GOVERNMENT OF TAMILNADU

DIRECTORATE OF TECHNICAL EDUCATION

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STATE PROJECT COORDINATION UNIT

Diploma in Mechanical Engineering

Course Code: 1020

M – Scheme

e-TEXTBOOK

on

Fluid Mechanics & Fluid Power

for

IV Semester Mechanical Engineering

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32043 FLUID MECHANICS & FLUID POWER

DETAILED SYLLABUS

Contents: Theory

Unit	Name of the Topic
I	**PROPERTIES OF FLUIDS AND PRESSURE MEASUREMENTS - 18 Hrs** **Page NO.5 - 45** Introduction - Definition of fluid - Classification of Fluids - ideal and real fluids -properties of a fluid – definition and units - Pressure-units of Pressure - Pressure head-atmospheric, gauge and absolute pressure – problems - Pascal's law- proof - applications of Pascal's law - Hydraulic press - Hydraulic jack - Pressure measurement - Piezometer tube - Simple U-tube manometer – Differential U-tube manometer - Inverted Differential manometer - Micro- manometer - Inclined tube micro-manometer - Mechanical Gauges -Bourdon's Tube Pressure Gauge - Diaphragm pressure gauge - Dead weight pressure gauge.
II	**FLOW OF FLUIDS AND FLOW THROUGH PIPES -18 Hrs Page NO.46 - 94** **Types of fluid flow** - path line and stream line - mean velocity of flow - discharge of a flowing fluid - equation of continuity of fluid flow - energies of fluid - Bernoulli's theorem - statement, assumptions and proof - applications and limitations of Bernoulli's theorem - problems on Bernoulli's theorem – **venturimeter** - derivation for discharge - orifice meter - derivation for discharge - difference between venturimeter and orifice meter -problems on venturimeter and orifice meter - Pitot tube – description only – orifice –types – applications - hydraulic co-efficients - determining hydraulic co-efficients – problems - discharge through a small orifice discharging freely only - problems – experimental method of finding C_V, C_C and C_d - **Flow through pipes** - laws of fluid friction - hydraulic gradient line - total energy line - wetted perimeter - hydraulic mean radius - loss of head due to friction - Darcy-Weisbach equation and Chezy's formula –problems - minor losses (description only) - Power transmission through pipes - problems.
III	**IMPACT OF JETS, HYDRAULIC TURBINES, CENTRIFUGAL AND RECIPROCATING PUMPS – 18Hrs Page NO.95 - 155** Impact of jet - on a stationary flat plate held normal to the jet and inclined to the direction of jet - Impact of jet on a flat plate moving in the direction of jet - Impact of jet on a series of moving plates or vanes - force exerted and work done by the jet - problems. Hydraulic turbines – classifications - Pelton wheel - components and working - speed regulation (theory only) - Francis and Kaplan turbines - components and working - draft tube - functions and types - surge tank - differences between impulse and reaction turbines. Centrifugal Pumps – classifications - construction and working of single stage centrifugal pumps - components with types - theory only - multi stage pumps – advantages - priming – cavitation. Reciprocating Pumps – classifications - construction and working of single acting and double acting reciprocating pumps - plunger and piston pumps - discharge of a reciprocating pump - theoretical power required - coefficient of discharge – slip – problems - negative slip - indicator diagram – separation - air vessel (functions and working) - Special pumps - Jet pump - Turbine pump - Submersible pump.

IV **PNEUMATIC SYSTEMS – 18 Hrs Page NO.156 - 183**

Pneumatic Systems **–** elements – filter – regulator - lubricator unit - pressure control valves - pressure relief valves - pressure regulation valves - directional control valves - 3/2 DCV - 5/2 DCV – 5/3 DCV flow control valves – throttle valves –shuttle valves – quick exhaust valves –ISO symbols of pneumatic components – pneumatic circuits – direct control of single acting cylinder – operation of double acting cylinder – operation of double acting cylinder with metering-in control - operation of double acting cylinder with metering-out control

– use of shuttle valve in pneumatic circuits – use of quick exhaust valve in pneumatic circuits - automatic operation of double acting cylinder single cycle – Multiple cycle – merits and demerits of pneumatic system - applications.

HYDRAULIC SYSTEMS – 18 Hrs Page NO.184 - 211

V **Hydraulic system** – Merits and demerits – Service properties of hydraulic fluids Hydraulic accumulators – Weight of gravity type accumulator – Spring loaded type accumulator - Gas filled accumulator – Pressure intensifier – Fluid power pumps – External and internal gear pump, Vane pump, Radial piston pump – ISO symbols for hydraulic components – Hydraulic actuators – Cylinders and motors – Valves – Pressure control valves, Flow control valves and direction control valves – types – including 4/2 DCV and 4/3 DCV – their location in the circuit.

Hydraulic operation of double acting cylinder with metering-in and metering-out control – application of hydraulic circuits – Hydraulic circuit for - shaping machine - table movement in surface grinding machine and milling machine – Comparison of hydraulic and pneumatic systems.

Text Books:

1) A Text Book of Hydraulics, Fluid Mechanics and Hydraulic Machines, R.S. Khurmi, - Edn.18, S.Chand & Co., Ram Nagar, New Delhi – 110 055, Ram Nagar, New Delhi – 2002

2) A Text Book of Fluid Mechanics and Hydraulic Machines – by, R. K Rajput and S. Chand & Co,Ram Nagar, New Delhi – 110 055.

Reference Books:

1) Hydraulic Machines, Jagadishlal, , Metropolitan Book Co. Pvt. Ltd., 1, Faiz Bazaar, New Delhi – 110 006.

2) Hydraulics,Andrew Parr (A Technician's and Engineer's Guide)

3) Fundamentals of pneumatic control Engineering -FESTO Manual

4)Fluid Mechanics and Hydraulic Machines,R. K. Bansal, Laxmi Publications Pvt.,Ltd,22,Golden House, Daryaganj, New Delhi – 110 002

UNIT –I PROPERTIES OF FLUIDS AND PRESSURE MEASUREMENTS

Objectives:

- Study about Static fluid and dynamic fluid.
- Explain the classification of fluid.
- Discuss the liquid and gaseous fluid.
- Define fluid pressure, atmospheric pressure, gauge pressure,

  vacuum pressure and absolute pressure and derive the relation between them.
- Solve problems in Properties of a fluid and pressure relations.
- Derive Pascal's law and notify its applications
- Explain the construction and working principle of Hydraulic press and Hydraulic jack.
- Explain the type of manometers and solve problems in manometers
- Discuss about Mechanical Gauges
- Explain the construction and working principle of different types of Mechanical Gauges.

1.1 Introduction

Fluid Mechanics

Fluid Mechanics is the branch of engineering which deals with the properties and behavior of fluids at rest and in motion.

Hydraulics

Hydraulics is the branch of engineering deals with the properties and behavior of water.

1.2. Definition of Fluid

Fluid can be defined as the substance which can flow with or without the aid of force

A fluid may be in three form like as liquid (or) a vapour (or) a gas

1.3. Types of Fluid

Fluids are classified as follows.

1. **Ideal (or) perfect fluid**

   A fluid having density only as property is called Ideal fluid . Ideal fluid one which has no viscosity, surface tension, cohesion and adhesion etc.

Ex. Imaginary fluid

2. **Real fluid (or) Practical fluid**

A fluid having viscosity, surface tension, cohesion, adhesion and density is called Real Fluid.

Ex; water, air, lubricating oil

3. **Newtonian Fluid**

A fluid which obeys Newton's Law of viscosity is called Newtonian fluid.

Ex; Water, Lubricating oil etc.

4. **Non – Newtonian Fluid**

A fluid which does not obey Newton's Law of viscosity is called Non-Newtonian fluid.

Ex; Paints, Plastics etc.

1.4. Properties of Fluid

1. **Density**

It is defined as the mass per unit volume.

Density = $\frac{Mass}{Volume}$

Unit is kg/m^3 Density of water is 1000 kg/m^3 .

2. **Specific weight (weight density)**

It is defined as the weight per unit volume.

Specific weight = $\frac{Weight}{Volume}$

Unit is kN/m^3

Relation between the Specific weight and density is **w = ρ x g**

3. Specific volume

It is defined as the volume per unit mass.

Specific volume = $\frac{Volume}{Mass}$ (or) $\frac{1}{Density}$

Unit is m^3/kg.

Relation between the Specific volume and density is **v =** $1/\rho$

4. Relative density (or) Specific gravity

It is defined as the ratio between the density of any liquid to the density of water .

$$\text{Relative density} = \frac{\text{Density of fluid}}{\text{Density of water}}$$

$$\text{Relative density} = \frac{\text{Specific weight of liquid}}{\text{Specific weight of water}}$$

Specific gravity of water = 1

Specific gravity of mercury = 13.6

5. Compressibility

It is the change in volume due to change in pressure of fluid.

As the change in volume of a liquid under pressure is so small ,

a liquid considered to be an incompressible fluid.

Air considered to be a compressible fluid.

6. Cohesion

The inter molecular attraction between the molecules of same liquid is known as cohesion.

7. Adhesion

It is the attraction between molecules of different substances.

Ex. Water molecules stick in the container wall.

In this way water has both Adhesion and Cohesion properties.
But mercury has no Adhesion but it has Cohesion property.

8. Viscosity

It is one of the important of fluid property which resist the flow of fluid .

It is denoted by “μ”. Unit is Ns/m^2.

Ex. Oil has high Viscosity and water has less Viscosity

9. Kinematic viscosity

It is defined as the ratio between absolute viscosity and density of fluid

$$\text{Kinematic viscosity} = \frac{\text{Absolute viscosity}}{\text{Density of liquid}}$$

Unit $= m^2/sec$

10. **Surface Tension**

The surface tension of liquid is defined as the tangential force per unit length acting at right angles on either side of the surface.

Ex: Falling drops of rain water become sphere.

11. Capillarity

When a smaller diameter capillary tube with open ends is dipped in a liquid, the liquid surface inside the tube rises (or) falls relative to the adjacent general level of liquid. It is known as capillarity. It can be capillary rise(water) (or) capillary fall(mercuryr) as shown in fig.1.1.

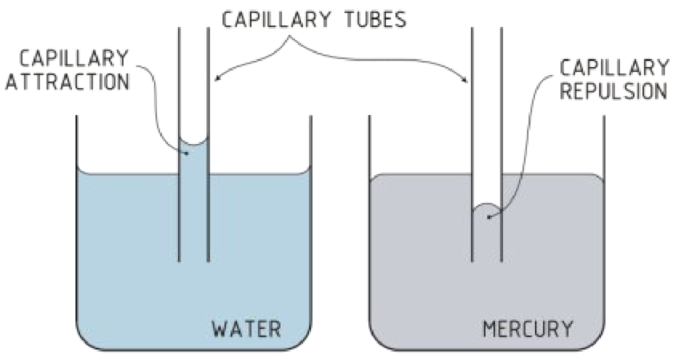


Fig.1.1

12. Vapour pressure

When liquid in the closed vessel evaporates, the vapour exerts a pressure, on the liquid surface. This pressure is known as vapour pressure.

1.5. Worked Examples

1. One Litre of petrol weighs 7 Newton. Calculate its Specific weight, Density, Specific Volume and Relative density.

Given Data

Volume of petrol = 1 litre

$= 1 \times 10^{-3}\ m^3$

Weight of petrol = 7 N

Solution

1. Specific weight = $\frac{\text{weight}}{\text{Volume}}$

$= \frac{7}{1 \times 10^{-3}}$

$= 7000$ N

2. Density $= \frac{\text{Mass}}{\text{Volume}}$

Mass $= \frac{\text{Weight}}{\text{Gravity}} = \frac{W}{g}$

$= \frac{7}{9.81}$ kg

Density $= \frac{7}{9.81 \text{x} 1 \times 10^{-3}}$

$= 713.557 kg/m^3$

3. Specific Volume $= \frac{\text{Volume}}{\text{Mass}} = \frac{1}{\text{Density}}$

$= \frac{1}{713.557}$

$= 1.40 \times 10^{-3}\ m^3/kg$

4. Relative Density = $\frac{\text{Specific Weight of liquid}}{\text{Specific Weight of water}}$

$= \frac{7000}{9810}$

$= 0.7135$ No unit

2. One cubic meter of crude oil weights 9.44 KN. Calculate the density, specific weight, specific volume and relative density.

Given Data

Volume = 1 m

Weight of petrol = 9.44 k N = 9440 N

Mass = W/g = 9440/9.81

= 962.28 kg

Solution

1. Density = $\frac{\text{Mass}}{\text{Volume}} = \frac{962.28}{1} =$ = 962.28 kg/m^3

2. Specific weight = $\frac{\text{weight}}{\text{Volume}}$

$= \frac{9440}{1} = 9440\ N/m^3$

3. Specific Volume = $\frac{\text{Volume}}{\text{Mass}} = \frac{1}{\text{Density}}$

$= 0.00104\ m^3/kg$

4. Relative Density = $\frac{\text{Specific Weight of liquid}}{\text{Specific Weight of water}}$

$= \frac{9440}{9810}$

$= 0.962$ No unit

3. If the density of liquid is 837 kg/m^3. Find its specific weight , Specific volume and Relative density

Given Data

Density = 837 kg/m^3

To find

1.Specific weight 2.Specific volume 3.Relative density

Solution

1. Specific weight = $\frac{\text{weight}}{\text{Volume}}$ (0r) Density(ρ) x g

$= 873 \times 9.81\ \text{N/m}^3$

$= 8210.97\ \text{N/m}^3$

2. Specific Volume = $\frac{\text{Volume}}{\text{Mass}} = \frac{1}{\text{Density}} = \frac{1}{\rho}$

$= \frac{1}{837} = 1.19 \times 10^{-3}\ \text{m}^3/\text{kg}$

3. Relative Density = $\frac{\text{Specific Weight of liquid}}{\text{Specific Weight of water}}$

$= \frac{8210.97}{9810} = 0.837$ No unit

1.6. Important Formula

1.Weight W= m x g m-Mass

g-acceleration due to gravity

2. Density(ρ) = $\frac{\text{Mass}}{\text{Volume}} = \frac{m}{v}$

3. Specific volume = $\frac{\text{Volume}}{\text{mass}} = \frac{v}{m}$

4. Specific weight = $\frac{\text{weight}}{\text{Volume}} = \frac{m \times g}{v}$

5. Relative Density = $\frac{\text{Specific Weight of liquid}}{\text{Specific Weight of water}}$ (or) = $\frac{\text{Density of liquid}}{\text{Density of water}}$

6. Specific gravity of water = 1

7. Specific gravity of mercury = 13.6
8. Density of water = 1000 kg/m^3
9. Density of mercury = 1000x13.6 kg/m^3
10. Specific weight water = 9810 N/m^3

EXERCISE

A. Theoretical Questions

1. Define fluid.
2. Define density.
3. Define specific volume.
4. Define specific weight.
5. Define relative density.
6. What is viscosity?
7. What is the unit of surface tension?
8. How fluids are classified?
9. Which fluid is called as Newtonian fluid?
10. Give the example of real fluid.

11. Distinguish between absolute viscosity and kinematic viscosity.
12. State the relation between absolute viscosity and kinematic viscosity.
13. What is the difference between ideal and real fluid?

B. Numerical Problems

1. If a liquid weighs 200 N and occupies 2.5 m^3. Find its specific weight, mass density and relative density.
2. One liter of fuel weighs 8.02 N. Calculate its,
    - Specific weight.
    - Density.
    - Specific volume.
    - Relative density.

1.7.PRESSURE OF A FLUIDS

Pressure of Fluid

The normal force acting on unit area is known as “pressure” (or) “intensity of pressure”.

Intensity of pressure (P) = $\frac{\text{Force(F)}}{\text{Area(A)}}$

Unit of pressure is N/m^2 (or) kN/m^2.

1 Pascal = 1 N/m^2

1 bar = 10^5 N/m^2 **= 10^5**pascal.

1 Torr (Torricelli) = 1 mm of Hg.

1 pieza = 1 KPa.

1.8.Law of pressure

The intensity of pressure of a liquid at rest is always acts normal to the surface. The intensity of pressure of a fluid at rest, is acting equally in all directions. This is known as pascal's law. The intensity of pressure depends only upon the vertical height of the liquid and not upon the size and shape of the vessel. If a vessel contains a fluid, a slight in cress in the intensity of pressure at any point will be immediately transmitted to all other points in the fluid.

When a pressure gauge is connected to the points A, B, C, &D respectively. It will indicate the same reading as shown in fig.

Pressure at A = pressure at B = pressure at C

Pressure at D = pressure at B

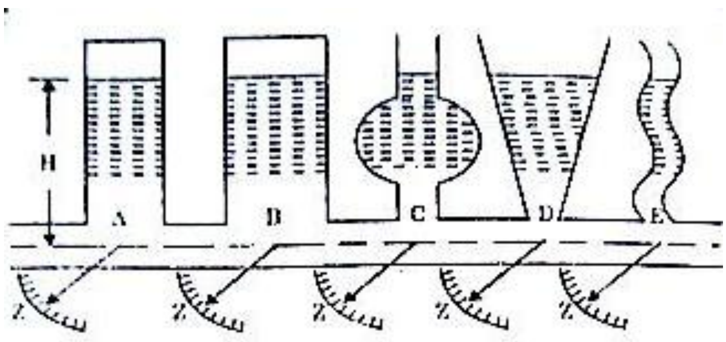


Fig 1.2

pressure at a point in a liquid

pressure at a point in a liquid is, due to the weight of liquid column above the point. consider a small area “a” at a depth of H below the liquid surface. Force acting on the area a is due to weight of liquid prism standing over is as shown in fig.1.3

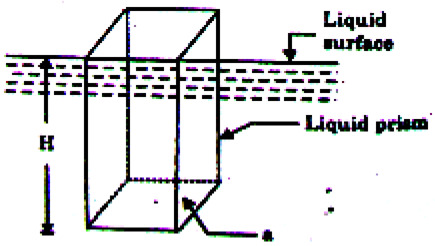


Fig.1.3

Pressure(p)=weight of liquid prism/area

(p) =volume of the prism x sp.weight of liquid/area

$$P = \frac{a \times H \times w)}{a}$$

$$P = wH.$$

where

H- Pressure head

w- specific weight

pressure head of a liquid

The vertical height of the liquid corresponding to particular pressure is known as pressure head.

$$\text{Pressure head} = \frac{\text{Pressure}}{\text{Specific weight of liquid}}$$

Atmospheric Pressure

- Atmospheric Pressure is due to the weight of air column acting on unit area, at sea level.
- Barometer is used to measure the atmospheric pressure .
- Atmospheric pressure is 101.325 kN/m^2 (or) 760 mm mercury (or) 10.33 m of water.

Gauge pressure

If the pressure to be measured is more than the atmospheric pressure, then the pressure indicated by a gauge is known as Gauge pressure.

Ex :Boiler steam pressure, Air compressor pressure.

Vacuum pressure

If the pressure to be measured is less than the atmospheric pressure , than the pressure indicated by a gauge is known as “vacuum pressure”.

The relationship between the absolute pressure gauge pressure and vacuum pressure are as shown in fig.

Mathematically

1.Absolute pressure = Atmospheric pressure+ gauge pressure

2.vacuum pressure =atmospheric pressure – absolute pressure

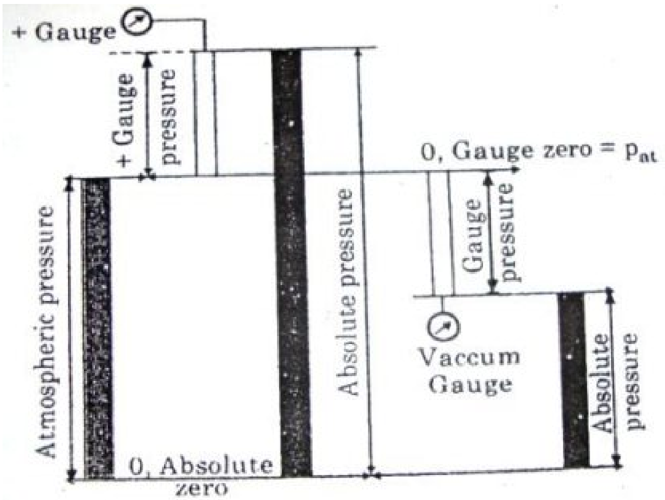


Fig1.4

1.9.Pascal's law

Pascal's law states that the intensity of pressure at any point in a fluid at rest, is acting equally in all direction**.**

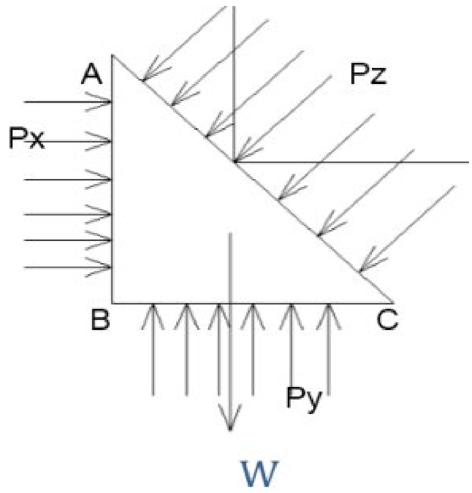


Fig.1.4

proof

P_x – Intensity of pressure acting on AB,

P_y – Intensity of pressure acting on BC

P_Z – Intensity of pressure acting on AC, θ- Angle between AC & BC

W-weight of element

Consider unit length of element in a direction perpendicular to the direction of paper

Force on the face AB = P_x x AB

Force on the face BC = P_y x BC

Force on the face AC = P_z x AC

Self weight of the element W

Resolving the forces horizontally

$F_x = F_z \sin\theta$

$P_x \times AB = P_z \times AC \times \sin\theta$

From triangle ABC $\sin\theta = \frac{AB}{AC}$

AB = AC sin θ put AB value in the previous equation

$P_x \times AC \sin\theta = P_z \times AC \times \sin\theta$

$\mathbf{P_x = P_z}$ **-------------------------------(1)**

Resolving the forces vertically

$F_z \cos\theta + W = F_y$

$P_z\, AC \cos\theta + W = P_y\, BC$ W is very small. So it is negligible

$P_z\, AC \cos\theta = P_y\, BC$

From triangle ABC $\cos\theta = \frac{BC}{AC}$

BC = AC cos θ

$P_z\, AC \cos\theta = P_y\, AC \cos\theta$

$\mathbf{P_z = P_y}$ **---(2)**

From equation (1) & (2)

$\mathbf{P_x = P_y = P_z}$ hence Pascal's law proved.

1.10.Hydraulic press

Hydraulic press is used to lift heavy weights by the applications of a much smaller force. it is working under Pascal's law.

Elements Hydraulic press

1. Reservoir
2. plunger
3. Ram
4. check valves
5. Release valve
6. Handle

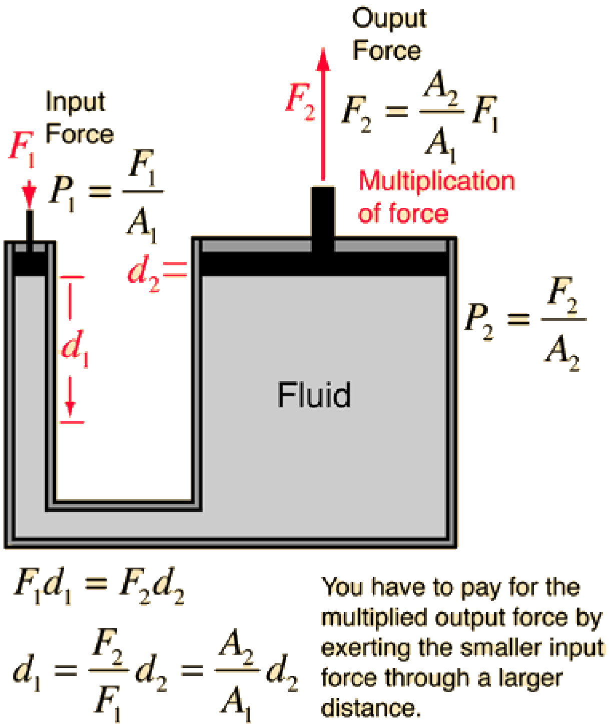


Fig.1.5

Construction

Hydraulic press consists of two cylinders. One is larger then the other. larger cylinder contains a ram and smaller cylinder contains a plunger. These two cylinders are connected by a pipe. Cylinders and pipe contain a liquid through which pressure is transmitted. one plate is fixed and other plate is attached to the ram . A release valve is fitted at the bottom of the ram side.

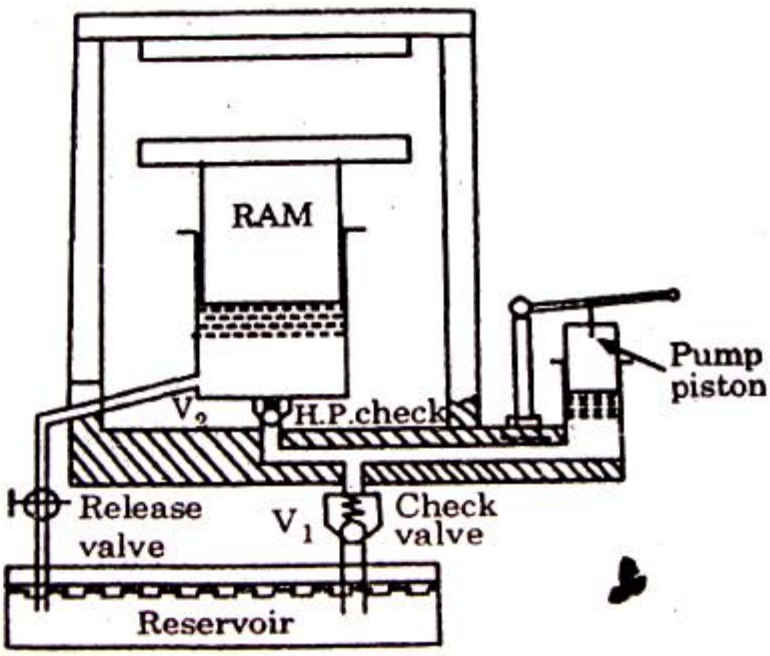


Fig .1.6. Hydraulic press

Working principle

When the handle moves upward then upward movement of the plunger take place. Partial vacuum is created in the bottom of the plunger.

The liquid from the reservoir is drawn through the check valve “v_2” and enters into the small cylinders. Now the delivery valve will be in closed position.

The plunger increases the liquid pressure at its bottom. At same time, the check valve “V_1” closes and check valve “V_2” opens. The liquid is forced to the ram cylinder through the check valve “V_2”. The high pressure liquid acting at the bottom of the ram moves the ram up. Thus the load on the ram is lifted up and then the object is pressed between the two plates.

To lower the load the release valve is opened to allow the liquid the reservoir. This caused the ram to move down.

1.11.Hydraulic jack

The hydraulic jack is used to lift heavy loads by the application of a much smaller force. It is working under Pascal’s law. The diagram of hydraulic jack is shown in fig.1.7

Elements of Hydraulic Jack

1.Ram	2.plunger with handle
3.Suction&delivery valve.	4 Reservoirs

Working principle

The plunger will be moved up and down by actuating the handle. During the upward movement of the plunger, partial vacuum is produced in the plunger side. Now liquid flows to the plunger side from the reservoir by opening the suction valve. Now the delivery valve will be in closed position.

During the downward movement of the plunger the liquid moves at the bottom of ram and the ram be moves up. The heavy load at the top of the ram is lifted. There is lowering screw at the bottom of ram side. It is unscrewed to allow the liquid to the reservoir. Hence the ram will be moved downward to lower the load.

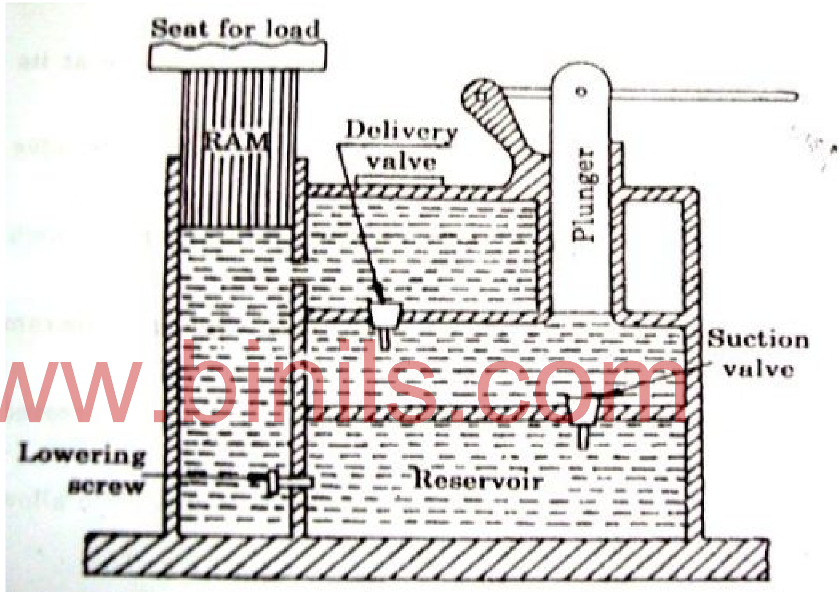


Fig. 1.7.Hydraulic jack

1.12.PRESSURE MEASUREMENTS

The pressure of a fluid is measured by the following devices.

1. Manometer 2. Mechanical gauges

1.12.1. Manometers

Manometer are the pressure measuring instruments based on the principle of balancing the liquid columns.

Uses of manometer

Used for accurate measurements of

*Low pressure

*Vacuum pressure

*Difference of pressure

Advantages

*simple construction

*precise measurement

*-ve pressure can be measured.

Types of Manometers

- Barometer
- Piezometer tube
- U tube manometer
- Differential manometer
- Inverted u tube manometer
- Micro manometer
- Inclined manometer

1.12.2. Barometer

Barometer is used to measure the atmospheric pressure.

Types of Barometer

1. Mercury Barometer

2. Aneroid Barometer

Mercury barometer

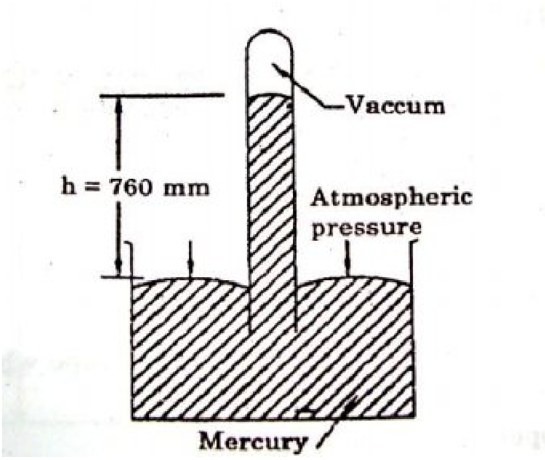


Fig. 1.8.

Mercury barometer

Mercury barometer is used to measure atmospheric pressure. It consists of a vertical glass tube having one end closed and other end opens to atmosphere. Glass tube is graduated in “m.m”. To measure the atmospheric pressure the glass tube is completely filled with mercury and then it is immersed upside down into a vessel containing mercury as shown in fig.1.8. It is seen that the mercury stands in the tube to a height of 760 mm above the mercury level in the vessel.

Atmospheric pressure = 760mm of hg

1.12.3. Piezometer tube

Piezometer tube is used to measure the low pressure. It consists of a vertical graduated glass tube with open ends. The length of the tube is so selected that the liquid will rise in the tube freely with our overflow. If the pressure of water flowing in a pipe is to be measured then the piezometer tube is connected to the pipe the water will rise in the tube corresponding to the pressure of water available in the pipe as shown in fig.1.9

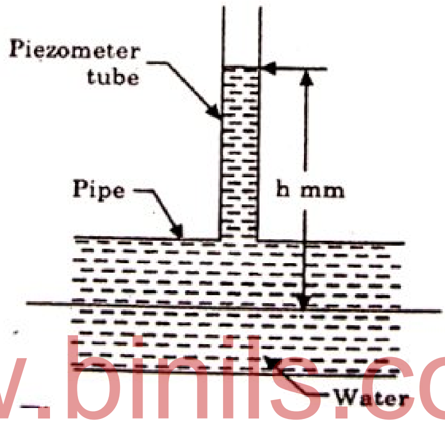


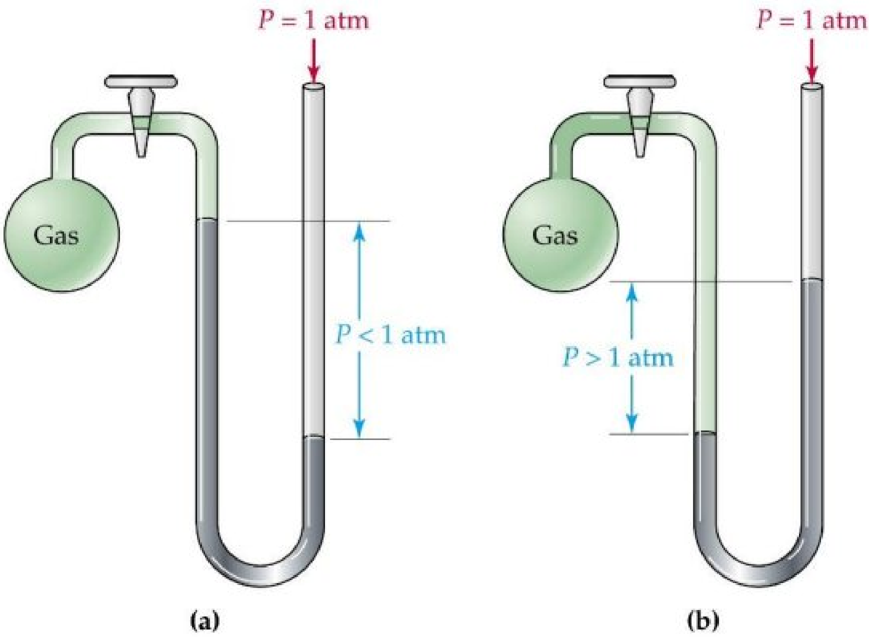
Fig.1.9

Pressure in the pipe = Rise of water in the tube is” h” mm

P = ” h” mm of water.

1.12.4. Simple U tube manometer

This is used to measure the pressure at a point in a static or dynamic fluid. Gauge pressure and vacuum pressure can be measured.



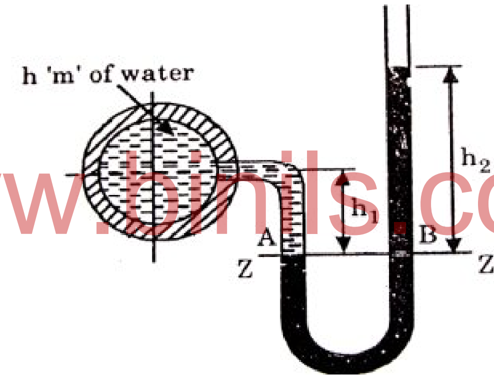


Fig.1.10

It consists of a glass tube bent in the form of “u” us shown in fig.1.10. This glass tube is open at both ends. General the tube contains mercury. Mercury is 13.6 times heavier than water. It is suitable for measuring high pressure. One end of the “U” tube is connected to the pipe whose pressure is measured and the other end is open to atmosphere. The pressure of water in the pipe forces the mercury level in the left arm to go down and a corresponding amount will rise in the right arm.

Let

Take Datum line is A-A

$h_{1=}$ height of light liquid above the datum line.

H_2=height of heavy liquid above the datum line.

S_1=specific gravity of light liquid.

S_2=specific gravity of heavy liquid.

Total pressure head in the left limp = Total pressure head in the right limp

$$h + h_1 s_1 = h_2 s_2$$

$$\mathbf{h = h_2 s_2 - h_1 s_1}$$

Measuring negative (vacuum) (or) suction pressure

To measure the suction pressure connect one of the limbs of the u-tube to the pipe and other limb is open to atmosphere. The level of the mercury in the manometer will be shown in fig.1.11.

Let

Take Datum line is A-A.

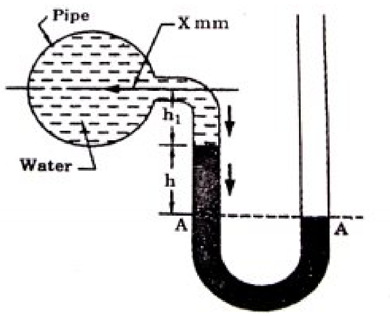


Fig.1.11

h=vacuum pressure in pipe line.

h_1=height of liquid in the left limb above mercury level.

h_2=height of mercury in the left limb above AA.

S_1- Specific gravity of liquid in pipe line.

S_2=specific gravity of mercury.

Total pressure head in the left limp = Total pressure head in the right limp

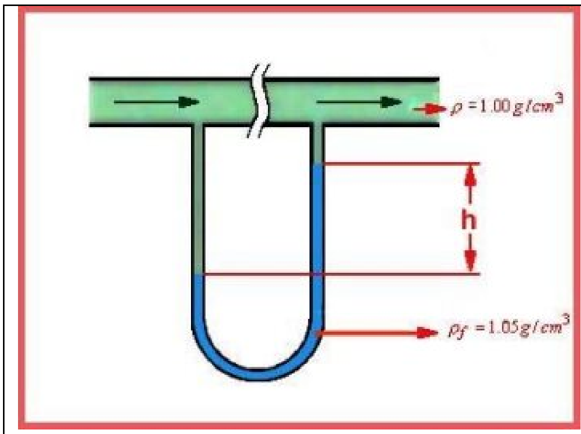
$h+h_1 s_1+h_2 s_2$=atmospheric pressure

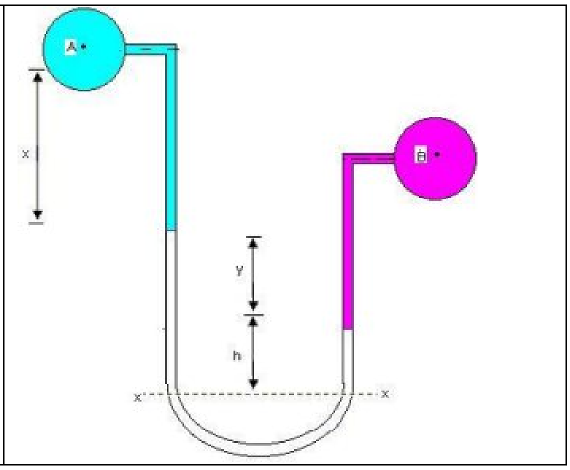
pr.head $\mathbf{h=-(h_1 s_1+h_2 s_2)}$ Since atmospheric pressure is neglected

_ ve sign indicate the vacuum pressure.

1.12.15. Differential U tube manometer.

Differential manometer is used to measure the difference of pressures between two points in the same pipe line or in two different pipes.





It consists of a simple u tube and containing a heavy liquid whose two ends are connected to the points whose difference of pressure is to be measured.

Let the two points A and B are at different level and also contains liquids of different specific gravity.

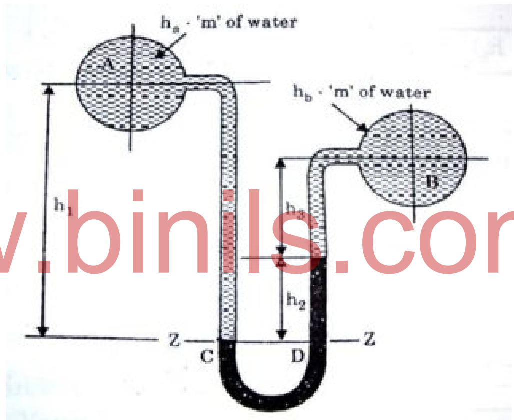


Fig.1.12

These two points are connected to the u tube differential manometer as shown in fig.1.12.

Let h_A=pressure of liquid in the pipe A.

h_B=pressure of liquid in the pipe B.

h_1=height of liquid of pipe A in the left limb above AA.

h_2=height of mercury in the right limb above AA.

h_3=height of liquid of pipe B in the left limb above mercury level.

S_1=specific gravity of liquid in pipe "A"

S_2=specific gravity of mercury in pipe "A".

S_3=specific gravity of liquid in pipe "B".

Total pressure head in the left limp = Total pressure head in the right limp

$$h_a+h_1s_1=h_b+h_2s_2+h_3s_3$$

$$\mathbf{h_a - h_b = h_2s_2+h_3s_3 - h_1s_1} \qquad \text{m of water.}$$

Let the two points A & B are same level and contains liquid of different specific gravity as shown in fig.1.13 .then

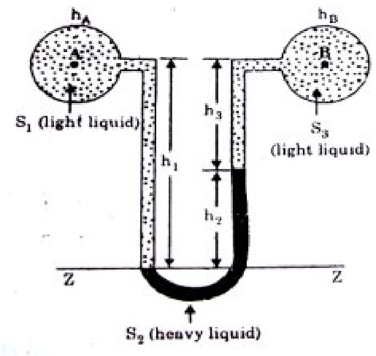


Fig.1.13.

Total pressure head in the left limp = Total pressure head in the right limp

$h_A + h_1s_1 = h_B + h_2s_2 + h_3s_3$

$h_A - h_B = h_2\, s_2 + h_3s_3 - h_1s_1$

$\quad = h_2\, s_2 + h_3s_3 - (h_2 + h_3)s_1$

$\mathbf{h_A - h_B = h_2(s_2-s_1) + h_3(s_3-s_1)}$

1.12.16. Inverted Differential U-tube manometer

This manometer is used to measure the difference of low pressure between the two points.

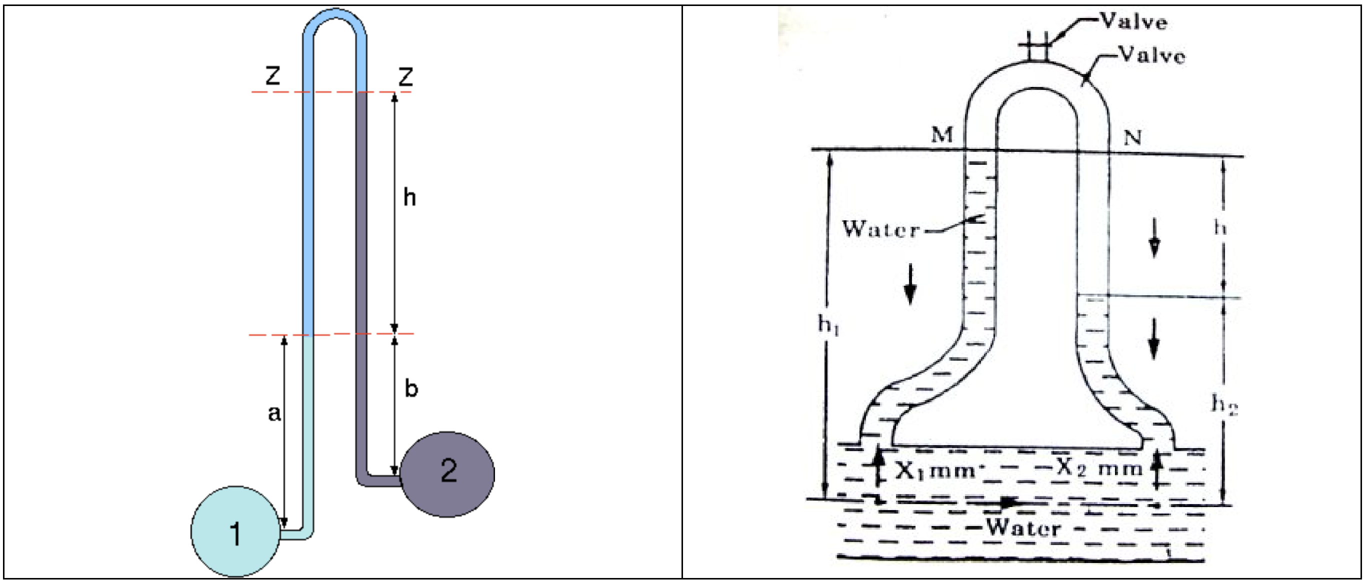


Fig.1.14

It consists of an inverted “U” tube. It containing a light liquid. The two ends of the tube are connected to the point whose difference of pressure is to be measured. Fig.1.14. shows an inverted U-tube differential manometer connected to the two points A and B. The pressure at “A” is more than the pressure at “B”.

Let h_1=height of liquid in left limb below the datum line AB.

h_2 = height of liquid in right limb.

h=difference of light liquid.

S_1=specific gravity of liquid at “A”.

S_2=specific gravity of liquid at “B”.

S_3=specific gravity of light liquid.

h_a=pressure of liquid in the pipe “A”.

h_b=pressure of liquid in the pipe “A”.

Taking A-A as datum line.

Pressure in the left lime below AA = pressure in the right limb below “AA”.

$h_a - h_1 s_1 = h_b - h_2 s_2 - h s_3$

$(h_a - h_b) = h_1 s_1 - h_2 s_2 - h s_3$

1.12.17. Micro manometer

Micro manometer is used for measuring low pressure with high degree of accuracy. Micro manometer is a modified form of manometer. In this manometer cross sectional area of one of limb (left limb) is made much larger than (about 100 times) that of the other limb. Micro manometer is shown in fig.1.15

Types of micrometer

1. Vertical tube micro manometer
2. Inclined tube micro manometer

1. Vertical tube micro manometer

Now consider a vertical tube micro manometer connected to a pipe containing light liquid under a very high pressure. The pressure in the pipe will force the light liquid to push the heavy liquid in the basin downwards. Due to larger area of the basin, the fall of heavy liquid level will be very small. This downward movement of the heavy liquid in the basin will cause a considerable rise of the heavy liquid in the right limb.

Let us consider our datum line Z-Z corresponding to heavy liquid level before the experiment.

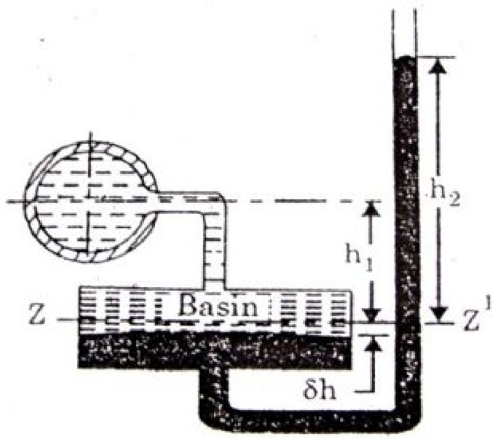


Fig 1.15 Vertical Micro manometer

δh=fall of heavy liquid level in the basin in cm.

h_1=height of liquid above the datum line in cm.

h_2=height of heavy liquid (after experiment) in the right limb above this datum line in cm.

h=pressure in the pipe, expressed in terms of head of water in cm.

A=cross sectional area of the basin in cm^2.

a=cross sectional area of the tube in cm^2.

S_1=specific gravity of the light liquid and

S_2=specific gravity of the heavy liquid.

We known that the fall of heavy liquid level, in the basin, will cause a corresponding rise of heavy liquid level,

$A\,\delta h = ah_2$ or $\boldsymbol{\delta h = \frac{a}{A}\, h_2}$

Now let us take horizontal surface in the basic, at which the heavy and light liquid meet, as datum line. We also known that the pressures in the left limb and right limb above the datum line are equal.

Pressure in the left limb above the datum line

$= h + s_1 h_1 + s_1 \delta h$ cm of water

and pressure in the right limb above the datum line.

$=s_2h_2+s_2\delta h$ cm of water

equating these two pressure,

$h+s_1h_1+s_1\delta h = s_2h_2+s_2\delta h$ or

$h=s_2h_2+s_2\delta h-s_2h_1-s_1\delta h$

$\mathbf{h=s_2h_2-s_1h_1+\frac{a}{A}h_2(s_2-s_1)}$

2. Inclined tube micromanometer

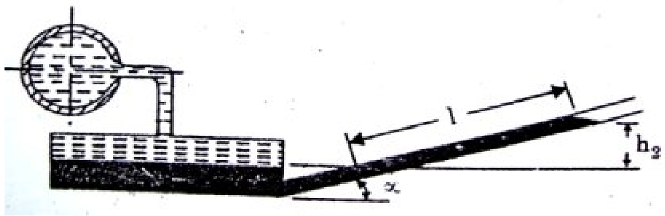


Fig. 1.16

Sometimes, the vertical tube of the micromanometer is made inclined as shown in fig.1.16

This type of inclined micromanometer is more sensitive than the vertical tube.Due to inclination the distances moved by the heavy liquid, in the narrow tube, will be comparatively more and thus it can give a higher reading for then given pressure.

From he geometry of figure, we find

h_2 =sin α

h_2=1.sin α

By substituting the value of h_2 in the micro manometer equation, we can find out the required pressure in the pipe.

1.12.18. Problem

1) Determine the pressure in a pipe containing a liquid of specific gravity 0.8. A micro manometer was used a s shown in fig.1.17. The ratio of area of the basin to that of the limp is 50.

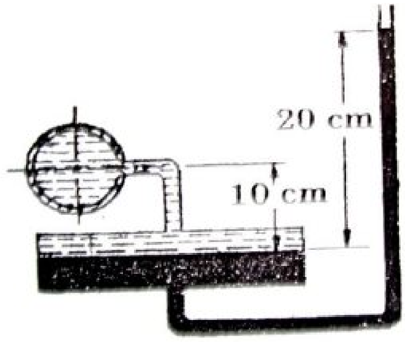


Fig. 1.17

Given

Sp. Gravity of liquid in the pipe $S1 = 0.8$

Ratio of area of the basin to that of the limb (A/a) = 50

Height of liquid in the left Limb h1 = 10 cm = 0.1 m

Height of liquid in the right Limb h2 = 20 cm = 0.2 m

Sp.Gravity of Mercury S2 = 13.6

Solution

Pressure in the pipe $h = s_2h_2 - s_1h_1 + \frac{a}{A} h_2(s_2 - s_1)$ m of water

$= (13.6 x 20) - (0.8 x 10) + \frac{1}{50} x 20(13.6-0.8)$ cm of water

$= 269.12$ cm of water

$h = 2.6912$ m of water

Pressure in the pipe $p = W h = 9810 \times 2.6912 = 26.40 \times 10^3 \text{ N/m}^2$

Note: W – Specific weight of water = 9810 N/m^3

1.13. MECHANICAL GAUGES

Introduction

Mechanical gauges are one of the direct pressure measuring instruments. Example the pressure gauges are known as mechanical gauges.

Types of mechanical pressure gauges

- Bourdons tube pressure gauge.
- Diaphragm pressure gauge.
- Dead weight pressure gauge.
- Bellows pressure gauge.

Advantages of mechanical gauges

- Durable
- Portable
- Giving direct reading
- Long life

1.13.1. Bourdons pressure gauge

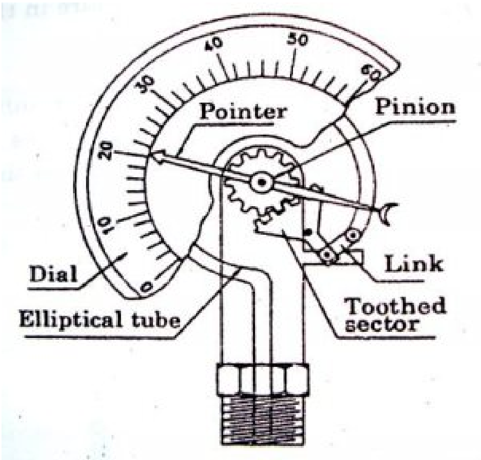


Fig.1.18

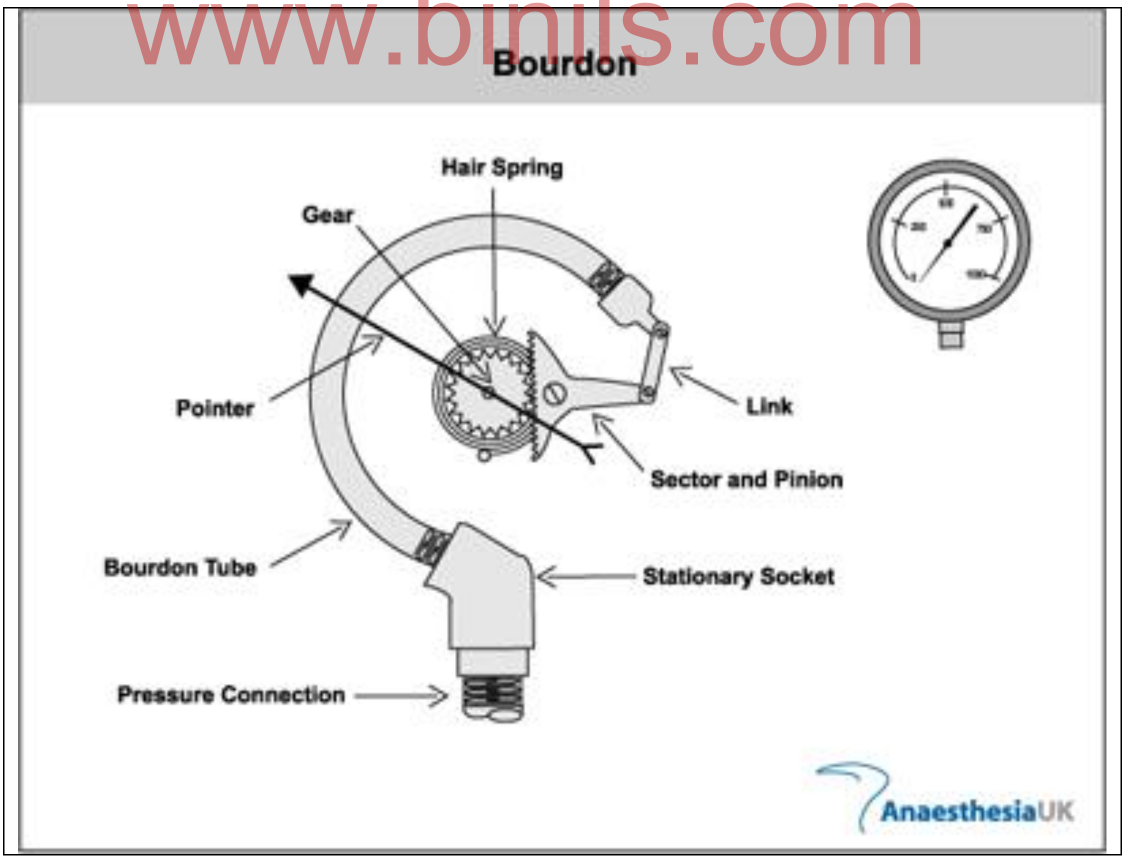


Fig.1.19

This gauge used for measuring high pressure. The principle used in this gauge is an elastic deformation of a metallic tube which is proportional to the fluid pressure as shown in fig.1.18.

It consists of the following parts.

Parts

1.Elliptical tube 2.Toothed sector

3.Links 4.Pinion

5.Pointer

Function

When the gauge is connected to the pressure enters into an elliptical spring tube. The fluid under the pressure of fluid, the tube tends to deform. As a result of increased pressure of fluid the tube tends to deform. One end of elliptical tube is fixed. The free end moves out. This elastic deformation of the bourdons tube rotates the pointer through the links. This pointer moves over a calibrated dial which shows the pressure reading directly.

1.13.2. Diaphragm Gauge

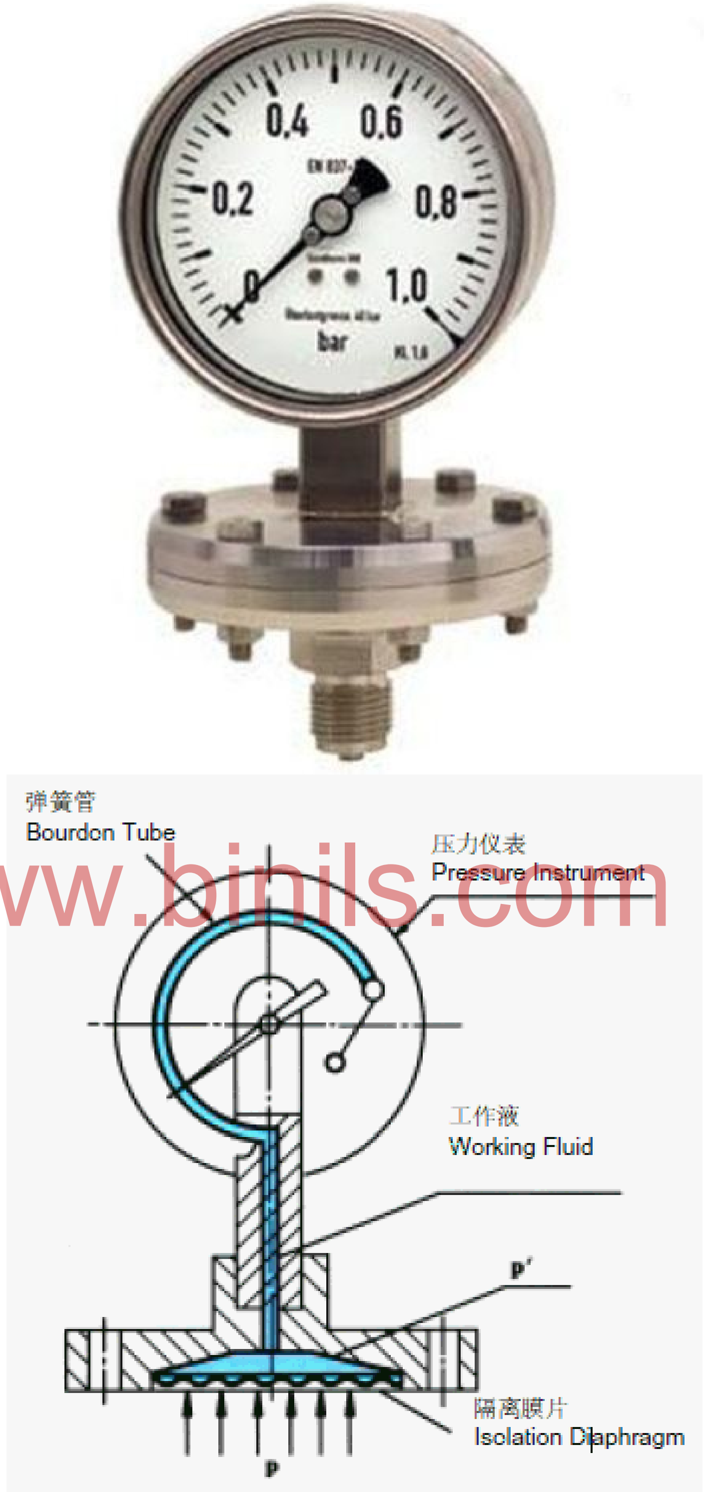


Fig.1.20

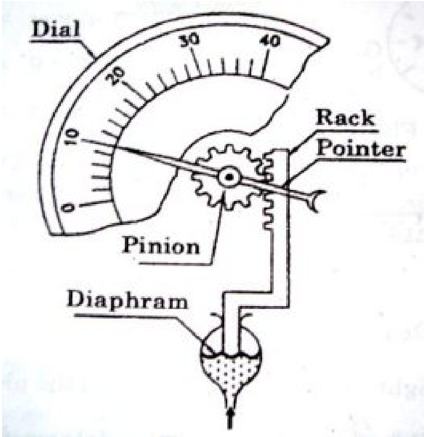


Fig .1.21

This gauge is used for measuring low pressure. The principle used in this gauge is elastic deformation of a thin element called a diaphragm is proportional to the pressure .

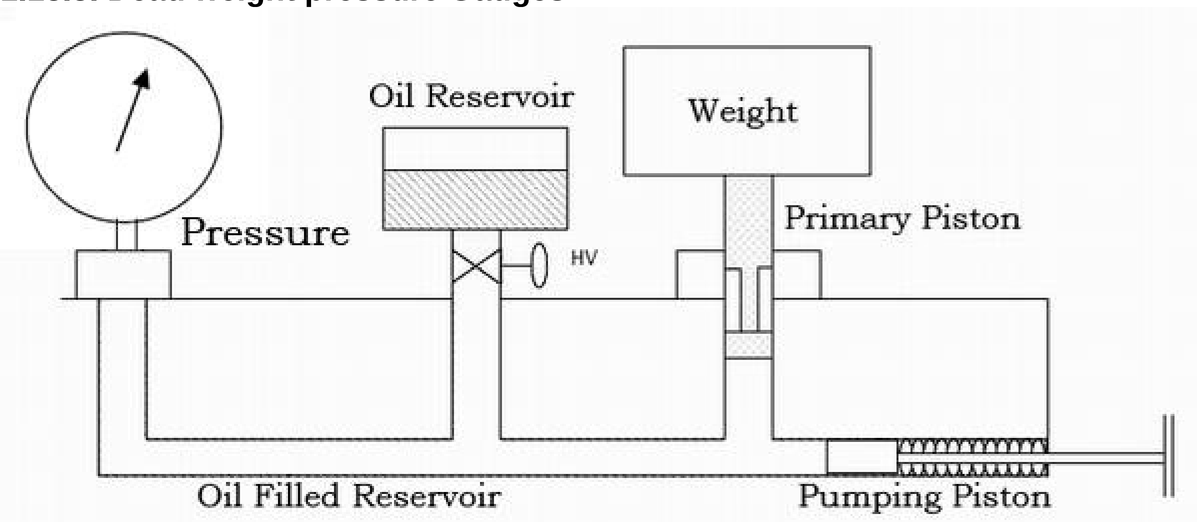
It consists of

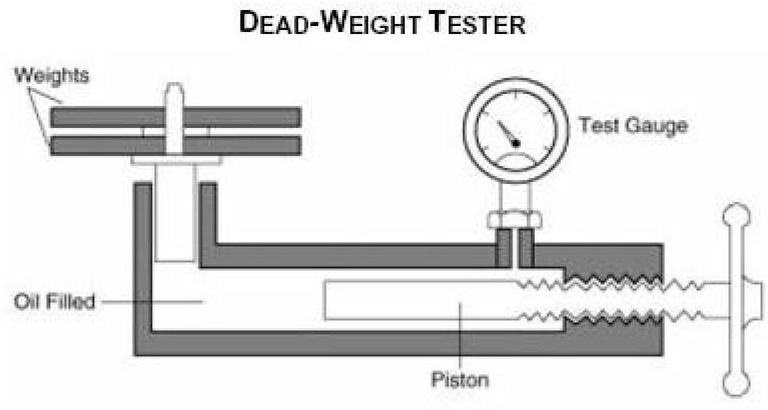
- Diaphragm
- Rack
- Pinion
- Pointer
- Dial

Working

The working principle of diaphragm pr gauge as shown in fig.1.21. When the gauge is connected to the pressure point whose pressure is to measured. The fluid under pressure causes some deformation of the diagram. Upward movement of the diagram causes the rack to move up. Pinion attached to the rack rotates. With the help of rack and pinion mechanism the pointer moves over a calibrated dial, which directly reads the pressure of the fluid.

1.13.3. Dead weight pressure Gauges





This gauge is most accurate pressure gauge. This gauge is direct method of pressure measurement.

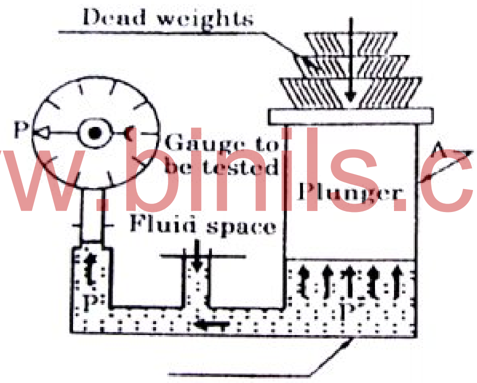


Fig 1.22

Generally it is used for calibration of other pressure gauge. This gauge consists of plunger which can slide within a vertical cylinder. When the inlet pressure and is connected to the fluid whose pressure is to be measured. The fluid extra force on the plunger. This force on the plunger is balanced by the weight loaded on the top of the plunger. Known dead weights are placed on the top of the plunger. The pressure “P” of the fluid can be determined as follows. The diagram is shown in fig.1.22.

Pressure(P) = dead weights (W)/ area of the plunger

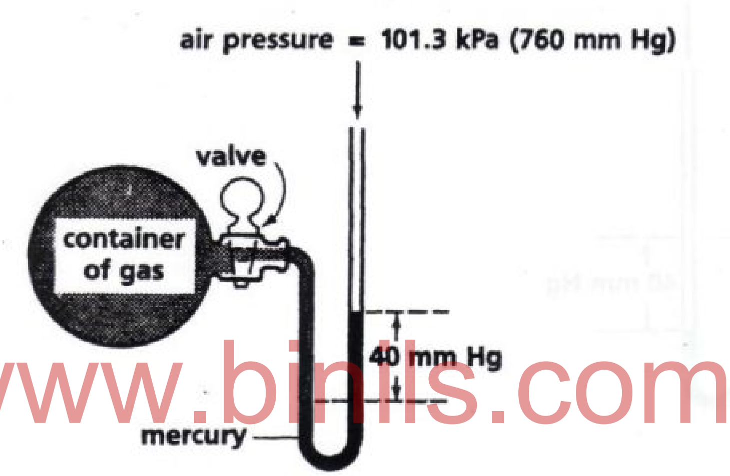
Where d=dia of the plunger

W=weight

1.14. Important Formula

1. Pressure p = W x H
2. Absolute Pressure = Atmospheric pressure + Gauge pressure
3. Absolute Pressure = Atmospheric pressure - Vacuum pressure
4. Atmospheric pressure = 760 mm of Hg = 1.01325x105 Pascal = 1.01325x105 N/m^2
5. Simple U tube Manometer $h = h_2S_2 – h_1S_1$
6. Differential Manometer ha-hb = h2S2+h3S3-h1s1
7. Inverted Differential Manometer ha-hb = h1s1- h2S2-hS3

1.15. Simple u tube manometer problems



Assuming that the valve is open, what pressure, in kilopascals, is the gas exerting?

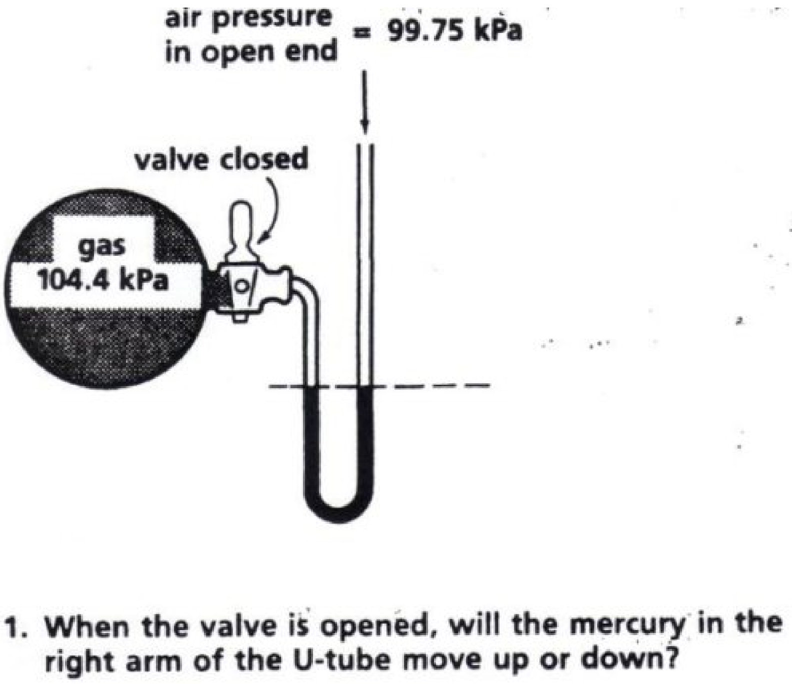


Fig. 1.23

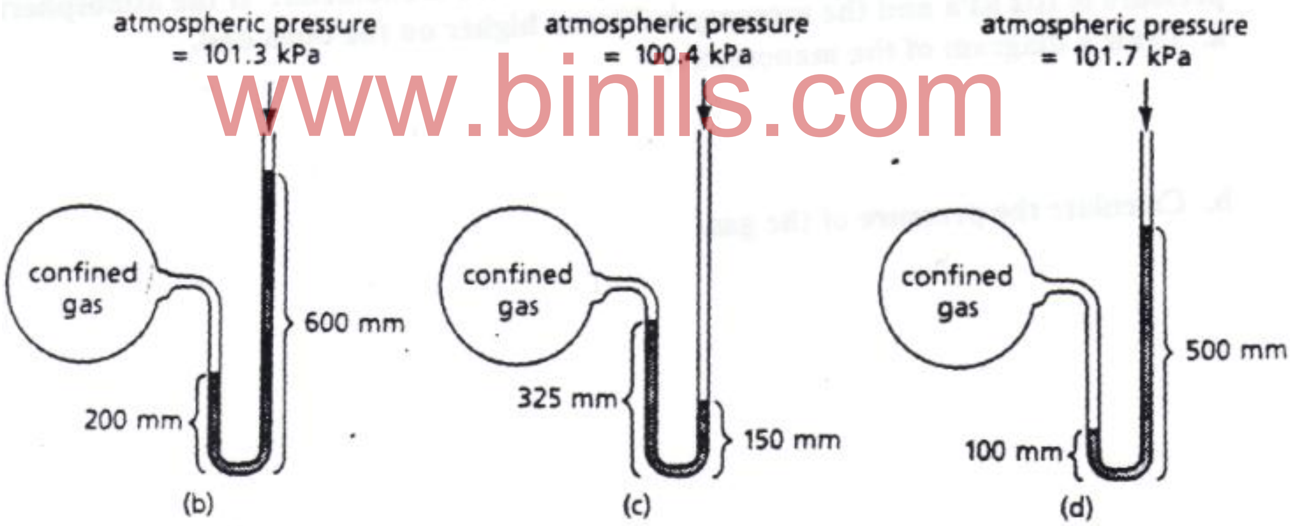


Fig 1.23

1. What is the atmospheric pressure, in kPa, indicated by the barometer in Figure A?
2. What is the pressure, in kPa, of the confined gas as indicated by the open-ended manometer in Figure B?
3. What is the pressure, in kPa, of the confined gas indicated by the open-ended manometer in Figure C?
4. What is the pressure, in kPa, of the confined gas indicated by the open-ended manometer in Figure D?

1. An open ended manometer is attached to a container of gas that is exerting a pressure of 104.5 kPa. The atm. pressure is 99.8 kPa.
a. Draw a diagram of the manometer.

b. When the valve is opened, will the mercury in the open arm of the u-tube move up or down?

c. After the Hg in the U-tube stops moving what will be the difference in height of the Hg levels in the 2 arms.

2. A container of gas is hooked up to an open ended monometer. If the atmospheric pressure is 102 kPa and the mercury is 30 mm higher on the open end.
a. Draw a diagram of the manometer.

Problems

1. Determine the pressure at a depth of 20 m in an oil of relative density 0.8.

Given data

Depth of Oil h = 20 m

Relative density of oil = 0.8.

Solution

Relative Density = $\frac{\text{Specific weight of oil}}{\text{Specific weight of water}}$

$0.8 = \frac{\text{Specific weight of oil}}{9810}$

Specific weight of oil = 0.8 x 9810

Pressure of oil = Specific weight of oil x h

= 0.8 x 9810 x 20

Pressure of oil =156.96x10^3 kN/m^2

2. Express the pressure intensity in absolute pressure in i)kN/m^2 ii)in meter of water. if gauge pressure is 0.7356 N/mm^2

Given Data

Gauge Pressure = 0.7356 N/mm^2 = 0.7356x 10^6 N/m^2

Solution

i) absolute pressure = Atmospheric pressure +Gauge pressure

$= 1.01325 \times 10^5 + 0.7356 \times 10^6$

absolute pressure = 8.37 x 10^5 N/m^2

ii) Atmospheric pressure = 10.33 m of water

Gauge Pressure = 0.7356×10^6 N/m^2

$= \frac{0.7356x\ 10^{\wedge}6}{9810}$ [P=wH]

= 74.985 m of water

absolute pressure = Atmospheric pressure +Gauge pressure

= 10.33 + 74.985

absolute pressure = 85.315 m of water

3. A gauge fitted to a gas cylinder records a pressure of 16.27 kN/m^2. Compute the corresponding absolute pressure in i)kN/m^2 ii)in meter of water. The Atmospheric pressure is 700 mm of Hg

Given Data

Atmospheric pressure = 1.01315×10^5 N/m^2 = 101.325 KN/m^2

Note: The given pressure is lower than the Atmospheric pressure . Hence the pressure is taken as vacuum pressure.

vacuum pressure = 16.27 kN/m^2

given atmospheric pressure = 700 mm of Hg = 0.7 m of Hg

= 0.7x13.6 m of water

= 0.7x13.6x9.810 KN/m^2

= 93.39 KN/m^2

Solution

i) absolute pressure = atmospheric pressure - vacuum pressure

= 93.39 - 16.27

P_{abs}=77.12 KN/m^2

ii) absolute pressure in m of water

P=wH

H=P/w

= 77.12/9.810

H = 7.86 m of water

4. A gauge records a pressure of 24.52 kN/m^2 vacuum. Compute the corresponding absolute pressure in i) kN/m^2 ii) in meter of water. The local atmospheric pressure is 0.75 m of Hg. Specific gravity of mercury is 13.6.

Given Data

vacuum pressure = 24.52 kN/m^2

local atmospheric pressure(h) = 0.75m of Hg

= 0.75x13.6 m of water

= 0.75x13.6x9.810 KN/m^2 [p=wh]

p= 100.062 KN/m^2 w-specific weight of water

W=9810 N/m^2 = 9.810 KN/m^2

Solution

i) absolute pressure = atmospheric pressure - vacuum pressure

= 100.062 - 24.52

P_{abs}=75.542 KN/m^2

ii) absolute pressure in m of water

P=wH

H=P/w

= 75.542 /9.810

H = 7.7 m of water

5. The pressure of water in a pipe line was measured by means of a Simple manometer containing mercury. The mercury level in the open tube is 150 mm higher than that of the left tube. The height of water level in the left tube is 40 mm. Determine the pressure in the pipe

i) in m of water ii) kN/m^2

Given data

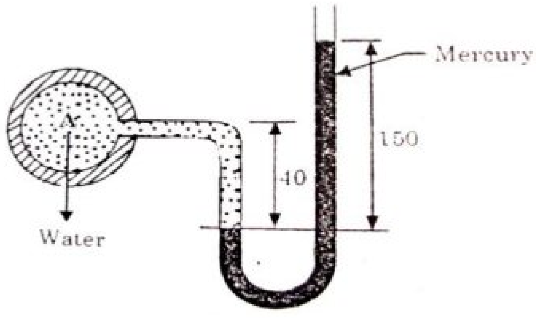


Fig.1.24

h_1= 40 mm

h_2= 150 mm

S_1(Specific gravity of water) = 1

S_2(Specific gravity of mercury) = 13.6

Solution

total pr.head in left limp = total pr.head in right limp

$h_A + h_1 s_1 = h_2 s_2$

i) = (150x13.6)-(40x1)

h_a = 2000 mm = 2 m of water

ii) pressure P = w h_a = 9.810x2

p = 19.62 KN/m^2

6. The left limb of a U tube manometer containing mercury is open to the atmosphere and the right limb is connected to the pipe line carrying water under pressure. The centre of pipe is at the face surface of mercury. Find the difference in level of mercury in limbs if the absolute pressure of water in the pipe is 12.5 m of water.

Given Data

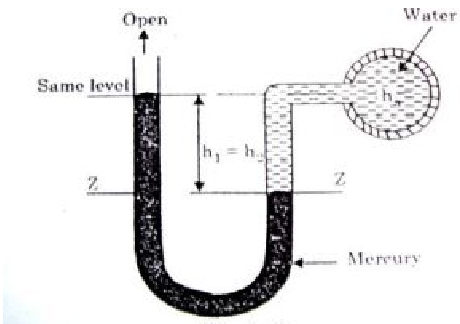


Fig.1.25

absolute pressure = 12.5 m

Gauge pressure (h_a) = absolute pressure – atmospheric pressure

= 12.5-10.33 atmospheric pressure = 10.33 m

h_a = 2.17 m of water

solution

total pr.head in left limp = total pr.head in right limp

$h_1s_1 = h_A + h_2S_2$ here h1 = h2 let take h1 = h2 = h

$h(S_2\text{-}S_1) = h_A$

$h = h_A/(S_2\text{-}S_1)$

h = 2.17 / (13.6-1)

Difference in Hg level h = 0.172 m

7. A differential manometer connected to two point A & B in a pipe line containing an oil of relative density 0.8as shown in fig 1.26. Difference in mercury level is 100mm. Determine the difference in pressure between the two points in terms of

i) m of water ii) kN/m^2 abs

Given data

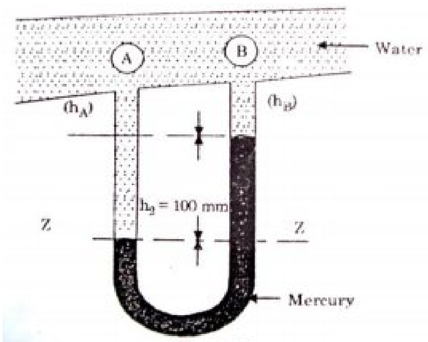


Fig.1.26

Relative density (or) Specific gravity of oil (S_1)= 0.8
Specific gravity of mercury (S_2)= 13.6
Difference in mercury level h_2=100mm

To find

i) $h_a\text{-}h_b$ in m of water ii) $P_a\text{-}P_b$ in kN/m^2

Solution

Note Both points connected in the same pipe and same liquid

i) $h_a\text{-}h_b = h_2(S_2\text{-}S_1)$

= 100(13.6-0.8)

= 1280 mm of water

= 1.280 m of water

ii) $P_a\text{-}P_b = w(h_a\text{-}h_b)$

= 9.810x1.280 = 12.556 kN/m^2

Pr difference (gauge) $P_a\text{-}P_b$ = 12.556 kN/m^2

Pr difference (abs) $P_a\text{-}P_b$ = Atm Pr + Gauge Pr

= 101.325 + 12.556

Pr difference (abs) P_a-P_b = 113.856 kN/m^2

8 A vacuum pressure in a pipe line carrying water was measured by U tube manometer, the deflection of mercury between the lines was 0.05 m and the free surface of mercury in the open limb was 0.1 m below the centre line of the pipe. Find the pressure in the pipe in absolute unit in terms of m of water

Given data

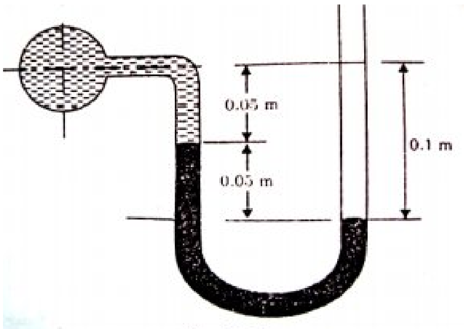


Fig.1.27

h_1 - height of liquid in the left limb above the mercury level = 0.05 m

h_2 - height of liquid in the left limb above AA = 0.05 m

S_1- Specific gravity of water = 1

S_2- Specific gravity of mercury = 13.6

Solution

Formula h $= h_1S_1 + h_2S_2$

$= 0.05x1+0.05x13.6$

h= 0.73 m of water

absolute pr= Atm Pr – vacuum Pr

= 10.33-0.73 = 9.6 m of water

Absolute Pr h = 9.6 m of water

9 A Differential manometer connected to two pipes A & B as shown in fig 1.28 . The pipe A contains liquid of specific gravity 1.5 and the pipe B contains liquid of specific
gravity 0.85 and the difference in pressure between the two pipes is 10 m of water. Find the difference in mercury level

Given data

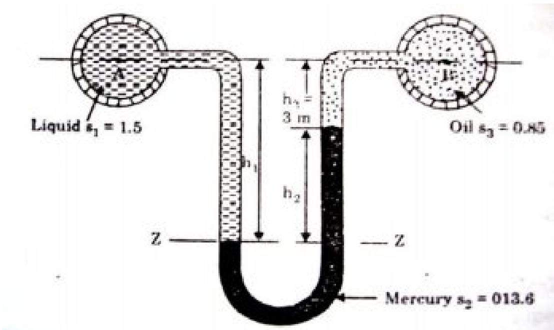


Fig.1.28

S_1 = 1.5

$S_2 = 13.6$

$S_3 = 0.85$

$h_a - h_b = 10$ m $\quad\quad h_3 = 3$ m

$h_1 = h_2 + 3$

Solution

$h_a + h_1S_1 = h_b + h_2S_2 + h_3S_3$

$(h_a - h_b) + h_1S_1 = h_2S_2 + h_3S_3$

$10 + (h_2 + 3)1.5 = h_2 \times 13.6 + 3 \times 0.85$

after simplification $h_2 = 0.988$ m

difference in mercury level $h_2 = 0.988$ m = 988 mm

10 A Differential manometer connected to two pipes A & B. The pipe A contains carbon tetra chloride having relative density 1.594 under a pressure of 118 kN/m^2.The pipe B contains oil of specific gravity 0.8 under a pressure of 200 kN/m^2.The pipe A lies 2.5 m above pipe B.The centre of pipe B is at the level of face surface of mercury in the pipe A. Find the difference in mercury level

Given data

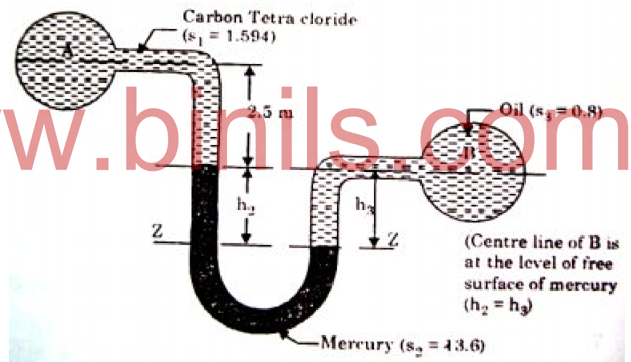


Fig.1.29

$P_A = 118$ kN/m^2 $\quad\quad P_B = 200$ kN/m^2

$S_1 = 1.594$ $\quad\quad S_2 = 13.6$ $\quad\quad S_3 = 0.8$

$h_a = P_a/W = 118 / 9.810 = 12.03$ m of water

$h_b = P_b/W = 200 / 9.810 = 20.387$ m of water

Solution

sum of pressure in the left limb = sum of pressure in the right limb

$h_a + h_1S_1 + h_2S_2 = h_b + h_3S_3$

$12.03 + 2.5 \times 1.594 + 13.6\, h_2 = 20.387 + h_2 \times 0.8$

$h_2 = 0.3416$ m

Difference in mercury level h_2 = 0.3416 m

11 An inverted U tube Differential manometer connected to two pipes A & B both are containing same liquid of specific gravity 1.4. Its two ends are at same horizontal line.The relative density of manometric liquid is 0.8 . Find the difference in pressures between the two pipes. The manometer reading is 370 mm.

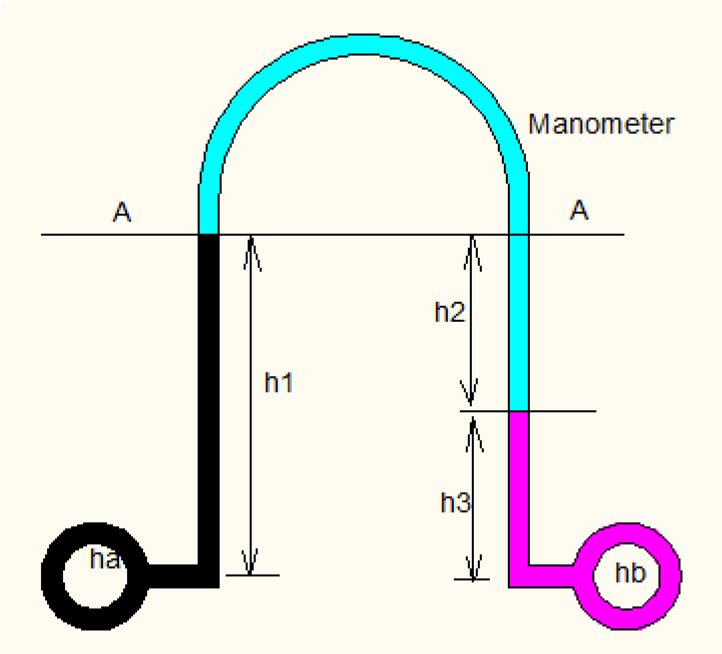


Fig1.30

Given Data

$S_1=S_3=1.4$

$S_2=0.8$

$h_2=370$ mm = 0.37 m

$h_1=h_2+h_3 = 0.37 + h_3$

To find

Difference in pressure P_a-P_b

Solution

$h_a - h_1S_1 = h_b - h_2S_2 - h_3S_3$

$h_a - (0.37+ h_3) \times 1.4 = h_b - 0.37 \times 0.8 - h_3 \times 1.4$

$h_a - h_b = - 0.37 \times 0.8 - h_3 x1.4 + 0.37x1.4 + h_3 x1.4$

$= 0.222+0$

$= 0.222$ m of water

$P_a-P_b = w(h_a-h_b)$

$= 9.810 \times 0.222$

$\mathbf{P_a-P_b = 2.178}$ **kN/m^2**

1.16. Numerical Problems

Note: Pr – Pressure Atm – atmospheric abs-absolute Ans-answer respt-respectively

1. Convert a pressure head of 500 mm of mercury into oil of relative density o.75 **Ans 9.066 m of Oil**
2. A driver can sustain a pressure of 110 kN/m^2 under sea water. Upto what depth under a sea water he can work. **Ans 11.213 m**
3. The pressure at a point which is 40m below the surface of sea is 439.49 kN/m^2. Find the density of sea water.
4. A gauge fitted to a compressor shows a reading of 30 kN/m^2. Compute the corresponding absolute pressure. Assume the local atm Pr is 101.325 kN/m^2. **Ans 131.325 kN/m^2**
5. Measurement at the base and top of mountain are 720 and 550 mm of mercury respt. Compute the height of mountain when the air has a constant density of 11.97 kN/m^2. **Ans 1.89 m.**
6. A siple manometer is used to measure the Pr of water flowing in a pipe line. Its right limb is open to atm and the left limb is connected to the pipe. The centre of the pipe is in level with that of mercury in the right limb. Determine the Pr in the pipe if the difference of mercury level is 125 mm **Ans 1.575 m of water.**
7. A simple U tube manometer is used to measure the pressure of oil of relative density 0.75 flowing in a pipe line. Its right limb is open to atm and the left limb is connected to the pipe. The centre of pipe is 0.1 m below the level of mercury in the right limb. If the difference of mercury level is 0.2m. Determine the Abs Pr of oil in the pipe
8. A differential manometer connected to two point A & B in a horizontal venturimeter containing an oil of relative density 0.8. If the deflection of mercury level is 0.8 m. Determine the difference in pressure between the two points in terms of kN/m^2 **Ans 100.54 kN/m^2**
9. A differential manometer connected to a vertical pipe. The oil of relative density 0.85 is flowing through the pipe. The distance between the two gauge points is 1 m. Difference of mercury level is 0.2m. Determine the difference in pressure between the two points in terms of kN/m^2. **Ans 70.87 kN/m^2**
10. An inverted U tube Differential manometer connected to two pipes A & B carrying liquid of specific gravity 1.6. Its two ends are at same horizontal line. The relative density of manometric liquid is 0.75 . Find the difference in pressures between the two pipes. The manometer reading is 400 mm. Ans 0.34 m of water.

UNIT-II FLOW OF FLUIDS AND FLOW THROUGH PIPES

Objectives

- Discuss the types of fluid
- Explain the energies of fluid
- State and prove Bernoulli's theorem
- Explain the applications Bernoulli's theorem
- Problems solve in venturi meter orifice meter
- Discuss about hydraulic coefficients and their relations
- Explain the methods of finding hydraulic coefficients experimentally.
- Explain the major & minor losses of energies in flow through pipes
- Derive Darcy's & Chezy's formula
- Solve problems in power transmission through pipes

2.1. FLOW OF FLUIDS

Introduction

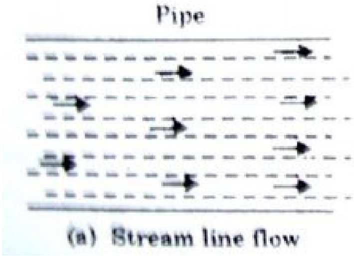
- Hydro statics deals with the study of liquid when it is at rest.
- Hydro dynamics deals with the motion of liquid by taking into consideration the force (or) energy causing the flow.
- Hydro kinematics deals with the study of velocity and acceleration of the liquid particles with out taking into consideration the force or energy causing the flow.

Types of fluid flow

The type of flow depends upon the conditions of fluid flow.

1. Laminar flow	5.uniform flow
2. Turbulent flow	6.Non-uniform flow
3. Steady flow	7.compressible flow.
4. Unsteady flow	8.In compressible flow.

2.1.1. Laminar flow



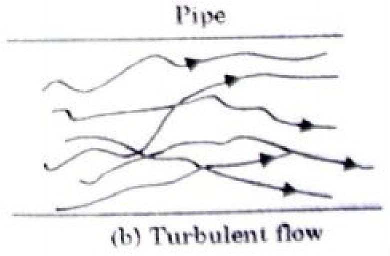


Fig. 2.1.a **Fig. 2.1.b**

- Laminar flow is a smooth and regular flow.
- Laminar flow is a flow in which each liquid particle has a definite path, and the paths of individual particles do not across with each other.
- This type of flow is called as stream line flow.

Conditions for this type of flow

- Low velocity of flow.
- Highly viscous fluid.
- Reynolds number is less than 2000.
- Ex : high viscous oil moves slowly in a very small pipe.

2.1.2.Turbulent flow (eddy flow)

- Turbulent flow is flow in which the velocity of a particle will very in magnitude and direction form point and time to time.
- In this flow each liquid particles does not have a definite path and moves in and irregular way.
- Turbulent flow is shown in fig.2.1 (b)
- It is also called eddy flow.

Conditions for this type of flow

- High velocity of flow.
- Reynolds number is more than 2000.

  Ex: flow of water in the pump. flow in river during floods, Waterfalls.

2.1.3.Steady flow

- If at any section of flow the quantity of liquid flowing per seconds is constant, the flow is called steady flow.

(or)

- If the liquid properties such as velocity, pressure, density at any point of liquid do not change with respect to time, it is called steady flow.
  Ex: Flow through a tap, when the water level in a tank is constant.

2.1.4.Unsteady flow

If at any section of flow, the quantity of liquid flowing per second is not constant the flow is called unsteady flow. **Ex**: flow through a tap when the head is not constant.

2.1.5.Uniform flow

If the magnitude and direction of velocity at a point of liquid in motion do not vary with respect to time then the flow is called uniform flow.
Ex: flow of fluids through a pipe line whose cross sectional area is constant.

2.1.6. Un – uniform flow

If the magnitude and direction of velocity change from point to point in a liquid flow, it is called uniform flow.

2.1.7.Compressible flow

Compressible flow in which density of fluid is same in all sections.
Ex: liquid flow in pipe.

2.1.8. Incompressible flow

In compressible flow in which density of fluid is not same in all section.
Ex: Gas flow in pipe.

2.2. Type of lines in fluid flow

1. Path line **2. Stream line**

2.2.1.Path line

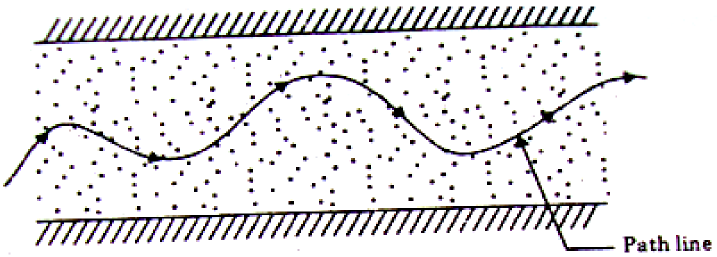


Fig 2.2. Path lines

The path followed by a fluid particle in motion is called a path line.
Thus the path line shows the direction of a particles, for a certain period of time.

2.2.2.Stream line

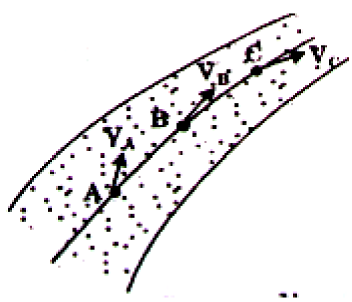


Fig 2.3 stream line

The imaginary line drawn in the fluid in such way that the tangent to which at any point gives the direction of motion at that point is called stream line. Stream line shows the direction of motion of a number of particle at the same time.

2.3. Rate of flow (or) discharge

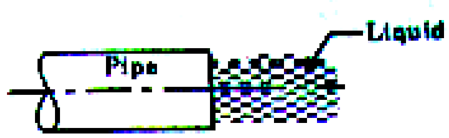


Fig.2.4

Volume of liquid flowing per seconds is known as the rate of discharge or simply discharge.

Consider a liquid flowing through the pipe as shown in fig.2.4

Let a=area of the pipe.

V=velocity of flow

Q=rate of discharge

Discharge =volume of cylinder

=area x velocity

Discharge **Q =a x v** unit :m^3 / sec.

2.4.Continuity equation

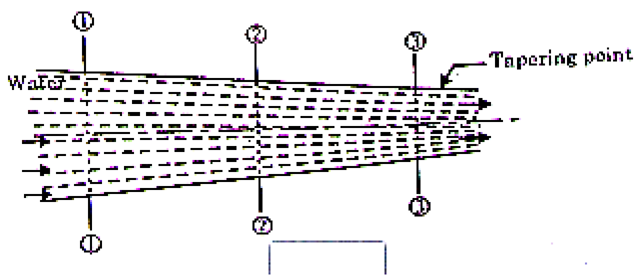


Fig 2.5a

"If an incompressible liquid is continuously flowing through a pipe or a channel whose section may or may not be uniform the quantity of liquid passing per sections". Consider a tapering pipe through which some liquid is flowing as shown in fig.2.5a

Let a_1 = area of pipe in section 1-1

v_1 = velocity of liquid in section 1-1

Similarly $a_2 v_2$ = corresponding values at section 2-2

Total quantity of fluid passing through section 1-1

$Q_1 = a_1 v_1$

Total quantity of fluid passing through section 2-2

$$Q_2 = a_2 v_2$$

Similarly Total quantity of fluid passing through section 3-3

$$Q_3 = a_3 v_3$$

Discharge is same through all sections.

Hence **$Q = a_1 v_1 = a_2 v_2 = a_3 v_3$**

This is called as continuity equation.

2.5.Mean velocity of fluid flow (V_{avg}):

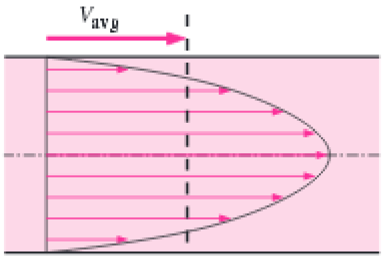


Fig.2.5b

The fluid velocity in a pipe changes from zero at the surface because of the no-slip condition to a maximum at the pipe center. In fluid flow, it is convenient to work with an

Average velocity Vavg or mean velocity , which remains constant in incompressible flow when the cross-sectional area of the pipe is constant as shown in fig.2.5b.

The regime of flow when velocity is lower than "critical" is called laminar flow (or viscous or streamline flow). At laminar regime of flow the velocity is highest on the pipe axis, and on the wall the velocity is equal to zero. When the velocity is greater than "critical", the regime of flow is turbulent

2.6.Energy of a liquid in motion

Energy is defined as the capacity to do word. A fluid in motion is said to possess only the following three forms of energies.

1.potential energy

2.kinetic energy

3.pressure energy

2.6.1.potential energy of a liquid in motion

Potential energy is the energy possessed by a liquid particle, by virtue of its position. If a liquid particle is "Z" meters above the horizontal datum- line.

Potential energy = WZ **unit N-m**

Where, W = Weight of liquid (N)

Z=height of liquid above the datum line (m).

2.6.2.Kinetic energy

Kinetic energy is the energy possessed by a liquid particle, by virtue of its moment (or) velocity.

Kinetic energy = ½ m v^2 =1/2 (w/g) v^2

Where, m=mass of liquid m=wg

W=weight of liquid (N)

V=velocity of the liquid (m/sec.).

2.6.3.pressure energy

Pressure energy is the energy possessed by virtue of its existing pressure. If a liquid particle is under a pressure of "P" (kg/m^2) then the pressure energy of the particle will be p/w mk /kg of the liquid.

Where w = specific weight of the liquid.

Total Energy = Potential Energy + Kinetic Energy + Pressure Energy

$$= WZ + W\frac{V^2}{2g} + W\frac{P}{W}$$

$$\textbf{Total Energy} = W[Z + \frac{V^2}{2g} + \frac{P}{W}]$$

Datum head

Datum head is defined as the height of the liquid above the datum line. It is also defined as the potential energy per unit weight of a liquid.

Potential energy = W x Z

Datum head = Z

velocity head

- Velocity head is defined as the height of liquid. Corresponding to a particular velocity of the liquid.
- It is also defined as the kinetic energy of unit weight of a liquid.
- Kinetic energy = W v^2/2g
- Velocity head = v^2/2g

Pressure head

The height of liquid corresponding to a particle pressure is known as pressure head.

Pressure head, H=P/W

Total head of liquid

Total head of a liquid is defined as the sum of datum head pressure head & velocity head.
Total head = datum head+ pressure head + velocity head.

Total Head $= [Z + \frac{V^2}{2g} + \frac{P}{W}]$

2.7. Bernoulli's theorem

Bernoulli's theorem states "for a perfect in compressible liquid, flowing in a continuous stream, the total energy of a particle remains same while the particle moves from one point to another point".

Total Energy $= [Z + \frac{V^2}{2g} + \frac{P}{W}]$ **= constant**

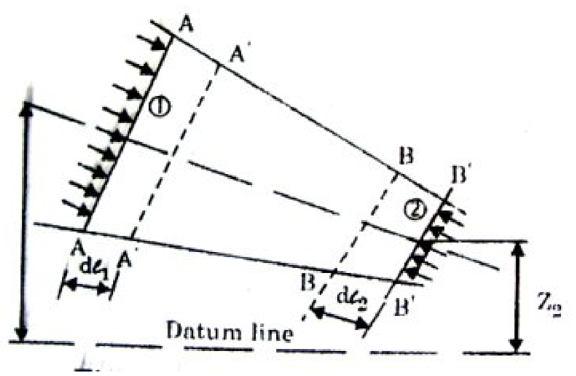


Fig 2.6 Bernoulli's theorem

Let take two sections AA and BB of the pipe .
Let

Z_1 = Height of AA above the datum
P_1 = Pressure at AA
V_1 = Velocity at AA
a_1 = area of the pipe at AA
Z_2, P_2, V_2, a_2 corresponding values at BB

- Let the liquid move from AA to A'A' and from BB to B'B' through the small length dl_1 and dl_2
- Quantity of liquid movements is constant
- Hence the shaded volumes are equal
- Let "W" be the weight of the liquid between AA and A'A'

$W = wa_1dl_1 = wa_2dl_2$

$a_1dl_1 = W/w$--------------(1)

$a_2dl_2 = W/w$ ----------(2) W-Total weight of liquid

$\mathbf{a_1dl_1 = a_2dl_2}$ ----------(3) w- specific weight of liquid

Work done by the pressure at AA in moving the liquid to A'A'= Force x Distance

$= P_1a_1dl_1$

Similarly Work done by the pressure at BB in moving the liquid to B'B'= $-P_2a_2dl_2$

Note (-ve) sign is taken Pressure P_2 is opposite to P_1

Total workdone by the pressure $= P_1a_1dl_1 - P_2a_2dl_2$ Here $a_1dl_1 = a_2dl_2$

$= P_1a_1dl_1 - P_2a_1dl_1$

$= a_1dl_1(P_1-P_2)$

$= \frac{W}{w}[P_1-P_2]$ from (1)

Loss of potential energy $= W[Z_1-Z_2]$---------------------(4)

Gain in kinetic energy $= W[\frac{V_2^2}{2g} - \frac{V_1^2}{2g}]$----------------(5)

$= \frac{W}{2g}[v_2^2-v_1^2]$ ------------------(6)

Loss of potential energy + Work done by the pressure = Gain in kinetic energy

$$W[Z_1-Z_2] + \frac{W}{w}[P_1-P_2] = \frac{W}{2g}[v_2^2-v_1^2]$$

$$[Z_1-Z_2] + [\frac{P1}{w} - \frac{P2}{w}] = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$$

$$Z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = Z_2 + \frac{P2}{w} + \frac{v_2^2}{2g} \text{ -----------(7)}$$

Hence Bernoulli's equation is proved

Assumptions in Bernoulli's equation

- Flow is incompressible and homogeneous.
- Flow is steady.
- Flow is continuous.
- Flow is ideal.
- Flow is one – dimensional.
- Flow is along a stream line.
- No energy transfer to the flow (or) from the flow.

Limitations of Bernoulli's theorem

1.velocity of flow is constant.

2.frictional force is neglected.

3.no loss of energy is assumed.

Application of Bernoulli's theorem

1. Venturimeter

2. Orifice meter

3. Pitot tube

4. Nozzle meter or flow Nozzle.

2.8.Verturimeter

Verturimeter is an instrument used for measuring the discharge quantity of liquid flowing in a pipe Tthe diagram is shown in fig.2.7. It consists of

1. Convergent cone
2. Throat
3. Divergent cone.

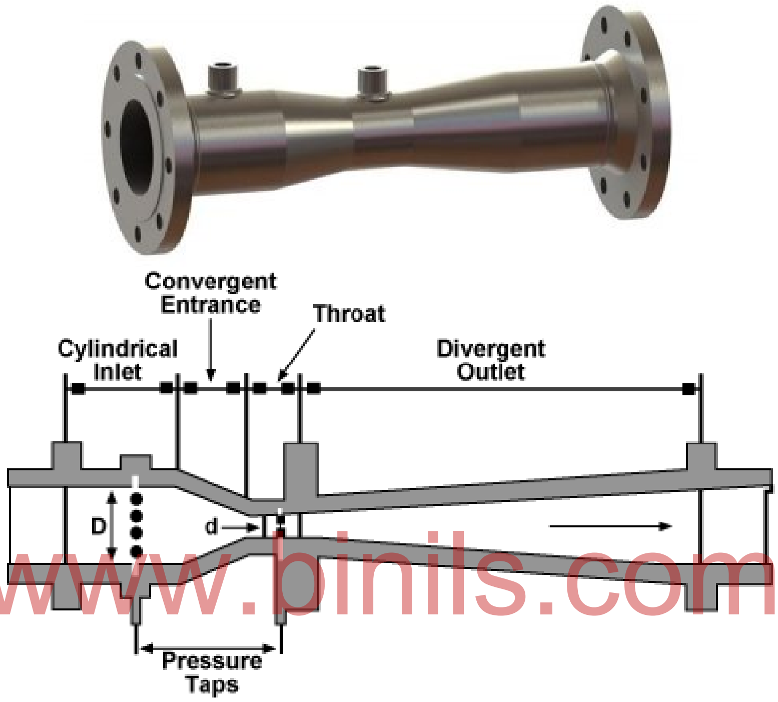


Fig: 2.7.Venturimeter

Convergent cone

It is a short pipe which converges from a diameter (d_1) to a smaller diameter (d_2). Convergent cone is also known as inlet of the venturimeter.

Throat

It is a small portion of circular pipe, in which diameter d_2 is kept constant.

Divergent cone

It is a pipe which diverges from a diameter (d_2) to a large diameter (d_1). Divergent cone is also known as outlet of the discharge through a venturimeter. The pressure head difference between the enlarged and throat is measured by a differential manometer. Consider a horizontal venturimeter through which some fluid is flowing as shown in fig 2.8

Applying Bernoulli's equation at sections 1-1 and 2-2

$$z_1 + \frac{P_1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{w} + \frac{v_2^2}{2g}$$

For horizontal venturimeter $Z_1 = Z_2$ then the above equation becomes

$$\frac{P1}{w} + \frac{v_1^2}{2g} = \frac{P2}{w} + \frac{v_2^2}{2g} \quad \text{-------------------(1)}$$

$$\frac{P1}{w} - \frac{P2}{w} = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} \quad \text{-----------------(2)}$$

Hence the discharge at section 1-1 and 2-2 are constant

$Q = a_1 v_1 = a_2 v_2$

$v_1 = \frac{a_2 v_2}{a_1}$

$v_1^2 = \frac{a_2^2 v_2^2}{a_1^2}$ ------------------------------(3)

Pressure head difference $\frac{P1}{w} - \frac{P2}{w} = h = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} = \frac{1}{2g}[v_2^2 - v_1^2]$

From equation (3) $h = \frac{1}{2g}[v_2^2 - \frac{a_2^2 v_2^2}{a_1^2}]$ $a_1^2 - a_2^2$

After simplification $v_2 = \sqrt{2gh}[\frac{a_1}{\sqrt{a_1^2 - a_2^2}}]$ --------------(4)

From Equation (4) v_2 value can be found

Discharge through venturimeter (Q_t) = $a_1 v_1 = a_2 v_2$

Coefficient of discharge $C_d = \frac{\text{actual discharge}(Qa)}{\text{Theoritical discharge}(Qt)}$

Actual discharge $Q_a = C_d Q_t = C_d a_2 [\frac{a_1}{\sqrt{a_1^2 - a_2^2}}] \sqrt{2gh}$ -----------------(5)

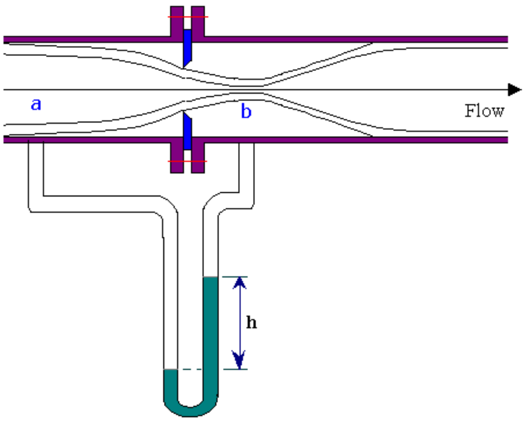
Venturimeter constant $C = a_2 [\frac{a_1}{\sqrt{a_1^2 - a_2^2}}] \sqrt{2g}$

Put equation C value in (5) then (5) becomes

Actual discharge $\mathbf{Q_a = C_d C \sqrt{h}}$

2.9. Orifice meter

Orifice meter is used to measure the discharge of the liquid flowing in a pipe. It consist of sharp edged circular hole plate and is fixed inside the pipe. The working principle of Orifice meter is similar to Venturimeter. A differential manometer is used to measure the pressure difference between the two sides of Orifice meter.



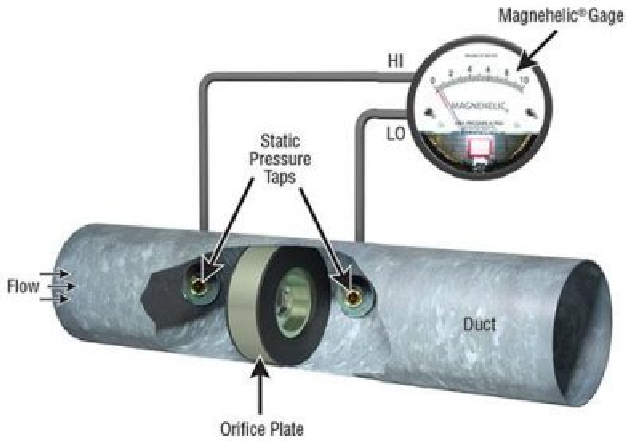


Fig.2.8.a **Fig.2.8.b**

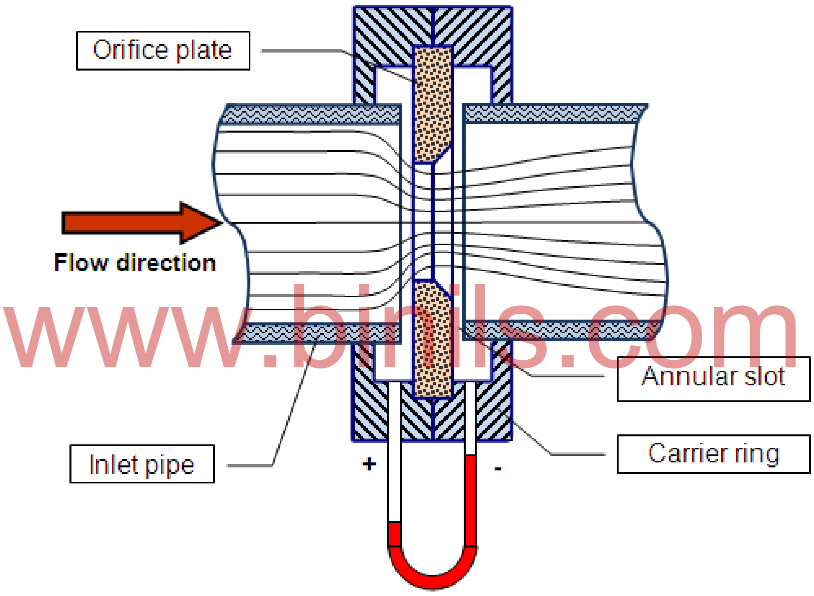


Fig 2.9 Orifice meter

h =reading of differential manometer

P_1= Pressure at inlet

V_1 = velocity at inlet

A_1 = area of the pipe at inlet

P_2 v_2 & a_2 = corresponding values at throat. Now apply Bernoulli's equation

$$z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P2}{w} + \frac{v_2^2}{2g}$$

For horizontal Orificemeter $Z_1 = Z_2$ then the above equation becomes

$$\frac{P1}{w} + \frac{v_1^2}{2g} = \frac{P2}{w} + \frac{v_2^2}{2g} \quad \text{-------------------(1)}$$

$$\frac{P1}{w} - \frac{P2}{w} = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} \quad \text{------------------(2)}$$

Hence the discharge at section 1-1 and 2-2 are constant

$$Q = a_1v_1 = a_2v_2$$

$$v_1 = \frac{a_2 v_2}{a_1}$$

$$v_1^2 = \frac{a_2^2 v_2^2}{a_1^2} \quad \text{--------------------------------(3)}$$

Pressure head difference $\frac{P1}{w} - \frac{P2}{w} = h = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} = \frac{1}{2g}[v_2^2 - v_1^2]$

From equation (3) $h = \frac{1}{2g}[v_2^2 - \frac{a_2^2 v_2^2}{a_1^2}]$ $a_1^2 - a_2^2$

After simplification $v_2 = \sqrt{2gh}[\frac{a_1}{\sqrt{a_1^2 - a_2^2}}]$ --------------(4)

From Equation (4) v_2 value can be found

Discharge through venturimeter $(Q_t) = a_1v_1 = a_2v_2$

Coefficient of discharge $C_d = \frac{\text{actual discharge}(Qa)}{\text{Theoritical discharge}(Qt)}$

Actual discharge $Q_a = C_d Q_t = C_d\ a_2 [\frac{a_1}{\sqrt{a_1^2 - a_2^2}}] \sqrt{2gh}$ ---------------(5)

Orificemeter constant $C = [\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}] \sqrt{2g}$

Put equation C value in (5), then (5) becomes

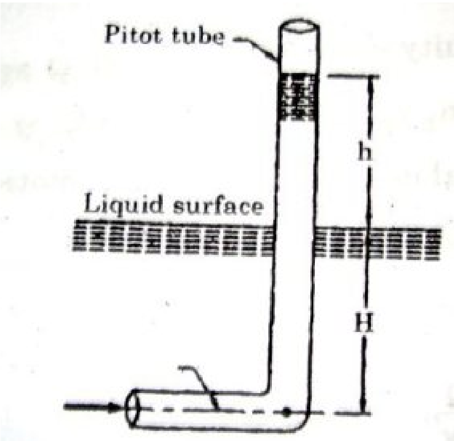
Actual discharge of Orificemeter $\mathbf{Q_a = C_d C \sqrt{h}}$

Differences between venturimeter & Orificemeter

Si.No	Venturimeter	Orificemeter
1	Used in large pipes	Used in small pipes
2	Cd is high	Cd is less
3	Require more space	Require less space
4	Losses are less	Losses are high
5	High pressure recovery is attainable	pressure recovery is poor

2.10.Pitot Tube

Pitot tube is an important instrument used to measure the velocity of flow in a river or in open channel. It is a glass tube, both ends are open and bent through 90 deg as shown in fig 2.10. The Liquid flow in to the tube and rises in the tube until all its kinetic energy converted into the potential energy.



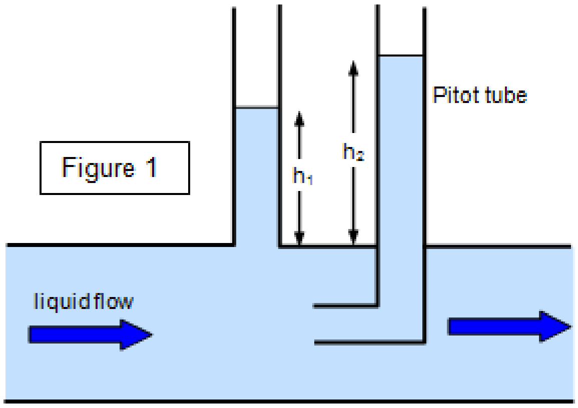


Fig 2.10 pitot tube

- By measuring the rises of liquid in the tube, the velocity of liquid can be determined.

Let h = Height of liquid in the pitot tube above the water surface

H = Depth of the tube in the liquid

V = velocity of the liquid

Applying Bernoulli's equation

$$z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P2}{w} + \frac{v_2^2}{2g}$$

$$H + \frac{v^2}{2g} = H + h$$

After simplification theoretical velocity (Vt) = $\sqrt{2gh}$

Then actual velocity (Va) = Cv x $\sqrt{2gh}$

2.11. Important Formula

1. Rate of discharge Q = AV
2. Continuity equation $a_1v_1 = a_2v_2 = a_3v_3 =$ constant
3. Potential energy of liquid in motion = WZ
4. Kinetic energy = $W\frac{v^2}{2g}$

5. Pressure energy =W $\frac{P}{w}$

6. Total energy = WZ + W$\frac{v^2}{2g}$ + W $\frac{P}{w}$

7. Total head of liquid = Z + $\frac{v^2}{2g}$ + $\frac{P}{w}$

8. Bernoulli's equation $z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P2}{w} + \frac{v_2^2}{2g}$

9. Venturimeter & Orificemeter **$Q_a = C_d C\sqrt{h}$**

Constant C = $[\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}]\sqrt{2g}$

10. Pitot tube actual velocity Va = Cv x $\sqrt{2gh}$

2.12.Solved problems

1. Determine the diameter of a pipe line which carries 100 lit/min of water with a velocity of 0.25 m/s

Given Data

Discharge(Q)= 100 lit/min = $\frac{100}{1000 \times 60}$ = 0.0017 m^3/s

Velocity (v) = 0.25 m/s

To Find Diameter of pipe(d)

Solution

$$Q = a \times v = \frac{\pi d^2}{4} \times V$$

$$0.0017 = \frac{\pi d^2}{4} \times 0.25$$

After simplification d = 0.093 m = 93 mm

2. A pipe line tapers from 80 mm to 40 mm diameter . The discharge through the pipe is 0.2 m^3/sec. Find the average velocities at the two sections

Given Data

d_1 = 80 mm = 0.08 m 1 mm = (1/1000) m

d_2 = 40 mm = 0.04 m

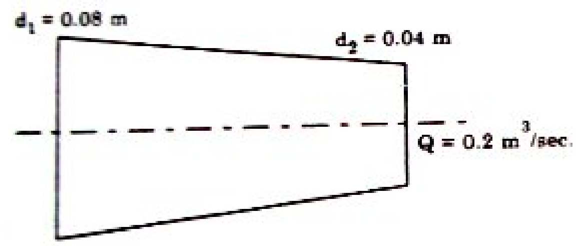


Fig.2.11

Discharge Q = 0.2 m^3/sec

To find velocities V_1 & V_2

Solution

Area of larger end a_1 $= \frac{\pi d_1^2}{4} = \frac{\pi \, x \, 0.08^2}{4}$

$= 5.026 \times 10^{-3} \ m^2$

Area of larger end a_2 $= \frac{\pi d_2^2}{4} = \frac{\pi \, x \, 0.04^2}{4}$

= m²

Discharge Q = $a_1v_1 = a_2v_2$

$0.2 = 5.026 \times 10^{-3} \times V_1$

V_1 = 39.789 m/sec

Q = a_2v_2

0.2 = $1.2566 \times 10^{-3} \times v_2$

v_2 = 159.15494 m/sec

3. A 0.3 m diameter pipe carrying water, branches into two pipes of diameter 0.2 m and 0.15 m. If the mean velocity of 0.3 m pipe is 2.5 m/s and that in the 0.2 m pipe is 2 m/s. Determine the discharge in the pipes and the velocity in the 0.15 m pipe.

Given data

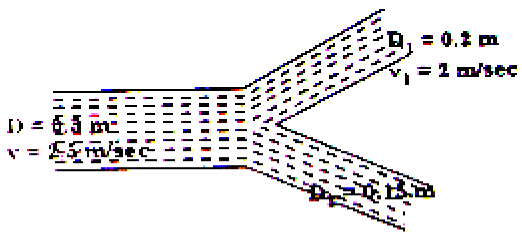


Fig.2.12

D = 0.3 m d_1 = 0.2 m d_2 =0.15 m

V = 2.5 m/s v_1 = 2 m/sec v_2 = ?

Solution

Discharge in main pipe(Q) = Discharge in pipe-1 (Q_1)+ Discharge in pipe-2 (Q_2)

Discharge in main pipe(Q) = A x V = $\frac{\pi D^2}{4}$ x V

$$= \frac{\pi 0.3^2}{4} \times 2.5$$

Discharge in main pipe(Q) = 0.1756 m^3/sec

Discharge in pipe -1 (Q_1) = a_1 x v_1 = $\frac{\pi d_1^2}{4}$ x v_1

$$= \frac{\pi 0.2^2}{4} \times 2$$

Discharge in main pipe(Q_1)= 0.0628 m^3/sec

$$Q = Q_1 + Q_2$$

$$0.1756 = 0.0628 + Q_2$$

$$\mathbf{Q_2 = 0.1137\ m^3/sec}$$

Discharge in pipe -2 (Q_2) = a_2 x v_2 = $\frac{\pi d_2^2}{4}$ x v_2

$$0.1137 = \frac{\pi 0.15^2}{4} \times v_2$$

After simplification **V_2 = 6.42 m/sec**

4. A pipe is running full of water. At a point "A" in the pipe the velocity of flow is 1 m/sec and the pressure is 1.875 kN/m^2. If "A" is 16.5 m above the datum, determine the total energy of 1 kg of water at point A. If 30 kg of water moving in the pipe then find the total energy in joules.

Given Data

V = 1 m/sec

P = 1.875 kN/m^2

Z = 16.5 m

Solution

Total Energy = $WZ + W\frac{v^2}{2g} + W\frac{P}{w}$ here W = mg = 1x9.81 = 9.81 N

$= 9.81 \times 16.5 + 9.81 \times \frac{1^2}{2 \times 9.81} + 9.81 \times \frac{1.875}{9.81}$

= 161.865+1.875+0.5

Total Energy/kg = 164.24 Nm/kg (or) J/kg

Total Energy for 30 kg of water = (Total Energy/kg) x 30

= 30x164.24

Total Energy for 30 kg of water = 4927.2 Joules

5. A pipe 300 m long has a slope of 1 in 100 and tapers from 1.5 m diameter at the higher end and 0.625 m diameter at the lower end. The discharge of water through the pipe is 100 lit/sec. The pressure at the higher end is 110 kN/m^2. Find the pressure at the lower end and neglecting the friction.

Given Data

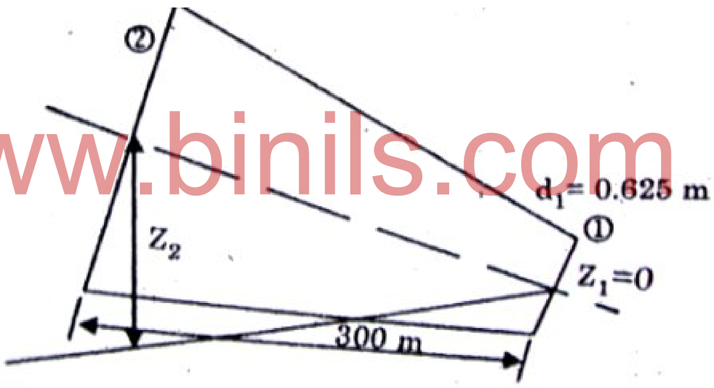


Fig.2.13

Discharge(Q)= 100 lit/sec = 100/1000 = 0.1 m^3/sec

P_2 = 110 kN/m^2

d_2 = 1.5 m

d_1 = 0.625 m

length = 3 m

slope = 1:100

To find

Pressure at lower end P_1

Solution

slope = 1:100

Vertical height = $\frac{1}{100}$ x 300 = 3 m

Hence $Z_1 = 0$ & $Z_2 = 3$ m

Discharge (Q) = $a_1v_1 = a_2v_2$

Q = $a_1v_1 = \frac{\pi d_1^2}{4}$ x v_1

0.1 = $\frac{\pi 0.625^2}{4}$ x v_1

V_1 = 0.32594 m/sec

Q = $a_2v_2 = \frac{\pi d_2^2}{4}$ x v_2

0.1 = $\frac{\pi\ 1.5^2}{4}$ x v_2

V_2 = 0.05658 m/sec

Apply Bernoulli's equation $z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P2}{w} + \frac{v_2^2}{2g}$

$$0 + \frac{P1}{9.81} + \frac{0.32594^2}{2x9.81} = 0 + \frac{110}{9.81} + \frac{0.05658^2}{2x9.81}$$

After simplification $P_1 = 139.378$ k/Nm^2

Pressure at lower end **$P_1 = 139.378$ k/Nm^2**

6. A pipe line is carrying full of water at a point 'A' in the pipe line the diameter is 600 mm and the pressure is 70 kN/m^2 and velocity is 2.4 m/sec. At another point 'B' in the same pipe line the diameter is 300 mm and the pressure is 14 70 kN/m^2 and is 2 m higher than "A". Determine the direction of flow.

Given Data

d_1 = 600 mm = 0.6 m

P_1 = 70 kN/m^2

V_1 = 2.4 m/sec

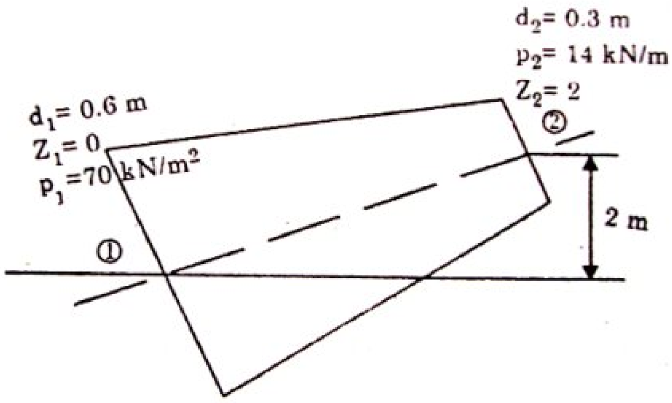


Fig.2.14

d_2 = 300 mm = 0.3m

P_2 = 14 kN/m^2

To find Direction of flow

Solution

Find total head at point A & B and then find the Direction of flow

Apply Bernoulli's equation $z_1 + \frac{p_1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{w} + \frac{v_2^2}{2g}$ -----(1)

First find velocity at B V_2

Continuity euation $Q = a_1v_1 = a_2v_2$------------------------------(2)

$$a_1 = \frac{\pi d_1^2}{4} = \frac{\pi 0.6^2}{4} = 0.2827 \text{ m}^2$$

$$a_2 = \frac{\pi d_2^2}{4} = \frac{\pi 0.3^2}{4} = 0.07068 \text{ m}^2$$

put a_1&a_2 values in (2) 0.2827 x 2.4 = 0.07068 x V_2

V_2 = 9.6 m/sec

Total head at point (1) = $z_1 + \frac{p_1}{w} + \frac{v_1^2}{2g}$

$$= 0 + \frac{70}{9.81} + \frac{2.4^2}{2x9.81}$$

Total head at point (1) = 7.429 m

Total head at point (2) = $z_2 + \frac{p_2}{w} + \frac{v_2^2}{2g}$

$$= 0 + \frac{14}{9.81} + \frac{9.6^2}{2x9.81}$$

Total head at point (2) = 8.1243 m

Hence Total head at point (2) > Total head at point (1)

Direction of flow is (2) to (1)

7. A tapered section pipe is running full of water. The diameter of pipe at inlet and outlet are1.0 m and 0.5 m respectively. The outlet is at a vertical height of 5 m above the inlet. The loss of head in the pipe is 1/10 th of velocity head at outlet. The pressure at the outlet section is 100 kN/m^2 and at inlet is 400 KN/m^2. Calculate the rate of discharge through the pipe. Determine also velocities at inlet and outlet

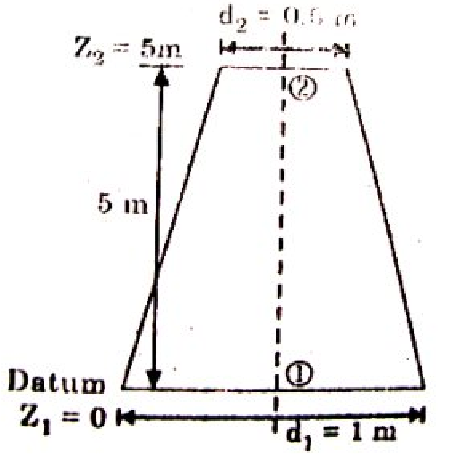


Fig.2.15

Given Data

d_2 = 0.5 m

P_1 = 400 kN/m^2

V_1 = 2.4 m/sec

d_1 =1 m

Z_1 = 0 m

Z_2 = 5 m

Loss of head h_c = 1/10 x velocity head at outlet

$= 1/10 \times \frac{v_2^2}{2g}$

To find

Discharge (Q), V_1 & V_2

Solution

$$a_1 = \frac{\pi d_1^2}{4} = \frac{\pi x\ 1^2}{4} = 0.78539\ m^2$$

$$a_2 = \frac{\pi d_2^2}{4} = \frac{\pi 0.5^2}{4} = 0.196349\ m^2$$

by continuity equation $a_1v_1 = a_2v_2$

$0.78539 \times 2.4 = 0.196349 \times v_2$

$\mathbf{v_2 = 4\ v_1}$

Apply Bernoulli's equation $z_1 + \frac{P_1}{w} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{w} + \frac{v_2^2}{2g} + h_c$

$$0 + \frac{400}{9.81} + \frac{v_1^2}{2x9.81} = 5 + \frac{100}{9.81} + \frac{v_2^2}{2\ x\ 9.81} + \frac{v_2^2}{20\ x\ 9.81}$$

$$0 + \frac{400}{9.81} + \frac{v_1^2}{2x9.81} = 5 + \frac{100}{9.81} + \frac{4v_1^2}{2\ x\ 9.81} + \frac{4v_1^2}{20\ x\ 9.81}$$

After simplification $\mathbf{V_1 = 5.498\ m/sec}$

$V_2 = 4 \times V_1$

$= 4 \times 5.498$

$\mathbf{V_2 = 21.995\ m/sec}$

Discharge Q $= a_1v_1$

$= 0.78539 \times 5.498$

Q $\mathbf{= 4.3186\ m^3/sec}$

8. A venturimeter is to be fitted to a 250 mm diameter pipe in which the maximum flow is 120 lps and the pressure head 6 m. What is the minimum diameter at throat that there is no (-ve) head in it. $C_d = 0.97$.

Given data

Q $= 120$ lps(lit/sec) $= 0.120\ m^3/sec$

d_1 $= 250$ mm $= 0.250$ m

Solution

a1 $= \frac{\pi d_1^2}{4} = \frac{\pi\ 0.250^2}{4} = 0.0491\ m^2$

Pressure head at inlet $\frac{P_1}{w}$ = H= 6 m

Coefficient of discharge $\mathbf{C_d = 0.97}$

no (-ve) head means , the pressure head at that point must be equal to zero

hence Pr head at throat $\frac{P_2}{w} = 0$

Discharge Q $= Cd.C\sqrt{H}$

$0.12 = 0.97 \times Cx\sqrt{6}$

C $\mathbf{= 0.0505}$

$$C = \left[\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\right]\sqrt{2g}$$

$$0.0505 = \left[\frac{0.0491\, a_2}{\sqrt{0.0491^2 - a_2^2}}\right]\sqrt{2x9.81}$$

a_2 = 0.01172 m^2

$$a_2 = \frac{\pi d_2^2}{4}$$

$$0.01172 = \frac{\pi d_2^2}{4}$$

Diameter at throat d_2 = 0.112 m

9. An oil of specific gravity of 0.9 is flowing through a venturimeter having inlet diameter 20 cm and throat diameter 10 cm. The mercury manometer shows a reading 20 cm. Calculate the discharge of oil through the horizontal venturimeter . Take Cd = 0.98

Given Data

d_1 = 20 cm =0.2 m d_2 = 10 cm= 0.1 m

Specific gravity of oil   (S_{oil}) = 0.9

Cd = 0.98

Manometer reading = 20 cm = 0.2 m

To find   Discharge (Q)

Solution

Formula Venturi head $H = h\left[\frac{S_2}{S_1} - 1\right]$

S_1 – Specific gravity of venturimeter fluid = 0.9

S_2 – Specific gravity of Manometric fluid = 13.6

Put all values in the above formula $H = 0.2\left[\frac{13.6}{0.9} - 1\right]$

H = 2.82 m

Area of pipe at section 1 & 2 is a_1 & a_2

$$a_2 = \frac{\pi d_2^2}{4} \qquad a_1 = \frac{\pi d_1^2}{4}$$

a_2 = 0.00785 m^2 & a_1 = 0.0314 m^2

$$C = \left[\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\right]\sqrt{2g}$$

$$= \left[\frac{0.0314 \times 0.00785}{\sqrt{0.0314^2 - 0.00785^2}}\right]\sqrt{2x9.81}$$

C = 0.03591

Discharge Q $= Cd.C\sqrt{H}$

Discharge Q $= 0.98x0.03591\sqrt{2.82}$

Q = 0.059 m^3/sec

10. Venturimeter has a diameter 0.15 m at the enlarged end and a diameter of 0.08 m at the throat. Oil of specificgravity0.8 is flowing at the rate of 4.2 m^3/min. If the coefficient of meter is 0.98. Determine the deflection of mercury gauge in mm which is used to find the pressure difference.

Given Data

d_1 = 0.15 m d_2 = 0.08 m

Specific gravity of oil (S_{oil}) = 0.8

Cd = 0.98

Q= 4.2 m^3/min = 4.2/60 = 0.07 m^3/min

To find

deflection of mercury(h)

Solution

Area at enlarged end $a_1 = \frac{\pi d_1^2}{4}$ = 0.01767 m^2

Area at throat $a_2 = \frac{\pi d_2^2}{4}$ = 5.08 x 10^{-3} m^2

$$C = \left[\frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\right]\sqrt{2g}$$

$$= \left[\frac{0.01767 \times 5.08 \times 10^{-3}}{\sqrt{0.01767^2 - (5.08 \times 10^{-3})^2}}\right]\sqrt{2x9.81}$$

venturimeter constant C = 0.00232 no unit

Discharge Q $= Cd.C\sqrt{H}$

0.07 $= 0.98 \times 0.0232 \times \sqrt{H}$

H $= 9.4593$ m

Venturi head $H = h\left[\frac{S_2}{S_1} - 1\right]$

$9.4593 = h\left[\frac{13.6}{0.8} - 1\right]$

Deflection of mercury gauge **h = 0.5912 m**

Theoritical Questions

Part A

1. Define uniform flow.
2. Define Turbulent flow
3. Give an examples of laminar flow.
4. Give an examples of Turbulent flow.
5. Write the equation of continuity flow
6. Define steady flow
7. Write any two applications of Bernoullis theorem.
8. Write any two assumptions of Bernoullis theorem.
9. Write any two limitations of Bernoullis theorem.
10. Write the formula to find the actual discharge of venturimeter.
11. Write the formula for the total energy of flow.
12. What is the use of pitot tube
13. List any two difference of venturimeter & Orificemeter.

2.13.Numerical Problems

1. Determine the size of the pipe line in which water is flowing at the rate of 3.5 m^3/sec with a velocity of 2.5 m/sec. ans d = 1.35 m

2. Find the total head and total energy per kN of the flowing fluid at the section of pipe carrying oil of specific gravity 0.8. The pipe diameter is 0.35 m. Discharge 200 lit/sec pressure at the section is 400 kN/m^2. The section is 3.5 m above the datum

3. 100 lit/min of glycerine flowing in 80 mm diameter pipe line . Calculate velocity of flow.
Ans v=0.33157 m/sec

4. A pipe AB inclined at 60 deg to the horizontal. The diameter at the higher end “A” of the pipe is 0.5 m and diameter at the lower end “B” of the pipe is 0.15 m. The length of pipe is 30 m. The velocity of flow at B = 2.5 m/sec and the pressure at B is 450 kN/m^2. Compute the pressure at A. Ans Pr=198.2 kN/m^2.

5. A vertical pipe line 1.5 m long tapers from top to bottom from 75 mm dia to 150 mm dia. Find the difference of pressure if the discharge through the pipe is 25 lps.
Ans 29.73 kN/m^2.

6.A 30 cm dia of pipe conveying water branches into two pipes of diameter 20 cm & 15 cm. If the mean velocity in the 30 cm pipe is 2.5 m/sec and that in the 20 cm pipe is 2 m/sec. Determine the discharges in the pipes and the velocity in the 15 cm pipe.

7.Apipe has a slope of 1 in 50 and tapers from 1500 mm dia at the higher end to 650 mm dia at the lower end. The length of the pipe is 500 m. If the pressure at the higher end is 110 kN/m^2. Determine the pressure at lower end. The rate of discharge is 100 lps .
Ans 208 kN/m^2.

8.Determine the rate of discharge in a venturimeter of inlet dia 75 mm and throat dia 25 mm. Assume Cd = 0.97 and venturi head is 412 mm of water. Ans 1.37 lit/sec.

9.A horizontal venturimeter of 300 mm x 150 mm is used to measure the flow of oil of relative density 0.8. Determine the deflection of mercury gauge if the discharge of the oil is 100 lps. Assume Cd = 0.98

10. A venturimeter of 150 mm x 75 mm is used to measure the flow of water. Find the discharge through the venturimeter, if the deflection of mercury gauge is 175 mm and C_d = 0.95. Ans 0.0285 m^3/sec

2.14. ORIFICES

Introduction

- An opening in a vessel through which the liquid flows out is known as and orifice.
- An orifice may be provided in the vertical side of the vessel or in the base.
- Orifice are used for measuring the rate of flow of liquids in a system.

Types of orifices

There are many types of orifices, depending upon their size, shape and nature of discharge.

1) **According to the size**
   a)Small orifice b)Large orifice

2) **According to the shape**
   a. Circular orifice
   b. Rectangular orifice
   c. Triangular orifice
3) **According to nature of discharge**
   a. Fully submerged orifice
   b. Partially submerged orifice.
4) **According to shape of the edge.**

a. Sharp- edged orifice.
b. Bell – mouthed orifice.

Jet of water

The continuous stream of a liquid that comes out or flows out of an orifice is known as the jet of water.

Vena-contracta

Consider a tanks fitted with an orifice as shown in fig.2.16.

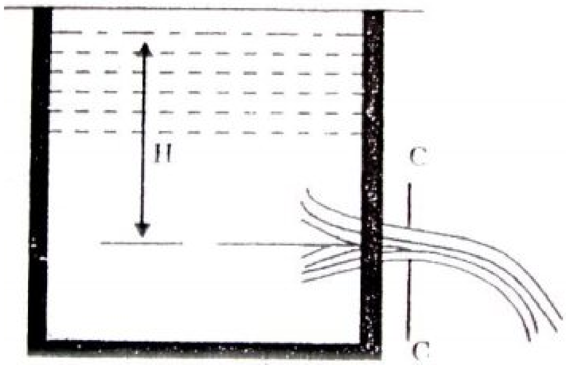


Fig 2.16 Vena-contracta

Any liquid passing through an orifice is in the form of a jet.The jet after leaving the orifice, gets contracted. Maximum contraction takes place at a section slightly on the downstream side of the orifice, where the jet is more or less horizontal.

2.15.Velocity of flow through Orifice

Consider a discharging free as shown in fig 2.17. Top surface of the liquid in the tank is exposed to atmosphere. .Head of liquid "H" above the centre of the orifice causes flow through orifice. Head H is maintain constant. Particles of jet outside the orifice at C-C(vena -contracta).

Let Vt = velocity of flow at C-C
Ha = atmospheric pressure head

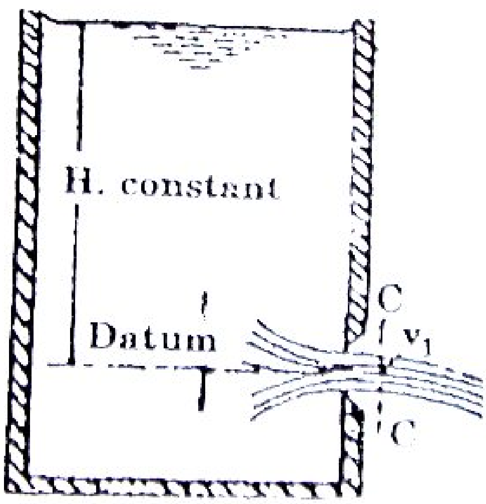


Fig 2.17

Consider point 1&2 along datum line
Applying Bernoulli's equation

$$Z_1 + \frac{P1}{w} + \frac{v_1^2}{2g} = Z_2 + \frac{P2}{w} + \frac{v_2^2}{2g}$$

Here $Z_1 = Z_2$

$\frac{P1}{w} = H_a + H$

V1 = 0

V2 = Vt applying all values in Bernoulli's equation then

$0+(Ha+H)+0 = Ha + \frac{v_t^2}{2g}$ after simplification

Theoretical velocity $V_t = \sqrt{2gH}$

Actual velocity $Va = C_v \times V_a$ C_v – coefficient of velocity

$$Va = C_v\sqrt{2gH}$$

2.16. Hydraulic coefficients

1. Co efficient of contraction(Cc) average value = 0.64
2. Co efficient of velocity(Cv) average value = 0.97
3. Co efficient of Discharge(Cd) average value = 0.62

Relation between the three Hydraulic coefficients Cd = Cv x Cc

Discharge through a small orifice

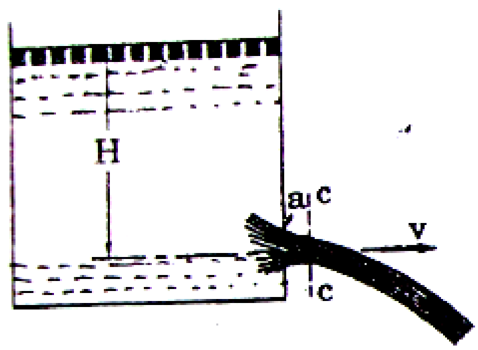


Fig2.18

- An orifice is said to be small, when the head causing the flow is greater than 5 times its diameter
- Consider a tank containing liquid under a head of h above the centre line of the orifice as shown in fig.2.18.

- Since the orifice is very small the velocities at bottom edges of the orifice are more or less equal.
- Velocity through small orifice, $v=\sqrt{2gh}$
- Discharge through orifice(Q) = area of orifice x velocity
- Theoretical discharge (Q)=a $\sqrt{2gh}$
- The actual discharge will be less than the theoretical discharge.
- Actual discharge = C_d x theoretical discharge
- $Q_a=C_d\ a\ \sqrt{2gh}$ a-cross sectional area of the orifice

  C_d -Coefficient of orifice

Applications of small orifice

- In swimming pools for emptying purpose.
- Used in balancing reservoirs and surge tanks.
- Sluices of tanks are circular shaped orifice.
- Used in vent ways holes or openings of culverts vent in tanks sluices and vents in pipe outlet.

2.17.Experimental method of finding (c_v)

Consider a tank containing liquid under constant head as shown in fig 2.19. When the liquid is flowing through the orifice , it moves horizontally and vertically downwards. Horizontal movement is due to the pressure head and the vertical movement is due to gravity.

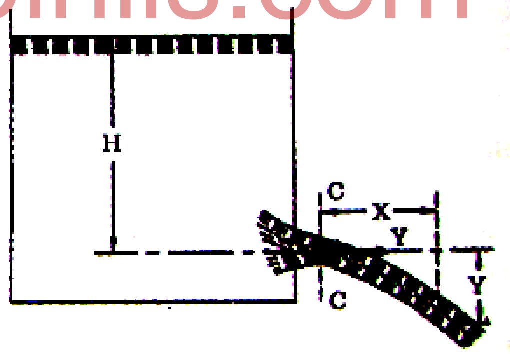


Fig 2.19

Let

H- constant head of water

X-Horizontal distance between C-C and P

Y- Vertical distance between C-C and P

V-velocity of jet

t-Time taken by the particle to reach from C-C to P

Horizontal distance (X) = V x t

$$t = X/V$$

$$S = ut + \frac{1}{2} gt^2 \qquad (u=0,\ S = y)$$

$$y = 0 + \frac{1}{2} gt^2$$

Vertical distance

$y = \frac{1}{2} gt^2$ put t value

$y = \frac{1}{2} g (X/V)^2$

$y = (gx^2)/2V^2$

$v = \sqrt{\frac{gx^2}{2y}}$

$Cv = \frac{v^2}{\sqrt{2gH}}$

$Cv = \frac{\frac{gx^2}{2y}}{\sqrt{2gH}}$

$Cv = \sqrt{\frac{x^2}{4yH}}$

2.18.Experimental Method for finding (C_d)

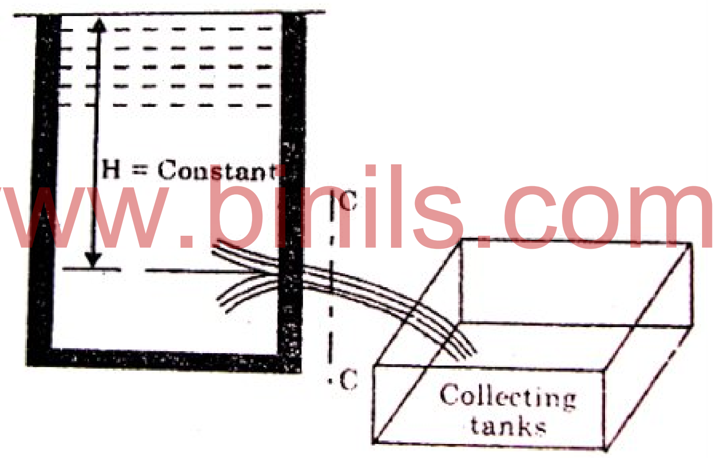


Fig.2.20

Consider a tank of liquid under constant head (H) as shown in fig 2.20. The actual discharge is measured by collecting the liquid in a vessel of known dimension for definite period of time "t" sec. Actual discharge Qa = $\frac{volume\ of\ liquid\ collected}{time}$

- Theoretical discharge Qt = a $\sqrt{2gH}$
- Coefficient of discharge Cv = Qa/Qt

Experimental method of finding (Cc)

- The diameter of the jet at vena contract is actually measured using a micrometer contraction gauge.
- This gauge consists of a ring with four micrometer screw fitted radially as shown in fig.2.21.

- In closed position the pointed ends of the screws meet at the centre of the ring and the reading on the scale of each micrometer screw is zero.

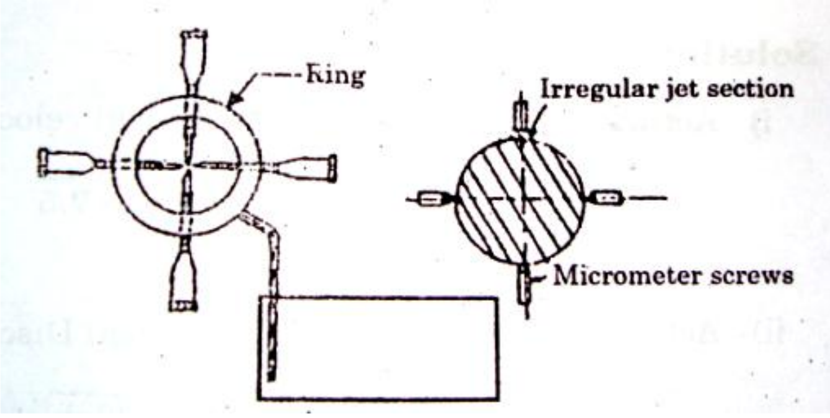


Fig.2.21

- To determine the diameter of jet screws point touch the periphery of the jet.
- The reading of each micrometer screws gives the radius of the het.
- To determine area of cross section of the jet at vena-contracta (a_c).
- Measuring the diameter of the orifice & find area of orifice(a).
- $C_c = a_c/a$

Important Formula

1. Coefficient of Contraction(Cc) = $\frac{area\ at\ vena\ contracta}{area\ of\ orifice}$ = 0.64
2. Theoretical velocity (v) = $\sqrt{2gH}$
3. Coefficient of velocity Cv = $\frac{actual\ velocity}{theoretical\ velocity}$ = 0.97
4. Coefficient of Discharge Cd = $\frac{actual\ Discharge}{theoretical\ discharge}$ = 0.62

   Cd =Cv x Cc
5. Actual discharge Qa = $C_d\, a \sqrt{2gH}$

2.19.Solved Problems

1. Water discharging at the rate of 98.2 lit/sec through a 120 mm diameter vertical sharp edged orifice placed under a constant head of 10m. A point on the jet measured from the venacontracta of the jet has coordinates 4.5m horizontal and 0.54m vertical. Find coefficients C_c,C_v and C_d of the orifice

   Given data

   Actual discharge Q_a = 98.2 lit/sec = 0.982 m^3/sec

   Diameter d = 120 mm =0.12 m

   Head H = 10 m

   X = 4.5 m

   y = 0.54 m

   To find C_d, C_v and C_c

   Solution

   Area of Orifice a_1 = $\frac{\pi}{4} d^2 = \frac{\pi}{4} \times 0.12^2$

$a_1 = 0.0113\ m^2$

theoretical discharge $Q_t = a\sqrt{2gH}$

$= 0.0113 \times \sqrt{2x\ 9.81x10}$

$= 0.1584\ m^3/sec$

Coefficient of Discharge $C_d = \frac{actual\ Discharge}{theoretical\ discharge}$

$= \frac{0.982}{0.1584}$

C_d **= 0.62**

Coefficient of velocity $C_v = \sqrt{\frac{x^2}{4yH}}$

$= \sqrt{\frac{4.5^2}{4x0.54x10}}$

Cv**= 0.968**

Cd = Cv x Cc

Cc = Cd/Cv

= 0.62/0.968

Coefficient of contraction **Cc = 0.64**

2. A 50 mm diameter orifice is discharging water under a head of 7.5 m . Determine the actual discharge in m^3/sec and actual velocity of jet. Take Cd = 0.6 , Cv=0.9

Given data

d = 50 mm = 0.05 m area a = $\pi d^2/4$

H = 7.5 m

Cd = 0.6

Cv = 0.9

To find

i) Actual discharge ii) actual velocity

Solution

actual velocity Va $= C_v\sqrt{2gH}$

$= 0.9 \times \sqrt{2x\ 9.82x7.5}$

actual velocity Va = 10.92 m/sec

Actual discharge $Q_a = C_d\, a\sqrt{2gH} = C_d\ (\pi d^2/4)\sqrt{2gH}$

$= 0.6\ (\pi \times 0.052^2/4)\sqrt{2x\ 9.81x7.5}$

Actual discharge Q_a = 0.0143 m^3/sec

3.The head of water over an orifice of diameter 40 mm is 10 m. Find the actual discharge and an actual velocity of the jet at vena- contracta. Take C_d=0.6 and C_v = 0.98.

Given data

d = 40 mm = 0.04 m

area a = $\pi d^2/4$

= $\pi 0.04^2/4$ = 0.001256 m^2

H = 10 m

Cd = 0.6

Cv = 0.98

To find

i) Actual discharge ii) actual velocity

Solution

actual velocity V_a = $C_v\sqrt{2gH}$

= 0.98 x $\sqrt{(2x9.81x10)}$

= 14 m /s.

actual velocity Va = 14 m/sec

Actual discharge $Q_a = C_d\, a\sqrt{2gH} = C_d (\pi d^2/4)\sqrt{2gH}$

= 0.6x0.001256x $\sqrt{(2x9.81x10)}$

=0.01055

Actual discharge Q_a = 0.01055 **m^3/sec**

4. The head of water at the centre of an orifice of diameter 20 mm is 1 m. The actual discharge through the orifice is 0.85 lit/s. Find the co-efficient of discharge.

Given data

d = 20 mm = 0.02 m area

area a = $\pi d^2/4$

= $\pi 0.02^2/4$

= 0.000314 m^2

H = 1 m

Q_a = 0.85 lit/s

Solution

Theoretical discharge $Q_t = a\sqrt{2gH}$ = $(\pi d^2/4)\sqrt{2gH}$

=0.000314 x $\sqrt{(2x9.81x1)}$

Theoretical discharge Q_t $= 1.390 \times 10^{-3}\ m^3/s$

Coefficient of Discharge C_d $= \frac{actual\ Discharge}{theoretical\ discharge}$

$= 0.00085/0.00139$

C_d **= 0.61**

2.20. FLOW THROUGH PIPES

Introduction

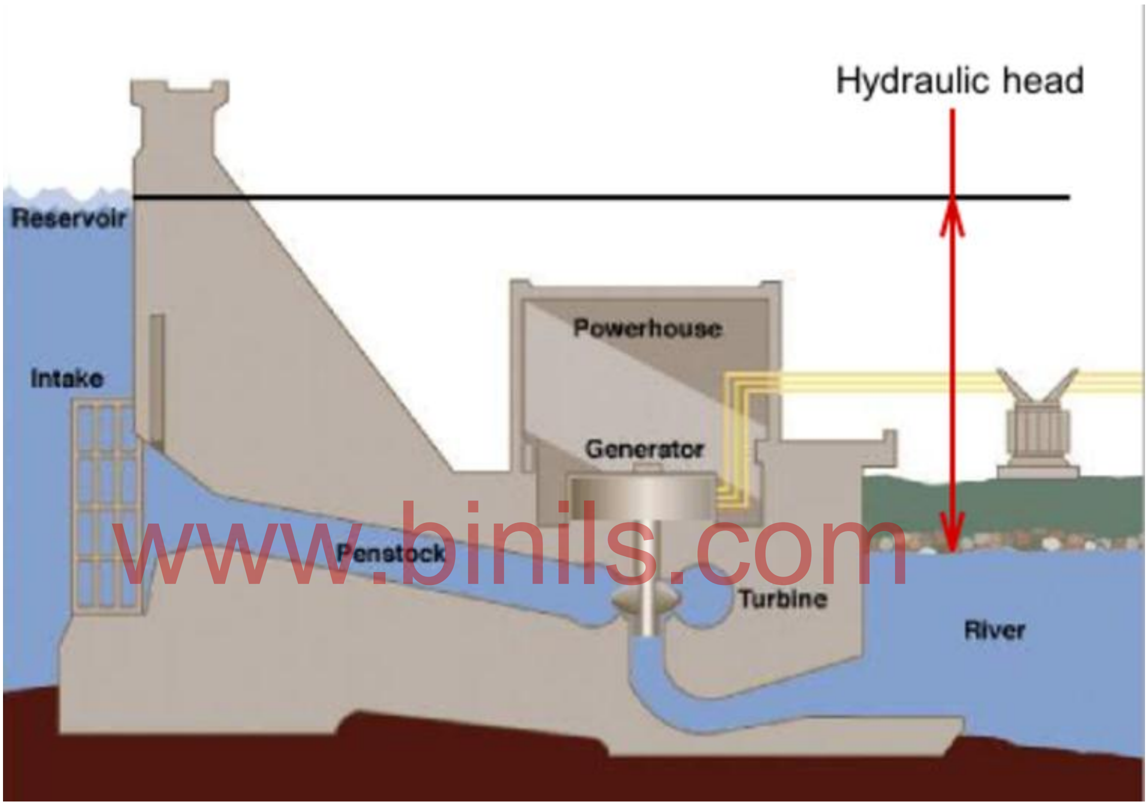
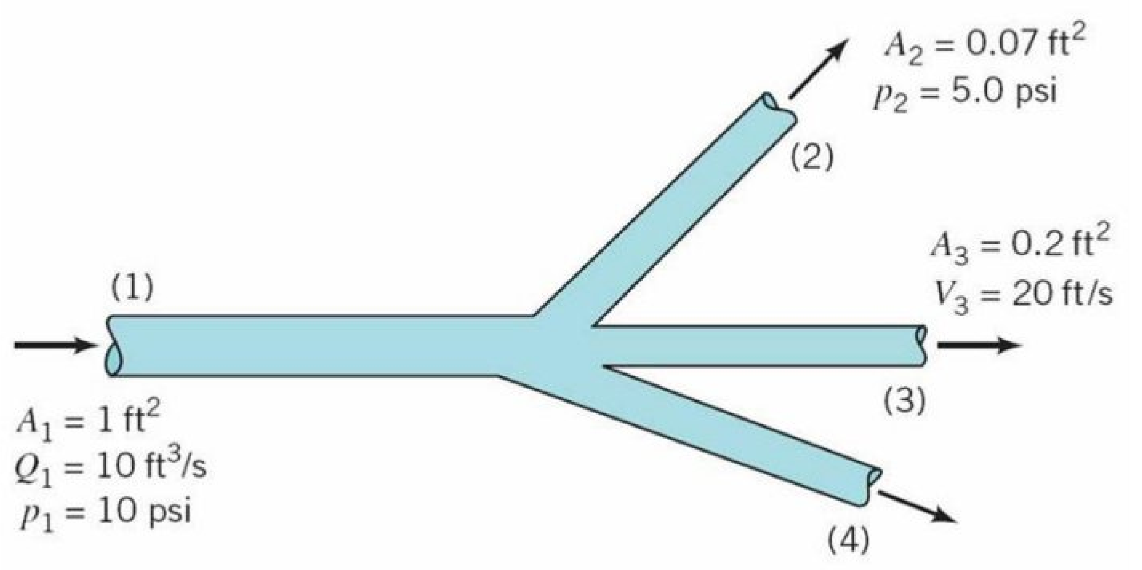


Fig.2.22



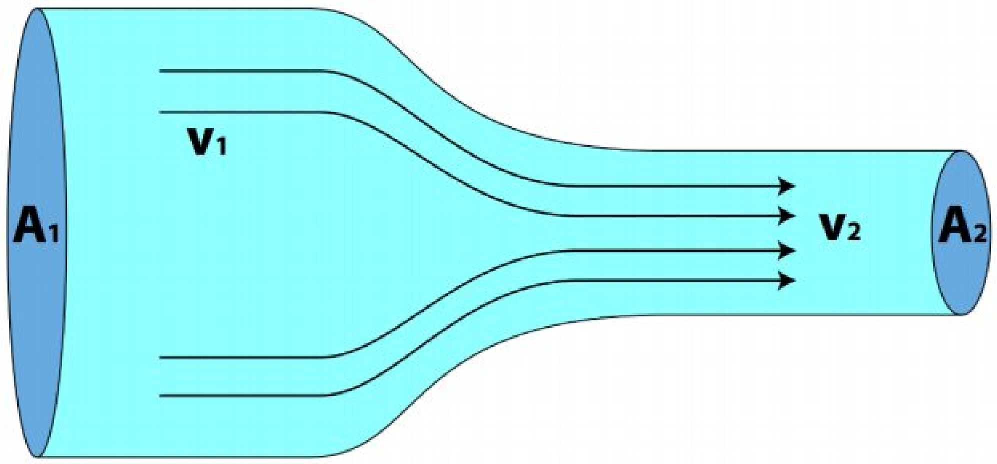


Fig.2.23

2.21.Hydraulic gradient line

The distance between the pipe centerline and the hydraulic grade line is the pressure head, or piezometric height, at the section. The line showing the pressure head, or piezometric height, at any point in a pipe. The slope of the hydraulic grade line is known as the hydraulic gradient.

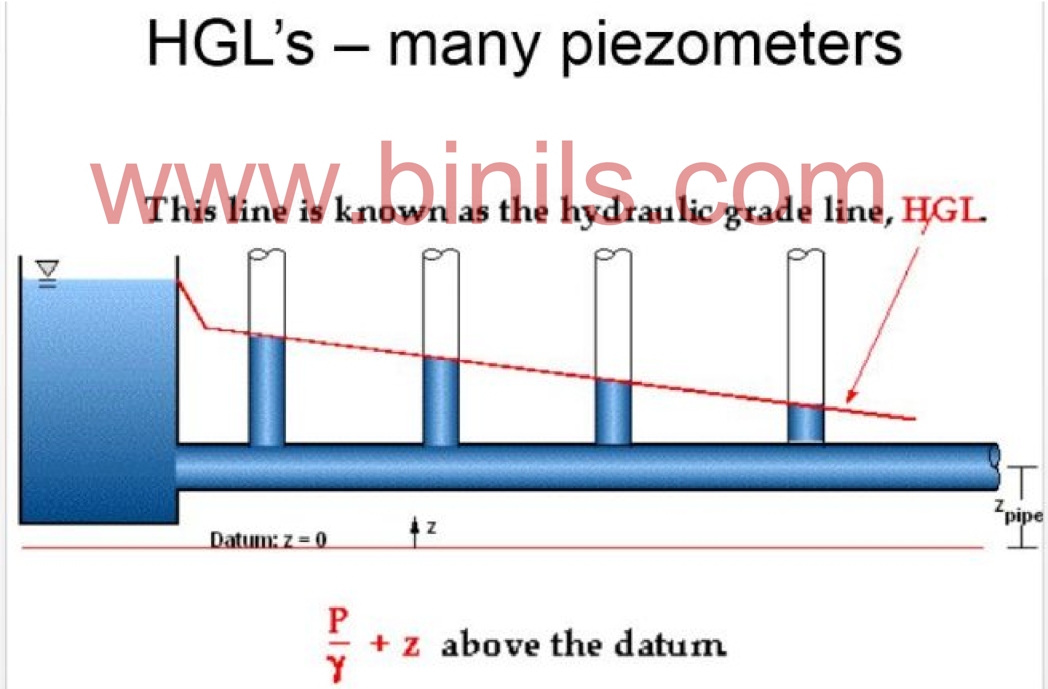


Fig.2.24

2.22.Total Energy line

The Energy Line is a line that represent the total head available to the fluid and can be expressed as:

EL = (p / w)+ (v^2 / 2 g) + z= constant along a streamline

where

EL = Energy Line

For a fluid flow without any losses due to friction (major losses) or components (minor losses) - the energy line would be at a constant level. In a practical world the energy line decreases along the flow due to losses. A turbine in the flow reduces the energy line and a pump or fan in the line increases the energy line

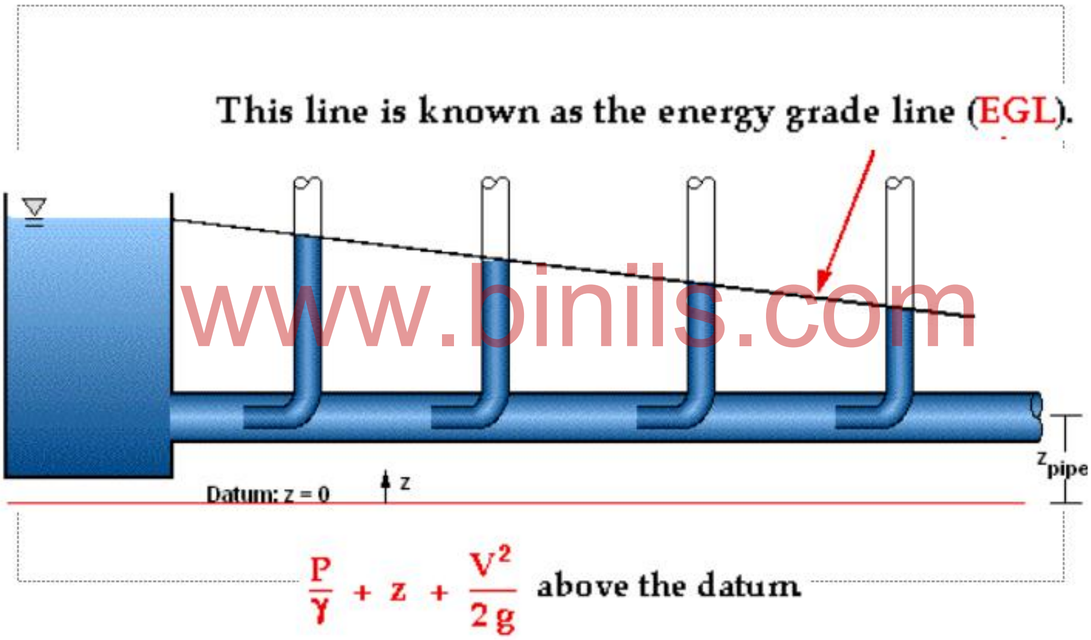


Fig.2.25

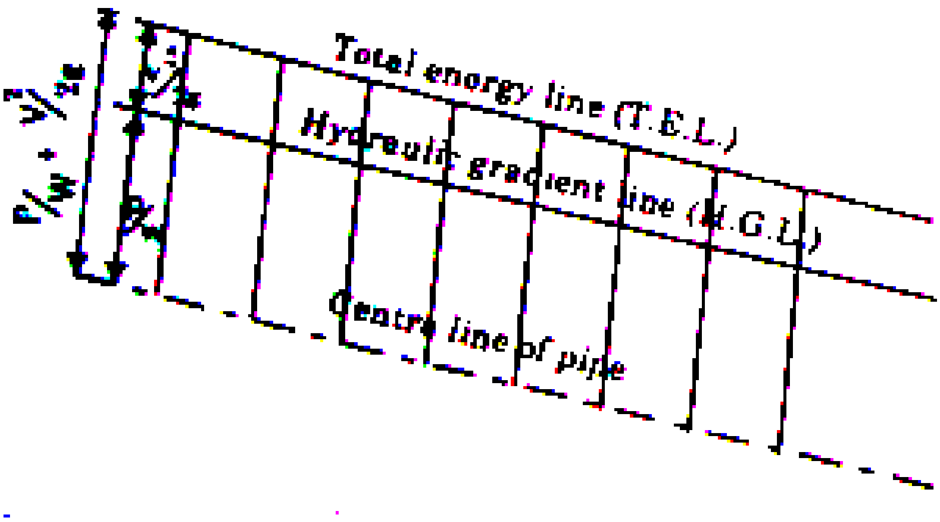


Fig.2.26

- A pipe is 2 closed conducted and it is used for carrying fluids or water under pressure.
- General pipe is circular cross section
- When the pipe is running full of flow is under pressure.

2.23.Laws of fluid friction

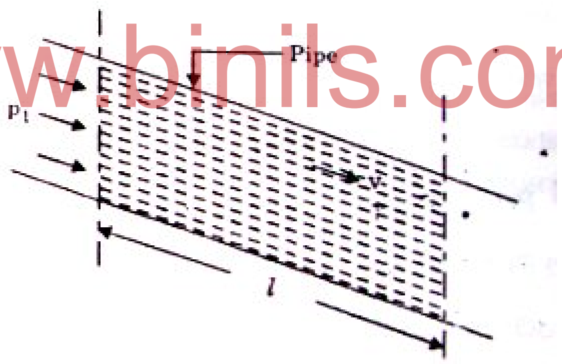


Fig. 2.27

Whenever a liquid is flowing in a pipe, it loss of head or energy due to frictional resistance and other reasons.

1. major losses – due to frictional resistance.
2. Minor losses – due to sudden change in velocity of flow either in magnitude or direction

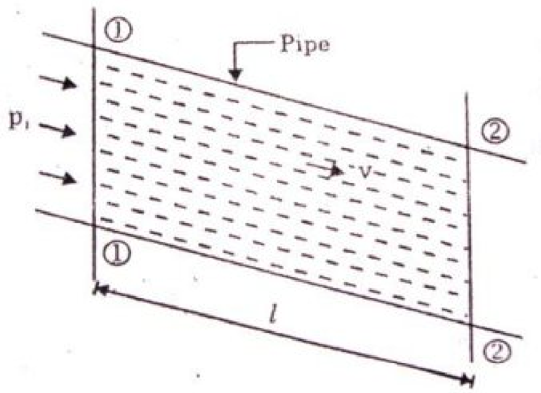


Fig. 2.28

The frictional resistance offered to the flow of a fluid depends on the type of flow laminar or turbulent.

2.23.1.Laws of fluid friction for laminar flow

The frictional resistance in the laminar flow is

- Proportional to the velocity of flow.
- Proportional to the area of surface in contact.
- Greatly decreased if the temperature of the fluid is increased
- Independent of pressure.
- Independent of pressure.
- Independent of the nature of surface in contact.

2.23.2.Laws of fluid friction for turbulent flow

The frictional resistance in the turbulent flow is

- Proportional to the area of surface in contact.
- Proportional to the square of velocity.
- Proportional to the density of fluid.
- Dependent on the nature of surface in contact.
- Independent of pressure.
- Slightly vary with temperature.

1.3.5 Reynolds number

Reynolds number is a non-dimensional number.

Reynolds number = $\frac{\rho v D}{\mu}$ where ρ –density

v-velocity

μ - absolute viscosity

2.24. Critical velocity

The velocity of flow changes from laminar to turbulent is called critical velocity.

2.25. Total energy line

If sum of pressure heads and velocity heads of a liquid flowing in a pipe be plotted as vertical ordinates on the center line of the pipe.

2.26.Hydraulic gradient line

If the pressure head p/w of a liquid flowing in a pipe be plotted as vertical ordinates in the centre line of the pipe.

The line joining the tops of such ordinates is known as hydraulic gradient line.

Wetted perimeter(P)

Wetted perimeter is the surface which is in contact with water. Consider a pipe of circular cross section in which a liquid as flowing in full.

Wetted perimeter(P)=πd

Hydraulic mean depth or Hydraulic radius

$$\text{Hydraulic mean depth} = \frac{area\ of\ the\ flow\ (a)}{wetted\ perimeter(p)}$$

$$\text{For circular pipe ,Hydraulic mean depth} = \frac{\frac{\pi d^2}{4}}{\pi d} = \frac{d}{4}$$

2.27. Head loss due to friction

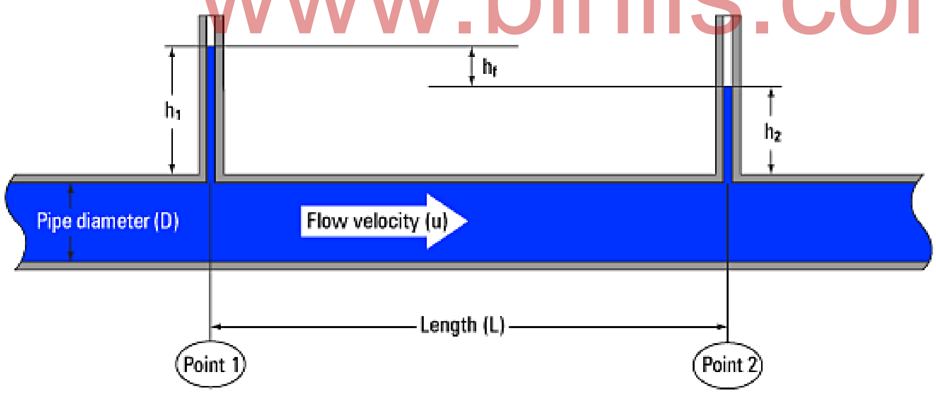


Fig.2.29

Let

P_1- inlet pressure and P_2-outlet pressure

v-velocity of the flow

L-length of the pipe and d-diameter of the pipe

A- cross sectional area of pipe

f'-frictional resistance per unit area(Froud's constant)

Consider section 1-1 & 2-2 of the pipe

$P_1A = P_2A$ + Frictional resistance

Frictional resistance = $P_1A - P_2A$

Dividing both sides by w(specific weight of water)

$$\frac{\text{Frictional resistance}}{w} = \frac{P_1A - P_2A}{w}$$

$$\frac{\text{Frictional resistance}}{A\,w} = \frac{P_1 - P_2}{w} = h_f \text{ (loss of head due to friction)}$$

$$h_f \text{ (loss of head due to friction)} = \frac{\text{Frictional resistance}}{A\,w}$$

Frictional resistance = $f' \times \pi dl \times v^2$ then

$$hf = \frac{f' \times \pi dl \times v^2}{\pi/4 d^2 w}$$

$$hf = \frac{4f' \, l \, v^2}{wd}$$

$f' = \frac{fw}{2g}$ substitute f' value in hf equation

then **Darcy's formula for loss of head due to friction h_f** $= \frac{4f\,l\,v^2}{2gd}$

where 4f – friction factor

f – Darcy's frictional coefficient.

2.28. Head loss due to friction in the pipe (Chezy's formula)

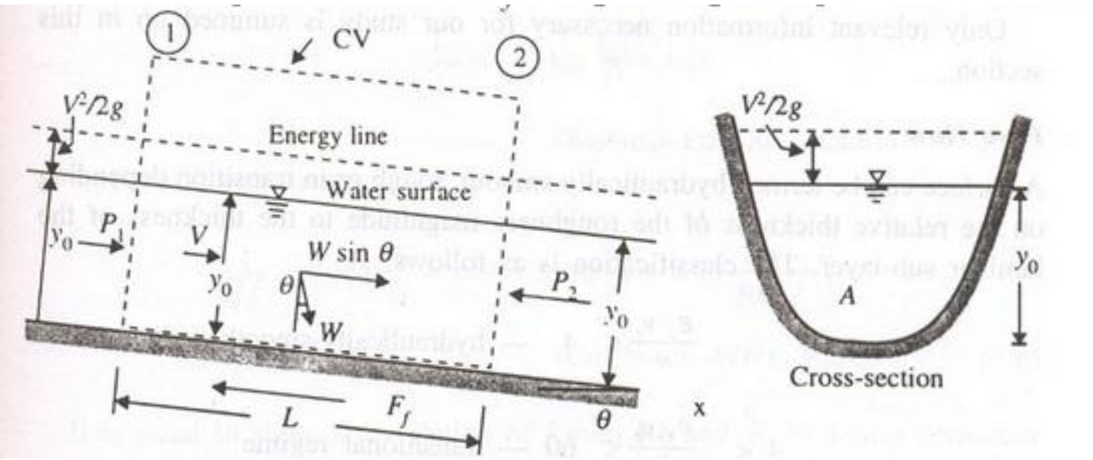


Fig.2.30

Let

P_1- inlet pressure and P_2-outlet pressure
v-velocity of the flow
L-length of the pipe and d-diameter of the pipe
A- cross sectional area of pipe

f'-frictional resistance per unit area(Froud's constant)

Consider section 1-1 & 2-2 of the pipe

$$P_1A = P_2A + \text{Frictional resistance}$$

Frictional resistance = $P_1A - P_2A$
Dividing both sides by w(specific weight of water)

$$\frac{\text{Frictional resistance}}{w} = \frac{P_1A - P_2A}{w}$$

$$\frac{\text{Frictional resistance}}{A\,w} = \frac{P_1 - P_2}{w} = h_f \text{ (loss of head due to friction)}$$

$$h_f \text{ (loss of head due to friction)} = \frac{\text{Frictional resistance}}{A\,w}$$

Frictional resistance = f' x πdl x v^2 then

$$hf = \frac{f' \times \pi dl \times v^2}{Aw} = \frac{f' \times pxl \times v^2}{Aw}$$ where perimeter(p)= πd

Hydraulic mean depth (m) = A/p

$$hf = \frac{f' \times l \times v^2}{w \times m}$$

$$v^2 = \frac{wmhf}{f'l} = \frac{wm}{f'} \times i$$

where hf/l = i(slope of hydraulic gradient line)

$$\sqrt{w/f'} = C \text{(chezy's constant)}$$

$v = C\sqrt{mi}$

2.29.Minor losses

1.Loss of head due to sudden Enlargement
2. Loss of head due to sudden contraction
3. Loss of head at entrance of pipe
4. Loss of head at exit of pipe
5. Loss of head due to an obstruction in a pipe

1. Loss of head due to sudden Enlargement

Fig.2.30

Loss of head due to sudden Enlargement (h_f) = $\frac{v_1 - v_2}{2g}$

V_1-velocity at inlet
V_2-velocity at Exit

2.Loss of head due to sudden Contraction

Fig.2.31

Loss of head due to sudden Contraction =0.375 $\frac{v^2}{2g}$

v- velocity of flow at exit of pipe

3.Loss of head at Entrance of pipe

Loss of head at Entrance of pipe = 0.5 $\frac{v^2}{2g}$

4.Loss of head at Exit of pipe

Loss of head at Exit of pipe = $\frac{v^2}{2g}$

5.Loss of head due to an obstruction in a pipe

Loss of head due to an obstruction in a pipe = $[\frac{A}{Cc(A-a)} - 1]^2 \frac{v^2}{2g}$

Where **A- area of pipe**
a- Area of Obstruction
v- velocity of liquid
Cc- Coefficient of contraction

Transmission of power through the pipe
Total head available at outlet = Total head available at inlet – loss of head due to friction
Total head available at outlet = H- h_f

2.30.Power transmitted to outlet(p)

P = w a v (H-h_f)

Where w- specific weight of fluid
a- area of the pipe

v- velocity of flow

H- total head at inlet

h_f- loss of head due to friction

Efficiency of power Transmission

2.31.Efficiency = η = $\frac{\textbf{Total head available at outlet}}{\textbf{Total head available at inlet}}$ **x 100 =** $\frac{\mathbf{H - h_f}}{\boldsymbol{H}}$ **x 100**

2.32. Condition for Maximum power Transmission

Power transmission = wav($H-h_f$)

$$P = wav\,[H - \frac{4flv^2}{2gd}]$$

For maximum power transmission differentiate the above equation with respect to V and then equate to zero

(i.e) $\frac{d(p)}{dv} = 0$

$$\frac{d([H - \frac{4flv^3}{2gd}])}{dv} = 0$$

$$H - 3[\frac{4flv^2}{2gd}] = 0$$

$$H - 3h_f = 0$$

$$\mathbf{h_f = \frac{H}{3}}$$

hence loss of head is 1/3 of the total head at inlet

2.33.Important Formula

1. Reynolds number = $\frac{\rho v D}{\mu}$
2. Wetted perimeter(P)= πd
3. Hydraulic mean depth (m) = d/4
4. Head loss due to friction (Darcy's formula) $h_f = \frac{4f\,l\,v^2}{2gd}$
5. Chezy's formula v = C $\sqrt{mi}$
6. Loss of head due to sudden Enlargement (h_f) = $\frac{v_1 - v_2}{2g}$

7. Loss of head due to sudden Contraction =0.375 $\frac{v^2}{2g}$

8. Loss of head at Entrance of pipe = 0.5 $\frac{v^2}{2g}$

9. Loss of head at Exit of pipe = $\frac{v^2}{2g}$

10. Loss of head due to an obstruction in a pipe = $[\frac{A}{Cc(A-a)} - 1]^2 \frac{v^2}{2g}$

11.power transmitted in the pipe P =wav [H-$\frac{4flv^2}{2gd}$]

12. Efficiency = η = $\frac{\text{Total head available at outlet}}{\text{Total head available at inlet}}$ x 100 = $\frac{H - h_f}{H}$ x 100

13.condition for maximum power transmission $h_f = \frac{H}{3}$

2.34.Solved problem

1.Calculate the head loss due to friction in a pipe of 600 mm diameter and 1.5 km long. The velocity of flow of water is 2.5 m/sec and the friction factor is 0.02

Given:

Diameter of pipe d = 600 mm = 0.6 m

Length of pipe L = 1.5 km = 1500 m

Velocity of flow v= 2.5 m/s

Friction factor F or 4f = 0.02

Solution:

Head loss due to friction (Darcy's formula) $h_f = \frac{4f\,l\,v^2}{2gd}$

$= \frac{0.02 X 1500 X 2.5^2}{2 X 9.82 X 0.6}$

= 15.92 m

2. Calculate the head loss due to friction in a pipe of 200 mm diameter and 500 m long. The velocity of flow of water is 5 m/sec and f is 0.008

Given:

Diameter of pipe d = 200 mm = 0.2 m

Length of pipe l = 500 m

Velocity of flow v= 5 m/s

Friction factor f = 0.008

Solution:

Head loss due to friction (Darcy's formula) $h_f = \frac{4 f l v^2}{2gd}$

$= \frac{4X0.008X500X5^2}{2X9.82X0.2}$

= 101.9368 m

3. Two reservoirs are connected by a 50 mm diameter and 2 km long pipe line. The difference of water level between the two reservoirs is 20 m. calculate the discharge in lit/sec. take friction factor = 0.0248

Given:

Diameter of the pipe d = 500 mm = 0.5 m

Length of the pipe l = 2 km = 2000 m

Difference of water level h_f = 20 m

Friction factor F = 4f = 0.0248

Solution:

Head loss due to friction (Darcy's formula) $h_f = \frac{4 f l v^2}{2gd}$

$20 = \frac{0.0248X2000XV^2}{2X9.81X0.5}$

V = 1.9889 m/s

Discharge Q = av = $(\pi d^2/4)v$

= $(\pi 0.5^2/4)$x1.9889

= 0.3905 m^3/sec = 390.05 lit/sec

4. Compare the discharge of 150mm and 300 mm diameter pipes when the loss head due to friction in the pipe is the same. Consider both pipes having equal length and equal value of f.

Given:

d_1 = 150 mm = 0.150 m

d_2 = 300 mm = 0.300 m

Solution:

the loss of head due to friction for pipe 1 = pipe 2

$$\frac{4 f l v^2}{2gd} = \frac{4 f l v^2}{2gd}$$

4f, l, 2g are cancelled $\frac{V_1^2}{0.150} = \frac{V_2^2}{0.300}$

$$\frac{V_1}{V_2} = 0.707$$

Discharge of pipe ratio $\frac{Q_1}{Q_2} = \frac{a_1 V_1}{a_2 V_2} = \frac{0.15^2}{0.300^2} \times 0.707$

$$\frac{Q_1}{Q_2} = 0.17675$$

5. A pipe line 8 km long delivers a power of 40 kw at its outlet end. The pressure at inlet is 4000 kN/m^2 and pressure drop per Km of pipe is 50 kN/m^2. Take friction factor = 0.02. calculate the diameter of pipe and the efficiency.

Given:

Length of pipe l =8 km = 8000 m

Power delivered p = 40 kw

Pressure at inlet p_1 = 4000 kN/m^2

Pressure drop per km = 50 kN/m^2

Total pressure drop for 8 km pipe = 8 x 50 = 400 kN/m^2

Solution:

Convert the pr at inlet and loss of pr into pr head at inlet and loss of pr head

Pr head at inlet H = p_1/9.81= 4000/9.81 = 407.747 m of water

Loss of Pr head h_f = 400/9.81= 40.7747 m of water

Efficiency $\eta = \frac{H - h_f}{H} \times 100 = \frac{407.747 - 40.7747}{407.747} \times 100$

η = 89.999 = 90%

Power transmitted in the pipe P =wav [H- h_f]

= wxQx [H- h_f]   where Q =av

40 = 9.81xQx[407.747 – 40.7747]

Q = 11.111x10^{-3} m^3/sec

Loss of head $h_f = \frac{4f\,l\,v^2}{2gd}$

$$40.7747 = \frac{0.02 \times 8000 \times v^2}{2 \times 9.81 \times d}$$

$V^2 = 5d$ & $V = \sqrt{5d}$

$$Q = av = \frac{\pi d^2}{4}\sqrt{5d}$$

11.111x 10^{-3} = 1.7562 $d^{5/2}$

d = 131.96 x 10^{-3} m = 131.96 mm

6. Using Chezy's formula find the loss of head due to friction in a pipe 800 mm dia and 36 m long. The velocity of flow is 2 m/sec. Take Chezy's constant C = 100.

Given:

d = 80 mm = 0.08 m

l = 36 m

v = 2 m/sec

C = 100

Solution:

Chezy's formula $v = C\sqrt{mi}$

Hydraulic mean depth m=d/4 = 0.08/4 = 0.02 m

$2 = 100\sqrt{0.02 X i}$

i = 0.02

$i = h_f/l$

$0.02 = h_f/36$

Loss of head $\mathbf{h_f = 0.72\ m}$

7. Water is supplied to a factory a hydro power station by means of a pipe of 200 mm diameter and 12 km long. The pressure at the power station 45000kN/m^2. Find the maximum power that can be transmitted to the factory. Assume F = 0.028.

Given:

d = 200 mm = 0.2 m

l = 12 km = 12000 m

P = 45000 kN/m^2

F = 0.028 = 4f

Solution:

Condition for maximum power transmission $h_f = H/3$.

Pressure at the power station = Pressure head at inlet H = 45000/9.81

H = 4587.156 m

Head loss due to friction $h_f = H/3 = 4587.156/3$

$h_f = 1529.052$ m

$$h_f = \frac{4f\,l\,v^2}{2gd}$$

$$1529.052 = \frac{0.028 X 12000 X\ v^2}{2 X 9.81 X 0.2}$$

$V = 4.226$ m/s

Area of the pipe a = $\frac{\pi d^2}{4} = \frac{\pi 0.200^2}{4}$ = 31.416 m^2

Power transmission P = wav [H- h_f]

= 9.81x31.416x4.226[4587.156-1529.052]

= 3982.911 kw

8. A pipe line 10 km long delivers a power of 50 kw at the outlet end. The pressure at inlet is 4500 kN/m^2 and the pressure drop per km of pipe is 50 kN/m^2. Take F = 0.0125. Determine the diameter of the pipe and the efficiency of power transmission.

Given:

l = 10 km = 10000 m

P = 50 kw

P_1 = 4500 kN/m2

Pr head at inlet H = p_1/w = 4500/9.81

H = 458.7 m

Loss of pr per km = 50 kN/m^2

Loss of pr. for 10 km = 50x10 = 500 kN/m^2

Loss of pr head h_f = 500/9.81 = 50.9683 m

Solution:

Efficiency $\eta = \frac{\text{Total head available at outlet}}{\text{Total head available at inlet}} \times 100 = \frac{H - h_f}{H} \times 100$

$= \frac{458.7 - 50.9683}{458.7} \times 100$

η = 88.88 %

loss of head $h_f = \frac{4f\,l\,v^2}{2gd}$

$50.9683 = \frac{0.0125 X 10000 X v^2}{2 X 9.81 X d}$

$V^2 = 8d$

$V = \sqrt{8d}$

Power transmission P = wav [H- h_f]

$50 = 9.81 x \frac{\pi d^2}{4} x \sqrt{8d}$ (458.7-50.9683)

Diameter of the pipe d = 0.12593 m =125.93 mm

2.35.Theoretical questions

Part A

1.Define hydraulic gradient line

2.Define wetted perimeter

3.Define hydraulic mean depth

4.List out the minor losses

5.Write the formula for head loss due to friction

6.Write the formula for sudden enlargement

7. Write the formula for sudden contraction

8.What is the formula for power transmission through the pipe.

9.Write the formula to find the velocity of flow using Chezy's formula

10.Define Laminar flow

11.Define turbulent flow

12.What is the formula for maximum efficiency

13.Write the condition for maximum power transmission.

Part-B

1.Derive the Chezy's formula for loss of head due to friction.

2. Derive the Darcy formula for loss of head due to friction.

3.Derive the Expression for power transmission through the pipe.

4.Derive the condition for maximum power transmission through the pipe.

2.36.Numerical Problems

1.A pipe line 300 mm diameter connects two reservoirs whose difference in water level is 10 m. The length of the pipe is 400 m. Take friction factors as 0.02. Find the discharge through the pipe. Ans = 0.1917 m^3

2.A pipe of 1 m diameter and 1 km long delivers water to a town at the rate of 10 m^3/sec. What is the head loss due to friction if F = 0.04. Ans = 333.4 m

3.Using Chezy's formula find the loss of head due to friction in a circular pipe of 30 m long and 75 mm dia when the velocity of flow is 1.8 m/sec. Ans o.5184 m

4. Water flow with a velocity of 5 m/sec , 1 m dia and 1 km long. The loss of head due to friction is 10 m of water. Find the value of Chezy's constant C. Ans C = 100.

5.Compare the velocities of water in two pipes of diameter 1.5 m and 3 m. when the loss of head due to friction ,length of pipe and chezy's contant for each pipes are same. Ans $V_1 = 0.702V_2$

6.Find the maximum that can be transmitted through the pipe of diameter 250 m long and 80 mm diameter. The head of water at the inlet of pipe is 60 m. take f = 0.01.

7.A pipe of dia 1 m and a length f 10 km transmits power to a Hydraulic turbine in the power house. The pressure of water in the pipe at the power house is 10,000 kn/m^2. Find the discharge and maximum power transmission .Take F=0.04 Ans Q=3190 lps, P=21266.7 kw.

UNIT – III

IMPACT OF JETS, HYDRAULIC TURBINES, CENTRIFUGAL AND RECIPROCATING PUMPS – 18HRS

Objectives

- Impart the knowledge in jet of water and the force exerted by the jet.
- Differentiate positive and non positive displacement pumps.
- Explain the construction and working principle of centrifugal pump.
- Impart the practical knowledge of priming of centrifugal pump.
- Explain the function of single acting & double acting Reciprocating pump with video animation and solve problems.
- Discuss the importance of hydraulic turbines.
- Explain the function of Hydraulic turbines with video animation.
- Give brief knowledge in special pump with video animation.

3.1.1. IMPACT OF JETS

Introduction

Nozzle is a Tapering short pipe. The stream of liquid issuing from a nozzle is known as a jet. Whenever a Jet of liquid impinges on a fixed plate. It exert some force on the plate. This dynamic force is called impact of Jet. It is named as

Force = Rate of change of momentum
= Change of momentum / Time

Momentum = mass x velocity

= m x v

Thrust on a stationary Flat Plate

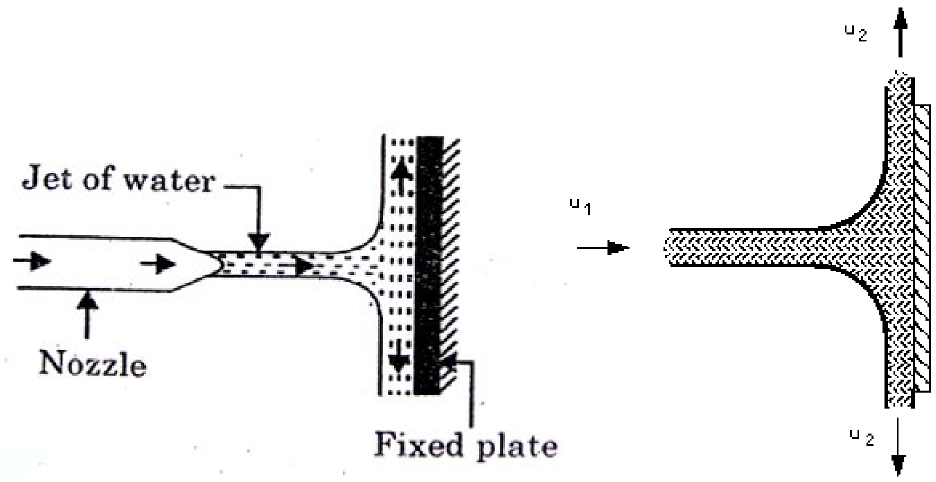


Fig.3.1

i. Plate is Held Normal to the Jet

Consider a Jet of water impinging normally on a fixed plate as shown in fig.3.1

Let,

V= Velocity of the Jet in m\sec.

a= cross sectional are of the Jet in (m^2)

w= Specific weight of liquid (kN\m^2)

Force = rate of change of momentum

Mass of water flowing\sec. = wav\g (kg)

Force exerted by the Jet on the plate,

F= mass of water flowing\sec x change of velocity.

$$= \frac{waV}{g} \times (v-0)$$

$$F = \frac{wav^2}{g} (\text{ kN})$$

ii). Plate is Held Inclined Fixed Plate

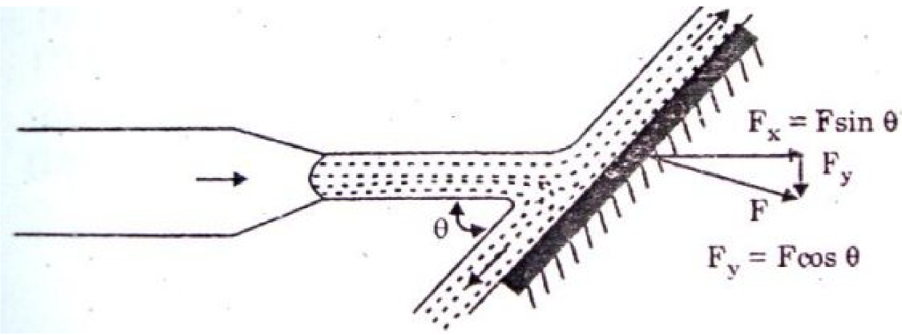


Fig.3.2

Consider a Jet impinging on an Inclined Plate as shown in fig .3.2

Let, v = Velocity of Jet in (m\sec)

a = Cross sectional area of Jet in (m^2)

θ = angle which the pate is inclined with the Jet.

w = Specific weight of fluid ($kN\backslash m^3$)

We know that the force exerted by the Jet in its original direction.

Force = Mass of water x Change in velocity

Flowing \ sec

$$= \frac{waV}{g} \times (v - 0)$$

$$= \frac{wav^2}{g}$$

- Force exerted by the Jet in a direction normal (i.e. Perpendicular) to the plate.

$$F = \frac{wav^2}{g} \sin\theta$$

- Force exerted by the Jet in the direction of flow.

$$F_x = F\sin\theta = (wav^2 \ \sin^2\theta)/g$$

- Similarly, force exerted by the Jet in direction normal to flow.

$$F_y = F\cos\theta = \frac{wav^2 \sin\theta \cos\theta}{g}$$

(Multiplying and dividing by 2)

$$F_y = (wav^2 \ 2\sin\theta\cos\theta)/2g$$

$$F_y = \frac{wav^2 \sin 2\theta}{g}$$

iii. Thrust on a moving Flat Plate

- Consider a Jet of water, impinging normally on a plate.
- As a result of the impact of Jet, Let the plate move in the Direction of the Jet as shown in fig 3.3

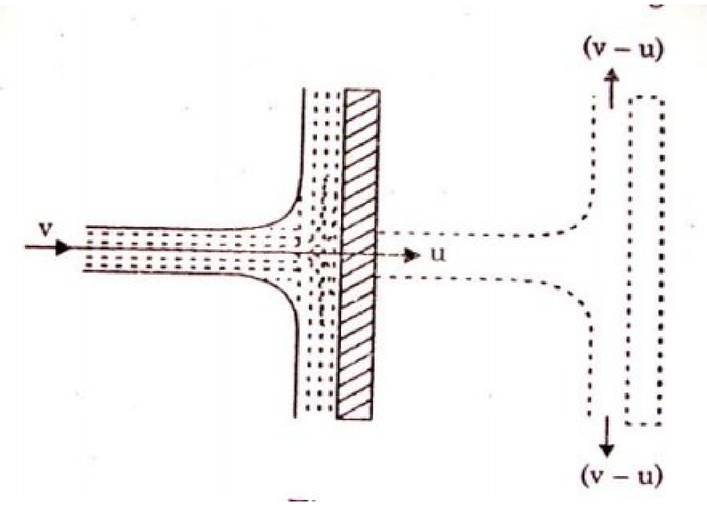


Fig.3.3

Let v = Velocity of Jet in m\sec.

a = area of the Jet in m^2

u = Velocity of the plate in m\sec.

w = specific weight of liquid (kN\m^2)

The relative velocity of the Jet with respect to the plate is Equal to (v – u) m\sec.

∴ Force exerted by the Jet = mass of water flowing per sec. X change in velocity

$$= \frac{wa(v-u)}{g} \times (v-u)$$

$$= \frac{wa(v-u)^2}{g} \quad \text{(kN)}$$

Work done by the Jet = Force x distance moved by the plate\sec.

$$= \frac{wa(v-u)^2}{g} \times u \quad \text{kN m\textbackslash sec (or)} \quad \text{K Joule \textbackslash sec.}$$

Efficiency of the Jet = $\frac{Work\ done\ by\ the\ Jet}{Energy\ supplied\ by\ the\ Jet}$

Energy supplied by the Jet = Kinetic energy of fluid flowing

$$= \frac{1}{2} mv^2$$

$$= \frac{1}{2}\frac{w}{g} v^2$$

$$= \frac{1}{2}\frac{wav}{g} \ v^2$$

$$= \frac{wav^3}{2g}$$

η **of the Jet** = $\frac{\textit{Workdone by the Jet}}{\textit{Kinetic energy supplied by the Jet}}$

$$= \frac{wa}{g}(v-u)^2 \ u \backslash \frac{wav^3}{2g}$$

$$= \frac{2(v-u)^2}{v^3}u$$

Efficiency of the Jet will be maximum,

When $\frac{d\eta}{du} = 0$

Differentiating the efficiency .w.r.t. ‘u’

$$\frac{d\eta}{du} = \frac{d}{du}[\frac{2(v-u)2\,u}{v3}] = 0$$

$$= \frac{2}{v3}[(v\text{-}u)^2 + u.2\,(v\text{-}u)(\text{-}1)] = 0$$

$$= \frac{2}{v3}[(v\text{-}u)^2 - 2u\,(v\text{-}u)] = 0$$

$$= \frac{2(v-u)}{v3}[v - u - 2u] = 0$$

V – u – 2u = 0

V – 3u = 0

V = 3u

If the velocity of Jet v is 3 times of velocity of moving plate (u), The efficiency will be maximum.

iv. Thrust on series of moving Flat Plate

The Jet impinging on a single moving plate is not practically possible. But in actual practice, a case similar to this arises, in which a Jet of water impinges on a series of pates (vanes) mounted on a circumference of a large wheel as shown in fig.3.4 & 3.5.

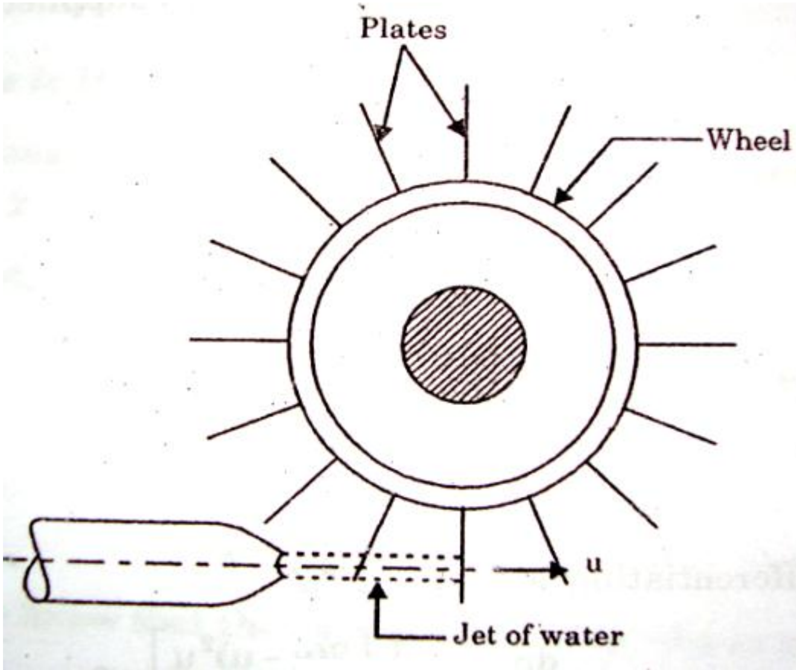


Fig.3.4

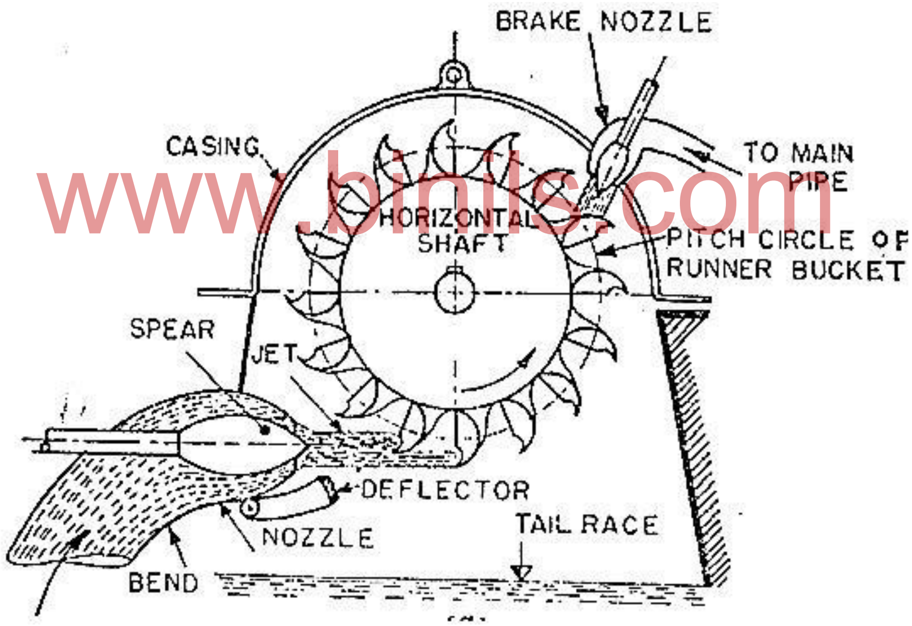


Fig. 3.5

Let, v = Velocity of the Jet in m\sec.

a = area of Jet in m^2

u = Tangential velocity of Jet

Force exerted by the Jet = Mass of water flowing \ sec x change in velocity

$$= \frac{wav}{g}(v-u)$$

Work done by Jet = Force x Distance

$$= \frac{wav}{g}(v-u) \times u$$

Efficiency of Jet water,

$$\eta = \frac{Work\ done\ by\ the\ wheel}{Kinetic\ energy\ of\ the\ Jet} \times 100$$

$$= \frac{wav\ (v-u)u}{g} / \frac{wav3}{2g}$$

$$\boldsymbol{\eta} = \frac{2(v-u)u}{v^2}$$

For maximum efficiency,

Differentiating the efficiency w.r.t.'u' and equating to zero.

$$\frac{d\eta}{du} = \frac{d}{du}[\frac{2(v-u)u}{v2}]$$

$$= \frac{2}{v^2}[v-2u] = 0$$

$$= \frac{2}{v^2} \neq 0 \text{ and } v-2u = 0 \therefore$$

v = 2u

Substituting v = 2u in the efficiency equation

Maximum efficiency, $\eta_{(max)} = \frac{2(2u-u)u}{(2u)2}$

$$= \frac{4u2-2u2}{4u2}$$

$$= \frac{2u2}{4u2}$$

$$= \frac{2}{4} = 0.5$$

$$\eta_{(max)} = 50\%$$

IMPORTANT FORMULA

1. Thrust on a stationary Flate Plate.

- Plate is held normal to the Jet.

$$F = \frac{wav2}{g}$$

work done = 0

- Plate is held inclined to Jet & the plate is fixed

$$F_x = \frac{wav^2}{g}\sin^2\theta$$

F_x = Direction of flow

$$F_y = \frac{wav^2}{2g}\ \sin 2\theta$$

F_y = Normal to flow

work done = 0

2. Thrust on a moving Flat Plate.

$$F = \frac{wa\ (v-u)^2}{g}$$

$$\text{Work done} = \frac{wa\ (v-u)^2}{g} \times u$$

$$\eta\ \ of\ the\ Jet\ = \frac{\textbf{Work done by the Jet}}{\textbf{Energy supplied by the Jet}}$$

Condition for **maximum η** **v = 3u.**

3. Thrust on series of Moving Flat Plates or moving vanes

$$F = \frac{wav\,(v-u)}{g}$$

$$\text{Work done} = \frac{wav\,(v-u)\times u}{g}$$

$$condition\ for\ \max\ efficiency\ \ \boldsymbol{v = 2u}$$ η_{max}=50%

3.1.2.Numerical problems

1. A jet of water 50 mm diameter moving with a velocity of 10 m/sec strikes a fixed flat plate. Calculate the force exerted by the jet if the plate is held normal to the direction of jet.

   Given:

   d = 50 mm= 0.05 m
   V = 10 m/sec

Solution:

Area of Jet a = $\frac{\pi d^2}{4} = \frac{\pi(0.05)^2}{4} = 1.963 \times 10^{-3}$ m^2

Force exerted by the Jet F $= \frac{wav^2}{g}$

$= \frac{9.81 \text{ X } 1.963 \times 10^{-3} \times 10^2}{9.81}$

= 0.196 KN.

2. A jet of water 75 mm diameter nozzle impinges normally with a velocity of 40 m/sec on a flat plate which remains at rest. Find the force exerted by the jet on the plate.

Given:

Dia of jet d =75 mm= 0.075 m

Velocity of jet V = 40 m/sec

Solution:

Area of Jet a = $\frac{\pi d^2}{4} = \frac{\pi(0.075)^2}{4} = 4.41786 \times 10^{-3}$ m^2

Force exerted by the Jet F $= \frac{wav^2}{g}$

$= \frac{9.81 \text{ X } 4.41786 \times 10^{-3} \times 40^2}{9.81}$

= 7.068 KN.

3. A Jet of water 100 mm diameter moves in the velocity 25 m/sec strikes a stationary plate. Find the normal force on the plate when

i)The plate is normal to the jet ii)the plate is inclined 45^0 to jet

Given: d=100 mm = 0.1 m v=25m/s θ=45^0

Solution: **i)The plate is normal to the jet**

Area of Jet a = $\frac{\pi d^2}{4} = \frac{\pi(0.1)^2}{4} = 7.853 \times 10^{-3}$ m^2

Force exerted by the Jet F $= \frac{wav^2}{g}$

$= \frac{9.81 \text{ X} 7.853 \times 10^{-3} \times 25^2}{9.81}$

$= 4.908$ KN.

ii) the plate is inclined 45^0 to jet

Force exerted by the Jet F $= \frac{wav^2}{g} \sin\theta$

$= \frac{9.81 \times 7.853 \times 10^{-3} \times 25^2 \times \sin 45^0}{9.81}$

$= 3.47$ KN.

4. A jet of water 0.25 m diameter is moving with a velocity of 30 m/s. Find the force Exerted by the jet if, i)the plate is fixed. Ii)the plate is moving with a velocity of 12 m/s in the direction of flow.

Given: d=0.25 m v=30 m/s u=12 m/s

Solution:

i)the plate is fixed.

Area of Jet $a = \frac{\pi d^2}{4} = \frac{\pi (0.25)^2}{4} = 0.04908 \text{ m}^2$

Force exerted by the Jet F $= \frac{wav^2}{g}$

$= \frac{9.81 \times 0.04908 \times 25^2}{9.81}$

$= 44.172$ KN.

Work done by fixed plate = 0.

Ii)the plate is moving with a velocity of 12 m/s in the direction of flow.

$F = \frac{wa\,(v-u)^2}{g} = \frac{9.810 \times 0.04908\,(30-12)^2}{9.81}$

$= 15.901$ KN

Work done = Fx u

$= 15.901 \times 12$

= 190.823 watt

3.1.3.THEORETICAL QUESTIONS

One mark & 3 marks

1. What is an Impact of Jet ?
2. What is meant by nozzles?
3. Write the formula for finding Impact of Jet on fixed plate.
4. Write the formula for finding Impact of Jet on a moving plate.
5. Write the formula for finding Impact of Jet on a series of moving plate.

Five marks & 10 marks

1. Derive an expression for force exerted by the Jet on a Stationary plate normal to the Jet.
2. Derive an expression for force exerted by the Jet striking
   On an inclined plate which is moving in the direction of Jet of water.
3. Derive an expression for force of impact of Jet over a
   Fixed vertical plate in the direction of Jet.

3.1.4.NUMERICAL PROBLEMS

1. A Jet of water 50 mm diameters moving with a velocity of 10m\sec. strikes a Fixed flat plate. Calculate the force exerted by the Jet if the plate is held Normal to the direction of Jet. (Ans: F = 0.196 kN)

2. A Jet of water of diameter 7.5m is moving with a velocity of 25 m\sec. Strikes a fixed plate in such a way that the angle between the Jet and the Plate is 60°. Find force exerted by the Jet on the plate if
   I. Direction normal to the plate.
   II. The direction of Jet when the plate is inclined.

   (Ans :F_1 = 2.761 kN, F_2 = 2.391kN)

3. A Jet 250mm in diameter having a velocity of 10m\sec. impinges normally
   On a Flate Plate moving at 2m\sec. in the same direction of Jet. Find the force
   Exerted by the Jet and work done.(Ans : F =3,136kN, Work done = 6.272 Kwatt)

4. A Jet of water 60mm diameter moves with a velocity of 25m\sec and strikes on a
   Series by vanes moving with a velocity of 10m\sec. Find
   1) Force exerted by theJet.
   2) Work done by the Jet.
   3) η of the Jet.

   Ans: F = 1.06 kN, Work done = 10.602 Kwatts, η = 48%

3.2. HYDRAULIC TURBINES

3.2.1.Introduction

- The Hydraulic energy was first converted into mechanical energy in India about 2200 years back.
- The water wheels were made of wood.

- They were able to produce less power.
- Then the water wheels have been replaced by modern water Turbines.

3.2.2.Classification of Turbines

1. **According to action of water on moving blades.**
   i. Impulse turbine
   ii. Reaction turbine
2. **According to the direction of flow.**
   i. Radially inward flow turbine.
   ii. Radially outward flow turbine.
   iii. Parallel (axial) flow turbine.
   iv. Mixed flow turbine.
3. **According to the name of originators.**
   i. Pelton wheel
   ii. Francis turbine
   iii. Kaplan turbine
   iv. Girard turbine
4. **According to head of water**
   i. Low head
   ii. Medium head
   iii. High head

5. **According to the position of the turbine**
   i. Vertical turbine
   ii. Horizontal turbine
6. **According to the discharge**
   i. Low discharge
   ii. Medium discharge
   iii. High discharge

3.2.3.Impulse Turbine

- In an Impulse Turbine all the energy of water is first converted into kinetic energy by passing it through Nozzles.
- The water enters the running wheel in the form of a Jet which impinges on the buckets.
- The pressure of water is atmosphere throughout It’s passage through the turbine as shown in fig 3.6.

(Example: Pelton wheel)

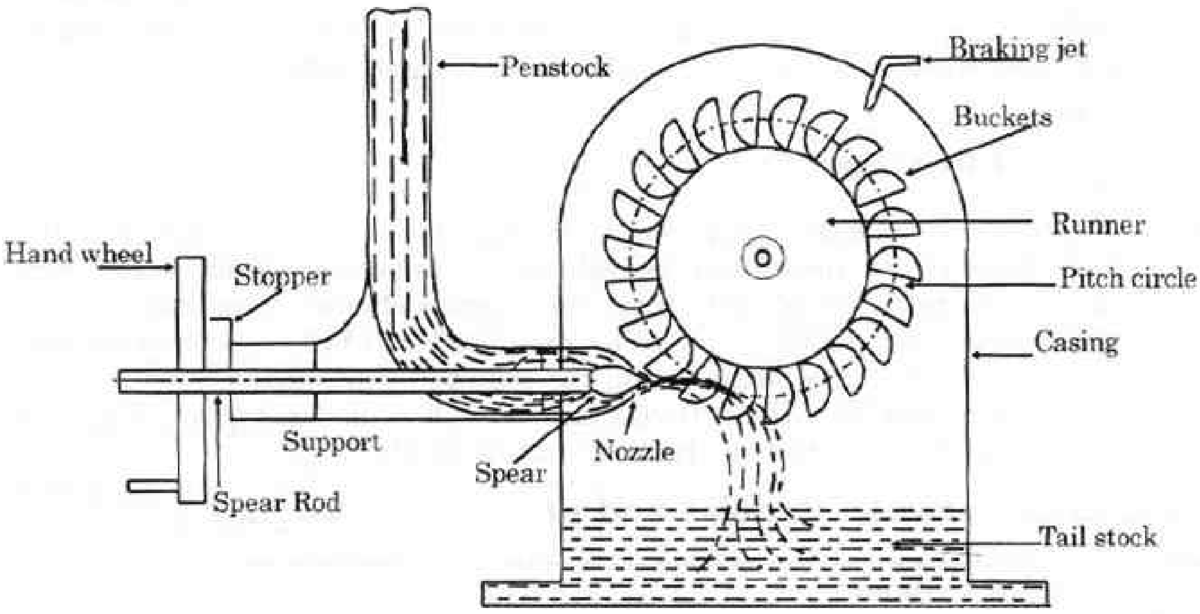


Fig. 3.6

3.2.4.Reaction Turbine

- This Reaction Turbine operates due to the pressure difference in the inlet and outlet of turbines as shown in fig.3.7.
- Water entering the runner have pressure energy as well as kinetic energy.
- Both the pressure energy and kinetic energy provide turning movement of the runner.

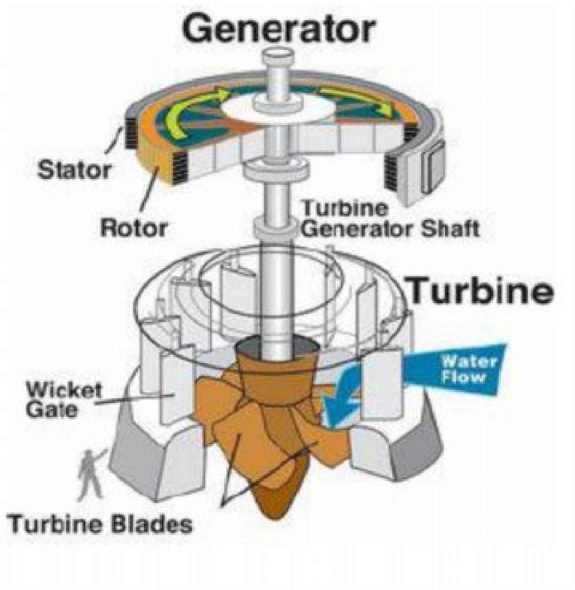


Fig. 3.7

Example (1) Francis turbine (2) Kaplan turbine

3.2.5.Pelton Wheel turbine

The Pelton wheel is an impulse type water turbine. It was invented by **Lester Allan Pelton** in the 1870s. The Pelton wheel extracts energy from the impulse of moving water.

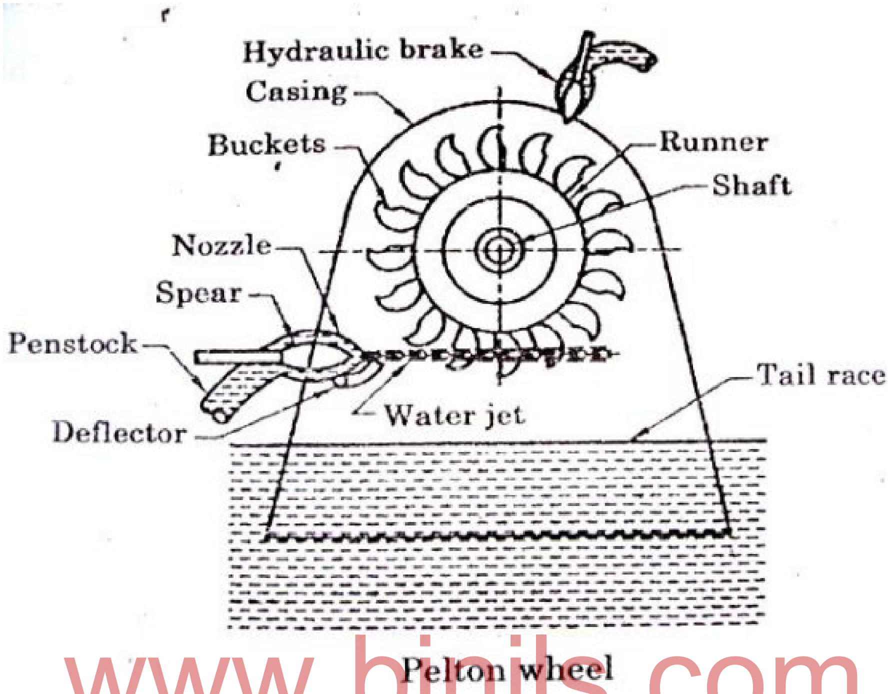


Fig. 3.8

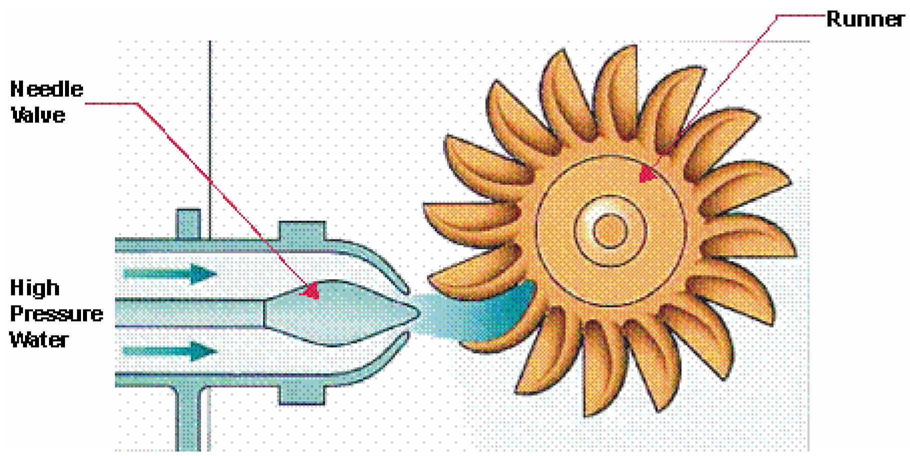


Fig. 3.9

Elements

i. Nozzle and guide mechanism
ii. Deflector
iii. Runner and buckets

iv. Casing
v. Breaking Jet.

Nozzle and guide Mechanism

Nozzle is a guide tube. Nozzle is fitted at the end of the penstock pipe. It converts all the available energy of water into Kinetic energy. This water in the form a Jet, strikes the buckets. A conical needle or spear operates inside the nozzle in an axial direction. The purpose of this spear is to control or regulate the quantity of water flowing through the nozzle as shown in fig.3.8 & 3.9. The movement of the spear is regulated by hand or governor.

Deflector

The Deflector is a plate connected to the needle rod by means of levers. When the load is suddenly reduced, the Governor Operates the needle rod which brings the deflector Plate in front of the buckets thus deflect the water from impinging on the buckets.

Runner and Buckets

The runner of a pelton wheel is a circular disc mounted on a shaft. On the periphery of the runner, a number of buckets are fixed uniformly. The buckets are generally divided into two hemispherical cups by a sharp control ridge, which divides the Jet into two parts. The surface of the buckets is made very smooth. For Low heads, the buckets are made of cast iron, and for high heads they are made of bronze. The Jet of water issuing through the nozzle impinges on the buckets in centre and is divided into two parts.

Casing

Casing of a pelton wheel does not perform any Hydraulic function.

Casing is made of cast (or) fabricated parts.

It is used to:

i. Prevent the splashing of water.
ii. Prevent accidents caused by the falling bodies.
iii. Lead the water to the tail-race.

Braking Jet

Whenever the turbine has to be brought to rest, the nozzle is completely closed. It has been observed that the runner goes on revolving for a considerable time, due to inertia, before it comes on rest. In order to bring the runner to rest in a short time, a small nozzle is provided in such a way; that it will direct a Jet of water on the back of the buckets in opposite direction. It acts as a brake for reducing the speed of the runner.

Working

Nozzles direct forceful, high-speed streams of water against a rotary series of spoon-shaped buckets, also known as impulse blades, which are mounted around the circumferential rim of a drive wheel—also called a runner. As the water jet impinges upon the contoured bucket-blades, the direction of water velocity is changed to follow the contours of the bucket. Water impulse energy exerts torque on the bucket-and-wheel system, spinning the wheel. Thus, "impulse" energy does work on the turbine. For maximum power and efficiency, the wheel and turbine system is designed such that the water jet velocity is twice the velocity of the rotating buckets Typically two buckets are mounted side-by-side on the wheel, which permits splitting the water jet into two equal streams.This balances the side-load forces on the wheel and helps to ensure smooth, efficient transfer of momentum of the fluid jet of water to the turbine wheel.

A wheel power divided by the initial jet power, is the turbine efficiency,

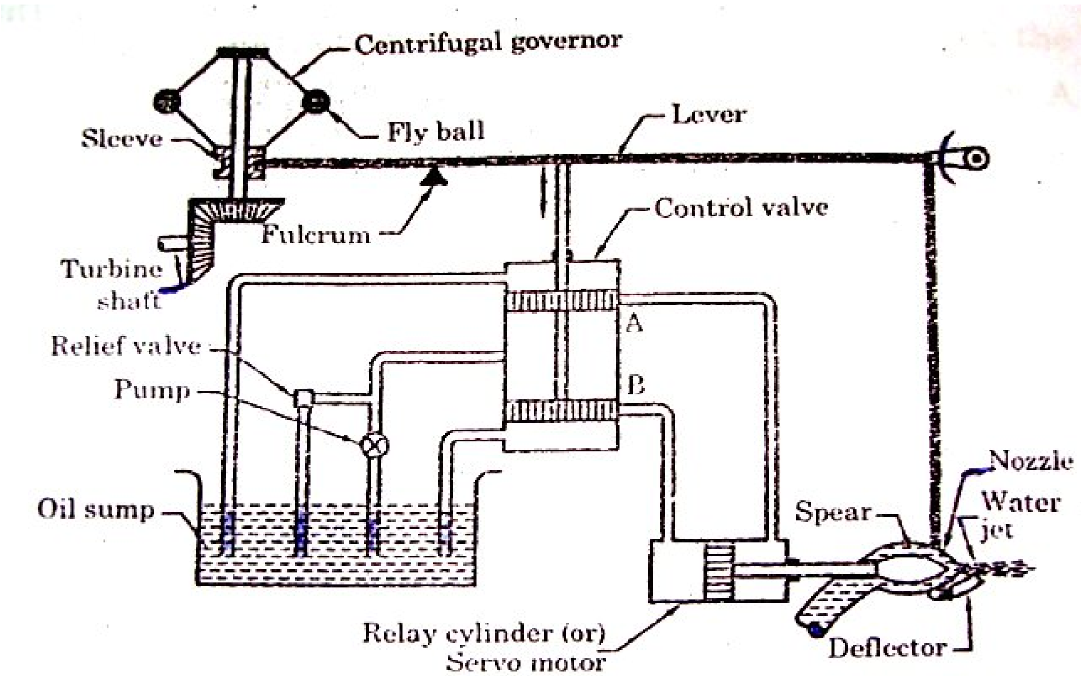
$$\eta = \frac{wheel\ power}{initial\ jet\ power} = 4u(Vi - u) / Vi2.$$

η is zero for u = 0 and maximum for u = Vi.

Where Vi- initial velocity of jet

u- velocity of bucket(wheel)

3.2.6.Governing of pelton wheel turbine



Governing of Pelton wheel turbine

Fig.3.10

Governing of turbine is defined as the operation by which the speed of the turbine is kept constant under various load conditions. i.e control the supply of water with respect to load. The figure shows a line diagram of an oil pressure governor with all its components used in pelton turbine to regulate the speed as shown in fig 3.10.

Working principle of Governing mechanism of pelton wheel turbine

a) When the load on the turbine is constant

When the load on the turbine is constant, the turbine runs at normal speed. The ports A and B of the relay valve are closed by its piston and the lever connected to the sleeve is in horizontal position. In this position, there is no passage for the oil pumped from the pump and hence it is flowing back to the oil sump through the relief valve.

b) When the load on the turbine is decreases

- ➢ When the load on the turbine decreases, the speed start to increase. Due to the centrifugal action, the fly balls of the governor are flying away. This causes the sleeve to move up. The upward movement of the sleeve operates the lever to move upwards about its fulcrum. When the lever is moving upwards, the following actions are taking place.
- ✓ The ball crank lever is rotated about its fulcrum in anticlockwise direction . This causes the deflector to come in front of the nozzle.
- ✓ This prevents the water jet from striking on the runner buckets and diverts the water to tail race.
- ✓ The relay valve piston is moved downwards. This causes the Ports A and B to open.
- ✓ The high pressure oil supplied by the Pump enters into the left side of servomotor cylinder through Port B while right side is connected to sump through port A. Due to the high pressure of oil, the piston of servomotor moves from left to right .This will reduces the nozzle opening by pushing the spear.
- ✓ Thus, the quantity of water impinging on the runner buckets through the nozzle is reduced so as to decrease the speed of runner.
- ✓ When the speed reaches the normal speed, the bell crank lever becomes horizontal.

c) When the load on the turbine is increases

- ❖ When the load on the turbine increases, the speed start to decrease. As the governor speed also decreases, the fly balls of the Governor are moving inwards. This cause the sleeve to move downwards.
- ❖ The downward movement of the sleeve operates the lever to move downwards about its fulcrum. When the lever is moving downwards, the following actions are taking place. The bell crank lever is rotated about its fulcrum in clockwise direction. This causes the deflector to move away from the nozzle. This allows more quantity of Water to impinge on the runner buckets.

- ❖ The relay valve piston is moved upwards. This causes the ports A and b to open. The high pressure oil supplied by the pump enters into the right side of servomotor cylinder through port A while left side is connected to sump through port B. Due to the high pressure of oil, the piston of Servomotor moves from right to left. This in turn increases the nozzle opening by publishing the spear.
- ❖ Thus, the quantity of water impinging on the runner buckets through the nozzle is increased so as to increase the speed of runner. When the speed reaches the normal speed, the bell crank lever becomes horizontal. Thus, the governor maintains a constant speed by regulating both deflectors and spear.

3.2.7.Francis Turbine

The Francis turbine is an inward mixed flow reaction turbine. In this turbine, the water enters into the runner from the guide vane towards the center in radial direction and leaves out of the runner axially. It is suitable for medium head and medium discharge.

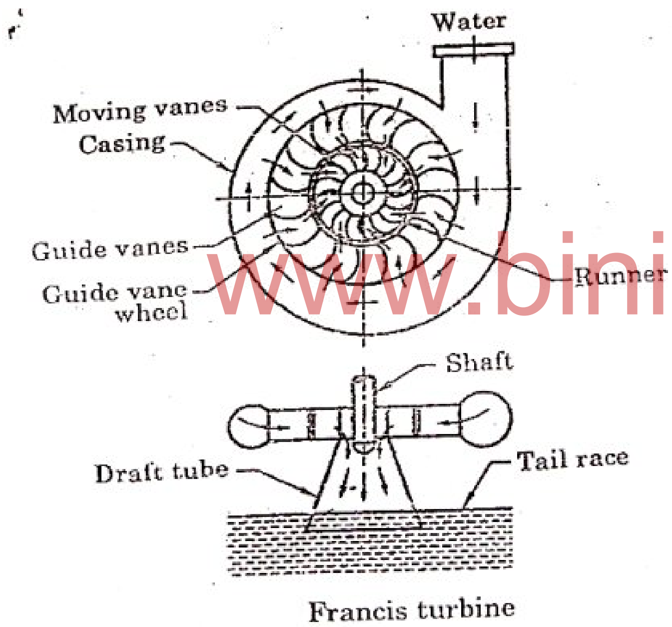


Fig.3.11

Fig.3.12

Construction

- ➢ This turbine consists of a runner (moving vane wheel) which is connected to the turbine shaft. The runner is surrounded by a fixed guide vane wheel as shown in fig 3.11. The guide vane blades guide the water to enter the runner vanes at the correct angle without giving shock to the runner. Each guide vane can be rotated about its pivot, which is connected to ring by means of a link and lever. Thus, the guide vanes can be opened or closed by operating the rig for varying the quantity of water to control the speed of runner. Both the runner and guide vane wheel are enclosed by scroll casing.

- Scroll casing is used to distribute the water evenly around the guide vane. The cross sectional area of casing is gradually decreasing around the circumference from inlet to outlet that no eddies are formed.
- The runner outlet is connected to a gradually diverging tube called draft tube. The water after doing work on the runner, discharges through the draft tube to tail race. The draft tube is submerged to 0.8m below the tail race.

Working principle

The Francis turbine is a type of reaction turbine in which the working fluid comes to the turbine under high pressure and the energy is extracted by the turbine blades from the working fluid. A part of the energy is given up by the fluid because of pressure changes occurring in the blades of the turbine, quantified by the expression of Degree of reaction, while the remaining part of the energy is extracted by the volute casing of the turbine. At the exit, water acts on the spinning cup-shaped runner features, leaving at low velocity and low swirl with very little kinetic or potential energy left. The turbine's exit tube(draft tube) is shaped to help decelerate the water flow and recover the pressure.

3.2.8.Kaplan Turbine

Kaplan turbine is an axial flow reaction turbine. This turbine is similar to Francis turbine except the runner. In this turbine, the water enters into the runner from the guide vane in axial direction and leaves out of the runner in same direction. It is suitable where large quantity of water is available with low head.

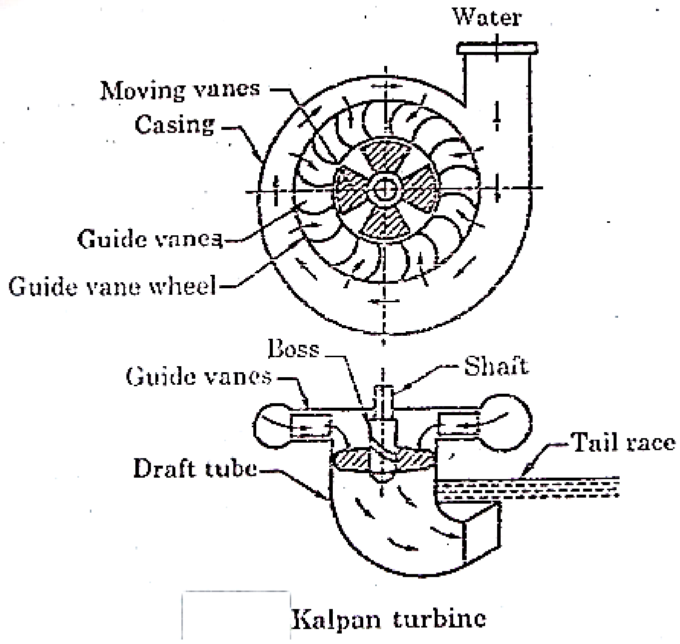


Fig.3.13

Fig.3.14

Construction

The runner of Kaplan turbine is in the form of boss. 3 to 6 (usually4) Blades are fixed on the boss. The blades can be adjusted to any required angle. As the Runner resembles the propeller of a ship, this turbine is also known as propeller engine. The runner is surrounded by a fixed guide vane wheel as shown in fig 3.13 & 14

The guide vane blades guide the water to enter the runner vanes at the correct angle without giving Shock to the runner. Each guide can be rotated about its pivot, which is connected to a Rig by means of a link and lever. Thus, the guide vanes can be opened or closed by Operating the rig for varying the quantity of water to control the speed of runner.

Both the runner and guide vane wheel are enclosed by scroll casing. Scroll casing is used to distribute the water evenly around the guide vane. The cross Sectional area of casing is gradually decreasing around the circumference from inlet. So that no eddies are formed. The runner outlet is connected to a draft tube. The Water after doing work on the runner discharges through the draft tube to tail race.

Working principle

The water from the reservoir is allowed to flow through the penstock pipe and enters the casing. The casing distributes the water evenly to flow through the guide vanes. The guide vanes direct the water to enter the runner in the direction parallel to the axis of the turbine. The force exerted on the blades of the runner causes the shaft to rotate. The water, after doing work, passes to the tail race through the draft tube.

3.2.9.Draft tube

Draft tube is a air tight pipe or passing made out of steel plates or concrete. Its cross section is gradually increasing towards the outlet. One end of this diverging tube is connected to the runner exit and the other end is located below the level of tailrace. It is used only in reaction turbine.

Fig.3.15

Fig 3.16

Functions of Draft tube

1. It decreases the pressure at the runner exit less than atmosphere pressure and thereby increase the working head.
2. The turbine can be installed above the tailrace and hence the Turbine can be inspected and repaired properly.
3. As the working head increases, efficiency of the turbine will increase.

Types of draft tubes

The commonly used important types of draft tubes are given below:

1. Conical draft tube
2. Hydra cone draft tube
3. Simple elbow tube
4. Elbox with circular inlet and rectangular outlet.

1. Conical draft tube

It takes in the form of the frustum of a cone as shown in fig3.17 (a). The diameter of the tube gradually increases from the turbine outlet to the lower end which is immersed in the tailrace. The maximum cone angle is 82° with vertical so as to prevent the possibility of flow separation and for maximum efficiency of 90%. It is more suitable for Francis turbine with low specific speed.

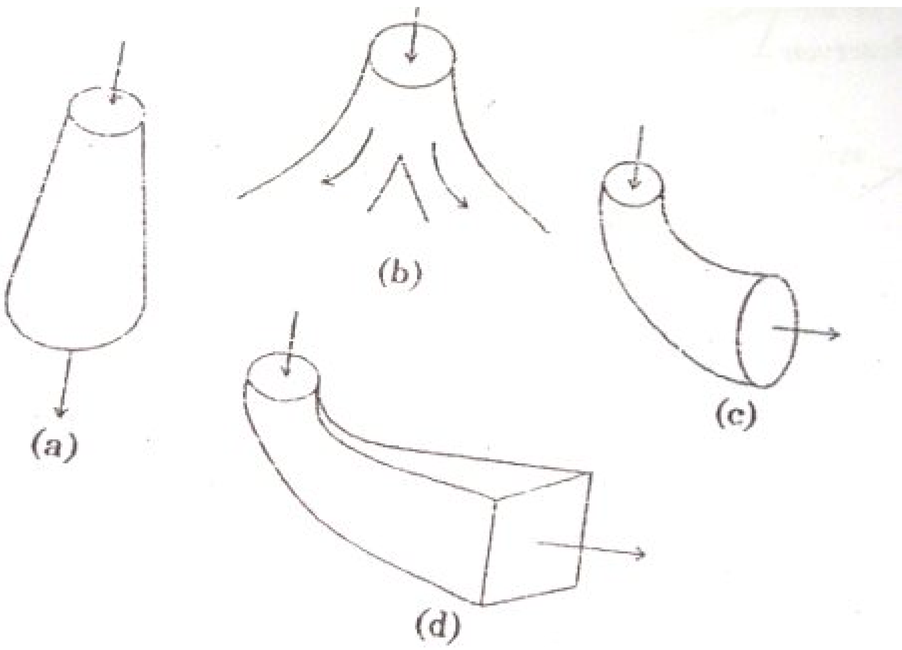


Fig.3.17

2. Hydra cone draft tube (Moody spreading tube)

It is a straight conical tube provided with a flare at the discharged end of tube and central cones as shown in fig 3.17 (b). the central cone spreads the flow evenly and reduces the whirling action of discharged water. It is used where runner exit velocities are quite high and its efficiency is about 80 to 85%.

3. Simple elbow tube

It is a bend conical tube as shown in fig 3.17(c). It is used in place where excavation cost is very high. Its vertical height should be minimized for reducing the excavation cost. It has a maximum efficiency of 60%.

4. Elbow with circular inlet and rectangular outlet

It has a circular section at inlet and rectangular or square section at outlet which is immersed in the tailrace. It is shown in fig 3.17(d). It also reduces the vertical height and reduces the excavation cost. It is generally used in Kaplan turbine and has a maximum efficiency of 85%.

3.2.10. Surge Tank

Importance of Surge Tank

Rapid velocity fluctuations occur in pipe lines during

1. Sudden closure and opening of valves.
2. Start and shut down of a turbine.
3. Closure of wicket gates.

Due to the rapid velocity fluctuations, high pressure waves are setup in the penstock pipe which produces noise similar to hammering sound. This phenomenon is called water hammer or hammer blow. It may lead to bursting of pipes. Hence, the device called surge tank is provided on the penstock to sage guard the penstock against bursting.

Therefore, surge tank is a storage reservoir which receives the rejected water when turbine load decreases and supplies the water. when Turbine load increases to maintain a constant flow rate to the turbine as shown in fig3.18.

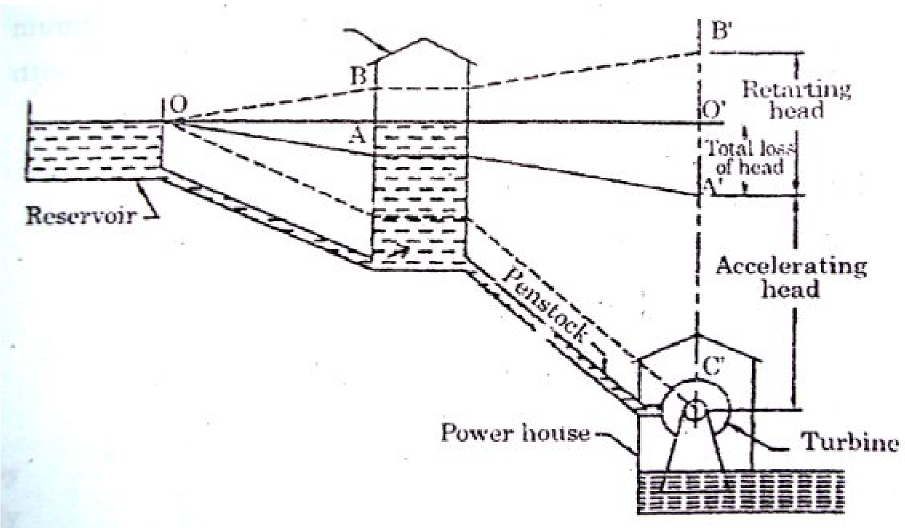


Fig.3.18

Function of surge tank

- To relieve the excess pressure setup in the penstock due to sudden closing of valve in the turbine and eliminates the water hammer effect.
- To store the rejected water when load on turbine decreases.
- To supply sudden requirement of water to the turbine when Load on turbine increases.
- To maintain a constant speed of the turbine by regulating the flow of water to the turbine.

Location of a surge Tank

The most suitable place to locate the surge tank in the Penstock pipe is very close to the turbine in case of medium and high head Turbines, if the surge tank is located near the turbine, the water will over flow through the surge tank, as the head race water level is higher than that of the surge tank. In such cases, if the over flow is to be prevented then the Surge tank has to be made very high, up to the level of head race water. Construction of surge tank to such a large height is practically difficult and hence it is located at the entrance of the penstock pipe.

Principles of surge Tank

When the turbine is running at steady load, there will be no surge in the flow of water through the penstock. Referring to the fig 3.10 .at steady load conditions,

The pressure gradients = OAA'
Total loss of head between reservoir and turbine = O'A'
Operating head = C'A'

When the load on the turbine is reduced, the speed of the Turbine tends to increase. But the governor immediately closes the gates of the Turbine, thus diverting the main flow into the surge tank. The water level in the Surge tank rises until it exceeds level in the reservoir.

Function of surge tank

1. Collects water and acts as storage reservoir.
2. Relieves the pressure at its top and
3. Provides retarding head to the main flow.

The pressure gradient = OBB'
Retarding head = A'B'

Working principle

When the load on the turbine is increased the speed of the Turbine tends to decrease. Then the surge tank provides sufficient water to the turbine in addition to the penstock flow, until the water level falls below its original level. Therefore the surge tank,

1. Supplies water to the turbine and
2. Provides accelerating head to the flow through Penstock.

Then, pressure gradient = OCC'
Accelerating head = A'C'

3.2.11.Types of surge Tank

There are three common types of surge tanks.

They are,

1. Simple surge tank

This is the most simple types of surge tank. It consists of A cylindrical tank connected to the penstock by a short length of Pipe is shown in the fig 3.19. The diameter of the tank is govern med by,

1. Making the area sufficient to ensure stability and
2. To store and provide sufficient retarding accelerating head

The disadvantages of this type are:

1. Un-economical due to its large size.
2. Its action is sluggish and
3. Most expensive.

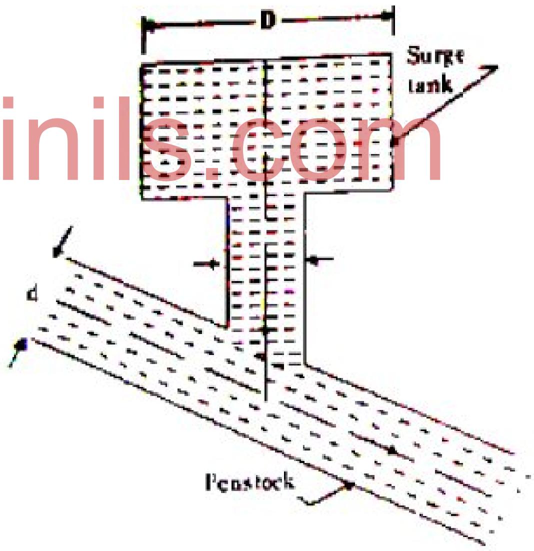


Fig.3.19

2. Restricted orifice type

This is a modification of a simple surge tank. It improves the damping action and minimizes the cost. The tank size can be greatly reduced by introducing a restricted orifice as shown in the fig.3.20. The purpose of this orifice is to create a applicable frictional loss when the water is flowing to or from the surge tank.

When the load on the turbine is reduced, surplus water passes through the restricted orifice and a retarding head equal to the loss of head is built up in the conduit. The size of the orifice can be designed to any desired retarding head.

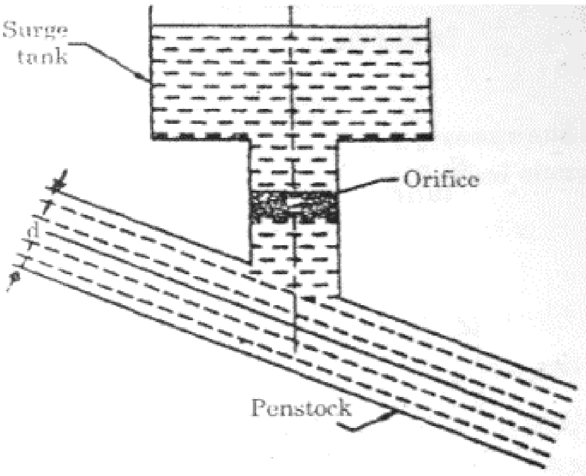


Fig.3.20

3. Differential surge tank

Fig 3.21 represents a differential type of surge tank. It consists of a cylindrical tank with central riser whose area is equal to that of the penstock pipe. The riser is connected to the tank by ports at its base. On changes of load the water level in the riser, rises or falls very rapidly thus providing a rapid acceleration and retardation of the penstock flow. When the pressure in the pipe line is increased a small quantity of water enters the surge tank through the ports but the large volume of water flows vertically upwards through the riser and then spills over into the tank. This produces considerable retardation, but in the tank the heads buildup gradually as the tank fills up.

The advantages of this surge tank over the other types are,

1. Simple in construction.
2. Smaller capacity is required for producing the same Effects.
3. No water is spilled over to waste.

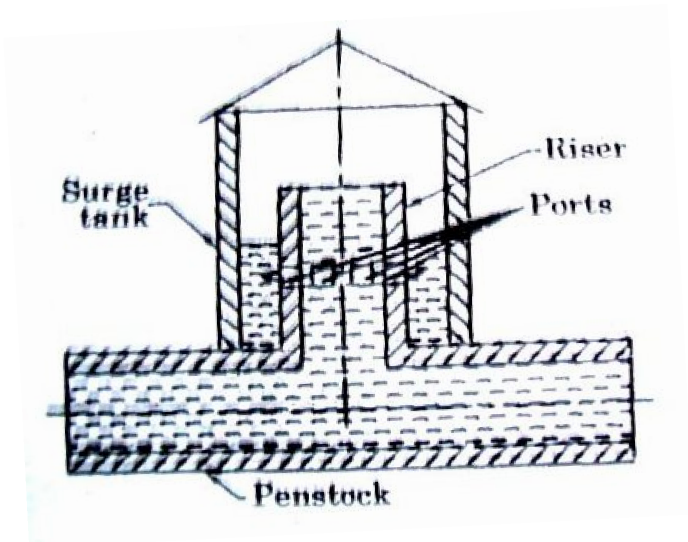


Fig.3.21

3.2.12.Comparison between Impulse and Reaction Turbine

S.No.	Impulse Turbine	Reaction Turbine
1.	All the available energy of water is converted into kinetic energy before entering the turbine blades. Then the kinetic energy is converted into mechanical energy when the water flows through the blades.	Both the pressure and kinetic energies of water are converted into mechanical energy when it passes through the turbine blades.
2.	The pressure of water in the turbine is atmospheric pressure.	The pressure of water through the turbine is gradually reduced when it passes through the blades.
3.	The water impinges on the buckets, with kinetic energy.	The water glides over the blades with pressure energy.
4.	The Jet of water coming out from the nozzle impinges on the buckets.	The guide blades are used to direct the water through the moving blades without giving shock to the turbine wheel.
5.	Since the pressure in the turbine is atmospheric pressure it is not necessary that the turbine should run full.	Since, the water flows through the turbine with pressure, it is necessary that the turbine should run full.
6.	It is possible to regulate the flow without loss.	It is not possible to regulate the water without loss.
7.	This turbine does not require an air tight casing. But, casing is used, just to prevent the accidents caused by falling bodies.	Since, the water flows through the blades under pressure it requires an air tight cover. In other words the casing of the reaction turbine performs the hydraulic function.
8.	Used for high heads.	Used for low and medium heads.

3.2.13.Comparison of Francis Turbine and Kaplan Turbine

S.No	Francis turbine	Kaplan turbine
1.	It is an inward mixed flow reaction turbine.	It Is an axial flow reaction turbine.
2.	The numbers of vanes in the runner are between 16 and 24.	The numbers of vanes in the runner are between 3 and 6.
3.	The vanes in the runner are fixed	The vanes in the runner can be adjusted to any angle.
4.	The water flows over the runner vanes radially.	The water flows over the runner vanes axially.
5.	It is suitable for medium head.	It is suitable for low head.
6.	Efficiency is low as the vanes are fixed,	Efficiency is high as the vanes are adjustable.

EXERCISE

3.2.14.THEORATICAL QUESTIONS

Part – A (one mark & three marks)

1. What is a water turbine?
2. What is the energy conversion in turbines?
3. Write the example for impulse turbine.
4. Write the example for reaction turbine.
5. Name the turbine where the water enters radially and leaves the runner axially.
6. What is the range of Low Head Turbine?
7. Write any one difference between Kaplan and Francise turbine.
8. What is the function of draft tube?
9. Name the device which is used to relieve the excess pressure in penstock.
10. What are different types of surge tank?
11. What are different types of draft tubes?
12. What is a reaction turbine?
13. Name the type of turbine where both pressure and kinetic energy of water converted into mechanical energy.
14. Define Impulse Turbine.

Part – C(Five marks & ten Marks)

1. With a help of neat sketch, explain the working of a pelton turbines.
2. What is dynamic brake in pelton wheel? State its uses.

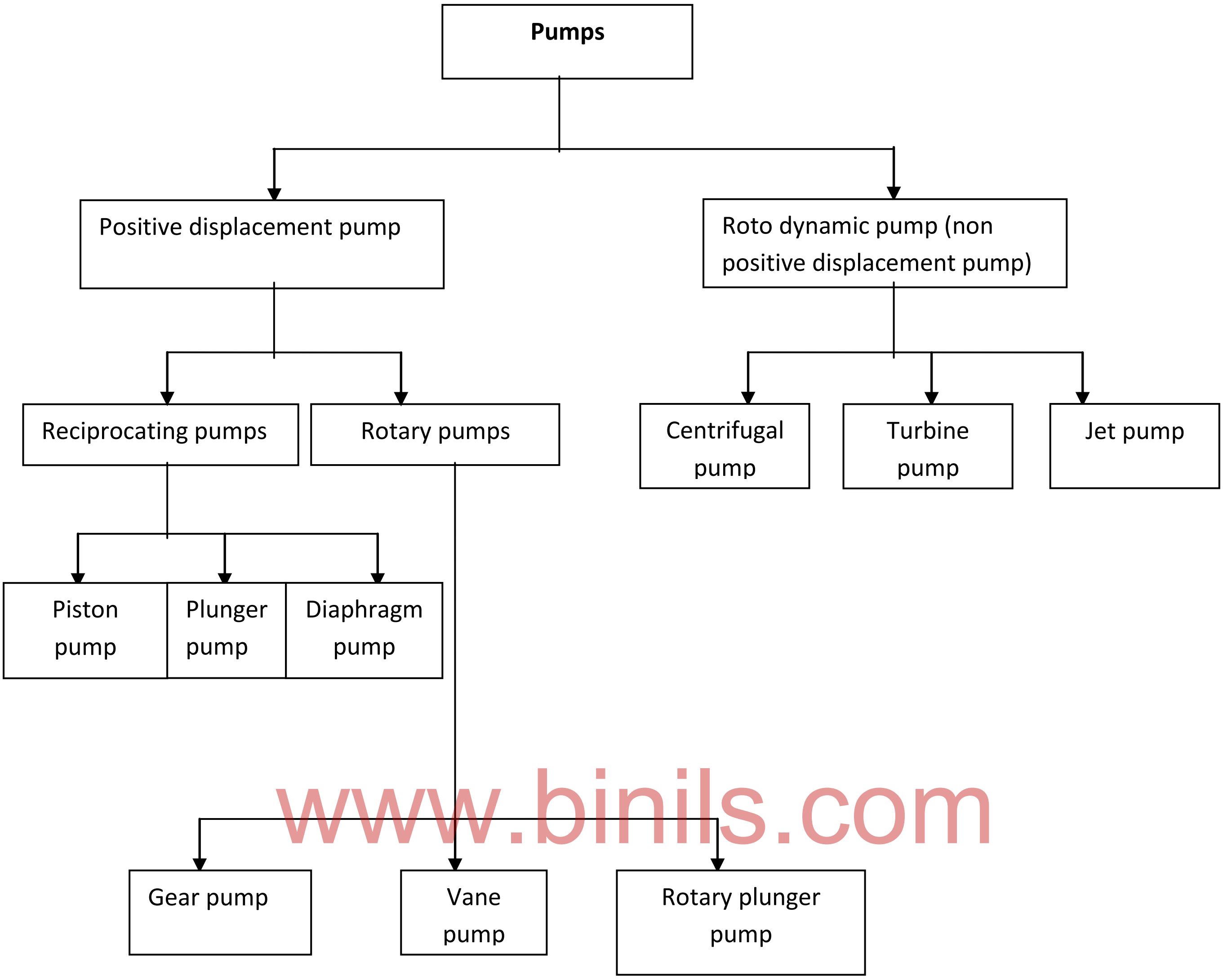
3. What are difference between impulse and reaction turbine?
4. Explain the construction and working of a francise turbine with a neat sketch.
5. Explain the construction and working of Kaplan turbine.
6. Describe with sketch, two different types of draft tubes. States its functions.
7. Differentiate between turbines and pumps.

3.3. CENTRIFUGAL PUMP

3.3.1.Introduction

It may be defined as a mechanical device which coverts mechanical energy into Hydraulic energy. Generally pumps are used to lift liquids from a lower level to a higher level. Pumps are used in agriculture, power plants, municipal water works and many other utility services.

3.3.2.Classification of pumps



Centrifugal Pumps

Centrifugal pumps is a mechanical device that converts mechanical energy into pressure energy by means of centrifugal force.It has a rotating element called impeller. The impeller gives energy to raise the liquid from a lower level to higher level.

Classification of centrifugal pump

1. According to the type of casing
   a) Volute
   b) Vortex
   c) Diffuser (or) Turbine pumps.
2. According to the direction of flow through impeller.
   a) Radial flow pump
   b) Mixed flow pump
   c) Axial flow pump
3. According to the number of impellers

a) Single stage pump
b) Multi stage pumps

4. According to the construction of Impellers
a) Closed impeller pumps
b) Semi closed impeller pumps
c) Open impeller pumps

5. According to the position of shaft
a) Horizontal pumps
b) Vertical pumps

6. According to the working head
a) Low head pumps
b) Medium head pumps.

3.3.3.Element of centrifugal pumps.

1.Impeller

Rotating part of a centrifugal pump is called impeller. Impeller is a circular disc provided with a number of curved vanes (Or) blades. It is fitted to a shaft, driven by the power from an external source.

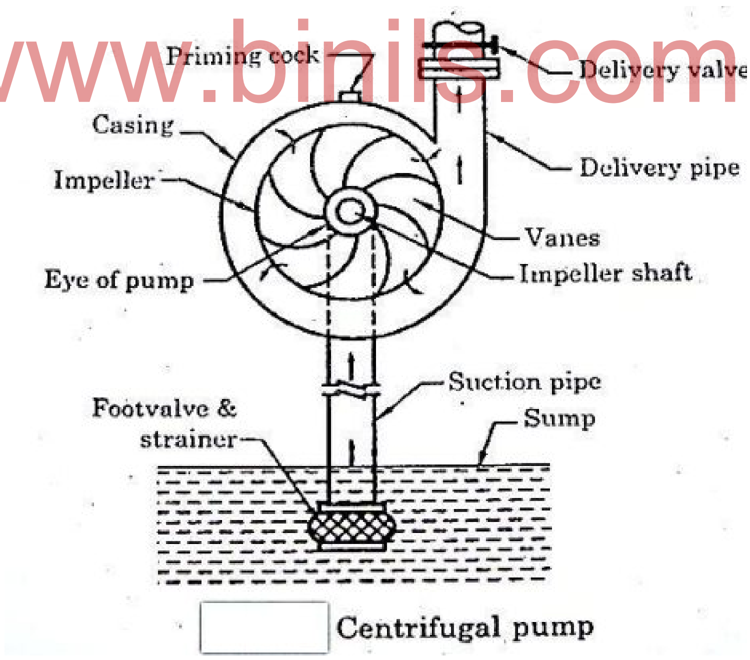
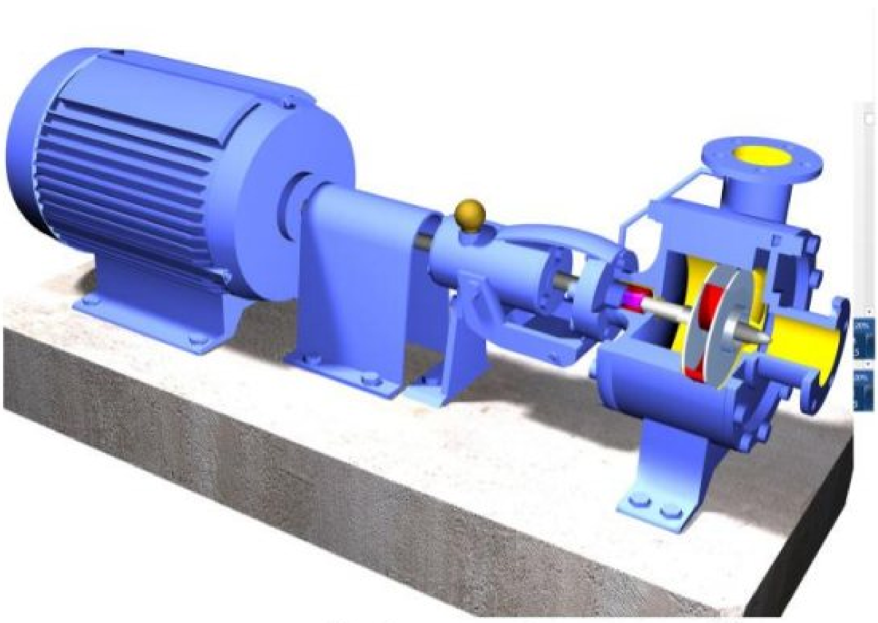


Fig 3.23



Centrifugal pump with motor assembly

Fig.3.24

A centrifugal pump consists of the following elements as shown in fig.3.23 & 24

3.4.Casing

- Casing is an air tight chamber.
- Impeller is surrounded by a chamber known as casing.
- It is designed with a gradually increasing area.

Function of casing

i. Casing is used to collect the liquid from the impeller and to transmit it to delivery pipe.
ii. To convert the kinetic energy of the liquid into pressure energy.
iii. To reduce the loss of energy due to turbulence in the casing.

Types of casing

i. Volute casing
ii. Vortex casing
iii. Diffuser casing

Suction pipe

The upper end of the suction pipe is connected to the inlet of the pump. The lower end of the suction pipe is submerged into the Water sump.

Delivery pipe

- Lower end of the delivery pipe is connected to the outlet Of the casing.

- Upper end delivers the water at required level.

Strainer

Strainer is connected to lower end of suction pipe. So, as to prevent the entry of solid particles such as leaves wooden pieces etc., into the pump.

Foot valve

- Foot valve is a Non-return valve located above the strainer.
- It serves to fill the pump with the liquid before it is started.

Prime mover

Prime mover is usually an Electric motor (or) an oil engine. It rotates the impeller inside the casing.

Working principle of centrifugal pump

Before starting the centrifugal pump, the air present inside the Casing and suction pipe should be removed. The process of filling up water in the suction pipe, casing and a Portion of delivery pipe to remove the air is called priming. After priming the Impeller is rotated by a prime mover. The rotary motion of Impeller blades courses a centrifugal force to act on the liquid. Due to centrifugal liquid flows in a radially outward direction through the impeller blades with a very high velocity. As the liquid flows along the spiral casing, its kinetic energy is gradually converted into pressure energy. The high pressure water is discharged through the delivery pipe to the required height.

3.3.5.Types of casing

The liquid leaving the impeller is having very high velocity. This high velocity liquid produces eddy currents in the circular casing which will result in loss of kinetic energy and reduce efficiency.

To increase the efficiency of the pump, the kinetic energy of kinetic energy of kinetic energy of liquid is converted into pressure energy while it is flowing through the casing. Therefore, the pump casing is so designed to minimize the loss of kinetic energy in order to increase the efficiency. There are three types of casings commonly used. They are,

i) Volute casing
ii) Vortex casing (or) whirlpool casing
iii) Turbine (or) diffuser casing.

1. Volute casing

Fig 3.25.a . shows sectional view of a volute casing. The impeller is surrounded by a casing of spiral shape and hence it is called a spiral casing or volute casing. The liquid leaving the impeller flows through the volute chamber. As the area of flow increases, the velocity decreases. Consequently the pressure increases. When it reduces the outlet of the casing the velocity is considerably, reduced the pressure is increased. When the velocity of liquid is reduced by volute casing.

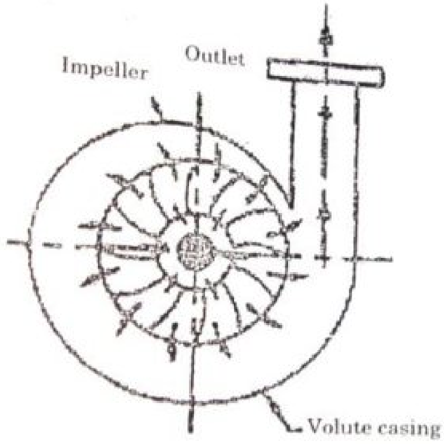


Fig.3.25 .a

Fig.3.25.b

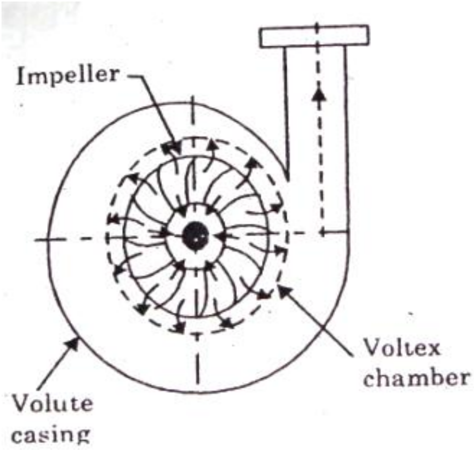
1. The pressure at outlet of casing is increased, as a result the liquid raises to a greater height.
2. Loss of kinetic energy which would occur if a circular casing is employed is avoided.However, this type of casing increases the efficiency of the pump only to a small extent.

2. Vortex or whirlpool casing

This is an improved type of volute casing. The impeller is surrounded by a casing which is a combination of a circular and volute casing as shown in the fig3.26.a. Such casing is known as vortex or whirlpool casing.

When the liquid flows through this type of casing, the velocity of whirl is reduced in building up of assume.

In this type of casing, there is better conversion of kinetic energy into pressure energy. Hence an increased efficiency is obtained by means of this type of casing.



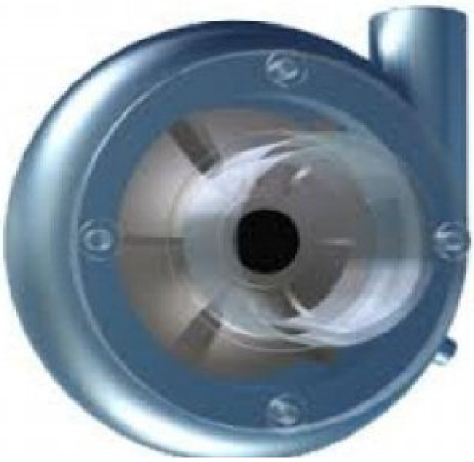


Fig.3.26.a

Fig.3.26.b

3. Turbine or Diffuser casing

In this type of pump, the impeller is surrounded by a guide ring. The space between the guide blades is gradually increasing and acts as a diffuser. Hence it is often referred to as diffuser pump. The guide blades are fixed at such an angle that liquid enters without shock. It is surrounded by a circular chamber through which the liquid reaches the delivery pipe a shown in fig.3.27.a.

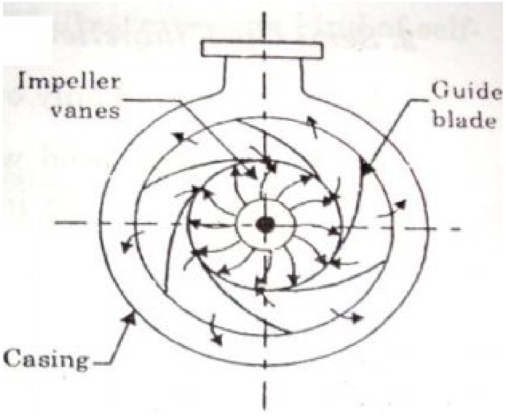
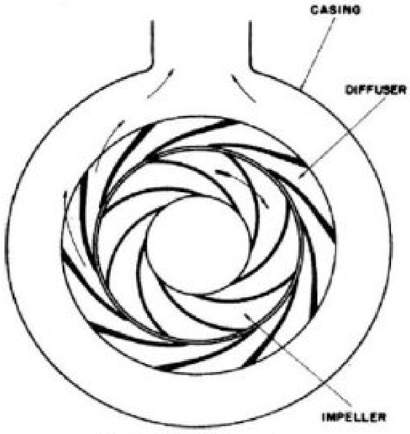


Fig.3.27.a



Typical diffuser-type pump.

Fig.3.27.b

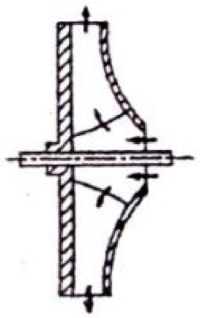
The pump fitted with guide blades is known as turbine pump since it resembles an inward flow reaction turbine. This type of pump is used where the total head against which the pump works is more than 60m. Generally this arrangement is used in multistage pumps.

3.3.6.Types of Impeller

A centrifugal pump have many types of impellers depending upon the viscosity and type of liquid used in centrifugal pump. They are:

Fig.3.28.a **Fig.3.28.b** **Fig.3.28.c**

1. Closed impeller

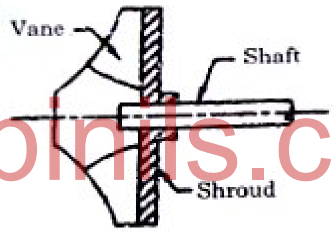


Closed impeller

Fig.3.28.a.

It has shrouds on both sides. It is used for handling, non viscous pure liquids such as water, oil, chemicals and acids. Material of the impeller depends upon the liquid to be handled. Hot water – cast steel, Chemicals and acids – Non ferrous materials coated with stone. Liquid must be free from foreign materials or debris.

2. Semi open impeller



Semi open impeller

3.28.b

It has shroud only on one side. This type is used when non clogging is more important than the efficiency. Used for handling liquids such as sewage water, paper pulps, cane and sugar molasses etc.

3. Open impeller

Vanes have no shrouds. Vanes are attached to a web plate which fixed to the shaft. Used to handle the liquids having coarse debris as in sewage disposal, mud and clay etc. Vanes are made of Cast steel.

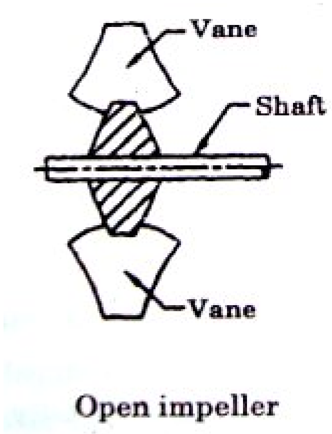


Fig.3.28.c

3.3.7.Multistage Centrifugal pump

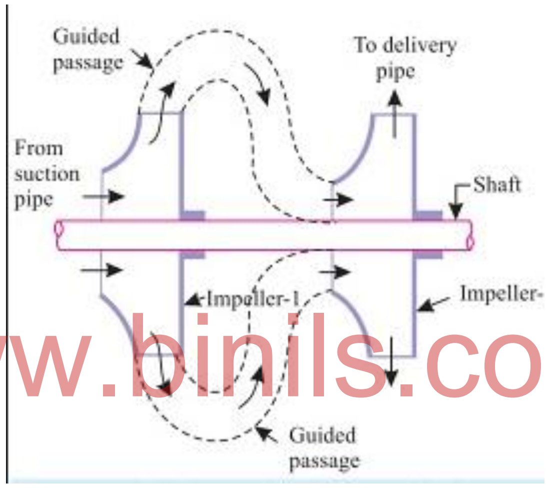


Fig.3.29.a Series

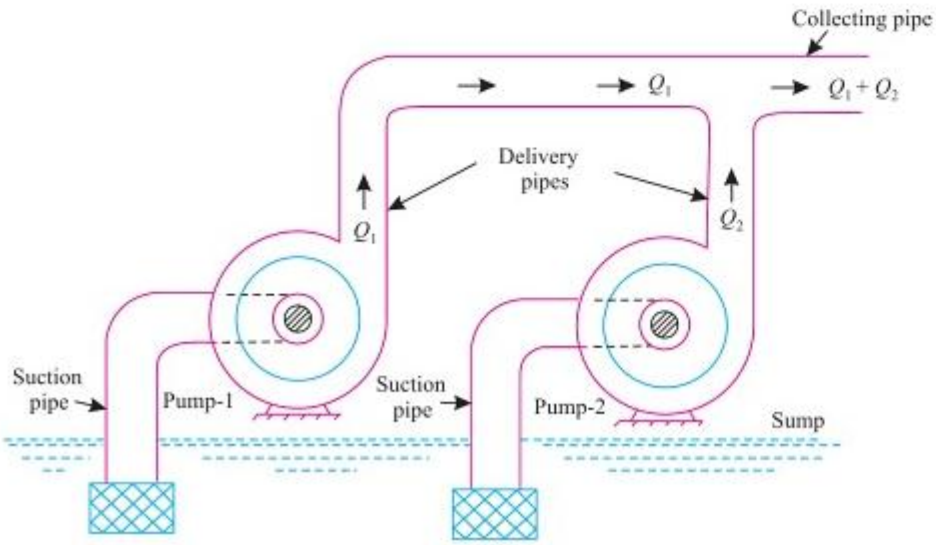


Fig.3.29.b Parellel

For a given discharge and diameter of the pump, the head developed is proportional to the square of the speed. If the head to be developed is more, the speed should be considerably increased. But too much speed is not desirable because,

1. Cavitations may occur.
2. Centrifugal stress induced in the impeller is too high.
3. High speed may result in high velocity. Therefore turbulence and frictional losses will be more.

Because of the above said reasons, multistage pumps are designed.

A multistage pump is called as Two Stage pump when it has two impellers mounted on the same shift. Their casings are arranged in series as shown in the fig.3.29.a & b . The delivery from the first impeller is guided into the inlet of the second impeller. The delivery from the second impeller passes into the delivery pipe. As the liquid flows through each impeller the manometric head 'H' is impressed on it. Suppose if there are 'n' impellers then the total head developed will be 'nH'. The same discharge 'Q' passes through all the impellers and is finally delivered into the delivery pipe. The impellers are surrounded by guide vanes which deflects the water into the eye of the next impeller.

Advantages of multistage pumps

- Head per stage is less. Hence leakage losses are avoided.
- Speed is not high.
- Efficiency of the plant will be increased.
- Head per stage is small. Hence the impeller size will be small.
- Pump the fluid to considerable height

3.3.8.Priming

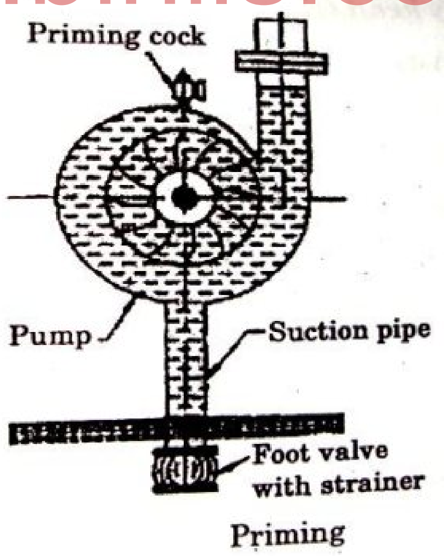


Fig.3.30

When the centrifugal pump is stopped, the pump casing and suction pipe are occupied with air. Then it will not start again, since vacuum will not be created due to presence of air in the casing. Hence priming is always necessary in centrifugal pump before starting. Removal of air present in the casing, impeller and suction pipe by filling in the pump with liquid is known as priming as shown in fig.3.30.

3.3.9.Self – priming Device of centrifugal pump

In centrifugal pump priming is necessary in every time when the pump has to be started. Self-priming device overcomes this difficulty. The Fig.3.31. illustrates one kind of self-priming devices. In this type, a specially constructed priming tank is provided between the suction pipe and pump. The pump is connected to the bottom of priming tank while its top is connected to the suction pipe.

After the installation of priming devices, the priming tank is filled with water through priming valve up to air valve as shown in fig. For quick filling of water, the air valve must be opened at that time. Then the priming valve and air valve are closed and the pump is started. Now the pump works and sucks the water in the priming tank and produces a partial vacuum in the priming tank even if the air is present in the suction pipe. Now this partial vacuum draws water from suction pipe with air. After some time the pump delivers water only.

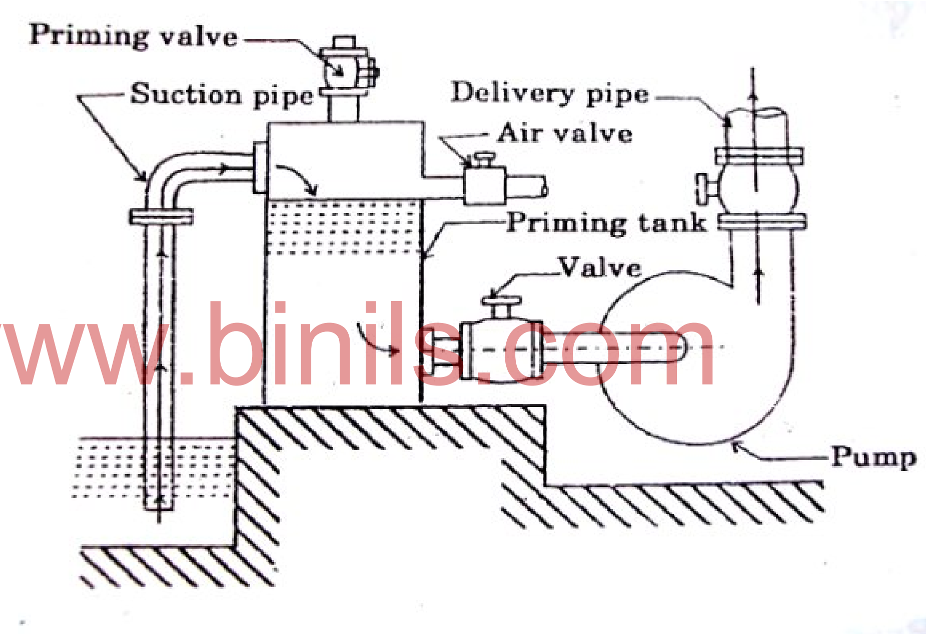


Fig.3.31

When the pump has to be stopped, the water in the suction pipe may passes entirely to the sump through foot valve if it has leakages. But the casing is always filled with water. Hence, now the motor is started, the same operations are repeated and deliver the water. Therefore pump does not require priming for every restarting of the motor.

3.3.10.Cavitations

Cavitations may be defined as the phenomenon of formation of water bubbles at low pressure side and collapsing of these water bubbles at high pressure side. This is called cavitations.

Effect of cavitations

1.Due to sudden collapse of vapour bubbles, considerable noise and vibrations are produced.

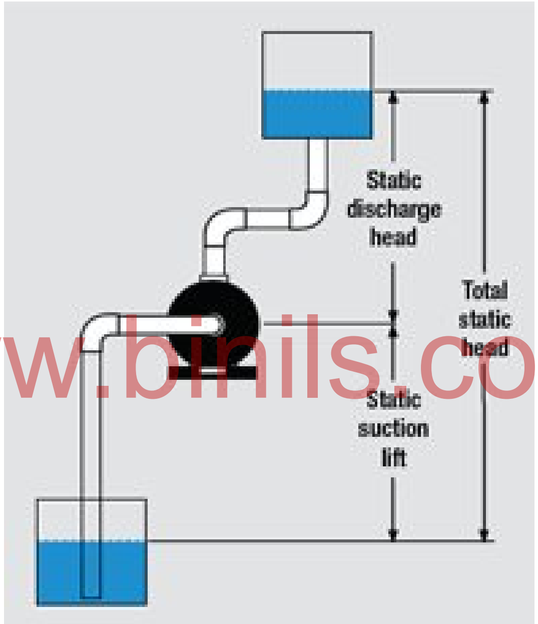
2.Metallic surfaces of the impellers are damaged and cavities are formed on the surfaces.

3.Reduce the efficiency.

Precaution against cavitation

1. Velocity in the suction pipe should be low.
2. Suction head is 5m to 6m.
3. Reduce the pump speed reasonably.
4. Sharp bends in suction pipe should be avoided.
5. To reduce turbulence.

3.3.11.Head of the pump



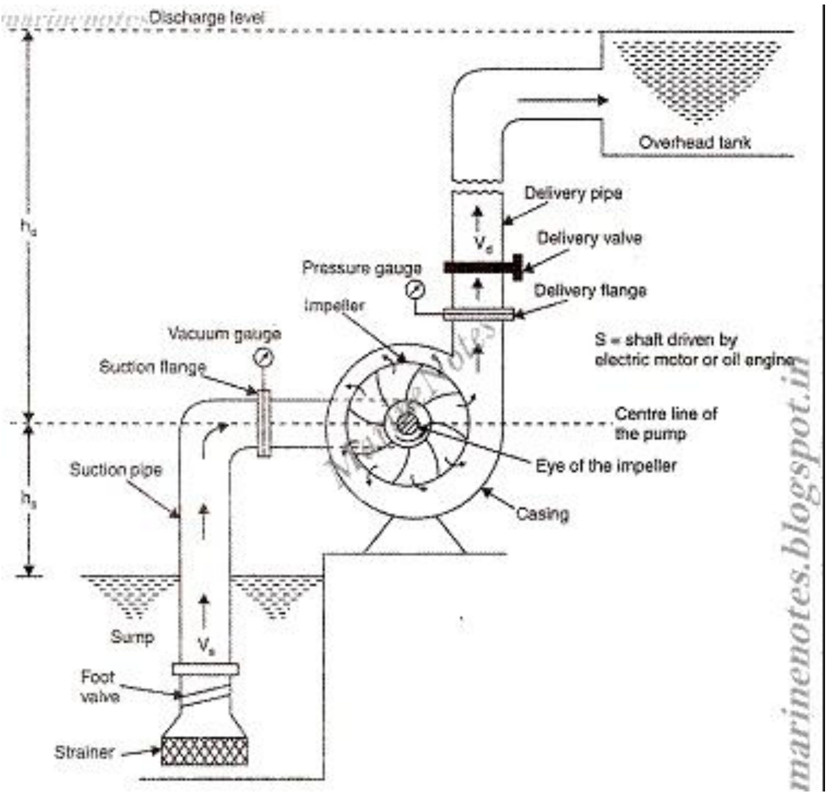


Fig.3.32.

Suction head

Suction head is the vertical distance between the centre of the pump and water surface in the sump. It is denoted as H_s. Head of the pump as shown in fig.3.32.

Delivery head (Hd)

Delivery head is the vertical distance between the centre line of the pump and a point to which water is delivered. It is denoted by $\mathbf{H_d}$

Static head

1. Static head is the sum of suction and delivery head.
2. It is denoted by H_{static}.
   $H_{static}. = H_s + H_d$

Manometric head (Total head)

1. This is the actual head against which the pump has to work.
2. It is denoted by H_m.
   $$H_m = H_s + h_{fs} + H_d + h_{fd} + Vd^2/2g$$

Manometric Efficiency = $\frac{output\ of\ pump}{work\ done\ by\ impeller}$

$$\eta_{mano} = \frac{H_{mano}}{\frac{V_{w2}u_2}{g}}$$

V_{w2}-velocity of whirl

u_2-tangential velocity of impeller

Mechanical efficiency

Mechanical Efficiency $\eta_{mech} = \frac{Workdone\ by\ Impeller}{Work\ supplied\ by\ motor}$

Overall efficiency $\eta_o = \eta_{mano} \times \eta_{mech}$

3. 3.12.Exercise

Part – A (one mark & three marks)

1. What is centrifugal pump?
2. What are different types of casing?
3. What are different types of impeller?
4. What is the name of the champers used to surround the impeller?
5. What is priming?
6. What is meant by cavitation?
7. Define manometric efficiency.
8. Define mechanical efficiency.
9. Define overall efficiency.
10. State the function of casing in the centrifugal pump.
11. State the function of foot valve in the centrifugal pump.
12. State the function of strainer in the centrifugal pump.
13. Write any one advantages of multi-stage pump.
14 State the classification of centrifugal pump.
15. State the components of centrifugal pump.
16. Why is priming important in centrifugal pump.
17. Why the suction lift of a centrifugal pump is limited.
18. How the vortex chamber is superior in performance.
19. Explain the need of a foot valve in a centrifugal pump.
20. How cavitation is prevented.
21. State the causes of cavitation.
22. State the advantages of multistage.
23. Describe the multistage pump with impellers in parallel.

Part-B (five marks & ten marks)

1. Explain with a neat sketch the construction and working of a single stage centrifugal pump.
2. Explain with sketches, the construction and working of a volute casing and diffuser casing in centrifugal pump.
3. Briefly explain any one type of casing of a centrifugal pump.
4. Explain the need of foot valve in centrifugal pump.
5. What are the various of efficiencies of a centrifugal pump?
6. What is priming? Why it is necessary? Draw a neat sketch of a self priming pump and explain its working principle.
7. Explain the working of multistage centrifugal pump state the reason for multistaging.
8. What is meant by cavitation? State its causes and how it is prevented?

3.4. RECIPROCATING PUMP & SPECIAL PUMPS

3.4.1.Introduction

- A reciprocating pump is a positive displacement pump.
- The positive displacement pump the liquid is transferred positively by to and from motion of a member known as piston (or) plunger of the pump.

3.4.2.Classification of reciprocating pump.

1) According to the number of cylindrical provided.
   - Single cylinder pump.
   - Double cylinder pump.
   - Triple cylinder pump.
   - Duplex double acting pump.
2) According to the water being in contact
   - Single acting pump
   - Double acting pump

Single acting Reciprocating pump

When the liquid pressure is acting on only one face of the piston then the pump is known as a single acting reciprocating pump. The pump has one suction pipe and delivery pipe on only one side of the cylinder as shown in fig 3.33.

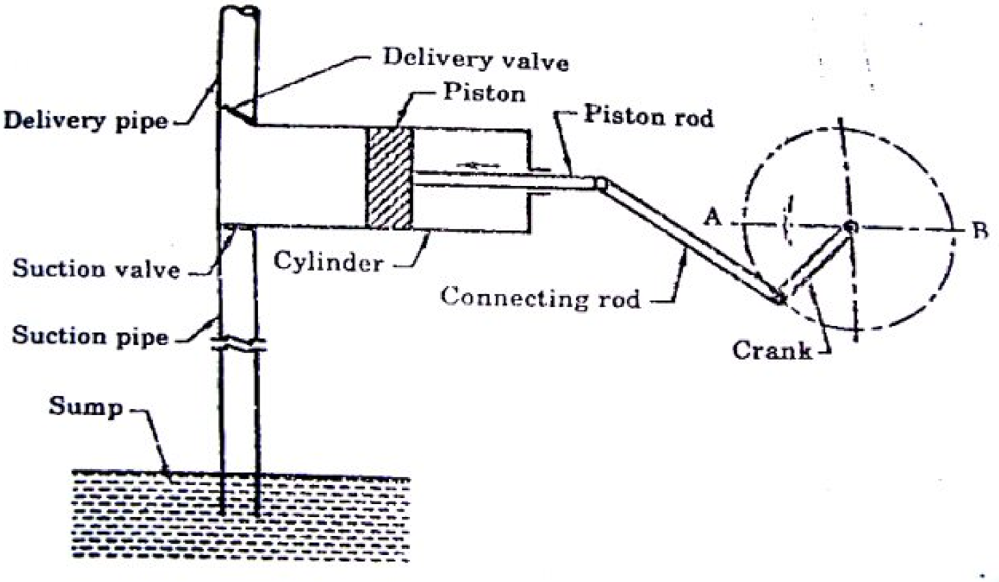


Fig.3.33.a

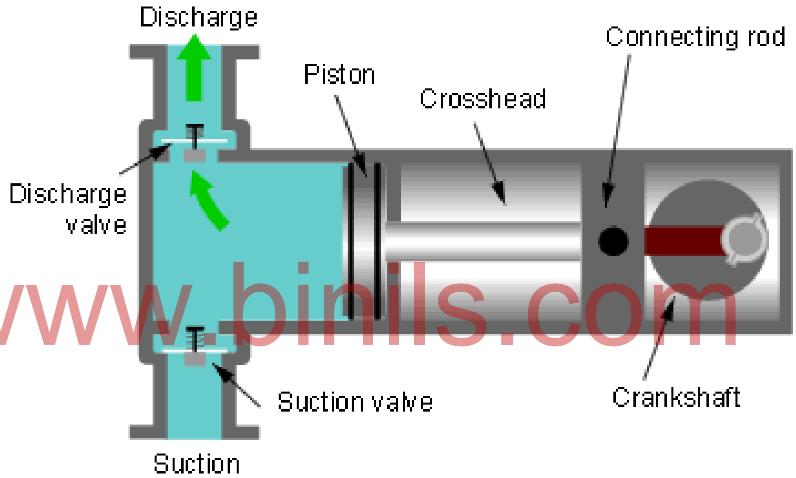


Fig.3.33.b

Construction

A reciprocating pump consists of the following parts.

1. Cylinder
2. Piston (or) plunger
3. Crank
4. Crank shaft
5. Connecting rod
6. Suction & delivery pipe with non-return valves.

The piston reciprocates inside the cylinder. The reciprocating motion of the piston is obtained by connecting the piston rod to a crank by means of a connecting rod. An Electric motor rotates the crank. One end of the suction pipe is immersed into the sump and another end is fitted to the bottom of the cylinder with a suction valve. The delivery pipe is connected to the top of the cylinder with a delivery valve. Both suction and delivery valves are one way valves.

Working principle

Suction stroke

During this stroke, the crank rotates from A to B in clockwise direction. The piston is moved from left to right by means of connecting rod. This creates a vacuum inside the cylinder. Due to the low pressure, the suction valve opens and the liquid from the sump enters into the cylinder through suction pipe and suction valve. Delivery valve remains closed during suction stroke.

Delivery stroke

During this stroke, the crank rotates from B to A in clockwise direction. This piston is moved from right to left. Due to the high pressure, the delivery valve opens and the liquid is delivered to the required height through the delivery valve and delivery pipe.Suction valve remains closed during delivery stroke. The same cycle is repeated as the crank rotates.

Double acting Reciprocating Pump

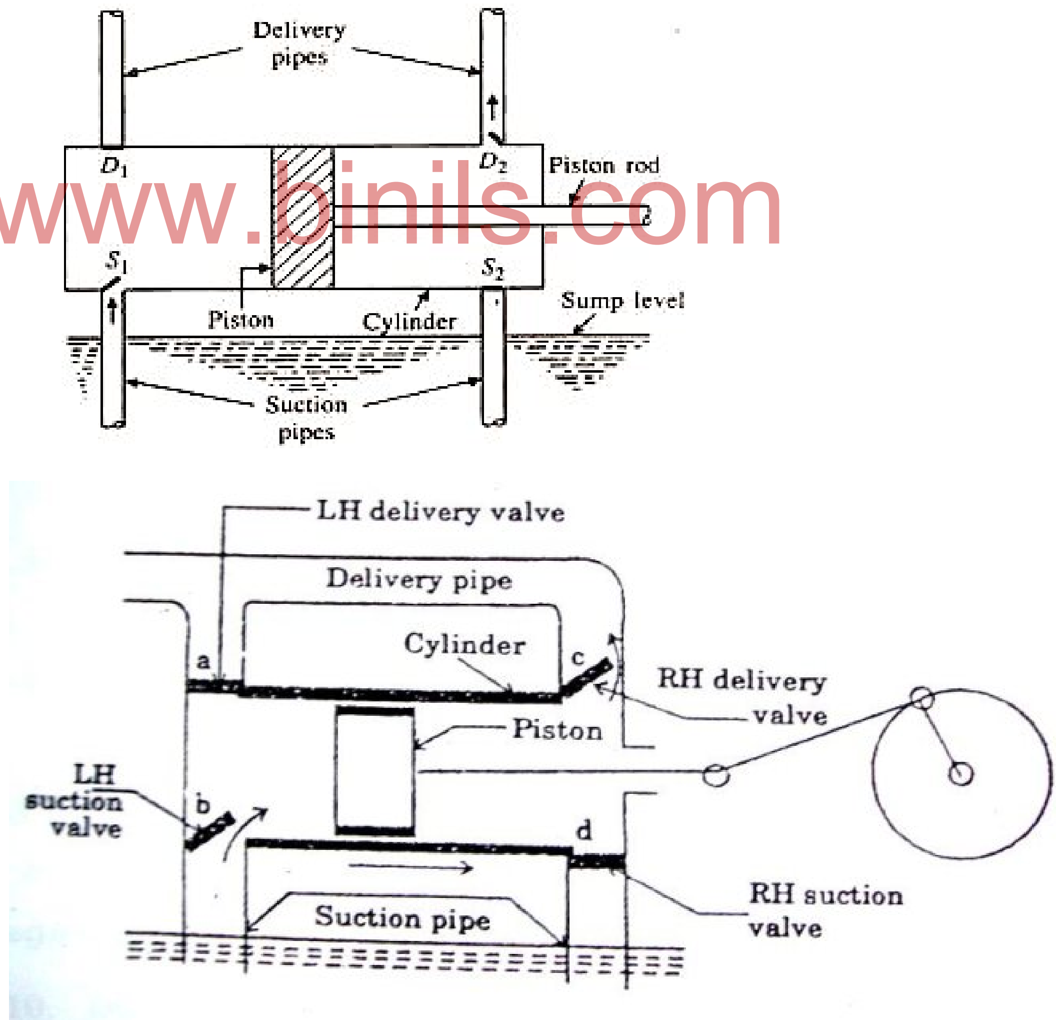


Fig.3.34.

This pump is said to be double acting, when the liquid pressure acts on both sides, of the piston (or) plunger. Two suction and delivery pipes with non-return valves are provided on each end of the cylinder as shown in fig. Since both the end of cylinder is closed, the piston is connected to a crank through a cross-head. When the crank starts rotating, the piston or plunger reciprocates inside the cylinder. When the plunger or piston moves from left to right, the following two activities are taking place as shown in fig.3.34.

1. The partial vacuum is created inside the cylinder on the left side of the piston or plunger.
2. Therefore, the atmosphere pressure acting on the liquid surface forces the liquid into the cylinder through suction pipe, by opening the suction valve ‘b’ (refer fig .)

The liquid already available on the right side of the piston or plunger is compressed which increases the pressure of liquid. Due to the increment of pressure, the suction valve ‘d’ closes and delivery valve ‘c’ opens. Then, the liquid is delivered to the delivery pipe through the valve ‘c’. Therefore, when the piston moves from left to right, suction is taking place on the left side of the piston, while in right side, the delivery is taking place. Similarly, when the piston moves from right to left, the actual cycle is repeated and the liquid is delivered to the delivery pipe through ‘a’.

Thus in a double acting reciprocating pump, when there is suction on left side, there will be delivery on the right side. Hence the discharge of a double acting pump is double times the single acting pump.

3.5.1.Plunger pump

It is similar to piston pump except that the plunger is used instead of piston. A plunger is a hollow cylinder and contains no rings. All the other elements are similar to piston pump. Since the length of the plunger is greater than its diameter, they produce high pressure and generally used for rough work. Refer fig .3.35 (a),(b) and (c).

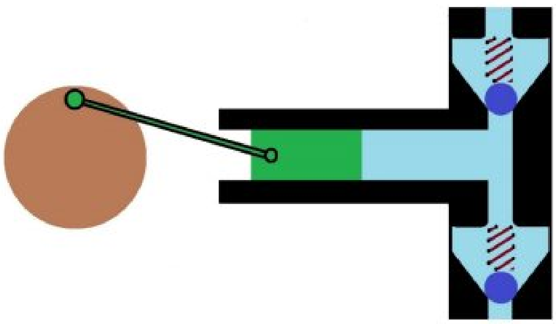


Fig.3.35a

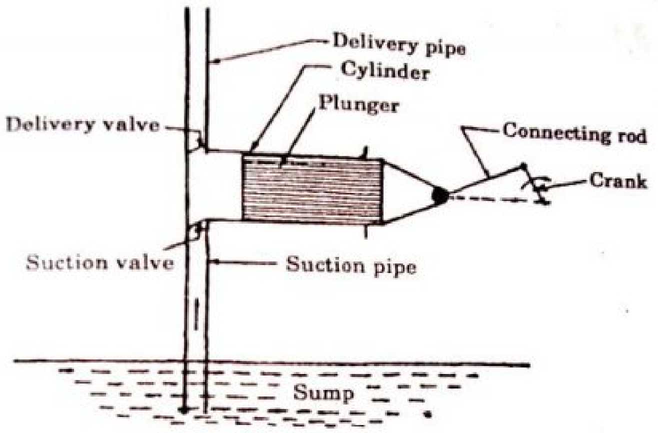


fig. 3.35b

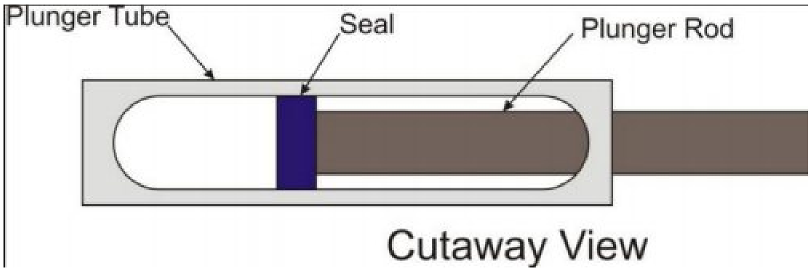


Fig.3.35c

3.5.2.Difference between piston pump and plunger pump.

The piston and plunger pump have the following differences are given below.

Piston pump	Plunger pump
1. Length of the piston is less than its diameter.	Length of the piston is greater than its diameter.
2. Piston carries piston rings. It reciprocates with the piston.	Plunger carries no rings.
3. Cylinder is provided with liners which can be easily replaced.	No liners are used due to low wear and tear.
4. Piston pump is not suitable for handling liquid containing sand and other particles.	It is suitable for handling liquid containing sand and other particles.

3.5.3.Discharge of Reciprocating pump

Theoretical discharge is the volume swept by the piston (or) plunger. In case of a **single acting** pump, for each revolution of the crank (For every two strokes of the piston) there is only one delivery stroke.

Theoretical discharge of single acting Q_t = ALN in (m^3\sec)

A = Area of piston in (m^2)
L = Stroke length in (m)
N = Speed of crank shaft in (rps)

In case of a **double acting pump,** there are two delivery stroke for one revolution of the crank.

Theoretical discharge of single acting **Q_t = 2ALN (m^3\sec)**

Co-efficient of discharge

The ratio between the actual discharge and theoretical discharge is known as co-efficient of discharge. **$C_d = Q_a / Q_t$.**

3.5.4.Slip

The difference between the theoretical discharge (Q_t) and actual discharge (Q_a) is called as slip $Slip = Q_t - Q_a$

3.5.5.Negative Slip

When the delivery Head is low and long suction pipe, the dynamic pressure of liquid entering the cylinder during the suction stroke is greater than the pressure on the outside of delivery valve.

It causes the delivery valve to open before the completion of suction stroke. Therefore the actual discharge is more than that of the Theoretical Discharge.

The difference between the actual discharge and Theoretical discharge is called Negative Slip.

$$\text{Negative slip} = Q_t - Q_a$$

Work done (or) Theoretical power (P) :

This is a power required to drive the pump

Work done (or) Theoretical power (P) = $w\, Q_t\, (H_s+H_d)$ watts

Actual power = $w\, Q_a$ (Hs+Hd) = w ALN (Hs+Hd) / 60

Efficiency (η)

This is ratio between the actual power & theoretical power.

Efficiency (η) = $\dfrac{Actual\ power}{Theoretical\ power}$

3.5.6.Separation (or) Cavitation

During the suction stroke of the reciprocating pump, the absolute pressure falls below 2.6m of water absolute, the water commences to vaporize and dissolved gases are formed. This will cause the water in the pipe to separate. Hence the flow of water in the pipe is not continuous and vibrations and knocking will occur. This phenomenon is known as separation (or) cavitation which must be prevented.

3.5.7.Air Vessels

- Air vessels are a cast iron chamber having an opening at the bottom through which water flows into (or) out of the chamber.
- Air vessels are fitted to the suction and delivery pipes, Very close to the cylinder.
- The top portion of air vessel contains compressed air. This will be further compressed, when the liquid enters the vessels. It will expand when the liquid flows out from the vessel.

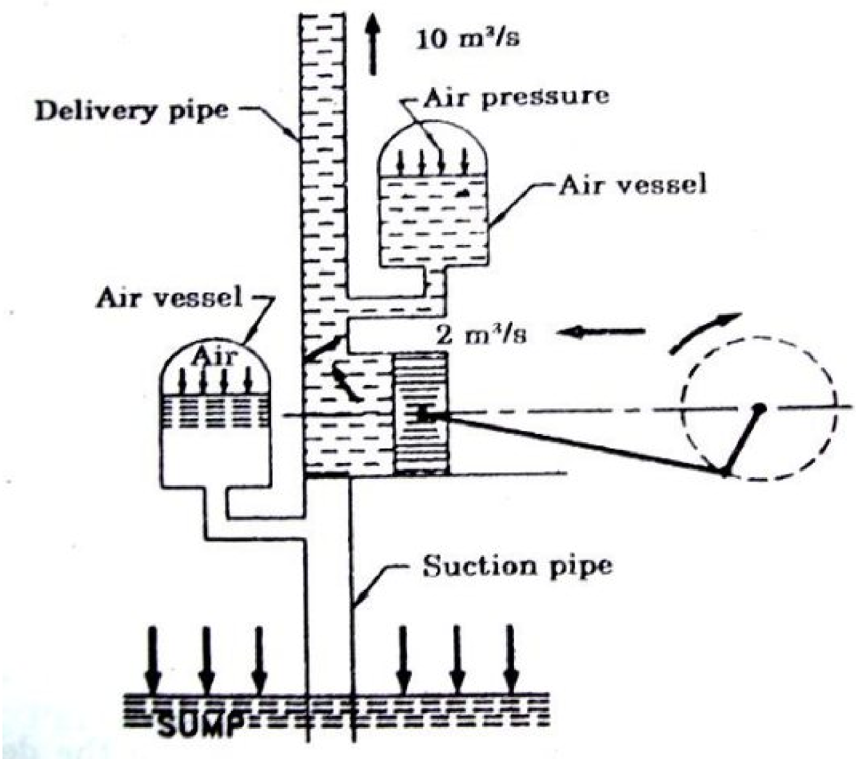


Fig.3.39

Importance of air vessel (Functions of air vessel)

Suction side

- Pump can run at a higher speed.
- Considerable frictional work is saved.
- Reduces the possibility of separation.
- Length of suction pipe below the air vessel can be increased.

Deliver side

- Large amount of power is saved.
- Constant rate of discharge (uniform delivery of liquid)

Working principle of air vessel

The air vessels are fitted to the suction and delivery pipes of single acting reciprocating pump as shown in fig.

In reciprocating pump, the piston having acceleration during first half of each stroke and retardation during next half of each stroke. During the acceleration period the discharge will be more. During the retardation period the discharge will be less. Example acceleration period discharge is $12m^3$\sec. Retardation period discharge is $8m^3$\sec. If there is no air vessel fitted to the delivery pipe, then the discharge will fluctuate from $12m^3$\sec to $8m^3$\sec. Therefore Air vessel is fitted with delivery pipe as shown in fig .

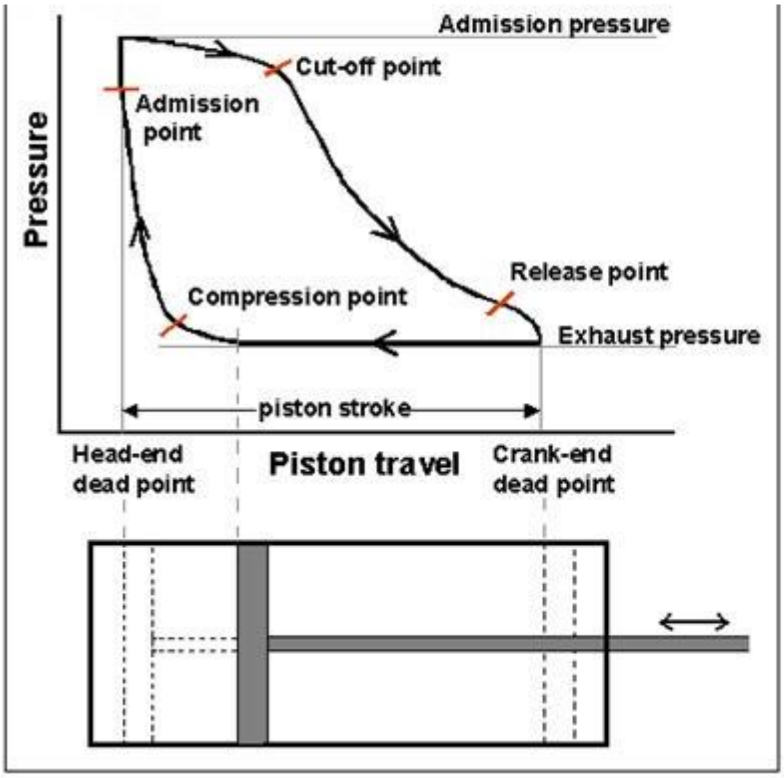
Delivery side

During the acceleration period, the piston delivers $12m^3$\sec. It is more than the mean discharge $10m^3$\sec. Now the excess amount $2m^3$\sec is entering into air vessel by compressing the air at its top. Hence the remaining discharge $10m^3$\sec is flowing through the delivery pipe beyond the air vessel. During the retardation period, the piston delivers only $8m^3$\sec. into delivery pipe. It is less than the mean discharge $10m^3$\sec. Now the compressed air expands which supplies $2m^3$\sec to the deliver side. Therefore the discharge is always uniform beyond the air vessel.

Suction side

As there is no fluctuation in velocity in the delivery pipe beyond air vessel loss of head due to friction is also reduced and power is saved. During the acceleration period, the discharge of water entering into the cylinder is more than the mean discharge $10m^3$\sec. Since the flow through the suction pipe below the air vessel is uniform, air vessel supplies $2m^3$\sec. of discharge to the cylinder. During the retardation period, the piston sucks less quantity of water which is less than $10m^3$\sec. Hence the excess $2m^3$\sec of water flows into air vessel and stored. This excess stored quantity is supplied during the first half of the net suction stroke.

Indicator diagram of a Reciprocating Pump



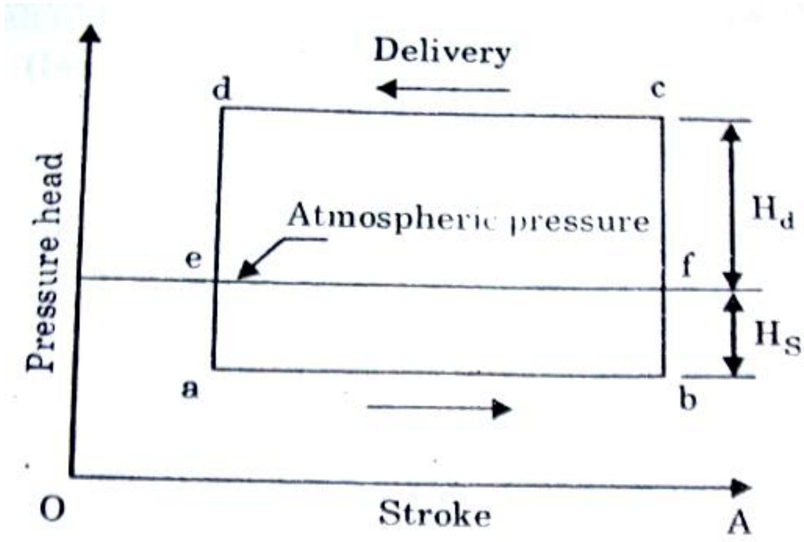


Fig.3.40

It is a graphical representation showing the pressure heads available inside the cylinder at various points of piston movements during the suction and delivery stroke of the piston. It is drawn by plotting the pressure head on the vertical ordinate (y-axis) and stroke length on the horizontal ordinate (x-axis). Fig shows the indicator diagram of a reciprocating pump.

In indicator diagram, 'OA' represents the absolute zero pressure 'ef' represents its atmospheric pressure 'ab' represents the pressure head during the suction stroke at a distance H_s below the atmospheric pressure line and 'cd' represents the pressure head during the delivery stroke at a distance H_d above the atmospheric pressure line. H_s is the suction head, it means that the pressure inside the cylinder during the suction stroke is sufficient to lift the liquid through a distance H_s.

Therefore Pressure head developed throughout the suction stroke = H_s m of vacuum. Similarly, H_d is the delivery head, it means that the pressure inside the cylinder during the delivery stroke is enough to lift the liquid through a distance H_d. Therefore ,pressure head developed throughout the delivery stroke = H_d m of gauge.

The area 'abef' represents the work done during the suction stroke and the area 'cdef' represents the work one during the delivery stroke. Therefore, the area 'abcd' represents the total work done during suction and delivery stroke. It is equal to $(H_s + H_d)L$. where, L is the length of stroke. In the case of double acting pump, it is twice the above amount.

3.6.Special pumps

3.6.1.Jet pumps

Construction

Jet pump is a combination of single stage centrifugal pump and an ejector usually known as jet. The motor and centrifugal pumps are placed on the top of the sump and the jet is placed inside the sump at a distance less than 7.5 m from the water surface.

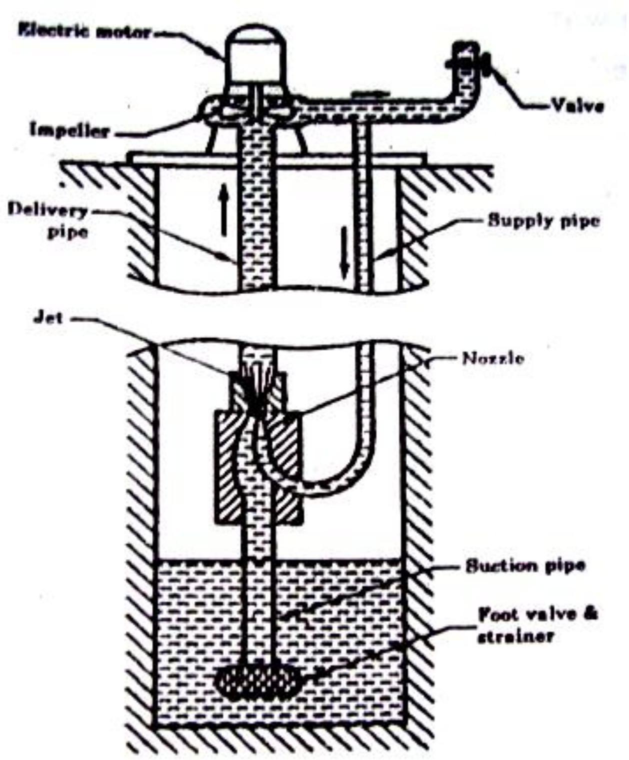
The jet consists of a converging nozzle and diverging nozzle. Threaded openings are provided on the jet to fit necessary piping. The jet is connected to the pump by means of delivery pipe. There is another pipe called supply pipe which is by passed to the nozzle from the outlet of the pump. The suction pipe is provided below the jet.

Working principle

Before starting the pump, the air present in the pipe and jet are removed by priming. When the pump is started, the high pressure water from discharge side of the pump will flow through the supply pipe to the conveying nozzle of the jet.

At the exit of the nozzle, the velocity of water is increased with a reduction in pressure below atmospheric pressure. This causes water from the sump to be sucked into the nozzle through the suction pipe. This water combines with high velocity jet and the combined stream of water passes through the diverging nozzle.

In the divergent nozzle, the kinetic energy of the stream is partly converted into pressure energy and is forced into the delivery pipe. Then the water is sucked by the centrifugal pump and is discharged with high pressure.



Jet pump

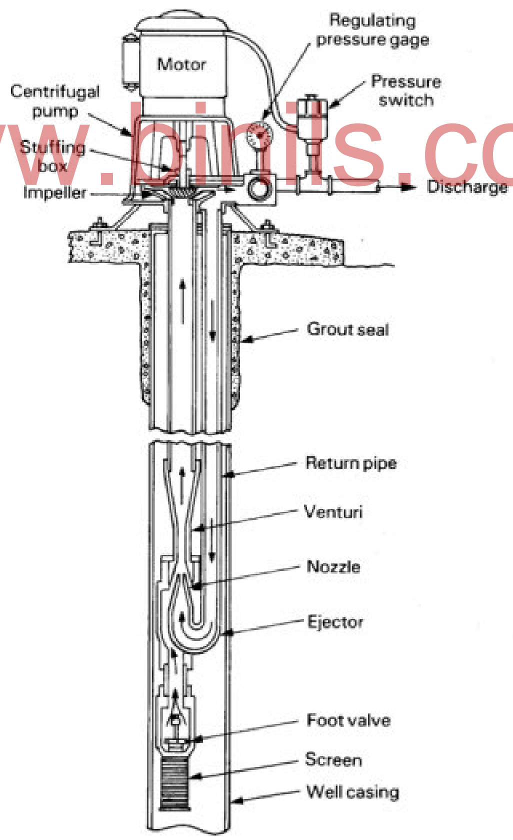


Fig.3.41.

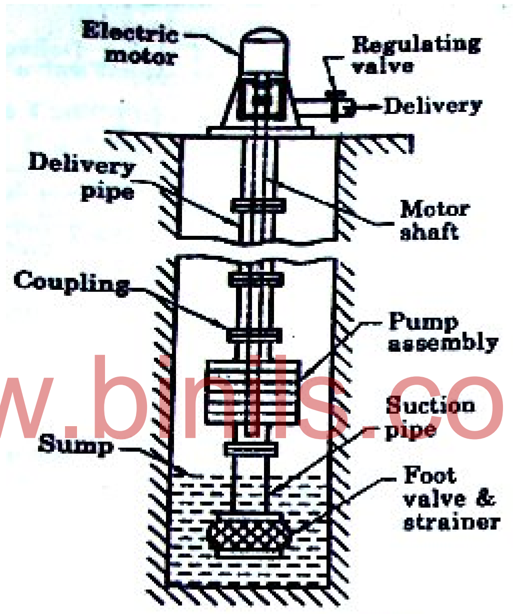
The amount of water required for the operation of jet is by passes through the supply pipe. The jet pump is used to lift water to a height up to 120 meters.

Advantages

1. The design of jet pump is simple.
2. Less wear and tear as there are no moving parts.
3. Lubrication is not necessary.
4. Maintenance cost is less.

3.6.2.Deep well pump

A pump which is used to lift the liquids from a larger depth is known as deep well pump. Turbine pumps are widely used to now a day for deep well pumping. These pumps are usually vertical multistage type. The pumping element is suspended from the discharge pipe. These pumps have been built for heads up to 300 meters and for capacities up to 500 liters per second. The diagram is shown in fig.3.42.



Deep well pump

Fig.3.42

Deep well turbine pump or bore well pump

The figure shows the constructional details of a multistage deep well turbine pump. The pump consists of the following parts.

i. Driving unit.
ii. Pumping unit.
iii. Delivery unit.
iv. Driving shaft and bearing.

Driving unit

The driving unit consists of a vertical driving motor located at the ground level. A driving shaft is used to transmit the energy from the motor to the pump and is carried centrally down the delivery pipe.

Pumping unit

The pumping unit is installed below the surface of the ground. It has a multistage centrifugal pump and the number of stages depends upon the required head. The impellers are assembled in series in the pump unit and are suspended at the end bronze. A suction pipe is fitted at the bottom of the pump unit. Another end of suction pipe is immersed into the liquid.

Driving shaft and bearing

The driving shaft is made of stainless steel and is enclosed in a delivery pipe with bronze bearing at suitable intervals to prevent the vibrations. Bearing retainers are provided in each coupling to guide the driving shaft and are clamped between the flanges of delivery pipes. A thrust bearing is provided at the upper end of the shaft to withstand the weight of the impellers and shaft.

Working principle

When the pump is started by an electric motor, the impeller rotates inside the casing. This gives a centrifugal head to the water in the casing. Since, it is a multistage pump. The water leaving out the last impeller will have a very high pressure. This high pressure water is discharged through the delivery valve.

3.6.3.Turbine pump

The turbine pump is a multistage, vertical centrifugal pump. Since the impellers of this pump resembles the shape of runners of Francis turbine, it is called turbine pump. It has number of impellers connected in series to discharge liquids against a head from 60m to 300m.

Construction

This pump consists of suction unit, delivery unit and driving unit. It is shown in fig.3.43.a The suction unit is provided with a strainer and foot valve at the bottom. The other end is connected to the centrifugal pump which has number of impellers. This unit is always submersible in liquid. The delivery unit connects the suction unit with the motor. The delivery unit has a delivery pipe with the line shaft.

The line shaft is coupled with the centrifugal pump which is made up of short pieces of 3m to 4m for the required length. They are coupled together and enclosed with a delivery pipe. Since the shafts are very long, they are supported at suitable intervals by bronze or rubber bearings. The driving unit has the electric motor placed vertically at the ground level. The motor is properly protected by suitable shielding.

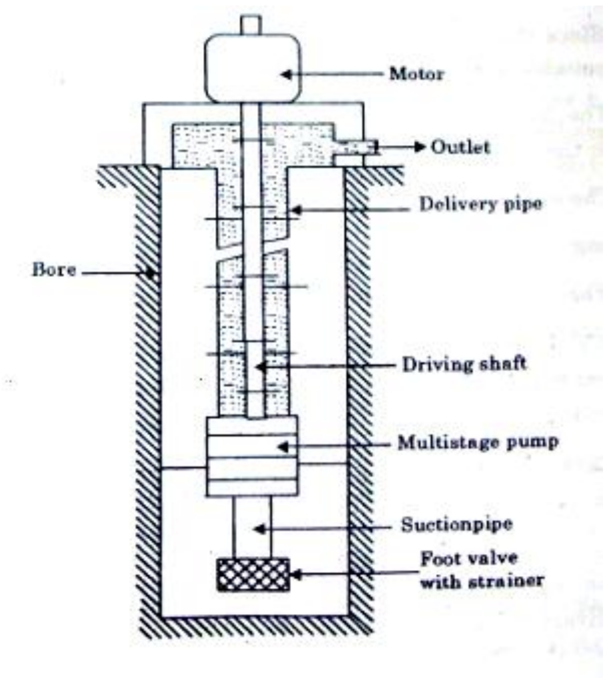


Fig.3.43.a

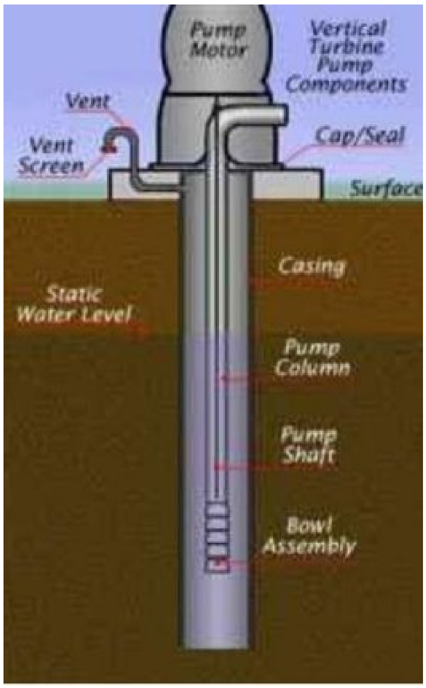


Fig.3.43.b

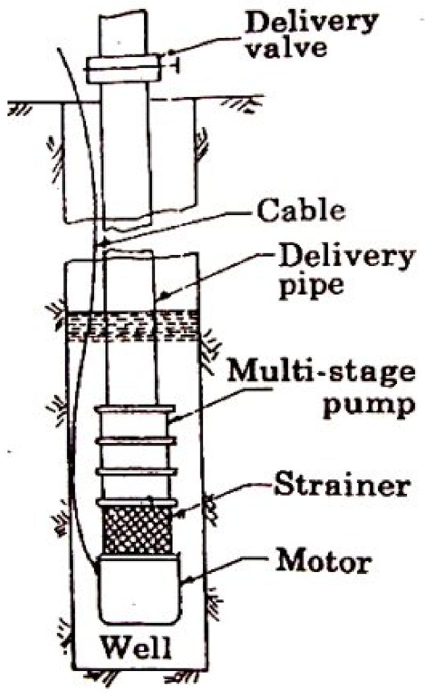
Working

When the electric motor is switched on the pump starts running. Due to the high rotation of impeller, a partial vacuum is produced at the eye of first impeller. Since the impellers are connected in series, the first impeller sucks the liquid through suction pipe and delivers to the next stage. The same process is repeated at the other stages which delivers the liquid to the ground level. Hence it gains head one after the other and finally delivered the liquid to the high level.

3.6.4.Submersible pump

In turbine pump, the pump and motor are connected by means of long shaft which is giving lot of trouble. These troubles are avoided by using a submersible pump. This is a multistage vertical centrifugal pump with radial (or) mixed flow impellers. The motor is fitted below the pump as shown in fig.3.43

The suction housing of the pump is fitted between the pump and motors and provided with a perforated strainer. The electric motor is wet squirrel cage type and is fitted completely inside water. The windings of motor are insulated well and cooled by water. A gate valve, which is a non-return valve, is provided at the top of the pump, to discharge the water.



Submersible Pump

Fig.3.43

The motor must be filled with clean non-acidic water before installation. The pump must be started with the valve slightly open. If the water is discharged with the sand content, it should be operated with the same position of valve opening until the sand contents are reduced for an acceptable quantity. Then the valve may be opened gradually.

3.6.5.Comparison between Centrifugal pump and reciprocating pump:

Centrifugal pump	Reciprocating pump
1. Discharging capacity is very much greater.	Discharging capacity is smaller.
2. Used for lifting high viscous liquid.	Used for lifting low viscous liquid.
3. It can be operated at high speeds.	Runs of low speed.
4. It gives uniform flow.	Flow is fluctuating.
5. Total weight for a given capacity is less.	Total weight
6. It requires less running and maintenance cost.	Running and maintenance cost is high.
7. Installation is easy and cheap.	Installation is difficult.
8. Simple in construction and it requires less number of parts.	Complicated in construction and more spare parts required.
9. Priming is necessary.	Priming is not necessary.
10. It requires lighter foundation.	It requires heavy foundation.
11. It occupies less floor space.	It occupies more floor space.

Important Formula

1. Theoretical discharge Q_t = LAN/60 m^3/sec for single acting Reciprocating pump
2. Theoretical discharge Q_t =2 LAN/60 m^3/sec for Double acting Reciprocating Pump
3. Co efficient of Discharge $Cd = \frac{Qa}{Qt}$
4. Slip $= Q_t - Q_a$
5. Percentage of slip = $\frac{Qt-Qa}{Qt}$ x 100 = (1-Cd) x 100
6. Work done (or) Theoretical power (P) = w $Q_t (H_s+H_d)$ watts
7. Efficiency (η) = $\frac{Actual\ power}{Theoretical\ power}$
8. Actual power = w Q_a(Hs+Hd) = wALN(Hs+Hd)/60 watts

3.6. 6.Solved Problems

1) A single acting reciprocating pump has a piston diameter 150 mm and stroke length 250 mm discharges 4 litres of water per second. The crank rotates at 60 rpm and its total head is 20 m. Find i)Theoretical discharge ii) % of slip iii) Theoretical power required to drive the pump

Given Data:

Dia of cylinder D= 150 mm = 0.150 m

Stroke length L =250 mm = 0.250 m

Total head H = 20 m

Crank speed N = 60 rpm

Actual discharge Qa = 4 lit/sec = 4 x 10^{-3} m^3/sec

Solution:

i) Theoretical discharge Q_t = LAN/60 m^3/sec for single acting Reciprocating pump

$$= 0.25x \frac{\pi}{2} (0.15)^2 x\ 60\ /60$$

$$= 0.00442\ m^3/sec$$

ii) Percentage of slip = $\frac{Qt-Qa}{Qt}$ x 100 = (1-C_d) x 100

$$= \frac{0.00442-0.004}{0.00442} x\ 100 = 9.5\ \%$$

iii) Theoretical power (P) = wQt(Hs+Hd)

= 9.81x 0.00442x(20)

= 0.8672 watts

2) water is lifted to a height of 18 m by a Double acting reciprocating pump having a piston diameter of 150 mm and stroke of 300 mm. Find the theoretical discharge

and theoretical power required , if the pump is running at 40 rpm and the actual discharge of 400 lpm. Find i) % of slip ii) Cd

Given:

Total head(Hs + Hd) = H = 18 m
Piston dia D = 150 mm = 0.150 m
Stroke length L= 300 mm = 0.300 m
Speed N = 40 rpm
Qa = 40 lpm = $40 \times 10^{-3}/60$ = 6.6666×10^{-3} m^3/sec

Solution:

Theoretical discharge Q_t = 2LAN/60

for double acting Reciprocating pump

$= 2 \times 0.300 \times \frac{\pi}{2} (0.15)^2 \times 40/60$

= 0.007667 m^3/sec

Theoretical power(P) = wQt(Hs+Hd)

= 9.81 x0.007667 x 18

= **1.2478 watts**

Co efficient of Discharge Cd = $\frac{Qa}{Qt} = \frac{6.6666 \times 10^{-3}}{0.007667}$

= 0.9432

Percentage of slip = $\frac{Qt - Qa}{Qt} \times 100$

$= \frac{0.007667 - 6.6666 \times 10^{-3}}{0.007667} \times 100$

5.68 %

3) A single acting reciprocating pump has a piston diameter 100 mm and stroke length200 mm .The pump is used to raise the water to a height of 20 m when it is running at 50 rpm. Find i)Theoretical discharge ii) % of slip iii) Theoretical power required to drive the pump if the efficiency is 90%

Given

Total head(Hs + Hd) = H = 20 m
Piston dia D = 100 mm = 0.100 m
Stroke length L= 200 mm = 0.200 m
Speed N = 50 rpm
Efficiency η = 90% = 0.90

Solution

i) Theoretical discharge Q_t = LAN/60

$$= 0.200x \frac{\pi}{2} (0.100)^2 \text{ x } 50 /60$$

$$= \mathbf{0.0.001308\ m^3/sec}$$

Theoretical power(P) $= \frac{wQt(Hs+Hd)}{\eta} = \frac{9.81x0.001308 \text{ x } 20}{0.90}$

= 0.285 KW

4) Double acting reciprocating pump having a piston area of 0.1 $m^2$and stroke of 300 mm. The pump discharging 40 lps when the pump is running at 45 rpm through a total height of 10 m . Find i) the slip of pump ii)power required to drive the pump.

Given

Total head(Hs + Hd) = H = 10 m

Piston area A = 0.1 m^2m

Stroke length L= 300 mm = 0.300 m

Speed N = 45 rpm

Actual discharge Qa = 40 lps = 0.04 m^3/sec

Solution :

i) Theoretical discharge Q_t =2 LAN/60 m^3/sec for Double acting Reciprocating pump

=2x 0.300x 0.1 x 45 /60

= 0.045 m^3/sec

Slip = Q_t - Q_a = 0.045 – 0.04 = 0.005 m^3/sec

ii) Theoretical power (P) = wQt(Hs+Hd)

= 9.81x 0.045x 10

= 4.415 KW

5) A Double acting reciprocating pump has a piston diameter of 150 mm and a stroke length of 300 mm. It raises the water to a height of 20 m at a speed of 60 rpm. The discharge is 10 lps. Calculate i)Theoretical discharge. ii)% of slip iii) Cd iv)Efficiency of pump.

Given:

Total head(Hs + Hd) = H = 20 m

Piston diameter D = 0.150 m

Stroke length L= 300 mm = 0.300 m

Speed N = 60 rpm

Actual discharge Qa =10 lps = 0.01 m^3/sec

Solution:

i) Theoretical discharge Q_t =2 LAN/60 m^3/sec for Double acting Reciprocating pump

=2x 0.300x πx0.15^2 x 60 /60

4

= 0.0106 m^3/sec

ii)Percentage of slip = $\frac{Qt-Qa}{Qt}$ x 100

$\frac{0.0106-0.01}{0.0106}$ x 100

= 5.65%

iii) Cd = $\frac{Actual\ Discharge}{Theoretical\ Discharge}$

= $\frac{0.01}{0.0106}$

= **0.94**

iv) Efficiency = $\frac{Actual\ power}{Theoretical\ power}$

= $\frac{0.01}{0.0106}$ x 100

= **94%**

6) A single acting reciprocating pump has a plunger diameter 0.15m and stroke length of 0.3m and discharges 300 lit/min when it is running at 60 rpm. The suction and delivery heads are 6 m and 14 m respectively. Find i)Theoretical discharge ii) slip of pump iii) Theoretical power required to drive the pump if the efficiency is 70%

Given:

Total head(Hs + Hd) = H = 20 m

Piston dia D = 0.15 m

Stroke length L = 0.300 m

Speed N = 60 rpm

Actual discharge Q_a = 300x10^{-3}/60 = 0.005 m^3/sec

Efficiency η =70% = 0.70

Solution:

i) Theoretical discharge Q_t = LAN/60

= 0.300x $\frac{\pi}{2}$ $(0.150)^2$ x 60 /60

= **0.005301 m^3/sec**

ii) Slip = Qt- Qa

= 0.005301 - 0.005 = **3.01 x 10^{-4}** m^3/sec

iii)Theoretical power(P) = $\frac{wQt(Hs+Hd)}{\eta}$ = $\frac{9.81x.0.005301\ x\ 20}{0.70}$

= **1.485 KW**

Exercise
Theoretical Questions

Part- A

1. What is meant by positive displacement pump?
2. Write any one advantage of double suction pump.
3. Define in the term slip.
4. Define negative slip.
5. What is indicator diagram?
6. What is an air vessel?
7. Write any one difference between piston pump and plunger pump.
8. Define percentage of slip.
9. Define coefficient of discharge.
10. Write the formula to find theoretical discharge of pump.
11. Define separation in a reciprocating pump.
12. How are the reciprocating pumps classified?
13. .What is the difference between piston pump and plunger pump?
14. Distinguish between positive displacement pump and non-positive displacement pump
15. What condition the negative slip will occur?
16. How separation of reciprocating pump can be avoided?
17. What is the function of air vessel?
18. How air vessel is used to overcome the cavitations?
19. What are the principle uses of deep well pump?
20. Under what condition Jet pump is used?

Part- B

1. Describe with a neat sketch, working of a single acting reciprocating pump.
2. Explain with a neat sketch, the working of a single acting plunger pump.
3. With a neat sketch, explain the working of a double acting reciprocating pump.
4. Derive an expression for the theoretical power required to operate a single acting reciprocating pump.
5. What is indicator diagram? Draw a theoretical indicator diagram and explain.
6. Compare the centrifugal pump and reciprocating pump.
7. Explain with neat sketch of working deep well pump.
8. Explain with neat sketch of working of Jet pump.
9. Explain with neat sketch of working of a turbine pump.
10. Explain with neat sketch of working of a submersible pump.

Numerical problem

1. A single acting reciprocating pump has a plunger of 500mm diameter and stroke of 0.4m. The speed of the pump is 60rpm and C_d =0.9. Find the percentage of slip and actual discharge of the pump.(Ans : percentage of slip = 30.5% , Q_{ac} = 0.0761 m^3\sec)

2. A single acting reciprocating pump has a plunger of 500mm dia and stroke of 0.4m. The speed of the pump is60rpm and C_d -0.97. Find
    i) Percentage of slip
    ii) Actual discharge of pump   (Ans: Percentage slip = 3% ,Q_{ac} = 0.0785 m^3\sec)
3. A single acting reciprocating pump running at 50rpm delivers 0.01m^3\sec of water. The diameter of piston is 200mm and stroke length 400mm. Determine
    i) Theoretical discharge
    ii) Coefficient of discharge
    iii) Percentage of slip   (Ans: Q_{th} = 0.01046m^3\sec; C_d = 0.956; percentage slip = 4.4%)
4. The piston of a single acting pump has a diameter of 100mm and a stroke of 200mm. The pump is used to raise the water to a height of 20m. When it is running at 50rpm. Calculate the theoretical discharge and the power required by the pump. If its efficiency is 90%.

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UNIT-IV PNEUMATIC SYSTEMS

Objective

- ❖ Impart the knowledge about pneumatic systems
- ❖ Explain the various application and advantages of pneumatic system
- ❖ Explain the importance of pneumatic circuit in automation
- ❖ Brief discussion about the pneumatic circuits and working principle
- ❖ Differentiate hydraulic and pneumatic system
- ❖ Explain the pneumatic system direction control valve's symbols and function.

4.1.Introduction

Pneuma is a Greek word means Breath or Wind or Air. A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic systems are used in controlling train doors, automatic production lines, mechanical clamps, etc. In this chapter, we shall discuss the various devices used in pneumatic system and its applications.

Pneumatics means the study of air movement and air phenomena. Today it is not possible to imagine the modern industry without using Pneumatics for the automation. It finds application in the diverse branch of the industry. The real practical industrial application of Pneumatics in production dates back to about 1950.

4.2. TYPES OF MOTION PERFORMED BY PNEUMATIC COMPONENTS:

- ➢ Linear
- ➢ Swivel
- ➢ Rotary.

4.3.Merits and demerits of pneumatic system

Merits

1. Leakages can be easily identified.
2. Maintenance is less.
3. Light weight machines or equipment can be operated at faster.
4. Less pollution.
5. Air is safe and readily available fluid.
6. Since the air is stored in compressor, we can operate the machines for a shorter period during power cut.
7. Since air is inflammable fluid, fire and explosion hazard are avoided in painting and mining industries.
8. Air can be used even in high ambient temperature.

9. It is less expensive than hydraulic system.

Demerits

1. Noisy operation.
2. Since the air is compressible, it is difficult to get precision control.
3. Power loss and operation cost is more due to heat losses.
4. It requires heaters in high moisture region.
5. It requires more lubricant for the smooth movement of components.
6. It requires larger actuators.

4.4.Applications of pneumatic systems

The industrial applications of pneumatic system are:

1. Pneumatic tools like drills, riveters etc.
2. In automobile industry, air brakes, power jacks and sprays painting.
3. In mines for loading, unloading, clamping etc.
4. In agriculture, paddy transplants, harvesting machines etc.
5. In printing industry speed control of equipment and automation etc.
6. In plastic industry, processing of plastic and blow moulding etc.
7. In ceramics and glass industries, moulding of glass and blowing of porcelain etc.
8. In leather industry, air operated cutters and finishing of leather etc.
9. In textile industry, speed regulation of spinning, weaving and colour feeding etc.

4.5. Element of pneumatic system

The major elements of pneumatic system are shown in fig.

1. Compressor : To supply pressurized air.
2. Valves : To control the direction, pressure and volume or quantity of flow.
3. Filters : To remove dust particles in air.
4. Regulators : To supply the required pressure of air to the system.
5. Lubricators : To mix the lubricating oil with air for lubricating the devices.
6. Direction control valve : It determines the path of flow.
7. Actuator : To convert the pressure energy into linear or rotary motion.

i. Compressor

Compressor is one of a main element of pneumatic system. It is used to increase the pressure of air. Compressor can compress air to the required pressures. It can convert the mechanical energy from motors and engines into the potential energy in compressed air. A single central compressor can supply various pneumatic components with compressed air, which is transported through pipes from the cylinder to the pneumatic components. Compressors can be divided into two classes: Reciprocatory and rotary Compressor.

ii. Valves

Valves control the direction and pressure of the flow.

iii. FRL Unit

The FRL unit basically consists of the following three separate elements.

1. Filter 2. Regulator 3. Lubricator

They are connected as a single unit to supply a clean pressurized and lubricated air to the actuator.

Normally the regulator is incorporated between filter and lubricator. FRL unit is shown in fig.4.1

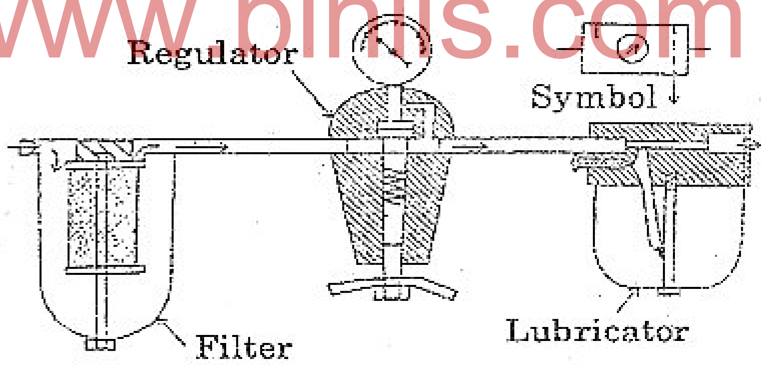


Fig.4.1

iv. Symbol of FRL Unit

The Symbol of FRL Unit is shown in fig.4.2

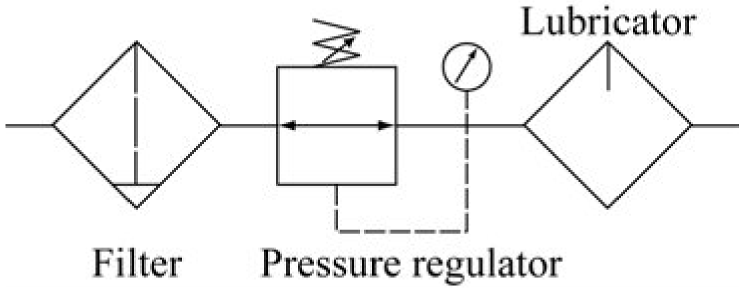


Fig. 4.2

v. Air filter

In pneumatic system, air filters are used to remove all dusts and moisture from the compressed air. Filters allow clean and dry air to the system. The degree of filtration depends upon the size of the particles which are to be removed. Air filters are classified based on degree of filtration.

4.6.Types of air filters

1. Screen filter
2. Bowl filter

1. Screen filter

The arrangement of a screen filter is shown in fig.4.3. Basically it consists of cover, filtering element and body. The filtering element usually wires mesh of different grades is placed between the body and cover of the filter. Air enters the filter through inlet opening provided at the top of the filter. Then it passes through the wire mesh of different grades which removes the dusts and moisture. Thus the clean air passes out to the bottom of the body and rises upwards and finally passes out through the outlet. The heavy particles and moisture are settled down at the bottom of the body which is removed out through the drain plug.

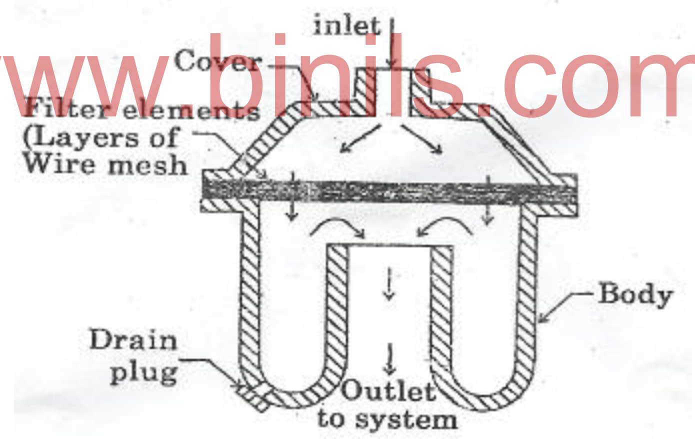


Fig.4.3

2. Bowl filter

The arrangement of a bowl type filter is shown in fig.4.4. Basically it consists of filter element called inner cup and bowl called outer cup. The filter element is made of porous sintered bronze in the form of wire mesh. Around the inner cup, there is a deflector blade which causes the air to swirl. Air enters the filter through inlet provided at the side and it passes to the filter element through deflector blades. Due to the swirling of air in the blades, the heavy particles are separated and settled down at the bottom. Then, the air passes through the inner cup which removes the foreign particles and finally passes out through the outlet to the pneumatic system.

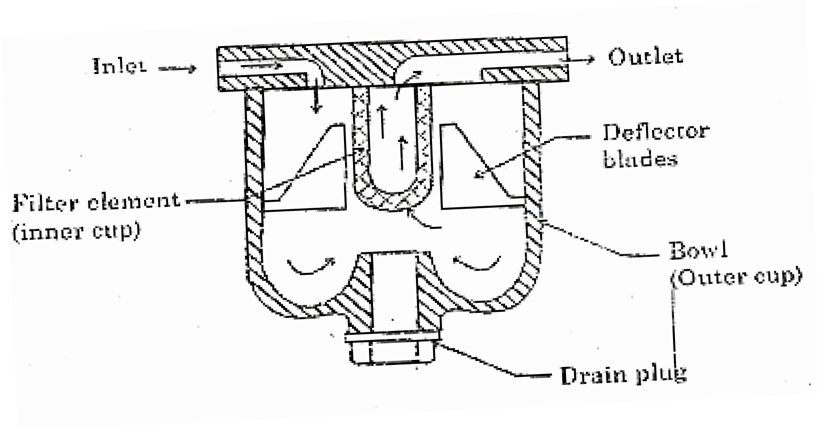


Fig. 4.4.

4.7. Regulator

The main function of the pressure regulator is to maintain and supply a constant pressure air to the system irrespective of supply from the reservoir. It is usually installed between the receiver and the system.

Types of pressure regulators

1. Diaphragm type regulator.
2. Piston type regulator.

i. Diaphragm type regulator

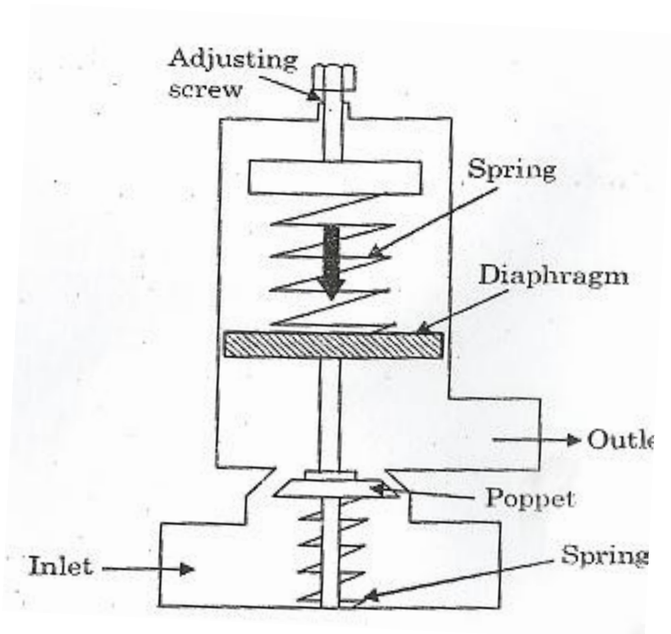


Fig.4.5

Fig.4.5. shows the diaphragm type pressure regulator. The diaphragm is made out of bronze. The required pressure is set by adjusting the set screen which forces the spring on diaphragm. If the pressure on the outlet side is too high, the air pressure deflects the diaphragm upwards by compressing the spring above it. Then, the poppet connected to the diaphragm rod is also moving up which restricts the flow of air through poppet. Hence the outlet pressure falls back to the required set pressure. When the outlet pressure is low, the spring above the diaphragm deflects the diaphragm to move down which moves the poppet downwards. Hence, the opening of air inlet is increased. As a result of this, more air is admitted through poppet to the outlet and maintains a constant pressure at the outlet.

ii. Piston type pressure regulator

Fig.4.6.shows the piston type pressure regulator. Here the diaphragm is replaced by a piston which is moving up and down to maintain a constant pressure at the outlet.

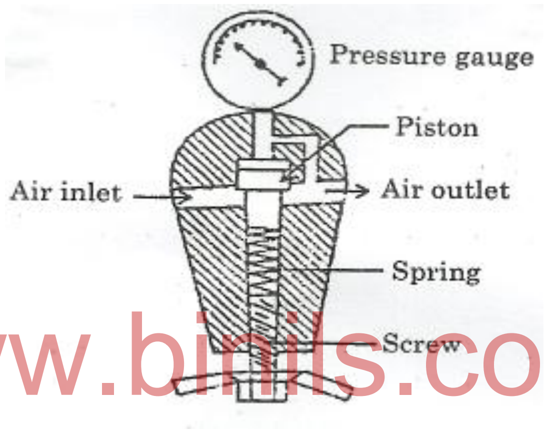


Fig. 4.6

4.8. Lubricator

Pneumatic components like actuators, rotating shafts etc., need lubrication for its smooth functioning. The lubrication mixes the oil into air system and it is supplied to all moving parts of the system. Fig.4.7. shows the arrangement of an air lubricator. It consists of casing, needle valves, feed tube, ball check valve and venture. In this lubricator, there is an oil reservoir at the lower portion of the casing. The oil is a mixture of 50% kerosene and 50% of SAE 30 oil which is used to serve as a lubricant in pneumatic system.

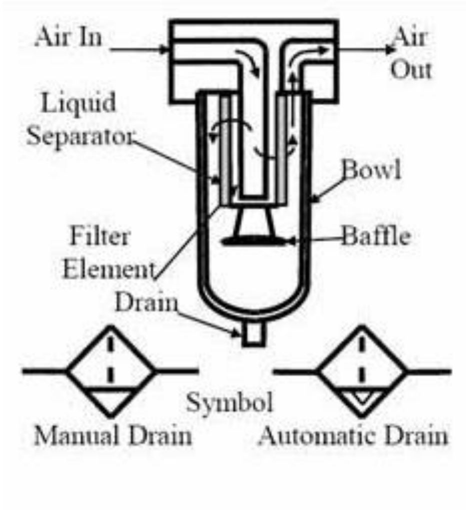


Fig.4.7.

The casing is made out of glass for easy inspection. When air passes through a venture, a partial vacuum is created at the throat of venture tube. The air passing through the air bleed passage exerts a pressure on the lubricating oil surface. Due to the difference of pressure between throat and oil surface, oil is sucked through the feed tube and it is mixed with air in the venture tube. Then the mixture of oil and air pass out through the outlet to the pneumatic system. The quantity of oil entering into the venture tube is controlled by the needle valve by adjusting the lead screw. The ball check valve helps to maintain a column of oil in the feed tube.

4.8. Pressure control valves

The primary function of the pressure control valve is to limit or control the working pressure in a pneumatic system. They are classified depending upon the method of control as:

1. Pressure relief valve
2. Pressure reducing valve

1. Pressure relief valve

Pneumatic system is designed for a particular pressure for its normal working. Whenever the pressure in the system exceeds the normal working pressure, pneumatic elements such as pipe lines, cylinders etc. may burst. In order to avoid such happenings, the system pressure should not rise above the normal working pressure. The device used for this purpose is known as relief valve.

Fig .4.8. shows the spring loaded type pressure relief valve. They are generally used to relieve the pressure in the circuit when required. It consists of the following essential parts.

1. body
2. Ball
3. Spring

4. Adjustable screw

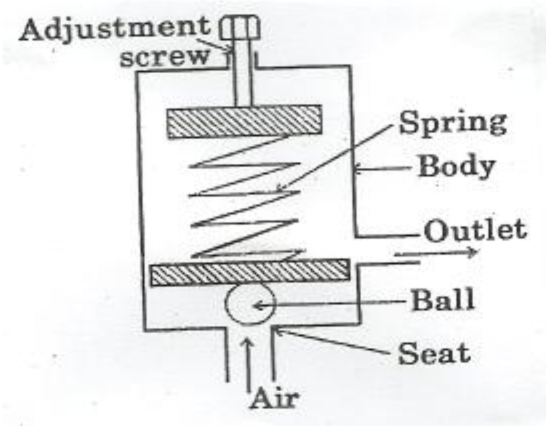


Fig.4.8.

Function

The valve body having inlet and outlet ports. In inlet port a ball is seated on the valve opening by a spring force. The spring tension can be adjusted by means of adjustable screw to set the working pressure. The inlet port is connected to the pipe line whose maximum pressure is to be controlled. The outlet port is connected to the atmosphere. In normal working condition, the downward thrust of the spring is greater than that of upward system pressure. Therefore, the ball is held in its seats which restrict the flow of air. If the system pressure exceeds the normal working pressure, the ball is lifted up from its seat by compressing the spring. Hence, the valve is opened and allows air to atmosphere through outlet port. When the system pressure again reaches the normal pressure, the ball is reseated by the spring force and the valve is closed. Thus a relief valve acts as a protection device which is normally located near the compressor.

Disadvantages

- It opens and closes rapidly causing pressure pulsating and vibration.
- Immediately, after its opening the poppet suddenly jumps due to increases in force.
- It permits the system pressure to raise higher than its setting.

2. Pressure reducing valve

In pneumatic system, sometimes more than one actuators are used. If one of the actuator requires a lesser pressure than the main system pressure, then a pressure reducing valve is used. It maintains a constant pressure at its outlet irrespective of the inlet pressure. Depending upon the method of control, they are classified as follow.

1. Diaphragm type pressure reducing valve.
2. Piston type pressure reducing valve.

4.9. Diaphragm type pressure reducing valve

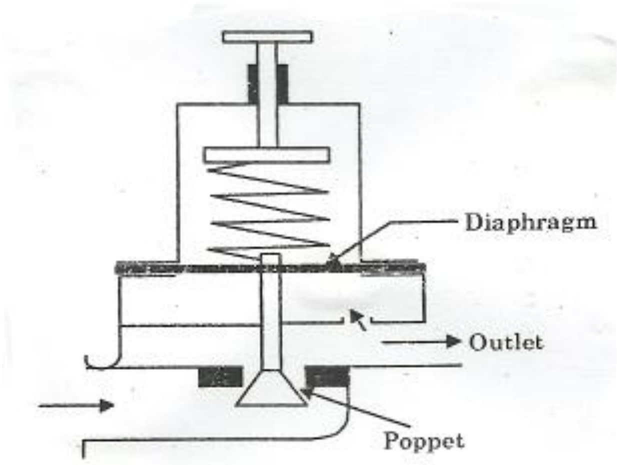


Fig .4.9

Fig.4.9. shows the internal arrangement of diaphragm type pressure reducing valve. It essentially consists of valve with inlet and outlet openings. There is a poppet to increase or decrease the size of opening between the inlet and outlet. The spring keeps the diaphragm for its normal working pressure. A small passage called pilot passage is introduced between the outlet port and diaphragm. Normally this valve remains open during the operation of the system. When the pressure at outlet port exceeds the predetermined pressure the diaphragm is lifted up by the air flow from pilot passage to the diaphragm area. Since the poppet is connected to the diaphragm, poppet also moves up and reduces the areas of air flow.

1. It reduces the pressure at outlet again to the predetermined working pressure.
2. It maintains a constant pressure at outlet irrespective of inlet pressure.

Piston type pressure reducing valve

The internal arrangement of piston type pressure reducing valve is shown in fig .4.10

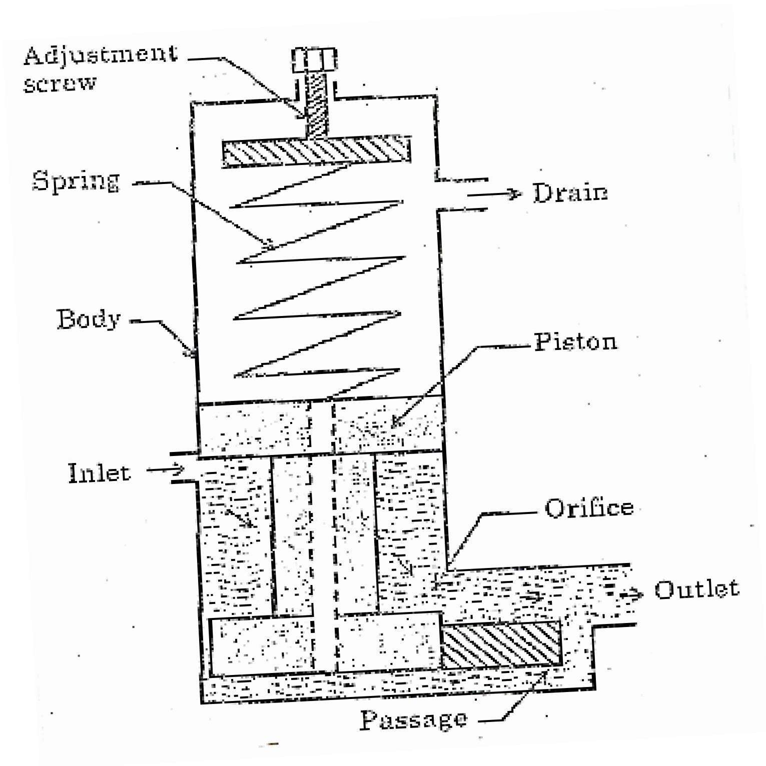


Fig.4.10

When the pressure at the outlet port exceeds the normal working pressure, the piston is lifted up by compressing the spring above the piston. Hence, the passage of air flow called orifice is partially closed which causes a greater pressure drop. It reduces the pressure at outlet again to the normal working pressure. Thus it maintains a constant pressure at outlet and supply to the pneumatic system.

4.10. Flow control valve or needle valve

Construction & working:

In pneumatic system, flow control valve is used to control the speed of the actuator. It can be achieved by varying the area of flow through which air is passing. When area is increased, more quantity of air will be sent to actuator which increases the speed. Similarly when area is reduced, quantity of air entering into the actuator is reduced which decreases the speed.

The internal arrangement of a flow control valve is shown in fig.4.11. Assume that the needle valve is in closed position as shown in figure. Then, the compressed air from inlet will freely flow through check valve to outlet. At this position, air flow cannot take place from outlet to inlet. If the needle valve is slightly opened, the check valve is closed due to the action of spring provided at its bottom. Hence, the compressed air flows through needle valve opening to outlet which is connected to actuator. Thus the piston reciprocates inside a cylinder.

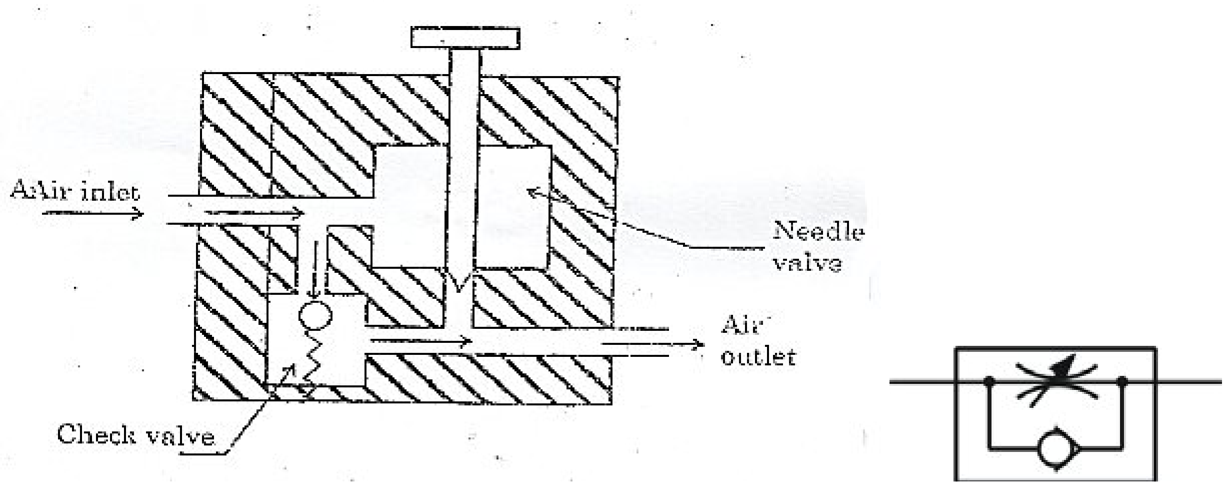


Fig. 4.11

The speed of the piston wholly depends upon the area of opening provided at the needle valve. The area of flow can be varied by means of adjustable screw.

4.11. Check valve (Non-return valve)

It is used to allow the air in only one direction and reverse flow is not at all possible. Hence it is known as non-return valve. Fig.4.12. shows the internal arrangement of a check valve. It consists of valve body (cover), poppet, spring and valve seat. When the pressure at inlet exceeds the spring force, the poppet is lifted up from its seat by compressing the spring above poppet.

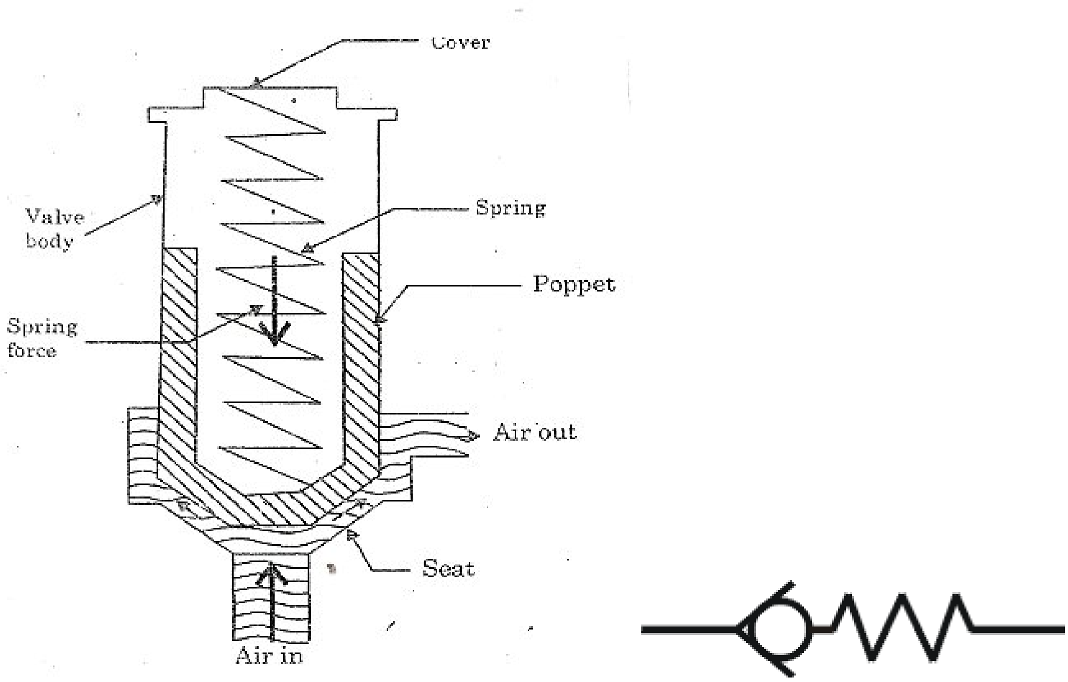


Fig. 4.12

The air flows through the inlet opening and escapes to atmosphere through outlet port. If the pressure falls in the inlet port, the valve is closed by the action of down ward spring force and back pressure of air at outlet. Hence the reverse flow is prevented. They may be installed directly in a line to allow flow in one direction only. This valve is also having the following applications in a pneumatic circuit.

- To create back pressure.
- To minimize leakages.
- To hold a load against gravity.
- To isolate compressor (or) valves.

4.12.Shuttle valve

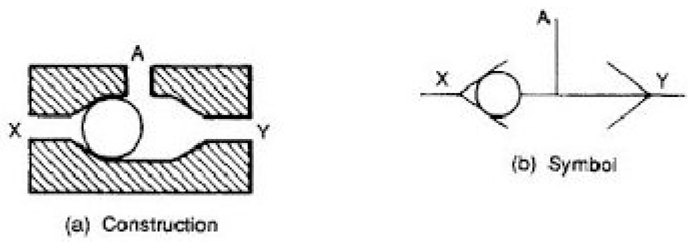
Construction

The basic structure of a shuttle valve is like a tube with three openings; one on each end, and one in the middle. A ball or other blocking valve element moves freely within the tube. When pressure from a fluid is exerted through an opening on one end it pushes the ball towards the opposite end. This prevents the fluid from traveling through that opening, but allows it to flow through the middle opening. In this way two different sources can provide pressure without the threat of back flow from one source to the other.

working

In certain pneumatic circuits, the air flow can be controlled from more than one point. Fig.4.13. shows the arrangement of a three port shuttle valve. It provides path for air from two alternative sources. It consists of two inlet port, one outlet port and a shuttle piston. When the pressure at port- Y is greater than the pressure at port -X, then the shuttle piston blocks the flow of air at port-X. Hence the air can flow from port-Y to outlet port-A.

If the pressure at port- X is greater than the pressure at port -Y, then the shuttle piston blocks the flow of air at port-Y. Hence the air can flow from port-X to outlet port-A.



Pneumatic shuttle valve

Fig.4.13

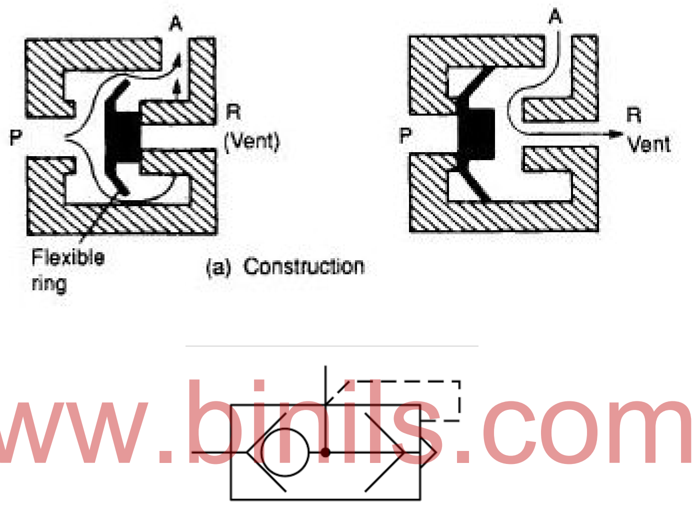
Application of shuttle valve

1. The use of more switches on one machine: by using the shuttle valve, more than one switch can be operated on a single machine for safety, and each switch can be placed at any suitable location. This application is normally used with heavy industrial machinery.

2. Winch brake circuit: a shuttle valve provides brake control in pneumatic winch applications. When the compressor is operated the shuttle valves direct air to open the brake shoes. When the control valve is centered, the brake cylinder is vented through the shuttle valve, and the brake shoes are allowed to close.

3. Air pilot control: converting from air to oil results in locking of the cylinder. Shifting the four-way valve to either extreme position applies the air pilot through the shuttle valve, holding the two air-operated valves open and applying oil under air pressure to the corresponding side of the cylinder. Positioning a manual valve to neutral exhausts the air pilot pressure, closing the two-way valves, and trapping oil on both sides of the cylinder to lock it in position.

4..14. Quick Exhaust valve



(a) Construction

(b) symbol

Fig.4.14

A quick exhaust valve is primarily used with spring return single acting pneumatic cylinder to exhaust air quickly from the cylinder during return stroke. It is used to control the quantity of air flow for the piston movement.

Fig.4.14. shows simple arrangement of quick exhaust valve. It has a movable disc which allows the air from pressure port 1 to cylinder through a small port 2. Hence the speed of the piston is reduced. When the return movement of the piston, the movable disc blocks the pressure port 1 and opens the large port 3. Hence the returned air from the cylinder is quickly exhausted to the port 3 through a small port 2. Generally the return movement of piston can be actuated by the spring action. Thus the piston movement may be increased to three times by using this valve.

4.15. Direction control valve

A direction control valve is used to change the direction of air flow when required by the system for the reciprocating movement of machine tool devices. It may be classified according to the construction of internal moving parts as:

1. Rotary spool type
2. Sliding spool type

The moving internal part rotator spool or sliding spool will connect or disconnect the air flow passage within the valve body. This action results in a control of air flow direction for reversing the machine tool device.

4.15.1.Rotary spool type

This valve consists of a cylindrical bore and rotor. The cylindrical bore containing the three or four ports in which a rotor is closely fitted and rotated. The rotor is also drilled with passages for air flow as shown in fig .4.15.

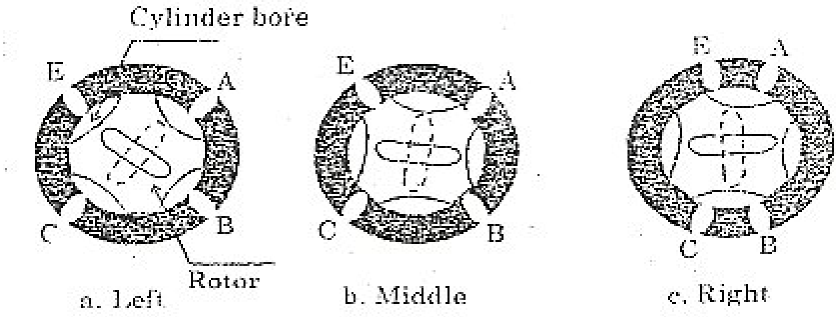


Fig. 4.15

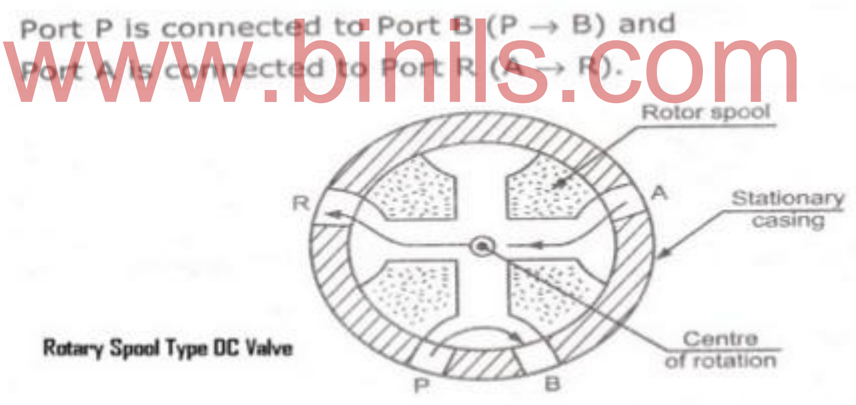


Fig. 4.16

When the system is not required for any movement all the ports are closed as shown in fig4.15(b). For the forward movement of machine tool, the compressor port C is connected to the cylinder port A while cylinder port B is connected to exhaust port E as shown in fig.4.15(a). For reversing the machine tool , the compressor port C is connected to cylinder port B while the cylinder port A is connected to exhaust port E as shown in fig 4.15.(c). This can be achieved by rotating the rotor either clockwise or anticlockwise. The compressor supply can be connected to the port A or port B.

4.15.2.Sliding spool type

The flow direction of air is controlled by a sliding spool inside the cylinder. Many types of DCV are available in sliding spool type control valve.

The symbol of this type of valve is shown in fig. 4.17

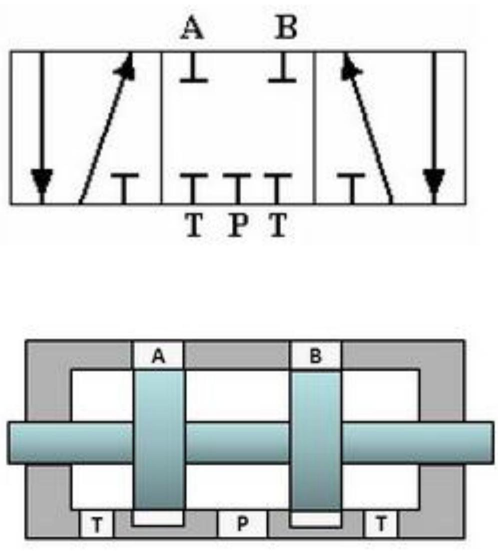


Fig. 4.17

It contains three squares which represents three position of valve. Generally they are actuated by manually or mechanically. It consists of a rectangular body in which a precision hole is bored and a spool. The spool is closely fitted and moved to the right or left throughout the longitudinal axis of the rectangular body. The lands of the spool divide the bore into series of separate chambers. The ports are provided in the valve body and the position of the sliding spool determines the flow passage. Depending upon the number of port connection, the valve may be classified as one way, two ways, three ways, four ways and five way directional control valves.

i) 3/2 DC valve

Normally closed type   Normally opened type

Fig. 4.18

3/2 directional control valve is mainly used in single acting cylinders. It has one cylinder port A, one pressure port or compressor port C and one exhaust port E. The arrangement and symbolic representation of this valve is shown in fig.4.18.

In normally closed type the left position of the spool the pressure port C is connected to cylinder port A and the exhaust port E is closed. Hence the air actuates the piston in the cylinder and doing work. When the spool is in right extreme position, the cylinder port A is connected to the exhaust port E and the pressure port C is closed. Hence the air is released to atmosphere.

ii) 4/2 DC valve

This four way directional valve is mainly used in double acting cylinders. It has two cylinder ports A and B, one pressure port C and one exhaust port E.

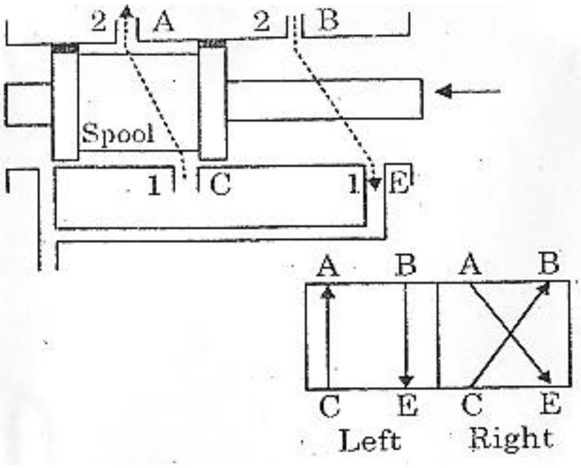


Fig. 4.19

The arrangement and symbolic representation of this valve is shown in fig .4.19.When the spool is in Left extreme position, the pressure port C is connected to cylinder port A and the cylinder port B is connected to the exhaust port E. Now the air actuates the piston in forward direction and doing work. At the same time, the air is released to exhaust through port B. When the spool is in Right extreme position, the pressure port C is connected to cylinder port B and the cylinder port A is connected to exhaust port E. Hence the air actuates the piston in backward direction and doing work. At the same time, the air is released to exhaust through port A.

iii) 4/3 DC valve

This four way directional control valve is used in double acting cylinder. It has two cylinder ports A and B. One pressure port C and one exhaust port E.

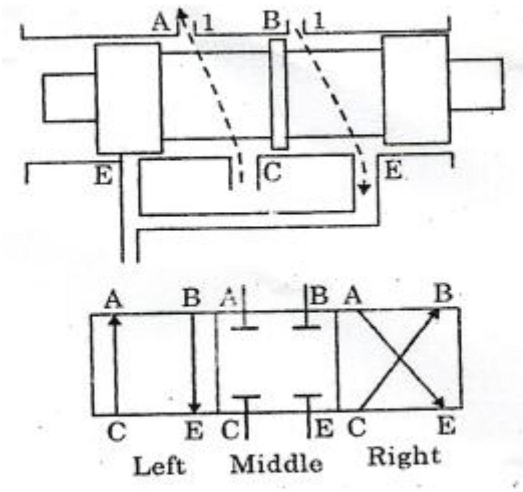


Fig.4.20

The arrangement and symbolic representation of this valve is shown in fig.4.20(a). When the spool is in left position, the pressure port C is connected to cylinder port A and the cylinder port B is connected to exhaust port E. Now the air actuates the piston in forward direction and doing work. At the same time, the air is released to exhaust through the port B. When the spool is in the right extreme position, the pressure port C is connected to cylinder port B. Now the air actuates the piston towards backward direction and doing work. At the same time, air is released to exhaust the port A.

In the middle position of spool all ports are closed. Now the cylinder is hold in stationary position and no work done.

iv) 5/2 DC valve

This five way directional control valve is used in double acting cylinders. It has two cylinder ports A and B, one pressure port C and two exhaust ports E. The arrangement and symbolic representation of this valve is shown in fig .4.21

Fig. 4.21

When the spool is in left extreme position, the pressure port C is connected to cylinder port A while the cylinder port B is connected to exhaust port E. Now the air actuates the piston towards forward direction and doing work. At the same time, the air is released to exhaust. When the spool is in right extreme position, the pressure port C is connected to cylinder port B. Now the air actuates the piston towards backward direction and doing work. At the same time, the cylinder port A is connected to exhaust port E which results the release the air to atmosphere.

v) 5/3 DC valve

5/2 directional control valve has two cylinder ports A and B one pressure port C and two exhaust ports E. Totally it has five ports and three position.

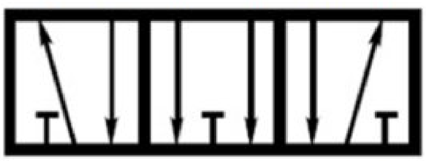


Fig. 4.22

The arrangement and symbolic representation of this valve is shown fig.4.22. When the spool is in left position, the pressure port C is connected to cylinder port A and actuate the piston in the forward direction and doing work. At the same time, the cylinder port B is connected to exhaust port E and air is released to atmosphere.

When the spool is in middle position, two cylinder ports A and B are connected to exhaust ports E and no air is supplied to actuator.

When the spool is right position, the pressure port C is connected to cylinder port B and actuates the piston in the backward direction and doing work. At the same time the cylinder port A is connected to exhaust port E and air is released to atmosphere.

4.16.Basic pneumatic circuits

Pneumatic circuits may be defined as a systematic arrangement of pneumatic elements to perform a specific machine tool operation. Here compressed air is used to operate the pneumatic circuits. After doing the work in the actuator air is released to atmosphere by using the control valves.

4.16.1.Single acting cylinder pneumatic circuit

The Single acting pneumatic cylinder will do the work in forward stroke only and the return stroke is idle. Fig.4.23. shows the arrangement of simple pneumatic circuit for single acting cylinder with its major elements.

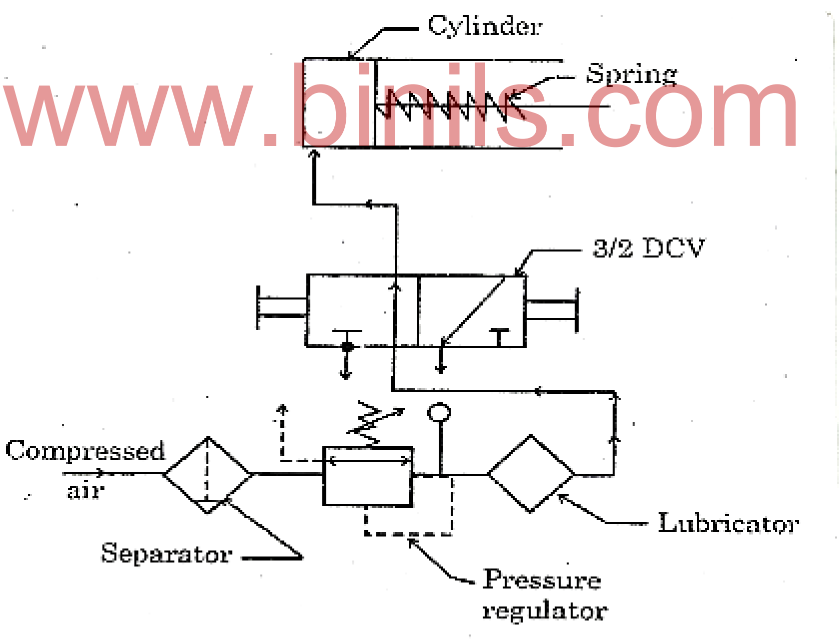


Fig. 4.23

Working principle

Compressed air passes through the FRL unit which consists of filter, pressure regulator and lubricator for air treatment. Then it enters into 3/2 direction control valve to actuate the cylinder. The position of 3/2 DCV as shown in figure indicates the air form 3/2 DCV enters into cylinder at its left side. Therefore the piston moves from left to right position and doing the work. To reverse the piston 3/2 DCV is changed to its right position.

Now the cylinder is connected to atmosphere. When reversing the piston, the spring force in the cylinder is used to speed up the piston.

4.16.2.Double acting cylinder

The double acting pneumatic cylinder will do the work both in forward & return stroke of the piston. Both forward and return stroke are controlled by DCV. The speed of return stroke is somewhat high with respect to the area of piston rod.

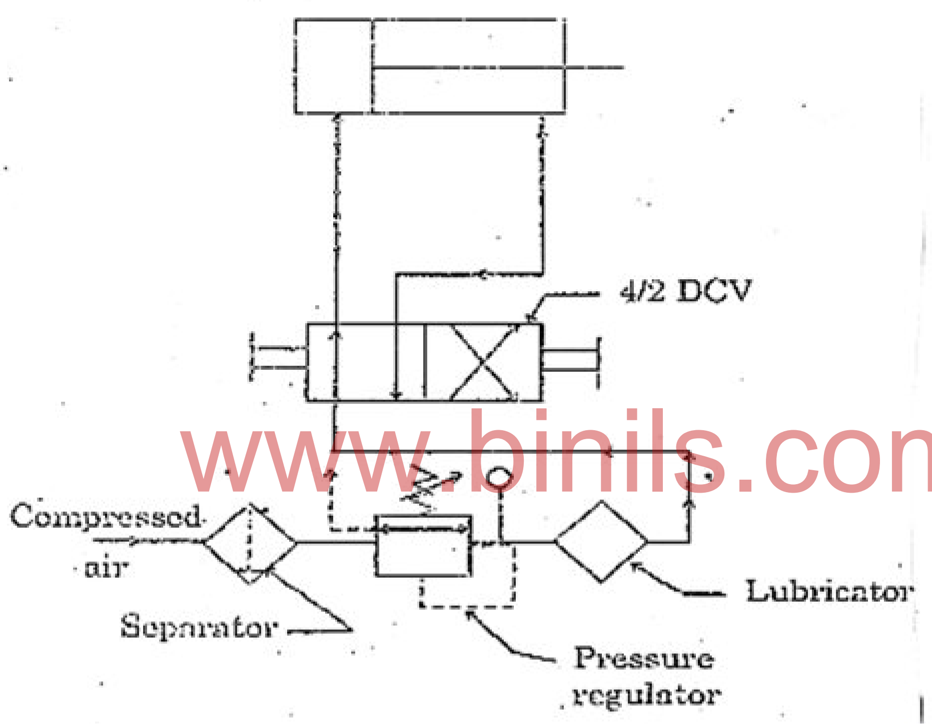


Fig. 4.24.

Fig. 4.24.shows the arrangement of double acting cylinder circuit. A 4/2 DCV is connected to the cylinder.

Working

The air from 4/2 DCV enters into the cylinder in the left side , moves the piston from left to right and doing the work. At the same time, the air is released from cylinder to exhaust. During the return movement of the piston, the air from 4/2 DCV enters into the right side of the cylinder. Hence the piston moves from right side to left side. At the same time, the air present in the left side of the cylinder released to exhaust.

4.16.3.Double acting cylinder with meter-in circuit

The double acting pneumatic cylinder will do the work both in forward & return stroke of the piston. Both forward and return stroke are controlled by DCV.

Forward Stroke

It is a working stroke and Air inlet to the cylinder is controlled by flow control valve. Hence the piston will move slowly.

Return Stroke

It is a idle stroke , the air is not controlled and freely exhaust to atmosphere. In this the speed is high.

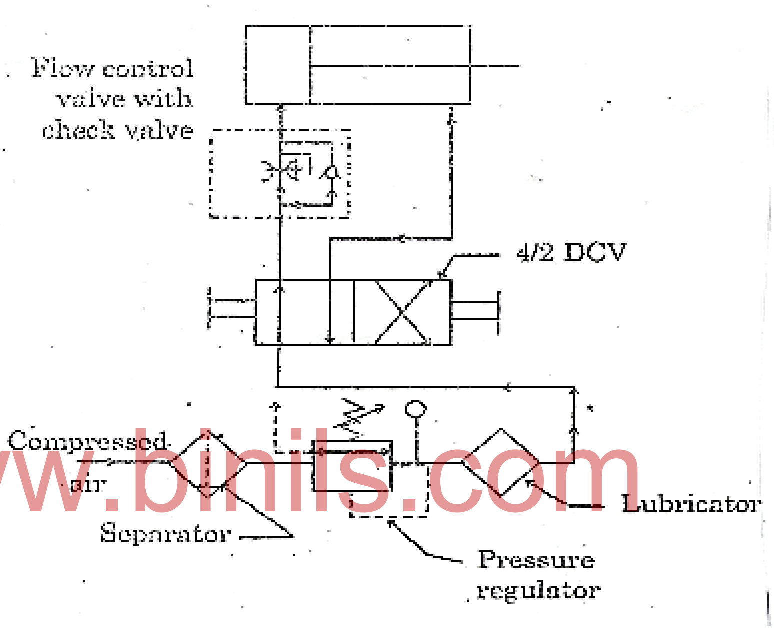


Fig. 4.25

Fig.4.25. shows the arrangement of double acting cylinder with meter-in pneumatic circuit. The speed of the piston can be controlled by quantity of air entering into the cylinder. Hence it is called meter-in circuit. It is done by using a flow control valve integral with a check valve. In this circuit the flow control valve is located in the line between 4/2 DCV and cylinder.

Working

The air from 4/2 DCV enters into the cylinder in the left side through flow control valve and moves the piston from left to right and doing the work. At the same time, the air is released from cylinder to exhaust. During the return movement of the piston, the air from 4/2 DCV enters into the right side of the cylinder. Hence the piston moves from right side to left side. At the same time, the air present in the left side of the cylinder released to exhaust through check valve and 4/2 DCV. Hence the speed of the piston is increased.

4.16.4. Double acting cylinder with meter-out circuit

The construction and working principle of Double acting cylinder with meter-out circuit is same as that of Meter-in circuit except the flow control valve is connected in the exhaust line of the forward stroke. Hence the air exhaust from the cylinder is controlled.

Fig.4.26. shows the arrangement of double acting cylinder with meter-out pneumatic circuit. In this circuit the return air from the cylinder is controlled by flow control valve. Thus, the speed of the piston is controlled. Hence it is called meter-out circuit. It is located in between the cylinder and 4/2 DC valve in the return line of the circuit.

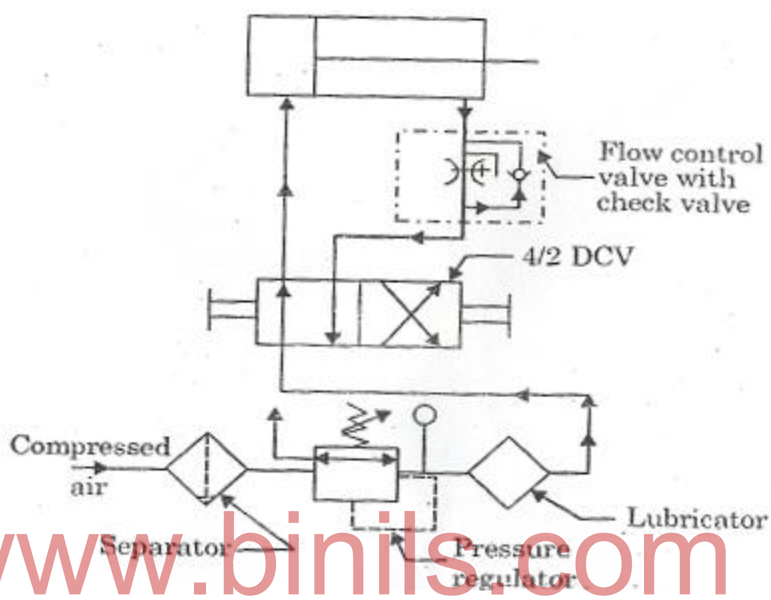


Fig. 4.26

Working

For the forward movement of the piston, the air from 4/2 DCV enters into the cylinder in left side and doing the work. At the same time, the air present in the right side of the cylinder release to exhaust through the restricted passage of flow control valve. Hence the piston moves slowly for the forward movement. For the return movement of the piston, the air from 4/2 DCV enters into the cylinder in right side through the check valve. Hence the speed of the piston increases.

4.16.5. Use of shuttle valve in circuits

This circuit is used to operate a double acting cylinder forward stroke at various speed. The first half of forward stroke is fast and the second half of forward stroke is slow.

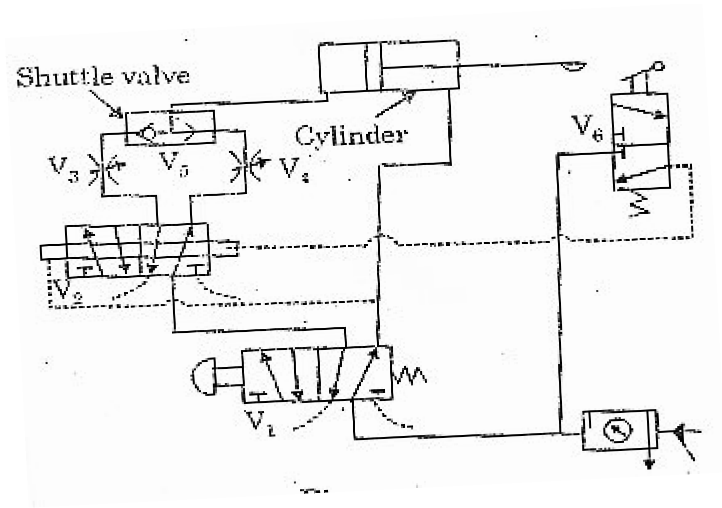


Fig. 4.27

Fig.4.27. shows the use of shuttle valve in a two step speed control pneumatic system.

In this circuit V_1, V_2 and V_6 are used as direction control valves (DCV). The flow control valves V_3 and V_4 are used to control the flow of air into the cylinder through the shuttle valve V_5. Assuming that flow control valve V_3 is adjusted to supply more flow rate than valve V_4

Initially the piston is fully retracted (Left position). When the push-button valve is actuated, air flows through valves V_2, V_3 and shuttle valve V_5 to move the piston in forward direction at high speed. When the piston is in middle of forward movement, the piston rod can actuates valve V6 which shifts valve V_2. Now the flow is diverted through valve V_4 and shuttle valve V_5 to cylinder. Now the forward speed of piston is reduced due to low flow setting of valve V_4.After full forward movement of the piston, valve V_1 is released by the operator to return back the piston for the next cycle.

4.16.6. Use of quick exhaust valve

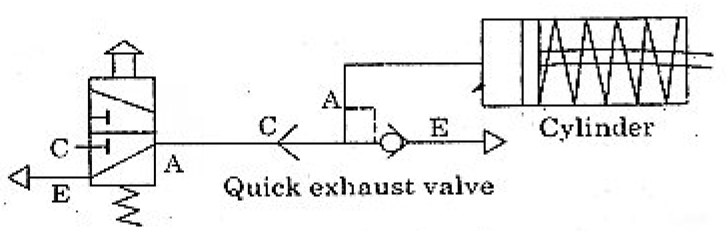


Fig. 4.28

Fig. 4.28.shows the use of quick exhaust valve in a single acting cylinder pneumatic circuit. This valve is primarily used to release the exhaust air quickly from the cylinder. Spring return single acting cylinder is used. Hence, the return speed of the piston is increased. Hence the exhaust air should by allowed for fast releasing. For this the Quick

exhaust valves are usually mounted directly on the cylinder. This valve also permits simple control valves in the circuit.

4.16.7. Automatic operation of double acting cylinder.

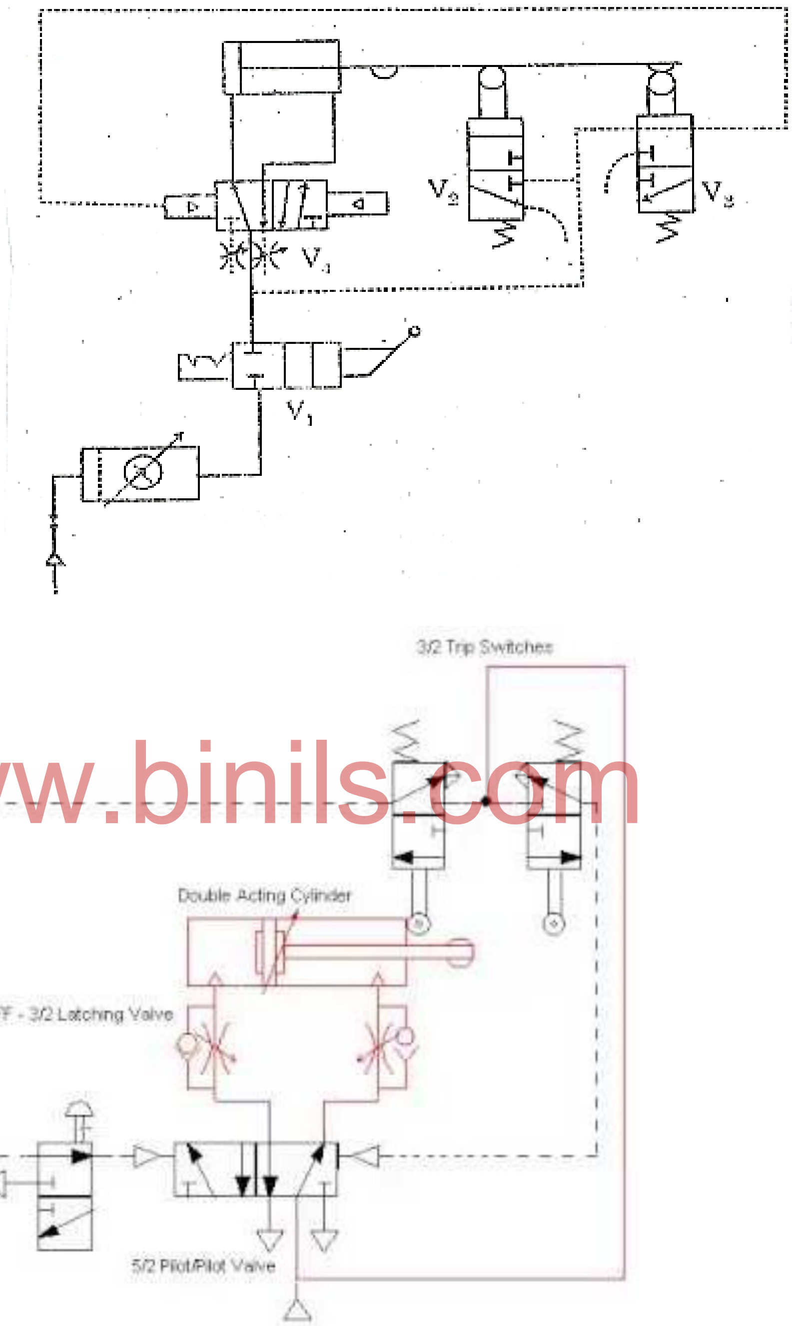


Fig.4.29a single cycle

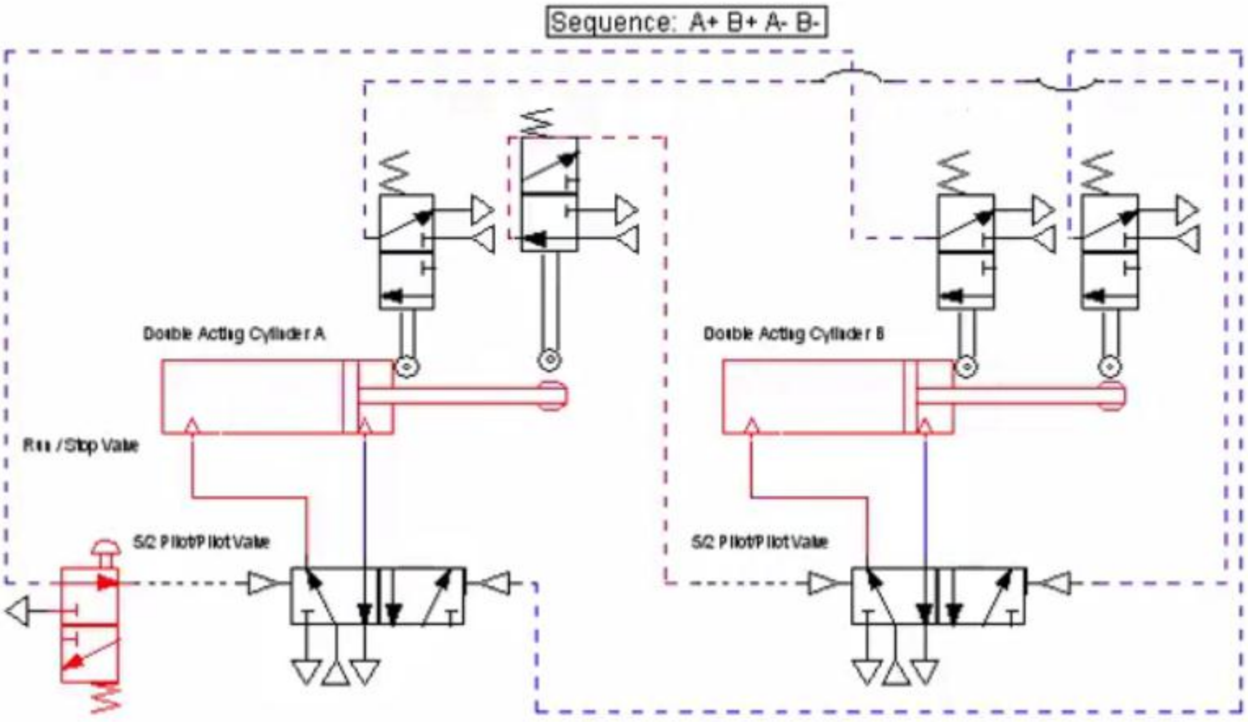


Fig. 4.29b Multi cycle

Fig.4.29a. shows a pilot-controlled automatic double acting cylinder pneumatic circuit. In this arrangement V_1 is the two way valve, V_2 and V_3 be the 3 way valve and V_4 is the main control valve. When the valve V1 is manually operated, the air from the FRL unit enters the valve V_1 and opens the circuit for the reciprocating movement. The reciprocating movement of the piston is predetermined according to the magnitudes of load resistance and settings of flow control valves. The flow control valves are located in the main control valve V4 to meter-out the return air from the cylinder.

Working

When the piston is in left position, one of the pilots in the piston actuates the valve V_3. Now the air from the two way valve V_1 flows through V_3 to main control valve V_4 and reciprocates the piston towards right side. At the end of forward stroke, another pilot in the piston rod actuates the valve V_2. Now the air from the valve V_1 flows through valve V_2 to main control valve V4 and actuates the piston towards left side. Thus, the automatic cycling is achieved by three way valves V_2 and V_3 which are acting as a limit switches. The length of stroke of the piston is adjusted by the locating adjustable pilot on the piston rod.

Working of Multi cycle Automation

Multi cycle automation is working based on the sequence A+ B+ A- B-.as sown in fig.4.29b.

A+ forward stroke of cylinder A

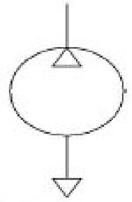
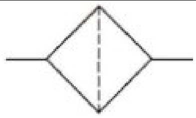
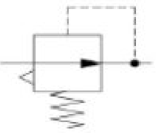
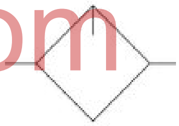
B+ forward stroke of cylinder B

A-   return stroke of cylinder A

B- return stroke of cylinder B

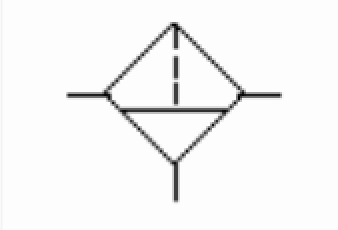
4.17. ISO symbols of Pneumatic symbols

The lists of standard symbols of pneumatic components are given below.

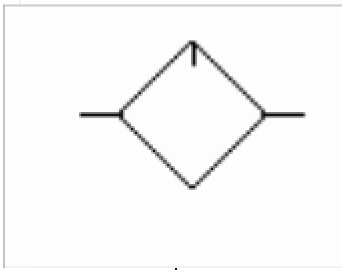
component name	Symbol
Compressor	
Pressure source	
Filter	
Regulator	
Lubricator	

Air Service Equipment

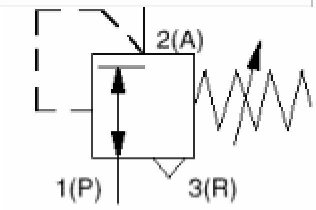
Air filter



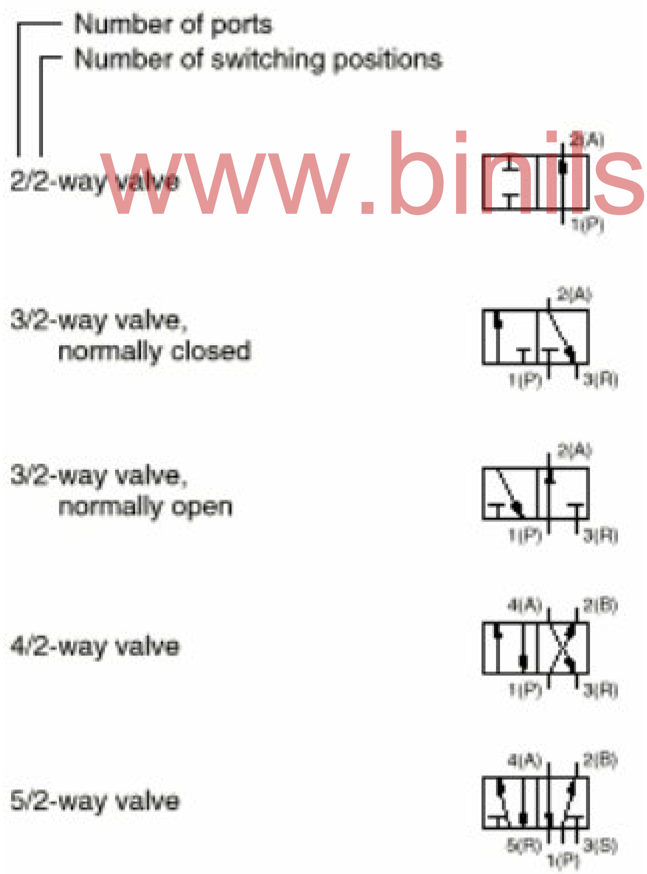
Air lubricator



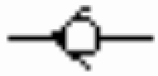
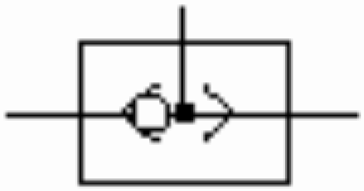
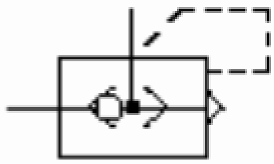
Pressure regulator



Direction control Valves



Non return valves

Check valve	
Spring loaded check valve	
Shuttle valve: ‘or’ function	
Quick exhaust valve	
Flow control valve adjustable	
One-way flow control valve	

EXERCISE
THEORETICAL QUESTIONS

PART – A

1. What is pneumatic system?
2. State any one purpose of relief valve in a pneumatic circuit.
3. What is the function of air filter in pneumatic system?
4. What is FRL unit?
5. Why a pressure regulator is needed in pneumatic system?
6. What is the function of directional control valve?
7. Name any two types of DCV’s
8. What is the use of pressure regulator?
9. Draw the ISO symbol for 3/2 DCV
10. Draw the ISO symbol for shuttle valve.
11. What is the use of flow control valve?
12. What is the use of check valve?
13. What is the use of quick exhaust valve?
14. State the type of direction control valve.
15. Mention any two applications of pneumatic systems.
16. State any one disadvantage of pneumatic systems.

17. State any one advantages of pneumatic systems.
18. What is the use of shuttle valve?
19. Draw ISO symbol for check valve.
20. Draw ISO symbol for sequence valve.
21. Draw ISO symbol for speed control valve.
22. Mention the elements of the system.
23. State the purpose of relief valve in a pneumatic circuit.
24. Describe the shuttle valve.
25. Draw a pneumatic shuttle valve.
26. What is the function of a directional control valve?
27. Describe with a line sketch the FRL unit.
28. Draw any five pneumatic symbols.
29. Explain the function of quick exhaust valve.
30. Sketch and explain the lubricator used in pneumatic system.
31. Explain with sketches, the working of check valve.
32. Explain with sketches, the working of air filter.

Part – B

1. Briefly explain the elements of pneumatic system with neat sketch.
2. Explain the working principle of pressure reducing valve with a neat sketch.
3. Explain the working of 3/2 directional control valve used in pneumatic system.
4. Explain the working of 4/2 and 5/2 DC valve with neat sketch.
5. Explain the working of 4/3 DC valve with the aid of the sketches.
6. Explain the working of 5/3 DC valve with the aid of the sketches.
7. Draw a circuit diagram for the operation of a double acting cylinder with metering in control.
8. Draw a circuit diagram for the operation of a double acting cylinder with metering out control.
9. What are the applications of pneumatic system?
10. State the advantages and disadvantages of pneumatic system.

References:

1. **Pneumatics basic level- Festo**
2. **The Pneumatics & Hydraulics - Madan M.Pandey**
3. **Fluid Mechanics & Fluid Power – D.S.Kumar**

UNIT-V HYDRAULIC SYSTEMS

Objective

- Study about Hydraulic system, elements, merits and demerits & service properties of hydraulic fluids.
- Study about different types of Hydraulic pumps.
- Explain the flow control vales and symbols
- Explain the applications of hydraulic circuit for various mahines.
- Compare of hydraulic and pneumatic systems.
- Discuss the types of DCV and their location in the circuit.

5.1. Introduction

Hydraulic systems work based on Pascal's law. Hydraulic system is a system in which force and power are transmitted from one place to another place through the medium of incompressible fluid. Hydraulic system is widely used in machine tool engineering for heavy power transmission.

Hydraulics and hydraulic systems can be found almost everywhere. Hydraulics can be found at any construction site. Some machines that use hydraulics are bulldozers, fork lifts, and cranes. Hydraulics are used to lift cars so mechanics can work underneath them. Many elevators use the same operating technique.

WHY ARE HYDRAULIC SYSTEMS USED

There are many reasons. Some of these are that hydraulic systems are versatile, efficient and simple for the transmission of power. This is the hydraulic system's job, as it changes power from one form to another. The science of hydraulics can be divided into two sciences:

1. Hydrodynamics
2. Hydrostatics.

Hydrodynamics

This describes the science of moving liquids.

Ex. Hydraulic turbines

Hydrostatics

This describes the science of liquids under pressure.

Ex. Hydraulic press & Hydraulic jack.

5.2. Elements of Hydraulic system

The main elements of hydraulic system as shown in fig. 5.1.

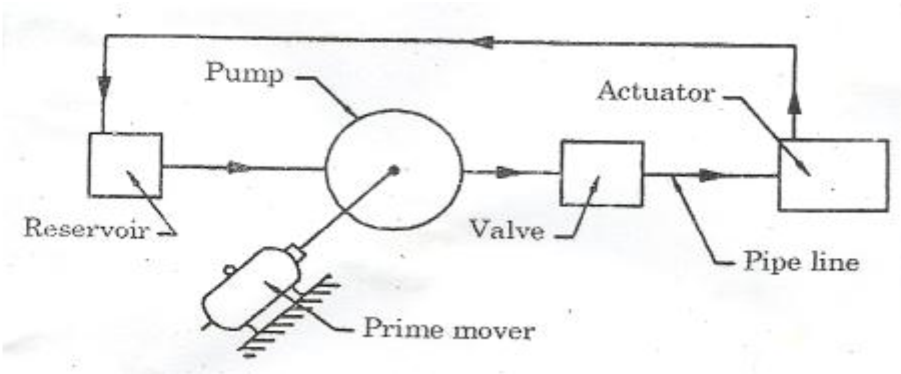


Fig. 5.1

1.Prime mover and pump

Prime mover drives a pump. Pump is the heart of the hydraulic of the hydraulic system. Pump is converts mechanical energy in to hydraulic systems.

2.Pipe lines and valves

Pipe lines connect the various elements of the hydraulic systems. Control valves are used to control the pressure, quantity and direction of the following fluids.

3.Fluid motor (or) actuator

Actuator is used to converts Hydraulic energy into mechanical energy. It produces linear (or) rotatory motion to actuate the machine. If the actuator is having linear motion it is called cylinder and rotator motion it is called fluid motor.

4.Reservoir

Hydraulic fluid is stored in the reservoir. The fluid is supplied to the system from the reservoir and will do the useful work then return to the reservoir. The same fluid is recirculated.

5.3. Merits and Demerits of Hydraulic system

Merits

- **i.** More compact and eliminates the mechanical linkages.
- **ii.** Working fluid itself serves as a lubricant.
- **iii.** Less maintenance.
- **iv.** Absorbs stock loads.
- **v.** Increase the life of machine.
- **vi.** Step less speed can easily be obtained by varying the quantity of oil flow.
- **vii.** Very high degree of dependability.

viii. Idle times of machining operations are reduced.

Demerits

i. Hydraulic system may fail due to leakage of fluids.
ii. Greater possibility of leakages.
iii. Leakage are always there, which makes the machine ugly and dust and dirt are adhering to them.
iv. Cost of oil is high.
v. Life of parts (Ex) seals, packings and gaskets etc., are very short.

5.4. Service properties of Hydraulic Fluid.

- As hydraulic fluid is a medium of power transmission in a hydraulic system.
- It must passes certain service properties for maximum power transmission.
  i) Viscosity
  ii) Viscosity index.
  iii) De-emulsibility
  iv) Oxidation stability
  v) Lubricity
  vi) Rust and correction prevention.
  vii) Flash point fire point & cloud point.

1. Viscosity

Viscosity is the properties of fluid to resisting flow of fluid. If the fluid viscosity is more than the required, it is difficult to flow through the small passages. If the fluid viscosity is less than the required, leakages will be more. Hence the viscosity should be optimum.

2. Viscosity index

The rate of change viscosity with temperature is called viscosity index. If the change in viscosity of oil is very small to a particular change in temperature, then the oil is said to have high viscosity index. Oil having higher viscosity index is preferable for Hydraulic system.

3. Oxidation stability

Oxidation is a chemical reaction between oil and oxygen in air. Oxidation stability is defined as the ability of the fluid to resist oxidation. Complete prevention of oxidation is impossible but it can be reduced by adding some additives.

4. De – emulsibility

The capacity of oil to separate rapidly and completely from water is known as de-emulsibility. So the oil must have the property to resist mixing of oil with water and avoid foaming.

5. **Lubricity**

It is the capacity of oil to lubricate the moving components. Wear and tear is reduced if the components are lubricated by an oil which has more lubricity. The wear reduces the life of machine and produces noise and vibration.

6. **Rust and corrosion prevention**

   The oil selected for hydraulic system must have a capacity to resist rust and corrosion.

7. **Flash point, fire point and cloud point.**

   i) Flash point

   It is the lower temperature at which momentary flash occurs when a flame is introduced.

   ii) **Fire point**

   The lowest temperature at which the oil vapor burns continuously when a flame is introduced is known as fire point.

   iii) Cloud point

   iii) Cloud point

   The lowest temperature at which the oil crystallizes into wax is known as cloud point. When the temperature is very low waxes are formed. Hydraulic actuators

5.5. HYDRAULIC ACCUMULATOR

Hydraulic Accumulator

Hydraulic accumulators are used for temporary storage of hydraulic energy. It resembles the engine fly wheel and electrical battery in its functions.

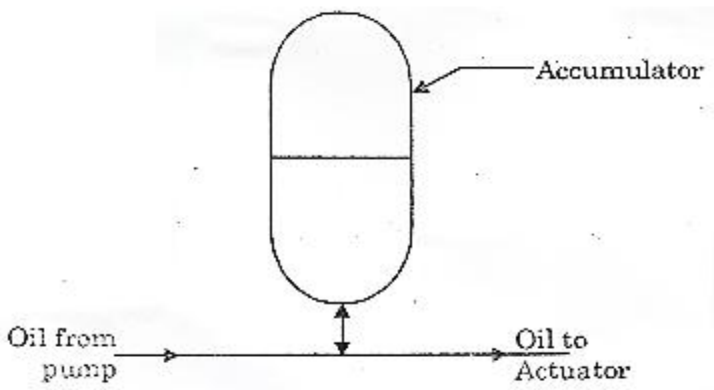


Fig. 5.2

Purpose of Hydraulic Accumulator

- To act as a pressure regulator for starting and stopping of the pumps.
- To use as a fluid compensator to make up the leakages of fluid when the pump is switched off.
- To act as a shock absorber for providing cushioning effect in the hydraulic circuit.
- To maintain pressure for some period of time as in case of clamping jaws.
- To store the hydraulic oil under pressure and supply the oil as when required.

i. Gravity (Dead weight) type accumulator

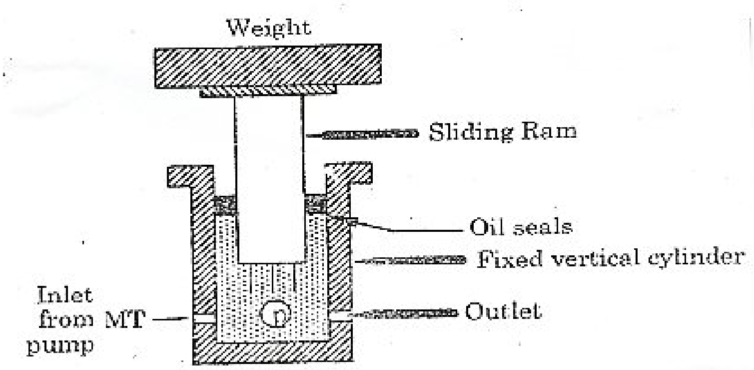


Fig.5.3

It consists of a sliding ram in a cylinder. The ram movement is opposed by placing dead weights on its top. This weight is chosen to exert a predetermined pressure on the hydraulic fluid. Line diagram of gravity type accumulator is as shown in fig.5.3. As the flow is directed into the bottom of the cylinder the ram and weight moves upwards. Thus the fluid is stored by raising the dead weights.

When the demand in the system rises, the ram forces the fluid from the cylinder to the system due to gravitational force of weight.

Advantage

- This type is always maintained constant pressure.

Disadvantage

- This type requires heavy weight and larger size.

ii. Spring loaded type accumulator

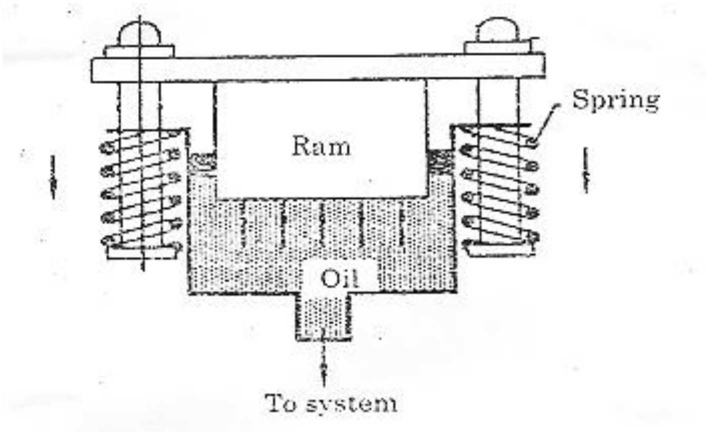


Fig.5.4

The line diagram of a spring loaded type accumulator as shown in fig.5.4. It consists of a cylinder, ram, a spring and adjustable nut. A spring loaded ram is used to compress the fluid. The spring force can be adjusted by the nut depending upon the amount of system pressure. When the system pressure is more, the fluid flows into the shell, the ram moves up and the springs are compressed. When the system pressure is falls, the circuit requires more fluid. The spring force moves the ram downward and forces the fluid in the circuit.

Advantages

- This type can be mounted in any position.

Disadvantage

- This type requires heavy spring size for storing larger quantity of fluid.

iii. Gas filled bladder accumulator

i) Bladder (or) Gas charged type accumulator

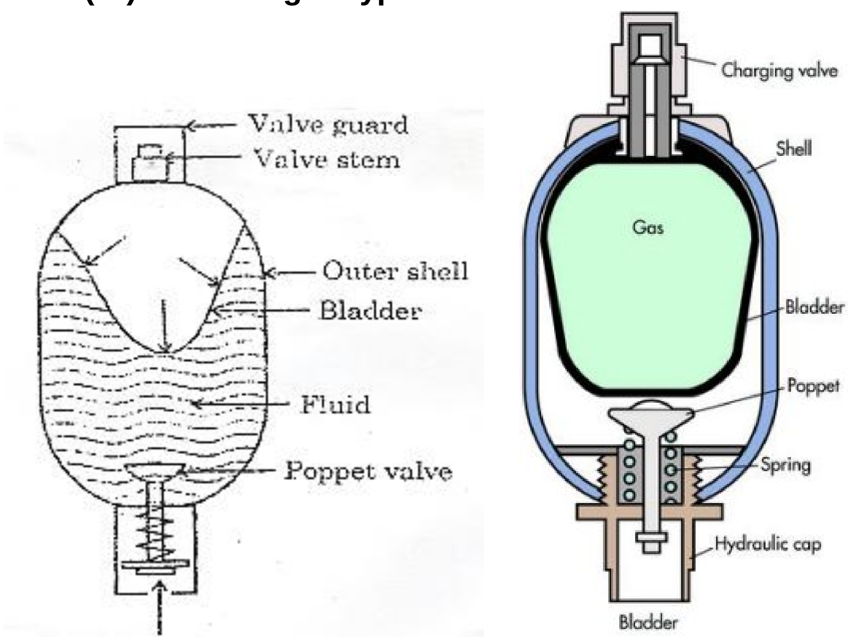


Fig.5.5

This accumulator has a bladder inside a cylindrical shell. The bladder is to be filled with Nitrogen gas. The remaining part of shell is to be filled with Hydraulic fluid. Due to the pressure of Nitrogen, the bladder expands and forces the fluid which closes the poppet valve at the bottom. Bladder type accumulator is as shown in fig.5.5. When the system pressure increases than the required, the fluid from the system enters into the shell by opening the poppet valve. It compresses the bladder. The oil is stored under pressure. When the system pressure falls below than the required gas expands and forces the fluid into the hydraulic circuit through poppet valve.

vi. Free piston gas charged type accumulator

Free piston gas charged type accumulator is as shown in fig.5.6. It has a floating piston inside cylindrical shell with seals. Space above the piston is filled with a gas. Bottom portion is filled with hydraulic fluid.

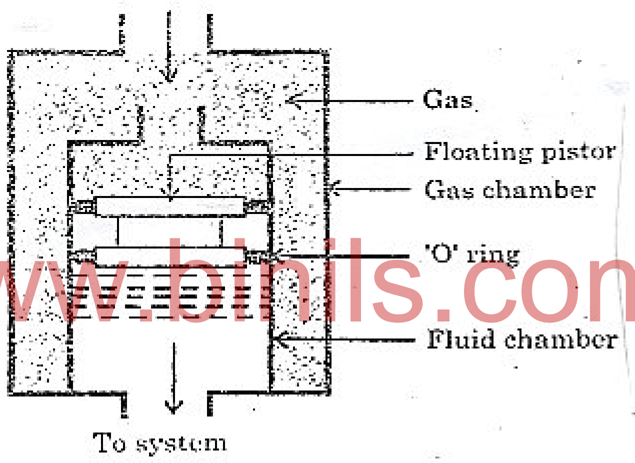


Fig. 5.6

A pressurized gas chamber envelops the fluid chamber. When the system pressure increases than the required, oil enters into the cylinder and lifts the piston. The oil is stored under the pressure. When the system pressure falls below than the required, the gas expands and forces the piston downwards and the piston forces the fluid into the circuit.

Disadvantages

- Frequently replacement of "O" ring for wear.
- Direct contact between the oil and gas.

v. Non-separator Gas type Accumulator

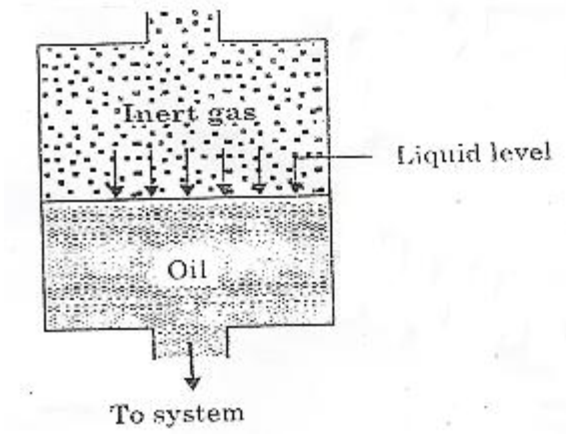


Fig.5.7

Non- separator gas type accumulator is as shown in fig.5.7. In this type there is no separate arrangement of the gas and hydraulic fluid. Both the gas and fluid are having direct contact. Hence it is called non- separator type accumulator. The gas is charged from the top part. The fluid inlet is at the bottom. When the system pressure increases than the required, the fluid enters into the shell by compressing gas at its top. When it falls below than the required, the fluid flows out of the shell by the expansion of gas at the top. To avoid chemical reactions only inert gas should be used.

Limitations

This accumulator requires that always some fluid is to be left at the bottom of the shell.

5.6. Pressure Intensifier (Hydraulic Intensifier)

Hydraulic intensifiers are used to convert low pressure fluid into high pressure fluid. They are called as boosters. It is used in hydraulic press, cranes and lift. The arrangement of the pressure intensifier is as shown in fig.5.8.

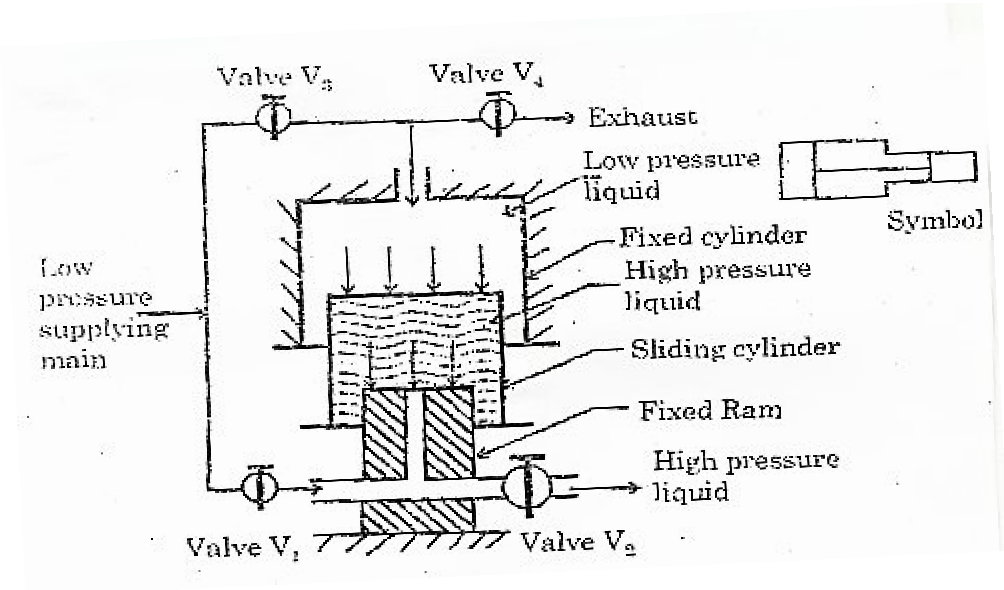


Fig.5.8.

It consists of two cylinders. One is fixed and other is sliding. The sliding cylinder moves up and down inside the fixed cylinder which contains low pressure fluid. At the same time the sliding cylinder is sliding up and down over the fixed ram. The fixed ram and fixed cylinder are provided with valves V_1, V_2, V_3 and V_4.

When the sliding cylinder is at the bottom of its stroke, the fixed cylinder is full of low pressure liquid. Now the valve V_3 & V_2 are closed and the valve V_1 &V_4 are open. Now low pressure liquid supply enters into the sliding cylinder causing it rise up. Then the water in the fixed cylinder is exhausted through the valve (V4).

When the sliding cylinder reaches the top position, close the valves V_1& V_4 and open the valves V_2& V_3. Now the low pressure liquid supply enters into the fixed sliding cylinder to move down which produce high pressure in the sliding cylinder. Then the high pressure liquid from sliding cylinder is sent to the system.

Let, A = area of fixed cylinder.
a = area of sliding cylinder.
P_1 = low pressure with fixed cylinder.
P_2 = High pressure with sliding cylinder.

Downward force due to down ward force due to
Low pressure liquid in the fixed cylinder = high pressure liquid in the sliding cylinder.

$$P_1 A = P_2 a$$

$$P_1 \frac{A}{a} = P_2$$

5.7. FLUID POWER PUMPS (Hydraulic pumps)

Introduction

A hydraulic pump is a device to pressurize the Hydraulic fluid and to transfer it to the system to do some useful work. Pump converts mechanical energy to hydraulic energy.

Classification of Hydraulic pumps

1. **Positive displacement pump**
   A positive displacement pump is increases the fluid pressure. It is commonly used in Hydraulic system.

2. **Non positive displacement pump**
   A non positive displacement pump is only transfers the fluid.

5.8. Positive displacement pump

i. Gear Pump

1. External Gear Pump

The External gear pumps are shown in fig.5.9. The main function of this pump is increases the fluid pressure and transfer the fluid from reservoir to actuator.

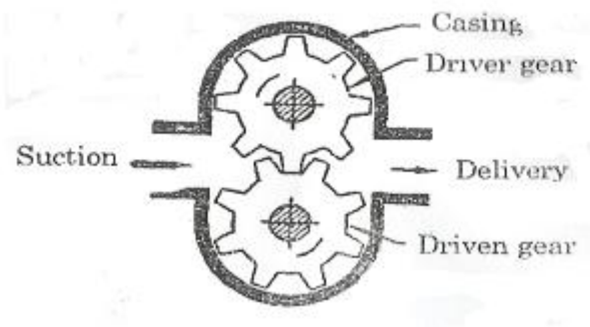


Fig.5.9

This pump consists of two identical spur gears meshing externally. One gear is driven by motor and acts as driver. Other gear is driven gear. Two gears are enclosed in closely fitted casing. When the pump starts a partial vacuum is created in the suction chamber. Oil from the reservoir enters into this chamber due to atmospheric pressure acting on the oil surface in the reservoir. Oil is trapped between the tooth and casing. It is carried to the discharge spot as the gear rotates. Tight meshing of gears provides a tight seal between inlet and outlet of pump.

2. Internal Gear pump

Internal gear pumps arrangement are as shown in fig.5.10. In this pump, two gears are meshing internally.

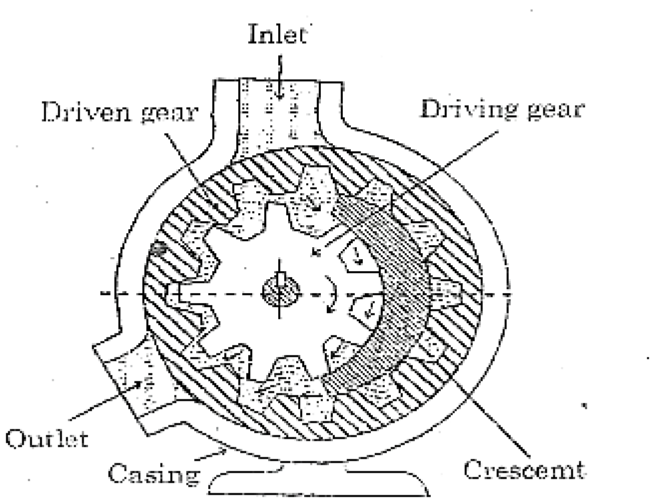


Fig.5.10

It consists of internal gear, & external gear. Crescent is housed in a casing. Driving gear called external gear rams eccentrically in casing. Driven gear called internal gear is concentric with the casing is meshing with the driven gear internally. The space between the outside diameter of driving gear and inside diameter of driven of driven gear is sealed by crescent. The crescent is an integral part of casing. Crescent acts as a partition to prevent the liquid on the discharge side from entering the suction side.

Working

When the pump starts, the two gears mesh with each other completely between the inlet and outlet and then gradually part with each other. When the teeth come out of mesh has increasing volume, partial vacuum is created there. Since this portion is connected to the reservoir, oil enters into the space between the teeth of gears and the casing. As the gears further moves, the liquid is trapped between crescent and internal gears then crescent and external gear. Then this liquid is discharged in the outlet end, as the gears moves further.

iii. Vane pump

vane pump arrangements are as shown in fig.5.11. Vane pump is positive displacement pump.

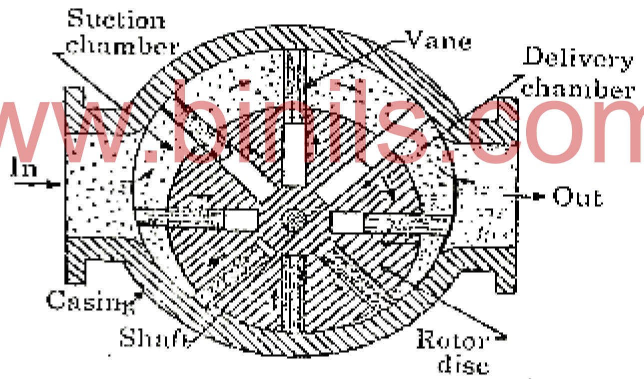


Fig.5.11

It consists of casing, rotor disc and vanes. The center of the disc is eccentric to the centre of casing. Disc has radial slots. Rectangular vanes are provided in the slots. These vanes are free to move in the slots.

Working

When the rotor rotates in the casting, the vanes are moving outward due to centrifugal force which produces air tight contact with the casing. Due to the rotation of rotor the space between the chamber and vanes expands at the inlet and partial vacuum is created in it. Therefore the oil is sucked into it. The oil is trapped between the vanes. This oil is carried around the casting and discharged in the delivery spot, as the disc rotates. The delivered oil can’t return back to the suction chamber, because of fluid tight seal produced by the vanes and casing surface.

iv. Radial piston pump

The radial piston pumps as shown in fig.5.12.

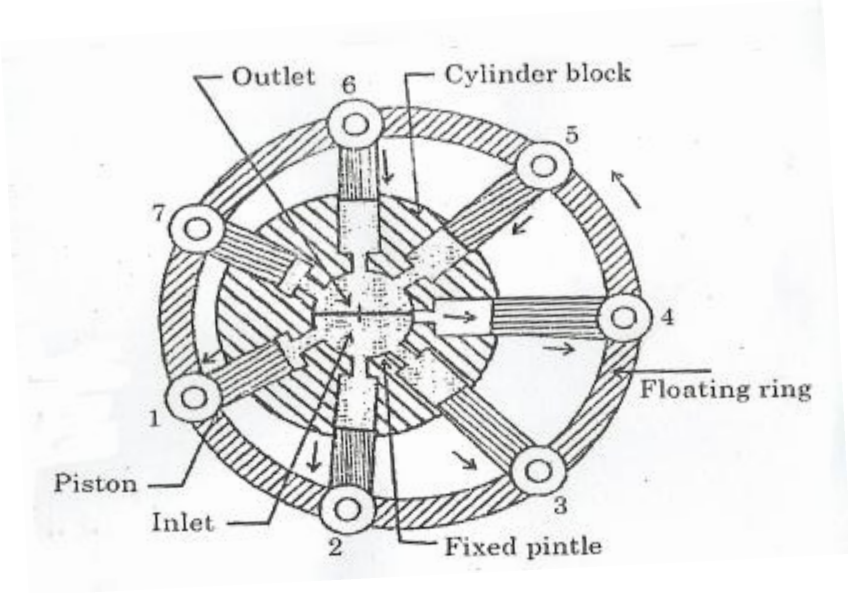


Fig. 5.12.

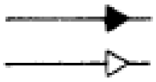
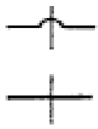
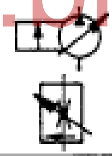
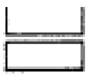
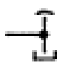
It consists of a fixed pintle, cylinder block and a floating ring. Cylinder block consists of a number of cylinders from which the pistons are moving in and away from the cylinder. It also revolves around the fixed pintle. Cylinder block is connected to the pump shaft. Floating ring is eccentric with the cylinder block.

Working

When the pump rotates in anticlockwise direction, the cylinder clock and floating ring, revolve in the same direction. As a result of this, the piston in the cylinder 1,2and 3 are moving away from the cylinder. It increases the volume resulting in partial vacuum being created. Therefore the oil is sucked into it. At the same time, the piston in the cylinders 4,5, 6 and 7 move into the cylinder which forces the oil into delivery side through the outlet part of the fixed pintle. Each piston sucks the oil from the reservoir during one half of its revolution and delivers during another half of its revolution. Therefore the oil is discharged continuous and uniform.

5.9. ISO symbols of Hydraulic circuit

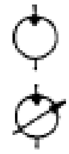
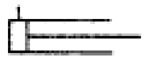
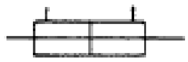
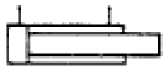
Lines

LINE, WORKING (MAIN)	
LINE, PILOT (FOR CONTROL)	
LINE, LIQUID DRAIN	
FLOW, DIRECTION OF — HYDRAULIC / PNEUMATIC	
LINES CROSSING	
LINES JOINING	
LINE WITH FIXED RESTRICTION	
LINE, FLEXIBLE	
STATION, TESTING, MEASUREMENT OR POWER TAKE-OFF	
VARIABLE COMPONENT (RUN ARROW THROUGH SYMBOL AT 45°)	
PRESSURE COMPENSATED UNITS (ARROW PARALLEL TO SHORT SIDE OF SYMBOL)	
TEMPERATURE CAUSE OR EFFECT	
RESERVOIR — VENTED / PRESSURIZED	
LINE, TO RESERVOIR — ABOVE FLUID LEVEL / BELOW FLUID LEVEL	
VENTED MANIFOLD	

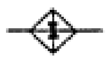
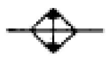
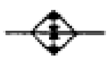
Pumps

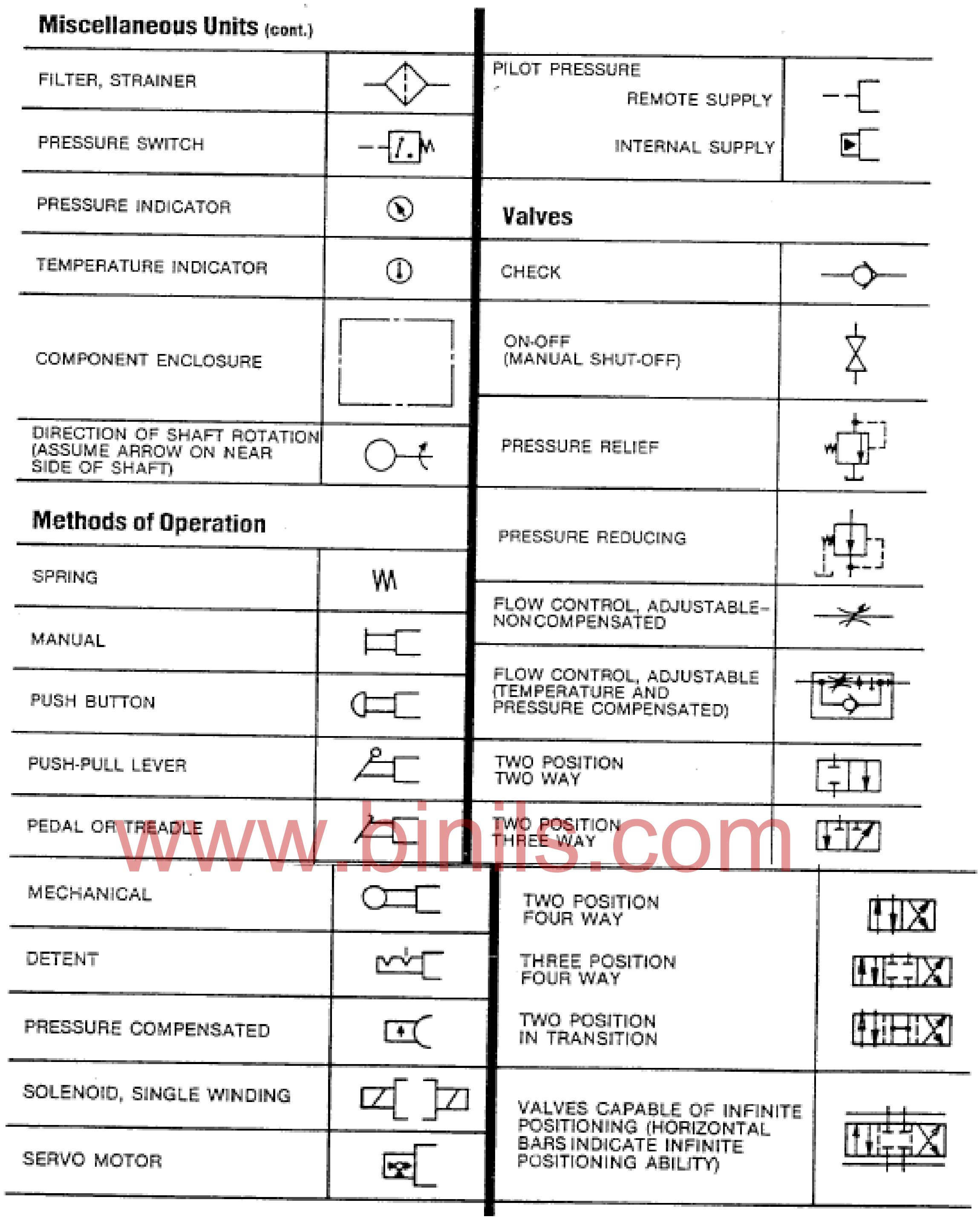
HYDRAULIC PUMP — FIXED DISPLACEMENT / VARIABLE DISPLACEMENT	

Motors and Cylinders

HYDRAULIC MOTOR — FIXED DISPLACEMENT / VARIABLE DISPLACEMENT	
CYLINDER, SINGLE ACTING	
CYLINDER, DOUBLE ACTING — SINGLE END ROD	
DOUBLE END ROD	
ADJUSTABLE CUSHION ADVANCE ONLY	
DIFFERENTIAL PISTON	

Miscellaneous Units

ELECTRIC MOTOR	
ACCUMULATOR, SPRING LOADED	
ACCUMULATOR, GAS CHARGED	
HEATER	
COOLER	
TEMPERATURE CONTROLLER	



5.10. Operation of double acting cylinder with metering in control

Working principle

Double acting cylinder is a cylinder in which both forward and return stroke are controlled by fluid. Forward stroke is a working stroke and return stroke is idle stroke. So the forward stroke should be slow and return stroke should be fast. This is done by control the fluid flow to the cylinder. A flow control valve is used to control the velocity of fluid flow.

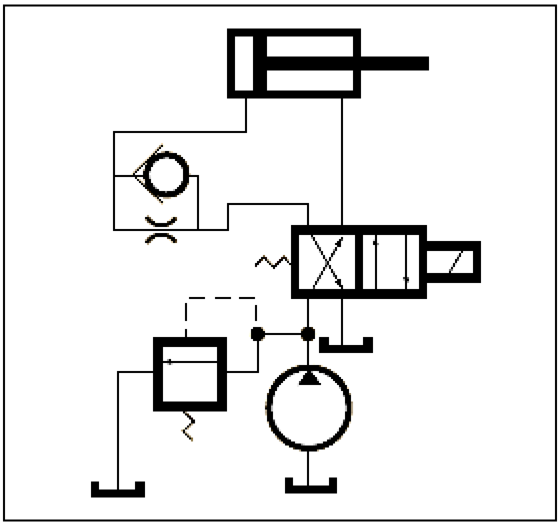


Fig. 5.13

This is connected between the direction control valve and the inlet of double acting cylinder. Hydraulic fluid is pumped from the reservoir by hydraulic pump. This fluid enter to the front side of the cylinder through the flow control valve. Now the piston moves forward slowly by oil enter to front side and the back side of the cylinder oil return to the reservoir as shown in fig.5.13.

During return stroke direction flow is changed by direction control valve. Now the fluid flow to back side of the cylinder and return from the front side of the cylinder without flow control. So the return stroke (or) idle stroke is done fast. The forward and return stroke are done in cyclic manner.

5.11. Operation of double acting cylinder with metering out control

Working principle

Double acting cylinder is a cylinder in which both forward and return stroke are controlled by fluid as shown in fig.5.14. Forward stroke is a working stroke and return stroke is idle stroke. So the forward stroke should be slow and return stroke should be fast. This is done by control the fluid flow to the cylinder. A flow control valve is used to control the velocity of fluid flow. This is connected between the direction control valve and the exit of double acting cylinder. Hydraulic fluid is pumped from the reservoir by hydraulic pump. This fluid flow to the front side of the cylinder and the piston moves forward. At the same time the fluid in the back side of the piston return slowly to reservoir through the flow control valve. So the forward stroke is done slowly and return stroke is done fast.

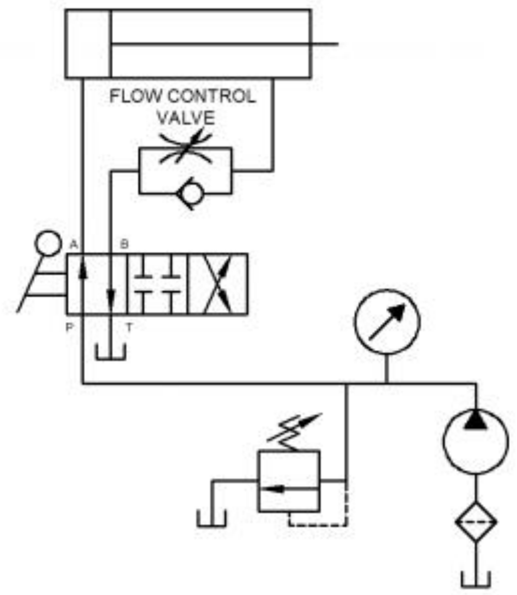


Fig.5.14

During return stroke direction flow is changed by direction control valve. Now the fluid flow to back side of the cylinder without flow control and return from the front side of the cylinder . So the return stroke (or) idle stroke is done fast. The forward and return stroke are done in cyclic manner.

5.12. Hydraulic actuators

Introduction

Hydraulic systems are used to control and transmit power. A pump driven by a prime mover such as an electric motor creates a flow of fluid, in which the pressure, direction and rate of flow are controlled by valves. An actuator is used to convert the energy of fluid back into the mechanical power. The amount of output power developed depends upon the flow rate, the pressure drop across the actuator and its overall efficiency. Thus, Hydraulic actuators are devices used to convert pressure energy of the fluid into mechanical energy.

Depending on the type of actuation, hydraulic actuators are classified
As follows:
1. Linear actuator: For linear actuation (hydraulic cylinders)
2. Rotary actuator: For rotary actuation (hydraulic motor)
3. Semi –rotary actuator: For limited angle of actuation (semi -rotary actuator)

Hydraulic linear actuators , as their name implies, provide motion in a straight line. The total movement is a finite amount determined by the construction of the unit. They are usually referred to as cylinders, rams and jacks. All these items are synonymous in general use although ram is sometimes intended to mean a single acting cylinder and jack often refers to a cylinder used for lifting .The function of hydraulic cylinder is to convert hydraulic power into linear mechanical force or motion. Hydraulic cylinders extend and retract a piston rod to provide a push or pull force to drive the external load along a straight line path.

Continuous angular movement is achieved by rotary actuators, more generally known as a hydraulic motor Semi - rotary actuators are capable of limited angular movements that can be several complete revolutions but 360o or less is more usual
.

Types of Hydraulic Cylinders

Hydraulic cylinders are of the following types:

• Single -acting cylinders
.• Double - acting cylinders
• Telescopic cylinders
.•Tandem cylinders.

1. Single-acting cylinder:

It consists of a piston inside a cylindrical housing called barrel. On one end of the piston there is a rod, which can reciprocate .At the opposite end , there is a port for the entrance and exit of oil as shown in fig.5.15. Single -acting cylinders produce force in one direction by hydraulic pressure acting on the piston. (Single -acting cylinders can exert a force in the extending direction only). The return of the piston is not done hydraulically. In single - acting cylinders , retraction is done either by gravity or by a spring.

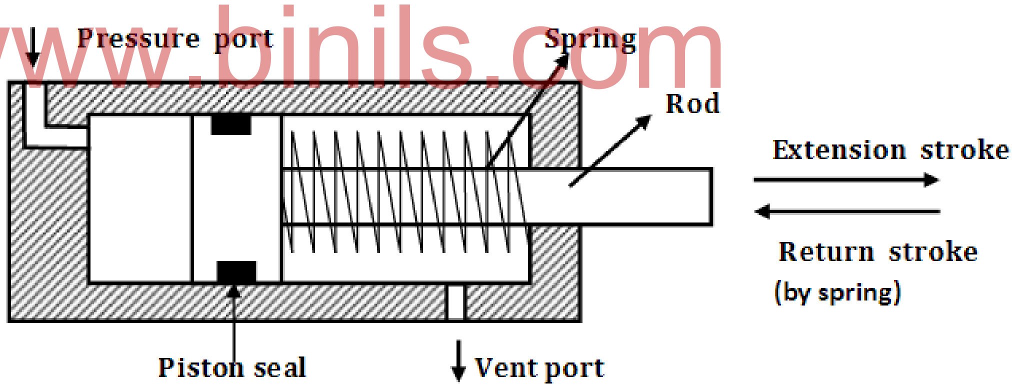


Fig.5.15

2. Double -acting cylinder

Figure 1.4 shows the operation of a double -acting cylinder with a piston rod on one side. To extend the cylinder, the pump flow is sent to the blank - end port as in Fig.5.16(a). The fluid from the rod - end port returns to the reservoir. To retract the cylinder, the pump flow is sent to the rod - end port and the fluid from the blank - end port returns to the tank as in Fig.5.16 .(b).

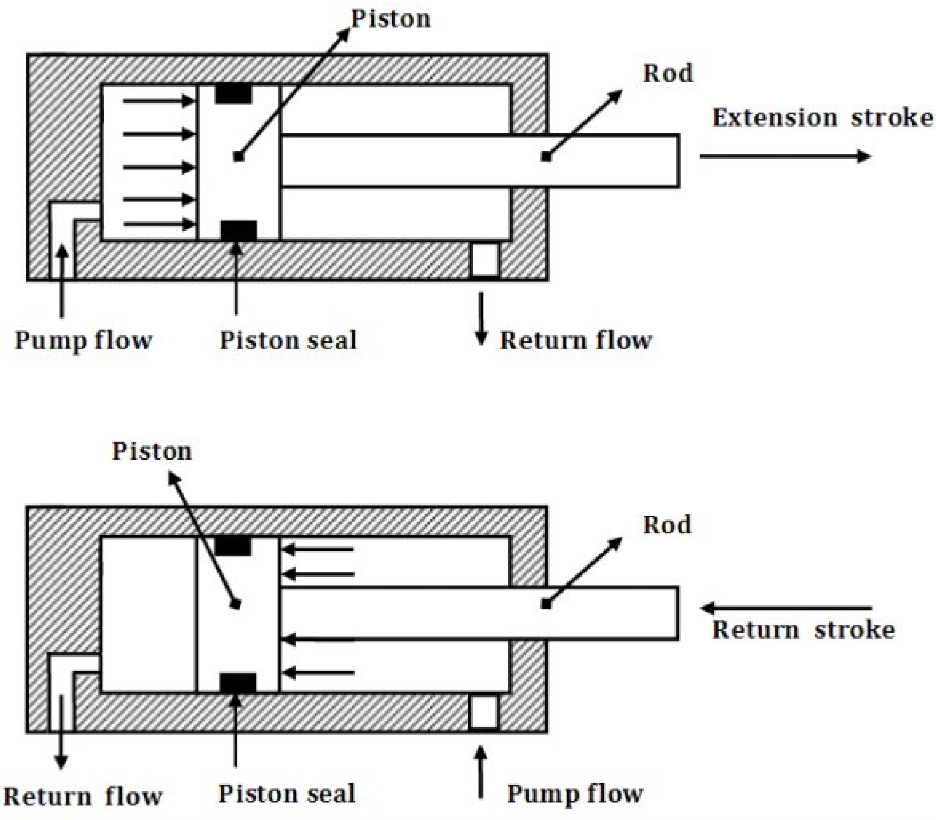


Fig. 5.16

3.Telescopic Cylinder

A Telescopic cylinder (shown in Fig. 5.17. is used when a long stroke length and a short retracted length are required. The telescopic cylinder extends in stages, each stage consisting of a sleeve that fits inside the previous stage. One application for this type of cylinder is raising a dump truck bed. Telescopic cylinders are available in both single - acting and double - acting models. They are more expensive than standard cylinders due to their more complex construction.

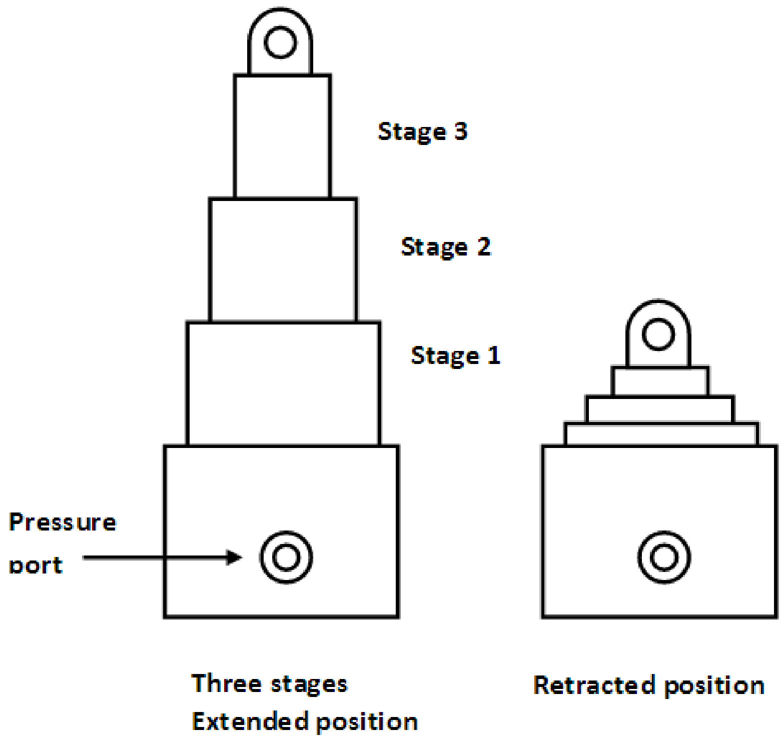


Fig.5.17

4. Hydraulic motors

The function of hydraulic motors is to convert hydraulic pressure and flow into rotational mechanical energy via an output shaft. Motors are used where a rotational output is required and actuators are used where linear output is required. However, in operation motors are more similar to pumps than actuators and, in fact; the equations for motors are identical to the equations for pumps.

The output of a motor is a torque and an angular velocity as shown in fig. 5.18.

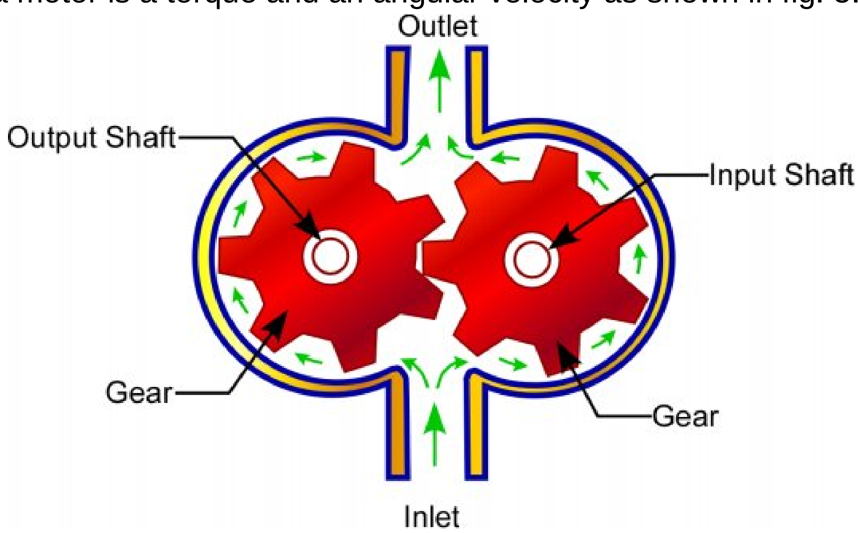


Fig.5.18

(note: power = torque x angular velocity). Motors operate exactly opposite of pumps and, in fact, some motors/pumps take on dual roles (will operate as a pump or a motor depending on the position of controlling valves) in a hydraulic system.

Like pumps, the governing equation for an ideal motor is

$$Power = P = Q\Delta p = T\omega$$

where Q is the flow rate,
Δp is the pressure drop across the motor,
T is the output motor torque and ω is the motor angular velocity.

5.13. Flow Control Valve

The purpose of flow control in a hydraulic system is to regulate speed. All the devices discussed here control the speed of an actuator by regulating the flow rate. Flow rate also determines rate of energy transfer at any given pressure. The two are related in that the actuator force multiplied by the distance through which it moves (stroke) equals the work done on the load. The energy transferred must also equal the work done. Actuator speed determines the rate of energy transfer (i.e., horsepower), and speed is thus a function of flow rate.

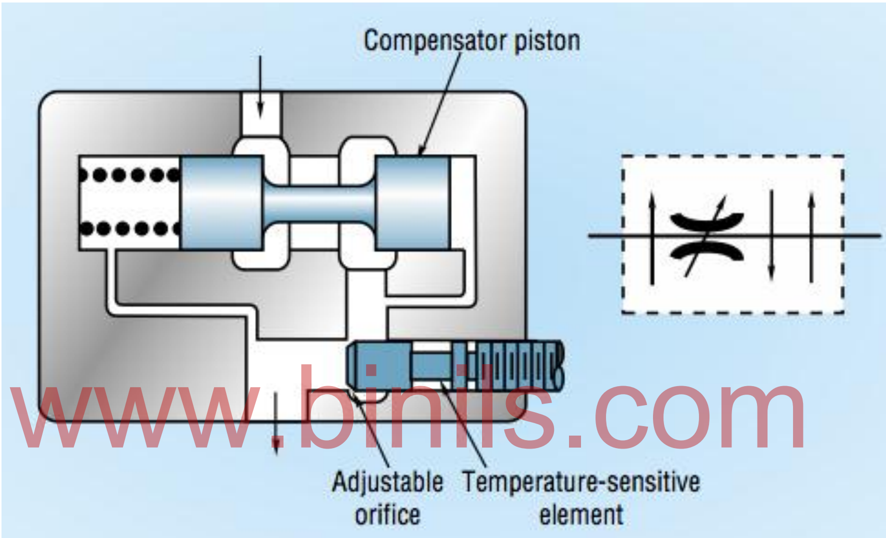


Fig.5.19

Directional control, on the other hand, does not deal primarily with energy control, but rather with directing the energy transfer system to the proper place in the system at the proper time. Directional control valves can be thought of as fluid switches that make the desired "contacts." That is, they direct the high-energy input stream to the actuator inlet and provide a return path for the lower-energy oil as shown in fig.5.19.

It is of little consequence to control the energy transfer of the system through pressure and flow controls if the flow stream does not arrive at the right place at the right time. Thus, a secondary function of directional control devices might be defined as the timing of cycle events. Because fluid flow often can be throttled in directional-control valves, some measure of flow rate or pressure control can also be achieved with them.

5.14. Directional Control Valve, Hydraulic - Description

Hydraulic valves function to control pressure, control flow or direct flow in response to external commands. Directional valves are valves that direct flow in response to external commands. Directional valves are usually servos (see servos) where the servo is positioned in response to solenoids, torque motors or mechanical input. Directional valves do not provide flow or pressure regulation and functional only to direct flow (much like a switch). Sometimes directional valves are packaged with other components such as orifices or check valves. This has the advantage of combining several functions into 1 assembly (or 1 part number) to simplify installation. Directional valves are either open or closed (in 1 position or another). Directional valves do not utilize a spool in a sleeve design, but quite frequently use this configuration. Also, the spool may be zero lapped or have underlapping or overlapping designs.

2/2 Directional valves

Directional valves are referenced by the number of positions the spool will take (2, 3 or 4 positions are typical) and the number of hydraulic ports in the valve (2 way, 3 way and 4 way are typical). Examples are shown below.

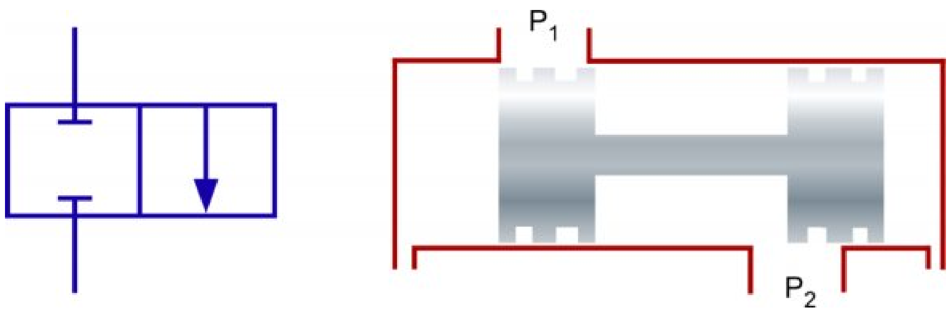


Fig .5.20. Two Way, Two Position (2/2) Valve

In a two way, two position valve, the servo can be in one of two positions and the two ways because there are 2 fluid ports in the valve (or, if you prefer, the valve housing). Although a spool arrangement is shown, any type of check valve could be considered a two way, two position valve.

Three Way, Two Position (3/2) Valve

In a three way, two position valve, there are three inlet/outlet ports in the valve and the spool can be in one of two positions. A 3/2 valve would be used to allow fluid flow into or out of actuator or motor.

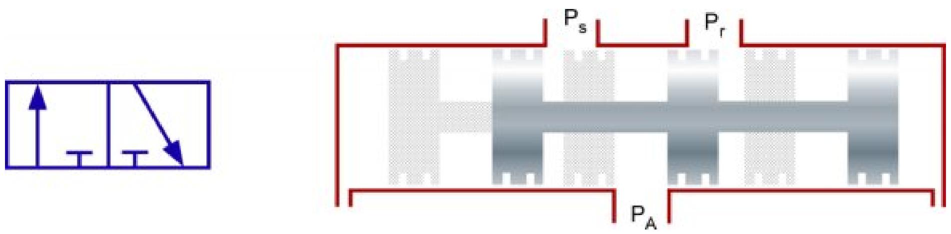


Fig. 5.21

Four Way, Two Position (4/2) Valve

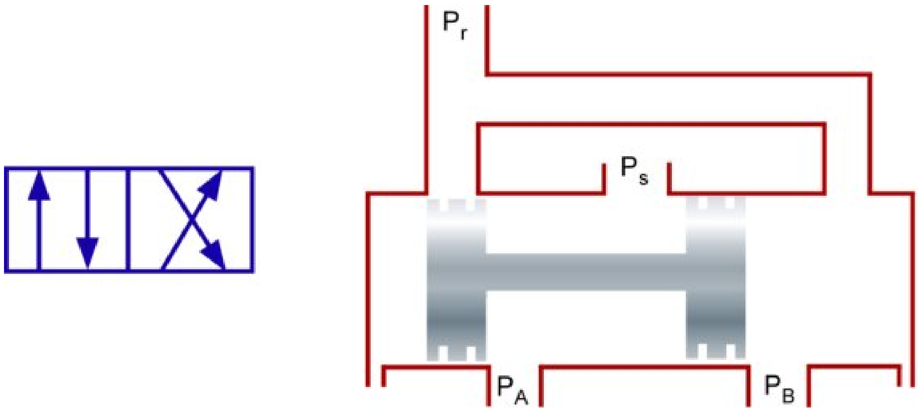


Fig .5.22

In a four way, two position valves there are four inlet/outlet ports in the valve and the spool can be located in one of two positions. For 4/2 valve fluid is always flowing through the valve with system pressure supplied to one of the two outlet ports at all times. The other port would then be ported to return. 4/2 valves would normally be used in hydraulic systems in conjunction with an upstream shut valve (or 2/2 valve). In this case a 4/3 valve usually makes more sense. However, 4/3 valves can be found in power control units (PCUs), where a shutoff valve is installed in the PCU where a shut valve is not packaged with the 4/2 valve due to other design considerations in the PCU.

Four Way, Three Position (4/3) Valve

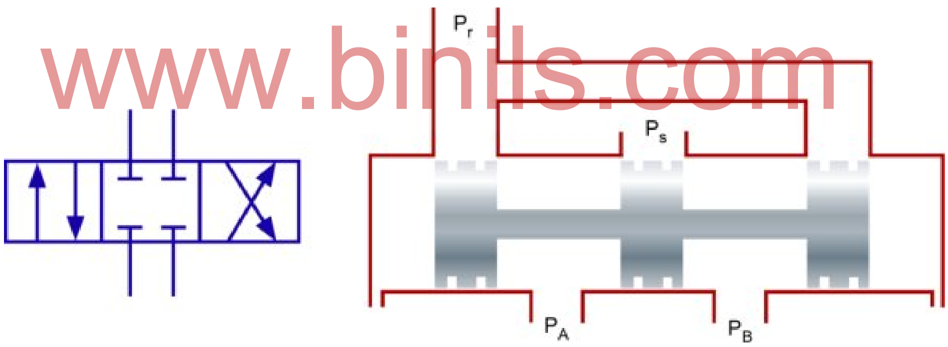


Fig.5.23

In a four way, three position valve, the spool is in one of three positions and there are 4 inlet/outlet ports in the valve. In the mid stroke position there is no flow through the valve. A good application of a 4/3 valve is actuator control, where the actuator control goal is to extend, retract or hold a position. 4/3 valves are used in servo valves, where the spool is controlled by a flapper valve or a jet pipe valve.

5.15. Hydraulic circuit for shaping machine

Shaping machine is used to produce flat surface. Shaping machine is a reciprocating motion of machine tool. A hydraulic circuit for obtaining quick return motion in a sharper is shown in fig.5.25.

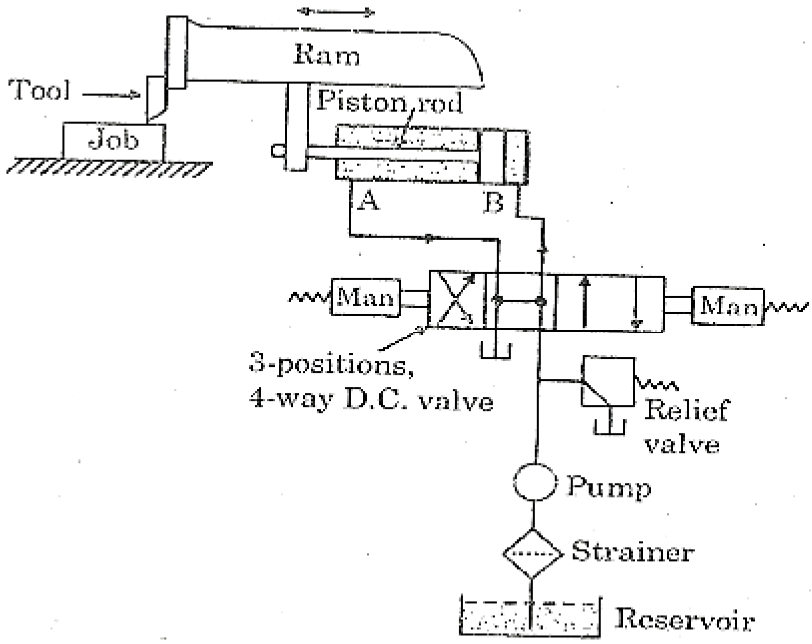


Fig.5.25

It consists of the following elements

1. Hydraulic cylinder with piston rod.
2. 4/3 DCV
3. Relief valve.
4. Pump
5. Reservoir

Working

When DCV is in middle position, the pump supply directly goes to the reservoir and resulting in no motion in the cylinder. When DCV is shifted towards right, the pump supply enters the Hydraulic cylinder through the port "B" and causes the piston to move towards left. Now the tool moves in the forward direction and removes the metal. At the same time, oil on the left of the cylinder directly goes to reservoir.

When the DCV is shifted towards left, the pump supply enters the cylinder through the port "A" and causes the piston to move towards right. Now the tool moves in the return stroke. During this movement, tool does not cut the metal and it is called idle stroke. At the same time the oil on the right of the cylinder directly goes to reservoir. This stroke will be fast due to the less area of cylinder in one side. Because of piston rod occupy some space.

Quick return motion

The piston rod occupies some area in the left side of the cylinder. However the pump supply is constant by constant discharge pump. Since the fluid fills the space quickly in the left side. It causes more forces on the piston which reduces the time for return stroke. Thus quick return motion is obtained to increase these productions.

5.16. Hydraulic circuit for surface grinding machine

Grinding is a finishing process. In this machine grinding wheel rotates in a fixed position. The job is fixed on the table which moves longitudinally and transversely against the grinding wheel. In this machine the metal is removed on both forward and return stroke. Therefore the motion of job is uniform on the both strokes.

This circuit consists of:

1. Hydraulic cylinder with piston rods on both sides of piston.
2. 4/3 DCV
3. Relief valve
4. Pump
5. Reservoir

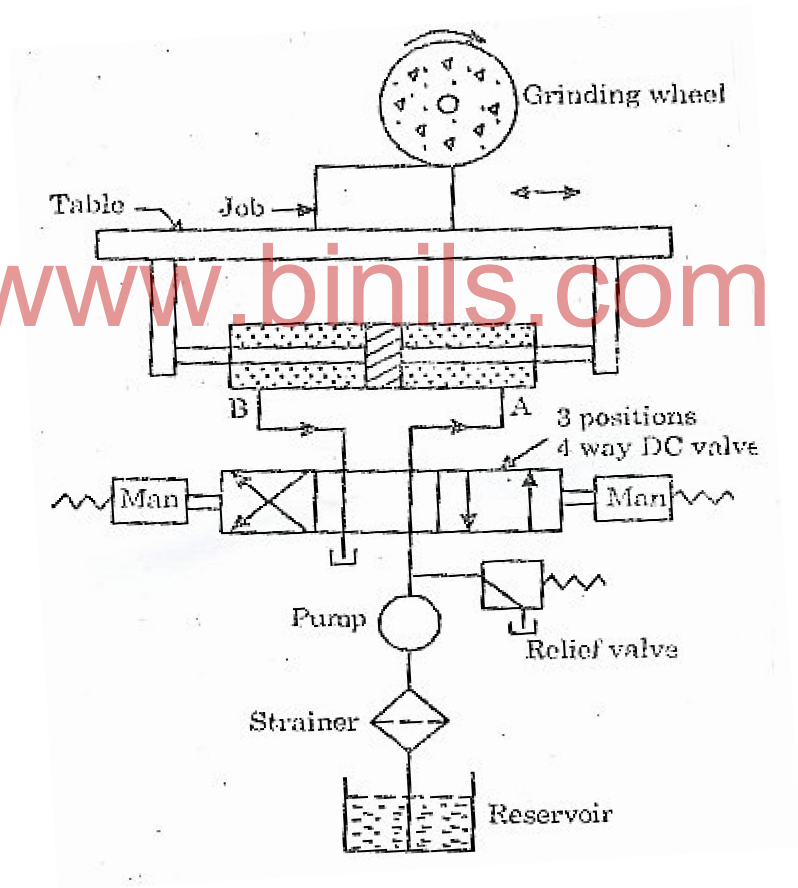


Fig.5.26

Fig.5.26. shows a hydraulic circuit for a surface grinder with manual operation. When 4/3 DCV is in neutral position the pump supply directly goes to reservoir and no action in the cylinder. When 4/3 DCV is shifted towards left, the pump supply enters the cylinder through the port -A. The oil on the other side goes back to the reservoir through the port - B. Now the job moves from right to left. When 4/3 DCV is shifted towards right, the pump

supply enters the cylinder through the port-B. The oil on the other side goes back to the reservoir through the port -A. Now the job moves from left to right. In both cases the grinding wheel removes the metal.

5.17. Hydraulic circuit for milling machine

In a milling machine the milling cutter rotates in a fixed position. Milling cutter is a multipoint tool. Cutting force will be heavier. Return movement of table takes more time. Forward movement of table takes less time (Rapid return motion). The forward motion of table is performed in two steps.

1. Rapid forward motion till the job touches the milling cutter.
2. Slow feed motion during cutting. Return movement is idle strike. Therefore quick return motion arrangements are made to reduce the idle time.

Fig.5.27. shows the Hydraulic circuit arrangement for milling machine. It consists of:

1. Hydraulic cylinder.
2. Piston rod with Cam
3. Flow control valve
4. 4/3 DCV
5. Relief valve
6. Pump
7. Reservoir

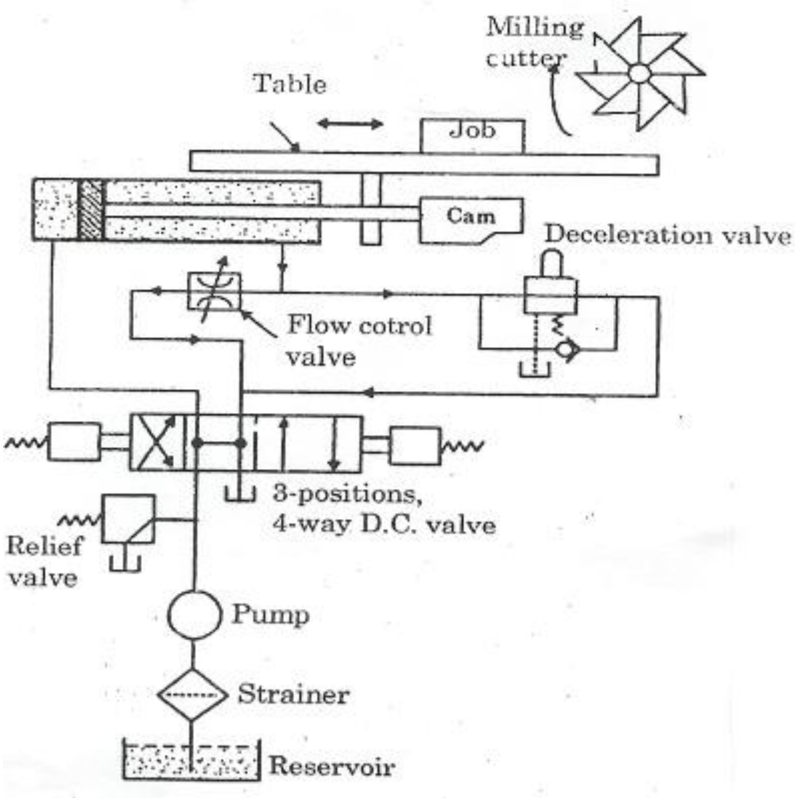


Fig.5.27

When 4/3 DCV is shifted towards left, the pump supply enters the left side of the cylinder through the port –B which causes the piston move towards right for forward stroke. At the same time, the oil on the right side of the piston flows to the reservoir through the opened deceleration valve. Hence the table advances rapidly till the cam closes the deceleration valve. The remaining forward stroke, the table moves with slow motion for machining. During that time, the oil on right side of the piston goes to reservoir through the restricted valve as it is closed. It will flow only through the restricted passage of flow control valve.

Forward stroke is performed in two steps

1. Rapid motion till the job touches the cutter
2. Feed motion during cutting.

Return stroke

During return stroke DCV is shifted to the right. The pump supply enters the rod side of the piston through port –A. At the same time, the oil on the left side of the piston directly goes to the reservoir. The quantity of oil required for the same piston travel will be less due to presence of piston rod. Thus the quick return motion is obtained.

5.18. Comparisons between Hydraulic and pneumatic systems

Sl .No.	Hydraulic system	Pneumatic system
1.	Working fluid is oil	Working fluid is air
2.	Operating at low speed.	Operating at high speed.
3.	Consists of compressors, valves, cylinders etc.	Consists of pumps, valves cylinders etc.
4.	Oil is spilled around the system.	It is very clean.
5.	Auxiliary equipments used for reservoirs, filters, accumulators.	Auxiliary equipments filters, requlators, lubricators.
6.	Initial cost is low	Initial cost is high. (Compressor requires high cost)
7.	Operating cost is low	Operating cost is high.
8.	Space requirements is less	Space requirements is high
9.	Used in high power applications.	Used for low power applications.

Exercise

Theoretical questions

Part –A

1. What are the important elements of Hydraulic circuit?
2. What is Hydraulic system?
3. Define viscosity.
4. What is viscosity index?
5. Define de-emulsibility
6. What is flash point?
7. What is cloud point?
8. Write any one application of Hydraulic system.
9. Draw the BIS symbol for relief valve.
10. Draw the BIS symbol for sequence valve.
11. Draw the BIS symbol for accumulator.
12. What is the function of accumulator?
13. What is the use of pressure intensifier?
14. Draw the BIS symbol for check valve.
15. Draw the BIS symbol for reducing valve.
16. Draw the BIS symbol for 2/3DCV.
17. Write the function of Hydraulic pump.
18. What is the application of hydraulic system?
19. What is the purpose of counter balance valve?
20. Write any two service properties of hydraulic fluid.
21. List the advantages of hydraulic system.
22. List the different types of accumulators.
23. What is the function of a directional control valve?
24. What are the essential qualities of a good hydraulic fluid?
25. Explain the use of a shuttle valve.

26. State the functions of the accumulator.
27. Explain the purpose of a check valve in a hydraulic circuit.
28. How sequence valve is used in hydraulic system?
29. What is the function of counter balance valve?
30. What is meant by hydraulic intensifier?
31. State the advantages and disadvantages of hydraulic system.

PART – B

1. Explain external and internal gear pump with a sketch.
2. Explain briefly about hydraulic circuit for milling machine.
3. Differentiate between hydraulic circuit and pneumatic system.
4. Explain the important service properties of a hydraulic fluid.
5. Explain the working of radial piston pump with a neat sketch.
6. Draw the hydraulic circuit diagram with ISO symbols for the table movement of a surface grinding machine.
7. Explain the working of spring loaded accumulator with a neat sketch.
8. Explain the purpose of a check valve in a hydraulic circuit.
9. Explain the working of a bladder type accumulator.
10. Compare hydraulic system with pneumatic system.
11. Draw the hydraulic circuit with BIS symbols for the table movement of a surface grinding machine.

32043 FLUID MECHANICS AND FLUID POWER

MODEL QUESTION PAPER - I

Duration-3 Hrs **Max Marks-100**

Note:

1. Answer any 10 questions in part-A, Each question carries one mark
2. Answer any 5 questions in part-B, Each question carries three marks
3. Answer all questions in part-C, by choosing compulsory question - A carries 5 marks and one question from either - B (or) C carries 10 marks.

PART-A **1X10=10**

1. Define specific weight of fluid.
2. Define viscosity of fluid.
3. What is mean by Vacuum pressure?
4. What is mean by Turbulent flow ?
5. What are the minor losses occurs in flow through pipes.
6. State the types of draft tubes used in hydraulic turbines.
7. State the types of casings used in centrifugal pump.
8. What is the use of air vessels in a reciprocating pump?
9. What is FRL unit?
10. What is the use of quick exhaust valve?
11. Draw the ISO symbol of 4/3 DCV valve.
12. State the function of accumulator.
13. What is mean by cloud point?

PART-B **5X3=15**

14. What is the difference between ideal and real fluid?
15. State the Pascal's law
16. List any three differences between venturimeter & Orificemeter.
17. Define cavitations of centrifugal pump.
18. State the function of 3/2 DCV with symbol.
19. Compare Hydraulic and pneumatic systems.

20. Write short notes about shuttle valve with ISO symbol.

21. What are the industrial applications of hydraulic system?

PART-C **5X15=75**

22. A. One cubic meter of crude oil weights 9.44 KN. Calculate its density, specific weight , specific volume . **5**

B. A differential manometer connected to two point A & B in a horizontal venturimeter containing an oil of relative density 0.8 and the deflection of mercury level is 0.8 m. Determine the difference in pressure between the two points in terms of KN/m^2. **10**

(OR)

C. Sketch and explain the working principle of Hydraulic press **10**

23. A. Two reservoirs are connected by a 50 mm diameter and 2 km long pipe line. The difference of water level between the two reservoirs is 20 m. calculate the discharge of water in lit/sec. take friction factor = 0.0248. **5**

B. A venturimeter is to be fitted to a 250 mm diameter pipe in which the maximum flow is 120 lps and the pressure head is 6 m. What is the minimum diameter at throat and that there is no (-ve) head in it. Assume C_d = 0.97. **10**

(OR)

C. Derive the equation for Actual discharge of Orifice meter. **10**

24. A. Derive the force exerted by the jet on a fixed Plate which is held normal to the Jet. **5**

B. Explain the working principle of Francis Turbine with neat sketch. **10**

(OR)

C. A Double acting reciprocating pump has a piston diameter of 150 mm and a stroke length of 300 mm. It raises the water to a height of 20 m at a speed of 60 rpm. The discharge is 10 lps. Calculate i) Theoretical discharge. ii) % of slip iii) Cd iv) Efficiency of pump. **10**

25. A. Briefly explain the elements of pneumatic system with simple sketch. **5**

	B.	Explain the function of double acting cylinder with metering in control with neat sketch.	**10**
		(OR)	
	C.	Explain the function of pressure reducing valve with a neat sketch.	**10**
26.	A.	Briefly explain the function of sequence valve in hydraulic system.	5
	B.	Explain the function of bladder type accumulator and spring loaded accumulator with simple sketches	10
		(OR)	
	C.	Draw and explain the hydraulic circuit for Milling machine.	10

32043 FLUID MECHANICS AND FLUID POWER

MODEL QUESTION PAPER - II

Duration-3 Hrs **Max Marks-100**

Note:

1. Answer any 10 questions in part-A, Each question carries one mark
2. Answer any 5 questions in part-B, Each question carries three marks
3. Answer all questions in part-C, by choosing compulsory question - A carries 5 marks and one question from either - B (or) C carries 10 marks.

PART-A **1X10=10**

1. Define specific gravity of fluid.
2. State the advantages of mechanical gauges.
3. What is the use of micro manometer?
4. What are the applications of Bernoulli's theorem?
5. What is mean by critical velocity?
6. What is the use of Surge tank in Hydraulic turbines?
7. What is mean by priming ?
8. What is mean by negative slip?
9. State any three advantages of pneumatic systems.
10. What is the use of relief valve in pneumatic systems?
11. Draw the ISO symbol of check valve.
12. Define viscosity index.
13. What is the use of hydraulic pressure intensifier?

PART-B **5X3=15**

14. Convert a pressure head of 500 mm of mercury into oil of relative density 0.75.
15. State the relations between the absolute pressure, atmospheric pressure and g pressure.
16. Define Hydraulic coefficients.
17. Classify Hydraulic Turbines.
18. Write short notes about speed control valve used in pneumatic systems?
19. What are the industrial applications of pneumatic systems?
20. List the advantages of hydraulic system.

21. State the function of counter balance valve used in hydraulic system.

PART-C **5X15=75**

22. A. If the density of liquid is 837 kg/m^3. Find its specific weight , Specific volume and Relative density. 5

B. An inverted U tube Differential manometer connected to two pipes A & B carrying liquid of specific gravity 1.6. Its two ends are at same horizontal line. The relative density of manometric liquid is 0.75 . Find the difference in pressures between the two pipes. The manometer reading is 400 mm. 10

(OR)

C. Dead weight pressure Gauges. 10

23. A. A 0.3 m diameter pipe carrying water, branches into two pipes of diameter 0.2 m and 0.15 m. If the mean velocity of 0.3 m pipe is 2.5 m/s and that in the 0.2 m pipe is 2 m/s. Determine the discharges in each pipes. 5

B. The diameter of a tapered pipe at inlet and outlet are 1.0 m and 0.5 m respectively. The outlet is at a vertical height of 5 m above the inlet. The loss of head in the pipe is 1/10 th of velocity head at outlet. The pressure at the outlet section is 100 kN/m2 and at inlet is 400 KN/m2. Calculate the rate of discharge of water and the velocity at outlet. 10

(OR)

C. A pipe line 10 km long delivers a power of 50 kw at the outlet end. The pressure at inlet is 4500 kN/m2 and the pressure drop per km of pipe is 50 kN/m2. Take F = 0.0125. Determine the diameter of the pipe and the efficiency of power transmission. 10

24.

A. Compare Impulse and Reaction Turbines. **5**

B. Explain the function of Submersible pump with neat sketch **10**

(OR)

C. A Jet of water 60mm diameter moves with a velocity of 25m\sec and strikes on a series by vanes moving with a velocity of 10m\sec. Find **10** i)force exerted by the jet, ii)Work done by the jet and iii) efficiency of the jet

25.	A.	Briefly explain the working of 4/3 DC valve with simple sketch.	**5**
	B.	Explain the function of double acting cylinder with metering out control with neat sketch.	**10**
		(OR)	
	C.	Explain the automatic operation of double acting cylinder with neat sketch.	**10**
26.	A.	Define any four service properties of a hydraulic fluid.	**5**
	B.	Explain the working of internal gear pump with neat sketch.	**10**
		(OR)	
	C.	Explain the hydraulic circuit with ISO symbol for quick return motion of a Shaper.	**10**