34.8 In a Rankine cycle, steam enters a turbine at $600 psia$ and $700°F$. After isentropic expansion, the resulting saturated mixture goes through a condenser that operates at $5 psia$. Saturated liquid leaves the condenser. How much heat per unit mass is removed by the condenser?

A. $380 \frac{Btu}{lb}$

B. $840 \frac{Btu}{lb}$

C. $1110 \frac{Btu}{lb}$

D. $1220 \frac{Btu}{lb}$

In alignment with the Rankine Cycle diagram provided in the reference handbook, consider the steam entering the turbine as State 3, the saturated mixture leaving the turbine and entering the condenser as State 4, and the saturated liquid leaving the condenser as State 1. Work around the cycle starting with State 3. Use the properties of Superheated Steam table to obtain the enthalpy and entropy at State 3.

$$P_3 = 600 psia$$

$$T_3 = 700°F$$

$$h_3 = 1351 \frac{Btu}{lb}$$

$$s_3 = 1.588 \frac{Btu}{lb \cdot R}$$

State 4 is a saturated mixture. Since the turbine expansion from State 3 to State 4 is isentropic, the entropy at State 4 is the same as State 3. Collect entropy and enthalpy values from the properties of Saturated Water and Steam table and determine the quality and enthalpy for State 4.

$$P_4 = 5 psia$$

$$s_4 = s_3 = 1.588 \frac{Btu}{lb \cdot R}$$

$$s_f = 0.2348 \frac{Btu}{lb \cdot R}$$

$$s_{fg} = 1.6092 \frac{Btu}{lb \cdot R}$$

$$\chi_4 = \frac{s_4 - s_f}{s_{fg}} = \frac{\left(1.588 \frac{Btu}{lb \cdot R} - 0.2348 \frac{Btu}{lb \cdot R}\right)}{1.6092 \frac{Btu}{lb \cdot R}} = 0.841$$

$$h_f = 130.13 \frac{Btu}{lb}$$

$$h_{fg} = 1000.57 \frac{Btu}{lb}$$

$$h_4 = h_f + \chi_4 h_{fg} = 130.13 \frac{Btu}{lb} + (0.841)\left(1000.57 \frac{Btu}{lb}\right) = 971.5 \frac{Btu}{lb}$$

The pressure and thermodynamic state are known at State 1, which is a saturated liquid. Obtain the enthalpy at State 1.

$$h_1 = h_{f@P=5psia} = 130.13 \frac{Btu}{lb}$$

Determine the change in heat per unit mass across the condenser from State 4 to State 1 by calulating the difference in enthalpy.

$$h_4 - h_1 = 971.5 \frac{Btu}{lb} - 130.1 \frac{Btu}{lb} = 841 \frac{Btu}{lb}$$

Answer B