PUMPS
Performance, Maintenance and Troubleshooting

FOR ENGINEERS

Presented By

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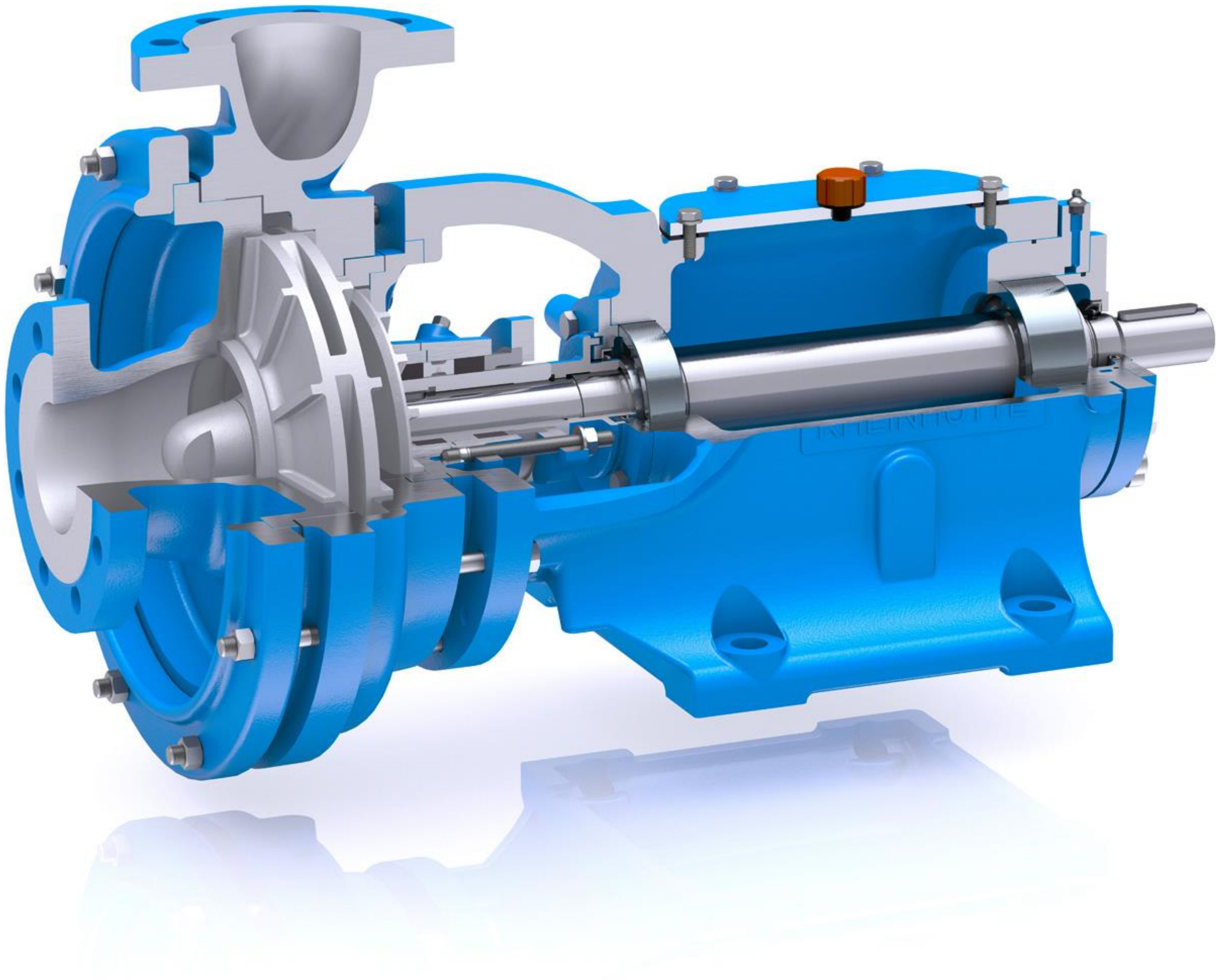
Pump or Compressor ?

Pumps

A mechanical device used to move incompressible fluids through piping system from one point to another.



Pump or Compressor ?

Pumps

Pumps or Compressor ?

Compressors

Applications of Pumps

1- Gas Facilities/Oil Refineries (Recirculation Pumps)

Applications of Pumps

2- Oil Transmission (Transmission Pumps)

Applications of Pumps

3- High Pressure Injection (Hydraulic, Lubrication and Odorization Pumps)

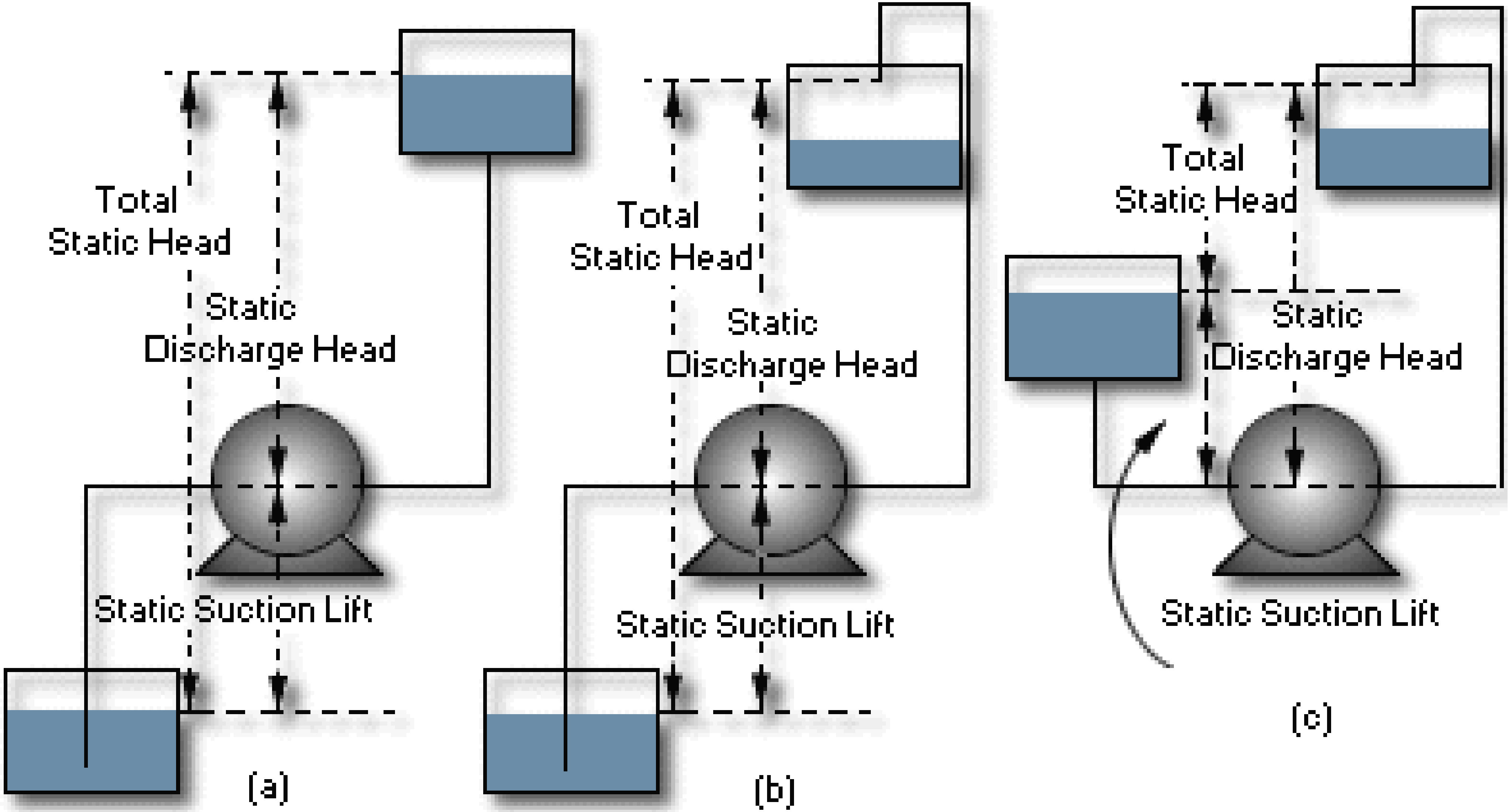
Introduction

One of the first pieces of powered machinery to be invented at the dawn of the industrial age was a crude form of pump. The pump has since evolved into an endless variety of types, sizes, and applications.

Operators should become familiar with the diversity of pumps that are in existence as they may be required to safely operate pumps in the normal course of their daily routines. A functional understanding of pumps, their use, and application, is essential to understanding how most processes are handled in plants today.

Theory of Pumping

Important Definitions



Theory of Pumping

Friction Head

When the pump puts the water in motion, this water will meet resistance in the pipes, valves and fittings. To overcome this resistance a certain amount of pressure is required. This pressure is called the friction head and is also expressed in metres or feet of water.

Velocity Head

A force is required to put the water in motion. This is called the velocity head.

Pressure or Equivalent Head

When the pump discharges the water into a vessel under pressure, such as a boiler, it has to impart additional pressure to the water in order to overcome the boiler pressure. This extra pressure is called the pressure or equivalent head.

Theory of Pumping

Dynamic Head

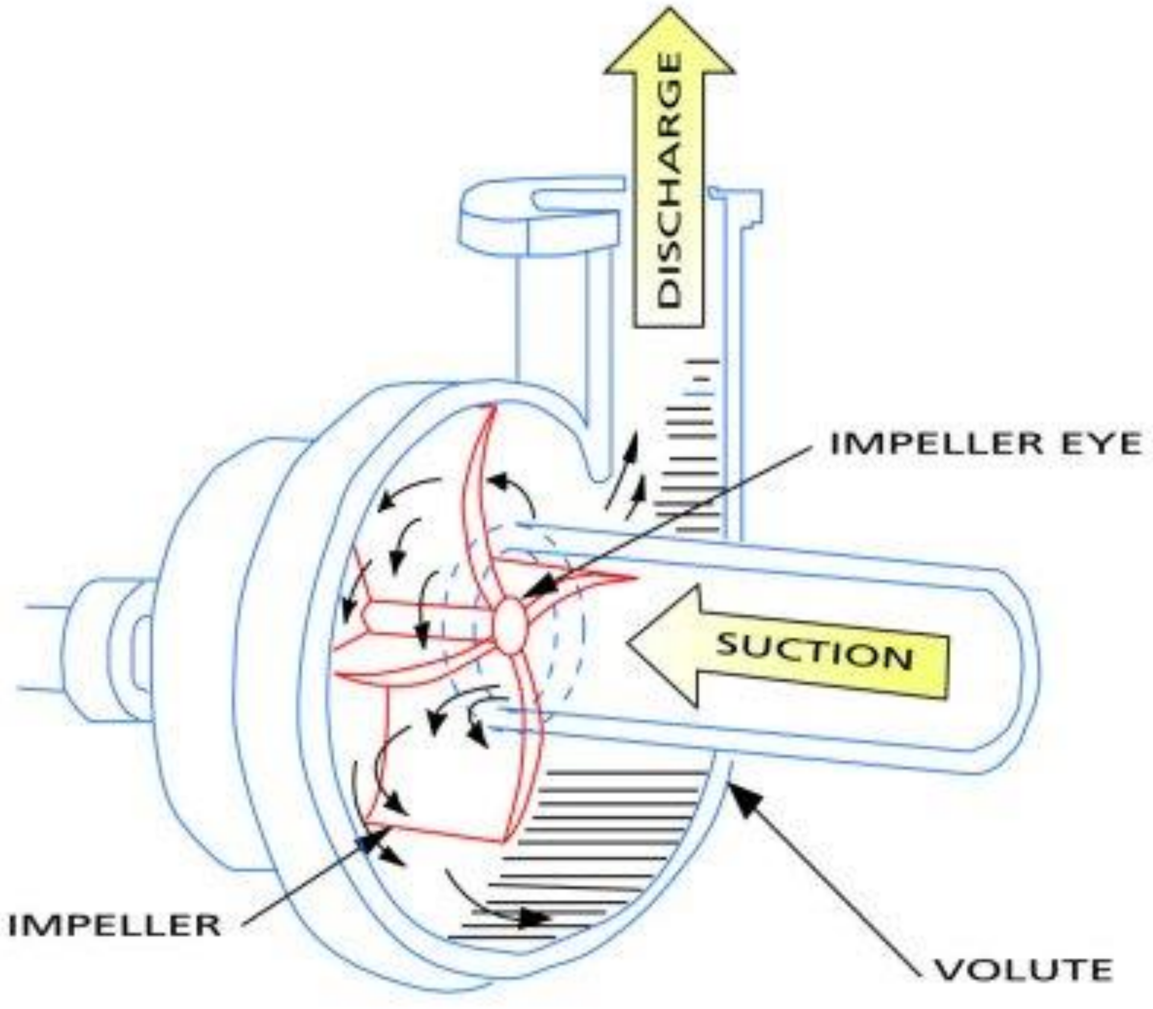
Friction, and velocity head are required to move the water from the source of supply into the discharge vessel. For this reason we call the sum of these heads the dynamic (force in motion) head.

Total Head

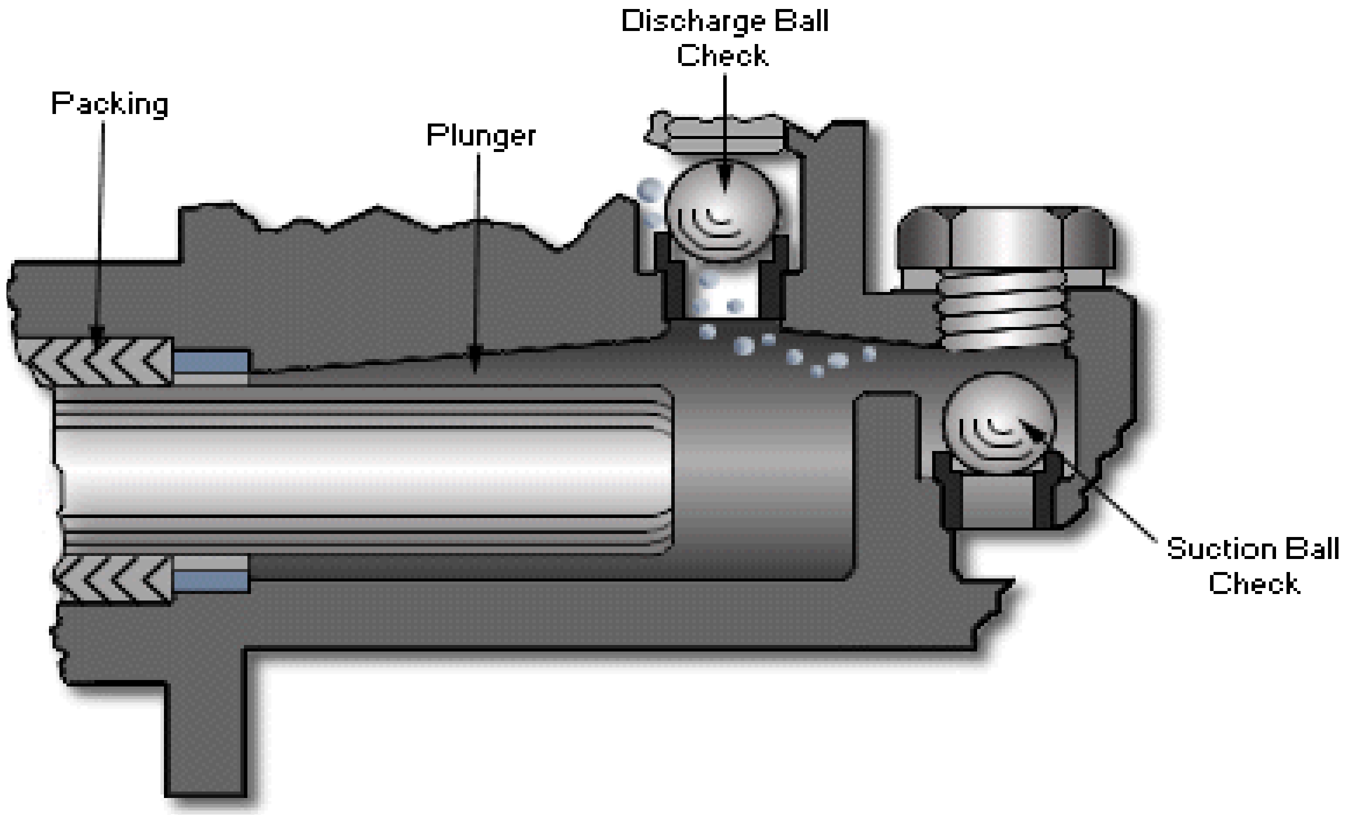
The total head required to move the water from the source of supply to the point of discharge is the sum of static and dynamic head.

The power required to drive a pump is determined by the amount of liquid pumped and the total head against which the pump operates.

Theory of Pumping

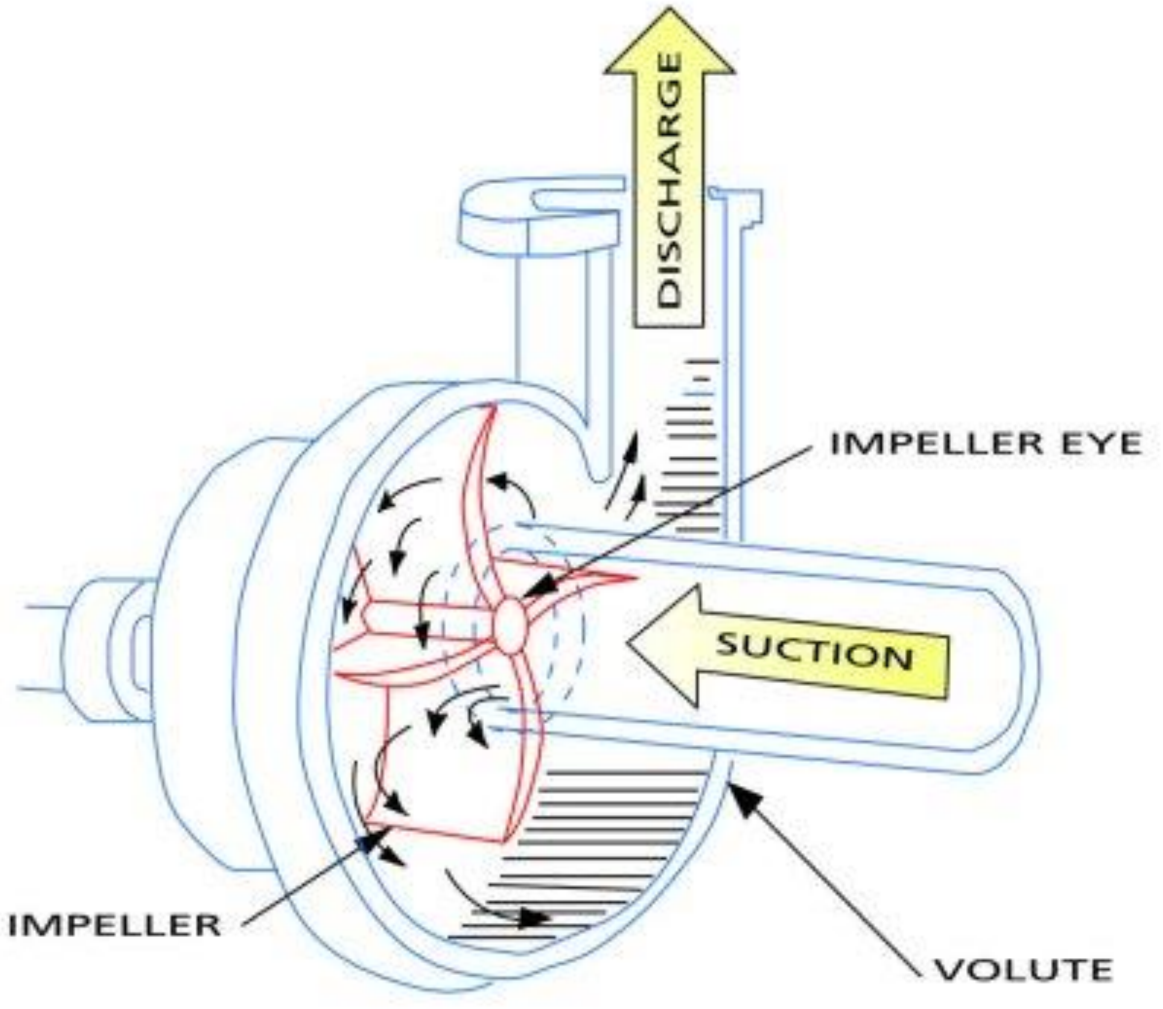


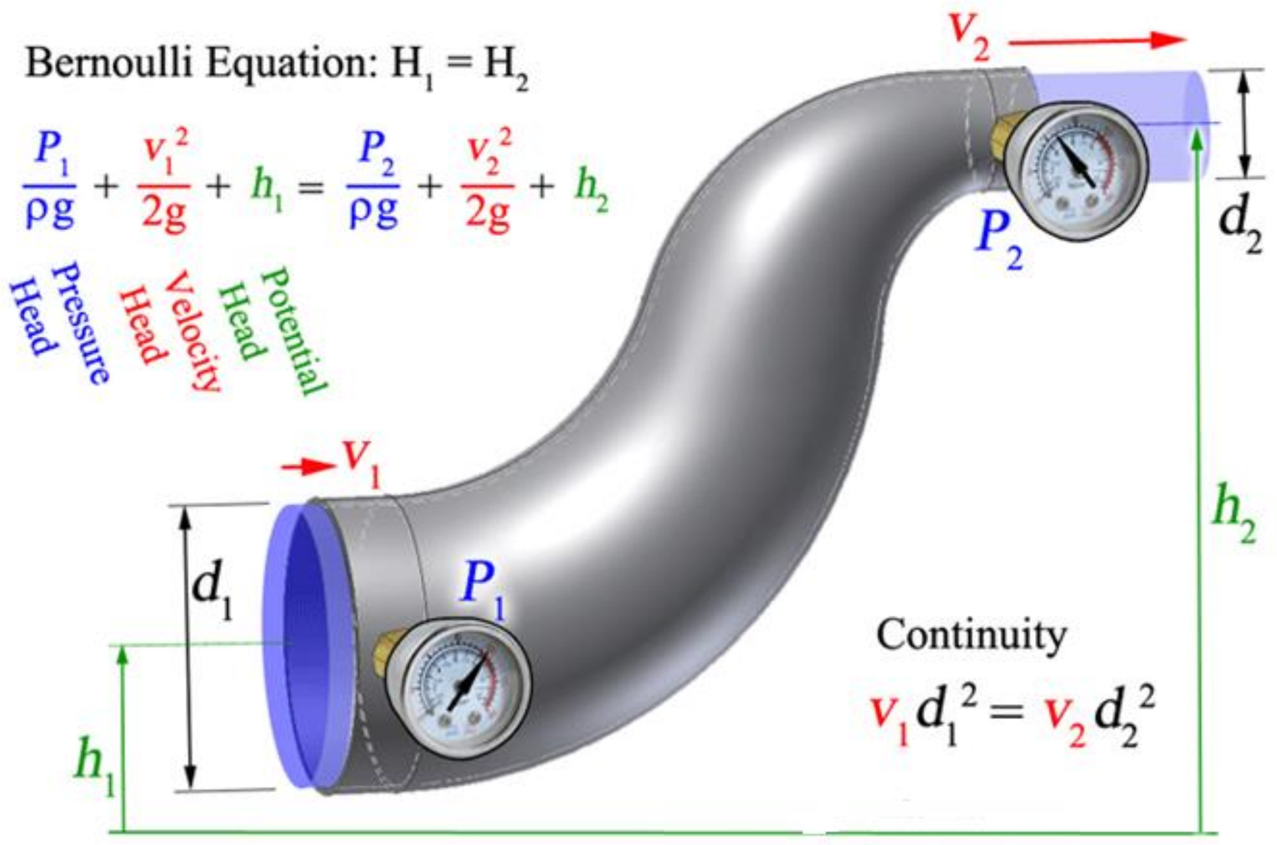
Dynamic Pumping



Positive Pumping

Theory of Pumping

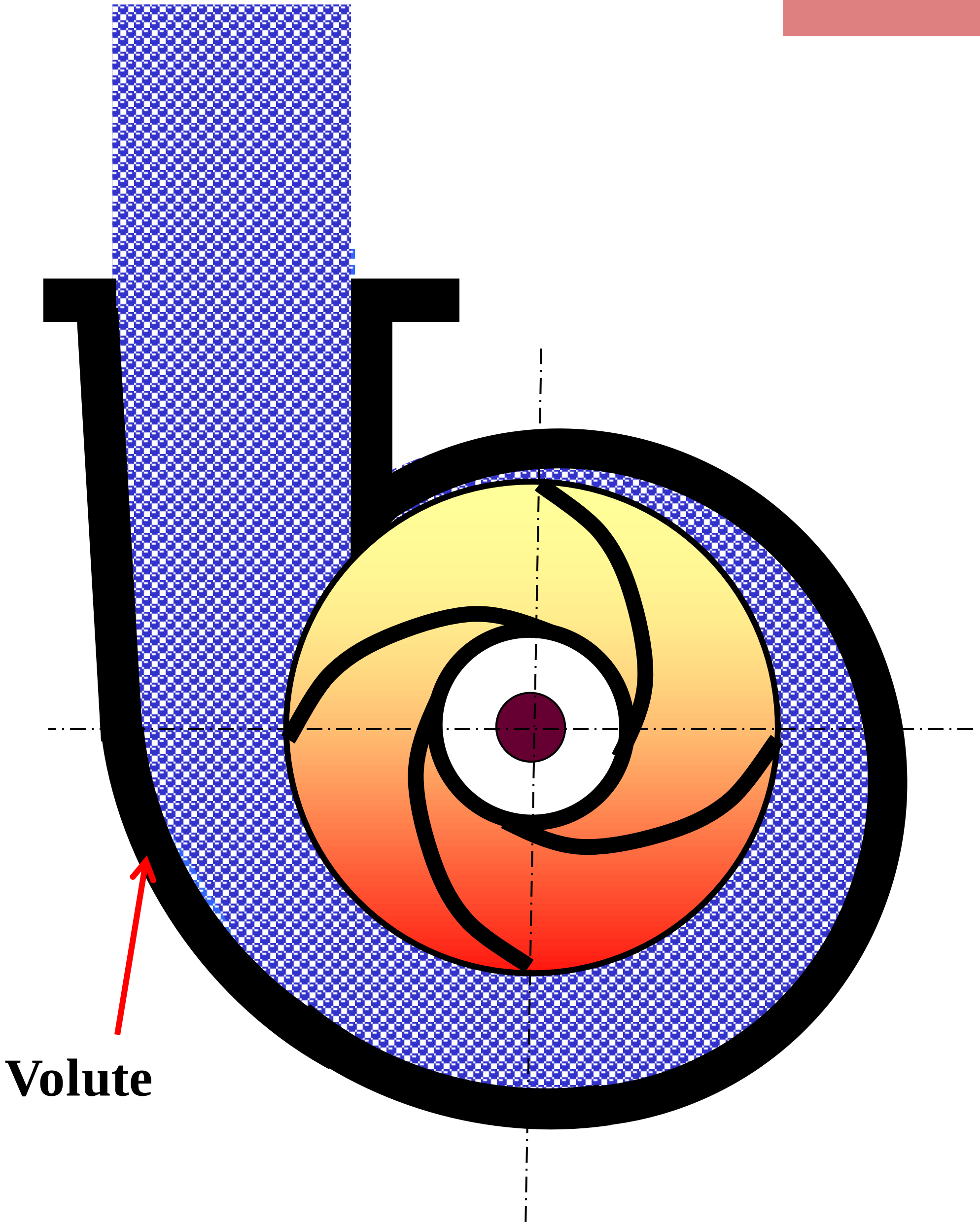




Dynamic Pumping

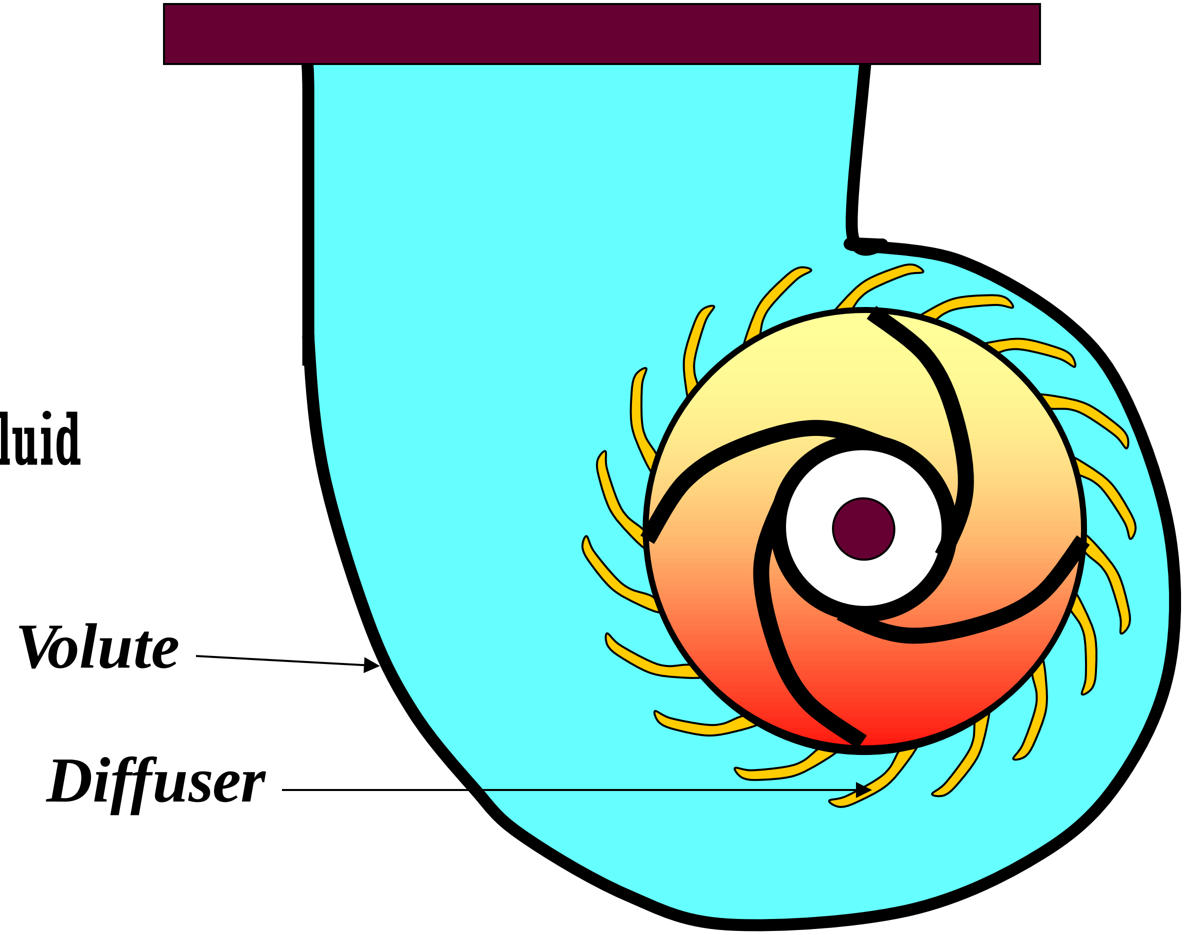
1- WITHOUT DIFFUSER

Volute function is to convert most of the Velocity energy $(v^2/2g)$ to pressure P

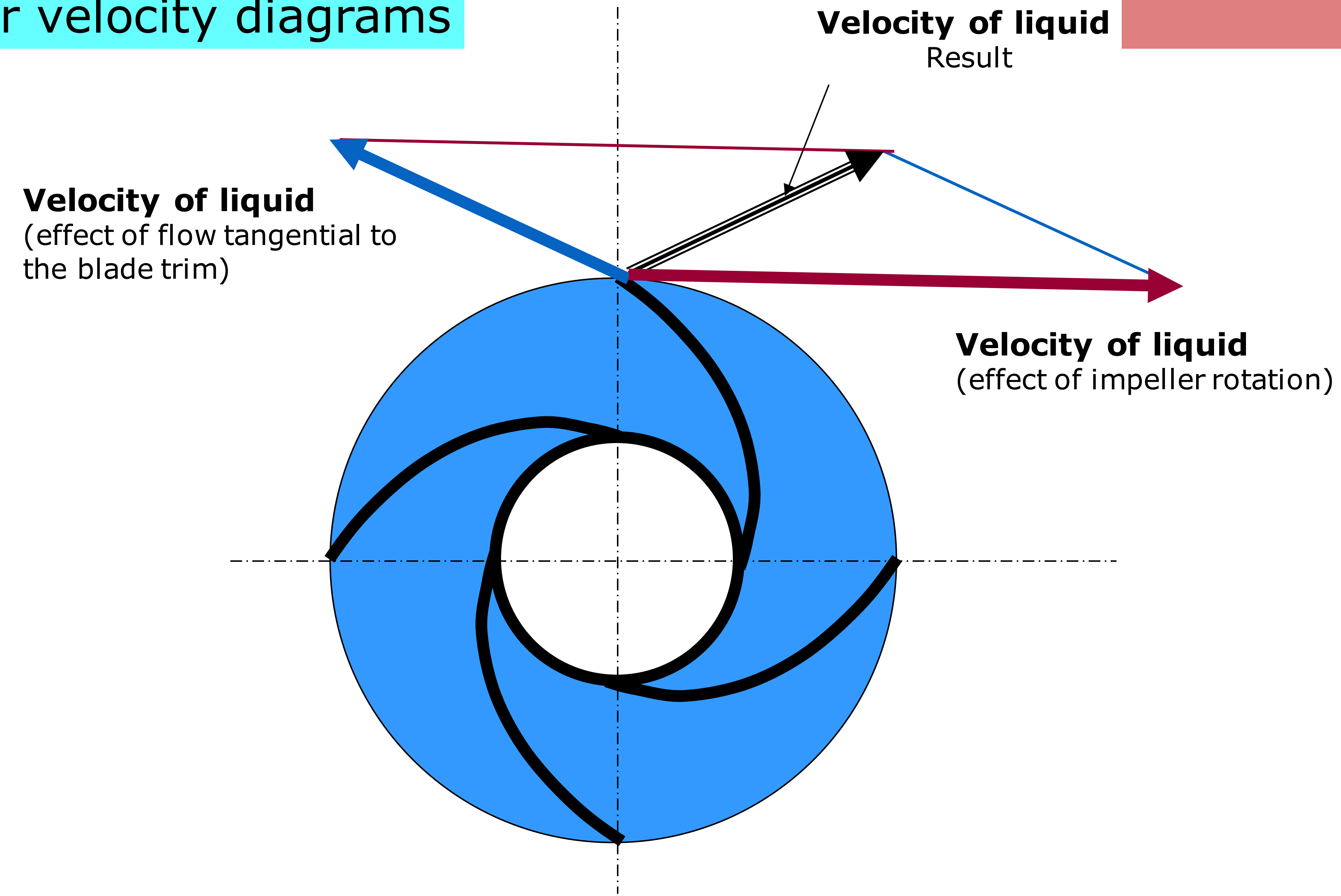


2- WITH DIFFUSER

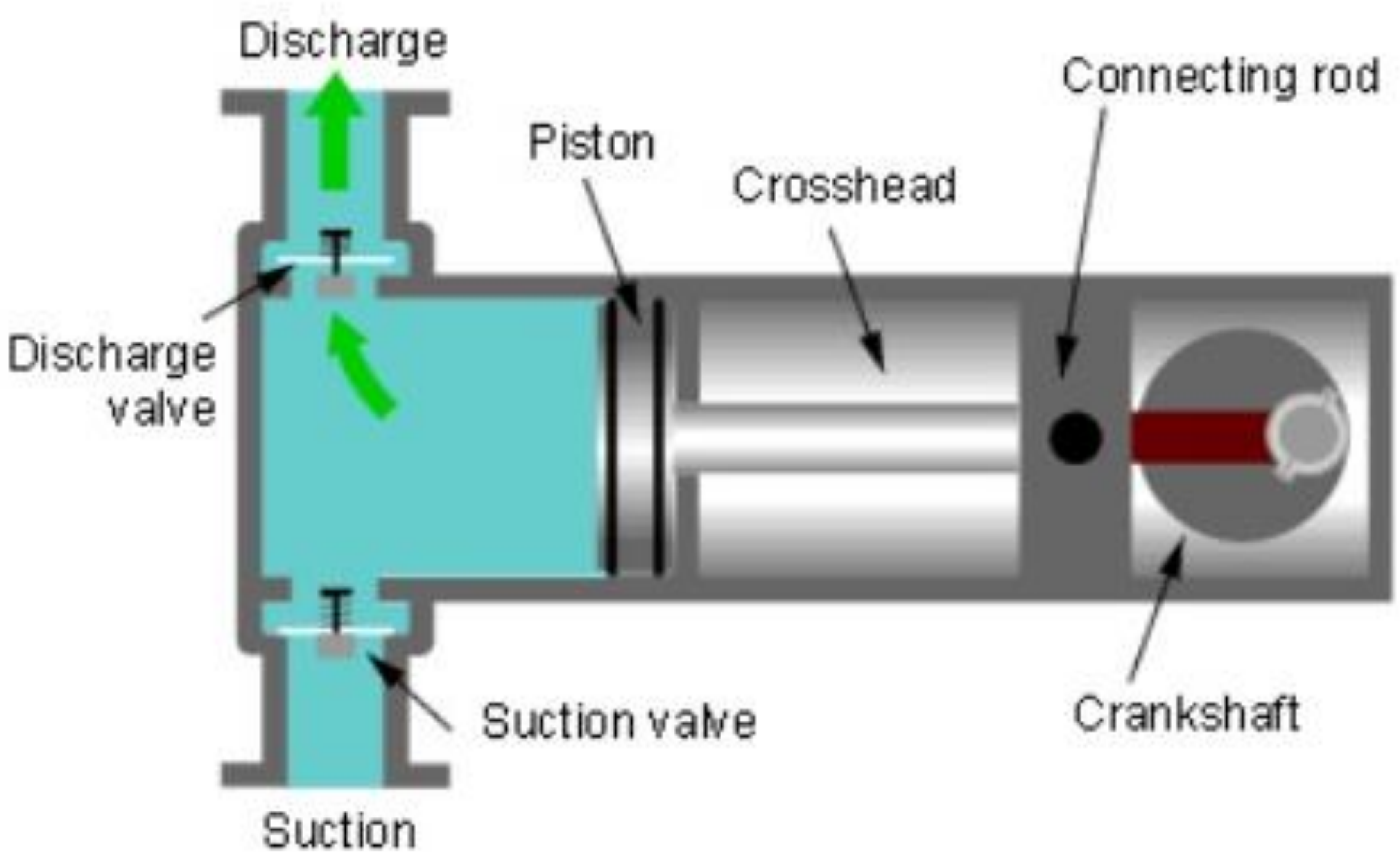
Diffuser function is to decrease the turbulence losses and unify the direction of the outlet fluid



Impeller velocity diagrams

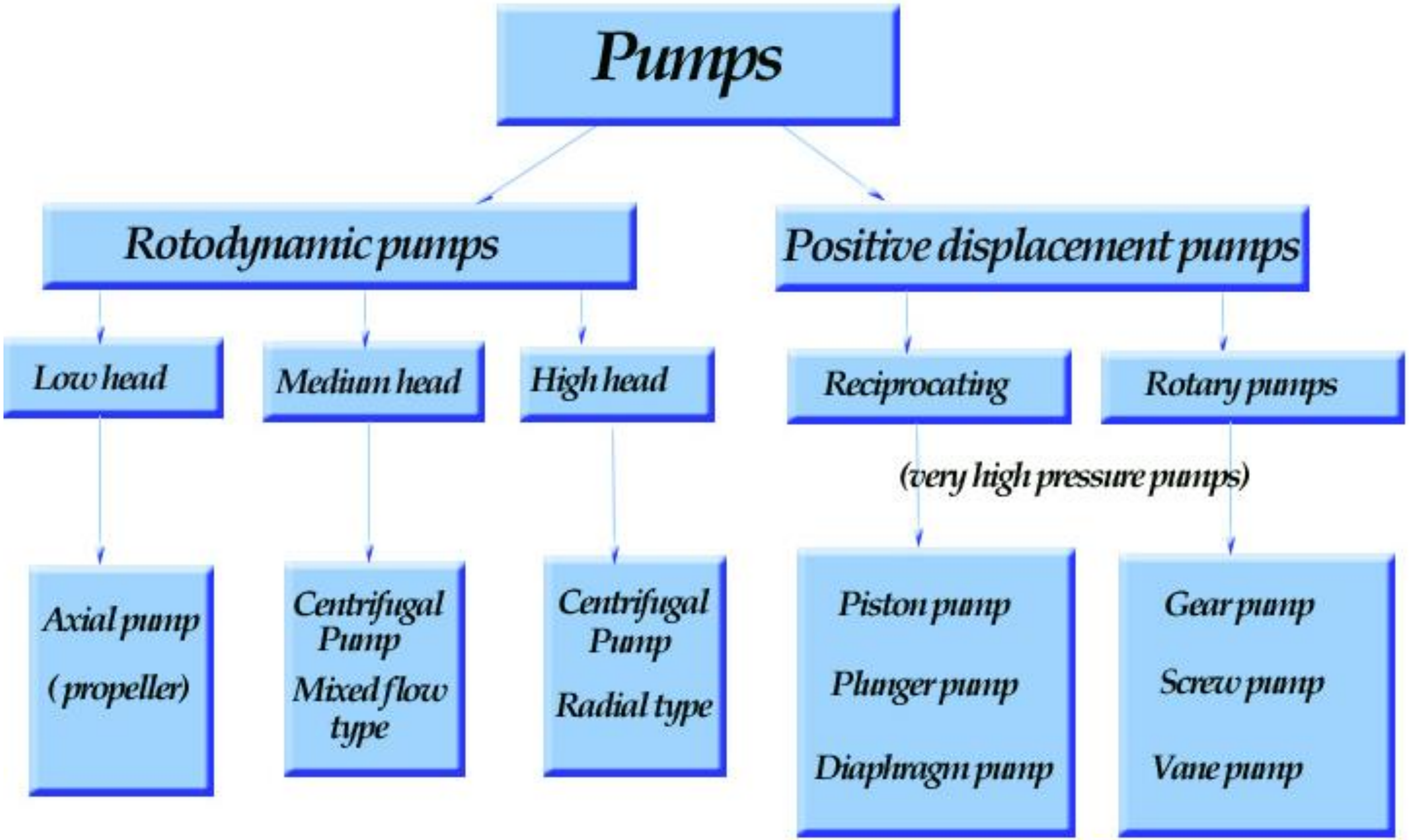


Theory of Pumping

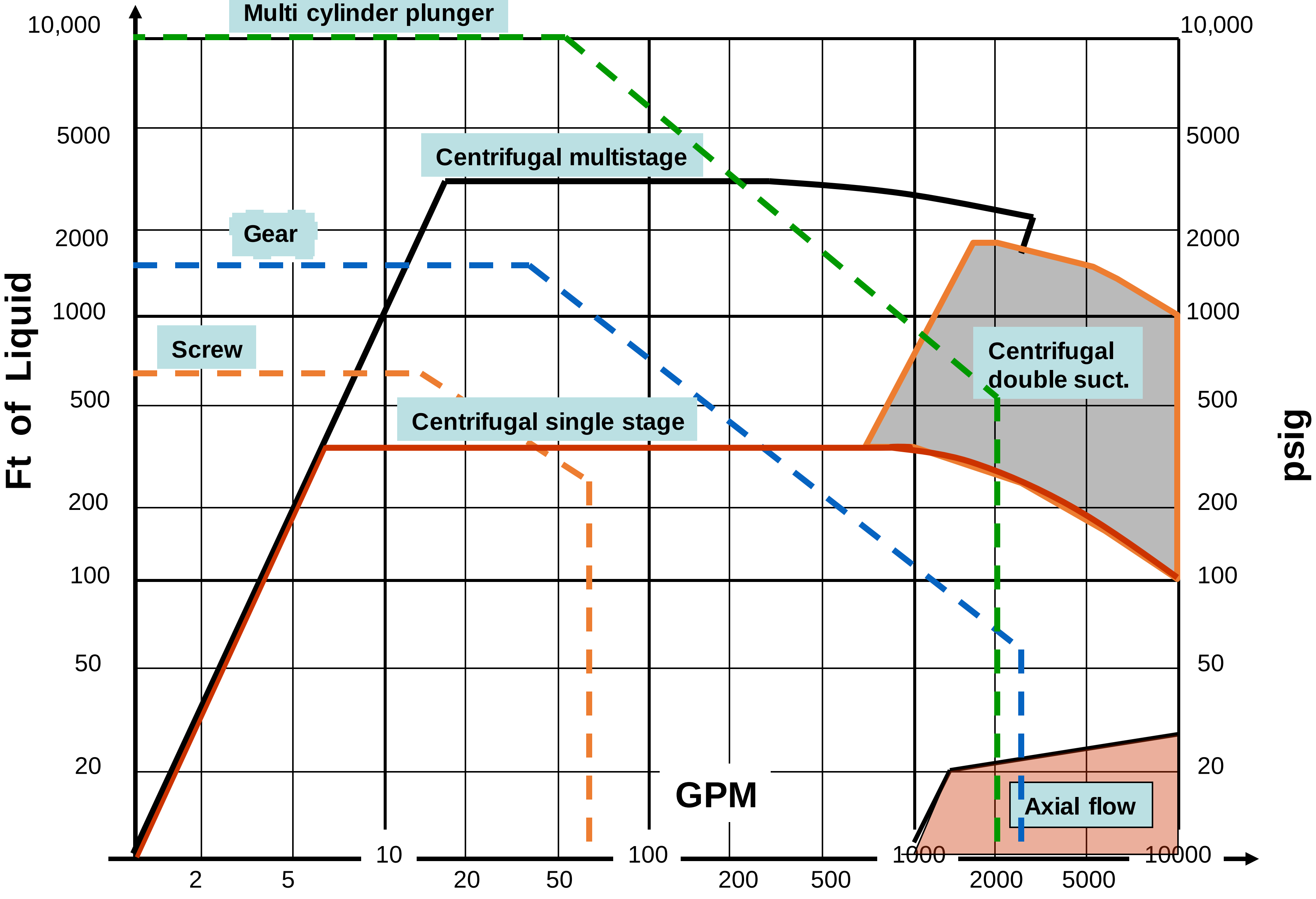


Positive Displacement Pumping

Types of Pumps

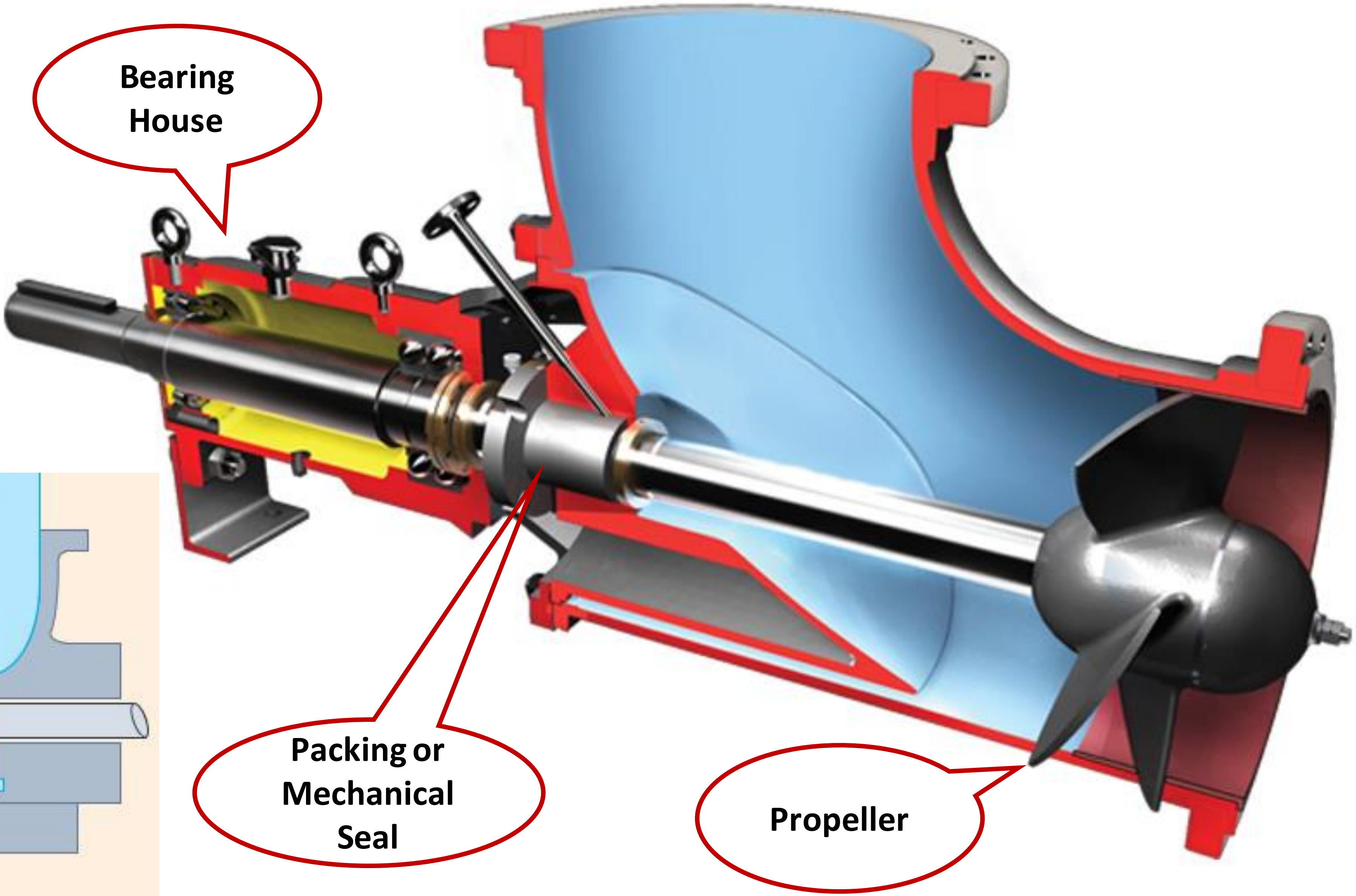


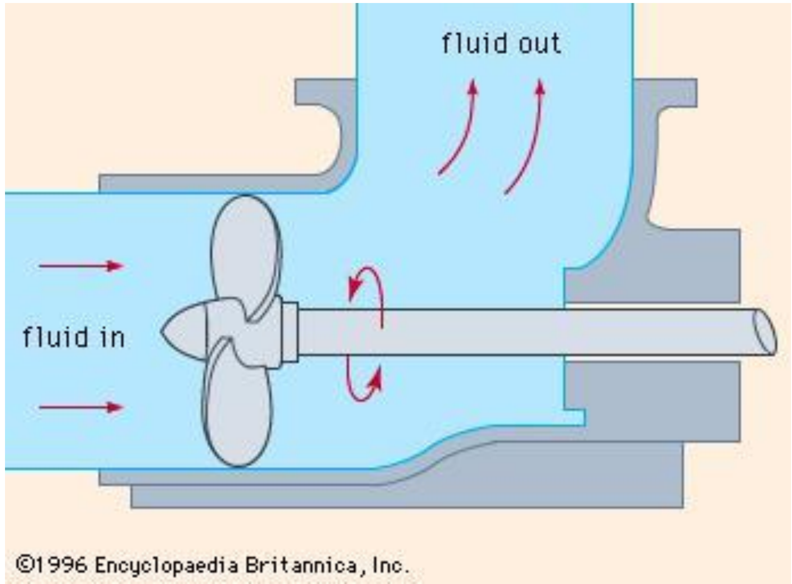
Types of Pumps



Types of Pumps

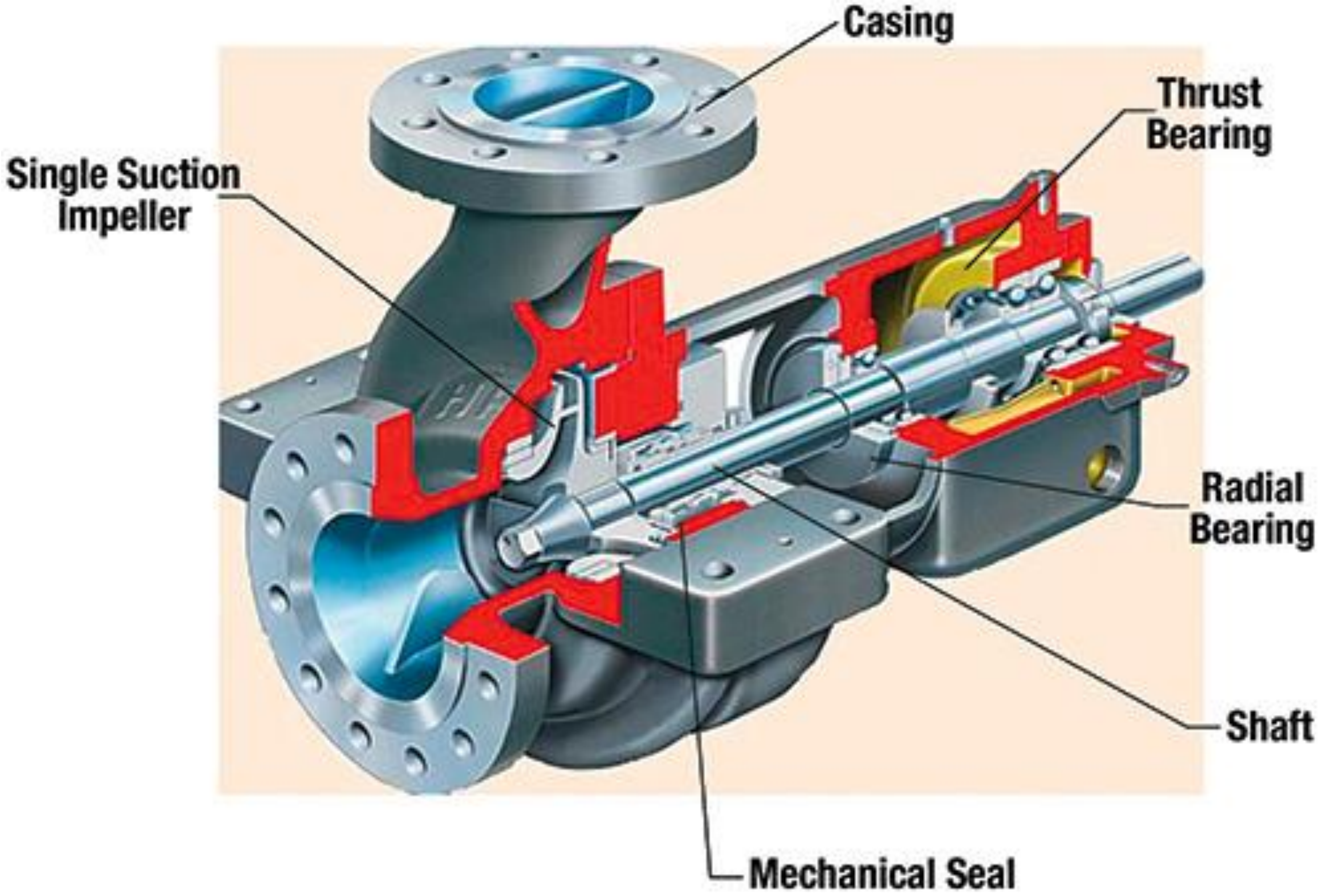
Axial Pump





Types of Pumps

Centrifugal Pump

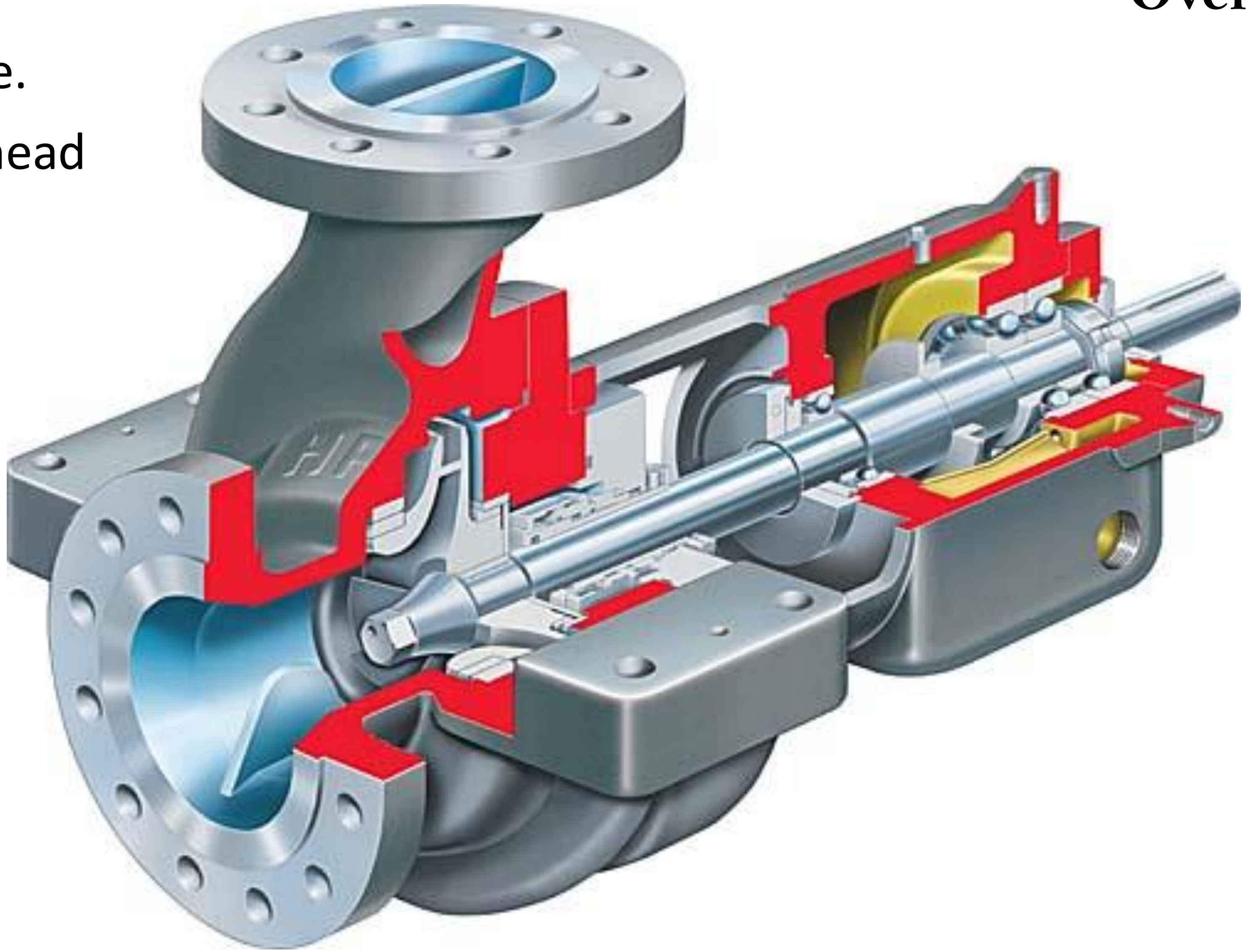


Types of Pumps

Centrifugal Pumps

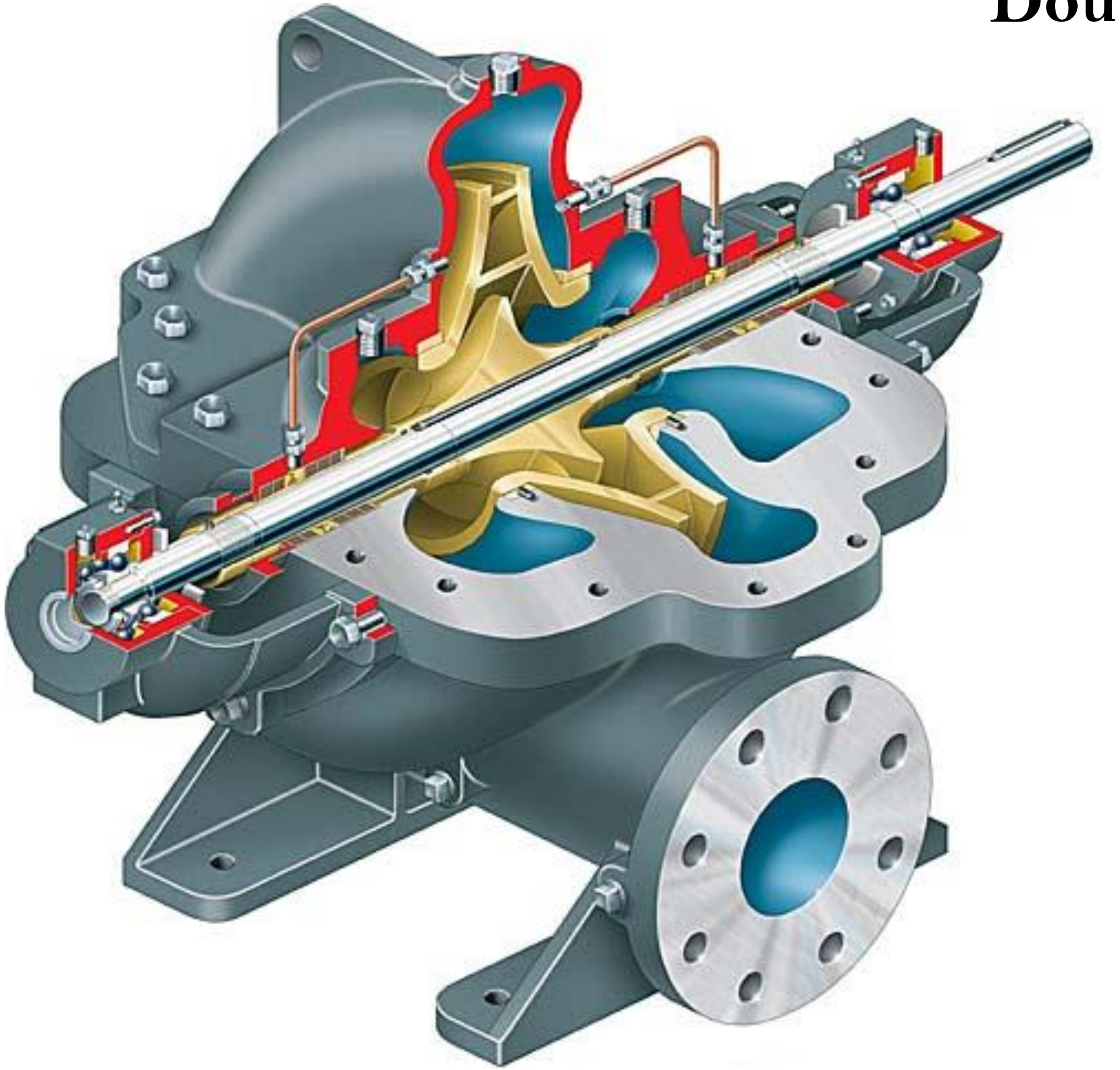
Single Stage Overhung Pump

- Most common type.
- Used for medium head range < 500 ft



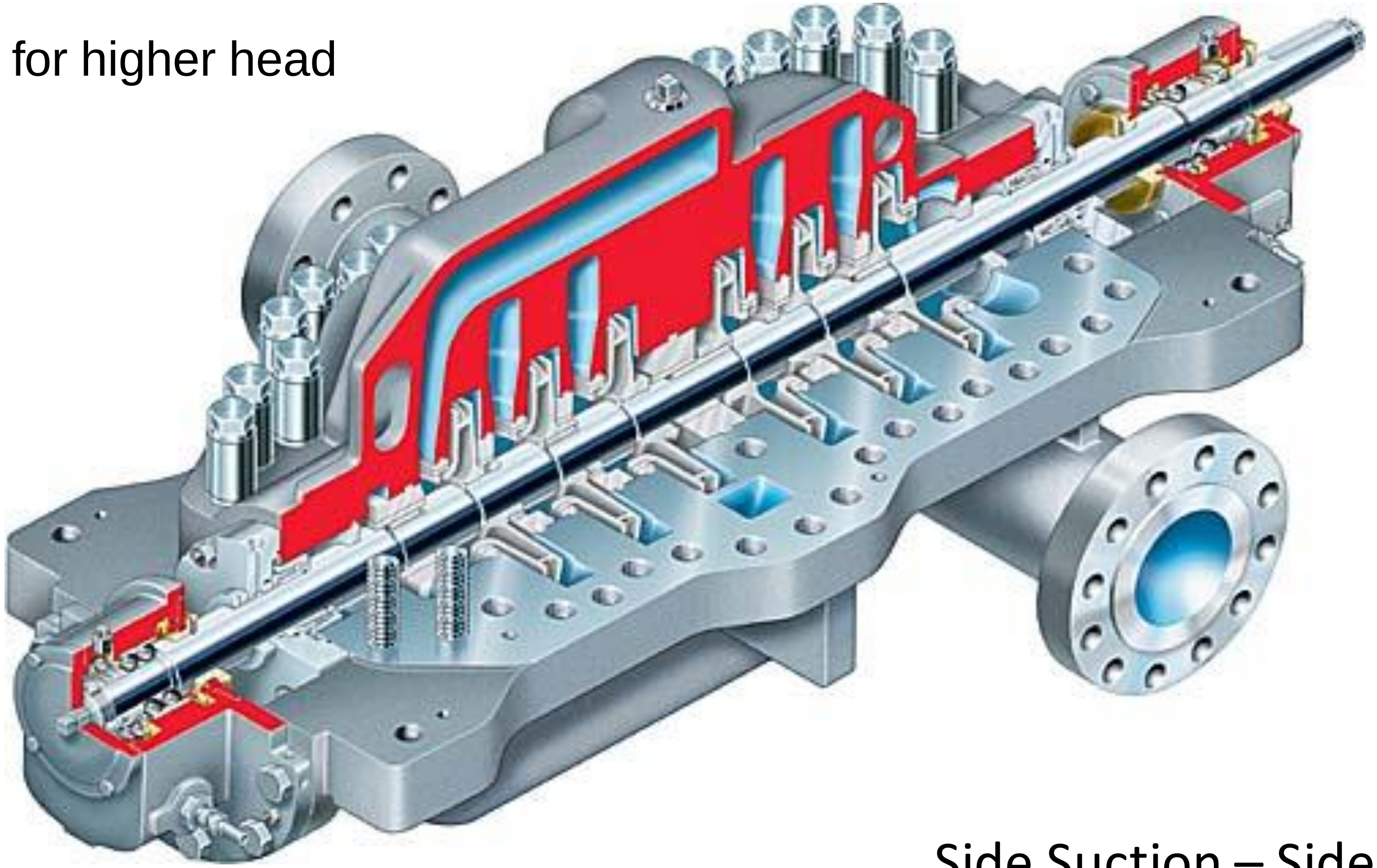
Double Suction Pump

- Jockey Pumps for Fire Fighting Applications



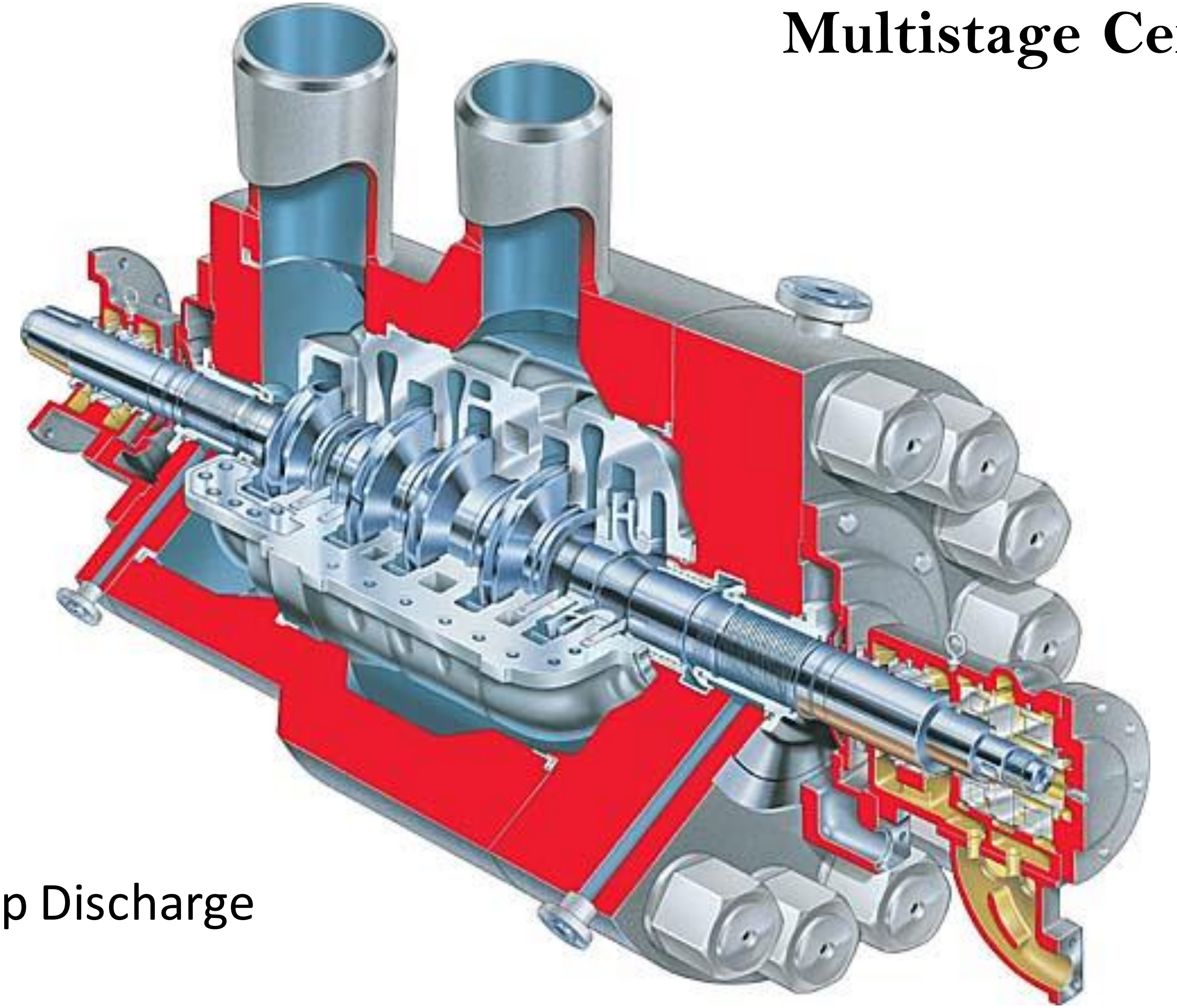
Multistage Centrifugal Pump

- Up to 13 impeller for higher head
- 13000 gpm
- 7000 ft



Side Suction – Side Discharge

Multistage Centrifugal Pump



Top Suction – Top Discharge

Types of Pumps

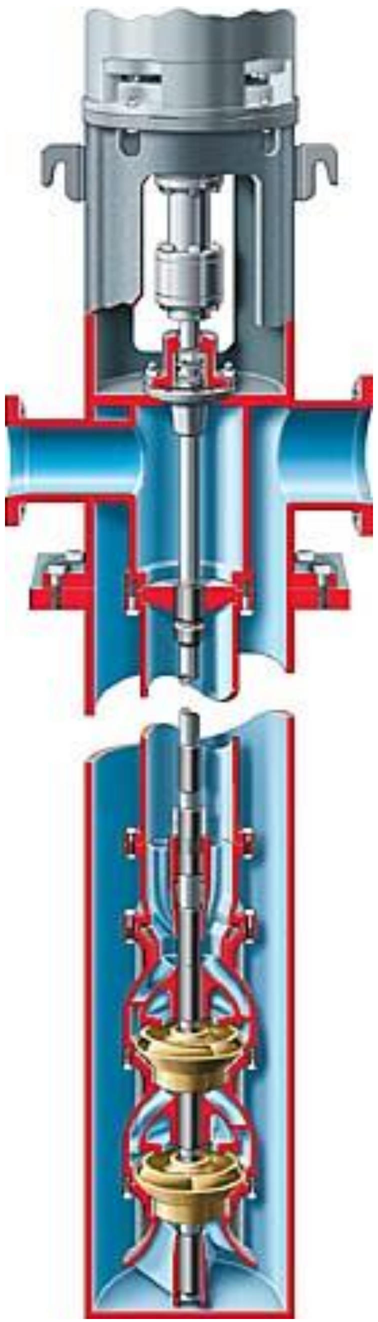
Vertical Can Pump

Typically used for condensate service

Low NPSH Application (specify to inlet flange)

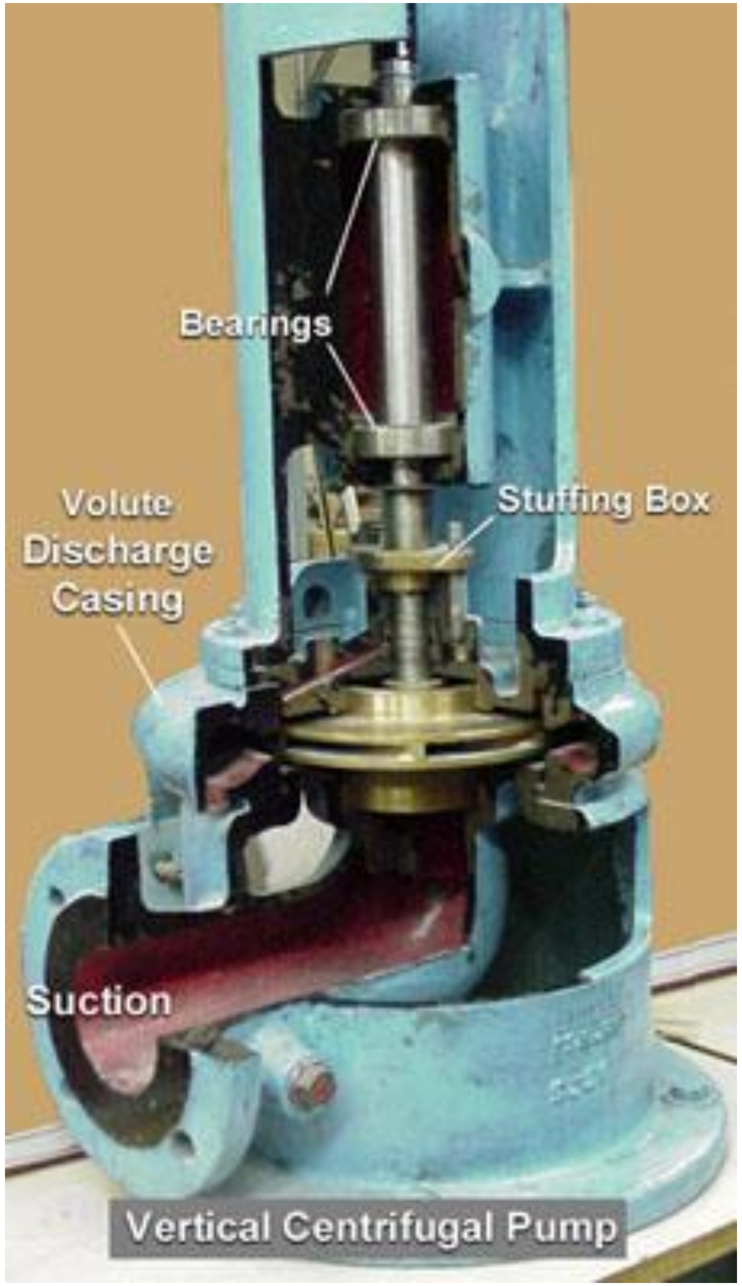
60,000 gpm

700 ft head



Vertical Inline Pump

- Supported by piping or small foundations
- Motor supported by the pump, Piping forces do not affect alignment.
- Lower cost – simpler maintenance
- Slightly higher NPSHreq



Types of Pumps

Centrifugal Pumps

API 610

ASME B73.1 & B73.2 Most common pumps

API 685 Seal less Pumps

Liquid Ring Vacuum Pumps

API 681

Positive Displacement Pumps

API 674 Reciprocating

API 675 Controlled volume

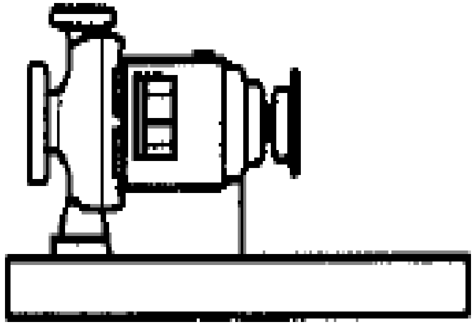
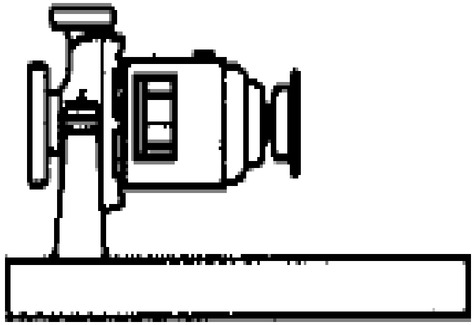
API 676 Rotary

Firewater Pumps

NFPA 20

Types of Pumps

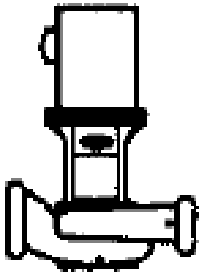
API Centrifugal Pump Configurations

CODE	SPECIFIC CONFIGURATION	ILLUSTRATION
OH1[a]	Foot mounted	
OH2	Centerline mounted	

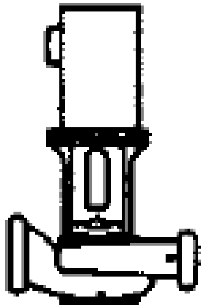
Types of Pumps

API Centrifugal Pump Configurations

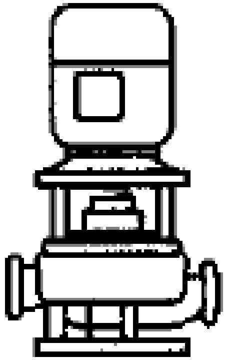
OH3 — Vertical in-line separate bearing frame



OH4* — Vertical in-line rigidly coupled



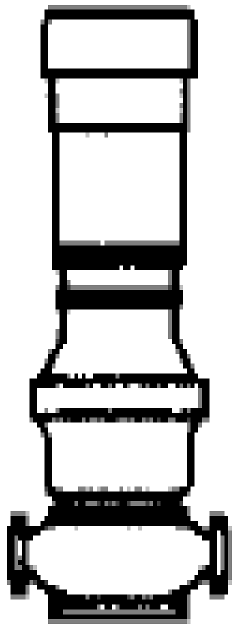
OH5* — Vertical in-line closed coupled



Types of Pumps

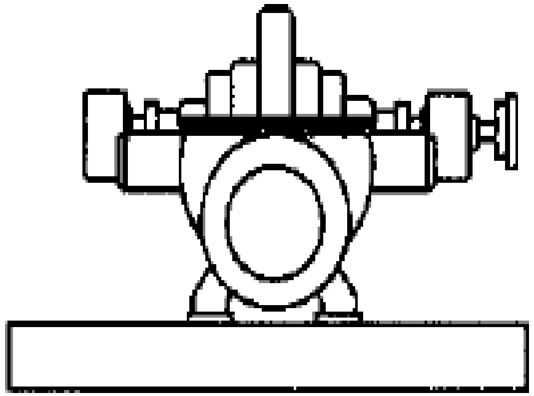
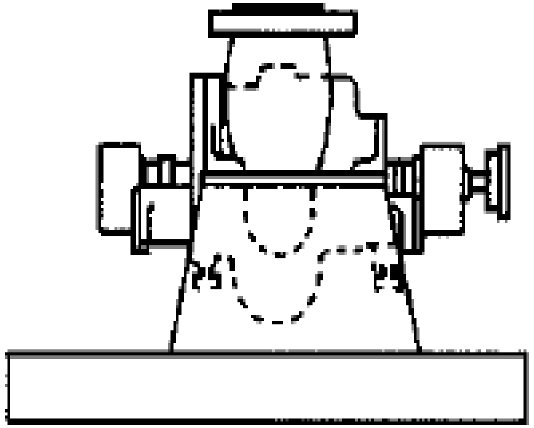
API Centrifugal Pump Configurations

OH6 High speed integral gear



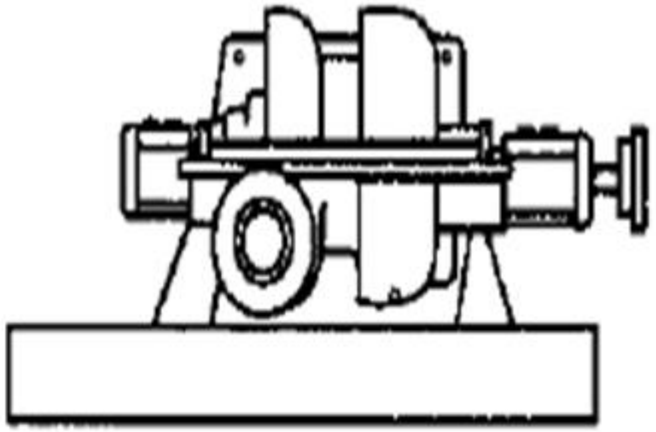
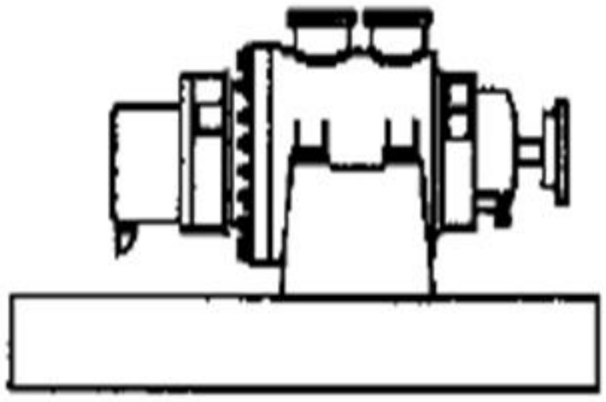
Types of Pumps

API Centrifugal Pump Configurations

CODE	SPECIFIC CONFIGURATION	ILLUSTRATION
BB1	Axially split, 1 and 2 stage	
BB2	Radially split, 1 and 2 stage	

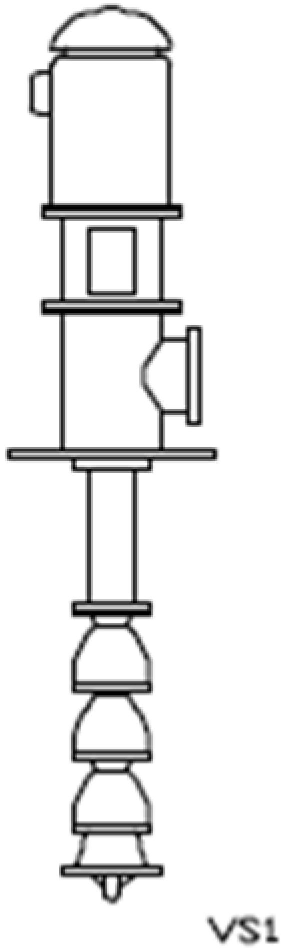
Types of Pumps

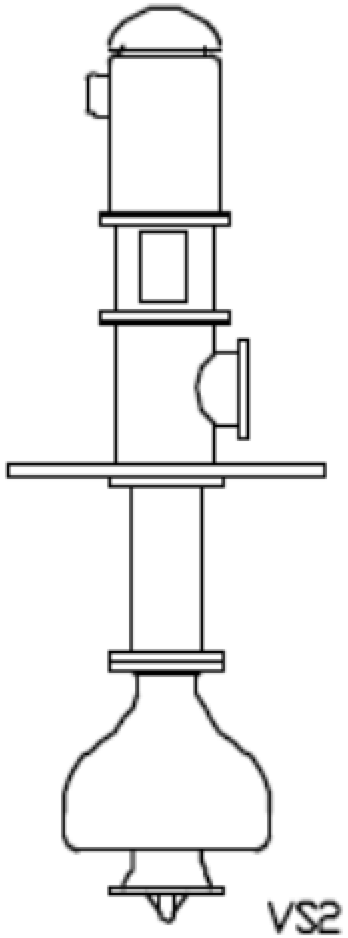
API Centrifugal Pump Configurations

BB3	Axially split, multistage	
BB4 BB5	Radially split, multistage: Single casing Double casing	

Types of Pumps

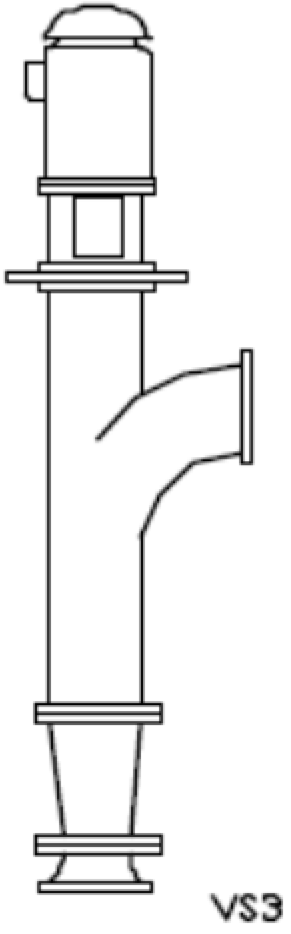
API Centrifugal Pump Configurations



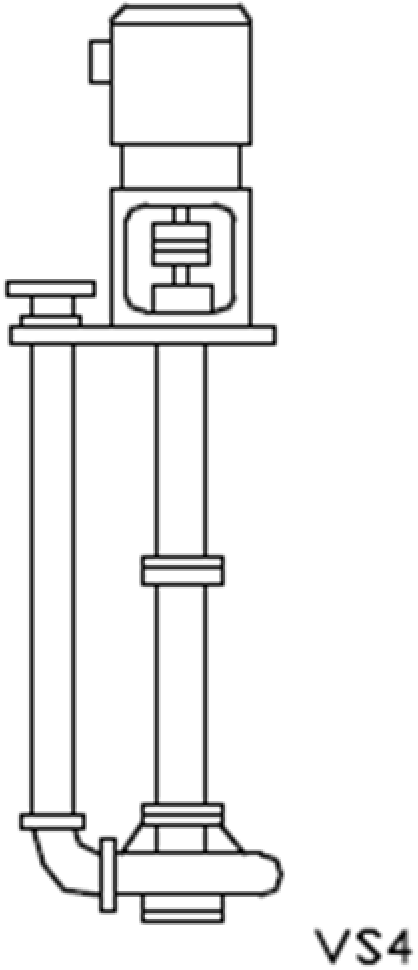


Types of Pumps

API Centrifugal Pump Configurations



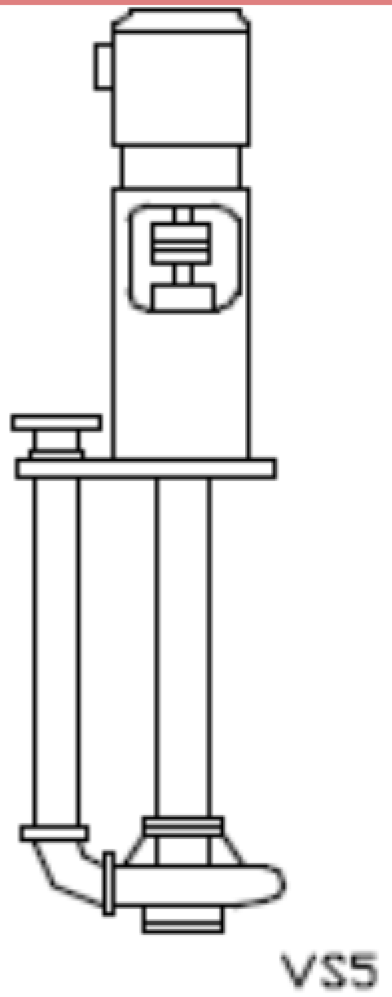
Wet pit, vertically-suspended, single-casing axial flow



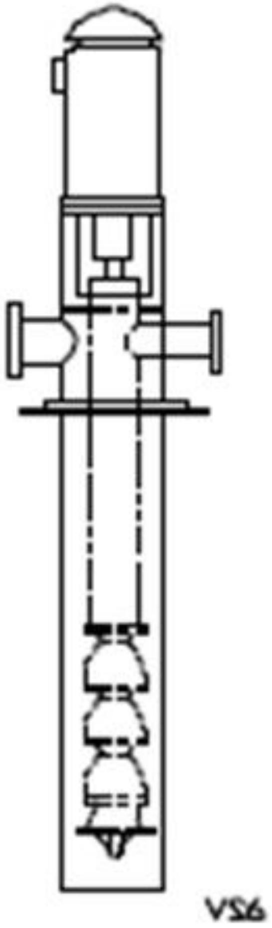
Vertically-suspended, single-casing volute line-shaft (

Types of Pumps

API Centrifugal Pump Configurations



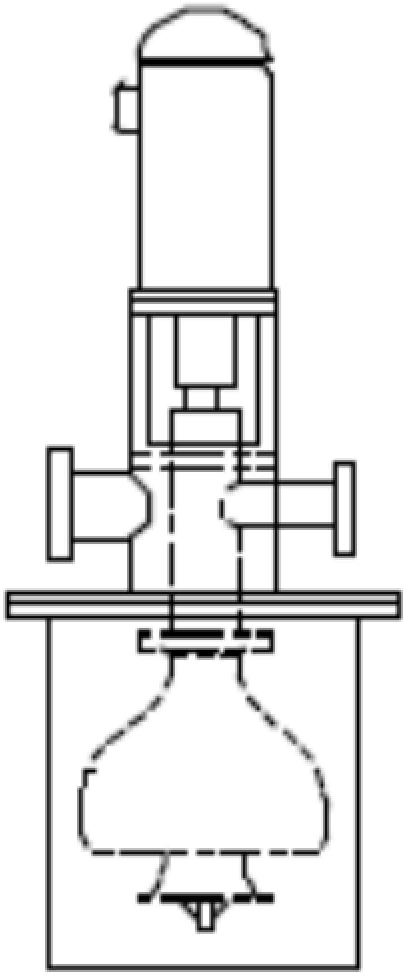
Vertically-suspended cantilever sump



Double-casing diffuser vertically-suspended

Types of Pumps

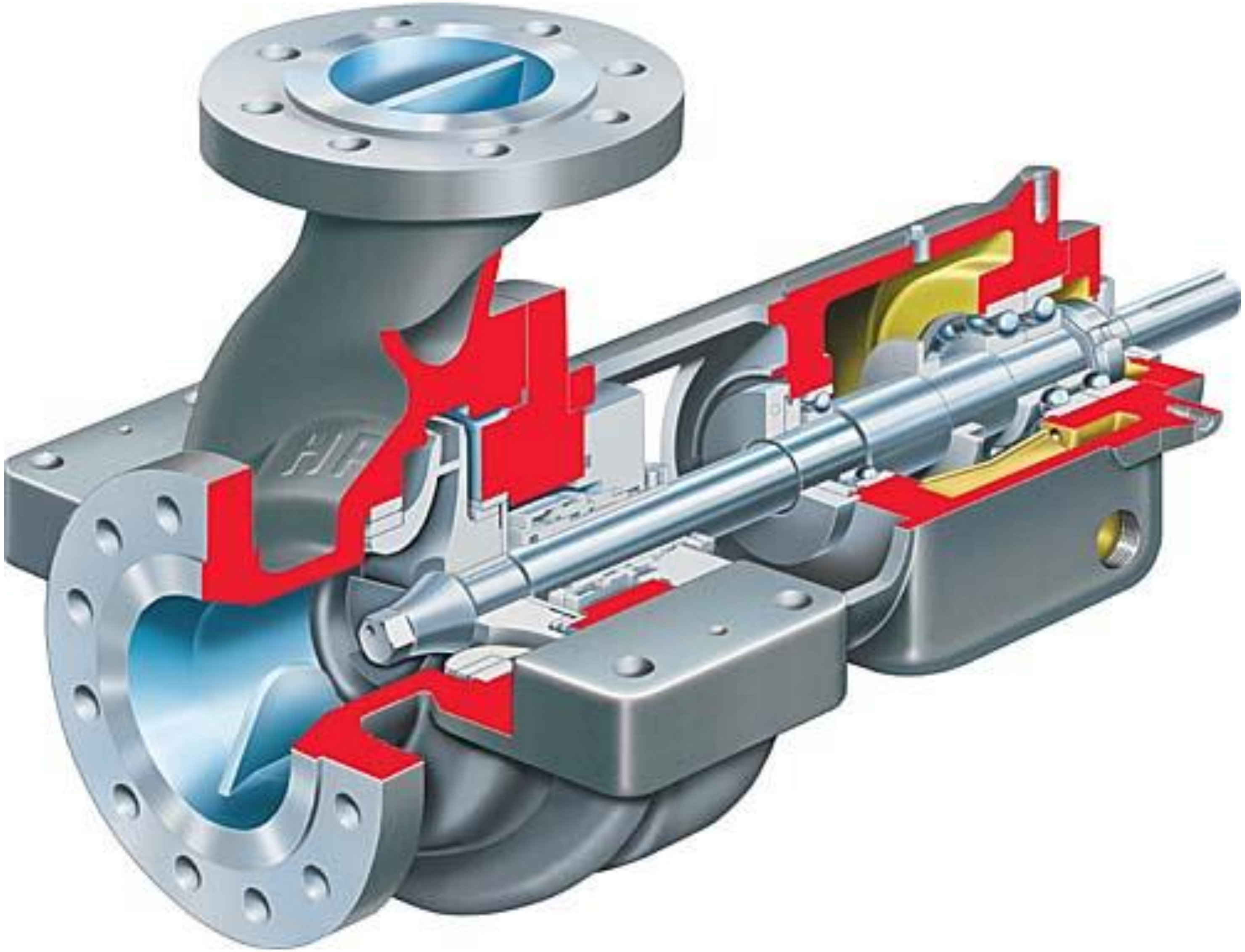
API Centrifugal Pump Configurations



VS7

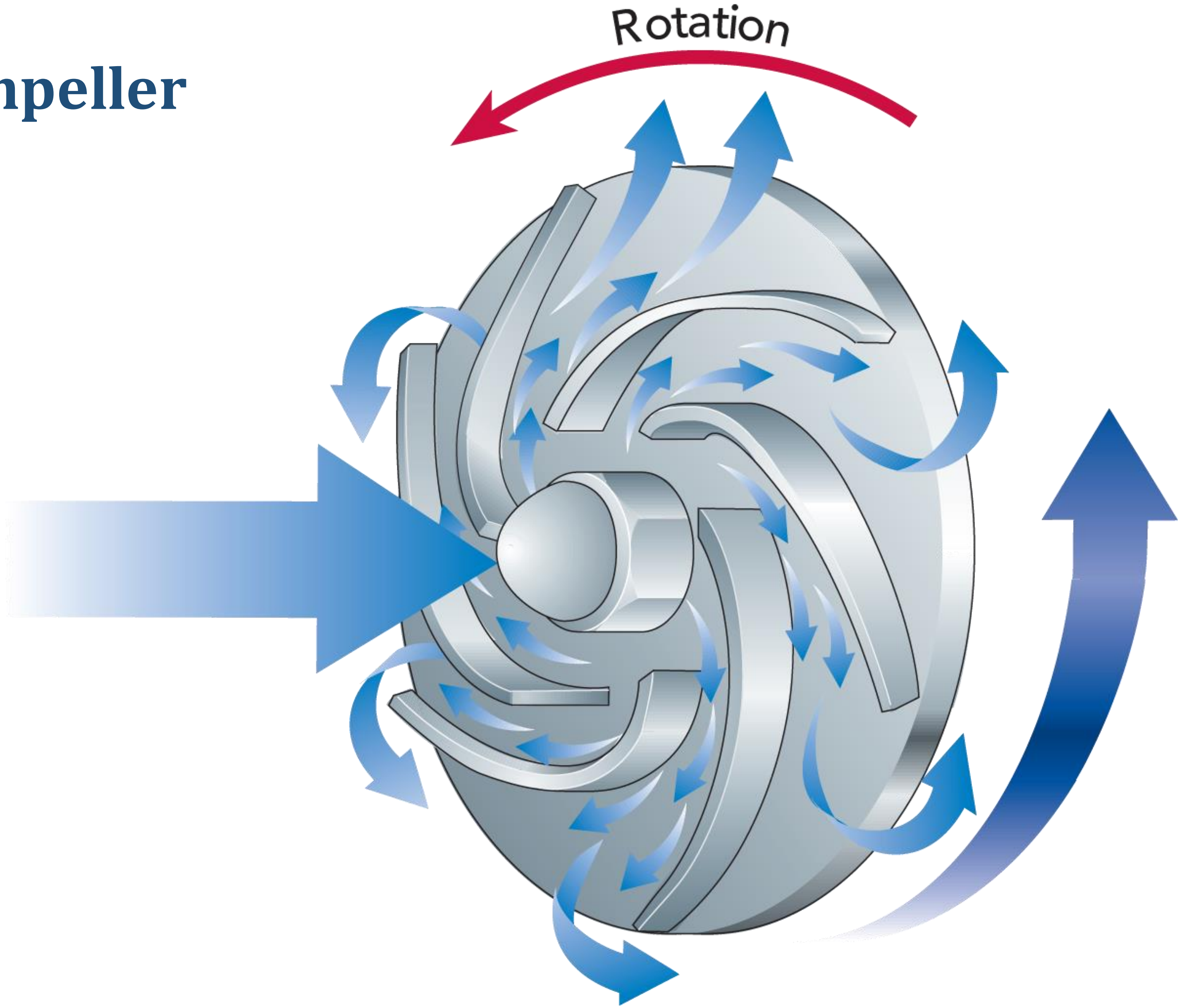
Double-casing volute vertically-suspended

Construction



Construction

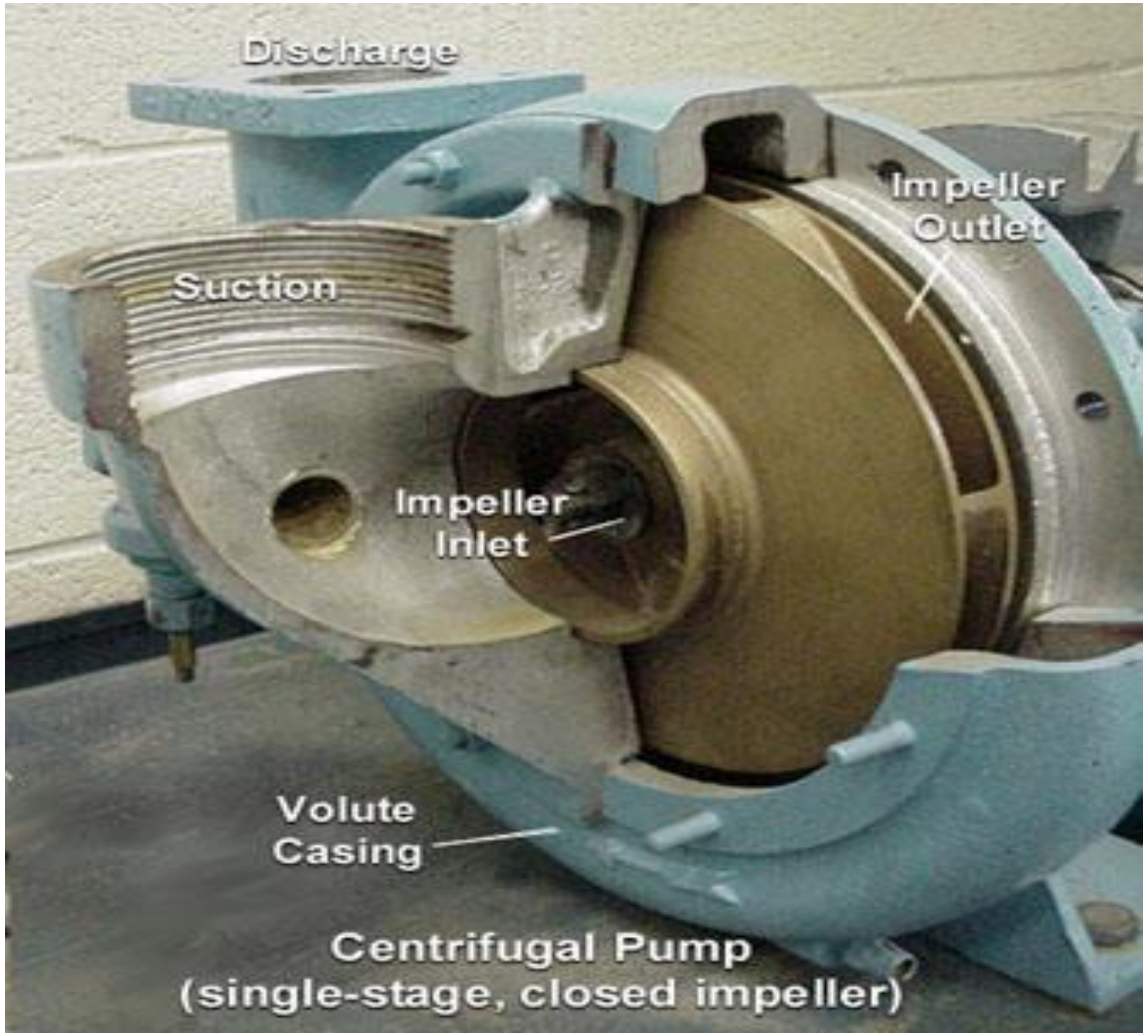
1- Impeller



Construction

1- Impeller

- It converts the mechanical rotation to the velocity of the liquid.
- It has an inlet eye through which the liquid suction occurs. The liquid is then guided from the inlet to the outlet of the impeller by vanes. The angle and shape of the vanes are designed based on flow rate.
- The guide vanes are usually cast with a back plate, termed *shroud or back cover, and a front plate, termed front cover.*
- Impellers are generally made in castings and very rarely do come across fabricated and welded impellers. Impellers can have many features on them like balancing holes and back vanes. These help in reducing the axial thrust generated by the hydraulic pressure.



Construction

Impeller Types

Open
Solids handling, low flow, entrained gases, reduced efficiencies

Semi-Open
moderately abrasive slurries, if blocking is a concern

Closed
High heads, high flow, improved efficiencies

Construction

Closed Impellers

The closed impeller consists of radial vanes (typically 3–7 in number), which are enclosed from both sides by two discs termed ‘shrouds’. These have a wear ring on the suction eye and may or may not have one on the back shroud. Impellers that do not have a wear ring at the back typically have back vanes. Pumps with closed type impellers and wear rings on both sides have a higher efficiency.

Construction

Semi-Open Impellers

The semi-open type impellers are more efficient due to the elimination of disk friction from the front shroud and are preferred when the liquid used may contain suspended particles or fibers. The axial thrust generated in semi-open impellers is usually higher than closed impellers.

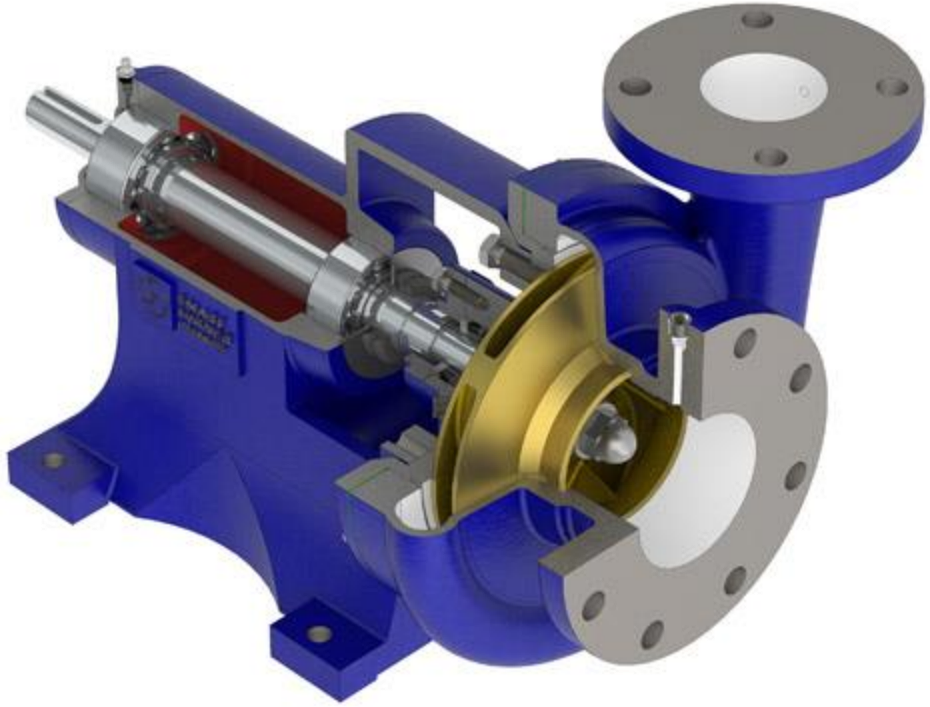
Construction

Open Impellers

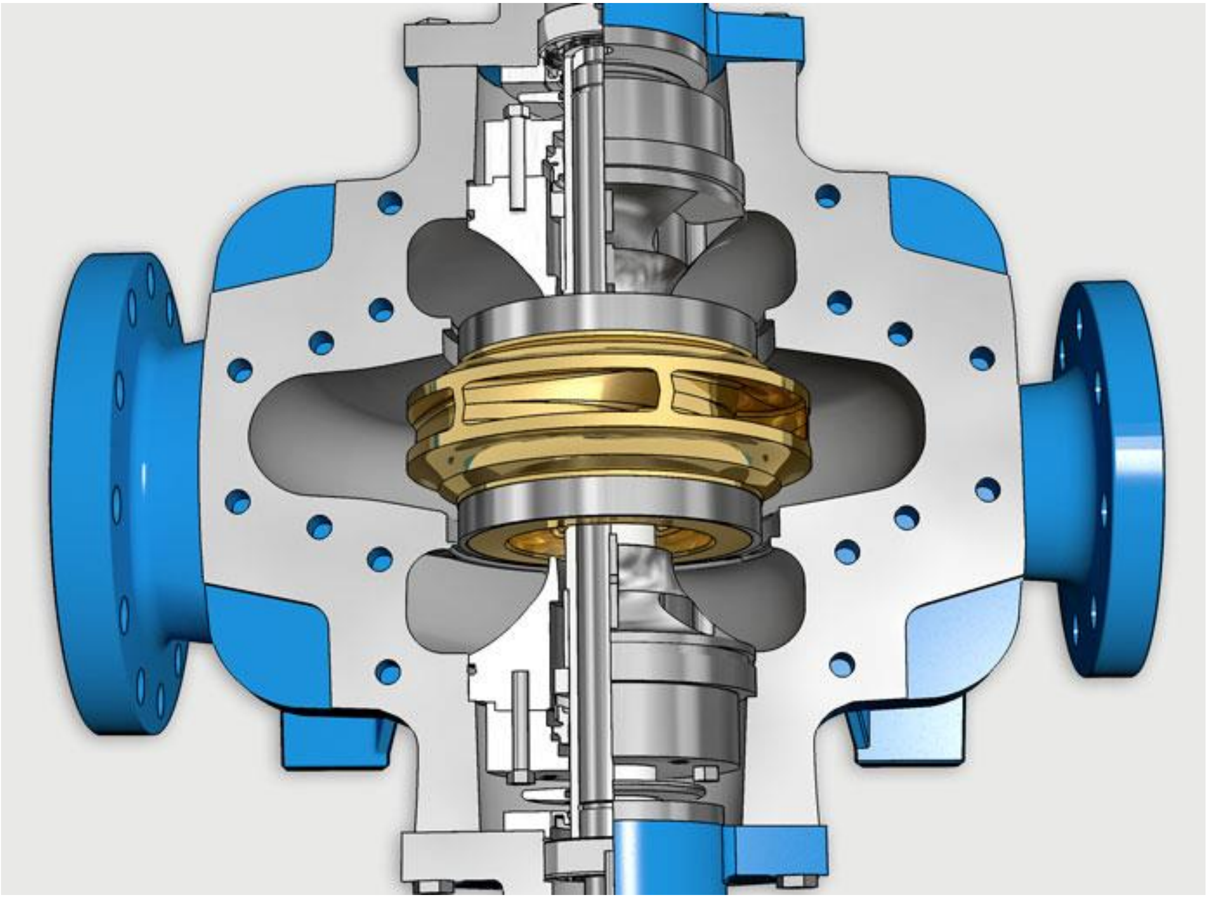
These are used in applications where the suspended solid's size maybe large or the solid's maybe of crystals and fibers type.

Construction

Impeller Arrangements



Single Suction

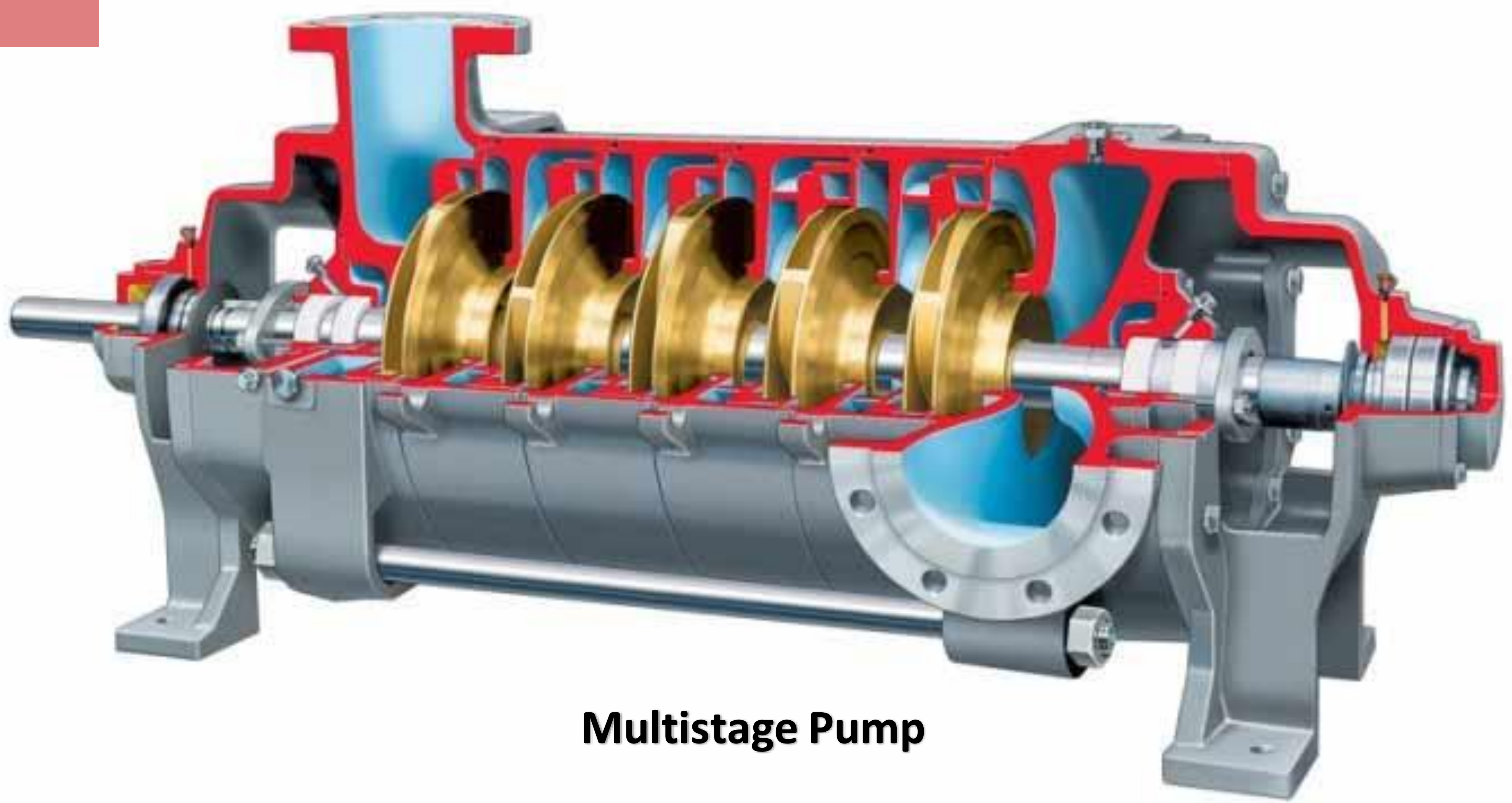


Double Suction

Impeller Arrangements

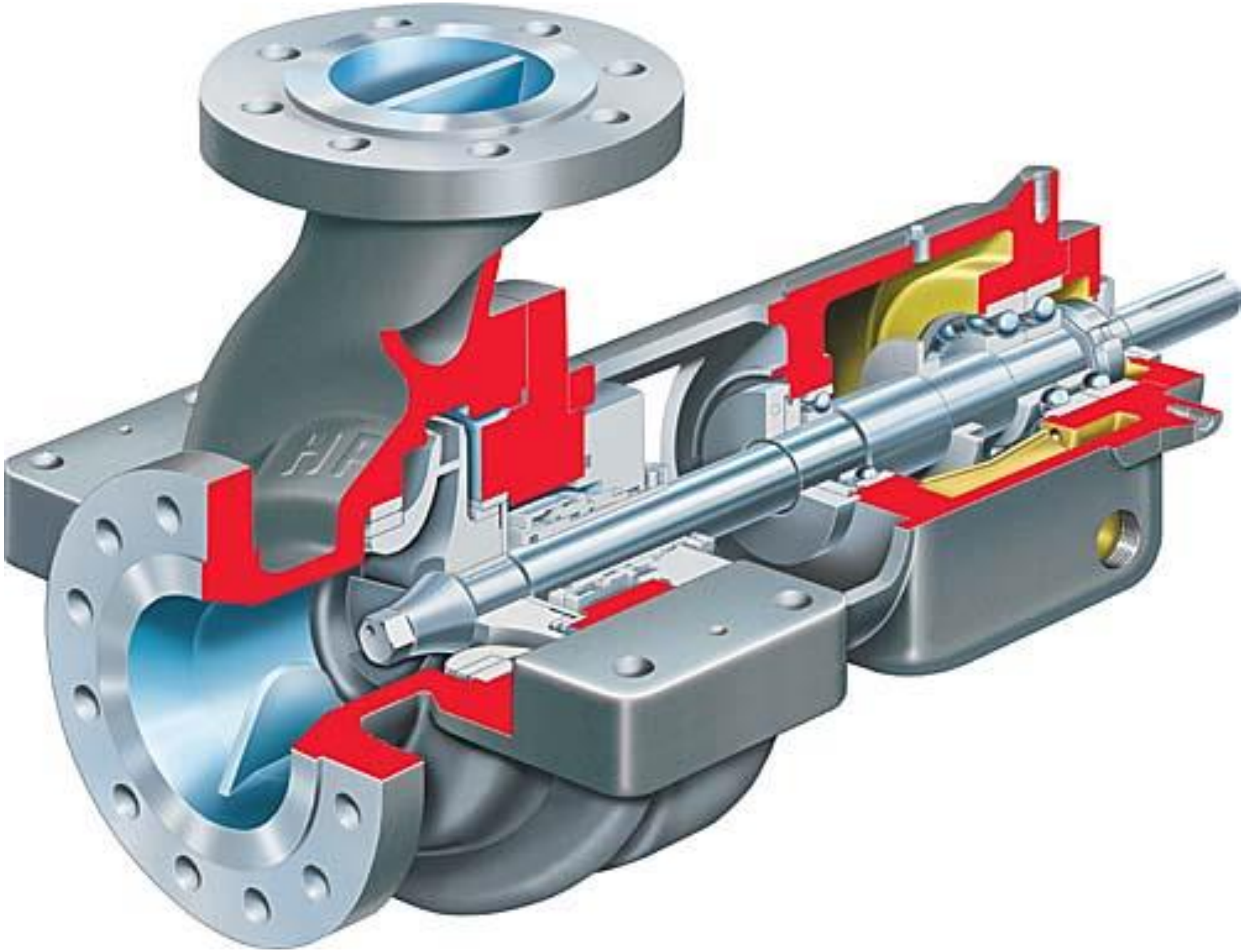
Double Suction Impeller

Impeller Arrangements



Multistage Pump

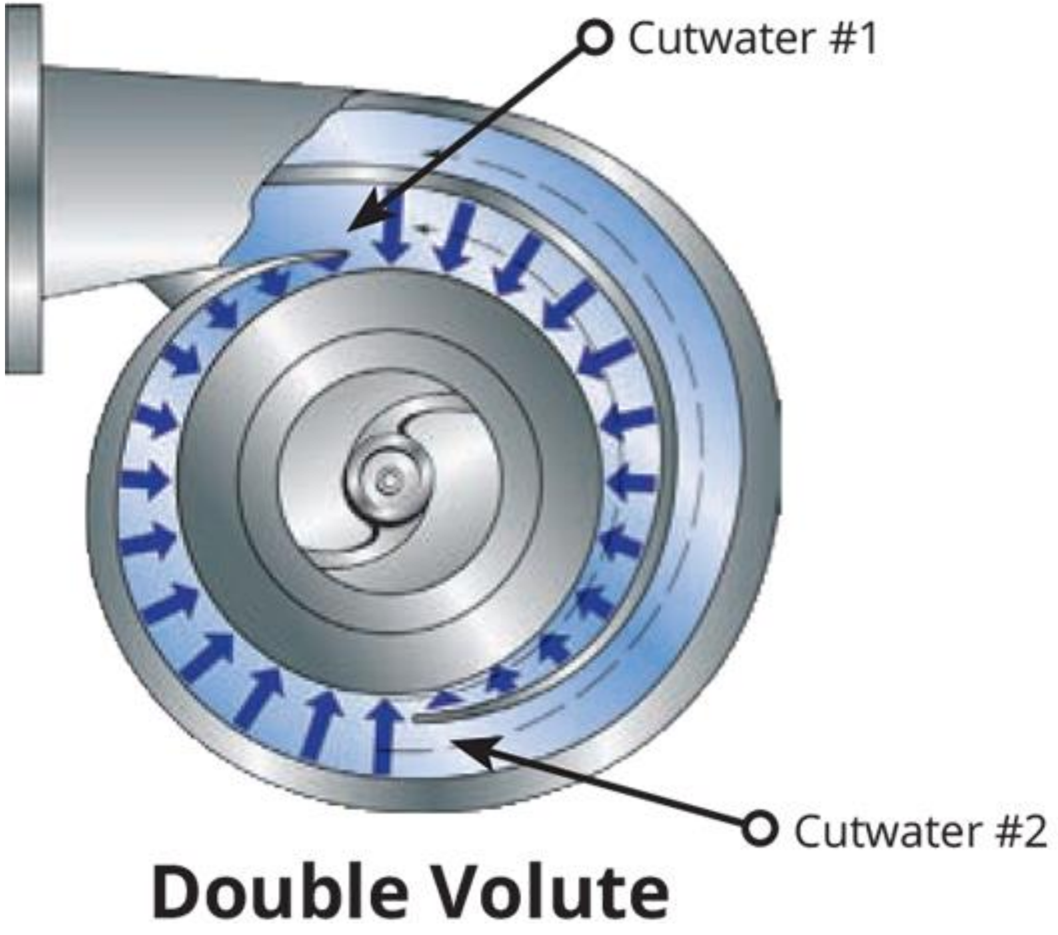
Construction

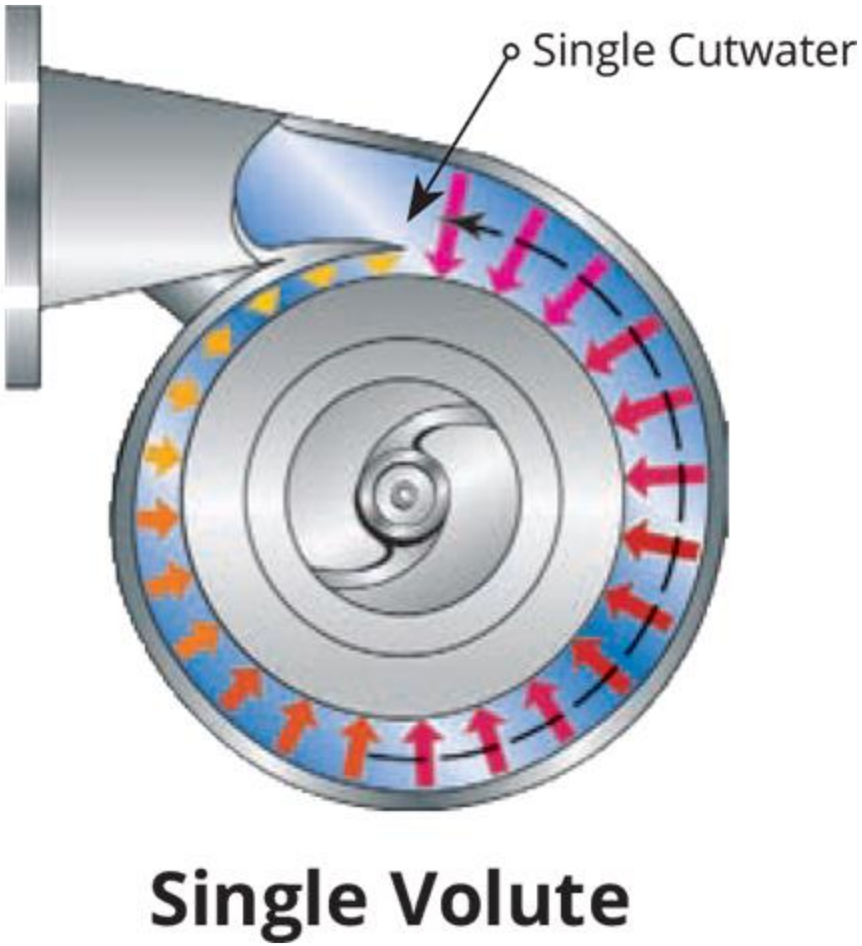


Construction

2- Pump Casing

Volute Casing



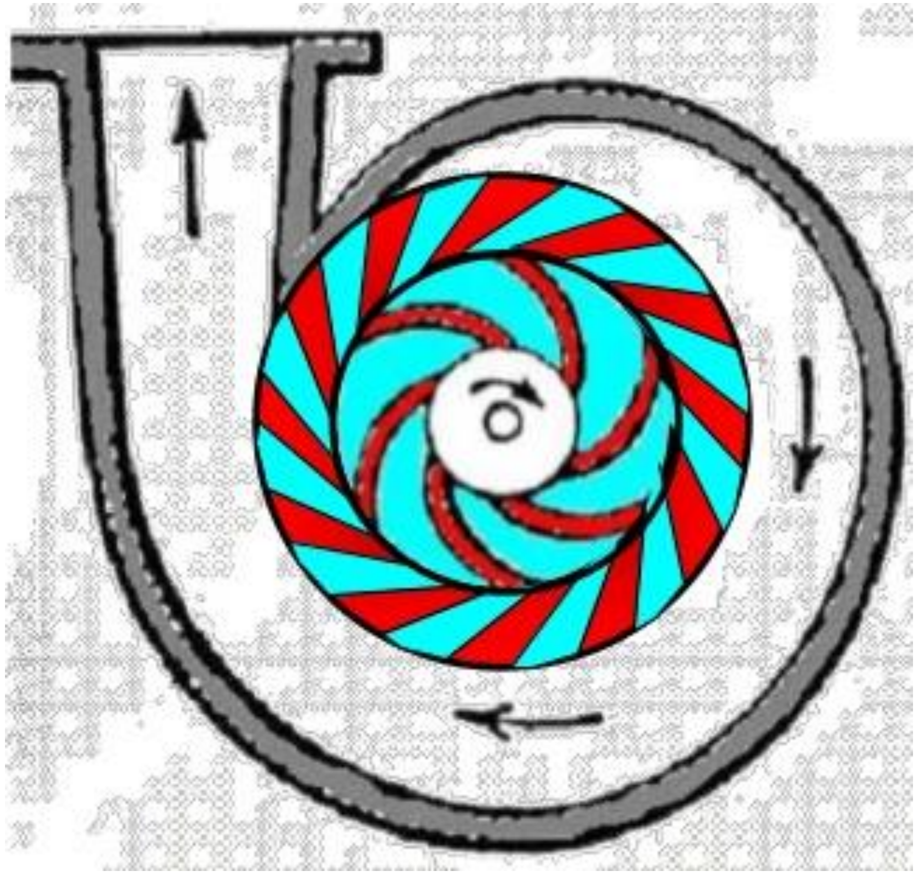


Construction

Volute Casing

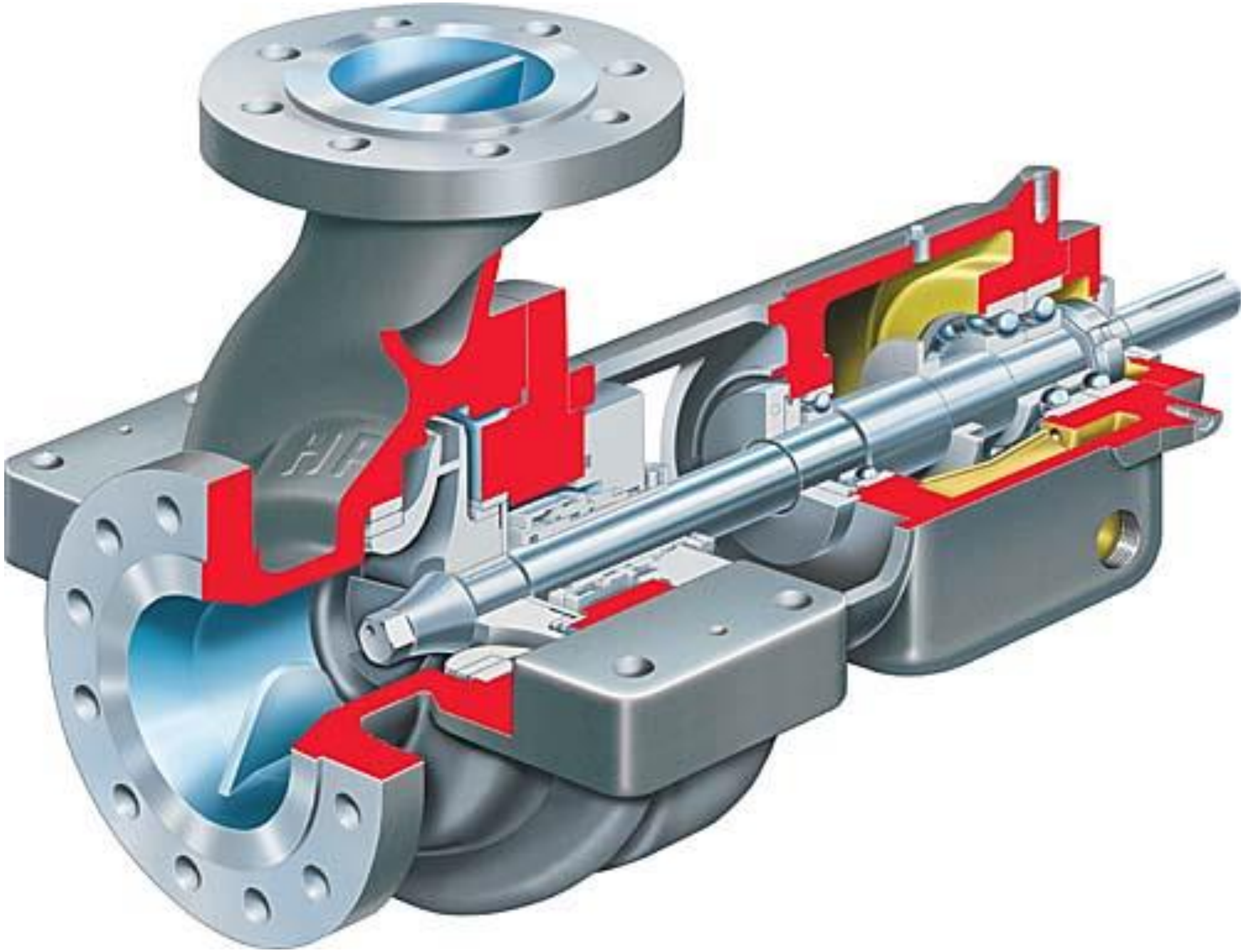
Construction

2- Pump Casing



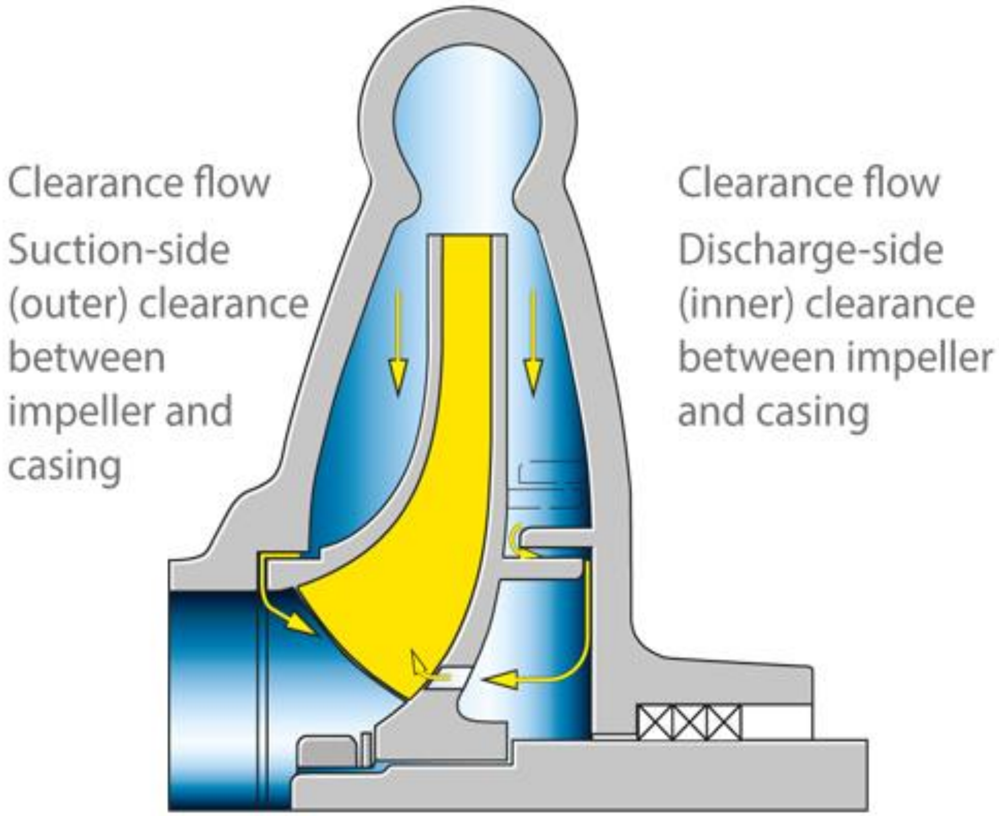
Diffuser Casing

Construction



Construction

3- Wear Rings



- In order to prevent leakage between the rotating impeller and pump casing wear rings are used.
- They are installed on impeller or casing or both. They reduced the clearance between the impeller and the casing to a very small amount.
- The smaller the clearance the smaller amount of liquid transferred from the high pressure discharge side to the low pressure suction side and the higher the efficiency will be.
- They also prevent the wear of pump impeller and/or the casing, hence their name. They are made of soft material that can be sacrificed like bronze or cast iron.

Construction

3- Wear Rings

Construction

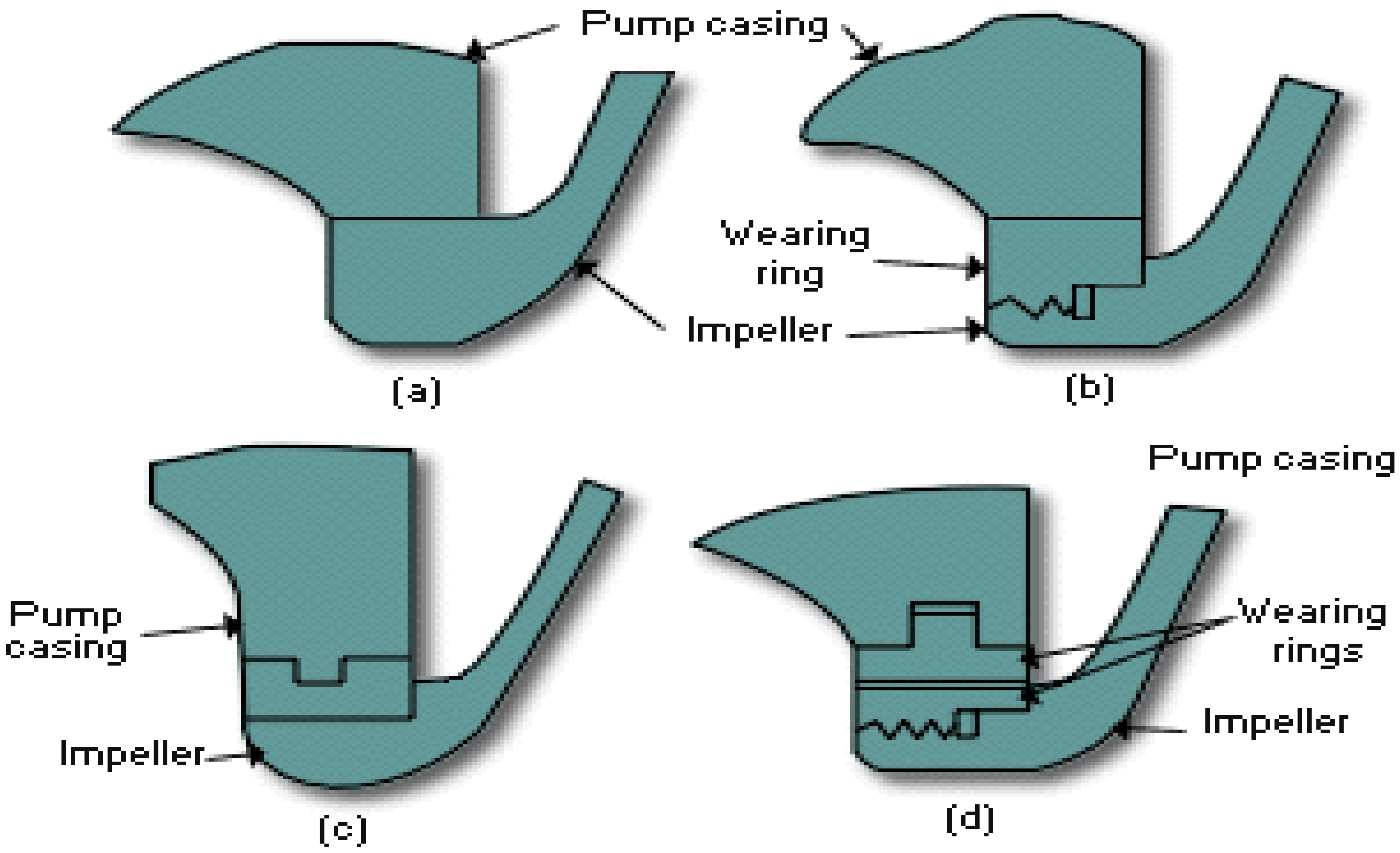
3- Wear Rings

Wearing rings are installed on the hub of the impeller by either threading or shrinking.

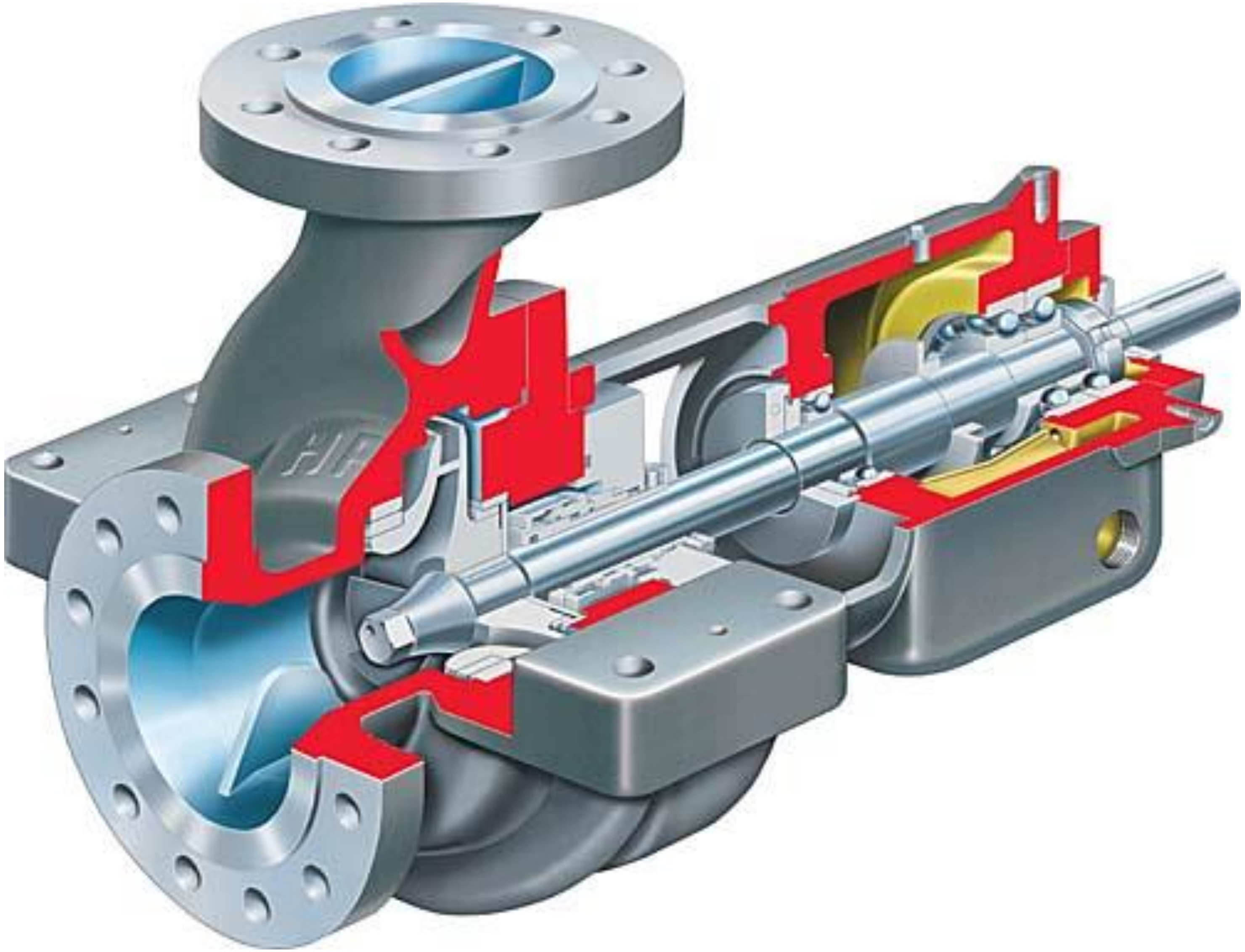
Casing wearing rings consist of either a continuous ring or two half rings which are pressed into place.

The continuous ring is used with vertically split casings while horizontally split casings are equipped with wearing rings consisting of two halves.

Split rings can be fitted onto a ridge or into a groove of the casing which will prevent any axial movement should the rings work loose.



Construction

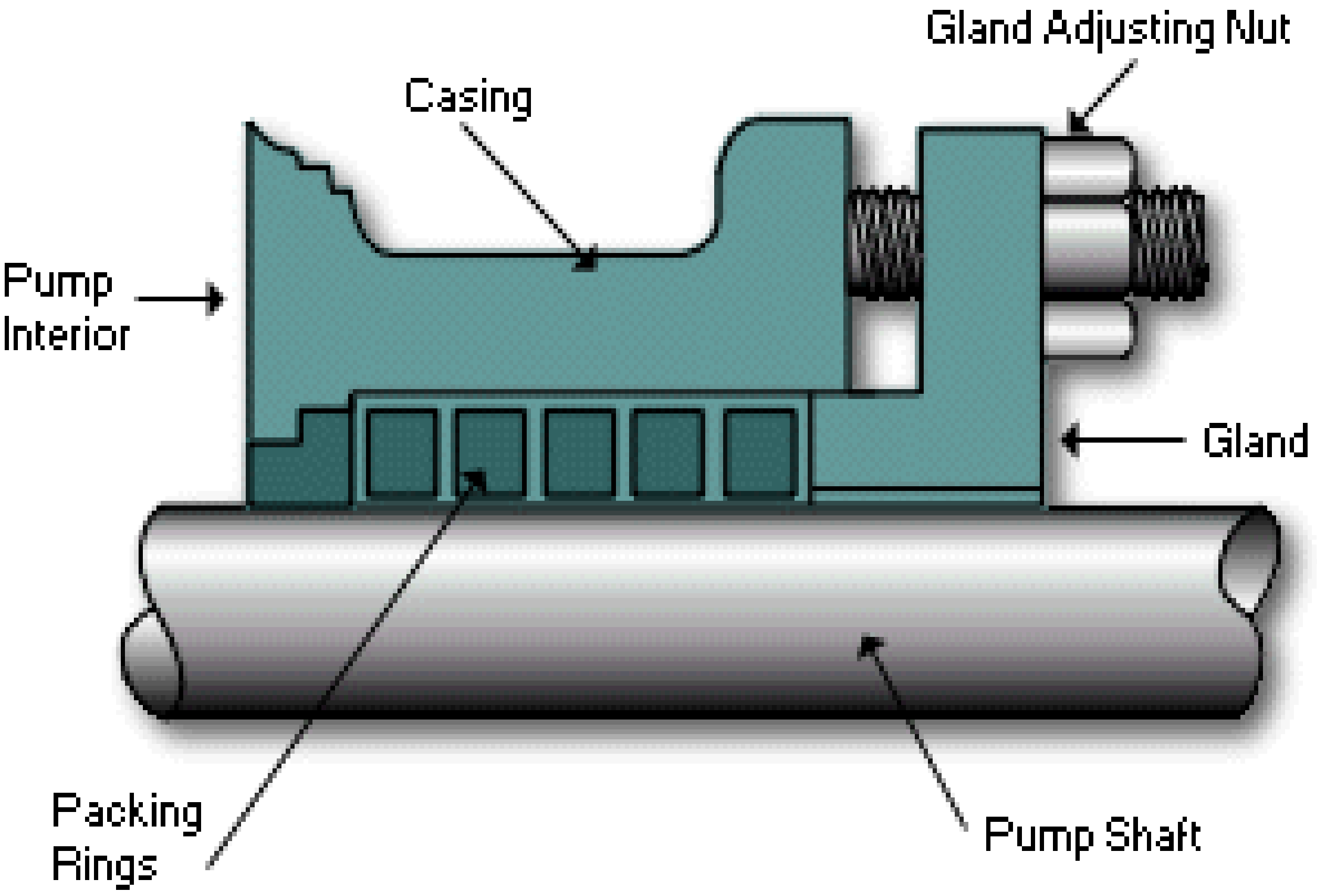


Construction

4- Shaft Sealing

Compression Packing

- Packing is made from a wide variety of materials, some of which are asbestos, nylon, flax, Teflon, lead, copper and aluminum.
- Frequently a lubricating material, called the saturant, such as graphite or grease, is incorporated into the packing material.



Construction

4- Shaft Sealing

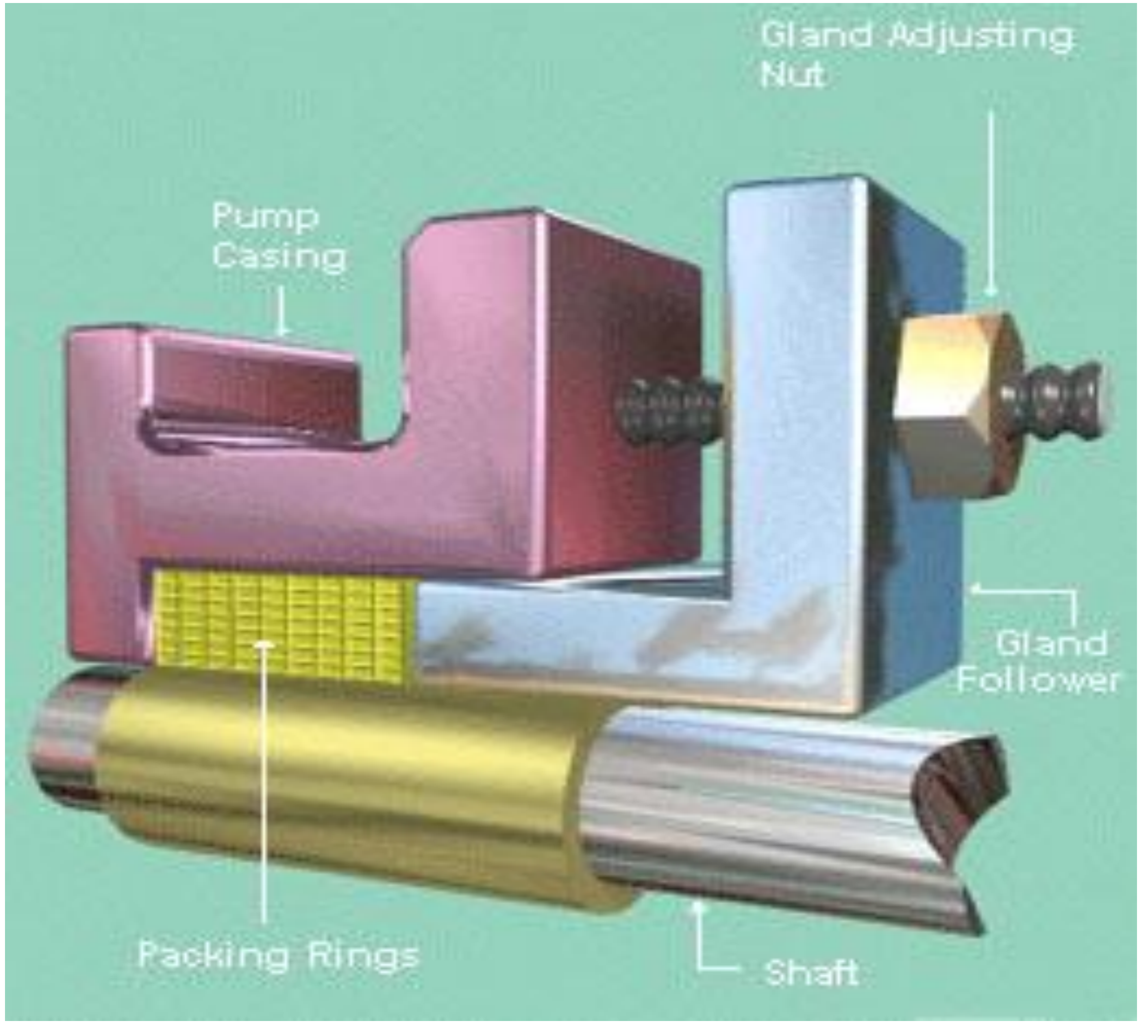
Compression Packing

Construction

4- Shaft Sealing

Compression Packing

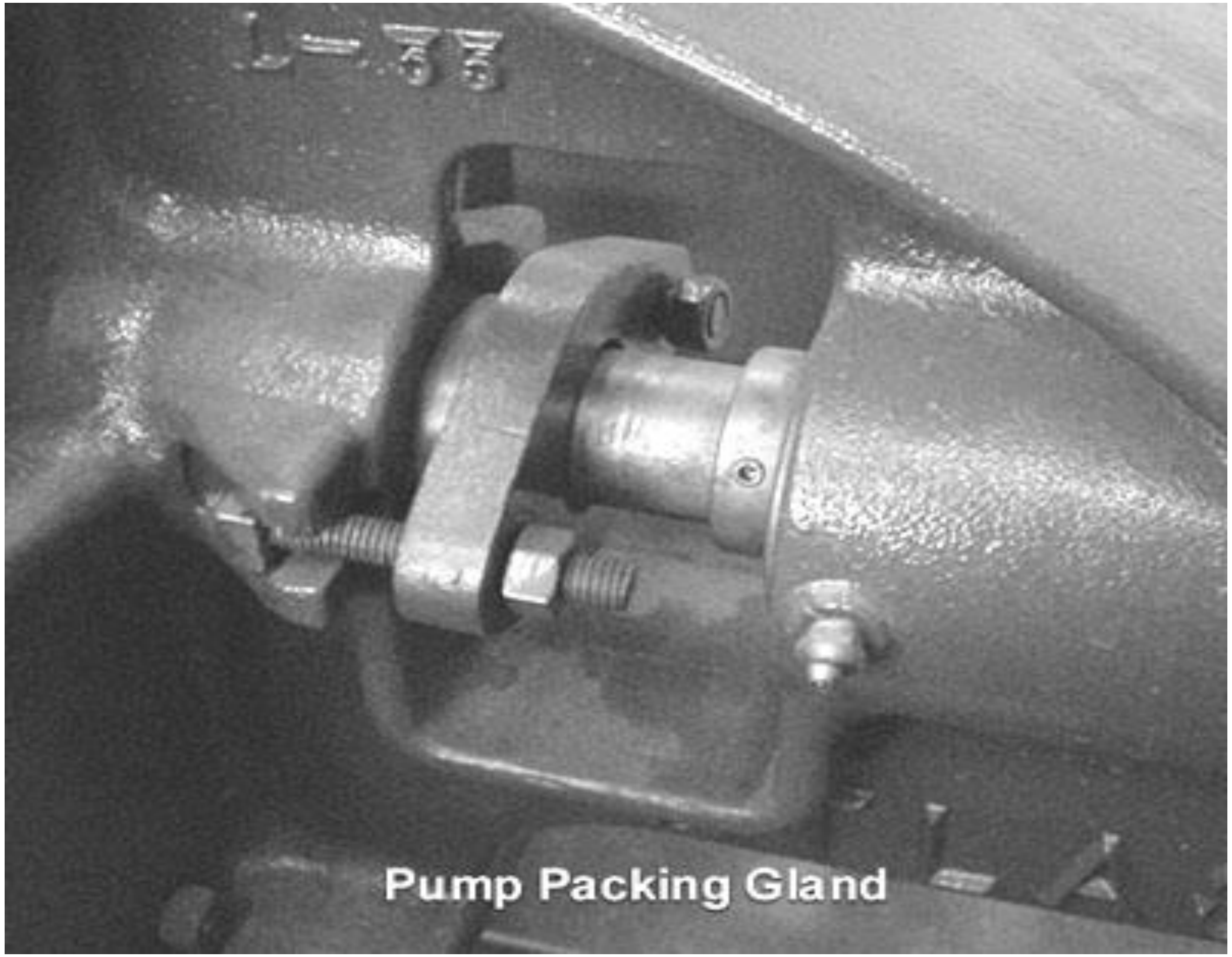
Packing in the stuffing boxes of a centrifugal pump is not supposed to stop leakage entirely, it only should throttle the fluid. The reason for this is that the packing acts as a bearing and must be lubricated as such. Lubrication comes from slight leakage of fluid from the pump or, in emergency, from a lubricant in the packing. It is sometimes necessary to provide lubricant from an outside source.



Construction

4- Shaft Sealing

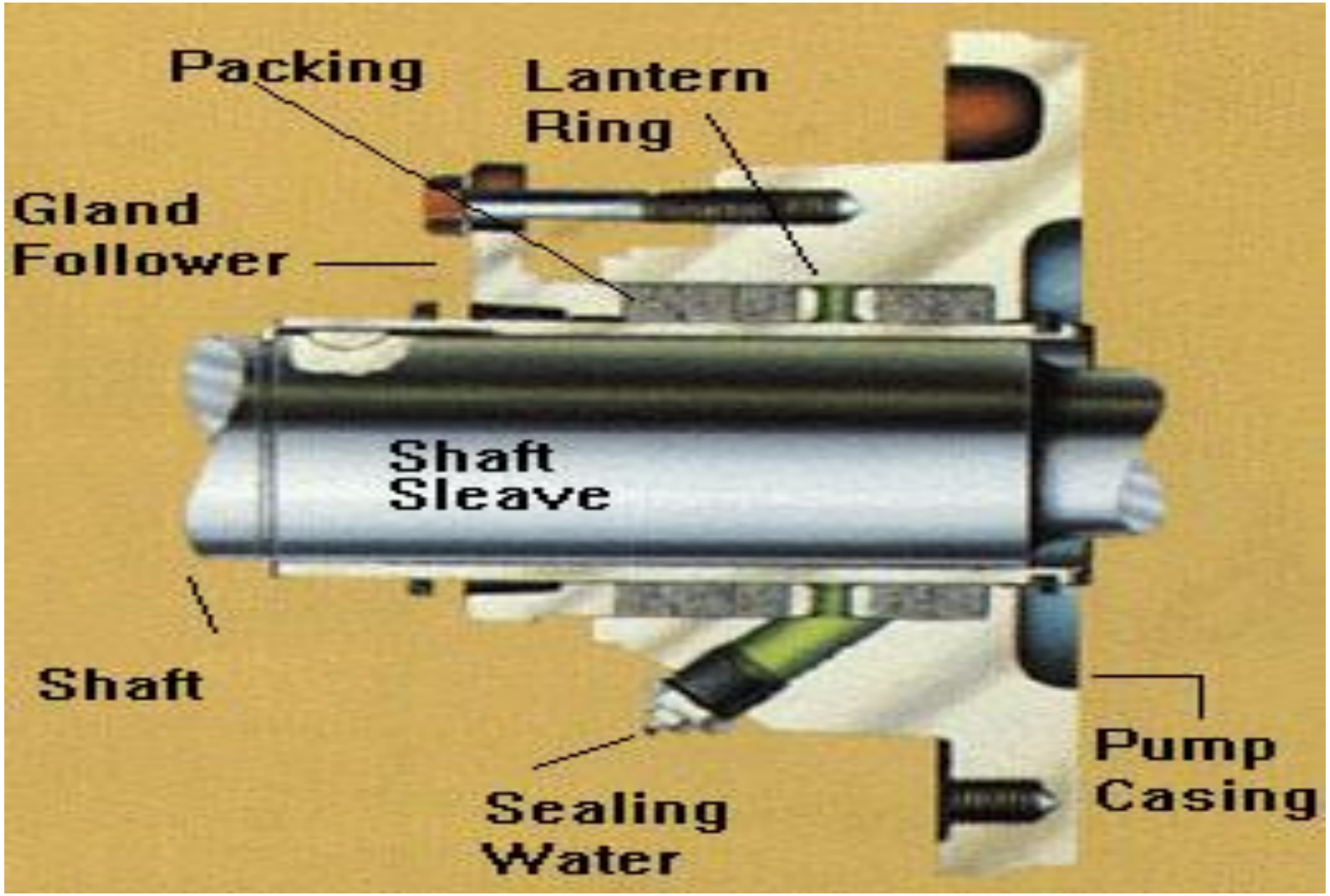
Compression Packing



Construction

4- Shaft Sealing

Compression Packing

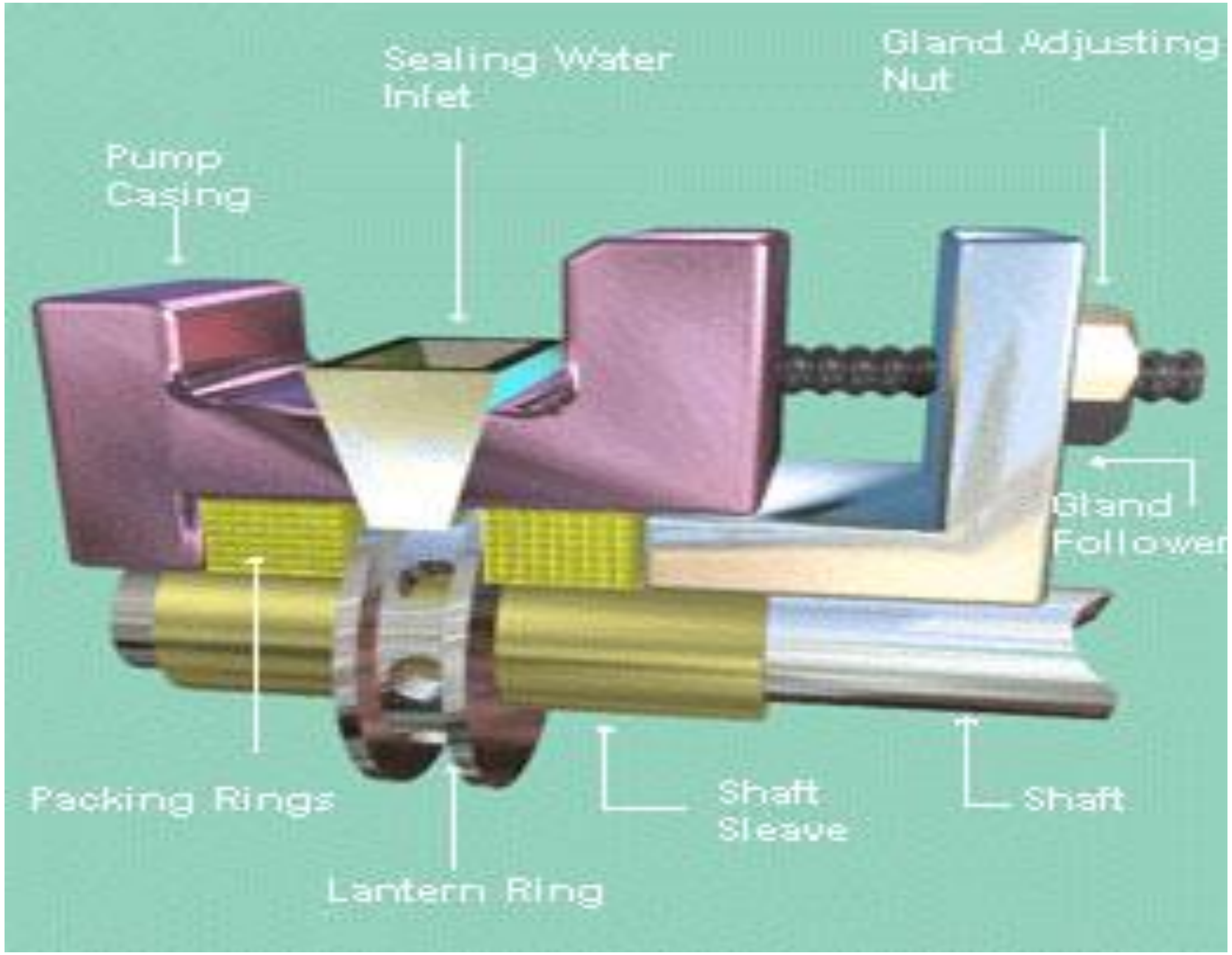


Construction

4- Shaft Sealing

Compression Packing

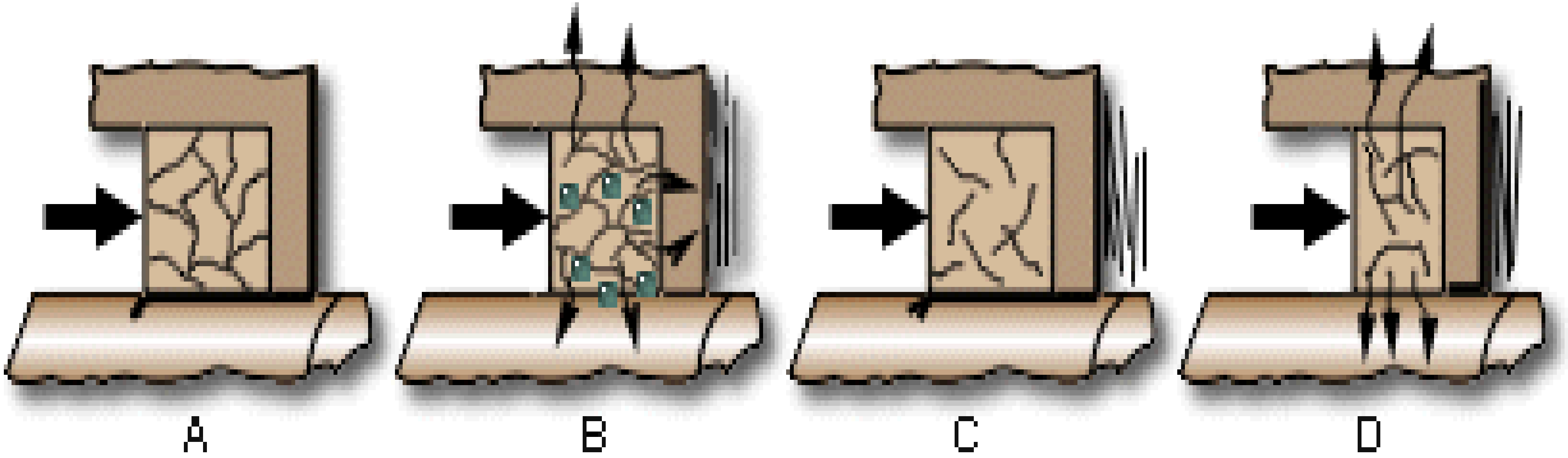
The lantern ring (also called the seal cage) is a metal ring having radial holes and it serves to distribute the sealing water to the packing. The sealing water not only helps to prevent air leakage but also lubricates the packing and this water is usually supplied from a higher pressure section of the pump. In cases where the pump is pumping water containing sand or grit or other abrasives, then clean sealing water may be supplied from a separate source.



Construction

4- Shaft Sealing

Compression Packing

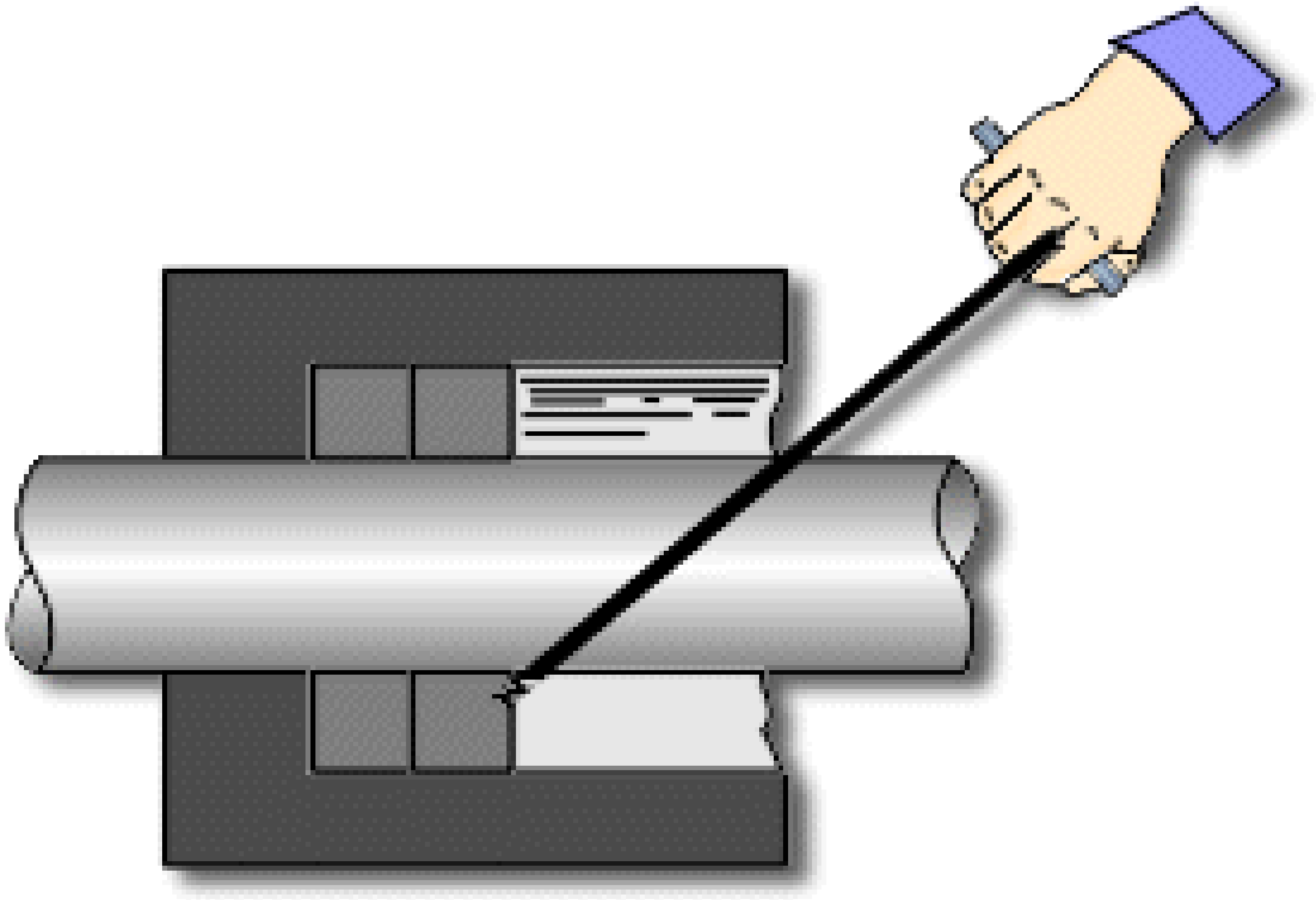


Construction

4- Shaft Sealing

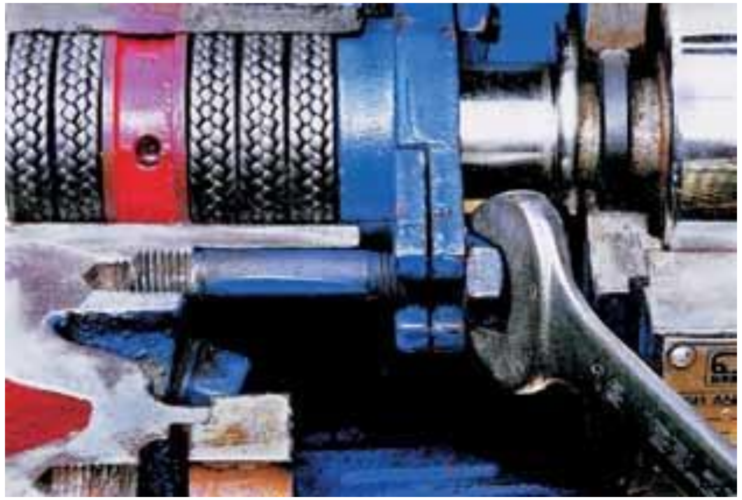
Compression Packing

Pump packing has to be replaced periodically due to its deterioration from being compressed and from loss of saturant. How often this has to be done will depend upon the operating conditions of the pump, the quality of the packing used, and the care with which the packing was installed and adjusted. The frequency of replacement of the packing may vary between a matter of months in the case of severe operating conditions, to several years under more moderate conditions.



Construction

4- Shaft Sealing



Compression Packing Replacement

The recommended steps for replacing packing are as follows:

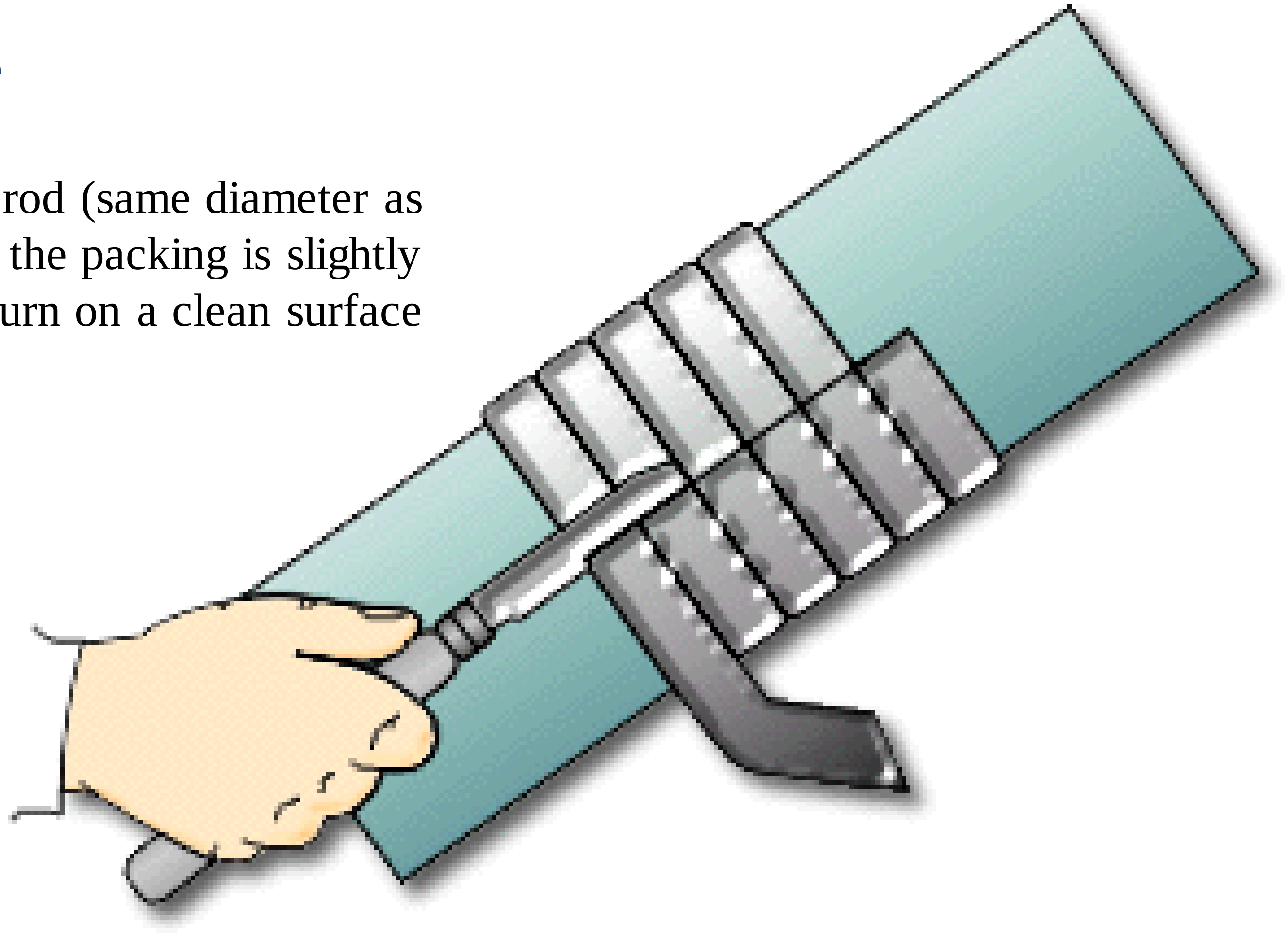
- Shut down, isolate and drain pump. Make sure pump motor switch is locked open or fuses removed and switch tagged with a "Do Not Operate" warning tag.
- Remove gland adjusting nuts and slide gland away from the stuffing box. Then remove all the old packing using some type of packing hook. Make sure the stuffing box is thoroughly clean and free from any small pieces of old packing. Check that the sealing water connection to stuffing box is clear.
- Check the conditions of the shaft or the shaft sleeve if a sleeve is installed over the shaft. If the surface is grooved or scored, then it should be replaced as any rough surface will damage the packing.
- To determine the correct size (thickness) of packing to use, measure the bore of the stuffing box and subtract the diameter of the pump shaft and divide the difference by two.

Construction

4- Shaft Sealing

Compression Packing Replaceme

- Then wrap a coil of the correct size packing around a rod (same diameter as shaft and held in a vise) and cut through each turn. If the packing is slightly too large, never flatten it with a hammer. Place each turn on a clean surface and roll it out with a piece of pipe.

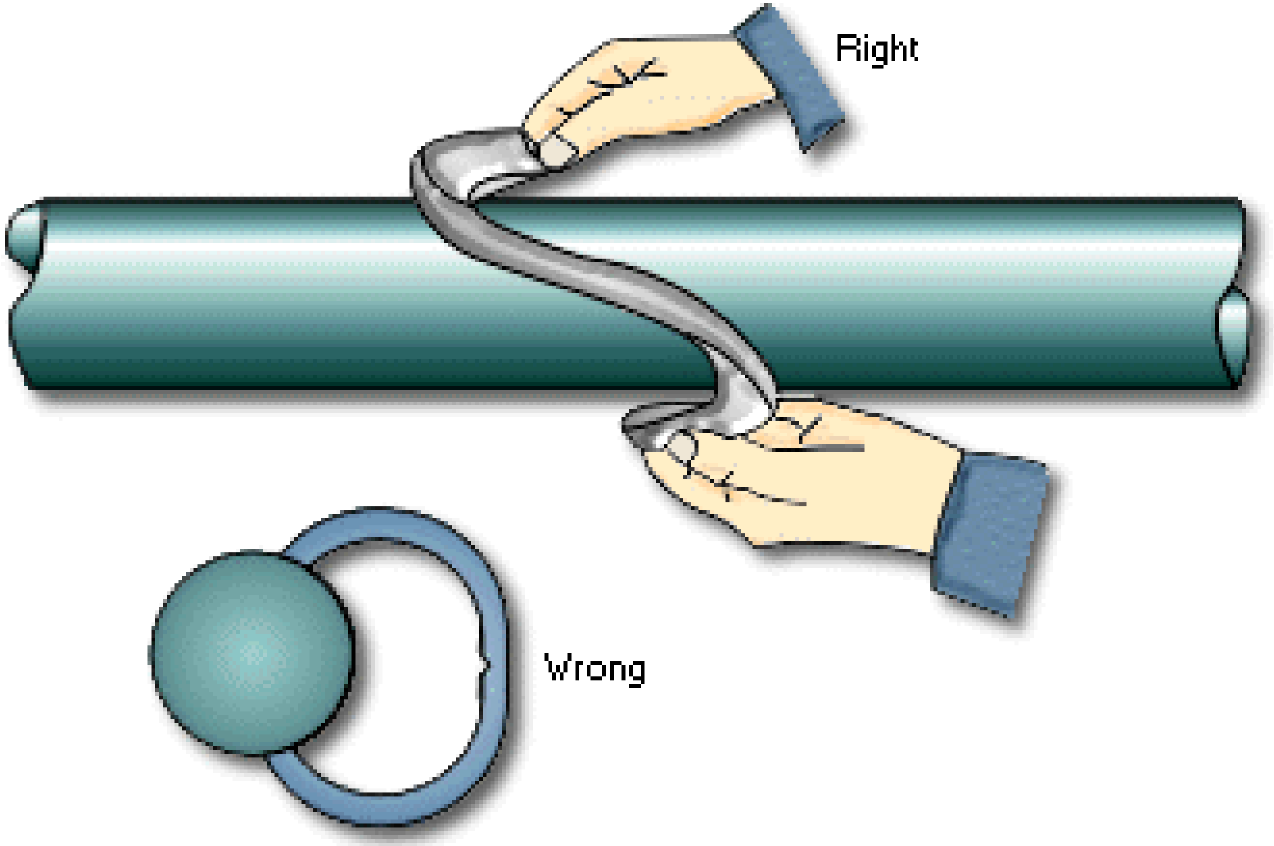


Construction

4- Shaft Sealing

Compression Packing Replacement

- Install the packing rings one at a time after putting a light coating of oil or grease on the inner diameter of each ring. Slide each ring sideways over the shaft. to prevent breaking of the ring.

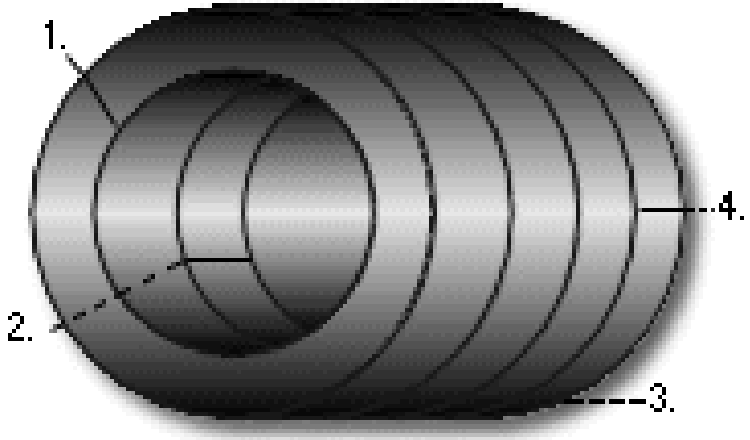


Construction

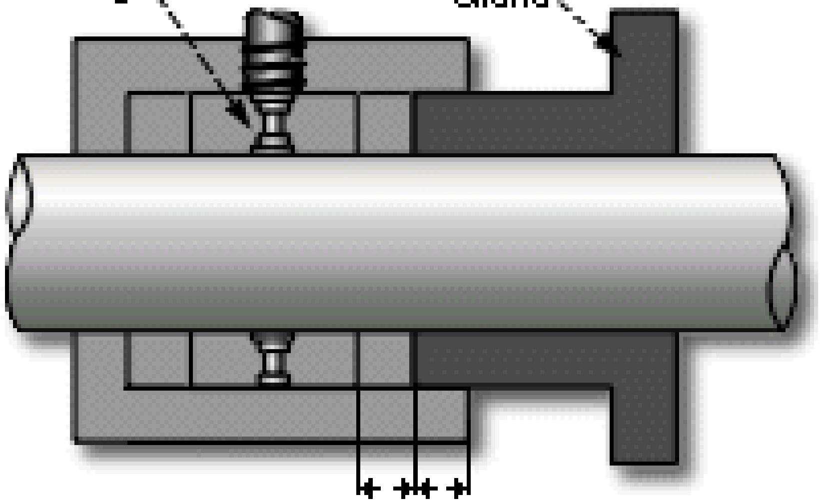
4- Shaft Sealing

Compression Packing Replacement

- Tamp the rings into place one at a time using a split wooden bushing or metal ring to push each ring into the stuffing box.
- Make sure the ring joints are staggered and the lantern ring lines up properly with the sealing water inlet.



Staggered Ring Joints
(a)



Lantern Ring Location
(b)

Construction

4- Shaft Sealing

Compression Packing Replacement

- Put packing follower in place and compress the packing slightly by tightening the gland nuts. Then slacken off to just finger tight to allow for packing expansion. In the case of small pumps the shaft should turn freely by hand.
- The packing should be allowed to leak freely when the pump is first started. After about twenty minutes of running the follower should be gradually tightened until only the necessary operating leakage is apparent.
- The above method of installation of packing in stuffing boxes is essentially the same for centrifugal, rotary and reciprocating pumps.

Construction

4- Shaft Sealing

Mechanical Seal

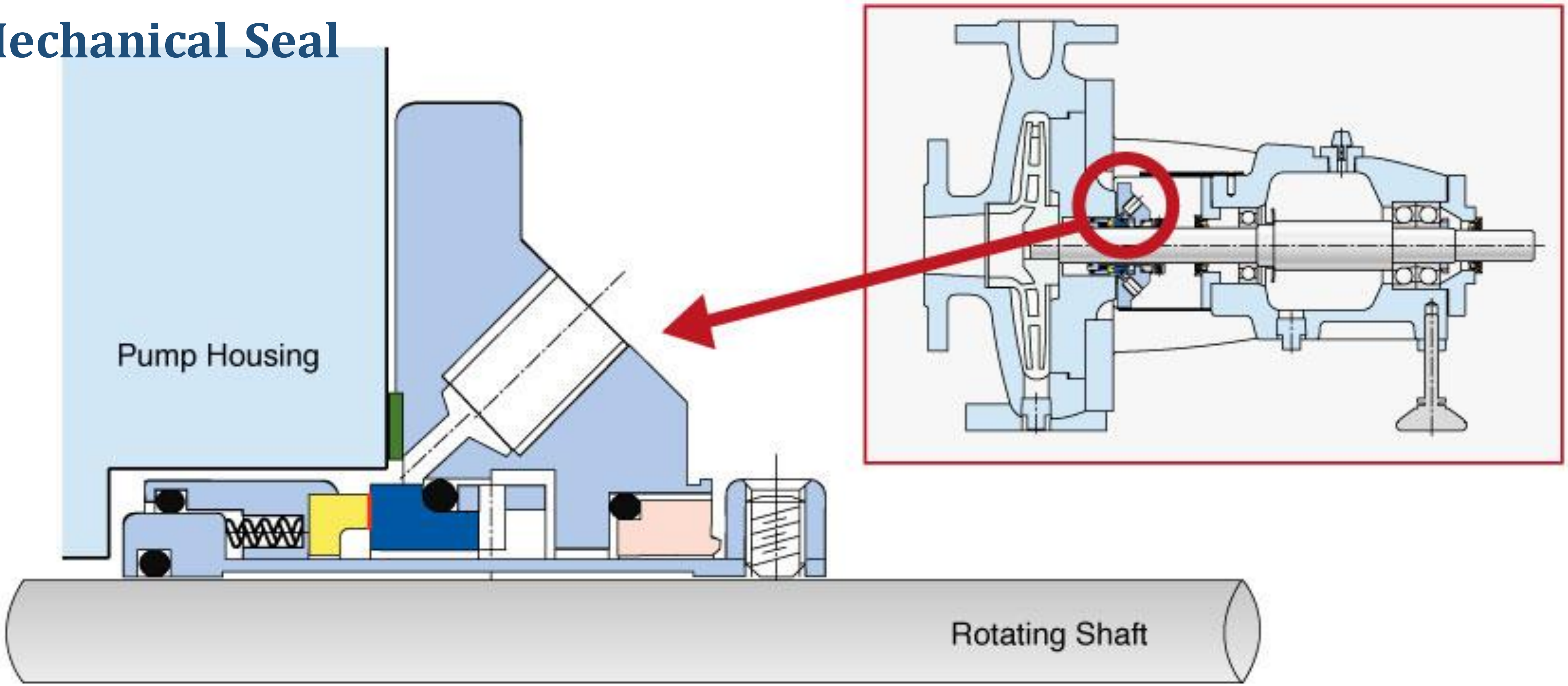
Instead of employing a stuffing box with packing, many pumps use mechanical seals to prevent leakage along the shaft. Mechanical seals have the following advantages over packing.

1. They require much less maintenance.
2. They do not produce wear of shafts or shaft sleeves as do packing rings.
3. They reduce leakage to a minimum.
4. They can be designed to work under very high temperatures and pressures.

Construction

4- Shaft Sealing

Mechanical Seal

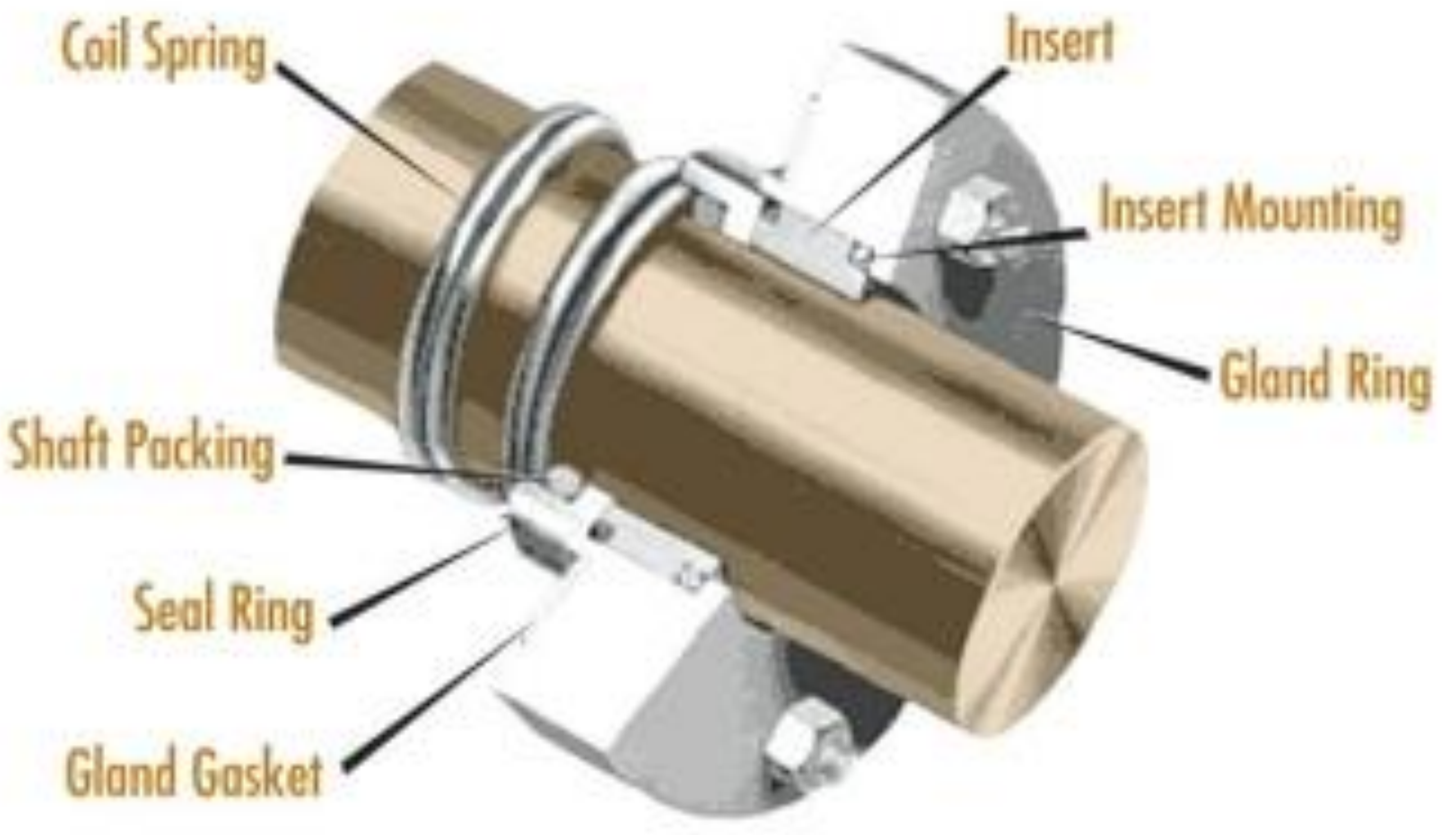


Construction

4- Shaft Sealing

Mechanical Seal

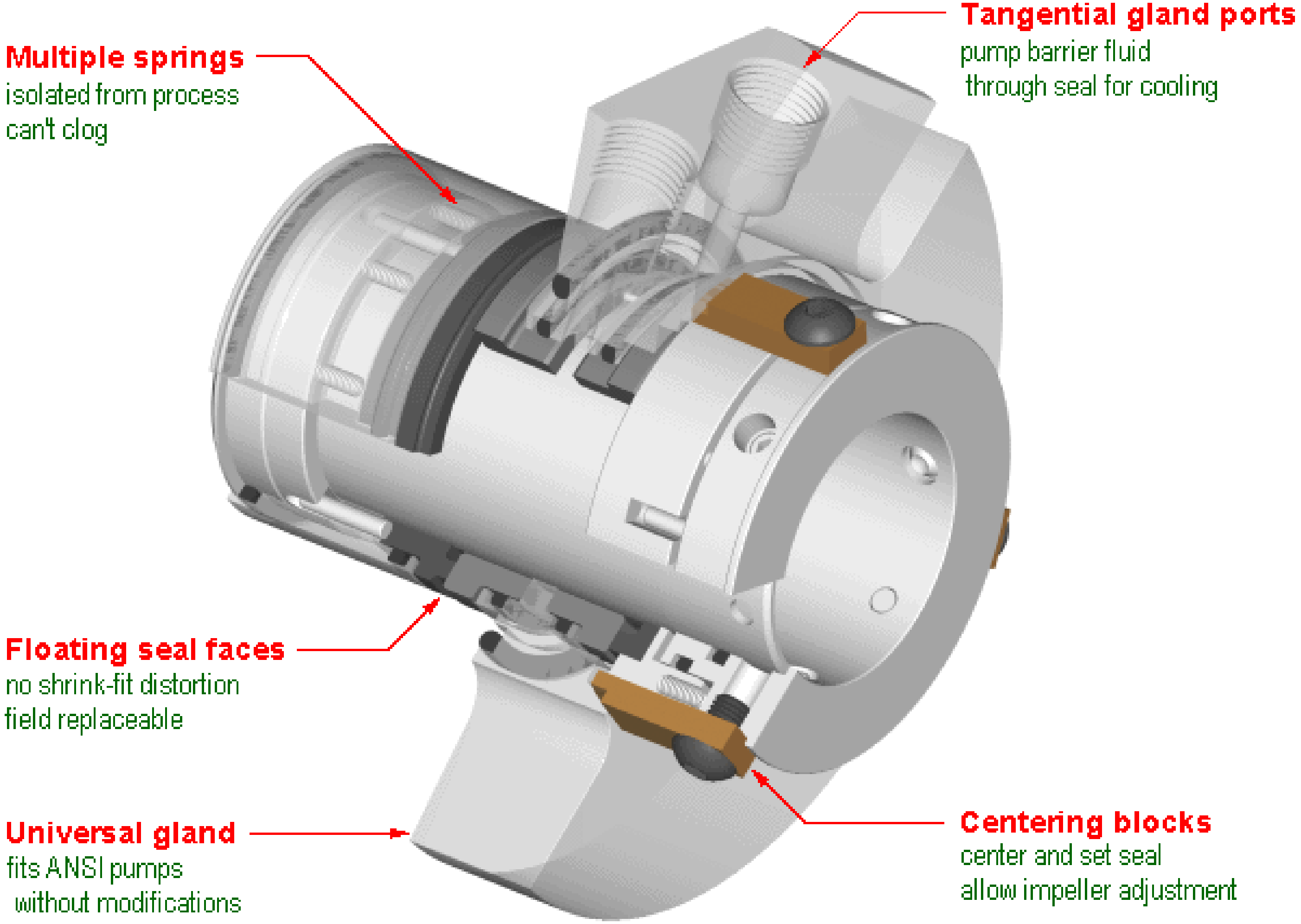
Figure 1: Single Typical Mechanical Shaft Seal



Construction

4- Shaft Sealing

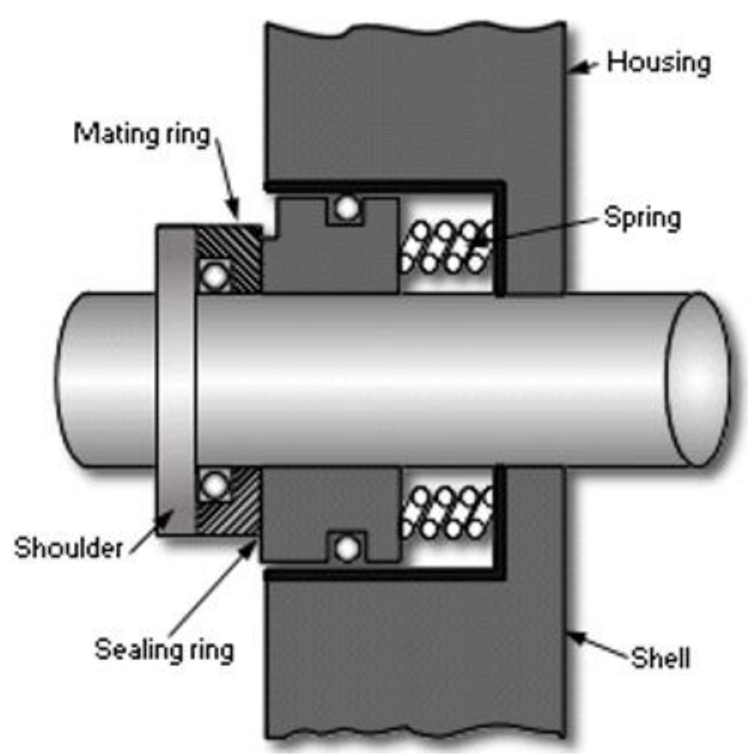
Mechanical Seal



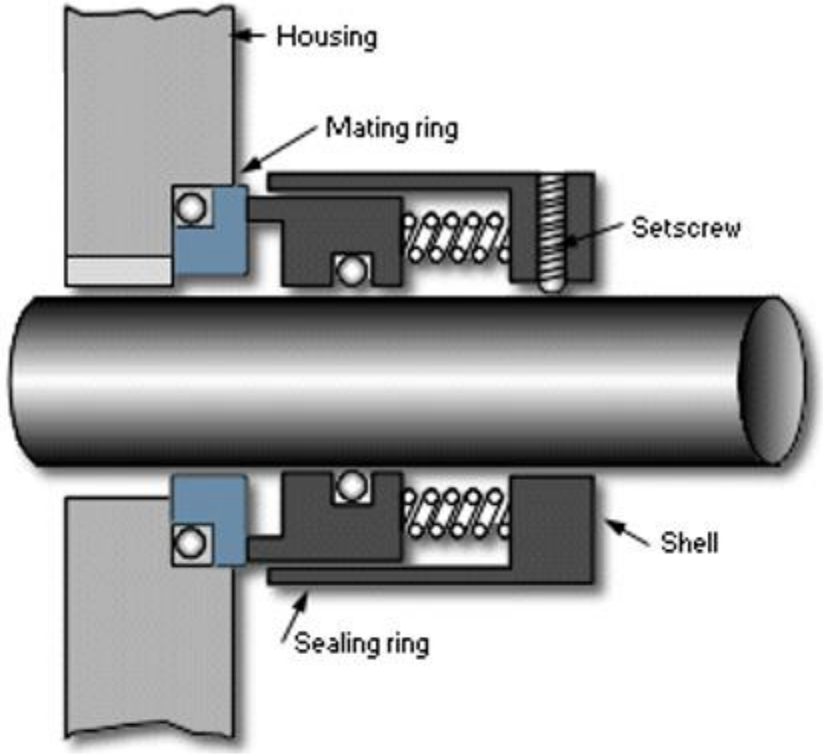
Construction

4- Shaft Sealing

Mechanical Seal



Stationary Seal



Rotating Seal

Construction

4- Shaft Sealing

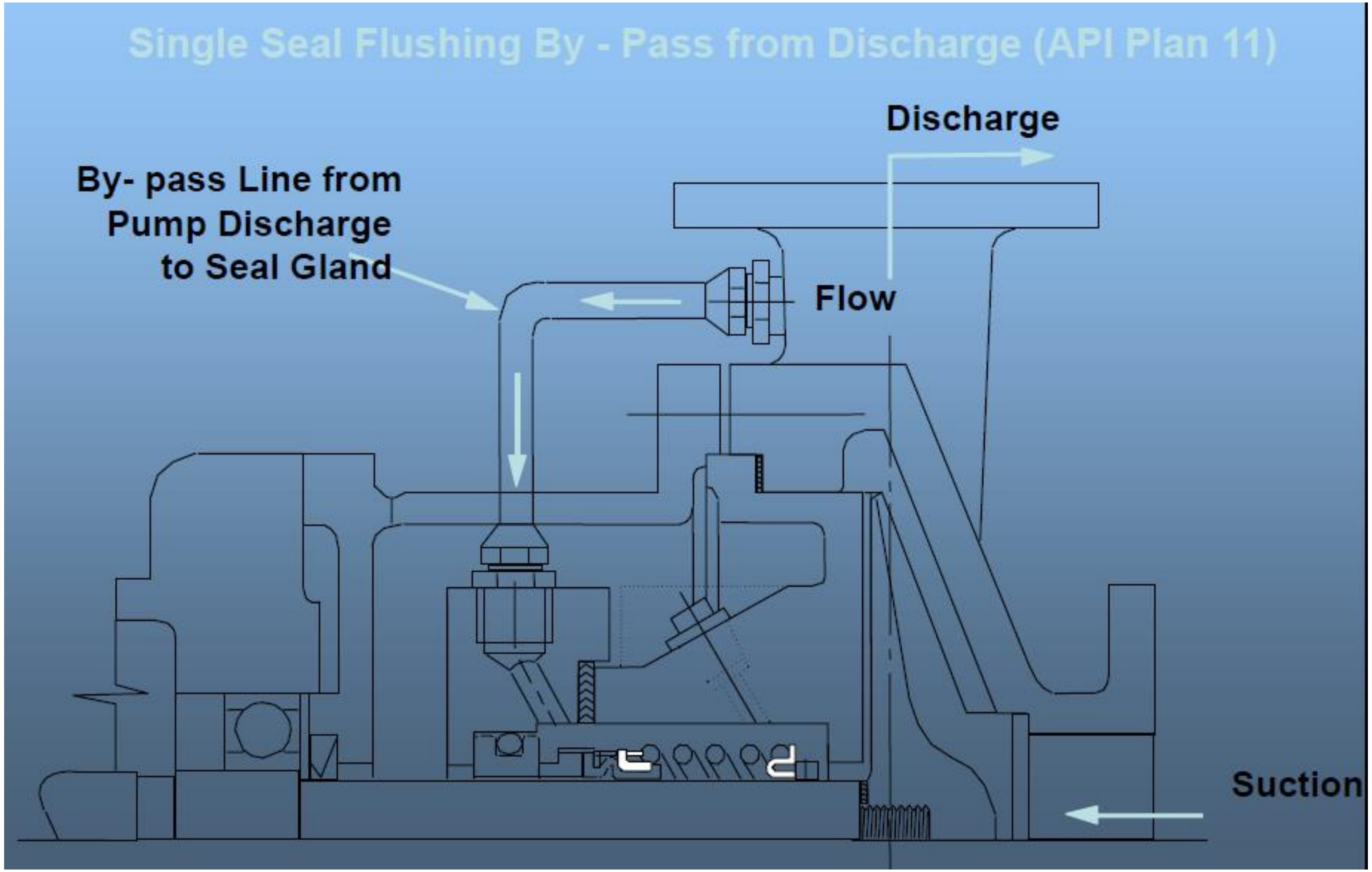
Mechanical Seal

On the other hand, mechanical seals have a greater first cost than packing, and when they fail, the pump must be taken out of service for a longer period to replace the seal than would be necessary with the simple stuffing box and packing method.

Construction

4- Shaft Sealing

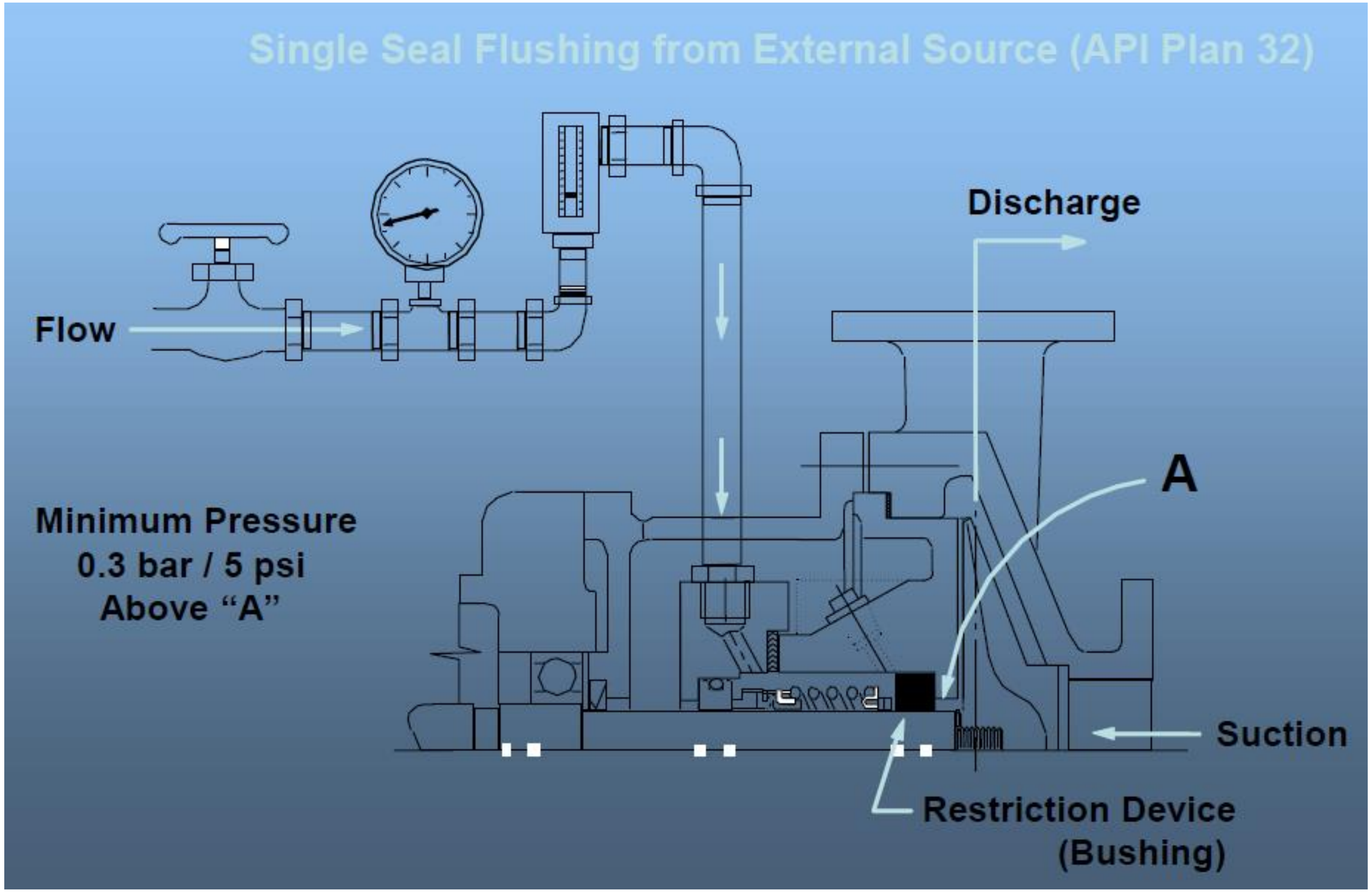
Mechanical Seal



Construction

4- Shaft Sealing

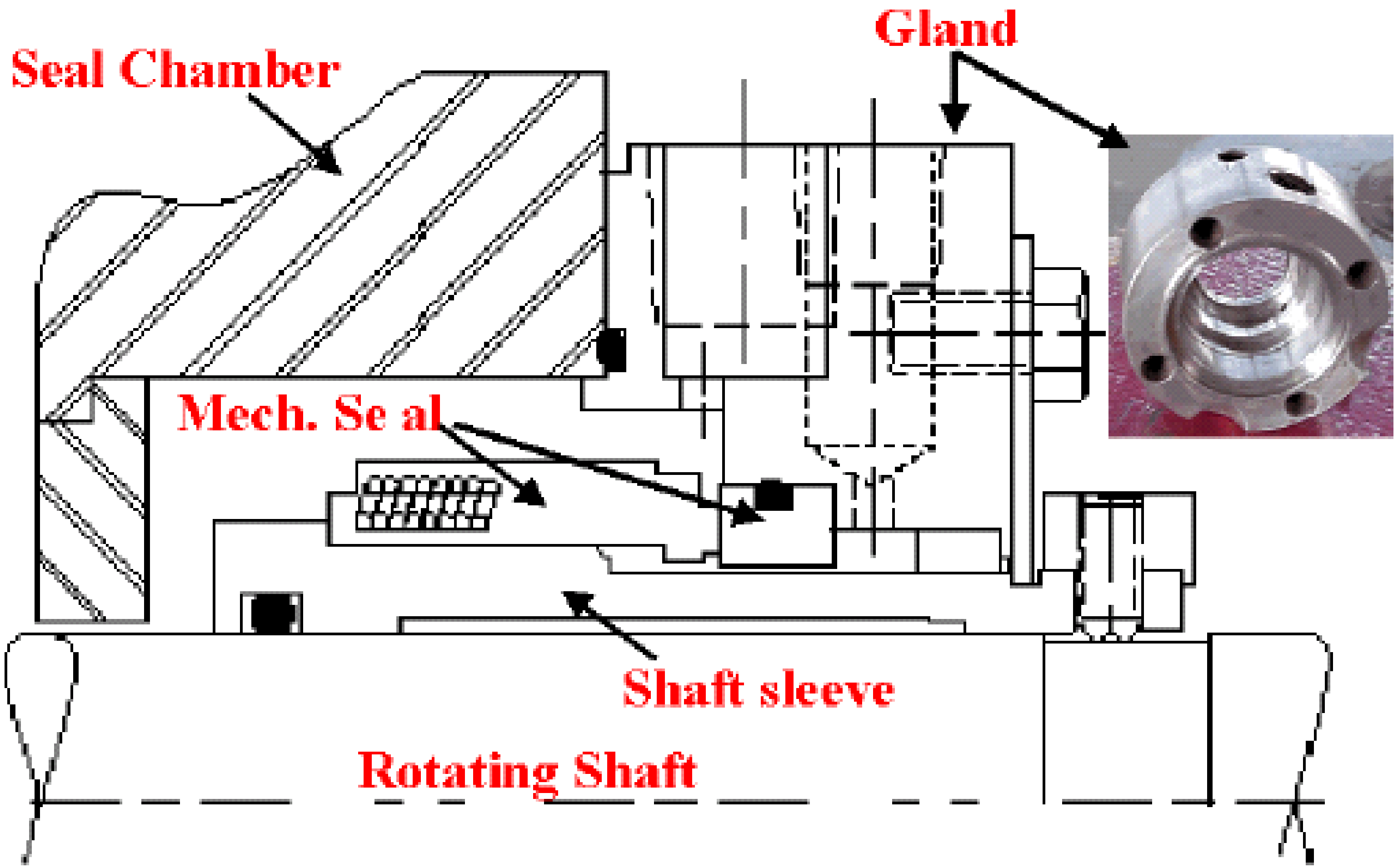
Mechanical Seal



Construction

4- Shaft Sealing

Mechanical Seal



Seal Chamber housing a single mech. seal

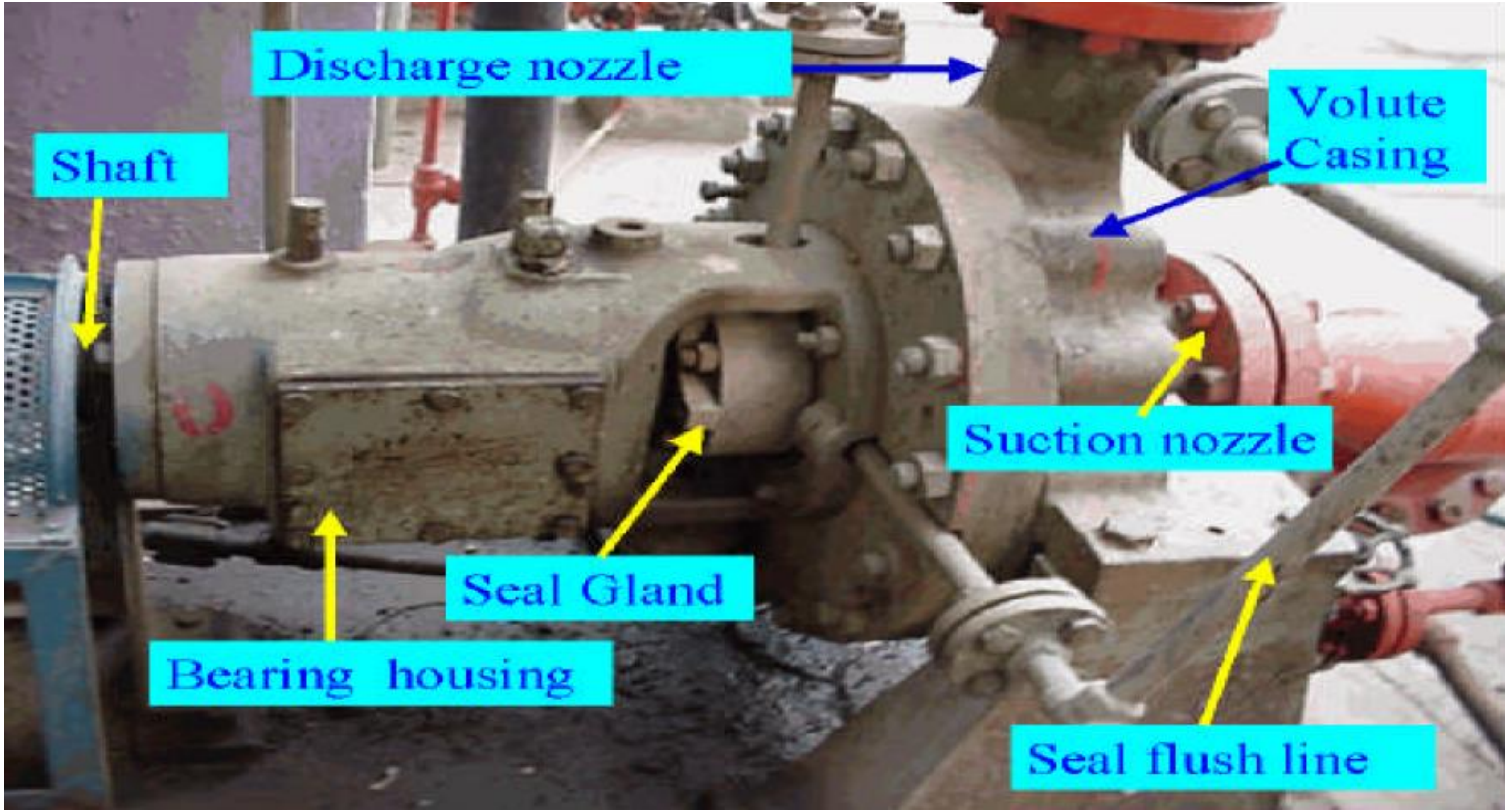
Construction

4- Shaft Sealing

Mechanical Seal

- The materials chosen for the sealing and mating rings depend upon such things as the type of liquid being pumped, its temperature, its pressure, pump speed and seal design.
- Materials frequently used by various seal manufacturers are bronze, carbon graphite, ceramics, stellite, and tungsten carbide.

Construction



Construction

4- Shaft Sealing

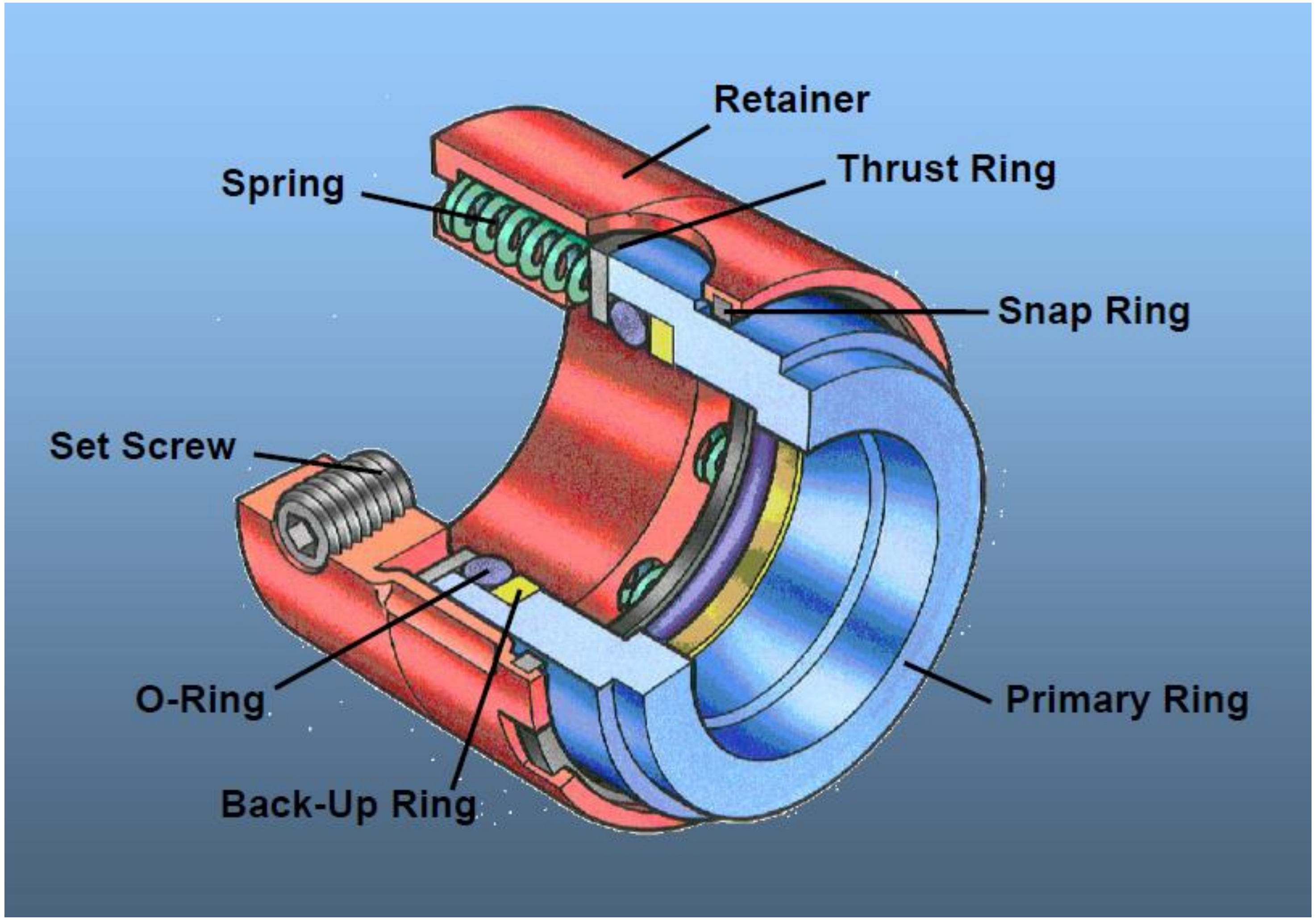
Mechanical Seal

Tandem Type

Construction

4- Shaft Sealing

Mechanical Seal

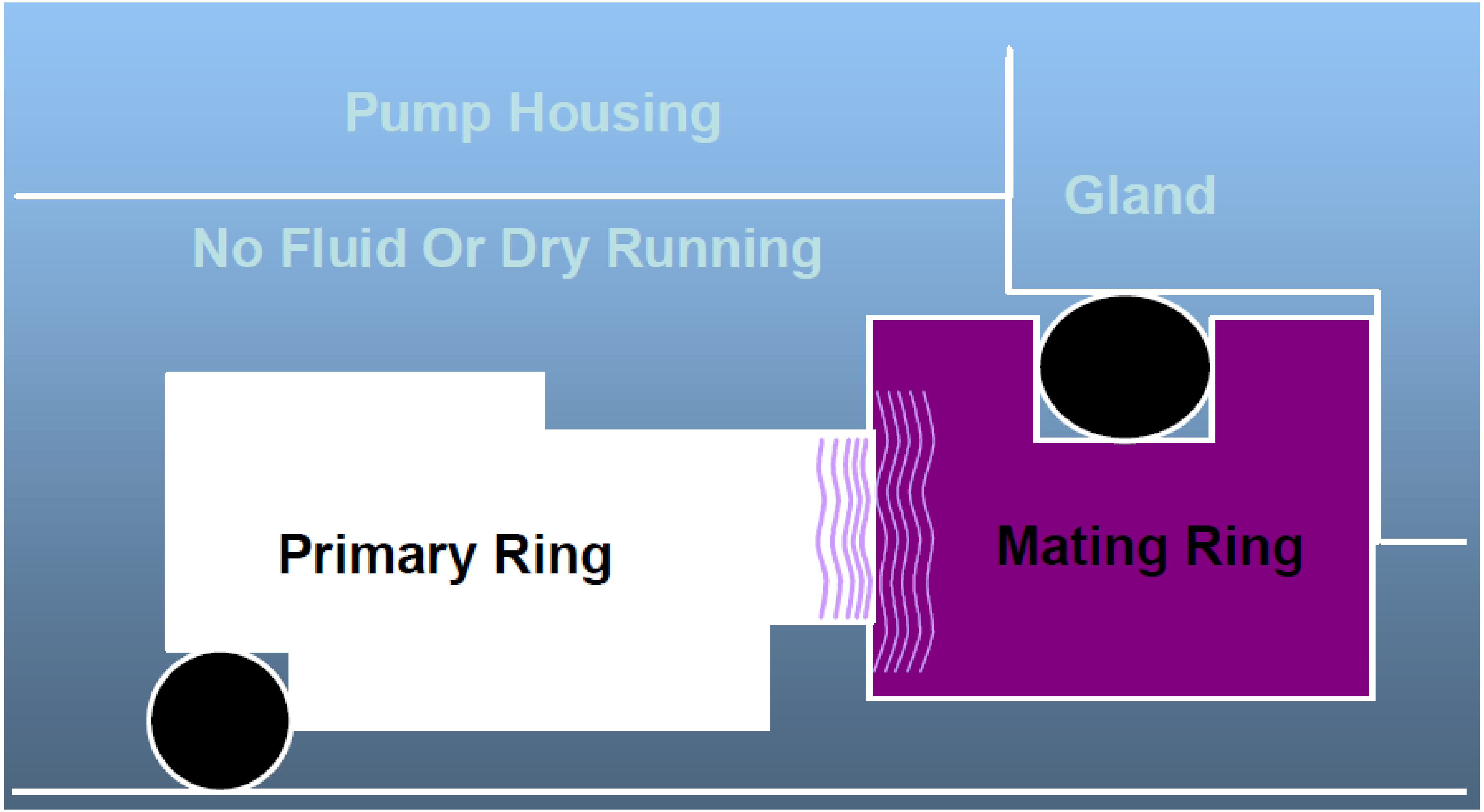


Construction

4- Shaft Sealing

Mechanical Seal

Dry Running ?



Construction

4- Shaft Sealing

Mechanical Seal

Heat Generation

- Rubbing
- Viscous Shear

Construction

4- Shaft Sealing

Mechanical Seal

Care of Mechanical Seals

It is extremely important that the seals never run in a dry condition, otherwise the faces will become grooved and scored. The following precautions should therefore be followed:

1. Never run the pump in a dry condition even for a few minutes.
2. Vent any air present from the seal housing before start up.
3. Make sure an adequate flow of quenching or cooling liquid is flowing to the seal.

A squealing sound is an indication of a dry seal but this sound is not always present if the seal runs dry.

Construction

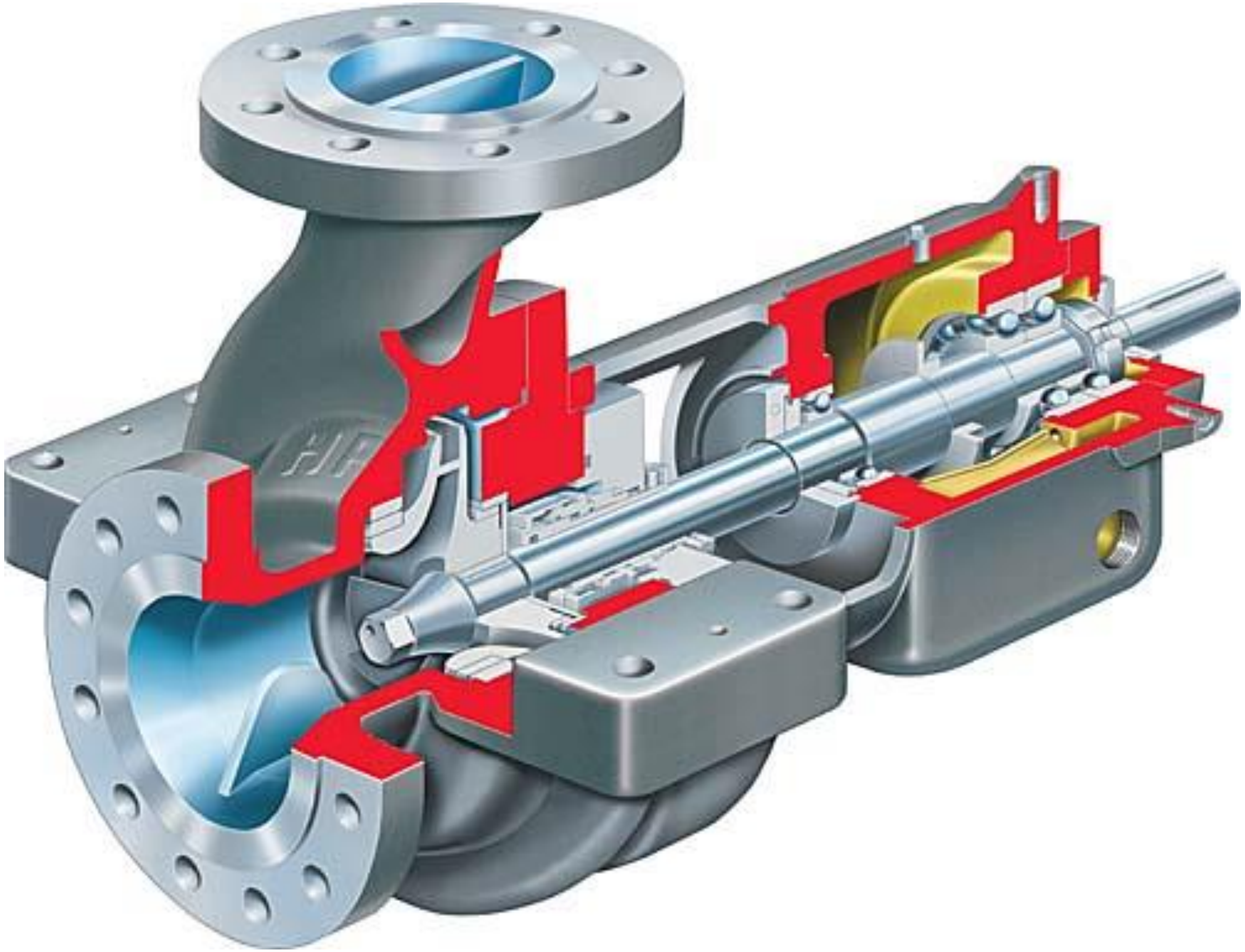
4- Shaft Sealing

Mechanical Seal

A leaking seal may be caused by the following:

1. Seal faces scored or grooved.
2. Seal housing bolts too tight, causing distortion of rings.
3. "O" ring gaskets cut or nicked during installation.
4. Misalignment of piping, causing distortion of pump parts.
5. Excessive pump shaft vibration.

Construction

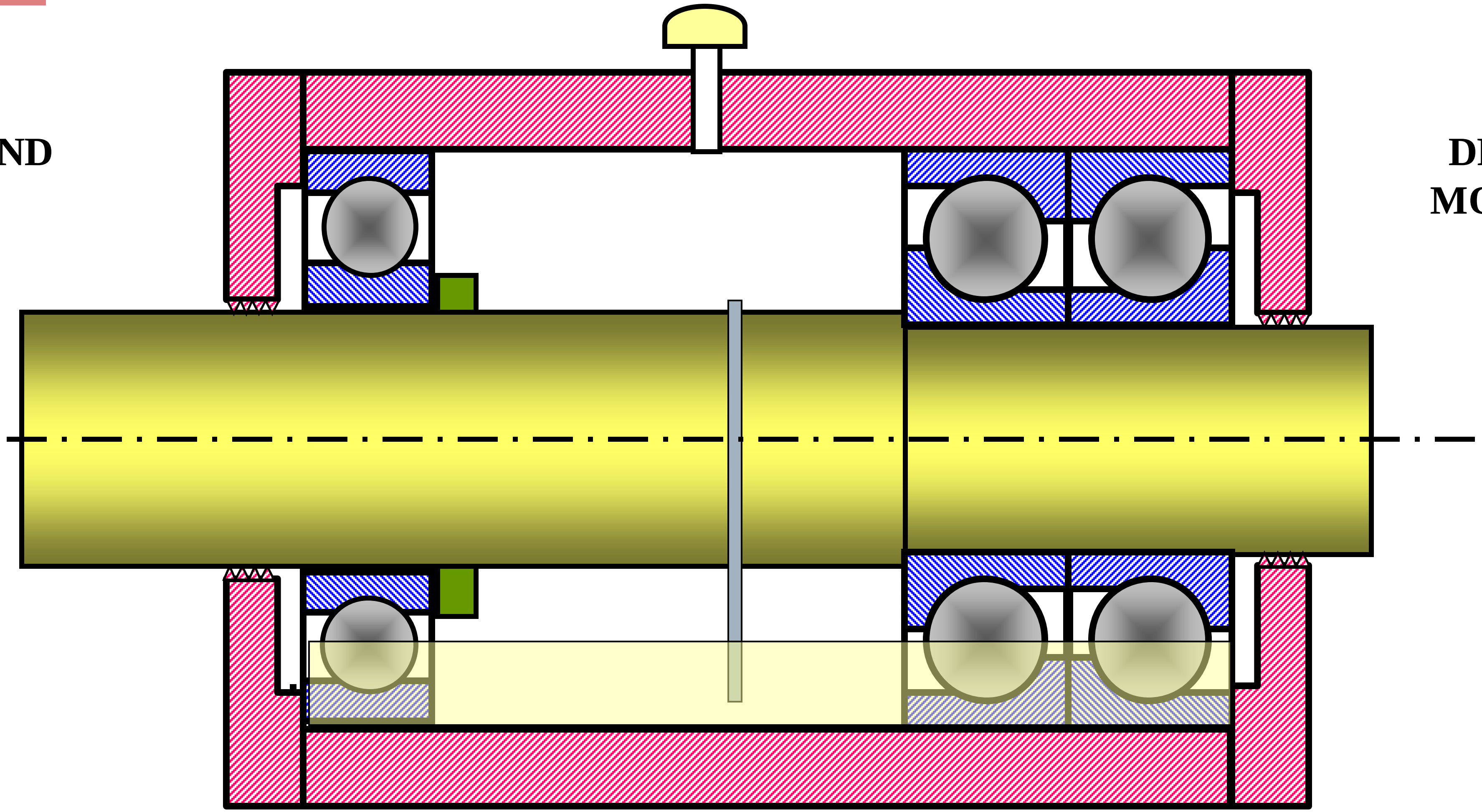


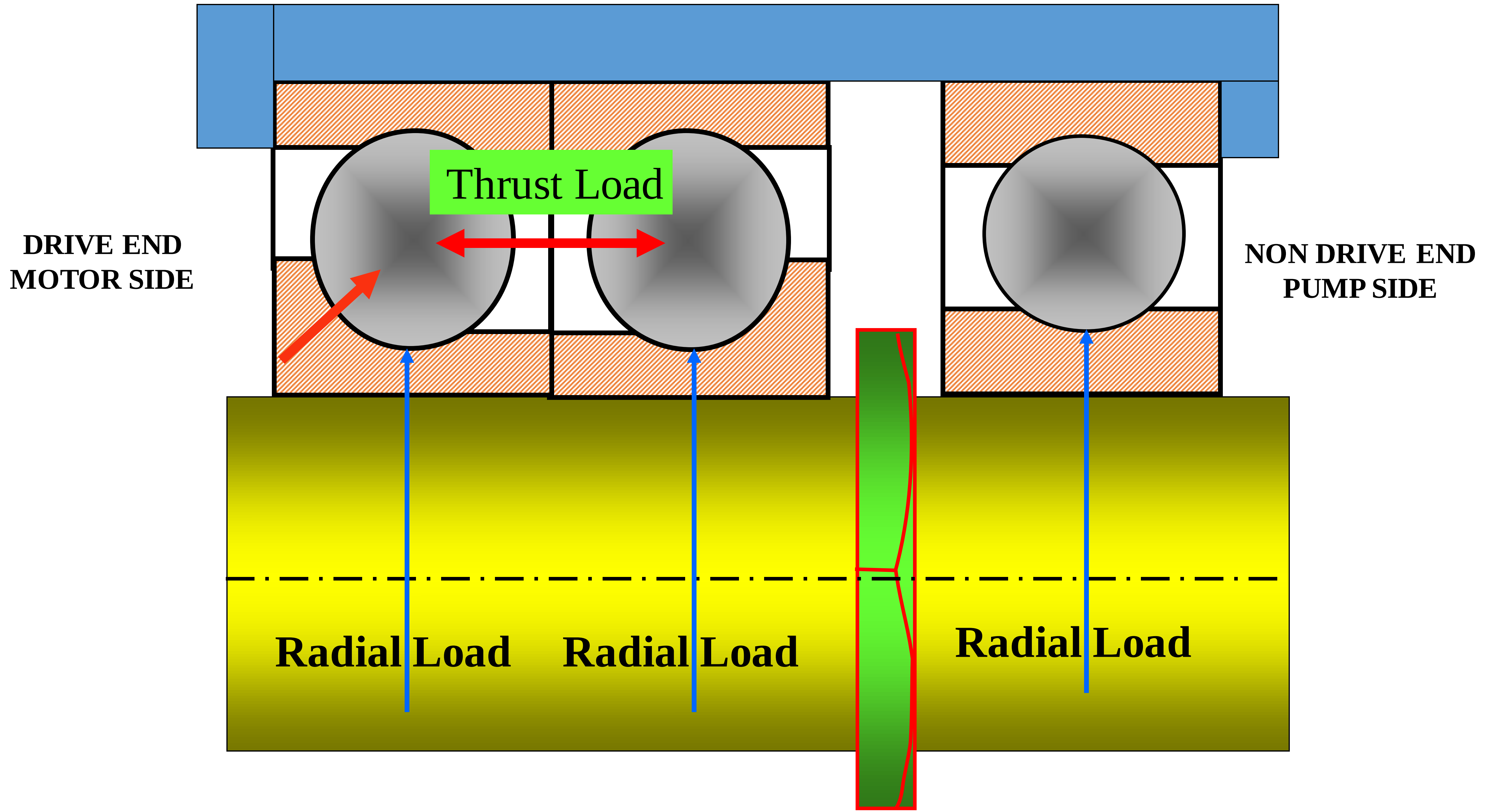
Construction

5- Bearings

NON DRIVE END
PUMP SIDE

DRIVE END
MOTOR SIDE



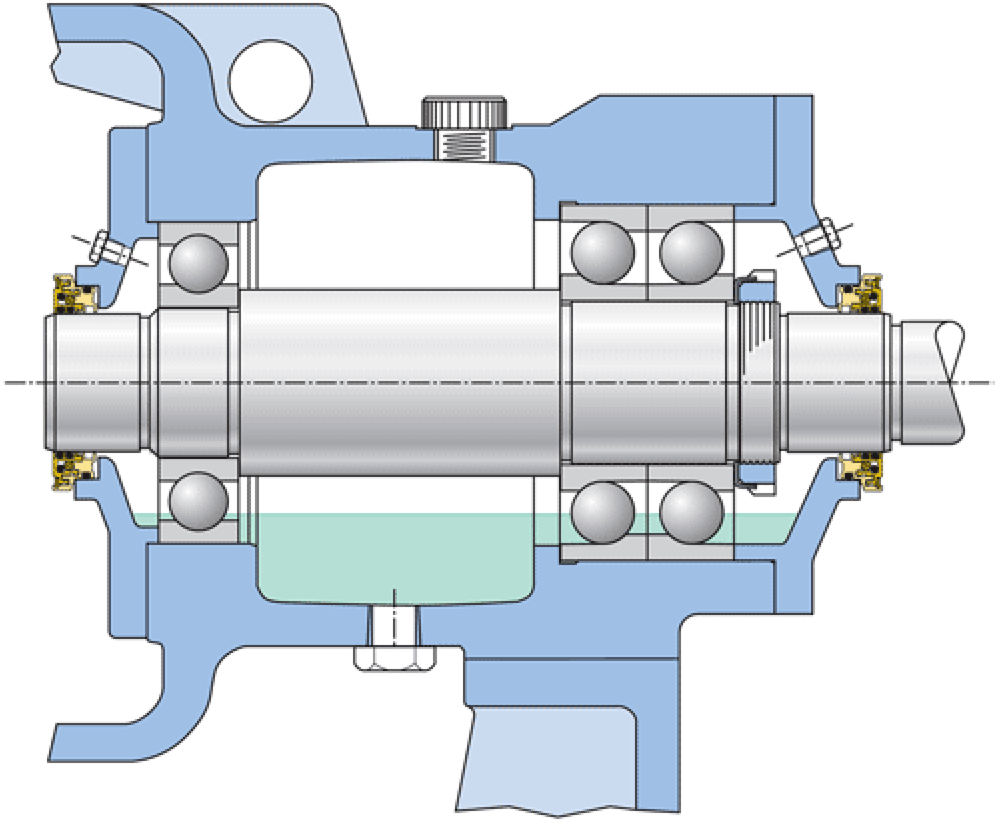

DRIVE END
MOTOR SIDE
Thrust Load
NON DRIVE END
PUMP SIDE
Radial Load
Radial Load
Radial Load

Deep Groove Ball Bearings

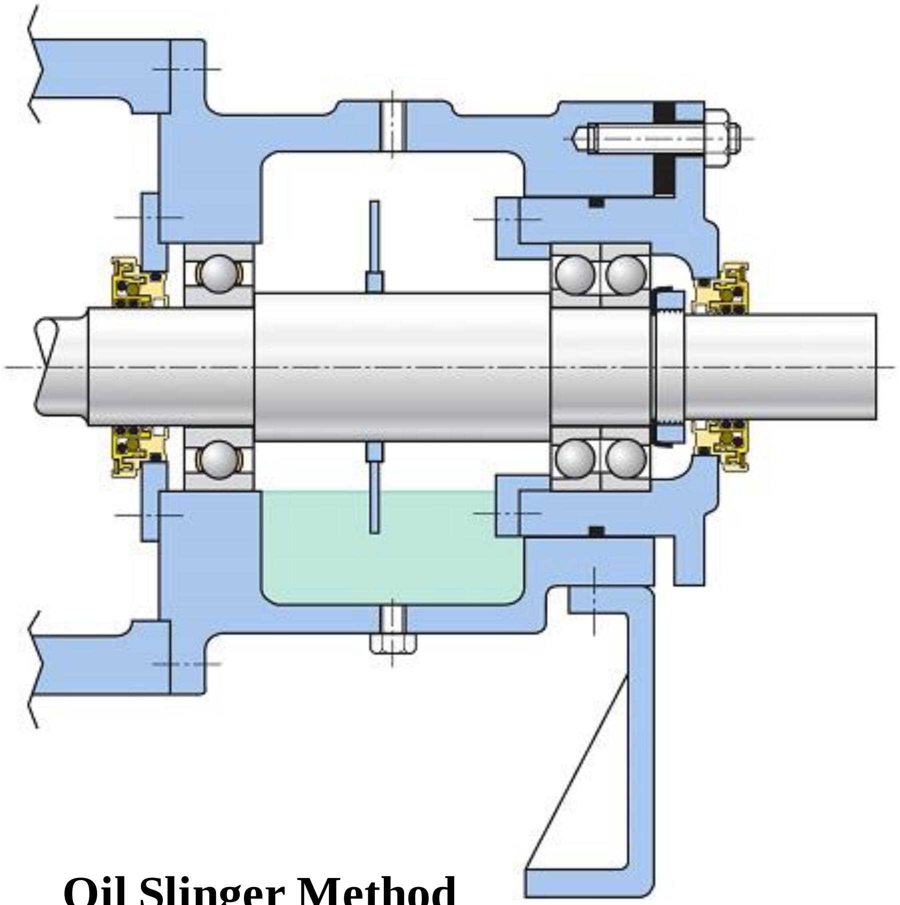
Angular Contact Ball Bearings

Construction

6- BEARING LUBRICATION METHOD



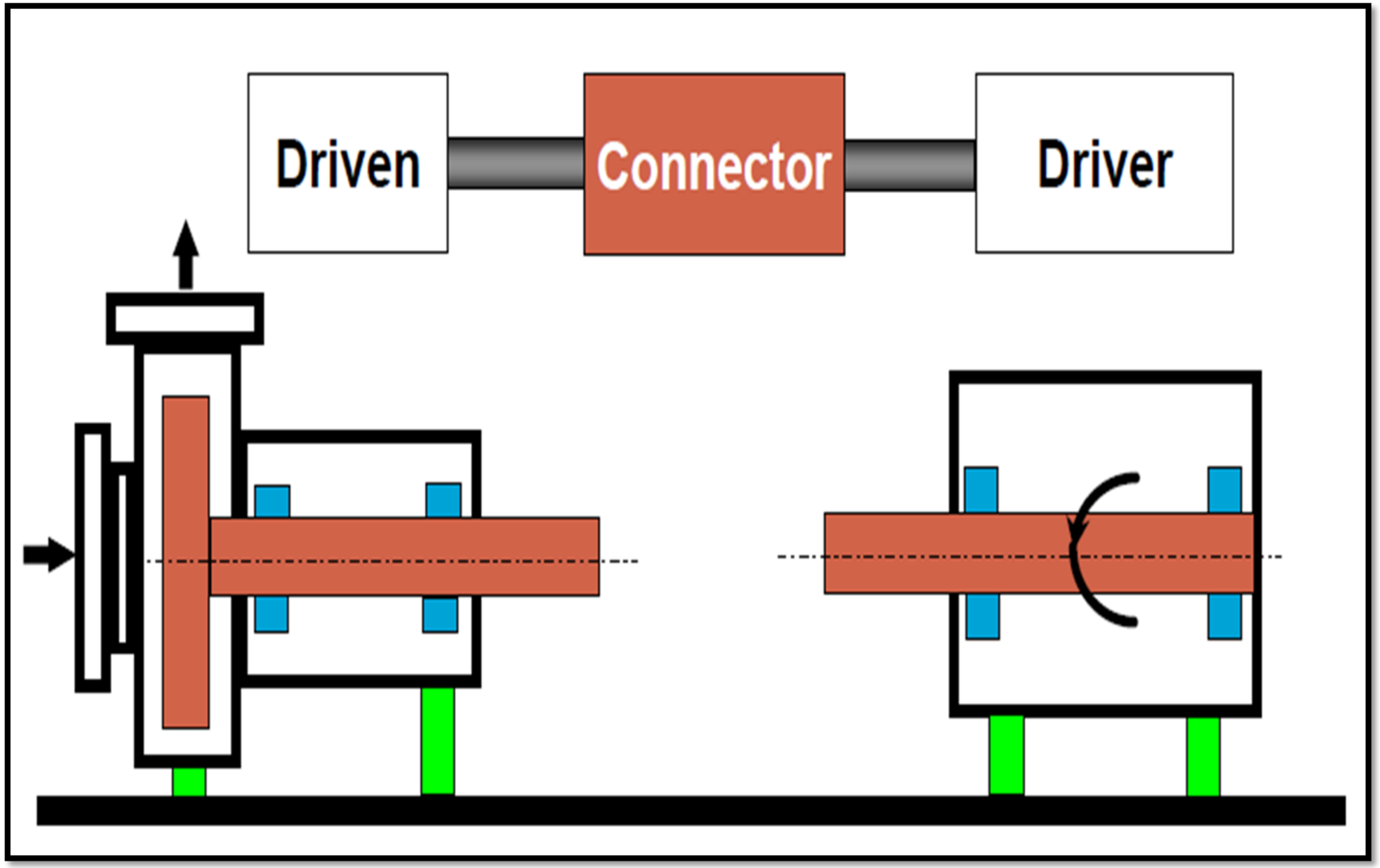
Oil Bath Method



Oil Slinger Method

Construction

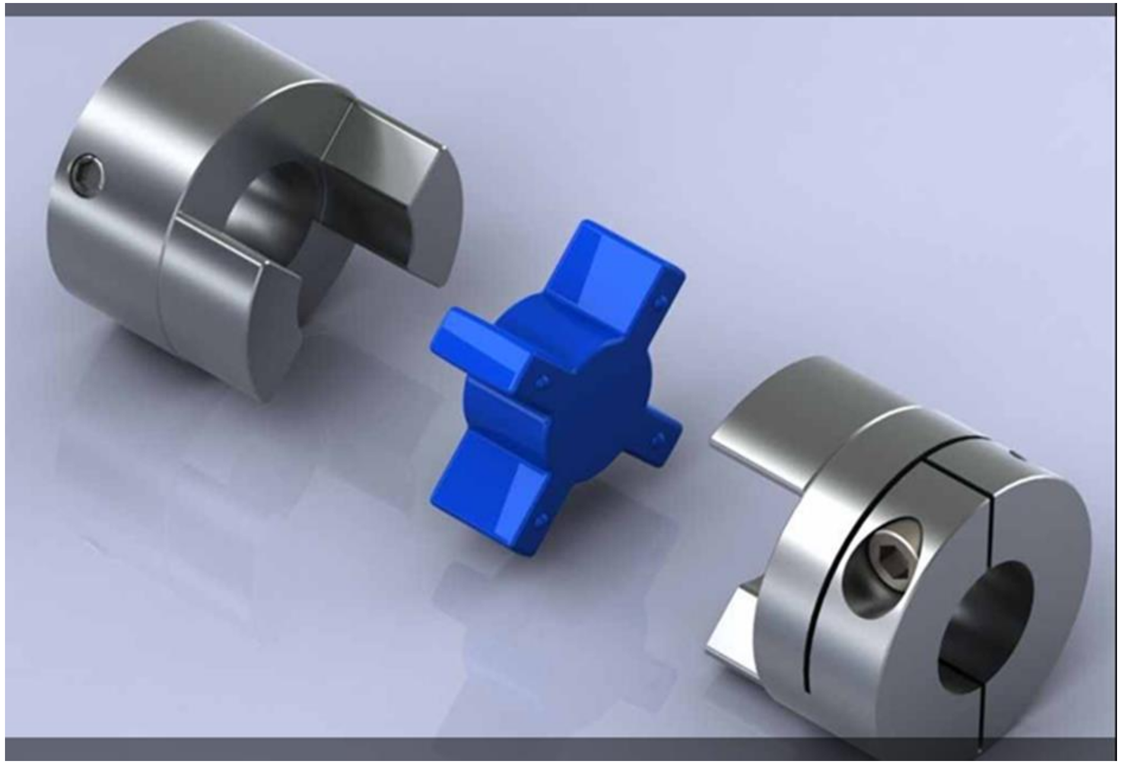
7- Pump Coupling



Construction

7- Pump Coupling

Grid Type Coupling

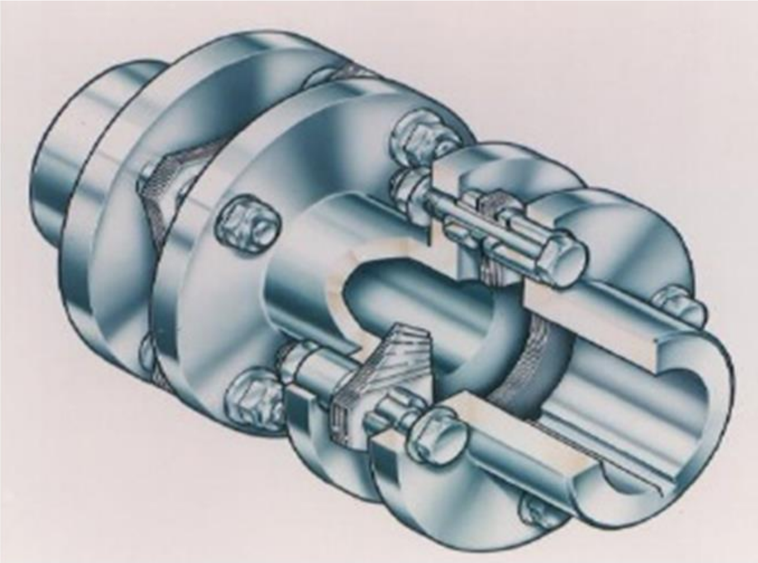


Jaw Coupling

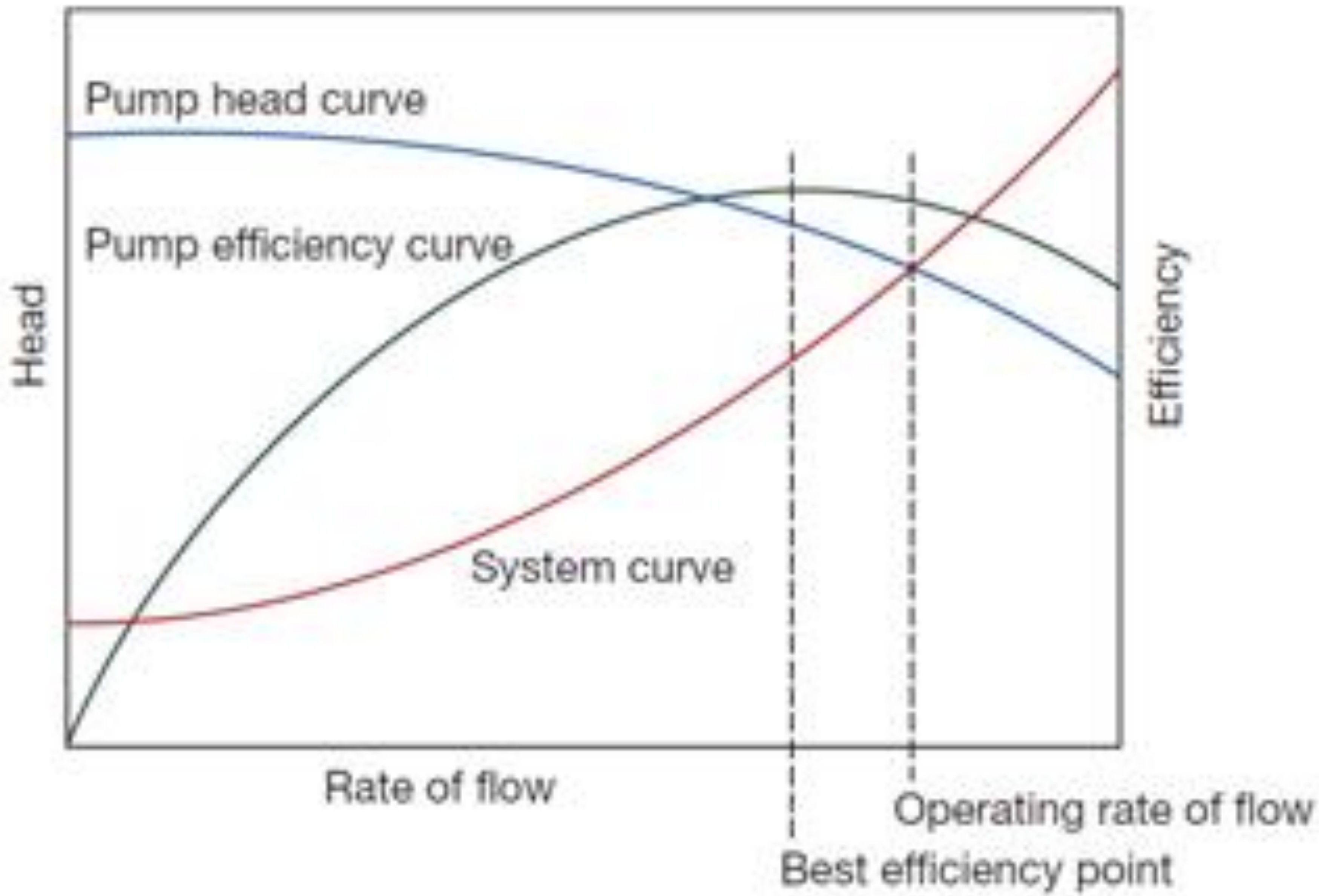
Construction

7- Pump Coupling

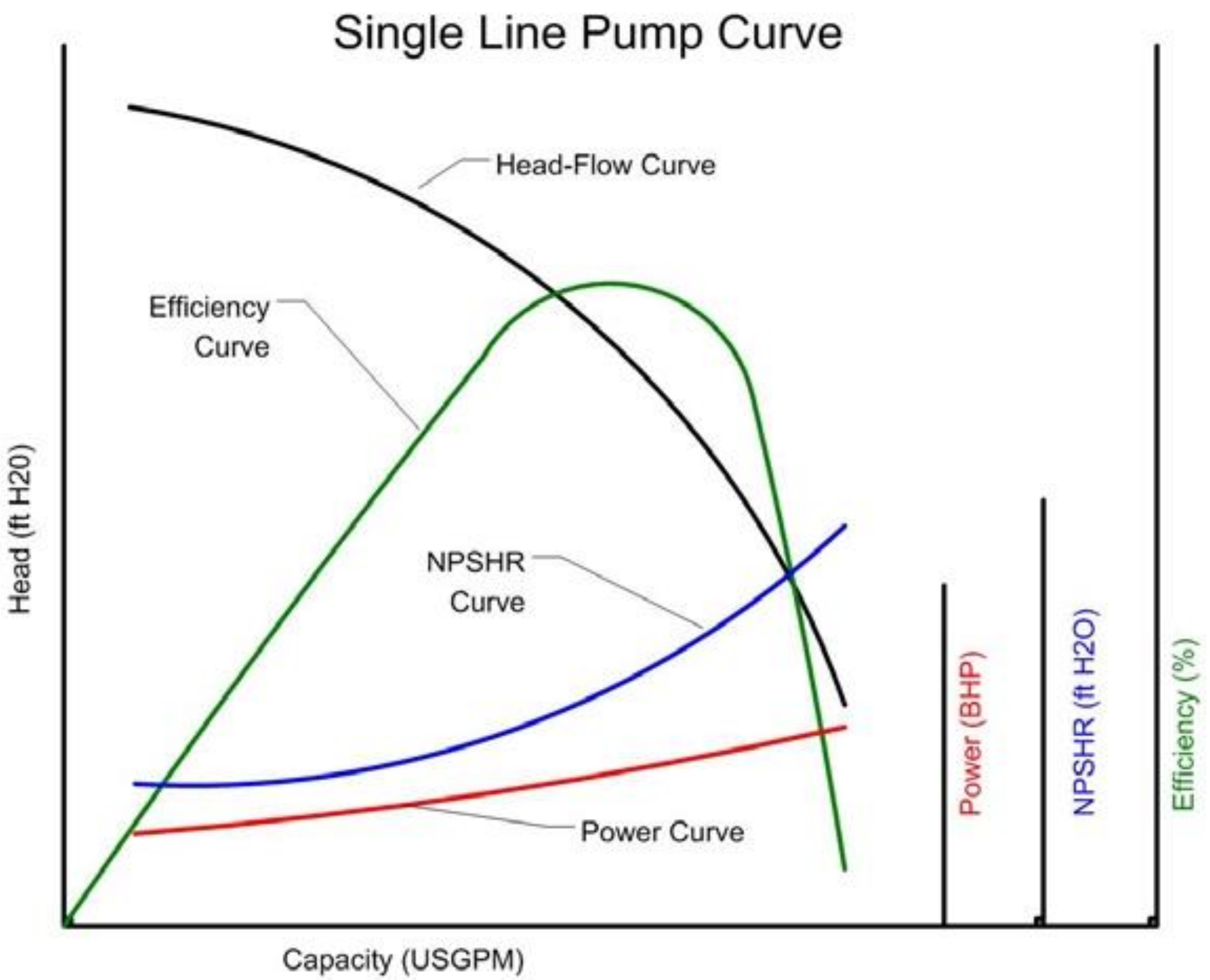
Disc Type Coupling



Operation


Pump head curve
Pump efficiency curve
System curve
Head
Efficiency
Rate of flow
Operating rate of flow
Best efficiency point

Operation


Single Line Pump Curve
Head-Flow Curve
Efficiency Curve
NPSHR Curve
Power Curve
Head (ft H20)
Capacity (USGPM)
Power (BHP)
NPSHR (ft H2O)
Efficiency (%)

Operation

CAUTION:

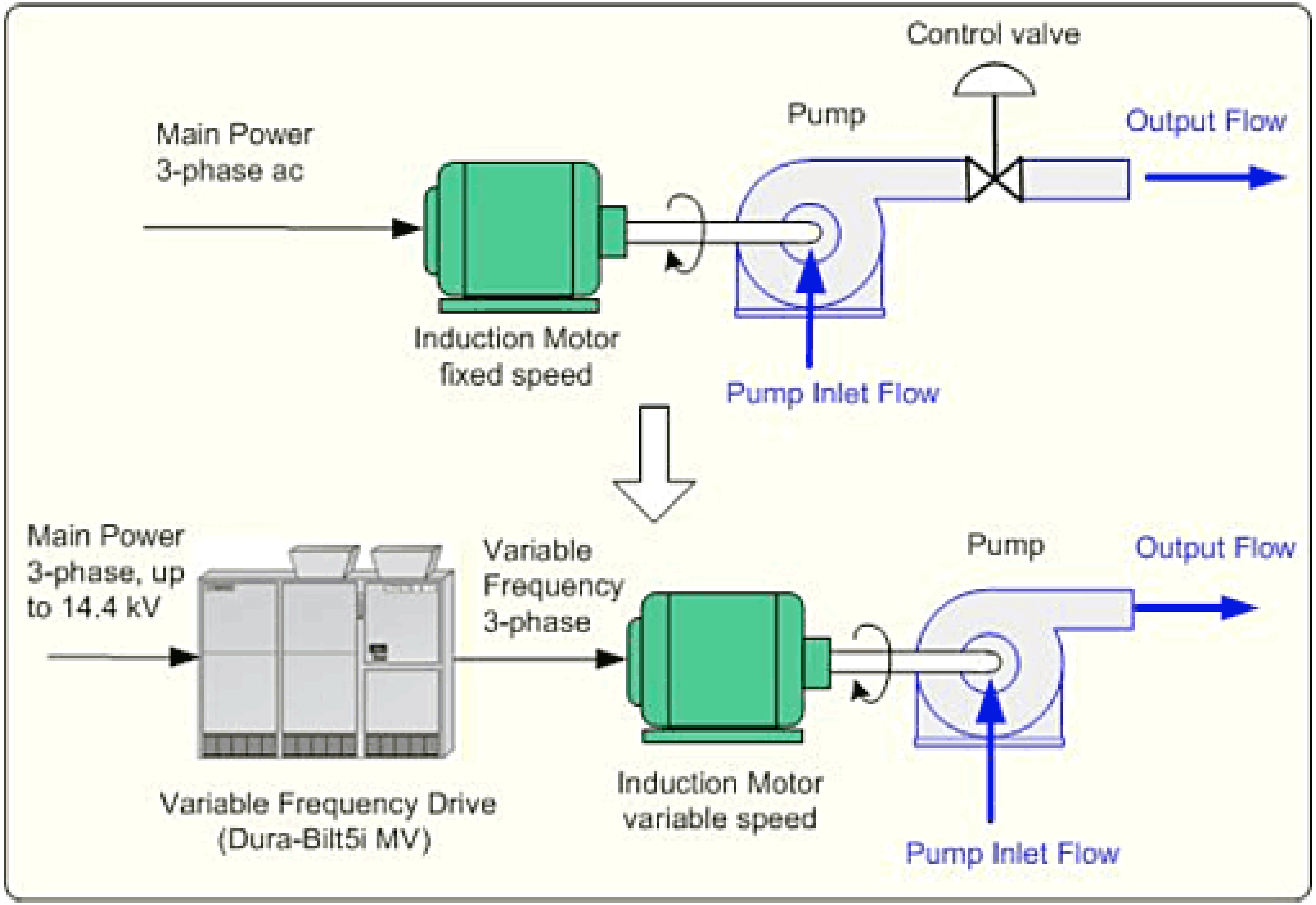
1. Never run a centrifugal pump continuously with the discharge valve completely closed. The mechanical power applied to the impeller is dispelled as friction to the water trapped and churned about in the casing. This friction causes overheating of the water to the point where it turns into steam which may result in damage to the pump.

2. Always operate a centrifugal pump with its suction valve wide open. Never use it for flow control. Throttling or closing of this valve starves the impeller of its water supply and the casing becomes partially empty resulting in excessive vibration which may ruin the bearings. The lack of liquid also affects stuffing boxes and seals which require a certain amount of liquid for lubrication and cooling.

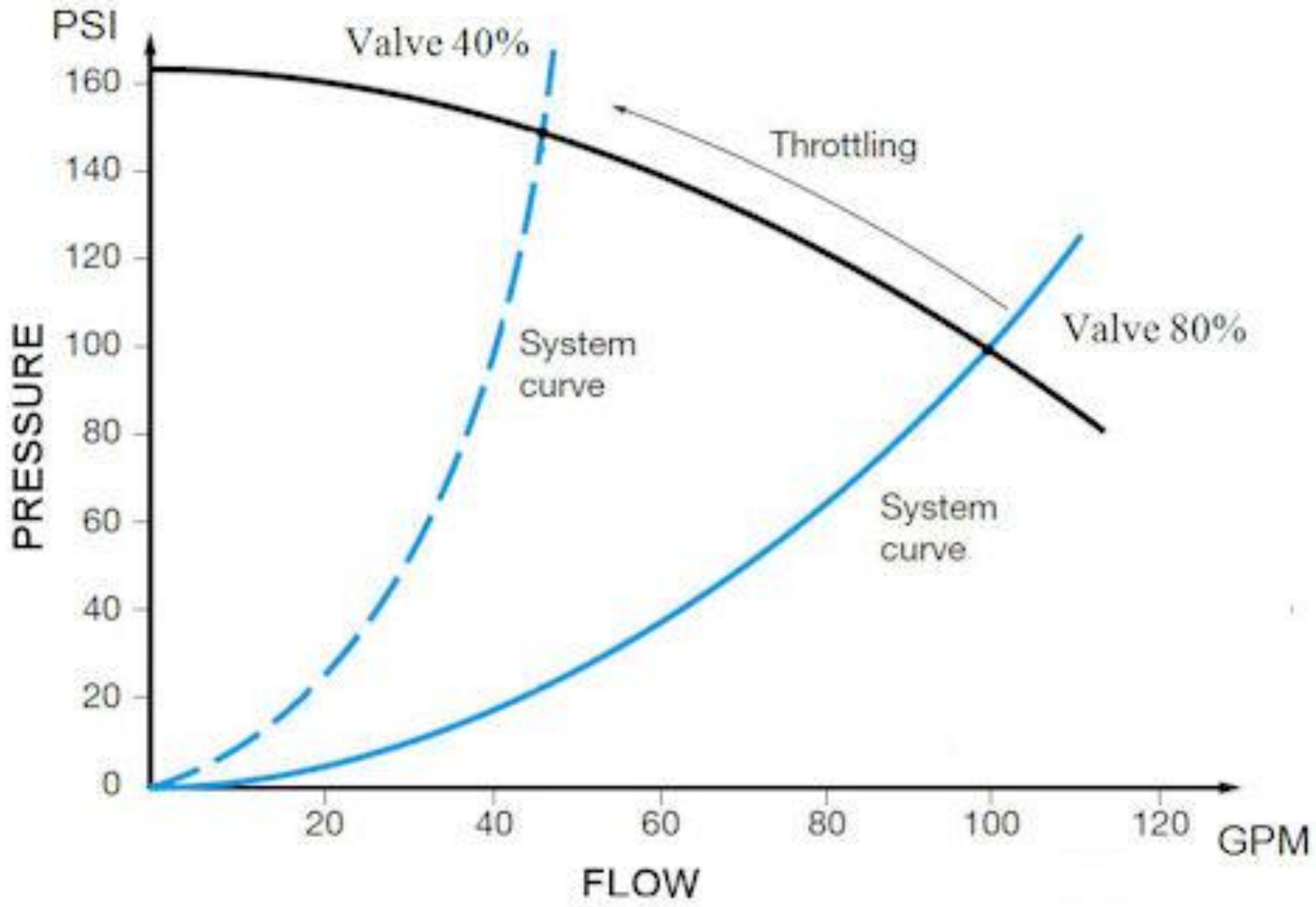
Types of Pumps

Centrifugal Pumps

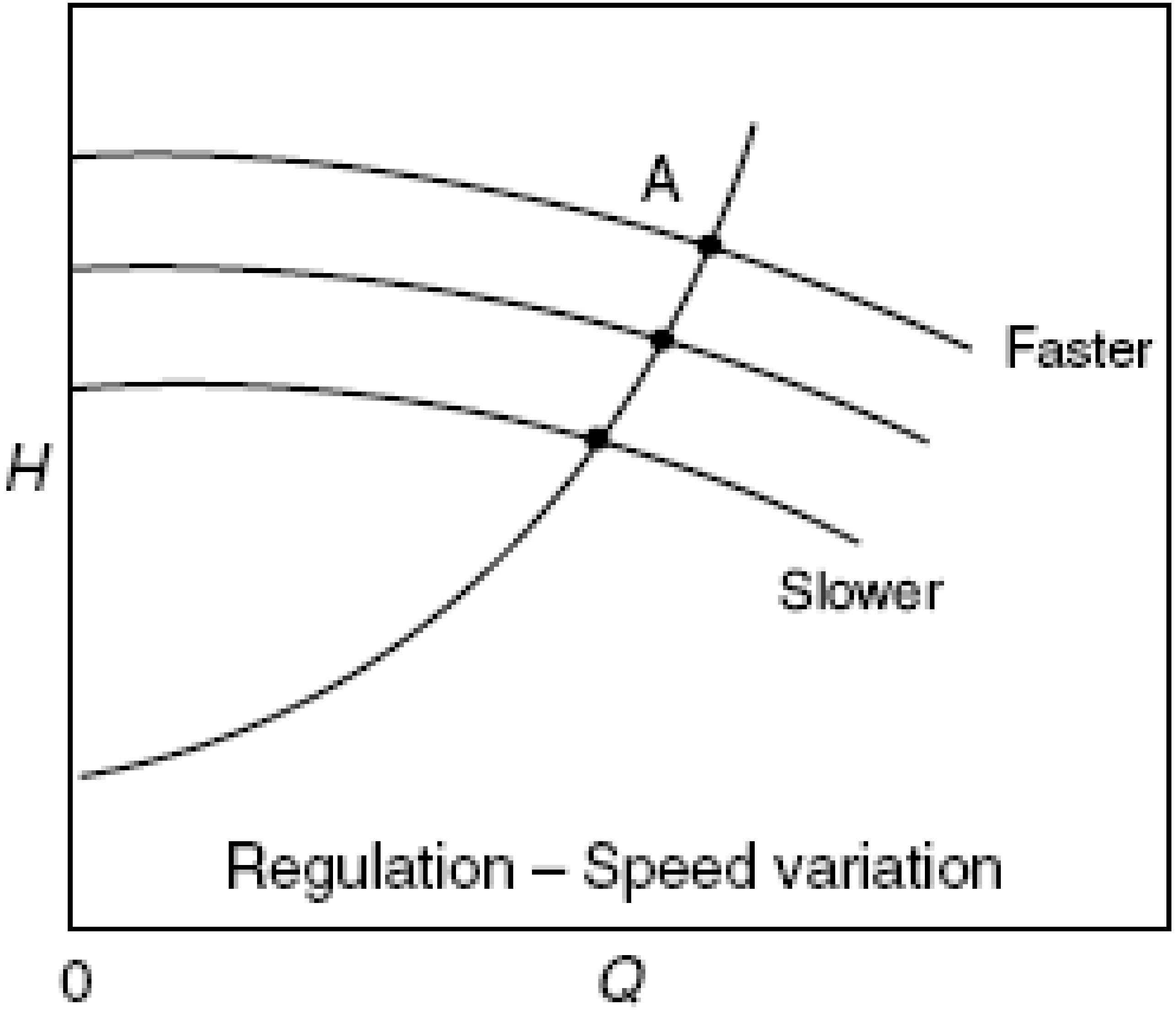
Operation



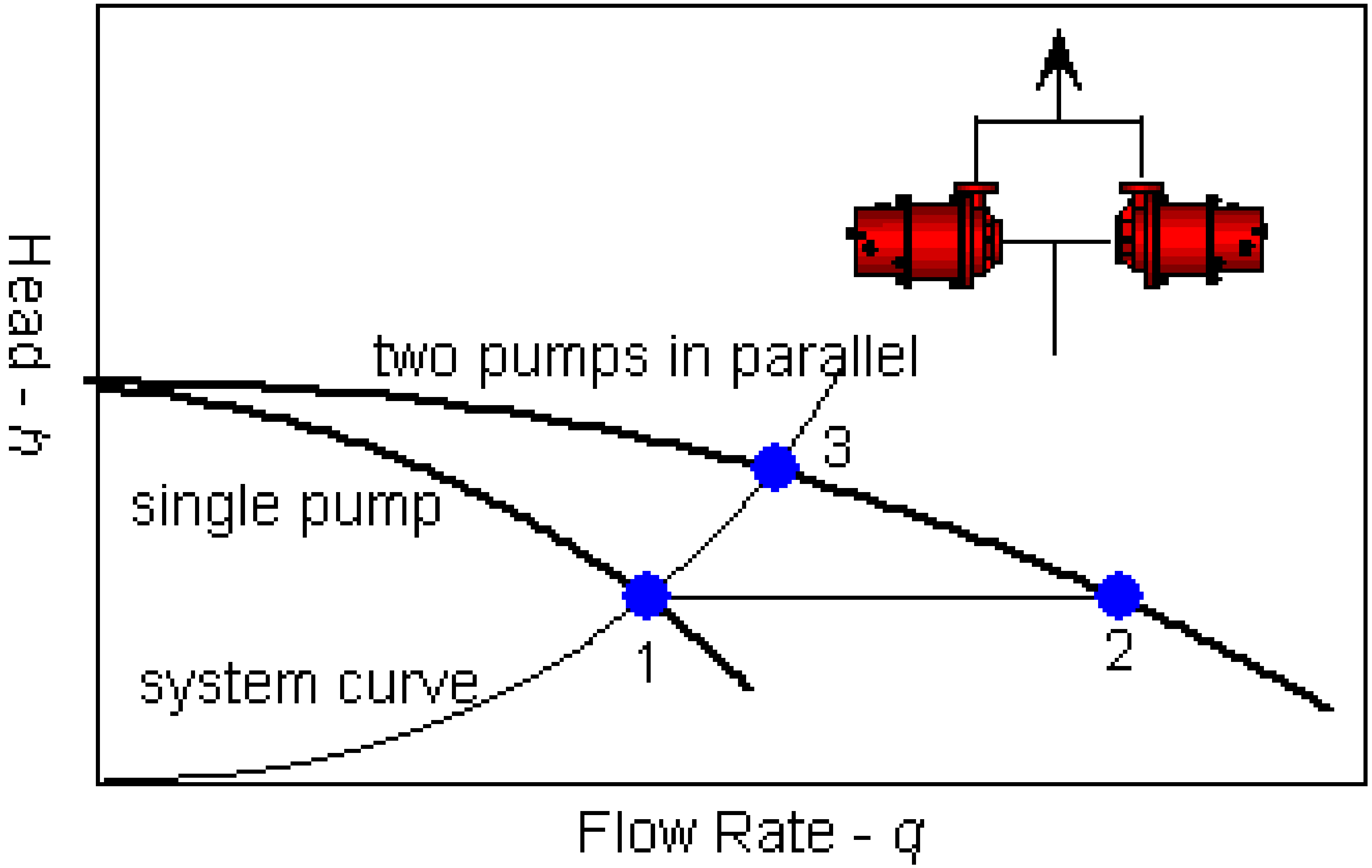
Operation


PSI
Valve 40%
Throttling
Valve 80%
System curve
System curve
PRESSURE
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
GPM
FLOW

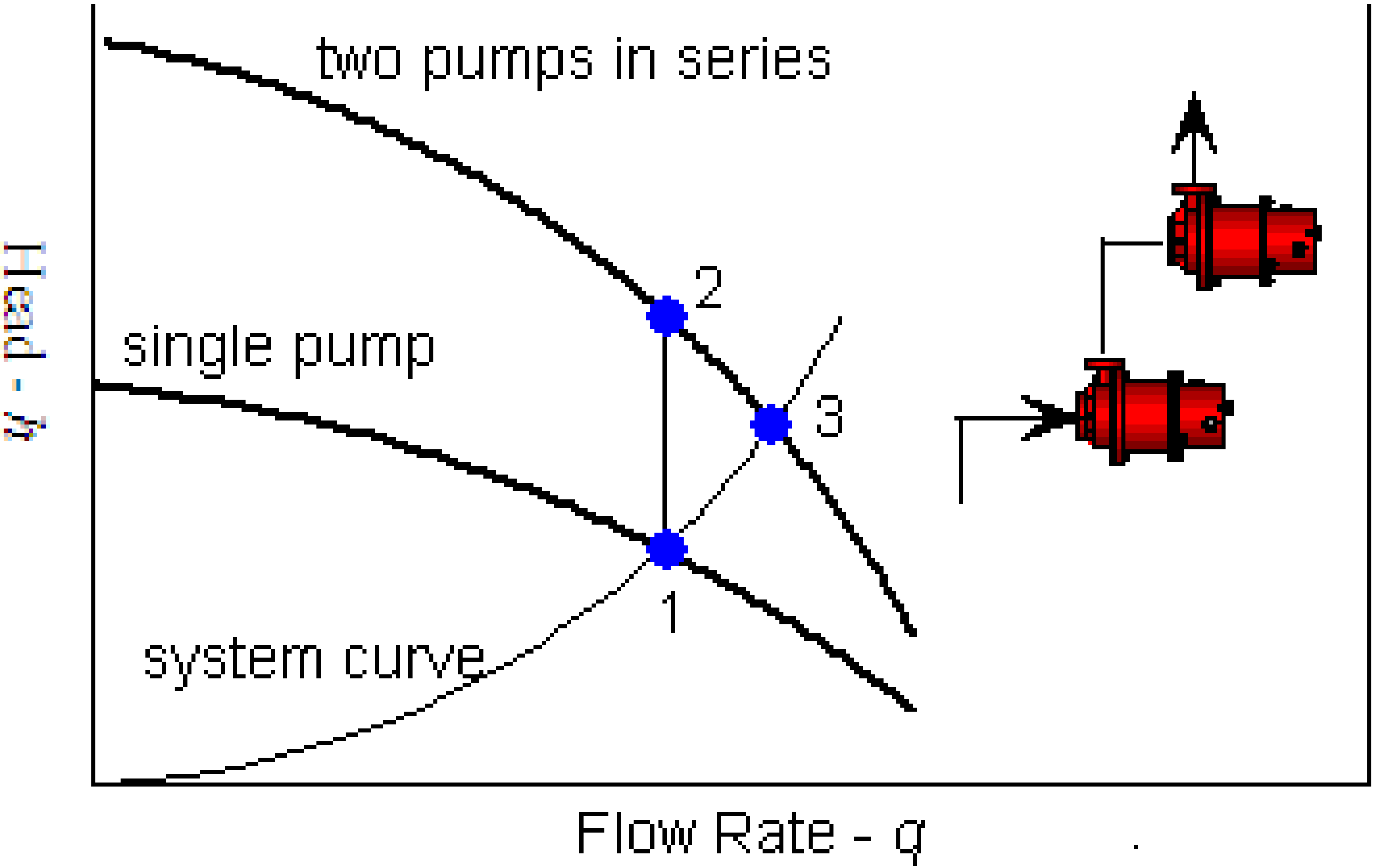
Operation



Operation

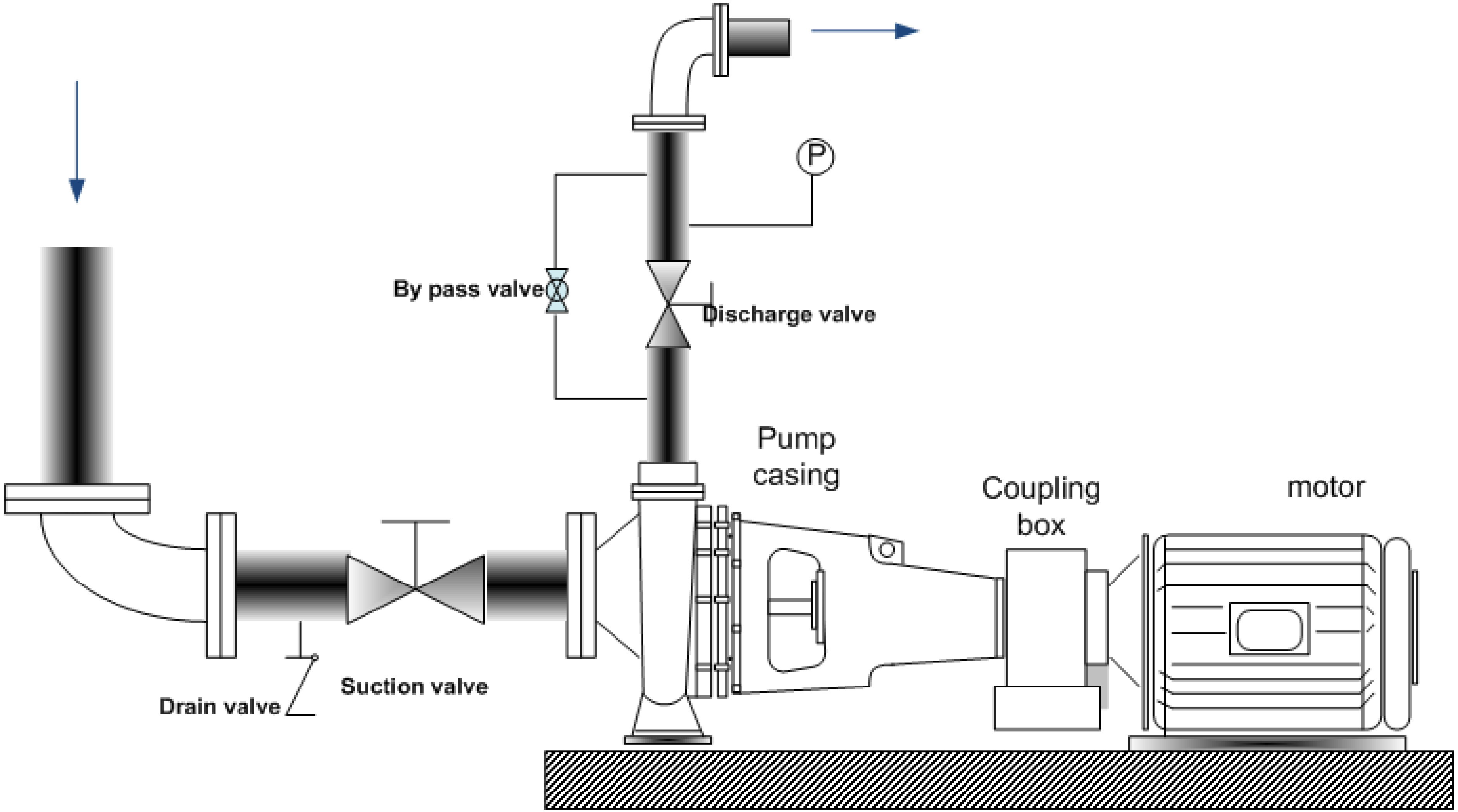

two pumps in parallel
single pump
system curve
1
2
3
Head - h
Flow Rate - q

Operation


two pumps in series
single pump
system curve
2
3
1
Head - h
Flow Rate - q

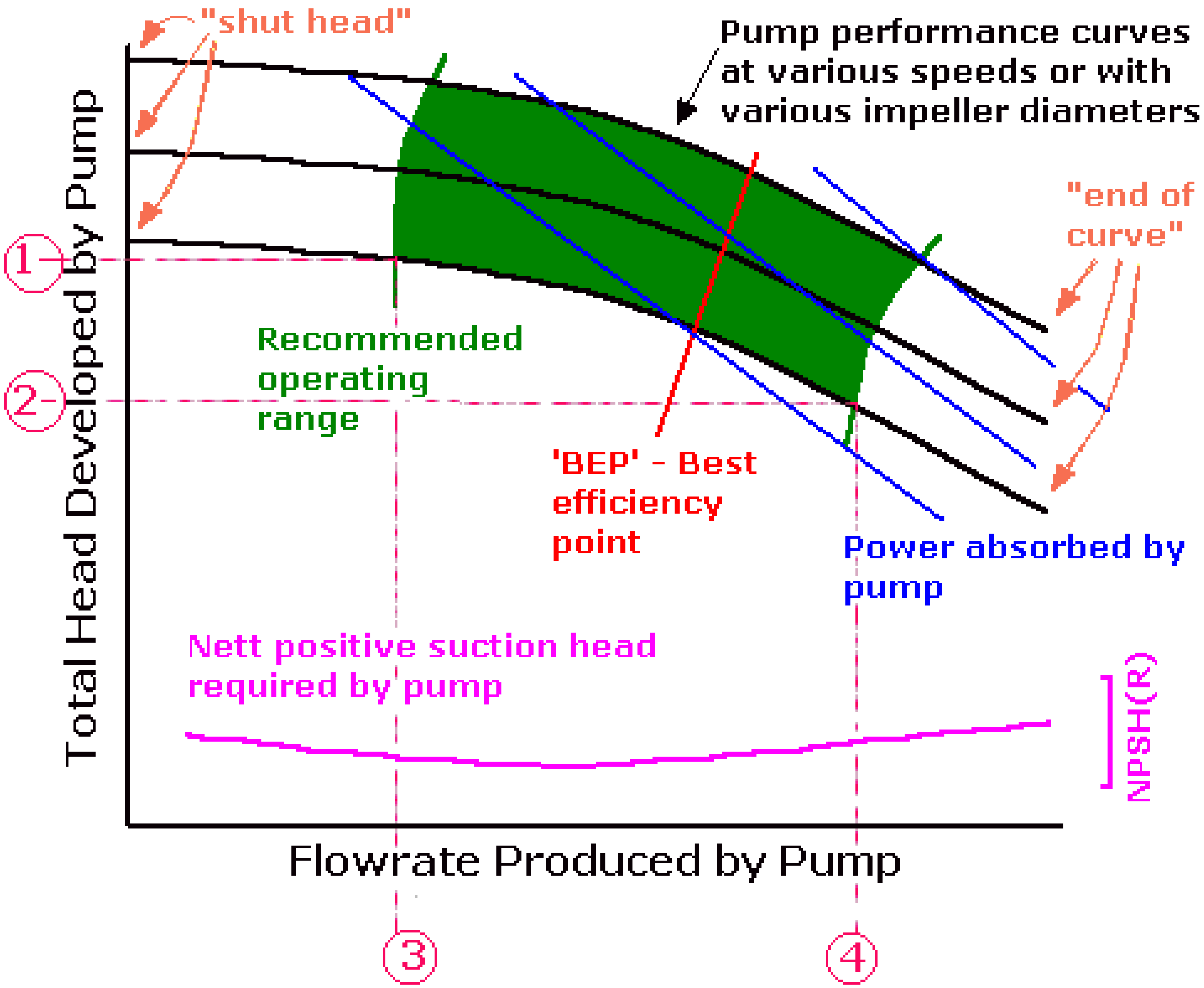
Operation

Start-Up



Centrifugal pump system

Operation


"shut head"
Pump performance curves at various speeds or with various impeller diameters
"end of curve"
1
2
Recommended operating range
'BEP' - Best efficiency point
Power absorbed by pump
Nett positive suction head required by pump
NPSH(R)
Total Head Developed by Pump
Flowrate Produced by Pump
3
4

Operation

Cavitation

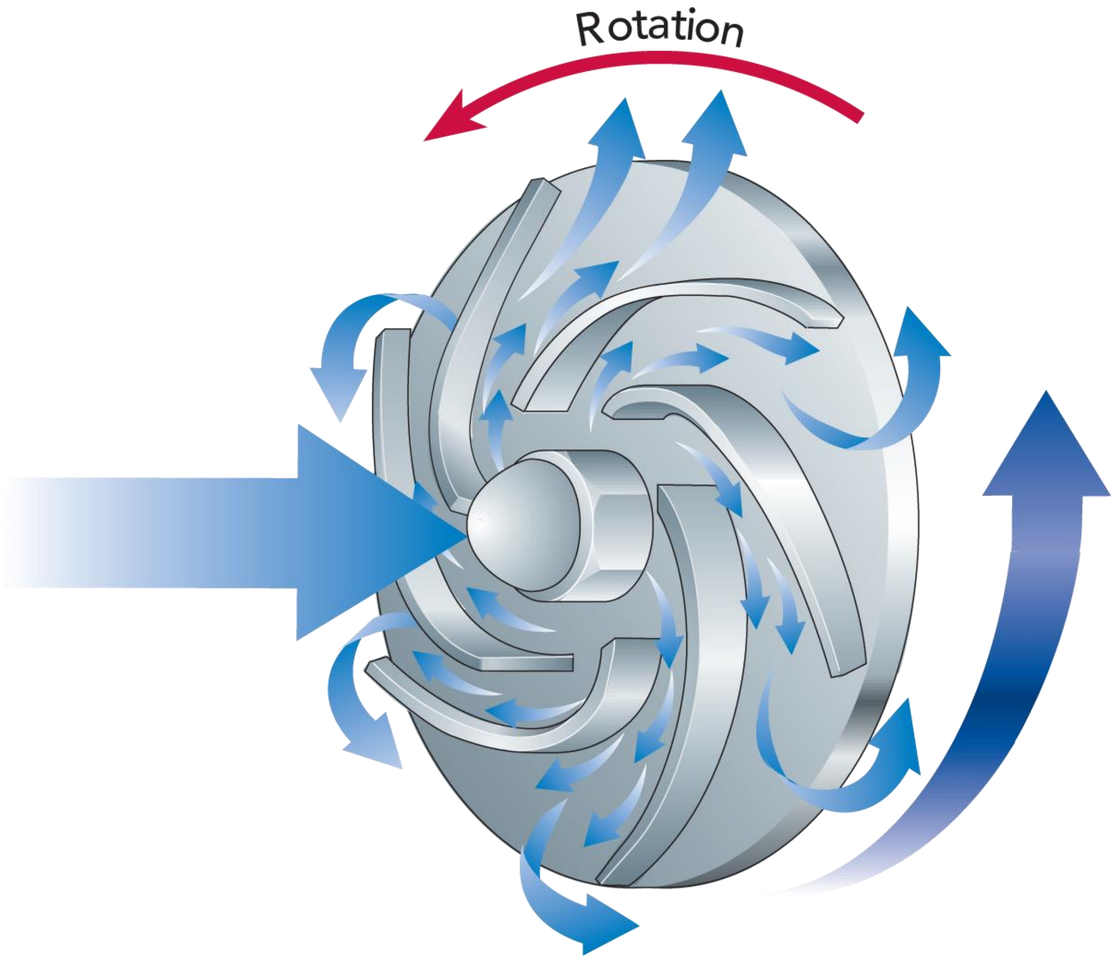
General Symptoms of Cavitation and its Affects Pump Performance and Pump Parts

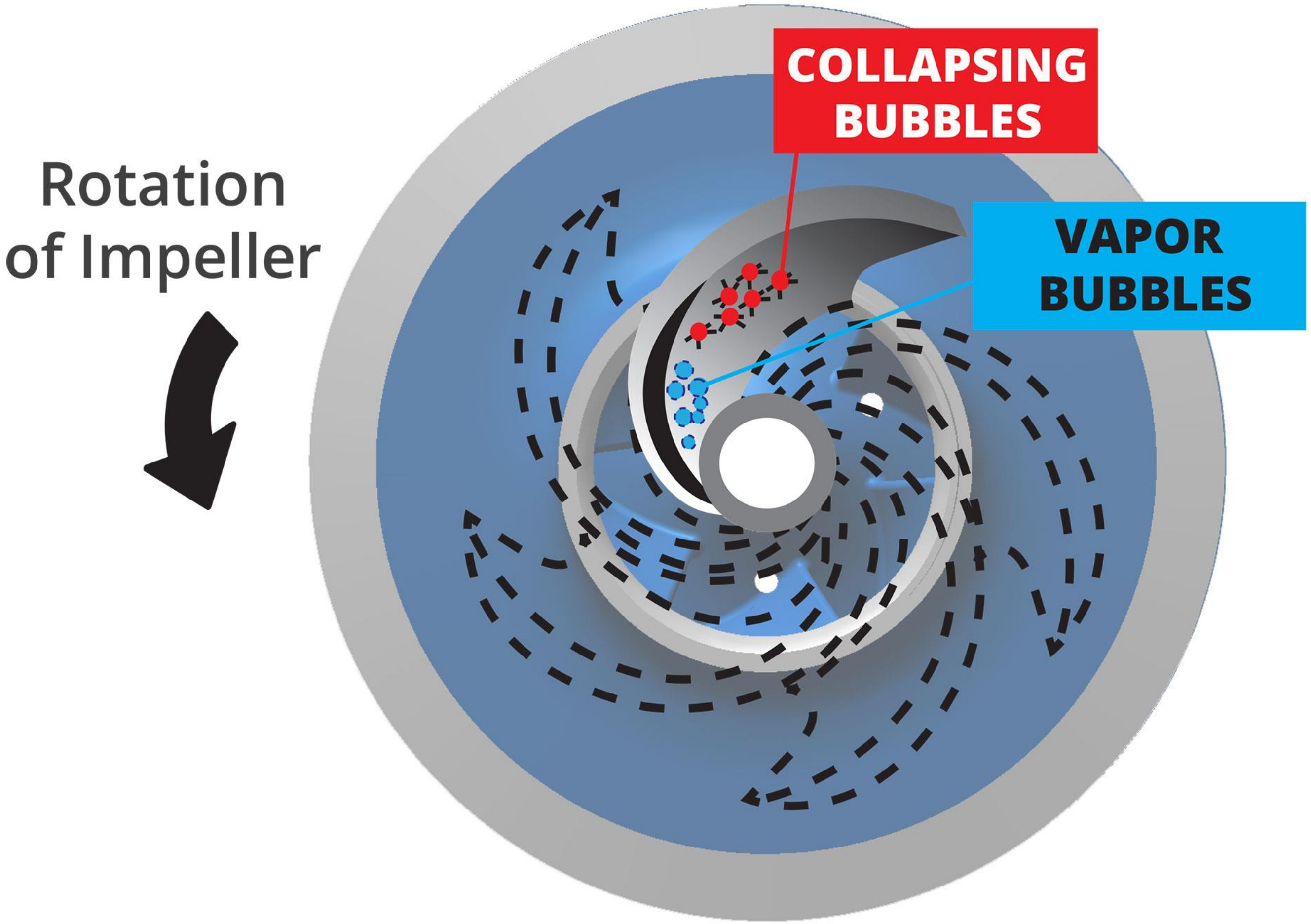
- Reduction in capacity of the pump
- Decrease in the head developed
- Abnormal sound and vibrations

Cavitation implies a dynamic process of formation of bubbles inside the liquid, their growth and subsequent collapse as the liquid flows through the pump.

Operation

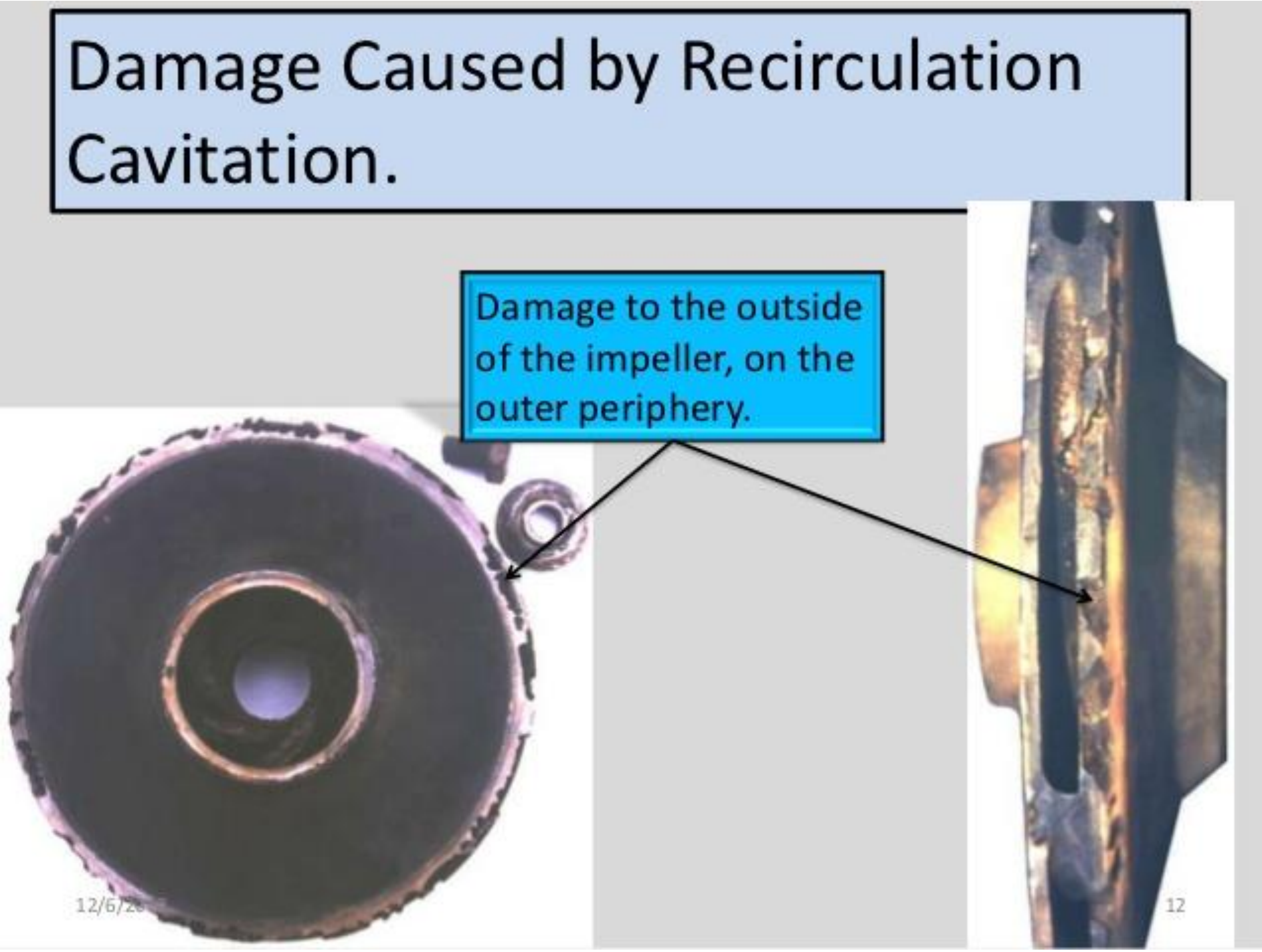
Cavitation





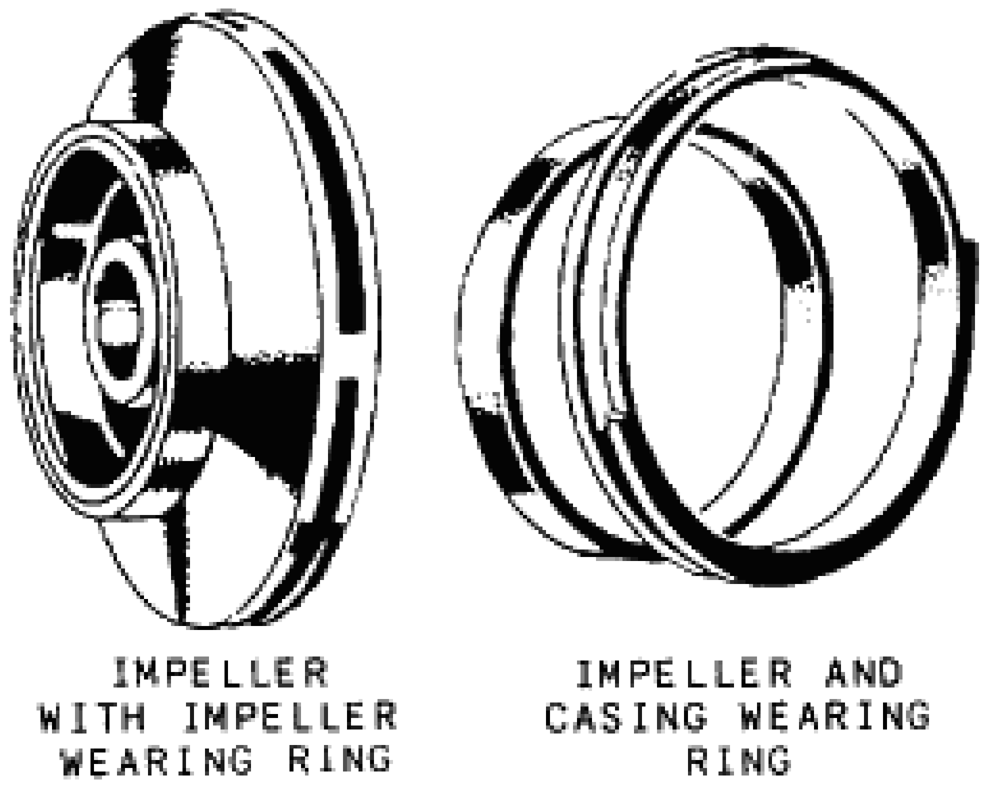
Operation

Operation

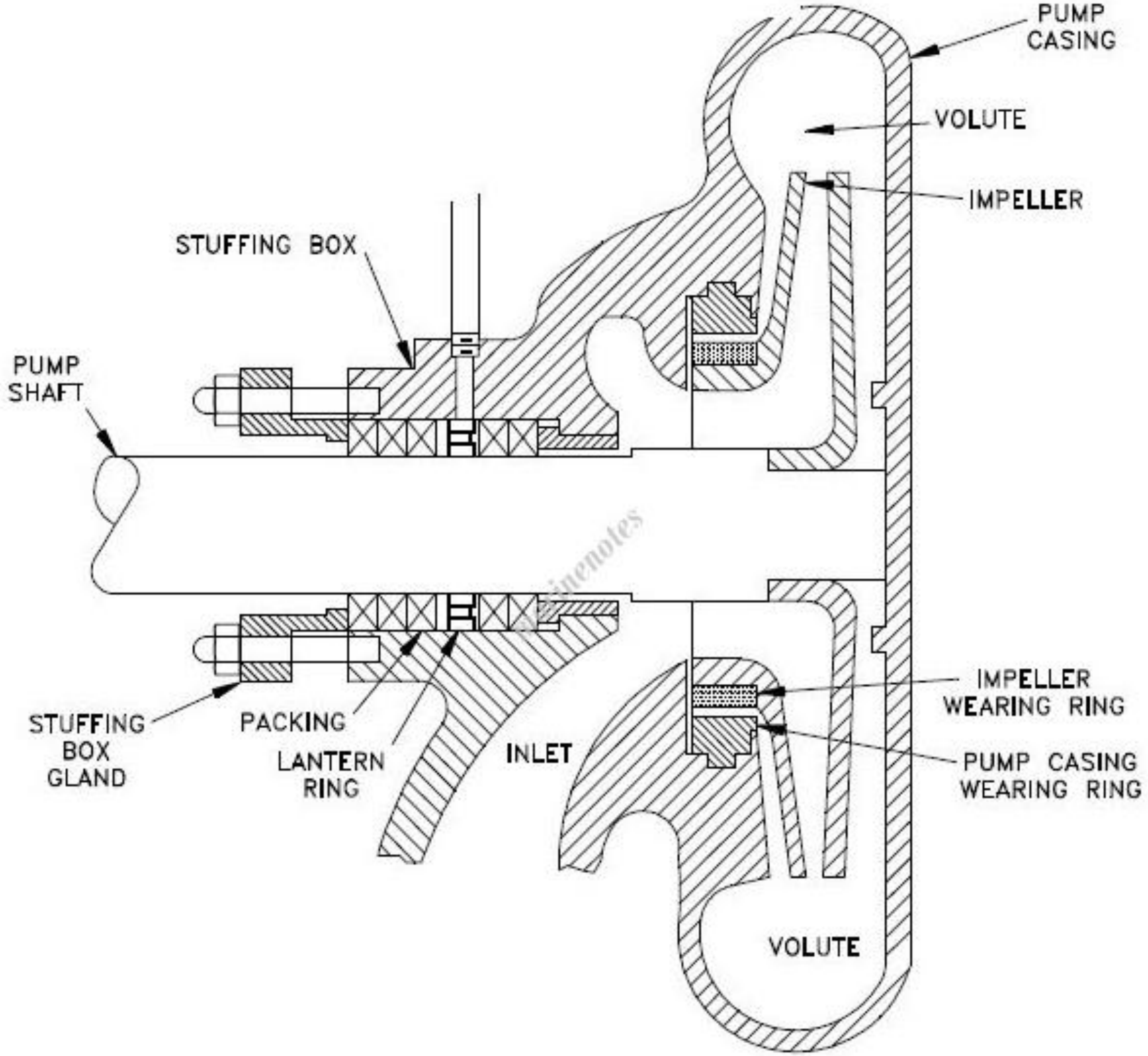

Damage Caused by Recirculation Cavitation.
Damage to the outside of the impeller, on the outer periphery.
12

Troubleshooting and Maintenance

1- Wear Rings

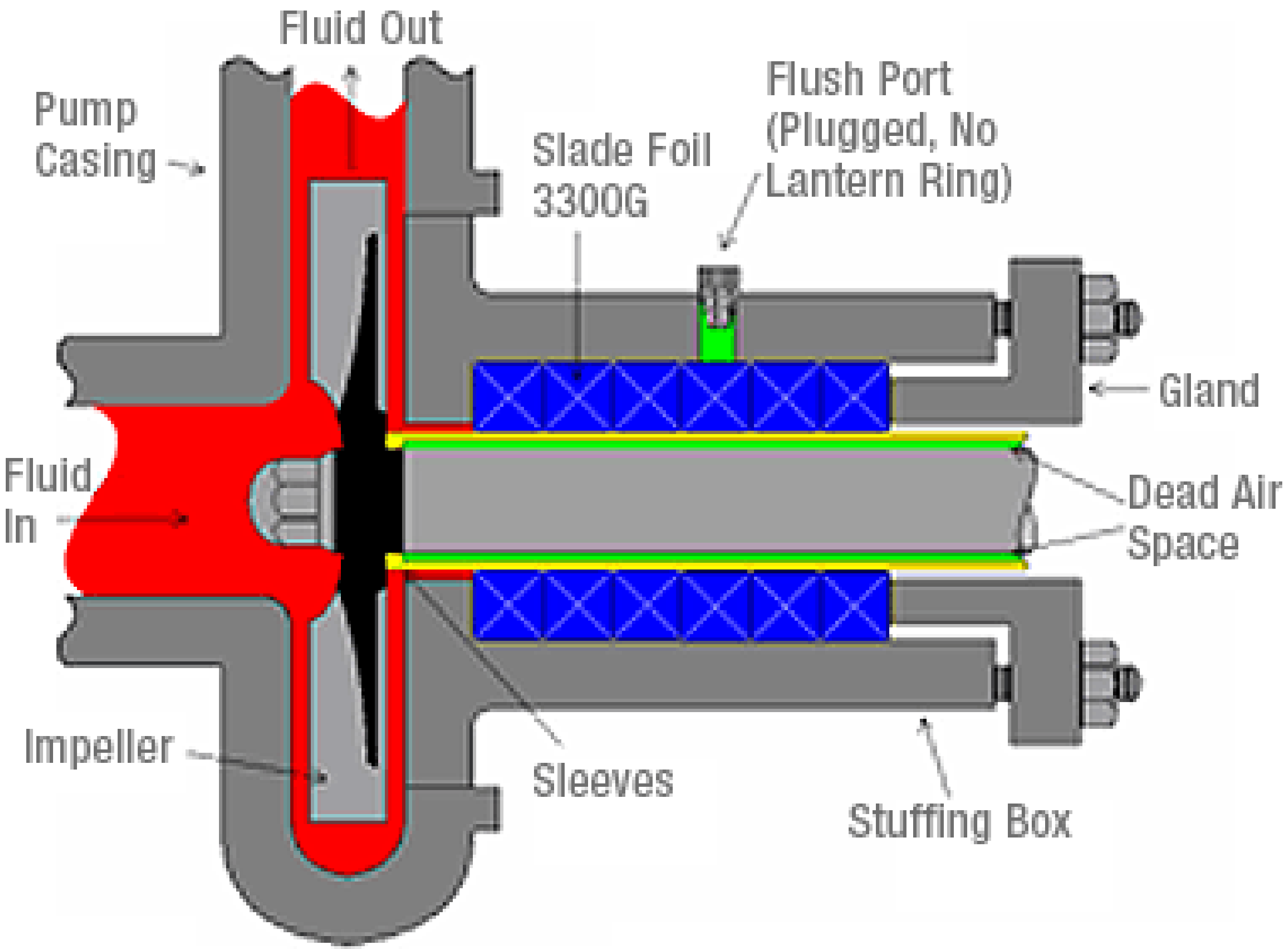


Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

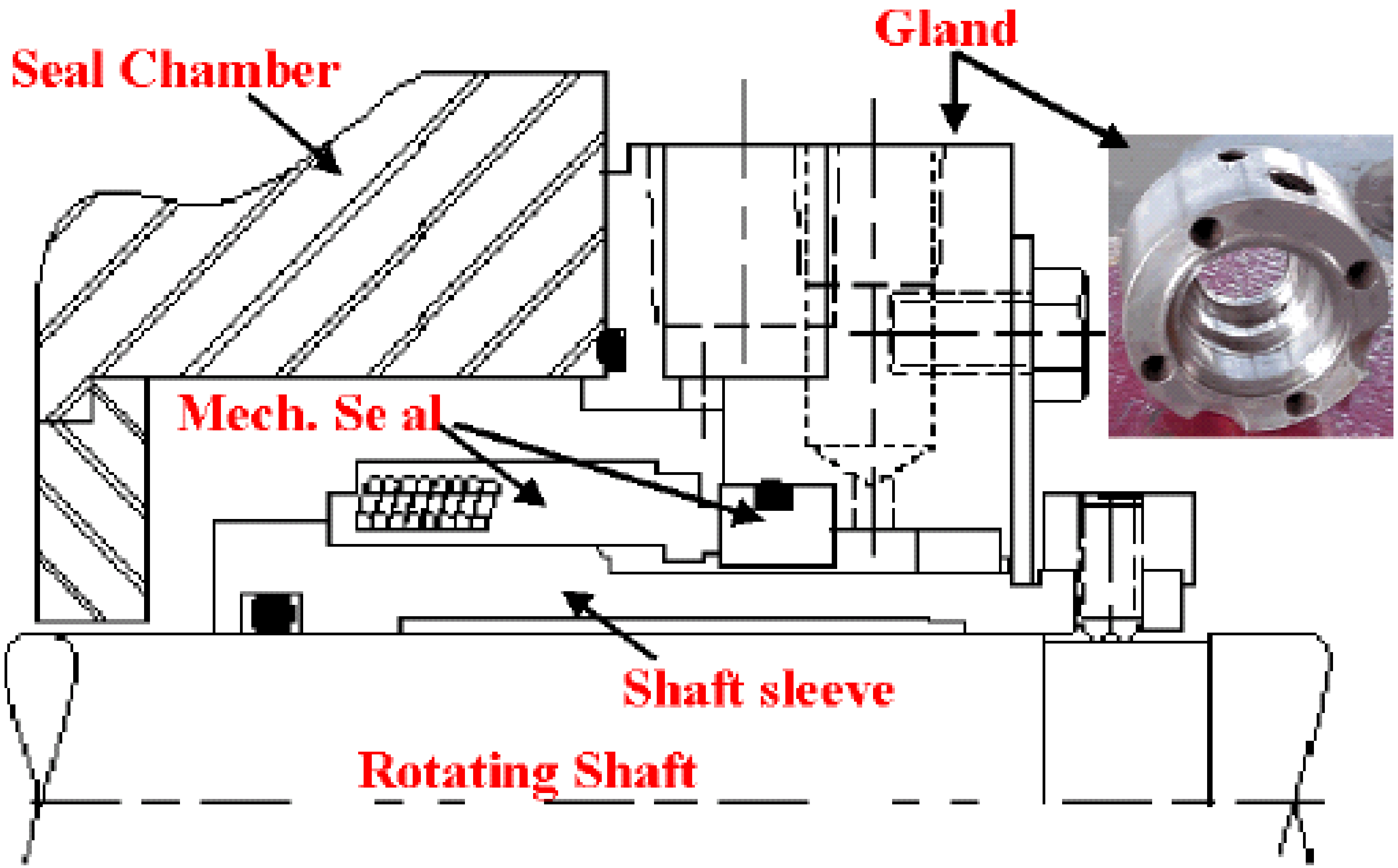


Troubleshooting and Maintenance

2- Packing

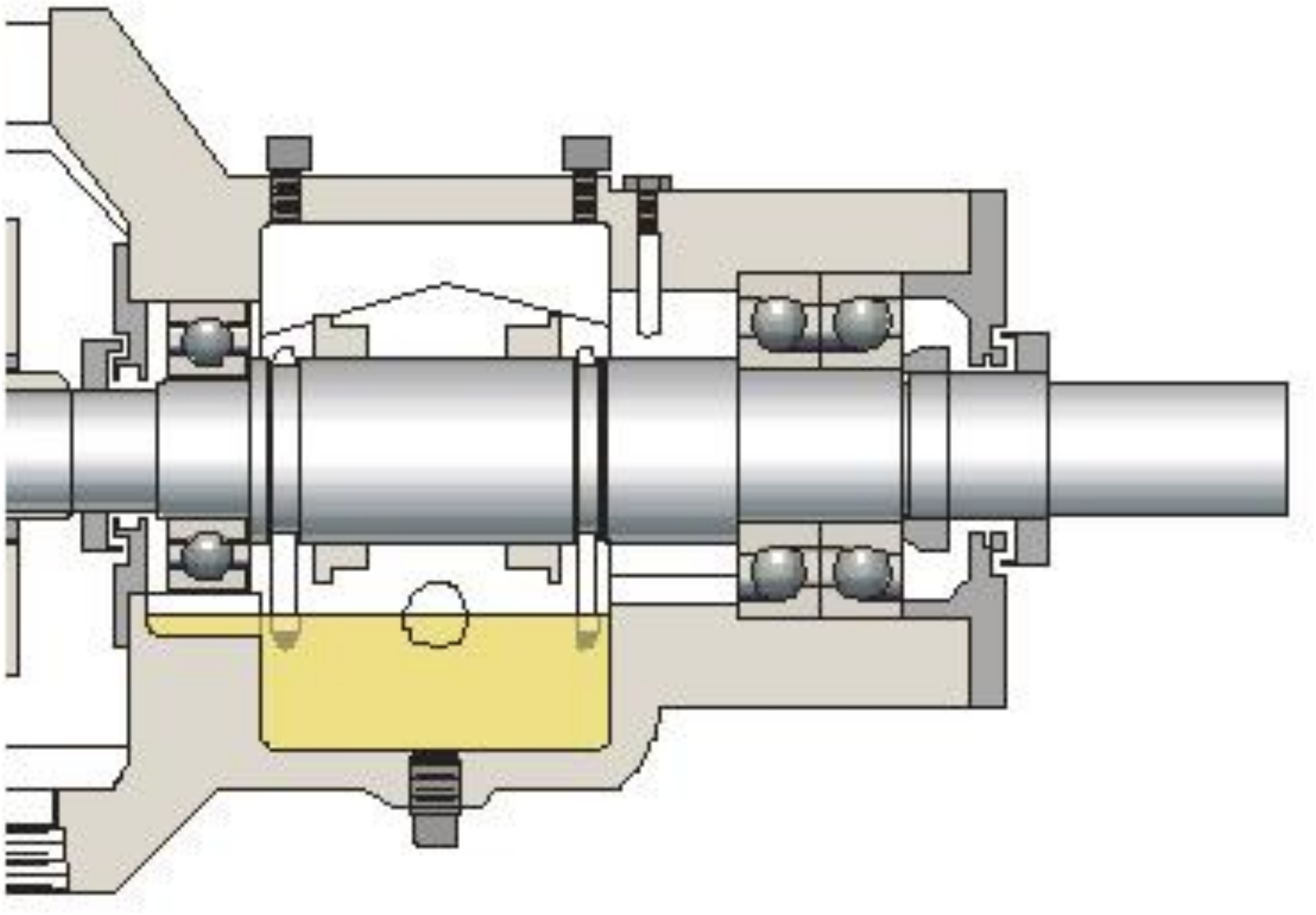


3- Mechanical Seal



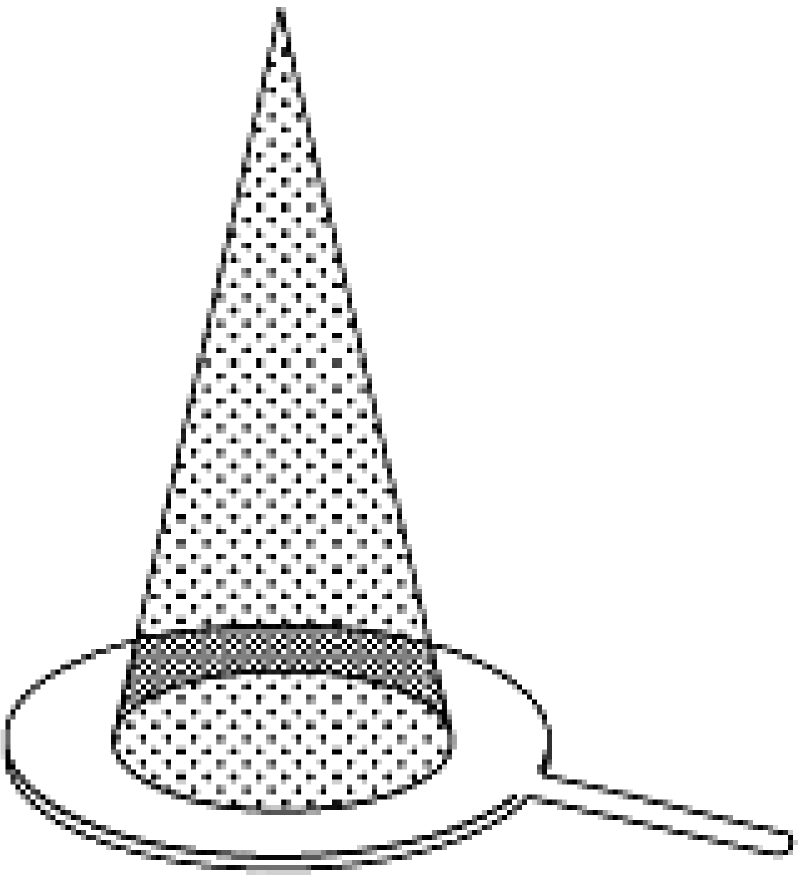
Seal Chamber housing a single mech. seal

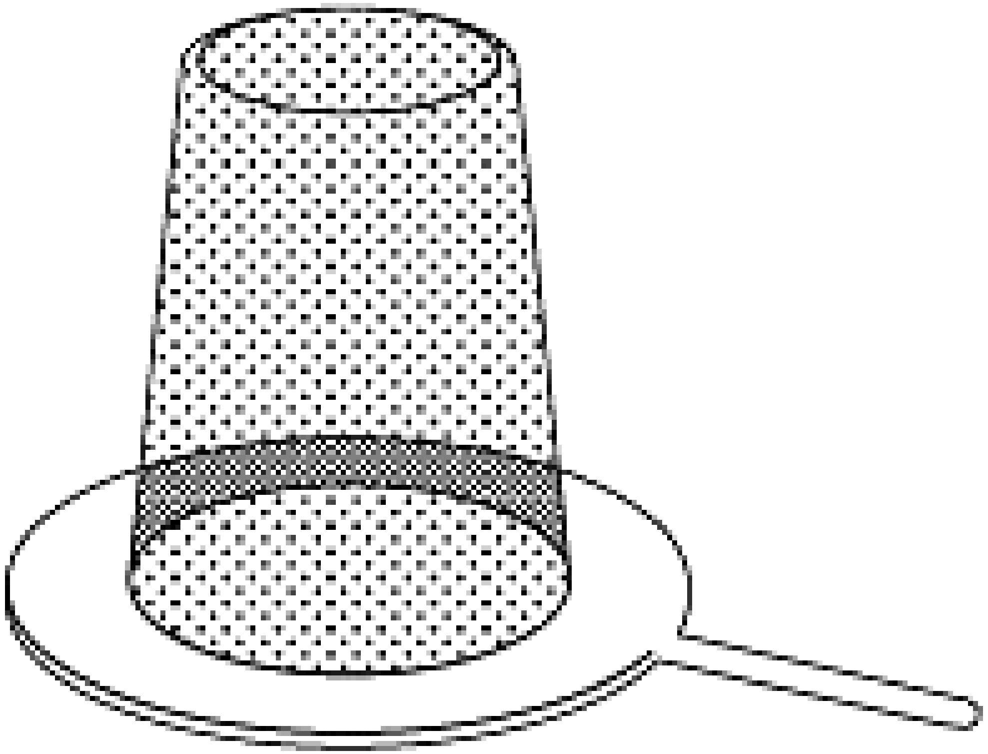
4- Bearing House



Troubleshooting and Maintenance

4- Pump Strainer





Troubleshooting and Maintenance

THE CAUSE	THE PROBLEM									
	HIGH VIBRATION	HIGH NOISE	LOSS OF P DISH.		HI BEARING OIL T	WATER IN LUBE OIL	MECH SEAL FAILURE	CAN NOT DO ALIGNMENT	FAIL TO START	MOTOR TRIP
Insufficient inlet quantity (Cavity)		0								
Lube Oil heat exch. Tubes leak						0				
Operating in critical speed range”	0									
Piping strain	0							0		
Poor oil condition					0					
Rotor imbalance	0				0					0
Misalignment	0								0	0
Journal/thrust bearing damaged	0				0					0
Oil reservoir low temperature									0	

Troubleshooting and Maintenance

	THE PROBLEM									
THE CAUSE	HIGH VIBRATION	HIGH NOISE	LOSS OF P DISH.	LOW OIL PR	HI BEARING OIL T	WATER IN LUBE OIL	MECH SEAL FAILURE	CAN NOT DO ALIGNMENT	CAN NOT START	MOTOR TRIP
Clogging lube oil strainer/ filter		0		0						
Condensate in oil reservoir						0				
Damaged rotor	0									
Excessive bearing clearance	0									
Excessive Inlet temperature			0							
Faulty temperature switch				0	0					0
Improper assembled parts	0								0	0

Troubleshooting and Maintenance

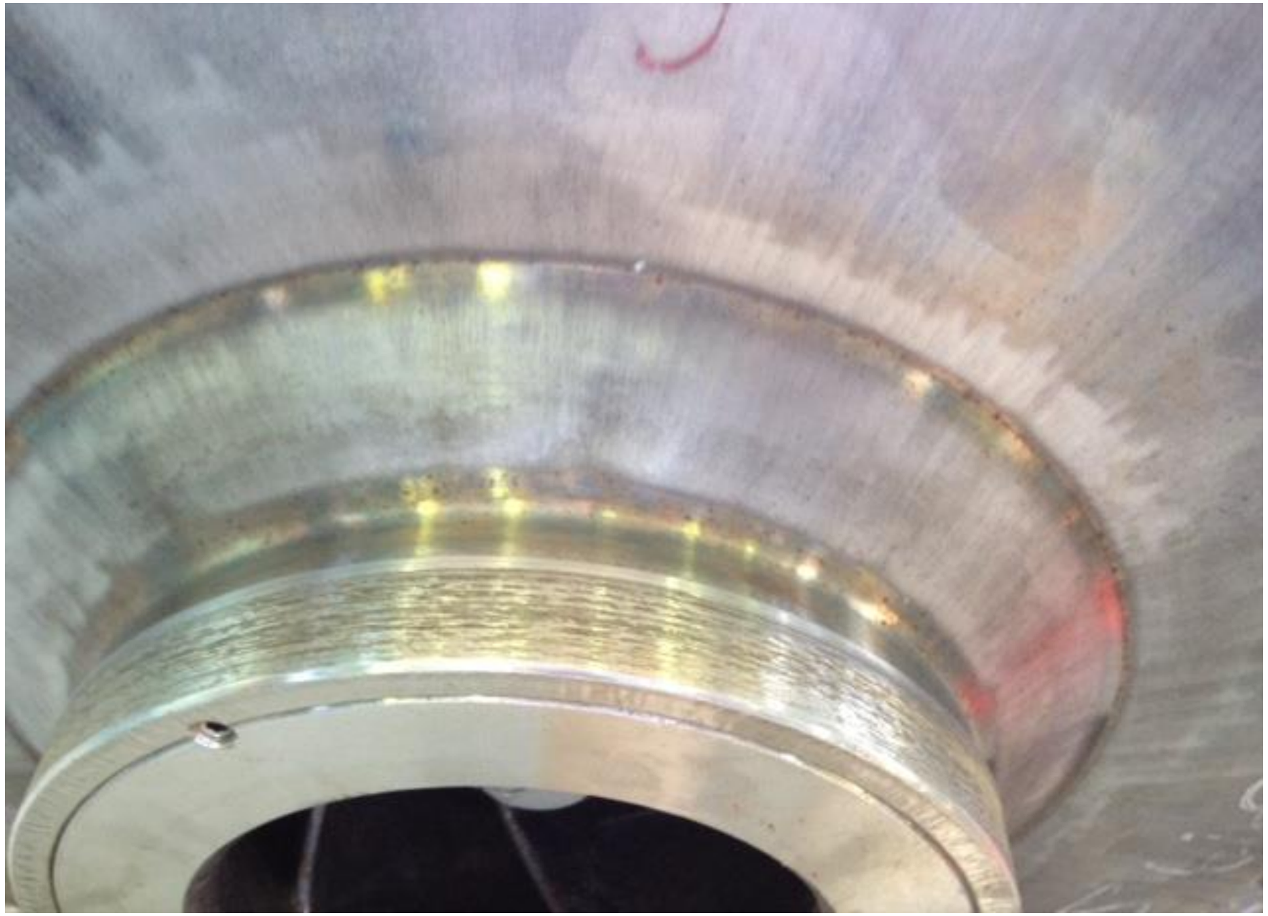
	THE PROBLEM									
THE CAUSE	NO Q DISH.	LOW P DISH.	LOW Q DISH.	EXCESSIVE WEAR	EXCESSIVE HEAT	SHORT BEARING LIFE	HIGH VIBRATION	HIGH A mps	HIGH NOISE	
INSUFFICIENT LUBE OIL (Lubricators)				0*	0	0	0	0		
Misalignment						0	0		0	
Internal parts wear fluid end	0	0	0							
Strainer partially clogged	0	0	0							
Internal parts wear Power end					0		0		0	
P.R.V. problem		0	0							
Insufficient lube oil cooling				0	0	0				
WRONG DIRECTION OF ROTATION	0	0								

Troubleshooting and Maintenance

	THE PROBLEM									
THE CAUSE	NO Q DISH.	LOW P DISH.	LOW Q DISH.	EXCESSIVE WEAR	EXCESSIVE HEAT	SHORT BEARING LIFE	HIGH VIBRATION	HIGH A mps	HIGH NOISE	
INSUFFICIENT LUBE OIL				0	0	0	0	0	0	
Misalignment				0		0	0		0	
EXCESSIVE SYSTEM PRESSURE			0	0	0	0	0	0		
EXCESSIVE INLET TEMPERATURE			0							0
INSUFFICIENT LIQUID IN SUCTION		0	0	0			0			
INTERNAL COMPONENT WEAR	0	0	0							
STRAINER PARTIALLY CLOGGED	0	0	0				0			
SPEED TOO LOW		0	0							
P.R. VALVE LEAKS OR WRONG SET		0	0							
ROTARY ELEMENTS BINDING				0	0	0	0	0	0	
PIPING STRAIN				0	0	0	0			
WRONG DIRECTION OF ROTATION	0	0								

Case Study

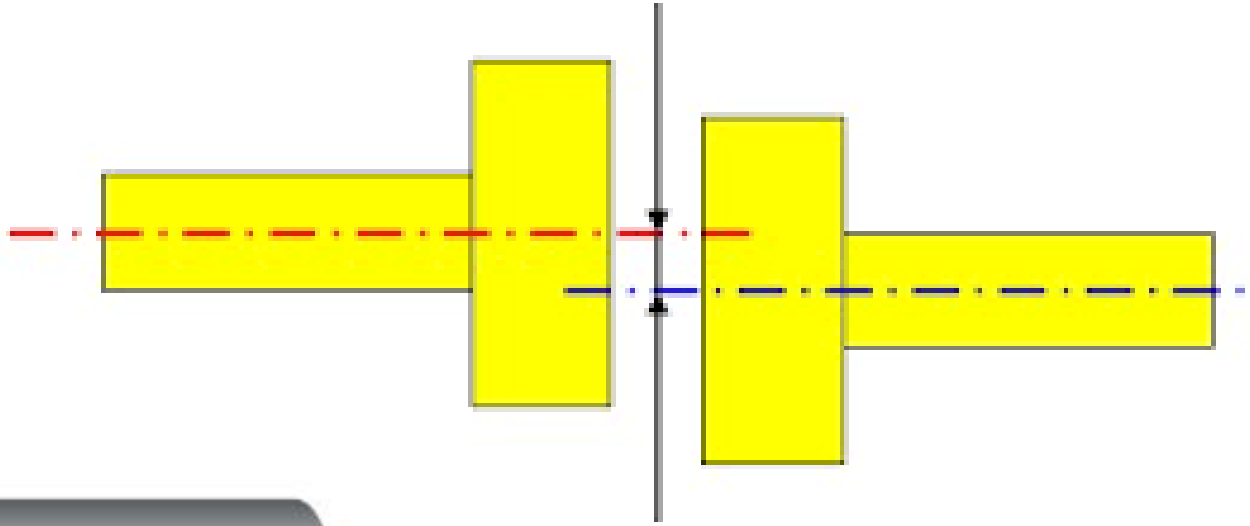
- Very high temperature of pump 20-P-01A bearing house was noticed with severe bearing noise.
- Flow rate : 123-140 m^3/hr (till 48 hours before the failure), 180 m^3/hr within the moment of failure and 48 hours before.
- Thrust Bearings found overheated and damaged, Radial Bearing found normal.
- Oil thrower of radial bearing side was found lose while the another one was found fixed in place.
- Impeller and casing wear rings were found worn and out of tolerance. They were replaced.
- Mechanical Seal was in good condition.

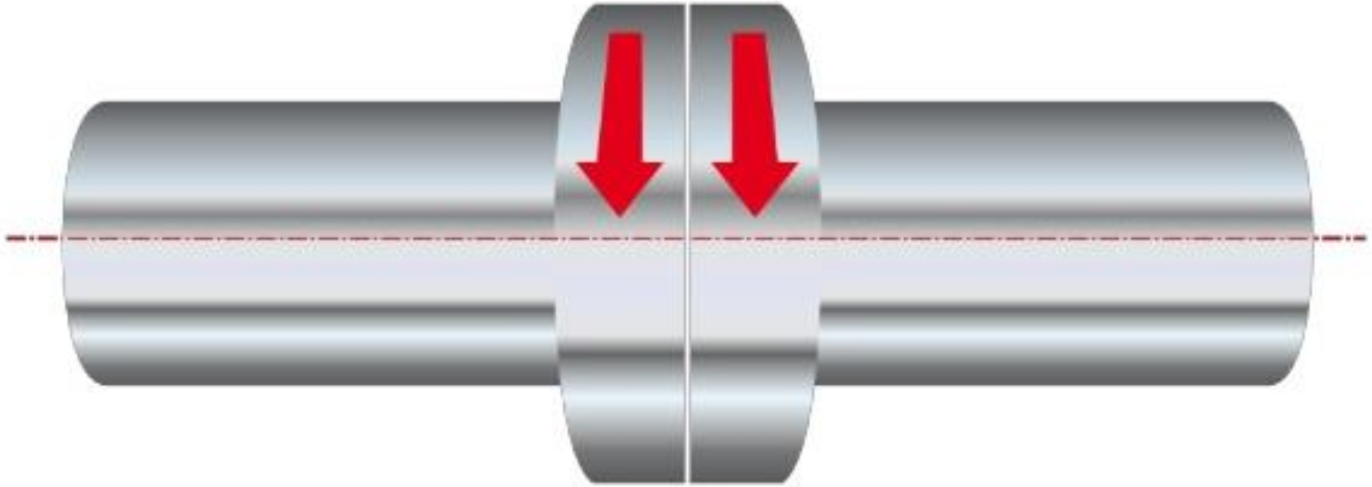


Alignment ?

Definition

The process of reducing the misalignment of two adjacent shafts so that the center line for each shaft is as near collinear as practical.

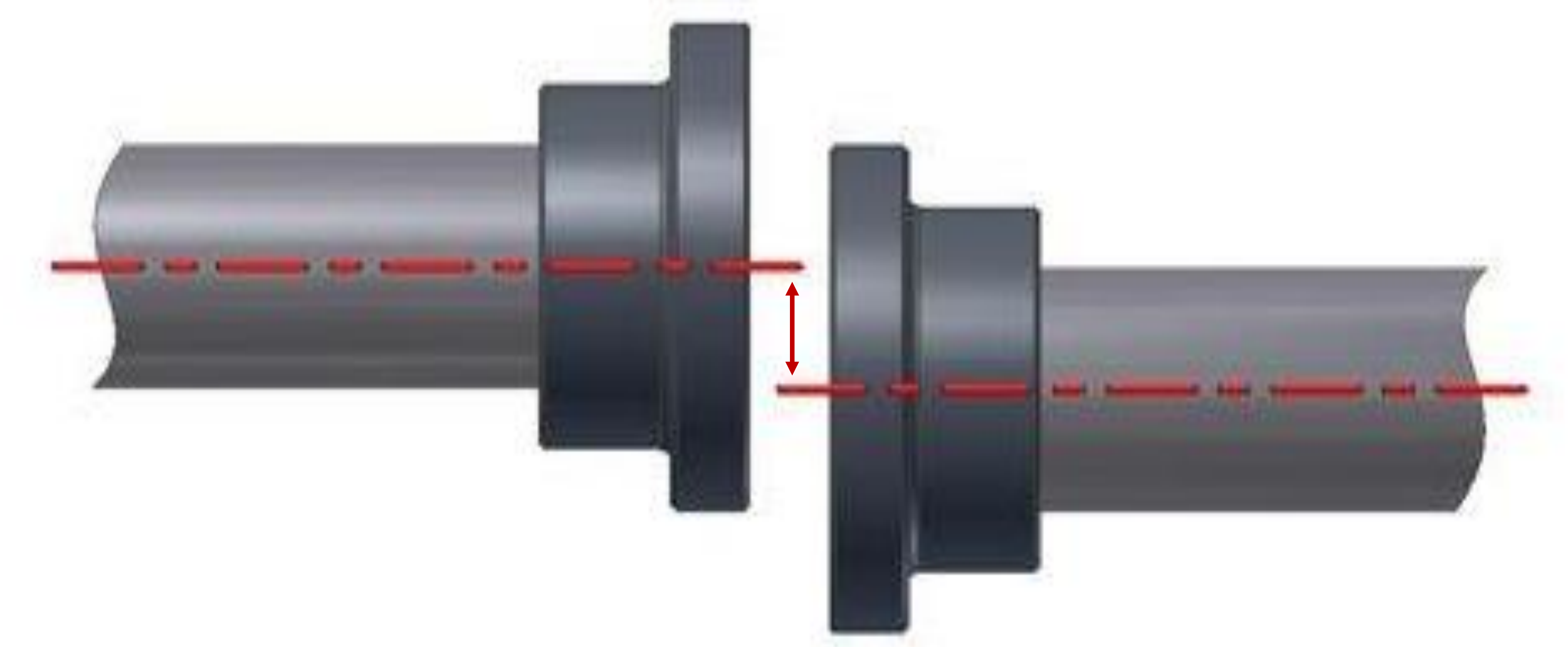




Parallel (Offset) Misalignment?

Definition

The distance between two adjacent and parallel shaft centerlines. This offset is normally described in a unit (millimeters or mils) at the flex element location.



Angular Misalignment ?

Definition

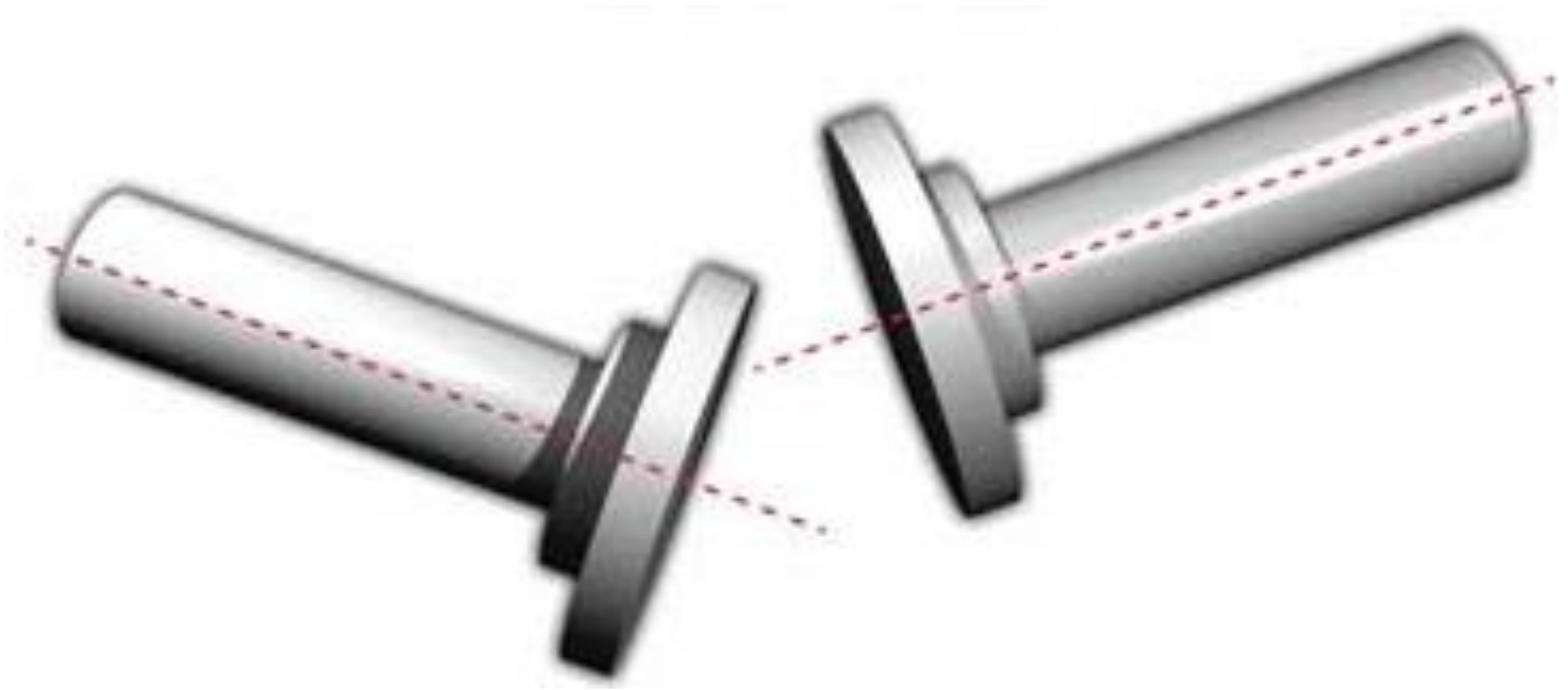
The angle between the shaft centerline of two adjacent shafts. This angle is normally reported in slope of millimeter of change per meter of linear distance (mils per in.) (1 mil = 0.001 in.).

Millimeters of change per meter of linear distance

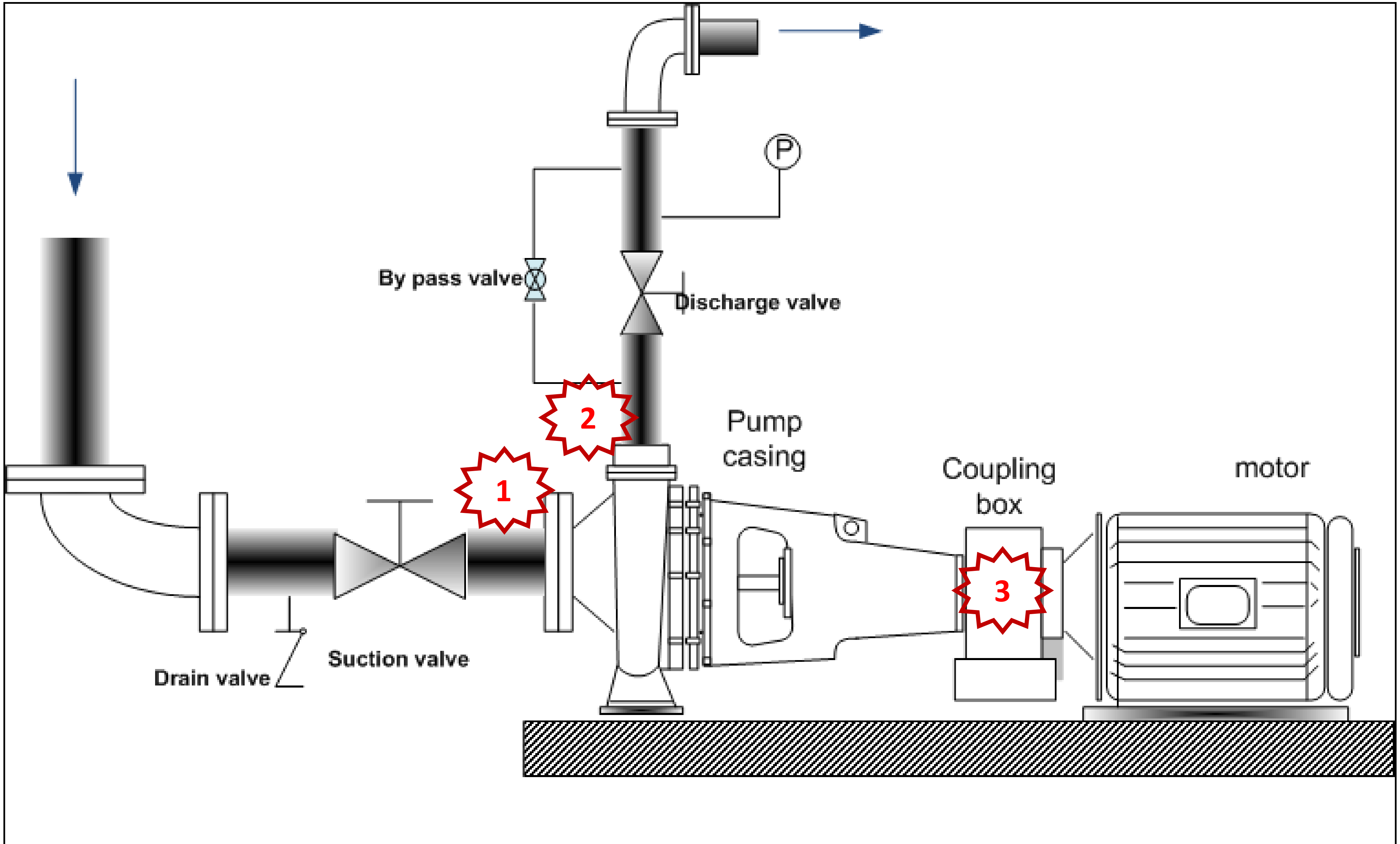
Combination Misalignment ?

Definition

When the centerlines of two adjacent shafts are neither parallel nor intersect. This misalignment is normally described in both angular and offset terms.

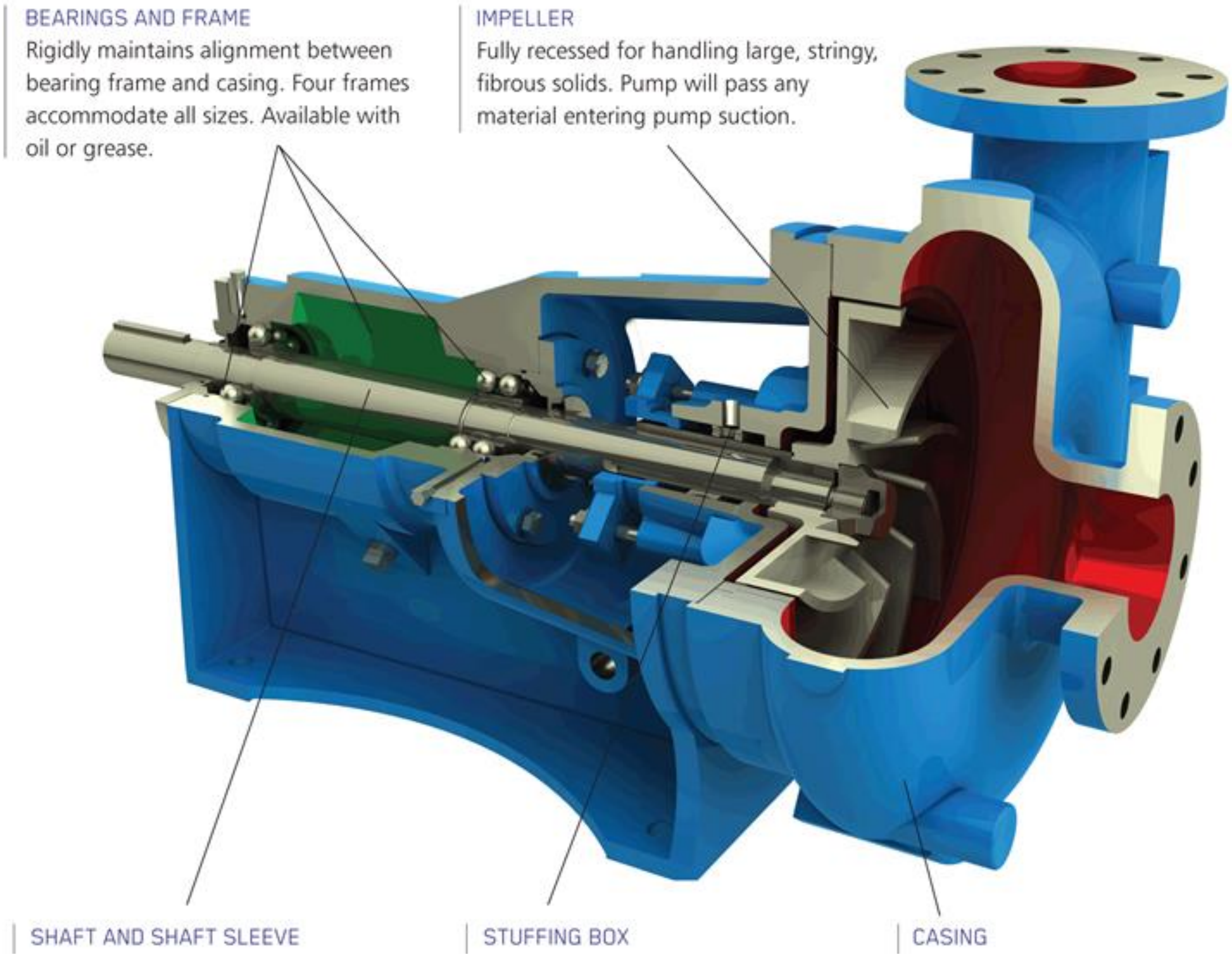


Locations of Potential Misalignment



Centrifugal pump system

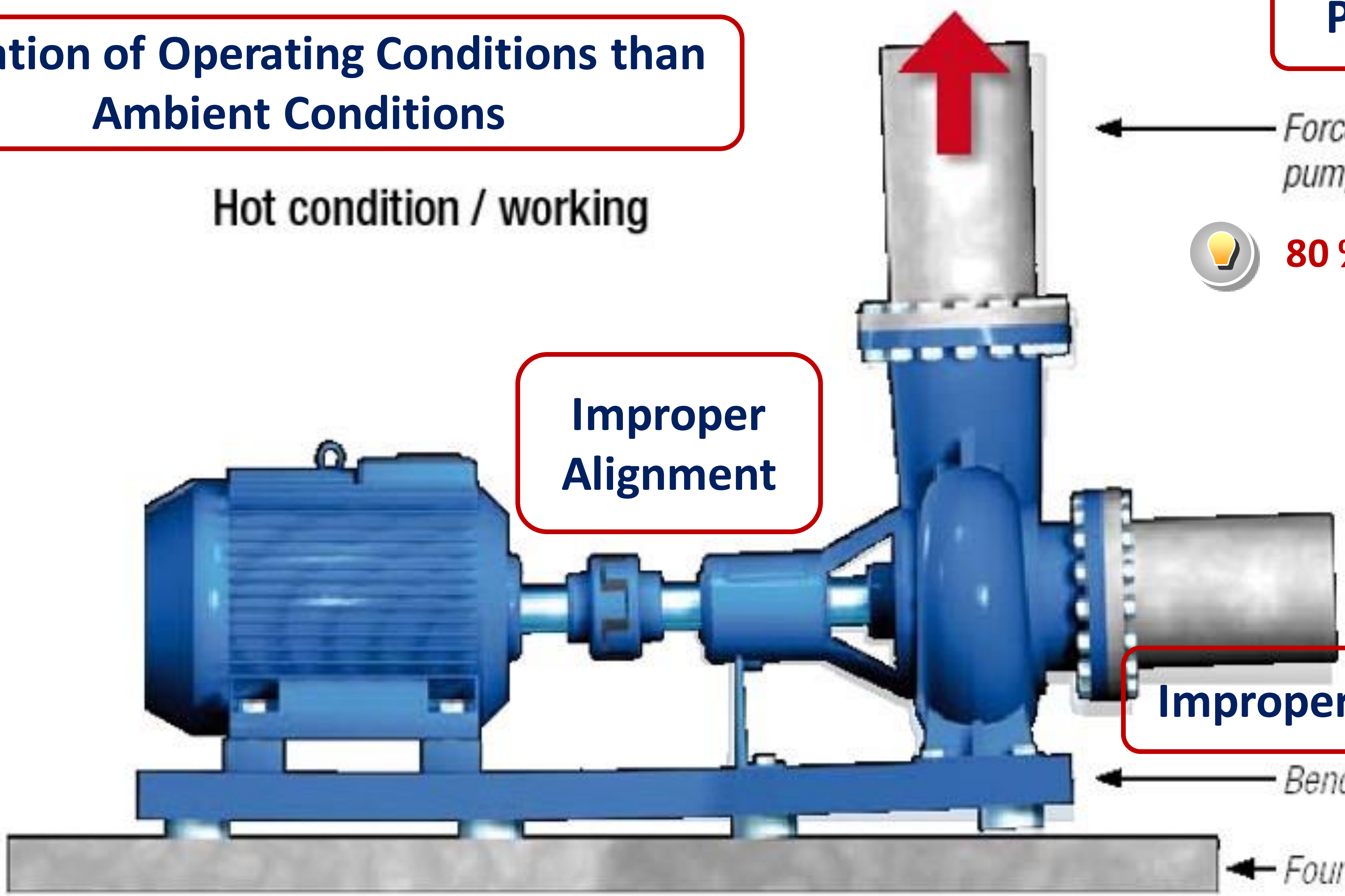
Consequences of Misalignment



Sources of Misalignment

Deviation of Operating Conditions than Ambient Conditions

Piping Strain



80 % of Chronic Failures

Improper Alignment

Improper Foundation Design

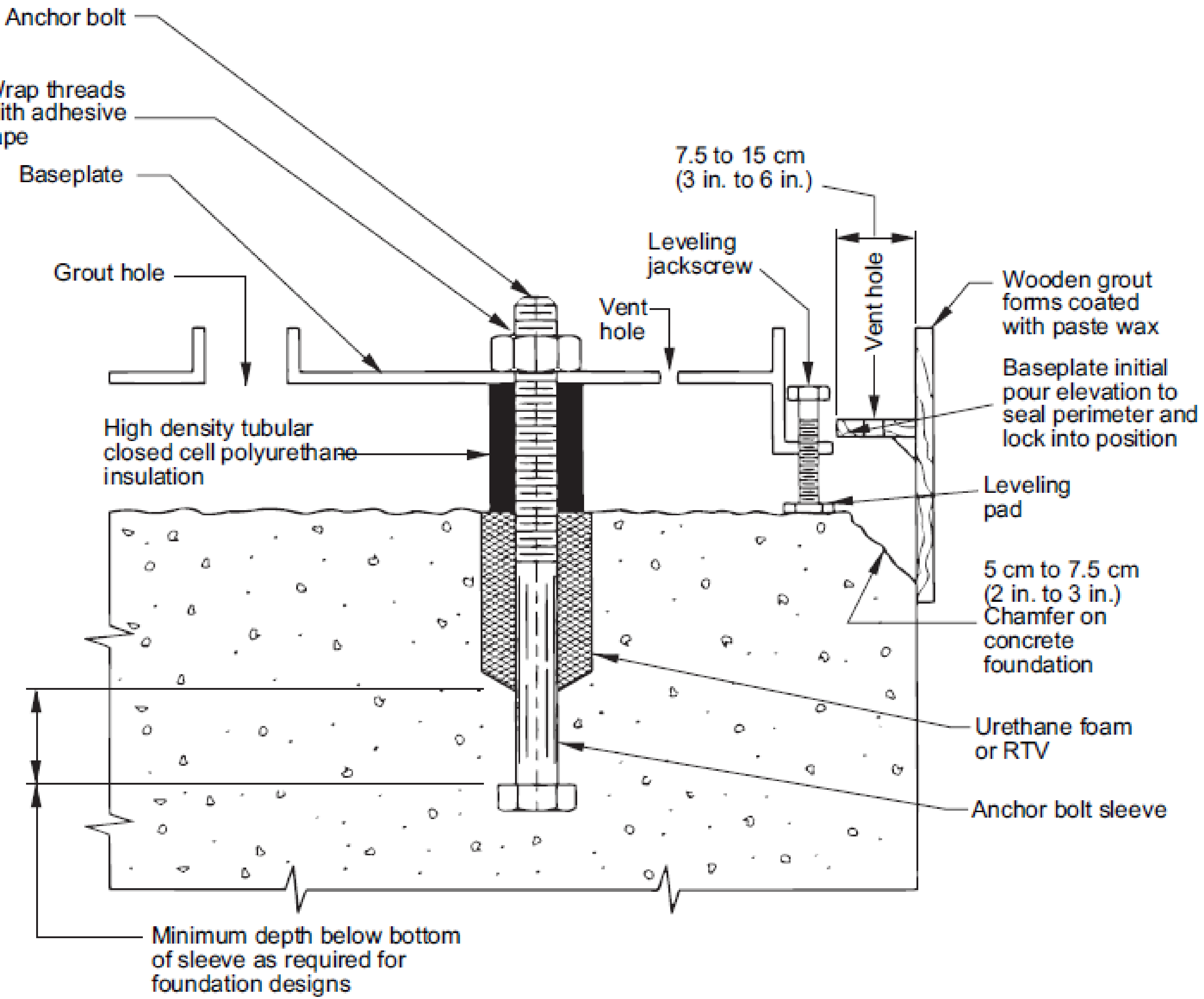
Sources of Misalignment

Improper Base Plate /Foundation Design

Pump Base Plate

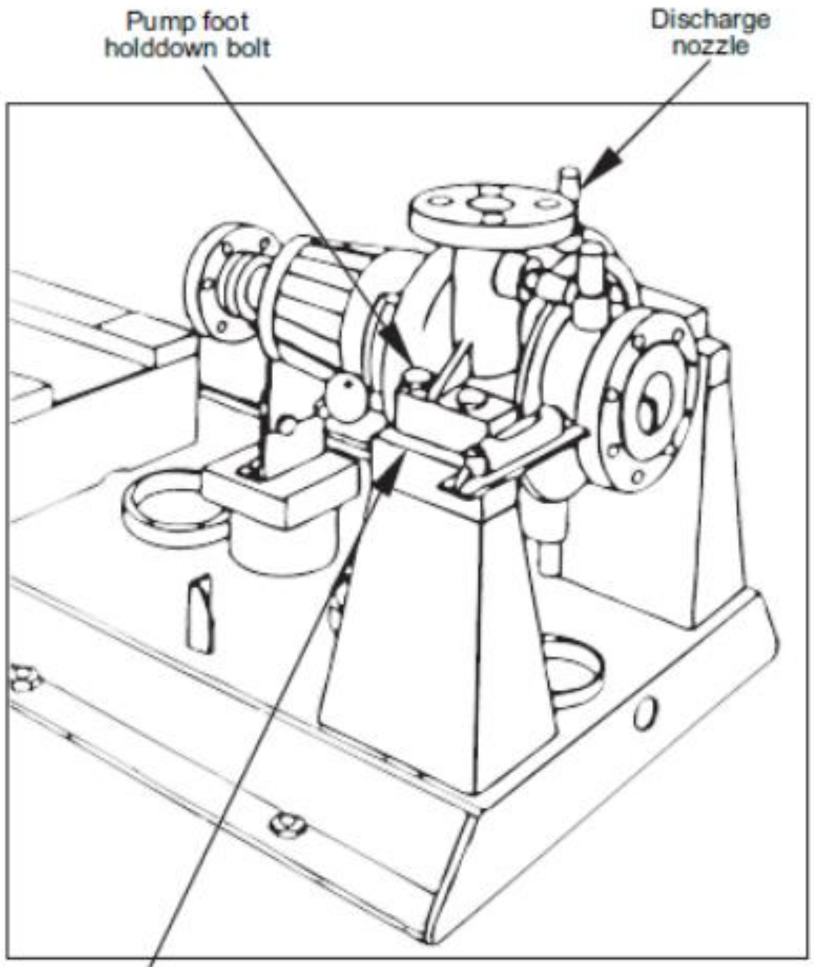
A fabricated (or cast) metal structure used to mount, support, and align, machinery and its auxiliary components.

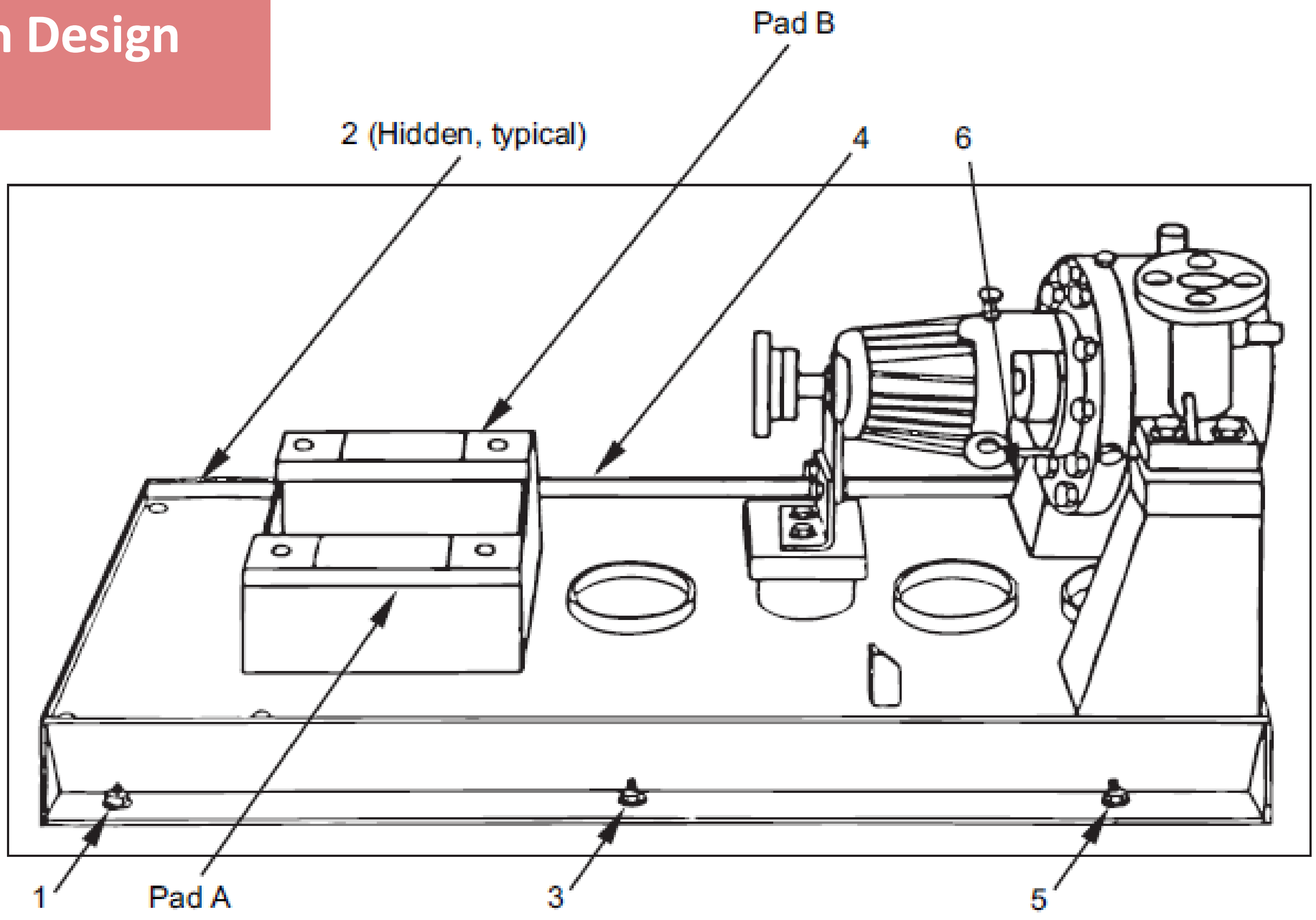
Base Plate /Foundation Design



Sources of Misalignment

Improper Base Plate /Foundation Design

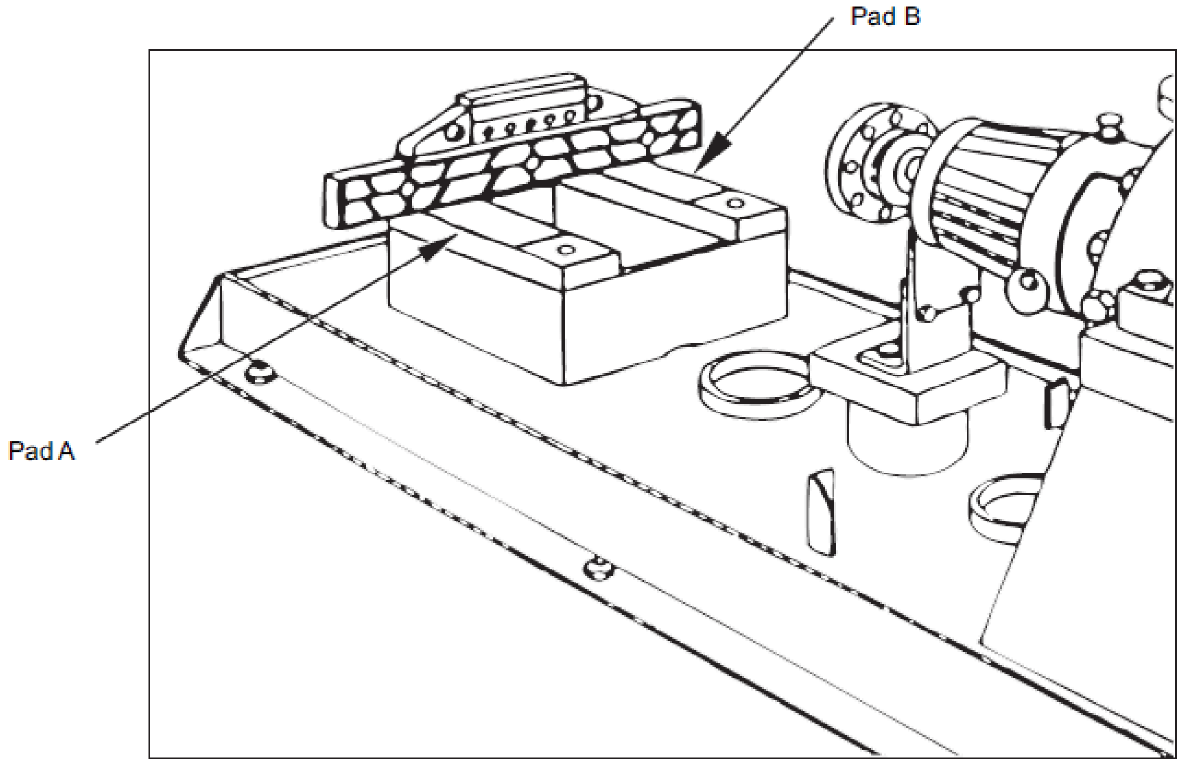


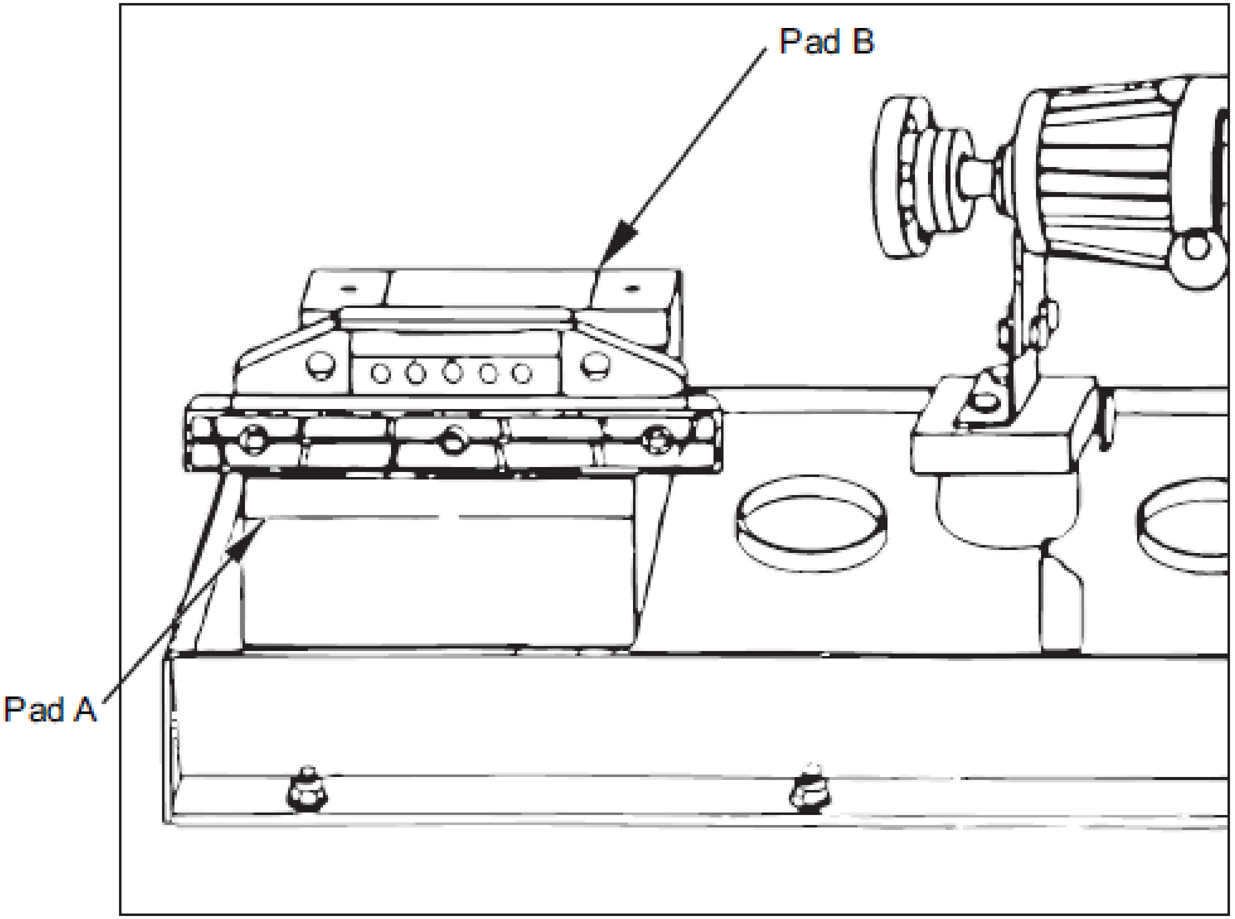


2, 4, and 6 are directly across from points 1,3, and 5, respectively.

Sources of Misalignment

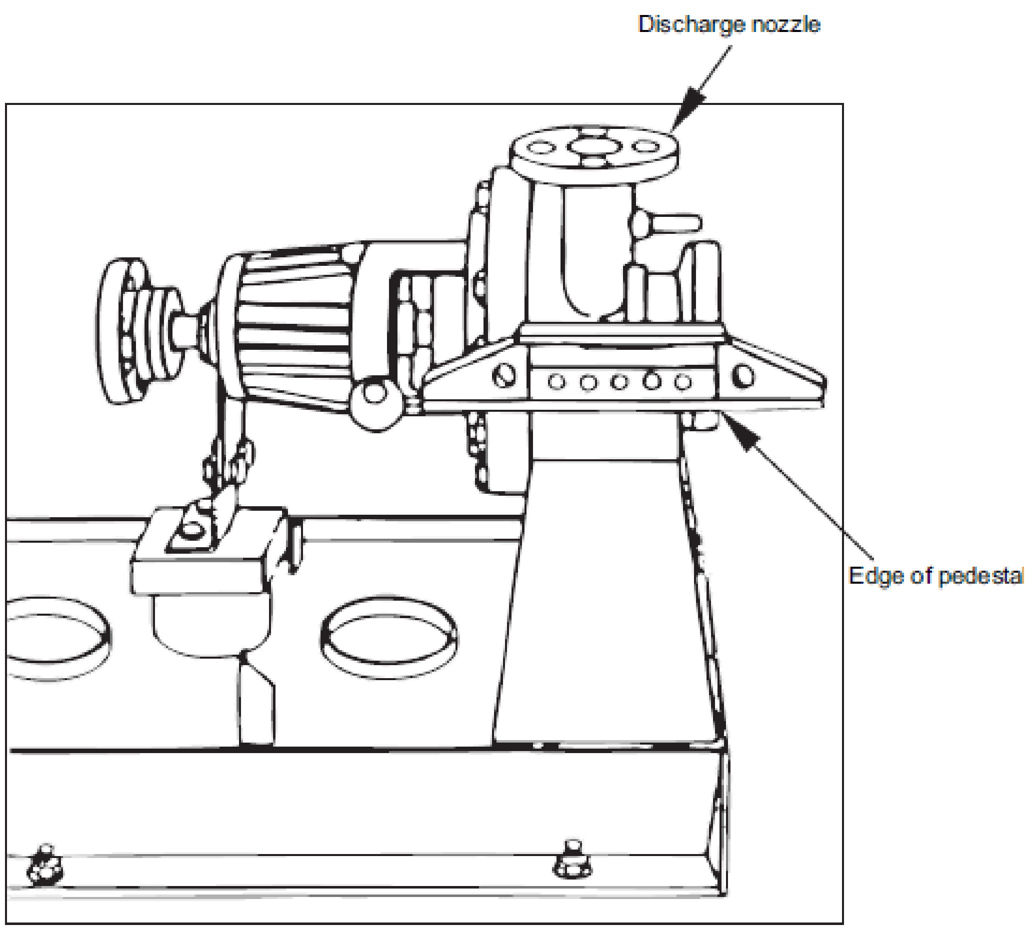
Improper Base Plate /Foundation Design

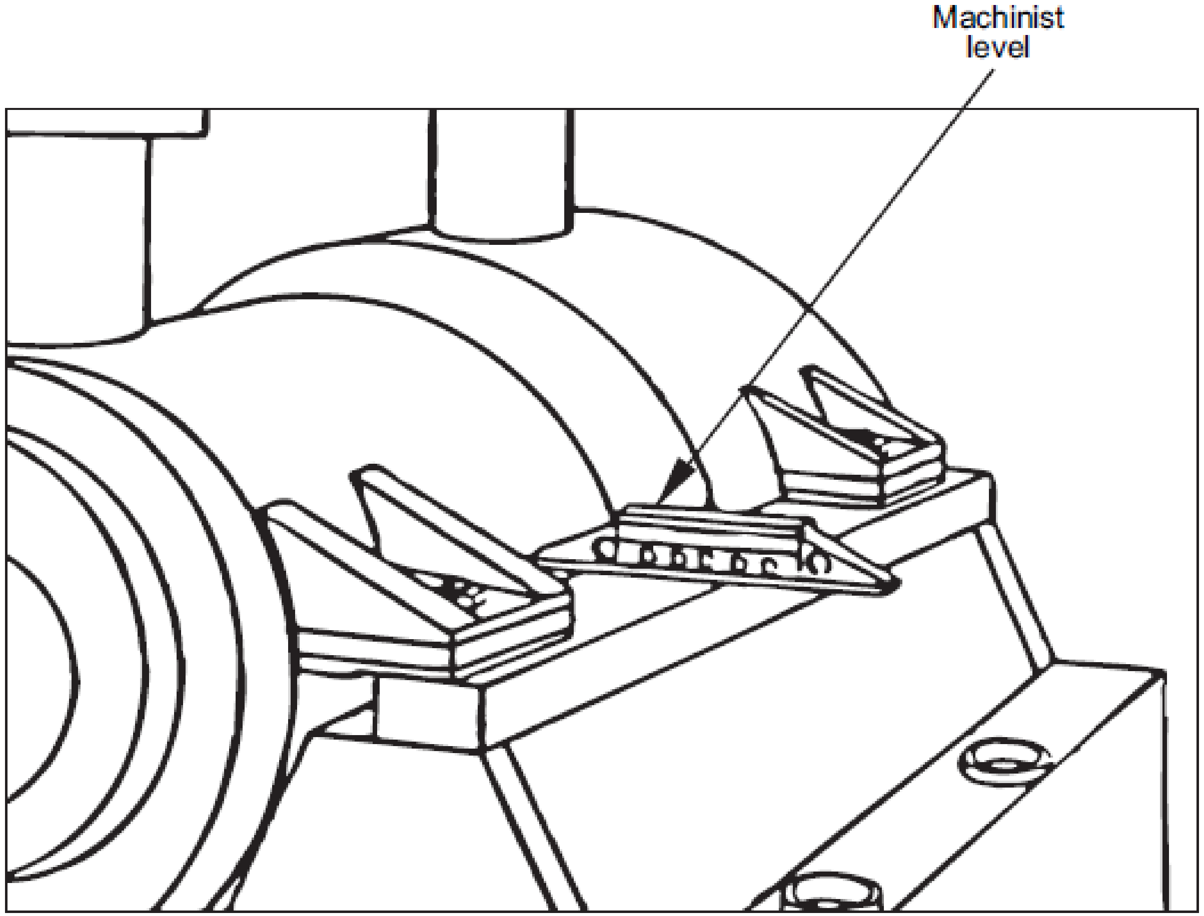




Sources of Misalignment

Improper Base Plate /Foundation Design





Piping Misalignment Check

API 686

Piping Tolerances

Machinery Installer: ______________________ Machinery Identification: ______________________

Feeler Gauge Readings Between
Gasket Faces

Flange Size: __________

INLET — Top or North

1. ________
2. ________
3. ________
4. ________
5. ________
6. ________
7. ________
8. ________

OUTLET — Top or North

1. ________
2. ________
3. ________
4. ________
5. ________
6. ________
7. ________
8. ________

Maximum Allowable Tolerances: (difference between high & low readings)

- 10 Micrometers/centimeter (0.001 in./in.) of flange outside diameter, not to exceed 750 micrometers (0.030 in.).
- Piping smaller than NPS 10: 250 micrometers (0.010 in.) or less.
- Only 4 feeler gauge readings, equally spaced, required on flanges 15 centimeters (6 in.) outside diameter and smaller.

Note:

Pipe Strain Readings

- For horizontal machinery - Dial indicator or laser readings on coupling hub flange.
- For vertical machinery - Dial indicator or laser readings on driver-mount flange.

Net Indicator Readings	Inlet Flange Bolt Up	Outlet Flange Bolt Up
Horizontal Orientation (1)	+ or – __________ µm or in.	+ or – __________ µm or in.
Vertical Orientation (2)	+ or – __________ µm or in.	+ or – __________ µm or in.

(1) For vertical machinery, the horizontal orientation is perpendicular to pipe centerline when viewed from top.
(2) For vertical machinery, the vertical orientation is parallel to pipe centerline when viewed from top.
(3) Maximum shaft movement in either direction is 50 micrometers (0.002 in.)

Remarks: ______________________________

Piping Inspector: ______________________ **Date:** ______________

Piping Misalignment Check

API 686

Verifying Piping Strain

OVERALL OBJECTIVE:
To verify that strains imposed by the piping on the machinery are minimized.

Piping Alignment Overview

a. The basic method of verifying pipe strain consists of bolting up the piping to the machine flanges while measuring the deflection of the machine shaft with dial indicators or laster alignment tooling.

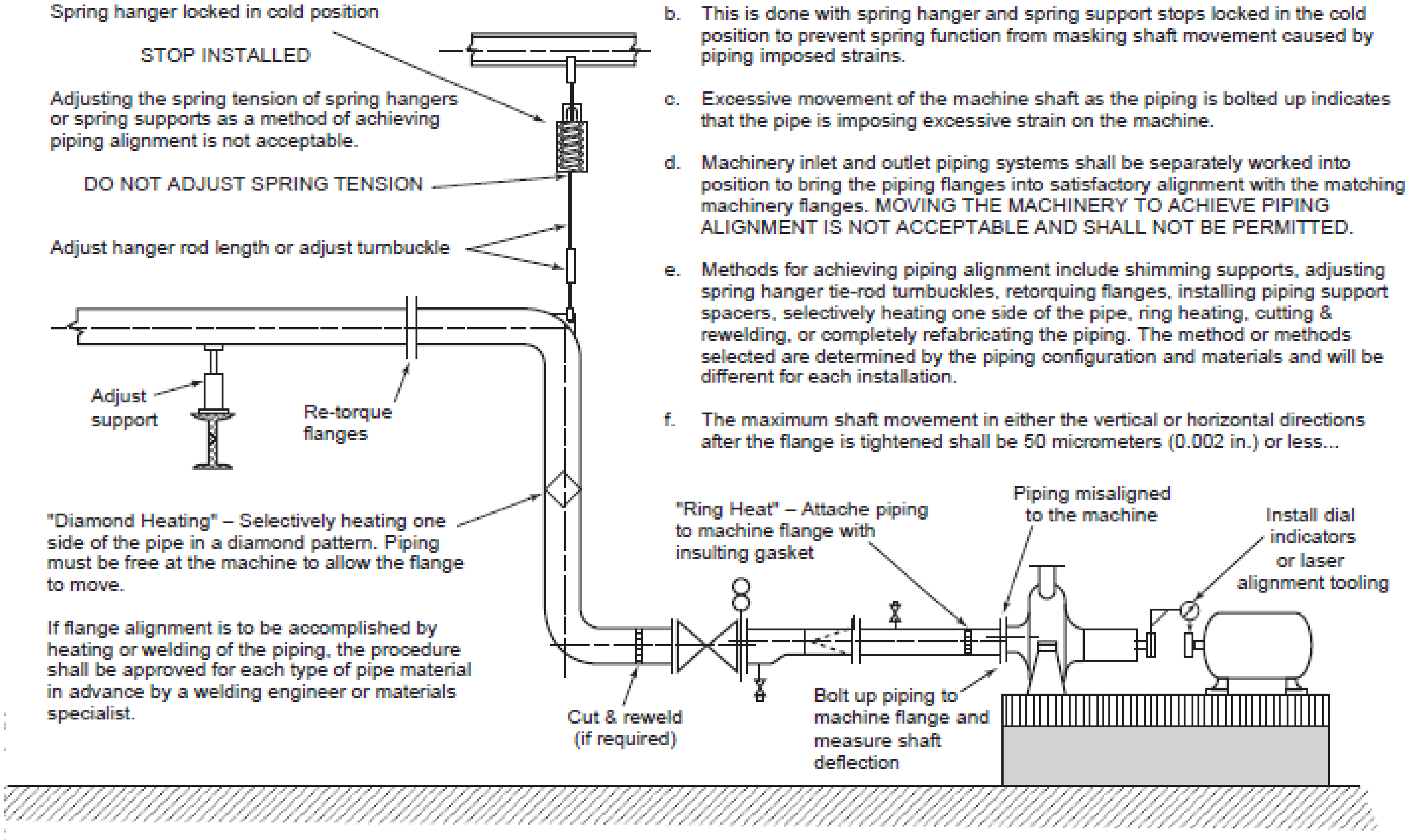
b. This is done with spring hanger and spring support stops locked in the cold position to prevent spring function from masking shaft movement caused by piping imposed strains.

c. Excessive movement of the machine shaft as the piping is bolted up indicates that the pipe is imposing excessive strain on the machine.

d. Machinery inlet and outlet piping systems shall be separately worked into position to bring the piping flanges into satisfactory alignment with the matching machinery flanges. MOVING THE MACHINERY TO ACHIEVE PIPING ALIGNMENT IS NOT ACCEPTABLE AND SHALL NOT BE PERMITTED.

e. Methods for achieving piping alignment include shimming supports, adjusting spring hanger tie-rod turnbuckles, retorquing flanges, installing piping support spacers, selectively heating one side of the pipe, ring heating, cutting & rewelding, or completely refabricating the piping. The method or methods selected are determined by the piping configuration and materials and will be different for each installation.

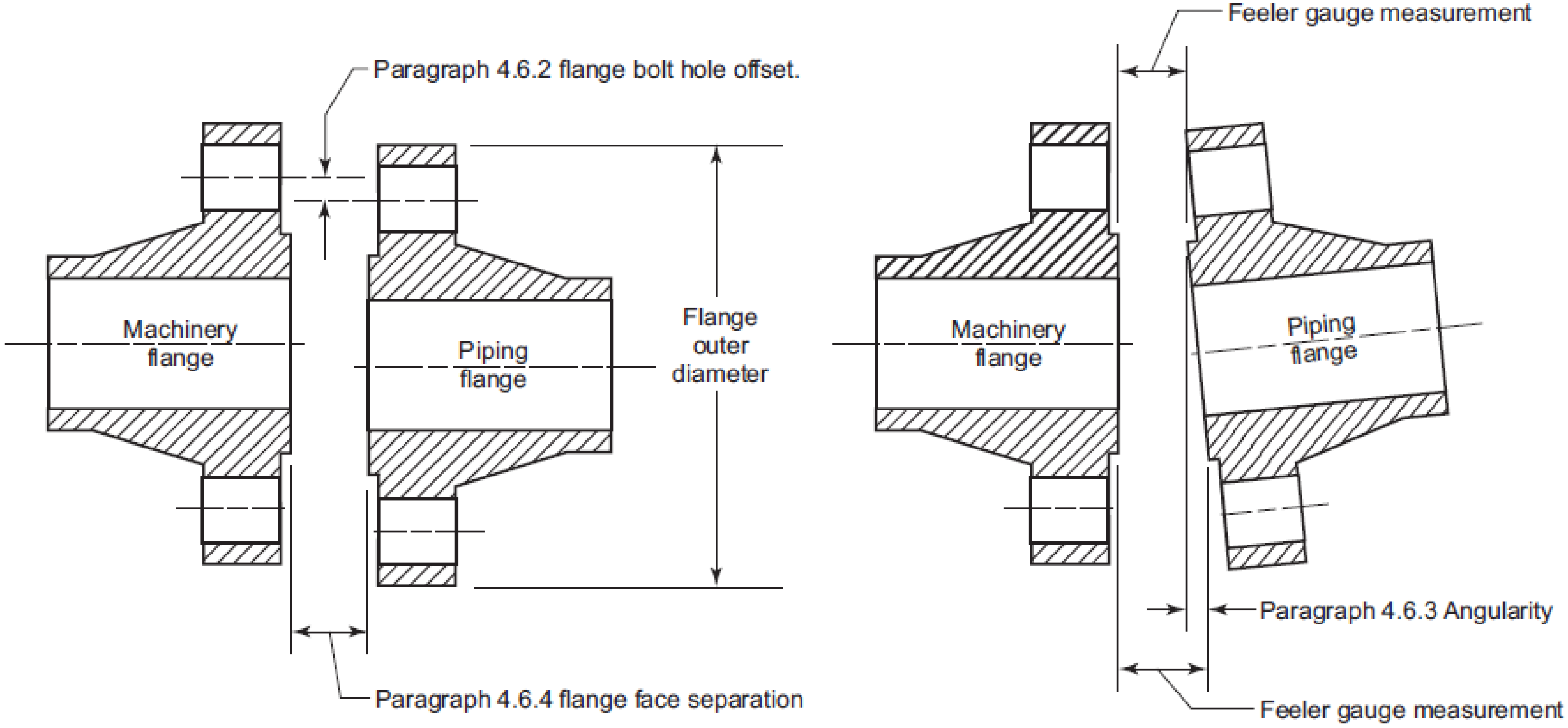
f. The maximum shaft movement in either the vertical or horizontal directions after the flange is tightened shall be 50 micrometers (0.002 in.) or less...



Piping Misalignment Check

API 686

Piping Alignment Requirements



4.6.2 Pipe flange bolt holes shall be lined up with machinery nozzle bolt holes within 1.5 mm (1/16 in.) maximum offset from the center of the bolt hole to permit insertion of bolts without applying any external force to the piping.

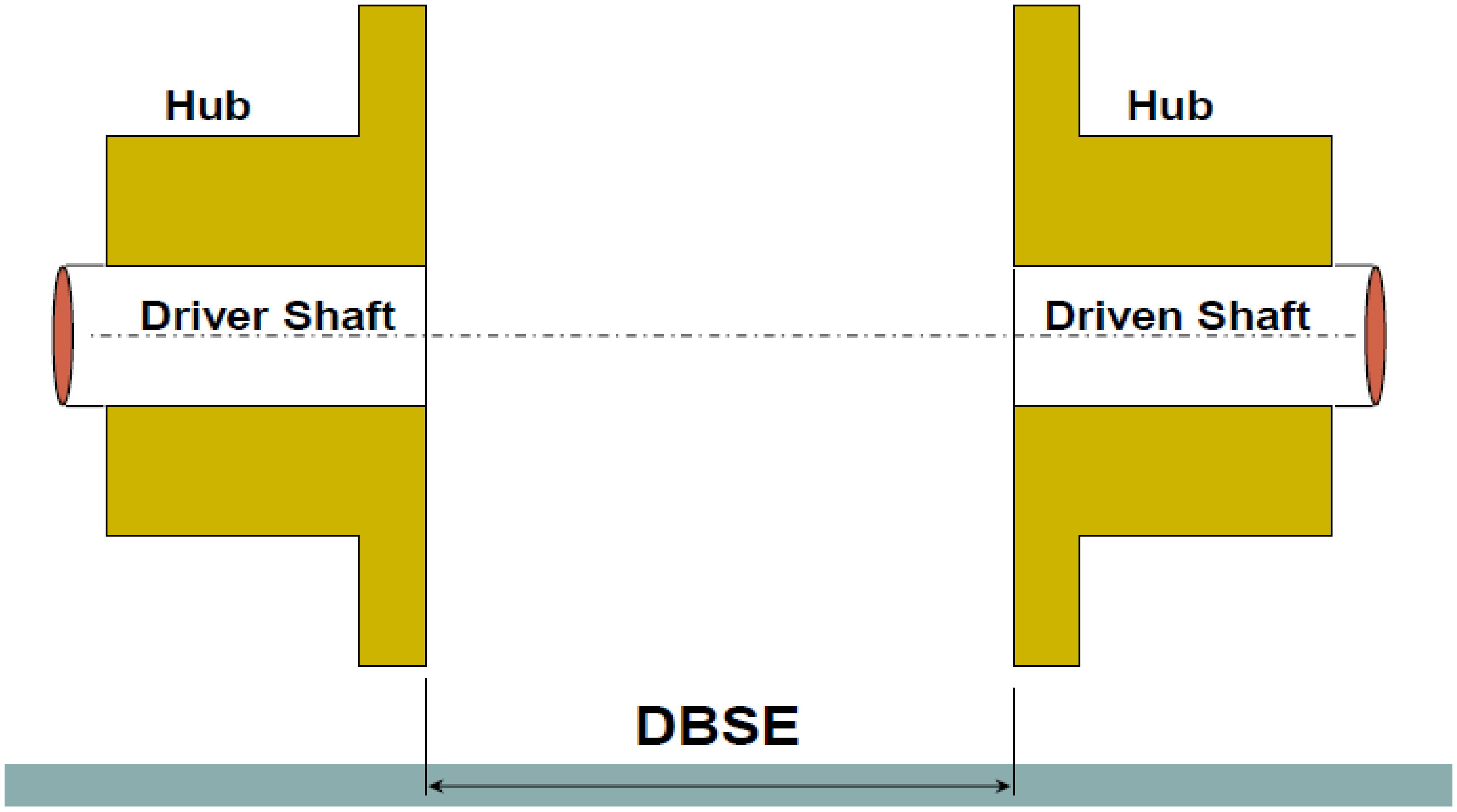
4.6.4 Flange face separation shall be within the gasket spacing plus or minus 1.5 mm (1/16 in.). Only one gasket per flanged connection shall be used.

4.6.3 The machine and piping flange faces shall be parallel to less than 10 micrometers per centimeter (0.001 in. per in.) of pipe flange sealing surface outer diameter up to a maximum of 750 micrometers (0.030 in.). For piping flange sealing surface outer diameters smaller than 25 cm (10 in.), the flanges shall be parallel to 250 micrometers (0.010 in.) or less. Feeler gauge readings shall be taken at the outer diameter of the flange sealing surfaces.

NOTE The sealing surface of a raised face flange is the raised face. Thus feeler gauge readings are taken at the raised face. The sealing surface of a flat faced flange is the entire flange face. Thus feeler gauge readings for a flat faced flange are taken at the flange outer diameter. The sealing surface of a ring-joint flange are taken at the outer diameter of the raised face.

Couplings

Installation



Alignment Tools

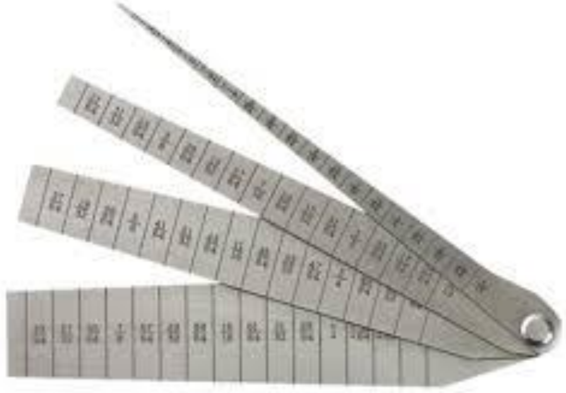
Dial Indicator

Clamps

Shims

Feeler Guage

Straight Edge



Taper Guage

Alignment Tools

Vernier Caliper

Laser Alignment Kit

Torque Wrenches

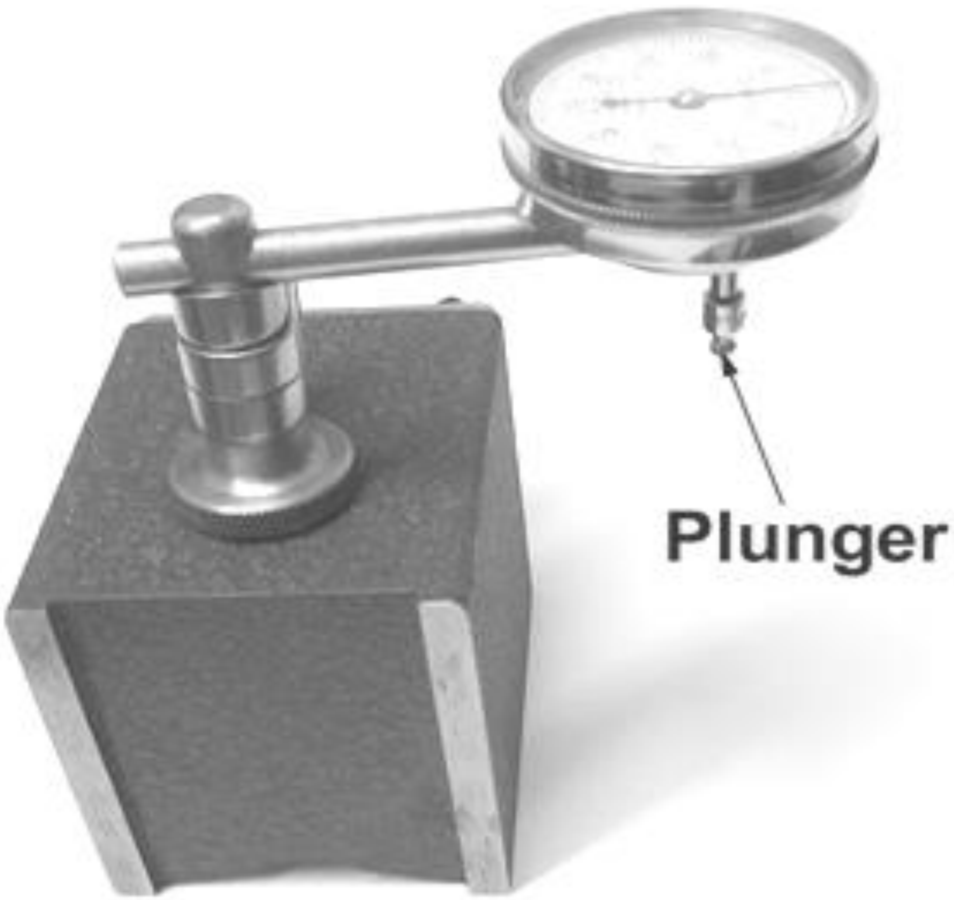
Open/Closed Wrenches

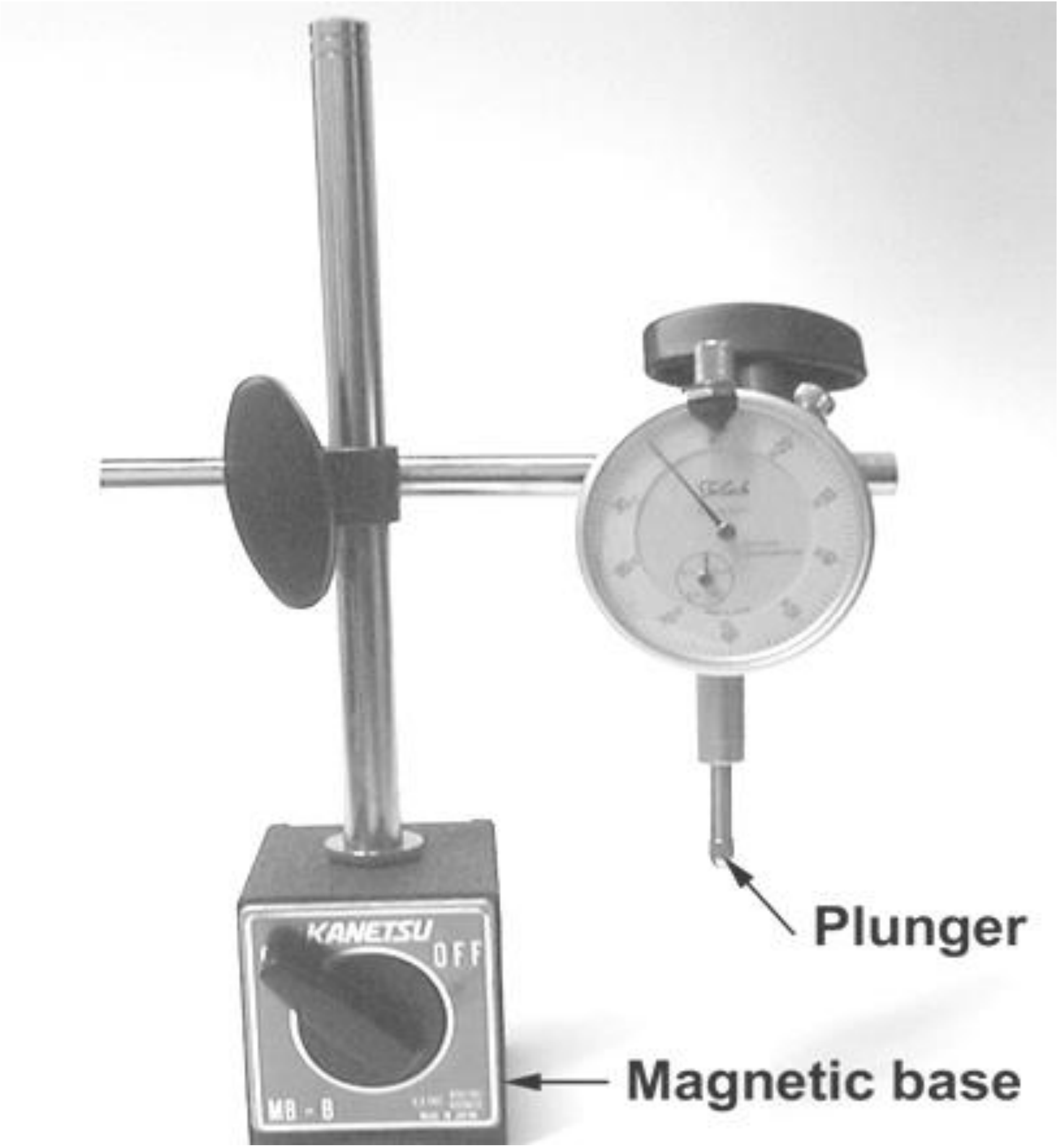
Mirror

Level Bar

Alignment Tools

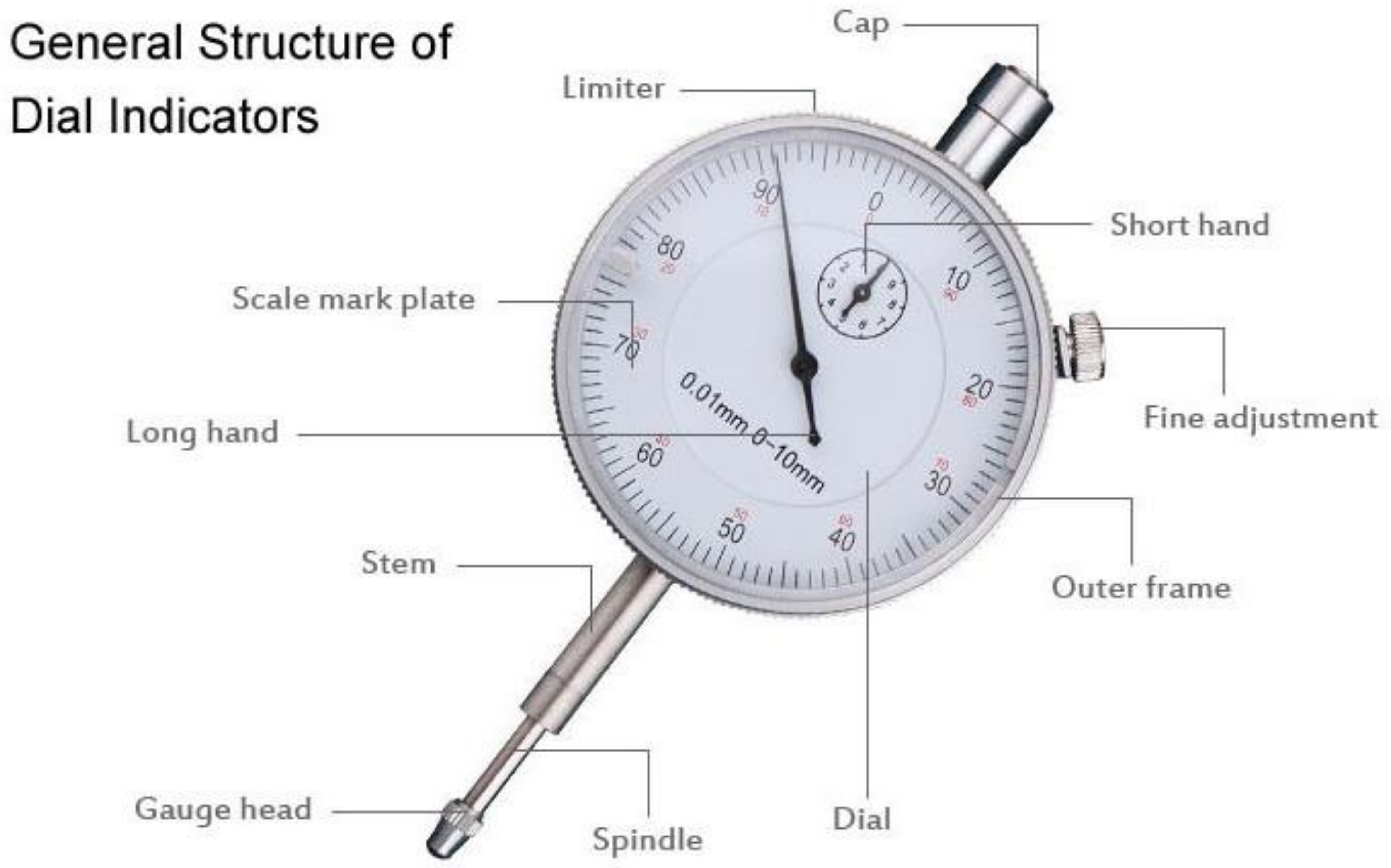
Dial Guage/Indicator





Alignment Tools

Dial Guage/Indicator



Alignment Tools

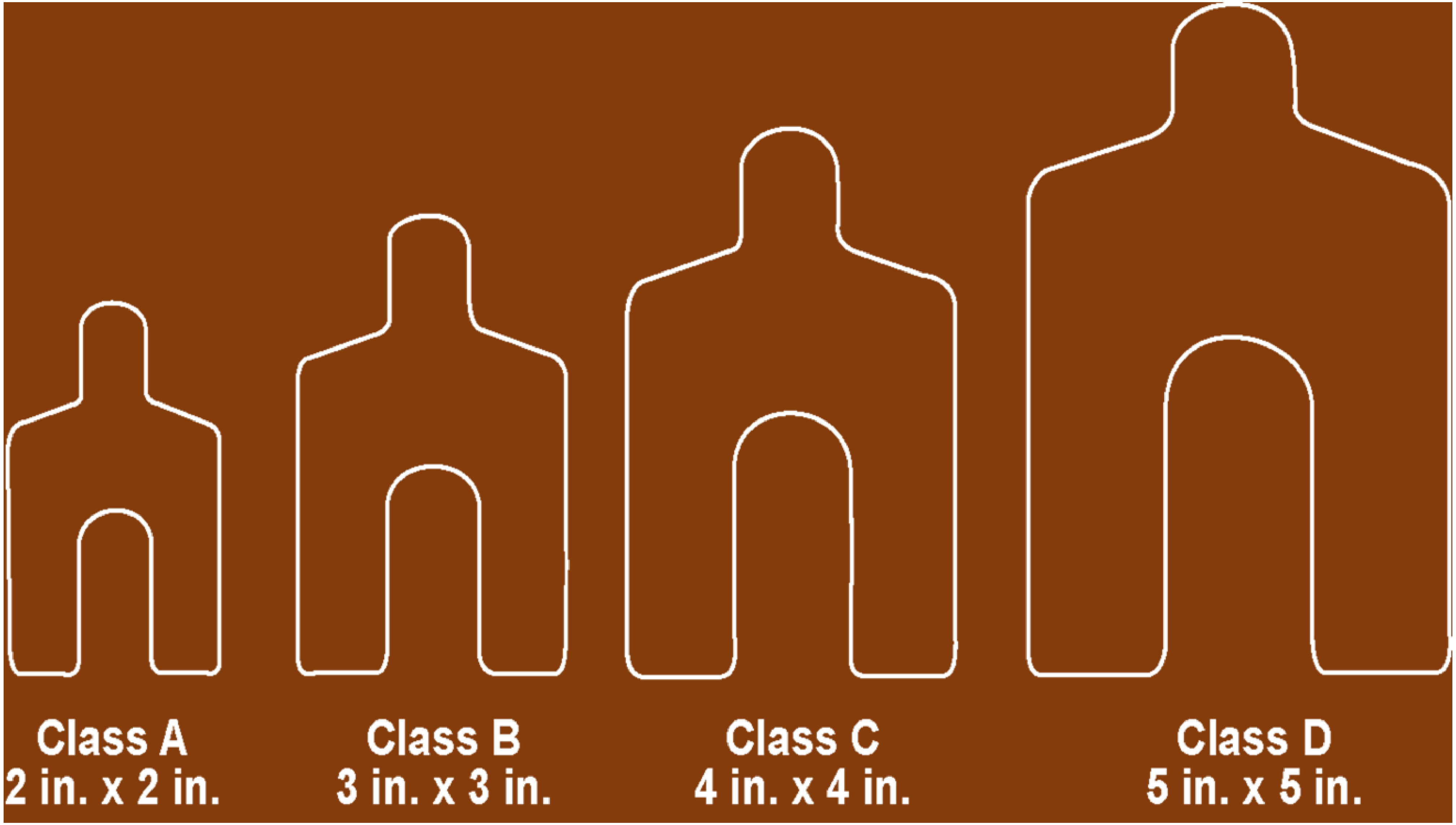
Dial Guage/Indicator

Various Styles, Sizes and Ranges

Metric Dial Indicator

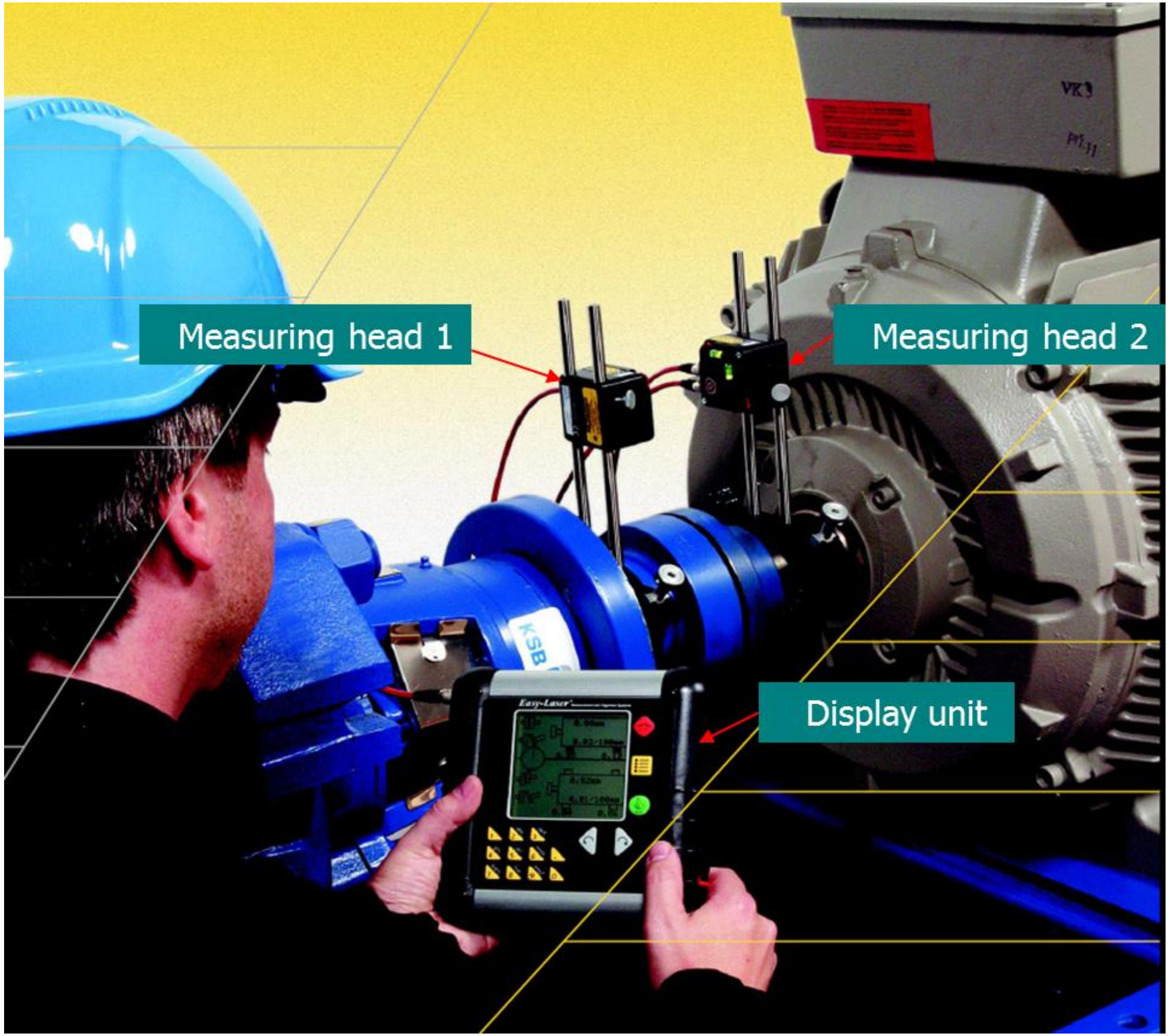
Alignment Tools

Shims



Alignment Techniques

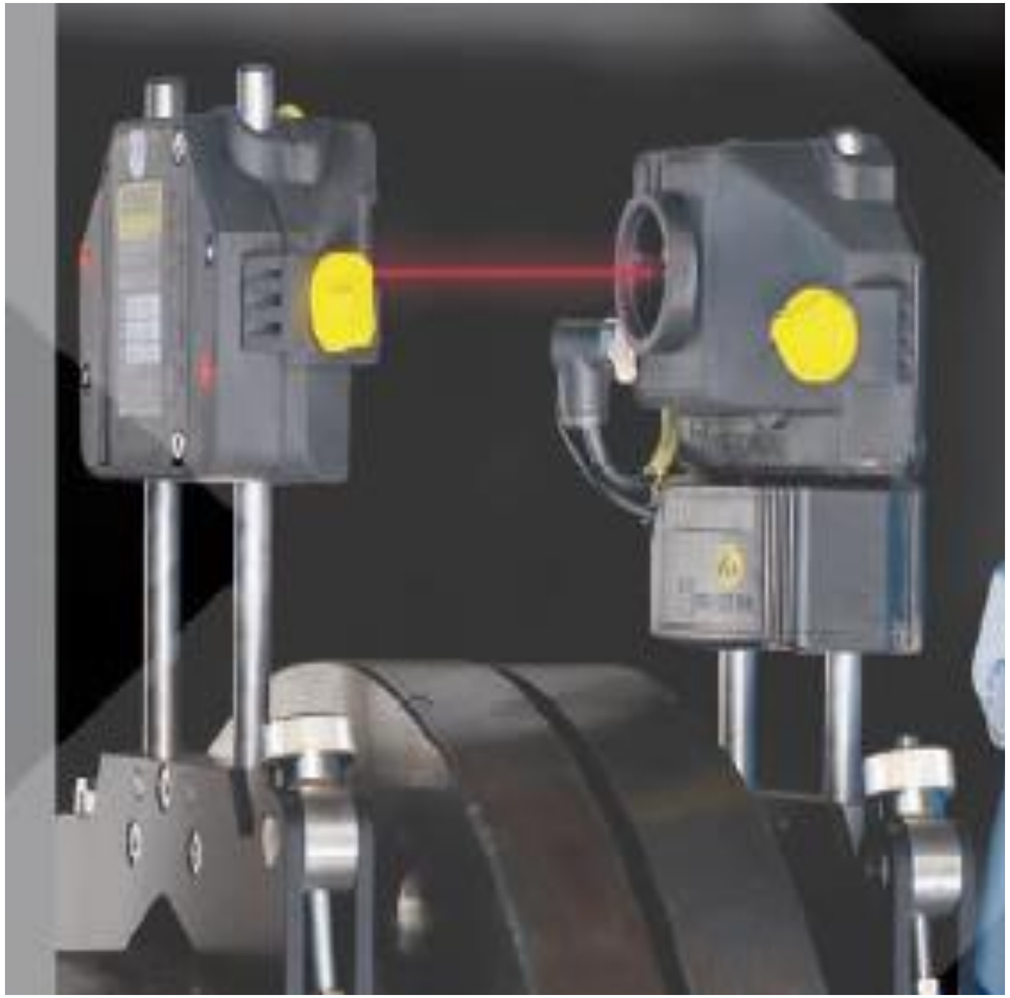
Laser Alignment



Alignment Techniques

Laser Alignment

- With the advent of laser technology, alignments can be achieved to high degrees of accuracy.
- A laser alignment system uses a laser diode to produce a straight laser beam.
- These beams can be either visible or invisible to the naked eye.
- The laser beams may be Class 1 (invisible) or Class 2 (visible).
- Looking directly into the laser beam without protection is not recommended.

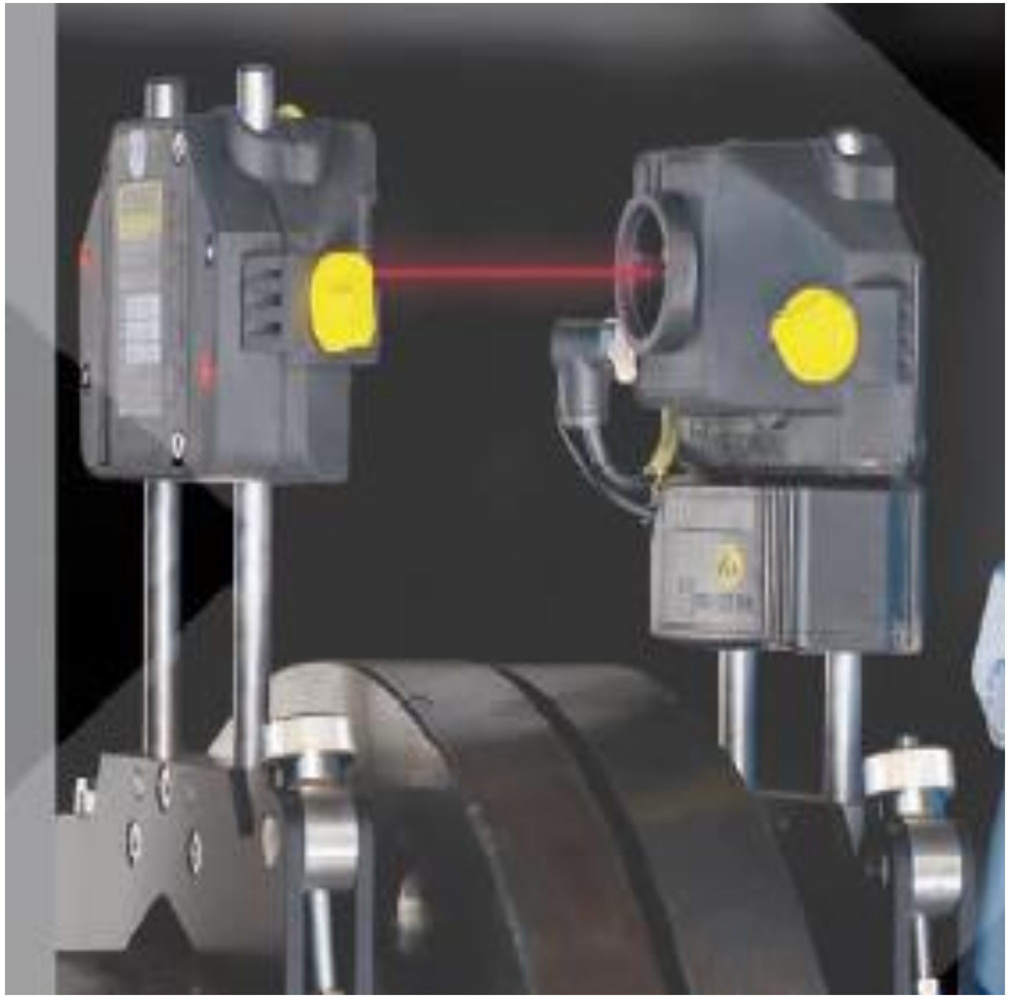


Alignment Techniques

Laser Alignment

Advantages of Laser Alignment

- Good for long spans
- Gives consistent, accurate results
- Avoids mistakes in calculation
- Has fast set-up and most system brackets are easily attached to the machine
- Avoids the problem of bracket sag

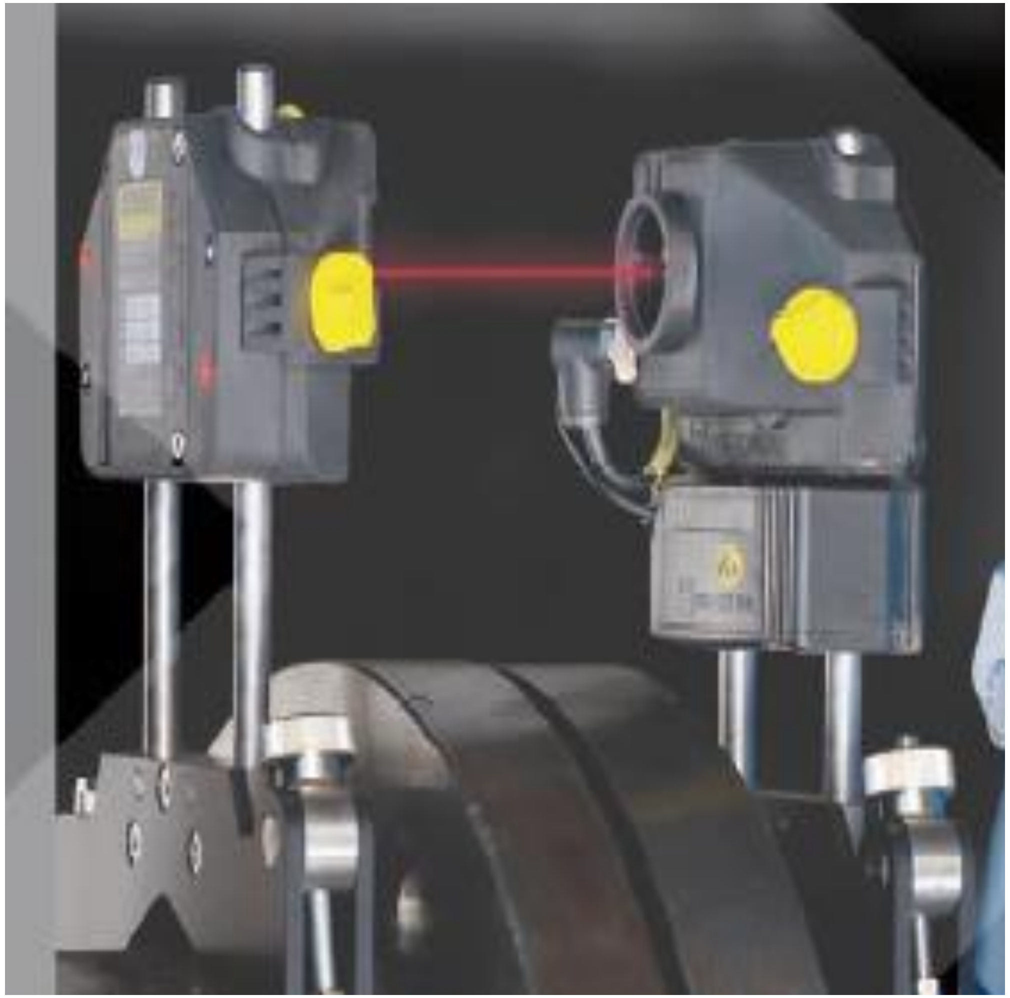


Alignment Techniques

Laser Alignment

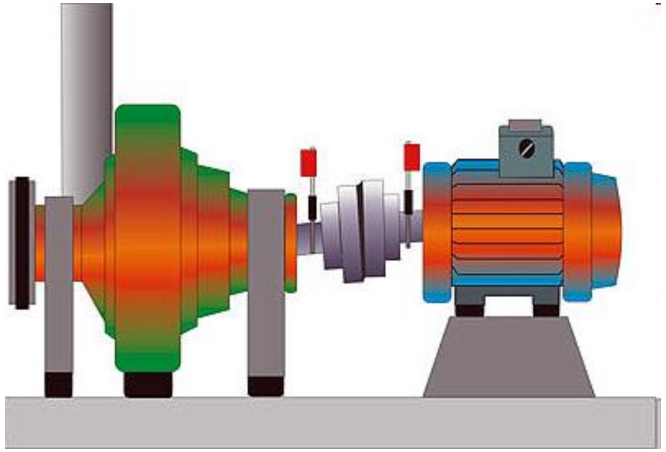
Disadvantages of Laser Alignment

- The equipment has high initial cost
- Heat sources can have a negative effect on the accuracy of the beam
- Equipment calibration must be checked regularly



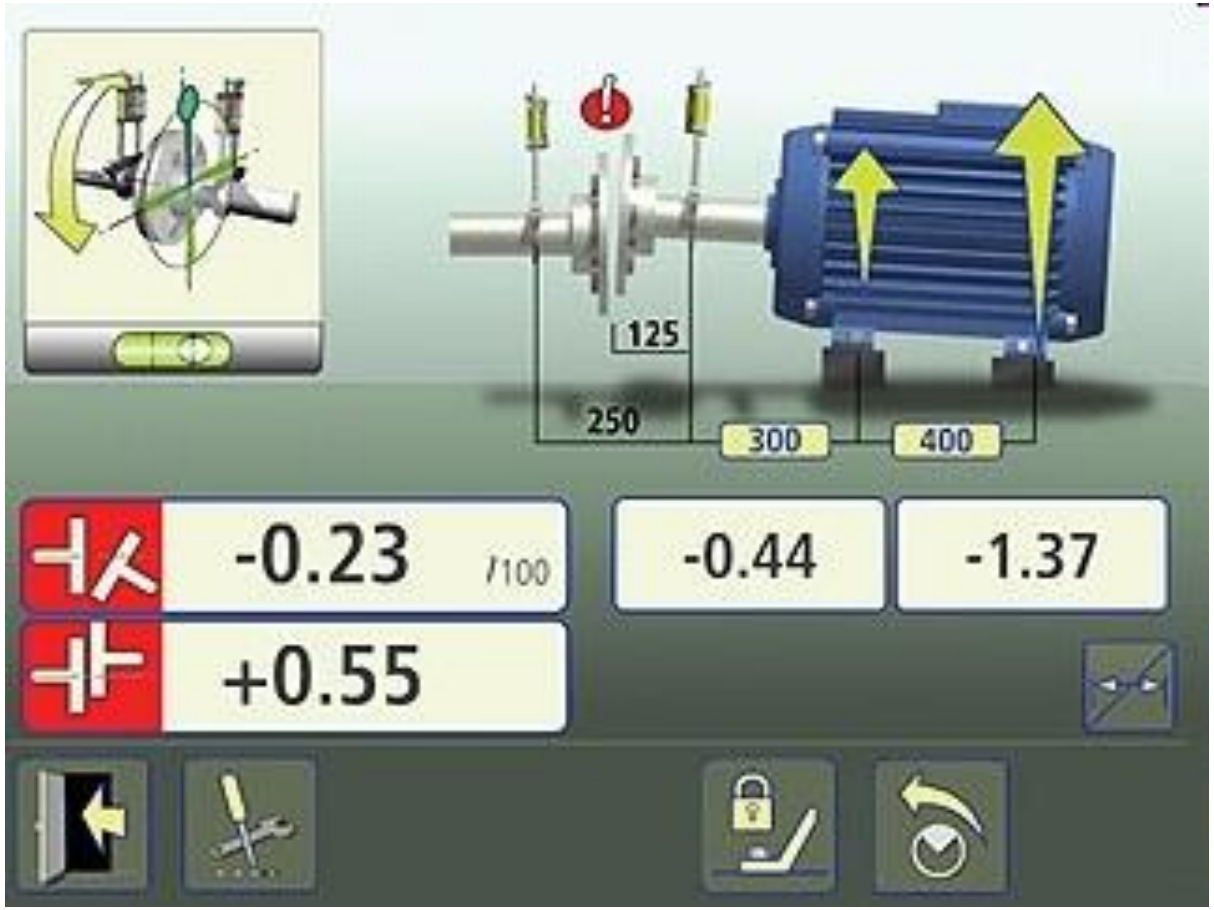
Alignment Techniques

Laser Alignment



Aligning Motor to Pump

LASER Aligning Display Unit

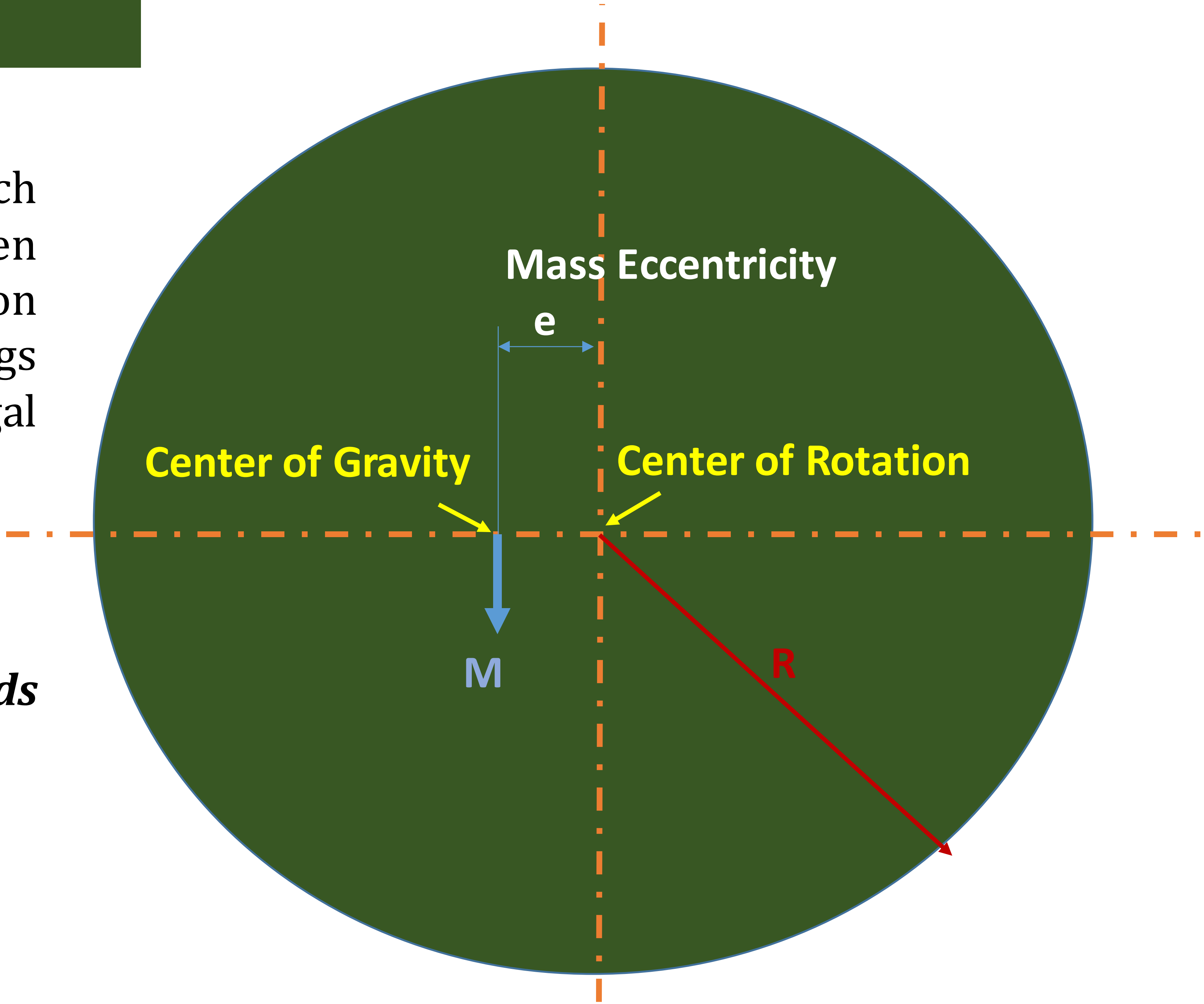


Reading Shows Angular & Parallel Deviation

Unbalance ?

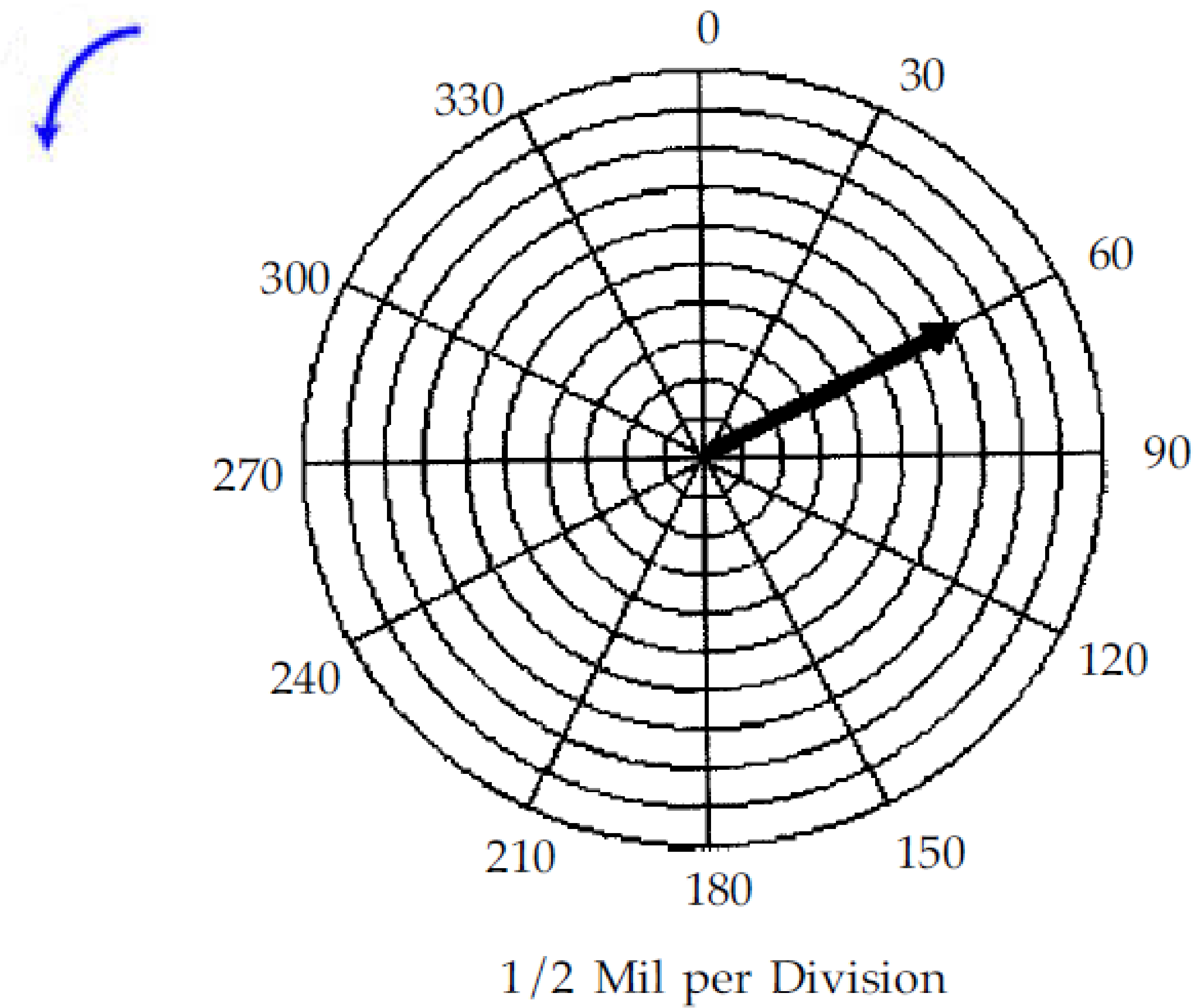
‘That condition which exists in a rotor when vibratory force or motion is imparted to its bearings as a result of centrifugal forces’

International Standards Organization (ISO)



Single Plane Balancing

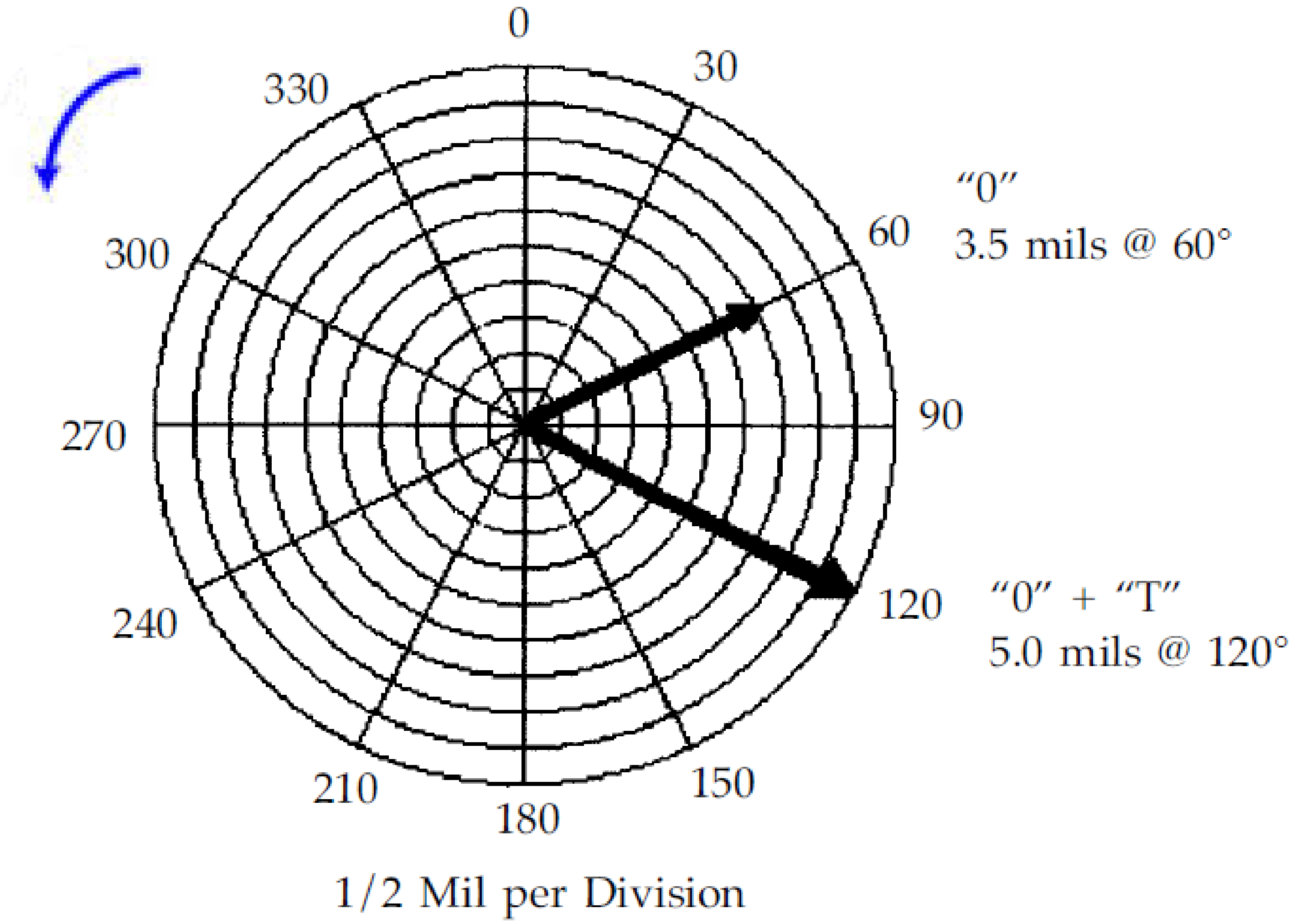
Original Readings (O)



Single Plane Balancing

After putting a trial weight

Trial + Original Readings (O+T)

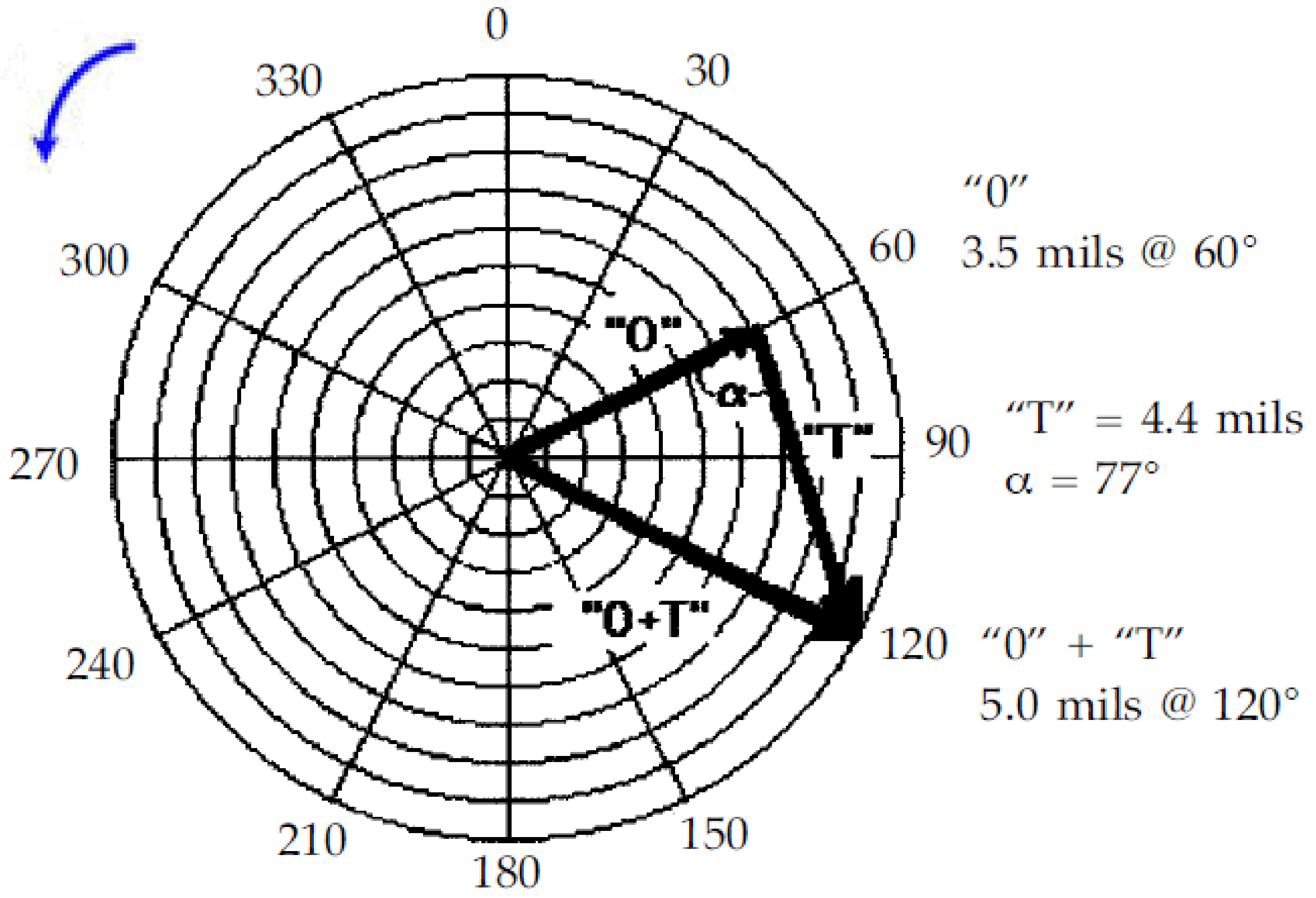


Single Plane Balancing

Using Vector Summation to determine the trial weight effect.

To determine amount of correction weight:

$$\text{Correction weight} = Trial\ weight\ x\,\frac{O}{T}$$



Residual Unbalance

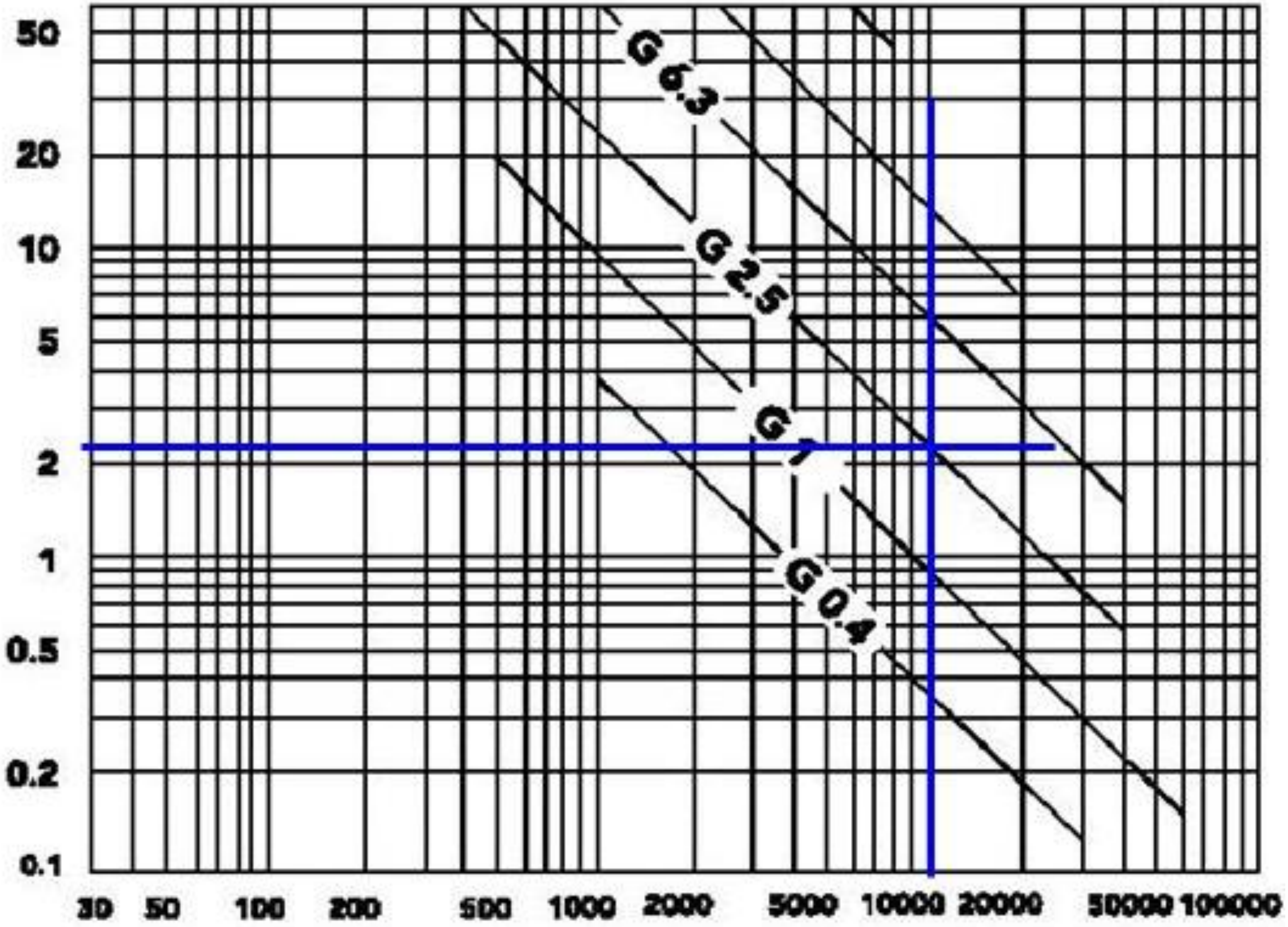
ISO 1940 G2.5

Example for Turbine Rotor

Rotor weight = 400 kg
Maximum speed = 10000 rpm

ISO 1940 G2.5

U_{max} = 2.4 µm x 400 kg
= 960 g.mm



Residual Unbalance

ISO 1940

ROTOR CLASSIFICATION (Balance Quality)	ROTOR DESCRIPTION (Examples of General Types)
G 40	Passenger Car Wheels and Rims
G 16	Automotive Drive Shafts Parts of crushing and agricultural machinery.
G 6.3	Drive shafts with special requirements Rotors of processing machinery Centrifuge bowls; Fans Flywheels, Centrifugal pumps General machinery and machine tool parts Standard electric motor armatures
G 2.5	Gas and steam turbines, Blowers, Turbine rotors, Turbo generators, Machine tool drives, Medium and bigger electric motor armature with special requirements, Armatures of fractional hp motors, Pumps with turbine drive
G 1 Precision Balancing G 0.4 Ultra Precision Balancing	Jet engine and super charger rotors Tape recorder and phonograph drives Grinding machine drives Armatures of fractional hp motors with special requirements Armatures, shafts and wheels of precision grinding machines

Selection of Trial Weights

There are numerous ways to add trial weights to a rotor, and a close inspection of the exact application will reveal the most appropriate method.

Modelling Clay

Flat Washers

Lead Weights

Hose Clips

Reinforced Tape

Epoxy

Attachment of Trial Weights

There are numerous ways to attach trial weights to a rotor,

Soldering

Brazing

Welding

Adding Washers To Bolts

Drilling or Tapping New Bolts

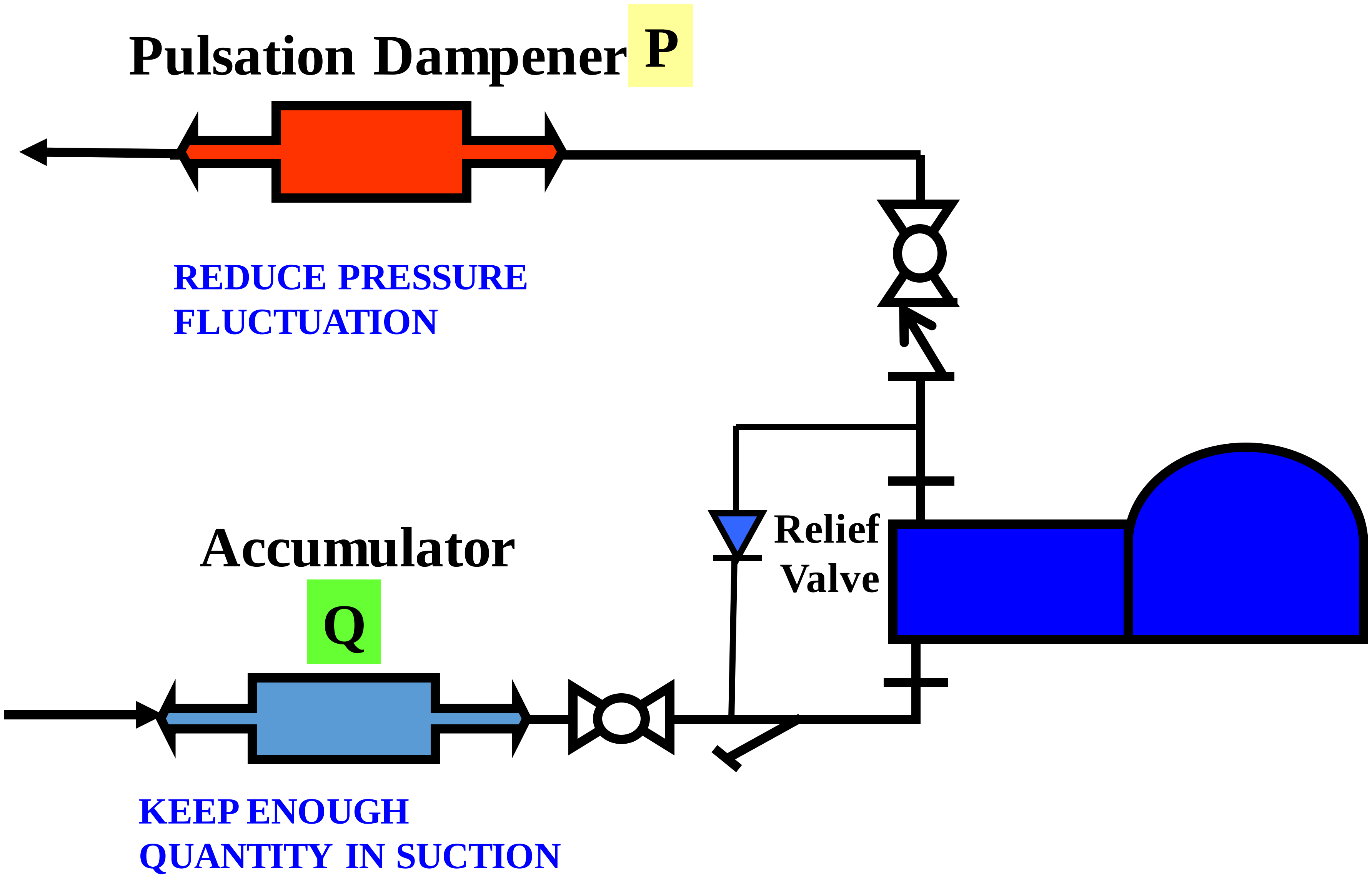
Attachment of Trial Weights

There are numerous ways to attach trial weights to a rotor,

Balancing Ring

Types of Pumps

Reciprocating Pump

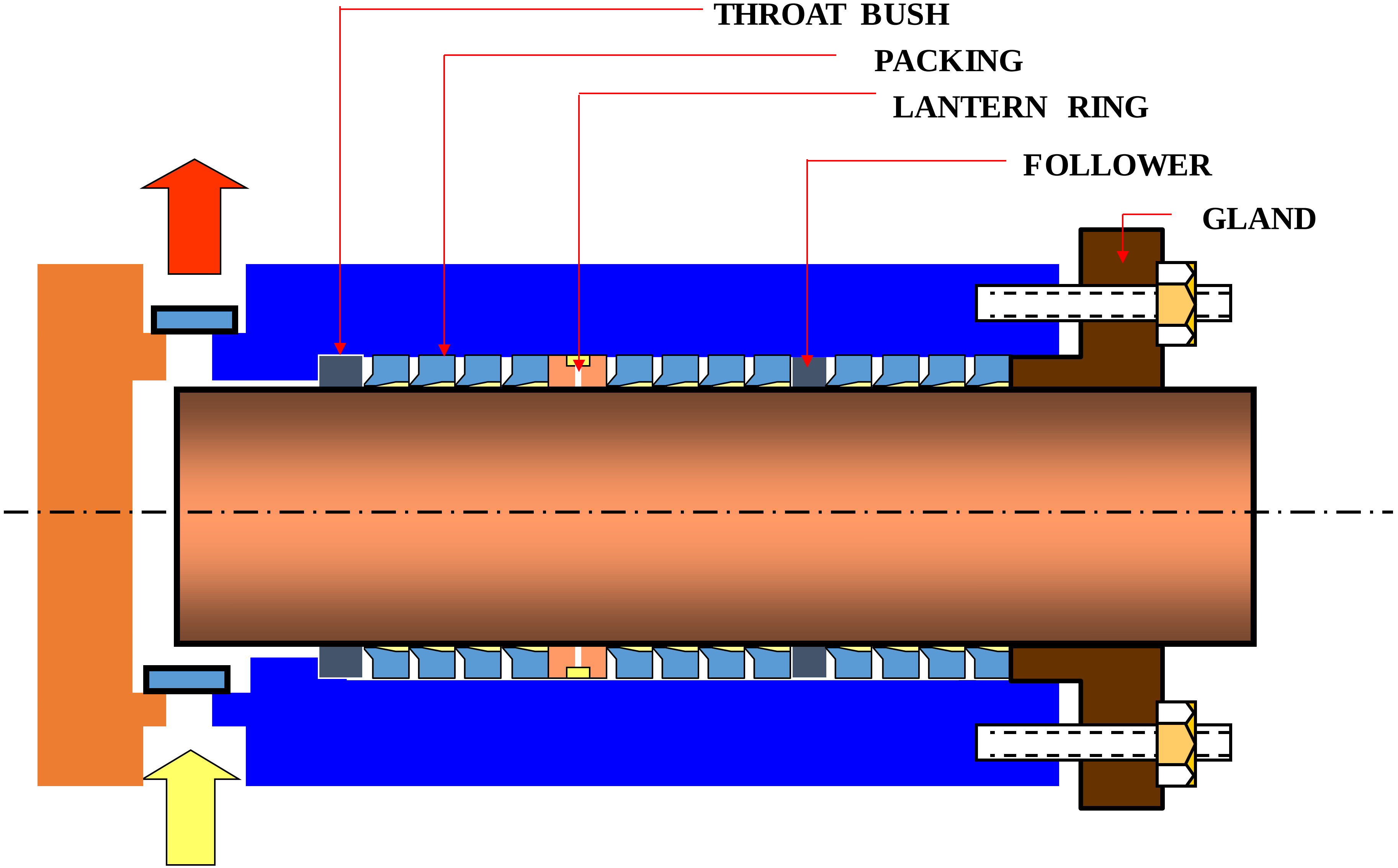


Types of Pumps

Reciprocating Pump

Plunger Pump

- Displaces only part of the liquid inside the cylinder as it does not touch the cylinder walls.
- No cylinder liner is used.



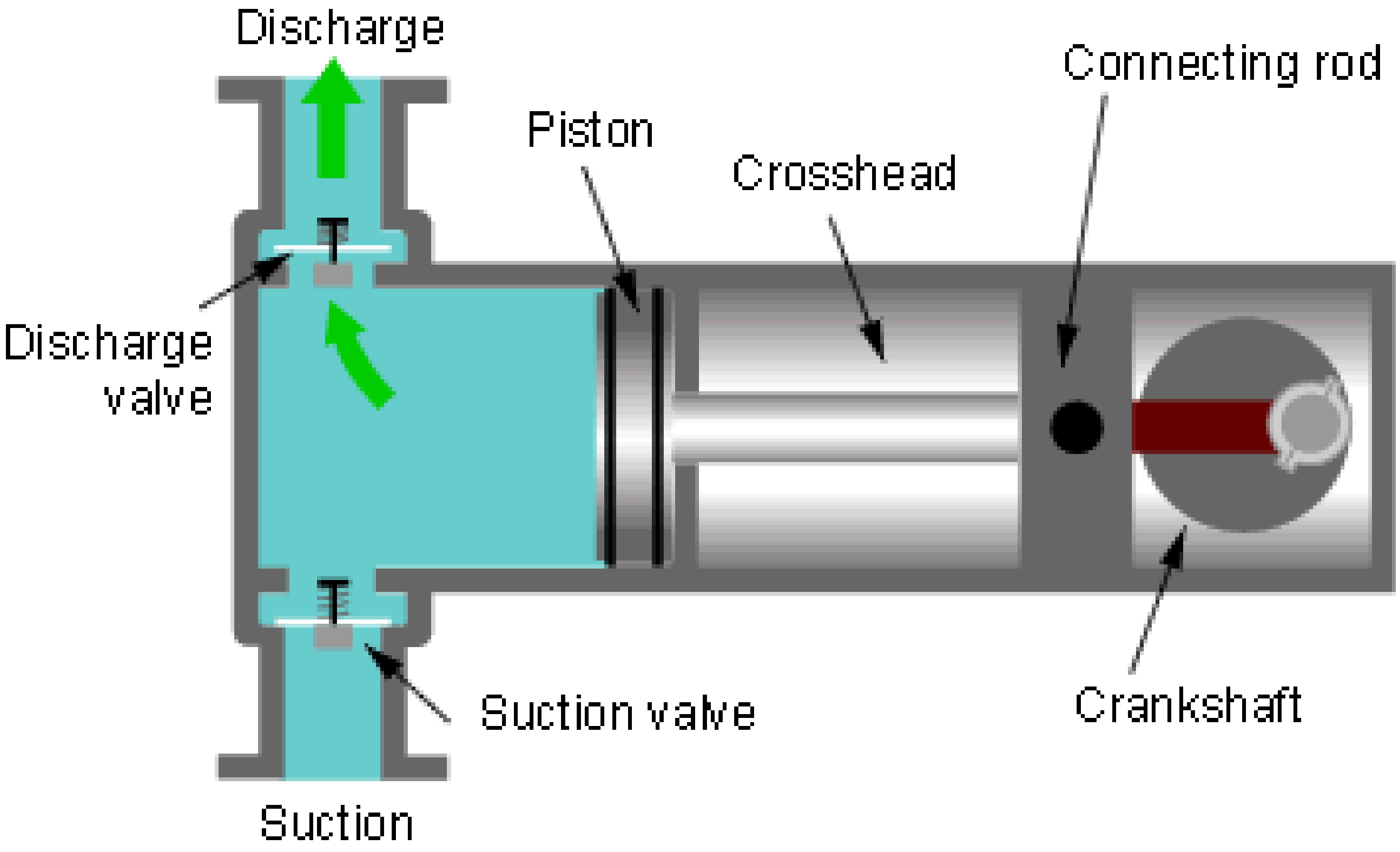
Types of Pumps

Reciprocating Pump

Piston Pump

- Cylinder liner is used.

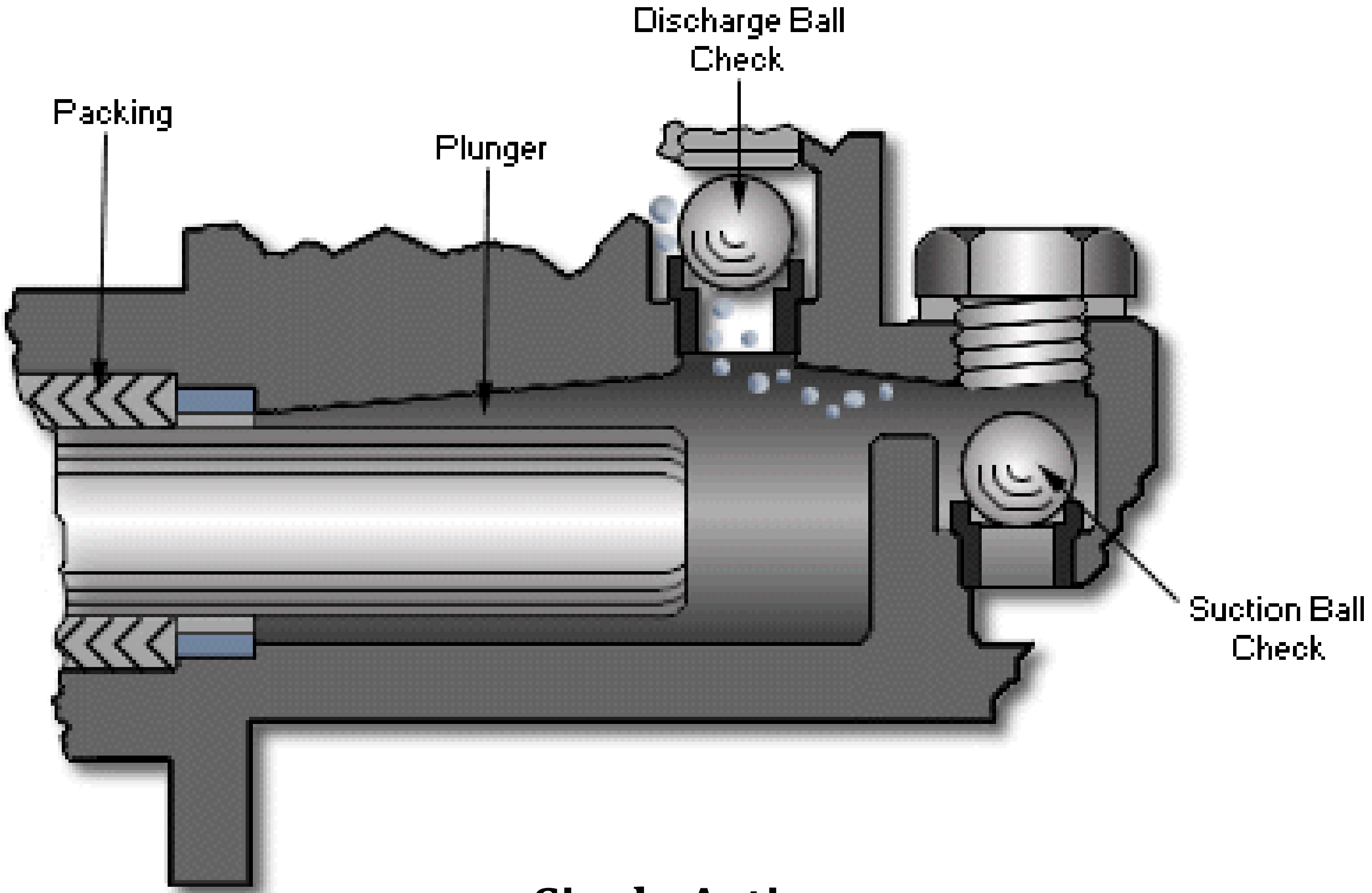
- The movement of the piston in the cylinder in one direction is called the stroke of the plunger. The distance the piston moves in and out of the cylinder is called the length of the stroke.



Types of Pumps

Reciprocating Pump

Piston Pump

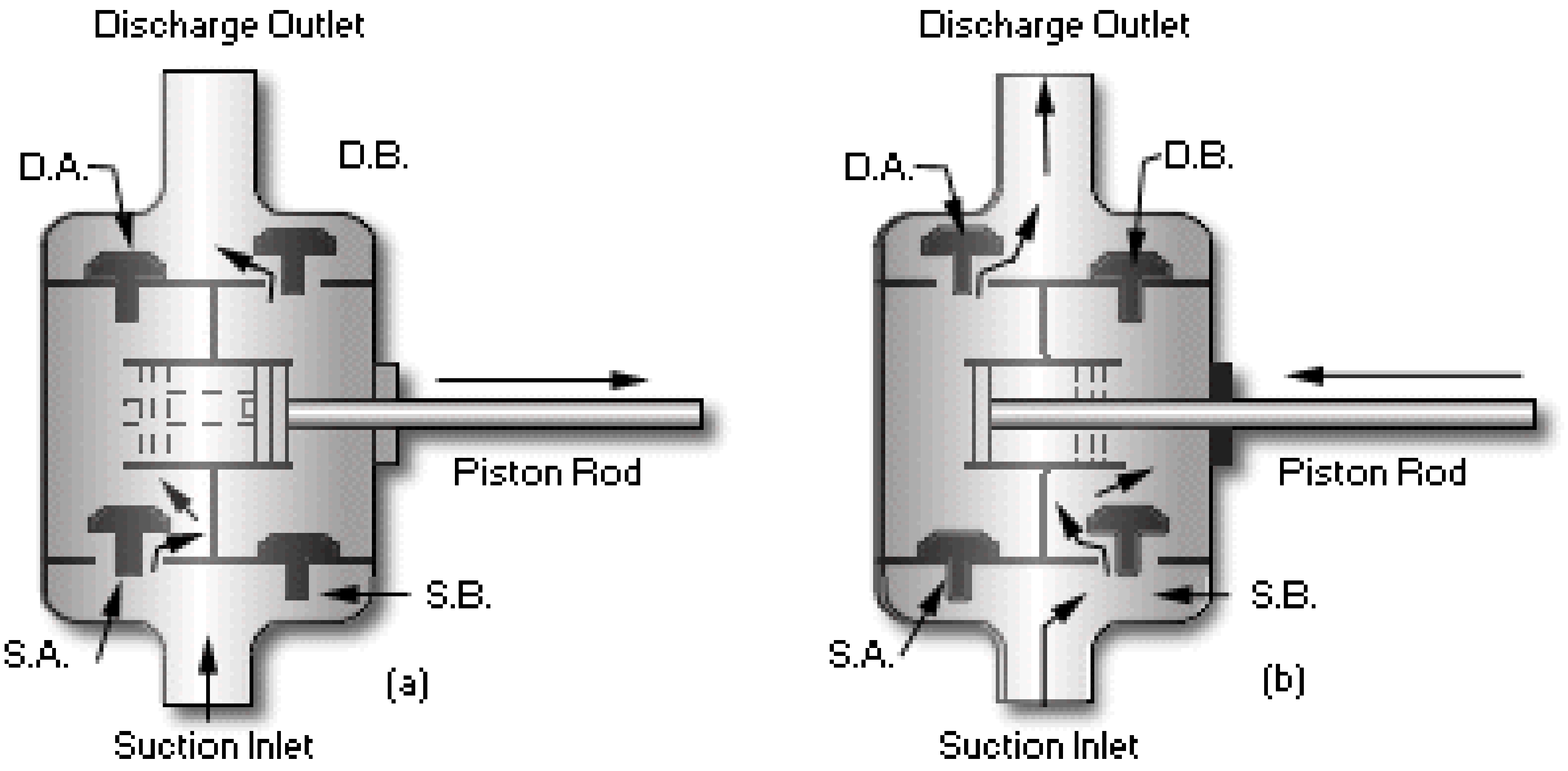


Single Acting

Types of Pumps

Reciprocating Pump

Piston Pump

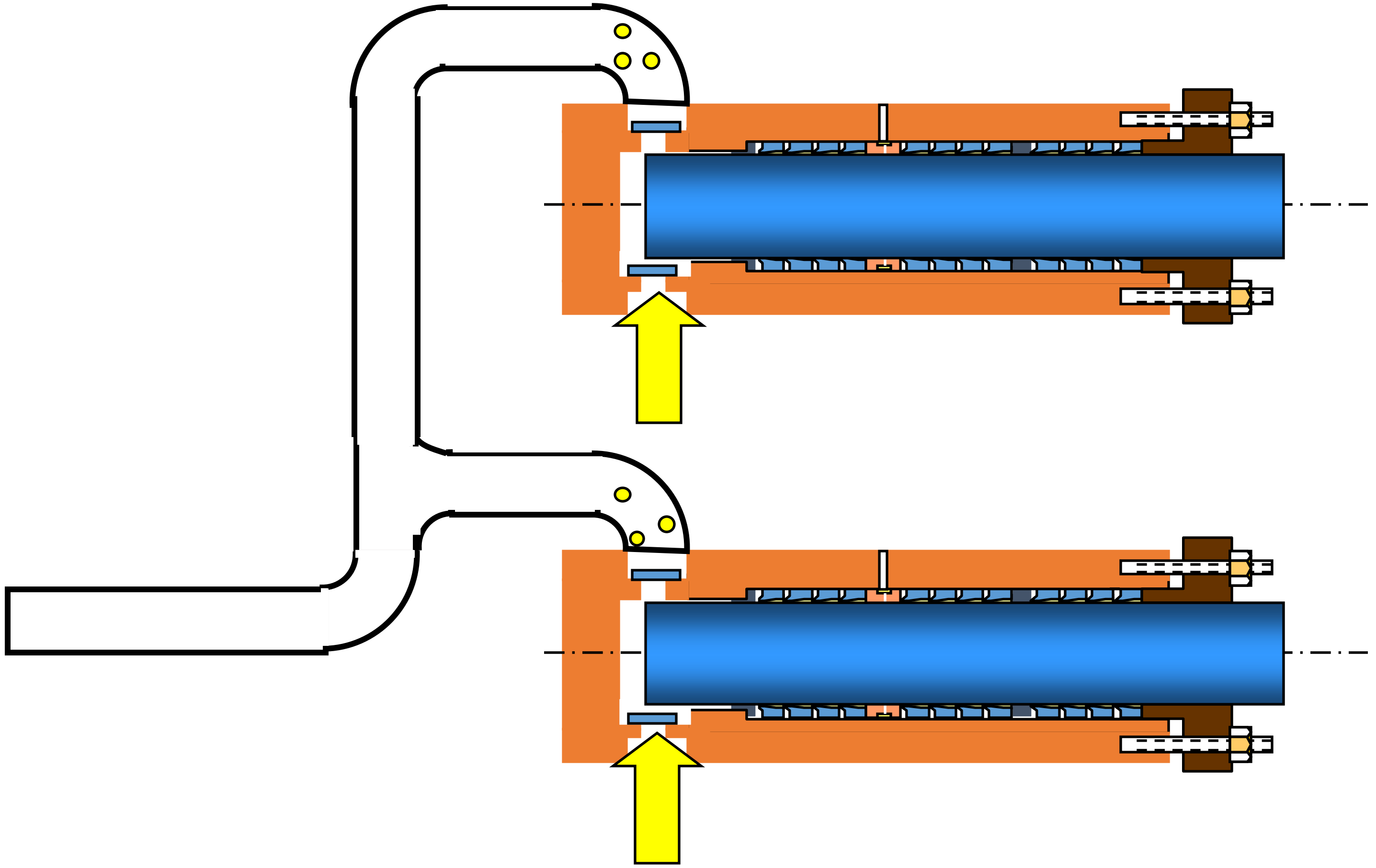


Double Acting

Types of Pumps

Reciprocating Pump

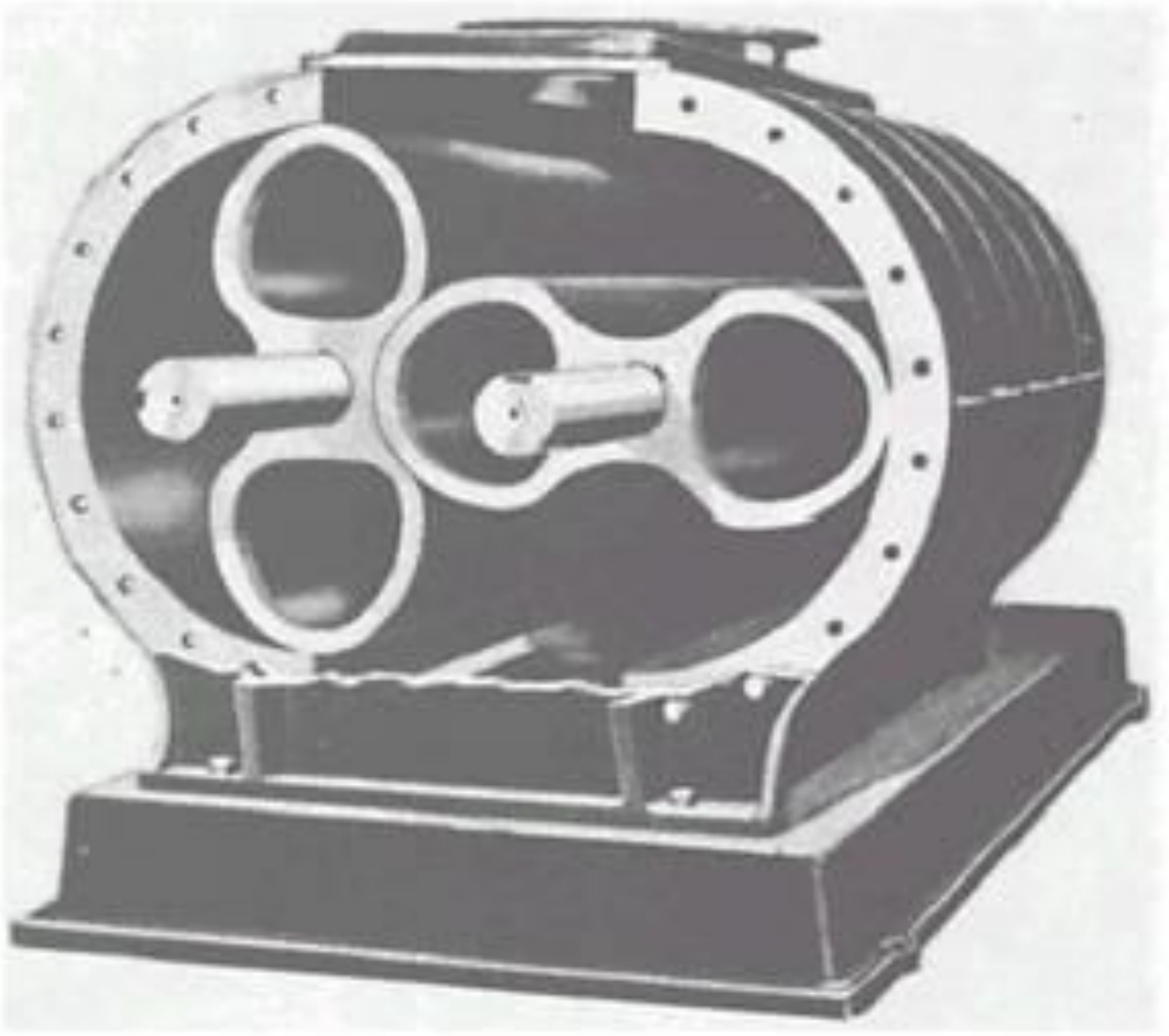
Duplex Pump



Types of Pumps

Rotary Pumps

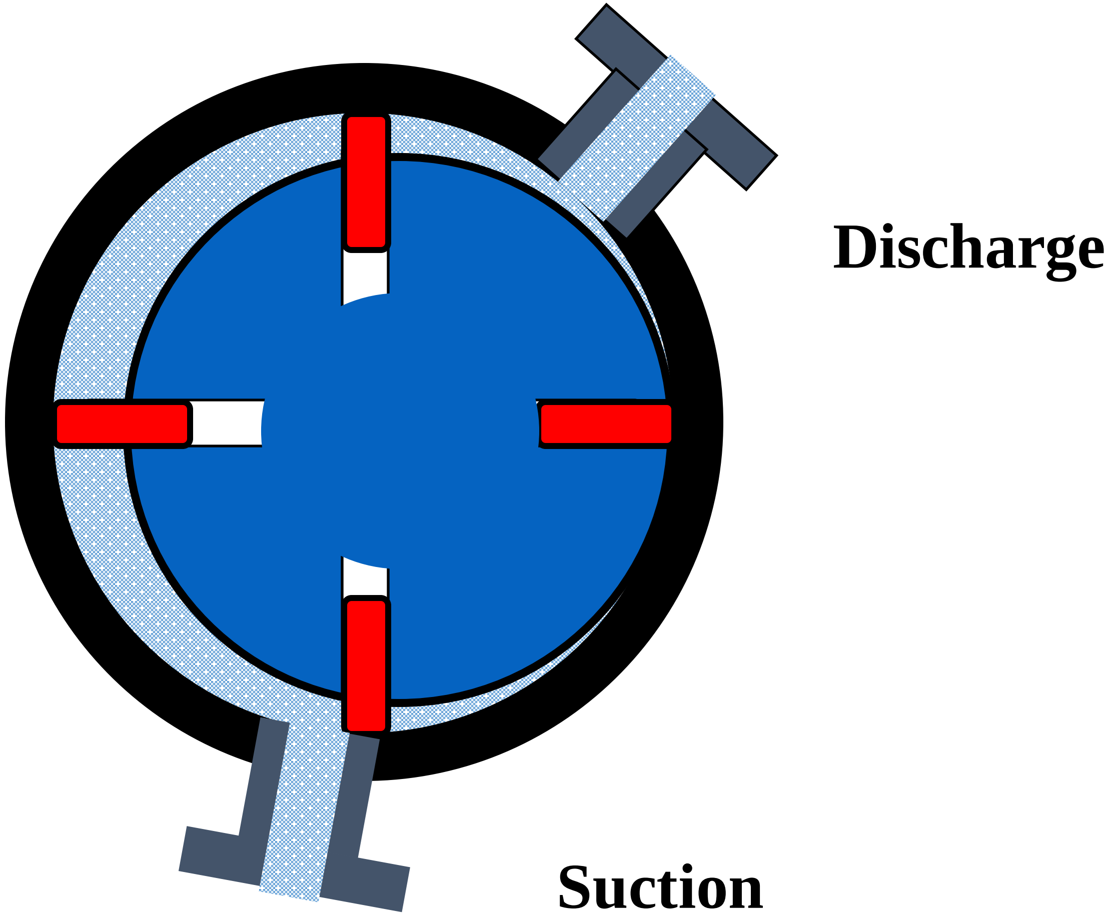
Twin Lube Pump



Types of Pumps

Rotary Pumps

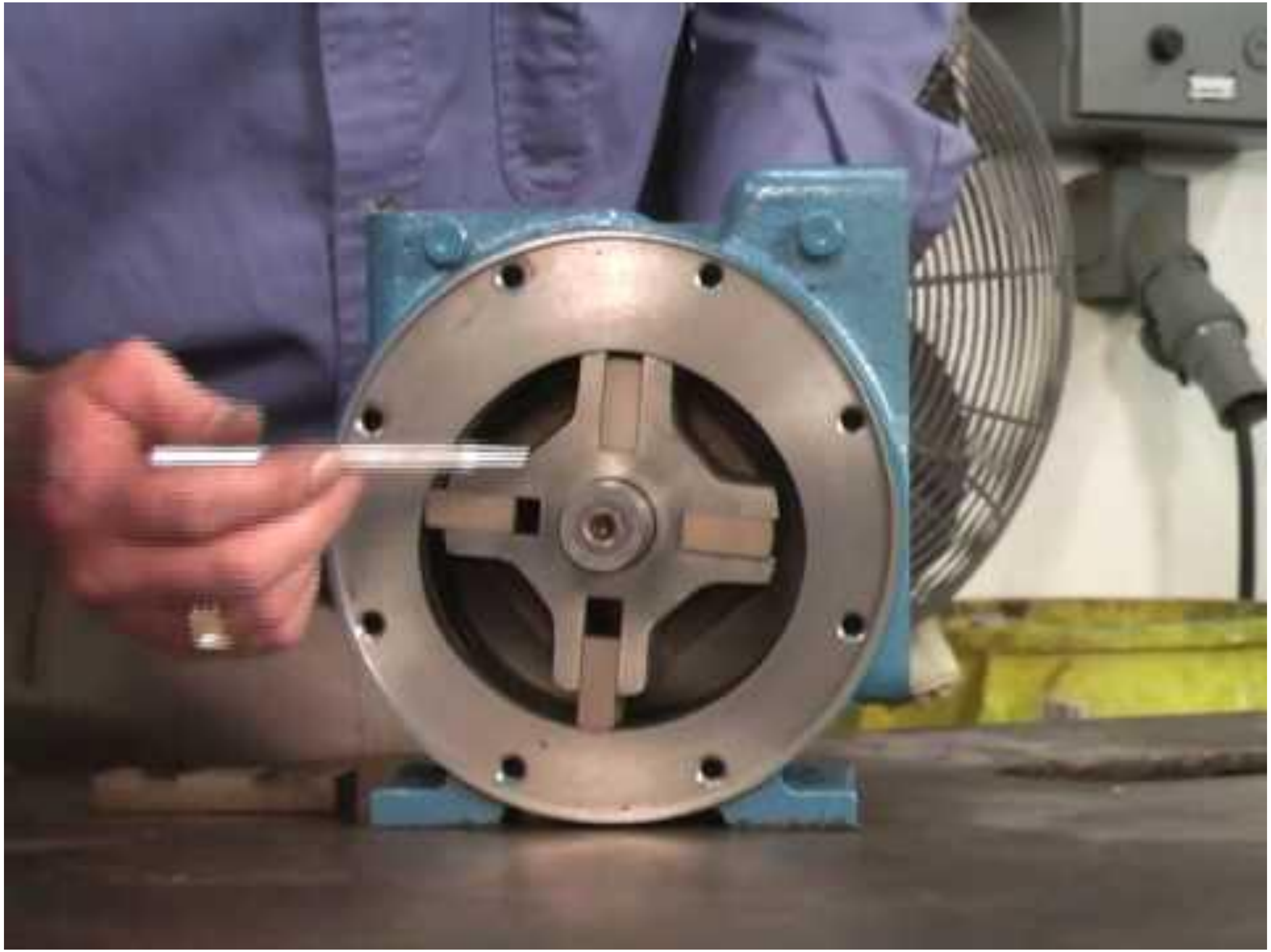
Sliding Vane Pump



Types of Pumps

Rotary Pumps

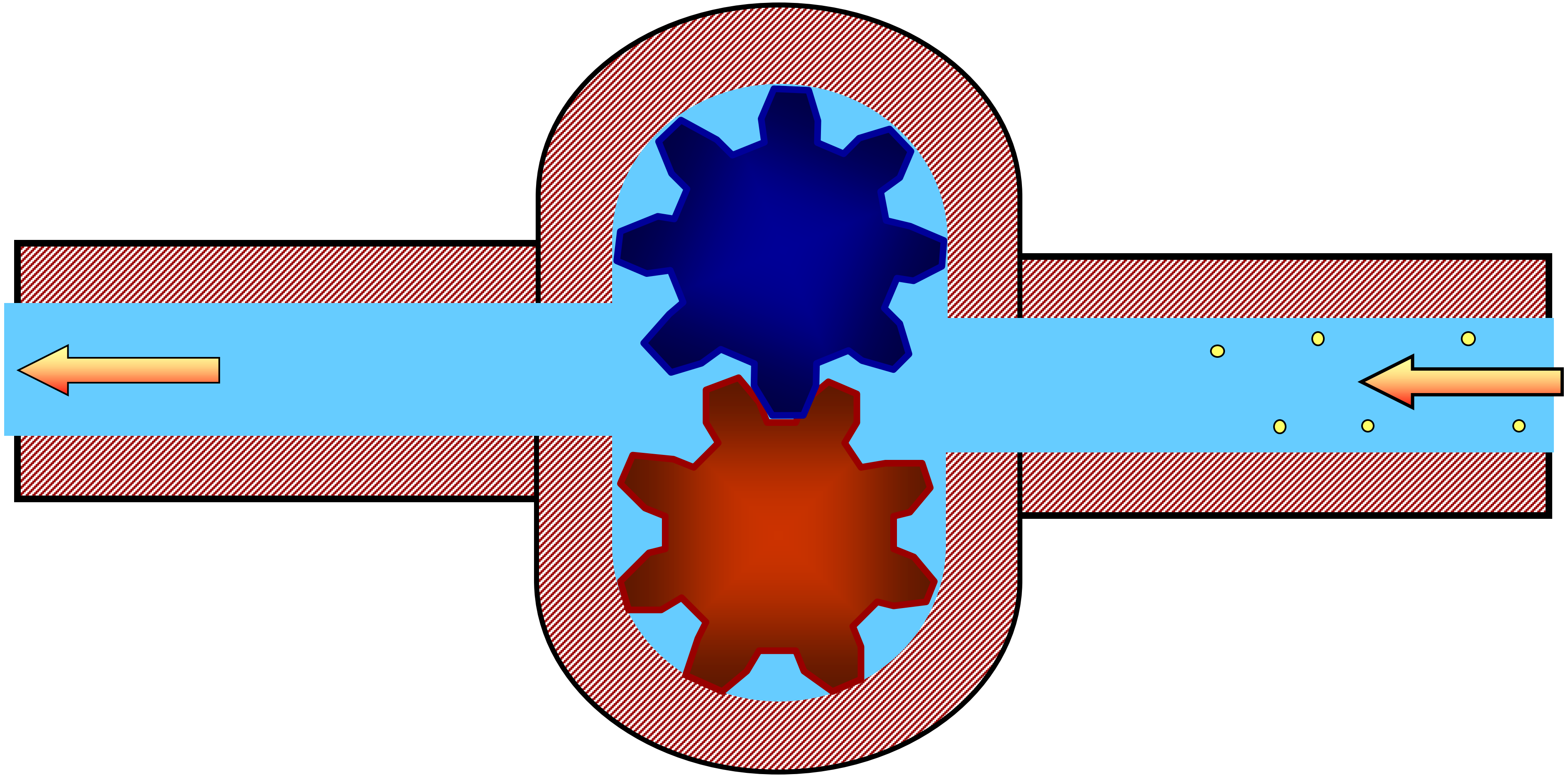
Sliding Vane Pump



Types of Pumps

Rotary Pumps

Gear Pump



Types of Pumps

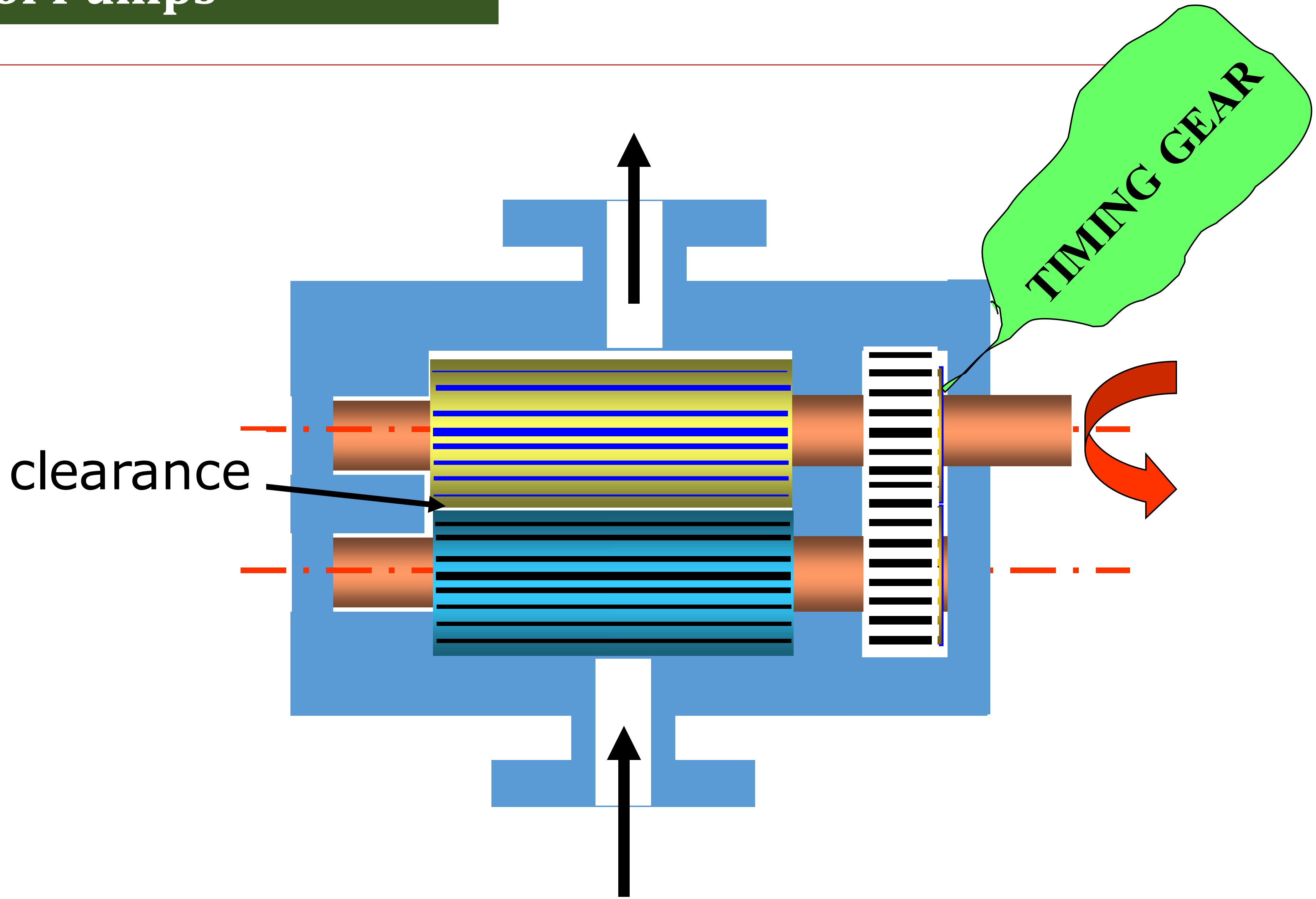
Rotary Pumps

Internal Gear Pump

Types of Pumps

Rotary Pumps

Gear Pump



Types of Pumps

Rotary Pumps

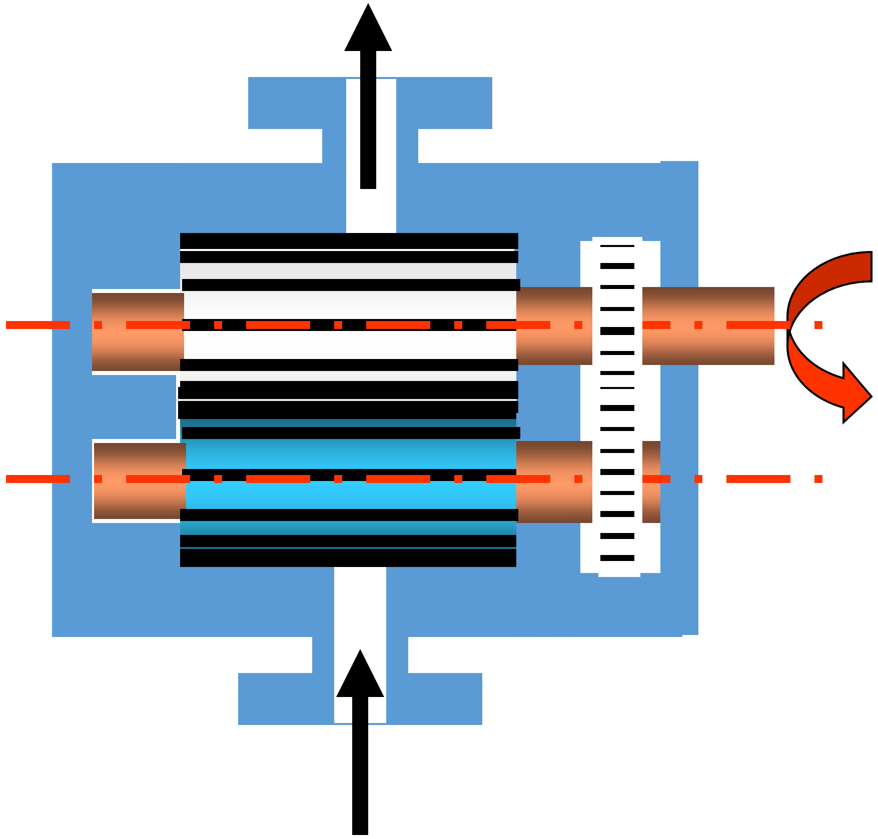
Gear Pump

TIMING GEAR FUNCTION

1- TRANSMIT MOTION TO OTHER ROTOR

2- KEEPS NO CONTACT BETWEEN ROTORS

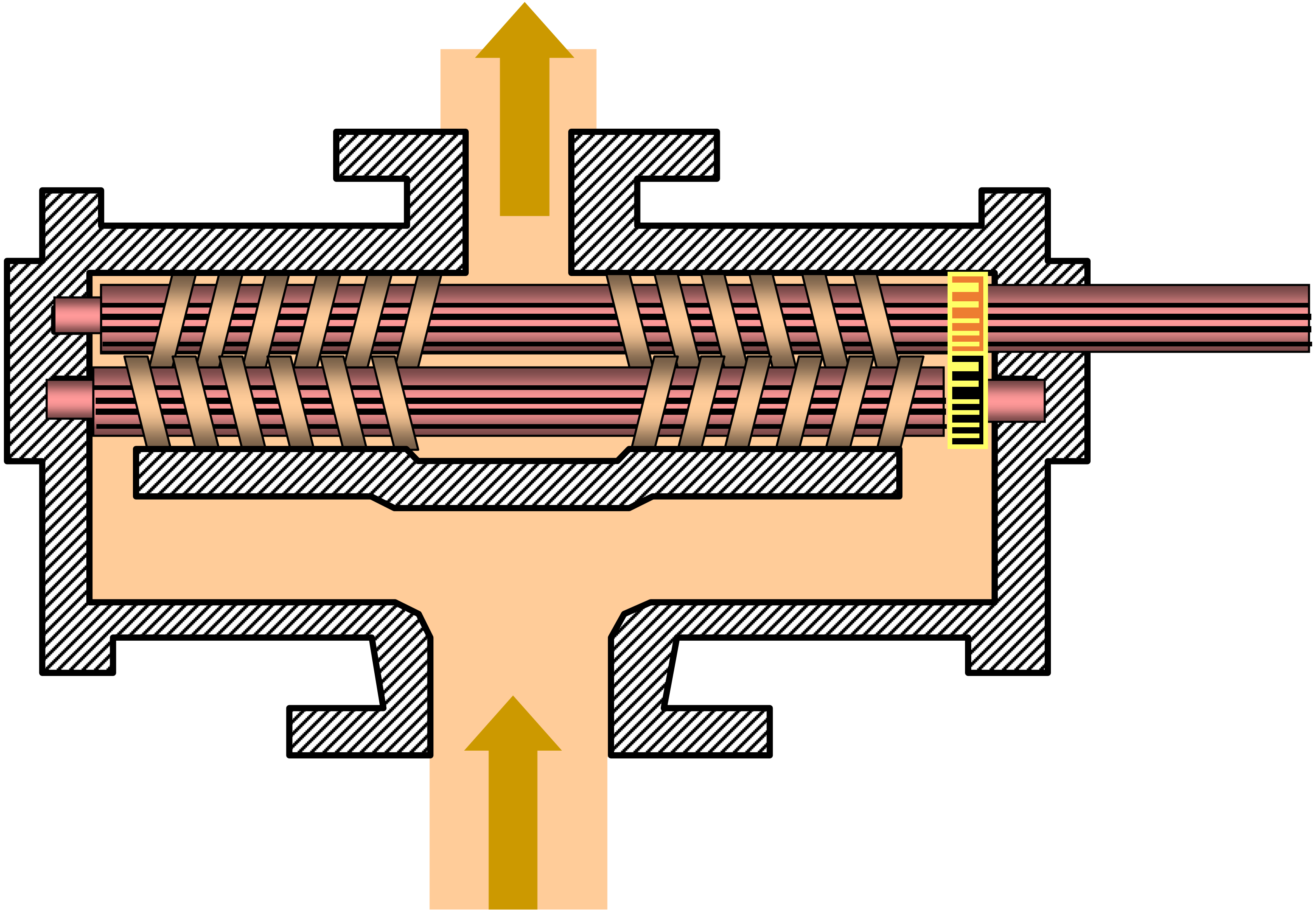
3- PREVENT WEAR BETWEEN ROTORS



Types of Pumps

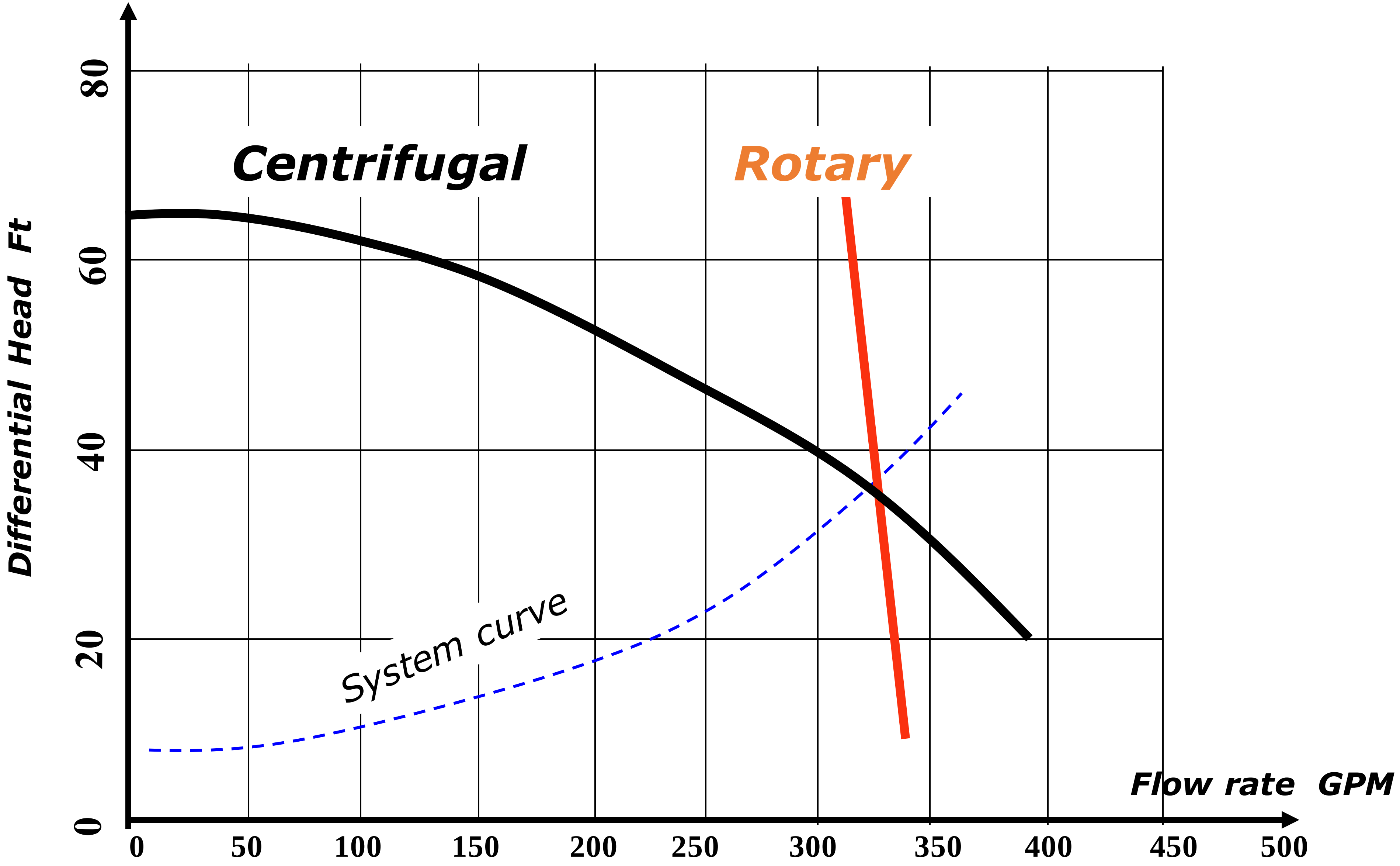
Rotary Pumps

Multiple-Screw Double-End Pump



Types of Pumps

Rotary Pumps



Thank you for your attention!

Any Questions?

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