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.

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

$$Q = 40gpm$$

$$D = 2.067in\left(\frac{1ft}{12in}\right) = 0.1723ft$$

$$v = 3.82\frac{ft}{s}$$

$$\frac{\epsilon}{D} = \frac{0.0002ft}{0.1732ft} \approx 0.0012$$

$$Re = \frac{vD}{\nu} = \frac{\left(3.82\frac{ft}{s}\right)(0.1723ft)}{1.217 \times 10^{-5}\frac{ft^2}{s}} \approx 54,000 \approx 5.4 \times 10^4$$

$$f = f(Re, \frac{\epsilon}{D}) = 0.025$$

$$h_f = \frac{fLv^2}{2gD} = \frac{(0.025)(50ft)\left(3.82\frac{ft}{s}\right)^2}{2(0.1723ft)\left(32.2\frac{ft}{s^2}\right)} = 1.64ft$$

Calculate the $NPSH_A$:

$$NPSH_A = h_p + h_z - h_{vpa} - h_f = 33.96ft + 15ft - 0.6ft - 1.64ft = 46.7ft$$

Answer D