$$\dot{Q}_{total} = (200 boiler\ hp)\left(33,470 \frac{Btu}{hr \cdot boiler\ hp}\right) = 6,694,000 \frac{Btu}{hr}$$

Express the total heating as the sum of the sensible heating of water to the boiling point and the latent heat of vaporization. Factor out and solve for the mass flow rate. Convert to the volume flow rate in gpm.

$$\dot{Q}_{total} = \dot{Q}_S + \dot{Q}_L = \dot{m} c_p \Delta T + \dot{m} \Delta h$$

$$\dot{Q}_{total} = \dot{m} c_p (T_{sat} - T_1) + \dot{m} h_{fg} = \dot{m}\left[c_p (T_{sat} - T_1) + h_{fg}\right]$$

$$\dot{m} = \frac{\dot{Q}_{total}}{c_p (T_{sat} - T_1) + h_{fg}}$$

$$\dot{m} = \frac{6,694,000 \frac{Btu}{hr}}{\left(1 \frac{Btu}{lb \cdot {}^\circ F}\right)(240^\circ F - 50^\circ F) + 952 \frac{Btu}{lb}} = 5861.6 \frac{lb}{hr}$$

$$Q = \left(5861.6 \frac{lb}{hr}\right)\left(\frac{1 gal}{8.34 lb}\right)\left(\frac{1 hr}{60 min}\right) = 11.7 gpm$$

Answer A

47.64 A centrifugal pump rotating at $3600 rpm$ delivers $150 gpm$ of water against $50 ft$ of head. The pump efficiency is 78% and the motor efficiency is 88%. What is the annual cost to run the pump Monday-Friday 6am-6pm at an average electricity rate of \$0.12/kWh?

A. \$600

B. \$680

C. \$770

D. \$1080

Calculate the Water Horsepower delivered by the pump. To use the formula below, the volume flow rate, Q, must be in gpm and the head, h, must be in ft. The standard density of water is embedded in the formula, so it is important to apply this formula only when dealing with water.

$$whp = \frac{Q \Delta h}{3960} = \frac{(150)(50)}{3960} = 1.893 hp$$

The input power to the motor driving the pump must account for both the pump efficiency and the motor efficiency, and be converted to KW.

$$\dot{W} = \frac{whp}{\eta_m \eta_p} = \frac{1.893 hp}{(0.78)(0.88)}\left(\frac{0.7457 KW}{1 hp}\right) = 2.057 KW$$

Determine the number of annual run hours based on hours per day and days per week for one year.

$$\left(\frac{12hr}{day}\right)\left(\frac{5days}{wk}\right)(52wks) = 3120hrs$$

Calculate the annual running cost based on demand, annual run hours, and the cost of electricity.

$$Cost = (2.057KW)(3120hrs)\left(\frac{\$0.12}{kWhr}\right) = \$770$$

Answer C

47.65 A continuously running $460V$ 3-phase motor draws $23A$. The motor has a power factor of 0.91 and an efficiency of 88% and drives a centrifugal pump with an efficiency of 77%. The pump supplies $300gpm$ of water against $200ft$ of head. To save energy and avoid cost, operators determine that the pump may be turned off for $8hours$ per day with no impact to the operation and no change to the operating parameters while in use. Electricity costs $\$0.15/kWh$ for consumption and $\$15/KW$ for peak demand. What are the expected annual savings for this initiative?

A. \$5400

B. \$6200

C. \$7100

D. \$7300

There will be no changes in the demand charge because the operating parameters are the same when the pump is in use. In other words, the maximum power draw is unchanged. Only the reduced electrical consumption will drive savings.

Calculate the input power demand to run the motor using the fourth formula on the right side of the table under Power for Different Motor Phases. There is no need to work backwards from water horsepower and apply the pump and motor efficiencies since the current, voltage, and power factor are all given.

$$P_{KW} = \frac{\sqrt{3}IV\,(pf)}{1000} = \frac{\sqrt{3}\,(23)\,(460)\,(0.91)}{1000} = 16.67KW$$

Multiply the electrical demand by time and the unit rate for electricy to determine the annual savings.

$$Savings = (16.67KW)\left(\frac{8hr}{day}\right)(365days)\left(\frac{\$0.15}{kWh}\right) = \$7304$$

Answer D