8.80

8.80 According to fire regulations in a town, the pressure drop in a commercial steel horizontal pipe must not exceed 1.0 psi per 150 ft of pipe for flowrates up to 500 gal/min. If the water temperature is never below 50 °F, what diameter pipe is needed?

$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g}$, where $p_1 - p_2 = 1\,\frac{lb}{in.^2}$, $z_1 = z_2$, $\ell = 150\,ft$,

and $V_1 = V_2 = V$, with

$$V = \frac{Q}{A} = \frac{(500\,\frac{gal}{min})(\frac{1\,min}{60\,s})(231\,\frac{in.^3}{gal})(\frac{1\,ft^3}{1728\,in.^3})}{\frac{\pi}{4}D^2} = \frac{1.418}{D^2}\,\frac{ft}{s}, \text{ where } D \sim ft$$

Thus, $\frac{p_1 - p_2}{\gamma} = f\frac{\ell}{D}\frac{V^2}{2g}$. Use $T = 50°F$ so that from Table B.1:

$\gamma = 62.41\,\frac{lb}{ft^3}$; $\nu = 1.407 \times 10^{-5}\,\frac{ft^2}{s}$

or

$$\frac{(1\,\frac{lb}{in.^2})(144\,\frac{in.^2}{ft^2})}{62.41\,\frac{lb}{ft^3}} = f\left(\frac{150\,ft}{D}\right)\frac{\left(\frac{1.418}{D^2}\right)^2}{2(32.2\,\frac{ft}{s^2})}$$

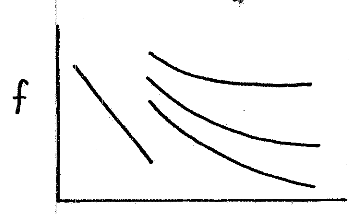
That is,

$D^5 = 2.03f$, where $D \sim ft$ (1)

Also, with $\varepsilon = 0.00015\,ft$ (see Table 8.1) we have $\frac{\varepsilon}{D} = \frac{1.5 \times 10^{-4}}{D}$ (2)

and $Re = \frac{VD}{\nu} = \frac{\left(\frac{1.418}{D^2}\right)D}{1.407 \times 10^{-5}}$ or $Re = \frac{1.01 \times 10^5}{D}$ (3)

Finally, from Fig. 8.20 (4)



Trial and error solution of Eqs. (1), (2), (3), and (4) for f, D, $\frac{\varepsilon}{D}$, and Re.

Assume $f = 0.02$; from (1) $D = 0.526\,ft$; from (2) and (3) $\frac{\varepsilon}{D} = 2.85 \times 10^{-4}$ and $Re = 1.92 \times 10^5$; thus from (4) $f = 0.0176 \neq 0.02$ Not the solution.

Assume $f = 0.0176$; from (1) $D = 0.513\,ft$; from (2) and (3) $\frac{\varepsilon}{D} = 2.92 \times 10^{-4}$ and $Re = 1.97 \times 10^5$; thus from (4) $f = 0.0176$, which agrees with the assumed value.

Thus, $\underline{\underline{D = 0.513\,ft}}$

An alternate solution method is to use the Colebrook equation (Eq 8.35) rather than the Moody chart (Eq (4)). Thus, $\frac{1}{\sqrt{f}} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$ which when combined with Eqs. (1), (2), and (3) gives:

$$(2.03/D^5)^{1/2} = -2.0\log\left[\frac{1.5 \times 10^{-4}}{3.7D} + \frac{2.51D}{1.01 \times 10^5}/(D^5/2.03)^{1/2}\right] \quad (5)$$

A computer root-finding solution of Eq (5) gives $D = 0.514\,ft$ which is consistent with the above trial and error solution.