What is Pump

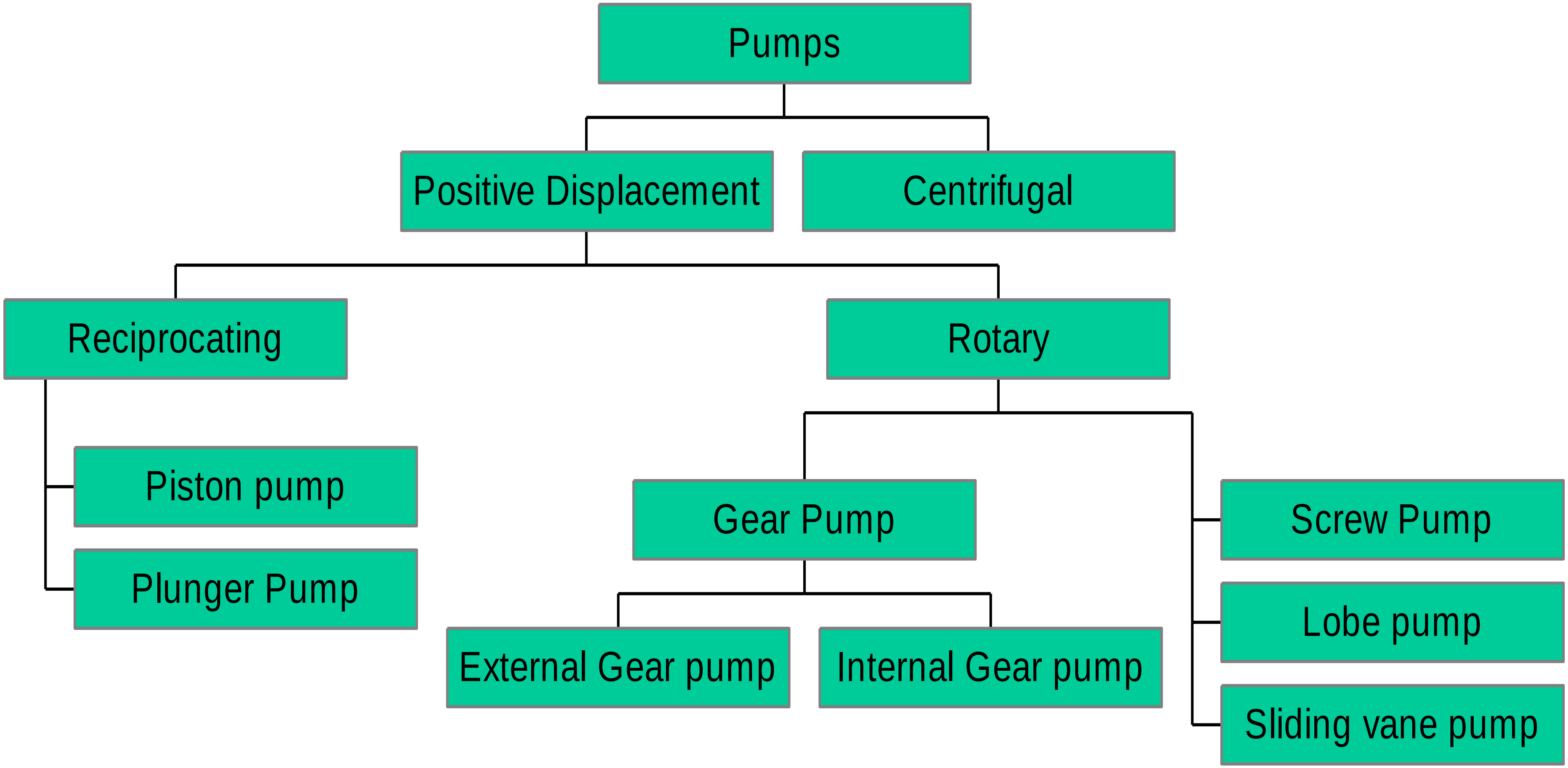
Pump is a mechanical device to transfer the incompressible fluid from low energy level to high energy level when driven by prime mover.

Classification of pumps

Pumps can be classified on following parameters.

- Nature of the liquid to be pumped.
- Pumping rate and pressure requirement.
- Suction condition
- Relative cost
- nature of the drive.

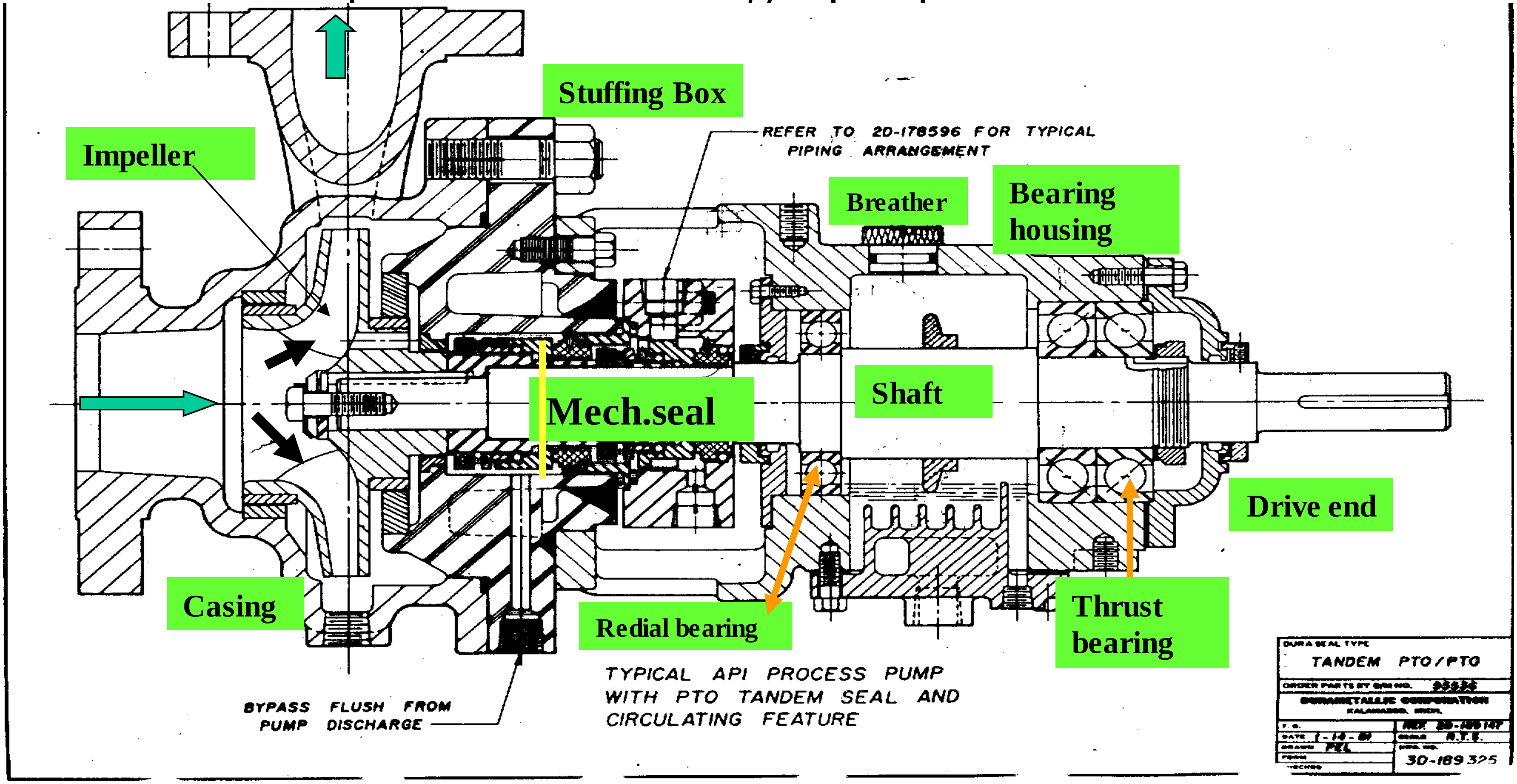
Classification of pumps



Introduction to centrifugal pump

It is rotating device to impart kinetic energy to liquid which is required to transfer liquid flow form lower energy level to higher energy level.

The main components of centrifugal pump

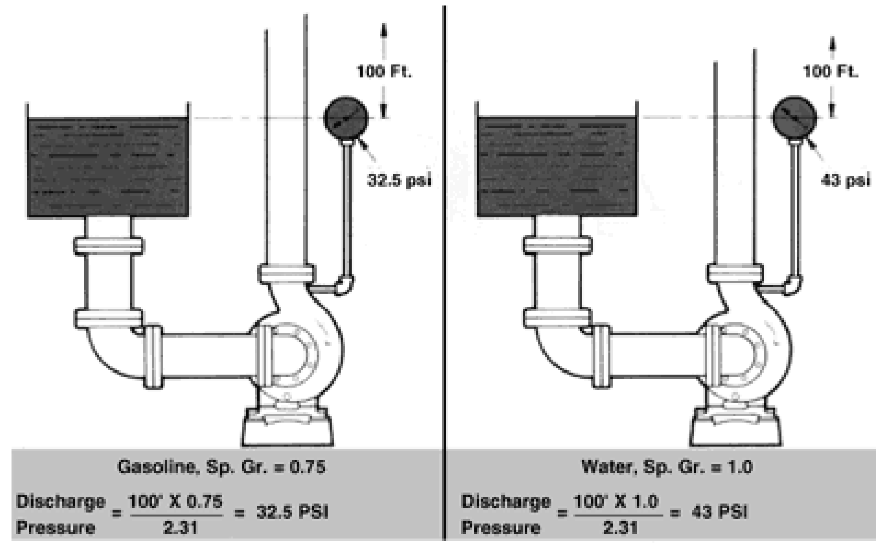


Basic information on head, capacities, speeds, Affinity Laws, Pump and System Curves

Head

The static head corresponding to any specific pressure is dependent upon the weight of the liquid according to the following formula.

$$\text{Head in Feet} = \frac{\text{Pressure in psi} \times 2.31}{\text{Specific Gravity}}$$



A Centrifugal pump imparts velocity to a liquid. This velocity energy is then transformed largely into pressure energy as the liquid leaves the pump.

Therefore, the head developed is approximately equal to the velocity energy at the periphery of the impeller This relationship is expressed by the following well-known formula:

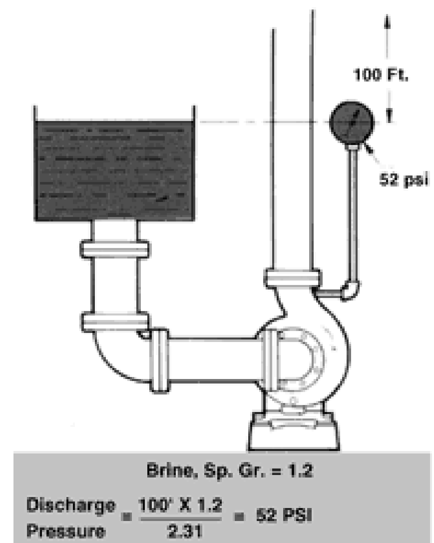
$$H = \frac{v^2}{2g} \qquad v = \frac{\text{RPM} \times D}{229}$$

Where H = Total head developed in feet.

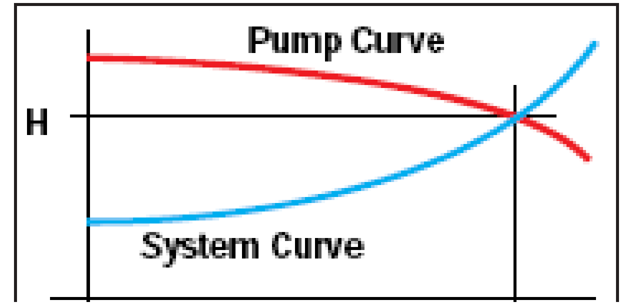
v = Velocity at periphery of impeller in feet per sec.

g = 32.2 Feet/Sec2 **D** = Impeller diameter in inches

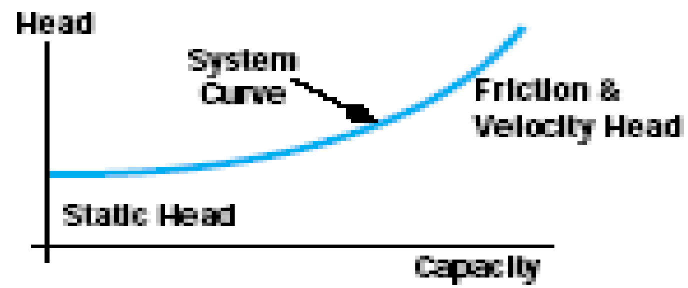
V = Velocity in ft./sec



Capacity – The flow delivered at discharge nozzle against a given system pressure- i.e. How much & How fast



Pump Characteristics curves- Graphical representation of pump performance

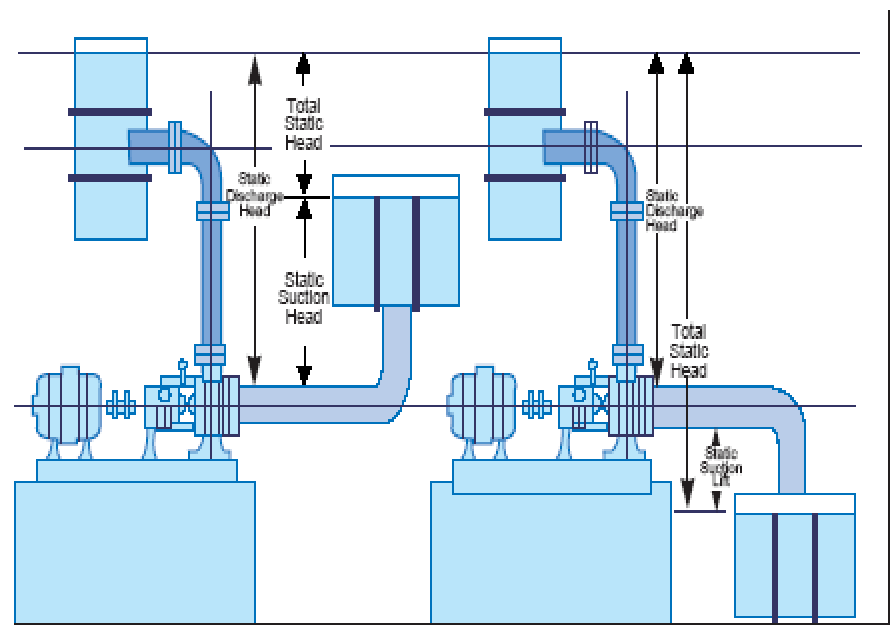


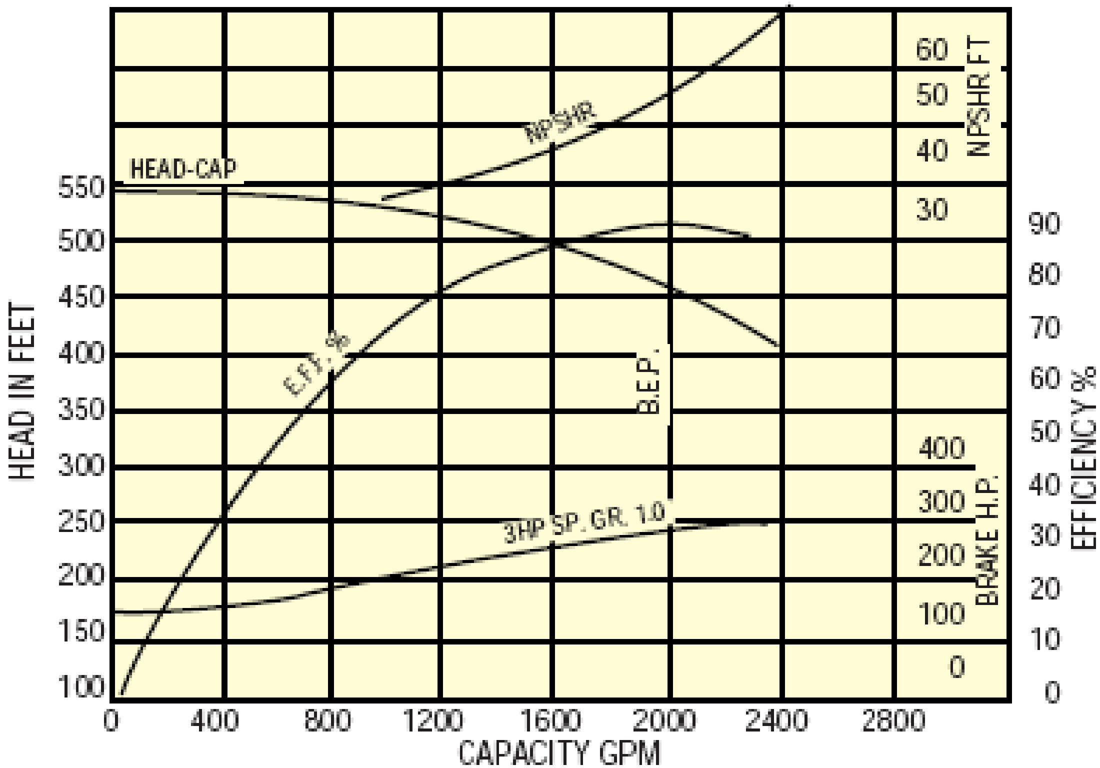
System Curve-The system curve represents the pressures needed at different flow rates to move the product through the system.

Net positive suction head- The head required to push liquid to impeller eye of pump

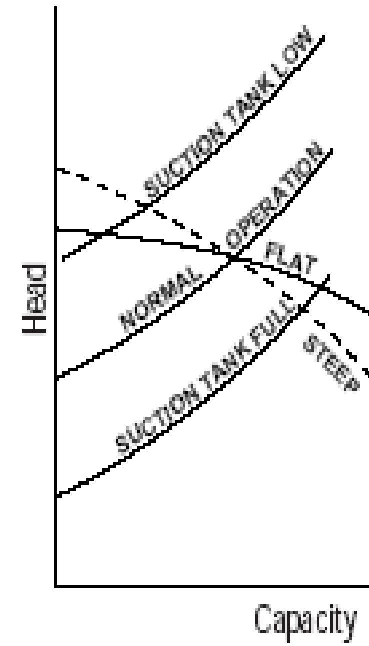
Power and efficiency –The work performed by the pump

Affinity law-Performance variable relationship

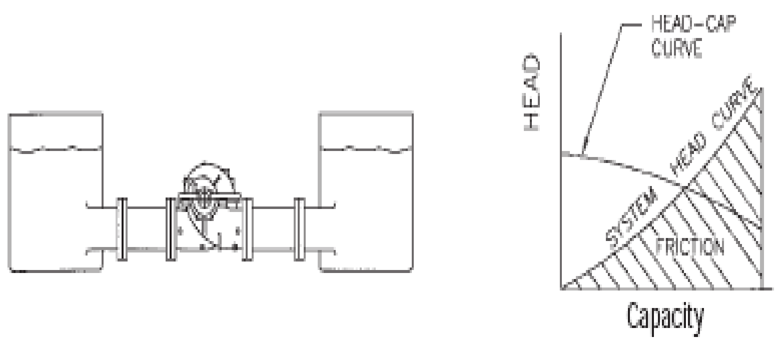




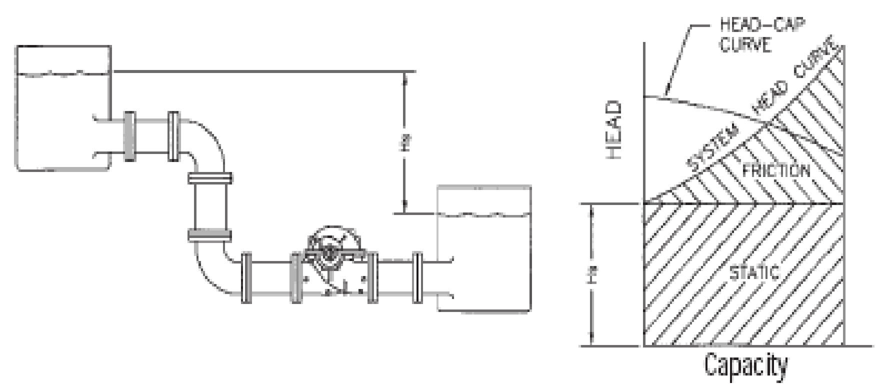
EVALUATING PUMP CURVES AGAINST VARIABLE SYSTEM HEAD CURVES



SYSTEM HEAD CURVE, ALL FRICTION



SYSTEM HEAD CURVE, STATIC HEAD PLUS FRICTION



Classification of centrifugal pumps

Based on the head & flow characteristics , the centrifugal pumps can be classified under three general categories as:

Radial Flow :

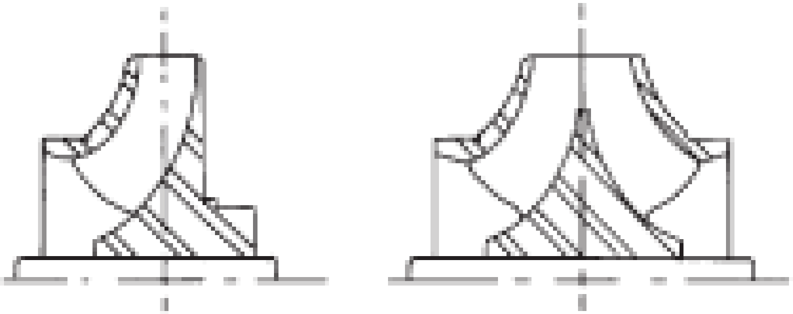
A pump in which the pressure is developed by the action of centrifugal force. The liquid normally enters at the hub and flows radially to the periphery. Pumps in this class usually have a specific speed below 4200 (US units), for single inlet impellers.

Classification of centrifugal pumps

- **Mixed flow :**
  A pump in which the head is developed partly by centrifugal force and partly by the lift of the vanes on the liquid. This type of pumps has a single impeller, with the flow entering axially and discharging in an axial and radial direction. Pumps of this type have specific speeds varying from 4200 to 9000 (US units).

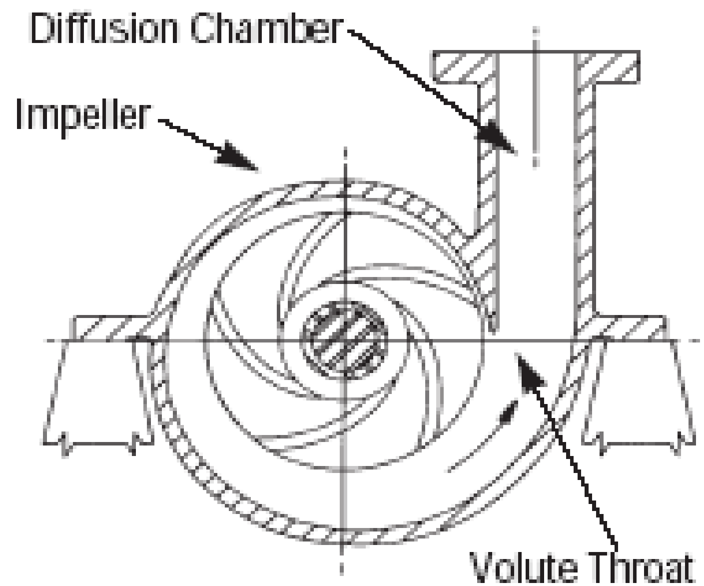
Classification of centrifugal pumps

- **Axial flow :**
  A pump of this type, also called the propeller pump, develops most of its head by the propelling or lifting action of the vanes on the liquid. It has a single inlet impeller, with the flow entering axially and also discharging axially. Pumps of this type usually have a specific speed above 9000 (US units).



SINGLE SUCTION IMPELLER

DOUBLE SUCTION IMPELLER



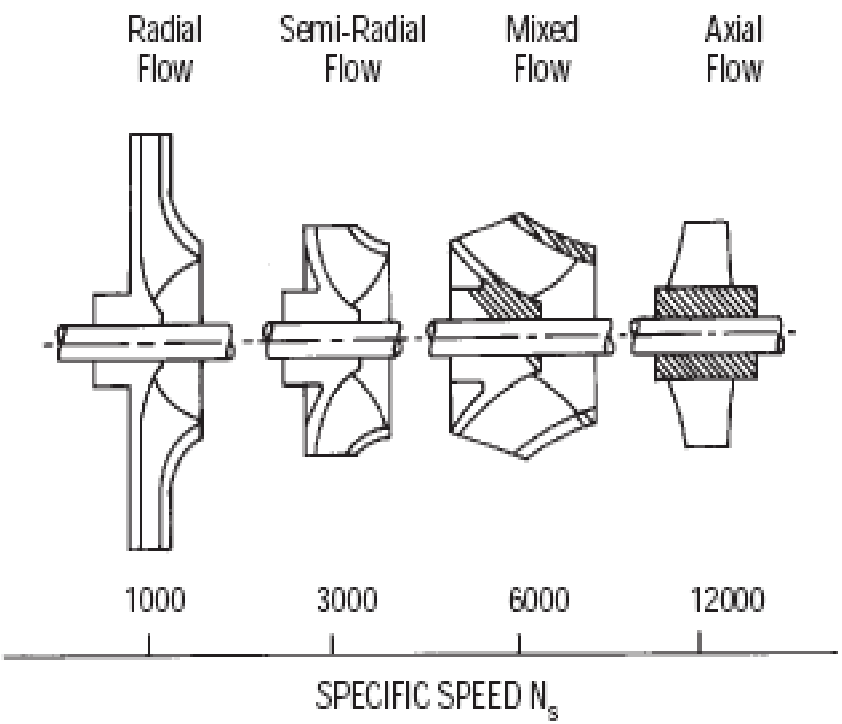
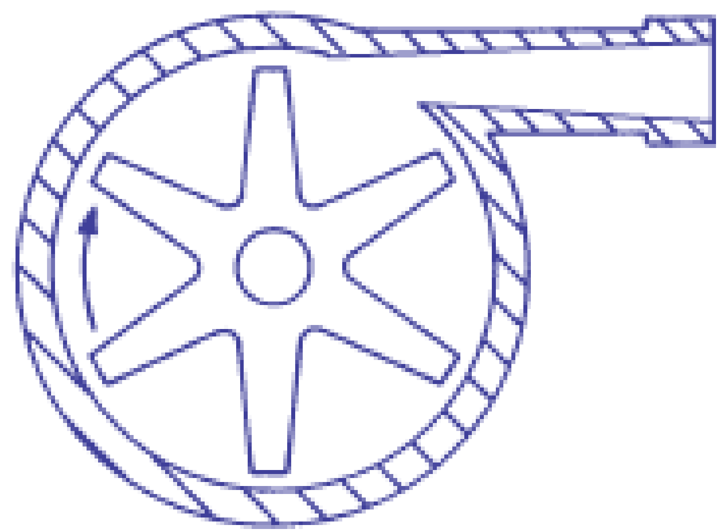
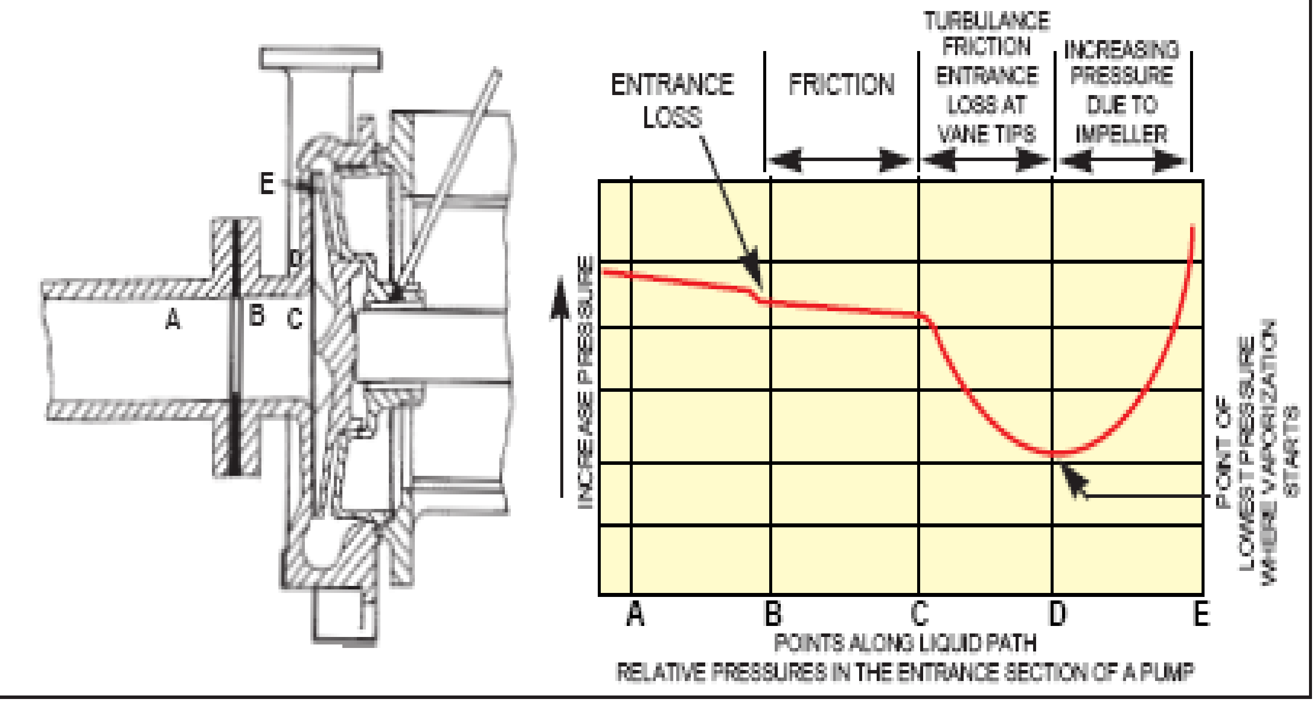


FIGURE 1. OPEN IMPELLER

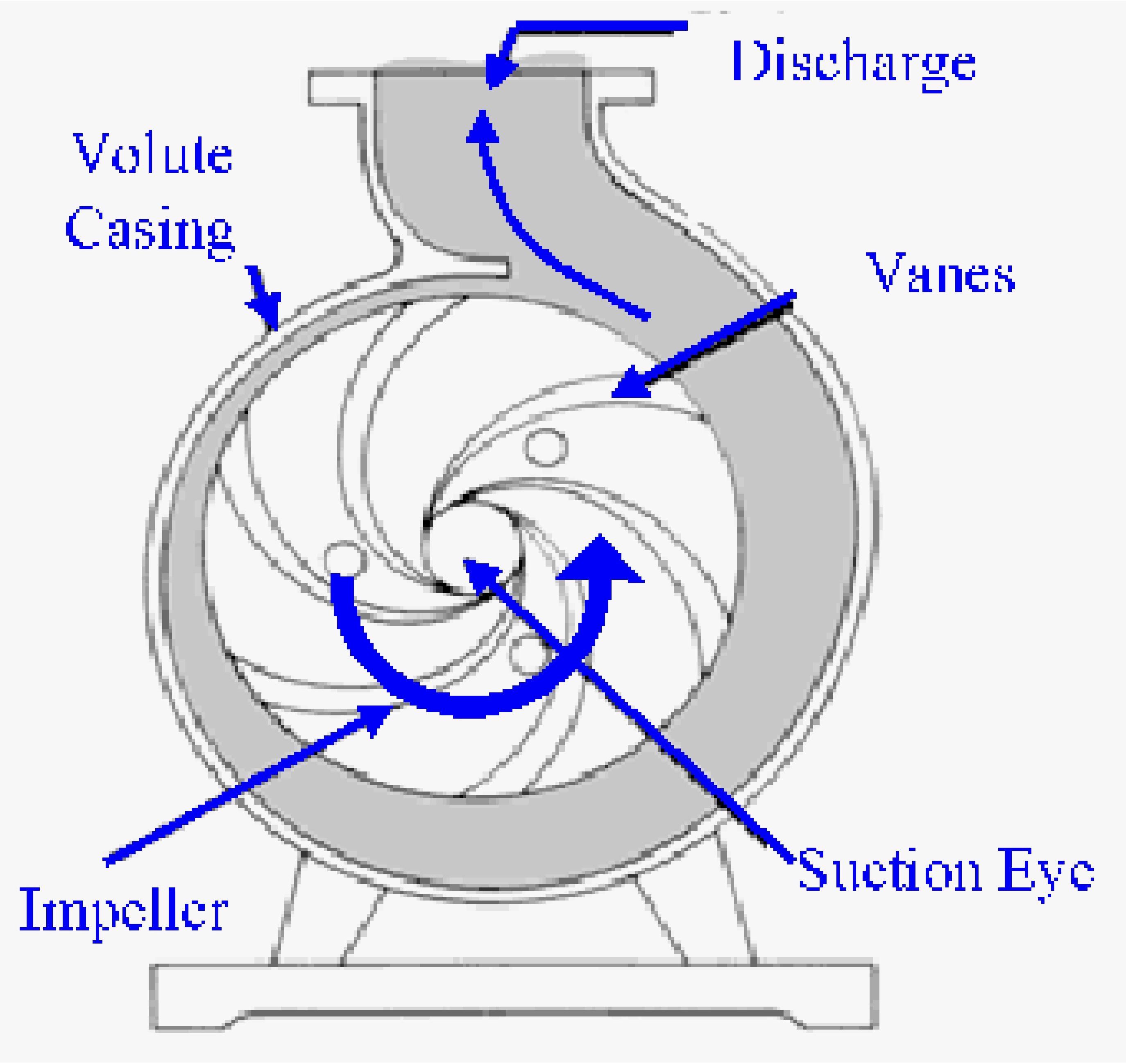


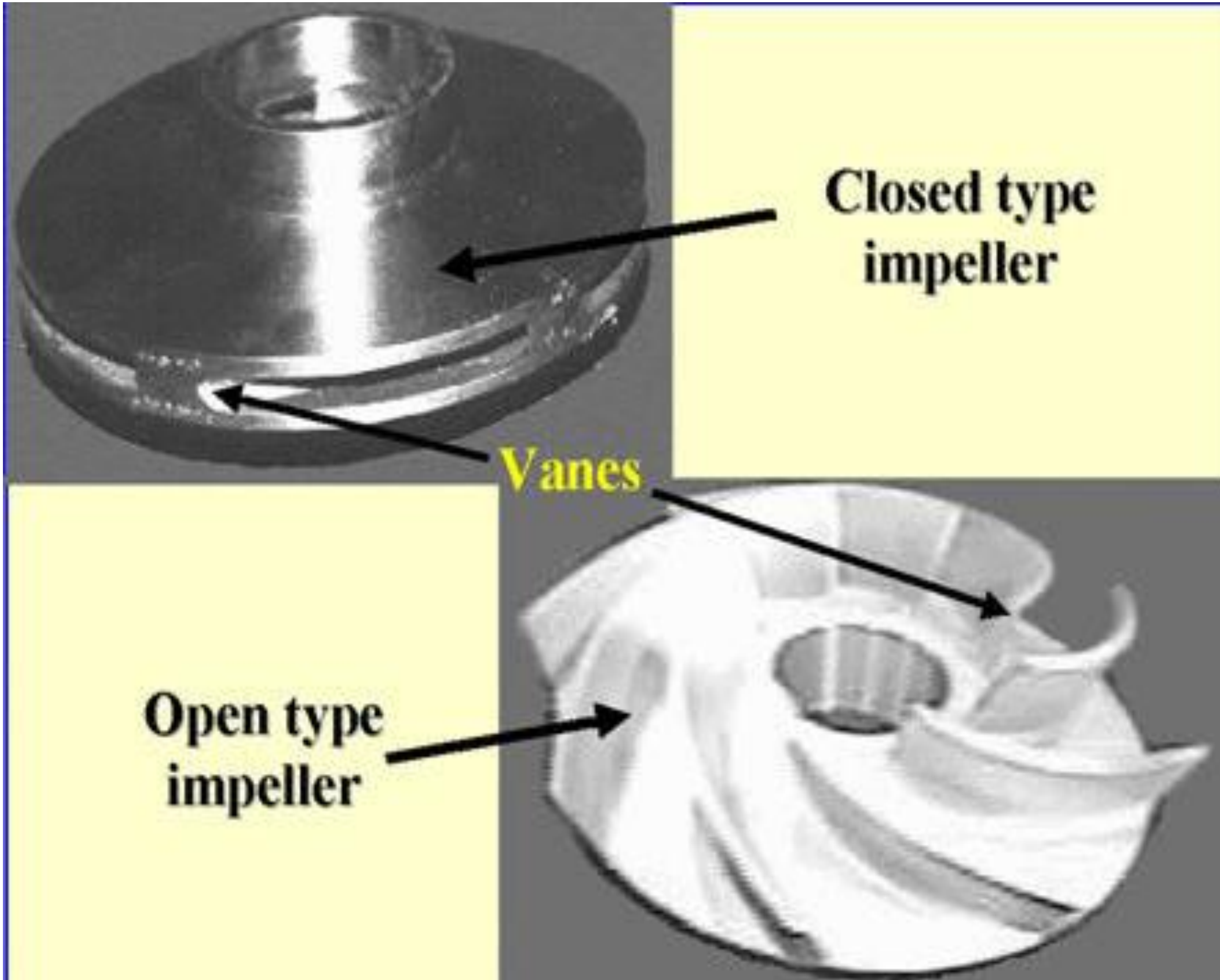


The pressure profile across a typical pump at a fixed flow condition.

Basic components of Pump

- **Casing**: the body of the pump which encloses the impeller.
- **Impeller**: the rotating element of a pump which imparts movement and pressure to a fluid


Discharge
Volute
Casing
Vanes
Impeller
Suction Eye


Closed type impeller
Vanes
Open type impeller

Various Terminology used in pump

- **Best Efficiency Point (B.E.P.)**: the point on a pump's performance curve that corresponds to the highest efficiency
- **Cavitation**: the sudden collapse of gas bubbles due to the sudden pressure increase

Various Terminology used in pump

- **Centrifugal force**: a force associated with a rotating body. In the case of a pump, the rotating impeller pushes fluid on the back of the impeller blade, imparting motion. Since the motion is circular there is a centrifugal force associated with it. The force pushes the fluid against a fixed pump casing thereby pressurizing the fluid

Various Terminology used in pump

- **Discharge Static Head**: the difference in elevation between the liquid level of the discharge tank and the centerline of the pump. This head also includes any additional head that may be present at the discharge tank fluid surface.
- **Friction head difference**: the difference in head required to move a mass of fluid from one position to another at a certain flow rate

Various Terminology used in pump

- **Head**: refers to the pressure produced by a vertical column of fluid
- **Net Positive Suction Head (N.P.S.H.)**: the head in feet of water absolute as measured or calculated at the pump suction flange, less the vapor pressure (converted to feet of water absolute) of the fluid
- Performance curve: a curve of flow vs. Total Head for a specific pump model and impeller diameter

Various Terminology used in pump

- **Shut-off head**: the Total Head corresponding to zero flow on the pump performance curve
- **Specific gravity**: the ratio of the density of a fluid to that of water at standard conditions
- **Suction Static Head**: the difference in elevation between the liquid level of the source of supply and the centerline of the pump. This head also includes any additional head that may be present at the suction tank fluid surface

Various Terminology used in pump

- **Suction Static Lift**: the same definition as the Suction Static head. This term is only used when the pump centerline is above the suction tank fluid surface.
- **Total Head**: the difference between the head at the discharge and suction flange of the pump
- **Turbulent**: a type of flow regime characterized by the rapid movement of fluid particles in many directions as well as the general direction of the overall fluid flow

Various Terminology used in pump

- **Vapor pressure**: the pressure at which a liquid boils at a specified temperature
- **Velocity Head difference**: the difference in velocity head between the outlet and inlet of the system
- **Viscosity**: a property, which measures a fluid's resistance to movement. The resistance is caused by friction between the fluid and the boundary wall and internally by the fluid layers moving at different velocities

Selection of Pump

For selection of pump following information's are required

A) Characteristics of the fluid

- What it is
- Pumping temperature
- Specific Gravity at pumping temp.
- Is there any corrosive elements presents if yes than what they are
- Vapor pressure at pumping temp.

Selection of Pump

B) Desired pumping rate

C) Pressure conditions required

- Discharge Pressure
- Suction pressure
- Differential Pressure
- Whether pump has to be operated in series or parallel with other pump.

Selection of Pump

D) NPSH available

E) Type of pump desired

F) Flange ratings

G) Is mechanical seal required

H) Is cooling water available

I) Preferred metallurgy of metal parts

Selection of Pump

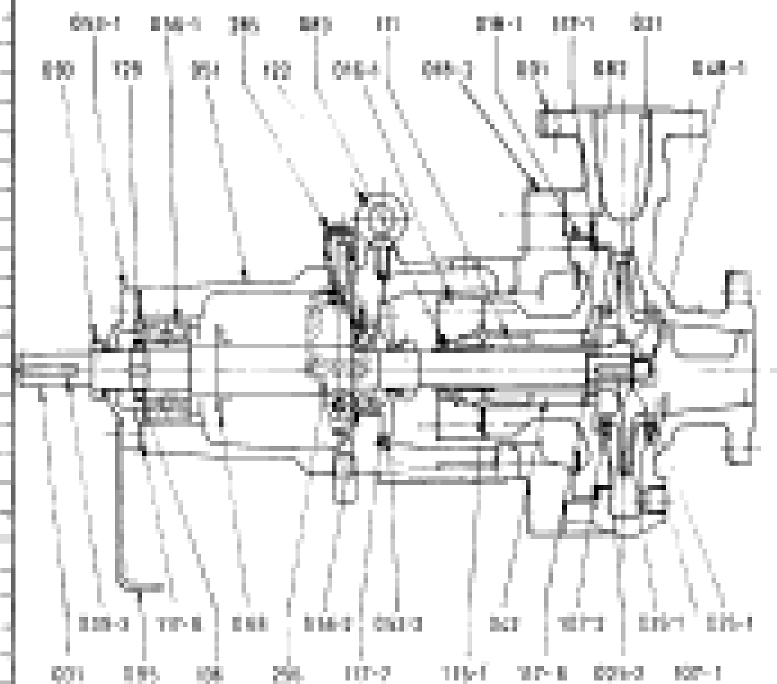
J) Type of driver & Characteristics of electrical power or steam

K) Whether pump must confirm to API standard 610

L) Space limitation if any.

PART No.	NAME OF PART	MATERIAL	STANDARD	No. PL.
001	PUMP CASING	C.S.	ASTM A216 - Gr WCB	1
003-1	SEAL END PLATE	F.S.	ASTM A216 - WCB	1
018-1	GLAND COVER - I	C.S.	ASTM A216 - WCB	1
018-2	GLAND COVER - II	C.S.	IS 2062 Gr. Fe 410B	1
021	IMPELLER	13% Cr Steel	ASTM A743 - CA-6NM	1
025-1	IMPELLER WEAR RING	13% Cr steel	ASTM A743 - CA15	1
025-2	IMPELLER WEAR RING	13% Cr steel	ASTM A743 - CA15	1
031	SHAFT	AISI 4140	ASTM A322 Gr 4140	1
039-1	KEY	C.S.	IS 1570 - 40C8	1
039-2	KEY	C.S.	IS 1570 - 40C8	1
042	MECHANICAL SEAL SLEEVE	SS 316	ASTM A276 Gr 316	1
048-1	IMPELLER NUT	C.S.	IS 1570 - 40C8	1
051	BEARING HOUSING	C.I.	IS 210 Gr FG 260	1
053-1	BEARING COVER	C.I.	IS 210 Gr FG 260	1
053-2	BEARING COVER	C.I.	IS 210 Gr FG 260	1
056-1	BALL BEARING	Steel	SKF 3306	1
056-2	BALL BEARING	Steel	SKF 6307 - C3	1
058	OIL FLINGER	Bronze	IS 318 Gr II	1
080	THROAT BUSH	13% Cr steel	ASTM A 276 - 410 H	1
081	THROTTLE BUSHING	Bronze	IS 318 Gr II	1
083	DEFLECTOR	Bronze	IS 318 Gr II	1
085	STAY	C.S.	IS 1570 - 45C8	1
107-1	CASE WEAR RING	13% Cr steel	ASTM A743 CA15	1
107-2	CASE WEAR RING	13% Cr steel	ASTM A743 CA15	1
111	MECHANICAL SEAL	Sealol / Burgmann	API 682	1
115-1	O' RING	Viton		1
117-1	GASKET	18-8 SS spiral wound asbestos		1
117-6	GASKET	CAF		1
117-7	GASKET	CAF (A/F)		1
117-8	GASKET	CAF (A/F)		1
122	HOOK BOLT	Carbon steel		1
129	BEARING NUT	Carbon steel		1
136	WASHER	Carbon steel		1
258	CONSTANT LEVEL OILER	Aluminium with glass		1
265	AIR BREATHER	Steel		1

Hardness: 225 to 275 BHN
325 to 375 BHN
API 682 - 8th Edn.



MECH. SEAL FLUSHING PLAN : API 11
COOLING PLAN : N.A.

REV. No.	REVISION		DATE

CROSS SECTIONAL ASSEMBLY OF 50×40 UCW M13 PUMP			
ENQ. No.		P.O. No.	GE/ORD/489
PURCHASER NAME	GOUR ENTERPRISES	CUSTOMER	HINDUSTAN PETROLEUM CORP. Ltd.
CONSULTANT		SERVICE	
PROJECT	FR - VPS		
JOB No.		EQUIPMENT No.	
DRAWN / CHD / APPD	KIRLOSKAR EBARA PUMPS LTD.	DRG. No.	

HINDUSTAN PETROLEUM CORPORATION LIMITED

CENTRIFUGAL PUMP SPECIFICATION SHEET

OPERATING CONDITIONS

PERFORMANCE

CONSTRUCTION AND MATERIALS

MATERIAL CODE

APPROVED

Understanding Centrifugal Pump Performance Curves

The capacity and pressure needs of any system can be defined with the help of a graph called a ***system curve***. Similarly the capacity *vs*. pressure variation graph for a particular pump defines its characteristic ***pump performance curve***.

The pump suppliers try to match the system curve supplied by the user with a pump curve that satisfies these needs as closely as possible. A pumping system operates where the pump curve and the system resistance curve intersect. The intersection of the two curves defines the operating point of both pump and process. However, it is impossible for one operating point to meet all desired operating conditions. For example, when the discharge valve is throttled, the system resistance curve shift left and so does the operating point.

Figure D.01: Typical system and pump performance curves

Developing a system curve

The *system resistance or system head curve* is the change in flow with respect to head of the system. **It must be developed by the user based upon the conditions of service.** These include physical layout, process conditions, and fluid characteristics. It represents the relationship between flow and hydraulic losses in a system in a graphic form and, since friction losses vary as a square of the flow rate, the system curve is parabolic in shape. Hydraulic losses in piping systems are composed of pipe friction losses, valves, elbows and other fittings, entrance and exit losses, and losses from changes in pipe size by enlargement or reduction in diameter.

Developing a Pump performance Curve

A pump's performance is shown in its characteristics performance *curve* where its
capacity i.e. flow rate is plotted against its developed head. The pump performance curve
also shows its efficiency (BEP), required input power (in BHP), NPSHr, speed (in RPM),
and other information such as pump size and type, impeller size, etc. This curve is
plotted for a constant speed (rpm) and a given impeller diameter (or series of diameters).

It is generated by tests performed by the pump manufacturer. Pump curves are
based on a specific gravity of 1.0. Other specific gravities must be considered by the
user.

Normal Operating Range

A typical performance curve (Figure D.01) is a plot of Total Head vs. Flow rate for a specific impeller diameter. The plot starts at zero flow. The head at this point corresponds to the shut-off head point of the pump. The curve then decreases to a point where the flow is maximum and the head minimum. This point is sometimes called the run-out point. The pump curve is relatively flat and the head decreases gradually as the flow increases. This pattern is common for radial flow pumps. Beyond the run-out point, the pump cannot operate. The pump's range of operation is from the shut-off head point to the run-out point. Trying to run a pump off the right end of the curve will result in pump cavitation and eventually destroy the pump.

In a nutshell, by plotting the system head curve and pump curve together, you can determine:

1. Where the pump will operate on its curve?
2. What changes will occur if the system head curve or the pump performance curve changes?

Two Basic Requirements for Trouble-Free Operation of Centrifugal Pumps

Centrifugal pumps are the ultimate in simplicity. In general there are two basic requirements that have to be met at all the tim es for a trouble free operation and longer service life of centrifugal pumps.

The **first** requirement is that no cavitation of the pump occurs throughout the its consequences is very much essential in effective analyses and troubleshooting of the cavitation problem.

broad operating range and the **second** requirement is that a certain minimum continuous
flow is always maintained during operation.
A clear understanding of the concept of cavitation, its symptoms, its causes, and

Cavitaion

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

The bubbles form inside the liquid when it vaporises i.e. phase change from liquid to vapor.

But how does vaporization of the liquid occur during a pumping operation?

Vaporization of any liquid inside a closed container can occur if either pressure on the liquid surface decreases such that it becomes equal to or less than the liquid vapor pressure at the operating temperature, or the temperature of the liquid rises, raising the vapor pressure such that it becomes equal to or greater than the operating pressure at the liquid surface.

Impeller cavitation regions

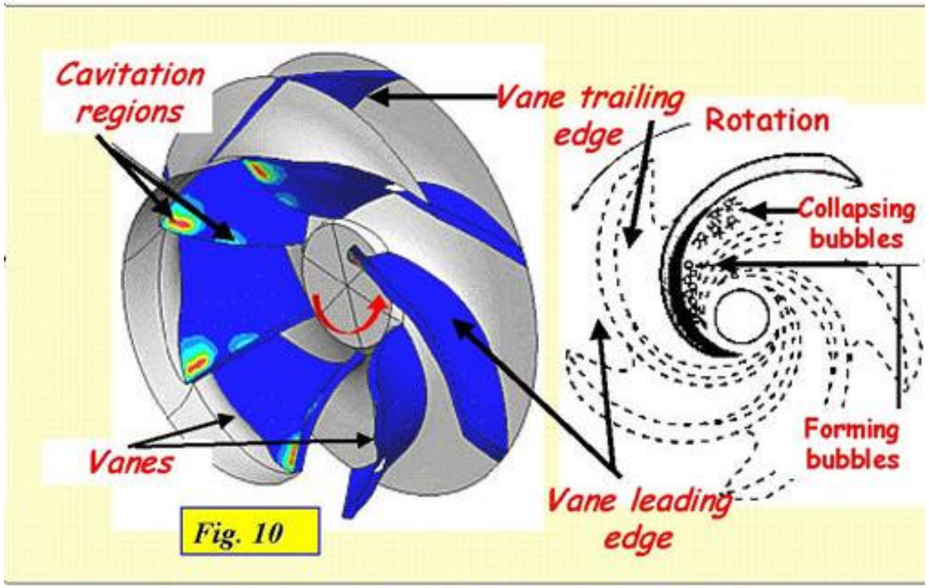
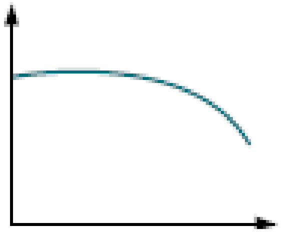
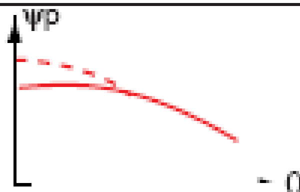
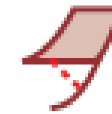
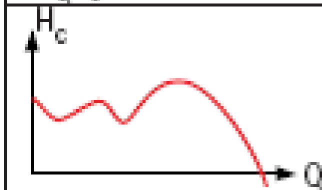
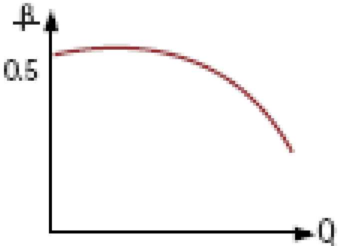
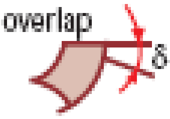
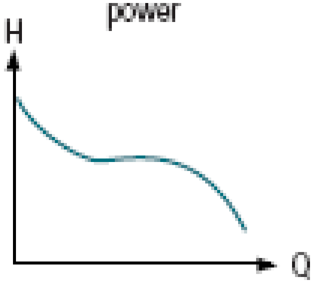
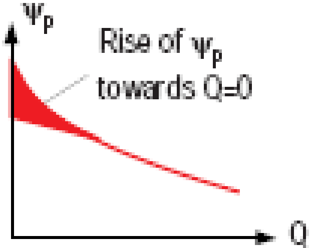
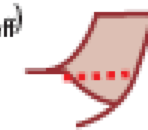
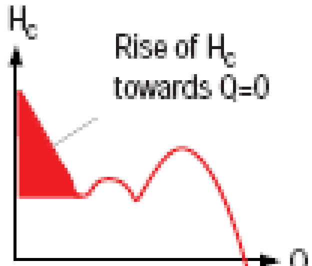
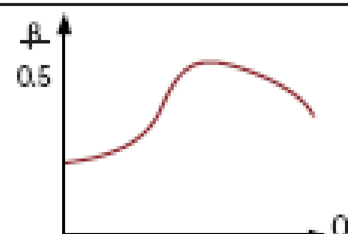
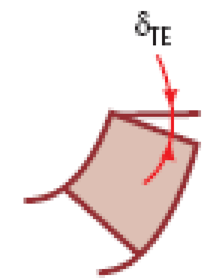


Fig. 10

www.cheresources.com , *The Chemical Engineer's Resource Page*

TABLE 1. MEANS TO UNDERSTAND AND TO MODIFY THE SHAPE OF THE HEAD/CAPACITY CHARACTERISTIC (HCC)

<table>
<tr><th colspan="3">Symptoms</th><th rowspan="2">Possible causes or mechanisms</th><th>Possible remedies</th></tr>
<tr><th>Q-H-curve</th><th>Internal pressures</th><th>Axial thrust, β/ω = f (Q)</th><th>NOTE: any modifications may have side-effects which should be carefully assessed</th></tr>
<tr><td rowspan="2">1. HCC drooping towards shut-off

Typical for $n_q < 30$</td><td>
H_p, ψ_p flat towards Q=0</td><td></td><td>• Insufficient recirculation at impeller inlet (insufficient centrifugal head increase at low flow)</td><td>• advance impeller vane leading edge (reduce $d_{1\,eff}$)
• advance return vane trailing edge (reduce c_{ou})
• increase d_{1a} (increase $\Delta d_{1\,eff}$)
• reduce hub dia. (increase $\Delta d_{1\,eff}$)
</td></tr>
<tr><td>
H_c, flat or drooping towards Q=0</td><td></td><td>• Insufficient recirculation at impeller outlet (insufficient exchange of momentum between impeller and diffuser at low flow)</td><td>• reduce a_3 or s_8
• increase b_3 / b_2
• reduce gap A, increase overlap
• increase δ_{TE}
• increase b_2
• reduce gap B (with small n_q) but beware of increased pressure pulsations
</td></tr>
<tr><td rowspan="2">2. Excessive shut-off head and/or excessive shut-off power

Typical for $n_q > 35$

H = total dynamic head
Q = net flow through pump</td><td></td><td></td><td>• Excessive recirculation at impeller inlet</td><td>• reduce d_{1i} (increase $d_{1\,eff}$)
• cut back return vane (increase c_{ou})
• reduce d_{1a}
• increase hub dia.
• inlet ring
} reduce $d_{1\,eff}$
</td></tr>
<tr><td>
ψ_p = static head rise of impeller / $(u_2^2/2g)$
H_c = head rise in casing</td><td>
Sudden decrease of β due to outlet recirculation
F_{ax} = axial thrust towards suction
$\frac{\beta}{\omega}$ = ratio fluid/shroud rotation</td><td>• Excessive recirculation at impeller outlet</td><td>• increase a_3 or s_8
• reduce b_3 / b_2
• reduce b_2
• increase δ_{TE}
</td></tr>
</table>

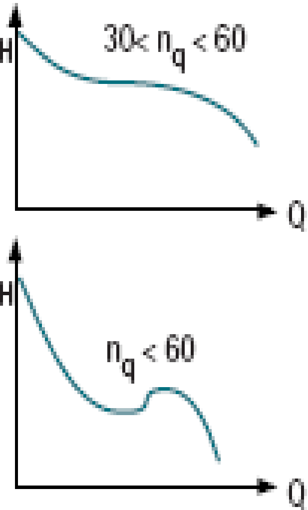
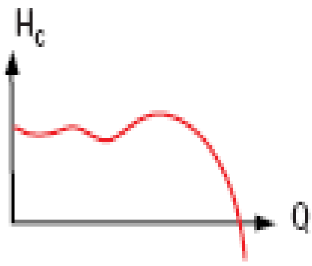
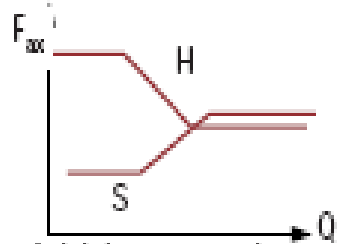
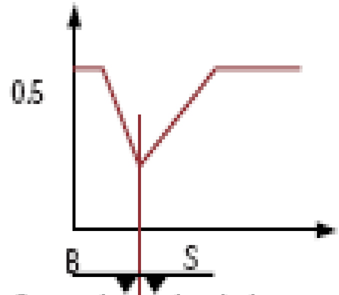
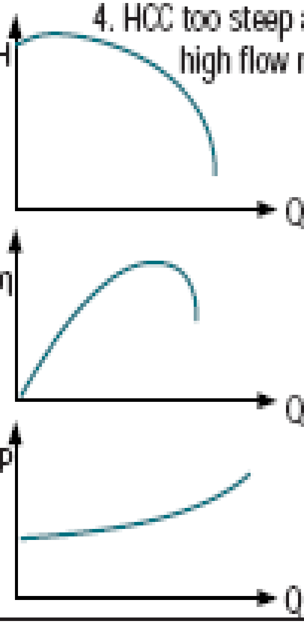
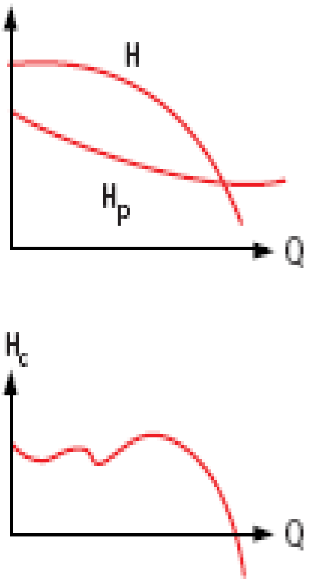
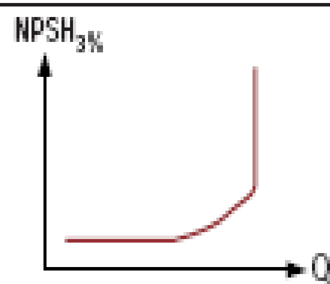
<table>
<tr>
<td>3. HCC with saddle or flat position
</td>
<td></td>
<td>
Axial thrust excursions

S = outlet recirculation on shroud
B = outlet recirculation on hub</td>
<td>• Flow separation in diffuser (volute) but not yet fully developed recirculation
• Shifting of flow patterns (zones of recirculation / flow separation)
• Very sensitive to manufacturing tolerances of diffuser and impeller
• Very sensitive to impeller inlet flow conditions and impeller inlet geometric parameters
• Sensitive to axial rotor position: HCC and F_{ax}</td>
<td>• Axial thrust fluctuations and sensitivity to rotor position / axial stage stacking tolerances can be eliminated by reducing gap A and introducing proper overlap
• To remove saddle type instability detailed flow analysis and / or testing often required
• Differences in stage geometry to get onset of flow separation in different stages at different flow rates</td>
</tr>
<tr>
<td>4. HCC too steep at high flow rates
</td>
<td></td>
<td>
Steep rise of NPSH little or not at all affected by impeller inlet</td>
<td>• Excessive flow acceleration in diffuser or volute throat
• Cavitation in diffuser or volute</td>
<td>• Increase diffuser or volute throat area</td>
</tr>
</table>

TABLE 2. EFFECT OF HYDRAULIC EXCITATION ON COMPONENT FAILURE

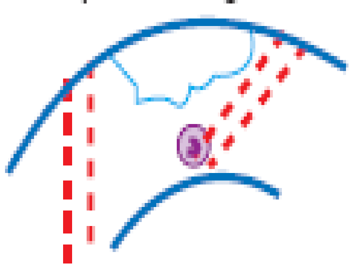
Failure / incident	Possible hydraulic causes or mechanisms	Possible remedies	Possible non-hydraulic causes / remarks
1. Fracture of impeller blades at outlet, diffuser vanes at inlet, tie bolts, instrument piping, or other components	• High dynamic stresses induced by pressure pulsations (impingement of wake flow from impeller blade trailing edge on diffuser vanes or volute cut-water)	• Increase gap B by cutting back (1) diffuser vanes if diffuser throat does not increase by more than 3% (2) impeller blade trailing edge (head of pump will be reduced unless speed cannot be adapted) • Reduce excitation at part load by modifying hydraulic components (careful analysis and redesign)	• There are a number of other failure mechanisms related to design, material selection and quality <u>Remark</u> Pressure pulsations and dynamic stresses are expected to decrease with a power of -0.77 of gap B. For example to achieve half of the original level gap B must be increased by a factor of about 2.5
2. Side plate breakage 	• High dynamic stresses induced by pressure pulsations • Impeller side plate resonance if $\lvert z_3 - z_2 \rvert = 2$ and $z_3\,n/60$ close to impeller side plate natural frequency	• Increase gap B (see previous item) • Change z_3 / z_2 combination • Modify natural frequency • Reduce exciation at part load by modifying hydraulic components	• Insufficient quality of impeller casting and / or finish (notch effect) • Insufficient thickness of impeller side plates
3. Mechanical seals	• High pressure pulsations caused by wake flow or recirculation / separation • High frequency pressure pulsation due to cavitation • Shaft vibrations	• (see above) • Reduce cavity volume by redesign of impeller and / or inlet • see table 3	• There are a number of other failure mechanisms related to design, material selection and quality

TABLE 2. EFFECT OF HYDRAULIC EXCITATION ON COMPONENT FAILURE

Failure / incident	Possible hydraulic causes or mechanisms	Possible remedies	Possible non-hydraulic causes / remarks
4. Excessive labyrinth wear	• Excessive radial thrust • Excessive vibration	• Reduce flow asymmetries around impeller by - double volute in case of single volutes - analyzing / eliminating cause of asymmetry (casting tolerances, differences in resistance in channels of double volutes, discharge and suction nozzle,...) • see table 3	• Thermal deformations of casing and rotor
5. Failure of radial bearings	• Excessive radial thrust • Excessive vibration	• see above item • see table 3	• Mechanical / design
6. Failure of axial bearings	• Axial thrust excursions • Excessive labyrinth wear (high leakage increases rotation on shroud; reduces rotation on hub with multistage-pumps)	• see table 1, item 3 • Replace wear rings	• Mechanical / design • Transients

Steps in Cavitation

Formation of bubbles inside the liquid

Growth of bubbles

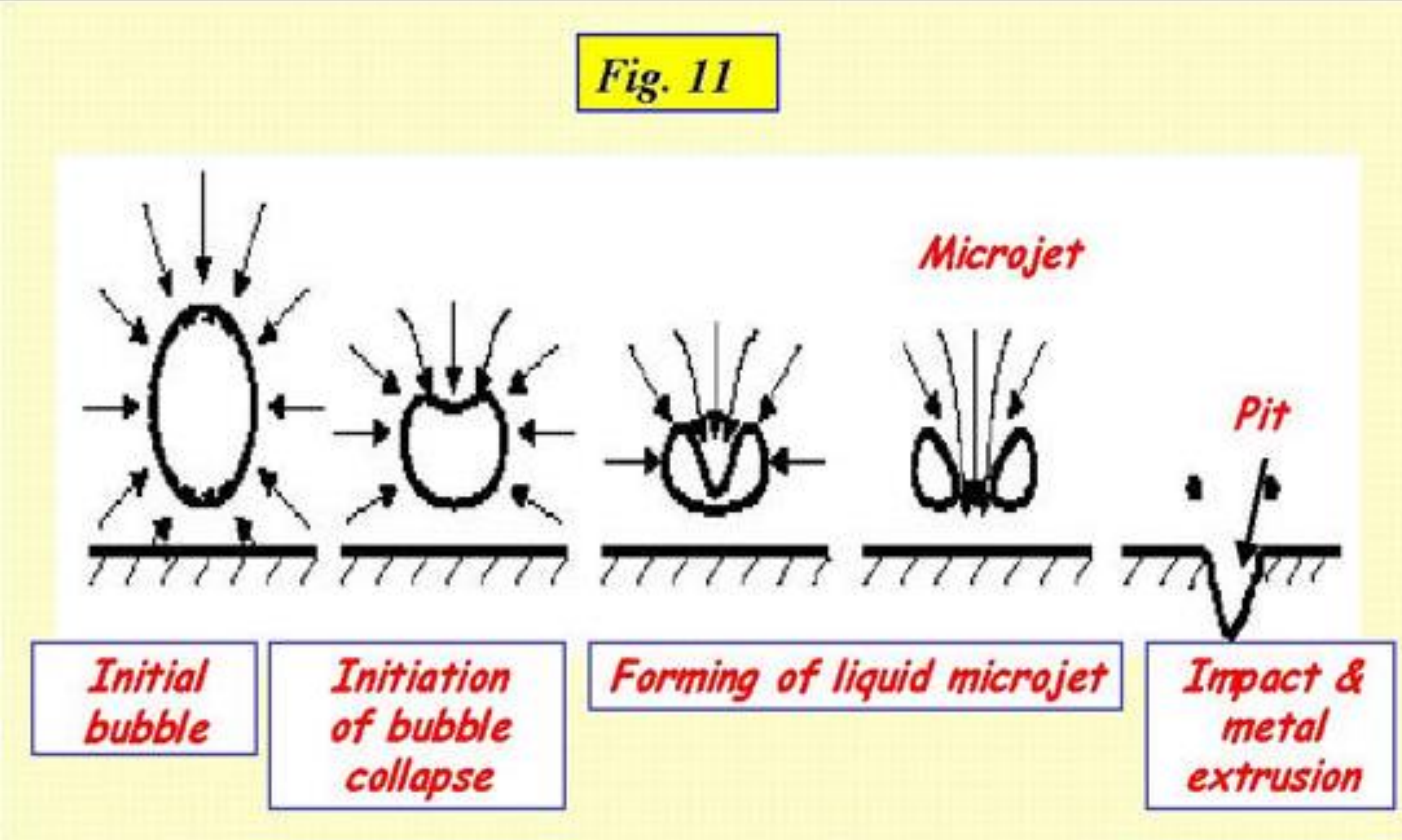
Collapse of bubbles

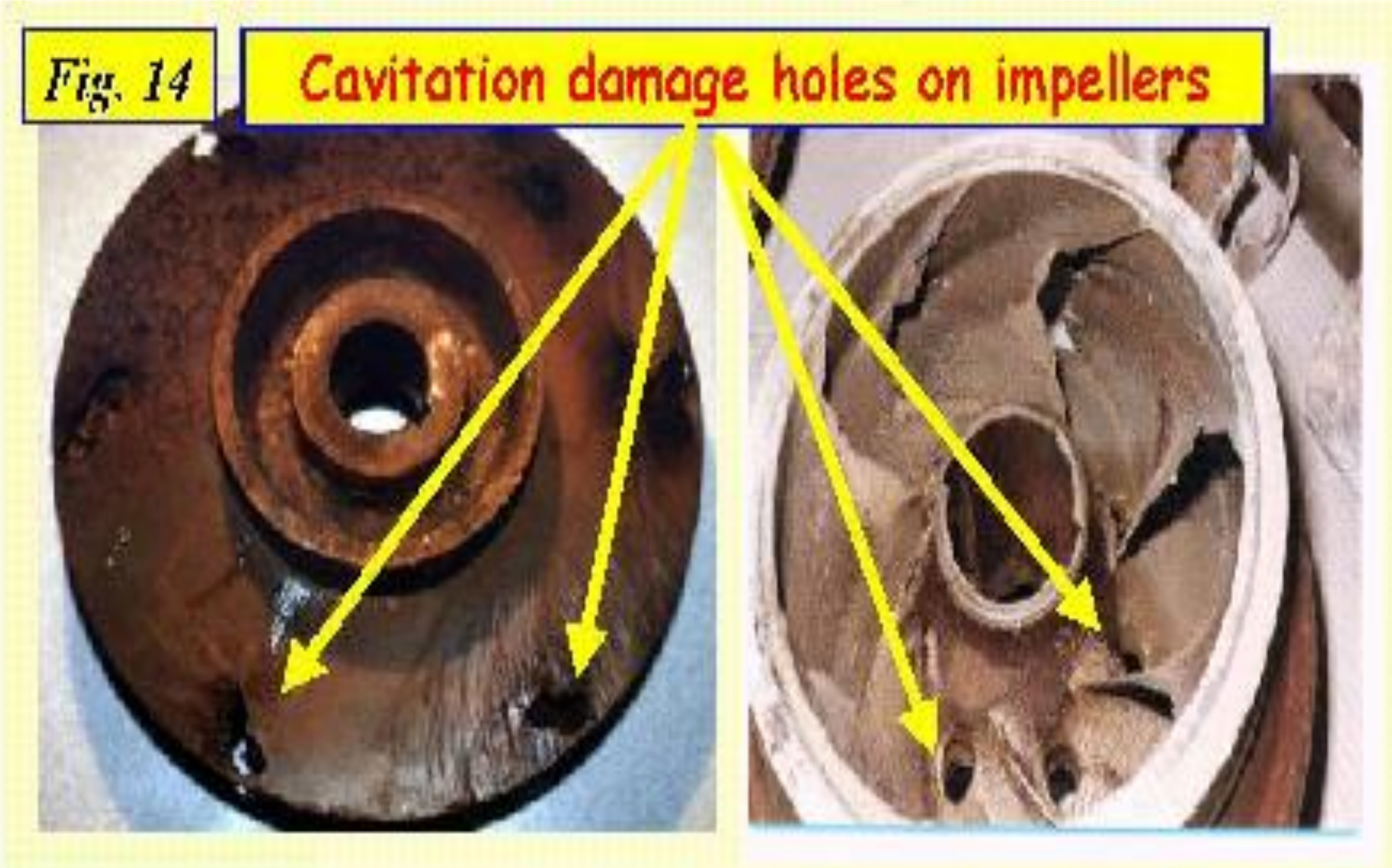
Cavitation

Fig. 2

www.cheresources.com , *The Chemical Engineer's Resource Page*

Collapse of a vapor bubble





www.cheresources.com , *The Chemical Engineer`s Resource Page*

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

Reduction in capacity of the pump:

Decrease in the head developed:

Abnormal sound and vibrations:

- *Damage to pump parts*:
  - *Cavitation erosion or pitting*

Mechanical deformations

Apart from erosion of pump parts, in bigger pumps, longer duration of cavitation condition can result in unbalancing (due to un-equal distribution in bubble formation and collapse) of radial and axial thrusts on the impeller. This unbalancing often leads to following mechanical problems:

- bending and deflection of shafts,
- bearing damage and rubs from radial vibration,
- thrust bearing damage from axial movement,
- breaking of impeller check-nuts,
- seal faces damage etc.

In short, Cavitation can be termed as "the heart attack of the pump".

The Affinity Laws

The Affinity Laws are mathematical expressions that define changes in pump capacity, head, and BHP when a change is made to pump speed, impeller diameter, or both.

According to *Affinity Laws*:

- **Capacity, Q** changes in direct proportion to impeller diameter **D** ratio, or to speed **N** ratio:

$$Q_2 = Q_1 \times [D_2/D_1]$$

$$Q_2 = Q_1 \times [N_2/N_1]$$

- **Head, H** changes in direct proportion to the square of impeller diameter **D** ratio, or the square of speed **N** ratio:

$$H_2 = H_1 \times [D_2/D_1]^2$$

$$H_2 = H_1 \times [N_2/N_1]^2$$

BHP changes in direct proportion to the cube of impeller diameter ratio, or the cube of speed ratio:

$$BHP_2 = BHP_1 \times [D_2/D_1]^3$$

$$BHP_2 = BHP_1 \times [N_2/N_1]^3$$

Where the subscript: 1 refers to initial condition, 2 refer to new condition

If changes are made to both impeller diameter and pump speed the equations can be combined to:

$$Q_2 = Q_1 \times [(D_2 \times N_2)/(D_1 \times N_1)]$$

$$H_2 = H_1 \times [(D_2 \times N_2)/(D_1 \times N_1)]^2$$

$$BHP_2 = BHP_1 \times [(D_2 \times N_2)/(D_1 \times N_1)]^3$$

Specific Speed

Specific speed as a measure of the geometric similarity of pumps

Specific speed (Ns) 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. Pumps of the same Ns but of different size are considered to be geometrically similar, one pump being a size-factor of the other.

Specific speed as a measure of the shape or class of the impellers

The specific speed determines the general shape or class of the impellers. As the specific speed increases, the ratio of the impeller outlet diameter, D2, to the inlet or eye diameter, D1, decreases. This ratio becomes 1.0 for a true axial flow impeller. *Radial flow impellers* develop head principally through centrifugal force.

Radial impellers are

generally low flow high head designs. Pumps of higher specific speeds develop head partly by centrifugal force and partly by axial force. A higher specific speed indicates a pump design with head generation more by axial forces and less by centrifugal forces.

NPSHa in a nutshell

In a nutshell, NPSH available is defined as:

NPSHa = Pressure head + Static head **-** Vapor pressure head of your product – Friction
head loss in the piping, valves and fittings.

“All terms in feet absolute”

In an existing system, the NPSHa can also be approximated by a gauge on the pump suction using the formula:

NPSHa = hpS - hvpS ± hgS + hvS

- **hpS =** Barometric pressure in feet absolute.
- **hvpS** = Vapor pressure of the liquid at maximum pumping temperature, in feet absolute.
- **hgS** = Gauge reading at the pump suction expressed in feet (plus if above atmospheric, minus if below atmospheric) corrected to the pump centerline.
- **hvS** = Velocity head in the suction pipe at the gauge connection, expressed in feet.

Minimum Flow

Minimum flow can be determined by examining each of the factors that affect it. There are five elements that can be quantified and evaluated:

1. Temperature rise (minimum thermal flow)
2. Minimum stable flow
3. Thrust capacity
4. NPSH requirements
5. Recirculation

The highest flow calculated using these parameters is considered the minimum flow.

$$\Delta T = \frac{H}{778 \times C_p} \times \frac{1}{\eta - 1}$$

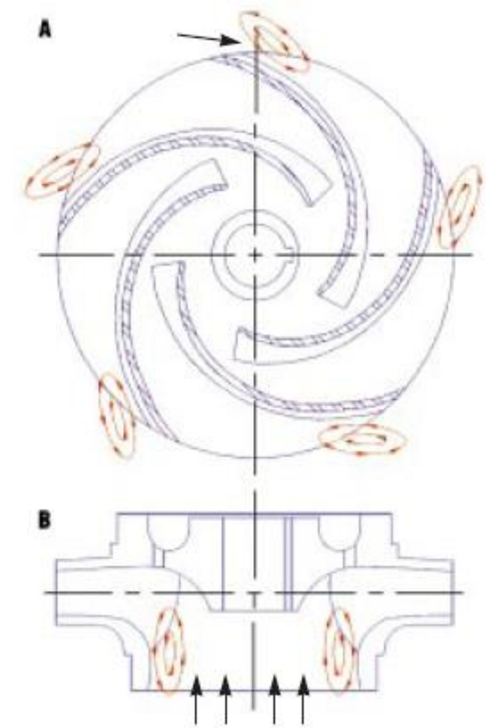
where

H = total head in feet

C_p = specific heat of the liquid, Btu/lb x °F

η = pump efficiency in decimal form

778 ft–lbs = energy to raise the temperature of one pound of water 1°F



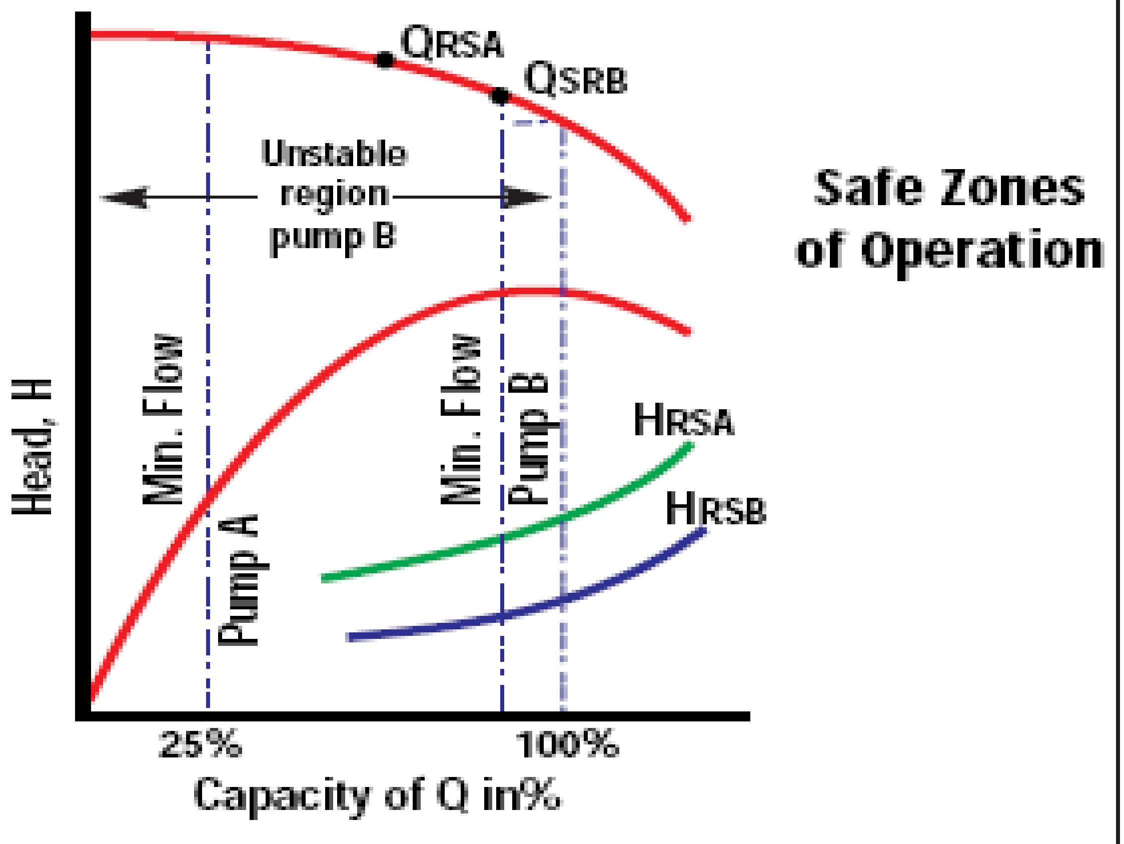
Recirculation zones are always on the pressure side of the vane. A shows discharge recirculation (the front shroud has been left out for clarity). B shows inlet recirculation.

TEMPERATURE RISE

Temperature rise comes from energy imparted to the liquid through hydraulic and mechanical losses within the pump. These losses are converted to heat, which can be assumed to be entirely absorbed by the liquid pumped. The difference between the allowable temperature and the temperature at the pump inlet is the maximum allowable temperature rise.

Minimum flow based on the shape of the performance curve is not so much a function of the pump as it is a function of the system where the pump is placed. A pump in a system where the above criteria are present should not have a drooping curve in the zone of operation.

The new phenomenon has been discovered that affects the setting of minimum flows. At certain reduced flows, all centrifugal pumps are subject to internal recirculation, both in the suction and discharge areas of the impeller. This produces pulsations at both the suction and discharge, and the vibration can damage impeller material in a way similar to classic cavitations, although taking place in a different area of the impeller. Each of these effects may dictate a different minimum operating capacity. Clearly, the final decision must be based on the greatest of the individual minimums.



Comparison of safe zones of operation for normal and for high S value impellers

Effect of Viscosity

Heavy crude oils can have viscosities high enough to increase the friction drag on a pump's impellers significantly. The additional horsepower required to overcome this drag reduces the pump's efficiency. Viscosity of most liquid remarkably varies with temperature which is an important aspect to be taken into account while determining the effect of viscosity on pump performance. The relationship is expressed in following formula.

$$\mu = Ae^{B/T}$$

where

μ = the absolute viscosity of the fluid

A and B = constants

T = the absolute temperature of the fluid

Losses that affect the performance of pumps as being of the following types:

- **mechanical losses**
- **impeller losses**
- **leakage losses**
- **disk friction losses**

Of all external mechanical losses, disk friction is by far the most important, This is particularly true for pumps designed with low specific speeds. The physics of a rotating impeller and simple equation that summarizes the drag force acting upon it.

$$(hp)_d = KD^2\gamma u^3$$

where

K = a constant based on the Reynolds number

D = impeller diameter

γ = fluid density

u = impeller tip speed

TABLE 1. WATER-BASED AND VISCOUS PERFORMANCE

Water Curve-Based Performance	% of BEP Capacity			
	60%	80%	100%	120%
Capacity, gpm	450	600	750	900
Differential Head, ft.	120	115	100	100
Efficiency	0.70	0.75	0.81	0.75
Horsepower	18	21	21	27
Viscous (1,000 ssu) Performance				
Capacity, gpm	423	564	705	846
Differential Head, ft.	115	108	92	89
Efficiency	0.45	0.48	0.52	0.48
Horsepower	25	29	28	36

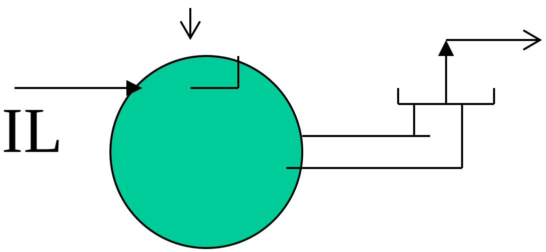
Note: Pumped fluid specific gravity = 0.9

CENTRIFUGAL PUMP

- **<u>BEARING CHECK</u>**
- Touch the bearing housing and try to hold for minimum five sec. If not able to hold ,then temperature is in alarming range.
- Check for oil ring rotation . In case ,it is stationery, switch over to stand by pump, and stop problematic one.
- Check for oil condition ,in case it is blackish , flush the oil by pouring from housing breather vent, allowing contaminated oil to exit from oil cup.

Centrifugal pump

- Bearing housing breather



Check for vibration .The level of vibration assessment by freehand check is solely depends on experience and daily monitoring of same equipment. If vibration appears to be high check for cavitation,partial vapor locking etc. Incase no such problem, inform machinist for check up. In case high vibration clubs with high bearing temperature, switch over operation to stand by and stop the equipment.,specially for light hydro-carbon service.

Check bearing cooling system for proper flow and heat transfer incase any problem inform maintenance for further action.

Centrifugal pump

- DO
- Check the lube oil to be sure of right lubricant , before putting into housing.
- Incase excessive oil loss check for possible leakage or inform rotary section
- Replenish oil in oil cup when ever found empty.
- Flush the bearing oil if found contaminated.or stop the pump &inform rotary section.

Centrifugal pump

- Inform rotary section ,incase very high vibration, sudden temperature rise,abnormal coupling play. Stoppage of equipment advisable,incase stand by available.
- Incase bearing housing deflector found loose,inform rotary section,and stoppage of pump advisable particularly for hydrocarbon service having rotational speed above 1500rpm.
-

Centrifugal pump

- DON’TS
- Don’t keep bearing housing breather cap
- open.
- Don’t put water hose on bearing housing for cooling.
- Don’t run the pump without cooling water circulation(where ever applicable) for prolong period.
- Don’t run the pump with contaminated oil
-

Centrifugal pump

- **MECHANICAL SEAL CHECK**
- **ELEVATED TEMPARETURE SERVICE WITH SELF FLUSHING &STEAM PURGING AND STUFFING BOX COOLING**
- Ensure flushing is on by sensing the temperature of the line. It should be hot.
- Ensure flushing line is insulated
- Incase seal smoking, check for proper cooling water circulation to stuffing box,flushing flow is adequate.

Centrifugal pump

- Ensure LP dry steam to seal chamber.Flow to be adjusted so that, steam does not impinge on bearing housing.
- Ensure proper insulation of steam lines.
- Incase of seal puffing check for condensate in purging steam, contamination in product,inadequate flushing at seal ,periodic vapor locking of pump. If no problem detected ,inform rotating section for further check.

Centrifugal pump

- **<u>SEAL WITH EXTERNAL FLUSH /STEAM PURGING/STUFFING BOX COOLING.</u>**
- Ensure flow of flushing fluid to seal by sensing the line temperature close to seal box.It should be less than pumping temperature.
- Quantity of flush should be 3-4liters/min .(ensure installation of RO).
- Other observations are same as in previous case .

Centrifugal pump

- **<u>LIGHT HYDROCARBON PUMPS (LPG.PROPANE,GASOLINE ETC</u>)**
- Check free rotation of pump before starting the pump.
- Ensure designed suction pressure,and pump is properly primed before starting.
- Incase ECS seal(double mechanical seal),ensure vent is connected to flare line with a NRV,and pressure alarm is hooked up at control room.Apart from this check local pressure gauge on stuffing box for any pressure rise.

Centrifugal pump

- In case any pressure rise / pressure alarm, inform rotary section for check.
- Don’t run the pump if product is leaking to atmosphere from any sealing area.
- Incase of tandem seal with pot lubrication at outer seal , check the oil level and alarm of level switch must be hooked up at control room. Incase alarm ,check for high level at field ,and inform rotating section for further check.

Centrifugal pump

- In case pump is jam due to ice formation on mechanical seal(happens due to throttling expansion of gaseous LPG / propane to stuffing box when pump is idle.), treated water may be put from out side on gland box to remove the ice inside.
- Don’t try to start the pump if it is found jam.
-

Centrifugal pump

- **General suggestions**
- Carry out proper priming of pump before start.
- In case vapor lock, stop the pump and prime it again, before restart.
- Routine Change over of service on standby enhances seal and bearing life considerably.
- Check free rotation, cooling water system,lubrication system before start up.
- Monitor running equipment parameters at least twice in a shift.

Reciprocating pump

- **Diaphram pump**
- Ensure hydraulic oil in the chamber, before start. In case of addition , proper priming to be done to remove entrapped air , vapor.
- Keep hydraulic chamber covered to avoid ingress of impurities.
- **In case of loss of pumping, check,**
- hydraulic oil chamber for oil quantity,and for any contamination.

Reciprocating pump

- Safety valve condition. If popping check for back pressure or inform rotating equipment section for checking . Pump should be stopped.
- Check strainer at the suction for possible clogging.
- Suction valve not closing fully, during delivery stroke.This will raise temperature at suction valve area marginally.
- Check for discharge line releif valve passing/ pooping.

Reciprocating pump

- Check for diapharm rupture. This case service liquid will mix into hydraulic oil.
- Please inform rotating section in case any of above said problems noticed. If no specified problem found, stop the pump and inform rotary section for further check.
- Always open suction and discharge valve before starting the pump. Never run the pump with discharge throttled condition.
-

RECIPROCATING PUMP

- In case of actual back pressure on the pump due to high system pressure ,first reduce the stroke and watch for safety reset. I n case it doesn’t reset stop the pump.
- Ensure gear box oil level is adequate.
- Don’t run the pump ,if vibration is excessive.

Rotary screw pumps.

- Don’t start the pump with discharge valve closed condition.
- For heavy hydrocarbon service, pump must be properly warmed up,and free rotation must be ensured before start.
- Flushing with light oil is advisable before and after use of pumps which are in ash phault. LSHS service. Don’t use high sulfur diesel as flushing fluid.

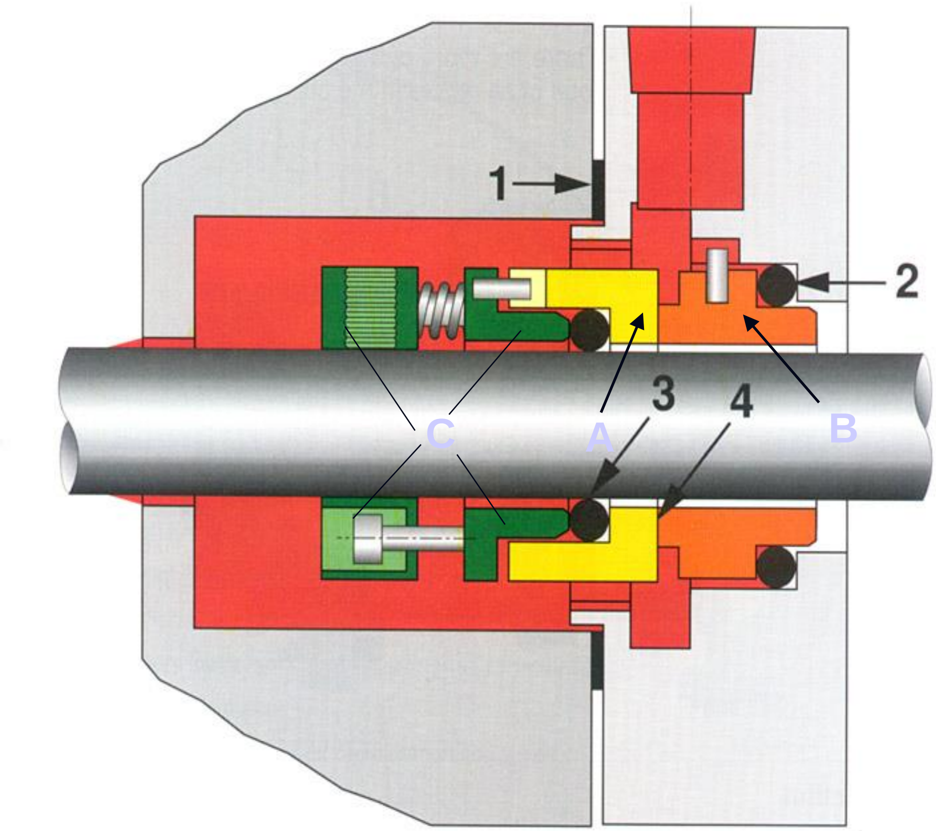
Rotary screw pump

- Don’t put wet steam to mechanical seal, which may create boil over situation.
- While stopping, first stop the pump and then close the discharge block valve.
- In case any abnormal noise and vibration please inform rotating section for necessary checking.
- In case poor pumping check the following
-

Rotary screw pump

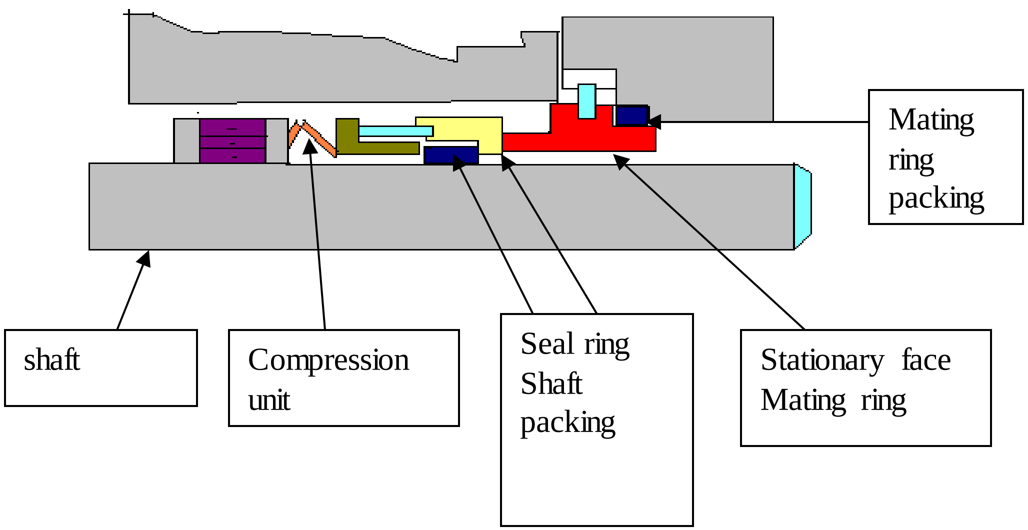
- Check suction strainer for possible clogging.
- Check rotation.
- Check for possible releif valve opening.
- Check for abnormal noise and vibration ,which may happen in case of high internal circulation. Stop the pump & inform rotating section for further check.
-

Leak Paths



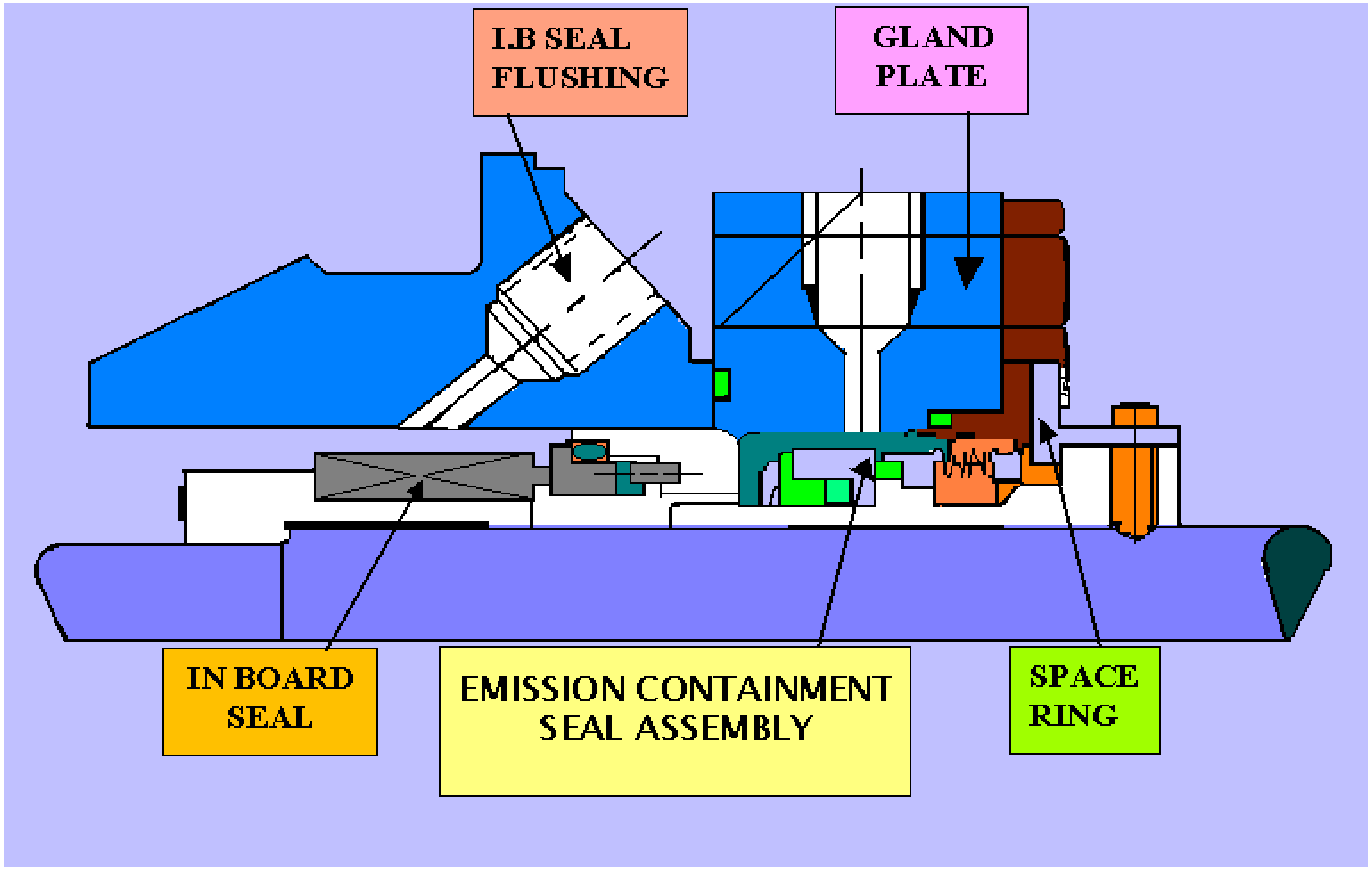
Mechanical Seal essentially consists of three components :-

1. A rotating component known as seal ring.
2. A stationary component known as mating ring.
3. A spring or composition of multiple springs known as compression unit, which produces a face load.



Simple mechanical seal

Multiple Seal installations
ECS Seal



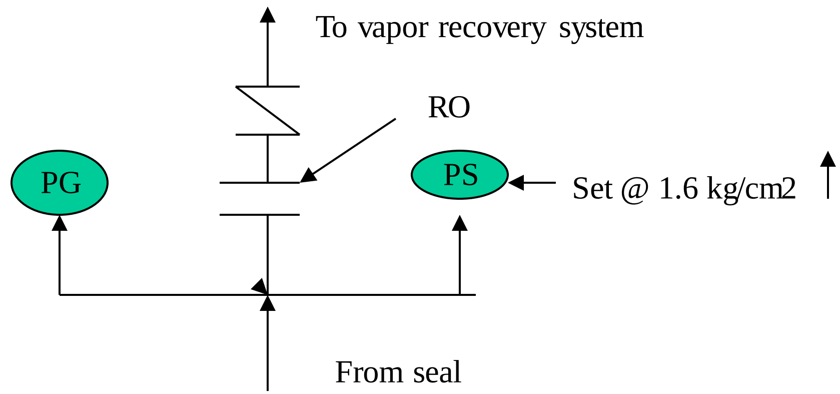
BASIC FEATURES OF ECS SEAL

#Does not require seal lubrication hence complicated circuit of pot
oil lubrication in case of double tandem/back to back mechanical seal is eliminated.
#Close control of face loading by controlled bellow design
#Capable of combining with any standard primary seal
#Simple seal performance monitoring system
#Facility to handle toxic hazard through nitrogen purging
P Pressure range is up to 20 bar and temperature range is up to 200 degree C

FUNCTION

In case of failure of in board seal ECS seal contains the emission and through a pressure alarm system the user comes to know about failure of first seal which facilitates proper planning for repair and also avoid sudden emission of hazardous fluid.

The G.A FOR ALARM SYSTEM



Pressure alarm setting to be kept 0.5 kg/cm2 higher than closed flare header pressure.
Highly suitable for LPG,PROPANE service because of its simple operation.