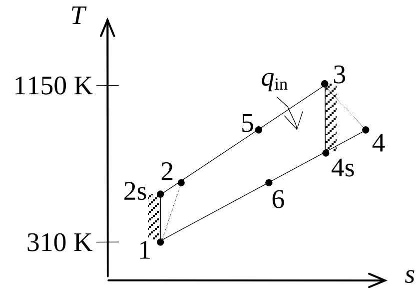
9-154 The total exergy destruction associated with the Brayton cycle described in Prob. 9-116 and the exergy at the exhaust gases at the turbine exit are to be determined.

Properties The gas constant of air is R = 0.287 kJ/kg·K (Table A-1).

Analysis From Prob. 9-116, q_{in} = 480.82, q_{out} = 372.73 kJ/kg, and



$$T_1 = 310\text{ K} \longrightarrow s_1^\circ = 1.73498\text{ kJ/kg}\cdot\text{K}$$
$$h_2 = 618.26\text{ kJ/kg} \longrightarrow s_2^\circ = 2.42763\text{ kJ/kg}\cdot\text{K}$$
$$T_3 = 1150\text{ K} \longrightarrow s_3^\circ = 3.12900\text{ kJ/kg}\cdot\text{K}$$
$$h_4 = 803.14\text{ kJ/kg} \longrightarrow s_4^\circ = 2.69407\text{ kJ/kg}\cdot\text{K}$$
$$h_5 = 738.43\text{ kJ/kg} \longrightarrow s_5^\circ = 2.60815\text{ kJ/kg}\cdot\text{K}$$

and, from an energy balance on the heat exchanger,

$$h_5 - h_2 = h_4 - h_6 \longrightarrow h_6 = 803.14 - (738.43 - 618.26) = 682.97\text{ kJ/kg}$$
$$\longrightarrow s_6^\circ = 2.52861\text{ kJ/kg}\cdot\text{K}$$

Thus,

$$x_{\text{destroyed},12} = T_0 s_{\text{gen},12} = T_0(s_2 - s_1) = T_0\left(s_2^\circ - s_1^\circ - R\ln\frac{P_2}{P_1}\right)$$
$$= (290\text{ K})(2.42763 - 1.73498 - (0.287\text{ kJ/kg}\cdot\text{K})\ln(7)) = \mathbf{38.91\text{ kJ/kg}}$$

$$x_{\text{destroyed},34} = T_0 s_{\text{gen},34} = T_0(s_4 - s_3) = T_0\left(s_4^\circ - s_3^\circ - R\ln\frac{P_4}{P_3}\right)$$
$$= (290\text{ K})(2.69407 - 3.12900 - (0.287\text{kJ/kg}\cdot\text{K})\ln(1/7)) = \mathbf{35.83\text{ kJ/kg}}$$

$$x_{\text{destroyed,regen}} = T_0 s_{\text{gen,regen}} = T_0[(s_5 - s_2) + (s_6 - s_4)] = T_0\left[(s_5^\circ - s_2^\circ) + (s_6^\circ - s_4^\circ)\right]$$
$$= (290\text{ K})(2.60815 - 2.42763 + 2.52861 - 2.69407) = \mathbf{4.37\text{ kJ/kg}}$$

$$x_{\text{destroyed},53} = T_0 s_{\text{gen},53} = T_0\left(s_3 - s_5 - \frac{q_{R,53}}{T_R}\right) = T_0\left(s_3^\circ - s_5^\circ - R\ln\frac{P_3}{P_5}^{\nearrow 0} - \frac{q_{in}}{T_H}\right)$$
$$= (290\text{ K})\left(3.12900 - 2.60815 - \frac{480.82\text{ kJ/kg}}{1500\text{ K}}\right) = \mathbf{58.09\text{ kJ/kg}}$$

$$x_{\text{destroyed},61} = T_0 s_{\text{gen},61} = T_0\left(s_1 - s_6 + \frac{q_{R,61}}{T_R}\right) = T_0\left(s_1^\circ - s_6^\circ - R\ln\frac{P_1}{P_6}^{\nearrow 0} + \frac{q_{\text{out}}}{T_L}\right)$$
$$= (290\text{ K})\left(1.73498 - 2.52861 + \frac{372.73\text{ kJ/kg}}{290\text{ K}}\right) = \mathbf{142.6\text{ kJ/kg}}$$

Noting that $h_0 = h_{@\,290\text{ K}}$ = 290.16 kJ/kg and $T_0 = 290\text{ K} \longrightarrow s_1^\circ = 1.66802\text{ kJ/kg}\cdot\text{K}$, the stream exergy at the exit of the regenerator (state 6) is determined from

$$\phi_6 = (h_6 - h_0) - T_0(s_6 - s_0) + \frac{V_6^2}{2}^{\nearrow 0} + gz_6^{\nearrow 0}$$

where

$$s_6 - s_0 = s_6 - s_1 = s_6^\circ - s_1^\circ - R\ln\frac{P_6}{P_1}^{\nearrow 0} = 2.52861 - 1.66802 = 0.86059\text{ kJ/kg}\cdot\text{K}$$

Thus,

$$\phi_6 = 682.97 - 290.16 - (290\text{ K})(0.86059\text{ kJ/kg}\cdot\text{K}) = \mathbf{143.2\text{ kJ/kg}}$$