46.70 Steam enters a 75% efficient turbine at a pressure of $800psia$ and a temperature of $700°F$ and exits at atmospheric pressure. What is the specific work produced by the turbine?

A. $250\frac{Btu}{lb}$

B. $330\frac{Btu}{lb}$

C. $1010\frac{Btu}{lb}$

D. $1190\frac{Btu}{lb}$

Consider the entering steam as State 1 and the exiting steam as State 2. Use the properties of Superheated Steam tables to obtain the enthalpy and entropy at State 1.

$$P_1 = 800psia$$

$$T_1 = 700°F$$

$$h_1 = 1338.4\frac{Btu}{lb}$$

$$s_1 = 1.548\frac{Btu}{lb \cdot R}$$

Find the *ideal* entropy and enthalpy at State 2 by imagining the turbine was isentropic i.e. 100% efficient. Use the properties of Saturated Water and Steam table to look up entropy values to determine the ideal quality for State 2, and use the quality to find the ideal enthalpy at State 2.

$$s_2 = s_1 = 1.548\frac{Btu}{lb \cdot R}$$

$$P_2 = 14.7psia$$

$$s_f = 0.3122\frac{Btu}{lb \cdot R}$$

$$s_{fg} = 1.4443\frac{Btu}{lb \cdot R}$$

$$h_f = 180.18\frac{Btu}{lb}$$

$$h_{fg} = 970.07\frac{Btu}{lb}$$

$$\chi_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.548\frac{Btu}{lb \cdot R} - 0.3122\frac{Btu}{lb \cdot R}}{1.4443\frac{Btu}{lb \cdot R}} = 0.856$$

$$h_2 = h_f + \chi_2 h_{fg} = 180.18\frac{Btu}{lb} + (0.856)\left(970.07\frac{Btu}{lb}\right) = 1010.2\frac{Btu}{lb}$$

Determine the *actual* change in enthalpy by applying the efficiency. This is the specific work produced by the turbine.

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

$$w = h_1 - h_2^{'} = \eta\,(h_1 - h_2) = 0.75\left(1338.4\frac{Btu}{lb} - 1010.2\frac{Btu}{lb}\right) = 246.2\frac{Btu}{lb}$$

Answer A

46.71 The overall efficiency of a gas turbine combined cycle is 55%. The gas turbine cycle standing alone has an efficiency of 40%. What is the efficiency of the Rankine cycle?

A. 9%

B. 25%

C. 75%

D. 91%

Refer to the Brayton Cycle for the gas turbine standing alone. Refer to the Combined Cycle when waste heat recovery is included. The heat recovery section can be modeled as a Rankine Cycle. The product of the *losses* from the Brayton Cycle and the *losses* from the Rankine Cycle equals the *losses* from the Combined Cycle. Solve for the efficiency of the Rankine Cycle.

$$(1 - \eta_{Brayton})\,(1 - \eta_{Rankine}) = (1 - \eta_{Combined})$$

$$(1 - 0.4)\,(1 - \eta_{Rankine}) = (1 - 0.55)$$

$$1 - \eta_{Rankine} = \left(\frac{0.45}{0.6}\right) = 0.75$$

$$\eta_{Rankine} = 0.25$$

Another way to conceptualize this scenario is to notice that since the standalone Brayton Cycle has 40% efficiency, that implies 60% losses. Reason that to increase the overall efficiency of the combined cycle to from 40% to 55%, 15% of the wasted 60% must be converted into useful work, which is one fourth or 25% of the waste energy from the Brayton Cycle which is heat input to the Rankine Cycle.

Answer B