Data Sheet for Fluid Mechanics Course

One atmosphere = 760 mm Hg = 101.3 kN = 14.7 psia

ρ_{H_2O} = 1000 kg m^{-3} = 62.3 lb$_m$/ ; ρ_{Hg} = 13600 kg^{-3} = 845 lb$_m$/ft^3

μ_{H_2O} = 0.001 Pa s = 1cP = 2.09 x 10^{-3}lb$_f$.s/ft^2

Acceleration due to gravity = 9.81 ms^{-2} = 32.2 fts^{-2} ; g$_c$= 32.2 lbm ft/lb$_f$ s^2

1 ft^3 = 28.1 L = 7.48 gal

1hP = 0.746 kW = 550 ft lb$_f$/s

1ft = 12 in, 1 in = 2.54 mm , 1 m = 100 cm = 1000 mm

Universal gas constant = $10.73 \dfrac{(\text{lbf/in}^2)\text{ft}^3}{\text{lbmol.°R}}$; °R = °F + 460 ; K = °C + 273

Equations required for problems involving pipe fittings, pipe friction, and entrance and exit losses.

1] Bernoulli's equation:

$$\Delta\left(\frac{p}{\rho} + gz + \frac{V^2}{2}\right) = +\frac{dW_{ao}}{dm} - \mathcal{F}_{tot}$$

$$\mathcal{F}_{tot} = \mathcal{F}_{\text{pipe friction}} + \mathcal{F}_{\text{fittings}} + \mathcal{F}_{enlargement\ and\ contraction}$$

2] Continuity equation:

$$\dot{m} = \rho AV = \rho Q$$

3] Reynolds:

$$Re = \frac{\rho VD}{\mu} = \frac{4\rho Q}{\pi\mu D} = \frac{4\dot{m}}{\pi\mu D}$$

4] Hagen equation:

$$Q = \frac{\pi\Delta\mathcal{P}D^4}{128\mu\Delta x}$$

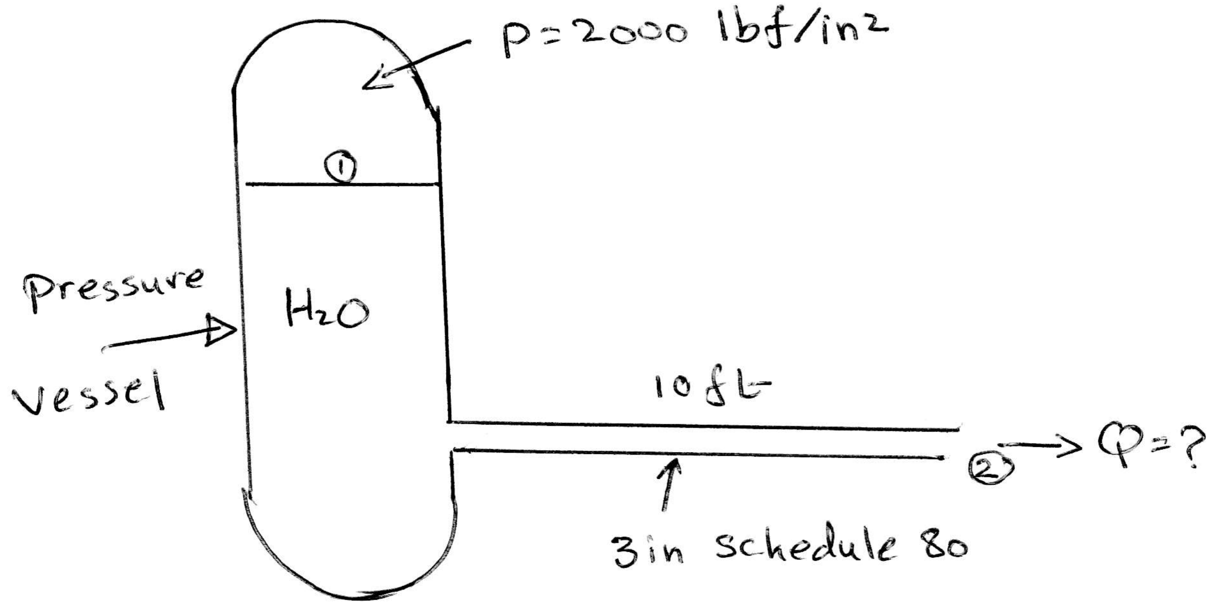
5] Friction Losses

- Pipe friction $\quad \mathcal{F}_{Pipe} = \dfrac{4f\Delta x V^2}{2D}$
- Entrance losses (Contraction) $\quad \mathcal{F}_{Contraction} = K\dfrac{V^2}{2}$; K from chart
- Exit losses (Expansion) $\quad \mathcal{F}_{Expansion} = K\dfrac{V^2}{2}$; $K = \left[1 - \left(\dfrac{D_1}{D_2}\right)^2\right]^2$
- Pipe fittings $\quad \mathcal{F}_{Fittings} = \dfrac{4f[\sum nD]V^2}{2D} = 4f[\sum n]\dfrac{V^2}{2}$

6] Friction Factor

- Laminar: $f = \dfrac{16}{Re}$
- Turbulent :$f = 0.001375\left[1 + \left(20000\dfrac{\epsilon}{D} + \dfrac{10^6}{Re}\right)^{1/3}\right]$ (or any other convenient method)

ex



Given:

pipe size : 3in schedule 80

Length : 10 ft

P_{tank} : 2000 psia

P_2 : P_{atm} = 14.6 psia.

Required : Q

Solution :

This is a type 2 problem.

Apply BE between ① and ②

$$\frac{P_2 - P_1}{\rho} + g\Delta z + \frac{V_2^2 - V_1^2}{2} = -\mathcal{F}_{tot}.$$

$V_1 \simeq 0$ (Large cross section.

$\Delta z \simeq 0$ (negligible compared to other terms

$$\mathcal{F}_{tot} = \mathcal{F}_{pipe} + \mathcal{F}_{entrance}$$

$$= 4f \frac{\Delta x}{D} \cdot \frac{V_2^2}{2} + K\frac{V_2^2}{2}$$

Substitute in BE and rearrange

$$\frac{P_1 - P_2}{\rho} = \frac{V_2^2}{2} + \underbrace{\left[\frac{K V_2^2}{2} + 4f\frac{\Delta x}{D}\frac{V_2^2}{2}\right]}_{F_{tot.}}$$

$$= \left[1 + K + 4f\frac{\Delta x}{D}\right]\frac{V_2^2}{2}$$

$$\therefore V_2 = \left[\frac{2(P_1 - P_2)/\rho}{1 + K + 4f\frac{\Delta x}{D}}\right]^{1/2} \quad \boxed{1}$$

since $D_{pipe} << D_{tank}$ $\therefore$ $K = 0.5$ (from chart)

For 3in schedule 80, ID = 2.9 in (from table).

Assume commercial steel → ε = 0.0018 in

$$\therefore (\varepsilon/D) = \frac{0.0018}{2.9} = 0.00062$$

To solve the problem we must solve equation $\boxed{1}$ and $\boxed{2}$ simultaneousl, or using the procedure explained earlier.

$$f = 0.001375\left[1 + \left(20000\frac{e}{D} + \frac{10^6}{Re}\right)^{1/3}\right] \quad \boxed{2}$$

$$Re = \frac{\rho V_2 D}{\mu}$$

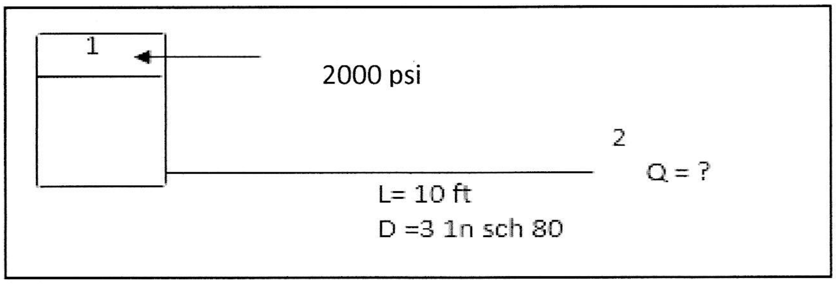
ρ_{H_2O} = 62.3 lbm/ft^3

$\mu_{H_2O} = 2.09 \times 10^{-3}$ lbf s/ft^2

solution: Similar trial and error as in H/w

$Q = 16$ ft^3 s^{-1}

6.34



1] Apply BE Between 1 and 2

$$\frac{P_2 - P_1}{\rho} + g\Delta Z + \frac{V_2^2 - V_1^2}{2} = -\mathcal{F}_{Total} \quad ; \qquad g\Delta Z \cong 0 \ and \ V_1^2 \cong 0 \ (\ large\ cross\ section\ )$$

$$\mathcal{F}_{Total} = \left[1 + K + 4f\frac{\Delta x}{D}\right]\frac{V_2^2}{2} \ ;$$

$$V_2 = \left[\frac{2(P_1 - P_2)}{\rho\left(1 + K + 4f\frac{\Delta x}{D}\right)}\right]^{1/2}$$

$$Q = V_2 * \pi\frac{D^2}{4} = \left[\frac{2(P_1 - P_2)}{\rho\left(1 + K + 4f\frac{\Delta x}{D}\right)}\right]^{1/2} * \pi\frac{D^2}{4} = K_1 * \left[\frac{1}{\left(1 + K + 4f\frac{\Delta x}{D}\right)}\right]^{1/2}$$

$$K_1 = \left[\frac{2(P_1 - P_2)}{\rho}\right]^{1/2} * \pi\frac{D^2}{4}$$

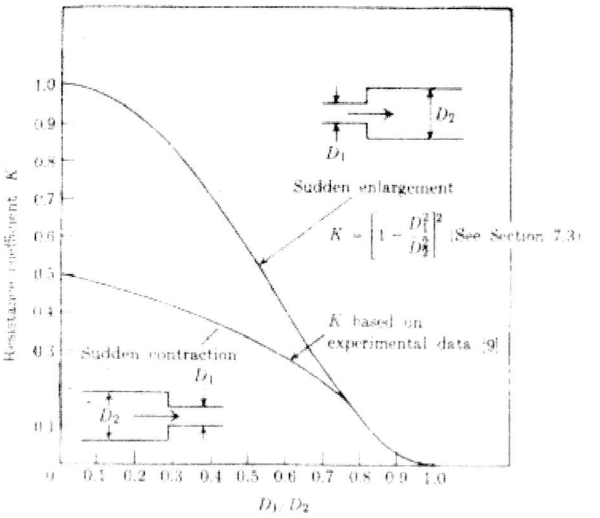
$$\mathrm{Re} = \frac{4\rho}{\pi\mu D} Q = K_2 Q \quad ; \quad K_2 = \frac{4\rho}{\pi\mu D}$$

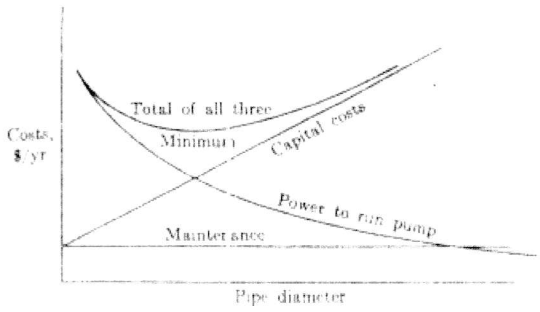
(P1-P2). Psi	2000				
Density, lbm/ft3	62.3	K entrance	0.5	K1=	25.02756
Viscosity,lbf s/ft2	2.09E-03	Length, ft	10	K2=	4877.298
g, ft/s^2	32.2	ϵ/D=	0.000621		
Roughness, in	0.0018				
Diameter of pipe,in	2.9				

- Laminar: $f = \frac{16}{\mathrm{Re}}$
- Turbulent : $f = 0.001375\left[1 + \left(20000\frac{\epsilon}{D} + \frac{10^6}{\mathrm{Re}}\right)^{1/3}\right]$

Trial	f	Q=K1*[ ]	Re = K_2 . Q	f from eq or Chart	Criteria
1	0.005	16.4046	80010.11737	0.005390813	7.816256904
2	0.005391	16.18129	78920.98075	0.00540006	0.171526421
3	0.0054	16.17612	78895.74757	0.005400276	0.004013712

6.35


Resistance coefficient, K
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.1
Sudden enlargement
$K = \left[1 - \frac{D_1^2}{D_2^2}\right]^2$ (See Section 7.3)
K based on experimental data [9]
Sudden contraction
D_1
D_2
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
D_1/D_2


Costs, $/yr
Total of all three
Minimum
Capital costs
Power to run pump
Maintenance
Pipe diameter