

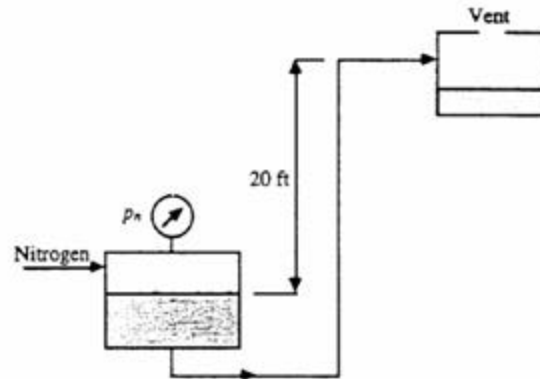
1. Do Problems 3.9, 3.10 and 3.13 of textbook.

3.9Pumping KetoseneReynolds number

$$Re = \frac{\rho u_m D}{\mu}$$

$$= \frac{51 \times u_m \times \frac{2.067}{12}}{4.38/3600}$$

$$Re = 7,220 u_m$$

Case 2-type problem

$$u_m = \sqrt{\frac{D}{2 f_F \rho L} [(P_1 - P_2) - \rho g \Delta z]}$$

$$= \sqrt{\frac{2.067/12}{2 f_F \times 51 \times 150} [15 \times 144 \times 32.2 - 51 \times 32.2 \times 20]}$$

36,708

$$u_m = \frac{0.643}{\sqrt{f_F}}$$

Now roughness ratio is $\frac{E}{D} = \frac{0.00015 \times 12}{2.067} = 8.71 \times 10^{-4}$

ft/s			
u_m	Re	f_F	
-	-	0.005	
9.09	65,654	0.0057	
8.52	61,491	0.0058	
8.44	60,958	0.0058	

Flow rate:

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

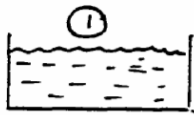
$$= \frac{\pi}{4} \left(\frac{2.067}{12}\right)^2 \times 8.44$$

$$= 0.197 \times 60 \times 7.48$$

$$Q = \underline{\underline{88.3 \text{ gpm}}}$$

3.10

Lodge Water Supply



$$Q = \frac{200}{60 \times 7.48} = 0.446 \frac{\text{ft}^3}{\text{sec}}$$

$L = 2,000 \text{ ft}$

$p_2 = 40 \text{ psig}$



Reynolds Number

$$Re = \frac{\rho u_m D}{\mu} = \frac{4 Q \rho}{\pi D \mu}$$

$$= \frac{62.4 \times 4 \times 0.446}{\pi D \times 1 \times 0.000672} = \frac{5.27 \times 10^4}{D} \quad (D - \text{ft})$$

Pressure Drop

$$-\Delta p = 2 f_F \rho u_m^2 \frac{L}{D} + \rho g \Delta z$$

$$-40 \times 144 \times 32.2 = \frac{32}{\pi^2} \frac{f_F \times 62.4 \times 0.446^2 \times 2000}{D^5}$$

$$-1.85 \times 10^5$$

$$10^4 \times 8.05 \frac{f_F}{D^5}$$

$$- \frac{62.4 \times 32.2 \times 2000}{D^5} = -4.02 \times 10^5$$

Hence $D = 0.820 \times f_F^{0.2}$

$\epsilon = 0.00015 \text{ ft}$

$D(\text{ft})$	Re	ϵ/D	f_F
0.25	2.11×10^5	0.00060	0.0049
0.283	1.86×10^5	0.00053	0.0049

} agreement

Hence $D = 0.283 \text{ ft} = \underline{\underline{3.40 \text{ in}}}$

Next size up = 4.026 in (nominal 4-in)

3.13

Pumping and Piping

Energy ② → ③ $\frac{p_3 - p_2}{\rho} + g(z_3 - z_2) + 2f_f u_m^2 \frac{L}{D} = 0$

Flow rate $Q = \frac{\pi D^2}{4} u_m$ at $u_m^2 = \frac{16Q^2}{\pi^2 D^4}$

Hence $p_2 - p_3 = \rho g(z_3 - z_2) + \frac{32 f_f \rho Q^2 L}{\pi^2 D^5}$

$= \frac{62.4 \times 32.2 \times 25}{32.2 \times 144} + \frac{32 f_f \times 62.4 \times Q^2 \times 1000}{\pi^2 \times \left(\frac{4.026}{12}\right)^5 \times 32.2 \times 144}$

$p_2 - p_3 = 10.83 + 10,265 f_f Q^2 = \Delta p_{pipe}$

Cross-section $A = \frac{\pi}{4} \left(\frac{4.026}{12}\right)^2 = 0.0884 \text{ ft}^2$

Roughness (comm. steel) $k = \epsilon = 0.0018 \text{ in}$ $\frac{\epsilon}{D} = \frac{0.0018}{4.026} = 0.00045$

For large Re, $f_f = 0.0045$

Pump Equation $\Delta p_{pump} = 19.2 - 133.4 Q^{4.5}$

Check on f_f $u_m = \frac{0.38}{0.0884} = 4.30 \text{ ft/sec}$

$Re = \frac{62.4 \times 4.30 \times \frac{4.026}{12}}{1 \times 0.00672}$

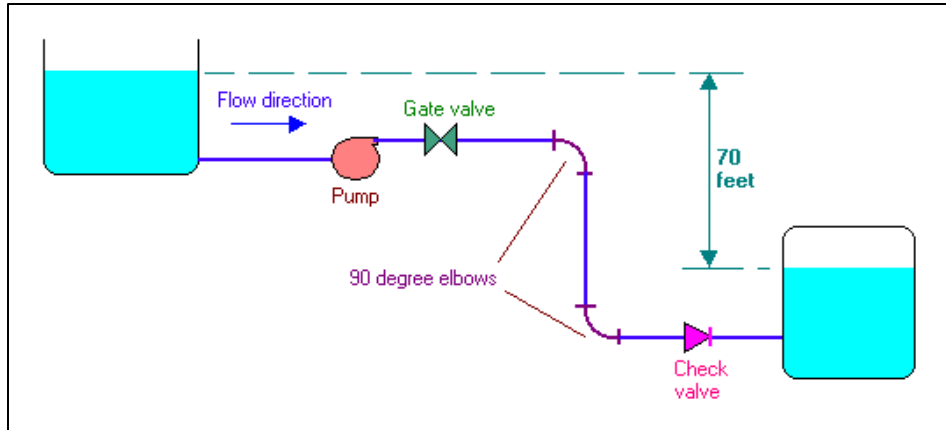
$= 1.34 \times 10^5$

$f_f = 0.0045$ - no change.

Further refinement not needed.

Q ft ³ /sec	Δp_{pipe} psi	Δp_{pump} psi
0.3	14.99	18.61
0.38	17.50	17.49
0.4	18.22	17.07

2. A 35° API distillate is being transferred from a storage tank at 1 atm absolute pressure to a pressure vessel at 50 psig by means of the piping arrangements shown in figure. The liquid flows at the rate of 23100 lb/hr through 3-inch Schedule 40 steel pipe; the length of the straight pipe is 450 feet. Calculate the minimum horsepower input to the pump having an efficiency of 60 percent. The properties of the distillate are: viscosity = 3.4 cP, density = 52 lb/ft³. The following are the data for the pipe and fittings:
- For 3 inch Schedule 40 Nominal pipe, OD = 3.5 inch; Thickness = 0.216 inch
 - Flow coefficients for the fittings (K) are:
 - Gate valve = 0.25; 90o elbow = 0.9; Check valve = 10
 - Friction factor can be calculated from Blasius equation. Account for entry and exit losses also.



Conversion Factors			
1 feet		0.3048	m
1 lb		0.454	kg
1 inch		0.0254	m
1 centipoise		0.001	kg/m.sec
1 atm		14.7	psi
1 atm		1.01E+05	N/m ²
g		9.812	m/sec ²

Data given:				Converted data:			
Mass flow rate		23100	lb/hr	=	2.913167	kg/sec	
Density	ρ	52	lb/ft ³	=	833.7087	kg/m ³	
Viscosity	μ	3.4	cP	=	0.0034	kg/m.sec	
Pipe OD		3.5	inch				
Pipe thickness		0.216	inch				
Pipe length	L	450	feet	=	137.16	m	
Vertical height	$z_1 - z_2$	70	feet	=	21.336	m	
Pump efficiency (in fraction)		0.6					
Loss coefficient of Gate Valve		0.25					
Loss coefficient of elbow		0.9					
Loss coefficient of check valve		10					
Valve							
Pipe ID	D	3.068	inch	=	0.077927	m	

Pressure at 2	P_2	50	psig	=	344642.9	N/m^2
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Calculations:			
Volumetric flow rate	Q	0.00349	m^3/sec
Velocity	v	0.7326	m/sec
Reynolds Number	NRe	13999	
Friction factor	f	0.00726	
h_f of pipe		1.3985	m
$v^2/2g$		0.02735	m
h_f of Gate valve		0.00684	m
h_f of 2 number of elbows		0.04923	m
h_f of Check valve		0.27351	m
h_f of sudden contraction at inlet		0.01094	m
h_f of sudden expansion at outlet		0.02735	m
Total frictional head		1.76642	m
Pump head		22.561	m
Minimum power for the pump		1074.81	Watt