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.

\[
\frac{h_p}{\gamma} + h_{p} = Z_1 + \frac{V_1^2}{2g} + h_p - h_L = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}, \text{ where } \gamma = 0, Z_1 = 0, V_1 = 0, \text{ and } Z_2 = 20 ft.
\]

Thus,

\[(1) \quad h_p = h_L + \frac{P_2}{\gamma} + Z_2\]

Also,

\[Q = \left[\frac{1000 \text{ gal}}{\text{10 min}}\right] \left(\frac{1 \text{ ft}^3}{7.48 \text{ gal}}\right) \left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 0.223 \frac{\text{ft}^2}{\text{s}}\]

so that,

\[h_p = \frac{W_p}{\gamma Q} = \frac{(3 \text{ hp})(550 \frac{\text{ft} \cdot \text{lb}}{\text{hp} \cdot \text{s}})}{(62.4 \frac{\text{lb}}{\text{ft}^3})(0.223 \frac{\text{ft}^2}{\text{s}})} = 119 \text{ ft}\]

(a) If \( P_2 = 2 \text{ atm} = 2 (14.7 \frac{\text{lb}}{\text{in}^2}) (144 \frac{\text{in}^2}{\text{ft}^2}) = 4,230 \frac{\text{lb}}{\text{ft}^2}, \text{ then from Eq. (1)}\]

\[h_p = h_L + \frac{4,230 \frac{\text{lb}}{\text{ft}^2}}{(62.4 \frac{\text{lb}}{\text{ft}^3})} + 20 \text{ ft} = h_L + 87.8 \text{ ft}\]

Thus, if

\[h_L \leq h_p - 87.8 \text{ ft} = 119 \text{ ft} - 87.8 \text{ ft} = 31.2 \text{ ft} \quad \text{the given pump will work for } P_2 = 2 \text{ atm.}\]

(b) If \( P_2 = 3 \text{ atm} = 6.350 \frac{\text{lb}}{\text{ft}^2}, \text{ then}\]

\[h_p = h_L + \frac{6,350 \frac{\text{lb}}{\text{ft}^2}}{(62.4 \frac{\text{lb}}{\text{ft}^3})} + 20 \text{ ft} = h_L + 122 \text{ ft}\]

Thus, if this pump is to work

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

Since it is not possible to have \( h_L < 0 \), the pump will not work for \( P_2 = 3 \text{ atm.} \)