BRANCH: MECHANICAL ENGINEERING
SEMESTER: 5^{TH}
SUBJECT: HYDRAULIC MACHINE & INDUSTRIAL FLUID POWER
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CHAPTER 1

HYDRAULIC TURBINES.

- 1.1 Definition and classification of hydraulic turbines
- 1.2 Construction and working principle of impulse turbine.
- 1.3 Velocity diagram of moving blades, work done and derivaûon of various efficiencies of impulse turbine.
- 1.4 Velocity diagram of moving blades, work done and derivation of various efficiencies of Francis turbine.
- 1.5 Velocity diagram of moving blades, work done and derivation of various efficiencies of Kaplan turbine
- 1.6 Numerical on above
- 1.7 Distinguish between impulse turbine and reaction turbine.

Introduction-

s Hyoaulic Machines are those machines which convert either hydraulic energy (energy possessed by water) in to mechanical energy (which is further converted in to electrical energy) or mechanical energy to hydraulic energy.

- Hyoaulic energy is produced by the water which is stored in reservoirs and lakes at a high altitude (so that it has gravitational potential energy).
- The Hyoaulic Machines which convert hyoaulic energy to mechanical energy is called turbines while the hydraulic machines which convert mechanical energy into hyoaulic energy is called pumps.
- Thus the study of Hydraulic machines consists of turbines and pumps.

Turbines

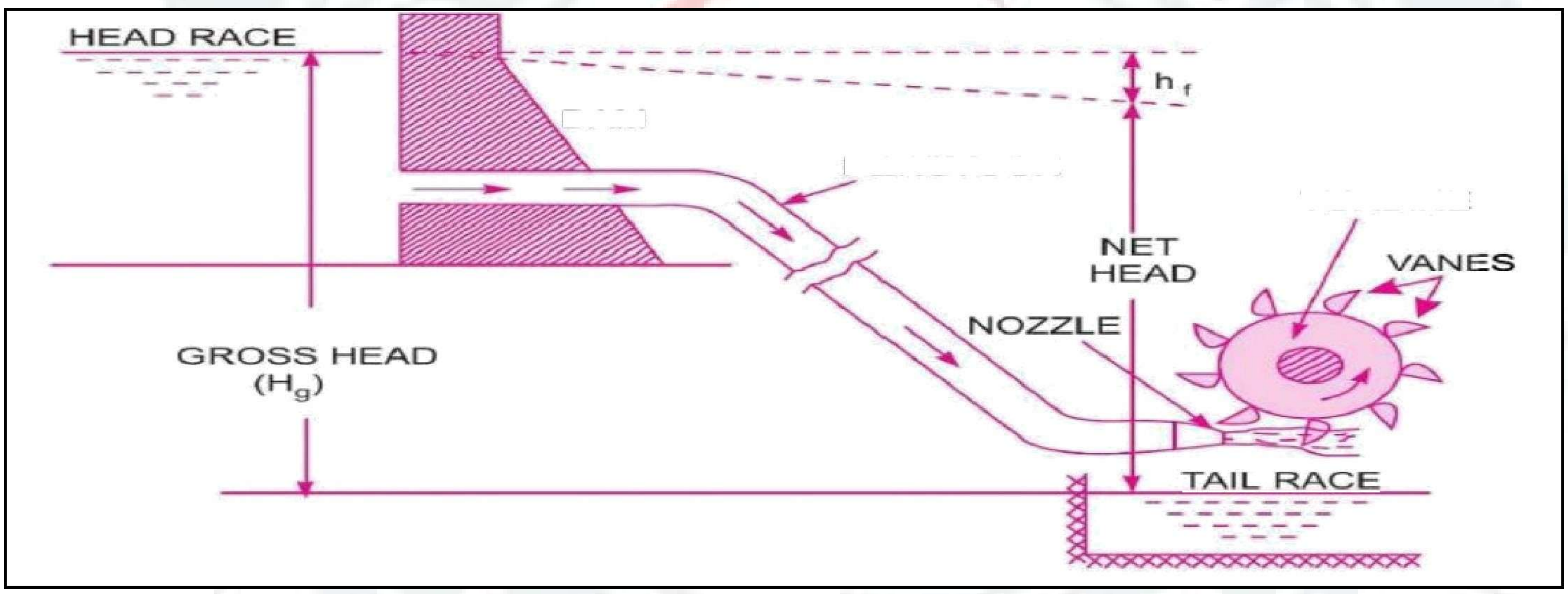
o Turbines are defined as hyoaulic machines which converts hydraulic energy into mechanical energy.

- This mechanical energy is used in running an elecYic generator which is directly coupled to the shaft of turbine. Thu» the mechanical energy is convened into electrical energy.

- The electric power which is obtained from hydraulic energy is known as hydroelectric power.
- At present the generation of hydroelectric power is cheaper as compared to power generated by other sources like coal, oil etc.

General layout of a Hydroelectric Power plant

- A dam constructed across a river to store water
- Pipes of large diameter called penstock, which carries water under pressure from the storage reservoir to turbine.
- Turbines having different types of vanes fitted to the wheels.
- Tail race, which is a channel which carries water away from the turbine after the water has worked on the turbine.
- The surface of water in the tail race channel is also called tail race.



Gross Head

The difference between head race level and tail race level where no water is flowing is known as gross head (Hg)•

Net Head

- It is defined as the head available at the inlet of turbine.
- When water flowing from head race to turbine a loss of head due to friction between the water and penstock occurs.

» There are other losses due to bend pipe fittings, loss at ie enYance of penstock etc. which has smaller magnitude as compared to head loss due to friction(h_f)

- Net head (H) = Hg h_f

$$h_f = \frac{4 \times F \times L \times V^2}{D \times 2 \times g}$$

Where V= Velocity of ñow in penstock, L= length of penstock and D= Diameter of the penstock

d   u ie T   ine C ass fca on:

It has been categorized into four pa<s such as:

1. According to the type of energy at Inlet:

- Impulse Turbine: The energy is in the form of kinetic. e.g.: Pelton wheel.
- Reaction Turbine: The energy is in the form of both Kinetic and Pressure. e.g.: Kaplan, Propeller, Francis turbine.

2. According to the direction of ñow through Runner:

- Tangential flow: water flows in a direction tangential to the path of rotational, i.e. Perpendicular to boT axial and radial directions.
- Radial flow: Water flows in the radial direction through the runner.
- Inward radial flow: If the water flows from outwards to inwards, radially.
- Outward radial flow: If ie   water flows from inwards to outwards, radially.
- Axial ñow: Water ñows parallel to the axis of the turbine. e.g.: Girard, Jonval, Kaplan turbine.
- Mixed flow: Water enters radially at the outer periphery and leaves axially. e.g.: Modern Francis turbine.

3. According to the head under which the turbine works:

- High head- The turbine capable of working under the high potential head of water above 300m (Impulse turbine. e.g.: Pelton turbine.)

- Medium head- The turbine is capable of working under a medium range of potential head about 60m to 300m (Reaction turbine. e.g.: Francis turbine.)
- Low head- The turbine is capable of working under a low range of potential head less than 60m (Reaction turbine. e.g: Kaplan turbine, propeller turbine.)

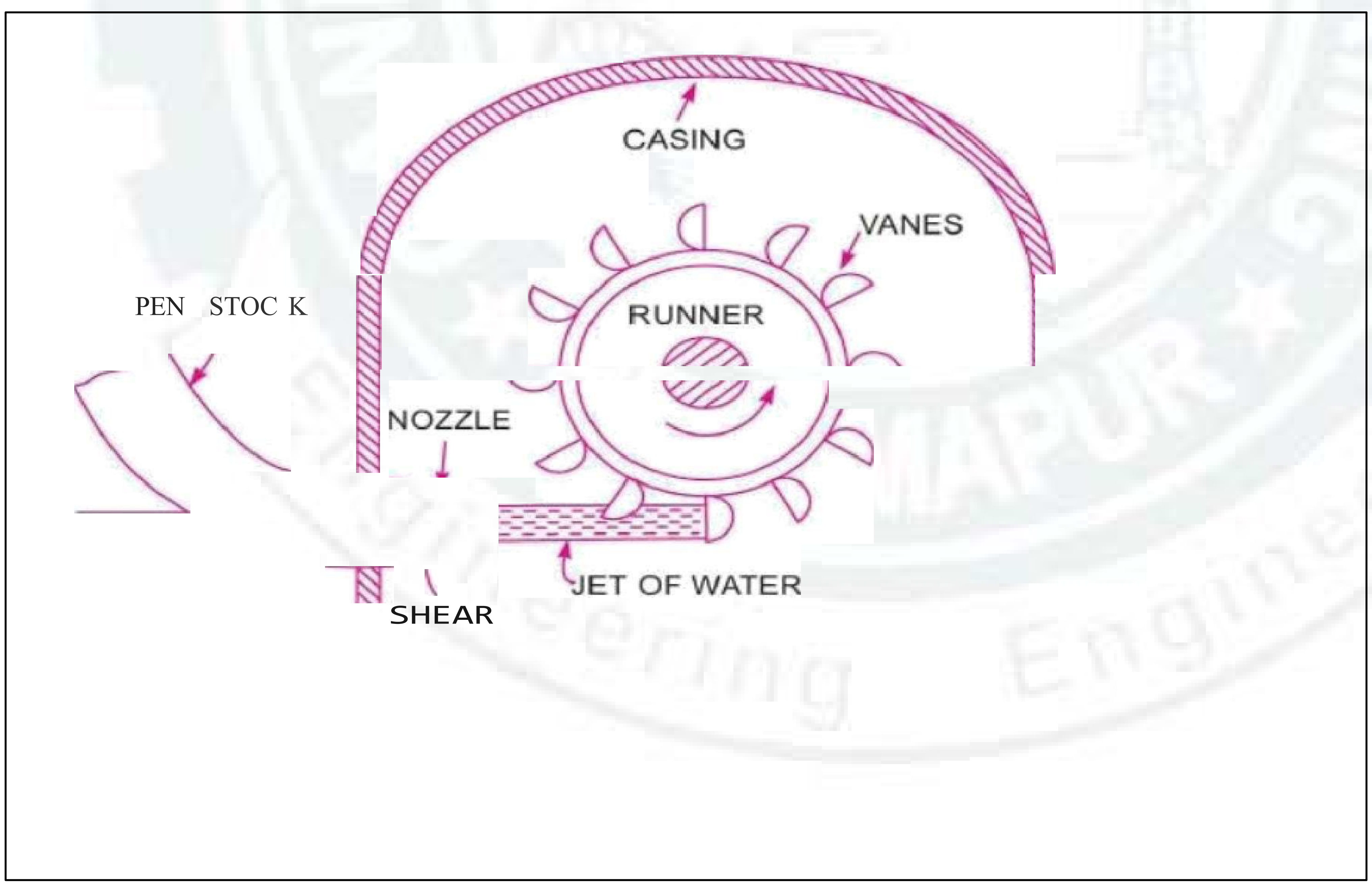
4. According to the specific speed of the turbine:

- Low specific speed - (Impulse turbine. e.g.: Pelton wheel.)
- Medium-specific speed - (Reaction turbine. e.g.: Francis wheel.)
- High specific speed - (Reaction turbine. e.g.: Kaplan and Propeller turbine.)

Impulse Turbine-

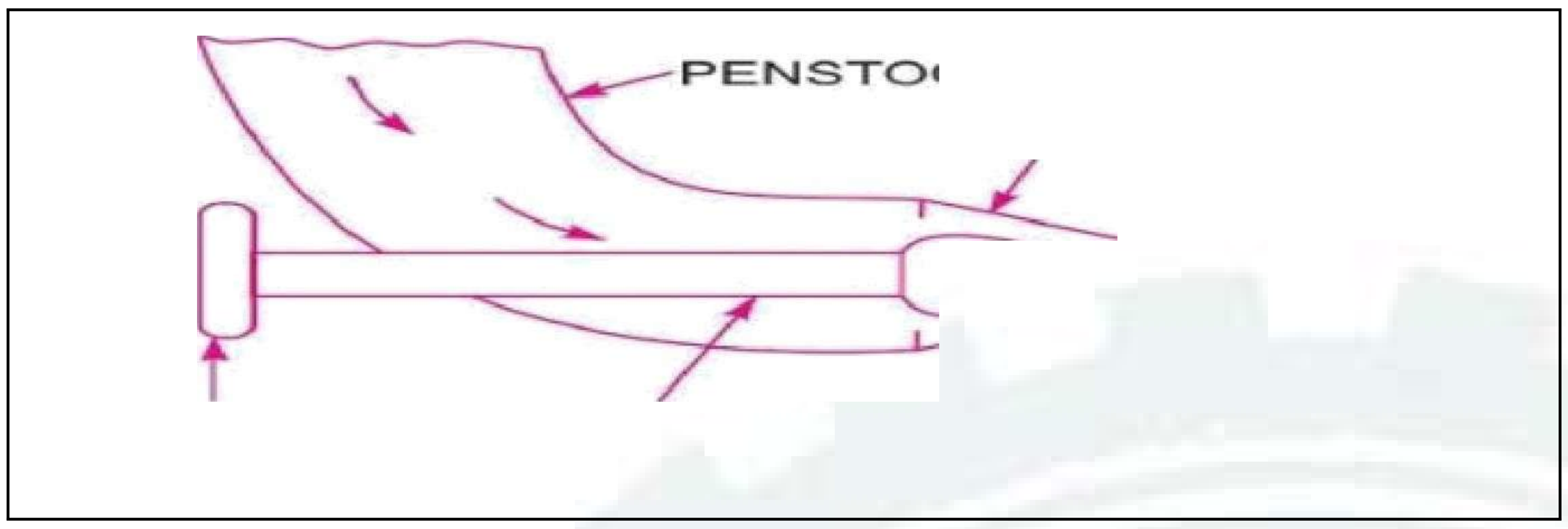
s Impulse turbine works on the basic principle of impulse.
- The water strikes the bucket along the tangent of the runner
- The energy available at the inlet is only kinetic energy
- The pressure at the inlet and outlet of turbine is atmospheric.
- This turbine is used for high heads.

Construction-



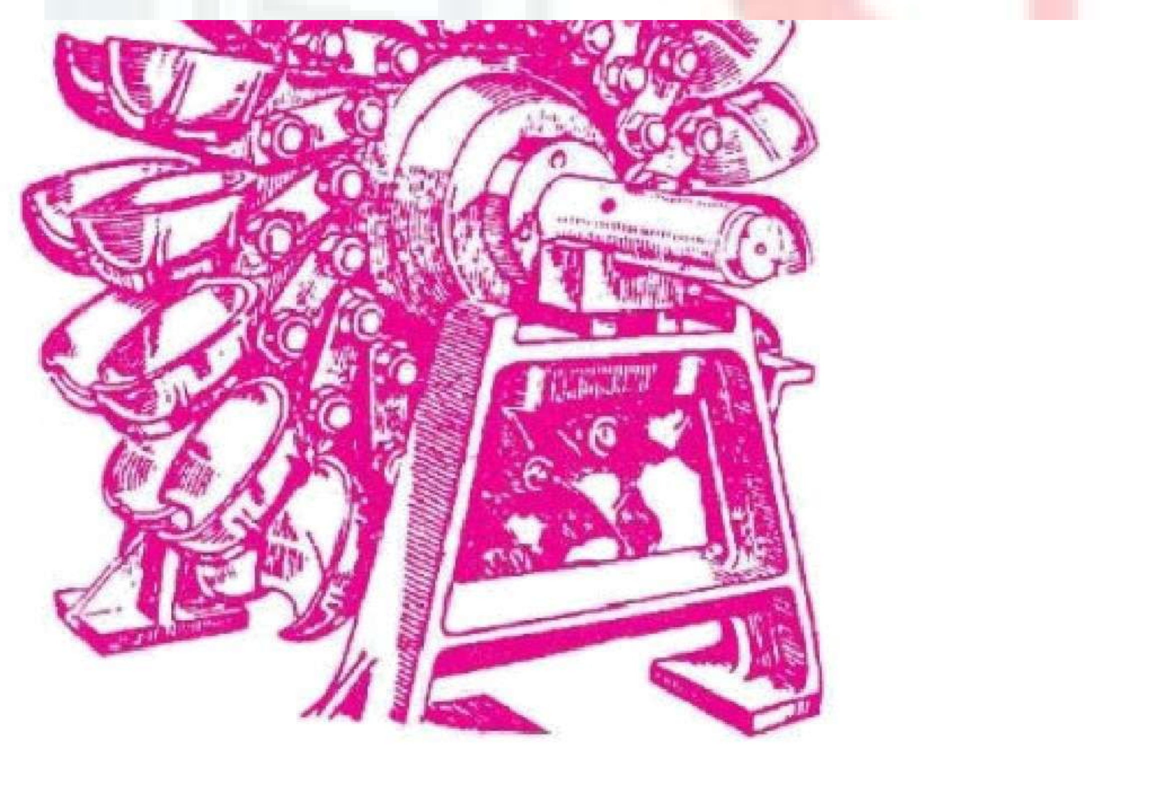
Nozzle and Spear- Nozzle directs the flow of water to the buckets, with an increased velocity coming from a high head.

Spear is a conical structure which is moved in and out of nozzle to regulate the flow of water striking the buckets



Runner with Buckets — It consists of circular disk where number of buckets evenly spaced are fixed.

The shape of bucket is double hemispherical up or bowl. Each bucket is divided into two symmetrical parts dividing by a wall is called splitter.



The jet of water strikes on the splitter. The splitter divide the jet into two equal part and the jet comes out at the outer edge of the bucket.

Casing - It is provided to prevent the splashing of water and to discharge water to the tail race. It also act as safeguard against accident.

Braking Jet - When the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner is reduced to zero but the runner due to inertia continues revolving for long time.

In order to bring the runner to rest in a short time, a nozzle (brake) is provided which directs the jet of water on the back of bucket ; his jet of water is called breaking jet.

Working Principle

- High pressure water flow form dam (high head) to nozzle (low head).
- This water flows throughdivergentnozzle where lt's all pressure energy change into kinetic energy. It forms a water jet.
- The water jet strikes the blade at high speed which rotates the rotor.
- It transfers all kinetic energy of water to the rotor, which furler use to rotate ie generator.
- After Yansferring energy, water flows to Te tail race.
- This process mn continuously until sufficient power generates

DiGerent EWiciencies *o$* Turbines-

Hydraulic EfFiciencv - It is defined as the ratio of power given by water to the runner of a turbine to the power supplied by water at the inlet of turbine.

$$\eta_h = \frac{\text{Power delivered to the runner}}{\text{Power supplied at inlet}} = \frac{R.P}{W.P}$$

Mechanical EiFiciencv — The ratio of power available at the shalt of turbine to the power delivered by runner is defined as mechanical efficiency.

$$\eta_m = \frac{\text{Power at the shaft of turbine}}{\text{Power delivered by water to the runner}} = \frac{SP}{RP}$$

Volumetric Efi"iciency = It is defined as the ratio of volume of water actually striking the runner to the volume of water supplied to the turbine

$$\eta_v = \frac{\text{Volume of water actually striking the runner}}{\text{Volume of water supplied to the turbine}}$$

Overall Efficiency - It is defined as the ratio of power available at the shaft of turbine to the Power supplied at inlet of turbine.

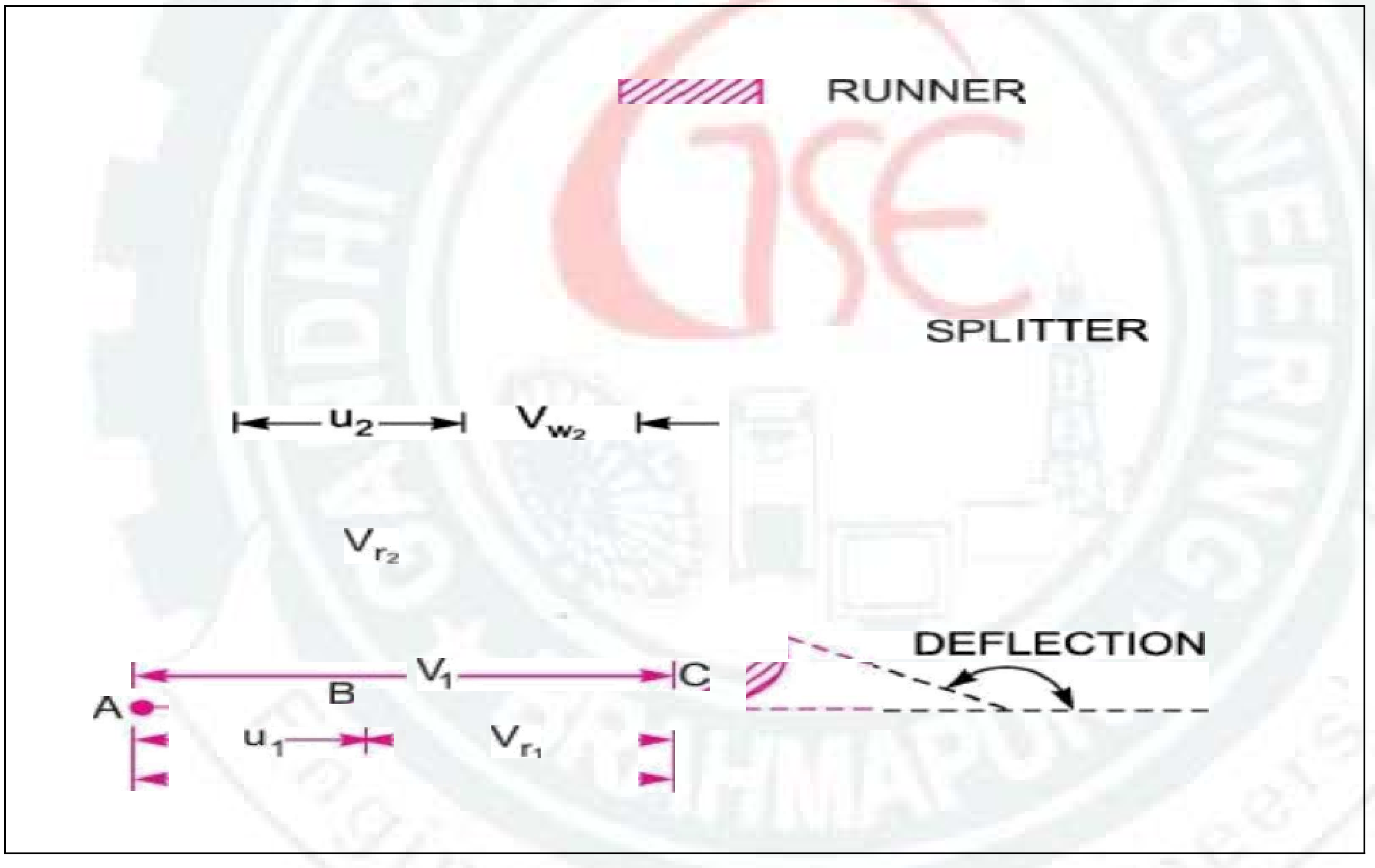
$\eta_o = \frac{\text{Volume available at the shaft of the turbine}}{\text{Power supplied at the inlet of the turbine}} = \frac{\text{Shaft power}}{\text{Water Power}} = \frac{S.P.}{W.P.}$

$\frac{S.P.}{W.P.} = \frac{R.P.}{R.P.} \frac{S.P.}{R.P.} \frac{R.P.}{W.P.}$, rn h

- n h

Velocity Triangles Diagram For Pelton Wheel :

- The jet of water from the nozzle strikes the bucket at the splitter, which splits up the jet into two parts. These parts of the jet glides over the inner surfaces and comes out at the outer edge.
- The splitter is the inlet tip and the outer edge of the bucket is the outlet tip of the bucket.
- The inlet velocity triangle is drawn at the splitter and the outer velocity triangle is drawn at the outer edge of the bucket.



Where,

V_l—velocityof jet at inlet

u_S- velocity of the vane/bucket at inlet

m] relative velocity of jet at inlet

Vo]—Velocity of whirl at inlet

n = angle between the direction of the jet and the direction of motion of the vane, guide blade angle (Here in this figure it is zero)

8 = angle made by r1 Wit?1 the direction of motion of vane at the inlet, vane angle at inlet (=0)

<2 Velocity of jet at outlet of vane

u2= Velocity of vane at outlet

V_rJ= relative velocity of jet at outlet

V,,, = velocity of whirl at outlet

Vf2= velocity of flow at the outlet

9 = angle betweenv2 with the direction of motionof vaneat the outlet

$ = angle made by vr2 with the direction of motion of vane at the outlet, vane angle at outlet

H' Hi hf

$$h_f = \frac{4 \times F \times L \times V^2}{D^* \times 2 \times g}$$ (D„ = Diameter of penstock)

= H (H = net head acting on turbine)

$$u_1 = u_2 = \frac{\pi D N}{60}$$ (D = Diameter of wheel, N = speed of the wheel in rpm)

The velocity triangle at inlet will be a straight line where,

r1' < - uS= V — u

«i' i

If the vane surface is assumed to be very smooth the loss of energy due to friction will be zero.

The water will gliding over the surface of vane with a relative velocity r1 and will come out of ie vane with relative velocity V_{r2}, which means V_r, = V_{r2}

From the velocity triangle at outlet,V_{r2} = J*r1 and Vp2 = V_rJcos $ -th

The force exeGed by the jet of water in the direction of motion

$$x \frac{\text{Inltlal Momentum—Final Momentum}}{\text{Time}}$$

Fg = Mate (Initial velocity — final velocity)

$\frac{}{t}$(Initial velocity — final velocity)

$\frac{pv}{t}(V_{w1} + V_{w2}) = \frac{pal}{t}$ (W1+ W2)

F,= paVi [** i+ VpJ]

Net work done by the jet on the runner per second

= Fg x u = paV₁ [* +< 21 x u Nnv's

$W = \rho a V_1 [V_{w1} + V_{w2}] \times u$

The energy supplied to the jet at inlet is in the form of K.E and is equal to $\frac{1}{2}$mI7", 2

Kinetic energy of jet per second = $\frac{1}{2}$ (pa'fi) x $ 2

Hydraulic efficiency, qh = $\frac{\text{Work done per second}}{\text{K.E of jet per second}}$

$= \frac{paVg [V_{w1} + V_{w2}] x u}{\frac{1}{2}(\rho a V_1) \times V_1^2} = \frac{2[V_{w1} + V_{w2}]}{V_1^2}$

qh = $\frac{2[V_{w1} + V_{w2}]}{V_1^2}$

<u>Design of Pelton Wheel</u>:

» Velocity of jet at inlet Vl= Cv 12gH where Cv = coefficient of velocity 0.98-0.99

» Velocity of wheel where u Q °J2gH ... .Where p is the speed ratio = 0.43-0.48

The angle of detection is 165° unless mentioned.

- Pitch or men diameter D can be expressed by, u= itDN / 60
- Jet ratio M =D/d (12 in most cases/calculate), d = nozzle diameter

- Number of bucket on a runner Z = 15 + D/2d = 15 + 0 5 m
- Number of Jets = obtained by dividing the total rate of flow through the turbine by the rate of flow through the single jet
- Size of Bucket: Axial Width, radial length, depth

Numerical Problems

Q 1. A Pelton wheel has a mean bucket speed of 10 meter per sec with a jet of water flowing at the rate of 700 liters per sec under a head of 30 mt. the bucket deflect through an angle of 160 degree. Calculate the power given by water to the Runner and hydraulic efficiency of Turbine Assume Co-efficient of velocity as 0.98

Solution:

Given data:

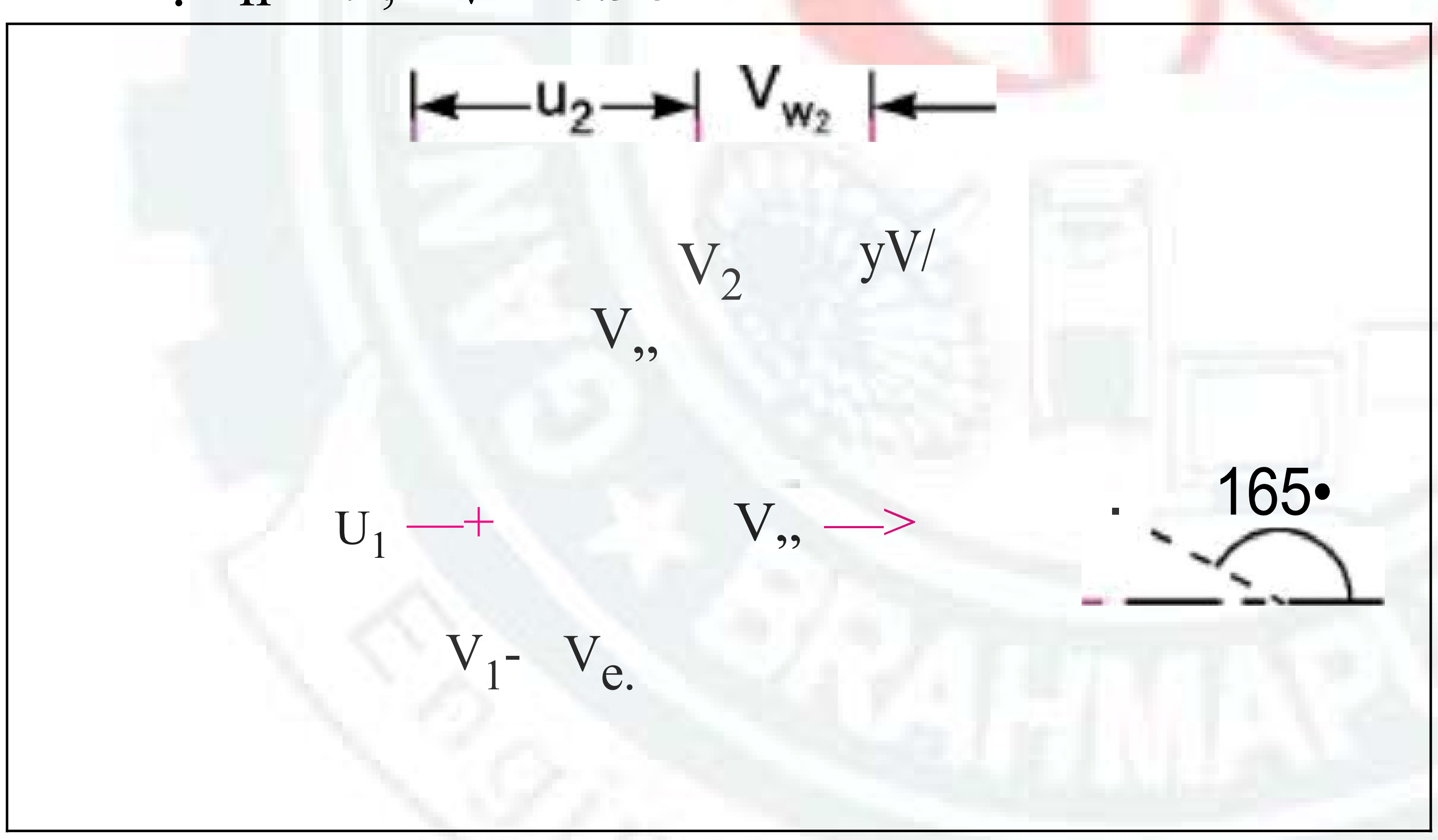
speed of bucket, U = U1 = U@= 10 "*/SeC

Q = 700 litrey/$eC = 700 X 10 3 3/eC

H = 30 m

angle deflected = 160^0 Q = 180 − 160 = 20^0

RP =*. h =? , C_V = 0.98



From velocity triangle at inlet

velocity of jet * = C, x g x H = 0.98 x 2 x 9 81 x 0 = 23.77 /$eC

We have from velocity diagram at inlet V_1 = Vp_i = 2 3.7 7 J$eC

V_G,= Vq_1 − U, = 23.77 − 10 = 13.77 /$e

We have from velocity diagram at out let tr = r2 = 1 J•77 Sec

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$V_{w_2} = V_{r_2} \cos 8 - U_2 = 13.77 \cos 20 - 10 = 2.94$ "' Sec

Now work done by jet of water on Bucket or Runner Power

$$R.P = \frac{paV_1(V_{w} \text{ -t } Vp_2) \times U}{1000} KW$$

$$= \frac{pQ(Vp, + Vp,) \times U}{1000} = \frac{1000 \times 0.7(23.77 \text{ —F } 2.94) \times 10}{1000}$$

$$R.P = 186.97 \text{ XW}$$

The hydraulic efficiency of the turbine is given by

$$Ëh = \frac{(*' \bullet \quad V_{w_2}) > U}{+v_2} = \frac{2(23.77\text{-F}2.94) \times 10}{23.77^2}$$

$$Ëh' \quad 0.9454 \text{ say } 94.54\%$$

Q2. A Pelton wheel is to be designed for the following Specification:
Shaft power = 11772 KW; head = 380 m; speed = 750 RPM; overall eWiciency= 86%, jet diameter not to exceed one-sixth of the wheel diameter. Determine:

i. The wheel diameter ii. Number of jet required

iü. Diameter of jet, take Kgb = 0. 985 and $K_{,1}$ = 0. 45

Solution:

Given data:

S. P = 11772 KW

H = 750 RPM,

$Ëo = 1 \quad 6\% \quad j$

$= \frac{D}{BS}$

D, d, Z =*

We have overall efficiency of Pelton wheel Turbine

$$o \equiv \frac{S.P}{W.P} = ', \quad \frac{S.P}{0.86} \equiv$$

$$11772$$

• W. P' g$ ' 13688.37 KW

velocity of jet $V_, = Cv \quad 2 \quad g \times H = 0.985 \times \quad 2 \times 9\ 81 \times 380 = 85.$' JSec

- we havewater power

$$W.P = \frac{pgQH}{1000} = 13688.37$$

$$\Rightarrow Q = \frac{13688.37 \times 1000}{\rho g H} = \frac{13688.37 \times 1000}{1000 \times 9.61 \times 380} = 3.62 \ m^3/Sec$$

We have speed ratio

$$K_{u1} = \frac{U_1}{\sqrt{2gH}} = 0.45$$

$$U = U_1 = U_2 = 0.45 \times \sqrt{2gH} = 0.45\sqrt{2 \times 9.80 \times 380} = 38.85 \ m/Sec$$

We have mean velocity of bucket

$$U = \frac{\pi DN}{60} = 38.85$$

$$\Rightarrow D = \frac{60 \times 38.85}{\pi \times 750} = 0.9893 m \text{ .... Mean Diameter of Bucket}$$

Now we have dia. of jet

$$d = \frac{D}{6} = \frac{0.9893}{6} = 0.1648 \ m$$

Discharge of water through single jet $Q = aV_1 = \frac{\pi}{4} \times d^2 \times V_1 = 85.05 \times \frac{\pi}{4} \times 0.1648^2 = 1.81305 \ m^3/Sec$

No of jet

$$n = \frac{Total}{jet} = \frac{3.62}{1.81305} = 1.99 \text{ say 2 no.s}$$

Q3. A Pelton wheel is having a mean Bucket diameter of 1 m and is running at 1000 R.P.M. the net head on the Pelton wheel is 700 m. if the side ctearance angle is 15 degree and discharge through nozzle is 0.1 meter cube per sec find: I. Power available at the Nozzle ü. Hydraulic eiFiciency of the turbine

Solution:

Given data:

Diameter of wheel $D = 1.0$ m

speed of wheel $N = 1000$ r. p. m side

clearance angle means vane angle at outlet $= 15°$

$Q = 0.1 \ m^3/Sec$, Net Head $H = 700$ m

Assume C_v as 0.98

From velocity triangle at inlet

\ft?lclt7ity €tf jtÑ)í * $= C.72g$ ž'í $H = 0.98 \times 2 \quad 9\,8 \quad 700 = 114.4$ „ „/Sec

We have from velocity diagram at inlet $VJ = V_{„,} = 114•84$ „/Sec

Wheel velocity

$$U = <i = U, \equiv \frac{aDN}{60} \equiv \frac{v \times 1 \times 1000}{60} = S2Ø35 \ ***/Sec$$

Relative velocity at inlet $r, = \quad - U_i = 114o84 - S\,2R35 = 62\,R49$ „ŽSec

We have from velocity diagram at out let $r, = r2 = 62.49$ fÑC

$$Vp_2 = V_{r_2} \cos 8 - U, = 62.49 \cos 1S - 52.3S = 8.01 \ *** \ Ş\$Ñ¡J$$

1. Power available at nozzle (W.P):

we havewater power

$$W\,P = \frac{pg\breve{g}H}{1000} KW = \frac{1000 \times 9.81 \times 0.1 \times 700}{1000} KW = 686.70\ KW$$

2. The hydraulic efficiency of the turbine is given by

$$Ńh = \frac{(Vp_i + V_{„,_2}) \times U}{2\ V_1^2} = \frac{2(114.84 + 8.01) \times S2.34}{114.84^2} = 0.9684 \text{ say } 97\%$$

$$q_h = 0.9684 \text{ sky } 97\%$$

Q4. A 137 mm diameter jet of water issuing from a nozzle impinges on the BuckeŁ of a Pelton wheel and the jet is deflected through an angle 165degree by the buckets. The head available at the nozzle is 400 m assuming co-efPicient of velocity as 0.97, speed ratio as 0.46 and reduction in relative velocity while passing through buckets as 15% find:

i. the force exerted by the jet on Buckets in tangential direction

ii. The power developed

Soìution:

Given Data:

Dia of jet $d = 137$ mm $= 0.137$ m

angle $Q = 15^0$

$H = 400m$

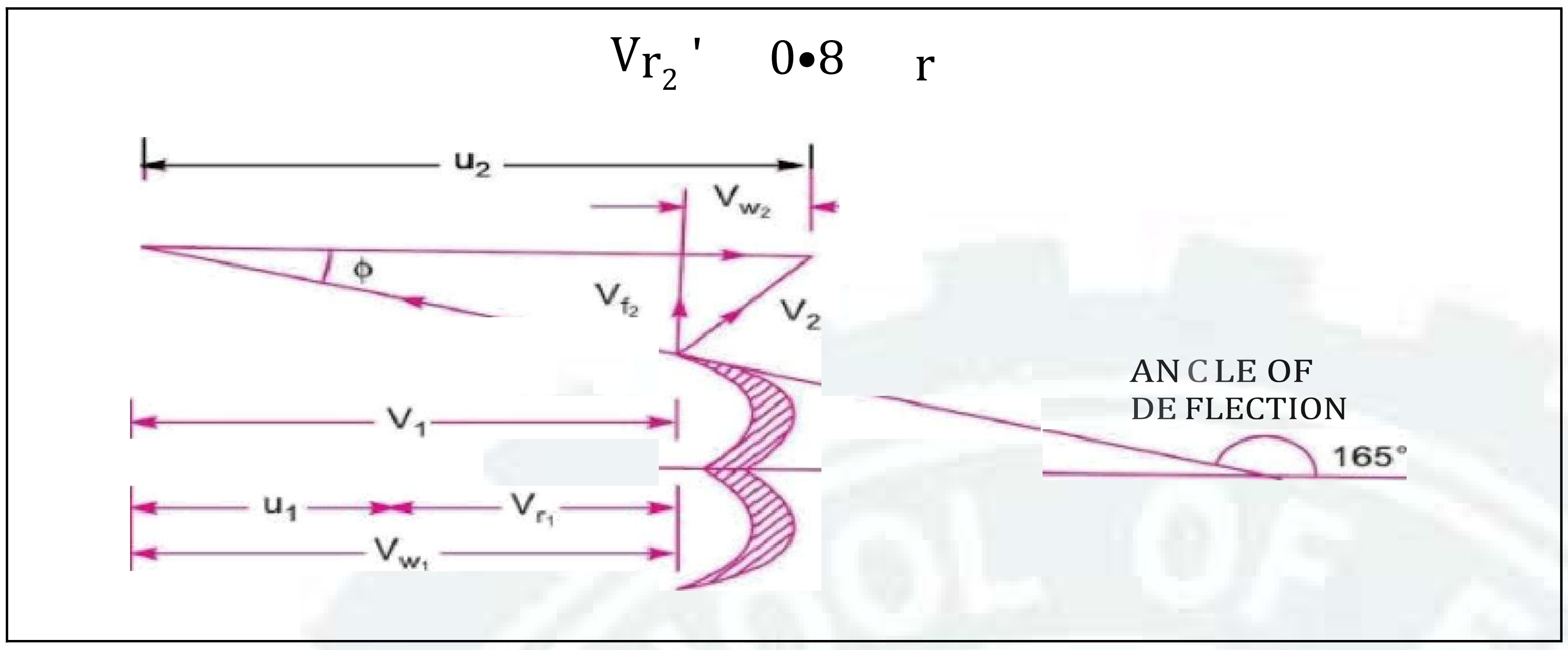
$Cy = 0•97$

speed ratio $= 0.46$

area of jet a $= \frac{}{4}$ x $d^2 = \frac{}{4}$ x $0.137^2 = 0.01474\ m^2$

as per question relative valocity of water at oulet

V_{r_2} ' 0•8 r



From velocity triangle at inlet

velocity Of jet $V_1 =$ C, x g x H

$= 0.97$ x 2 x 9 81 x 400 $= 85.$ „/'Sec

We have from velocity diagram at inlet

$V_1 = Vp_i = 8S•93$ „tSec

Now velocity of wheel

U= i = Uz= 0.46 x 9 81 x 400= 40.75 „/$eC

Relative velocity at inlet V_r, $= Vp_i - U_1 = 8S.93 - 40•75 = 4S\ 18$„tSec

We have from velocity diagram at out let$V_{r_2} = 0.85 V_{r_i} = 38.40$ $eC

V $= U/ -$ rt 8 $= 40•75 - 38.40$ cos 15 $= 3.658$ Sec

Now work done by jet of water on Bucket or Runner Power

$$RP = \frac{pa\ (Vp, - V_{,,,,})\ x\ U}{1000}$$ ... ... neagtive sign since U2 > V_{r_2}

$$= \frac{1000 \times 0.01474 \times 85.93(85.93 - 3.658) \times 40.75}{1000}$$

$$R.P = 4246.4 \text{ KW}$$

Force exeaed by jet of water in tangential direction

$$F_{,} = paV_{,}(Vp_{,} - Vp_{,}) = 1000 \times 0.01474 \times 85.93(8S.93 - 3.6S8)$$

$$= 104206 \text{ N}$$

Q5. Two jets strike the buckets of a Pelton wheel, which is having shaft Power 15450 KW. The diameter of each jet is given as 200 mm. if the net head on the turbine is 400m find overall efFiciency of the turbine. Take C, = 1. 0.

Ans.:

Given Data

Shaft Power, SP = 15450 KW

Diameterof jet, d = 200mm = 0.2m

Net head, H = 400m

C_v 1.0

$$\text{areaof jeta} = \frac{-}{4} \times d' = \frac{-}{4} \times 0.2' = 0.0314m'$$

From velocity triangle at inlet

$$\text{velocity of jet } V_1 = C_v \quad 2 \times \quad x \quad = 1.0 \ x \quad 2 \times 9 \quad \times 400 = 86.58 \frac{}{Sec}$$

Total discharge of water from two nozzles at inlet of Turbine is given by

$$Q = 2 \times (a \times >) = 5.562_{„*'S£iC}$$

Power available at inlet of Turbine

we havewater power

$$W.P = \frac{pgQH}{1000} KW$$

$$= \frac{1000 \times 9.81 \times 5.S62 \times 400}{1000} KW = 21817.44 KW$$

overall efficiency of Turbine

$$\circ = \frac{S.P}{W.P} = \frac{15450}{21817.44} = 0.708$$

$$to' \quad 0 \bullet 708 = 70.8 \ ^0Jo$$

Q6. A Pelton wheel turbine is to be designed for a head of 60m when running at 200 rpm .the Pelton wheel develops 95.6475 KW shaft Power. The velocity of Buckets is 0.45 times the velocity of jet Overall efficiency is 0.85 and coeiFicient of Velocity is equal to 0.98.

Solution:

Given Data:

Head H = 60 m

Speed of wheel N = 200 rpm

Shaft Power SP = 95.6475 KW

overall efficiency *to = 0•85

v = 0.98

veloci/ of bucket U = 0.45 x V,

Design of Pelton wheel means we have find the calculation of Values

a. Diameter ofjet (d),
b. Diameter of Wheel (D),
c. No of Bucket on Runner (Z),
d. No of Jet Required(n)

area of jet a = $\frac{}{4}$ x d^2 = $\frac{}{4}$ x 0.2' __0.0314 m'

From velocity triangle at inlet

velocity of jet

= v 2 X g × H = 0.98 x 2 x 9 1 x 60 = 33. 62 $\frac{}{Sec}$

Now velocity of bucket

U = Ui = >, = 0.4S x < = 0.45 x 33.62 = 15 3 $\frac{m}{sec}$

* $\frac{S}{W}$ = 088S

w. P = $\frac{95.6475}{0.85}$ = 112' 2 $\frac{m}{Sec}$

We have Power available at inlet of Turbine

W. P = $\frac{pgQH}{1000}$ = 112.52KW

$\frac{112.52 \times 1000}{1000 \times 9.81 \times 60}$

,, ' ',, 19 2 Sec

1. Diameter of Jet (d)

Total discharge of water from nozzles at inlet of Turbine is given by

$Q = (a \times V_1) = 0{\cdot}1912\ m^3/sec$

$$a = \frac{0.1912}{V_1} = \frac{0.1912}{33.62}$$

$$\frac{\pi}{4} \times d^2 = \frac{0.1912}{33.62}$$

$$d^2 = \frac{0.1912 \times 4}{33.62 \times \pi}$$

$$d = \sqrt{\left(\frac{0.1912 \times 4}{33.62 \times \pi}\right)} = .085m \text{ say } 85 \text{ mm}, \quad d = .085m \text{ say } 85 \text{ mm}$$

2. Diameter of Wheel

We have

$U = 15.13\ \frac{m}{Sec}$

$$\frac{\pi DN}{60} = 15.13$$

$$= \frac{60 \times 15.13}{\pi \times N} = \frac{60 \times 15.13}{\pi \times 200} = 1.44 \text{ m}$$

$D = 1.44$ m

3. No of Bucket

$$Z = 15 + \frac{D}{2d} = 15 + \frac{1.44}{2 \times 0.085} = 23.5 \text{ say } 24 \text{ No.s}$$

4. Size of Bucket

Width of Buckets $= 5 \times d = 5 \times 85 = 425$ mm

DepL of Bucket $= 1.2 \times 85 = 102$ mm

Q7. Determine the power given by the jet of water to the runner of a Pelton wheel turbine which is having tangential velocity as 20 mls. The net head on the Turbine is 50 m and discharge through the jet is 0. 03 $\frac{m^3}{Sec}$ The side clearance angle is l5degree and take velocity coeiFicient as 0.975

Ans.:

Given data:

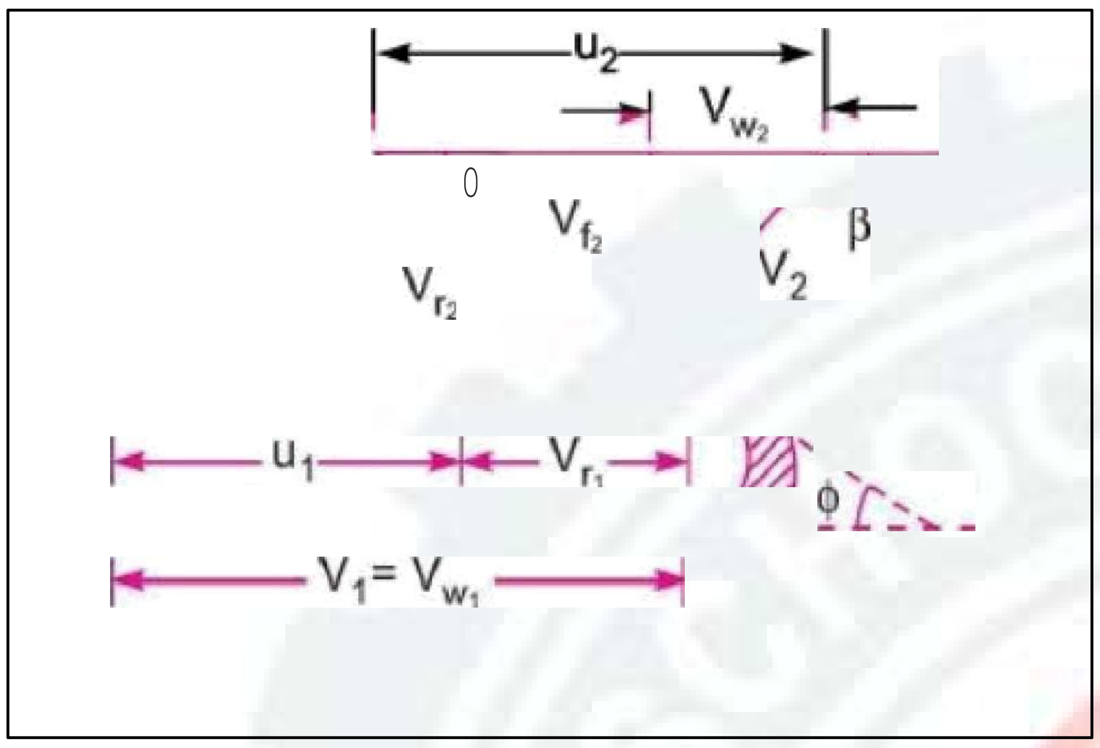
Velocity of Wheel,

$U = U_1 = U_2 = 20 \frac{m}{e}$ H = 50 m § = 0.03 " '*Sec 3

side clearance angie, $Q = 15°$

$C, = 0.975$

R. P =?



From velocity triangle at inlet

velocity of jet * $= C_V$ x g x H

$= 0.975$ x 2 x 9 81 0 = 30 54„/'Sec

We have from velocity diagram at inlet

$V_1 = Vp_i =$ 30a S4„tSec

Relative velocity at inlet $A_{re} =$ "• $- U_1$

= 30 54− 20= 10 54„JSec

We have from velocity diagrani at out let

V = rt = 10•5 4 Sec

$Y_2 = U_2 - r_2 COs Ø = 20 - 10.54 \cos 1S = 9.82$ „J'Sec

Now work done by jet of water on Bucket or Runner Power

$R.P = \frac{paVl(\quad - Vp\ )\ X\ U}{1000} = \frac{pQ(Vp, \ - Y_{„„2})\ x\ U}{1000}$ (neagtive sign since U_2

> $_r ø \cos Ø) = \frac{1000 \ x \ 0.03 \ x \ (30.54 - 9.82) \ x \ 20}{1000}$

$$R.P = 124.32 \ KW$$

Reaction Turbine:

- In this type of Turbine the water at the inlet of the turbine possesses kinetic energy as well as Pressure energy

- As the water ñows over the runner blades some part of pressure energy is changed into kinetic energy .Thus the water through runner is under pressure. The runner is completely enclosed in an airtight casing and casing and runner is always full of water.

Types of Reaction Turbine:

» Radial Flow reaction Turbine

1. Inward Flow Reaction Turbine

2. Outward Now Reaction Turbine

- Axial Flow Reaction Turbine

- Mixed ñow reaction Turbine

<u>Radial Flow Reaction Turbine:</u>

- It is type of turbine in which the water flows in the radial direction. The water may flow from inwards to outwards or from outwards to inwards

- It is divided into two types

1. Inward Flow Reaction Turbine

2. Outward Flow Reaction Turbine

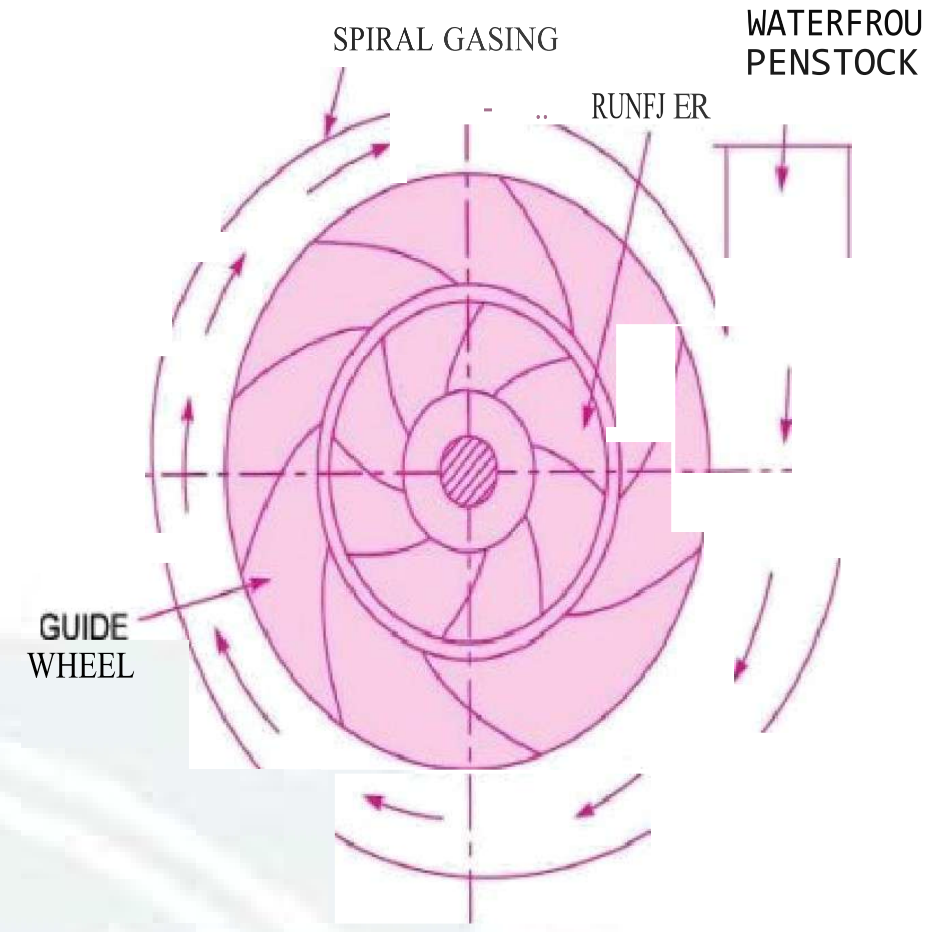
o In inward flow reaction turbine ie flow of water takes place from outwards to inwards through Te runner

» In outward flow reaction turbine flow of water takes place from inwards to outwards through the runner

<u>Construction of Radial ñow Turbine:</u>

The following are the main parts of Radial flow turbine

- Casing
- Guide Mechanism
- Runner
- Draft Tube



Casing:

- The water from penstock enters the casing which is of spiral shape in which area of section of casing goes on decreasing gradually.
- The casing completely surrounds the runner of the turbine.
- It is made spiral so that the water may enter the runner at constant velocity throughout circumference of the runner. It is made of concrete, Cast iron or plate steel.

Guide Mechanism:

- It consists of a circular wheel all-round the runner of the turbine. The stationary guide vanes are fixed on the guide mechanism.
- The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet. Also by a suitable arrangement,
- The width between two adjacent vanes of guide mechanism can be altered so that the amount of water striking on runner can be varied.

Runner:

- It is a circular wheel on which a series of radial curved vanes are fixed.
- The surface of vanes are made smooth.

- The radial curved vanes are so shaped that water enters and leaves the runner without shock.

- The runner are made of cat steel, cast Iron or stainless steel. They are keyed to shaft

Draft tube:

- The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure.

- The water at exit cannot be directly discharged to the tail race.

- A tube or pipe of gradually increasing area is used for discharging of water from exit of the turbine to the tail race.

- The tube of increasing area is called draft tube

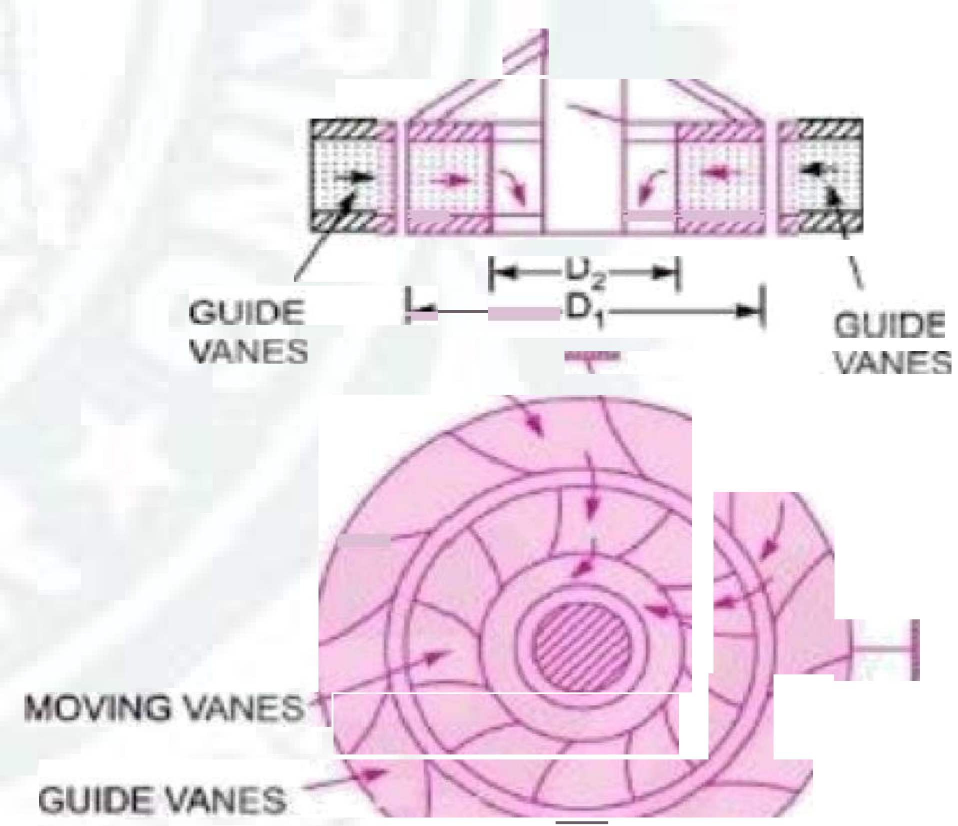
Inward Flow reaction Turbine:

- In an inward flow reaction turbine in which the water from casing enters the stationary guiding wheel.

- The guiding wheel consists of guide vanes which direct the water to enter the runner which consists of the moving vanes.

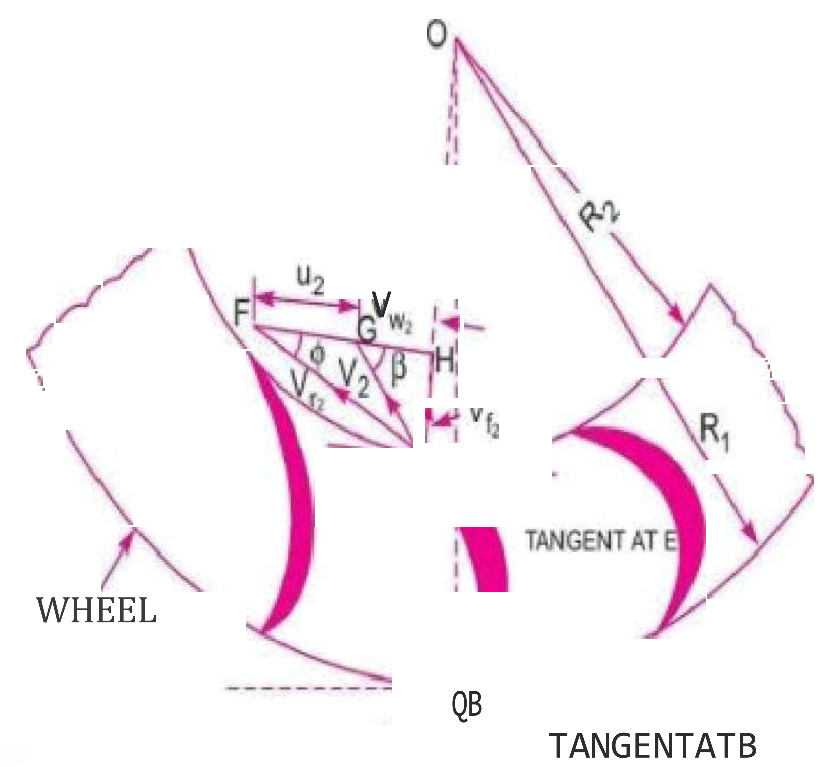
- The water flows over the moving vanes in the inward radial direction and is discharged at the inner diameter of the runner.

- The outer diameter of the runner is the inlet and inner diameter is the outlet.



Velocity triangles and Work done by water on the runner:

(Inward radial Flow turbine Velocity triangle Diagram)

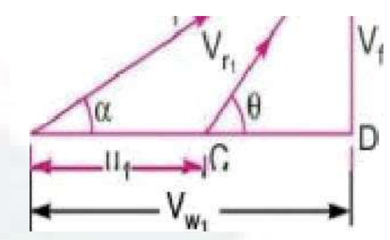


fit = Radius of wheel at inlet of vane

fi2—Radius of wheel at outlet of vane

in = Angular speed of the wheel

$u_1 = \omega R_1$, $u_2 = \omega R_2$



$U_1 = \frac{\pi D_1 N}{60}$ $U, = \frac{D2N}{60}$

where $D_o . D_o$ = internal and outer diameter of runner respctively

U_l U_S = Tangential velocity of wheel at inlet and outlet respectively

Vp and Vp_2 – velocity of whirl at inlet and outlet respectively

The mass of water striking per second for a series of vane = the mass of water coining out from nozzle per second

= paVl (a= area of jet, Ve—velocity of jet)

Momentum of water striking the vane in the tangential direction per second at inlet

Mass of water per second x component of *1 in the tangential direction

pa* x V_{ol}(component of * in the tangential direction = V cost =Vp)

Momentum of at outlet per second

= Mass of water per second x component of V_2 in the tangential direction

paV1x V 2(component of * in the tangential direction =–V2cos§ =)

-ve sign is taken as the velocity V at outlet in opposite direction.

Angular momentum per second at inlet =

Momentum at inlet x radius at inlet = pa<1 X VU x A

Angular momentum per second at outlet — paV_1 x Vp_2 x A

Torque exerted by water on wheel = T Rate of change of angular momentum.

T= [Initial angular momentum per second — Final angular momentum per .second]

pa* x Vol x * — (—pa*1 X V„,gX IU)

= pa/i x V ix **i + pa/i x Vwzx ft2

= paV1('fW1 1 + W2 2)

Work done per second on wheel = Torque x Angular velocity = TX O

= paV ('<W1 "1 +Vp2 "2) • • ' pa'*1(VU q X fj) '- W2 "2 X fjj)

= pa+ (Vol u, +V„,, u2) f« = 1 . 2' 2]

The general expression for the work done per second is

** = PO(<W1 u±*p, u2)

+ve sign will be taken if angle § is an Acuteand
if angle § is obtuse then -ve signwill be taken
if § = 90^0 then Vp, = 0

Water power (WP) = pQgIV1000

Runner Power (RP) = pQ(Vp, us='* 2 u_2) /1000

Hydraulic efficiency = (/«i » = V 2 u,) /gH

SpeedRatio:
It is defined as $\frac{U_1}{2\ H}$

Flow Ratio:

Il is ratio of the velocity of flow at inlet (V_{f_1}) to the velocity given 2 is known as flow ratio

$$\text{flow ratio} = \frac{V_{f_1}}{\sqrt{2gH}}$$

Discharge through Turbine:

Discharge of water flows over the runner blades

Q = +iDi Bi fg ' $D_2B_2V_{f_2}$

Where

D„ D2 — dia meter of blade at inlet and outlet respectively

B_1B, — wid4 of bli2de at inlíÑt and outlet of runníÑr respecWely

V_{f_1}, V_{f_2} — viÑlocity of flow at iIllfÑt alld outlet I £ispectively

Head of turbine:

The head of turbine is algebraic sum of Pressure head and Kinetic Head. It is given by „K"

H = "* / P8 °/° •$¿ 2 / 2g

Q. In an inward ñow reaction turbine has external and internal diameters as 0.9 m and 0.45 m respectively. The turbine is running at 200 r. p.m. and width of turbine at inlet is 200 mm. the velocity of ñow through the runner is constant and is equal to 1.8 m/s. The guide lades make an angle of 10^0 to the tangent of wheel and discharge at the outlet of turbine is radial. Draw the inlet and outlet velocity trianQes and determine

1. The absolute velocity of water at inlet of Runner 2. The velocity of whirl at inlet
3. The relative velocity at inlet 4. Runner blade angle
5. Width of runner at outlet 6. Mass of water ñowing through runner per Sec.
7. Head at inlet of the turbine 8. Power developed and hydraulic efficiency

Solution:

Given data:

Externaldiameter,Dǂ 0.9m

internal diameter D, = 0.45 m N = 200Rpm

Flow velocity *f, = ft = *•' 7'Sec

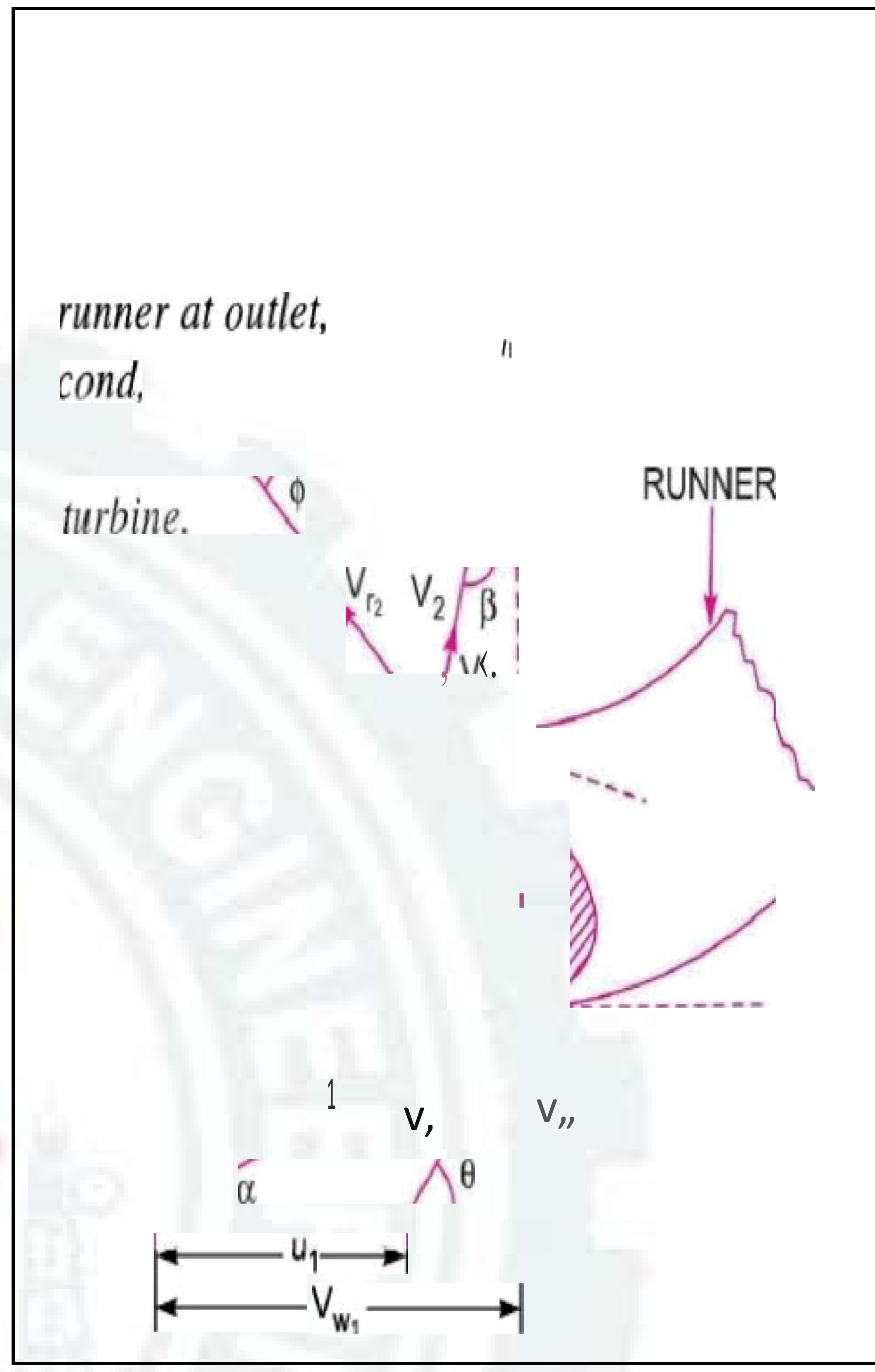
Guide bladeangle a = 10°

Discharge at out let is Radial, $V_{f_2} = 0$, § = 90°

tangential velocity of blade at inlet and out let

$$U_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.45 \times 200}{60} = 9.424 \text{ m/sec}$$

$$U_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.9 \times 200}{60} = 4.712 \text{ m/sec}$$



1. Absolute velocity at inlet of Runner(VJ):

From inlet velocity triangle at inlet

$$\sin\alpha = \frac{V_{f_1}}{V_1} \Rightarrow V_1 = \frac{f_t}{\sin n} = \frac{1.8}{\sin 10}$$

$= 10.365$ '*'/sec

1 = 10.365 "/sec

2. Velocity of Whirl at inlet(VU):

From inlet velocity triangle at inlet

$$\tan a = \frac{V_{f\phi}}{V_{w_1}} \Rightarrow V_{w_1} = \frac{f\phi}{\tan a} = \frac{1.8}{\tan 10}$$

Vp$= 10. 207 /sec

3. The Relative velocity at inlet (V_{r_1}):

From inlet velocity triangle we have

$$V_{r_1} = \sqrt{{V_{f_1}}^2 - (V_{w_1} - U_1)^2}$$

=

= =

= — — — =

= =

= — —

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1 8^2 (10 207 9 424)

3 24 —F 0 613 1. 963 /5e

4. Runner blade angle (8, Q)

From inlet velocity triangle

tan8 p Off 1.8 ZZ98

V U 10.207 9.424

æ 8 tan 1 2.298 66. 48°

from outlet velocity triangle , we have

tanØ fø 1.8

U 4.712

1 Ø = tan 1 = 20. 9^0

4.712

5. widŁ of runner at outlet (02):

We have from continuity equation

Q' $D_i B J ¥_f$ ' D B_2 f_Z

$$< D_i B_i = D_2 B_2 \quad \frac{D\ B}{D_2} = B_2$$

$$\Rightarrow B_2 = \frac{0.90 \times 0.20}{0.45} = 0.40m = 400mm$$

$$\Rightarrow \mathbf{B_2} \quad \mathbf{400mm}$$

6. Mass of water flowingthrough runner per sec:

we have

$$Q = nD_1 B_i V_{f,} = n \times 0.9 \times 0.20 \times 1.8 = 1.0178\$_{£J}$$

Now mass of water per see

$$\frac{Mass}{sec} = X(\$ = 1000 \times 1.0178 = 1017u\ 8 \quad ' \quad Sec$$

6. Head of water at inlet of turbine:

We have already

$$H \frac{“f_2{}^2}{2g} - \frac{1}{g}(V_{w_1}.U_1 \quad V_{w_1}.U_2) = \frac{1}{g}(Vp,\quad 1)$$

$$* - \frac{1}{g}(¥p\ .\ U_i) + \frac{V_{f_2}{}^2}{2g} = \frac{1}{9.81}(10.207 \times 9.424) + \frac{1.8*}{2 \times 9.81} = 9.97m$$

$$H = 9.97\ m$$

7. Power developed (RP):

Runner power

$$R\ P = \frac{1}{1000}pQ(Vp,.\ U_i) = \frac{1000 \times 1.0178 \times 10.207 \times 9.424}{1000}$$

$$R\ P = 97.9\ KW$$

8. Hydraulic EWiciency:

We have

$$Ńh = \frac{Vp,.\ U_i}{gH} = \frac{10.207 \times 9.424}{9.81 \times 9.97} = 0.9834 \text{ say } 98.34\%$$

$$q_h = 98.34\%$$

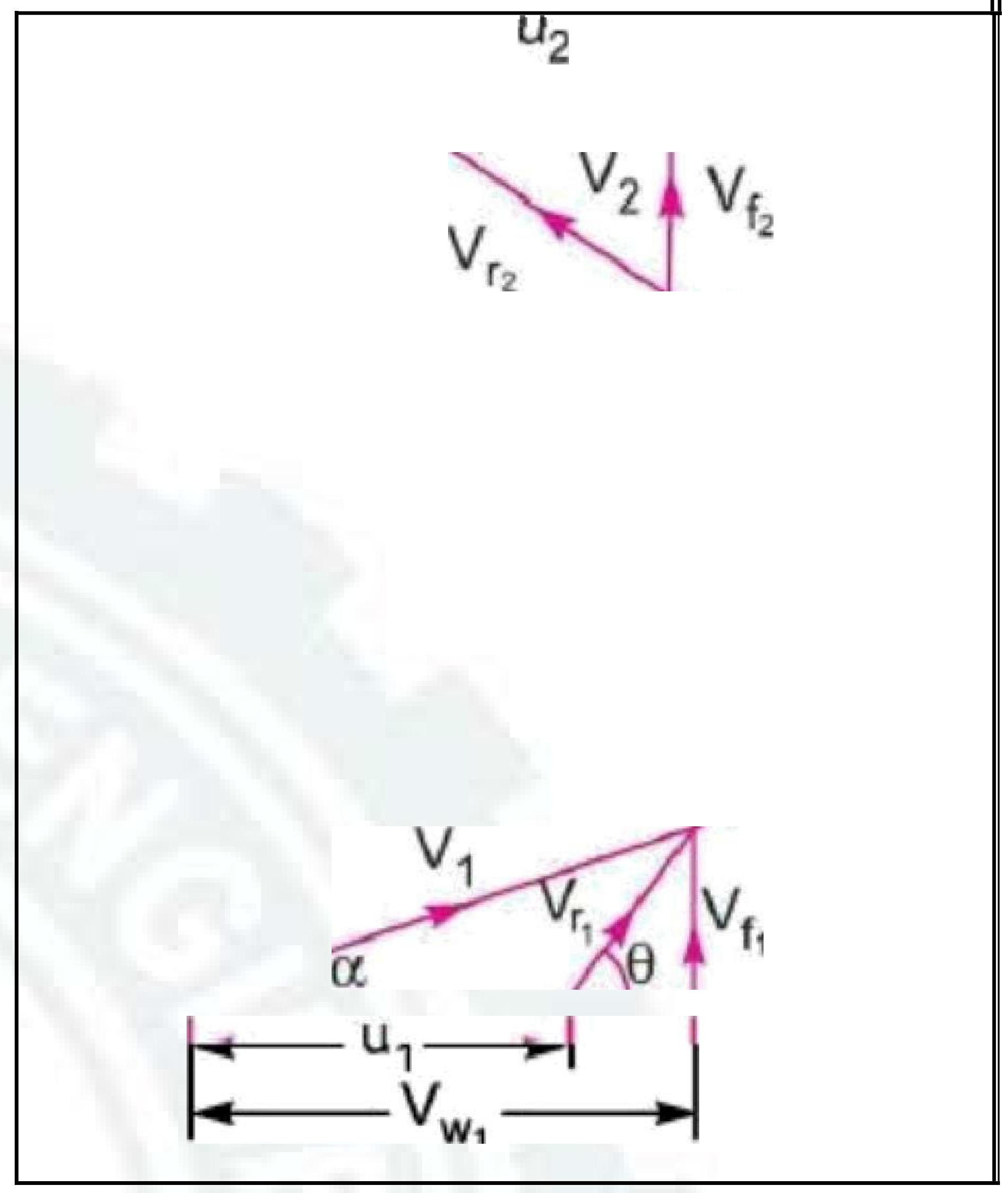
Q. A reaction turbine works at 450 rpm under a head of 120 m. its diameter at inlet is 120 cm and the ñow area is 0.4m^z the angle made by absolute velocity and relative velocity at inlet are 20° and 60° respectively with the tangential velocity :Determine

1. The volume flow rate 2. Power developed 3. Hydraulic efficiency

Assume whirl at outlet to be zero.

Solution:

Given data



internal diameter D_1 = l20cm = 1.2 m

N = 450 Rpm flow area = 0.4 m^2

H = 120 m

8 = 60^0 n = 20^o

whirl at outlet to be zero, $Vp_2 = 0$, § = 90°

tangential velocity of blade at inlet and out let

$$U_1 = \frac{nD_1 N}{60} = \frac{n \times 1.2 \times 450}{60} = 28.27 \ /sec$$

Velocity of Whirl at inlet (Vo_1):

From inlet velocity triangle at inlet

$$= \frac{V_{f_1}}{} =$$

=

=

= =

= =

= =

=

$\tan \alpha = \frac{}{V_{w_1}}$ Vp, tan 20 Vf,

VU 0. 364V 1

From inlet velocity triangle

$\tan 8 = \frac{V_{f_1}}{U}$ p V

f, — Vp, U, x tan60 0 364Yp,

V- 28.27 x tan60 0.364V-

48.96

(1.73 2 0.0 364) 35. 79„/sec

Now flow velocity at inlet

f 0.364V,,, 0.364 x 35.79

V_f\$ 13. 027 "'/sec

1. volume flow rate :

We have from continuity equation

$$Q = D_1 B_1 V_{f1} = 0"4 \times 13"027 = 5" 2 \quad \frac{\mathbf{m^3}}{\text{Sec}}$$

Power developed (RP):

Runner power

$$R\,P = \frac{1}{1000} V_{w_1} . u_1 = \frac{1000 \times 5.211 \times 35.79 \times 28.27}{1000}$$

$$R\,P = 5\,272.402\ KW$$

Hydraulic EIFiciency:

We have

$$\eta_h = \frac{V_{w_1} . u_1}{gH} = \frac{35.79 \times 29.27}{9.81 \times 120} = 0.8595 \text{ say } 85.95\%$$

Francis Turbine:

- It is inward reaction turbine having radial discharge at outlet.
- It is a medium head turbine in which the head of water is in between 50 to 250 m
- It is named after J B Francis a American Engineer.
- In modern Francis Turbine the water enters the runner of turbine in the radial direction at outlet and leaves through in the axial direction at the inlet of Runner.
- Thus it is a mixed ñow reaction turbine.
- The constructional features of turbine is as like in case of Reaction Turbine.
- The velocity triangle diagram at inlet and outlet of the turbine are Oawn in the same way that of inward ñow reaction turbine.

As in the case of Francis turbine the discharge is radial at out let hence whirl

Velocity at outlet is zero

As in case of Francis turbine the discharge is radial at outlet the velocity of whirl at outlet will be zero. V_{w_2} =0

Some Important Notes:

1. Discharge at Outlet is Radial

$$V_{w_2} = 0, \beta = 90°$$

2. Work done by water on runner per Sec

$$R.P = \frac{\text{Work Done}}{\text{Sec}} = \frac{P * V_{w_1} u_1}{1000} KW$$

3. Work done per Second per unit Weight of water Striking per Sec

$$\frac{\text{Work Done}}{\text{Sec}} / \text{Unit Weight} / \text{Sec} = \frac{V_{w_1} U_1}{g}$$

4. Hydraulic Efficiency

$$\eta_h = \frac{V_{w_1} U_1}{gH}$$

5. The flow ratio is given as

$$\text{Flow ratio} = \frac{V_{f_1}}{\sqrt{2gH}}, \text{ it varies from } 0.15 - 0.30$$

6. The Speed ratio

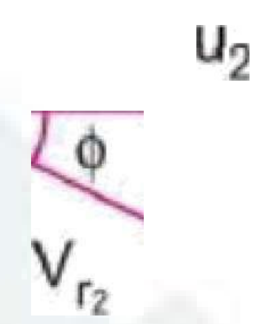
$$\text{Speed ratio} = \frac{U_1}{\sqrt{2gH}}, \text{ it varies from } 0.6 - 0.9$$

7. The ratio of width to its diameter is given by

n =p—, the value of n varies 0.10 – 0. 40

Q. A Francis turbine with an overall efficiency of 75% is required to produce 148.25 KW power. It is working under a head of 7.62 m. the peripheral velocity = 0.26 2xgxH and the radial velocity of flow is 0. 96 2 x g x H. The wheel runs at 150 r.p.m. and the hydraulic losses in the turbine is 22% of available energy. Assume radial Discharge, Determine:

i. The Guide blade angle
ii. The Wheel vane angle at inlet
iii. Diameter of wheel at inlet
iv. Width of the wheel at inlet



$V_{f_2} = V_2$

Solution:

Given Data:

overall efficiency , to = % = 0•75

Shaft Power = 148.25 KW

H = 7.62 m

Peripherial Velocity , U_1 = 0.26 2 x H

Flow velocity *f, = 0.96 2x × H

U_1 v,,,

speed of wheel, N = 150 r. p. m

Hydraulic loss = 22% of Head(H)

Discharge radial at outlet, $V_{w_2} = 0$, § = 90°

Now we have

Peripherial Velocity , U, = 0.26 2 x g x H = 0.26 2 x 9 8 x 7 62

= 3.179 /sec

Flow velocity f, = 0.96 2 x × H = 0 . 96 2 × 9.81 × 7.62 = 11.738 '**/sec

Hydraulic efficiency of turbine is given by

$$\#h = \frac{\text{Total head available} - \text{Hydraulic loss}}{\text{Head at inlet}} = \frac{H - 0.22H}{H} =$$

th = 0.78

i. Guide Blade angle:

We know that

η_h - $\frac{}{gH}$

< $V_{p,} = \frac{gH \times \eta_h}{U_i} = \frac{9.81 \times 7.62 \times 0.78}{3.179} = 18.34$ "‘/sec

^ *•i = 18.34 „Jsec

from inlet *ve!otity* triangle

$\tan Œ = \frac{V_{f_1}}{V_{w_1}} = \frac{11.738}{18.34} = 0.64$

mŒ= An 1 0.64 = 32.61º

ii. The wheet vane anQe at inlet:

we have from inlet velocity Triangle

tan 8 =' f ' ;Jg — i $= \frac{11.738}{18.34 - 3.179} = 0.774$

m B = tan 1 0.774 = 37.74º

iii. Diamt?ter of Whet?l at inlet (D_I):

We have peripheral Velocity

$U_1 = \frac{xD,N}{60} = \frac{g \; x\; 2\; x\; 250}{60} = 3.179$ JJJ /sec

• D $= \frac{60 \times U_1}{nN} = \frac{60 \times 3.179}{ri \times 150}$ D$ = 0.4047m

iv. Width of the whetl at inlet (B_I):

Ëo = 5% = 0• = 'W. P

m W » = S e0.75 - $\frac{148.25}{0.75}$

$\frac{pgQH}{1000} = \frac{148.25}{0.7S}$

$$\Rightarrow Q = \frac{148.25 \text{ x } 1000}{0.75 \text{ x } 1000 \text{ x } 9.81 \text{ x } 7.62} = 2.644 \quad \text{sec}$$

$$Q' \quad 2\ 644,, \ ^{3} \ \text{Sec}$$

we have discharge of water

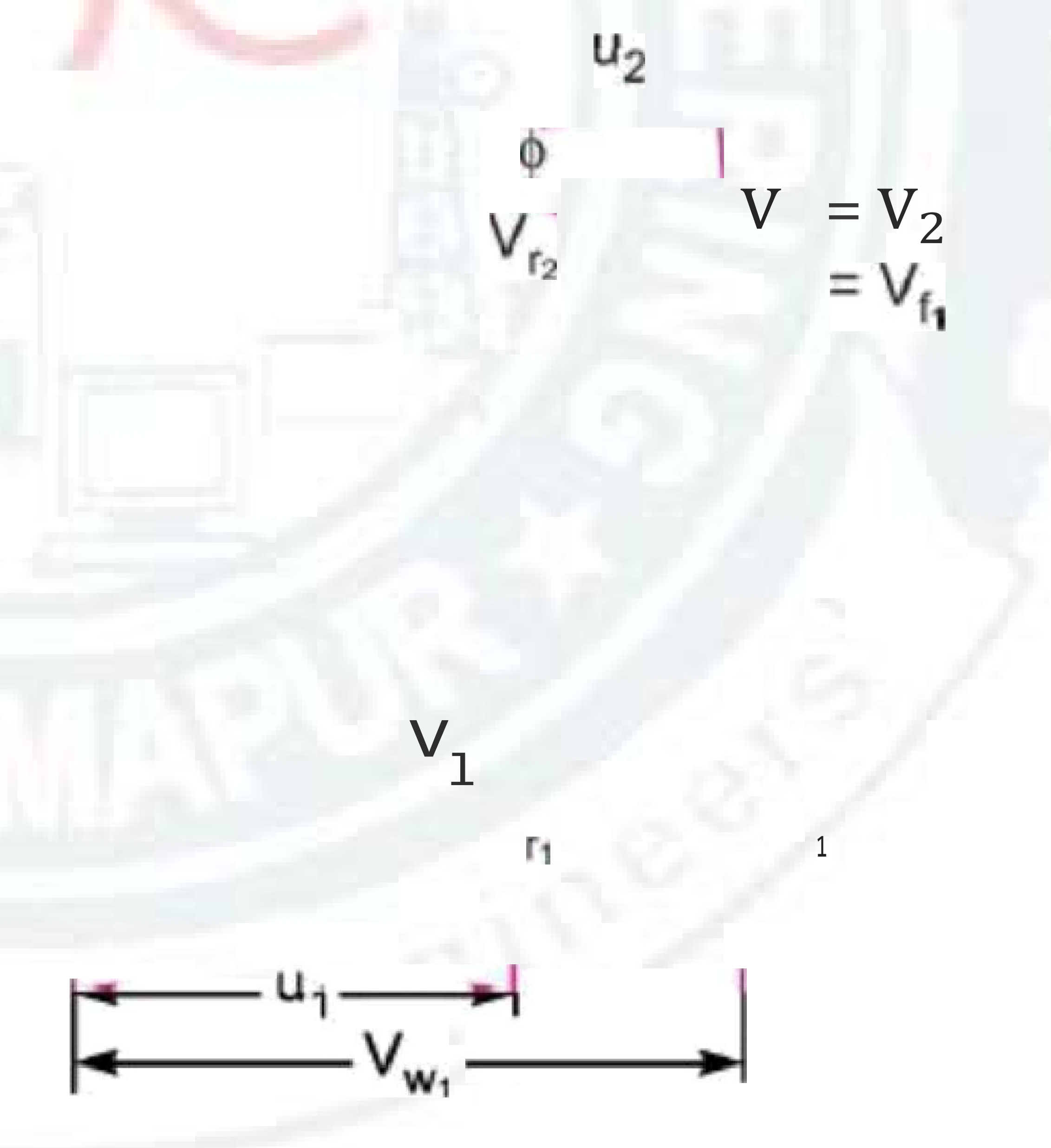
$$Q = nD\ B_{i\bullet} M_{fg} = 2.644$$

$$\Rightarrow B_1 = \frac{2.644}{nD_1\ f,} = \frac{2.644}{n \text{ x } 0.4047 \text{ x } 11.738} = 0177m$$

$$B_y = 0.177m$$

Q. The following data is given for a francis turbine. The Net head H= 60 m speed N= 700 rpm: shaft power = 294.3 KW: overall efficiency is 84% , Hydraulic efficiency is 93%: flow ratio is 0.20 breadth ratio n is 0.1: Outer diameter of the runner is two times inner diameter of runner . the thickness of vanes occupy 5% of circumferential area of the runner , velocity of flow is constant at inlet and out let and discharge is radial at outlet determine:

i. Guide blade angle
ii. Runner vane angle at inlet and outlet
iii. Diameters of runner in inlet



Solution:
Given Data:

Net head H = 60 m

speed N = 700 rpm

shaft power = 294.3 KW:

overall efficiency, q = 84% ,

Hydraulic efficiency, t_h = 93%:

flow ratio = 0.20

breadth ratio n = 0.1 Outer diameter of the runner is two times inner diameter of runner, $D_o = 2D_1$

Flow velocity $*f, = ft$

Discharge Radial at outlet $V_{w_2} = 0$, $V_f = v,$

Flow Velocity of Water:

We have flow ratio $= \frac{'}{2xg\,xH} = 0.20$

$V_{fg} = 0.20 \quad 2 \quad 9\,81\,x \quad 0 = 6.82$ „/sec

Discharge of water: We have overall efficiency

$\eta_o \quad \frac{S.P}{W.P} \quad 84\%$

$<\bullet\ W.P = \frac{S.P}{0.84} = \frac{294.3}{0.84} = 350.357KW$

$W\ S = \frac{pgQH}{1000} = 350.357$ $\quad Q \frac{1000x\,350.357}{pgH} = \frac{1o0Ox3 \quad 0.357}{1000x9.Blx60} = 0.5952\ ^{3}$ ^* Sec

$Q = 0.5952„^{3}$ 'st?c

Diameter of Wheel :

we have discharge of water

Q = Actual area of flow x Veloci/of flow

$Q = 0.95aD_1 \times B_1 \times V_{f_1} = 0.5952$

I $\quad 0.95aD_1 \times 0.1D \quad X \quad fg = 0.5952$

$\frac{0.5952}{0.95 \times a \times 0.1 \times \quad f} = '_1{}^2$

$D_1 = \sqrt{\left(\frac{0.5952}{0.95 \times \pi \times 0.1 \times V_{f_1}}\right)} = 0„S4\ m$

m $D_1 = 0.54$ m

now widL of blade $B = 0.1 \times 0.54 = 0.054$ m

Tangential veocity of runner at inlet

$U_1 = \frac{D_1}{60} = \frac{a \times 0.54 \times 700}{60} = 19.79$ "'/sec

We have know

$$ Ñh = \frac{V_{w_1} . U_1}{gH} \Rightarrow V_{w_1} \frac{gH \times *lh}{U,} = \frac{9 • 81 \times 60 \times 0.93}{19\ 79} = 27.Ö6\ JJJ/sec $$

< $Vp_1 = 27.66$ ***/sçi£i.. … … … … . . vcîlO£!i/ of whirl ä)I inlcîÈ

from inlet veloci¡y triangle

$$ \tan \propto \ V_{f_1} / V_{w_1} = \frac{6.862}{27.66} = 0.248 $$

$$ ==5Œ\ täH\ * 0.248 = 13.928^0 $$

v. The wheel vane anQe at inlet:

We have from inlet velocity Triangle

$$ \tan 8 = \frac{``ft/}{-\ **} = \frac{6.862}{27.66 - 19.79} = 0.872 $$

$$ m\ 8 = \tan^{1} 0.872 = 41.09^0 $$

now fom veloci/ triangle at outlet

$$ U_2 = \frac{»D_2}{60} = \frac{p_8 \quad (0.54/2) \times 700}{60} = 9.896\ ***/sec $$

$$ \tan Q = \frac{``f2}{-*2} $$

$$ =:•\ Q = \tan^{1} \frac{*I/*f2}{U,} = \tan^{1} \frac{6.862}{9.896} = 3.66° $$

$$ Q = 34.74° $$

<u>Axial F2ow Reaction Turbine:,</u>

- If the water ñows parallel to the axis of the rotation of the shaft, the turbine is known as axial ñow Turbine.
- At the inlet of the turbine the Sum of pressure Energy and Kinetic energy is present and during the flow of water through runner a part of Pressure energy is converted into Kinetic energy, the turbine is called reaction turbine.
- For axial ñow turbine the shaft of turbine is vertical. the lower end of the shaft is made larger which is known as hub or boss
- The vanes are fixed on the hub and hence hub acts as a runner for the axial ñow turbine.

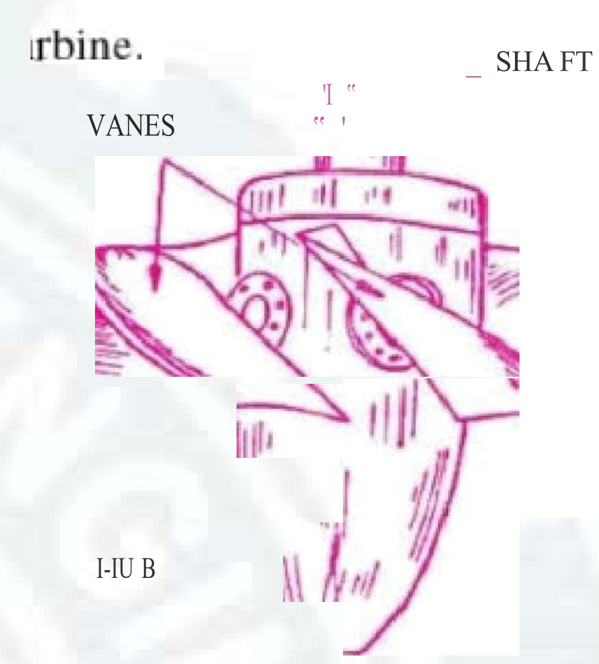
- The following are the important types of axial flow turbine.

1. Propeller Turbine
2. Kaplan Turbine

Kaplan Turbine:

- It is named after the Austrian Engineer V Kaplan
- It is a Low Head Turbine i.e. Head available at inlet is below 50 m
- It is suitable where a large Quantity of water at low head available.
- It is type of axial flow turbine in which the vanes on the hub are adjustable.

Construction & Working Principle



It consists of following Parts

1. Scroll Casing
2. Guide Vanes Mechanism
3. Hub with vanes or runner of the Turbine
4. Draft Tube

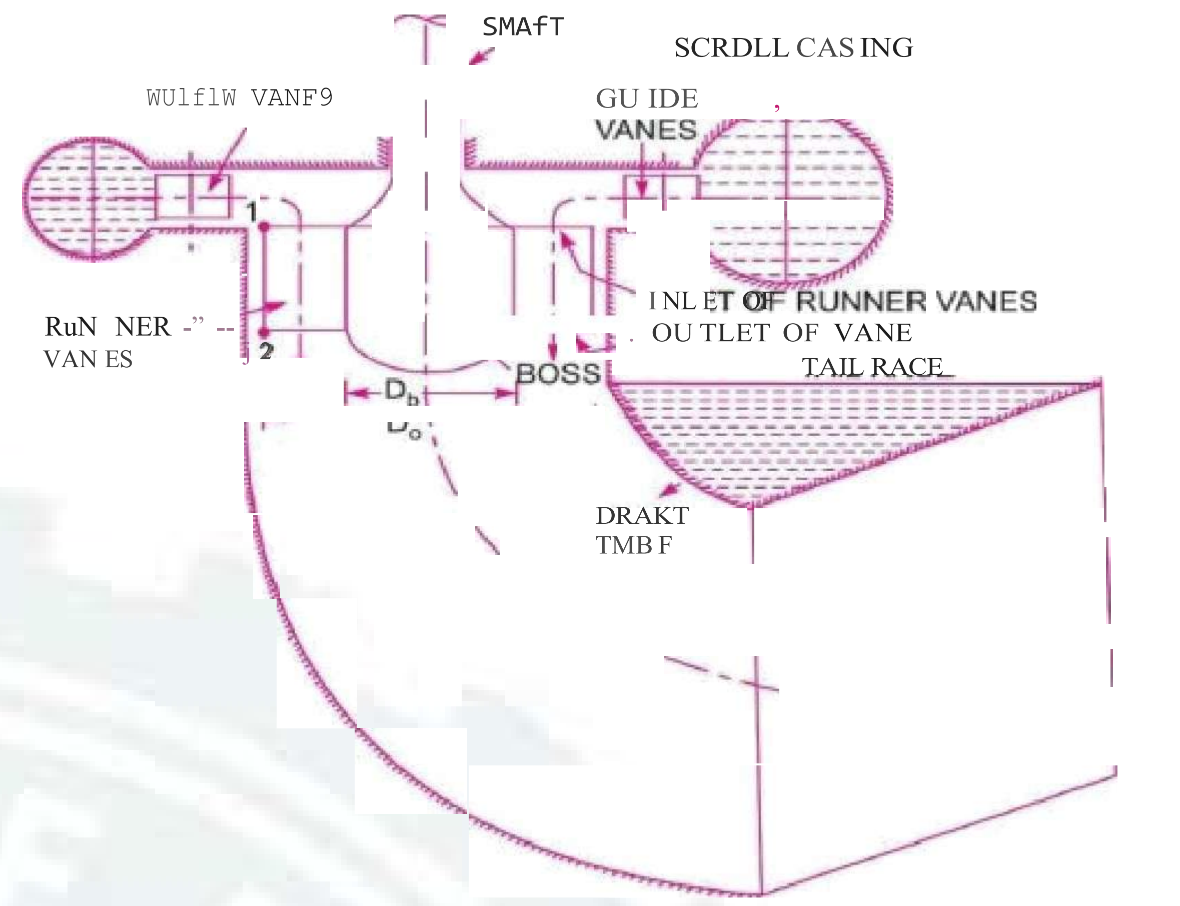
Scroll Casing:

- It is a spiral type of casing that has decreasing cross section area. The water from the penstocks enters the scroll casing and then moves to the guide vanes where the water turns through 90° and flows axially through the runner.

- Runner: Runner Blades are the blades that are rotated by the flow of water. In Kaplan turbines, runner blades has twist along its length and are adjustable to an optimum angle for maximum power output.

Draft Tube:

- A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tail race. This tube of increasing area is called Draft Tube.



Working Principle:

- The water coming from the pen-stock is made to enter the scroll casing. The scroll casing is made in the required shape that the flow pressure is not lost.
- The guide vanes direct the water to the runner blades. The vanes are adjustable and can adjust itself according to the requirement of flow rate.
- The water takes a 90 degree turn, so the direction of the water is axial to that of runner blades. The runner blades start to rotate as the water strikes due to reaction force of the water.
- The rotation of the turbine is used to rotate the shaft of generator for electricity production.

Important points:

From velocity triangle (Inlet and Outlet)

'2 = 'fg • r, = 0

1. The peripheral velocity in inlet and outlet

$$U_1 \quad U_2 = \frac{nD \ N}{60}$$

2. Velocity of flow at inlet and outlet are equal

$$V_{f_1} \quad V_{f_2}$$

3. Area of flow at inlet equal to area of flow at outlet

$$= \frac{\pi}{4} (» \quad 2—»_b{}^{z})$$

4. Discharge of water

$$Q \quad \frac{''}{4}\left(D_o{}^2 \quad D_b{}^2\right) \times V_{f_1}$$

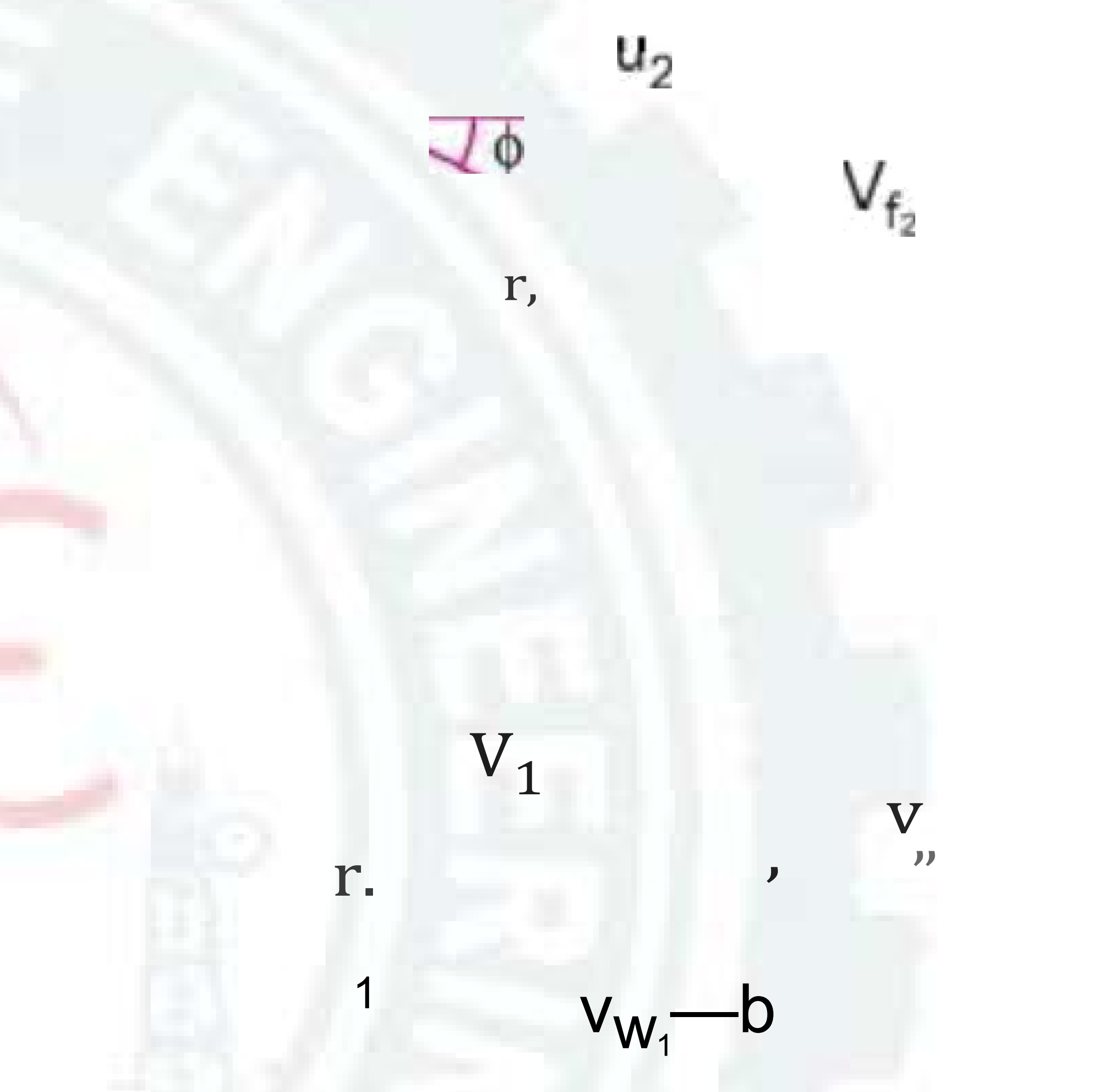
5. Hydraulic Efficiency

$$\eta_h = \frac{= \bullet U}{gH}$$

Q. A Kaplan Turbine working under a head of 20 m develops 11772 KW shaft Power. The outer diameter of the runner is 3.5 m and hub diameter is 1.75m. The Guide blade angle at the extreme edge of the runner is 35degree. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of wheel is zero at outlet Determine:

i. Runner vane angles at inlet and outlet at the extreme edge of the turbine

ii. Speed of the Turbine



Given Data:

Net head H = 20 m

shaft power = 11772 KW:

overall efficiency, q = 84% ,

Hydraulic efficiency, rh = 88%:

flow ratio= 0.20

breadth ratio n = 0.1

Outer diameter of the runner D=3.5 m

Inner diameter of runner, Db=1.75 m

Guide blade angle a =35 °

Flow velocity $V_f = V_f$

Discharge Radial at outlet, $V_{,,,,} = 0$, $Y_{f_2} = v_2$

Flow Velocity of Water:

Discharge of water:

We have overall efficiency

$$o = \frac{}{w.} = 84\%$$

$$W.P = \frac{S.P}{0.84} = \frac{11772}{0.84} = 1401428KW$$

$$W.P = \frac{\rho g Q H}{1000} = 14014.28$$

$$Q = \frac{1000 \times 14014.28}{\rho g H} = \frac{1000 \times 14014.28}{1000 \times 9.81 \times 20} = 71.428\ m^3/Sec$$

$$Q = 71.428\ m^3/Sec$$

Diameter of Wheel :

we have discharge of water Q = Actual area of how x Velocityofhow

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) \times V_f = 71.428$$

$$V_f = \frac{71.428}{\frac{\pi}{4}(D_o^2 - D_b^2)} = \frac{71.428}{\frac{\pi}{4}(3.5^2 - 1.75^2)} = 9n9\ m/Sec$$

i' „/Sec

from inlet velocity triangle

$$\tan \alpha = \frac{V_f}{V_{w_1}} = \frac{6.862}{27.6} = 0.7002$$

p y 1 9'9 /0.7002' 14. 14 m/sec

We have known that Hydraulic efficiency

$$\eta_h = \frac{V_{w_1} . U_1}{gH}$$

$$\Rightarrow U_1 = \frac{gH \times \eta_h}{V_{w_1}} = \frac{9.81 \times 20 \times 0.88}{14.14} = 12.21\ m/sec$$

< U, = 1 2. 21 "'/5£2£; ……………….. Ti2ngtSn)iii2l V£iIIJci/ i2)? inltst

Speed of Runner:

Tangential *veocit:y* of runner at inlet

!*i = y = 12.21 ***7sec

$$= \frac{60 \times 12.21}{\pi \times 3.5} = 63\ R.P.M$$

vi. The wheel vane anQe at inlet:
We have from inlet velocity Triangle

$$\tan \theta = \frac{V_f}{V - U_1} = \frac{9.9}{14.14 - 12.21} = 5.13$$

$$\theta = \tan^{-1} 5.13 = 78.97°$$

now fom velocity triangle at outlet

For Kaplan Turbine , Tangential Velocity at inlet and outlet, $U_2 = U_1 = 12.21$ sec

$$\tan \phi = \frac{V_{f2}}{U_2} \quad \phi = \tan^{-1} \frac{V_{f2}}{U_2} = \tan^{-1} \frac{9.9}{12.21} = 39.035°$$

$$\phi = 39.035^o$$

Q. The hub diameter of a Kaplan turbine working under a head of 12 m is 0.35 times the diameter of the runner. The turbine is running at 100 rpm. If the vane angle of the extreme edge of the runner at outlet is 15 degree. And flow ratio 0.6

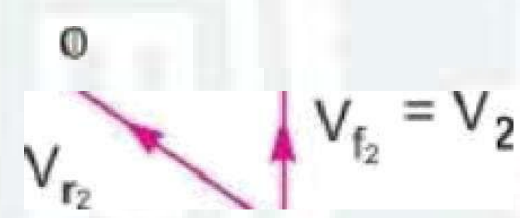
Find.

i. Diameter of Runner

ii. Diameter of Boss

iii. Discharge through the runner

The velocity of whirl at outlet is given as zero.



Solution:

Given Data:

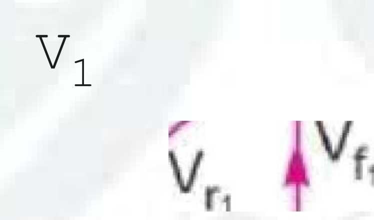
Net head $H = 12$ m

speed $N = 100$ rpm

$Q = 15$

flow ratio = 0.20

$D_b = 0.3\ D_o$



Outer diameter of the runner is two times inner diameter of runner, $D_o = 2 D_o$

Flow velocity $V_{f_i} = V_f$

Discharge Radial at outlet $V_{w2} = 0$, $V_{f_2} = V_2$

Flow Velocity of Water

$$\text{We have flow ratio} = \frac{V_{ft}}{\sqrt{2 \times g \times H}} = 0.6$$

$$*f, = 0.6\sqrt{2 \times 9.81 \times 12} = 9.2 \; ^{*}**/sec$$

now fium veloci/triangle at outlet

$$\tan = \frac{V_{f_2}}{U,}$$

$$\Rightarrow U_2 = \frac{f_2}{\tan} = \frac{9.2}{\tan 15} = 34.55 \text{,,/sec}$$

$$"\bullet *_1 = *_2 = 34.55 \; ^{*}**/sec$$

$$\text{we have tangential velocity, } U_2 = \frac{aD\ N}{60}$$

$$D_o = \frac{U, \times 60}{lr \times 100} = \frac{34\ SS \times 60}{u \times 100} = 6.55 \text{ m}$$

$D_o = 6.55$ m ……………….. Diamter of Rllnncir

We have from above data $D_b = 0.35 \times D = 0.35 \times 6.35 = 2.3$m

$D_b = 2.3$ m ………….. Dii2mter of BOss

we have discharge of water = Actual area of flow x Velocity of flow

$$= \frac{3}{4}(D_O * - D_b 2) \quad *f, = \frac{}{4}(6.55^2 - 2.3^2) \times 9¥2 = 271¥77\ " **Sec° =$$

271. 77,, st?c

Impulse Turbine	Reaction Turbine
1. Energy available at inlet is Kinetic Energy 2. It is high head turbine 3. The flow of water is in a tangential direction upon the runner blades 4. It produces more mechanical energy 5. The striking of water produces shock in blades of Runner 6. The turbine does not run full and air has a free access to the bucket	1. Energy available at inlet is sum Kinetic Energy and Pressure energy 2. it may be Medium or low head Turbine 3. It is Radial flow, Axial flow or mix flow type turbine 4. It produces quietly less than impulse turbine. 5. The flow of water is smoo\h on the curved blades

7. No use of Draft tube 8. Flow regulation is done by means of Needle valve fitted in to Nozzle 9. Example : Pelton Wheel	6. Water completely fills at the passage between blade and wheel 7. Draft tube is used to drag the water at outlet of Runner 8. Flow regulation is carried out by means of Guide vane Mechanism ,Scroll Casing 9. Example: Francis Turbine, Kaplan Turbine

Chapter 2

Syllabus

CENTRIFUGAL PUMPS

2.1 Construction and working principie of centrifugai pumps

2.2 work done and derivation of various e0iciencies of centrifugai pumps.

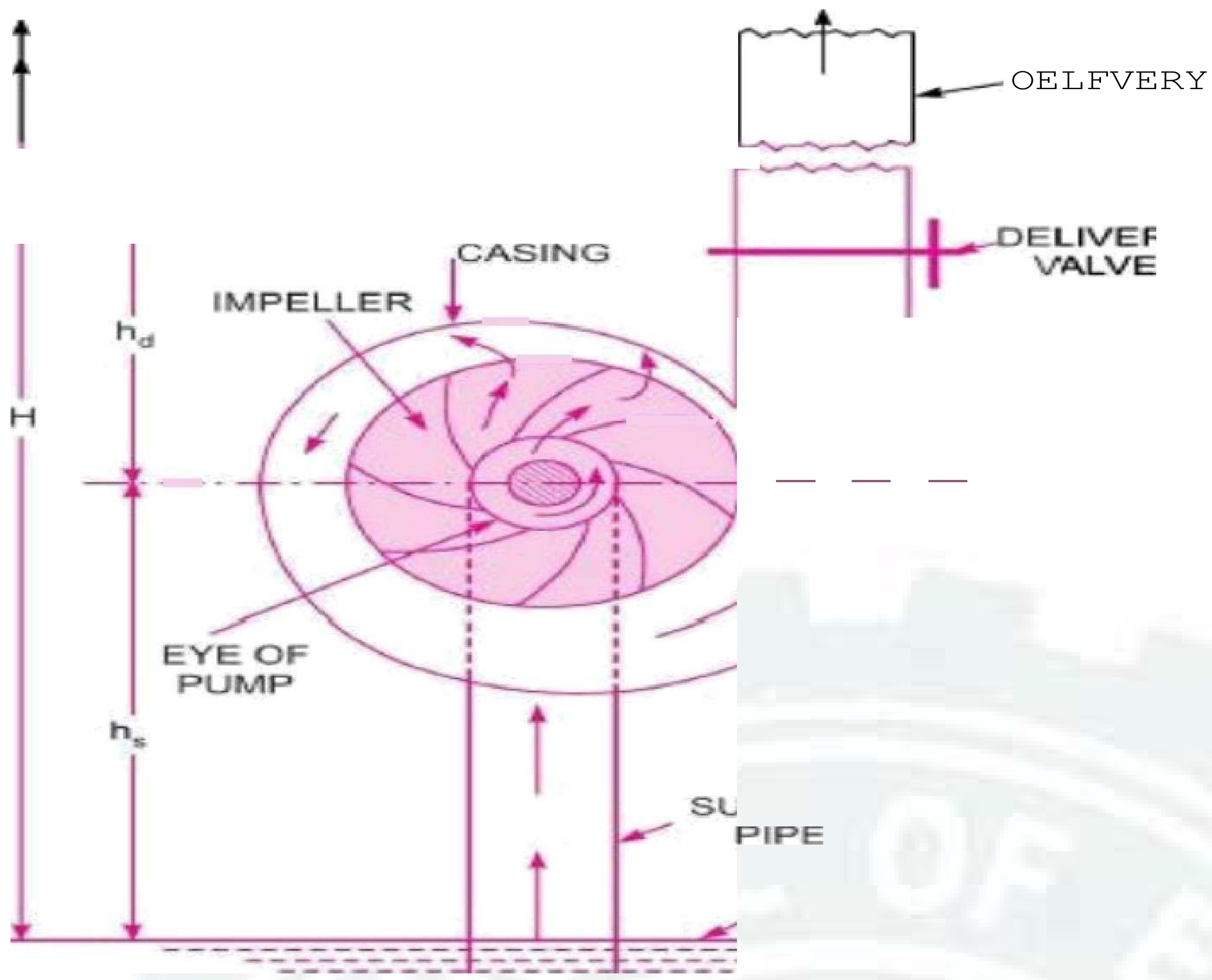
2.3 Numericai on above

introduction-

- s The hydraulic machines which convert the mechanical energy into hydraulic energy are called as pump.
- Pump is a device which transmits a fluid under pressure from one location to other location
- It converts Mechanical energy into Hydraulic energy.
- It is driven by Prime Mover like motor, Diesel engine etc.
- The hydraulic energy is in the form of pressure energy.
- [Centrifugal Force- Centrifugal force is the tendency of an object moving in a circle to travel away from the center of the circle.]
- It acts as a reverse of an inward radial flow reaction turbine
- e The flow in the centrifugal pump will be radially outward direction.
- It works on the principle of Force Vertex which means a certain mass of liquid is rotated by an external torque, thus the rise in pressure head of rotating liquid takes place.
- Due to high Pressure head the liquid can be delivered to a high level

Construction –

- Main parts are
- Impeller
- Casing
- Suction pipe with a foot valve and a strainer
- Delivery pipe



Impeller –

- The rotating part of centrifugal pump is called impeller.
- It consists of a series of backward curved vanes.
- The impeller is mounted on a shak which is connected to the shaft of an electric motor

Casing —

- It is similar to the casing of reaction Turbine
- It is an air tight passage surrounding the impeller of the pump.
- It is designed in such a way that the area of flow of water is gradually increases so that kinetic energy of water discharge at the outlet of impeller is converted into Pressure energy before the water leaves the casing and enters the delivery pipe
- 3 types of casing there volute casing, vortex casing, casing with guide blades.

Suction pipe with a foot valve and a strainer—

- A pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump is known as suction pipe.
- The suction of water is carried out in this pipe
- A foot valve is a Non Return Valve or one way type of Valve which allow the flow of water in one direction i.e. flow water from Sump to the Casing only
- Foot Valve is attached at the lower end of Suction Pipe
- A strainer is also fitted at the lower end of the Suction Pipe.
- It prevents the entry of foreign bodies in to the suction pipe.

De i e Pi e

- A pipe whose one end is connected to the outlet of casing of pump and other end delivers the water at required height is known as delivery pipe.
- The diameter of delivery pipe should be less than the diameter of Suction Pipe

Working

- The first step in the operation of a centrifugal pump is priming.
- It works on the principle that when a certain mass of fluid is rotated by an external source, it is thrown away from the center of axis of rotation and a centrifugal head is impressed which enables it to rise to a higher level.
- The delivery valve is closed and the pump is primed that is, suction pipe, casing and portion of delivery pipe up to delivery valve are completely filled with the liquid (to be pumped) so that no air pocket is left.

- Keeping the delivery valve closed the electric motor is started to rotate the impeller.
- The rotation of impeller causes strong action or vacuum just at the eye of casing.
- The speed of the impeller is gradually increased till the impeller rotates at its normal speed and normal energy required for pumping the liquid.
- Aker the impeller attains the normal speed the delivery valve is opened when the liquid is continuously sucked up the suction pipe, it passes through the eye of casing and enters the impeller at its center.
- This liquid is impelled out by the rotating vanes and it comes out at the outlet tips of the vanes into the casing.
- Due to impeller action the pressure head as well as velocity head of the liquid head are increased.
- From casing , the liquid passes into pipe and is liked to the required height discharged from the outlet / upper end of the delivery pipe.
- So long as motion is given to the impeller and there is supply of liquid to be lifted , the process of lifting the liquid to the required height remains continuous
- When pump is to be stopped the delivery valve should be first closed, otherwise there may be some backflow from the reservoir.

W rk one b the cen rif a o a er

- The water enters the impeller radially at inlet for best eHiciency of the pump.

- Absolute velocity of water at inlet makes an angle of 90 degree with the direction of motion of the impeller at inlet.
- Angle a=90°, and F„/=0
- N= Speed of the impeller in rpm
- ^1' Diameter of impeller at inlet
- u_1= Tangential velocity of impeller at inlet

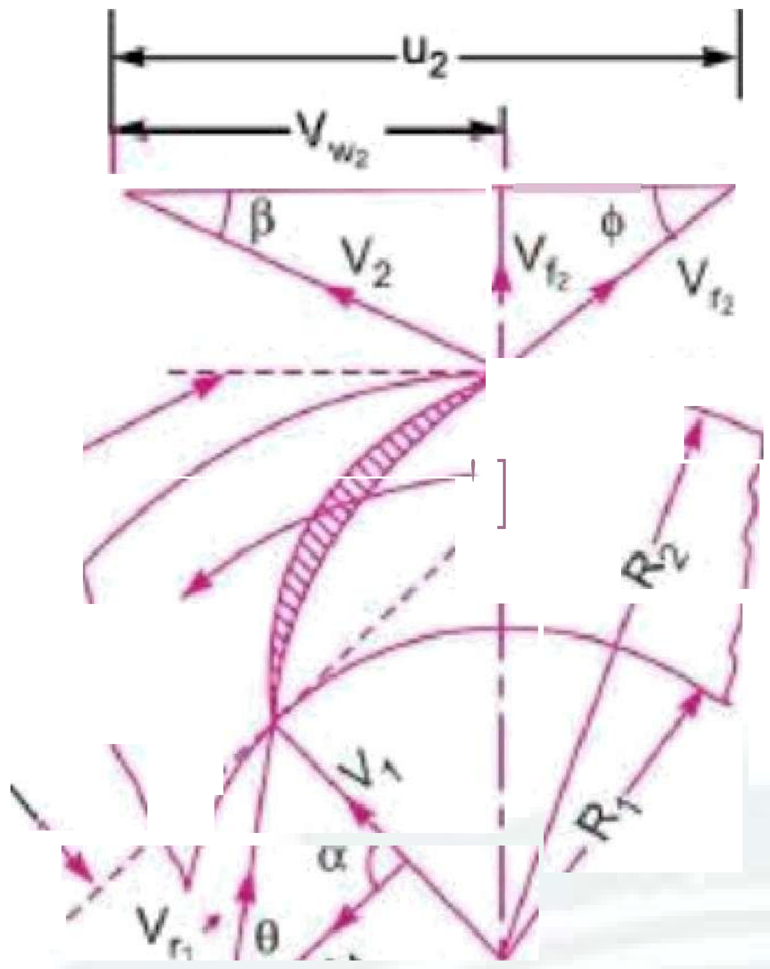
p p $_1 \frac{prrD\ \ N}{oo}$

- *D/*-- Diameter of impeller at inlet
- **2 Diameter of impeller at outlet.
- u_2= Tangential velocity of impeller at outlet
- $u_2 = \frac{\pi D_2 N}{gp}$
- *1° Absolute velocity of water at inlet
- *‹1=Relativevelocity of water at inlet

e o= Angle made by absolute velocity F_1 at inlet with the direction of motion of blade.

v 6 = Angle made by relative velocity F,\ at inlet with the direction of motion of blade.

- *‹ . § and g are corresponding values at outlet.



- A centrifugal pump is the reverse of a radially inward flow reaction turbine.
- In case of radially inward flow reaction turbine the work done is
  W =pO ’w1 1" ’w2 2]
  Work done by the impeller = -(work done in case of turbine)
  = -ρQ $[V_{w1}u_1$- $V_{w2}u_2]$= ρQ$[V_{w2}u_2$-$V_{w1}u_1]$
- W = p9['w2 2 I (\/’„,t=0) a=9O
- Work done by impeller on the water per second per unit weight=
  [w2• I/^ = **S2•2 J/g
  Where W= Weight of water = p x g x Q
  Q= Area x Velocity of flow = nD_1B_1 x {f/ = nD_2B_1 x f_2
  Where B •nd Btwidth of impeller at inlet and outlet are
  ff and \f are velocity of flow at inlet and outlet.

Heads of Pump:

There are four types of head

1. Suction Head
2. Delivery Head
3. Manometric Head

4. Static Head

Suction Head: it is the vertical height of the center line of the centrifugal pump above the water surface in the tank or pump from which water is to be liked.

It is denoted by symbol ’h,’

Deli e Head

The Vertical distance between the center line of the pump and the water surface in the tank to which water is delivered is known as delivery head.

It is denoted by symbol ’h_d

Static Head:

The sum of suction and delivery head is known as static head.

It is denoted by symbol’H,’.

Manometric Head:

It is defined as the head against which a centrifugal pump has to work

It is denoted by the symbol ’H„,’.

E i ien ies o centrif a u —

- Mechanicai EHiciency:

It is the ratio of power available at the impeller to the power supplied to the impeller. It id denoted by ’yT_{ech}’

$$\eta_{\wedge ech} = \frac{\text{power availableat impeller}}{\text{power supplied to impeller}} = \frac{pQ(Vp_2.U_2)}{\text{Shaftpower}}$$

$$\eta_{mech} = \frac{\$q(v_{.2}\ U_Z)}{\text{shaft power}}$$

- <u>Manometeric Efficiency:</u>

It is the ratio of output power of the pump to power available at the impeller.

It is denoted by symbol ’y „,‚alt’

$$\eta_{man} = \frac{\text{output power of impeller}}{\text{power available at impeller}} = \frac{\text{WaterPower}}{gq(vp_z.U_2)}$$

$$\eta_{man} = \frac{pgQHg,}{p_{o(*'**z}FU_2)} - \frac{gHg,}{(V_{\bullet 2}U_2)}$$

a ifglp <u>Overall Efficiency:</u>

It is the ratio of the output power of pump to the input power of pump.

It is denoted by symbol ’y o

$$\eta_o = \frac{\text{output power of impeller}}{\text{power available at inlet of impeller}} = \frac{\text{WaterPower}}{\text{Shaft power}}$$

$$\eta_{man} = \frac{pgQHp}{p}$$

Numerical

Problem 19.1 *Yhe internal and external diameters af the impeller of a centrifugal pump are 200 mm and 400 mm respecNvely. The pump is running at 1200 r.p.m. The vane angles of the impeller* nf *inlet and outlet are 20° ond 30° resR•^"•ely. The water enters the impellₑr radiolly and velocity of flow is consfont. Determine the work done by the impeller per unit weight of* irnfer.

Soludoo. Given :

Internal diameter of impeller, D, = 200 mm = 0.20 m

Extern£ diameRr o£ impeller, O» = 400 mm = 0.40 m

5peed, N = l2& r.p.m.

Vane angle at inlet, 8 = 20°

Vane angle et ouflet, ¢ = 30°

Water entcrs radially* means, o =90° and U',. =0

Velocity of flow, V = V z

Tangential velocity of impeller at inlet and outlet are.

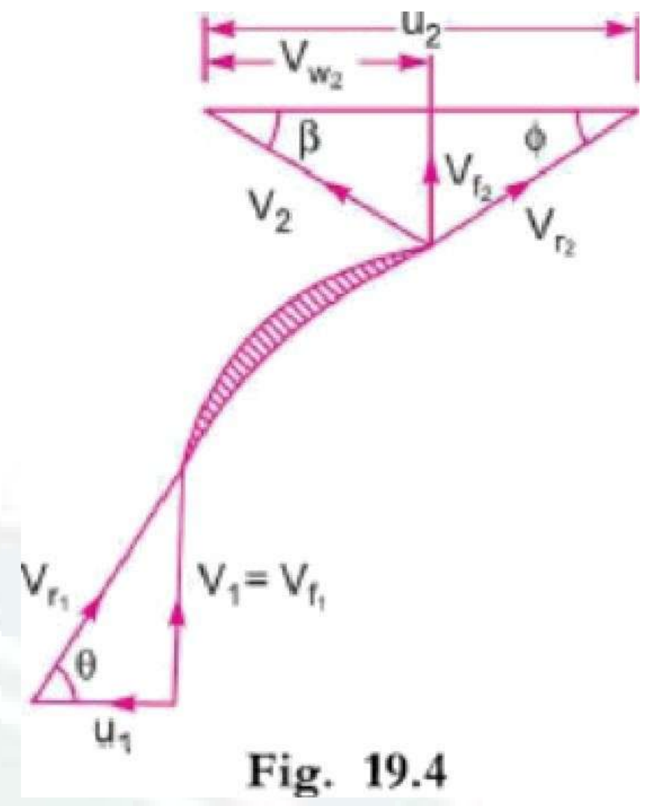


Fig. 19.4

pt _ nD N _ z x 0.20 x 1200 = 12.3d /.

and 2 " _ n x 0.4 x 1200 / so — 25 13 mlS.

From inlet vclocity a1anglc, Bn 6 = $\frac{V_{f_1}}{u_1} = \frac{V_{f_1}}{12.56}$

. Van = 12.56 tan 8 = 12.5ó x tan 20º « 4.57 m/s

$V_{f_2} = V_{f_1}$ = 4.57 m/s.

From outlet vclocity trianglc,tan $ = Q, / u, – P,. _ 4.57 / * 25.13- Y„

or 25.1.3 Vq,= 4.57 / = 4.57 / –›.cu

V,. = 25.1.3— 7.915 = 17.215 m/s.

The work done by impellcr per kg of waicr per second is givcn by equaüon (19.11 as

$= \frac{1}{g} V_{w_2}$ 17.215x 25.Í3 / 9.81 = 44•1 hlm/N- Ans.

PfiOb&m d *c;gz*trifñ$al j:izzzp is to discharge O. 118 m 1s at a speed of 1450 r.p.m. against a head of 25 m. The impeller diameter is 250 mm, its width at outlei is 50 mm and manometric e@ciency is 75&. Determine the vane angle at the Dute^Reriphery of the impeller.*

SOlUdOft. Given :

Oivharge, ¡3 = 0.118 n'Js

Speed, N = 1450 r.p.m.

Head, ?fp = 25 m

Diameter al outlet, D; = 250 mm = 0.25 m

Width at ouüet, &, = 50 mm = 0.05 m

Manomcaic efficiency, qqg « 75'$ = 0.75.

Let vane angle at outlet = $

Tangential velocity of impeller at outlet,

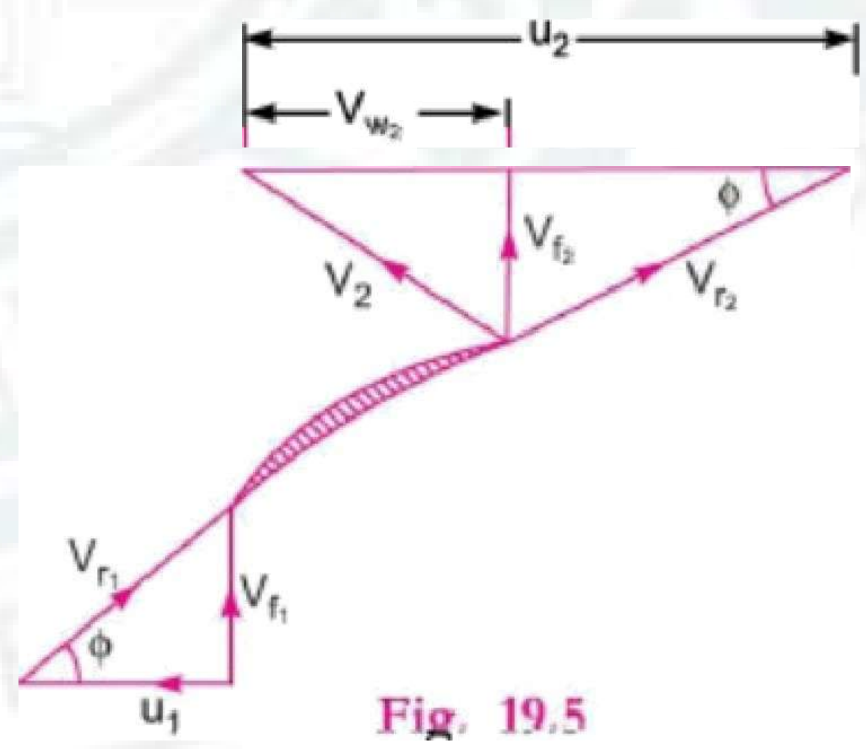


Fig. 19.5

Discharge is given by $Q = \pi D_2 B_2 \times V_{f_2}$

$V_{f_2} = \frac{p}{\pi D_2 B_2} = \frac{0.118}{\pi \times 0.23 \times .05}$ 3

Using equation (19.8), $\eta_{man} = \frac{g H_m}{V_{w_2} u_2} = \frac{9.81 \times 25}{V_{w_2} \times 18.98}$

$\therefore \quad V_{w_2} = \frac{9.81 \times 25}{\eta_{man} \times 18.98} = \frac{9.81 \times 25}{0.75 \times 18.98} = 17.2$à.

From outìet velocity toægle, we have

$\tan \phi = \frac{V_{f_2}}{(u_2 - V_{w_2})} = \frac{*\bullet**}{(18.98 - 17.23)} = 1.714.3$

$\therefore \quad \phi = \tan^{-1} 1.7143 = 59.74°$ or 59º 44. Ans.

Problem J9.3 *A centrifugal ;ump delii'ers wafer against a net head of 14.5 mefres and a design speed of 1000* r.p.n. *The vanes are curi•ed back to an angle of 30‘ »'ith flu periphery. The impeller diameter i.c 300 mm and nutlet width i 50 mm. Determine the discharge nf the pump if manometric efficienc y is !25'ñ:.*

SolUÕOR. Pziven :

Net hcad, $H_m = 14.5$ m

Speed, $N = 1000$ r.p.m.

Vaneangłe at ouüei, $\phi = 30°$

Impeller diameter means the diameter of the impeller at outlet

Diameter. $D_2 = 300$ mm = 0.30 m

Outlet width, $B_2 = 50$ mm = 0.0.5 m

Manomctñc efficiency, η_{man} = 9S'ä› = 0.95

TangenŃal velcCity of imțteller at outlet,

$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1000}{60}$ ».70 w*.

Now ming equation (19•8). $\eta_{man} = \frac{g H_m}{V_{w_2} \times u_2}$

o is $= \frac{9.81 \times 14.5}{V_{w_2} \times 15.70}$

$V_{w_2} = \frac{9.81 \times 14.5}{0.95 \times 15.70} =$ .Mm/s,

Refer to Fig. 19.5. From outlet velocity oìangle, we have

$\tan \phi = \frac{V_{f_2}}{(u_2 - V_{w_2})}$ or $\tan 30° = \frac{V_{f_2}}{(15.70 - 9.54)} = \frac{V_{f_2}}{6.16}$

$\therefore \quad V_{f_2} = 6.16 \tan 30° = 3.556$ **m/s.**

Discharge, $Q = \pi D_2 B_2 \times V_{f_2}$

$= \pi \times 0.30 \times 0.05 \times 3.556$ m³/s = 0.167$ m³/s. Ans.

Problefr› 19.4 *A cenirif•BaI p••p h‹n'iny ouler diamcler equal io* f»'*o times the inncr diameI«r and running nt IOOO r.p.m. w'orks against a tatal head of 40 m. The velocity of flow through the impeller is constant and equal to 2.5 m/s. The vnnes are set brick ni an angle of 40° at outlet. If the outer diameter of the impeller is 500 mm and widift* ar *ourfet* is *50 mm, determine :*

(i) Vane ang)e at inlet, (ii) Work done by impeller on water per second, and
miii) Manomelric e iciency.

SOlMtiDn. Given :

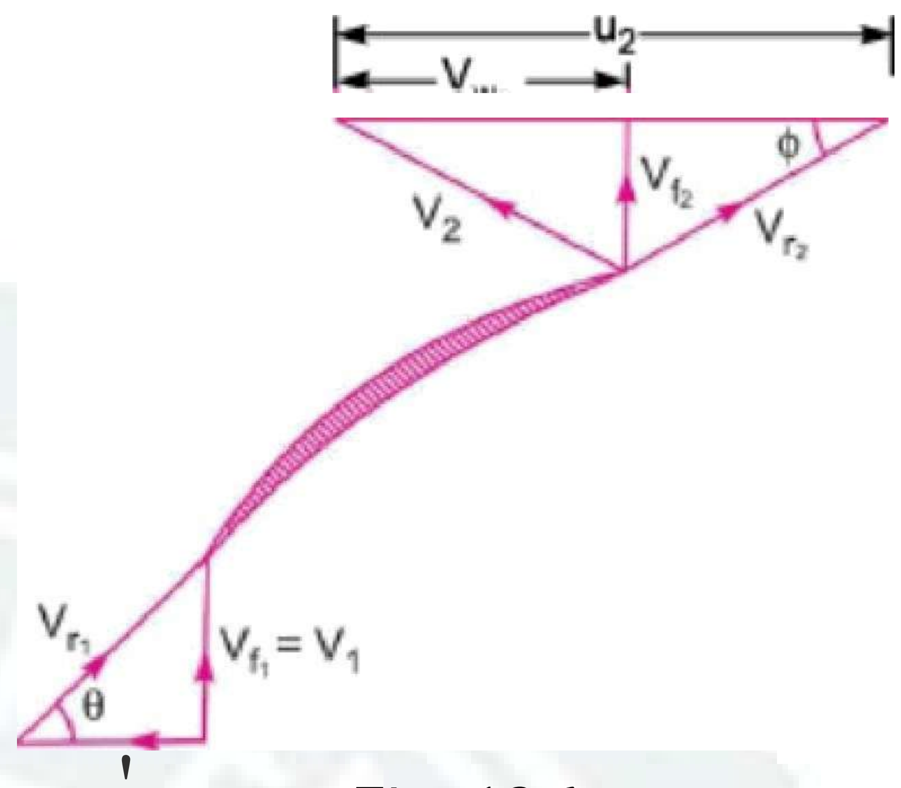


Fig. 19.6

Speed, N --)000 r.p.m.
Head, H = 40 m
Velocity of flow, Vy = Yip = 2.5 m/s
Vane angle at outlet. $ = 40°
Outer dia. of inn her, D -- 500 mm = 0.50 m
Inner dra. of impeller, $D|$ -- $\frac{D,}{2}$ $\frac{050}{2}$ = 0.25 m
Width at outlet, $B;$ -- 50 mm = 0 05 rn

Tangeniial velocity of impeller at inlet and outlet are

u = $\frac{xD_1 N}{æ}$ = $\frac{n \text{ x } 0.25 \text{ x } 1000}{sc}$ = 13.09 m/s

and $u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.50 \times}{60}$ = 26.18 in/s.

Discharge is given by, Q = $nD;B_2$ x V, = n x 0.50 x .05 x 2.5 = 0 l9t›3 m³fs.

(i} Vane angle at lalet (8).

From inlet velocity triangle tan B = $\frac{V_1}{u}$ $\frac{1S}{1109}$ = 0.191

8 = tan ' .191 = 10.81° or 10° 48". Ans.

{ii) Work doxe by impeller ‹›n water per secnnd is given fry equation (19.2) as

$$= \frac{W}{g} \times V_{w_2} u_2 = \frac{\rho \times g \times Q}{g} \times V_{w_2} \times u_2$$

$\frac{100fl \text{ x } 9.81 \text{ x } 019\ 3}{9.81}$ « $v_{,,}$ • 26 18

But from outlet velocity triangle. we have

$$\tan \$ = \frac{V_{f_2}}{u_2 \quad V_{w_2}} \quad \frac{2.5}{(26.18 - V_{w_2}}$$

26.18 _ V $\frac{2.5}{}$ $\frac{2.5}{,}$ = 2.979

V = 26.18 -- 2.979 = 23.2 m/s.

Substituting this value of Pq, in equation *(i},* we get the work done by impeller as

$\frac{1000 \text{ x } 9.81 \text{ x } 0.l9,,,,5}{9\&1}$ x 23.2 x 26.18

= 119227.9 Nm/s. Ans.

Chapter 3

Syllabus:-

3.0 RECIPROCATING PUMPS

3.1 Describe construction & working of singie acting reciprocating pump.

3.2 Describe construction & working of double acting reciprocating pump.

3.3 Derive the formula foe power required to drive the pump (Single acting & double acting)

3.5 Define slip.

3.5 State positive & negative slip & establish relation between slip & coe0icient of discharge.

3.6 Solve numerical on above

Reciprocating pump

Introduction

- The reciprocating pump is a positive displacement pump.
- Reciprocating pumps are in use where a certain quantity of fluid (mostly sump) has to be transported from the lowest region to the highest region by the application of pressure.
- Here the mechanical energy is converted into hydraulic energy which is mainly in the form of pressure energy.

- If the mechanical energy is converted into hydraulic energy by sucking the fluid into a cylinder in which a piston is reciprocating, which exerts the thrust on the liquid and increases its hydraulic energy, the pump is known as reciprocating pump.
- It is best suited for relatively small capacities and high head

Classification of reciprocating pump

- According to the water being in contact with one side or both the side of piston
  - Single acting pump
  - Double acting pump
- According to the number of cylinder provided
  - Single cylinder pump
  - Double cylinder pump
  - Triple cylinder pump

Application:

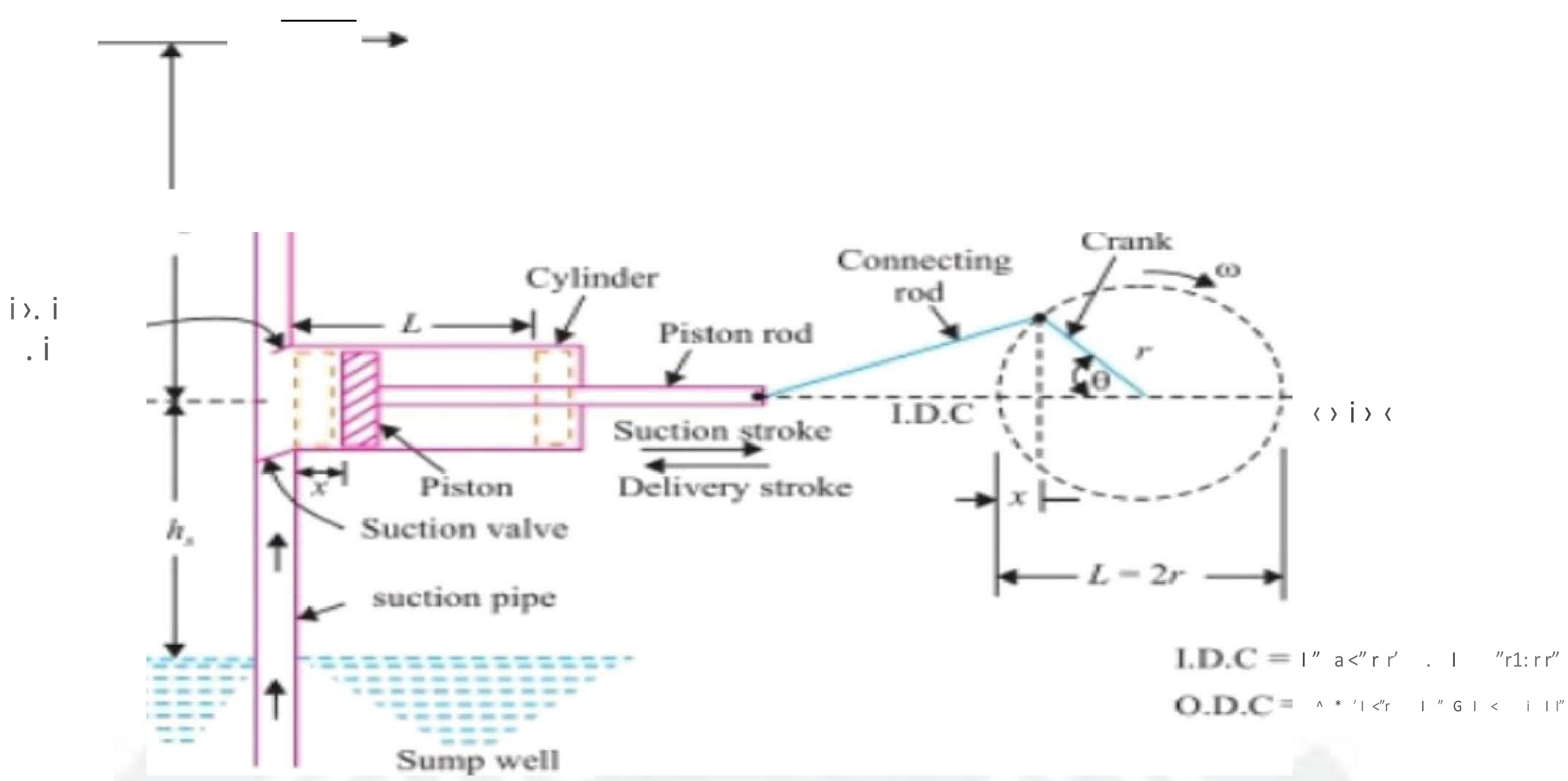
The applications of Reciprocating Pump are as follows.

- Gas industries
- Petrochemical industries
- Oil refineries
- Vehicle water servicing centers etc.

Construction of single acting reciprocating Pump

The main parts are

- Water Sump
- Strainer
- Cylinder
- Piston
- Suction Valve
- Delivery valve
- Suction Pipe
- Delivery Pipe
- Crank and connecting rod mechanism



Water Sump:

- It is the source of water. From the sump, water is to be transported to the delivery pipes by the usage of the piston.

Strainer:

- It acts as a mesh that can screen all the dirt, dust particles, etc. from the sump. If there is no strainer, then the dirt or dust also enters into the cylinder which can jam the region and affects the working of the pump.

Suction Pipe:

- The main function of the suction pipe is to collect the water from the sump and send it to the cylinder via a suction valve. The suction pipe connects the water sump and the cylinder.

Suction Valve:

- It is a non-return valve which means it can take the fluid from the suction pipe and send it to the cylinder but cannot reverse the water back to it. In the sense, the flow is unidirectional.
- This valve opens only during the suction of fluid and closes when there is a discharge of fluid to outside.

Cylinder:

- It is a hollow cylinder made of cast iron or steel alloy and it consists of the arrangement of piston and piston rod.

Piston and Piston rod:

- For suction, the piston moves back inside the cylinder and for discharging of fluid, the piston moves in the forward direction.
- The Piston rod helps the piston to move in a linear direction i.e. either the forward or the backward directions.

Crank and Connecting rod:

- For rotation, the crank is connected to the power source like engine, motor, etc. whereas the connecting rod acts as an intermediate between the crank and piston for the conversion of rotary motion into linear motion.

Deli e Pi e:

- The function of the delivery pipe is to deliver the water to the desired location from the cylinder.

Delivery valve:

- Similar to the suction valve, a delivery valve is also a Non-return valve. During suction, the delivery valve closes because the suction valve is in opening condition and during Discharge, the suction valve is closed and the delivery valve is opened to transfer the fluid.

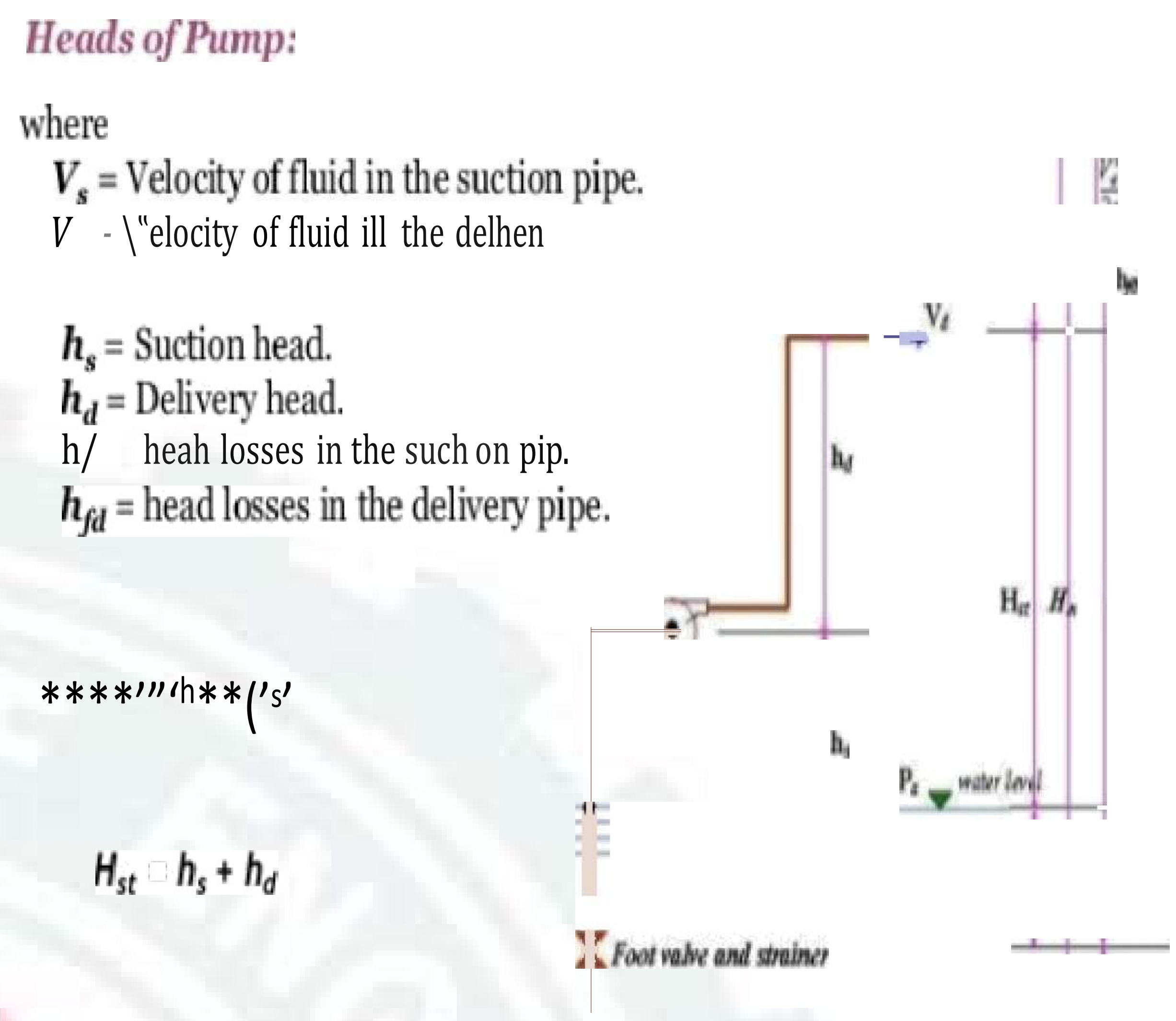
Working of single acting reciprocating pump

- Single acting means the water is acting on one side of the piston
- This pump has one suction pipe and one delivery pipe.
- It is usually placed above the liquid level in sump.
- When the crank rotates the piston moves forward and backward inside the cylinder.
- Initially the crank is at inner dead center i.e. at A and crank rotates in the clockwise direction.
- As the crank rotates the piston move towards right and a vacuum is created at lek side of the piston.
- The vacuum causes suction valve to open and consequently the liquid is forced from the sump into the left side of the piston
- When the crank is at outer dead center i.e. at C the suction stroke is completed and the IeH side of the cylinder is full of liquid
- When the crank returns from ODC to IDC the piston moves inward to the left and high pressure is built up in the cylinder.
- The delivery valve opens and the liquid is forced into the delivery pipe.
- The liquid is carried to the discharge tank through the delivery pipe
- At the end of delivery stroke the crank comes to the IDC and the piston is at the extreme IeH position.

Heads of Pump:-

There are three types of Head in a reciprocating Pump

1. Suction Head:
   - It is the height through which water is entering through the Suction pipe to inlet end of Cylinder
   - It is the length of Suction Pipe is calculated from the Center of cylinder to the level of liquid in sump
   - It is denoted by symbol
2. Delivery Head:
   - It is the length of Delivery Pipe is calculated from the Center of cylinder to the level of water in Overhead Tank
   - It is denoted by symbol
3. Static Head:
   - It is the total head through which the pump has to work
   - It is the Sum of Suction Head and Delivery Head of Pump
   - It is denoted by symbol



Co-efficient of discharge

In a reciprocating pump the actual discharge () is always slightly different from theoretical discharge () due to following reason

- Leakage through the valves and piston packing
- Imperfect operation of the valve
- Partial filling of the liquid

The ratio between actual discharge and theoretical discharge is known as the coefficient of discharge () of the pump.

Slip

The difference between the theoretical discharge and actual discharge is called slip of the pump.

Slip

% Slip x 100 (1-) 100 (1-) 1o0

Positive slip

In most of the reciprocating pumps is less than , in such a case the value of is less than unity and the slip of the pump is positive.

Negative slip

If actual discharge is more than the theoretical discharge ; in such a case is more than unity and the slip will be negative.

Negative slip occurs when delivery pipe is short, suction pipe is long and pump is running at high speed.

Discharge, Work done and Power Required to Drive Single -acting Reciprocating Pump

Let D= diameter of the cylinder

A= cross- sectional area of the piston / cylinder =

r= radius of the crank

N= Speed of the crank in r.p.m

L= length of the stroke = 2r

= Height of the center of the cylinder above the liquid surface

= Height to which the liquid is raised above the center of the liquid.

Vol of liquid sucked in during the suction stroke = A×L

No. of revolution per second =

Discharge of the pump per second = vol of liquid sucked in during suction stroke x No. of revolution per second

Q= A×L×

Weight of water delivered per second, W= wQ= (w= pg)

Work done per second = weight of water lifted /sec x total height through which liquid is lifted

= ^ (*

Where, (+ is total height through which water is lifted.

We know W=

Work done = (+

Power required to drive the pump= P =

P= (+kw

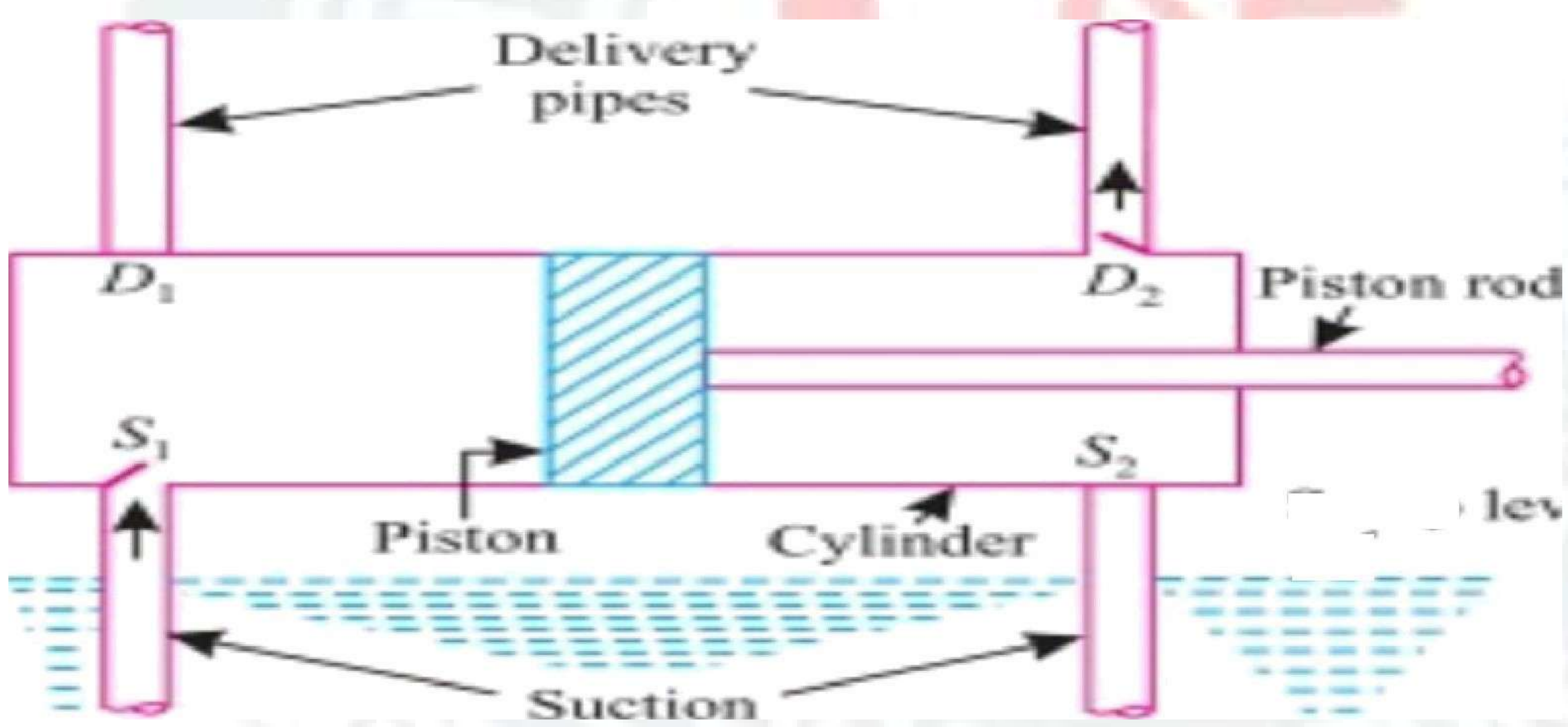
Where w= weight density of liquid in N/

Construction of Double acting Reciprocating Pump

It is the type of reciprocating Pump in which the delivery and Suction of water is taking place twice in a complete revolution of Crank with the help of Mechanical energy from Prime Mover.

The main parts are

- Cylinder
- Piston
- Suction Valve
- Delivery valve
- Suction Pipe
- Delivery Pipe
- Crank and connecting rod mechanism



Working

- Here we require two suction pipe and two delivery pipe
- Here suction and delivery stroke occurs simultaneously
- When the crank rotates from IDC in the clockwise direction, a vacuum is created on the left side of piston and the liquid is sucked in from the sump through S1.
- At the same time, the liquid on the right side of the piston is pressed and a high pressure causes the delivery valve D2 to open and the liquid is passed on to the discharge tank.

- This operation continues till the crank reaches ODC.
- With further rotation of the crank, the liquid is sucked in from the sump through the suction valve S2 and is delivered to the discharge tank through the delivery valve D1.
- When the crank reaches IDC, the piston is in the extreme left position.
- Due to continuous delivery stroke, a double acting reciprocating pump gives more uniform discharge as compared to single acting pump.
- Advantages
- 1. High pressure is obtained at the outlet.

  2. Priming process is not needed in this pump.

  3. It provides high suction lift.

  4. It is also used for air.

Disadvantages

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

A **ication**

• It is used at a place where low discharge rate is required with high pressure. It is mostly used to deliver water at large heights such as in deep well.

• It is used for inflation of tyres of bicycles

Dischar ge, Work done and Power Required to Drive Sin ge -actin g Reciprocating Pump

In Case of Double acting reciprocating pump there is two delivery stroke in one revolution of the driving shaft

Let

Difierence between Centrifu gal Pump & Reci procating Pump

Centrifugal Pump

- Flow is Smooth and even
- Weight of Pump is less for a given delivery rate
- It is compact and occupies less floor space for a given delivery rate
- Initial Cost is High

- Installation is easy
- No Air vessel is required
- It can handle viscous liquid as like paper Pulp, muddy water etc.
- It requires priming
- It is suitable for large discharge and small head
- Maintenance cost is less. Periodical checkup is suRicient

Reciprocating Pump

- Flow is Intermittent
- Weight of Pump is less for a given delivery rate
- Floor space required is about 6 to 8 times the floor space occupied by the centrifugal pump
- Initial cost is about 4 times of Centrifugal Pump
- Installation is difficult
- Air Vessel is required
- It cannot handle viscous liquid because valves and glands cause trouble when required to handle viscous liquid.
- It does not require priming
- It is suitable for low discharge at high head
- Maintenance cost is high, because valves require constant attention

Numerical

Problem 20.1 *A single-acting reciprocating pump, at 50 r.p.m., delivers 0.01 m^3/s of water. The diameter of the piston is 200 mm and stroke length mm. Determine :*

(i) The theoretical discharge of the pump, (ii) Co-efficient of discharge, and (iii) Slip and the slip aj° che pump.

@oludon. Given :

Speed of the purnp. N 50 r.p.m.

Wctuef climhargo, @m,,= .0 I xi,,/»

Oia. of piston, 0 = 200 mm = .20 m

$$A \quad \frac{\pi}{.} (.2)^2 \quad .031416\ m^2$$

Strokc. L 400 mm 0.AO m.

(c) Thcnreticaf dischargc for single-acting rcciprocating pump is given by equation (20.1} as

$$Q_{th} \quad \frac{.031416 \times .40 \times 50}{60} \quad \mathbf{0.01047\ m^3/s.\ Ans.}$$

(i?) Cc›-ofCicient cal di harto is gi von fry

$$c = \frac{'\bullet\bullet''}{Q_{,,}} - \frac{oo\,i}{.01047} = 0.ssfi.\ \textbf{Ans.}$$

{/T/) LJsi njg cc§uatierz {NO.A). wu _w-t

$$\textbf{Slip} = Q_{th} - Q_{act} = .01\,04Y - .0\,1 = 0.Wa{>}47\ mn*fa.\ Hm\bullet-$$

AnÓ jxzrc«ntag« »lip - $\frac{(.03\,047 - .0\,t)}{} \times I\,OIM$

$$= \frac{.00047}{Q_{th}} \times 100 \quad \mathbf{4.489\%.\ Ans.}$$

Problem 20.2 A *double.-ac7ing re.ci[irocaiing pump, running al 40 r.p.m., is discharging 1.0 m' of waier per minuie.* the *pump has a sn•oke of mm. The diameter of the piston is mm. The deliver, and saciion head €/FB 20 m and S m respectively. Hind fhe sli(i of fhe pum[i and power required io drive Ilie pump.*

Solu9on. Given:

Speedof pump, N - 40 r.p.m.

Actual dischargc, §,,,, = 1.0 m”/min= $\frac{10}{}$ ls = 0.0lóób m ls

Smoke. £ = 400 mm = 0.40 m

Diameter o£ piston, O = 200 mm = 0.20 m

Area, $A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (.2) = 0.011416\ m^2$

Suction head. h, -- 5 m

Delivery hcad. fry = 20 m.

Theoretical discharge for double-aeting pump is given by equation (20.5) 21,

$$pqq \quad \frac{2A2W}{} - \frac{2 \times .03\,l4l6 \times b4 \times 40}{} \quad .0\,ld75\ m\ ls.$$

Using etjuation (20.8), Élip = Çy — Ç,,, = .0l675 — .0l6óó = **.00009** m la Ans.

Power required to dÑve the double-arting pump is given by equation (20.7) as,

$$p\,p \quad \frac{2 \times pg \times ALV \times (it, + h;)q}{} \quad \frac{2 \times lOD \times 9.81 \times .03141ñ \times .4 \times 40 \times (5 \times 201}{}$$

rn

filled with air.

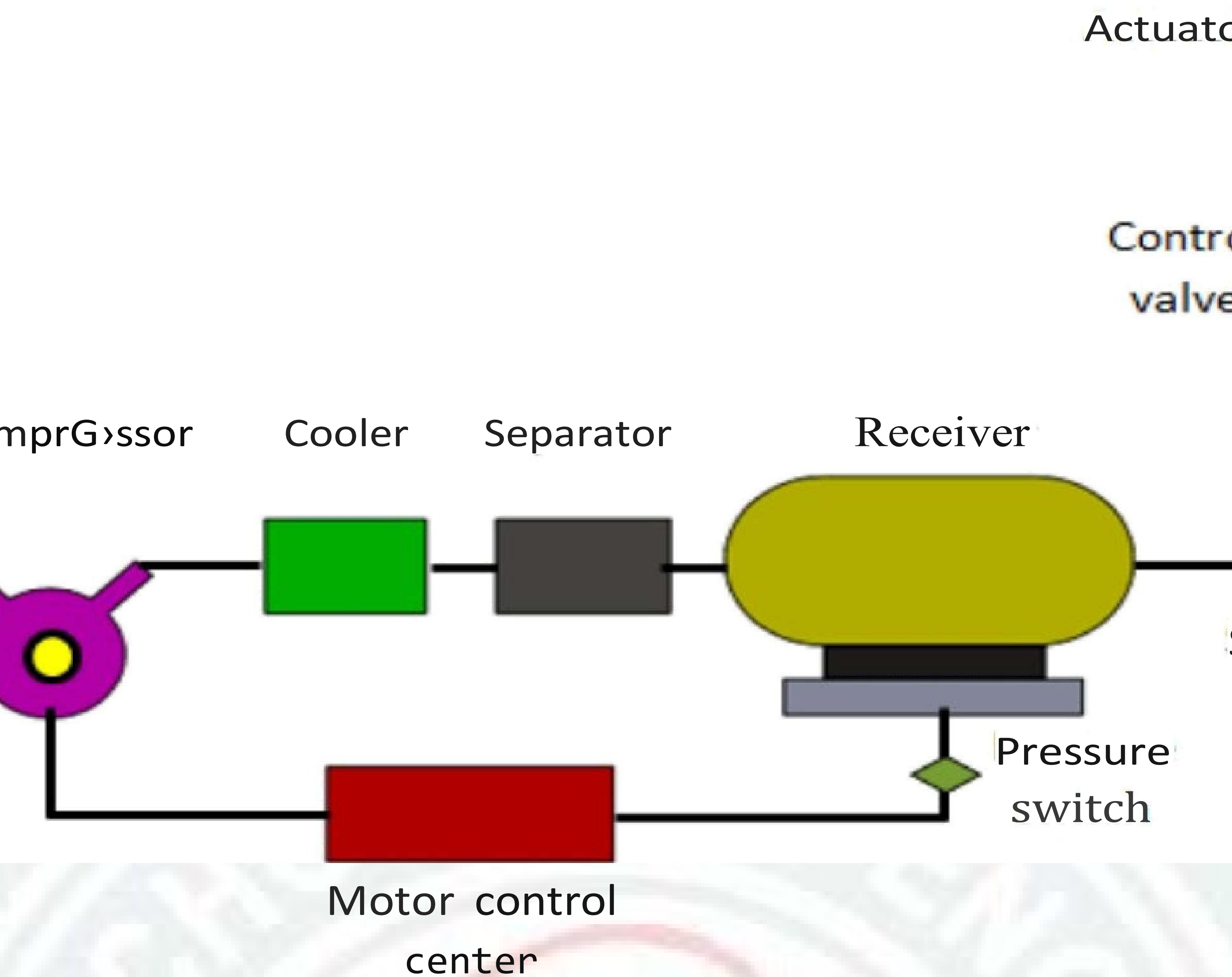
deals with the study of behavior and applicaiions of compressed air in
ufacturing automation in pariicular.
ns use air as the medium which is abundantly available and can be exh
compleiion of the assigned task.
ranch of mechanics that deals with the mechanical properties of gases.
study of pressurized gas that produces mechanical moiion, and the app

pneumatics are found in factories that deals with compressed air and

of air
f air
on of compressed air in pressure vessels, containers and in long pipes.
nd reproducibility
lity
teristics of medium.
on & easy handling
eaper than oAer systems.

controllers

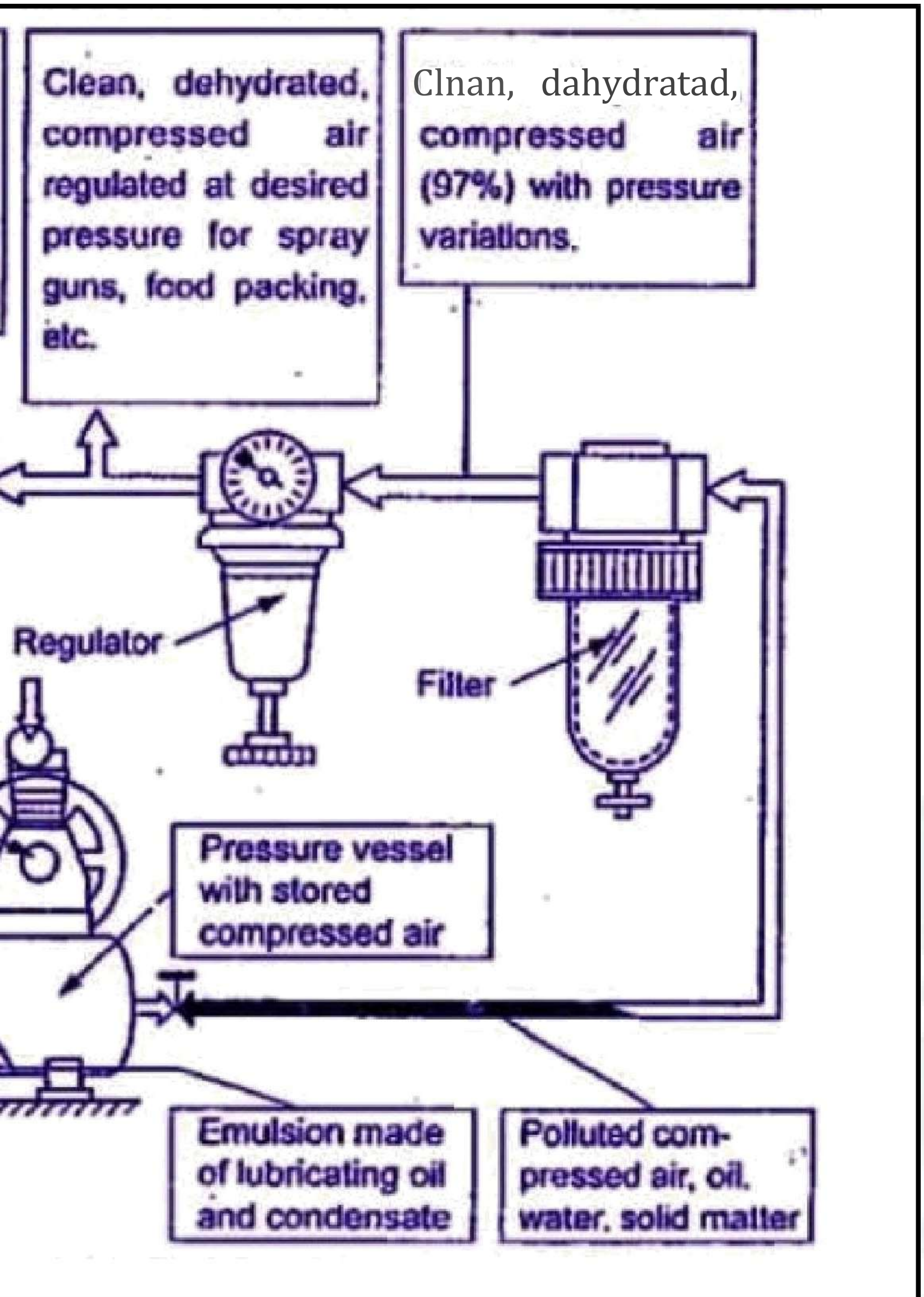
pneumatic system



are used to filter out the contaminants from the air.

mpressed air is generated by using air compressors. Air compress
ted. Based on the requirement of compressed air, suitable capacity co
e compression operation, air temperature increases. Therefore coolers
e compressed air.

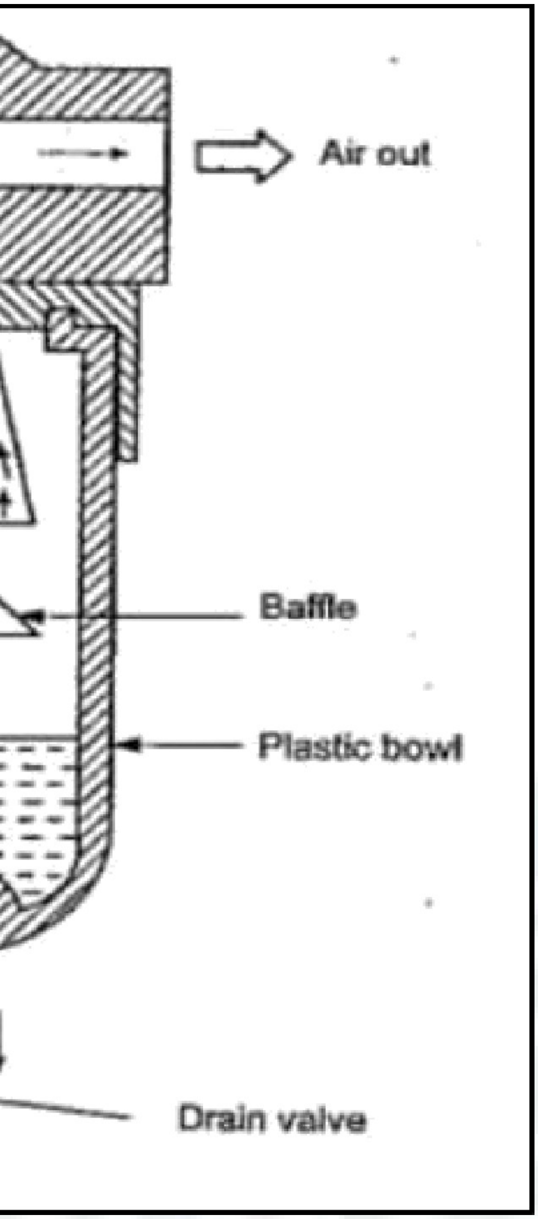
vapor or moisture in the air is sepvaled from the air by using a dryer



ce of solid contaminants to the system.

d remove ihe water vapor that is present in the air.

on particles that may pose a problem in the system components.



• At the bottom of the filter bowl, ihere is a
which could be manually opened to drain off
and solid particle.

n is to regulate the incoming pressure to the system so fat the desired
eady condition.
air leaving the compressor should be properly prepared before it goes

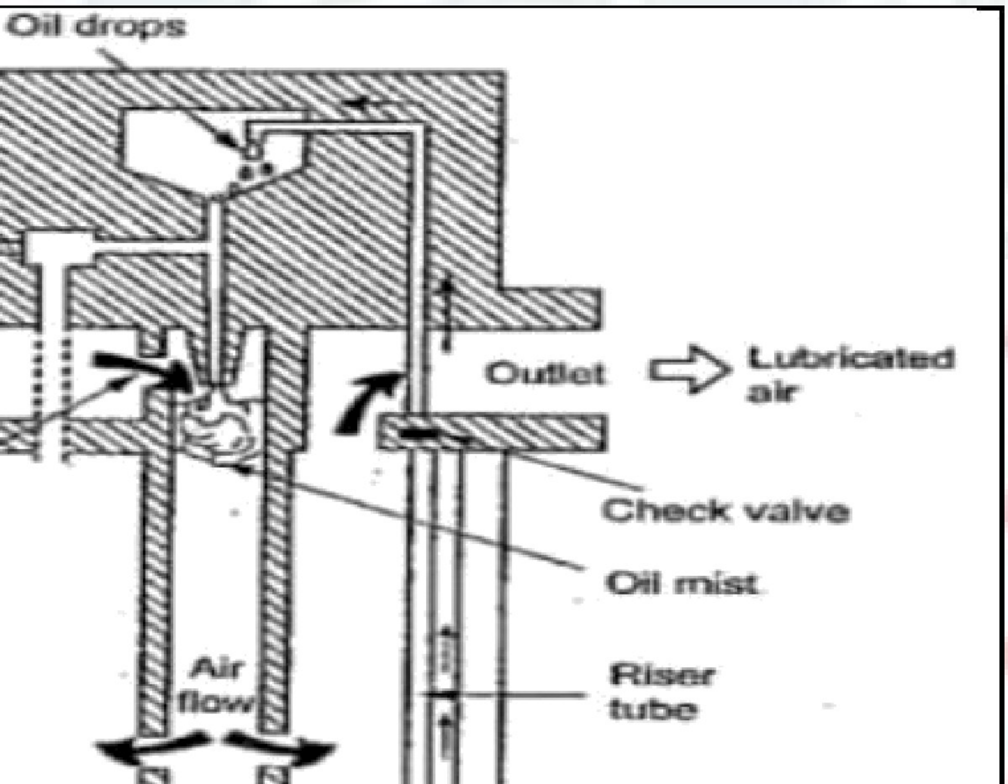
ng screw is iurned to compress the adjusting and dampening springs, th
owed from the inlet port to the outlet port. The pressure of lhe ouilet a
ing that is maintained.

d by the compression of the adjustable spring. Higher the spring comp
ening and hence more the pressure and vice versa.

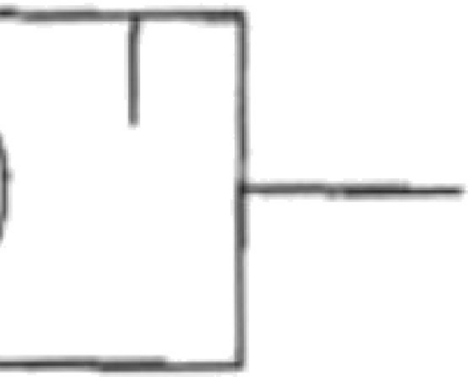
e provided io let out the undesirable excessive outlet pressure. if any,
pring is provided to act as a dampening device needed to stabilize the

lubricator is to add a conirolled amount of oil with air to ensure prope
pneumatic components.

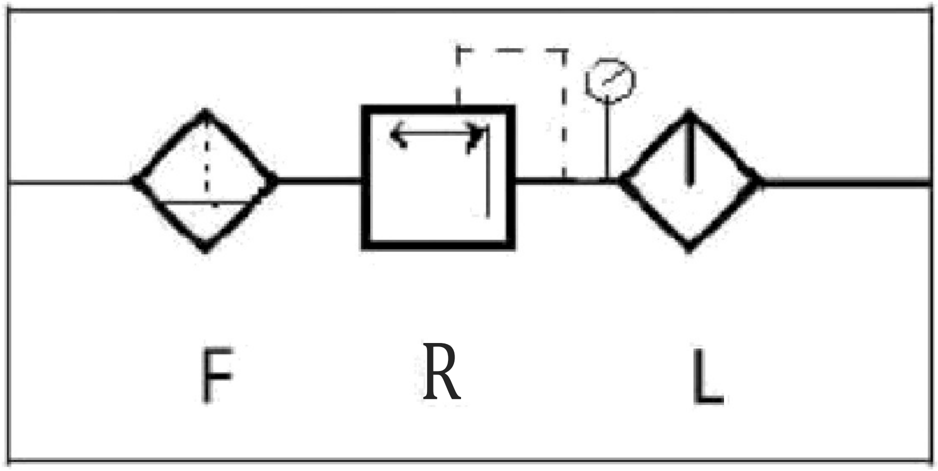
ds the lubrication oil in the form of a fine mist to reduce the friction an
ic components such as valves, packings used in air cylinders, etc.



sJrnibol



Combined Symbol

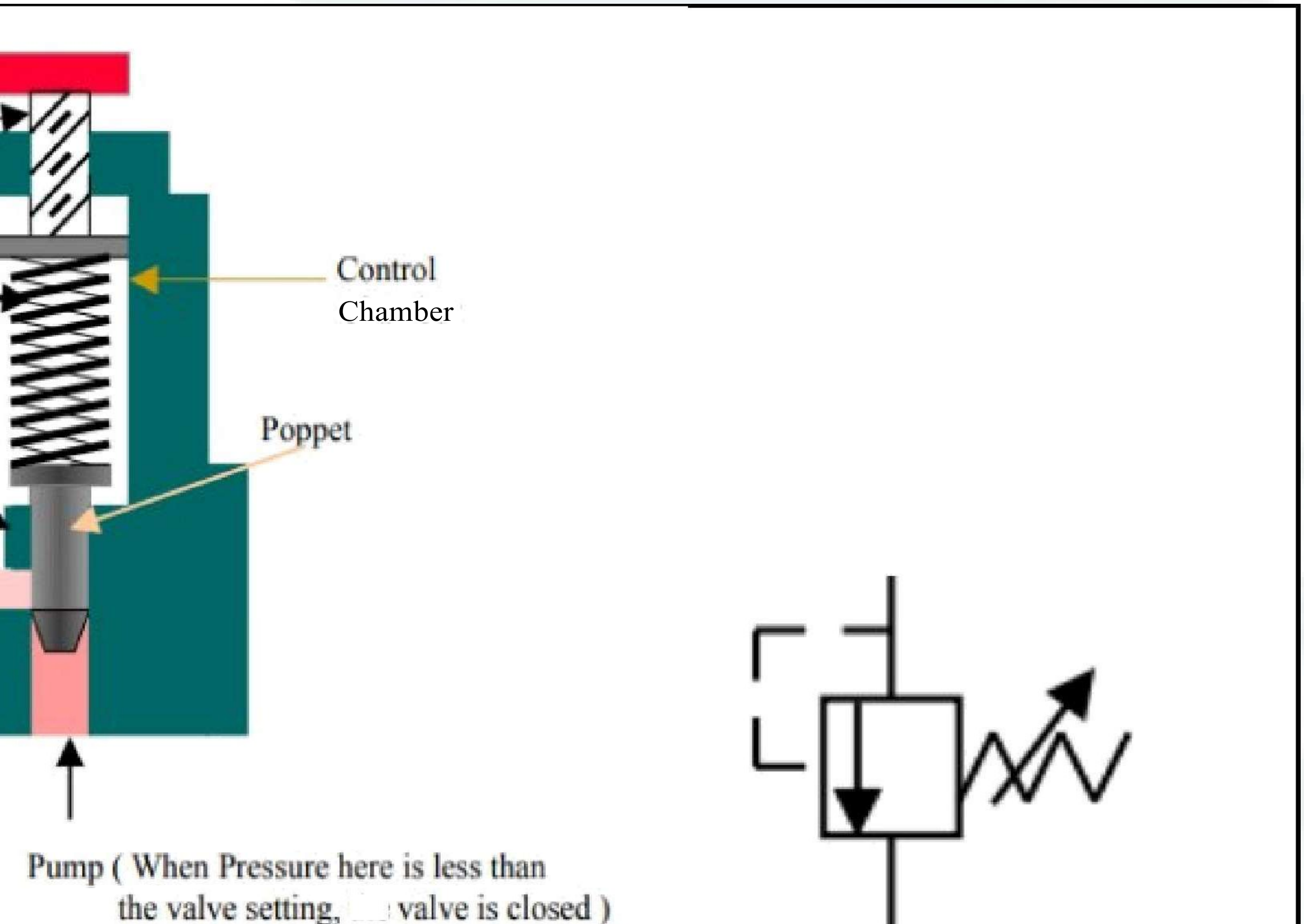


s avoid pressure drop or rise so that leAages and parts damages may b
me may increase.
y.
nce and servicing.

ced in the place of heavy vibration then it may damage the Unit.
without flexibility. such as steel tube piping, are prone to be affected by
om the piping side. Use flexible tubing in between to avoid such effe

ol the quantity of pressure and how rate to generate the desired level o
device that conveys energy typically in the form of compressed air int

essure is thus relieved to the desired figure, the valve closed againby s
cted to pump and the other to the tank.
s of a spring chamber (control chamber) with an adjustable bias spring
closing the valve.
onnecting the tank is provided in the control chamber to drain the oil t
by preventing the failure of valve.
opposes the poppet, which is held on its seat by an adjustable spring.
rinfi is set to limit the maximum pressure that can be attained within t
d in position by spring force plus the dead weight of spool.
xceeds this force, the poppet is forced off its seat and excess fluid in th
voir.
ssure drops to or below established set value, the valve automatically r



ol Valve —

used in pneumatic system to direct or stop the flow of compressed air
ave two or more ports and liilfil various circuit functions.

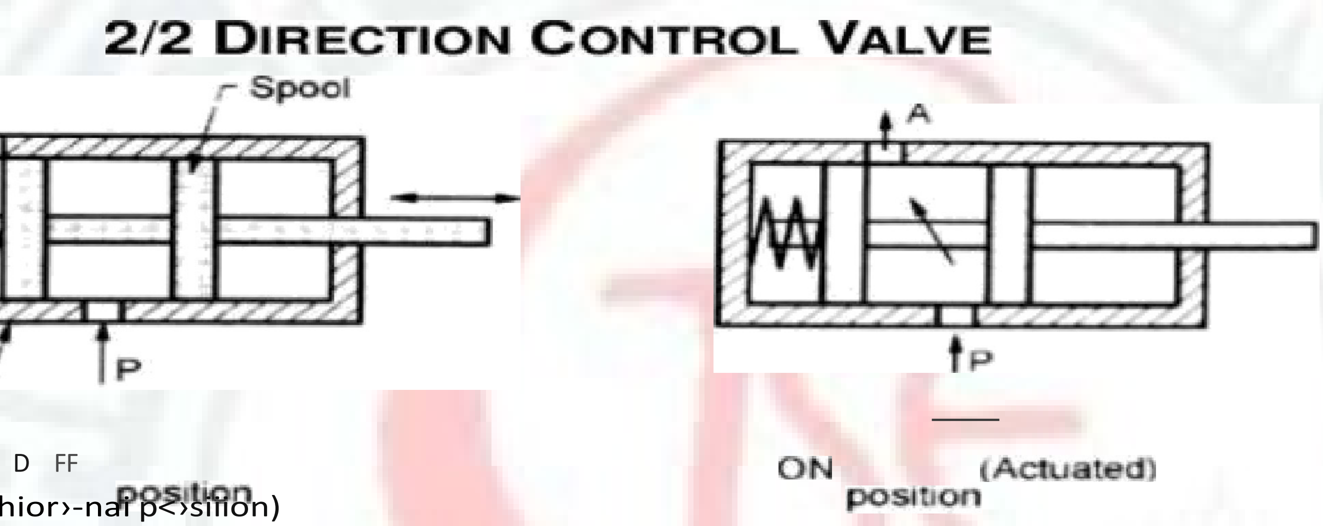
v in to different path from one or more sources.

nsist of a spool inside a cylinder which is mechanically or electrically
pool restricts or permit ilow, thus it controls the fluid flow.

appointed with two numbers. The first number shows how many ports
ihe amount of state for example, a 2/2 ray valve has two ports(in/out
/2 way valve has five ports and two states.

n and most simple valve is the 2/2-way valve. It has two poes and two
erefore also called a shut-off valve.

pneumatic applications where the supply of air must periodically be cl



hior›-nal p<›siiion)

s of three ports like 'A', 'R', 'P' as shown in above fig. Port A represents pass
essed Air delivered to the Actuator for Reciprocating Action of piston.

ts the path for return of Compressed air from port A to deliver back to the c
elivery of high pressure air from Air Container to the DCV for actuator passe

on (Neutral Position) the return of compressed air from actuator through P
deliver to the air container. Port 'P' is closed. For actuation the electric curr
d with spindle of spoDlS

Position spools move towards the right position and there by the passage
rward motion of piston in actuator is taking place by the compressed air en
gh Port 'A' to the hose connected with the actuator

ergy in spring attached with the spool Spindle causing the spools to move t
pened and while Port P is Closed, during this time return stroke of the pisto
ressed air from actuator returns through the Port A and Port R, then enter

e:

has five ports and two states.

used for instance to control double acting cylinders.

cylinder requires two outlet ports of the valve.

s 'A' & 'B' provided at top of DCV which are allowing the Compressed Air fo

wing the exhaust of return compressed air from Actuator to Air Container t

the supply of high Pressure Air to be used for reciprocating action of piston

es inside the main bore and according to spool position, the port get conne

n the spool is actuated towards outer direction, port P gets connected to B a ve

a valve that controls the flow of air. Examples include non-return val
t.

ve allors air to flow in one direction only. When air flows in the oppos

lve is formed by a non-return valve and a variable throttle

es are available in two modes

(control passage is not adjustable)

rol / Throttle valve- Here an adjustable conrol needle is positioned a
te the iJow as per need of flow quantity.

v valve it is better to lock the needle position by a lock nut in order to
ugh that position.

position may change subjecting the valve to allow either less or more e

pe of" electromaxnet, the purpose of which is io generate a controlle
ound into a tightly packed helix.

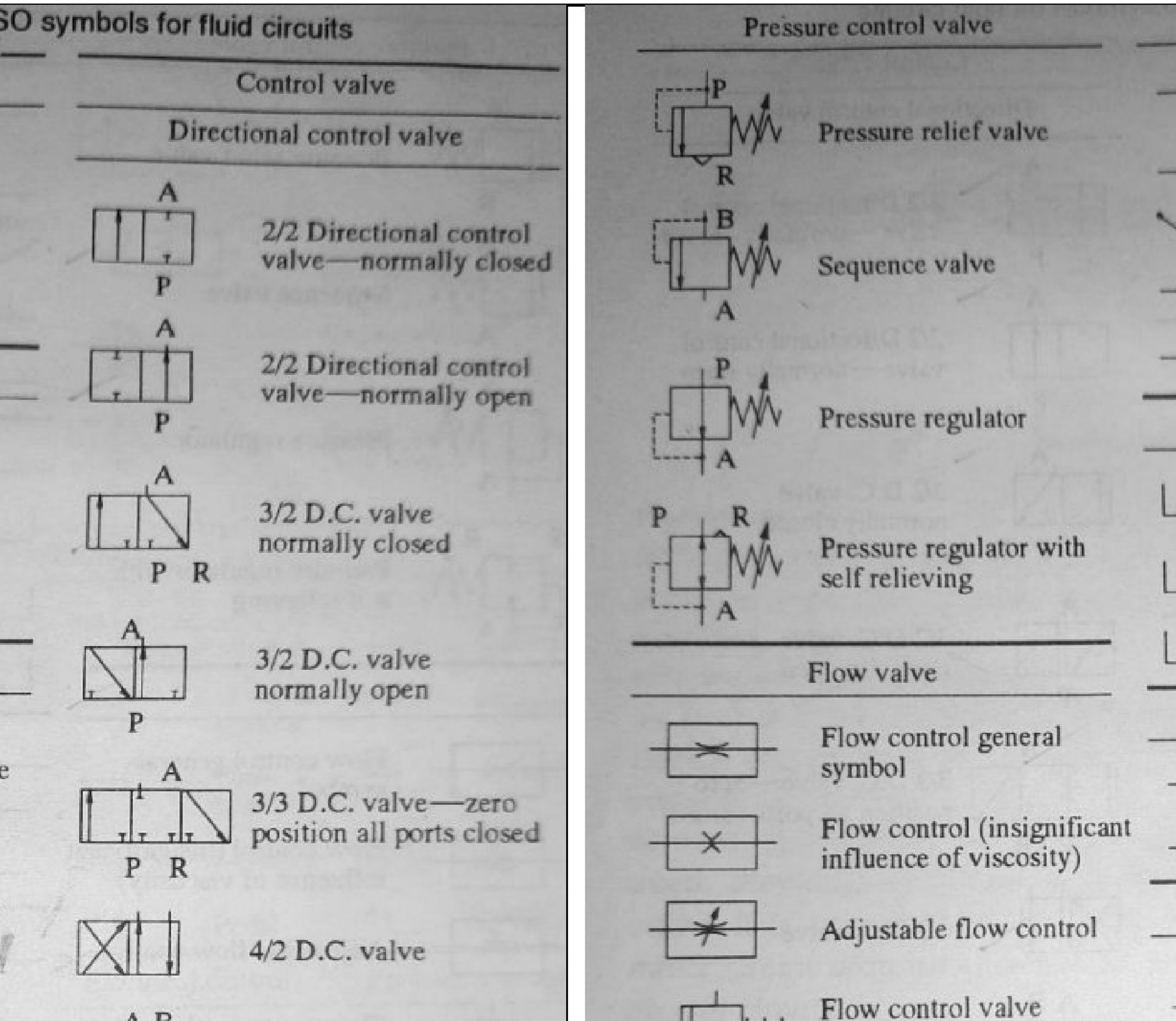
ranged to produce a uniform magnetic field in a volume of space whe
.

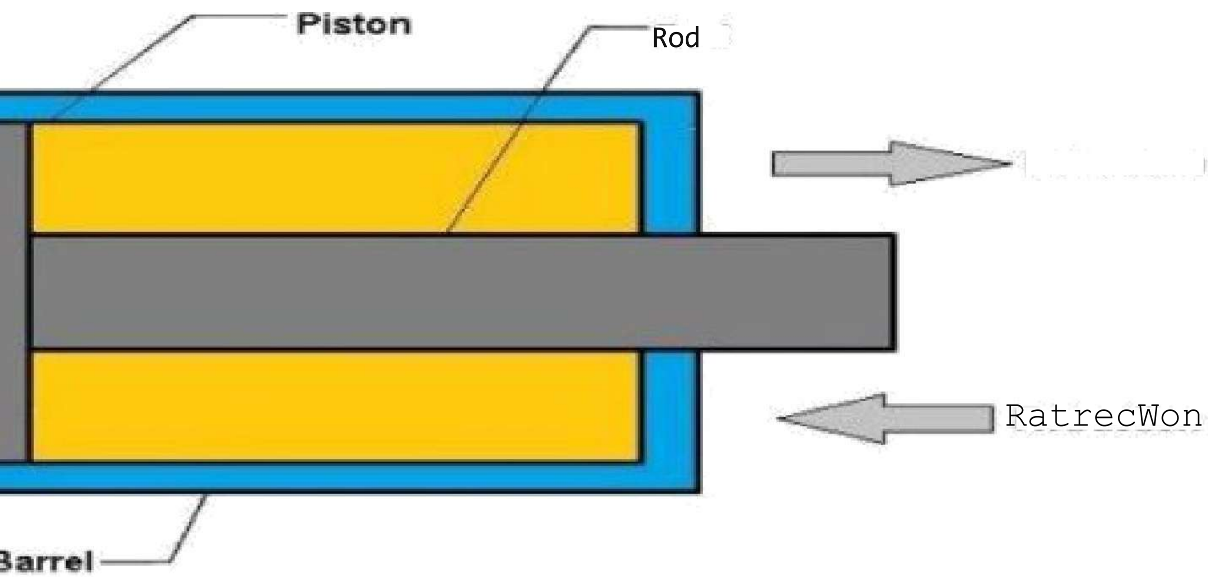
e ierm may also refer to a variety of transducer devices that convert en

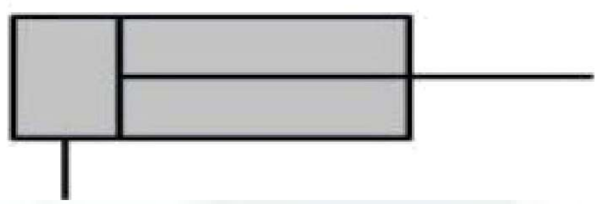
rts electrical energy into mechanical work.

often used to refer to a solenoid valve, an integrated de
l solenoid which actuales either a pneumatic or hydraulic valve, or a so

air while being exhausted from Ge pneumatic sysiem components like
es a lot of noise.
atic components are to be provided wi% noise reducing &r-mufflers
n the noise level to a tolerable limit and go a long way in reducing heal





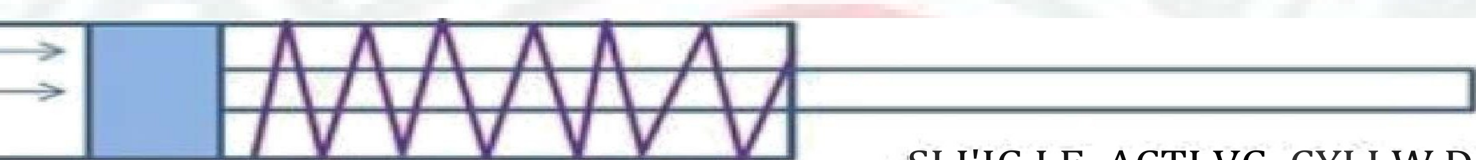


representation

Gywstzollc representatlz>n

ctin g cylinder

of SII'sIGLE ac€inp c'yli nclev



SI I'IG LE ACTI VG CYLI W DE R
SPR I f'•IG RETLJ R t'4 E D

A port of the valve shifting the valving element and thus SA cylinder

ng force from lhe push button is released, the valve spring resets lhe c
he cylinder.

d to po< A due io reseiting of calving element.

pen to port R.

ne cylinder gets exhausted through the R port of the valve.

force of the spring pushes the piston rod of the cylinder and the cylin

ng cylinder in which kuid under pressure can be applied to either side
nent.

aciing cylinder

el is made of steel tubing which is seamless.

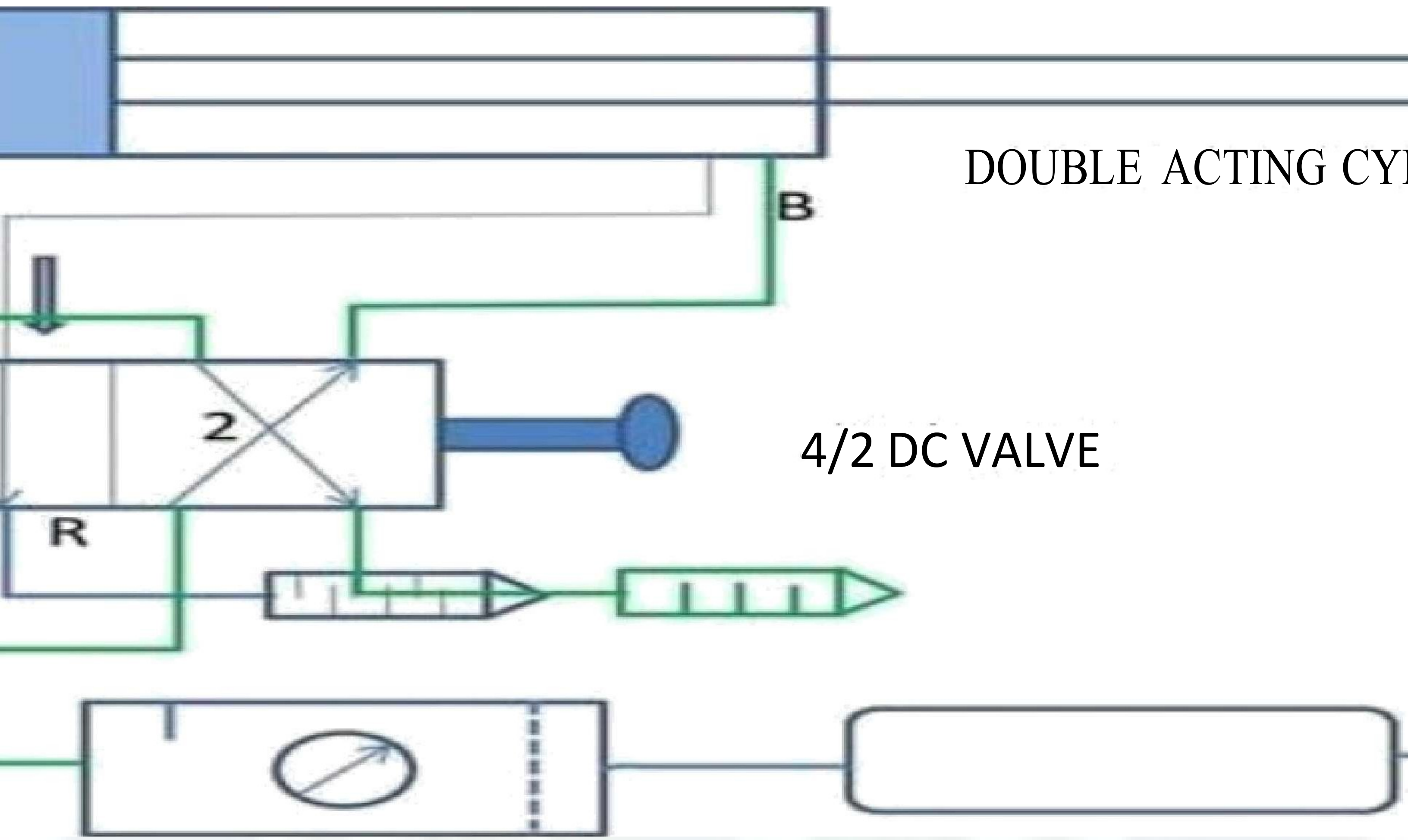
is perfectly boned.

ufactured by ductile iron.

d to prevent leakage between the piston & the barrel.

ends caps.

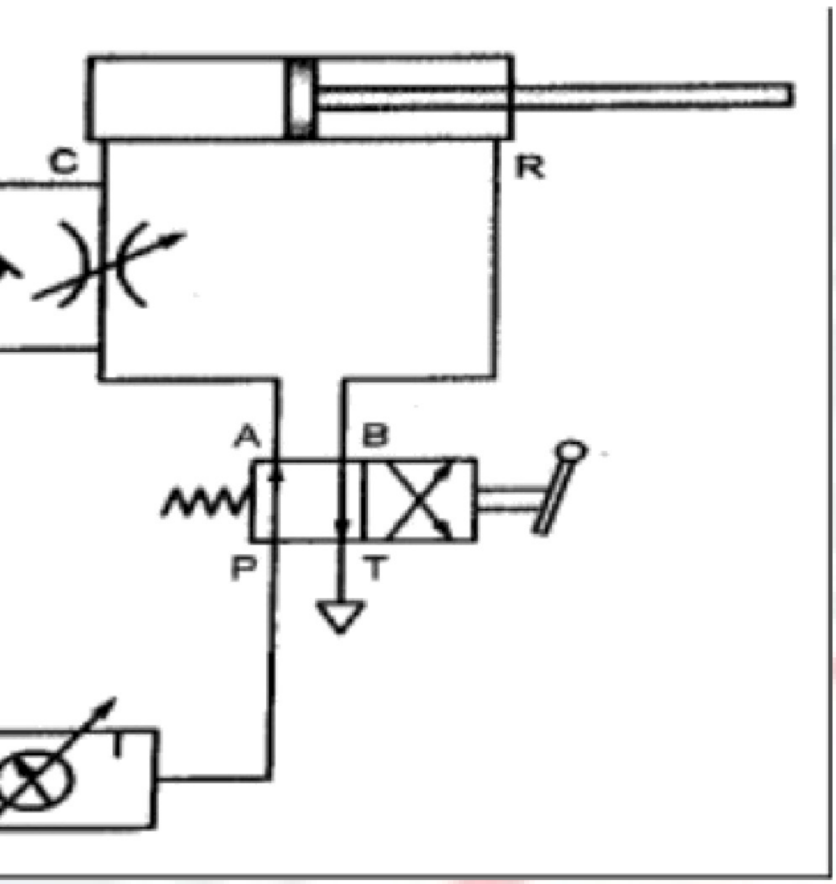
to the barrel by tie rods.



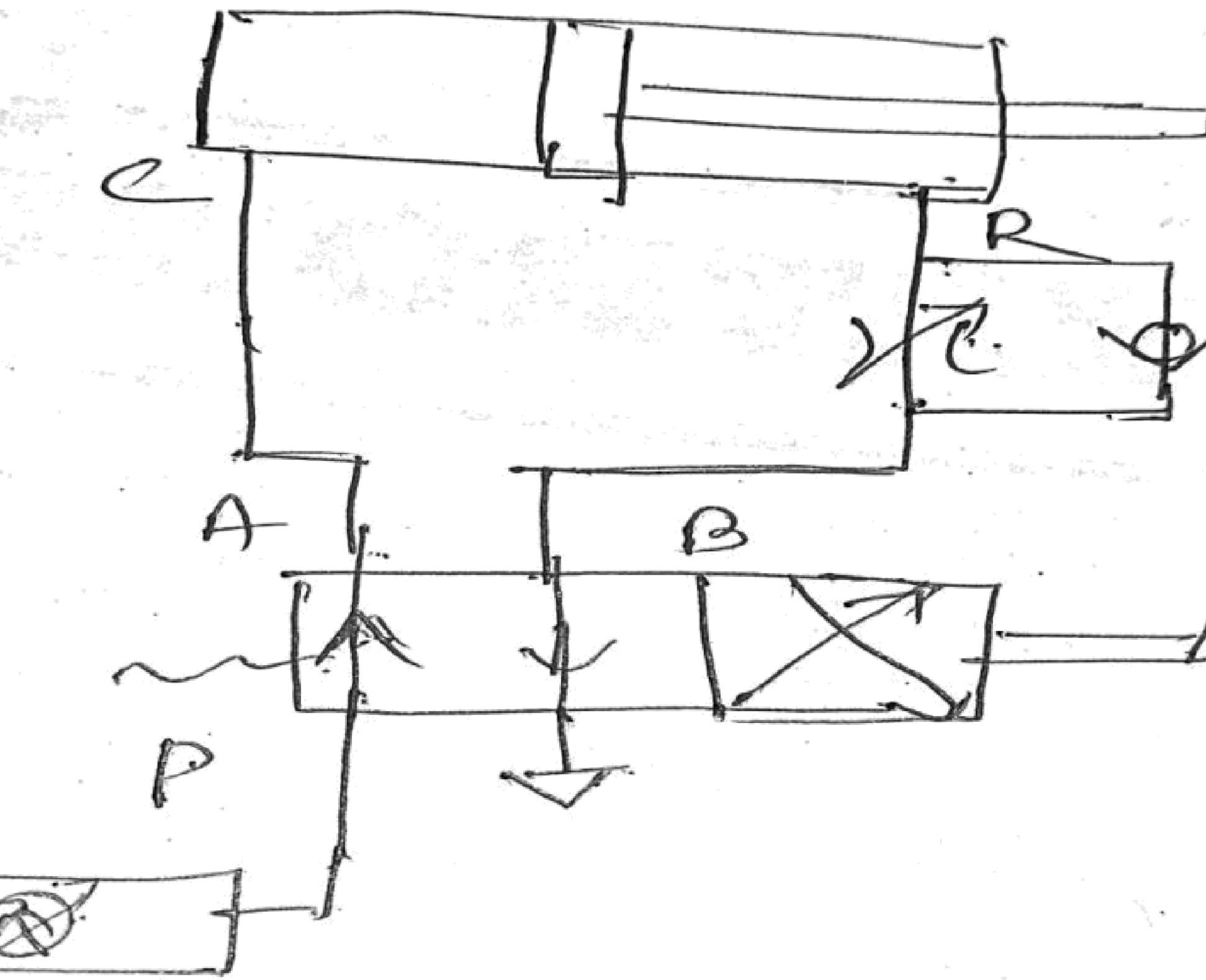
ne DCV the compressed air tlor from air compresser to air receiver th
flow to P to A the piston extends in a forward motion mean while the
to R Port.
ne DCV ihe compressed air flow from Port P to B and the piston retrac
hile the air in the piston side of the cylinder release from A to R port.

Acting Cylinder & Double Acting Cylinder t for Double actin **g actuator:-**

olling the actuator speed in a pneumatic system, the flow control valve
ne rate of flow of compressed will vary the speed of the actuator.
n circuit the rate Gor of compressor air is controlled at inlet of ihe act
is going in to the actuator is metered.
n pneumatic circuit flow conirol valve is fitted between DCV and actu
control of actuator during extension ssoke, FCV rith check valve is f
or.



ter in circuit fluid eniei-s in to the actuator at a controlled rate
of flow of compressed air in to the cylinder is controlled by FCV.
ced at inlet of the cjllnder cap end port c is lnfiet for extenslon and

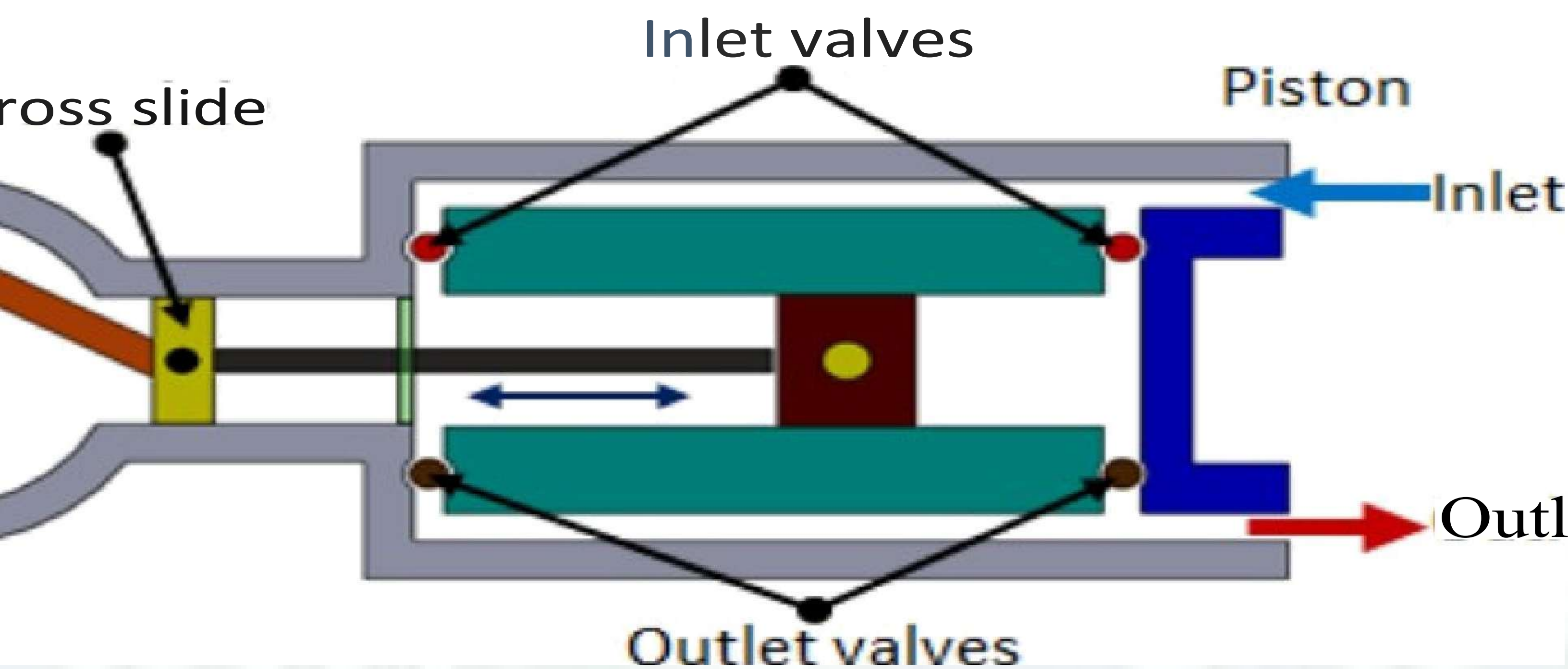


r:

l device which converts mechanical energy into Uuid energy. The co
pressure by reducing its volume which also increases the temperatu

pressor:

air can be reduced by using double acting compressor as shown in Fig
valves and a crosshead. As the piston moves, the air is compressed on o
er side of the piston, ihe air is sucked in.
ocating action of the piston, the air is compressed and delivered twice
ssure higher than 30bar can be produced.



-

the air increases, its temperature rises.
duce the air temperature to avoid damage of compressor and other mec
ullisiage compressor with intercooler in-between is shown in Figure.

e the temperature of compressed air during the compression stages.
reduces the volume of air which used to increase due to heat. The com
stage enters the intercooler where it is cooled.

r

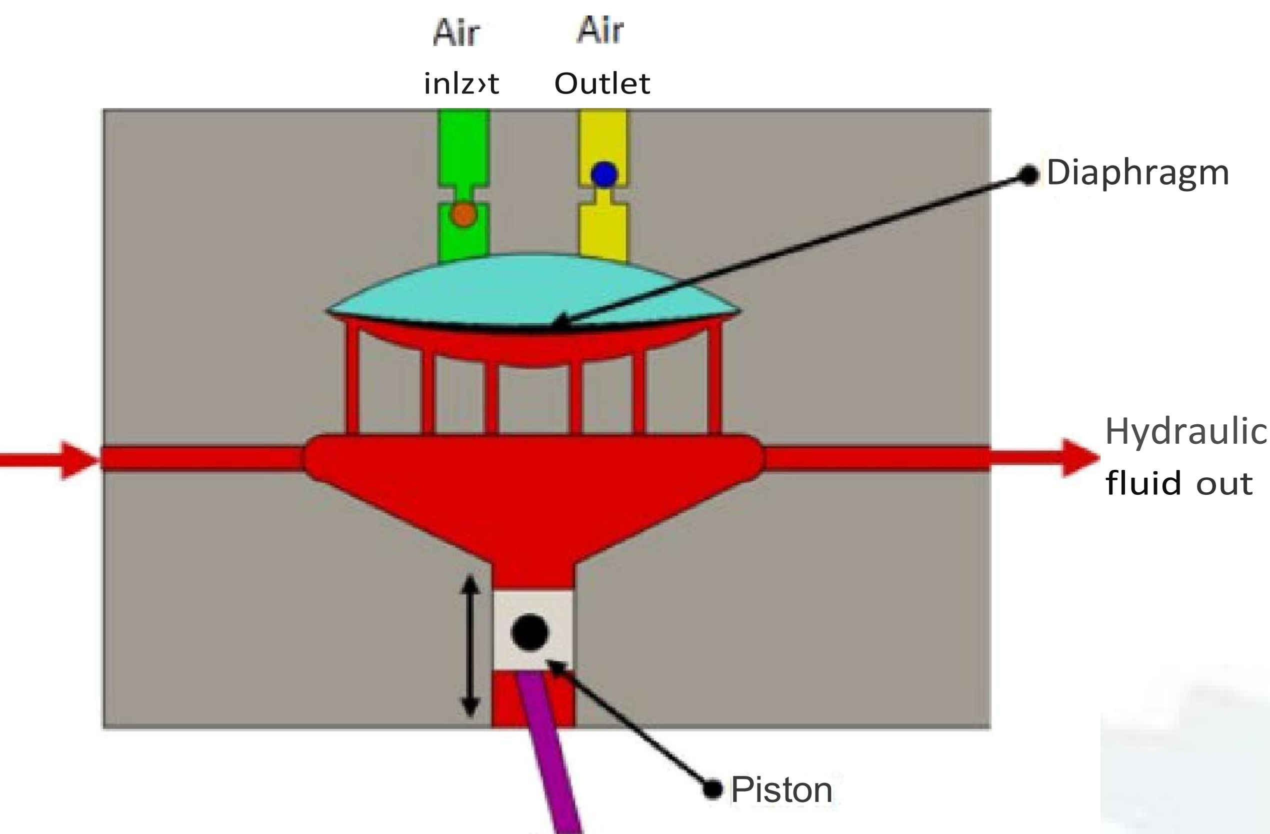


Fig. 6.2.1 D%phragm compressor

small capacity compressors. In piston compressors the lubricating oil f
alls may contaminate the compressed air.
mination is undesirable in food, pharmaceutical and chemical industri
applications diaphragm type compressor can be used.
ows the consiruction of Diaphragm compressor.
n reciprocates by a motor driven crankshaft.
ton +noves down it pulls the hydraulic fluid down causing the diaph
ng and the air is sucked in.
piston moves up the fluid pushes the diaphragm up causing the ejecti

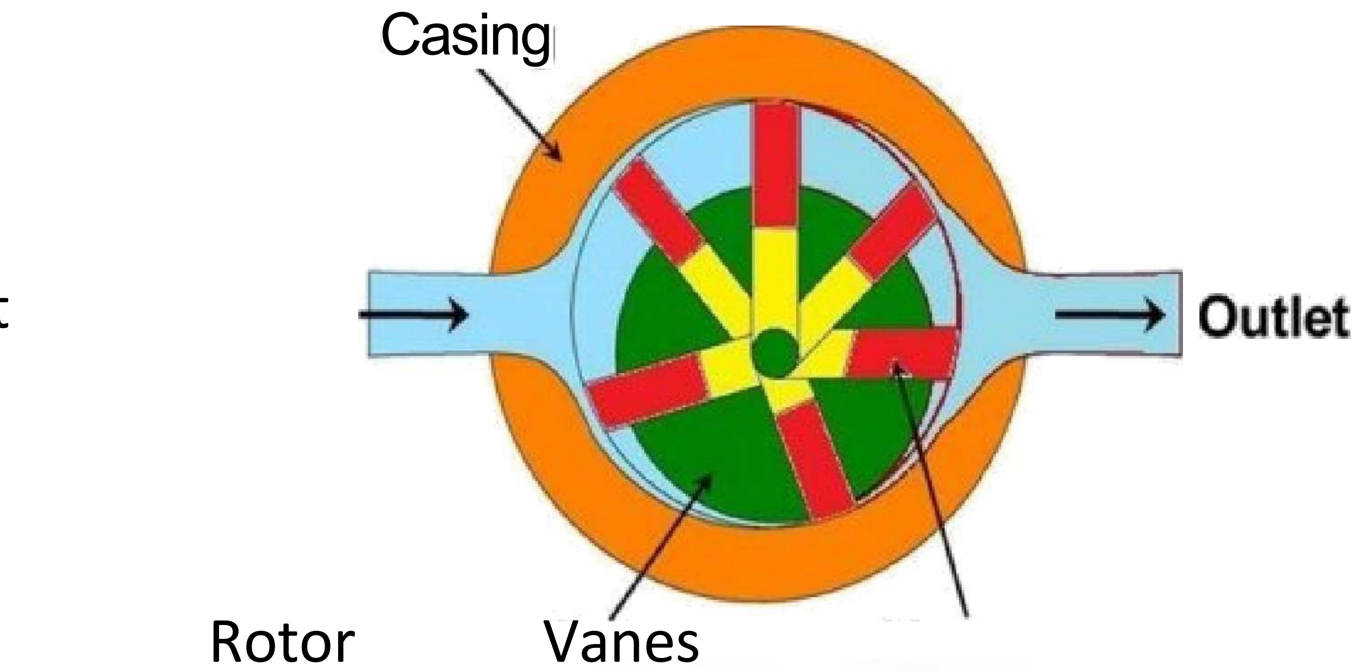


Fig. 6.2.3 Rotary vane compressor

peration of vane compressor is similar to the hydraulic vane pum
vane compressor consists of spring loaded vanes seating in the

on occurs due to movement of the vanes along a cam ring. The
am ring. As the rotor rotates, the vanes follow the inner surfac

en the vanes decreases near the outlet due to the eccentric
ion of the air. These compressors are free from pulsation
no flow takes plaCe..

Compressor

ring vane compressor is a variation of vane compressors.

Chapter 5

SYSTEM

used for transmission of power through the medium of hydraulic oil.

works on the principle of Pascal's law which says that "the pressure

y in all directions".

d is hydraulic oil, which may be mineral oil or water or combinatiDns.

ulic system

nected to the output shah in an enclosed cylinder

g hydraulic fluid

on line of pump inside the tank or on tank inlet line.

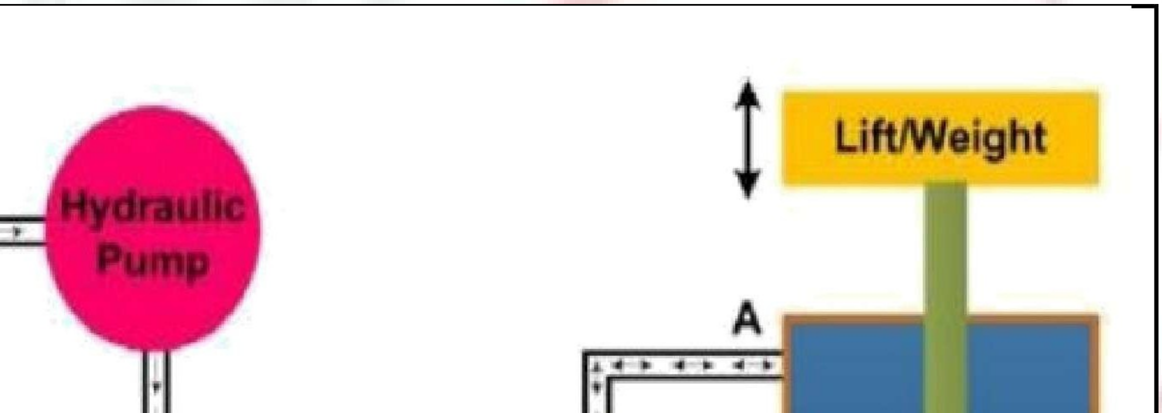
l or petrol engine which is the primary source of power

n by motor or engine

piping.

e which controls the direction of fluid flow so as to change the directio

for linear movement or a hydraulic motor for rotary actuation of load.



nk, piping, cylinder and piston can be corroded with the hydraulic flu
ing materials and hydraulic fluid.
size of the system is more which makes it unsuitable for the smaller
hydraulic fluid can permanently damage the complete system. There

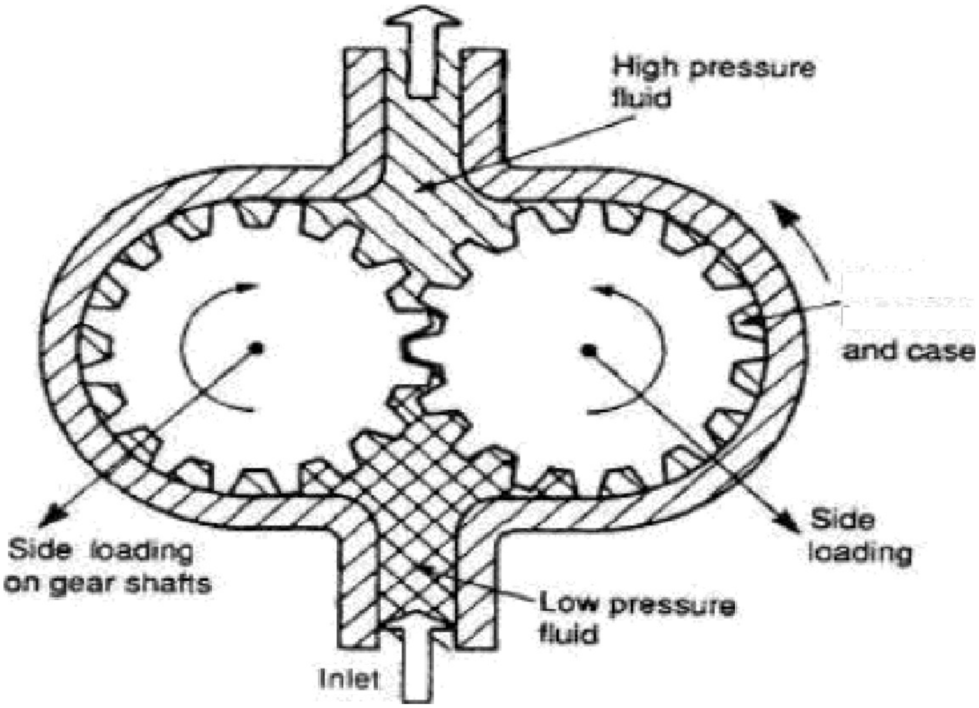
luid is also a critical issue and suitable prevention method and seals m
t disposed properly, can be harmful to the Environment.
n hot areas it may catch fire
they can cause serious injuries.
s required.

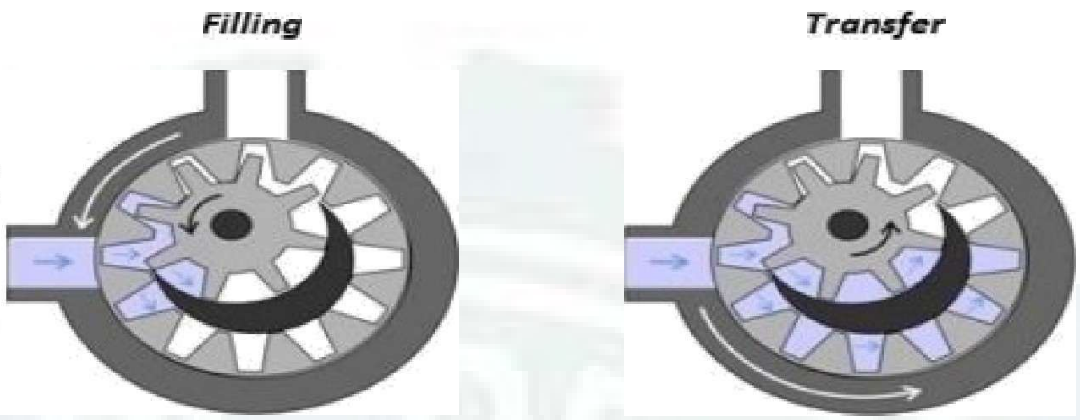
ee types of hydraulic pump constructions found in mobile hydraulic a
nd vane; however, there are also clutch pumps, dump pumps, and pu
nps.
the component of the hydraulic system that takes mechanical energ
m of oil flaw. This mechanical energy is taken from what is called the p
wer take-off or directly from the truck engine.

ed by the of the propeller and the fluid pressure is proport

sure and high-volume flo

ment pumps:





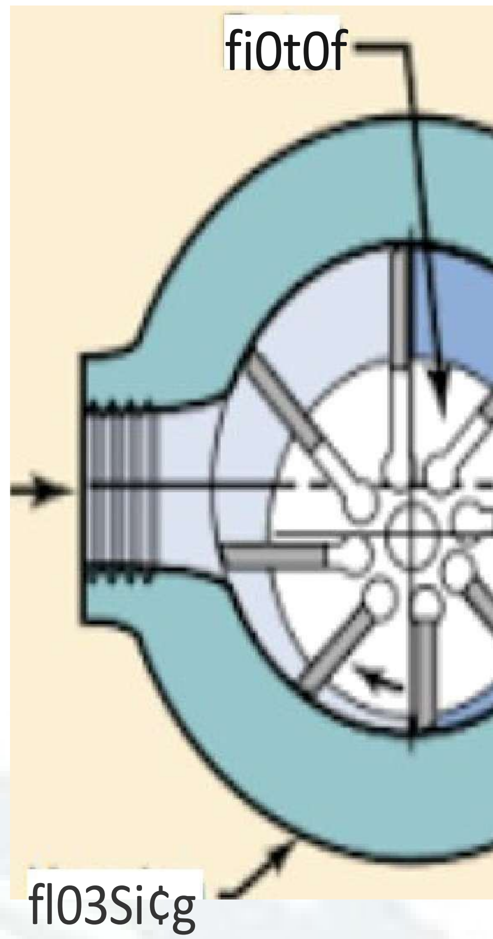
e suction port
r (large exterior
all interior gear)
vs indicate the
np and liquid.

„ „ ,

gh the pump between the teeth of the "gear-within-a-gear“ principle.
d acts as a seal between the suction and discharge ports.
ow nearly flooded, just prior to forcing the liquid out of the discharge
d rotor form locked pockets for the liquid which assures volume con
n mesh completely to form a seal equidistant from the discharge and
d out of the discharge port.

is illustrated in Figure

vanes are inserted into a numerous



urns the centrifugal force throws the ylindrical wall and creates a chamber r and the cylinder. As the rDtor the chamber volume between the ging due to the rotor positioned the inlet to outlet

me becomes bigger and then smaller.

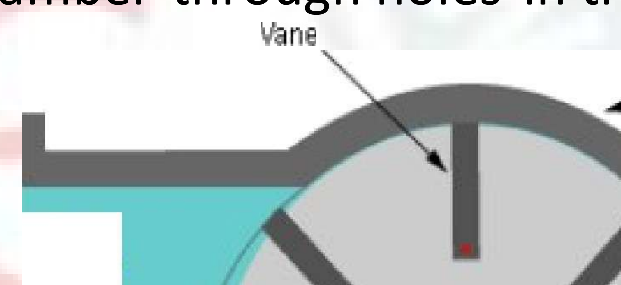
gets bigger a vacuum is produced as rotation of the vanes making air er from the inlet.

r gets smaller due to the compressed duced at the outlet.

sign combines low cost with high reliability and easy maintenance. Th rotor is eccentrically supported in a cycloid cam.

close to the wall of the cam so a crescent shaped cavity is formed. Tv

as blades, slide in and out of the rotor slots to seal off a volume betw id enters the crescent shaped pumping chamber through holes in th



the fluid to the opposite side of the

is squeezed through the discharge,

the inner dead center (IDC) with suction process. Aker a rotation ang
orkspace of the piston is filled with the moved medium.

the outer dead center (ODC).

the piston displaces the previously sucked medium in the pressure ch

ations for a radial piston pump:

, displace of cutting emulsion, supply for hydraulic equipment like cyl

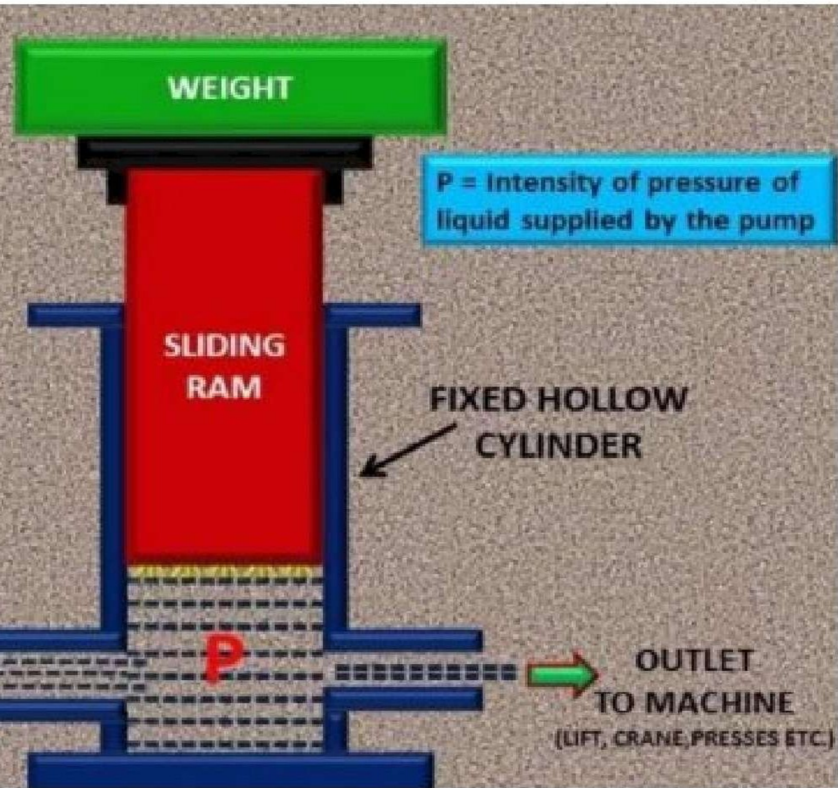
(HPU) (e.g., for overload protection of presses)

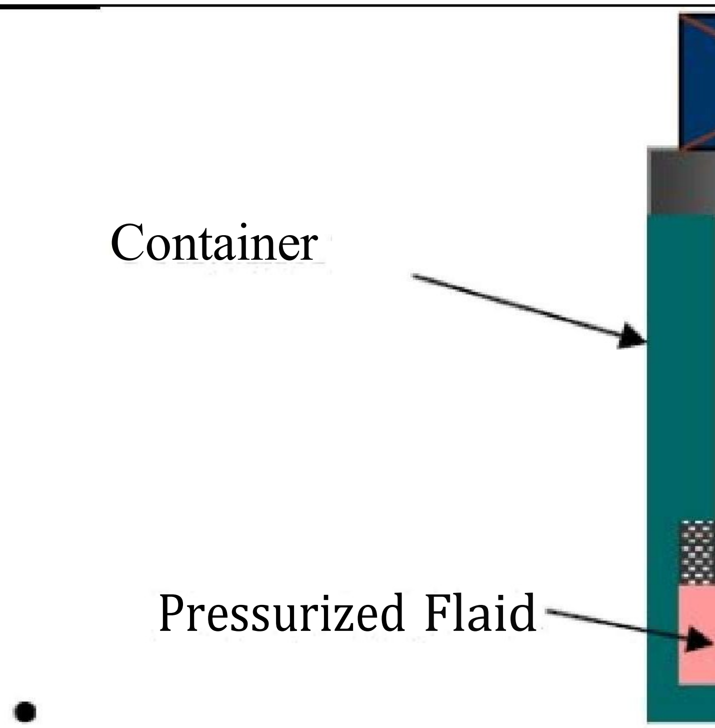
(e.g., automatic transmission, hydraulic suspension control in upper-c

r injection molding

upply additional fluid when main line fluid pump is inadequate to pe
n energy storage device: a device which accepts energy, stores ener

s accept energy at a low rate (low power) over a long time interval a
ower) over a short time interval.
ulators include steam accumulators, mainsprings, flywheel energy st
argeable batteries, capacitors, compensated pulsed alternators (co
ydroelectric plants
ulator is a pressure storage reservoir in which an incompressible hyd
plied by an external source of mechanical energy.
e can be an engine, a spring, a raised weight, or a compressed gas.
ables a hydraulic system to cope with extremes of demand using a le

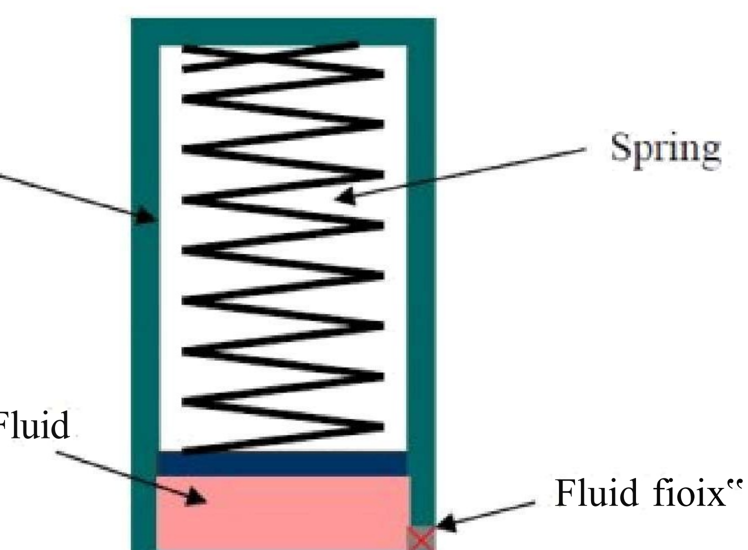




mulator:

umulator is similar to the weight — loaded type except that the piston

urce of energy that acts against the piston, forcing the fluid in to the

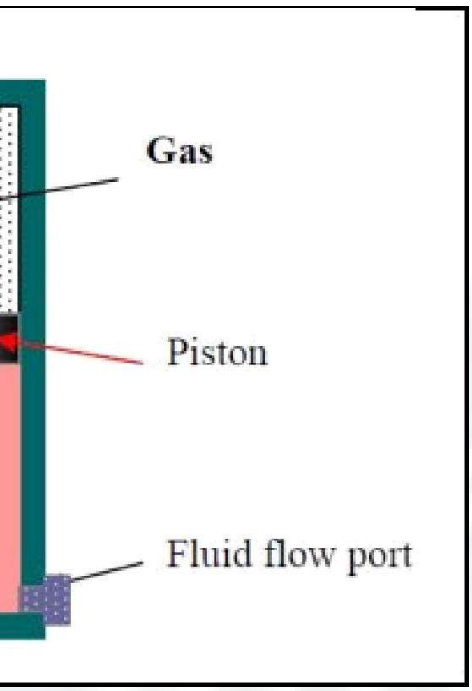


tor

ed design of gas loaded accumulators is the separator type. In this ty
gas and the oil.

of separator accumulator are

umulator cDnsists of a cy1inder containing a freely floatïng piston with



barrier between the gas and oil.

he piston types of accumulator are that they are expensive to manufa
n.

piston accumulator is its ability to handle very high or low temperature
n to compatible O- ring seals.

ulator:

ccumulator consists of a diaphragm, secured in the shell, which serves
as.

h is secured at the base of the diaphragm, covers the inlet of the line ves for controlling pressure include relief, reducing, sequence, count

es are found in virtually every hydraulic system, and they assist in a va
ures safely below a desired upper limit to maintaining a set pressure
es
Valves

ve

ems are designed to operate within a preset pressure range.
n of the forces the actuators in the system must generate to do the r
these forces, the fluid power components (and expensive equipment
hazard.
ds which limit maximum pressure in a system by diverting excess oil v

a relief valve first opens to allow fluid to flow through is known as cr
assing its full rated flow, it is in a state of full-flow pressure. The diffe
is sDmetimes known as pressure differential, also known as pressur
relief valve
nay consist of a poppet or ball, held exposed to system pressure on o
e on the other.
nally closed relief valve (Fig. 1), the force exerted by the compression
em pressure acting on the ball or poppet.
ball or poppet tightly seated. A reservoir port on the spring side of th

ure begins to exceed the setting of the valve spring, the fluid unseats t
amount of fluid to bypass to reservoir, maintaining system pressure a

Relief Valve:

ses, the pressure in passage B rises as well, and, when it reaches the se

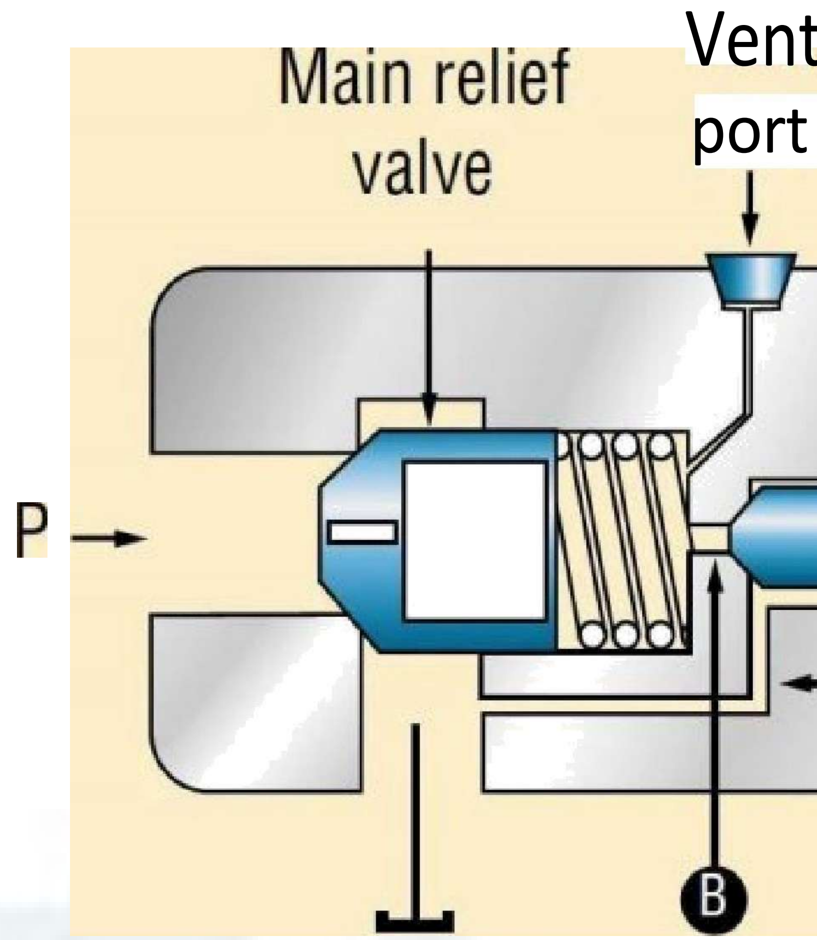
opens.

the main valve through passage B through the drain port.

e drop across orifice A in
opens it and excess oil
ing any further rise in inlet

n when inlet oil pressure
e setting.
do not start opening until
9D% of full pressure, the
em is protected because

suited for high- pressure,
ations. Although their
han that of direct-acting
operated relief valves
a more constant pressure



alve:
mponents for maintaining secondary, lower pressure in a hydraulic sy

ves are normally open, 2-way valves that close when subjected to su

e

ves are essentially used for distribution of energy in a fluid power sys

th through which a fluid traverses in a given circuit.

lves are used to control the direction Df flow in a hydraulic circuit.

to control the start, stop and change in direction of flow of pressurize

e controlled in various lines of a hydraulic circuit.

rol of actuator speeds depends on flow rates. This type of control is a

valves.

ves can be classified in a number of ways:

ruction.

orking ports:

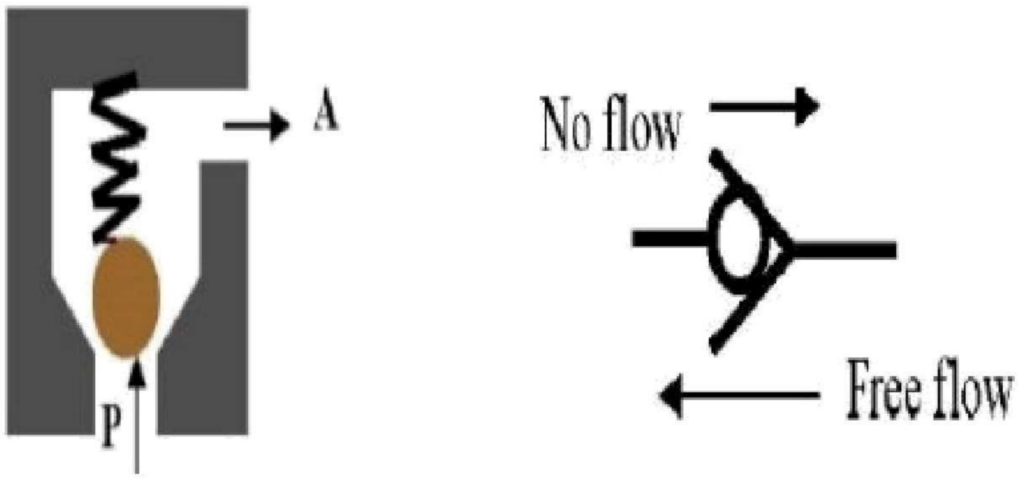
vitching position:

chanism:

tuation

On

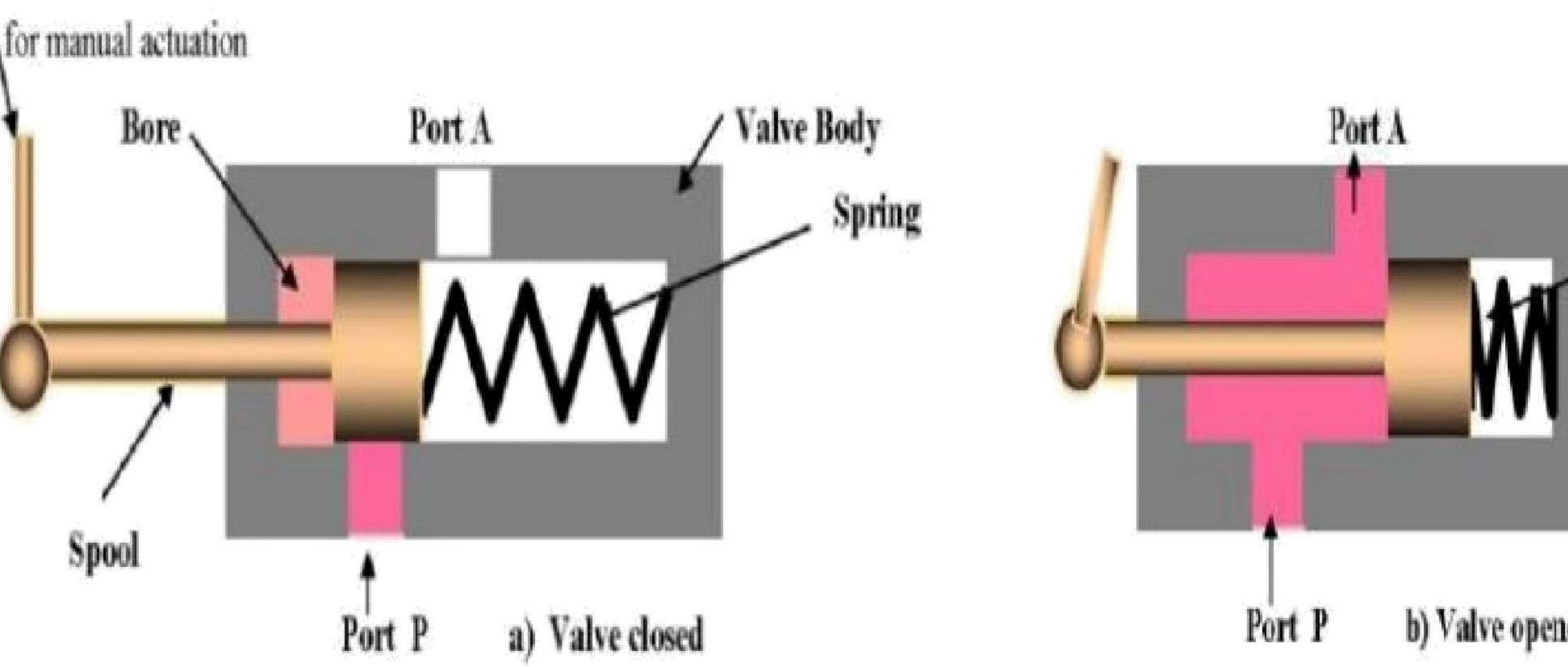
eck valve is as shown. It is also called in-off or Non-return valve.



simplest type

l valve is a check valve which is a two way valve because it contains tw
so called as on-off valves because they allow the fluid flow in only in
losed.
is usually the spDol or poppet design with the poppet

off valve



control valves

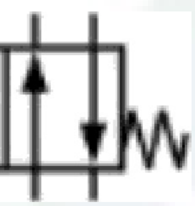
three working ports. These ports are: inlet, outlet, and exhaust (or ta
to an actuator, but allows fluid to return from it as well.

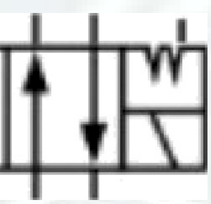
d, 3-way, 3-position valve. A valve of this type connected to a single-
ylinder could extend, retract, or stop at any place in the stroke.

s select fluid flow paths Use a spool-type valve for this operation. And
shown. A diverter valve sends fluid to either of two paths.

capable to control double-acting hydraulic cylinder and it can also cont
DCV valves has four ports in which two of them would be outlet port
e inlet and return to the tank.

2 position directional valves





shown are four-way two position valves. The ' way' means it has ' pipe connec
turn, Port A and Port B. The 'two position' means that it has two switched positi
r B position

e is operated by a manual lever and includes spring return.

valve is enoid operated with two detent tions to hold the valve in its last

aulic Actuators

k fluid. Like pneumatic actuators, lass of fluid leads to less efficiency a
in potential damage tD surrounding components and areas.
s recluire many complementary parts, including a fluid reservoir, mot
xchangers, along with noise reduction equipment

ctuation, hydraulic actuators are classified as follows:
limar actuation (hydraulic cylinders).
rotary actuation (hydraulic motor).
r: For limited angle of actuation (semi-rotary actuator).

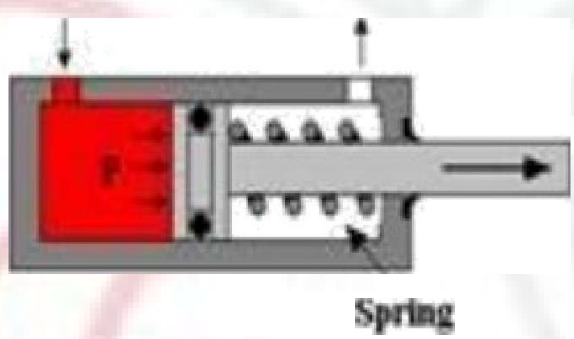
tuators, as their name implies, provide mDtion in a straight line.
nt is a finite amount determined by the construction of the unit.
draulic cylinder is to convert hydraulic power into linear mechanical f
s Extend and retract a piston rod to provide a push or pull force to driv
n.

ders

e of the following types:
g cylinders.
ng cylinders.
cylinders.
inders

on inside a

Push Action
Oil to yx\rnd, Spring for rclurn



Oil t

cific pressure, the load shifting capacity decreases for each of the suc

r is used in application where a large amount of force is required to

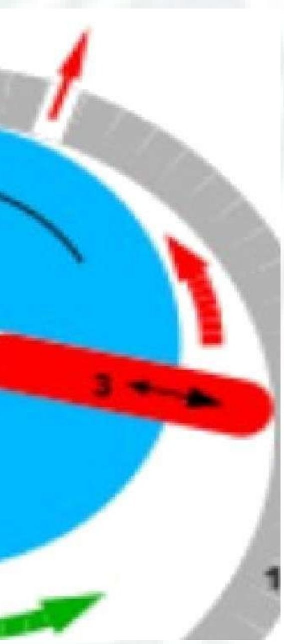
l to bath the pistons, resulting in a increased farce because of a large
k is that this cylinders must be longer than a standard cylinder to
must go to both the pistons simultaneously.

ists of a housing with an eccentric bore, in which runs a rotor with va

tial created by the unbalanced force of the pressurized fluid on the va
On.

n vane motor design is how the vanR tips are machinRd at the contact
g. Several types of "lip™ designs are used,

is to provide a tight seal between the inside of the motor housing a
mize wear and metal-to-metal contact.



Uses of Rotary Actuator

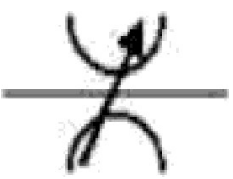
are used for many applications now such as

drives, wheel motors for military vehicles, self-driven cranes, excavato
drives,

drives, roll mills, drum drives far digesters, shredders,

cutters, high-powered lawn trimmers, and plastic injection machine

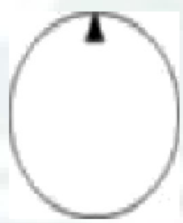
I\Miscellaneous fluids dra



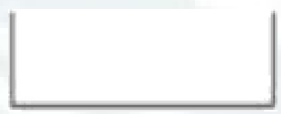
Piping

Riot line

Cra
lin

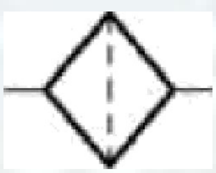


J



Resendir

Ele
mo



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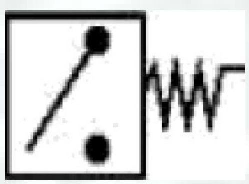
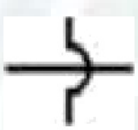
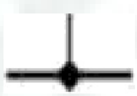
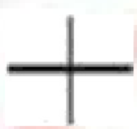
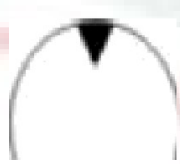


rrzsszac

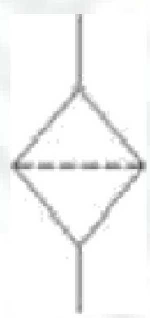








Hydraulic
IT1OtOF



Filter

Accur

3/2 DCV NO 3/2 DCV NC 4/2 DCV NC

Double-acting cylinder

Pressure Regulator

nd Analysis

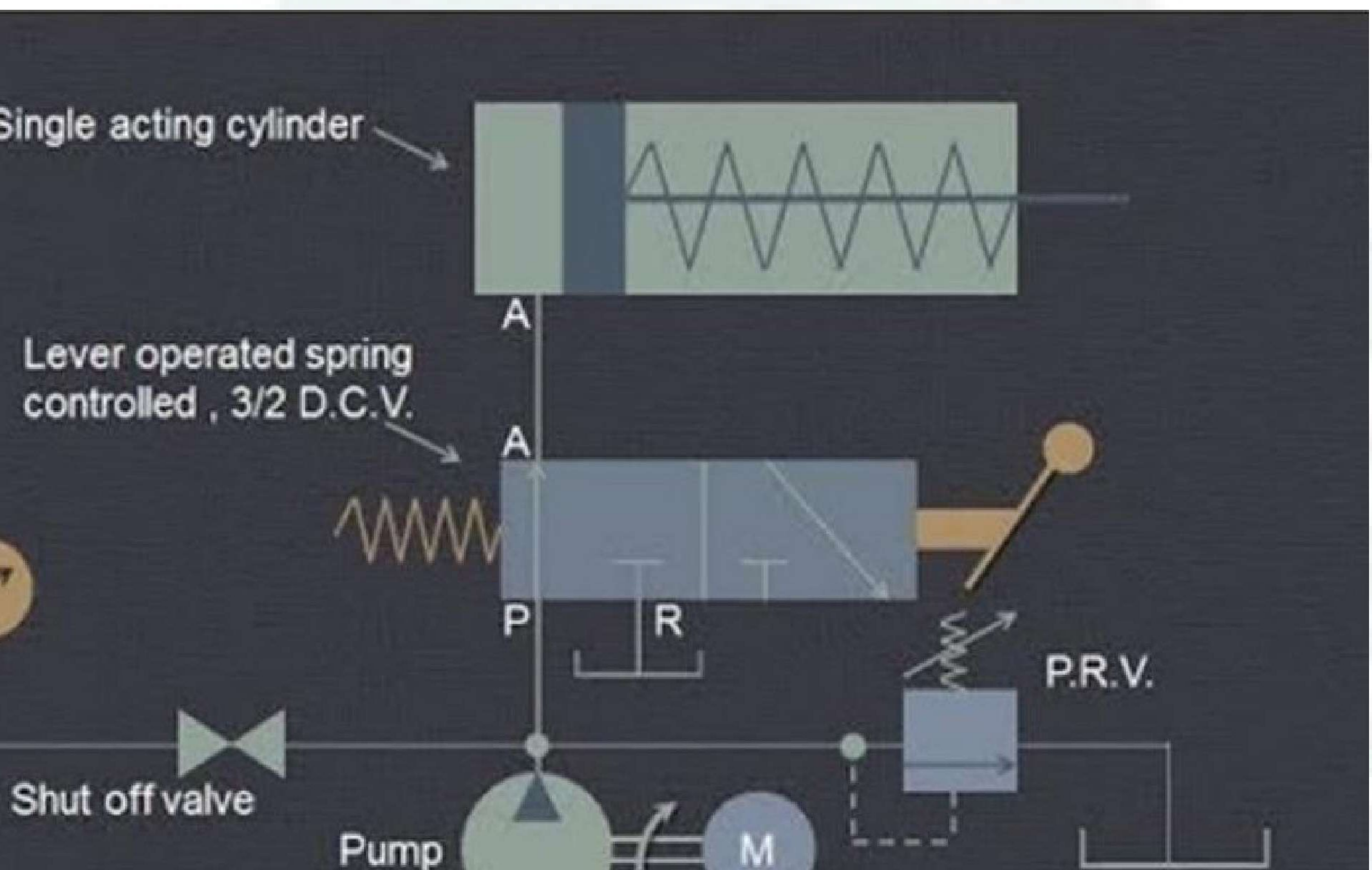
is a group of components such as pumps, actuators, and contrDl valv
ful task.

designing a hydraulic circuit, the following three important considerat

n

sired function

tion It is very important for the fluid power



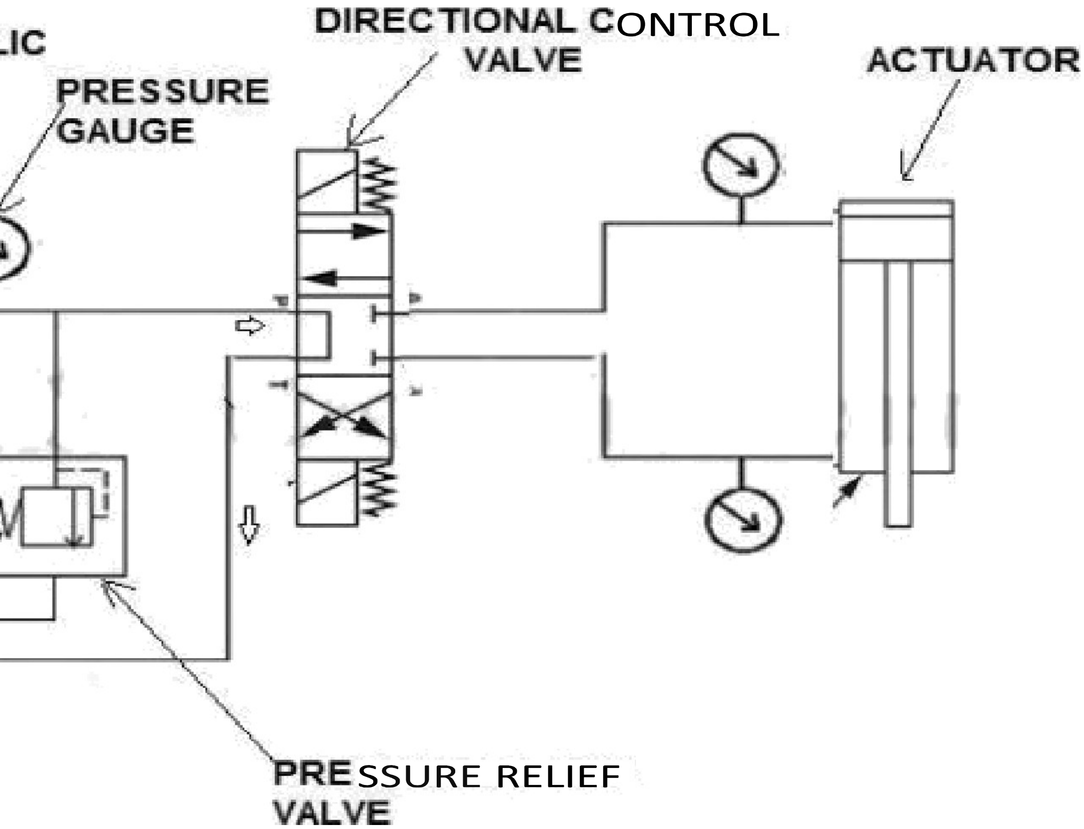
f valve is used with the pipe line through which high pressurized liqu
iquid exceeds the limit then it will help in escaping the excess liquid

ges are fitted with the pipe line to meter the flow Df liquid pressure
pressure for the reciprocating action of piston in cylinder (actuatDr).
at outlet of Pumping unit and also helps in measuring the pressure o
ell as the pressure of liquid during return form single acting actuator.
ts the hydraulic liquid from pumping unit to the inle.t of actuator and
om actuator to the reservoir.
ator is used for transmitting of mechanical force by utilizing liquid pre
DCV. The Spool type DCV is a handle ape.rated type and handle is
ponent of Machinery Unit.

ed above for the representation of various components used in opera

on there is no fIDW Of hydraulic oil taking place through the pipe lines
the Actuator. This is also known as the ideal period for actuator
ition:
re.nt is switched on, the motor transmits the mechanical power to the

ump drags the oil from sump coming out thrDugh filter and converts t
id to the required pressure at the actuation point
uge measure the outlet pressure of oil from Pump and if pressure exc
ipe line to make it working pressure
ontrol valve opens its passage from Port P tO PDrt A and delivers the



il used for the operation of actuator is stored in the reservoir. The oi
with atmospheric pressure.

d to separate the impurities, dusts, small insects floats on oil and puri
Pumping Unit

ump is required to transmit the fluid frDm reservoir to the direction c
equired pressure for the actuation of Double Acting Cylinder. The sha
he shak of prime mover as shown in above hydraulic circuit. The inlet
pipe connecting from sump through filter.

lief valve is used with the pipe line through which high pressurized li
pressure of liquid exceeds the limit then it will help in escaping the e
ipe line pressure.

auges are fitted with the pipe line to meter the flow of liquid pressur
required level of pressure for the reciprocating action of piston in cy
ressure of liquid pressure at outlet of Pumping unit and also helps i

at the rod end of piston is return to the tank through PDrt B and pas
e and port T of DCV to the tank

on:

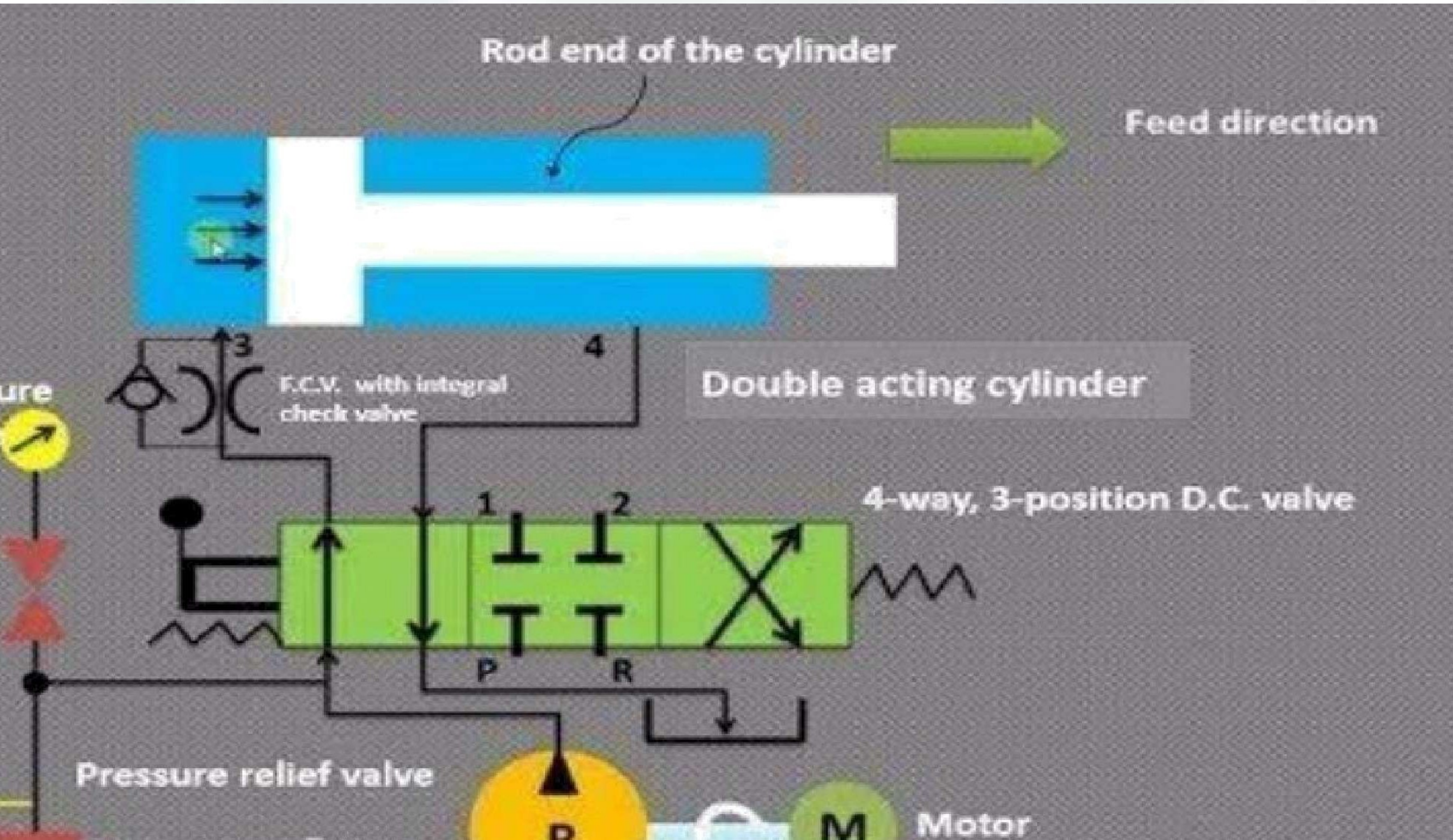
ontrol valve opens its passage from Port P to Part B and delivers the h
e connected to the Right side or ODC position of Piston in actuator.
t T are used for return of Oil

l force is exerted by the high pressure Dil to move the piston form OD
ce is utilized in moving the parts of machine.

at the rod end of piston is return to the tank through Port A and pas
e and port T of DCV to the tank

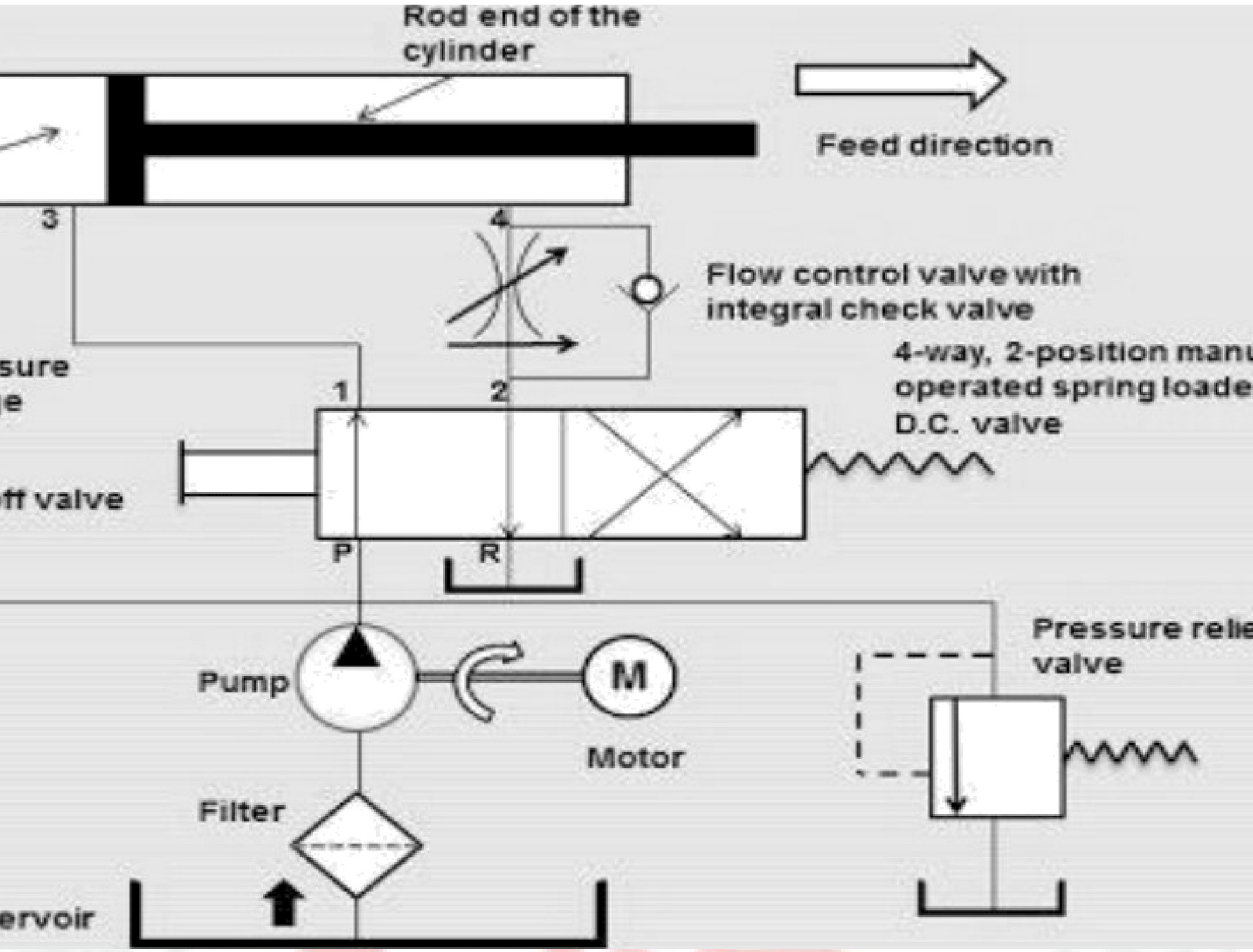
double actine cylinder is operated by the fluid pressure

cting cylinder with metering in control



e flow control valve is on the right side of the piston, the differential a
. This increased pressure helps to overcome the pressure drop acros

pressure required will be relatively lDw, it makes this circuit marginal
ke. Initially, the compensatory spool is fully open, and full pump flov
ston moves forward building up pressure at the flow control valve.



Difference between Hydraulics and pneumatics

Hydraulic systems

The working fluid is hydraulic oil.

As oil is incompressible,oil can be pressurized to very high pressure. (500 bar or even more)

Since pressure is high, the force developed is also very high (thousands of tones).

Since pressure is high, components are yery strong, made of steel, and are heavy.

As oil has more viscosity, it cannot flow fast. Hence hydraulic systems are slower in operation.

Due to continuous recirculation, the temperature of oil increases.

Hydraulic oils are petroleum-based oils; they are inflammable and there is eyery chance of fire hazard if neglected.

Leakage of oil results in dirty and slippery Surroundings that may lead to accidents.

The pump used is a positive displacement pump, So a pressure relief valve is necessary

There is no need for a separablelubrication System, because, hydraulic oil itself is a lubricant.

Applications: CNC. Machine tools, eanh- moving machines, automobiles.aviation etc

Pneumatic **systems**

Working fluid is compressed air.

Air is compressible; hence air can be pressurized to lesser pressure. (Only up to 10 bar approx.)

Since pressure is very less, the force developed is very less (up to I ton)

Components of the pneumatic system are lighter in weight, are made of aluminum.

Air has very less viscosity, it can flow fast. Hence pneumatic systems are quicker in operation.

The harder it runs, the cooler it works. Free expansion of air in cylinders and motors causes a chilling effect.

No chance of fire hazard. Hence pneumatic tools are preferably used inside mines, where flammable gasses may present.

The very clean and dry surrounding is maintained.

Nr] need for a pressure relief valve. □

A lubricator is necessary. Oil is mixed with the compressed air in the lubricator and then supplied to the system.

Applications: Material handling systems, hand tools mining works, automation, automobiles, etc.