NATIONAL EXAMS - MAY 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 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)

A small office building has a design cooling load of 195,500 Btu/hr sensible heat and 34,500 Btu/hr latent heat. Room design conditions are 78°F dB and 67°F wB. Outside air at 90°FdB and 70%RH is supplied to the office at a rate of 3000 CFM for ventilation; infiltration is negligible. 11,000 CFM of return air at room condition is mixed with outside air before being conditioned in the cooling coil. The air leaves the coil and is supplied to the room. Neglect all friction losses and fan and pump work. Assume sea level conditions.

a. Draw a diagram of the system.
b. Draw the operating cycle on the psychrometric chart provided and 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. Determine the Room sensible Heat Factor and the Grand (total) Sensible Heat Factor.
d. Determine the condition of air supplied to the room.
e. Calculate the total energy input.
f. Find the coil Apparatus Dew point and the coil By Pass Factor.

PROBLEM 2. (10 POINTS)

a. 10 points

An office has one external wall, 5 m long, containing a window of area 4 m^2; the width of the office from the window to the wall adjacent to the corridor is 4 m, and the ceiling height is 3 m. There are similar offices above, below, and on the either side.
The temperature in the corridor is 16°C, the temperature in the room is 20°C, and the outside design temperature is -1°C.
Taking thermal heat transfer values for the external wall, window, and internal wall as 1.0 W/m^2K, 5.6 W/m^2K, and 2.7 W/m^2K respectively, and an air change rate of one per hour, calculate the required heat rate input to the room.

b. 10 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 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)

A ground source heat pump is used to heat a building. The supply of heat is taken from ground (earth) at 5°C . Air is required to be delivered to the building at atmospheric pressure and 32°C at a rate of 1.5 m^3/s.
The outside air at 8°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 under cooling in the condenser.
A temperature difference of 15°C is necessary for the transfer of heat from the ground to the refrigerant in the evaporator. The delivery pressure of the compressor is 1.0164 MPa.

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 swept volume of the compressor (cm^3) which is single acting and runs at 350 rpm. The volumetric efficiency of the compressor is 85%.
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 5. (20 POINTS)

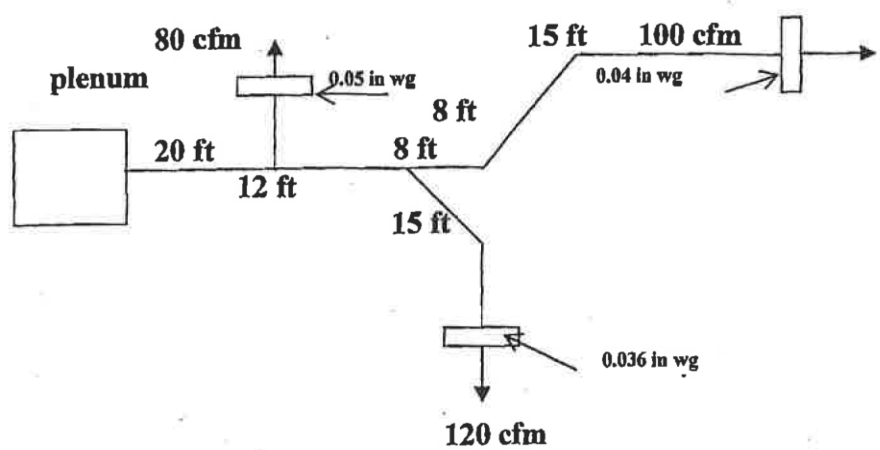
A 10-story office building with floor dimensions 60 ft x 100 ft and a height of 130 ft has curtain walls with windows that are fixed and airtight. The window wall ratio is 0.5. The draft coefficient for airflow between floors is C_d=0.65. There are two vestibule-type doors on each of the 100-ft facades. The traffic rate corresponds to each of the occupants (one per 150 ft^2 of gross floor area) making an average of four entrances or exits per 10 hours. The indoor and outdoor temperatures are 70°F and 20°F, and the wind is parallel to the 50-ft facade at 15 miles/hr. Assume that infiltration through the roof is negligible (all infiltration occurs through the curtain walls and through the doors).

a. Calculate the pressure differences for each wall due to stack effect and wind for floors 1, 5, and 10.

b. Calculate the total infiltration rates for these floors if the ventilation system is balanced for neutral pressure.

PROBLEM 6. (20 POINTS)

Select the round duct sizes for the duct system shown in the figure below, using equal-friction method. A total pressure of 0.14 in. wg. is available at the plenum.
State all your assumptions.



PROBLEM 7. (20 POINTS)

A small commercial building located in Ottawa, Ontario has a heating load of 350,000 Btu/hr sensible and 55,000 Btu/hr latent. Design conditions are 70°F and -17°F. The owner has to decide between two heating options:

- natural gas warm air furnace with an efficiency of 80%.
- electric resistance heating elements with an efficiency of 100%.

The heating value of natural gas is 1000 Btu/std ft^3 (standard cubic feet).

Using the degree day method, and knowing that the price of natural gas is $5.5 per million cubic feet, and the price of electricity is 0.11$/kWh, compare the annual heating costs. Neglect the cost of initial installation.

A contractor suggested to the owner of the above building, to install a heat pump. The contractor claims that the heat pump has a COP (coefficient of performance) of 4.5. The compressor/motor has an efficiency of 82%. How much will be the yearly heating cost with the heat pump.

Comment on your results. What are the environmental impacts of each alternative? Comment on the fact that the power plant that produces electricity uses coal as the fuel, and has an overall efficiency of 35%.

PROBLEM 8. (20 POINTS)

Determine the instantaneous heat gain through a 1 m x 2 m west-facing window at 6 p.m. solar time, on a clear day, July 21, at 40 deg. north latitude. The window has two sheets of glass with 1.6 cm air space between them. The outer layer is gray heat absorbing glass; the inner layer is standard glass. Assume an interior film coefficient of 8 $W/m^{2}{}^{\circ}C$, an outdoor temperature of 35°C and an indoor temperature of 26°C.

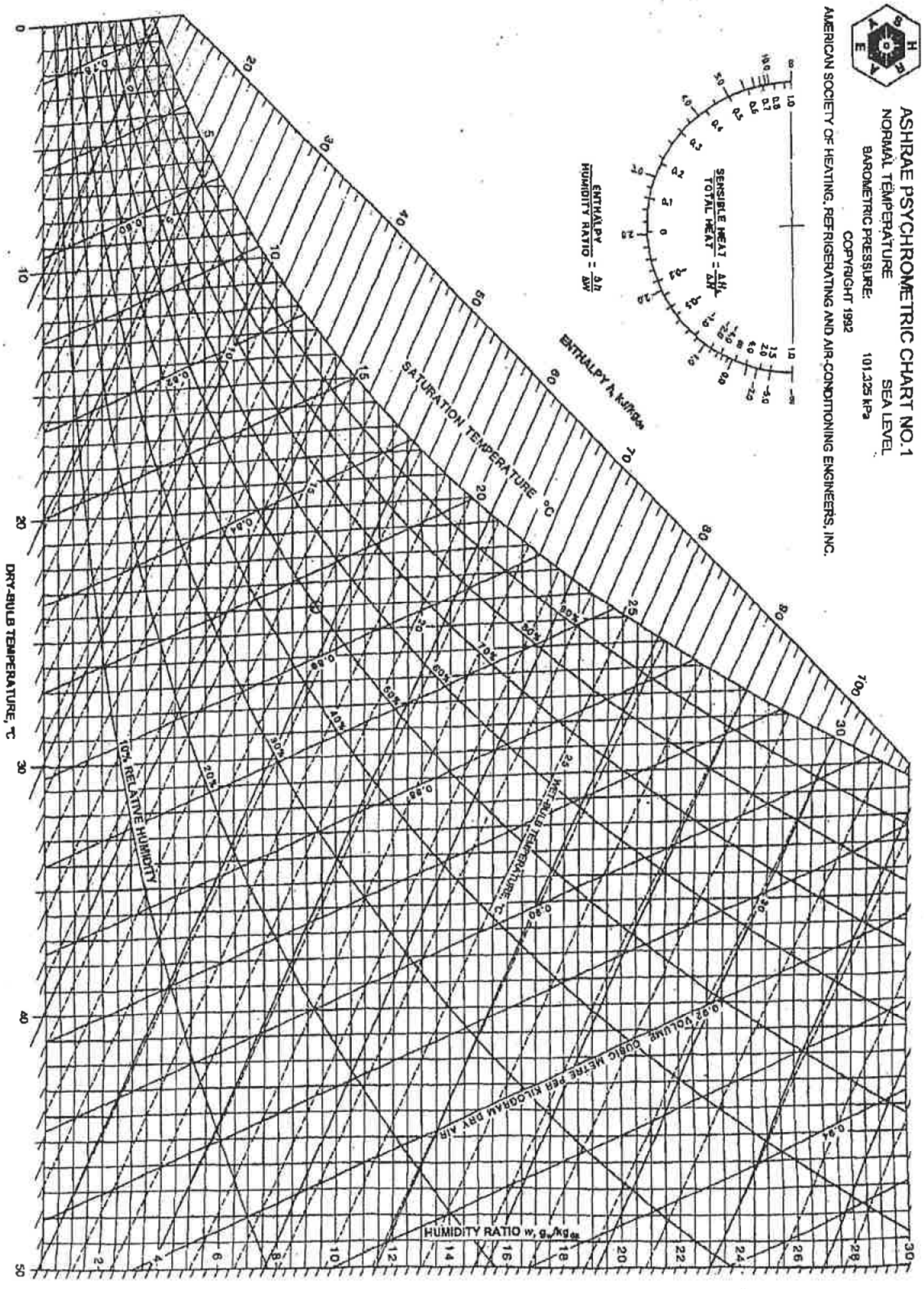
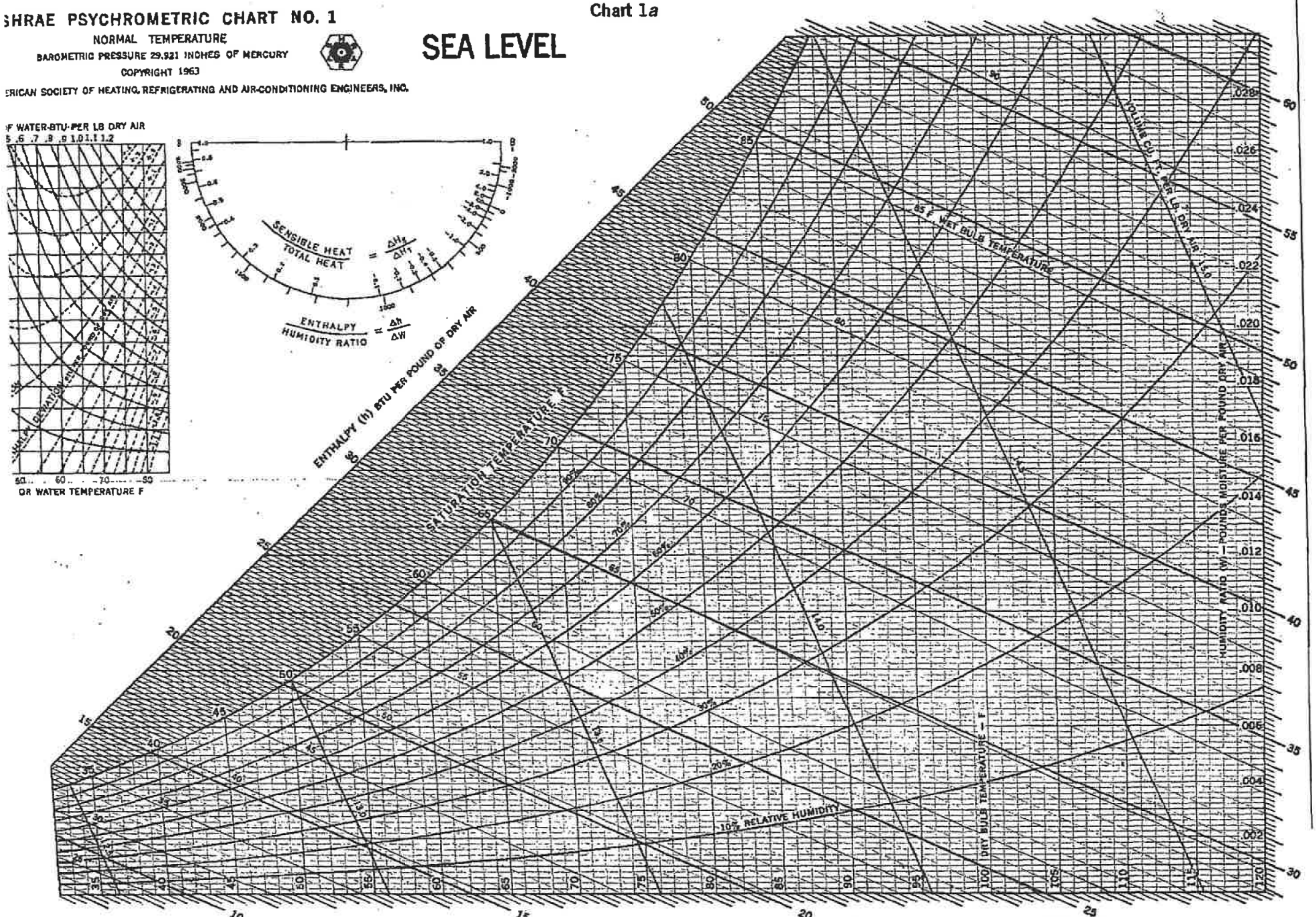
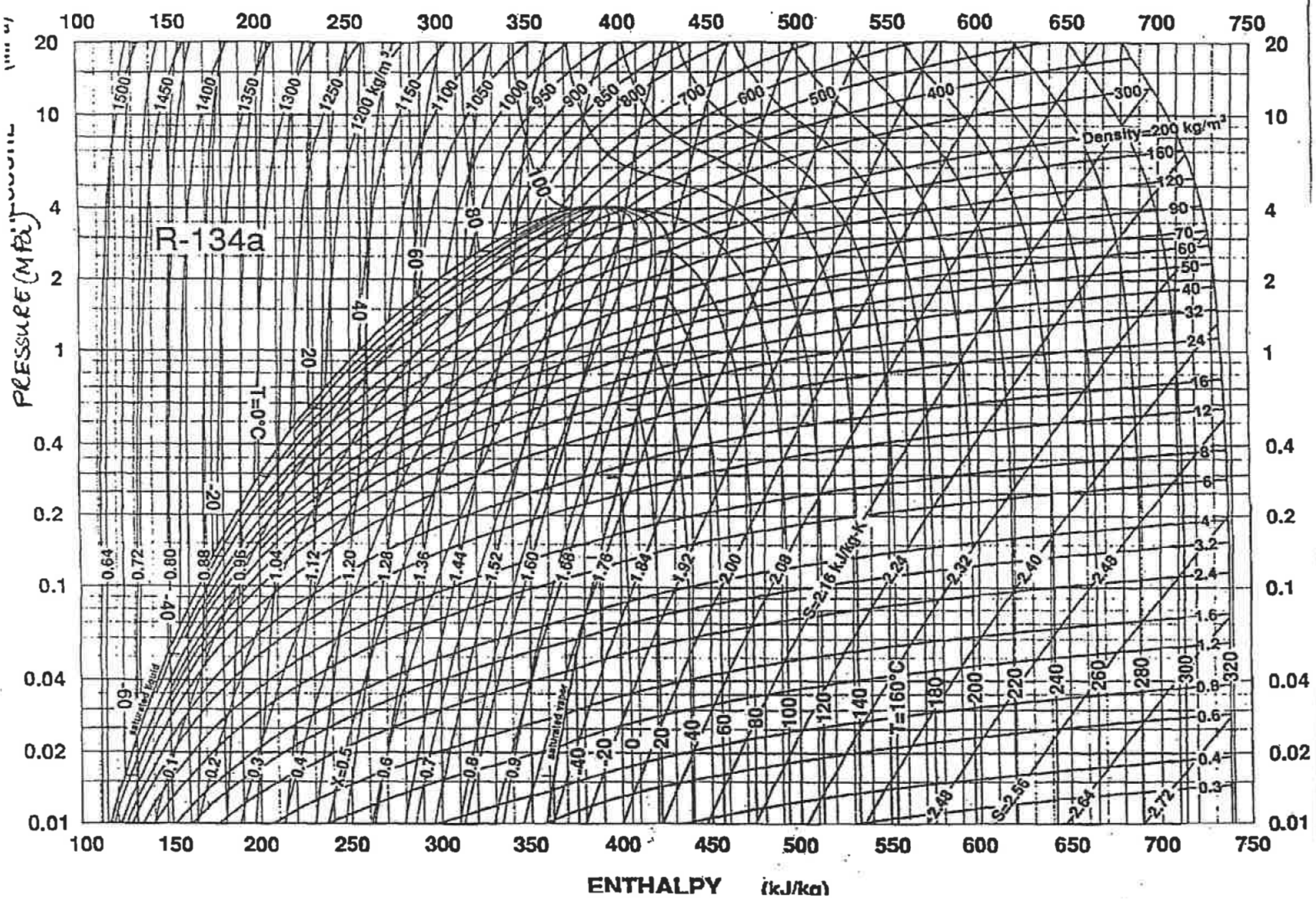


Fig. 1 ASHRAE Psychrometric Chart No. 1

Chart 1a


SHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
ERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔHt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
85 F WET BULB TEMPERATURE
VOLUME CU. FT. PER LB. DRY AIR
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE — F
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
OR WATER TEMPERATURE F



R-134a
PRESSURE (MPa)
ENTHALPY (kJ/kg)
Density=200 kg/m³
S=2.16 kJ/kg-K
T=0°C
T=160°C
X=0.5
saturated liquid
saturated vapor