Robert Slade

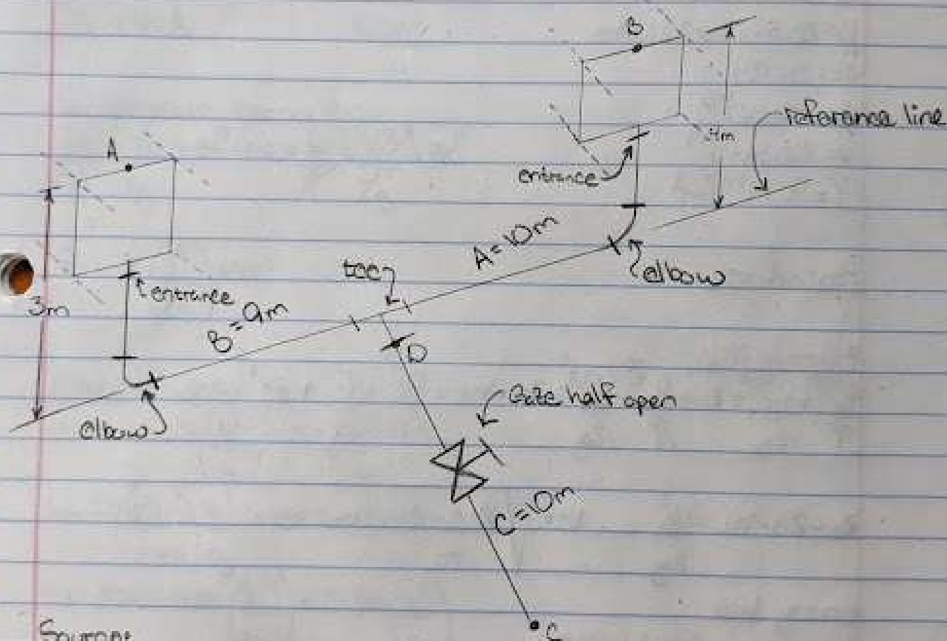
Exam 2 problem 1

Purpose:

Determine the flow out of the system if the gate valve is half open

Compute the pressure at the exit of the tee

drawing:



Source:

mott Robert L, Untener, Joseph Applied fluid mechanics 7th 2015 Reprinted by permission of pearson Education Inc New York New York

Design Considerations

The following must be assumed

1) Incompressable fluid
2) Isothermal Process
3) Steady State

Data and Variables

$K_1 = 0.25$ entrance loss

$D = 20.9\,mm \rightarrow 0.0209\,m$

$f_t = 0.024$

$\varepsilon = 4.6 \times 10^{-5}$

$v = 8.03 \times 10^{-7}$

$\gamma = 9.77\,kN/m^3$

Procedure:

Bernoullis

$$\cancel{\frac{P_a}{\gamma}}^{0} + \cancel{\frac{V_a^2}{2g}}^{0} + z_a + \cancel{\frac{P_b}{\gamma}}^{0} + \cancel{\frac{V_b^2}{2g}}^{0} + z_b - h_L = \cancel{\frac{P_c}{\gamma}}^{0} + \frac{V_c^2}{2g} + \cancel{z_c}^{0}$$

$$z_a + z_b - h_L = \frac{V_c^2}{2g} \longrightarrow V_c = \sqrt{\frac{2 \cdot g \cdot z_A + z_b}{h_L}}$$

energy loss

$$h_L = h_1 + h_2 + h_3 + h_4 + h_5$$

$$h_1 = K_1\left(\frac{V_c^2}{2g}\right) \quad h_2 = f\,\frac{L V_c^2}{D 2g} \quad h_3 = f_t\left(\frac{L_e}{D}\right)\frac{V_c^2}{2g} \quad h_4 = f_t\left(\frac{L_e}{D}\right)\frac{V_c^2}{2g}$$

entrance x 2 — Pipe friction — elbow x 2 — Valve

$$h_5 = f_t\left(\frac{L_e}{D}\right)\frac{V_c^2}{2g}$$

find f

D

ε

use D/ε to select from range of ~f (moody chart)

use ~f to find ~Vc

use ~Vc to determine ~Nr

use moody chart to determine f (Repeat steps using f)

$Q_C = V \cdot A$ $\quad A = \frac{\pi D^2}{4}$

for pressure Bernoullis

$$\frac{P_D}{\gamma} + \frac{V_D^2}{2g} + \cancel{Z_A} - h_L = \cancel{\frac{P_C}{\gamma}} + \cancel{\frac{V_C^2}{2g}} + \cancel{Z_C}$$

$$P_D = \gamma\left(\frac{V^2}{2g}\right) + h_L$$

Calculations

$$h_1 = 2 \cdot 0.25\left(\frac{V_C^2}{2g}\right) = 0.5\left(\frac{V_C^2}{2g}\right)$$

$$h_2 = f\left(\frac{29}{.0209}\right)\frac{V_C^2}{2g} = 1387.56f\left(\frac{V_C^2}{2g}\right)$$

$$h_3 = 20 \cdot 0.024\left(\frac{V_C^2}{2g}\right) = 0.96\left(\frac{V_C^2}{2g}\right)$$

$$h_4 = 160 \cdot 0.024\left(\frac{V_C^2}{2g}\right) = 3.84\left(\frac{V_C^2}{2g}\right)$$

$$h_5 = 60 \cdot 0.024\left(\frac{V_C^2}{2g}\right) = 1.44\left(\frac{V_C^2}{2g}\right)$$

$$h_L = 6.74 + 1387.56f$$

$$\frac{D}{\varepsilon} = \frac{0.0209}{4.6\times10^{-5}} = 454.35 \rightarrow N_r \text{ range } 0.024-0.04 \rightarrow \sim N_r = 0.03$$

$$\sim V_C = \sqrt{\frac{2 \cdot 9.81 \cdot 7}{6.74 + 1387(0.03)}} = 1.69 \text{ m/s}$$

$$\sim N_R = \frac{1.69(.0209)}{8.03 \times 10^{-7}} = 4.3986 \times 10^{4}$$

$\therefore f = 0.027$ (moody chart)

$$V_C = \sqrt{\frac{2 \cdot 9.81 \cdot 7}{6.74 + 1387(0.027)}} = \boxed{1.76 \text{ m/s}}$$

$$Q_C = 1.76 \text{ m/s} \cdot .000343 \text{m}^2 = \boxed{0.000604 \text{ m}^3/\text{s}}$$

$$\frac{P_0}{\gamma} + \frac{V_0^2}{2g} + \cancel{z_0}^{0} - h_L = \cancel{\frac{P_C}{\gamma}}^{0} + \cancel{\frac{V_C^2}{2g}}^{0} + \cancel{z_C}^{0}$$

$$P_0 = 9.77\left(\frac{1.76}{2 \cdot 9.81}\right) + 3.84\left(\frac{1.76}{2 \cdot 9.81}\right) = 0.876 + 0.344 = \boxed{1.22 \text{ KPa}}$$

Summary:

The flow out of the system if the gate valve is half open is 6.04×10^{-4} m³/s. The pressure at the exit of the tee is 1.22 KPa

material

water, 3/4" commercial steel pipe, Gate Valve

Analysis

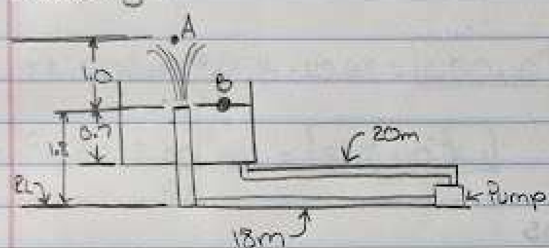
The velocity criterion of 3 m/s was not violated however if it did an increase of the pipe diameter would bring the velocity of the system lower.

Problem 2

Purpose:

Determine the pump power required for the fountain.
Determine the electrical power requirements for pump-motor efficiency of 92%

Drawings:



Sources:

Mott Robert L, Untener, Joseph. Applied fluid Mechanics 7th - 2015 Reprinted by Permission of Pearson Education Inc New York New York

Design considerations

The following must be assumed
1) Incompressable fluid
2) Isothermal Process
3) Steady State

Data and Varibles

$O_L = 18m$ Diameter 1" (0.0212m) $Q = 2.3\,m^3/s$ $V = 1.1\,m/s$ $\varepsilon = 3.0\times10^{-7}\,m$

$I_L = 20m$ Diameter 3/4" (0.017m) $Q = 2.3\,m^3/s$ $V = 1.8\,m/s$

Annular flow

$D_o = 10cm \rightarrow 0.1m$

$D_i = 7cm \rightarrow 0.07m$

$K = 2$

$L = 1.8m$

$\nu = 1.02\times10^{-6}$

Procedure

$$h_a + \cancelto{0}{\frac{P_a}{\gamma}} + \cancelto{0}{\frac{V_a^2}{2g}} + z_a = \cancelto{0}{\frac{P_b}{\gamma}} + \cancelto{0}{\frac{V_b^2}{2g}} + z_b + h_L$$

$$h_a + z_a = z_b + h_L$$

$$h_a = (z_b - z_a) + h_L$$

$$\text{Power} = \gamma Q h_a$$

$$P_{input} = \frac{\text{Power}}{\eta}$$

$$h_L = h_1 + h_2 + h_3 + h_4 + h_5$$

$$h_1 = f\frac{LV^2}{D2g} \quad h_2 = f\frac{LV^2}{D2g} \quad h_3 = f\frac{LV^2}{4R2g} \quad h_4 = 1.0\frac{V^2}{2g} \quad h_5 = K\frac{V^2}{2g}$$

$$R = \frac{\text{Area}}{WP}$$

Calculations

$$\text{Suction} = \frac{D}{\varepsilon} = \frac{0.0212}{3.0\times10^{-7}} = 7.1\times10^{4} \quad \text{Discharge} = \frac{0.017}{3.0\times10^{-7}} = 5.7\times10^{4}$$

$$\text{Suction } N_r = \frac{1.1\,(0.0212)}{1.02\times10^{-6}} = 2.2\times10^{4} \quad \text{Discharge} = \frac{1.8\,(0.017)}{1.02\times10^{-6}} = 3\times10^{4}$$

moody $f = 0.024$ moody: $f = 0.023$

$$R = \frac{\pi(D^2 - d^2)}{4} = 0.024$$

$$h_1 = 0.024\left(\frac{20 \cdot 1.1^2}{0.021 \cdot 2 \cdot 9.81}\right) = 1.41 \quad h_2 = 0.023\left(\frac{18 \cdot 1.8^2}{0.017 \cdot 2 \cdot 9.81}\right) = 9.77$$

$$h_3 = 0.023\left(\frac{1.8 \cdot 1.8^2}{4 \cdot 0.024 \cdot 2 \cdot 9.81}\right) = 0.041 \quad h_4 = 1.0\left(\frac{1.1^2}{2 \cdot 9.81}\right) = 0.071$$

$h_s = 2\left(\frac{1.8^2}{2 \cdot 9.81}\right) = 0.33$

$h_L = 1.41 + 9.77 + 0.041 + 0.071 + 0.33 = 11.62$

$h_a = (1.8 - 2.8) + 11.62$
$h_a = 10.62m$

$P = 1.02 \times 10^{-6} \cdot 2.3 \cdot 10.62 = \boxed{2.50 \times 10^{-5}\ kw}$

$P_{input} = \frac{2.50^{-5}\ kw}{.92} = \boxed{2.72 \times 10^{-5}\ kw}$

Summary:
The pump power required for the fountain is 2.5×10^{-5} kw and the electrical power requirement at 92% efficiency is 2.72×10^{-5} kw.

material
1" PVC pipe
3/4" PVC pipe
annular flow line
Pump.