MECHANICAL SEAL BASICS

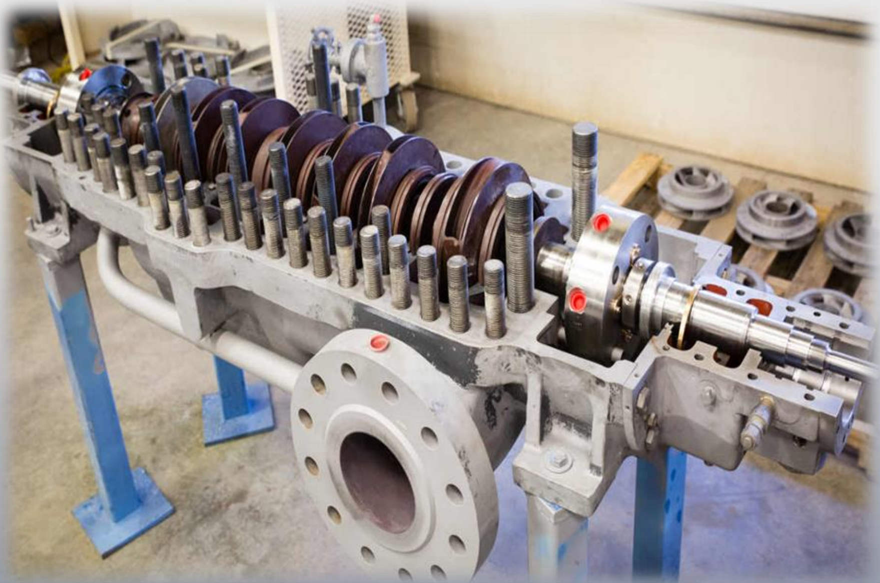
Prepared by:
PESB Technical Service Department (2019)

CONTENTS

Introduction

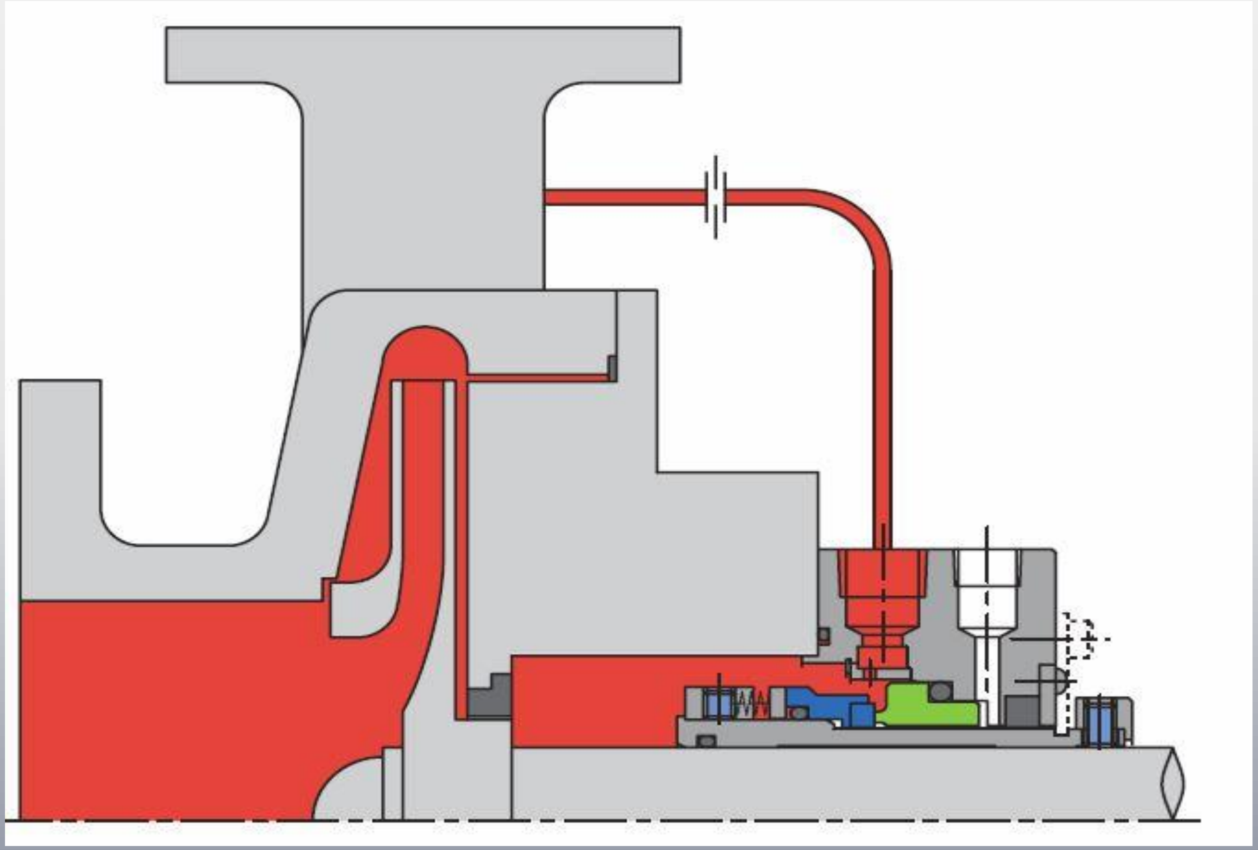
- Mechanical seal is used to control leakage in rotating equipment.
- Water pumps, compressor, washing machine and any machine used to transfer liquid/gases.
- Traditional methods use packing wrapped around shaft and clamped by gland bolts.
- Mechanical seal replaces packing due to its reliability, better emission control, higher efficiency and less damage to costly pump parts.



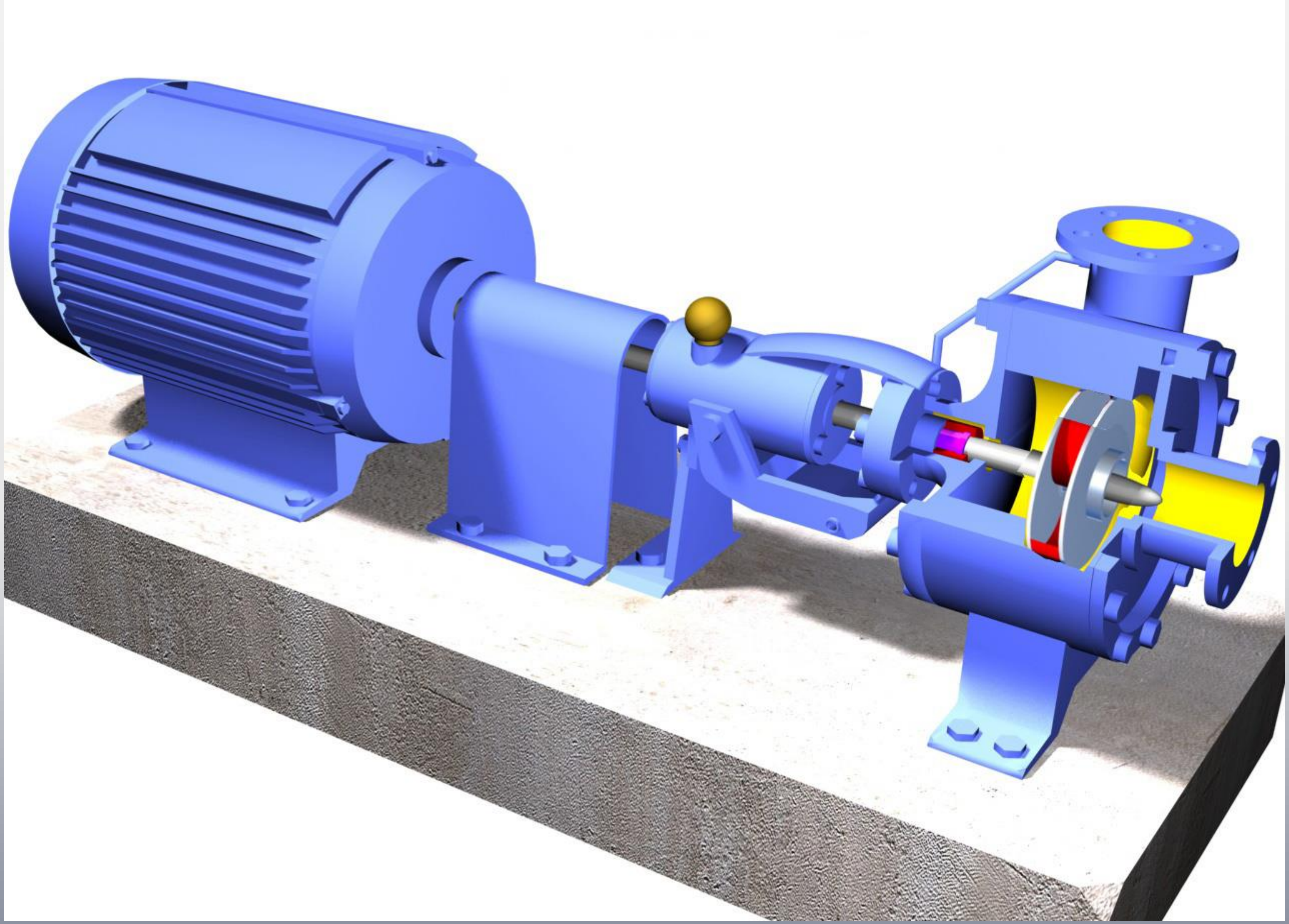



Application of Mechanical Seal

- Mechanical seal is installed inside seal chamber (stuffing box) of equipment.



Basic Overhung Centrifugal Pump Model

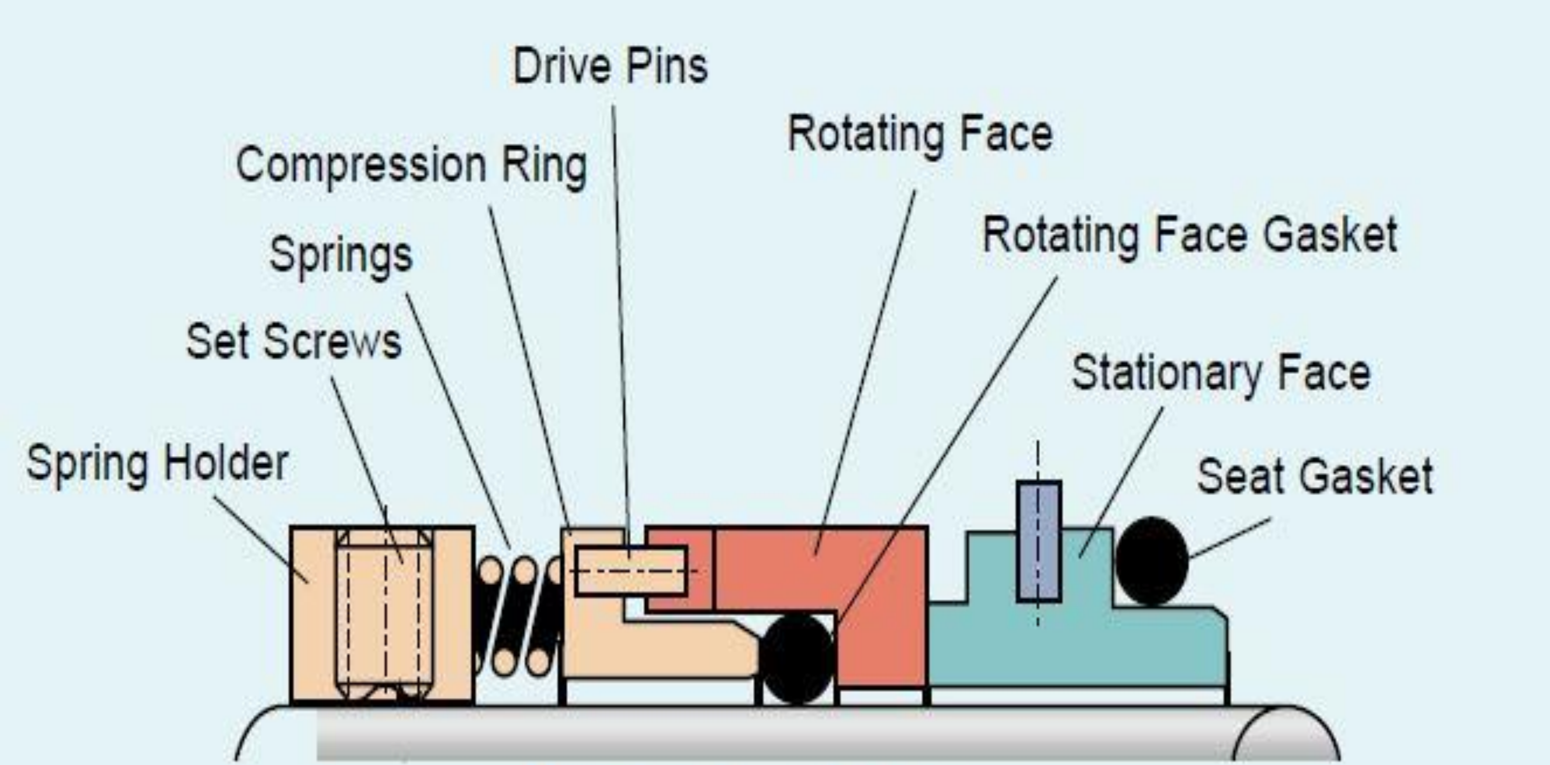


Mechanical Seal Classification

- By Arrangement
  - Single
  - Double
- By Design
  - Balanced/Unbalanced
  - Pusher/Non-pusher
  - Single/multiple springs
  - Cartridge/Component

Basic Mechanical Seals

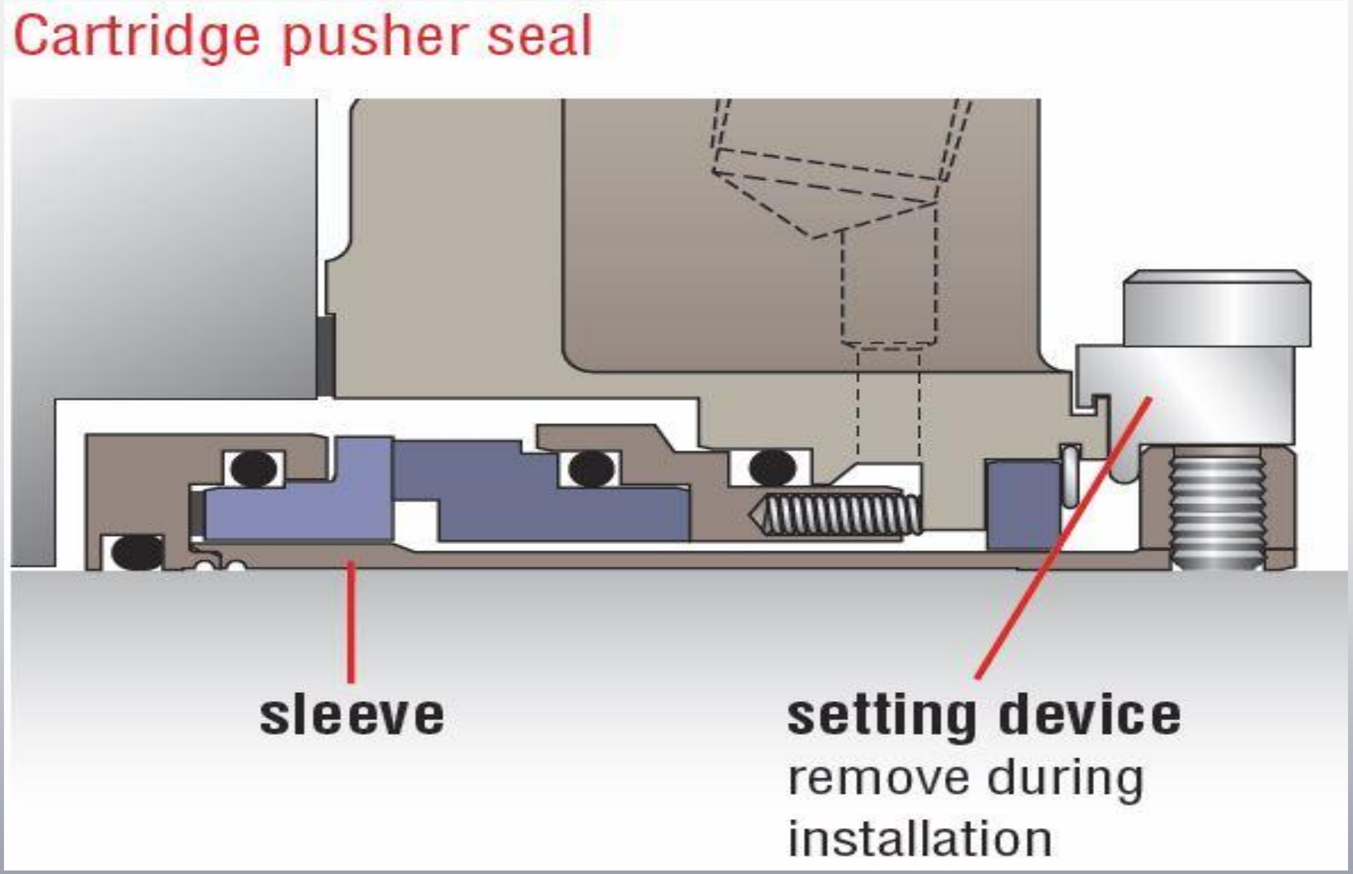
- Component Pusher seal



Pusher nomenclature

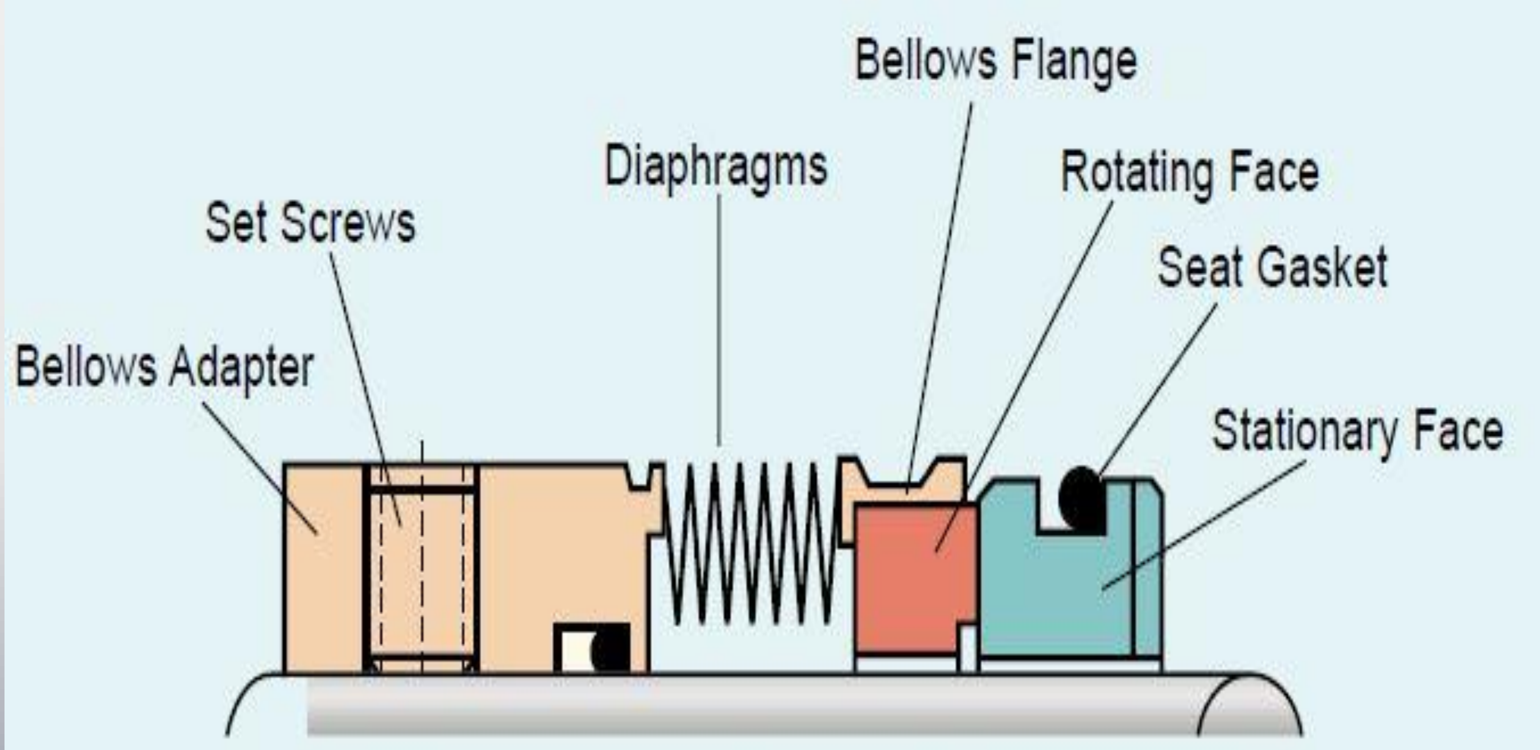
Basic Mechanical Seals

- Cartridge Pusher seal



Basic Mechanical Seals

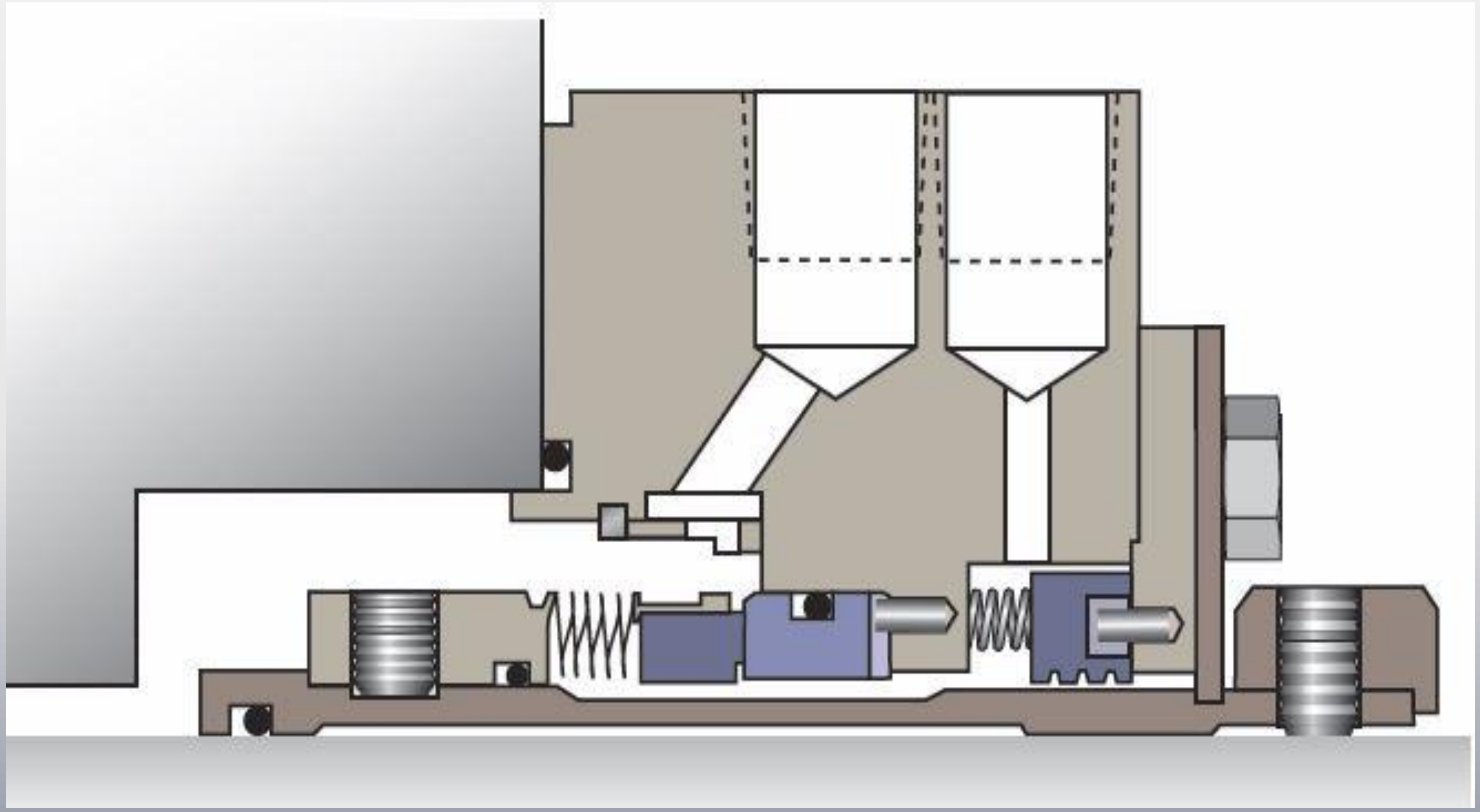
- Component Non-Pusher (Bellow) seal



Bellows nomenclature

Basic Mechanical Seals

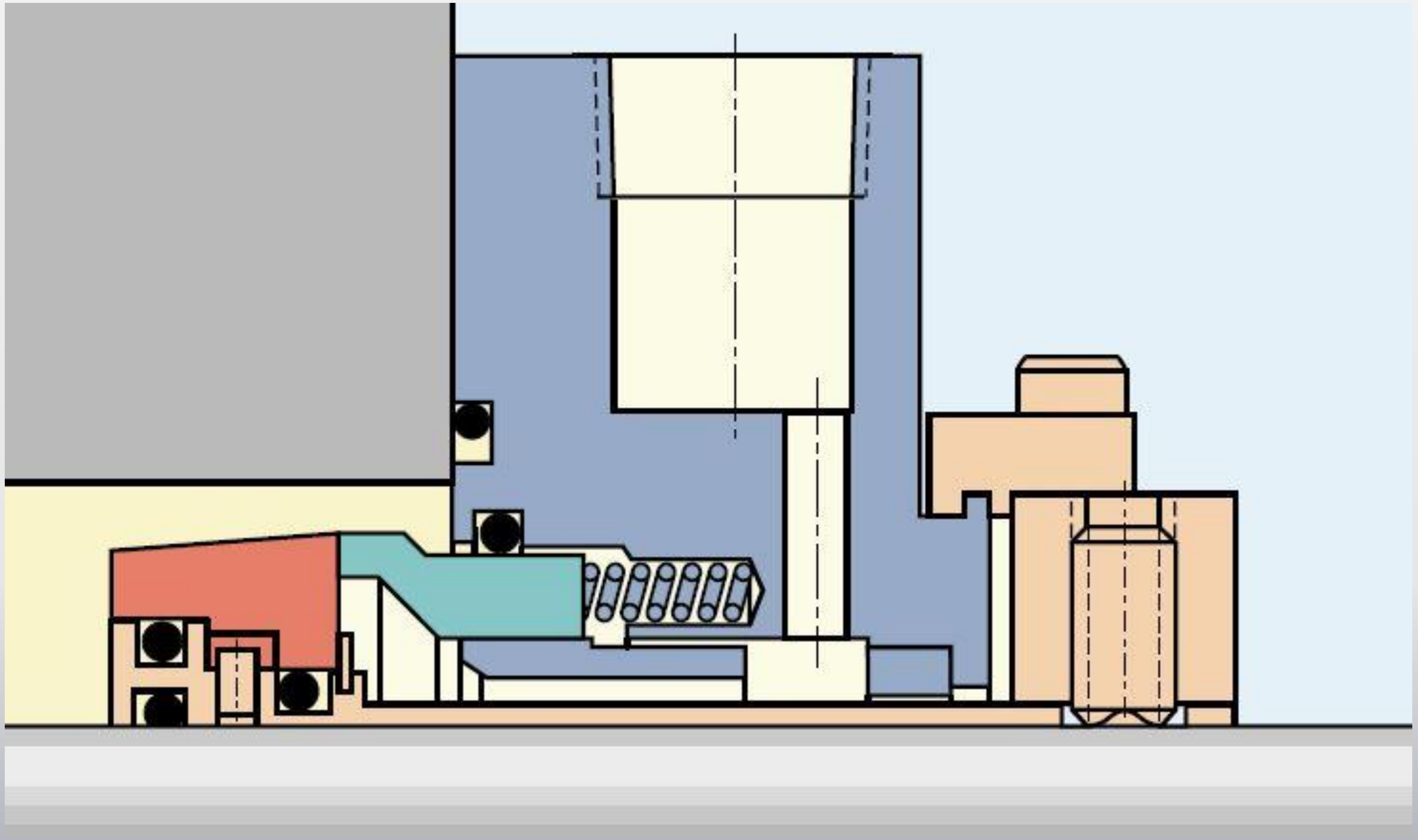
- Cartridge Non-Pusher (Bellow) seal



Parts Identification

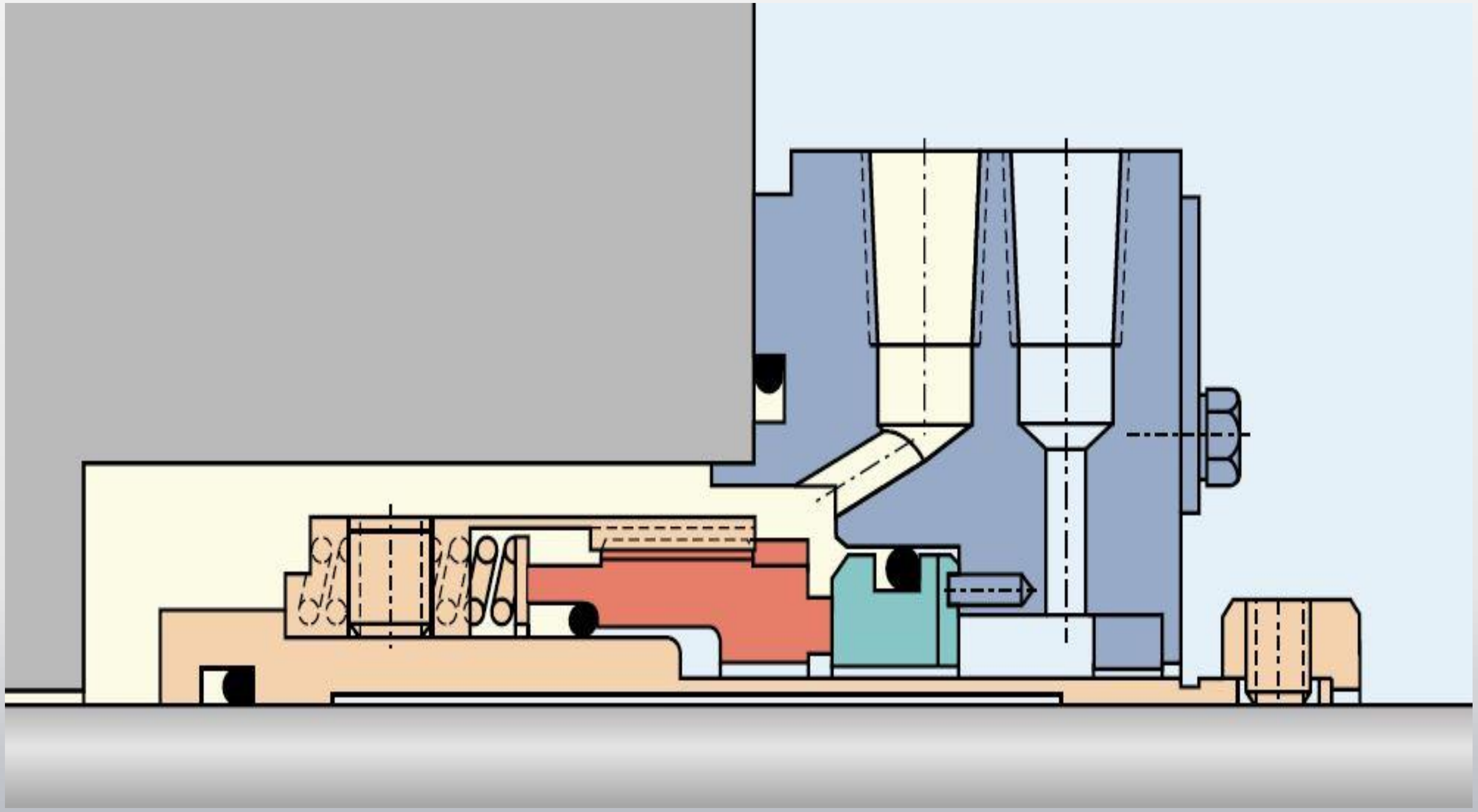
- Stationary parts – fixed at seal gland or pump housing.
- Rotating parts – fixed to shaft sleeve and rotates when shaft turns.
- Dynamic secondary seal – o-ring/gasket that experience motion with surface contact.
- Flexible elements – parts that contains spring/bellow. Can be either stationary parts/ rotating parts.(stationary spring/rotating spring)

Flexible stator



- Default config for Type C seals
- Flexible stator can be more reliable when used for following conditions:
  - High temperature pumps (above 176 °C)
  - Pumps are susceptible to alignment/seal chamber face issue.
  - High pressure pump that cause distortion of chamber face/alignment.
  - High pipe loads
  - Balance diameter over 115 mm (4.5 inches)
  - Equipment speed exceed 23 m/s (4500ft/min)

Flexible Rotor



- Flexible rotor is a default configuration for Type A and Type B seals
- Flexible element will flex with each rotation to accommodate lack of perpendicularity.
- Excellent self flushing/cleaning properties.

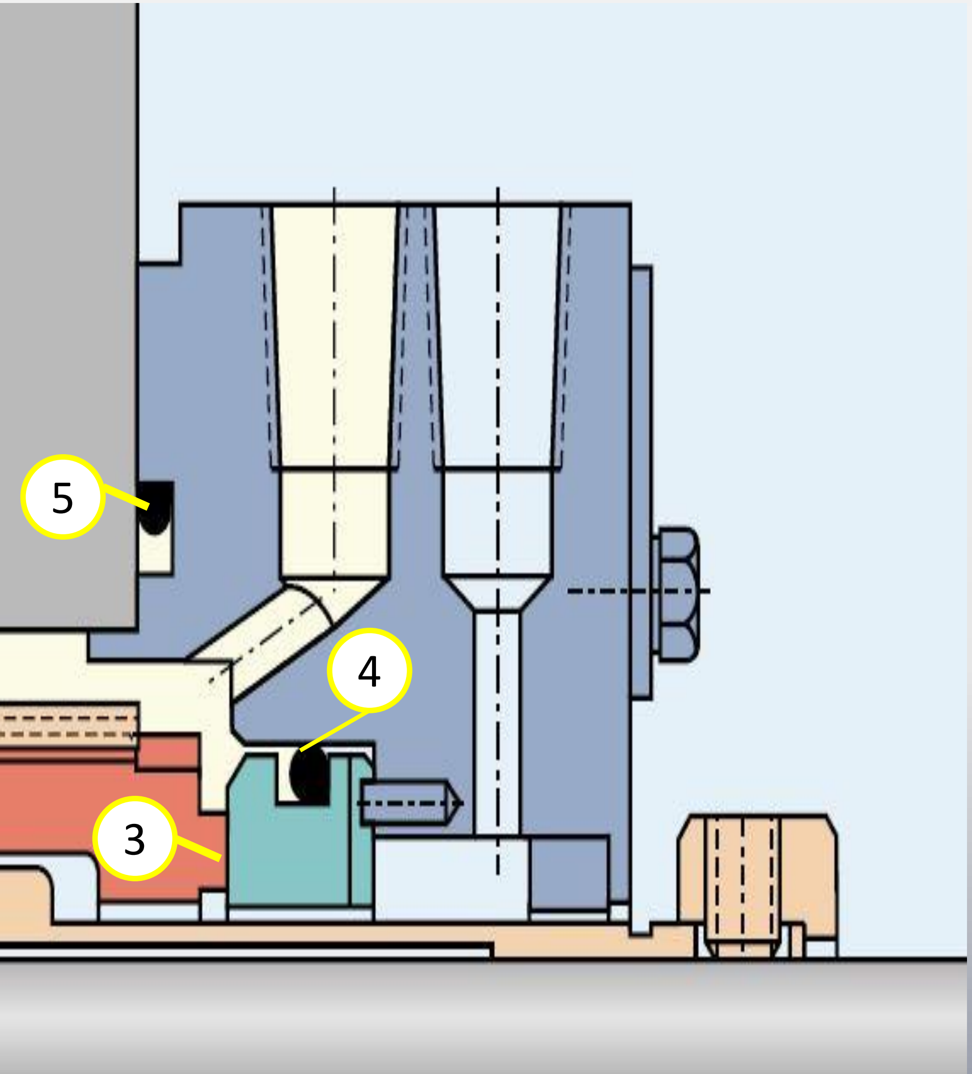
Sealing category

- Primary seal
  - Seal faces (rotary/stationary)

- Secondary seal
  - O-rings/gaskets

Leak Paths in Mechanical Seal

1. Sleeve o-ring
2. Rotor o-ring
3. Between seal faces
4. Stator o-ring
5. Gland o-ring/gasket



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ESSENTIAL REQUIREMENTS FOR MECHANICAL SEAL OPERATION

- Face flatness of 1-3 helium light band (average roughness, Ra of 0.3μm to 0.9 μm).
- Face lubrication film thick enough to prevent dry running and thin enough to prevent high leakage rate.
- Sufficient closing force by either spring or hydraulic.
- Face must be perpendicular to shaft. 5 point check for pump must be within allowable tolerance.

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ıst be within allowable tolerance.

FACE FLATNESS

- Face flatness can be achieved by **LAPPING** and **POLISHING PROCESS.**
- Any faces that is still within tolerance and free from any defects (chipping, cracks, grooving) can be lapped to be reused.
- Face is lapped using either lapping machine with diamond table plate or hand-lapped(special hand lapping plate).
- Lapping plate is lubricated and sprayed with diamond paste of different roughness (3, 6 or 14μm) depending on face material and finishing desired.
- Constant pressure/weight applied onto the face, table flatness and conditioning ring condition is essential to ensure quality of finishing of lapped products.

KEMET LAPPING PROCEDURE

- The dispenser should be set to spray at the above intervals with the individual air regulators at the back of the Diamond Dispenser both set to 1/2bar (7.5 PSI). The lapping plate should first be charged for 10 minutes by running the machine and applying the above spray quantities.
- It is important to ensure when lapping or polishing that the lapping plate is neither too wet nor too dry. If the plate is too wet, the diamond becomes flooded by lubricant and the stock removal will be very low; if the plate is too dry, the parts can come into direct contact with the lapping plate, and this will negatively affect the resulting surface finish and cause the plate to heat up.
- Seals can then be lapped by placing them inside the machine's control rings and applying a pressure. If multiple parts are to be lapped inside the same conditioning ring, it is essential that they are the same thickness (+/- 0.5mm). To keep the parts in position during lapping either a work-holder, (sometimes called a nest), should be manufactured. This is typically a 3mm disc of Tufnell with the profile of the parts to be lapped machined into it. Alternatively the pressure weights themselves can be faced with a Kemet Facing Kit. This special material has non-skid properties that hold the parts in position during lapping without the need for a work-holder.
- Single seals may be allowed to run freely inside a control ring, but it is important to apply a weight to obtain optimum stock removal. This weight should be balanced. An ideal weight is a large steel ball that can simply be placed on top of the seal. It is also recommended that a rubber band be placed around single seals as this gives them drive within the control rings, thus avoiding tracking on the lapping plate.

RECOMMENDED SETTINGS

Typical Kemet dispenser settings when lapping mechanical seals

15" machine		24" machine	
Diamond	Fluid	Diamond	Fluid
2 seconds Duration 20 seconds Interval	1 second Duration 120 seconds Interval	2 seconds Duration 20 seconds Interval	2 seconds Duration 40 seconds Interval

Suggested approximate pressure applications

Carbon 100g/cm²	**Tungsten Carbide** 300g/cm²	**Silicon Carbide** 200g/Cm²	**Ceramic** 600g/Cm²
Nickel Iron 200g/Cm²	**Stellite** 200g/Cm²	**Chrome Oxide** 300g/Cm²	**Spray Coated** 200g/Cm²

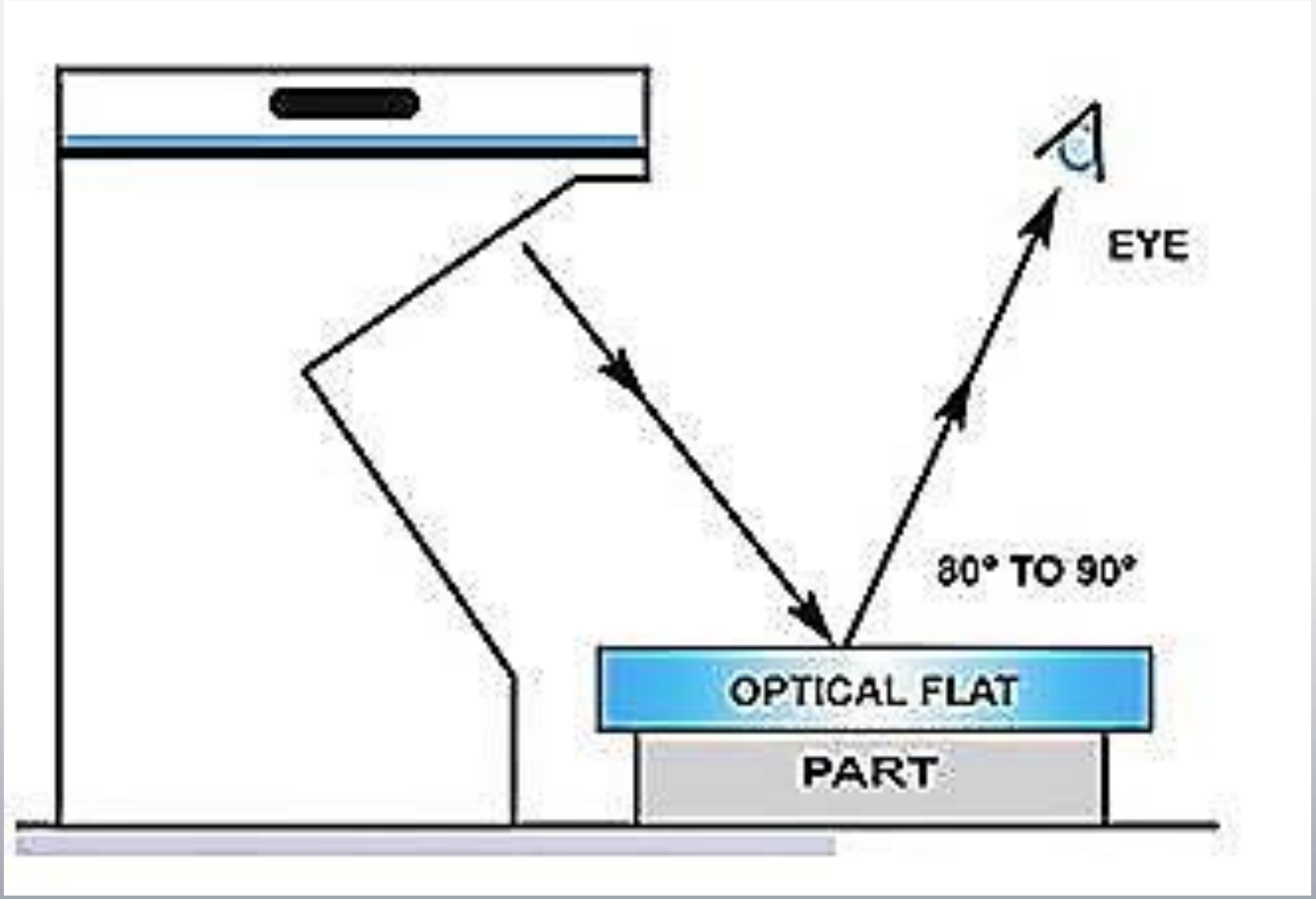
FLATNESS CHECK

- Lapped faces are checked for flatness to achieve 1 to 3 light band.

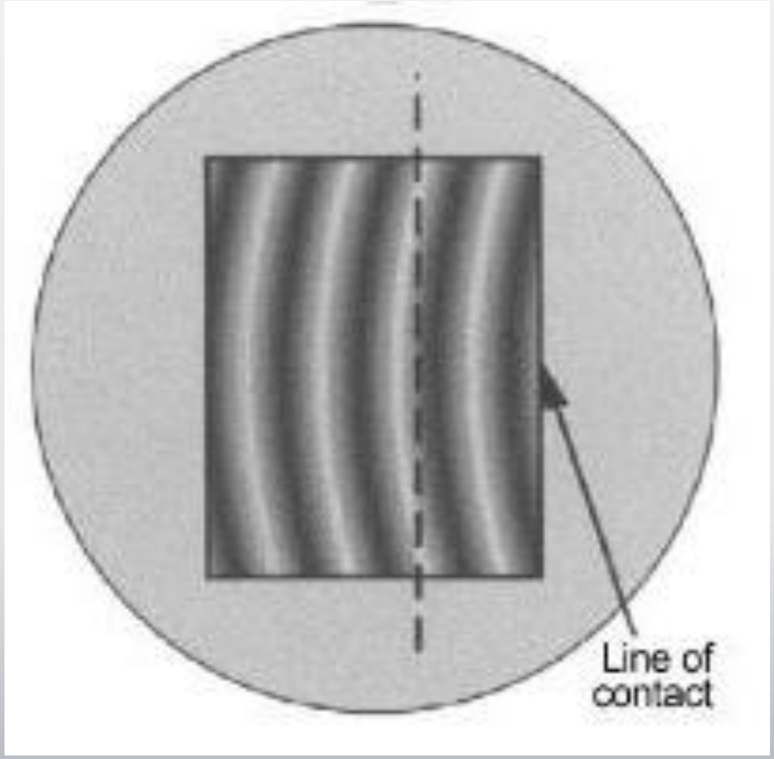
1 Light band 0.00029mm	2 Light bands 0.00058mm	3 Light bands 0.00087mm	9 Light bands 0.00261mm

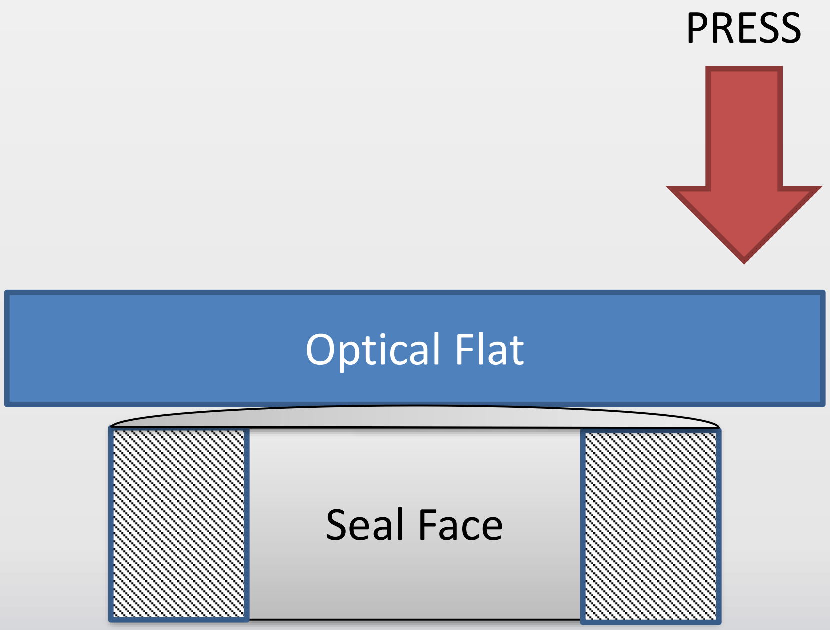
- Monochromatic sodium light unit and optical flat are used to carry out flatness check.
- This method is more accurate than common CMM measurements.
- Face and optical flat must be cleaned from oil/dirt using lint free cloth/lens tissue and cleaning alcohol.
- Only extremely polished surface will produce light band fringes.

How to read light band

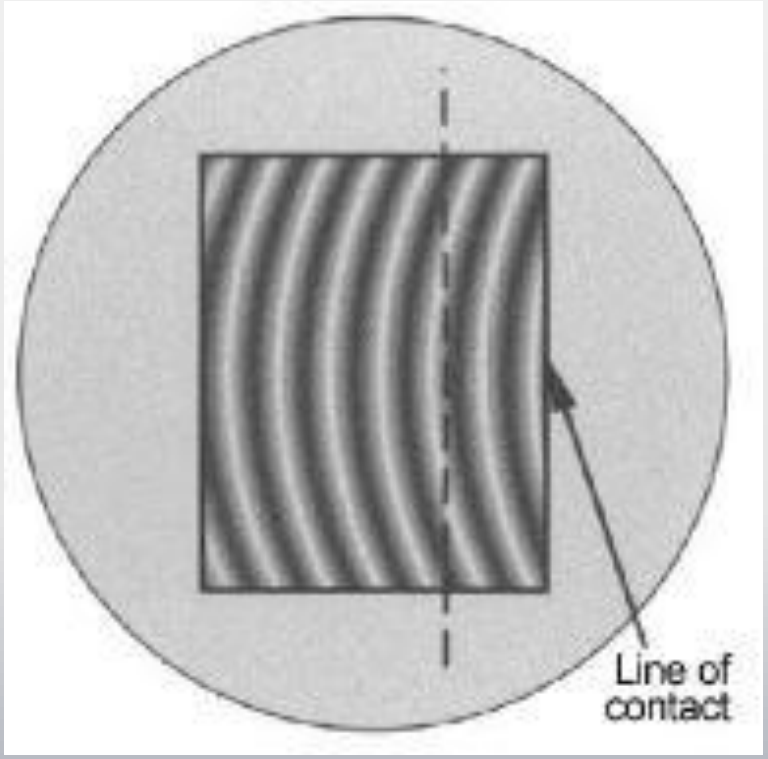


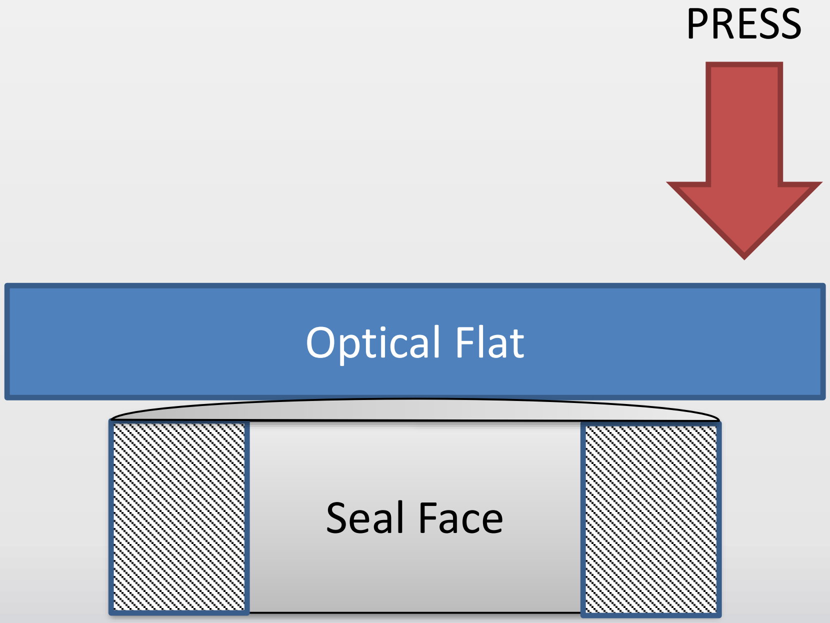
½ light band flat convex



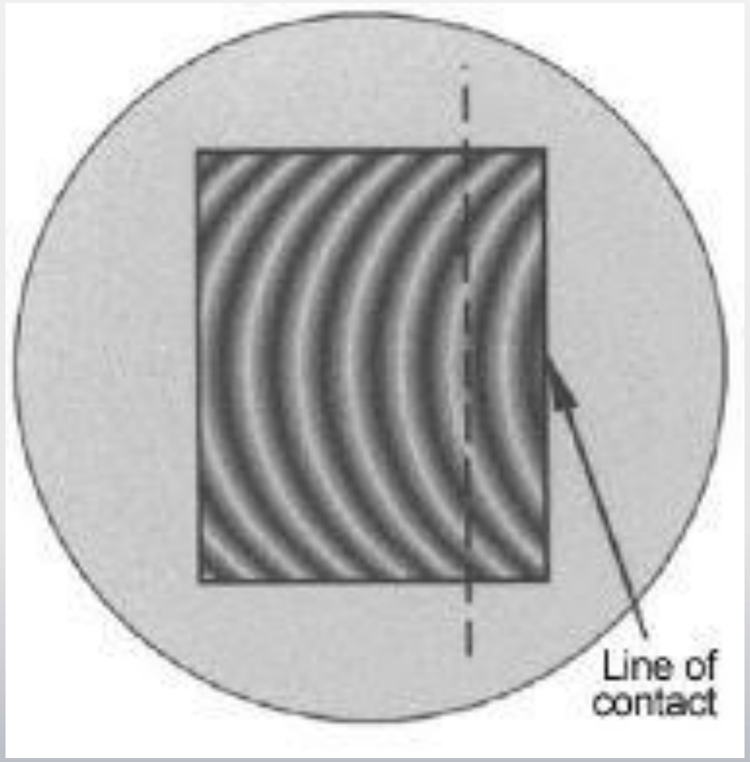


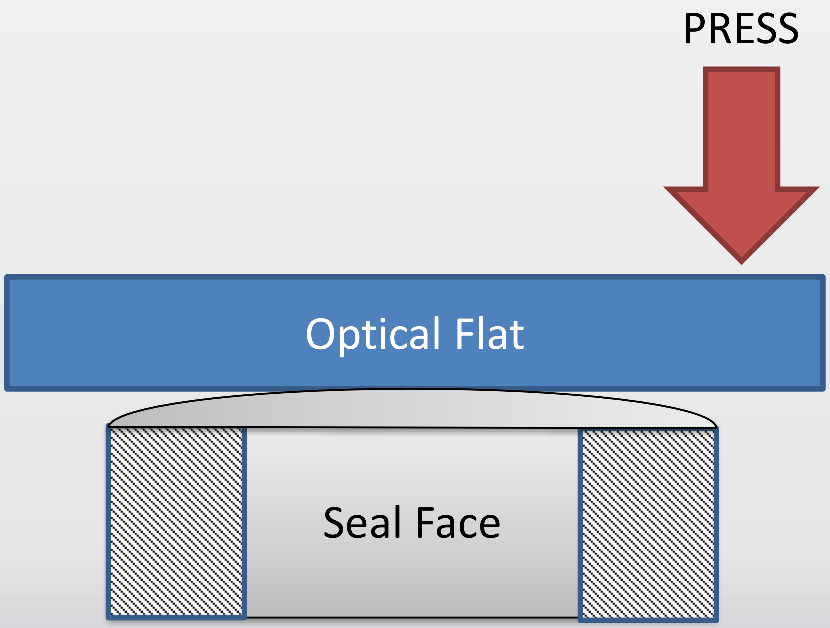
1 light band flat convex



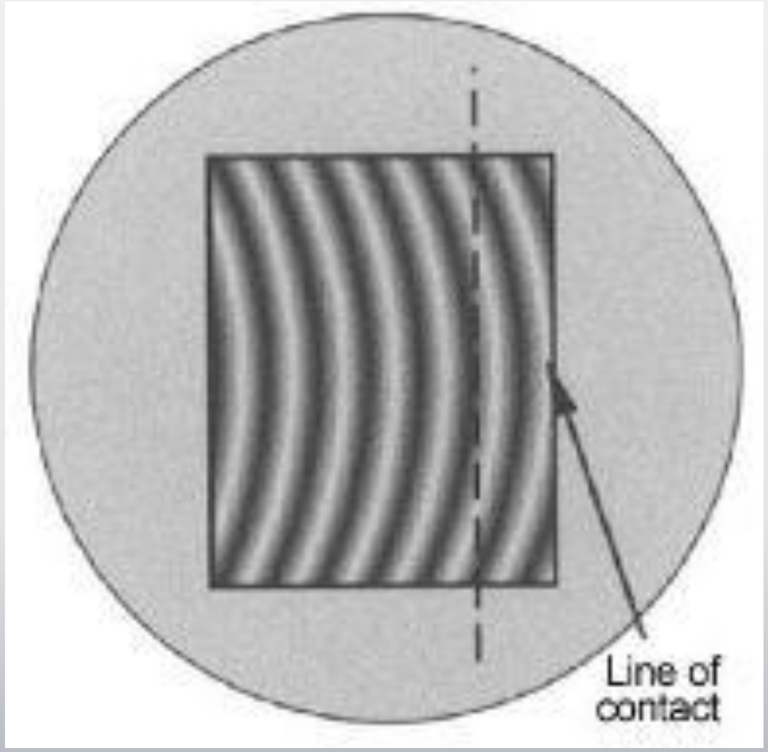


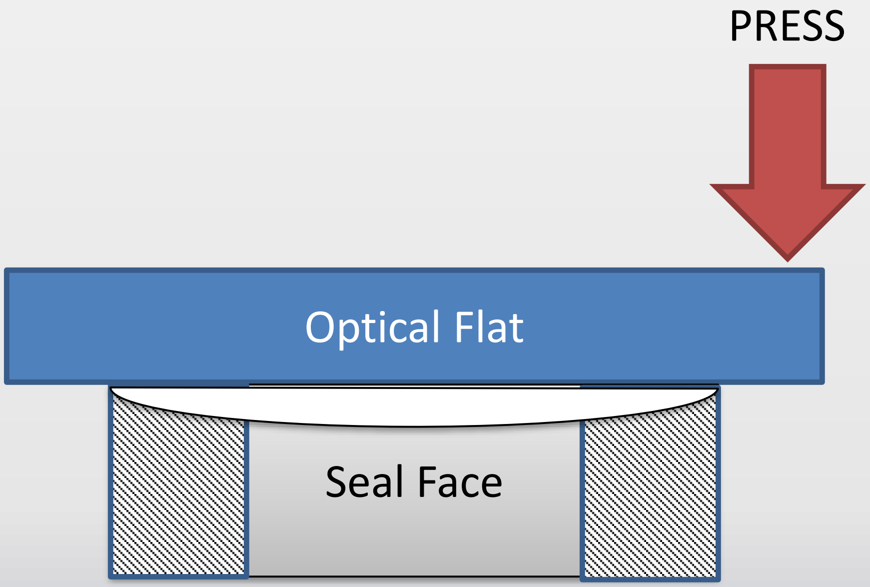
2 light band flat convex



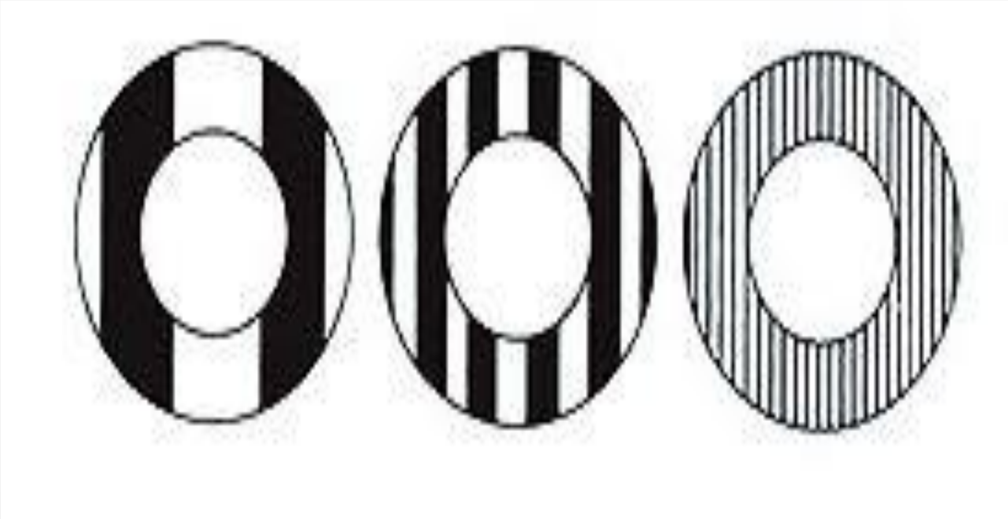


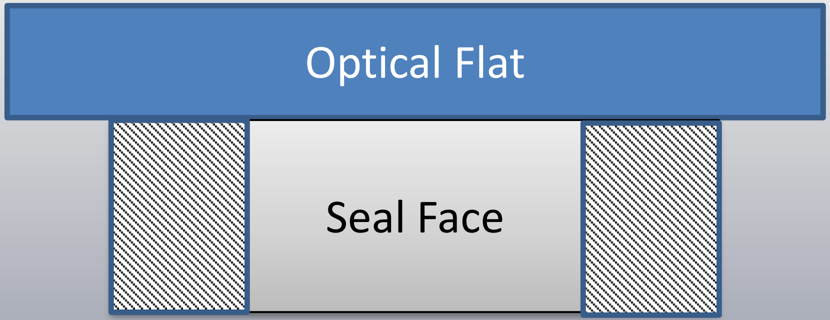
1 light band flat concave



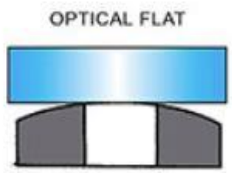
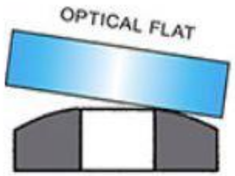
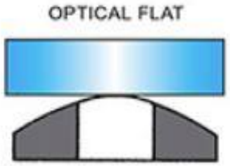
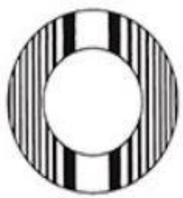
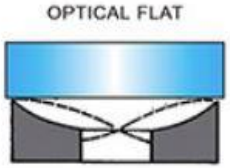


Perfect Flatness





How to read light band

Surface geometry		1 Light band 0.00029mm	2 Light bands 0.00058mm	3 Light bands 0.00087mm	9 Light bands 0.00261mm
Convex or Concave Surface parallel to flat **Symmetrical Pattern**					
Convex With concave surface band will curve in opposite direction **Non-Symmetrical Pattern**					
Cylindrical Convex or Concave **Symmetrical Pattern**					
Saddle Shaped **Symmetrical Pattern**					

How to read light band

CONVEX

Ring pattern moves towards finger pressure. If workpiece is convex the lapping plate is concave.

Lapping plate concave

The control rings must be moved to the outside of the plate to correct this condition

CONCAVE

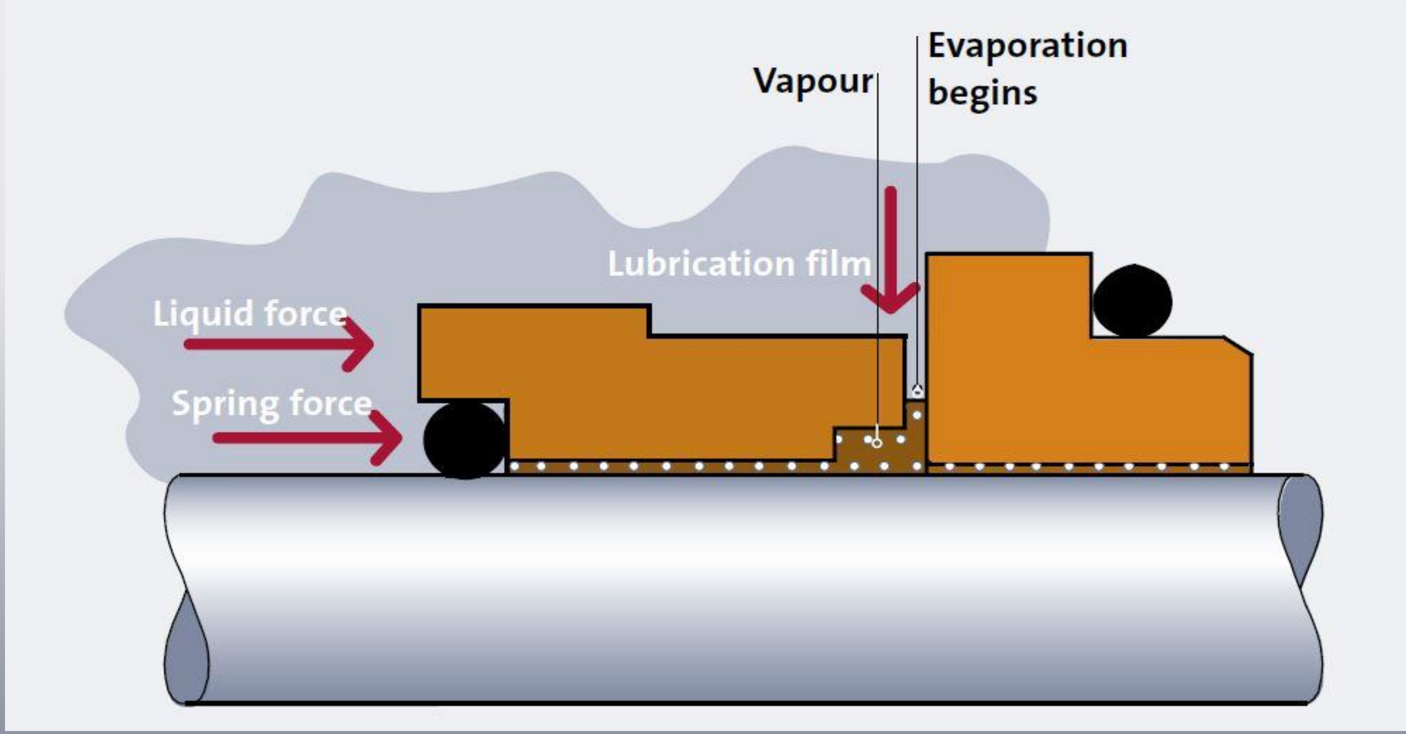
Ring pattern moves away from finger pressure. If workpiece is concave the lapping plate is convex.

Lapping plate convex

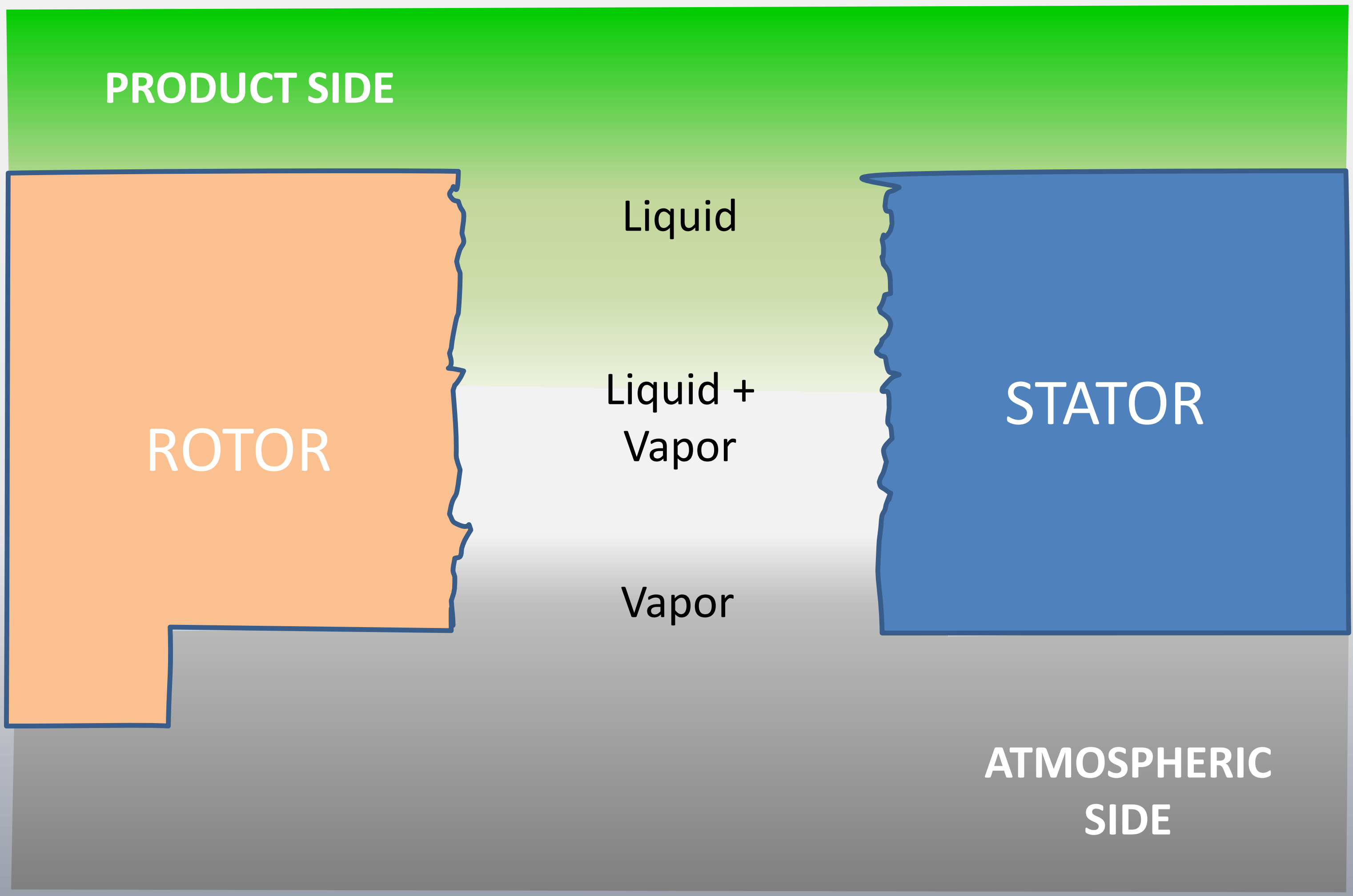
The control rings must be moved to the inside of the plate to correct this condition

LUBRICATION PRINCIPLES

- Two optically flat faces sliding towards each other create sealing.
- Pressure and force from fluid sealed and spring/bellow act upon faces.
- Thin lubrication film is created between very small face opening.
- Typically 1micron (75x smaller than human hair thickness).



Lubricating Film



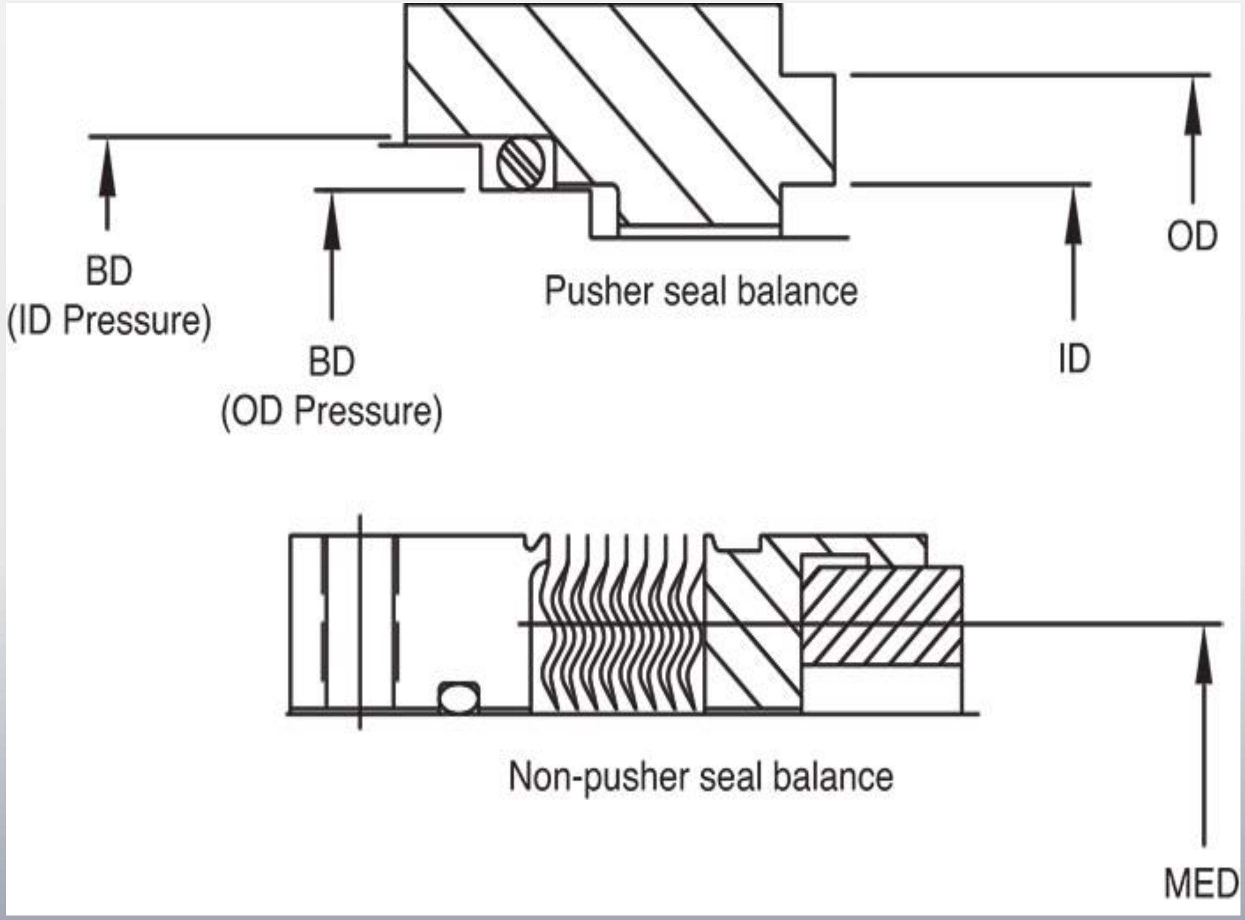
Seal Leakage

- All mechanical seal leak to some extent.
- Majority of pump shows no visible leakage, depending on the types of fluid sealed.
- Acceptable leakage rate can vary according to different laws/plant standards.
- Double seal may not allow pumped fluid to leak to the atmosphere, but will leak buffer/barrier fluid instead.
- Other factors affecting leakage can include pump operation at off-design conditions, pipe strain, bearing failure, fitting leak at gland or sleeve gasket damaged.

Seal Balance

- Seals are designed with balance ratio to minimize generated heat at seal face.
- This can lead to optimum seal life expectation and emission limits.
- Balance ratio affects:
  - *face loading/face closing force*
  - *heat generated*
  - *pressure rating of the seal.*

Seal Balance



Pressurized OD

$$b = \frac{D_o^2 - D_b^2}{D_o^2 - D_i^2}$$

Pressurized ID

$$b = \frac{D_b^2 - D_i^2}{D_o^2 - D_i^2}$$

Balanced seal

- B < 1
- Typical range is 0.6 to 0.9
- Uses stepped shaft sleeve to reduce face load and heat generated.
- Costlier than unbalanced seal to design and manufacture.

Unbalanced seal

- B > 1
- Low cost.
- Can tolerate more misalignment/vibrations.
- High face load = more heat generated.
- Faster wear rate.

Seal Face Materials

Face Materials	Maximum temperature (℃)
Sintered Silicon Carbide	1650
Reaction Bonded Silicon Carbide	1400
Tungsten Carbide	1100
Graphite Sintered Silicon Carbide	550
Graphite Reac. Bonded Silicon Carbide	550
Carbon Antimony	500
Carbon Resin	285

* Values taken from API Standard 682 11th Edition 2014 , pg 118. Properties may change depending on manufacturers.

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Carbon Resin

- Lower elasticity
- More corrosion resistance than antimony carbon
- Wear resistance
- Most widely used face materials
- Temperature limit of 285 ℃

Carbon Antimony

- Metal impregnated carbon
- Higher elasticity and temperature limit
- Less corrosion resistance
- High pressure application
- Useful in limited lubrication application (flashing HC)
- Superior blister resistance
- Temperature limit of 500 °C

Reaction Bonded Silicon Carbide

- Silicon metal + carbide + carbon graphite
- Best wear and lubricating properties of hard faces
- High pressure + speed application
- Good chemical resistance
- Some chemicals can attack free silicon inside the structure.
- Temperature limit of 1400 °C

Sintered Silicon Carbide

- 100% silicon carbide. No free silicon
- Virtually inert in all corrosive environment.
- Low pressure-velocity (PV) capability
- Brittle and cracks easily
- Temperature limit of 1650 °C

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Graphite Silicon Carbide

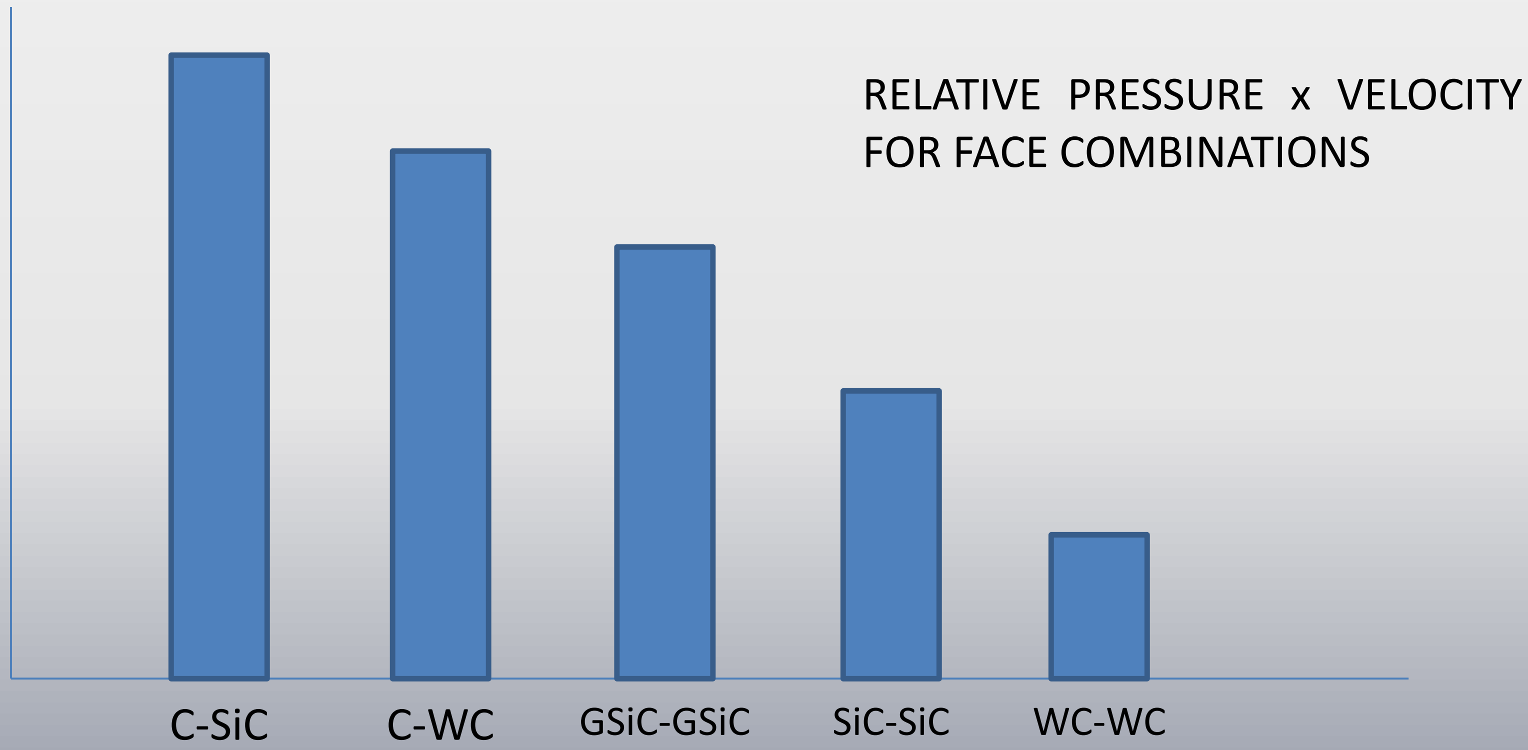
- Improved dry running capability of SiC
- Higher PV limit
- Decreased ability to handle abrasives than other SiC but better than carbon.
- Immature technology requires further testing.
- Temperature limit of 550 ℃

Tungsten Carbide

- High caustic and acidic application
- Normally bonded with metals (nickel/cobalt)
- Excellent hardness and wear resistance
- Can be distinguished with Silicon Carbide from its heavier weight.
- Temperature up to 1000°C

Seal Face Combination Selection

- Default selection of face nowadays is Silicon Carbide vs Carbon



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Hard Face Combinations

- Two hard face is selected on these factors:
  - Abrasive products
  - Viscosity
  - Crystallization
  - Polymerizing product
  - High shock and vibration
  - High face tensile strength required

Secondary Seal Materials

Material	Min Temperature ℃	Max Temperature ℃
Fluoroelastomer (VITON)	-7	176
Perfluoroelastomer (KALREZ/CHEMRAZ)	-7	290
Nitrile(NBR/BUNA-N)	-40	121
EPDM	-50	150
FEPM/TFE	-7	210
PTFE/TEFLON	-270	315
FLEXIBLE GRAPHITE	-240	480
FLUOROSILICONE	-60	180

* API 682 requires all O-ring grooves to be designed to fit FFKM O-ring size. Some FFKM O-ring is known to swell or expand under thermal. Chemical-induced swelling in FFKM often mistaken with thermal expansion and vice versa.

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Seal Flush

- Stable flush rate is required to maintain seal chamber temperature.
- Max allowable temperature rise should be between 5 - 6 °C for arrangement 1
- 16 °C for Plan 23 and barrier/buffer fluid.

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