Reflection

The first problem:

First of all, the main difference of my equation and the answer is that I included a reduction fitting on mine and the value of the gate valve I used is 150fT. My first Q1 = 4.51, Q2 = 3.36, and Q3 = 1.15. I think I probably switch a conversion somewhere which made me have 10^3. My reasonable assumptions and application of Bernoulli's were correct as well as my third equation. The equation is similar too in addition of the reduction fitting and the valve value. I handle my minor losses well as well. I carry everything over correctly. I would not have exactly the same exact assumption, but I want to say, it was handled correctly. I probably put the equation incorrectly. Thus, end up increasing the decimal points. I think my conversion had minor problem along the way which made my numbers a bit higher than usual. Because of that my assumption were incorrect. I did not know the system is not bad. I thought it was bad. The value is not far off if I put the decimal point in the correct location. The conclusion is not entirely ruined. I think I still should have an 85-90. Compared to the other 2 test, I did not feel discourage on this one and I even sent my first pretest submission. Having 100% similar to the answer test is insane. I mean, I did not see any reduction on the correct answer. Not all the fitting is accountable. We do not know where the critical velocity is accountable too. All we are doing is assuming. If I, could I think I could ask someone else to verify my calculation. I believe I accidentally put something on my numbers.

The second problem:

For the second problem, procedures were correct, but I did not put the last problem in excel. I did not have enough time. But, despite that, I think I still could get a partial grade for trying. The grade given is 10 points and I did half of the work. I just did not have enough time to put the second equation in the excel.

I do not believe I will use this knowledge anywhere else except on my own water source in the house if it breaks and that probably would only happen to me once in my life. In the place I work I typically only deals with cable drawing, premade drawings, and fab drawings. I never encounter using pipes or pump. I do not believe I will be able to use everything I learned in class anywhere except probably using excel I notice I use excel at work a lot for the BOMs. I probably going to use using F4 in excel but other than that, I never thought of using anything I learned in the class anywhere. I am trying to b a principal engineer or a design engineer. The places I work for never need anything involving fluid. But I do notice we use a lot of Microsoft and excel a lot. It's weird because at work we barely use any of this equation and all the variables were given in specs already. It even says the min and max or the capacity of each product. I think everything is given to us already. I really just want to graduate and finish school. I think I have a couple more semester to graduate.

<u>PROBLEM 1 or 2)</u>

1. Reasonable assumptions (reductions, valve, tubing diam, lengths) 1/10

2. Apply Bernoulli twice or get 2 equations from Bernoulli 1/10
3. Consider ALL minor losses? Handled them correctly? 1.95/10
4. Handled correctly the pipe losses? .95/10
5. Obtained 3 equations with 3 unknowns? 1/10
6. Solved system of equations correctly (Excel?)? 2.95/10
7. Final results .5/10

TOTAL **9.35/10**

FINAL GRADE:

(90)*(9.35/10) = 84.15

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

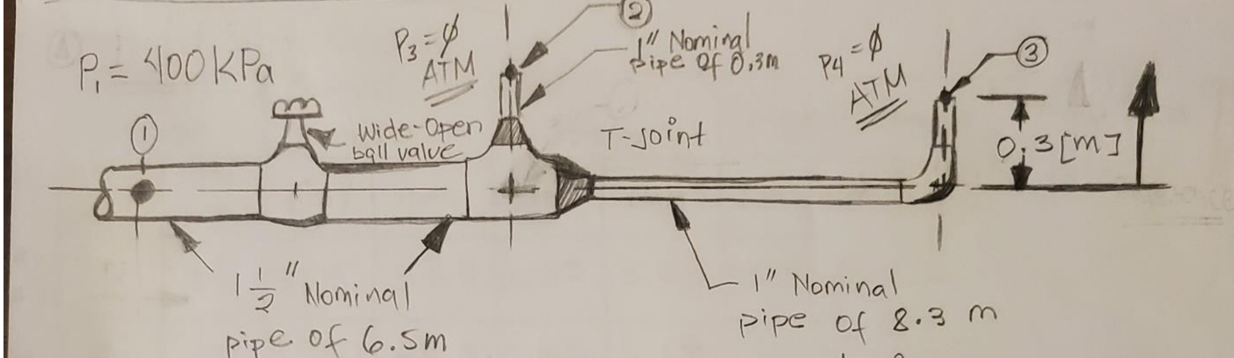
Part 1

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?

• Sprinkler head
K = 50

DRAWING & DIAGRAMS



• 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 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

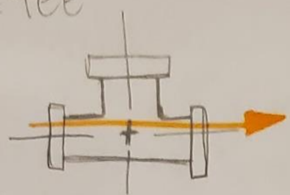
Table F.1 Schedule 40

	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	5.574×10^{-4}
#1	$1\frac{1}{2}$	40	1.900	48.3	0.145	3.68	1.610	0.1342	409	0.01414	1.314×10^{-3}

* Pipe #1 ($1\frac{1}{2}$")
  * Inside Diameter = 40.9 [mm] = 0.0409 [m]
  * Flow Area = 1.314×10^{-3} [m^2]
  * Length = 6.5 [m]
* Pipe #2 (1")
  * Inside Diameter = 26.6 [mm] = 0.0266 [m]
  * Flow Area = 5.574×10^{-4} [m^2]
  * Length = 0.3 [m]
* Pipe #3 (1")
  * Inside Diameter = 26.6 [mm] = 0.0266 [m]
  * Flow Area = 5.574×10^{-4} [m^2]
  * Length = 8.3 [m]
* Wide-Open ball value
  TABLE 10.4
  * check valve - ball type ($Le/D = 150$)

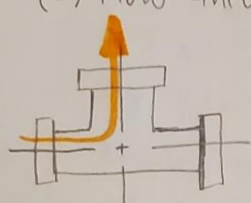
$$K = (Le/D) f_T = 150 f_T$$

* TEE



$K = 20 f_T$

(a) Flow through run



$K = 60 f_T$

(b) Flow through branch

* Pipe elbow

$K = 20 f_T$

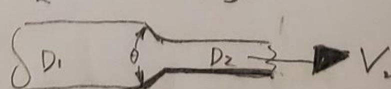
(b) 90° long radius elbow

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

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

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

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



- 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

$P_1 = 400\, kPa$ ✓

$\gamma_w = 9.81\ [\frac{kN}{m^3}]$ ✓

$A_1 = 1.314 \times 10^{-3}\ [m^2]$ ✓

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

$A_3 = 5.574 \times 10^{-4}\ [m^2]$ ✓

$D_1 = 0.0409\ [m]$ ✓

$D_3 = 0.0266\ [m]$ ✓

$Z_3 = 0.3\ [m]$ ✓

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

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

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

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

$K_{ball\ valve} = 150\, f_T$

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

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

$K_{elbow} = 20\, f_T$

$K_{SUDDEN\ CONTRACTION} = 0.05$ 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 → R_{E_1} $\left(\frac{D_1}{\varepsilon}\right)$ → 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

EQUATION #1

$$Q_1 = Q_2 + Q_3$$

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

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

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

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

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

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

EQUATION #2

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

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

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

*

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

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

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

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

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

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

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

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

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

EQUATION # 3

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

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

(I) $Q_1 = Q_2 + Q_3$

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

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

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%

Iteration	Assume Q1 (m3/s)	Re1	(D/e)1	f1	fT1	NUM	Assume 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.

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

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

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

$$Q_1 = Q_2 + Q_3$$

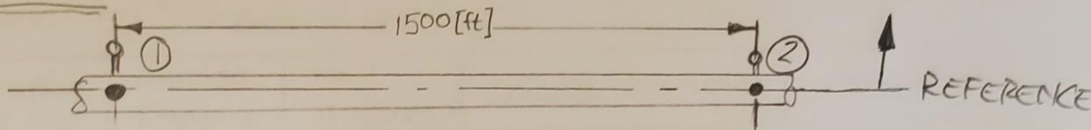
$$4.28 \left[\frac{m^3}{s}\right] = 3.13 \left[\frac{m^3}{s}\right] + 1.15 \left[\frac{m^3}{s}\right]$$

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

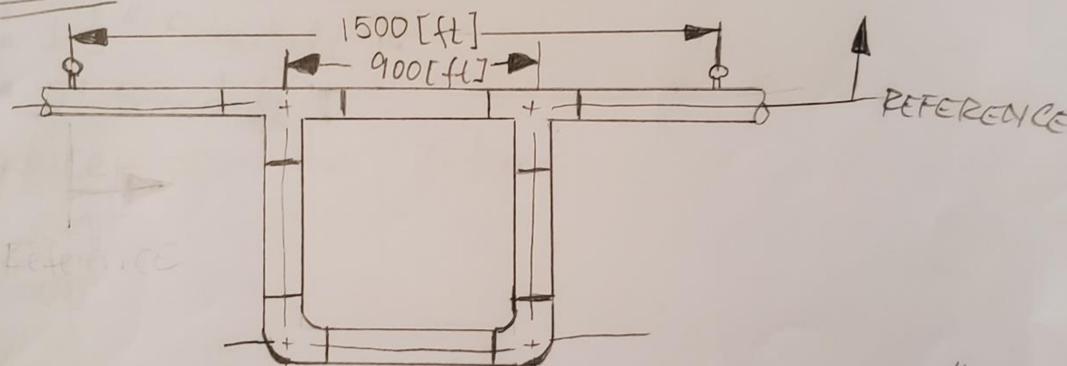
DRAWING & DIAGRAMS

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

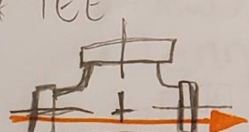
DATA & VARIABLES

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)	(ft²)	(m²)
$1\frac{1}{2}$	40	1.900	48.3	0.145	3.68	1.610	0.1342	40.9	0.01414	1.314×10^{-3}
2	50	2.375	60.3	0.154	3.91	2.067	0.1723	52.5	0.02333	2.168×10^{-3}

* All pipes are Schedule 40
- $1\frac{1}{2}$" Schedule 40
- 2" Schedule 40

* Reducer after the T-joint
* T-joint
* Elbow
* TEE



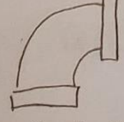
$K = 20 f_T$

(a) Flow through run

$K = 60 f_T$

(b) Flow through branch

* Pipe elbow



$K = 20 f_T$

(b) 90° long radius branch

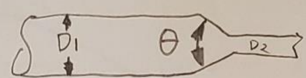
$g = 9.81 \times 10^3 \left[\frac{N}{m^3}\right]$

* 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 = 1.314×10^{-3} [m²]
  - Length = 1500 [ft] = 457.2 [m]
* Pipe #2 (2")
  - Inside Diameter = 0.0525 [m]
  - Flow Area = 2.168×10^{-3} [m²]
  - 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(γ)(KN/m³)	Density ($\frac{KN}{m^3}$)	η (Pa·s)	ν ($\frac{m^2}{s}$)
5	9.81	1000	1.52×10^{-3}	1.52×10^{-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	U.S. (in)	Metric (mm)	factor, f
1/2	DN 15	0.026	3, 3 1/2	DN 80, DN 90	0.017
3/4	DN 20	0.024	4	DN 100	0.016
1	DN 25	0.022	5, 6	DN 125, DN 150	0.015
1 1/4	DN 32	0.021	8	DN 200	0.014
1 1/2	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
2 1/2	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 Ⓘ

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

(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

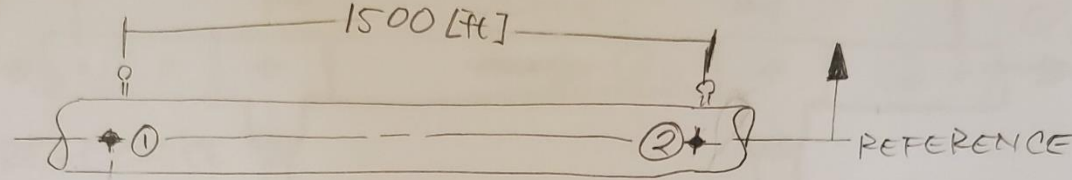
(9.2) compare new & old P_2

(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



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

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

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

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

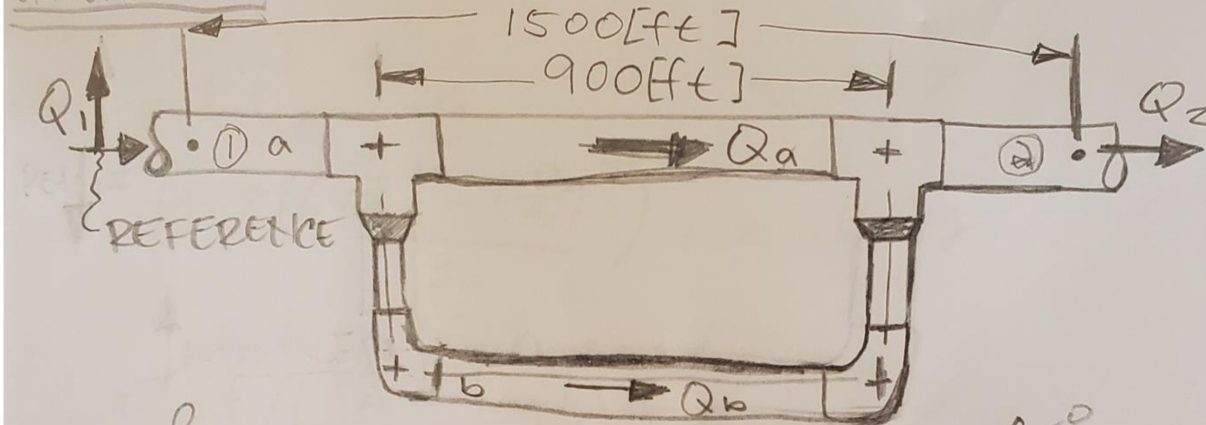
$$P_2 = P_1 - h_L \cdot \gamma = P_1 - \left(f \times \frac{L}{D} \times \frac{V^2}{2g}\right)\gamma$$

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

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

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

CALCULATION: Parallel system with two branches



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

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

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

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

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

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

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

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

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

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

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

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

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

IV

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

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

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%