PUMPS

Pump

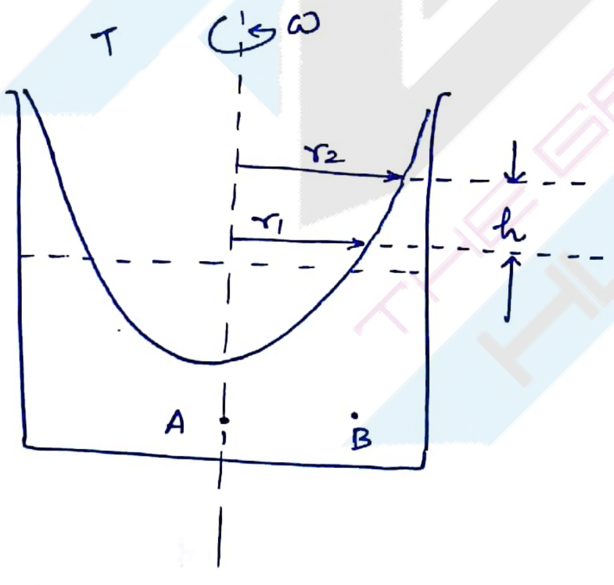
⇒ Mech. Energy → hydraulic energy

- → Rotodynamic → centrifugal pump
- → Positive displacement → Reciprocating Pump

→ Centrifugal Pump

Principle → The centrifugal Pump works on the principle of forced vortex which says when a mass of water is rotated about an axis, then there is a rise in pressure in the Radially outward direction and the pressure decreased in the inward direction. The rise in pressure is directly proportional to square of speed.

$F/A \propto \omega^2 r$



$v \propto r$

$$\frac{P_2 - P_1}{\rho g} = h = \frac{\omega^2 (r_2^2 - r_1^2)}{2g}$$

$$\boxed{\Delta P \propto \omega^2}$$

S → Entry to pump

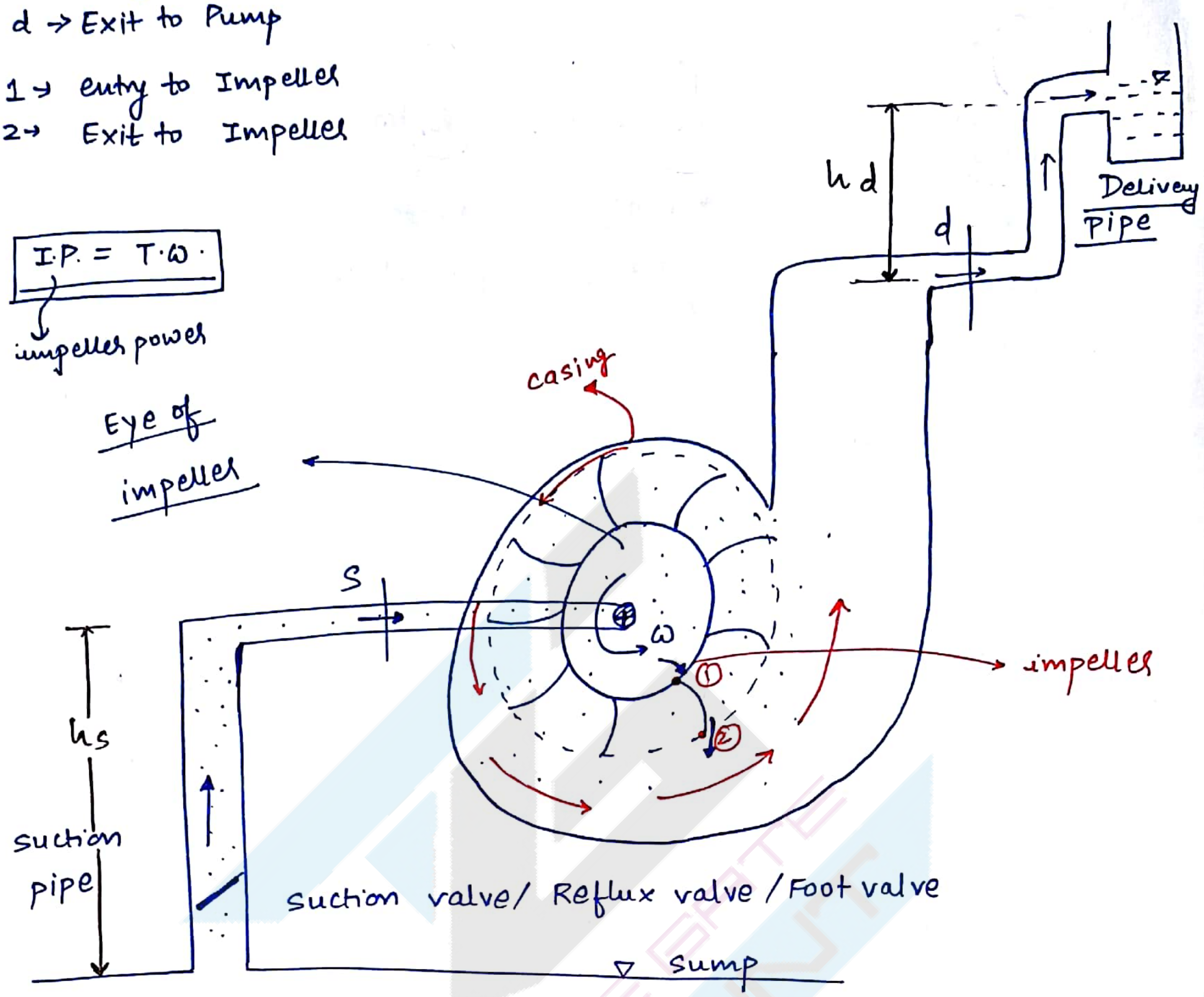
d → Exit to Pump

1 → entry to Impeller

2 → Exit to Impeller

$\boxed{I.P. = T \cdot \omega}$

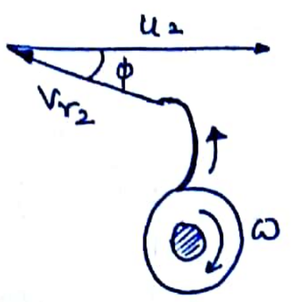
I.P. → impeller power



Component

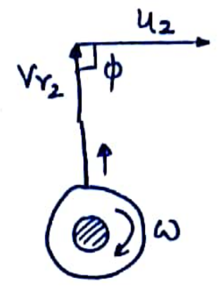
1. Casing ⟶ spiral/ volute/ scroll casing
2. Impeller

MOHIT CHOUKSEY



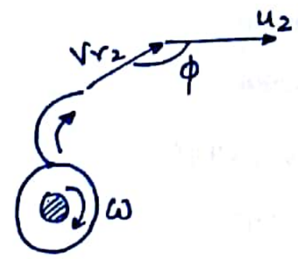
$\phi < 90°$

Backward Vane



$\phi = 90°$

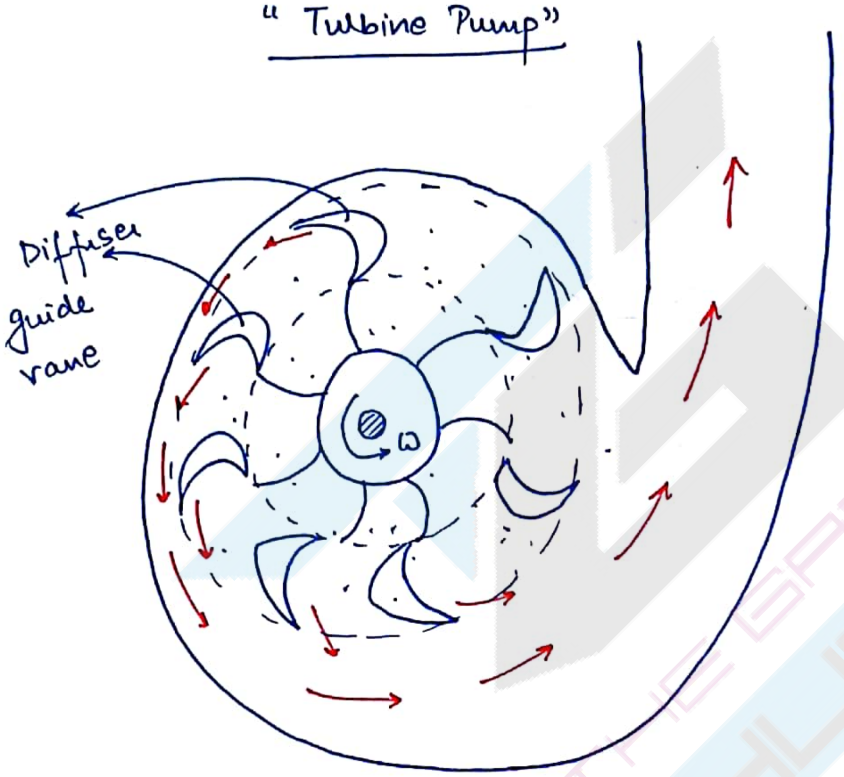
Radial vane



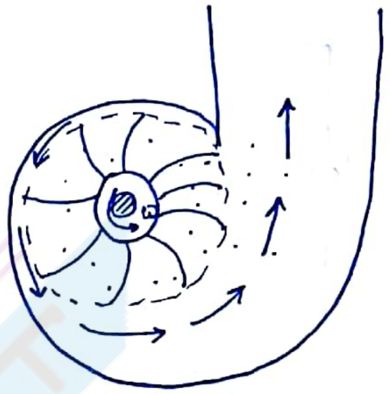
$\phi > 90°$

forward Vane

"Turbine Pump"



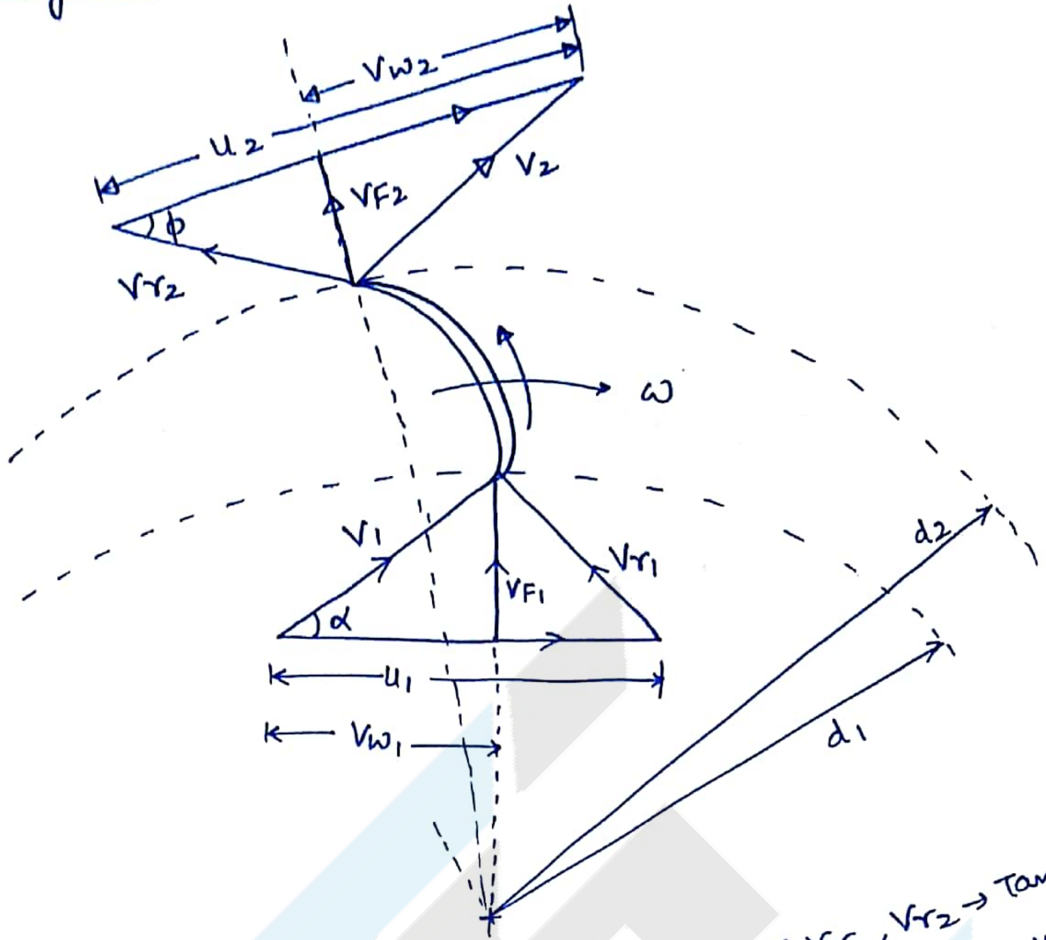
volute casing with Diffuser guide vane



Volute casing

MOHIT CHOUKSEY

* Velocity Δ



[$V_{r1}, V_{r2} \rightarrow$ Tangential for smooth entry always]

$$\frac{\pi d_1 N}{60} = u_1 = \omega r_1$$

$$\frac{\pi d_2 N}{60} = \underline{u_2 = \omega r_2}$$

$$d_2 > d_1$$

$$u_2 > u_1$$

$$IP = T \cdot \omega$$

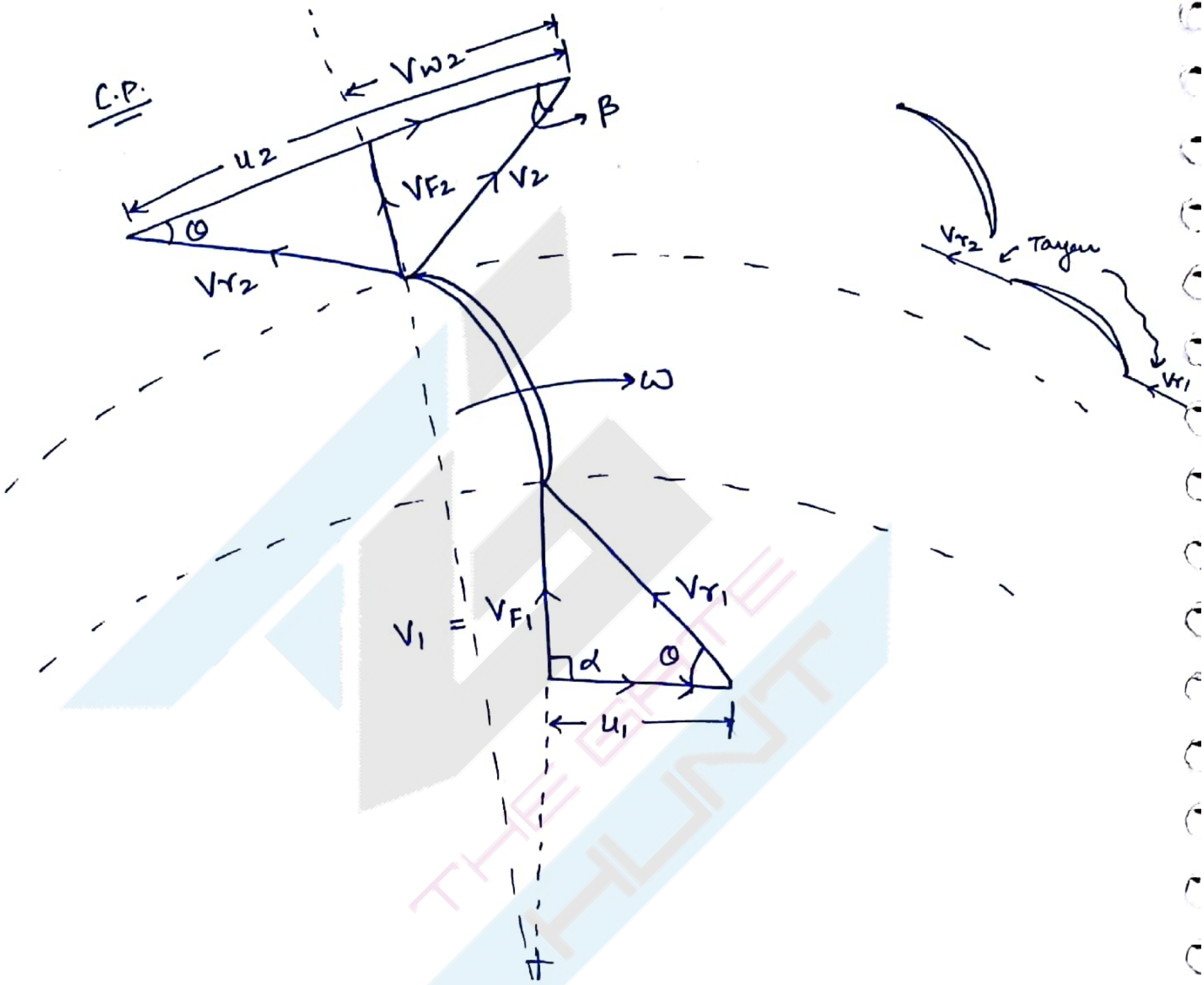
$$\rightarrow T = \dot{m} V_{w_2} r_2 - \dot{m} V_{w_1} r_1$$

$$I.P. = T \cdot \omega = \dot{m}\left(V_{w_2} r_2 - V_{w_1} r_1\right)\omega$$

$$\rightarrow I.P. = \rho Q\left(V_{w_2} \cdot u_2 - V_{w_1} u_1\right)$$

$$\frac{IP}{\dot{m} g} = \frac{\left(V_{w_2} u_2 - V_{w_1} u_1\right)\dot{m}}{g} = \underline{\underline{H_e}} \leftarrow \text{euler head}$$

Francis	C.P.
$V_{w_2} = 0$	$V_{w_1} = 0$
$V_2 = V_{F_2}$	$V_1 = V_{F_1}$
$\beta = 90^\circ$	$\alpha = 90^\circ$



$$IP = \rho Q (V_{w_2} u_2)$$

$$\frac{IP}{mg} = \frac{V_{w_2} u_2}{g} = H_e$$

MOHIT CHOUKSEY

Types of Head

→ **static head**

$H_s = h_s + h_d$

h_d → delivery height

h_s → suction height

s: P_s, V_s, Z_s

d: P_d, V_d, Z_d

→ **Manometric Head (H_m)**

It is the head against which pump has to work (or) it is the net energy or head given by pump to water.

→ if No loss in pump

$$H_m = \frac{IP}{\dot{m}g} = \frac{V_{w2}u_2}{g}$$

→ if loss in Pump

$$H_m = \frac{V_{w2}u_2}{g} - \left[\begin{array}{c}\text{loss in impeller} \\ + \\ \text{loss in casing}\end{array}\right]$$

$$\rightarrow H_m = \left[\frac{P_d}{\rho g} + \frac{V_d^2}{2g} + Z_d\right] - \left[\frac{P_s}{\rho g} + \frac{V_s^2}{2g} + Z_s\right]$$

$Z_s \approx Z_d$

$$H_m = \frac{P_d - P_s}{\rho g} + \frac{V_d^2 - V_s^2}{2g}$$

→ $\dot{m}_s = \dot{m}_d$

$$\rho\left(\frac{\pi}{4} d_s^2\right) \cdot V_s = \rho\left(\frac{\pi}{4} \cdot d_d^2\right) \times V_d$$

if $d_s = d_d$

then $V_s = V_d$

$$\boxed{H_m = \frac{P_d - P_s}{\rho g}}$$

$$\rightarrow H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{V_d^2}{2g}$$

→ Area of flow

$AF_1 = \pi d_1 b_1$

$AF_2 = \pi d_2 b_2$

→ Discharge

$Q = AF_1 V_{F_1} = A_{F_2} V_{F_2}$

→ Power

→ $WP/MP = mg\, Hm = \rho g Q Hm$ watt

→ $IP = \rho Q (Vw_2 u_2 - Vw_1 u_1)$

$IP = \rho Q (Vw_2 u_2)$ c.P.

→ $SP = IP +$ Mech. loss

→ η

→ $\eta_{mano} = \frac{WP}{IP} = \frac{gHm}{Vw_2 u_2}$

→ $\eta_{mech} = \frac{IP}{SP}$

→ $\eta_o = \frac{WP}{SP} = \frac{WP}{IP} \times \frac{IP}{SP}$

→ $\eta_o = \eta_{mano} \times \eta_{mech}$

→ dia. Ratio

$\frac{d_1}{d_2} = 0.5$

→ Speed Ratio

$K_u = \frac{u_2}{\sqrt{2gHm}}$

→ Flow Ratio

$K_F = \frac{V_{F_2}}{\sqrt{2gHm}}$

Sheet Q9 $Q = 50\,litr/sec$

$H = 40\,m$

$P = ?$

$P = \rho g Q H = 1000 \times 9.81 \times 50 \times 40$

$P = \underline{19.62\,kW}$

(c) ✓

34 (b) ✓

37 (b) ✓

WBook

(29) (a) 1,2,3

$\boxed{37}$ $\eta = 0.90$

$H = 155\,m$

$Q = 7.5\,m^3/s$ $h_f = 13\,m$ $P = ?$

$$\eta_o = \frac{WP}{IP} \times \frac{IP}{SP}$$

$$0.90 = \frac{\rho g Q H_m}{SP}$$

$H_m \rightarrow H + h_f$

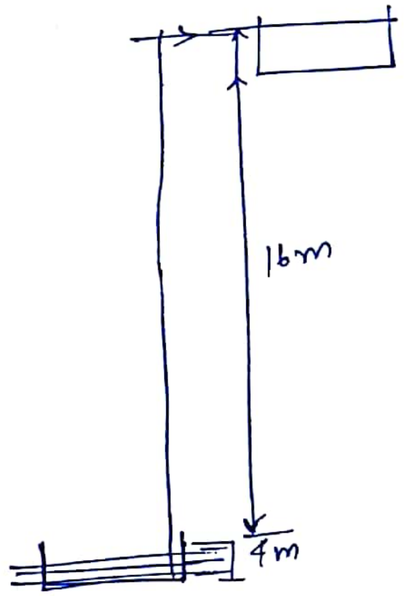
(a) ✓

(38)

(38) $0.65 = \frac{\rho g Q H_m}{SP}$

$= 1000 \times 9.81 \times 0.025 \times$

(a) ✓

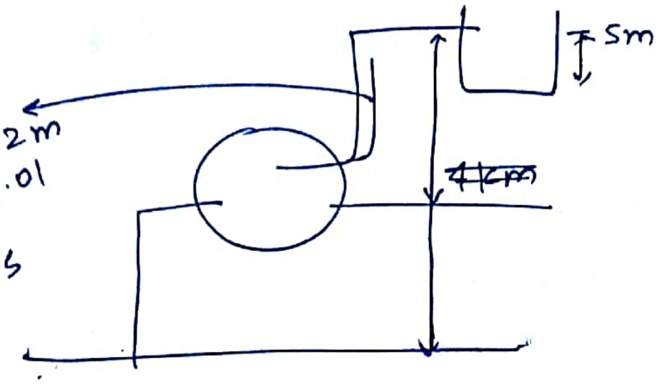


42

$d = 0.2m$

$f = 0.01$

$v = 2m/s$



$\rho g H$.

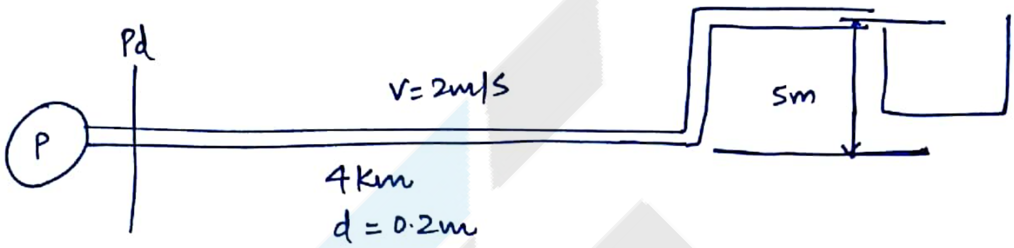
$$h_f = \frac{fLV^2}{2gd}$$

$$= \frac{0.01 \times 4 \times 10^3 \times 2^2}{2 \times 9.81 \times 0.2}$$

$$h_f = 40.77 \text{ m}$$

$H_m =$

SIR



$d = 0.2m$

$F = 0.01$

$$\rightarrow H_s = h_f + 5 = \frac{FLV^2}{2gd} + 5 = \frac{0.01 \times 4000m \times (2^2)}{2 \times 9.81 \times (0.2) \times 1} + 5$$

$$= \underline{45.77\ m}$$

$\rightarrow P = \rho g H_s = 1000 \times 9.81 \times 45.77$

$\rightarrow$ $\underline{P = 4.49 \text{ bar}}$ $\rightarrow$ gauge में होता।

Absolute Pressure $= 4.49 + 1.013 = \underline{5.50 \text{ Bar}}$

40

$Q = 0.118\ m^3/s$

$N = 1450$ rpm $H = 25m$, $d = 25cm$

$b = 5cm$

$\eta_m = 0.75$

$\alpha = ?$

$$\eta_m = \frac{gH_m}{V_{w_2} u_2}$$

$$0.118 = \frac{9.81 \times 25}{V_{w_2} \times \frac{\pi D N}{60}}$$

$V_{w_2} = 109.50\ m/s$

$u_2 = \frac{\pi D N}{60}$ 18.98

$$\eta_m = \frac{9.81 \times 25}{V_{w_2} \times \pi D b}$$

$Q = 0.118\ m^3/sec$

$N = 1450\ rpm$

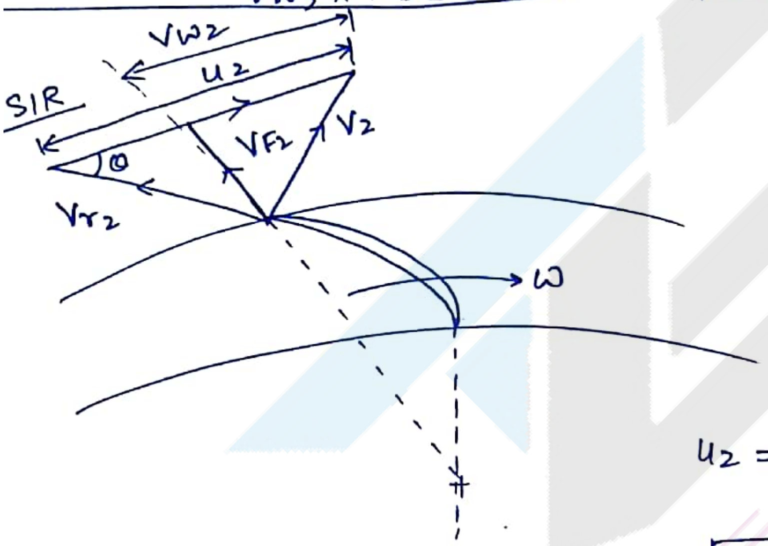
$H_m = 25m$

$d_2 = 0.25m$

$b_2 = 0.05m$

$\eta_{mano} = 75\%$

$\boxed{\phi = ?}$



$$\tan\phi = \frac{V_{F2}}{u_2 - V_{w2}}$$

$Q = \pi d_2 b_2 V_{F2}$

$0.118 = \pi \times 0.25 \times 0.05 \times V_{F2}$

$\boxed{V_{F2} = 3m/s}$

$$u_2 = \frac{\pi d_2 N}{60} = \frac{\pi \times 0.25 \times 750}{60}$$

$\boxed{u_2 = 18.98\ m/s}$

$$\eta_{mano.} = \frac{gH_m}{V_{w2} u_2}$$

$$0.75 = \frac{9.81 \times 25}{V_{w2} \times 18.98}$$

$V_{w2} = 17.22\ m/s$

$$\tan\phi = \frac{3}{18.98 - 17.22}$$

$\boxed{\phi = 59.70}$

* Specific speed — specific speed (N_S)

$\boxed{H, Q, N}$

P

→ It is the speed of the pump at which it would deliver unit discharge when working against unit head.

$$Q = A_F \cdot V_F$$

$$Q \propto D^2 \sqrt{H_m}$$

$$u \propto DN \propto \sqrt{H_m}$$

$$\because \left\{ \begin{array}{l} A_F \propto D^2 \\ V_F \propto \sqrt{H_m} \\ u \propto \sqrt{H_m} \end{array} \right.$$

$$D \propto \frac{\sqrt{H_m}}{N}$$

$$Q \propto \left(\frac{\sqrt{H_m}}{N}\right)^2 \cdot \sqrt{H_m}$$

$$Q = k \cdot \frac{H_m^{3/2}}{N^2}$$

Defn → H_m = unit head = 1m

$$Q = 1 m^3/sec$$

$$N = N_S$$

$$1 = \frac{k \cdot 1^{3/2}}{N_S^2}$$

$$\boxed{K = N_S^2}$$

$$Q = \frac{N_S^2 \cdot H^{3/2}}{N^2}$$

$$\boxed{N_S = \frac{N\sqrt{Q}}{H_m^{3/4}}} \quad (M \cdot L \cdot T.)$$

HW

→ Multiple Pumps

① Series

total Hm = n × Hm

n = no. of pumps

Q = const.

② Parallel

total Q = n × Q

Hm = constant.

→ Model-Prototype

→ head coeff.

$u \propto DN \propto \sqrt{H_m}$

$H_m \propto D^2 N^2$

$$\left.\frac{H_m}{D^2 N^2}\right|_M = \text{const} = \left.\frac{H_m}{D^2 N^2}\right|_P$$

→ Discharge coff.

$Q \propto D^3 N$

$$\left.\frac{Q}{D^3 N}\right|_M = \left.\frac{Q}{D^3 N}\right|_P$$

→ Power coeff.

$P \propto D^5 N^3$

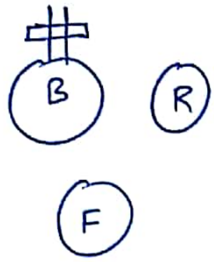
$$\left.\frac{P}{D^5 N^3}\right|_M = \left.\frac{P}{D^5 N^3}\right|_P$$

→ specific speed

$$\left.\frac{N\sqrt{Q}}{H_m^{3/4}}\right|_M = \left.\frac{N\sqrt{Q}}{H_m^{3/4}}\right|_P$$

* Effect of Vane angle over head and discharge →

N = constant



$\boxed{Q \rightarrow H_m}$

$$\rightarrow H_m = \frac{V_{w_2} u_2}{g}$$

$$V_{w_2} = u_2 - V_{F_2} \cot\phi$$

$$H_m = \frac{(u_2 - V_{F_2} \cot\phi) \cdot u_2}{g}$$

$$H_m = \frac{u_2^2}{g} - \frac{u_2}{g} \frac{A_{F_2} V_{F_2}}{A_{F_2}} \cot\phi \quad \rightarrow Q$$

$$H_m = \underbrace{\frac{u_2^2}{g}}_{A} - \underbrace{\frac{u_2}{g A_{F_2}}}_{B} Q \cot\phi$$

MOHIT CHOUKSEY

N = const

d_2 = const

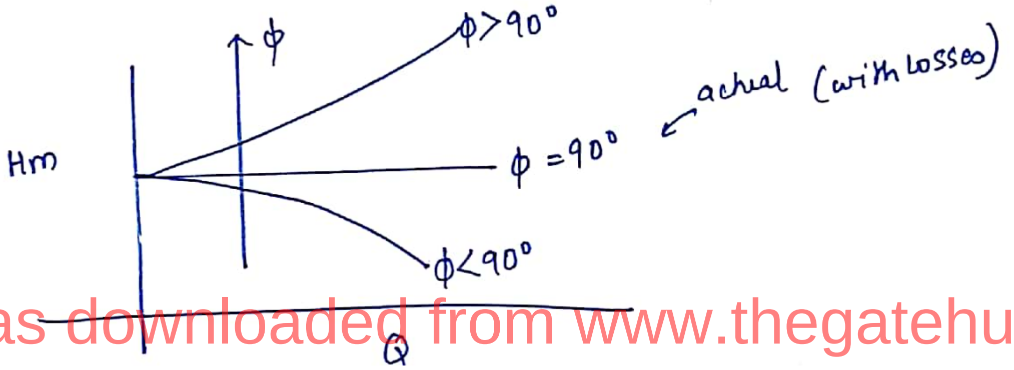
$u_2 = \frac{\pi d_2 N}{60}$ = const

A_{f_2} = const

$$\boxed{H_m = A - BQ\cot\phi}$$

A, B → const

ϕ:
- $\phi < 90° \rightarrow \cot\phi \rightarrow +ve$
- $\phi = 90° \rightarrow \cot\phi = 0$
- $\phi > 90° \rightarrow \cot\phi \rightarrow -ve$



Q57 WBook

$H = 150\,m$

$N_s = 30$

$N = 1450$

$Q = 0.2\,m^3/s$

$N_{pumps} = ?$

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

SIR $\rightarrow$ $H_m = 150\,m$

$N_s = 30$

$N = 1450$

$\rightarrow$ $Q = 0.2\,m^3/sec$

$n = ?$

Series

$Q = $ const.

$150\,m = $ Total $H_m = n \times H_m$.

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}} \Big|_{\text{Each pump}}$$

$$30 = \frac{1450 \times \sqrt{0.2}}{H_m^{3/4}} \Big|_{\text{Each pump}}$$

$H_m = 60.21\,m$

$150 = n \times 60.21\,m$

$n = 2.49$

$\boxed{n = 3 \text{ pumps}}$

(39) $D = 20\,cm$

$H = 45\,m$

$N = 1350\,rpm$

$D = 15\,cm$

$N = 1350\,rpm$

$$\frac{45}{0.2^2\,\cancel{1350}}\Bigg|_M = \frac{H_p}{0.15^2 \times \cancel{1350}}$$

$$\frac{\overset{11.1}{\cancel{45}} \times 0.15 \times 0.15}{\cancel{0.04}}$$

225×11.11.

$25.3\,m$ (a) ✓

(47) a

(67) $D_{impeller} = 0.30\,m$

$N_{imp} = 2000\,rpm$

$Q = 3\,m^3/s$

$H_m = 30\,m$

$\eta_o = 0.75$

(1) no. of stages, dia. of each stage

$Q = 5\,m^3/s$ $\quad H = 200\,m$ $\quad N = 1500\,rpm$

$$\eta_o = \frac{g H_m}{V_w u_2} \times = \frac{WP}{SP}$$

$\eta_o = 9.81 \times H_m$

$8 + 200 = 208\,m$ (कुछ भी लिखोगे का दो मुर्गा)

$$Q = \frac{\sin\theta}{d h\sqrt{2}} + \frac{9.5}{6} + \frac{2}{4}$$

67

$d = 30cm$ ← similar
$N = 2000 rpm$
$Q = 3 m^3/sec$
$H_m = 30 m$
$\eta_0 = 75\%$

$n = ?$
$d = ?$
$Q = 5 m^3/sec$
$H_m = 200 m$
$N = 1500 rpm$

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

$$N_s = \frac{2000 \times \sqrt{3}}{30^{3/4}}$$

$$N_s = 270.24$$

→ Series

$Q = const = 5 m^3/sec$

$200 = total\ H_m = n \times H_m$

$$270.24 = N_s = \frac{N\sqrt{Q}}{H_m^{3/4}} \Bigg|_{Each\ pump}$$

$$270.24 = \frac{1500\sqrt{5}}{H_m^{3/4}} \Bigg|_{Each\ pump}$$

$$\boxed{H_m = 28.74 m}$$

$200 = n \times 28.74$

$n = 6.96 \approx$ 7 pumps

$$\frac{H_m}{D^2N^2}\Bigg|_1 = \frac{H_m}{D^2N^2}\Bigg|_2$$

$$\frac{30}{30^2 \times 2000^2} = \frac{28.74}{D_2^2 \times 1500^2}$$

$$\boxed{D_2 = 39.14 cm}$$

sheet
Q50 → $\boxed{N_s \to 15}$
correction

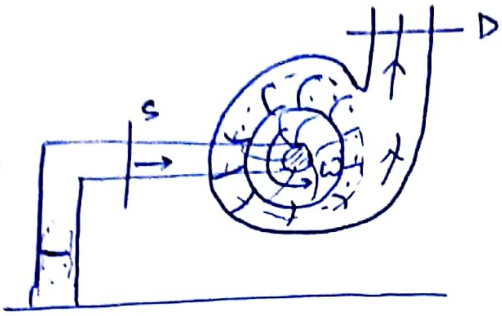
answers all → made easy mech ← FB page

MOHIT CHOUKSEY

23/11/2016

Priming of pump

It is the process of filling the water "or" removing the air from casing and suction pipe. The priming is done just to ensure that the impeller does the work directly on water.



$\rightarrow IP = T \cdot \omega = \rho Q (V_{w_2} u_2)$

water, Air

$H_m = \frac{IP}{mg}$

very-very less

$\rho_{air} <<<<<< \rho_{water}$

when pump → air → don't use → damage occurs.

min^m. starting speed of pump

$IP = T\omega$ (min, min)

$$H_m = \frac{IP}{mg} - \text{loss in pump}$$

$$\frac{IP}{mg} = H_m + \text{loss in Pump}$$

$$\frac{IP}{mg} \geqslant H_m \Rightarrow \left.\frac{IP}{mg}\right|_{min} = H_m$$

$$\frac{IP}{mg} = \frac{V_{w_2}u_2 - V_{w_1}u_1}{g}$$

$$\frac{RP}{mg} = \frac{V_{w_1}u_1 + V_{w_2}u_2}{g} = \frac{V_1^2 - V_2^2}{2g} + \frac{u_1^2 - u_2^2}{2g} + \frac{V_{r_2}^2 - V_{r_1}^2}{2g}$$

Similarily

$$\frac{IP}{mg} = \frac{V_2^2 - V_1^2}{2g} + \frac{u_2^2 - u_1^2}{2g} + \frac{V_{r_1}^2 - V_{r_2}^2}{2g}$$

just @ starting of pump

$V_1,\ V_2,\ V_{r_1},\ V_{r_2} = 0$

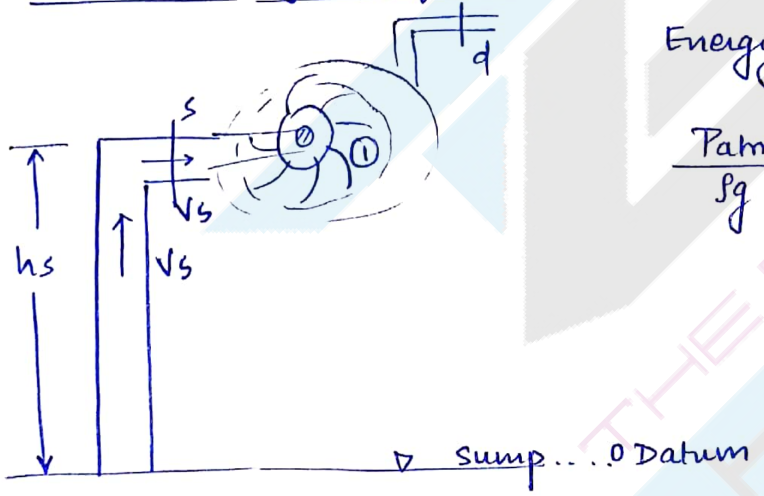
$$\frac{IP}{mg} = \frac{u_2^2 - u_1^2}{2g} \geq H_m$$

$$\frac{\omega^2 (r_2^2 - r_1^2)}{2g} \geq H_m$$

$$\frac{2\pi N}{60} = \omega = \sqrt{\frac{2g H_m}{(r_2^2 - r_1^2)}}$$

N → minm. starting speed of pump.

→ Suction Height of CP



Energy Equation 0 - 1

$$\frac{P_{atm}}{\rho g} + 0 + 0 = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + h_s + h_F$$

$(\because V_1 \approx V_s)$

$$h_s = \frac{P_{atm}}{\rho g} - \left[\frac{P_1}{\rho g} + \frac{V_s^2}{2g} + h_F\right]$$

very very less

$$\frac{P_1}{\rho g} < \frac{P_{atm}}{\rho g}$$

$h_s \rightarrow max$

$$\left.\frac{P_1}{\rho g}\right|_{min} > \frac{P_v}{\rho g}$$ (to avoid cavitation).

Net Positive Suction head → It is the energy available with water at inlet to the pump in the form of head which can be utilised in the form of suction height. The NPSH gives the range in which the pump can be installed without cavitation.

$$\boxed{\text{NPSH}} \Rightarrow \frac{P_1}{\rho g} - \frac{P_v}{\rho g} \ (m)$$

P_v → vapour pressure

(m) → metre

→ Thoma's cavitation Factor (σ)

$$\sigma = \frac{\text{NPSH}}{H} = \frac{H_{atm} - h_s - h_F - h_v}{H}$$

Pump: H_m

Turbine: H = Net head

$\sigma > \sigma_c$ → No cavitation

$\sigma < \sigma_c$ → cavitation occurs

σ_c → critical cavitation factor.

WB

(28) P_{atm} → 9 m

P_v = 1 m

h_F = 40 m

σ = 0.15

$$0.15 = \frac{9 - h_s - \cancel{40}\,0 - 1}{\cancel{H_m}\ 40}$$

$0.60 - 9 + 1 = h_s$

2 m.

(34) a (32) $Q = 260 \times 10^{-3}$ m³/sec

N = 600 rpm

D_0 = 80 cm R_0 = 40 cm

H = 15.3 m

N_s = ?

$$\frac{2\pi \times \cancel{600}\,10}{\cancel{60}}$$

$20\pi = \omega = \sqrt{\frac{2g H_m}{(r_2^2 - r_1^2)}}$

$A_1V_1 = A_2V_2$

$\frac{\pi}{4} d_2^2 \times$

Q32 $Q = 260\times10^{-3}\,m^3/sec$

$A_1 V_1 = 260\times10^{-3}\,m^3/s$

$r_1 = ?$ $\Rightarrow$

$$\omega = \sqrt{\frac{2gH_m}{(r_2^2 - r_1^2)}}$$

$$\Rightarrow \omega = \sqrt{}$$

(28) $$\sigma = \frac{H_{atm} - h_s - h_F - h_v}{H}$$

$$0.15 = \frac{9 - h_s - 1}{40}$$

$$\boxed{h_s = 2m}$$

S/R

$$\frac{2\pi N}{60} = \omega = \sqrt{\frac{2gH_m}{(r_2^2 - r_1^2)}}$$

$$\frac{2\pi N}{60} = \sqrt{\frac{2\times9.81\times15.3}{(0.4^2 - 0.2^2)}}$$

$N = 477$ rpm (C)

$d_2 = 80$ cm $\quad r_2 = 40$ cm

$r_1 = 20$ cm $\left(\because \frac{d_1}{d_2} = 0.5,\ d_1 = 0.5 d_2\right)$

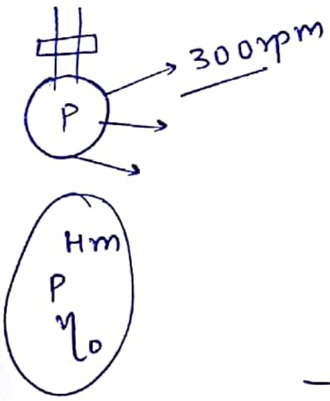
$r_1 \neq 0$ ($\because$ Practically not possible)

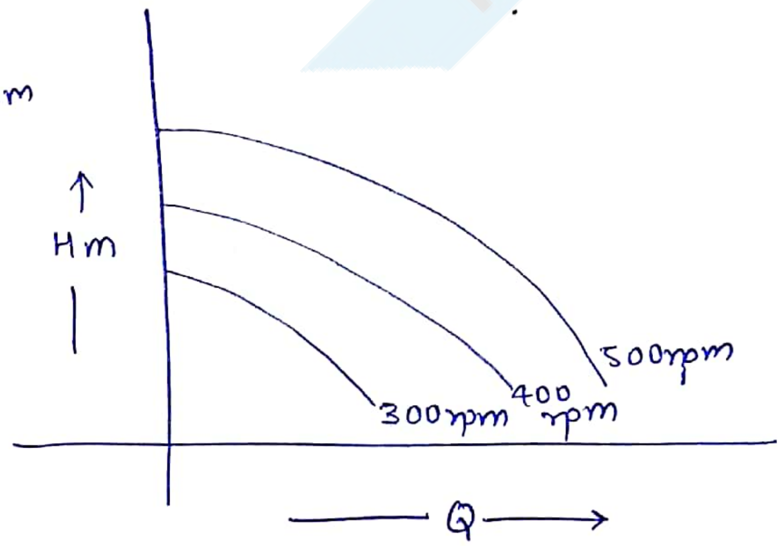
Performance Curve

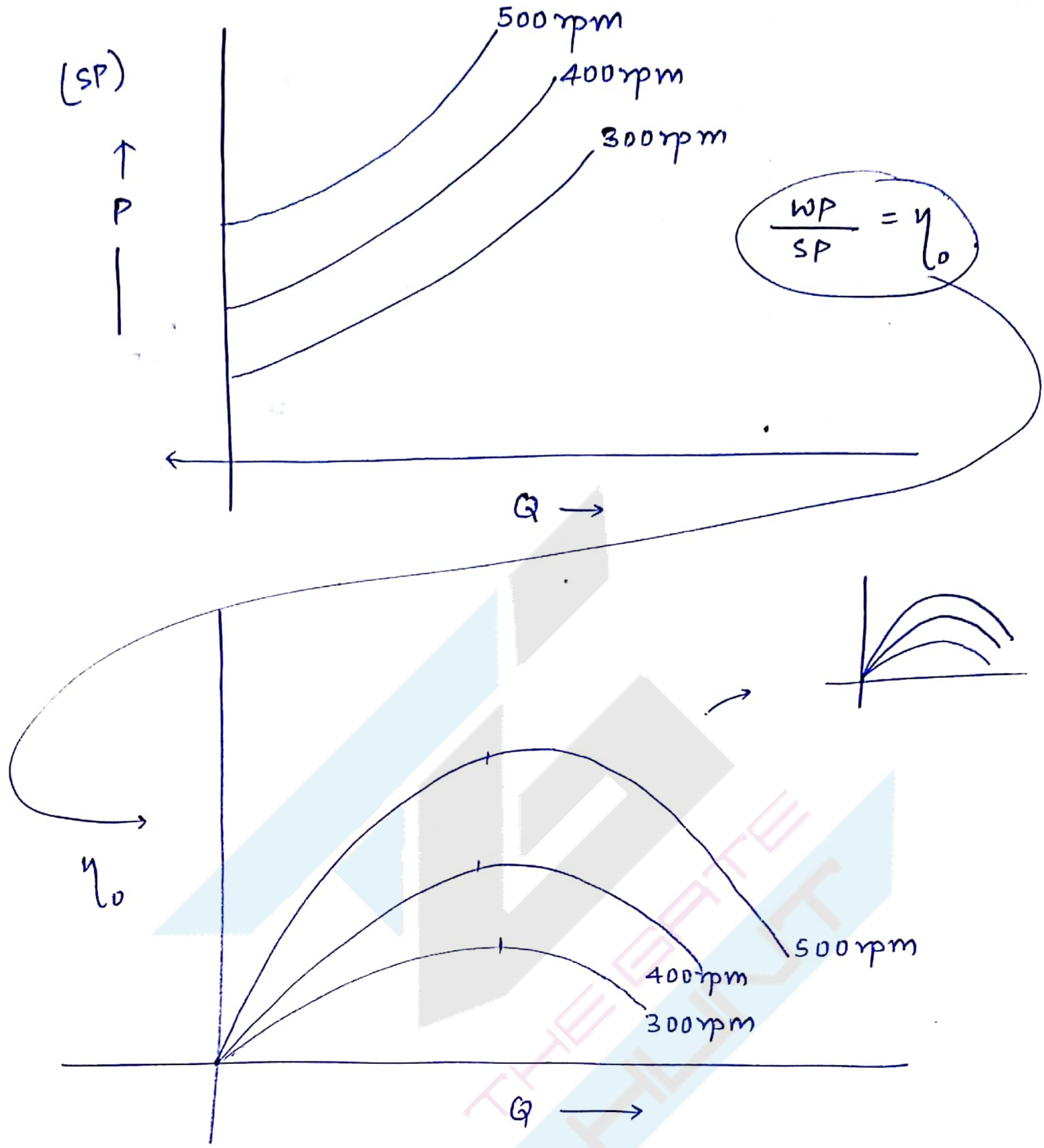
① → Main characteristic's Curve ⟶ (at different conditions of pump)

These curves are plotted at constant speed with respect to variable discharge. The discharge is controlled with the help of delivery valve fitted in delivery pipe.

(P)

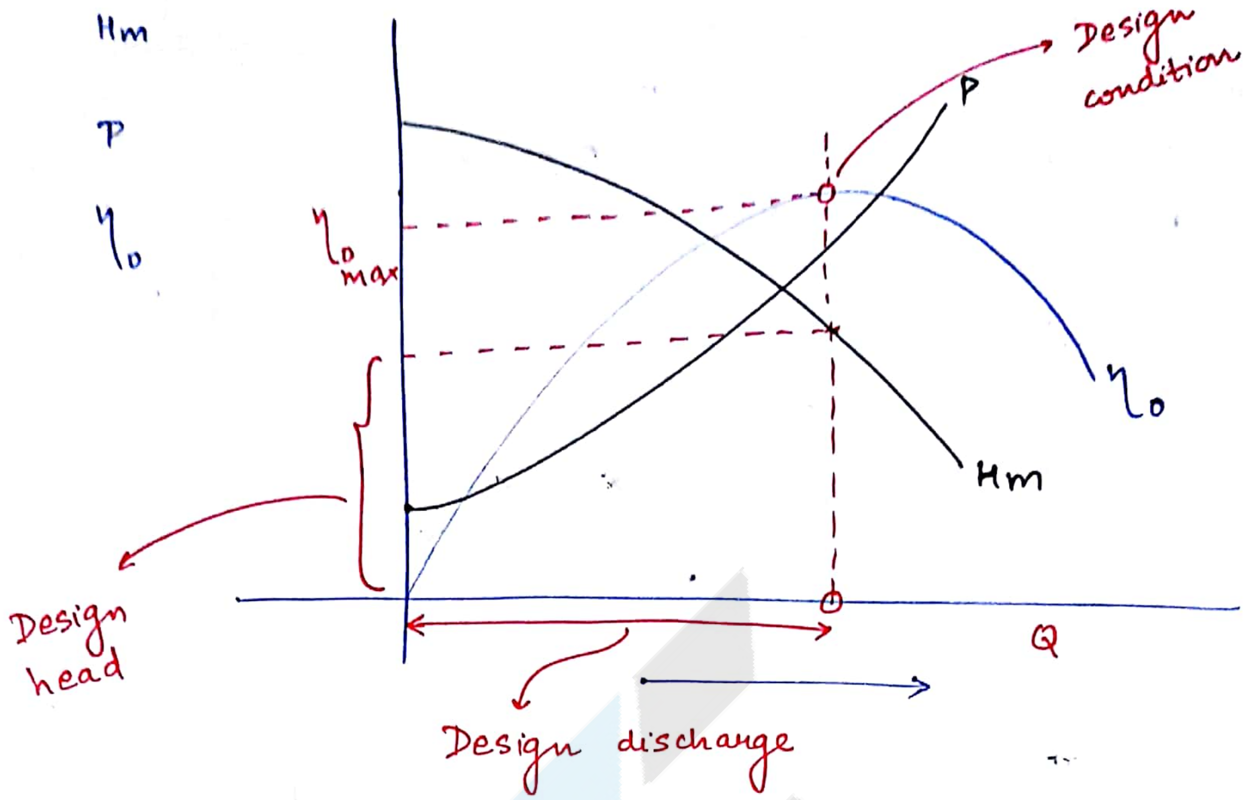






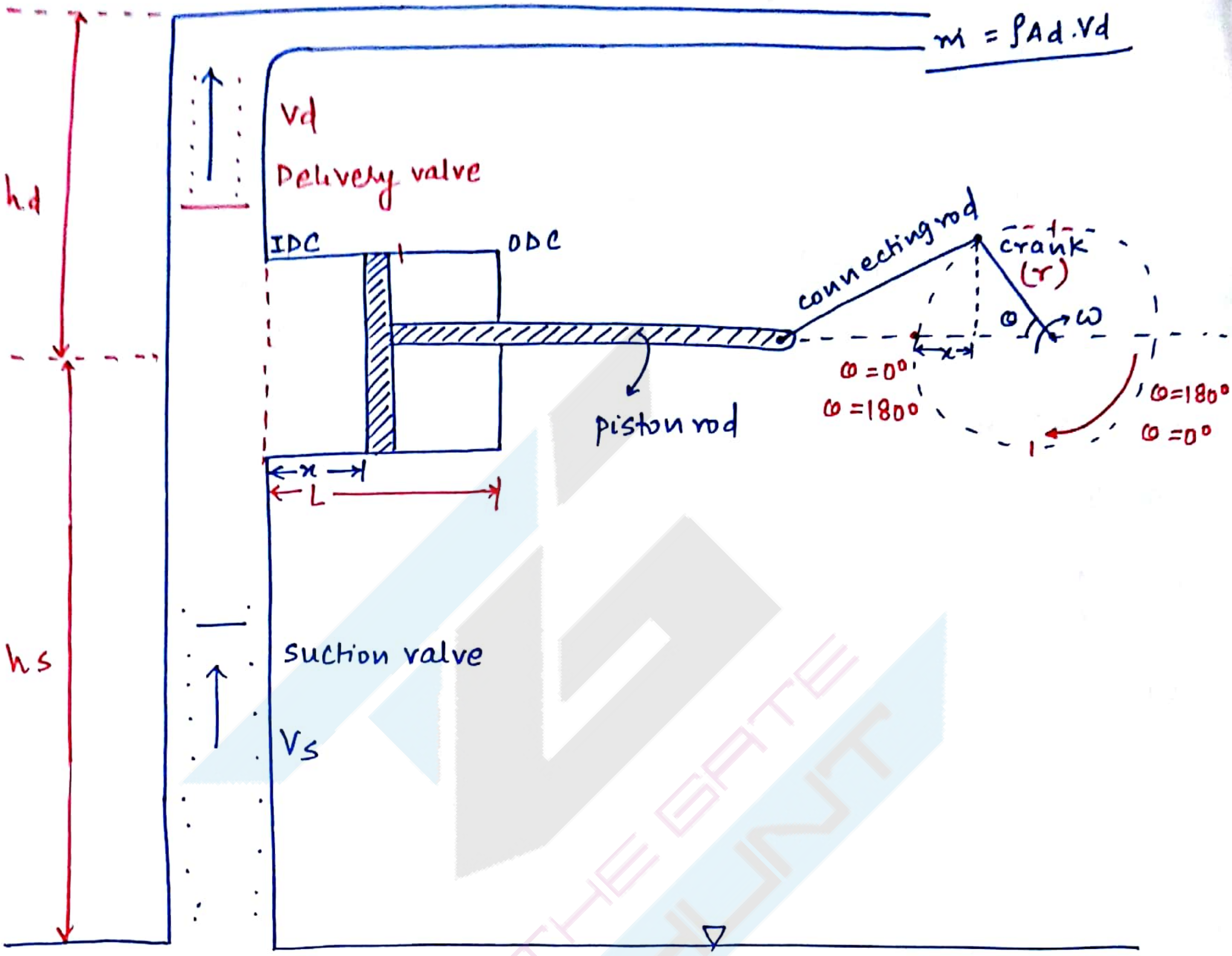
⇒ <u>Operating Curve</u>

<u>N = const = 300 rpm</u>


Hm
P
η_o
$\eta_{o\,max}$
Design condition
P
η_o
Hm
Q
Design head
Design discharge

RIP

RECIPROCATING PUMP



→ d = dia. of piston/Bore

A = c/s area of piston/cylinder

$A = \frac{\pi}{4} d^2$

L = stroke

r = crank radius

N = speed(rpm)

$\boxed{L = 2r}$

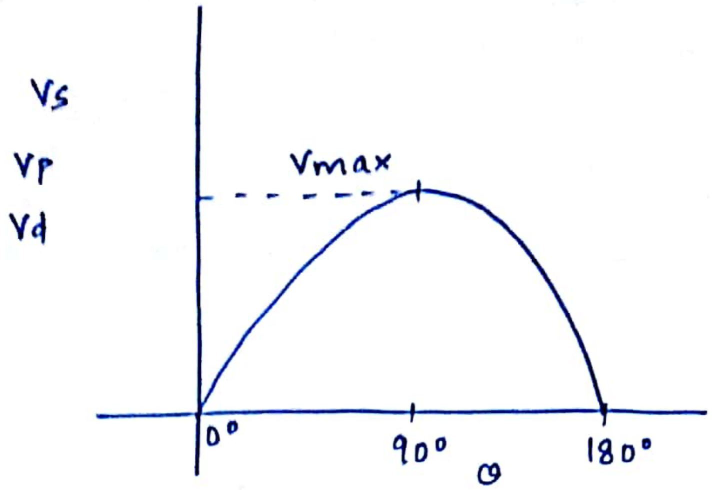
$x = r - r\cos\theta$

$\theta = \omega t$

$x = r - r\cos\omega t$

$V_p = \frac{dx}{dt} = 0 - r\omega(-\sin\omega t)$

$\boxed{V_p = +r\omega\sin\theta}$



SHM

$\dot{m}_s = \dot{m} = \dot{m}_d$

$\rho \cdot A_s \cdot V_s = \rho \cdot A \cdot V_p = \rho \cdot A_d \cdot V_d$

$V_s = \frac{A}{A_s} \cdot V_p = \frac{A}{A_s} \cdot r\omega \sin\theta$

$V_d = \frac{A}{A_d} \cdot V_p = \frac{A}{A_d} \cdot r\omega \sin\theta$

→ Disadvantage

① Pulsating discharge

② Discharge is variable

③ $h_F = \frac{FLV^2}{2gd}$

$V_s, V_d \rightarrow max$

$h_F \rightarrow max$

consumes more power

④ low Discharge

→ Theoretical Discharge

$$Q_{th} = \frac{ALN}{60} \left(\frac{m^3}{sec}\right)$$

→ slip = $Q_{th} - Q_{Act}$

if $Q_{Act} > Q_{th}$

"Negative slip condition"

① High speed

② Short Delivery pipe

→ coefficient of Discharge

$$C_d = \frac{Q_{Act}}{Q_{th}}$$

→ % slip $= \frac{Q_{th} - Q_{Act}}{Q_{th}} = 1 - C_d$

→ $P_{th} = \rho g Q_{th} (h_s + h_d)$

→ $P_{act} = \frac{P_{th}}{\eta}$

Air Vessel

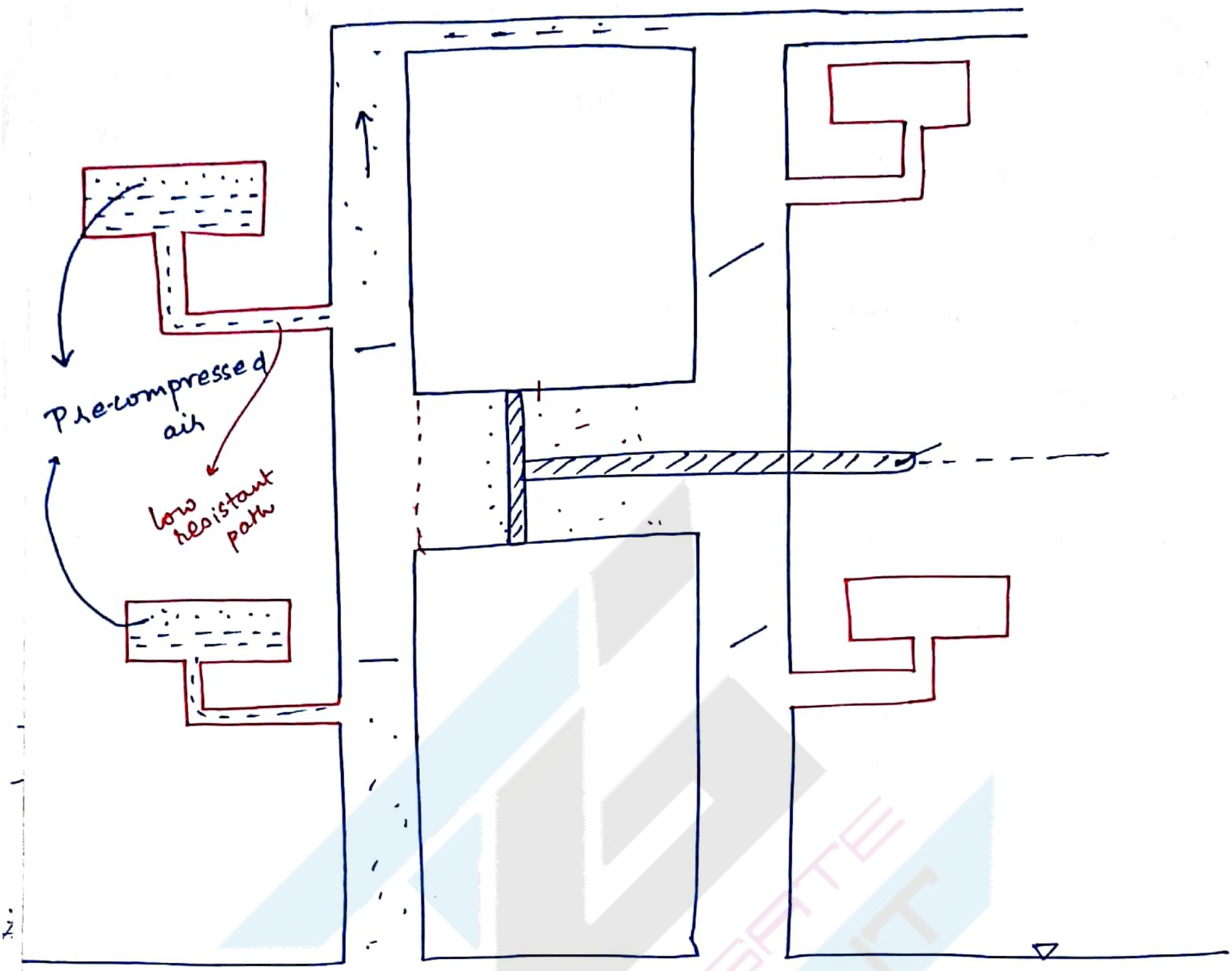
it is a reservoir of water placed near to pump in suction and delivery pipe.

Advantage

→ ① used to maintain constant and continuous discharge.

→ ② used to decrease power consumption.

→ ③ used to ↑ speed as well as discharge.



Theoretical discharge

$$Q_{th} \cong \frac{2 A L N}{60} \; m^3/sec$$

∵ piston volm.

Single Cylinder Double Acting R.P.

WB
(6) → a ✓
30

$r_1 = 10cm$ $H_{m_1} = 10cm$

$r_2 = ?$ $H_{m_2} = ?$

Model prototype → $\left.\frac{H_m}{D^2N^2}\right|_1 = \left.\frac{H_m}{D^2 N^2}\right|_2$

$$\frac{Hm_1}{r_1^2 \cancel{N_1^2}} = \frac{Hm_2}{r_2^2 \cancel{N_2^2}}$$

$$\frac{10}{10^2} = \frac{Hm_2}{r_2^2}$$

if $r_2 = 9cm$

$$\boxed{Hm_2 = 8.1m}$$

if $r_2 = 8cm$

$$\boxed{Hm_2 = 6.4m}$$

48 Load Factor $= LF = \dfrac{kWh}{kW \times \text{No. of Days}}$

$$= \frac{\cancel{8,400,000}}{\cancel{10,000} \times \cancel{7} \times \cancel{24}}$$

$= 1/2 = 50\%$