PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – May 2016

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. 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 <u>solve five</u> 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 are attached.

PROBLEM 1. (20 POINTS).

A small commercial building located in Winnipeg, Manitoba, has a heating load of 150 kW sensible heat and 15 kW latentheat.Design conditions are 22°C and -33°C. The building is heated with a natural gas warm-air furnace, with an efficiency of 83%.

Calculate the yearly heating fuel requirements.

An energy contractor, after an energy audit of the building, 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 performauce) of 3.6. The compressor motor has an efficiency of 82%.

Draw a schematic as to how an air to air heat pump will provide the heating load. Is this is a good solution for this location? Do you know of any other types of heat pumps? Explain. What will be your advice to the building owner?

Make assumptions as to the cost of natural gas and electric energy, and base your answer on good engineering practice, considering the environmental implication for each solution. Comment ou the fact that the power plaut that produces electricity uses coal as the fuel, and has an overall efficiency of 32%.

PROBLEM 2. (20 POINTS)

In winter, a building is maintained at 21°C DB and 35% relative humidity (RH). The outdoor air enters the preheater coil at -14°C DB and 0% RH. The outdoor air is heated to 16°C and mixed with return air; then it is heated and humidified in a separate process to 40°C DB and 30% RH for supply to the space. Saturated vapour at 2 psig is used for humidification. Twenty five percent (25%) of the supply air by mass is outdoor air. The total space heating load is 215 kW.

a. Draw a diagram of the system.
b. Draw the operating cycle 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 total air supply volume.
d. Calculate the total energy input in each of the coils (preheater and heater).
e. Calculate the steam flow rate.

PROBLEM 3 (20 POINTS).

a. 10 points

A small fast food cafeteria building, 30 x 100 x 9 ft, located in Ottawa, Ontario has windows and doors located on the east and north sides, but none on the south and west. The HVAC system is to include a humidifier. Estimate the winter design heat losses due to ventilation and/or infiltration. Indoor and outdoor design conditions are 72°F, 30% RH, and -7°F, respectively.

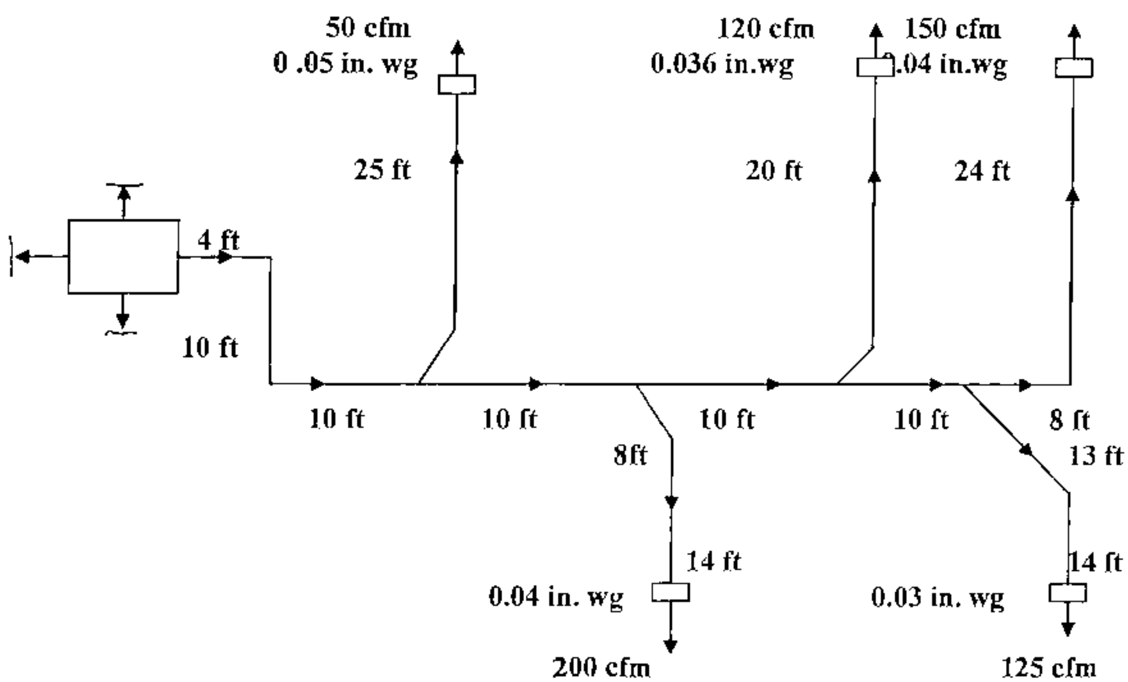
b. 10 points

To preclude attic condensation, an attic ventilation rate of 59 l/s is provided with outside air at -13 °C. The roof area is 244 m^2 and $U_{roof} = 2.7$ W/m^2 °K. The ceiling area is 203 m^2 and $U_{ceiling} = 0.30$ W/m^2 °K . Inside design temperature is 22 °C.
Determine the ceiling heat loss, and compare to the loss if there had been no ventilation.

PROBLEM 4 (20 POINTS).

Consider the duct layout shown below. Air is supplied by a rooftop unit, which develops 0.30 in. wg. total pressure external to the unit. The return system requires 0.12 in. wg.
The ducts are round cross section, the maximum velocity in the main run is 850 ft/min and the branch velocities must not exceed 650 ft/min.

a. Size the ducts using the equal friction method. Show the location of any required dampers (if any?).
b. Calculate the total pressure loss for the system.



NOTE: typical diffuser boot has 20 ft equivalent length.

PROBLEM 5. (20 POINTS)

Sketch an induced draft counter-flow cooling tower, showing how it may be regulated to control the operation of a refrigeration plant.

A small size cooling tower is designed to cool 5.5 l/s of water with an inlet temperature of 44°C. The motor-driven fan induces 9 m^3/s of air through tower and the power absorbed is 4.75 kW. The air entering the tower is at 18°C, and has a relative humidity of 60%.The air leaving the tower can be assumed to be saturated and its temperature is 26°C.

Calculate the final temperatnre of the water and the amount of cooling water make-up required per second. Assume the pressure remains constant throughout the tower at 1.013 bar.

PROBLEM 6. (20 POINTS)

A refrigeration system uses two stages of compression and a flash chamber of inter-cooling between the two expansion valves. Between the two compressor stages there is a direct contact heat exchanger. Refrigerant R-134a is the working fluid. Saturated vapour at -30°C enters the first compressor stage. The flash chamber and the direct contact heat exchanger operate at 4bar, and the condenser pressure is 12bar. Saturated liquid streams at 12 and 4 bars respectively enter the high and low pressure expansion valve respectively. The isentropic efficiency of low stage compressor is 0.85 and that of the high pressure stage is 0.88. The refrigerating capacity of the system is 10 tons.

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

a. Calculate the mass flow of the refrigerant.
b. Calculate the power input of each compressor.
c. Calculate the coefficient of performance.

PROBLEM 7. (20 POINTS)

You are involved in selecting the revamping and modernizing of heating and cooling system for a big hospital in a downtown location. You must consider the costs and the environmental impacts of different options.

Comment on 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 that provides cold water and hot water for heating and cooling –district cooling and heating.
- Cogeneration or Trigenaration

PROBLEM 8. (20 POINTS)

A building has a calculated cooling load of 12 tons of which 3 tons is latent load. The space is to be maintained at 78°F dB (dry bulb) temperature and 50% relative humidity.
Ventilation air of 1000 cfm (cubic feet per minute) is required on a day when outside air conditions are 94°F dB and 55% relative humidity.

After leaving the room, some of the air exhausts to the outside and the remainder mixes with the ventilation air and then passes through a filter, fan, and the cooling coil.

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 (kW), apparatus dew point, coil by-pass factor.

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

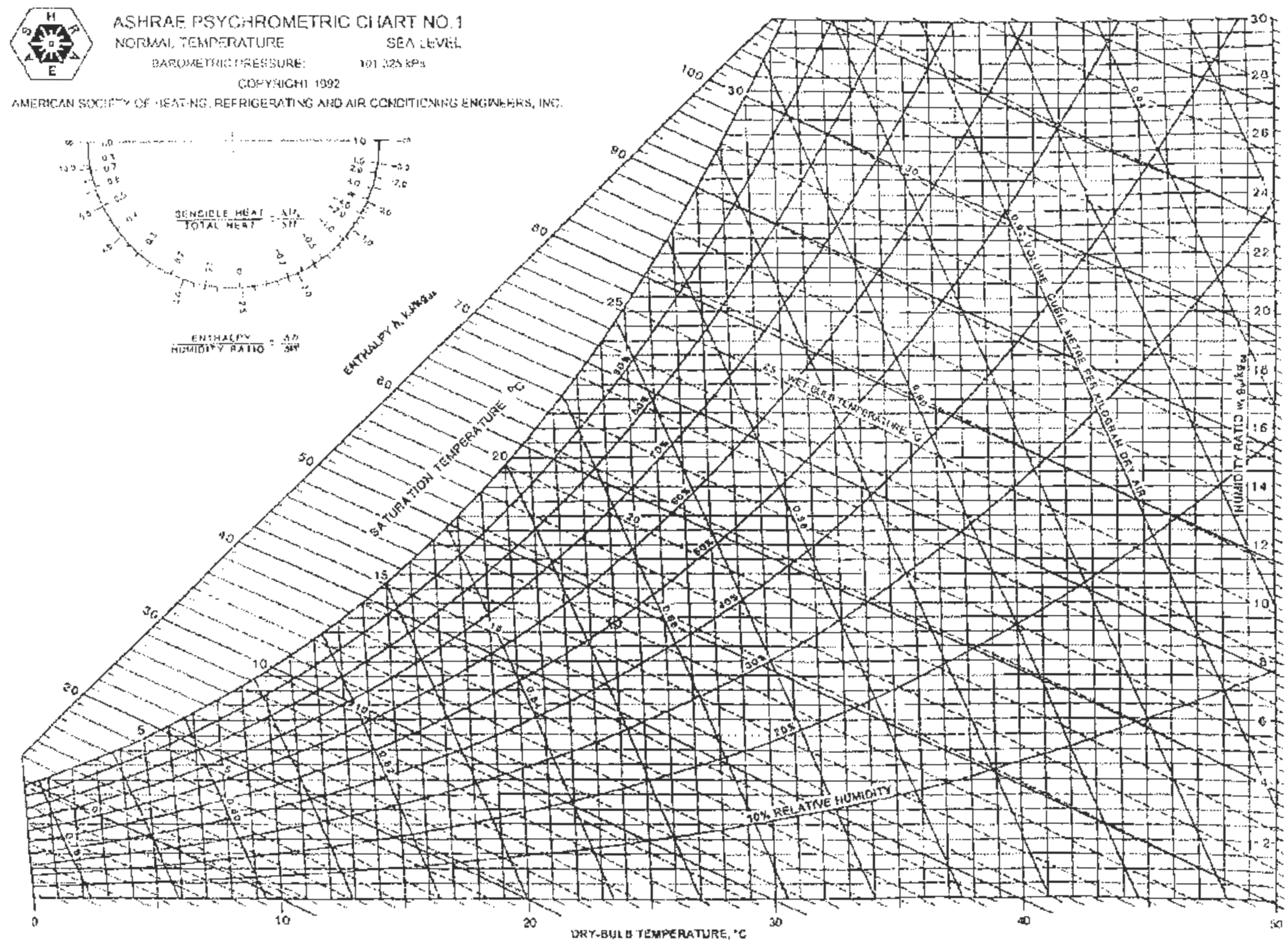
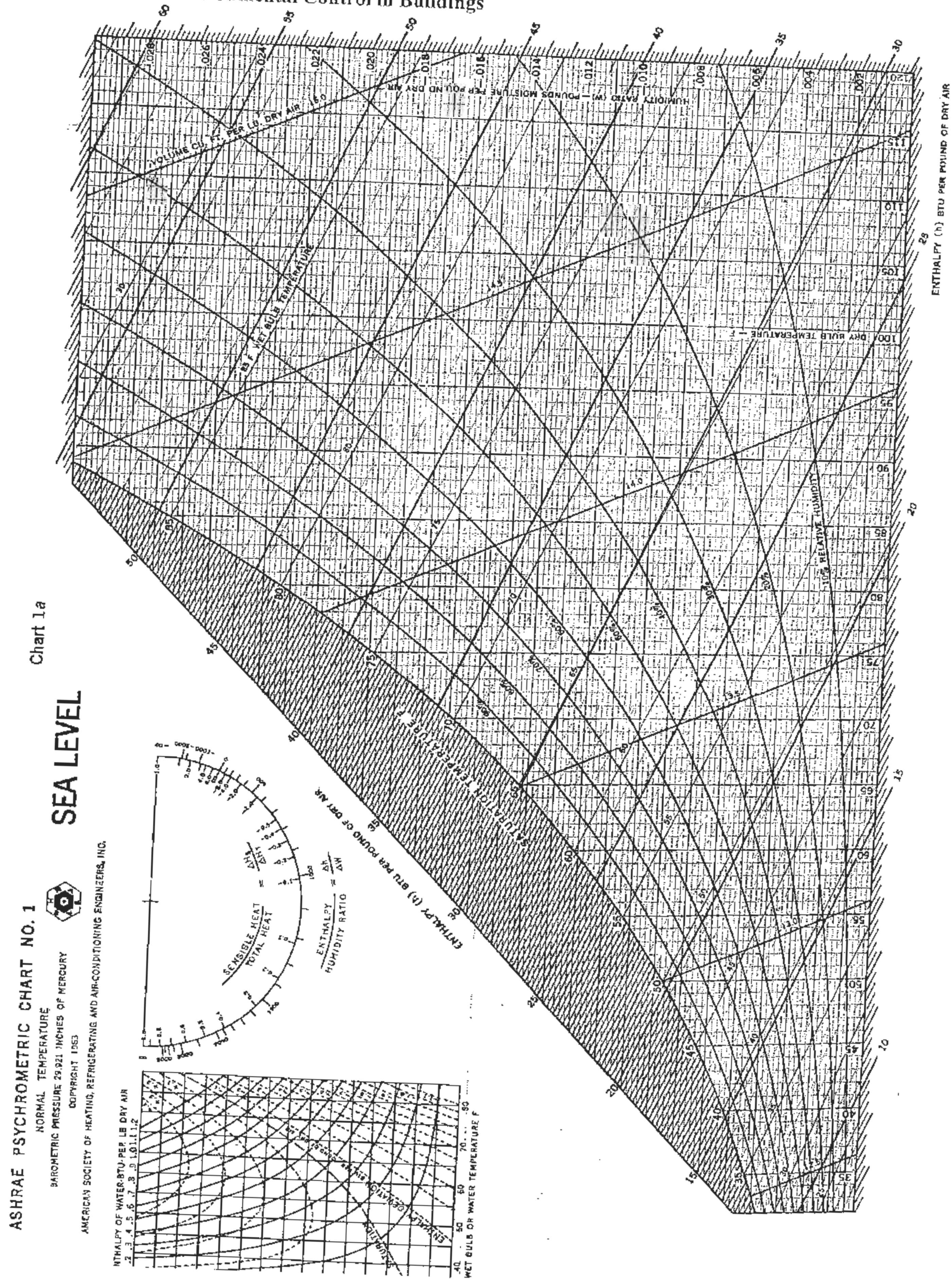
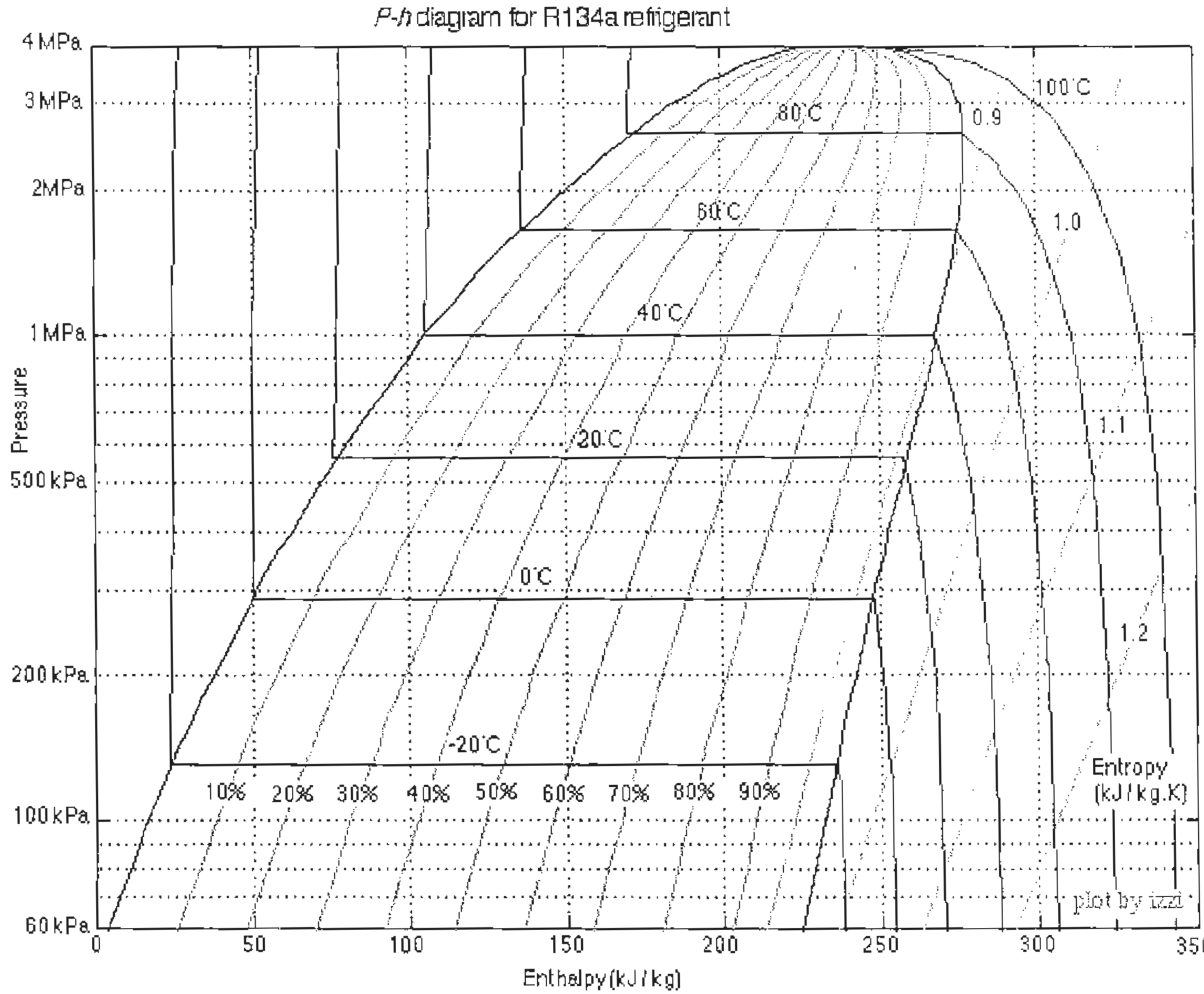


Fig. 1 ASHRAE Psychrometric Chart No. 1


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
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE F
DRY BULB TEMPERATURE — F
WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
ENTHALPY OF WATER-BTU-PER LB DRY AIR
WET BULB OR WATER TEMPERATURE F
SATURATION
ENTHALPY DEVIATION


P-h diagram for R134a refrigerant
4 MPa
3 MPa
2MPa
1 MPa
500 kPa
200 kPa
100 kPa
60 kPa
Pressure
0
50
100
150
200
250
300
350
Enthalpy (kJ / kg)
80°C
60°C
40°C
20°C
0°C
-20°C
100°C
0.9
1.0
1.1
1.2
10%
20%
30%
40%
50%
60%
70%
80%
90%
Entropy
(kJ / kg.K)
plot by izzi