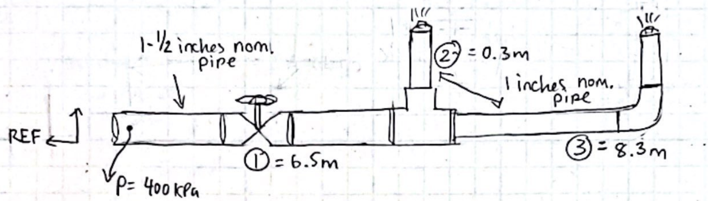
Purpose :
- Determine the flow rate delivered to each sprinkler head.
- Are the flow the same for each sprinkler ? If not, what would make them the same ?
- How does the fluid velocity compare to the critical velocity 3 m/s ? if it is too far off, what can be done ?

Drawing :



Sources: Mott R. and Untener J. Applied Fluid Mechanics. 7th Edition. Pearson 2014.

Design Consideration:

Incompressible fluid
Isothermal process
Steady state
Minor losses

Data and Variables:

$P = 400$ KPa
$\gamma_{water} = 9.81\ kN/m^3$
$\nu = 1.15\times10^{-6}\ m^2/s$
$g = 9.81\ m/s^2$

$D_1 = 40.9$ mm
D_2 & $D_3 = 26.6$ mm
$K_{sprinkler} = 50$
$K_{tee} = 60$

Wall roughness $= 4.6\times10^{-5}$ m
$K_{elbow} = 30$
$K_{valve} = 340$

procedure :

First we pick a reference than use the Bernoulli's equation. Since this is a parallel pipeline with 2 branches, label the pipes and consider all energy losses

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

$$\frac{P_1}{\gamma} = h_L$$

Calculation:

(I) Branch 1

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1}\frac{V_1^2}{2g} + K_{valve}\frac{8Q_1^2}{g\pi^2 D_1^4} + K_{tee}\frac{8Q_1^2}{g\pi^2 D_1^4} + f_2 \frac{L_2}{D_2}\frac{V_2^2}{2g} + K_{sprinkler}\frac{8Q_2^2}{g\pi^2 D_2^4}$$

(II) Branch 2

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1}\frac{V_1^2}{2g} + K_{valve}\frac{8Q_1^2}{g\pi^2 D_1^4} + K_{tee}\frac{8Q_1^2}{g\pi^2 D_1^4} + f_3 \frac{L_3}{D_3}\frac{V_3^2}{2g} + K_{elb}\frac{8Q_3^2}{g\pi^2 D_3^4} + K_{sprinkler}\frac{8Q_3^2}{g\pi^2 D_3^4}$$

(III) $Q_1 = Q_2 + Q_3$

$$Re_1 = \frac{4Q}{\pi D_1 KV} \qquad V = \frac{4Q_1}{\pi D^2}$$

$$V = \frac{4(0.0076)}{\pi(0.0409)} = 0.237 \text{ m/s}$$

1) Assume Q_1
2) Solve for Q_2
   - Assume f_2
   - Compute for D_2/e, f_{t2}
   - Solve for Q_2
   - Compute Re_2
   - Compute for New f_2
   - Compare old f_2 and New f_2
3) Solve for Q_3
   - Assume f_3
   - Compute for D_3/e, f_{t3}
   - Solve for Q_3
   - Compute Re_3
   - Compute for New f_3
   - Compare old f_3 and New f_3
4) Add Q_2 & Q_3 to get Q_1
5) Compare New Q_1 to assume Q_1

$$Q_2 = \sqrt{\frac{\frac{\Delta P}{\gamma} - \left(f_1\frac{L_1}{D_1} + K_{valve} + K_{tee}\right)\frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_2\frac{L_2}{D_2} + K_{sprinkler}\right)\frac{8}{\pi^2 g D_2^4}}}$$

$$Q_3 = \sqrt{\frac{\frac{\Delta P}{\gamma} - \left(f_1\frac{L_1}{D_1} + K_{valve} + K_{tee}\right)\frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_3\frac{L_3}{D_3} + K_{elbow} + K_{sprinkler}\right)\frac{8}{\pi^2 g D_3^4}}}$$

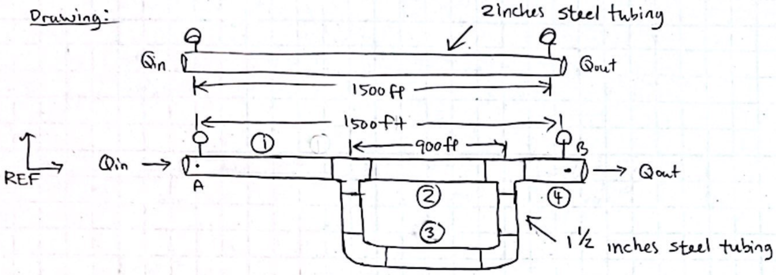
Materials : Water

Summary : $0.0055\ m^3/s$ for sprinkler head #1
$0.0021\ m^3/s$ for sprinkler head #2

Analysis: The flow for each sprinkler are different. By adjust both branches to have the same energy losses would give the same flow rate at each sprinkler head. The fluid velocity in this case is 0.237 m/s which is far off from 3 m/s. Maybe changing the pipe size can help increase the flow velocity.

Purpose:
- Determine the pressure drop
- What is the expected increase flow rate.

Drawing:



Sources: Mott R. and Untener J. Applied Fluid Mechanics 7th Edition Pearson 2014.

Design Consideration:

Incompressible fluid
Isothermal process
Steady state
Minor losses

Data and Variables:

$\gamma_w = 62.4 \text{ lb/ft}^3$
$L_1 = L_4 = 300 \text{ ft}$
$L_2 = L_3 = 900 \text{ ft}$
$D_1 = D_2 = D_4 = 0.1558 \text{ ft}$
$D_3 = 0.1142 \text{ ft}$

Flowrate $= 65 \text{ gpm } (0.002228 \text{ ft}^3/\text{s})$
$= 0.14482 \text{ ft}^3/\text{s}$

$K_{tee} = 60$
$K_{elbow} = 30$

Procedure:

Pick a reference and plot points. Use the Bernoulli's equation.
Break into 2 branches, label the pipes and consider all energy losses.

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

$$\frac{\Delta P}{\gamma} = h_L$$

Calculation :

Solve for pressure $\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D_1^4} = \Delta P = \frac{f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D_1^4}}{\gamma}$

I

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D_1^4} + K_{tee} \frac{8Q_1^2}{g\pi^2 D_1^4} + f_2 \frac{L_2}{D_2} \frac{8Q_2^2}{g\pi^2 D_2^4} + K_{tee} \frac{8Q_2^2}{g\pi^2 D_2^4} + f_4 \frac{L_4}{D_4} \frac{8Q_4^2}{g\pi^2 D_4^4}$$

II

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} \frac{8Q_1^2}{g\pi^2 D_1^4} + 2K_{tee} \frac{8Q_1^2}{g\pi^2 D_1^4} + f_3 \frac{L_3}{D_3} \frac{8Q_3^2}{g\pi^2 D_3^4} + 2K_{elbow} \frac{8Q_3^2}{g\pi^2 D_3^4} + f_4 \frac{L_4}{D_4} \frac{8Q_4^2}{g\pi^2 D_4^4}$$

III $Q_1 + Q_2 + Q_3 = Q_4$ New flow rate.

1) Solve for Q_2
   - Assume f_2
   - Compute D_2/e, f_{T2}
   - Solve for Q_2
   - Compute for Re_2
   - Compute for New f_2
   - Compare New f_2 and Old f_2
2) Solve for Q_3
   - Assume f_3
   - Compute D_3/e, f_{T3}
   - Solve for Q_3
   - Compute for Re_3
   - Compute for New f_3
   - Compare New f_3 and Old f_3
3) Compare Q_1 New & old
4) Add $Q_1 + Q_2 + Q_3 = Q_4$ New flow rate.

$$Q_2 = \sqrt{\frac{-\frac{\Delta P}{\gamma} + \left(f_1 \frac{L_1}{D_1} + 2K_{tee} + f_4 \frac{L_4}{D_4}\right) \frac{8Q_1^2}{g\pi^2 D_1^4}}{f_2 \frac{L_2}{D_2} \frac{8}{g\pi^2 D_2^4}}}$$

$$Q_3 = \sqrt{\frac{-\frac{\Delta P}{\gamma} + \left(f_1 \frac{L_1}{D_1} + 2K_{tee} + f_4 \frac{L_4}{D_4}\right) \frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(f_3 \frac{L_3}{D_3} + 2K_{elbow}\right) \frac{8}{g\pi^2 D_3^4}}}$$

Material : Water

Summary : New increased flow rate is 0.1724 ft^3/s or 77.36 gpm

Analysis : The inrease flowrate was due to the added parallel branch to the single pipe. The increase of the flow rate can be controlled by the new branch pipe diameter and the length of the pipe.