Jacob Schwartz | MET330 | HW4 | 2-13-20

35) Given: $sg = 0.93$
$Q = 0.389 \ ft^3/s$
$P_I = 28.4 \ Hp$
$\eta = 80\%$

$h_{L_{1-2}} = 2.8 \ lb\text{-}ft/lb$
$h_{L_{3-4}} = 28.5 \ lb\text{-}ft/lb$
$h_{L_{5-6}} = 3.5 \ lb\text{-}ft/lb$

$$\frac{P_4}{\gamma} + z_4 + \cancel{\frac{V_4^2}{2g}} + \cancel{h_A} - h_R - \cancel{h_L} = \frac{P_5}{\gamma} + z_5 + \cancel{\frac{V_5^2}{2g}}$$

$$\frac{P_4}{\gamma} + z_4 - h_R = \frac{P_5}{\gamma} + z_5$$

$$h_R = -\left(\frac{P_5 - P_4}{\gamma} + (z_5 - z_4)\right) \longrightarrow 1$$

$$\cancel{\frac{P_1}{\gamma}} + z_1 + \cancel{\frac{V_1^2}{2g}} + \cancel{h_A} - \cancel{h_R} - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

$$z_1 - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

$$P_2 = \gamma\left((z_1 - z_2) - \frac{V_2^2}{2g} - h_L\right)$$

$\gamma = sg(\gamma_w)$

$\gamma = (0.93)(62.4)$

$\gamma = 58.032 \ lb/ft^3$

$$P_2 = (58.032)\left((-4) - \frac{7.57^2}{2(32.2)} - 2.8\right)$$

$$\boxed{P_2 = 446.21 \ lb/ft^2}$$

$P_2 = 3.1 \ psi$

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

$V_2 = \frac{0.3899}{0.05132}$

$V_2 = 7.57 \ ft/s$

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35) $P_3 = \gamma\left(\frac{P_2}{\gamma} + \frac{(v_2^2 - V_3^2)}{2g} + h_A\right)$

$h_A = \frac{P_A}{\gamma Q}$

$P_A = e_m P_I$

$P_A = (0.8)(28.4)$

$P_A = 12496 \text{ lb}\cdot\text{ft/s}$

$h_A = \frac{12496}{(58.032)(0.39)}$

$h_A = 552.18 \text{ lb}\cdot\text{ft/lb}$

$V_3 = \frac{0.389}{0.03326}$

$V_2 = \frac{0.389}{0.05132}$

$V_3 = 11.73 \text{ ft/s}$

$V_2 = 7.6 \text{ ft/s}$

$P_3 = 58.032\left(\frac{-446.2}{58.032} + \frac{(7.6^2 - 11.23^2)}{2(32.2)} + 552.18\right)$

$\boxed{P_3 = 31525.88 \text{ lb/ft}^2}$

$P_3 = 219 \text{ psi}$

$P_4 = \gamma\left(\frac{P_3}{\gamma} - h_L\right)$

$P_4 = 58.032\left(\frac{31525.88}{58.032} - 28.5\right)$

$\boxed{P_4 = 29871.97 \text{ lb/ft}^2}$

$P_4 = 207.44 \text{ psi}$

$P_5 = \gamma((z_6 - z_5) + h_L)$

$P_5 = 58.032((-1) + 3.5)$

$\boxed{P_5 = 145.08 \text{ ft/lb}^2}$

$P_5 = 1.01 \text{ psi}$

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35)

Equation 1

$$h_A = -\left(\frac{P_5 - P_4}{\gamma} + (z_5 - z_4)\right)$$

$$h_A = -\left(\frac{145.08 - 29\,860.62}{58.032} + (-2)\right)$$

$$h_A = 514.19 \text{ ft}$$

$$P_A = h_A(\gamma)(Q)$$

$$P_A = (514.19 \text{ ft})(58.032 \text{ lb/ft}^3)(0.39 \text{ ft}^3/\text{s})$$

$$P_A = 11637.45 \text{ lb}\cdot\text{ft/s} \left(\frac{1 \text{ hp}}{550 \text{ lb}\cdot\text{ft/s}}\right)$$

$$\boxed{P_A = 21.16 \text{ hp}}$$

We learned about open channel flow last week, and were instructed on what it was and how to calculate different parts of it. For example, in class we were told to find the height of the depth. This was said to not be solved for very often, as in a typical design we would know this, but were taught how manipulate the equations $AR^{2/3} = nQ/1.49S^{1/2}$ and $R=(h/2)/h+\sqrt{1+h^2}$ Once we learned how to manipulate these, most problems in open channel can be solved. Although you can't solve for h directly and must use a table and interpolate a little bit.

Problem chapter 8.46

unknown: Compute the Pressure at the outlet of the pump,

Solution

$$h_A - h_L + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g}$$ velocity cancels each other out at point 1

$$\therefore P_1 = \gamma(z_2 - z_1) + h_L$$

$$V = \frac{Q}{A}$$

$Q = 4$
$A = 0.3472\ ft^2$ from Appendix F

$$\therefore V = \frac{4}{0.3472} = 11.52\ ft/s$$

$$\therefore h_L = f \times \frac{L}{d} \times \frac{v^2}{2g}$$

$\nu = 1.21 \times 10^{-5}\ ft^2/s$ from Table

$$h_L = 0.0153 \times \frac{2500}{\left(\frac{8}{12}\right)} \times \frac{(11.52)^2}{2(32.2)}$$

$$N_R = \frac{VD}{\nu} = \frac{(11.52)\left(\frac{8}{12}\right)}{1.21 \times 10^{-5}} = 631404.95$$

$$h_L = 117\ ft$$

ε = roughness of pipe $= 1.5 \times 10^{-4}\ ft$

Calculating Pressure

$$\frac{\varepsilon}{d} = \frac{1.5 \times 10^{-4}\ ft}{\frac{8}{12}\ ft} = 0.000225$$

$$P_1 = \gamma[(z_2 - z_1) + h_L]$$

$$P_1 = 62.4 \times [(210 - 0) + 117) \times \frac{1}{144}$$

$$\therefore P = 141.7\ psig$$

Problem 62

formula

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right]}$$

$$N_R = \frac{vD}{\nu} = \frac{(12)(0.5054)}{1.27 \times 10^{-3}}$$
$$= 4775.43$$

* Reynolds number is greater than 400, therefore it is turbulent *

$$\therefore f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right.}$$

$$= \frac{0.25}{\left[\log\left(3.7\frac{1}{\left(\frac{0.5054}{1.5\times10^{-4}}\right)} + \frac{5.74}{(4775)^{0.9}}\right)\right]}$$

$$= \frac{0.25}{\left[\log\left(3369.33\right) + \left(28\times10^{-3}\right)^2\right.}$$

$$= \frac{0.25}{\log(3{,}369.33)^2} = \boxed{0.0388}$$

$\therefore$ friction factor $= 0.0388$ //

CH — 8

(33) The Bernoulli's equation is,

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

Taking z_2 as zero, z_1 as h and v_1 as zero,

$$\frac{P_1}{\gamma} + h - h_L = \frac{P_2}{\gamma} + 0 + \frac{V_2^2}{2g}$$

Taking $P_1 = P_2$

$$\Rightarrow h = h_L + \frac{V_2^2}{2g} \quad \text{———} \quad (1)$$

Now, the velocity can be found using,

$$V = Q/A$$

where,

$$D = 0.5054 \ ft$$

$$A = 0.2006 \ ft^2$$

$$\Rightarrow V = \frac{2.50}{0.2006} = 12.46 \ ft/s$$

From table A1,

$$\nu = 9.15 \times 10^{-6} \ ft^2/s$$

The Reynold's number is,

$$R.N = \frac{vD}{\nu} = \frac{12.46 \times 0.5054}{9.15 \times 10^{-6}}$$

$$= 6.8 \times 10^{5}$$

The relative roughness is,

$$R_r = \frac{D}{\varepsilon}$$

where, $\varepsilon = 1.5 \times 10^{-4}\,ft$ from table 8.2

Thus,

$$R_r = 3369.3$$

From Moody's chart,

$$f = 0.0165$$

The head loss is,

$$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g}$$

$$= 0.0165 \times \frac{550}{0.5054} \times \frac{(12.46)^2}{2 \times 32.2}$$

$$= 43.287\,ft$$

Substituting in eq ①

$$h = \frac{12.46^2}{2 \times 32.2} + 43.287$$

$$\boxed{h = 45.69\,ft}$$

Data

$$z_2 - z_1 = 1\,ft$$
$$L_D = 75\,ft$$
$$L_s = 25\,ft$$
$$Q = 300\,gall/min$$
$$= 0.6684\,ft^3/s$$

$$A_D = 0.05132\,ft^2$$
$$D_D = 0.2557\,ft$$

Solution

$$V_D = \frac{0.668}{0.05132} = 13.024\,ft/s$$

The energy equation is,

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_L + h_A = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

Using the given conditions,

$$h_A = h_L + (z_2 - z_1) + \frac{v_2^2}{2g}$$

Now, the area of 4in steel pipe used in suction system is $A_s = 0.0884\,ft^2$ and dia $D_s = 0.3355\,ft$. Now, the velocity in suction pipe is,

$$0.0884$$

$$R_N = \frac{13.024 \times 0.2557}{2.15 \times 10^{-3}}$$

$$= 1548.947 < 4000 \text{ (Laminar)}$$

$$f_D = \frac{64}{R_N} = 0.04132$$

The area of pipe is $A_s = 0.088$.

The Reynold's number for suction pipe,

$$R.N_s = \frac{7.56 \times 0.3355}{2.15 \times 10^{-3}} = 1179.711$$

$$f_s = \frac{64}{R.N} = 0.054$$

Head due to friction in 3-in schedule 40 steel,

$$h_D = f_D \times \frac{L_D}{D_D} \times \frac{V_D^2}{2g}$$

$$= 31.92 \text{ ft}$$

For 4 in schedule 40 steel,

$$h_s = \frac{0.054 \times 25 \times 7.56^2}{0.3355 \times 2 \times 32.2} = 3.57 \text{ ft}$$

Total head loss

$$h_T = h_D + h_s$$

$$= 35.49 \text{ ft}$$

$\gamma = SG \times \gamma_w$

$= 0.89 \times 62.4$

$= 55.536\ lb/ft^3$

So,

$$h_A = 35.49 + 1 + \frac{13.024^2}{2 \times 32.2}$$

$$= 39.1\ ft$$

The power delivered by pump is,

$$P = 55.536 \times 0.6684 \times 39.1 \times \frac{1}{550}$$

$$= 2.64\ hp$$

44

$$V_A = \frac{Q}{A_A} = \frac{0.5}{0.06868}$$

$$= 7.28\ ft/s$$

$$V_B = \frac{Q}{A_B} = \frac{0.5}{0.03326}$$

$$= 15.03\ ft/s$$

$$\rho_f = 1.026 \times 1.94$$

$$= 1.9904\ slugs/ft^3$$

$$R.N_B = \frac{V_B D_B \rho_f}{\mu}$$

$$= \frac{15.03 \times 0.2058 \times 1.9904}{4.0 \times 10^{-5}}$$

$$= 1.54 \times 10^5 > 2000 \quad (\text{turbulent})$$

$$R_r = \frac{D_B}{\varepsilon} = \frac{0.2058}{1.5 \times 10^{-4}} = 1372$$

The friction factor is,

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.47}{R.N^{0.9}}\right)\right]^2}$$

$$= 0.02$$

$$h_L = \frac{f L v_B^2}{2 g D_B} = 27.27 ft$$

The specific weight is,

$$\gamma_f = 1.026 \times 62.4 \; lb/ft^3$$

$$= 64.0224 \; lb/ft^3$$

Bernoulli's equation applied to gives system,

$$h_A = \left(\frac{25-(-3.5)}{64.0224}\left(144\right)\right) + (80-0) + \left(\frac{15.03^2 - 7.28^2}{2(32.2)}\right) + 27.27$$

$$= 174.485 \; ft$$

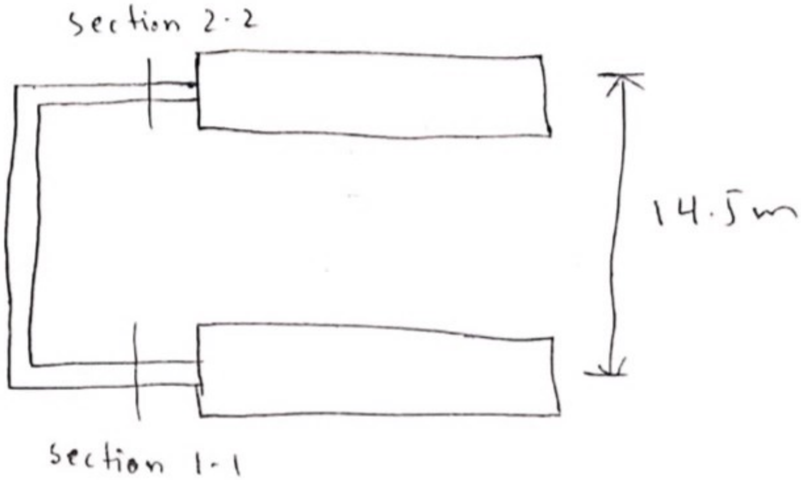
$$P = \frac{h_A \gamma_f Q}{550} = 10.155 \text{ hp}$$

CH — 7

Q.16

(a)

The schematic of the sections is,



$$P = \dot{m} W_P$$

But,

$$\rho_{oil} = 0.85 \times 1000$$
$$= 850 \text{ kg/m}^3$$

The mass flow rate is,

$$\dot{m} = \rho_{oil} Q = \frac{850 \times 840}{1000}$$
$$= 11.9 \text{ kg/s}$$

Bernoulli's equation applied gives

$$\frac{P_1}{\rho_{oil}} + \frac{V_1}{2} + z_1 g = \frac{P_2}{\rho_{oil}} + \frac{V_2}{2} + z_2 g + W_P + (h_L) g$$

$$\frac{\quad}{850} + \frac{\quad}{2} + (0 \times 9.81) = \frac{825 \times 10}{850} + \frac{0}{2} + (14.5 \times 9.81) + W_p + (4.2 \times 9.81)$$

Solving for W_p

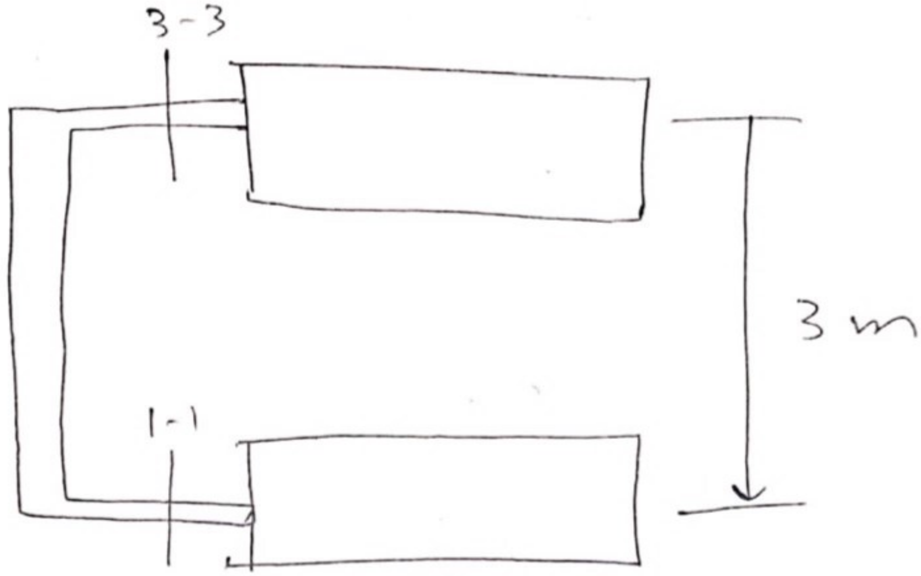
$$W_p = -1154.03 \ \mathrm{N.m/kg}$$

Finally,

$$P = \dot{m} W_p = 13733 \ \mathrm{Watt}$$

(b)

Schematic is,



$$Q = A_3 V_3$$

$$= \left(\frac{\pi}{4} d^2\right) V_3$$

$$\Rightarrow V_3 = Q \Big/ \left(\frac{\pi}{4} d^2\right)$$

$$= \frac{840/60}{\frac{\pi}{4} \times 0.0627^2}$$

$$= 4.534 \ \mathrm{ms^{-1}}$$

Substituting values in Bernoulli's eq.

$$\frac{0}{850} + \frac{0}{2} + (0 \times 9.81) = \frac{P_3}{850} + \frac{4.534^2}{2} + (3 \times 9.81) + (1.4 \times 9.81)$$

$$\Rightarrow P_3 = -45.42 \times 10^3 \; N/m^2$$
$$= -45.4 \; kPa$$

Q11

$Q = 745 \; gal/h$

$z_1 - z_2 = 120 \; ft$

$h_L = 10.5 \; lb \cdot ft/lb$

$P_1 = 1 \; hp$

$P_2 = 40 \; psig = 5760.03 \; lb/ft^2$

Using Bernoulli's equation and recognizing that both point have no energy removed from system thus, $h_R = 0$. Further velocity of point 1 is zero and $P_1 = 0$ because of atmospheric pressure.

$$z_1 + h_A - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\Rightarrow h_A = \frac{P_2}{\gamma} + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$$

$$V_2 = \frac{Q}{A} = \frac{745}{\frac{449 \times 60}{0.006}} = 4.61\ ft/s$$

So,

$$h_A = \frac{5760.36}{62.4} + 120 + \frac{4.61^2}{2 \times 32.18} + 10.5$$

$$= 223.13\ ft$$

The power developed is,

$$P_A = 223.13 \times 62.4 \times \frac{745}{449 \times 60}$$

$$\boxed{(a)\quad P_A = 0.70\ hp}$$

Now,

$$\eta = \frac{P_A}{P_1} = \frac{0.7}{1} = 0.7$$

$$\boxed{(b)\quad \eta = 70\%}$$

$p_1 = 30\ \text{psig} = 4320\ lb/ft^2$

$h_L = 15.5\ lb.ft/lb$

$z_1 - z_2 = 220\ ft$

$Q = 40\ gal/min$

$= 0.089\ ft^3/s$

$$P_A = h_A \gamma Q$$

where h_A is the energy added to the pump.

Applying the bernoulli's equation

$$z_1 + h_A - h_L = \frac{p_2}{\gamma} + z_2$$

$$\Rightarrow h_A = \frac{p_2}{\gamma} + (z_2 - z_1) + h_L$$

$$= \frac{4320}{62.4} + 220 + 15.5$$

$$= 304.73\ ft$$

Finally, power is,

$$P_A = 304.73 \times 62.4 \times 0.089$$

$$= 1692.35\ lb.ft/s$$

$$\boxed{P_A = 3.08\ hp}$$

ch7. 22, 30
ch8. 38

HW. ch7.

22.) gravity = .90 lose = 11.5
dia = 5 in i = 35
T = 15 s
L = 20 in 3/8 in schedulel 80 steel pipe
F = 11,000

Solution:

A) $A = \frac{\pi d^2}{4}$ $A = \frac{\pi(5)^2}{4} = 19.635 in^2$

$Q = \frac{A \cdot L}{t}$ $Q = \frac{(19.635 in^2)\left((20)\left(\frac{1}{12}\right)\right)}{15} \cdot \frac{1}{144}$

$\boxed{Q = .01515 ft^3/s}$

B.) $P_0 = \frac{F}{A}$ $p = \frac{11000 lb}{19.635 in^2}\left(\frac{144 in^2}{1 ft^2}\right) = \boxed{80672.27 lb/ft^2}$

C) $V_c = \frac{Q}{A_c}$

$V_c = \frac{.01515 ft^3/s}{.000976 ft^2} = 15.52 ft/s$

$v_d = \frac{L}{t}$ $\frac{20 in}{15 s} \cdot \left(\frac{1 ft}{12 in}\right) = .1111 ft/s$

$y_o = Sg(y_w)$

$y_o = .90(62.4 lb/ft^3) = 56.16 lb/ft^3$

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$$\frac{P_C}{\gamma_0}+\frac{V_C^2}{2g}+Z_C-h_{LD}=\frac{P_D}{\gamma_0}+\frac{V_D^2}{2g}+Z_D$$

$$P_C=P_D+\gamma_0\left[\left(\frac{V_D^2-V_C^2}{2g}\right)+(Z_D-Z_C)+h_{LD}\right]$$

$$P_C=80672.27+56.16\left[\left(\frac{1.1111^2-15.52^2}{2(32.2)}\right)+(10-0)+35\right]$$

$$P_C=82990.499\ \text{lb/ft}^2$$

d.) $$P_B=\gamma_0\left[(Z_A-Z_B)-\frac{V_B^2}{2g}-h_{LS}\right]$$

$$P_B=56.16\left[(-5-0)-\frac{(15.52)^2}{2(32.2)}-11.5\right]$$

$$P_B=-1136.69\ \text{lb/ft}^2$$

E.) $$h_A=\frac{P_D}{\gamma_0}+\frac{V_D^2}{2g}+(Z_D-Z_A)+h_{LS}+h_{LD}$$

$$h_a=\frac{80672.27}{56.16}+\frac{(.1111)^2}{2(32.2)}+(10-(-5))+11.5+35$$

$$=1497.97\text{ft}$$

$$P=\frac{h_A\gamma_0 Q}{550}$$

$$P=\frac{(1497.97)(56.16)(.01515)}{550}=2.32\ \text{hp}$$

Ch. 7

problem 30.

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_t + h_A - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

$$h_R = \frac{P_A}{\gamma Q} \qquad h_R = \frac{37 \times 550}{62.4 \times 2.227} = 146.43\,ft$$

$$V = \frac{Q}{A} = \quad V_2 = \frac{2.227}{.3472} = 6.41\,ft/s$$

$$h_L = (z_1 - z_2) - \frac{V_2^2}{2g} - h_R$$

$$= 165 - \frac{6.41^2}{2 \times 32.2} - 146.43$$

$$\boxed{= 18\,ft}$$

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Ch 8.

problem 38.)

Known:
$G = 1.10$
$v = 2.0 \times 10^{-3} Pa \cdot S$
$ID = 25mm$
$140kPA$

Solution:

$A = \frac{\pi D^2}{4}$ $A = \frac{\pi (.025)^2}{4} = 4.909 \times 10^{-4} m^2$

$Q = 95 L/min$ $= 95L \times \frac{1m^3}{10^3 L} \times \frac{1m}{60s}$

$= 1.583 \times 10^{-3} m^3/s$

$V_1 = V_2 = V_3 = \frac{Q}{A}$ $v = \frac{1.583 \times 10^{-3}}{4.909 \times 10^{-4}} = 3.22 m/s$

$P = (G_g)(P_w)$ $P = (1.10)(1000 kg/m^3) = 1100 kg/m^3$

$Re = \frac{PvD}{n}$ $= \frac{11000 \times 3.22 \times .025}{2 \times 10^{-3}} = 44275$

$h_L = f \frac{L}{D} \times \frac{v^2}{2g}$ $h_L = .024 \times \frac{95}{.025} \times \frac{3.22^2}{2 \times 9.81}$

$= 43.122m$

$y = S_g \times y_w$ $y = (1.10)(9.81) = 10.791 kN/m^3$

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$$h_A = \left(\frac{P_2}{\gamma} - \frac{P_{atm}}{\gamma}\right) + (z_2 - z_1) + \frac{v_2^2}{2g} + h_L$$

$$h_A = \left(\frac{140}{10.791} - \frac{101}{10.791}\right) + (10 - (1.5 + 1.2)) + \frac{3.22^2}{2 \times 32.2} + 43.122$$

$h_A = 54.197$ m

So,

$$P = h_A \times \gamma \times Q$$

$$P = 54.197 \times 10.791 \times 1.58 \times 10^{-3}$$

$$\boxed{= .924 \text{ kW}}$$

B.) $$\frac{P_1}{\gamma} + z_1 + h_A = \frac{P_3}{\gamma} + z_3 + \frac{V^2}{2g}$$

$$\frac{101}{10.791} + 1.2 + 54.197 = \frac{P_3}{10.791} + 0 + \frac{3.22^2}{2 \times 9.81}$$

$$64.756 = \frac{P_3}{10.791} + .528$$

$$\boxed{P_3 = 693.084 \text{ kPA}}$$