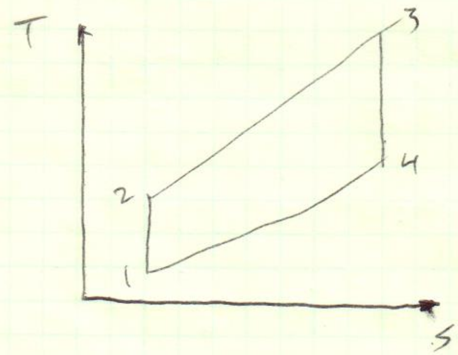
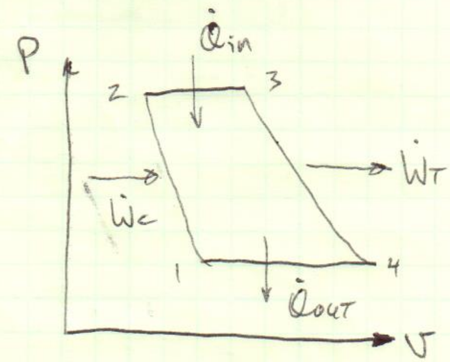
9–91E A gas-turbine power plant operates on a simple Brayton cycle with air as the working fluid. The air enters the turbine at 120 psia and 2000 R and leaves at 15 psia and 1200 R. Heat is rejected to the surroundings at a rate of 6400 Btu/s, and air flows through the cycle at a rate of 40 lbm/s. Assuming the turbine to be isentropic and the compresssor to have an isentropic efficiency of 80 percent, determine the net power output of the plant. Account for the variation of specific heats with temperature. *Answer:* 3373 kW





$P_3 = 120$ PSIA, $T_3 = 2000°R$, $P_4 = 15$ PSIA, $T_4 = 1200°R$

${}_4\dot{Q}_1 = -6400 \frac{Btu}{s}$, $\dot{m} = 40 \frac{LBM}{s}$

$\eta_T = 1.0$, $\eta_c = 0.80$ FIND $\dot{W}_{net} = \dot{W}_c + \dot{W}_T$

PROCESS 4 TO 1:

${}_4\dot{Q}_1 - {}_4\dot{W}_1 = \dot{m}(h_1 - h_4)$

$h_1 = h_4 + \frac{{}_4\dot{Q}_1}{\dot{m}}$

TABLE A-17E: $T_{4,a} = 1200°R$

$h_4 = 291.30 \frac{Btu}{LBM}$, $Pr_4 = 24.01$

$$h_1 = \left(291.3\ \frac{Btu}{LBM}\right) + \frac{\left(-6400\ \frac{Btu}{s}\right)}{\left(40\ \frac{LBM}{s}\right)} = 131.3\ \frac{Btu}{LBM}$$

TABLE A-17E:

$$Pr_1 = (1.3860) + \frac{(1.5742 - 1.386)}{(133.86 - 129.06)} \cdot (131.3 - 129.06) = 1.474$$

PROCESS 1 TO 2:

$$_1\dot{Q}_2^{\,\nearrow 0} - {_1\dot{W}_2} = \dot{m}(h_2 - h_1)$$

$$_1\dot{W}_2 = \dot{m}(h_1 - h_{2,a})$$

COMPRESSOR EFFICIENCY:

$$\eta_c = \frac{h_{2,s} - h_1}{h_{2,a} - h_1}$$

$$h_{2,a} = h_1 + \left(\frac{1}{\eta_c}\right)(h_{2,s} - h_1)$$

TABLE A-17E: FIND $h_{2,s}$

$$\left(\frac{P_2}{P_1}\right)_s = \frac{Pr_2}{Pr_1}$$

$$Pr_2 = Pr_1 \left(\frac{P_2}{P_1}\right)_s = (1.474)\left(\frac{120}{15}\right) = 11.79$$

$$h_{2,s} = (236.02) + \frac{(240.98 - 236.02)}{(12.30 - 11.43)} \cdot (11.79 - 11.43) = 238.1\ \frac{Btu}{LBM}$$

$$h_{2,a} = (131.3) + \left(\frac{1}{0.8}\right)(238.1 - 131.3) = 264.8 \ \frac{Btu}{LBM}$$

$$_1\dot{W}_2 = \left(40 \ \frac{LBM}{s}\right)\left(131.3 - 264.8 \ \frac{Btu}{LBM}\right) = -5340 \ \frac{Btu}{s}$$

PROCESS 3 TO 4:

$$_3\dot{Q}_4^{\,0} - {_3\dot{W}_4} = \dot{m}(h_4 - h_3)$$

STATE 3:

$$T_3 = 2000°R$$

TABLE A-17E:

$$h_3 = 504.71 \ \frac{Btu}{LBM}$$

$$_3\dot{W}_4 = \left(40 \ \frac{LBM}{s}\right)\left(504.71 - 291.30 \ \frac{Btu}{LBM}\right) = 8536 \ \frac{Btu}{s}$$

$$\dot{W}_{net} = \dot{W}_C + \dot{W}_T = (-5340) + (8536) = 3196 \ \frac{Btu}{s}$$

$$\boxed{\dot{W}_{net}} = \left(3196 \ \frac{Btu}{s}\right)\left(\frac{0.7457 \ KW}{0.7068 \ Btu/s}\right) = \boxed{3372 \ KW}$$