3.5.2

To determine the friction factor, we must solve for the relative roughness and the Reynolds number.

$e/D = (0.00015 \text{ ft})/(1.5 \text{ ft}) = 0.0001$

$V = Q/A = (12 \text{ ft}^3/\text{s})/[(\pi/4)(1.5 \text{ ft})^2] = 6.79 \text{ ft/sec}$

$N_R = DV/\nu = [(1.5 \text{ ft})(6.79 \text{ ft/s})]/(1.08 \times 10^{-5} \text{ ft}^2/\text{s})$

$N_R = 9.43 \times 10^5$ From Moody diagram; **f = 0.014**

Thus, the flow is **turbulent – transition zone.**

3.5.4

The pressure drop is computed from the energy eq'n:

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + h_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + h_2 + h_L \text{ ; where } h_L = h_f$$

$e/D = (0.0005 \text{ ft})/(1.25 \text{ ft}) = 0.0004$

$V = Q/A = (18 \text{ ft}^3/\text{s})/[(\pi/4)(1.25 \text{ ft})^2] = 14.7 \text{ ft/sec}$

$N_R = DV/\nu = [(1.25\text{ft})(14.7 \text{ ft/s})]/(1.08 \times 10^{-5} \text{ ft}^2/\text{s})$

$N_R = 1.70 \times 10^6$ From Moody diagram; **f = 0.016**

$h_f = f (L/D)(V^2/2g)$; for a 65 ft length of pipe

$h_f = (0.016)(65\text{ft}/1.25\text{ft})[(14.7 \text{ ft/s})^2/(2 \cdot 32.2 \text{ ft/s}^2)]$

$h_f = 2.79$ ft; and from the energy equation ($v_1 = v_2$);

$$\frac{P_1 - P_2}{\gamma} = h_2 - h_1 + h_f = (65 \text{ ft})(1/50) + 2.79 \text{ ft} = 4.09 \text{ ft}$$

ΔP = $(62.3 \text{ lb/ft}^3)(4.09 \text{ ft}) = 255 \text{ lb/ft}^2$ (**1.77 lb/in²**)

3.5.5

The tower height can be found from energy eq'n:

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + h_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + h_2 + h_L \text{ ; where } h_L = h_f$$

$e/D = (0.045 \text{ mm})/(450 \text{ mm}) = 0.0001$;

$V = Q/A = (0.85 \text{ m}^3/\text{s})/[(\pi/4)(0.45 \text{ m})^2] = 5.34 \text{ m/sec}$

$N_R = DV/\nu = [(0.45\text{m})(5.34 \text{ m/s})]/(1.57 \times 10^{-6} \text{ m}^2/\text{sec})$

$N_R = 1.53 \times 10^6$ From Moody diagram; **$f = 0.013$**

$h_f = f(L/D)(V^2/2g)$; for a 50 m length of pipe

$h_f = (0.013)(200\text{m}/0.45\text{m})[(5.34 \text{ m/s})^2/(2 \cdot 9.81 \text{ m/s}^2)]$

$h_f = 8.40$ m; from the energy eq'n ($V_1 = P_1 = P_2 = 0$);

$h = (V_2)^2/2g + h_2 + h_f$; w/datum at the ground elev.

$h = (5.34\text{m/s})^2/(2 \cdot 9.81 \text{ m/s}^2) + (-2 \text{ m}) + 8.40 \text{ m}$

$h = 7.85$ m

3.5.10

Apply the Darcy-Weisbach eq'n: $h_f = f\,(L/D)(V^2/2g)$

$9.8\text{ m} = f\cdot(400/D)[V^2/(2\cdot 9.81\text{m/s}^2)]$; but $V = Q/A = 4Q/\pi D^2$

Thus; $V = 4(0.045\text{ m}^3/\text{sec})/[\pi(D^2)] = 0.0573/D^2$ and

$9.8\text{ m} = f\cdot(400/D)[(0.0573/D^2)^2/(2\cdot 9.81\text{m/s}^2)]$; yielding

$D^5 = 0.00683\cdot f$; Neither D nor V is available so e/D and N_R cannot be determined. Iterate with $f = 0.02$ as a first trial, which is near midrange of typical f values. Solving for D: $D^5 = 0.00683\cdot(0.02)$; $D = 0.169$ m

Now, $e/D = 0.045\text{mm}/169\text{mm} = 0.000266$

$V = 0.0573/D^2 = 2.01$ m/s; and w/$\nu = 1.14 \times 10^{-6}\text{ m}^2/\text{s}$

$N_R = 2.98 \times 10^5$ From Moody, $f = 0.0175$; the new D:

$D^5 = 0.00683\cdot(0.0175)$; **D = 0.164 m**