PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS -December 2008

07-Mec-B2 Environmental Control in Buildings

3 hours duration

INSTRUCTIONS:

1. **If doubt exists as to the interpretation of any of the questions, the candidate is urged to submit a clear statement of the assumption(s) that he/she has had made with the answer.**

2. **The examination paper is open book and so candidates are permitted to make use of any textbooks, references or notes that they wish.**

3. **Any non-communicating calculator is permitted. Candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the first inside left hand sheet of the first examination workbook.**

4. **Candidates are expected to have copies of both an environmental control book and steam tables, since it will be necessary to use information presented in the tables and graphs contained in books.**

5. **Candidates are required to solve five questions.**

6. **All questions carry the same value. Indicate which five questions are to be graded on the cover of the first examination workbook.**

7. **Psychrometric charts and the p-h diagram for the refrigerant R-134a are attached.**

PROBLEM 1. (20 POINTS)

An air conditioning system consists of a mixing chamber, cooling coil, fan and afterheater. The cooling coil bypass factor is 0.15. The mixing ratio for both summer and winter design conditions is 2.5 kg of re-circulated air for every kilogram of fresh air.
The afterheater is not used for summer design case, which results in a room RH of 60% when the supply temperature is 15°C.

Data:
Room temperature 21°C (winter and summer).
Summer outside conditions 28°C dB, 23°C wB.
Winter outside conditions at -2°C saturated.
Summer loads 40 kW sensible gain, 10 kW latent gain.
Winter loads 30 kW sensible loss, 10 kW latent gain.

a. **Draw a diagram of the system.**
b. **Draw the operating cycles on the psychrometric chart provided. Identify each significant point, on the diagram and psychrometric chart, and note for each of these points its dry bulb and wet bulb temperature.**
c. **Calculate the design cooling coil load.**
d. **The room conditions in winter.**
e. **Calculate the design afterheater load.**

It may be assumed that there is negligible change in the mass flow rate of air supplied through the year.

PROBLEM 2. (20 POINTS).

Estimate the indoor-outdoor pressure differential for the first and fifteenth floors of a 15-story office building with plan dimensions of 120 ft x 30 ft and 10 ft floor height.

The structure has fixed windows and is of conventional curtain wall construction.
There are double vestibule-type doors on all four sides.
Under winter conditions a 12 mph wind blows normal to one of the long dimensions.
Consider only wind and stack effect. The indoor-outdoor temperature difference is 70°F.

PROBLEM 3. (20 POINTS)

Sketch an induced draft contra flow cooling tower, showing how it may be regulated to control the operation of a refrigeration plant.

A cooling tower is operating in atmospheric conditions of 65°F dB (dry bulb), 57°F wB (wet bulb). The tower cools 3000 lb/min of water from 100°F through a range of 30°F. The air is assumed to leave the top of the tower at 90°F db, 95% RH.

a. **Calculate the enthalpy, specific volume and relative humidity of the air entering the tower.**
b. **Find the air volumetric flow at the tower inlet (ft^3/min)**
c. **Find the evaporative loss (%).**

d. **Find the make-up water required, taking into account that some moisture is gained by the cooling air and also that there is a drift of 0.3% of the total water flow.**

PROBLEM 4. (20 POINTS)

A room is located at the middle floor of a multi-storey office building in Ottawa, Ontario. The room is to be maintained at 75°F in summer. It has an exterior all-glass wall facing east, 10 ft high and 20 ft wide, no internal shading. The glass is double pane (1/2" air space) insulating glass with heat absorbing outer pane and clear inner pane. The other three walls, the floor and the suspended ceiling are all interior surfaces with no heat loss or gain. The room is occupied by six office workers (light physical work) from 8:00 to 18:00. There are a total of 7 fluorescent lighting fixtures in the room, each with two 40-watt tubes. The lights are turned on continuously from 8:00 to 18:00.
Determine the cooling load for the room at hour 15:00 in July due to people, lights and the glass wall.
State clearly your assumptions. (i.e. wind, partition, room mass, etc.)

PROBLEM 5. (20 POINTS)

An ammonia two-stage vapour compression refrigeration plant operates with a condenser pressure of 12 bar, a flash chamber pressure of 5 bar and an evaporator pressure of 2 bar. Saturated liquid leaves the condenser and after being throttled to 5 bar the saturated liquid and saturated vapour are separated in the flash chamber. The saturated vapour is then mixed with the superheated vapour from the LP (low pressure) compressor discharge before it enters the HP (high pressure) compressor, while the saturated liquid is throttled down to the evaporator pressure.
The vapour leaving the evaporator is at -16°C. Each stage of the compressor has an isentropic efficiency of 90%.

a) **Sketch the system.**
b) **Draw the cycle on the *p-h* diagram provided.**

c) **Calculate:**
- **the mass fraction of the vapour leaving the flash chamber;**
- **the coefficient of performance of the plant;**
- **the mass flow of the refrigerant through the condenser when the refrigeration load is 400 kW.**

PROBLEM 6. (20 POINTS)

The wall of a house consists of two 125mm thick brick walls with an inner cavity. The inside wall has a 5 mm coating of plaster and there is cement rendering of 5 mm on the outside wall. In one room of the house the external wall is 5 m x 3 m, and contains a window of 1.8 m x 1.2 m of 1.5mm thick glass. The heat transfer coefficients for the inside and outside surfaces of the wall and window are 8.5 and 31 W/m^{2}K, respectively. The thermal conductivities of brick, plaster, cement and glass are 0.43, 0.14, 0.86, and 0.76 W/m K, respectively.

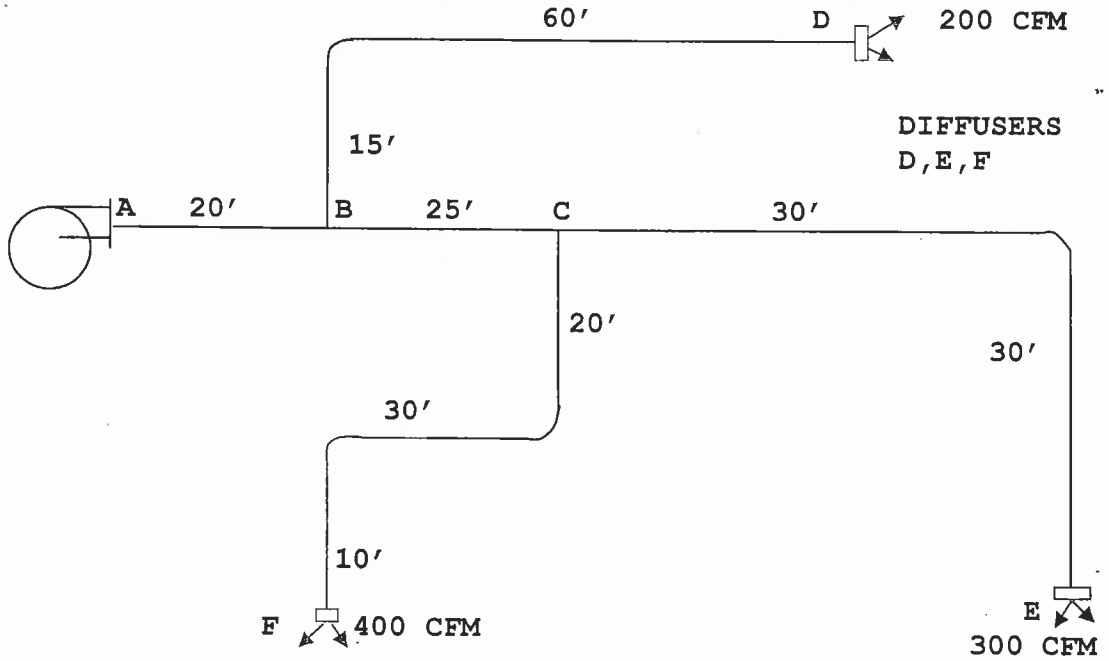
Calculate the proportion of the total heat transfer which is due to the heat loss through the window. Assume that the resistance of the air cavity is 0.20 m^{2}K/W. Neglect all end effects, and neglect radiation.

PROBLEM 7.(20 POINTS)

Use equal friction method to select duct sizes for the small duct system shown below.

Data:
- **the velocity in section AB is limited to 1000 FPM.**
- **total pressure loss across each diffuser is 0.015 in. w.g. at the given flow rates.**

Calculate the total pressure loss that the fan must supply at A.
Calculate duct sizes in diameter as well as equivalent rectangular dimensions.



PROBLEM 8. (20 POINTS)

You are involved in selecting the heating and cooling system for a campus of a big university in a downtown location.
Comment on environmental implication of the following heating or cooling systems (your comments must be short and dealing with the issue):

- **vapour compression air conditioning system using R22.**
- **vapour compression air conditioning system using R134A.**
- **absorption chiller air conditioning system using steam from district heating.**
- **absorption chiller air conditioning system using natural gas.**
- **Heating and cooling from a central station that provides cold water and hot water for heating and cooling.**

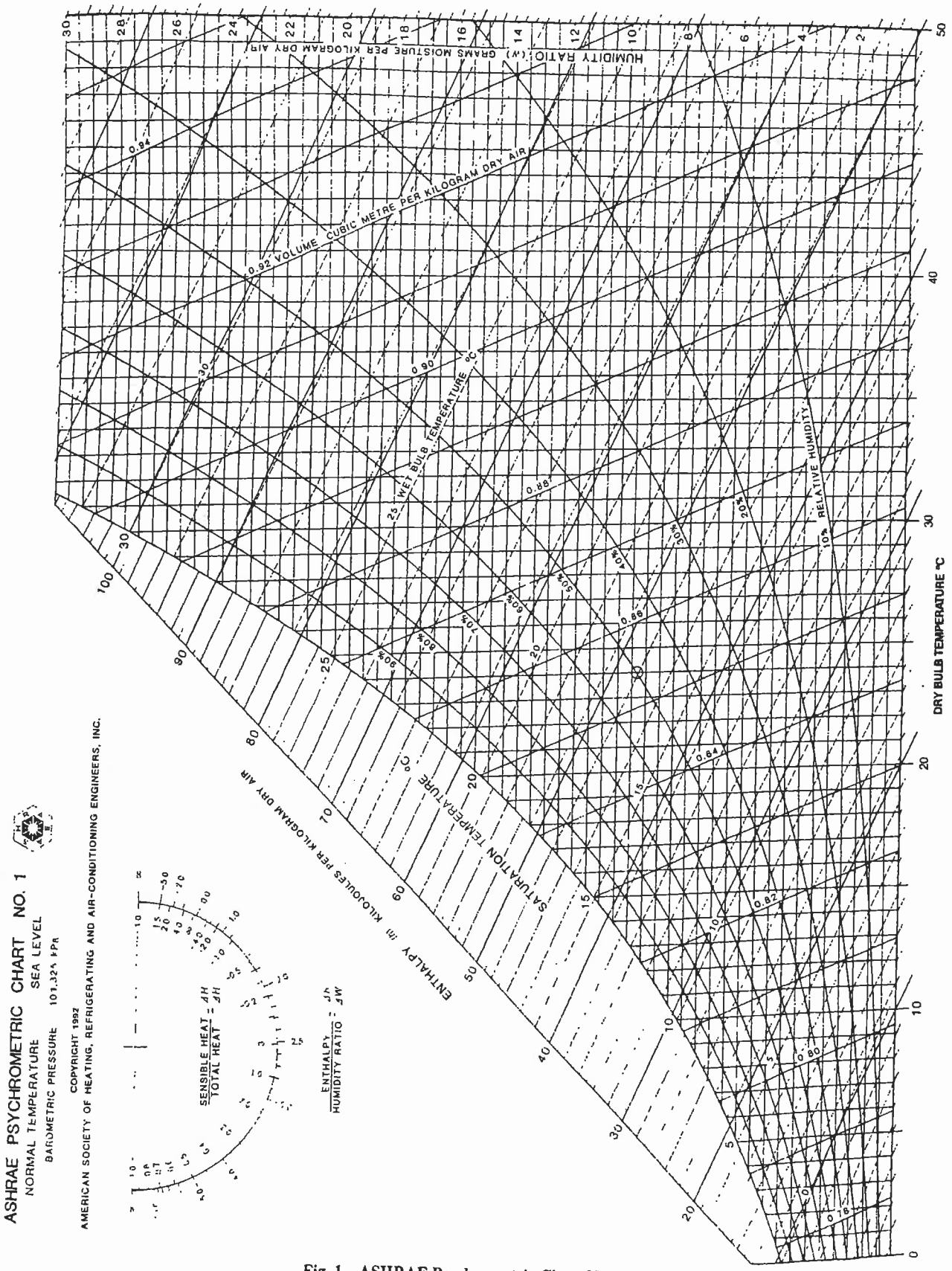


Fig. 1 ASHRAE Psychrometric Chart No. 1

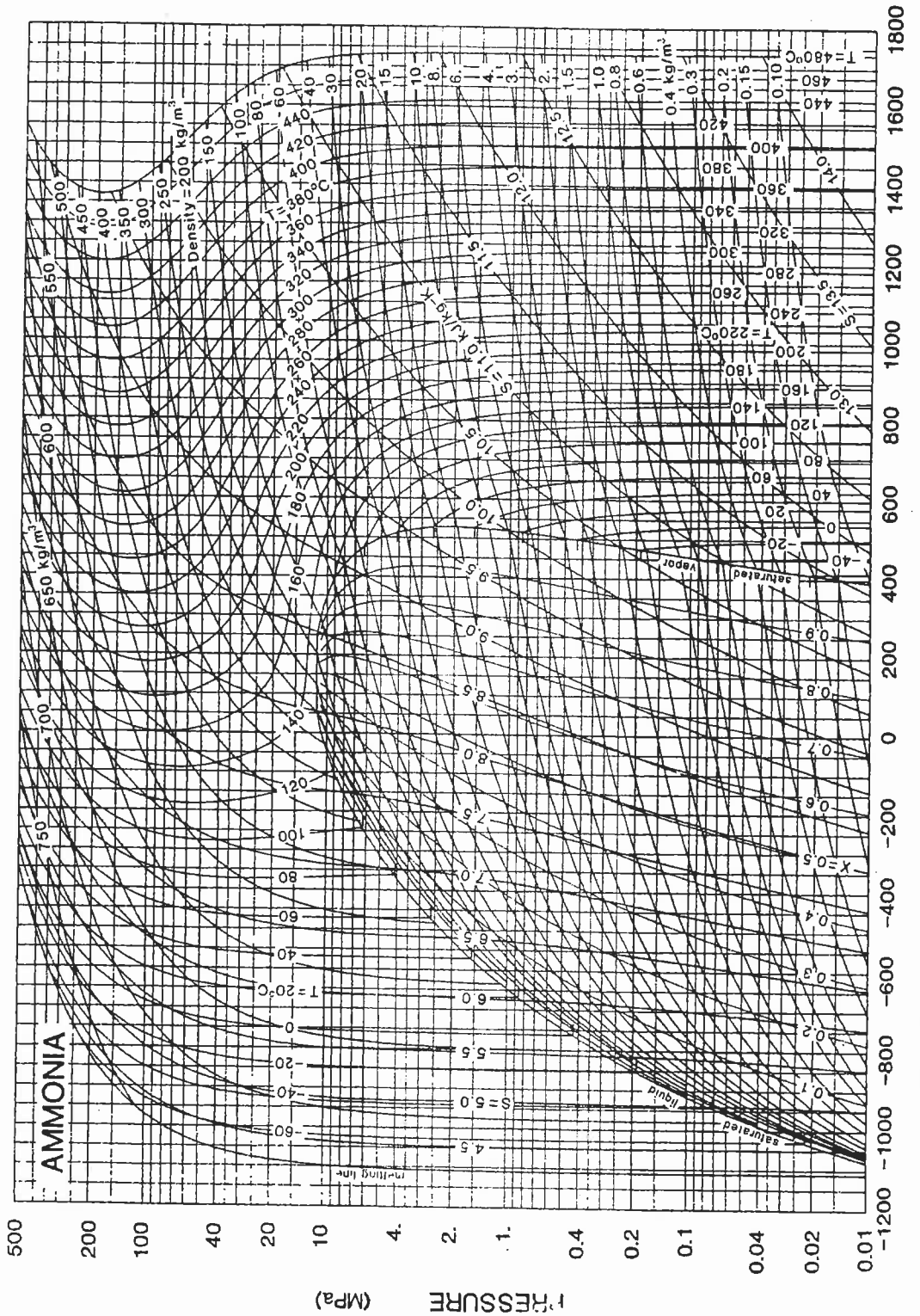


Fig. 21 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)
Note: The reference states for enthalpy and entropy differ from those in the table.