31.23 **$200°F$ water enters an open feedwater heater operating at $100psia$ and is heated by $100psia$,$400°F$ steam. The output from the feedwater heater is saturated liquid. Assuming steady state operation, what percentage of the total flow comes from the $200°F$ water?**

A. 4%

B. 12%

C. 88%

D. 96%

Let the $200°F$ water be considered State 1, the $400°F$ steam be considered State 2, and the exiting saturated liquid be considered State 3.

For State 1, using the Properties of Saturated Water and Steam table by pressure, notice the temperature, T_1, is less than the saturation temperature, T_{sat}, for $P_1 = 100psia$.

$$P_1 = 100psia$$

$$T_1 = 200°F$$

$$T_{sat@100psia} = 327.8°F$$

$$T_1 < T_{sat}$$

Therefore, the water at State 1 is a compressed liquid. To find the enthalpy, h_1, use the specific heat capacity and temperature differential.

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

$$h_{sat} - h_1 = c_p \left(T_{sat} - T_1\right)$$

$$h_1 = h_{sat} - c_p \left(T_{sat} - T_1\right) = 298.5\frac{Btu}{lb} - \left(1\frac{Btu}{lb°F}\right)(327.8°F - 200°F) = 170.7\frac{Btu}{lb}$$

For State 2, look up the enthalpy, h_2, using the Properties of Superheated Steam table.

$$P_2 = 100psia$$

$$T_2 = 400°F$$

$$h_2 = 1228.2\frac{Btu}{lb}$$

For State 3, the exit condition is saturated liquid. Use the Properties of Saturated Water and Steam table again to specify the enthalpy at State 3, h_3.

$$P_3 = 100psia$$

$$T_3 = T_{sat@100psia} = 327.8°F$$

$$h_3 = 298.5\frac{Btu}{lb}$$

Write the mass balance for a Steady-Flow System. For simplicity, let the mass flow rate for State 3, $\dot{m}_3$, equal $1\frac{lb}{hr}$. Write an expression for $\dot{m}_1$ to be used in substitution in the next step.

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

$$\dot{m}_3 = 1\frac{lb}{hr}$$

$$\dot{m}_1 = 1\frac{lb}{hr} - \dot{m}_2$$

Write the energy balance. Substitute for $\dot{m}_1$. Solve for $\dot{m}_2$. Plug back into the expression above to solve for $\dot{m}_1$.

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

$$\dot{m}_1\left(170.7\frac{Btu}{lb}\right) + \dot{m}_2\left(1228.2\frac{Btu}{lb}\right) = \dot{m}_3\left(298.5\frac{Btu}{lb}\right)$$

$$\left(1\frac{lb}{hr} - \dot{m}_2\right)\left(170.7\frac{Btu}{lb}\right) + \dot{m}_2\left(1228.2\frac{Btu}{lb}\right) = \left(1\frac{lb}{hr}\right)\left(298.5\frac{Btu}{lb}\right)$$

$$170.7\frac{Btu}{hr} - \dot{m}_2\left(170.7\frac{Btu}{lb}\right) + \dot{m}_2\left(1228.2\frac{Btu}{lb}\right) = 298.5\frac{Btu}{hr}$$

$$\dot{m}_2\left(1057.5\frac{Btu}{lb}\right) = 127.8\frac{Btu}{hr}$$

$$\dot{m}_2 = 0.121\frac{lb}{hr}$$

$$\dot{m}_1 = 1\frac{lb}{hr} - \dot{m}_2 = 1\frac{lb}{hr} - 0.121\frac{lb}{hr} = 0.879\frac{lb}{hr}$$

Since $\dot{m}_3$ was set equal to $1\frac{lb}{hr}$, the mass flow rates already represent the respective fractions of each stream entering the feedwater heater, as shown below.

$$\frac{\dot{m}_1}{\dot{m}_3} = \frac{0.879\frac{lb}{hr}}{1\frac{lb}{hr}} = 0.879$$

Answer C