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1. Ideal flow rate = Nominal displacement × Speed

$\Rightarrow 10 \times 1500 = 15000\ cm^3/min$

$\Rightarrow 15\ dm^3/min$

i. Volumetric efficiency = $\frac{\text{Actual flow}}{\text{Ideal flow}} = \frac{10}{15} \times 100$

$= 0.67 \times 100$

$= 67\%$

ii. Fluid power = $Q \Delta P$

$Q = 10\ dm^3/min \Rightarrow 16.7 \times 10^{-5}\ m^3/s$

$\Delta P = 12 \times 10^5\ N/m^2$

fluid power $= 16.7 \times 10^{-5} \times 12 \times 10^5$

$= 200.4$ Watts

iii. Shaft power $= \frac{2\pi NT}{60}$

$= \frac{2 \times \pi \times 1500 \times 15}{60}$

$= 2356.2\ Nm$

iv. Overall efficiency = $\frac{\text{Fluid power}}{\text{Shaft power}} = \frac{200.4}{2356.2}$

$= 0.09$

(2) Overall efficiency $= 87\% \Rightarrow 0.87$
~~fluid power = $Q\Delta P$~~
$Q = 35\ dm^3/min \Rightarrow 58.3 \times 10^{-5}\ m^3/s$
$\Delta p = 100 \times 10^5\ N/m^2$

fluid Power $= 58.3 \times 10^{-5} \times 100 \times 10^5$
$= 5830$ watts

Shaft power $= \dfrac{\text{fluid power}}{\text{Overall efficiency}}$
$= \dfrac{5830}{0.87} = \cancel{6701\ watt}$
$= 6701$ watts / $6.7\ kW$

(3) Actual flow rate $= 35\ dm^3/min$ | Speed $= 850$ rpm
Speed of rotation $= 850$ rpm.
Shaft power $= 15\ kW$
Ideal flow rate $=$ Nominal displacement $\times$ speed
$= 50 \times 850 = 42{,}500\ cm^3/min$
$\Rightarrow 42.5\ dm^3/min$

Volumetric Efficiency $= \dfrac{\text{Actual flow}}{\text{Ideal flow}} = \dfrac{35\ dm^3/min}{42.5\ dm^3/min}$
$= 0.82$ or 82%

fluid power $= Q\Delta P$
$Q = 35\ dm^3/min \Rightarrow 58.3 \times 10^{-5}\ m/s$
Change in Pressure $= 100 \times 10^3\ N/m^2$
fluid Power $= 58.3 \times 10^{-5} \times 100 \times 10^3$
$= 58.30$

Overall efficiency $= \dfrac{58.30}{15000} = \cancel{0.0039 \times 100}$
$= 0.39 \times 100$
$= 39\%$

4 $Z_1 = 2400 cm \Rightarrow 240 m$

$Q = 13$ litres/sec $= 13 \times 10^{-3} m^3 s^{-1}$

$V = 66 m s^{-1}$

The jet issued from the nozzle will be at atmosphere pressure and datum head

$\therefore P_2 = 0 \; ; \; Z_2 = 0$

$$Power = PQ + \frac{\rho Q V^2}{2} + \rho g Q P$$

$$= \frac{\rho Q V^2}{2} = \frac{1000 \times 13 \times 10^{-3} \times (66)^2}{2}$$

$$= 28.31 kW$$

ii For power supplied from a reservoir

$$Power = PQ + \frac{\rho Q V^2}{2} + \rho g Q Z$$

$P = 0 \quad V = 0$

$$P = \rho g Q Z$$

$$= 1000 \times 9.81 \times 13 \times 10^{-3} \times 240$$

$$= 30.6072 kW$$

(iii) Power Loss = Reservoir Power − Jet Power

$$= 30.6072 - 28.314$$

$$= 2.293 kW$$

$$Head \ loss = \frac{Power \ loss}{\rho g Q}$$

$$= \frac{\cancel{30.6072}}{} \quad \frac{2293.2}{100 \times 9.81 \times 13 \times 10^{-3}}$$

$$= 17.982 m$$

iv Efficiency of the pipeline $= \frac{Jet \ Power}{Reservoir \ Power} \times 100$

$$= \frac{28.314}{30.6072} \times 100$$

$$= 92.5\%$$

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

$Z = 30000\,cm = 300\,m$

$s.g. = 0.89$

$Q = 220$ litres/sec $= 2.2 \times 10^{-1}\,m^3 s^{-1}$

Velocity of jet $= 7\,ms^{-1}$

(i) Power of Jet $= \frac{\rho q v^2}{2}$

$= \frac{(0.89 \times 1000) \times 0.22 \times 7^2}{2}$

$= 4797.1$ Watts

ii Power Supplied from reservoir $= \rho g Q Z$

$= (0.89 \times 1000) \times 9.81 \times 0.22 \times 300$

$= 576239\,W$

iii Power Loss in transmission $= 576239 - 4797.1$

$= 571441.9\,W$

Head Loss $= \frac{\text{Power Loss}}{\rho g Q} = \frac{571441.9}{(0.89 \times 1000) \times 9.81 \times 0.22}$

$= 297.5\,m$

iv Efficiency $= \frac{4797.1}{576239} \times 100$

$= 0.83\%$

(6) $h = 20\,m$

$d = 10\,cm \Rightarrow 0.1\,m$

$g = 9.81\,ms^{-2}$

Flow rate $= A \cdot V$

$V = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 20} = 19.8\,ms^{-1}$

flow rate $= \frac{\pi d^2}{4} \cdot V$

$= \frac{\pi (0.1)^2}{4} \times 19.8$

$= 0.156\,m^3 s^{-1}$

Mass flow rate $= \rho . Q$

$= 1000 \times 0.156$

$= 156\ kgs^{-1}$

Power $= \frac{\text{Work done}}{\text{time}} = \frac{mgh}{t}$

$= \frac{m}{t} \times g \times h$

$= 156 \times 9.81 \times 20$

$= 30607.2\ W$

$= 30.6\ kW$

7 $d_1 = 0.3m \quad d_2 = 0.2m$

$C_d = 0.96 \quad \rho g = 19.62\ Nm^{-3}$

$A_1 = \frac{\pi d_1^2}{4} = 0.0707m^2$

$A_2 = \frac{\pi d_2^2}{4} = 0.0314m^2$

$Q = A.V, \quad V_1 = \frac{Q}{A_1} = \frac{Q}{0.0707}$

$V_2 = \frac{Q}{A_2} = \frac{Q}{0.0314}$

For the manometer,

$P_1 + \rho g z = P_2 + \rho g (Z_2 - R) + P_w g R$

$P_1 - P_2 = 19.62(Z_2 - Z_1) + 587.423 \quad \text{--} (i)$

for the Venturimeter

$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$

$P_1 - P_2 = 19.62(Z_2 - Z_1) + 0.803V_2^2 \quad \text{--} (ii)$

(i) = (ii)

$0.803 V_2^2 = 587.423$

$V_2 = 24.047\ ms^{-1}$

$Q_{ideal} = A_2 \cdot V_2 = 0.0314 \times 24.047$

$= 0.85 m^3 s^{-1}$

$Q = C_d Q_{ideal} = 0.96 \times 0.85$

$= 0.816 m^3 s^{-1}$

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9 $D_1 = 300mm = 0.3m$

$A_1 = \frac{\pi d^2}{4} = \frac{\pi(0.3)^2}{4} = 0.0707m^2$

$D_2 = 150mm = 0.15m$

$A_2 = \frac{\pi d^2}{4} = \frac{\pi(0.15)^2}{4} = 0.01767m^2$

$P_1 = 400 kNm^{-2}$

$Z_1 = 10m, \quad Z_2 = 6m$

$Q = 40 \text{ litres/sec} = \frac{40 \times 1}{10^3} = 0.04m^3s^{-1}$

$Q = A_1V_1 = A_2V_2$

$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.0707} = 0.566ms^{-1}$

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.01767} = 2.264ms^{-1}$

Using Bernoulli's equation

$$\frac{P_1}{W} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{W} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{P_2}{W} = \frac{P_1}{W} + \left[\frac{V_1^2 - V_2^2}{2g}\right] + [Z_1 - Z_2]$$

$$= \frac{400}{9.81} + \left[\frac{0.566^2 - 2.264^2}{2(9.81)}\right] + [10 - 6]$$

$$= 44.525m$$

$P_2 = W \times 44.525$

$= 9.81 \times 44.525$

$= 436.8 kNm^{-2}$

10 Manometer reading $= 200mm = 0.2m\,Hg$

S.G of mercury, $S_{hg} = 13.6$

S.G of Seawater, $S_2 = 1.025$

$h = y\left[\frac{S_{hg}}{S_2} - 1\right]$

$h = 0.2\left[\frac{13.6}{1.025} - 1\right] = 2.45$

$V = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.45}$

$= 6.93ms^{-1}$