

42.3 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.

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

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

$$q_{steam} = \dot{m}(h_1 - h_2)$$

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.

$$P_1 = 20psia$$

$$T_1 = 350^\circ F$$

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

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:

$$P_2 = 20psia$$

$$\chi_2 = 0.95$$

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

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

$$h_2 = h_f + \chi_2 h_{fg} = 196 \frac{\text{Btu}}{\text{lb}} + (0.95) \left(960 \frac{\text{Btu}}{\text{lb}} \right) = 1108 \frac{\text{Btu}}{\text{lb}}$$

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

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

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

Answer B

42.4 A skylight is comprised of two layers of $\frac{1}{2}$ inch thick laminated glass with a 1in air gap $\left(R = 0.5 \frac{\text{hr} \cdot \text{ft}^2 \cdot ^\circ \text{F}}{\text{Btu}} \right)$ in between. The inside and outside film coefficients are $1.5 \frac{\text{Btu}}{\text{hr} \cdot \text{ft}^2 \cdot ^\circ \text{F}}$ and $2.0 \frac{\text{Btu}}{\text{hr} \cdot \text{ft}^2 \cdot ^\circ \text{F}}$, respectively. The outside design temperature is 10°F and the inside conditions are 70°F with 60% relative humidity. What is the maximum allowable thermal conductivity of the glass to prevent condensate from forming on the inside of the skylight?

- A. $0.04 \frac{\text{Btu}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}$
- B. $0.08 \frac{\text{Btu}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}$
- C. $0.2 \frac{\text{Btu}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}$
- D. $0.9 \frac{\text{Btu}}{\text{hr} \cdot \text{ft} \cdot ^\circ \text{F}}$

The inside conditions are known. Determine the **dew point** temperature using the **psychrometric chart**. This is the minimum temperature on the inside surface of the glass before which condensate will form.

$$T_{i,db} = 70^\circ \text{F}$$

$$\phi_i = 60\%$$

$$T_{i,dp} = 55.6^\circ \text{F}$$