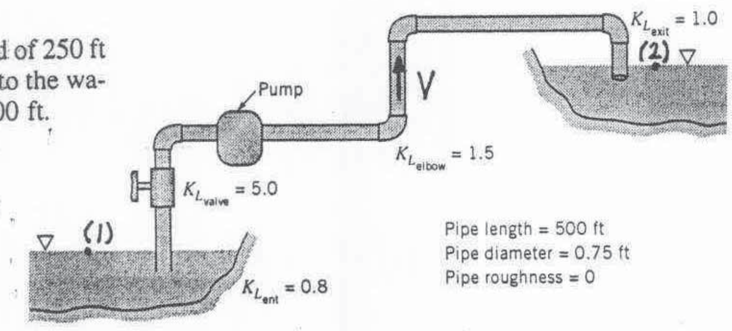
8.96

8.96 The pump shown in Fig. P8.96 delivers a head of 250 ft to the water. Determine the power that the pump adds to the water. The difference in elevation of the two ponds is 200 ft.



■ FIGURE P8.96

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} - h_L + h_p = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$

where $p_1 = p_2 = 0,\ V_1 = V_2 = 0,\ z_1 = 0,\ z_2 = 200\ ft,\ h_p = 250\ ft$

Thus,

$$-f\frac{\ell}{D}\frac{V^2}{2g} - \sum_i K_{L_i}\frac{V^2}{2g} + h_p = z_2 \quad \text{so that with } \sum_i K_{L_i}\frac{V^2}{2g} = (0.8 + 4(1.5) + 5.0 + 1)\frac{V^2}{2g} = 12.8\frac{V^2}{2g}$$

$$\left[-f\left(\frac{500}{0.75}\right) - 12.8\right]\frac{V^2}{2(32.2)} + 250 = 200$$

or

(1) $$(667f + 12.8)V^2 = 3220$$

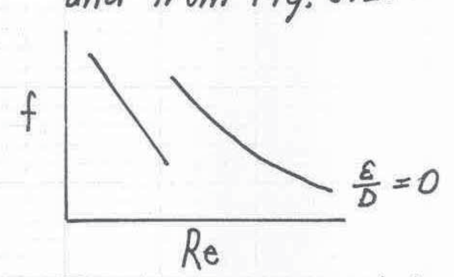
Also, $$Re = \frac{\rho V D}{\mu} = \frac{(1.94\ \frac{slugs}{ft^3})\,V\,(0.75\,ft)}{2.34\times10^{-5}\ \frac{lb\cdot s}{ft^2}}$$

or

(2) $$Re = 6.22\times10^4\, V$$

and from Fig. 8.20:

(3)



Trial and error solution. Assume $f = 0.02 \xrightarrow{(1)} V = 11.1\ \frac{ft}{s} \xrightarrow{(2)} Re = 6.9\times10^5$
$\xrightarrow{(3)} f = 0.012 \neq 0.02$

Assume $f = 0.012 \xrightarrow{(1)} V = 12.4\ \frac{ft}{s} \xrightarrow{(2)} Re = 7.7\times10^5 \xrightarrow{(3)} f = 0.0121 \approx 0.012$

Thus, $V = 12.4\ \frac{ft}{s}$ and

$$\dot{W}_s = \gamma Q h_p = (62.4\ \tfrac{lb}{ft^3})\tfrac{\pi}{4}(0.75\,ft)^2(12.4\ \tfrac{ft}{s})(250\,ft) = 8.55\times10^4\ \tfrac{ft\cdot lb}{s}$$

$$= 8.55\times10^4\ \tfrac{ft\cdot lb}{s} \times 1\ \frac{hp}{550\ \frac{ft\cdot lb}{s}} = \underline{\underline{155\ hp}}$$

Alternatively, we could replace Eq. (3) (the Moody chart) by Eq 8.35

(con't)

8.96 (con't)

(the Colebrook equation) and obtain V as follows.
From Eq. (1),

$V = \left[3220/(667f + 12.8) \right]^{1/2}$, which when combined with Eq. (2) gives

(4) $Re = 6.22 \times 10^4 \left[3220/(667f + 12.8) \right]^{\frac{1}{2}} = 3.53 \times 10^6 / (667f + 12.8)^{\frac{1}{2}}$

Also, the Colebrook equation with $\varepsilon/D = 0$ is

(5) $\frac{1}{\sqrt{f}} = -2.0 \log \left(\frac{2.51}{Re\sqrt{f}} \right)$

By combining Eqs (4) and (5) we obtain a single equation involving only f:

$$\frac{1}{\sqrt{f}} = -2.0 \log \left[\frac{2.51(667f + 12.8)^{1/2}}{3.53 \times 10^6 \sqrt{f}} \right]$$

Using a compute root-finding program to solve Eq (6) gives
f = 0.0123, consistent with the above trial and error method.