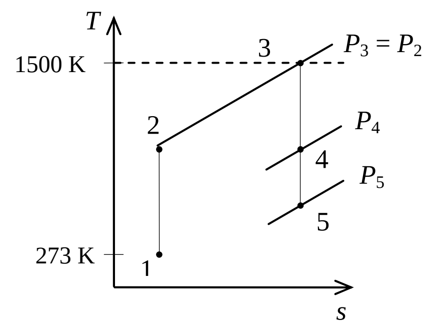
9-102 A modified Brayton cycle with air as the working fluid operates at a specified pressure ratio. The *T*-*s* diagram is to be sketched and the temperature and pressure at the exit of the high-pressure turbine and the mass flow rate of air are to be determined.

Assumptions **1** Steady operating conditions exist. **2** The air-standard assumptions are applicable. **3** Kinetic and potential energy changes are negligible. **4** Air is an ideal gas with constant specific heats.

Properties The properties of air are given as c_v = 0.718 kJ/kg·K, c_p = 1.005 kJ/kg·K, R = 0.287 kJ/kg·K, k = 1.4.

Analysis (b) For the compression process,

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k} = (273\,\text{K})(8)^{0.4/1.4} = 494.5\,\text{K}$$



The power input to the compressor is equal to the power output from the high-pressure turbine. Then,

$$\dot{W}_{\text{Comp,in}} = \dot{W}_{\text{HP Turb,out}}$$

$$\dot{m}c_p(T_2 - T_1) = \dot{m}c_p(T_3 - T_4)$$

$$T_2 - T_1 = T_3 - T_4$$

$$T_4 = T_3 + T_1 - T_2 = 1500 + 273 - 494.5 = \mathbf{1278.5\ K}$$

The pressure at this state is

$$\frac{P_4}{P_3} = \left(\frac{T_4}{T_3}\right)^{k/(k-1)} \longrightarrow P_4 = rP_1\left(\frac{T_4}{T_3}\right)^{k/(k-1)} = 8(100\,\text{kPa})\left(\frac{1278.5\,\text{K}}{1500\,\text{K}}\right)^{1.4/0.4} = \mathbf{457.3\ kPa}$$

(c) The temperature at state 5 is determined from

$$T_5 = T_4\left(\frac{P_5}{P_4}\right)^{(k-1)/k} = (1278.5\,\text{K})\left(\frac{100\,\text{kPa}}{457.3\,\text{kPa}}\right)^{0.4/1.4} = 828.1\,\text{K}$$

The net power is that generated by the low-pressure turbine since the power output from the high-pressure turbine is equal to the power input to the compressor. Then,

$$\dot{W}_{\text{LP Turb}} = \dot{m}c_p(T_4 - T_5)$$

$$\dot{m} = \frac{\dot{W}_{\text{LP Turb}}}{c_p(T_4 - T_5)} = \frac{200{,}000\,\text{kW}}{(1.005\,\text{kJ/kg}\cdot\text{K})(1278.5 - 828.1)\text{K}} = \mathbf{441.8\ kg/s}$$