

46.72 Water is pumped from an open tank by a pump located $15ft$ below the top of the tank's waterline. The pump adds $50ft$ of total head. The discharge pressure is $28psig$. Neglecting losses on the suction side of the pump, what is the velocity of the flowing water?

- A. $5\frac{ft}{s}$
- B. $11\frac{ft}{s}$
- C. $18\frac{ft}{s}$
- D. $47\frac{ft}{s}$

Sketch the reservoir and pump. Consider the reservoir as State 1 and the pump discharge as State 2. Write the modified Bernoulli equation for the total head added by a pump. A useful version may be obtained by starting with the **Mechanical Energy Equation** in section 9.6.4 of the Reference Handbook.

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

The head added by the pump is given as $h_A = 50ft$. The static pressure at the source, State 1, is atmospheric pressure and the static pressure at the pump discharge, State 2, is measured by a gauge as $28psig$. Since the difference in pressure is needed, it is not necessary to convert to absolute pressure terms. Simply subtract and use the conversion factor rule of thumb, $2.31\frac{ft}{psi}$ to convert the units of the static pressure term from psi to ft .

$$\frac{P_2 - P_1}{\gamma} = (28psig - 0psig) \left(2.31\frac{ft}{psi} \right)$$

For the velocity term, the velocity of the water in the reservoir is zero. The velocity at the pump discharge, State 2, is the unknown being sought in this problem.

$$\frac{v_2^2 - v_1^2}{2g} = \frac{v_2^2}{2g}$$

For the elevation term, the pump is $15ft$ below the top of the reservoir, therefore the Δz term will be negative, which aligns with the expectation that *less* work will need to be done by the pump since the source water on the suction side is at a relatively higher elevation.

$$z_2 - z_1 = 0ft - 15ft = -15ft$$

Substitute and solve for the velocity term, then solve for the discharge velocity, v_2 .

$$50ft = (28psig - 0psig) \left(2.31\frac{ft}{psi} \right) + \frac{v_2^2}{2g} - 15ft$$

$$\frac{v_2^2}{2g} = 0.32ft$$

$$v_2^2 = (0.32ft)(2) \left(32.2 \frac{ft}{s^2} \right) = 20.6 \frac{ft^2}{s^2}$$

$$v_2 = \sqrt{20.6 \frac{ft^2}{s^2}} = 4.5 \frac{ft}{s}$$

Answer A

46.73 A boiler produces saturated steam at atmospheric pressure. 20gpm of feedwater enters at 160°F and 14.7psia. What is the boiler horsepower rating?

- A. 270boiler hp
- B. 280boiler hp
- C. 290boiler hp
- D. 300boiler hp

Consider the feedwater entering the boiler as State 1 and the steam leaving the boiler as State 2. To find the enthalpy at State 1, recall from Thermodynamics that the change in enthalpy is the product of the specific heat capacity and the change in temperature. State 1 is compressed water which has been cooled sensibly past the saturation temperature of 212°F. Use the properties of **Saturated Water and Steam** table to obtain the enthalpy for a saturated liquid at 14.7psia, and determine h_1 .

$$P_1 = 14.7psia$$

$$T_1 = 160^\circ F$$

$$\Delta h = c_p \Delta T$$

$$h_{sat} - h_1 = c_p (T_{sat} - T_1)$$

$$h_1 = h_{sat} - c_p (T_{sat} - T_1) = 180.18 \frac{Btu}{lb} - \left(1 \frac{Btu}{lb \cdot ^\circ F} \right) (212^\circ F - 160^\circ F) = 128.2 \frac{Btu}{lb}$$

Use the properties of **Saturated Water and Steam** table again to obtain the enthalpy for State 2.

$$P_2 = 14.7psia \text{ (saturated)}$$

$$h_2 = 1150.25 \frac{Btu}{lb}$$