8.89

8.94 The pump shown in Fig. P8.94 adds 25 kW to the water and causes a flowrate of 0.04 m^3/s. Determine the flowrate expected if the pump is removed from the system. Assume $f = 0.016$ for either case and neglect minor losses.

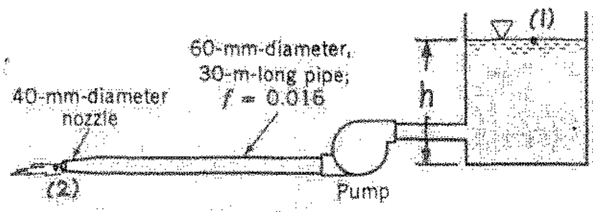

FIGURE P8.94

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g}, \text{ where } p_1 = p_2 = 0,\ z_1 = h,\ z_2 = 0,$$

$$V_1 = 0,\ V_2 = \frac{Q}{A_2} = \frac{0.04\ \frac{m^3}{s}}{\frac{\pi}{4}(0.04m)^2} = 31.8\ \frac{m}{s},\ V = \frac{Q}{A} = \frac{0.04\ \frac{m^3}{s}}{\frac{\pi}{4}(0.06m)^2} = 14.15\ \frac{m}{s}$$

Thus,

$$h + h_p = \frac{(31.8\ \frac{m}{s})^2}{2(9.81\frac{m}{s^2})} + 0.016\left(\frac{30\ m}{0.06\ m}\right)\frac{(14.15\ \frac{m}{s})^2}{2(9.81\frac{m}{s^2})} = 133.2\ m$$

but,

$$h_p = \frac{P}{\gamma Q} = \frac{25 \times 10^3\ \frac{N\cdot m}{s}}{(9.80\times10^3\ \frac{N}{m^3})(0.04\ \frac{m^3}{s})} = 63.8\ m$$

Hence,

$$h = 133.2m - 63.8\ m = 69.5m$$

Without the pump $h_p = 0$ and $z_1 = \frac{V_2^2}{2g} + f\frac{\ell}{D}\frac{V^2}{2g}$ where $h = 69.5m = z_1$

and

$$V_2 = \frac{AV}{A_2} = \left(\frac{D}{D_2}\right)^2 V \quad \text{or} \quad V_2 = \left(\frac{60mm}{40mm}\right)^2 V = 2.25V$$

Thus,

$$69.5\ m = \frac{(2.25V)^2 + 0.016\left(\frac{30\ m}{0.06\ m}\right)V^2}{2(9.81\frac{m}{s^2})} \quad \text{or } V = 10.22\ \frac{m}{s}$$

so that

$$Q = AV = \frac{\pi}{4}(0.06m)^2(10.22\ \frac{m}{s}) = \underline{\underline{0.0289\ \frac{m^3}{s}}}$$