40.24 A pump transfers $100gpm$ of water from an open reservoir at atmospheric pressure. The static suction lift is $5ft$, the static discharge head is $30ft$, and the working pressure at the outlet is $10psig$. The pump efficiency is 85% and the motor efficiency is 80%. Assuming losses are insignificant, what size motor is required?

A. $1^1/_2 hp$

B. $2hp$

C. $3hp$

D. $5hp$

Write the form of the Bernoulli Equation suited for pumping applications:

$$h_A = \frac{P_2 - P_1}{\gamma} + \frac{v_2^2 - v_1^2}{2g} + z_2 - z_1 + h_f$$

The working pressure at the outlet, P_2, is given. The static pressure in the open reservoir, P_1, is atmospheric pressure. Therefore, the gauge pressure at P_2 is the differential pressure. Use the rule of thumb conversion factor for water $2.31\frac{ft}{psi}$ for convenience converting between pressure units and feet of head.

$$\frac{P_2 - P_1}{\gamma} = \frac{(10psi + 1atm) - (1atm)}{\gamma} = \frac{10psi}{\gamma} \rightarrow (10psi)\left(2.31\frac{ft}{psi}\right) = 23.1ft$$

The velocity at the outlet, v_2, is greater than in the reservoir, $v_1 \approx 0; v_2 > v_1$. However, the velocity term remains negligible. Feel free to include and show this to be the case.

$$\frac{v_2^2 - v_1^2}{2g} \approx 0$$

The height differential is the sum of both the static suction lift and the discharge head.

$$\Delta z = z_2 - z_1 = 30ft + 5ft = 35ft$$

The problem states losses are insignificant. Therefore:

$$h_f = 0$$

The head added by the pump is then:

$$h_A = 23.1ft + 35ft = 58.1ft$$

The motor sizing is based on the bhp; therefore, the motor efficiency is not needed. The brake hp depends on the pump efficiency and hydraulic horsepower, whp, which is a function of volume flow rate and head added by the pump. Solve for bhp and select the smallest sufficient motor size:

$$bhp = \frac{whp}{\eta_p} = \frac{Q_{[gpm]}\Delta h_{[ft]}}{3960 \cdot \eta_p} = \frac{(100)(58.1)}{(3960)(.85)} = 1.73hp$$

Answer B

40.25 A $40gpm$ cold water booster pump is located $15ft$ below the top of a storage tank held at atmospheric pressure from which water is supplied. The suction piping is made up of $50ft$ equivalent length of $2in$ schedule 40 steel. The stored water is never warmer than $60°F$. What is the net positive suction head available?

A. $0ft$

B. $16ft$

C. $28ft$

D. $46ft$

Start by looking up net positive suction head available in the Reference Handbook and stating the formula:

$$NPSH_A = h_p + h_z - h_{vpa} - h_f$$

where h_p is the atmospheric pressure at the source reservoir surface, h_z is the height of the fluid column on the suction inlet, h_{vpa} is the vapor pressure at the temperature of the fluid, and h_f is the friction loss from the fluid source to the pump inlet. Note this formula is best suited for ***design*** purposes. After a system is installed and fitted with gauges and sensors, it may be suitable to use the *existing conditions* formula instead. In this case, there is no known pressure gauge on the suction side, therefore the best formula is the one selected. For consistency, all terms should be converted to units of ft.

Convert h_p to units of ft using the rule of thumb conversion factor for water $2.31\frac{ft}{psi}$.

$$h_p = 14.7psi\left(2.31\frac{ft}{psi}\right) = 33.96ft$$

Since the pump is located below the top of the storage tank, h_z has a positive value. The column of fluid exerts pressure on the pump inlet. Note that if the pump were placed above the source, this term would be subtracted.

$$h_z = 15ft$$

Look up the saturation pressure of water at $60°F$ by searching properties of saturated water and using the steam table organized by temperature. The vapor pressure reduces the $NPSH_A$, thus is it subtracted in the formula. Convert units from psi to ft:

$$h_{vpa@T=60°F} = .26psi\left(2.31\frac{ft}{psi}\right) = .6ft$$

For the losses, write the Darcy Equation, find the kinematic viscosity by looking up Properties of Water, find the diameter and velocity in the Steel Pipe Friction Tables, and determine the friction factor from the Moody Diagram. The equivalent length of piping from the source to the pump inlet is given.

$$h_f = \frac{fLv^2}{2gD}$$