May 2018

16-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. The usage of computers, internet and smart phones 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. **Problem one is 30 points, and problem 2 is 10 points, the rest are all 20 points each. Indicate which five questions are to be graded on the cover of the first examination workbook.**

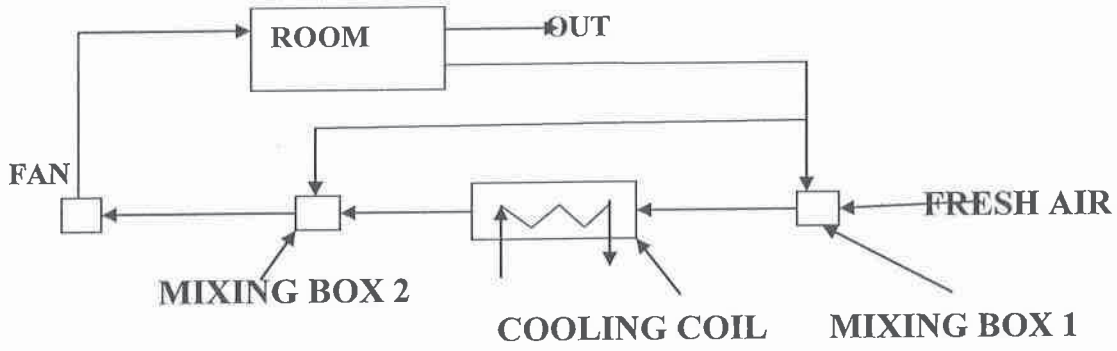
7. **Psychrometric charts and the p-h diagram for the refrigerant are attached.**

PROBLEM 1. (30 POINTS)

In summer a room is to be maintained at 20°C, RH 50%, when the outside air is at 26°C, percentage saturation 50%. The mass flow of dry air supplied to the room is 2 kg/s at 15°C. Fresh air is mixed with recirculated air in the ratio three parts recirculated air to one part fresh air. The air after mixing is passed over a cooling coil with an apparatus dew point of 4 °C and a coil bypass factor of 0.1.
On leaving the cooling coil the air passes over a heating coil and is the delivered to the room by the fan; the fan and the ducting cause a 2°C rise in temperature between the heating coil and the room.

a. **Draw a diagram of the system.**
b. **Draw the operating cycle on the psychrometric chart provided.**
c. **Identify each significant point, on the diagram and psychrometric chart, and note for each of these points its dry bulb and wet bulb temperature.**
d. **Calculate the capacity of the cooling coil (kW),**
e. **Calculate the heating coil load**

Since there is no need to control the humidity in the room it is decided to remove the heating coil and use an arrangement as in the figure below, to supply the same mass flow of air as the same supply temperature as before. The design conditions for the room are assumed to be unchanged. The mixing ratio for the first mixing box is now one part fresh air to one part recirculated air. Assuming that the cooling coil has the same apparatus dew point and bypass factor, and that there is 2°C rise in temperature from the fan and ducting as before, calculate the percentage saturation of the air supplied to the room.



PROBLEM 2. (10 POINTS)

a. 5 points

An apartment is maintained at 72°F, 50% RH in the winter. The owners have enclosed a balcony and are complaining of moisture on the outside walls of the enclosed balcony. The pressure is 14.5 psia.
At what temperature the walls of the enclosed balcony will begin to have condensation?

b. 5 points

What is the proper construction technique to avoid this phenomenon?

PROBLEM 3. (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/ft^3

(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 4. (20 POINTS)

A heat pump is used to heat a building. The supply of heat is taken from ground water at 4°C. Air is required to be delivered to the building at atmospheric pressure and 35°C, at a rate of 0.8 m^3/s. The outside air at 6°C is heated as it passes over the condenser coils of the heat pump. The refrigerant R-134a, leaves the evaporator dry saturated, and there is no undercooling in the condenser.
A temperature difference of 14°C is necessary for the transfer of heat from the ground water to the refrigerant in the evaporator. The delivery pressure of the compressor is 1.0164 MPa.

Draw a simple diagram of the system and show the complete cycle on the p-h chart attached.

a. **Calculate the coefficient of performance COP.**
b. **Calculate the mass flow of the refrigerant**
c. **Calculate the swept volume of the compressor (cm^3) which is single acting and runs at 300 rpm. The volumetric efficiency of the compressor is 85%.**
d. **Calculate the cost of heating per hour if the overall efficiency (compressor/motor) is 87% and the cost of electricity is 0.10 $/kWh. Compare with electric heating with electrical radiators. Comment.**

PROBLEM 5. (20 POINTS)

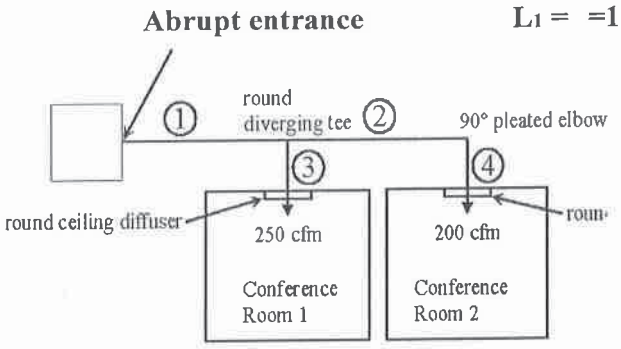
What is a zero net energy building?
Explain in no more then two pages, this concept, the design techniques and energy harvesting and conservation used to achieve this goal.

PROBLEM 6. (20 POINTS)

Use a design pressure loss of 0.08 in. wg per 100 ft to design the ductwork of a conference centre, as shown below.

a. **Using the equal friction method, determine the diameters (*in.*) of the ducts. The duct sizes must conform to the standard sizes.**
b. **Determine the total pressure loss and noise criterion (NC) number of each round ceiling diffuser.**
c. **Determine the total pressure loss of each run of ducts (in. wg) from plenum to each diffuser outlet, including diffuser loss.**
d. **Is damper necessary for balancing the system? If yes, where should it be placed?**

Note: Beware of the limiting air velocities in the ducts and the NC numbers of diffusers for acceptable noise level.



PROBLEM 7. (20 POINTS)

A conference room in a building in Toronto, Ontario, has two exposed walls (front and back) and measures 120 ft long, 60 ft wide and has a ceiling height of 20 ft. The conference room is on the second floor of a four-story building, and is not mechanically ventilated. The conference room is surrounded by conditioned space, left, right, up and down. Each of the exposed walls (each 120 ft long) contains 15 windows. The windows are double-hung (both upper and lower halves operable), wood framed, single glazed, non-weather-stripped, average fit, and each measures 3 ft wide by 5 ft tall. The window frame-wall joint is caulked. One of the exposed walls faces prevailing wind direction. The pressure difference between the outside and inside is estimated to be 0.2 in water (outside pressure is greater).

The wall construction is as follows:

- **4 in. face brick**
- **12 in. concrete block (sand and aggregate)**
- **4 in. fibreglass board insulation**
- **vapour barrier (plastic film)**
- **½ in plaster board**

a. **Indicate the indoor and outdoor design conditions. Justify your selection.**
b. **Calculate the heat loss from the room. Assume that there is no heat transfer between the room and conditioned spaces.**

PROBLEM 8. (20 POINTS)

a. 10 points

Each person in a room is assumed to be producing CO_2 at an average rate of 0.005 l/sec. Air with a CO_2 concentration of 260 ppm is being supplied to the room at a rate of 3.2 m^3/sec. It is desired to keep the concentration of CO_2 in the space below 1000 ppm. Assuming complete mixing how many persons could occupy the room and not exceed the desired CO_2 level.

b. 10 points

A mixed group of men and women occupy a space maintained at 70°F db and 64°F Wb. All are lightly clothed, with sedentary activity.

a. **Using the recommended limits of comfort, comment on the comfort of the group.**
b. **The MRT is 78°F. Suppose the group is moving around (light activity) instead of sitting. What is your conclusion about their comfort.**
c. **Suppose that the group is composed of retired people (65 years of age or more) playing cards. What is their comfort level? It will be necessary to change room conditions to ensure their comfort?**

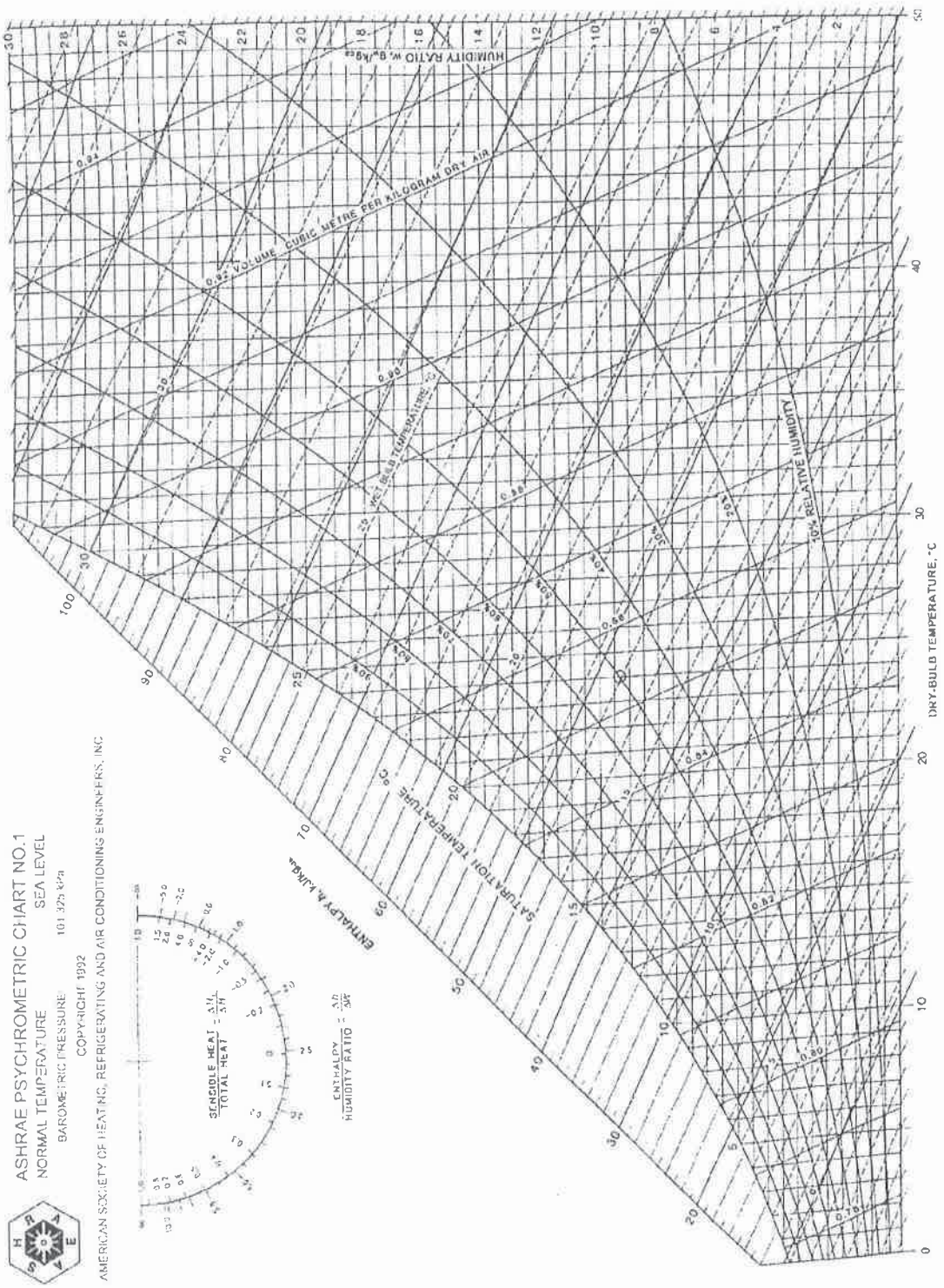
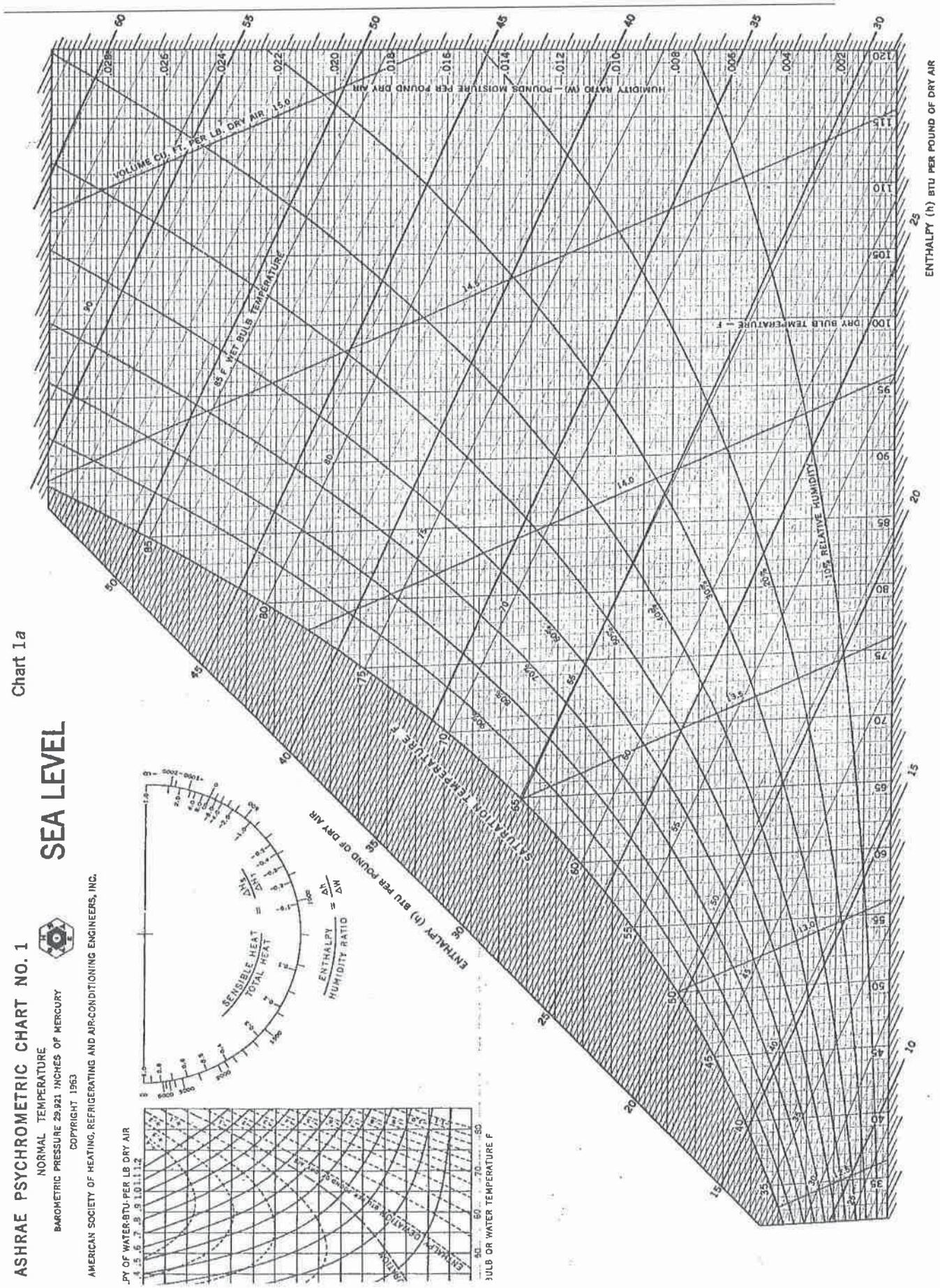
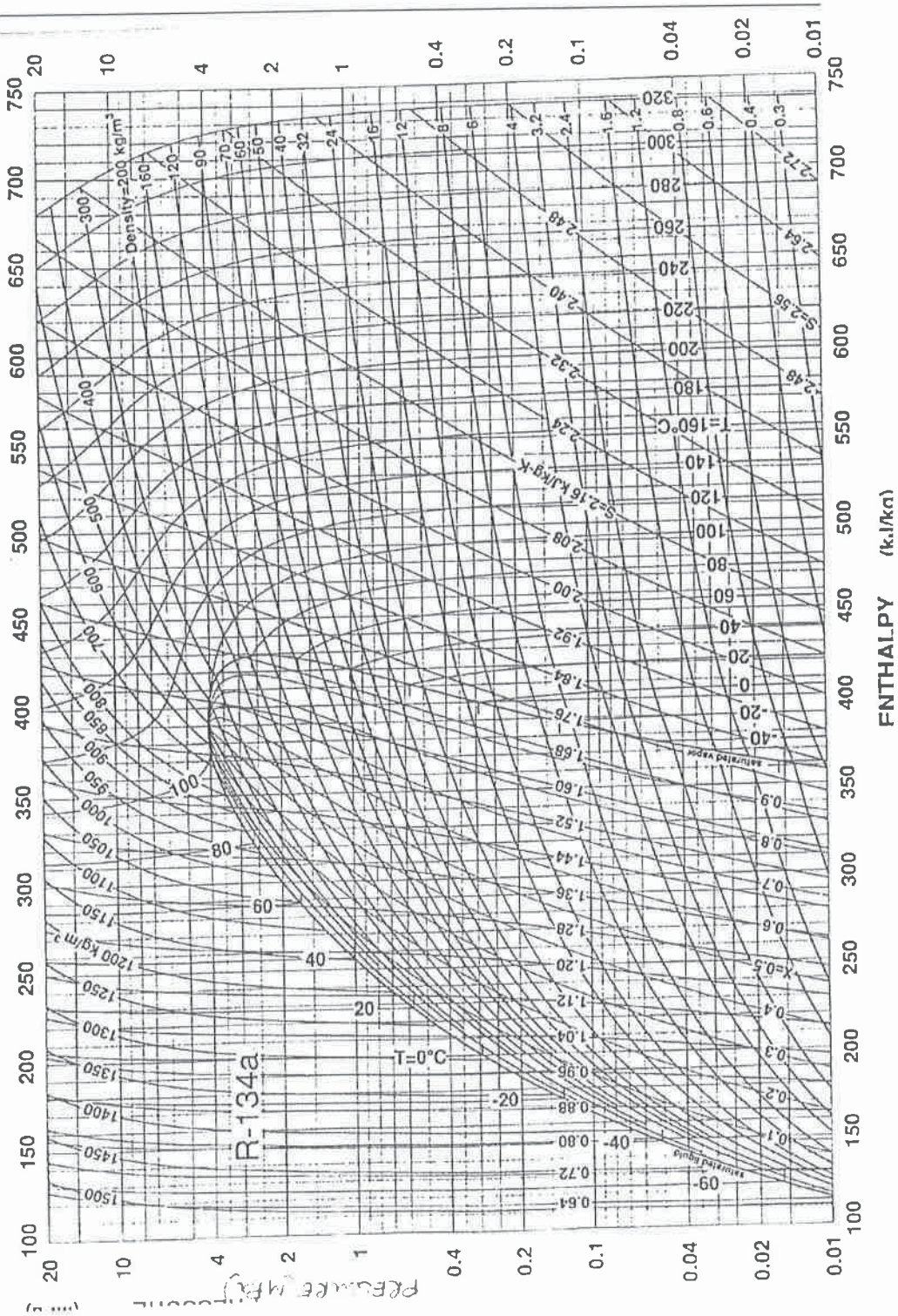


Fig. 1 ASHRAE Psychrometric Chart No. 1


ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1953
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
Chart 1a
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE — F
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE — F
ENTHALPY (h) BTU PER POUND OF DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
85 F WET BULB TEMPERATURE
100% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
PY OF WATER-BTU PER LB DRY AIR
ULB OR WATER TEMPERATURE F


R-134a
ENTHALPY (kJ/kg)
T=0°C
T=160°C
Saturated vapor
Saturated liquid
Density=200 kg/m³
X=0.5