PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – May 2011

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. The usage of computers and internet is prohibited.**

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 ammoniaa are attached.**

PROBLEM 1. (20 POINTS)

A space is to be maintained at 24°C and 50% relative humidity. The total cooling load is 35 kW of which 70% is sensible heat. Ventilation air at 500 L/s is required on a day when the outside conditions are 35°C and 55% relative humidity. Assume that the building is at sea level elevation, and that the supply air temperature is 14°C. For simplicity ignore the duct heat transfer and the fan air temperature rise.

a. **Make a diagram of the system, identifying each characteristic point.**
b. **Draw the operating cycle on the psychrometric chart provided and show for each significant point its dry bulb temperature and relative humidity.**
c. **Calculate the air supply rate.**
d. **Calculate the capacity of the coil (kW), apparatus dew point, coil by-pass factor.**
e. **Calculate grand sensible heat factor (GSHF) required for operation on this specific day.**

PROBLEM 2. (20 POINTS)

A building has a total heating load of 240,000 Btu/hr. The sensible heat factor for the space is 0.8, and the space is to be maintained at 74°F and 30% relative humidity.
Outdoor air at 40°F and 20% relative humidity in the amount of 1200 cfm is required for ventilation. Air is supplied to the space at 120°F. Outdoor air is mixed with return air, then heated and humidified.
Water vapour at atmospheric pressure is used to humidify the air.

a. **Sketch the system.**
b. **Find the conditions and the amount of air supplied to the space**
c. **Calculate the temperature rise of air in the heating coil (furnace).**
d. **Draw the process on the psychrometric chart, identifying each significant point.**
e. **Calculate the amount of water vapour required.**
f. **Calculate the capacity of the heating coil (furnace).**

PROBLEM 3. (20 POINTS)

Determine the combined ceiling and roof winter U value for the following construction:

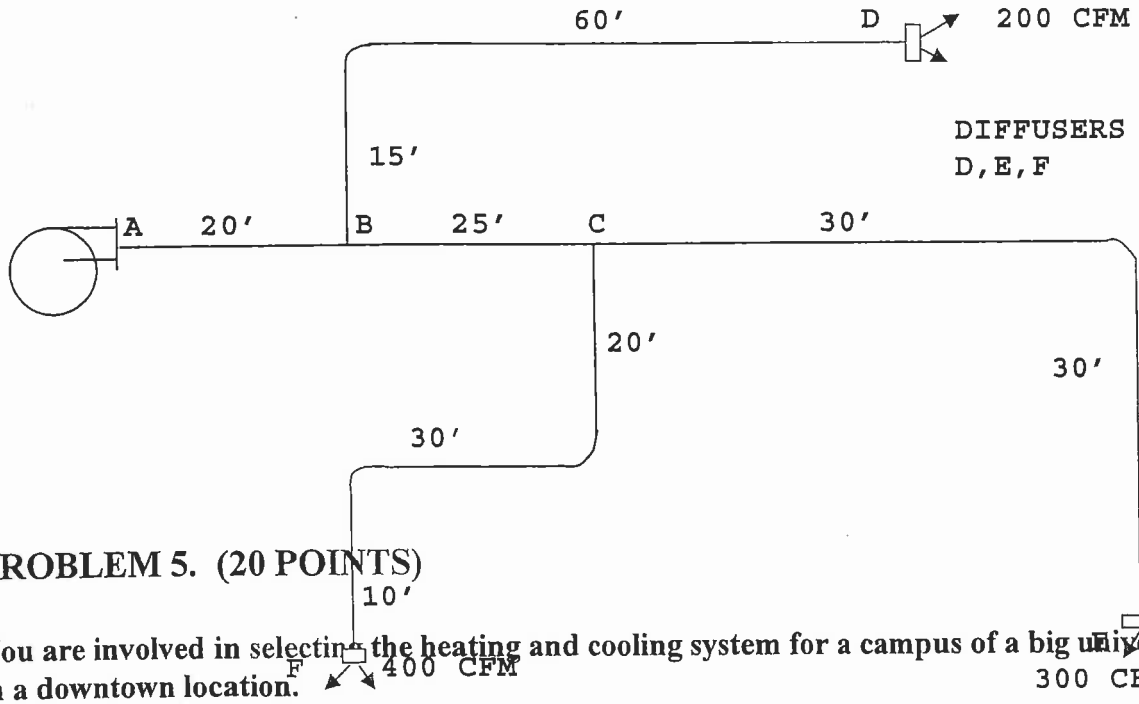
The ceiling consist of 3/8-in. gypsum board on 2 by 6 in. ceiling joists.
Six inches of fiberglass (mineral/glass wool) insulation fills the space between joists.
The pitched roof has asphalt singles on 25/32-in. solid wood sheathing with no insulation between rafters.
The ratio of roof area to ceiling area is 1:3. The attic is unvented in winter.

PROBLEM 4. (20 POINTS)

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

Data:
- **velocity in section AB is limited to 1000 FPM.**
- **total pressure loss across each diffuser is 0.02 in. w.g. at the given flow rates.**

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



PROBLEM 5. (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 energy and 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 (not located on campus) that provides cold water and hot water for heating and cooling.**
- **Cogeneration : generating own power and heating (if also cooling is provided is called trigeneration.)**
- **Usage of thermal storage.**

PROBLEM 6. (20 POINTS)

A test on a fan running at 1000 r.p.m gave the characteristics shown below. The fan has a two-speed motor so it can also run at 1500 r.p.m.
The fan is used for air flow in a duct which has a resistance of 38.1 mm of water at a flow rate of 1.42 m^3/s . For some process a filter is used which has a resistance of 12.7 mm of water at a flow rate of 1.42 m^3/s and in this case the fan is run at the higher speed.

Volume flow rate (m^3/s)	*0.5*	*1.0*	*1.5*	*2.0*	*2.5*	*3.0*
Pressure (mm water)	46	52	53	48	37	19
Power consumption(kW)	0.80	1.10	1.40	1.70	2.05	2.60

Calculate:

a. The volume rate of air delivered when the filter is fitted
b. The power required under these conditions
c. The fan efficiency at the operating point
d. The resistance required to be put in series with the system to reduce the flow rate by 0.47 m^3/s

PROBLEM 7. (20 POINTS)

An ammonia two-stage vapour compression refrigeration plant operates with a condenser pressure of 180 psi, a flash chamber pressure of 75 psi and an evaporator pressure of 30 psi. Saturated liquid leaves the condenser and after being throttled to 75 psi, 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 3°F. 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 115 tons.

PROBLEM 8 (20 POINTS)

a. 10 points

Determine the instantaneous heat gain through a 1m x 2 m west-facing window at 5 p.m. solar time, on a clear day, July 21, at 40 deg. north latitude. The window has two sheets of glass with 1.7 cm air space between them. The outer layer is grey heat absorbing glass; the inner layer is standard glass. Assume an interior film coefficient of

7 $W/m^2\,^oC$, an outdoor temperature of 32°C and an indoor temperature of 25 °C.

b. 10 points

Using the degree-day method, estimate the quantity of natural gas required to heat a building in Ottawa, Ontario. Design conditions are 70 °F inside and -12 °F outside. The heating load is 350,000 Btu/hr. Furnace efficiency is 80% and fuel heating value is 1000 Btu/ft^3 (at standard conditions).

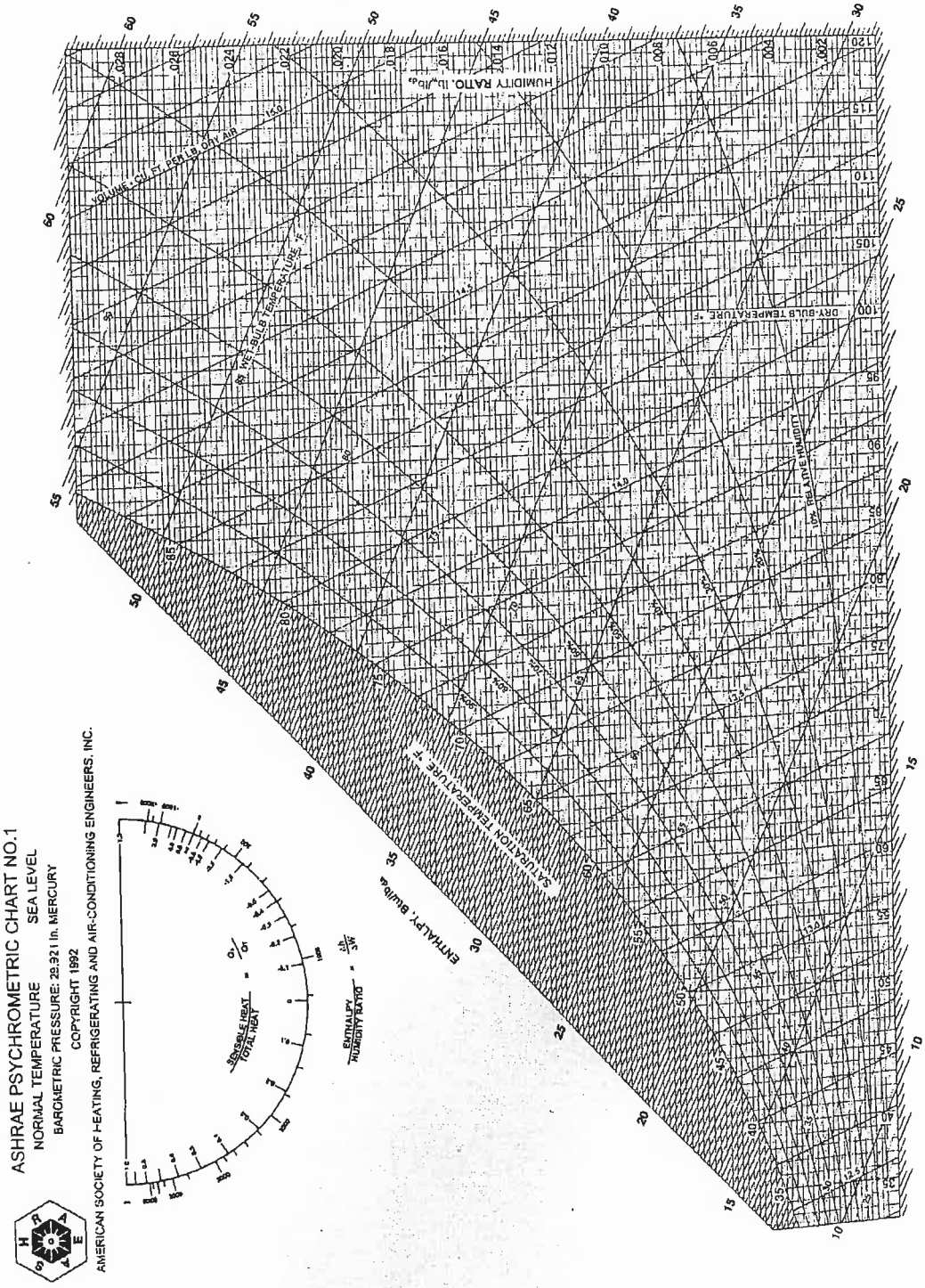
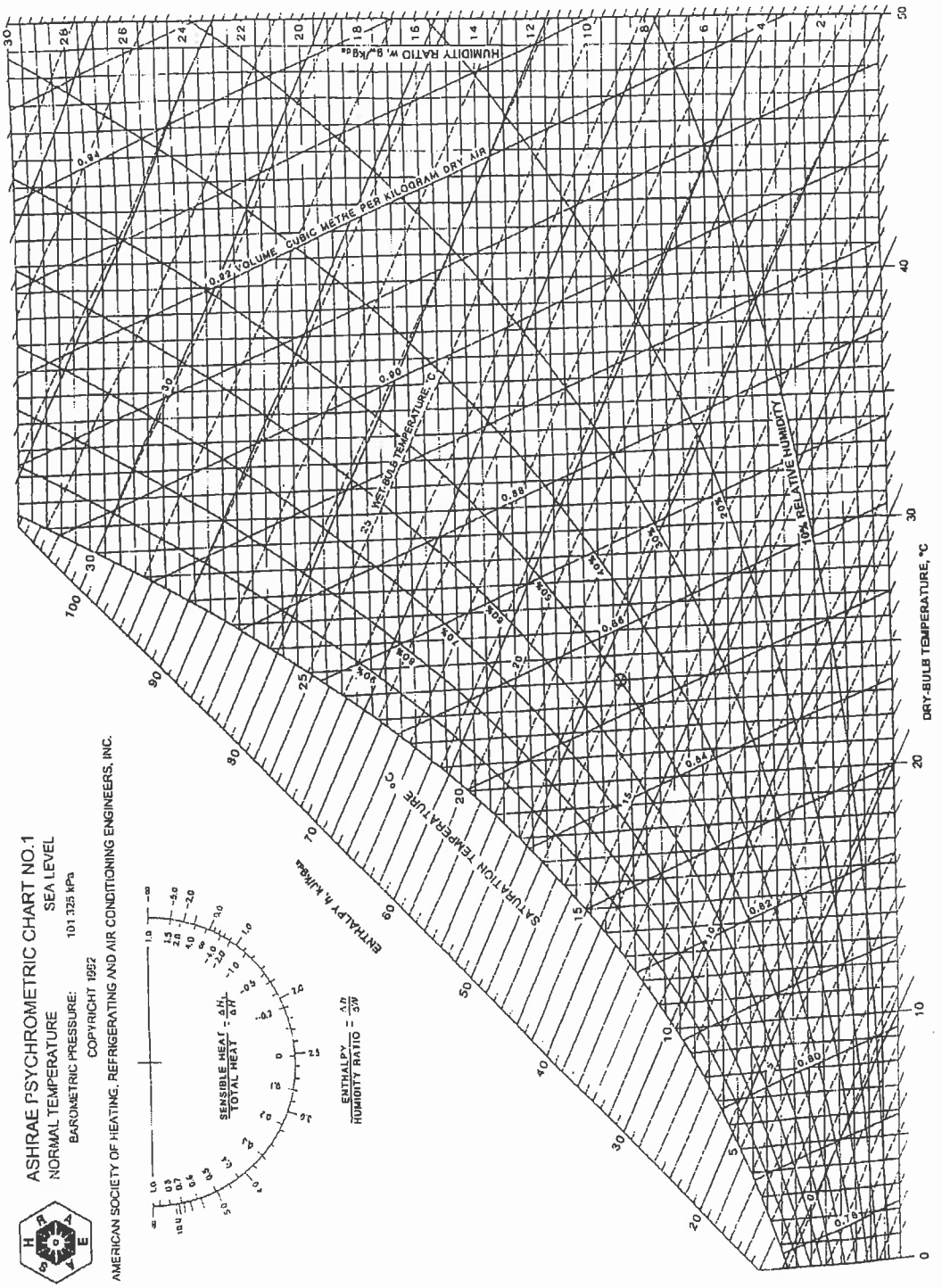


Fig. 1 ASHRAE Psychrometric Chart No. 1



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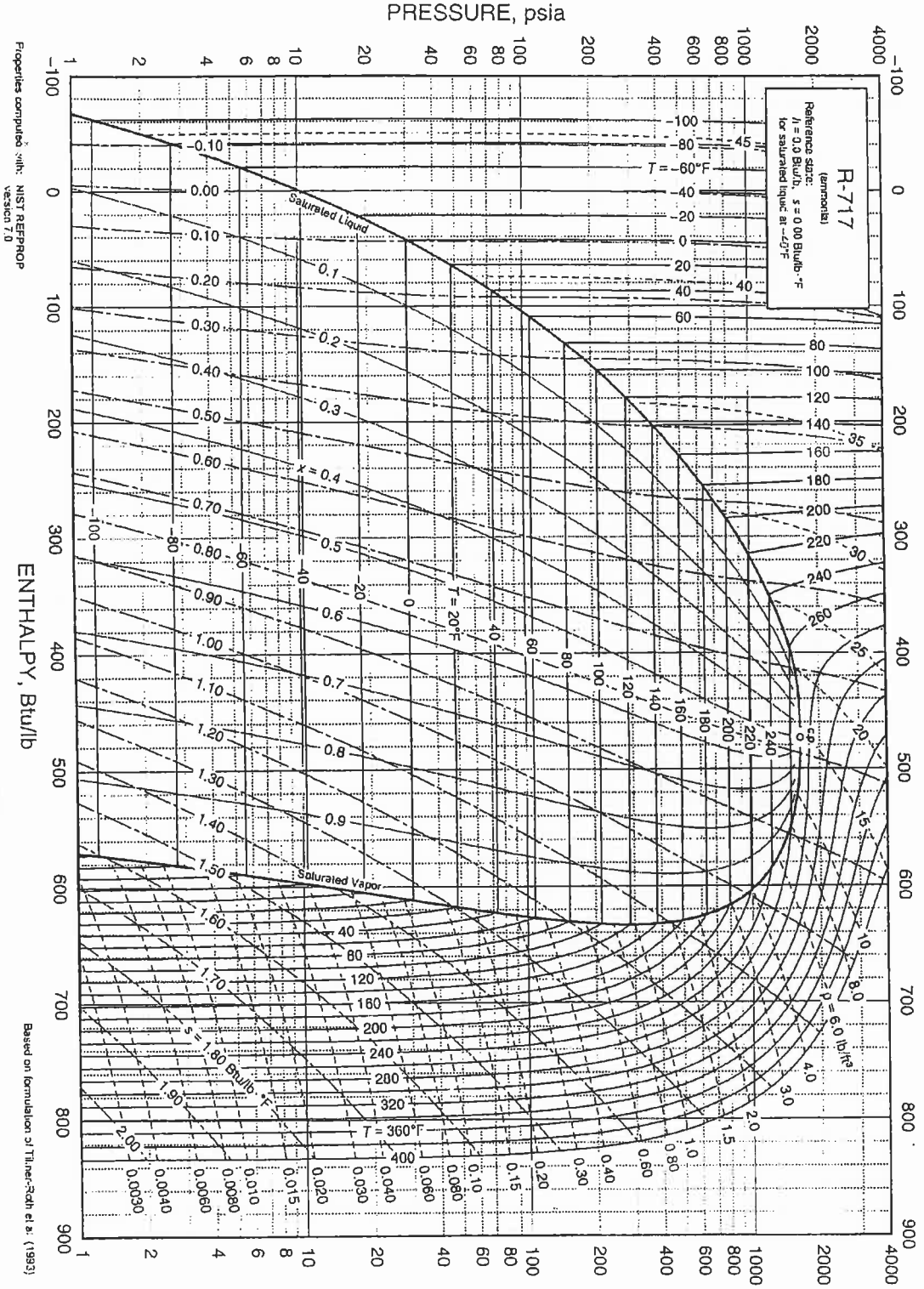

Fig. 16 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)