$$\frac{\epsilon}{D} = 0.0003$$

$$f = f\left(Re, \frac{\epsilon}{D}\right) \approx 0.021$$

Use the Steel Pipe Friction Tables to obtain the velocity and exact diameter based on the gpm and nominal pipe size.

$$v = 5.77\frac{ft}{s}$$

$$D = 7.981in$$

Substitute into the Darcy Equation and solve. Keep the final result with units of ft.

$$h_f = \frac{(0.021)\,(500ft)\left(5.77\frac{ft}{s}\right)^2}{2\left(\frac{7.981in}{12\frac{in}{ft}}\right)\left(32.2\frac{ft}{s^2}\right)} = 8.2ft$$

Answer D

47.63 $50°F$ water enters a steam boiler with a capacity 200 boiler horsepower. The boiler has an operating pressure of $10psig$. What is the required flow rate of feedwater at maximum capacity?

A. $12gpm$

B. $180gpm$

C. $290gpm$

D. $700gpm$

The feedwater must first be heated sensibly from its initial temperature, $T_1 = 50°F$, to the boiling point. Use the table Properties of Saturated Water and Steam (Pressure) to obtain the saturation temperature i.e. boiling point of water at the operating pressure. Also obtain the latent heat of vaporization, h_{fg}, from the same line in the steam table.

$$P = 10psig + 14.7psi \approx 25psia$$

$$T_{sat} = 240°F$$

$$h_{fg} = 952\frac{Btu}{lb}$$

Use Measurement Relationships to convert the heating capacity of the boiler from *boiler hp* to $\frac{Btu}{hr}$.

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

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.

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