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5.116 A pump is to move water from a lake into a large, pressurized tank as shown in Fig. P5.116 at a rate of 1000 gal in 10 min or less. Will a pump that adds 3 hp to the water work for this purpose? Support your answer with appropriate calculations. Repeat the problem if the tank were pressurized to 3, rather than 2, atmospheres.
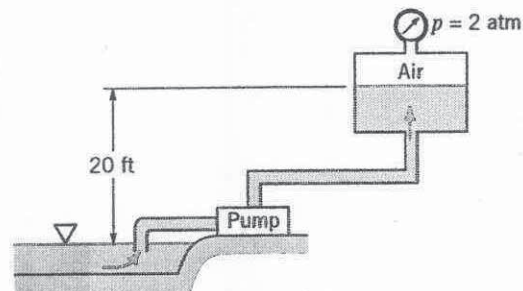

■ FIGURE P5.116

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_s - h_L = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g}, \text{ where } p_1 = 0, \ z_1 = 0, \ V_1 = 0, \text{ and } z_2 = 20ft.$$

Thus,

(1) $\quad h_s = h_L + \frac{p_2}{\gamma} + z_2$

Also,

$$Q = [(1000 \, gal)/(10 \, min)] \left(\frac{1 \, ft^3}{7.48 \, gal}\right) \left(\frac{1 \, min}{60 \, s}\right) = 0.223 \, \frac{ft^3}{s}$$

so that

$$h_s = \frac{\dot{W}_s}{\gamma Q} = \frac{(3 \, hp)(550 \, \frac{ft \cdot lb/s}{hp})}{(62.4 \, \frac{lb}{ft^3})(0.223 \, \frac{ft^3}{s})} = 119 \, ft$$

(a) If $p_2 = 2 \, atm = 2(14.7 \, \frac{lb}{in.^2})(144 \, in.^2/ft^2) = 4,230 \, \frac{lb}{ft^2}$, then from Eq.(1)

$$h_s = h_L + \frac{4,230 \, \frac{lb}{ft^2}}{(62.4 \, \frac{lb}{ft^3})} + 20ft = h_L + 87.8 \, ft$$

Thus, if

$$h_L \le h_s - 87.8 \, ft = 119ft - 87.8ft = 31.2 \, ft \quad \text{the given pump will work for } p_2 = 2 \, atm.$$

(b) If $p_2 = 3 \, atm = 6,350 \, \frac{lb}{ft^2}$, then

$$h_s = h_L + \frac{6,350 \, \frac{lb}{ft^3}}{(62.4 \, \frac{lb}{ft^3})} + 20ft = h_L + 122 \, ft$$

Thus, if this pump is to work

$119 \, ft = h_L + 122 \, ft, \text{ or } h_L \le -3 \, ft$

Since it is not possible to have $h_L < 0$, the pump will not work for $p_2 = 3 \, atm.$

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