5.111

5.111 A pump is to move water from a lake into a large, pressurized tank as shown in Fig. P5.111 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.

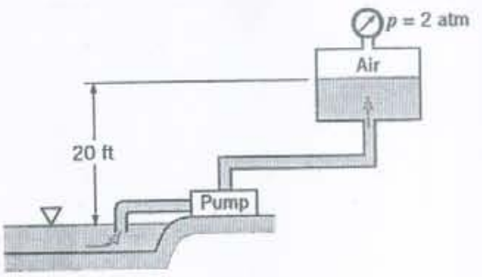

FIGURE P5.111

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

Thus,

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

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

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

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

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

Thus, if

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

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

$h_s = h_L + \frac{6{,}350\,\frac{lb}{ft^2}}{\left(62.4\,\frac{lb}{ft^3}\right)} + 20\,ft = h_L + 122\,ft$

Thus, if this pump is to work

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

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