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

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

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. $270 boiler\ hp$

B. $280 boiler\ hp$

C. $290 boiler\ hp$

D. $300 boiler\ hp$

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 termperature. 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.

$$P_1 = 14.7psia$$

$$T_1 = 160°F$$

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

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

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

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

$$P_2 = 14.7psia\ (saturated)$$

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

Find the mass flow rate in $\frac{lb}{hr}$. Use the Properties of Water table to obtain the density at State 1.

$$\dot{m} = \rho Q$$

$$\dot{m} = \left(61\frac{lb}{ft^3}\right)\left(20\frac{gal}{min}\right)\left(\frac{1ft^3}{7.48gal}\right)\left(\frac{60min}{1hr}\right) = 9786\frac{lb}{hr}$$

Determine the heat added by the boiler. Find the converstion factor from $\frac{Btu}{hr}$ to *boiler hp* in the Measurement Relationships table.

$$\dot{Q} = \dot{m}\Delta h$$

$$\dot{Q} = \frac{\left(9786\frac{lb}{hr}\right)\left(1150.25\frac{Btu}{lb} - 128.2\frac{Btu}{lb}\right)}{\left(33,470\frac{Btu}{hp\cdot boiler\,hp}\right)} = 299 boiler\,hp$$

Answer D

46.74 A three-phase AC generator supplies $700A$ at $480V$ with a power factor of 0.8 and an efficiency of 90%. The engine speed is $3600rpm$. What is the torque needed to drive the generator?

A. $610ft\cdot lb_f$

B. $750ft\cdot lb_f$

C. $820ft\cdot lb_f$

D. $1010ft\cdot lb_f$

Adapt the last formula in the table Power for Different Motor Phases for a generator. Normally the formula is used to calculate the output horsepower from a motor that receives a certain input of electricity, hence the efficiency is placed in the numerator to account for the motor's losses. However, in this case the generator receives horsepower as its input and produces electricity as its output, therefore it is appropriate to *divide* by the efficiency to account for the generator's losses.

$$P_{[hp]} = \frac{\sqrt{3}IV\,(pf)}{746\eta}$$

$$P = \frac{\sqrt{3}\,(700A)\,(480V)\,(0.8)}{(746)\,(0.9)} = 693.4hp$$

On the same page in reference handbook under Torques, use the formula relating the torque to the horsepower and rotational speed. Provided the speed is in rpm, the torque will be in $ft\cdot lb_f$. No additional unit conversion is neeeded. Calculate the torque.

$$T = 5250\left(\frac{hp}{rpm}\right)$$