47.41 Saturated steam at $300psia$ enters a closed feedwater heater and heats entering water with a temperature of $60°F$. The steam leaves as a saturated liquid. If the mass flow rate of water is 10 times the mass flow rate of steam, what is the exit temperature of the water?

A. $99°F$

B. $101°F$

C. $139°F$

D. $141°F$

Assuming 100% efficiency, all of the heat provided by the steam is added to the water. Set the heat removed from the steam equal to the heat gained by the water.

$$\dot{Q}_{steam} = \dot{Q}_{water}$$

Write an expression for the steam based on mass flow rate and the change in enthalpy, and express the heat gain by the water using mass flow rate, specific heat capacity, and change in temperature.

$$\dot{m}_{steam}\Delta h = \dot{m}_{water}c_p\Delta T$$

Since the mass flow rate of water is 10 times the mass flow rate of steam, substitute for the mass flow rate of water, then cancel $\dot{m}_{steam}$ on both sides.

$$\dot{m}_{water} = 10\dot{m}_{steam}$$

$$\dot{m}_{steam}\Delta h = 10\dot{m}_{steam}c_p\Delta T$$

$$\Delta h = 10c_p\Delta T$$

Solve for ΔT. Use the Properties of Saturated Water and Steam table by pressure to obtain the change in enthalpy for $300psia$ steam. The steam enters as saturated steam and therefore has enthalpy h_g, and leaves as saturated liquid and therefore has enthalpy h_f. For convenience, recall that the change in enthalpy is provided in the table directly, and $h_{fg} = h_g - h_f$.

$$\Delta T = \frac{\Delta h}{10c_p} = \frac{h_g - h_f}{10c_p} = \frac{h_{fg}}{10c_p} = \frac{809.42\frac{Btu}{lb}}{10\left(1\frac{Btu}{lb\cdot°F}\right)} = 80.9°F$$

Expand the water ΔT and solve for the leaving water temperature, T_2.

$$\Delta T = T_2 - T_1$$

$$T_2 = T_1 + \Delta T$$

$$T_2 = 60°F + 80.9°F = 140.9°F$$

Answer D

47.42 An exterior wall is constructed from $\frac{5}{8}in$ plaster board $\left(R = 0.56\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu}\right)$, $3.5in$ batt insulation ($R = 13\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu}$), and $3.5in$ brick ($k = 6\frac{Btu\cdot in}{hr\cdot ft^2\cdot{}^\circ F}$). The inside surface of the plasterboard is maintained at $72°F$. The outside film coefficient is $1.5\frac{Btu}{hr\cdot ft^2\cdot{}^\circ F}$ and the outside temperature is $20°F$. What is the temperature at the interface of the brick and the insulation?

A. $24°F$

B. $36°F$

C. $56°F$

D. $68°F$

Find the total resistance for the Composite Wall, accouting for all resistances in series including the plasterboard, insulation, brick, and outside film coefficient. Note the inside surface is maintained at a specific temperature, so there is no need to account for an inside film coefficient. Make sure the units for each term are the same before adding.

$$R_{total} = R_{plasterboard} + R_{insulation} + \frac{L_{brick}}{k_{brick}} + \frac{1}{h_o}$$

$$R_{total} = 0.56\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu} + 13\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu} + \frac{3.5in}{6\frac{Btu\cdot in}{hr\cdot ft^2\cdot{}^\circ F}} + \frac{1}{1.5\frac{Btu}{hr\cdot ft^2\cdot{}^\circ F}} = 14.8\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu}$$

Write an expression for the total heat flux through the wall. The total heat transfer, $\dot{Q}$, cannot be determined without the area of the wall being known, but the heat transfer per unit area i.e. heat flux, $\dot{q}$, can be found.

$$\dot{Q} = UA\Delta T$$

$$\frac{\dot{Q}}{A} = \dot{q} = U\Delta T$$

The overall heat transfer coefficient, U, is the inverse of the total resistance, R_{total}. $U = \frac{1}{R_t}$. Express heat flux in terms of total resistance. Substitute and solve.

$$\dot{q} = \frac{\Delta T}{R_t} = \frac{72°F - 20°F}{14.8\frac{hr\cdot ft^2\cdot{}^\circ F}{Btu}} = 3.5\frac{Btu}{hr\cdot ft^2}$$

The heat flux is the rate at which heat is conducted through the entire composite wall based on the total resistance of the wall. However, heat travels quickly through layers with minimal insulating properties and slowly through good insulators. Therefore, the temperature gradient throughout the composite wall is not uniform. To find the temperature at the interface of any two layers of the wall, find the resistance of all layers on one side of the interface. In this case, consider