34.23 $100,000\frac{lb}{hr}$ **of** $800°F$**,** $400psia$ **steam is supplied from a boiler within a Rankine cycle. The condenser pressure is** $10psia$**. The turbine is 80% efficient. What is the power output from the turbine?**

A. $6MW$

B. $8MW$

C. $10MW$

D. $12MW$

Refer to the Rankine Cycle schematic and start by analyzing State 3, the superheated steam exiting the boiler and entering the turbine. State 3 is fully defined. Use the properties of Superheated Steam table to obtain the enthalpy and entropy.

$$P_3 = 400psia$$

$$T_3 = 800°F$$

$$h_3 = 1416.9\frac{Btu}{lb}$$

$$s_3 = 1.685\frac{Btu}{lb \cdot R}$$

The steam exiting the turbine at State 4 is a saturated mixture. Set the entropy at State 4 equal to the entropy at State 3 to specify the *ideal* State 4 based on a hypothetically isentropic expansion process. Use the properties of Saturated Water and Steam table by pressure to look up the entropy and enthalpy values needed to calculate the quality and enthalpy.

$$P_4 = 10psia$$

$$s_4 = s_3 = 1.685\frac{Btu}{lb \cdot R}$$

$$s_f = 0.2836\frac{Btu}{lb \cdot R}$$

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

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

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

$$\chi_4 = \frac{s_4 - s_f}{s_{fg}} = \frac{1.685\frac{Btu}{lb \cdot R} - 1.504\frac{Btu}{lb \cdot R}}{1.504\frac{Btu}{lb \cdot R}} = 0.932$$

$$h_4 = h_f + \chi_4 h_{fg} = 161.24\frac{Btu}{lb} + (0.932)\left(981.82\frac{Btu}{lb}\right) = 1076.1\frac{Btu}{lb}$$

Determine the *actual* enthalpy at State 4 by relaxing the assumption that $s_4 = s_3$ and applying the turbine efficiency.

$$\eta = \frac{h_3 - h_4^{'}}{h_3 - h_4}$$

$$h_4^{'} = h_3 - \eta\,(h_3 - h_4)$$

$$h_4^{'} = 1416.9\frac{Btu}{lb} - (0.8)\left(1416.9\frac{Btu}{lb} - 1076.1\frac{Btu}{lb}\right) = 1144.2\frac{Btu}{lb}$$

Calculate the work produced by the turbine using the mass flow rate and change in enthalpy between State 3 and State 4 *actual*. Convert units to MW.

$$\dot{W}_{out} = \dot{m}\left(h_3 - h_4^{'}\right)$$

$$\dot{W}_{out} = \frac{\left(100,000\frac{lb}{hr}\right)\left(1416.9\frac{Btu}{lb} - 1144.2\frac{Btu}{lb}\right)}{\left(3412\frac{Btu}{hr\cdot KW}\right)\left(\frac{1000KW}{1MW}\right)} = 7.99MW$$

Answer B