



TRAINING PROJECT SPECIFIC COURSE

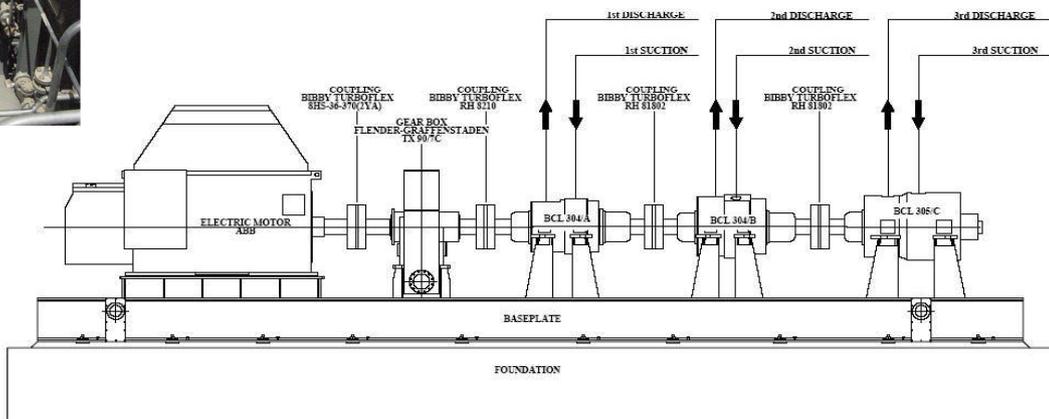
Injection gas compressor unit System Description



Prepared by :Benny

The process gas is compressed from 70.9 Bar a (7090 kPa a) to 522.5 Bar a (52250 kPa a) by three compression stages utilizing three centrifugal compressors of type

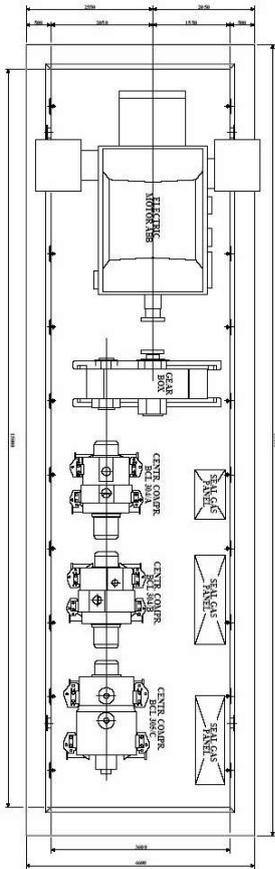
- BCL 304/A,
- BCL 304/B and
- BCL 305/C arranged in series.



16100 X4600 mm

General lay out

GE GEPS Oil & Gas



The compressors are driven by means of an electric motor (supplied by ABB) coupled to the compressors **BCL 304/A** by means of a gear box and couplings.



 **GEPS Oil & Gas**

 **GEPS Oil & Gas**

The compressor **BCL 304/B** is coupled in series to the compressor BCL 304/A by means of a coupling.



The compressor **BCL 305/C** is coupled in series to the compressor BCL 304/B by means of a coupling.



The electric motor and gear box, the centrifugal compressor BCL 304/A, BCL 304/B and BCL 305/C are assembled on a common base plate.

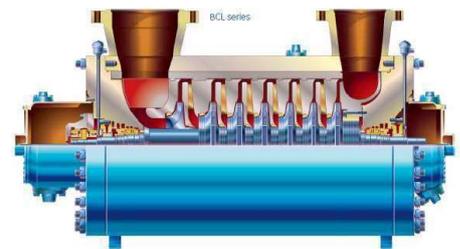
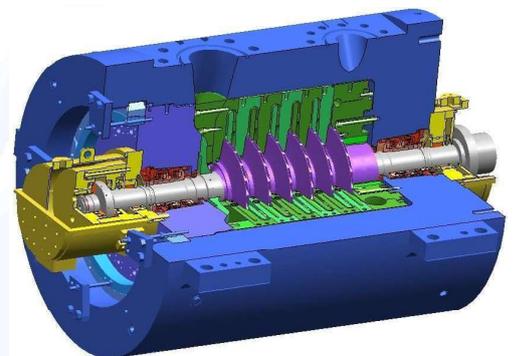
Component Weight

MAIN WEIGHTS	
Equipment	Weight/ kg
Electric Motor	33600
Gear box	13000
CO/CE BCL 304/A	7700
CO/CE BCL 304/B	9350
CO/CE BCL 305/C	13750
Total weight skid	115000



OPERATING CONDITIONS

COMPRESSOR STAGE		1 ST	2 ND	3 RD
GAS HANDLED	(Main components)	Methane (75.14%); Ethane (10.63%) Propane (6.54%); Carbon Dioxide (3.72%)		
WEIGHT FLOW	Kg/h	111525	120859	120859
SUCTION CONDITIONS				
Molecular weight		22.35	22.35	22.35
Cp/Cv K = Cp/Cv		-	-	-
Compressibility		0.791	0.745	0.860
Pressure	Bar a	70.9	157.8	292.2
Temperature	°C	36.6	60	60
DISCHARGE CONDITIONS				
Pressure	Bar a	159.2	293.9	522.5
Temperature	°C	109.6	113.4	116.3



COMPRESSOR BCL TYPE & IDENTIFICATION



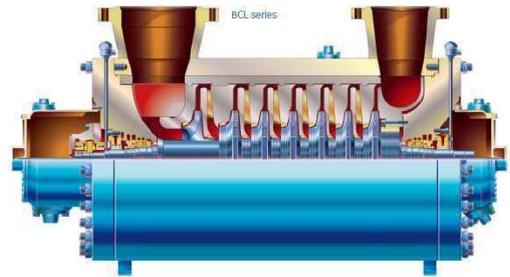
BCL :The capital letters describe the casing features; BCL indicates a compressor with the vertically split casing (barrel shaped casing type).

C: Close Type Impeller

L: Free vortex diffuser type without blade

BCL 406

The numbers, after the letters, describe the compressor nominal “size” and the impellers number. the designation BCL 406 indicates a compressor of nominal “size” 400, with one compression stage, by vertically split casing and containing a rotor with six impellers.



COMPRESSOR BCL TYPE & IDENTIFICATION

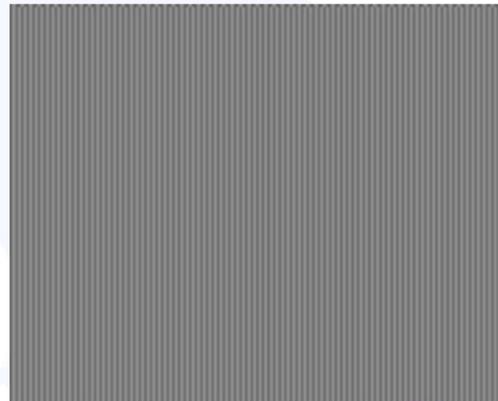
Small letters description

In the case when a small letter (a, b, c, d) is placed after the numbers, this shows the casing design pressure which is higher than the standard design for this compressor type.



COMPRESSOR BCL .../c, BCL .../d

The small letter "c" or "d", placed after the numbers, shows that the compressor is expressly designed to deliver gas at very high pressure and the casing is opened vertically only at one end (thrust bearing side).



Example

The designation BCL 305/c indicates a compressor designed for a very high pressure of nominal "size" 300, with one compression stage, by a casing with one vertically split containing a rotor with five impellers.

COMPRESSOR BCL TYPE & IDENTIFICATION

The gas connections (suction and discharge) of these compressors are turned upward.

BCL 304/A

The BCL 304/A centrifugal compressor with a compression stage and nominal "size" of 300 mm has a shaft with four impellers.

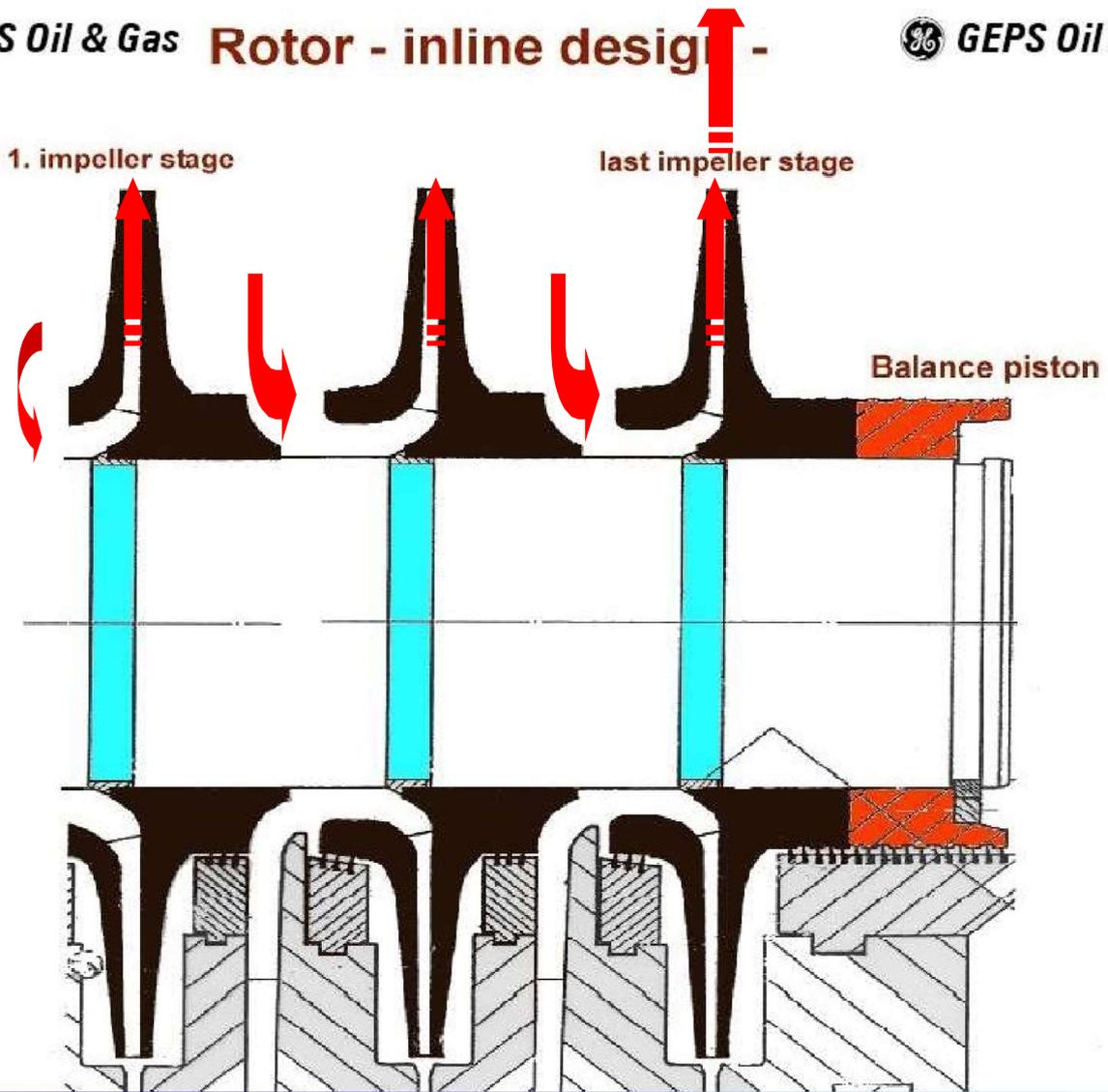
BCL 304/B

The BCL 304/B centrifugal compressor with a compression stage and nominal "size" of 300 mm has a shaft with four impellers.

BCL 305/C

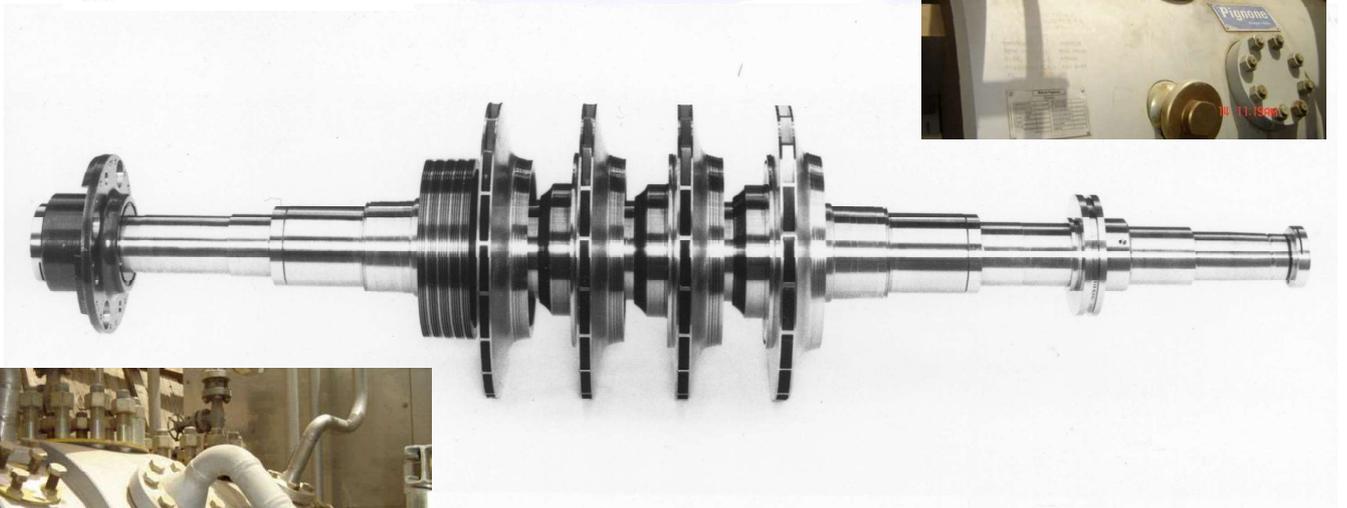
The BCL 305/C centrifugal compressor with a compression stage and nominal "size" of 300 mm has a shaft with five impellers.





Rotor Inline Design

 **GEPS Oil & Gas**



 **GEPS Oil & Gas**



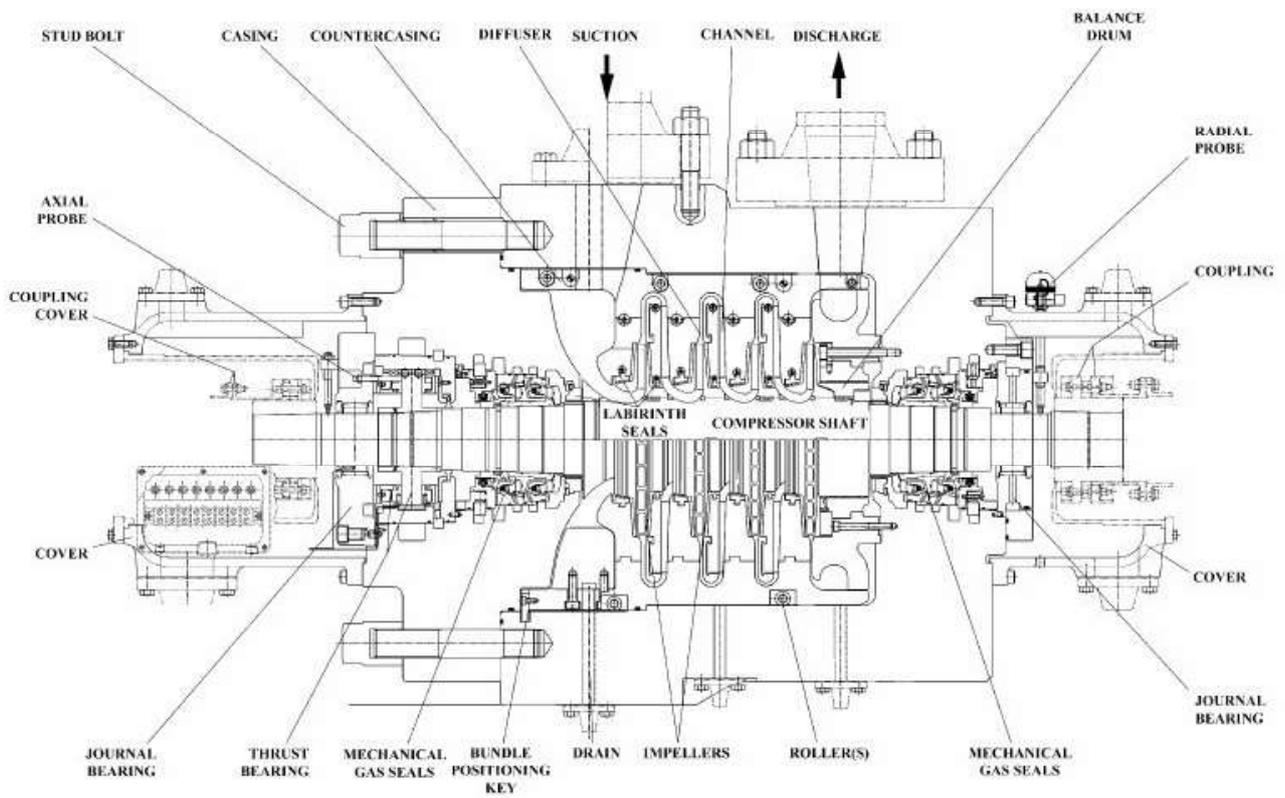
Prepared by : Benny

25-10-2011



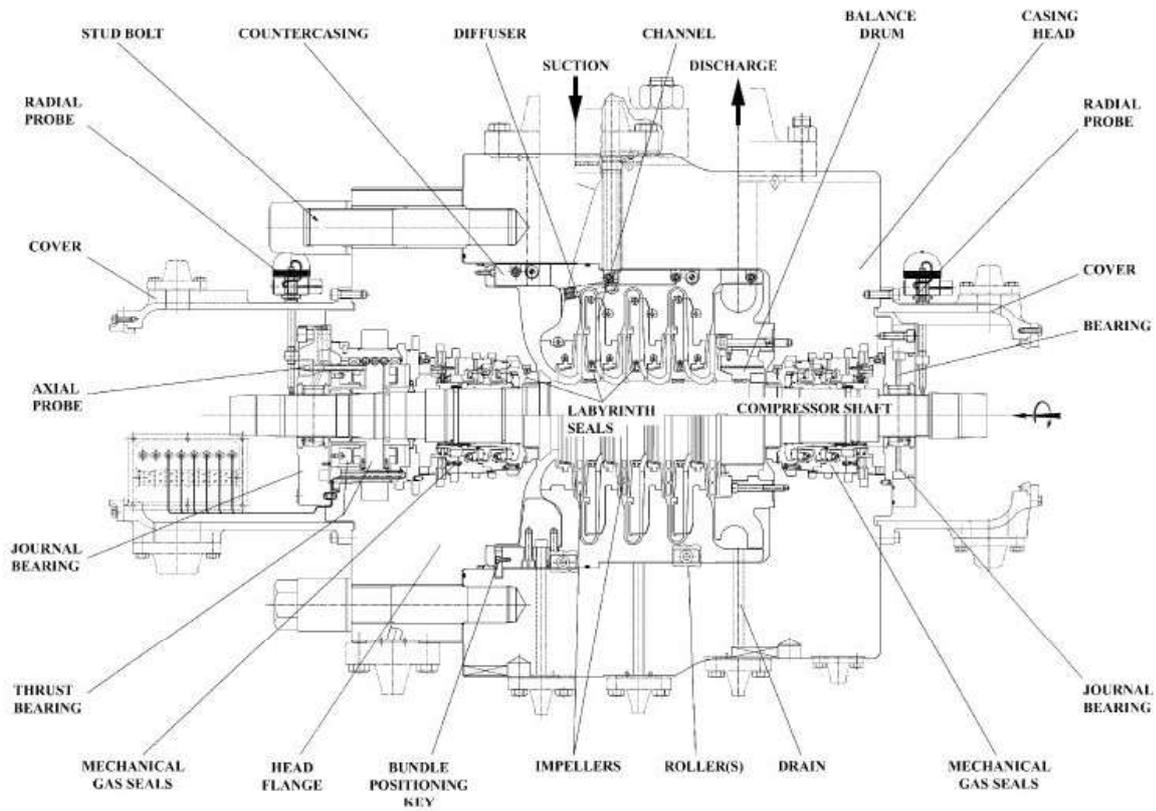
Compressor Assembly

BCL 304/A compressor



Compressor Assembly

BCL 304/B compressor



Prepared by : Benny

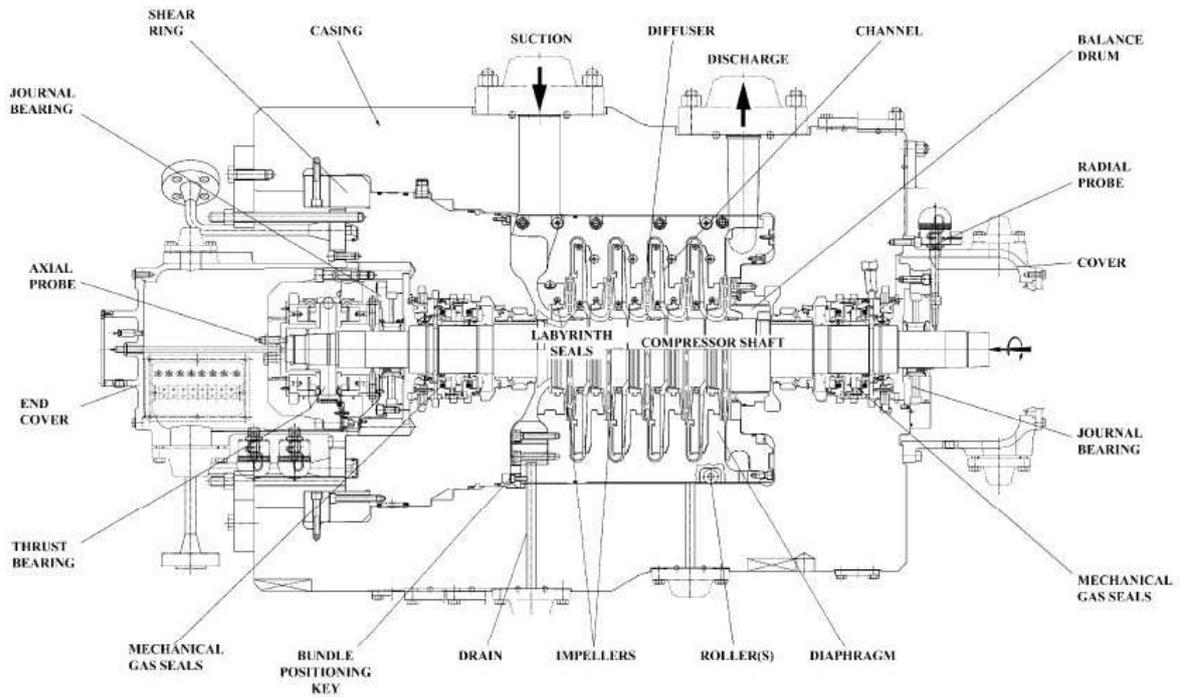
25-10-2011





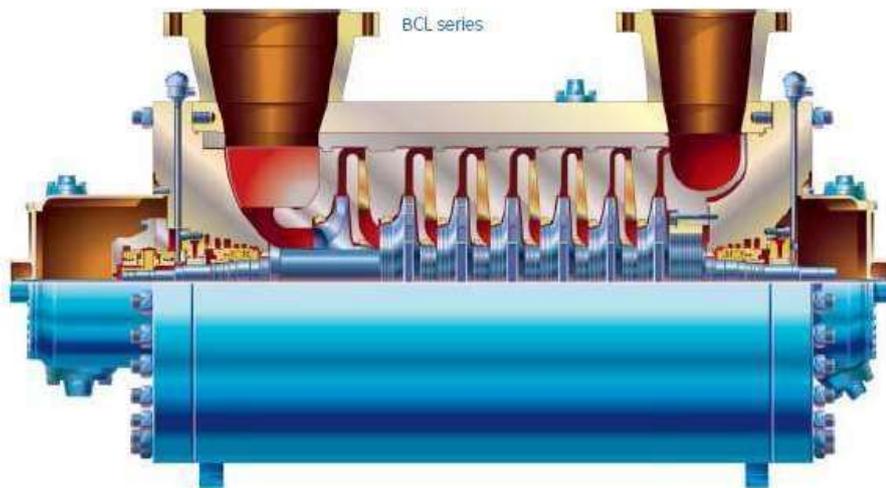
Compressor Assembly

BCL 305/C compressor



CASING BCL 304/A – BCL 304/B

The casing of the BCL compressors is barrel shaped and closed at the ends by two vertical flanges (casing heads).



The casing heads and casing matching surfaces are accurately machined for the best assembly.
Casing heads and casing are held firmly together by casing stud bolts.
The suction and discharge nozzles are welded to the casing.

Compressors Casing

CASING BCL 304/A – BCL 304/B

Four feet projecting from the horizontal center line and laid on special pillars support the casing. The feet at the coupling end (or main coupling end) are provided with **feather keys** to position the machine in longitudinal direction.

 **GEPS Oil & Gas**



 **GEPS Oil & Gas**

Two feather keys welded to the casing along the compressor longitudinal centerline fit, in special corresponding guides welded to the base plate, and position the machine in the transverse direction. This arrangement permits thermal expansion without changing the machine alignment.

The two casing heads installed on the casing ends each carry the housing for rotor bearings and the housings for the end seals which prevent the gas leaking from the casing.

The casing heads are funnel shaped to provide a greater pressure strength and to reduce the span between the journal bearings.

Compressors Casing

BCL 305/C

The casing of these BCL compressors is barrel shaped, open only at suction end (thrust bearing side), this end is closed by one vertical casing head (flange).



 **GEPS Oil & Gas**

 **GEPS Oil & Gas**

The casing head and casing matching surfaces are thoroughly machined for the best assembly.

The casing head is assembled inside to the casing and it is assured by means of special sectors (shear rings) radially applied.

The gas connections (suction and discharge) are not flanged, but are machined so as to directly lock onto the pipe flanges.

Four feet projecting from the horizontal center line and laid on special pillars support the casing.

Compressors Casing

BCL 305/C

The feet at the coupling end (or main coupling end) are provided with feather keys to position the machine in longitudinal axis direction.



The positioning in the lateral direction is carried out with two keys which are placed on the baseplate in accordance with the longitudinal axis of the compressor. They are inserted in corresponding slides of the casing.

This arrangement permits thermal expansions without changing the machine alignment.

The casing at discharge end and the casing head installed on the suction carry the housing for rotor bearings and the housing for the end seals which prevent the gas leaking from the casing.

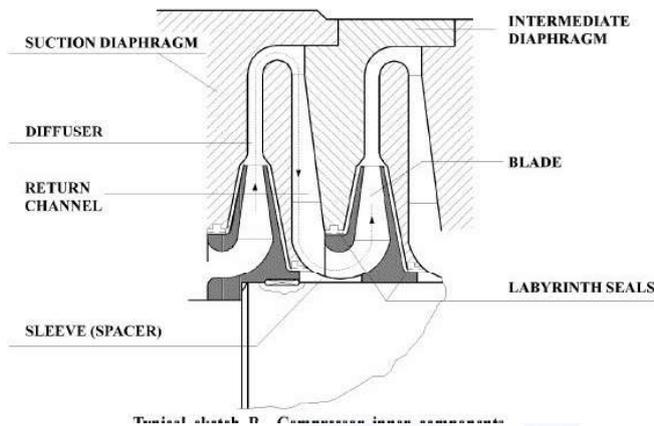
The bearings and the end seals may be inspected without opening the compressor casing.

DIAPHRAGMS BCL 304/A – BCL 304/B

The diaphragms assembly, built up around the rotor assembly, make-up the stationary parts of the compression stages.

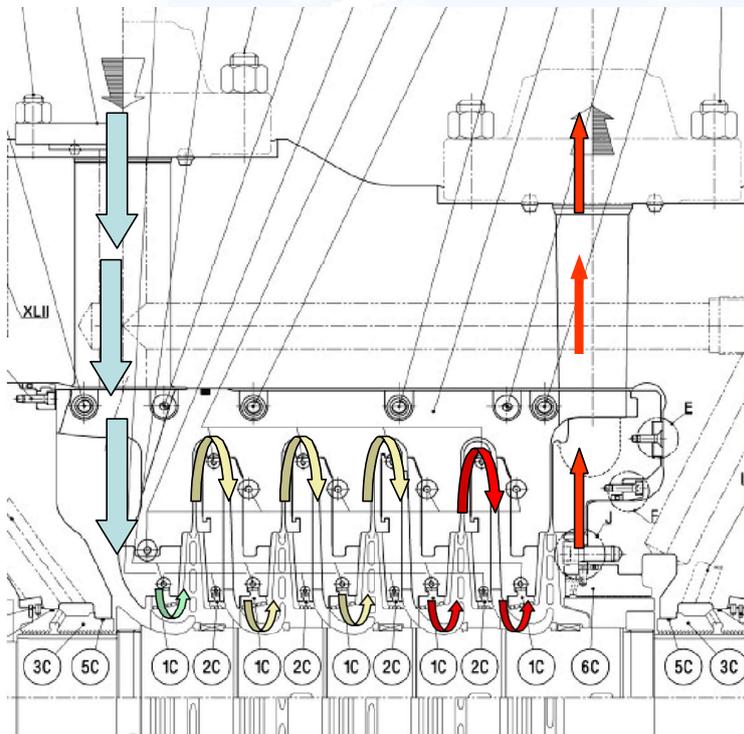


Annular passages through the diaphragms constitute the diffusers, where the kinetic energy of the gas at impeller outlet is turned into pressure. These passages constitute also the return channels that convey the gas efficiently into the eye of the impellers.

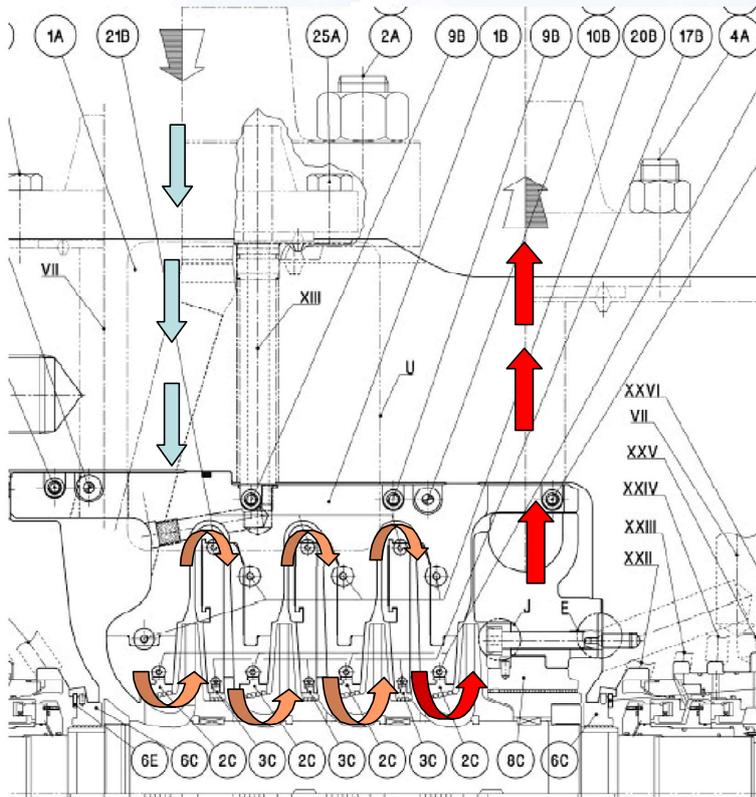


All diaphragms are in halves being split at the horizontal center line; the diaphragm halves are assembled into a counter casing split on the horizontal center line as well; making up two separate half bundles.

The upper halves of diaphragms are kept in their position in the counter casing by setscrews along the center line, thus allowing to lift the upper half-casing without any danger for diaphragms falling out



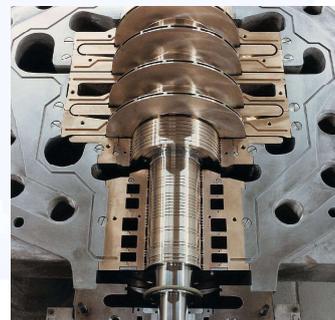
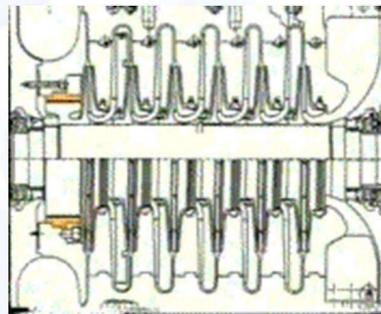
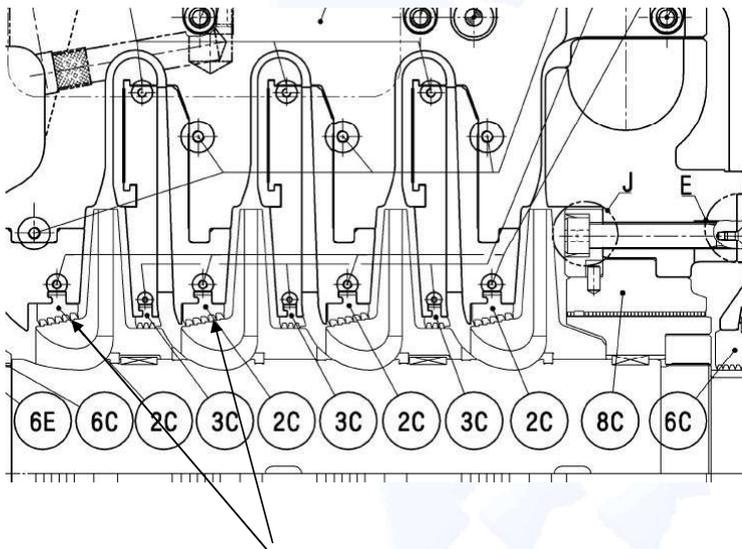
The upper halves of diaphragms are kept in their position in the counter casing by setscrews along the center line, thus allowing to lift the upper half-casing without any danger for diaphragms falling out



Labyrinth seals

BCL 304/A – BCL 304/B

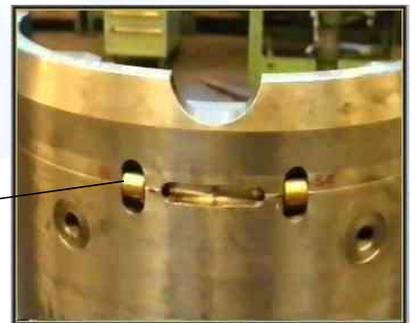
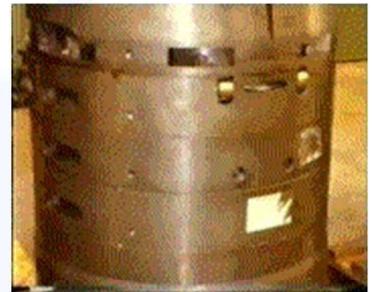
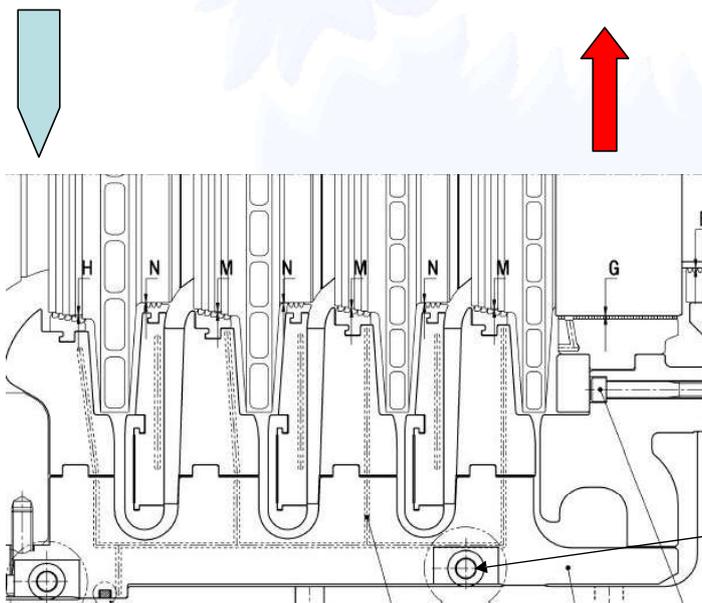
Labyrinth seals are installed in the diaphragms at all internal close-clearance points to minimize the gas leakages from discharge to suction pressure areas of the impellers.



Ring seals, installed in grooves machined at the periphery of the counter casing, prevent high pressure gas leaking to a lower pressure areas.

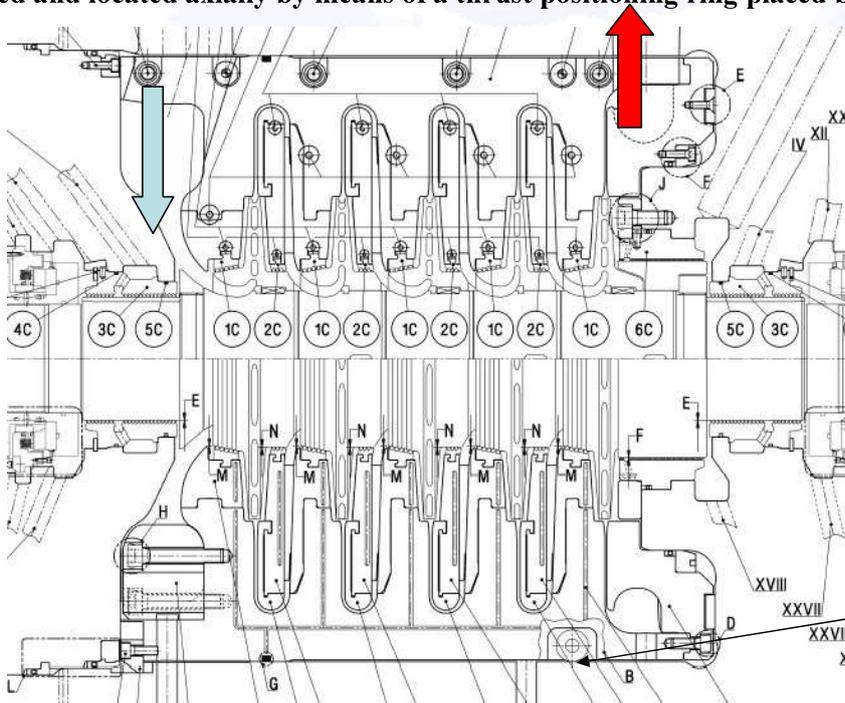
Compressor bundle rollers
BCL 304/A – BCL 304/B

A set of rollers is placed on the discharge side of the lower counter casing to facilitate the insertion of the complete diaphragm/rotor bundle into the casing; where it is retained and located axially by means of a casing head and a positioning key placed between bundle and casing.

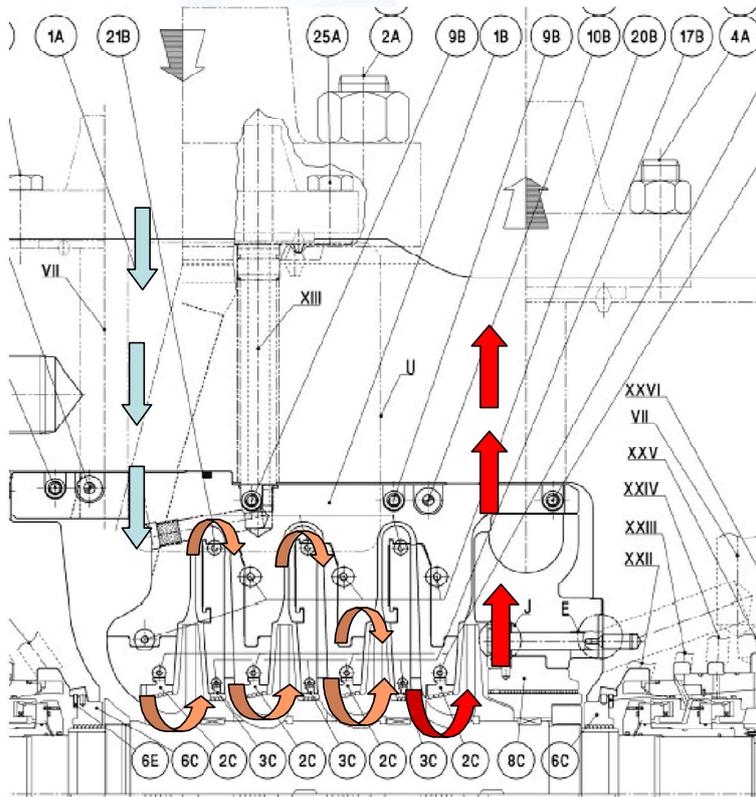


Compressor bundle rollers BCL 305/C

Two set of rollers are placed on the lower counter casing (one set on the suction side and the second on the discharge side) to facilitate the insertion of the complete diaphragm/rotor bundle into the casing; where it is retained and located axially by means of a thrust positioning ring placed between bundle and casing.



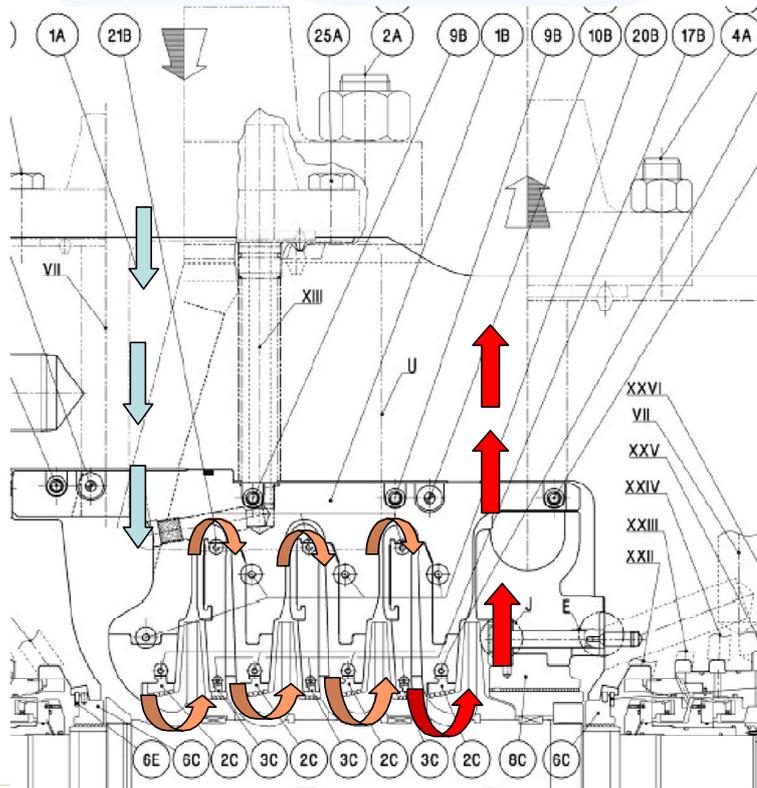
The diaphragms assembly, built up around the rotor assembly, make-up the stationary parts of the compression stages.



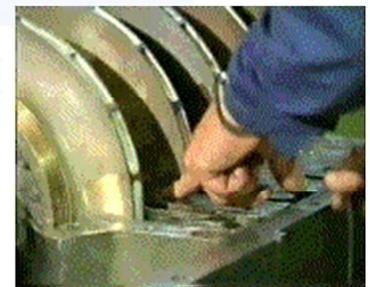
DIAPHRAGMS BCL 305/C

Annular passages through the diaphragms constitute the diffusers, where the kinetic energy of the gas at impeller outlet is turned into pressure.

These passages constitute also the return channels that convey the gas efficiently into the eye of the impellers. The upper halves of diaphragms are kept in their position in the counter casing by setscrews along the center line, thus allowing to lift the upper half-casing without any danger for diaphragms falling out.

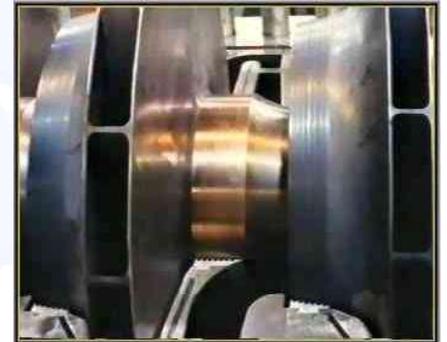
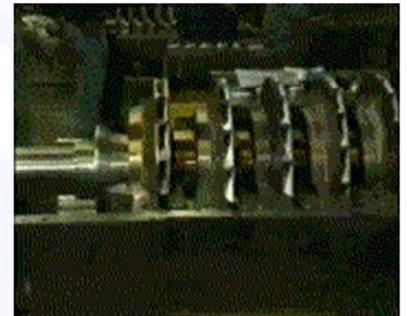
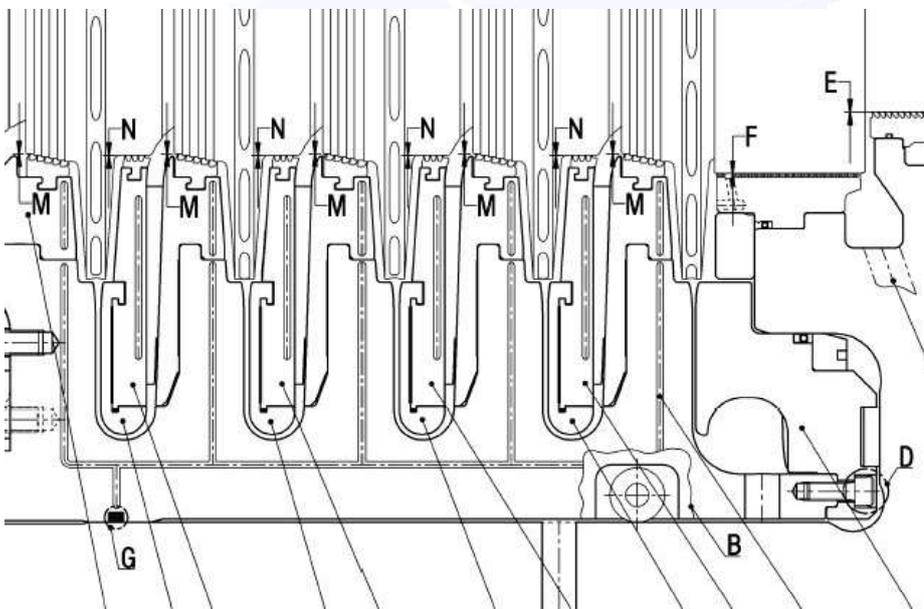


AVSEQ01.DAT:Clip2_of_2.0000390021-0000440000



LABY RINTHSEALS BCL 305/C

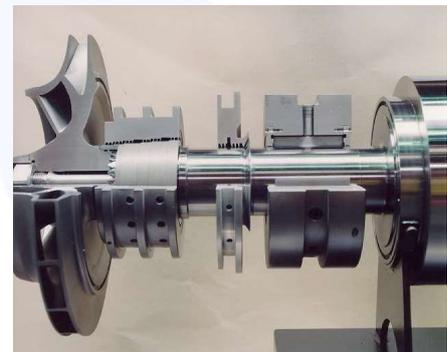
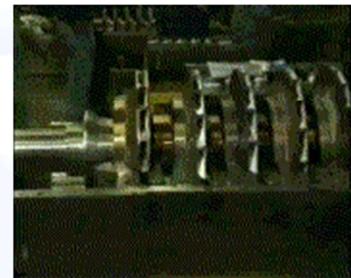
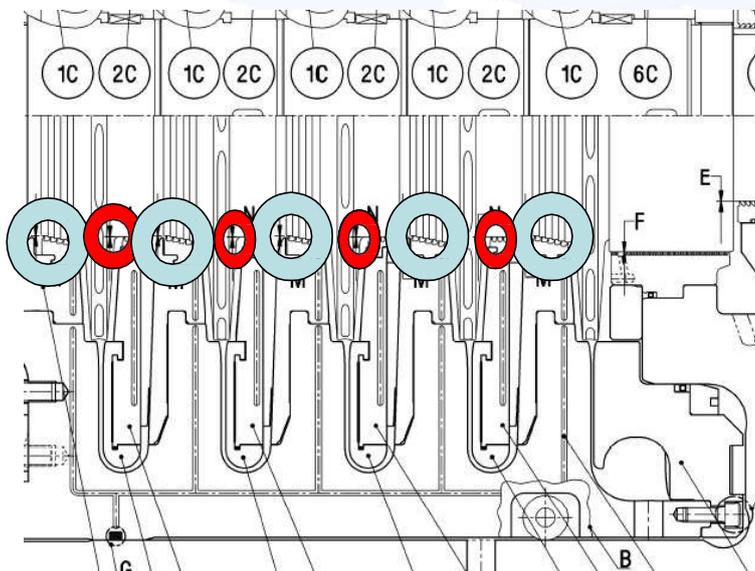
Labyrinth seals are installed in the diaphragms at all internal close-clearance points to minimize the gas leakages from discharge to suction pressure areas of the impellers.



Ring seals, installed in grooves machined at the periphery of the counter casing, prevent high pressure gas leaking to a lower pressure areas.

LABYRINTH SEAL (INTERNAL) GEPS Oil & Gas

The internal seals, used between rotating and stationary parts of the compressor to reduce gas leakage between areas of different pressure, are labyrinth type.



The labyrinth seal consists of a ring the periphery of which is shaped on a series of fins having small clearance with the rotor.

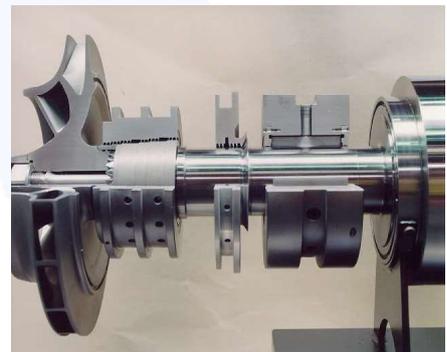
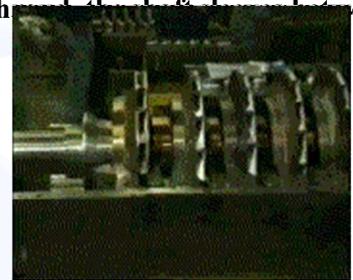
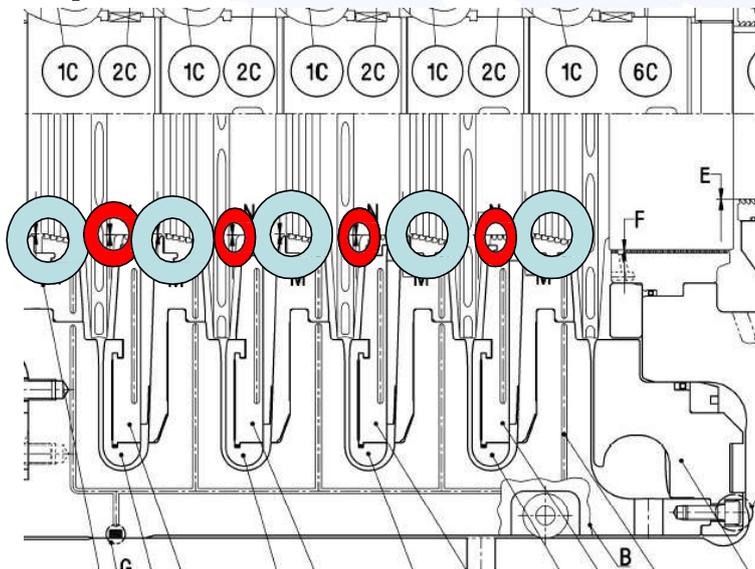
These rings are manufactured in 2 halves or quarters of a soft alloy resistant to corrosion to avoid damage to the rotor in the event of an accidental contact.

LABYRINTH SEAL (INTERNAL)



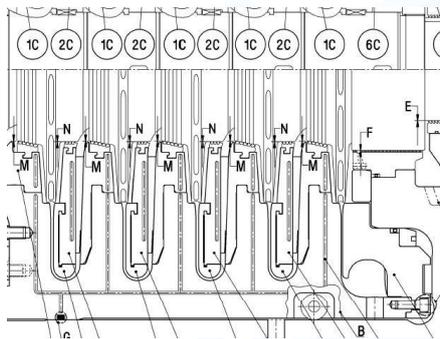
The upper halves of the rings are fastened to relevant diaphragm. The lower halves of the rings can be easily removed by rotating them in their grooved seat in the diaphragms.

The positions of the rotor incorporating the labyrinth seals are: the impeller shaft, the shaft between the impellers and the balance drum.



The same type of seals is located at the shaft end to limit the gas leakage out of the compressor.

The clearances between the labyrinths and the rotor are shown on the "**Clearance data sheet**" included in the "Drawings" section or volume of this manual.



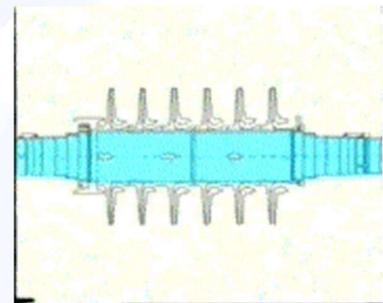
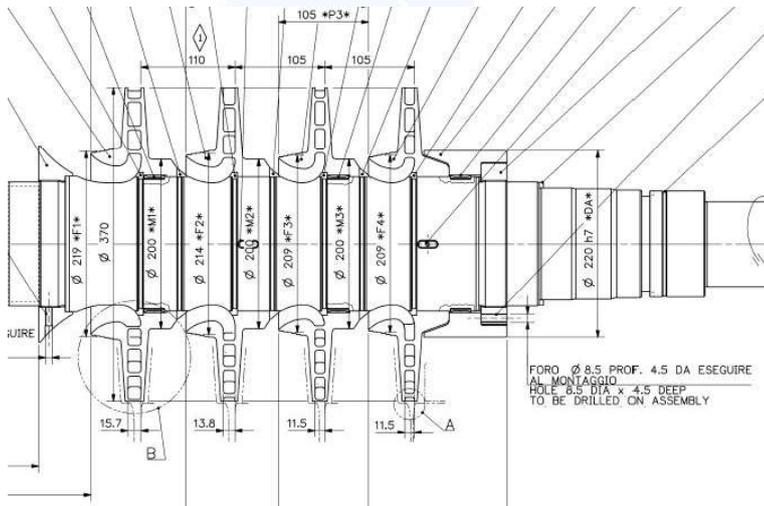
BCL304/B



POS	DENOMINAZIONE DENOMINATION	DIAM NOM.	VALORI GIOCHI AL MONTAGGIO		VALORE MAX. ACCETTABILE IN FUNZIONAMENTO
			CLEARANCE DATA AT ASSEMBLY (mm)		MAX ALLOWABLE VALUE DURING OPERATION (mm)
---	---	---	MIN.	MAX.	MAX
A	Gioco cuscini portanti (mm) Journal bearings clearance (mm)	90 mm	0.10	0.13	IDEM
B	Gioco tenute olio Oil seal ring clearance	---	0.20	0.27	0.41
D	Gioco assiale regg. (poll.) Thrust bearing end clear. (inch)	9"	0.25	0.35	IDEM
E	Gioco tenute estremità rotore Labyrinth seal clearance on rotor	---	0.30	0.38	0.51
H	Gioco ten. Labir. Su compensatore. Labyr. Seal clear. On balance drum end.	---	0.37	0.44	0.58

ROTOR 304 -A

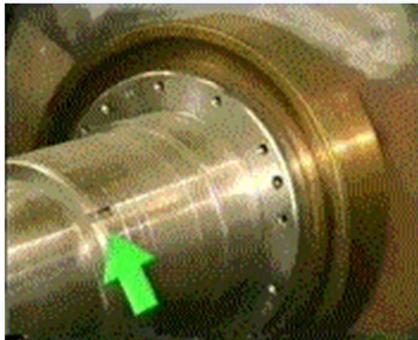
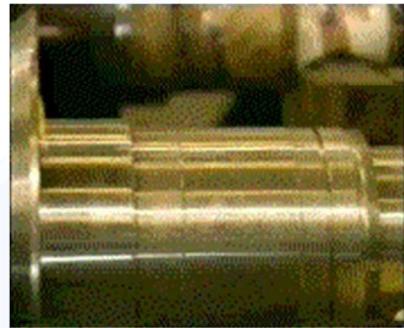
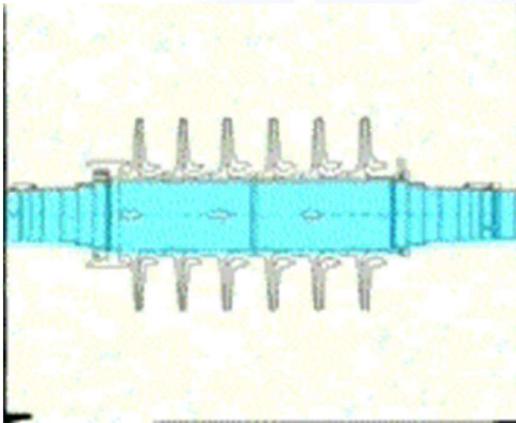
It consists of a shaft on which impellers and spacers are assembled. The spacers are shrunk on the shaft and they axially position the impellers and protect the shaft sections, between the impellers, from contact with the gas.



The impeller is the part of the centrifugal compressor that adds velocity to the gas.
 The impellers are of enclosed backward-bladed type and are shrunk and keyed on to the shaft.
 Before being mounted on the shaft each impeller is dynamically balanced and tested at a speed 15% higher than the maximum continuous speed.

ROTORS

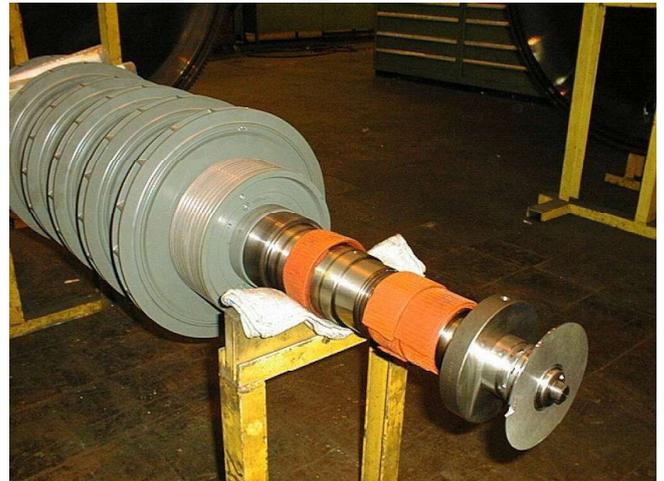
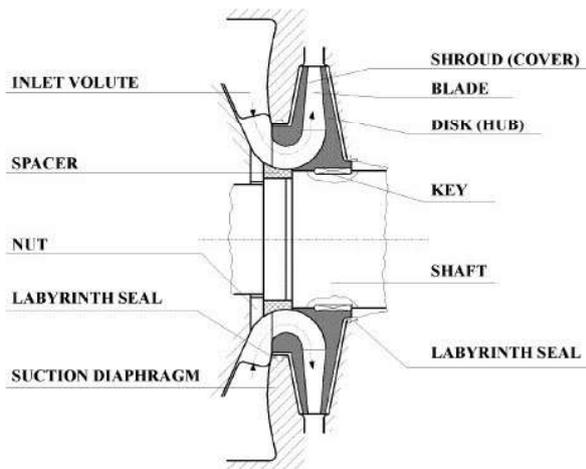
 **GEPS Oil & Gas**



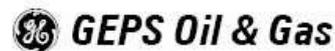
 **GEPS Oil & Gas**

ROTOR

During the compressor operation the rotor is subjected to an axial thrust in the direction of the suction and generated by the pressure difference acting on the shroud and disk of each impeller. The majority of the thrust is balanced by the balance drum. The resulting axial thrust is absorbed by the thrust bearing.



Axial Thrust Compensation -Single Shaft Compr., In-Line Design-



$$F_R = \sum F_{\text{imp}} - F_{\text{pist}} = A_{\text{bea}} \times P_{\text{SS}} \quad [\text{N}]$$

F_R = Residual Axial Thrust [N]

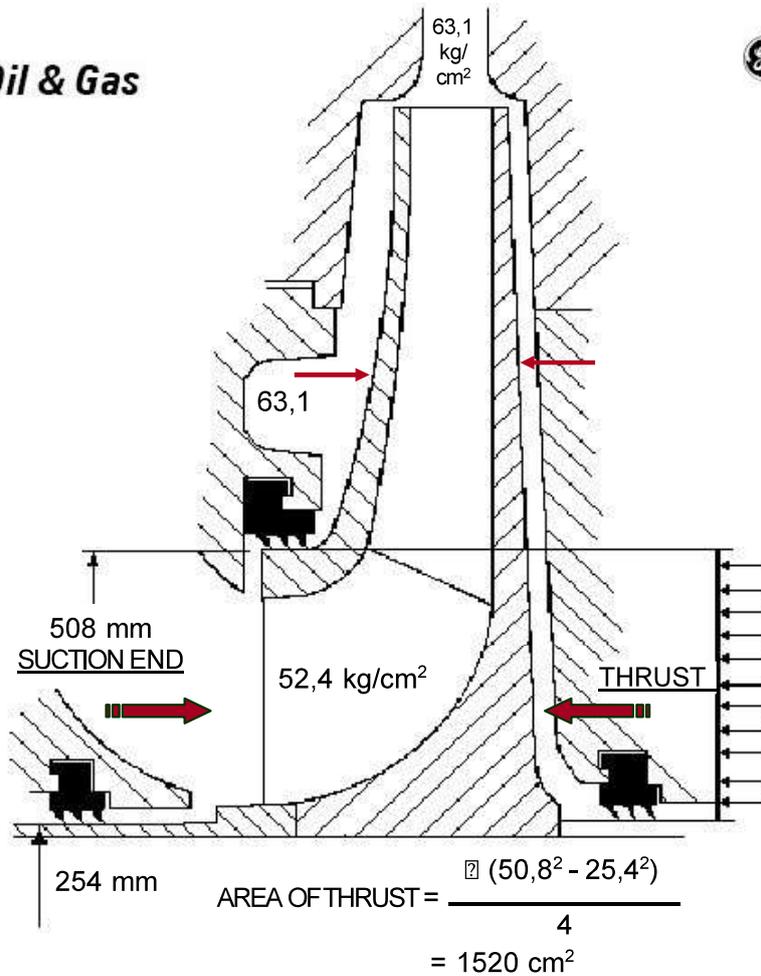
F_{imp} = Axial force generated by impeller [N]

F_{pist} = Axial force generated by balance piston [N]

A_{bea} = Area of thrust bearings [cm²]

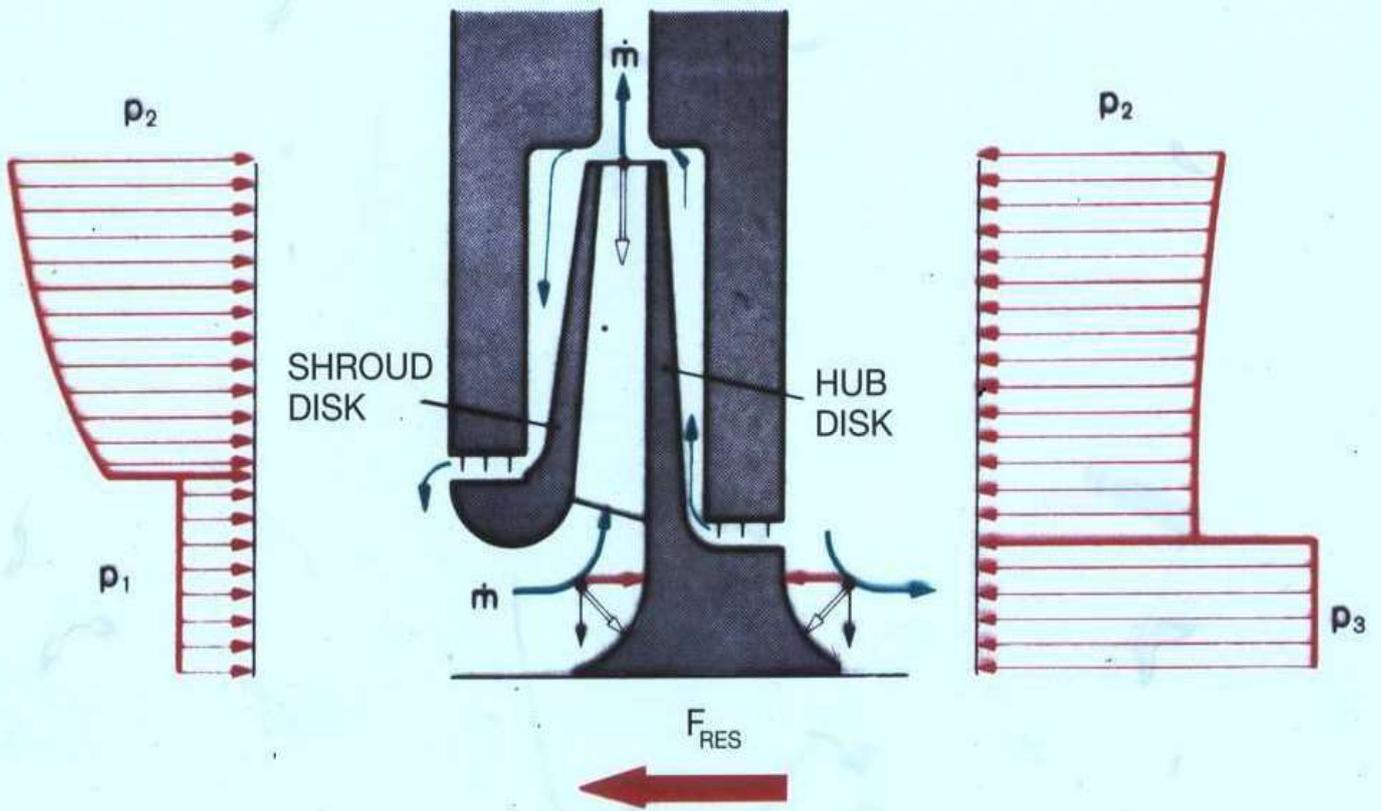
P_{SS} = Specific surface stress [N/cm²]

P_{SS} is limited on thrust bearing pads to $30 \leq P_{\text{SS}} \leq 60$ [N/cm²]

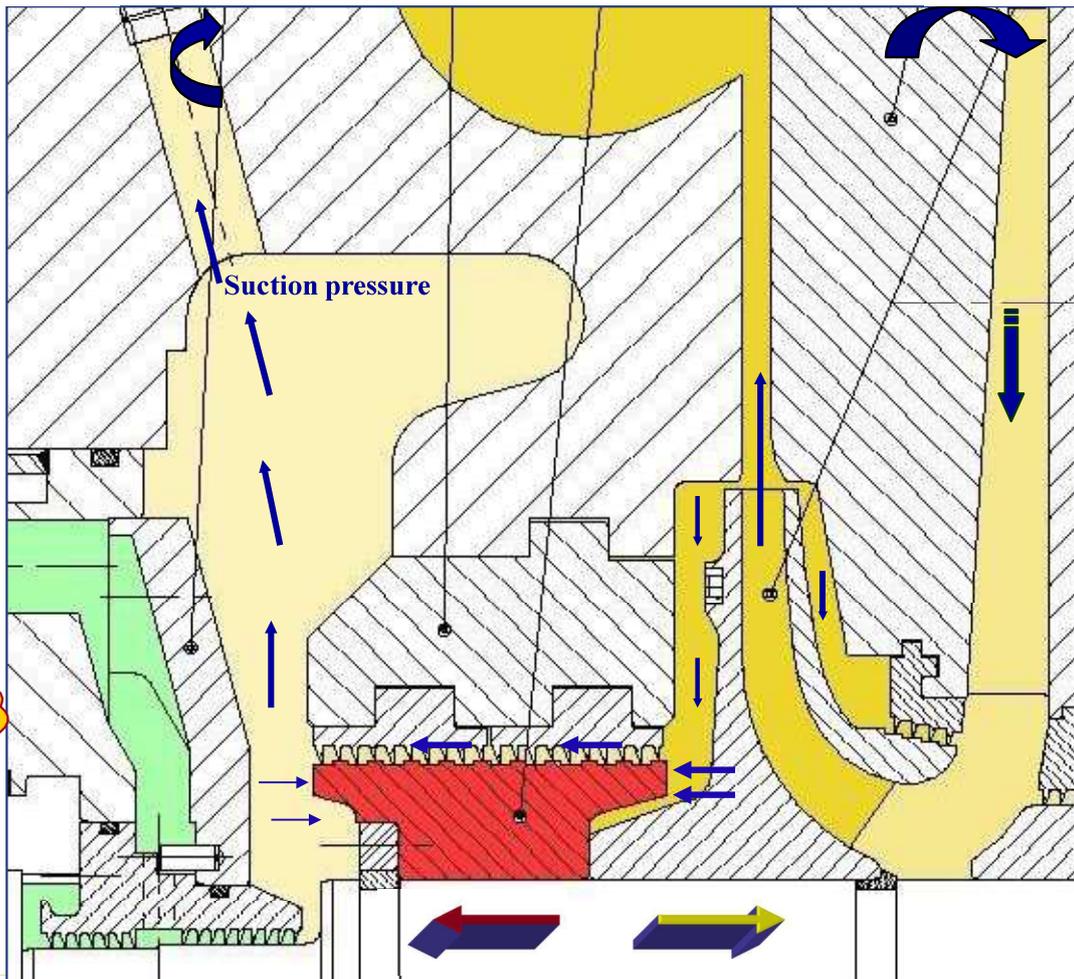


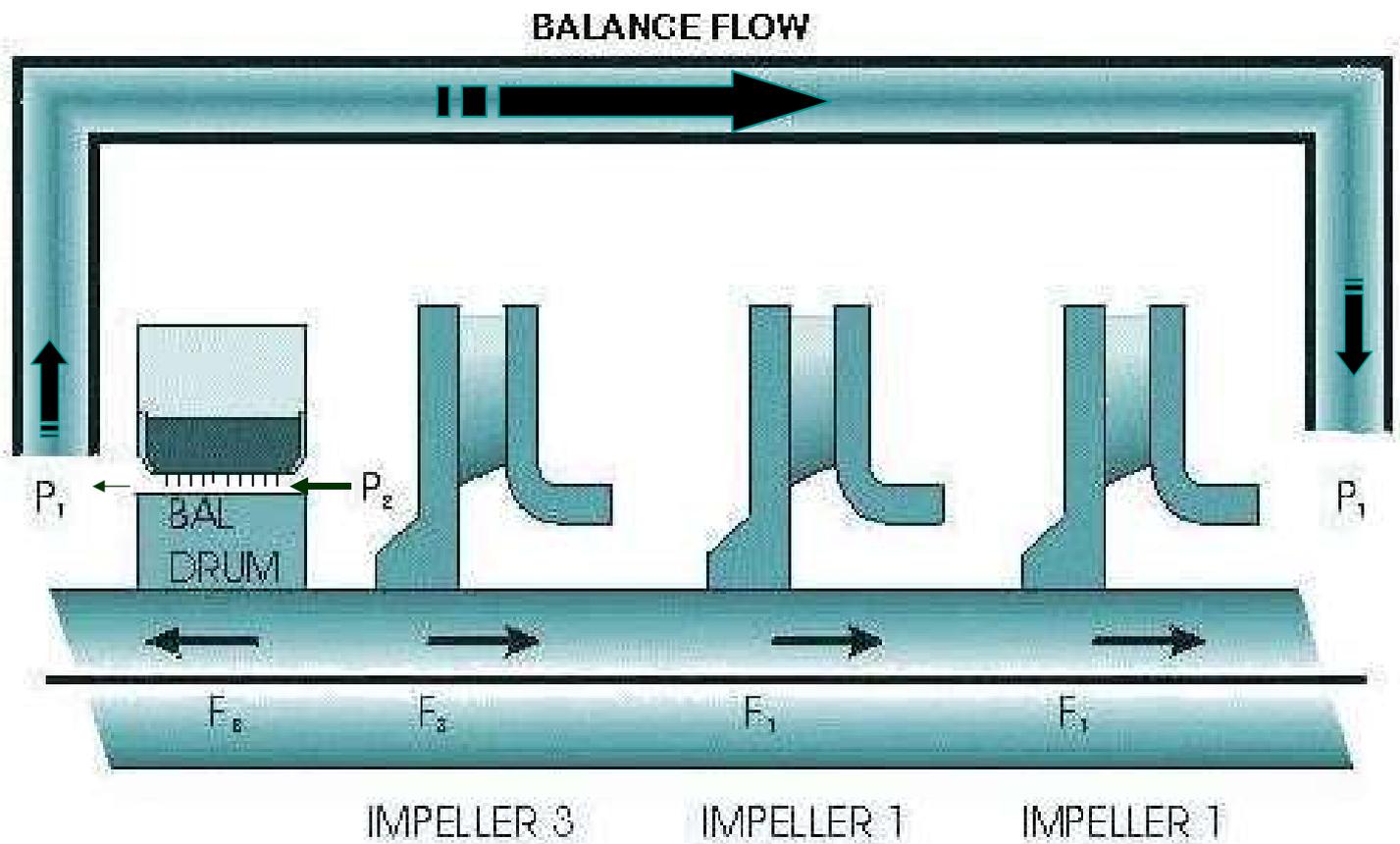
Pr ← **16 ton!**

DIFFERENTIAL PRESSURE = 10,7 kg/cm²
 AXIAL THRUST = 16.265 kg



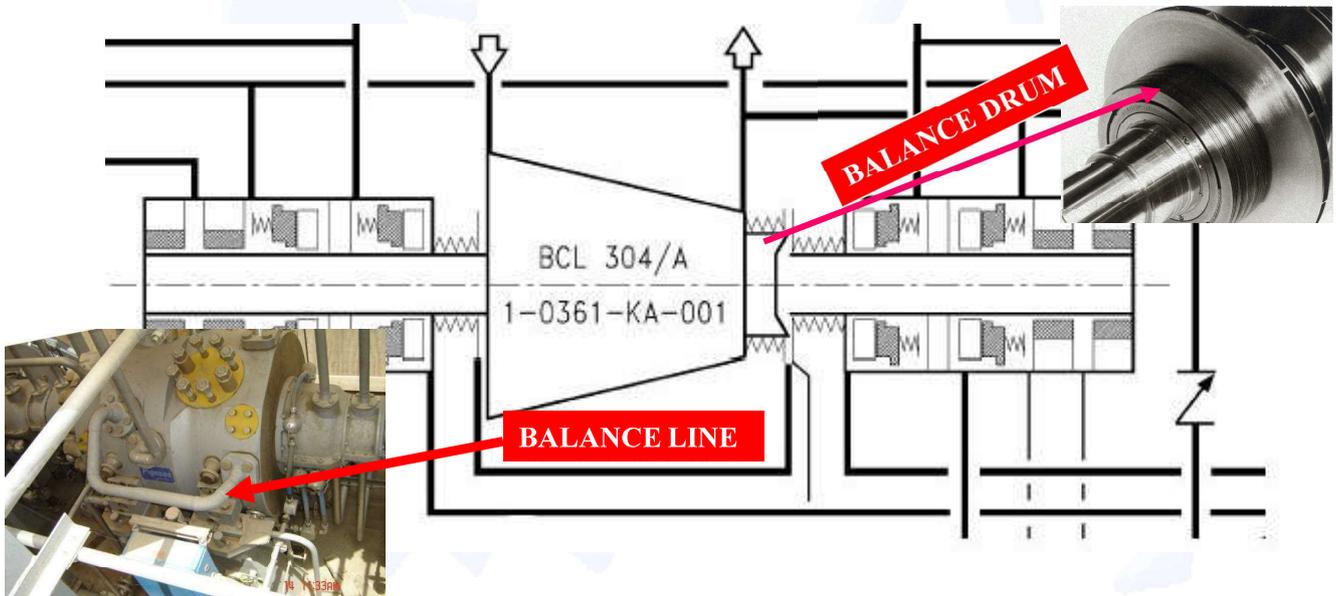
External seal





BALANCE DRUM

The centrifugal compressor rotor is subjected to an axial thrust towards the suction end due to the differential pressure generated on the disk and cover of each impeller. The majority of thrust is balanced by the balance drum fitted on the end of the shaft adjacent to the last stage impeller.

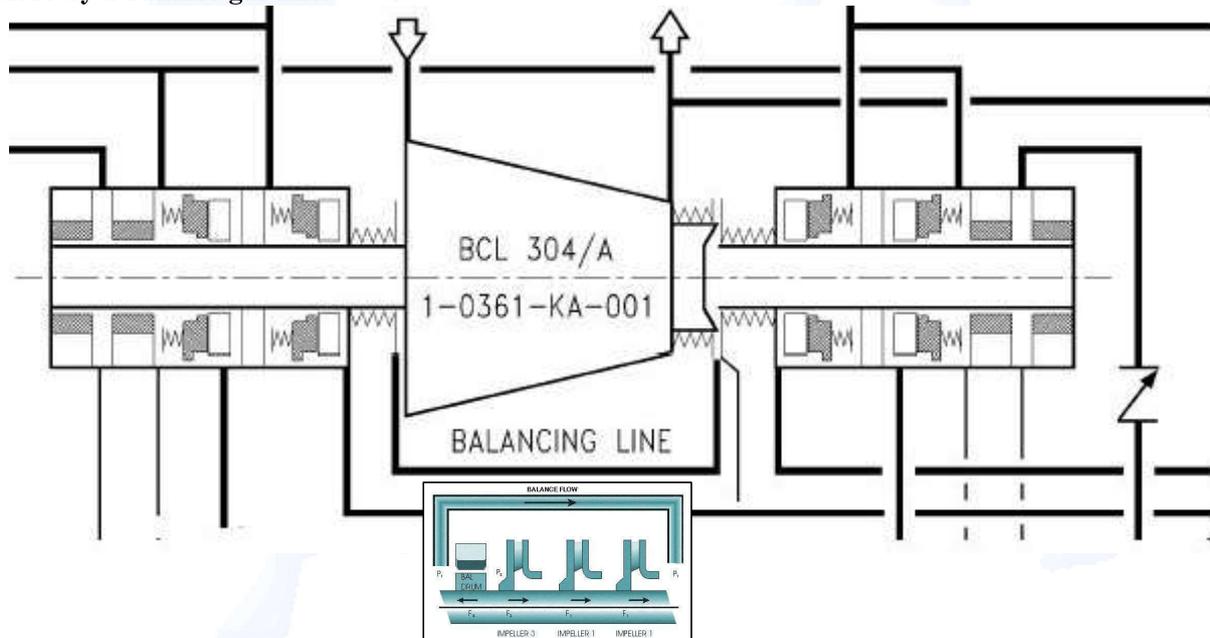


The balance drum is heat shrunk on to the shaft. The impellers, spacing sleeves and balance drum assembly are held on the shaft by a locking collar. After the balance drum has been fitted to the rotor, the assembly is dynamically balanced again.

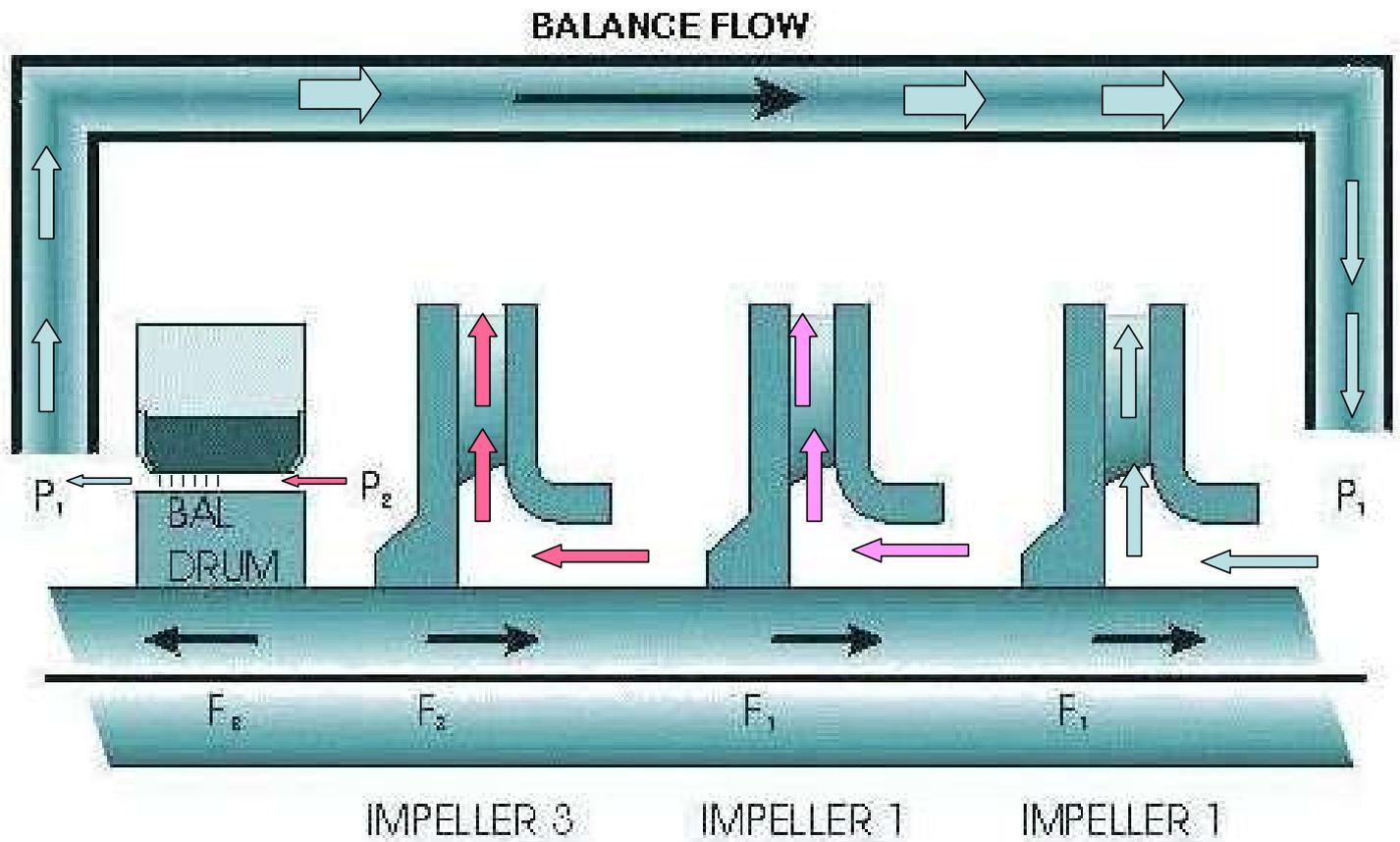
BALANCE DRUM

The balance drum and relevant labyrinth seal form, together with labyrinth seal provided on the shaft end, the so called balancing chamber.

This is accomplished by subjecting the area on the outboard side of the balance drum to a low pressure (approximately suction pressure), thereby creating a pressure differential opposite in direction to that on the impellers. This low pressure is achieved by connecting the area behind the balance drum to the suction of the compressor by a balance gas line.

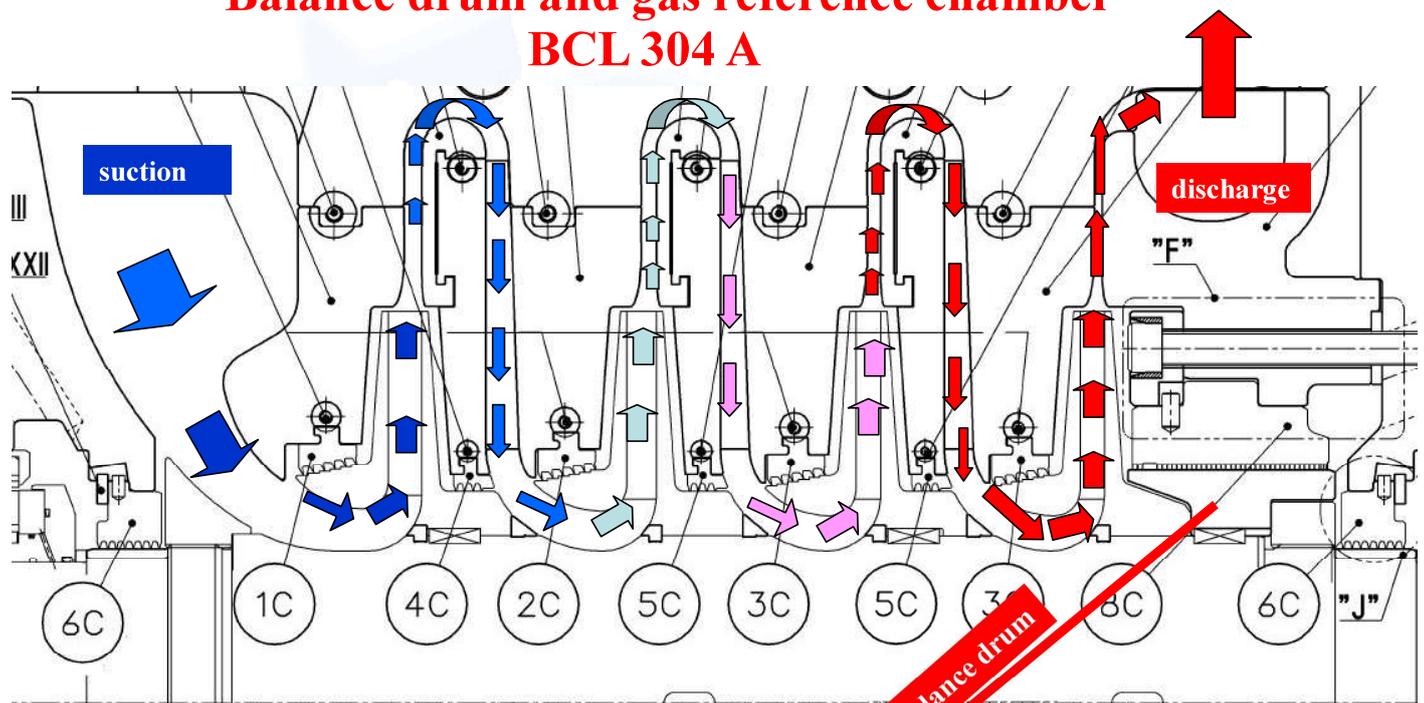


BALANCE DRUM



direction.

Balance drum and gas reference chamber BCL 304 A



 GEPS Oil & Gas



 GEPS Oil & Gas

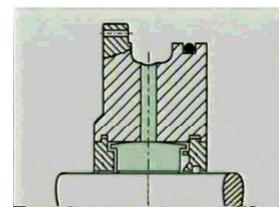


Prepared by : Benny

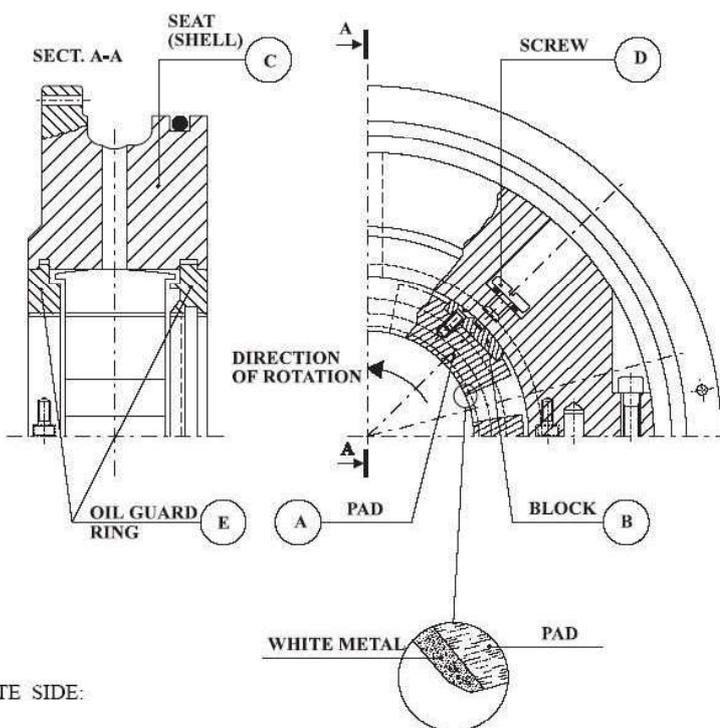
25-10-2011



JOURNAL BEARINGS



The journal bearings are of the tilting pad type with forced lubrication. Oil under pressure flows through the bearings radially, and passes through holes to lubricate pads and blocks. It is then laterally discharged.

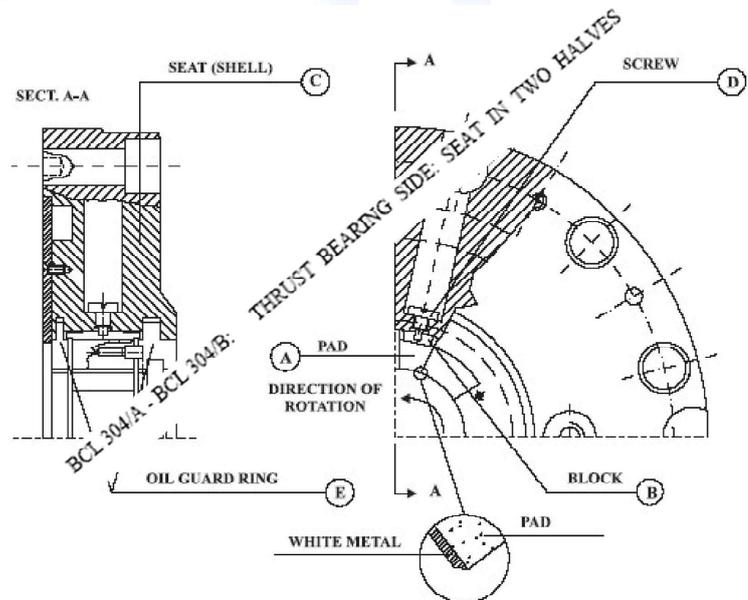
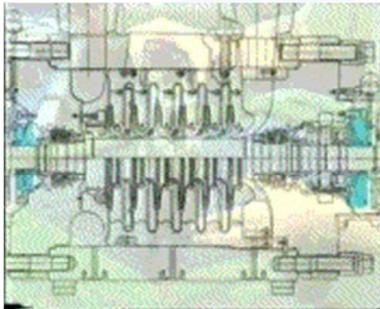


BCL 304/A - BCL 304/B - BCL 305/C: THRUST BEARING OPPOSITE SIDE:
SEAT IN TWO HALVES

JOURNAL BEARINGS

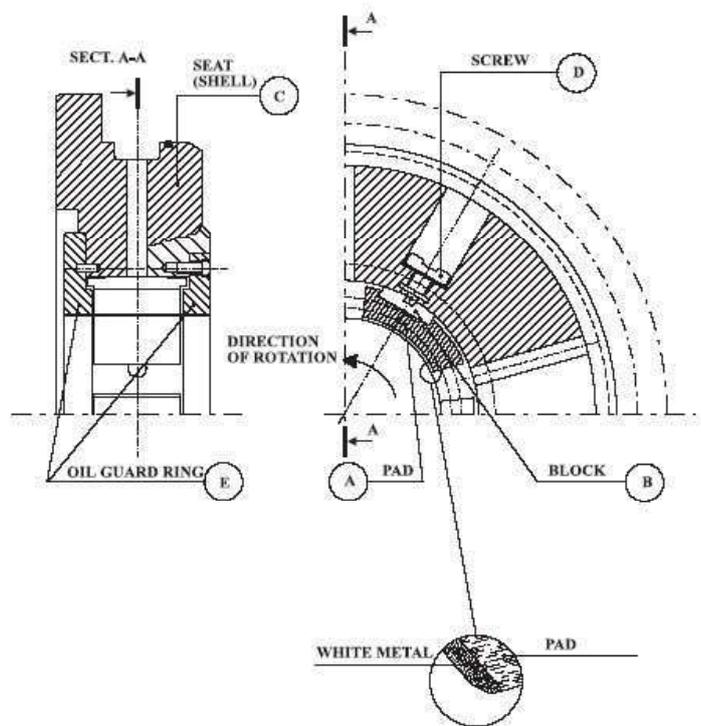
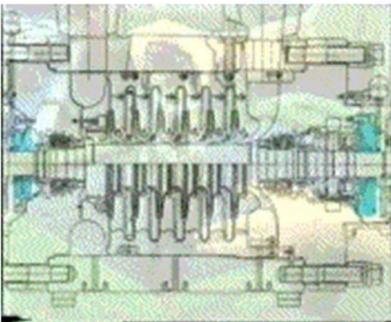
Bearings pads (A) are of steel, internally lined with white metal. They are integral with blocks of steel (B), and are located into the proper seat formed by the shell (C) and by two oil guard rings (E).

The pads can swing inside the shell both in the radial and axial direction for the maximum dampening of radial vibration of the rotor.



The rotation of pads inside the shell is prevented by pins protruding from screws (D) screwed in the shell. The bearing is axially fixed to the casing head, or compressor casing, by means of screws.

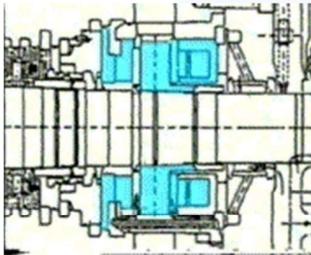
JOURNAL BEARINGS



THRUST BEARING

The thrust bearing, mounted on one casing end, is of the double acting type and is positioned at both sides of the rotor thrust collar.

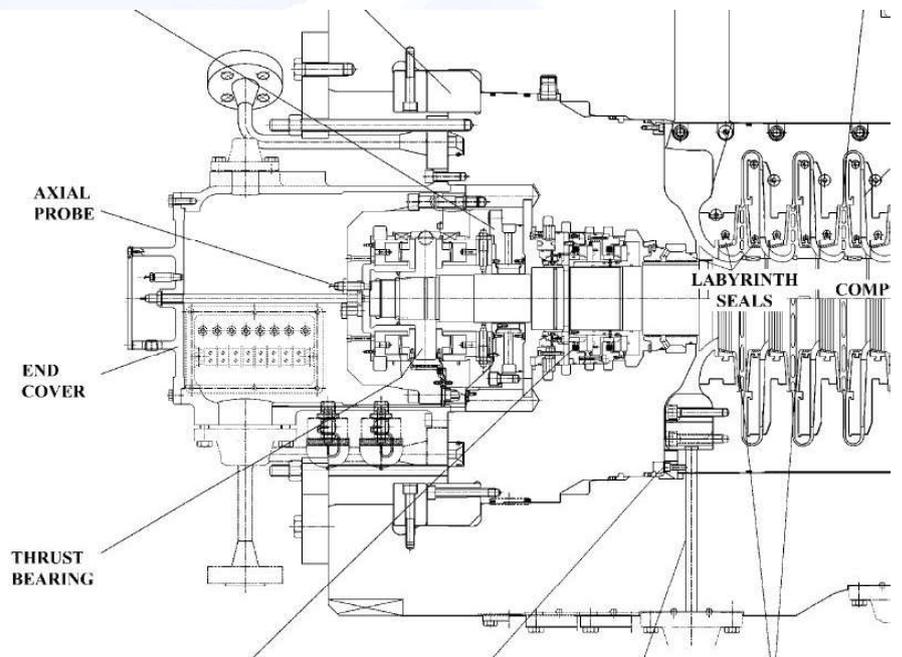
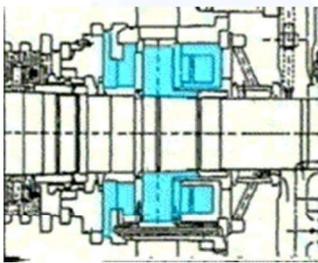
It is designed to absorb the residual axial thrust, operating on the rotor, that is not completely balanced by the balance drum.



It is provided with an oil control ring (O.C.R.) to minimize the power loss due to churning of the oil in the bearing cavity under high speed operation. In other cases a thrust bearing holder ring forms an annular chamber around the collar that makes the function of the O.C.R.

THRUST BEARING

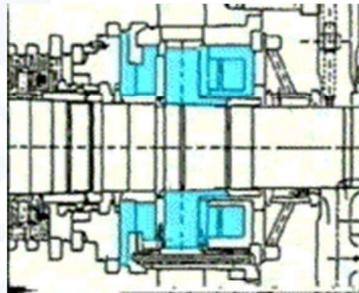
The specified clearance between the bearing pads and the thrust collar is shown on the "**Clearance data sheet**" included in the "Drawings" volume or section of this manual.



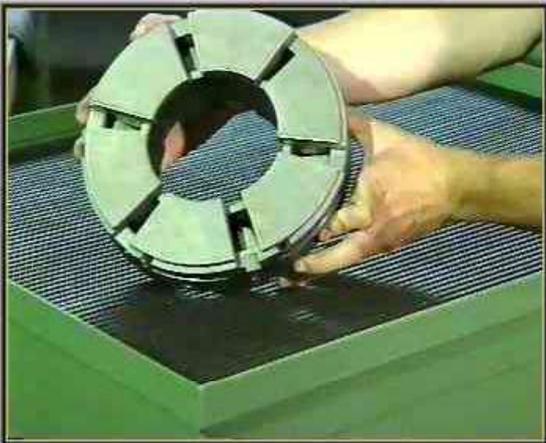
More detailed instructions proper of the thrust bearing are included in the "Auxiliary Equipment" volume of this manual.

THRUST BEARING

 **GEPS Oil & Gas**



 **GEPS Oil & Gas**



Sealing overview

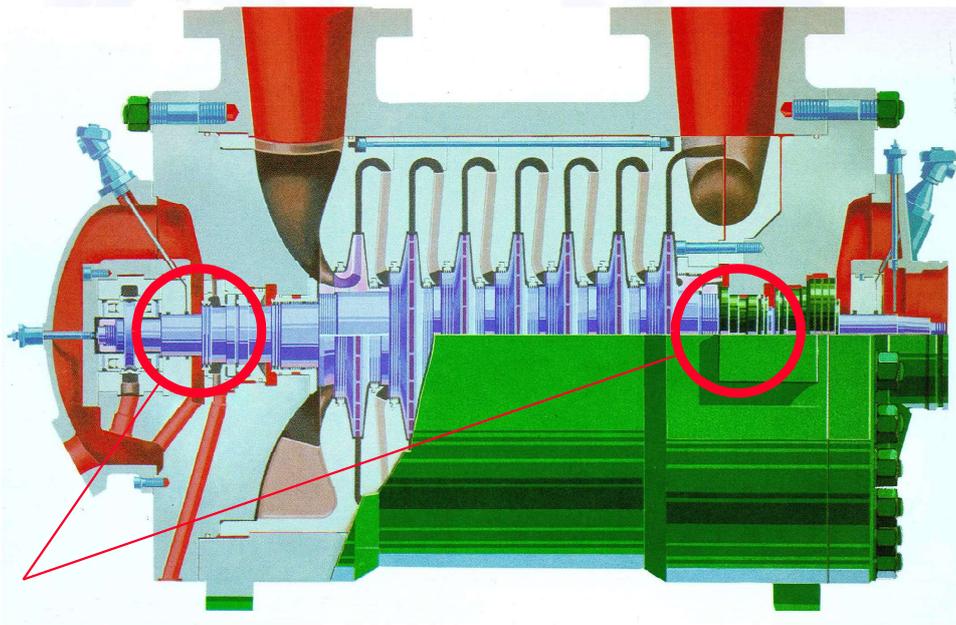
GE GEPS Oil & Gas



GE GEPS Oil & Gas

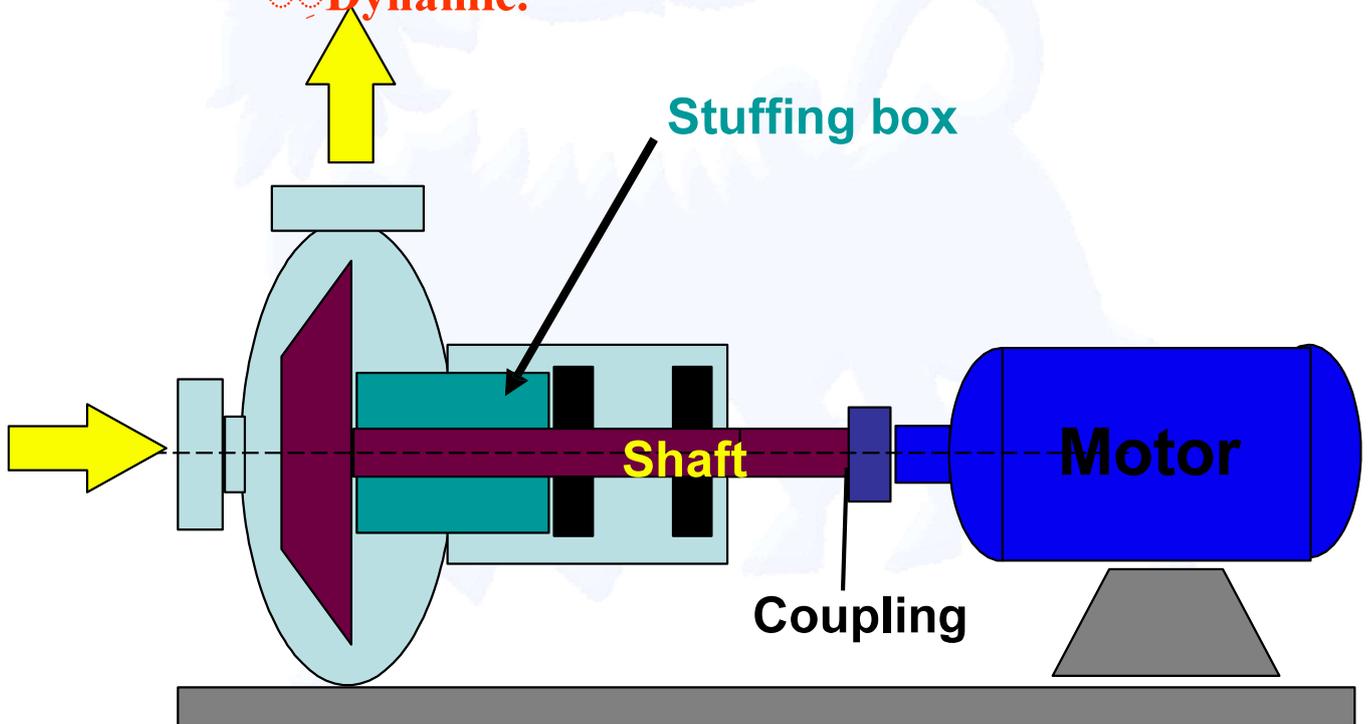
Suction Nozzle ↓

↑ Discharge Nozzle



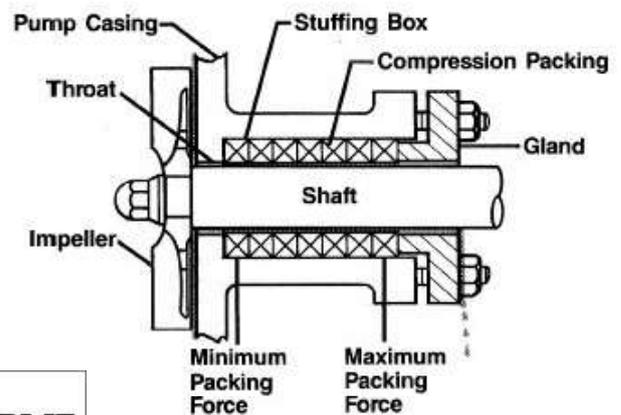
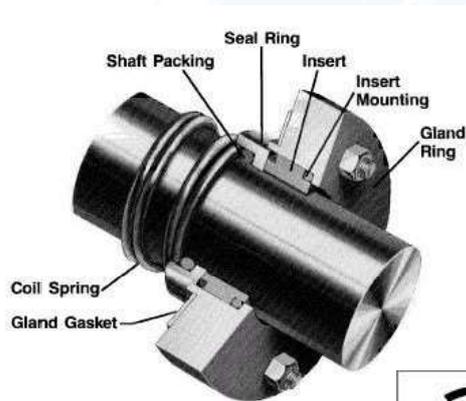
There are two basic kinds of seals:

- **Static**
- **Dynamic.**



Dynamic Seals may be divided into two main subcategories :

- Compression packing seal
- End face mechanical seal

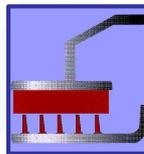


Internal seal elements

Dry System

Labyrinth seal

Brush seal



SEAL ELEMENTS

External seal elements

Dry System

Dry Gas Seal

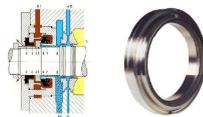
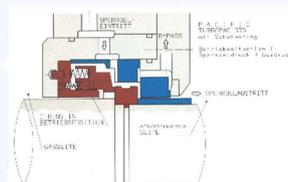
Labyrinth Seal

Brush seal

Wet System

Floating Ring Seal (Oil seal)

Mechanical Contact Seal

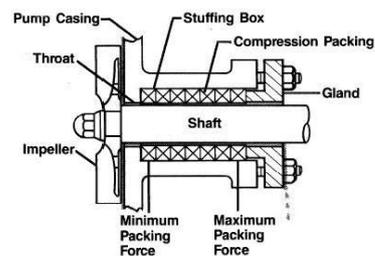
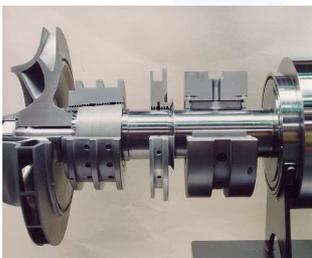
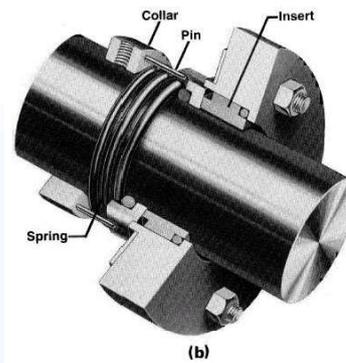
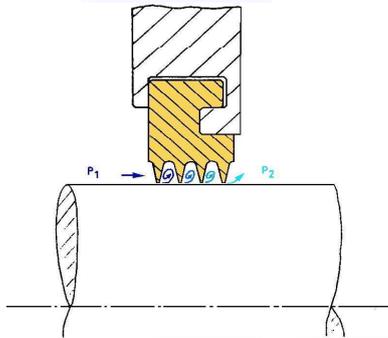


Mechanical contact seal
 1 Seal oil supply
 2 Floating ring
 3 Brush seal
 4 Collecting chamber
 5 Seal oil return
 6 Seal oil return
 7 Seal oil return
 8 Seal oil return
 9 Seal oil return
 10 Seal oil return
 11 Seal oil return
 12 Seal oil return
 13 Seal oil return
 14 Seal oil return
 15 Seal oil return
 16 Seal oil return
 17 Seal oil return
 18 Seal oil return
 19 Seal oil return
 20 Seal oil return
 21 Seal oil return
 22 Seal oil return
 23 Seal oil return
 24 Seal oil return
 25 Seal oil return
 26 Seal oil return
 27 Seal oil return
 28 Seal oil return
 29 Seal oil return
 30 Seal oil return
 31 Seal oil return
 32 Seal oil return
 33 Seal oil return
 34 Seal oil return
 35 Seal oil return
 36 Seal oil return
 37 Seal oil return
 38 Seal oil return
 39 Seal oil return
 40 Seal oil return
 41 Seal oil return
 42 Seal oil return
 43 Seal oil return
 44 Seal oil return
 45 Seal oil return
 46 Seal oil return
 47 Seal oil return
 48 Seal oil return
 49 Seal oil return
 50 Seal oil return
 51 Seal oil return
 52 Seal oil return
 53 Seal oil return
 54 Seal oil return
 55 Seal oil return
 56 Seal oil return
 57 Seal oil return
 58 Seal oil return
 59 Seal oil return
 60 Seal oil return
 61 Seal oil return
 62 Seal oil return
 63 Seal oil return
 64 Seal oil return
 65 Seal oil return
 66 Seal oil return
 67 Seal oil return
 68 Seal oil return
 69 Seal oil return
 70 Seal oil return
 71 Seal oil return
 72 Seal oil return
 73 Seal oil return
 74 Seal oil return
 75 Seal oil return
 76 Seal oil return
 77 Seal oil return
 78 Seal oil return
 79 Seal oil return
 80 Seal oil return
 81 Seal oil return
 82 Seal oil return
 83 Seal oil return
 84 Seal oil return
 85 Seal oil return
 86 Seal oil return
 87 Seal oil return
 88 Seal oil return
 89 Seal oil return
 90 Seal oil return
 91 Seal oil return
 92 Seal oil return
 93 Seal oil return
 94 Seal oil return
 95 Seal oil return
 96 Seal oil return
 97 Seal oil return
 98 Seal oil return
 99 Seal oil return
 100 Seal oil return

Brief Study on Seals

There are two major groups of seal for rotating shafts

- Non rubbing contact seal (bushing ,labyrinth seal)
- Direct rubbing contact (lip seal, compression packing ,mechanical seal)



Brief Study on Seals

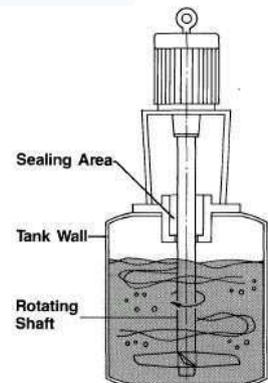
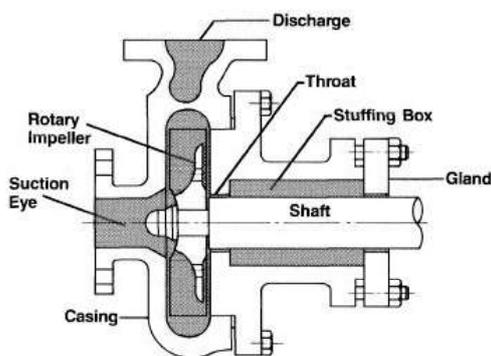
Static Seal

Static seals are employed where no movement occurs at the juncture to be sealed. Gaskets and O-rings are typical static seals.

Dynamic Seal

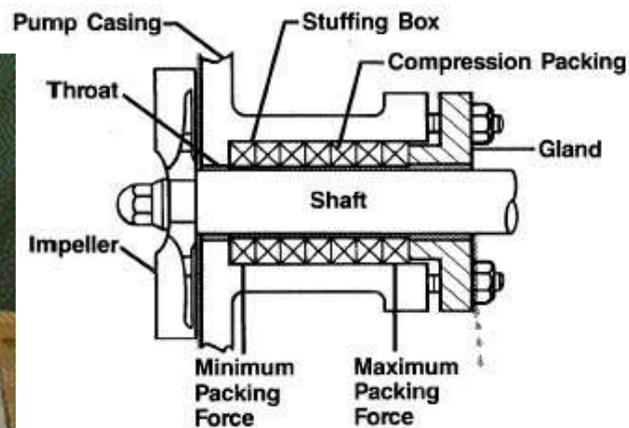
Dynamic seals are employed where surfaces move relative to one another. Dynamic seals are used, for example, where a reciprocating or rotating shaft transmits power.

Typical samples of DYNAMIC SEAL



Brief Study on Seals

Early attempts to control the leakage of the product around reciprocating or rotating shafts consisted of merely restricting the clearance between the shaft and the wall of the vessel or pump casing by packing a soft, resilient material around the shaft within an extension of the tank wall or pump back head called a stuffing box.



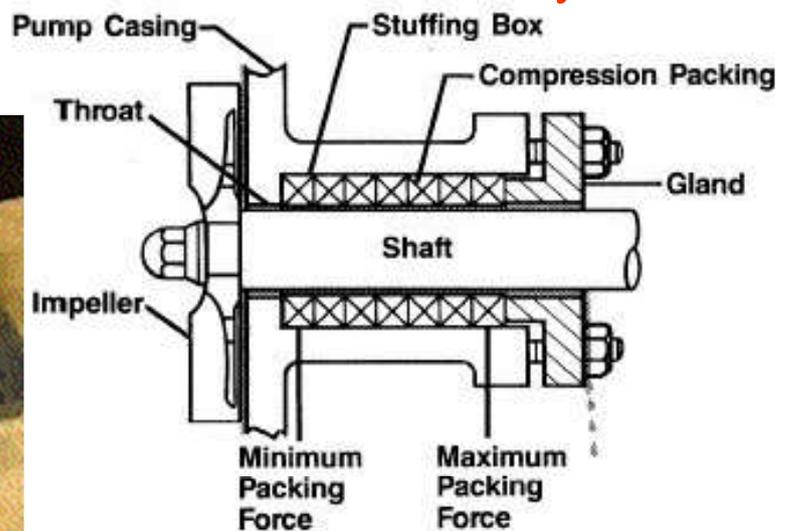
Dynamic Seals

○Above figure shows a typical stuffing box sealed with square rings of compression packing. The compression packing rings, which must be carefully installed in a clean stuffing box, are held in place by a gland. As the gland bolt nuts are tightened, pressure applied to the gland is transmitted to the compression packing, forcing it against the shaft or shaft sleeve and effecting a seal.

Brief Study on Seals

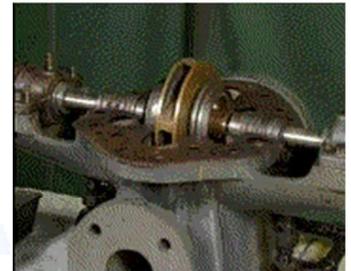
○ Seal pressure is not evenly distributed throughout the packing, most of the sealing, and consequently most of the wear occurs in the first few rings adjacent to the gland. Frictional heat, which develops where the compression packing contacts the rotating shaft or sleeve, is reduced by permitting the product to leak to the atmosphere at a controlled rate, generally about 90 drops (6 milliliters) per minute for a 2-inch (50-mm) shaft.

Dynamic Seals



Brief Study on Seals

COMPARATIVE LEAKAGE RATES BETWEEN PACKING AND MECHANICAL SEALS



PACKING

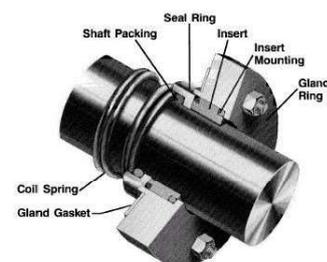
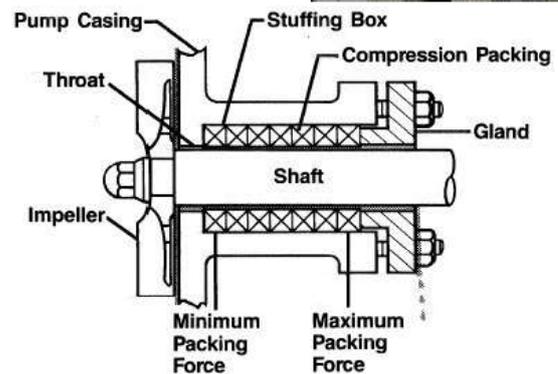
AVERAGE 90 DROPS PER MINUTE
OR 5,400 DROPS PER HOUR
OR 2.3 GALLONS (8.6 LITERS) PER DAY
OR 833 GALLONS (3153 LITERS) PER YEAR

MECHANICAL SEAL

(TOO SMALL TO MEASURE PER MINUTE)
AVERAGE 5 DROPS PER HOUR
OR 120 DROPS PER DAY
OR 0.8 GALLONS (2.9 LITERS) PER YEAR

$$\frac{5,400 \text{ DROPS/HOUR}}{5 \text{ DROPS/HOUR}} = 1,080$$

A LEAKAGE RATIO OF
PACKINGS TO SEALS OF 1,080:1

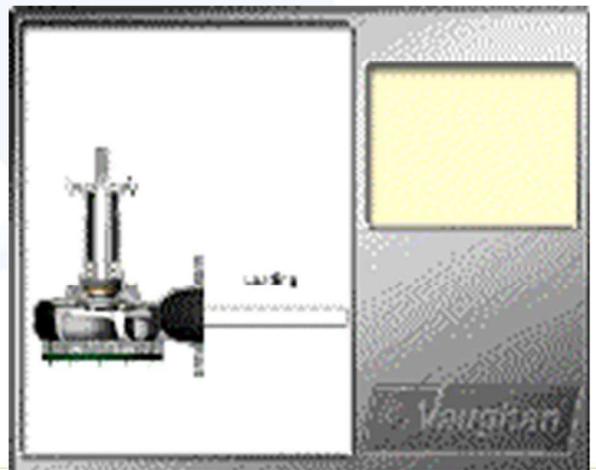
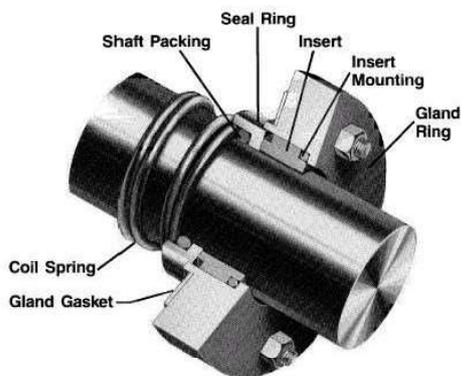


Brief Study on Seals

Mechanical Seal Main components

All mechanical seals are constructed of three basic sets of parts:

- Set of **primary seal faces**: one that rotates and one that is stationary such as seal ring and insert.
- A set of **secondary seals** known as shaft packings and insert mountings, such as O-rings, wedges, and V-rings.
- **Mechanical seal hardware** including gland rings, collars, compression rings, pins, springs, and bellows

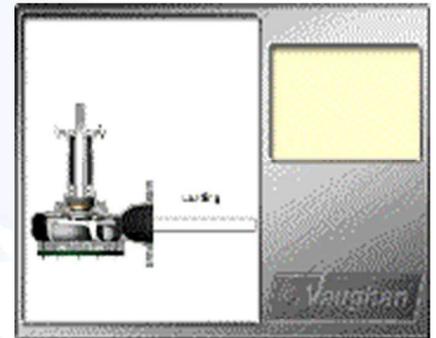
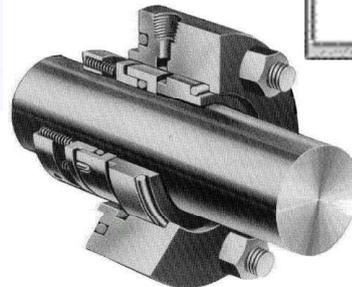
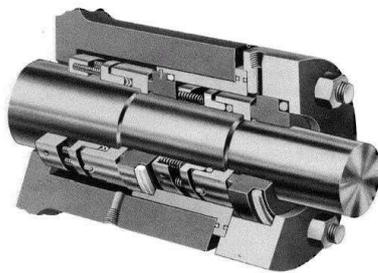


Seals classification

CLASSES OF SEAL TECHNOLOGY

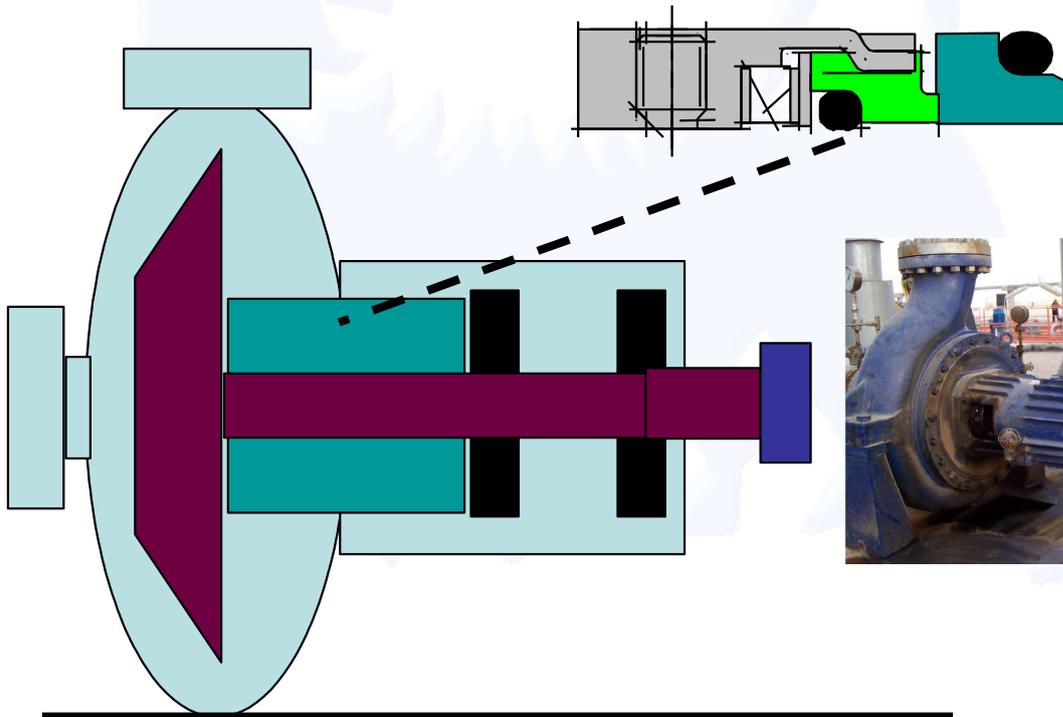
Emerging seal technologies are providing clear choices for sealing. Various plant services require the application of these new technologies for emissions control, safety, and reliability. Sealing systems are now available that are based on the preferred method of lubrication to be used. These classes of seals are as follows:

- Contacting liquid lubricated seals
- Non-contacting gas lubricated seals



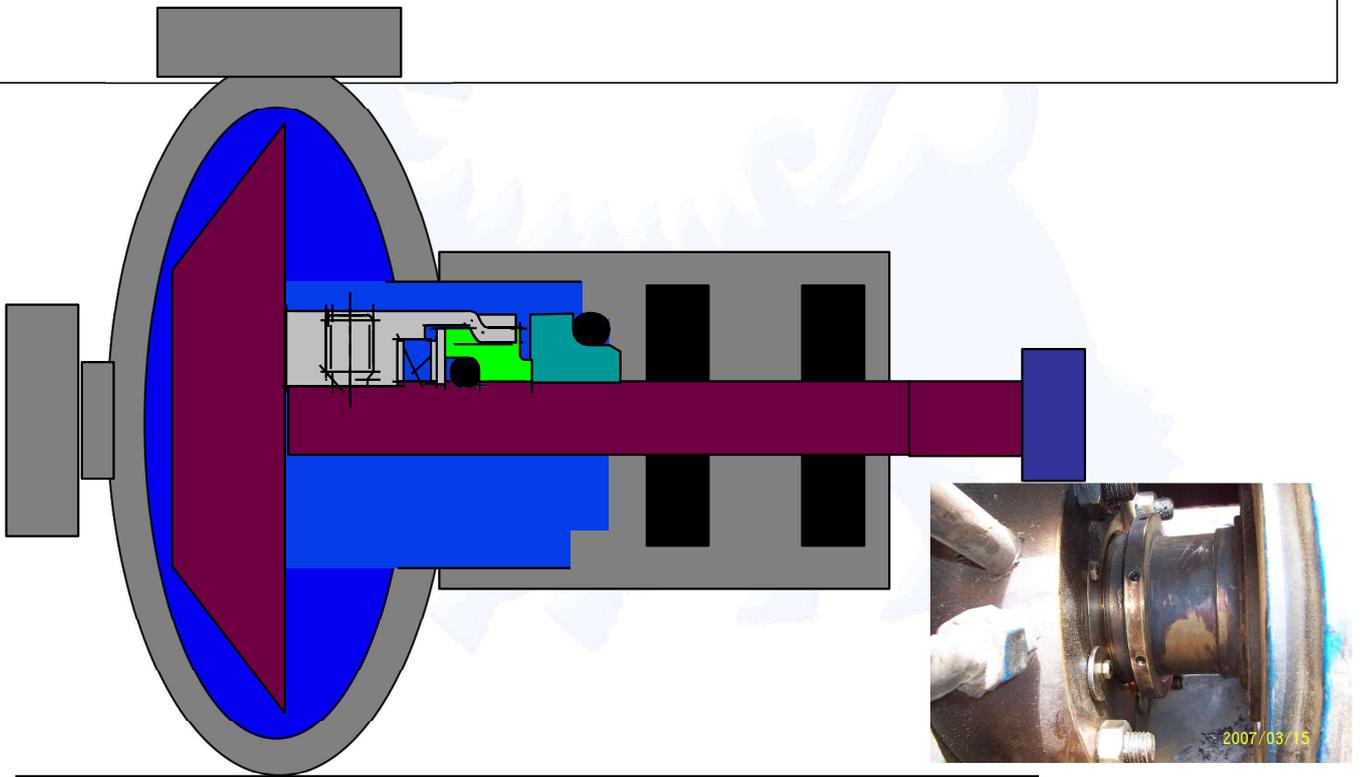
Brief Study on Seals

Location of the mechanical seal



Brief Study on Seals

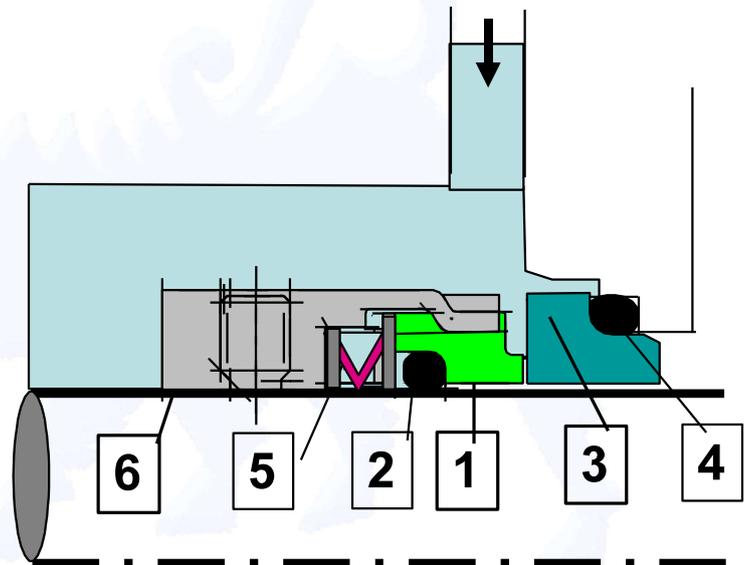
Installed seal



Brief Study on Seals

Basic Parts

- ◆ Rotating Sealface (1)
- ◆ Stationary sealface (3)
- ◆ Secondary sealing elements (2+4)
- ◆ Spring element (5)
- ◆ Torque transmission (6)



Brief Study on Seals

Mechanical Seal Main components

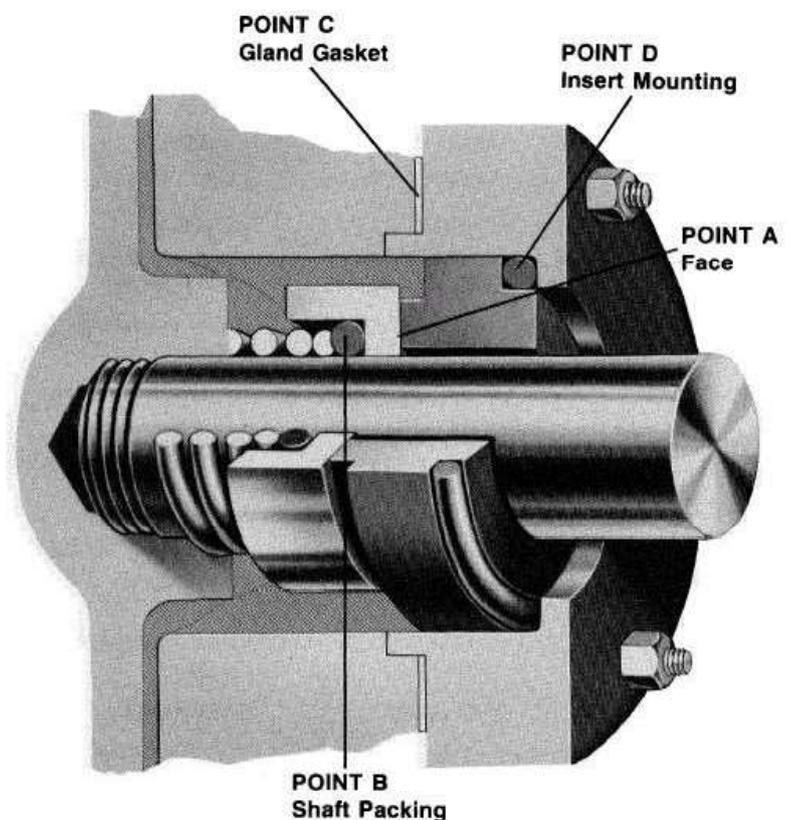
The faces in a typical mechanical seal are lubricated with a boundary layer of gas or liquid between the faces. In designing seals for the desired leakage, seal life, and energy consumption, the designer must consider how the faces are to be lubricated and select from a number of modes of seal face lubrication.

There are four main sealing points within an end face mechanical seal.

The **primary seal** is at the seal face, Point A.

The leakage path at Point B is blocked by either an O-ring, a V-ring, or a wedge.

Leakage paths at Points C and D are blocked by gaskets or O-rings.



Brief Study on Seals

Mechanical Seal- Main components

The primary seal is achieved by two very flat, lapped faces which create a difficult leakage path perpendicular to the shaft.

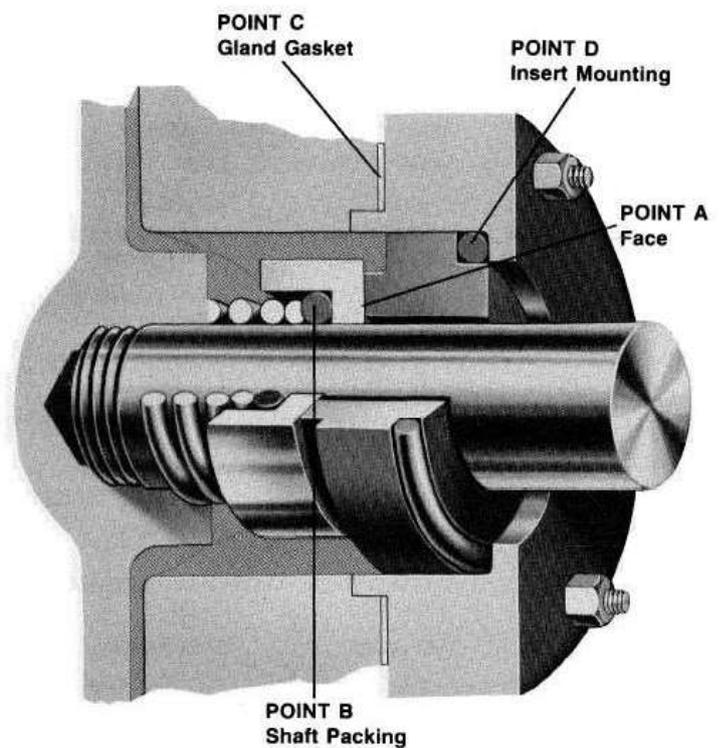
Rubbing contact between these two flat mating surfaces minimizes leakage.

As in all seals, one face is held stationary in a housing, and the other face is fixed to, and rotates with, the shaft.

One of the faces is usually a non-galling material such as carbon-graphite.

The other is usually a relatively hard material. Usually dissimilar materials are used for the stationary insert and the rotating seal ring face in order to help prevent adhesion of the two faces.

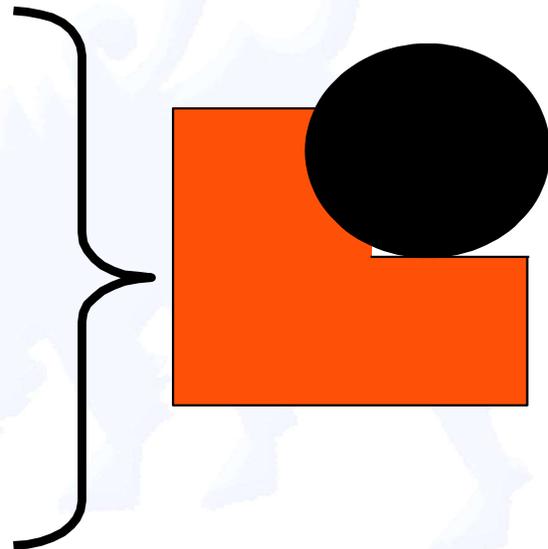
The softer face usually has the smaller mating surface and is commonly called the wear nose.



Brief Study on Seals

Features of Sealfaces

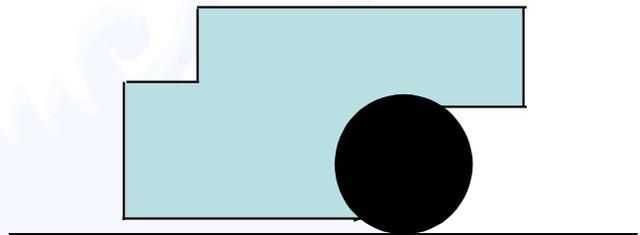
- Solid, homogen materials.
- Surface roughness (polished , lapped).
- Hardness.
- Face width.
- Good heat dissipation.



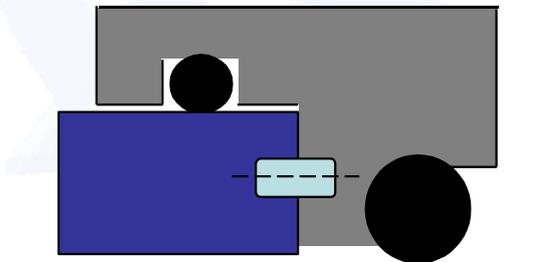
Brief Study on Seals

Rotating faces

- ◆ Solid faces.



- ◆ Inserted faces.

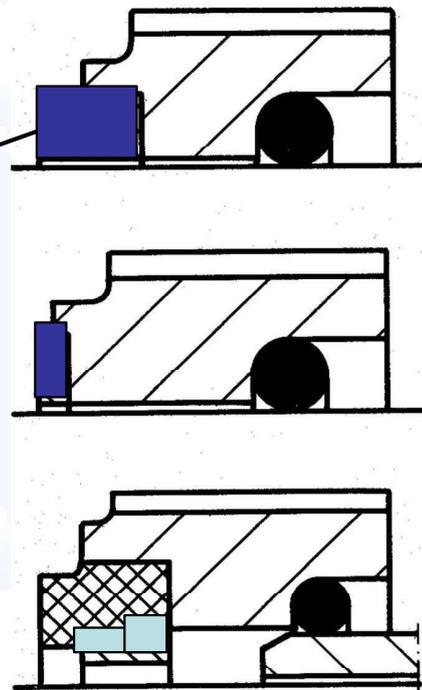


Brief Study on Seals

Rotating faces

Composite faces

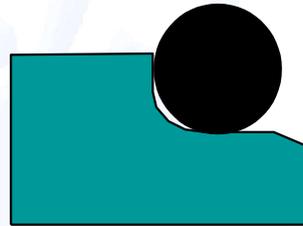
- Shrunk in
- Bonded
- Brazed
- Supported



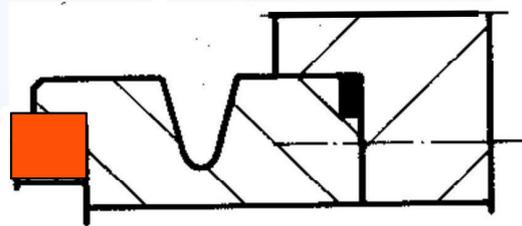
Brief Study on Seals

Stationary faces

◆ **Solid**



◆ **Composite type**



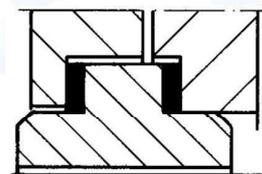
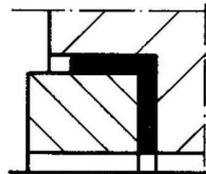
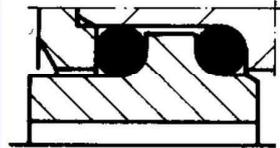
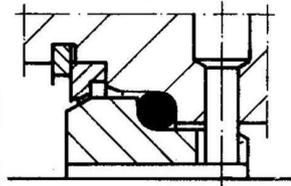
Brief Study on Seals

Stationary faces

Mounting

- O Ring mounted
 - Single O ring
 - Double O ring

- Elastomer cup
- Rigid clamped



Brief Study on Seals

Secondary sealing elements

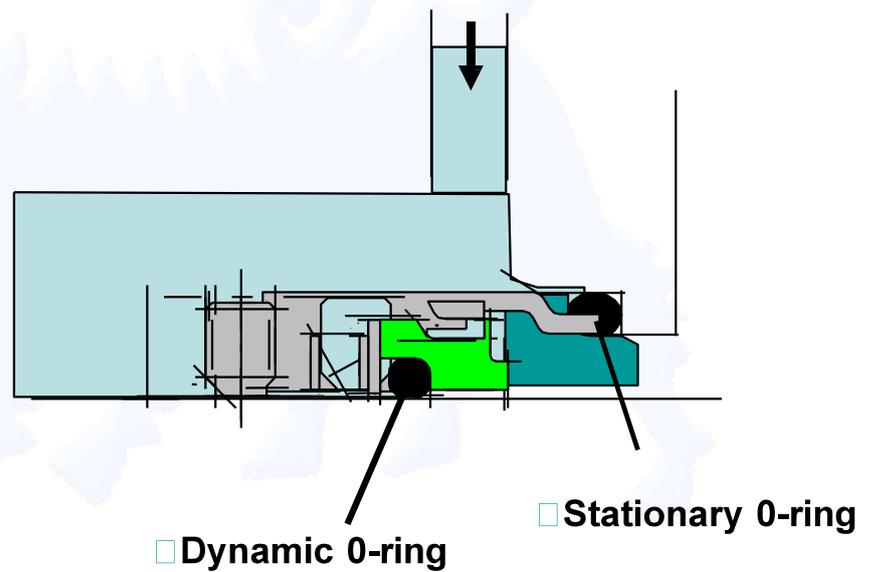
- ◆ **O-rings**
- ◆ **Enveloped rings**
- ◆ **Rubber cups**



Brief Study on Seals

0-rings: location and compression

- ◆ Dynamic 0-ring
- ◆ Stationary 0-ring



Brief Study on Seals

Springs

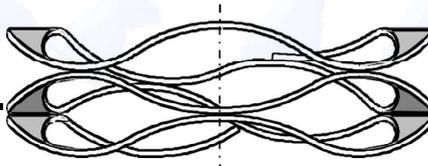
- ◆ Helical springs.



- ◆ Wave springs.



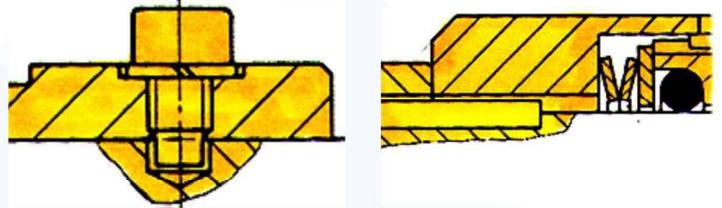
- ◆ Metal bellows.



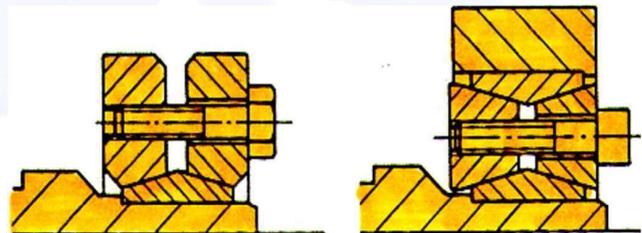
Brief Study on Seals

Torque transmissions

- ◆ Form locked transmission



- ◆ Friction locked transmission



API Sealing Definitions



Lubrication, Shaft-Sealing, and
Control-Oil Systems and Auxiliaries
for Petroleum, Chemical and Gas
Industry Services

Downstream Segment

API STANDARD 614
FOURTH EDITION, APRIL 1999

Scope

1.1 This international standard covers the minimum requirements for lubrication systems, oil-type shaft-sealing systems, dry gas face-type shaft-sealing systems, and control-oil systems for general or special purpose applications. General purpose applications are limited to lubrication systems. These systems may serve equipment such as compressors, gears, pumps, and drivers. This standard does not apply to internal combustion engines.

API Sealing Definitions

3.2 block-in time: The period required (after the driver is tripped) to isolate (valve in) a piece of equipment—such as a compressor—from its system and to de-pressurize it.



3.4 coast-down time: The period required (after the driver is tripped) for the equipment to come to rest.

API Sealing Definitions

3.20 maximum sealing pressure: The highest pressure expected at the seals during any specified static or operating conditions and during start-up and shutdown. Considerations should include relief valve settings plus relief valve accumulation pressure.



3.23 normal operating point: The point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies that performance is within the tolerances stated in this standard.

API Sealing Definitions

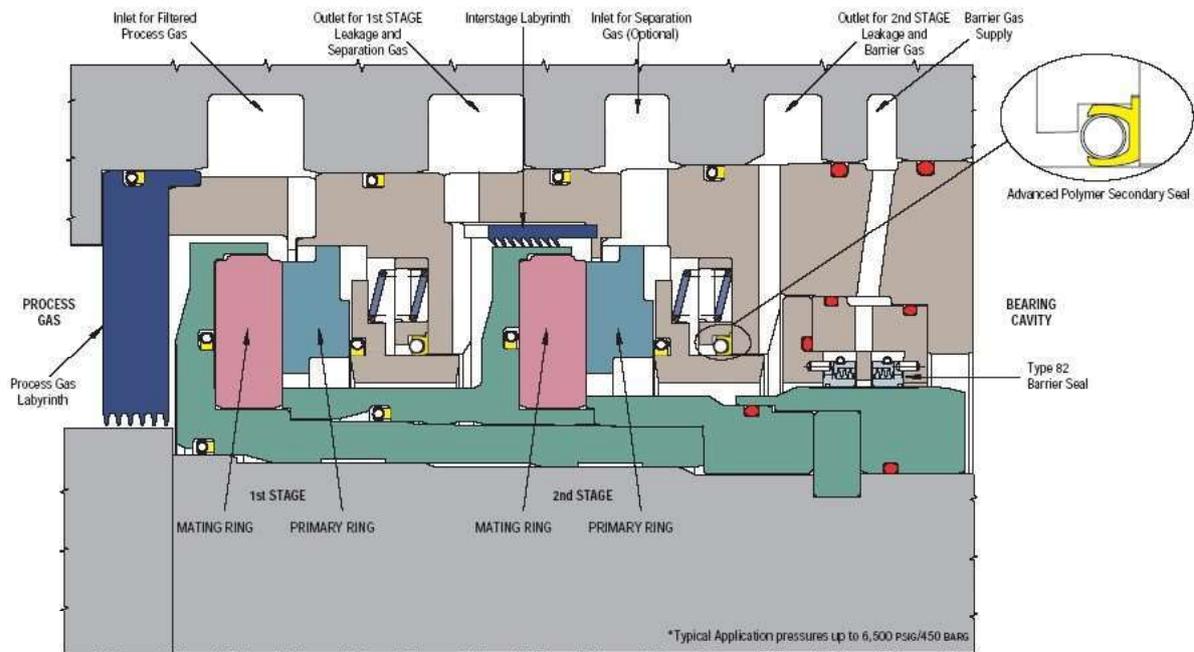
3.24 normal seal gas flow: The total amount of flow required by equipment seals. It does not include transient gas flows, or bypass flows.



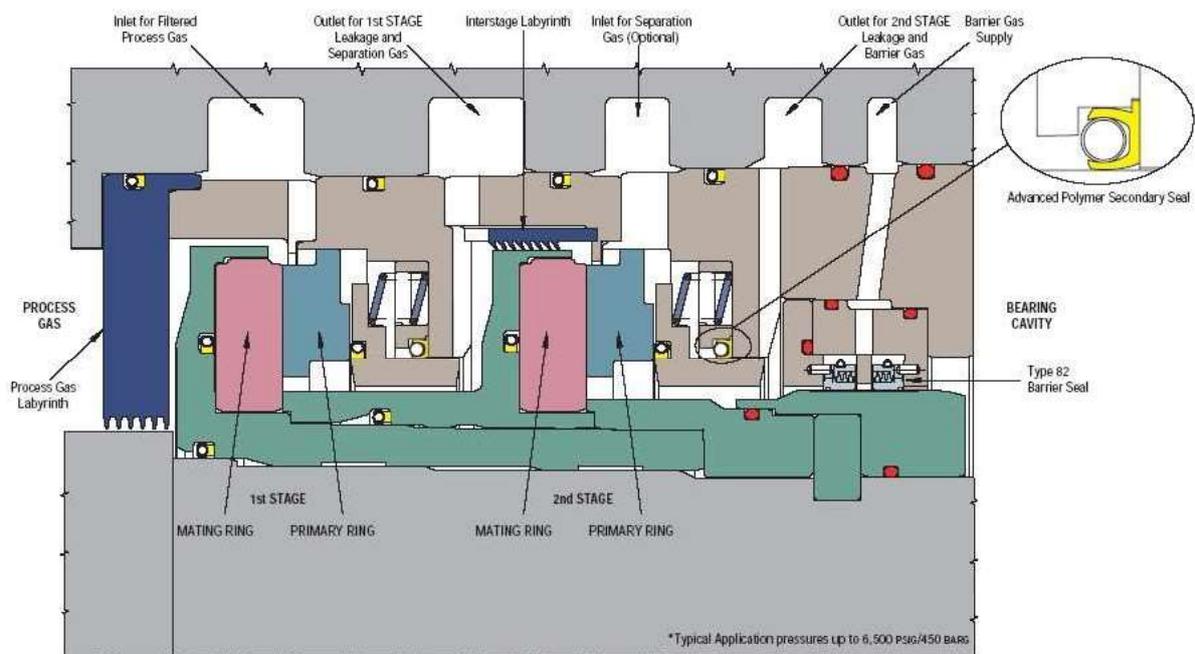
3.27 panel: An enclosure used to mount, display, and protect gauges, switches, and other instruments.

API Sealing Definitions

3.28 primary seal gas: Dry, filtered gas supplied to the high pressure side of a self-acting gas seal.



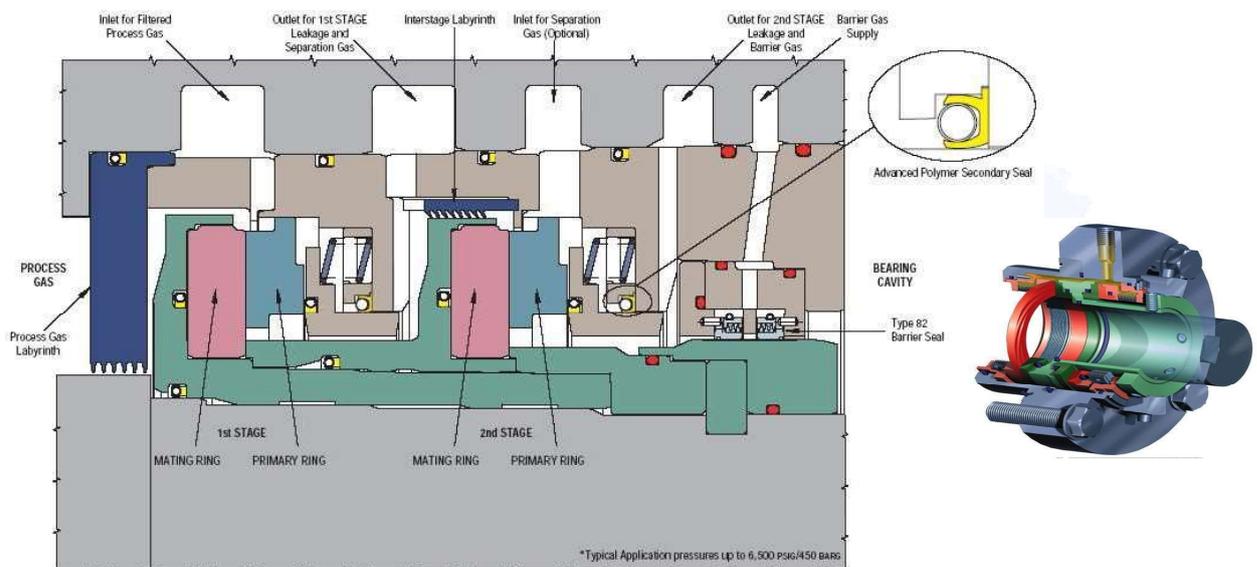
3.30 seal barrier gas: A clean gas supplied to the area between the seals of a dual seal arrangement at a pressure higher than the process pressure.



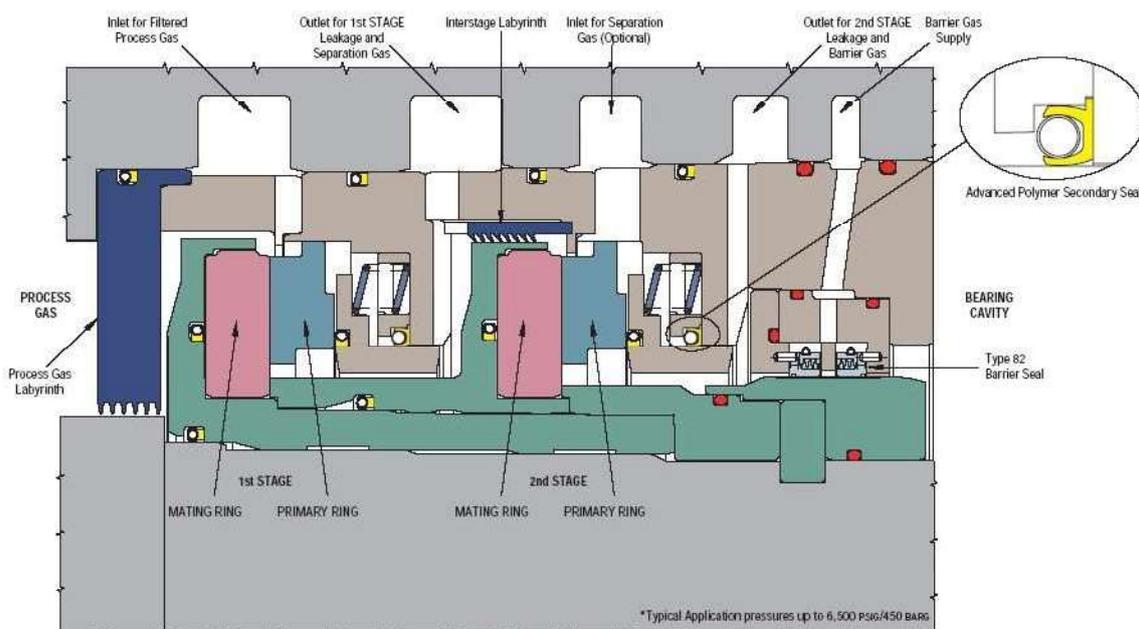
API Sealing Definitions

3.31 seal buffer gas: Clean gas supplied to the high pressure side of a seal.

Note: Seal gas is either supplied from the compressor discharge or from an external source. When supplied from an external source, it is referred to as seal buffer gas.

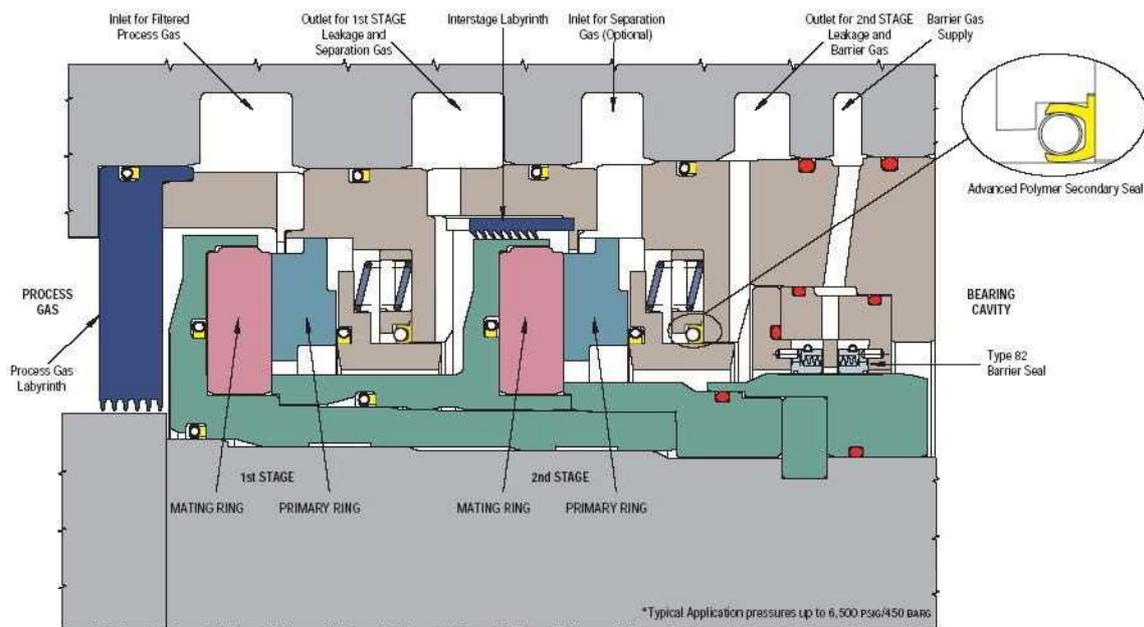


3.32 seal gas leakage: The gas which flows from the high pressure side of the seal to the low pressure side of the seal.



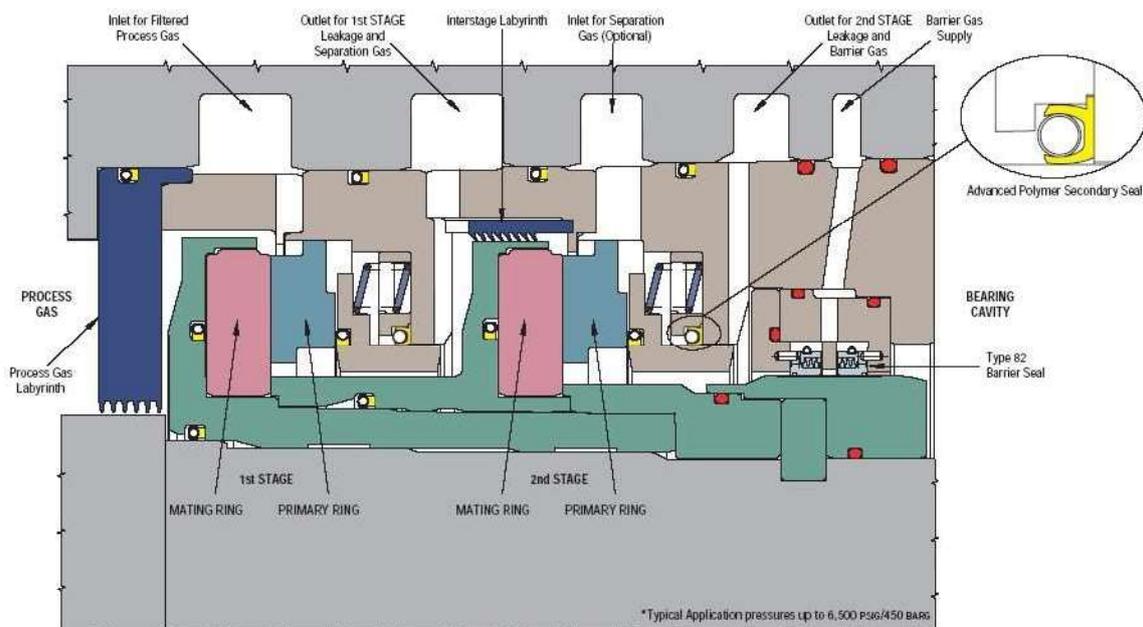
API Sealing Definitions

3.36 separation gas: A supply of inert gas or air fed into the region between the seal and the shaft bearing.



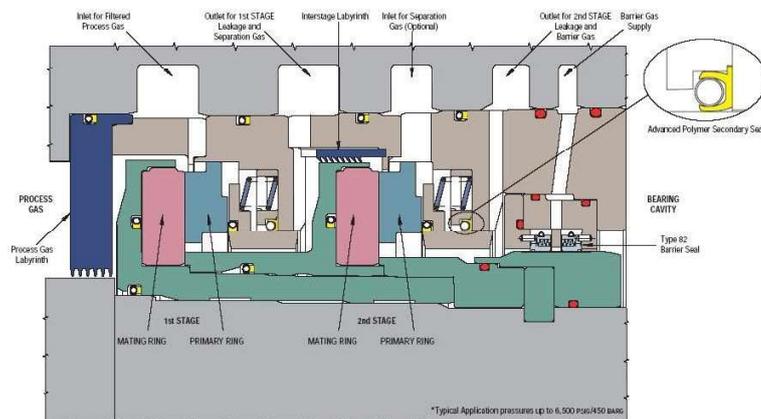
API Sealing Definitions

3.33 secondary seal gas: A clean purge gas supplied to the area between the seals of a tandem self-acting gas seal having an intermediate labyrinth. This gas is at a pressure lower than the process pressure



API Sealing Definitions

3.37 settling-out pressure: The maximum pressure the system can come to under static conditions.



3.47 vent system: The arrangement of piping and valves used to take gas to a safe location.

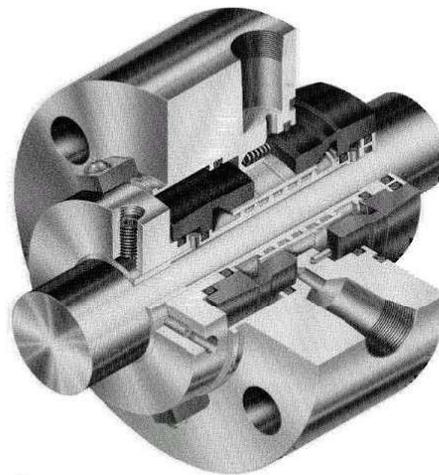
Seals classification

Contacting liquid lubricated seals:

- Normally, a single seal arrangement is cooled and lubricated by the liquid being sealed. This is the most cost-effective seal installation available to the industry.

- Dual seals are arranged to contain a pressurized or non-pressurized barrier or buffer liquid. Normally, this arrangement will be used on applications where the liquid being sealed is not a good lubricating fluid for a seal and for emissions containment.

These arrangements require a lubricatio

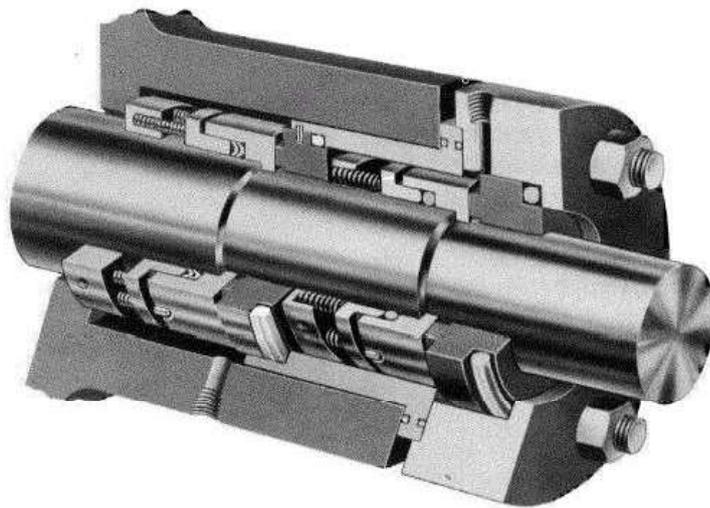


liquids.

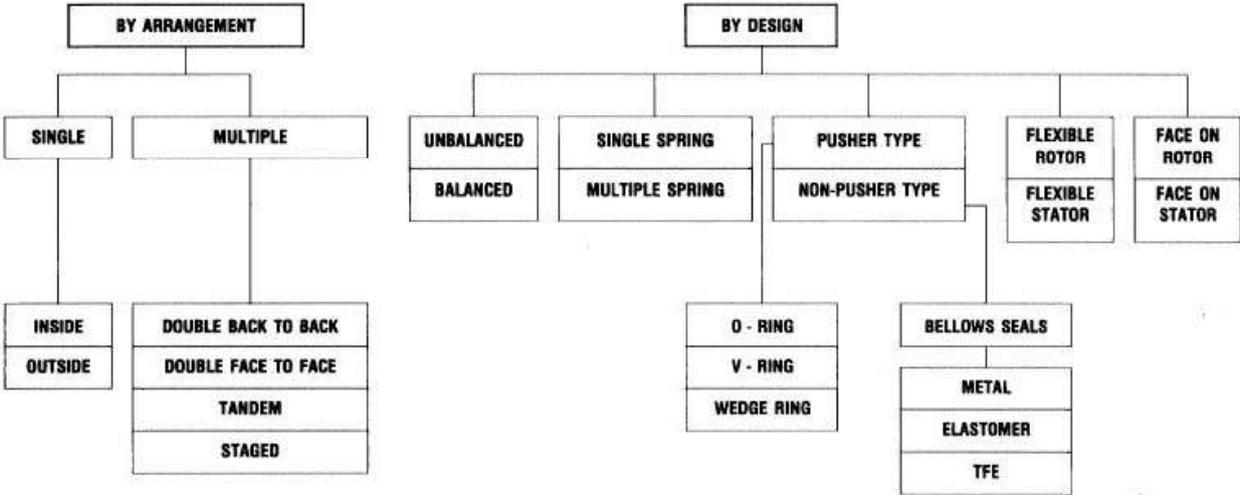
Seals classification

Non-contacting gas lubricated seals:

- Dual non-contacting, gas-lubricated seals are pressurized with an inert gas such as nitrogen.
- Dual non-contacting, gas-lubricated seals are used in a **tandem arrangement** and pressurized by the process liquid being sealed, which is allowed to flash to a gas at the seal. A tandem seal arrangement is used on those liquids that represent a danger to the plant environment. For non-hazardous liquids, a single seal can be used.

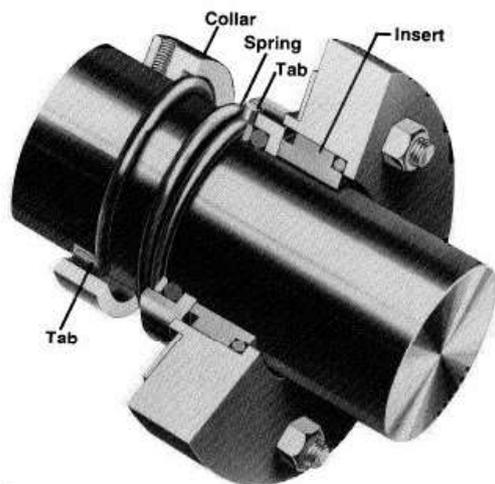


CLASSIFICATION OF MECHANICAL SEAL DESIGNS



Classification of seals By Design

Most mechanical seals can be classified into two basic seal designs: **pusher** seals and **nonpusher** seals. Neither design is inherently better than the other, but an understanding of the differences between the two is necessary for the selection and maintenance of the best design for a specific application.



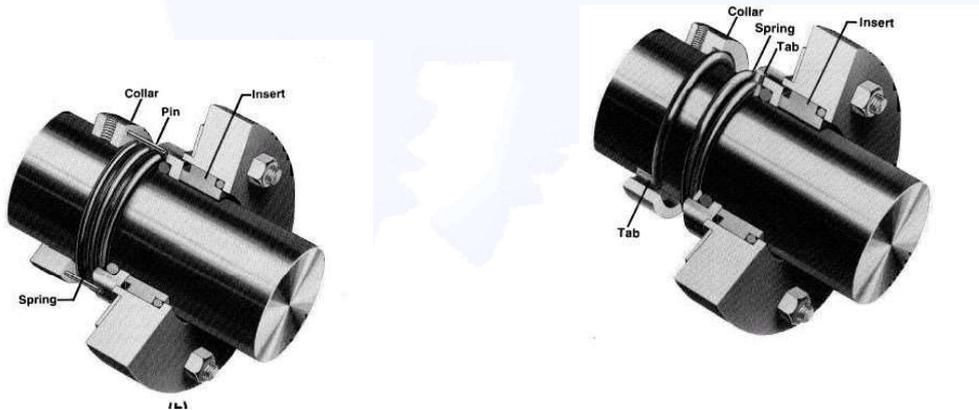
Pusher Type Seals.

Pusher seals incorporate secondary seals that move axially along a shaft or sleeve to maintain contact at the seal faces to compensate for seal face wear and for any seal wobble due to misalignment.

Advantages of Pusher Seals

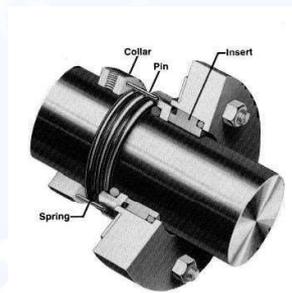
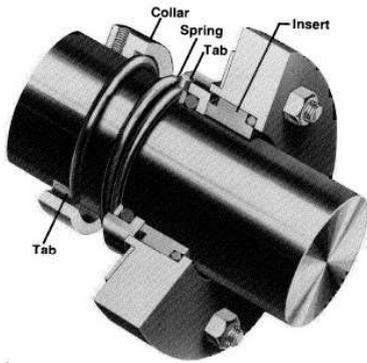
Pusher seals are relatively inexpensive and commercially available in a wide range of sizes for most popular rotating equipment.

Designs are available for high pressure applications and for the low quantity, high technology applications beyond the limits of nonpusher designs.



Limitations of Pusher Seals

Pusher seals rely on secondary seals made of elastomers or TFE resins. These materials can be used with a relatively narrow range of temperature. Swelling due to chemical attack must be limited in pusher seals to less than 5% for dynamic and 10% for static secondary seals. These problems of temperature and chemical attack can often be overcome by creating a compatible environment in the seal chamber, but the initial and continuing cost of environmental controls must be weighed against the cost of alternate seal designs.



A pusher seal is also susceptible to fretting corrosion of the shaft or sleeve. The slightest misalignment of seal or pump components can be transmitted to the seal, causing it to wobble. Then, as the shaft packing moves rapidly over the shaft or sleeve, the protective metal oxide coating can be repeatedly worn off the metal surface, forming a groove that can become a leakage path. Costly shaft or sleeve replacement is often necessary.

PUSHER AND NON-PUSHER SEALS COMPARISSON



	<u>PUSHER SEALS</u>	<u>NON-PUSHER SEALS</u>
COMPRESSION	<ul style="list-style-type: none"> • SINGLE COIL SPRING • MULTIPLE SPRINGS 	<ul style="list-style-type: none"> • WELDED METAL BELLOWS • ELASTOMER BELLOWS
SHAFT PACKING	<ul style="list-style-type: none"> • DYNAMIC 	<ul style="list-style-type: none"> • STATIC
COMMERCIALY AVAILABLE SIZE RANGE	0.5 TO 20 INCHES (13 TO 508 mm)	0.75 TO 12.00 INCHES (19 TO 305 mm)
TEMPERATURE RANGE	-450°F TO 450°F (-268°C TO 232°C)	-450°F TO 800°F (-268°C TO 427°C)
PRESSURE RANGE	TO 3000 psig (20690 kPa)	TO 350 psig (2410 kPa)
TYPICAL DURA SEAL DESIGNS	RO, PTO, CRO, BRO, HS, VRA, MX-201, MSS	CBR/CBS PBR/PBS X-100/X-101 X-200/X-201
ADVANTAGES	<ul style="list-style-type: none"> • BROAD SIZE RANGE • HIGH PRESSURE • SPECIAL DESIGNS AVAILABLE • SPECIAL METALS AVAILABLE 	<ul style="list-style-type: none"> • FEWER PARTS • INHERENTLY BALANCED • NO FRETTING • HIGH TEMPERATURE
COST	OFTEN LOWER	OFTEN HIGHER



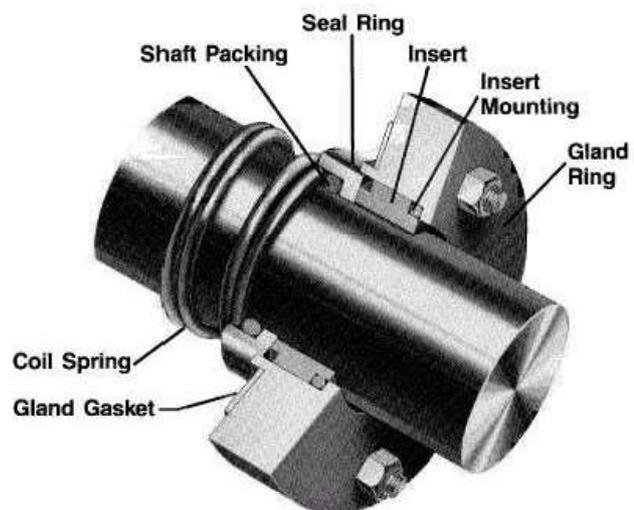
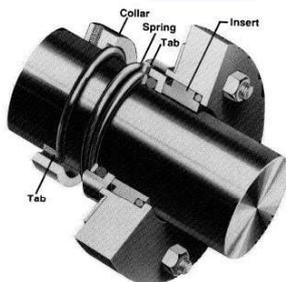
SINGLE COIL SPRING SEALS

SINGLE COIL SPRING SEALS

A mechanical seal using a single coil spring has a wide range of applications. Such a seal features a simple, easy-to-use design with large spring cross-sections which resist corrosion. Its chief limitations are its tendency to distort at high surface speeds, the large axial and radial space it requires, and the necessity to stock a different size spring for each seal size.

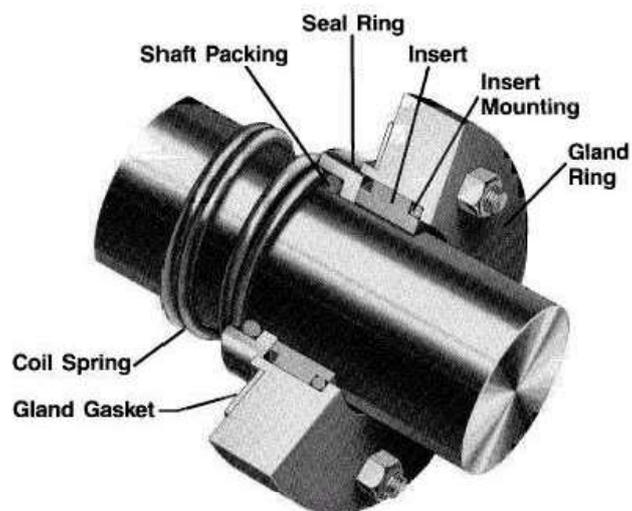
The rotary units of all types of mechanical seals are either

○ Friction drive
or positive drive.



Friction Drive

The simple pusher type seal with a single coil spring is driven by the friction provided by the O-ring shaft packing. The simplicity of this seal limits its range of applications. Because it depends on friction to drive the rotary unit, this seal can only be used with non-lubricating liquids such as water. Seals for use with oil and other lubricating liquids typically have a positive drive - rotary unit.

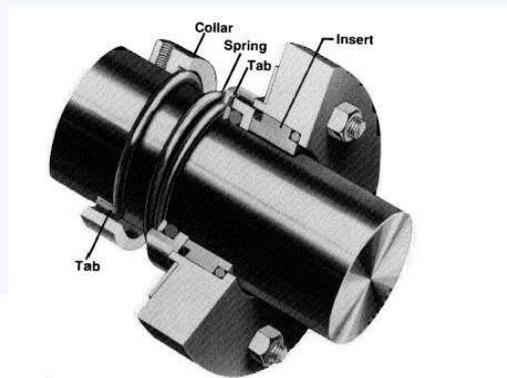


Positive Drive

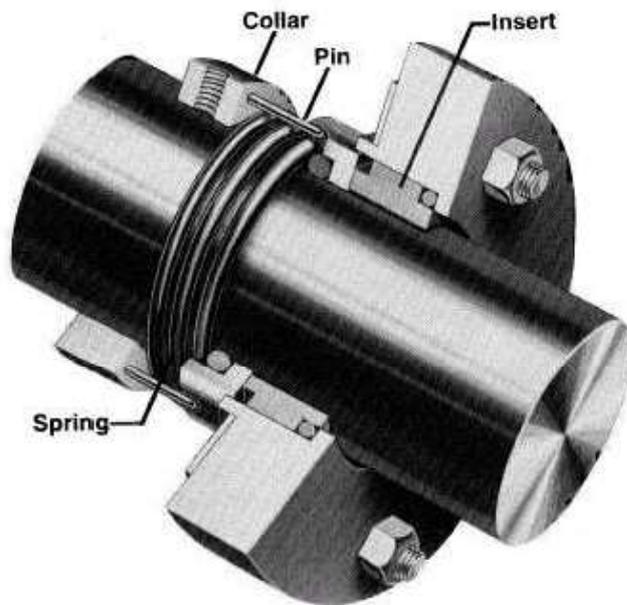
There are two methods of positive drive action in pusher type mechanical seals .

Both methods utilize a collar which is held in position on the shaft with set screws .

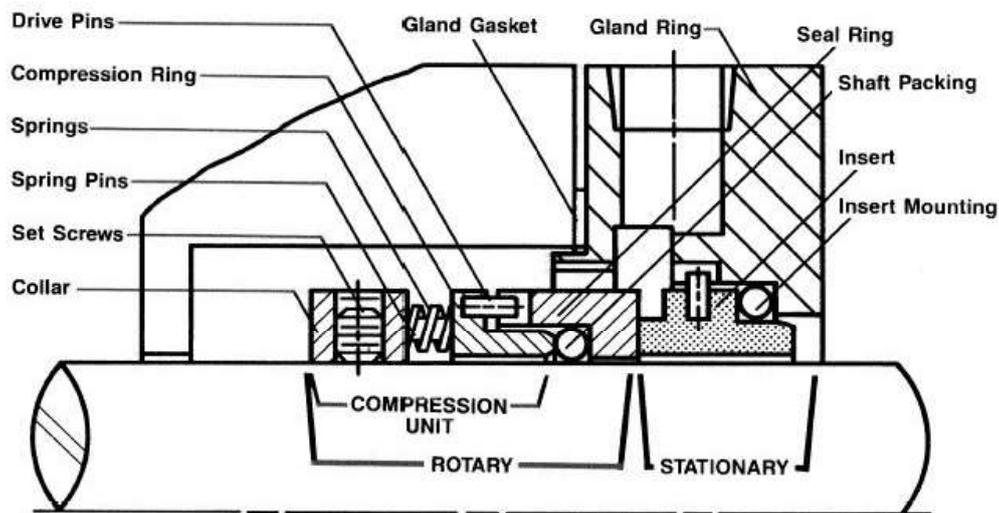
In first method tabs on either end of the spring engage notches in the collar and the seal ring. Thus torque is transmitted from the collar to the seal by the spring.



In second method positive connection achieved by means of pins extending over the spring from the collar to the seal ring. Other positive drive systems, such as lug drives are also available.



MECHANICAL SEAL WITH MULTIPLE SPRINGS



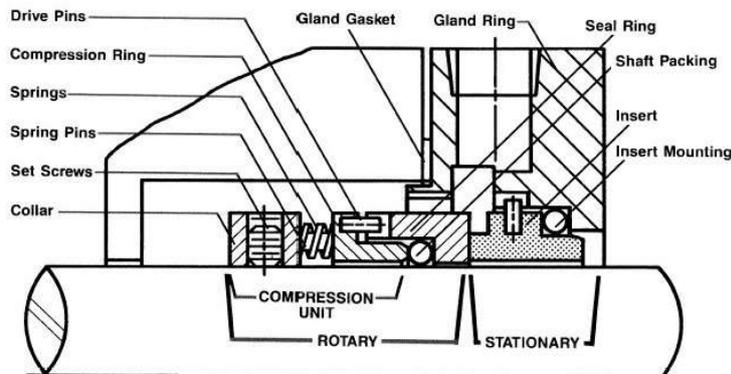
Some applications involving high speeds preclude the use of single coil spring seals. a pusher type seal design which utilizes a number of small coil springs spaced around the rotary unit. These small springs are not as susceptible to distortion at high speeds as are single coil springs, and they consequently exert an even closing pressure on the seal ring at all times. Moreover, the same size spring may be used with a wide range of shaft sizes.

MECHANICAL SEAL WITH MULTIPLE SPRINGS

The Rotary Unit

The collar of a multiple spring seal is normally secured to the shaft by multiple set screws. The sealing points of the above are identical to those of the single coil spring compression ring to the collar.

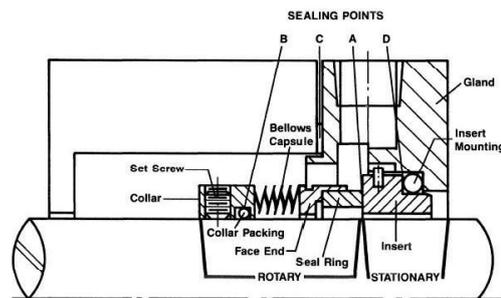
This compression ring presses against and energizes the shaft packing. Additional pins extend from the compression ring and drive the seal ring. The collar, compression ring, pins, springs, and set screws comprise a single unit, the compression unit, which is assembled at the factory.



Non pusher Seals.

• WELDED METAL BELLOWS SEALS

A second basic seal design is the nonpusher seal. The secondary seal in a nonpusher design does not have to move along the shaft or sleeve in order to maintain seal face contact.

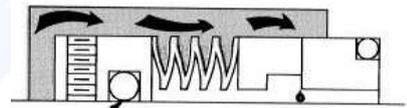
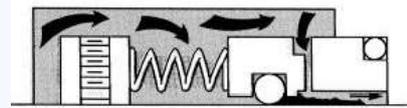
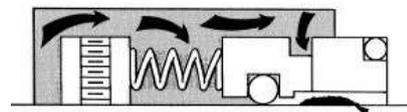
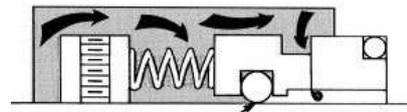


The welded metal and elastomer bellows seals are typical of this design. The bellows itself provides the spring loading necessary to maintain face contact. Because the bellows is a one piece unit supported both around its circumference and along its total length, an even pressure is applied to all points on the seal ring.

Advantages of the Welded Metal Bellows

The welded metal bellows seal offers, a cost-effective solution to a wide range of high and low temperature sealing applications. The welded metal bellows seal design does not require a dynamic shaft packing secondary seal along the shaft.

Therefore, problems due to shaft packing hang-up – wherein the shaft packing is robbed of its ability to move forward to compensate for face wear, misalignment and seal wobble is virtually eliminated. This also eliminates any possibility of shaft fretting which sometimes occurs where pusher type seals are used.

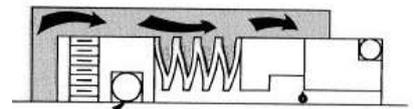
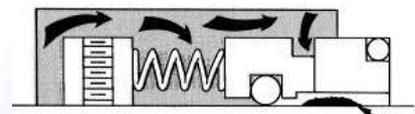
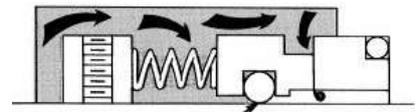


Limitations of Welded Metal Bellows

The welded metal bellows is actually a series of metal washers called leaflets. Because of the thin cross-sections of these leaflets, their metallurgy must be upgraded for use in corrosive environments.

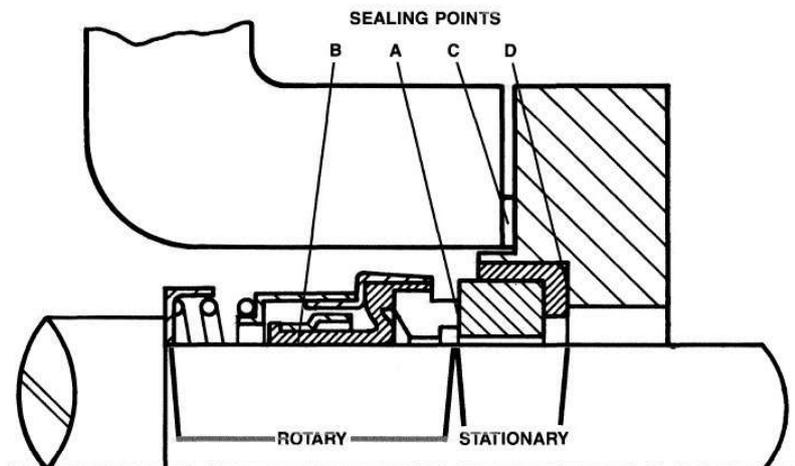
Sealing Points of Welded Metal Bellows

The sealing points of a welded metal bellows seal are the same as those of a pusher seal. Note that the shaft packing is a static secondary seal, which permits a wider range of elastomer selection than is possible with the dynamic shaft packing of a pusher seal.



ELASTOMER BELLOWS SEALS

The elastomer bellows seal, is energized by a single coil spring which fits over the shaft and elastomer bellows. The elastomer bellows seal offers many of the advantages of a metal bellows seal, but it is subject to the same speed limitations as a single coil spring seal.



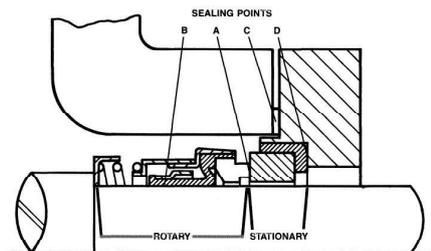
ELASTOMER BELLOWS SEALS

Advantages of Elastomer Bellows Seals

This seal is low cost and readily available in standard sizes and materials in balanced and unbalanced designs. Being a nonpusher seal, it is not subject to shaft packing hang-up.

Limitations of Elastomer Bellows Seals

In addition to speed limitations, this seal is not readily available in special sizes or elastomers, because of the special molding of the bellows it requires. This seal also suffers from repair problems, because the elastomer bellows tends to bond to the shaft.

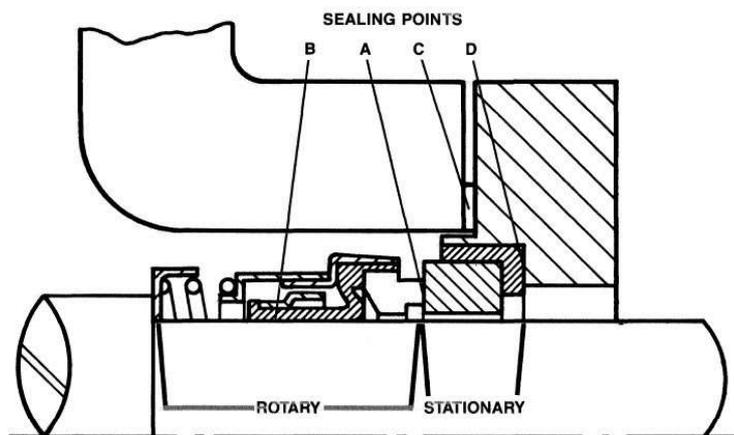


ELASTOMER BELLOWS SEALS

Sealing Points and Drive of Elastomer Bellows Seals.

The sealing points of an elastomer bellows seal are primarily the same as those for conventional seals.

The bellows sleeve grips the shaft at the rear of the rotary unit assembly, transmitting drive to the seal ring. For the location of sealing points and the nomenclature proper to this seal. Although the seal illustrated is a friction drive seal, the increased friction provided by the bellows sleeve exempts this seal from the non-lubricating liquid limitation imposed on conventional O-ring friction drive seals.

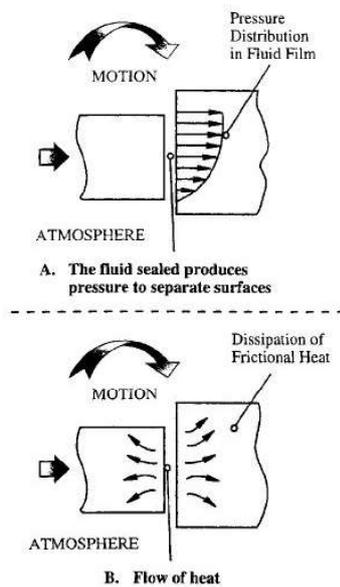


SEAL FORCE ANALOGY

In a contacting seal, as the shaft begins to rotate, a small fluid film develops, along with frictional heat from the surfaces in sliding contact.

These processes occurring at the seal faces

Processes involved at contacting seal faces



The amount of heat developed at the seal faces must be removed to prevent the liquid being sealed from flashing or beginning to carbonize.

Seal heat can be removed with a seal flush located at the seal faces.

SEAL FORCE ANALOGY

To analyze the performance of a seal and determine amount of cooling, calculations shall be made.

Seal Balance

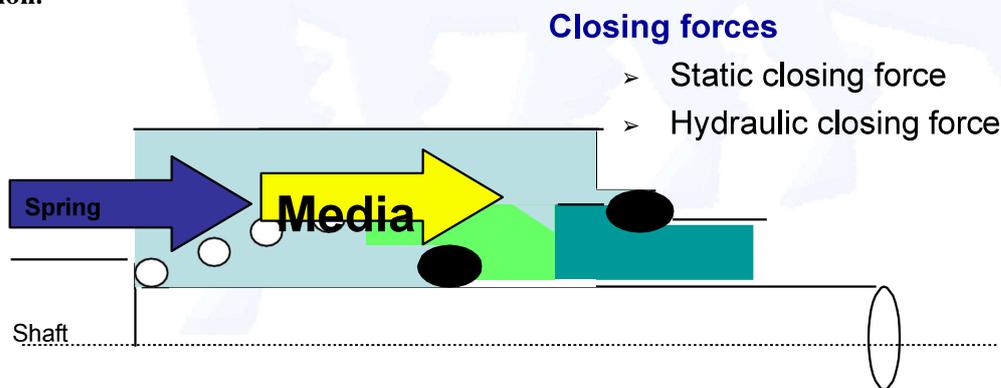
The greatest concern to the seal user is the dynamic contact between the mating seal surfaces.

The performance of this contact determines the effectiveness of the seal. If the load at the seal faces is too high, the liquid at the seal faces will vaporize or carbonize and the seal faces can wear out.

Damage to the seal faces can occur due to unstable conditions.

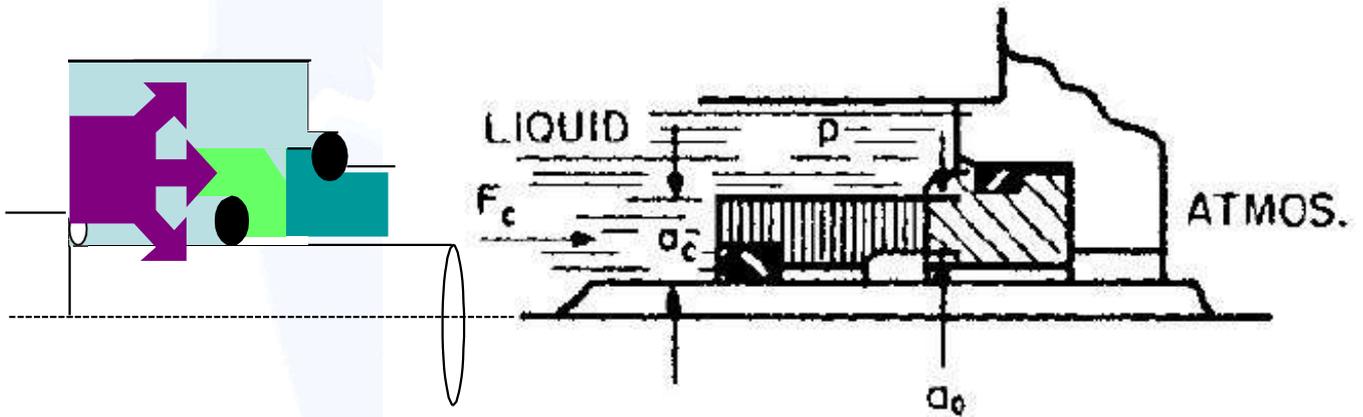
A high wear rate from solid contact and leakage can occur if the bearing limits of the materials are exceeded.

Seal balancing is a feature that is used to avoid these conditions and provide for a more efficient installation.



SEAL FORCE ANALOGY

The pressure in any seal chamber acts equally in all directions and forces the primary ring against the mating ring. Pressure acts only on the annular area ac , so that the force in pounds (Newtons) on the seal face is as follows:



$$F_c = p a_c$$

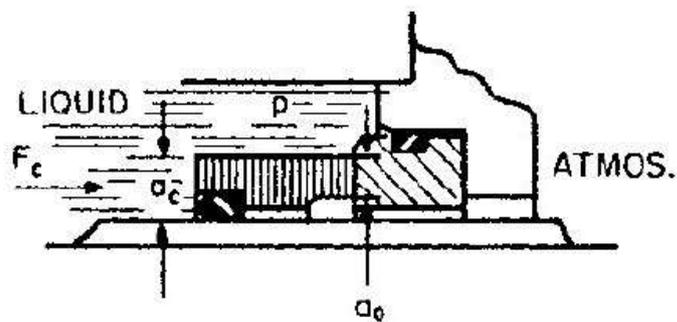
where p seal chamber pressure, lb/in² (N/m²) and a_c hydraulic closing area, in² (m²)

SEAL FORCE ANALOGY

The pressure in lb/in² (N/m²) between the primary ring and mating ring is

$$P'_f = \frac{F_c}{a_o} = \frac{p a_c}{a_o}$$

Where a_o hydraulic opening area (seal face area), in 2(m²)

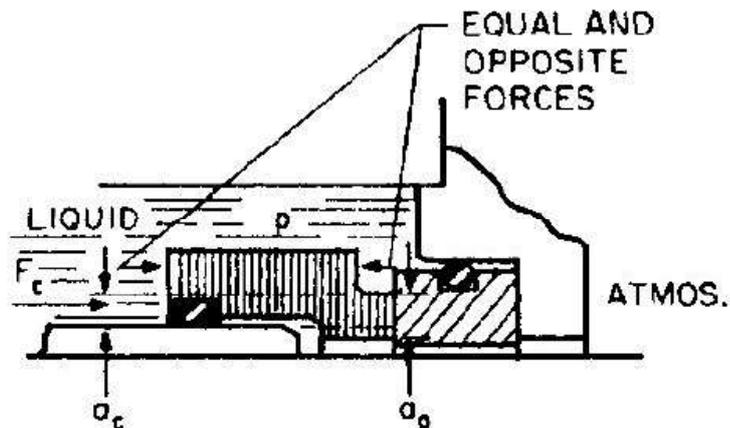


(a)

SEAL FORCE ANALOGY

To relieve the pressure at the seal faces, the relationship between the opening and closing forces can be controlled.

If a_o is held constant and a_c is decreased by a shoulder on a sleeve or seal hardware, the seal face pressure can be lowered.



This is called *seal balancing*. A seal without a shoulder in the design is referred to as an *unbalanced seal*.

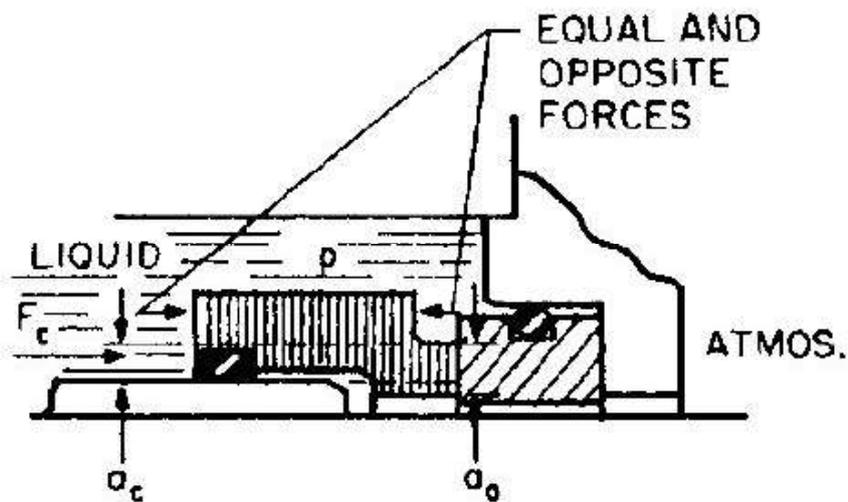
A balanced seal is designed to operate with a shoulder.

The ratio of the hydraulic closing area to the face area is defined as seal balance b :

$$b = \frac{a_c}{a_o}$$

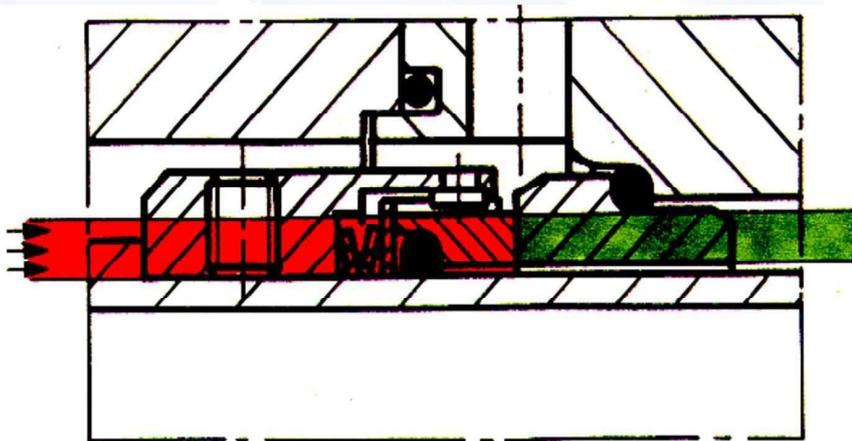
SEAL FORCE ANALOGY

This is typical for a seal mounted inside the seal chamber. Seals installed outside the seal chamber can be balanced for pressure at the inside diameter of the seal faces. In special cases, seals can be double-balanced for pressure at both the outside and inside diameters of the seal. Seal balances can range from 0.65 to 1.35, depending on operating conditions.



SEAL FORCE ANALOGY

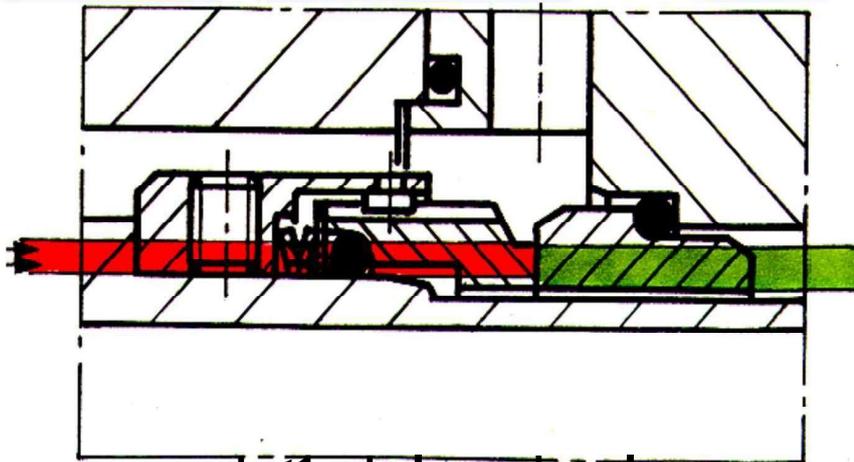
Unbalanced seals



- ◆ $k > 1$ = unbalanced seal
- ◆ used in the standard pressure range

SEAL FORCE ANALOGY

Balanced seals

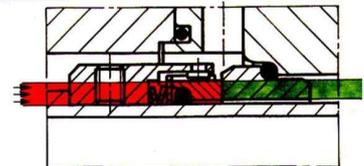


◆ $k < 1$ = balanced seal

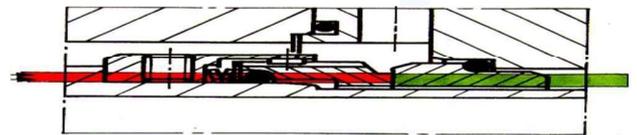
- ◆ used in the high pressure range and for sensitive media

Unbalanced / balanced seals

- ◆ Balance ratio of a seal



$$k = \frac{\text{hydraulic loaded area}}{\text{sliding face area}}$$



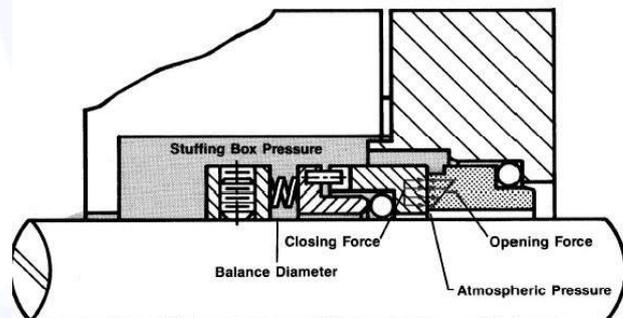
- ◆ Necessary to reduce the face load of a seal

VARIATION OF BASIC SEAL DESIGN

All basic seal designs can be modified to meet the specific requirements of the application. Many variations exist to meet specific operating conditions and environmental limitations. It is important to stress that no single type of seal is better than any other. Each must be evaluated solely on how well it meets the requirements of the application for which it was designed.

Unbalanced Seals

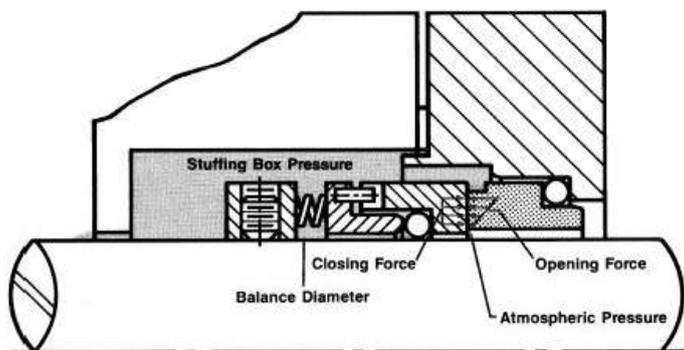
Unbalanced seals are often the design of choice for inside seals. The amount of seal face leakage is inversely proportional to the amount of seal face loading the higher the loading, the lower the face leakage. Unbalanced seals, having higher face loadings than balanced seals, leak less and are more stable when subjected to vibration, misalignment, or cavitation. They are often less expensive and more adaptable to standard stuffing boxes without the need for modification of either the shaft sleeve or the stuffing box.



Unbalanced Seals

One of the disadvantages of an unbalanced seal is its relatively low pressure limit. If the closing force exerted on the seal face exceeds that limit, the liquid lubricating film between the faces is squeezed out.

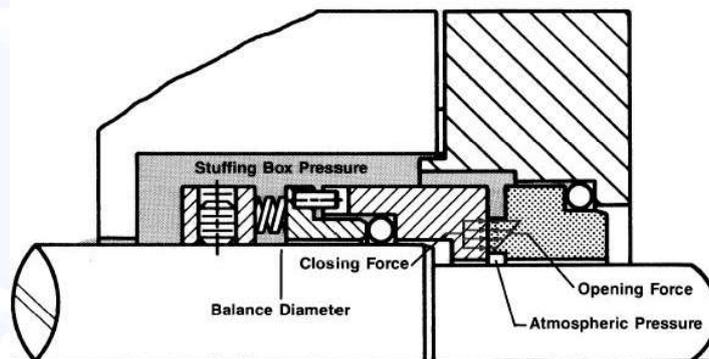
Deprived of lubrication and highly loaded, the faces soon destroy themselves. This problem is overcome by balancing the seal.



Balanced Seals

Balancing a seal involves a simple design change which reduces the hydraulic forces acting to close the seal faces. It has nothing to do with the dynamic balancing as performed on an automobile tire or a centrifugal pump impeller.

IN SIDE BALANCED SEAL



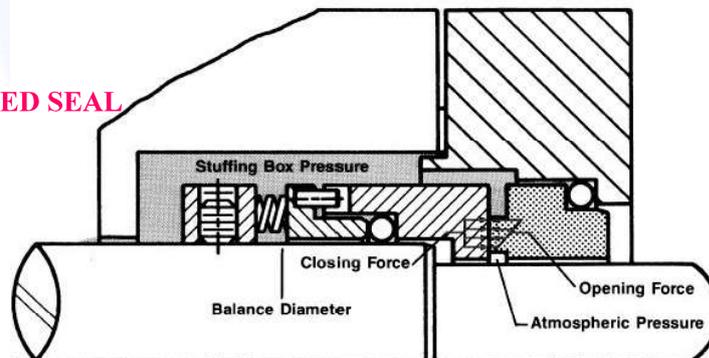
As seal faces rub together, the amount of heat they generate is determined by the amount of pressure applied, the lubricating film layer between the surfaces, and the relative speed of movement. High pressures and high velocities can produce excessive heat.

Balanced Seals

When excessive heat is generated, it can be removed by increasing the lubrication between the faces. Lubrication can be increased by reducing the effect of the seal cavity hydraulic pressure on the seal faces. Seal faces are held apart by a film of sealing fluid. The spring load and stuffing box hydraulic pressure act together on the exposed area of the seal ring to keep the faces closed, restricting leakage to an acceptable, usually undetectable, level.

The hydraulic pressure surrounding the seal acts equally in all directions on all parts of the seal. Increases in pressure within the seal chamber result in an increase of closing force, much as an increase of pressure within a hydraulic cylinder increases the force of a piston. Continuing this analogy: where pressure is constant, force may be reduced by changing the size of the piston.

IN SIDE BALLANCED SEAL

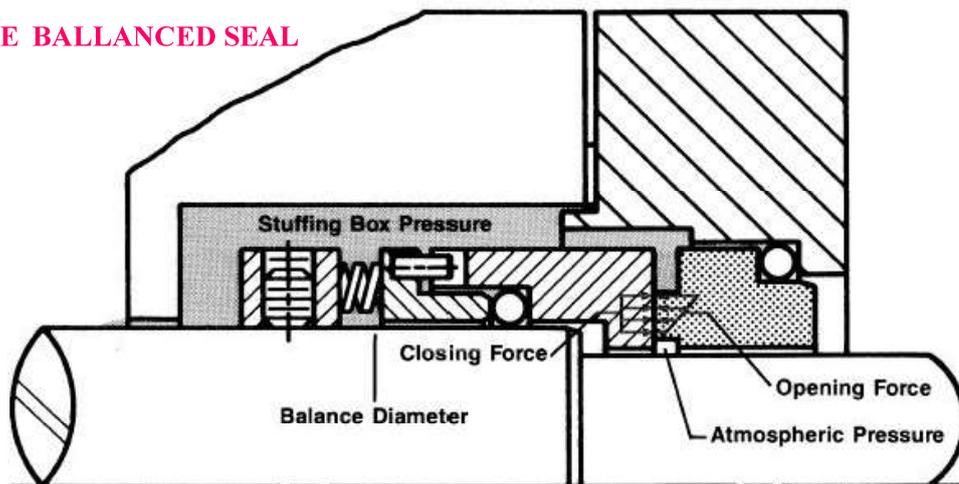


Balanced Seals

Balancing a typical inside seal involves reducing the area of the piston that the hydraulic forces can act upon. This is done by building a step in the sleeve which allows the wear nose of the stationary insert to be moved toward the center of the seal.

'More of the seal ring face is thus exposed to the seal chamber pressure, which, in turn, reduces the forces acting to close the seal faces.

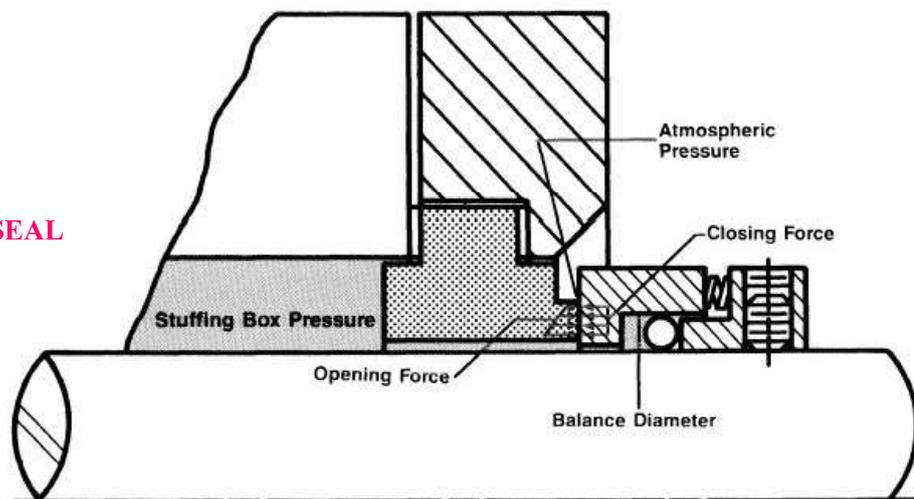
IN SIDE BALLANCED SEAL



Balanced Seals

The method of balancing an outside seal is the same as that for balancing an inside seal, except the action is just the reverse.

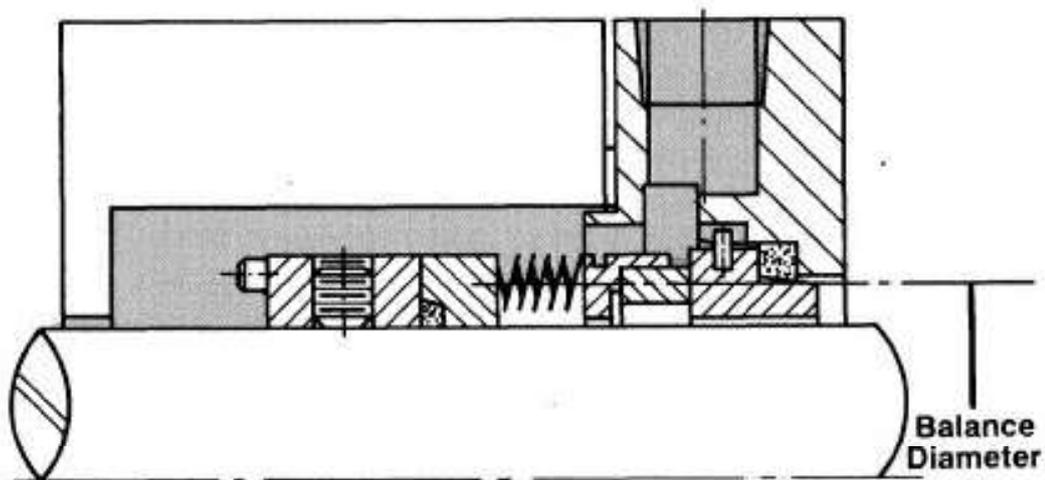
OUT SIDE BALANCED SEAL



The shaft packing is forced against the collar, leaving an area under the seal ring exposed to stuffing box pressure. The closing force exerted by the stuffing box pressure acting against the shoulder of the seal ring is slightly greater than the opening force exerted by the liquid film between the faces, thereby keeping the seal faces in contact at all times.

INSIDE WELDED METAL BELLOWS SEAL

Bellows seals are inherently balanced. The balance diameter must be determined at each given pressure because of leaflet distortion. At low pressures, the balance diameter -otherwise known as the **effective average diameter** of the bellows diameter-approximates the capsule.

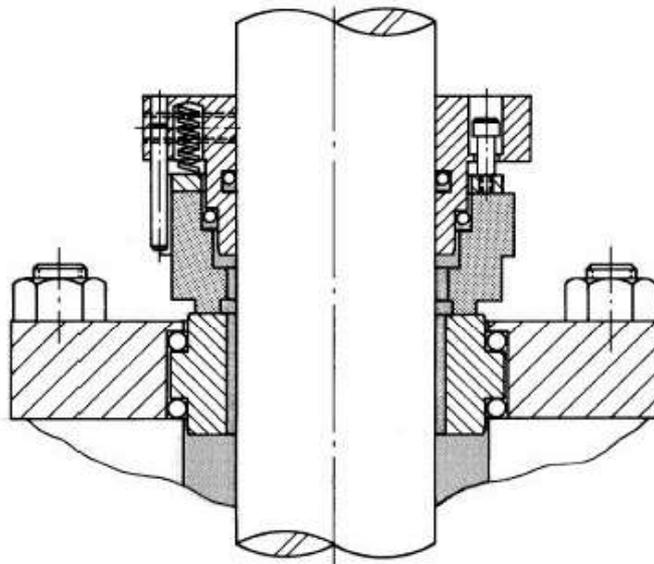


Mixer Seals

Applications requiring a high degree of radial deflection, such as mixers, require specially designed seals. The design must allow the shaft to deflect without damaging the seal parts. The seal faces must be designed to remain in contact during shaft deflection.

Under most conditions of shaft speed and pressure, the seal can be run dry: i.e., there can be a lubricating gas film between the seal faces.

The selection of the appropriate seal design is critical for these applications.



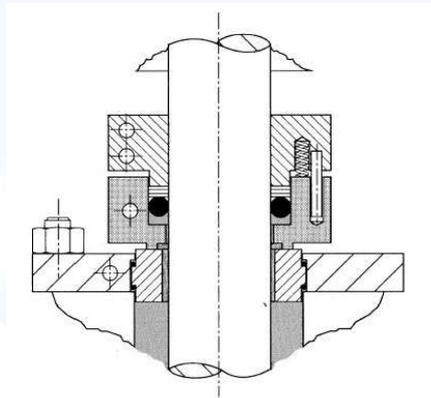
Split Seals

Split seals are available for applications involving equipment where it is hard to access the end of the shaft. This is most common with agitators or pump designs where access to the shaft sealing area from either the agitator, impeller, or drive end is difficult or impossible.

For these cases, special seal designs are available where either all or the replaceable components are split along the axis of the shaft.

These seals can be installed without equipment tear down and can be designed to run in dry or wet environments. The primary sealing faces must be carbon, ceramic, or a carbide that can be fractured cleanly into two pieces. The secondary elastomer seals are mechanically bonded or glued to produce a leak tight joint.

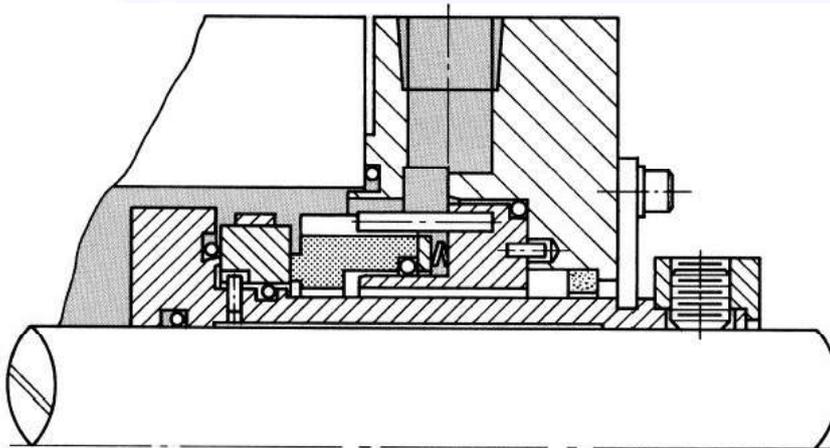
Machined two piece collars and glands are bolted together to hold the primary seal joints in a complete leak free assembly.



High Performance Seals

Applications involving seal chamber pressures over 600 psig (4140 kPa) or shaft speeds over 4500 fpm (23 m/s) require special seal designs.

Seal components are designed using Finite Element Analysis (FEA) engineering computer programs to define dimensions, leakage rates, and materials, as well as opening, closing, and centrifugal forces. In general, part cross sections are larger, compression springs become stationary, and gland insert mounting finishes are ground to **32 RMS** finish to ensure flatness to reduce distortion.

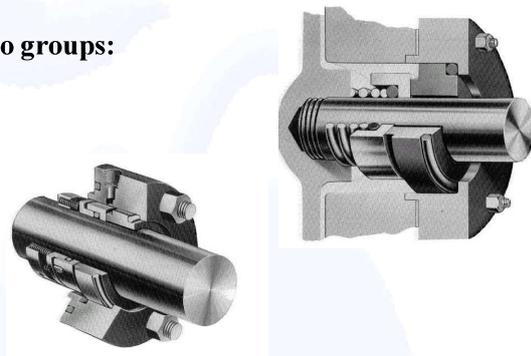


CLASSIFICATION OF SEALS BY ARRANGEMENT

Sealing arrangements can be classified into two groups:

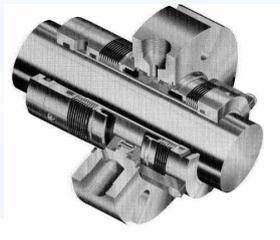
1. Single seal installations

- a. Internally mounted**
- b. Externally mounted**



2. Multiple seal installations

- a. Double seals**

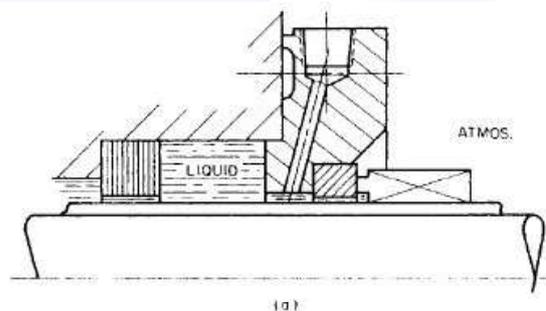


- b. Tandem seals**

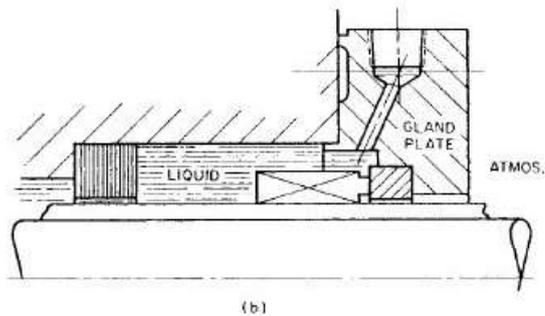


Single seals are used in most applications. This is the simplest seal arrangement with the least number of parts. An installation can be referred to as *inside-mounted* or *outsidemounted*, depending on whether the seal is mounted inside or outside the seal chamber.

Single seal installations:
a) outside mounted,
b) inside mounted



The most common installation is an inside-mounted seal. Here the liquid under pressure acts with the spring load to keep the seal faces in contact.

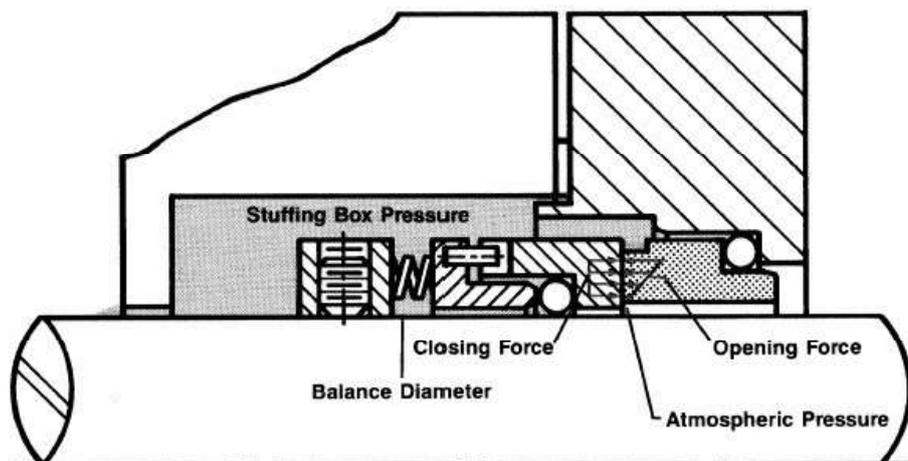


Outside-mounted seals are considered to be used for low-pressure applications since both seal faces, the primary ring and mating ring, are put in tension. This limits the pressure capability of the seal. An external seal installation is used to minimize corrosion that might occur if the metal parts of the seal were directly exposed to the liquid being sealed.

SINGLE INSIDE SIDE SEAL

These seals are easily modified to accommodate environmental controls and can be balanced to withstand high stuffing box pressures.

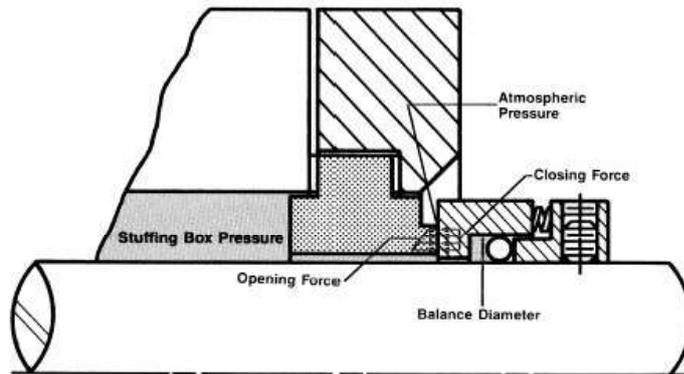
Inside seals require a suitable stuffing box housing for installation and cannot be adjusted without dismantling the equipment unless they are cartridge mounted.



- The materials of construction for the inside seal are selected to withstand corrosive liquids in the stuffing box.

Outside Seals

If an extremely corrosive liquid has satisfactory lubricating properties, an outside seal offers an economical alternative to the expensive metallurgies required for an inside seal to resist corrosion.

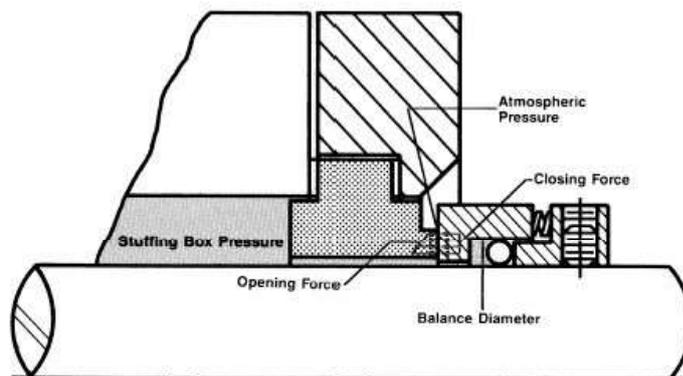


○ Above figure illustrate typical outside seal arrangement in which only the insert, seal ring and secondary seals are exposed to the product. All these components can be nonmetallic. The metallic rotary unit parts are exposed to the atmosphere.

Outside Seals

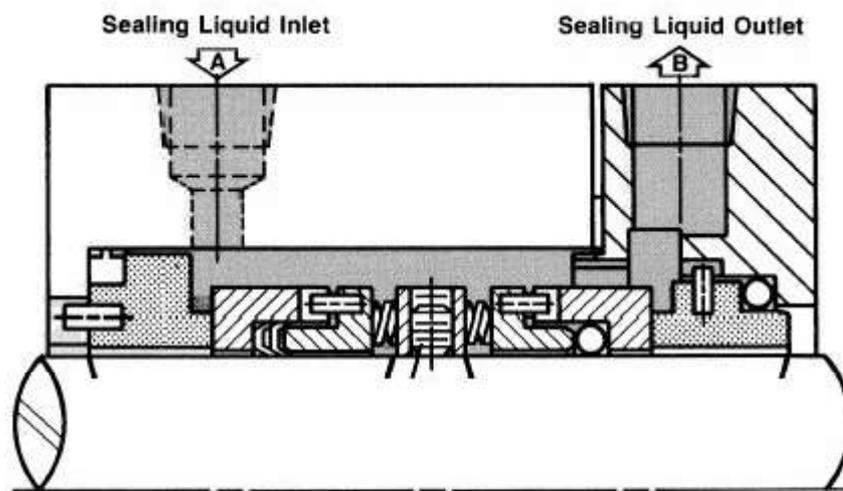
Outside seals can also be used in equipment with stuffing boxes which will not accommodate inside seals, and they are easier to access for adjustment and troubleshooting .

The outside seal does have **disadvantages**. Because it is exposed, the seal is vulnerable to damage from impact. Of greater importance, however, is an outside seal's pressure limitation.

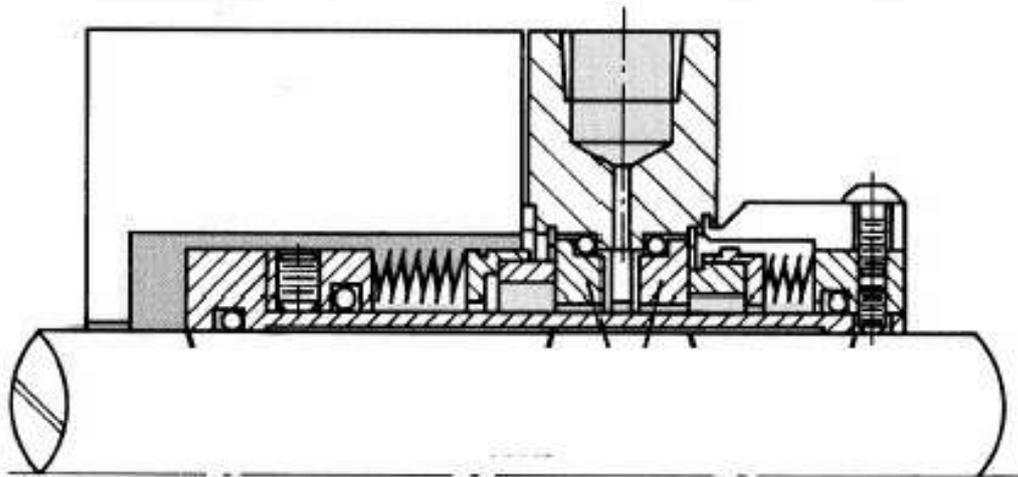


hydraulic pressure on an unbalanced outside seal works to open, rather than to close, the seal faces. The seal, therefore, relies upon the springs to maintain face contact. Even though a degree of balance can be designed into a balanced outside seal . **all outside seals are limited to applications having moderate pressures.**

Seal parts identification



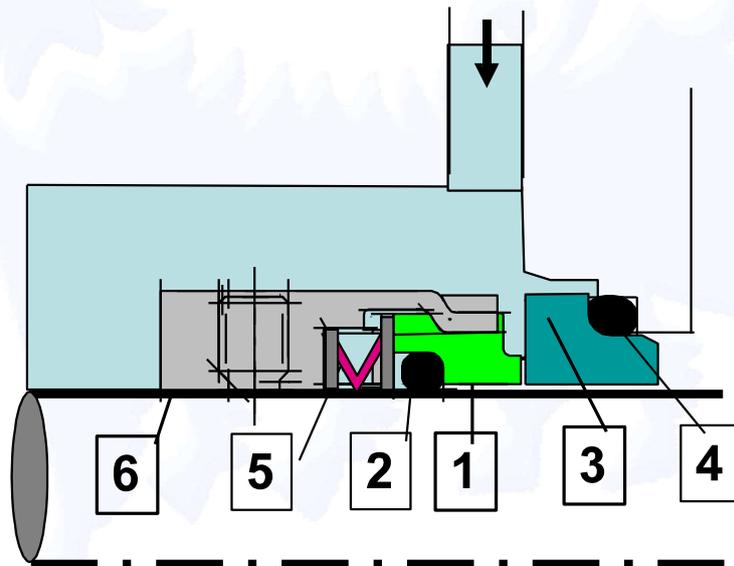
Seal parts identification



Seal parts identification



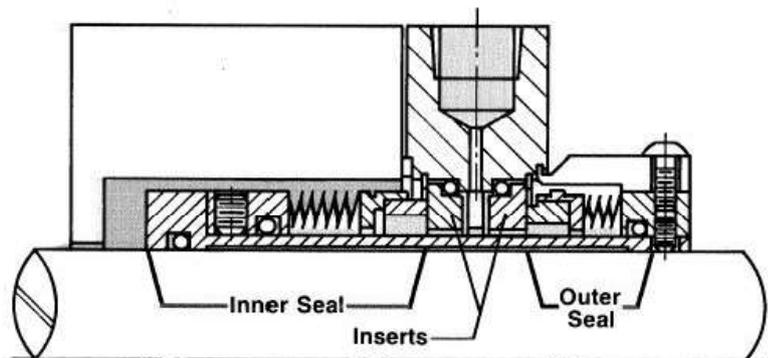
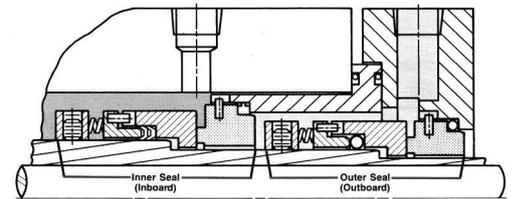
Seal parts identification



Multiple seals

are used in applications requiring

- A neutral liquid for lubrication
- Improved corrosion resistance
- A buffered area for plant safety

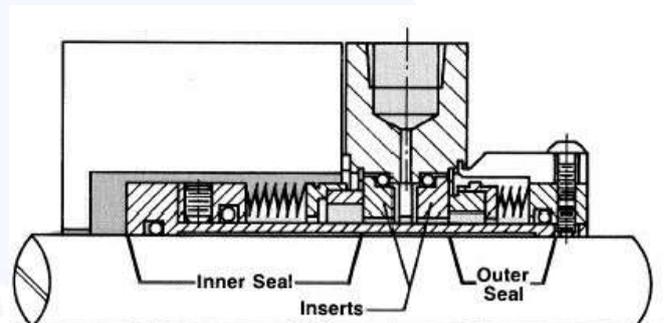
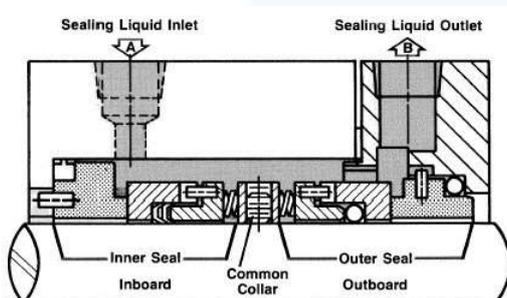


Double Seals

Some products are not compatible with a single mechanical seal.

Examples include toxic liquids whose leakage into the environment would be hazardous, liquids whose suspended abrasives would rapidly wear the faces, or corrosive liquids requiring seals made of costly materials.

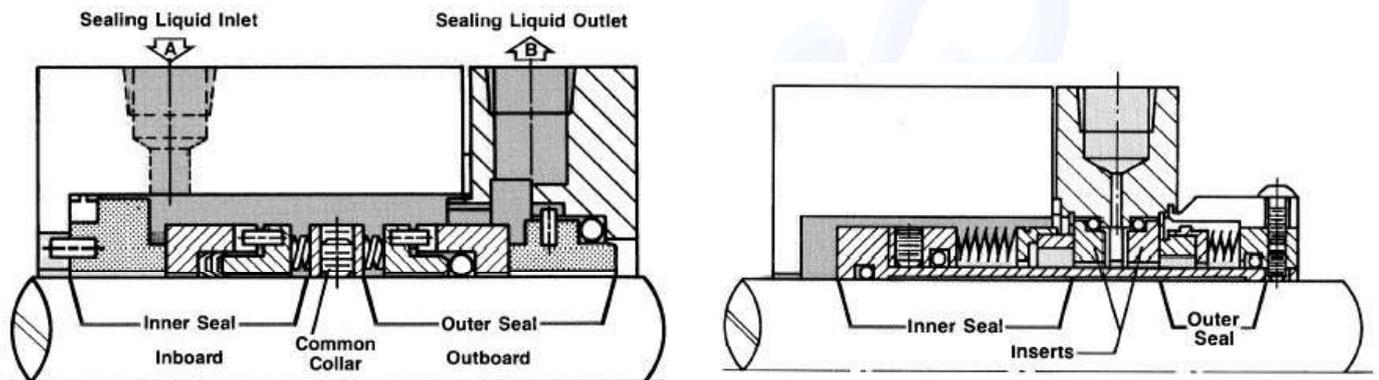
There are two ways to design for such products.



Double Seal Arrangement

There are two ways to design for such products.

- One method is to incorporate environmental control
- A more economical solution may lie in the application of double mechanical seals.

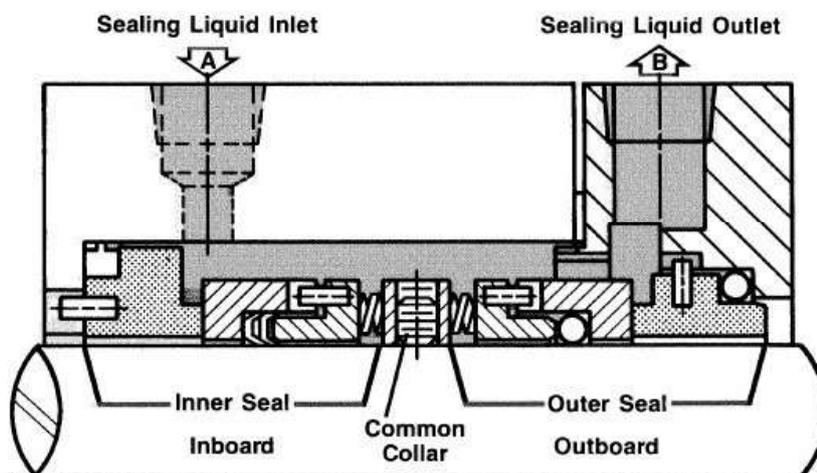


There are two basic double seal arrangements: **back-to-back** and **face-to-face**.

It is necessary to understand the differences between these two arrangements in order to select the best design for a specific application.

DOUBLE BACK-TO-BACK SEALS

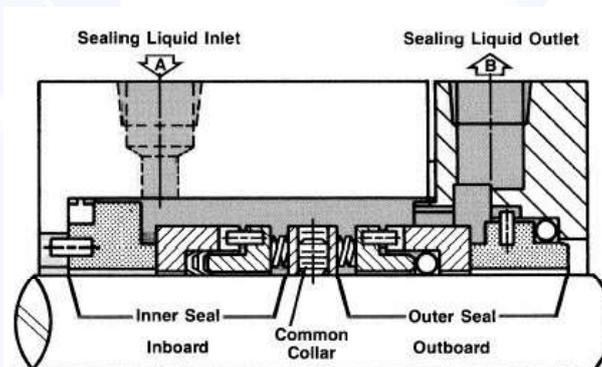
The inboard seal prevents the barrier fluid from entering the product, and the outboard seal prevents it from escaping to the atmosphere. The double seal is unaffected by the product being pumped.



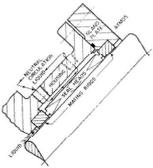
The life of a double back-to-back seal can be up to five times that of a single seal in certain severe environments. The metal inner seal parts are never exposed to the product, so viscous, abrasive or thermosetting products can be easily sealed without a need for expensive metallurgy. The differential pressure across the inner seal is the difference between the barrier fluid pressure and the product pressure acting on the seal housing.

DOUBLE BACK-TO-BACK SEALS

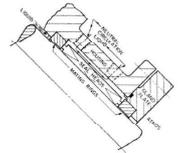
○A compatible liquid, usually water, is injected into the seal chamber at Point A and exits at Point B. This liquid, called the barrier fluid, must be maintained between the seals at a higher pressure than that of the product behind the impeller.



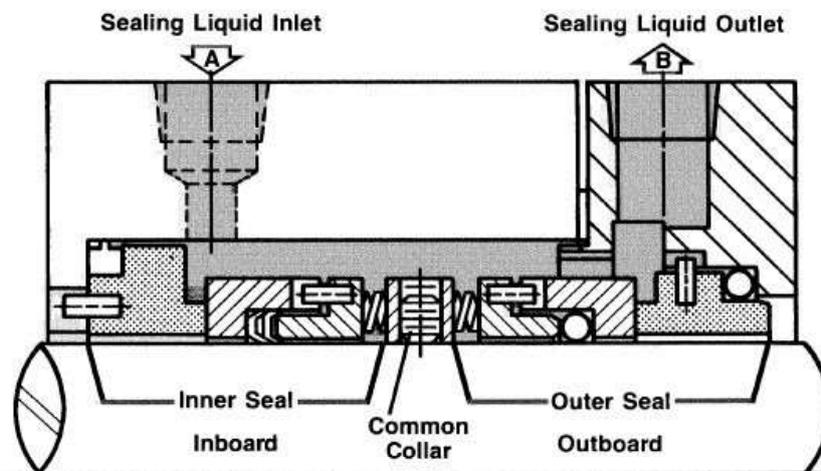
A valve located beyond Point B maintains this higher pressure within the double seal and, at the same time, permits a minimal circulation of water through the box to carry away heat generated by friction at the seal faces. In this design, the **barrier fluid** prevents the product from contacting the inner portion of the seal and provides lubrication to both sets of seal faces.



DOUBLE BACK-TO-BACK SEALS

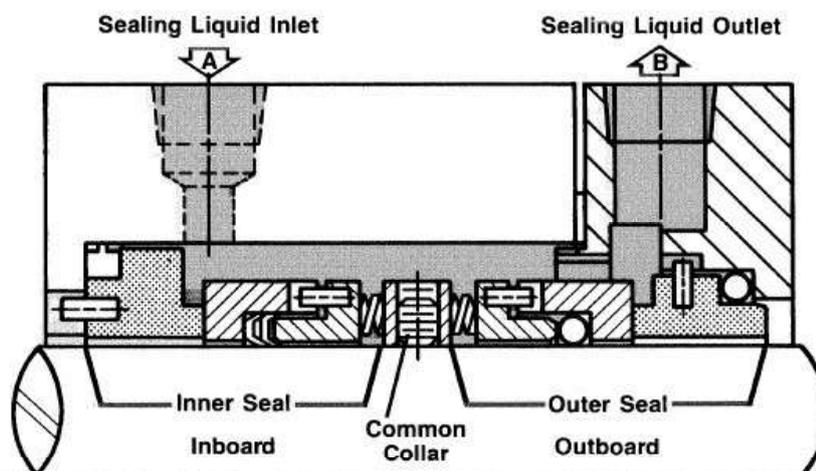


The differential pressure across the outer seal is the difference in pressure between the barrier fluid and the atmosphere.
Either or both of the components of a double seal may be balanced if the differential pressures exceed the limitations of an unbalanced seal.



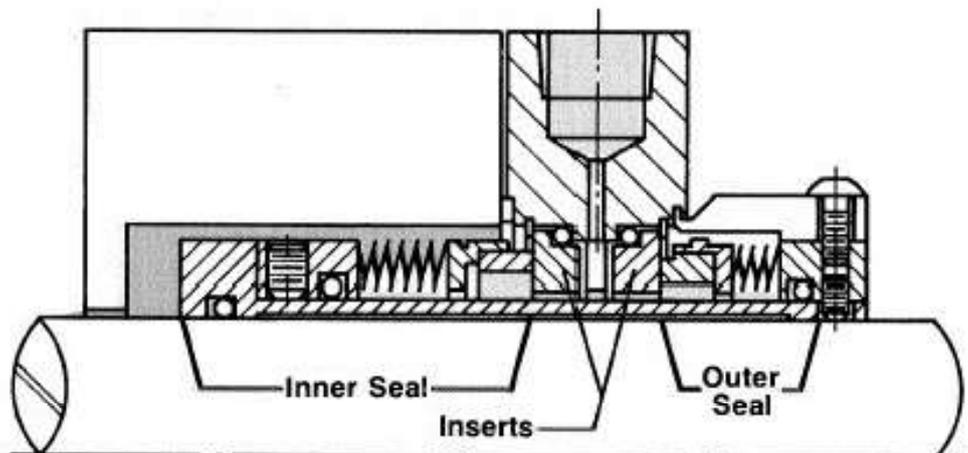
DOUBLE BACK-TO-BACK SEALS

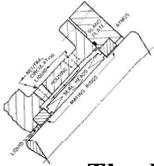
The seal's **performance** cannot be verified until it is actually assembled in the pump.



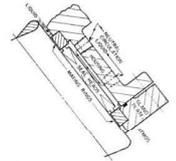
DOUBLE FACE-TO-FACE SEALS

Sometimes a stuffing box is too **shallow** to accommodate double back-to-back seals. An alternate seal arrangement for use in such cases is the double face-to-face seal.

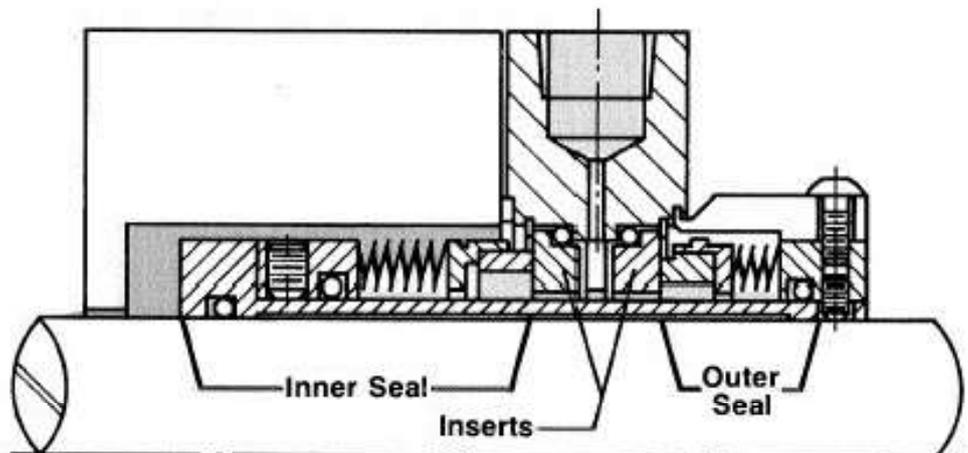


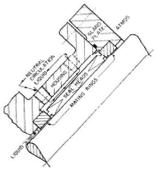


DOUBLE FACE-TO-FACE SEALS

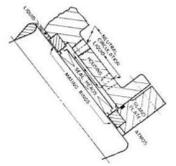


The double face-to-face seal is usually cartridge mounted with one seal inside the stuffing box and one seal on the outside. Both seals rotate against common or separate stationary inserts. seal. If the liquid between the seals is at a **higher** pressure than the product in the stuffing box, the inner seal is *lubricated* by a sealing liquid. This creation of an artificial environment for the mechanical seal is the role of a true double seal.

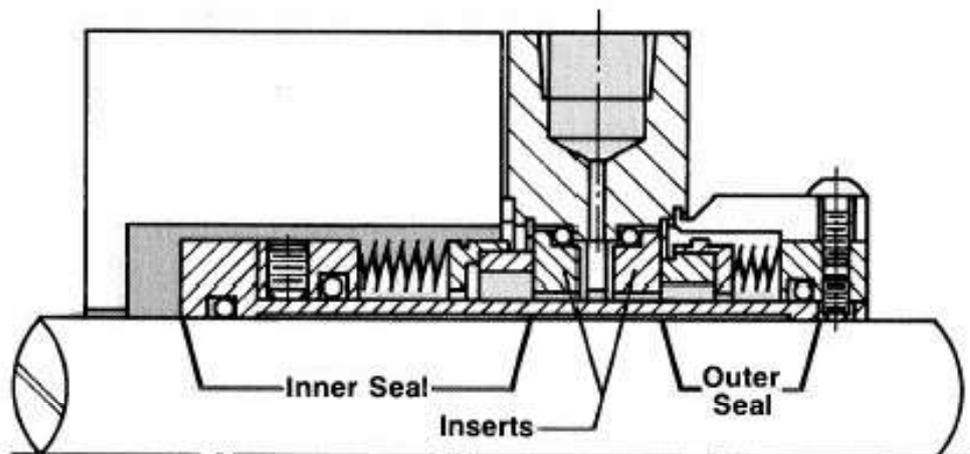




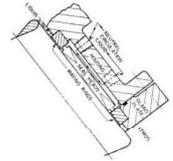
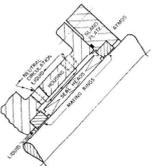
DOUBLE FACE-TO-FACE SEALS



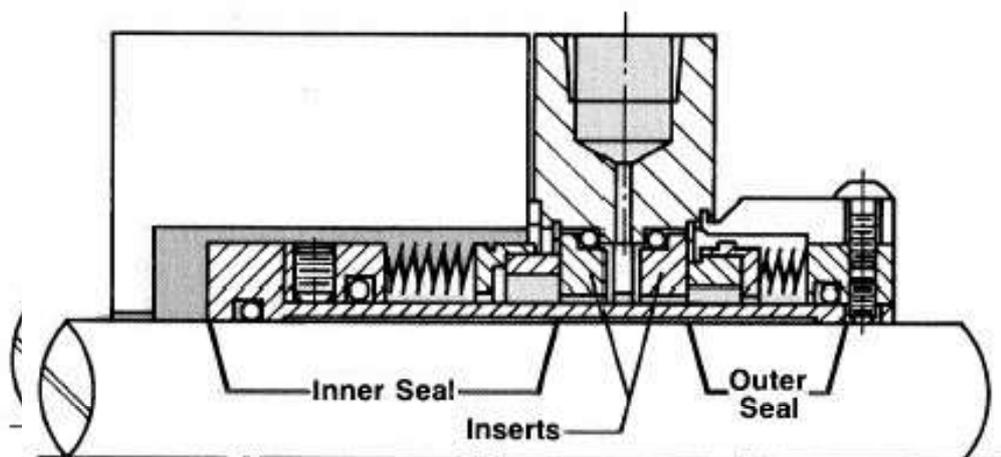
On the other hand, if the liquid is circulated between the seals at a lower pressure than the equipment stuffing box pressure, the purpose of the inner seal is the same as that of any single seal, and the outer seal simply serves as a backup or a tandem seal.

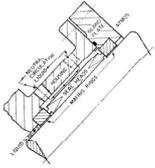


DOUBLE FACE-TO-FACE SEALS

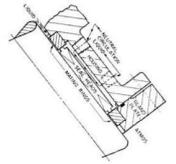


The double face-to-face seal cartridge, assembled at the factory, is compact and easy to install; it can be bench tested, using air as a barrier fluid, before pump assembly; and pressure reversals will not cause it to blow open.

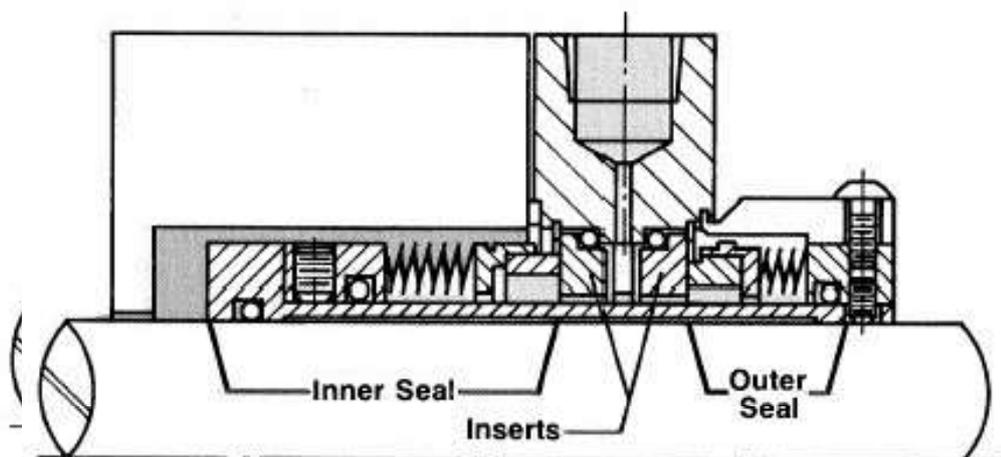




DOUBLE FACE-TO-FACE SEALS



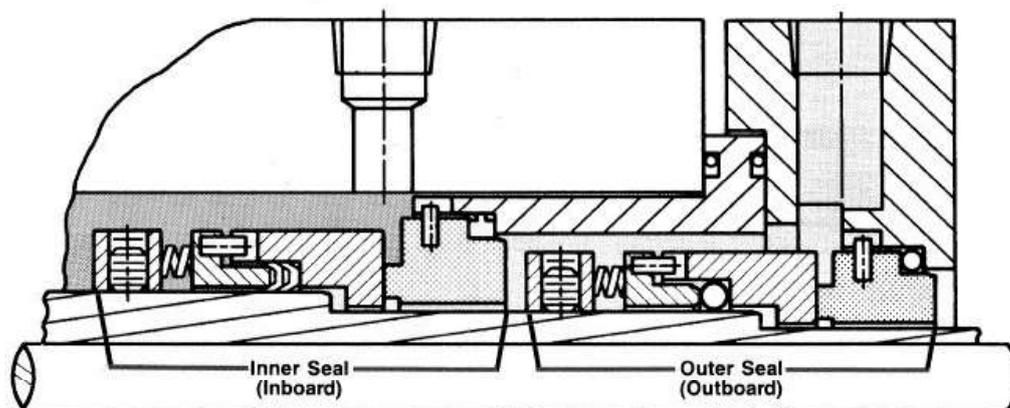
The main limitation of the faceto-face arrangement is in the exposure of the inner seal to the product. Viscous, abrasive, thermosetting, or corrosive products can damage the inner seal and cause leakage.



Tandem Seals

Due to health, safety and environmental considerations, there is a growing trend toward the use of a seal arrangement known as a **tandem** seal.

Under normal operating conditions, the inboard, or primary, seal is designed to withstand full product pressure. The outboard, or secondary, seal operates in a suitable buffer fluid at atmospheric or very low pressure.

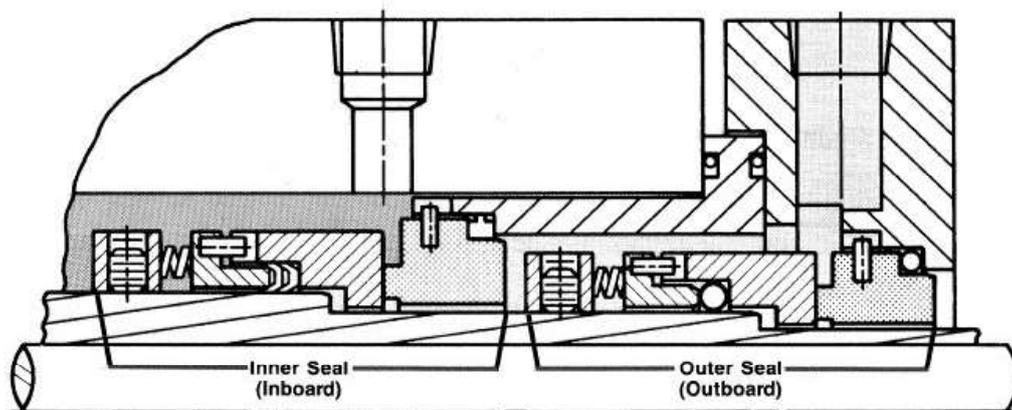


Tandem Seals

If the heat generated by the outboard seal is high, a pumping device is usually added to create flow from the outboard seal cavity through the buffer fluid supply tank in a closed loop. Cooling coils or a heat exchanger may be added if needed.

Under normal operating conditions, primary seal weepage is vented from the system through an orifice at the top of the outboard seal buffer fluid reservoir assembly.

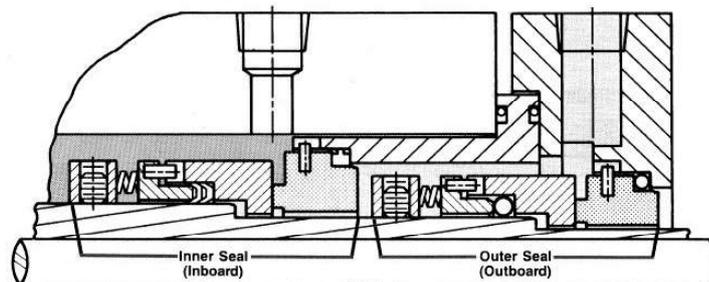
Tandem seal systems are used for products such as vinyl chloride, carbon monoxide, light hydrocarbons, and a wide range of other volatile, toxic, carcinogenic, or hazardous fluids.



Tandem Seals

Tandem seals eliminate icing and freezing of light hydrocarbons and other fluids which could fall below the atmospheric freezing point of water in air (32OF or 0°C).

Typical buffer fluids in these applications are ethylene glycol, methanol, and propanol.

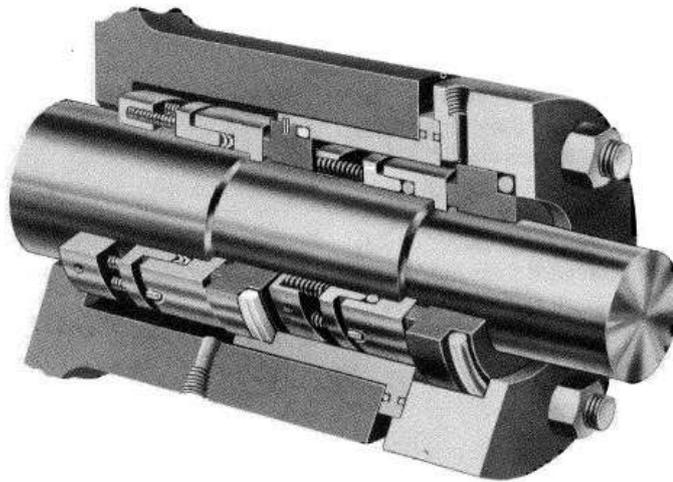


A tandem seal increases online reliability. If a primary seal failure occurs on a critical piece of equipment, the outboard seal can take over and function until maintenance of the equipment can be scheduled. Alarm systems are available.

Tandem Seals

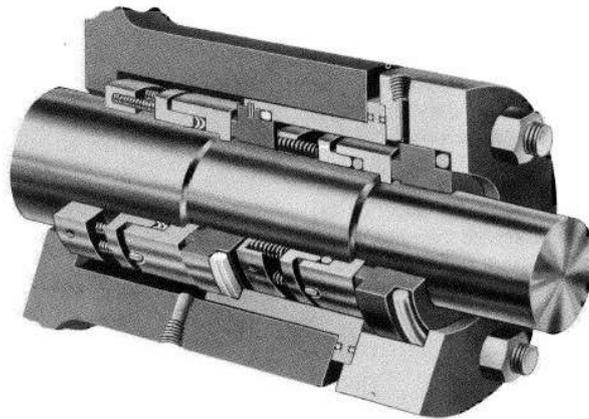
Seal designs can be arranged in a tandem mode. As explained, two seals are arranged either in series or face-to-face with a clean buffer fluid between the seals maintained at a pressure below the product pressure. The primary or inner - seal runs in the product while the

- Outer seal runs in the bufferfluid. While single seals using the best available sealing technology can meet emission control standards in services involving volatile and hazardous air pollutants, tandem and double seals can achieve zero emission levels.



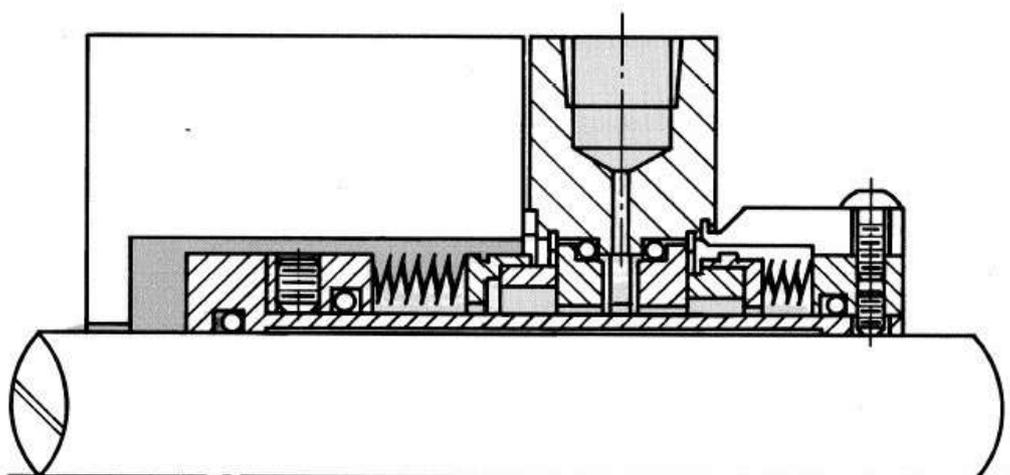
Tandem Seals

Other *Seal* as an outer secondary seal. As an inner seal in a standard seal chamber, a bypass flush from the pump discharge API Plan 11 , is usually used for cooling. With light hydrocarbons and other products that are pumped under conditions close to their boiling or flash points, a close fitting bushing in the throat of the inner seal chamber can be used to pressurize the product in the seal chamber to at least 25 psig (1 70 kPa) above the initial boiling point (IBP) of the sealing fluid. Otherwise the seal fluid must be cooled to at least 150F (80C) below its IBP to prevent flashing and popping at the seal faces that can lead to excessive weepage and premature seal failure. A circulating feature should be included in the secondary outer seal design to ensure adequate cooling circulation of the buffer fluid.



Cartridge Seals

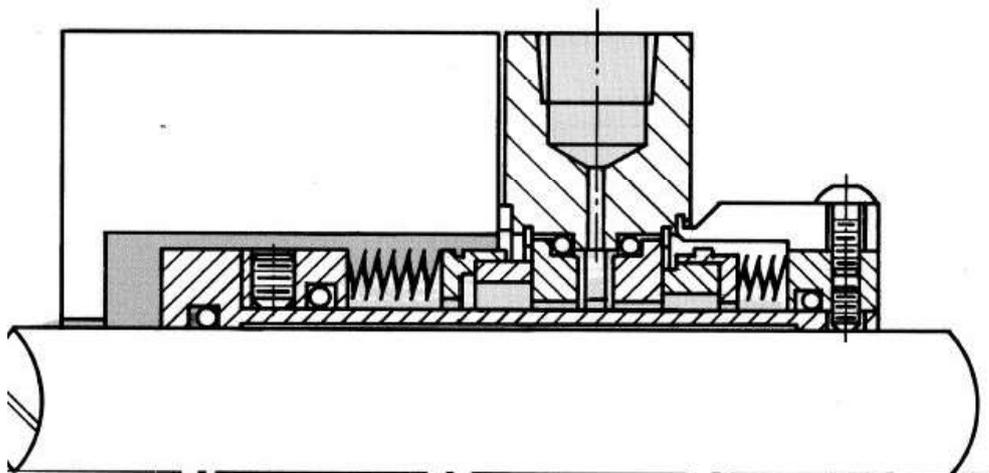
The use of cartridge seals adds to the cost of a seal assembly, and many stuffing boxes are too small to accommodate them. A cartridge mount will add 1/8 to 1/4 inches (3.2 to 6.4mm) to the seal assembly diameter.



Cartridge Seals

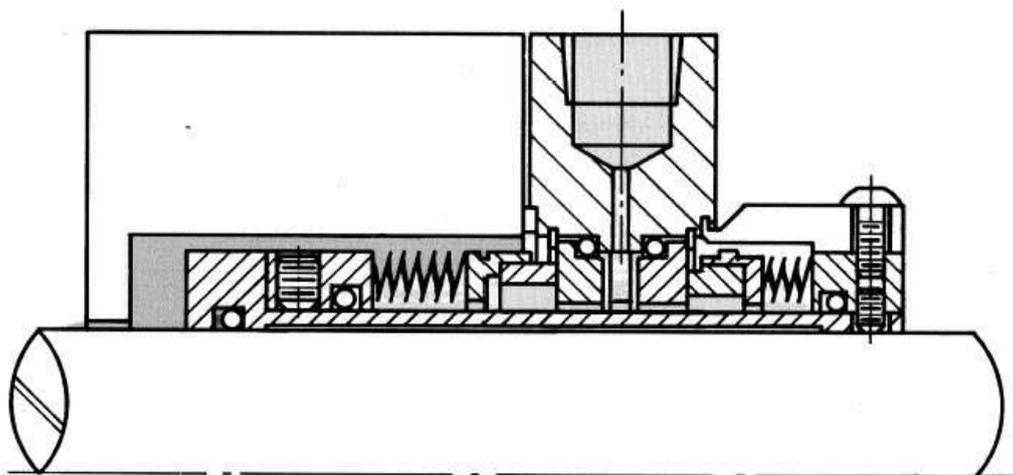
Nearly all mechanical seals can be provided in a cartridge design. The seal is mounted - usually with a gland ring - on a sleeve which fits directly over the equipment shaft or shaft sleeve.

Many configurations are available, but the major benefit of cartridge seals is that they do not require the usual seal setting measurements for their installation.



Cartridge Seals

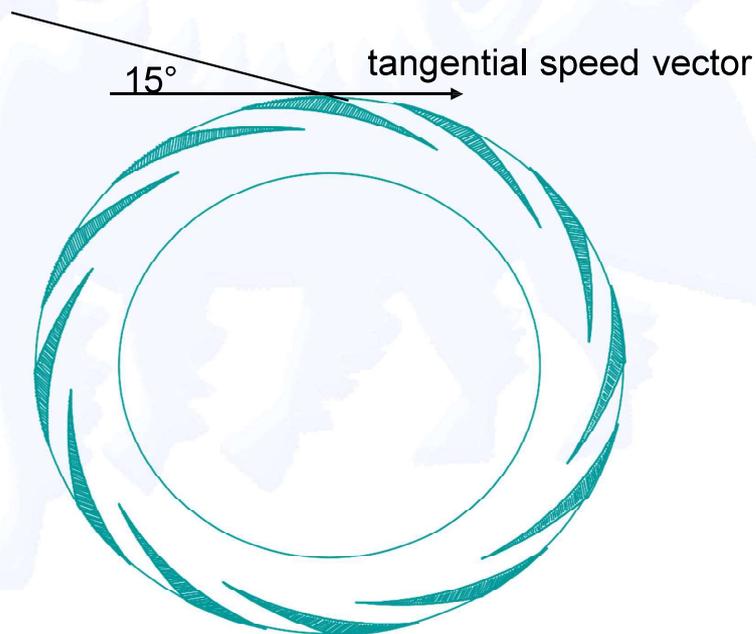
Cartridge seals have been available for over fifty years. Originally, they were used on vertical and between-bearing pumps where other designs could not be used. Today, cartridge seals are also used to reduce installation errors and turn-around time for repairs of equipment with overhung shafts .



Sealing overview

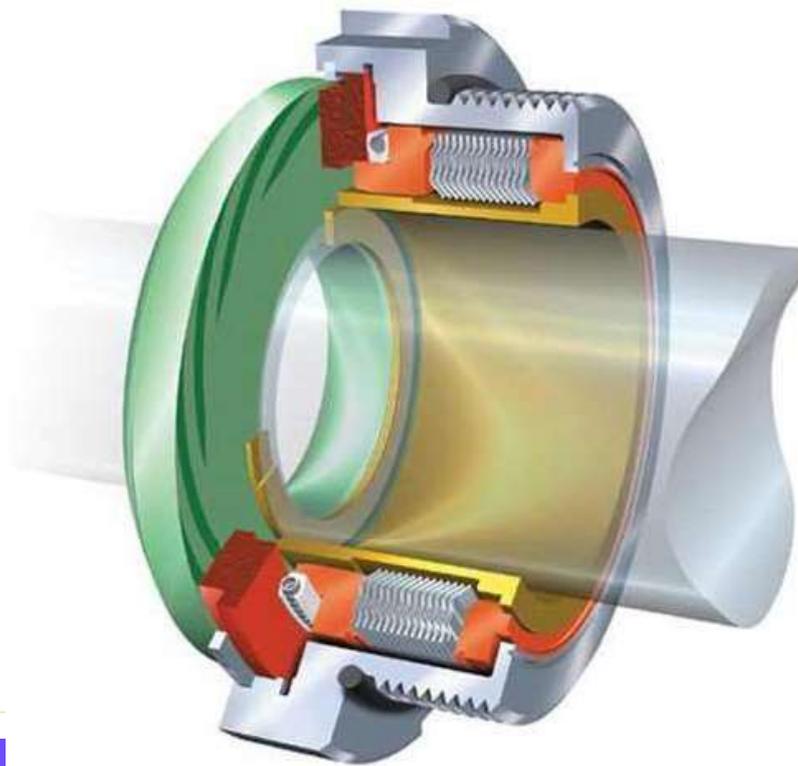
Essentials of Groove Design

- Studies of Whipple in 1947
- Studies of Muijderman in 1966



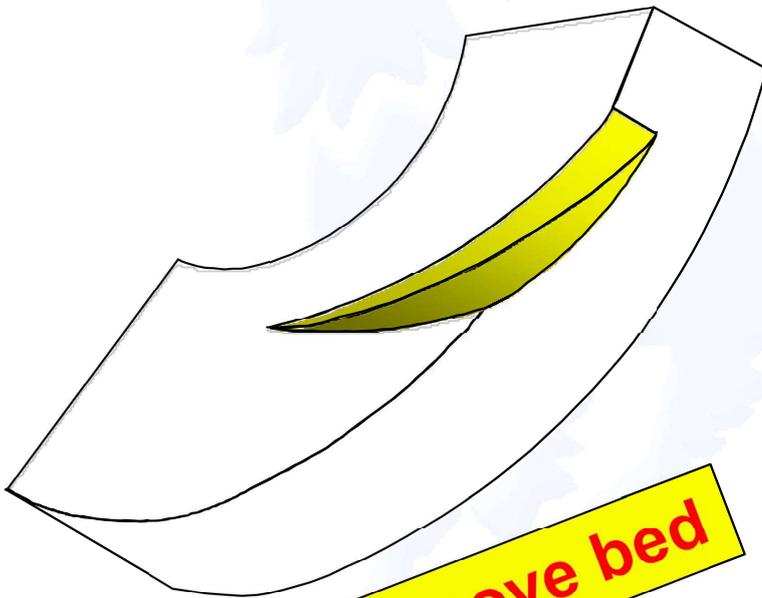
**FORCE ANALOGY IN NON-CONTACTING
GAS LUBRICATED DRY GAS SEAL**

Essentials of Groove Design

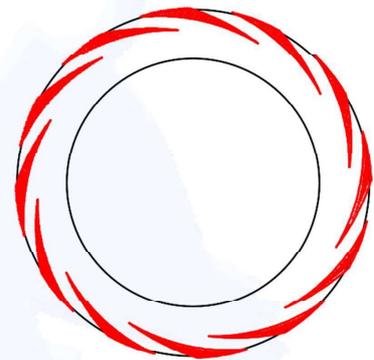


Sealing overview

uni - directional, V - Groove

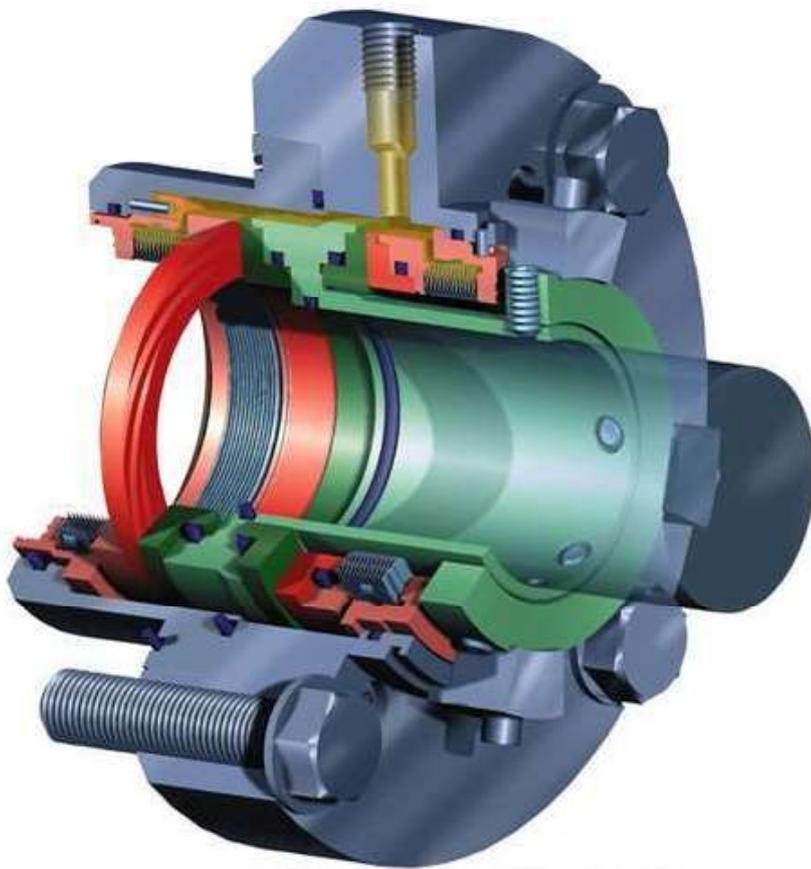


sloped groove bed

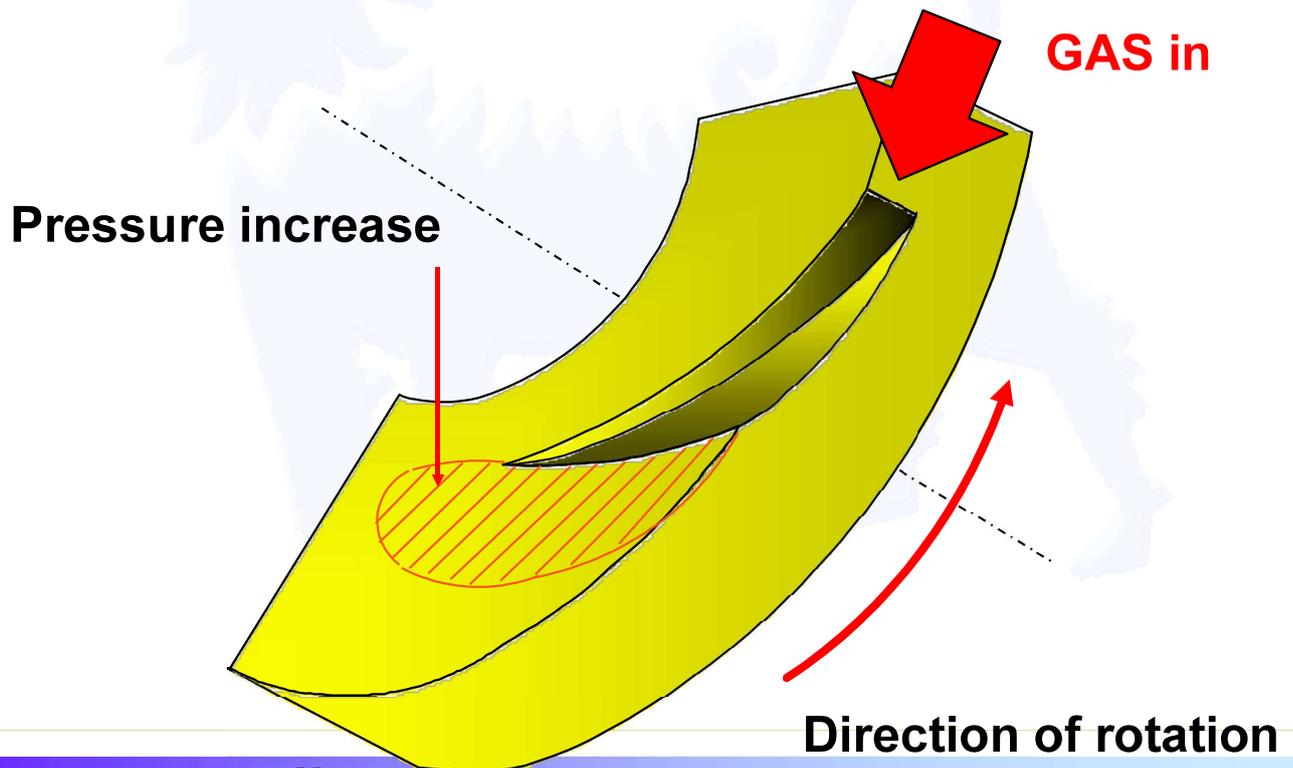


- aerodynamic contour
- variable depth
- operational safety

uni - directional, V - Groove



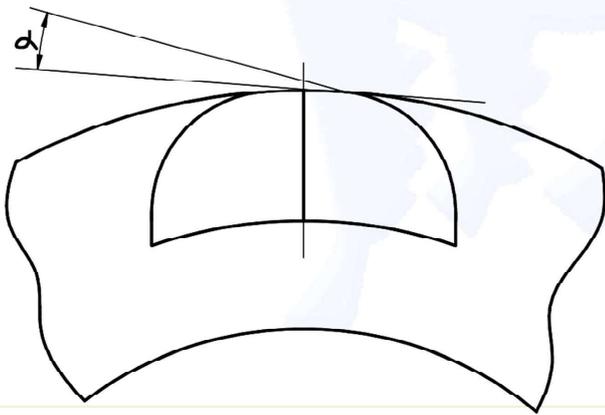
Dry Gas Seal Principle V-groove



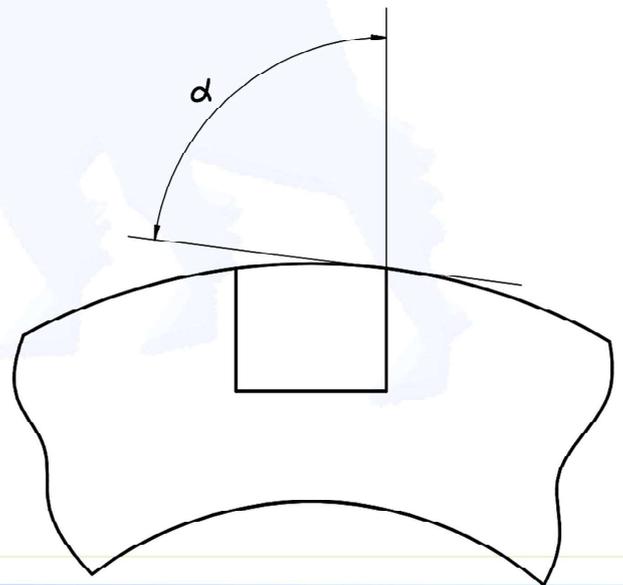
Sealing overview

Groove entry angle alpha

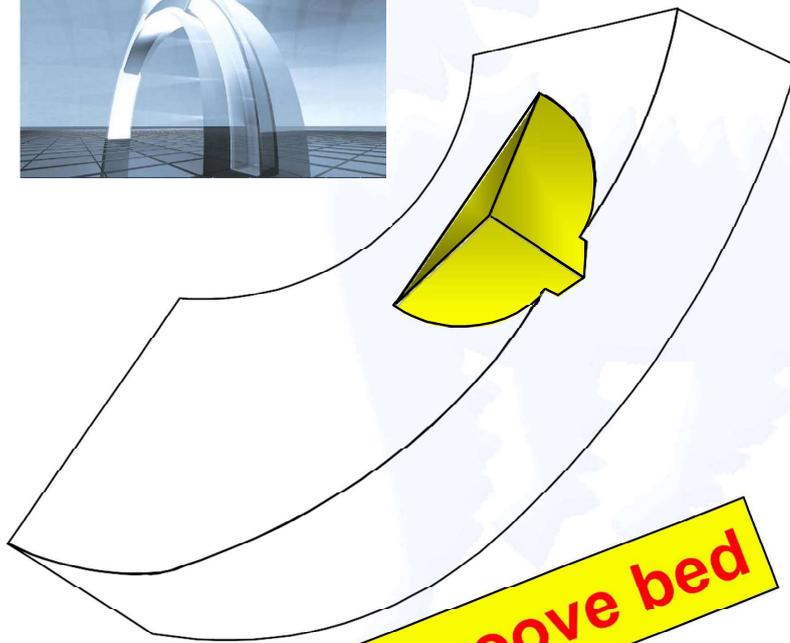
aerodynamic
groove contour



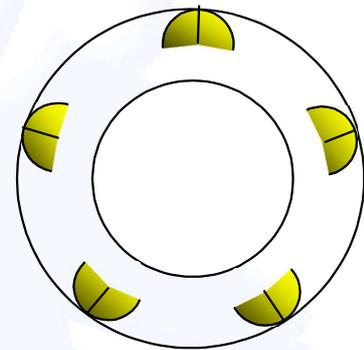
aerostatic groove
contour



bi - directional, U - Groove



sloped groove bed

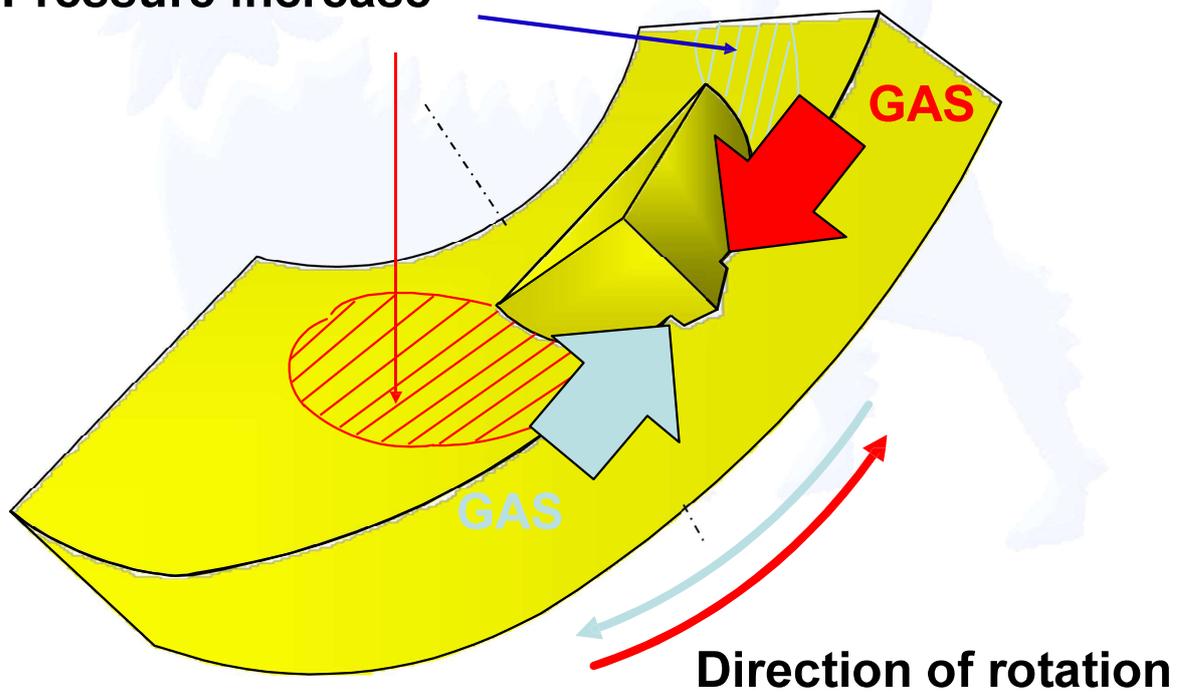


- aerodynamic contour
- variable depth
- operational safety

Dry Gas Seal Principle U-groove



Pressure increase



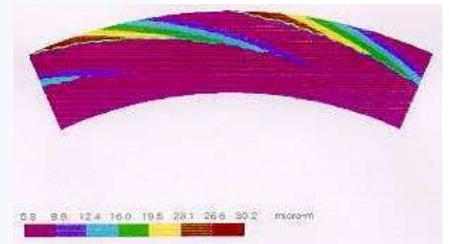
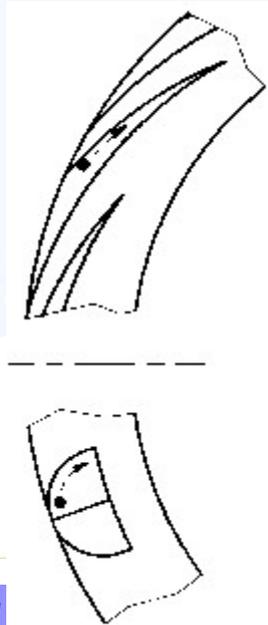
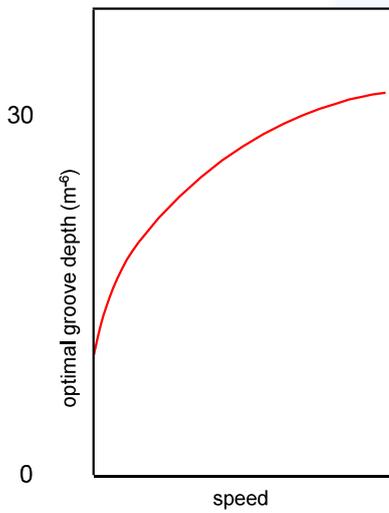


Sealing overview

optimal performance point

optimised contour

variing groove-depth

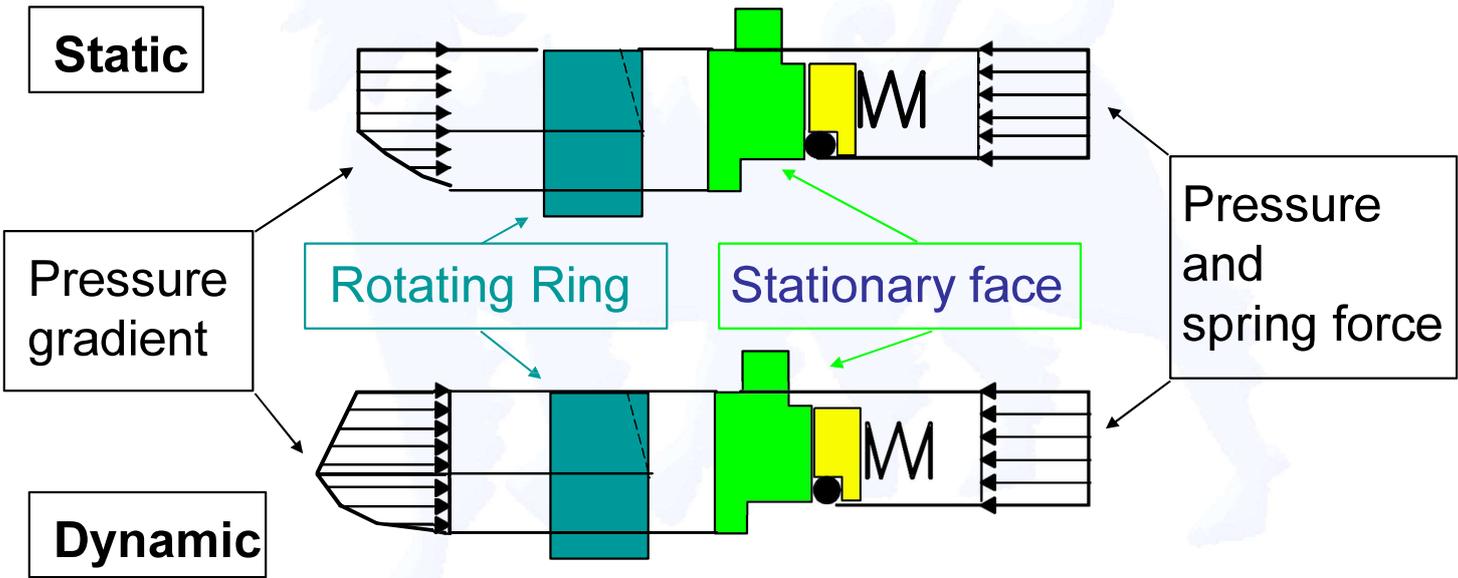


Prepared by : Benny





Forces



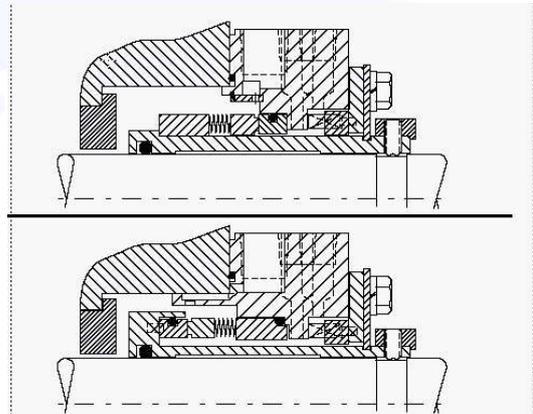
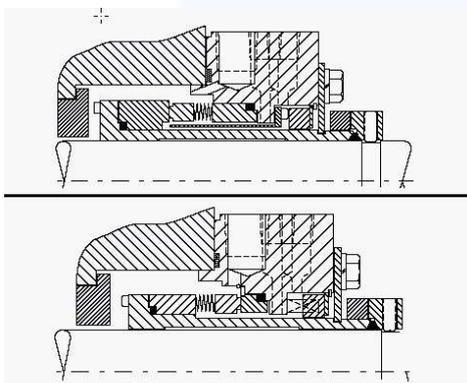
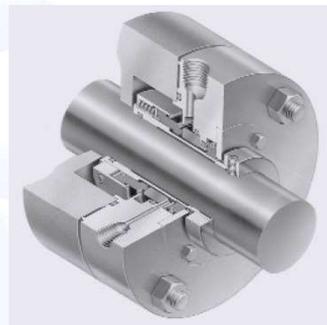
Seal Types as per API 682

Seal type are defined as :

Type A

Type B

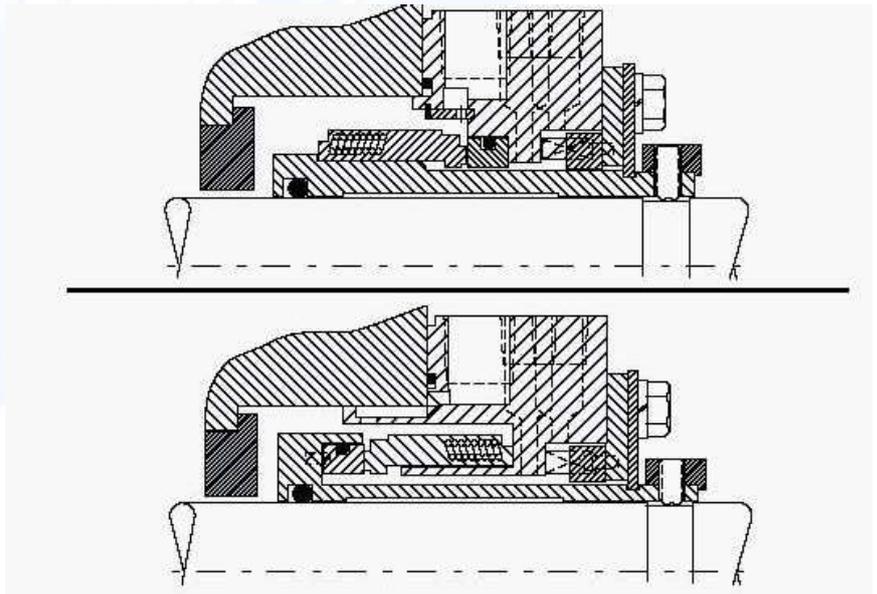
Type C



Seal Types as per API 682

TYPE A:

- Pusher Type with rotating flexible element
- Silicon Carbide versus carbon faces
- Alloy C276 spring
- Fluoroelstomer O ring
- SS 316 metal component



Seal Types as per API 682

Type B:

- Bellows Type (Non pusher type)
- Rotating flexible element
- Silicone carbide versus carbon faces
- Alloy C276 diaphragm, fluoroelastomer O ring
- 316 SS metal component

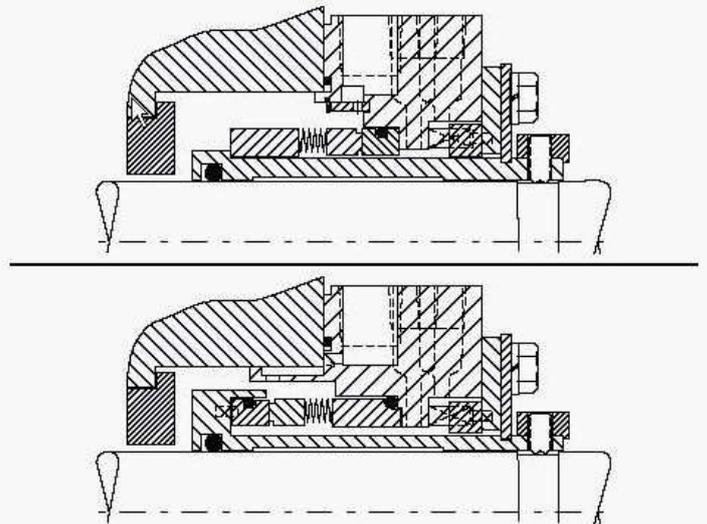
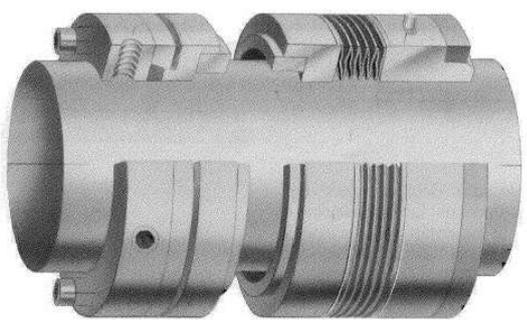


Figure 2. Standard and Alternative Type B Seal.

Seal Types as per API 682

Type C

- Bellows type
- Stationary flexible element
- Silicon carbide versus carbon face
- Alloy 718 diaphragm
- Flexible graphite secondary seal
- 316 metal components

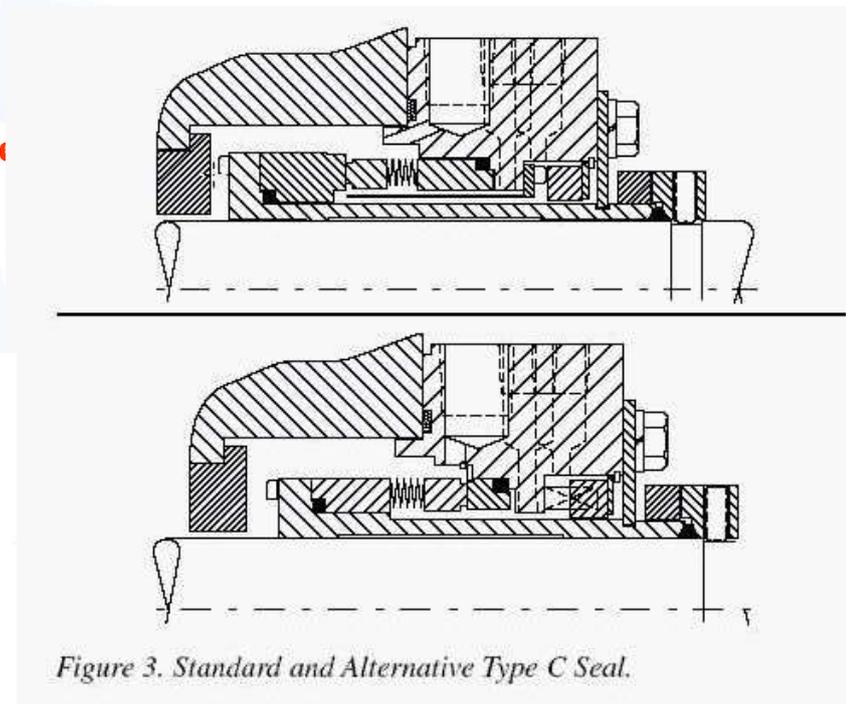
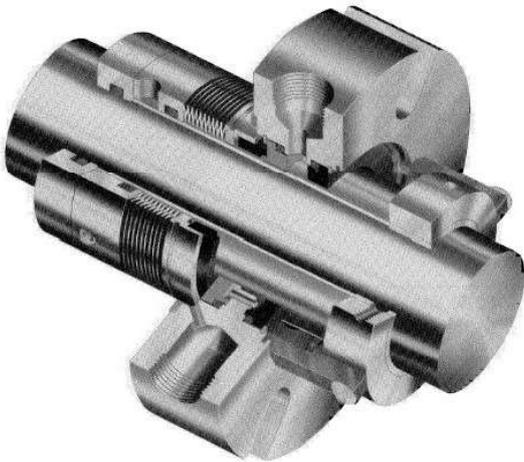


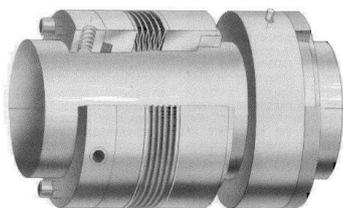
Figure 3. Standard and Alternative Type C Seal.

Mechanical seal indications API 682

APPENDIX D—STANDARD SEAL CODE DESIGNATIONS

Table D-1—Standard Seal Features

Code	Seal Type	Features
A	Pusher	<ol style="list-style-type: none"> 1. Rotating flexible element, multiple springs, O-ring secondaries. 2. Reaction-bonded silicon carbide versus premium-grade, blister-resistant carbon. 3. Fluoroelastomer O-rings. 4. Hastelloy C springs. 5. Type 316 SS sleeve, gland, retainer, and other metal parts. 6. Premium carbon floating bushing in gland.
B	Metal Bellows	<ol style="list-style-type: none"> 1. Rotating flexible element, O-ring secondaries. 2. Reaction-bonded silicon carbide versus premium-grade, blister-resistant carbon. 3. Fluoroelastomer O-rings. 4. Hastelloy C bellows. 5. Type 316 SS sleeve, gland, and other metal parts. 6. Premium carbon floating bushing in gland.
C	Metal Bellows	<ol style="list-style-type: none"> 1. Stationary flexible element, flexible graphite secondaries. 2. Reaction-bonded silicon carbide versus premium-grade, blister-resistant carbon. 3. Flexible graphite secondaries. 4. Inconel 718 bellows. 5. Type 316 SS sleeve, gland, and other metal parts. 6. Premium carbon floating bushing in gland. 7. Bronze anti-coking baffle.



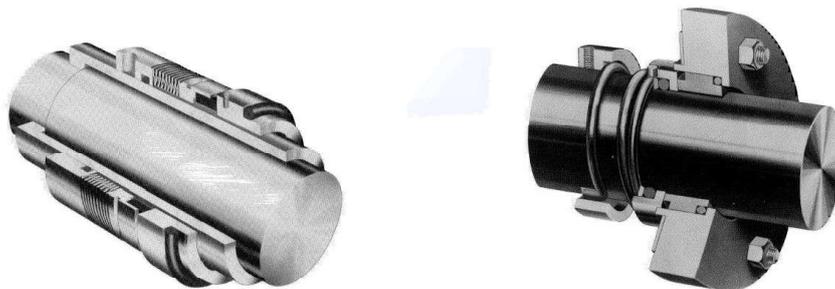
Mechanical seal indications API 682

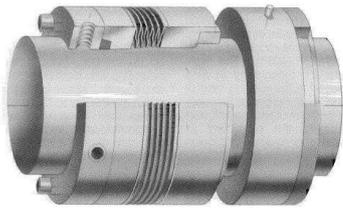
Table D-2—Special Features Codes

Code	Option
A	Ammonia-resistant carbon
B	Buna-N
C	Amine-resistant perfluoroelastomer (Kalrez 1018)
H	Two hard faces, silicon carbide versus tungsten carbide
K	Perfluoroelastomer
P	Internal circulating device
S	Single spring

Table D-3—Seal Code Examples

Code	Meaning
APS	A standard Type A pusher seal except with a single spring and a pumping device
BK	A standard Type B bellows seal with perfluoroelastomer O-rings
CH	A standard Type C bellows seal with silicon carbide versus tungsten carbide faces





Mechanical seal indications API 682



Table D-4—Sample Single Seal Code

Seal Type Code	Special Features Codes 2-letters	/	API Flush Plan	/	"R" for Rotating or "S" for Stationary	/	Seal Size: Inch Seals in hundredths, (for example 1-1/4" is 125). Metric seals in centimeters, (for example a 60 mm seal is 6).
----------------	-------------------------------------	---	----------------	---	--	---	--

Example:

APS/23/R/200 = A 2 inch, rotating, single spring pusher seal with a pumping device and a plan 23 flush.

A P S / 23 / R / 200

Pusher Seal	Internal Circ. Device Single Spring	API Flush Plan Plan 23	Rotating	Seal Size = 2"
-------------	--	---------------------------	----------	----------------

Note: A seal with two flush plans (such as a vertical with a Plan 32 and a Plan 13), would repeat the flush code with a hyphen (same format as used for dual seals).

Mechanical seal indications API 682

Table D-5—Sample Dual Seal Code

Inner Seal Code	Special Feature Codes	Outer Seal Type Code	Special Feature Codes	Inner Seal Flush Plan	Outer Seal Flush Plan	Inner Seal Rotating or Stationary	Outer Seal Rotating or Stationary	Inner Seal Size	Outer Seal Size
-----------------	-----------------------	----------------------	-----------------------	-----------------------	-----------------------	-----------------------------------	-----------------------------------	-----------------	-----------------

Example:

A-AP/11-52/R-R/200-175 = An arrangement 2 unpressurized dual pusher seal. The inner seal has no special features; the outer seal, a pumping device. The inner seal is cooled by a plan 11 and the buffer fluid circulates by means of a plan 52. Both seals rotate. The inner seal is a 2 inch and the outer seal is a 1-3/4 inch.

A	-	AP	/	11	-	52	/	R	-	R	/	200	-	175
Inner Pusher Seal, No Special Features		Outer Pusher Seal, internal circ. Device		Inner Seal Flush Plan 11		Outer Seal Flush Plan 52		Inner Seal Rotating		Outer Seal Rotating		Inner Seal Size 2"		Outer Seal Size 1-3/4"



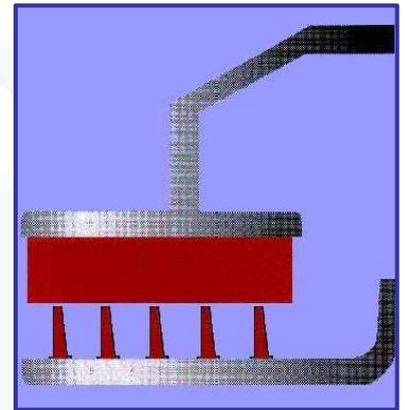
Sealing overview

Labyrinth seal

Labyrinth seals are widely used in most oil and gas industry applications. The labyrinth is one of the simplest of sealing devices. It consists of a series of circumferential strips of metal extending from the shaft or from the bore of the shaft housing to form a cascade of annular offices.

Labyrinth seals leakage is greater than that of contact seals, or film-riding seals.

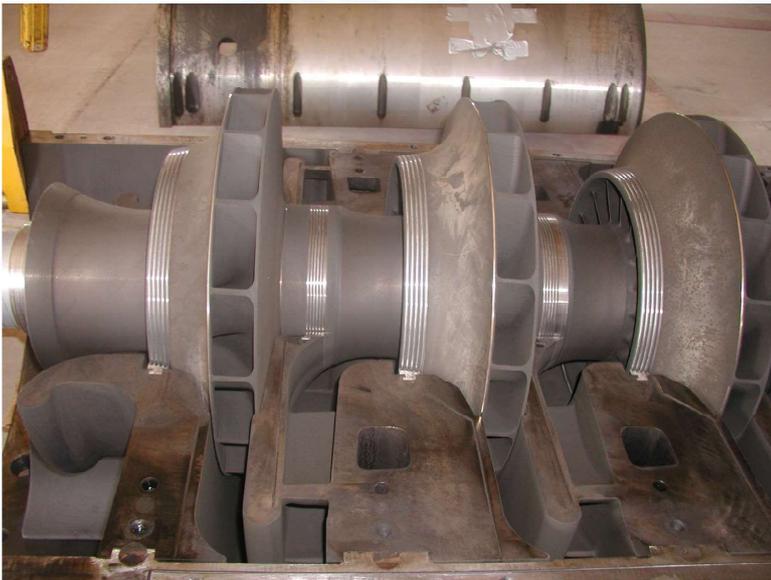
As a result, labyrinth seals are utilized when a small loss in efficiency is acceptable.



In gear unit for static sealing of the partition joints, a non-hardening surface sealing is used. The shafts are sealed with contact-less labyrinth seals.

Labyrinth seal

The major advantages of labyrinth seals are their simplicity, reliability, tolerance to dirt, system adaptability, very low shaft power consumption, material selection flexibility, minimal effect on rotor dynamics, back diffusion reduction, integration of pressure, lack of pressure limitations, and tolerance to gross thermal variations. The major disadvantages are the high leakage, loss of machine efficiency and increased buffering costs.

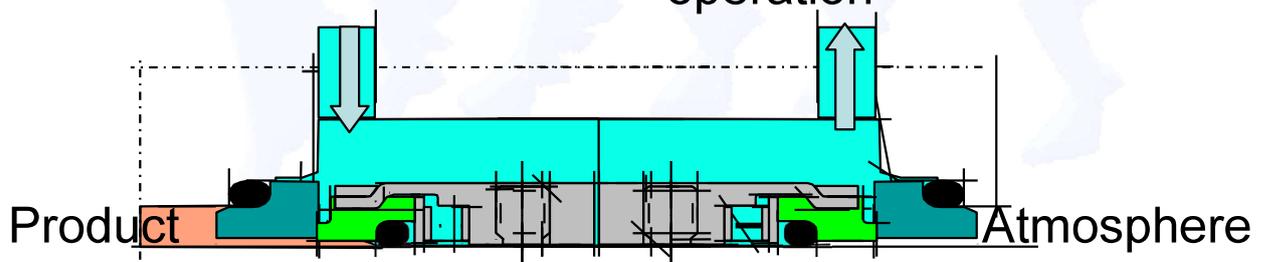


Double acting seal arrangements

Double acting seals

Multiple seal

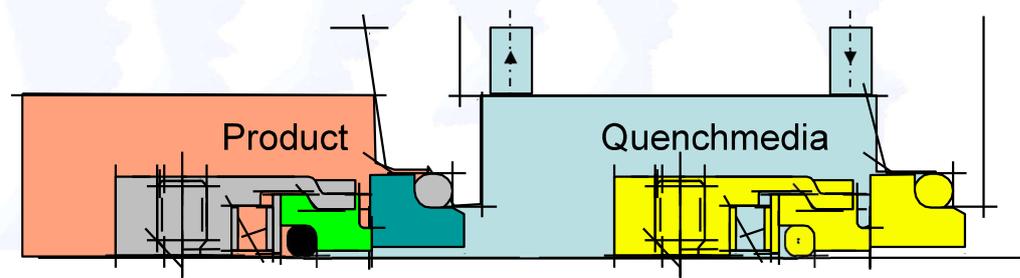
- Faces barrier fluid lubricated
- Back to back or face to face
- Pressurized barrier fluid ($P1 + 2..3 \text{ bar}$ resp. $+10\%$ over $P1$)
- No product leakage
- For aggressive media
- For solid loaded media
- For polymerising, sticky media
- Environmental safe operation



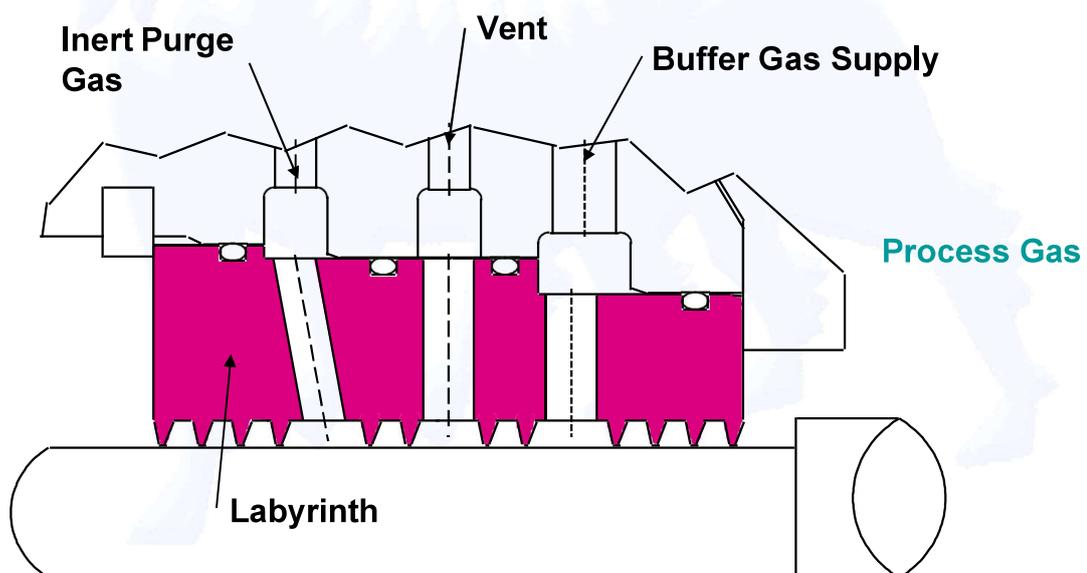
Tandem arrangement

Tandem seal

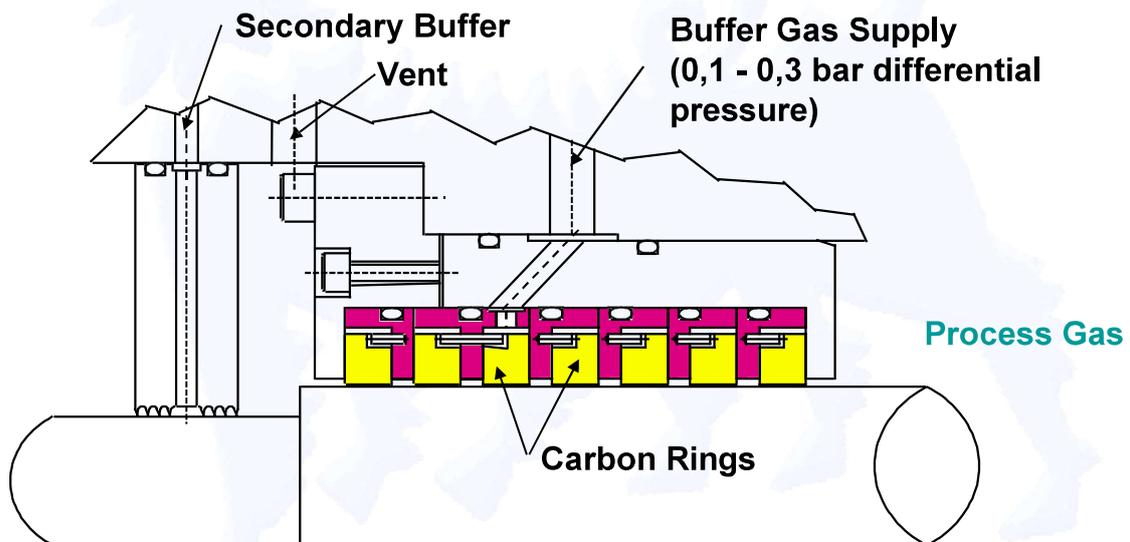
- Multiple seal
- Function as single seal with safety seal
- Quenchmedia pressureless (standard)
- Surveyance possibility of seal
- Leakagecontrol and drain



Current Methods of Sealing Compressors - Labyrinths

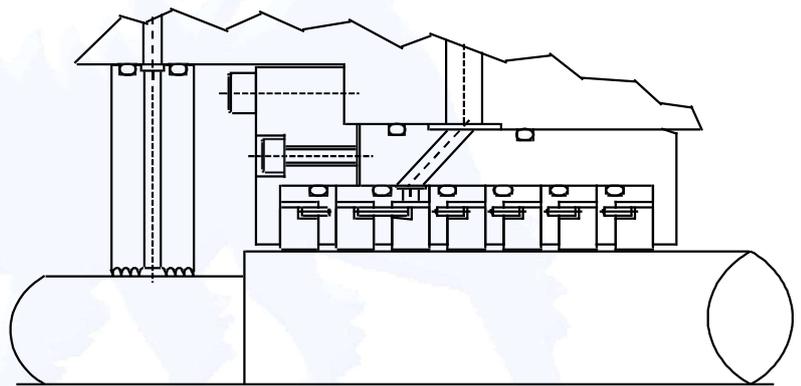


Current Methods of Sealing Compressors - Circumferential Carbon Seals

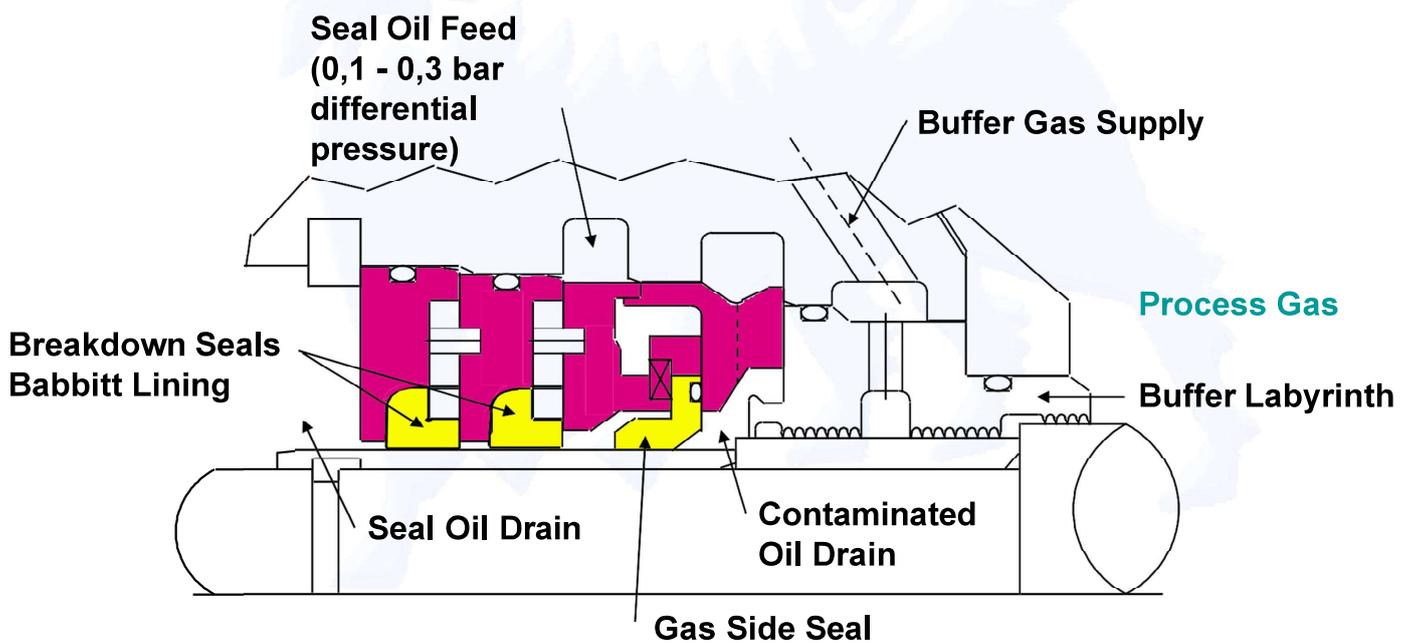


Current Methods of Sealing Compressors - Circumferential Carbon Seals

- Limited application
- Low pressures
- Services such as chlorine
- Moderate leakage (2-3 times < labyrinth)
- Low to moderate initial seal cost
- Wear during operation / lose efficiency

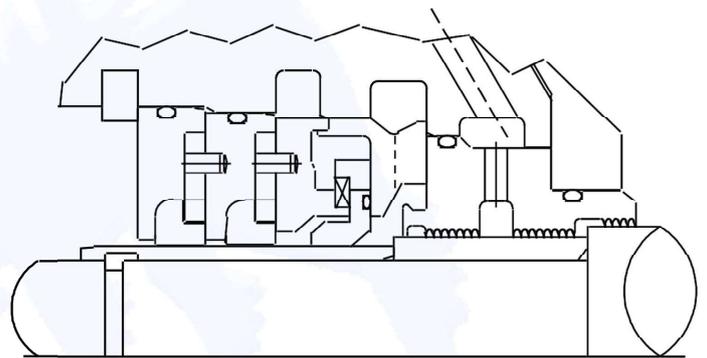


Current Methods of Sealing Compressors - Oil Film Seals

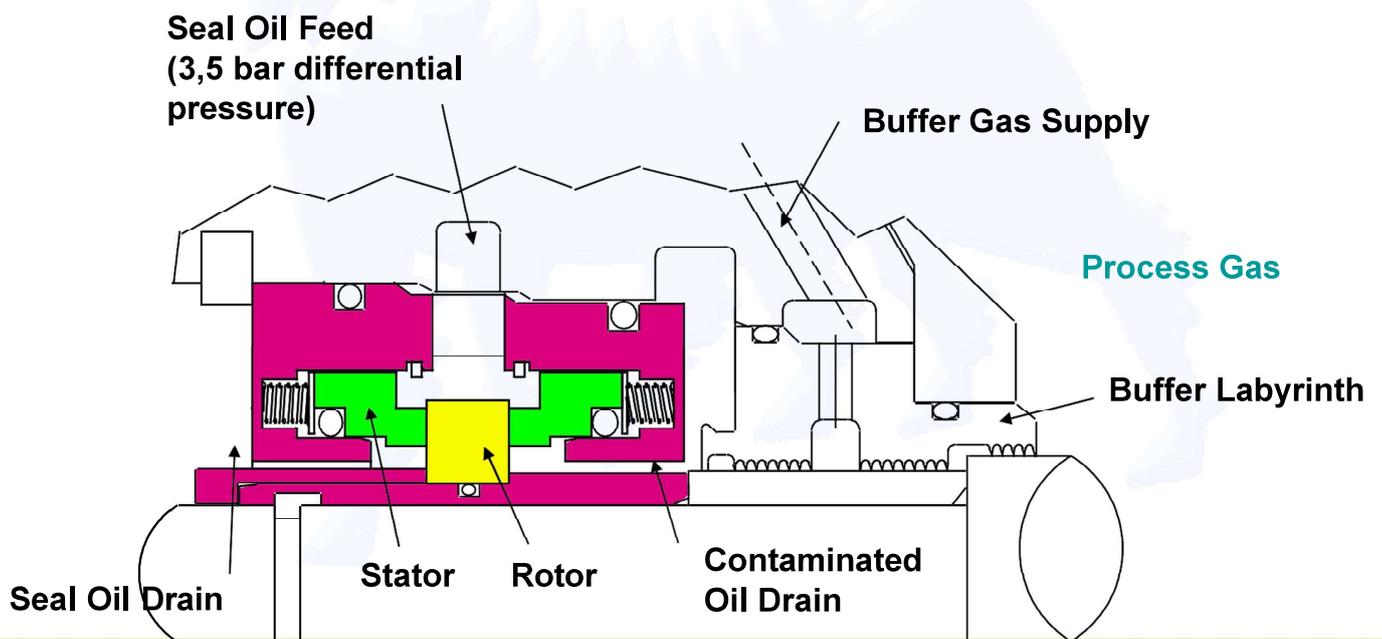


Current Methods of Sealing Compressors - Oil Film Seals

- **Pressure Range 0-275 bar**
- **Oil contamination of the process gas**
- **Requires minimum pressure / flow to cool**
- **Wear during operation / lose efficiency**
- **Elaborate control system**
- **High power losses**

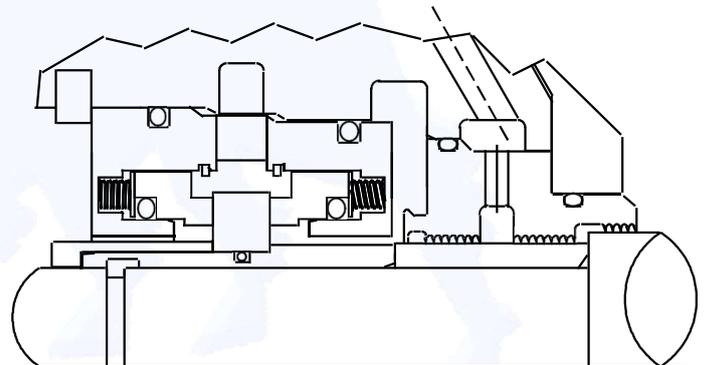


Current Methods of Sealing Compressors - Oil Lubricated Mechanical Seals



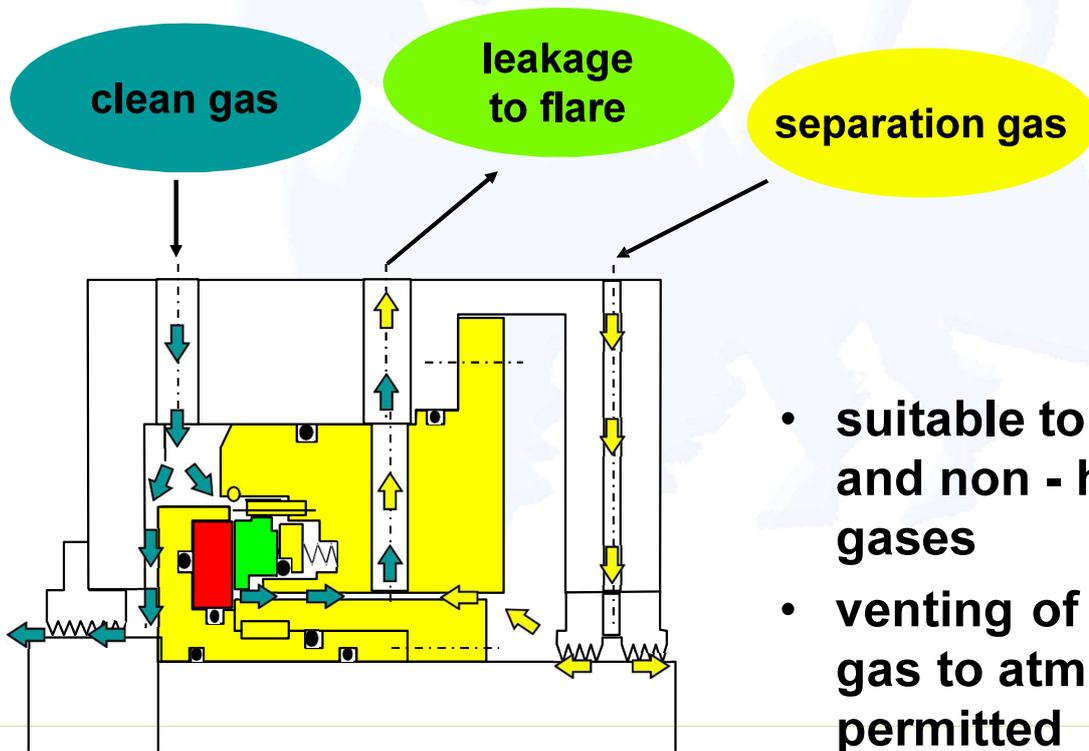
Current Methods of Sealing Compressors - Oil Lubricated Mechanical Seals

- Limited in speed and pressure
- Oil contamination of the process gas
- Requires minimum pressure / flow to cool
- Wear during operation / limited life
- Elaborate control system
- High power losses



Sealing overview

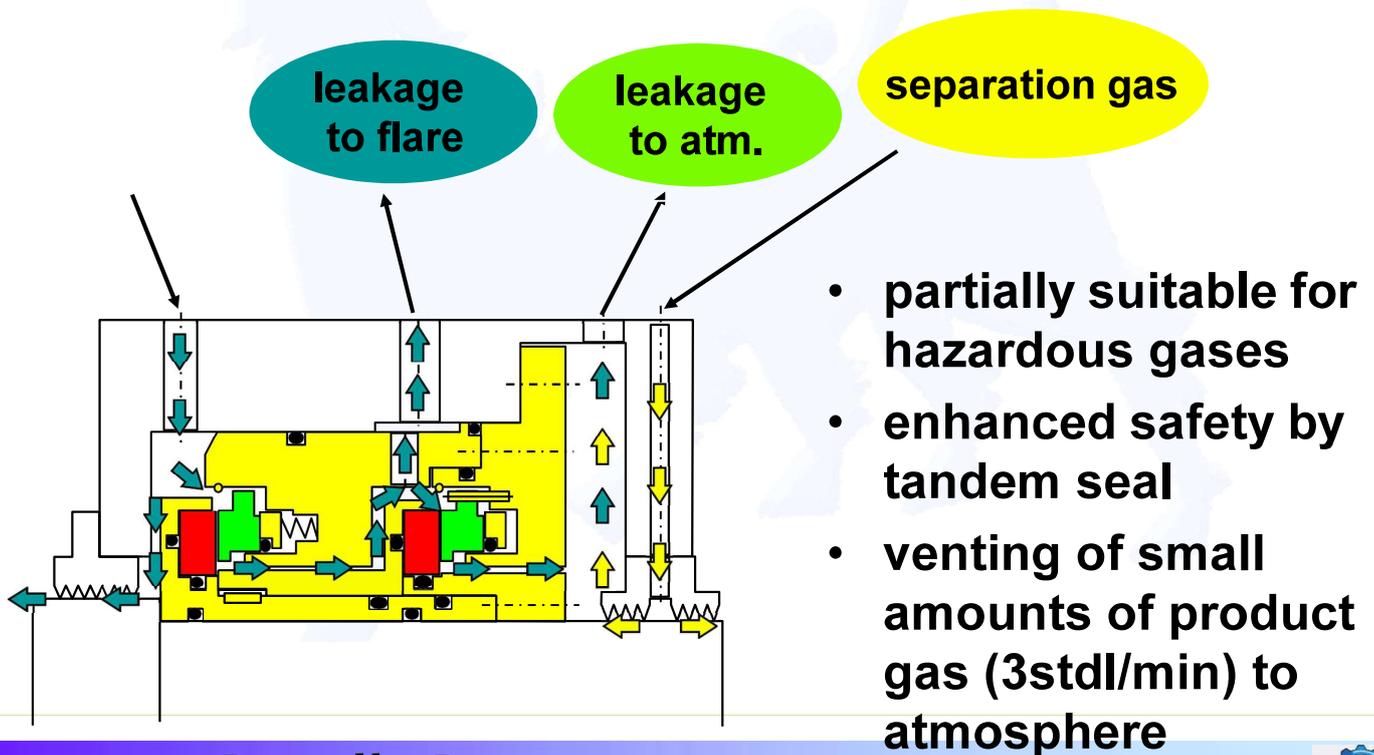
Single seal arrangement



- suitable to non - toxic and non - hazardous gases
- venting of product gas to atmosphere permitted

Sealing overview

Tandem seal arrangement



permitted



Eni

Prepared by : Benny

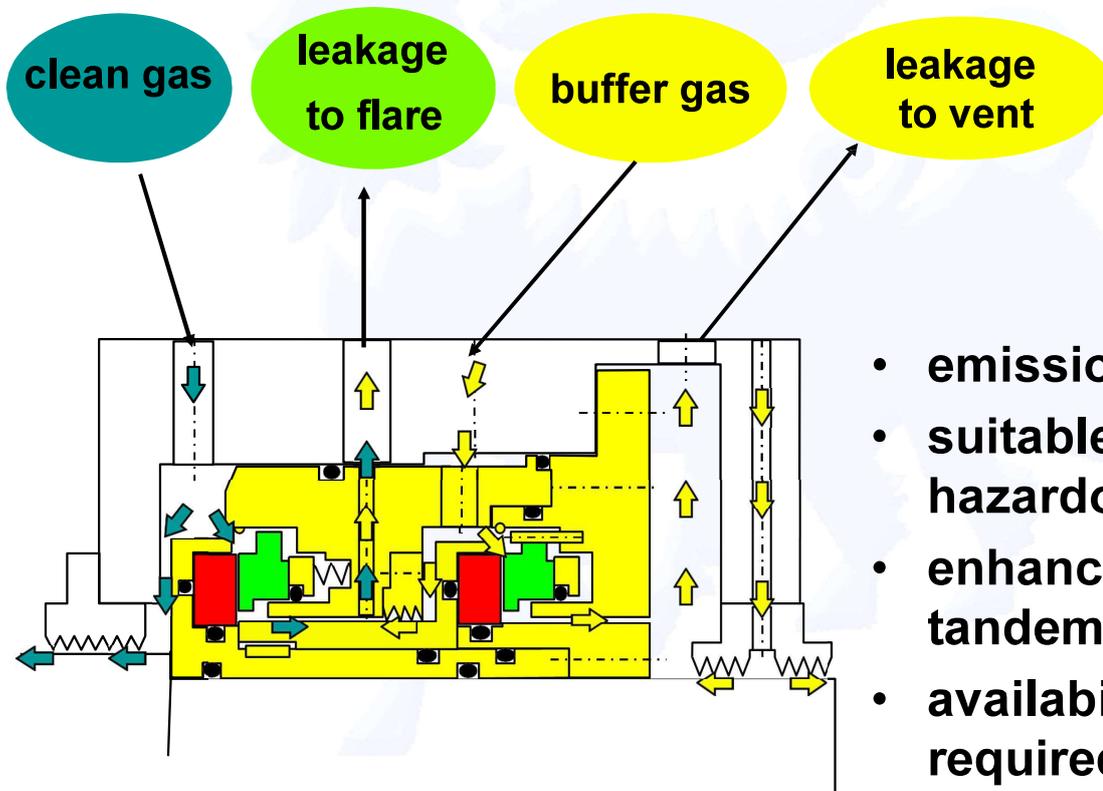
187



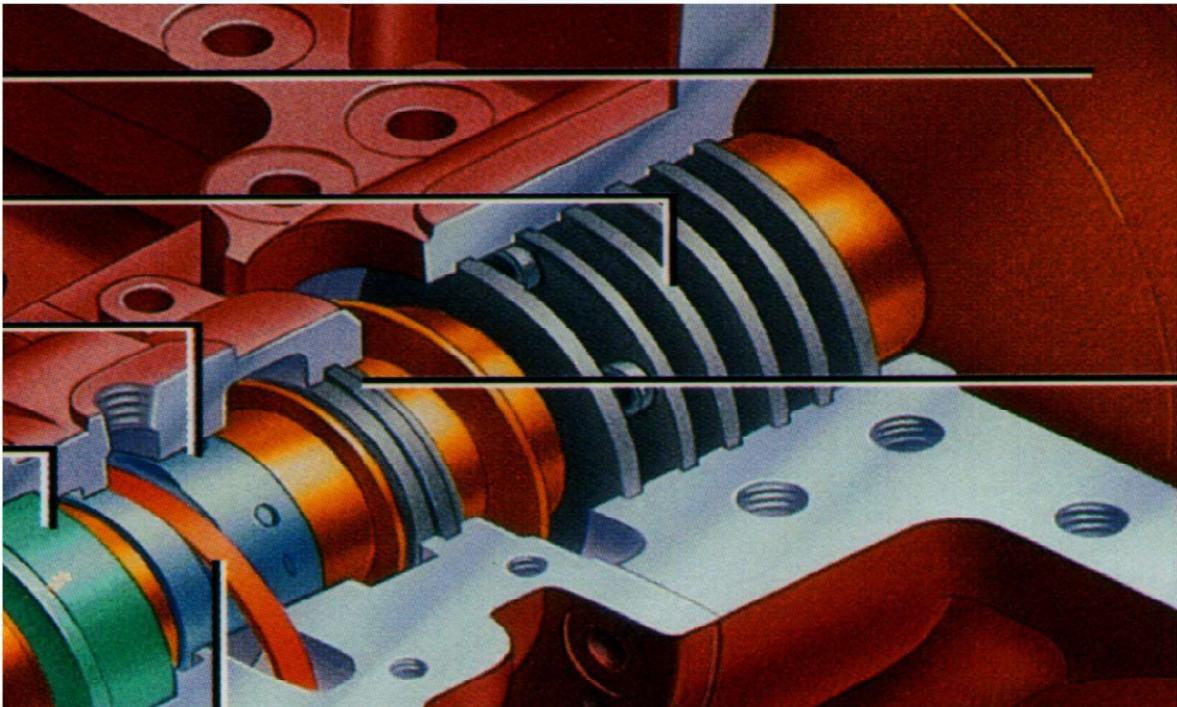
bennypass.com

Sealing overview

Tandem seal with internal labyrinth

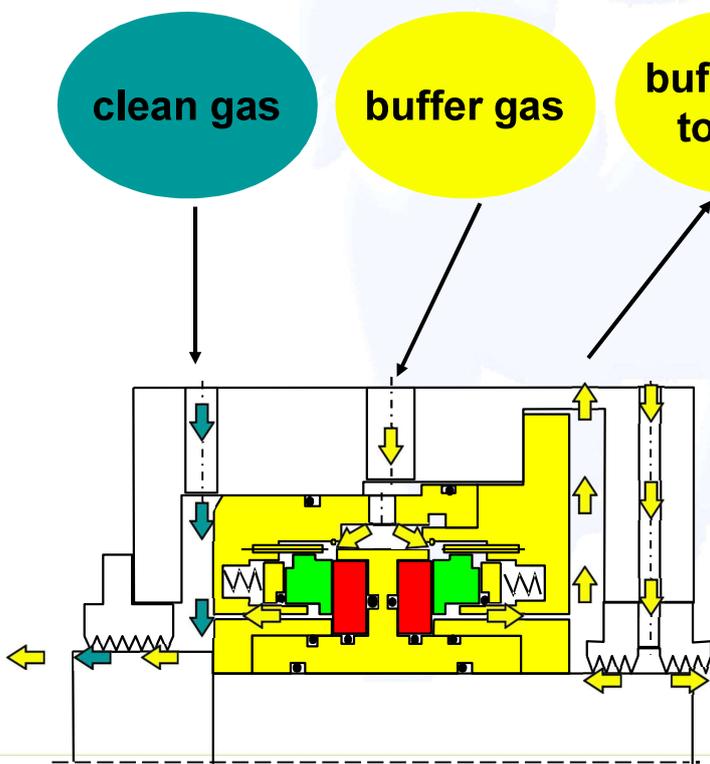


Integrated carbon ring box



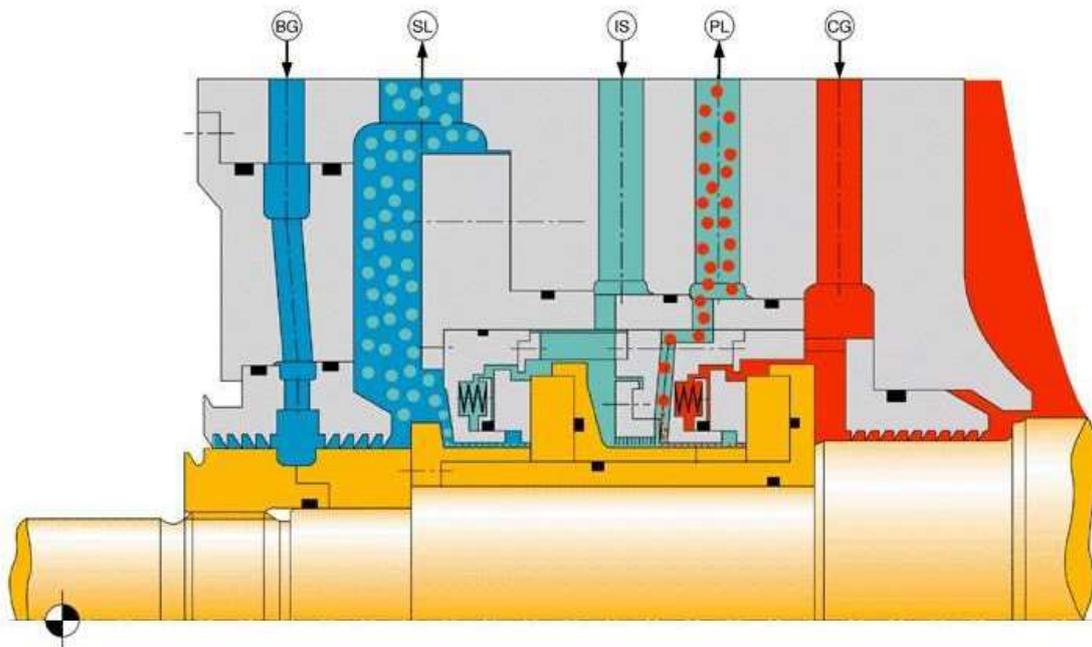
Sealing overview

Double seal arrangement



- emission free
- suitable for toxic and hazardous gases
- suitable for low pressure applications ($p < \text{flare pressure}$)
- no flare connection required
- available nitrogen pressure must be at least 2 bar over product gas pressure
- process must allow a nitrogen contamination

Sealing overview



Ⓟ BG - buffer gas

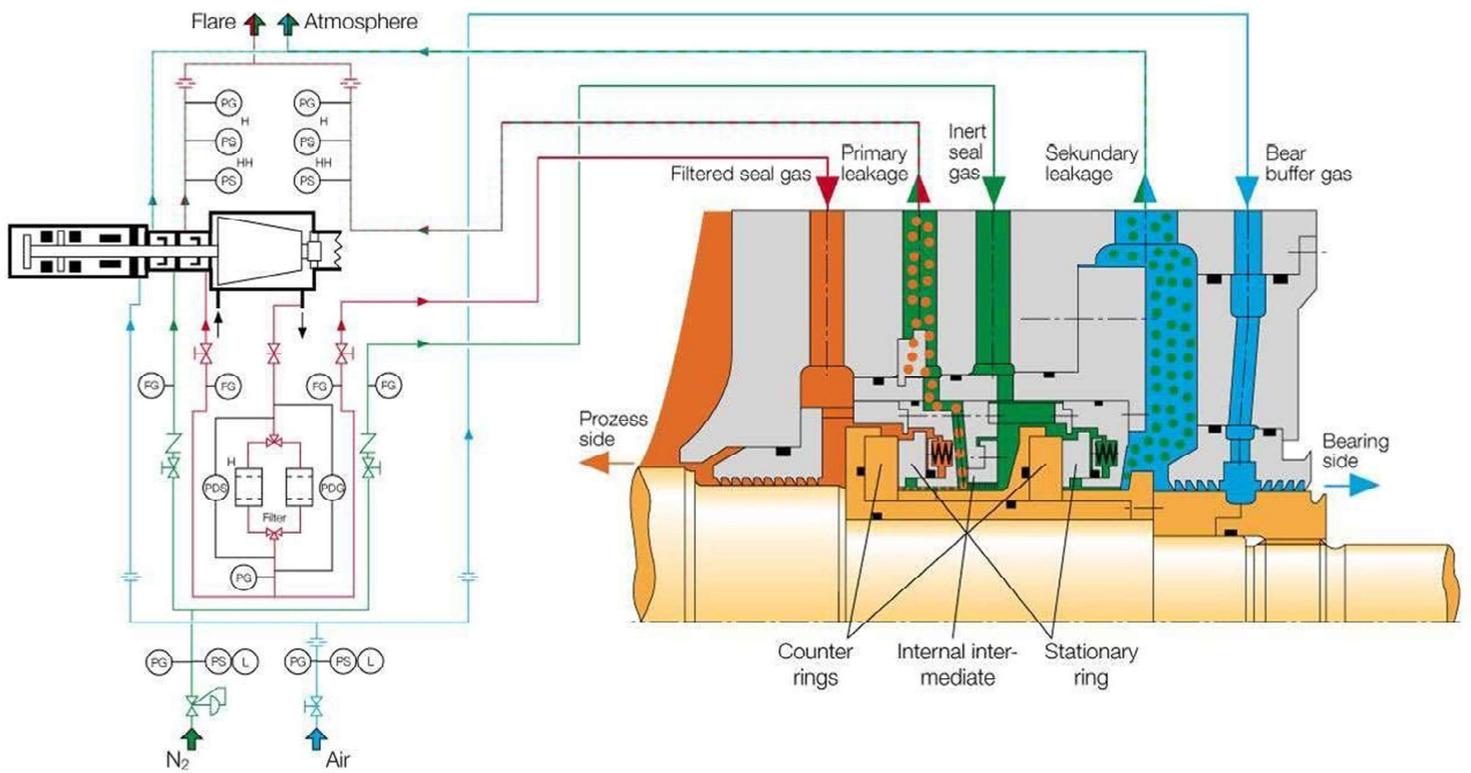
Ⓟ SL - secondary leakage

Ⓟ IS - internal seal gas

Ⓟ PL - primary leakage

Ⓟ CG - clean gas

Sealing overview



PDG Pressure difference gauge
 PDS Pressure difference switch

PG Pressure gauge
 PS Pressure switch

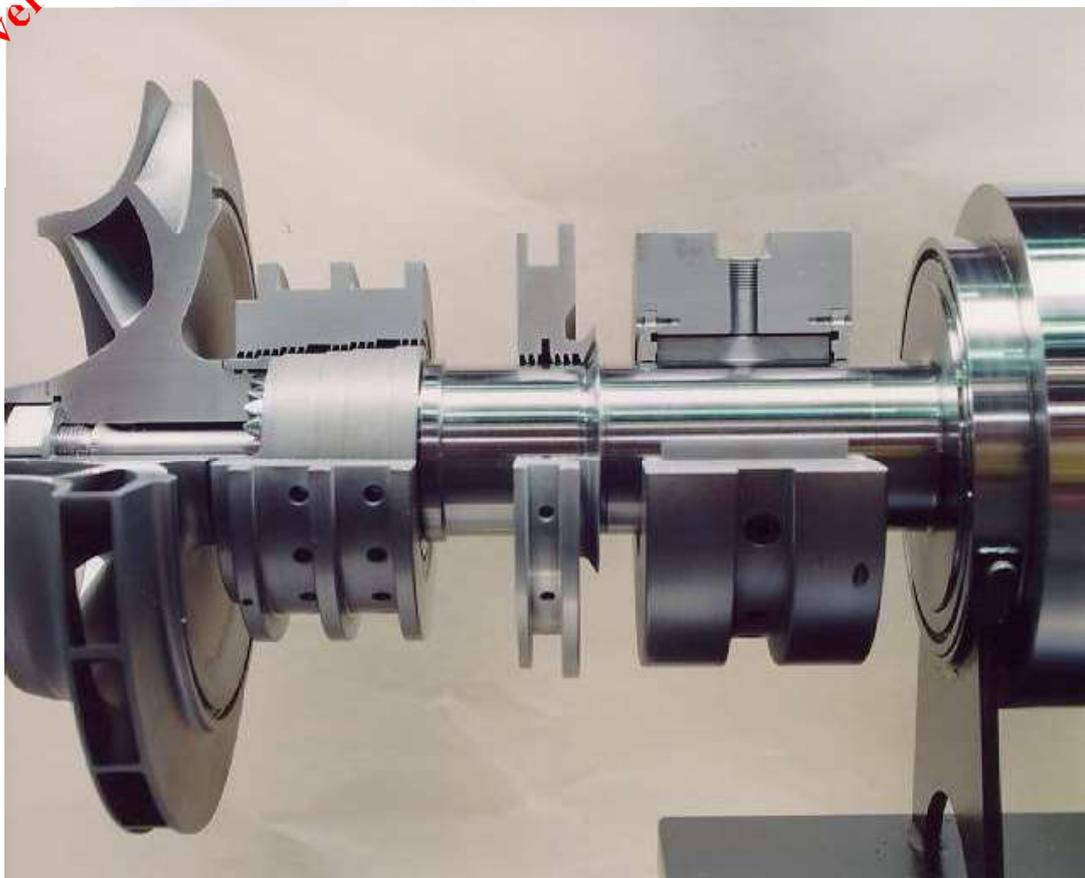
-L Alarm „low”
 -H Alarm „high”

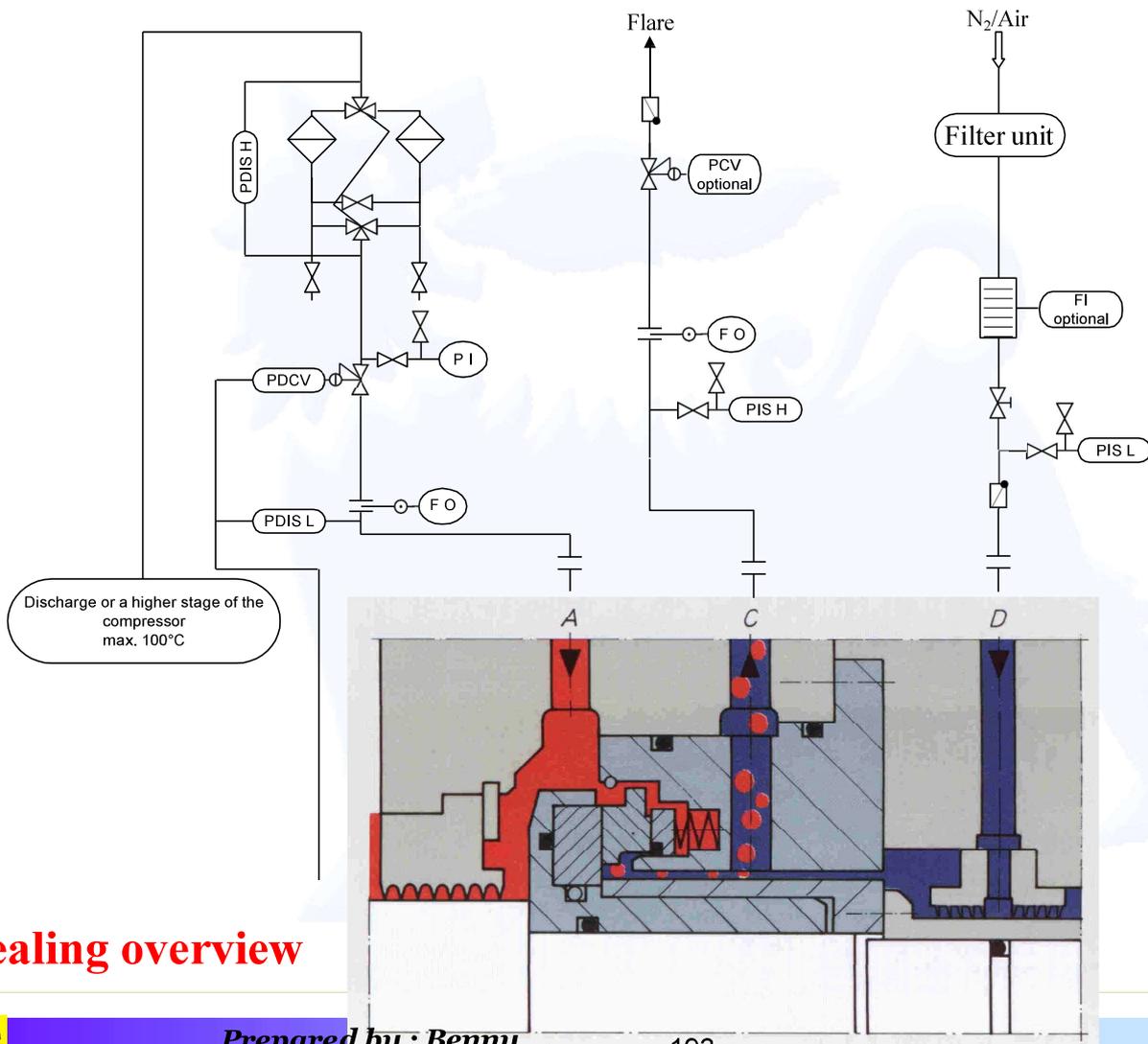
FG Flow gauge



Sealing overview

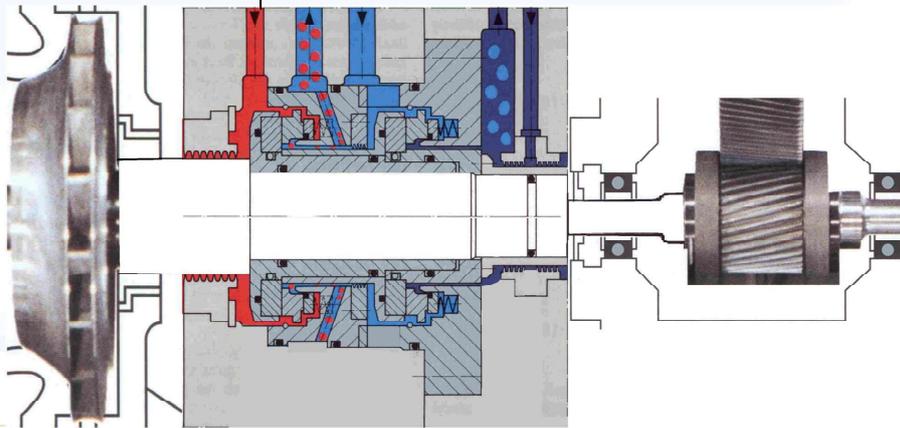
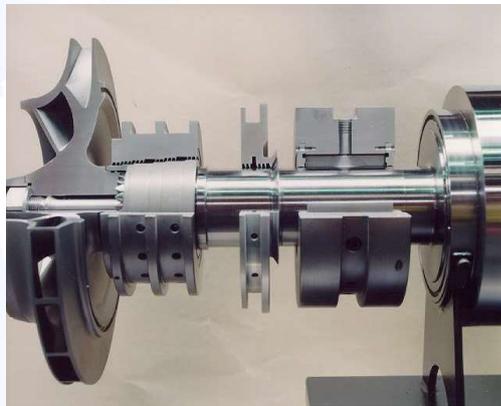
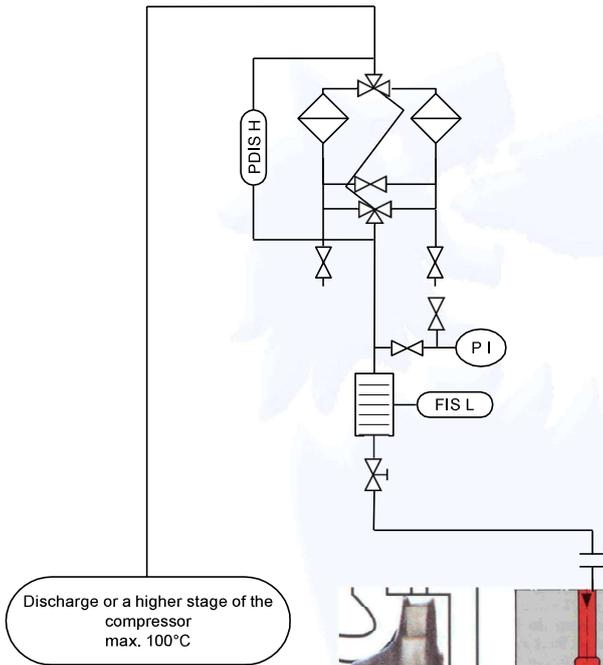
Rotor assembly sample

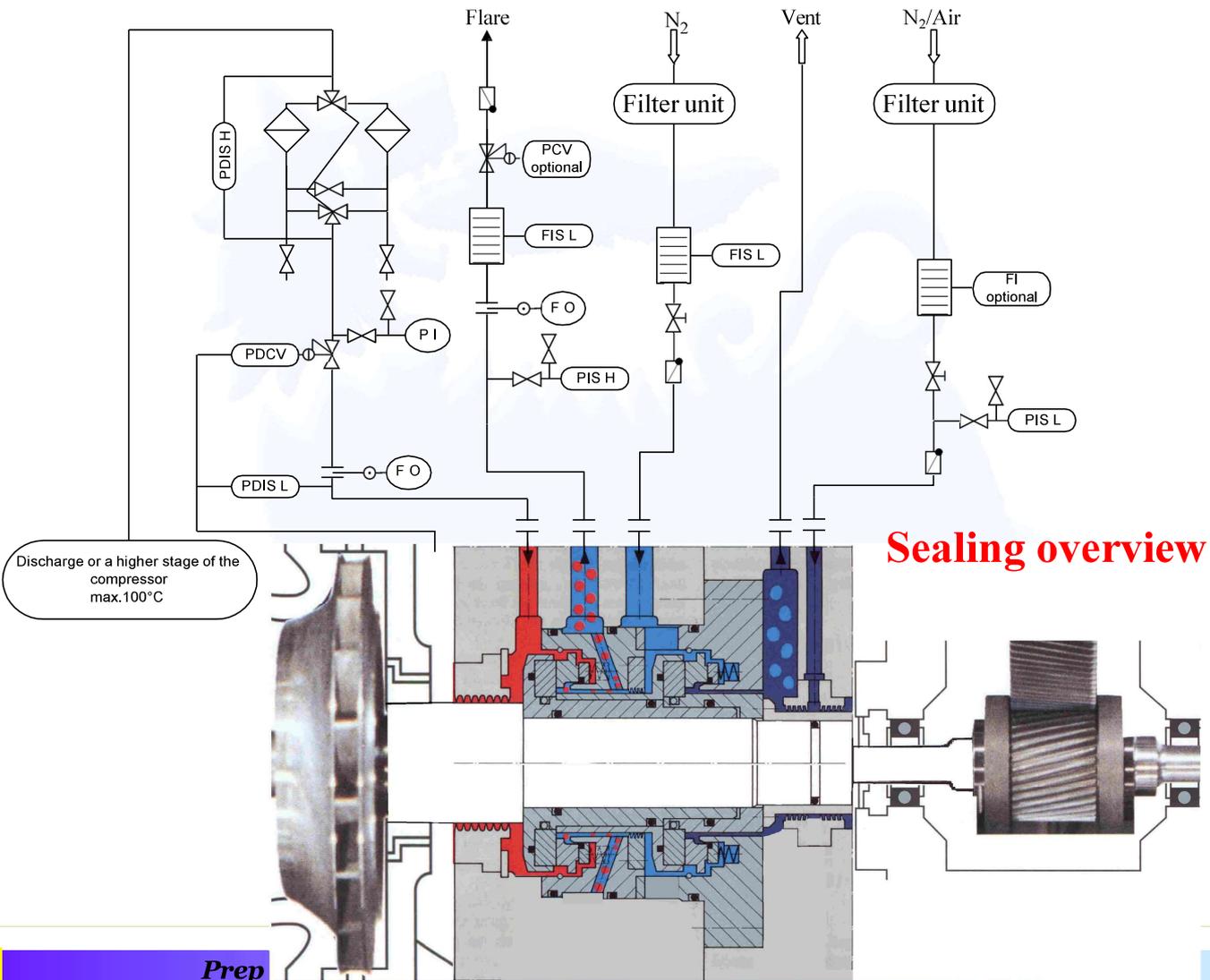


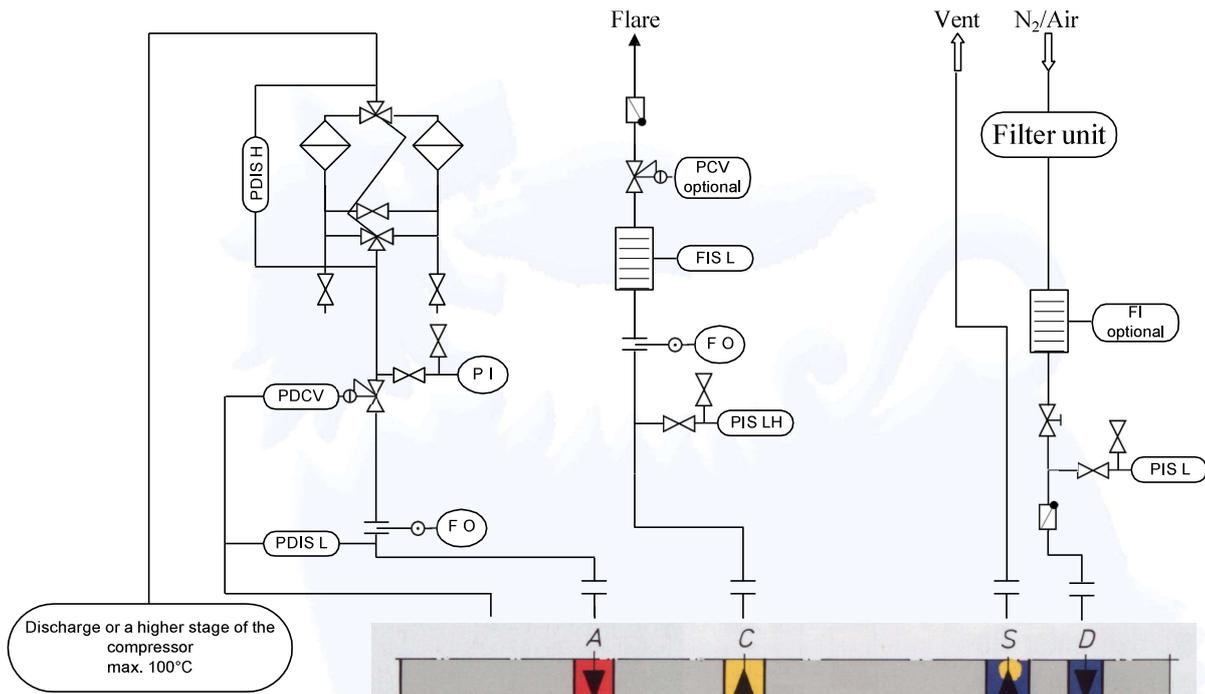


Sealing overview

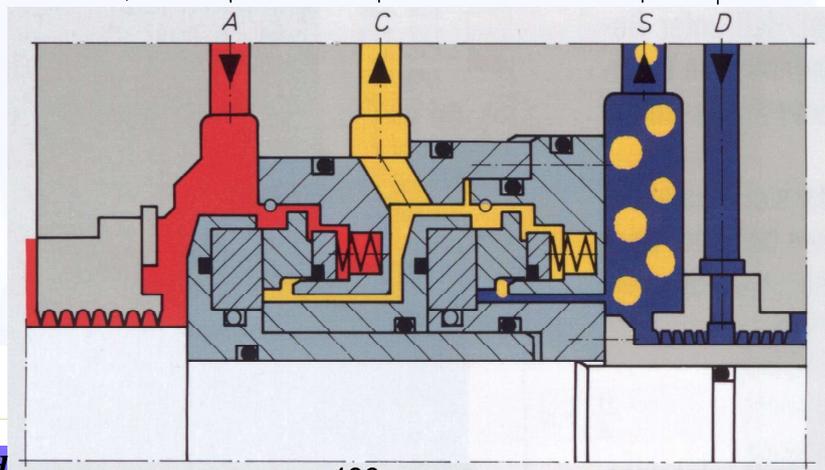
Sealing overview



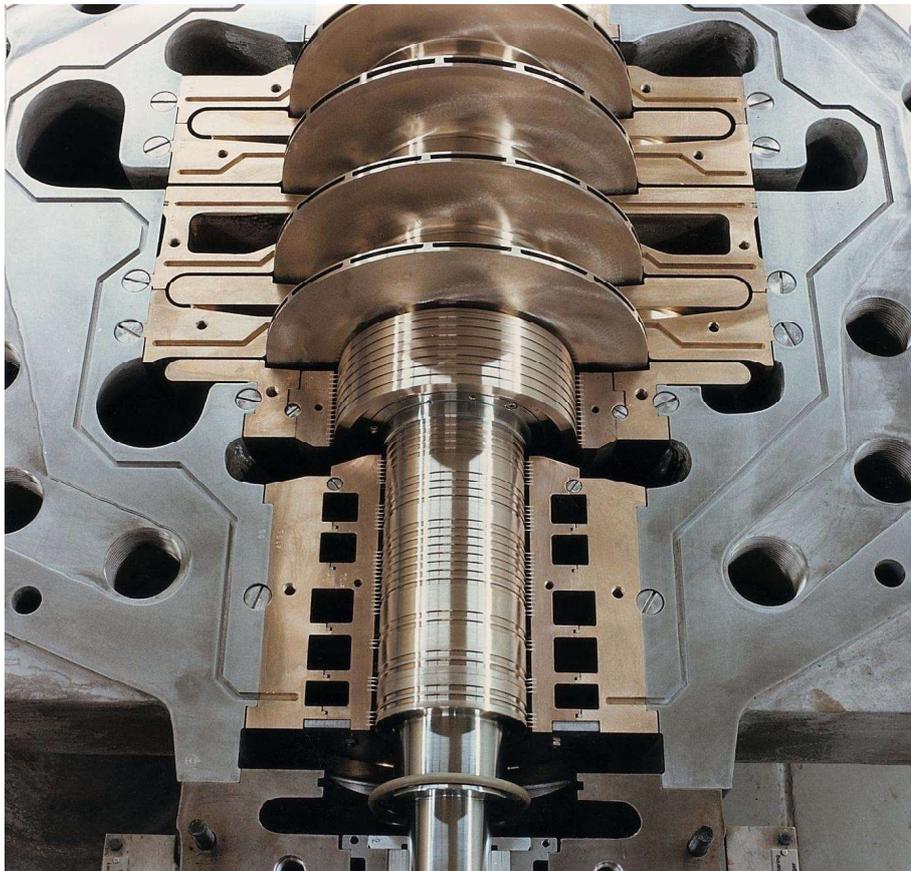


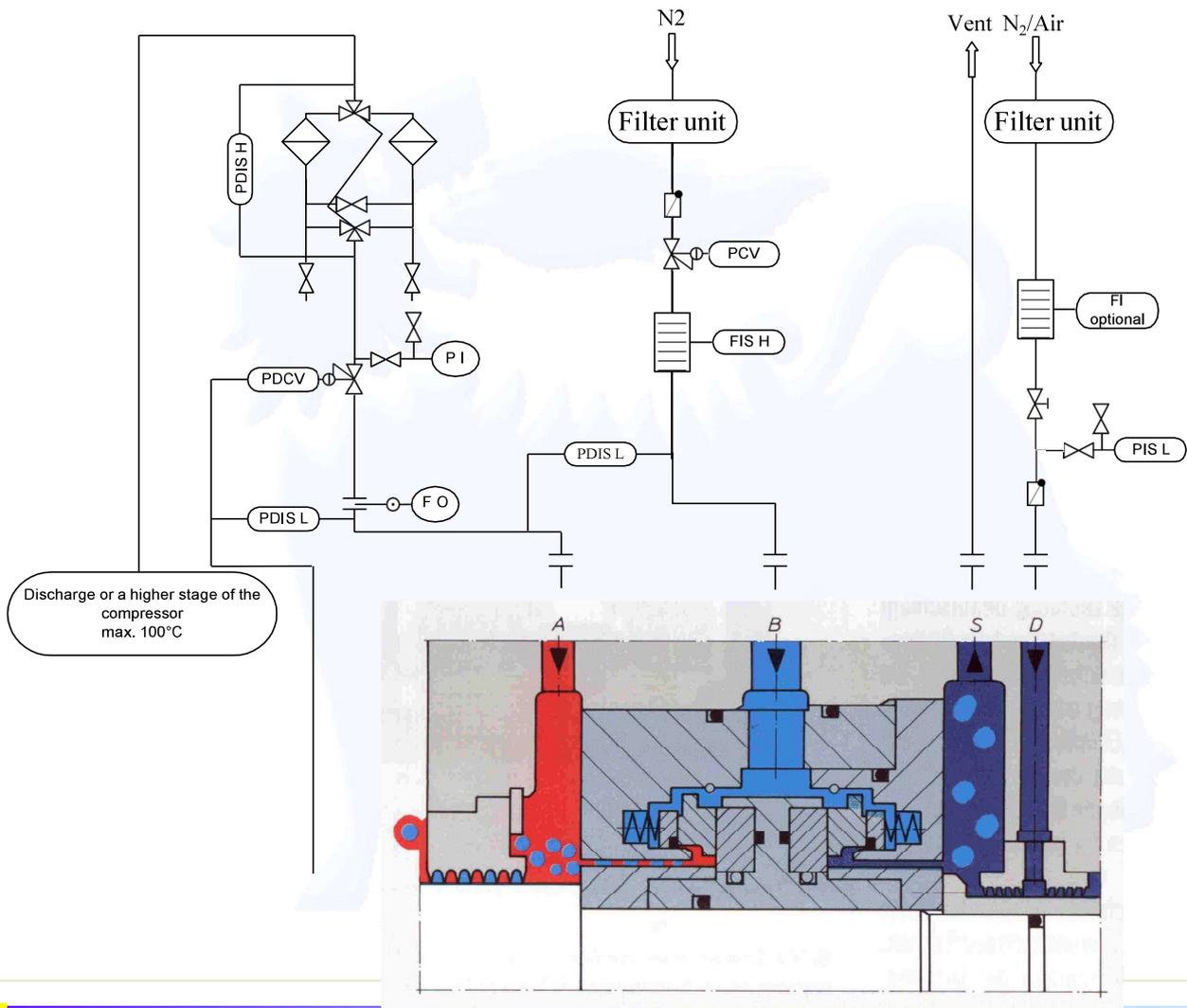


Sealing overview



Rotor and casing assembly for horizontal split compressor





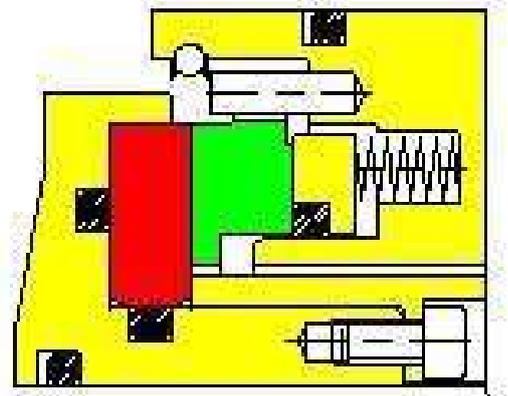


Sealing overview



Why Dry Gas Seals ?

- ***No oil usage***
- ***High reliability***
- ***High Safety***
- ***Low Maintenance Costs***
- ***Low Operating Costs***
- ***Low Process Gas Losses***
- ***Environmental Concerns***
- ***Operating Simplicity***



Sealing overview

Dry Gas Seal Materials

Metal parts
Gr.420

ASTM A276,

(DIN 1.4122)

UNS S42400

(DIN 1.4313,

DIN 1.4313S

(NACE))

Seal face

silicon carbide

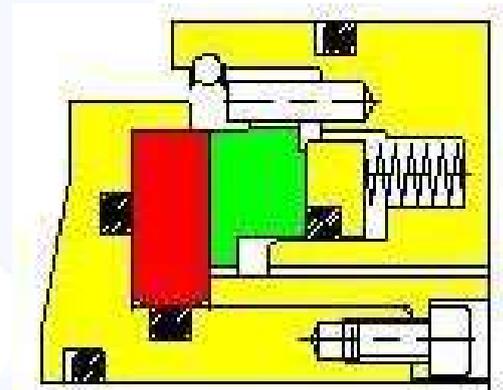
Grooved face

silicon carbide

**Secondary sealing
elements**

elastomers,

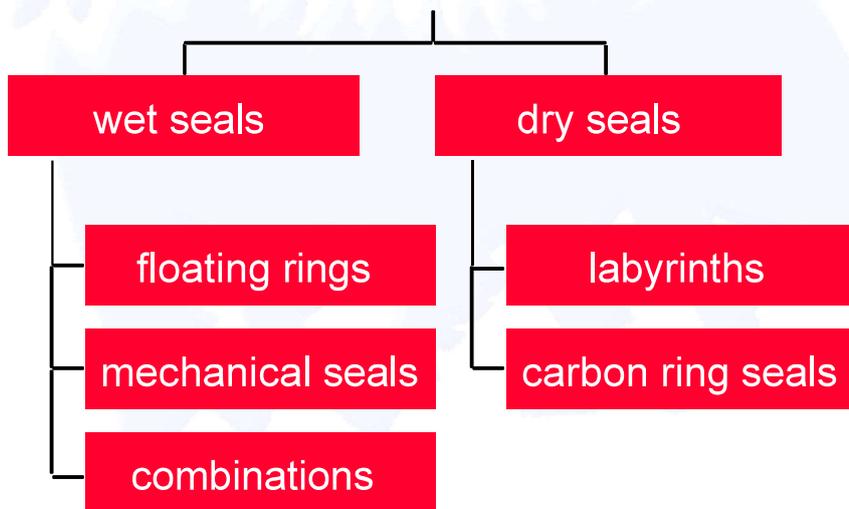
**metal spring
energized**





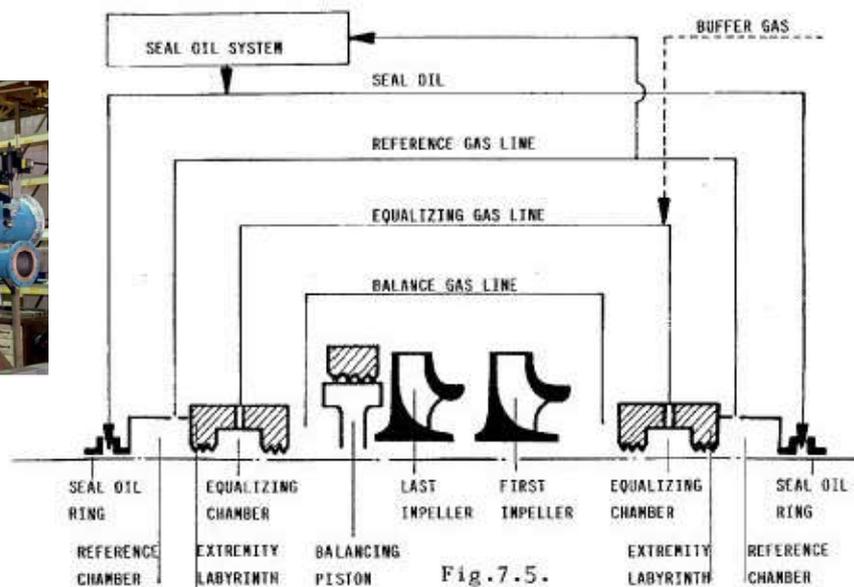
Sealing overview

sealing systems for turbocompressors



Compressors Seal Oil system

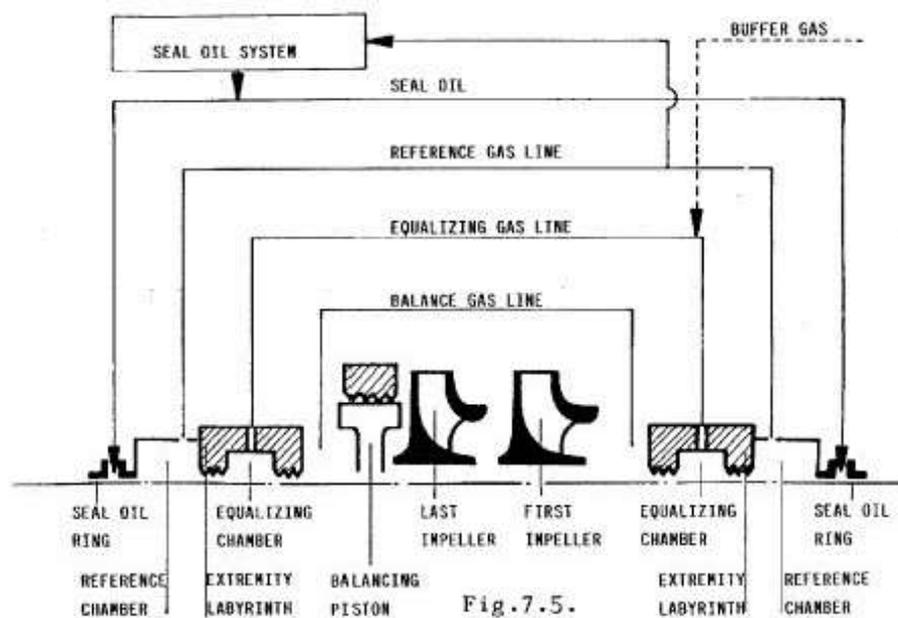
The oil system used as a compressor gas seal may either branch from a lubrication system oil header or be independent with its own oil tank, which may be different from the one used for lubrication. To illustrate the sealing system and its components better let's first see how the gas is buffered at the compressor shaft ends.



Having the end impeller delivery pressure on one side of the drum, the compressor inlet pressure is applied to the other by an external connection (balancing line). In this way gas pressures at both ends of the rotor are roughly balanced.

Compressors Seal Oil system

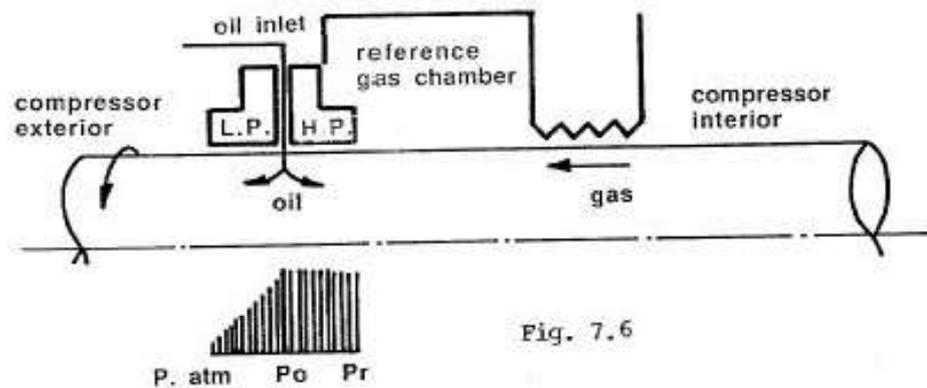
To get even closer pressure levels and therefore the same operating conditions for the shaft-end oil seals, another external connection is made between the balancing chambers.



Reference gas chambers are positioned outside the shaft-end labyrinths. They are connected to achieve the same pressure as that used as reference for the oil seal system.

Compressors Seal Oil system

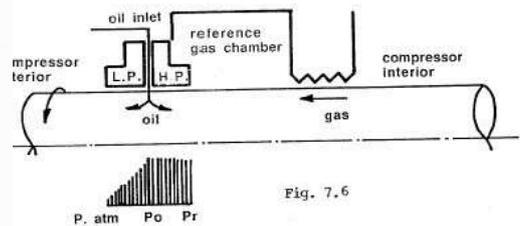
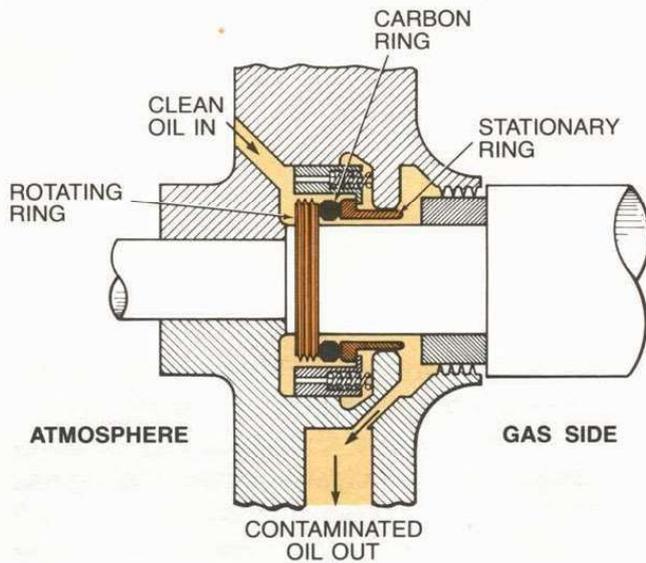
In special cases, when the seal oil and process gas have to be kept separate, inert gas is injected into the balancing chamber (buffer gas system) at a pressure that allows it to leak both inwards and outwards forming a seal.



The system adopted in 90% of the cases is an oil film between the floating rings and shaft with very tight clearances (a few hundredths of a millimetre) for the high pressure ring and approximately 0.75 mm. for the low pressure ring.

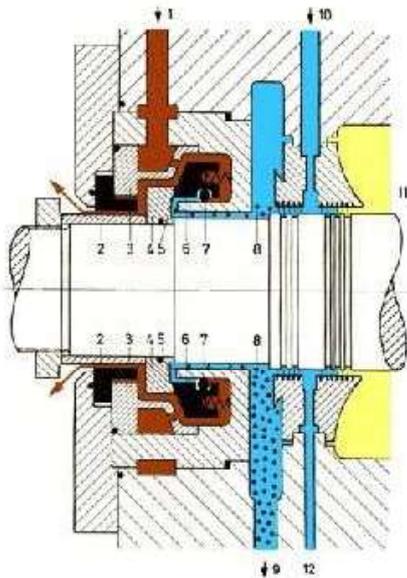
Compressors Seal Oil system

The oil is injected between the two rings (HP and LP) at a pressure maintained constantly above the gas pressure by approximately 0.5 kg/cm^2 so that there is no gas leakage towards the exterior and only a small quantity of oil passes through the H.P. ring and comes into contact with the gas (about ten litres per day).



The oil mixed in the gas reaches the traps where it is separated from the gas; after an additional separation it is returned to the main tank.

Mechanical contact seal oil system



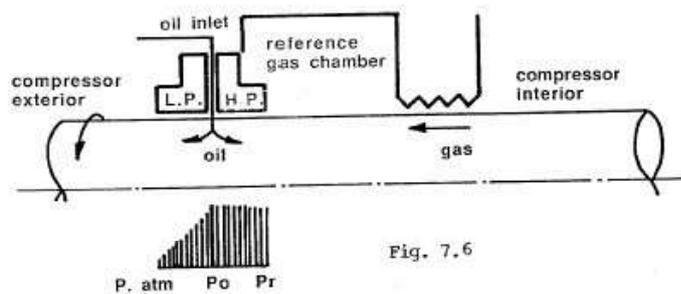
Mechanical contact seal

- | | |
|------------------------------|--|
| 1 Seal oil supply | 7 O-ring |
| 2 Floating ring | 8 Buffer gas and seal oil collecting chamber |
| 3 Distributor ring | 9 Drain from collecting chamber |
| 4 Rotating ring on the shaft | 10 Buffer gas supply |
| 5 Sealing interface | 11 Process gas |
| 6 Carbon ring | 12 Check drain |

Compressors Seal Oil system

The heat generated by friction in the HP ring gap is not disposed of by the oil flow through it which is low on account of the small clearance between the HP ring and shaft and the low oil / gas differential pressure.

To avoid damaging (burning) the bearing white metal, the LP ring clearance plus the high difference in pressure towards the exterior are such as to cause a good oil flow and therefore good heat absorption

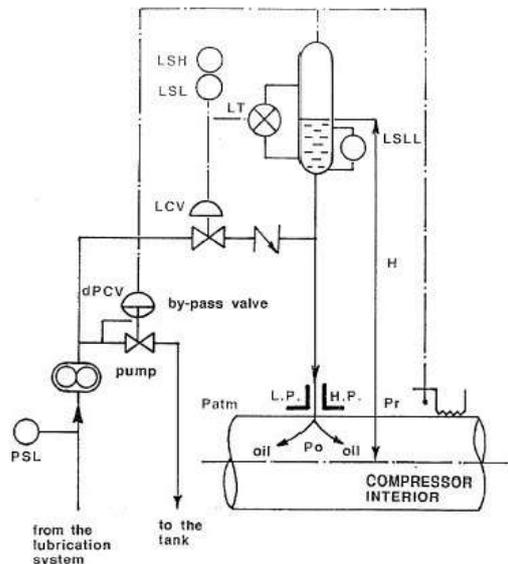


This oil, which is not in contact with the gas, is drained straight into the tank through the lube oil return line (in combined systems).

To maintain a constant differential pressure of approx. 0.4 to 0.5 kg/cm² between the oil and gas, two types of systems are normally used to suit different compressor plant requirements and operating conditions.

Compressors Seal Oil system

The first system consists in maintaining the overhead tank level constant about seven metres above the compressor axis so that the seal oil pressure (P_o) is the same as the gas pressure (P_r) plus the head. (H).



Seal oil System

The second system is essentially based on automatic control of a differential oil /gas valve, which maintains the desired differential pressure of approx. 0.5 Atm, keeping the overhead tank completely full and under pressure . In this case the tank position does not affect the operation of the system and therefore may be installed directly on the compressor thus eliminating all the problems related with an overhead tank. On any increase in oil flow through the seal rings the level valve will open wider and the vent valve closes correspondingly.

Seal oil relations

Let's see the relations between pressures at the various points of this system. First of all, if we want the head in metres of oil to give the differential pressure required at the sides of the high pressure ring, we have to connect the overhead tank and pressure chamber.

$$P_o = P_g + \gamma_o H - dp; \quad \text{where}$$

P_o = seal ring inlet oil pressure

P_g = overhead tank level gas pressure in turn expressed as:

$$P_g = P_r - \gamma_g H \quad (\gamma_g = \text{gas specific gravity})$$

γ_o = oil specific gravity

dp = losses in the tank-seal line to be considered if the oil flow is great compared with the diameter. It is disregarded for flows of 30 to 40 l/min. and 2 to 3 inch diameters.

$$P_o = P_r - \gamma_g H + \gamma_o H - dp = P_r + H(\gamma_o - \gamma_g) - dp;$$

$$(P_o - P_r) = \Delta p = (\gamma_o - \gamma_g)H - dp;$$

$$\Delta p + dp = H(\gamma_o - \gamma_g) \text{ and hence:}$$

$$H = \frac{\Delta p + dp}{\gamma_o - \gamma_g} \text{ (head in metres);}$$

$$\text{disregarding } dp \text{ and } \gamma_g, H = \frac{\Delta p}{\gamma_o}$$

$$P_o - P_r = \Delta p$$

When **dp** shall not be considered !

*While **dp** need not be considered when sufficient diameter pipes are used.*

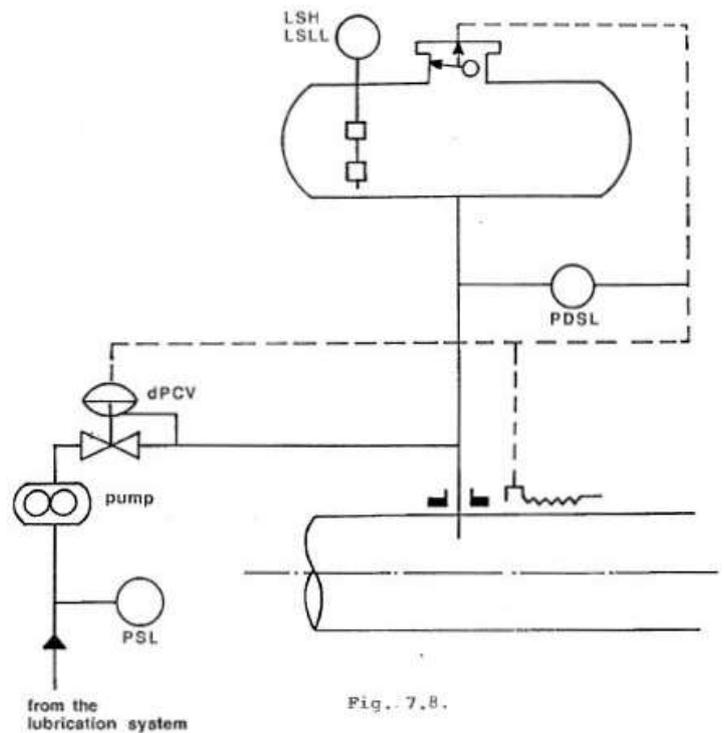
For high pressure heavy gas

If **gas specific gravity** which may even reach around 0.5, **oil specific gravity** for high pressure heavy gas in this case double the the head would be required to obtain the same differential pressure. For example, with oil specific gravity equal to 0.8 kg/dm³ roughly a 5 meter head is needed to achieve a differential pressure of approximately 0.4 kg/cm².

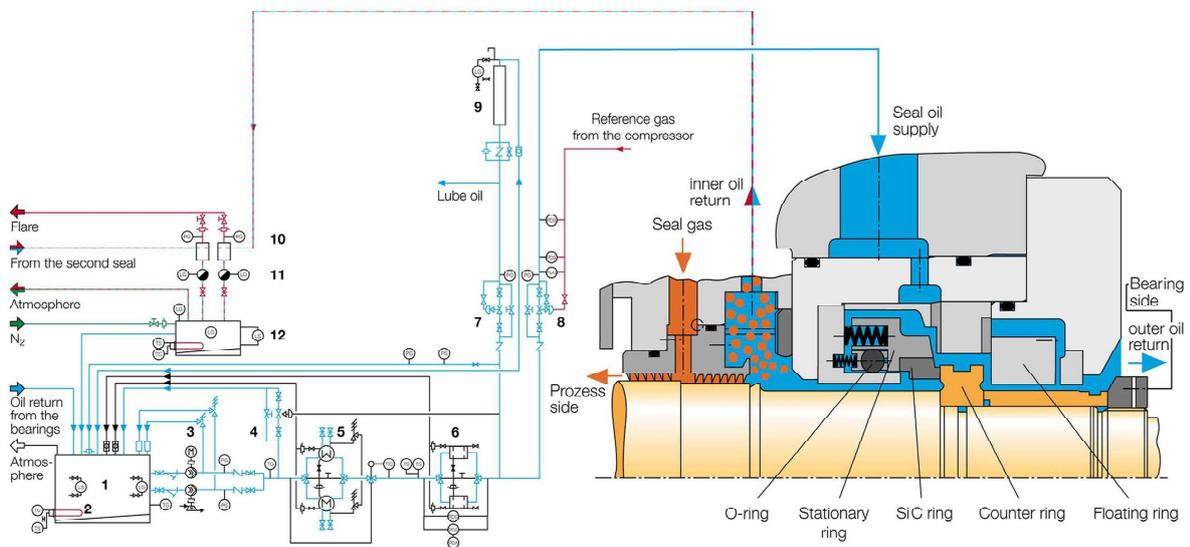
Second system

As previously mentioned, the oil pressure is maintained at approximately 0.7 to 1 kg/cm² higher than the gas by valve DPCV for any gas pressure.

The tank always works under pressure; its volume depends on the retention time one wishes to have on compressor shutdown due to the minimum oil /gas differential pressure .



Seal Oil system



Combined lube and seal oil supply system

- | | | | |
|-------------------------------------|--|--------------------------------|-------------------------|
| 1 Oil tank | 8 Pressure control valve (seal oil) | LG Level gauge | T Turbine |
| 2 Heater | 9 Lube oil overhead tank/ rundown tank | LS Level switch | TC Temperature control |
| 3 Oil pumps | 10 Seal oil separators | PDA Pressure difference alarm | TIC Temperature control |
| 4 Relief valve | 11 Demisters | PDG Pressure difference gauge | TS Temperature switch |
| 5 Oil coolers | 12 Degassing tank (lube oil) | PDS Pressure difference switch | -L Alarm „low” |
| 6 Oil filters | | PG Pressure gauge | -H Alarm „high” |
| 7 Pressure control valve (lube oil) | | PS Pressure switch | |

Instrumentation on the seal oil system

The instruments normally installed and able to depend on gas buffering in compressors are:

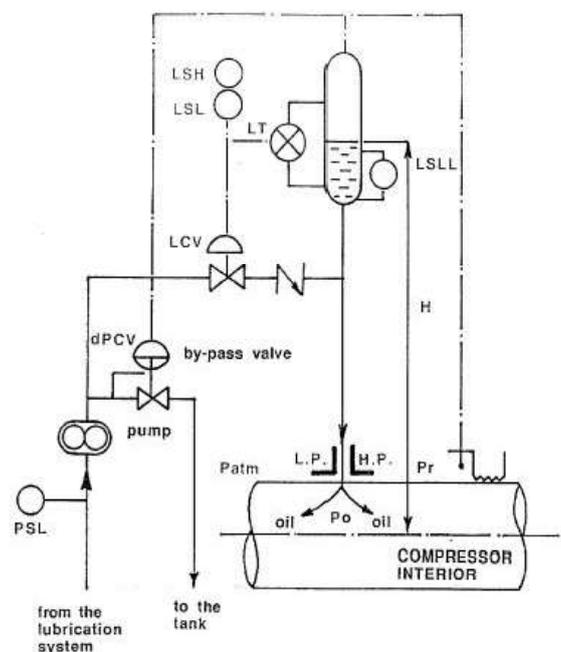
First system

PSL : **Pump suction low pressure alarm.**

LSH : **High tank oil level alarm.**

LSL : **Low level alarm and auxiliary pump start up.**

LSLL: **Minimum level trip.**



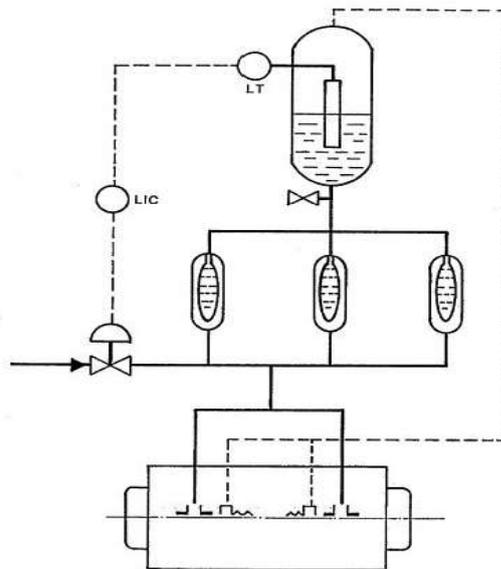
Second system

PSL : Pump suction low pressure alarm

LSH : Pressurization sequence admissive start.

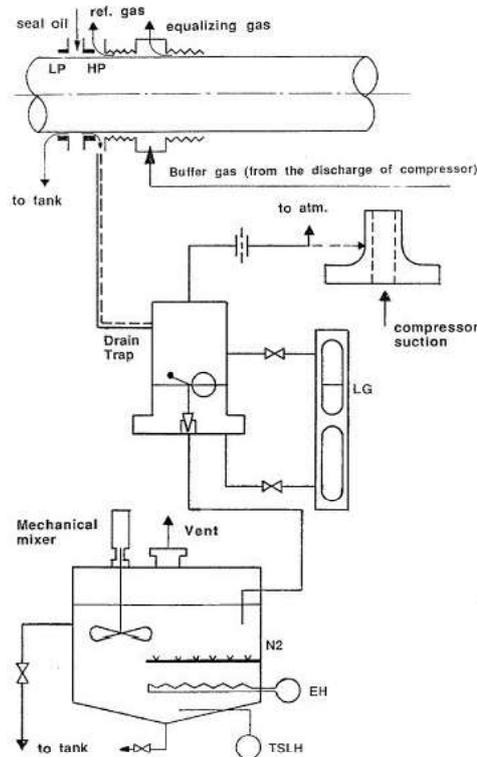
PDSL : Oil/gas low differential pressure alarm and auxiliary pump start up.

LSLL : Minimum level trip when *gas* is handled that would contaminate the oil (e.g. H₂S) vessels are used with diaphragms



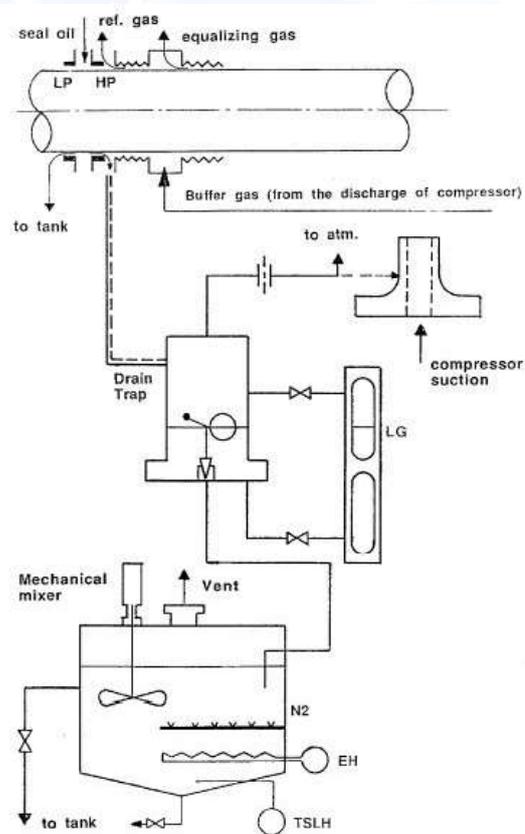
Below the overhead tank there are retention tanks to keep the general systems oil separate from the contaminated oil. The number of tanks depends on the retention time one wishes to obtain .

The oil that has sealed the gas, passes into the reference gas chamber and is drained by gravity to the traps where it is separated



A float valve sends the oil to the gas separating tank where it is kept at a temperature of approx. 85 to 90°C. A mechanical mixer or an inert gas (nitrogen) scrubber may be used if necessary for complete stripping of any gas left in the oil.

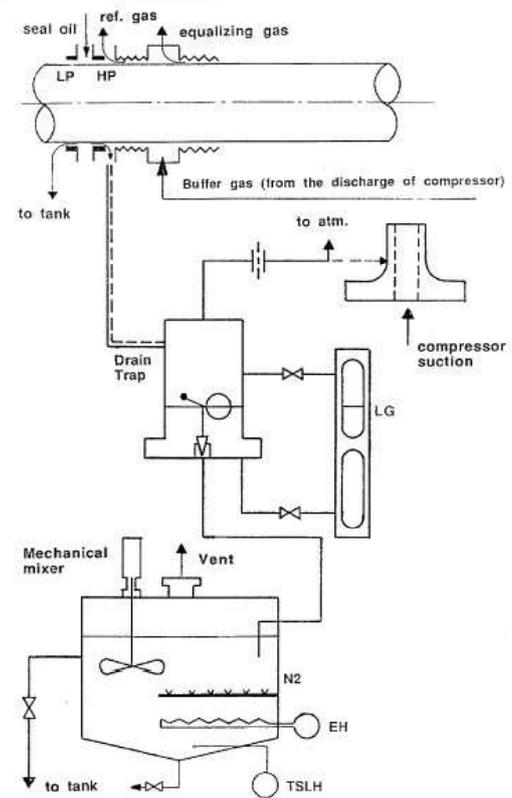
The oil is then analysed and may be returned to the main tank or further regenerated. The gas comes out the top of the trap and is released through a calibrated orifice a few millimeters wide thus creating a downward flow inside the compressor towards the trap entraining the seal oil.



Since the reference gas pressure is practically the same as the compressor suction pressure. It will have to be increased if the gas is to be returned from the traps to the compressor suction, with a buffer gas line on the balance line in order to always have a positive differential pressure on the orifice or by taking the reference gas from an intermediate compressor stage.

Seal oil drainage systems normally have the following Instrumentation and equipment.

- LG :** Trap level gauge.
- LAL :** Low trap level alarm.
- LSH :** High trap level alarm.
- TSLH:** Gas separating tank heater on-off temperature switch.



API 617 centrifugal compressors

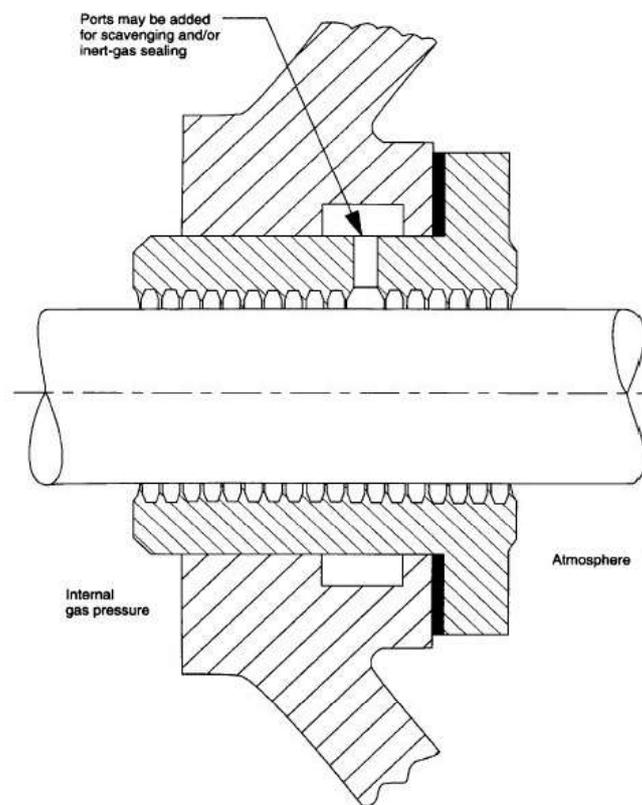


Figure 2—Labyrinth Shaft Seal

API 617 centrifugal compressors

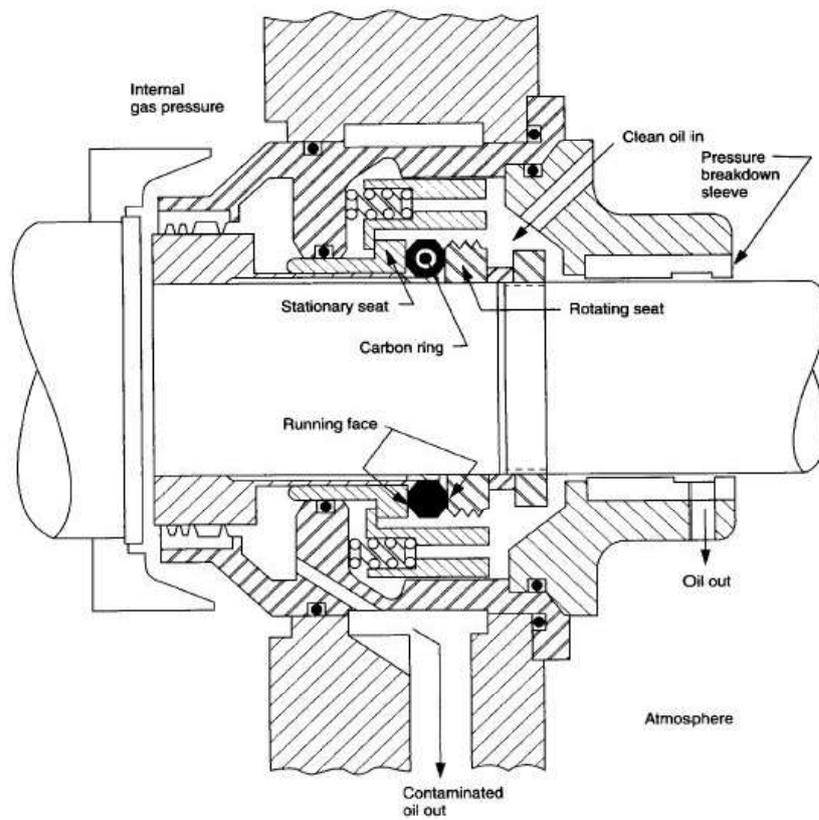


Figure 3—Mechanical (Contact) Shaft Seal

API 617 centrifugal compressors

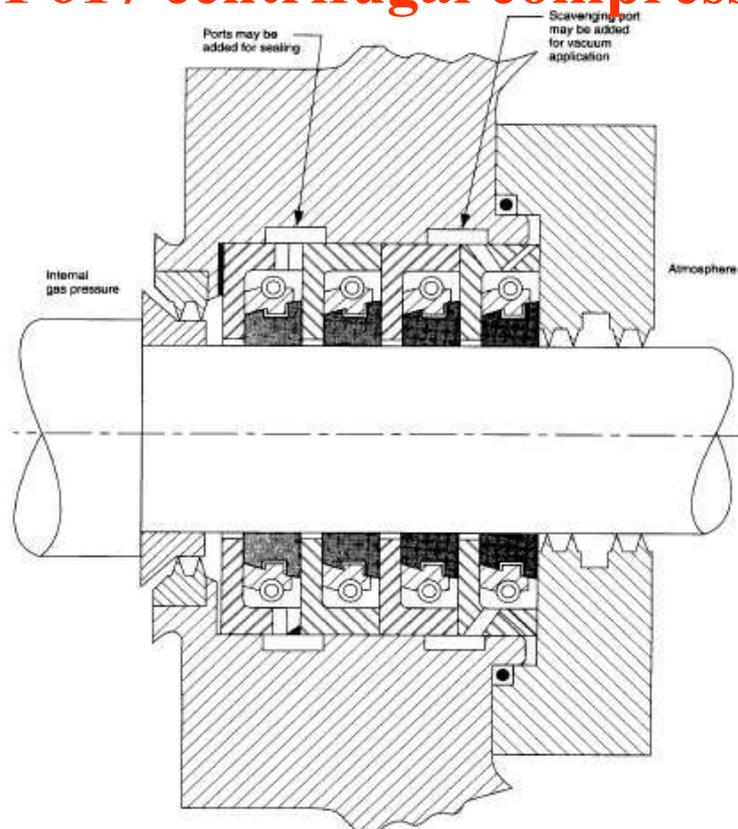


Figure 4—Restrictive-Ring Shaft Seal

API 617 centrifugal compressors

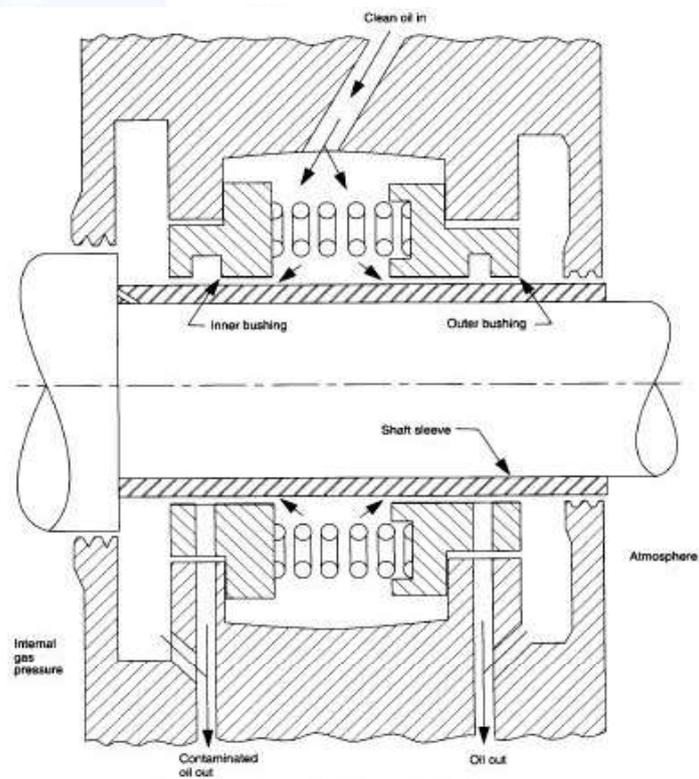


Figure 5—Liquid-Film Shaft Seal with Cylindrical Bushing

API 617 centrifugal compressors

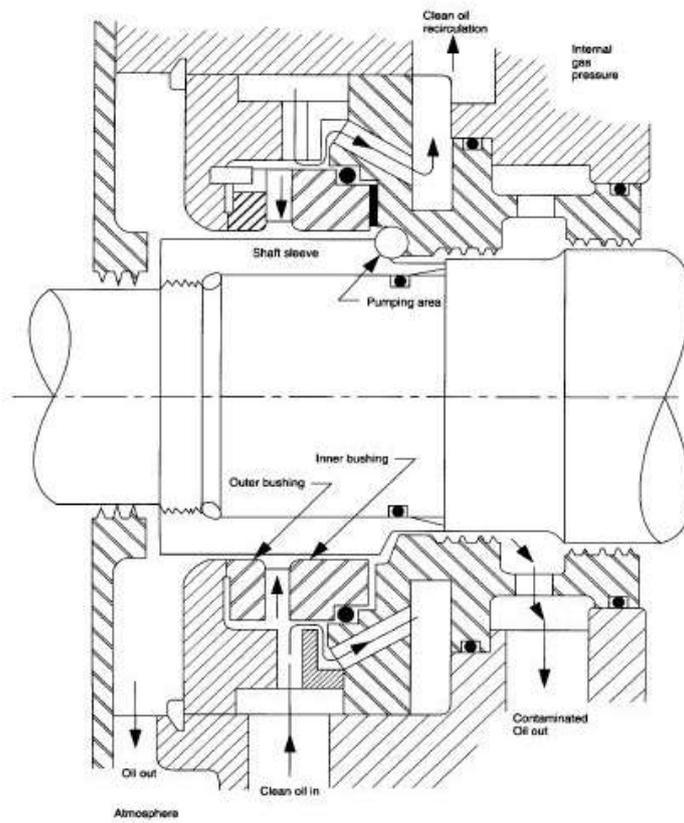


Figure 6—Liquid-Film Shaft Seal with Pumping Bushing

API 617 centrifugal compressors

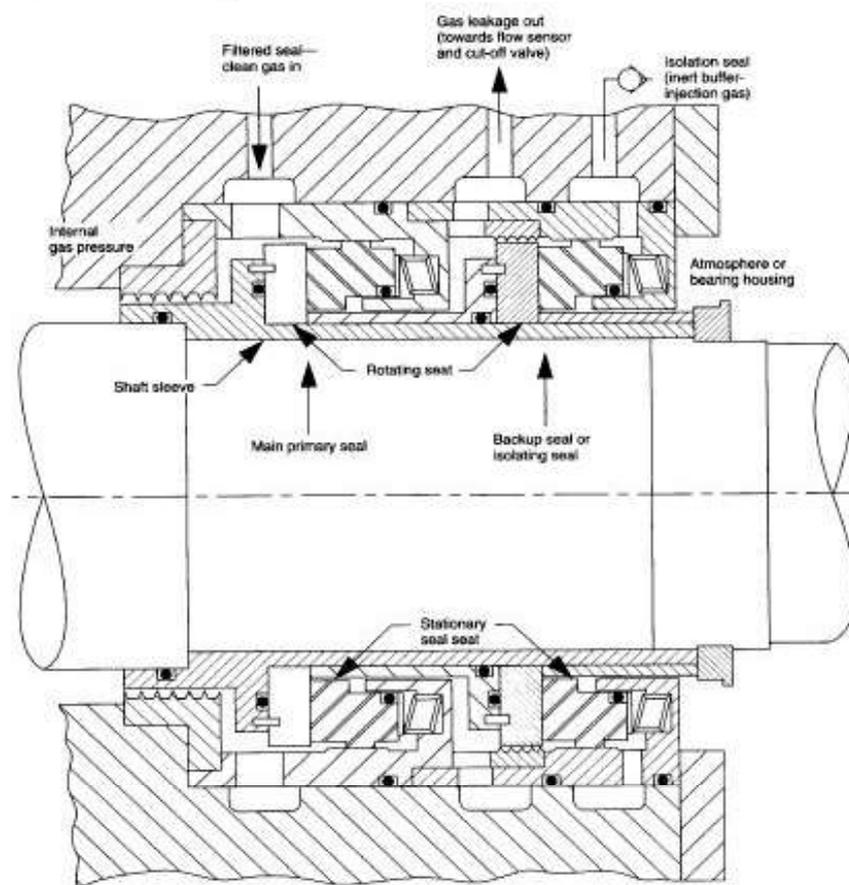


Figure 7—Self-Acting Gas Seal

Seal Arrangement and Configuration

A seal arrangement defines the number of seals in the cartridge
And the pressure in the cavity between DUAL SEALS

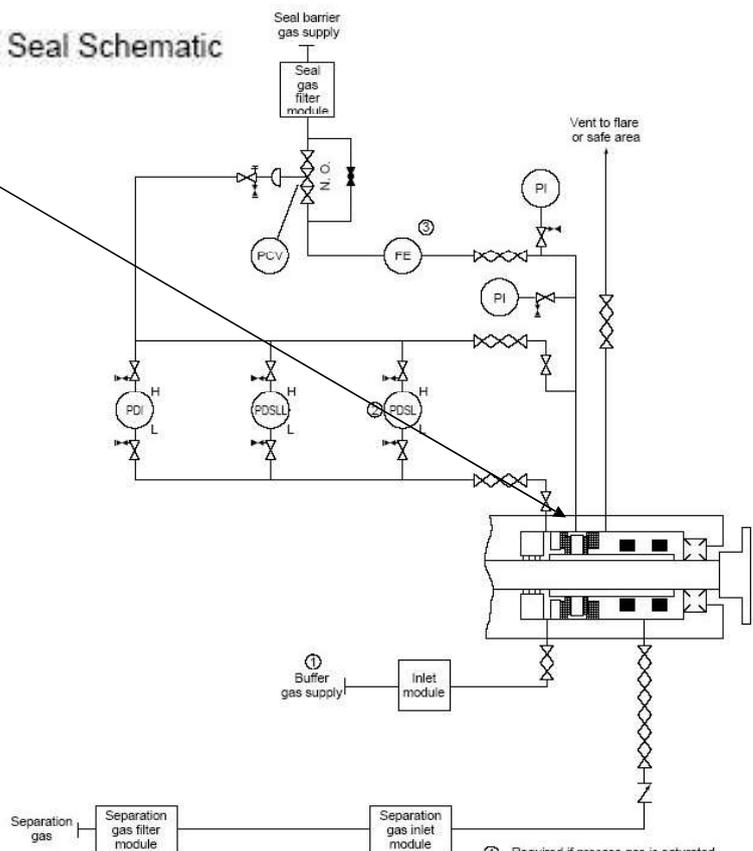
There were three arrangements in **API682** first edition as follows:

Arrangement 1: Single seal

Arrangement 2: Dual Seal in series (face to back) orientation .the buffer fluid cavity between two seals was maintained at a pressure lower than seal chamber pressure.

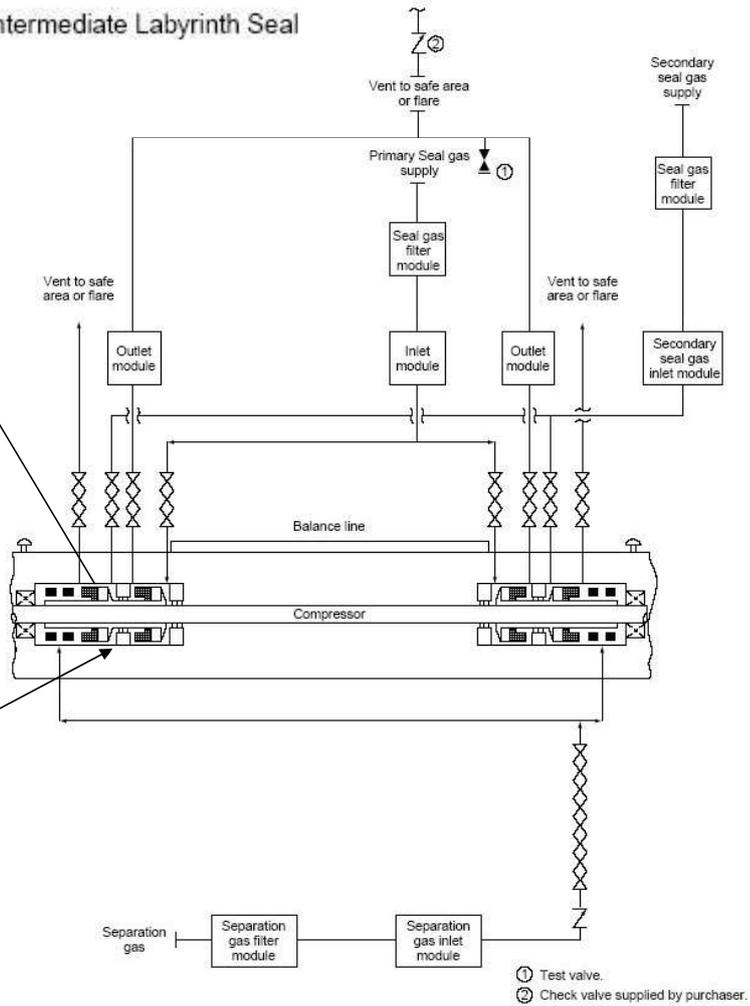
Arrangement 3: was a dual seal in series (face-to-back) orientation with a barrier Fluid pressure greater than the seal chamber pressure

-Double Opposed Dry Gas Seal Schematic



- ① Required if process gas is saturated or contains fines.
- ② Required to ensure seal gas flow across gas seal surfaces.
- ③ Optional flow element.
- ④ See 2.1.11.

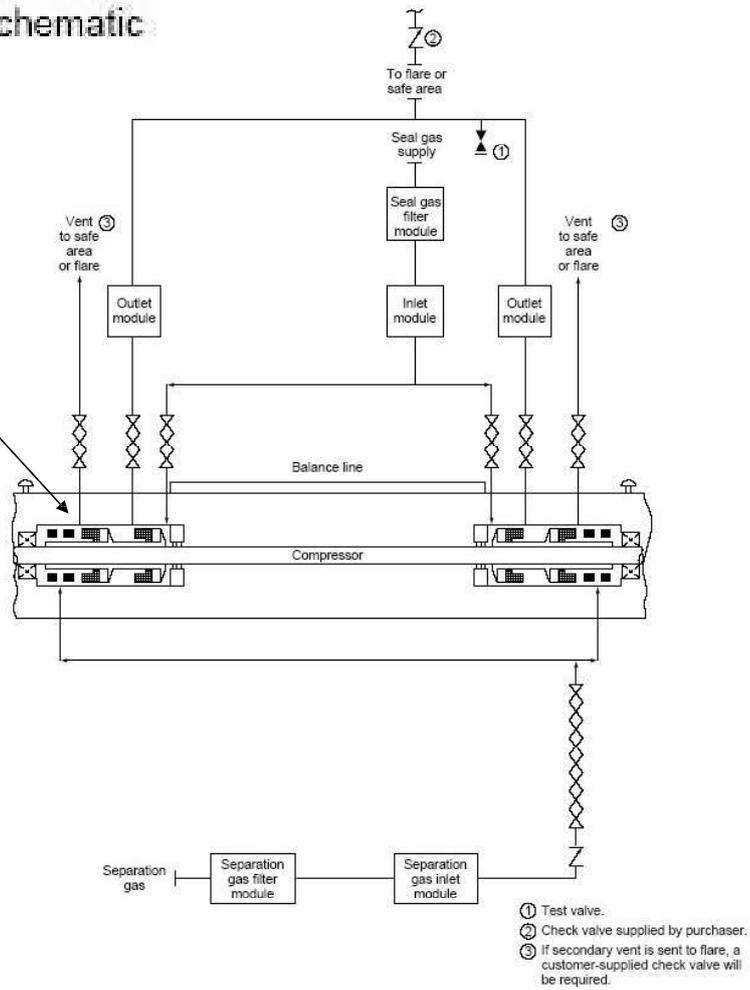
Tandem Dry Gas Seal Schematic With Intermediate Labyrinth Seal



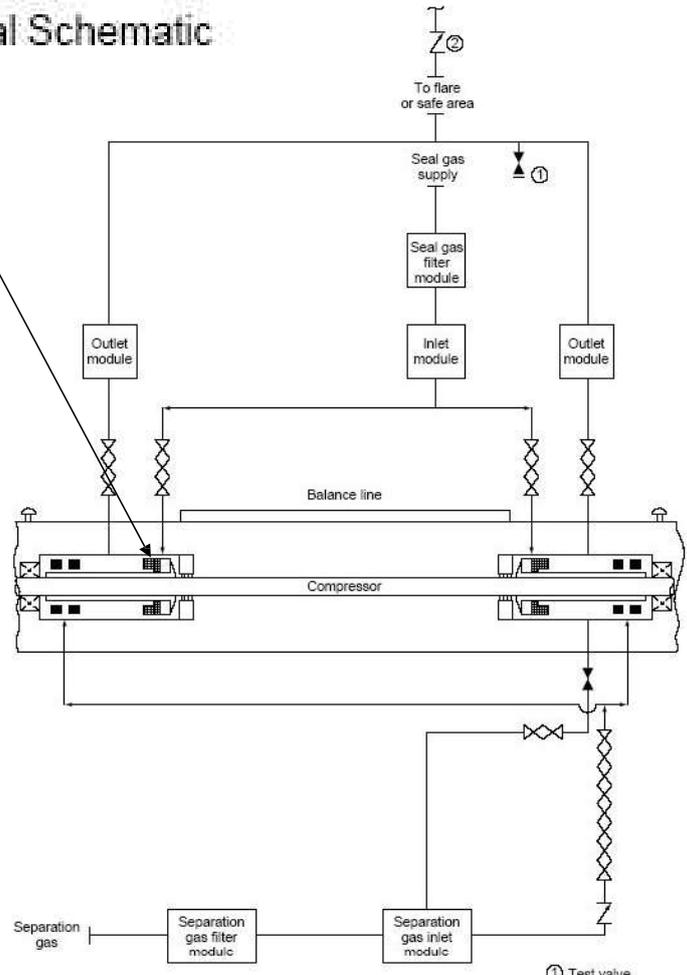
Labyrinth seal



Tandem Dry Gas Seal Schematic



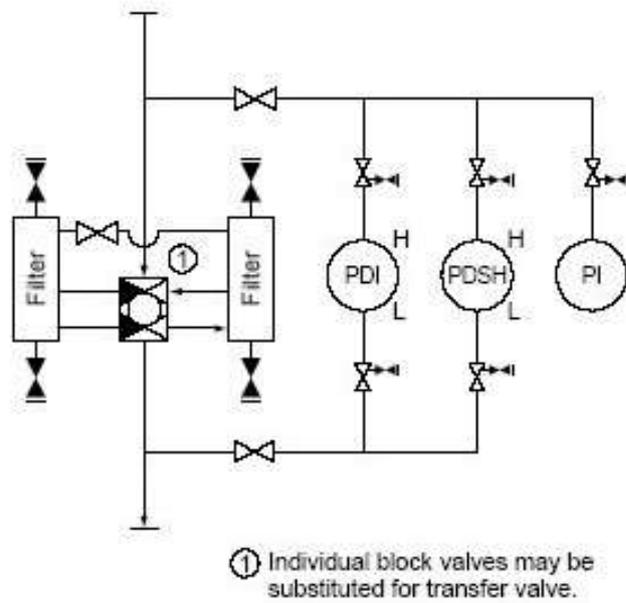
Single Dry Gas Seal Schematic



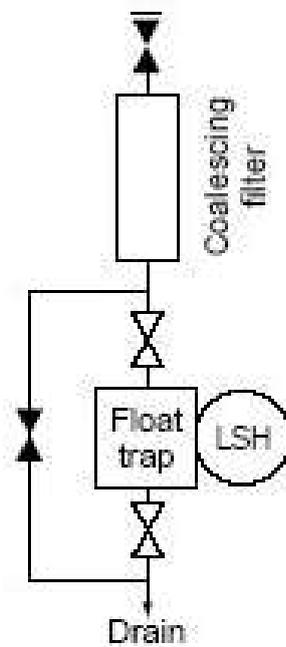
- ① Test valve.
- ② Check valve furnished by purchaser.



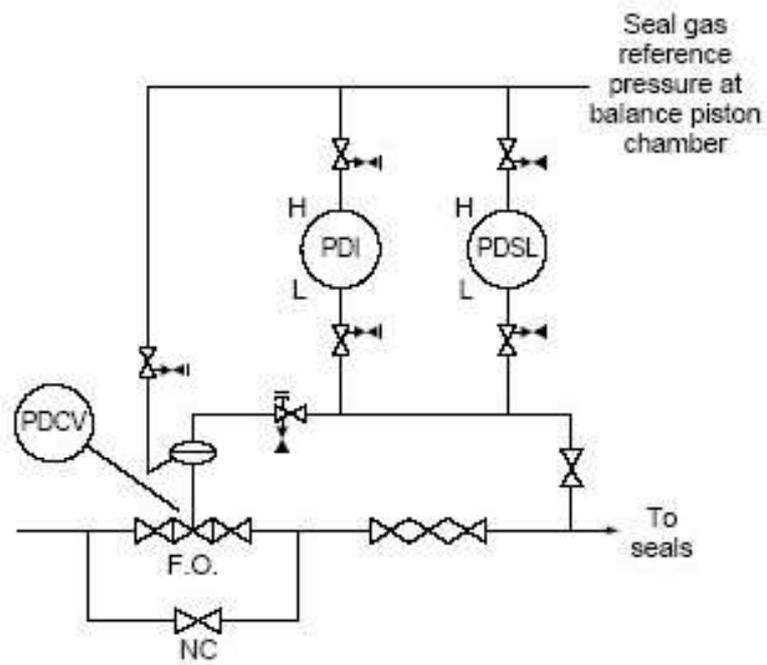
Seal Gas Filter Module



Optimal Automatic Liquid Drainer System for Coalescing Gas Filters



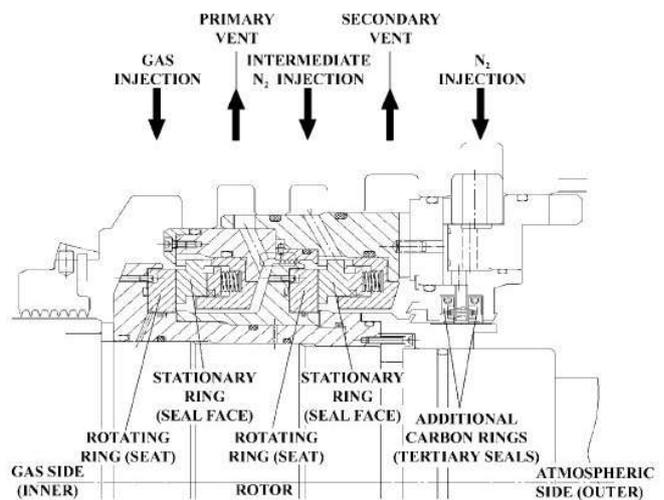
-Differential Pressure Control



SHAFT END SEALS

DRY GAS SEALS AND SEPARATION SEALS (BARRIER)

Seals are assembled at the two ends of each shaft of the compressors to prevent gas from escaping out of the machines.



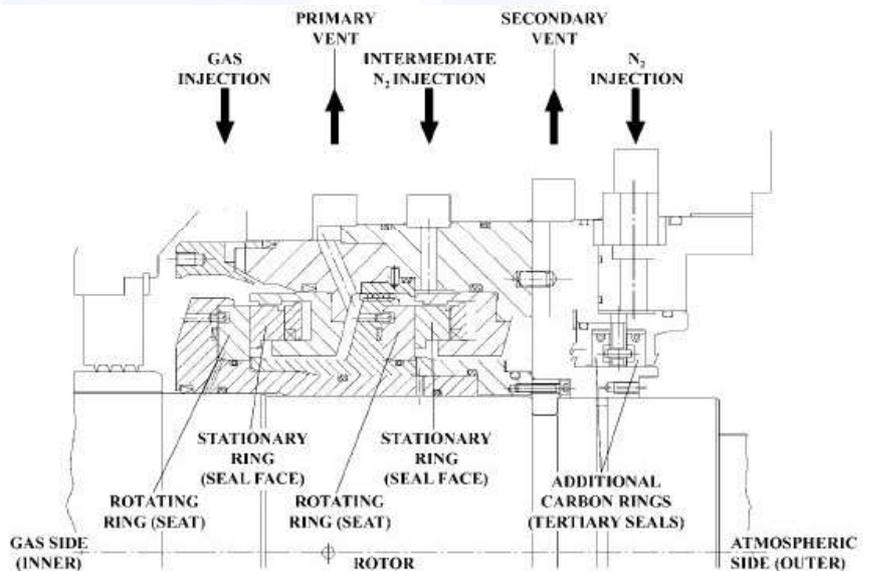
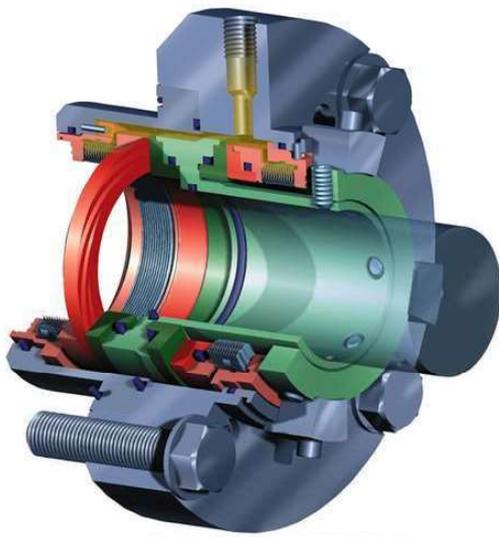
Typical mechanical gas seals assembly BCL 304/A dwg.

These seals consist of tandem dry gas seals with tertiary seals and labyrinth seals.

The dry gas seals and tertiary are supplied by **FLOWSERVE**.

DGS Dry Gas Seal

The dry gas seals consist of two mechanical seals with lapped faces, side by side, of two rotating rings (seat), in **tungsten carbide or silicon nitrite** and two stationary rings (seal face) in **silicon carbide**.



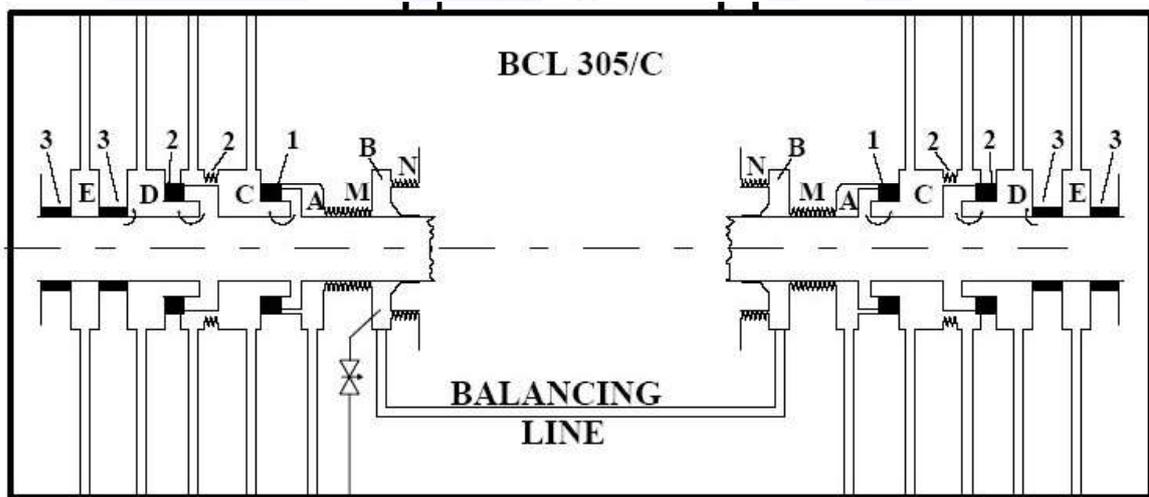
Typical dry gas seals assembly BCL 304/B - BCL 305/C dwg.

The inner part (gas side) of each mechanical seal is the part that supports the pressure of the seal gas, while the outer part is stand-by to it.

Tertiary seals.

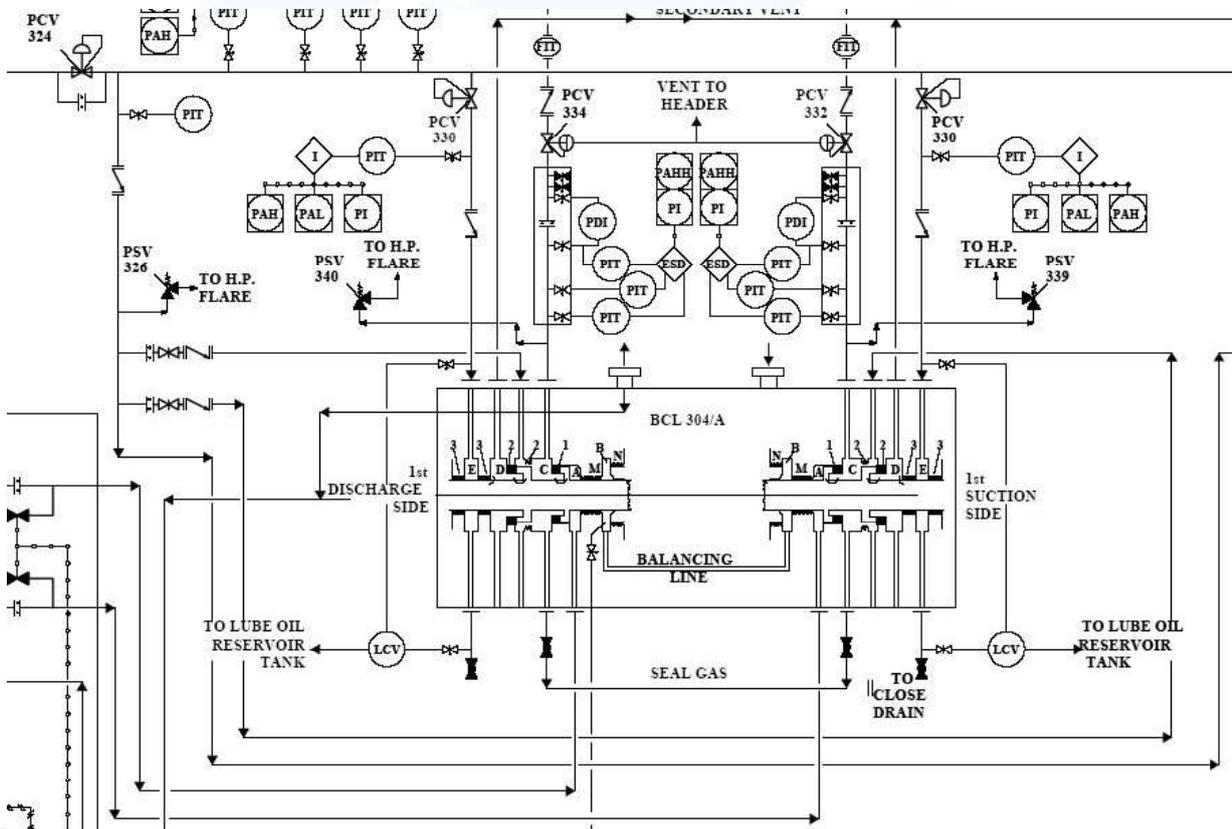
In addition at this tandem seal arrangement the complete dry gas seal includes two additional carbon rings: tertiary seals.

The tertiary seal is used to prevent the lube oil contamination on bearing housing chamber and the lube oil migration to the secondary tandem seals rings.

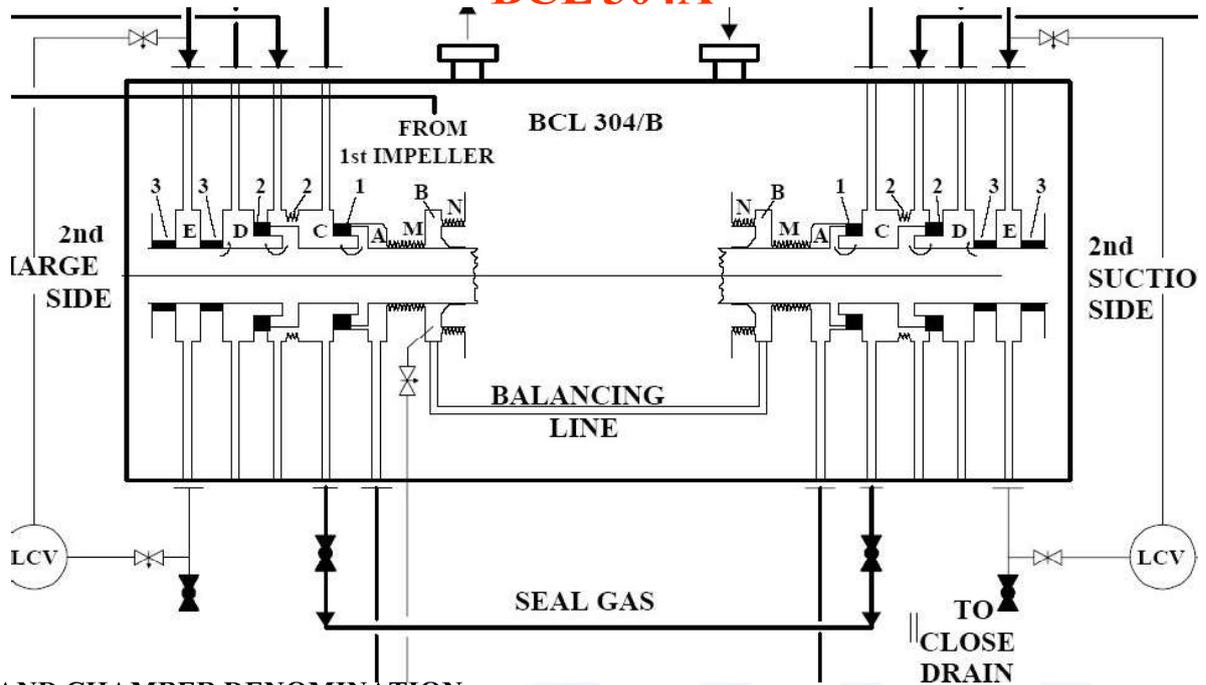


- 1 DRY GAS SEAL INNER RING
- 2 DRY GAS SEAL OUTER RING
- 3 TERTIARY SEALS

DGS BCL 304A



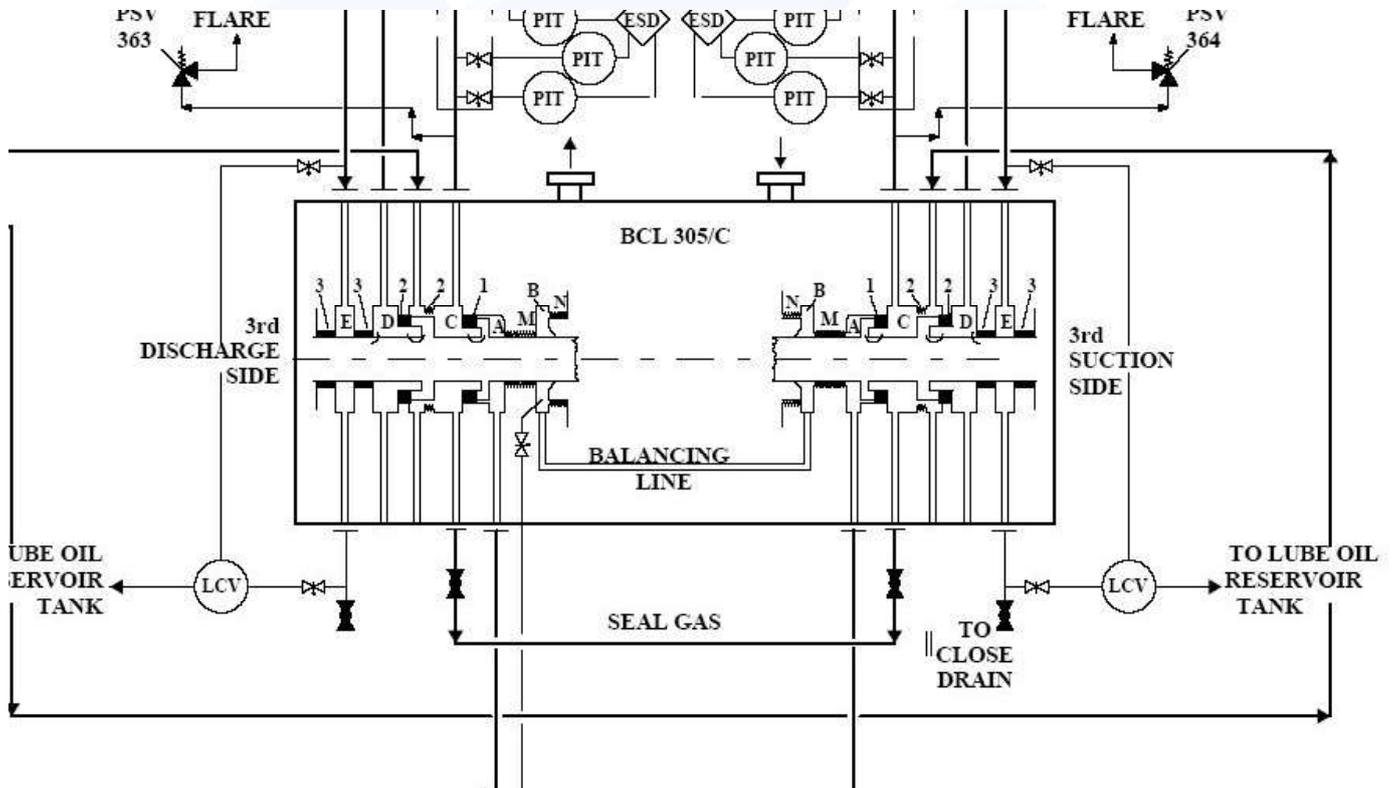
BCL 304A



SEAL AND CHAMBER DENOMINATION

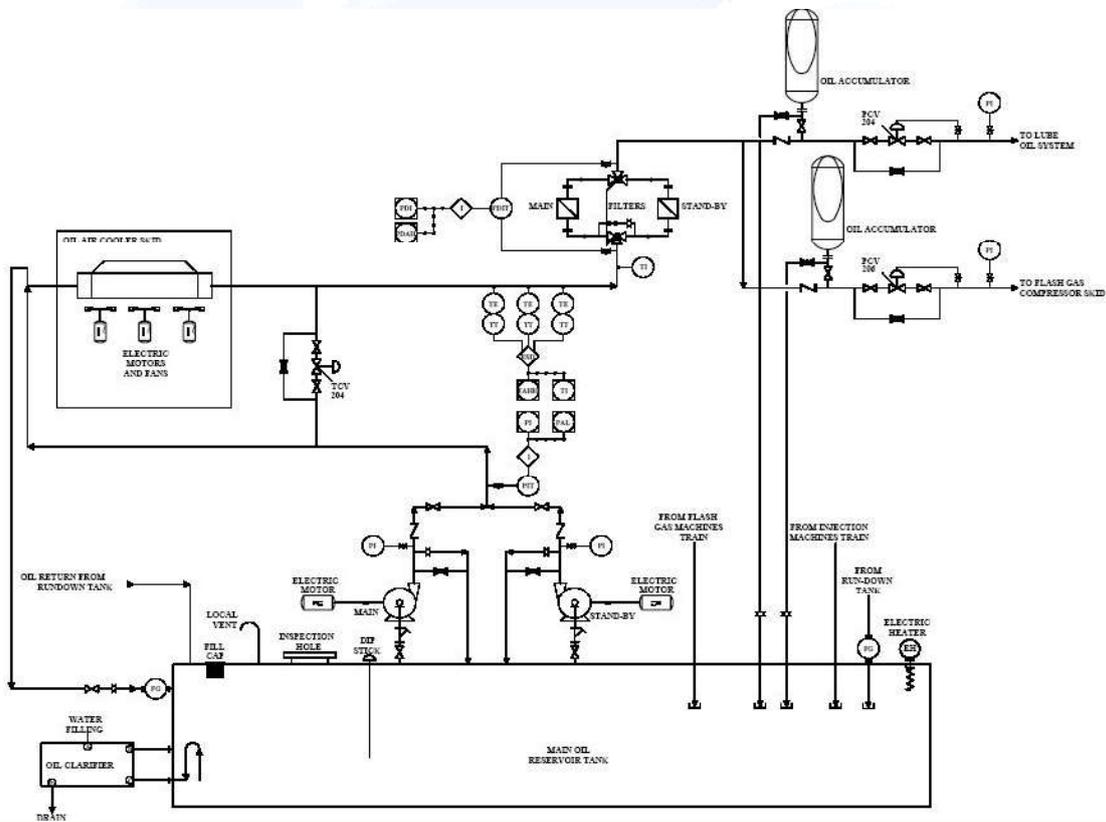
- | | | | | | |
|---|-------------------------|---|--|---|---|
| 1 | DRY GAS SEAL INNER RING | B | BALANCE DRUM GAS CHAMBER | F | ADJUSTING FLOW ORIFICE |
| 2 | DRY GAS SEAL OUTER RING | C | DRY GAS INNER CHAMBER | G | OUTER SEAL LIQUID DRAIN VALVE |
| 3 | TERTIARY SEALS | D | DRY GAS OUTER CHAMBER | M | INNER LABYRINTH |
| A | SEAL GAS CHAMBER | E | INTERMEDIATE BUFFER GAS SEAL AND JOURNAL BEARING | N | BALANCE DRUM LABYRINTH SEAL |
| | | | | P | INTERMEDIATE N ₂ INJECTION CHAMBER |

BCL 304C



LUBE OIL SYSTEM

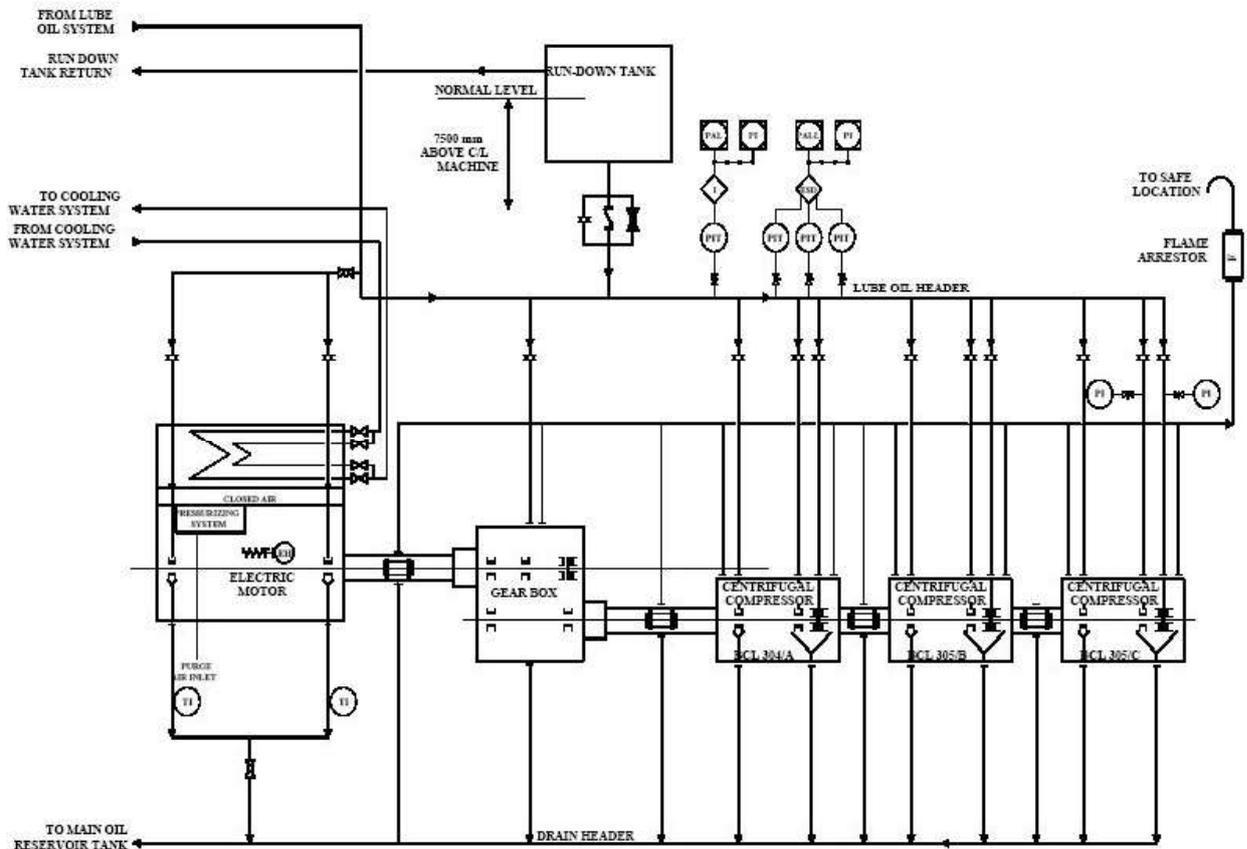
The system supplies cooled and filtered oil at the required pressure and temperature to the lubricating points by means of the suitable equipments.



OIL PRESSURE	PRELIMINARY		FINAL
	Bar g	kPa g	
Lube oil header	2.5	250	
Journal bearings	0.9 to 1.3	90 to 130	
Thrust bearing	0.3 to 0.5	30 to 50	

OIL TEMPERATURE (during normal running)		PRELIMINARY		FINAL
		°C	°F	
Minimum	Bearing oil inlet	35	95	
Normal	Bearing oil inlet	50	120	

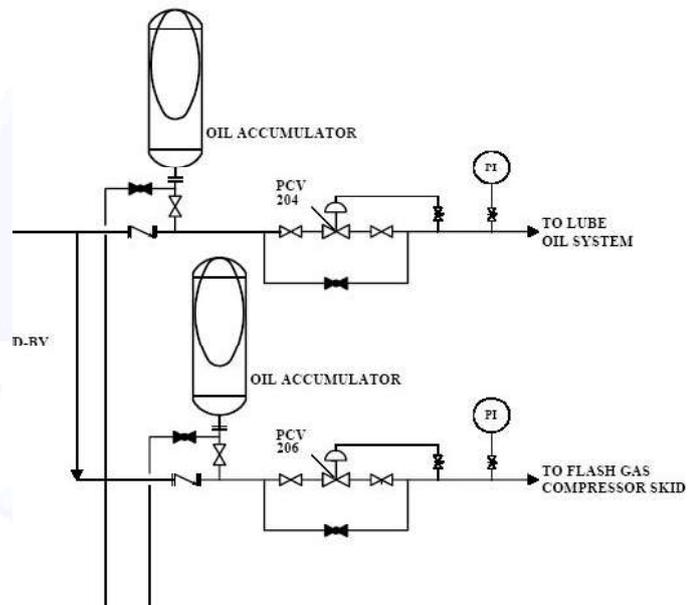
LUBE OIL SYSTEM



HYDROPNEUMATIC ACCUMULATOR

Two **hydropneumatic** accumulator of the type with precharged internal bag are installed in the lube oil header downstream filters and check valve.

These accumulator prevents the minimum oil pressure trip switch from entering into operation in case of main pump failure.

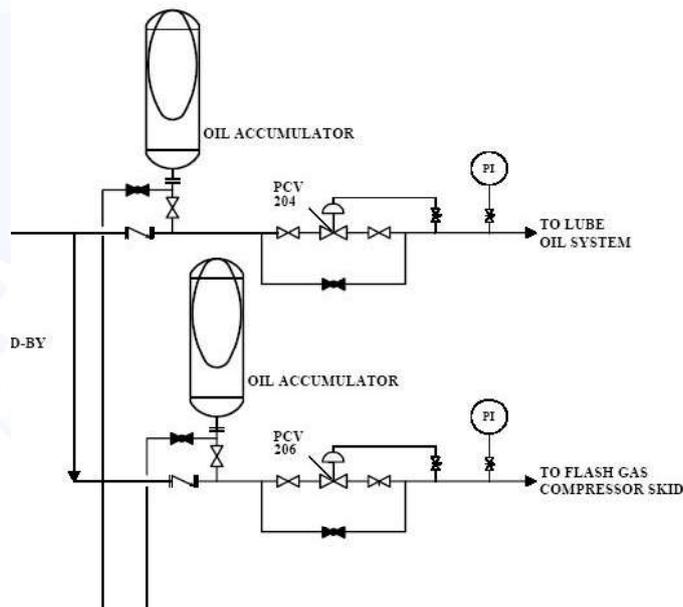


It guarantees a sufficient oil quantity to lube oil header for a period of time sufficient to allow the stand-by oil pump to reach the rated speed.

The bag is pre-charged by nitrogen at a pressure corresponding at 9/10 of the minimum operating value.

HYDROPNEUMATIC ACCUMULATOR

TO CHECK THE PRECHARGED INTERNAL BAG PRESSURE, DURING PLANT OPERATION, IT IS NECESSARY CLOSE THE ISOLATING VALVE IN THE OIL LINE TO ACCUMULATOR, DRAIN THE OIL FROM IT AND THEN BY MEANS OF THE PROPER PRESSURE GAUGE MEASURE THE PRECHARGED INTERNAL BAG. AFTER THIS CHECK OPEN GRADUALLY THE ISOLATING VALVE TO SET THE ACCUMULATOR IN OPERATING CONDITION.

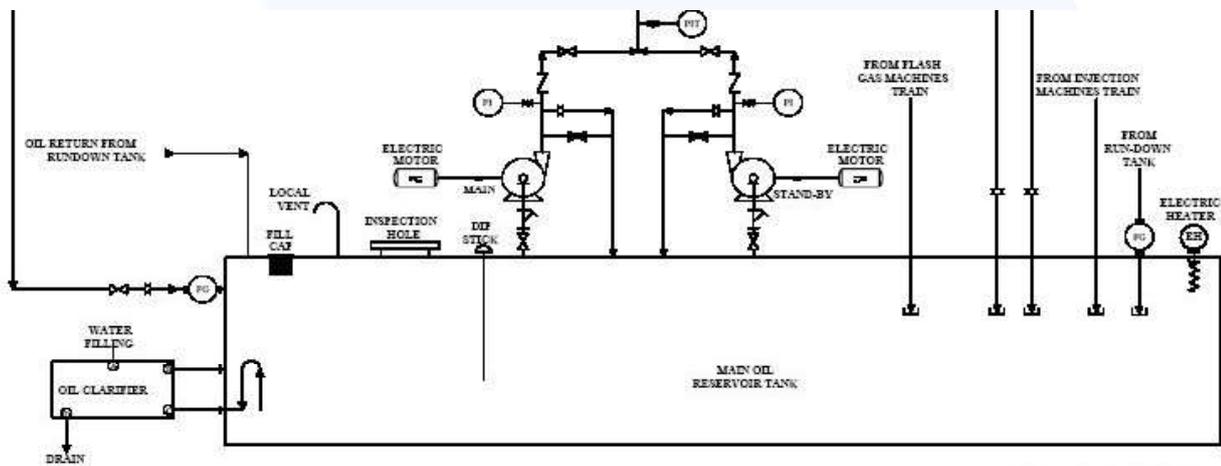


MAIN RESERVOIR

The charge capacity, corresponding to the run-down level, is shown in the sketch of the main reservoir for the oil system shown in the volume "Lube Oil Console".

The "Instrument List", included in the "Drawings" section or volume of this manual, shows the control and safety instrumentation supplied by **Nuovo Pignone**, with proper tags and setting values.

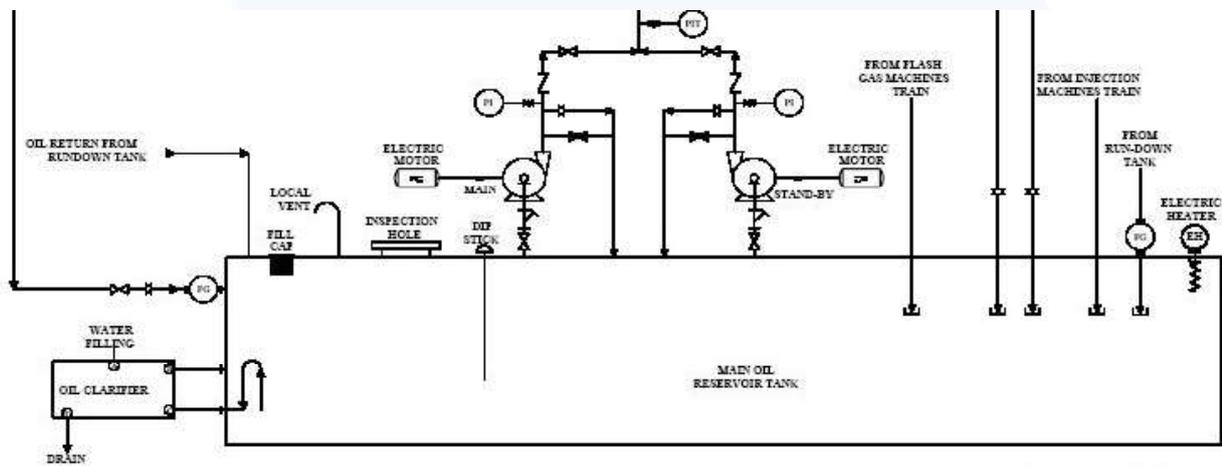
The reservoir is provided with the necessary connections for filling, draining, venting and inspecting.



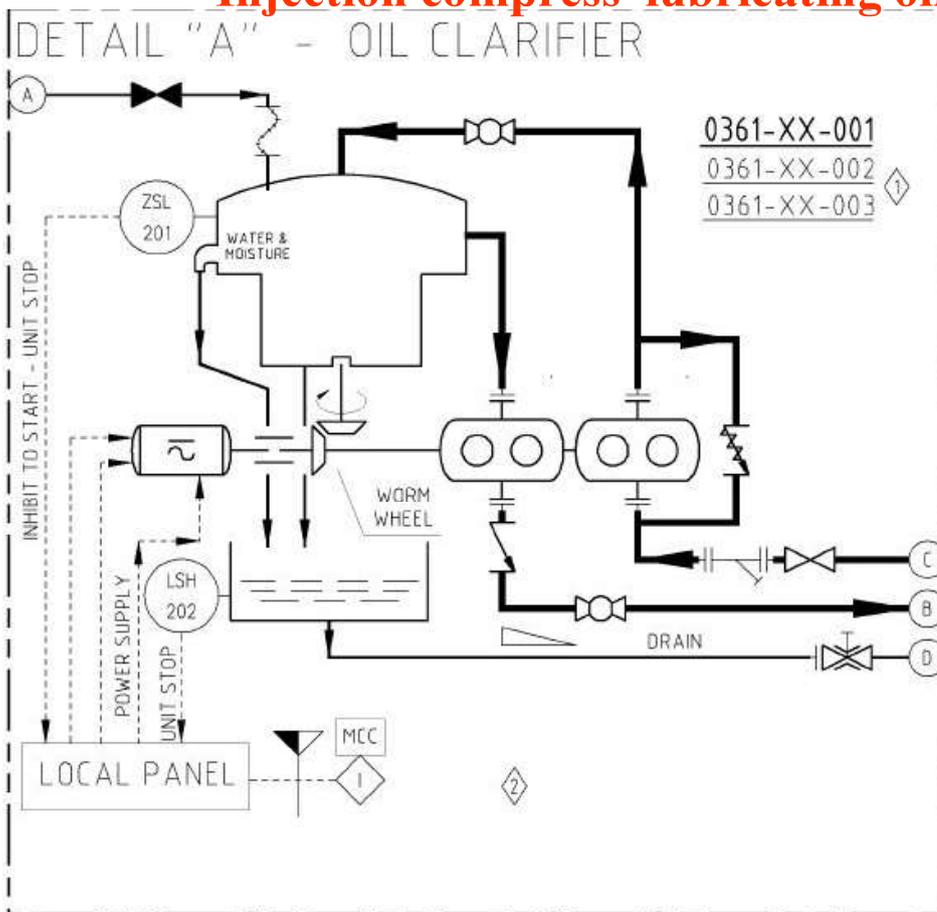
MAIN RESERVOIR

The oil contained in the reservoir is drawn from an oil separator, then is sent again into the reservoir.

A connection for the inert gas flushing is placed in the area by the oil level and the reservoir cover, this flushing prevents the direct contact of oil with the atmosphere, thus avoiding the oxidation and the explosive atmosphere inside the reservoir.

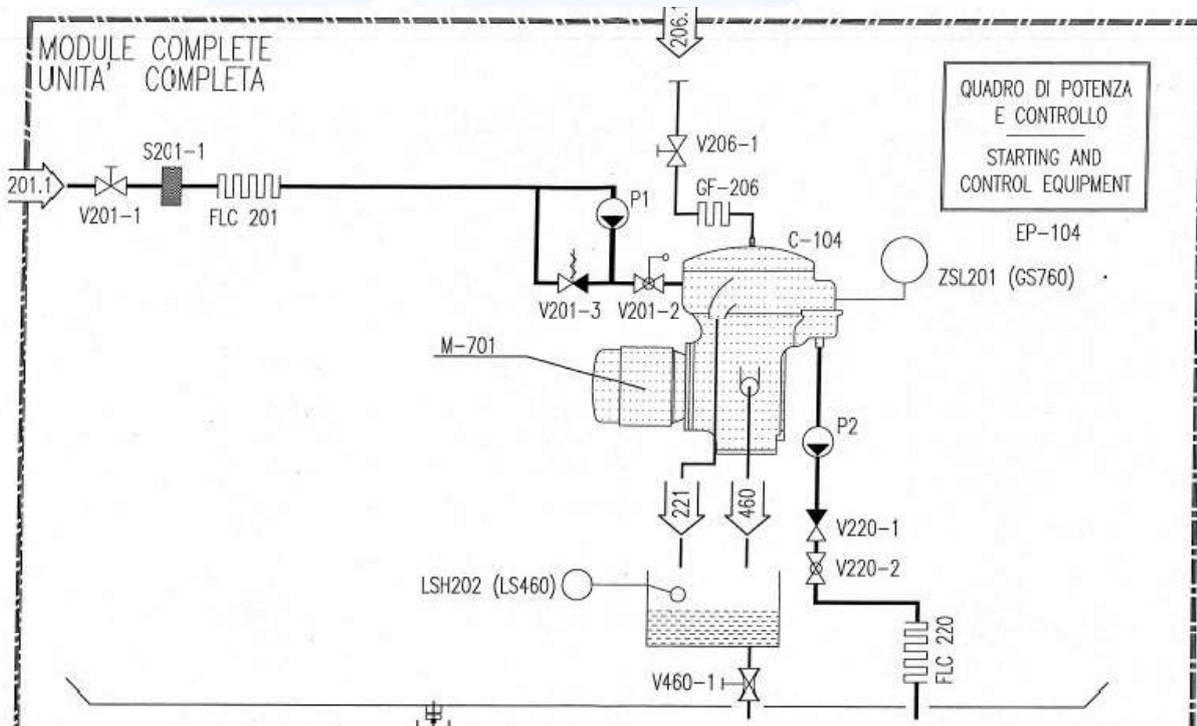


Injection compress lubricating oil clarifier



Purification and clarification

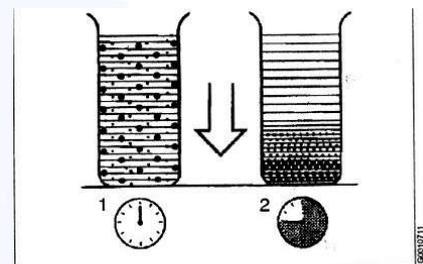
Injection compress lubricating oil clarifier



Basic principles of separation

The purpose of separation can be:

- to free a liquid of solid particles,
- to separate two mutually insoluble liquids with different densities while removing any solids presents at the same time,
- to separate and concentrate solid particles from a liquid.



Sedimentation by gravity

Separation by gravity

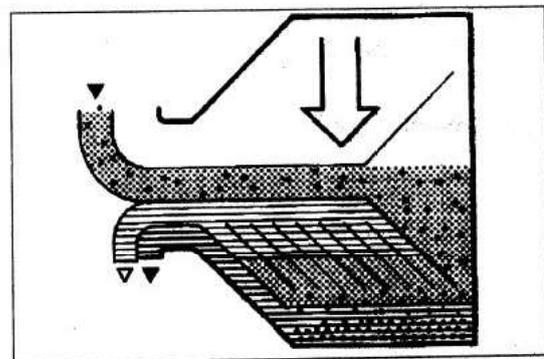
A liquid mixture in a stationary bowl will clear slowly as the heavy particles in the liquid mixture sink to the bottom under the influence of gravity.

A lighter liquid rises while a heavier liquid and solids sink.



Continuous separation and sedimentation can be achieved in a settling tank having outlets arranged according to the difference in density of the liquids.

Heavier particles in the liquid mixture will settle and form a sediment layer on the tank bottom



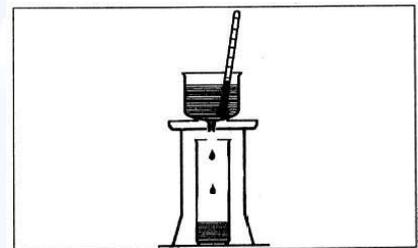
Sedimentation in a settling tank, with outlets making it possible to separate the lighter liquid parts from the heavier

Factors influencing the separation result



Separating temperature

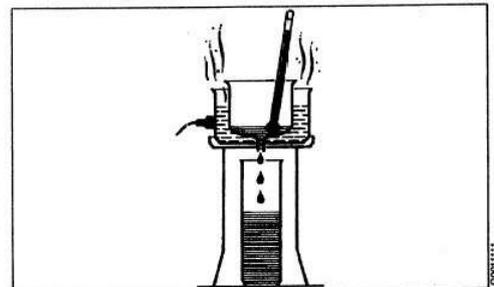
For some types of process liquids (e.g. mineral oils) a high separating temperature will normally increase the separation capacity. The temperature influences oil viscosity and density and should be kept constant throughout the separation.



High viscosity (with low temperature)

Viscosity

Low viscosity facilitates separation. Viscosity can be reduced by heating.

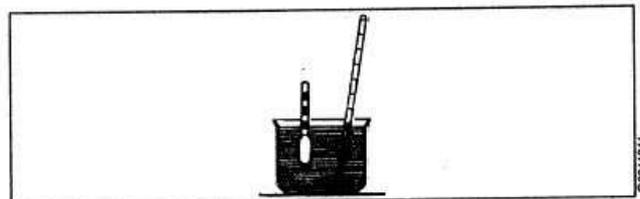


Low viscosity (with high temperature)

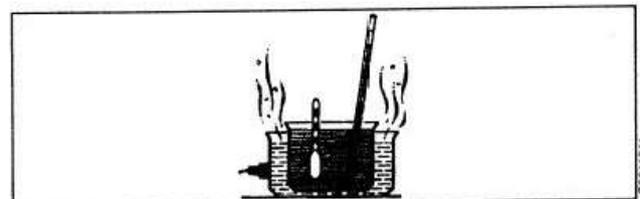
Factors influencing the separation result

Density difference (specific gravity ratio)

The greater the density difference between the two liquids, the easier the separation. The density difference can be increased by heating.



High density (with low temperature)



Low density (with high temperature)

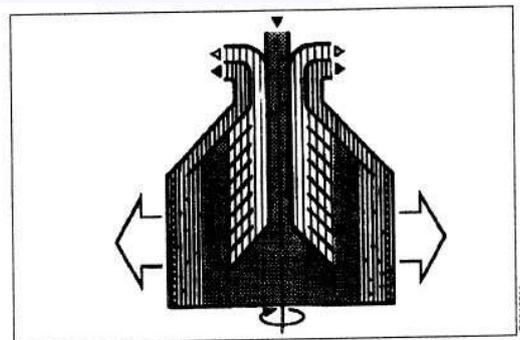
Centrifugal separation

In a rapidly rotating bowl, the force of gravity is replaced by centrifugal force, which can be thousands of times greater.

Separation and sedimentation is continuous and happens very quickly.



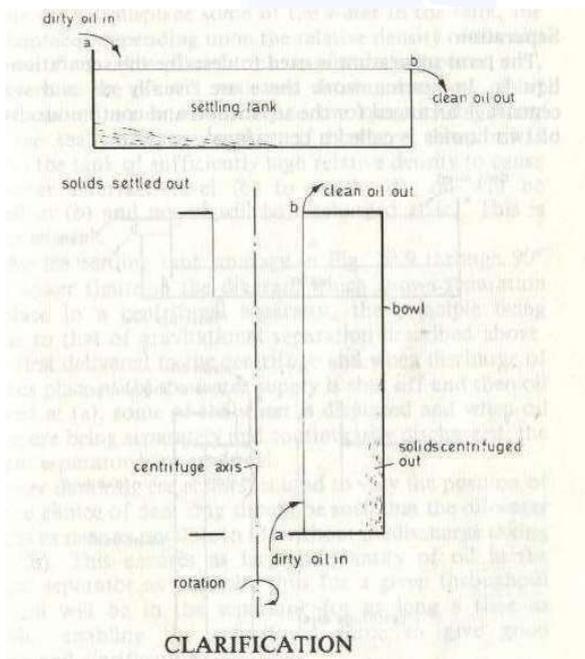
The centrifugal force in the separator bowl can achieve in a few seconds what takes many hours in a tank under influence of gravity.



The centrifugal solution

Clarification and Separation

The term of clarification is used to describe separation of solid from liquid.



Clarification and Separation

The separation of oil in separators is based on the difference of density of liquids and particles to be separated.

The objective is to remove water and impurities from oil.

Therefore purifier technology capable of separating oils up to 991kg/m³ was introduced. But practical difficulties in operation mainly due to engine room environment and degree of willingness of the engineer on watch brought about a further supplementary concept known as **clarifier**.



Clarification and Separation

This allows two separators to be used in series, first one as purifier and second one as clarifier to cover the mischief, by operator. Further technological improvement in 80s introduced ALCAP separators, capable of processing fuel up to 1010kg/m³. Thus heavier fuel can be processed.



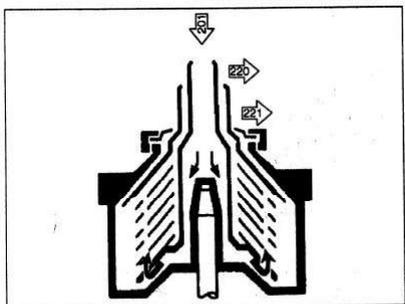
Sometimes in manuals it can be seen that value of 997 and 1100 kg/m³ is given. This is the limit for mechanical reason rather than separation capabilities.

This issue is divided into two sections; separation mechanism and cleaning mechanism

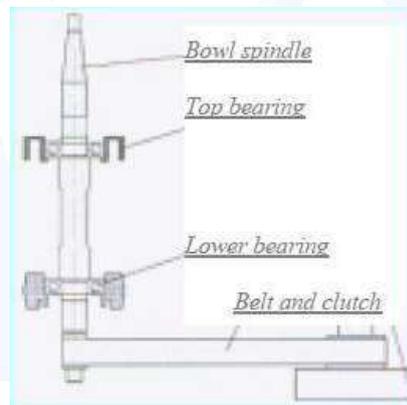
Separation technology

The separator comprises of a processing part and a driving part. The processing part is rotating at high speed and is driven by an electrical motor through bevel gear or by belt.

The gear and belt system are arranged so as the speed of processing part is increased to almost 10 times, considering limited motor speed.



Process flow through separator bowl



Due to required smooth acceleration during starting, and for safety reasons direct rigid coupling is avoided.

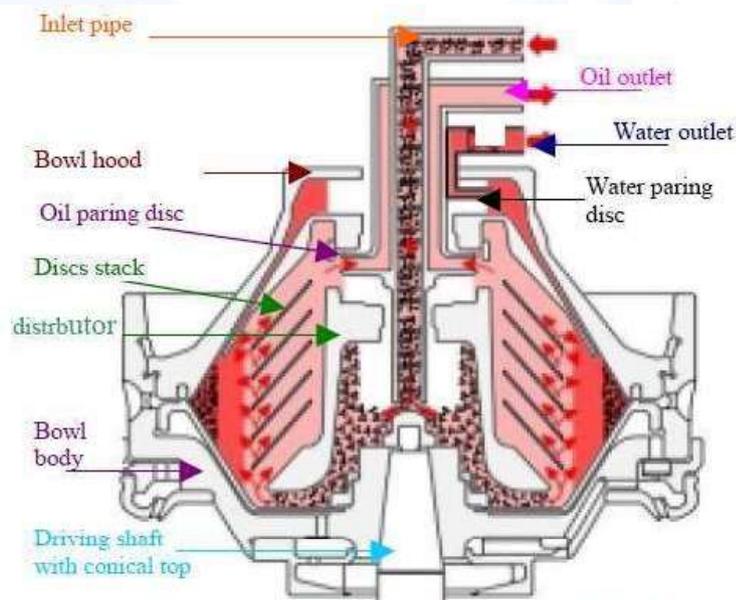
This has been accommodated by means of centrifugal friction clutch coupling. This avoids motor overloading during starting, and instrumental for designer to choose a more appropriate motor to reduce the cost.

The belt system although not as robust as that of gear system, it has the advantages of being less complicated and cheaper than the gear system.

The motor power transmitted to processing part through bowl spindle, well centrally positioned by two sets of top and bottom bearings.

Separation theory...

The top bearing, which is close to the bowl is mounted in spring-damped seat, to reduce vibration. The bearings are lubricated by the oil splash produced by an oil pump or worm wheel. The bowl spindle on top is conical and bowl is contoured to fit on the top and secured by a left hand cap nut.



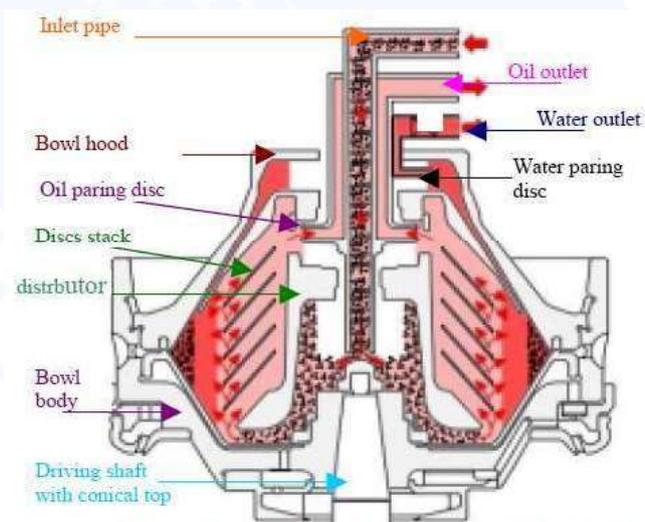
Principle parts of separator: courtesy of Alfa Laval

Separation theory...

Bowl unit basically consists of the bowl body and bowl hood, which are held together with a lock ring. Inside the bowl are the distributor and disc stack.

The disc stack is kept compressed by bowl hood. The cap nut and most of nuts and screws in moving parts are left hand thread to make sure that the tightening direction is towards direction of rotation to prevent getting loose during operation.

The bowl hood on the top accommodates the inlet and outlet. This is the means for inlet of the liquid to be treated into the bowl and outlet for treated oil and water.

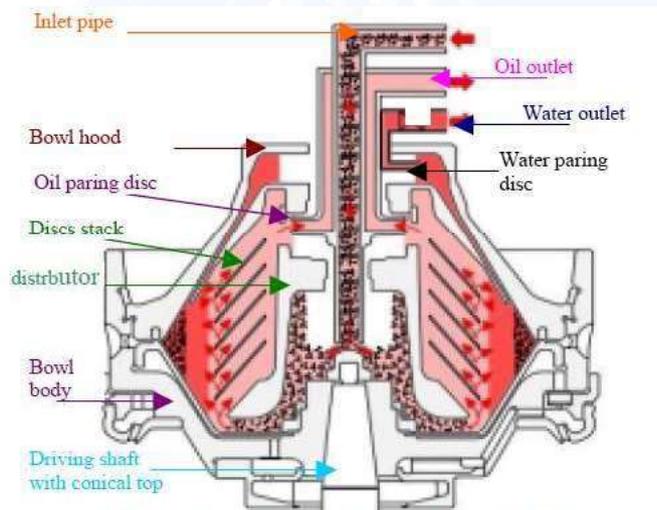


Principle parts of separator; courtesy of Alfa Laval

Separation theory...

The oil inlet is fed in by means of either independent gear oil pump or incorporated pump at the end of motor shafting, through heat exchanger, led to the inner part of distributor by long inlet pipe extended to the middle of bowl.

The outlet comprises of two separate coaxial housing round the inlet pipe. Water separated being the heavier phase, it is passed through the outer and oil as lighter phase is led out through the inner housing. The outlet liquids contain a high amount of kinematics' energy due to rotational speed. This energy is converted into the pressure energy by means of paring discs as part of outlet device.

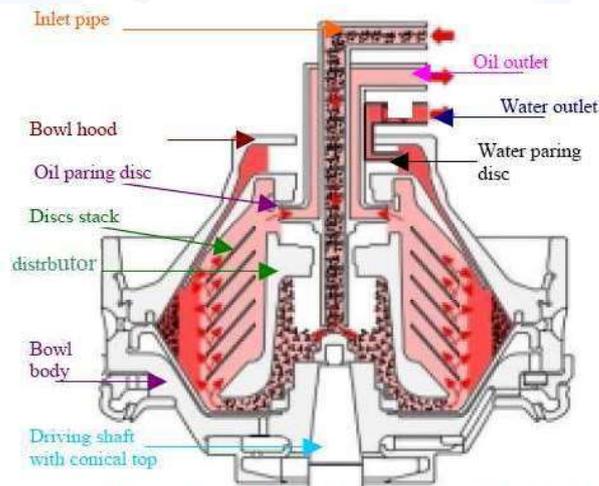


Principle parts of separator: courtesy of Alfa Laval



Separation theory...

The paring disc is idle impeller and allows the liquid in at its circumference and passes it out in the center in exact opposite principle to centrifugal pump. It is therefore sometimes called centripetal pump. In order to equalize the pressure between inside and outside of bowl, especially during and after discharging, when liquid levels move quickly the paring disc is made with some holes.



Principle parts of separator; courtesy of Alfa Laval

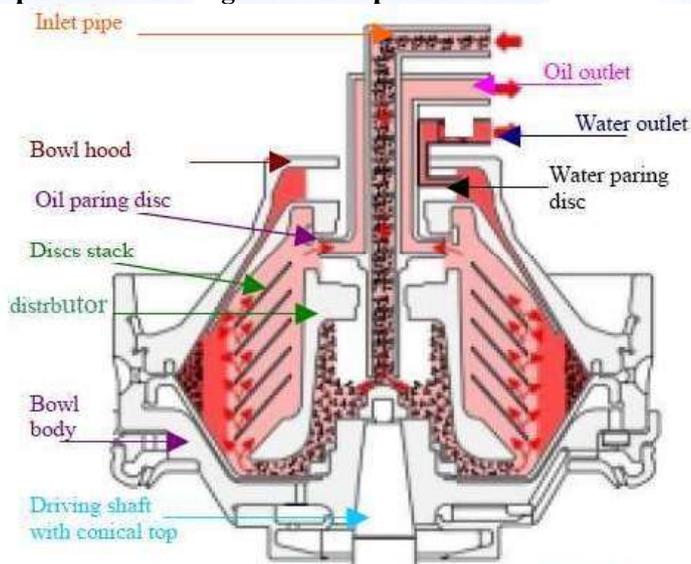


The liquid to be treated is fed into the bowl through inlet pipe and is processed by taking the sediments and water as heavy phase out of oil.

The heavier phases are centrifugally forced out to the periphery of the bowl while water is discharged through water outlet the sediment is collected on the bowl inside surface.

Separation theory...

The cleaned oil is directed inward as continuous phase through the inner housing. In a purifier, this could not take place without sealing water, which is making sure that the oil is directed inward. Therefore the principal of how sealing water is explained.



Principle parts of separator; courtesy of Alfa Laval

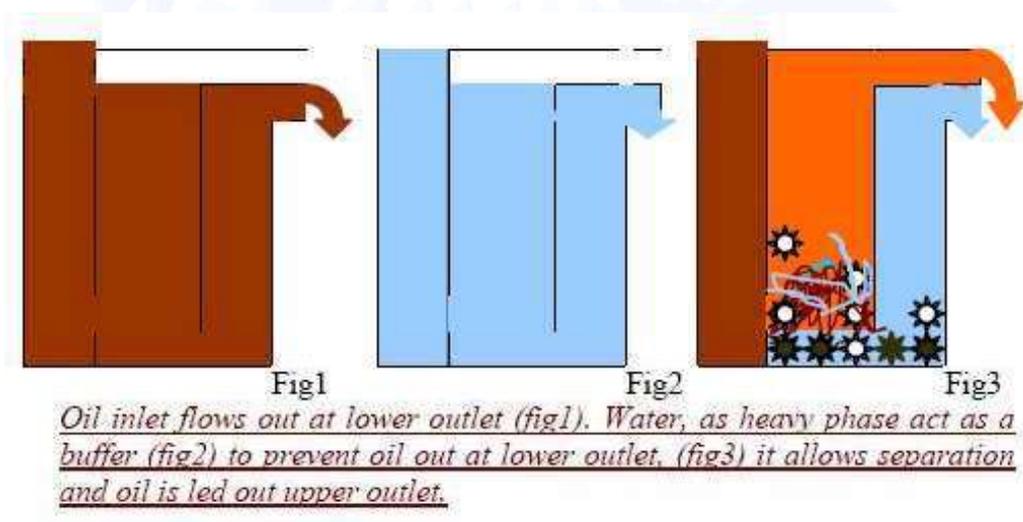


Let consider the diagrams below. when liquid is fed in, it flows out at lower in-let, but if a liquid seal (same as heavy phase liquid i.e. water) has been established before feeding the process liquid, the heavier phase will pass through the lower outlet and lighter phase will go out at upper outlet, (U-tube principle).

Separation theory...

Sealing water

As the separators are designed to work as purifiers, then sealing water is important issue. This is to separate water and sediments from fuel. And as it has been shown in separation theory the separation takes place between the discs.



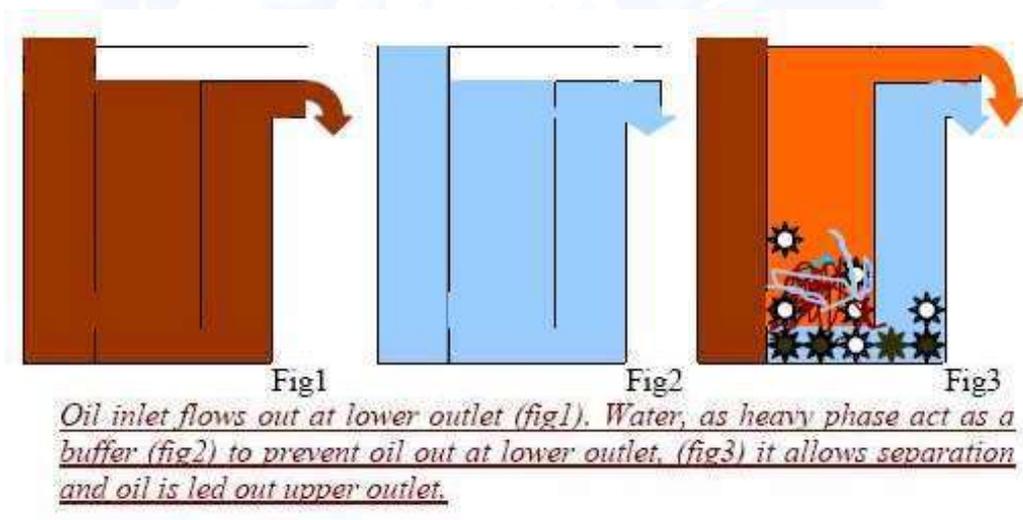
Separation theory...

Sealing water

Also it was shown that the total area of discs available for separation is a major factor for separator capacity.

Therefore the interface position is important first to be kept slightly outside the discs stack periphery. The factor influencing the interface position is liquids density.

The position of the interface can be adjusted by adjusting the height of the heavier phase, in this case the water.

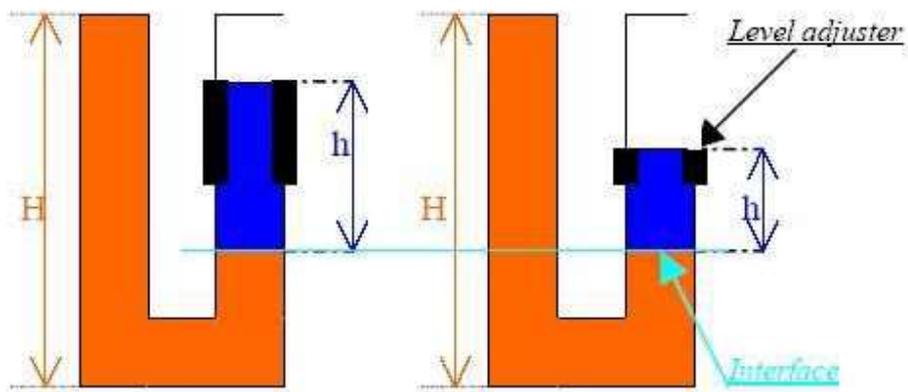


This is down by means of gravity disc.

Separation theory...

Sealing water

In order to understand gravity disc function let's go through the following diagrams.



$$H g \rho_{oil} = h g \rho_{water} \quad \text{or} \quad H \rho_{oil} = h \rho_{water}$$

$$\rho_{oil} = (H - h) \rho_{water}$$

Where H, h = liquids height, ρ = density

Separation theory...

Sealing water

In order to have equilibrium and maintain the interface at same position the pressure head in both column must be kept equal; thus if the oil density is decreased for any reason by temperature or change of oil; the interface can be maintained by changing the water height, by means of a dam ring called gravity disc.

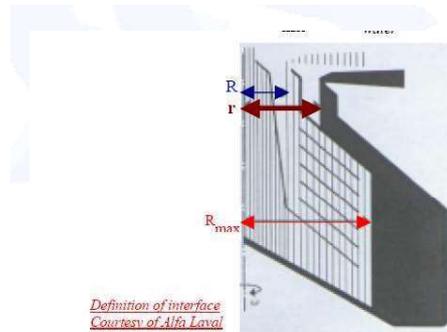
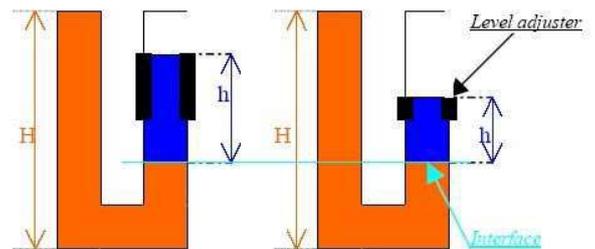
In a centrifugal separator the gravity force is replaced with centrifugal force and height is replaced with the radius of the liquids,.

$$R \omega^2 R \rho_{oil} = r \omega^2 r \rho_{water} \quad \text{or} \quad R^2 \rho_{oil} = r^2 \rho_{water}$$

But the effective radius equals to the maximum radius minus the radius of liquids outlet.

$$(R_{max}^2 - R^2) \rho_{oil} = (R_{max}^2 - r^2) \rho_{water}$$

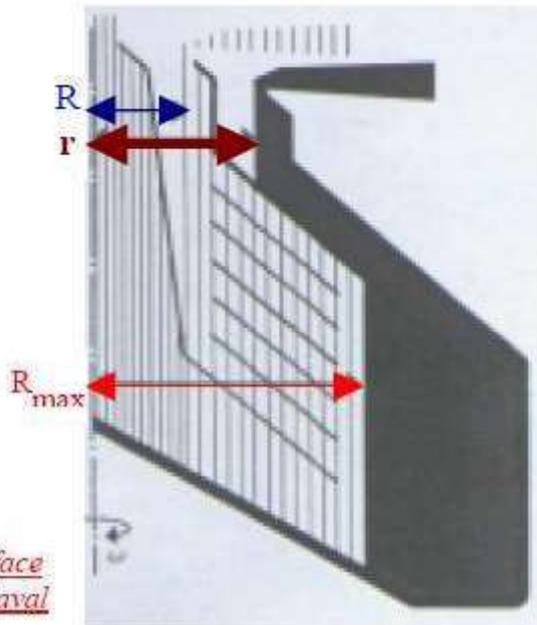
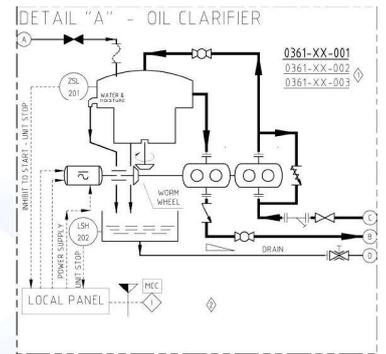
Therefore the interface can be adjusted by changing the water outlet to influence the value of $(R_{max}^2 - r^2) \rho_{water}$.



Separation theory...

Sealing water

To maintain the same interface again the value of "r" should be adjusted.



Definition of interface
Courtesy of Alfa Laval

Purifier and Clarifier

Further, since temperature influences fuel oil density to a relatively great extent in practice maintaining fuel oil at constant temperature is difficult, especially with Unattended Machinery Space (UMS) ships.

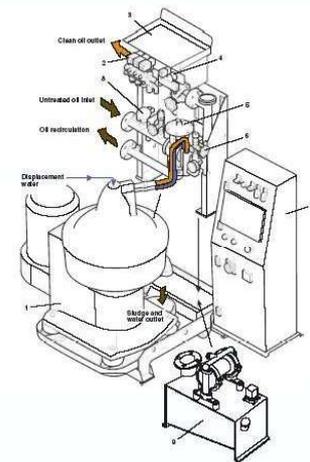
This normally is the reason to ship staff or another unman system in other industries to use a gravity disc with smaller inner diameter to keep a good margin, but this is on the expense of losing disc total area available for separating the sediments.



For this reason **Alfa Laval** introduced the concept of two separators working as **purifier** and **clarifier**. Clarifier is exactly same as purifier in construction, with no gravity disc but a disc known as clarifier disc. In clarifier there is no need for sealing water, since the intention is to compensate for loss of total area available by using wrong gravity disc, as described.

Purifier and Clarifier

Alfa Laval believes if the purifier is used properly there is no need for clarification, and recommends to use two separators in parallel with lower flow rate, instead of using them in series. This has been proved in Alfa Laval marine technology division at Tumba, Sweden. In a field experiment carried out by Mr. G. Astrom[†], the sedimentation of 6 kg was found in purifier but as low as 0.01 kg in the clarifier.



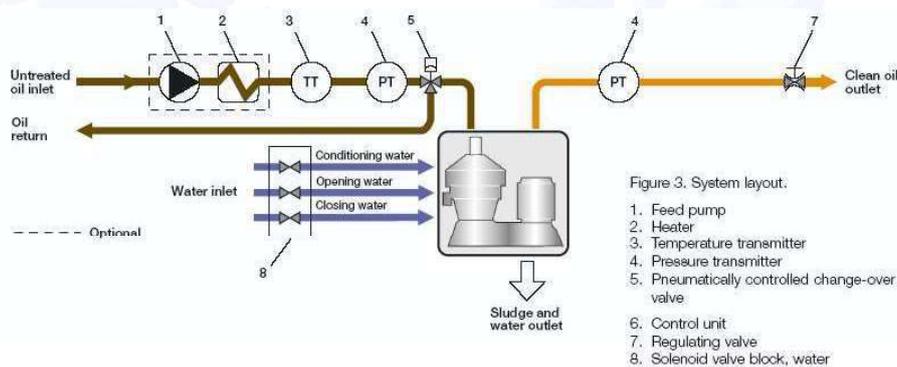
However this experiment is carried out by a group of highly trained professionals at all perfect condition, as their only task *for a limited time* with determination to prove the effectiveness of the separator they make, in comparison to those onboard, although professional, *but with limited time* and always with many task on their program, and adverse sea condition.

Purifier and Clarifier

What the **Alfa Laval** proven is the machine is capable of and it is up to operation staff to make sure that they can make best of what is available.

Perhaps that is the reason lead to ALCAP concept designed by Mr. Vilgot Nilsson. Some like to refer to

ALCAP as abbreviation for, **Alfa Laval Clarifier And Purifier**.



In a separator regardless of its function there is one oil level ring, which determines free oil level, this is the interface between oil and air inside of the bowl. In a purifier there are 2 liquid outlet, but in a clarifier an oil level ring of internal.

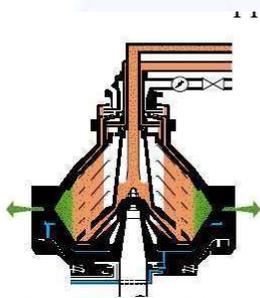
diameter large enough in combination with smallest possible gravity disc, so as the water outlet is virtually restricted.

This means that clarifier has only oil outlet.

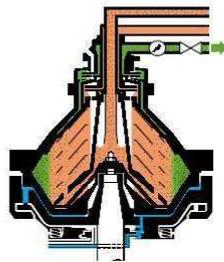
CLARIFIERS

Thus clarifier is intended to separate only sediments from liquid, and there is no need to have water seal.

In an ALCAP separator, which principally works as a clarifier the function of gravity or clarifier Gravity disc is taken over by a controllable valve. So during normal operation there is only one outlet, and as the water separated collected increased the interface moves inward and trace of water will get into clean oil outlet.



Water and sludge discharge during periodical de-slugging



Water discharge during Normal operation

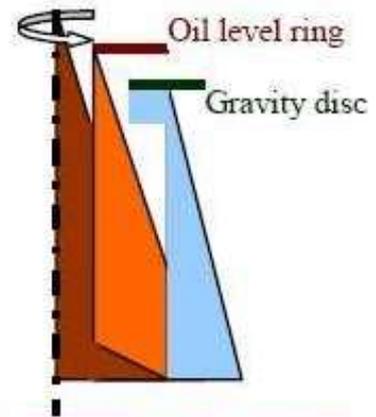


Illustration of liquid phases

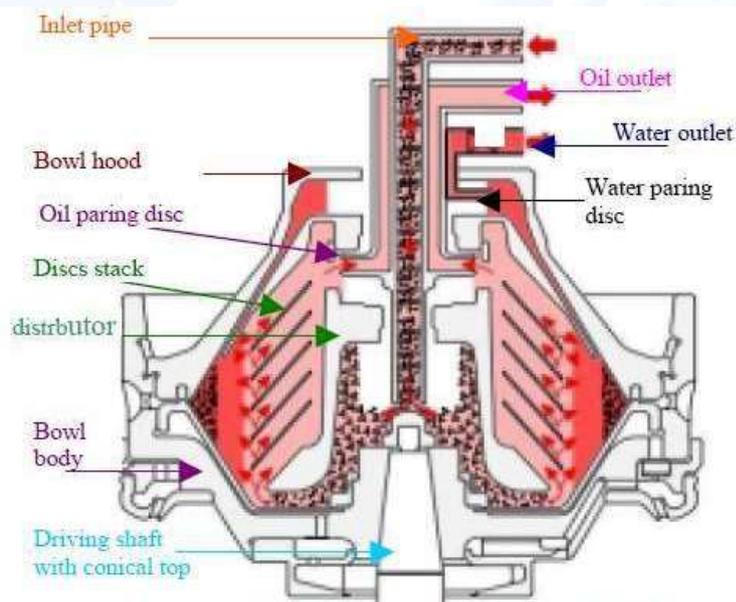
This is then detected with a water transducer on oil outlet pipe. The results will be processed according to the data and a signal is sent to the controllable valve to open, letting almost all the water out.

This is superimposed to the periodical discharging, as is the case with all kind of self-cleaning separators. Since there is no need to Equilibrate the interface condition, oil as high density as 1010kg/ m^3 can be separated. ■

Self-cleaning technology

The first generation separators had one practical draw back and that was the need for repeated cleaning due to sludge collected in the sludge space of the bowl. This was an obstacle for ship operators and cost effectiveness.

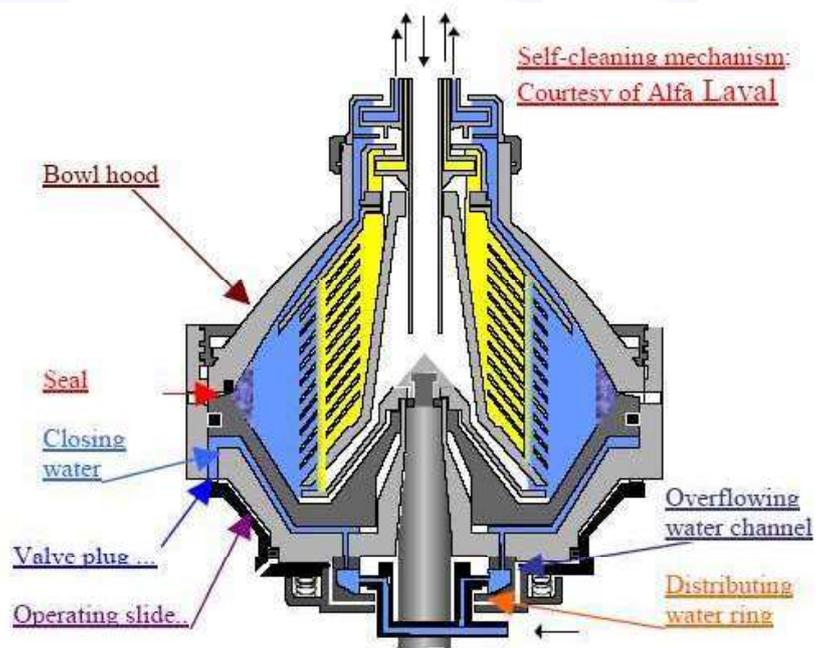
The problem was over come with introduction of cleaning mechanism-enabling operator to remove sludge from the bowl without stopping the separator, while stopping for few minutes the separation process.



Principle parts of separator; courtesy of Alfa Laval

Self-cleaning technology

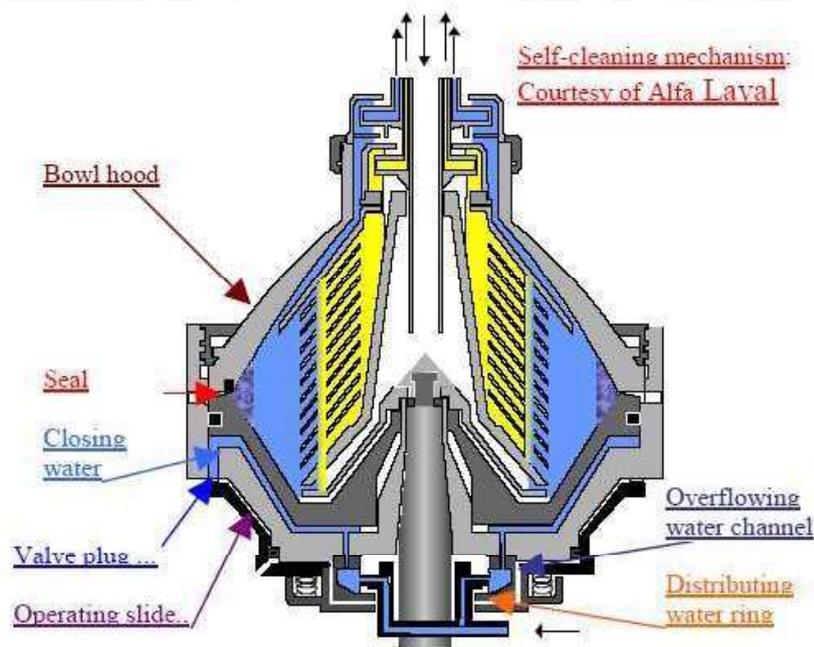
The cleaning mechanism whether manual or automatic, conventional or ALCAP, they all work on the same principle. In a self-cleaned separator the construction is same as non-self cleaned one with the exception of that the bottom comprises of sliding bottom forming an internal separate bottom in the bowl. The sludge is collected in the space between bowl hood, sliding bottom and the disc stack in the bowl periphery.



Self-cleaning technology

The sliding bottom, during normal operation, is forced up against a sealing ring in the bowl hood by operating water. During sludge discharge the sliding bowl bottom drops, by mechanism draining the operating water.

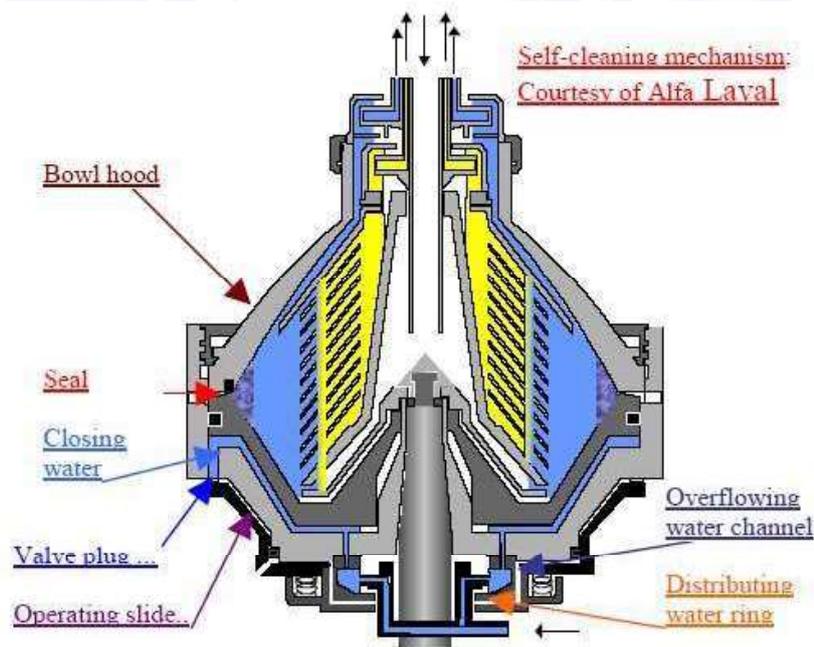
So as the sludge collected is ejected. Sludge discharge mechanism, which controls the bowl bottom movement, comprises an operating slide



Self-cleaning technology

As shown above, operating water closes the bowl. The water is fed through operating water ring for limited time. This water is trapped forcing the slide bottom up and its only outlet is kept closed by means of valve plugs.

It remains closed till the water is fed in and let to overflow over operating water ring, thus getting on top of operating slide forcing the plugs down and letting the closing water to be drained. The consequence effect is the slide bottom slides down and the sludge collected is let out through space between bowl bottom and bowl hood.



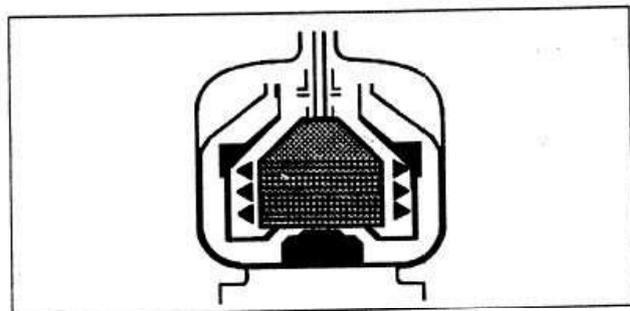
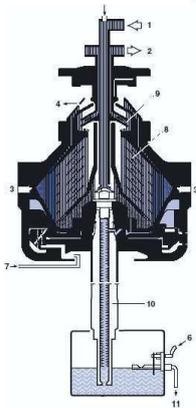
Phase proportions

An increased quantity of water in a oil will influence the separating result through the optimum transporting capacity of the disc stack. An increased water content in the oil can be compensated by reducing the throughput in order to restore the optimum separating efficiency.

The throughput

The throughput sets the time allowed for the separation of water and sediment from the oil. A better separation result can often be achieved by reducing the throughput, i.e. by increasing the settling time.

Sediment will accumulate on the inside periphery of the bowl. When the sludge space is filled up the flow inside the bowl is influenced by the sediment and thereby reducing the separating efficiency. In such cases the time between cleaning should be reduced to suit these conditions.



Sludge accumulation

SEPERATOR OVERVIEW

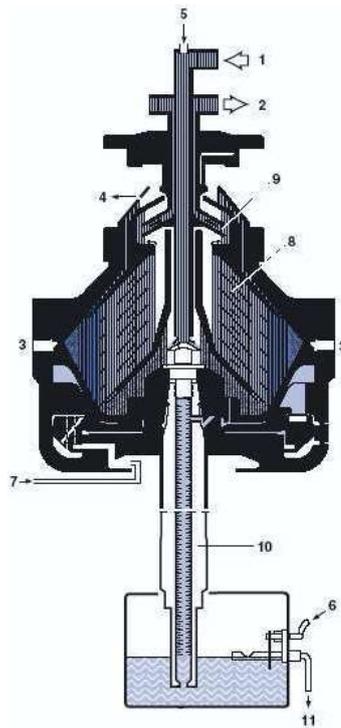


Figure 2. Separator bowl.

1. Oil inlet
2. Oil outlet
3. Sludge outlet
4. Water outlet
5. Water seal and displacement water inlet
6. Bowl closing water
7. Opening water
8. Disc stack
9. Paring disc
10. Bowl spindle
11. Overflow

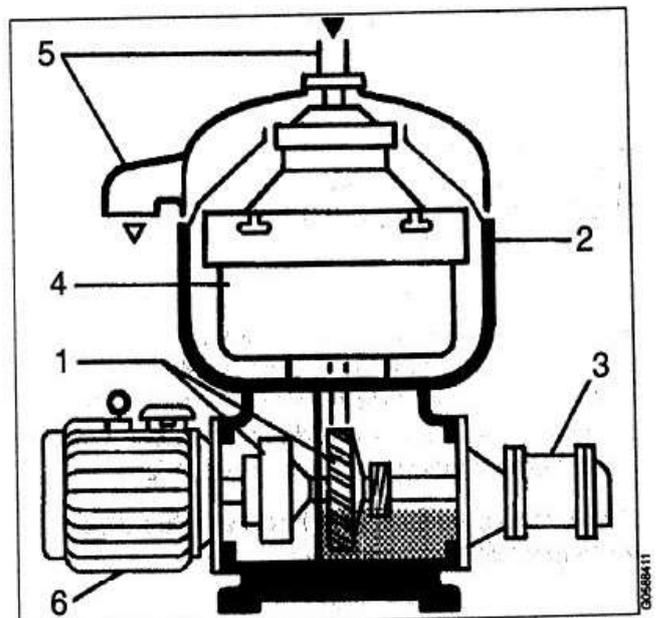
SEPERATOR OVERVIEW

The separator comprises a processing part and a driving part. It is driven by an electric motor (6).

Mechanically, the separator machine frame is composed of a bottom part, a top part and a collecting cover. The motor is flanged to the frame as shown in the illustration. The frame feet have vibration damping.

The bottom part of the separator contains the horizontal driving device (1), driving shaft with couplings, a worm gear and a vertical spindle.

The bottom part also contains an oil bath for the worm gear, a brake and a revolution counter, indicating speed.

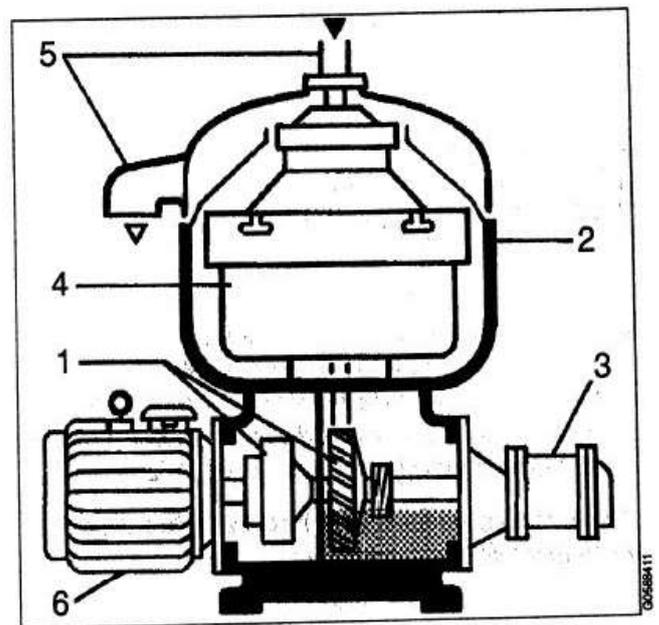


1. Horizontal driving device, friction coupling and worm gear
2. Collecting cover.
3. Inlet and outlet gear pump
4. Separator bowl
5. Inlet / outlet
6. Electric motor

SEPERATOR OVERVIEW

A pump (3) is attached to the driving spindle and located on the side of the bottom part. This pump has dual function. It is the feed inlet pump and the clean oil discharge pump.

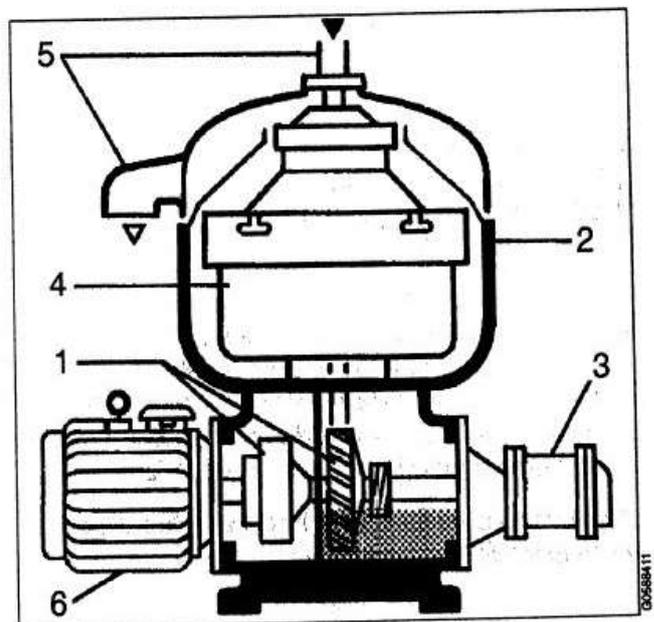
The frame top part and the collecting cover contain the processing parts of the separator, the inlet and outlets and piping.



1. Horizontal driving device, friction coupling and worm gear
2. Collecting cover.
3. Inlet and outlet gear pump
4. Separator bowl
5. Inlet / outlet
6. Electric motor

SEPERATOR OVERVIEW

The liquid is cleaned in the separator bowl (4). This is fitted on the upper part of the vertical spindle and rotates at high speed inside the space formed by the frame top part and collecting cover.



1. Horizontal driving device, friction coupling and worm gear
2. Collecting cover.
3. Inlet and outlet gear pump
4. Separator bowl
5. Inlet / outlet
6. Electric motor

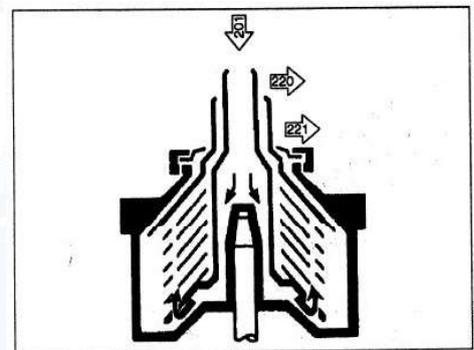
SEPERATION FUNCTION

Unseparated oil is fed into the bowl through the inlet pipe and is pumped via the distributor towards the periphery of the bowl.

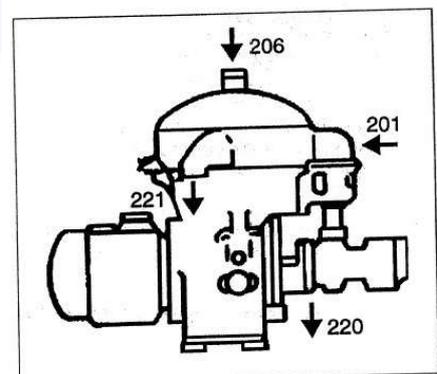
When the oil reaches holes of the distributor, it will rise through the channels formed by the disc stack where it is evenly distributed.

The oil is continuously cleaned as it flows towards the center of the bowl. When the cleaned oil leaves the disc stack it rises upwards, flows over the gravity disc and leaves the bowl through outlet (220). Separated water, sludge and solid particles are forced towards the periphery of the bowl and collected in the sludge space.

The space between bowl hood and top disc are normally filled with water.



Process flow through separator bowl



Inlet and outlet connections

SEPERATION FUNCTION

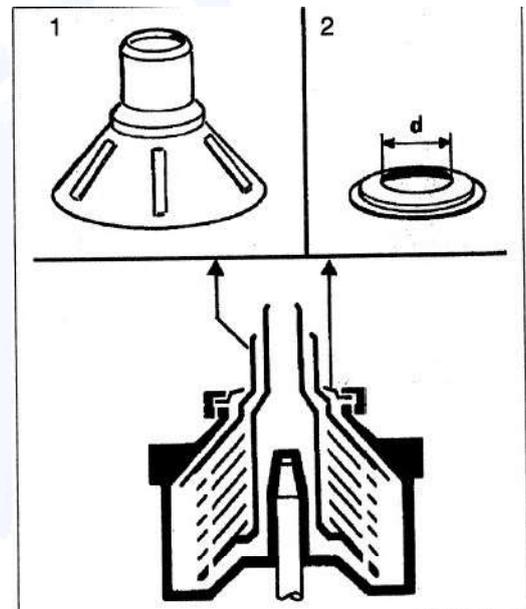
Purifier bowl

The illustration shows characteristic parts of the purifier bowl:

1. Top disc with neck
2. The gravity disc, which should be chosen according to directions in chapter "4.1.2 Selection of gravity disc" on page 30.

This bowl has two liquid outlets. The process liquid flows through the distributor to the interspaces between the bowl discs, where the liquid phases are separated from each other by action of the centrifugal force. The heavy phase and any solids move along the underside of the bowl discs towards the periphery of the bowl, where the solids settle on the bowl wall.

The heavy phase flows along the upper side of the top disc towards the neck of the bowl hood and leaves the bowl via the gravity disc the outer way.



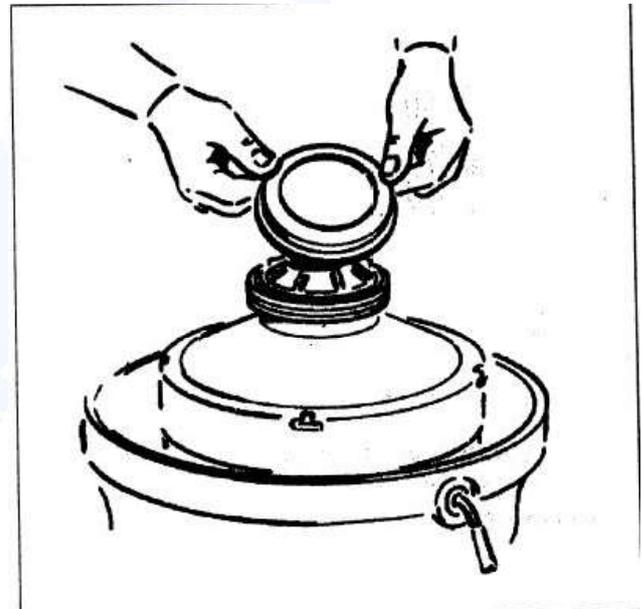
SEPERATION FUNCTION

Position of interface - gravity disc

In a purifier bowl the position of the interface should be located between the disc stack edge and the outer edge of the top disc.

The position of the interface is adjusted by altering the pressure balance of the liquid phases oil and water inside the separator. That is done by exchanging the gravity disc. For this purpose a number of gravity discs with various hole diameters is delivered with the machine.

The gravity disc is located inside the bowl hood. A gravity disc with a larger hole will move the interface towards the bowl periphery, whereas a disc with a smaller hole will place it closer to the bowl centre.



SEPERATION FUNCTION

Selection of gravity disc

For selection of gravity disc, see nomogram in chapter "8.1.1 Gravity disc nomogram" on page 120.

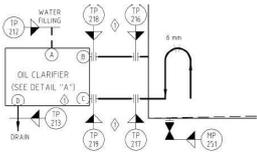
When selecting a gravity disc the general rule is to use the disc having the largest possible hole without causing a break of the water seal.

The heavier or more viscous the light phase and the larger the liquid feed the smaller the diameter should be.

When the heavy phase (water) is wanted more free from the light one (oil), the interface should be placed nearer the bowl centre, however not inside the outer edge of the discs (the gravity disc is too small), as this would prevent the liquid flow.



SEPERATION FUNCTION



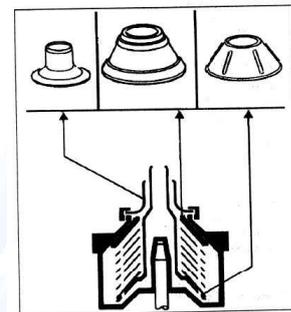
Clarifier bowl

The illustration shows characteristic parts of the clarifier bowl:

1. Discharge collar
2. Top disc without neck

This bowl has one liquid outlet. The process liquid flows through the distributor to the interspaces between the bowl discs. Through the action of the centrifugal force the heavy particles move along the underside of the discs towards the bowl periphery, where they settle on the bowl wall. The liquid proceeds towards the bowl centre and discharges through the bowl hood.

The separation is influenced by changes in the viscosity (rise in separating temperature) or in the throughput.



Clarifier bowl







OIL PUMPS AND DRIVERS

The oil system includes a main oil pump and a stand by oil pump of centrifugal type. Both pumps are suitable for continuous operation and have equal capacity.

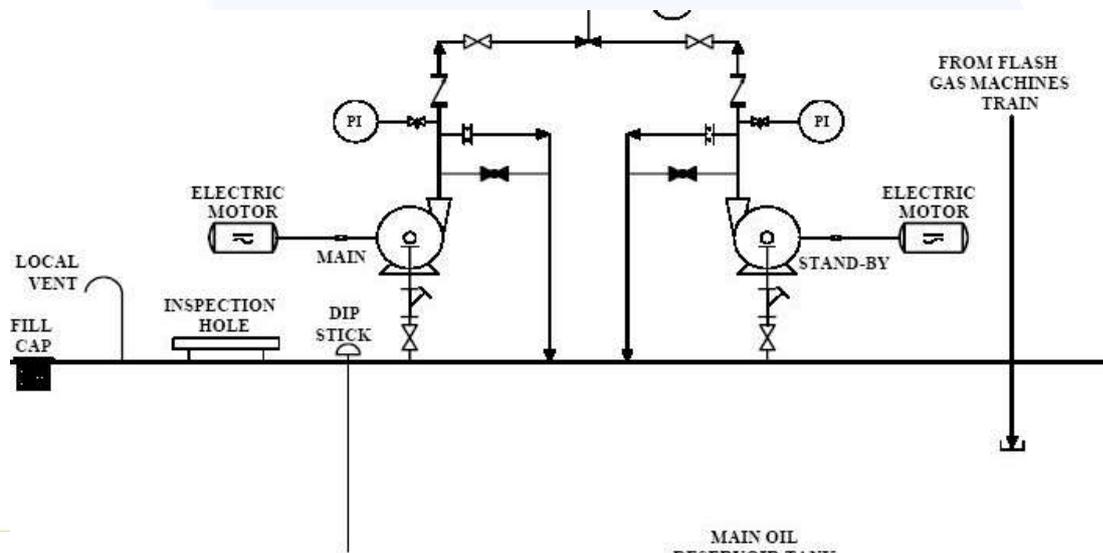
The pumps are electric motor driven.

The stand by oil pump is furnished with an automatic start-up control.

The suction line of each pump is provided with strainer and block valve.

The discharge line of each pump is provided with relief valve, check valve and block valve.

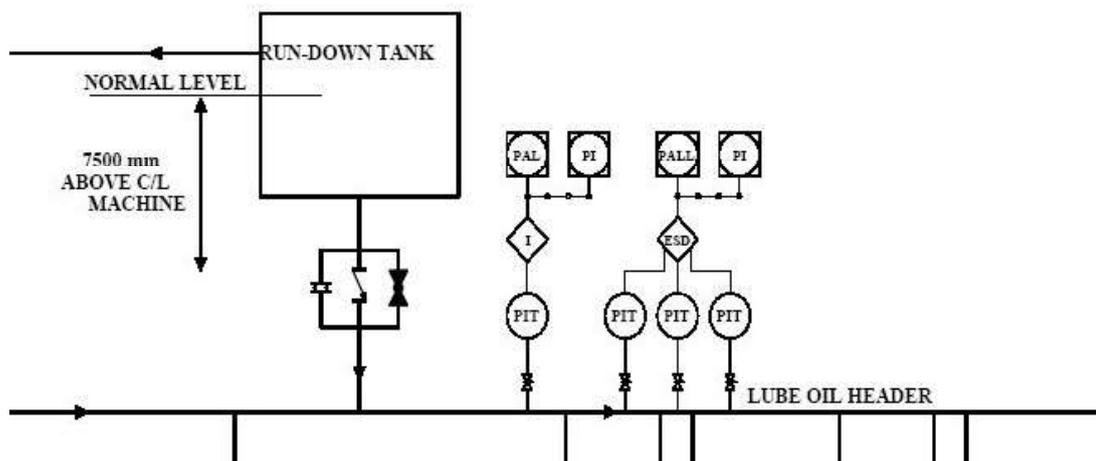
During pumps and drivers installation make sure that the radial (parallel) and axial (angular) **misalignment values** are not above the values given by the couplings manufacturer's.



EMERGENCY LUBE OIL SYSTEM

Overhead lube oil rundown tank

An overhead lube oil rundown tank is provided to supply the bearings header, during an emergency shutdown caused by a failure of main and stand-by lube oil pumps.



The tank is sized for an oil capacity sufficient to ensure bearings lubrication until the machinery unit comes to a complete stop.

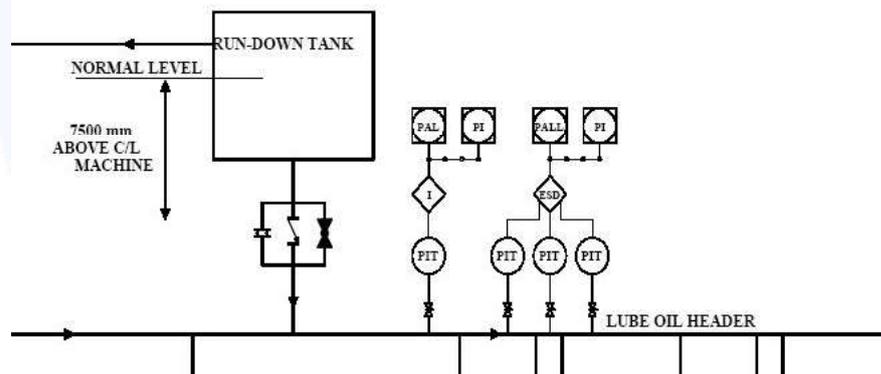
The oil is supplied through a line, provided with an orifice and a check valve, connected to the bearing headers of the machinery unit.

EMERGENCY LUBE OIL SYSTEM

Overhead lube oil rundown tank

The tank is initially charged with oil to proper level during the preparation of the lube oil system; while the main oil pump is running the oil inlet valve is open until the oil circulates through the overflow line back to the main reservoir.

Then close the oil inlet valve letting the pump run. The tank is maintained full during normal operation by a small quantity of oil which flows through the orifice into the tank and returns through the overflow line back to the main reservoir.

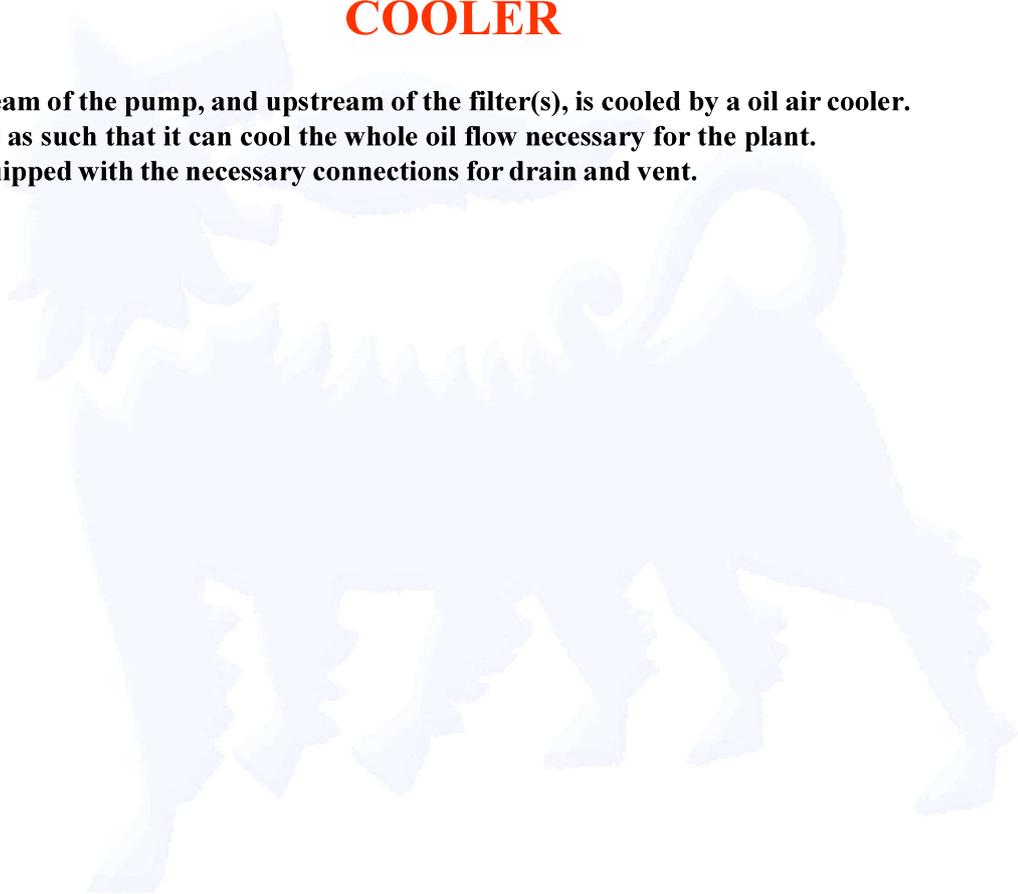


When the static pressure in the overhead tank exceeds the pressure in the supply header lube oil flows down through the check valve to the bearings.

Permissive starting feature for compressor driver is provided on the tank.

COOLER

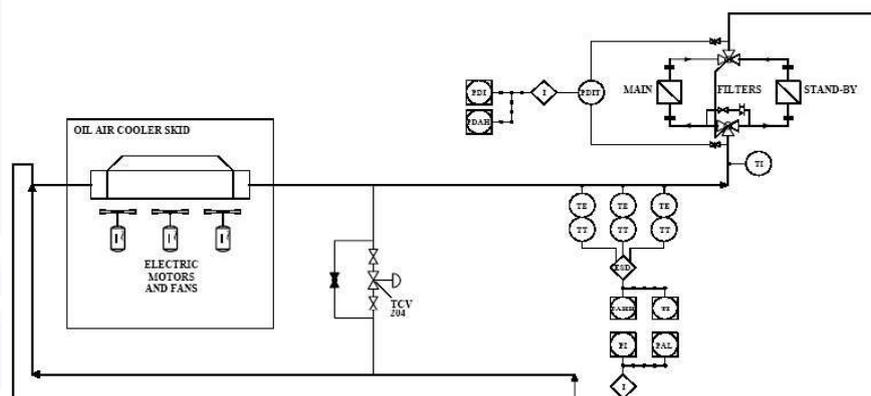
The oil downstream of the pump, and upstream of the filter(s), is cooled by a oil air cooler. It is dimensional as such that it can cool the whole oil flow necessary for the plant. The cooler is equipped with the necessary connections for drain and vent.



FILTERS

Twin oil filters are provided downstream of the coolers and are piped in a parallel arrangement utilizing a continuous flow transfer valve.

The transfer valve is installed between the filters to direct the oil through either filter and into the oil header. This feature permits either filter to be cut out of service for inspection or maintenance without interrupting oil flow to the machines.

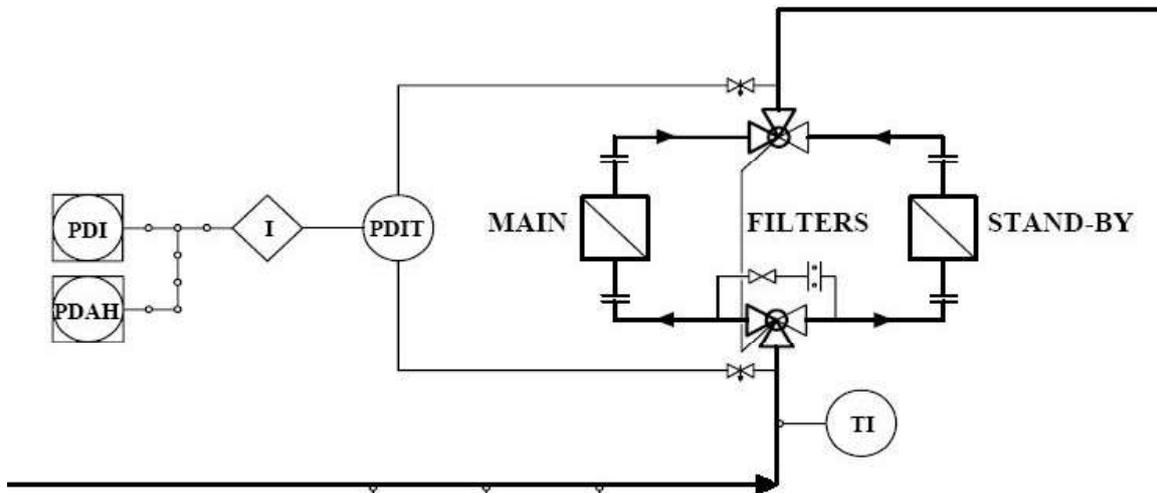


The filters are of the replaceable cartridge type.

The cartridges are to be replaced whenever the pressure drop across the filter, measured by a differential pressure instrument, approaches the set value indicated in "Instruments List" or once a year regardless of the pressure drop.

FILTERS

An equalizing flow line, provided with a restriction orifice, connects the two filters to permit the filling of the spare filter and ease the operation of the transfer valve.



procedure for changing over the filter

1. - Check that the valve on the filling (or equalizing flow) line connecting the two filters is open
2. Vent the air from the filter not in use and, when a constant stream of oil flows in the vent line, close the vent valve
3. Operate the transfer valve to bring the spare filter into operation
4. Close the valve on the filling line, crack open the vent valve of the filter now out of use for releasing the oil pressure and then fully open the vent and drain valves
5. Inspect, clean the filter not in use and replace the cartridges.
6. For keeping the cleaned filter available for immediate use in emergency, close the drain valve and open the valve on the filling line. **Close the vent valve as soon as the oil flows in the vent line**
7. Once the stand-by filter is commissioned as above the equalizing flow line maintains a continuous flow through the stand-by filter.

LUBE OIL LINES

The oil filtered and at required temperature arrives to a header into which the lube oil bearing lines are tapped.

The oil pressure in the lube oil header is maintained at a constant pressure of 2.5 Bar g 250 kPa g by means of the pressure reducing valve,

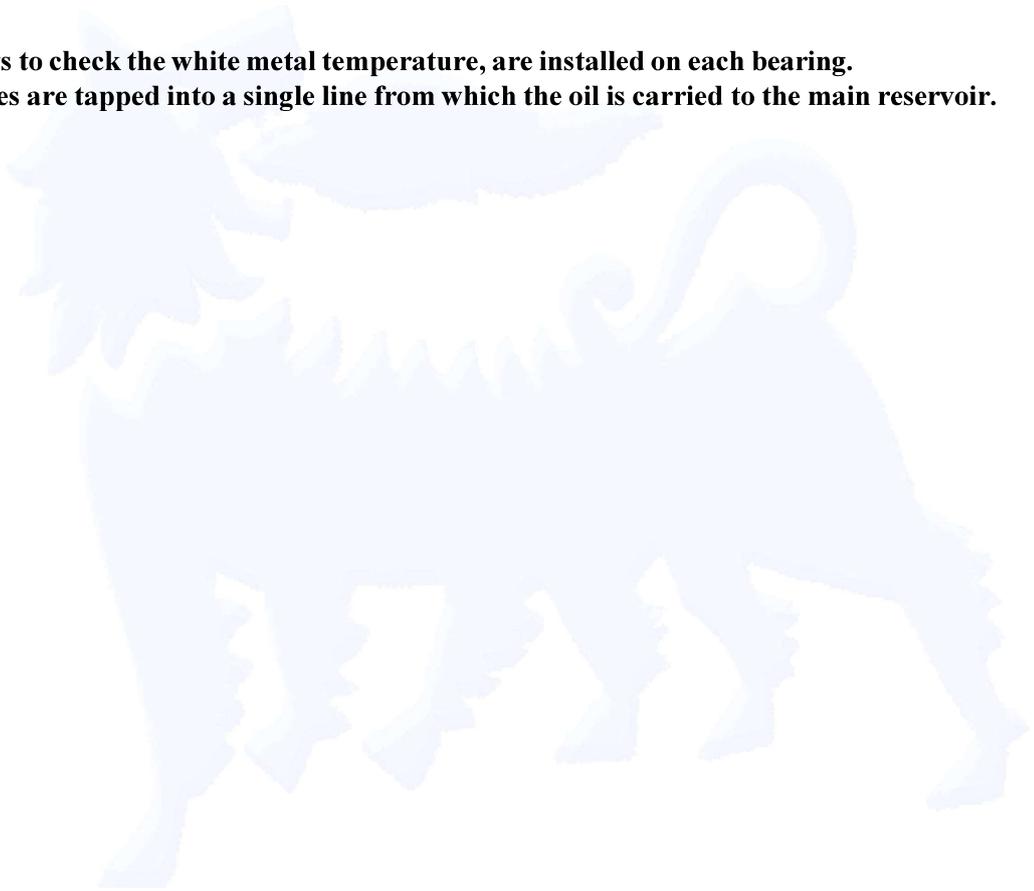


A calibrated orifice is fitted, in each bearing oil line, sized for maintaining a proper pressure level. The pressure level is indicated by a local pressure gauge.

Flow glasses and local thermometers are installed in the oil return lines from the lubrication points.

LUBE OIL LINES

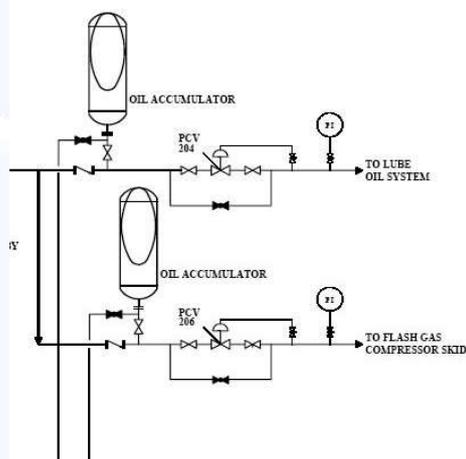
Thermo-elements to check the white metal temperature, are installed on each bearing.
The oil outlet lines are tapped into a single line from which the oil is carried to the main reservoir.



LUBE OIL PRESSURE TO BEARINGS

The lube oil pressure to the bearings is controlled by means of the calibrated orifice provided in each oil inlet line or conduit to bearings.

An oil pressure of 0.9 to 1.3 Bar g, 90 to 130 kPa g to journal bearings and of 0.3 to 0.5 Bar g, 30 to 50 kPa g, to thrust bearing.



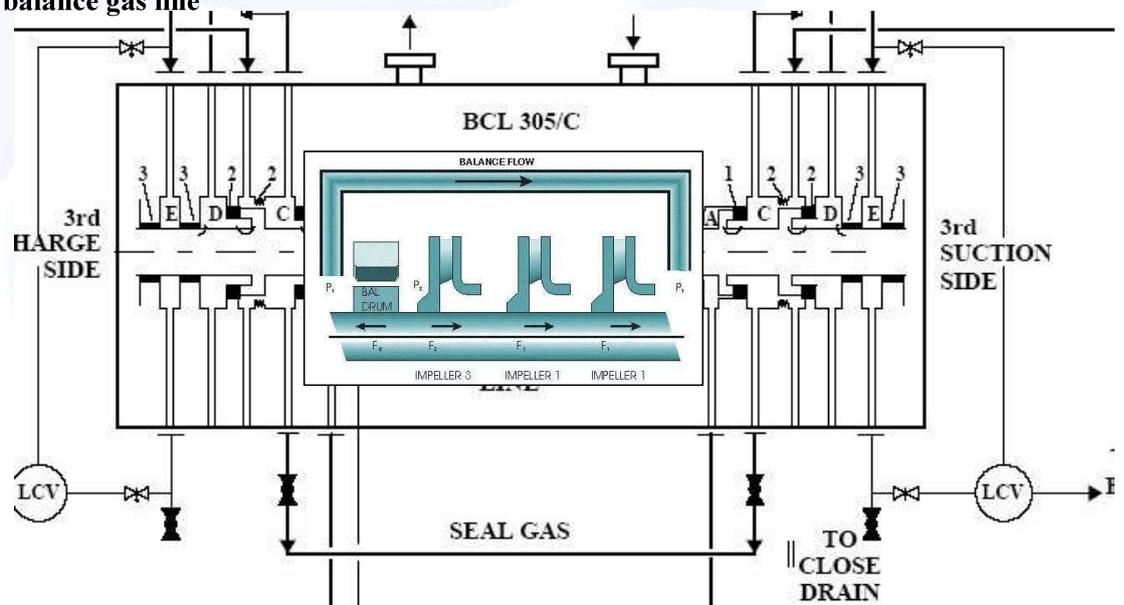
Check the regular lube oil flow through the bearings by means of the flow glass indicators.

1. Lube oil header control valve PCV 204 – PCV 206

This control valve maintains a constant pressure of about 2.5 Bar g 250 kPa g in the lube oil header.

SEAL GAS LINES

The discharge gas of the compressor, which comes out between the labyrinth seal "N" and the balance drum, goes into the chamber "B" and returns to the compressor suction compressor by means of an external connection called the "balance gas line"



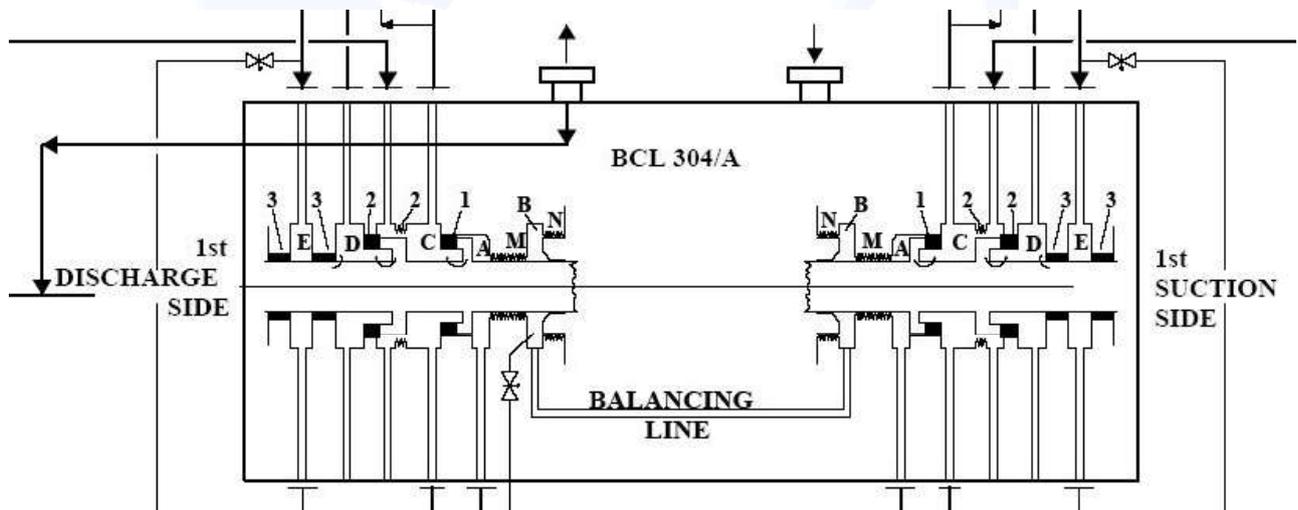
The above mentioned connection likewise provides for balancing the axial thrust on the rotor, as described in the para. "Balance drum"

In this way both ends of the rotor have a pressure close to the suction one and that permits to use two similar groups of sealing rings and the same seal (buffer) gas pressure for both ends of the rotor.

SEAL GAS LINES

Tertiary seals and dry gas seals form five chambers at suction end of the rotor and six chambers at discharge end of the rotor.

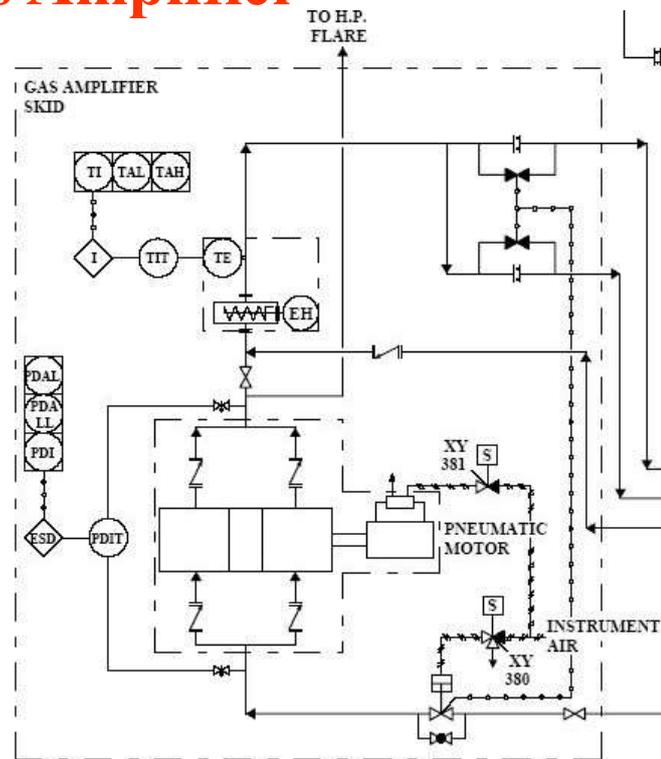
In order to prevent the process gas from escaping through the labyrinth seals "M", chambers "A" are pressurized



To be sure that the seals operate with clean and without condensate gas, is made an injection of filtered gas (buffer gas) at a pressure a little higher than the suction pressure.

To prevent Hydrocarbon concentration due to the flashing of gas contained in the casing of the compressor to the labyrinths of the seals during normal stop, shutdown sequence and pressurized stop condition, each compressor is equipped with Gas amplifier system.

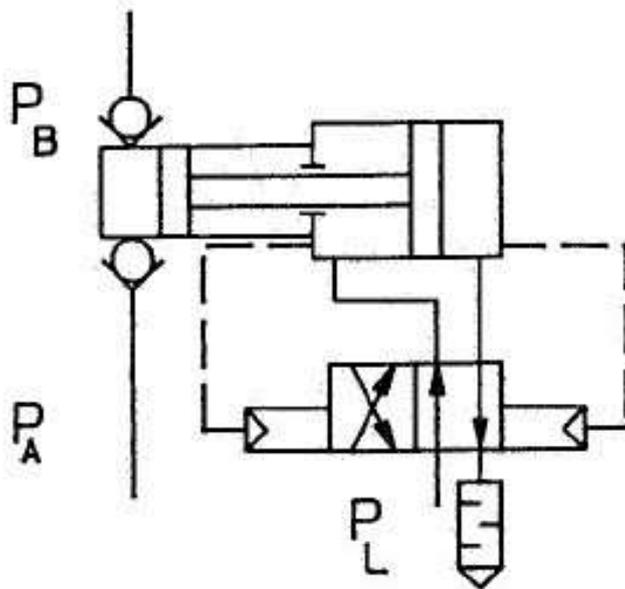
Gas Amplifier



In normal operating conditions the seal gas is heated by means of an electric heater located inside the Gas amplifier skid.
For the complete instructions regarding the “Gas amplifier skid” see the Volume VI of this manual.

Cameron Maximator

Single acting, single stage

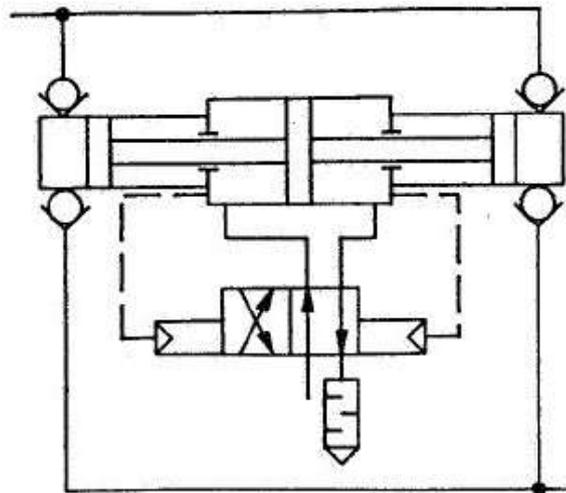


MAXIMATOR compressed air boosters and compressors are driven by compressed air and controlled by a floating control valve and pilot valves.

They include double-acting and single-acting machines and are available in single-stage and two-stage versions

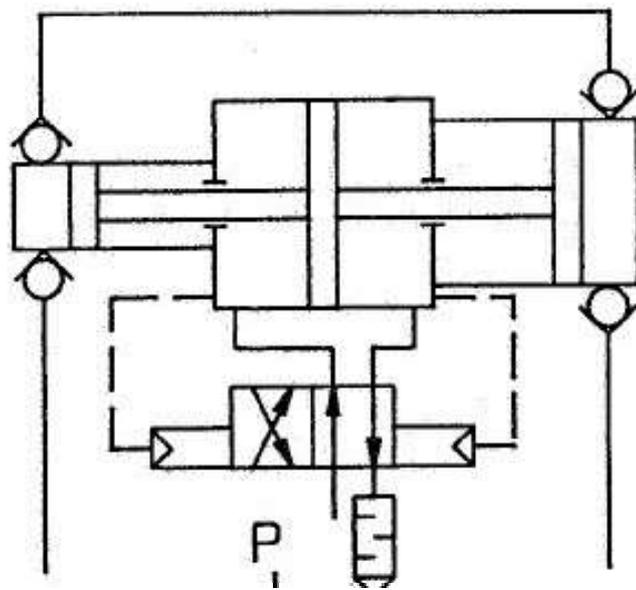
Cameron Maximator

Double acting, single stage



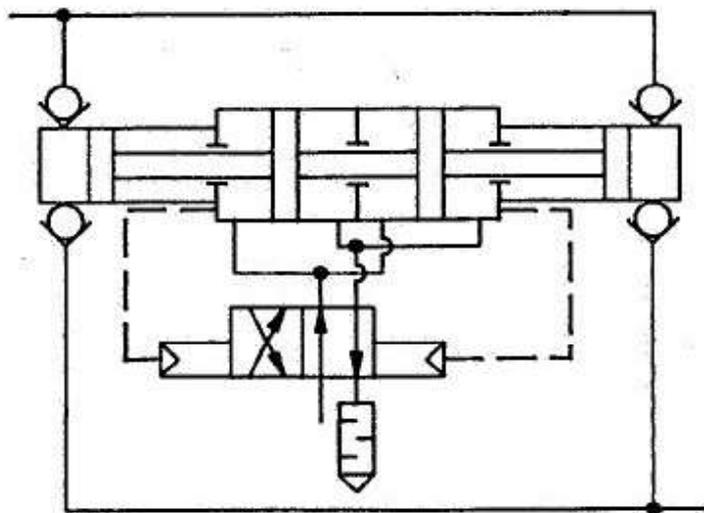
Cameron Maximator

Two stage

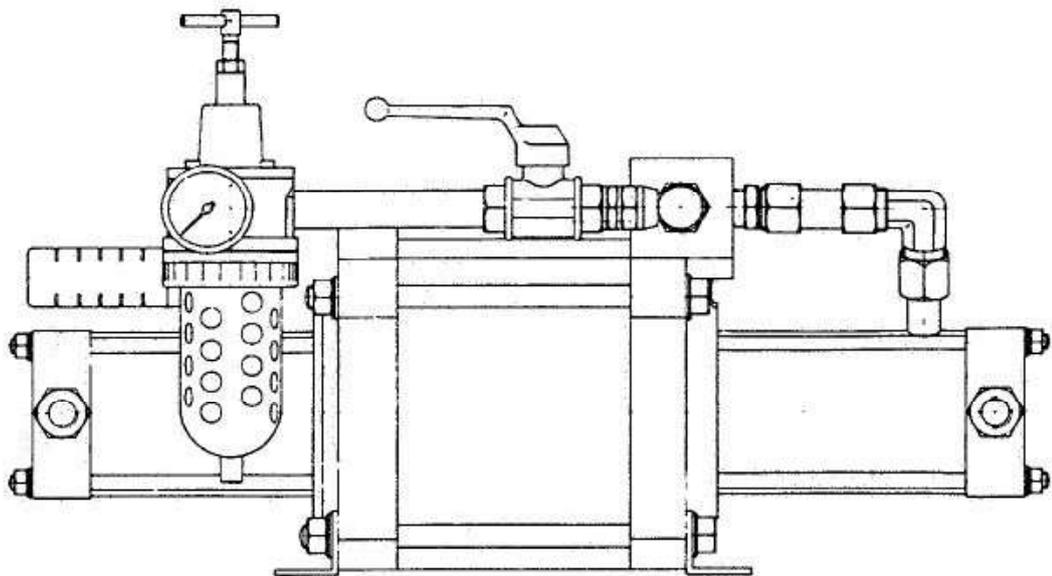


Cameron Maximator

Double acting, single stage



Cameron Maximator



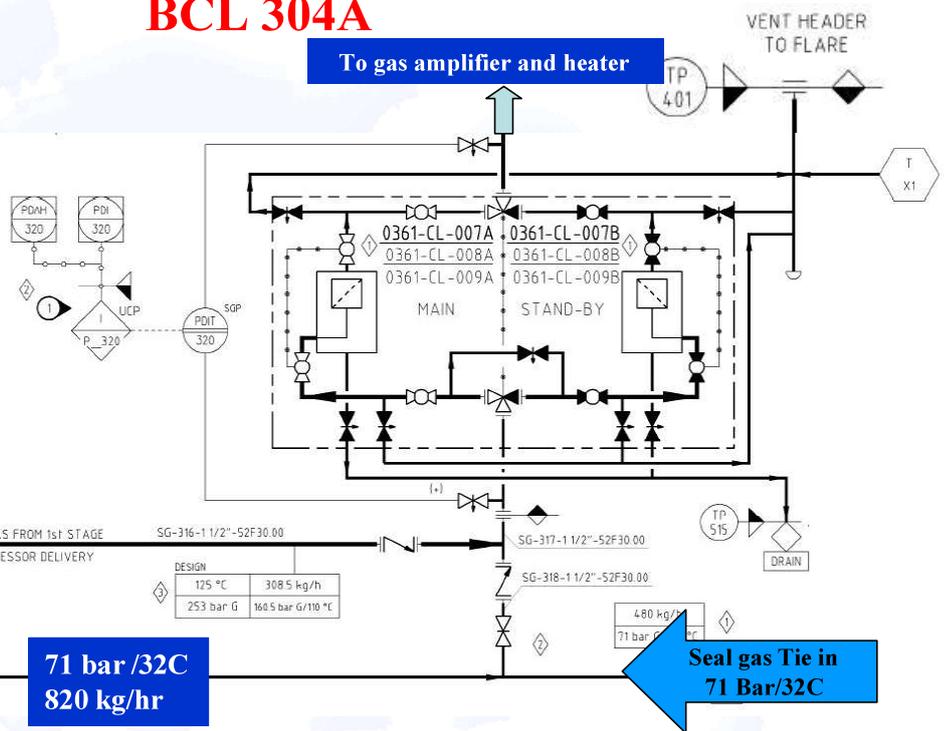
Cameron Maximator

Version	Type	Pressure ratio	Compression ratio*	Stage pressure ratio**	Suction pressure bar***		Discharge pressure bar	Displacement cm ³	max. Stokes (1/min.)	Connection****		max. working temperature (°C)	Weight (kg)	Material
					min.	max.				Suction	Discharge			
single acting single stage	DLE 2-1	1: 2	1: 10	-	0	5	25	850	100	G 1/2	G 1/2	60	16	1+2
	DLE 5-1	1: 5	1: 15	-	2	20	60	350	110	G 1/2	G 1/2	60	16	1+2
	DLE 15-1	1:15	1: 20	-	7	50	160	113	130	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 30-1	1:30	1: 20	-	15	80	320	50	130	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 75-1	1:75	1: 20	-	35	150	700	23	150	9/16"-18 UNF	9/16"-18 UNF	100	14	1
double acting single stage	DLE 2	1: 2	1: 10	-	1	25	25	1700	90	G 1/2	G 1/2	60	16	1+2
	DLE 5	1: 5	1: 15	-	2	60	60	700	110	G 1/2	G 1/2	60	16	1+2
	DLE 15	1:15	1: 20	-	7	160	160	225	120	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 30	1:30	1: 20	-	15	320	320	100	120	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 75	1:75	1: 20	-	35	700	700	45	130	9/16"-18 UNF	9/16"-18 UNF	100	14	1
double acting single stage 2 air cylinder	DLE 15-2	1:30	1: 20	-	7	160	160	225	120	9/16"-18 UNF	9/16"-18 UNF	100	23	1
	DLE 30-2	1:60	1: 20	-	15	320	320	100	120	9/16"-18 UNF	9/16"-18 UNF	100	23	1
	DLE 75-2	1:150	1: 20	-	50	1300	1300	45	130	9/16"-18 UNF	9/16"-18 UNF	100	23	1
double acting two stage	DLE 2- 5	1: 5	1: 25	1:2,5	1	0,8xPA	60	850	100	G 1/2	G 1/2	60	16	1+2
	DLE 5-15	1:15	1: 45	1:3	2	1,6xPA	160	350	110	G 1/2	9/16"-18 UNF	100	15	1+2
	DLE 5-30	1:30	1: 90	1:6	2	0,8xPA	320	350	110	G 1/2	9/16"-18 UNF	100	15	1+2
	DLE 15-30	1:30	1: 40	1:2	7	7,5xPA	320	113	120	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 15-75	1:75	1:100	1:5	7	3,0xPA	700	113	120	9/16"-18 UNF	9/16"-18 UNF	100	14	1
	DLE 30-75	1:75	1: 50	1:2,5	15	12xPA	700	50	130	9/16"-18 UNF	9/16"-18 UNF	100	14	1

Primary Seal gas filter BCL 304A

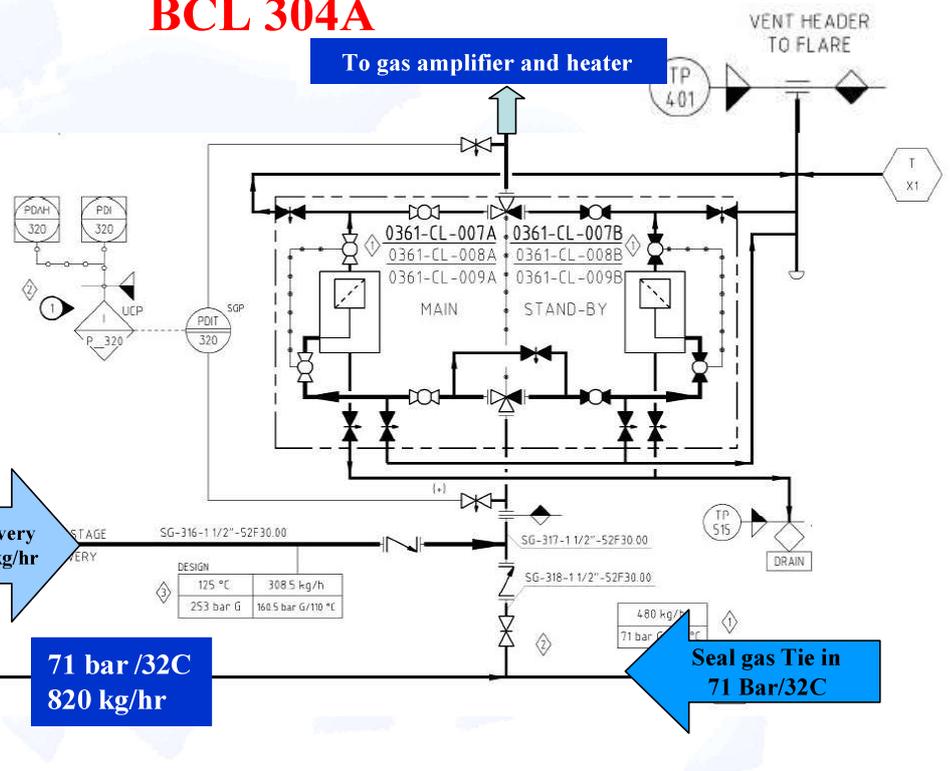


The filters are of the replaceable cartridge type.



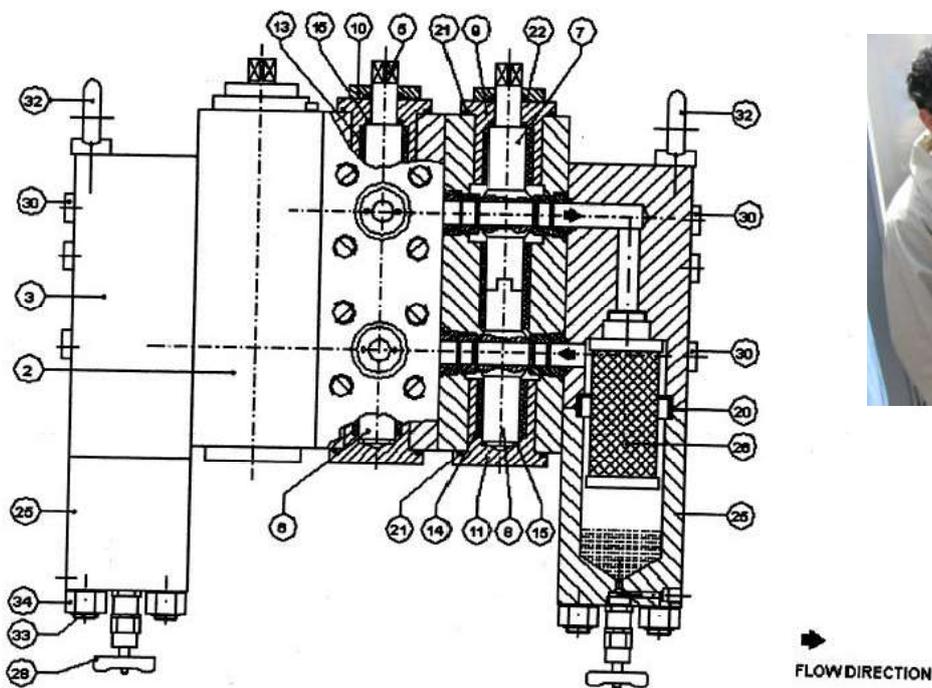
Twin gas filters are provided in the main seal gas line and in the flushing gas line. Each twin gas filters are piped in a parallel arrangement utilizing a continuous flow transfer valve.

Primary Seal gas filter BCL 304A



The cartridges are to be replaced whenever the pressure drop across the filter, measured by a differential pressure gauge, approaches the set value indicated in "Instruments List" included in the Volume or Section of this manual or once a year regardless of the pressure drop.

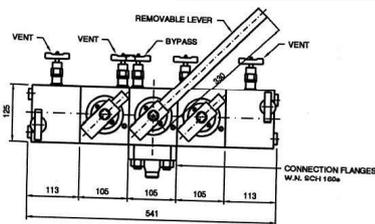
Primary Seal gas filter BCL 304A



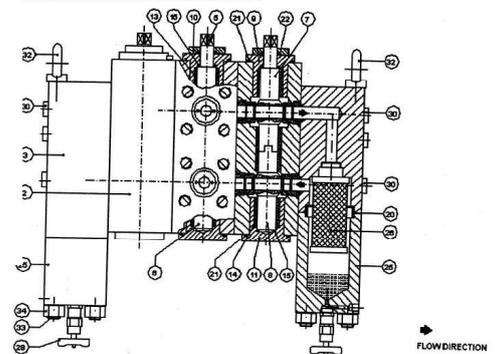
An equalization flow line, provided with a restriction orifice, connects the two filters to permit the filling of the spare filter and ease the operation of the transfer valve.

Primary Seal gas filter BCL injection gas compressor

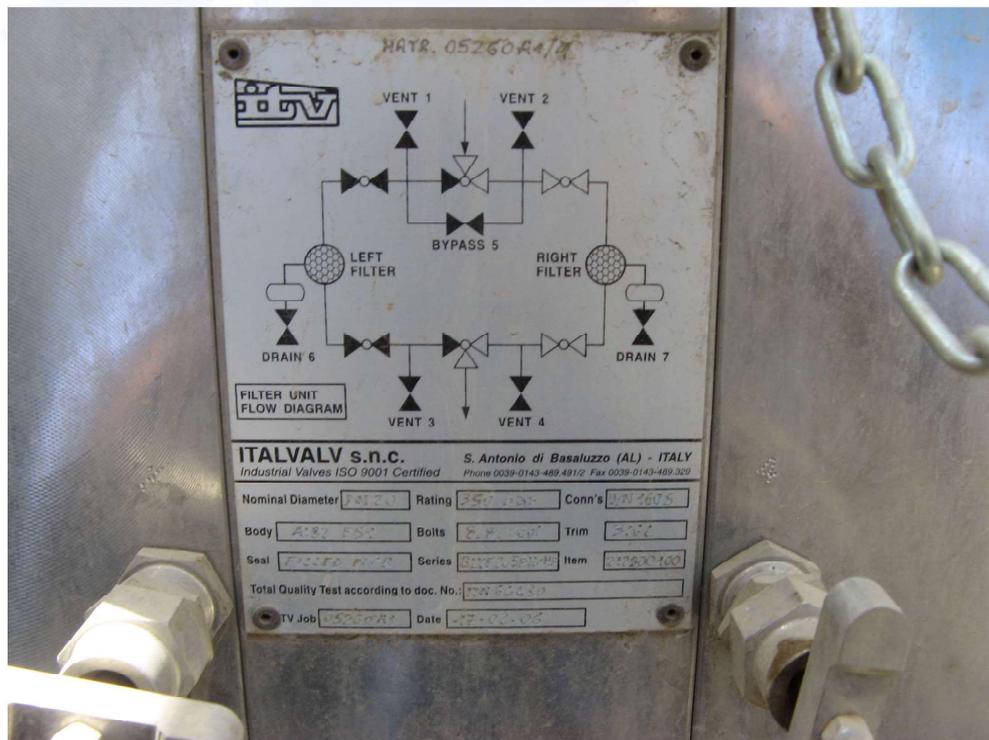
The procedure for changing over the filter, while the seal gas system is operating, includes the following steps:



- Check that the drain valve of the filter not in use is closed.
- Open the isolating valve(s) of the filter not in use.
- Open the valve on the filling (or equalizing flow) line connecting the two filters.
- Vent the air from the spare filter for a period of time that will assure the air is completely vented from the filter which is now full with seal gas, then close the vent valve.
- Operate the transfer valve to bring the spare filter into operation.
- Close the valve on the filling line, crack open the vent valve of the filter not more in use for releasing the gas pressure and then fully open the vent and drain valves.
- Close the isolating valves of the filter not in use.
 - Inspect and clean the filter not in use, replace the cartridges.
- Close the vent and drain valves of the filter not in use.

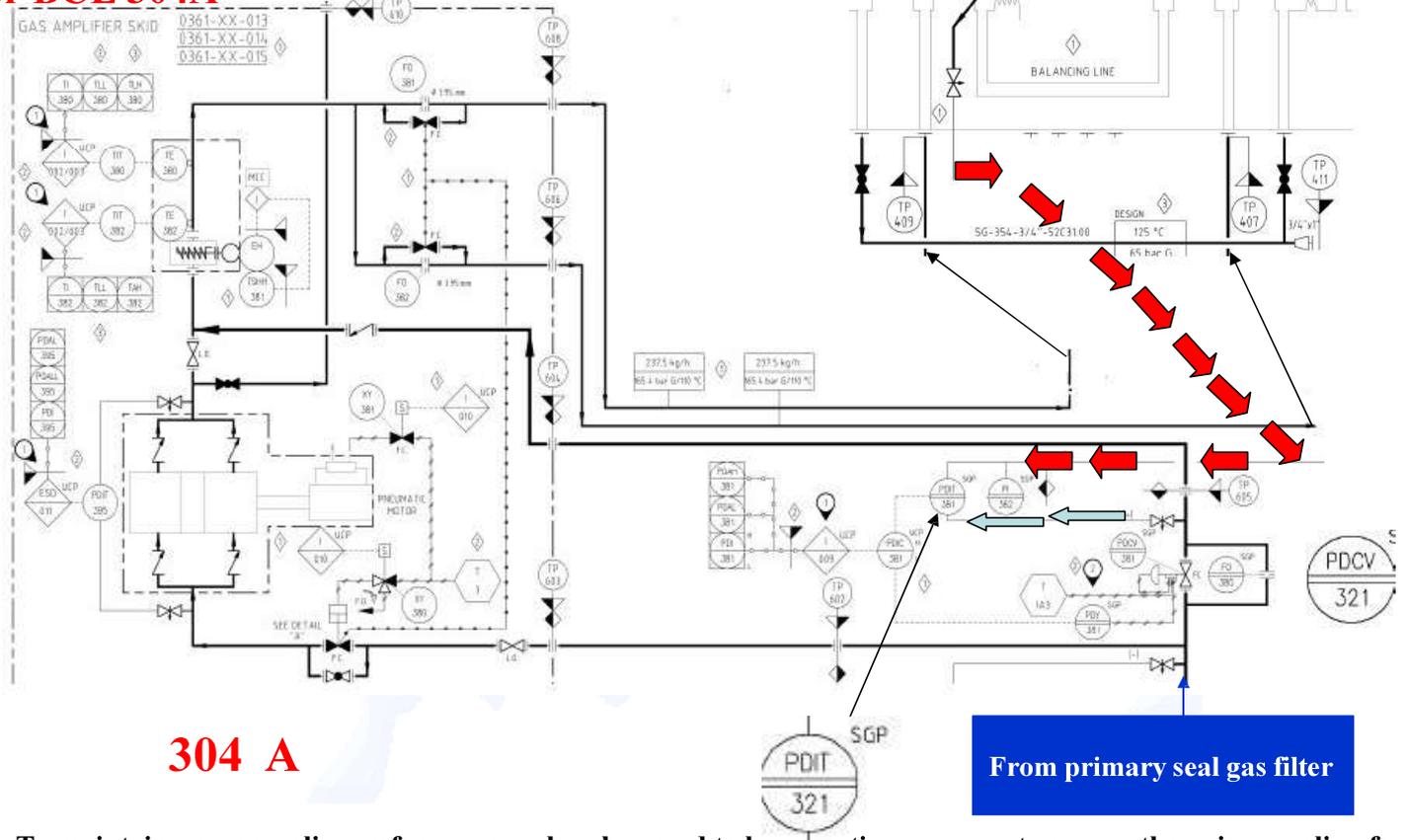


Primary Seal gas filter BCL injection gas compressor



**Primary Seal gas
/Ballancing or reference gas
For BCL 304A**

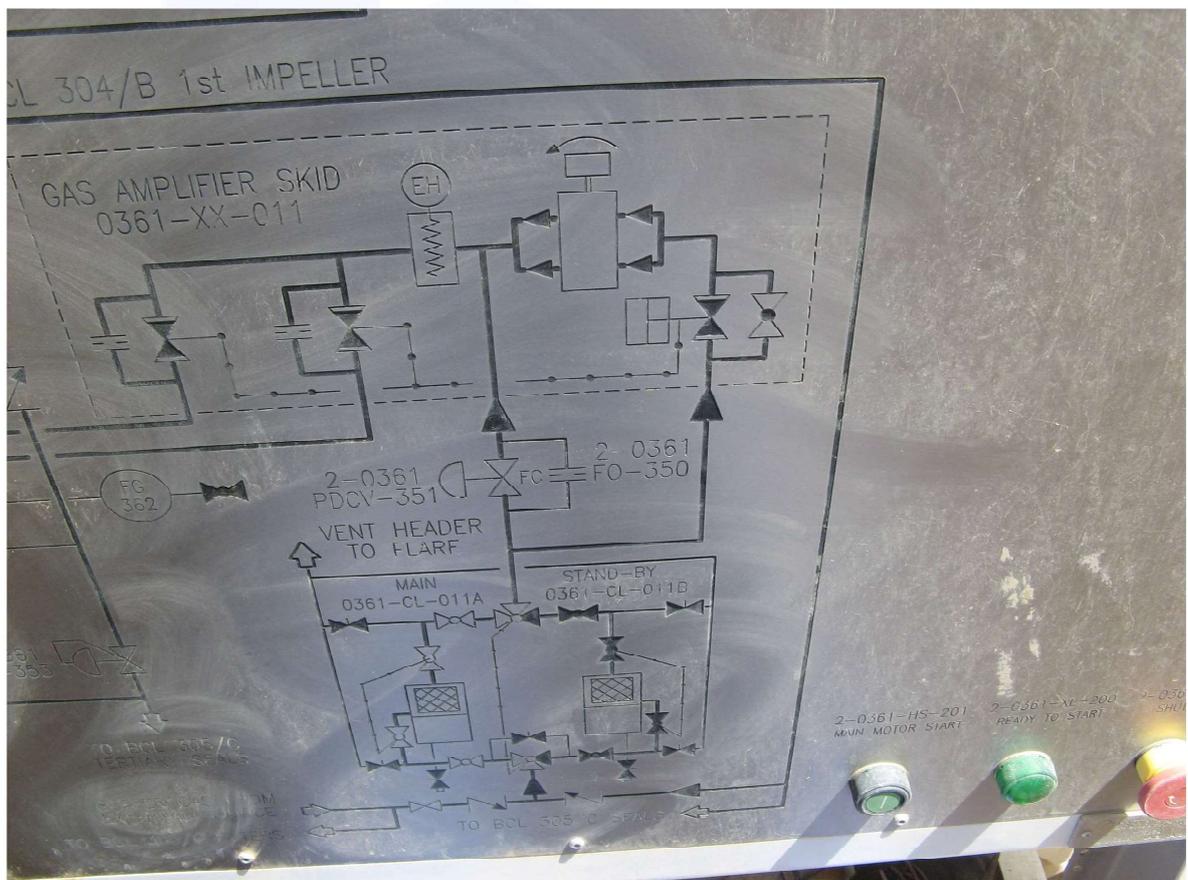
Reference gas chamber



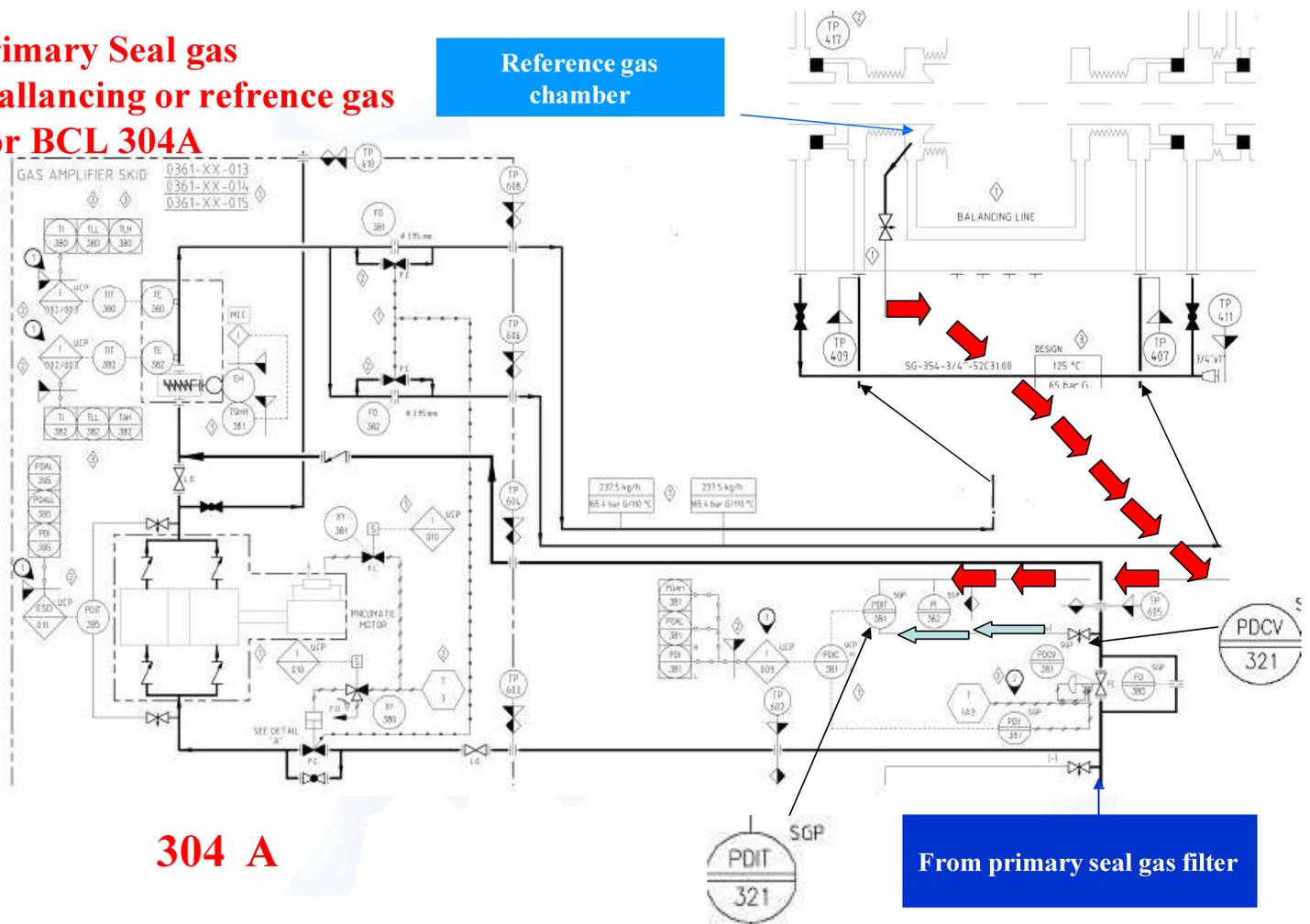
304 A

To maintain proper sealing ,reference gas chamber need to have suction pressure to govern the unique sealing for Both shaft end .

Gas Amplifier Skid on SGP



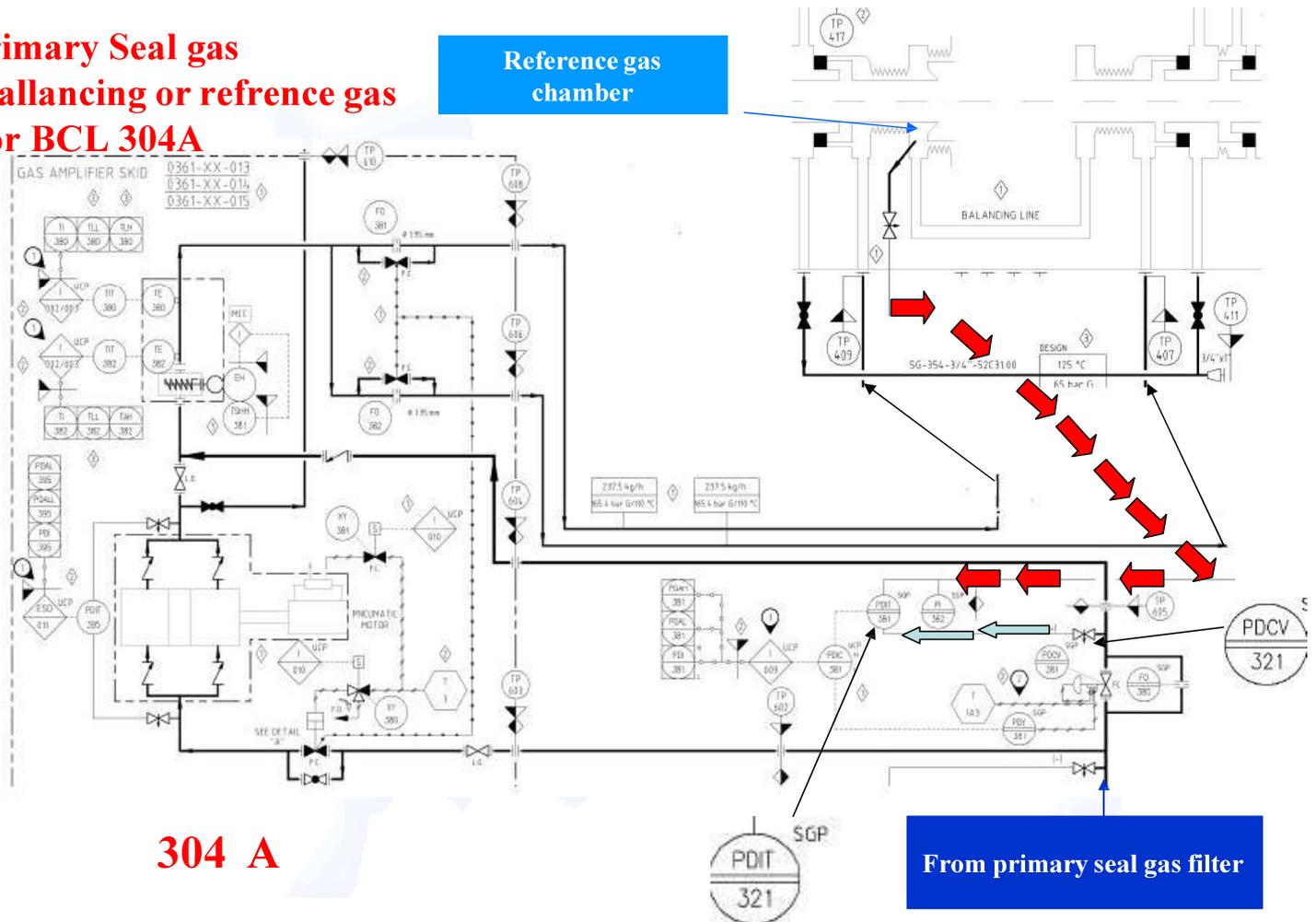
**Primary Seal gas
/Ballancing or reference gas
For BCL 304A**



304 A

Hence seal gas chamber pressure which is only depend to the compressor shaft and casing design must be measure And compare with inlet

**Primary Seal gas
/Ballancing or reference gas
For BCL 304A**

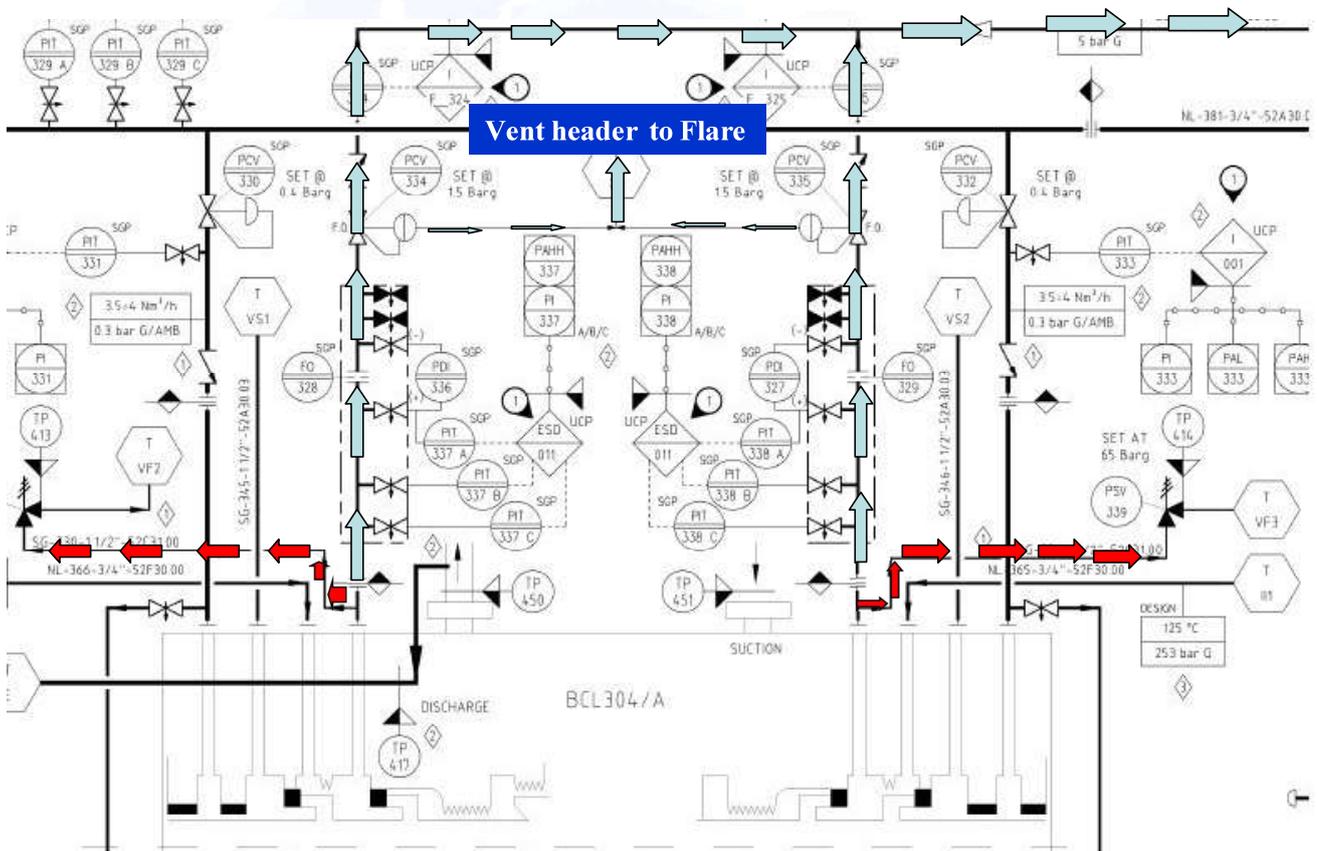


304 A

This purpose is assured by a differential pressure control system (one for each compressor) between the buffer gas and balancing gas ("reference gas chamber").

Primary Vent For BCL 304A

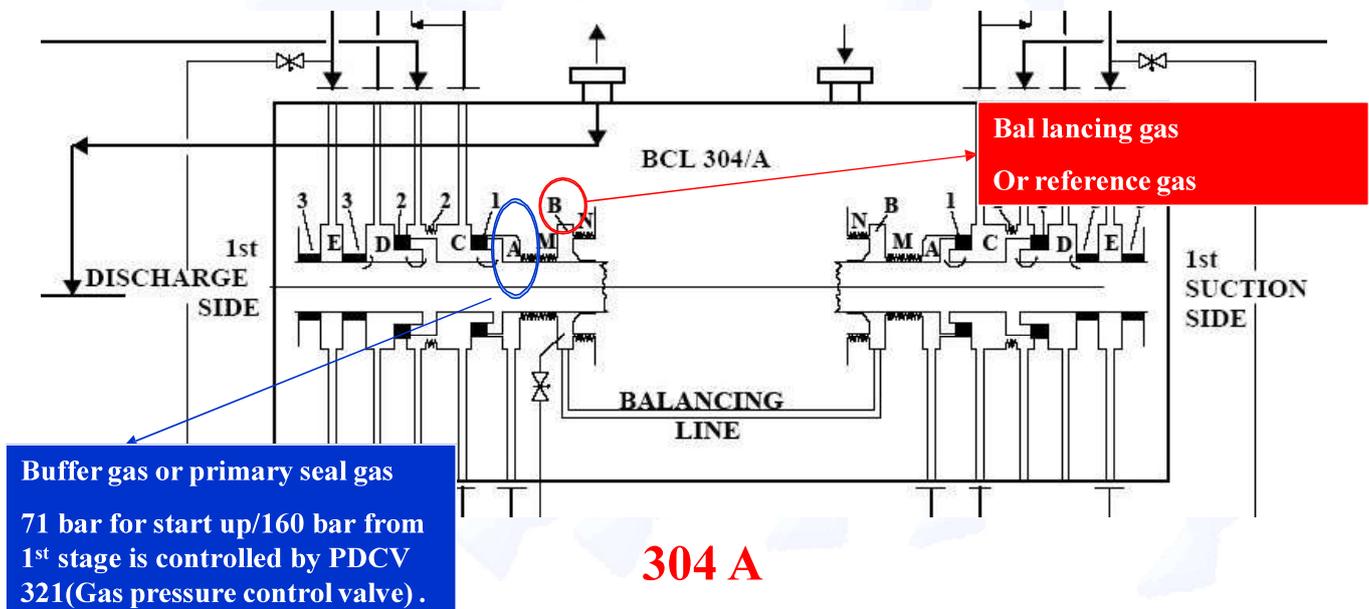
To primary Vent header
Max Back press
1.8 Normal 1.1 to 1.5



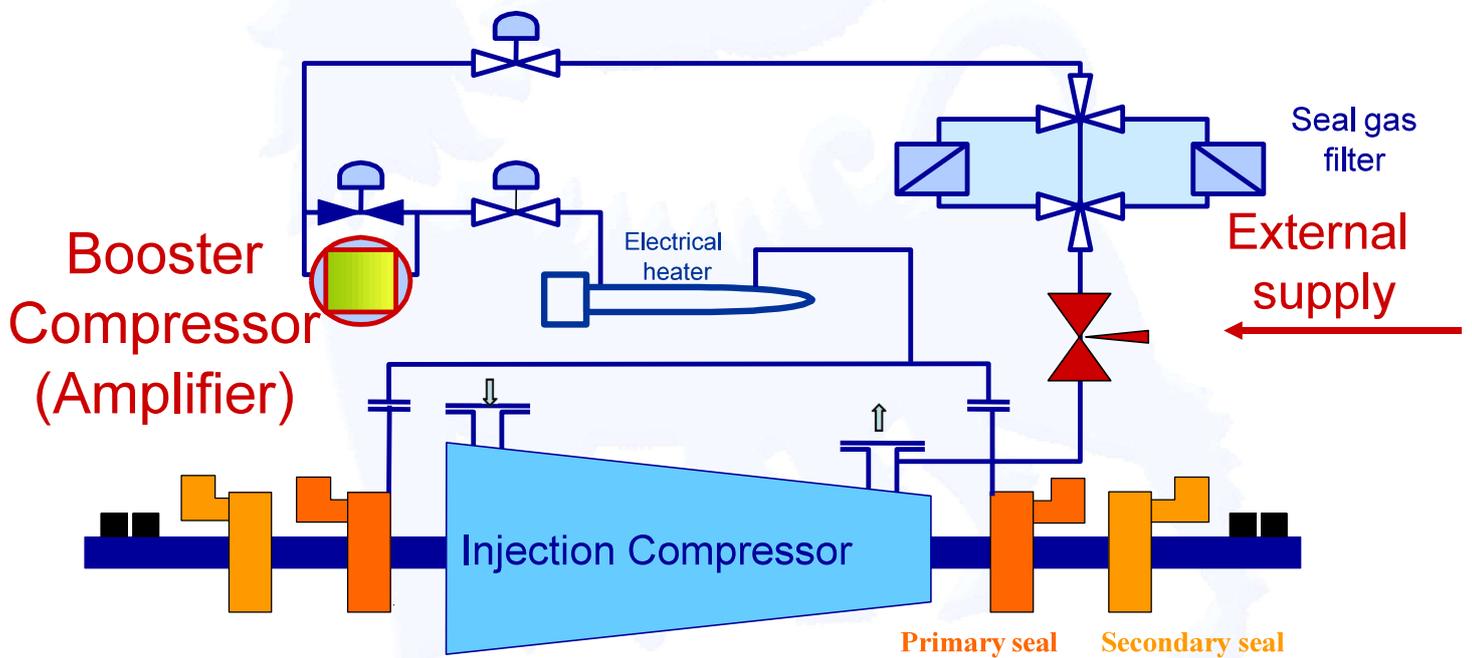
SEAL GAS LINES

This purpose is assured by a differential pressure control system (one for each compressor) between the buffer gas (chamber "A") and balancing gas (chamber "B").

The seal gas pressure in the chamber "A" is controlled by means of a pressure differential control valves (PDCV 321 for BCL 304/A, that is provided of a differential transmitter/controller groups as indicated in the paragraph "Gas pressure control valves".

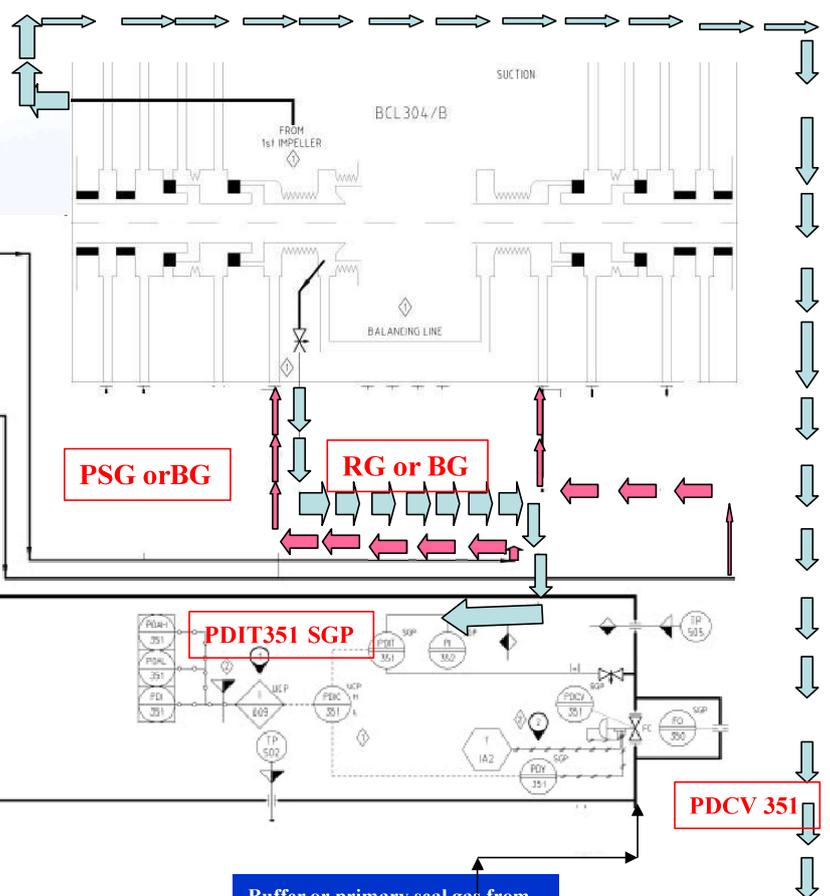


This system assures the corrected differential pressures between the seal gas and the balancing gas. The control valves is provided with: block valve and one by-pass lines, provided of a calibrated orifice.



**Primary Seal gas
/Ballancing or refrence gas
For BCL 304B**

To Vent Header

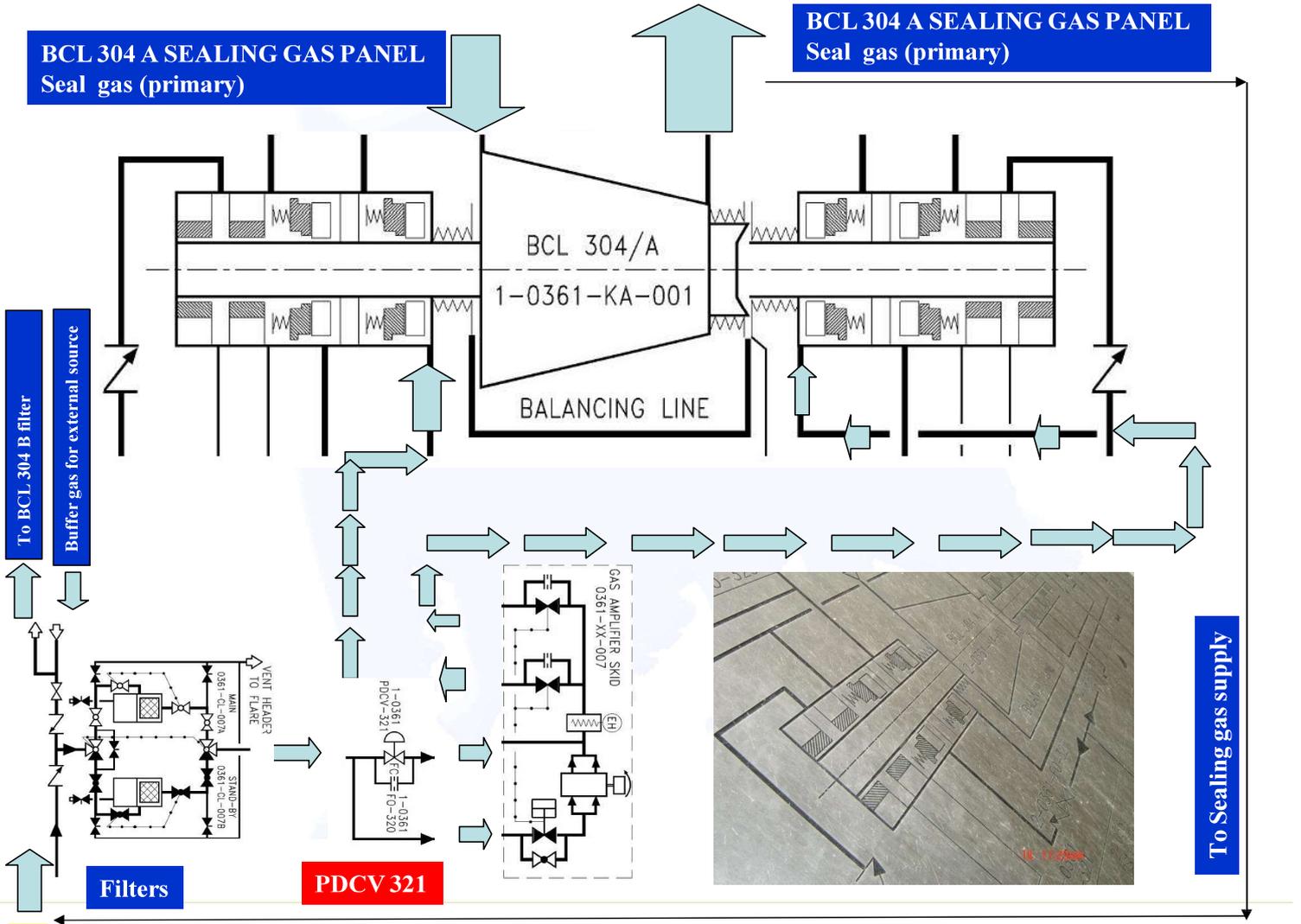


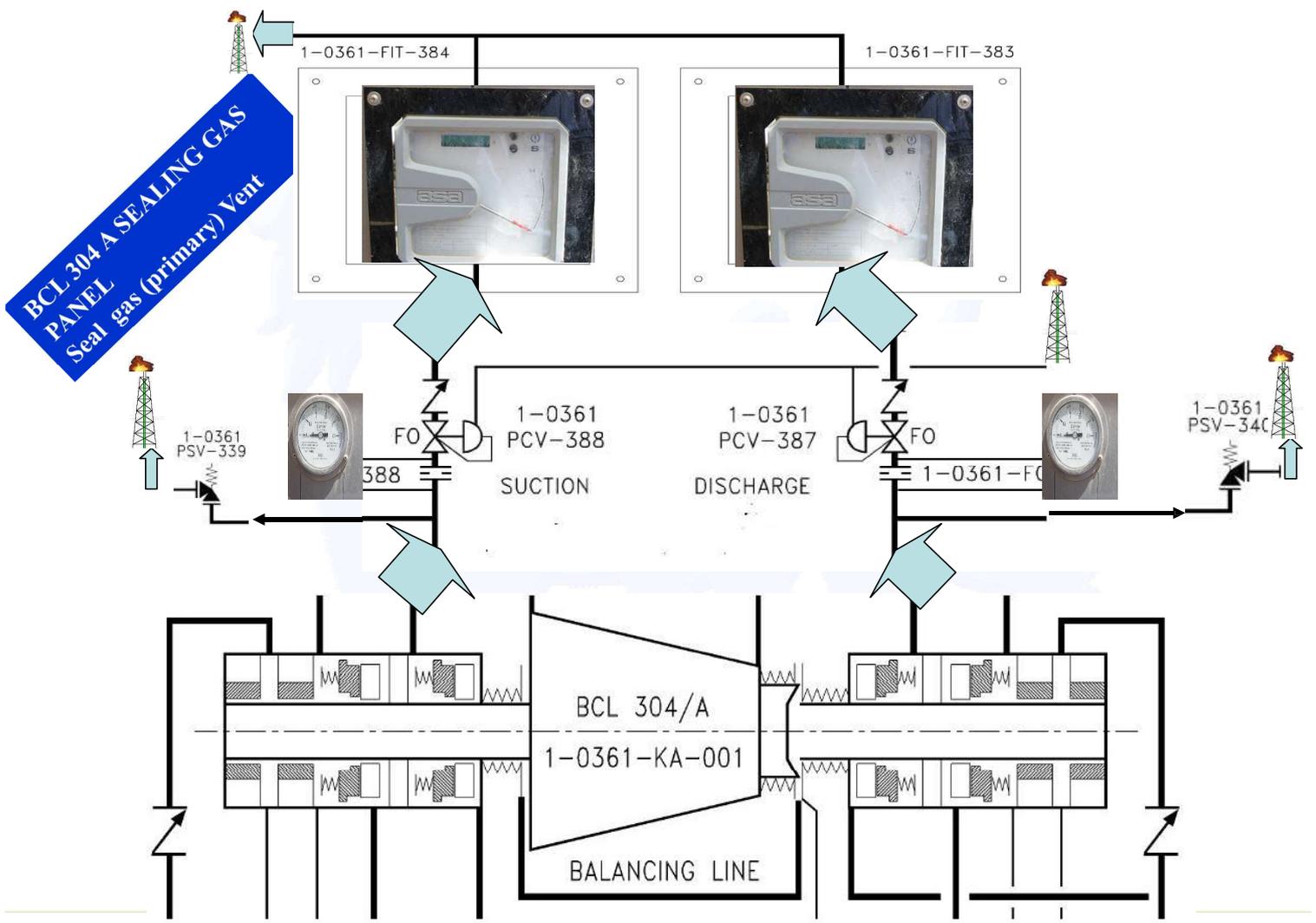
Buffer or primary seal gas from filter

71 bar/32 C for start up from external source and SG

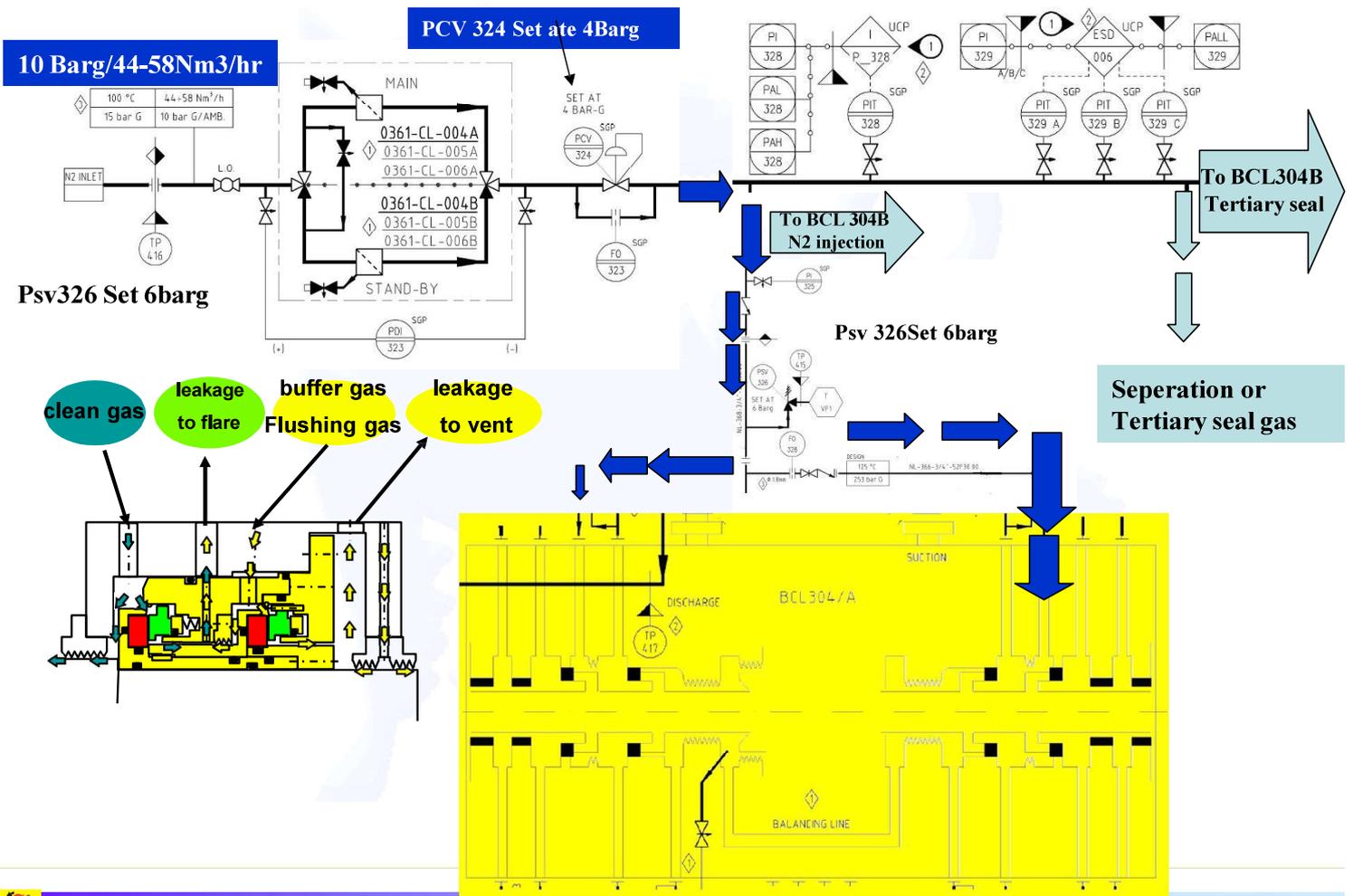
Seal Gas BCL304B
From First Impeller
256 bar/95C





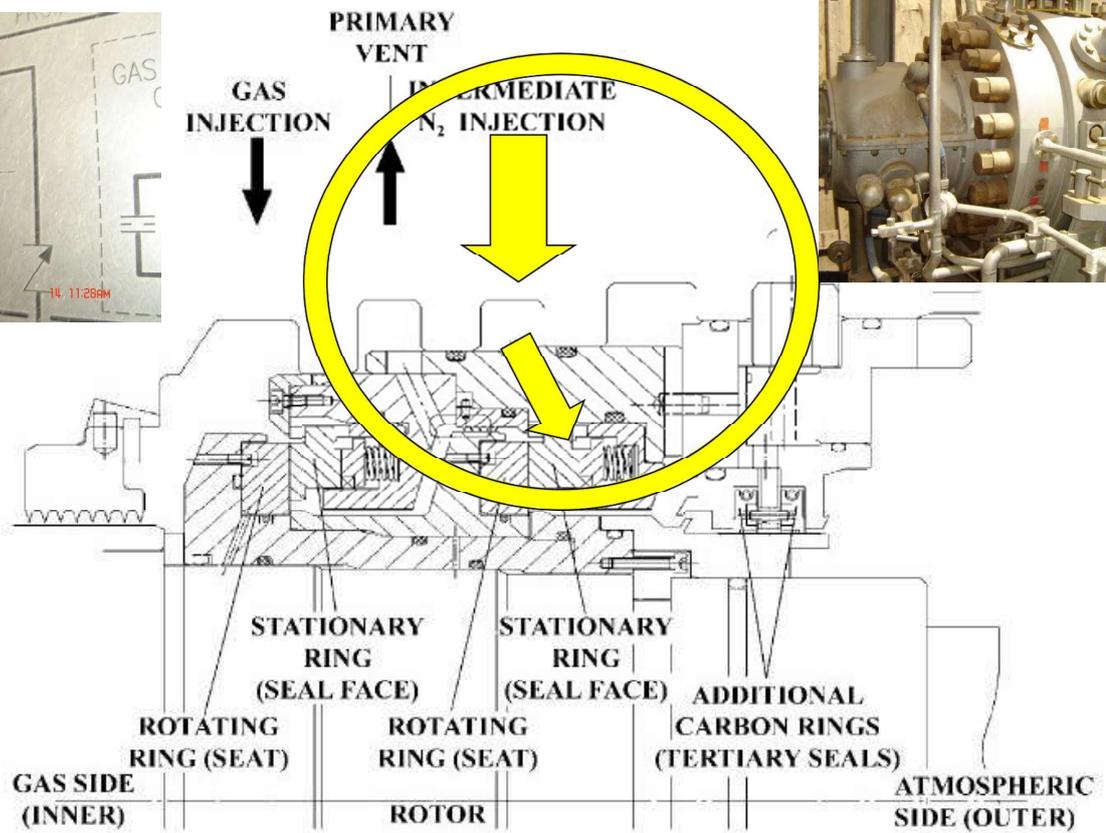
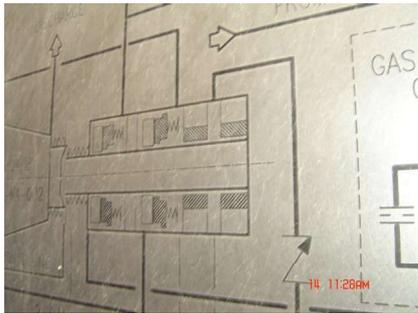


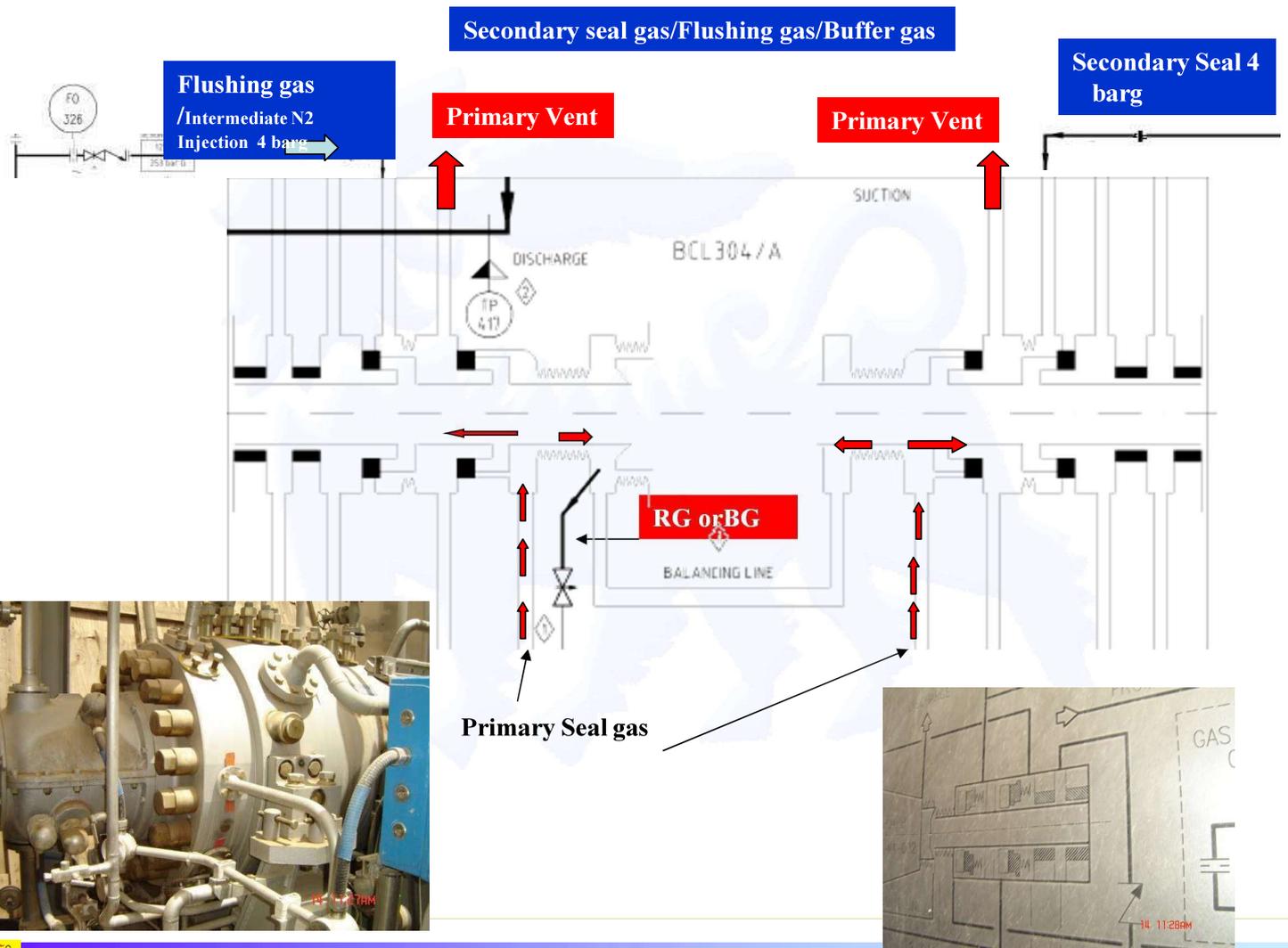
Flushing gas or Intermediate N2 Injection



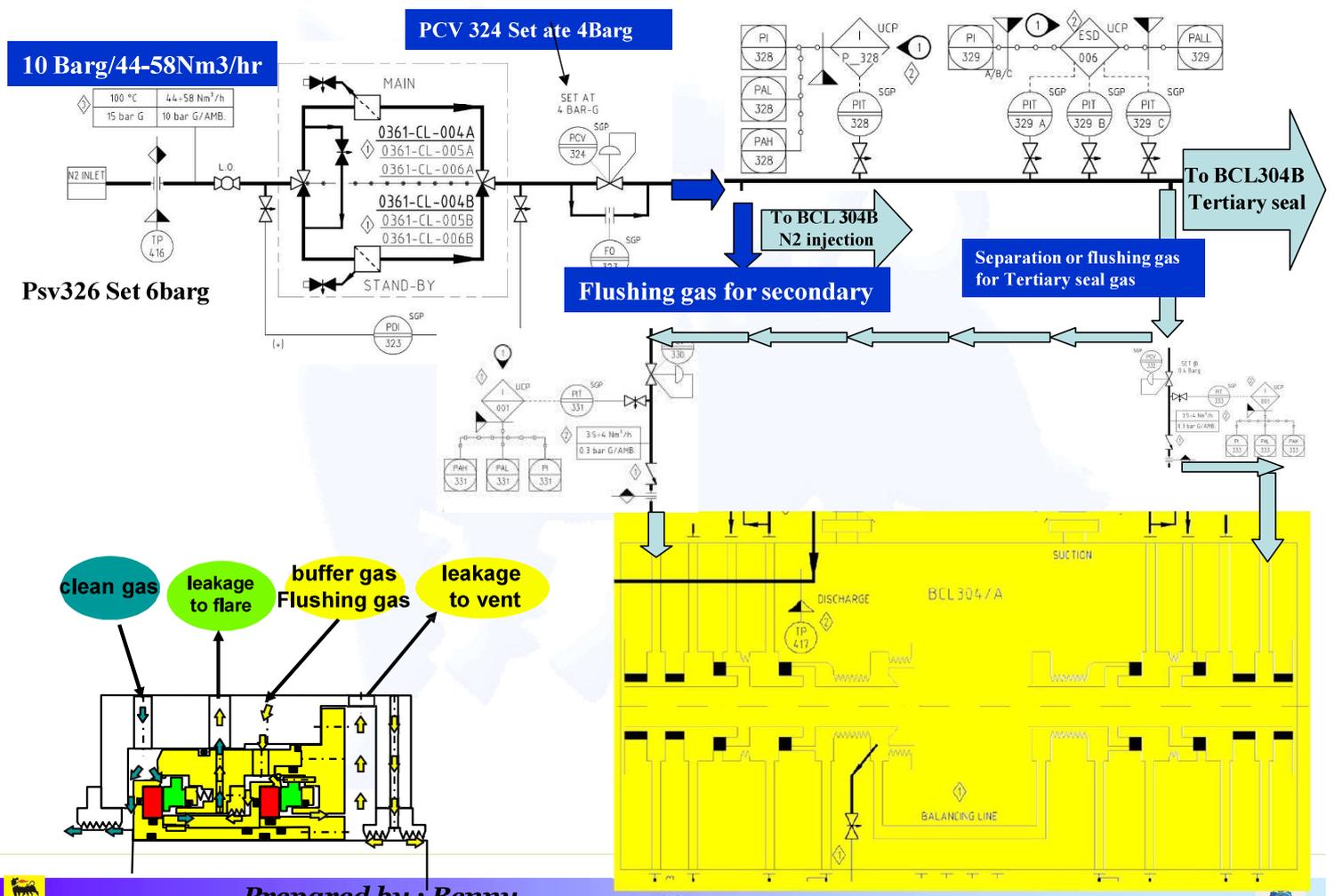
Prepared by : Benny

Flushing gas or Intermediate N₂ Injection

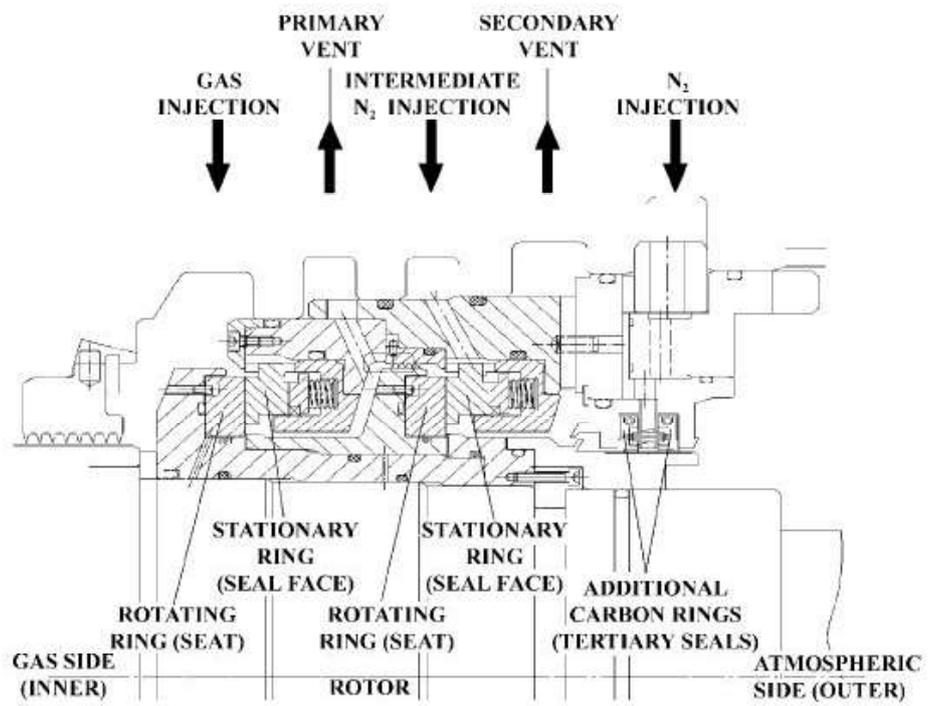


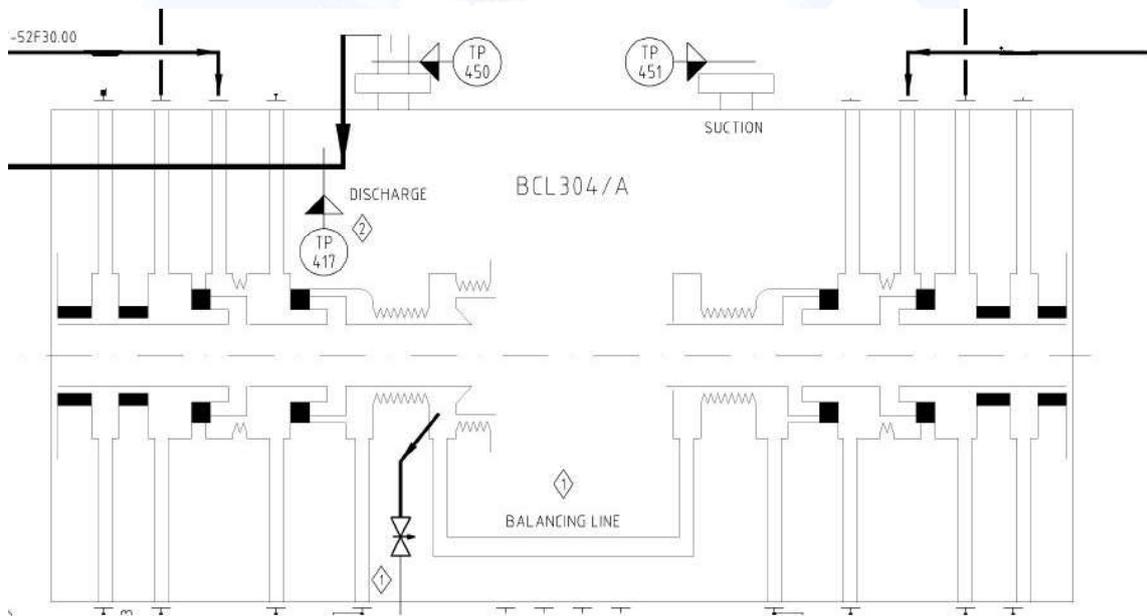


Flushing gas for Tertiary Seal



Prepared by : Benny





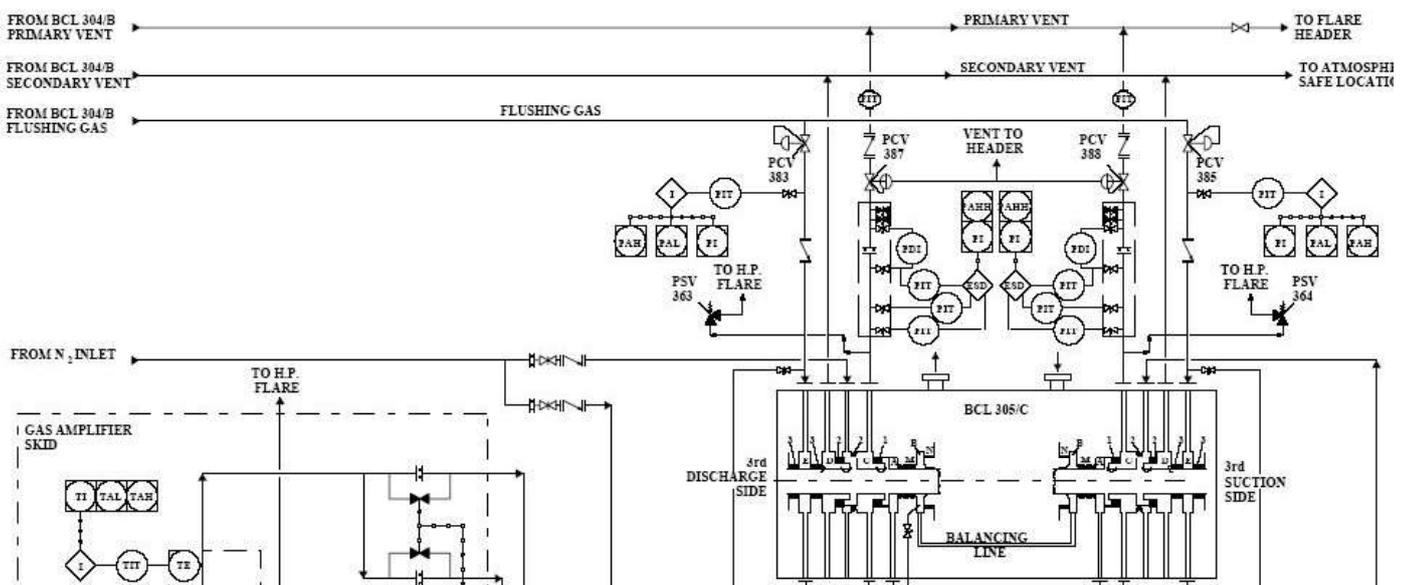


Primary vent lines

The seal gas that escapes from chambers "A" through the rings on the inner side of the dry gas seals (one for each seal) reaches the chambers "C" from where it is sent to a recovery system through, adjusting flow orifice valves by means of lines called "Primary vent lines".

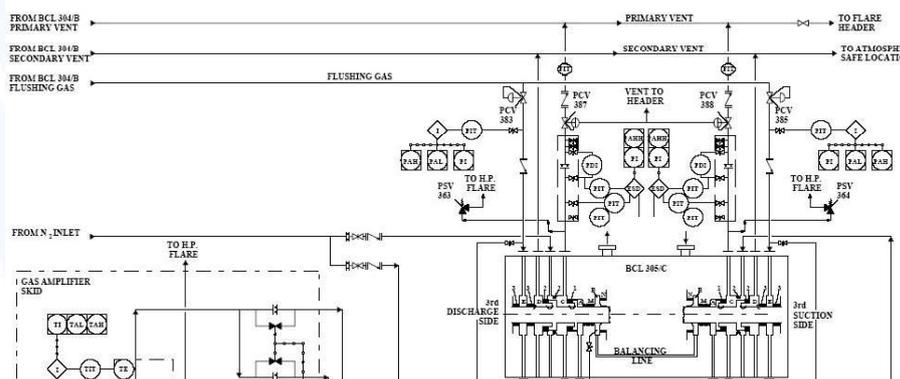
Safety valves assure the venting to the flare in case of emergency.

Pressure control valves assure the gas flow to the flare.



Primary vent lines

THE PRIMARY VENT FLOWS MAY DIFFER BETWEEN THE TWO SHAFT ENDS (DRIVE END/NON DRIVE END). THIS IS A NORMAL FACT DUE TO THE SENSITIVITY OF DRY GAS SEAL CARTRIDGES (WHICH OPERATE ON VERY NARROW GAPS OF APPROX. 5 MICRONS) TO MANUFACTURING VARIABILITY WITHIN ACCEPTANCE TOLERANCES. N.P.



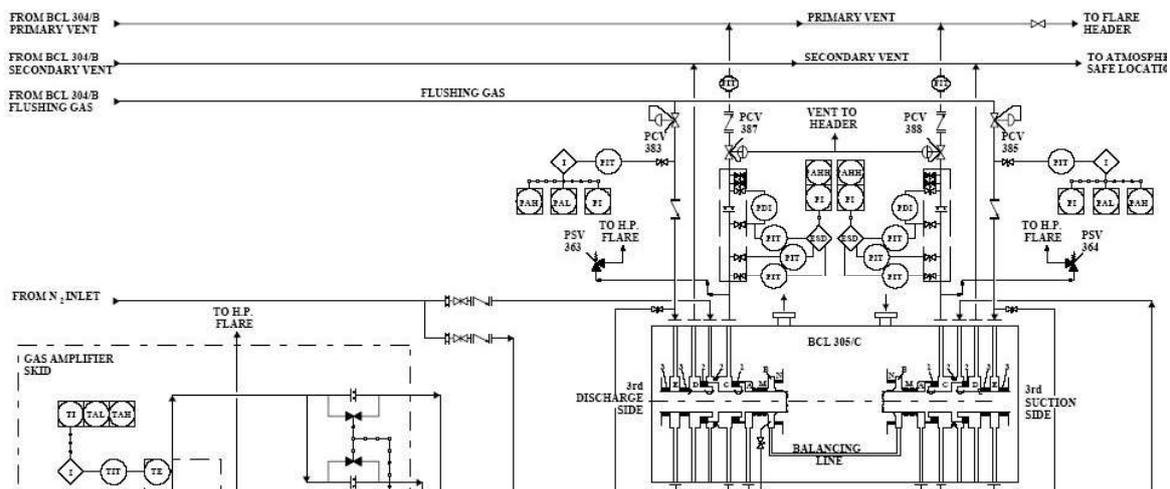
CONSIDER ACCEPTABLE A DIFFERENCE IN FLOWS BETWEEN THE TWO SHAFT ENDS SUBJECT THE FOLLOWING CONDITIONS ARE MET:

- 1) NO LOW OR HIGH FLOW ALARM IS ACTIVATED.**
- 2) MASS FLOW AMONG THE TWO ENDS DIFFERS LESS THAN 100% IN DYNAMIC CONDITIONS (I.E. THE HIGHER MASS FLOW DO NOT EXCEEDS TWICE THE LOWER MASS FLOW).**

IN ALL OTHER CASES, THE N.P. SERVICE SHALL BE CONTACTED.

Flushing gas

The flushing gas pressure is controlled by a pressure control valve (PCV 324) that is provided of block valves. This gas is sent to chambers "E" and intermediate chamber through adjusting flow orifices valves.



In each line other pressure control valve assure the correct pressure of the flushing gas.

The flushing gas in chambers "E" prevents any gas escaping from chambers "D" through the tertiary seals and rotor and prevents also that the oil vapour, drained from journal bearings, to becomes in contact with the mechanical gas seals.

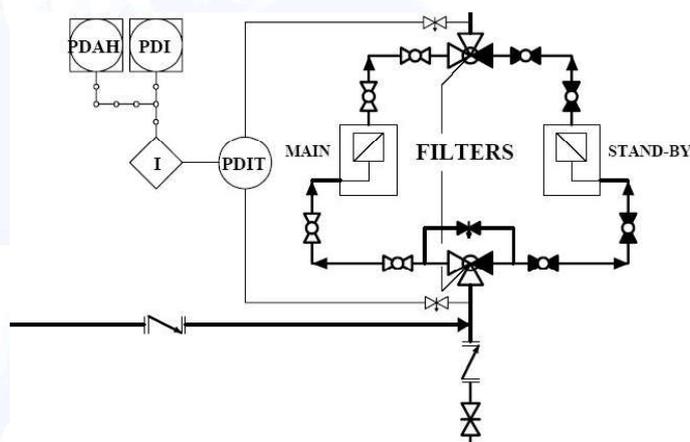
The chambers "E" can be drained opening the proper manual valves.

In the flushing chamber drain line are installed automatic traps (LCV) to assure the lube oil drain.

FILTERS

In the main seal gas line / In the flushing gas line

Twin gas filters are provided in the main seal gas line and in the flushing gas line. Each twin gas filters are piped in a parallel arrangement utilizing a continuous flow transfer valve. The transfer valve is installed between the filters to direct the gas through either filter and into the gas line. This feature permits either filter to be cut out of service for inspection or maintenance without interrupting gas flow to the machine.

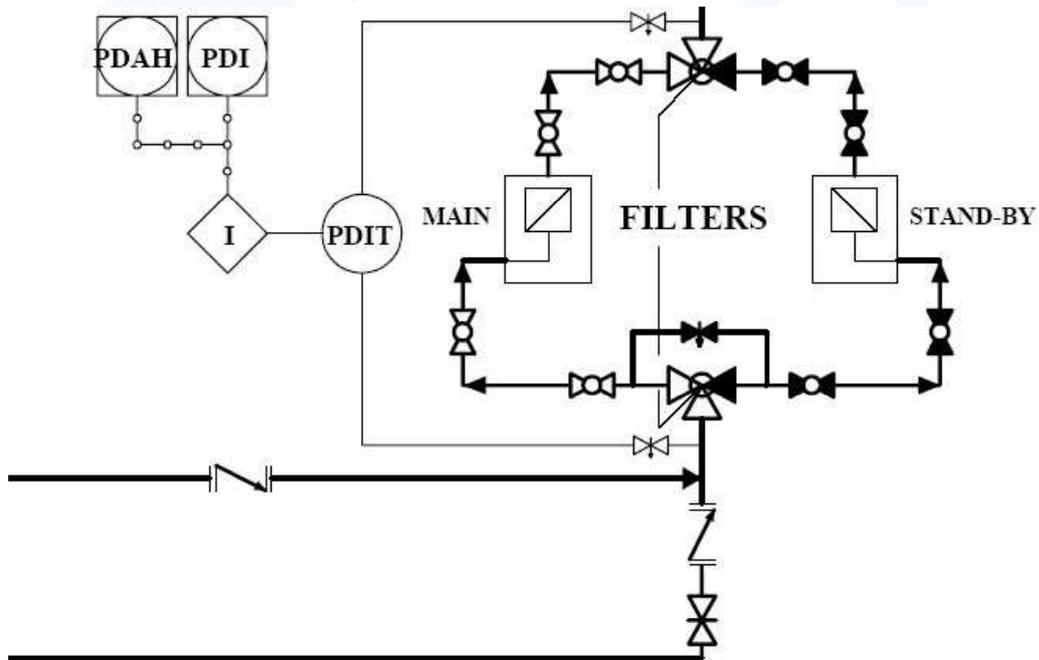


The filters are of the replaceable cartridge type.

The cartridges are to be replaced whenever the pressure drop across the filter, measured by a differential pressure gauge, approaches the set value indicated in "Instruments List" included in the Volume or Section of this manual or once a year regardless of the pressure drop.

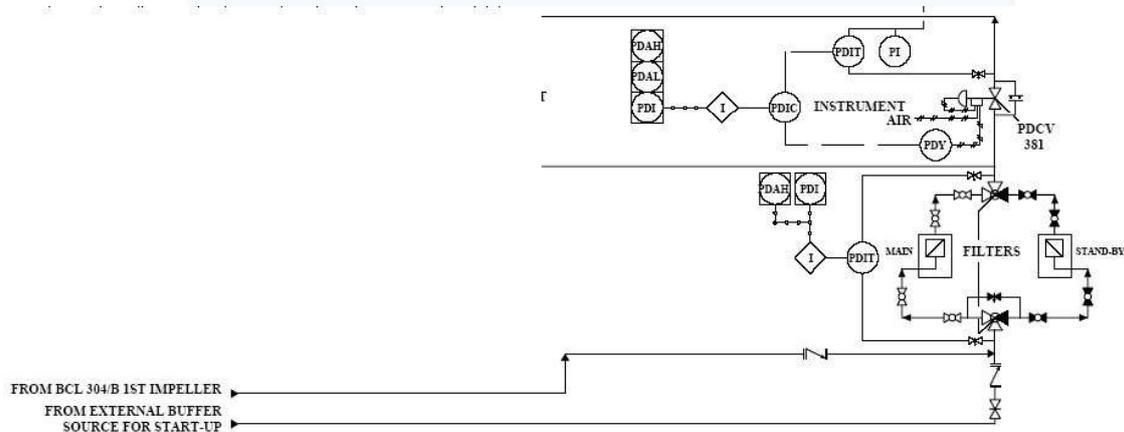
FILTERS

An equalization flow line, provided with a restriction orifice, connects the two filters to permit the filling of the spare filter and ease the operation of the transfer valve.



Procedure for changing over the filter,

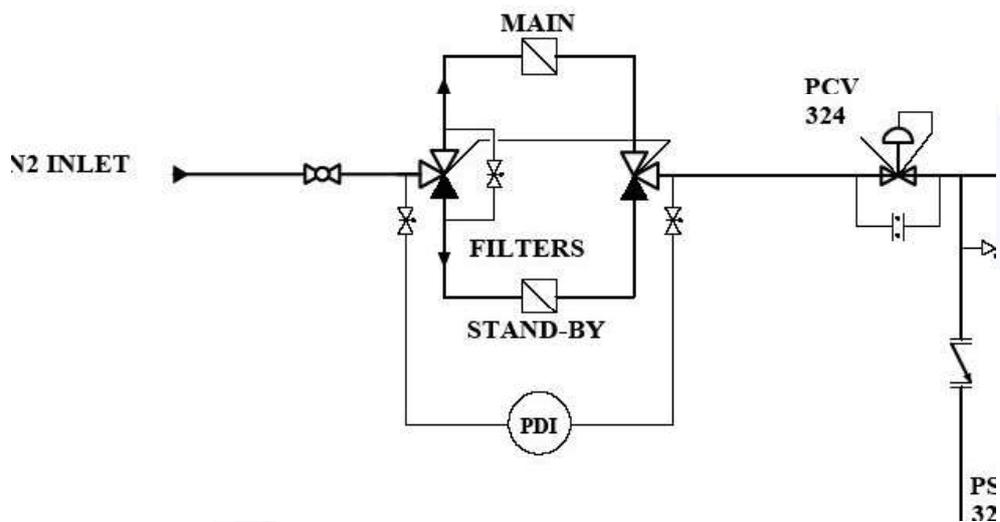
- Check that the drain valve of the filter not in use is closed.
- Open the isolating valve (s) of the filter not in use.
- Open the valve on the filling (or equalizing flow) line connecting the two filters.
- Vent the air from the spare filter for a period of time that will assure the air is completely vented from the filter which is now full with seal gas, then close the vent valve.
- Operate the transfer valve to bring the spare filter into operation.
- Close the valve on the filling line, crack open the vent valve of the filter not more in use for releasing the gas pressure and then fully open the vent and drain valves.
- Close the isolating valves of the filter not in use.
- Inspect and clean the filter not in use, replace the cartridges.
- Close the vent and drain valves of the filter not in use.



PRESSURE CONTROL VALVES

Flushing gas pressure control valve (PCV 324)

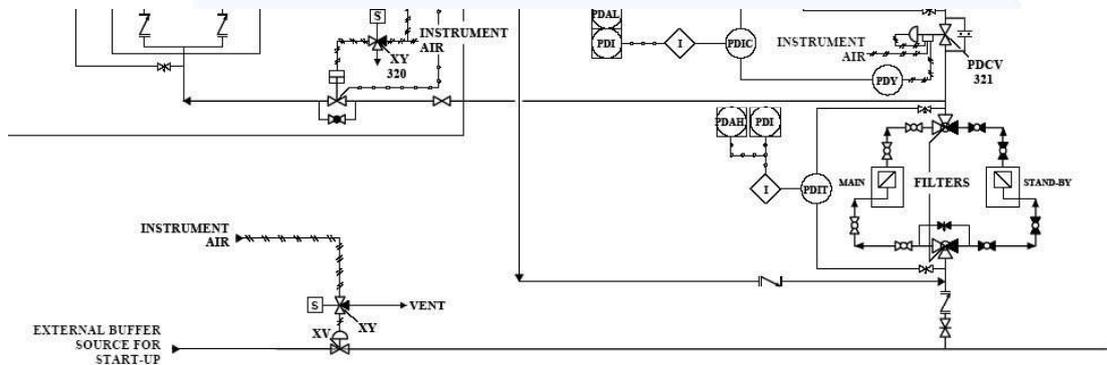
The control valve (PCV 324) maintains a constant pressure of about 4 Bar g, 400 kPag, in the flushing gas line to assure the pressurizing of the outer seals chambers (tertiary).



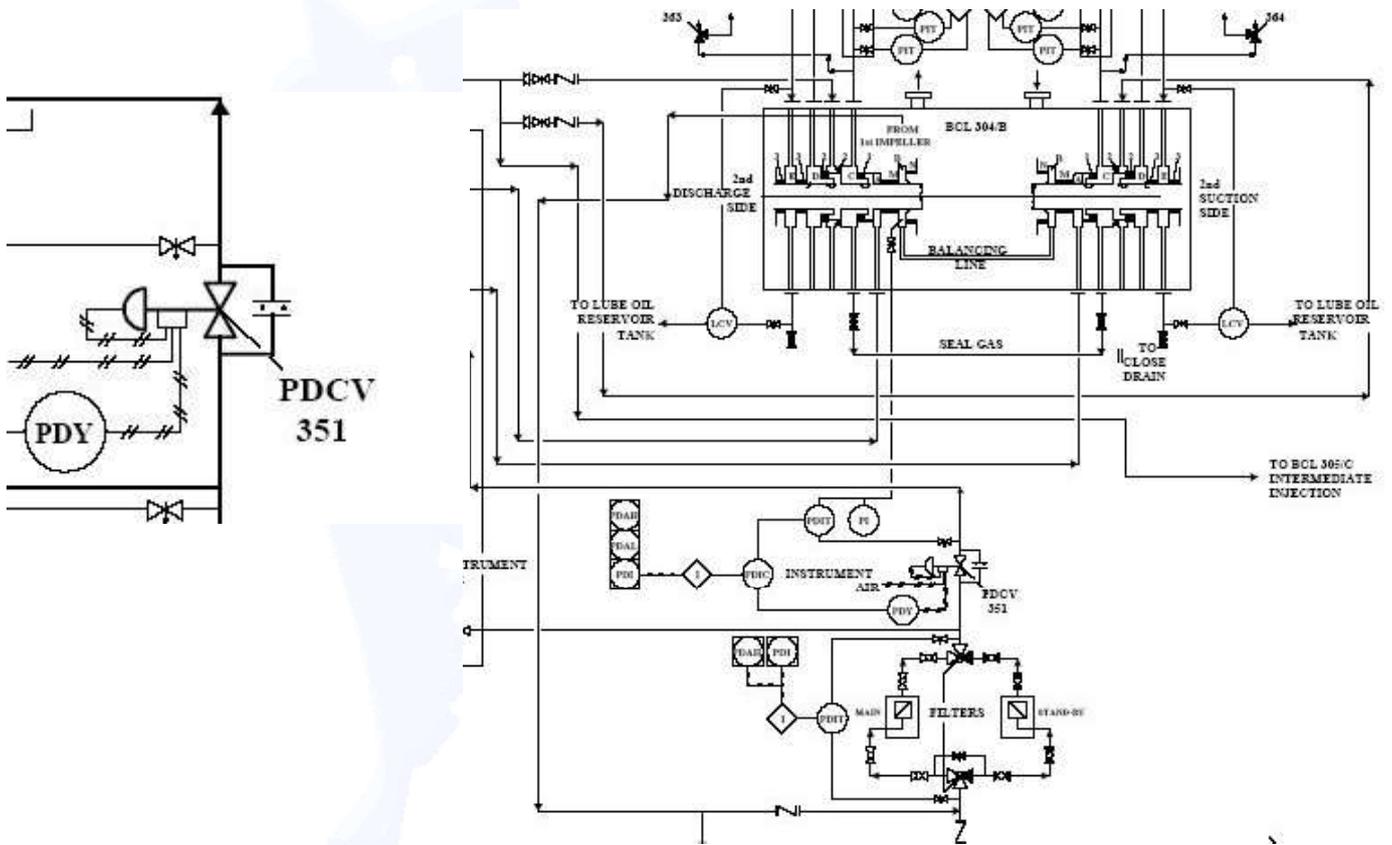
PRESSURE CONTROL VALVES

2. Differential pressure control valves (PDCV 321 – PDCV 351 – PDCV 381) in the seal gas line

- The seal (buffer) gas pressure in the seal gas line, is maintained constantly higher than the pressure balancing gas, by means of differential pressure control valve.
- These automatic valves, installed in the seal (buffer) gas line, are controlled by differential pressure controllers and differential pressure transmitters, installed between seal (buffer) gas line and balancing gas line.
- The seal (buffer) gas is maintained in our case at a pressure of about 3 Bar, 300 kPa higher than balancing gas.
- It assures a reverse flow from internal to external of the compressor, by means of internal labyrinth seals, preventing the gas process to blow in the compressor inner casing.



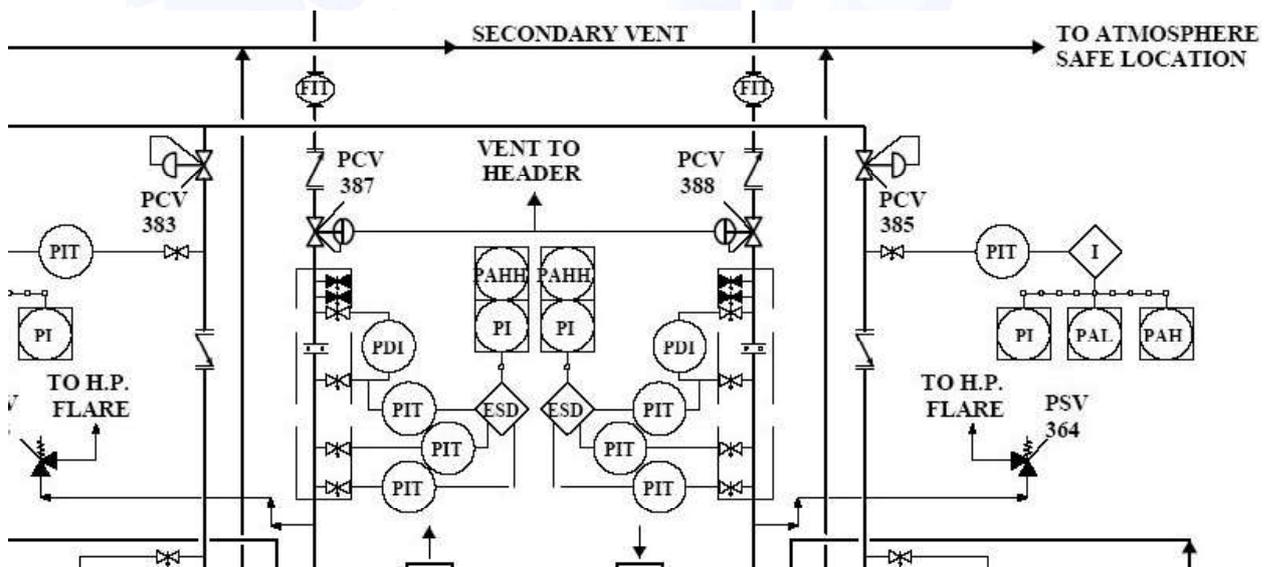
PDCV 351



PRESSURE CONTROL VALVES

3. Primary vent backpressure control valves (PCV 334, PCV 335, PCV 357, PCV 358, PCV 385, PCV 387)

The control valves maintains a pressure of 1.5 Bar g 150 kPag in the primary vent line to assure a constant gas flow to L.P. flare.



SEAL GAS PRESSURE	PRELIMINARY		FINAL
	Bar g	kPa g	
N ₂ flushing line (tertiary seals)	4.0	400	
Seal gas/balancing gas line gas differential pressure	3.0	300	
Backpressure primary control valve pressure	1.5	150	





























