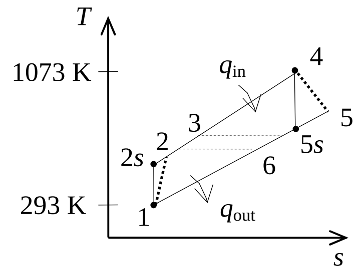
9-110 A Brayton cycle with regeneration produces 150 kW power. The rates of heat addition and rejection are to be determined.

Assumptions **1** The air standard assumptions are applicable. **2** Air is an ideal gas with constant specific heats at room temperature. **3** Kinetic and potential energy changes are negligible.

Properties The properties of air at room temperature are c_p = 1.005 kJ/kg.K and k = 1.4 (Table A-2a).

Analysis For the compression and expansion processes we have

$$T_{2s} = T_1 r_p^{(k-1)/k} = (293\text{ K})(8)^{0.4/1.4} = 530.8\text{ K}$$



$$\eta_C = \frac{c_p(T_{2s}-T_1)}{c_p(T_2-T_1)} \longrightarrow T_2 = T_1 + \frac{T_{2s}-T_1}{\eta_C}$$
$$= 293 + \frac{530.8-293}{0.87} = 566.3\text{ K}$$

$$T_{5s} = T_4\left(\frac{1}{r_p}\right)^{(k-1)/k} = (1073\text{ K})\left(\frac{1}{8}\right)^{0.4/1.4} = 592.3\text{ K}$$

$$\eta_T = \frac{c_p(T_4-T_5)}{c_p(T_4-T_{5s})} \longrightarrow T_5 = T_4 - \eta_T(T_4-T_{5s})$$
$$= 1073-(0.93)(1073-592.3)$$
$$= 625.9\text{ K}$$

When the first law is applied to the heat exchanger, the result is

$$T_3 - T_2 = T_5 - T_6$$

while the regenerator temperature specification gives

$$T_3 = T_5 - 10 = 625.9 - 10 = 615.9\text{ K}$$

The simultaneous solution of these two results gives

$$T_6 = T_5 - (T_3 - T_2) = 625.9 - (615.9 - 566.3) = 576.3\text{ K}$$

Application of the first law to the turbine and compressor gives

$$w_{\text{net}} = c_p(T_4-T_5) - c_p(T_2-T_1)$$
$$= (1.005\text{ kJ/kg}\cdot\text{K})(1073-625.9)\text{ K} - (1.005\text{ kJ/kg}\cdot\text{K})(566.3-293)\text{ K}$$
$$= 174.7\text{ kJ/kg}$$

Then,

$$\dot{m} = \frac{\dot{W}_{\text{net}}}{w_{\text{net}}} = \frac{150\text{ kW}}{174.7\text{ kJ/kg}} = 0.8586\text{ kg/s}$$

Applying the first law to the combustion chamber produces

$$\dot{Q}_{\text{in}} = \dot{m}c_p(T_4-T_3) = (0.8586\text{ kg/s})(1.005\text{ kJ/kg}\cdot\text{K})(1073-615.9)\text{K} = \mathbf{394.4\ kW}$$

Similarly,

$$\dot{Q}_{\text{out}} = \dot{m}c_p(T_6-T_1) = (0.8586\text{ kg/s})(1.005\text{ kJ/kg}\cdot\text{K})(576.3-293)\text{K} = \mathbf{244.5\ kW}$$