5.109 A pump is to move water from a lake into a large, pressurized tank as shown in Fig. P5.109 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.
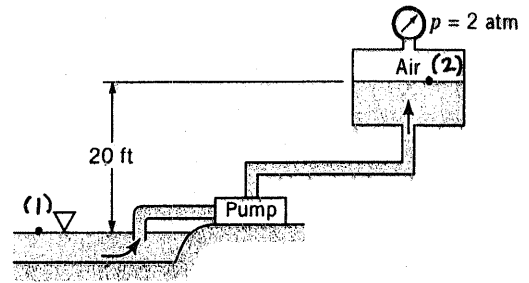

■ F I G U R E   P5.109

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

Thus,

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

Also,

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

so that

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

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

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

Thus, if

$h_L \leq h_p - 87.8 \, ft = 119 \, ft - 87.8 \, ft = 31.2 \, ft$ the given pump will work for $p_2 = 2 \, atm$.

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

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

Thus, if this pump is to work

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

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