Mechanical Seal Selection

API 682 (2nd Edition)

Table Of Contents:

Seal Selection Methods:

1. Refer To Seal Manufacturer (Safe, With Warranty, After Sale Service But Expensive)

2. Refer To Own Knowledge (Cheap But Unsafe And Without Warranty)

Fundamentals Of Sealing :

Seals Types:

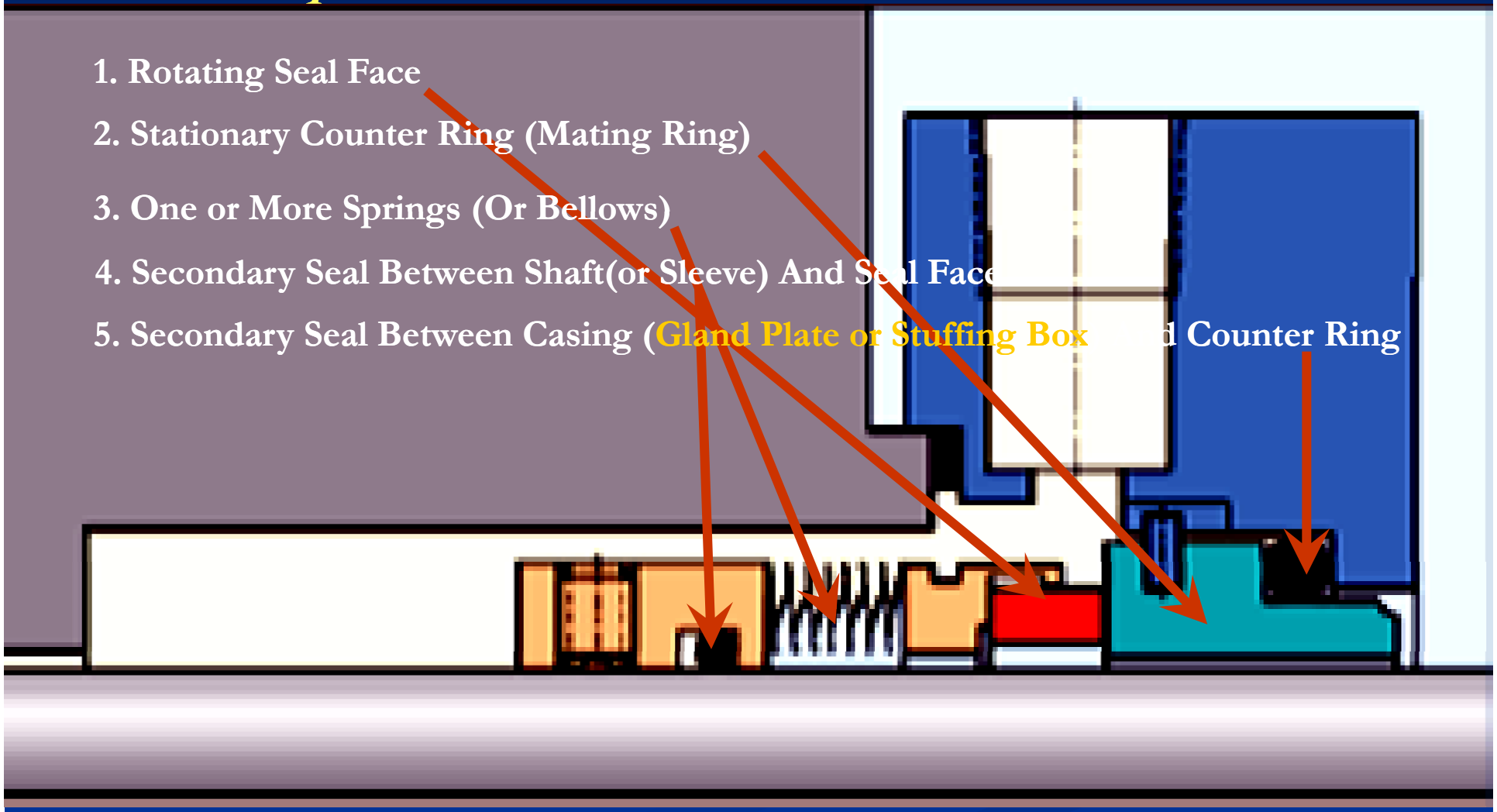
1. Static seal: O_rings, gasket, …

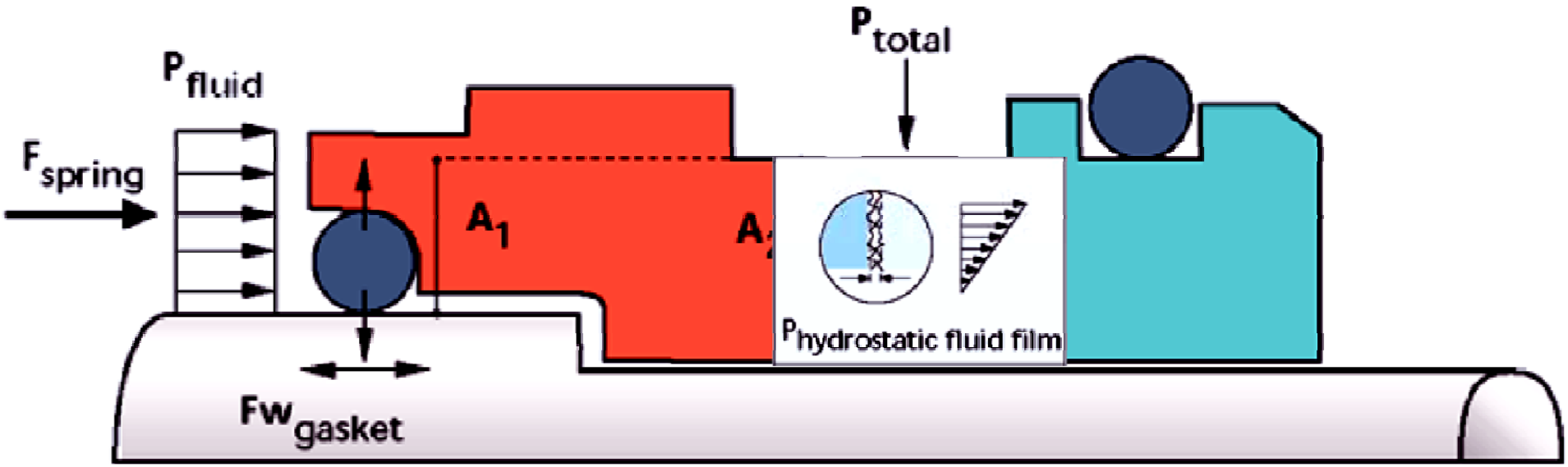
2. Dynamic Seals: Packings, Mechanical Seals,…

About Mechanical Seal:

- *Seal Components:*

1. Rotating Seal Face
2. Stationary Counter Ring (Mating Ring)
3. One or More Springs (Or Bellows)
4. Secondary Seal Between Shaft(or Sleeve) And Seal Face
5. Secondary Seal Between Casing (Gland Plate or Stuffing Box d Counter Ring





Equilibrium:

$$F_{spring} + Fw_{gasket} + P_{fluid} A_1 = P_{total} A_2$$

Balanced: $A_2 > A_1$

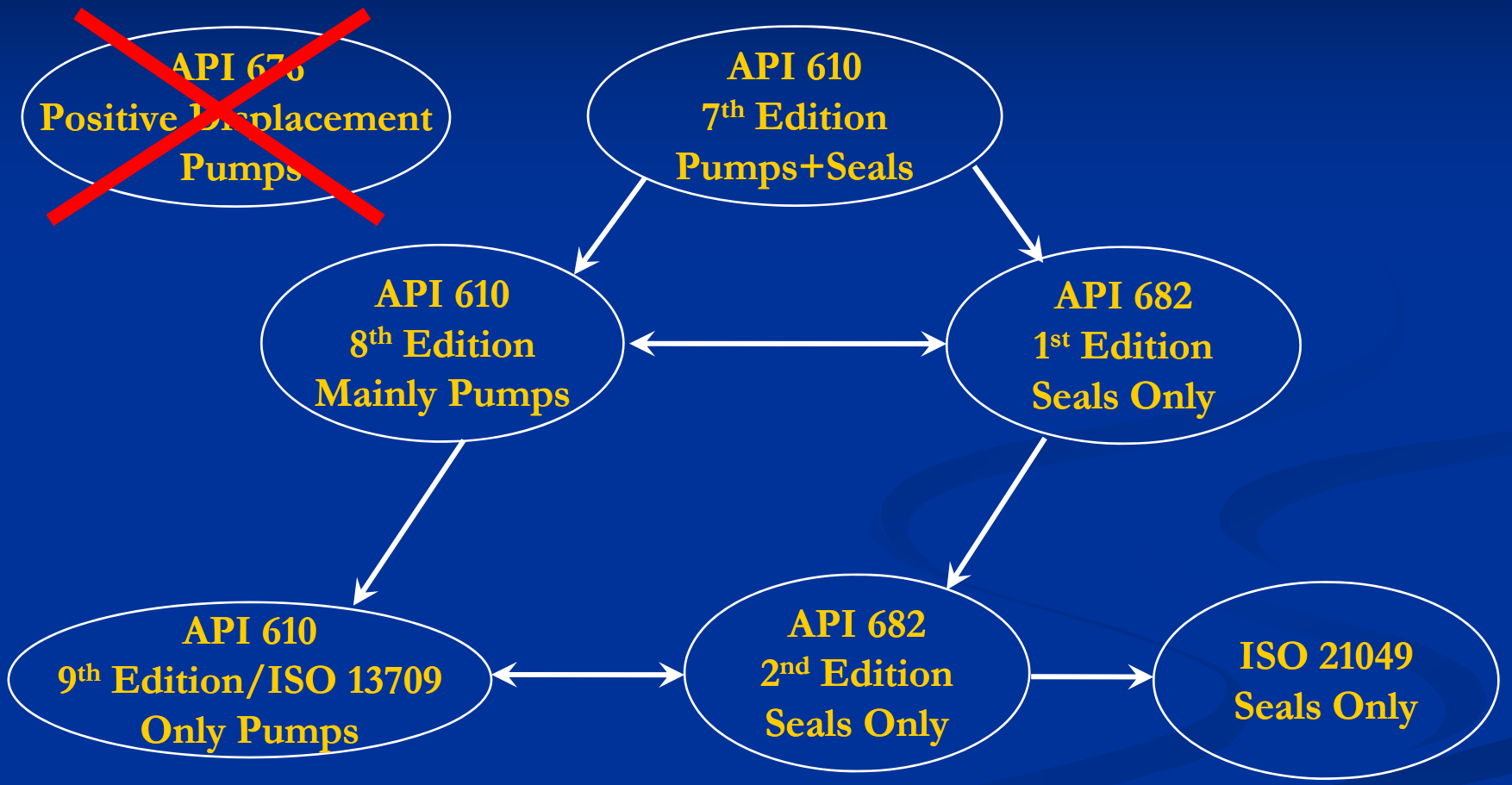
Unbalanced: $A_2 \leq A_1$

$$K = \frac{A_h}{A} = \frac{D^2 - d_h^2}{D^2 - d^2} \begin{cases} K < 1 & \textit{Balanced Seal} \\ K \geq 1 & \textit{Unbalanced Seal} \end{cases}$$

Mechanical Seals Classifications:

1. Pushing Type
   - A. Pusher Type
   - B. Non_Pusher Type:
2. Number Of Springs
   - A. Single Spring
   - B. Multi_Spring
3. Spring Positioning
   - A. Dynamic Spring
   - B. Stationary Spring
4. Balancing
   - A. Balanced
   - B. Unbalanced
5. Number Of Sealing Seals
   - A. Single seal
   - B. Dual Seal

Introduction To API 682(2nd Edition):



Significant Areas In "API 682" :

1) 3 categories, 3 seal types, and 3 arrangements are defined for nine basic applications found in refineries, petrochemical, and chemical plants.

2) Addition of dry running secondary containment seals to the specification

3) Addition of non-contacting seals to the specification

4) Addition of heavy-duty seals for enlarged bore chemical process pumps

5) All seals shall be cartridge design, balanced, and inside mounted.

6) The standard covers shaft sizes from 20mm to 110mm (0.75" to 4.3"). Minimum technical requirements established.

7) Dual seals in series (tandem arrangement) that can be pressurized, have replaced back-to-back double seals. In general, the specification allows for three orientations for Arrangement 2 and 3 seals as "face-to-back", "back-to-back" and "face-to-face".

8) Minimum standards for fluid reservoirs and seal flush coolers have been established.

9) All seals, including repaired seals, must receive an air integrity test before shipment.

10) Standard seal configurations and detailed material specifications are established. Auxiliary equipment, i.e. pumping rings, reservoirs have been addressed in the standard.

Several Important Terms That Used In API 682 :

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

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.

Bellows seal: Type of mechanical seal which uses a flexible metal bellows to provide secondary sealing and spring-type loading.

Cartridge seal: Completely self-contained unit (including seal faces, flexible elements, seal gland plate, sleeve, and mating ring) which is pre-assembled and preset before installation.

Contacting seal: Seal design where the mating faces are not designed to intentionally create aerodynamic or hydrodynamic forces to sustain a specific separation gap.

Containment seal: Seal design with one flexible element, seal ring and mating ring mounted in the containment seal chamber; it is the outer seal for all Arrangement 2 configurations.

Flashing: Rapidly changing fluid state, from liquid to gas.

Flexible element: Combination of components which move axially relative to the shaft/sleeve or seal chamber.

Several Important Terms That Used In API 682 :

Fluoroelastomer: Type of O-ring material commonly used in mechanical seals.

Flush: Fluid which is introduced into the seal chamber on the process fluid side in close proximity to the sealing faces and usually used for cooling and lubricating the seal faces.

Hook sleeve: Sleeve with a step or hook at the product end placed over the shaft to protect it from wear and corrosion; this step is usually abutted against the impeller to hold it in place with a gasket between the shaft and the step (hook).

Internal circulating device: Device located in the seal chamber to circulate seal chamber fluid through a cooler or barrier/buffer fluid reservoir .This is usually referred to as a pumping ring.

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

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

Several Important Terms That Used In API 682 :

Maximum dynamic sealing pressure (MDSP): Highest pressure expected at the seal (or seals) during any specified operating condition and during start-up and shutdown. In determining this pressure, consideration should be given to the maximum suction pressure, the flush pressure, and the effect of clearance changes within the pump. This is the process condition and is specified by the purchaser.

Maximum operating temperature: Maximum temperature to which the seal (or seals) can be subjected. This is the process condition and is specified by the purchaser.

Maximum static sealing pressure (MSSP): Highest pressure, excluding pressures encountered during hydrostatic testing, to which the seal (or seals) can be subjected while the pump is shut down. This is the process condition and is specified by the purchaser.

Non-hydrocarbon service: All services that are not predominantly hydrocarbons.

Pusher type seal: Seal design in which the secondary seal is mounted between the seal ring on the flexible element and the sleeve or seal gland plate in which this secondary seal slides axially to compensate for wear and misalignment.

Several Important Terms That Used In API 682 :

Quench: Neutral fluid, usually water or steam, introduced on the atmospheric side of the seal to retard formation of solids that may interfere with seal movement.

Vent: Eliminate gas or vapor from the seal chamber. This is normally accomplished through a gland connection, such as the flush connection.

Categories, Arrangements And Types Of Standard Seals:

- *Categories:*

Category I

Chemical & Petrochemical Industry Pumps.

Heavy duty seals designed for ANSI and ISO enlarged bore seal chambers.

Category II

Oil & Gas Industry API Pumps.

Handles services previously defined as API-610 applications.

Same qualification tested components as Cat. III Seals.

Category III

Oil & Gas Industry API Pumps.

Premium seals meeting highest specification of API 682.

Require full qualification test reports.

- *Seal arrangements:*

Arrangement 1
Single Seal

Arrangement 2
Unpressurized Dual Seal
(Tandem-2 Seals In Series)

Arrangement 3
Pressurized Dual Seal
(Double-BB,FB,FF)

- *Seal types:*

Type A

Rotating pusher seal Using O-rings & multiple springs

API 682

2nd Edition

Type B

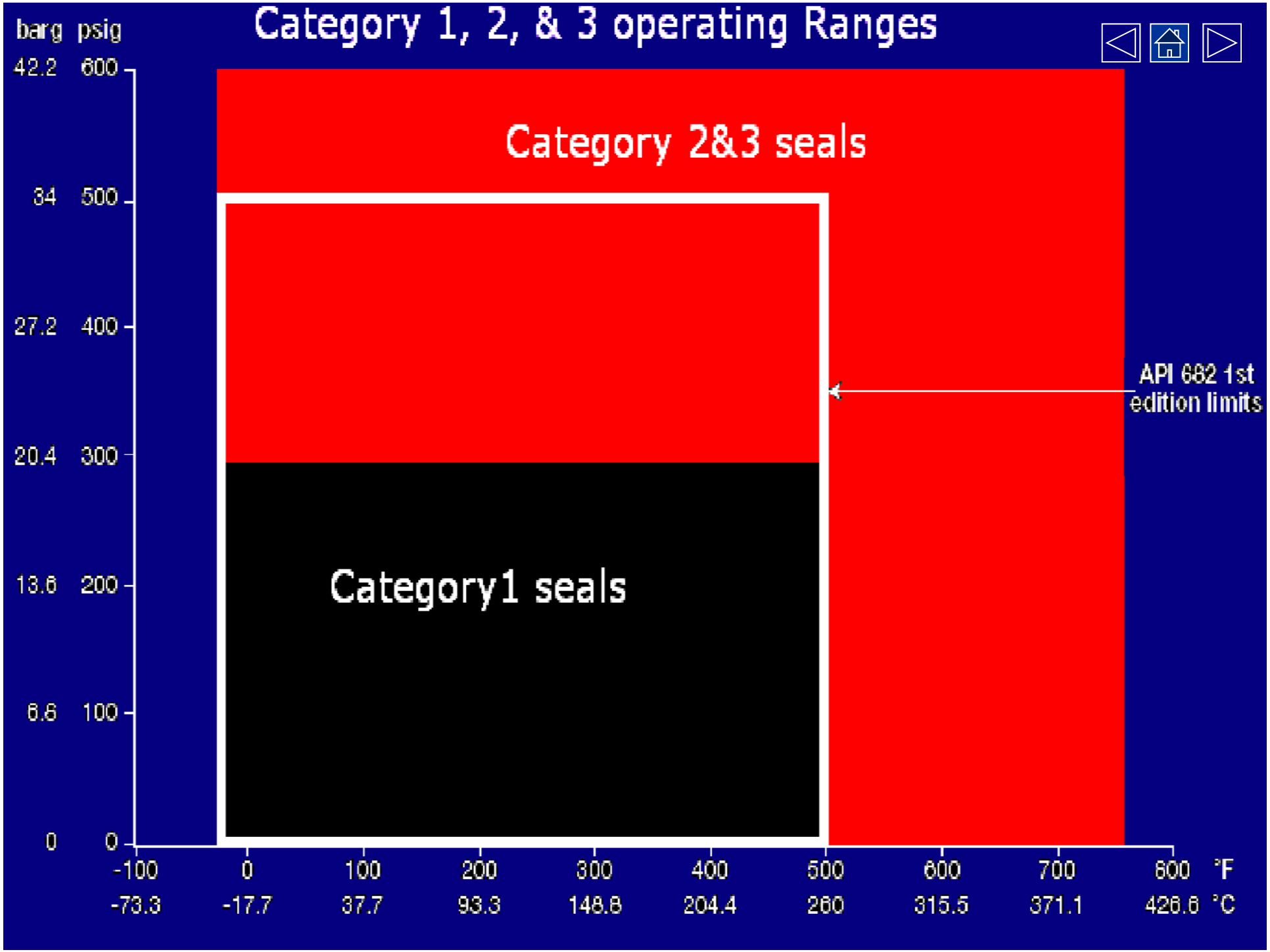
Non-Pusher

Rotating metal bellows seal Using O-rings

Type C

Non-Pusher

Stationary metal bellows seal Using flexible graphite gaskets


Category 1, 2, & 3 operating Ranges
barg psig
42.2 600
34 500
27.2 400
20.4 300
13.6 200
6.6 100
0 0
Category 2&3 seals
Category1 seals
API 682 1st edition limits
-100 0 100 200 300 400 500 600 700 800 °F
-73.3 -17.7 37.7 93.3 148.8 204.4 260 315.5 371.1 426.6 °C

Piping Plans

Defined In

API 682

API Plan Description

01, 02 . . . . . .Internal system for single seals
11, 12, 13, 14 . . . . .Simple recirculation system for single seals
21, 23, 31, 41 . . . . .Recirculation systems with auxiliary equipment for single seals
52, 53A-C, 54, 74 . External systems for dual seals
32, 62 . . . . . .External injection systems
72, 75, 76 . . . . . .External control system for containment seals

Arrangement	Flush Plan
1	01, 02, 11, 13, 14, 21, 23, 31, 32, 41, 51, 61, 62
2	01, 02, 11, 13, 14, 21, 23, 31, 32, 41, 52, 61, 62, 71, 72, 75, 76
3	01, 02, 11, 13, 32, 53A, 53B, 53C, 54, 61, 62, 74

Plan 11 / 62 ?

Advantages:

Flush Plans 11, 12, 13, 14, 21, 23, 31, and 41:

- No product contamination occurs.
- Do not require any reprocessing of the product.

Disadvantages:

- Disadvantage if the product being pumped is not a good face lubricant, the seal can become damaged or clogged.
- Circulation from the pump discharge back to pump suction will decrease pump efficiency and increase power required for the application

Flush Rate functionally related to :

1) Speed of Shaft
2) Size of Seal
3) Service conditions

Flush Rate ≥ 1 GPM/Inch of seal size

- Shaft speed < 3600 rpm
- Stb. Press. < 35 barg

Allowed Temperature Rise of Flush Flow?

Lub oils	16°C
Water & Low Volatility hydrocarbons	8°C
Volatility hydrocarbons	3°C

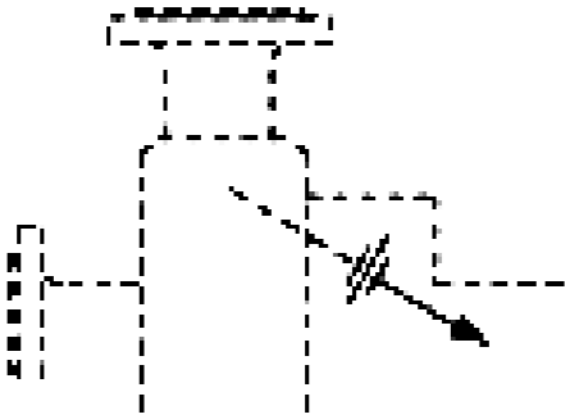
Plan 01

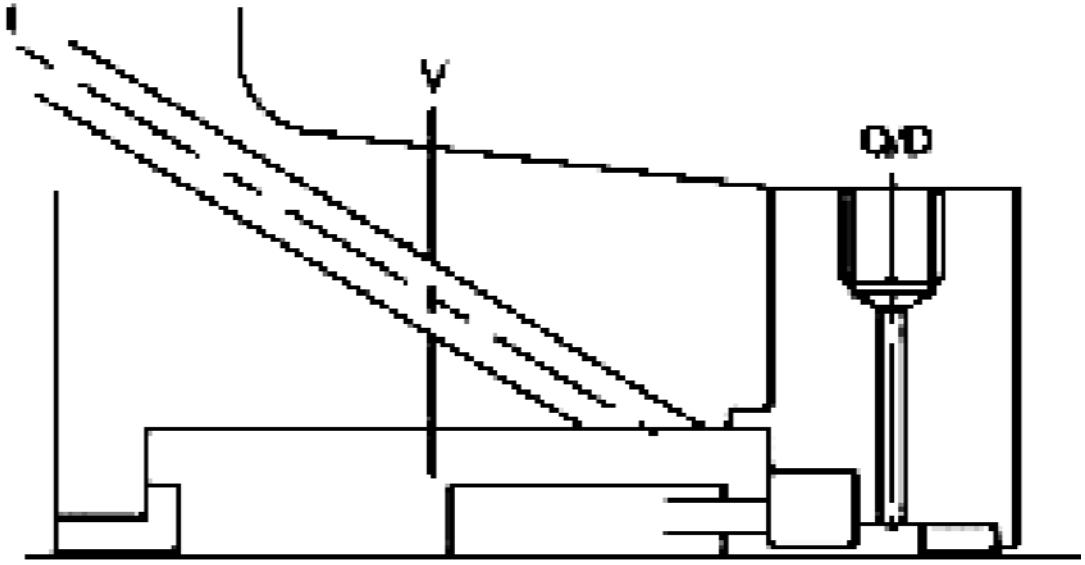
Recirculation from pump discharge to stuffing box

Recommended for : Only Clean pumpage

Limited to pumps with total differential head < 38 m

Note: Not Recommended for Vertical Pumps



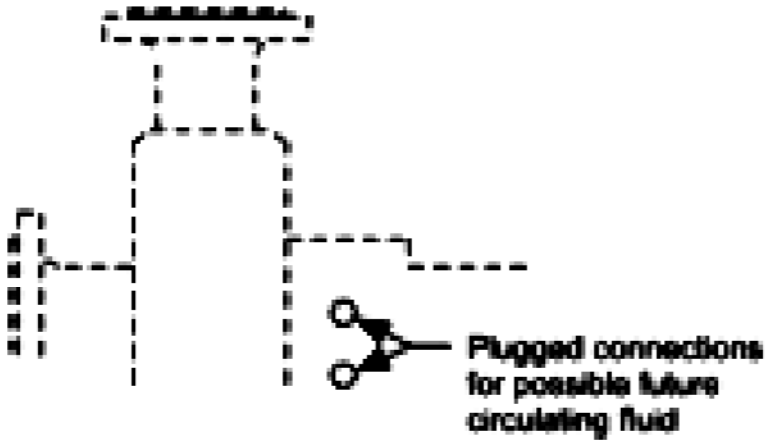


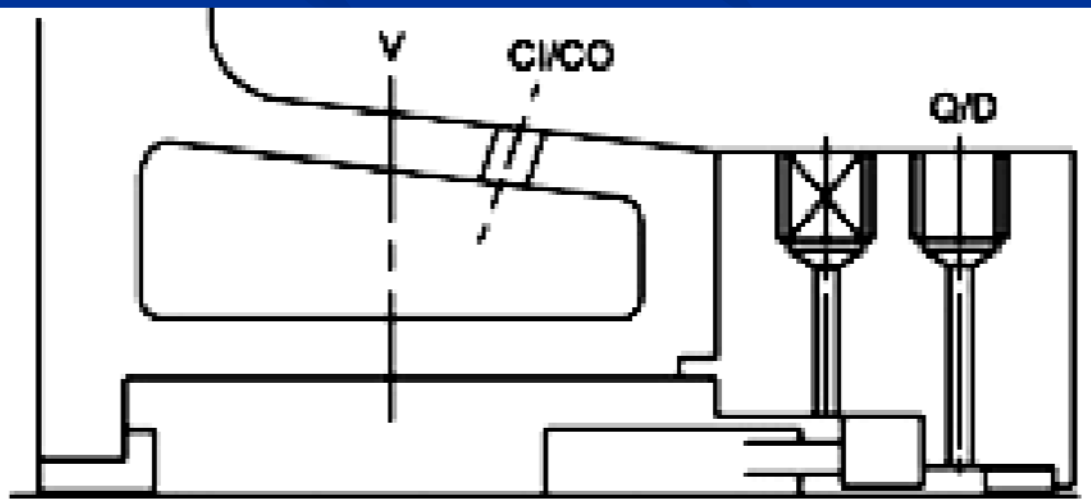
Plan 02

Non_Recirculation Flush Plan

Recommended for : Low Duty + Chemical Service Pumps

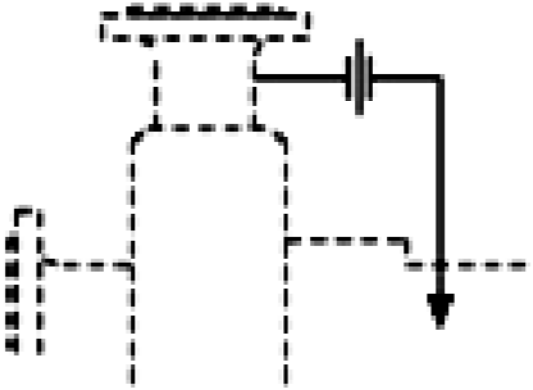
Often Used In Conjunction With API Plan 62
and/or
The Optional Use Of A Cooling Jacket.

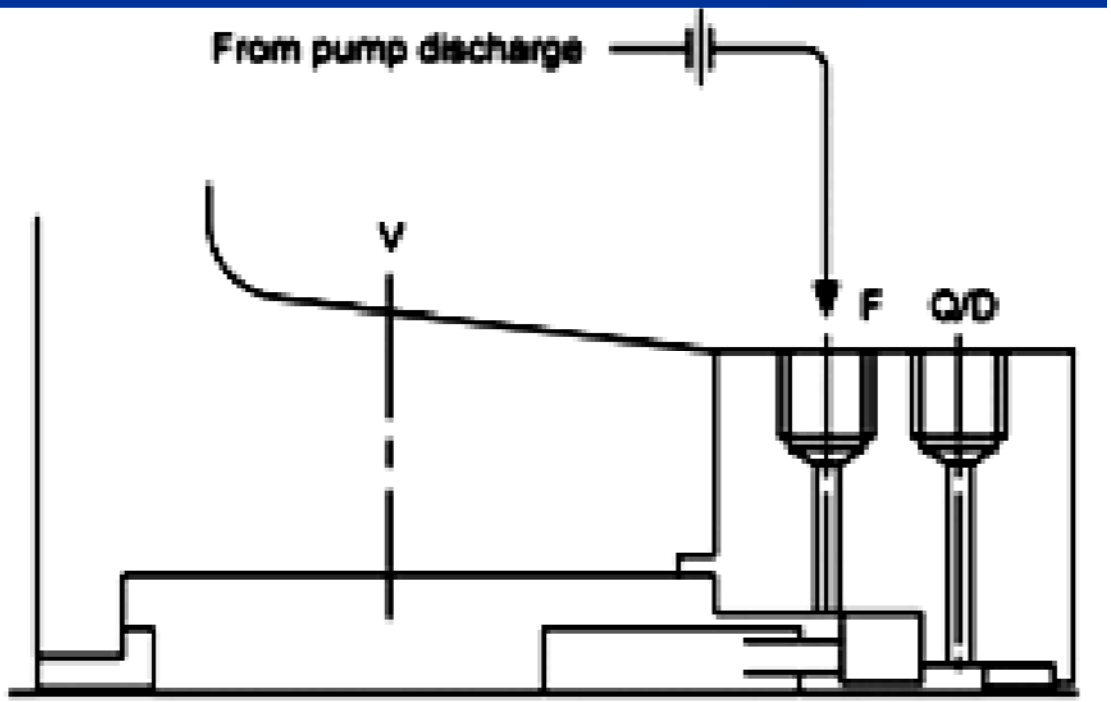




Plan 11

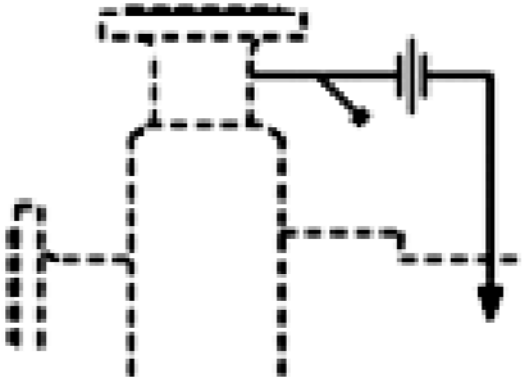
Taking Appropriate Amount Of Pumped Fluid From Pump Discharge And Putting Into Stuffing Box

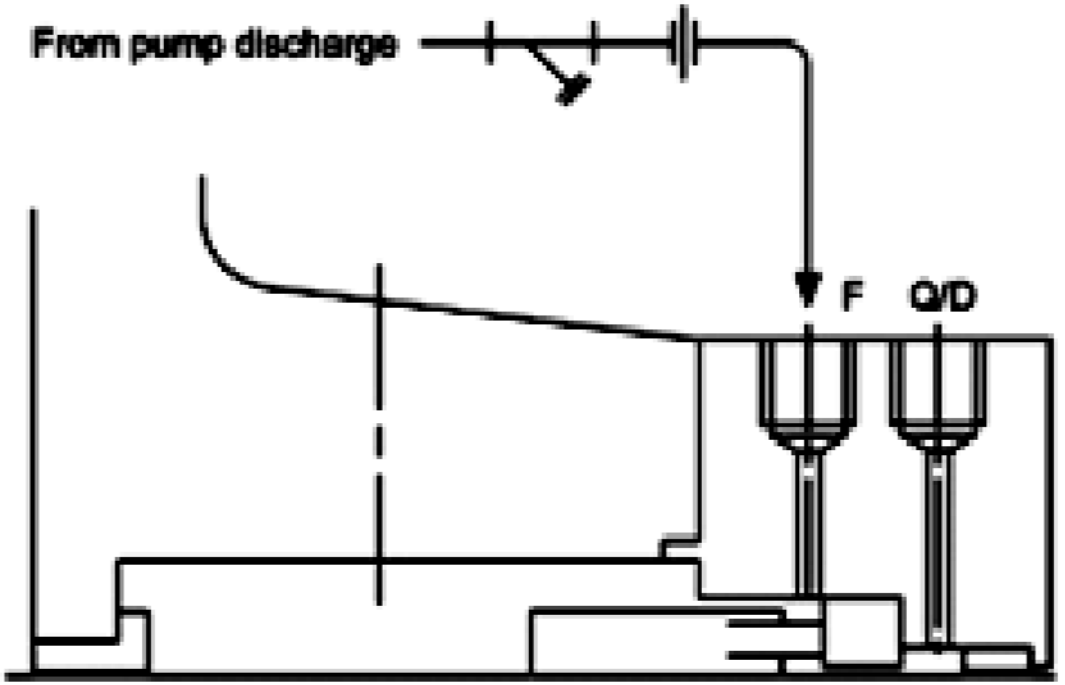




Plan 12

Recirculation Appropriate Amount Of Pumpage From Pump Discharge To Stuffing Box (Plan 11 + Strainer)

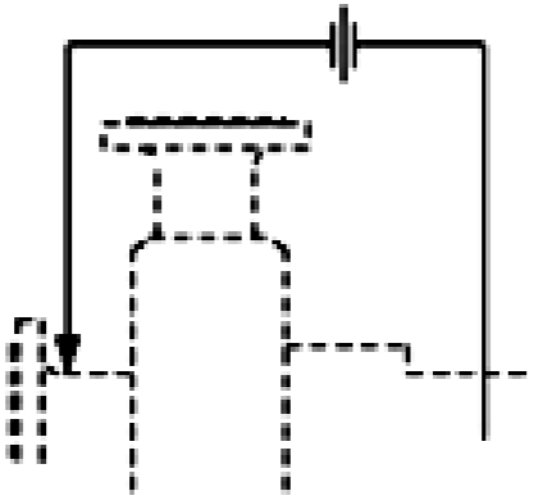


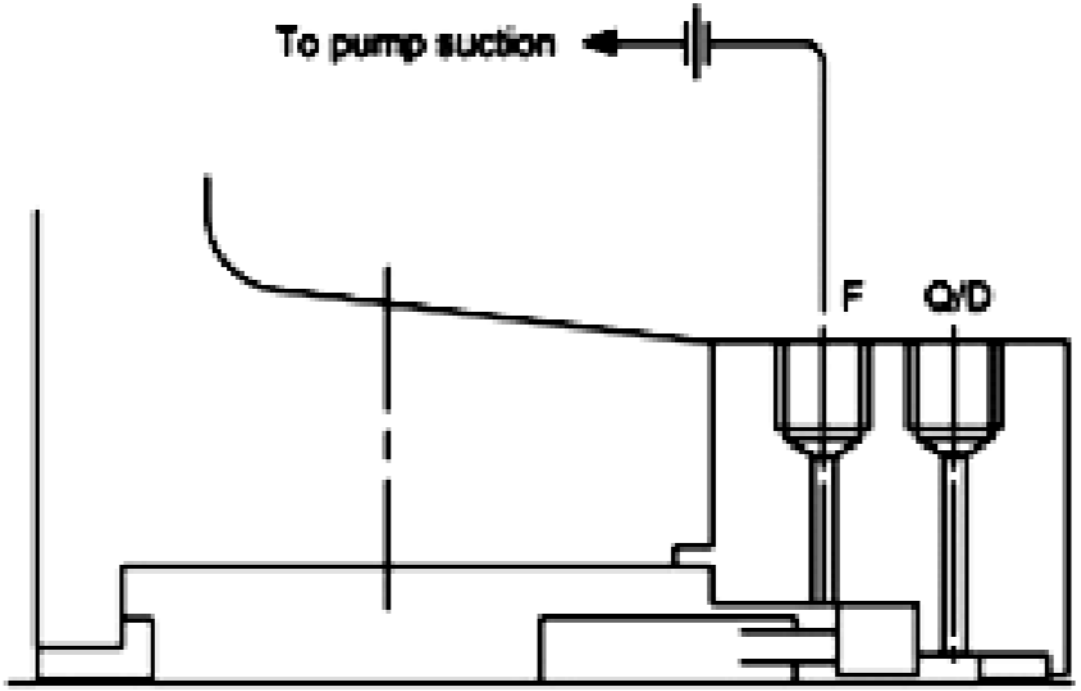


Plan 13

Recirculation Appropriate Amount Of Pumpage From Stuffing Box To Pump Suction

Typically Plan 13 Is Used On Vertical Pumps.

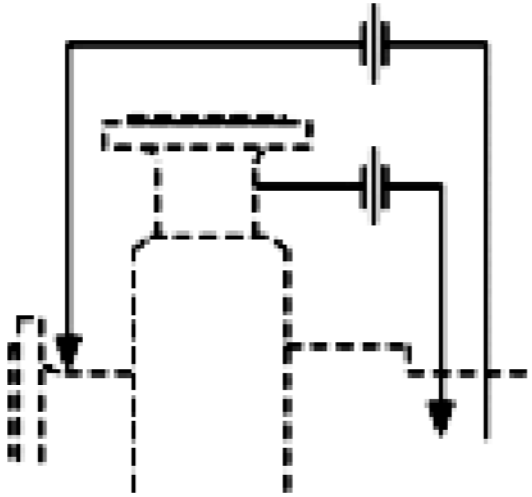


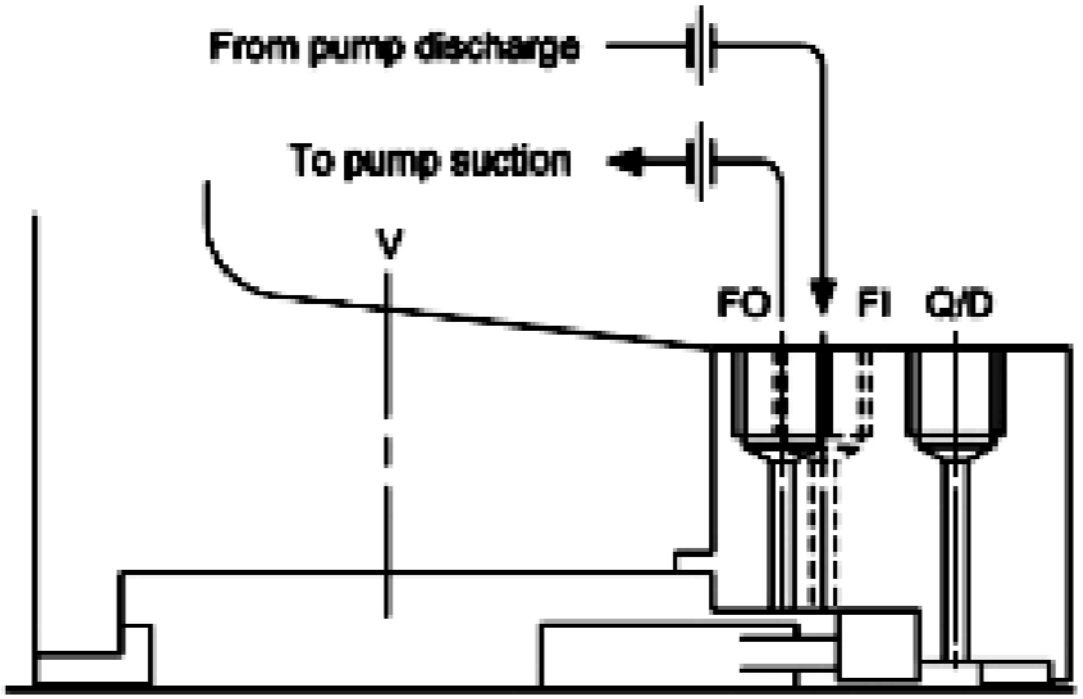


Plan 14

Plan 14 = Plan 11 + Plan 13

Typically Plan 13 Is Used On Vertical Pumps + Viscous Product

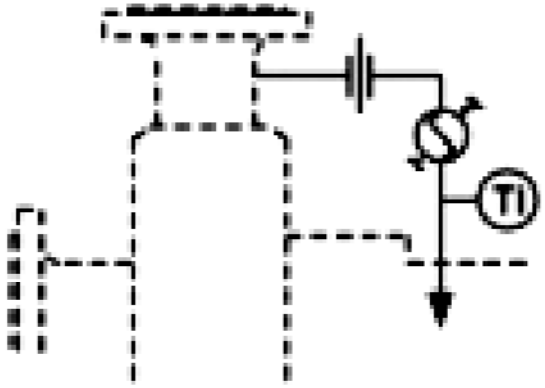


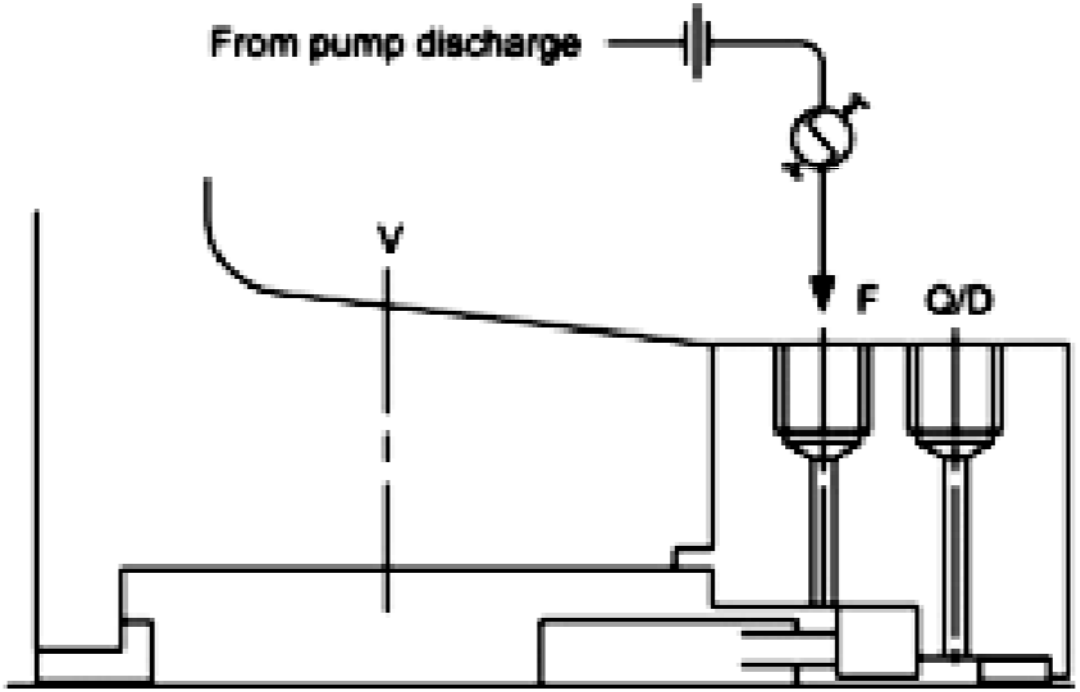


Plan 21

Cooled Version Of Plan 11 (Plan 11 + Heat Exchanger)

Note: Temperature Indicator Installed In Downstream Side Of Heat Exchanger



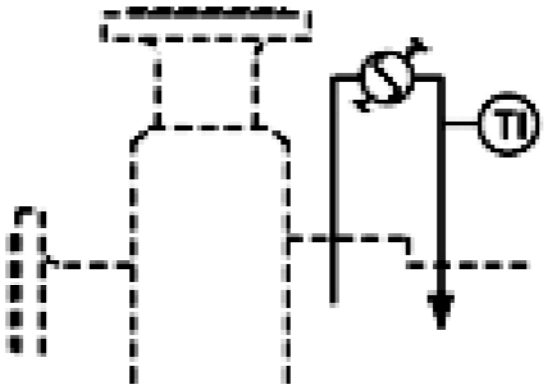


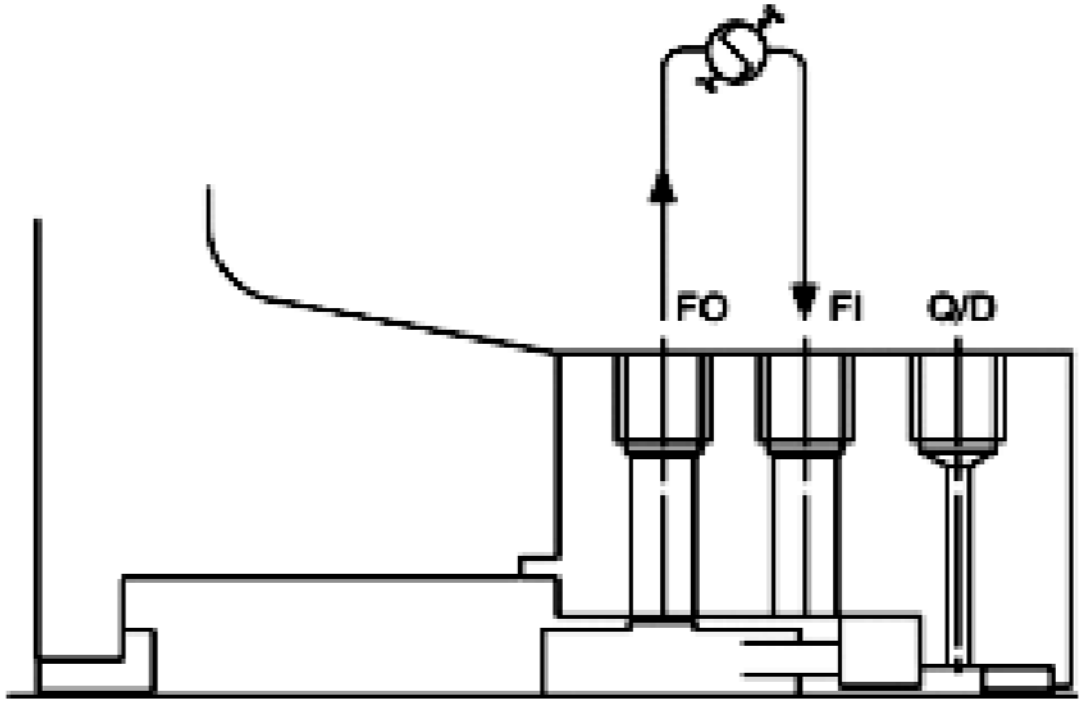
Plan 23

Closed Loop Circulation System Used On Hot Applications
For Flushing And Cooling Single Seals.

With Pumping Ring In The Seal Chamber

Hot Water Services
High Pressure Boiler Feed Water
Efficient Cooling In Hydrocarbon Services

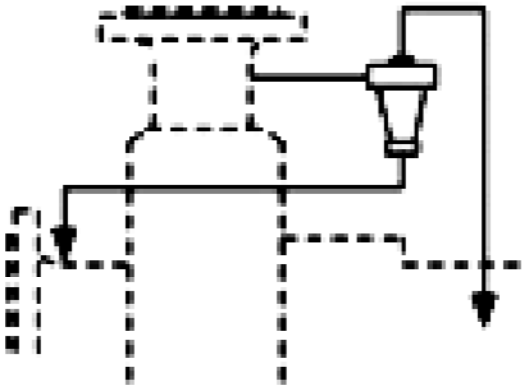


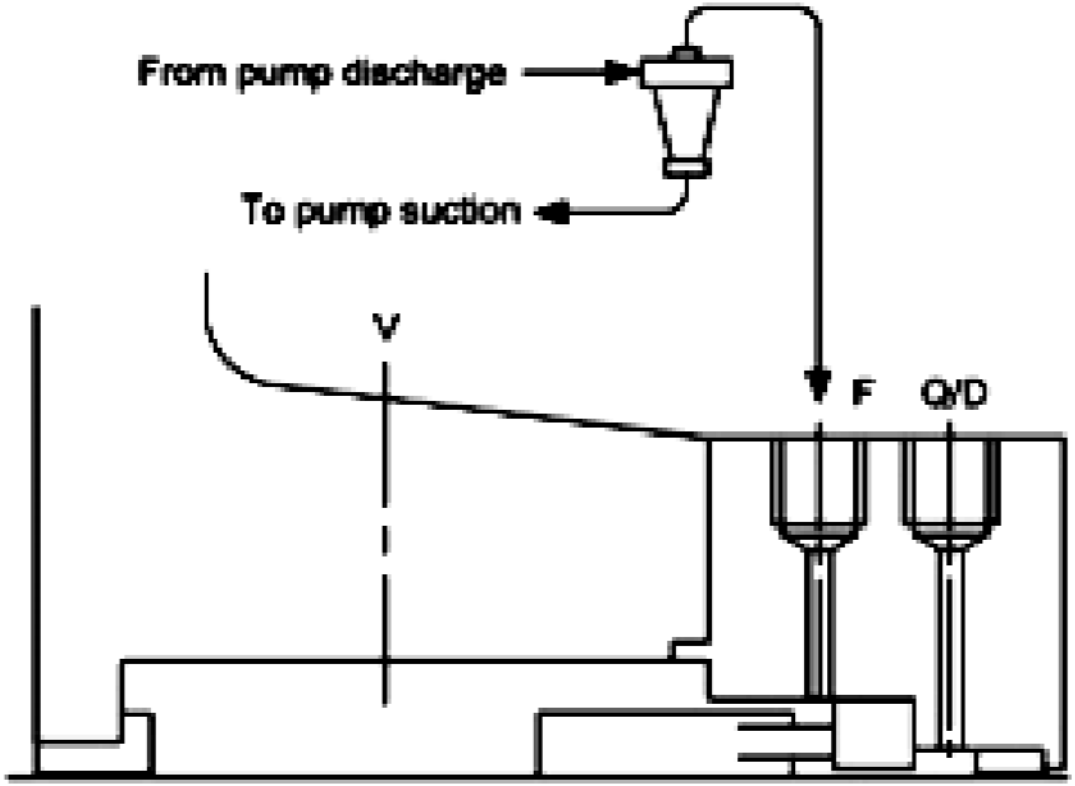


Plan 31

Plan 31 = Plan 11 + Cyclon

This plan should only be used for services containing solids that have a specific gravity at least twice that of the process fluid.





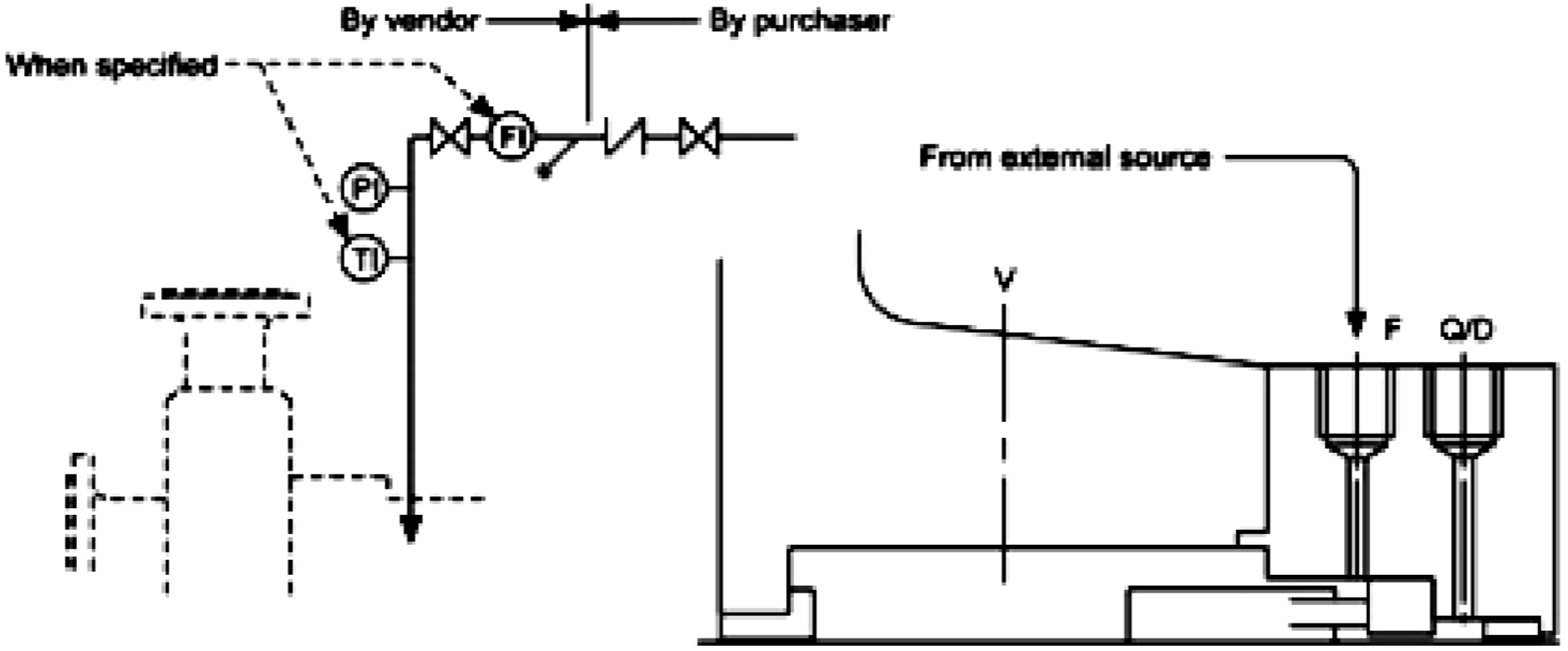
Plan 32

Plan 32 involves the use of a flush stream which is brought in from an external source to the seal.

Plan 31 Applications:

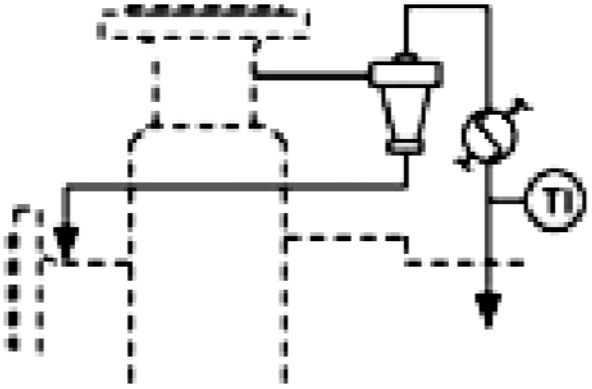
A. Process Streem Is Difficult To Cooling And Lubrication

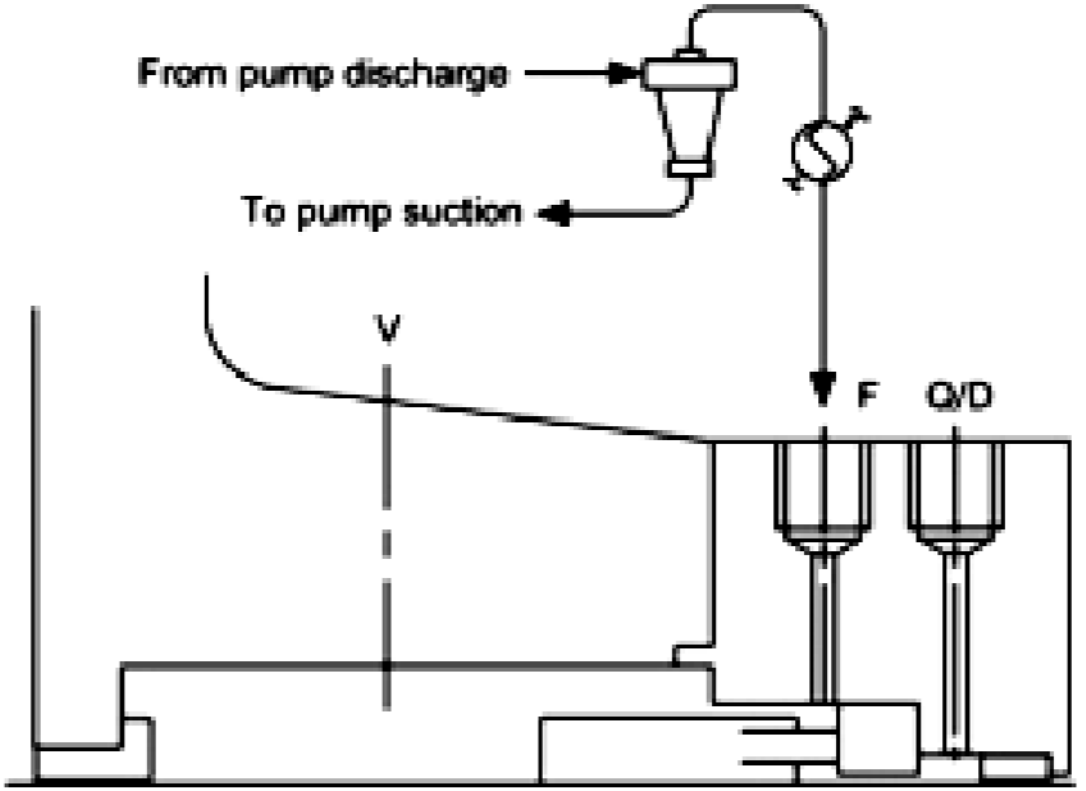
B. Process Streem Includes Components Which May Either Result In Abrasive Wear



Plan 41

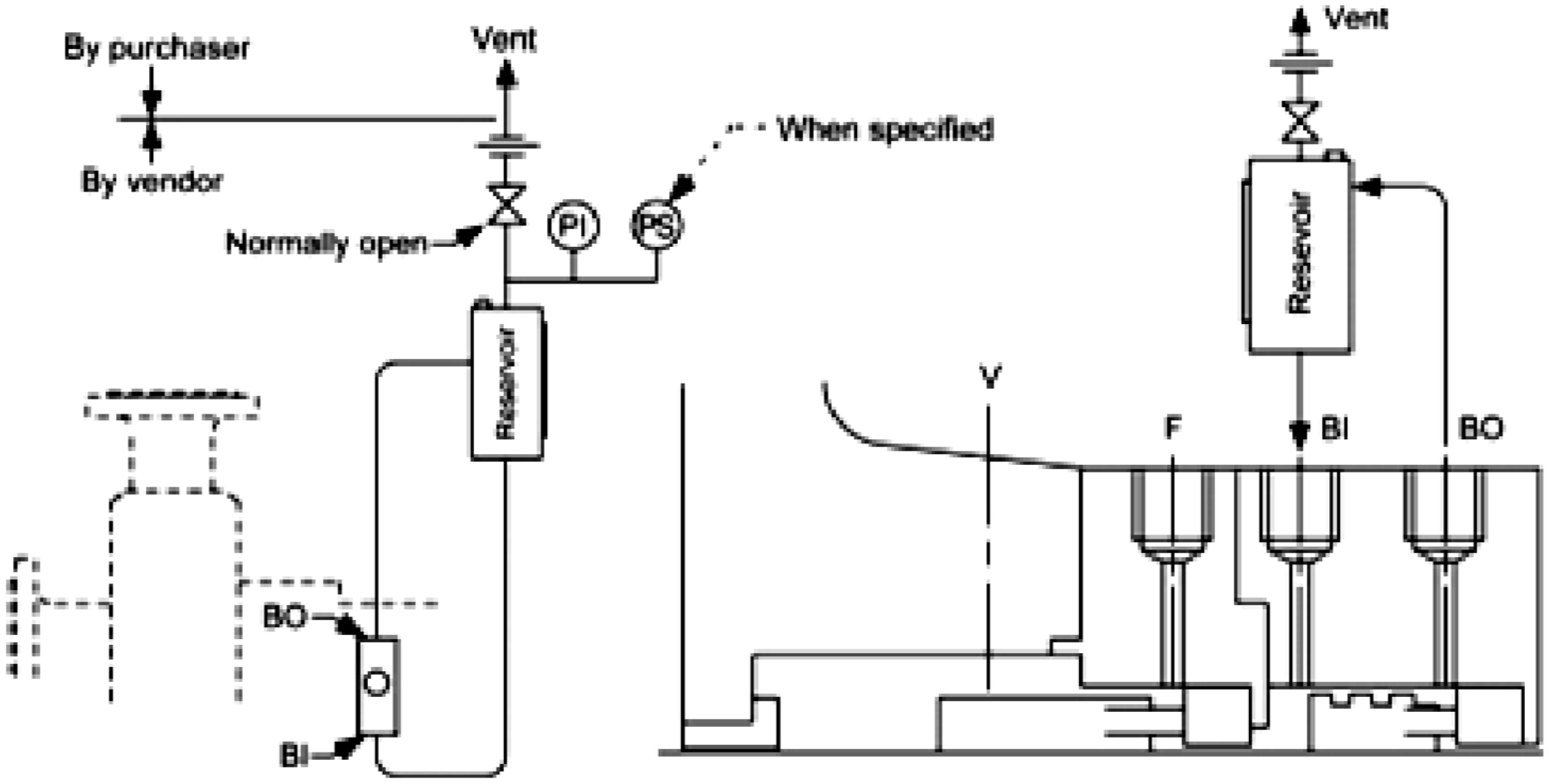
Plan 41 = Plan 31 + Plan 21





Plan 52

An External Reservoir To Provide Buffer Fluid For The Outer Seal Of An Unpressurized Dual Seal Arrangement (Tandem Arrangement).

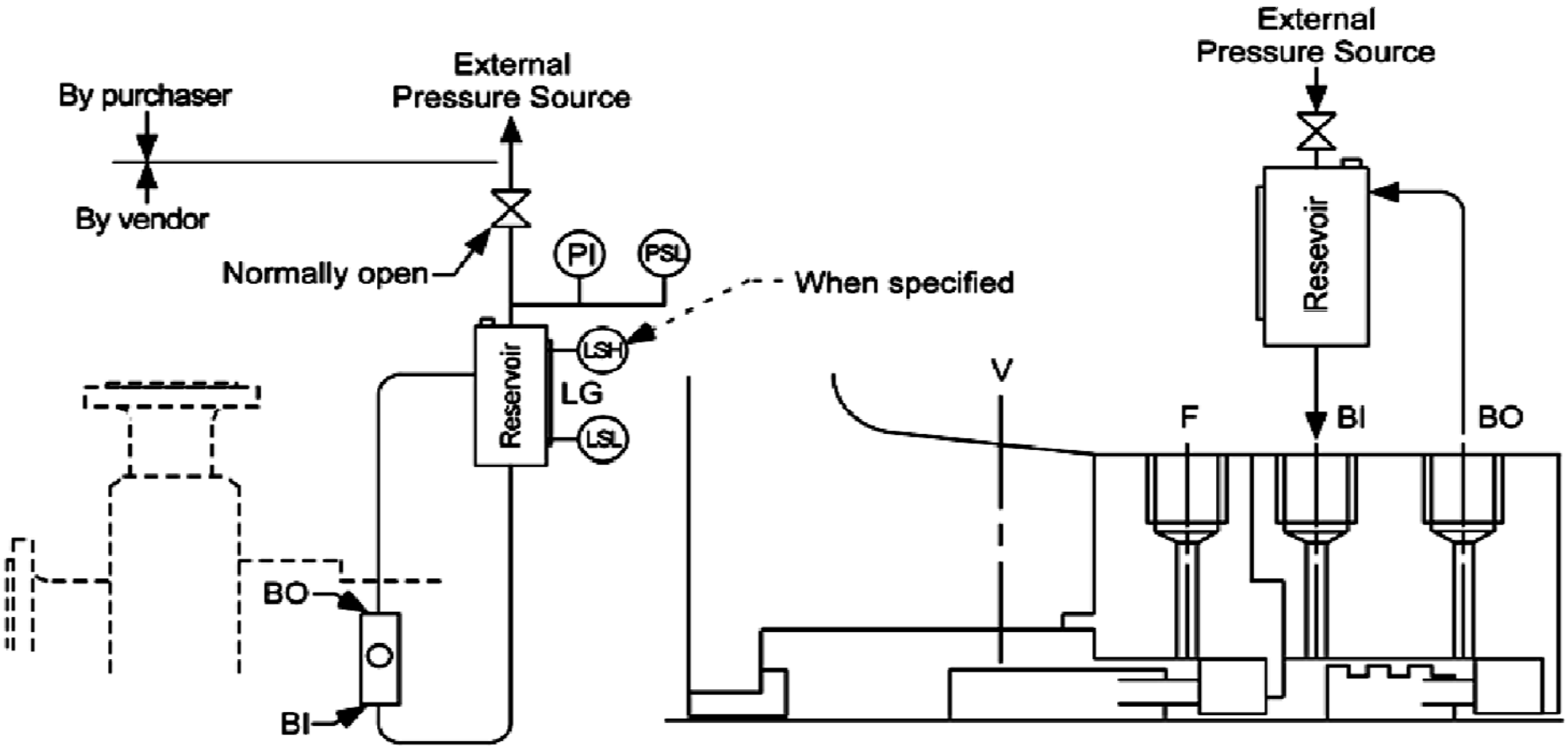


Pressurized Dual Seal Arrengement

Plan 53A (New Plan)

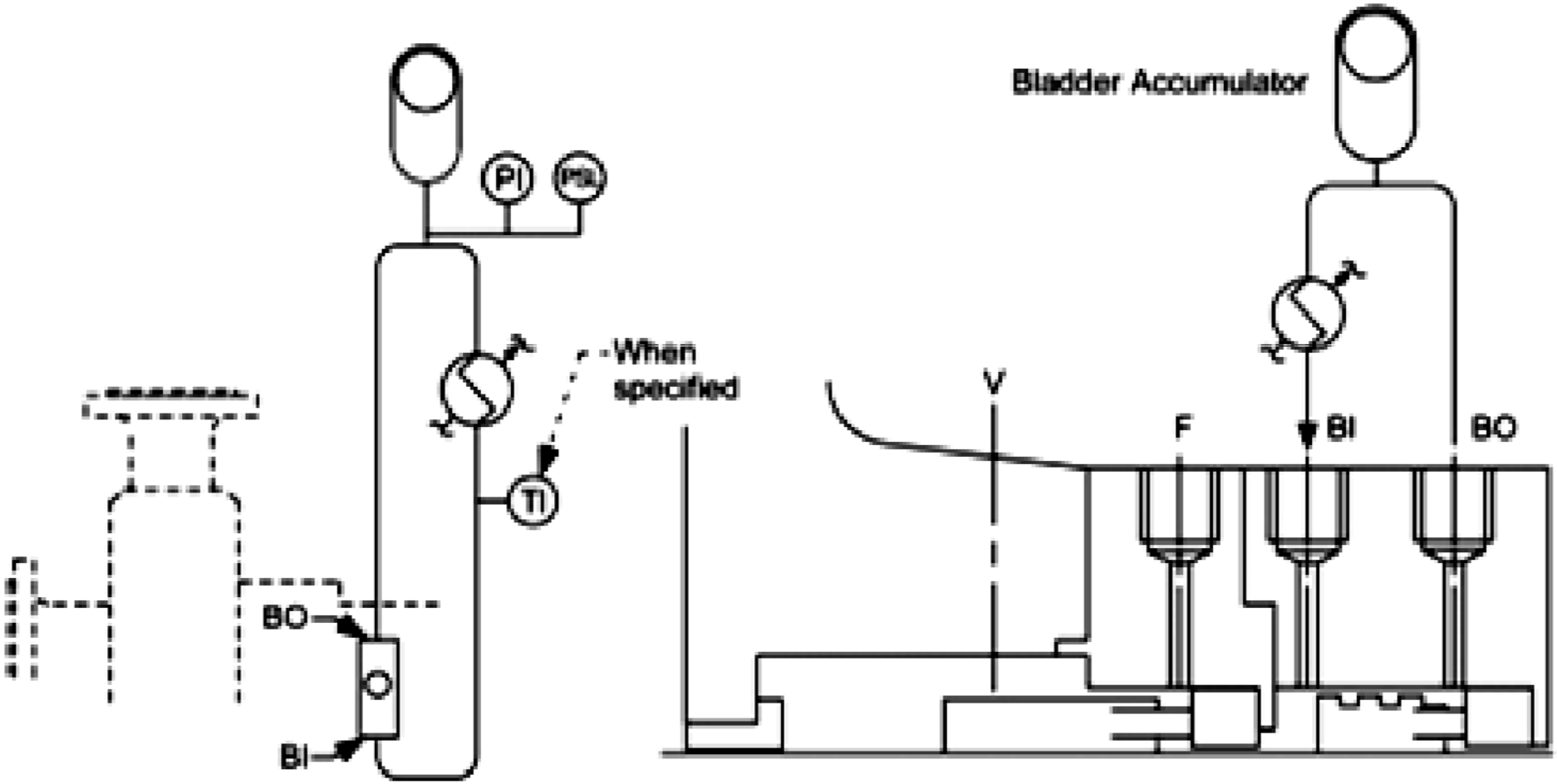
An external reservoir to provide barrier fluid for a pressurized dual seal arrangement.

- Reservoir pressure is produced by a gas, usually nitrogen, at a pressure greater than the maximum process pressure being sealed
- Plan 53A is pressurized above the process pressure. The usual guideline is to operate at least 10% above the process pressure but a minimum of 20 to 50 psi (1.4 to 3.5 bar) above the maximum process pressure



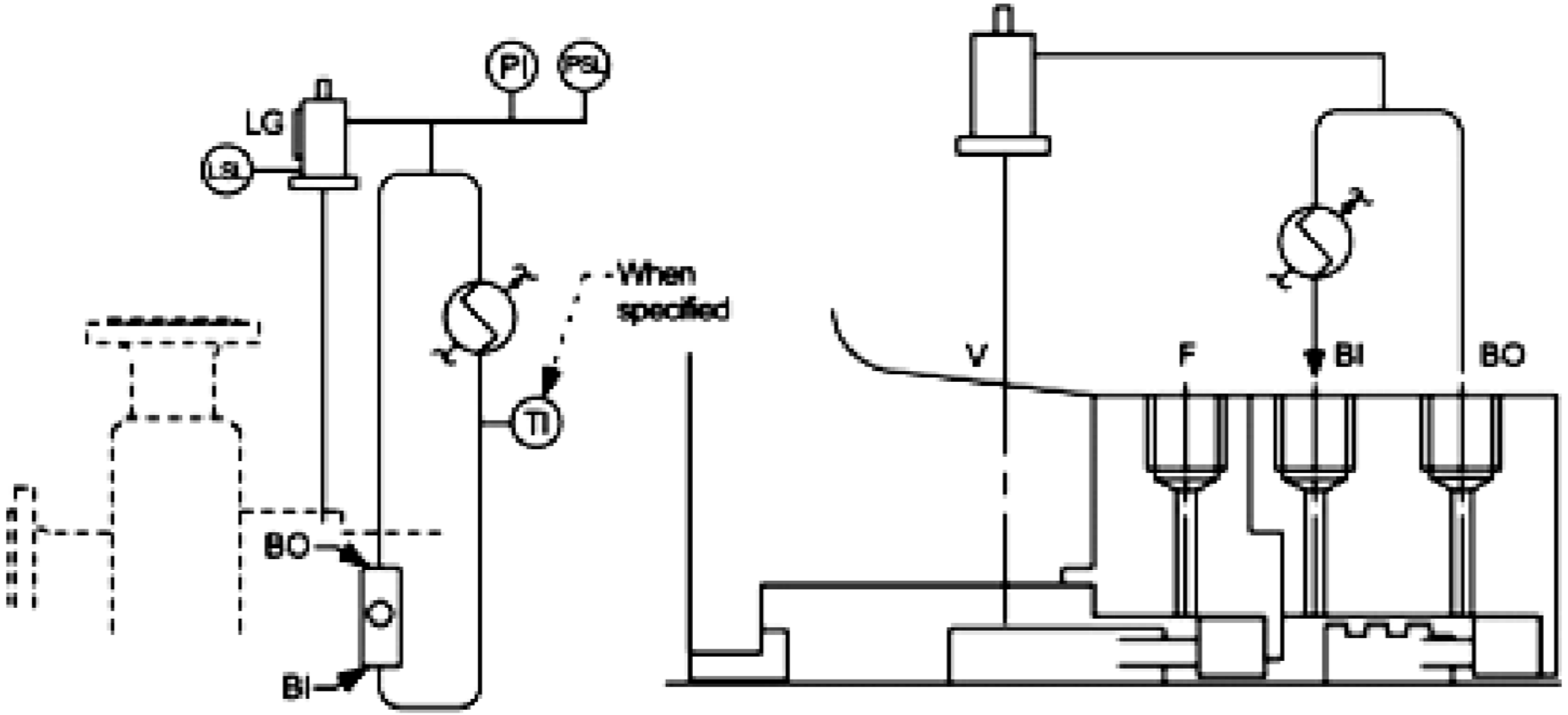
Plan 53B (New Plan)

Closed Loop & Pre-Pressurized By Bladder Accumulator



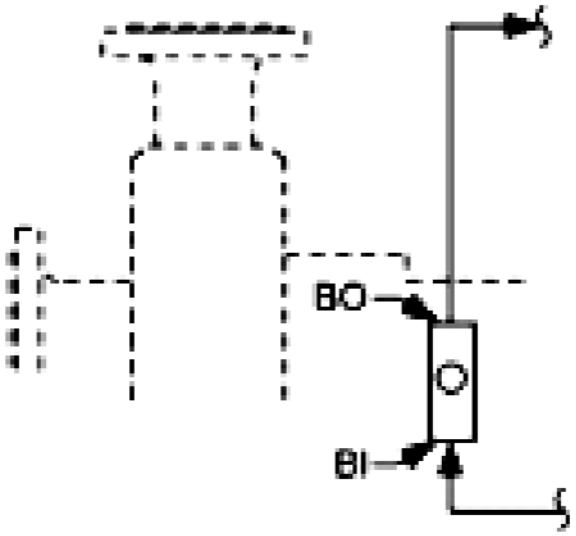
Plan 53C (New Plan)

Closed Loop & Pre-Pressurized By Piston Accumulator

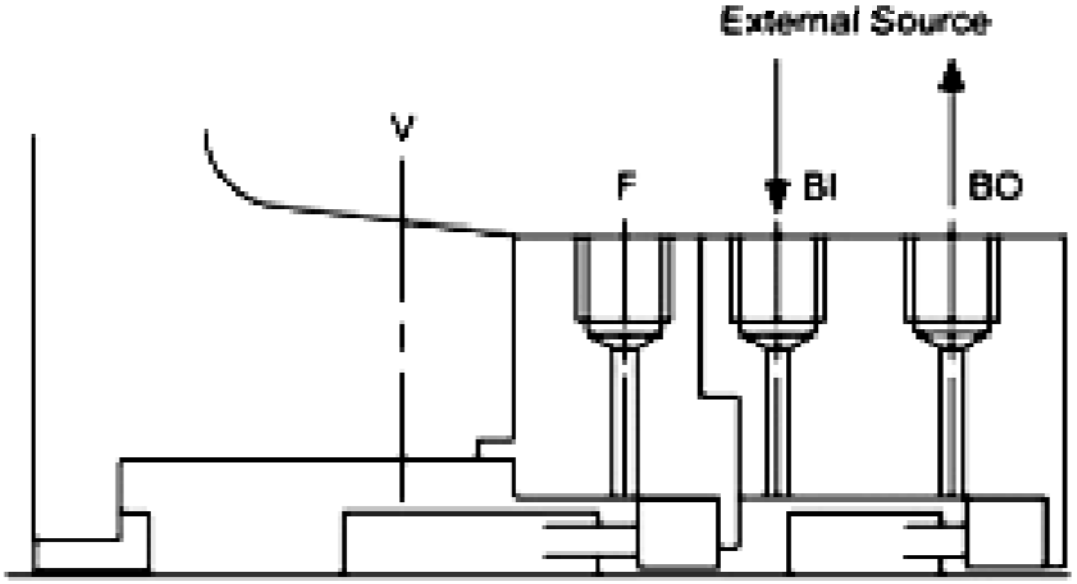


Plan 54 (New Plan)

Utilizes an external source to provide a clean pressurized barrier fluid to a dual pressurized (double) seal.



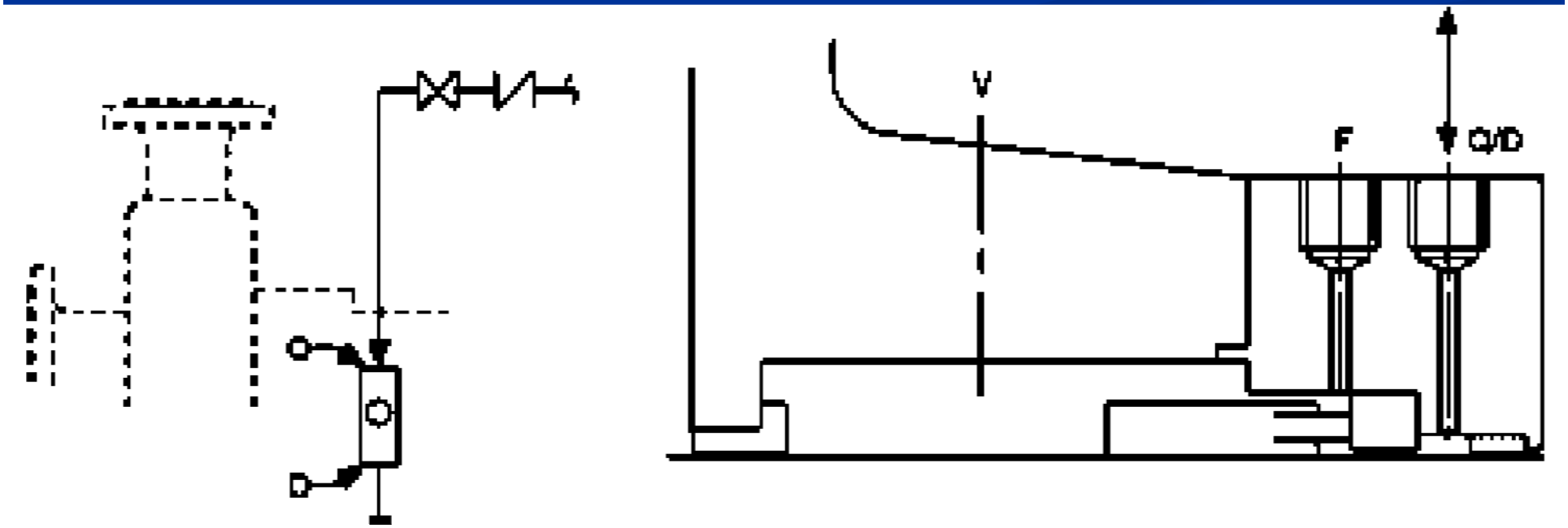
PLAN 54



SEAL CHAMBER FOR PLAN 54

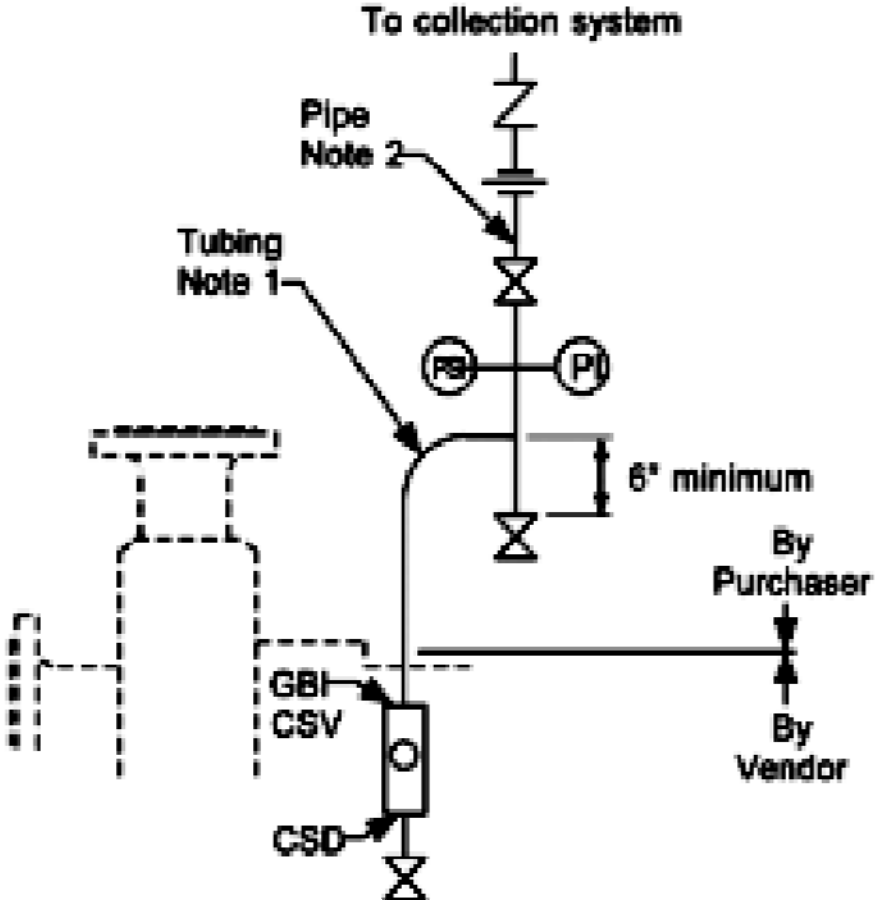
Plan 62

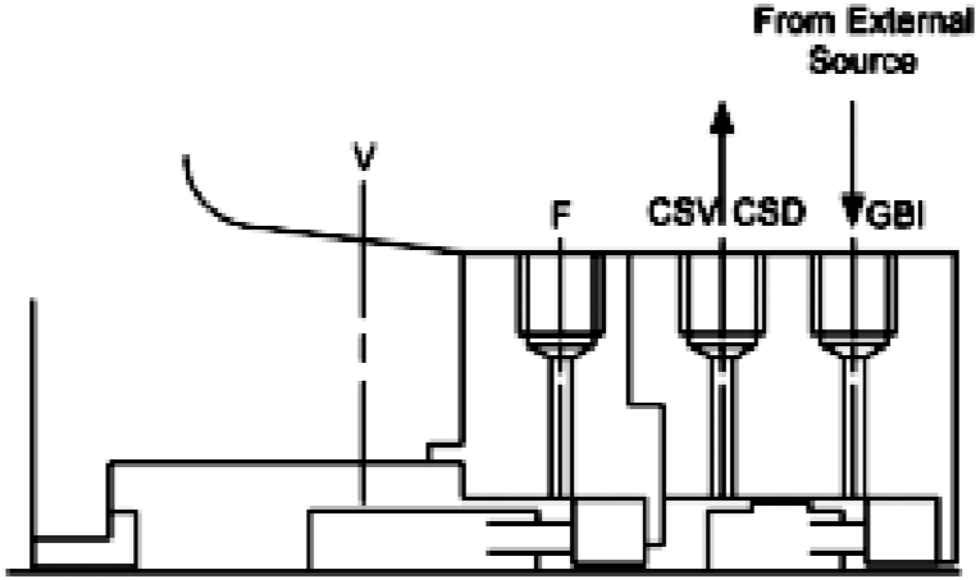
Plan 62 Is A Common Flush Plan To Improve The Environment On The Atmospheric Side Of Single Seals.



Plan 71 (New Plan)

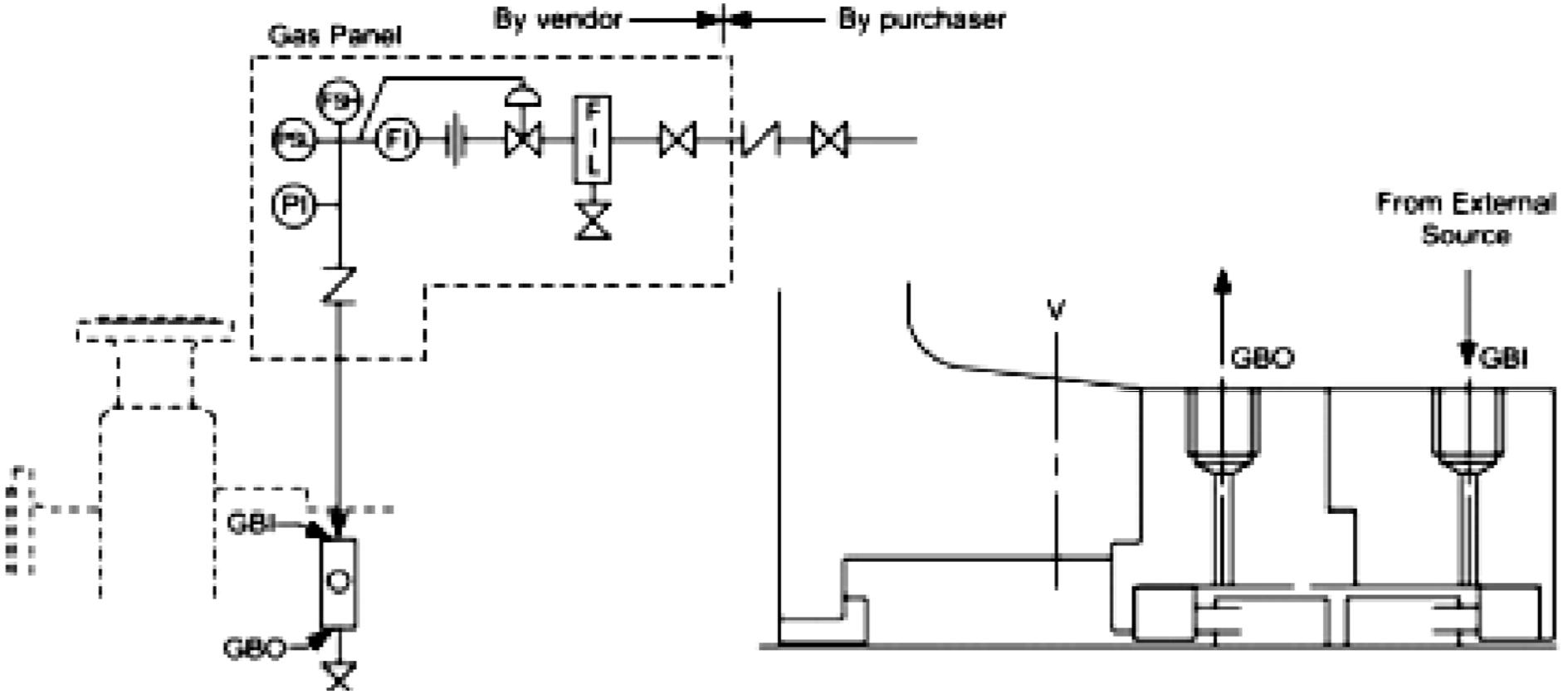
Plans 71, 72, 75, and 76 are new plans for dry running, secondary containment seals used in conjunction with a liquid lubricated primary seal.



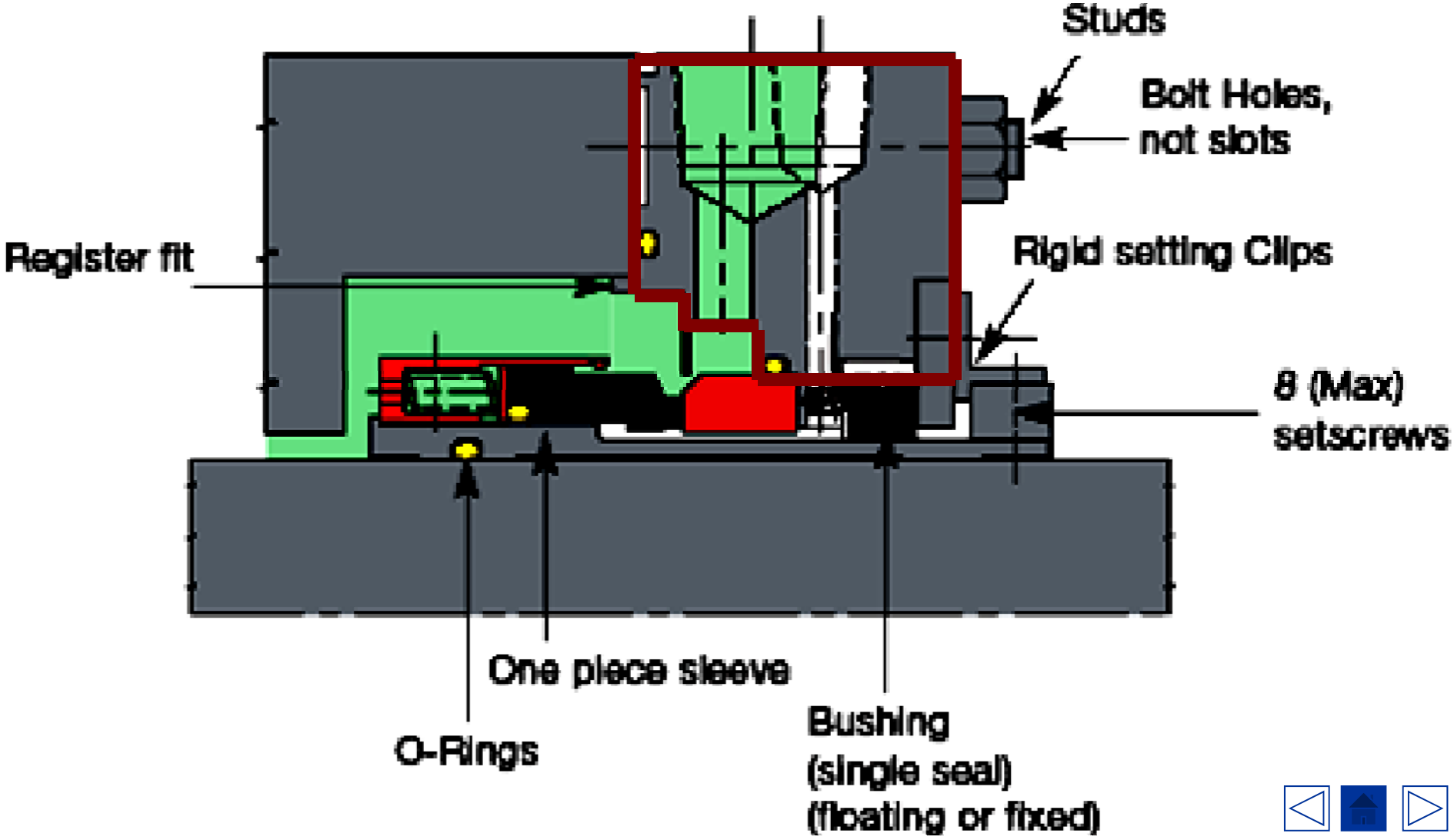


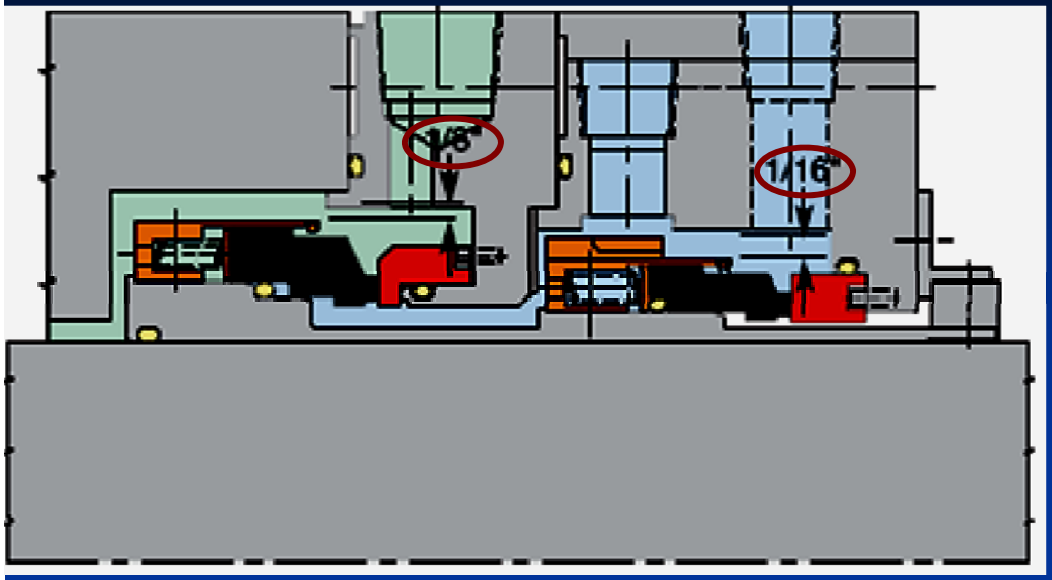
Plan 74 (New Plan)

New Plan For Dual Gas Seals



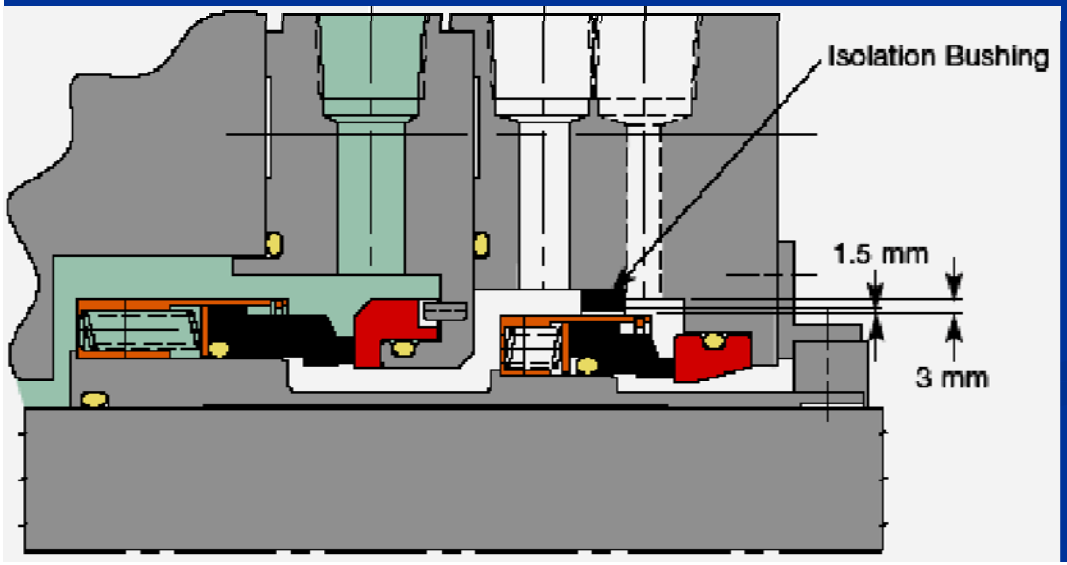
Gland Plate Requirements:





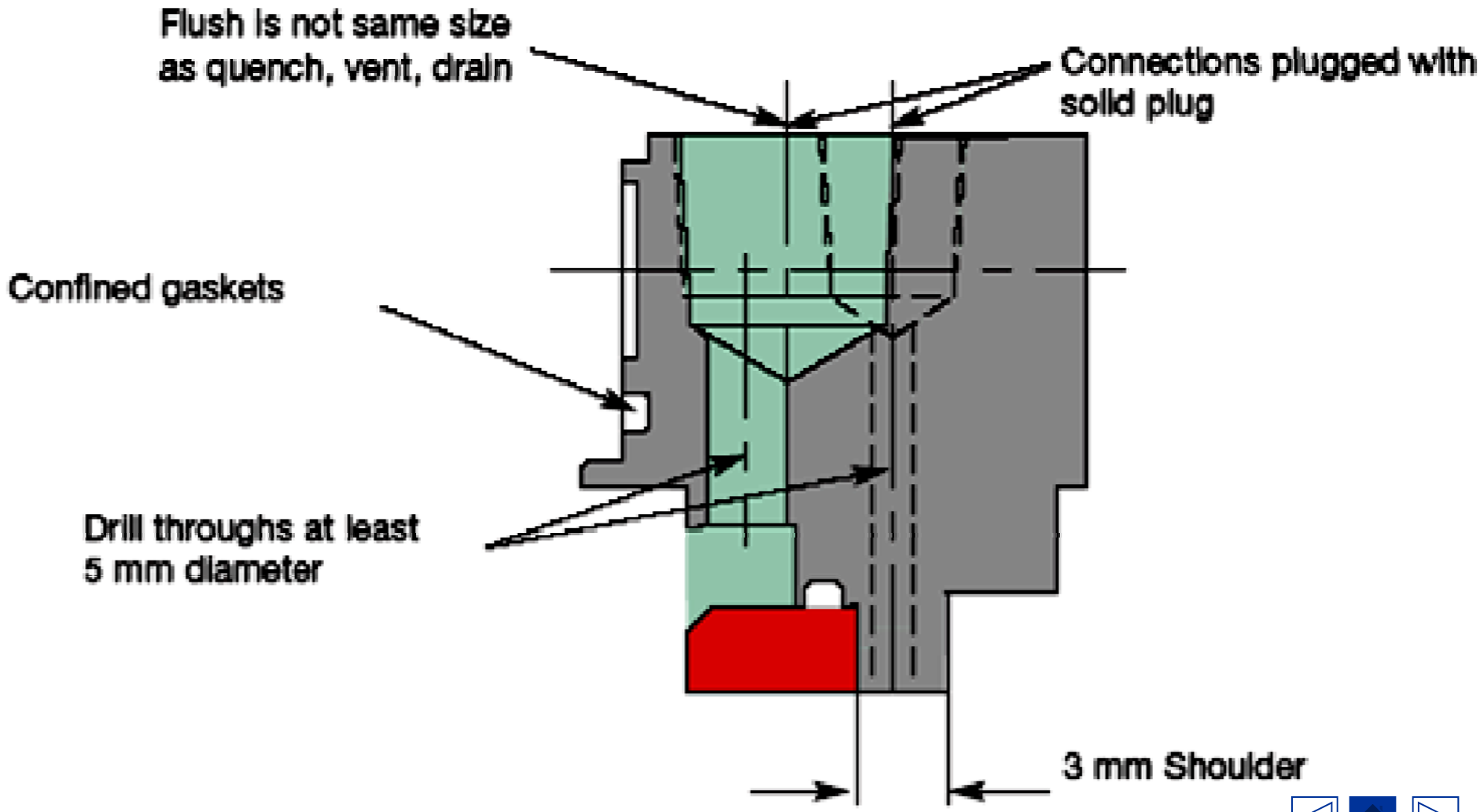
1• Minimum radial clearance between rotating components and stationary surfaces is 3 mm (1/8").

2• Minimum radial clearance for pumping rings can be 1.5 mm (1/16").



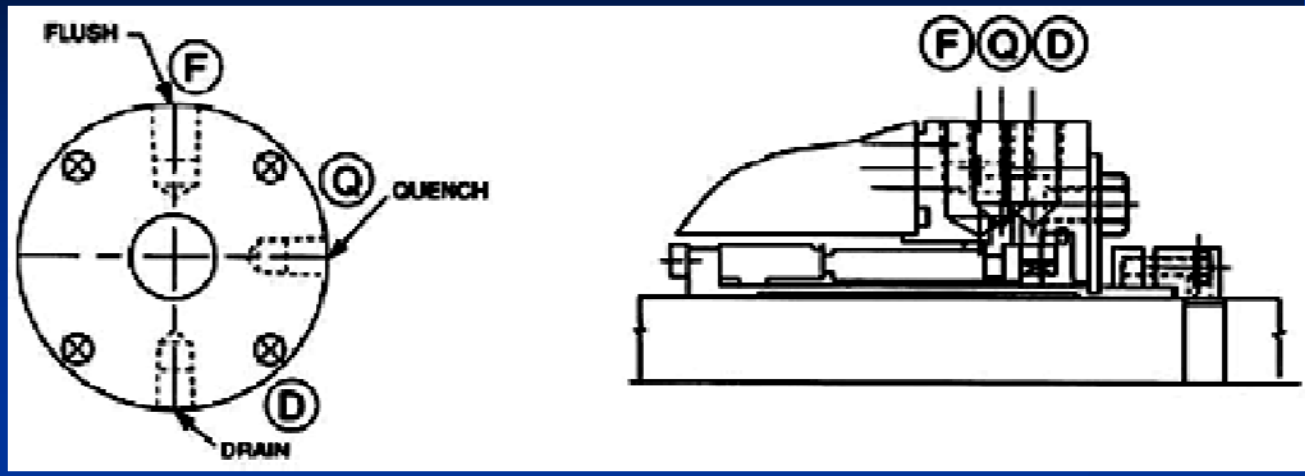
3• Isolation bushing for containment seals has 1.5 mm (1/16") radial clearance.

4• Gland should have corrosion allowance of 3 mm (1/8").
5• Gland must be hydrostatically tested at 1.5 times the Maximum Allowable Working Pressure (MAWP).
6• Mating surfaces contact inside and outside of bolt circle.



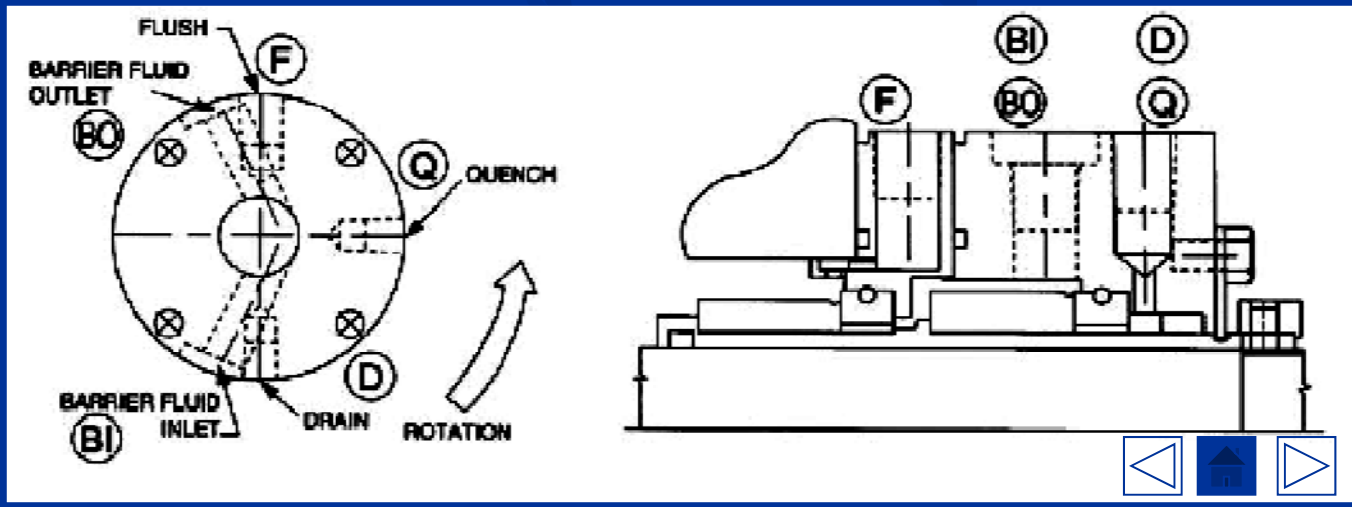
Gland Plate Connections For Single Seals By Size

Symbol	Size (inches)
F	1/2
D	3/8
Q	3/8
FI	1/2
FO	1/2



Gland Plate Connections For Dual Seals By Size

Symbol	Size (inches)
LBI	1/2
LBO	1/2
CSV	1/2
CSD	1/2
GBI	1/4
GBO	1/2



Symbol	Connections	Location	Type
BI	Barrier/Buffer Fluid In	180°	Process
BO	Barrier/Buffer Fluid Out	0°	Process
C	Cooling	--	Process
D	Drain	180°	Atmospheric
F	Flush	0°	Process
H	Heating	--	Process
Q	Quench	90°	Atmospheric
I	In	--	--
O	Out	--	--

Recommended Materials For Gland Plates:

Equal or better than pump case material.

316SS minimum

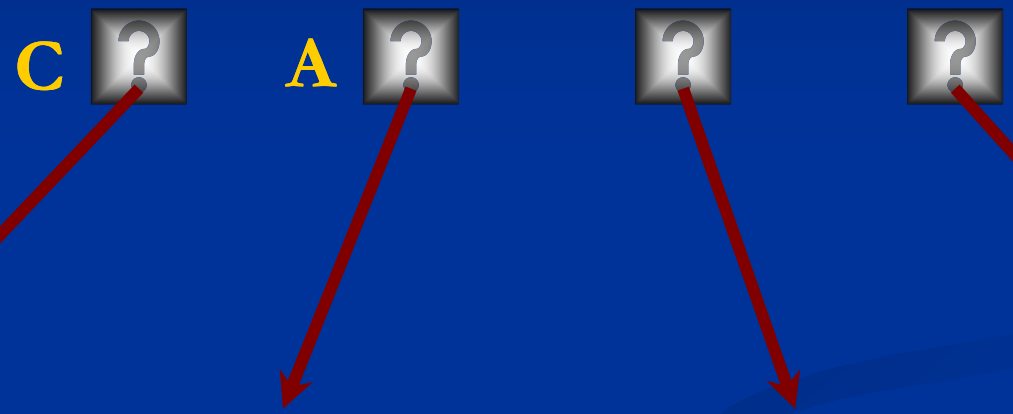
AISI Type 316 Stainless Steel.

EN 10088 Grade 1.4571 or an equivalent.

***** : Plugs should be same material as the gland plate.

Mechanical Seals Coding:

C2 A1 A 11?



CATEGORY (1, 2 or 3)

ARRANGEMENT (1, 2 or 3)

TYPE (A, B, C)

FLUSH PLAN

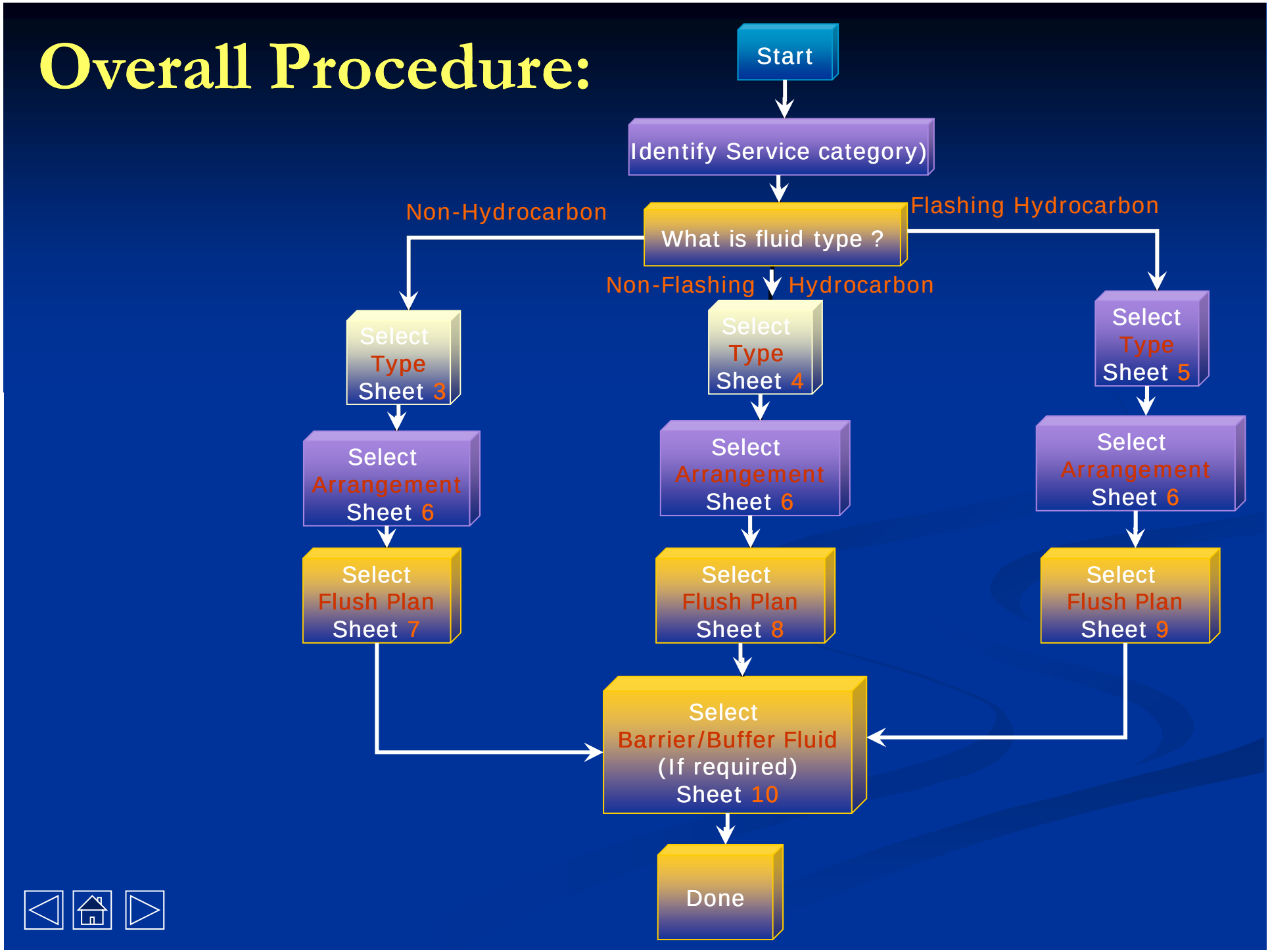
Example 1: C2 A1 A 11 (Single seal)

Example 2: C2 A2 B 1152 (Dual seal)

Mechanical Seal

Selection Procedure

Overall Procedure:



Non-hydrocarbon Services

		Water			Sour Water		Caustic, Amines, Crystallising Liquids		Acids	Other
Pump Temperature	F	< 180	< 180	< 180	< 180	< 180	< 180	< 180	< 180	
	C	< 80	< 80	< 80	< 80	< 80	< 80	< 80	< 80	
Seal Chamber Pressure				Category I Seals						
	psig	< 300		< 300	< 300		< 300		< 300	
	barg	< 22		< 22	< 22		< 22		< 22	
				Category II and III Seals						
	psig	< 300	< 600	< 600	< 300	< 600	< 300	< 600	< 300	
	barg	< 22	< 42	< 42	< 22	< 42	< 22	< 42	< 22	
Default Selection	Category I	A		A	A		A		A	
	Category II	A	A	A	A	A	A	A	A	
	Category III	A	A	A	A	A	A	A	A	
When Specified	Category I	B		(1, 2)	B		B		B	
	Category II	B	(1)	(1, 2)	B	(1)	B	(1)	B	
	Category III	B	(1)	(1, 2)	B	(1)	B	(1)	B	
When Specified	Category I									
	Category II	C	(1)	(1, 2)	C	(1)	C	(1)	C	
	Category III	C	(1)	(1, 2)	C	(1)	C	(1)	C	
Required Special Features				f	c	c	e	e	c, g	
Abrasive Particulates		d	d	d	d	d	d	d	d	

Engineered Seal

Non-Flashing Hydrocarbon Services

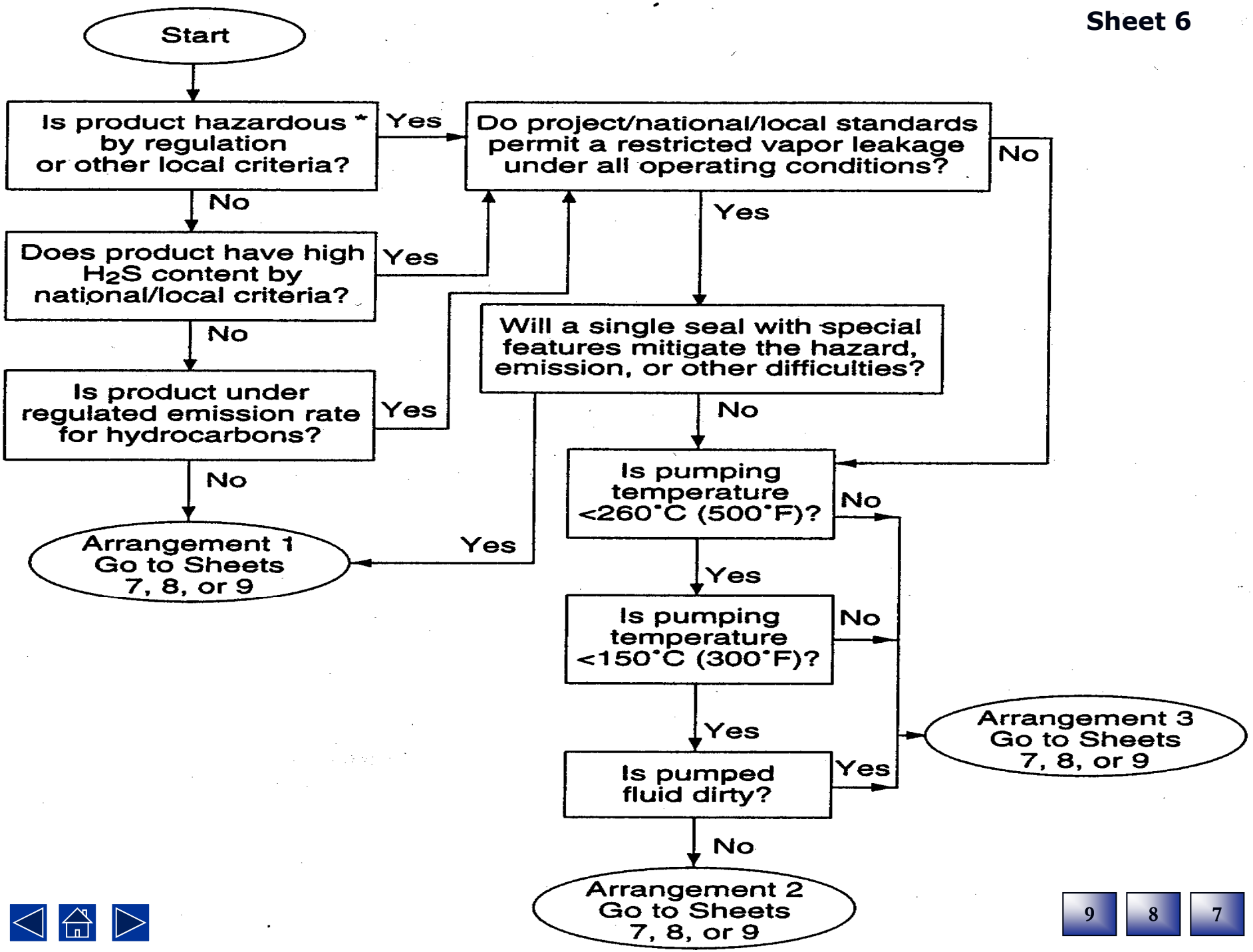
		1	2	3	4	5	6	7	8	Other
Pump Temperature	F	-40 to +20	-40 to +20	20 to 350	20 to 350	350 to 500	350 to 500	500 to 750	500 to 750	
	C	-40 to -5	-40 to -5	-5 to 176	-5 to 176	176 to 260	176 to 260	260 to 400	260 to 400	
Seal Chamber Pressure					Category I Seals					
	psig	< 300		< 300		< 300				
	barg	< 22		< 22		< 22				
					Category II and III Seals					
	psig	< 300	300 to 600	< 300	300 to 600	< 300	300 to 600	< 300	300 to 600	
	barg	22	22 to 42	< 22	22 to 42	< 22	22 to 42	< 22	22 to 42	
Default Selection	Category I	A		A		A(7)				
	Category II	A	A	A	A	C	A(7)	C	C(1)	
	Category III	A	A	A	A	C	A(7)	C	C(1)	
When Specified	Category I	B		B		B(7)				
	Category II	B	B(1)	B	B(1)	A(7)	C(1)	(2)	(2)	
	Category III	B	B(1)	B	B(1)	A(7)	C(1)	(2)	(2)	
When Specified	Category I									
	Category II	C	C(1)	C	C(1)	B(7)	(1, 2, 3)	(3)	(3)	
	Category III	C	C(1)	C	C(1)	B(7)	(1, 2, 3)	(3)	(3)	
Required Special Features		b	b			h	h	h	h	
Abrasive Particulates		d	d	d	d	d	d	d	d	
Caustic				c	c	c	c			
Aromatics and/or H_2S				c	c	c	c			
Amines				e	e	e	e			

Engineered Seal

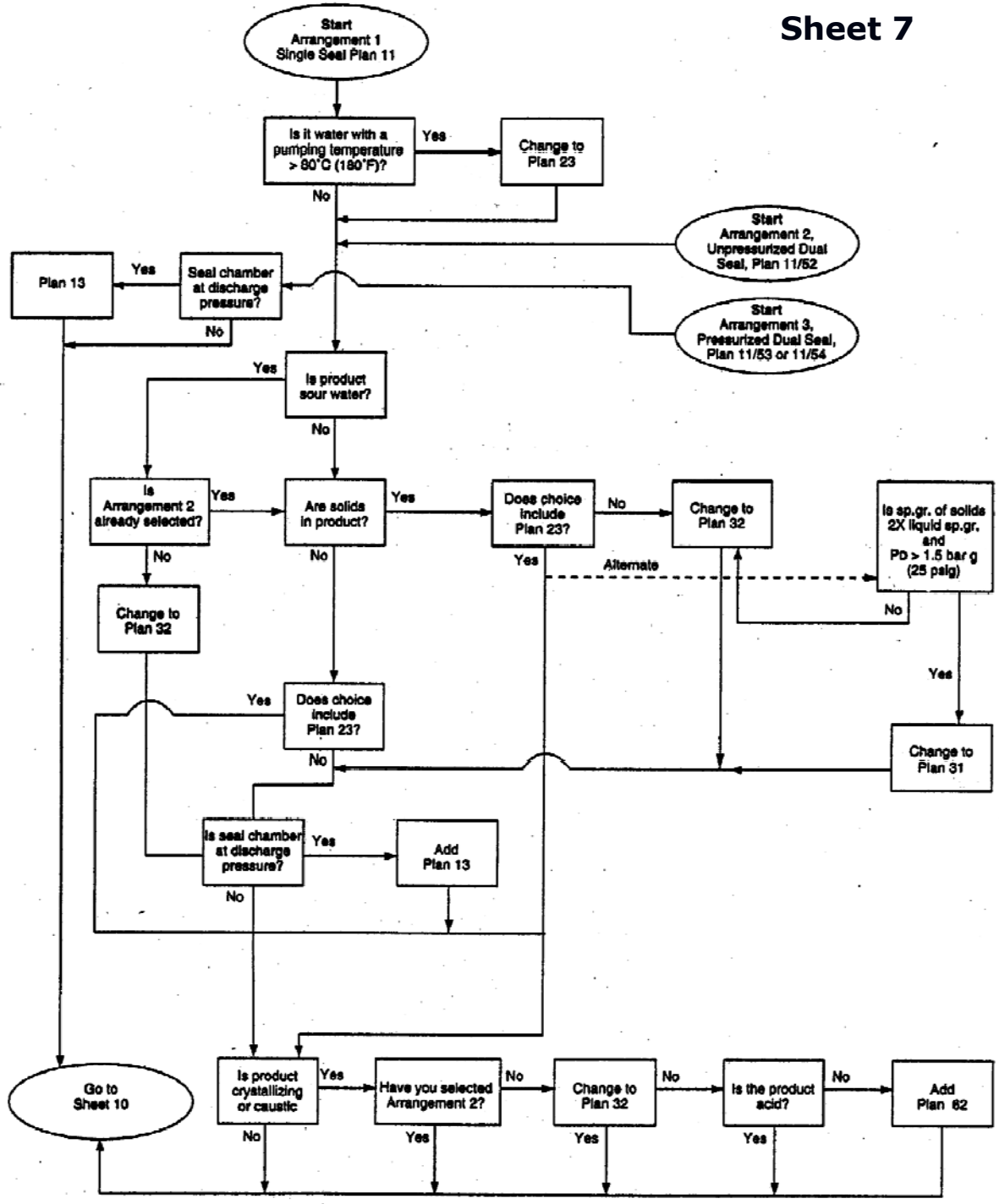
Flashing Hydrocarbon Services

		1	2	3	4	5	6	7	8	Other
Pump Temperature	F	-40 to +20	-40 to +20	20 to 350	20 to 350	350 to 500	350 to 500	500 to 750	500 to 750	
	C	-40 to -5	-40 to -5	-5 to 176	-5 to 176	176 to 260	176 to 260	260 to 400	260 to 400	
Seal Chamber Pressure					Category I Seals					
	psig	< 300		< 300		< 300				
	barg	< 22		< 22		< 22				
					Category II and III Seals					
	psig	< 300	300 to 600	< 300	300 to 600	< 300	300 to 600	< 300	300 to 600	
	barg	22	22 to 42	< 22	22 to 42	< 22	22 to 42	< 22	22 to 42	
Default Selection	Category I	A		A		A(7)				
	Category II	A	A	A(6)	A(6)	C(8)	A(7)	C	C(1)	
	Category III	A	A	A(6)	A(6)	C(8)	A(7)	C	C(1)	
When Specified	Category I	B(9)		B(9)		B(9)				
	Category II	B(9)	B(1,9)	B(9)	B(1,9)	A(7)	C(9)	(2)	(2)	
	Category III	B(9)	B(1,9)	B(9)	B(1,9)	A(7)	C(9)	(2)	(2)	
When Specified	Category I									
	Category II	C(9)	C(1)	C	C(1)	C(1)	(1, 2, 3)	(3)	(3)	
	Category III	C(9)	C(1)	C	C(1)	C(1)	(1, 2, 3)	(3)	(3)	
Required Special Features		b	b			h	h	h	h	
Abrasive Particulates		d	d	d	d	d	d	d	d	
Caustic				c	c	c	c			
Aromatics and/or H_2S				c	c	c	c			
Amines				e	e	e	e			
Ammonia		a	a	a	a	a	a	a	a	

Engineered Seal


Start
Is product hazardous * by regulation or other local criteria?
Yes
Do project/national/local standards permit a restricted vapor leakage under all operating conditions?
No
No
Yes
Does product have high H_2S content by national/local criteria?
Yes
No
Will a single seal with special features mitigate the hazard, emission, or other difficulties?
Is product under regulated emission rate for hydrocarbons?
Yes
No
No
Is pumping temperature <260°C (500°F)?
Arrangement 1 Go to Sheets 7, 8, or 9
Yes
Yes
Yes
Is pumping temperature <150°C (300°F)?
No
Yes
Arrangement 3 Go to Sheets 7, 8, or 9
Is pumped fluid dirty?
Yes
No
Arrangement 2 Go to Sheets 7, 8, or 9

Non-Hydrocarbon Arrangement And Flushing

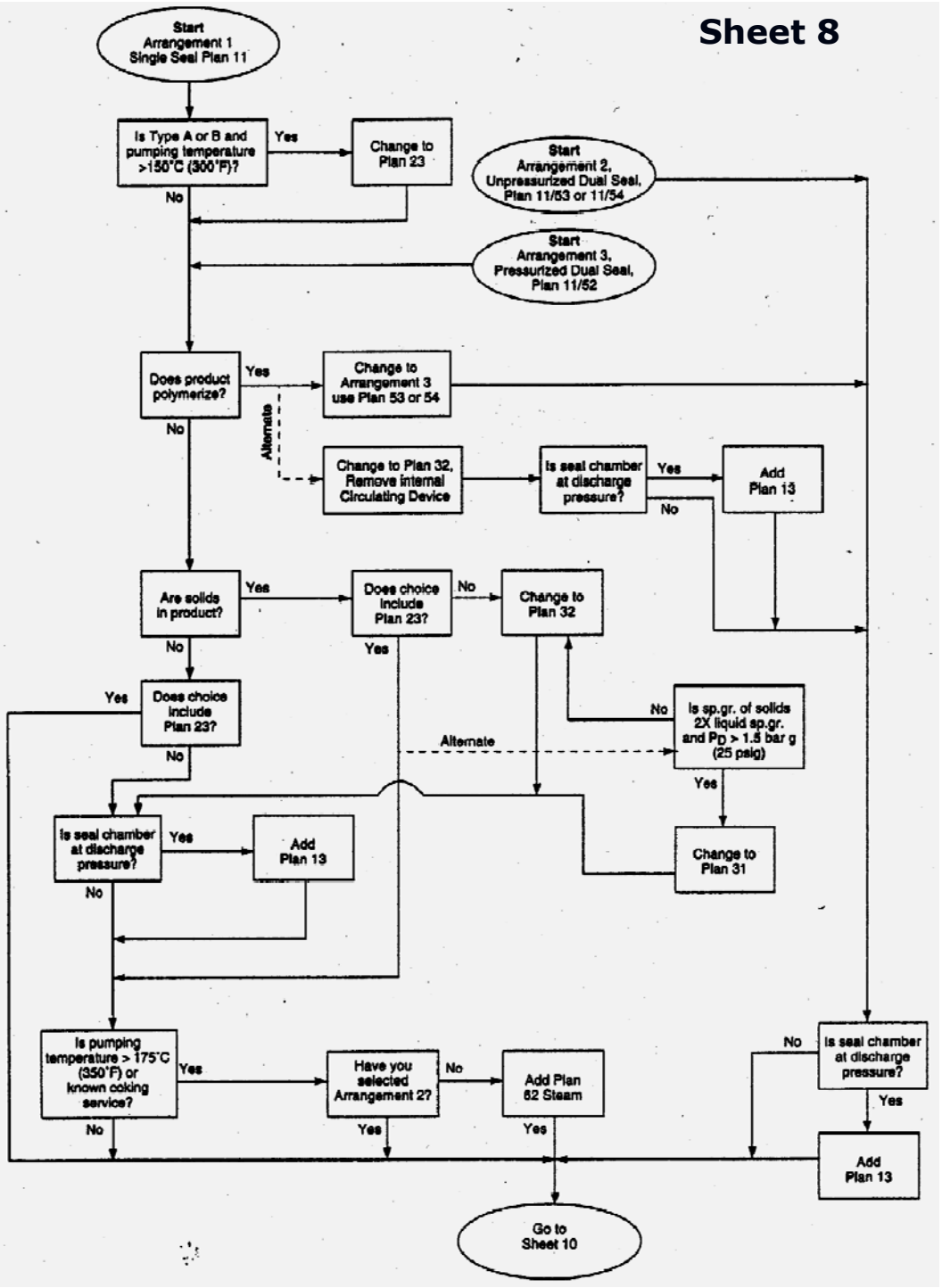


Non-Flashing Hydrocarbon

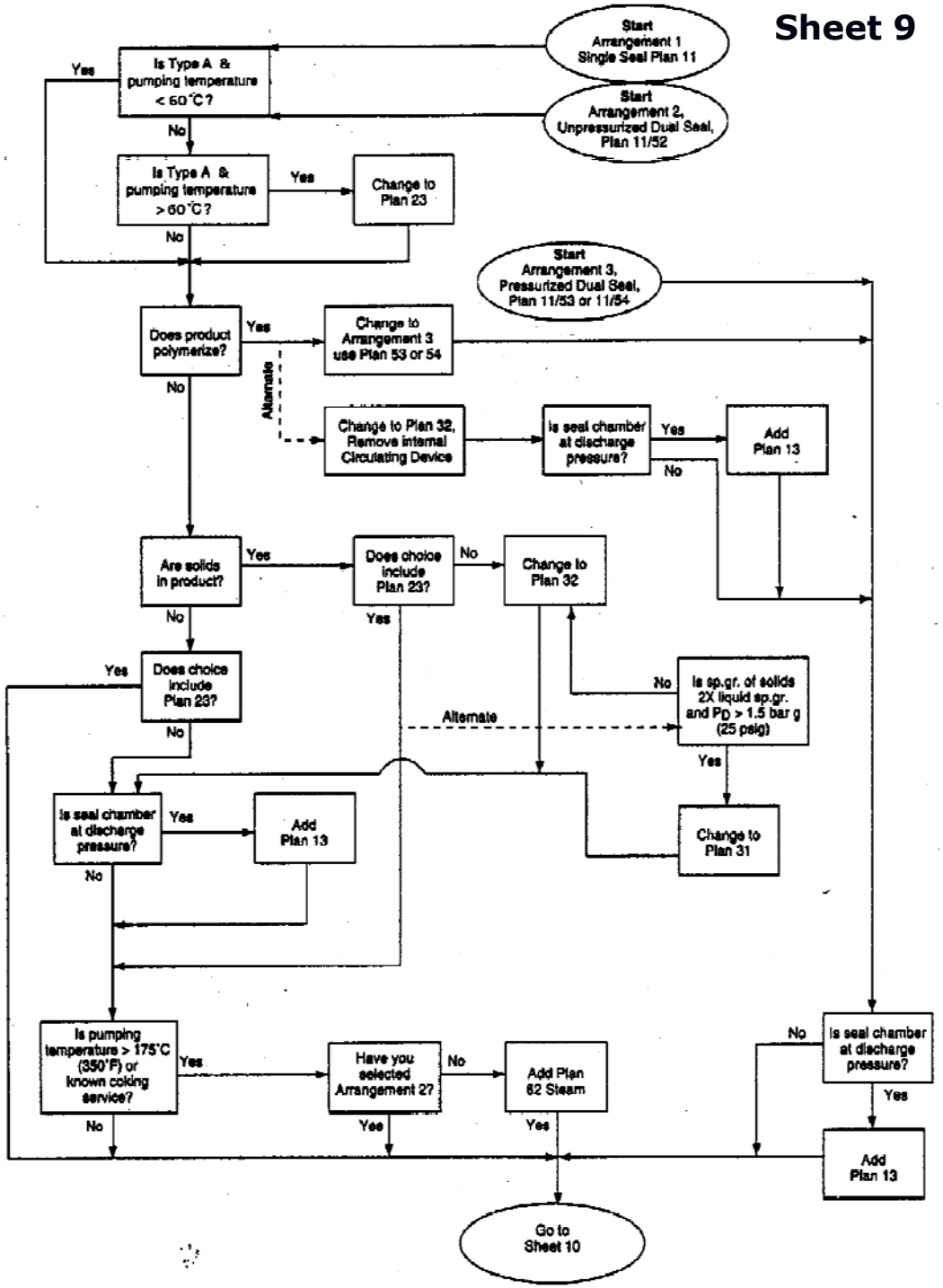
Arrangement

And

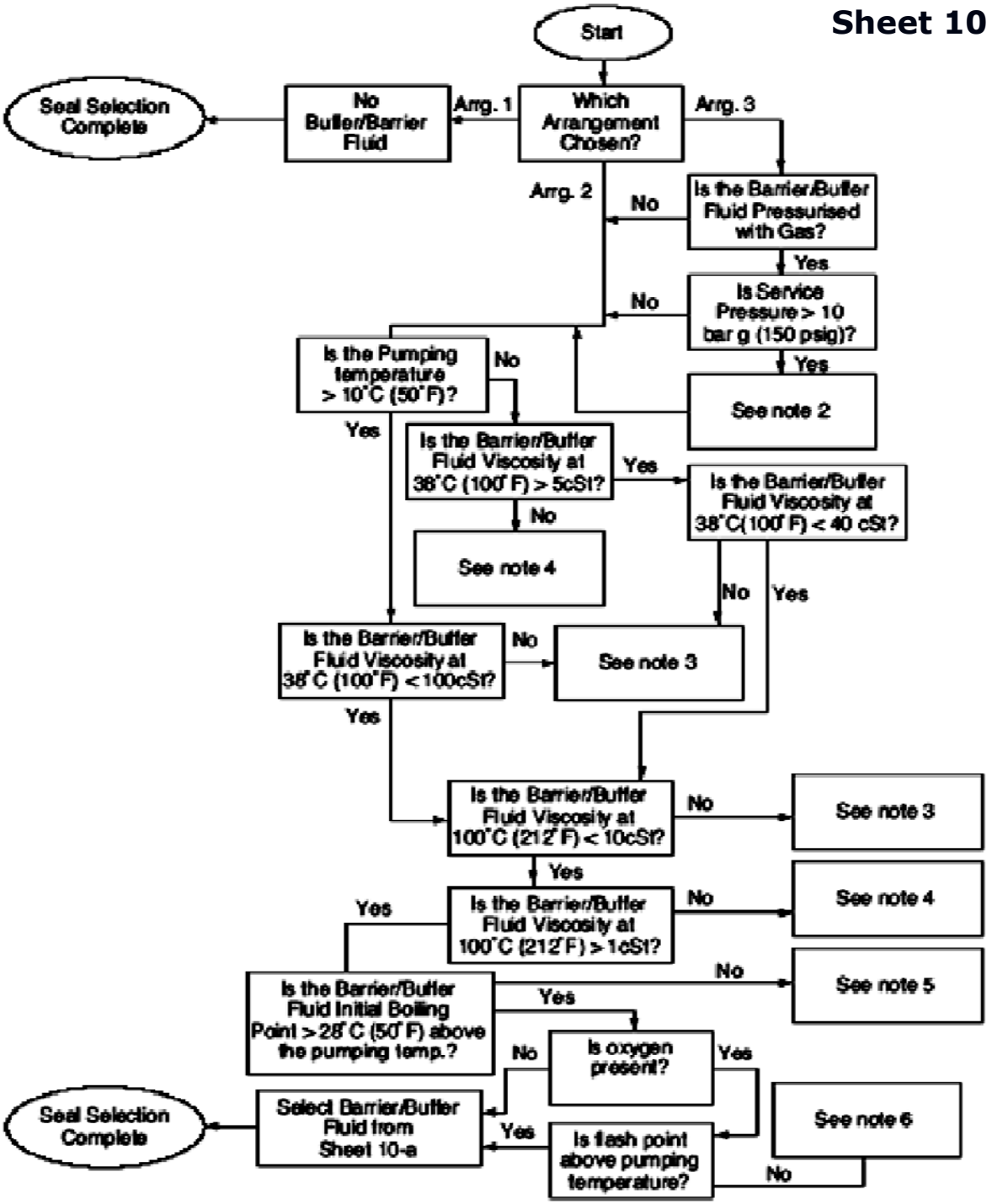
Flushing



Flashing Hydrocarbon Arrangement And Flushing



Buffer/Barrier Fluid Selection:



Notes:

1) High pressure bellows design (double ply bellows).

2) Engineered sealing system using metal bellows seals.

3) Engineered sealing system using pusher seals, possibly multiple seal arrangement.

4) Up to 20% H2SO4 at 25 C (77 F) only. Up to 20% H3PO4 at 80 C (176 F) only. All other acids, including hydrofluoric acid, fuming nitric, and hydrochloric acids require special engineering.

5) Limited to mixtures with pH between 4 and 11.

6) Requires pumping ring above 60 C(140F) and perfluoroelastomer if pumping temperature is above 176 C(350F).

7) May require perfluoroelastomer and external cooling, .

8) May require external cooling to reduce vapor pressure and increase viscosity.

9) Recommendations for using single metal bellows seals in flashing services include:
- Carbon vs. silicon carbide or tungsten carbide faces
- viscosity above 0.4 Cp
- ratio of seal chamber pressure to vapor pressure must be more than 1.5
- consider Arrangement 2 with liquid buffer system if viscosity and vapor pressure criteria cannot be met.
- consider Arrangement 2 with dry containment seal if low emissions are required
- always .

Required special features:

a. Ammonia resistant carbon graphite when carbon graphite is used.
b. Nitrile (Buna-N) when O-rings are used.
c. Chemical resistant perfluoroelastomer when O-rings are used.
d. Hardface vs hardface (default silicon carbide vs. silicon carbide; optional tungsten carbide vs silicon carbide).
e. Amine resistant perfluoroelastomer when O-rings are used.
f. Circulating device (either radial flow or axial flow pumping ring is acceptable).
g. Single spring instead of multiple springs.
h. High temperature perfluoroelastomer when O-rings are used.

Introductory Narrative (Buffer/Barrier Fluid):

Barrier Fluid: pressurized multiple seal support system

Buffer Fluid: Non-pressurized multiple seal support system

Barrier Fluid Requirements:

1. Good lubricant
2. Good heat transfer
3. Highly compatible with the process pumpage
4. Compatible with the metallurgy, elastomers and other materials in the system

Buffer Fluid Requirements:

1. Atmospheric boiling point must be considered
2. Above 10 bar g (150 psig) with a gas blanket pressurization is not recommend by API 682.

Example

Fluid : Propane

Temp. : 38˚C(100˚F)

Press. : 20 barg (290Psig)

Vapor Press. : 300 barg

Applied Standard : API 682

Solution:

Category :

API Application → Category II

Type:

Sheet 2 → Sheet 5

Sheet 5 → Type A (Pusher Type)

Arrangement:

Sheet 2 → Sheet 6

Sheet 6 → Arrangement 1(Single Seal)

Flush Plan :

Sheet 6 → Sheet 9

Sheet 9 → Plan 11

Barrier/Buffer Fluid :

Sheet 2 → Single Seal → Not required

Selection Done :

C2 A1 A 11

References:

1. "API 682"

American Petroleum Institute

1st edition, Sep. 1994

2. "API 682"

American Petroleum Institute

2nd edition, July 2002

3. "Mechanical Seals"

JohnCrane Inc.

Dec. 2000

4. "API 610"

American Petroleum Institute

10th edition, July. 2003

5. "Centrifugal Pump Handbook"

T.M.P. S.P.A. Termomeccanica Pompe-La Spezia-Italy

1st Edition,2003

6. "Mechanical Seals"

Mostafa Rezaei Zadeh

2001

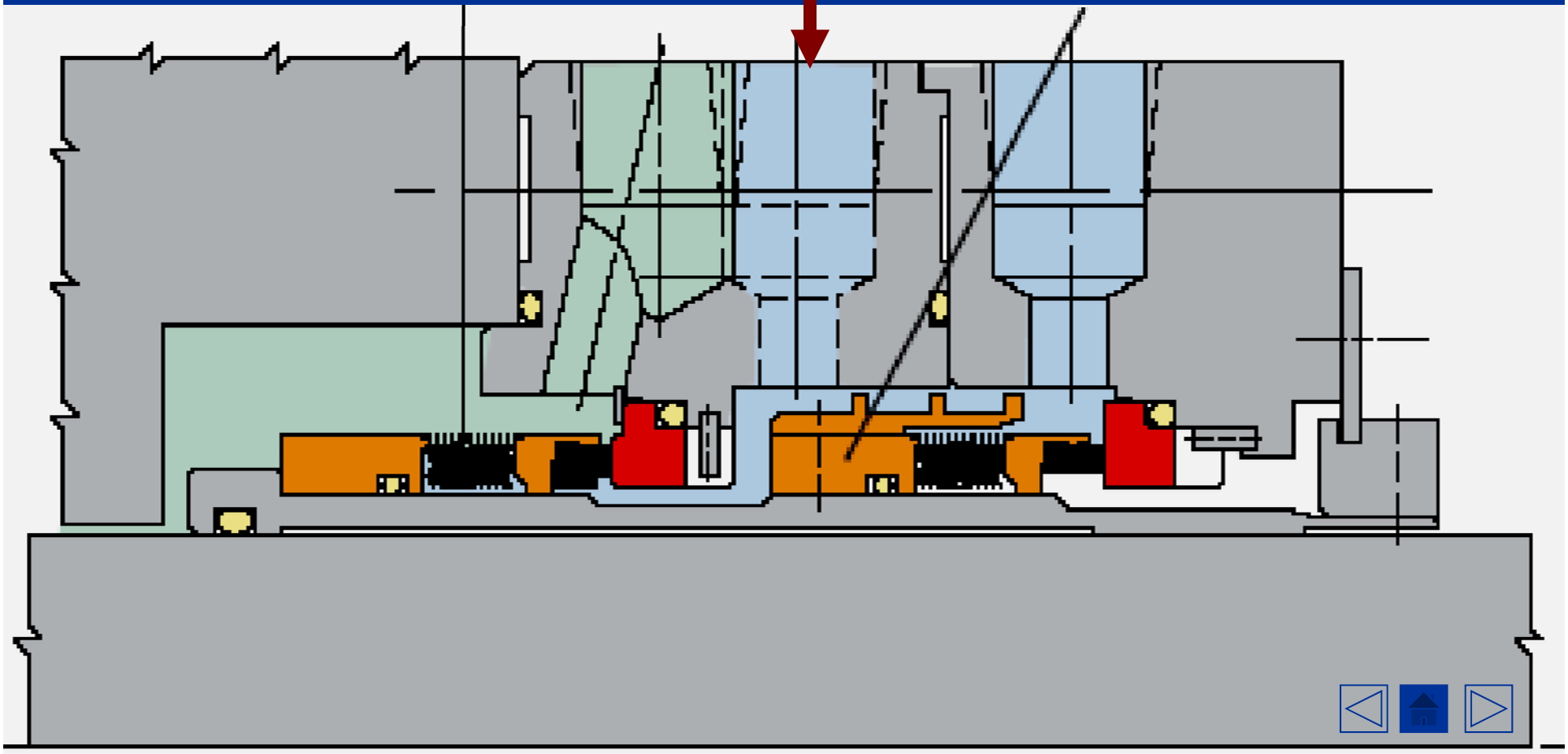
7. "Mechanical Seals"

Flowserve Inc.

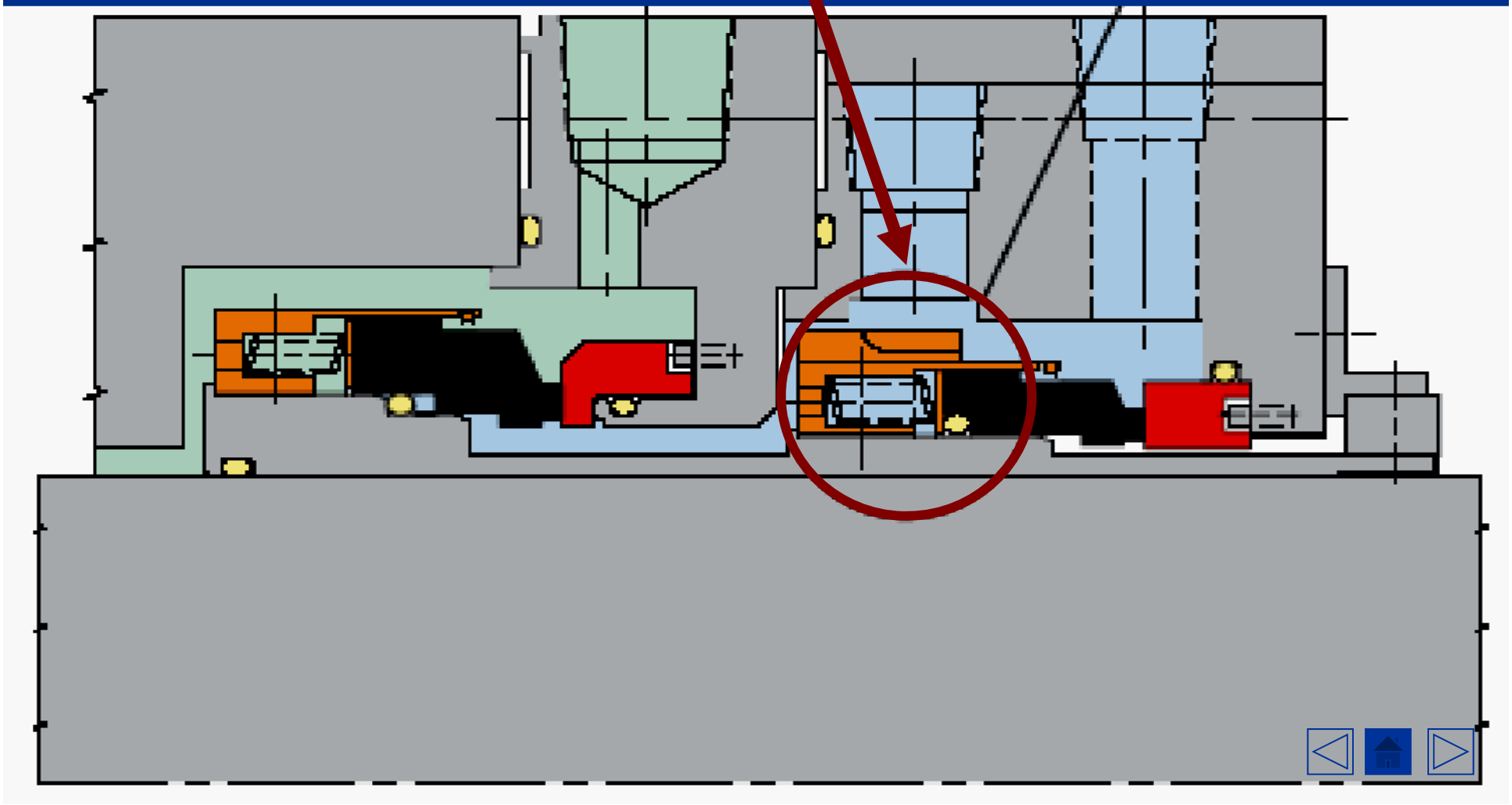
2000

Bellows

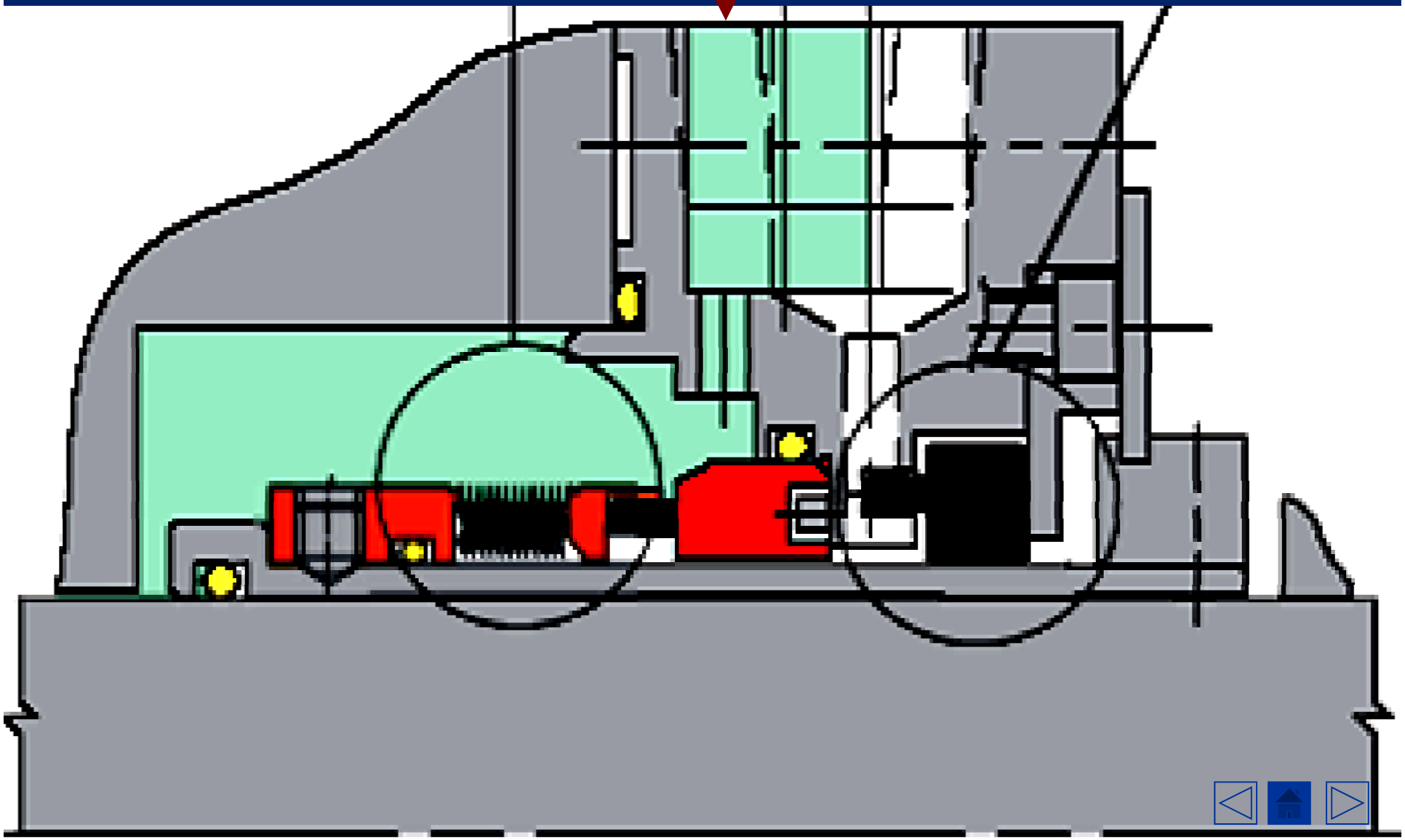
Barrier/Buffer Fluid Connection

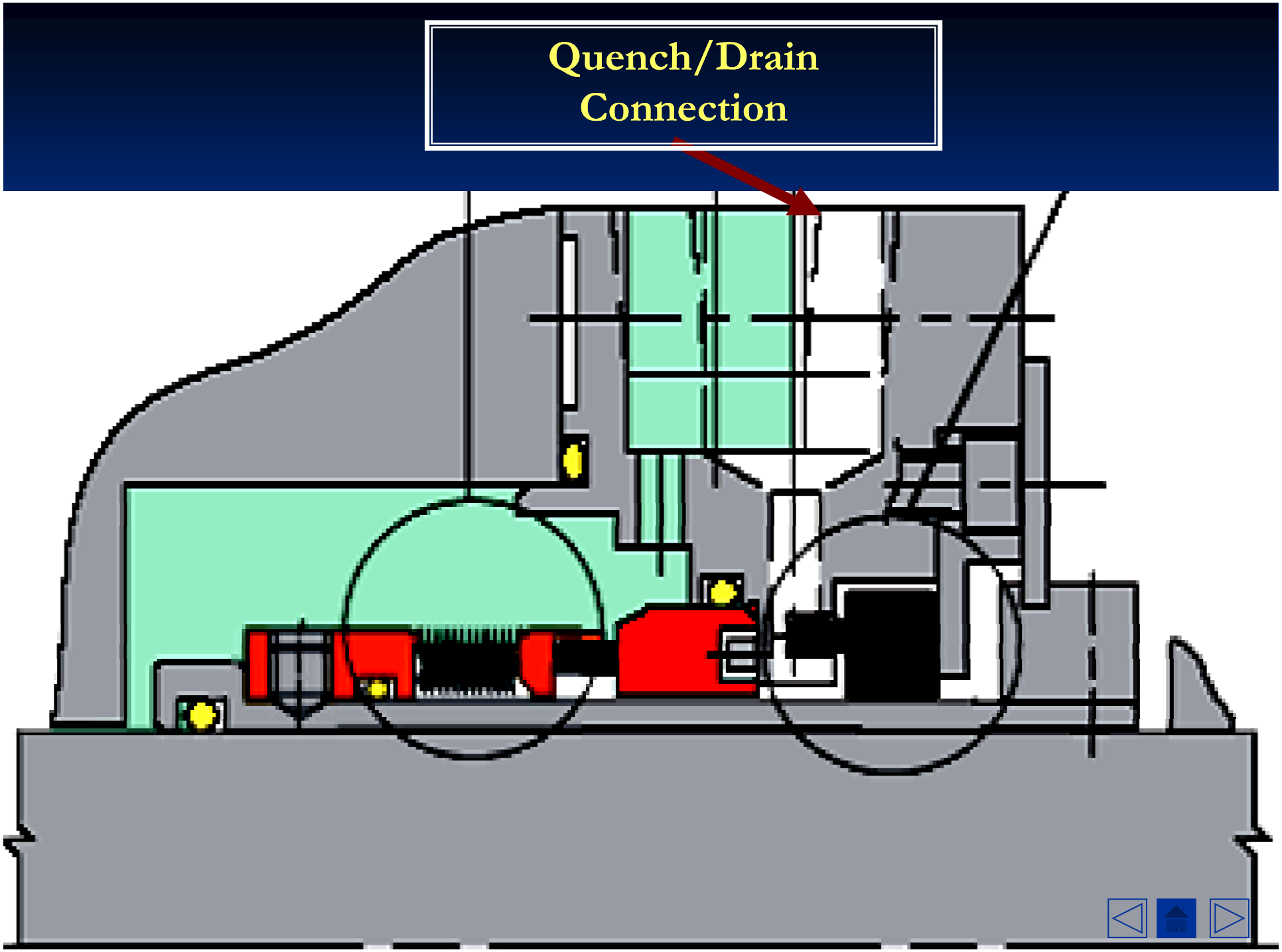


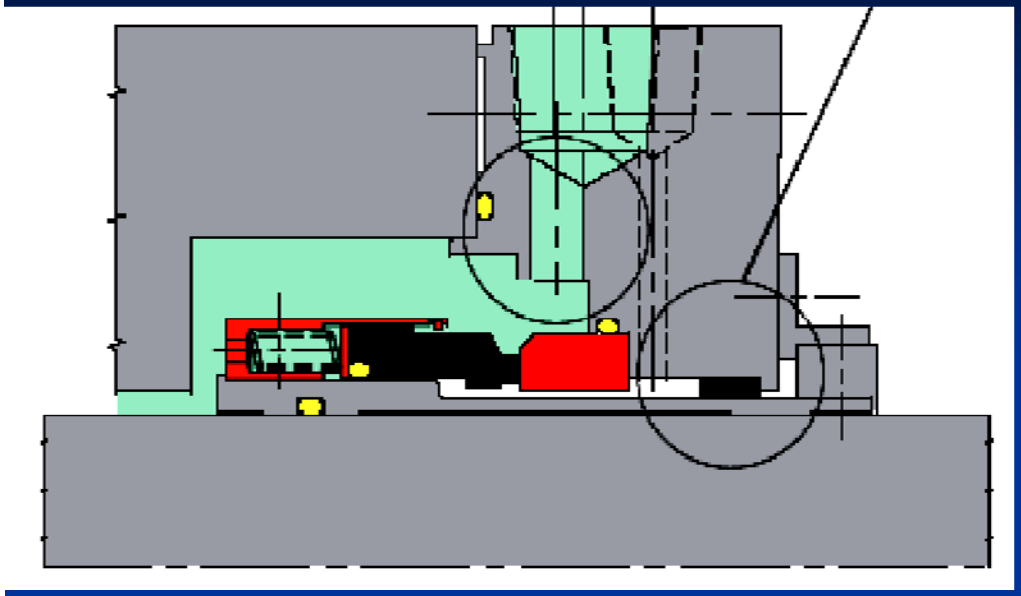
Pumping Ring



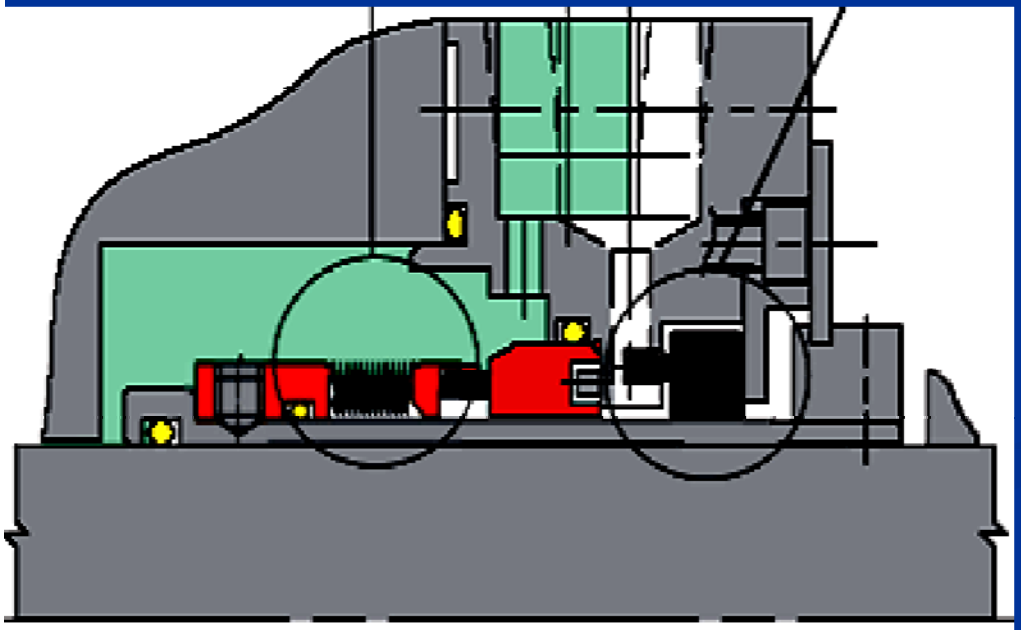
Flush Connection




Quench/Drain
Connection



Pusher Seal



Non_Pusher Seal