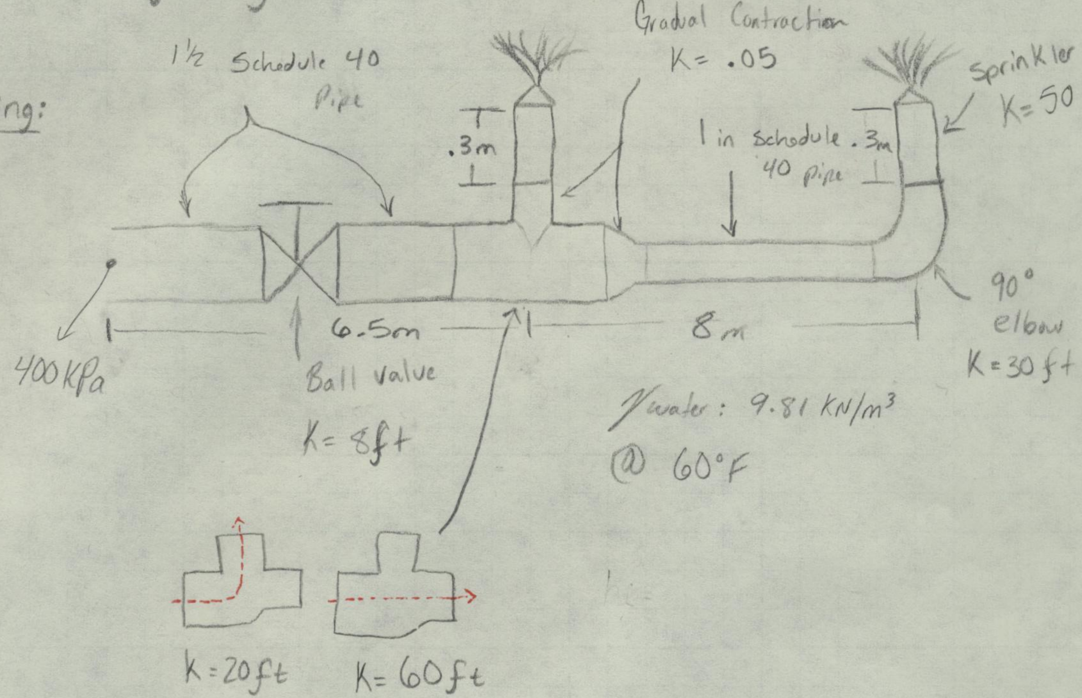
Problem 1	Test 2	Dezmond Banks

Purpose: The purpose of this problem is to determine the flow rate delivered to each sprinkler head without neglecting minor losses.

Drawing:



Sources: Mott, R, Utener, J.A "Applied Fluids Mechanics" 7th edition, Pearson Education INC, (2015)

Design Considerations:

- Assume water temp is 15°C
- Assume K for gate value is same as K for ball value
- Assume Gradual contraction $\theta = 15° - 40°$ $K = .05$
- Incompressible fluid
- Constant pressure

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Data and Variables:

@ 15°C

$\gamma_{water} = 9.81\ KN/m^3$

$h_L = f\frac{L}{D}\left(\frac{V^2}{2g}\right)$ $\quad h_L = K\left(\frac{V^2}{2g}\right)$

$N_R = \frac{VD}{V_{iscosity}}$ $\quad \frac{D}{\varepsilon}$

$\varepsilon = 4.6 \times 10^{-5}$ $\quad V_{iscosity} = 1.15 \times 10^{-6}$

Sprinkler "K" = 50

90° elbow "K" = 30ft

$V = \frac{4Q}{\pi D^2}$ $\quad f = \frac{.25}{\left[\log\left(\frac{\varepsilon/D}{3.7}\right)\right]^2}$

Valve "K" = 8ft

Flow Through run "K" = 20 ft

Flow Through branch "K" = 60 ft

@ 1½ in Schedule 40 pipe

$A = 1.314 \times 10^{-3}$

ID = 40.9mm = .0409m @ Appendix F

$f_t = .020$ @ Table 10.5

@ 1 in schedule 40 pipe

$A = 5.574 \times 10^{-4}$

ID = 26.6mm = .0266 @ Appendix F

$f_t = .022$ @ Table 10.5

Procedure:

1. Calculate K values for pipes and modifications
2. Calculate energy losses
3. Calculate Flow rate (Q) from 1-A, A-B, and A-C
4. Calculate flow velocity

Materials:

- Water
- 1½ in Schedule 40 pipe
- 1 in schedule 40 pipe
- 90° elbow
- Ball valve
- 2 Sprinklers
- 2 gradual contractions
- T Joint

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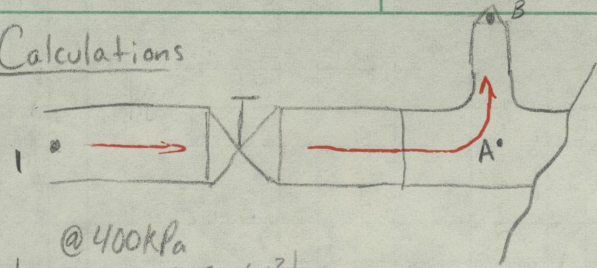
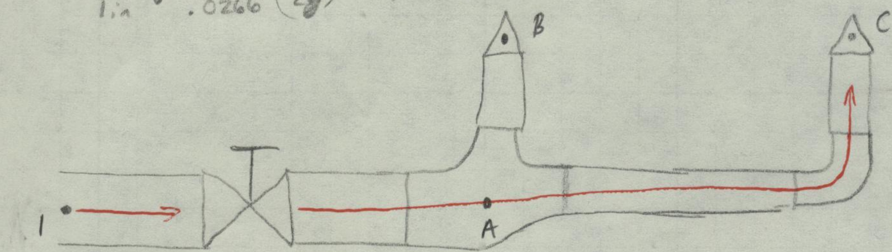
Calculations



@400KPa

- h_L pipe 1½ $f\frac{6.5}{.0409}\left(\frac{V^2}{2g}\right)$ K=3.18
- h_L valve 8ft $\left(\frac{V^2}{2g}\right)$ K=.16
- h_L T joint 20ft $\left(\frac{V^2}{2g}\right)$ K=.4
- h_L Sprinkler $50\left(\frac{V^2}{2g}\right)$ K=50
- h_L gradual Contrac $.05\left(\frac{V^2}{2g}\right)$ K=.05
- h_L pipe 1in $f\frac{.3}{.0266}\left(\frac{V^2}{2g}\right)$ K= .25



h_L pipe 1½ $f\frac{6.5}{.0409}\left(\frac{V^2}{2g}\right)$ K= 3.18

h_L valve $8ft\left(\frac{V^2}{2g}\right)$ K= .16

h_L T joint $60ft\left(\frac{V^2}{2g}\right)$ K= 1.2

h_L grad $.05\left(\frac{V^2}{2g}\right)$ K= .05

h_L pipe 1in $f\frac{8.3}{.0266}\left(\frac{V^2}{2g}\right)$ K= 6.86

h_L elbow $30ft\left(\frac{V^2}{2g}\right)$ K= .66

h_L sprinkler = $50\left(\frac{V^2}{2g}\right)$ K = 50

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Calculations: $h_{L\,1\text{-}B} = h_{L\,1\text{-}A} + h_{L\,A\text{-}B}$ $\quad \frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_1} = \cancel{\frac{P_B}{\gamma}} + \frac{V_B}{2g} + \cancel{z_B} + h_{L_{1\text{-}B}}$

$$\frac{P_1}{\gamma} = h_{L\,1\text{-}B}$$

$$h_{L_{1\text{-}A}} = \frac{8L_{1\text{-}A} f_{1\text{-}A}}{\pi^2 g D^5} Q_{1\text{-}A}^2 + \frac{8}{\pi^2 g D^4}\left(\overset{(.16)}{K_{valve}}\right) Q_{1\text{-}A}^2$$

$$h_{L1\text{-}A} = \frac{8(6.5)(.020)}{\pi^2(9.81)(.0409)^5} Q_{1\text{-}A}^2 + \frac{8}{\pi^2(9.81)(.0409)^4}(.16)\, Q_{1\text{-}A}^2$$

$$93693.69\, Q_{1\text{-}A}^2 + 4723.25\, Q_{1\text{-}A}^2$$

$$h_{L1\text{-}A} = 98416.94\, Q_{1\text{-}A}^2$$

$$h_{LA\text{-}B} = \frac{8L_{AB} f_{AB}}{\pi^2 g D^5} Q_{AB}^2 + \frac{8}{\pi^2 g D^4}\left(\overset{(.4)}{K_{T_{AB}}} + \overset{(.05)}{K_{\substack{Grad\\cont}}} + \overset{(50)}{K_{Sprinkler}}\right) Q_{AB}^2$$

$$h_{L\,AB} = \frac{8(.3)(.022)}{\pi^2(9.81)(.0266)^5} Q_{AB}^2 + \frac{8}{\pi^2(9.81)(.0266)^4}(50.45)\, Q_{AB}^2$$

$$40930.23\, Q_{AB}^2 + 8321649.49\, Q_{AB}^2$$

$$h_{LAB} = 8362579.72\, Q_{AB}^2$$

$$\frac{P_1}{\gamma} = h_{L1\text{-}B} \qquad \frac{400\text{ kPa}}{9.81\text{ kN/m}^3} = \boxed{40.77\text{m} = 98416.94\, Q_{1\text{-}A}^2 + 8362579.72\, Q_{AB}^2} \quad \mathrm{I}$$

$$h_{L1\text{-}C} = h_{L1\text{-}A} + h_{LAC} \qquad \frac{P_1}{\gamma} = h_{L1\text{-}C}$$

$$h_{LAC} = \frac{8L_{AC} f_{AC}}{\pi^2 g D^5} Q_{AC}^2 + \frac{8}{\pi^2 g D^4}\left(\overset{(1.2)}{K_{TAC}} + \overset{(.66)}{K_{elbow}} + \overset{(50)}{K_{sprinkler}}\right) Q_{AC}^2$$

$$h_{LAC} = \frac{8(8.3)(.022)}{\pi^2(9.81)(.0266)^5} Q_{AC}^2 + \frac{8}{\pi^2(9.81)(.0266)^4}(51.86)\, Q_{AC}^2$$

$$1132403\, Q_{AC}^2 + 8554226.8\, Q_{AC}^2$$

$$h_{LAC} = 9686629.9\, Q_{AC}^2$$

$$\mathrm{II}$$

$$\boxed{40.77\text{m} = 98416.94\, Q_{1A}^2 + 9686629.9\, Q_{AC}^2}$$

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Calculations:

$$\boxed{Q_{1-A} = Q_{AB} + Q_{AC}} \quad \underline{III}$$

$$\frac{8362579.72\, Q_{AB}^2}{8362579.72} = \frac{9686629.9\, Q_{AC}^2}{8362579.72}$$

$$\boxed{Q_{AB} = 1.076\, Q_{AC}} \quad \underline{IV}$$

$$40.77m = 98416.94\,(Q_{AB} + Q_{AC})^2 + 9686629.9\, Q_{AC}^2$$

$$40.77m = 98416.94\,(1.076Q_{AC} + Q_{AC})^2 + 9686629.9\, Q_{AC}^2$$

$$40.77m = 98416.94\,(2.076Q_{AC})^2 + 9686629.9\, Q_{AC}^2$$

$$40.77m = 424157.33\, Q_{AC}^2 + 9686629.9\, Q_{AC}^2$$

$$\frac{40.77m}{10110787.23} = \frac{10110787.23\, Q_{AC}^2}{10110787.23}$$

$$Q_{AC} = \sqrt{4.03\epsilon-6}$$

$$Q_{AC} = 2.01\epsilon-3$$

$$Q_{AB} = 1.076\,Q_{AC}$$

$$Q_{AB} = 1.076\,(2.01\epsilon-3)$$

$$Q_{AB} = 2.16\epsilon-3$$

$$Q_{1-A} = Q_{AB} + Q_{AC}$$

$$Q_{1A} = (2.16\epsilon-3) + (2.01\epsilon-3)$$

$$Q_{1A} = 4.17\epsilon-3$$

Comparing velocity to critical velocity.

$$V = \frac{4Q}{\pi D^2}$$

$$V_{AB} = \frac{4\,(2.16\epsilon-3)}{\pi\,(.0266)^2}$$

$$V_{AB} = 3.89 m/s$$

$$V_{AC} = \frac{4\,(2.01\epsilon-3)}{\pi\,(.0266)^2}$$

$$V_{AC} = 3.62 m/s$$

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Summary:

Using the K values provided in the book for each connection in the piping system I was able to calculate the energy losses throughout the system. After calculating my losses I then manipulated bernouli's equation to find the flow rates from points 1-A, A-B, and A-C. Once I knew the flow rate of the system I was able to calculate the flow velocity and Compare it to the critical velocity (3m/s). In this design the velocities were larger than the critical velocity, So to fix this issue the pipe sizes would need to be increased. Comparing the flow rate at each sprinkler, Q_{AB} wa slightly higher than Q_{AC} but still acceptable. If I were to modify the system to make them the same, I would increase the energy losses in pipe A-B.

Anaylysis:

Analyzing the system, I conclude that the pipe sizes should be increased to adjust the flow velocity. Also the system flow rate at each Sprinkler are similar enough to work effectively.