

11.63 The 36.75-in pump in Fig. 11.7a at 1170 r/min is used to pump water at 60°F from a reservoir through 1000 ft of 12-in-ID galvanized-iron pipe to a point 200 ft above the reservoir surface. What flow rate and brake horsepower will result? If there is 40 ft of pipe upstream of the pump, how far below the surface should the pump inlet be placed to avoid cavitation?

Solution: For galvanized pipe, $\varepsilon \approx 0.0005$ ft, hence $\varepsilon/d \approx 0.0005$. Assume fully-rough flow, with $f \approx 0.0167$. The pipe head loss is thus approximately

$$h_f = \Delta z + f \frac{L}{d} \frac{[Q/(\pi d^2/4)]^2}{2g} = 200 + 0.0167 \left(\frac{1000}{1} \right) \frac{[Q/(\pi(1)^2/4)]^2}{2(32.2)}$$

$$\approx 200 + 0.42Q^2 \quad (Q \text{ in ft}^3/\text{s})$$

Curve-fit Fig. 11.7a, $D = 36.75''$, to a parabola: $H_p \approx 665 - 0.051Q^2$ (again Q in ft^3/s)

Equate: $665 - 0.051Q^2 = 200 + 0.42Q^2$, solve $Q \approx 31.4 \text{ ft}^3/\text{s} \approx \mathbf{14100 \text{ gpm}}$ *Ans. (a)*

Figure 11.7a: $P = \rho g Q H / \eta = 62.4(31.4)(615)/0.78 \div 550 \approx \mathbf{2800 \text{ bhp}}$. *Ans. (b)*

Check $V = Q/A \approx 40 \text{ ft/s}$, $Re_d = Vd/\nu \approx 3.71E6$, Moody chart, $f \approx \mathbf{0.0168}$ (OK).

(c) Figure 11.7a @ 14000 gpm: read $NPSH \approx \mathbf{25 \text{ ft}}$. Calculate the head loss upstream:

$$h_{fi} = f \frac{L}{d} \frac{V^2}{2g} = 0.0168 \left(\frac{40}{1} \right) \frac{(40.0)^2}{2(32.2)} \approx 16.7 \text{ ft}, \text{ use Eq. 11.20:}$$

$$NPSH = 25 \leq \frac{P_a - P_v}{\rho g} - Z_i - h_{fi} = \frac{2116 - 39}{62.4} - Z_i - 16.7, \text{ solve } Z_i \leq \mathbf{-8.5 \text{ ft}} \quad \textit{Ans. (c)}$$

11.64 A leaf blower is essentially a centrifugal impeller exiting to a tube. Suppose that the tube is smooth PVC pipe, 4 ft long, with a diameter of 2.5 in. The desired exit velocity is 73 mi/h in sea-level standard air. If we use the pump family of Eq. (11.27) to drive the blower, what approximate (a) diameter and (b) rotation speed are appropriate? (c) Is this a good design?

Solution: Recall that Eq. (11.27) gave BEP coefficients for the pumps of Fig. 11.7:

$$C_Q^* \approx 0.115; \quad C_H^* \approx 5.0; \quad C_P^* \approx 0.65$$

Apply these coefficients to the leaf-blower data. Neglect minor losses, that is, let the pump head match the pipe friction loss. For air, take $\rho = 1.2 \text{ kg/m}^3$ and $\mu = 1.8E-5 \text{ kg/m}\cdot\text{s}$.