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UNIVERSITY OF CALIFORNIA
Mechanical Engineering

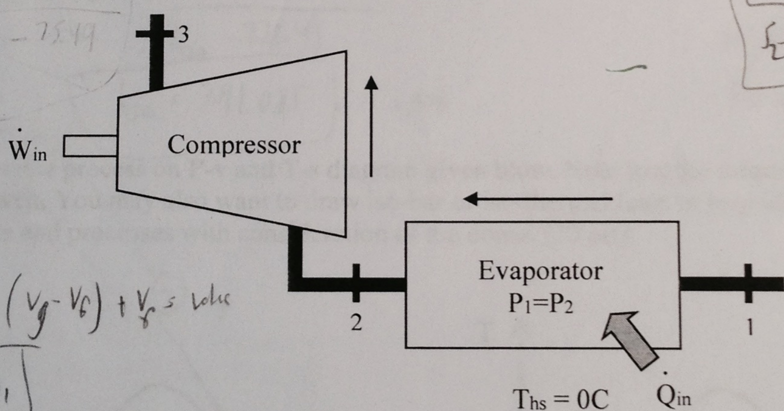
ME 40, Thermodynamics
Spring 2015/F-Pello

MIDTERM EXAMINATION #2 (4/10/2015)

NAME [redacted]

This examination is open book and open notes.
Please write your name in the space provided above.
Please **BOX** your answers.

Consider the refrigeration system consisting of an evaporator and a compressor as indicated in the figure below. Refrigerant 134a at a mass flow rate of 1kg/s enters the evaporator at T_1= -20C and v_1=0.01 m3/kg where heat is added from a constant temperature T_{hs} = 0C heat source to the refrigerant such that it exits the evaporator at the same pressure as the inlet and as saturated vapor. After the evaporator the refrigerant enters an adiabatic compressor that has an isentropic efficiency of 80% and compresses the refrigerant to 1 MPa.



$h_2 = 238.41$

$s_2 = 0.94564$

$X = \frac{0.01-0.000736}{0.147-0.000736}$

$X = 0.063$

$x(v_g - v_f) + v_f = v_{eliz}$

$x(h_{fg}) + h_f = 38.90 = h_1$

$x(s_{fg}) + s_f = 0.1576 = s_1$

$mh_1 + Q = mh_2$

$\dot{m}(38.9) + \dot{Q} = \dot{m} \cdot 238.41$

$\dot{Q} = 199.5$

$\eta_c = \frac{h_{3s} - h_2}{h_{3a} - h_2}$

$0.8 = \frac{h_{3s} - 238.41}{h_{3a} - 238.41}$

T = 47.0 C

continued

a) Find T, P, h, and s for the refrigerant at: (1) entering evaporator (2), exiting the evaporator (same as entering the compressor) (3) and the refrigerant leaving the compressor.

Write down your final answers in the **box** below and **show the work how you get them** (30 pts)

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	P (kPa)	T (°C)	h (kJ/kg)	s (kJ/kgK)
State 1	132.82	-20	38.9	0.1576
State 2	132.82	-20	238.41	0.94564
State 3	1000	57.8	291.085	0.978

$$\frac{0.9525-0.94564}{0.94564-0.9179} = \frac{282.74-h_3}{h_3-271.71}$$

0.9525

$h_{3s} = 280.55$

$$0.8 = \frac{280.55-238.41}{h_{3a}-238.41}$$

$h_{3a} = 291.085$ 1MPa

$h_{3a} = 291.085$, 1MPa

$$\frac{293.38-291.085}{291.085-282.74} = \frac{60-T}{T-50}$$

$T = 57.8$

$$\frac{293.38-291.085}{291.085-282.74} = \frac{0.985-s}{s-0.9525}$$

$s = 0.978$

b) Draw the process on **P-v** and **T-s** diagram given blow. Note that the saturation dome is given. You may also want to draw iso-bar or iso-thermal lines to help identify states and processes with consideration of the dome. (20 pts)

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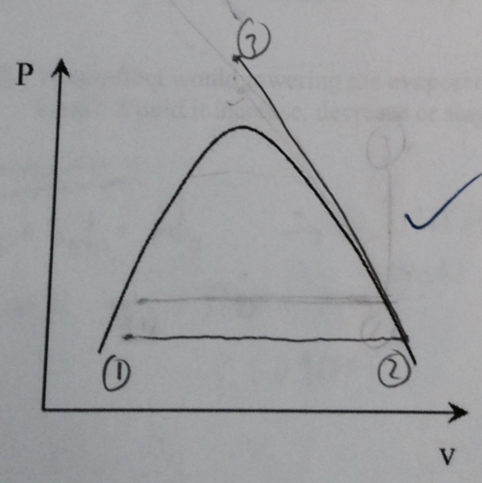

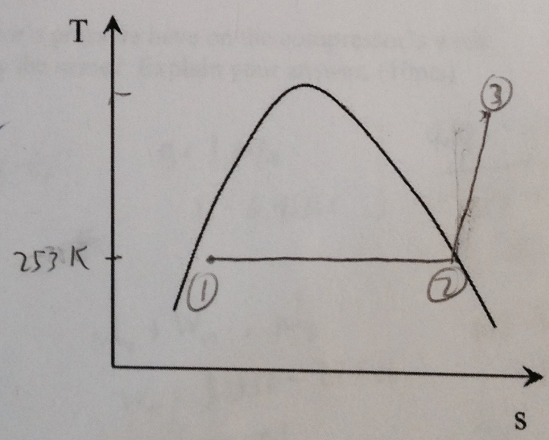

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c) Find the heat addition rate to the evaporator. (10pts)

$\dot{Q} = 199.51$ kJ/s

d) Find the power required for the compressor. (10pts)

$\dot{m}h_2 + \dot{W} = \dot{m}h_3$

$238.41 + \dot{W} = 291.085$

$\dot{W} = 52.675$ kJ/s

e) Find the entropy generation rate of the whole system. (20pts)

$S_{gen} = \dot{m}(s_2 - s_1) + \dot{m}(s_3 - s_2) + \frac{Q}{T}$

$= 0.94564 - 0.1576 + 0 - \frac{199.51}{273} + 0.978 - 0.94564$

$= 0.78804 - 0.7308$

$S = 0.0896$ kJ/kg·K per sec

f) What effect would lowering the evaporator's pressure have on the compressor's work input? Would it increase, decrease or stay the same? Explain your answer. (10pts)

evaporator

$\dot{m}h_1 + \dot{Q}_{in} = \dot{m}h_2 \rightarrow Q_{in} = 225.86 - 5.83$

$= 220.03$

$P_3 = 1$ MPa

$s_3 = 0.96866$

$\frac{0.985 - 0.96866}{0.96866 - 0.9525} = \frac{291.38 - h_3}{h_3 - 282.74}$

$h_3 = 288.03$

E. Take for example $P_{evap} = 51.25$

$h_2 = 225.86$

$s_2 = 0.96866$

$\dot{m}h_2 + \dot{W}_{in} = \dot{m}h_3$

$W_{in} = 303.57 - 225.86$

$= 77.71$

$0.8 = \frac{288.03 - 225.86}{h_{3a} - 225.86}$

$h_{3a} = 303.57$

$\frac{0.36081 - 0.01}{0.01 - 0.00075}$ ... $= \frac{225.86 - h_1}{h_1 - 0}$

$h_1 = 5.83$

10 ✓

lowering the pressure of the evaporator would result in a larger compressor work input. The substance that exits the evaporator will be at a lower enthalpy but a higher entropy. Compressor work is $W_{in} = h_3 - h_2$, and h_3 is larger and h_2 is thus smaller in this case, so W_{in} is greater.