Please grade me using problem 1 and I tried problem 2 for extra points.

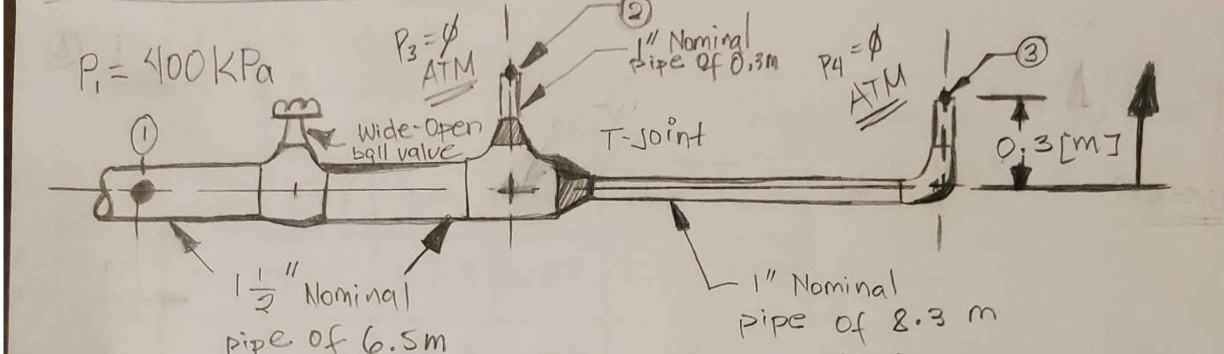
Part 1

Purpose:

1.) To find all the flow rate in the system.
    a. Find Q1
    b. Find Q2
    c. Find Q3
2.) To find if the two sprinklers have the same flow.
3.) How to make them the same
4.) How does the fluid velocity compare to the critical velocity?
    a. Is it far too off?
    b. What would I do to fix it?

# DRAWING & DIAGRAMS

• Sprinkler head
K = 50




• Sprinkler pipeline = Schedule-40 steel pipe

# SOURCES

• Mott, R, Untener, J.A., "Applied Fluid Mechanics," 7th edition Pearson Education, In (2015)

# DESIGN CONSIDERATION

• CONSTANT TEMPERATURE
• INCOMPESSIBLE
• CONSTANT PROPERTIES OF WATER
• CONSTANT PRESSURE OF 400kPa (from Main source)

# DATA & VARIABLES : PART 1 OF 2

• REDUCER
  • Sprinkler #1
  • After T-Joint
• All pipes are Schedule-40 steel pipe
  • $1\frac{1}{2}$" Nominal pipe of 6.5[m] (Pipe #1)
  • 1" Nominal of 0.3[m] (pipe #2)
  • 1" Nominal of 8.3 [m] (pipe #3)
• Constant pressure from the main source = $P_1$ = 400 KPa
• Wide-open ball valve
• T joint
• Elbow

DATA & VARIABLES: PART 2 OF 2

Table F.1 Schedule 40

| | Nominal Pipe Size | | Outside Diameter | | Wall Thickness | | Inside Diameter | | | Flow Area | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | NPS (in) | DN (mm) | (in) | (mm) | (in) | (mm) | (in) | (ft) | (mm) | ($ft^2$) | ($m^2$) |
| #2 #3 | 1 | 25 | 1.315 | 33.4 | 0.133 | 3.38 | 1.049 | 0.0874 | 26.6 | 0.00600 | $5.574 \times 10^{-4}$ |
| #1 | $1\frac{1}{2}$ | 40 | 1.900 | 48.3 | 0.145 | 3.68 | 1.610 | 0.1342 | 409 | 0.01414 | $1.314 \times 10^{-3}$ |

* Pipe #1 ($1\frac{1}{2}$")

- Inside Diameter = 40.9 [mm] = 0.0409 [m]
- Flow Area = $1.314 \times 10^{-3}$ [ $m^2$ ]
- Length = 6.5 [m]

* Pipe #2 (1")

- Inside Diameter = 26.6 [mm] = 0.0266 [m]
- Flow Area = $5.574 \times 10^{-4}$ [$m^2$]
- Length = 0.3 [m]

* Pipe #3 (1")

- Inside Diameter = 26.6 [mm] = 0.0266 [m]
- Flow Area = $5.574 \times 10^{-4}$ [$m^2$]
- Length = 8.3 [m]

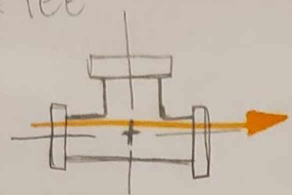
* Wide-open ball value

TABLE 10.4

- check valve - ball type ($Le/D = 150$)

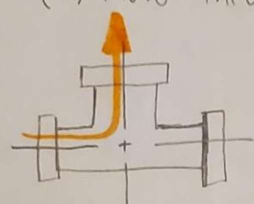
$$K = (Le/D) f_T = 150 f_T$$

* TEE



$K = 20 f_T$

(a) Flow through run



$K = 60 f_T$

(b) Flow through branch

* Pipe elbow

$K = 20 f_T$

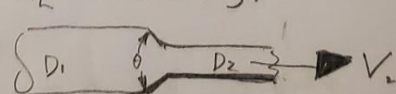
(b) 90° long radius elbow

$g = 9.81 \times 10^3 \left[\frac{N}{m^3}\right]$

$$\frac{D_1}{D_2} = \frac{0.0409\,[m]}{0.0266\,[m]} = 1.538\,[m] \approx 1.5\,[m]$$

- Sudden Contraction (10.6) → Gradual contraction (10.7)

$$h_L = K\left(V_2^2/2g\right)$$




- Resistance coefficient - gradual contraction $\theta \geq 15°$

$K =$ 0.05 TO 0.25 FIGURE 10.11

$K =$ 0.05 TO 0.075 FIGURE 10.12

$P_1 = 400\ kPa$ ✓

$\gamma_w = 9.81\ [\frac{kN}{m^3}]$ ✓

$A_1 = 1.314 \times 10^{-3}\ [m^2]$ ✓

$g = 9.81 \times 10^3\ [\frac{N}{m^3}]$ ✓

$A_3 = 5.574 \times 10^{-4}\ [m^2]$ ✓

$D_1 = 0.0409\ [m]$ ✓

$D_3 = 0.0266\ [m]$ ✓

$z_3 = 0.3\ [m]$ ✓

$\varepsilon = 1.5 \times 10^{-4}\ [ft] = 4.572 \times 10^{-5}\ [m]$ ✓ $\approx 4.6 \times 10^{-5}\ m$ ✓

$\nu = 1.52 \times 10^{-6}\ [\frac{m^2}{s}]$ ✓

$$V_1 = \frac{Q_1}{A_1}$$

$$V_3 = \frac{Q_3}{A_3}$$

$K_{\text{ball value}} = 150\ f_T$

$K_{\text{TEE FLOW THROUGH RUN}} = 20\ f_T$

$K_{\text{TEE FLOW THROUGH BRANCH}} = 60\ f_T$

$K_{\text{elbow}} = 20 \cdot f_T$

$K_{\text{SUDDEN CONTRACTION}} = 0.05$ TO $0.25$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)}\right)\right]^2}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D}{\nu}\right)^{0.9}}\right)\right]^2}$$

# PROCEDURE:

① Put reference point

② Put point 1 where $P_1 = 400$ KPa show in the diagram

③ put point 2 & point 3 to sprinkler #1 & #2

$P_2 = P_3 = \emptyset$ (ATM)

④ Assum $Q \rightarrow R_{E_1} \left(\frac{D_1}{\varepsilon}\right) \rightarrow f_1$

⑤ Solve for $Q_3$ using III

$$Q_3 = A_3 \left( \sqrt{2g \left( \frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - \left(f_1 \frac{L_1}{D_1} + K_{ballvalve} + K_{TEE} + K_{SUD\,CON}\right)\left(\frac{\left(\frac{Q}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_3 \frac{L_3}{D_3} + K_{elbow} + K_{sprinkler}\right)\right.} \right)} \right)$$

(5.1) Assume $f_3$

(5.2) solve for $Q_3$

(5.3) compute $Re_3 \left(\frac{D}{\varepsilon}\right)_3$

(5.4) Compute for $f_3$ new

(5.5) Compare new & old $f_3$

⑥ Solve for $Q_2$ using II (Repeat step 5)

(NEED TO ITERATE)

⑦ compute for $Q_1$ using I

⑧ Compare new & old $Q_1$

CALCULATION: Series Pipeline System

$$\boxed{\begin{array}{c}\text{EQUATION \#1}\\ Q_1 = Q_2 + Q_3\end{array}}$$

$$* \cancel{h_1}^{0} + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1}^{0} = \cancel{\frac{P_3}{\gamma}}^{0} + \frac{V_3^2}{2g} + z_3 + h_L + \cancel{h_R}^{0}$$

$$\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} = \frac{\left(\frac{Q_3}{A_3}\right)^2}{2g} + z_3 + h_L$$

$$Q_3 = \left(\sqrt{2g\left(\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - h_L\right)}\right) A_3$$

$$h_L = \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{VD_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} + K_{ballvalve}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + K_{TEE}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) +$$

$$K_{\substack{SUDDEN\\ CONTRACTION}}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_3}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{VD_3}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_3}{D_3} \times \left(\frac{\left(\frac{Q_3}{A_3}\right)^2}{2g}\right) + K_{elbow}\left(\frac{\left(\frac{Q_3}{A_3}\right)^2}{2g}\right) +$$

$$K_{sprinkler}\left(\frac{\left(\frac{Q_3}{A_3}\right)^2}{2g}\right)$$

EQUATION #2

$$\frac{\left(\frac{Q_3}{A_3}\right)^2}{2g} = \frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - \left(f_1\frac{L_1}{D_1} + K_{ballvalve} + K_{TEE} + K_{\substack{SUD\\ CON}}\right) \times \left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) -$$

$$\left(f_3\frac{L_3}{D_3} + K_{elbow} + K_{sprinkler}\right)\left(\frac{\left(\frac{Q_3}{A_3}\right)^2}{2g}\right)$$

$$\boxed{Q_3 = A_3\left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - \left(f_1\frac{L_1}{D_1} + K_{ballvalve} + K_{TEE} + K_{\substack{SUD\\ CON}}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_3\frac{L_3}{D_3} + K_{elbow} + K_{sprinkler}\right)\right)}\right)}\right)}$$

*

$$\cancel{h_1}^{0} + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \cancel{z_1}^{0} = \cancel{\frac{P_2}{\gamma}}^{0} + \frac{V_3^2}{2g} + z_2 + h_L + \cancel{h_R}^{0}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{V_3^2}{2g} + z_2 + h_L$$

$$\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} = \frac{\left(\frac{Q_2}{A_2}\right)}{2g} + z_2 + h_L$$

$$\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g} = \frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_2 + h_L$$

$$\left(\frac{Q_2}{A_2}\right)^2 = \left(\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)}{2g} - z_2 + h_L\right)2g$$

$$\boxed{Q_2 = \left(\sqrt{2g\left(\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)}{2g} - z_2 + h_L\right)}\right) * A_2}$$

$$h_L = \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{VD_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} + K_{ball\,valve}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) +$$

$$K_{TEE}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + K_{\substack{SUDDEN\\CONTRACTION}}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{VD_2}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_2}{D_2} \times \frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}$$

$$+ K_{sprinkling}\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right)$$

EQUATION # 3

$$\frac{\left(\frac{Q_2}{A_2}\right)}{2g} = \frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_2 - \left(f_1 \frac{L_1}{D_1} + k_{ballvalve} + k_{TEE} + k_{\substack{SUD \\ COM}}\right) \times \left(\frac{\left(\frac{Q_1}{A_1}\right)}{2g}\right) -$$

$$\left(f_2 \frac{L_2}{D_2} + k\,sprinkler\right)\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right)$$

$$\boxed{Q_2 = A_2\left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_2 - \left(f_1 \frac{L_1}{D_1} + k_{ballvalve} + k_{TEE} + k_{\substack{SUD \\ COM}}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_2 \frac{L_2}{D_2} + k\,sprinkler\right)\right.}\right)}\right)}$$

(I) $Q_1 = Q_2 + Q_3$

(II) $$Q_2 = A_2\left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_2 - \left(f_1 \frac{L_1}{D_1} + k_{ballvalve} + k_{TEE} + k_{\substack{SUD \\ COM}}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_2 \frac{L_2}{D_2} + k\,sprinkler\right)\right)}\right)}\right)$$

(III) $$Q_3 = A_3\left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - \left(f_1 \frac{L_1}{D_1} + k_{ballvalve} + k_{TEE} + k_{\substack{SUD \\ COM}}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_3 \frac{L_3}{D_3} + k_{elbow} + k_{sprinkler}\right)\right)}\right)}\right)$$

Please see the excel spreadsheet!

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| P1= | 4.00E+05 | Pa | | | | | | |
| V critical= | 3 | m/s | | | | | | |
| z3= | 0.3 | m | | | | | | |
| gamma= | 9.81E-03 | N/m3 | L1= | 6.5 | m | | V1= | 3.43E+03 |
| nu= | 1.52E-06 | m2/s | L2= | 0.3 | m | | V2= | 6.02E+03 |
| e= | 4.60E-05 | m | L3= | 8.3 | m | | V3= | 2.06E+03 |
| g= | 9.81E+03 | N/m2 | | | | | | |
| D1= | 0.0409 | m | A1= | 1.31E-03 | | m2 | | |
| D2= | 0.0266 | m | A2= | 5.57E-04 | | m2 | | |
| D3= | 0.0266 | m | A3= | 5.57E-04 | | m2 | | |

| | |
|---|---|
| Kteev2= | 60 |
| Kelbow= | 20 |
| Kballvalve= | 150 |
| Ksud con= | 0.25 |
| Ksprinkler= | 50 |
| kteev2= | 20 |

| V1= | V2= | V3= | Velocity critical | %diffv1 | %diffv2 | %diffv3 |
|---|---|---|---|---|---|---|
| 3.43E+03 | 6.02E+03 | 2.06E+03 | 3 | -99.91% | -100.02% | -100.05% |

| | Assume | | | | | | Assume | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Iteration | Q1 (m3/s) | Re1 | (D/e)1 | f1 | fT1 | NUM | f3 | (D/e)3 | fT3 | DEN3 | Q3 (m3/s) |
| 1 | 0.01 | 2.05E+05 | 8.89E+02 | 0.0216 | 0.0202 | 4.08E+07 | 0.010000 | 5.78E+02 | 2.25E-02 | 5.70E+00 | 1.49E+00 |
| | 0.01 | 2.05E+05 | 8.89E+02 | 0.0216 | 0.0202 | 4.08E+07 | 2.25E-02 | 5.78E+02 | 2.25E-02 | 9.61E+00 | 1.15E+00 |
| | 0.01 | 2.05E+05 | 8.89E+02 | 0.0216 | 0.0202 | 4.08E+07 | 2.26E-02 | 5.78E+02 | 2.25E-02 | 9.61E+00 | 1.15E+00 |
| | 0.01 | 2.05E+05 | 8.89E+02 | 0.0216 | 0.0202 | 4.08E+07 | 2.26E-02 | 5.78E+02 | 2.25E-02 | 9.61E+00 | 1.15E+00 |

| | | | Assume | | | | |
|---|---|---|---|---|---|---|---|
| Re3 | f3new | %diff3 | f2 | (D/e)2 | fT2 | DEN2 | Q2 (m3/s) |
| 4.70E+07 | 0.0225 | 125.50% | 0.010000 | 5.78E+02 | 2.25E-02 | 1.12E+00 | 3.36E+00 |
| 36148887 | 0.0226 | 0.01% | 0.022545 | 5.78E+02 | 2.25E-02 | 1.12E+00 | 3.36E+00 |
| 36147489 | 0.0226 | 0.00% | 0.022545 | 5.78E+02 | 2.25E-02 | 1.12E+00 | 3.36E+00 |
| 36147488 | 0.0226 | 0.00% | 0.022545 | 5.78E+02 | 2.25E-02 | 1.12E+00 | 3.36E+00 |

| | | | |
|---|---|---|---|
| Re2 | f2new | %diff2 | Q1 (m3/s) |
| 1.06E+08 | 0.0225 | 125.45% | 4.85E+00 |
| 1.06E+08 | 0.0225 | 0.00% | 4.505054 |
| 1.06E+08 | 0.0225 | 0.00% | 4.505009 |
| 1.06E+08 | 0.0225 | 0.00% | 4.505009 |

## Summary

The part 1 of test 3 is solving for the missing flow rates for all of the pipes. $Q_1 = Q_2 + Q_3$. By using bernoulli's equation and substituting $\frac{Q}{A}$ from $V$ I can solve for $Q_3$, $Q_2$, & $Q_1$. I did not breat down $\frac{Q}{A}$ TO $\frac{8Q^2}{g\pi^2 D^4}$ because I have the area of flow by using the table on the back of the book. Solve the flow Rate using the procedure.


## Material:

- Reducer
- All pipes size: Schedule 40 steel
- Wide-open ballvalue
- T-Joint
- Elbow
- Sprinkler
- Water

## Analysis: (part 1 of part 2)

The first flow is equal to the two other flow ($Q_1 = Q_2 + Q_3$). The pipeline system is a series and not a parallel. The two sprinklers are not exactly the same because of the difference in the minor losses.

$$Q_2 = \left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_2 - \left(f_1 \frac{L_1}{D_1} + K_{ballvalue} + K_{TEE} + K_{SUD\,CON}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_2 \frac{L_2}{D_2} + K_{sprinkler}\right)\right.}\right)}\right) * A_2$$

$$Q_3 = \left(\sqrt{2g\left(\frac{\frac{P_1}{\gamma} + \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} - z_3 - \left(f_1 \frac{L_1}{D_1} + K_{ballvalue} + K_{TEE} + K_{SUD\,CON}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)}{\left(1 + \left(f_3 \frac{L_3}{D_3} + K_{elbow} + K_{sprinkler}\right)\right.}\right)}\right) * A_3$$

Analysis: (part 2 of part 2)
as shown above, $Q_2$ & $Q_3$ are a little bit similar.
The top is similar but the bottom is different.

$Q_1 = 4.28184 \left[\frac{m^3}{s}\right]$

$Q_2 = 3.13 \left[\frac{m^3}{s}\right]$

$Q_3 = 1.15 \left[\frac{m^3}{s}\right]$

$Q_1 = Q_2 + Q_3$

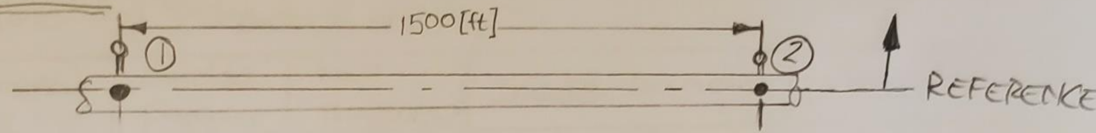
$4.28 \left[\frac{m^3}{s}\right] = 3.13 \left[\frac{m^3}{s}\right] + 1.15 \left[\frac{m^3}{s}\right]$

To make the two sprinkles the same, we need to have or to use a value eventually. My velocities are too far off from the critical velocity. If I need to have a velocity close to the critical velocity, we need to change the pipe size. But, doing so is not practical. The labor, material, and everything else in between will be expensive. Have a velocity difference of 100%. is bad, so the recommended action is to replaced the exsisting pipes.

Part 2

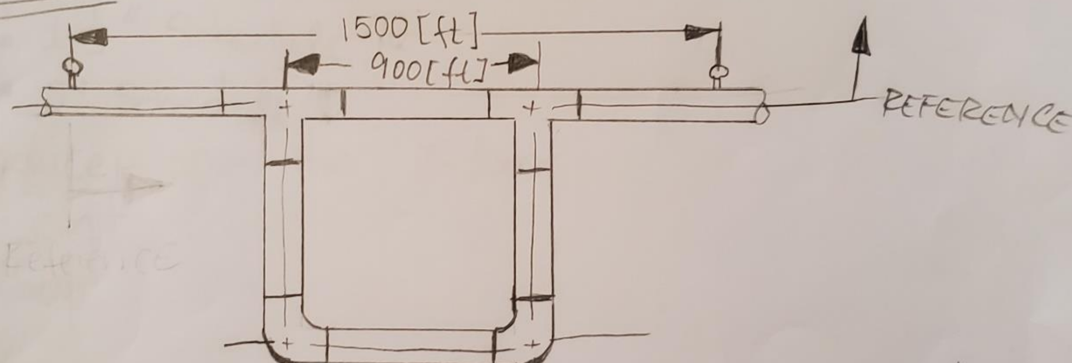
DRAWING & DIAGRAMS

FBD #1




- A horizontally laid 2" standard steel tubing is 1500 ft long and has water passing through it at a 65 GPM flow rate.

FBD #2




- The pipe is modified by adding a loop made of $1\frac{1}{2}$" standard steel tubing that is only 900 [ft] long.

SOURCES

- Mott, R, Untener, J.A., "Applied Fluid Mechanics," 7Th edition Pearson Education, In (2015)

DESIGN CONSIDERATION

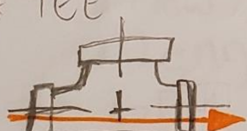
- CONSTANT TEMPERATURE
- INCOMPRESSIBLE
- CONSTANT PROPERTIES OF WATER

# DATA & VARIABLES

Standard steel tubing (schedule 40)
Table F.1 Schedule 40

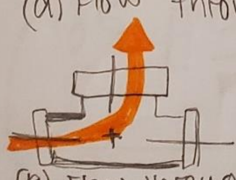
| Nominal Pipe size | | Outside Diameter | | Wall Thickness | | Inside Diameter | | | Flow Area | |
|---|---|---|---|---|---|---|---|---|---|---|
| NPS (in) | DN (mm) | (in) | (mm) | (in) | (mm) | (in) | (ft) | (mm) | ($ft^2$) | ($m^2$) |
| $1\frac{1}{2}$ | 40 | 1.900 | 48.3 | 0.145 | 3.68 | 1.610 | 0.1342 | 40.9 | 0.01414 | $1.314\times10^{-3}$ |
| 2 | 50 | 2.375 | 60.3 | 0.154 | 3.91 | 2.067 | 0.1723 | 52.5 | 0.02333 | $2.168\times10^{-3}$ |

* All pipes are Schedule 40
  - $1\frac{1}{2}$" Schedule 40
  - 2" Schedule 40
* Reducer after the T-joint
* T-joint
* Elbow
* TEE



$K = 20 f_T$

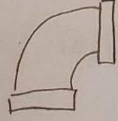
(a) Flow through run



$K = 60 f_T$

(b) Flow through branch

* Pipe elbow



$K = 20 f_T$

(b) 90° long radius branch

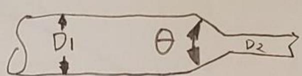
$g = 9.81 \times 10^3 \left[\frac{N}{m^3}\right]$

* Reducer

$\frac{D_1}{D_2} = \frac{52.5[mm]}{40.9[mm]} = 1.20[mm] = 0.0012[m]$

- Sudden Contraction (10.6) → Gradual contraction (10.7)

  $h_L = K(V_2^2/2g)$




- Resistance Coefficient - gradual contraction $\theta \geq 15°$

  K = 0.05 TO 0.25 (FIGURE 10.11)

  K = 0.05 TO 0.075 (FIGURE 10.12)

* Pipe #1 ($1\frac{1}{2}$")
  - Inside Diameter = 0.0409 [m]
  - Flow Area = $1.314 \times 10^{-3}$ [$m^2$]
  - Length = 1500 [ft] = 457.2 [m]
* Pipe #2 (2")
  - Inside Diameter = 0.0525 [m]
  - Flow Area = $2.168 \times 10^{-3}$ [$m^2$]
  - Length = 900 [ft] = 274.32 [m]
* 65 GPM flow rate

$$\left(\frac{65\left[\frac{Gal}{min}\right]}{1}\right)\left(\frac{1\left[\frac{m^3}{s}\right]}{15850\left[\frac{Gal}{min}\right]}\right) = .0041\left[\frac{m^3}{s}\right]$$

$\gamma = 9.81 \times 10^{-3} \frac{N}{m^3}$

TABLE A.1 SI units [101 kPa (abs)]

| TEMP (°C) | SW($\gamma$)(KN/m³) | Density ($\frac{KN}{m^3}$) | $\eta$ (Pa·s) | $\nu$ ($\frac{m^2}{s}$) |
|---|---|---|---|---|
| 5 | 9.81 | 1000 | $1.52 \times 10^{-3}$ | $1.52 \times 10^{-6}$ |

Table 10.5 Friction factor in zone of complete turbulence for new, clean, commercial Schedule 40 steel pipe

| Nominal Pipe Size | | Friction | Nominal Pipe Size | | Friction |
|---|---|---|---|---|---|
| U.S. (in) | Metric (mm) | factor, $f_T$ | U.S. (in) | Metric (mm) | factor, $f_T$ |
| ½ | DN 15 | 0.026 | 3, 3½ | DN 80, DN 90 | 0.017 |
| ¾ | DN 20 | 0.024 | 4 | DN 100 | 0.016 |
| 1 | DN 25 | 0.022 | 5, 6 | DN 125, DN 150 | 0.015 |
| 1¼ | DN 32 | 0.021 | 8 | DN 200 | 0.014 |
| 1½ | DN 40 | 0.020 | 10–14 | DN 250 to DN 350 | 0.013 |
| 2 | DN 50 | 0.019 | 16–22 | DN 400 to DN 550 | 0.012 |
| 2½ | DN 65 | 0.018 | 24–36 | DN 600 to DN 900 | 0.011 |

$D_a = 52.5 [mm] = 0.0525 [m]$

$\varepsilon = 1.5 \times 10^{-4} [ft] = 4.572 \times 10^{-5} [m]$

$V = \frac{Q}{A} = \frac{0.0041 [\frac{m^3}{s}]}{2.168 \times 10^{-3} [m^2]} =$

$Q = 0.0041 [\frac{m^3}{s}]$

$A = 2.168 \times 10^{-3} [m^2]$

$g = 9.81 \times 10^3 [\frac{N}{m^3}]$

$\nu = 1.52 \times 10^{-6} [\frac{m^2}{s}]$

# PROCEDURE: part 1 of 2

① Put a Reference to the 1st diagram
② put point ① & point ②
③ Convert Gallon per minut flow rate to $[\frac{m^3}{s}]$
④ Use Bernoullis equation and simplify $V = \frac{Q}{A}$

① $\cancel{h_1}^0 + \frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}}^0 + \cancel{z_1}^0 = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}}^0 + \cancel{z_2}^0 + h_L + \cancel{h_R}^0$

⑤ Use Bernoullis equation for the 2nd equation and the simplify to include $V = \frac{Q}{A}$

$$\cancel{h_1}^0 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}^0 + h_L + \cancel{h_R}^0$$

$Q_1 = Q_2 = Q_a + Q_b \qquad h_{L1-2} = h_a = h_b$

⑥ Assume $P_1$

⑦ Solve for $P_2$ using problem Ⅰ

$$P_2 = P_1 - \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)\gamma$$

7.1 Assume $P_2$

7.2 compare new & old $P_2$

7.3 Solve for $P_1$

$$P_1 = P_2 + \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)\gamma$$

7.4 Compare new & old $P_1$

⑧ PROBLEM #2 : Assume P

PROCEDURE: part 2 of 2

9. Solve for $P_2$ using problem IV

III $\boxed{Q_1 = Q_a + Q_b}$

IV

$$P_2 = P_1 + \gamma\left(\left(\frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g}\right) + z_1 - \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} + K_{TEE} + K_{sud\,cont}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_2}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_2}{D_2} + K_{elbow}\right)\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right)\right)$$

9.1 Assume $P_2$

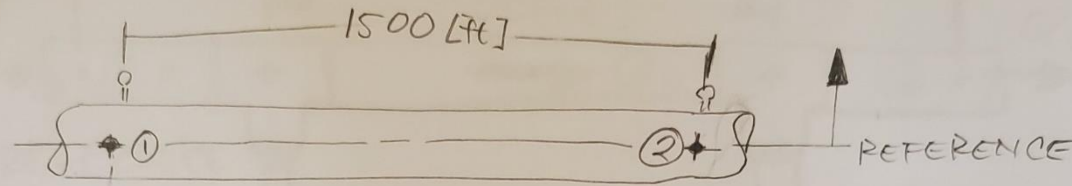
9.2 compare new & old $P_2$

9.3 solve for $P_1$

$$P_1 = P_2 - \gamma\left(\left(\frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g}\right) + z_1 - \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.9\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} + K_{TEE} + K_{sud\,cont}\right)\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + \left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{}{\left(\frac{V \cdot D_2}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_2}{D_2} + K_{elbow}\right)\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right)\right)$$

9.4 Compare new & old $P_1$

# CALCULATION #1




$$\cancel{h_1}^{0} + \frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{z_1}^{0} = \frac{P_2}{\gamma} + \cancel{\frac{V_2^2}{2g}}^{0} + \cancel{z_2}^{0} + h_L + \cancel{h_R}^{0}$$

$$\frac{P_1}{\gamma} = \frac{P_2}{\gamma} + h_L$$

$$\gamma\left(\frac{P_1}{\cancel{\gamma}} - h_L\right) = \left(\frac{P_2}{\cancel{\gamma}}\right)\cancel{\gamma}$$

$$P_1 - h_L \times \gamma = P_2$$

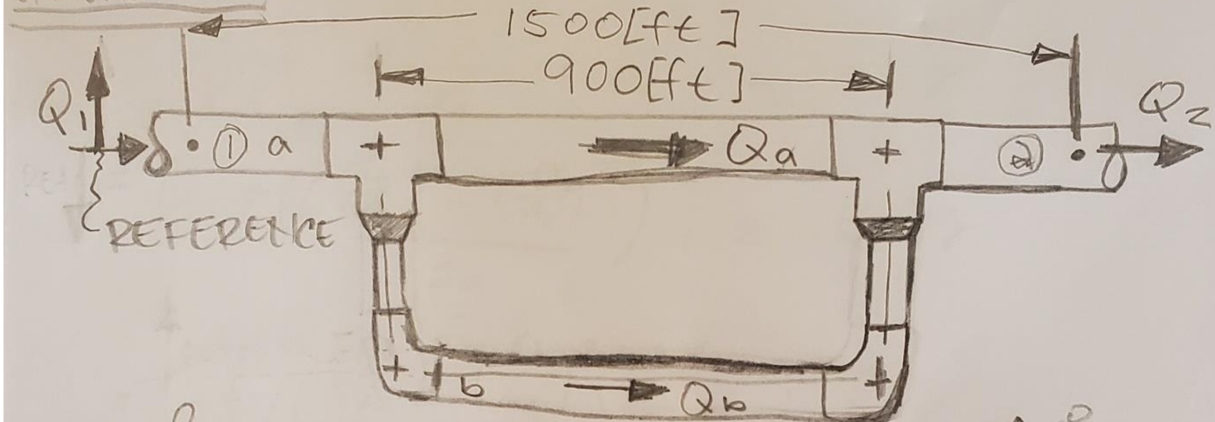
$$P_2 = P_1 - h_L \cdot \gamma = P_1 - \left(f \times \frac{L}{D} \times \frac{V^2}{2g}\right)\gamma$$

$$P_2 = P_1 - \left(f \times \frac{L}{D} \times \frac{\left(\frac{Q}{A}\right)^2}{2g}\right)\gamma$$

I $$\boxed{P_2 = P_1 - \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)\gamma}$$

II $$\boxed{P_1 = P_2 + \left(\left(\frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2}\right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right)\gamma}$$

## CALCULATION: Parallel system with two branches




$$\cancel{h_1}^{0} + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}^{REF=0} + h_{L_2} + \cancel{h_{R_2}}^{0}$$

III $\boxed{Q_1 = Q_2 = Q_a + Q_b}$

$h_{L_{1\text{-}2}} = h_a = h_b$

---

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

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

$$\boxed{P_2 = \left(\frac{P_1}{\gamma} + \frac{V_1^2 - V_2^2}{2g} + z_1 - h_L\right)\gamma}$$

$$P_2 = \left( \frac{P_1}{\gamma} + \frac{V_1^2 - V_2^2}{2g} + z_1 - h_L \right)\gamma$$

$$= P_1 + \left( \left( \frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g} \right) + z_1 - h_L \right)\gamma$$

$$P_2 = P_1 + \left( \left( \frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g} \right) + z_1 - h_L \right)\gamma$$

---

$$h_L = \left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_1}{D} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} + K_{TEE}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + K_{\substack{SUDDEN \\ CONTRACTION}}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) +$$

$$\left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_2}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_2}{D_2} \times \frac{\left(\frac{Q_2}{A_2}\right)^2}{2g} + K_{elbow}\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right)$$

$$P_2 = P_1 + \gamma\left( \left( \frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g} \right) + z_1 - \left( \left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_1}{D_1} \times \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} + \right.\right.$$

$$\left.\left. K_{TEE}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + K_{\substack{SUD \\ CON}}\left(\frac{\left(\frac{Q_1}{A_1}\right)^2}{2g}\right) + \left( \left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_2}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_2}{D_2} \times \frac{\left(\frac{Q_2}{A_2}\right)^2}{2g} + K_{elbow}\left(\frac{\left(\frac{Q_2}{A_2}\right)^2}{2g}\right) \right.\right.$$

$\boxed{V}$

$$P_2 = P_1 + \gamma\left( \left( \frac{\left(\frac{Q_1}{A_1}\right)^2 - \left(\frac{Q_2}{A_2}\right)^2}{2g} \right) + z_1 - \left( \left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_1}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_1}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_1}{D_1} + K_{TEE} + K_{\substack{SUD \\ CON}} \right) \right.$$

$$\left( \frac{\left(\frac{Q_1}{A_1}\right)^2}{2g} \right) + \left( \left( \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D_2}{\varepsilon}\right)} + \frac{5.74}{\left(\frac{V \cdot D_2}{\nu}\right)^{0.9}}\right)\right]^2} \right) \times \frac{L_2}{D_2} + K_{elbow} \right) \left( \frac{\left(\frac{Q_2}{A_2}\right)^2}{2g} \right) \Bigg)$$

| problem 1 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Assume | Assume | | | | |
| Iteration | Q1(m3/s) | Re1 | (D/e)1 | f1 | fT1 | P1 | P2 | P2 (new) | %diff P2 | P1 (new) | %diff P1 |
| 1 | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 0.010000 | 0.010000 | 9.42E-03 | 6.21% | 6.96E-02 | -85.63% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 0.069598 | 0.009415 | 6.90E-02 | -86.36% | 6.90E-02 | 0.85% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.000000 | 1.000000 | 9.99E-01 | 0.06% | 1.06E+00 | -5.62% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.059598 | 0.999415 | 1.06E+00 | -5.63% | 1.06E+00 | 0.06% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.059013 | 1.059013 | 1.06E+00 | 0.06% | 1.12E+00 | -5.33% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.118612 | 1.058429 | 1.12E+00 | -5.33% | 1.12E+00 | 0.05% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.118027 | 1.118027 | 1.12E+00 | 0.05% | 1.18E+00 | -5.06% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.177625 | 1.117442 | 1.18E+00 | -5.06% | 1.18E+00 | 0.05% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.177040 | 1.177040 | 1.18E+00 | 0.05% | 1.24E+00 | -4.82% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.236639 | 1.176456 | 1.24E+00 | -4.82% | 1.24E+00 | 0.05% |
| | 0.004101 | 6.54E+04 | 1.14E+03 | 0.0230 | 0.0190 | 1.236054 | 1.236054 | 1.24E+00 | 0.05% | 1.30E+00 | -4.60% |