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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Fall 2017
Test 2

Take home – Due Tuesday October 31st 2017 before class time.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)

2. The total points on this test are one hundred (100). FOR THE "WORKFORCE" SYLLABUS STUDENTS: Ten (10) points are from your HW assignments, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. FOR THE "OTHER" SYLLABUS STUDENTS: Ten (10) other points are based on the basis of technical writing. The other eighty (90) points will come from the problem solutions. For the technical writing I will follow the attached rubric.

3. There are 2 problems. Each problem will be worth (80/2) points for "Workforce" syllabus students and (90/2) for the "Other" syllabus students.

4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.

5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.

6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit only one file and it has to be a pdf file. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.

7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.

8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

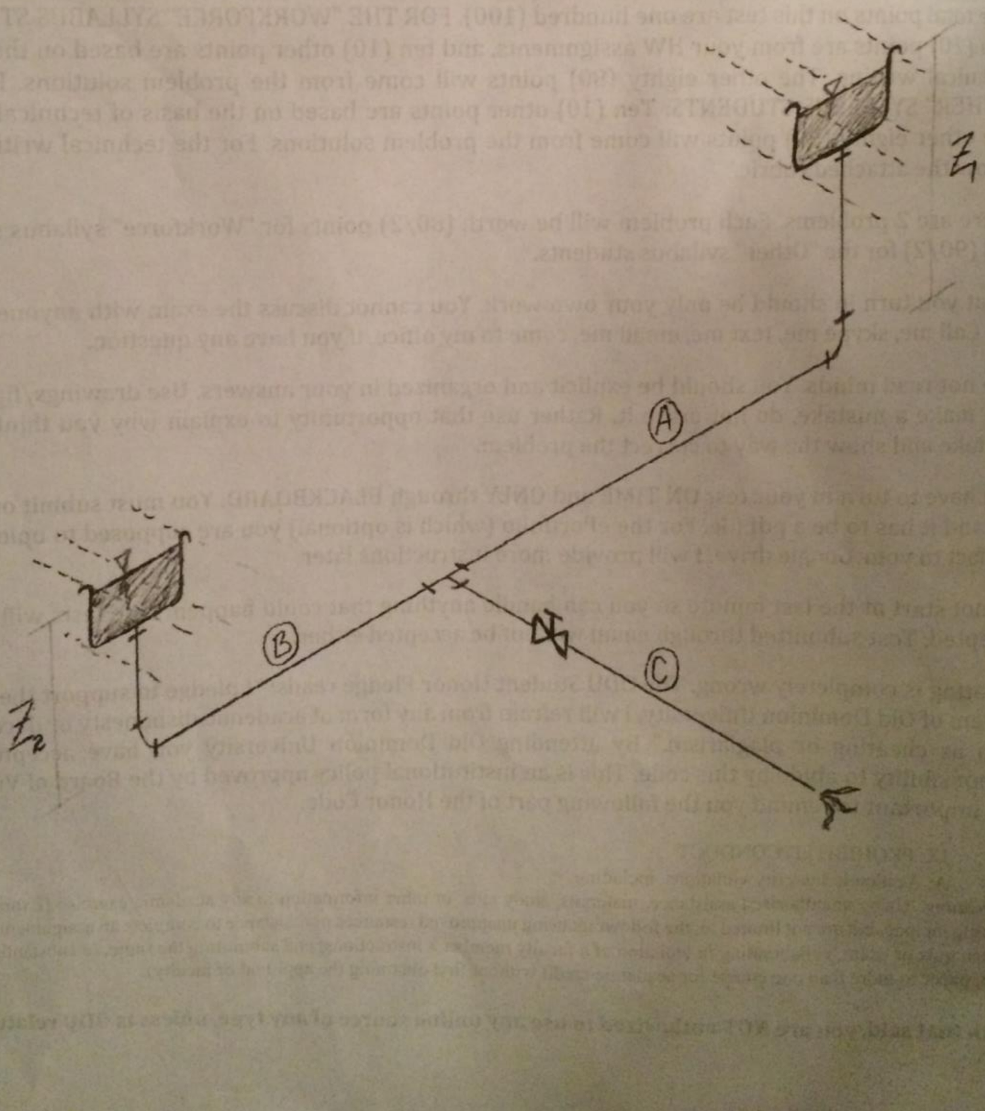
IX. PROHIBITED CONDUCT

A. Academic Integrity violations, including:

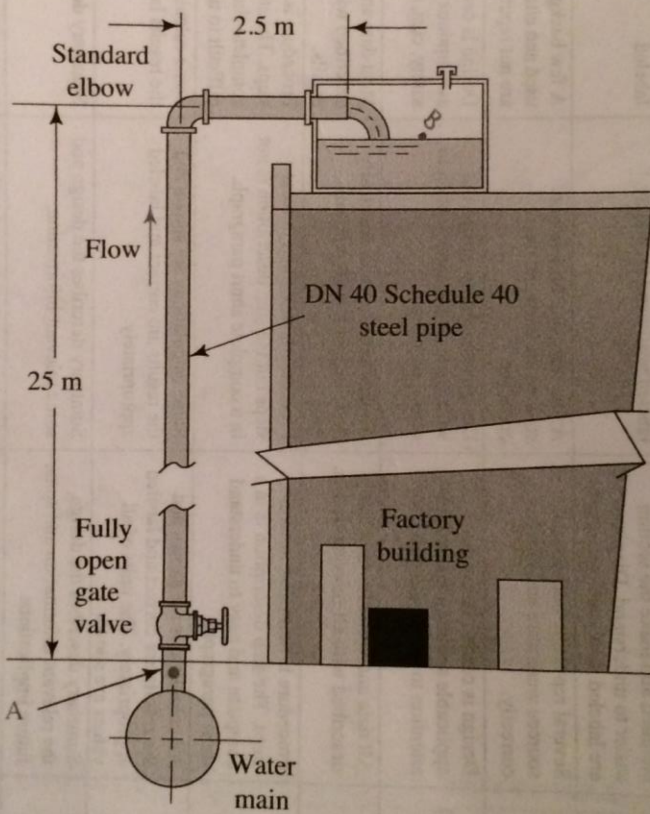
1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

1) There are two elevated house gutters connected together to bring the rainwater to ground floor during a heavy rain, as shown in the figure (please be aware that this is just a scketch, no real dimensions were intended). For some unknown reason, the engineer who designed the system decided to put a valve in the ground level pipe C (this is a bad decision but it is what was found). The lengths of the ¾ inch (inner diameter) commercial steel pipes are: L_A=10 m, L_B=9 m, L_C=10 m and the water surfaces in the gutters are elevated at Z_1=4 m, Z_2=3 m. The elevation is measured with respect to the ground level horizontal pipe 3. Determine the flow out of the system if the gate valve is <u>half open</u>. Assume that the friction factor is only a function of the relative roughness. Do not neglect the minor losses. Check the velocity criterion (Vmax = 3 m/s). Is it violated? If so, provide some suggestions to avoid it. Finally, compute the pressure at the tee.



2) For the system shown, when the pressure at point A is 300 kPa, the volume flow rate of water at 10°C delivered to the tank is 0.0035 m^3/s. If we want to reduce the flow rate in half, what should the valve opening (s/D) be? The pressure at A still remains at 300 kPa. Check the velocity criterion (Vmax = 3 m/s). Is it violated? If so, provide some suggestions to avoid it.



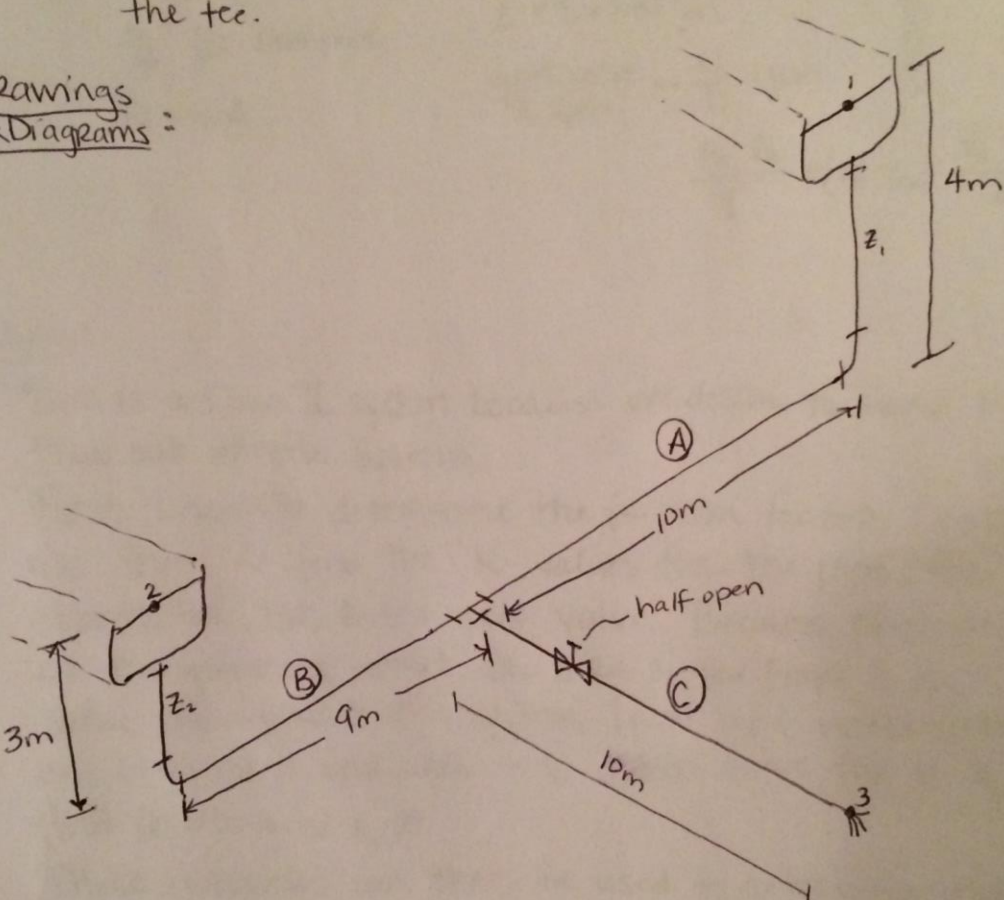
Problem solution rubric

	Exceeds Standard	Meets Standard	Approaches Standard	Needs Attention
	4	3	2	1
	10 points	7 points	4 points	0 points
1. Purpose 5%	The purpose of the section to be answered is clearly identified and stated.	The purpose of the section to be answered is identified, but is stated in a somewhat unclear manner.	The purpose of the section to be answered is partially identified, and is stated in a somewhat unclear manner.	The purpose of the section to be answered is erroneous or irrelevant.
2. Drawings & Diagrams 10%	Clear and accurate diagrams are included and make the section easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
3. Sources 5%	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	A few background sources are used and cited correctly, but some are not reputable sources.	Background sources are cited incorrectly.
4. Design considerations (assumptions, safety, cost, etc) 10%	Design is carried out with applicable assumptions and full attention to safety and cost, etc.	Design is generally carried out with assumptions and attention to safety, cost, etc.	Design is carried out with some assumptions and some attention to safety, cost, etc.	Assumptions, safety and cost were ignored in the design.
5. Data and variables 5%	All data and variables are clearly described with all relevant details.	All data and variables are clearly described with most relevant details.	Most data and variables are clearly described with most relevant details.	Data and variables are not described OR the majority lack sufficient detail.
6. Procedure 25%	Procedure is described in clear steps. The step description is in a complete and easy to understand short paragraph.	Procedure is described in clear steps but the step description is not in a complete short paragraph.	Procedure is described in clear steps. The step description is in a complete short paragraph but it is difficult to understand.	Procedure is not described in clear steps at all.
7. Calculations 20%	All calculations are shown and the results are correct and labeled appropriately. The units of all values are shown.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.
8. Summary 5%	Summary describes the design, the relevant information and some future implications.	Summary describes the design and some relevant information.	Summary describes the design.	No summary is written.
9. Materials 5%	All materials used in the design are clearly and accurately described.	Almost all materials used in the design are clearly and accurately described.	Most of the materials used in the design are clearly and accurately described.	Many materials are described inaccurately OR are not described at all.
10. Analysis 10%	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is discussed and analyzed. Argumentative predictions are made about what might happen in case of change in the operation.	The design is discussed and analyzed. No argumentative predictions are made about what might happen in case of change in the operation and how the design could be change.	The design is not discussed and analyzed.

1

Purpose: Determine the flow out of the system if the gate valve is half open. Is the velocity criterion violated? Compute the pressure at the tee.

Drawings & Diagrams:



Sources: Mott, Untener, Applied Fluid Mechanics. Global ed. 7th ed. Pearson, 2016.

Design Considerations:
1. Incompressible fluid
2. Friction factor only a function of relative roughness
3. ϕ pressure at 1, 2, & 3
4. Constant flow rate

B

Data & Variables:

Bernoulli's: $\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g} - h_L = \frac{P_B}{\gamma} + Z_B + \frac{V_B^2}{2g}$

$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g}$

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

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

3/4" ID steel pipe

gate valve ½ open $\rightarrow \frac{L_e}{D} = 160$

$Q = v \cdot A$

$$\frac{P_A - P_B}{\gamma} + (Z_A - Z_B) = \frac{V_B^2 - V_A^2}{2g} + h_{L_A}$$

Procedure:

This is a Class II system because we desire to know the flow out of the system.

First, I need to determine the friction factor. I can use that to find the K-values for the pipe, the elbows, the tee, & the gate valve. Because pressures at the gutters & outlet are zero & the flow is the same throughout the system, I am left with only one unknown variable – v. I can solve for v & find Q using v & A.

Those numbers can then be used to determine the pressure at the tee.

$\boxed{C}$

Calculations:

$$\cancelto{0}{\frac{P_1 - P_3}{\gamma}} + (z_1 - z_3) = \cancelto{0}{\frac{v_3^2 - v_1^2}{2g}} + h_{L_{1-3}}$$

Right gutter

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\frac{D}{\varepsilon}}\right)\right]^2} \qquad \frac{D}{\varepsilon} = 414.13$$

$$= \frac{0.25}{\left[\log\left(\frac{1}{1532.25}\right)\right]^2}$$

$$f = 0.0246$$

$$K_{pipe} = 0.0246\left(\frac{24\,m}{0.01905\,m}\right) = 30.99 \qquad K_{\text{gate valve}} = 0.0246(160) = 3.936$$

half open

$$K_{elbow} = 0.0246\,(30) = 0.738$$

standard elbow

$$K_{tee} = 0.0246\,(60) = 1.476$$

standard with flow through the branch

$$4\,m = (30.99 + 0.738 + 1.476 + 3.936)\frac{v^2}{2(9.81\,m/s^2)}$$

$$78.48\,m^2/s^2 = (37.14)\,v^2$$

$$\sqrt{2.113} = \sqrt{v^2}$$

$$v = 1.454\ m/s$$

$$Q = v \cdot A \qquad A = (0.01905)^2\pi = 0.00114$$

$$= (1.454)(0.00114)$$

$$\boxed{Q = 0.00166\ m^3/s}$$

No, the velocity criterion is not violated.

continued

$$\text{minor losses} = K\frac{V^2}{2g} = \frac{8K}{g\pi^2 D^4} Q^2$$

$$h_{L_{pipe}} = \frac{8fL}{\pi^2 g D^5} Q^2 \qquad h_{L_{elbow}} = \frac{8K_{elbow}}{\pi^2 g D^4} Q^2 \qquad K_{\underline{valve}} = 3.936$$

$$h_{L_{entrance}} = \frac{8K_{ent.}}{\pi^2 g D^4} Q^2 \qquad h_{L_{tee}} = \frac{8K_{tee}}{\pi^2 g D^4} Q^2$$

$$Z_1 - Z_3 = \frac{8}{\pi^2 g D^4} Q_C^2 + \frac{8K_{ent}}{\pi^2 g D^4} Q_A^2 + \frac{8K_{elb}}{\pi^2 g D^4} Q_A^2 + \frac{8K_{tee}}{\pi^2 g D^4} Q_A^2 + \frac{8fL_A}{\pi^2 g D^5} Q_C^2$$

$$4m = \frac{8}{\pi^2(9.81 m/s^2)(0.01905)^4} Q_C^2 + \frac{8K_{ent}}{\pi^2(9.81 m/s^2)(0.01905)^4} Q_A^2 + \frac{8(\cancel{0.738})^{0.738}}{\pi^2(9.81 m/s^2)(0.01905)^4} Q_A^2 + \frac{8(1.476)}{\pi^2(9.81)(0.01905)^4} Q_A^2$$

$$+ \frac{8(0.0246)(14)}{\pi^2(9.81)(0.01905)^5} Q_A^2 + \frac{8(0.0246)(10)}{\pi^2(9.81)(0.01905)^5} Q_C^2$$

$$4m = \frac{8}{0.00001275} Q_C^2 + \frac{4}{0.00001275} Q_A^2 + \frac{5.904}{0.00001275} Q_A^2 + \frac{11.808}{0.0001275} Q_A^2 +$$

$$\frac{2.7552}{0.000000243} Q_A^2 + \frac{1.968}{0.000000243} Q_C^2$$

$$4m = 627450.98\, Q_C^2 + 313725.49\, Q_A^2 + 463058.82\, Q_A^2 + 926117.65\, Q_A^2$$

$$+ 11338271.6\, Q_A^2 + 8098765.43\, Q_C^2$$

$$4m = \underline{1304\,1173.56\, Q_A^2} + \underbrace{8726216.41\, Q_C^2 + 2469428.203\, Q_C^2}$$

everything for left gutter is the same except original elevation & length of pipe B

$$3m = \cancel{15510601.76}\, Q_B^2 + \cancel{8726216.41}\, Q_C^2$$

$$= 13041173.56\, Q_B^2 + 11195644.61\, Q_C^2$$

Choose a Q by using established velocity criterion of $\underline{3 m/s}$

$$V_A = \frac{4Q_A}{\pi D_A^2} = \frac{4(Q_A)}{\pi(0.01905)^2}$$

$$V_A = 3508.49\, Q_A \qquad Q_A = \frac{3 m/s}{3508.49} \qquad \boxed{Q_A = 0.00086\, m^3/s}$$

Continued

$$4\text{m} = (1304173.56)(0.00086)^2 + 872621641\ Q_c^2 + 249428.203\ Q_c^2$$

$$4\text{m} = 9.64525 + 1119564461\ Q_c^2$$

$$\boxed{Q_c = 0.00071\ \text{m}^3/\text{s}}$$

$$Q_A + Q_B = Q_C$$

$$0.00086 + 0.00048 = 0.00071 \times$$

$$3\text{m} = \overset{1142142047}{\cancel{1304173.56}}\ Q_B^2 + 1119564461\ Q_c^2$$

$$\boxed{\cancel{Q_A < Q_B}} \quad \boxed{Q_B = 0.000481\ \text{m}^3/\text{s}}$$

$$\cancel{\frac{P_1}{9.81}}^{\phi} + 4 + \cancel{\frac{(0.75)^2}{19.62}} - 37.14 = \frac{P_{tee}}{9.81\text{kN/m}^3} + \phi + \cancel{\frac{(0.75)^2}{19.62}}$$

$$\boxed{P_{tee} = {}^-325.10\ \text{kPa}}$$

Summary:

The flow rate at pipe A is 0.00086 m^3/s, the flow rate at pipe B is 0.000 481 m^3/s, & the flow rate at C is 0.00071 m^3/s. Each velocity does not violate the velocity criterion. The pressure at the tee is ⁻325 kPa.

Materials: Water

E

Analysis:

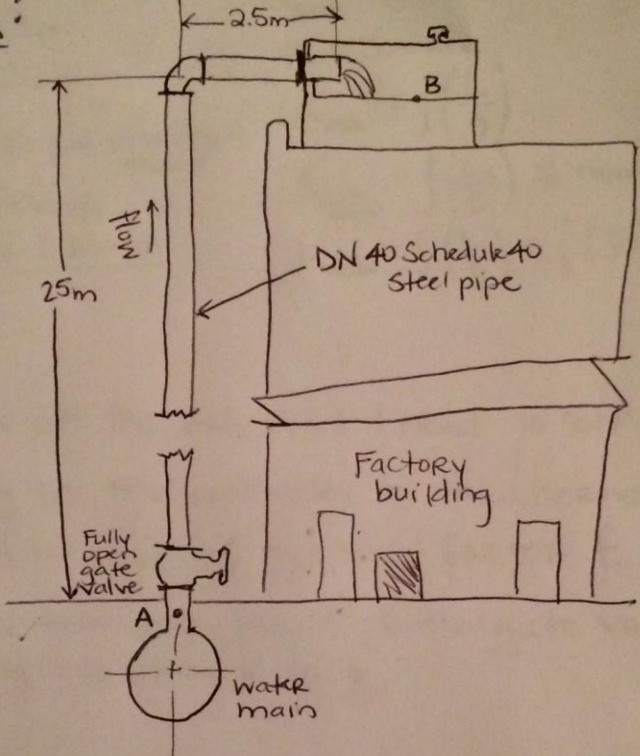
The system does not have a very large flow rate because it is driven by gravity. The pressure at the tee should be positive, so the work done is wrong. Also, the flow rates do not add up to equal the third, so there is an issue there. However, the low values are consistent with what would be expected.

(Also see additional work at end of test.)

G

(2) Purpose: Determine the valve opening $\left(\frac{S}{D}\right)$ if the flow rate is reduced by half.

Drawings & Diagrams:



Sources: Mott, Untener. Applied Fluid Mechanics. Global ed. 7th ed Pearson, 2016.

Design Considerations:

1. Incompressible fluid (water)
2. Constant flow rate
3. ϕ pressure at B
4. Constant temperature, constant properties

H

Data & Variables:

Bernoulli's: $\frac{P_A}{\gamma} + z_A + \frac{V_A^2}{2g} - h_L = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g}$

$\gamma = 9.81\ kN/m^3$

$z_A = \phi\ m$

$z_B = 25\ m$

$\frac{L_e}{D} = 30$ for standard elbow

$Q = 0.0035\ m^3/s \rightarrow V = 2.66\ m/s$

so, we use $1.33\ m/s$

total length of pipe $= 27.5\ m$

$\varepsilon_{steel} = 4.6 \times 10^{-5}$ $D = 0.0409\ m$

$P_A = 300\ kPa$

$K_{pipe} = f\left(\frac{L}{D}\right)$

$K_{gate\ valve} = f\left(\frac{L_e}{D}\right)$ * need to find this

$K_{elbow} = f\left(\frac{L_e}{D}\right) = f(30)$

Procedure:

I have all the variables I need to solve for K.

I plug in the variables to the Bernoulli's equation.

I need to find the friction factor f.

Then I will solve for K of the gate valve & use the graph relating K to $\frac{s}{D}$.

Calculations:

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

$\Downarrow$

$\left(\log 0.000303972\right)^2$

$\Downarrow$

$\frac{0.25}{12.37} = \boxed{0.0202}$

$\frac{D}{\varepsilon} = \frac{0.0409}{4.6 \times 10^{-5}} = 889.13$

$\times 3.7$

3289.78

0.020 from Table 10.5 in book

I'll use the friction factor to plug in the rest of the numbers to Bernoulli's

$\boxed{\text{I}}$

$$* \frac{(1.33)^2}{2(9.81)}$$

$$\frac{300\,\text{kPa}}{9.81\,\text{kN/m}^3} + \phi + \frac{(1.33\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)} - \left[0.0202\left(\frac{27.5}{0.0409}\right)^{*} + K_{\text{gate valve}}\left(\frac{\cancel{8}1.33^2}{2(9.81)}\right) + 0.0202(30)\left(\frac{1.33^2}{2(9.81)}\right)\right.$$

$$= \phi + 25 + \frac{(1.33\,\text{m/s})^2}{2(9.81\,\text{m/s}^2)}$$

$$\Downarrow$$

$$30.581 + 0.090158 - \left[1.2245 + K(0.090158) + 0.0546\right] = 25.090158$$

$$-1.2245 - K(0.090158) - 0.0546 = {}^{-}5.581$$

$$^{-}K(0.090158) = {}^{-}4.3019$$

$$K = 47.71$$

using the graph Relating K to S/D,

47.71 for K gives an $\frac{S}{D}$ of <u>0.75</u>

The velocity criterion of $V_{max} = 3\,\text{m/s}$ is not violated.

<u>Summary</u>:

The valve opening if we want to Reduce the flow rate in half should be 0.75 (S/D).

<u>Materials</u>:

water

J

Analysis:

To slow the rate half way, we don't want to close the valve half way because they are not related on a one-to-one ratio. The 0.75 S/D value make sense as a result. This tells us that 3/4 open will reduce the flow rate by half. This information can also help inform future decisions to increase the flow again or decrease the flow further.

(1)

Class II system because we desire to know the flow out of the system

3/4" inner diameter steel

total length of pipe @ A = 14 m + 1 elbow
total length of pipe @ B = 12 m + 1 elbow
pipe @ C = 10 m + 1 valve (gate)

$\downarrow$

½ open

$\Downarrow$

$L_e/D = 160$

I'm going to assume pressure @ each gutter is ϕ & at pipe outlet is ϕ

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$$

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

$$Q \Rightarrow -2.22\, D^2 \sqrt{\frac{gDh_L}{L}} \log\left(\frac{1}{3.7\frac{D}{\varepsilon}} + \frac{1.784\,\nu}{D\sqrt{gDh_L/L}}\right) \rightarrow \text{pipe not long enough for this I think}$$

$Q = A \cdot V$

$Q = 0.00137\ m^3/s$

compare — Assume f / compute D / compute Re & D/ε / get f

~~#~~ 1

B

$$\frac{P_A - P_B}{\gamma} + (Z_A - Z_B) = \frac{V_B^2 - V_A^2}{2g} + h_{L_{A-B}}$$

$$+ f\frac{L}{D}\frac{V^2}{2g} \rightarrow = f\frac{L}{D}\frac{16Q^2}{\pi^2 D^4}\frac{1}{2g}$$

Assume velocity is the same

$$\%\ diff = \frac{f_1 - f_2}{f_1} \times 100$$

1% difference
5%
10%

right gutter — both ϕ

$$\cancel{\frac{P_A - P_B}{\gamma}} + (Z_A - Z_B) = \cancel{\frac{V_B^2 - V_A^2}{2g}} + h_{L_{A-B}}$$

ϕ — ϕ same

$A = 0.00114$

$4m = h_{L_{A-B}}$

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

$$\frac{0.75}{4.6\times10^{-5}} = 16304.35$$

$$\frac{0.25}{17.74\ldots} = \cancel{0.014}$$

0.036

.1905 cm

0.01905 m

$$K_{pipe} = 0.036\left(\frac{24m}{\cancel{0.45m}\ 0.01905}\right) = \cancel{26.46}\ 45.35$$

$K_{gate\ valve} = 0.036(160) = 5.76$

$K_{elbow} = 0.036(30) = 1.08$

standard elbow

$4m = h_{L_{A-B}}$

$K_{tee} = 0.036(60) = 2.16$

standard w/ flow thru branch

$$4m = (45.35 + 1.08 + 2.16 + 5.76)\frac{V^2}{2(9.81)}$$

$257.6\cancel{8} = 54.35\ v^2$

$\sqrt{\cancel{4.73965}\ 1.44} = \sqrt{v^2}$

$V = \cancel{2.18}\ \cancel{ft}\ m/s$

$V = 1.202\ m/s$

$Q = 0.0035\,m^3/s$

Volume flow Rate

$Q = A \cdot V$

h_A = pump head

A)

300kPa

$$\frac{p_A}{\gamma} + z_A + \frac{V_A^2}{2g} - h_L = \frac{p_B}{\gamma} + z_B + \frac{V_B^2}{2g}$$

p_B: ϕ

z_A: ϕ

z_B: 25m

2

$$\frac{300}{62.4} + \phi + \frac{V_A^2}{2(32.2)} - h_L = \phi + 25 + \frac{V_B^2}{2(32.2)}$$

$Q = 0.0035\,m^3/s$

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

$V = \frac{0.0035}{0.001314} = 2.66\,m/s$

flow Rate $= 0.00175$

$Q = AV$

$V = 1.33\,m/s$

$$\frac{300}{\cancel{62.4}\ 9.81} + \frac{(2.66)^2}{64.4} - h_L = 25 + \frac{\left[(.5)(V_A)\right]^2}{64.4}$$

$$h_L = K_1\left(\frac{V_A^2}{2g}\right) + K_2\left(\frac{V_A^2}{2g}\right) + K_3\left(\frac{V_A^2}{2g}\right) + \cancel{K_4\left(\frac{V_A^2}{2g}\right)}$$

K_1: pipe = 25m + 2.5 m

K_2: fully open gate valve

K_3: standard elbow

K_4: maybe don't need

$K_1 = f\left(\frac{L_{pipe}}{D_{pipe}}\right)$

$\frac{D}{\varepsilon} = \frac{0.0409}{0.000046} = 889.13$

$f = 0.0231$

$K_2 = f\left(\frac{L_{e\,valve}}{D}\right) = 0.020(8)$ fully open

$K_3 = f\left(\frac{L_{e\,elbow}}{D}\right) = 0.020(30)$

(B) (No, the velocity criterion is not violated) #3

$$\frac{300}{62.4} + \frac{(2.66)^2}{64.4} - h_L = 25 + \frac{1.33^2}{64.4}$$

$$K_1\left(\frac{2.66^2}{64.4}\right) + K_2\left(\frac{2.66^2}{64.4}\right) + K_3\left(\frac{2.66^2}{64.4}\right)$$

$f = 0.020$

$\frac{D}{\varepsilon}$ $\quad \frac{L}{D} = 672.37$

$K_1 = 0.0231\left(\frac{27.5}{0.0409}\right) = \cancel{13.45}\ 15.53$

$\eta = 1.30 \times 10^{-3}$ Pa·s

$K_2 = ?$ $\cancel{0.020\times}$

$\nu = 1.30 \times 10^{-6}$ m²/s

$K_3 = 0.0231 \times 30 = 0.693$

$$4.81 + 0.1099 - \left[1.478 + K_2(0.1099) + 0.0659\right] = 25.027$$

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

$K_2(0.1099) = 21.651$

$K_2 = 197.006$

$V_I = \frac{4Q_I}{\pi D_I^2}$ $\quad R_e = \frac{\nu D}{\nu} = \frac{(2.66)(0.0409)}{0.00000130} = 8.37 \times 10^4$

Turbulent flow

$$f_T = \frac{0.25}{\left[\log\left(\underbrace{\frac{1}{3.7\frac{D}{\varepsilon}}}_{0.000304} + \underbrace{\frac{5.74}{R_e^{0.9}}}_{0.000213}\right)\right]^2} \quad \frac{0.25}{10.801} = 0.0231$$

$h_L = f \frac{L}{D} \frac{16Q^2}{\pi^2 D^4}$

#2

c)

$$4.81 + 0.1099 - \left[(15.53 \times 0.1099) + K_2(0.1099) + 0.693 \times 0.1099\right] = 25.02$$

$$-\left[15.53 \times 0.1099 + K_2(0.1099) + 0.693 \times 0.1099\right] = 20.1071$$

$$-1.7067 - K_2\,0.1099 - 0.0762 = 20.1071$$

$$-K_2\,0.1099 = 21.89$$

$$K_2 = -199.18$$

$$\frac{300}{9.81} + \frac{(2.66)^2}{19.62} - \left[15.53 \times 0.3606 + K_2 \times 0.3606 + 0.693 \times 0.3606\right] = 25.090$$

$$30.58 + 0.3606 - \left[5.6 + K_2 \times 0.3606 + 0.25\right] = -5.8504$$

$$-5.6 - K_2 \times 0.3606 + 0.25 = -5.8504$$

$$-K_2 \times 0.3606 = -0.0004$$

$$K_2 = 0.0011$$

$$\frac{S}{D} =$$