

ADVANCED PUMPS MAINTENANCE TECHNOLOGY

Eng. Hany El-sayed
Lecturer Assistant
Mechanical Power Department
Ain Shams University

Contents

- Introduction
- Pump classification
- Pump Theory
- Centrifugal pump
- Pump cavitations
- Pump Trouble shooting
- Positive displacement pump

Objectives

- Define the pressure, head and enthalpy
- How to transfer energy of fluid
- Fundamental concepts of different types of rotating equipment
- Pump classification and different types
- Define the terms associated with pump performance.
- Sketch the pump performance curve and system curve
- Define the pump cavitations and net positive suction head.
- Knowing Pump Trouble shooting

Introduction

1. Pressure:

Pressure is defined as the Force divided by the area.

$$P = \frac{F}{A} \quad \text{N/m}^2 (\text{pa})$$

- If we apply pressure to the surface of a liquid, the pressure is transmitted uniformly in all directions across the surface and even through the liquid to the walls and bottom of the vessel containing the liquid (Pascal's Law). This is expressed as pounds per square inch (lbs/in², or psi), or kilograms per square centimeter (k/cm²).

- Atmospheric pressure : (ATM) is the force exerted by the weight of the atmosphere on a unit of area. $ATM = 14.7 \text{ psia}$ at sea level. As elevation rises above sea level, the atmospheric pressure is less.
- Absolute pressure is the pressure measured from a zero pressure reference. Absolute pressure is 14.7 psia at sea level. Compound pressure gauges record absolute pressure.
- Gauge pressure is the pressure indicated on a simple pressure gauge. Simple pressure gauges establish an artificial zero reference at atmospheric pressure. The formula is: $\text{psig} = \text{psia} - ATM$.

2. The head:

Is defined as the fluid pressure divided by fluid specific weight

$$H = \frac{P}{\gamma} \quad \text{m}$$

Where, $\gamma = \rho_f g$ (specific weight)

$$g = 9.81 \text{m/s}^2$$

3. Enthalpy:

The sum of internal energy and fluid work.

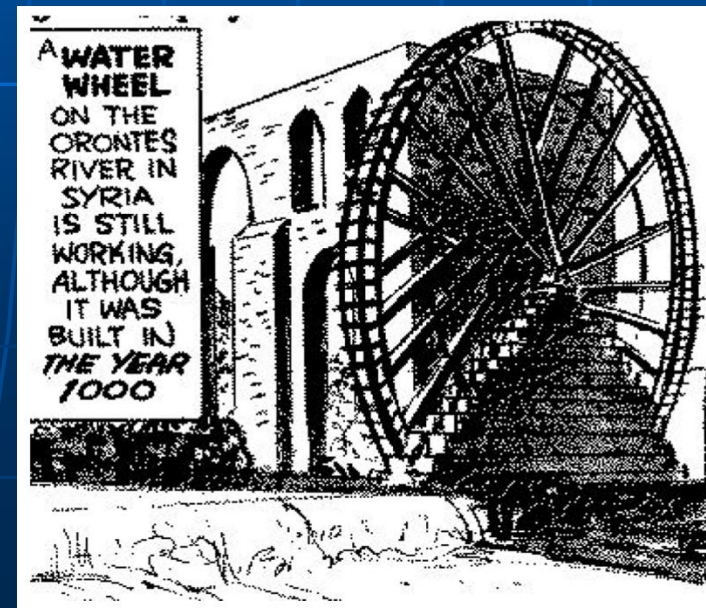
$$H = U + PV$$

Where, p : pressure V : volume

H : Enthalpy U : Internal energy

Introduction to pump

- A pump is one such device that expends energy to raise, transport, or compress liquids. The earliest known pump devices go back a few thousand years. One such early pump device was called 'Noria', similar to the Persian and the Roman water wheels
- The ancient Egyptians invented water wheels with buckets mounted on them to transfer water for irrigation.



Pump Applications

- Some of the more common types of pumps required in industrial plants are:
 1. Boiler feed water pump - supplies the boiler with feed water as required. It must be capable of forcing this water into the boiler against the pressure existing in the boiler.
 2. Fuel oil pump - used in oil-fired boilers to pump fuel oil to the burners.
 3. Lubricating oil pump - used to circulate oil to the bearings of a machine such as a turbine, engine, pump, or compressor.
 4. Circulating water pump - also called a cooling water pump. It is used to pump water through a heat exchanger such as a condenser or an oil cooler.
 5. Chemical feed pump - small capacity units are used to pump chemicals into boilers; larger units are used as process pumps.
 6. Fire pump - used to supply water to plant fire lines.
 7. Domestic water pump - used to supply water to plant washrooms, etc.
 8. Irrigation: To make dry lands agriculturally productive.
 9. Water supply: To supply water to inhabited areas.

Pump classification

- Pumps can be classified on various bases. For example, a typical classification of rotating shaft (kinetic) pumps is given in Appendix.
- Pumps based on their principle of operation are primarily classified into:
 - Positive displacement pumps (reciprocating, rotary pumps)
 - Roto-dynamic pumps (centrifugal pumps)
 - Others.

Pump classification

- Positive displacement pumps, which lift a given volume for each cycle of operation, can be divided into two main classes, reciprocating and rotary.
- Roto-dynamic pumps raise the pressure of the liquid by first imparting velocity energy to it and then converting this to pressure energy. These are also called centrifugal pumps. Centrifugal pumps include radial, axial, and mixed flow units.

Pump Classification

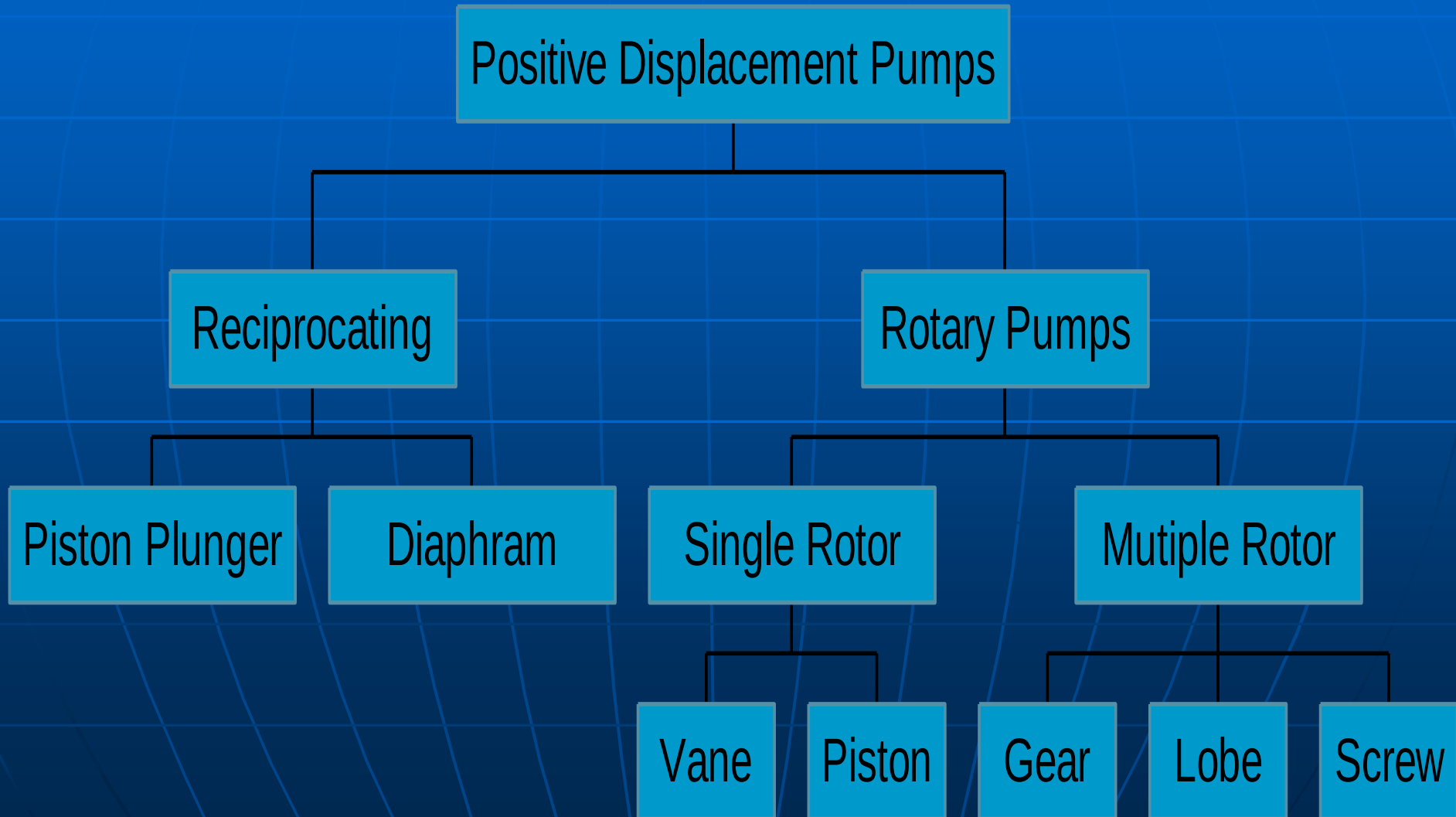
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graph TD; A[Pumps] --> B[Positive Displacement]; A --> C[Dynamic]
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Pumps

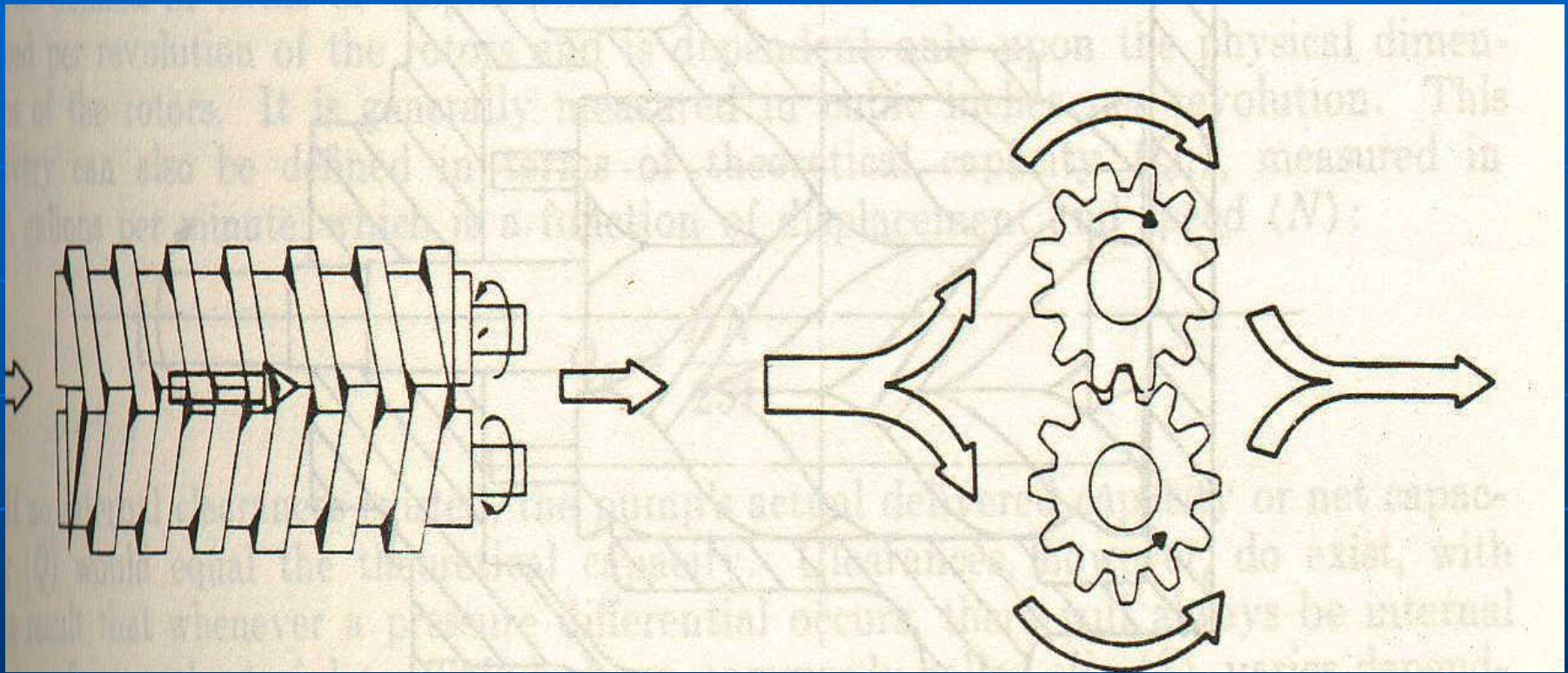
Positive Displacement

Dynamic

Pump Classification

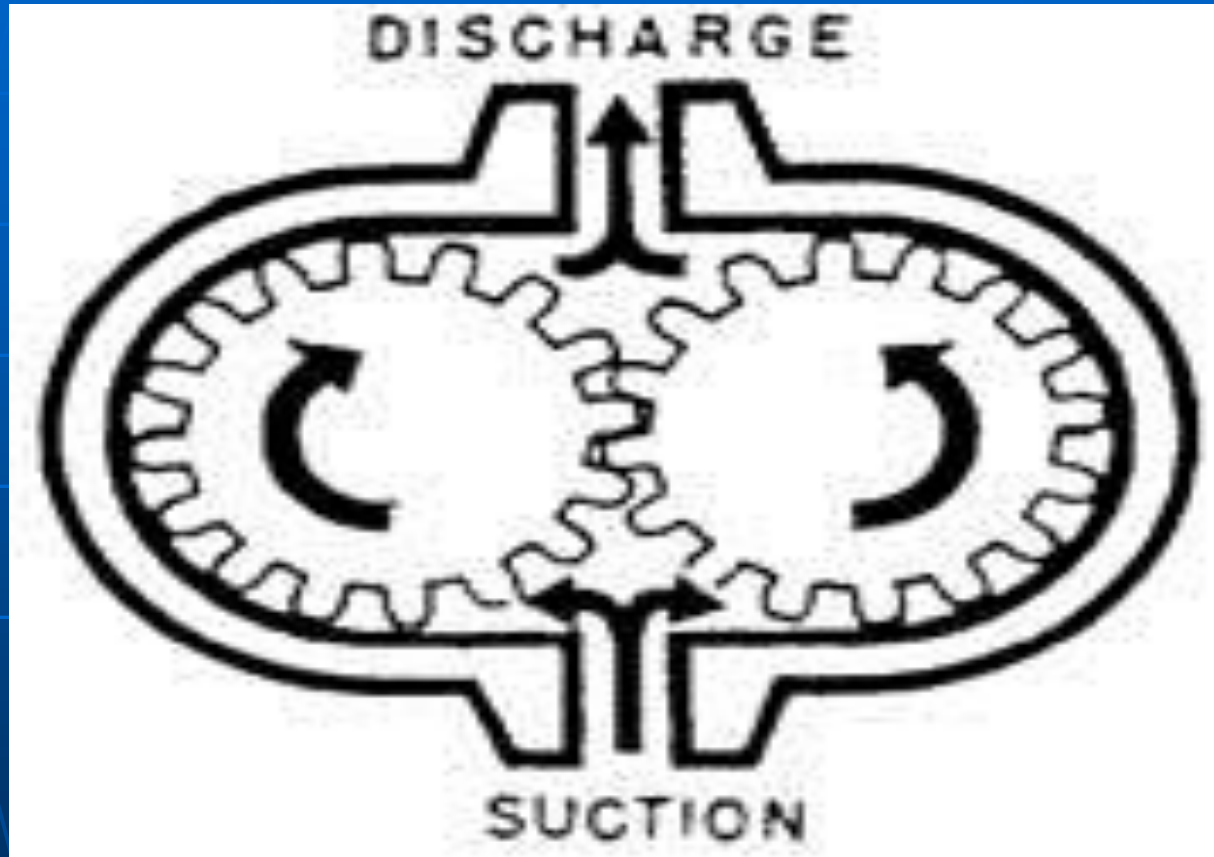


Pumps Classification



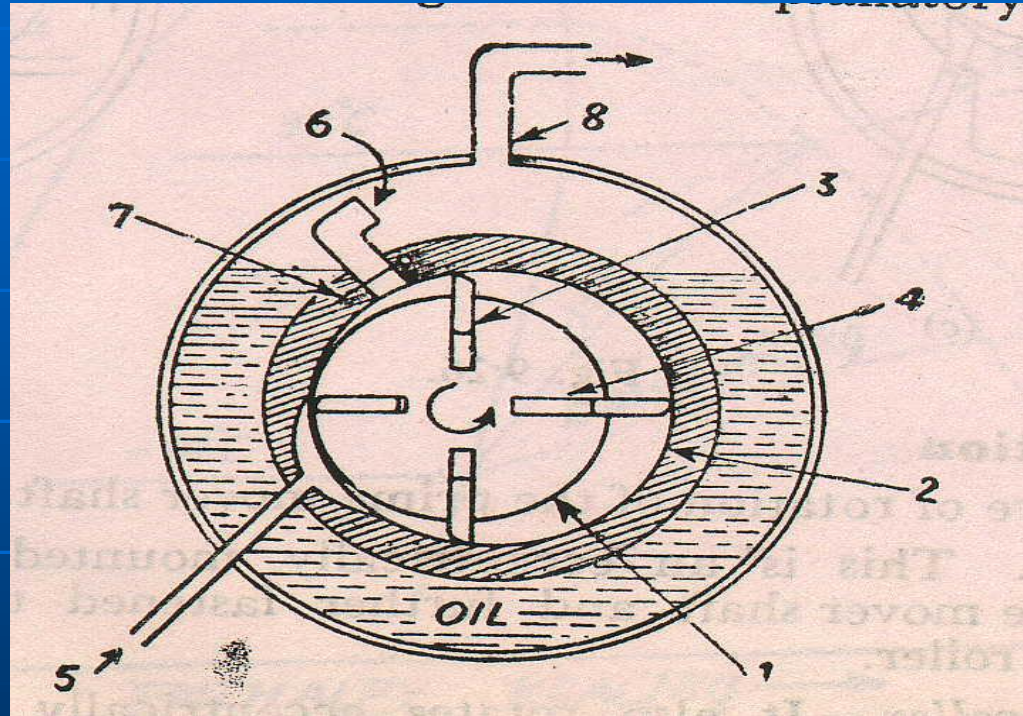
Screw pumps

Pumps Classification



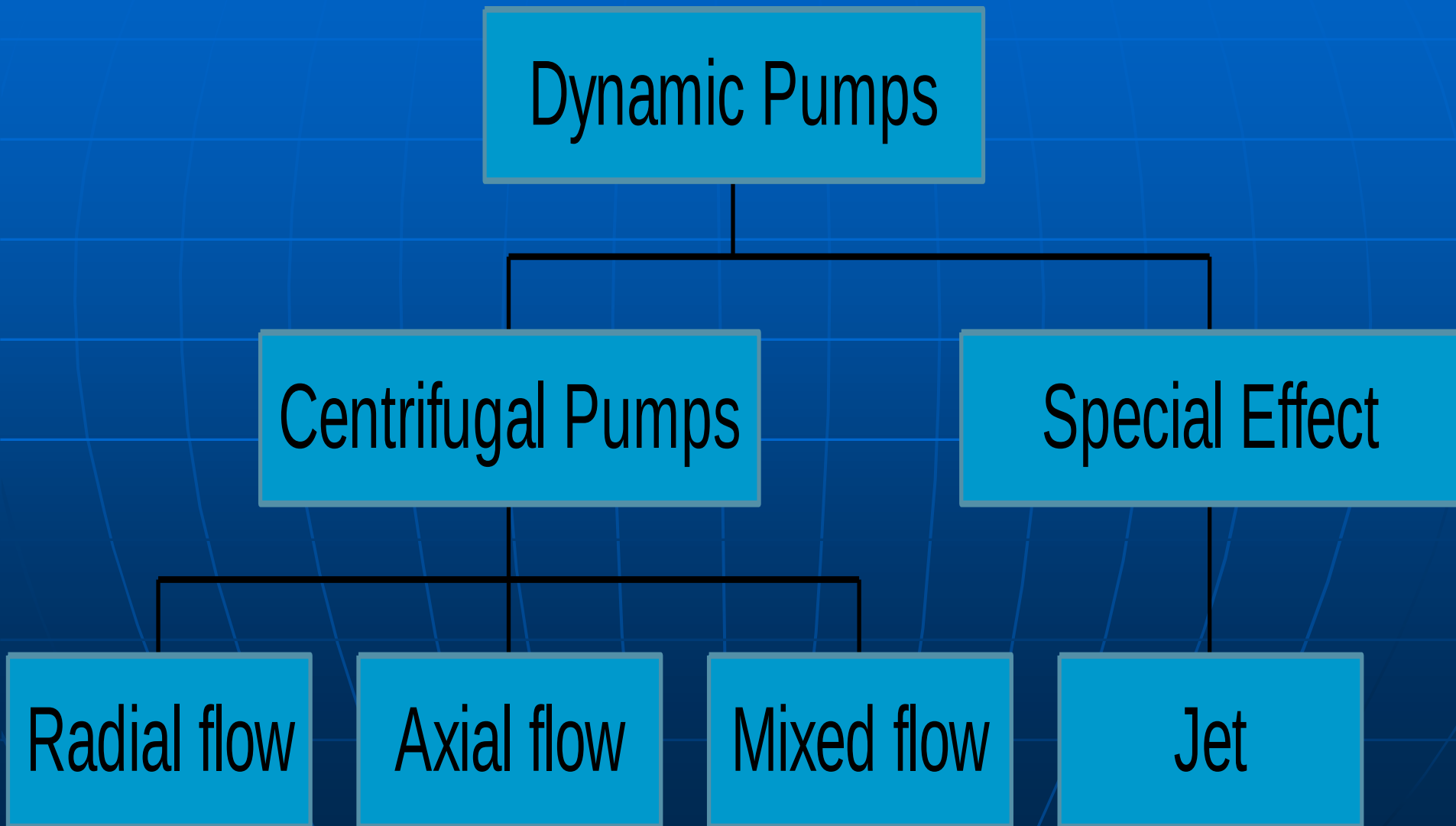
Gear pumps

Pumps Classification



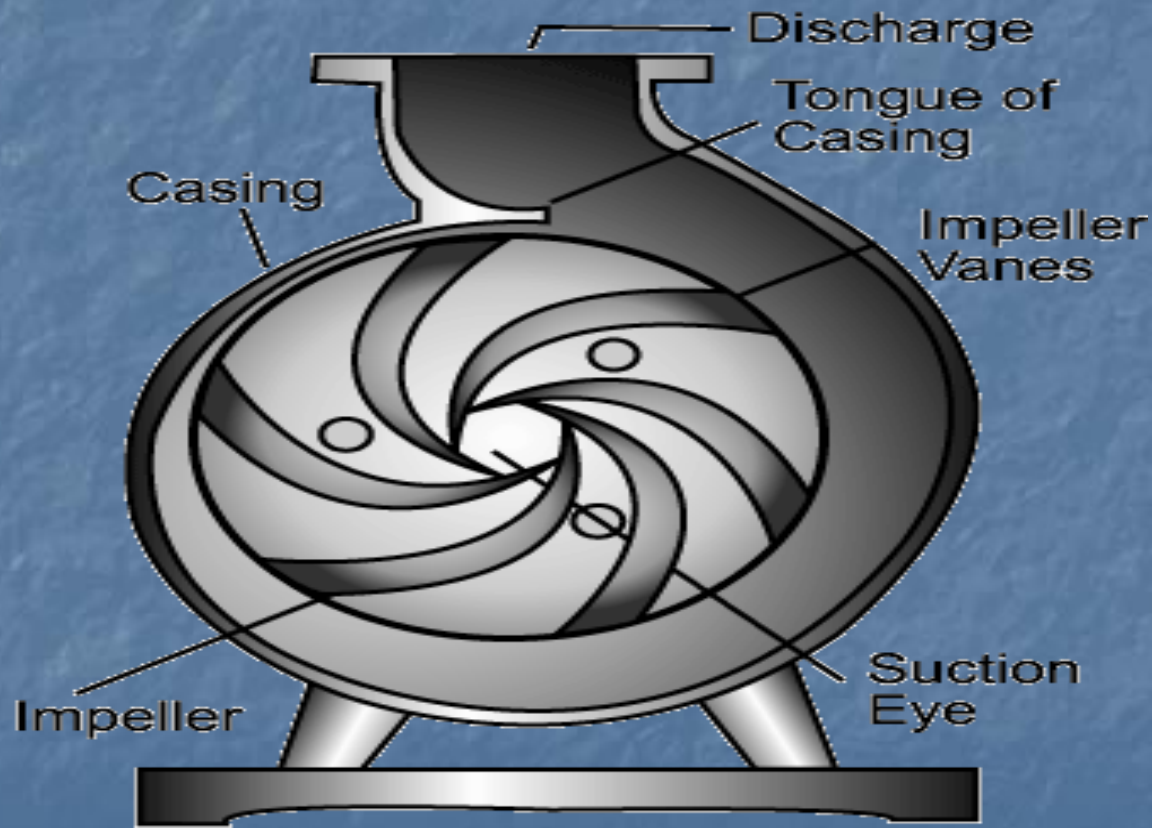
Vane pump

Pumps Classification



Centrifugal Pumps

Dynamic Pump (Centrifugal Pump)



Pump Classification

Parameter	Centrifugal Pumps	Reciprocating Pumps	Rotary Pumps
Optimum Flow	Medium/High Capacity	Low Capacity	Low/ Medium Capacity
Pressure	Low/Medium	High Pressure	Low/ Medium
Maximum Flow Rate	100,000+ GPM	10,000+ GPM	10,000+ GPM

Pumps Classification

Parameter	Centrifugal Pumps	Reciprocating Pumps	Rotary Pumps
Low Flow Rate Capability	No	Yes	YES
Maximum Pressure	6,000+ PSI	100,000+ PSI	4,000+ PSI
Requires Relief Valve	No	Yes	Yes
Smooth or Pulsating Flow	Smooth	Pulsating	Smooth

Pumps Classification

Parameter	Centrifugal Pumps	Reciprocating Pumps	Rotary Pumps
Variable or Constant Flow	Variable	Constant	Constant
Self-priming	No	Yes	Yes
Costs	Lower Initial	Higher Initial	Lower Initial
	Lower Maintenance	Higher Maintenance	Lower Maintenance

RANGE CHART

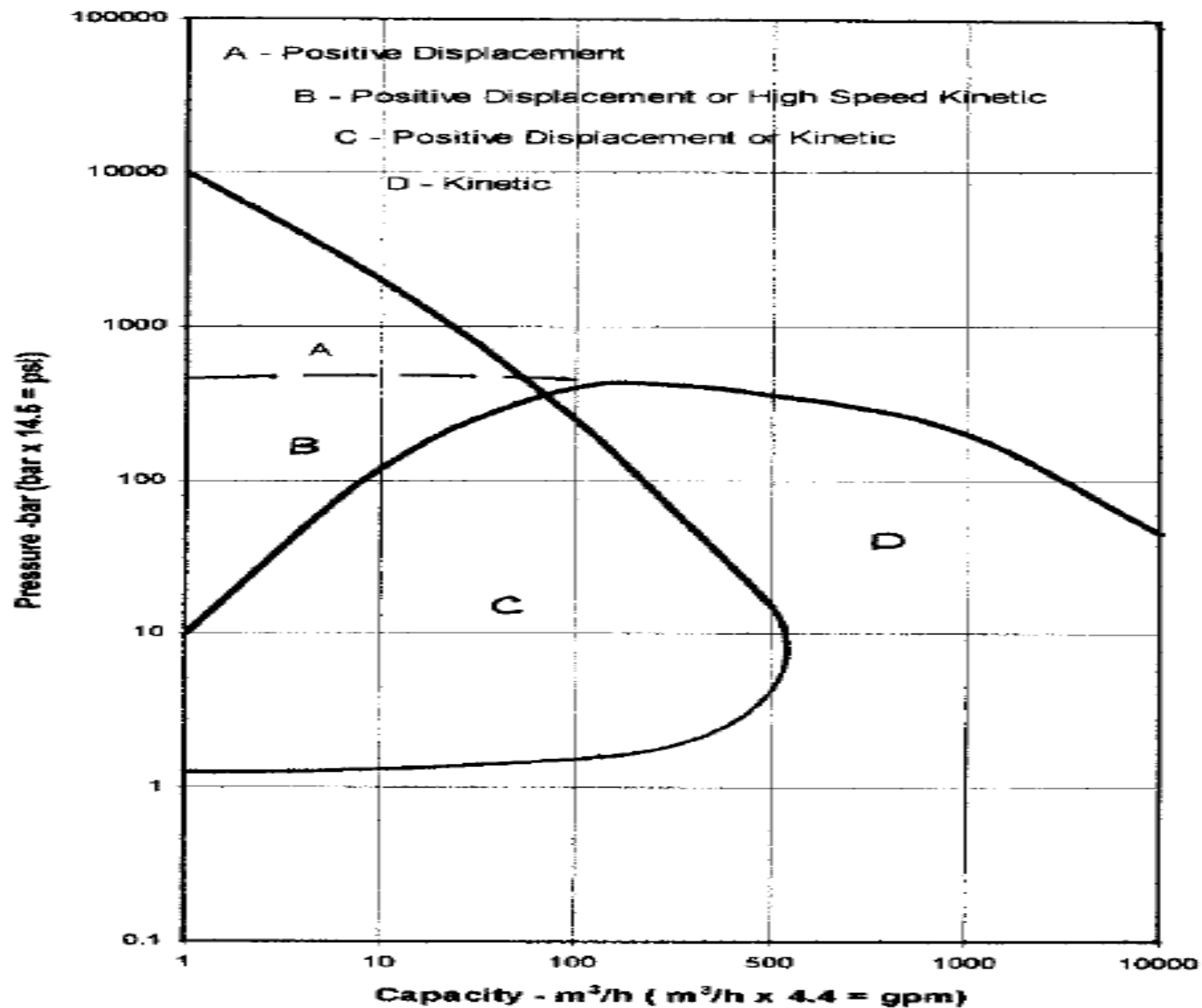
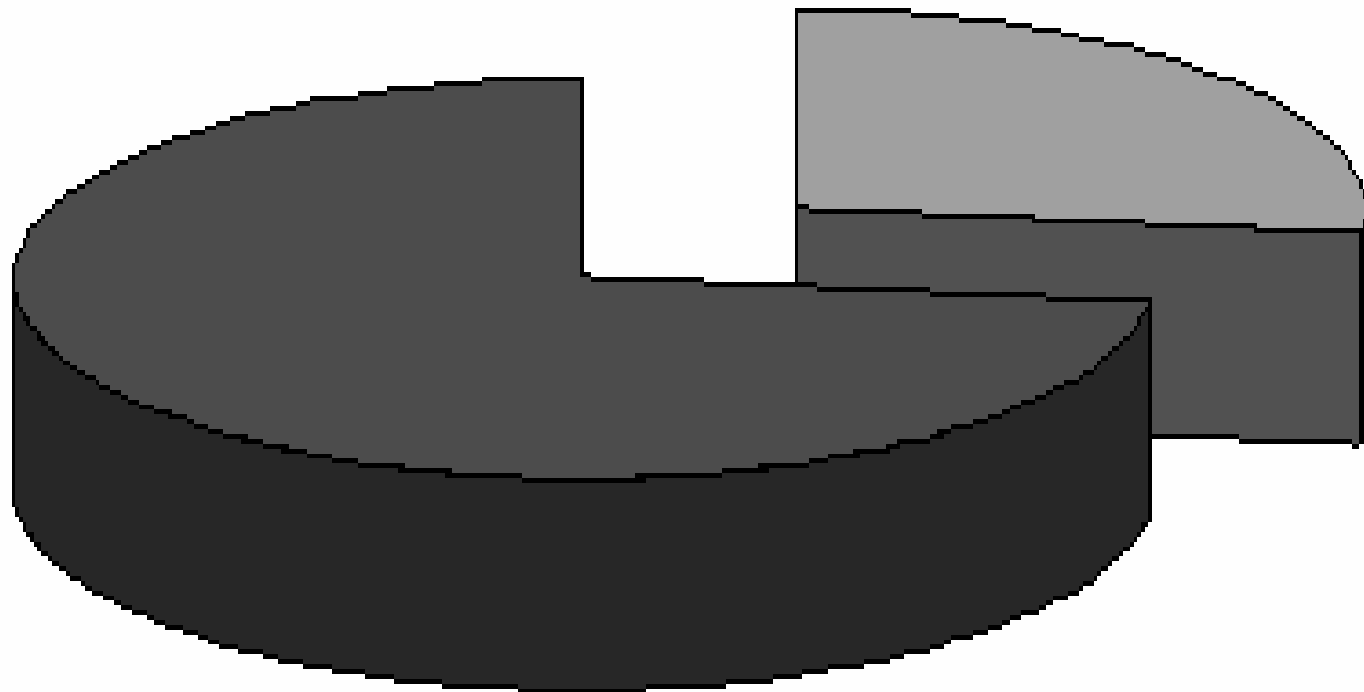


FIGURE 1 General pump overview

Positive Displacement Pumps 27%



Centrifugal Pumps 73%

Theory of Pumping

■ **Pump Location:**

Pumps may be small enough to be suspended by the pipe work that they are servicing, but are usually anchored to a firm location. Large pumps are supported by reinforced concrete foundations for stability and vibration control.

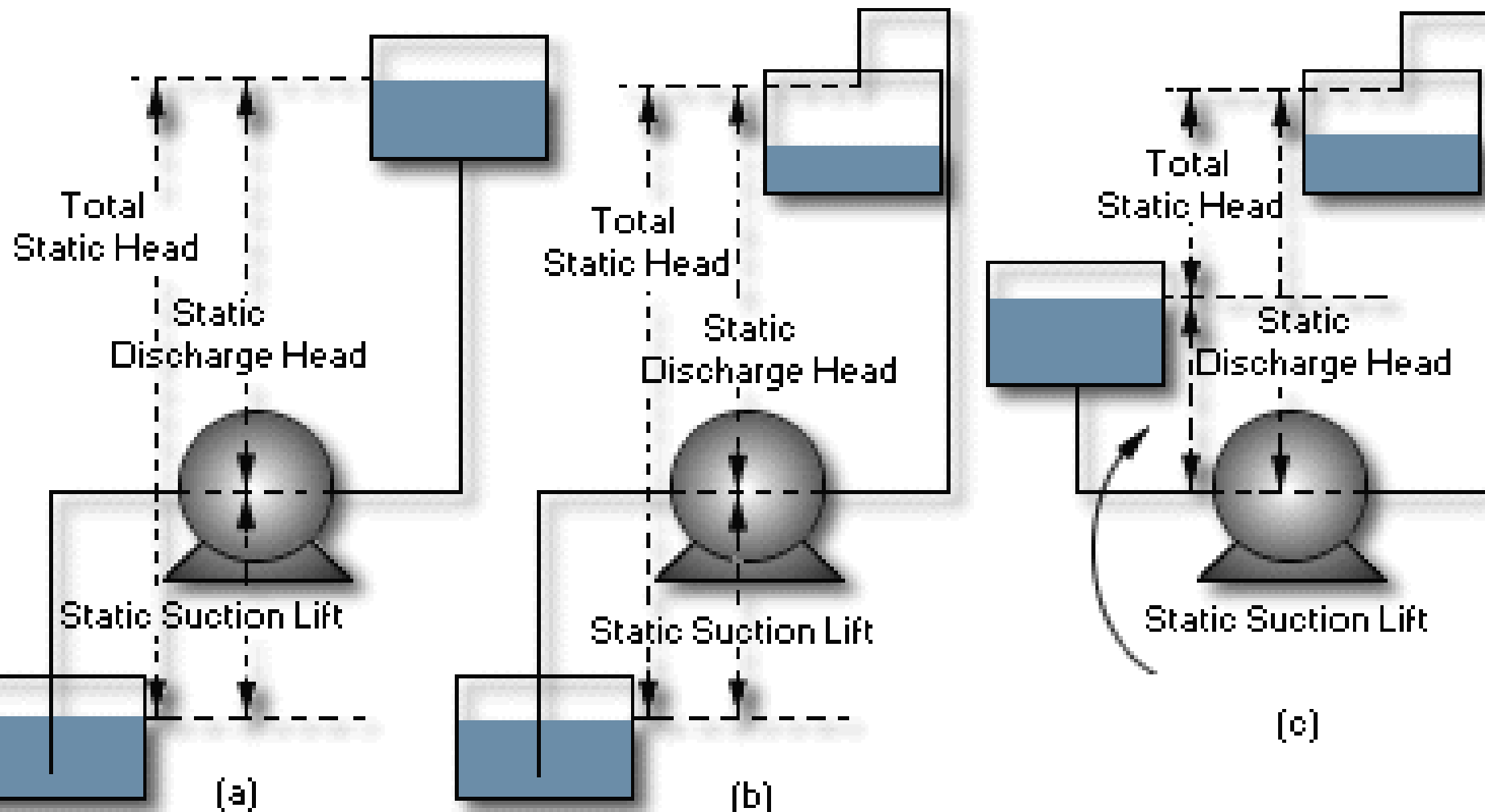
■ **1- Static Suction Lift**

Let us assume that a pump is used to move a certain amount of water and that this pump is located above its source of supply which may be a pond, tank or other source.

The pump has to lift the water through the suction line. The distance, measured vertically, that the intake of the pump is placed above the surface of the water is called the static suction lift.

2- Static Discharge Head

- The vertical distance, in meters or in feet, from the centre line of the pump to the free surface of the water in the discharge tank is called the static discharge head.



3- Total Static Head

- The vertical distance from the surface of the source of supply to the surface of the water in the discharge tank is called the total static head. This is the sum of static suction lift plus static discharge head, thus it is the total height the water is raised by the pump.

4- 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 meters or feet of water.

$$H_f = K \cdot \frac{V^2}{2g}$$

K = Loss coefficient

$\frac{V^2}{2g}$ = velocity head

$$H_f = f \cdot \frac{L}{d} \cdot \frac{V^2}{2g}$$

H_f = pressure drop due to friction (ft)
 f = Darcy friction factor
 L = pipe length (ft)
 V = velocity(ft/sec),
 g = gravitational acceleration(ft/sec²)
 d = pipe diameter (ft)
 $\frac{V^2}{2g}$ = velocity head (ft)

6- Velocity Head

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

$$h_v = \frac{v^2}{2g}$$

6- 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.

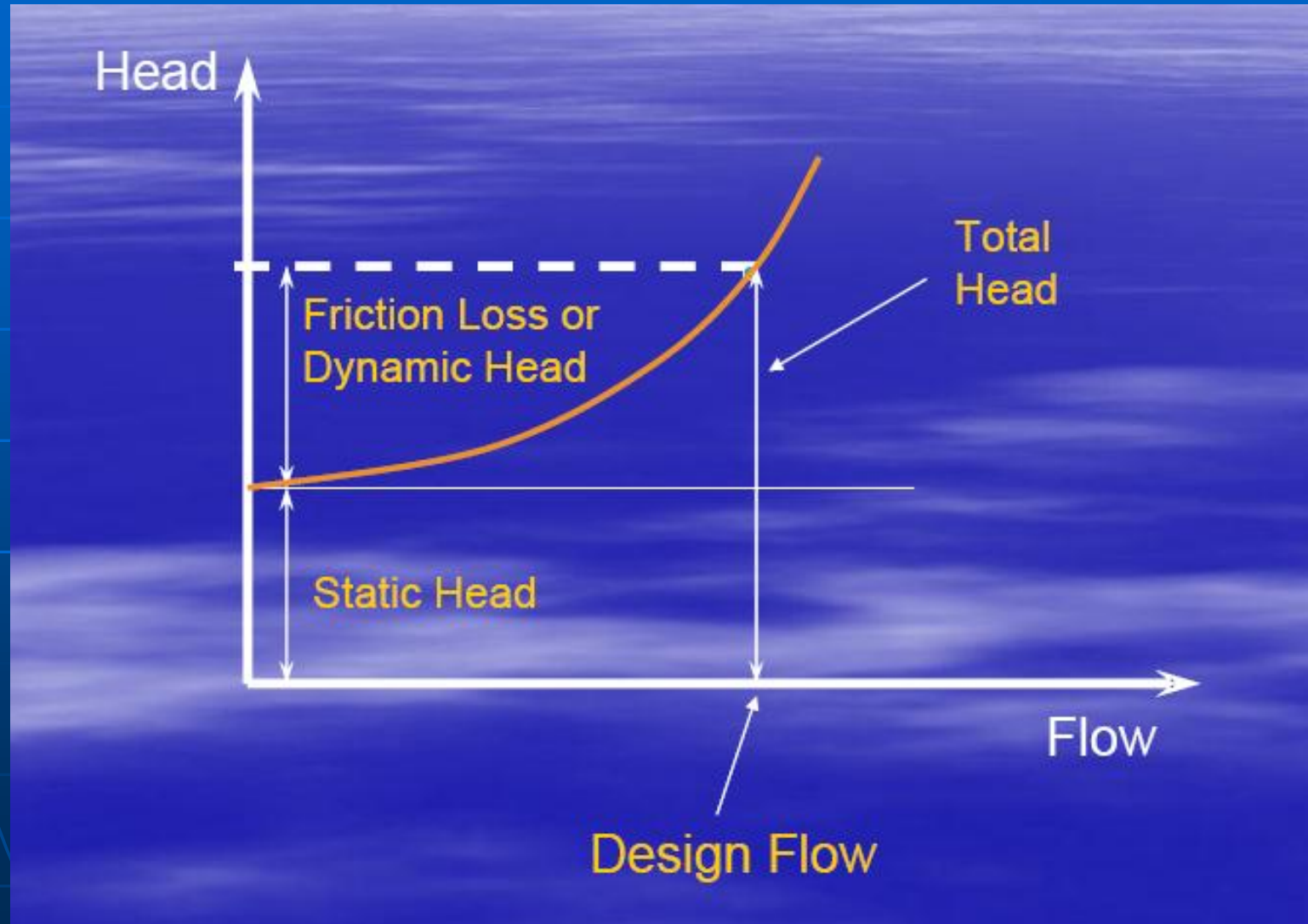
7- Dynamic Head

- Friction, velocity and pressure 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.

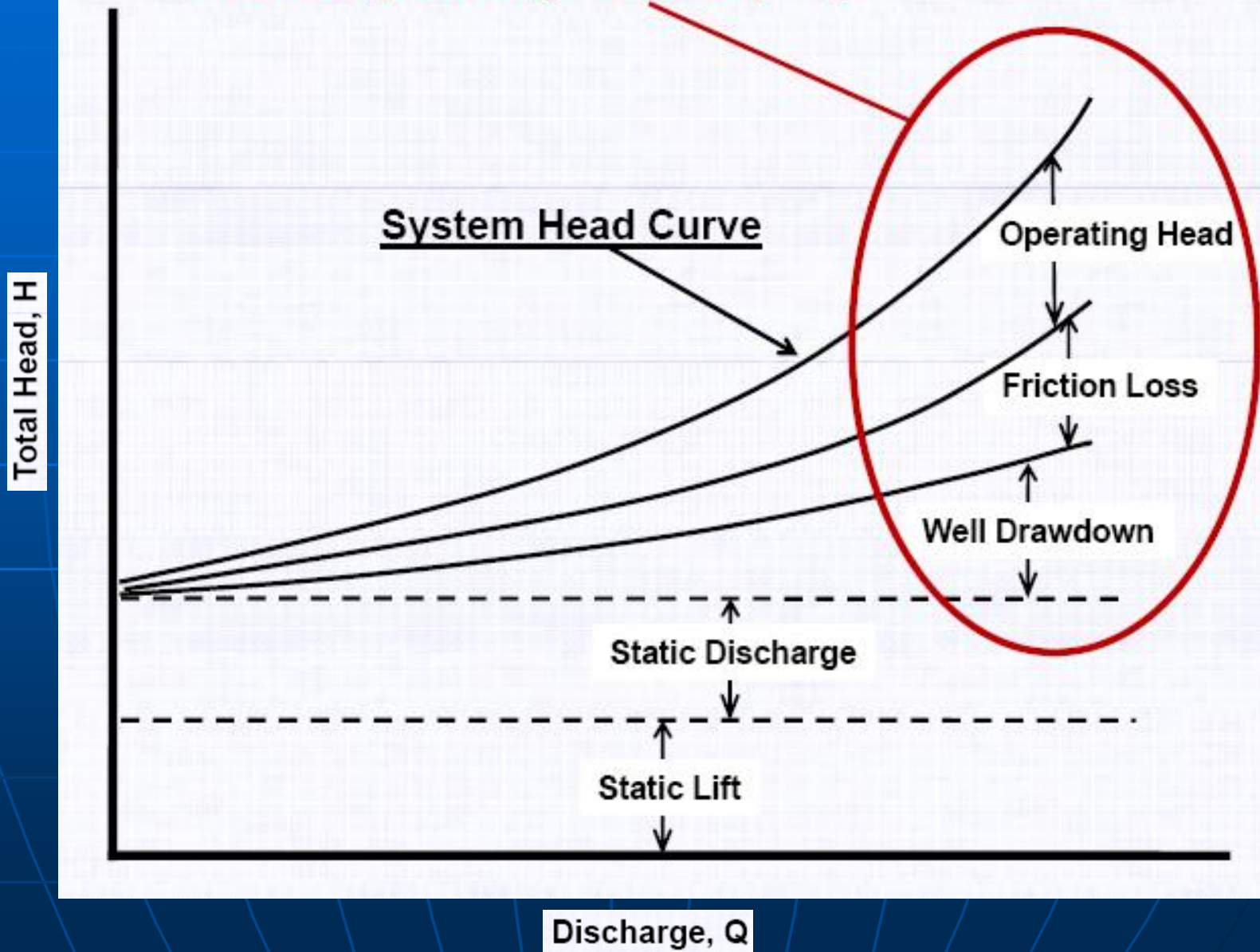
8- Total Head

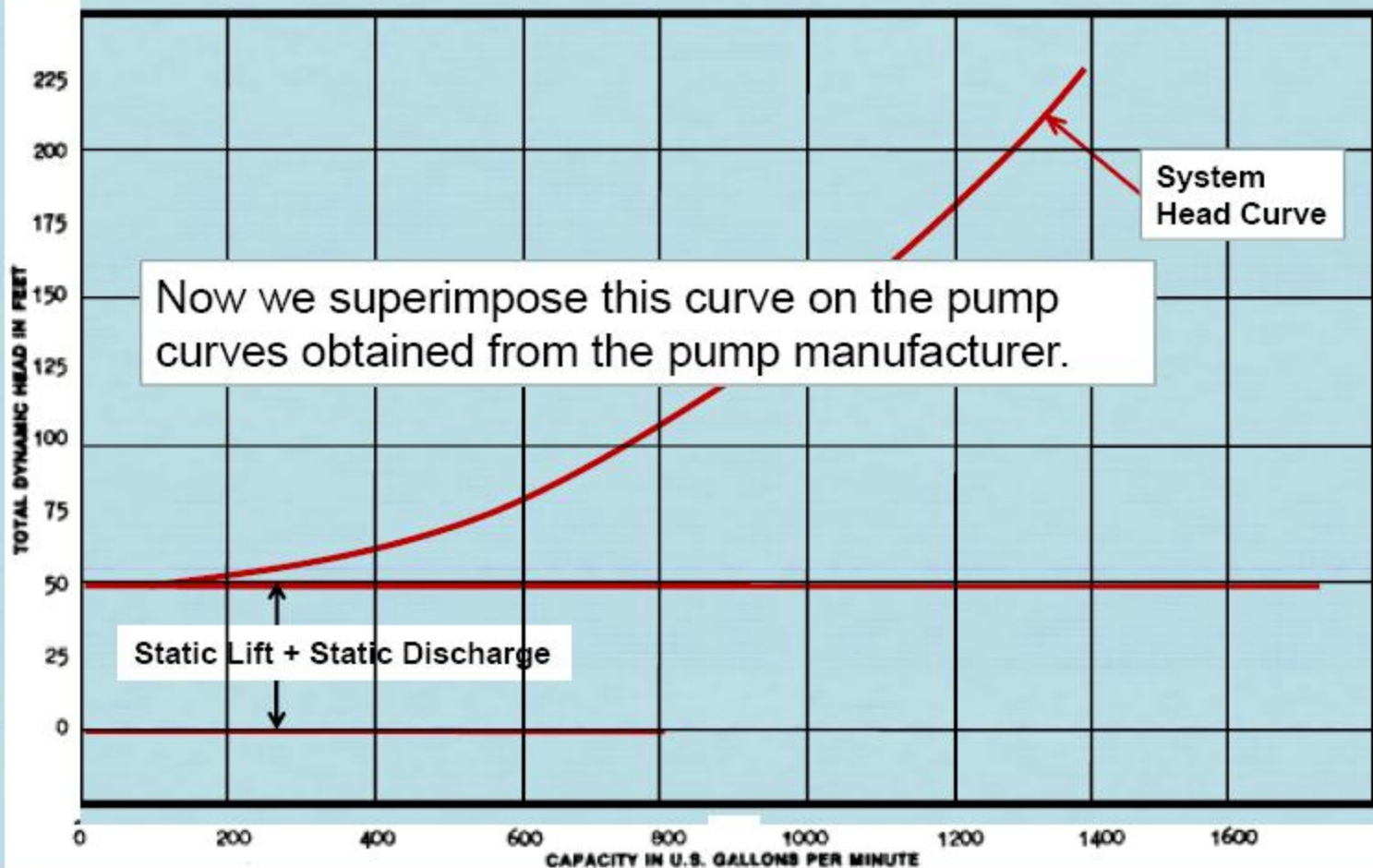
- The total head required to move the water from the source of supply to the point of discharge is the sum of static and dynamic head.

System curve



These are all dynamic – they increase with increasing discharge from the pump.



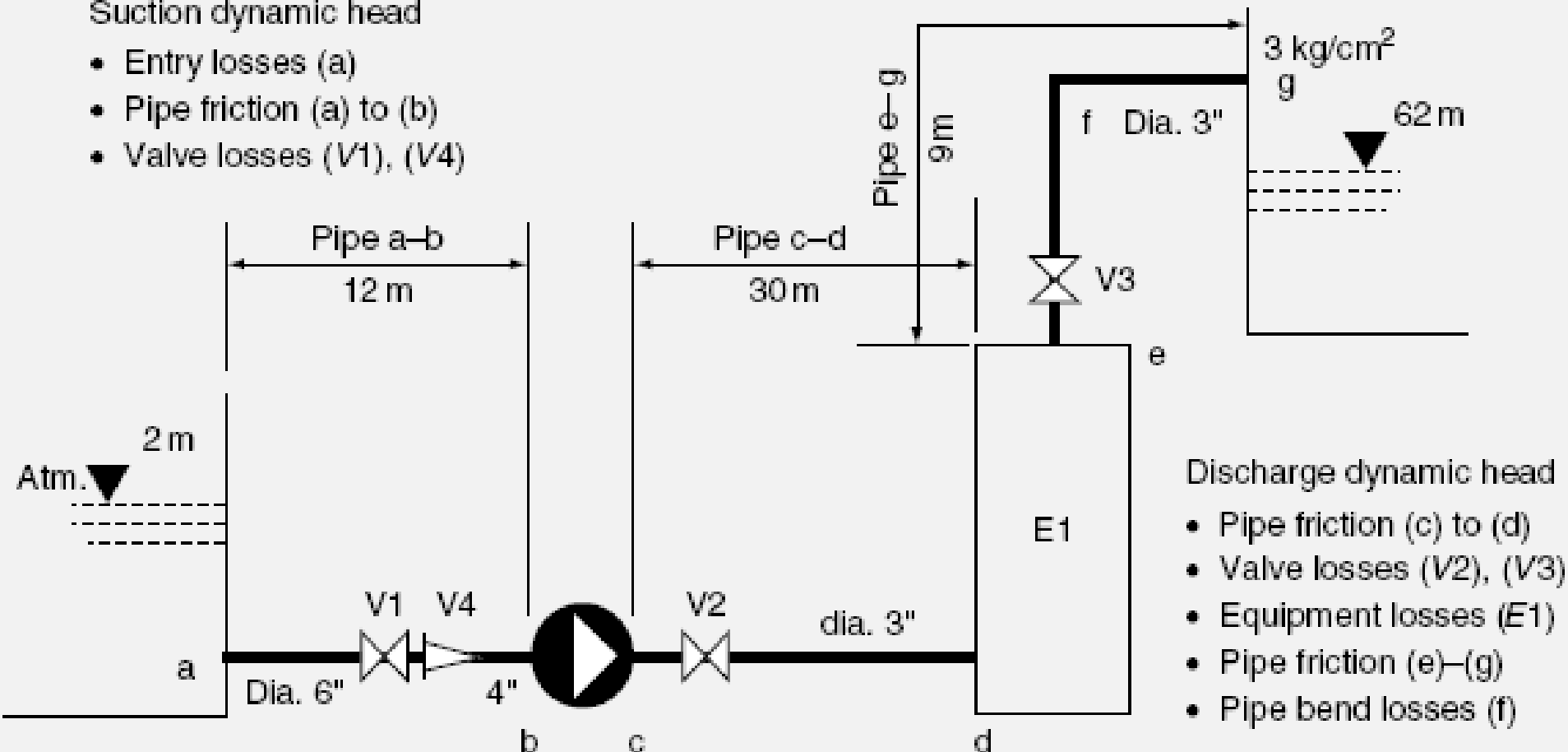


The pump curves from the manufacturer were determined in essentially the same way you determined your pump curves.

System connections

Suction dynamic head

- Entry losses (a)
- Pipe friction (a) to (b)
- Valve losses (V1), (V4)

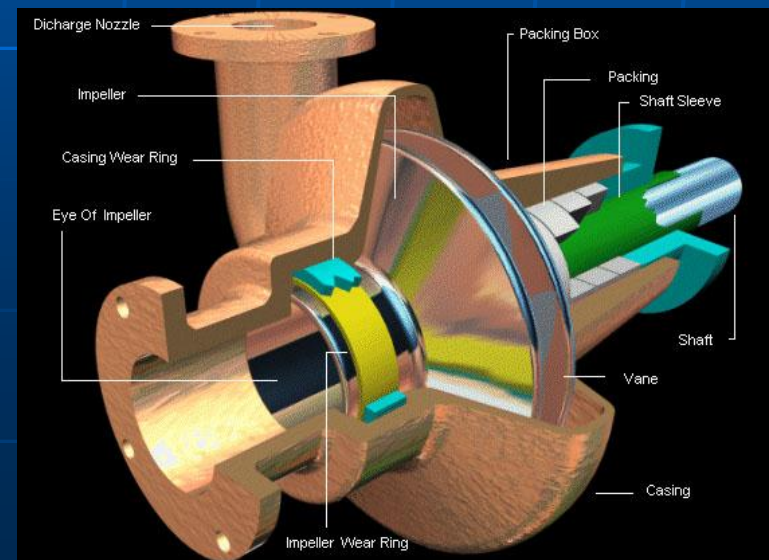


Discharge dynamic head

- Pipe friction (c) to (d)
- Valve losses (V2), (V3)
- Equipment losses (E1)
- Pipe friction (e)-(g)
- Pipe bend losses (f)

1-Centrifugal Pump

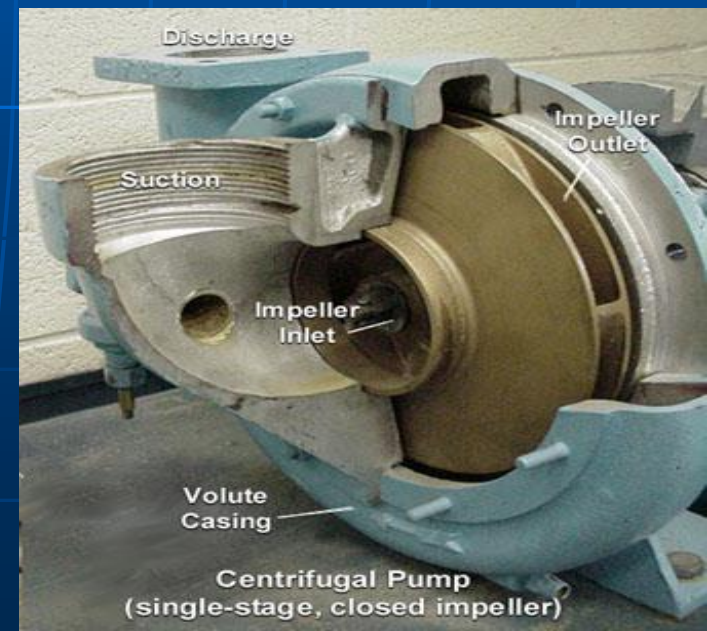
- A centrifugal pump may be defined as a pump which uses centrifugal force to develop velocity in the liquid being handled. The velocity is then converted to pressure when the liquid velocity decreases. As kinetic energy is decreased, pressure is increased. Centrifugal pumps can be subdivided into the following types: volute, diffuser, axial flow, mixed flow, and regenerative. Although the regenerative pump is not truly a centrifugal pump, it will be considered in this classification.



■ Construction:

1-Impeller:

- The impeller of the centrifugal pump converts the mechanical rotation to the velocity of the liquid. The impeller acts as the spinning wheel in the pump. 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.

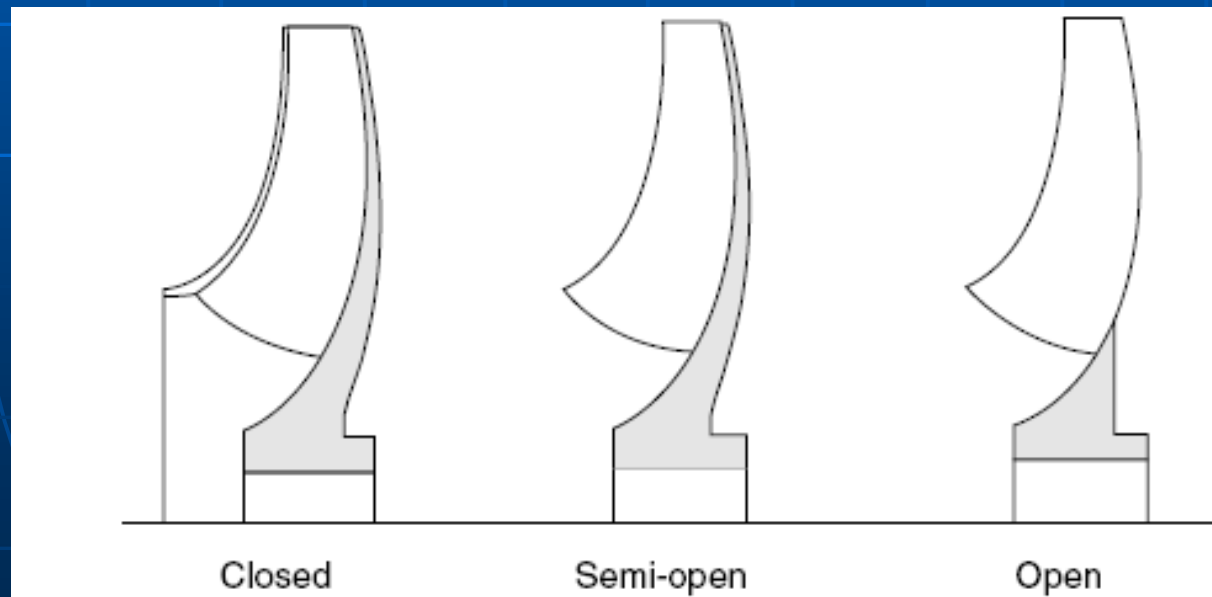


Types of Impellers

- There are three types of construction seen in an impeller. These are based on the presence or absence of the impeller covers and shrouds.

The three types are:

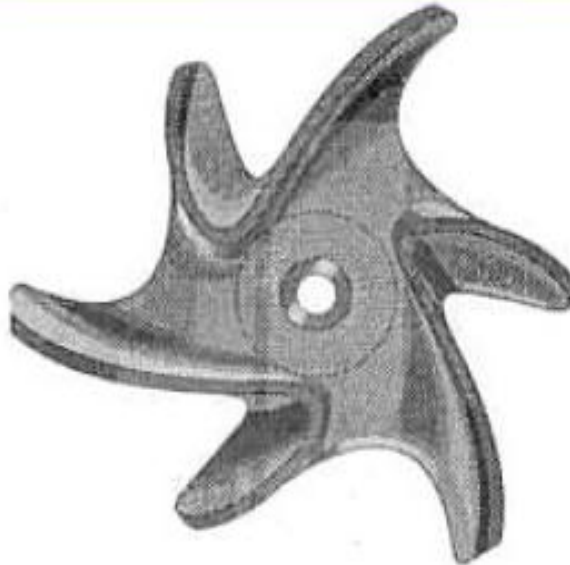
1. Closed
2. Semi-open
3. Open.



Impeller Type



Semi Open
Impeller



Fully Open
Impeller



Closed Impeller

■ **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.

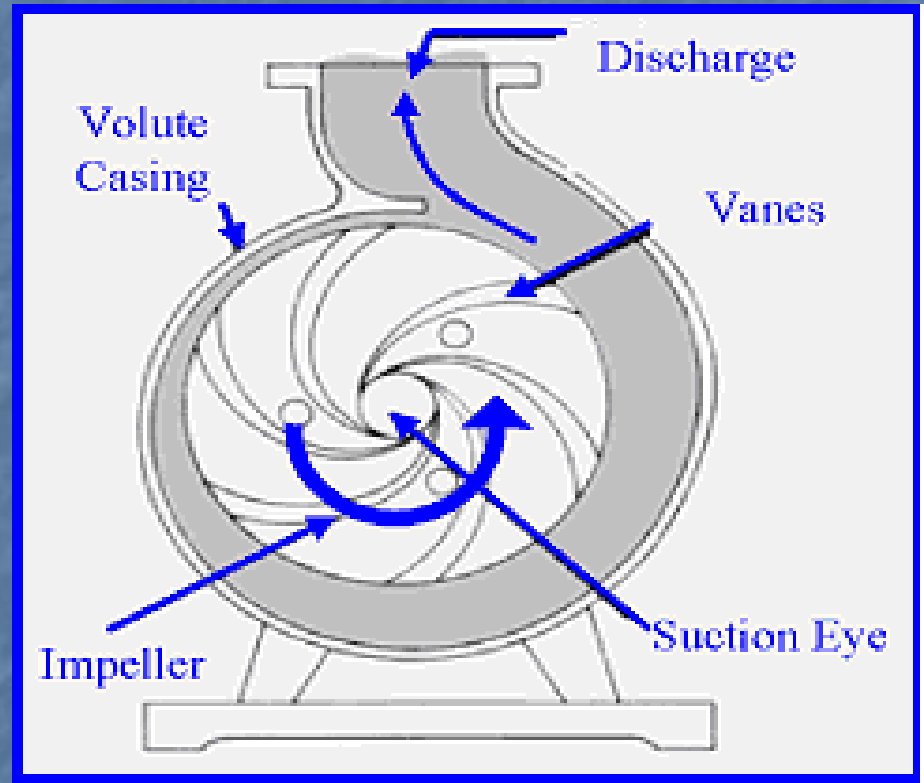
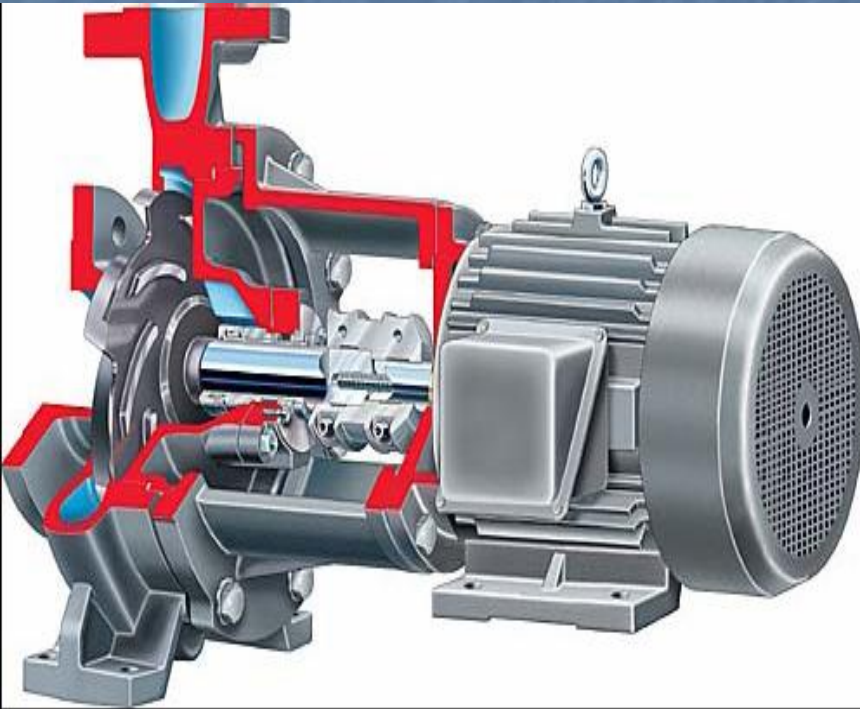
■ **Semi-open impellers:**

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.

■ **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.

Centrifugal Pumps



Working Mechanism of a Centrifugal Pump

2- Impeller suction

In general, an impeller has one eye or a single opening through which liquid suction occurs. Such impellers are called as single-suction impellers. Pumps with a single suction impeller (impeller having suction cavity on one side only) are of a simple design but the impeller is subjected to higher axial thrust imbalance due to the flow on one side of the impeller only.

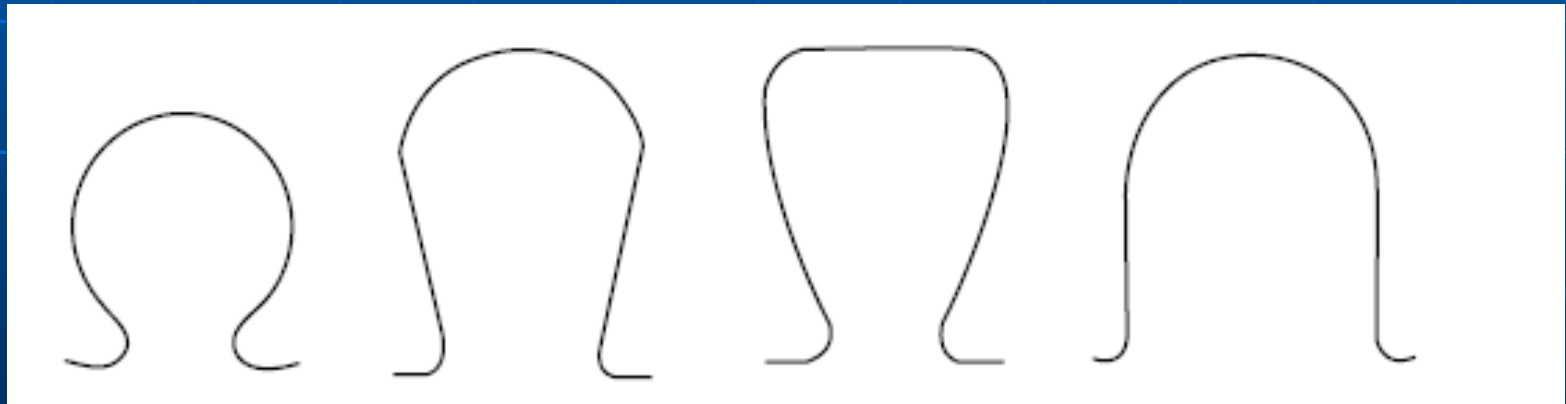
3- Flow outlet from impeller

The flow direction of the liquid at the outlet of the impeller can be:

- Radial (perpendicular to inlet flow direction)
- Mixed
- Axial (parallel to inlet flow direction).

4- Volute casing:

Volute casings when manufactured with smooth surfaces offer insignificant hydraulic losses. In pumps with volute casings, it is possible to trim down impeller vanes and shrouds with minimal effect on efficiency. In volute casings, the kinetic energy is converted into pressure only in the diffusion chamber immediately after the volute throat. The divergence angle is between 7° and 13° . The volutes encountered can be of various cross-sections .

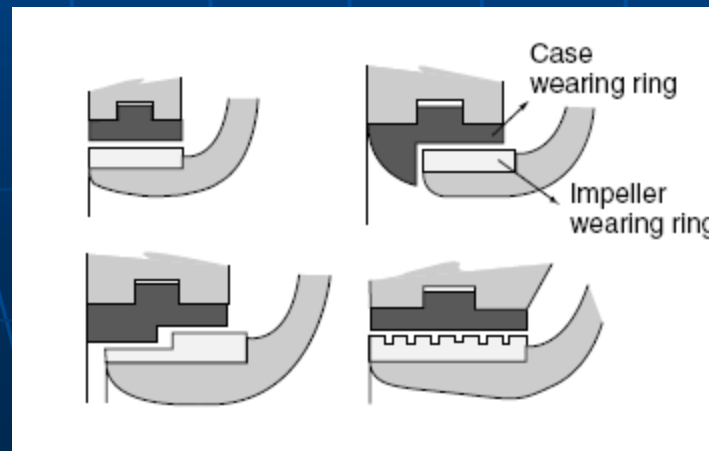


5- Wearing rings:

The impeller is a rotating component and it is housed within the pump casing. To prevent frictional contact, a gap between these two parts is essential. So there exists a gap between the periphery of an impeller intake and the pump casing.

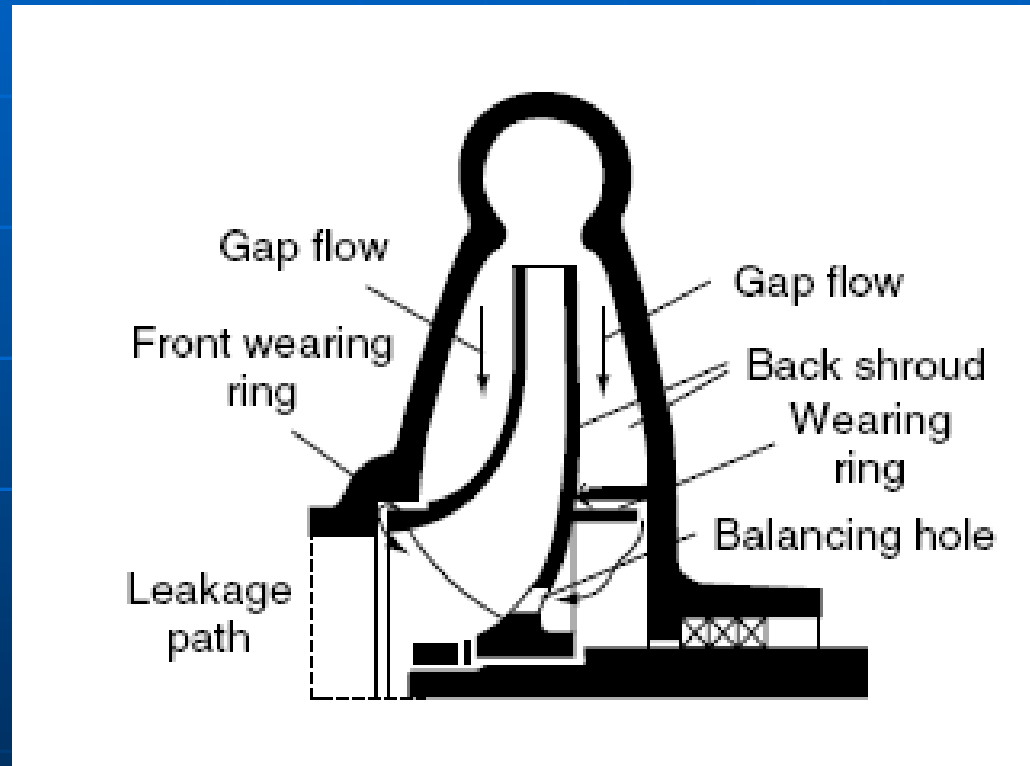
In addition, there is a pressure difference between them, which results in the recirculation of the pumped liquid. This leakage reduces the efficiency of the pump.

- The other advantages of lower clearance is that reduced leakage prevents erosion due to suction recirculation and also provides a much better rotor dynamic stability to the pump.



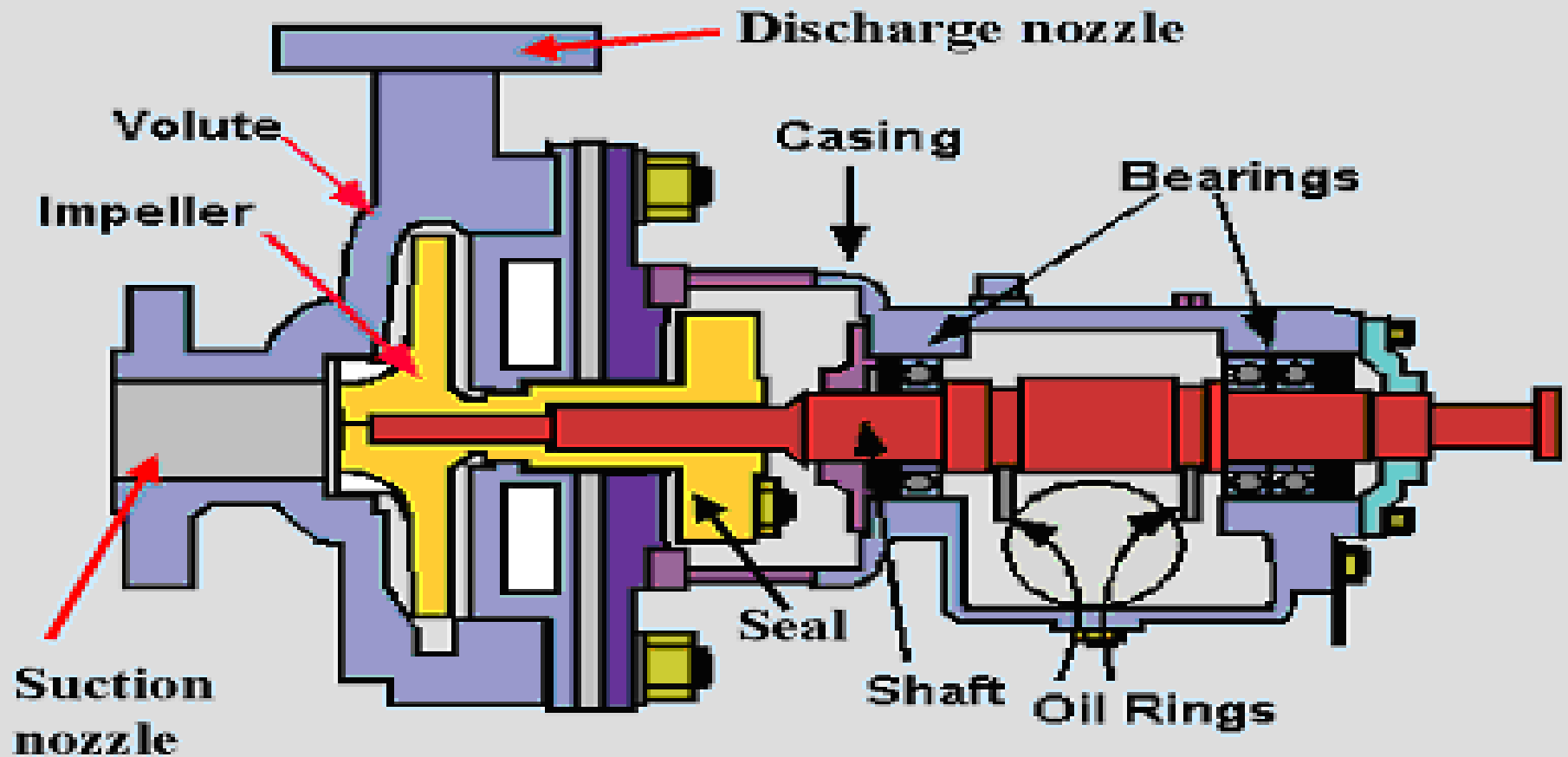
■ Wearing ring location

Usually, these are required when impellers are provided with balancing holes in order to minimize the axial thrust coming onto the pump impeller and consequently onto the bearings. The arrangement of the wearing rings on the back of the impeller is shown



- The material of the wearing rings is selected to prevent seizure on frictional contact. As a result, materials like SS-316 which have galling tendencies are not considered for this application.

General Components of Centrifugal Pump



Centrifugal Pump

6- Shaft

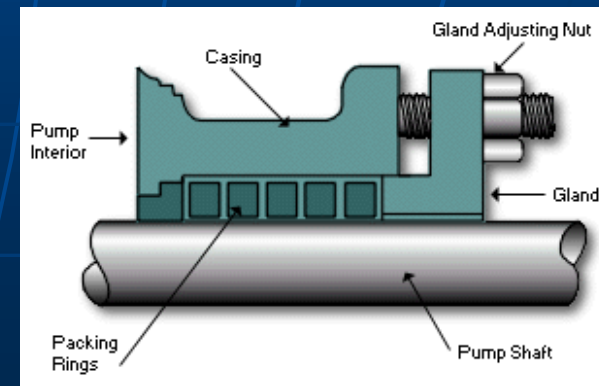
The pump rotor assembly comprises of the shaft, impeller, sleeves, seals (rotating element), bearings or bearing surfaces, and coupling halves. The shaft, however, is the key element of the rotor. The prime mover drives the impeller and displaces the fluid in the impeller and pump casing through the shaft.

The pump shaft is a stressed member for during operation it can be in tension, compression, bending, and torsion. As these loads are cyclic in nature, the shaft failure is likely due to fatigue.

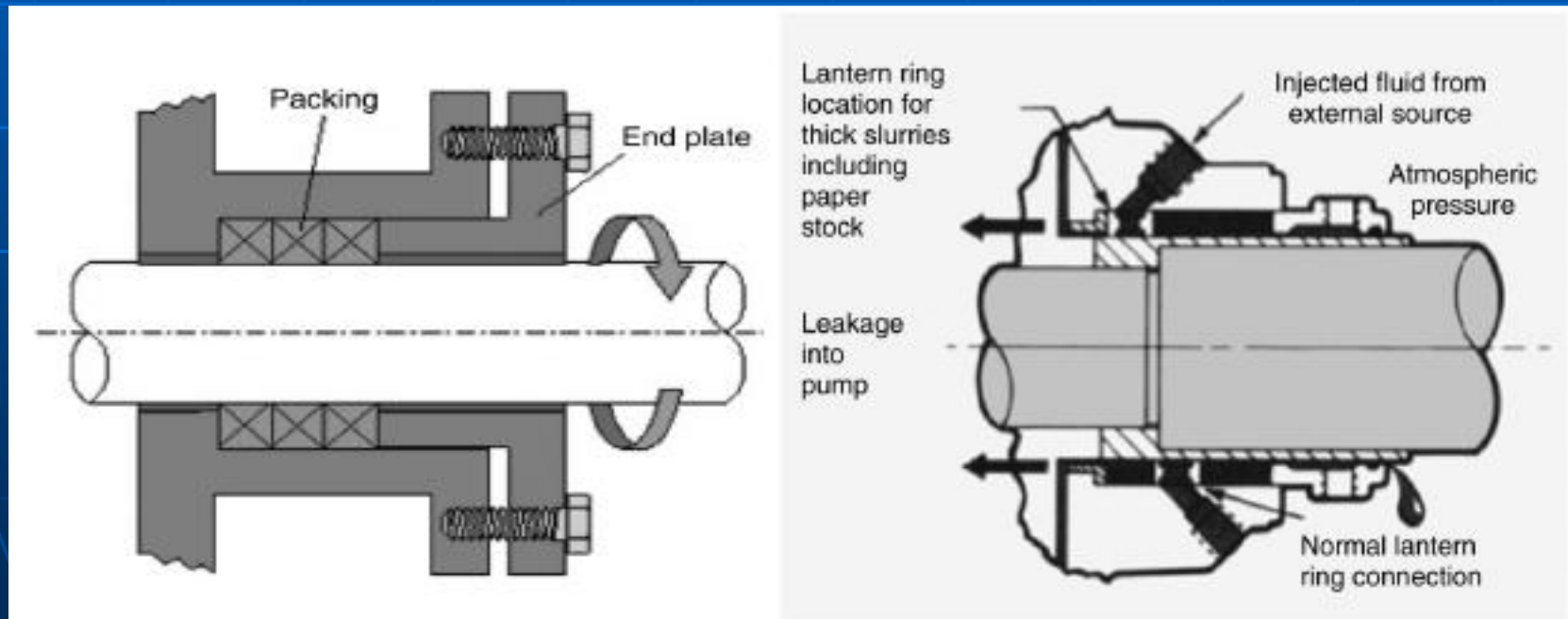
7- Stuffing boxes

The stuffing box is a chamber or a housing that serves to seal the shaft where it passes through the pump casing.

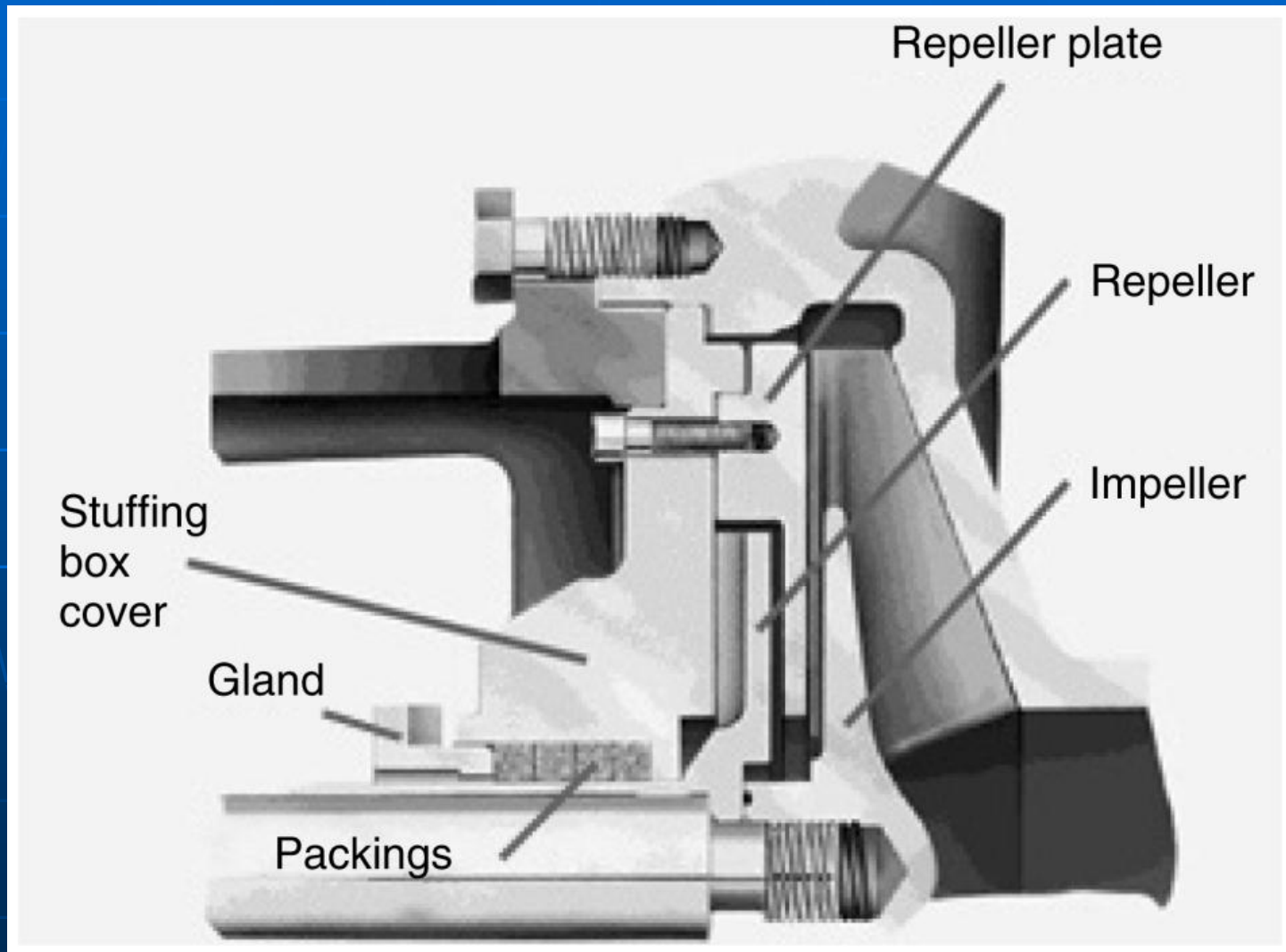
In a stuffing box, 4–6 suitable packing rings are placed and a gland (end plate) for squeezing and pressing them down the shaft.



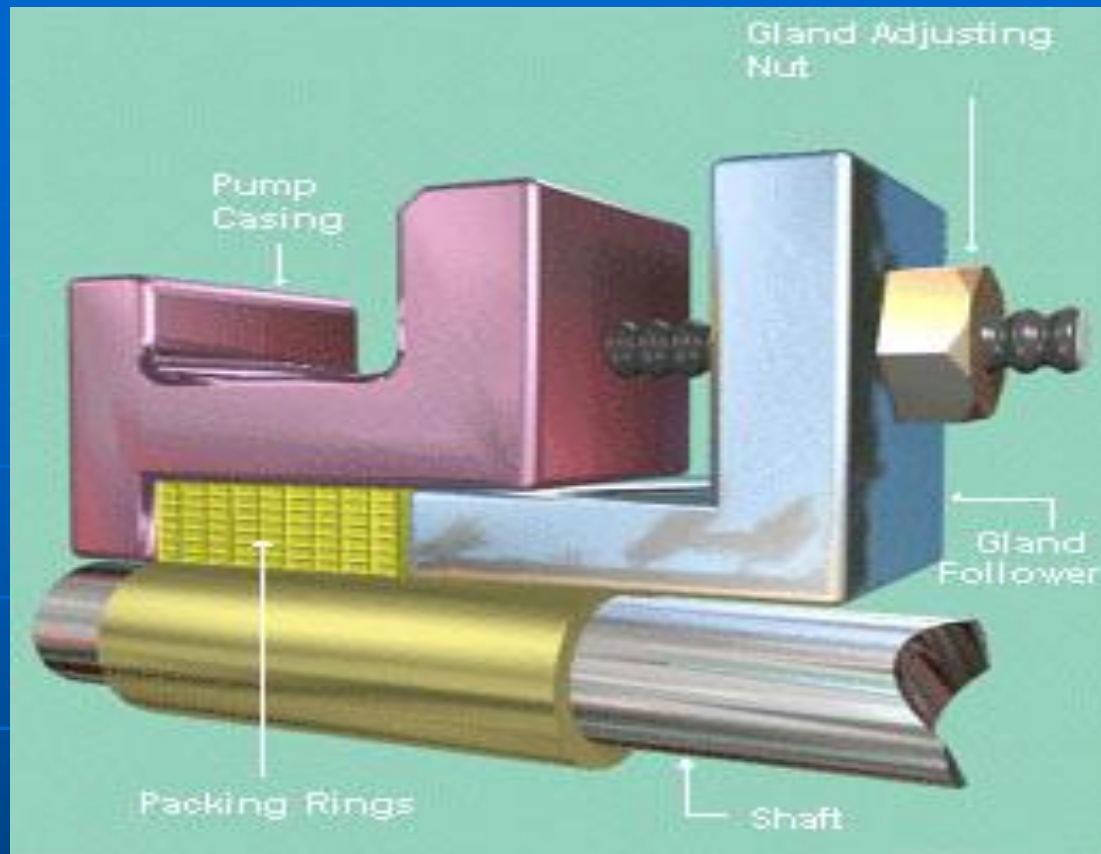
- The narrow passage, between the shaft and the packing housed in the stuffing box, provides a restrictive path to the liquid, which is at a high pressure within the pump casing. The restrictive path causes a pressure drop, prevents leakage resulting in considerable friction between the shaft and the packing, and causes the former to heat up. It is thus good practice to tighten the gland just enough to allow for a minimal leak through the packing.



- This is achieved by first reducing the pressure in front of the packings. The reduction in pressure is brought about by having radial blades at the back shroud of an auxiliary Impeller . This auxiliary impeller is also called as a repeller.

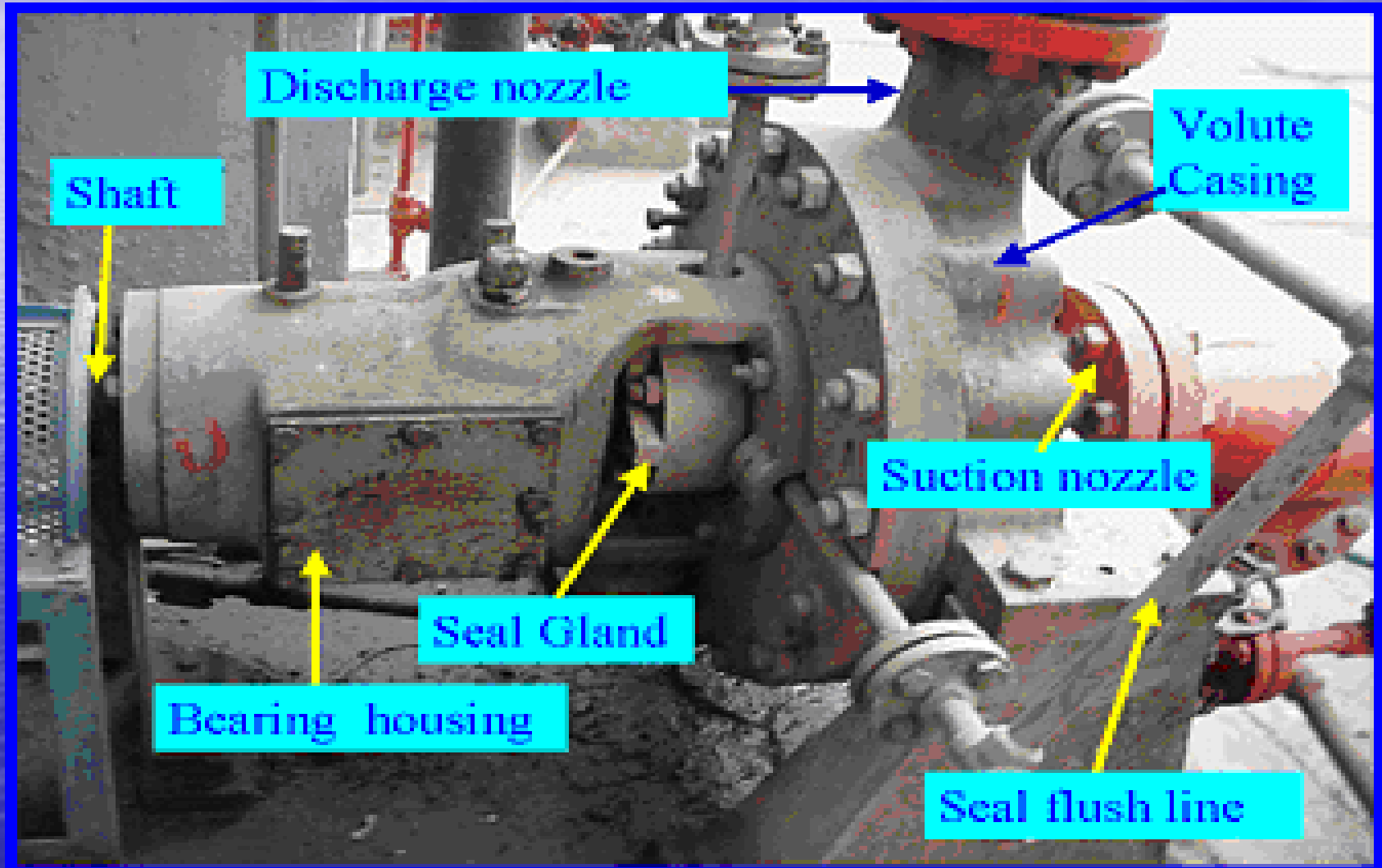


Stuffing box for a corrosive liquid



- This figure shows the basic construction of a stuffing box which holds five rings of packing. The gland holds the rings in place and can be adjusted to put pressure on the packing by tightening of the adjusting nuts.

General Components of Centrifugal Pumps

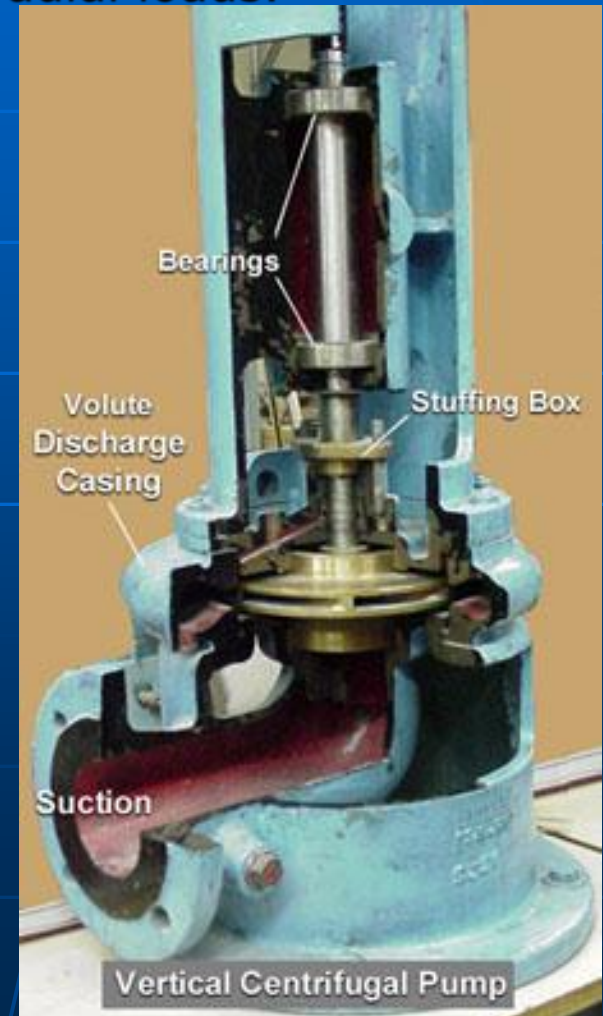
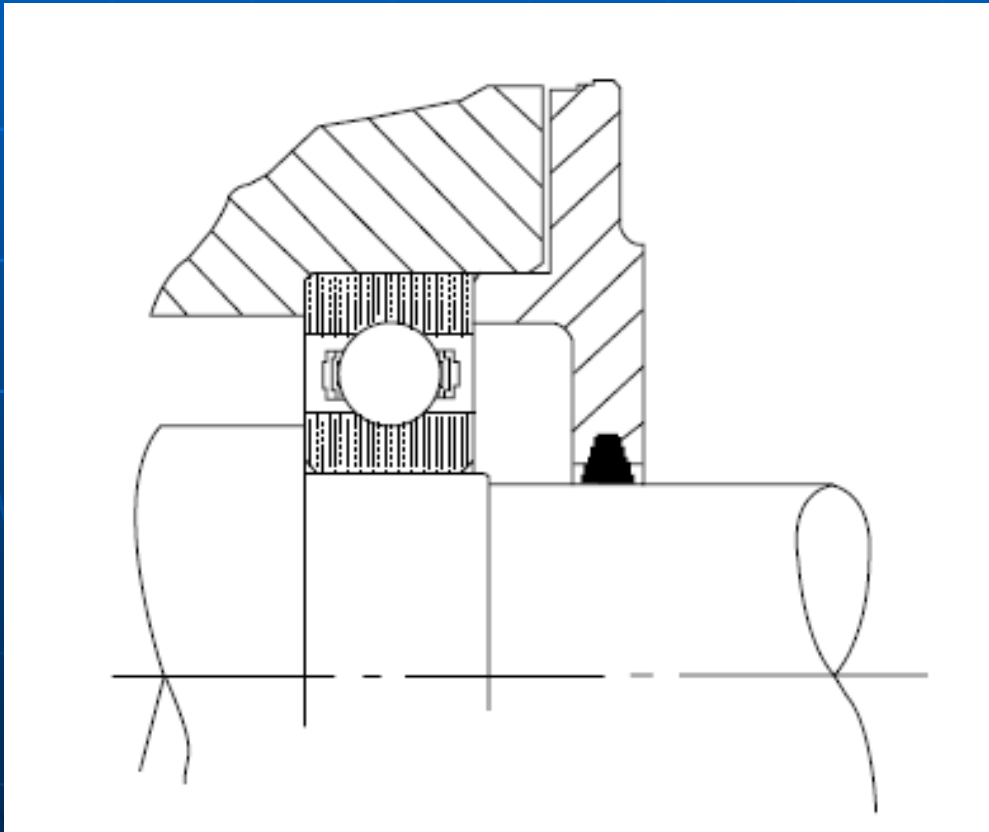


8- Mechanical seals and seal housings

- The stuffing boxes described above have many disadvantages and these include:
 - A persistent leakage and loss of product if the shaft surface is not smooth.
 - If the gland is too tightened, the shaft/sleeve gets hot and there can be rapid wear of the surface.
 - They require constant supervision.
- As a result, the use of gland packing is being phased out but is still used in noncritical and low-power applications. In most of the applications, mechanical seals are used. Most of the disadvantages of packing are eliminated by the use of mechanical seals.

■ 9-Bearing:

Overhung impeller pumps usually employ anti-friction bearings only. In a typical bearing housing arrangement, the radial ball or cylindrical roller bearing is located adjacent to the impeller or inboard position. It is arranged to take only radial loads.



10-Couplings

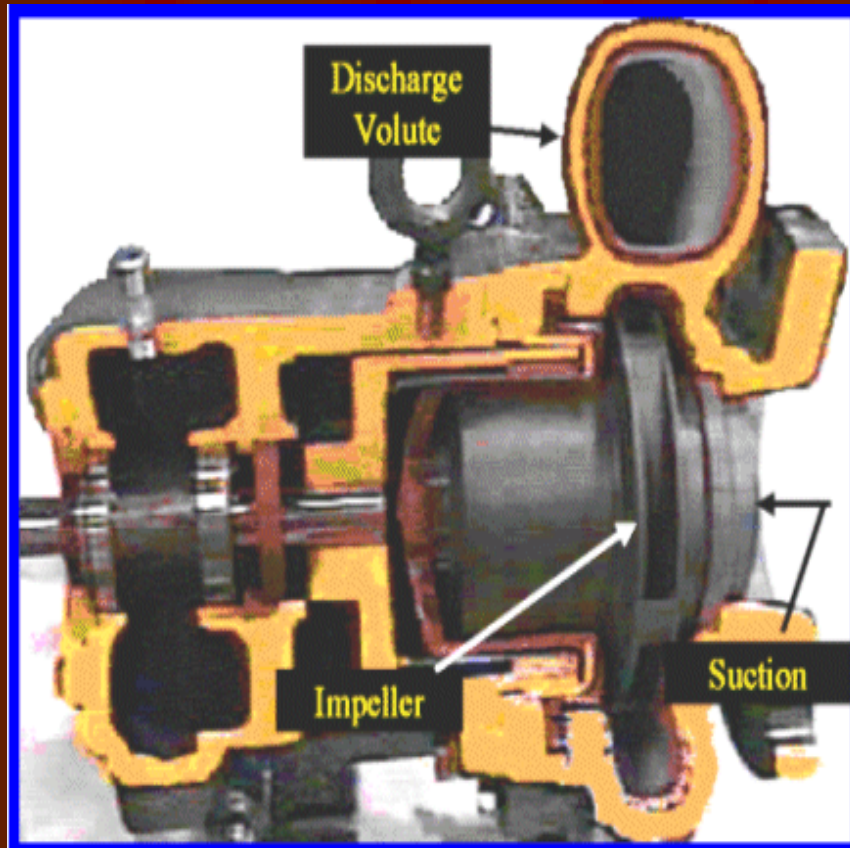
Couplings for pumps usually fall in the category of general-purpose couplings. General purpose couplings are standardized and are less sophisticated in design. The cost of such coupling is also on the lower side. In addition, there are special purpose couplings that can be used on turbo machines and are covered by the API 671 specification.



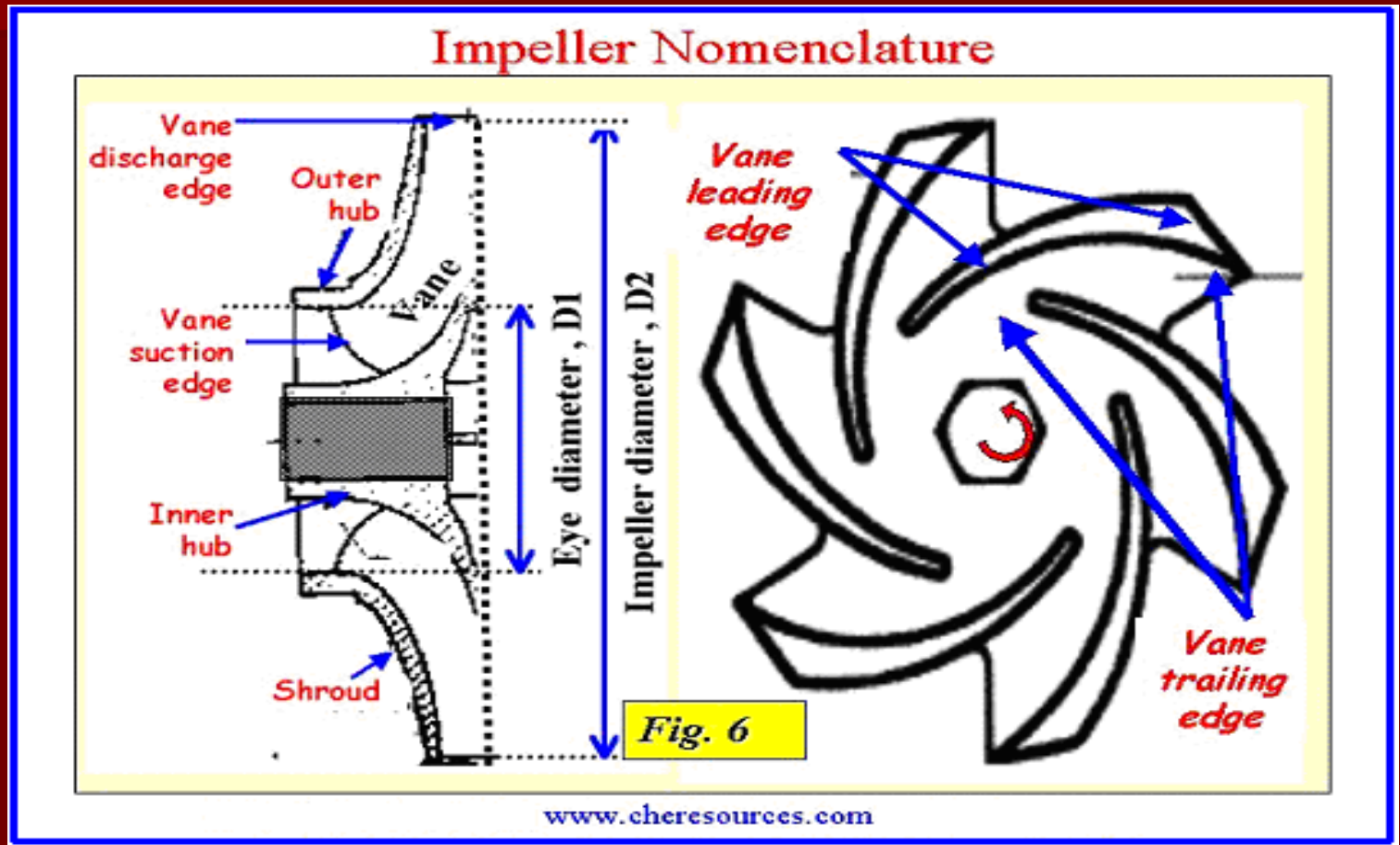
Stationary Components

casing

- volute casing

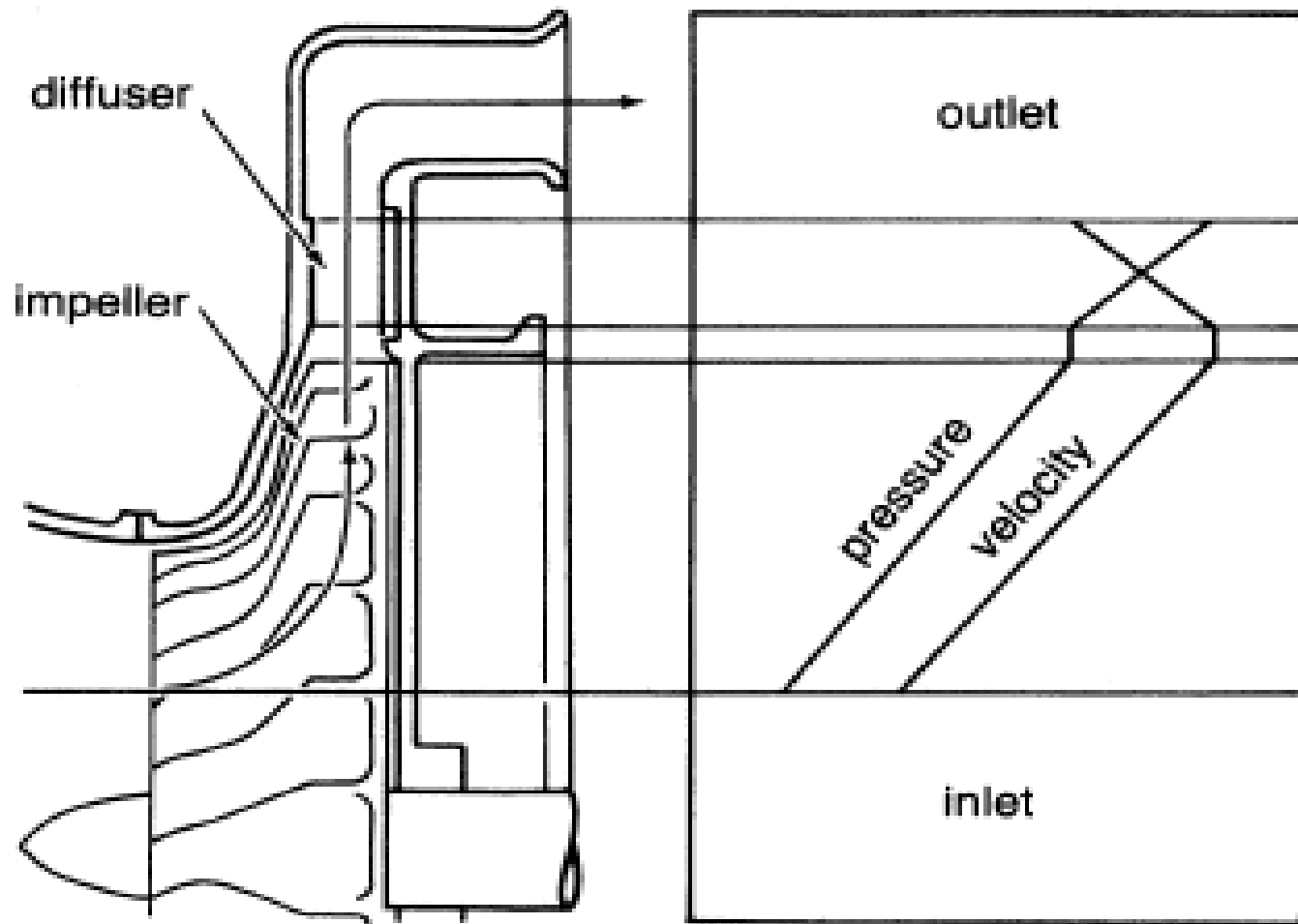


Rotating components



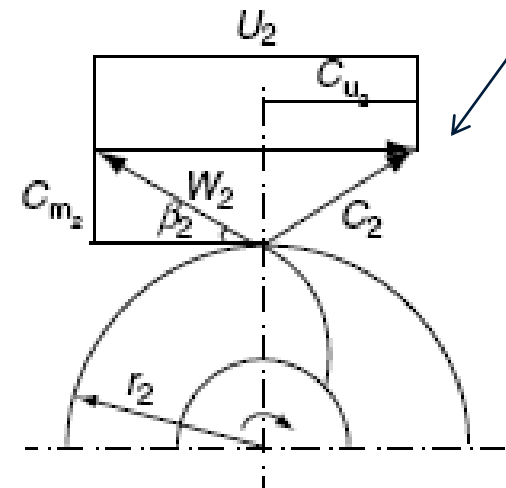
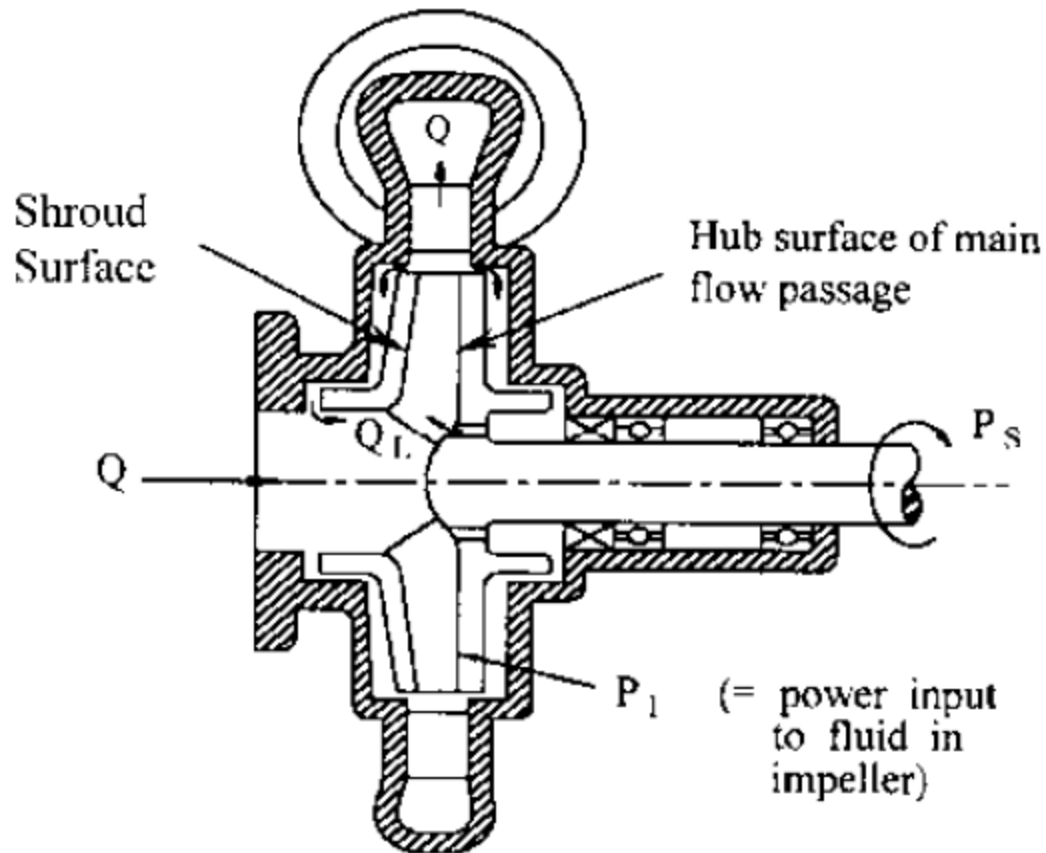
Impeller

Centrifugal Pumps

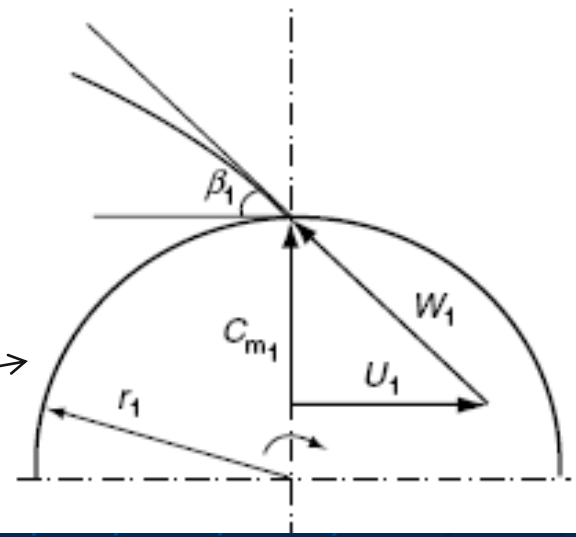


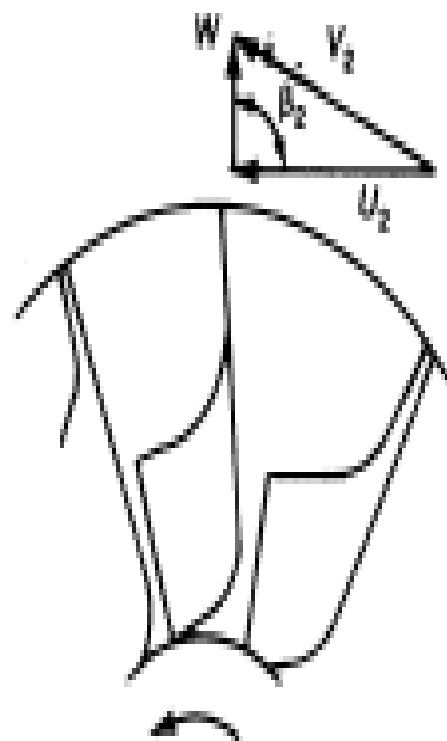
Velocity Triangles

Exit velocity triangle



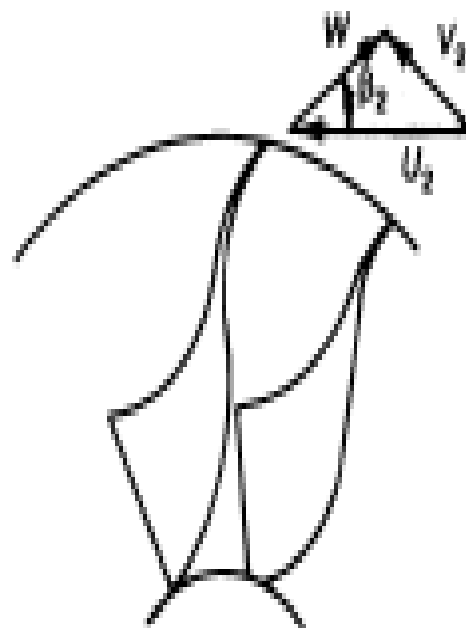
Inlet velocity triangle





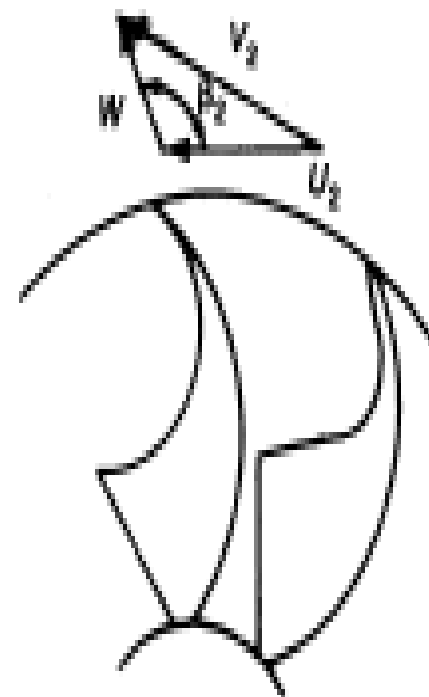
$$\beta_2 = 90^\circ$$

radial vanes



$$\beta_2 < 90^\circ$$

backward-curved vanes



$$\beta_2 > 90^\circ$$

forward-curved vanes

The Advantages and Disadvantages of Various Impellers

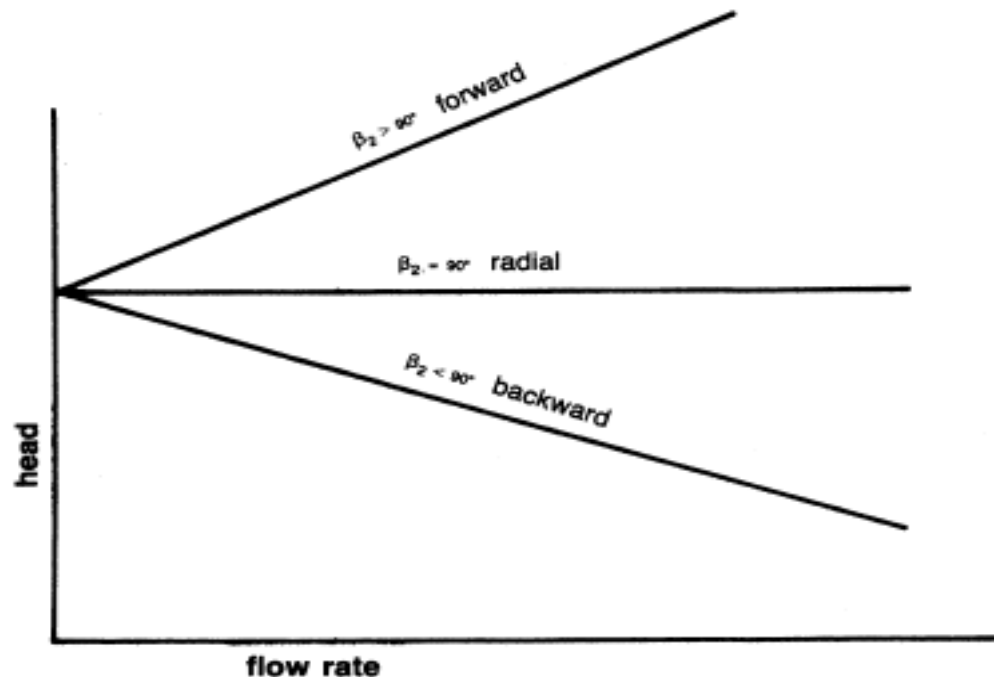
Types of Impellers	Advantages	Disadvantages
<i>Radial vanes</i>	1. Reasonable compromise between low energy transfer and high absolute outlet velocity 2. No complex bending stress 3. Easy manufacturing	1. Surge margin is relatively narrow
<i>Backward-curved vanes</i>	1. Low-outlet kinetic energy = low-diffuser inlet mach number 2. Surge margin is wide	1. Low-energy transfer 2. Complex bending stress 3. Hard manufacturing
<i>Forward-curved vanes</i>	1. High-energy transfer	1. High-outlet kinetic energy = High-diffuser inlet mach number. 2. Surge margin is less than radial vanes 3. Complex bending stress 4. Hard manufacturing

Eular pump head

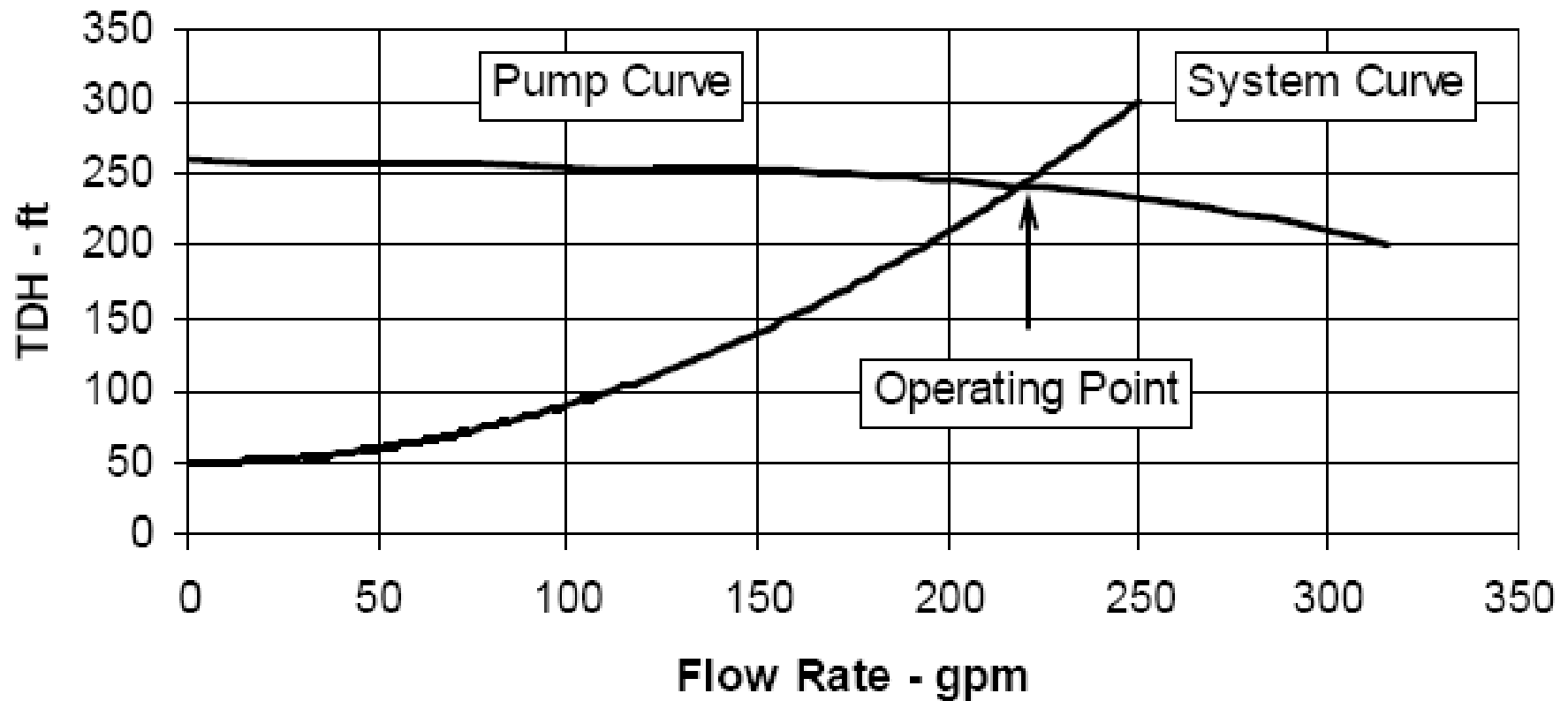
- $H = (1/g) (C_{u2} U_2 - C_{u1} U_1)$

For radial at inlet

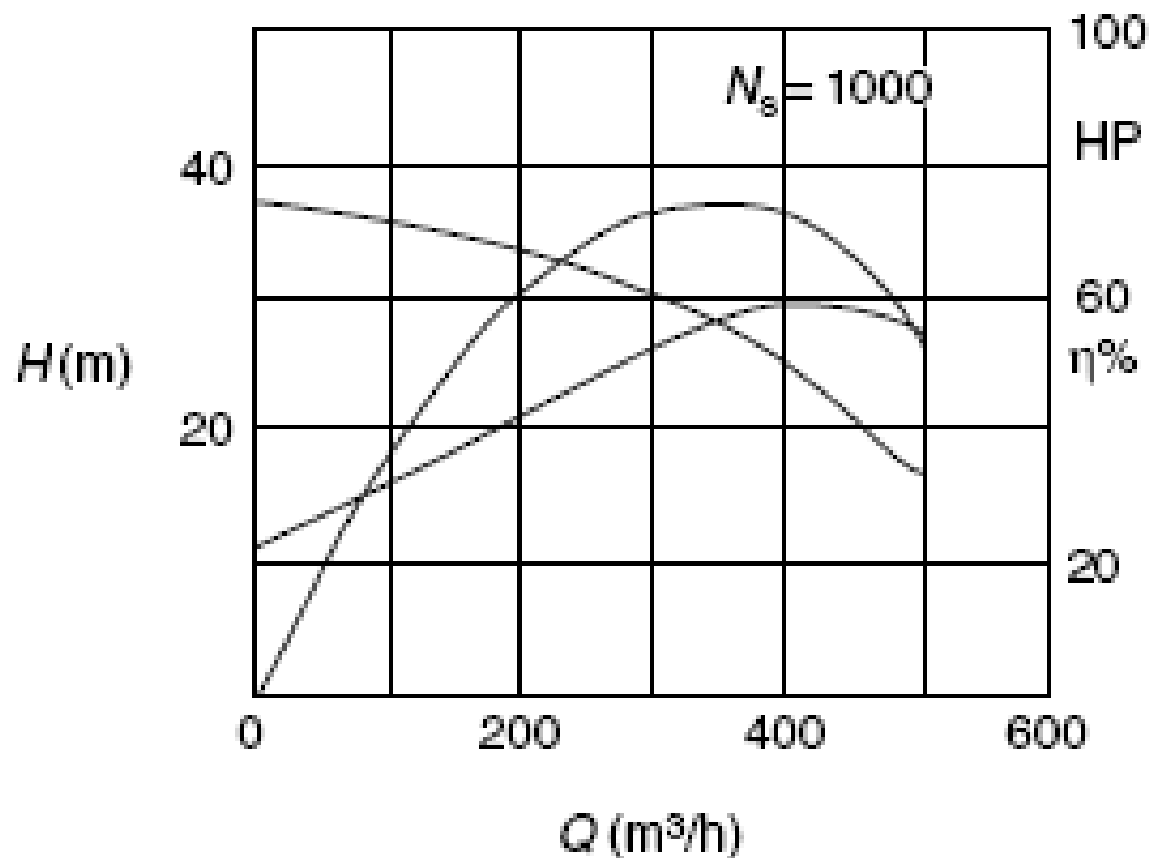
$$H = (1/g) (C_{u2} U_2)$$



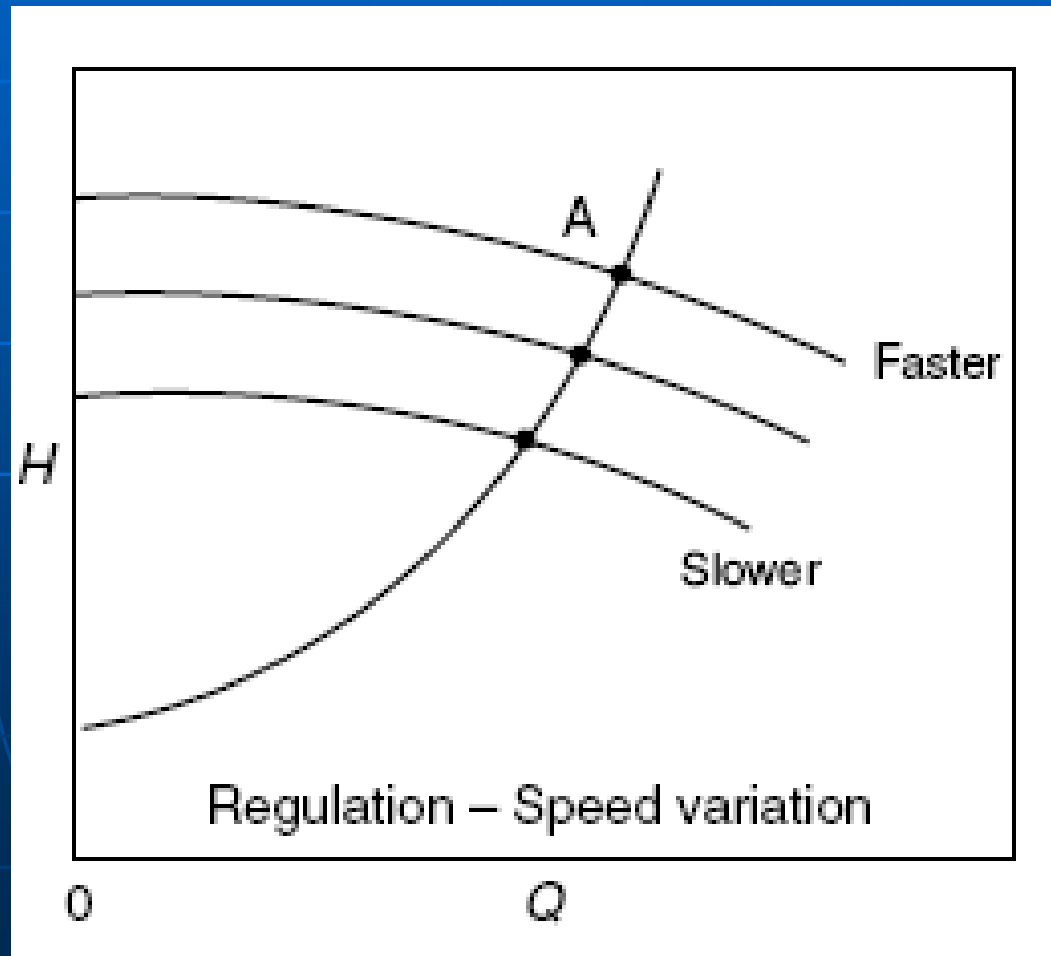
Pump Characteristic Curve and operating point



Efficiency curve and power



How to control operating point by changing pump speed



Affinity laws

- The 'Affinity laws' are mathematical expressions that best define changes in pump capacity, head, and power absorbed by the pump when a change is made to pump speed, with all else remaining constant.

According to affinity laws

Capacity Q changes in direct proportion to the change in pump speed N ratio:

$$Q_2 = Q_1 \times \left(\frac{N_2}{N_1} \right)$$

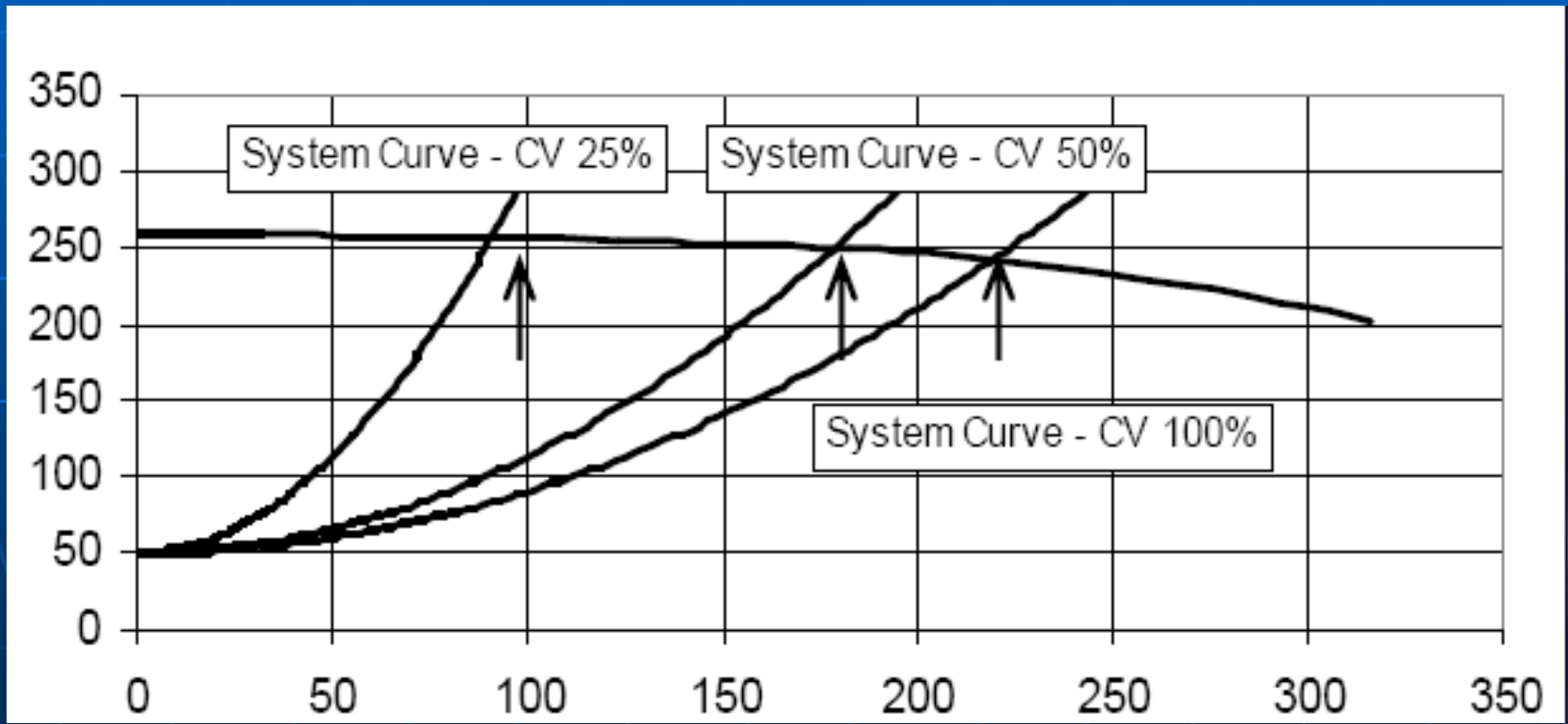
Head H changes in direct proportion to the square of the speed N ratio:

$$H_2 = H_1 \times \left(\frac{N_2}{N_1} \right)^2$$

Power P changes in direct proportion to the cube of the speed N ratio:

$$P_2 = P_1 \times \left(\frac{N_2}{N_1} \right)^3$$

Flow control by using control valve



Parallel connection

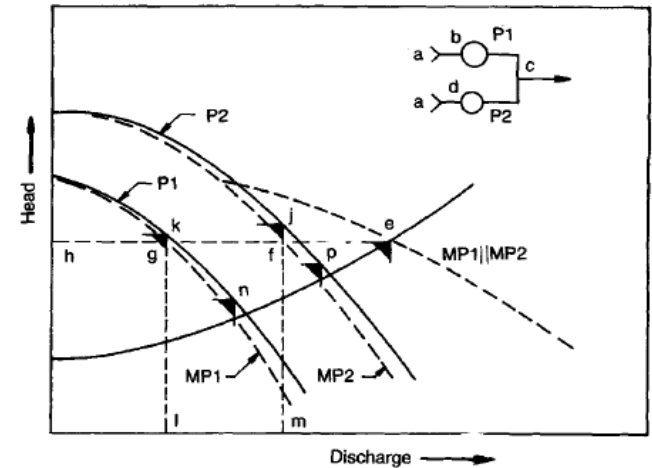
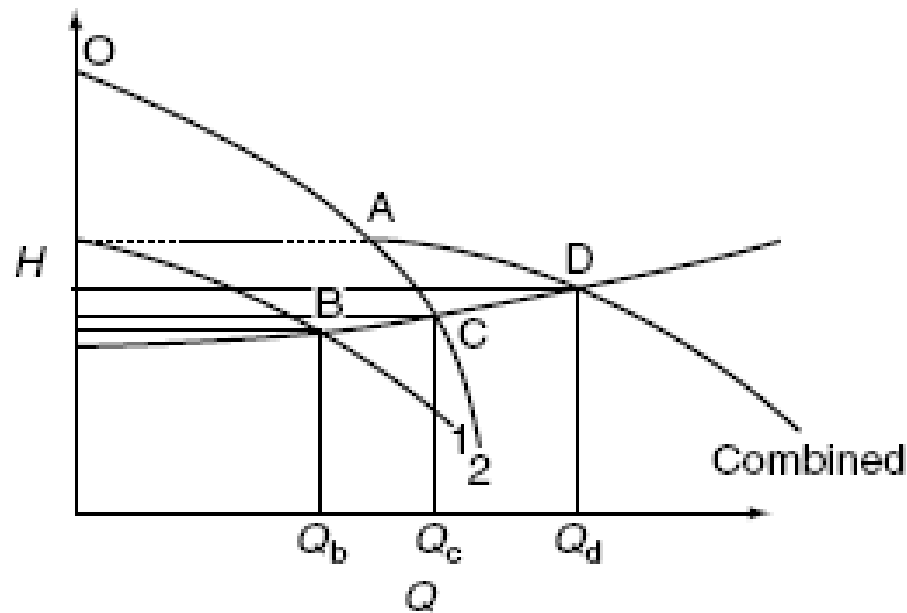
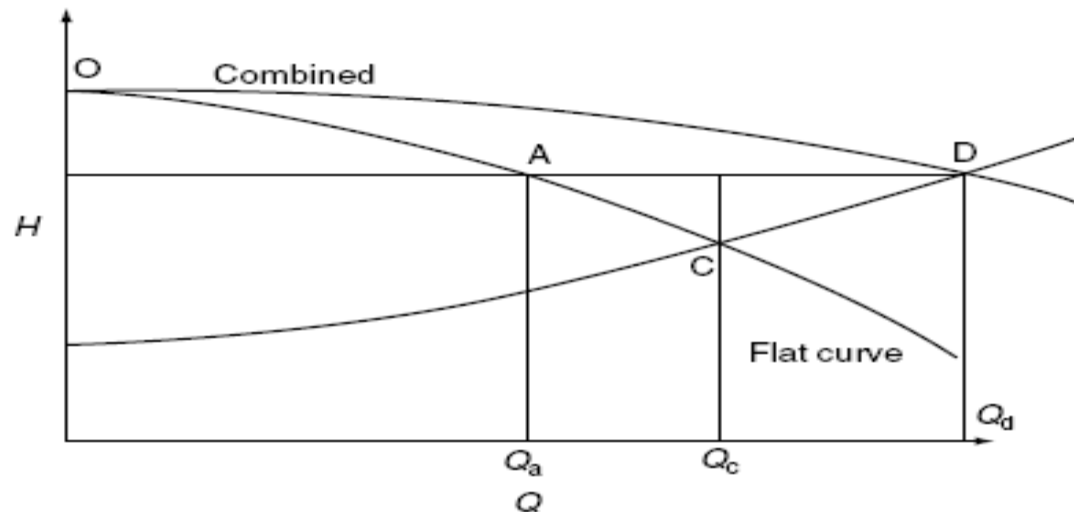
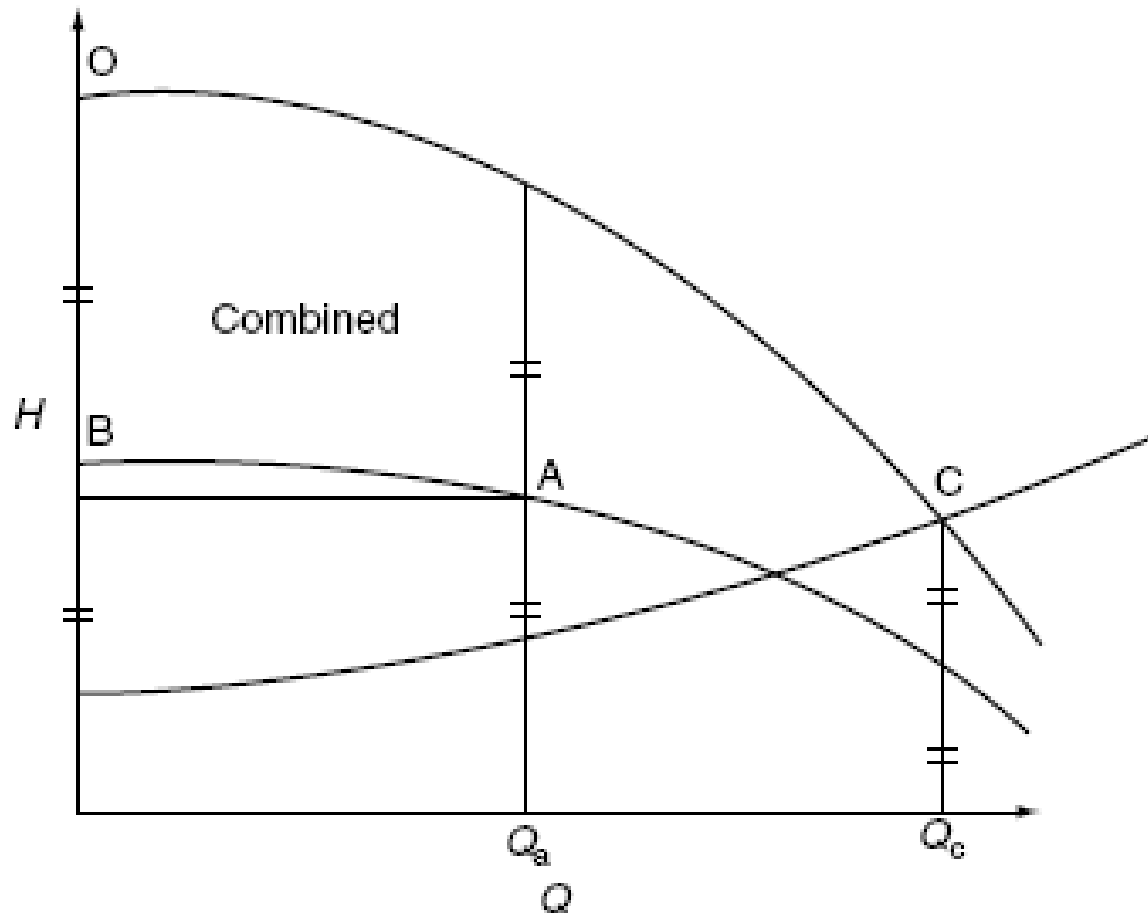


Figure 10-24. Operation of two pumps in parallel.



Series connections

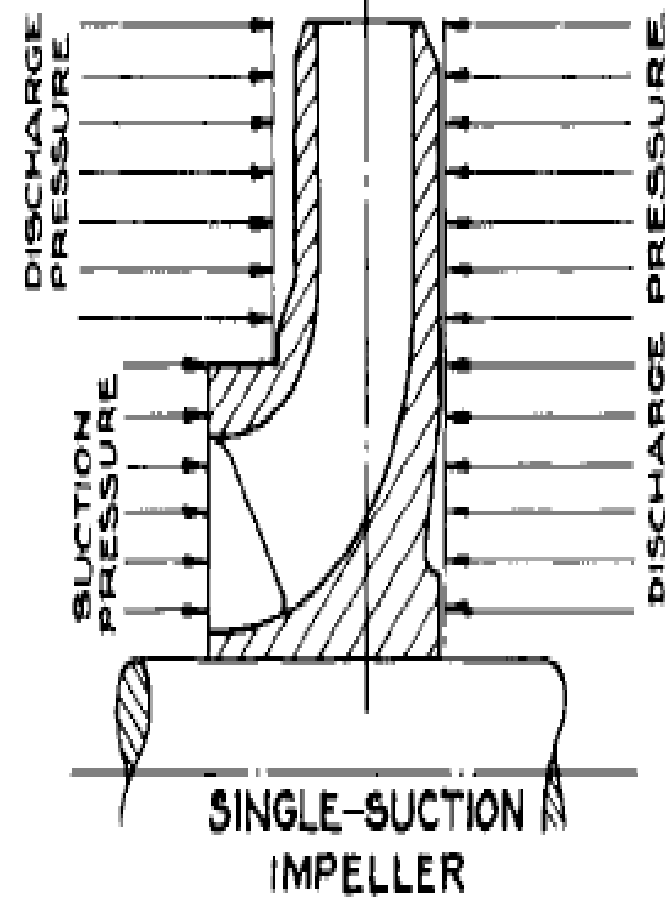
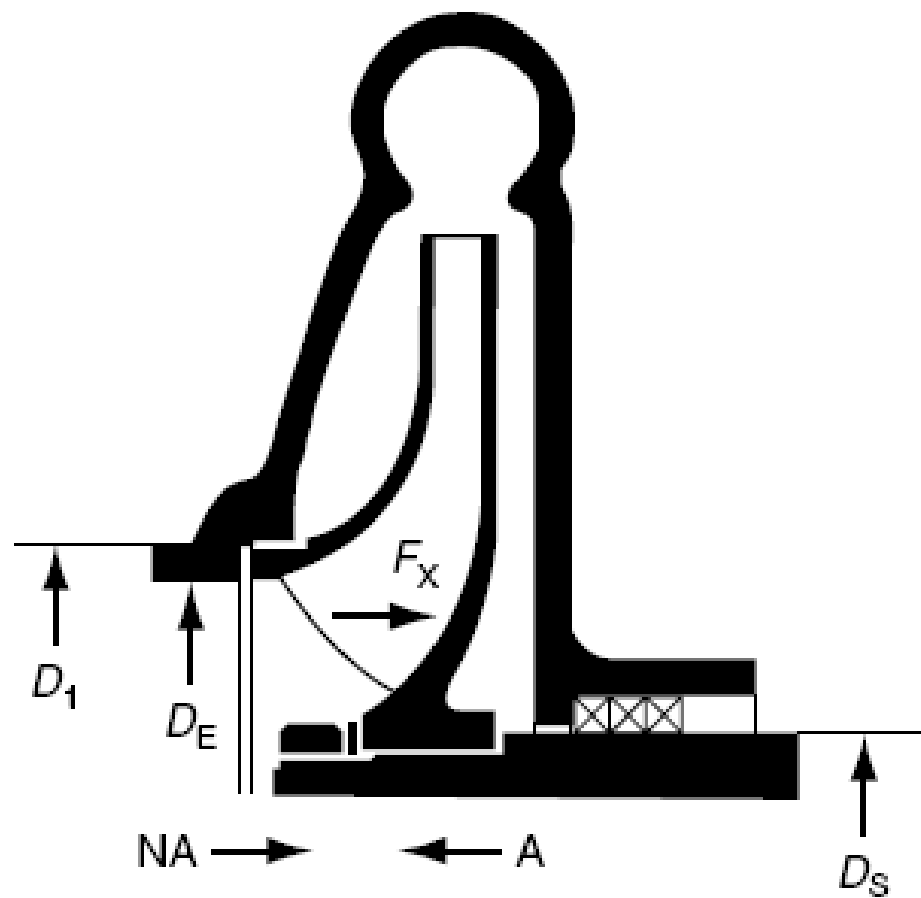


Axial thrust

- The axial forces of thrust generated in a centrifugal pump results from the internal pressures acting on the exposed areas of the rotating element. It may appear as simple as a product of the net of discharge and suction pressure and the exposed area of the impeller. Though this is truly the basis, there are many uncertainties that are not covered by this simple approach.

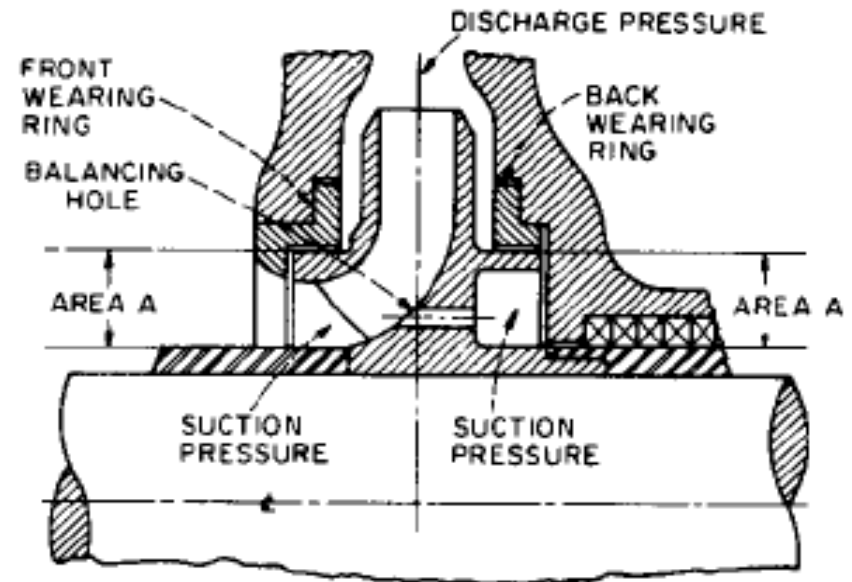
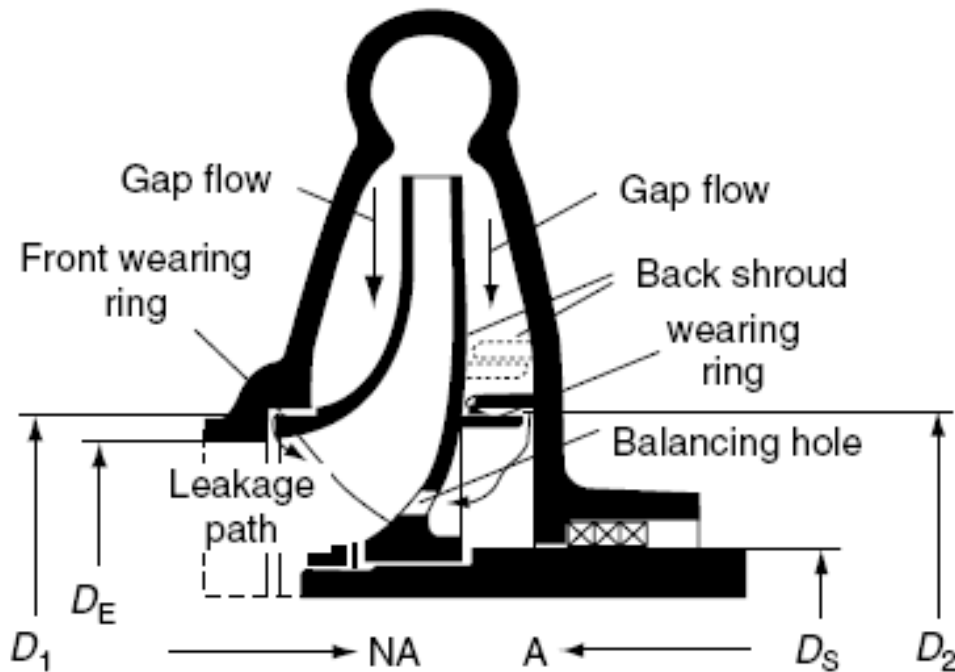
The other variables that may affect the evaluation of axial loads are:

- Location of the impeller relative to the casing wall
- Impeller shroud symmetry
- Surface roughness of the walls
- Wearing ring clearance
- Geometry of the balancing holes.

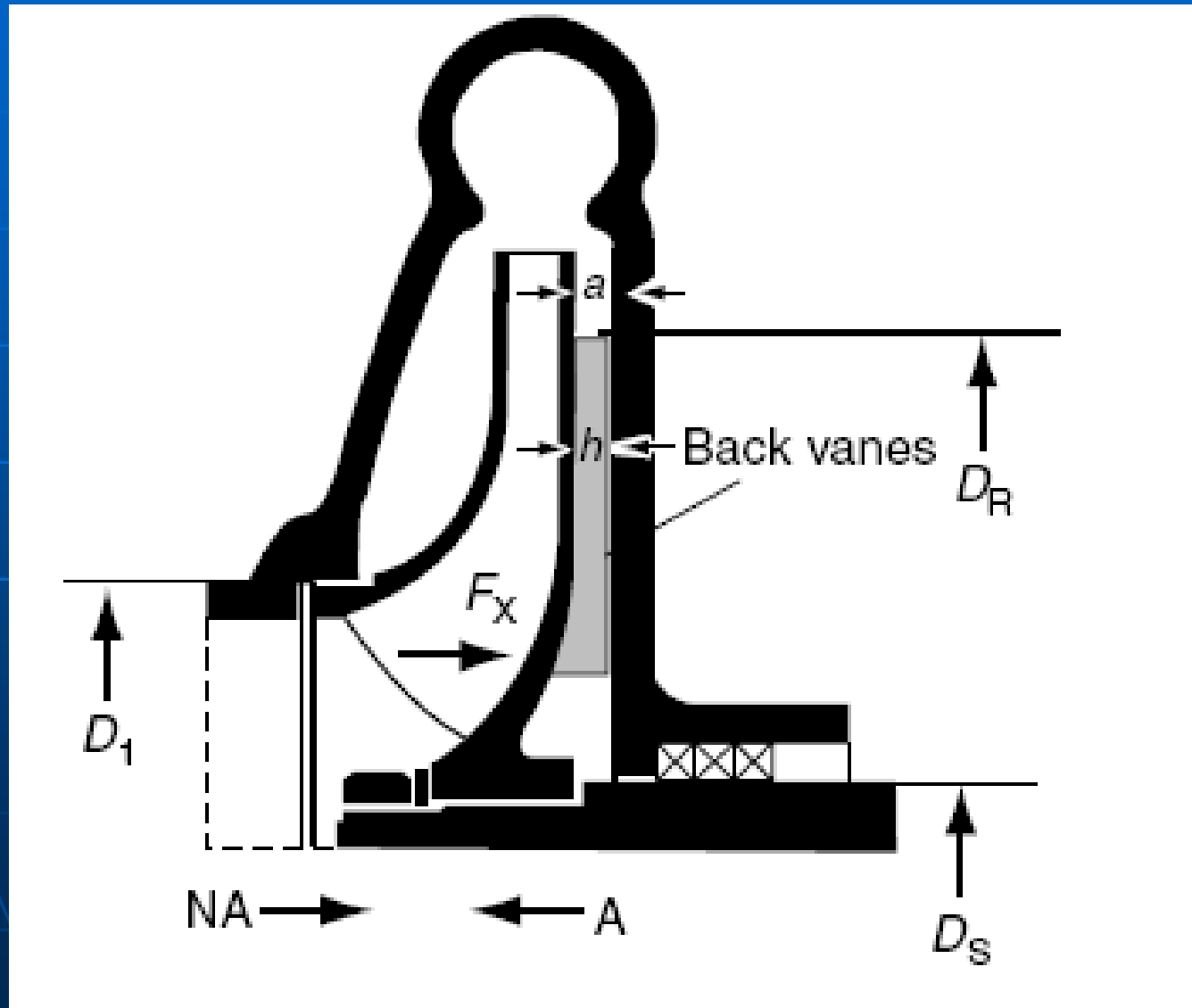


Different methods to eliminate axial thrust

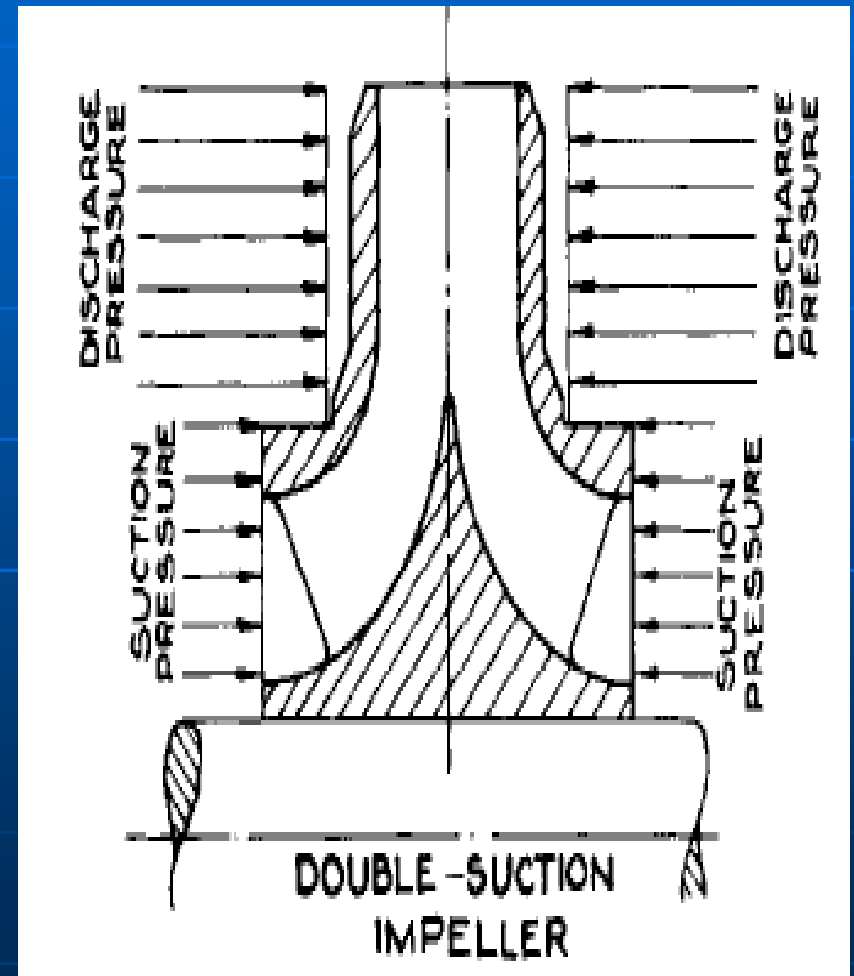
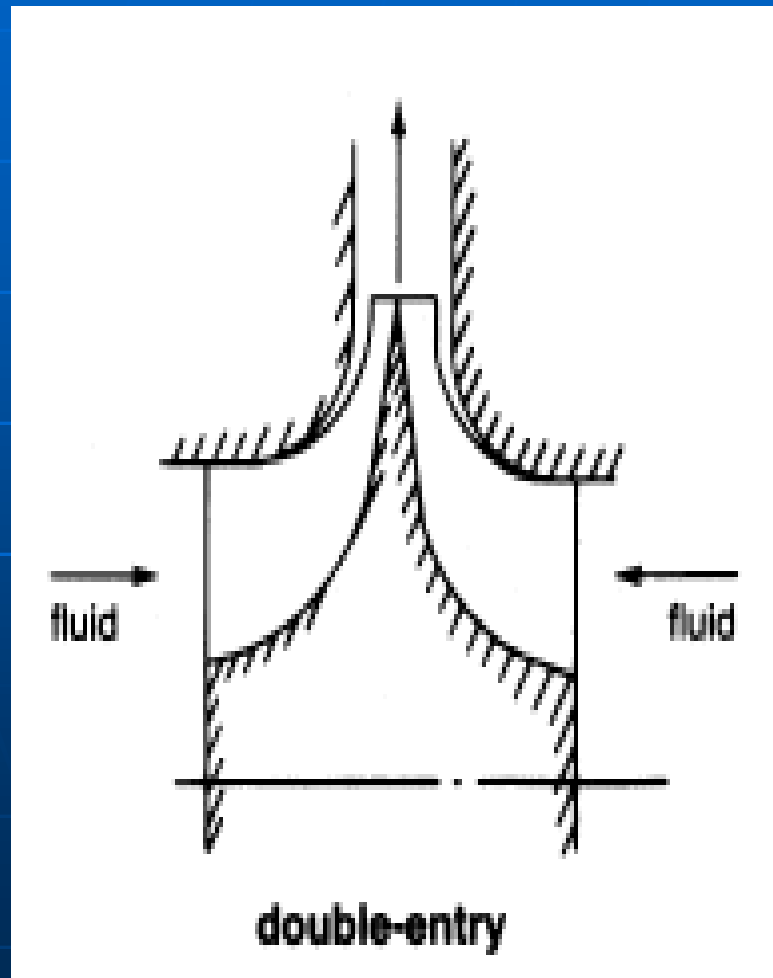
1- balancing chamber:



2-Radial ribs:

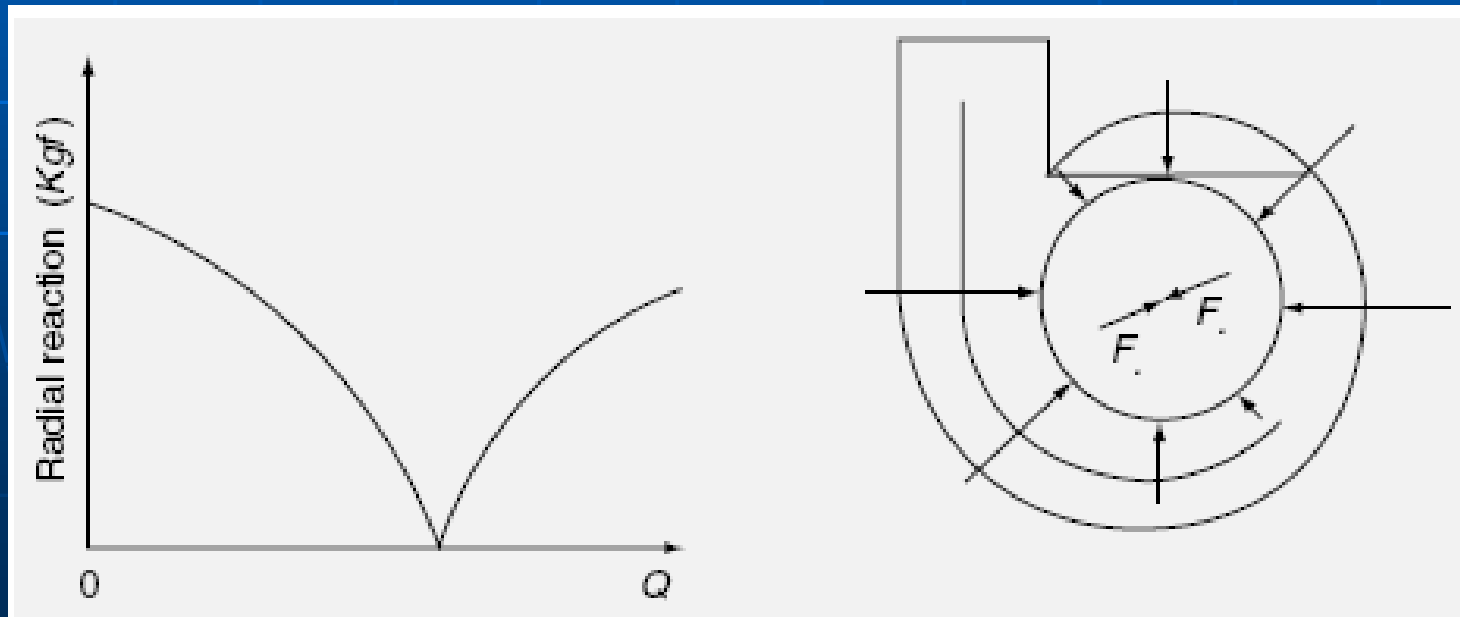


3- Double suction:

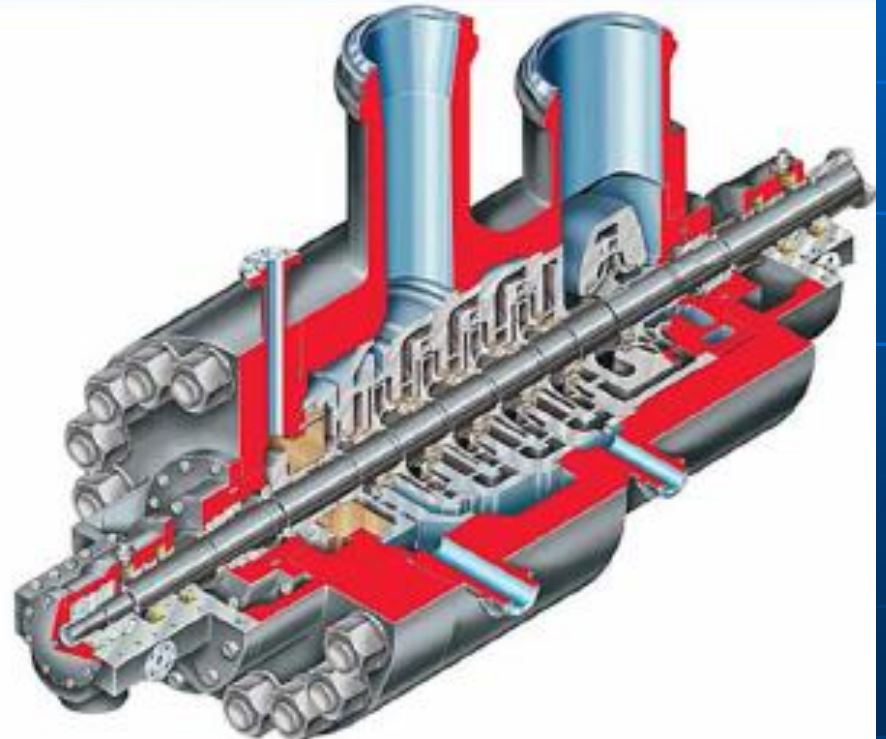
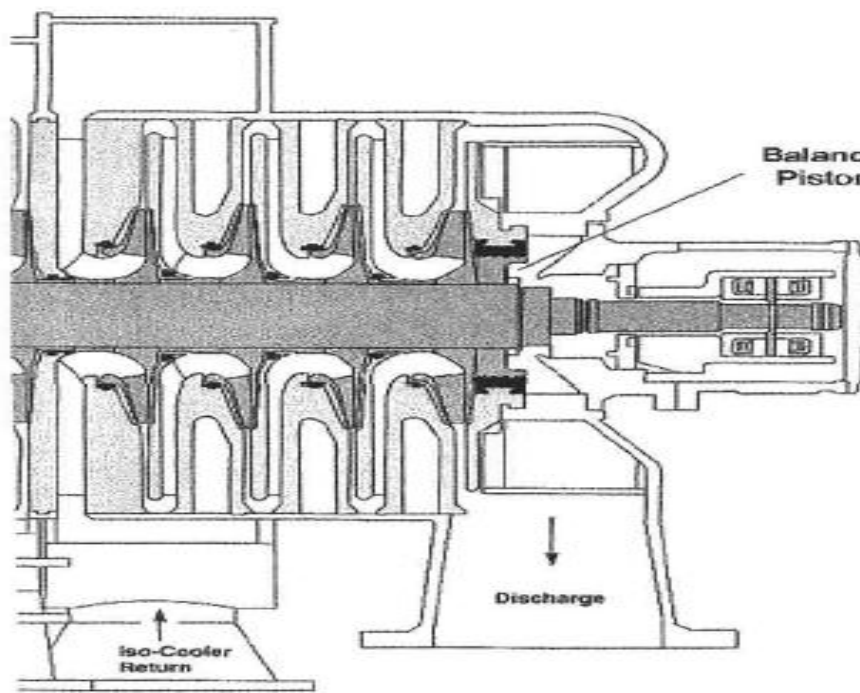


Radial loads

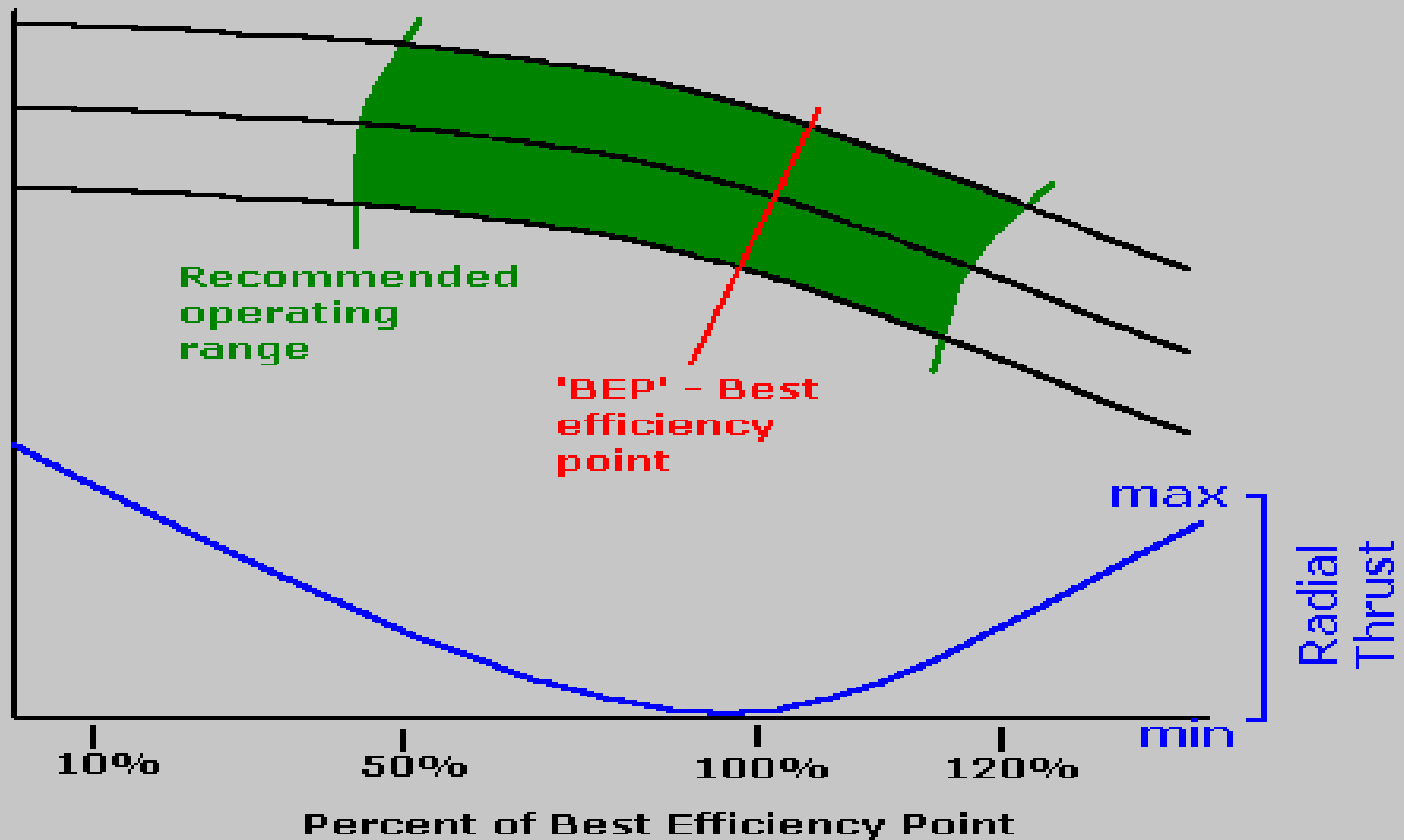
- In an end-suction centrifugal pump with an overhung impeller, the hydraulic radial load is due to the non-uniform velocity of the liquid within the pump casing or a volute. This unequal liquid velocity leads to a non-uniform pressure distribution of the pressure acting on the circumference of the pump impeller.



Multi Stage Centrifugal pump



Best Efficiency Point



Best Efficiency Point

- Best Efficiency Point (BEP) is the capacity at maximum impeller diameter at which the efficiency is highest. All points to the right or left of BEP have a lower efficiency.

Significance of BEP

- 1- *BEP as a measure of optimum energy conversion*
- 2- *BEP as a measure of mechanically stable operation*
- 3- *BEP as an important parameter in calculations*

Specific Speed

Specific speed (N_s) is a non-dimensional design index that identifies the geometric similarity of pumps. It is used to classify pump impellers as to their type and proportions.

Centrifugal Pumps

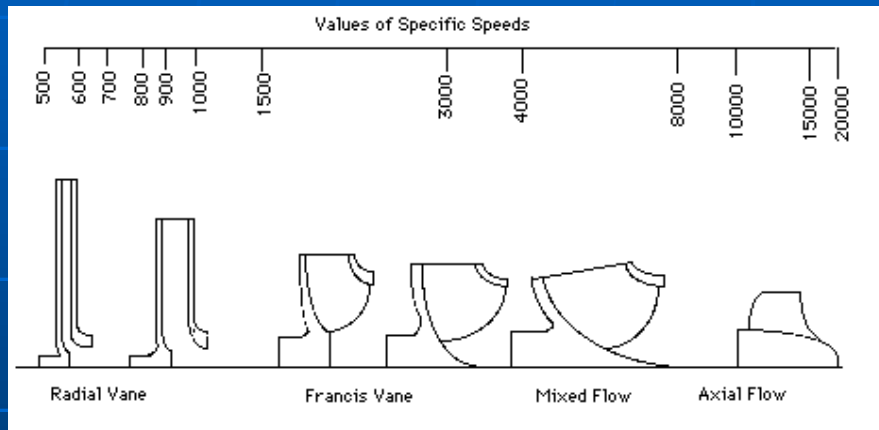
■ Specific Speed

$$N_s = \frac{N \times Q^{0.5}}{H^{0.75}}$$

where

- Q = Capacity at best efficiency point (BEP) at maximum impeller diameter, GPM
- H = Head per stage at BEP at maximum impeller diameter, ft
- N = Pump speed, RPM

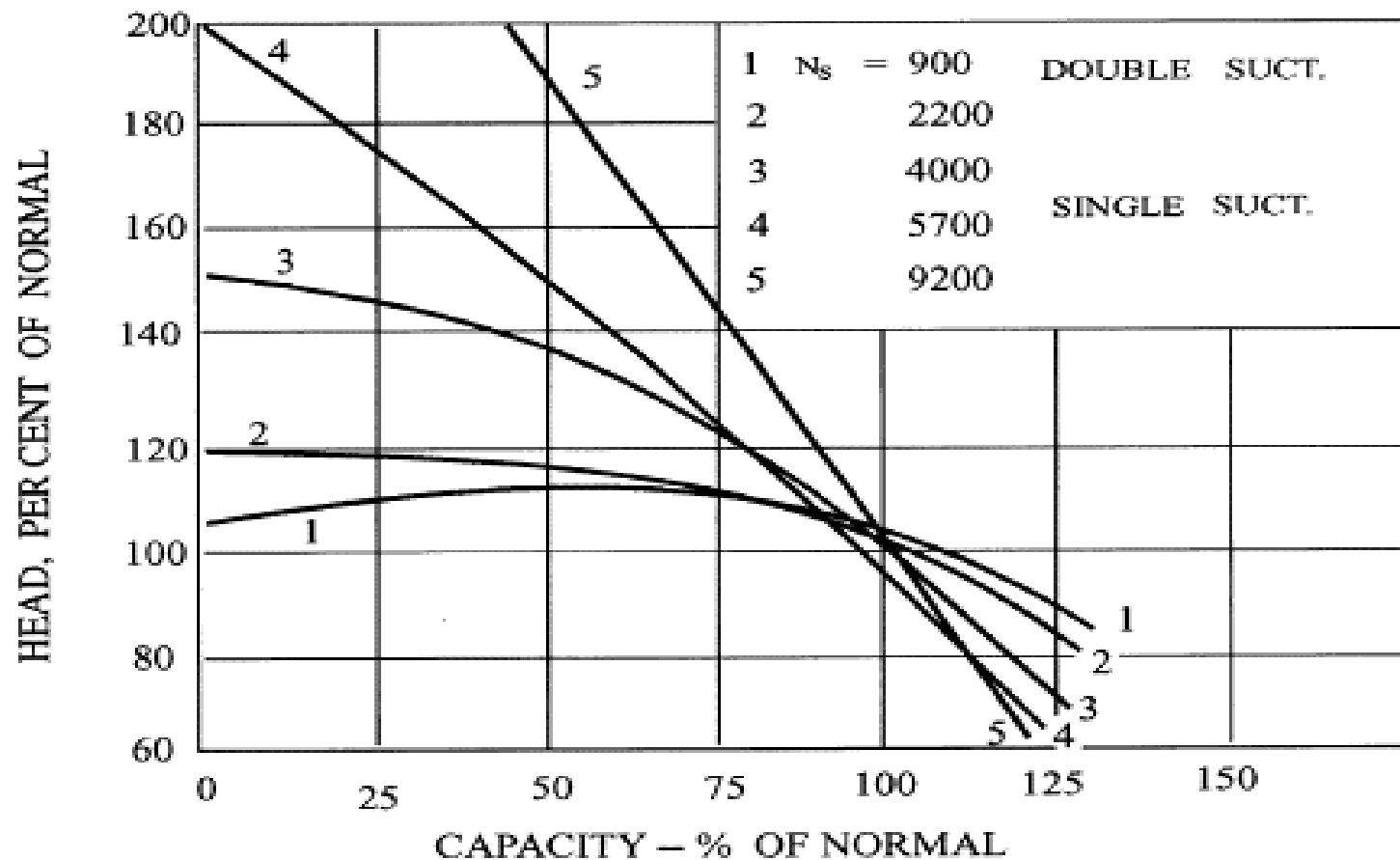
Centrifugal Pumps



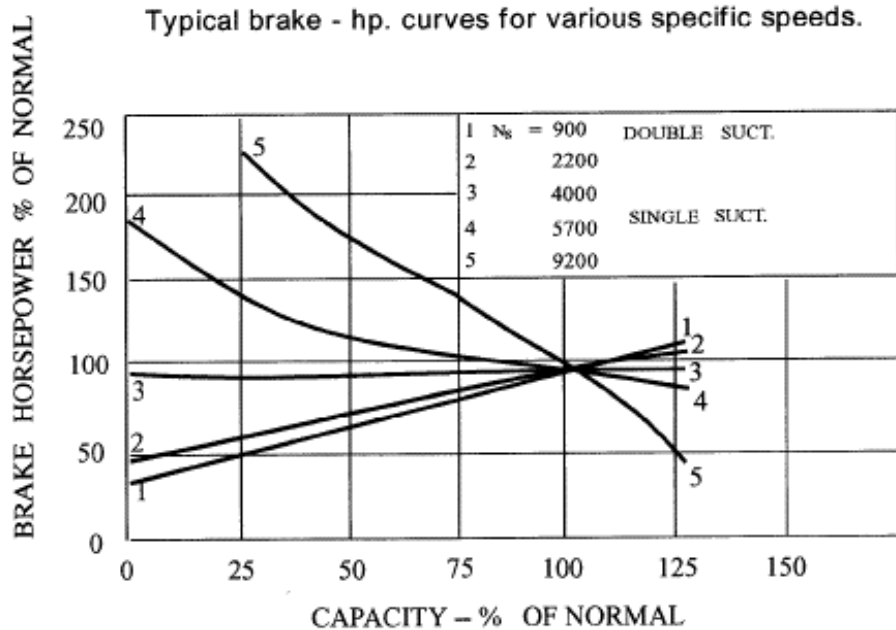
- Specific speed as a measure of the shape or class of the impellers
- N_s : 500 to 5000; $D_1/D_2 > 1.5$ - radial flow pump
- N_s : 5000 to 10000; $D_1/D_2 < 1.5$ - mixed flow pump
- N_s : 10000 to 15000; $D_1/D_2 = 1$ - axial flow pump

Centrifugal Pumps

head-capacity curves for various specific speeds.



Centrifugal Pumps



- N_s is commonly used as a basis for estimating the safe operating range of capacity for a pump. The higher the N_s is, the narrower is its safe operating range from its BEP.

Cavitation

- General Symptoms of Cavitation and its Effects Pump Performance and Pump Parts

1–*Reduction in capacity of the pump*

2–*Decrease in the head developed*

3–*Abnormal sound and vibrations*

Concept of Cavitation

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

Cavitation

- the bubbles that form inside the liquid are of two types: Vapor bubbles or Gas bubbles.
 - .Vapor bubbles are formed due to the vaporisation of a process liquid that is being pumped. The cavitation condition induced by formation and collapse of vapor bubbles is commonly referred to as Vaporous Cavitation.
 - .Gas bubbles are formed due to the presence of dissolved gases in the liquid that is being pumped (generally air but may be any gas in the system). The cavitation condition induced by the formation and collapse of gas bubbles is commonly referred to as Gaseous Cavitation.

Cavitation

- *Vaporous cavitation* occurs due to insufficiency of the available NPSH or internal recirculation phenomenon.
- *Gaseous cavitation* occurs when any gas (most commonly air) enters a centrifugal pump along with liquid.

Cavitation

- *Mechanism of Cavitation*

Steps in Cavitation

Formation of bubbles inside the liquid



Growth of bubbles



Collapse of bubbles



Fig. 2

Cavitation

Cavitation

- *Step One Formation of bubbles inside the liquid being pumped.*

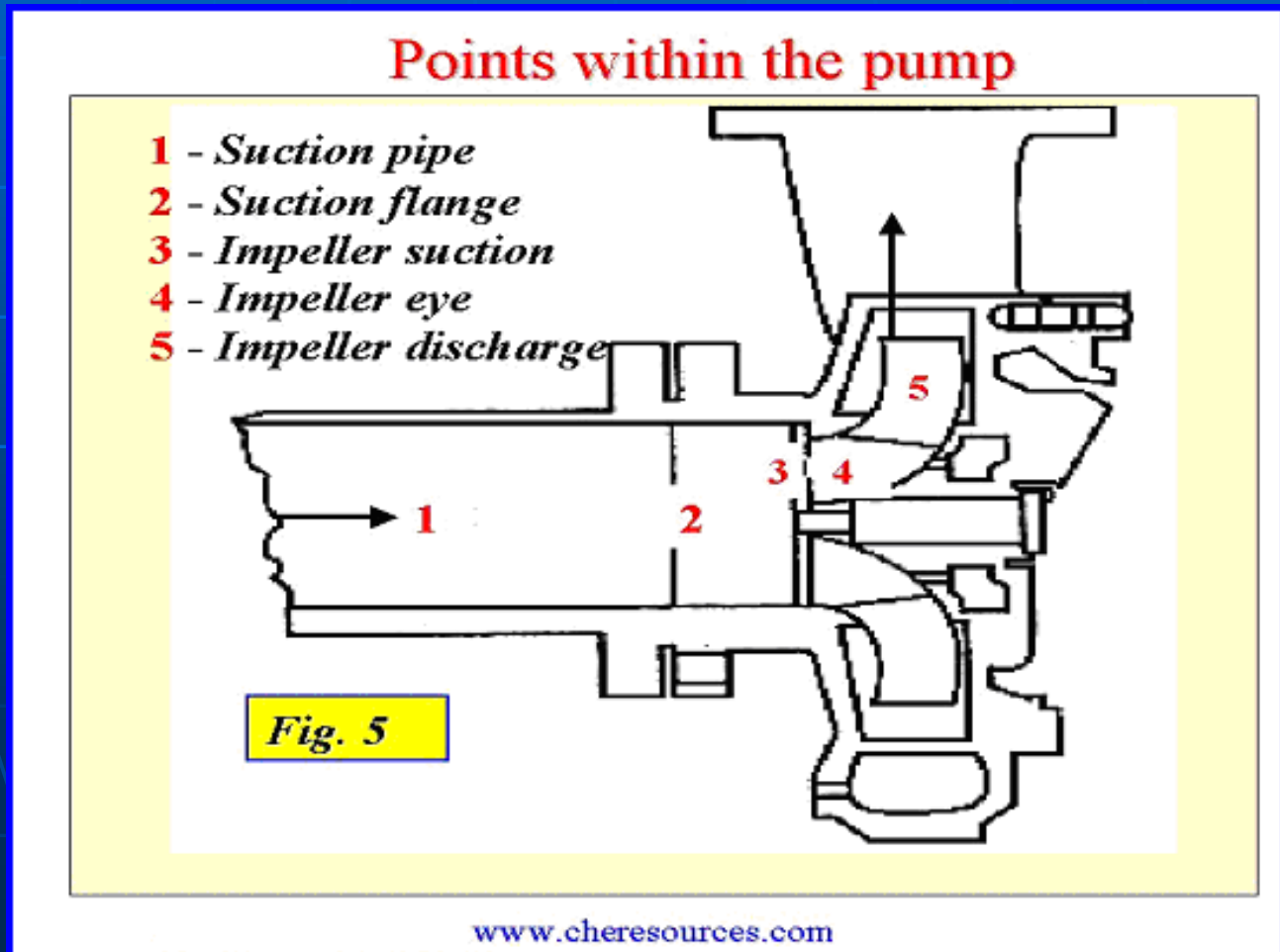
The bubbles form inside the liquid when it vaporises

Cavitation

- The reduction in local static pressure at any point inside the pump can occur under two conditions:
 - .The actual pressure drop in the external suction system is greater than that considered during design. As a result, the pressure available at pump suction is not sufficiently high enough to overcome the design pressure drop inside the pump.
 - The actual pressure drop inside the pump is greater than that considered during the pump design.

Cavitation

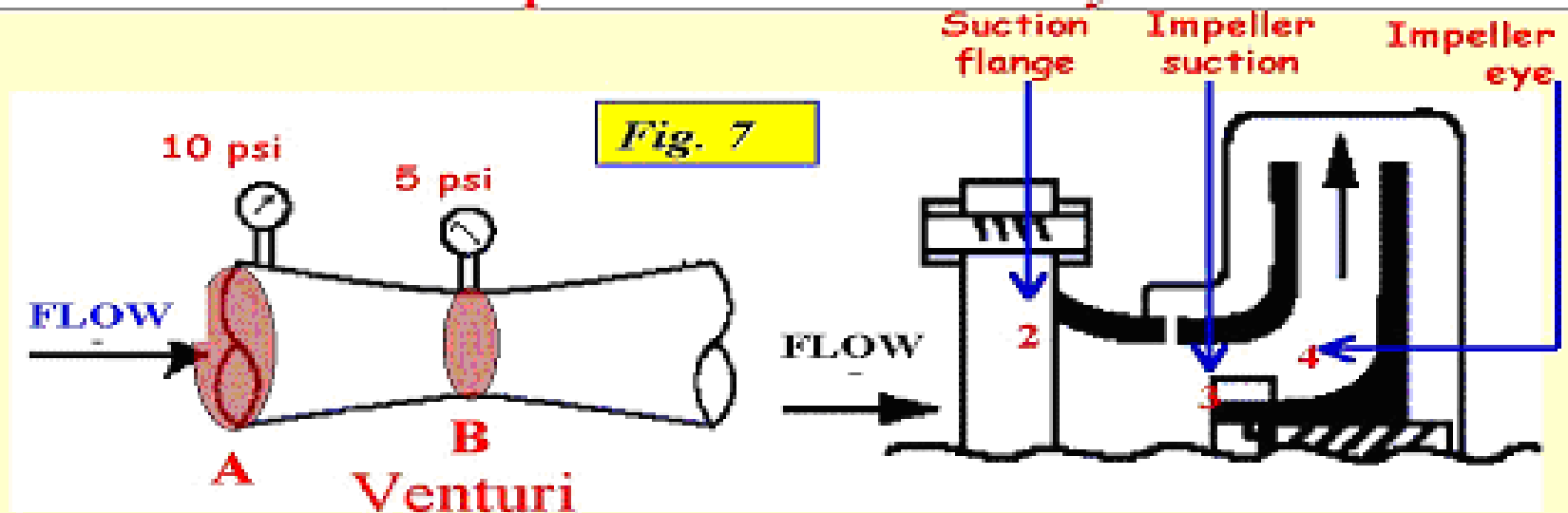
Flow path of the fluid inside the pump



Cavitation

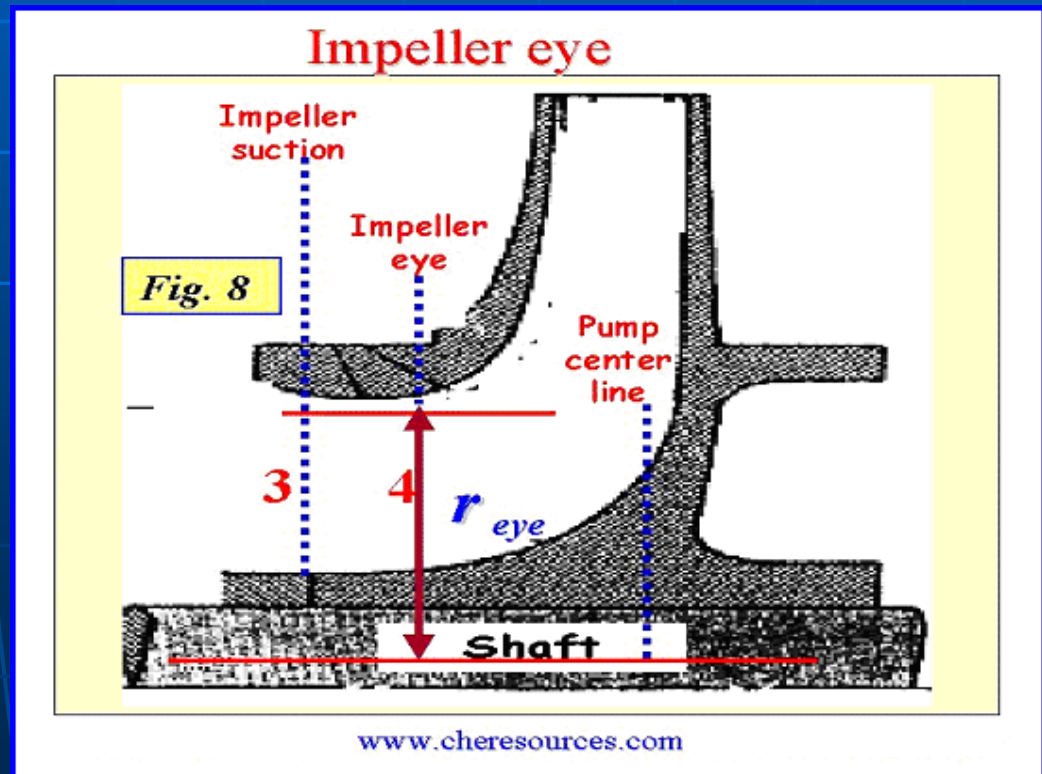
- Pressure reduction in internal suction system of the pump

Pump internal suction system



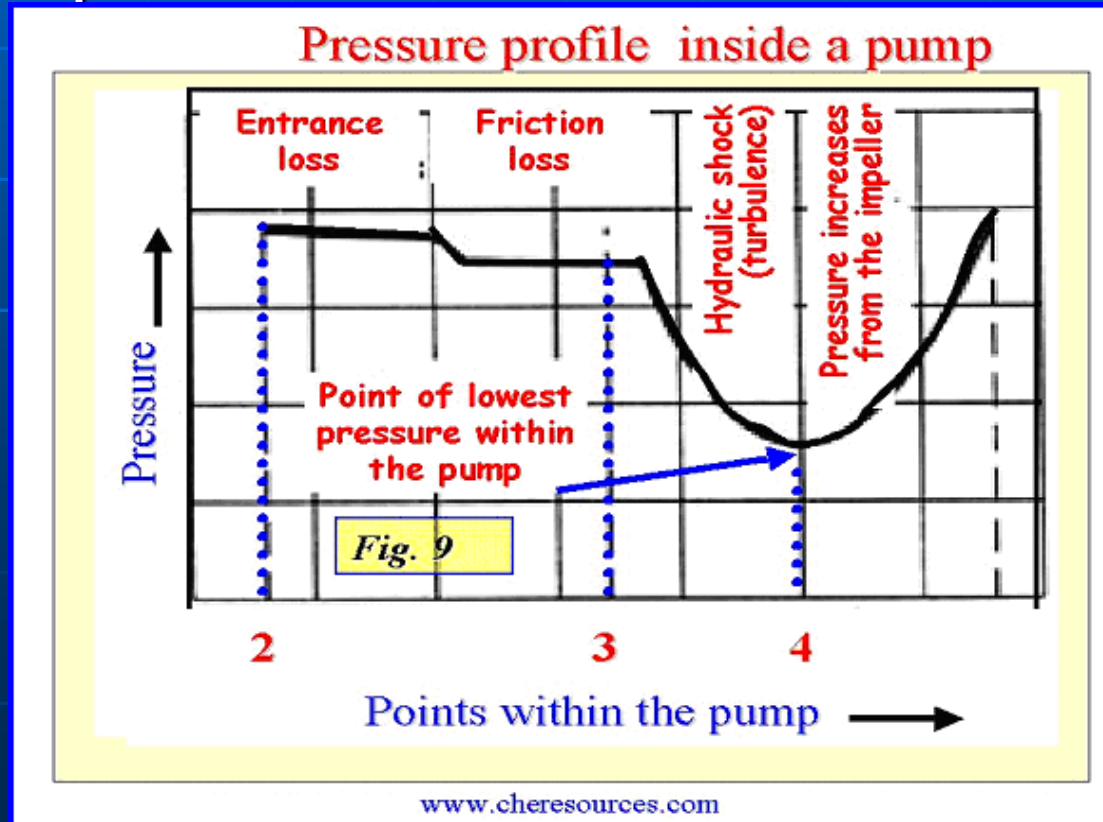
Cavitation

- Pressure reduction in internal suction system of the pump



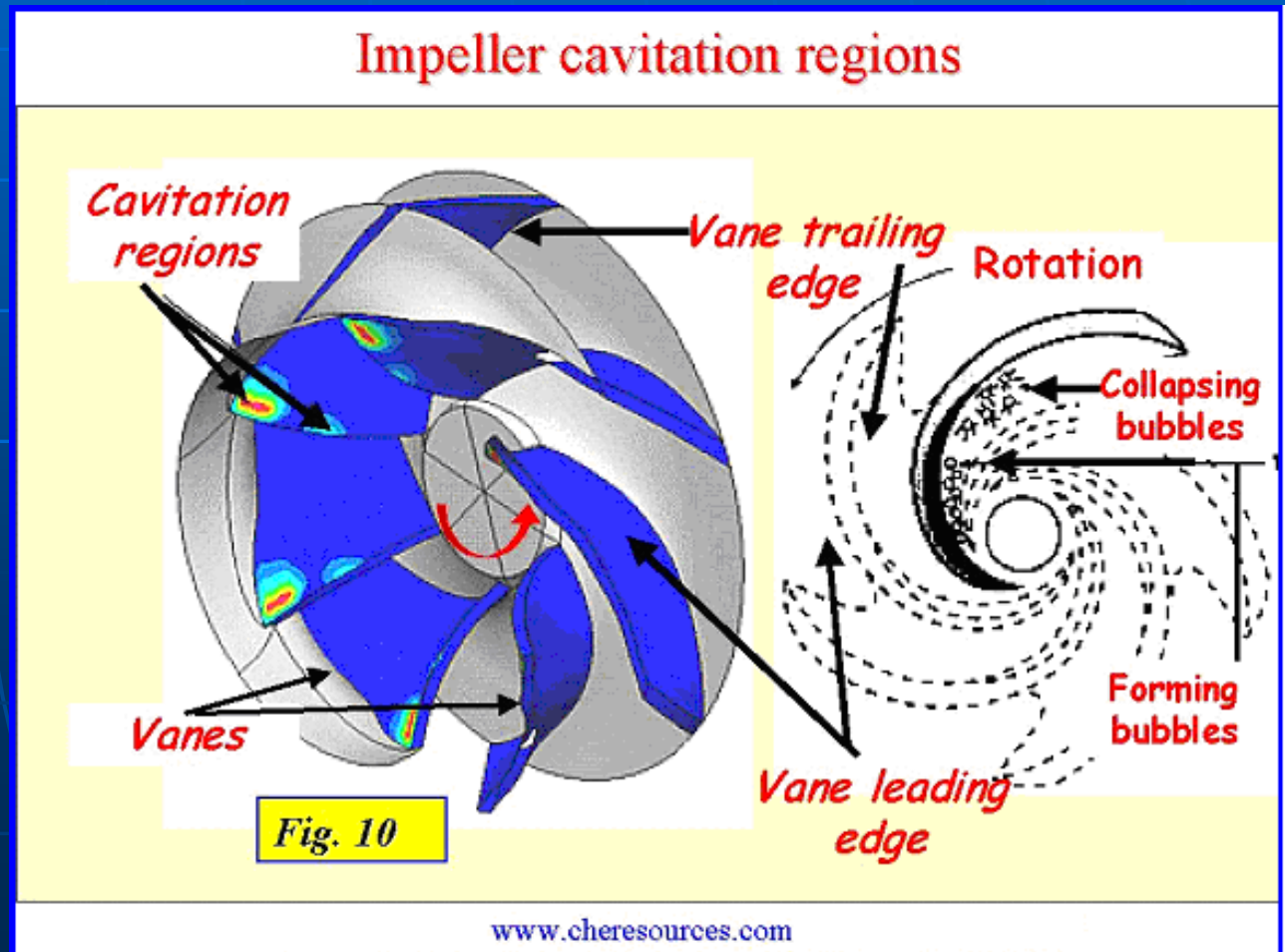
Cavitation

- Pressure reduction in internal suction system of the pump



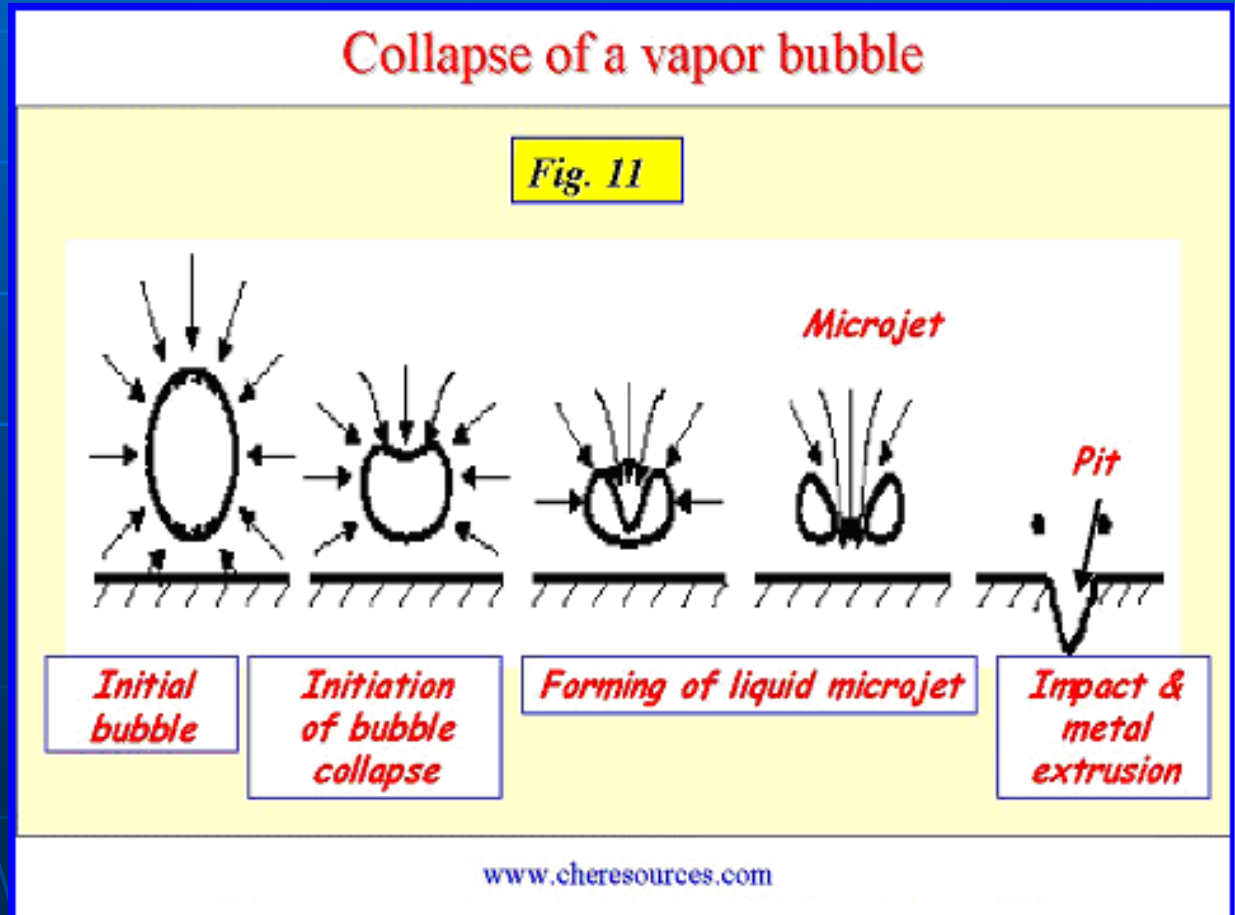
Cavitation

- Impeller cavitation region



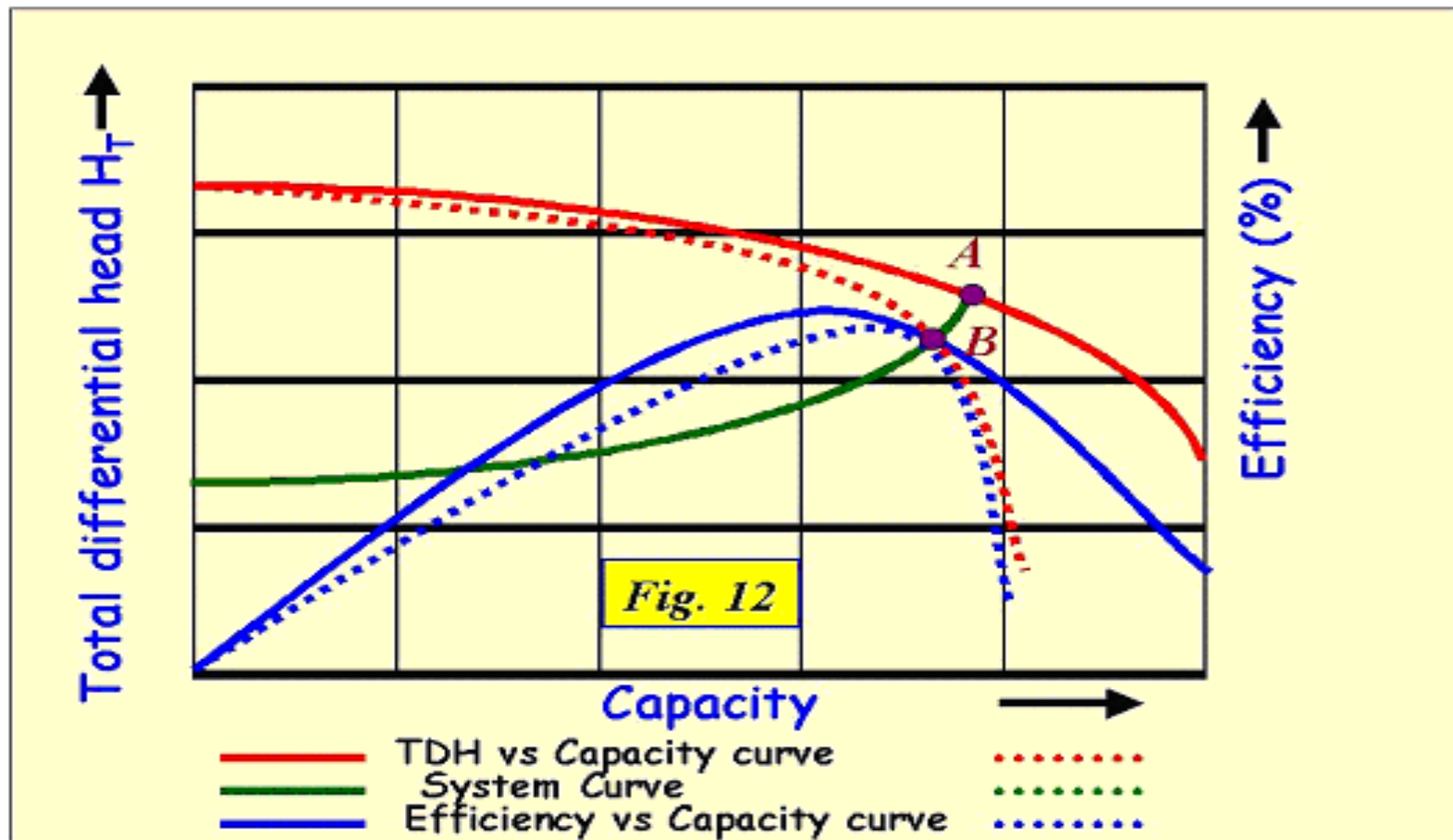
Cavitation

- *Step Three, Collapse of bubbles*



Cavitation

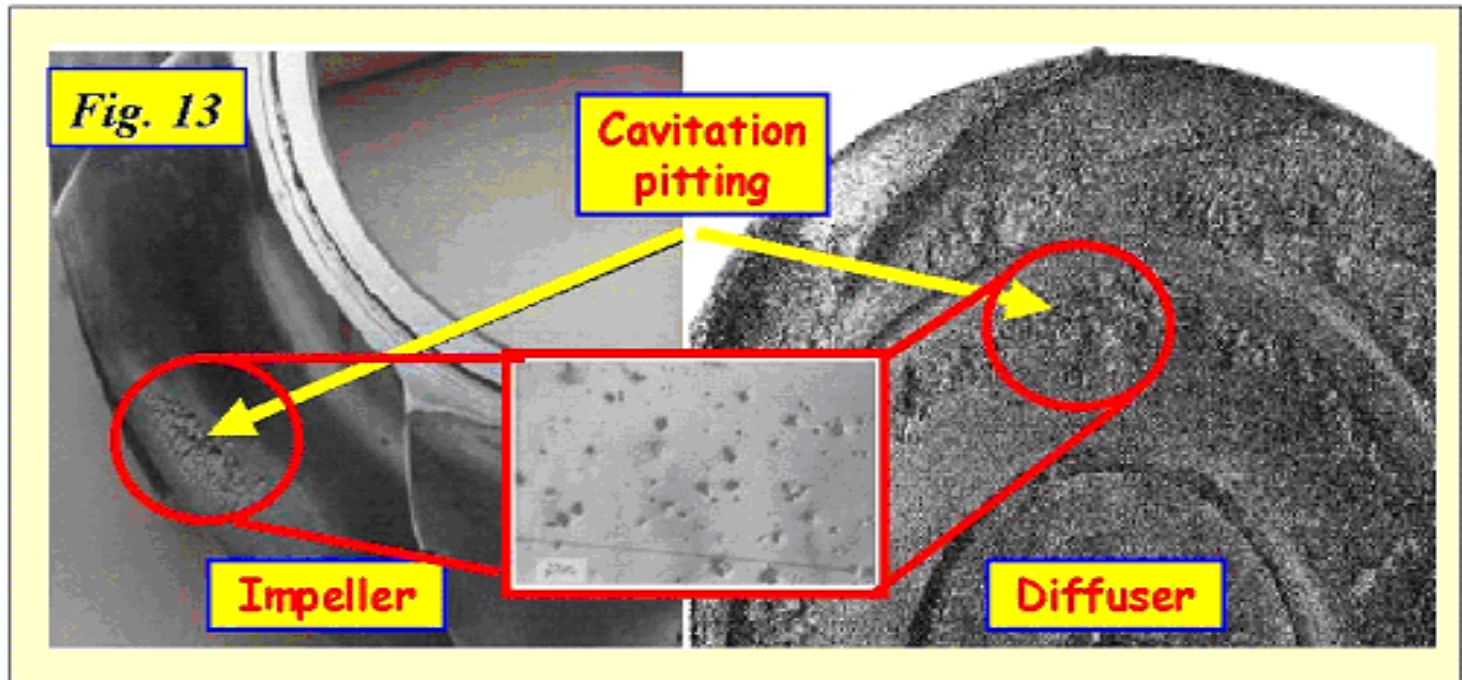
Performance curves



Cavitation

4- Damage to pump parts

Cavitation pitting

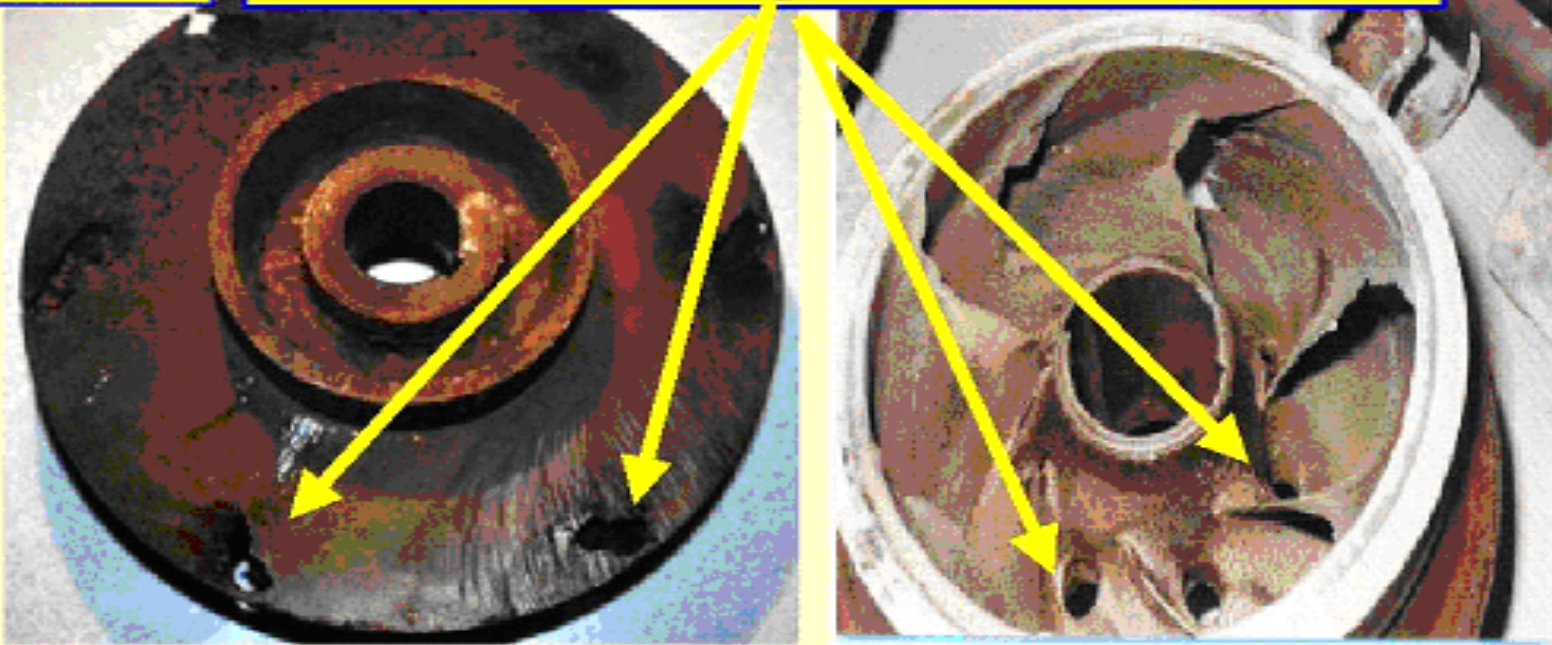


Cavitation

Cavitation damages

Fig. 14

Cavitation damage holes on impellers



■ Definition of NPSHr (required):

- It is the energy in the liquid required to overcome the friction losses from the suction nozzle to the eye of the impeller without causing vaporization. It is a characteristic of the pump and is indicated on the pump's curve. It varies by design, size, and the operating conditions. It is determined by a lift test, producing a negative pressure in inches of mercury and converted into feet of required NPSH.

■ Definition NPSHa (available)

This is the energy in the fluid at the suction connection of the pump over and above the liquid's vapor pressure. It is a characteristic of the system and we say that the NPSHa should be greater than the NPSHr ($NPSHa > NPSHr$).

- The NPSHa is in the system. The formula is:

$$NPSHa = H_a + H_s - H_{vp} - H_f - H_i$$

- Where:
- H_a = Atmospheric head
- H_s = Static head
- H_{vp} = the Vapor head of the fluid
- H_f = Friction head or friction losses
- H_i = Inlet head

Centrifugal Pumps

Two Basic Requirements for Trouble-Free Operation of Centrifugal Pumps

- The first requirement is that no cavitation of the pump occurs throughout the broad operating range.
- The second requirement is that a certain minimum continuous flow is always maintained during operation.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

1-Continuous Bypass

- The most significant negative aspect of this system is that the pump must be oversized in the first place to allow for the continuously bypassed flow.
- Still, this alternative is chosen by many industrial users for pumps in the range of 50 horsepower and below.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

2. Multi-Component Control Valve System

- This method of bypass eliminates the energy waste of continuous bypass, but relies on considerably more complexity than a continuous bypass system.

Multi-Component Control Valve System

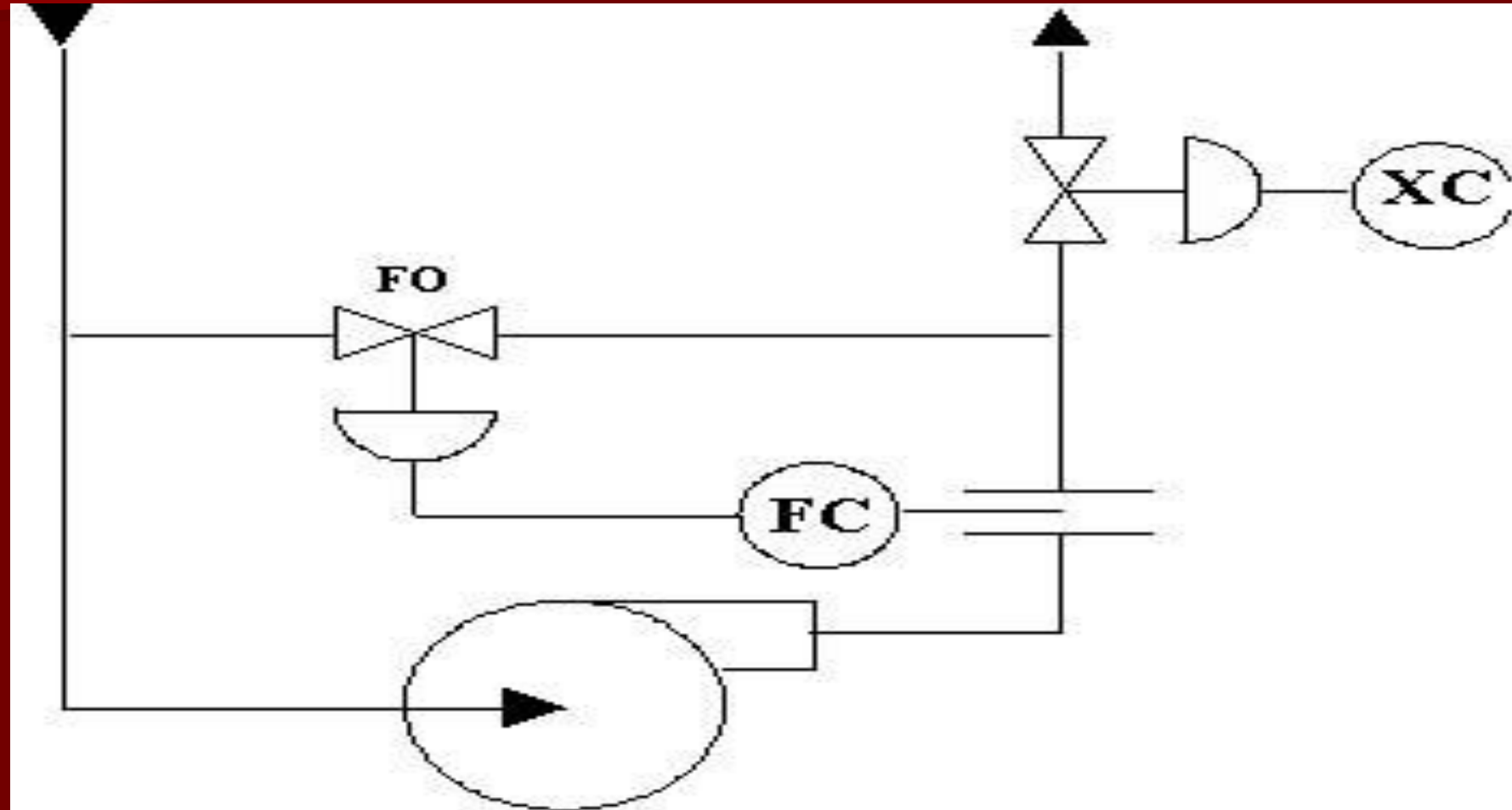


Fig. 1-9. Minimum Flow Control

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

3. Variable Frequency Drive

- Variable frequency drives (VFDs) change the frequency of the electric motor on the pump to slow the pump down when the demand for lower flow is called for by the process.
- VFDs are relatively expensive, although the cost has reduced dramatically in recent years with rapid improvements in technology.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

4. Automatic Recirculation Valve

- Disadvantages include its relatively high cost, and the fact that these valves are not normally available in alloys higher than stainless steel, thus eliminating many chemical services.
- ARC valves are generally unsuitable for fluids containing solids.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

5. Relief Valve

- A pressure relief valve is particularly appropriate for pumps with fairly steep capacity versus pressure curves.
- It is also the accepted method for protection of many fire pump systems.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

6. Pressure Sensor

- This device relies on the fact that as the flow decreases with a centrifugal pump, the amount of pressure produced by the pump increases.
- This high-pressure signal is then used to either open a bypass valve at a high-pressure (low-flow) indication, or to simply trip the pump.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

7. Amp Meter

- For many pumps, the amp draw of the pump is lower at lower flow rates, and increases with increasing flow.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

8. Power Monitor

- Power monitors measure motor horsepower. Since most pump curves have a horsepower curve that rises with increasing flow, it is possible to set the motor to shut off if the power drops below a minimum setpoint, so this is a reliable protection against low flow problems.

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

9. Vibration Sensor

- Some pump systems have vibration monitors to alarm or trip the pump if the pump begins to vibrate excessively.
- One of the things that occur at lower flow rates is that the pump may indeed vibrate significantly higher than normal.

10. Temperature Sensor

Ways to Prevent Low-Flow Damage in Centrifugal Pumps

10. Temperature Sensor

- At very low flow rates, the temperature of the pumped liquid increases because of the recirculation of the liquid within the pump that goes on at lower flow rates.

CENTRIFUGAL PUMPS

Troubleshooting

To effectively troubleshoot poorly performing pumps , follow these steps:

- 1- Clearly define the problem based on observations and accumulated information.
- 2- Review available historical system operation
- 3- Identify and obtain any additional information and analysis that may be required.
- 4- Identify and list potential root causes and consider each.
- 5- Deduce the root cause based on the accumulated information.
- 6- Execute corrective action.

CENTRIFUGAL PUMPS TROUBLESHOOTING

The pump is not producing enough capacity to satisfy the application

- 1. The Problem is in The Pump Its Self**
- 2. THE PROBLEM IS ON THE SUCTION SIDE OF THE PUMP**
- 3. Problems On The Discharge Side of The Pump Including The Piping**

The Problem is in The Pump Its Self

1. The impeller diameter is too small
2. The impeller width is too narrow
3. The impeller speed is too slow. Check the voltage and frequency
4. The impeller is damaged.
5. The impeller is clogged.
6. The open impeller clearance is too large.
7. The impeller has been installed backwards .
8. Air is coming into the pump suction through the packing.
9. Air is coming into the pump suction through an unbalanced mechanical seal.
10. The pump was not primed prior to start up.

THE PROBLEM IS ON THE SUCTION SIDE OF THE PUMP

1. There is too much piping between the pump suction and the source tank.
2. There is an elbow too close to the pump suction.
3. A filter or strainer is clogged.
4. Intermittent plugging of the suction inlet
5. A foot valve is stuck
6. The tank float is stuck. Showing a higher tank level that does not exist.
7. The tank vent is partially shut or frozen. .
8. A check valve is stuck partially closed
9. Solids have built up on the piping walls.
10. A globe valve has been substituted for a gate valve.
11. A check valve is stuck partially closed
12. Solids have built up on the piping walls

Problems On The Discharge Side of The Pump Including The Piping

1. Extra piping has been added to the system to accommodate extra storage capacity.
2. A bypass line has been installed in the pump discharge.
3. Piping or fittings have been added to the discharge side of the pump.
4. An orifice has been installed in the discharge piping to reduce the capacity or produce a false head.
5. A gate valve has been substituted for a globe valve in the discharge piping.
6. A check valve is stuck partially closed.
7. An orifice has been installed into the piping to restrict flow.
8. The piping was collapsed by a heavy object that hit the outside of the piping.

CENTRIFUGAL PUMPS TROUBLESHOOTING

Pump takes excessive power.

- Engine speed too high.
- Obstruction between impeller and casing.

Viscosity and / or SG of liquid being pumped too high

CENTRIFUGAL PUMPS TROUBLESHOOTING

- **Pump ceases to deliver liquid after a time.**
 1. Suction lift too great.
 2. Insufficient water at suction inlet.
 3. Suction inlet or strainer blocked.
 4. Suction hose collapsed.
 5. Excessive air leak in suction line.
 6. Mechanical seal / packing drawing air into pump.
 7. Obstruction in pump casing/impeller.
 8. Delivery hose punctured or blocked.

CENTRIFUGAL PUMPS TROUBLESHOOTING

- **Pump does not prime**
 1. Suction lift too great.
 2. Insufficient water at suction inlet.
 3. Suction inlet or strainer blocked.
 4. Suction line not air tight.
 5. Suction hose collapsed.
 6. Non return valve ball not seating.
 7. Mechanical seal / packing drawing air into pump.

CENTRIFUGAL PUMPS TROUBLESHOOTING

- **Pump vibrating or overheating**
 1. Engine speed too high.
 2. Obstruction in pump casing/impeller.
 3. Impeller damaged.
 4. Cavitation due to excessive suction lift.

Oil lubrication

Properties to consider in selecting and using oil are

- 1- corrosion protection additives
- 2- the pour point
- 3- the flash point
- 4- the viscosity index
- 5- carbon residue
- 6- the neutralization number.

Oil lubrication

Oil's advantages are:

1. Excellent friction reduction at high speeds.
2. Provides good lubrication at very high or low temperatures.
3. Good stability.
4. Heat transfer coefficient is 0.5 BTU/pound/degree Fahrenheit.
5. Works well through heat exchangers with refrigerated water for additional cooling in large high-speed bearings.

Oil lubrication

- Disadvantages to using oil, including:
 1. Difficult to seal and retain inside the bearing chamber requiring frequent refilling.
 2. Oil levels must be checked with more frequency as the temperature rises.
 3. Lower viscosity and more leaks as the temperature rises

Grease

- Grease is selected for use in a pump bearing for its advantages, including
 - 1- its resistance to dripping and running
 - 2- it's easy to seal and retain in the bearings.
- Grease also has some disadvantages.
 - 1- It is subject to separation and oxygen decomposition.
 - 2- It is difficult to clean and remove old grease from the bearing assembly

The background is a solid blue gradient. On the left side, there is a bright, glowing sunburst or lens flare effect that fades into the blue background towards the right. The overall tone is a deep, vibrant blue.

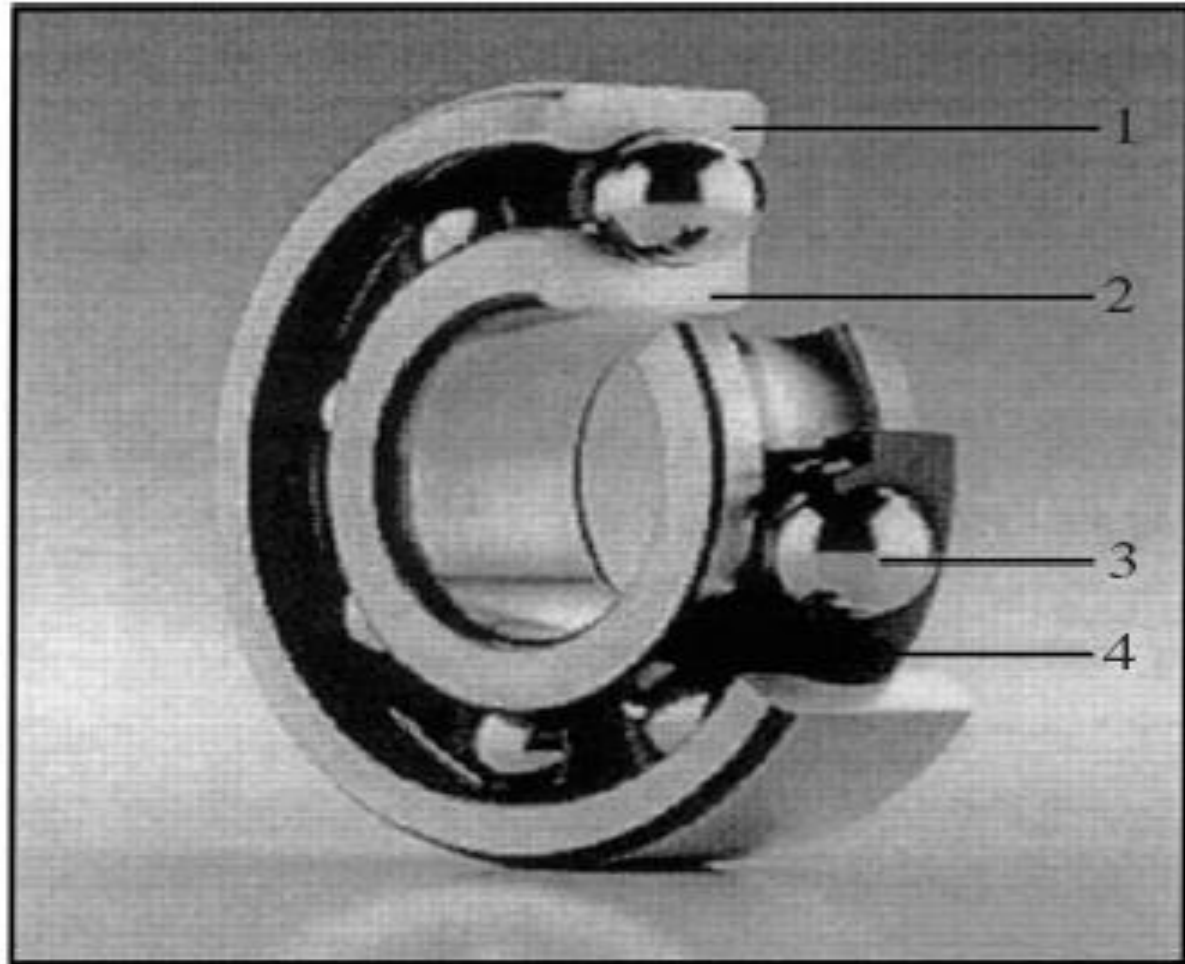
BEARINGS

- Pump bearings have two general classifications:

- 1- sleeve bearings

- 2- rolling element bearings.

Roller Bearings



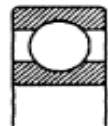
1 Outer ring, 2 Inner ring, 3 Rolling element, 4 Cage

Types of Bearing

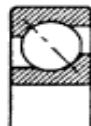
- The essential difference between ball bearings and roller bearings are that ball bearings have a lower carrying capacity and higher speeds while the roller have higher load carrying capacity and lower speeds.

Bearings

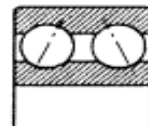
Radial ball bearings



Deep groove ball bearing



Angular contact ball bearing single row



Angular contact ball bearing double row

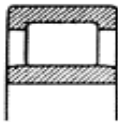


Four-point bearing

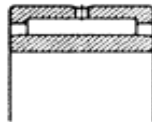


Self-aligning ball bearing

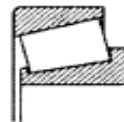
Radial roller bearings



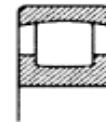
Cylindrical roller bearing



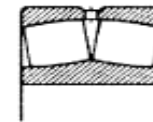
Needle roller bearing



Tapered roller bearing

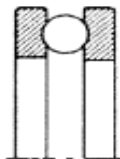


Barrel roller bearing

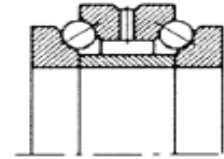


Spherical roller bearing

Thrust ball bearings

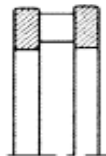


Thrust ball bearing

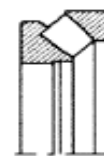


Angular contact thrust ball bearing double direction

Thrust roller bearings



Cylindrical roller thrust bearing

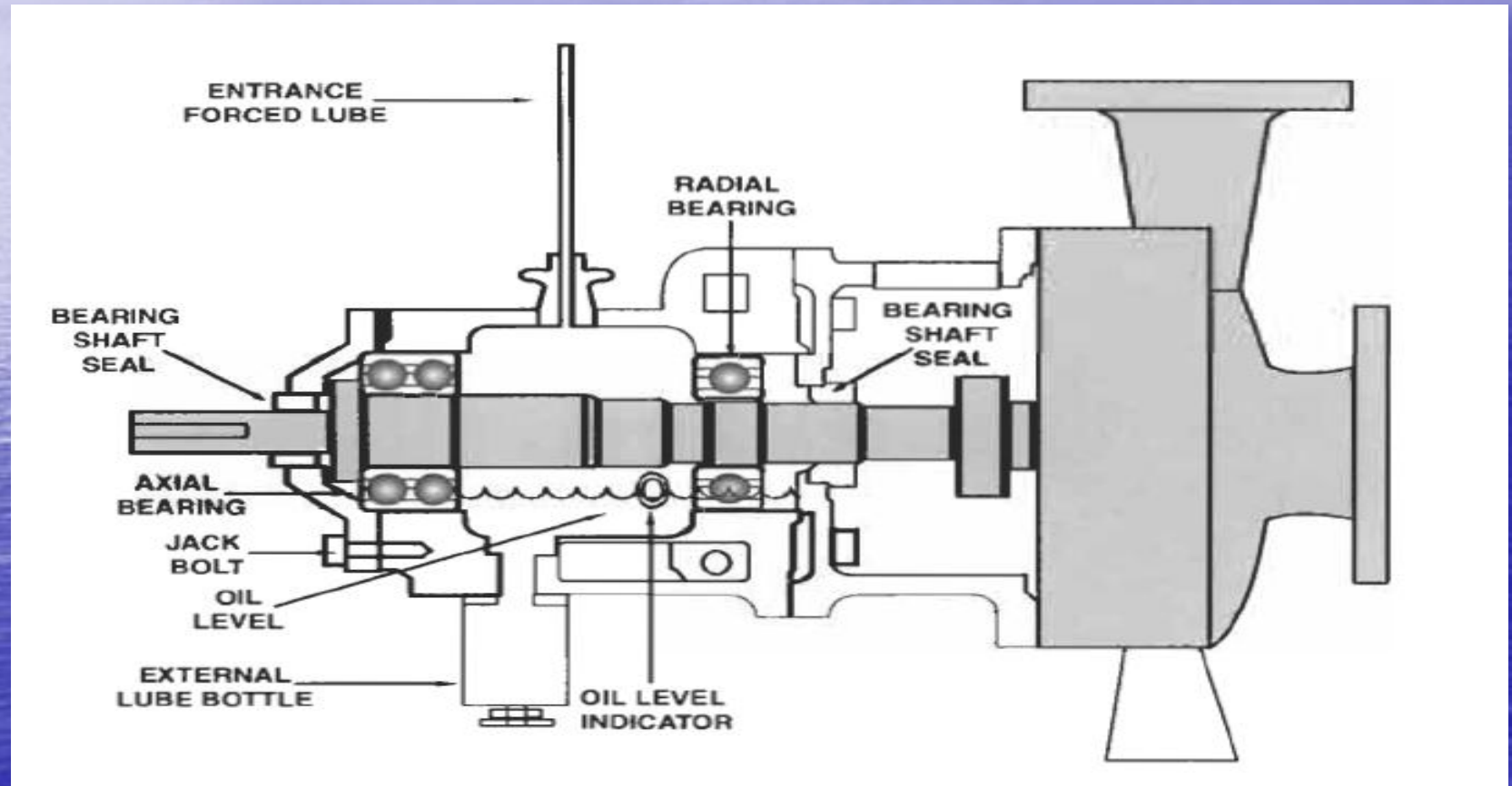


Spherical roller thrust bearing

TYPE	DESCRIPTION
Ball Bearing – Conrad Deep Groove	This is a single row bearing. It can handle moderate radial and axial loads from any direction.
Ball Bearing – Heavy Duty	This is also a single row design, but it has more balls in the assembly than the Conrad bearing.
Ball Bearing – Double Row, not self-aligning.	These bearings have two rows of balls and can handle 50% more radial load than the Conrad type bearing. Alignment is critical.

TYPE	DESCRIPTION
Ball Bearing – Double Row, self-aligning	These bearings have two rows of balls and they can handle some shaft misalignment. The axial or thrust loading is limited.
Ball Bearing – Angular Contact	These are single row ball bearings capable of handling extreme axial or thrust loads in one single direction only. They are generally mounted in pairs to handle any opposite axial/thrust loads.
Roller Bearing – Cylindrical	This bearing is best suited to handle radial loads. It doesn't work well with axial/thrust loads. This bearing is popular in electric motors.
Roller Bearing – Conical	These bearings are good handling extreme axial / thrust loads in one single direction only.
Roller Bearing – Needle	These are a type of roller bearing with a roller diameter normally less than .250" and about a 1:6 diameter to length ratio, thus the term needle.
Roller Bearing – Spherical Symmetrical	These spherical rollers are barrel shaped and mounted in two rows rolling inside a common inner and outer race housing.

Bearing lubrication in pumps



Failure

- 1. Improper mounting.**
- 2. Vibration**
- 3. Dirt and Abrasion**
- 4. Inadequate Lubrication**
- 5. Excessive Lubrication**

Cleaning bearings and re-lubrication

To remove old grease from the bearing internals and the housing:

1. Remove as much as possible by hand.
2. Flush the bearing and housing with warm kerosene.
3. Following by a flush with mineral oil SAE 10 viscosity.

Cleaning bearings and re-lubrication

If the old grease is caked and hardened:

1. Soak the bearing and housing in heated kerosene.
2. Slowly rotate the bearing by hand.
3. Rinse the bearing with clean kerosene or degreasing solvent.
4. Again, rotate the bearing's outer race by hand while applying a modest axial and radial load to the balls and races.
5. Soak and rinse again as necessary until the bearing rotates freely and smoothly.

Do's

1. Make sure all tools and surroundings are clean.
2. Use only clean, lint-free cloths with no strings to wipe bearings.
3. Use only clean flushing fluids and solvents.
4. Don't handle bearings by hand. It's best to use clean cotton gloves.
5. Remove all outside dirt from the housing before exposing the bearings.
6. Make sure the internal bearing chamber is clean before replacing bearings.

Don'ts

- Don't use chipped or dirty tools.
- Don't use cotton waste or dirty cloths to wipe bearings.
- Don't use leaded gasoline to rinse bearings. The chemical additives are harmful to your health.
- Don't handle bearings with wet or dirty hands.
- Don't work in a dirty surrounding.
- Don't scratch or nick any bearing, housing, or shaft contact surface.

- | | |
|---|--|
| 7. Place bearings on clean paper. | Don't expose bearings to rust or dirt. |
| 8. Keep bearings covered with oil or wax paper when not in use. | Don't spin un-cleaned bearings by hand. |
| 9. Protect disassembled bearings from dirt and rusting. | Don't spin un-cleaned bearings with a jet of compressed air. |
| 10. Treat new and used bearings with the same care. Use an induction heater for installation. | Don't install bearings with mallets, or hammers and wood blocks. |

Measurement of bearing temperature

- The temperature at which the grease carbonizes is the bearing's operating limit. Bearings are perfectly safe at 160 F.



CENTRIFUGAL PUMP PACKING

Types of Packing

- Compression packing
- Automatic packing
- Floating packing

Automatic Packing

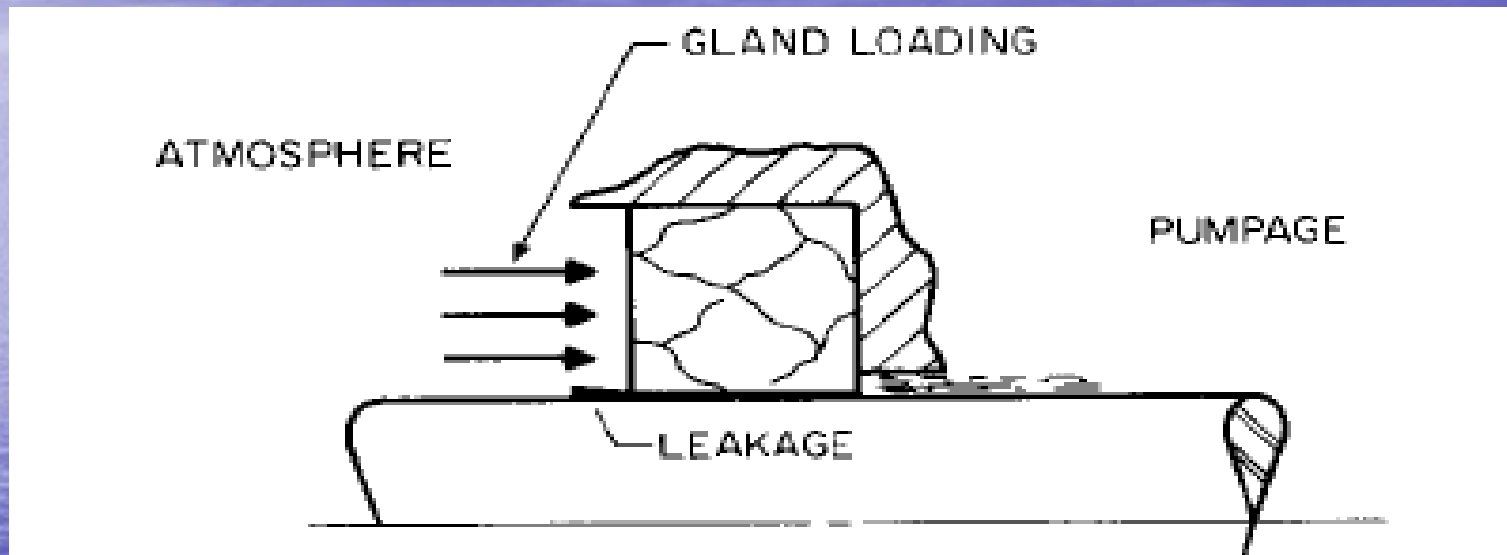
- Automatic packing are confined to a given space and are activated by the operating pressure.
- Automatic packing rings are designed in the form of V rings, U cups, and O rings.

Floating packing

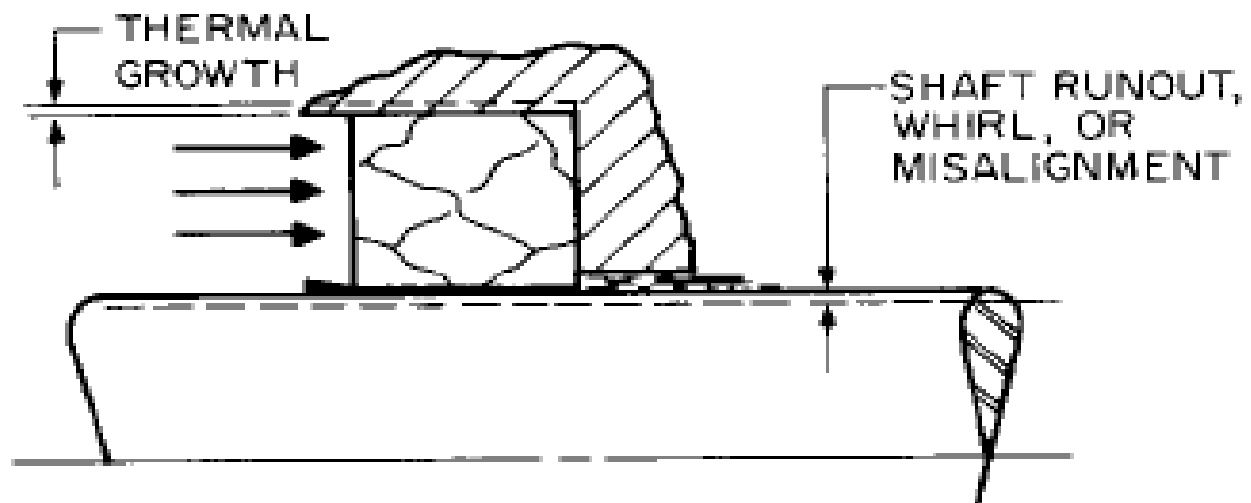
- Floating packing includes piston rings and segmental rings that may be energized by a spring.
- These types of packing are commonly used in reciprocating applications.

Compression packing

- Compression packing is most commonly used on rotating equipment.
- The seal is formed by the packing being squeezed between the inboard end of the stuffing box and the gland



Compression packing; new packing installation



Packing Materials

- A selection of the proper materials for the packing must include the chemical resistance to the product being sealed as well as the temperature, pressure, and shaft speed.

Packing Materials

Pump packings should be selected for •
their ability to compress.

When gland pressure is applied, the •
packing should react quickly to detain the
leakage and not damage (score) the shaft
or sleeve.

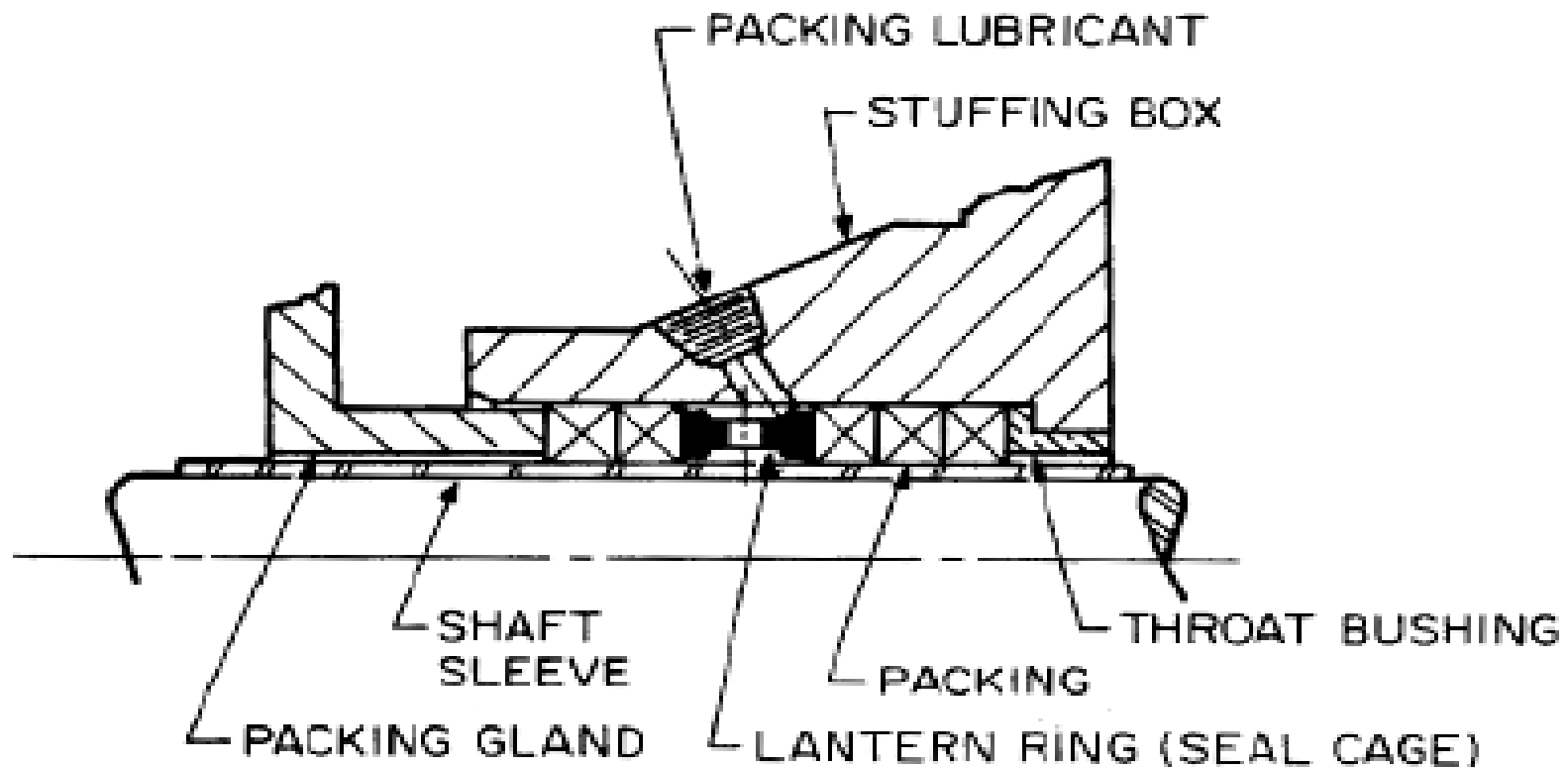
Common materials of construction for packing

Fibers				Metals
Mineral	Animal	Vegetable	Synthetic	Lead
Metal	Wool	Flax	Nylon	Copper
Graphite	Hair	Ramie	Rayon	Brass
	Leather	Jute	TFE	P-bronze
		Cotton	Carbon	Aluminum
		Paper	Aramid	Iron
			Polyamide	Stainless Steel
				Nickel
				Monel
				Inconel
				Zinc

Common lubricants and binders for packing

Lubricants		Dry Lubricants	Binders
Mineral	Animal	Graphite	Grease
Lube Oil	Tallow	Moly	Waxes
Paraffin	Glycerol	Mica	Elastomers
Petrolatum	Beeswax	Talc	TFE
Waxes	Lard Oil	Teflon	Other Resins
Greases	Fish Oil	Carbon	
	Soap	Tungsten Disulfide	
Vegetable	Synthetic		
Caster Oil	Oils		
Palm Oil	Waxes		
Cottonseed Oil	Fluorolubes		
Linseed Oil	Silicones		
Carnauba Wax			

Common packing arrangement



Packing sizes for rotating shafts

Shaft (or sleeve) Diameter, in (mm)	Packing size, in (mm)
$\frac{5}{8}$ to $1\frac{1}{8}$ (15 to 30)	$\frac{1}{4}$ (6.3)
$1\frac{1}{8}$ to $1\frac{7}{8}$ (30 to 50)	$\frac{5}{16}$ (8)
$1\frac{7}{8}$ to 3 (50 to 75)	$\frac{3}{8}$ (10)
3 to $4\frac{3}{4}$ (75 to 120)	$\frac{1}{2}$ (12.5)
$4\frac{3}{4}$ to 12 (120 to 305)	$\frac{5}{8}$ (16)

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CAUSES FOR A SHORT PACKING LIFE

Pump leaks
excessively at
stuffing

Defective packing

Replace worn packing or replace packing
damaged by lack of lubrication.

Wrong type of packing

Replace packing not properly installed or
run in. Replace improper packing with
correct grade for liquid being handled.

Shaft or shaft sleeve scored

Put in lathe and machine-true and smooth
or replace. Recheck dimensions for correct
packing size.

CAUSES FOR A SHORT PACKING LIFE

Stuffing box
overheats

Packing too tight

Release gland pressure and retighten.

Packing not lubricated

Release gland pressure and replace all packing if any burnt or damaged.

Wrong grade of packing

Check with pump or packing manufacturer for correct grade.

Insufficient cooling water
to jacket

Check for open supply line valve or clogged line.

Stuffing box improperly
packed

Repack.

CAUSES FOR A SHORT PACKING LIFE

Stuffing box overheats	Packing too tight	Release gland pressure and retighten.
	Packing not lubricated	Release gland pressure and replace all packing if any burnt or damaged.
	Wrong grade of packing	Check with pump or packing manufacturer for correct grade.
	Insufficient cooling water to jacket	Check for open supply line valve or clogged line.
	Stuffing box improperly packed	Repack.

CAUSES FOR A SHORT PACKING LIFE

Packing wears
too fast

Shaft or shaft sleeve worn
or scored

Remachine or replace.

Insufficient or no
lubrication

Repack, making sure packing is loose
enough to allow some leakage.

Packing packed
improperly

Repack properly, making sure all old
packing is removed and the box is clean.

Wrong grade of packing

Check with pump or packing manufacturer.

Pulsating pressure on
external seal liquid line

Remove cause of pulsation.

CAUSES FOR A SHORT PACKING LIFE

Not enough liquid delivered by pump

Air leaking into stuffing box

Check for leakage through stuffing box while operating. If no leakage occurs after after reasonable gland adjustment, new packing may be needed.

or

Lantern ring may be clogged or displaced and may need centering in line with sealing liquid connection.

or

Sealing liquid line may be clogged.

or

Shaft or shaft sleeve beneath packing may be badly scored, allowing air to be sucked into pump.

Defective packing

Replace packing and check the smoothness of the shaft or shaft sleeve.

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Shaft or shaft sleeve worn
or scored

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Insufficient or no
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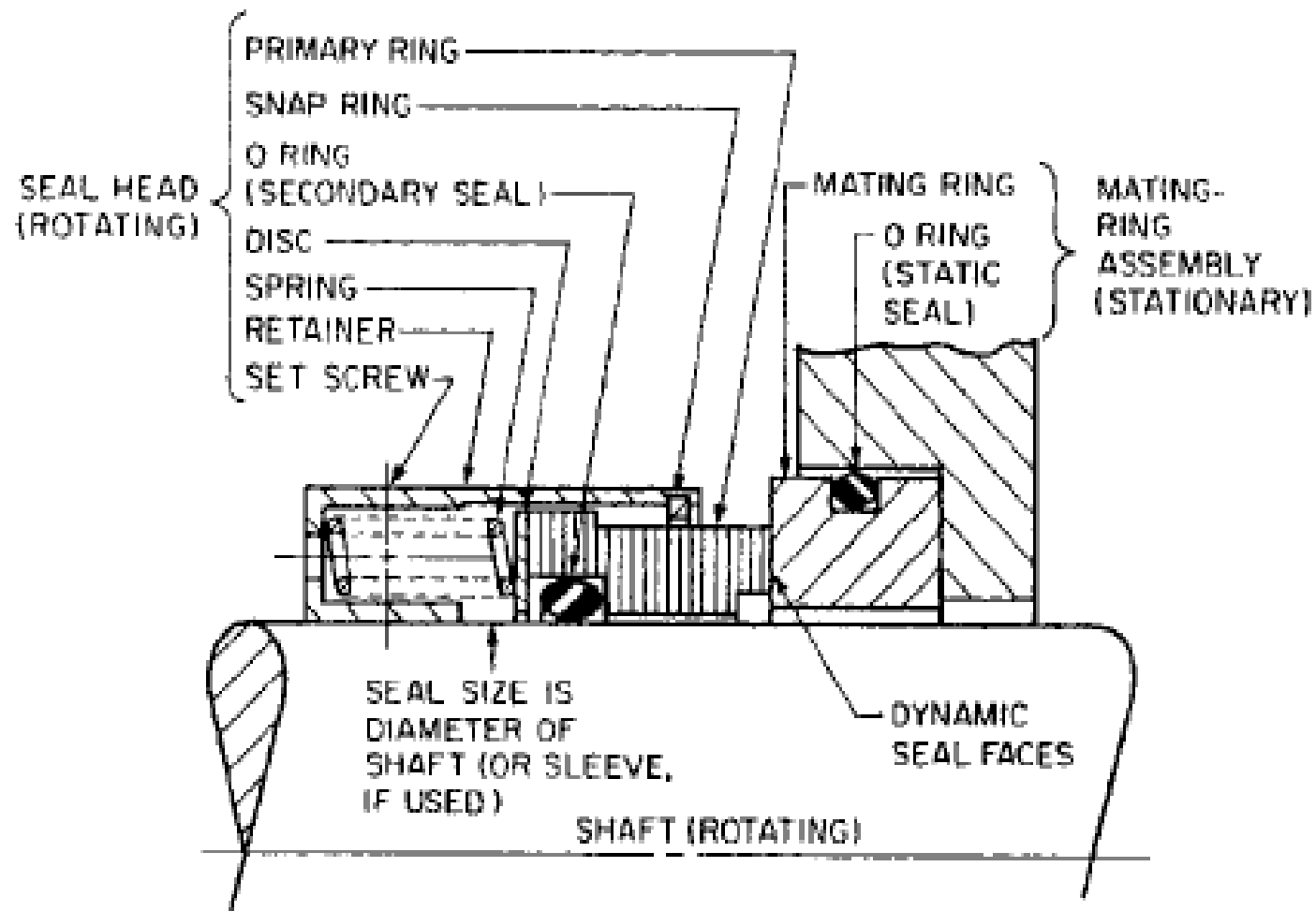
Defective packing

Replace packing and check the smoothness of the shaft or shaft sleeve.

MECHANICAL SEALS

1. Between the faces (rotary and stationary) of the seal.
2. Between the stationary element and the seal chamber housing of the pump.
3. Between the rotary element and the shaft or sleeve of the pump.

The basic components of a mechanical seal



CLASSES OF SEAL TECHNOLOGY

1. Contacting liquid lubricated seals:

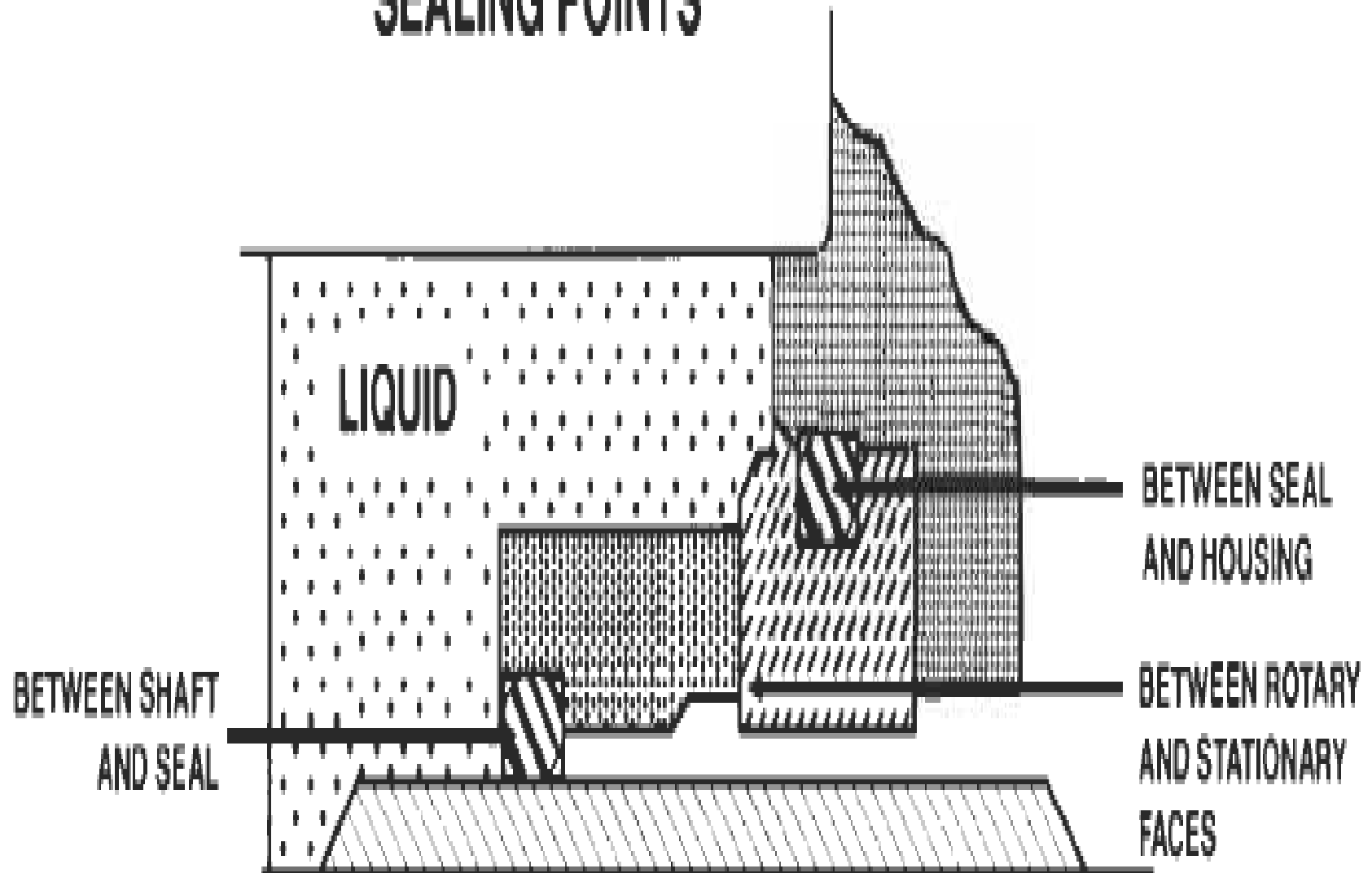
- Normally, a single seal arrangement is cooled and lubricated by the liquid being sealed. This is the most cost-effective seal installation available to the industry.
- Dual seals are arranged to contain a pressurized or non-pressurized barrier or buffer liquid. Normally, this arrangement will be used on applications where the liquid being sealed is not a good lubricating fluid for a seal and for emissions containment. These arrangements require a lubrication system for the circulation of barrier or buffer liquids.

CLASSES OF SEAL TECHNOLOGY

2- 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.

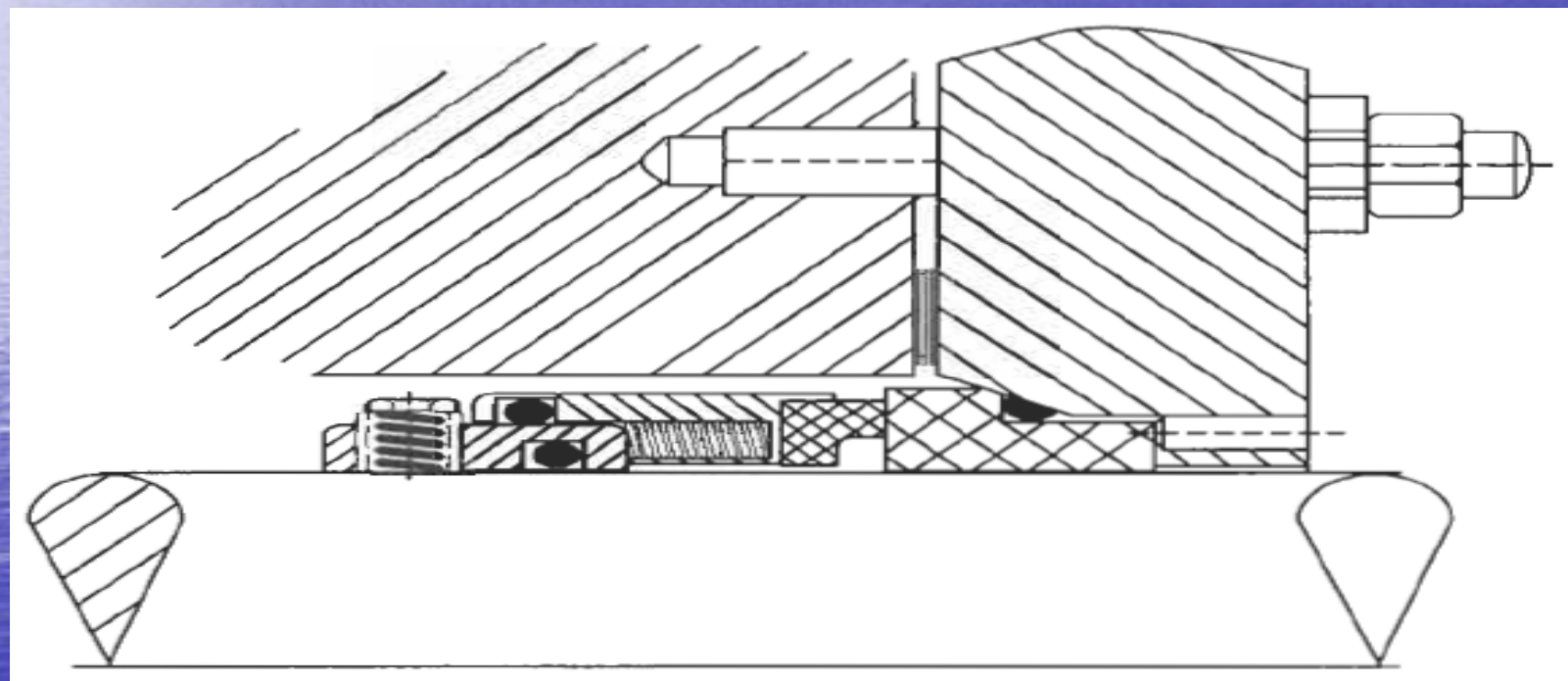
SEALING POINTS

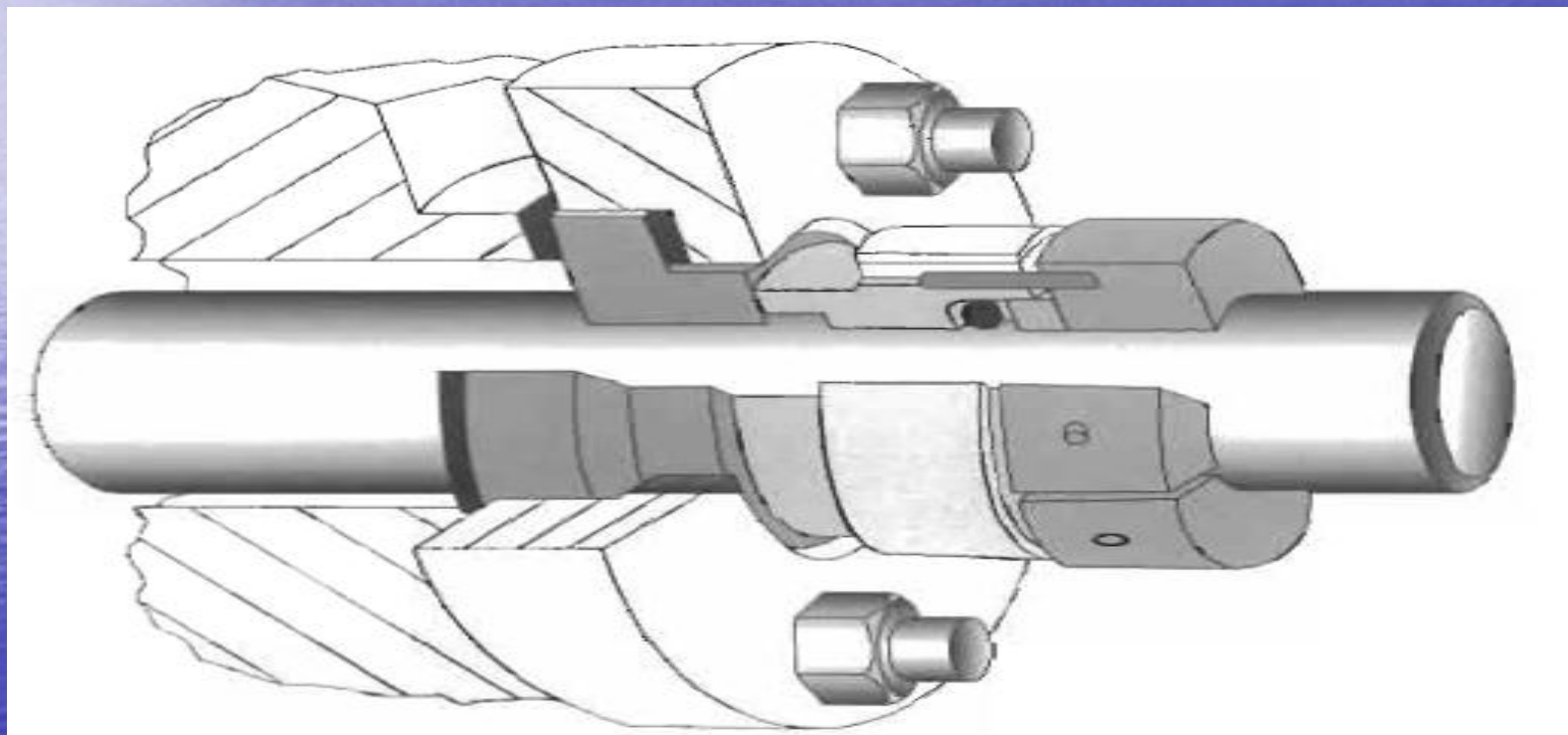


CLASSIFICATION OF SEALS BY ARRANGEMENT

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



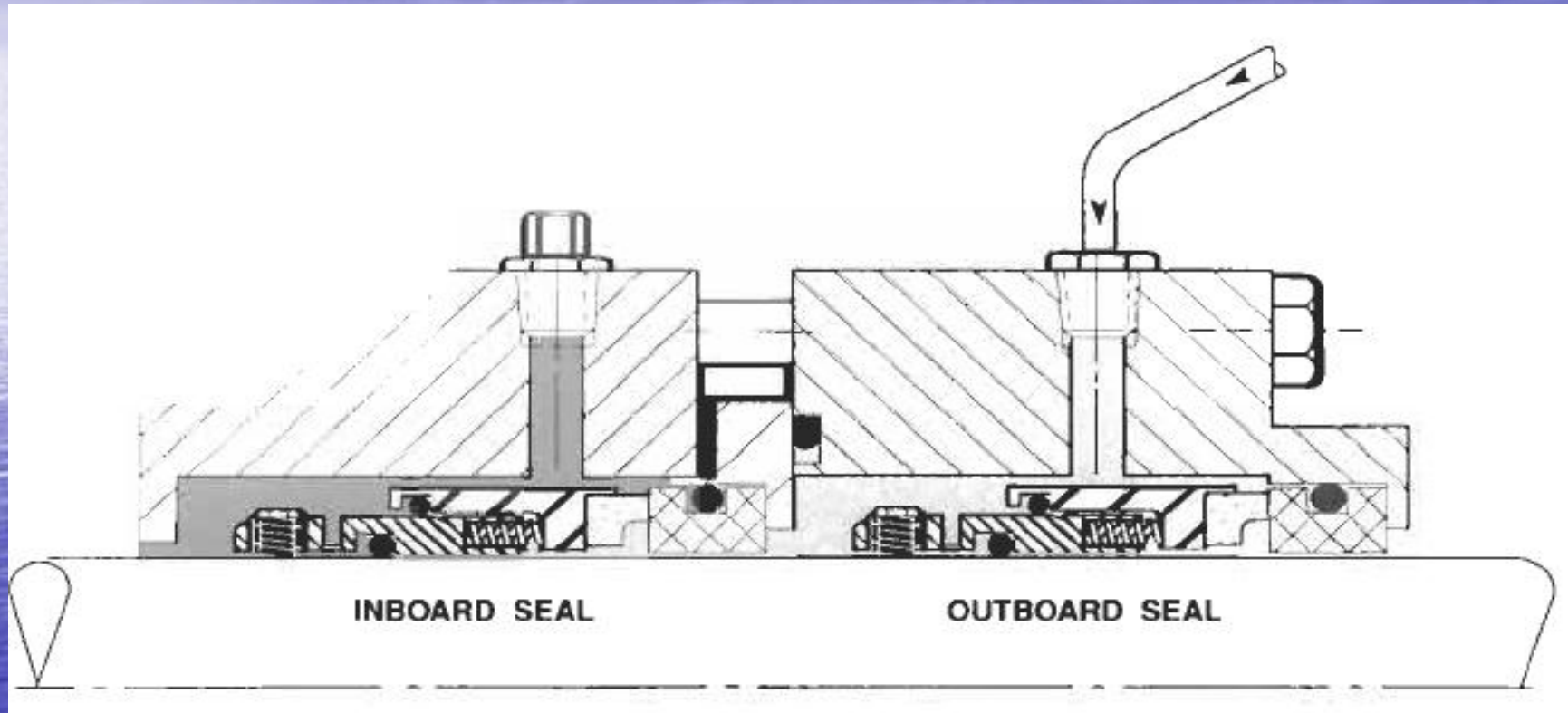


Multiple seal installations

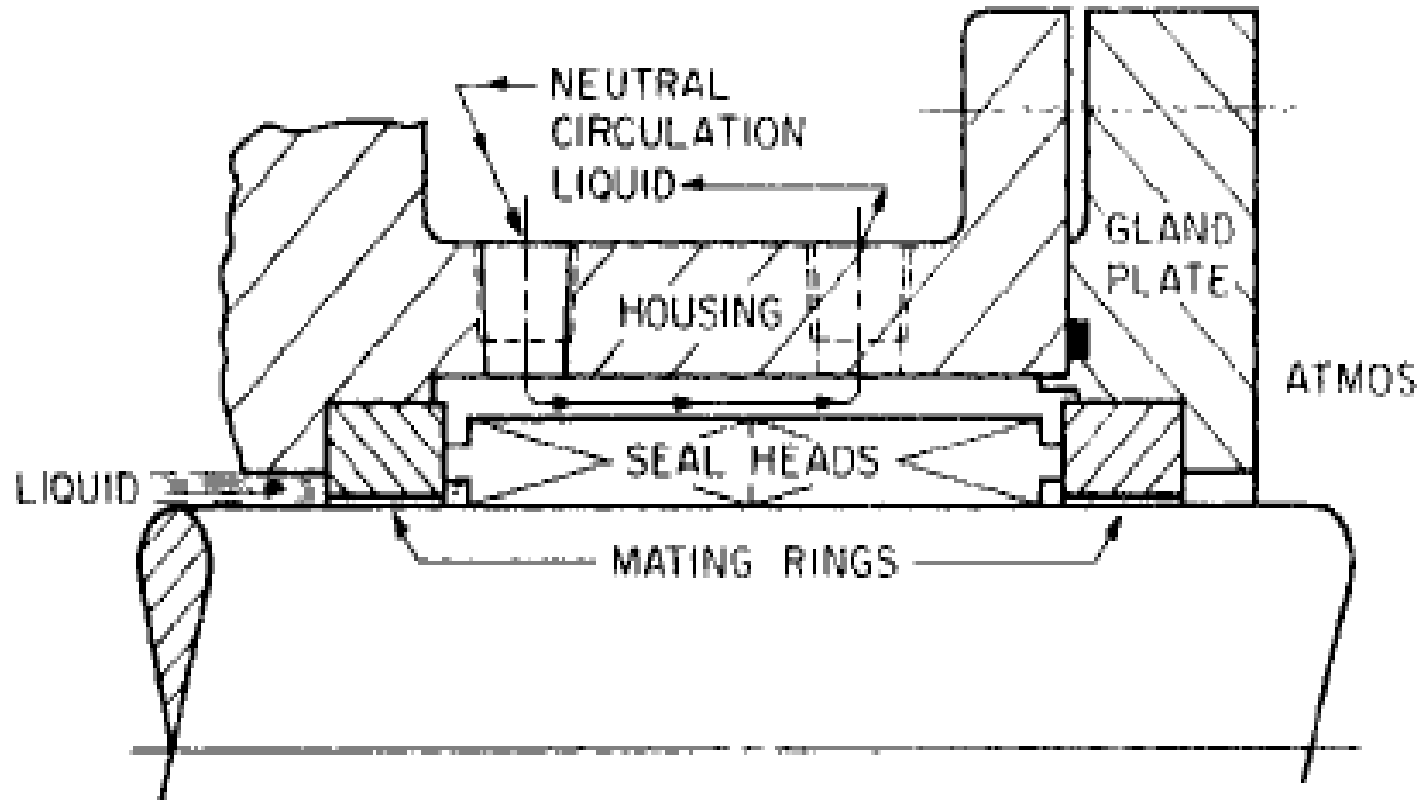
Multiple seals are used in applications requiring

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

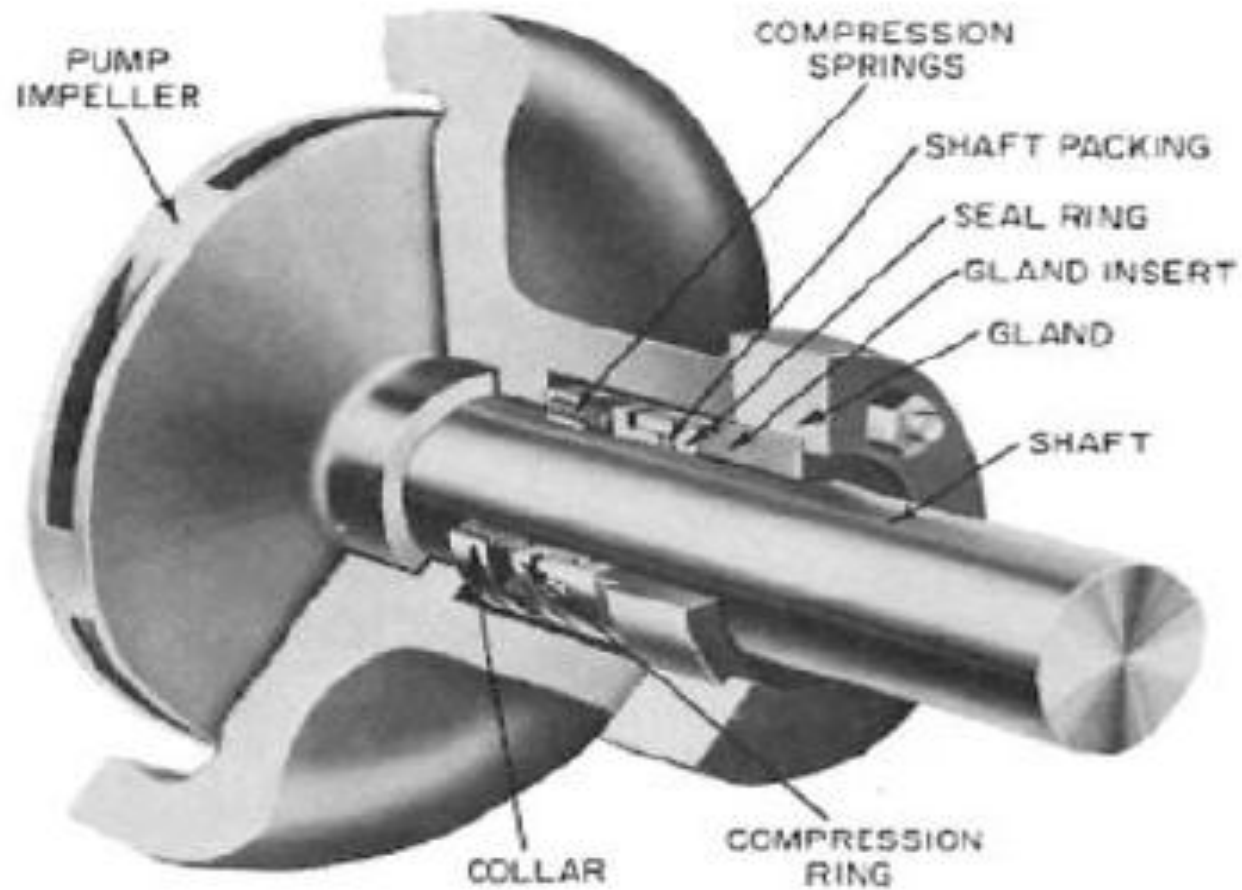
Tandem Seals



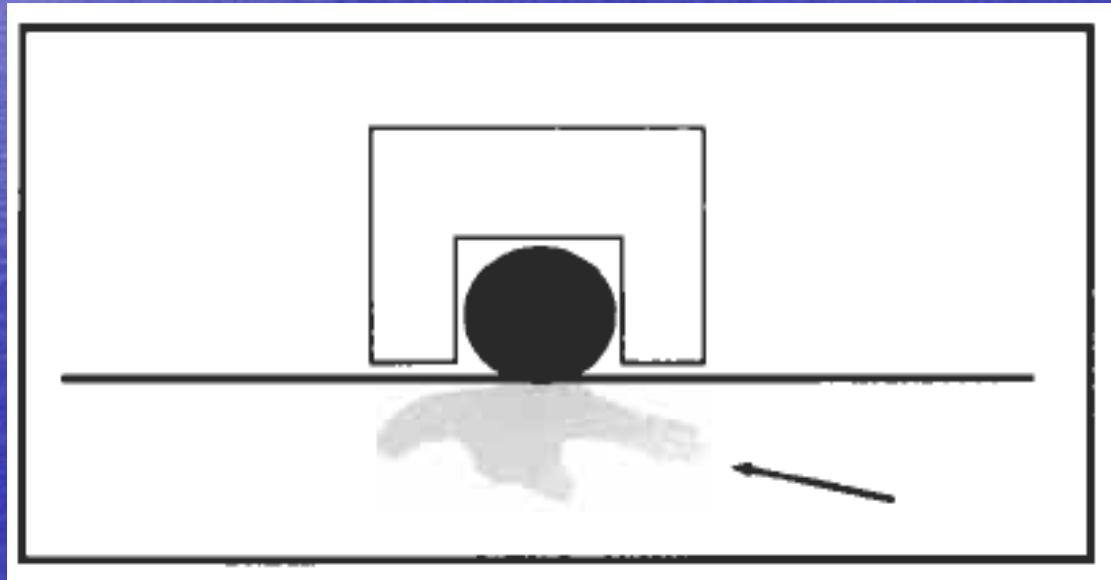
Back-to-Back Double Seals



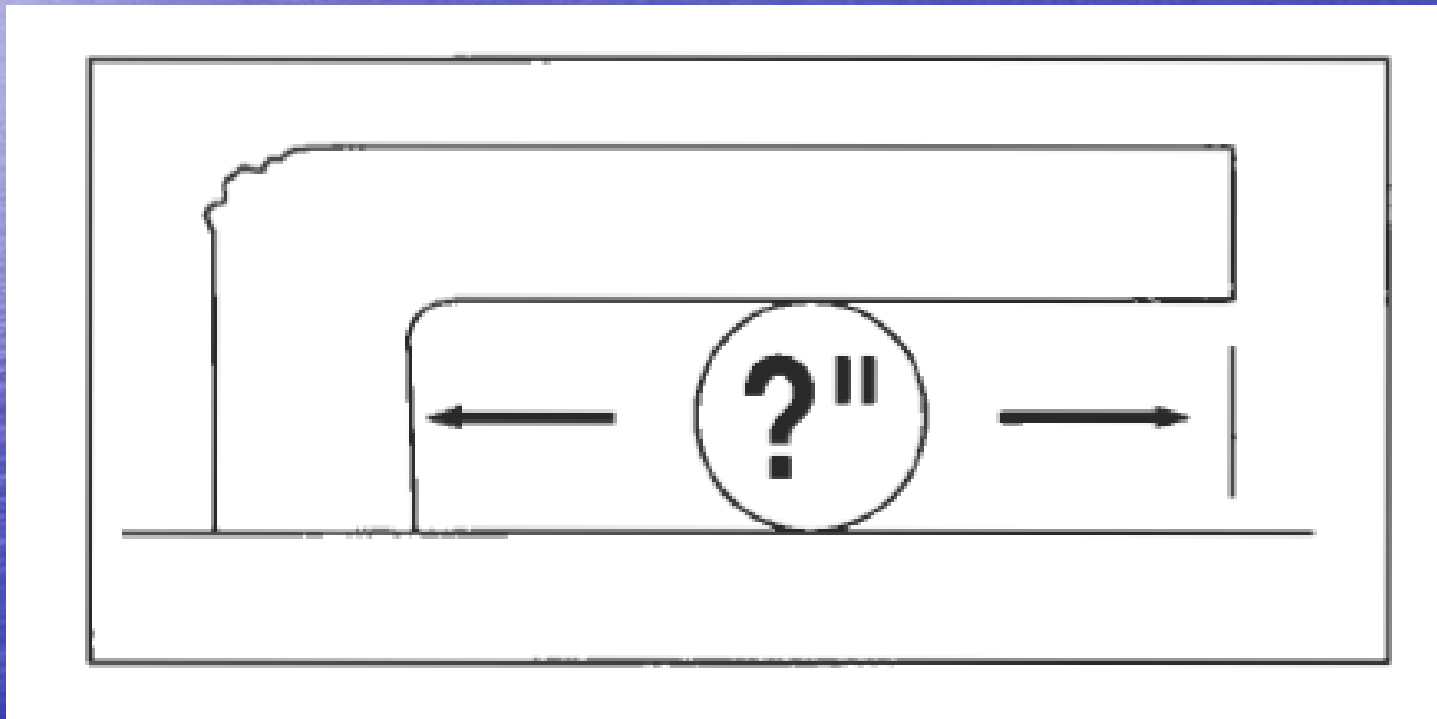
Pusher



O-ring failure



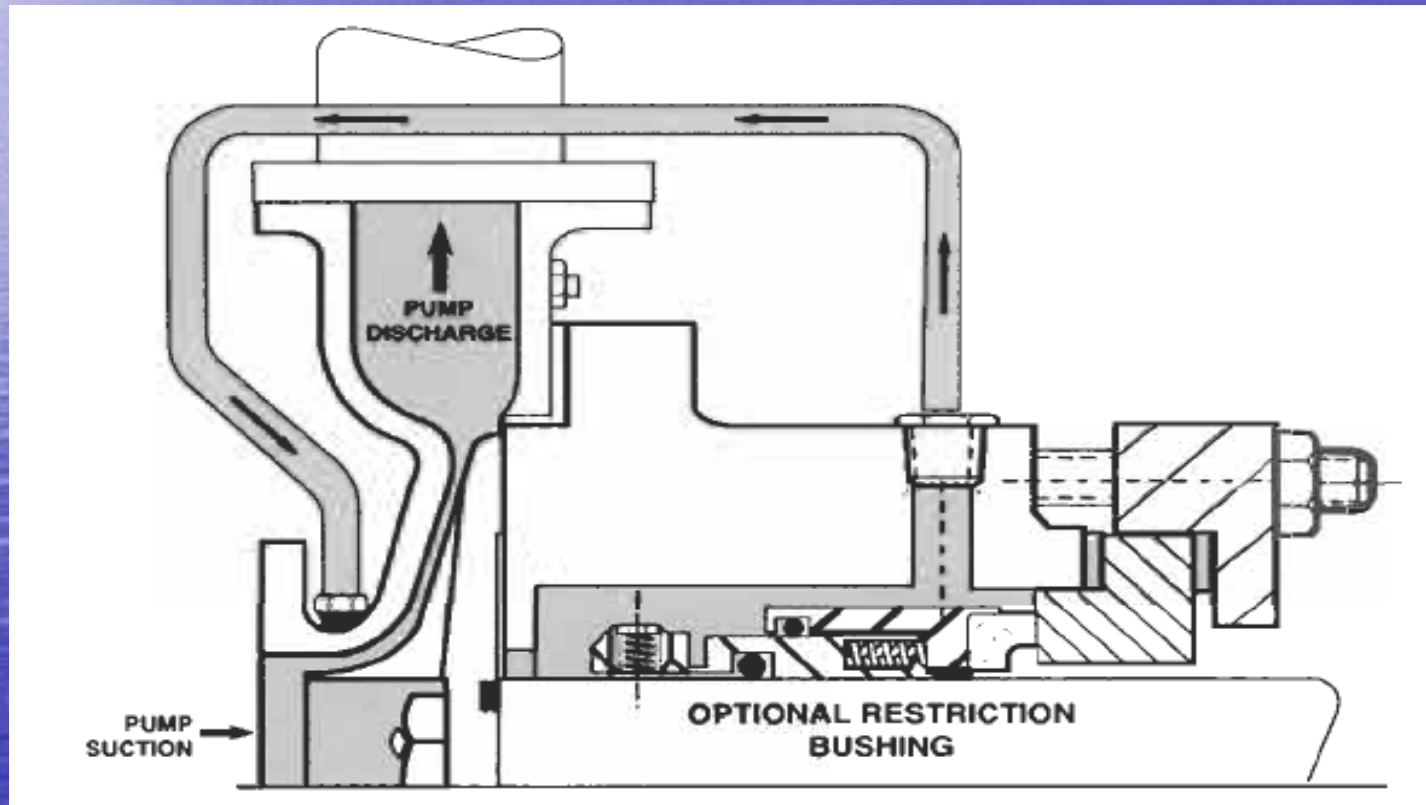
Incorrect installation dimension



Suction bypass

- The suction bypass is good for:
- Removing heat
- Removing suspended solids

Suction bypass

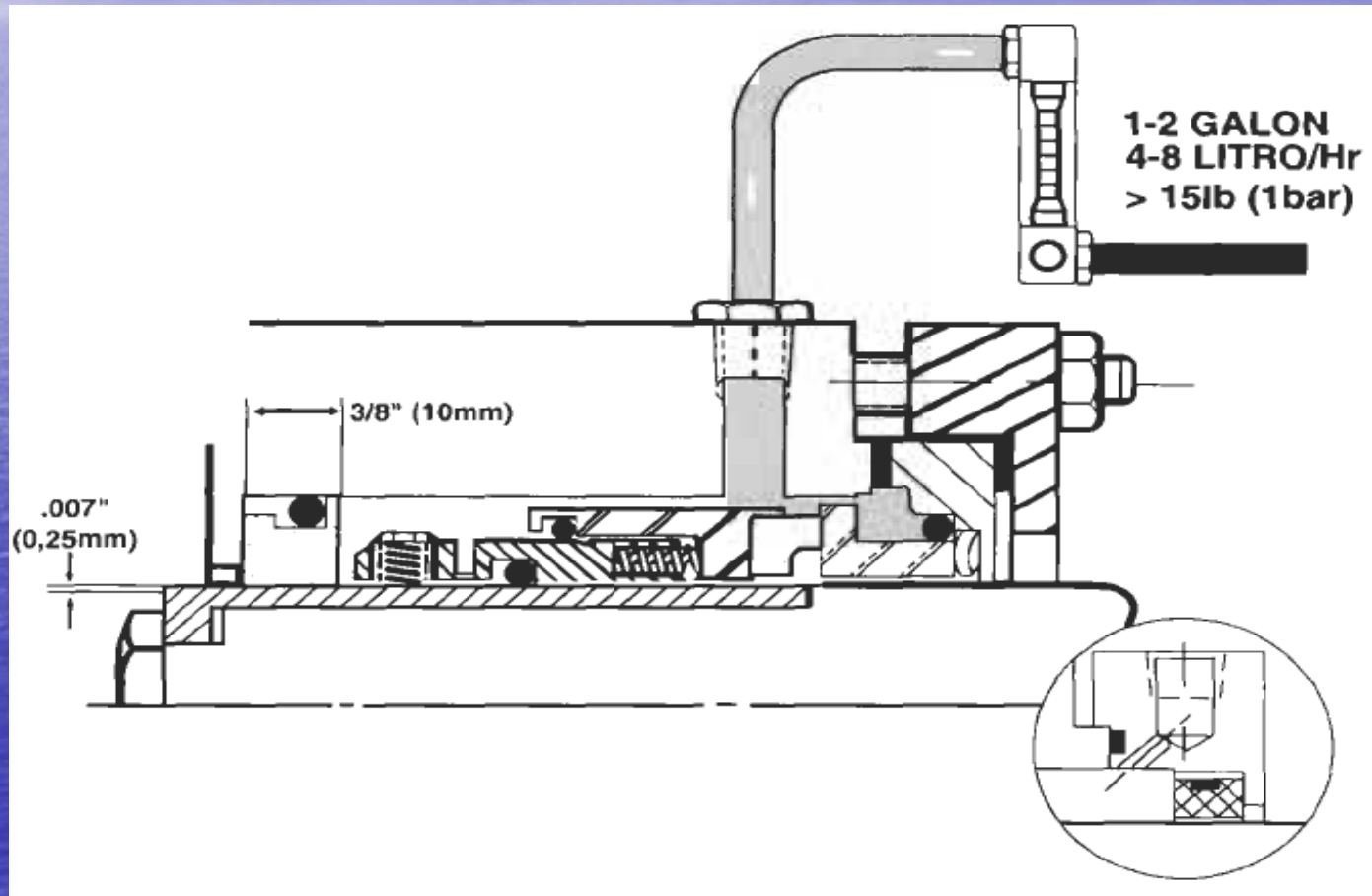


The external flush

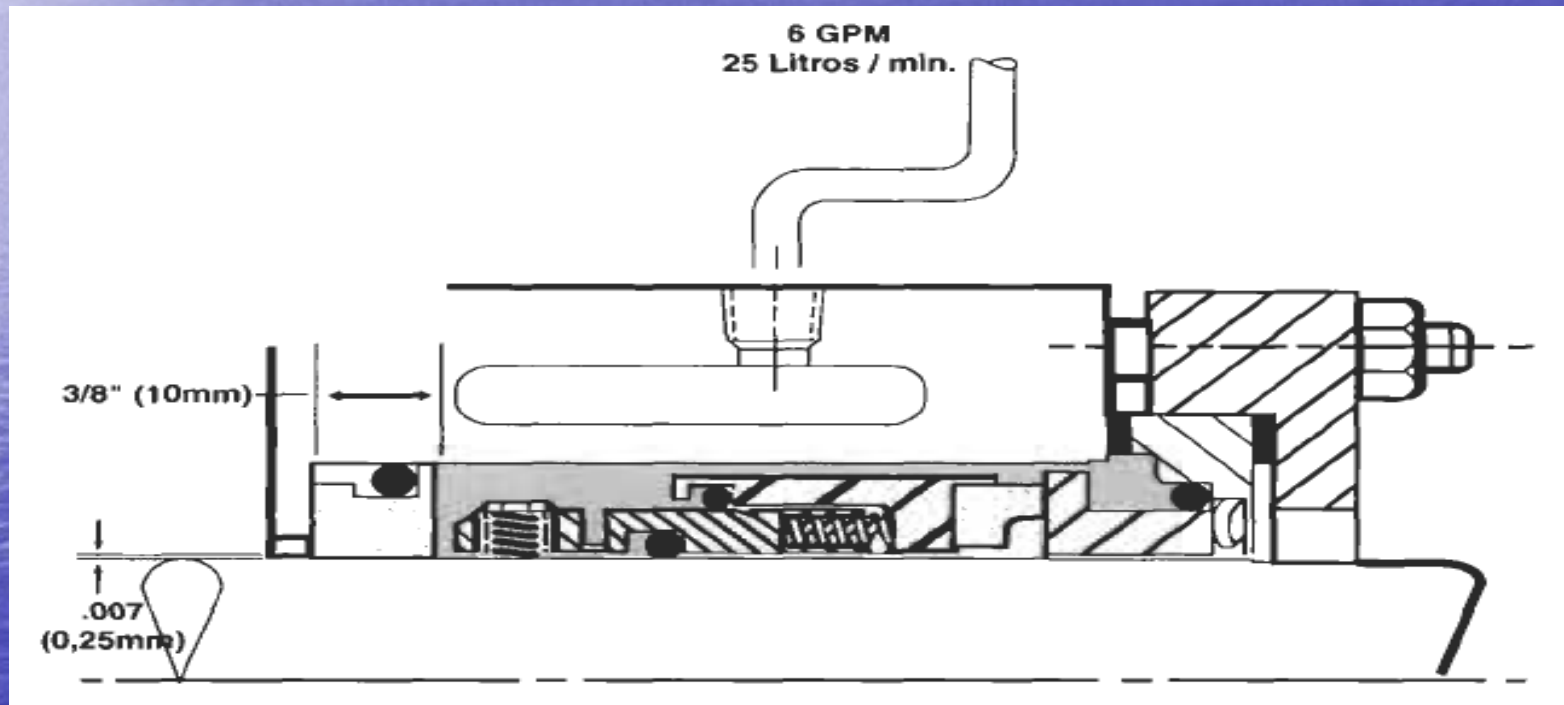
The external flush is good for:

1. Removing heat
2. Separating the seal environment from the pumped liquid

The external flush



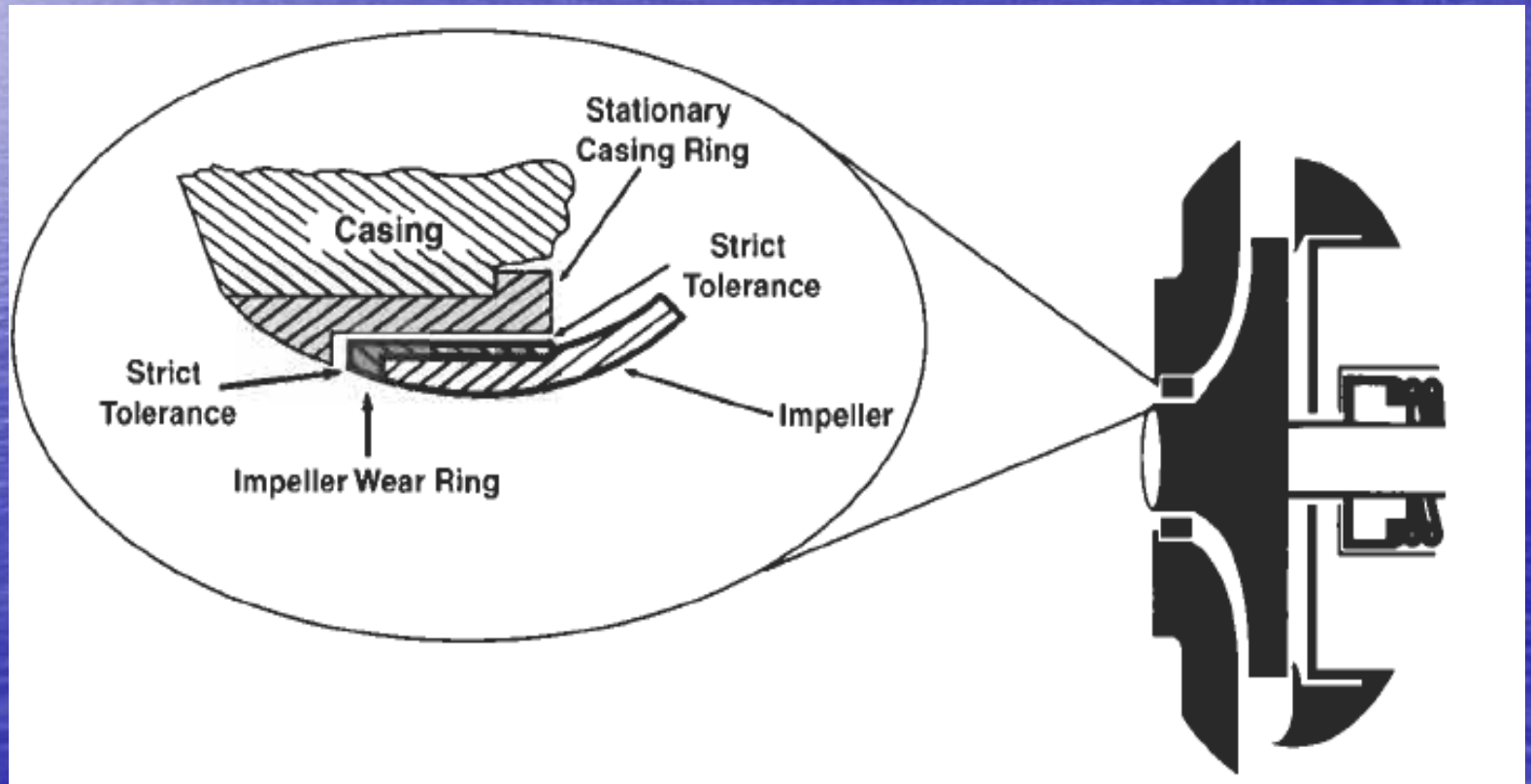
Thermal jacketed seal chamber



Wear rings

Wear rings provide for a close running, renewable clearance, which reduces the amount of liquid leaking from the high pressure zones to the low pressure zones in the pump. •

Wear rings



Wear rings

- The rate of wear is a function of the pumped liquid's lubricity.
- When the wear is excessive, the pump suffers degradation in its performance.
- The strict tolerance in the replaceable wear rings governs the efficiency of the pump.

Wear rings

- You can expect the pump to loose 1.5 to 2% efficiency points for each one thousandths (0.001 inch) wear in a wear ring beyond the original factory setting.

$$\text{Cost per year} = \frac{0.000189 \times \text{GPM} \times \text{TDH} \times \$\text{Kwh} \times \text{sp.gr.} \times 8,760}{\text{Eff. Pump} \times \text{Eff. Motor}}$$

Wear rings

- Effective and well planned maintenance can reduce the operating cost of your pumps and other equipment
- With differential pressure gauges on the pump, an amp meter and flow meter you can determine if strict tolerance parts are worn.

Reciprocating pumps Vs centrifugal pumps

The advantages of reciprocating pumps in general over centrifugal pumps may be summarized as follows:

- 1.They can be designed for higher heads than centrifugal pumps.
- 2.They are not subject to air binding, and the suction may be under a pressure less than atmospheric without necessitating special devices for priming.
- 3.They are more flexible in operation than centrifugal pumps.
- 4.They operate at nearly constant efficiency over a wide range of flow rates.

Reciprocating pumps Vs centrifugal pumps

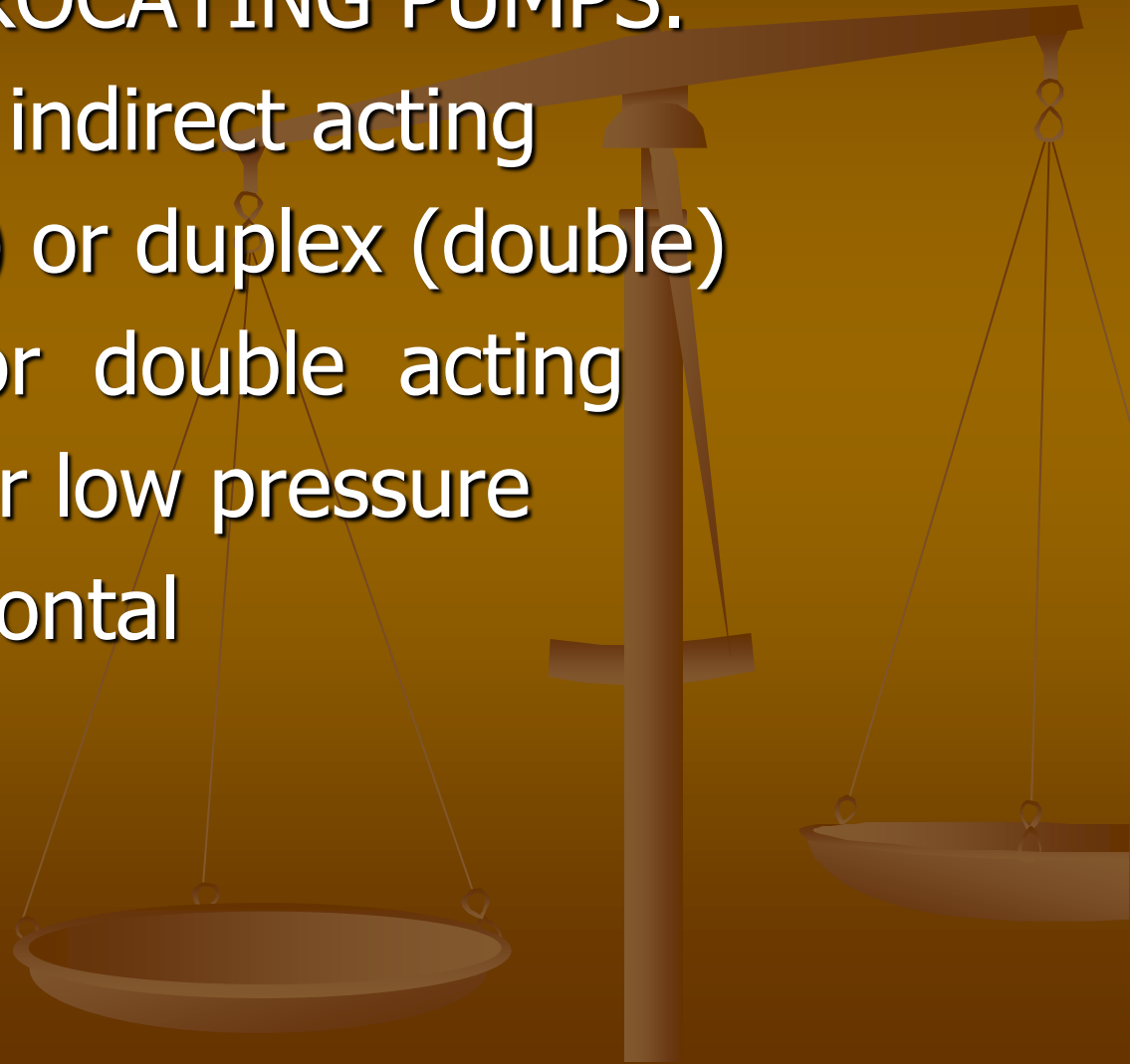
The advantages of centrifugal pumps over reciprocating pumps are:

- 1.The simplest centrifugal pumps are cheaper than the simplest reciprocating pumps.
- 2.Centrifugal pumps deliver liquid at uniform pressure without shocks or pulsation.
- 3.They can be directly connected to motor derive without the use of gears or belts.
- 4.Valves in the discharge line may be completely closed without injuring them.
- 5.They can handle liquids with large amounts of solids in suspension.

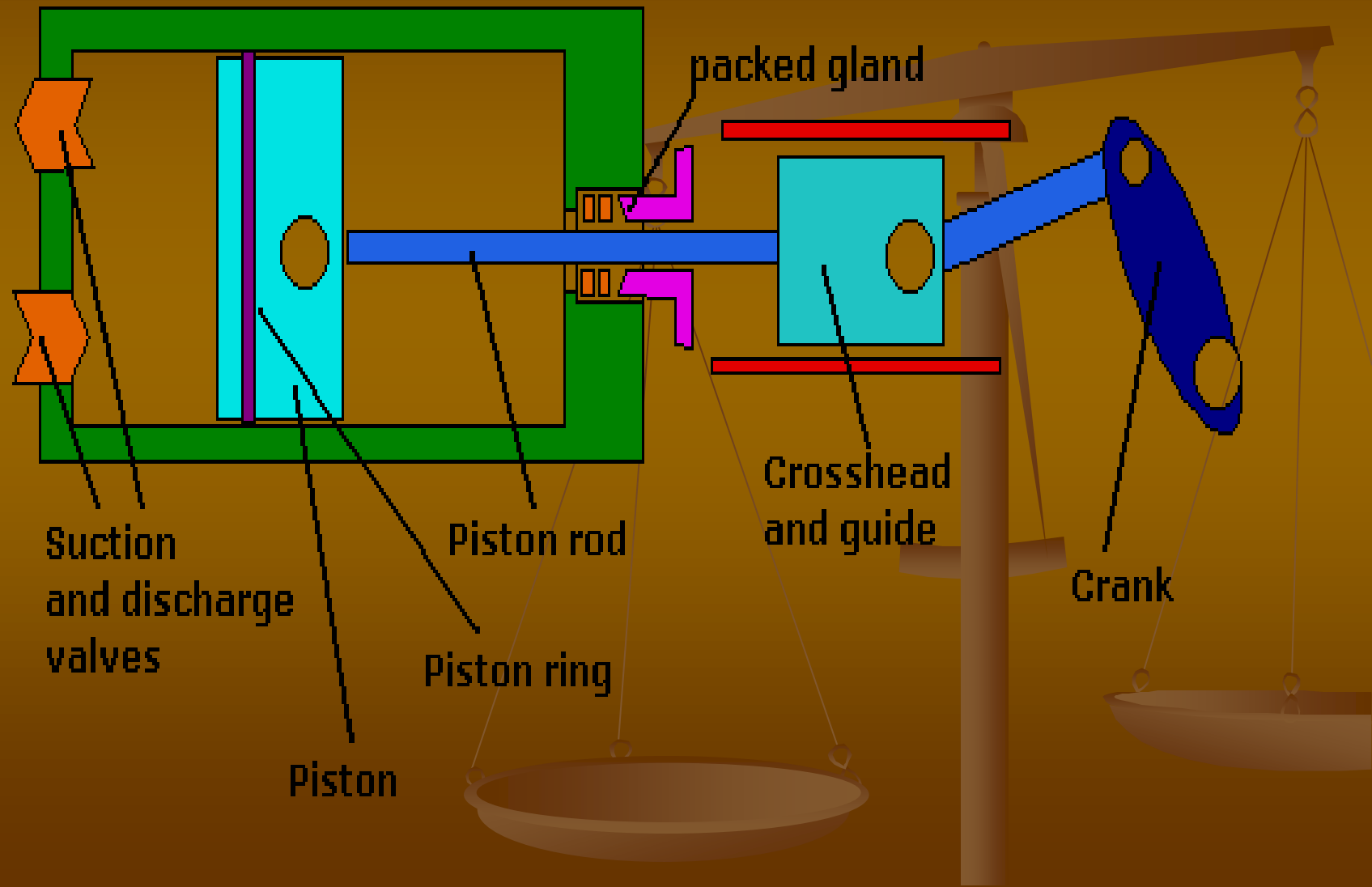
POSITIVE DISPLACEMENT PUMPS

TYPES OF RECIPROCATING PUMPS.

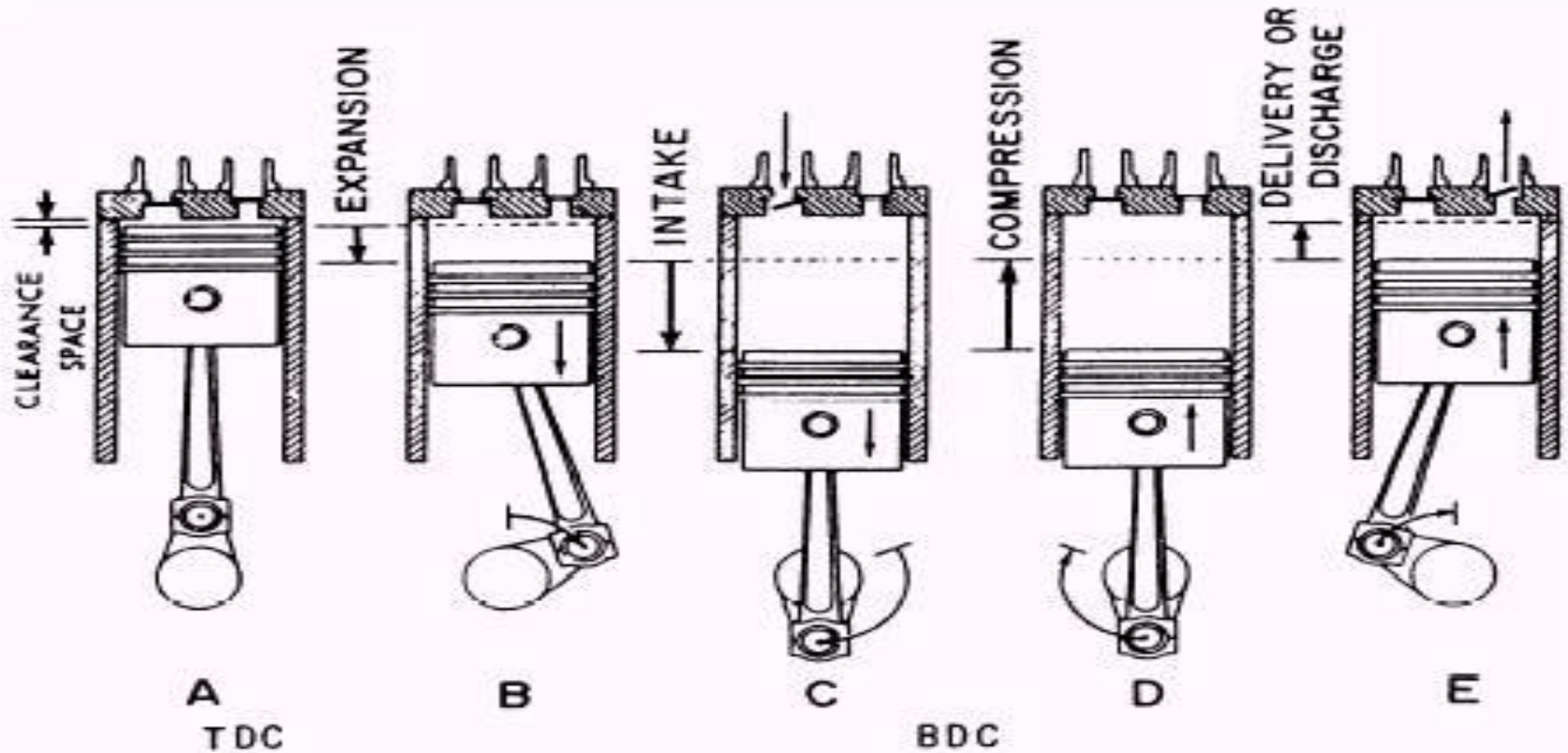
- Direct acting or indirect acting
- Simplex (single) or duplex (double)
- Single acting or double acting
- High pressure or low pressure
- Vertical or horizontal



RECIPROCATING PUMPS.



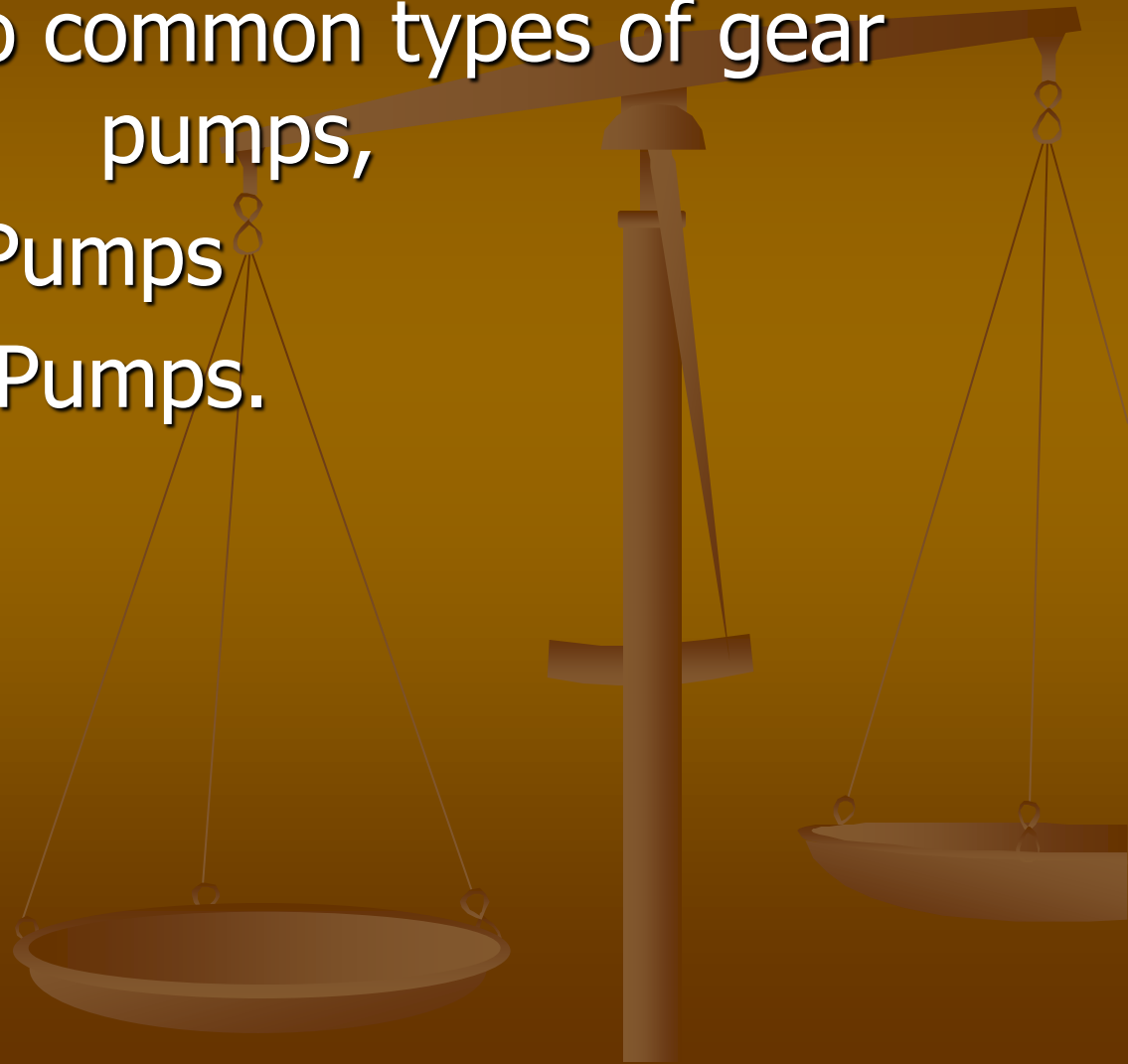
RECIPROCATING PUMPS.



POSITIVE DISPLACEMENT PUMPS

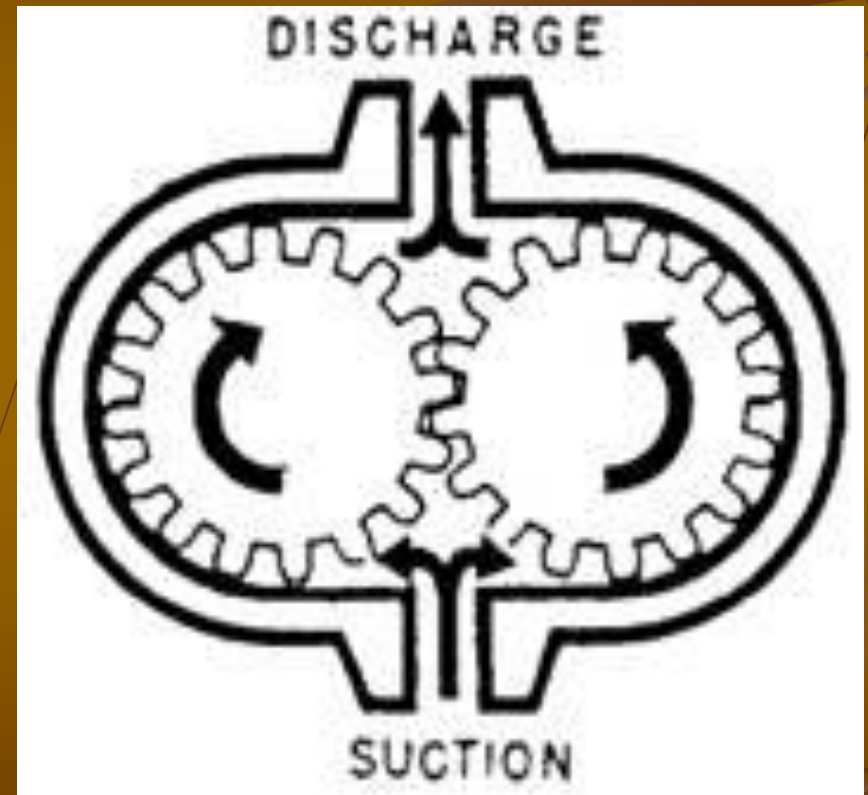
There are two common types of gear pumps,

1. internal Gear Pumps
2. external Gear Pumps.



External gear pumps

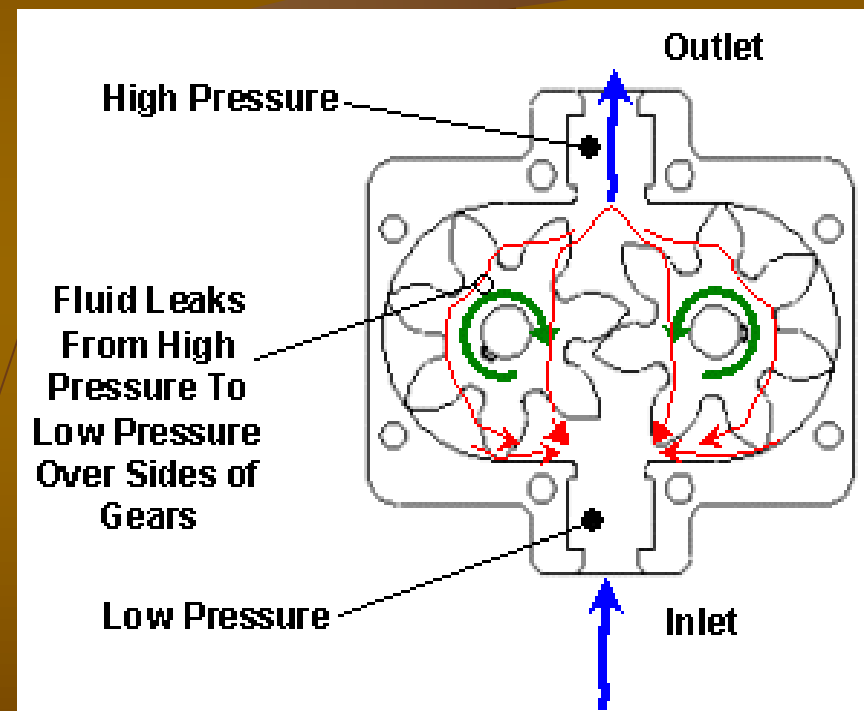
- External gear pumps are common and can handle pressures up to 3000 to 3500 psi.
- These gear pumps offer an inexpensive, mid-pressure, mid-volume, fixed displacement delivery to a system. Viscosity ranges for these types of pumps are limited



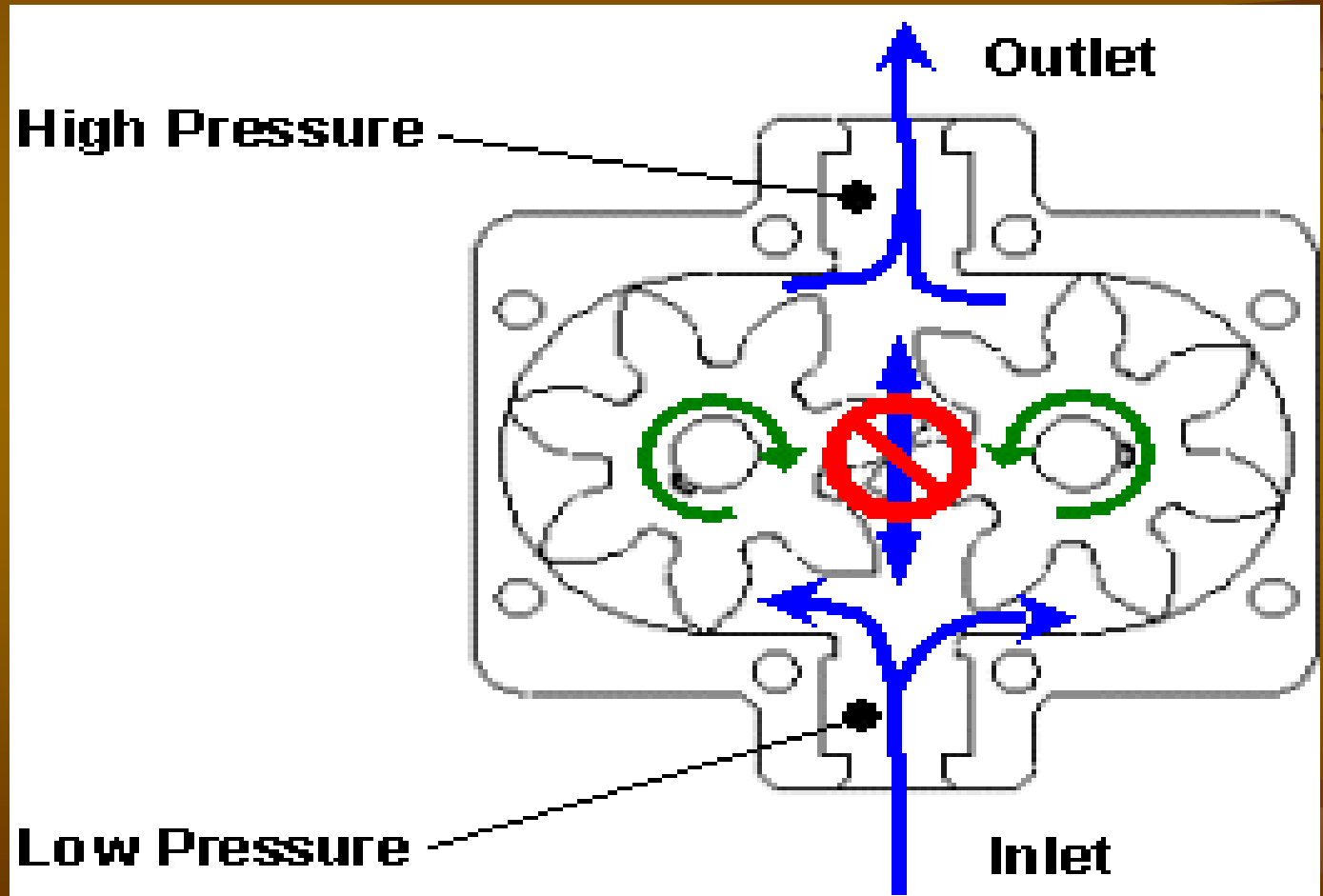
External gear pumps

Operation of External Gear Pumps Work

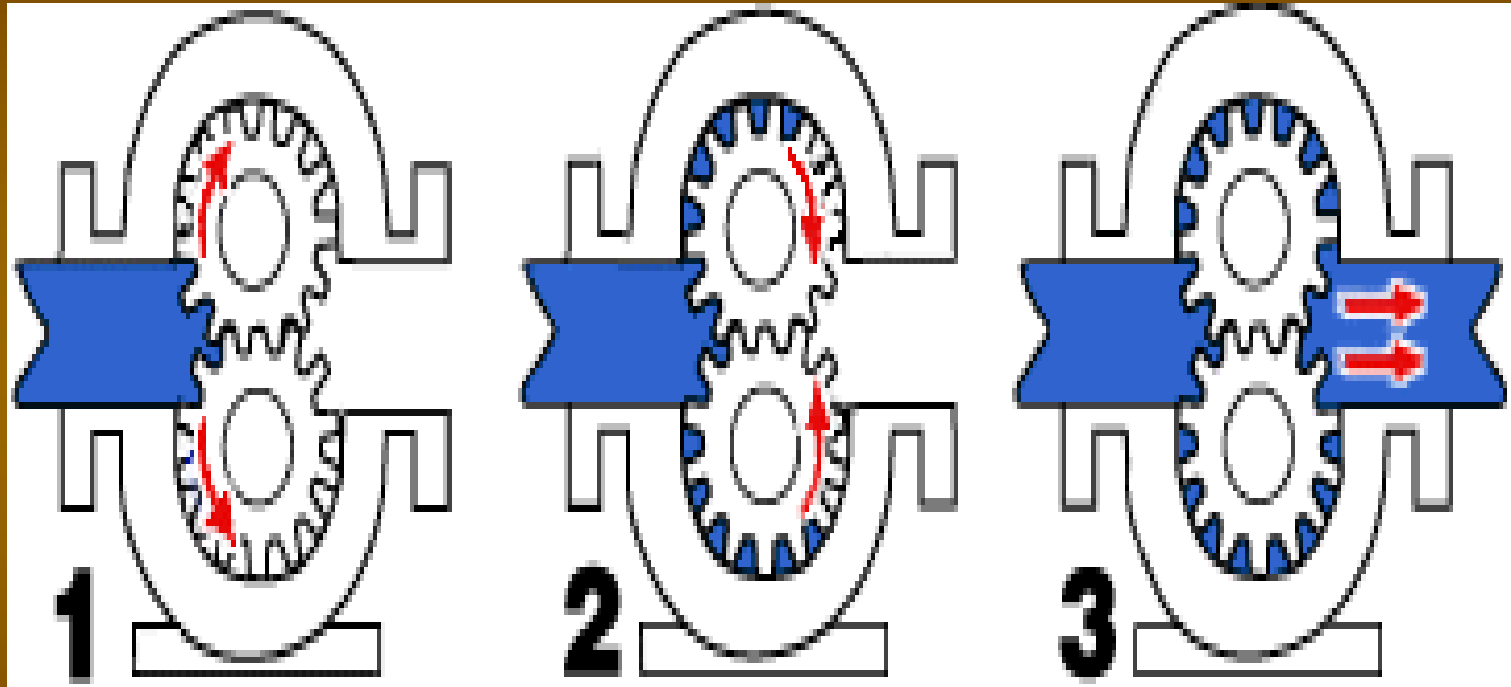
- against each other one gear is driven by a motor and it in turn drives the other gear. Each gear is supported by a shaft with bearings. External gear pumps use two identical gears rotating on both sides of the gear.



External gear pumps



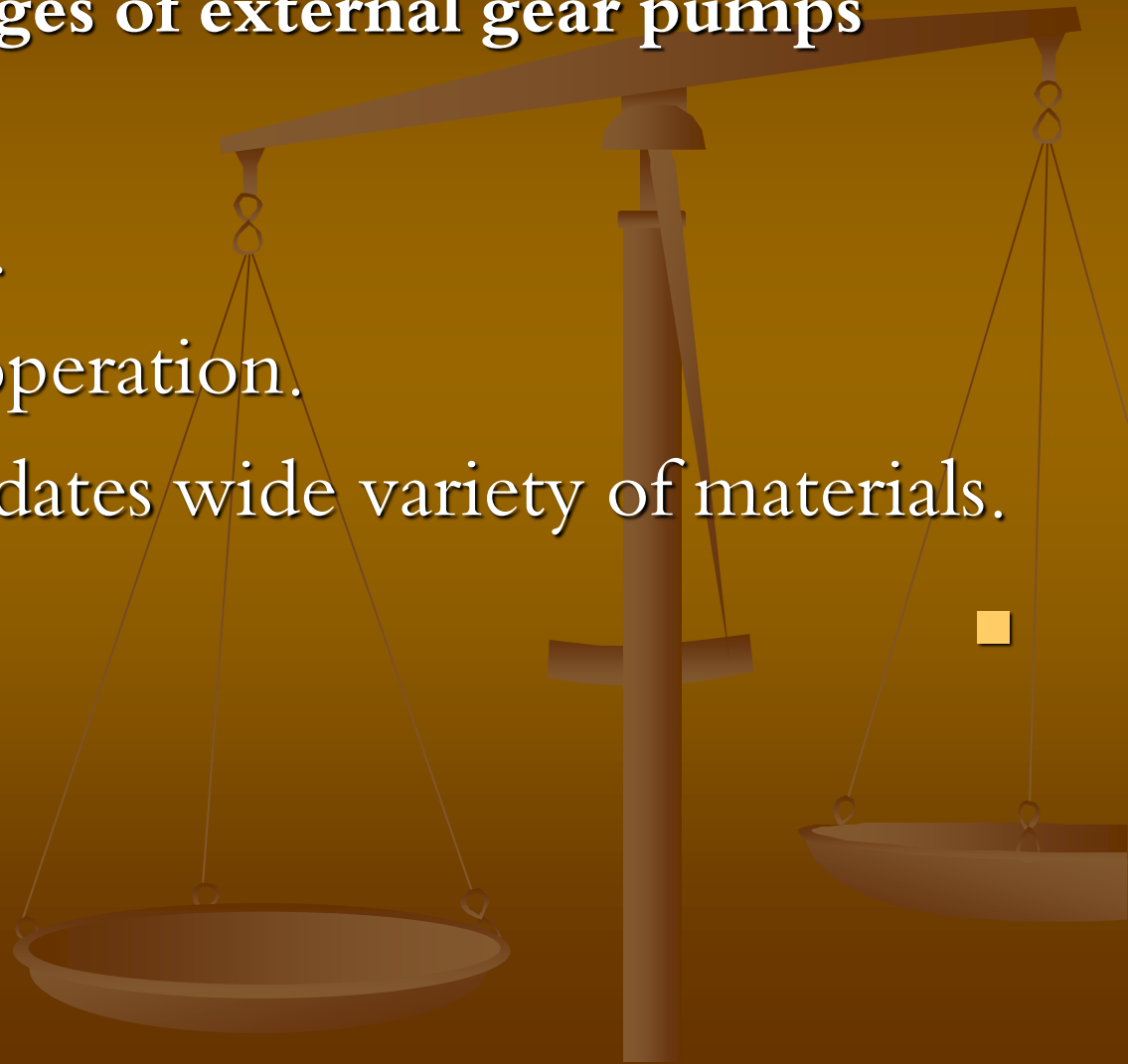
POSITIVE DISPLACEMENT PUMPS



External gear pumps

Advantages of external gear pumps

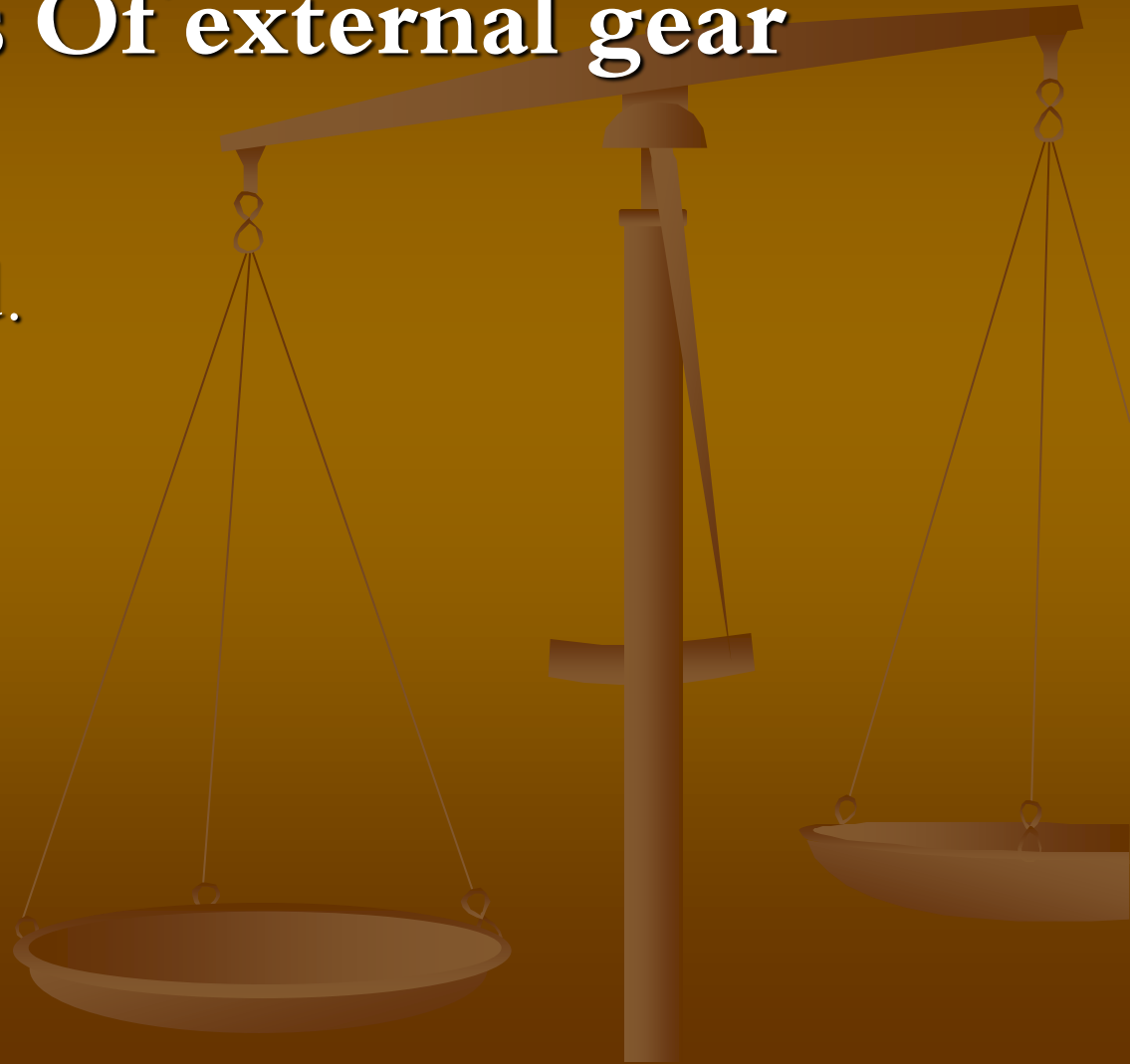
- High speed.
- Medium pressure.
- Relatively quiet operation.
- Design accommodates wide variety of materials.



External gear pumps

Disadvantages Of external gear pumps

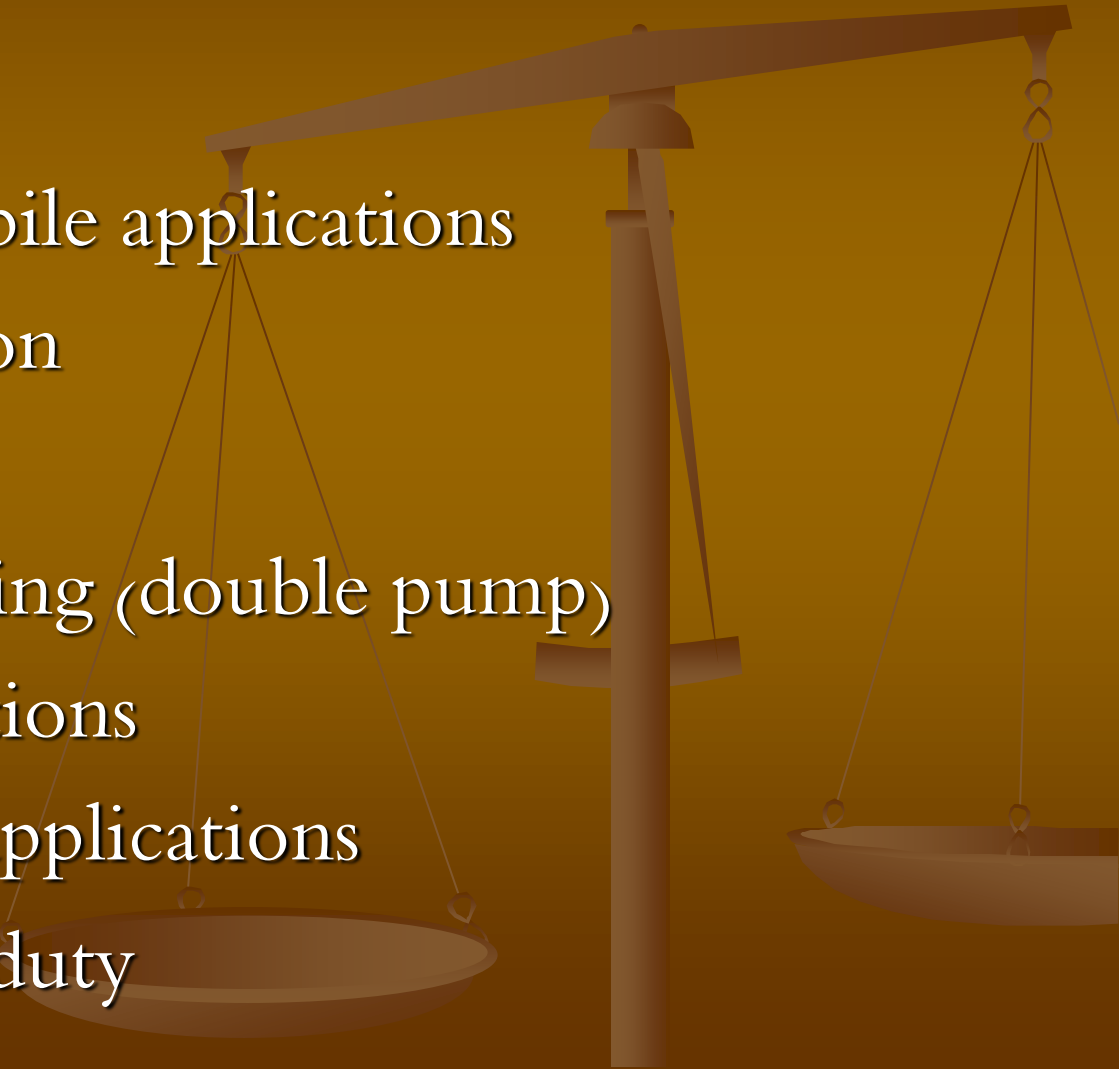
- No solids allowed.



External gear pumps

Applications

- Industrial and mobile applications
- Fuel and lubrication
- Metering
- Mixing and blending (double pump)
- Hydraulic applications
- Precise metering applications
- Light or medium duty

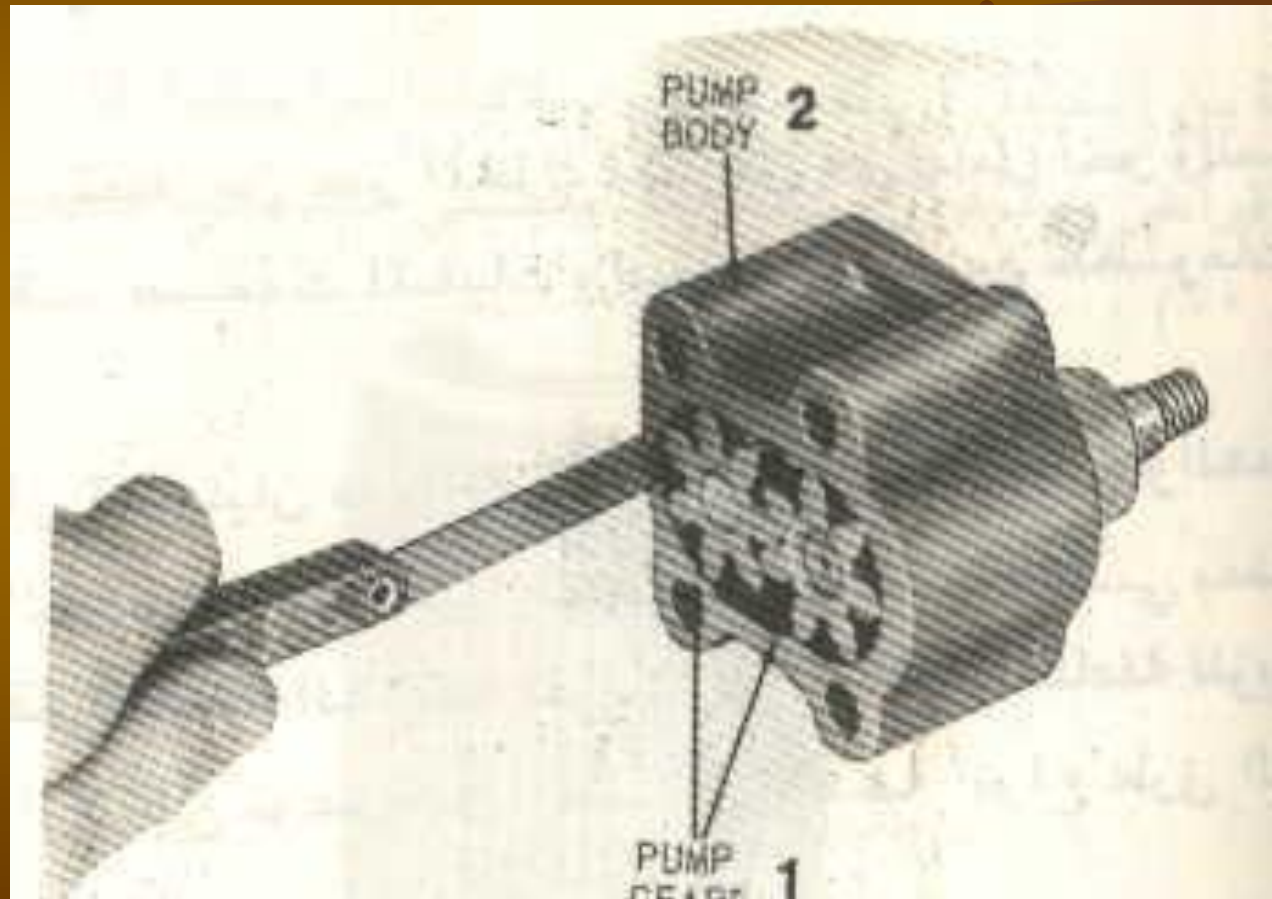


TROUBLESHOOTING MATRIX

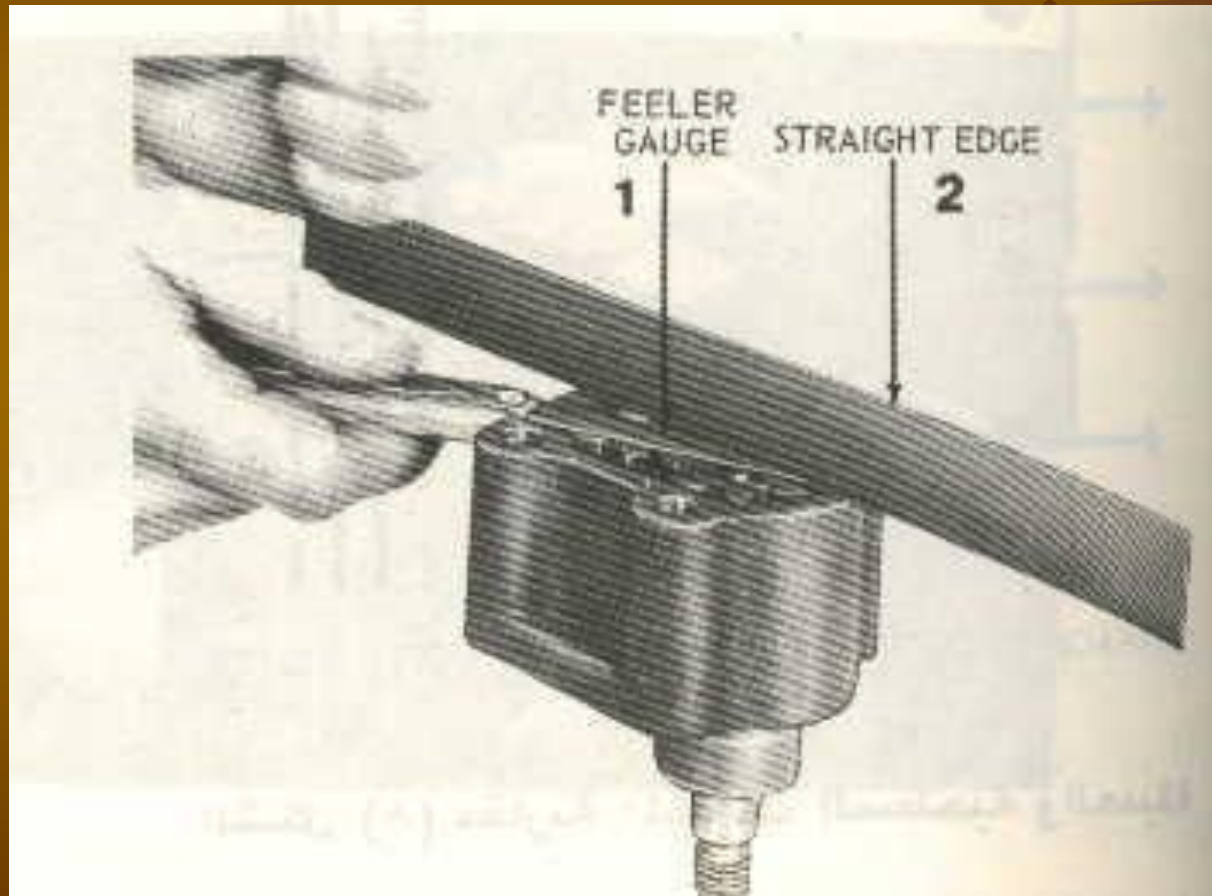
Difficulty	Probable Cause	Remedy
No Liquid Delivery	1) Closed valves	1) Open valves
	2) Plugged suction	2) Eliminate restriction
	3) Air leak at suction	3) Locate and repair leak
	4) Suction lift too high	4) Do not exceed vapor pressure of liquid
	5) Motor wired incorrectly	5) Check wiring diagram
	6) Wrong rotation	6) Correct rotation
Low Liquid Delivery	1) Pump shaft speed incorrect	1) Check driver speed, motor wiring, pulley tension
	2) Discharge pressure too high	2) Reduce downstream pressure
	3) Air leak at suction	3) Locate and repair leak
	4) Worn or damaged pump	4) Inspect and repair as required
	5) Low viscosity	5) Verify original application conditions
Gradually Loses Prime	1) Suction lift too high	1) Improve suction pressure
	2) Air or gas in fluid	2) Eliminate air or gas from fluid
	3) Air leak at suction	3) Locate and repair leak
	4) Worn or damaged pump	4) Inspect and repair as required
Noisy	1) Cavitating	1) Improve system suction pressure, provide adequate NPSH
	2) Solid particles in fluid	2) Install suction strainer. Clean suction strainer.
	3) Air or gas in fluid	3) Eliminate air or gas from fluid
	4) Worn or damaged pump	4) Inspect and repair as required

Motor Runs Hot or Overloads	1) Discharge pressure too high	1) Reduce downstream pressure. Check relief valve setting. Be sure discharge pressure gages function correctly.
	2) Shaft speed too fast	2) Reduce speed
	3) Fluid viscosity higher than expected	3) Change to larger horsepower or higher service factor motor. Thin fluid.
	4) Incorrectly wired motor	4) Check wiring diagram
	5) Binding internal pump parts	5) Inspect and correct condition
	6) Motors normally feel hot	6) Verify if actual motor amperage draw is within range
Seal Leaks	1) Dry running	1) Open valves. Prim pump
	2) Solids in fluids	2) Add suction strainer
	3) Damaged during field replacement	3) Inspect and replace damaged components
	4) Seal material incompatible with fluid	4) Verify original application conditions. Consult factory.

External gear pumps



External gear pumps



POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

■ Low volumetric efficiency (failure to deliver rated capacity and pressure

- 1) Air or vapor pocket in inlet line
- 2) Capacity of charge pump less than capacity of power pump
- 3) Air or vapor trapped in or above inlet manifold
- 4) Air leak in liquid supply piping system
- 5) Loose bolts in pump inlet manifold
- 6) Air or gases entrained in liquid
- 7) Foreign object holding pump inlet or discharge valve(s) open
- 8) Incorrect drive ratio
- 9) Loose belts

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

■ Low volumetric efficiency (failure to deliver rated capacity and pressure)

- 10) Incorrect motor or engine speed
- 11) Loose valve covers or cylinder head
- 12) Worn valves and seats
- 13) Safety relief valve partially open, or not holding pressure
- 14) Worn liners, piston rings or plungers
- 15) Bypass valve open, or not holding pressure
- 16) Blown liner gasket
- 17) NPSHA not sufficient

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

- 1) Inlet line partially clogged
- 2) Liquid vapor pressure too high
- 3) Liquid pumping temperature too high
- 4) Restricted inlet pipe fittings
- 5) Inlet line too NPSHA Too Low
long
- 6) Too many pipe fittings
- 7) Too small inlet line
- 8) Too low static inlet head

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

Excessive Valve Noise

- 1) Broken or weak valve spring
- 2) Pump cavitation
- 3) Air leak in inlet piping or loose bolts in pump inlet manifold
- 4) Air trapped above inlet valve

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

■ Oil Leakage from Crankcase

- 1) Oil Level/Temperature Too High
- 2) Worn seals
- 3) Worn Crankcase Packing
- 4) Loose Crankcase Cover

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

■ Water in Crankcase/Oil

- 1) Water Condensation
- 2) Worn seals
- 3) Clogged Air Breather(s)
- 4) Worn Crankcase Packing
- 5) Loose Covers

POSITIVE DISPLACEMENT PUMPS TROUBLESHOOTING

- Stuffing Box Leakage
 - 1) Worn Packing
 - 2) Worn rods or plunger
 - 3) Worn stuffing boxes
 - 4) Wrong size packing
 - 5) Worn O-ring seal (replaceable boxes)

Thank you