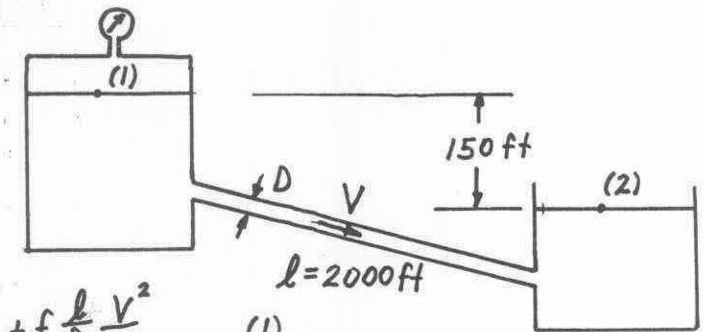
8.103

**8.103** Water is to be moved from a large, closed tank in which the air pressure is 20 psi into a large, open tank through 2000 ft of smooth pipe at the rate of 3 ft$^3$/s. The fluid level in the open tank is 150 ft below that in the closed tank. Determine the required diameter of the pipe. Neglect minor losses.




$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + f\frac{\ell}{D}\frac{V^2}{2g} \qquad (1)$$

where

$V_1 = V_2 = 0$, $z_1 - z_2 = 150\text{ ft}$, and $p_1 = 20\text{ psi}$, $p_2 = 0$

Also,

$$V = \frac{Q}{A} = \frac{3\frac{ft^3}{s}}{\frac{\pi}{4}D^2} = \frac{3.82}{D^2}, \text{ where } V \sim \frac{ft}{s},\ D \sim ft$$

Thus, Eq. (1) becomes

$$\frac{(20\frac{lb}{in.^2})(144\frac{in.^2}{ft^2})}{62.4\frac{lb}{ft^3}} + 150\text{ft} = f\,\frac{2000\text{ft}}{D}\,\frac{\left(\frac{3.82}{D^2}\right)^2}{2(32.2\frac{ft}{s^2})}$$

or

$$D = 1.18 f^{1/5} \qquad (2)$$

Also,

$$Re = \frac{\rho VD}{\mu} = \frac{\rho\left(\frac{3.82}{D^2}\right)D}{\mu} = \frac{1.94\,(3.82)}{2.34\times10^{-5}\,D}, \text{ or } Re = \frac{3.17\times10^5}{D} \qquad (3)$$

Trial and error solution:

Assume $f = 0.02$ so from Eq. (2), $D = 0.540$ ft and from Eq. (3) $Re = 5.87\times10^5$. Thus, from Fig. 8.20 (with $\frac{\varepsilon}{D} = 0$) $f = 0.013 \neq 0.02$

Assume $f = 0.013$ which gives $D = 0.495$ ft, $Re = 6.40\ 10^5$, and $f = 0.0125$

Assume $f = 0.0125$, so $D = 0.491$ ft, $Re = 6.46\times10^5$, $f = 0.0125$ (Checks)

Thus, $\underline{\underline{D = 0.491\text{ ft}}}$

Alternately, the Colebrook equation, Eq. 8.35, rather than the Moody chart, Fig. 8.20, could be used as follows:

(con't)

8.103 (con't)

With $\varepsilon/D = 0$, Eq. 8.35 is

$$\frac{1}{\sqrt{f}} = -2.0 \log\left(2.51/(Re\sqrt{f})\right) \quad \text{where} \tag{4}$$

from Eq. (2), $f = (D/1.18)^5$ (5)

Thus, combining Eqs. (3), (4), and (5) gives

$$1/(D/1.18)^{5/2} = -2.0 \log\left[2.51/((3.17\times10^5/D)(D/1.18)^{5/2})\right] \tag{6}$$

Using a computer root-finding technique gives the solution to Eq. (6) as $D = 0.492\,ft$, which is consistent with the above trial and error solution.