UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, APRIL 2001

Third Year – Program 03

MIE 311S – THERMAL ENERGY CONVERSION

Examiner – Prof. S. McCahan

Name: ______________________________

Student Number: ___________________________

This is a two and a half hour exam. You may use a calculator and any written material. Answer all parts of all questions. In order to obtain the maximum credit for your solutions, show all steps in your computations. Clearly indicate your answers in the spaces provided on the exam sheet or in your exam booklet <u>in the units shown</u>. The point values for each problem are given to help you allocate your time. Return both your booklet and your exam sheet when you are finished.

Exam: 5 pages

4 problems

1. (35 points, 8 parts) An ideal vapour-compression refrigerator, which uses R-134a as the working fluid, is modified to include two evaporators as shown in figure 1.1. The total mass flow leaving the condenser (state 3) goes through throttle valve A to state 4. There is a control valve located at state 4 that controls the mass flow through evaporator #1. The remaining refrigerant goes directly through throttle valve C. After exiting evaporator #1 the refrigerant is throttled from state 5 to state 6. At state 6 the refrigerant is mixed, adiabatically, with the fluid from throttle valve C (state 8). The total mass flows through evaporatoı #2 and the compressor. Some properties are shown for the various states on Table 1.1. You do <u>not</u> have to fill in the table completely to answer this question.

For parts (a) to (e) the control valve at state 4 is set such that 6.5 lb/min of R-134a flows through evaporator #1 (i.e. $\dot{m}_5 = 6.5$ lb/min) and the capacity of evaporator #2 is 4 tons.

a) Briefly list two advantages of using this type of system.

b) What is the refrigeration capacity of evaporator #1?

$\dot{Q}_{e1}(tons) =$ ________________

c) Determine the work input to the compressor.

$\dot{W}_c(kW) =$ ________________

d) Find the coefficient of performance for this system.

$C.O.P. =$ ________________

e) Approximately how warm could the "hot" space (surrounding the condenser) be before the refrigerator begins to fail?

$T_{H_{\max}} =$ ________________

f) We re-adjust the control valve at state 4 such that more of the flow goes through evaporator #1. The mass flow at state 8 is reduced and the refrigeration capacity of evaporator #1 and evaporator #2 are changed. Circle one answer for each of the following questions, no explanation is necessary. (Hint: draw a T-s diagram)

f.i) Will the capacity of evaporator #2 go: up down remain the same

f.i) Will the total refrigeration capacity go: up down remain the same

f.iii) Will the coefficient of performance go: up down remain the same

Table 1.1

| State | P (psi) | T (°F) | h (Btu/lb) | s (Btu/lb-R) | x |
|---|---|---|---|---|---|
| 1 | 26.651 | 10 | 103.19 | .2214 | 1 |
| 2 | | | | | |
| 3 | 140 | 100.56 | 44.43 | 0.0902 | 0 |
| 4 | | | | | |
| 5 | 40.788 | 30 | 106.01 | 0.2196 | 1 |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |

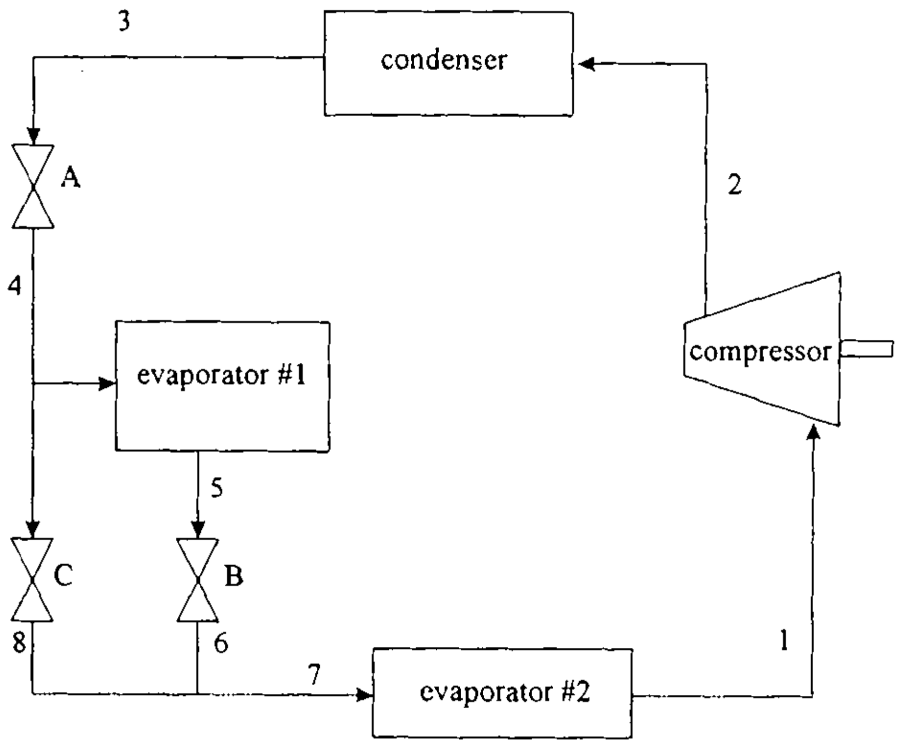



Figure 1.1. Ideal vapour-compression refrigeration system.

2. (32 points, 6 parts) Consider a fuel mixture that is 10% propane ($C_3H_8$), 10% carbon monoxide (CO), and 80% butane ($C_4H_{10}$) on a molar basis. Note: 1 kmol of this fuel mixture will burn <u>stoichiometrically</u> with 27.37 kmols of air (i.e., 5.75 kmols of $O_2$ + 21.62 kmols of $N_2$).

a) Determine the HHV of this fuel mixture.

HHV (KJ/$kg_f$) = ____________________

b) This fuel mixture is burned with air in a steady flow system at a constant pressure of 1 atm. The equivalence ratio ($\Phi$) of the reactant mixture is 1.05. The product mixture contains only $CO_2$, $H_2O$, $N_2$, and CO.

b.i) Is this combustion process: complete or incomplete

b.ii) Is the reactant mixture: rich lean or stoichiometric

b.iii) Determine the mol fraction of CO in the product mixture.

$y_{CO}$= ____________________

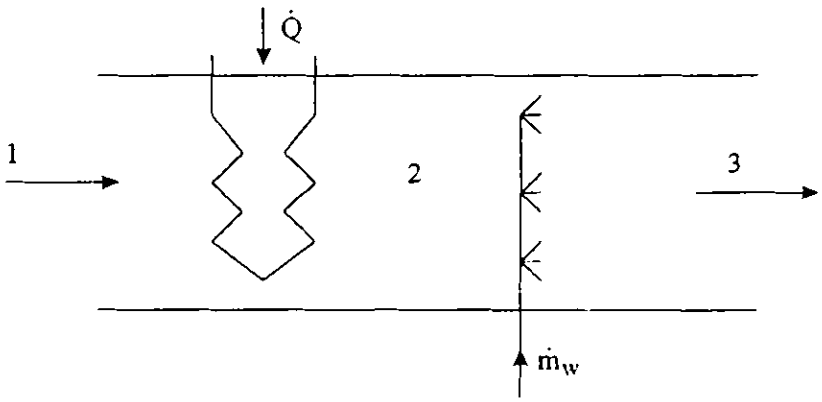
b.iv) What is the dewpoint temperature of the product mixture?

$T_{dp}$ (°C) = ____________________

b.v) If this product mixture is cooled to 25°C what fraction of the water in the mixture will condense.

$$\frac{\dot{n}_{H_2O(l)}}{\dot{n}_{H_2O_{total}}} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}$$

3. (35 points, 6 parts) Outdoor air (state 1) enters an air conditioning system at 50°F and 40% relative humidity at a steady rate of 500 cfm. The air leaves the system (state 3) at 74°F and 55% relative humidity. In the air conditioning system the air is first heated to 70°F (state 2) and then humidified. The process occurs at a total pressure of 1 atm. You can use the chart for this problem.




a) What is the mass flow rate of dry air through the system?

$\dot{m}_a$ (lb/min) = ____________________

b) What is the temperature of the steam used in the humidification process?

$T_w$ (°F) = ____________________

c) Determine the heat transfer to the heating section.

$\dot{Q}$ (Btu/min) = ____________________

d) Calculate the mass flow rate of water to the humidification section.

$\dot{m}_w$ (lb/min) = ____________________

e) Repeat parts (a) and (c) assuming the process takes place at a total pressure of 10.5 psi.

$\dot{Q}$ (Btu/min) = ____________________

$\dot{m}_a$ (lb/min) = ____________________

4. (3 points, 1 part) Answer one of the following questions that pertain to the article(s) you read for Assignment #8. The answer should be one paragraph or less.

   I. Fuel Cells: What is reforming?

   II. Supercars: Based on the articles, are diesel-electric or SI-electric engines technologies that can be used for the long-term future? Briefly explain why or why not.

   III. Nuclear: What is an "all-pathways" standard?

   IV. Thermoelectric: What is presently the most active area of research aimed at improving the efficiency of these devices?

   V. Carbon Cycle: What does the author mean by the "Anthropocene Era"?

   VI. Renewable Energy: What is $CO_2$ payback time and, briefly, why is this important?

   VII. Photovoltaic Cells: What are some advantages of crystalline silicon solar cells?

Chart 1*a*

# ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY



AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

## SEA LEVEL