34.19 $250\frac{lb}{hr}$ **of steam enters a turbine at** $900°F$ **and** $500psia$ **and exits at** $8psia$**. The turbine has an isentropic efficiency of 80% and a mechanical efficiency of 90%. What is the power produced by the turbine?**

A. $21KW$

B. $23KW$

C. $26KW$

D. $29KW$

Consider the entering superheated steam as State 1 and the exiting saturated steam as State 2. State 1 is full defined. Use the properties of Superheated Steam table to obtain the enthalpy and entropy for State 1.

$$P_1 = 500psia$$

$$T_1 = 900°F$$

$$h_1 = 1466.9\frac{Btu}{lb}$$

$$s_1 = 1.699\frac{Btu}{lb \cdot R}$$

Use the properties of Saturated Water and Steam table to obtain enthalpy and entropy values for saturated steam at P_2. Inititally assuming the expansion process is isentropic i.e. 100% efficient, calculate the *ideal* quality and enthalpy at State 2.

$$P_2 = 8psia$$

$$h_f = 150.85\frac{Btu}{lb}$$

$$h_{fg} = 988.15\frac{Btu}{lb}$$

$$s_f = 0.2676\frac{Btu}{lb \cdot R}$$

$$s_{fg} = 1.538\frac{Btu}{lb \cdot R}$$

$$s_2 = s_1 = 1.699\frac{Btu}{lb \cdot R}$$

$$\chi_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.699\frac{Btu}{lb \cdot R} - 0.2676\frac{Btu}{lb \cdot R}}{1.538\frac{Btu}{lb \cdot R}} = 0.93$$

$$h_2 = h_f - \chi_2 h_{fg} = 150.85\frac{Btu}{lb} + 0.93\left(988.15\frac{Btu}{lb}\right) = 1070.5\frac{Btu}{lb}$$

Apply the isentropic efficiency and the ideal enthalpy at State 2 to determine the *actual* enthalpy at State 2.

$$\eta_s = \frac{h_1 - h_2^{'}}{h_1 - h_2}$$

$$h_2^{'} = h_1 - \eta_s\left(h_1 - h_2\right)$$

$$h_2^{'} = 1466.9\frac{Btu}{lb} - 0.8\left(1466.9\frac{Btu}{lb} - 1070.5\frac{Btu}{lb}\right) = 1149.8\frac{Btu}{lb}$$

Finally, apply the mechanical efficiency and mass flow rate to determine the power produced by the turbine. Convert units to KW.

$$\dot{W}_{out} = \eta_m \dot{m}\left(h_1 - h_2^{'}\right)$$

$$\dot{W}_{out} = (0.9)\left(250\frac{lb}{hr}\right)\left(1466.9\frac{Btu}{lb} - 1149.8\frac{Btu}{lb}\right) = 71,347\frac{Btu}{hr}$$

$$\dot{W}_{out} = \left(71,347\frac{Btu}{hr}\right)\left(\frac{1KW}{3412\frac{Btu}{hr}}\right) = 20.9KW$$

Answer A