Lecture
on
Fluid Machinery

Prepared By :

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Lecturer

Department of ME (UGV)

BASIC COURSE INFORMATION

Course Title	Fluid Machinery
Course Code	ME-421
Credits	03
CIE Marks	90
SEE Marks	60
Exam Hours	2 hours (Mid Exam) 3 hours (Semester Final Exam)
Level	7^{th} Semester

Course Learning Outcomes (CLOs):

CLO 1

Understand functions of various valves, pump, turbine and Compressor

CLO 2

Apply the concepts of Valves, Pumps, Turbine and Compressor in Pipe design

CLO 3

Analyze Complex problems on Pump, Compressor and Turbine Design

CLO 4

Calculate both Pump and Turbine Efficiency to maintain smooth operation

Reference Books:

- Fluid Mechanics- Frank M. White
- Fluid Mechanics & Hydraulic Machines- Dr. R. K. Bansal
- A Textbook of Hydraulics, Fluid Mechanics & Hydraulic Machines- R.S Khurmi
- Fluid Mechanics and Hydraulic Machines: Problems and Solutions|| by K Subram

Serial No	Course Content	Hours	CLOs
01.	Valve, Valve Types, Application, Valve Design, P & ID Symbol	06	CLO 1, CLO 2
02.	Compressor, Compressor Types, Compressor Design	06	CLO 1,CLO 2, CLO 3
03.	Turbine, Turbine Types, Application, Turbine Design, Problem Solving	12	CLO 1, CLO 3,CLO 4
04.	Pump, Pump Types, Application, Pump Design, Problem Solving	10	CLO 1, CLO 3,CLO 4

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (90 Marks)

Bloom's Category Marks (out of 90)	Tests (45)	Assignments(10)	Class Test (20)	Quiz(5)	External Participation in Curricular/Co-Curricular Activities (10)
Remember	5		10	05	
Understand	5	05	10		
Apply	10				**10**
Analyze	15				
Evaluate	10				
Create		**05**			

SEE- Semester End Examination (60 Marks)

Bloom's Category	Test
Remember	10
Understand	10
Apply	10
Analyze	10
Evaluate	10
Create	10

Week No.	Topics	Teaching Learning Strategy	Assessment strategy	Alignment To CLO
1.	Gate, Globe and Ball Valve Application and Working Principle	Lecture, PPT	Quiz, Written exam, CT	CLO 1
2.	Butterfly, Foot, Pressure relief, Check Valve Application and Working Principle	Lecture, Video Presentation, PPT, Problem Practice	Quiz, Written exam, CT	CLO 1
3.	Valve Design , P& ID Symbol	Lecture, PPT, Video Presentation	Assignment, Quiz, Written exam, CT	CLO 1, CLO 2
4.	Compressor & Compressor Types	Lecture, Problem Practice, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 2

Week No.	Topics	Teaching Learning Strategy	Assessment strategy	Alignment To CLO
5.	Compressor (Working Principle)	Lecture, Video Presentation, PPT	Quiz, Written exam, CT	CLO 2, CLO 3
6.	Compressor Design	Lecture, Video Presentation, PPT, Problem Solving	Quiz, Written exam, CT	CLO 3
7.	Turbine Classifications	Lecture, Oral Presentation, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 1
8.	Turbine Design	Lecture, Oral Presentation, Video Presentation, PPT, Problem Practice	Assignment, Quiz, Written exam, CT	CLO 3,CLO 4

Week No.	Topics	Teaching Learning Strategy	Assessment strategy	Alignment To CLO
9.	Turbine Selection	Lecture, Oral Presentation, PPT	Quiz, Written exam, CT	CLO 3,CLO 4
10.	Turbine Specific Speed, Turbine Characteristics Curve	Lecture, PPT	Assignment, Quiz, Written exam, CT	CLO 3,CLO 4
11.	Turbine Performance, Draft Tube & Surge Tank	Lecture, Oral Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 3,CLO 4
12.	Problem Solving on Turbine	Lecture, PPT, Problem Solving	Assignment, Quiz, Written exam, CT	CLO 3,CLO 4

eek No.	Topics	Teaching Learning Strategy	Assessment strategy	Alignment To CLO
13.	Pump Classifications	Lecture, Oral Presentation, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 1
14.	Centrifugal Pump	Lecture, Oral Presentation, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 3, CLO 4
15.	Reciprocating Pump	Lecture, Oral Presentation, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 3, CLO 4
16.	Reciprocating Pump	Lecture, Oral Presentation, Video Presentation, PPT	Assignment, Quiz, Written exam, CT	CLO 3, CLO 4

Week	Topic	Page No.
1	Gate, Globe and Ball Valve Application and Working Principle	13-26
2	Butterfly, Foot, Pressure relief, Check Valve Application and Working Principle	27-40
3	Valve Design , P& ID Symbol	41-49
4	Compressor & Compressor Types	50-52
5	Compressor (Working Principle)	53-58
6	Compressor Design	59-71
7	Turbine Classifications	72-74
8	Turbine Design	75-82
9	Turbine Selection	83-91
10	Turbine Specific Speed, Turbine Characteristics Curve	92-101
11	Turbine Performance, Draft Tube & Surge Tank	102-107
12	Problem Solving on Turbine	108-109
13	Pump Classifications	110-121

Week -1

Lecture

on

Valve

Gate, Globe and Ball Valve Application and Working Principle

What is a Valve?

In simple terms, a valve is an internal component that controls and regulates the flow of fluid in a system by closing, opening, or partially cutting off the flow of a fluid for various reasons. Therefore, the valves are used to regulate the fluid's flow and pressure within a system.

Valves are critical components in piping systems for controlling the flow of fluids, vapors, or gases. They offer an effective way to regulate the volume and pressure of gases or liquids that pass through pipelines.

It is important to understand which valve type is required for a specific application before installing it in pipework systems.

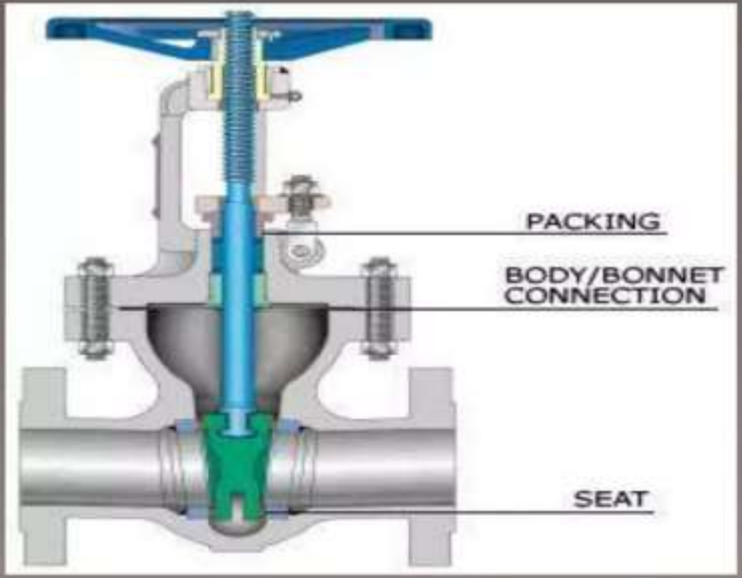
Types of Valves

Following are the main types of valves:

•Gate valve
•Globe valve
•Ball valve
•Butterfly valve
•Check valve
•Needle valve
•Diaphragm valve
•Solenoid valve
•Control valve
•Relief or pressure relief valve
•Piston valve
•Safety valve
•Rotary valve
•Thermostatic mixing valve
•Pressure regulating valve

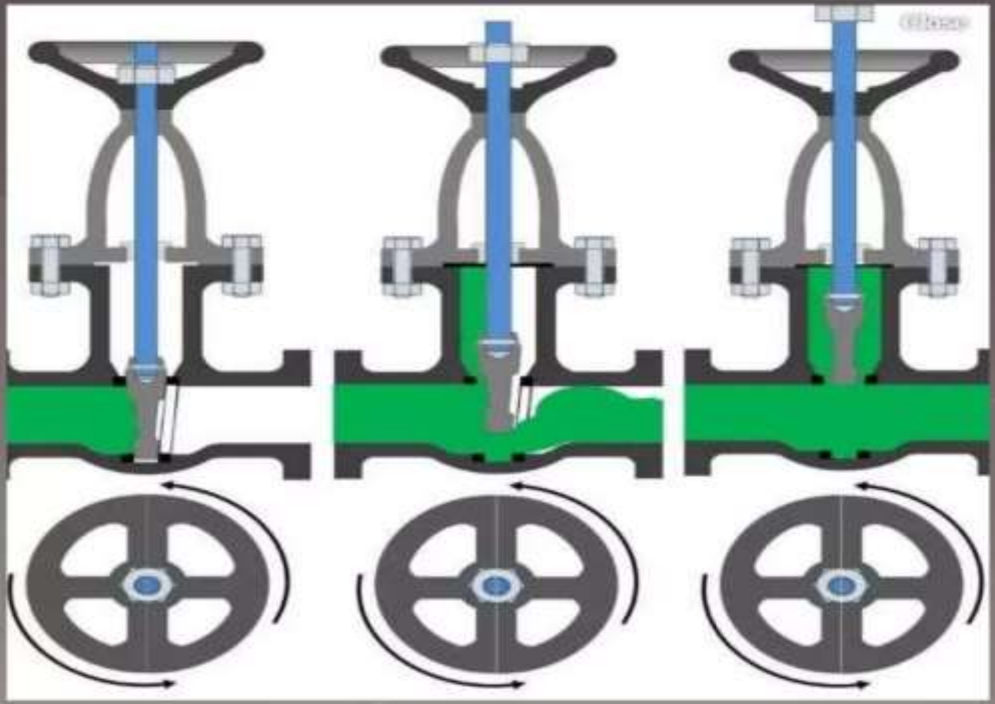
Gate Valve

A **gate valve**, also known as a **sluice valve**, is a valve which opens by lifting a round or rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar, so gate valves are often used when a straight-line flow of fluid and minimum restriction is desired



Working mechanism of a gate valve

- When handle wheel will be rotated in clockwise direction, steam and gate will move in downward direction across the fluid flow line and gate will be tightly located between the two seats. Hence there will not be any leakage of fluid through the valve once valve is closed completely.
- When handle wheel will be rotated in anti-clockwise direction, steam and gate will move in upward direction across the fluid flow line and valve will be opened from closed position and will permit the flow of fluid through the gate valve. Once gate valve is completely opened, it will permit no resistance or very little resistance to the flow of fluid.

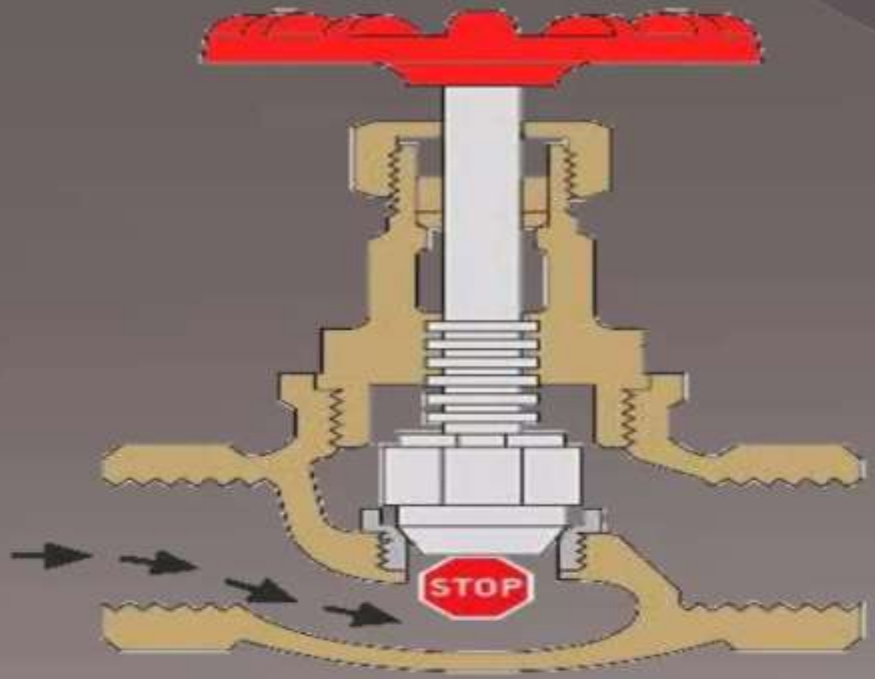


Application

- Gate valves are designed for fully open or fully closed service. They are installed in pipelines as isolating valves, and should not be used as control or regulating valves. Operation of a gate valve is performed doing an either clockwise to close (CTC) or clockwise to open (CTO) rotating motion of the stem. When operating the valve stem, the gate moves up- or downwards on the threaded part of the stem.

Globe Valve

A **gate valve**, also known as a **sluice valve**, is a **valve** which opens by lifting a round or rectangular **gate**/wedge out of the path of the fluid.



Working

- Globe valves contain an important device called a baffle. This is the device that is responsible for regulating fluid flow. The baffle consists of two parts, a flat plug and a ring-shaped seat. When the plug is completely fit into the seat, fluid flow is totally restricted. You can control the baffle by either opening it a little or closing it, depending on the amount of fluid flow you want.

Application

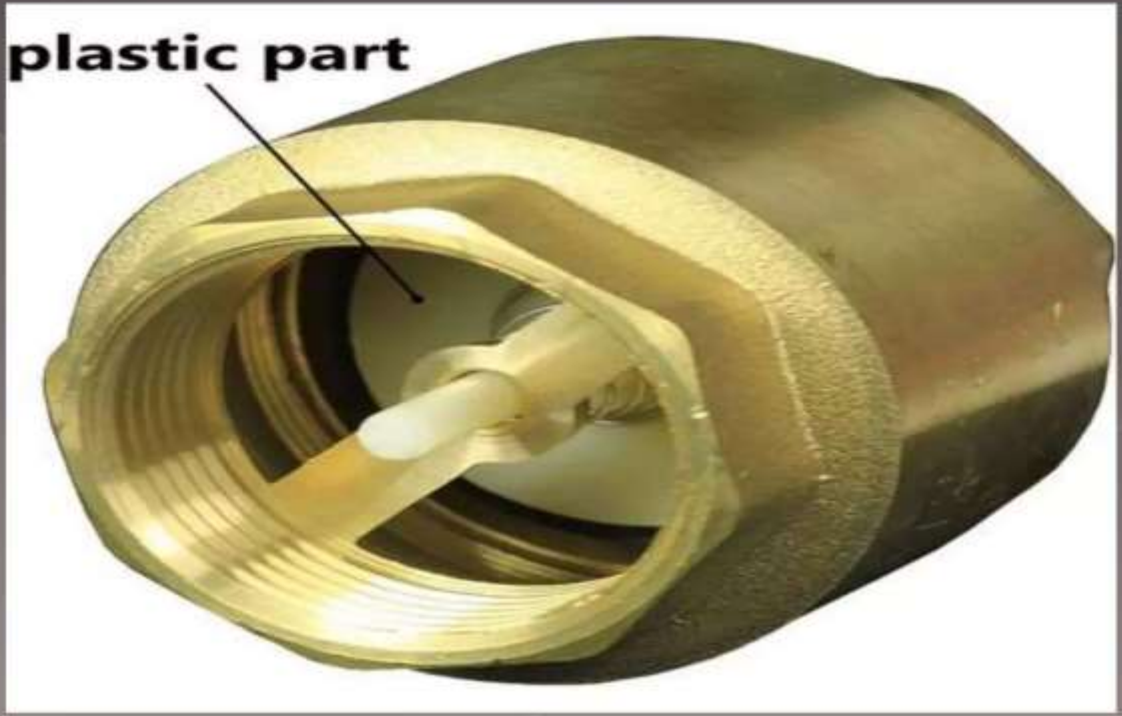
Globe valves are usually used in applications where constant flow of fluid is not required. Even when the valve is fully open, the baffle can sometimes restrict fluid flow. The valves are usually used as sample valves i.e. opened only when a sample of a fluid is needed.

Check Valve

A **check valve**, **clack valve**, **non-return valve**, **reflux valve**, **retention valve** or **one-way valve** is a valve that normally allows fluid (liquid or gas) to flow through it in only one direction

Working

Check valves are controlled based on a system's flow velocity. Once the system reaches the cracking pressure or the minimum upstream pressure needed for the valve to operate, the disc will lift and allow the fluid to pass through. If the fluid pressure decreases or if the flow direction starts to reverse, the disc will automatically close the valve to keep fluid from flowing through. This helps to prevent backflow.

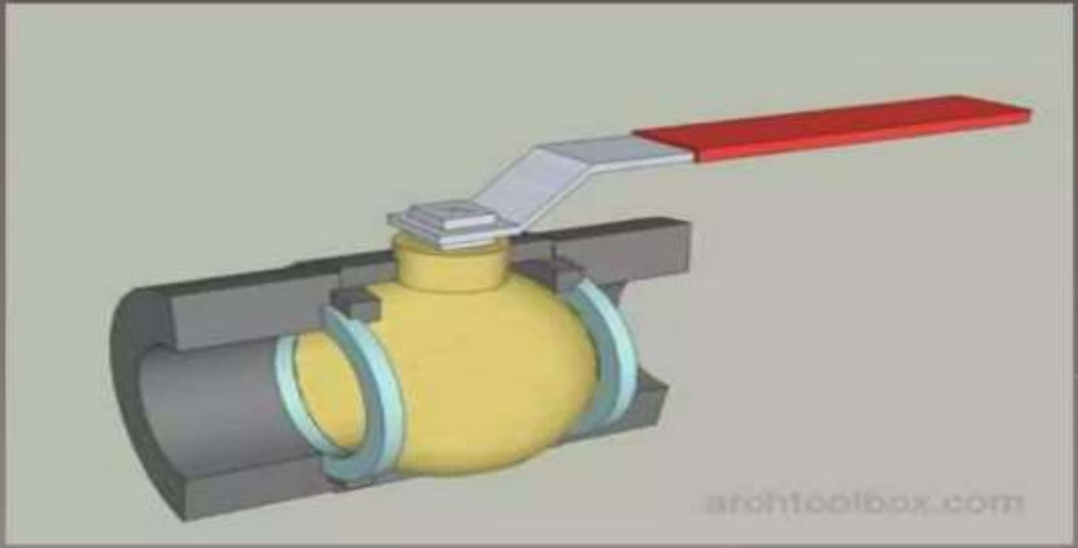


Applications

Check valves are commonly used for industrial pumps and fluid systems in the oil and gas industry. Chemical and power plants also use check valves to prevent reverse flow in advanced machinery. On top of that, check valves can be installed in many process systems to keep fluids of different pressures separated.

Ball Valve

A **ball valve** is a form of quarter-turn valve which uses a hollow, perforated and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle. The handle lies flat in alignment with the flow when open, and is perpendicular to it when closed, making for easy visual confirmation of the valve's status



Applications

Ball valves are commonly found in flowing systems on ships, fire safe protection services and chlorine manufacturers. They are not recommended for use in pharmaceutical, bio processing, or food and beverage applications because they cannot be cleaned easily. Exceptions can be made for chemical or non-sterile applications

Week -2

Lecture

on

Valve

Butterfly, Foot, Pressure relief, Check Valve Application and Working Principle

Butterfly valve

Butterfly valves are most simple yet versatile valves. They are quarter turn operated valves which are commonly used in multiple industries for varied applications. Quarter turn operation ensures quick operating of the valve. In the open condition there is minimum obstruction to the fluid flow through the valve as the flow passes around the disc aerodynamically. This results in very less pressure drop through the valve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Working

A butterfly valve consists of a circular disc or plate built with a stem through the middle or attached offset. When opened, the disc pivots 90 degrees in the valve bore, aligning with the flow, creating a nearly unrestricted flow path. Butterfly valves operate similar to ball valves in their 90 degree rotation and allow for quick shutoff.

Applications

In the pharmaceutical, chemical and food industry a butterfly valve is used to interrupt product flow (solid, liquid, gas) within the process.

Butterfly valves can be used in many applications because they can be used with many different media types including water applications, corrosive materials and some slurries.

Typical applications include:

- Cooling water, air, gases, fire protection, etc.
- Slurry and similar services
- Vacuum service
- High-pressure and high-temperature water and steam services.

Foot valve

- Foot Valves are basically the marriage of a check valve (two varieties of which I wrote about a few weeks ago) and a straining element.
- They are generally used in conjunction with suction pumps to maintain pressure in a plumbing system while keeping out solids which could gum up the works.
- Although they are often found in water wells, **foot valves can be used for many systems where a liquid needs to be pumped from a lower level holding area.**

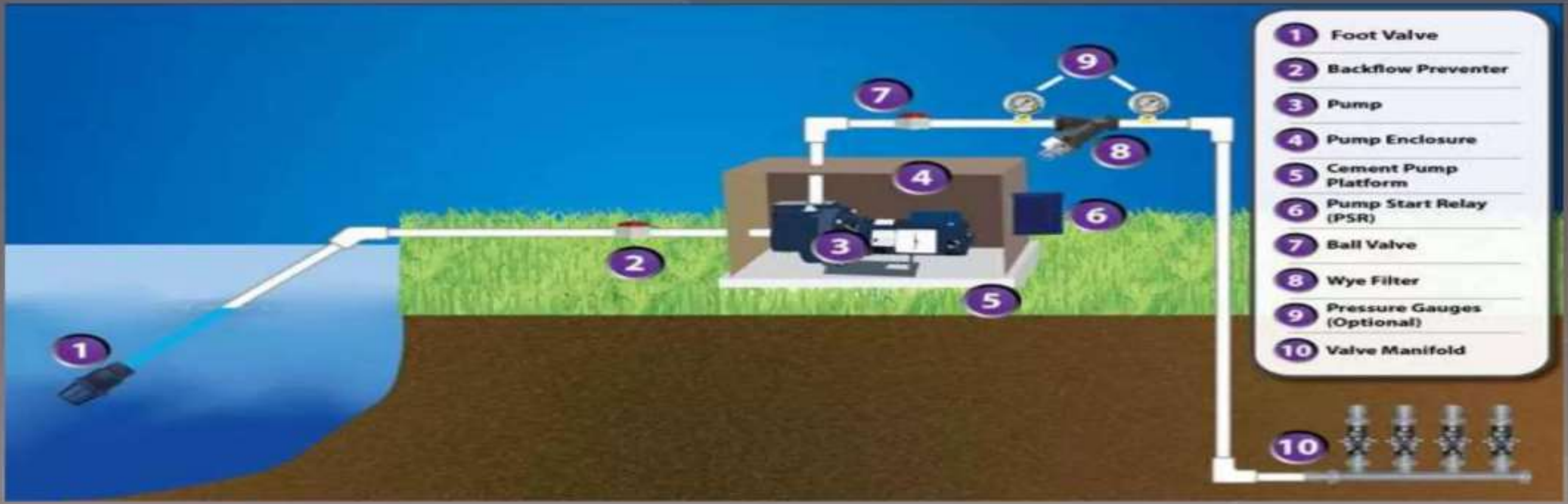
Working

When the water pump is running, suction is created, which pulls the water in the upward direction through the pipe. The foot valve is so designed that it opens up easily because of the upward pressure from the incoming water, and thus, normal water flow through the pipe is established. This is shown in the image below.

Now, when the pump is turned off, the upward pulling force on the water is removed. As soon as this happens, the Earth's gravitational pull acts on the water in the pipe, and it tries to flow back into the well with only the foot valve in its way.

Application

- Municipal Water Treatment
- Industrial
- Rural Fire Protection
- Irrigation
- Car Wash Systems

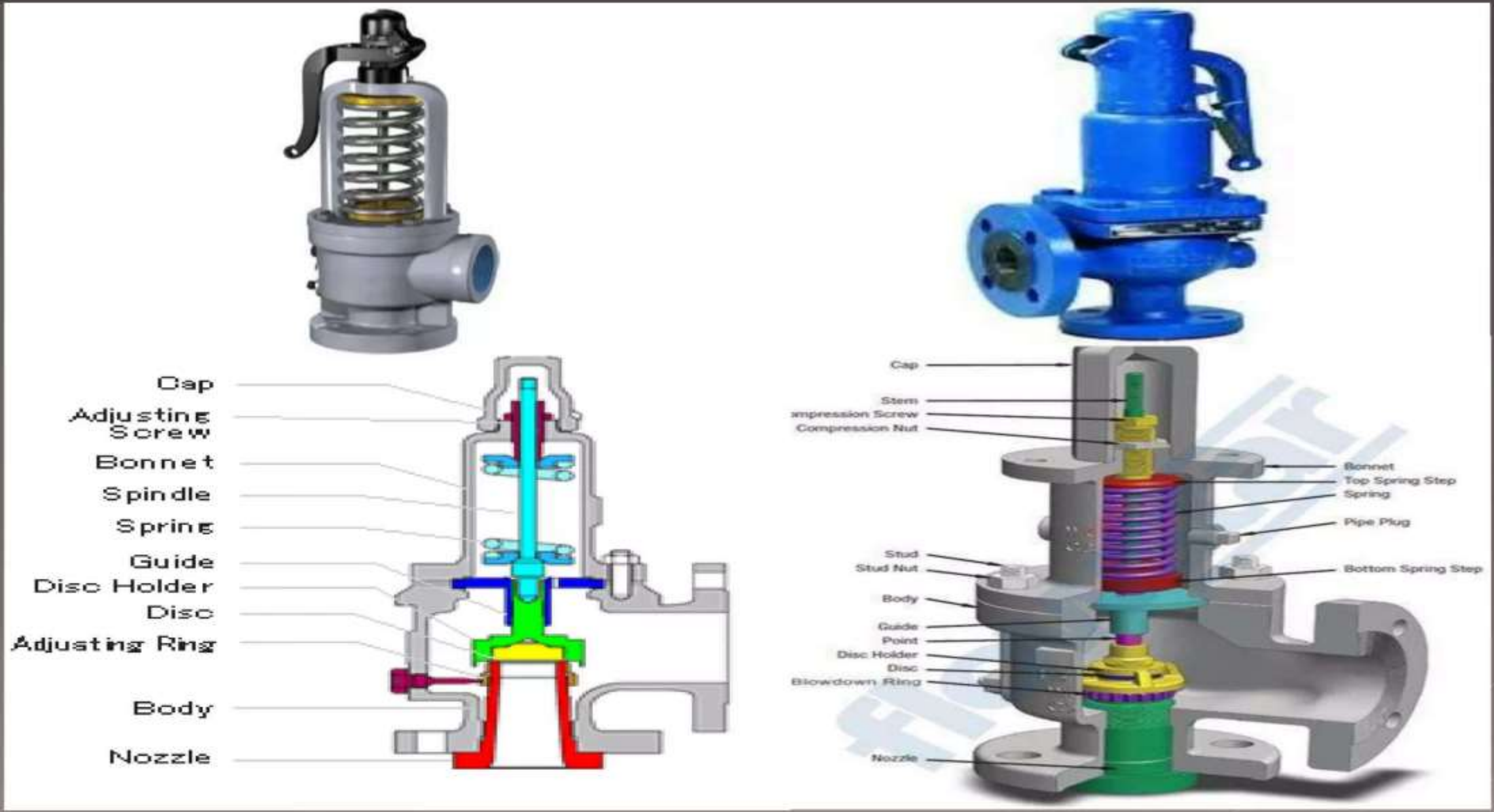


Pressure Relief Valve (Safety Valve)

A valve that opens automatically to relieve excessive pressure.

A **safety valve** is a valve that acts as a fail-safe. An example of safety valve is a pressure relief valve (PRV), which automatically releases a substance from a boiler, pressure vessel, or other system, when the pressure or temperature exceeds preset limits.

Safety valves were first developed for use on steam boilers during the Industrial Revolution. Early boilers operating without them were prone to explosion unless carefully operated.


Cap
Adjusting Screw
Bonnet
Spindle
Spring
Guide
Disc Holder
Disc
Adjusting Ring
Body
Nozzle
Cap
Stem
mpression Screw
Compression Nut
Bonnet
Top Spring Step
Spring
Pipe Plug
Stud
Stud Nut
Bottom Spring Step
Body
Guide
Point
Disc Holder
Disc
Blowdown Ring
Nozzle

Working

In operation, the pressure relief valve remains normally closed until pressures upstream reaches the desired set pressure. The valve will crack open when the set pressure is reached, and continue to open further, allowing more flow as over pressure increases. When upstream pressure falls a few psi below the set pressure, the valve will close again.

Application

Industrial

Steam engine

Pressure pump

Refineries

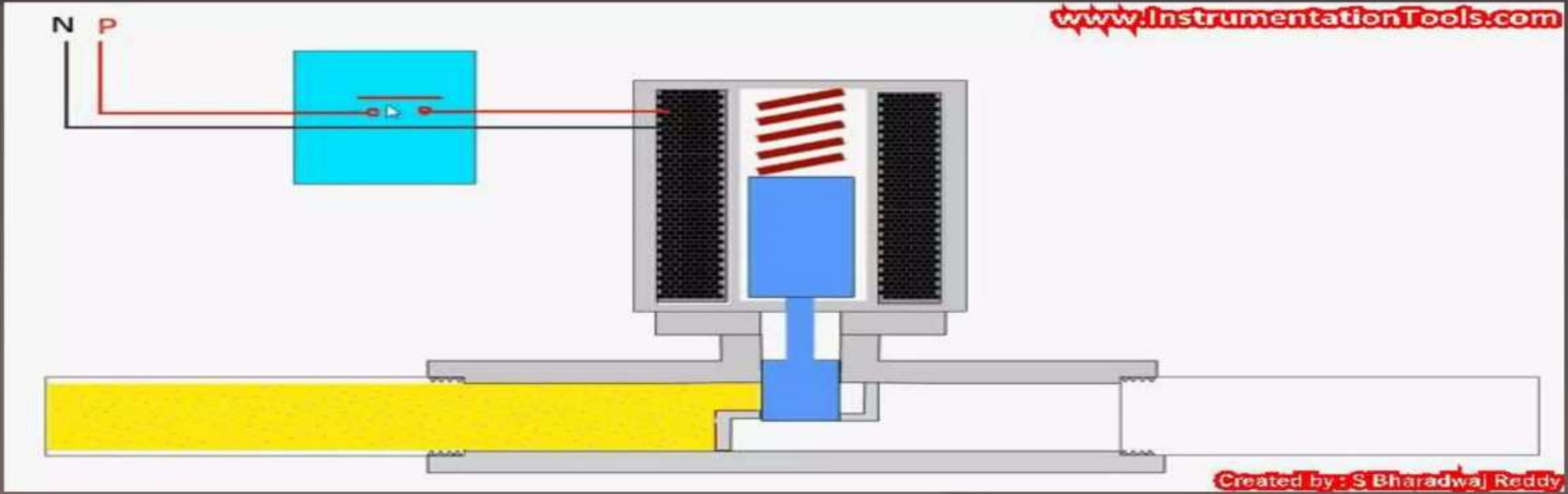
Solenoid valve

A **solenoid valve** is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid.

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

Working principal

Direct operated (direct acting) solenoid valves have the most simple working principle. The medium flows through a small orifice which can be closed off by a plunger with a rubber gasket on the bottom. A small spring holds the plunger down to close the valve. The plunger is made of a ferromagnetic material. An electric coil is positioned around the plunger. As soon as the coil is electrical energized, a magnetic field is created which pulls the plunger up towards the centre of the coil. This opens the orifice so that the medium can flow through. This is called a Normally Closed (NC) valve. A Normally Open (NO) valve works the opposite way: it has a different construction so that the orifice is open when the solenoid is not powered.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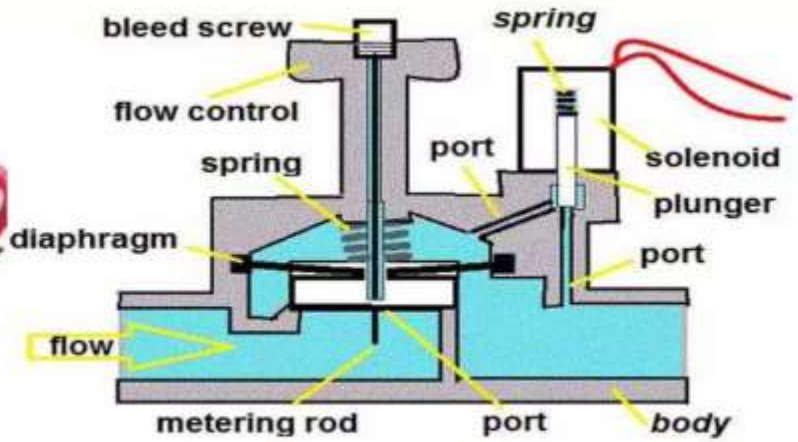
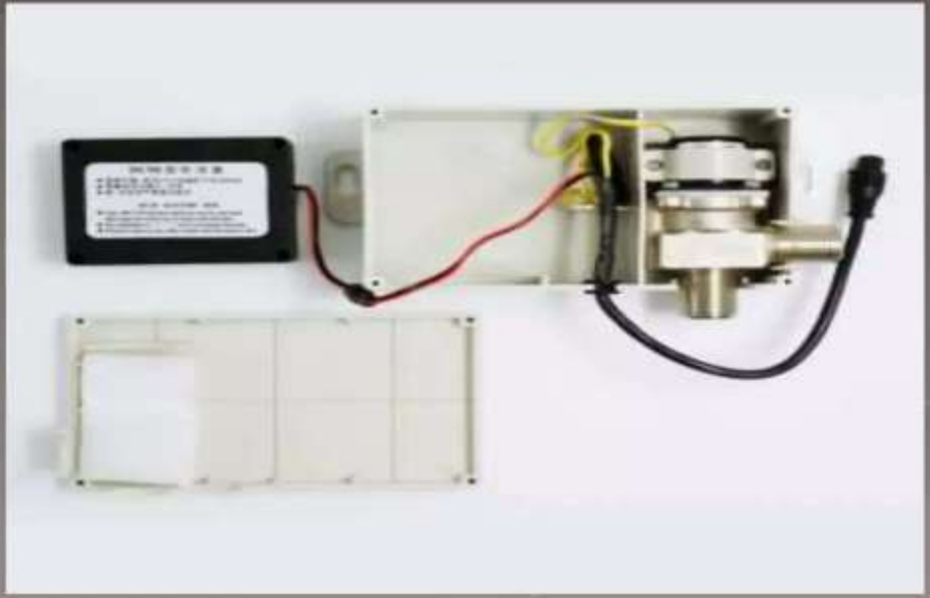
www.InstrumentationTools.com
Created by : S Bharadwaj Reddy


bleed screw
spring
flow control
port
solenoid
spring
plunger
diaphragm
port
flow
metering rod
port
body


CE
ISO 9001:2000

Application

- These are applicable in controlling the hydraulic action .
- These are used in plumbing for controlling the water flow.
- These are applicable in RO purifier
- These are used for mixing and distributing air.



Diaphragm Valves

A diaphragm valve is a linear motion valve that is used to start, regulate, and stop fluid flow. The name is derived from its flexible disk, which mates with a seat located in the open area at the top of the valve body to form a seal.

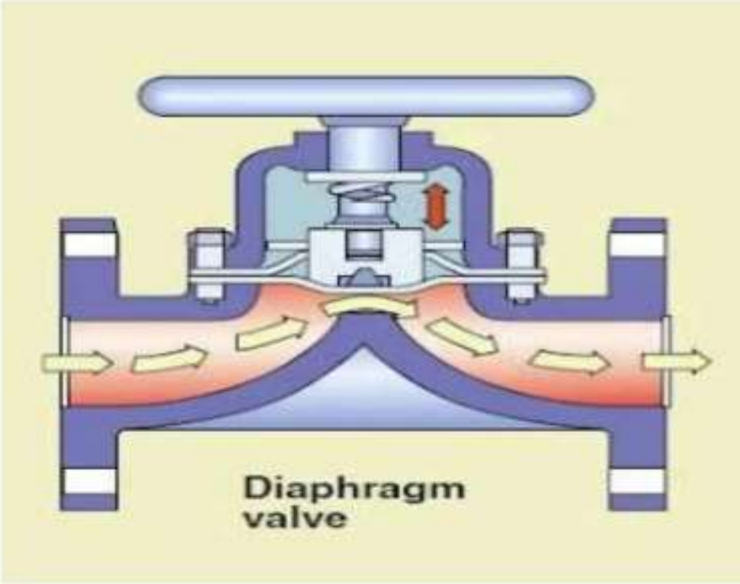
Advantages

- valve components can be isolated from the process fluid.
- Valve construction prevents leakage of the fluid without the use of a gland seal (packing)

Disadvantages

- The diaphragm becomes worn more easily and regular maintenance is necessary.

- These types of valves are generally not suited for very high temperature fluids and are mainly used on liquid systems.



Week -3

Lecture

on

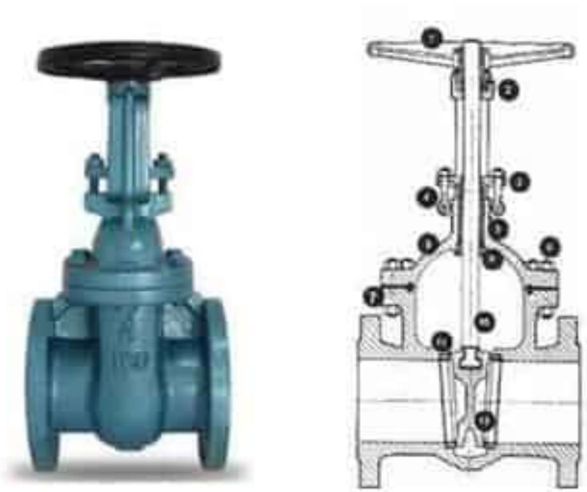
Valve

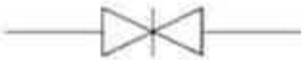
Valve Design , P& ID Symbol

Gate valve

P&ID Symbol

Isometric Symbol





Butt-welding ends

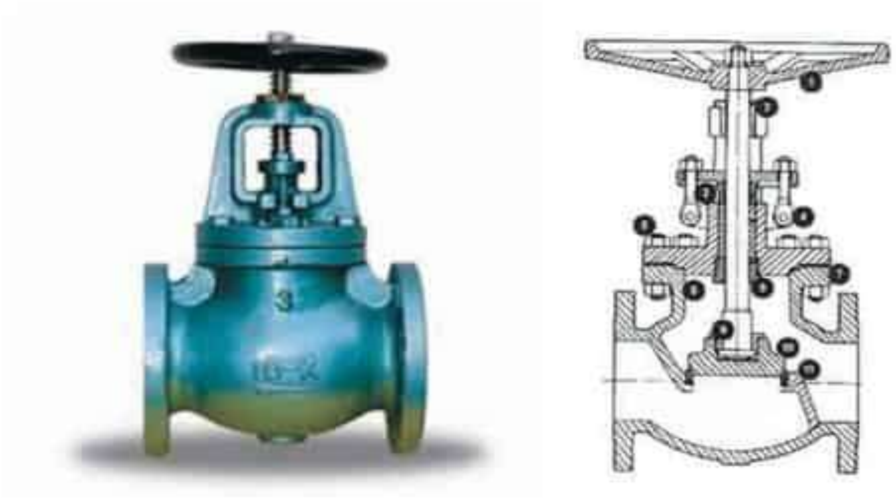
Flanged ends

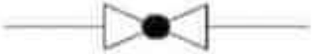
Socket ends

Globe valve

P&ID Symbol

Isometric Symbol





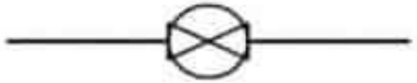
Butt-welding ends

Flanged ends

Socket ends

Ball valve

P&ID Symbol



Isometric Symbol

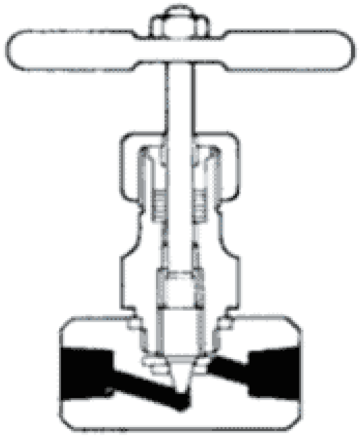
Butt-welding ends

Flanged ends

Socket ends

Needle valve

P&ID Symbol



Isometric Symbol

Butt-welding ends

Flanged ends

Socket ends

Butterfly valve

P&ID Symbol

Isometric Symbol

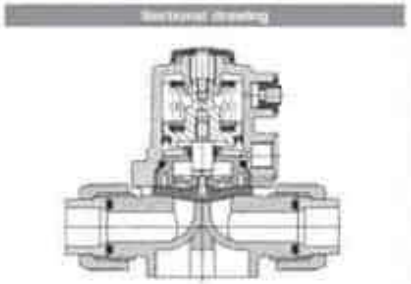
Butt-welding ends

Flanged ends

Socket ends

Diaphragm valve

P&ID Symbol



Isometric Symbol

Butt-welding ends

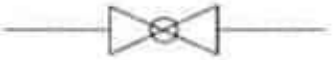
Flanged ends

Socket ends

Plug valve

P&ID Symbol

Isometric Symbol

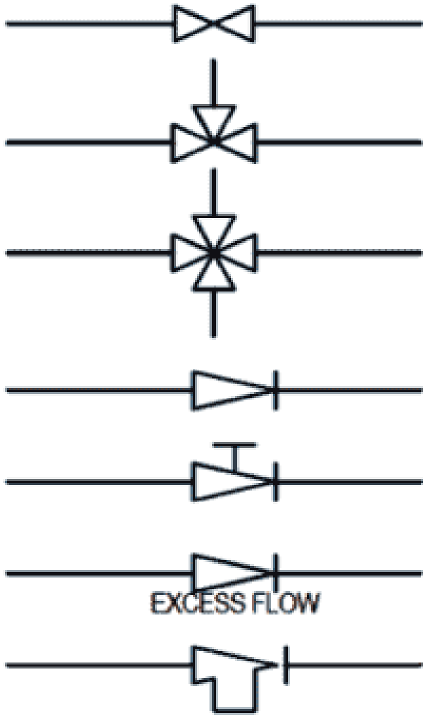


Butt-welding ends

Flanged ends

Socket ends

P&ID Symbols Valve - Generic



VALVE

3 WAY VALVE

4 WAY VALVE

CHECK VALVE

STOP CHECK VALVE
(NON RETURN)

EXCESS FLOW VALVE

AUTOMATIC RECIRCULATION VALVE

Week -4

Lecture

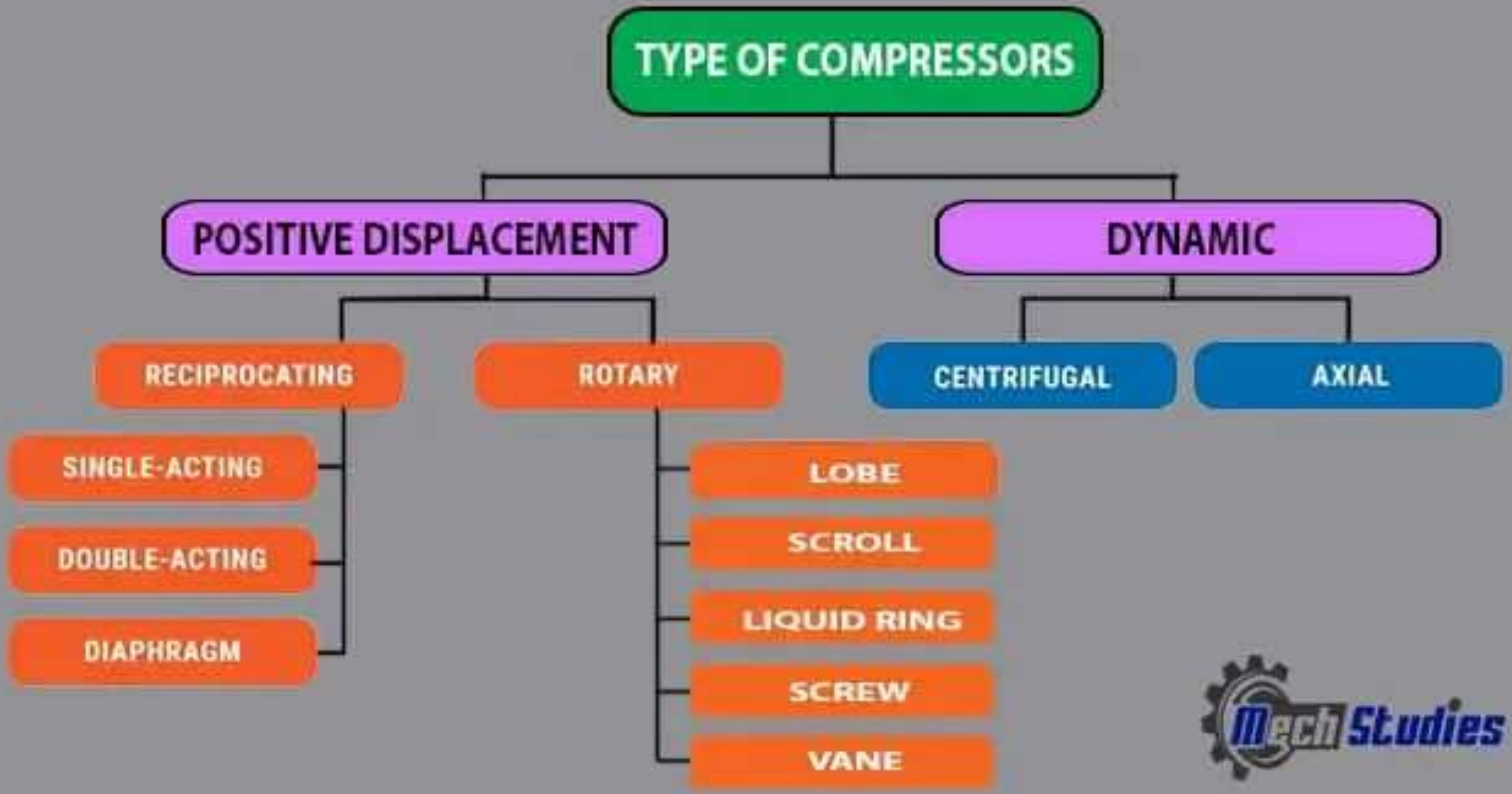
on

Compressor & Compressor Types

Compressor:

The compressor is pretty much an important component in most industrial machines and even for some household applications. From internal combustion engines to refrigerators the compressors are used and have a very important role in the operations. They have a wide range of applications. Let’s know more about them in detail.

- The compressor is basically, increases the pressure of the fluid by reducing its volume.
- The word compression obviously means reducing the volume of fluid.
- Later the fluid will be used for various applications or further processes.
- The gases are compressible and the compressor makes the best use of that characteristics.


TYPE OF COMPRESSORS
POSITIVE DISPLACEMENT
DYNAMIC
RECIPROCATING
ROTARY
CENTRIFUGAL
AXIAL
SINGLE-ACTING
DOUBLE-ACTING
DIAPHRAGM
LOBE
SCROLL
LIQUID RING
SCREW
VANE
Mech Studies

Week -5

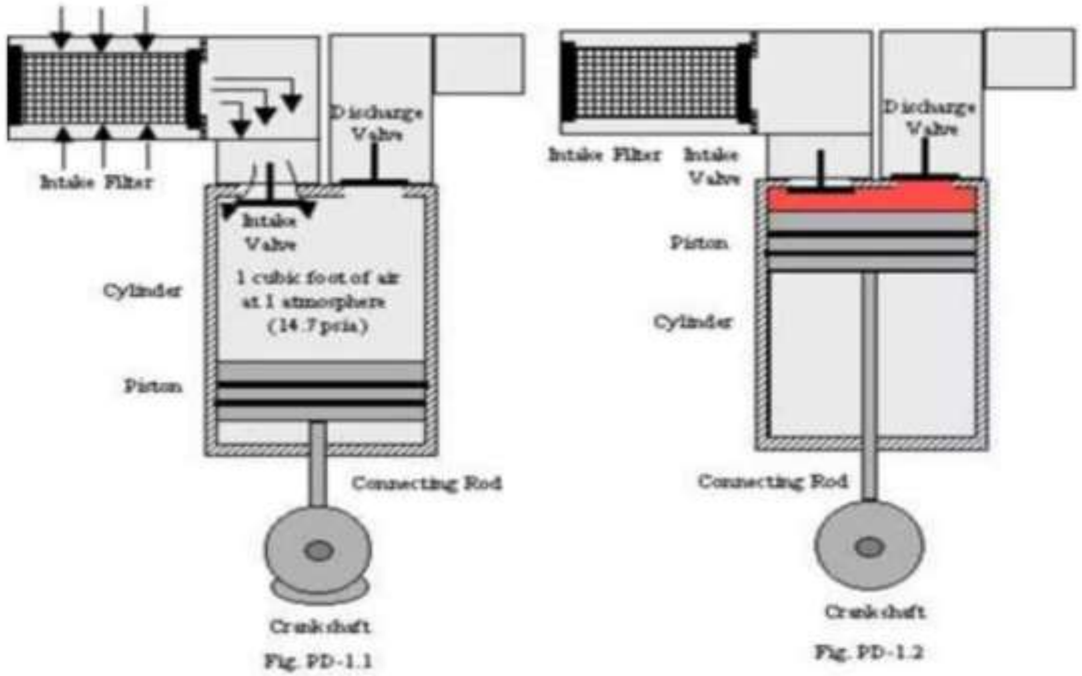
Lecture

on

Compressor Working Principle

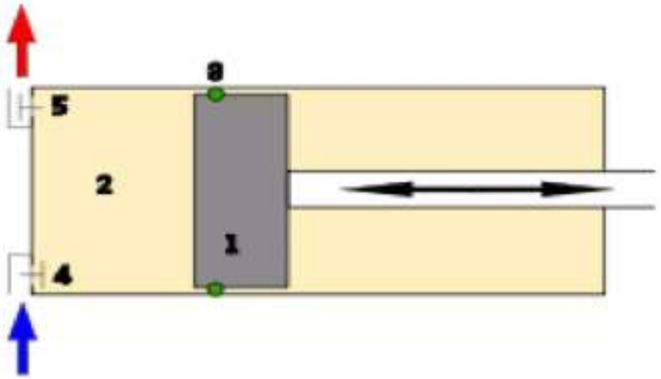
Positive Displacement

The compressors which compresses the air by the displacement of a mechanical linkage reducing the volume.



Reciprocating Compressor

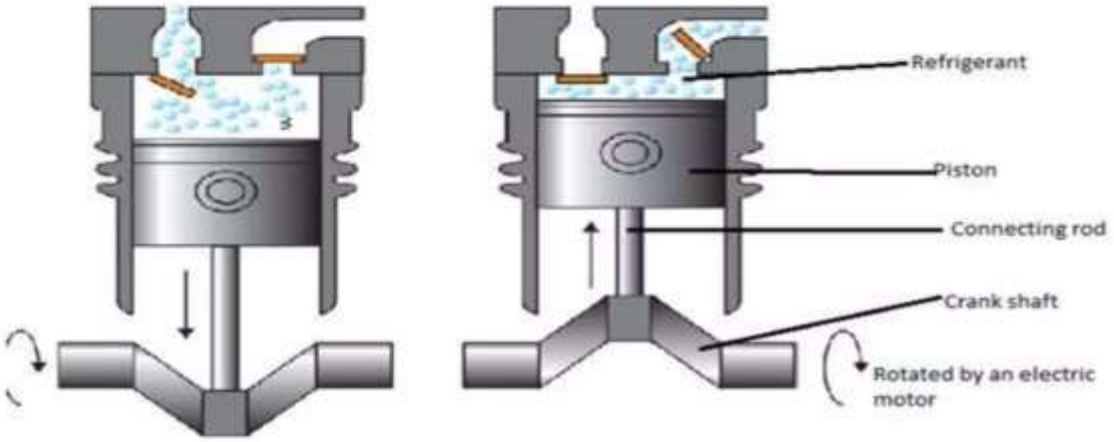
These compressors use the piston driven by the crankshaft. They can be either stationary or portable. It can be single staged or multistage and can be driven by the electric motors or internal combustion engines as well. They are made for intermittent duty.



Reciprocating Types

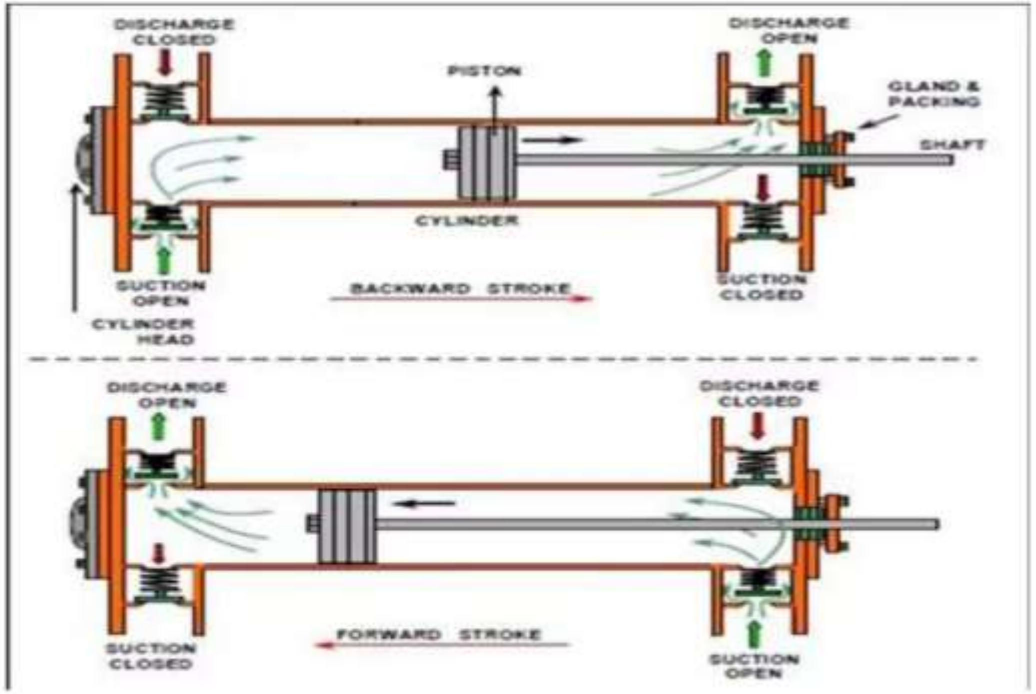
Single Acting Comp:

Compressor which compresses the air in one direction only having single piston.



Double Acting Compressor:

It also has just one cylinder but is pipe up such way that its capable of taking in discharging fluids from both ends and hence increases the **efficiency**



Multistage Compressors:

Multistage compressor is simply the compression of the fluid in two or more cylinders instead of one cylinder.

Week -6

Lecture

on

Compressor Design

Pressure as per Stages of Compressor

Single Stage Compressor : Low delivery pressure(**< or = 10 bar**)
Multistage Compressor : Low delivery pressure(**> or = 10 bar**)

Pressure as per final delivery of gas

Low pressure compressors(final pressure **<10 bar**)
Medium pressure compressors(final pressure b/w **10 bar to 80 bar**)
High pressure compressors(final pressure b/w **80 bar to 1000 bar**)

Advantages and Disadvantages of Reciprocating Compressors

Advantage:

- Suitable for high pressure ratios
- Easy maintenance
- Easy to operate
- Relatively cheap

Disadvantage:

- Multiple Machines are required
- Maintenance prone
- Sounds too much
- High outlet temperature of compressed air

Cooling Methods

Heat dissipation is happened with the help of fins over the cylinder. Air blows across the fins and hence decreasing the effect of heat during pistons movement is created .

Efficiency

- Reciprocating compressor with double or more acting piston is very efficient
- These compressors are more efficient when not running at full load while running on full load screw compressors are more suitable.

Rotary Compressors

These compressors does not have any reciprocating motion in fact it has rotating motion with screws, scrolls, and vanes rotating along side a shaft

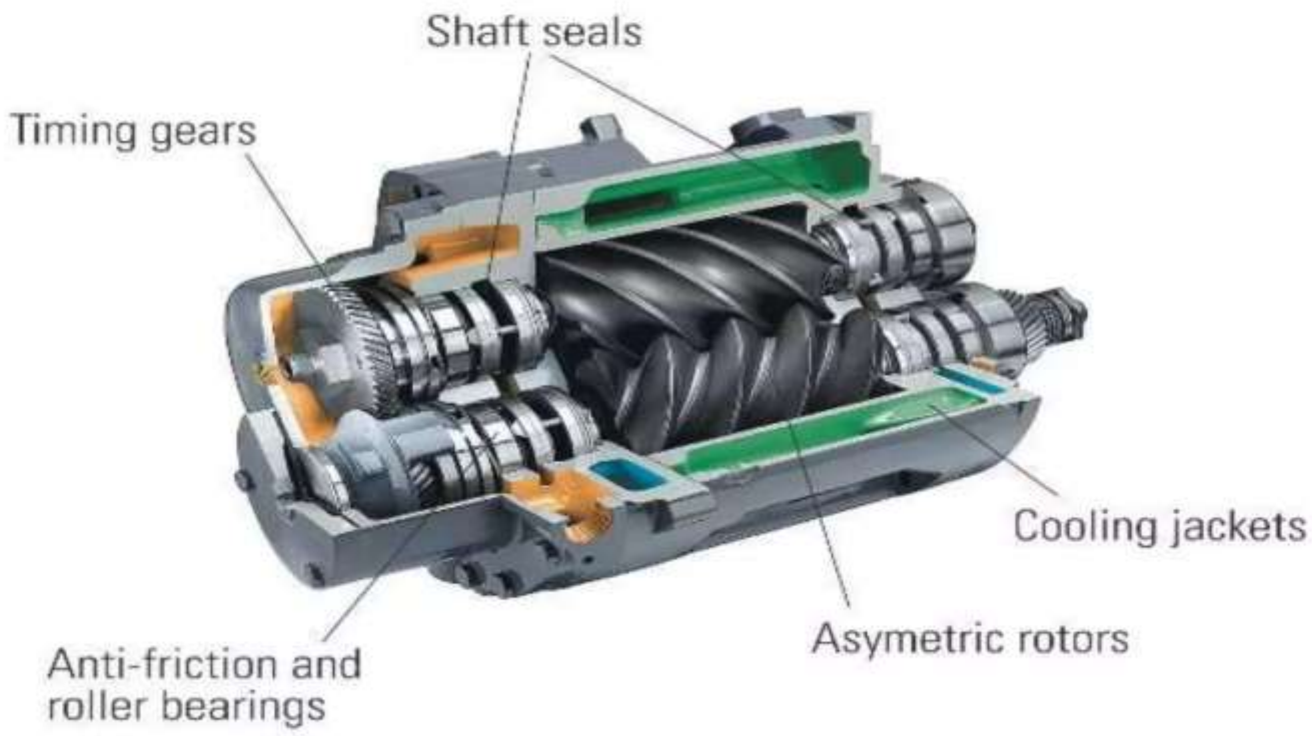
(1):Screw compressors

A type of gas compressor that uses a rotary type positive displacement. They are used in place of piston comp where large volume of air compression is needed and without intermittence. It has a pair of helical rotors where it traps air, as the rotor rotates in the cylinder. The male rotor and female rotor are being built inside the cylinder for compression. They are generally used in large industrial areas.

Applications

- They are used for larger industrial units
- Where continuous supply is required
- They are commonly seen at construction sites and with road repair crew throughout the world

Screw Compressors



Vane Compressor

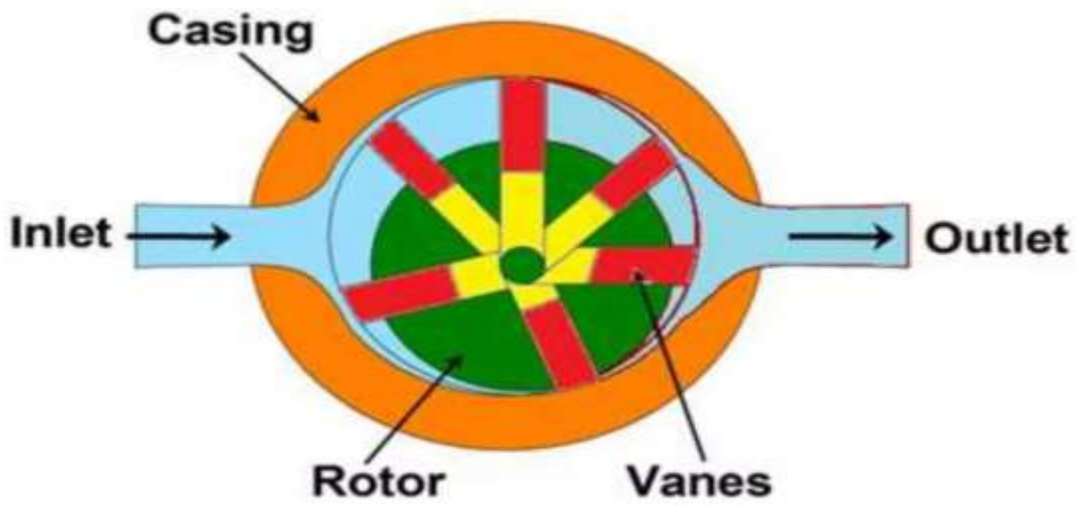
Rotary vane compressor consists of a rotor with a number of blades inserted in radial slots in the rotor. As the rotor turns, blades slide in and out of the slots keeping contact with the outer wall of the housing. Thus, a series of increasing and decreasing volumes is created by the rotating blades. They can be either stationary or portable , can be single staged or multistage driven by electric motors or I.C engines.

Pressure

Dry vane machines are used at relatively low pressures(e.g., **2bar** or **29 psi**) for bulk material movement while oil injected machines have the necessary volumetric efficiency to achieve pressures up to about **13 bar** or **190 psi** in a single stage. A vane compressor is comparatively quieter in operation than piston compressor.

They can have mechanical efficiency of about **90%**

Vane Compressors



Roto Dynamic Compressors

Compression is carried out by a rotating element which is imparting velocity to the flowing air or gas and hence developed desired pressure, and compression is achieved by the dynamic action of rotor.

Two major types of dynamic compressors

- Centrifugal Compressors
- Axial compressors

Centrifugal Compressors

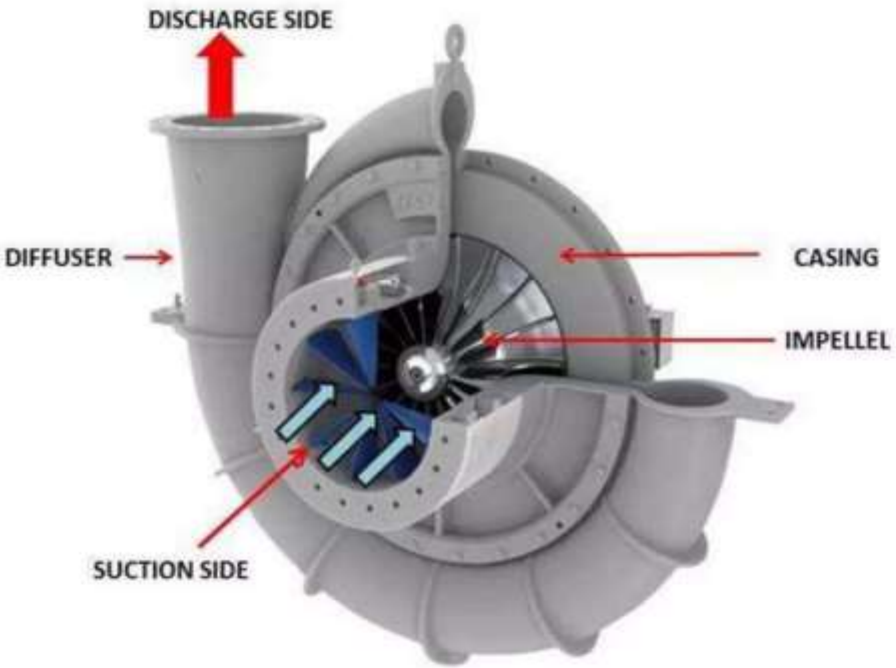
They use a rotating disk or impeller in a shaped housing to force the gas to the rim of the impeller, increasing the velocity. A diffuser or divergent duct converts the velocity energy to pressure energy.

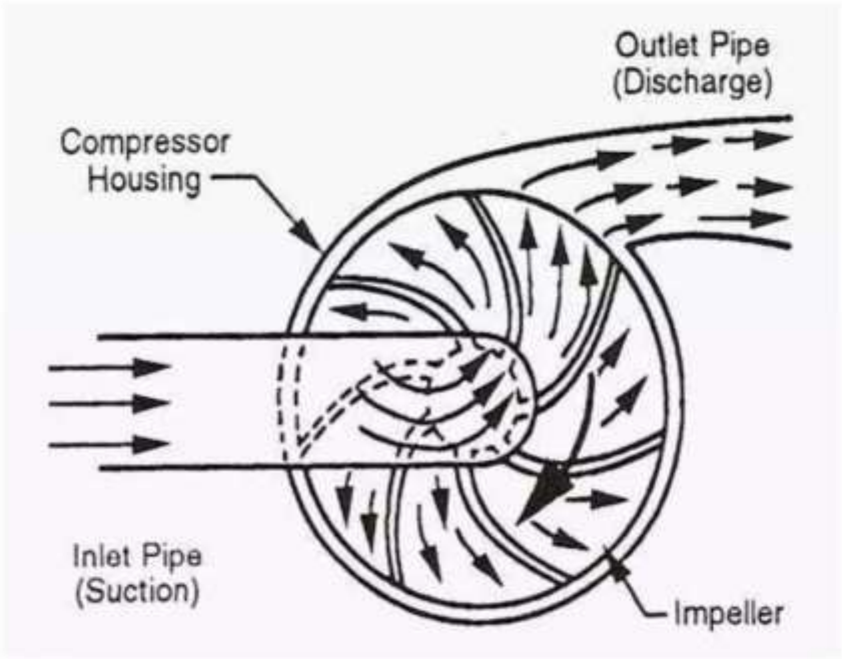
Application:

Used in stationary service in industries such as **oil refineries**, **chemical** and **natural gas processing** plants, small **gas turbine engines** also can be used in I.C engines as **supercharger** and **turbocharger**

Pressure:

Their application can be from 100 horsepower(75 kw) to thousands of horsepower with multiple staging, they can achieve high output pressures greater than **10,000 psi**





CENTRIFUGAL COMPRESSOR

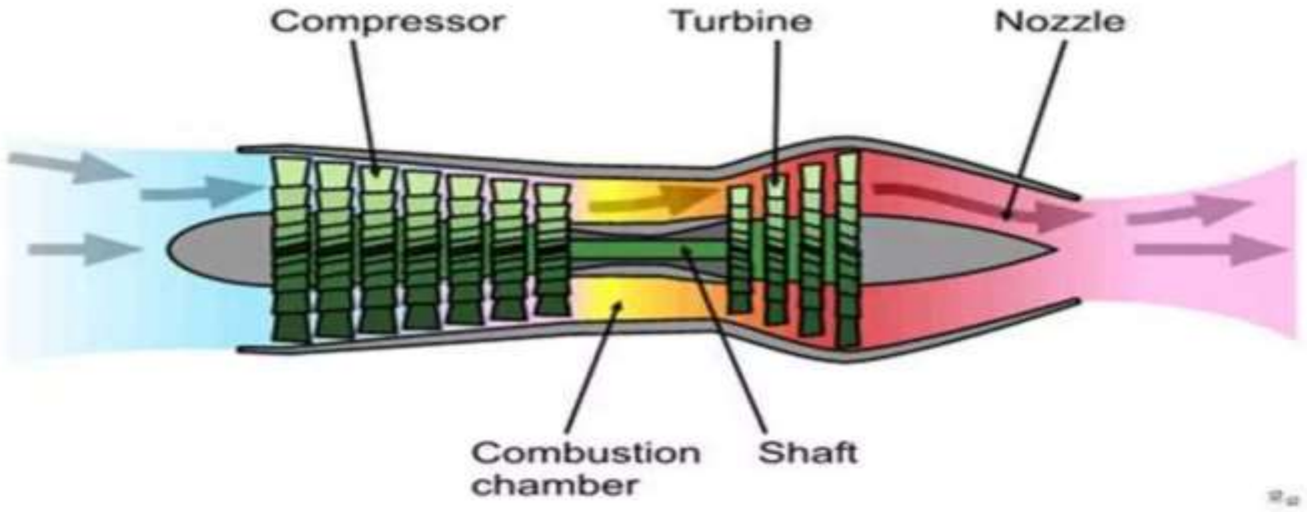
Axial Flow Compressors

Axial flow compressors are dynamic compression that use arrays of fan like airfoils to progressively compress a fluid. They are used where high flow rates or a compact designs are required.

The arrays of airfoils are set in rows, usually as pairs: one rotating and one stationary. These rotating airfoils are known as blades transport and compress the fluid

These compressors can have high efficiency of up to 90%

Axial flow compressors(Turbine)



Week -7

Lecture

on

Turbine Classifications

TURBINES

Turbines are the hydraulic machines which convert hydraulic energy into mechanical energy.

HYDRAULIC ENERGY → TURBINES → MECHANICAL ENERGY

Classification of Turbines

According to the Type of Energy at Inlet
- Impulse
- Reaction

Direction Of Flow Through Runner
- Tangential flow turbine
- Radial flow turbine
- Axial flow turbine
- Mixed flow turbine.

According To the Head at the Inlet of Turbine
- High head turbine
- Medium head turbine
- Low head turbine

According to the specific speed of the turbine
- High specific speed turbine
- Medium specific speed turbine
- Low specific speed turbine

Week -8

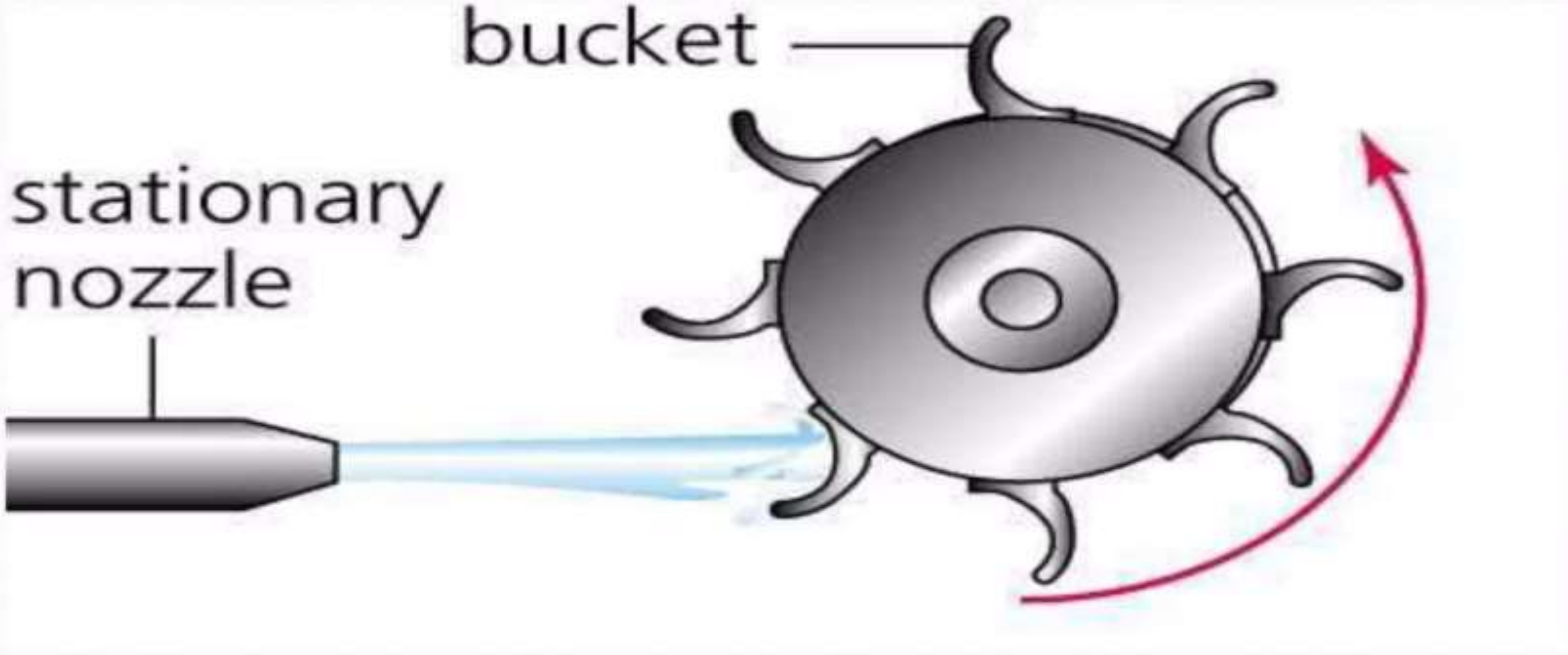
Lecture

on

Turbine Design

Impulse Turbine

- If at the inlet of turbine the energy available is only kinetic energy, the turbine is known as **Impulse Turbine**.



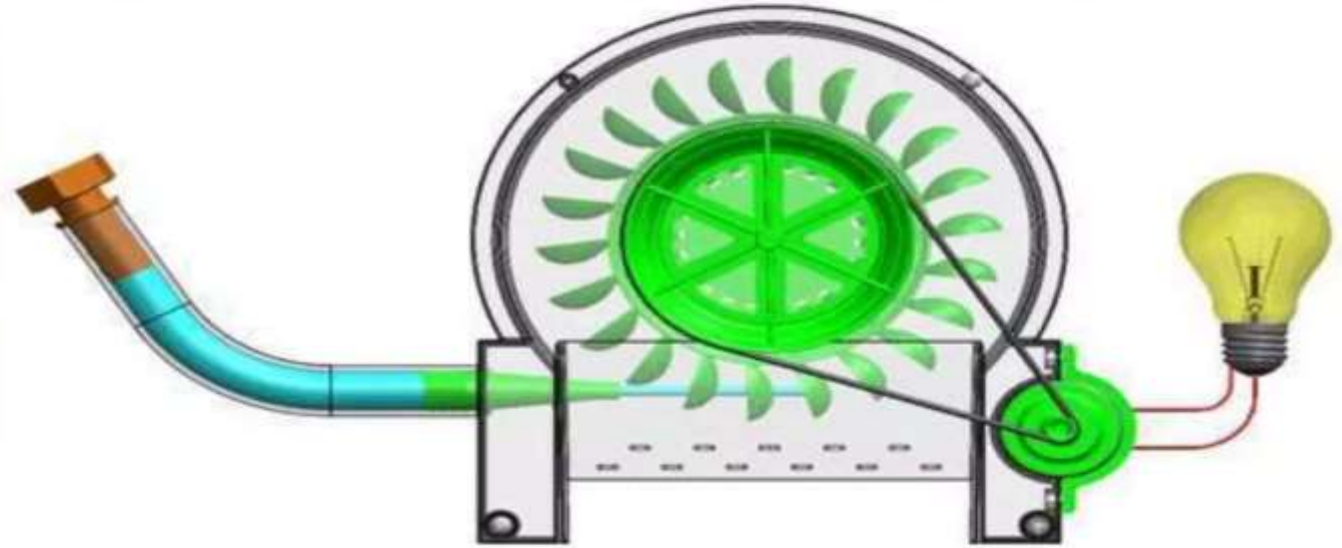
Types of Impulse Turbines

I. Pelton Turbine

II. Cross-flow Turbine

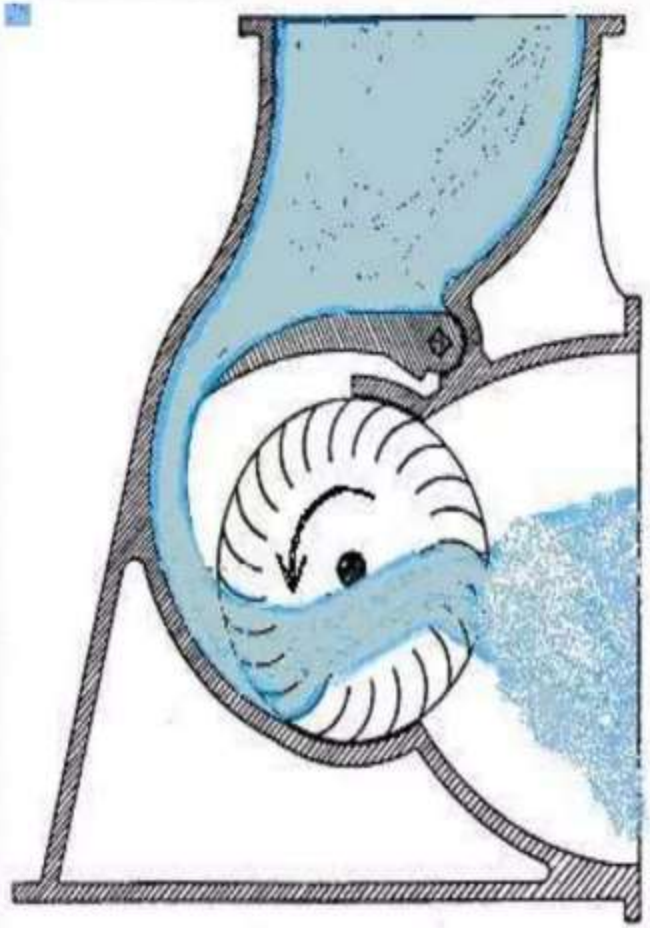
Pelton Turbine

- It was invented by Lester Ella Pelton in the 1870s.
- Pelton turbine is suitable for high head and low flow rate.
- Energy available at the inlet of the turbine is only kinetic energy. Pressure at the inlet & outlet is atmospheric.



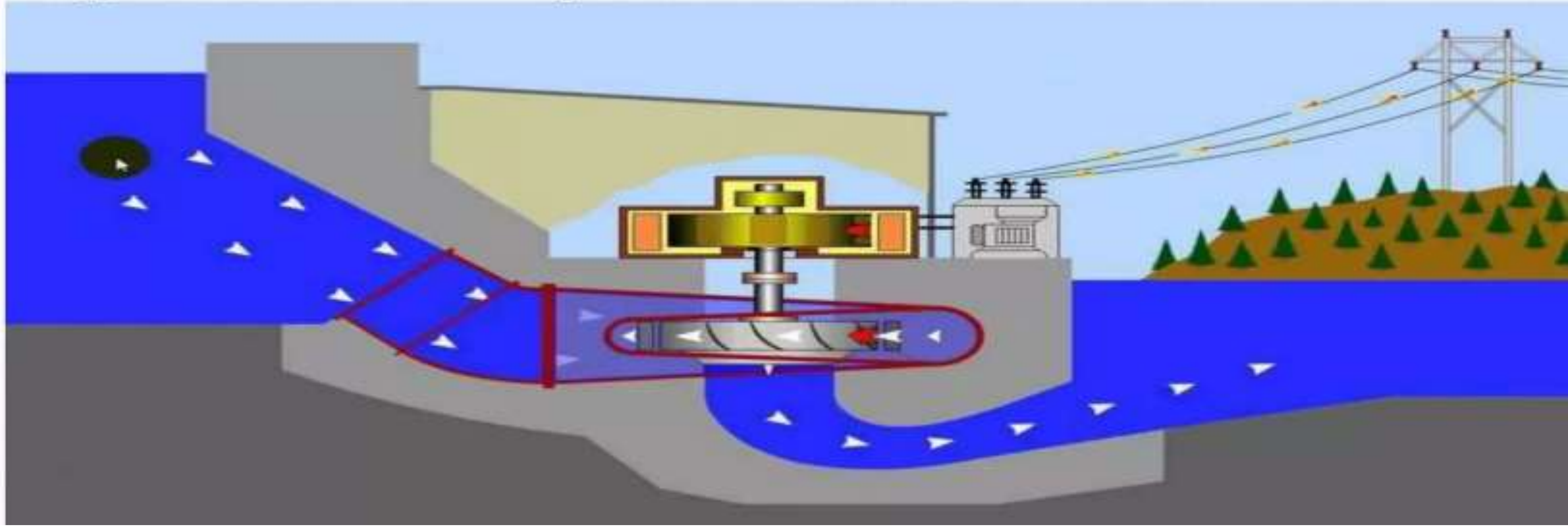
Cross-flow Turbine

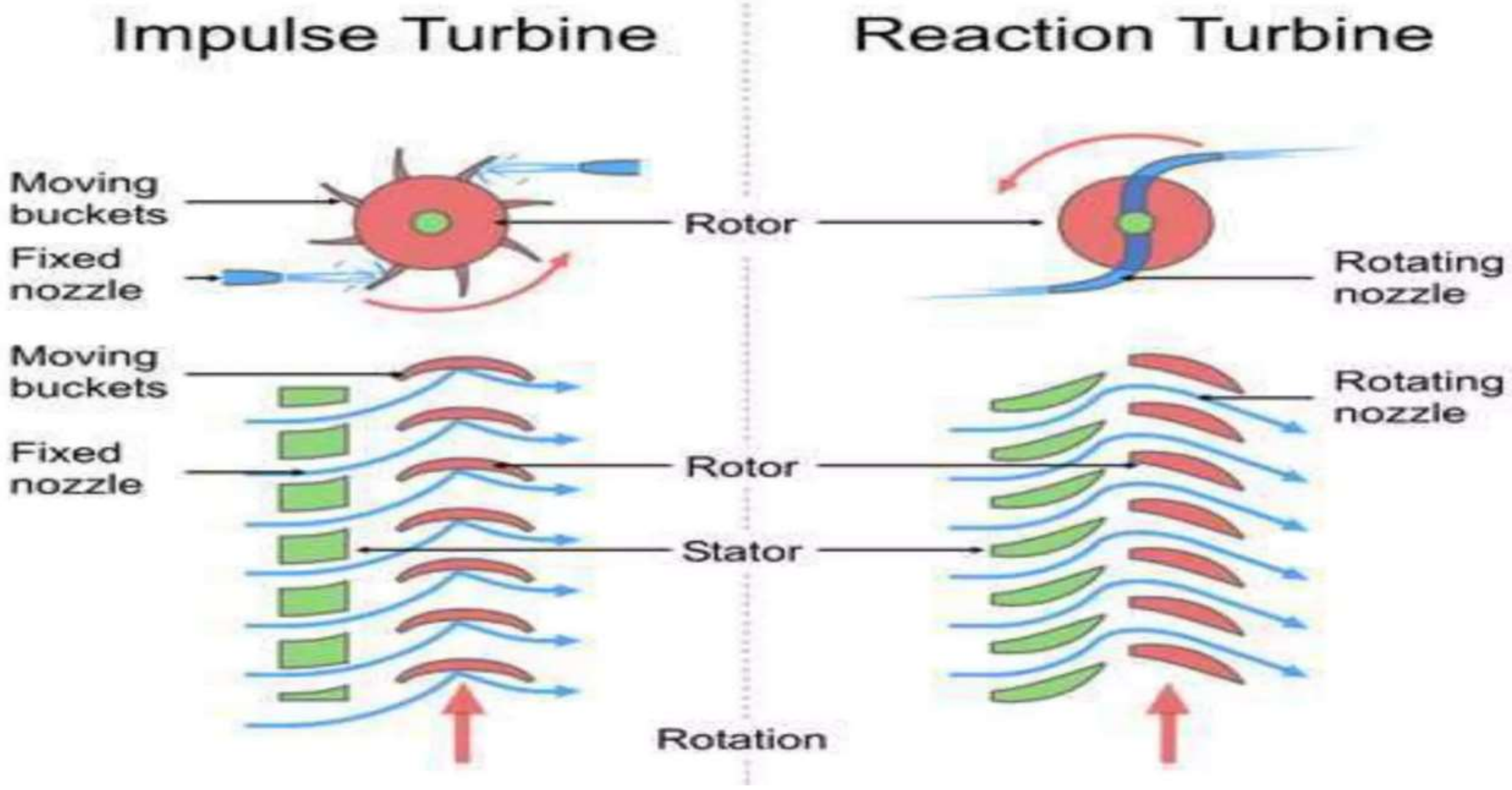
- It is developed by Anthony Michel, in 1903 and is used for low heads. (10–70 meters)
- As with a water wheel, the water is admitted at the turbine's edge. After passing the runner, it leaves on the opposite side.
- Going through the runner twice provides additional efficiency.
- The cross-flow turbine is a low-speed machine that is well suited for locations with a low head but high flow.



Reaction Turbine

- If at the inlet of turbine water possesses kinetic energy as well as pressure energy, the turbine is known as **Reaction Turbine.**
- In a reaction turbine, forces driving the rotor are achieved by the reaction of an accelerating water flow in the runner while the pressure drops.




Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Stator
Rotating nozzle
Rotation

- **Types of Reaction Turbines**
- Kaplan Turbine
- Francis Turbine
- Kinetic Turbine

Week -8

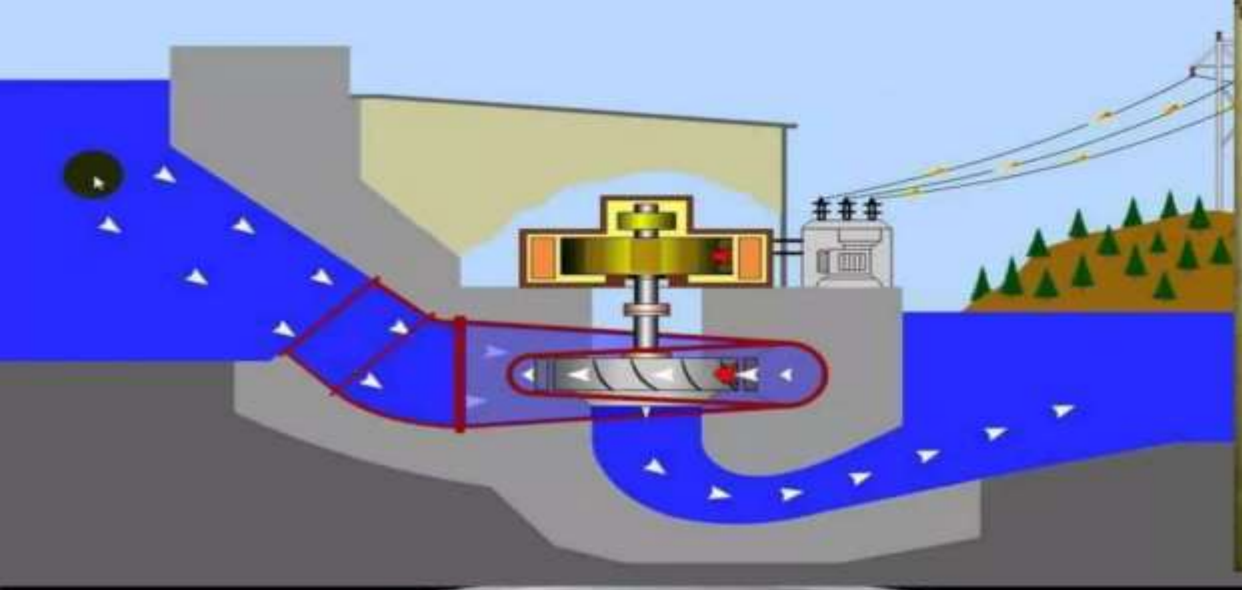
Lecture

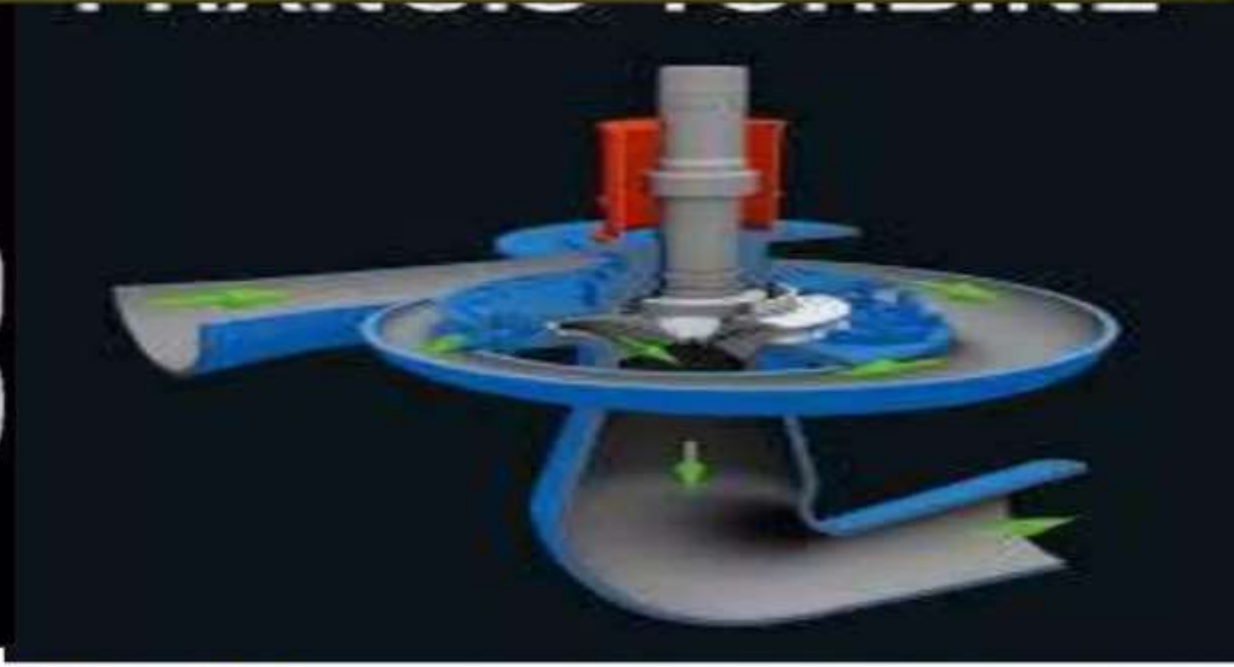
on

Turbine Selection

Francis Turbine

- The Francis turbine is a type of water turbine that was developed by James B. Francis and are used for medium head(45-400 m) and medium discharge.(10-700 m^3/s)
- The Francis turbine is a type of reaction turbine, a category of turbine in which the working fluid comes to the turbine under immense pressure and the energy is extracted by the turbine blades from the working fluid.
- The turbine's exit tube is shaped to help deaccelerate the water flow and recover the pressure.

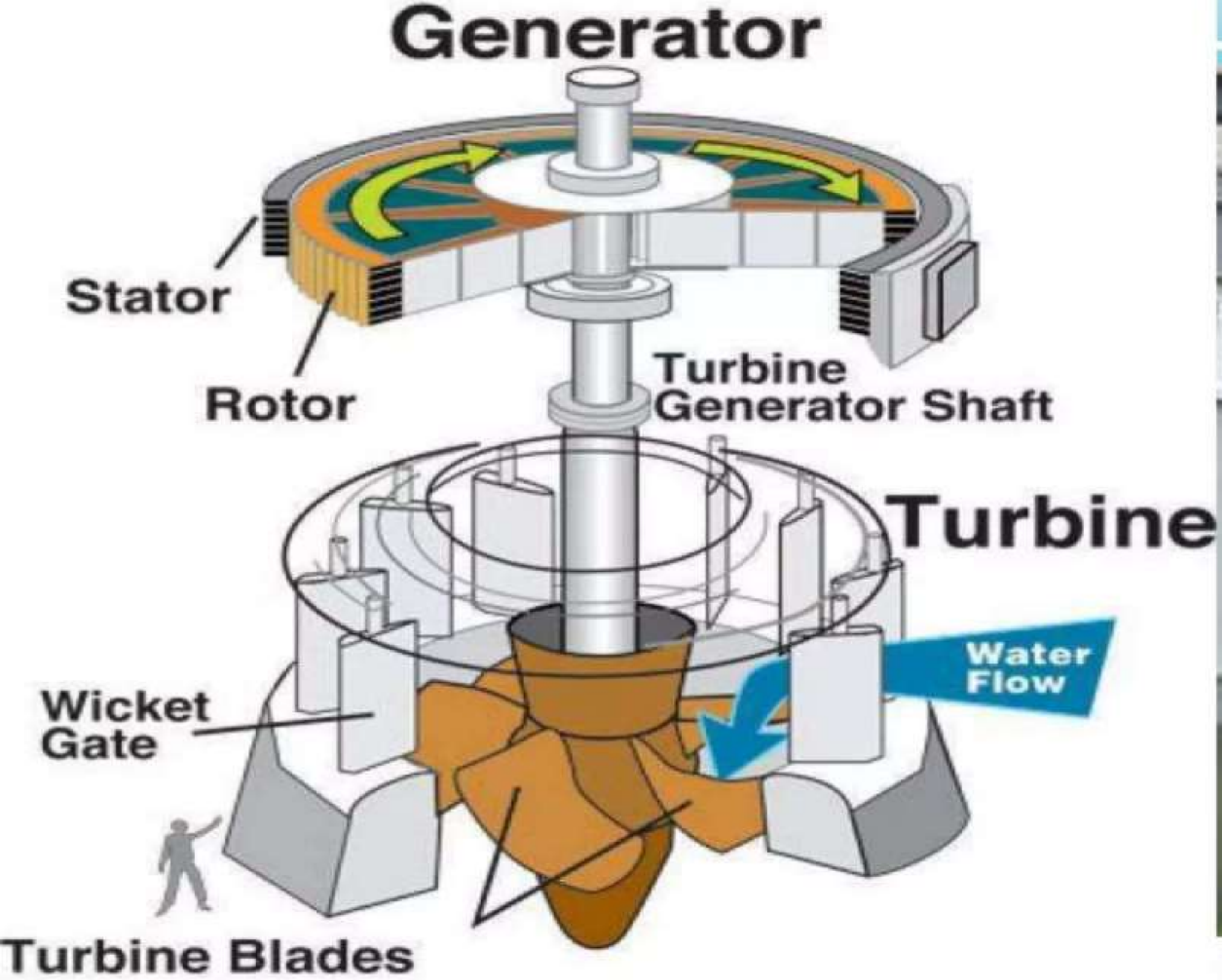




Francis Turbine

Kaplan Turbine

- The Kaplan turbine is a water turbine which has adjustable blades and is used for low heads and high discharges.
- It was developed in 1913 by the Austrian professor Viktor Kaplan.
- The Kaplan turbine having drop height: 10 - 700 m and Flow rate 4 - 55 m3/s

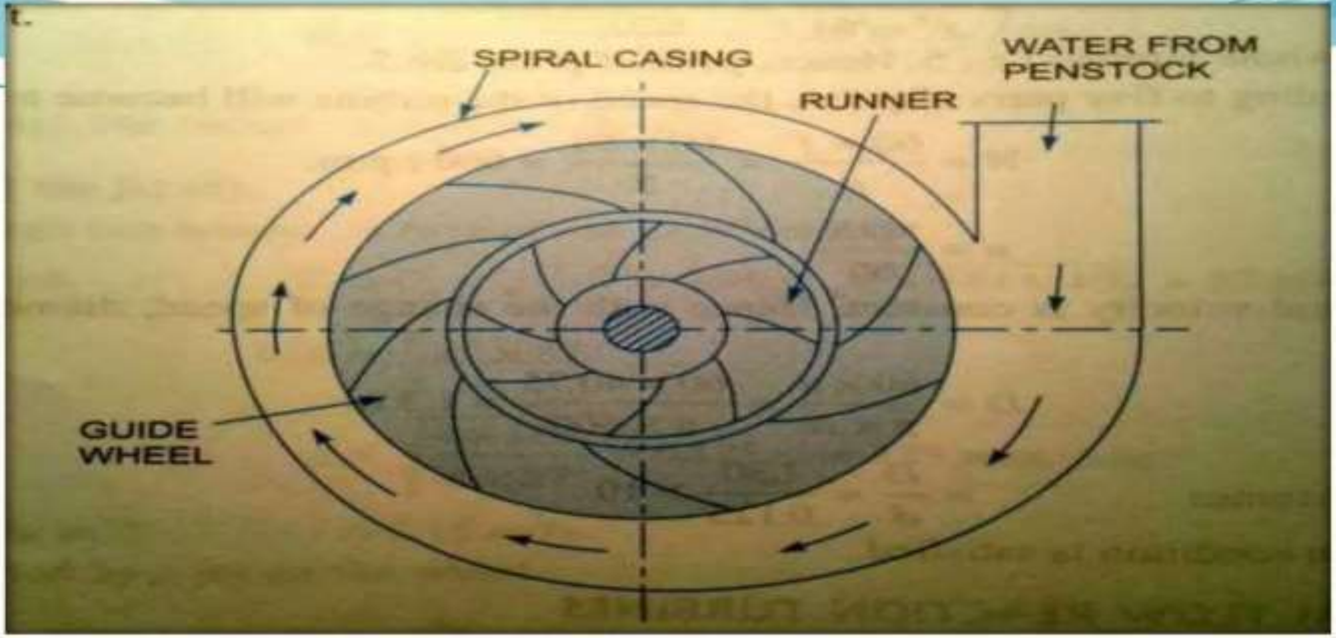

Generator
Stator
Rotor
Turbine
Generator Shaft
Turbine
Water
Flow
Wicket
Gate
Turbine Blades

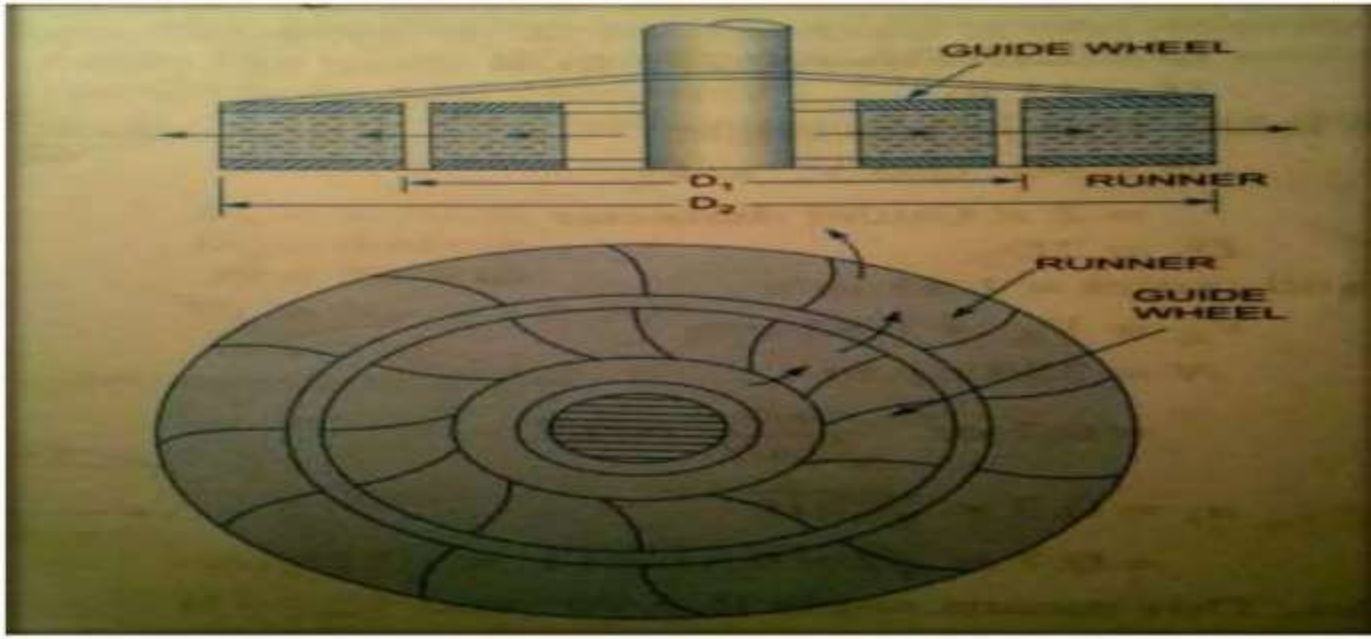
According to Direction Of Flow Through Runner

- If water flows along the tangent of runner, the turbine is known as **Tangential flow turbine.**
- If the water flows in radial direction through the runner,the turbine is known as **Radial flow turbine.**
  - If the water flows from outward to inward radially,the turbine is known as **Inward radial flow turbine.**
  - If the water flows from inward to outward radially,the turbine is known as **Outward radial flow turbine.**
- If water flows along the direction parallel to the axis of rotation of runner, the turbine is known as **Axial flow turbine.**
- If water flows in radial direction but leaves in the direction parallel to the axis of rotation,the turbine is known as **Mixed flow turbine.**

□If the water flows from outward to inward the turbine is known as **Inward radial flow turbine.**

□If the water flows from inward to outward the turbine is known as **Outward radial flow turbine.**

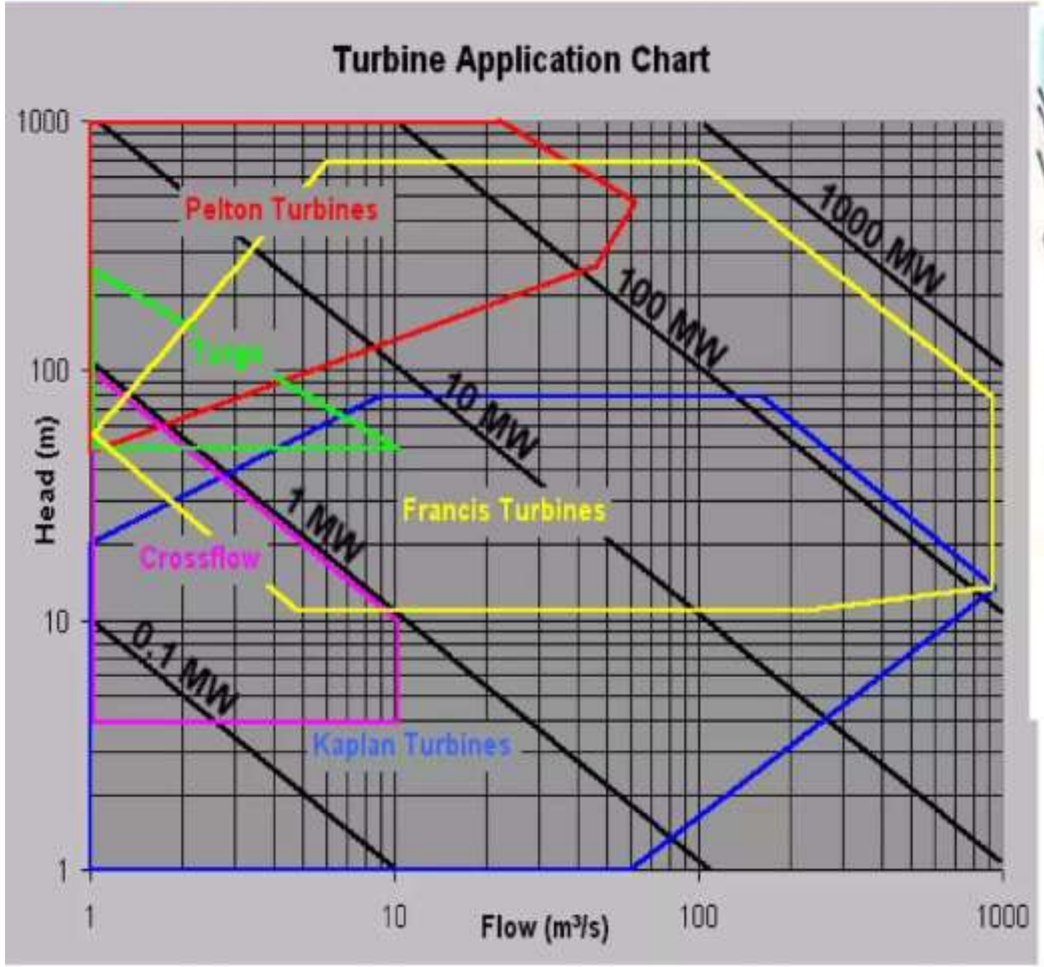


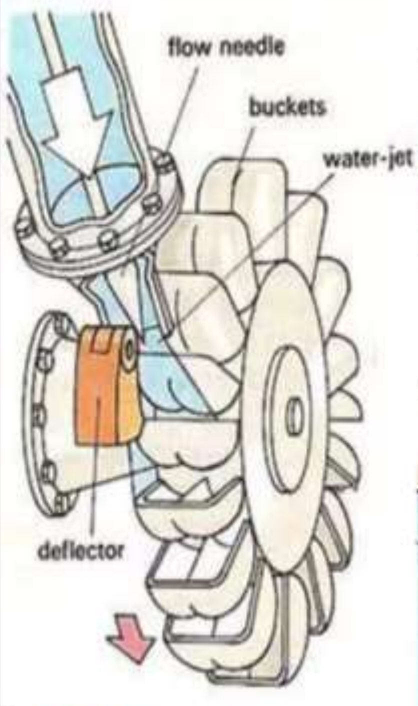


According to Head Available

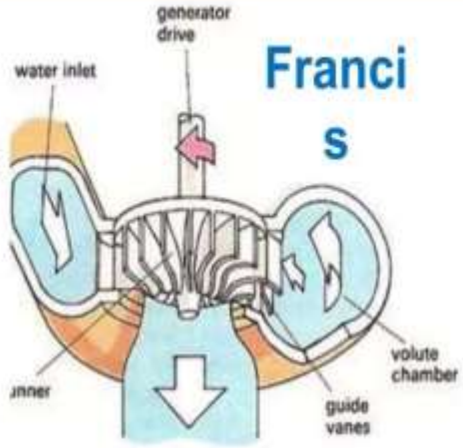
- Very High Heads (**350m and above**): **Pelton Turbine**
- High Heads (**150 m to 350 m**): **Pelton or Francis turbine**
- Medium Heads (**60 m to 150 m**): a **Francis turbine**
- Low Heads (**below 60m**): **Kaplan turbine**

Selection of Turbine

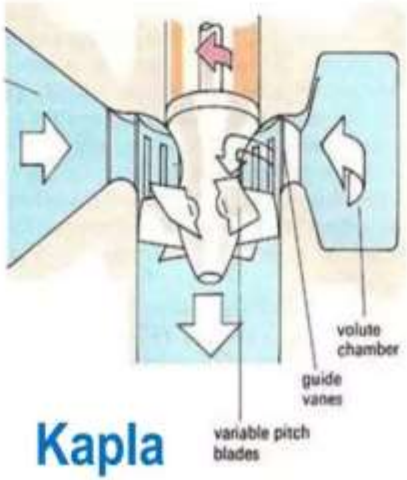




Pelton



Franci
s



Kapla

Week -9

Lecture

on

Turbine Specific Speed, Turbine Characteristics Curve

Specific Speed of Turbine

Specific Speed of a Turbine **(N_s)**

The specific speed of a turbine is the speed at which the turbine will run when developing unit power under a unit head. This is the type characteristics of a turbine. For a set of geometrically similar turbines the specific speed will have the same value.

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

Classification according to Specific Speed of Turbines

Type of turbine	Type of runner	Specific speed
Pelton	Slow Normal Fast	10 to 20 20 to 28 28 to 35
Francis	Slow Normal Fast	60 to 120 120 to 180 180 to 300
Kaplan	–	300 to 1000

Performance of Turbines under unit quantities

The unit quantities give the speed, discharge and power for a particular turbine under a head of 1m assuming the same efficiency. Unit quantities are used to predict the performance of turbine.

1. Unit speed (N_u) - Speed of the turbine, working under unit head

$$Nu = \frac{N}{\sqrt{H}}$$

2. Unit power (P_u) - Power developed by a turbine, working under a unit head

$$Qu = \frac{Q}{\sqrt{H}}$$

3. Unit discharge (Q_u) - The discharge of the turbine working under a unit head

$$Pu = \frac{P}{H^{3/2}}$$

Unit Speed, Unit discharge and Unit Power is definite characteristics of a turbine.

If for a given turbine under heads $H_1, H_2, H_3, \ldots$. the corresponding speeds are $N_1, N_2, N_3, \ldots$, the corresponding discharges are $Q_1, Q_2, Q_3, \ldots$. and the powers developed are $P_1, P_2, P_3, \ldots$. Then

$$\text{Unit speed} = N_u = \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}} = \frac{N_3}{\sqrt{H_3}}$$

$$\text{Unit Discharge} = Q_u = \frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}} = \frac{Q_3}{\sqrt{H_3}}$$

$$\text{Unit Power} = P_u = \frac{P_1}{H\sqrt{H_1}} = \frac{P_2}{H\sqrt{H_2}} = \frac{P_3}{H\sqrt{H_3}} \text{ or } P_u = \frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}} = \frac{P_3}{H_3^{3/2}}$$

Thus if speed, discharge and power developed by a turbine under a certain head are known, the corresponding quantities for any other head can be determined.

Characteristics Curves of Turbine

These are curves which are characteristic of a particular turbine which helps in studying the performance of the turbine under various conditions. These curves pertaining to any turbine are supplied by its manufacturers based on actual tests.

The characteristic curves obtained are the following:

a) Constant head curves or main characteristic curves
b) Constant speed curves or operating characteristic curves
c) Constant efficiency curves or Muschel curves

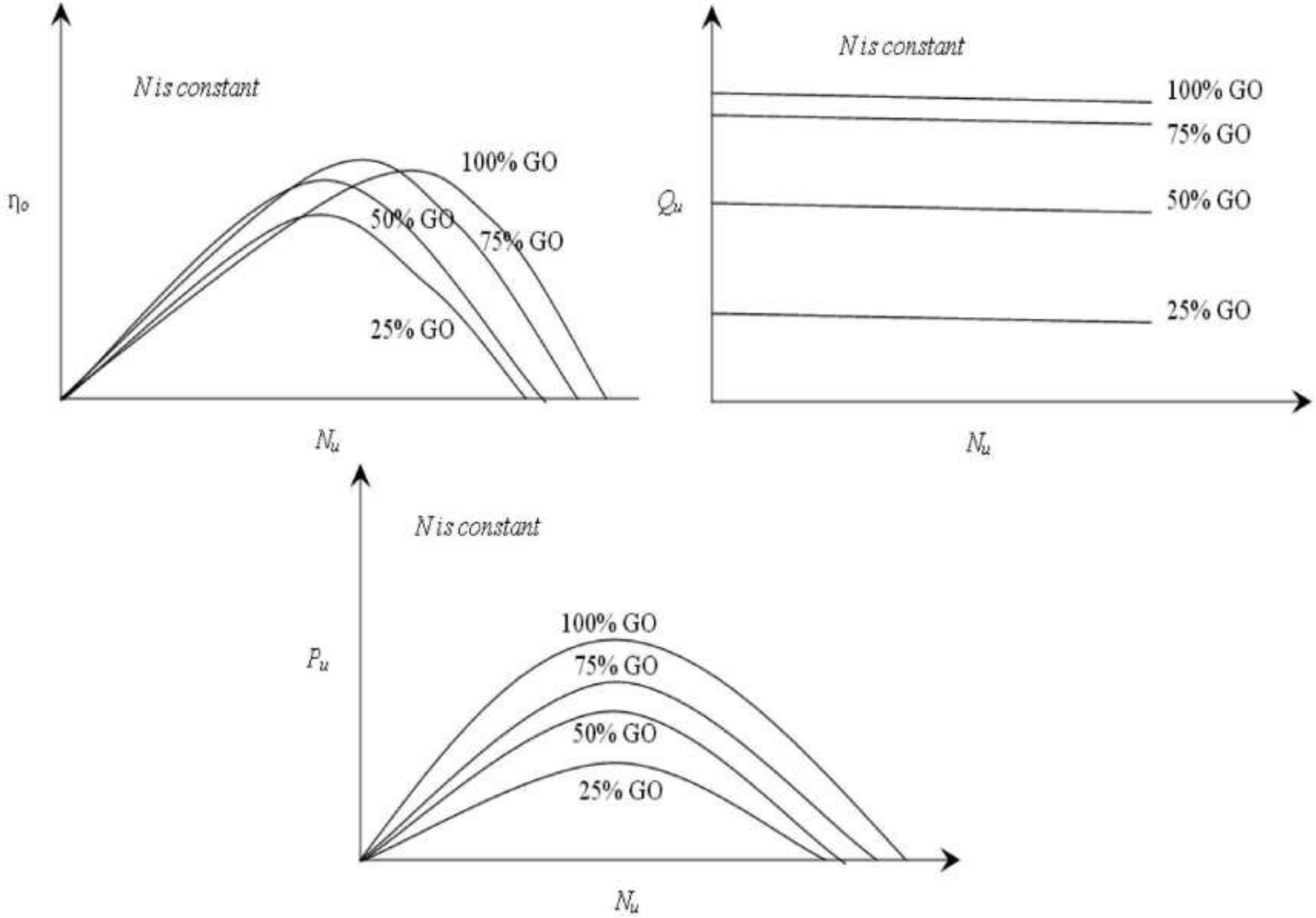
Constant head curves or main characteristic curves

Constant head curves:

Maintaining a constant head, the speed of the turbine is varied by admitting different rates of flow by adjusting the percentage of gate opening. The power P developed is measured mechanically. From each test the unit power Pu, the unit speed Nu, the unit discharge Qu and the overall efficiency are determined.

The characteristic curves drawn are

a) Unit discharge vs unit speed
b) Unit power vs unit speed
c) Overall efficiency vs unit speed



Main Characteristic curves of a Pelton turbine

Constant speed curves or operating characteristic curves

Constant speed curves:

In this case tests are conducted at a constant speed varying the head H and suitably adjusting the discharge Q. The power developed P is measured mechanically. The overall efficiency is aimed at its maximum value.

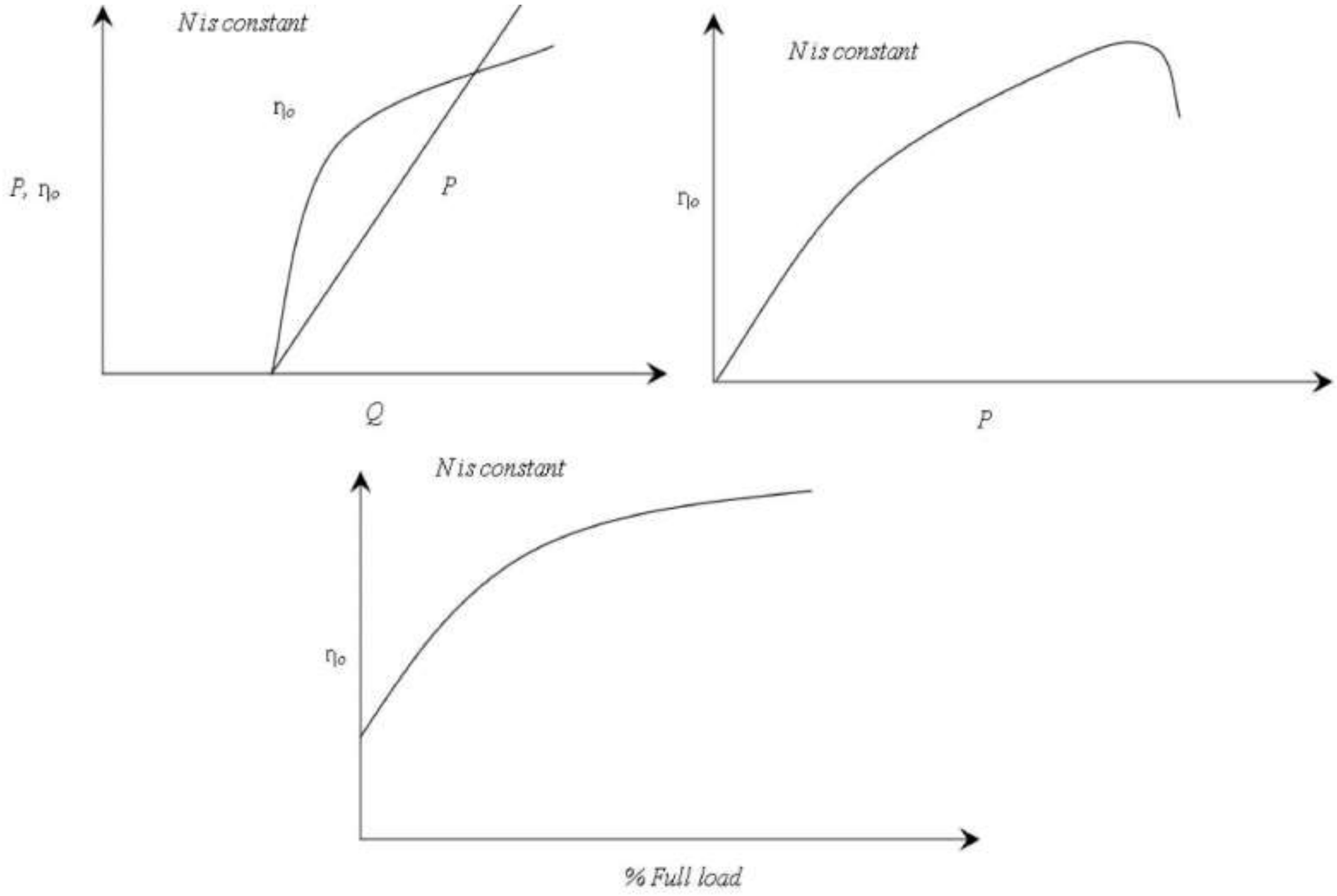
The curves drawn are

P vs Q

η_o vs Q

η_o vs P_u

$\eta_{o\,max}$ vs % Full load



Operating Characteristic curves of a turbine

Week -11

Lecture

on

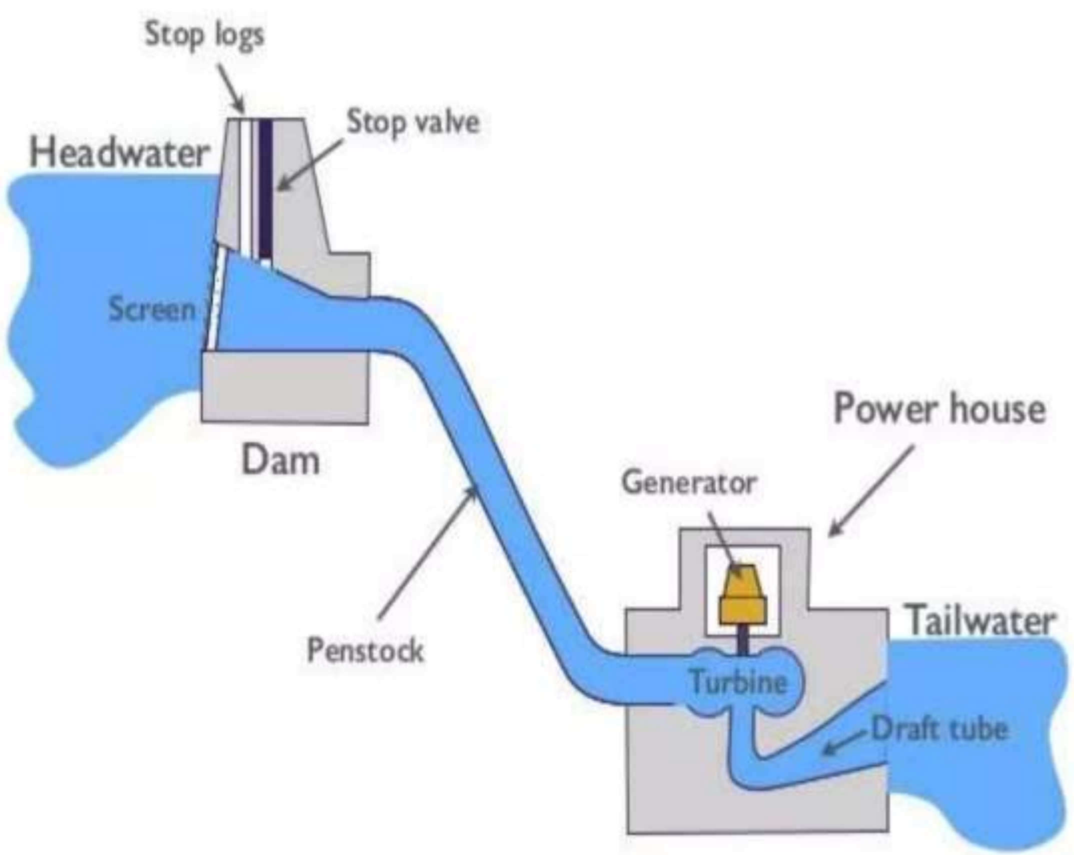
Turbine Performance, Draft Tube & Surge Tank

Draft Tube

The water after working on the turbine, imparts its energy to the vanes and runner, there by reducing its pressure less than that of atmospheric Pressure. As the water flows from higher pressure to lower Pressure, It can not come out of the turbine and hence a divergent tube is Connected to the end of the turbine.

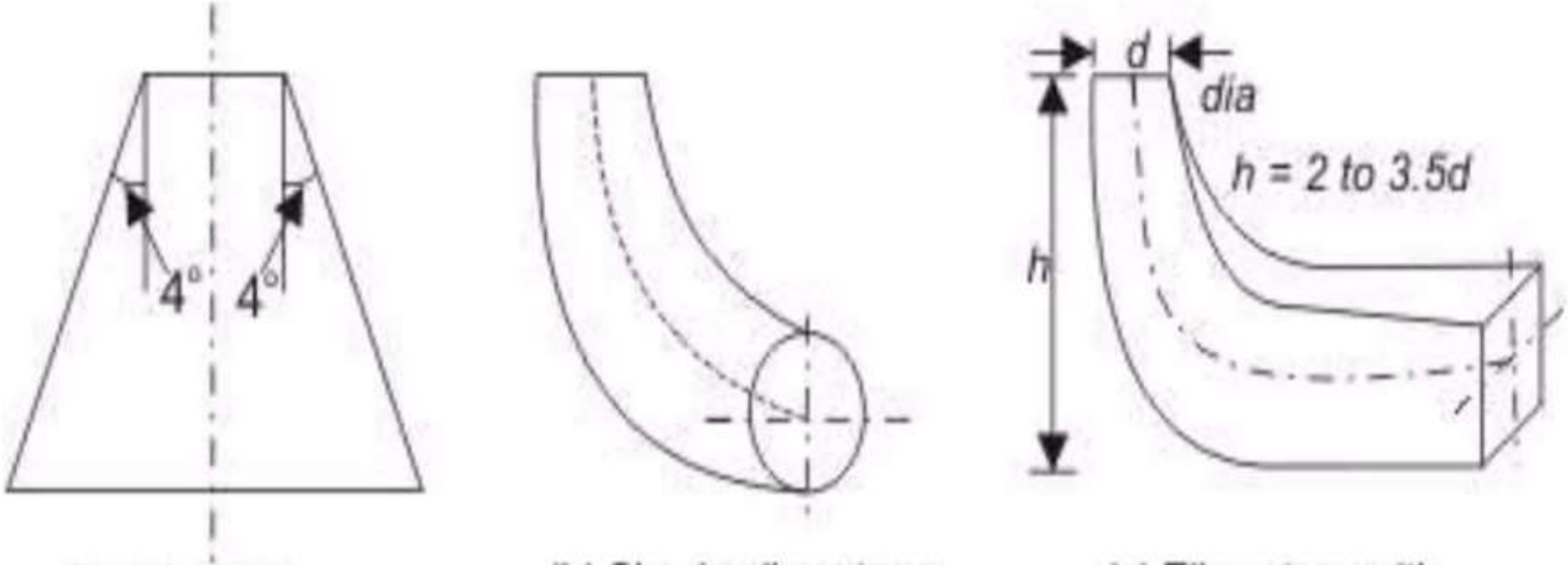
Draft tube is a divergent tube one end of which is connected to the outlet Of the turbine and other end is immersed well below the tailrace (Water level).

The major function of the draft tube is to increase the pressure from the inlet to outlet of the draft tube as it flows through it and hence increase it more than atmospheric pressure. The other function is to safely Discharge the water that has worked on the turbine to tailrace.


Stop logs
Stop valve
Headwater
Screen
Dam
Power house
Generator
Penstock
Tailwater
Turbine
Draft tube

Draft Tube

Types of Draft Tube



(a) Straight type

(b) Simple elbow type

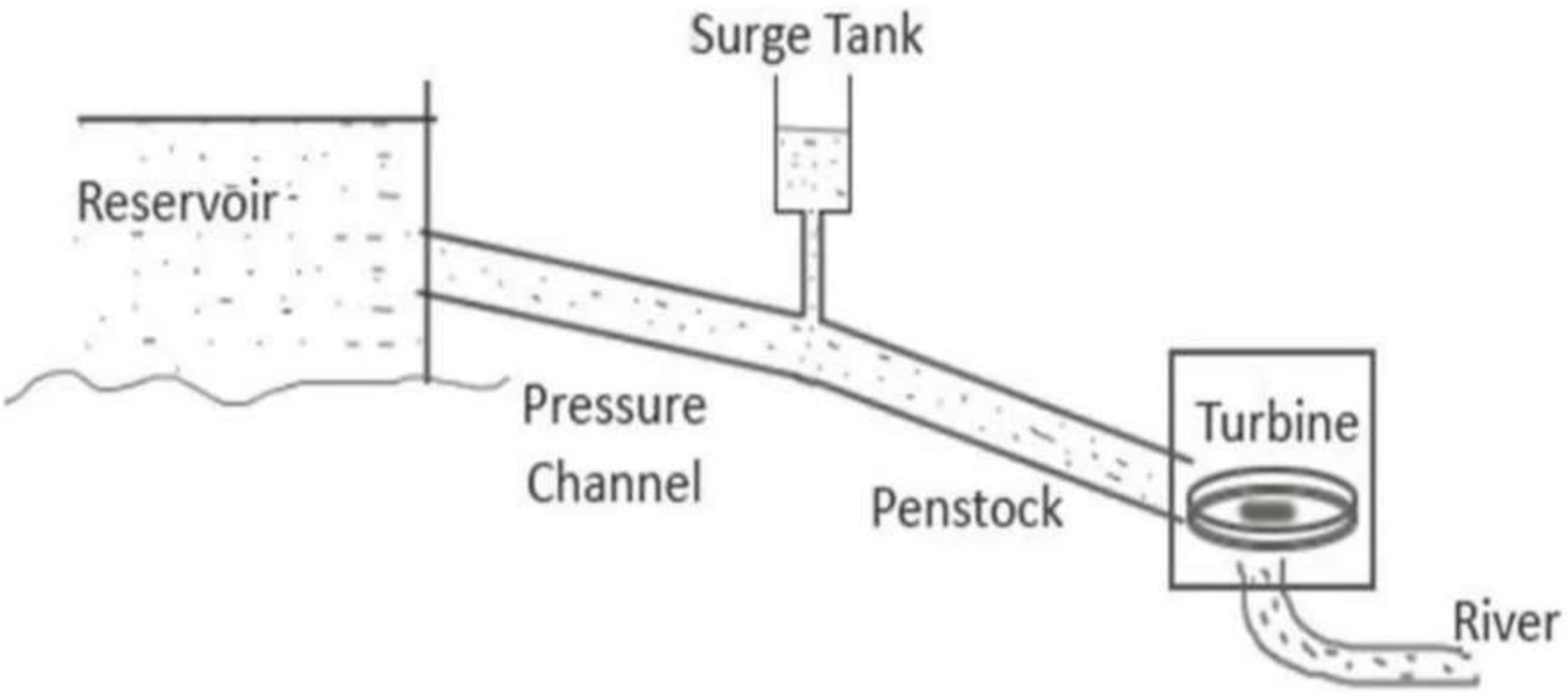
(c) Elbow type with varying cross-section

Surge Tanks

Surge tank (or surge chamber) is a device introduced within a hydropower water conveyance system having a rather long pressure conduit to absorb the excess pressure rise in case of a sudden valve closure. The surge tank is located between the almost horizontal or slightly inclined conduit and steeply sloping penstock and is designed as a chamber excavated in the mountain.

It also acts as a small storage from which water may be supplied in case of a sudden valve opening of the turbine.

In case of a sudden opening of turbine valve, there are chances of penstock collapse due to a negative pressure generation, if there is no surge tank.


Surge Tank
Reservoir
Pressure
Channel
Penstock
Turbine
River

Surge Tank

Week -11

Lecture

on

Problem Solving

(Turbine)

Mathematical Problems on Turbine

Mathematical problems related to Turbine will be practiced and solved during classroom sessions. Problems from the prescribed reference book will be addressed, and additional practice materials will be provided to enhance understanding and proficiency.

Week -13

Lecture
on
Pump Classification

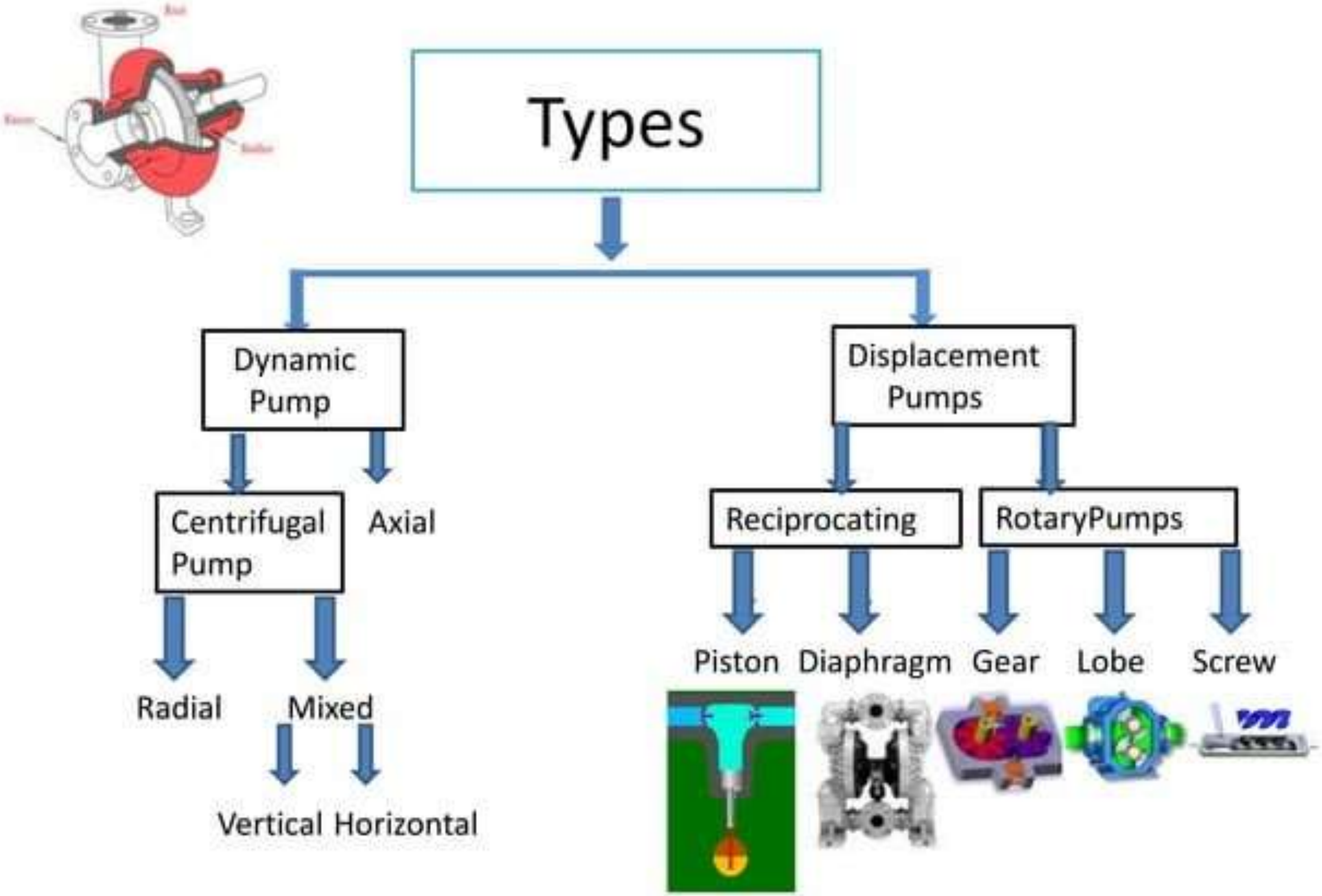
WHAT IS PUMP?

- A pump machine is a device for converting the energy held by mechanical energy into fluid.
- **Function:-**
- Flow from a region of low pressure to one of high pressure
- Flow from a low level to a higher level

Flow at a faster rate.

Propties:-

- Pumps operate by some mechanism and consume energy to perform mechanical work by moving the fluid.
- Pumps operate via many energy sources.


Types
Dynamic Pump
Displacement Pumps
Centrifugal Pump
Axial
Reciprocating
RotaryPumps
Radial
Mixed
Vertical
Horizontal
Piston
Diaphragm
Gear
Lobe
Screw

Centrifugal Pump

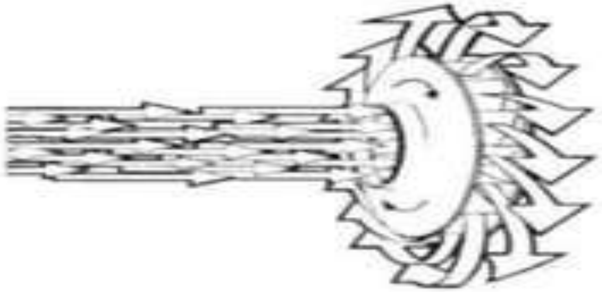
- <u>Working Principle</u>:

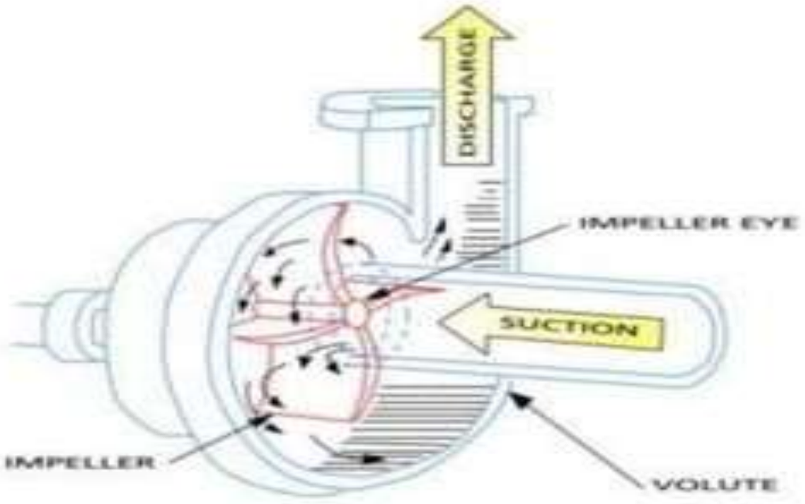
  Works on the principle of centrifugal force. This is the force that pushes the liquid away from the centre(in tangential direction).

  Converting Prime Mover energy into Mechanical energy through shaft .

  Converting Mechanical energy into fluid energy impeller.

  Converting kinetic Energy into pressure energy through the volute casing.

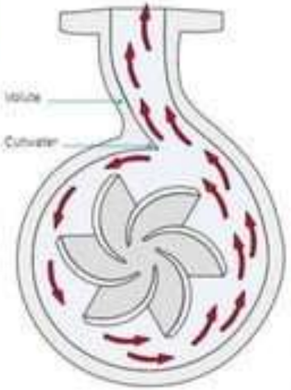




Major Parts

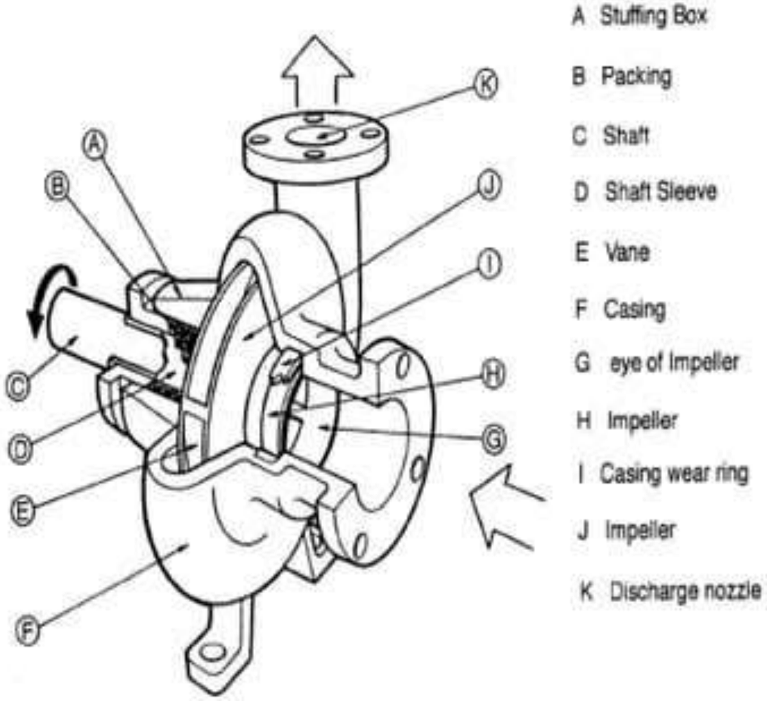
Impeller/
Blades

Volute Casing



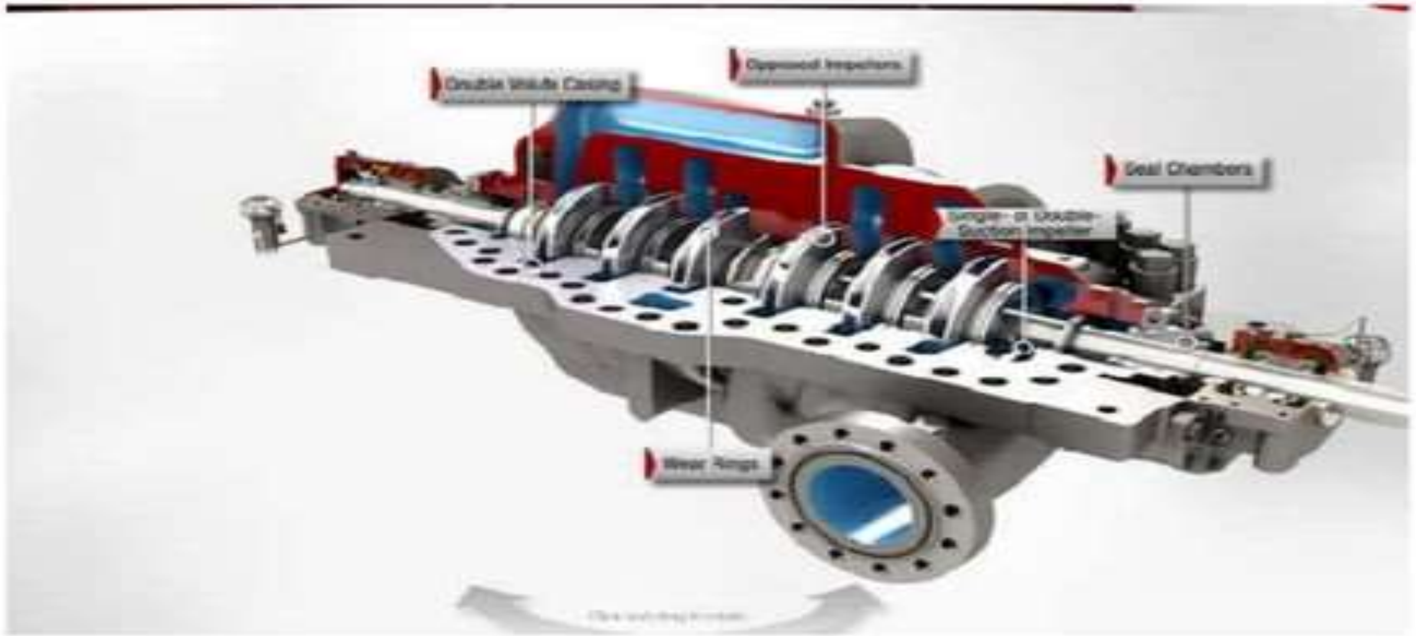
Shaft

Major Parts


A Stuffing Box
B Packing
C Shaft
D Shaft Sleeve
E Vane
F Casing
G eye of Impeller
H Impeller
I Casing wear ring
J Impeller
K Discharge nozzle

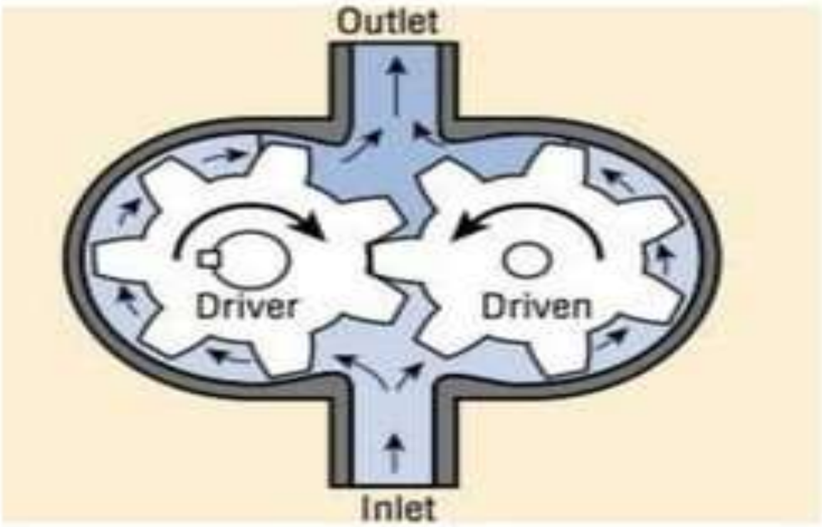
Multistage Centrifugal Pumps.

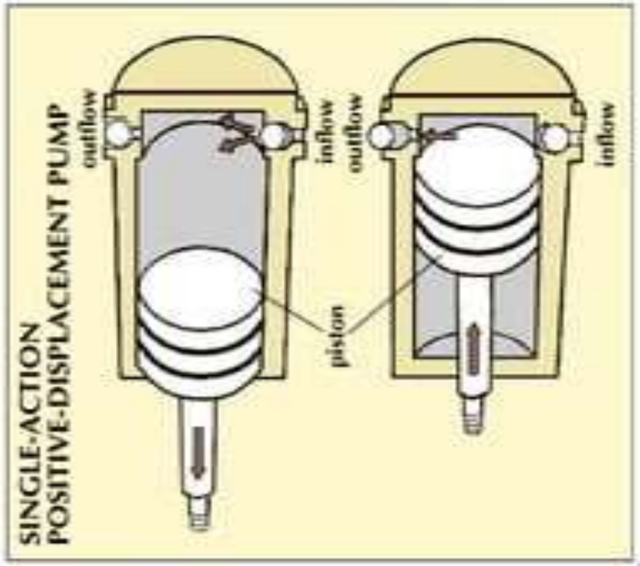
- In order to achieve a higher discharge pressure multiple impellers are used within a single pump. Depending upon the requirement.



Positive Displacement Pumps

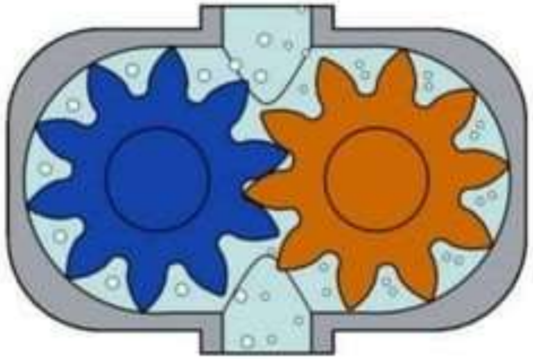
- <u>Working Principle:</u> *Positive Displacement Pump has an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side. Liquid is allowed to flow into the pump as the cavity on the suction side expands and the liquid is forced out of the discharge as the cavity collapses.*





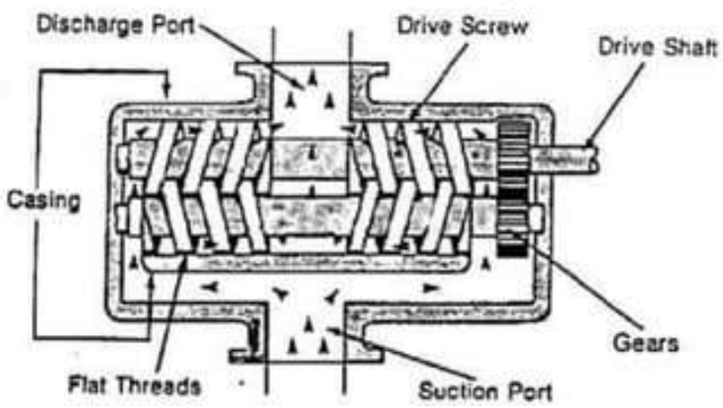
Gear Pumps

<u>Working Principle:</u>



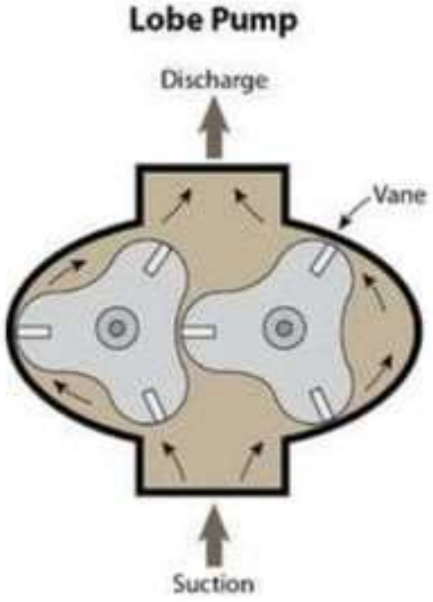
Screw Pumps

- <u>Working Principle</u>:



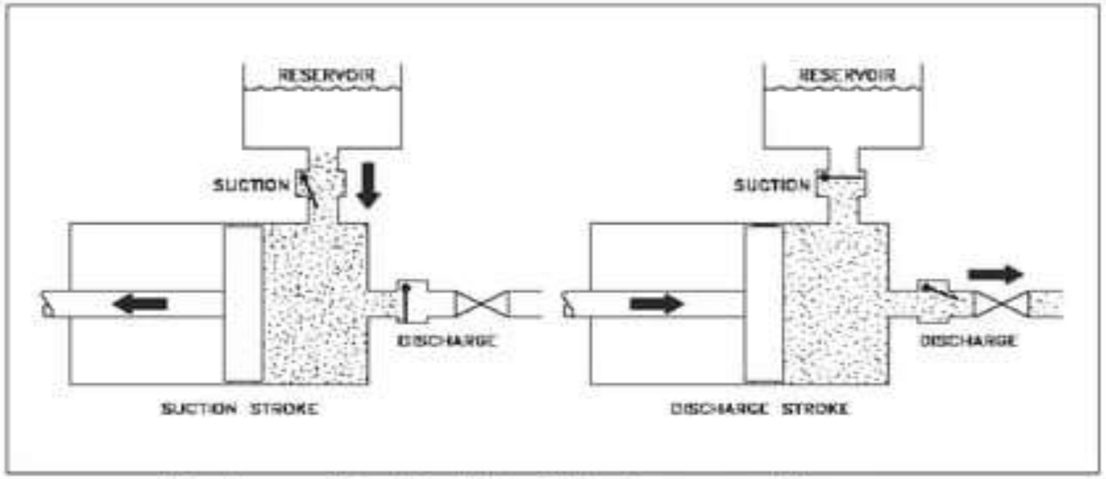
Lobe Pump

- Working Principle

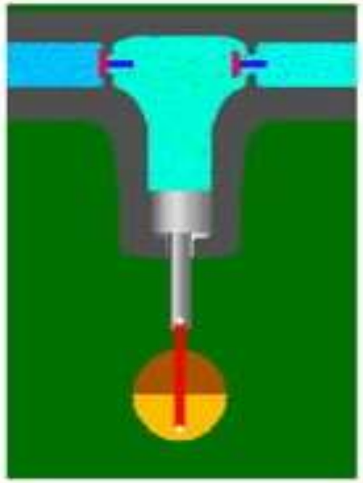


Reciprocating Pumps:

Working Principle



Reciprocating Positive Displacement Pump

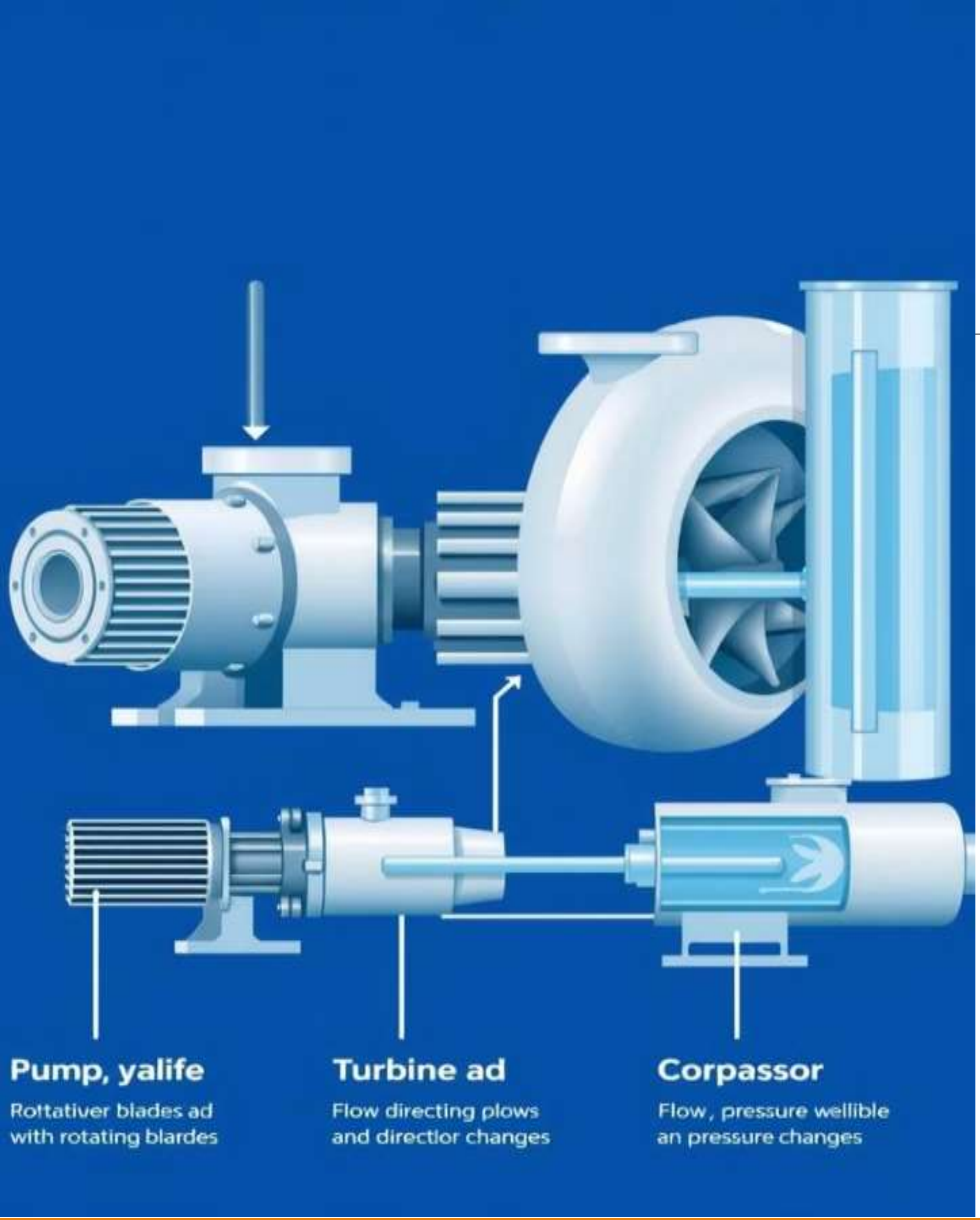


Week -14

Lecture

on

Centrifugal Pump



Fluid Machinery: Pumps, Turbines, and Compressors

1

Pumps

Pumps are used to increase the pressure of a fluid and move it from one point to another.

2

Turbines

Turbines convert fluid energy (kinetic or potential) into mechanical energy. They are used in power generation and other applications.

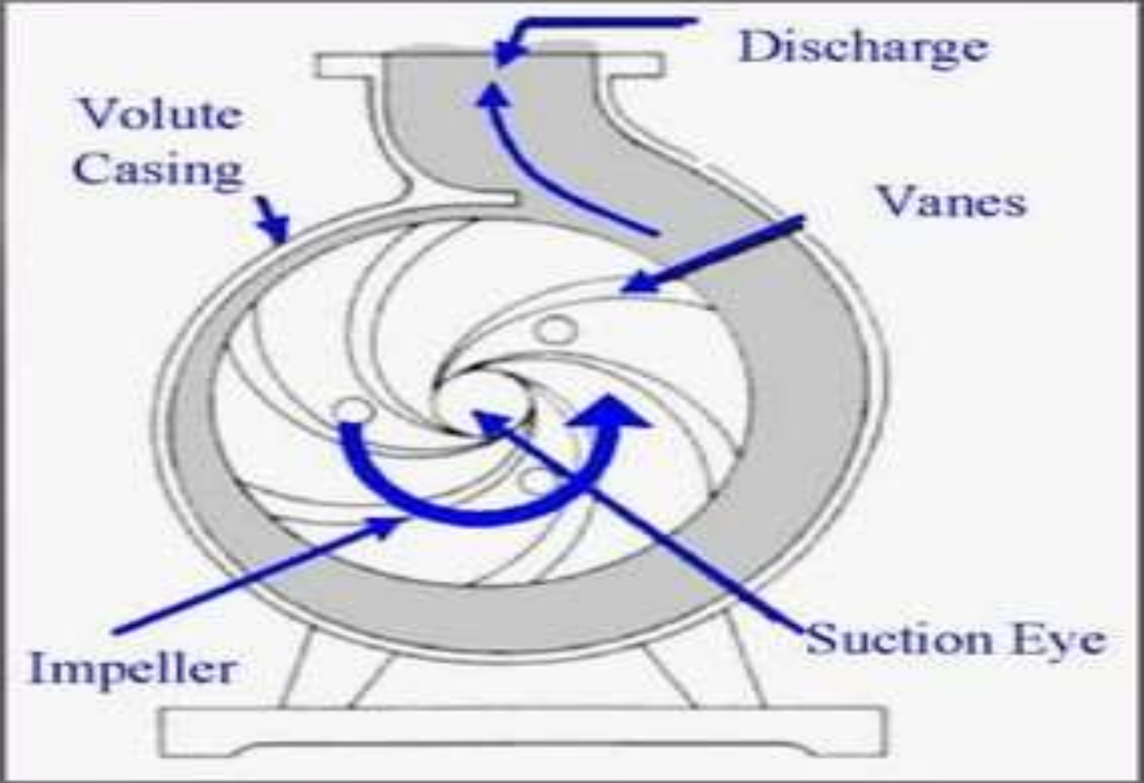
3

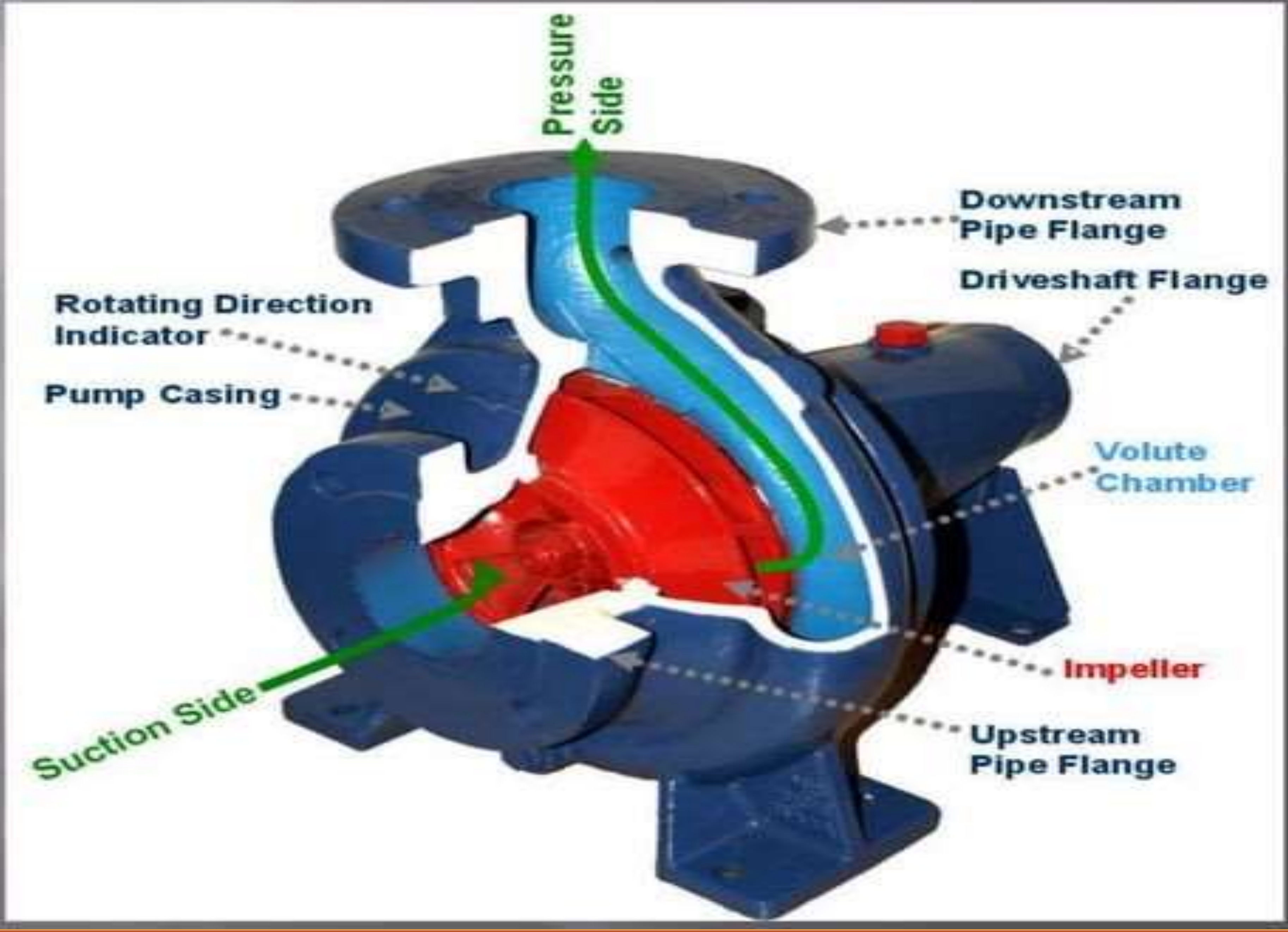
Compressors

Compressors increase the pressure and density of a gas. They are essential in refrigeration, air conditioning, and other industries.

COMPONENTS

- Impeller
- Casing
- Suction pipe
- Foot valve and strainer
- Delivery pipe




Pressure Side
Downstream Pipe Flange
Driveshaft Flange
Rotating Direction Indicator
Pump Casing
Volute Chamber
Impeller
Suction Side
Upstream Pipe Flange

ROTATING COMPONENTS

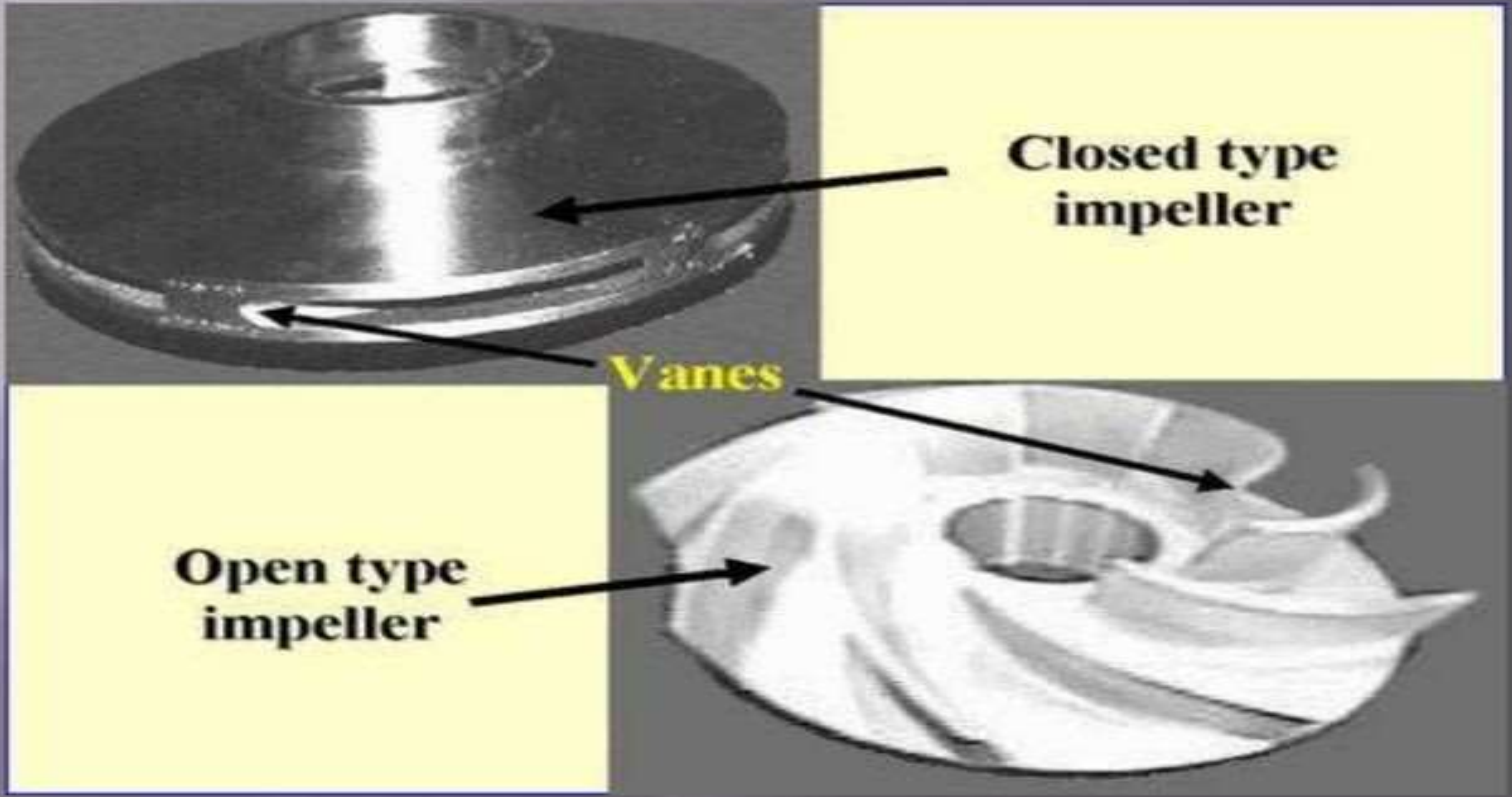
- Impeller:

  The impeller is the main rotating part that provides the centrifugal acceleration to the fluid.

- Shaft:

  Its purpose is to transmit the torques encountered when starting and during operation.

  Supports the impeller & other rotating parts.


Closed type
impeller
Vanes
Open type
impeller

STATIONARY COMPONENTS

- Casing:

The main purpose of casing is to convert kinetic energy into pressure energy.

Casings are generally of three types:

a) Volute : Used for higher head, eddy currents formed
b) Vortex : Eddy currents are reduced.
c) Circular : Used for lower head.

- A *volute* is a curved funnel increasing in area to the discharge port. As the area of the cross-section increases, the volute reduces the speed of the liquid and increases the pressure of the liquid.

- **Vortex Casing :A circular chamber is introduced between casing and impeller. Efficiency of pump is increased**

- **Circular casing** have stationary diffusion vanes surrounding the impeller periphery that convert velocity energy to pressure energy.
- Conventionally, the diffusers are applied to multi-stage pumps.

PRIMING

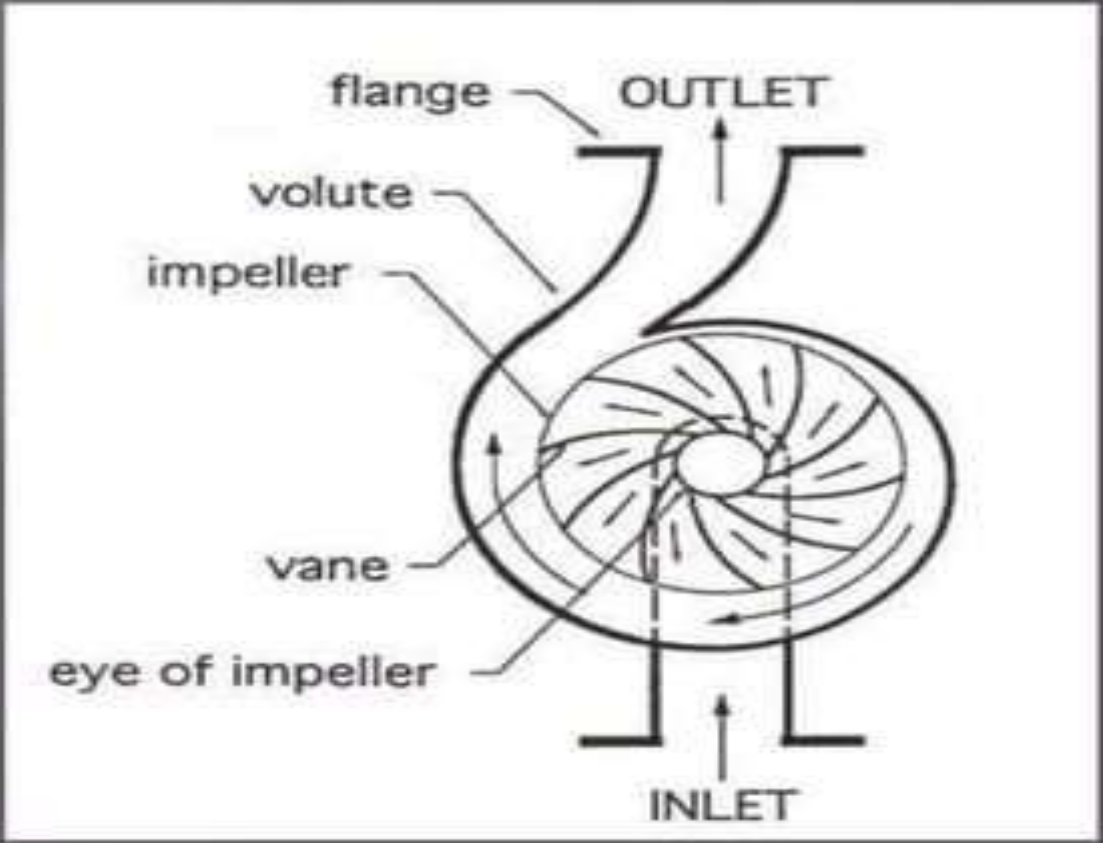
- It is the process of filling suction pipe, casing and delivery pipe upto delivery valve with water.
- Used to remove air from these parts.
- It is of 2 types:

a) Positive Priming:-The one which speeds up processing.

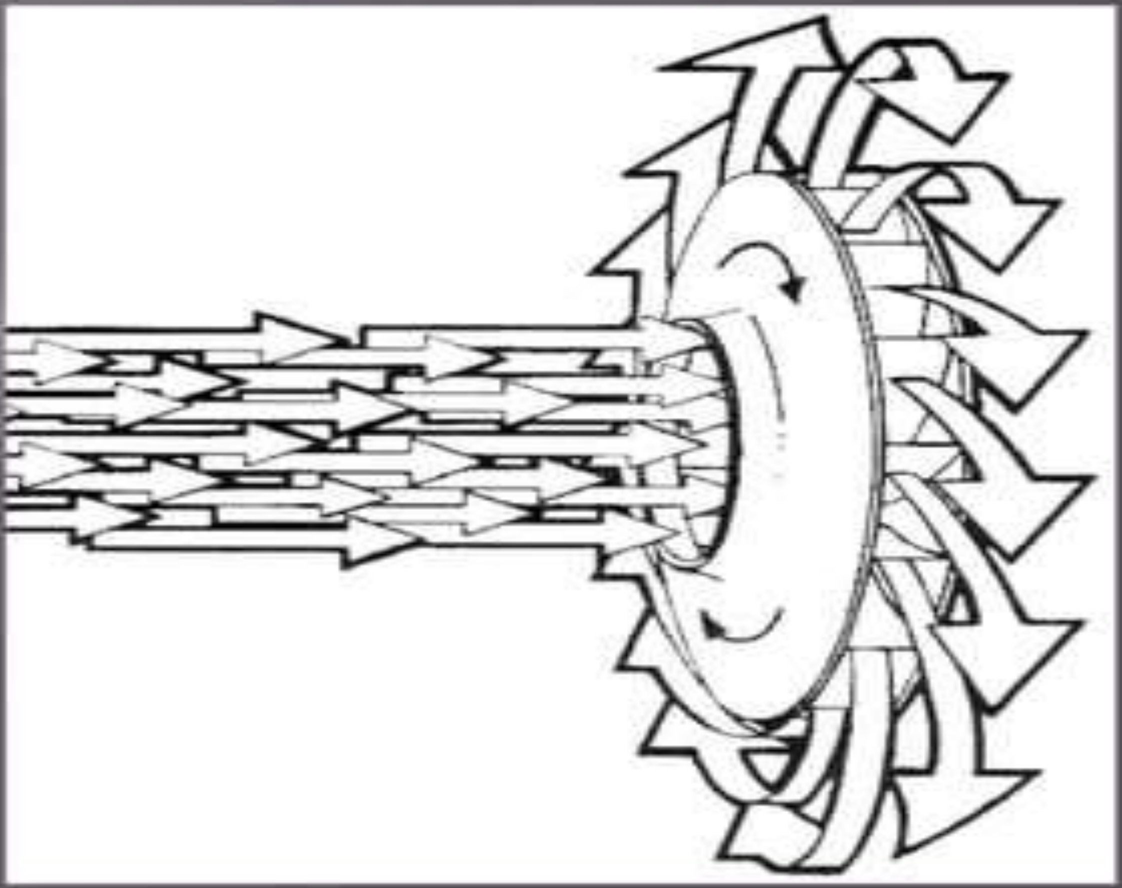
b) Negative Priming:-The one which slows down the processing.

How do they work?

- Liquid forced into impeller
- Vanes pass kinetic energy to liquid: liquid rotates and leaves impeller
- Volute casing converts kinetic energy into pressure energy



- It consists of an *IMPELLER* rotating within a casing.
- Liquid directed into the center of the rotating impeller is picked up by the impeller's vanes and accelerated to a higher velocity by the rotation of the impeller and discharged by centrifugal force into the casing .

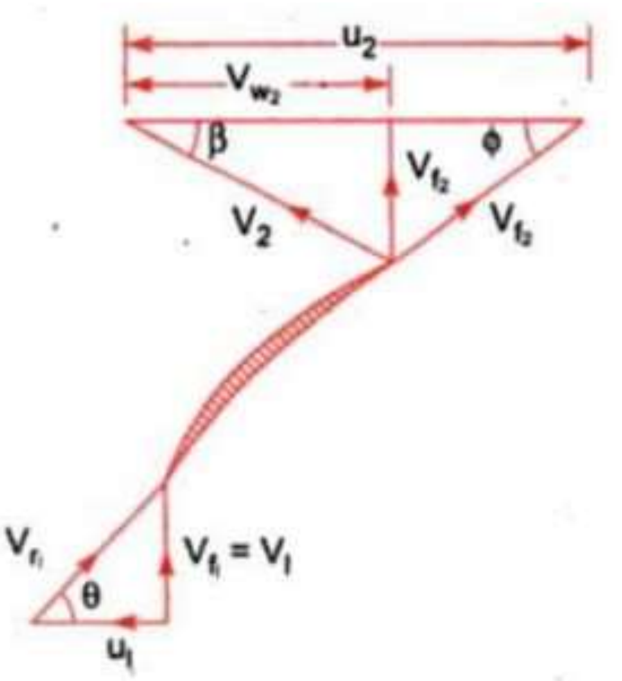


Week -15

Lecture

on

Centrifugal Pump



Velocity Triangles at Inlet and Outlet

WORK DONE

- Work is done by the impeller on the water

$$W=[V_{w2}U_2-V_{w1}U_1]/g$$

where,

W=work done per unit wg. of water per sec.

V_{w2}=whirl component of absolute vel. of jet at outlet.

U_2=tangential vel. of impeller at outlet.

V_{w1}=whirl component of absolute vel. of jet at inlet.

U_1=tangential vel. of impeller at inlet.

Minimum Starting Speed of Pump

A centrifugal pump will start delivering liquid only if the head developed by the impeller is more than the manometric head (H_m). If the head developed is less than H_m no discharge takes place although the impeller is rotating. When the impeller is rotating, the liquid in contact with the impeller is also rotating. This is a forced vertex, in which the increase in head in the impeller is given by

$$\text{Head rise in impeller} = \frac{u_2^2}{2g} - \frac{u_1^2}{2g}$$

Discharge takes place only when

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} \geq H_m$$

substituting for u_1, u_2 and H_m in Equation (10.13), we obtain

$$N = \frac{120\eta_m V_{w_2} D_2}{\pi(D_2^2 - D_1^2)}$$

which is the minimum speed for the pump to discharge liquid.

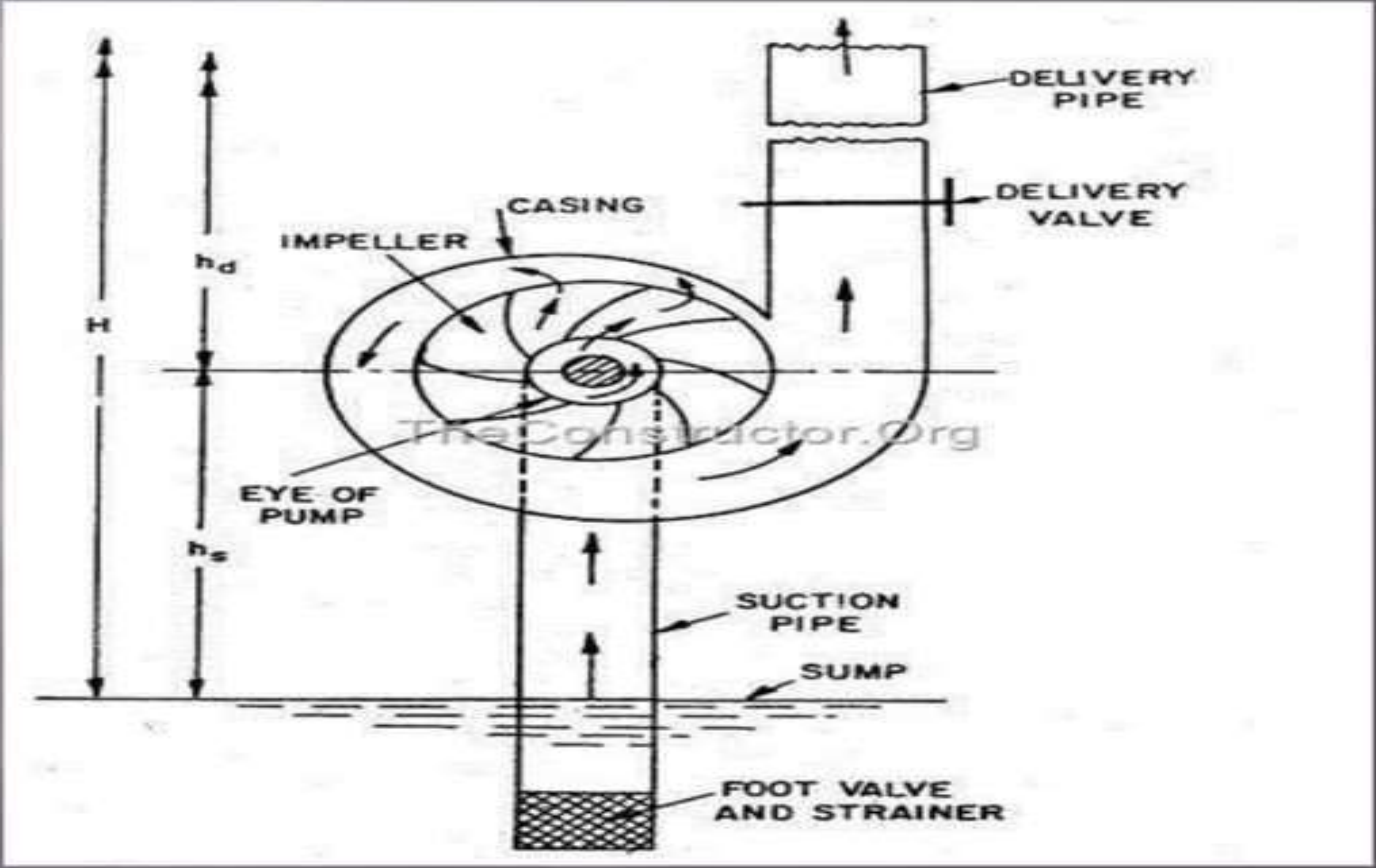
Specific Speed of Pump

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver *one cubic metre* of liquid per second against a head of *one metre*. It is denoted by 'N_s'.

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

HEADS IN CENTRIFUGAL PUMP

- Suction Head:- Vertical height of center line of centrifugal pump above the water surface to the pump from which water to be lifted.
- Delivery Head:- Vertical distance between center line of the pump and the water surface in the tank to which water is delivered.
- Static Head:- Sum of suction head and delivery head.
- Manometric Head:- The head against which a centrifugal pump has to work.
- $H_m = h_s + h_d + h_{fs} + h_{fd} + (V_d * V_d)/2g$


DELIVERY
PIPE
DELIVERY
VALVE
CASING
IMPELLER
H
h_d
h_s
EYE OF
PUMP
TheConstructor.Org
SUCTION
PIPE
SUMP
FOOT VALVE
AND STRAINER

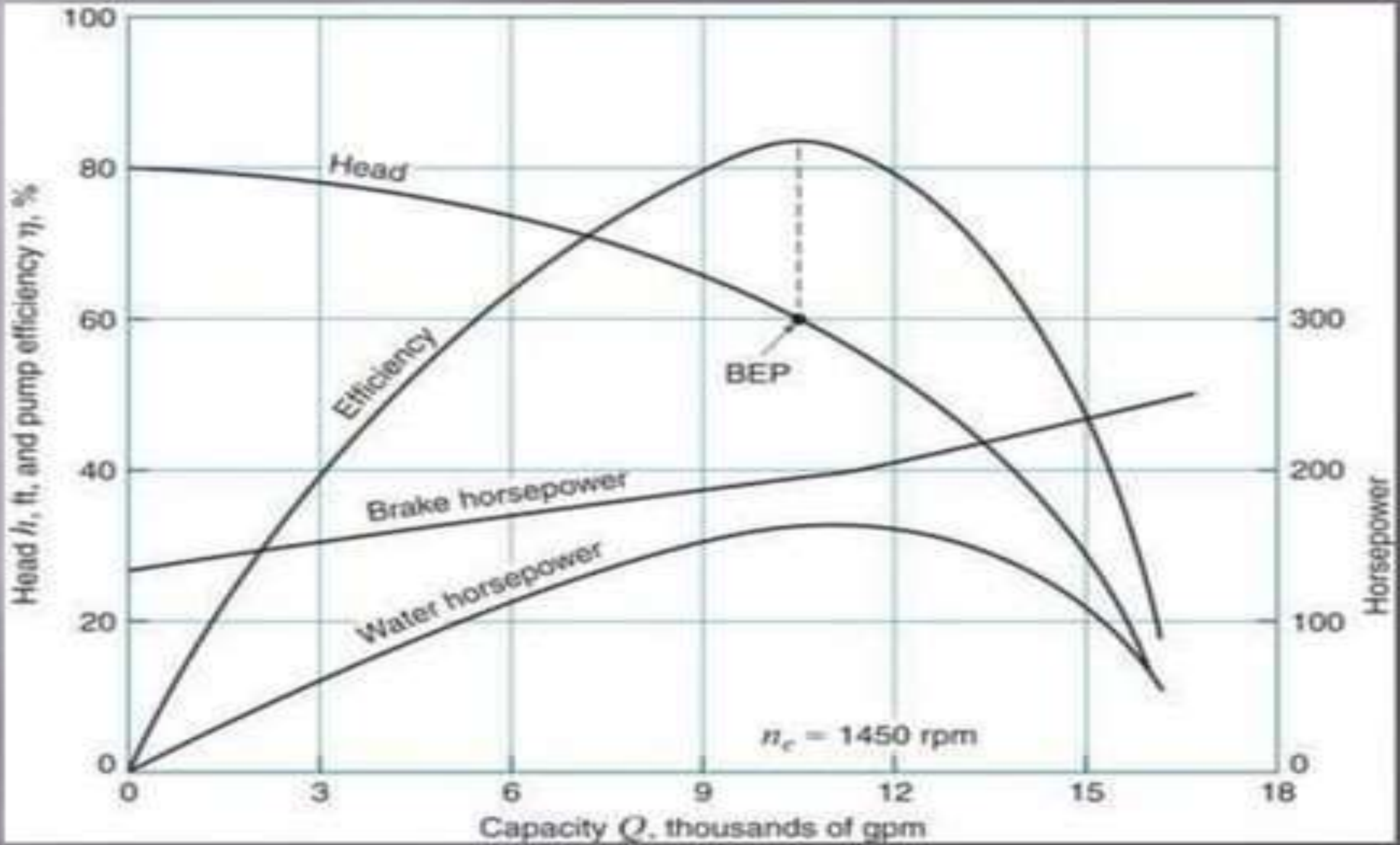
EFFICIENCES

- Manometric efficiency:-The ratio of manometric head to the head imparted by impeller.

  $$=H_m/(V_{w2}\, u_2/g)$$

- Mechanical efficiency :-The ratio of power delivered by the impeller to the liquid to the power input to the shaft.

  $$=(WV_{w2}u_{2/}g)/(\text{power input to the pump shaft})$$



$NQ^{1/2}/H_m^{3/4}=C$

$P/(D^5N^3)=C$

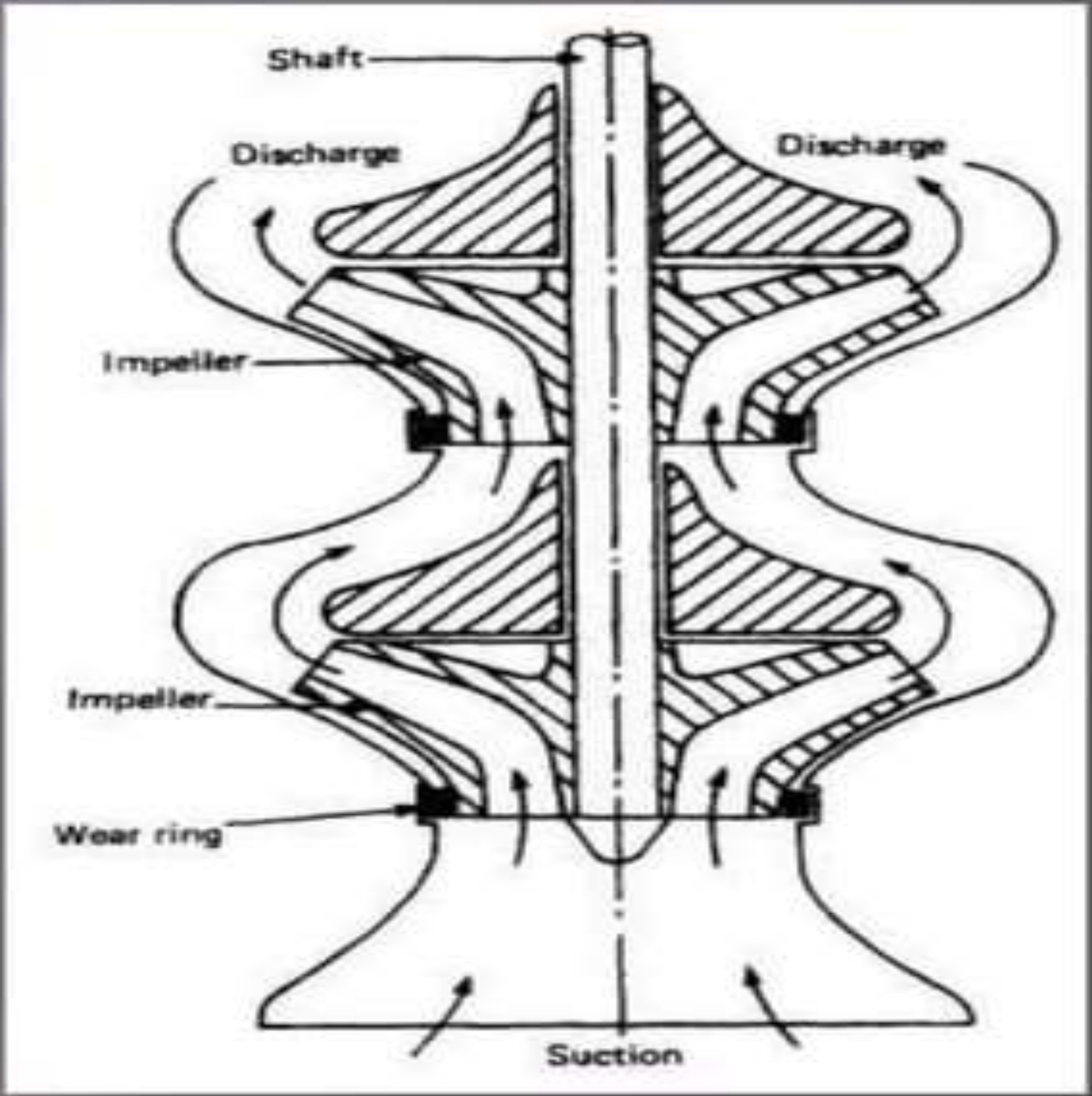
$\eta=\rho QgH/S.P.$

Operating characteristic curve

MULTISTAGE CENTRIFUGAL PUMP

- It consists of two or more impellers.
- There are two types as follows:
  a) SERIES :To produce high head.
  b) PARALLEL :To discharge large quantity of liquid.

Series combination for high head



Parallel combination for high discharge

Cavitations in Pump

Cavitation is the formation of bubbles or cavities in liquid, developed in areas of relatively low pressure around an impeller. The imploding or collapsing of these bubbles trigger intense shockwaves inside the pump, causing significant damage to the impeller and/or the pump housing.

If left untreated, pump cavitations can cause:

a) Failure of pump housing
b) Destruction of impeller
c) Excessive vibration leading to premature seal and bearing failure
d) Higher than necessary power consumption

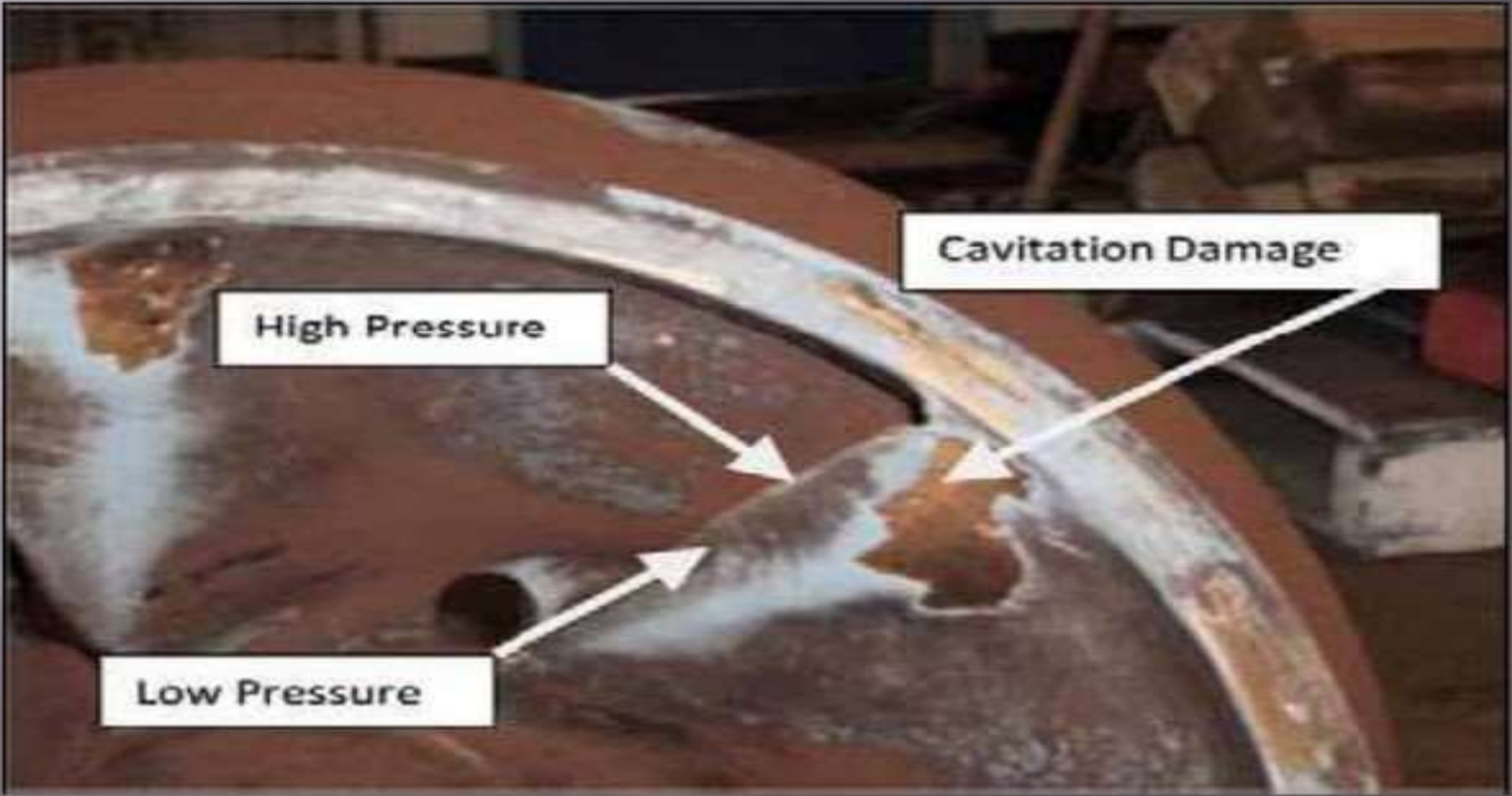
Precaution: NPSHA > NPSHR

Where NPSHA = Net Positive Suction Head Available

NPSHR = Net Positive Suction Head Required

CAVITATION

- It is a phenomena of formation of vapour bubble where the pressure falls below the vapour pressure of flowing liquid .
- Collapsing of vapour bubble causes high pressure results in pitting action on metallic surface.
- Erosion, noise & vibration are produced.

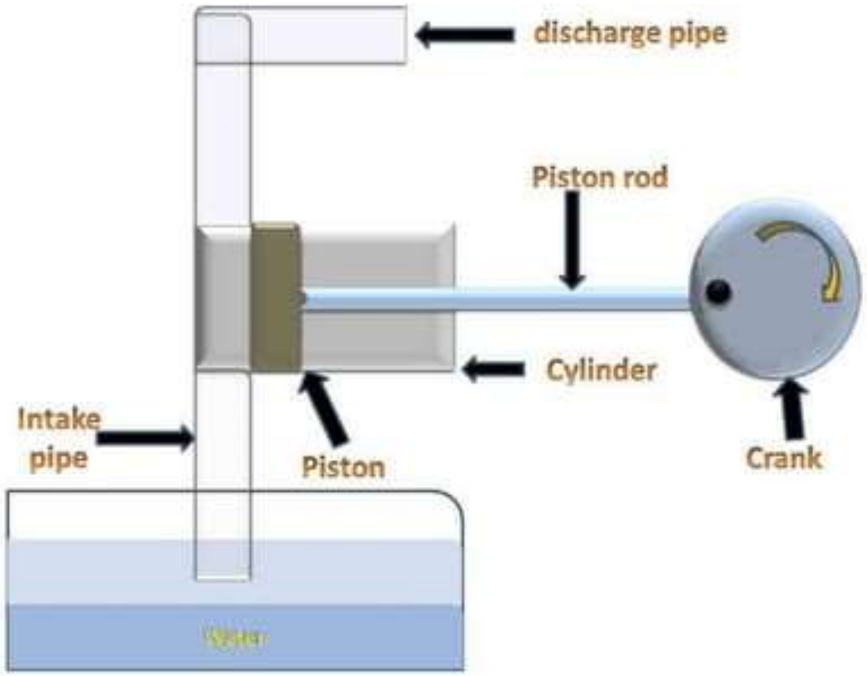

Cavitation Damage
High Pressure
Low Pressure

EFFECT OF CAVITATION

- Metallic surface are damaged & cavities are formed.
- Efficiency of pump decreases.
- Unwanted noise and vibrations are produced.

Week -16

Lecture
on
Reciprocating Pump


discharge pipe
Piston rod
Cylinder
Intake
pipe
Piston
Crank

Introduction

Reciprocating pump is a hydraulic machine which converts the mechanical energy into hydraulic energy.

It works by sucking liquid into a cylinder containing a reciprocating piston which exerts a thrust force on the liquid and increases its hydraulic energy (pressure energy of liquid).

It is also called as **positive displacement pump** which consists of piston or plunger. Piston is present in a cylinder in which it does reciprocating motion (back and forth motion).

It is used at a place where **relatively small amount of water** is to be delivered **at higher pressure/ head.**

Classification of Reciprocating Pump

1. Piston Pumps:

Hand pump is a simplest form of piston pump used in villages for lifting water from the tube well..

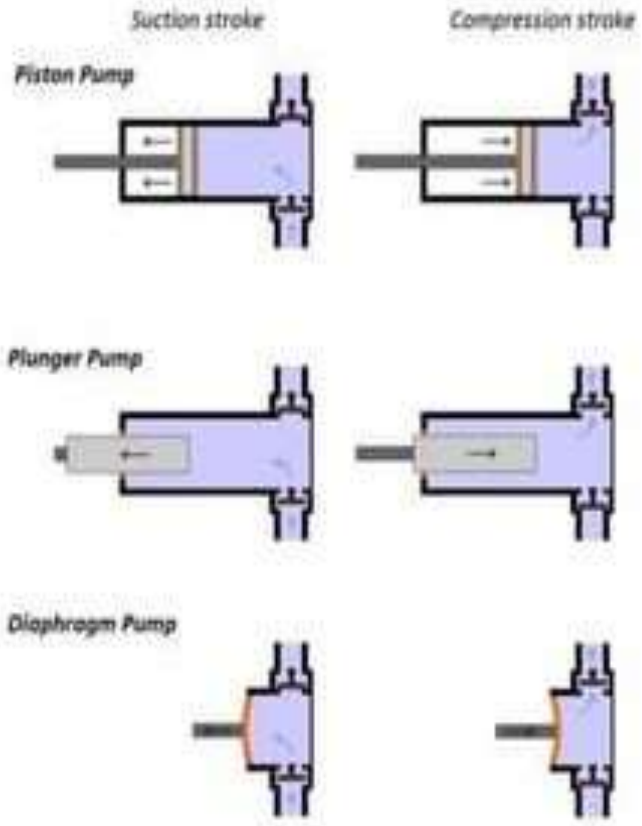
a) Single Acting
b) Double Acting

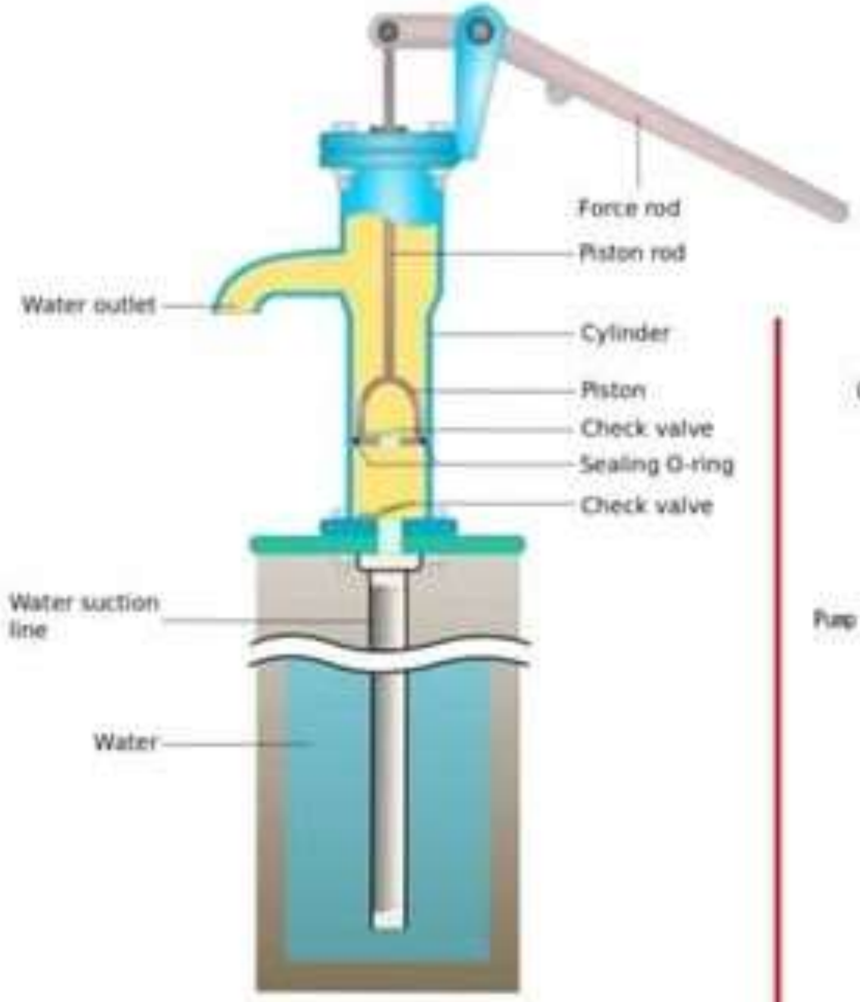
2. Plunger Pumps:

A plunger pump is a type of positive displacement pump where the high-pressure seal is stationary and a smooth cylindrical plunger slides through the seal. This makes them different from piston pumps and allows them to be used at higher pressures.

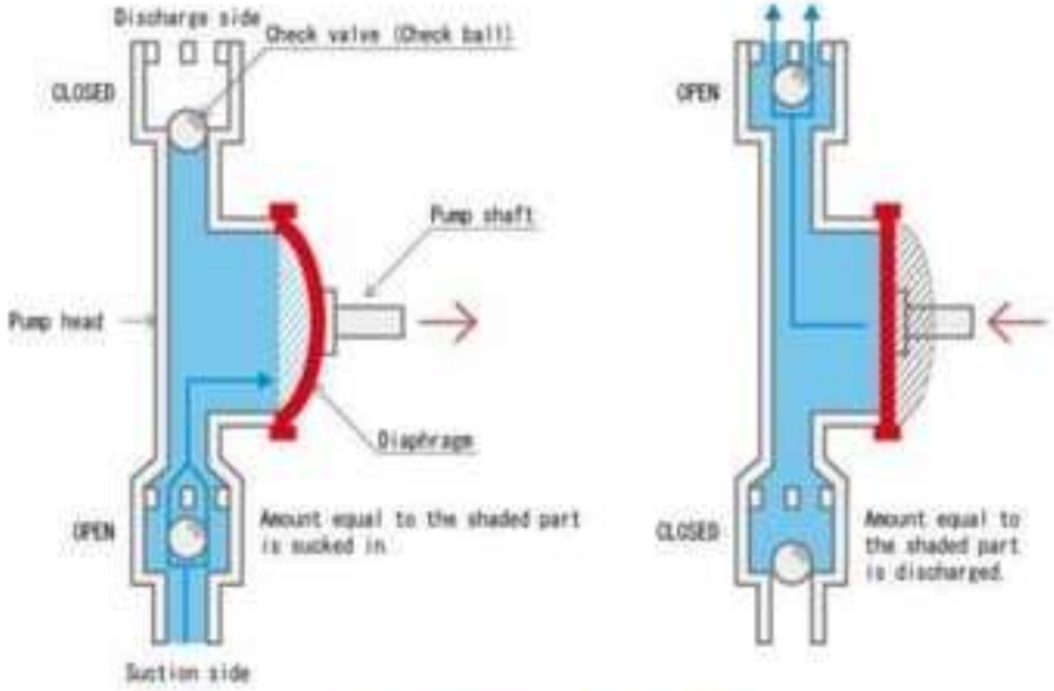
3. Diaphragm Pumps:

Diaphragm pumps employ a flexible membrane instead of a piston or plunger to displace the pumped fluid. They are truly self priming and can run dry without damage.





Piston Pump

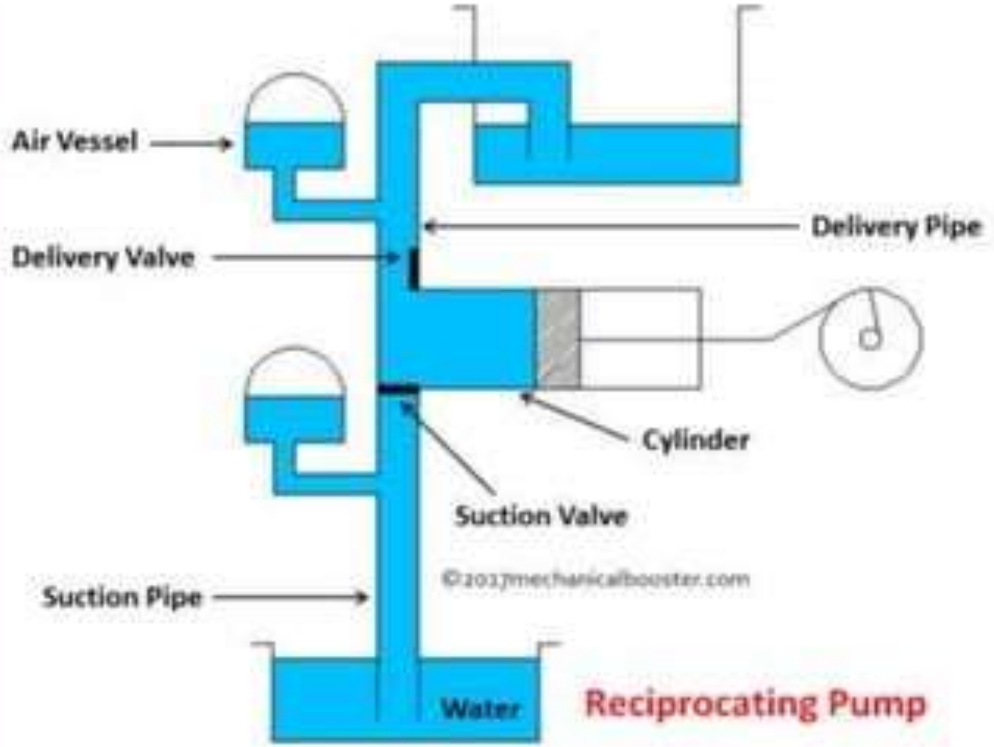


Diaphragm Pump

Main Parts of Reciprocating Pump

Main Parts of Reciprocating Pump:

1. A cylinder with piston, piston rod, connecting rod and a crank
2. Suction Pipe
3. Delivery Pipe
4. **Suction Valve:** It opens during suction of water from the tank to the cylinder and remains closed during compression of the liquid.
5. **Delivery Valve:** It opens during compression of the liquid and remains closed when the water is sucked from the water tank.
6. Air Vessels



Significance of Air Vessel

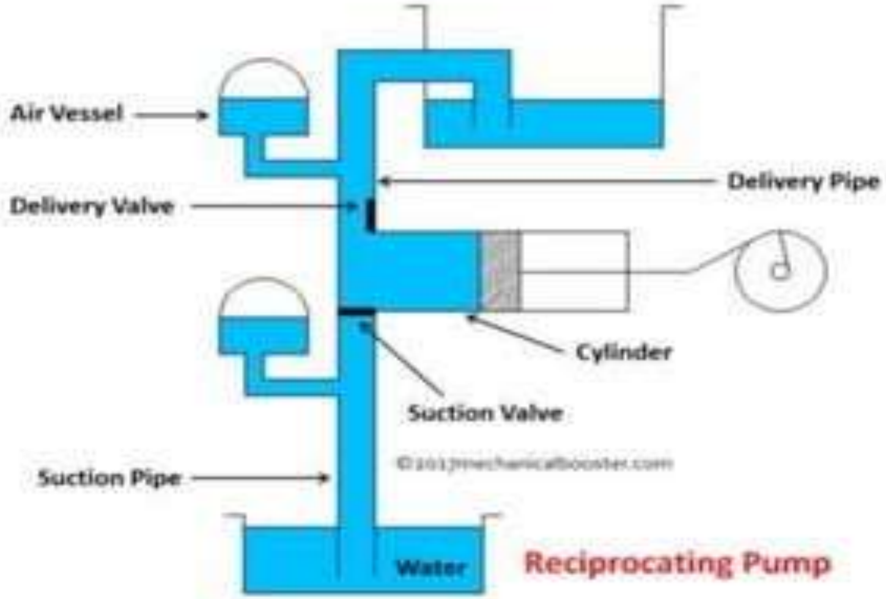
Air vessels are closed containers, in which the lower half is water & the upper half is compressed air.

These air vessels are installed near the suction & delivery valve to avoid separation. An air vessel is usually fitted in the discharge pipe to dampen out the pressure variations during discharge.

As the discharge pressure rises, the air in the vessel gets compressed. Similarly, air expands when the pressure falls. The peak pressure energy is thus stored in the air and returned to the system when pressure falls.

Purposes of Air vessel:

1. To obtain liquid at a uniform discharge.
2. Due to air vessels frictional head and acceleration head decreases

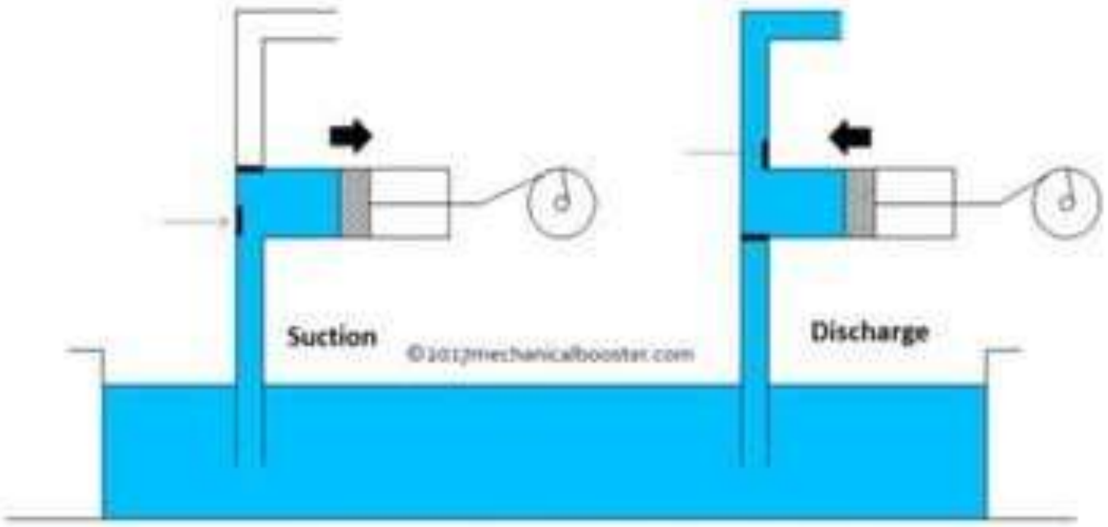


Single Acting Reciprocating pump

Working Principle:

During suction stroke, the piston moves backward and this opens the suction valve making the water enter into the cylinder. During suction the delivery valve remains closed and no water is discharged through it.

After suction stroke, the piston moves forward, delivery valve gets open and suction valve come into close position. As the piston moves forward it exerts thrust force on the liquid and it starts escaping out of the cylinder through delivery pipe.



Single Acting Reciprocating Pump

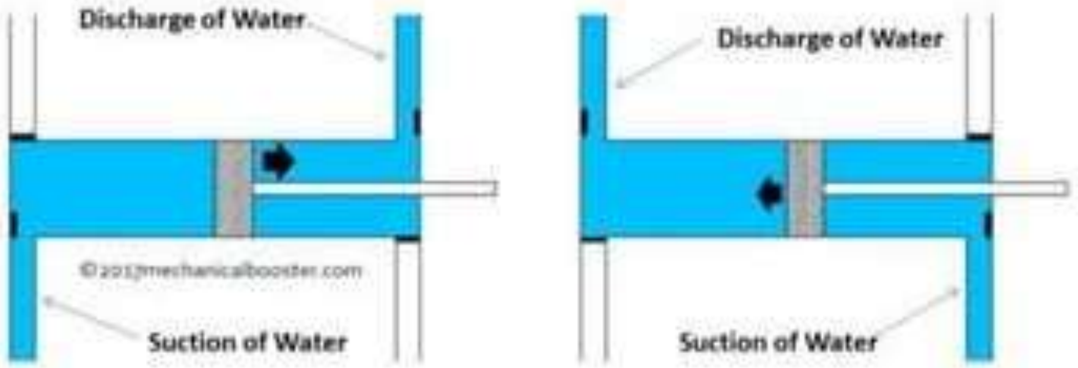
Double Acting Reciprocating Pump

Working Principle:
As the piston moves to the right hand side as shown in the fig. The following process takes plac at left and right side.

At left side:
The suction valve opens and delivery valve ge closed. The water from the water reservoir sucked into the cylinder.

At right side:
The suction valve is gets closed and delivery valv gets open. the water sucked in the previous strok is discharges out of the cylinder.

In each stroke of the piston, both suction and discharge of liquid takes place at the same time. If suction is taking place at right side than discharge takes place at left and vice-versa.

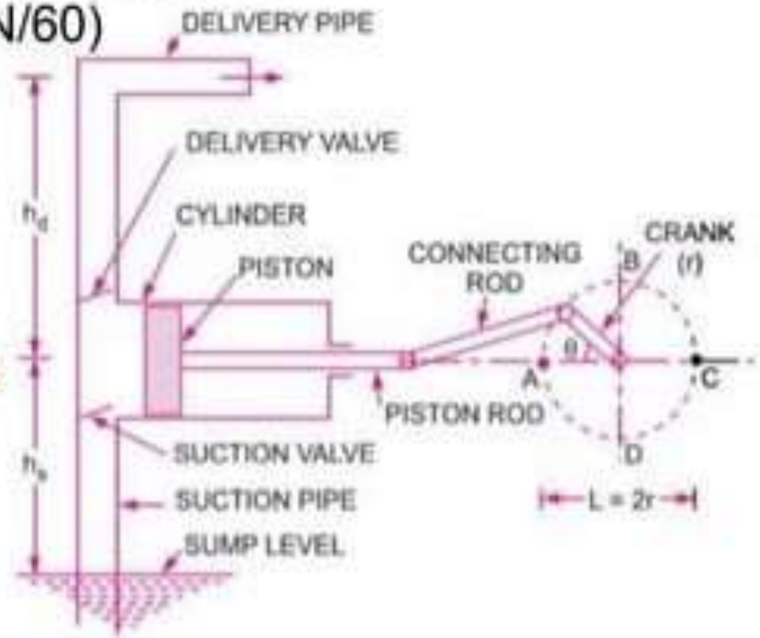


Double Acting Reciprocating Pump

Discharge through Reciprocating Pump

Discharge through Single acting Reciprocation Pump (Q)
= Discharge in One Revolution x No. of Revolutions per Second
= Volume of Water Delivered in One Revolution x (N/60)
= (AL) (N/60)
= ALN/60

Where
D = Dia. of Cylinder
A = Cross-sectional Area of the Piston or Cylinder = $\pi D^2/4$
N = RPM of Crank
No. of Revolutions per Second = N/60
L = Length of the Stroke = 2r
r = Radius of Crank



Work done and Power by Reciprocating Pump

A). Work done by Single Acting Reciprocating Pump per Second is given by

= Weight of Water Lifted per Second x Total Height through which water is Lifted

$= W (H_s + H_d)$

$= (\rho g Q) (H_s + H_d)$

$= [\rho g(ALN/60)] (H_s + H_d)$

$= \rho gALN (H_s + H_d)/60$ → for Single Acting Reciprocating Pump

Similarly,

B). Work done by Double Acting Reciprocating Pump per Second is given by

$= \rho g2ALN (H_s + H_d)/60$

Power required to the drive the Pump, P = (Work done per Second/1000) kW

Slip of Reciprocating Pump

Slip in reciprocating pump is defined as the difference between the theoretical discharge and actual discharge of the reciprocating pump.

Actual discharge of a reciprocating pump will be less than the theoretical discharge of the pump due to leakage of water during operation of pump.

$$\text{Slip} = Q_{th} - Q_{act}$$

But slip is mostly expressed as percentage slip which is given by,

$$\text{Percentage slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100 = \left(1 - \frac{Q_{act}}{Q_{th}}\right) \times 100 \qquad \left(\because \frac{Q_{act}}{Q_{th}} = C_d\right)$$

$$= (1 - C_d) \times 100$$

where C_d = Co-efficient of discharge.

Advantages and Disadvantages of Reciprocating Pump

Advantages:

1. High pressure is obtained at the outlet.
2. Priming process is not needed in this pump.
3. It provides high suction lift.
4. It is also used for air.

Disadvantages

1. It requires high maintenance because of more wear and tear of the parts.
2. Low flow rate i.e. it discharges low amount of water.
3. They are heavy and bulky in size.
4. High initial cost.

Applications:

1. The reciprocating pump is used in oil drilling operations.
2. It is useful in pneumatic pressure systems.
3. Mostly used in light oil pumping.
4. It is used for feeding small boilers condensate return.

Week -17

Lecture

on

Problem Solving on Pump

Mathematical Problems on Pump

Mathematical problems related to Pump will be practiced and solved during classroom sessions. Problems from the prescribed reference book will be addressed, and additional practice materials will be provided to enhance understanding and proficiency.

Thanks

For

Your Attention