

**Problem: 9-75**

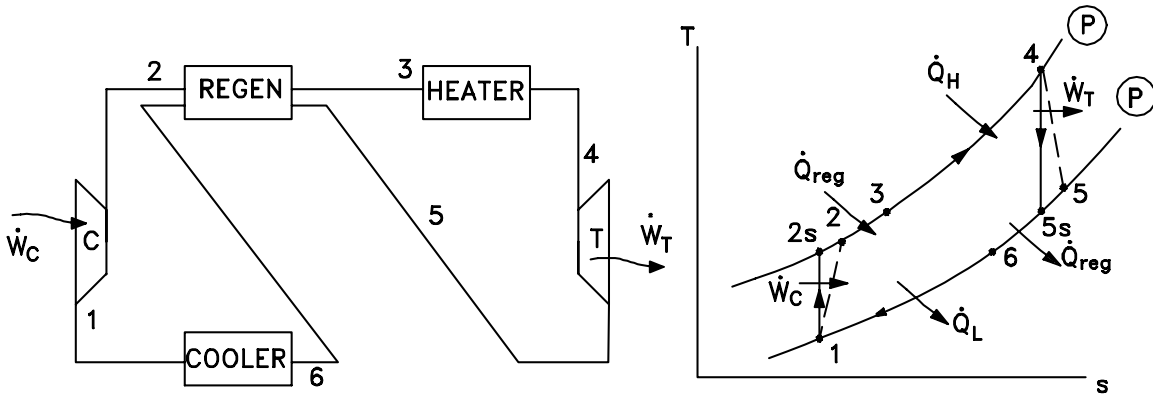
**Given:** Same as Problem 9-73 except

$$\eta_c = 0.8$$

$$\eta_t = 0.85$$

$$\eta_r = 0.85$$

**Find:** Thermal efficiency and net work output per lbm flow



**Full Load**

From Problem 9-73,

$$T_{2s} = 867.6 R$$

$$T_{5s} = 1199 R$$

compressor:

$$\eta_c = \frac{h_{2s} - h_1}{h_2 - h_1} = \frac{c_p (T_{2s} - T_1)}{c_p (T_2 - T_1)}$$

$$T_2 = T_1 \left( \frac{T_{2s} - T_1}{\eta_c} \right) = (520 + (867.6 - 520)/0.8) = 954.5 R$$

turbine:

$$\eta_t = \frac{h_4 - h_5}{h_4 - h_{5s}} = \frac{c_p (T_4 - T_5)}{c_p (T_4 - T_{5s})}$$

$$T_5 = T_4 - \eta_t (T_4 - T_{5s}) = 2000 - 0.85(2000 - 1199) = 1320 R$$

regenerator:

$$\eta_r = \frac{h_3 - h_2}{h_5 - h_2} = \frac{c_p (T_3 - T_2)}{c_p (T_3 - T_2)}$$

$$T_3 = \eta_r(T_5 - T_2) + T_2 = 0.85(1320 - 954.5) + 954.5 = 1265 \text{ R}$$

$$\eta_t = \frac{\dot{W}_t - \dot{W}_c}{\dot{Q}_{in}}$$

$$\frac{\dot{W}_t}{\dot{m}} = c_p(T_4 - T_5) = 0.24(2000 - 1320) = 163.2 \text{ Btu/lbm}$$

$$\frac{\dot{W}_c}{\dot{m}} = c_p(T_2 - T_1) = 0.24(954.5 - 520) = 104.3 \text{ Btu/lbm}$$

$$\frac{\dot{Q}_{in}}{\dot{m}} = c_p(T_4 - T_3) = 0.24(2000 - 1265) = 176.4 \text{ Btu/lbm}$$

$$\begin{aligned} \eta_t &= \frac{163.2 - 104.3}{176.4} \\ &= \boxed{33.3\%} \end{aligned}$$

$$\frac{\dot{W}_{net}}{\dot{m}} = 163.2 - 104.3 = \boxed{58.9 \text{ Btu/lbm}}$$

### Part Load

From Problem 9-73,

$$T_{2s} = 711.7 \text{ R}$$

$$T_{5s} = 1140 \text{ R}$$

compressor:

$$T_2 = T_1 \left( \frac{T_{2s} - T_1}{\eta_c} \right) = (520 + (711.7 - 520)/0.8) = 759.6 \text{ R}$$

turbine:

$$T_5 = T_4 - \eta_t(T_4 - T_{5s}) = (1560 - 0.85(1560 - 1140)) = 1203 \text{ R}$$

regenerator:

$$T_3 = T_2 + \eta_r(T_5 - T_2) = 795.6 + 0.85(1203 - 795.6) = 1136 \text{ R}$$

$$\eta_t = \frac{\dot{W}_t - \dot{W}_c}{\dot{Q}_{in}}$$

$$\frac{\dot{W}_t}{\dot{m}} = c_p(T_4 - T_5) = 0.24(1560 - 1203) = 85.7 \text{ Btu/lbm}$$

$$\frac{\dot{W}_c}{\dot{m}} = c_p(T_2 - T_1) = 0.24(795.6 - 520) = 57.5 \text{ Btu/lbm}$$

$$\frac{\dot{Q}_{in}}{\dot{m}} = c_p(T_4 - T_3) = 0.24(1560 - 1136) = 101.8 \text{ Btu/lbm}$$

$$\begin{aligned} \eta_t &= \frac{85.7 - 57.5}{101.8} \\ &= \boxed{27.7\%} \end{aligned}$$

$$\frac{\dot{W}_{net}}{\dot{m}} = 85.7 - 57.5 = \boxed{28.2 \text{ Btu/lbm}}$$