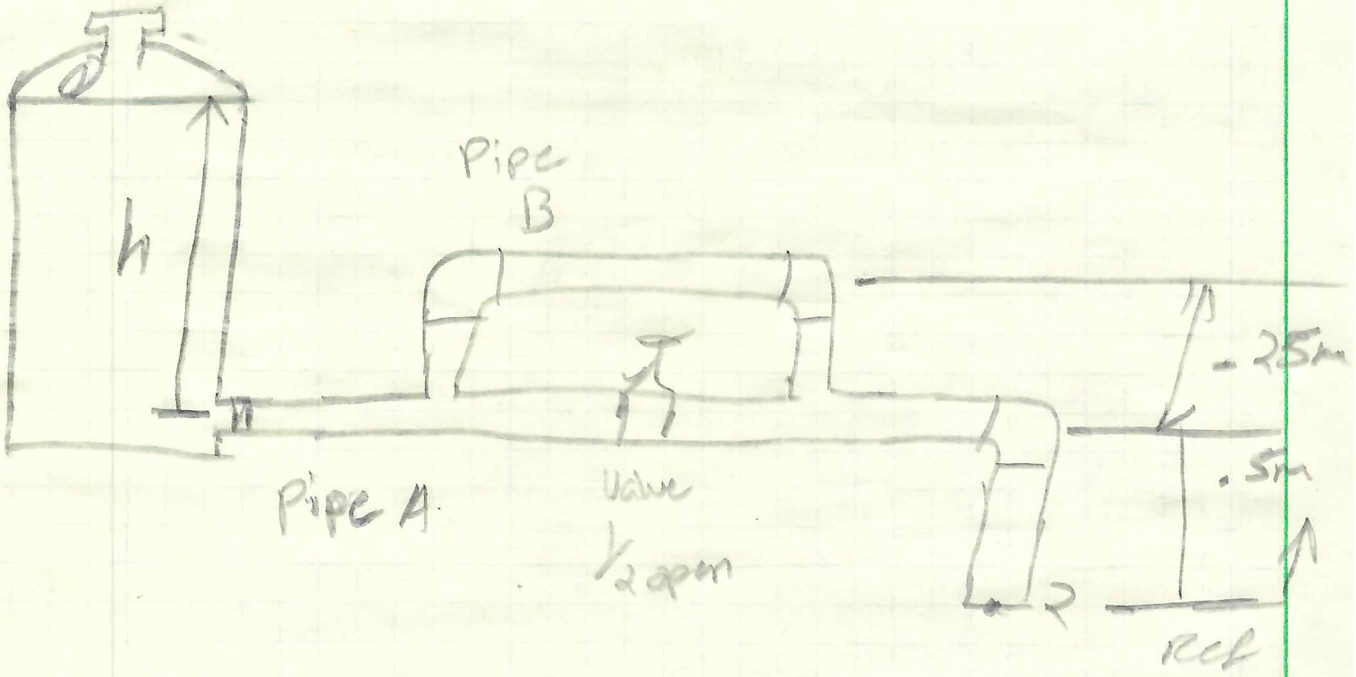
MET330 | EXAM 3 | FRIAS-GARCIA



Purpose: Find How Much Total Flow Rate would you get if you modify pipeline to figure 2.

Sources: Mott, R, Untener, JA, "Applied Fluid Mechanics" 7th edition, Pearson Education Inc. (2015).

Design Considerations: New branch is made up of horizontal pipe whose length is 2/3 of previous horizontal pipe length figure 1. Vertical portions are .25m long, Diameter Same as 1st test & gasoline depth remains same from 1st test.

Pipe 1 length

$L = 2.25m$

Pipe 2 length

$L = 2.25m\left(\frac{2}{3}\right) = 1.5m$

Depth of gasoline

$h = 3.65m$

$Q_{total} = \sum_{n} Q_i$

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

$h_{L_1} = h_{L_2} = h_{L_n} = h_{L_{total}}$

$\Delta P_{L_1} = \Delta P_{L_2} = \Delta P_{L_n} = \Delta P_{L_{total}}$

$$h_{L_B} = \frac{P_1 - P_3}{\gamma} + \frac{v_1^2 - v_3^2}{2g} + z_1 - z_3$$

What we know in pipe 1

Length = 2.25m

DN 90 schedule 40 steel pipe

$\gamma_{gas} = 6.67 \frac{kN}{m^3}$

$\nu_{gas} = 4.22 \times 10^{-7} \frac{m^2}{s}$

Diameter = 90.1×10^{-3} m
Area = $6.381 \times 10^{-3} m^2$ } table F.1

P = 0 atm

$k_{elbow} = 30 f_T$ $k_{entrance} = .5$
$k_{valve\,1/2} = 160 f_T$ } Table 10.4, figure 10.14

$h_{pipe} = .4235$ m

$h_{minor\ losses} = 2.936$ m

$\varepsilon = 4.6 \times 10^{-5}$ m → table 8.2

Gate valve $\frac{1}{2}$ $L_e/D = 160$ $L_e/D_{elbow} = 30$ } table 10.4

What we know in Pipe 2

DN 90 schedule 40 steel pipe

$\gamma_{gas} = 6.67 \frac{kN}{m^3}$

Diameter = 90.1×10^{-3} m
Area = $6.381 \times 10^{-3} m^2$ } table F.1

$\nu_{gas} = 4.22 \times 10^{-7} m^2/s$

Length 1.5m

$k_{elbow} = 30 f_T$ $k_{entrance} = .5$ } Table 10.4, figure 10.14

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

P = 0 atm

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{12}}$$

$Q_3 = Q_1 + Q_2$

$h_{L_{pipe}} = f \frac{L}{D} \frac{V^2}{2g}$

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B + h_{L_{AB}}$$

$Re = \frac{\rho v D}{\mu} = \frac{vD}{\nu}$

$$\cancel{\frac{P_A}{\gamma}} + \cancel{\frac{V_A^2}{2g}} + z_A = \cancel{\frac{P_B}{\gamma}} + \cancel{\frac{V_B^2}{2g}} + \cancel{z_B} + h_{LAB}$$

both velocities will be the same

$$z_A = h_{LAB}$$

Pipe A $\quad 4.15 = \frac{V^2}{2g} + f_1 \left(\frac{Le}{D}\right)_{Valve} \frac{V^2}{2g} + f_1 \left(\frac{Le}{D}\right)_{elbow} + f_1 \frac{L}{D_1} \frac{V_1^2}{2g}$

Pipe B $\quad .75 = \frac{V^2}{2g} + 2f_2 \left(\frac{Le}{D}\right)_{elbow} \frac{V^2}{2g} + f_2 \frac{L}{D_2} \frac{V^2}{2g}$

Change V into Q

Pipe A $\quad 4.15 = \frac{1}{2g} \frac{16Q_1^2}{\pi^2 D_1^4} + f_1 \left(\frac{Le}{D}\right)_{Valve} \frac{1}{2g} \frac{16Q^2}{\pi^2 D_1^4} + f_1 \left(\frac{Le}{D}\right)_{elbow} \frac{1}{2g} \frac{16Q_1^2}{\pi^2 D_1^4}$

$+ f_1 \frac{L}{D_1} \frac{1}{2g} \frac{16Q_1^2}{\pi^2 D_1^4}$

Pipe B $\quad .75 = \frac{1}{2g} \frac{16Q_2^2}{\pi^2 D_2^4} + 2f_2 \left(\frac{Le}{D}\right)_{elbow} \frac{1}{2g} \frac{16Q_2^2}{\pi^2 D_2^4} + f_2 \frac{L}{D_2} \frac{1}{2g} \frac{16Q_2^2}{\pi^2 D_2^4}$

Simply and plug in Values

Pipe A

$$4.15 = \frac{8}{9.81\pi^2(90.1\times10^{-3})^4} \times Q_1^2 + f_1 (160) + (30) + \frac{2.25}{90.1\times10^{-3}}\Big) \frac{1}{90.1\times10^{-3}}$$

$$\times \frac{8}{9.81\pi^2} Q_1^2$$

$$4.15 = 626.892 \times Q_1^2 + f_1 (197.142) \times Q_1^2$$

Pipe B

$$.75 = \frac{8}{9.81\pi^2(90.1\times10^{-3})} \times Q_2^2 + \Big[f_2 \Big(\underbrace{2(30)}_{\text{elbow}} + \Big(\frac{4.5}{90.1\times10^{-3}}\Big)\frac{1}{90.1\times10^{-3}}\Big]$$

$$\times \frac{8}{9.81\pi^2} Q_1^2$$

$$.75 = 1253.784 \times Q_2^2 + f_2 (20.225) \times Q_2^2$$

Set equations to solve for Q

$$Q_1 = \sqrt{\frac{4.15 - 626.892 \times \frac{s^2}{m^5} \times Q_A^2}{f_1 (197.142) \times \frac{s^2}{m^5}}}$$

$$Q_2 = \sqrt{\frac{.75 - 1253.784 \times \frac{s^2}{m^5} \times Q_B^2}{f_2 (20.225) \times \frac{s^2}{m^5}}}$$

$$Q_3 = Q_1 + Q_2$$

$$\% diff = \frac{f^{(old)} - f^{(New)}}{f^{(old)}} \times 1$$

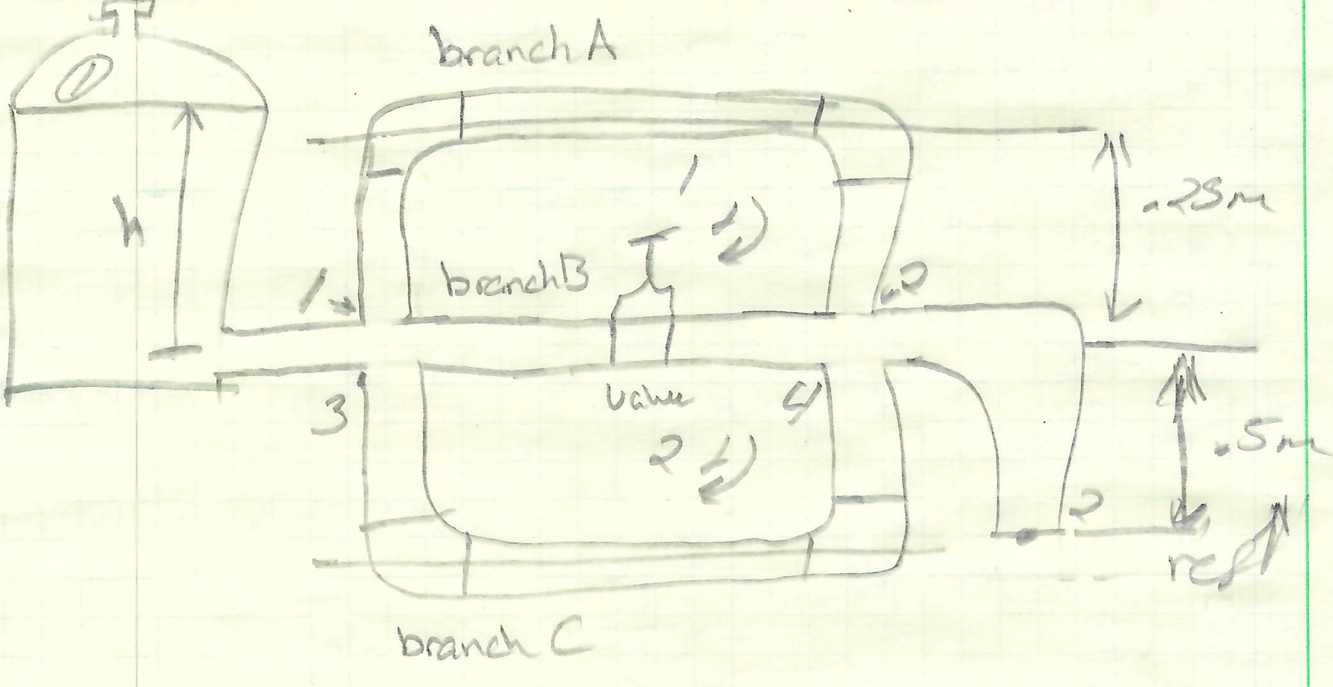
$$f = \frac{.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

$$\% diff = \frac{Q_3^{(New)} - Q_3^{(old)}}{Q_3^{(New)}} \times 100$$

neglected the Junctions and

$$Q_1 = \sqrt{\frac{4.15 \times Q_1^2}{f_1 (197.142)}}$$

$$Q_2 = \sqrt{\frac{.75 \times Q_3^2}{f_2 (20.225)}}$$



Purpose: Use Hardy-Cross Method to prove the new lower branch flow rate will be equal to the upper branch flow rate.

Procedure: Compute each branch losses

$$k_i = \frac{8(L_i + \Sigma L_{e_i}) f_i}{\pi^2 g D_i^5}$$

1) Node law $\Sigma_{Q_i} = 0$

2) Fluids flow on paths with less resistance

Circuit Law $\sum_n h_i = 0$

4 Nodes

Circuit 1	Pipe	Q (m^3/s)	D (m)	e (m)	L	Le
	A	1.4478	90.1×10^{-3}	4.60×10^{-5}	1.5m	60
	B	−1.0292	90.1×10^{-3}	11	2.25m	190

Circuit 2	Pipe	Q (m^3/s)				
	B	1.0292	90.1×10^{-3}	11	2.25m	190
	C	−1.4478	90.1×10^{-3}	11	1.5m	60

For each pipe calculate Values of $2kQ$

for each Circuit $\Sigma(2kQ) \rightarrow \mathrm{abs}(2kQ)$

For each circuit calculate Values of ΔQ

from $\Delta Q = \dfrac{\Sigma h}{\Sigma(2kQ)}$

head loss $h = kQ^2$

or $\mathrm{abs}(kQ)Q$

Find % Error

Error % $= \Delta Q / Q\ (m^3/s) \times 100$