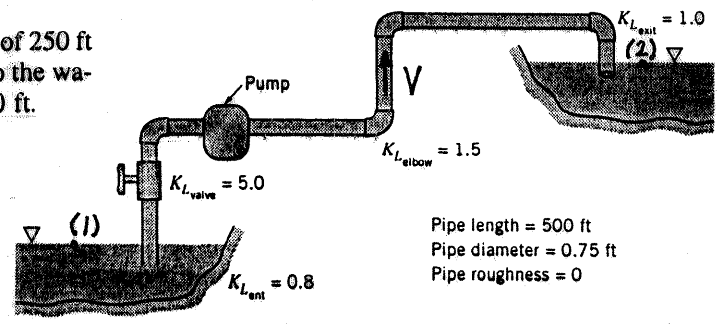
8.75

8.75 The pump shown in Fig. P8.75 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 P8.75

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

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

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

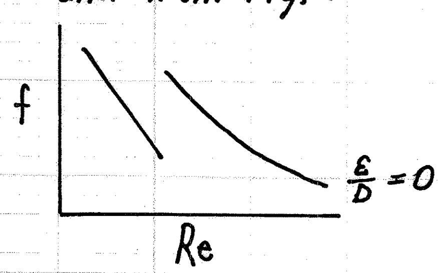
(1) $$(667f + 12.8)V^2 = 3220$$

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

or

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

and from Fig. 8.20:

(3) 

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

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

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

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

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

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

(con't)

8.75 (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) $\quad Re = 6.22\times10^4\left[3220/(667f+12.8)\right]^{\frac{1}{2}} = 3.53\times10^6/(667f+12.8)^{\frac{1}{2}}$

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

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

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

$$\frac{1}{\sqrt{f}} = -2.0 \log\left[\frac{2.51(667f+12.8)^{1/2}}{3.53\times10^6\sqrt{f}}\right]$$

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