PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – May 2010

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)

A factory has two zones. Zone 1 and 2 are both maintained at 75°*FdB*. The design supply air flow rates to Zone 1 and 2 are 3200 and 2000 *CFM*, respectively. At a certain hour in summer, the cooling loads for Zone 1 and 2 are 60,000 *Btu/hr* and 30,000 *Btu/hr*, respectively.
Assume dry air conditions and air density of 0.075 *lbm/ft3*.

(a) If a single-duct constant-volume system with local reheat boxes is used with discriminator control, what would the required amount of reheat (*Btu/hr*) to be provided in each zone at the hour?
The design cold air supply temperatures are 55°*FDB*.

(b) If a VAV system with 20% minimum position is used with discriminator control, what would the required amount of reheat (*Btu/hr*) be provided by a reheater in each zone at the hour? The design supply air temperature is 55°*FDB*.

PROBLEM 2. (20 POINTS)

A space is to be maintained at 78°F and 50% relative humidity. The total cooling load is 150,000 Btu/h of which 70% is sensible heat. Ventilation air at 1500 ft^3/min (CFM) is required on a day when the conditions are 95°F and 55% relative humidity. Assume supply temperature of 55° F dB, and neglect the effect of the fans.

- 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 space air supply.**
- d. **Calculate the cooling coil rating. Can you find the by-pass factor?**

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

PROBLEM 3. (20 POINTS)

A building has a total heating load of 155 kW and the space design conditions are 21°C and 30% relative humidity.

Outdoor air enters the preheating coil at -15°C and essentially 0% relative humidity and is heated to 16°C and mixed with the return air. The mixture is first heated and then humidified in two separate processes to 40°C and 30% relative humidity for supply to the space. Saturated vapour at 1.13 bar (absolute) pressure is used to humidify the air. Ventilation air required is 1/3 (by volume) of the supply air.

a. Sketch the system.
b. Find the amount of air supplied to the space
c. Calculate the temperature rise of air in the heating coil.
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 and the preheater.

PROBLEM 4. (20 POINTS)

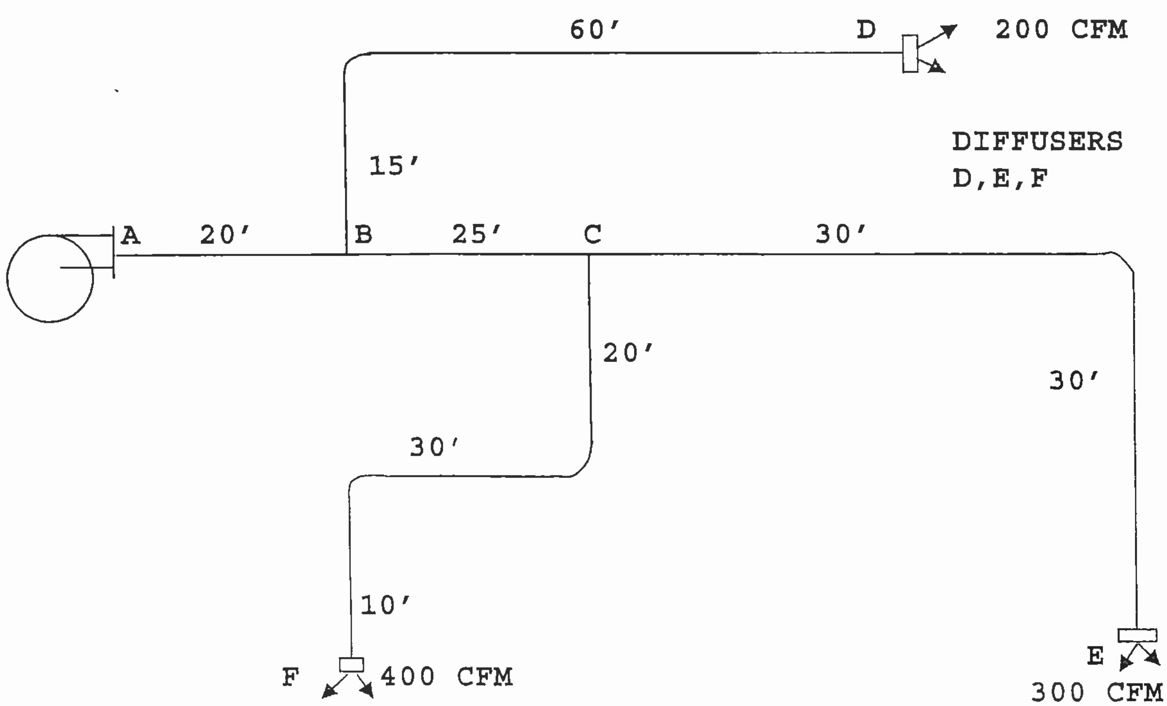
Estimate the indoor-outdoor pressure differential for the first and sixteenth floors of a 16-story office building with plan dimensions of 150 ft x 50 ft and 10 ft floor height.
The structure has fixed windows and is of conventional curtain wall construction.
There are double vestibule-type doors on 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 80°F.

PROBLEM 5. (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 0.02 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 the equivalent rectangular dimensions.



PROBLEM 6. (20 POINTS)

a. 7 points

Describe succinctly the advantages and disadvantages of VAV systems

b. 6 points

Suppose there is a source of NOx in a building that produces 120 μg/s of NOx. If the air inside the building is always well mixed, and if the outdoor air has already a NOx concentration of 40 μg/m^3, what outdoor airflow is needed to satisfy the required (recommended by standard) conditions in the building.

c. 7 points

Describe how building systems can be improved, in order to achieve more sustainability.

PROBLEM 7. (20 POINTS)

The exterior wall of a room in an office building has:

- a solid wood door without a storm door; 3 ft. by 6 ft. 10 inches, thick 1.75 inches;
- three 40 inches by 36 inches glass windows with no sash, double insulating glass with 0.5 inches air space, aluminium frames with thermal break.

The wall is 8 ft. high by 24 ft. long. The wall construction is such that it has a U (overall heat transfer) factor 0.19 Btu/hr. ft^2 °F.

Assume parallel heat flow through the wall, windows and door, and calculate the overall thermal resistance and the overall U factor for the combined wall, windows and door.

PROBLEM 8. (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 450 kW

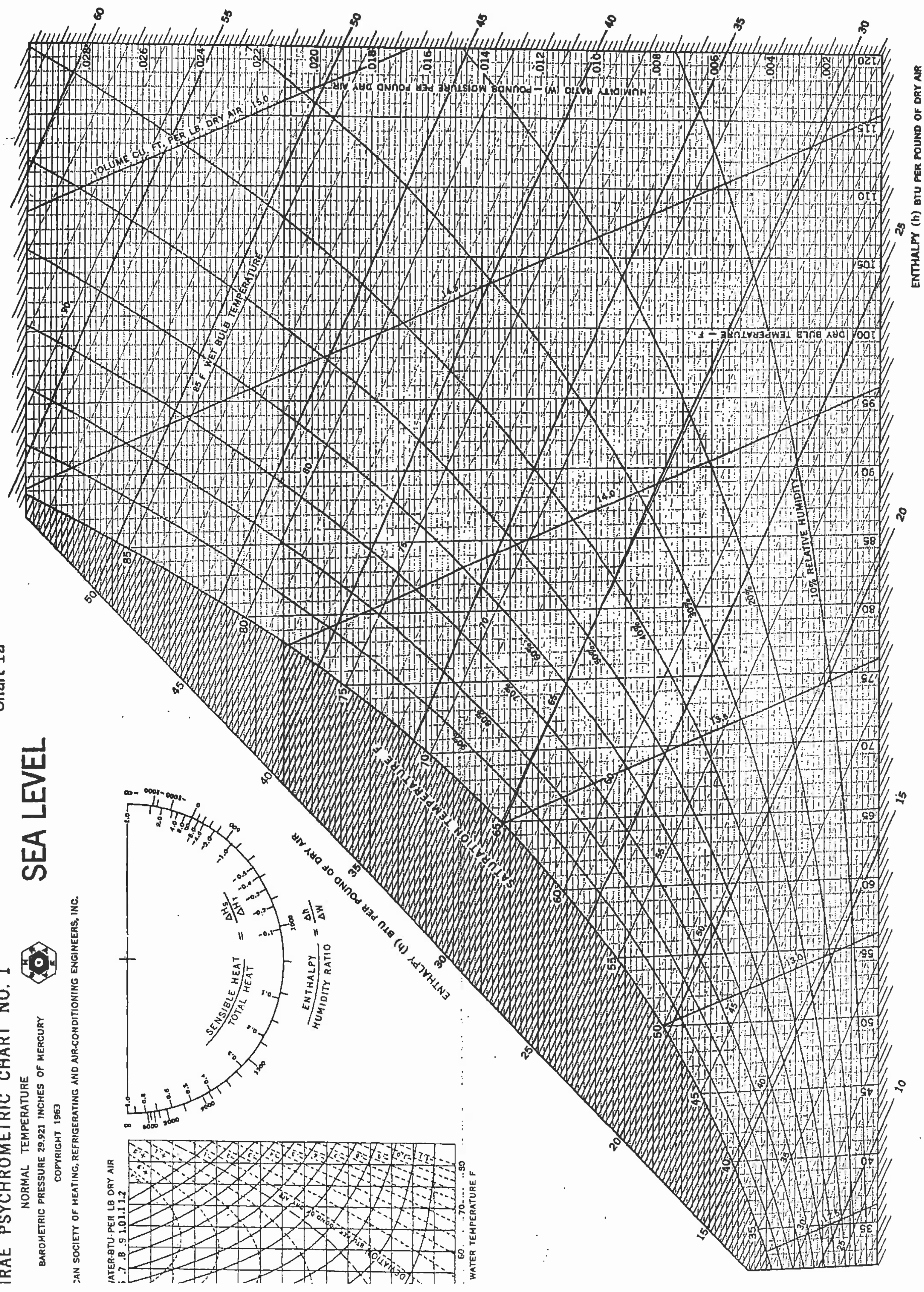


Chart 1a
SEA LEVEL
IRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
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CAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔHT
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
DRY BULB TEMPERATURE — F
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
85 F WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
WATER TEMPERATURE F

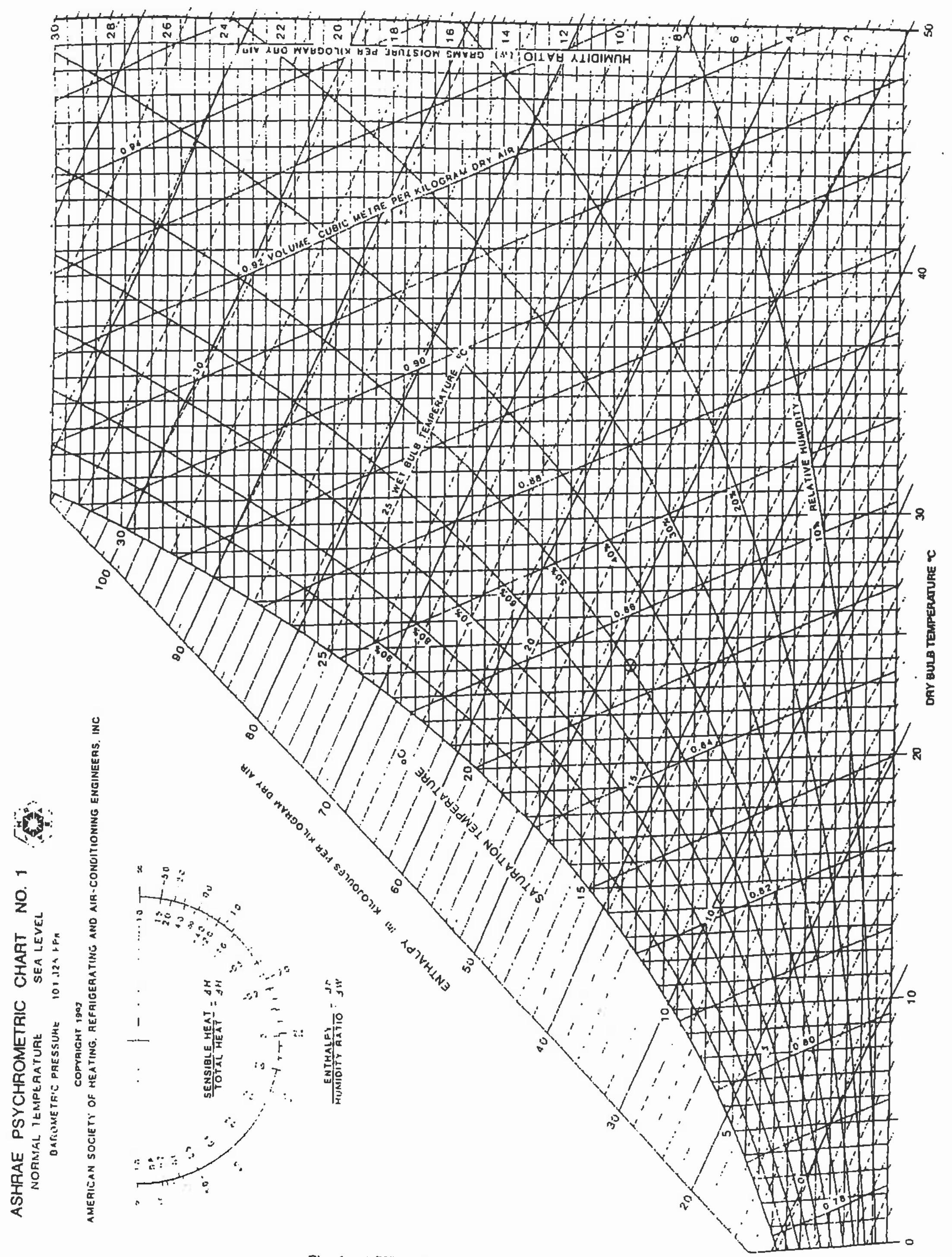

Fig. 1 ASHRAE Psychrometric Chart No. 1

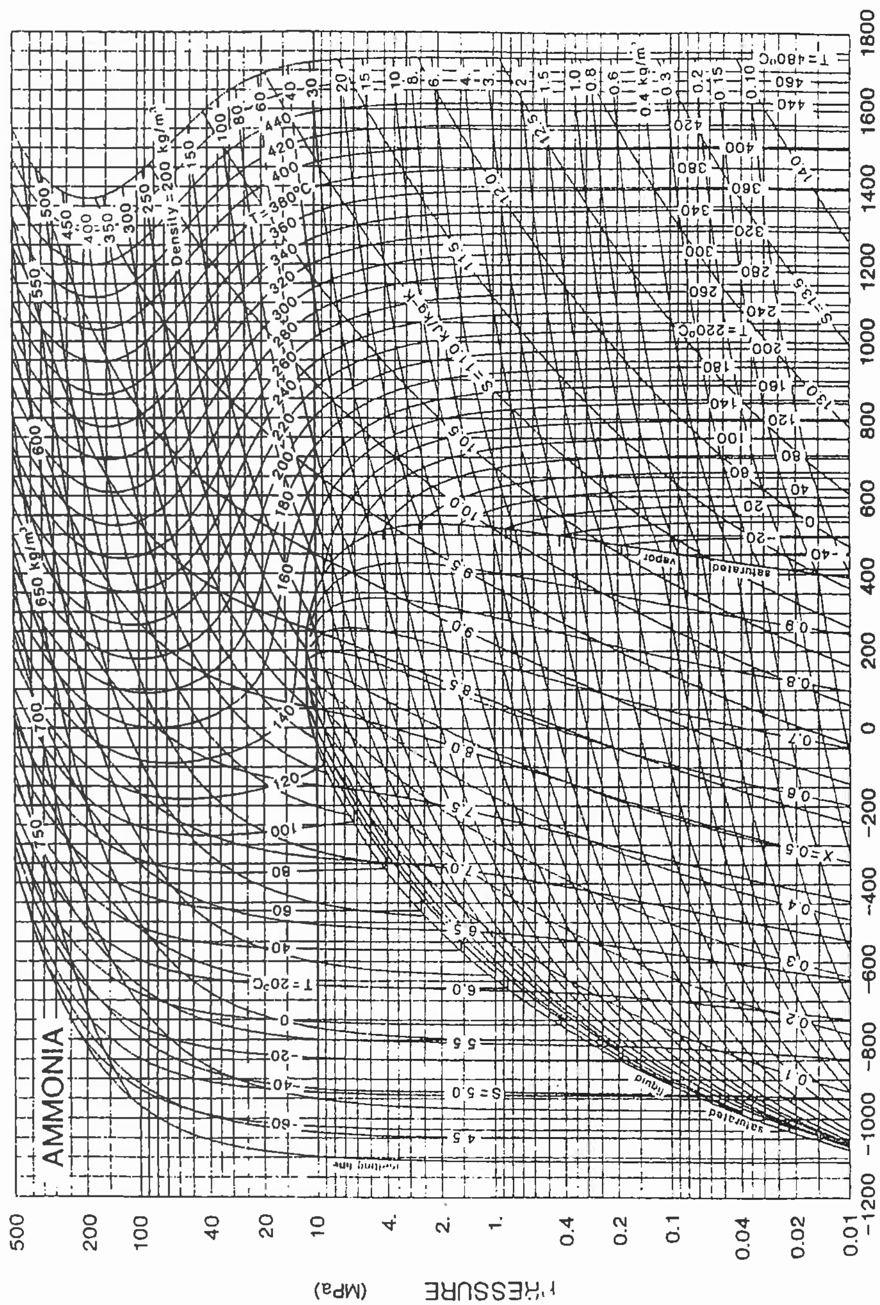

Fig. 21 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)