineering purposes—Part 4: Stainless steels*

[53] EN 10269, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

[54] FSA 0010 13, *Mechanical Seal Handbook*

[55] HI 14, *Mechanical Seals for Pumps: Application Guidelines, ISBN 1-880952-73-4*

[56] JIS G 3214 15, *Stainless steel forgings for pressure vessels*

[57] JIS G 4303, *Stainless steel bars*

[58] JIS G 4319, *Stainless steel blooms and billets for forgings*

[59] JIS G 5121, *Stainless steel castings*

[60] EC 1272/2008, European Union Regulation on the classification, labeling and packaging of substances and mixtures

[61] EEC 67/548, *Dangerous Substances Directive*

[62] Pruitt, Kenneth M., *Chemical Resistance for Elastomers III*, 2005

[63] United Nations Globally Harmonised System of Classification and Labeling of Chemicals (GHS), 2009