PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – December 2013

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 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 are attached.**

PROBLEM 1 (20 POINTS).

An inside swimming pool has a sensible heat loss of 130 kW and a latent heat gain of 160 kW on a design day when the outdoor air is at 2°C and 20% relative humidity (RH). The space is to be maintained at 24°C and 50% relative humidity. Outdoor air is to be mixed with recirculated air from space and the mixed air is to be heated to the supply conditions. Neglect all friction losses and fan and pump work. Assume sea level conditions.

Draw a diagram of the system.
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.

a. **Calculate the air quantity to be supplied to the space if the supply temperature is 35°C.**
b. **What is the ratio between outside and recirculated air?**
c. **What is the heat transfer rate for the preheat process?**
d. **What is the heat transfer rate for the mixing process?**

PROBLEM 2. (20 POINTS)

A summer air conditioner mixes 2,000 cfm of outside air at 90°F DB, 73°F WB with 6,000 cfm of space or return air at 75°F DB, 50%RH. The mixture is passed over a cooling coil. Air off the coil is at 90% saturation. The room sensible heat factor (SHF) is 0.68

Draw a diagram of the system.
Draw the operating cycle on the psychrometric chart provided.

Determine the following:

a. **The apparatus dew point (ADP) the air dew point and the air of coil dry bulb temperature.**
b. **The cooling coil capacity in Btu/hr.**
c. **How much of the total load is latent heat and how much is sensible heat?**

PROBLEM 3 (20 POINTS).

A heat pump is used to heat a building. The supply of heat is taken from ground water at 5°C. Air is required to be delivered to the building at atmospheric pressure and 32°C, at a rate of 0.8 m^3/s. The outside air at 10°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 15°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.

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 240 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 0.11 $/kWh. Compare with electric heating with electrical radiators. Comment.

PROBLEM 4. (20 POINTS)

A 22-story office building with floor dimensions 150 ft x 200 ft and a height of 250 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 200-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 75°F and 20°F, and the wind is parallel to the 150-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, 10, and 22.
b. Calculate the total infiltration rates for these floors if the ventilation system is balanced for neutral pressure.

PROBLEM 5. (20 POINTS)

a. 15 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 45 deg. north latitude. The window has two sheets of glass with 1.7 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 $W/m^{2o}C$, an outdoor temperature of 33°C and an indoor temperature of 27°C.

b. 5 points.

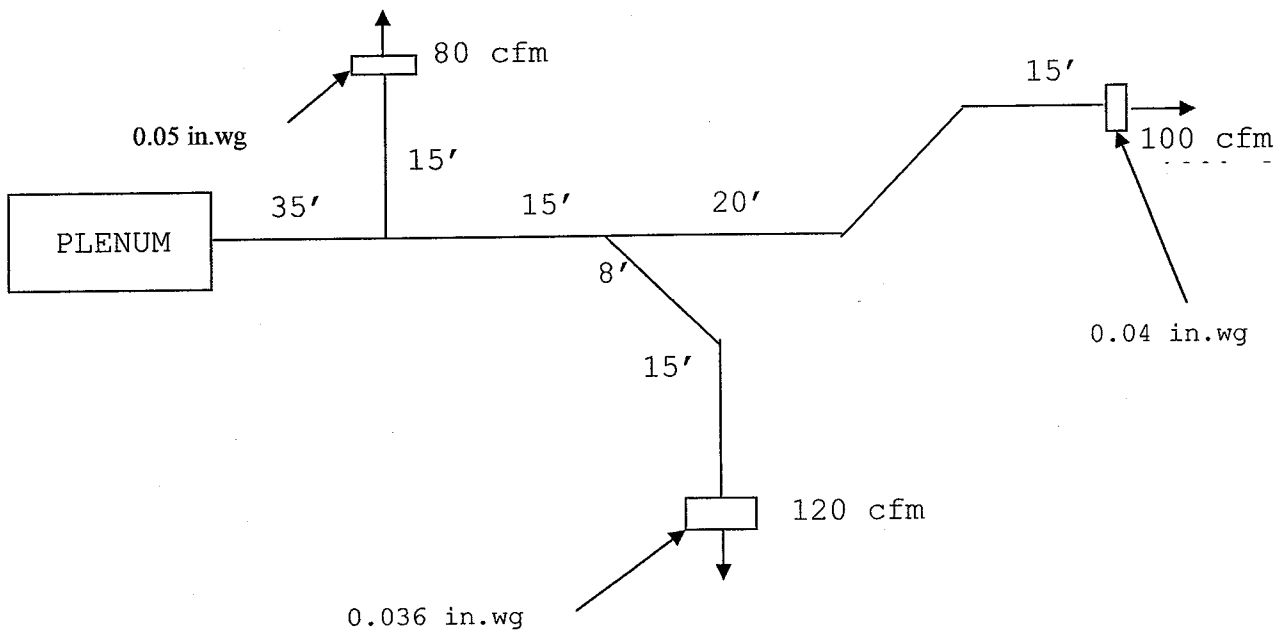
Give an expression for the sensible and latent heat load due to infiltration.

PROBLEM 6 (20 POINTS).

The duct system shown below is a branch of an air distribution system. The system is a perimeter type located below the floor. The diffusers boots have the pressure drop indicated in the layout diagram.

A total pressure of 0.15 in. wg is available at the plenum.

Size the various sections of the system using equal friction method and round pipe. Compute the actual loss in total pressure for each run, assuming that the proper amount of air is flowing.



PROBLEM 7. (20 POINTS)

a. 5 points

Describe succinctly the advantages and disadvantages of VAV systems. Where it is recommended to use VAV systems?

b. 10 points

How many people could occupy a room where the concentration level of carbon dioxide CO_2 is to be kept below 1000 ppm, if air with a concentration of 200 ppmCO_2 is being supplied to the room at a rate of 5000 cfm (cubic feet per minute). State your assumptions.

c. 5 points

Explain the ASHRAE comfort chart and the perception of thermal comfort.

PROBLEM 8. (20 POINTS)

Calculate the transmission heat loss through the walls of a frame dwelling, if the inside temperature is being held at 72°F when outside temperature is 10 °F.

The walls are constructed as follows:

- **redwood siding 22/32" thick**
- **on fir 25/32" thick sheathing**
- **2 by 4 studs with 3- in rock-wool blanket insulation between studs**
- **gypsum lath and plaster**

The studs are on 16" centres, covering about 15% of surface area between exterior sheath and the gypsum lath and plaster.

There are 4 windows 120"x30", double glass with no thermal break, and a wood door 1 3/8"solid core flush without storm door, with dimensions of 80"x32".
The total wall area (including windows and door) is 1800ft^2.

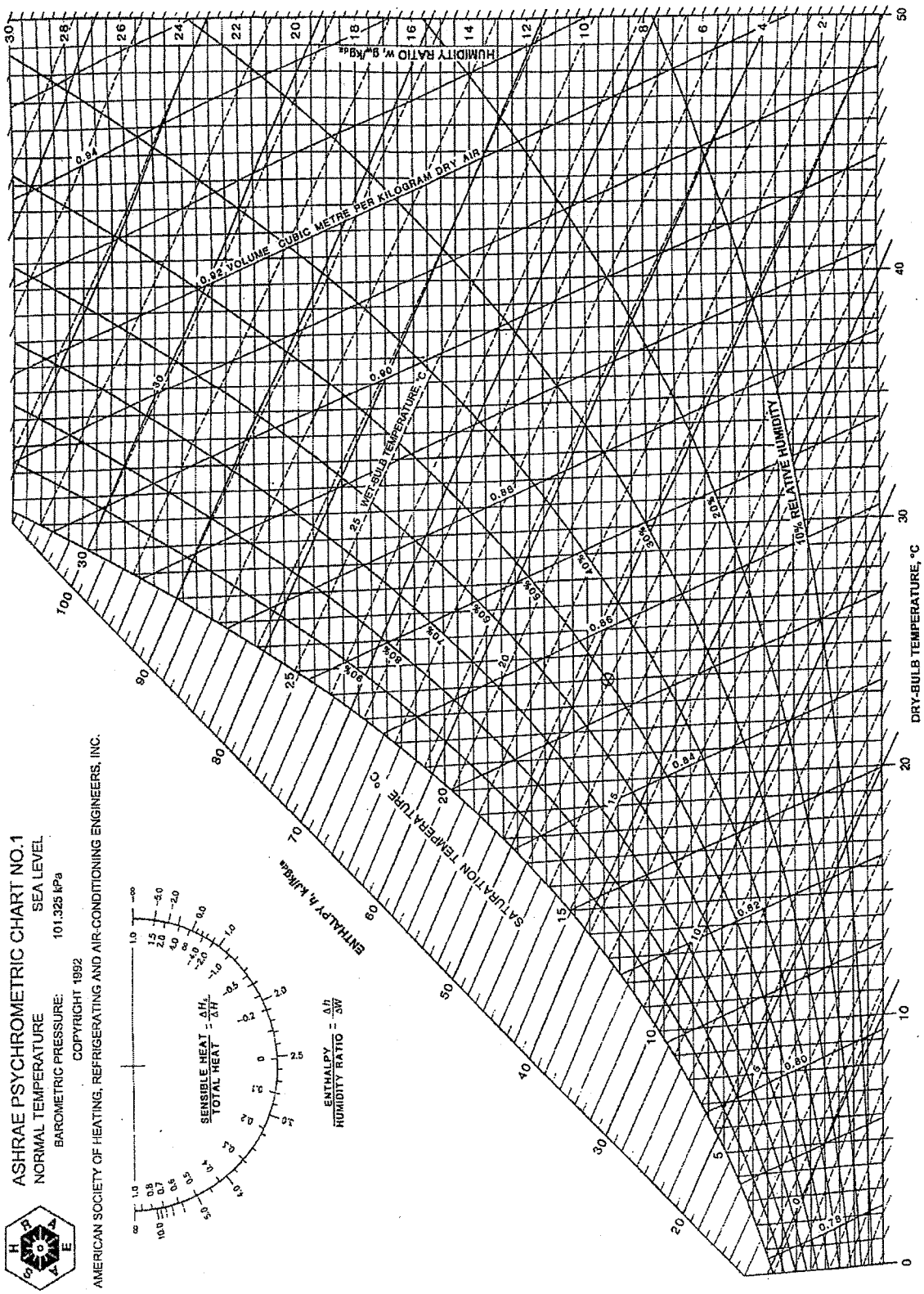
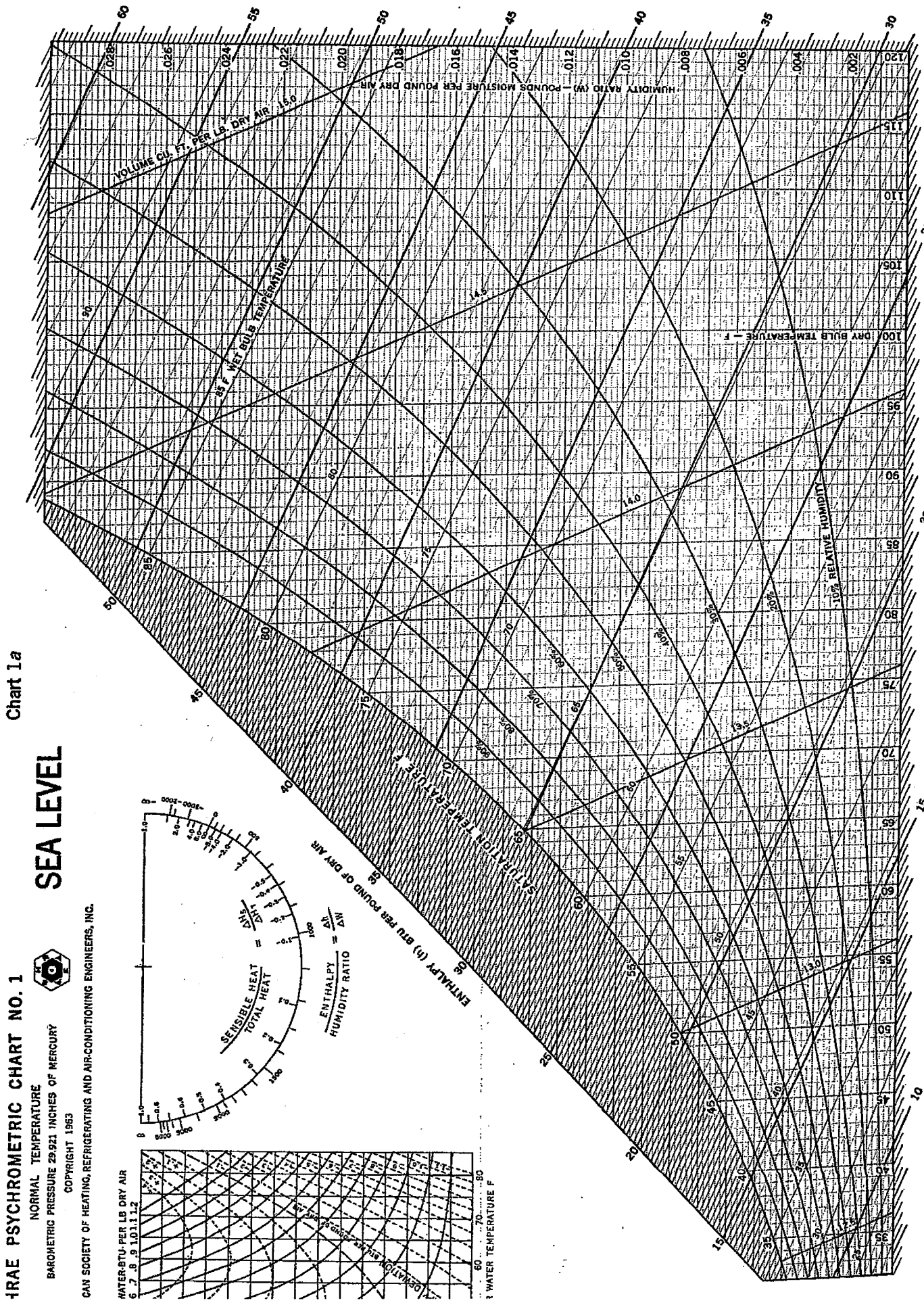
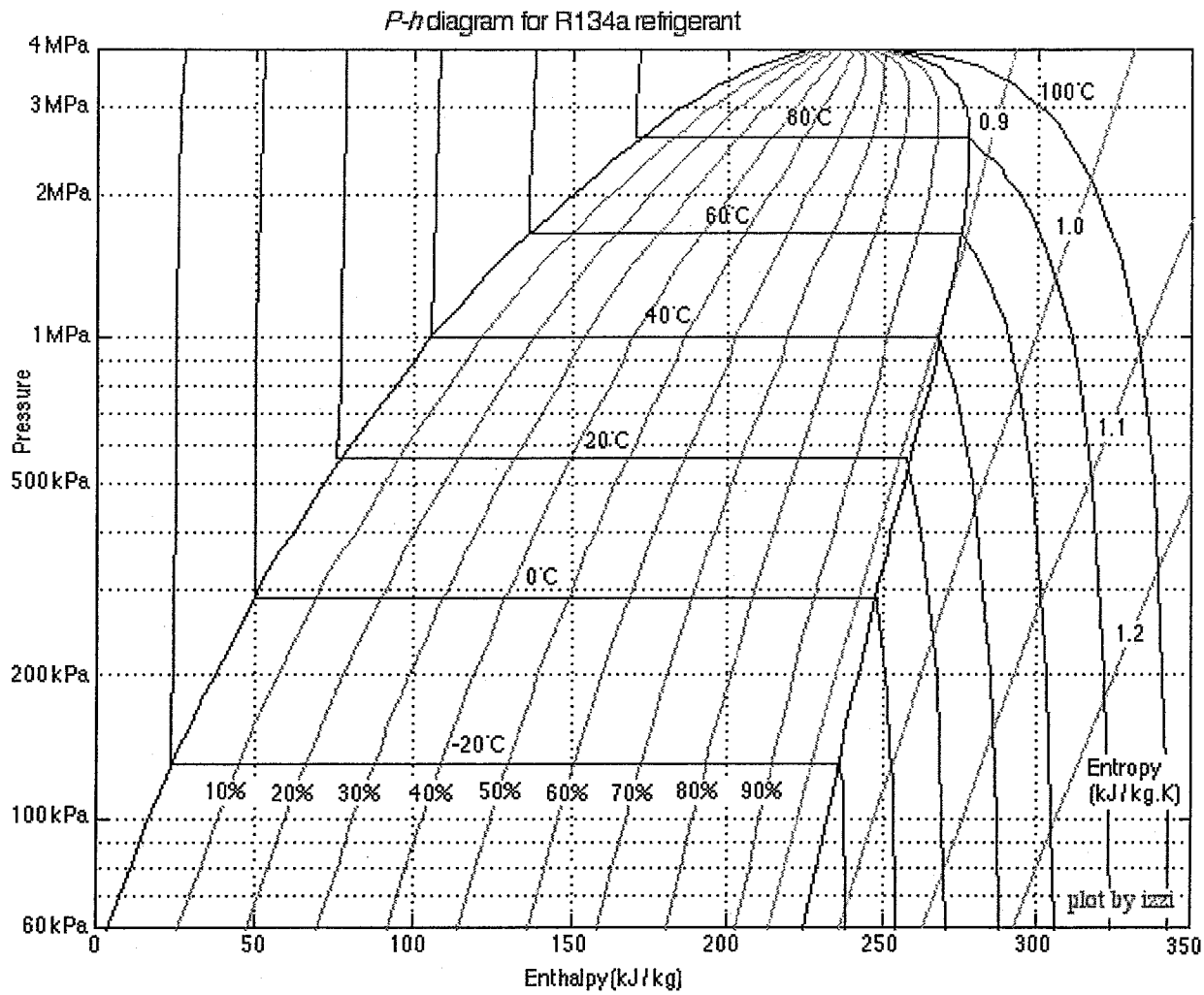


Fig. 1 ASHRAE Psychrometric Chart No. 1


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


P-h diagram for R134a refrigerant
4 MPa
3 MPa
2MPa
1 MPa
500 kPa
200 kPa
100 kPa
60 kPa
Pressure
100°C
80°C
60°C
40°C
20°C
0°C
-20°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
0
50
100
150
200
250
300
350
Enthalpy(kJ/kg)