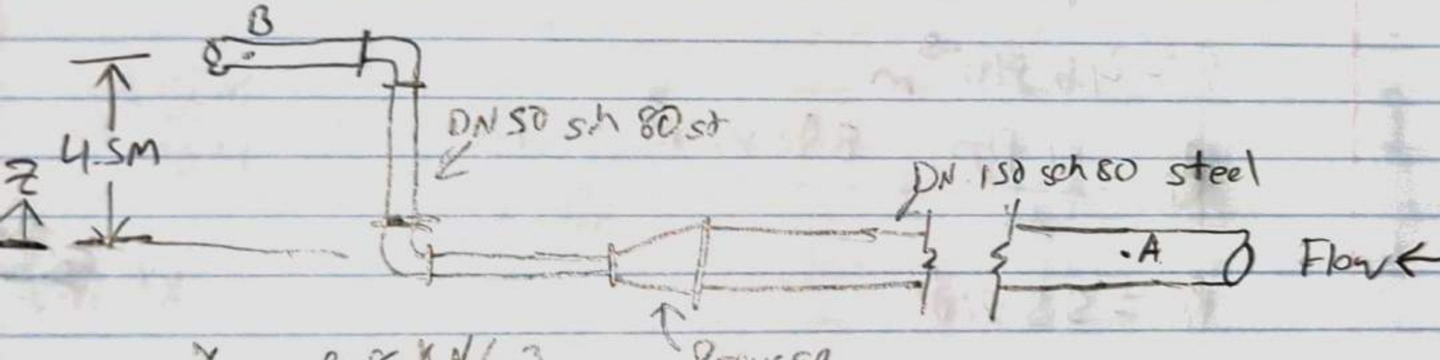
After reviewing the parallel and series pipeline equations in class it is made clear that are two main things that you should always do. First, look at the whole system to see what is happening. Think about how to the fluid is flowing from one point to the other and look at what might be adding energy losses between those points. Next, you should always use Bernoulli's equation as a starting point. Even on the more complex parallel systems, this will still serve to examine what is happening between points. The main difference between the series and parallel problems is that in series, you will have one starting equation to start with, but in parallel you will have just as many conservation equations as there are fluid paths in the system. Another thing to consider is that when examining the equations, it can be helpful to replace velocity with Q/A. Once you have the entire equation written out, plug in what numbers you have to lessen the risk of missing variables as the equation becomes more complex.

11.5)

Purpose: Determin energy losses.

Drawings:



$\gamma_{oil} = 8.8 \text{ kN/m}^3$

$\mu = 2.12 \times 10^{-5} \text{ m}^2/s$

$L_{DN150} = 180m$

$L_{DN50} = 8$

$Z_2 = 4.5m$

$D_A = 146.3mm \quad A_A = 1.682 \times 10^{-2} \text{ mm}^2$

$D_B = 49.3mm \quad A_B = 1.905 \times 10^{-3} \text{ mm}^2$

$Q = 0.015 \text{ m}^3/s$

CALCULATIONS:

$$h_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + z_A = h_L + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_B$$

$V = Q/A$

$$\frac{P_A - P_B}{\gamma} - z_B + \frac{V_A^2}{2g} - \frac{V_B^2}{2g} = h_L$$

$$h_L = h_{L,reducer} + h_{LA} + h_{LB} + 2(h_{L,elbow})$$

$h_{L,reducer} = K\left(V_B^2/2g\right)$

$h_{L,elbow} = K \, V_B^2/2g$

$D_1/D_2 = \frac{146.3}{49.3} = 2.97$

$K_{elbow} = 30 f_T$

$$h_{LA} = f \frac{L_A}{D_A} \cdot \frac{V_A^2}{2g}$$

$$h_{LB} = f \frac{L_B}{D_B} \cdot \frac{V_B^2}{2g}$$

$h_{L,elbow} = 30 \cdot f_T \left(\frac{V_B^2}{2g}\right)$

$V_B = \frac{0.015 m^3/s}{1.905 \times 10^{-3} m^2} = 7.87 \; m/s$

$V_A = \frac{0.015 m^3/s}{1.682 \times 10^{-2} m^2} = 8.92 \; m/s$

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

$Re = \frac{v D \rho}{\mu} = \frac{8.92 \times 10^5 \cdot .1463 m \cdot \frac{8.8}{9.82}}{212 \times 10^3}$

$Re = 5.5 \times 10^7$

$f = 0.25 / \left(\log\left(\frac{1}{3.7\left(\frac{.1463}{4.6 \times 10^{-5}}\right)} + \frac{5.74}{(5.5 \times 10^7)^{0.9}}\right)\right)^2$

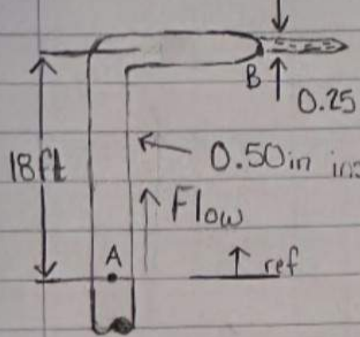
$f = 0.0151$

$h_L = 2\left(30 \cdot (0.015)\left(\frac{(7.87)^2}{2(9.81)}\right)\right) + 138\left(\frac{7.87^2}{2(9.81)}\right)$
$+ 0.0187 \cdot \frac{180}{.1463} \cdot \frac{8.92^2}{2(9.81)} + 0.0151 \cdot \frac{8}{0.0493} \cdot \frac{7.87^2}{2(9.81)}$

$h_L = 2.86 + 1.20 + 75.34 + 7.74$

$\boxed{h_L = 87.14 m}$

11.13 A device designed to allow cleaning of walls and windows on the 2nd floor of homes is similar to the system shown in Fig 11.20. Determine the velocity of flow from the nozzle if the pressure at the bottom is (a) 20 psig & (b) 80 psig. The nozzle has a loss coefficient K of 0.15 based on the outlet velocity head. The tube is smooth drawn aluminum and has an ID of 0.50in. The 90° bend has a radius of 6.0in. The total length of straight tube is 20.0ft. The fluid is H_2O at 100°F



Assumptions:

1. Incompressible fluid
2. Isothermal Process
3. Steady State

$h_L - 13.16$

Data:

$D = 0.0417ft$

$A = \frac{\pi}{4}D^2 = 0.00137ft^2$

Tube length(L) = 20ft

Specific weight H_2O @100°F = $62.0 lb/ft^3$

$K_{nozzle} = 0.15$

$Z_B = 18ft$

$P_B = 0$ goes to atmosphere

$P_A = 20 psig$

$g = 32.2 ft/s^2$

$\varepsilon = 1.00 \times 10^{-8} ft$

$\nu = 7.37 \times 10^{-6} ft^2/s$

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{Z_A} = \cancel{\frac{P_B}{\gamma}} + \frac{V_B^2}{2g} + Z_B + h_{L\,AB}$$

$$\frac{D}{\varepsilon} = 417{,}000$$

$$\frac{P_A}{\gamma} - Z_B = \left(f\frac{L}{D} + K_{elb} + K_{nozzle}\right)\frac{8}{g\pi^2 D^4} Q^2$$

* Q Trials on Excel

$f_T = 0.02116$

$f\frac{L}{D} = 0.02116\left(\frac{20ft}{0.0417ft}\right) = 10.149$

$K_{elb} = 30 f_T =$

$K_{nozzle} = 0.15(V_2/V_1)^2 = 0.15(4)^2 = 2.40$

a.) $Q_A = Q_B$

$V_A A_A = V_B A_B$

$$V_B = \frac{(8.109 ft/s)(\pi/4(0.0417ft^2))}{(\pi/4 \times (0.0208ft)^2)}$$

$V_B = 32.59 ft/s$

b. $Q_A = Q_B$

$V_A A_A = V_B A_B$

$$V_B = \frac{(20.282 ft/s)(\frac{\pi}{4}(0.0417ft)^2)}{(\pi/4 \times (0.0208ft)^2)} = 81.52 ft/s$$

Input Variables		
Specific Weight=	62	lb/ft^3
Kinematic Viscosity=	7.38E-06	ft^2/s
Pressure A =	20	psig
Pressure B =	0	psig
Zb=	18	ft
Tube Length=	20	ft
Diameter=	0.0417	ft
Wall Roughness=	1E-08	ft

2880 lb/ft^2

0 lb/ft^2

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

Precomputable Variables		
ative roughness (D/e)=	417000	
fT=	0.02116	
K noozle=	2.4	
K elbow=	0.6348	
LHS=	28.45161	ft

g= 32.2 ft/s^2

Iteration	Q (m3/s)	V (m/s)	Re	f	RHS	%diff
1	0.01	7.32214	41373.07	0.021685	11.18482	-60.7%
2	0.011	8.054354	45510.37	0.021217	13.30785	-53.2%
3	0.01105	8.090964	45717.24	0.021195	13.41845	-52.8%
4	0.011075	8.10927	45820.67	0.021184	13.47391	-52.6%
5	0.012	8.786568	49647.68	0.020804	15.59968	-45.2%
6	0.013	9.518782	53784.99	0.020434	18.05844	-36.5%
7	0.014	10.251	57922.29	0.0201	20.68246	-27.3%
8	0.015	10.98321	62059.6	0.019797	23.4702	-17.5%
9	0.016	11.71542	66196.9	0.01952	26.42028	-7.1%
10	0.017	12.44764	70334.21	0.019264	29.53141	3.8%
11	0.018	13.17985	74471.52	0.019028	32.80242	15.3%
12	0.0187	13.6924	77367.63	0.018873	35.18666	23.7%

Input Variables		
Specific Weight=	62	lb/ft^3
Kinematic Viscosity=	7.38E-06	ft^2/s
Pressure A =	80	psig
Pressure B =	0	psig
Zb=	18	ft
Tube Length=	20	ft
Diameter=	0.0417	ft
Wall Roughness=	1E-08	ft

11520 lb/ft^2

0 lb/ft^2

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

Precomputable Variables		
elative roughness (D/e)=	417000	
fT=	0.0173	
K noozle=	2.4	
K elbow=	0.519	
LHS=	167.8065	ft

g= 32.2 ft/s^2

Iteration	Q (m3/s)	V (m/s)	Re	f	RHS	%diff
1	0.01	7.32214	41373.07	0.021685	11.08842	-93.4%
2	0.011	8.054354	45510.37	0.021217	13.1912	-92.1%
3	0.01105	8.090964	45717.24	0.021195	13.30074	-92.1%
4	0.011075	8.10927	45820.67	0.021184	13.35566	-92.0%
5	0.012	8.786568	49647.68	0.020804	15.46086	-90.8%
6	0.013	9.518782	53784.99	0.020434	17.89552	-89.3%
7	0.014	10.251	57922.29	0.0201	20.4935	-87.8%
8	0.015	10.98321	62059.6	0.019797	23.25329	-86.1%
9	0.016	11.71542	66196.9	0.01952	26.17348	-84.4%
10	0.017	12.44764	70334.21	0.019264	29.2528	-82.6%
11	0.018	13.17985	74471.52	0.019028	32.49007	-80.6%
12	0.0187	13.6924	77367.63	0.018873	34.84954	-79.2%
13	0.019	13.91207	78608.82	0.018809	35.88418	-78.6%
14	0.02	14.64428	82746.13	0.018604	39.43413	-76.5%
15	0.023	16.84092	95158.05	0.018064	51.00968	-69.6%
16	0.025	18.30535	103432.7	0.017752	59.48979	-64.5%
17	0.027	19.76978	111707.3	0.017472	68.57339	-59.1%
18	0.0275	20.13588	113775.9	0.017406	70.93796	-57.7%
19	0.0277	20.28233	114603.4	0.01738	71.89423	-57.2%
20	0.028	20.50199	115844.6	0.017342	73.33982	-56.3%
21	0.029	21.23421	119981.9	0.017218	78.25517	-53.4%

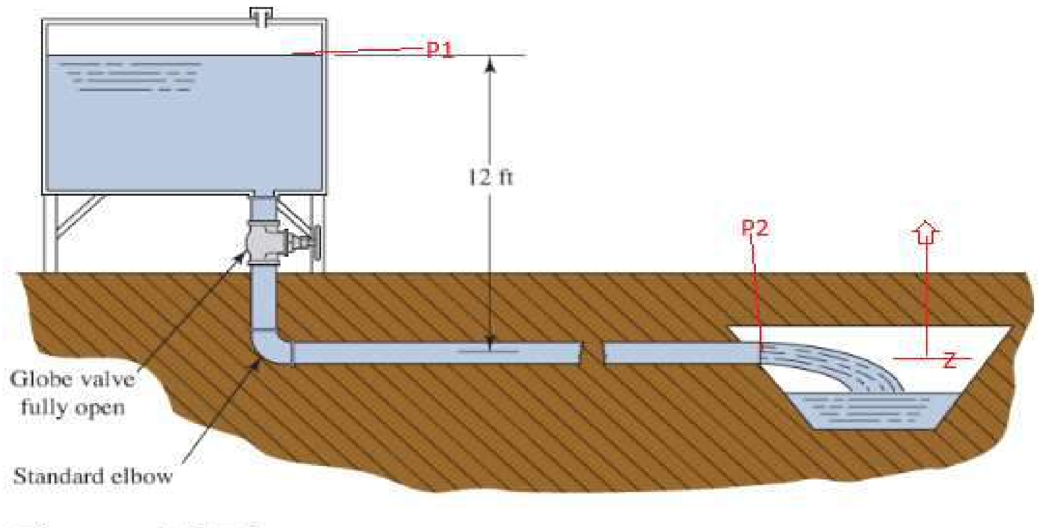
Problem 11.20

The tank shown in Fig. 11.24 is to be drained to a sewer. Determine the size of new Schedule 40 steel pipe that will carry at least 400 gal/min of water at 80°F through the system shown. The total length of pipe is 75 ft.

Purpose

To determine the smallest pipe that will carry the required flow in this system.

Drawings and Diagrams



Sources

Mott, R. L., & Untener, J. A. (2015). *Applied Fluid Mechanics.* Pearson.

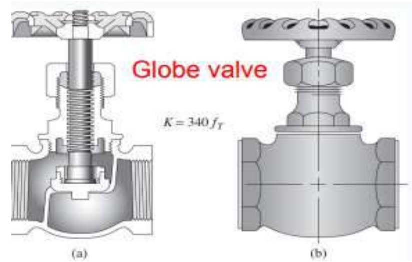
Design Considerations

P1 and P2 are assumed to be zero

Data and Variables

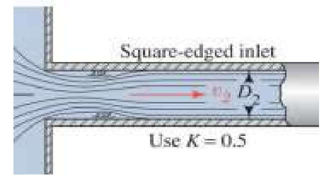
Description	Symbol	Qty	Unit	Source
Flow	Q	400	gpm	given in task statement
Pipe Length	L	75	ft	given in task statement
H2O Temp	T	80	F	given in task statement

Flow	Q	0.891	ft^3/s	gpm * 0.002228
Specific Weight	gamma	62.200	lb/ft^3	Table A.2 (Mott 2015)
Kinematic Viscosit	v	9.15E-06	ft^2/s	Table A.2 (Mott 2015)
Roughness	e	1.500E-04	ft	Table 8.2 (Mott 2015)



Procedure

Determine maximum allowable hL. Then use 3.0 m/s as system starting point and grab the specifications for several pipe sizes near to the starting size. Use excel to find the smallest pipe with a hL less than the calculated maximum.

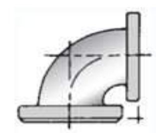


Calculations

$$h_A + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_R + h_L$$

V1 = V2 by inspection
P1 = P2 = 0
hA = hR = 0
Z2 = 0
Z1 = 12ft

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



$K = 30 f_T$
(a) 90° elbow

Z1 = hL
hL <= 12ft

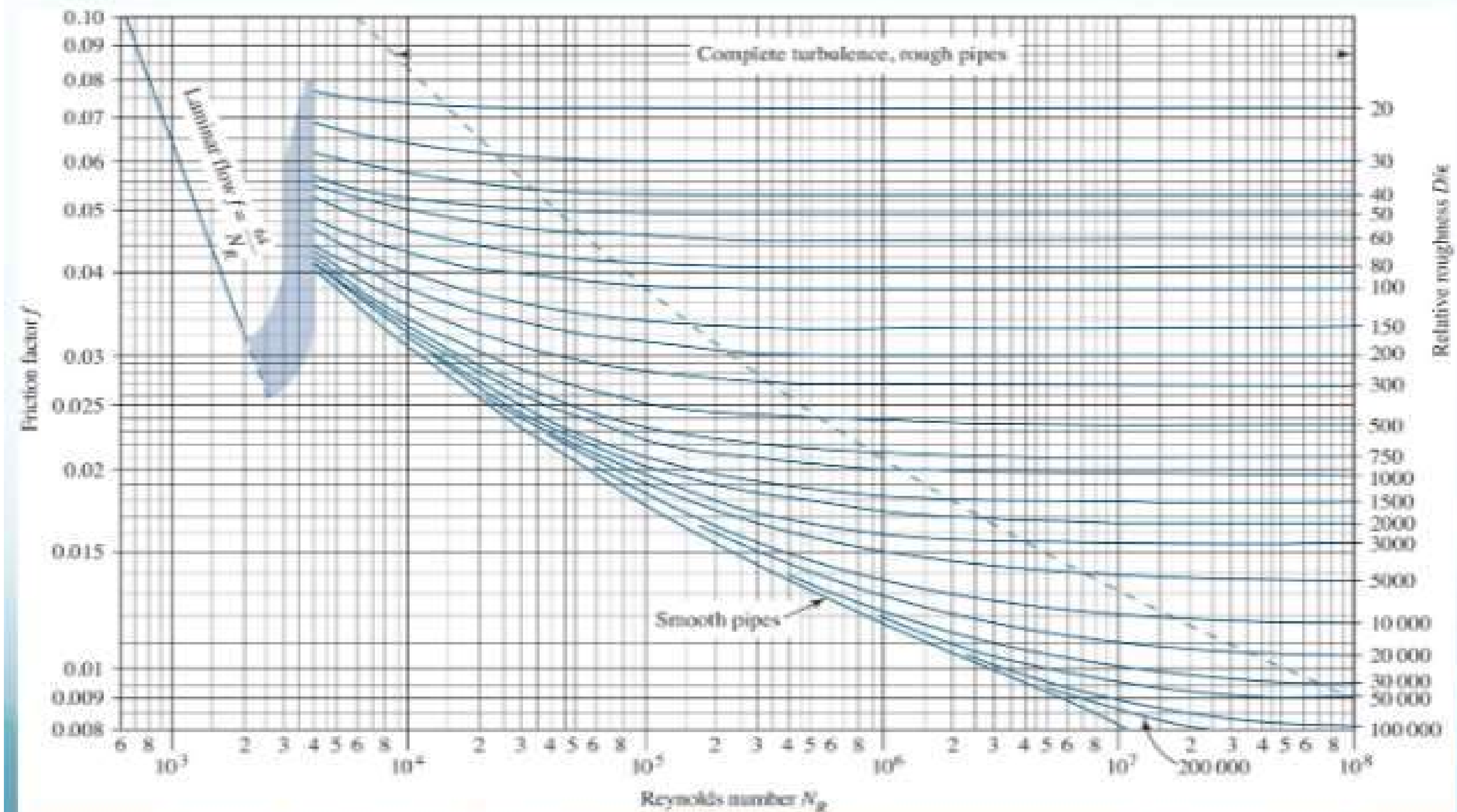
NPS	A (ft^2)	D(ft)	V(Q/A)	Re(VD/v)	D/e	f	fT	hL (Pipe)	hL(90)	hL(Globe)	hL(Ent)	hL(Total)
3.5	0.06868	0.2957	12.9761211	4.19E+05	1971.33	0.018	0.0165	11.93676	1.294223	14.667861	1.307296	29.20614
4	0.0884	0.3355	10.081448	3.70E+05	2236.67	0.0177	0.016	6.244562	0.757532	8.5853669	0.789096	16.37656
4.5	0.139	0.4206	6.41151079	2.95E+05	2804.00	0.017	0.0155	1.934977	0.296816	3.3639188	0.319157	5.91487

Summary

The chosen pipe size is 4.5" NPS

Materials
Water at 60F
New Schedule 40 Iron Pipe

Analysis
Globe Valves have a very high K value (340*fT) so it drives a bigger pipe size and is the biggest loss in this system. If a gate valve was chosen 4" NPS could be used.


Complete turbulence, rough pipes
Laminar flow $f = \frac{64}{N_R}$
Smooth pipes
Friction factor f
Relative roughness D/ϵ
Reynolds number N_R
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
20
30
40
50
60
80
100
150
200
300
500
750
1000
1500
2000
3000
5000
10 000
20 000
30 000
50 000
100 000
200 000
10^3
10^4
10^5
10^6
10^7
10^8