Problem Set 13, PS13 due Friday June 18

PS13-1 The power output of an adiabatic turbine is 8 MW. Steam enters the turbine at 600 C, 6 MPa and 80 m/sec. Steam leaves the turbine at 50 kPa, 100 C and 140 m/sec. Determine a) the turbine steam mass flow rate, b) the isentropic efficiency of the turbine. c) the entropy change in the expansion process.

PS13-2
6-102 An air compressor has an adiabatic efficiency of 84%. Air enters the compressor at 100 kPa , 17 C and a negligible velocity. Air leaves the compressor at 257 C and a negligible velocity. Determine a) the compressor exit pressure and b) the power input to the compressor.

PS13-3 Consider the effect of varying the isentropic efficiency of an adiabatic nozzle from 80% to 100% on the nozzle exit temperature and pressure. Inlet conditions and the exit velocity are held constant. Air enters the nozzle at 60 psia, 1020 F and a low velocity. Air leaves the nozzle at with a velocity of 800 ft.sec.

PS13-1

$$h_1 = 3658.4 \text{ BTU/lb}$$

$$s_1 = 7.1677$$

$$s_1' = s_1 = 7.1677$$

$$x = \frac{7.1677 - 1.0910}{6.5029} = .9345$$

$$h_1' = h_f + x \times h_{fg}$$

$$h_1' = 340.49 + .9345 \times 2305.4$$

$$h_1' = 2495.26 \text{ BTU/lb}$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2} + \frac{W}{m}$$

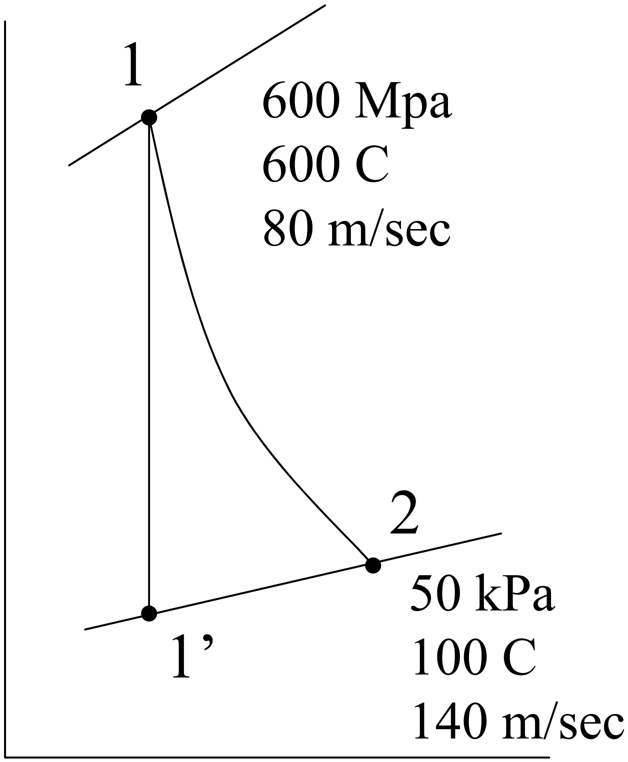
$$W = m \times \left(h_1 + \frac{V_1^2}{2} - h_2 - \frac{V_2^2}{2} \right)$$

$$8000 \text{ kJ/sec} = m \times \left(3658.4 - 2682.5 + \left(\frac{80^2}{2} - \frac{140^2}{2} \right) \times \frac{1}{1000} \right)$$

$$8000 \text{ kJ/sec} = m \times (875.9 - 13.2)$$

$$m = 8.3 \text{ kg}$$

steam

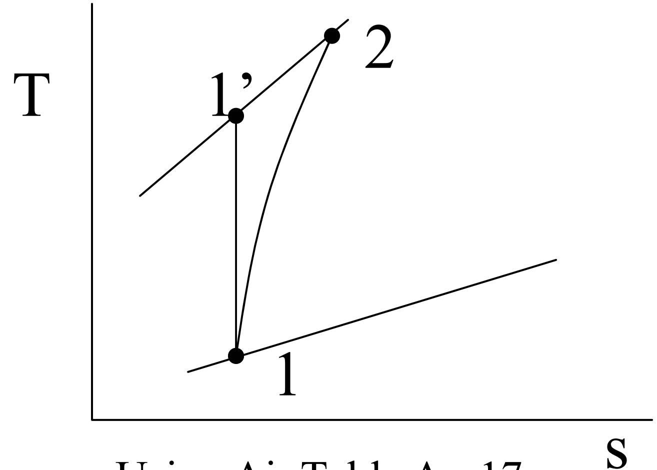


$$W_{isentropic} = 8.3 \text{ kg} \times (3658.4 - 2682.5 - 13.2)$$

$$W_{isentropic} = 9556 \text{ KW}$$

$$\eta = \frac{W_{actual}}{W_{isentropic}} \frac{8000}{9556} = 83.7\%$$

PS13-2



$$\eta = \frac{W_{ideal}}{W_{actual}} = \frac{h_1^{'} - h_1}{h_2 - h_1} = \frac{c_p(T_1^{'} - T_1)}{c_p(T_2 - T_1)} = .84$$

$$T_1^{'} = T_1 + .84 \times (T_2 - T_1)$$

$$T_1^{'} = 218.6 + .84 \times \left(257 - 17\right) = 491.75^{O}K$$

$$\left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}} = \frac{p_2}{p_1}$$

$$p_2 = 100 \times \left(\frac{491.75}{290.15}\right)^{3.5} = 633.76^{O}K$$

$$m = \frac{PV}{RT} = \frac{100\,\text{kPa} \times 2.4\ \text{m}^3/\text{sec}}{.287 \times 290} = 2.884\ \text{kg/sec}$$

$$W = m \times c_p (T_2 - T_1)$$

$$W = 2.884 \times 1.005 \times (257 - 17) = 695.6\,KW$$

Using Air Table A – 17

$$@T_1 = 290^{O}K, \quad h_1 = 290.16 \quad \text{kJ/kg}, \quad p_r = 1.2311$$

$$@T_2 = 530^{O}K, \quad h_2 = 533.98 \ \text{kJ/kg}$$

$$\eta = \frac{h_1^{'} - h_1}{h_2 - h_1} = .84$$

$$h_1^{'} = h_1 + .84\left(h_2 - h_1\right)$$

$$h_1^{'} = 290.16 + .84 \times \left(533.98 - 290.16\right)$$

$$h_1^{'} = 494.97\ \text{kJ/kg}$$

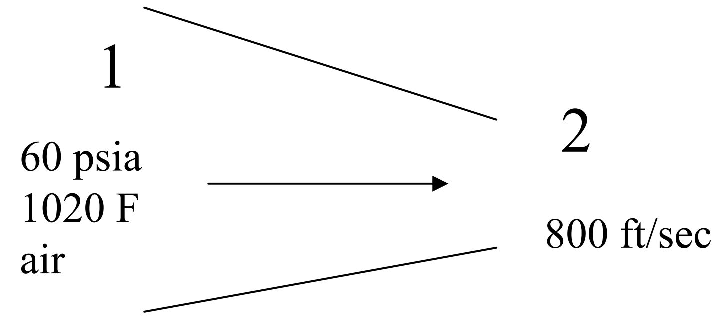
$$@\,494.97 \ \text{kJ/kg}, \quad p_{r2} = 7.951 \ \text{by interpolation}$$

$$p_2 = p_1\left(\frac{p_{r2}}{p_{r1}}\right) = 100 \times \left(\frac{7.951}{1.2311}\right) = 645.8 \ \text{kPa}$$

$$W = m \times \Delta H = 2.884 \times (533.98 - 290.16)$$

$$W = 703.2 \ \text{KW}, \approx 1\%\text{difference}$$

PS13-3



$$@\,T_1 = 1480^{O}R,\quad p_{r1} = 53.04,\quad h_1 = 369.89\ \text{BTU/lb}$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

$$h_2 = h_1 + \frac{V_2^2 - V_1^2}{2} = 369.89 + \frac{800^2}{2} \times \frac{1\ \text{BTU/lb}}{(778 \times 32.2)\text{ft}^2/\text{sec}^2}$$

$$h_2 = 351.1\,\text{BTU/lb}\ \ \text{actual exit enthalpy}$$

$$@h_2 = 351.1\ \text{BTU/lb}\quad \text{TableA} - 17\text{E}\quad T_2 = 1431.3^{O}R$$

$$\eta = \frac{h_1 - h_2}{h_1 - h_1^{'}}$$

$$h_1^{'} = h_1 - (h_1 - h_2)/.9 = 363.89 - (363.89 - 351.1)/.9$$

$$h_1^{'} = 349.68\ \text{BTU/lb}$$

$$\text{TableA} - 17\text{E}\ @\ h = 349.68\ \text{BTU/lb},\quad P_{r2} = 46.04$$

$$\frac{p_2}{p_1} = \frac{p_{r2}}{p_{r1}}$$

$$p_2 = p_1 \frac{p_{r2}}{p_{r1}} = 60\,\text{psia} \times \frac{46.04}{53.04} = 52.1\ \text{psia}$$

p_2 will vary with efficiency.