11.41 It is desired to build a centrifugal pump geometrically similar to Prob. 11.28 (data at right) to deliver 6500 gal/min of gasoline at 1060 rpm. Estimate the resulting (a) impeller diameter; (b) head; (c) brake horsepower; and (d) maximum efficiency.

Q, ft^3/s:	0	2	4	6	8	10
H, ft:	340	340	340	330	300	220
bhp:	135	160	205	255	330	330

Solution: For gasoline, take $\rho \approx 1.32$ slug/ft^3. From Prob. 11.28, BEP occurs at $Q^* \approx 6$ ft^3/s, $\eta_{max} \approx 0.88$. The data above are for $n = 2134$ rpm $= 35.6$ rps and $D = 14.62$ in.

$$\text{Then}\quad C_Q^* = \frac{6.0}{35.6(14.62/12)^3} = 0.0933 \overset{?}{=} \frac{6500/449}{(1060/60)D^3},$$

$$\text{Solve for}\quad D_{imp} \approx \mathbf{2.06\ ft} \quad \textit{Ans.}\text{ (a)}$$

$$C_H^* = \frac{32.2(330)}{(35.6)^2(14.62/12)^2} = 5.66 \overset{?}{=} \frac{32.2H}{(1060/60)^2(2.06)^2},\quad \text{solve for } H \approx \mathbf{233\ ft} \quad \textit{Ans.}\text{ (b)}$$

Step-up the efficiency with Moody's correlation, Eq. (11.29a), for $D_1 = 14.62/12 \approx 1.22$ ft:

$$\frac{1-\eta_2}{1-0.88} \approx \left(\frac{D_1}{D_2}\right)^{1/4} = \left(\frac{1.22}{2.06}\right)^{1/4} = 0.877,\quad \text{solve for } \eta_2 \approx 0.895$$

$$\text{Then}\quad P_2 = \frac{\rho g Q_2 H_2}{\eta_2} = \frac{1.32(32.2)(6500/449)(233)}{0.895} = 160200 \div 550 \approx \mathbf{290\ bhp} \quad \textit{Ans.}\text{ (c)}$$

11.42 An 8-inch model pump delivering water at 180°F at 800 gal/min and 2400 rpm begins to cavitate when the inlet pressure and velocity are 12 psia and 20 ft/s, respectively. Find the required NPSH of a prototype which is 4 times larger and runs at 1000 rpm.

Solution: For water at 180°F, take $\rho g \approx 60.6$ lbf/ft^3 and $p_v \approx 1600$ psfa. From Eq. 11.19,

$$NPSH_{model} = \frac{p_i - p_v}{\rho g} + \frac{V_i^2}{2g} = \frac{12(144) - 1600}{60.6} + \frac{(20)^2}{2(32.2)} = 8.32\ \text{ft}$$

$$\text{Similarity:}\quad NPSH_{proto} = NPSH_m\left(\frac{n_p}{n_m}\right)^2\left(\frac{D_p}{D_m}\right)^2 = 8.32\left(\frac{1000}{2400}\right)^2\left(\frac{4}{1}\right)^2 \approx \mathbf{23\ ft} \quad \textit{Ans.}$$

11.43 The 28-in-diameter pump in Fig. 11.7*a* at 1170 r/min is used to pump water at 20°C through a piping system at 14,000 gal/min. (a) Determine the required brake horsepower. The average friction factor is 0.018. (b) If there is 65 ft of 12-in-diameter pipe upstream of the pump, how far below the surface should the pump inlet be placed to avoid cavitation?

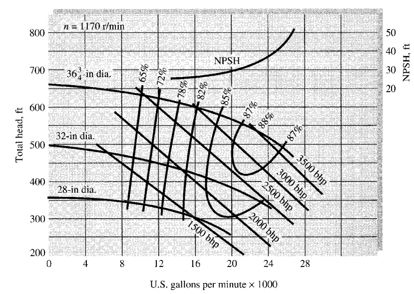

Fig. 11.7a

Solution: For water at 20°F, take $\rho g \approx 62.4$ lbf/ft^3 and $p_v \approx 49$ psfa. From Fig. 11.7a (above), at 28″ and 14000 gpm, read H ≈ 320 ft, $\eta \approx 0.81$, and P ≈ **1400** bhp. *Ans.*

$$\text{Or: Required bhp} = \frac{\rho g Q H}{\eta} = \frac{(62.4)(14000/449)(320)}{0.81} = 769000 \div 550 \approx \textbf{1400 bhp} \quad \textit{Ans.}$$

From the figure, at 14000 gal/min, read NPSH ≈ 25 ft. Assuming $p_a = 1$ atm = 2116 psf,

$$\text{Eq. 11.20:}\quad \text{NPSH} = \frac{p_a - p_v}{\rho g} - Z_i - h_{fi} = \frac{2116-49}{62.4} - Z_i - h_{fi} \approx 25 \text{ ft},\quad h_{fi} = f\frac{L}{D}\frac{V^2}{2g},$$

$$V = \frac{Q}{A} = \frac{14000/449}{(\pi/4)(1\text{ ft})^2} \approx 39.7\ \frac{\text{ft}}{\text{s}},$$

$$\text{so:}\quad Z_i = 33.1 - 25 - 0.018\left(\frac{65}{1}\right)\left[\frac{(39.7)^2}{2(32.2)}\right] \approx \mathbf{-21\ ft} \quad \textit{Ans.}$$

11.44 The pump of Prob. 11.28 is scaled up to an 18-in-diameter, operating in water at BEP at 1760 rpm. The measured NPSH is 16 ft, and the friction loss between the inlet and the pump is 22 ft. Will it be sufficient to avoid cavitation if the pump inlet is placed 9 ft below the surface of a sea-level reservoir?

Solution: For water at 20°C, take $\rho g = 62.4$ lbf/ft^3 and $p_v = 49$ psfa. Since the NPSH is *given*, there is no need to use the similarity laws. Merely apply Eq. 11.20:

$$\text{NPSH} \le \frac{p_a - p_v}{\rho g} - Z_i - h_{fi},\quad \text{or:}\quad Z_i \le \frac{2116-49}{62.4} - 22 - 16 = -4.9 \text{ ft, } \textbf{OK,}$$

$$\mathbf{Z_{actual} = -9\ ft} \quad \textit{Ans.}$$

This works. Putting the inlet 9 ft below the surface gives 4 ft of margin against cavitation.
