

Lecture Notes

on

Hydraulic Machines

&

Industrial Fluid Power

(Th.3)

5th Semester, Mechanical Engg.



Prepared by

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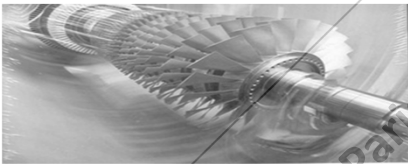


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HYDRAULIC MACHINES & INDUSTRIAL FLUID POWER

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INTRODUCTION



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WHAT WE ARE GOING TO COVER IN HM&IFP....?

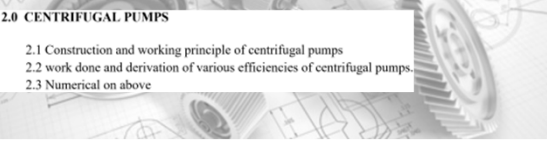


1.0 HYDRAULIC TURBINES.

- 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 derivation 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.

2.0 CENTRIFUGAL PUMPS

- 2.1 Construction and working principle of centrifugal pumps
- 2.2 work done and derivation of various efficiencies of centrifugal pumps.
- 2.3 Numerical on above



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WHAT WE ARE GOING TO COVER IN HM&IFP....?

3.0 RECIPROCATING PUMPS

- 3.1 Describe construction & working of single acting reciprocating pump.
- 3.2 Describe construction & working of double acting reciprocating pump.
- 3.3 Derive the formula for power required to drive the pump (Single acting & double acting)
- 3.5 Define slip.
- 3.5 State positive & negative slip & establish relation between slip & coefficient of discharge.
- 3.6 Solve numerical on above

4.0 PNEUMATIC CONTROL SYSTEM

- 4.1 Elements – filter-regulator-lubrication unit
- 4.2 Pressure control valves
 - 4.2.1 Pressure relief valves
 - 4.2.2 Pressure regulation valves
- 4.3 Direction control valves
 - 4.3.1 3/2DCV, 5/2 DCV, 5/3DCV
 - 4.3.2 Flow control valves
 - 4.3.3 Throttle valves
- 4.4 ISO Symbols of pneumatic components

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WHAT WE ARE GOING TO COVER IN HM&IFP....?

4.5. Pneumatic circuits

- 4.5.1 Direct control of single acting cylinder
- 4.5.2 Operation of double acting cylinder
- 4.5.3 Operation of double acting cylinder with metering in and metering out control

5.0 HYDRAULIC CONTROL SYSTEM

- 5.1 Hydraulic system, its merit and demerits
- 5.2 Hydraulic accumulators
 - 5.3.1 Pressure control valves
 - 5.3.2 Pressure relief valves
 - 5.3.3 Pressure regulation valves
- 5.3 Direction control valves
 - 5.3.1 3/2DCV, 5/2 DCV, 5/3DCV
 - 5.3.2 Flow control valves
 - 5.3.3 Throttle valves
- 5.4 Fluid power pumps
 - 5.4.1 External and internal gear pumps
 - 5.4.2 Vane pump
 - 5.4.3 Radial piston pumps

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WHAT WE ARE GOING TO COVER IN HM&IFP....?

5.5 ISO Symbols for hydraulic components.

5.6 Actuators

5.7 Hydraulic circuits

- 5.7.1 Direct control of single acting cylinder
- 5.7.2 Operation of double acting cylinder
- 5.7.3 Operation of double acting cylinder with metering in and metering out control

5.8 Comparison of hydraulic and pneumatic system

SL.NO	AUTHOR	TITLE OF THE BOOK	PUBLISHER
01	DR JAGDISH LAL	HYDRAULIC MACHINES	METROPOLITAN BOOK CO
02	ANDREW	HYDRAULICS	
03	K SHANMUGA, SUNDARAM	HYDRAULIC & PNEUMATIC CONTROL	S.CHAND
04	MAJUMDAR	HYDRAULIC & PNEUMATIC CONTROL	TMH
05	J.F. BLACKBURN, G. REETHOF & J.L. SHEARER	FLUID POWER CONTROL	

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THANK YOU



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CHAPTER-01: HYDRAULIC TURBINES

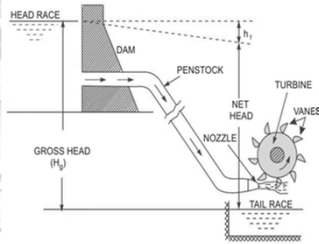


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Chapter-01: Hydraulic Turbines

LAYOUT AND FEATURES OF HYDROELECTRIC POWER PLANT

- The electric power which is obtained from the hydraulic (energy of water) is known as hydroelectric power.
- A Dam is constructed across a river to store water.
- Pipes of large diameter called penstocks carry water under pressure from the storage reserve reservoir to the turbine.
- Turbine having different types of vanes fitted to the wheels.
- Tail race is a channel which carries water away from the turbines after the water has worked on the turbines.



Layout of a hydroelectric power plant.

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TURBINES

- Hydraulic Machines are defined as those machines which convert either hydraulic energy (energy possessed by water) into mechanical energy (which is further converted into electrical energy) or mechanical energy into hydraulic energy.
- The Hydraulic Machines which convert the hydraulic energy into mechanical energy, are called **turbines** while the Hydraulic Machines which convert the mechanical energy into hydraulic energy are called **pumps**.



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TURBINES (CONTND.....)

Gross head

The difference between head race level and tail race level when no water is flowing is known as gross head and denoted by H_g .

Net head

It is also called effective head and is defined as the head available at the inlet of the turbine.

$$H = H_g - h_f$$

where H_g = Gross head, $h_f = \frac{4 \times f \times L \times V^2}{D \times 2g}$

in which

- V = Velocity of flow in penstock,
- L = Length of penstock,
- D = Diameter of penstock.

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TURBINES (CONTND.....)

Efficiencies of a turbine

o **Hydraulic efficiency**

It is defined as the ratio of power given by water to the runner of a turbine (runner is a rotating part of a turbine and on the runner vanes are fixed) to the power supplied by the water at the inlet of the turbine

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

where R.P. = Power delivered to runner i.e., runner power

$$= \frac{W}{g} \frac{[V_{w1} \pm V_{w2}] \times u}{1000} \text{ kW} \quad \dots \text{for Pelton Turbine}$$

$$= \frac{W}{g} \frac{[V_{w1} u_1 \pm V_{w2} u_2]}{1000} \text{ kW} \quad \dots \text{for a radial flow turbine}$$

W.P. = Power supplied at inlet of turbine and also called water power

$$= \frac{W \times H}{1000} \text{ kW} \quad \dots (18.2)$$

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TURBINES (CONTND.....)

where W = Weight of water striking the vanes of the turbine per second
 $= \rho g \times Q$ in which Q = Volume of water/s,
 V_{w_1} = Velocity of whirl at inlet,
 V_{w_2} = Velocity of whirl at outlet,
 u = Tangential velocity of vane,
 u_1 = Tangential velocity of vane at inlet for radial vane,
 u_2 = Tangential velocity of vane at outlet for radial vane,
 H = Net head on the turbine.

Power supplied at the inlet of turbine in S.I.units is known as water power. It is given by

$$W.P. = \frac{\rho \times g \times Q \times H}{1000} \text{ kW}$$

For water

$$\rho = 1000 \text{ kg/m}^3$$

\therefore

$$W.P. = \frac{1000 \times g \times Q \times H}{1000} = g \times Q \times H \text{ kW}$$

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HYDRAULIC TURBINES**



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TURBINES (CONTND.....)

o **Mechanical efficiency**

The power delivered by water to the runner of a turbine is transmitted to the shaft of the turbine. The ratio of the power available at the shaft of the turbine to the power delivered to the runner is defined as **mechanical efficiency**.

$$\eta_m = \frac{\text{Power at the shaft of the turbine}}{\text{Power delivered by water to the runner}} = \frac{\text{S.P.}}{\text{R.P.}}$$

o **Volumetric efficiency**

The volume of the water striking the runner of a turbine is slightly less than the volume of the water supplied to the turbine. Thus the ratio of the volume of the water actually striking the runner to the volume of water supplied to the turbine is defined as **Volumetric efficiency**.

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

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TURBINES (CONTND.....)



o **Overall efficiency**

The ratio of the power available at the shaft of the turbine to the power supplied at the inlet of the turbine is defined as **overall efficiency**.

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

$$= \frac{\text{S.P.}}{\text{W.P.}}$$

$$= \frac{\text{S.P.}}{\text{W.P.}} \times \frac{\text{R.P.}}{\text{R.P.}}$$

$$= \frac{\text{S.P.}}{\text{R.P.}} \times \frac{\text{R.P.}}{\text{W.P.}}$$

$$= \eta_m \times \eta_h$$

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**CHAPTER-01:
HYDRAULIC TURBINES**



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CLASSIFICATION OF TURBINES



1. According to the type of energy at inlet

- o **Impulse Turbine** - only kinetic energy is available at inlet
- o **Reaction Turbine** - kinetic energy as well as pressure energy at inlet

2. According to the direction of flow through Runner

- o **Tangential Flow Turbine** - water flows along the tangent of the runner
- o **Radial Flow Turbine** - water flows in the radial direction through the runner
- o **Axial Flow Turbine** - flows through the runner along the direction parallel to the axis of rotation of the runner
- o **Mixed Flow Turbine** - flows through the runner in the radial direction but leaves in the direction parallel to axis of rotation of Runner.

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CLASSIFICATION OF TURBINES

3. According to the head at the inlet of turbine turbine

- o High Head Turbine
- o Medium Head Turbine
- o Low Head Turbine

4. According to the specified speed of turbine

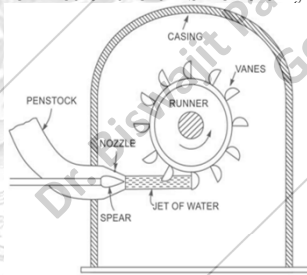
- o Low Specific Speed Turbine
- o Medium Specific Speed Turbine
- o High Specific Speed Turbine

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TURBINES (CONTND.....)

Pelton wheel (Impulse Turbine)

- o is a tangential flow impulse turbine and the water strikes the pocket along the tangent of the runner
- o the energy available at the inlet of the turbine is only kinetic energy and the pressure at the inlet and outlet of the turbine is atmospheric
- o This turbine is used for high heads



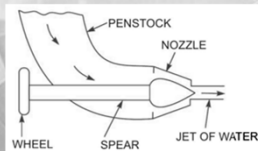
Pelton turbine.

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TURBINES (CONTND.....)

o Nozzle and flow regulating arrangement

The amount of water striking the vanes of the runner is controlled by providing a spear in the nozzle which is a conical needle operated by hand wheel.



o Runner with Vanes or Buckets

The runner consists of a circular disc (made of cast iron, cast steel or stainless steel) on the periphery of which a number of buckets evenly spaced are fixed and the shape of the buckets is of a hemispherical cup or bowl.



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TURBINES (CONTND.....)

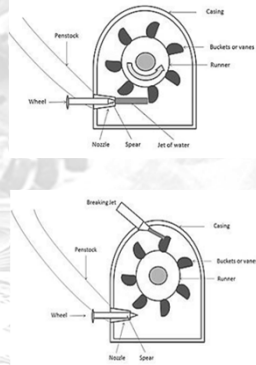
o **Casing**

It is to prevent slashing of the water and to discharge water to tail race and made of cast iron or steel plates.

o **Breaking Jet**

Due to inertia the runner goes on revolving for a long time even after the nozzle is completely closed by moving the spear in forward direction.

To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the veins which is called breaking jet



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TURBINES (CONTND.....)

Velocity Triangles And Work Done

$H =$ Net head acting on the Pelton wheel

$$= H_g - h_f$$

where $H_g =$ Gross head and $h_f = \frac{4fLV^2}{D^5 \times 2g}$

D^* = Dia. of Penstock,
 D = Diameter of the wheel,
 N = Speed of the wheel in r.p.m.,
 d = Diameter of the jet.

So,
 $V_1 =$ Velocity of jet at inlet = $\sqrt{2gH}$

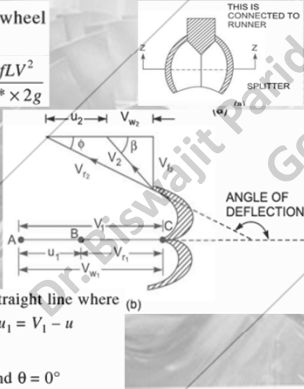
$$u = u_1 = u_2 = \frac{\pi DN}{60}$$

The velocity triangle at inlet will be a straight line where

$$V_{r1} = V_1 - u_1 = V_1 - u$$

$$V_{w1} = V_1$$

$$\alpha = 0^\circ \text{ and } \theta = 0^\circ$$



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TURBINES (CONTND.....)

From the velocity triangle at outlet, we have

$$V_{r2} = V_{r1} \text{ and } V_{w2} = V_{r2} \cos \phi - u_2.$$

The force exerted by the jet of water in the direction of motion is given by

$$F_x = \rho a V_1 [V_{w1} + V_{w2}]$$

Now work done by the jet on the runner per second

$$= F_x \times u = \rho a V_1 [V_{w1} + V_{w2}] \times u \text{ Nm/s}$$

Power given to the runner by the jet

$$= \frac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{1000} \text{ kW}$$

$a =$ Area of jet = $\frac{\pi}{4} d^2$.

Work done/s per unit weight of water striking/s

$$= \frac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{\text{Weight of water striking/s}}$$

$$= \frac{\rho a V_1 [V_{w1} + V_{w2}] \times u}{\rho a V_1 \times g} \left(\frac{1}{g} [V_{w1} + V_{w2}] \times u \right)$$

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CHAPTER-01: HYDRAULIC TURBINES



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Chapter-01: Hydraulic Turbines

TURBINES (CONTND.....)

$$\therefore \text{K.E. of jet per second} = \frac{1}{2} m V^2 = \frac{1}{2} (\rho a V_1) \times V_1^2$$

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

$$= \frac{\rho a V_1 [V_{w_1} + V_{w_2}] \times u}{\frac{1}{2} (\rho a V_1) \times V_1^2} = \frac{2 [V_{w_1} + V_{w_2}] \times u}{V_1^2}$$

$$V_{w_1} = V_1, V_{w_2} = V_1 - u_1 = (V_1 - u)$$

$$V_{w_2} = (V_1 - u)$$

$$V_{w_2} = V_2 \cos \phi - u_2 = V_2 \cos \phi - u = (V_1 - u) \cos \phi - u$$

Substituting the values of V_{w_1} and V_{w_2}

$$\eta_h = \frac{2 [V_1 + (V_1 - u) \cos \phi - u] \times u}{V_1^2}$$

$$= \frac{2 [V_1 - u + (V_1 - u) \cos \phi] \times u}{V_1^2} = \frac{2 (V_1 - u) [1 + \cos \phi] u}{V_1^2}$$

Hydraulic Efficiency

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Chapter-01: Hydraulic Turbines

TURBINES (CONTND.....)

The efficiency will be maximum for a given value of V_1 when

$$\frac{d}{du} (\eta_h) = 0 \quad \text{or} \quad \frac{d}{du} \left[\frac{2u(V_1 - u)(1 + \cos \phi)}{V_1^2} \right] = 0$$

$$\text{or} \quad \frac{(1 + \cos \phi)}{V_1^2} \frac{d}{du} (2uV_1 - 2u^2) = 0 \quad \text{or} \quad \frac{d}{du} [2uV_1 - 2u^2] = 0 \quad \left(\because \frac{1 + \cos \phi}{V_1^2} \neq 0 \right)$$

$$\text{or} \quad 2V_1 - 4u = 0 \quad \text{or} \quad u = \frac{V_1}{2}$$

$$\text{Max. } \eta_h = \frac{2 \left(V_1 - \frac{V_1}{2} \right) (1 + \cos \phi) \times \frac{V_1}{2}}{V_1^2}$$

$$= \frac{2 \times \frac{V_1}{2} (1 + \cos \phi) \frac{V_1}{2}}{V_1^2} = \frac{(1 + \cos \phi)}{2}$$

Maximum Efficiency

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TURBINES (CONTND.....)

Notes

(i) The velocity of the jet at inlet is given by $V_1 = C_v \sqrt{2gH}$
 where C_v = Co-efficient of velocity = 0.98 or 0.99
 H = Net head on turbine

(ii) The velocity of wheel (u) is given by $u = \phi \sqrt{2gH}$
 where ϕ = Speed ratio. The value of speed ratio varies from 0.43 to 0.48.

(iii) The angle of deflection of the jet through buckets is taken at 165° if no angle of deflection is given.

(iv) The mean diameter or the pitch diameter D of the Pelton wheel is given by

$$u = \frac{\pi DN}{60} \text{ or } D = \frac{60u}{\pi N}$$

Jet Ratio (m) = $\frac{\text{Pitch diameter (D) of the Pelton wheel}}{\text{Diameter (d) of the jet}} = \frac{D}{d} = 12 \text{ for most cases}$

(vi) Number of buckets on a runner is given by

$$Z = 15 + \frac{D}{2d} = 15 + 0.5m$$

where m = Jet ratio

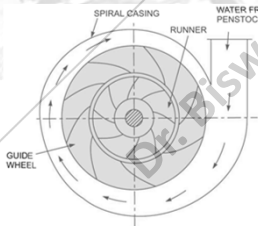
(vii) Number of Jets. $\frac{\text{Total rate of flow through the turbine}}{\text{Rate of flow of water a single jet}}$

TURBINE

It is a inward flow reaction turbine having radial discharge at outlet.

Radial flow reaction turbine

- o turbines in which water flows in the radial direction
- o the water may flow radially from outwards to inwards (inward radial flow turbine) or from inwards to outwards (outward radial flow turbine).



Main parts of a radial reaction turbines.

TURBINES (CONTND.....)

Main Parts

Casing-

- o Is made of spiral shaped concrete, cast steel or plate steel.
- o In case of reaction turbine the casing and runner are always full of water.

Guide mechanism -

- o It consists of a stationary circular wheel all round the runner of the turbine on which stationary guide vanes are fixed.
- o The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet.

Runner -

- o It is a circular wheel made of cast steel or cast iron on which a series of radial curved vanes are fixed.
- o The radial curved vanes are so shaped that the water enters and leaves the runner without shock.

Draft Tube

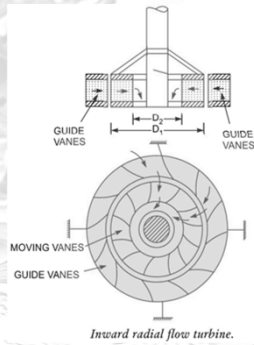
The tube is gradually increasing area which is used for discharging water from the exit of the turbine to the tail race.

TURBINES (CONTND.....)



Inward flow reaction turbine

- o In this case the water from the casing enters the stationary guiding wheel consisting of guiding vanes which direct the water to enter the runner which consists of moving vanes.
- o The water flows over the moving veins in the inward radial direction and is discharged at the inner diameter of the runner.
- o So the outer diameter of the runner is the inlet and the inner diameter is the outlet.



Inward radial flow turbine.

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TURBINES (CONTND.....)



The work done per second on the runner by water is given by equation

$$= \rho a V_1 [V_{w1} u_1 \pm V_{w2} u_2] = \rho Q [V_{w1} u_1 \pm V_{w2} u_2] \quad (\because a V_1 = Q)$$

where V_{w1} = Velocity of whirl at inlet,

V_{w2} = Velocity of whirl at outlet,

u_1 = Tangential velocity of wheel at inlet

$$= \frac{\pi D_1 \times N}{60}, \text{ where } D_1 = \text{Outer dia. of runner,}$$

u_2 = Tangential velocity of wheel at outlet

$$= \frac{\pi D_2 \times N}{60}, \text{ where } D_2 = \text{Inner dia. of runner, } N = \text{Speed of the turbine in r.p.m.}$$

The work done per second per unit weight of water per second.

$$= \frac{\text{Work done per second}}{\text{Weight of water striking per second}} = \frac{\rho Q [V_{w1} u_1 \pm V_{w2} u_2]}{\rho Q \times g} = \frac{1}{g} [V_{w1} u_1 \pm V_{w2} u_2]$$

It is known as **Euler's equation** of hydrodynamic machine or **Fundamental Equation** of hydrodynamic machine and derived by a Swiss scientist, **L. Euler**

Hydraulic efficiency

$$\eta_h = \frac{\text{R.P.}}{\text{W.P.}} = \frac{\frac{W}{1000g} [V_{w1} u_1 \pm V_{w2} u_2]}{W \times H} = \frac{(V_{w1} u_1 \pm V_{w2} u_2)}{gH}$$

where R.P. = Runner power

W.P. = Water power

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**CHAPTER-01:
HYDRAULIC TURBINES**



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Chapter-01: Hydraulic Turbines

TURBINES (CONTND.....)

If the discharge is radial at outlet, then $V_{w2} = 0$

$$\eta_h = \frac{V_{w1} u_1}{gH}$$

Notes

(i) **Speed Ratio.** The speed ratio is defined as $= \frac{u_1}{\sqrt{2gH}}$ where $u_1 =$ Tangential velocity of wheel at inlet.

(ii) **Flow Ratio.** The ratio of the velocity of flow at inlet (V_f) to the velocity given $\sqrt{2gH}$ is known as flow ratio or it is given as

$$= \frac{V_f}{\sqrt{2gH}}, \text{ where } H = \text{Head on turbine}$$

(iii) **Discharge of the Turbine.** The discharge through a reaction radial flow turbine is given by

$$Q = \pi D_1 B_1 \times V_{f1} = \pi D_2 \times B_2 \times V_{f2}$$

If the thickness of the vanes are taken into consideration then the area through which flow place is given by: $(\pi D_1 - n \times t)$ where $D_1 =$ Diameter of runner at inlet, $B_1 =$ Width of runner at inlet, $V_{f1} =$ Velocity of flow at inlet, and $D_2, B_2, V_{f2} =$ Corresponding values at outlet.

(v) **Radial Discharge.** This means the angle made by absolute velocity with the tangent on the wheel is 90° and the component of the whirl velocity is zero. Radial discharge at outlet means $\beta = 90^\circ$ and $V_{w2} = 0$, while radial discharge at inlet means $\alpha = 90^\circ$ and $V_{w1} = 0$.

(vi) If there is no loss of energy when water flows through the vanes then we have

$$H - \frac{V_2^2}{2g} = \frac{1}{g} [V_{w1} u_1 \pm V_{w2} u_2]$$

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Chapter-01: Hydraulic Turbines

FRANCIS TURBINES

For **Francis Turbine**, the discharge at outlet is radial, so the velocity of whirl at outlet (V_{w2}) will be zero.

The work done by water on the runner per second,

$$= \rho Q [V_{w1} u_1]$$

And work done per second per unit weight of water striking/s $= \frac{1}{g} [V_{w1} u_1]$

Hydraulic efficiency will be given by, $\eta_h = \frac{V_{w1} u_1}{gH}$

Notes

1. The ratio of width of the wheel to its diameter is given as $n = \frac{B_1}{D_1}$. The value of n varies from 0.10 to .40.

2. The flow ratio is given as,

Flow ratio $= \frac{V_f}{\sqrt{2gH}}$ and varies from 0.15 to 0.30.

3. The speed ratio $= \frac{u_1}{\sqrt{2gH}}$ varies from 0.6 to 0.9.

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Chapter-01: Hydraulic Turbines

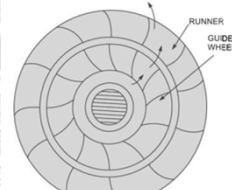
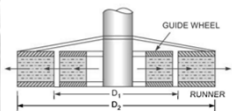
TURBINES (CONTND.....)

Outward Radial Flow Reaction Turbine

o In this turbine water from the casing enters the stationary guide wheel which consists of guide vanes and these vanes direct water to enter the runner which is around the stationary guide wheel.

o The water flows through the vanes of the runner in the outward radial direction and each discharged at the outer diameter of the runner.

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



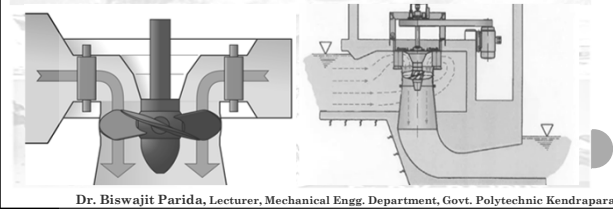
Outward radial flow turbine.

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Axial Flow Reaction Turbine

- Water flows parallel to the axis of rotation of the shaft and the head at inlet is the sum of **Pressure Energy** and **Kinetic Energy**.
- The shaft of the turbine each vertical and its lower end is made larger known as **Hub** or **Boss**.
- The vanes are fixed on the hub and hence the hub acts as a runner.



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Types

i) Propeller turbine

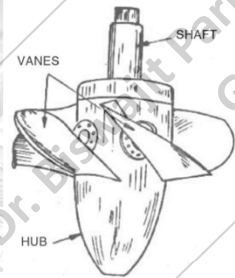
When the vanes are fixed to the hub and they are not adjustable.

ii) Kaplan turbine

If the vanes on the hub are adjustable (by an Austrian engineer V Kaplan) & is suitable for, where large quantity of water at low head.

The main parts are

- Scroll Casing
- Guide Vanes Mechanism
- Hub With Vanes (Runner)
- Draft Tube



Kaplan turbine runner

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KAPLAN TURBINES (CONTND.....)



The water from penstock enters the scroll casing and then moves to the guide vanes. From the guide vanes, the water turns to 90 degree and flows axially through the runner.

The discharge through the runner is given by,

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

where D_o = Outer diameter of the runner,
 D_h = Diameter of hub, and
 V_f = Velocity of flow at inlet.

Notes

- The peripheral velocity at inlet and outlet are equal

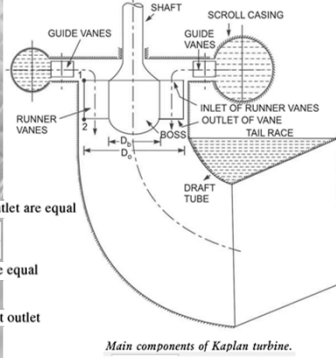
$$u_1 = u_2 = \frac{\pi D_o N}{60}$$

- Velocity of flow at inlet and outlet are equal

$$V_f = V_{f2}$$

- Area of flow at inlet = Area of flow at outlet

$$= \frac{\pi}{4} (D_o^2 - D_h^2)$$



Main components of Kaplan turbine.

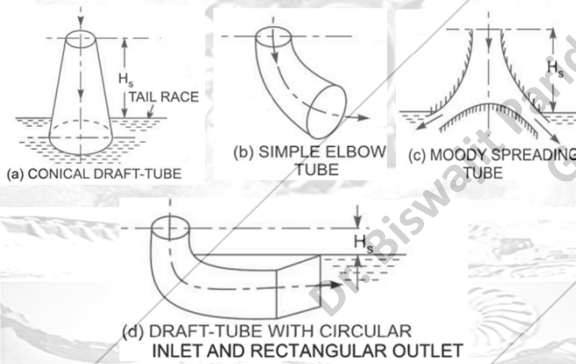
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Draft Tube

- o is a pipe of gradually increasing area which connects the outlet of the runner to the tail race.
- o one end of the draft tube is connected to the outlet of the runner while the other end is submerged below the level of water in the tail race
- o it permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine.
- o it converts a large proportion of kinetic energy rejected at the outlet of the turbine into successful pressure energy
- o so the net head on the turbine increases which leads in increase the power and efficiency of the turbine.

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Types of Draft Tube



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Specific Speed

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, get openings etc with the actual turbine but of such a size that it will develop unit power when working under unit head. It is given by,

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

where P - shaft power n-speed of actual turbine
H - head of the turbine.

Specific speed		Types of turbine
(M.K.S.)	(S.I.)	
10 to 35	8.5 to 30	Pelton wheel with single jet
35 to 60	30 to 51	
60 to 300	51 to 225	Francis turbine
300 to 1000	255 to 860	Kaplan or Propeller turbine

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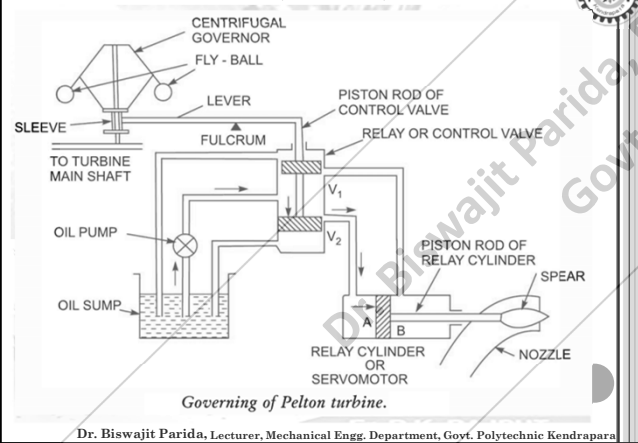
TURBINES (CONTND.....)

Governing of Turbine

- o Is defined as the operation by which the speed of the turbine is kept constant under all working conditions.
- o It is done automatically by means of a Governor, which regulates the rate of flow through the turbines according to the changing load conditions on the turbine.
- o It is necessary as the turbine is directly coupled to an electric generator, which is required to run at constant speed under all fluctuating load conditions.
- o This is only possible when the speed of the generator under all changing load conditions is constant for which the speed of the turbine need to be constant.
- o When the load on the generator decreases, the speed of the generator increases beyond the normal speed which leads in increase in turbine speed beyond the normal speed.
- o For the turbine for the generator to run at constant speed, the rate of flow of water to the turbine should be decreased till the speed becomes normal.

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TURBINES (CONTND.....)



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DISTINGUISH BETWEEN IMPULSE TURBINE AND REACTION TURBINE

Impulse Turbine	Reaction Turbine
The stream flows through the nozzle and strike on the moving blades.	First, the stream flows through the guide mechanism and then flows through the moving blades.
stream strikes on the buckets with kinetic energy.	The stream glides over the moving blades with both pressure and kinetic energy.
During the flow of stream through moving blades, its pressure remains constant.	During the flow its pressure reduces.
The stream may or may not be admitted to the whole circumference.	must be admitted over the whole circumference.
The blades of impulse turbine are symmetrical.	The blades of reaction turbine are not symmetrical.
While gliding over the blades the relative velocity of stream remains constant.	while gliding over the blades the relative velocity of stream increases.
For the same power developed, the number of stages required is less.	the number of stages required is more.
The direction of stream flow is radial to the direction of turbine wheel.	The direction is radial and axial to the turbine wheel.
It requires less maintenance work.	more maintenance work.
It is suitable for low discharge.	is suitable for medium and high discharge.
Ex:- Pelton Wheel	Ex:- Francis turbine, Kaplan turbine etc.

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**CHAPTER-02:
CENTRIFUGAL PUMPS**



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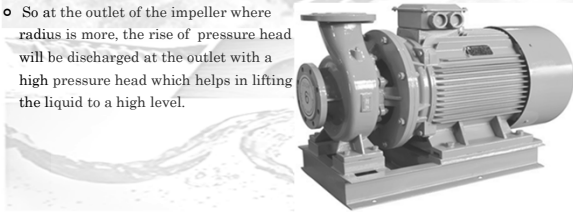
Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS

The Hydraulic Machines which converts mechanical energy into hydraulic energy are called **Pumps** and it is in the form of pressure energy.

Centrifugal Pumps

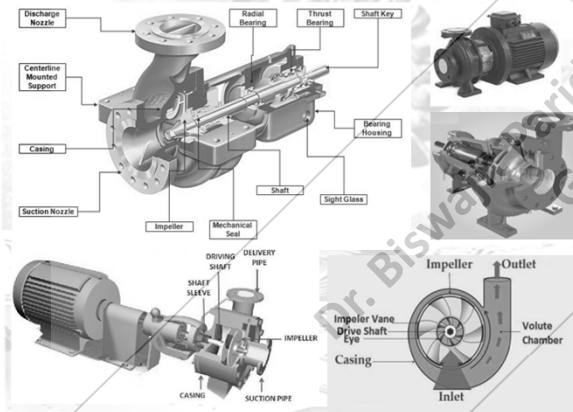
- o The Hydraulic Machines which converts mechanical energy into pressure energy by means of centrifugal force acting on fluid.
- o Acts as a reverse of an inward radial flow reaction turbine which means the flow is in radial outward direction.
- o It works in the principle of forced vortex flow which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place and at a point it is proportional to the square of tangential velocity of the liquid at the same point .
- o So at the outlet of the impeller where radius is more, the rise of pressure head will be discharged at the outlet with a high pressure head which helps in lifting the liquid to a high level.



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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)



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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)

Main Parts

a) Impeller:

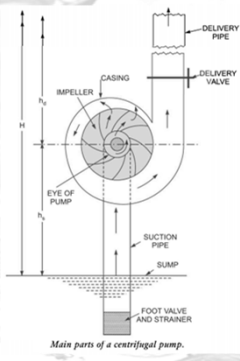
It is the rotating part of the centrifugal pump consisting of a series of backward curved vanes and is mounted on a shaft which is connected to the shaft of an electric motor.

b) Casing:

It is an air-tight passage surrounding the impeller and convert kinetic energy of water discharged at impeller outlet in to pressure energy before the water leaves the casing and enters the delivery pipe.

i) Volute Casing:

It is of spiral type in which area of flow increases gradually and this decreases the velocity and increases the pressure of the water flowing through the casing. Loss of energy due to eddy formation.



Main parts of a centrifugal pump.

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CENTRIFUGAL PUMPS (CONTD...)

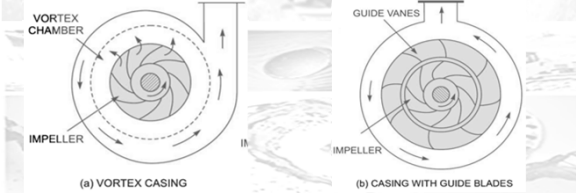
ii) Vortex Casing :

A circular chamber is introduced between the casing and the impeller by which loss of energy due to an eddy formation is reduced considerably and efficiency is more than volute casing.

iii) Casing with Guide blades:

Impeller is surrounded by a series of guide blades mounted on a ring called a diffuser and are designed in such a way that water enters the guide vanes without shock.

The area of the guide vanes increases, thus reducing the velocity of flow and subsequently increasing the pressure of water.



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CENTRIFUGAL PUMPS (CONTD...)

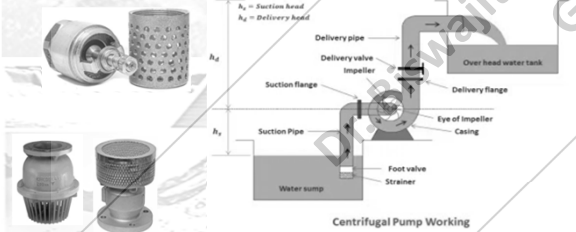
c) Suction Pipe with a Foot Valve and Strainer:

Suction pipe is a pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump.

A foot valve is a non-return or one-way type of valve fitted at the lower end of the suction pipe. A strainer is also fitted at the lower end of the suction pipe.

d) Delivery Pipe:

is a pipe whose one end is connected to the outlet of the pump and the other end delivers the water at a required height.



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CENTRIFUGAL PUMPS (CONTD...)

Work done by the pump or impeller on water:

Water enters the impeller radially at inlet which means the absolute velocity of water at inlet makes an angle of 90° with the direction of motion of the impeller at inlet.

So, $\alpha = 90^\circ$ and $V_{w1} = 0$

Let N = Speed of the impeller in r.p.m.,

D_1 = Diameter of impeller at inlet,

u_1 = Tangential velocity of impeller at inlet,

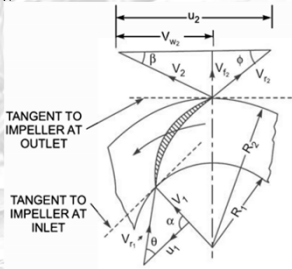
$$= \frac{\pi D_1 N}{60}$$

D_2 = Diameter of impeller at outlet,

u_2 = Tangential velocity of impeller at outlet

$$= \frac{\pi D_2 N}{60}$$

V_1 = Absolute velocity of water at inlet,
 V_{r1} = Relative velocity of water at inlet,



Velocity triangles at inlet and outlet.

α = Angle made by absolute velocity (V_1) at inlet with the direction of motion of vane,
 θ = Angle made by relative velocity (V_{r1}) at inlet with the direction of motion of vane, and V_{r2} , β and ϕ are the corresponding values at outlet.

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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)

For a radial flow reaction turbine, the work done by the water on the runner for second for Unit Weight of the water striking per second,

$$= \frac{1}{g} [V_{w_1} u_1 - V_{w_2} u_2]$$

Work done by the impeller on the water for second for Unit Weight of water striking per second,

$$= - [\text{Work done in case of turbine}]$$

$$= - \left[\frac{1}{g} (V_{w_1} u_1 - V_{w_2} u_2) \right] = \frac{1}{g} [V_{w_2} u_2 - V_{w_1} u_1] = \frac{1}{g} V_{w_2} u_2 \quad (\because V_{w_1} = 0 \text{ here})$$

Work done by impeller on water per second = $\frac{W}{g} \cdot V_{w_2} u_2$

where $W = \text{Weight of water} = \rho \times g \times Q$

where $Q = \text{Volume of water}$

and

$$Q = \text{Area} \times \text{Velocity of flow} = \pi D_1 B_1 \times V_{f_1} = \pi D_2 B_2 \times V_{f_2}$$

where B_1 and B_2 are width of impeller at inlet and outlet and V_{f_1} and V_{f_2} are velocities of flow at inlet and outlet.

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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)

Heads of Centrifugal Pump

a) Suction Head (h_s):

is the vertical height of the centre line of the centrifugal pump above the water surface in the tank or pump from which water is to be lifted.

b) Delivery Head (h_d):

is the vertical distance between the centre line of the pump and the water surface in the tank to which water is delivered.

c) Static Head (H_s):

the sum of suction head and delivery head.

$$H_s = h_s + h_d$$

d) Manometric Head (H_m):

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

(a) $H_m = \text{Head imparted by the impeller to the water} - \text{Loss of head in the pump}$

$$= \frac{V_{w_2} u_2}{g} - \text{Loss of head in impeller and casing}$$

$$= \frac{V_{w_2} u_2}{g} \quad \dots \text{if loss of pump is zero}$$

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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)

(b) $H_m = \text{Total head at outlet of the pump} - \text{Total head at the inlet of the pump}$

$$= \left(\frac{P_o}{\rho g} + \frac{V_o^2}{2g} + Z_o \right) - \left(\frac{P_i}{\rho g} + \frac{V_i^2}{2g} + Z_i \right)$$

where $\frac{P_o}{\rho g} = \text{Pressure head at outlet of the pump} = h_d$

$\frac{V_o^2}{2g} = \text{Velocity head at outlet of the pump}$

$= \text{Velocity head in delivery pipe} = \frac{V_d^2}{2g}$

$Z_o = \text{Vertical height of the outlet of the pump from datum line, and}$

$\frac{P_i}{\rho g}, \frac{V_i^2}{2g}, Z_i = \text{Corresponding values of pressure head, velocity head and datum head at the inlet of the pump,}$

i.e., $h_s, \frac{V_s^2}{2g}$ and Z_s respectively.

(c) $H_m = h_s + h_d + h_{f_s} + h_{f_d} + \frac{V_d^2}{2g}$ where
 $h_s = \text{Suction head, } h_d = \text{Delivery head,}$
 $h_{f_s} = \text{Frictional head loss in suction pipe,}$
 $h_{f_d} = \text{Frictional head loss in delivery pipe, and}$
 $V_d = \text{Velocity of water in delivery pipe.}$

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CENTRIFUGAL PUMPS (CONTD...)

Efficiencies of Centrifugal Pump

In case of a centrifugal pump from the power is transmitted from the shaft of the electric motor to the support of the pump and then to impeller.

a) Manometric Efficiency (η_{man}):

Manometric efficiency the ratio of the power given to the water at outlet of the form to the power available at the impeller.

Or

The ratio of the manometric head to the head imparted by the impeller to the water.

$$\eta_{man} = \frac{\text{Manometric head}}{\text{Head imparted by impeller to water}} = \frac{H_m}{\left(\frac{V_{w_2} u_2}{g}\right)} = \frac{g H_m}{V_{w_2} u_2}$$

The power given to water at the outlet of the form = $\frac{WH_m}{1000}$ kW

The power at the impeller = $\frac{\text{Work done by impeller per second}}{1000}$ kW = $\frac{W}{g} \times \frac{V_{w_2} \times u_2}{1000}$ kW

$$\eta_{man} = \frac{\frac{W \times H_m}{1000}}{\frac{W \times V_{w_2} \times u_2}{g \times 1000}} = \frac{g \times H_m}{V_{w_2} \times u_2}$$

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CENTRIFUGAL PUMPS (CONTD...)

b) Mechanical Efficiency (η_m):

The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump.

$$\eta_m = \frac{\text{Power at the impeller}}{\text{Power at the shaft}}$$

The power at the impeller in kW = $\frac{\text{Work done by impeller per second}}{1000} = \frac{W}{g} \times \frac{V_{w_2} u_2}{1000}$

$$\eta_m = \frac{\frac{W}{g} \left(\frac{V_{w_2} u_2}{1000}\right)}{\text{S.P.}} \quad \text{where S.P. = Shaft power.}$$

c) Overall Efficiency (η_o):

It is defined as the ratio of power output of the form to the power input to the pump.

$$\eta_o = \frac{\text{Weight of water lifted} \times H_m}{1000} = \frac{WH_m}{1000}$$

Power input to the pump = Power supplied by the electric motor = S.P. of the pump.

$$\eta_o = \frac{\left(\frac{WH_m}{1000}\right)}{\text{S.P.}} \quad \eta_o = \eta_{man} \times \eta_m$$

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CENTRIFUGAL PUMPS (CONTD...)

Minimum Speed for Starting a Centrifugal Pump

If the pressure rise in the impeller is more than or equal to manometric height hate (H_m), the centrifugal pump will start delivering water.

In case of forced vortex, the centrifugal hair or head due to pressure rise in the impeller,

$$= \frac{\omega^2 r_2^2}{2g} - \frac{\omega^2 r_1^2}{2g} = \frac{u_2^2}{2g} - \frac{u_1^2}{2g}$$

where ωr_2 = Tangential velocity of impeller at outlet = u_2 , and ωr_1 = Tangential velocity of impeller at inlet = u_1 .

The water will flow only if:

$$\text{Head due to pressure rise in impeller} \geq H_m \quad \text{or} \quad \frac{u_2^2}{2g} - \frac{u_1^2}{2g} \geq H_m$$

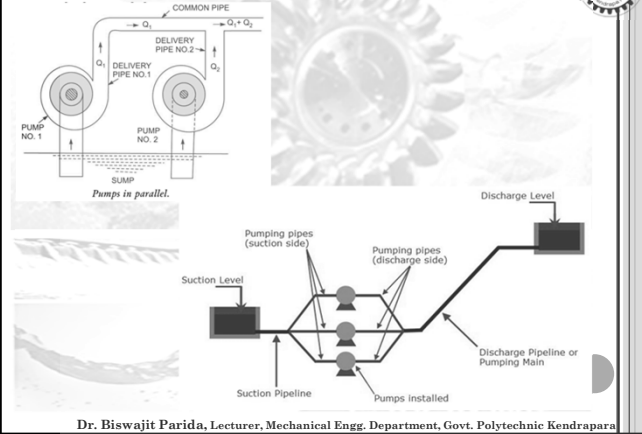
For minimum speed, we must have $\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = H_m$

$$\text{we have} \quad \eta_{man} = \frac{g H_m}{V_{w_2} u_2} \quad H_m = \eta_{man} \times \frac{V_{w_2} u_2}{g}$$

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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)



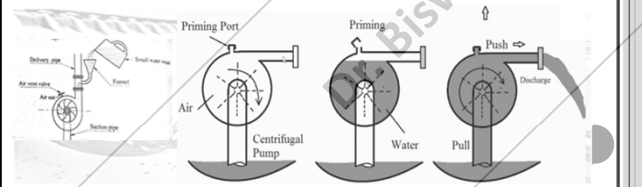
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Chapter-02: Centrifugal Pumps

CENTRIFUGAL PUMPS (CONTD...)

Priming

- It is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe upto to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump.
- The work done by the impeller for unit weight of liquid per second is known as the head generated by the pump $= (1/g) \sqrt{w_2} U_2$
- If the pump is primed with water, the head generated is same metre of water but if it will be the air which density is very low, the generated head of air in terms of equivalent metre of water head is negligible and hence water may not be sucked from the pump.



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Chapter-02: Centrifugal Pumps

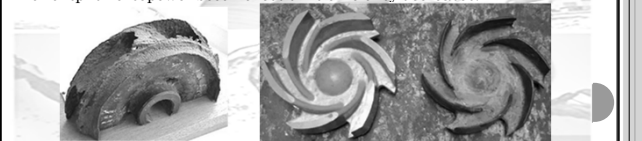
CENTRIFUGAL PUMPS (CONTD...)

Cavitation

- It is defined as the phenomenon of formation of vapour bubbles of a flowing fluid in a region where the pressure of the liquid falls below its vapour pressure (the liquid starts boiling and vapour bubbles are formed) and the sudden collapsing of these paper bubbles in the region of higher pressure and this cause pitting action on the surface.

Effects of Cavitation

- The metallic surfaces are damaged and cavities are formed on the surfaces.
- Due to sudden collapse of vapour bubble considerable noise and vibrations are produced.
- Due to pitting action, the surface of the turbine blades becomes rough and the force exerted by the water decreases. So the work done by water or output horsepower become less thus efficiency decreases.



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CHAPTER-03: RECIPROCATING PUMPS

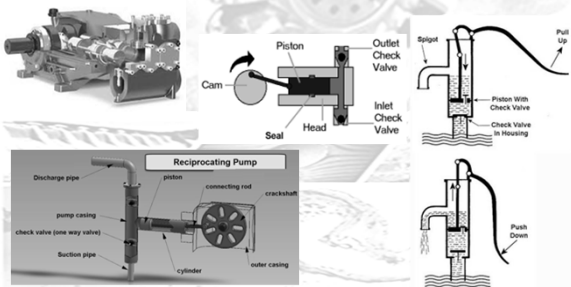


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Chapter-03: Reciprocating Pumps

RECIPROCATING PUMPS (CONTD...)

In this the mechanical energy is converted into hydraulic energy (or pressure energy) by sucking the liquid into a cylinder in which a piston is reciprocating (moving backwards and forwards), which exerts the thrust on the liquid and increases with hydraulic energy (pressure energy), the pump is known as reciprocating pump.

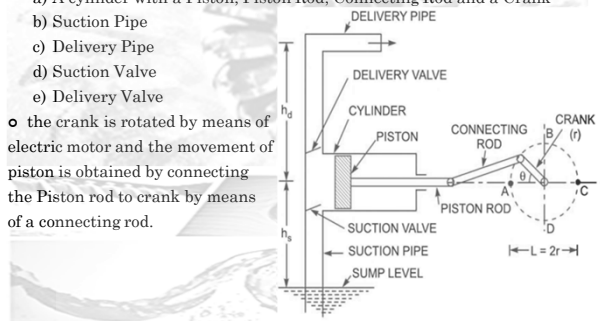


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RECIPROCATING PUMPS (CONTD...)

Working Principle

- o The main parts are
 - a) A cylinder with a Piston, Piston Rod, Connecting Rod and a Crank
 - b) Suction Pipe
 - c) Delivery Pipe
 - d) Suction Valve
 - e) Delivery Valve
- o the crank is rotated by means of electric motor and the movement of piston is obtained by connecting the Piston rod to crank by means of a connecting rod.

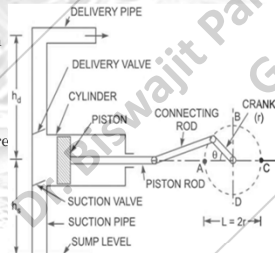


Main parts of a reciprocating pump.

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RECIPROCATING PUMPS (CONTD...)

- o When the crank is rotating from A to C (that is from $\theta = 0^\circ$ to 180°), the movement of the Piston towards right creates partial vacuum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting which is more than the pressure inside the cylinder due to which the liquid is forced in the suction pipe from the sump and opens the suction valve and enters the cylinder.
- o When crank is rotating from C to A (that is from $\theta = 180^\circ$ to 360°), the piston from its extreme right moves and this movement towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure
- o So the suction valve closes and delivery valve opens and the liquid is forced into the delivery pipe and is raised to the required height



Main parts of a reciprocating pump.

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RECIPROCATING PUMPS (CONTD...)

Discharge through a Single Acting Reciprocating Pump

Water acts on one side of the piston only.

Let D = Diameter of the cylinder

$$A = \text{Cross-sectional area of the piston or cylinder} = \frac{\pi}{4} D^2$$

r = Radius of crank

N = r.p.m. of the crank

L = Length of the stroke = $2 \times r$

h_s = Height of the axis of the cylinder from water surface in sump.

h_d = Height of delivery outlet above the cylinder axis (also called delivery head)

Volume of water delivered in one revolution or discharge of water in one revolution

$$= \text{Area} \times \text{Length of stroke} = A \times L$$

\therefore Discharge of the pump per second,

$$Q = \text{Discharge in one revolution} \times \text{No. of revolution per second}$$

$$= A \times L \times \frac{N}{60} = \frac{ALN}{60}$$

$$\text{Number of revolution per second,} = \frac{N}{60}$$

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RECIPROCATING PUMPS (CONTD...)

Work done by a Double Acting Reciprocating Pump

Work done per second = Weight of water delivered × Total height
 = $\rho g \times \text{Discharge per second} \times \text{Total height}$
 = $\rho g \times \frac{2ALN}{60} \times (h_s + h_d) = 2\rho g \times \frac{ALN}{60} \times (h_s + h_d)$

∴ Power required to drive the double-acting pump in kW,

$$P = \frac{\text{Work done per second}}{1000} = 2\rho g \times \frac{ALN}{60} \times \frac{(h_s + h_d)}{1000}$$

$$= \frac{2\rho g \times ALN \times (h_s + h_d)}{60,000}$$

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RECIPROCATING PUMPS (CONTD...)

Slip

The actual discharge of a pump is less than the theoretical discharge due to leakage, and this difference is known as the slip of the pump

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

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

$$= (1 - C_d) \times 100 \quad \left(\because \frac{Q_{act}}{Q_{th}} = C_d\right)$$

where C_d = Co-efficient of discharge.

Negative Slip

- If actual discharge is more than the theoretical discharge, the slip of the pump will become negative and in this case the slip of the pump is known as **Negative Slip**
- Negative slip occurs when delivery pipe is short, suction pipe is long pump is running at high speed.

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DISTINGUISH BETWEEN CENTRIFUGAL PUMPS AND RECIPROCATING PUMPS

Centrifugal Pumps	Reciprocating Pumps
the hydraulic machine which converts mechanical energy into pressure energy by means of centrifugal force acting on the fluid	which converts hydraulic energy into pressure energy by sucking liquid in a cylinder in which piston is reciprocate in
occupies less floor space	occupy six to eight times more floor space
easy installation	difficult
maintenance cost is less	more
requires priming	does not require priming
suitable for large discharge and small head	suitable for low discharge and high head

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THANK YOU



By
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CHAPTER-04: PNEUMATIC CONTROL SYSTEM



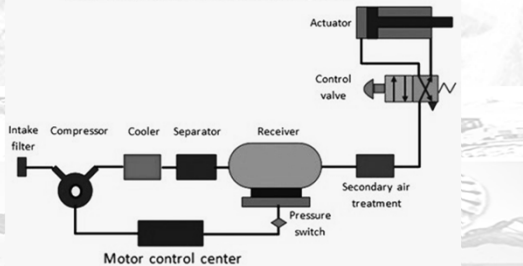
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Chapter-04: Pneumatic Control System

PNEUMATIC SYSTEM

- Pneumatic technology deals with the study of behavior and applications of compressed air in our daily life in general and manufacturing automation in particular.
- Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task

Main Components of a Pneumatic System

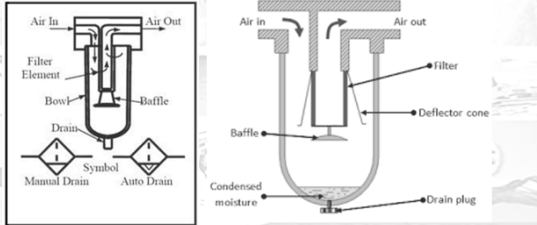


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COMPONENTS

a) Air filters:

- These are used to filter out the contaminants from the air.
- The intake filter channels either atmospheric air or an inert gas into the pneumatic system, filtering it of dust and other unwanted particles.
- At this stage the air has a low pressure to volume ratio.
- This will change as it progresses through the treatment system.



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COMPONENTS

b) Compressor:

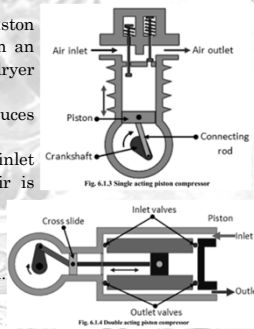
- Compressed air is generated by using air compressors.
- Air compressors are either diesel or electrically operated.
- Based on the requirement of compressed air, suitable capacity compressors may be used.
- It is a mechanical device which converts mechanical energy into fluid energy.
- The compressor increases the air pressure by reducing its volume which also increases the temperature of the compressed air.
- The compressor is selected based on the pressure it needs to operate and the delivery volume.
- There are several types of compressor, which operate under the principle of either positive displacement or dynamic displacement.

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COMPONENTS

Piston Compressor

- use a single acting or double acting piston to compress air and direct it through an outlet pipe into the cooler/separator/dryer unit.
- The single cylinder compressor produces one pulse of air per piston stroke.
- As the piston moves down during the inlet stroke the inlet valve opens and air is drawn into the cylinder.
- As the piston moves up the inlet valve closes and the exhaust valve opens which allows the air to be expelled.
- The valves are spring loaded.
- The single cylinder compressor gives significant amount of pressure pulses at the outlet port.
- The pressure developed is about 3-40 bar.



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COMPONENTS

Diaphragm compressors

- use a flexible rubber diaphragm in place of a piston to compress small quantities of air.
- These are used in sterile environments where contaminants from lubricating oil or piston surfaces may affect food, cosmetics or pharmaceuticals.
- The piston reciprocates by a motor driven crankshaft.
- As the piston moves down it pulls the hydraulic fluid down causing the diaphragm to move along and the air is sucked in.
- When the piston moves up the fluid pushes the diaphragm up causing the ejection of air from the outlet port.
- Since the flexible diaphragm is placed in between the piston and the air no contamination takes place.

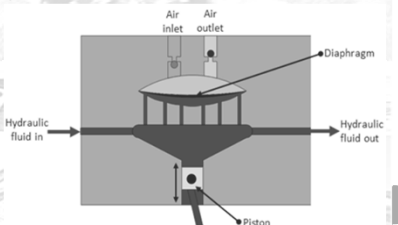


Fig. 6.2.1 Diaphragm compressor

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COMPONENTS

Screw Compressor

- It is simple in construction with less number of moving parts.
- The air delivered is steady with no pressure pulsation.
- It has two meshing screws.
- The air from the inlet is trapped between the meshing screws and is compressed.
- The contact between the two meshing surface is minimum, hence no cooling is required.
- These systems are quite in operation compared to piston type.
- The screws are synchronized by using external timing gears.
- Use a helical shaft to progressively compress air to high pressures.
- Useful when low to medium volumes of extremely compressed air are required.
- These compressors provide a continuous flow of compressed air, rather than the pulsating current characteristic of piston and diaphragm compressors.

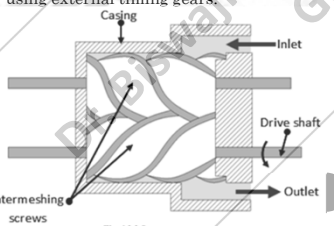


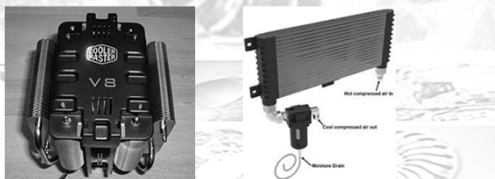
Fig. 6.2.2 Screw compressor

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COMPONENTS

c) Air Cooler:

- During compression operation, air temperature increases.
- Therefore coolers are used to reduce the temperature of the compressed air.
- Cooling units use a counter flow of air or water to extract and remove surplus heat from the compressed air.



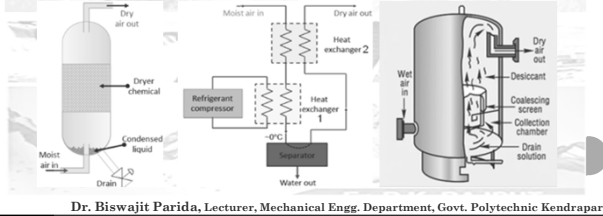
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Chapter-04: Pneumatic Control System

COMPONENTS

d) Separator & Dryer:

- o The Separator, or drying unit, purges the compressed air of excess water vapour and gaseous contaminants.
- o Dryers may use heat to drive off volatile components from the compressed gas, or chemical absorption (e.g. phosphoric pentoxide, calcium chloride or silicon dioxide).
- o Some systems use refrigerant compressors to remove moisture from the compressed air.
- o The pure, dry compressed air is channelled into the receiver tank, sometimes after further filtration, while the moist, contaminated air is condensed to liquid form and expelled through a drain.



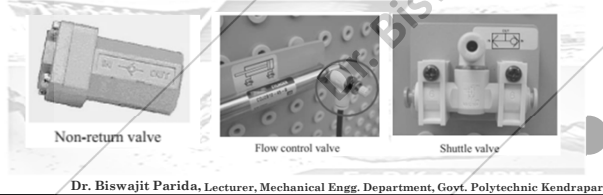
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Chapter-04: Pneumatic Control System

COMPONENTS

e) Control Valves:

- o Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.
- o The compressed gas as it enters the control valve to the actuator has a high pressure to volume ratio.
- o The control valve, or regulator, feeds the gas into the actuator to control its speed and movements.
- o Movement is achieved through motor displacement, so the purpose of the control valve is to moderate the flow rate and pump volume as the compressed air leaves the receiver tank.
- o This is achieved through a series of stop valves, controlled by flow transducers, proximity sensors and pressure gauges.



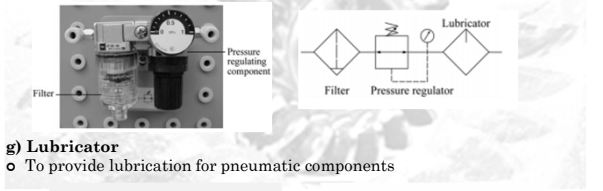
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Chapter-04: Pneumatic Control System

COMPONENTS

f) Pressure regulator components:

- o to stabilise the pressure and regulate the operation of pneumatic



g) Lubricator

- o To provide lubrication for pneumatic components



h) Electric Motor:

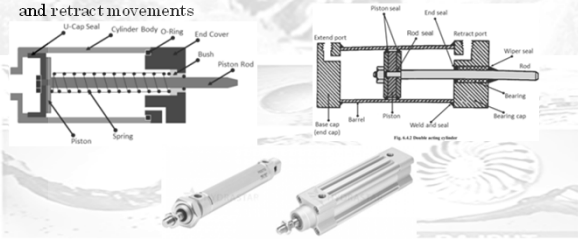
- o Transforms electrical energy into mechanical energy.
- o It is used to drive the compressor.

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COMPONENTS

i) Air Actuator:

- o Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system
- o The actuator is a pneumatic motor that generates outward force through unequal pressure in a pneumatic cylinder, often connected to a piston rod mechanism.
- o A single acting pneumatic cylinder exerts a unidirectional outward force when the cylinder is pressurised.
- o In a double acting cylinder, compressed gas is required for both outward and retract movements

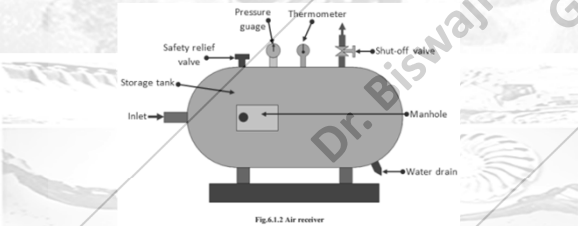


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COMPONENTS

j) Receiver Tank:

- o As pneumatic systems depend on a continuous supply of compressed air/gas, this fluid must be stored in a receiver tank.
- o The large internal surface area of the receiver tank further helps to dissipate excess heat while maintaining the required pressure.
- o Compressed air is fed into the control valve by an exit pipe linked to a shut-off valve.
- o As the pressure drops in the receiver tank the change is detected by pressure sensors at the inlet valve, which opens to refresh the tank.



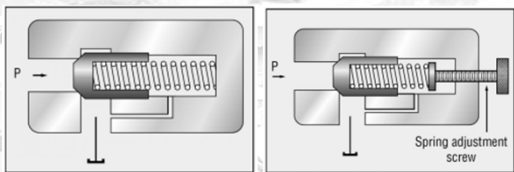
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PRESSURE CONTROL VALVE

Pressure control valves control the pressure of the air flowing through the valve or confined in the system controlled by the valve.

There are three types of pressure control valves

- o Pressure limiting valve
- o Pressure sequence valve
- o Pressure regulator or pressure reducing valve

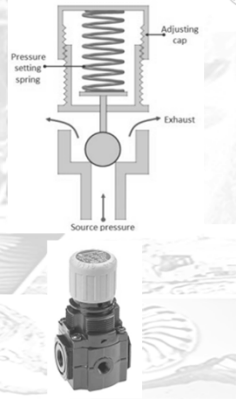


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PRESSURE RELIEF VALVES

- o Relief valve is the simplest type of pressure regulating device.
- o It is used as a backup device if the main pressure control fails.
- o It consists of ball type valve held on to the valve seat by a spring in tension. The spring tension can be adjusted by using the adjusting cap.
- o When the air pressure exceeds the spring tension pressure the ball is displaced from its seat, thus releasing the air and reducing the pressure.
- o A relief is specified by its span of pressure between the cracking and full flow, pressure range and flow rate.
- o Once the valve opens (cracking pressure), flow rate depends on the excess pressure.
- o Once the pressure falls below the cracking pressure, the valve seals itself.

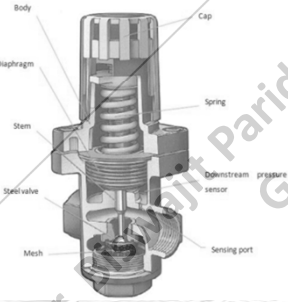


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PRESSURE REGULATION VALVES

- o Pressure regulators maintain constant output pressure in compressed-air systems regardless of variations in input pressure or output flow.
- o Regulators are a special class of valve containing integral loading, sensing, actuating, and control components.
- o They can be broadly classified as general purpose, special purpose, or precision.
- o **General-purpose or Utility Regulators** have flow and regulation characteristics that meet the requirements of most industrial compressed-air applications.
- o Such regulators provide long service life and relative ease of maintenance at competitive prices.



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PRESSURE REGULATION VALVES

- o **Precision Regulators** are for applications where regulated pressure must be controlled with close tolerances.
- o Such regulators are used when the outcome of a process or the results of a test depend on accurate pressure control.
- o **Special-purpose Regulators** often have a unique configuration or special materials for use with fluids other than compressed air.
- o Regulator construction can range from simple to complex, depending on the intended application and the performance requirements.



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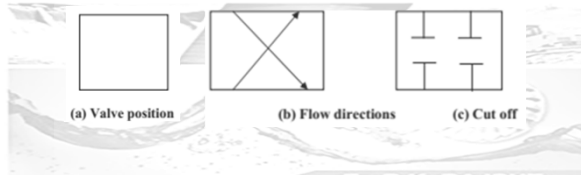
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DIRECTION CONTROL VALVE

- o The primary function of a Direction control valve (DCV) is to direct the fluid flow through the desired passages whenever required.
- o These flow of the fluid is then used to actuate the hydraulic cylinder of the position or reciprocate the other components in hydraulic system.

Valve Ports and Positions

- o A DCV has number of openings known as ports.
- o It different permutations of flow between its various ports. Thus these ports give different ways for the flow of fluid through the valve.
- o Number of permutations of flow offered by DCV are termed as 'Positions of valve'.

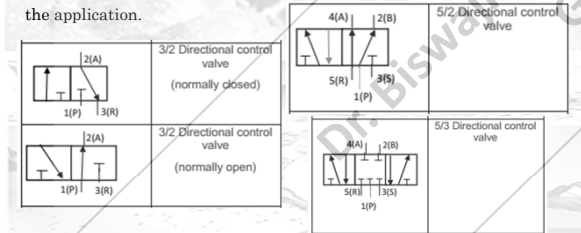


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DIRECTION CONTROL VALVE

- o A typical direction control valve has one normal position and two or here working positions.
- o **Normal position:** It is also known as zero position or neutral position. The neutral position is defined as the position to which the valve returns after the actuating force has been withdrawn. In all fluid power control systems, the neutral position is indicated as "0".
- o **Working position:** These are the position obtained with help of he actuating force. These positions are designed as per the requirement of the application.



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3/2 DCV - 3 PORT 2 WAY

- o We have a 3 port 2 way valve (3 ports and 2 possible positions) in its initial position.
- o Compressed air is connected to **port1**, **port2** is connected to the inlet port of the actuator and **port3** is the exhaust or outlet.
- o In its initial state port1 is closed, the piston is retracted under the pressure of the spring and any air in the actuator is forced out through to **port2** which in turn is connected to the exhaust **port3** and out to the atmosphere.
- o When the pushbutton is pressed and the valve is activated, **port1** is now connected to **port2** and to the inlet port on the actuator forcing the piston/rod out under the air pressure from the compressor. At this stage the exhaust **port3** is closed.
- o It will remain in this state until the pushbutton is released when it returns to its initial position. .



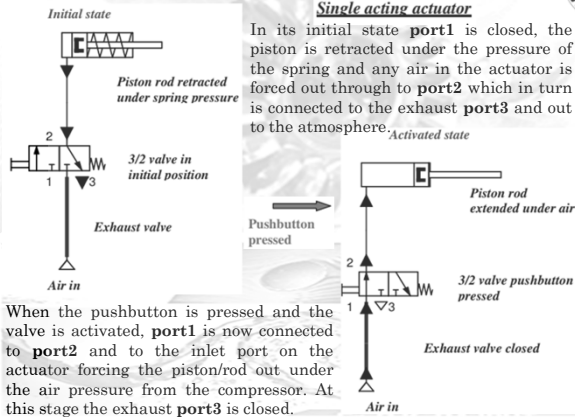
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3/2 DCV

Single acting actuator

In its initial state **port1** is closed, the piston is retracted under the pressure of the spring and any air in the actuator is forced out through to **port2** which in turn is connected to the exhaust **port3** and out to the atmosphere.



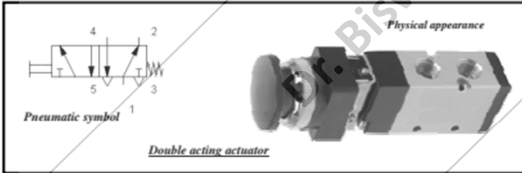
When the pushbutton is pressed and the valve is activated, **port1** is now connected to **port2** and to the inlet port on the actuator forcing the piston/rod out under the air pressure from the compressor. At this stage the exhaust **port3** is closed.

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5/2 DCV - 5 PORT 2 WAY

- A 5/2 pneumatic valve (5 ports, 2 possible positions) firstly in its initial position and then activated.
- Compressed air entering port 1 exits at port 2 retracting the piston rod, air exhausts through port 5 as shown in the diagram initial position.
- On pushing the button the valve changes over, compressed air still enters port 1 but now it exits at port 3 and the piston rod is extended as shown in the activated position.
- On releasing the button it returns to its initial position.

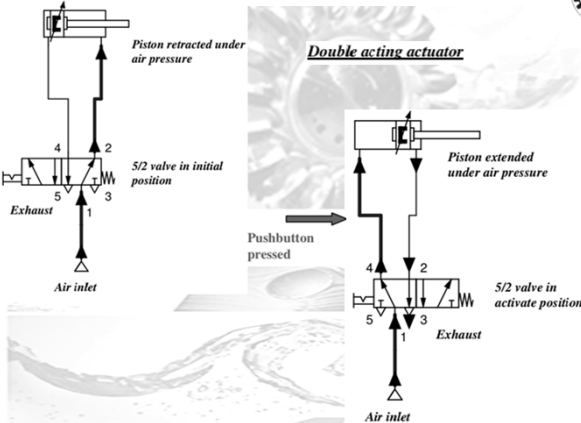


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5/2 DCV

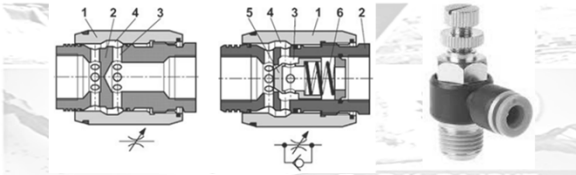
Double acting actuator



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THROTTLE VALVES

- The throttle valves are used to restrict the fluid flow in both directions while the throttle-check valves restrict the flow in one direction only.
- They consist of an adjustment sleeve (1) and an inner housing (2).
- The throttle valve restricts the flow in both directions.
- The fluid flows through the radial drillings (3) to the throttling area (4), which is defined by the inner housing (2) and the adjustment sleeve (1).
- The valve restriction area is controlled by turning the adjustment sleeve (1).

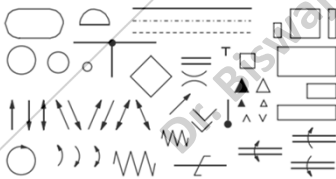


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ISO SYMBOLS

Shapes

- These shapes and lines in the relative proportions shown, make up a set of basic symbols from which fluid power symbols and circuits are constructed



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ISO SYMBOLS

Basic Symbols (shapes)

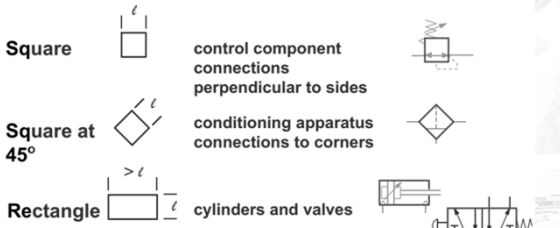
- Symbol sets can be drawn to any size but their scale and relative proportions are determined by a basic dimension of your choice "l"

Circles		energy conversion units	
		measuring instrument	
		mechanical link	
		roller	

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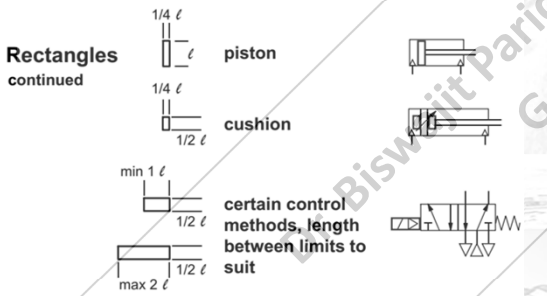
Basic Symbols (shapes)



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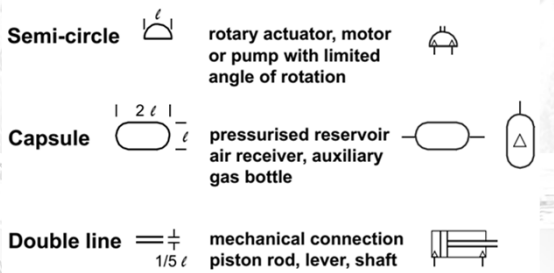
Basic Symbols (shapes)



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Basic Symbols



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Basic Symbols

Line		Working line, pilot supply, return, electrical	
Dashed		Pilot control, bleed, filter	
Chain		Enclosure of two or more functions in one unit	
Line		Electrical line	

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Functional Elements

Triangle		Direction and nature of fluid, open pneumatic or filled hydraulic	
Spring		size to suit	
Arrow		Long sloping indicates adjustability	

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





Functional Elements


Arrows		Straight or sloping path and flow direction, or motion	
Tee		Closed path or port	
Restriction		Size to suit	

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Functional Elements


Curved arrows  rotary motion

Shaft rotation  clockwise from right hand end
 anti-clockwise from right hand end
 both


Seating  90° angle 

Flowlines


Junction  Single




Junction  Four way junction

Crossing  not connected

Flexible line  Hose usually connecting parts with relative movement

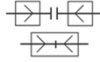
Connections

Air bleed **Continuous** 
Temporary by probe 

Air exhaust  **No means of connection** 
With means of connection 

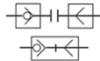
Connections

Coupling quick release



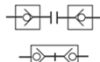
Both to exhaust

Coupling quick release self sealing



Source sealed

Coupling quick release self sealing



Both sealed

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Connections

Rotary connection one line



Rotary connection two lines



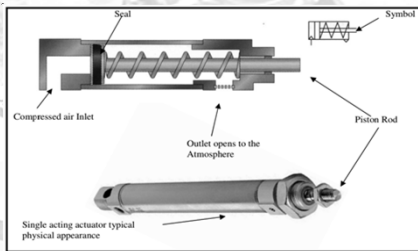
Rotary connection three lines



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Direct Control of Single Acting Cylinders

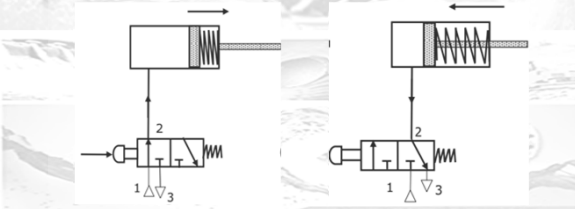
- Pneumatic cylinders can be directly controlled by actuation of final directional control valve.
- These valves can be controlled manually or electrically.
- This circuit can be used for small cylinders as well as cylinders which operates at low speeds where the flow rate requirements are less.



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PNEUMATIC CIRCUITS

- When the directional control valve is actuated by push button, the valve switches over to the open position, communicating working source to the cylinder volume. This results in the forward motion of the piston.
- When the push button is released, the reset spring of the valve restores the valve to the initial position [closed].
- The cylinder space is connected to exhaust port there by piston retracts either due to spring or supply pressure applied from the other port.

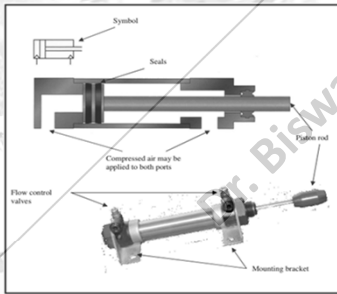


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PNEUMATIC CIRCUITS

Operation of Double Acting Cylinders

- These actuator use compressed air on both the outstroke and the in-stroke.
- Therefore they are useful for pushing and pulling operations.
- Speed control may be achieved by fitting flow control valves to the actuator.

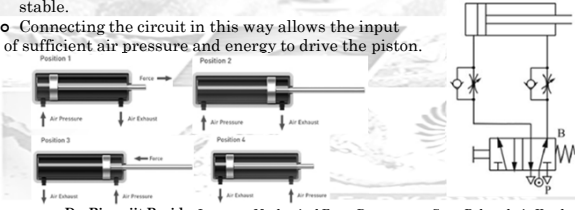


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PNEUMATIC CIRCUITS

Operation of Double Acting Cylinders

- A double acting cylinder is uses a 5/2 directional control valve
- Usually, when a double acting cylinder is not operated, outlet 'B' and inlet 'P' will be connected.
- In this circuit, whenever the operation button is pushed manually, the double acting cylinder will move back and forth once
- In order to control the speed in both directions, flow control valves are connected to the inlets on both sides of the cylinder.
- The direction of the flow control valve is opposite to that of the release of air by the flow control valve of the single acting cylinder.
- Compared to the throttle inlet, the flow control valve is tougher and more stable.
- Connecting the circuit in this way allows the input of sufficient air pressure and energy to drive the piston.

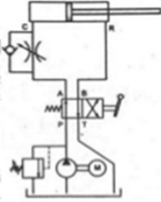


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PNEUMATIC CIRCUITS

Operation of Double Acting Cylinder with METERING IN control

- It consists of manually operated D.C. valve, a flow control valve.
- A flow control valve is placed in the pressure line such that the air flow rate is regulated as the air enters the blank end of double acting cylinder to perform forward stroke.
- When the spool is shifted to its left envelope mode the air from FRL unit is directed to enter the blank end of cylinder through flow control valve where the air flow rate is controlled to control the forward stroke of piston in the cylinder.
- The air from the other side of the piston is discharged out into the atmosphere.
- When the spool is shifted to right envelope mode the air enters the rod end of cylinder and acts on piston to perform return stroke quickly.
- The air from other side of piston is discharged out freely into the atmosphere through the check valve.

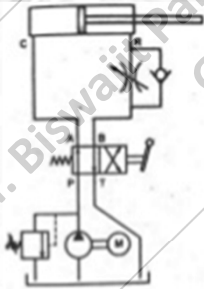


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PNEUMATIC CIRCUITS

Operation of Double Acting Cylinder with METERING OUT control

- It uses the flow control valve to control the rate of piston movement on the outstroke of machine
- It consists of pneumatic power unit, manually operated D.C. valve, flow control valve
- When spool is in its left envelope mode the air from FRL unit enters the blind end of cylinder and acts on the piston to perform forward stroke.
- The air from other end of cylinder is allowed to pass through a flow control valve to regulate the outstroke speed of piston.
- When the spool is in right envelope mode the piston retracts quickly.

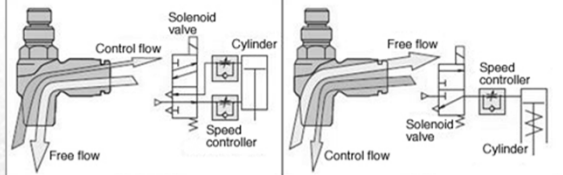


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PNEUMATIC CIRCUITS

Meter-out control

Meter-in control



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THANK YOU



By
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CHAPTER-05: HYDRAULIC CONTROL SYSTEM

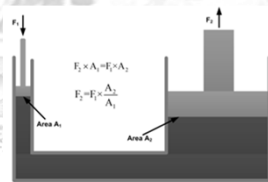


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Chapter-05: Hydraulic Control System

HYDRAULIC SYSTEMS

- The word "hydraulics" generally refers to power produced by moving liquids.
- Modern hydraulics is defined as the use of confined liquid to transmit power, multiply force, or produce motion.
- Hydraulic systems are used for transmission of power through the medium of hydraulic oil. The hydraulic system works on the principle of Pascal's law which says that "the pressure in a fluid at rest is transmitted uniformly in all directions".
- The force given by fluid is given by the multiplication of pressure and area of cross section.
- As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force.
- Therefore, a large force can be generated with smaller force input by using hydraulic systems.

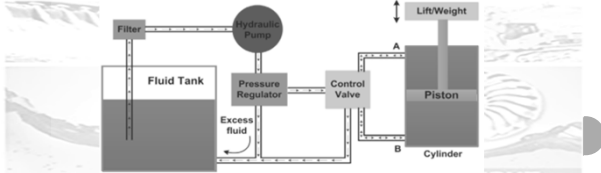


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HYDRAULIC SYSTEMS

A simple hydraulic system consists of:

- o **Movable piston** connected to the output shaft in an enclosed cylinder
- o **Storage Tank** containing hydraulic fluid
- o **Filter** which is in suction line of pump inside the tank or on tank inlet line.
- o **Electric motor / Diesel** or petrol engine which is the primary source of power
- o **Hydraulic pump** driven by motor or engine
- o **Pressure control valve**
- o **Leak proof closed loop piping.**
- o **Direction control valve** which controls the direction of fluid flow so as to change the direction of motion of a linear or rotary actuator
- o **Actuator** – A cylinder for linear movement or a hydraulic motor for rotary actuation of load



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HYDRAULIC SYSTEMS

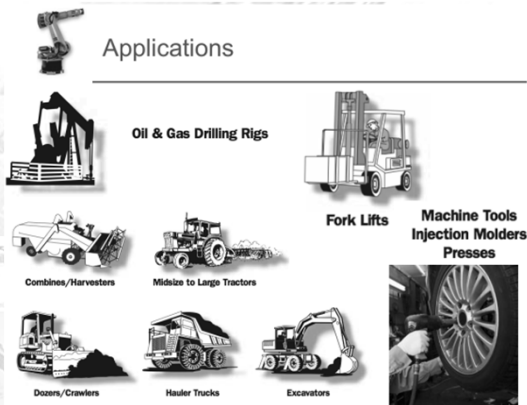
Applications

- o **Industrial:** Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushers, textile machineries, R & D equipment and robotic systems etc.
- o **Mobile hydraulics:** Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building and construction machineries and drilling rigs etc.
- o **Automobiles:** brakes, shock absorbers, steering system, wind shield, lift and cleaning etc.
- o **Marine applications:** Controls in ocean going vessels, fishing boats and navel equipment.
- o **Aerospace equipment:** R udder control, landing gear, breaks, flight control and transmission, rocket motor movement

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HYDRAULIC SYSTEMS

Applications



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HYDRAULIC SYSTEMS

Merits

- o High power to weight ratio compared to electrical systems
- o Allows easy control of speed and position, and direction
- o Facilitates step-less power control
- o Allows combination with electric controls
- o Delivers consistent power output which is difficult in pneumatic or mechanical drive systems
- o Performs well in hot environment conditions

Demerits

- o **Material** of storage tank, piping, cylinder and piston can be corroded with the hydraulic fluid. Therefore one must be careful while selecting materials and hydraulic fluid.
- o Structural **weight** and size of the system is more which makes it unsuitable for the smaller instruments.
- o Small **impurities** in the hydraulic fluid can permanently damage the complete system. Therefore suitable filter must be installed.
- o **Leakage** of hydraulic fluid is also a critical issue and suitable prevention method and seals must be adopted.
- o Hydraulic fluids, if not disposed properly, can be harmful to the **environment**.

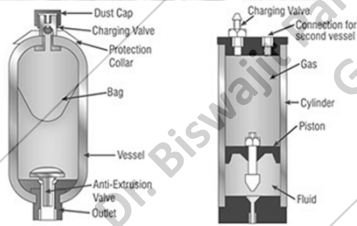
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HYDRAULIC ACCUMULATORS

- o These are used to supply additional fluid when main line fluid pump is inadequate to perform the actuation.
- o Usually gas filled bladders at high pressure act on the reservoir of fluid in the accumulator to make up for the required line flow.

Accumulators are used

- o to accommodate large flow rates or to compensate leakages.
- o Absorb pulsations and reducing noise
- o To absorb shocks

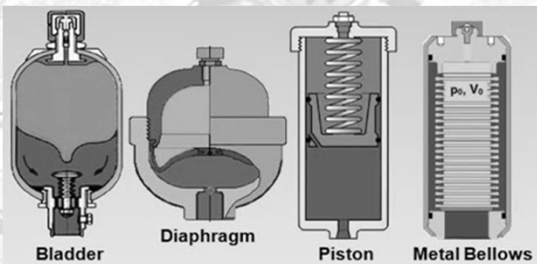


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HYDRAULIC ACCUMULATORS

Types

- 1) **Bladder type:** Separates gas from oil by a rubber bladder
- 2) **Diaphragm type:** Sometimes used as a small accumulator
- 3) **Piston type:** Shaped as a cylinder without a rod
- 4) **Spring type, weight loaded type**



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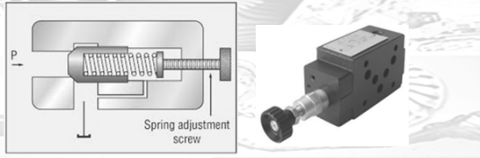
Chapter-05: Hydraulic Control System

PRESSURE CONTROL VALVES

These valves are used in hydraulic systems to control actuator force ($\text{Force} = \text{Pressure} \times \text{Area}$) and to determine and select pressure levels at which certain machine operations must occur.

Functions:

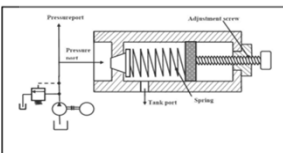
- Limiting maximum system pressure at a safe level.
- Regulating/reducing pressure in certain portions of the circuit.
- Unloading system pressure.
- Assisting sequential operation of actuators in a circuit with pressure control.
- Any other pressure-related function by virtue of pressure control.
- Reducing or stepping down pressure levels from the main circuit to a lower pressure in a sub-circuit.



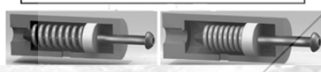
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Chapter-05: Hydraulic Control System

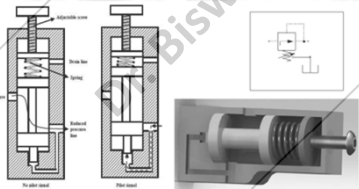
PRESSURE CONTROL VALVES



Pressure-Relief valve.



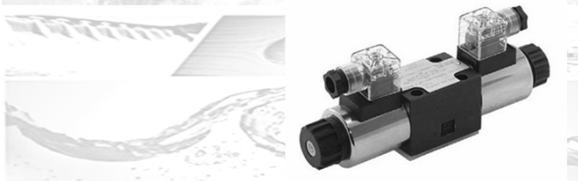
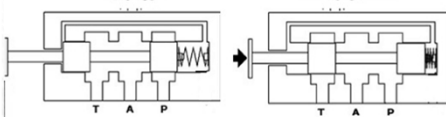
Pressure-Regulation valve.



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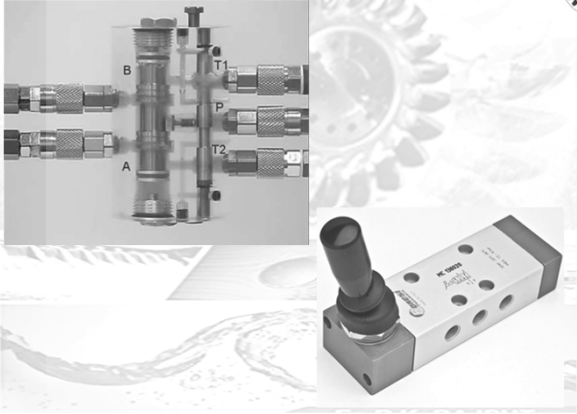
Chapter-05: Hydraulic Control System

3/2 DIRECTION CONTROL VALVES



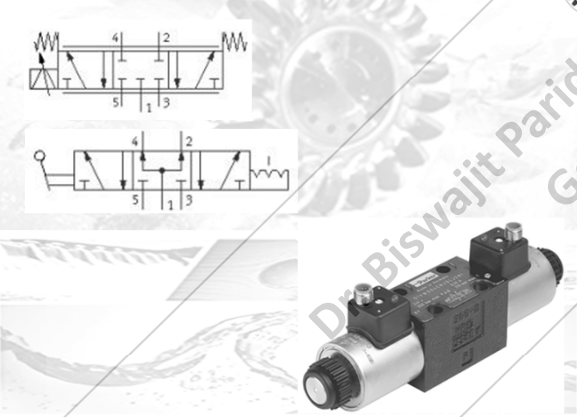
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5/2 DIRECTION CONTROL VALVES



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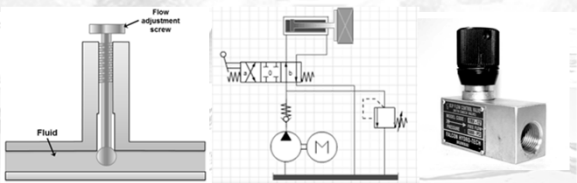
5/3 DIRECTION CONTROL VALVES



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FLOW CONTROL VALVES

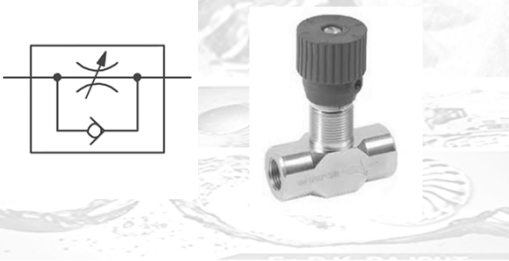
- o In practice, the speed of actuator is very important in terms of the desired output and needs to be controlled.
- o The speed of actuator can be controlled by regulating the fluid flow.
- o A flow control valve can regulate the flow or pressure of the fluid.
- o The fluid flow is controlled by varying area of the valve opening through which fluid passes.
- o The fluid flow can be decreased by reducing the area of the valve opening and it can be increased by increasing the area of the valve opening..



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THROTTLE VALVES

- Throttling valves are a type of valve that can be used to start, stop and regulate the flow of fluid through a rotodynamic pump.
- Throttling valves are one way of controlling flow rates, by throttling flow directly or in a bypass line.
- Variable speed operation is an alternative method of controlling the flow of a system.



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FLUID POWER PUMPS

- The pump converts the mechanical energy of its prime-mover to hydraulic energy by delivering a given quantity of hydraulic fluid at high pressure into the system.

Generally, all pumps are divided into two categories, namely,

1 - Hydrodynamic or Non-positive Displacement (In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstanding high pressures and generally used for low-pressure and high-volume flow applications. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load) because some of the fluid slip back at higher resistance) and

2 - Hydrostatic or Positive Displacement (These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed).

Hydraulic systems generally employ positive displacement pumps only.



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GEAR PUMPS

- Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes.
- These gears are the only moving parts in the pump.
- They are compact, relatively inexpensive and have few moving parts.
- Gear pumps are most commonly used for the hydraulic fluid power applications and are also widely used in chemical industries

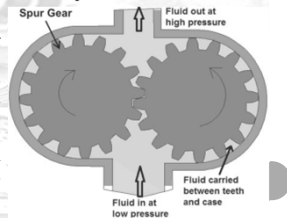
Based upon the design, the gear pumps are classified as:

- External gear pumps
- Lobe pumps
- Internal gear pumps
- Gerotor pumps

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EXTERNAL GEAR PUMPS

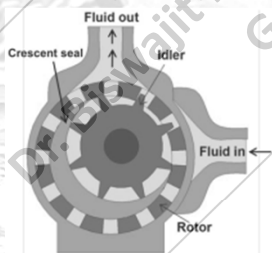
- The external gear pump consists of externally meshed two gears housed in a pump case.
- One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear.
- The rotating gear carries the fluid from the tank to the outlet pipe.
- The suction side is towards the portion whereas the gear teeth come out of the mesh.
- When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value.
- Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure.
- The fluid is trapped between housing and rotating teeth of the gears.
- The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth.
- The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port.



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INTERNAL GEAR PUMPS

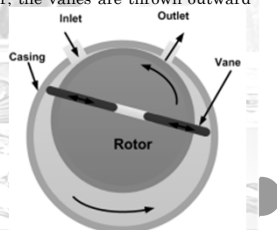
- Internal gear pumps are exceptionally versatile.
- They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature.
- This is nonpulsing, self-priming and can run dry for short periods.
- It is a variation of the basic gear pump.
- It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing.
- Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth.
- Liquid travels through the pump between the teeth and crescent.
- Crescent divides the liquid and acts as a seal between the suction and discharge ports.
- When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump



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VANE PUMPS

- Gear pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps.
- The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports.
- The rotor in a vane pump is connected to the prime mover through a shaft and the vanes are located on the slotted rotor.
- The rotor is eccentrically placed inside a cam ring and is sealed into the cam by two side plates.
- When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force.
- The vanes track along the ring and provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force.
- This produces a suction cavity in the ring as the rotor rotates and creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet.



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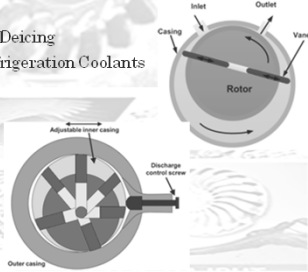
Chapter-05: Hydraulic Control System

VANE PUMPS

- The fluid is carried around to the outlet by the vanes whose retraction causes the fluid to be expelled.
- The capacity of the pump depends upon the eccentricity, expansion of vanes, width of vanes and speed of the rotor. It can be noted that the fluid flow will not occur when the eccentricity is zero.

These pumps have various applications for the pumping of following fluids:

- Aerosol and Propellants
- Aviation Service - Fuel Transfer, Deicing
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH₃
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freons, Ammonia
- Solvents
- Aqueous solutions



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Chapter-05: Hydraulic Control System

PISTON PUMPS

- Piston pumps are meant for the high-pressure applications.
- These pumps have high efficiency and simple design and needs lower maintenance.
- These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston.
- These pumps work similar to the four stroke engines.
- They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends.

Piston pumps are basically of two

- i. Axial piston pumps
- ii. Radial piston pumps

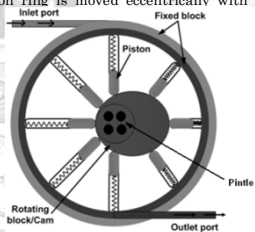


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Chapter-05: Hydraulic Control System

RADIAL PISTON PUMPS

- The piston pump has pistons aligned radially in a cylindrical block which consists of a pintle, a cylinder barrel with pistons and a rotor containing a reaction ring.
- The pintle directs the fluid in and out of the cylinder.
- Pistons are placed in radial bores around the rotor and the piston shoes ride on an eccentric ring which causes them to reciprocate as they rotate.
- The eccentricity determines the stroke of the pumping piston.
- Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting.
- This connection to the inlet and outlet port is performed by the timed porting arrangement in the pintle.
- For initiating a pumping action, the reaction ring is moved eccentrically with respect to the pintle or shaft axis.
- As the cylinder barrel rotates, the pistons on one side travel outward.
- This draws the fluid in as the cylinder passes the suction port of the pintle and it is continued till the maximum eccentricity is reached.
- When the piston passes the maximum eccentricity, pintle is forced inwards by the reaction ring.
- This forces the fluid to flow out of the cylinder and enter in the discharge (outlet) port of the pintle.



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Chapter-05: Hydraulic Control System

ISO SYMBOLS

PRESSURE CONTROL VALVES		
	Pressure relief valve	
	Direct operated	
	Pilot operated	
	Sequence valve	
	Direct operated	
	Pilot operated	
	Pressure reducing valve	
	Direct operated	
	Pilot operated	
	Counterpressure valve	

ENERGY TRANSMISSION AND ACCESSORIES		
Graphic symbol	Item	Description
	Motor	Electric
		Engine
	Pipings and connections	Main
		Pilot
		Drain
		Flexible hose
	Connection point	
	Crossing	

Graphic symbol	Item	Description
	Branching	Closed
		With connected piping
	Coupling	Fast coupling
		With check valves

Graphic symbol	Item	Description
	Reservoir	Pipings above level
		Pipings under level
	Pressurized reservoir	

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Chapter-05: Hydraulic Control System

ISO SYMBOLS

Graphic symbol	Item	Description
(a) (b)	Spool position sensor on-off	Mechanical microswitch (a)
		Inductive proximity sensor (b)
	Hydraulic accumulator	
	Filter	
	Heat exchanger	Heater
		Cooler
		Liquid operated cooler

Graphic symbol	Item	Description
	Pressure gauge	
	Pressure switch	
	Rotating shaft	1 direction
		2 directions

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Chapter-05: Hydraulic Control System

ACTUATORS

- Hydraulic Actuators, as used in industrial process control, employ hydraulic pressure to drive an output member.
- These are used where high speed and large forces are required.
- The fluid used in hydraulic actuator is highly incompressible so that pressure applied can be transmitted instantaneously to the member attached to it.

Principle Used in Hydraulic Actuator System

Pascal's Law

- Pressure applied to a confined fluid at any point is transmitted undiminished and equally throughout the fluid in all directions and acts upon every part of the confining vessel at right angles to its interior surfaces.

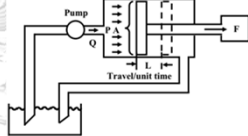
Amplification of Force

- Since pressure P applied on an area A gives rise to a force F, given as,

$$F = P \times A$$

Conservation of Energy

Since energy or power is always conserved, amplification in force must result in reduction of the fluid velocity.



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ACTUATORS

Components of Hydraulic Actuation Systems

Hydraulic Fluid

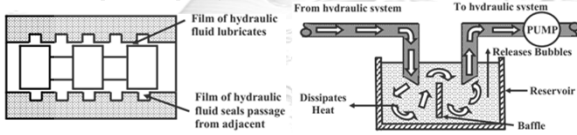
- Hydraulic fluid must be essentially non-compressible to be able to transmit power instantaneously from one part of the system to another.
- At the same time, it should lubricate the moving parts to reduce friction loss and cool the components so that the heat generated does not lead to fire hazards.
- It also helps in removing the contaminants to filter.

The Fluid Delivery Subsystem

- It consists of the components that hold and carry the fluid from the pump to the actuator. It is made up of the following components.

Reservoir

- It holds the hydraulic fluid to be circulated and allows air entrapped in the fluid to escape.
- It also helps in dissipating heat.



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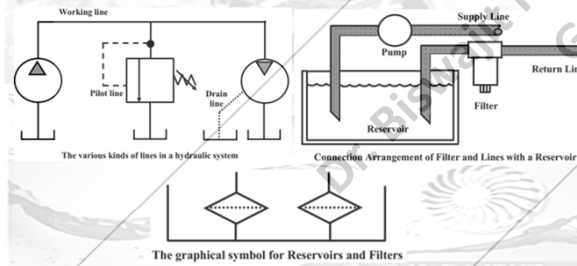
ACTUATORS

Filter

- The hydraulic fluid is kept clean in the system with the help of filters and strainers.
- It removes minute particles from the fluid, which can cause blocking of the orifices of servo-valves or cause jamming of spools.

Line

- Pipe, tubes and hoses, along with the fittings or connectors, constitute the conducting lines that carry hydraulic fluid between components.



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ACTUATORS

Fittings and Seals

- Various additional components are needed to join pipe or tube sections, create bends and also to prevent internal and external leakage in hydraulic systems.

Hydraulic Pumps

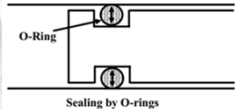
- The pump.....
- already discussed.....

Motors

- Motors work exactly on the reverse principle of pumps.
- In motors fluid is forced into the motor from pump outlets at high pressure.
- This fluid pressure creates the motion of the motor shaft and finally go out through the motor outlet port and return to tank.
- All three variants of motors, already discussed for pumps, namely Gear Motors, Vane Motors and Piston motors are in use....

Accumulators

- An accumulator in a hydraulic system provides a means of storing these incompressible fluids under pressure created either by a spring, compressed a gas.
- already discussed

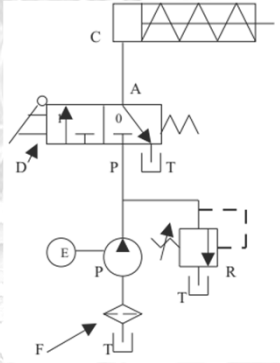


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HYDRAULIC CIRCUITS

Direct Control of Single Acting Cylinders

- C = Single acting cylinder
- P = Pump
- E = Electric Motor
- T = Tank
- F = Filter
- R = Relief Valve
- D = 2-position, 3 way DCV
- Manually operated and spring return



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HYDRAULIC CIRCUITS

Operation of Double Acting Cylinders

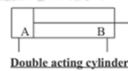
- o Double -Acting cylinders can be extended and retracted hydraulically. Thus, an output force can be applied in two directions.
- o During the extension stroke, fluid enters the blank end (A) of the cylinder through the entire circular area of the piston (A_p).
- o However during the retraction stroke, fluid enters the rod end through the smaller annular area between the rod and cylinder bore ($A_p - A_r$), where A_p = piston area, and A_r = rod area. Since A_p is greater than ($A_p - A_r$), the retraction velocity is greater than the extension velocity since the pump flow rate is constant..

Extending stroke :

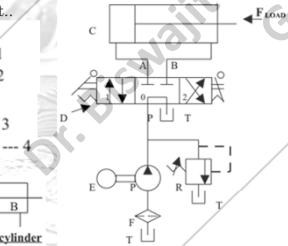
Force, $F_{ext} = p \cdot A_p$ ----- 1
 Velocity, $v_{ext} = Q_p / A_p$ ----- 2

Retraction Stroke :

Force, $F_{ret} = p \cdot (A_p - A_r)$ --- 3
 Velocity, $v_{ret} = Q_p / (A_p - A_r)$ --- 4



Double acting cylinder



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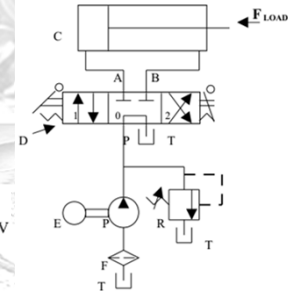
HYDRAULIC CIRCUITS

Operation of Double Acting Cylinders

- o The power developed by a hydraulic cylinder for either the extension or retraction stroke, can be found out by (velocity multiplied by force) or from (flow rate multiplied by operating pressure).
- Power (kW) = v_p (m / s) • F (kN) = Q (m³ / s) • p (kPa)

- C = Double acting cylinder
- P = Pump
- E = Electric Motor
- T = Tank
- F = Filter
- R = Relief Valve

D = 3-position, 4 way ,Tandem center,
 Manually operated and Spring Centered DCV

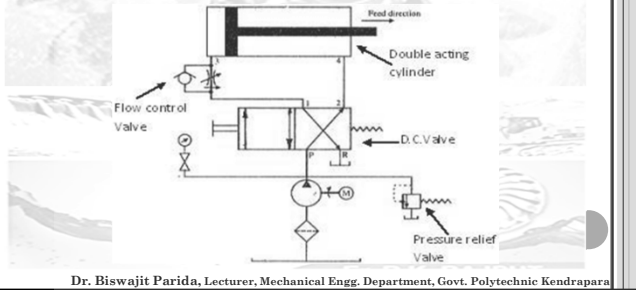


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HYDRAULIC CIRCUITS

Operation of Double Acting Cylinder with METERING IN control

- o In this flow control valve is connected between the D.C valve and blind end of the cylinder.
- o Here metered fluid enters the cylinder which controls the speed and feed of the piston.
- o When D.C. valve is manually shifted to right side the flow from pump passes through the compensated flow control valve into blind end of cylinder and the exhaust fluid is directed freely to the reservoir.

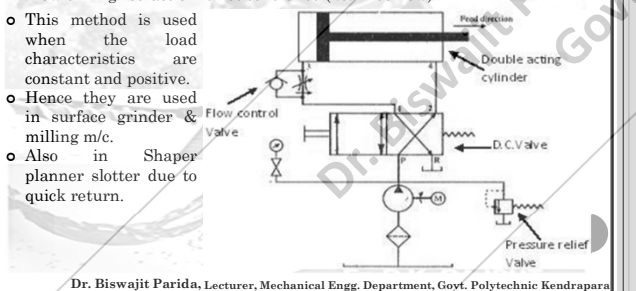


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HYDRAULIC CIRCUITS

Operation of Double Acting Cylinder with METERING IN control

- o When the force on D.C. valve is released, it permits the spool to return due to valve spring and the pump flow is directed to the rod end of the cylinder.
- o The fluid from blind end of the cylinder will pass through the integral check valve in the flow control mechanism and the piston can be retracted rapidly to its initial position.
- o Flow during retraction is not controlled (i.e. Free flow)
- o This method is used when the load characteristics are constant and positive.
- o Hence they are used in surface grinder & milling m/c.
- o Also in Shaper planner slotter due to quick return.

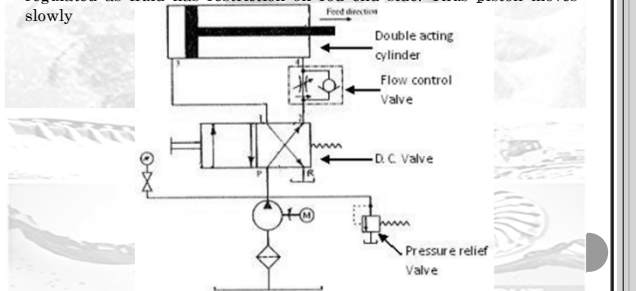


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HYDRAULIC CIRCUITS

Operation of Double Acting Cylinder with METERING OUT control

- o In this flow control valve is located between D.C. valve and rod end of cylinder in such a way that the fluid is metered as it leaves the cylinder.
- o When D.C. valve is manually shifted to right side the flow from pump passes to blind end of cylinder and the exhaust fluid is directed through flow control valve to the reservoir. Due to this the movement of piston is regulated as fluid has restriction on rod end side. Thus piston moves slowly

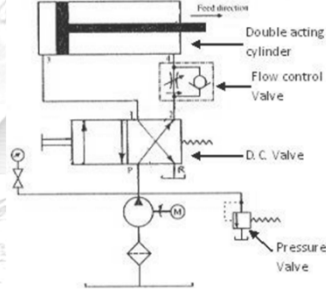


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HYDRAULIC CIRCUITS

Operation of Double Acting Cylinder with METERING OUT control

- o When the force on D.C. valve is released, it permits the spool to return due to valve spring and the pump flow is directed to the rod end of the cylinder through integral check valve in the flow control mechanism.
- o The fluid from blind end will flow to D.C. valve as there is no restriction and the piston can be retracted rapidly to its initial position.
- o Flow during retraction is not controlled (i.e. Free flow)
- o This method is used where free falling load or overhauling load tends to go out of control.
- o They are used in operations like drilling, boring, reaming, Shaper, planner, slotter due to quick return



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COMPARISON OF HYDRAULIC & PNEUMATIC SYSTEMS

Hydraulic Circuits

Pneumatic Circuits

- | | |
|--|--|
| 1. Working fluid used is oil | 1. Working fluid used is air |
| 2. The operation is complicated | 2. The operation is simple |
| 3. The operation is quiet | 3. The operation is noisy |
| 4. To pressurized the oil, pump is necessary | 4. Air compressor is necessary |
| 5. It require return lines, hence the circuit is complicated | 5. No return lines are required, hence circuit is simple |
| 6. Speed is limited | 6. Very high speed can be possible |
| 7. There is possibility of fire hazards when working with higher temperatures. | 7. It is safe in volatile atmosphere. |
| 8. Its operating pressure can be lower to very high | 8. Its operating pressure is limited to 6 bar |
| 9. In this the system rigidity is good | 9. In this system rigidity is poor |
| 10. It has simple maintenance | 10. It also has simple maintenance |

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COMPARISON OF HYDRAULIC & PNEUMATIC SYSTEMS

Hydraulic Circuits

Pneumatic Circuits

- | | |
|---|--|
| 11. It requires moderate operating cost | 11. It requires very low operating cost |
| 12. Overall cost is higher | 12. Overall cost is lower |
| 13. It is very much suitable where long strokes are required | 13. It is not suitable for long strokes |
| 14. It is suitable for feed movements of machine tools. Stroke control is easy and is very precise | 14. It is not suitable for feed movements. Stroke control is easy, but fluctuations cannot be avoidable. |
| 15. Applications:
Automatic lathe
Drilling machines
Grinding machines
Shaping machines
Crushers
Fork lift trucks
Dumpers
Truck loaders
Bulldozers
Hydraulic press | 15. Applications:
Automatic machines for holding, gripping, feeding, bottling, wrapping, packaging etc.
Clamping jigs & fixtures
Wire feeding
For raw material feeding
For hoist, Lift, Cranes
For furnace operations
For power tools
For mining boring, shoveling
Automatic tillers
For press tools |

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INDUSTRIAL FLUID POWER



Fluid Power

o The technology that deals with the generation, control and transmission of forces and movement of mechanical element or system with the use of pressurized fluids

o Both liquids and gases are considered as fluids.

Types of Hydraulic Fluids

- o Petroleum-based fluid
- o Emulsions
- o Water glycol
- o Synthetic fluids
- o Vegetable oils
- o Biodegradable hydraulic fluids



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INDUSTRIAL FLUID POWER



Various properties required for an ideal hydraulic fluid

- o Ideal viscosity.
- o Good lubrication capability.
- o Demulsibility (The ability of a hydraulic fluid to separate rapidly from moisture).
- o Good chemical and environmental stability.
- o Incompressibility.
- o Fire resistance.
- o Low flammability.
- o Foam resistance.
- o Good heat dissipation.
- o Low density.
- o System compatibility.



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THANK YOU



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THE END



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