

37.76 The net power output from a Rankine cycle with an isentropic turbine is $200MW$. Steam enters the turbine at $1000^{\circ}F$ and $1400psia$. The condenser pressure is $10psia$. What is the mass flow rate of steam through the cycle?

- A. $5 \times 10^5 \frac{lb}{hr}$
- B. $1.5 \times 10^6 \frac{lb}{hr}$
- C. $3.3 \times 10^6 \frac{lb}{hr}$
- D. $4.3 \times 10^6 \frac{lb}{hr}$

Consider the superheated steam entering the turbine as State 3 and the saturated mixture exiting the turbine as State 4. State 3 is fully defined. Use the properties of **Superheated Steam** table to obtain the enthalpy and entropy for State 3.

$$P_3 = 1400psia$$

$$T_3 = 1000^{\circ}F$$

$$h_3 = 1494 \frac{Btu}{lb}$$

$$s_3 = 1.61 \frac{Btu}{lb^{\circ}R}$$

Since the turbine is isentropic, the entropy at State 4 is the same as State 3. Obtain entropy and enthalpy values from the properties of **Saturated Water and Steam** table. The condenser pressure is the same as the turbine exit pressure. Use the entropy to determine the quality at State 4, then use the quality to determine the enthalpy at State 4.

$$P_4 = 10psia$$

$$s_4 = s_3 = 1.61 \frac{Btu}{lb^{\circ}R}$$

$$s_f = 0.2836 \frac{Btu}{lb^{\circ}R}$$

$$s_{fg} = 1.504 \frac{Btu}{lb^{\circ}R}$$

$$\chi_4 = \frac{s_4 - s_f}{s_{fg}} = \frac{1.61 \frac{Btu}{lb^{\circ}R} - 0.2836 \frac{Btu}{lb^{\circ}R}}{1.504 \frac{Btu}{lb^{\circ}R}} = 0.882$$

$$h_f = 161.24 \frac{Btu}{lb}$$

$$h_{fg} = 981.82 \frac{Btu}{lb}$$

$$h_4 = h_f + \chi_4 h_{fg} = 161.24 \frac{Btu}{lb} + (0.882) \left(981.82 \frac{Btu}{lb} \right) = 1027.1 \frac{Btu}{lb}$$

Ignoring the work added to the cycle by the pump, the net work is entirely due to the work produced by the turbine. Set the output work equal to the product of mass flow rate and the change in enthalpy through the turbine. Solve for mass flow rate, and convert units to $\frac{lb}{hr}$.

$$\dot{W}_{net} \approx \dot{W}_{out,turbine} = \dot{m} (h_3 - h_4)$$

$$\dot{m} = \frac{(200MW) \left(\frac{1000KW}{1MW} \right) \left(3412 \frac{Btu}{hr \cdot KW} \right)}{\left(1494 \frac{Btu}{lb} - 1027.1 \frac{Btu}{lb} \right)} = 1.46 \times 10^6 \frac{lb}{hr}$$

Answer B