

34.22 $620 \frac{lb}{hr}$ of $900^\circ F$, $500psia$ steam enters the first turbine in a Rankine cycle using regeneration. $80 \frac{lb}{hr}$ of steam is extracted from the high pressure turbine at $100psia$. The pressure at the low pressure turbine exit is $14.7psia$. Water leaving the condensate pump is $250^\circ F$. Assuming isentropic expansion in the turbines, what is the quality of the saturated mixture leaving the open feedwater heater?

- A. 0.06
- B. 0.13
- C. 0.34
- D. 0.86

Refer to the schematic for a **Rankine Cycle With Regeneration**. Make a table to organize the given information and to populate new values as they are discovered.

Reason that the extracted mass flow rate to provide heating in the open feedwater heater applies to State 2, and the remainder of the mass flow, $540 \frac{lb}{hr}$, continues through the low pressure turbine, condenser, and condensate pump, thereby applying to States 3/4/5/6. For State 7, the mass flow rate has recombined to the full $620 \frac{lb}{hr}$.

Use the properties of **Superheated Steam** to obtain the enthalpy and entropy for State 1. Since the expansion is isentropic, the entropy at State 2 has the same value as the entropy at State 1.

The pressure at the point of extraction, State 2, is given. Use the steam table again along with the entropy at State 2 to confirm the steam is still superheated, albeit at a lower pressure, and to obtain the enthalpy at State 2. Interpolate and/or estimate as necessary.

For State 6, the temperature is known. The pressure is implied by the use of an *open* feedwater heater. For the system to operate properly, the condensate pump must be configured to raise the pressure after the condenser to match the pressure of the extracted steam, $100psia$. Therefore, State 6 is fully defined. Use the properties of **Saturated Water and Steam** to find the enthalpy at State 6. Since $T_6 < T_{sat@100psia}$, the water is subcooled. Calculate h_6 using the temperature difference.

$$T_{sat@100psia} = 327.8^\circ F$$

$$h_{sat} = h_{f@100psia} = 298.1 \frac{Btu}{lb}$$

$$h_{sat} - h_6 = c_p (T_{sat} - T_6)$$

$$h_6 = h_{sat} - c_p (T_{sat} - T_6) = 298.1 \frac{Btu}{lb} - \left(1 \frac{Btu}{lb^\circ F} \right) (327.8^\circ F - 250^\circ F) = 220.7 \frac{Btu}{lb}$$

State	Temp [$^{\circ}F$]	Pressure [$psia$]	Enthalpy [$\frac{Btu}{lb}$]	Entropy [$\frac{Btu}{lb^{\circ}F}$]	Mass Flow Rate [$\frac{lb}{hr}$]
1	900	500	1466.9	1.699	620
2		100	1266	1.699	80
3					540
4					540
5					540
6	250	100	220.7		540
7		100	h_7		620
8		500			620

Determine the enthalpy at State 7 by performing a mixing calculation of the two streams entering the open feedwater heater, States 2 & 6.

$$h_7 = \frac{\dot{m}_2 h_2 + \dot{m}_6 h_6}{\dot{m}_7} = \frac{(80 \frac{lb}{hr})(1266 \frac{Btu}{lb}) + (540 \frac{lb}{hr})(220.7 \frac{Btu}{lb})}{620 \frac{Btu}{lb}} = 355.6 \frac{Btu}{lb}$$

Calculate the quality at State 7. Use the **Saturated Water and Steam** table again to collect enthalpy values at $P_7 = 100psia$.

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

$$h_{fg} = 889 \frac{Btu}{lb}$$

$$\chi_7 = \frac{h_7 - h_f}{h_{fg}} = \frac{355.6 \frac{Btu}{lb} - 298.5 \frac{Btu}{lb}}{889 \frac{Btu}{lb}} = 0.064$$

Answer A