32.1 **$10gpm$ of water is heated from $60°F$ to $125°F$ in a feedwater heater by steam. The steam side of the feedwater heater operates at $5psig$. Steam enters at $350°F$ and leaves as a saturated mixture with 95% quality. What is the required mass flow rate of steam?**

A. $5\frac{lb}{min}$

B. $50\frac{lb}{min}$

C. $120\frac{lb}{min}$

D. $360\frac{lb}{min}$

A feedwater heater is simply a steam heat exchanger that makes hot water. The heat added to the water comes entirely from the heat given up by the steam, minus any losses. This problem statement makes no mention of losses or efficiency, so losses may be neglected. Start by establishing the energy balance between the steam and the water. Then use the sensible heating rule of thumb to calculate how much heat is added to the water.

$$\dot{Q}_{steam} = \dot{Q}_{water} = 500gpm\Delta T = 500\,(10)\,(125-60) = 325,000\frac{Btu}{hr}$$

The steam side of the energy equation can be expressed as:

$$\dot{Q}_{steam} = \dot{m}\,(h_1 - h_2)$$

where State 1 corresponds to the entering condition, State 2 corresponds to the leaving condition, and the mass flow rate is unknown.

Look up the superheated steam table by searching Properties of Superheated Steam in the Reference Handbook and find the enthalpy for the entering steam condition. Note $5psig \approx 20psia$. If you were to check the saturated steam table first by searching Properties of Saturated Water by pressure, you would observe the saturation temperature for $20psia$ steam is $\sim 228°F$. The entering temperature $350°F > 228°F$, confirming that the entering steam is superheated.

$$P_1 = 20psia$$

$$T_1 = 350°F$$

$$h_1 = 1215\frac{Btu}{lb}$$

The question states that the exiting condition is a saturated mixture, so use the Properties of Saturated Water table again. The pressure is implied to be constant. Use the quality to calculate the enthalpy for State 2:

$$P_2 = 20psia$$

$$\chi_2 = 0.95$$

$$h_{fg} = 960\frac{Btu}{lb}$$

$$h_f = 196\frac{Btu}{lb}$$

$$h_2 = h_f + \chi_2 h_{fg} = 196\frac{Btu}{lb} + (.95)\left(960\frac{Btu}{lb}\right) = 1108\frac{Btu}{lb}$$

Rearrange the equation for the steam energy for the unknown mass flow rate, substitute, solve, and change units to $\frac{lb}{min}$:

$$q_s = \dot{m}\left(h_1 - h_2\right) \rightarrow \dot{m} = \frac{q_{steam}}{(h_1 - h_2)}$$

$$\dot{m} = \frac{325,000\frac{Btu}{hr}}{\left(1215\frac{Btu}{lb} - 1108\frac{Btu}{lb}\right)} = 3037\frac{lb}{hr}\left(\frac{1hr}{60min}\right) = 50.6\frac{lb}{min}$$

Answer B