

(1) Rate of pump delivery = $10 \text{ dm}^3/\text{min}$
 Pressure change = $12 \text{ bar} = 12 \times 10^5 \text{ N/m}^2$
 speed of rotation = $1500 \text{ rev/min} = \frac{1500 \text{ rev}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 25 \text{ rev/sec}$
 nominal displacement = $10 \text{ cm}^3/\text{rev}$
 Torque input = 12.5 Nm

(i) Volumetric efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100\%$

Actual flow rate = $10 \text{ dm}^3/\text{min} = \frac{10 \text{ dm}^3}{1 \text{ min}} \times \frac{1 \text{ m}^3}{1000 \text{ dm}^3} \times \frac{1 \text{ min}}{60 \text{ sec}} = 1.667 \times 10^{-4} \text{ m}^3/\text{sec}$

nominal displacement = $\frac{10 \text{ cm}^3}{1 \text{ rev}} \times \frac{1 \text{ m}^3}{1000 \text{ cm}^3} = 1 \times 10^{-5} \text{ m}^3/\text{rev}$

Ideal flow rate = nominal displacement \times speed
 $= 1 \times 10^{-5} \times 25 = 2.5 \times 10^{-4} \text{ m}^3/\text{sec}$

volumetric efficiency = $\frac{1.667 \times 10^{-4}}{2.5 \times 10^{-4}} \times 100 = 66.68\%$

(ii) fluid power = Actual flow rate \times pressure
 $= 1.667 \times 10^{-4} \times 12 \times 10^5 = 200.04 \text{ watts}$

(iii) shaft power = Torque input \times angular speed
 Torque input = 12.5 Nm

Angular speed = $\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 1500}{60} \text{ (rps)}$

\therefore shaft power = $12.5 \times 2 \times \pi \times 25 = 1963.5 \text{ watts}$

(iii) Overall efficiency = $\frac{\text{fluid power}}{\text{shaft power}} \times 100\%$

$$= \frac{200.4}{1963.5} \times 100$$

$$= 10.21\%$$

- (2) Rate of delivery = $35 \text{ dm}^3/\text{min} = 35/60 = 0.58 \text{ dm}^3/\text{sec}$
 Pressure change = $100 \text{ bar} = 100 \times 10^5 \text{ N/m}^2$
 Overall efficiency = 87%
 Shaft power = ?

$$\text{Rate of delivery} = \frac{0.58 \times 1}{1000} = 5.83 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$\text{Fluid power} = \text{Actual flow rate} \times \text{pressure change}$$

$$= 5.83 \times 10^{-4} \times 100 \times 10^5$$

$$= 5833.33 \text{ watts}$$

$$\text{Overall efficiency} = \frac{\text{Fluid power}}{\text{Shaft power}} \times 100$$

$$87 = \frac{5833.33}{\text{S.P}} \times 100$$

$$\frac{0.87}{5833.33} = \frac{1}{\text{S.P}}$$

$$\therefore \text{Shaft power} = 6704.977 \text{ watts.} //$$

- (3) Nominal displacement = $50 \text{ cm}^3/\text{rev} = \frac{50 \text{ cm}^3}{\text{rev}} \times \frac{1 \text{ m}^3}{1000 \text{ cm}^3} = 5 \times 10^{-4} \text{ m}^3/\text{rev}$

$$\text{Pressure change} = 100 \text{ bar} = 100 \times 10^5 \text{ N/m}^2$$

$$\text{Shaft power} = 15 \text{ kW} = 15,000 \text{ W}$$

$$\text{Actual flow rate} = 35 \text{ dm}^3/\text{min} = \frac{35 \text{ dm}^3}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} \times \frac{1 \text{ m}^3}{1000 \text{ dm}^3}$$

$$= 5.833 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$\text{Speed of rotation} = 850 \text{ rpm} = 14.2 \text{ rps} //$$

$$\text{Overall efficiency} = \frac{\text{Actual fluid power}}{\text{Shaft power}} \times 100$$

$$\begin{aligned}\text{Fluid power} &= \text{Actual flow rate} \times \text{pressure change} \\ &= 5.833 \times 10^{-4} \times 100 \times 10^5 \\ &= 5833 \text{ watts}\end{aligned}$$

$$\begin{aligned}\text{Shaft power} &= \text{Torque input} \times \text{angular speed} \\ &= 15 \text{ kW} = 15000 \text{ W}\end{aligned}$$

$$\begin{aligned}\text{Overall efficiency} &= \frac{5833 \times 100}{15000} \\ &= 388.9\% \quad //\end{aligned}$$

$$\text{Volumetric efficiency} = \frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100$$

$$\begin{aligned}\text{Ideal flow rate} &= \text{nominal displacement} \times \text{speed} \\ &= 5 \times 10^{-4} \times 14.2 \\ &= 7.1 \times 10^{-3} \text{ m}^3/\text{sec}\end{aligned}$$

$$\begin{aligned}\text{Volumetric efficiency} &= \frac{5.833 \times 10^{-4} \times 100}{7.1 \times 10^{-3}} \\ &= 8.22\%\end{aligned}$$

$$(4) \quad z = 24,500 \text{ cm} = \frac{24,500}{100} = 245 \text{ m}$$

$$\text{Flow rate} = 13 \text{ litres/sec}$$

$$\text{Since } 1000 \text{ litres} = 1 \text{ m}^3$$

$$\therefore 13 \text{ litres} = \frac{13 \times 1}{1000} = 0.013 \text{ m}^3/\text{sec}$$

$$\text{Velocity of jet} = 66 \text{ m/sec}$$

Jet issuing from nozzle is at atmospheric pressure and at datum level.

$$p = 0 ; z = 0$$

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

from equation; $P = \left(P + \rho g z + \frac{\rho v^2}{2} \right) Q$

Since

$$P = 0; z = 0$$

$$P = 0 \cdot Q + \frac{\rho Q v^2}{2} + \rho g \cdot 0$$

$$P = \frac{\rho Q v^2}{2} = \frac{1000 \times 0.013 \times 66^2}{2}$$

$$P = 28314 \text{ W} = 28.314 \text{ kW}$$

(ii) At this point; $P = 0$ while $v = 0$

$$P = \left(P + \rho g z + \frac{\rho Q v^2}{2} \right)$$

$$P = \rho g z = 1000 \times 0.013 \times 9.8 \times 240$$

$$= 30576 \text{ W}$$

$$= 30.576 \text{ kW}$$

(iii) Power loss in transmission = $30.576 - 28.314$
 $= 2.262 \text{ kW} = 2262 \text{ W}$

Head loss in pipeline;

$$h = \frac{\text{Power transmission loss}}{\rho g Q}$$

$$= \frac{2262}{1000 \times 9.81 \times 0.013} = 17.73 \text{ m}$$

(iv) Efficiency of the pipeline and nozzle;

$$\Rightarrow \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100 = \frac{28314}{30576} \times 100$$

$$\Rightarrow 92.6\%$$

(5) specific gravity of oil = 0.89

$$z = 30,000 \text{ cm} = 300 \text{ m}$$

$$Q = 220 \text{ litres/sec}$$

$$\text{Since } 1000 \text{ litres} = 1 \text{ m}^3$$

$$220 \text{ litres} = \frac{220 \times 1}{1000} = 0.22 \text{ m}^3/\text{sec}$$

$$\text{velocity of jet} = 7 \text{ m/sec.}$$

(i) specific gravity = $\frac{\text{specific weight of liquid}}{\text{specific weight of water}}$

$$0.89 \times 9.81 = \text{specific weight of liquid}$$

$$\Rightarrow 8.7309 \text{ kN/m}^3 = 8730.9 \text{ N/m}^3$$

$$\therefore \text{density } (\rho) = \frac{8730.9}{9.81} = 890 \text{ kg/m}^3$$

Recall:

At the point of jet issuing from nozzle; $P=0$; $z=0$
from equation; $(PQ + \rho g z Q + \frac{\rho V^2 Q}{2}) = \text{Power}$

$$P = \frac{\rho V^2 Q}{2} = \frac{890 \times 7^2 \times 0.22}{2}$$

$$= 4797.1 \text{ W} = 4.7971 \text{ kW}$$

(ii) Power supplied from reservoir; $P=0$; $V=0$

$$\text{Power} = (PQ + \rho g z Q + \frac{\rho V^2 Q}{2})$$

$$\text{Power} = \rho g z Q = 890 \times 300 \times 9.81 \times 0.22$$

$$= 576239.4 \text{ W} = 576.2394 \text{ kW}$$

(iii) Power loss in transmission = $576239.4 - 4797.1$

$$= 571442.3 \text{ W}$$

$$\text{Head used} = \frac{\text{Power loss in transmission}}{\rho g Q}$$

$$\Rightarrow \frac{571442.3}{890 \times 9.81 \times 0.22}$$

$$= 297.50 \text{ m}$$

$$(v) \text{ efficiency} = \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100$$

$$= \frac{4797.1}{576239.4} \times 100$$

$$= 0.83\%$$

(6) Power = pressure \times flow rate

$$\text{Pressure of water} = \rho gh = 1000 \times 9.81 \times 20$$

$$= 196200 \text{ N/m}^2$$

$$\text{Area} = \pi \times (0.05)^2 = 7.854 \times 10^{-3} \text{ m}^2$$

$$\text{Volume} = 7.854 \times 10^{-3} \times 20 = 0.1571 \text{ m}^3$$

$$Q = \text{flow rate} = \frac{0.1571}{60} = 2.62 \text{ m}^3/\text{s}$$

$$\text{Power} = 196200 \times 2.62 = 514044 \text{ W} = 514.044 \text{ kW}$$

$$(7) \text{ Inlet diameter } (D_1) = 0.3 \text{ m} \Rightarrow \frac{\pi \times 0.3^2}{4} = 0.071 \text{ m}^2 = \text{Inlet Area } (A_1)$$

$$\text{Throat diameter } (D_2) = 0.2 \text{ m} \Rightarrow \frac{\pi \times 0.2^2}{4} = 0.031 \text{ m}^2 = \text{Throat Area } (A_2)$$

$$C_d = 0.96 ; h = 0.06 \text{ m} ; \text{Sp. gr of mercury} = 13.6$$

$$\text{Sp. gr of water} = 1$$

$$\text{Sp. gr of gas}$$

$$\text{Sp. gr of gas} = 19.62$$

$$\text{Specific weight of gas} = 19.62 \text{ N/m}^3$$

$$\text{Sp. gr of gas} = \frac{19.62}{9.81} = 2.0$$

$$Q = C_d \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

$$Q = 0.96 \times 0.071 \times 0.031 \times \frac{\sqrt{2 \times 9.81 \times 0.06}}{\sqrt{(0.071)^2 - (0.031)^2}}$$

$$Q = 0.0359 \text{ m}^3/\text{s}$$

$$\text{Volume flowing} = 0.0359 \text{ m}^3$$

(8) Throat diameter (D_2) = 0.076 m

$$\text{Throat area } (A_2) = \frac{\pi \times (0.076)^2}{4} = 4.54 \times 10^{-3} \text{ m}^2$$

Relative density = 0.8

Pipe diameter = 0.152 m = D_1

Pipe Area (A_1) = 0.0181 m²

Difference between inlet and throat = 0.914 m

$C_d = 0.97$

$$\text{Since } h = \left(\frac{P_1}{\rho} - \frac{P_2}{\rho} \right) + (z_1 - z_2)$$

(a) When $P_1 = P_2$

$$\therefore h = (z_1 - z_2) \therefore h = 0$$

$$\text{Discharge } (Q) = C_d \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

Since $h = 0$

$$\therefore Q = 0$$

(b) When $P_1 - P_2 = 15170$; $0.8 \times 1000 = 800 \text{ kg/m}^3$ = density of liquid

$$h = \frac{15170}{7848}$$

$$W = \rho g$$

$$W = 800 \times 9.81 = 7.848 \text{ kN/m}^3$$

$$h = 1.933 \text{ m} + 0.914 \text{ m}$$

$$\therefore h = 2.847 \text{ m}$$

$$\therefore \text{Discharge } (Q) = C_d \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

$$Q = 0.97 \times 0.0181 \times 4.54 \times 10^{-3} \times \frac{\sqrt{2 \times 9.81 \times 2.847}}{\sqrt{(0.0181)^2 - (4.54 \times 10^{-3})^2}}$$

$$Q = 0.034 \text{ m}^3/\text{seconds}$$

(9) section 1 diameter = 300 mm = 0.3 m (D_1)
 section 1 Area = $\frac{\pi \times 0.3^2}{4} = 0.071 \text{ m}^2 (A_1)$

section 2 diameter = 150 mm = 0.15 m (D_2)
 section 2 Area = $\frac{\pi \times 0.15^2}{4} = 0.018 \text{ m}^2 (A_2)$

$Q = 40 \text{ litres/sec} = 0.04 \text{ m}^3/\text{sec}$

$z_1 = 10 \text{ m}; z_2 = 6 \text{ m}$

$P_1 = 400 \text{ kN/m}^2 \quad P_2 = ?$
 $= 400 \text{ kPa}$

$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.071} = 0.563 \text{ m/s}$

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.018} = 2.27 \text{ m/s}$

from Bernoulli's equation: $\frac{P_1}{\rho} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + z_2$

$\frac{400}{9.81} + \frac{0.563^2}{2 \times 9.81} + 10 = \frac{P_2}{9.81} + \frac{2.27^2}{2 \times 9.81} + 6$

$\frac{P_2}{9.81} = 44.53$

\therefore Intensity of pressure at section 2 $\Rightarrow 9.81 \times 44.53$

$P_2 = 436.82 \text{ kN/m}^2$

(10) axis = 12 m below sea-level.

$y = 170 \text{ mm} = 0.17 \text{ m}$ of mercury

sp. gravity of Hg = 13.6

sp. gravity of water = 1.026

$h = y \left(\frac{s_{hl}}{s_l} - 1 \right)$

$h = 0.17 \left(\frac{13.6}{1.026} - 1 \right)$

$h = 2.08 \text{ m}$

$$\therefore \text{Velocity of submarine (V)} = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.05} \\ = 6.39 \text{ m/s}$$