National Examinations December 2019

16-Mex-B4, 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 ONLY textbooks and reference books. NO NOTES AND SOLVED PROBLEMS.

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. Each problem is 20 points. Indicate which five questions are to be graded on the cover of the first examination workbook. The first five in exam book will be graded.

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

PROBLEM 1. (20 POINTS)

A hospital operating room air conditioning system is being designed to use a fan and a cooling coil. To avoid recirculating bacteria 100% outside filtered air is used. During summer the air leaving the coil and supplied to the space is at 55°F, 100% RH. The summer design loads are 40,000btu/hr sensible and 10,000 Btu/hr latent.
Outdoor design conditions are 95°F DB and 75°F WB.

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 air supply rate.
e. Calculate the capacity of the coil Btu/hr.
f. Determine the humidity of the air leaving the operating room %.

Assume sea level conditions, and neglect the effects of duct heat transfer and fan air temperature rise.

PROBLEM 2. (20 POINTS)

An industrial process requires 6 kg/s of cooling water which leaves the process heat exchanger at 46°C. It is proposed to use an induced draft to restore it to the required inlet temperature of 25°C.
The atmospheric air is at 15°C 50% saturation, the air leaving the tower is at 25°C saturated, the power input to the cooling tower fan is 4 kW, and the pressure throughout the tower is 1.01325 bar.
The make-up water is added external to the tower at a temperature of 10°C.

a. Sketch the draft cooling indicating the flows.
b. Calculate the air volumetric flow at fan outlet.
c. Calculate the mass flow of make-up water required.

PROBLEM 3. (20 POINTS)

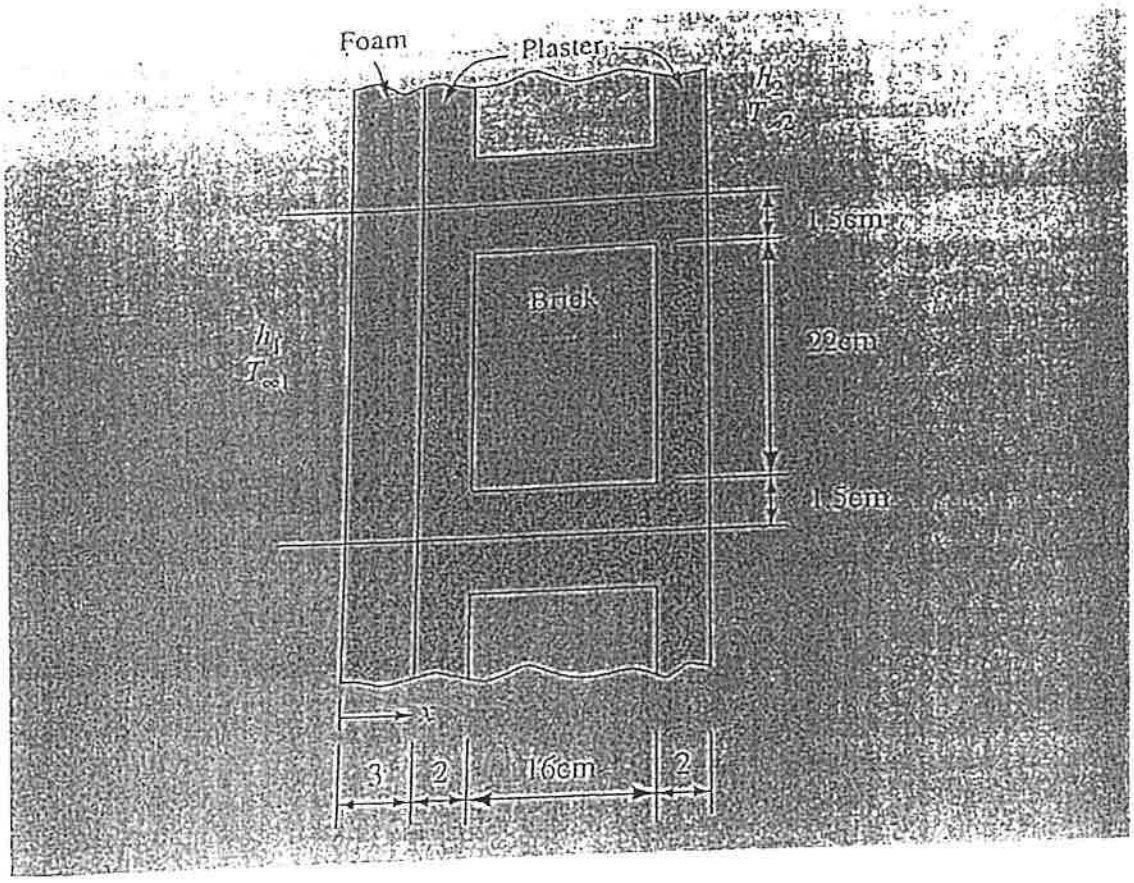
Describe succinctly, in maximum 3 pages, a self sustainable house.
Explain what is means a self sustainable house.
Describe how must be build and the house systems (power, heating and cooling, water and sanitary, waste management) that make it self sustainable.

PROBLEM 4. (20 POINTS)

a. 15 points

A 3-m-high and 5-m-wide wall consist of a long 16cm x 22cm cross section horizontal bricks (k=0.72 W/m°C) separated by 3-cm thick plaster layers (k=0.22 W/m°C). There are also 2-cm thick plaster layers on each side of the brick, and 3-cm thick rigid foam (k=0.026W/m°C) on the inner side of the wall as shown below.
The indoor and outdoor temperatures are 25°C and -10°C.
The convection heat transfer coefficients on the inner and the outer sides are h_1=10W/m^{2}°C and h_2=25W/m^{2}°C respectively.

Assuming one dimensional heat transfer and disregarding radiation, calculate the rate of heat transfer through the wall.



b. 5 points

Explain moisture flow through walls. Discuss vapour barriers, their role and installation.

PROBLEM 5. (20 POINTS)

A ground source heat pump is used to heat a building. The supply of heat is taken from ground (earth) at 45°F. Air is required to be delivered to the building at atmospheric pressure and 90°F at a rate of 3,200 CFM. The outside air at 45°F is heated as it passes over the condenser coils of the heat pump.
A temperature difference of 30°F is necessary for the transfer of heat from the ground to the refrigerant in the evaporator. The refrigerant R-134a, enters the compressor at 20°F and a pressure of 30psia. The refrigerant leaves the compressor at 200 psia and leaves the evaporator saturated.

a. Draw a simple diagram of the system and show the complete cycle on the p-h chart attached.
b. Calculate the coefficient of performance COP.
c. Calculate the mass flow of the refrigerant.
d. Calculate the power input to the heat pump.
e. 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 6. (20 POINTS)

A small commercial building is located in Winnipeg, Manitoba.
Using the degree-day method estimate the quantity of natural gas required to heat it. Select the design conditions. The computed heat load is 100 kW. Assume an efficiency factor of 85%.
The heating value of natural gas is 37MJ/m^3.
If electricity were used to heat the building, how much energy would be required in kWh, assuming 100 % efficiency factor. If electrical energy costs 10 cents per kWh and natural gas 11.75 cents per m^3, what are the relative heating costs?
Assuming that the power plant produces electricity with an efficiency of 33%, compare the prices required to heat the building using a gas furnace or an electrical furnace.
Comment about of environmental concerns.

PROBLEM 7. (20 POINTS)

a. 5 points

Suppose there is a source of NOx in a building that produces 115 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 55 μg/m^3, what outdoor airflow is needed to satisfy the required (recommended by standard) conditions in the building.

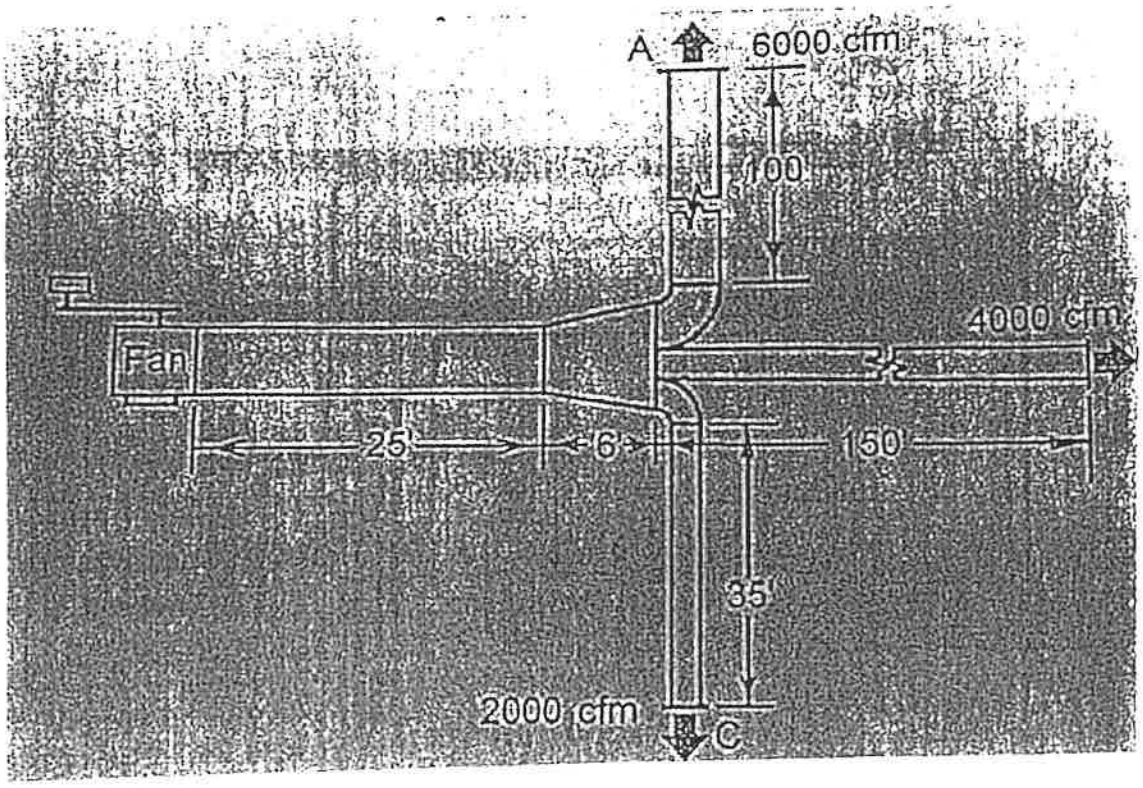
b. 15 points

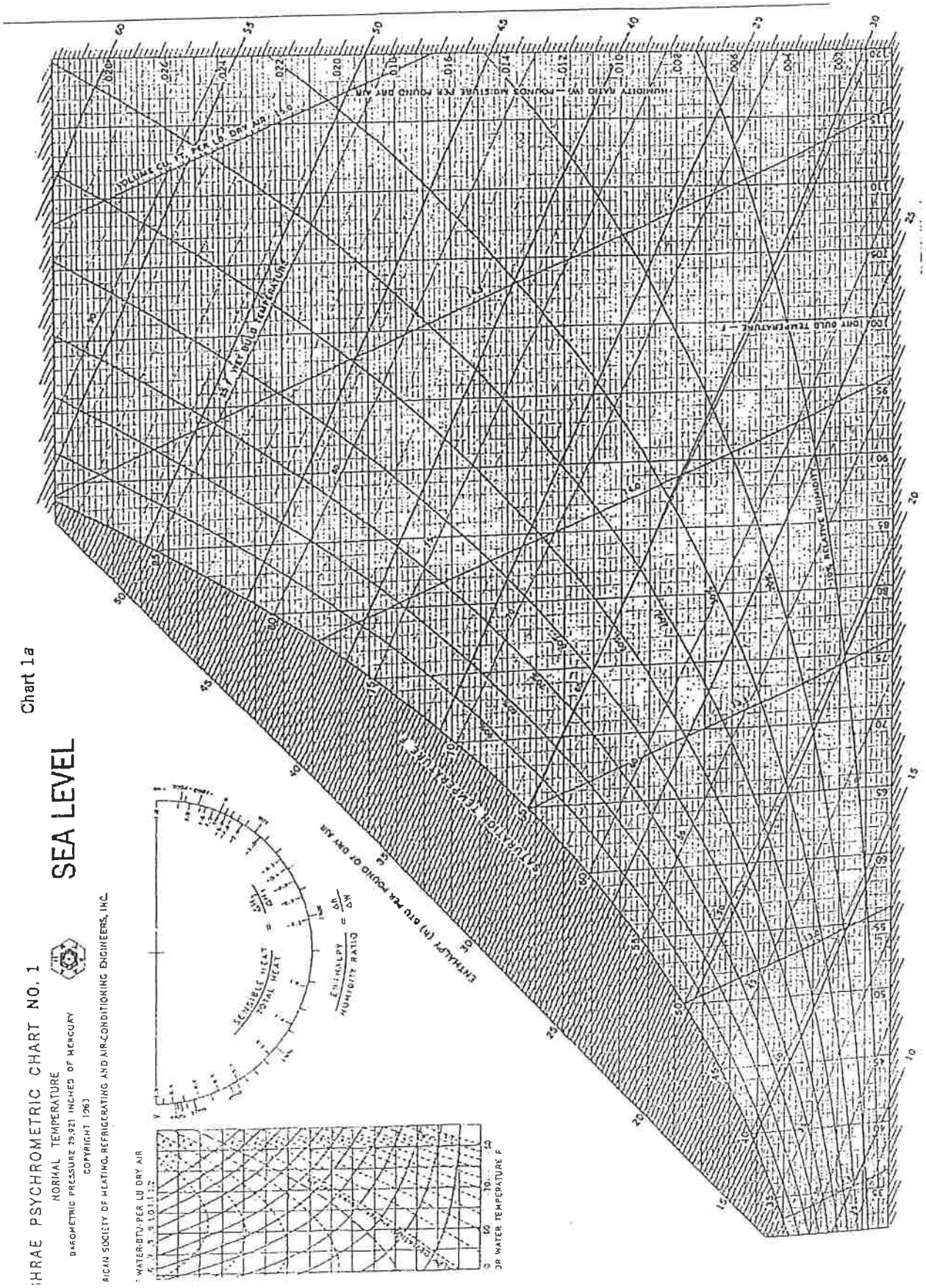
Estimate the indoor-outdoor pressure differential for the first and tenth floors of a 10-story office building with plan dimensions of 150 ft x 50 ft and 10 ft floor height.
The structure has fixed windows and is of conventional curtain wall construction.
There are double vestibule-type doors on long sides of the building. Under winter conditions a 15 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 8. (20 POINTS)

A 40 in by 24 in rectangular duct conveying 12,000 cfm of standard air divides into 3 branches (see below). Branch A carries 6,000 cfm for 100 ft, B carries 4,000 cfm for 150ft, and C carries 2,000 cfm for 35ft.

a. Size each branch for equal total friction of 0.15 in water. Do not exceed upper velocity of 2,000 fpm.
b. What is the total friction loss if the same quantity of air, 12,000 cfm at a temperature of 150°F and 14.0psia is passed through the same system as part (a).
c. Assuming a fan is selected for part, at what percentage of speed in part (a) must the fan run to satisfy part (b).




ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
Chart 1a
DRY BULB TEMPERATURE — F
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
ENTHALPY (h) BTU PER POUND OF DRY AIR
WET BULB TEMPERATURE
VOLUME CU. FT. PER LB. DRY AIR
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
DRY BULB TEMPERATURE F
WATER-BTU PER LB DRY AIR

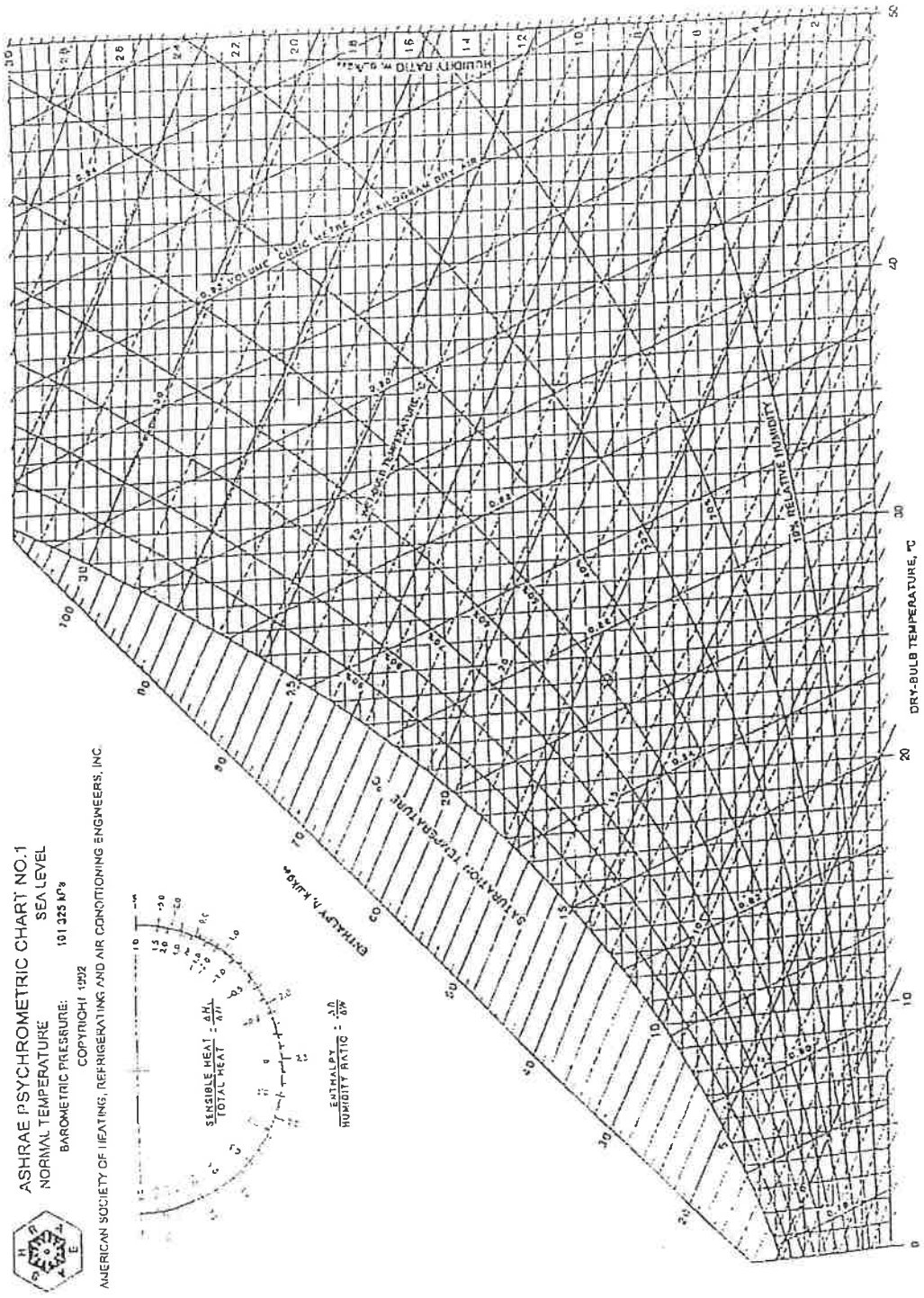
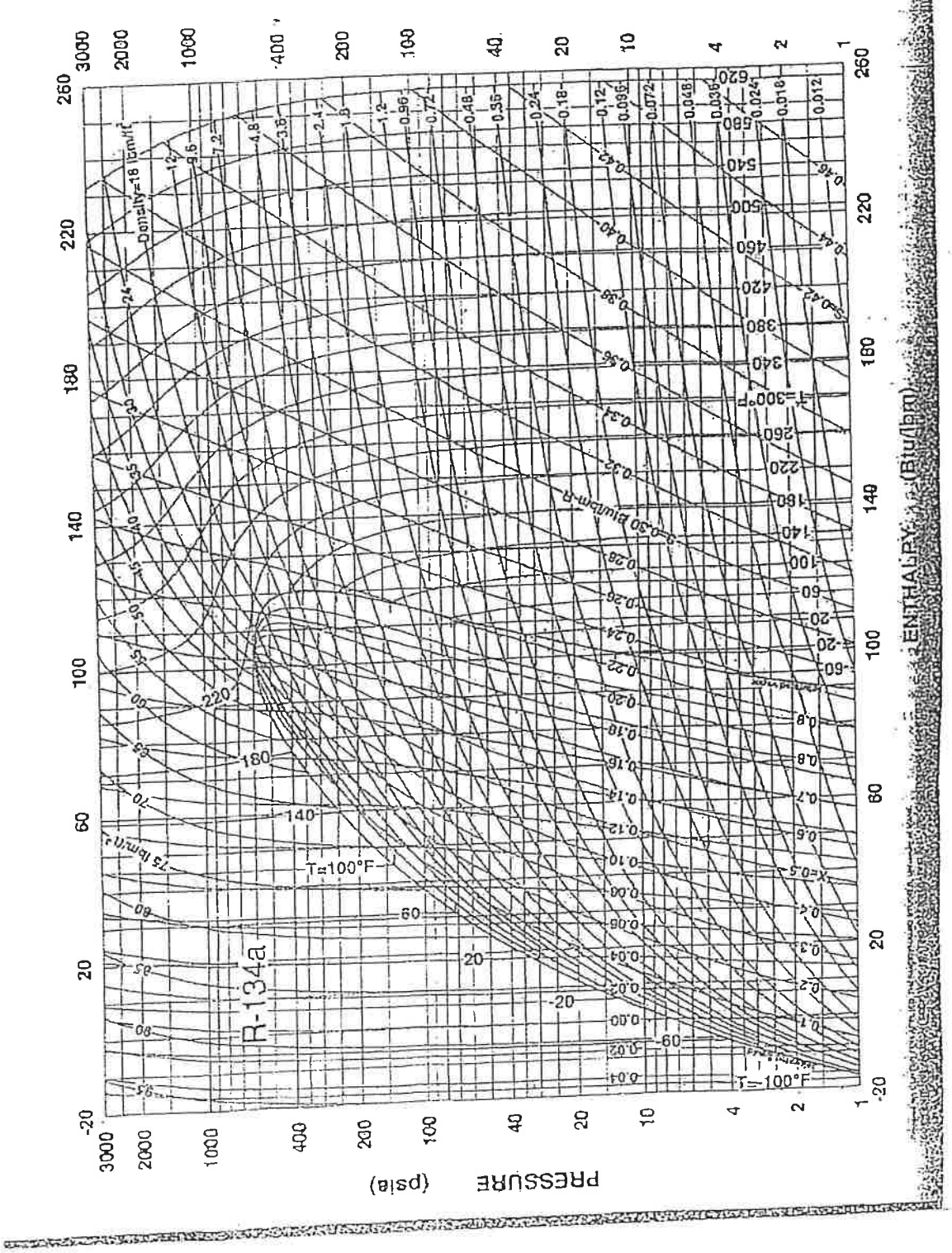


Fig. 1 ASHRAE Psychrometric Chart No. 1


R-134a
PRESSURE (psia)
ENTHALPY (Btu/lbm)
Density=18 lbm/ft³
T=300°F
T=100°F
T=-100°F
X=0.5
0.50 Btu/lbm-R
75 lbm/ft³