PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS –May 2009

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. Candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the first inside left hand sheet of the first examination workbook.

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 R-134a are attached.

PROBLEM 1. (20 POINTS)

A space is to be maintained at 78°F and 50% relative humidity. The total cooling load is 120,000 Btu/h of which 70% is sensible heat. Ventilation air at 1000 ft^3/min (CFM) is required on a day when the conditions are 95°F and 55% relative humidity.

a. Draw a diagram of the system.
b. Draw the operating cycles 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 space air supply.
d. Calculate the cooling coil rating. Can you find the by-pass factor?

It may be assumed that there is negligible change in the mass flow rate of air supplied through the year.

PROBLEM 2. (20 POINTS).

a. 10 points

Describe succinctly the advantages and disadvantages of VAV systems

b. 10 points

Suppose there is a source of NOx in a building that produces 110 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 40 $\mu g/m^3$, what outdoor airflow is needed to satisfy the required (recommended by standard) conditions in the building.

PROBLEM 3. (20 POINTS)

A winter heating and humidifying system uses equal volumes of recirculated room air and outside air. The mixed flow is preheated, then is passed through an adiabatic spray cabinet, then is re-heated and supplied to the room. The following conditions apply:

- room heating load is 58 kW all sensible.
- room design conditions 20°C dB (dry bulb), 15°C wB (wet bulb).
- outside air 7°C dB, 4°C dew point.
- supply temperature to the room is 40°C

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 characteristics.
d. Find the total system air mass flow.
e. Calculate the kW rating of the preheater and reheater.
f. Calculate the adiabatic efficiency of the spray cabinet, and the quantity of make-up water required in the operation of the spray cabinet.

PROBLEM 4. (20 POINTS)

A small commercial building located in Saskatoon, Saskatchewan, has a heating load of 100 kW sensible and 15 kW latent heat. Design conditions are 22°C and -35°C. The building is heated with a natural gas warm-air furnace, with an efficiency of 81%.
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 performance) of 3.5. 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. 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 on the fact that the power plant that produces electricity uses coal as the fuel, and has an overall efficiency of 32%.

PROBLEM 5. (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 34°C, at a rate of 0.5 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, there is no under cooling in the condenser. A temperature difference of 17°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 0.10 $/kWh. Compare with electric heating with electrical radiators. Comment.

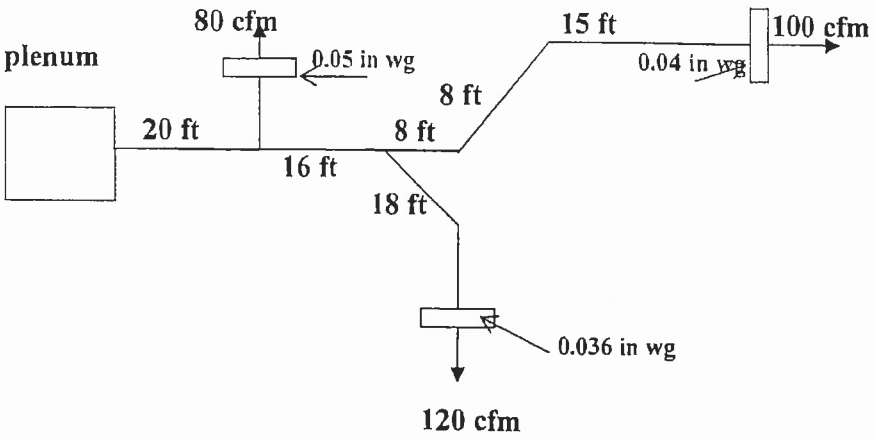
PROBLEM 6. (20 POINTS)

A building is located at 45 degrees north latitude. The building has a skylight that faces west of south at 20 degrees and is at a tilt angle of 60 degrees. Calculate the solar influx incident on the skylight at 1:30 solar time on 21 December and on 21 of June.

Make proper assumption for the winter and summer day, and explain the assumptions.

PROBLEM 7 (20 POINTS)

Select the round duct sizes for the duct system shown in the figure below, using equal-friction method. A total pressure of 0.15 in. wg. is available at the plenum.
State all your assumptions.



PROBLEM 8. (20 POINTS)

a. 5 points

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

b. 5 points

It is proposed, that in order to save energy in summer, for large office building using chilled water cooling systems to increase the temperature of the water circulating in the system. Comment on feasibility of this method and how it will affect the comfort conditions in the building.

c. 10 points

Explain the concept of cogeneration and how it can be use in an University campus. Explain all your assumptions.

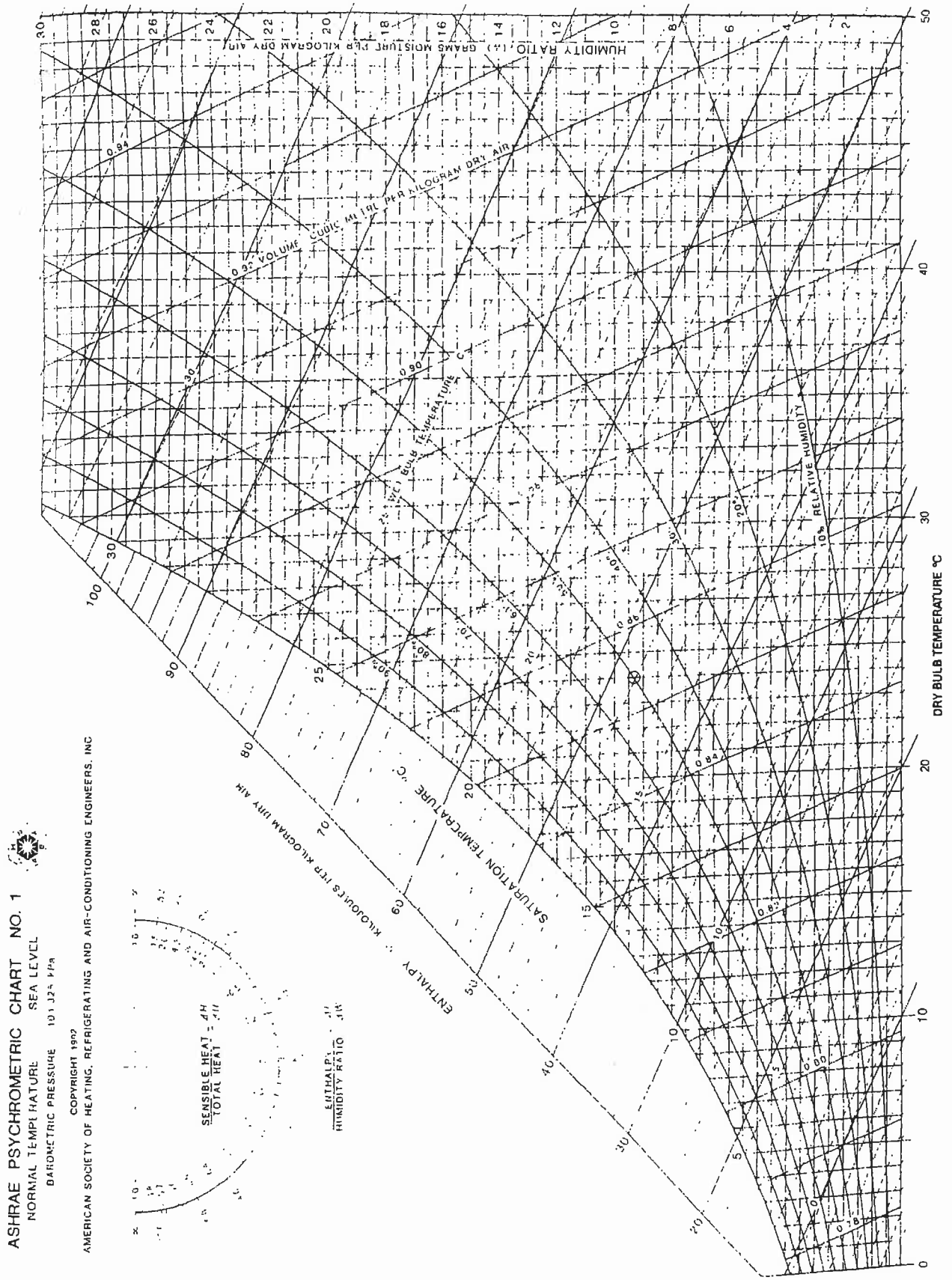
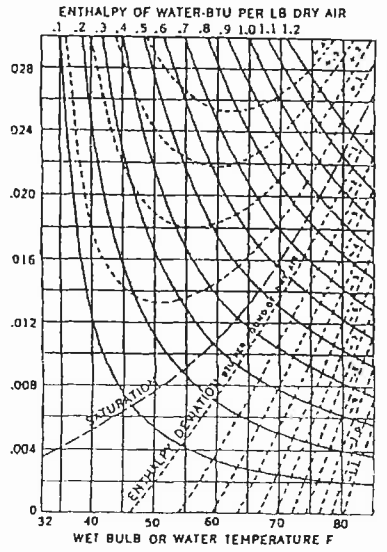


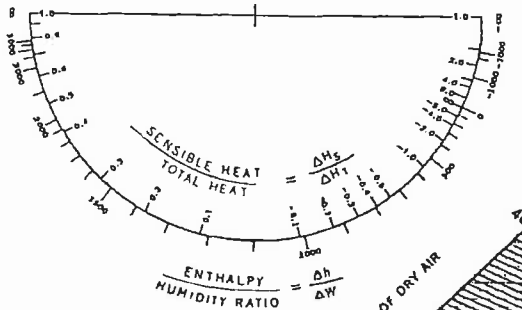
Fig. 1 ASHRAE Psychrometric Chart No. 1

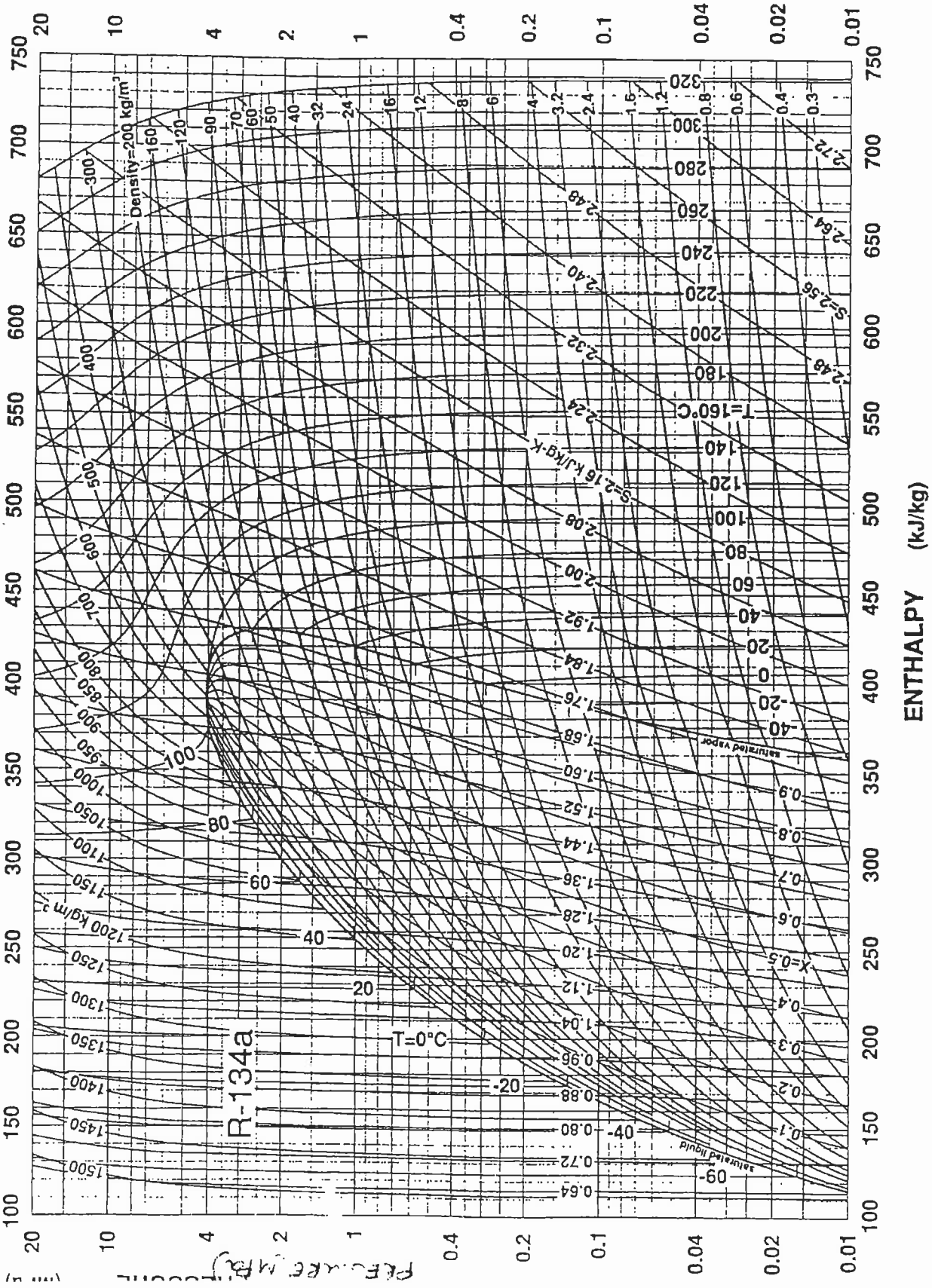
ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

SEA LEVEL






R-134a
ENTHALPY (kJ/kg)
PRESSURE (MPa)
Density=200 kg/m³
T=160°C
T=0°C
S=2.56 kJ/kg·K
S=2.48 kJ/kg·K
S=2.40 kJ/kg·K
S=2.32 kJ/kg·K
S=2.24 kJ/kg·K
S=2.16 kJ/kg·K
S=2.08 kJ/kg·K
S=2.00 kJ/kg·K
S=1.92 kJ/kg·K
S=1.84 kJ/kg·K
S=1.76 kJ/kg·K
S=1.68 kJ/kg·K
S=1.60 kJ/kg·K
S=1.52 kJ/kg·K
S=1.44 kJ/kg·K
S=1.36 kJ/kg·K
S=1.28 kJ/kg·K
S=1.20 kJ/kg·K
S=1.12 kJ/kg·K
S=1.04 kJ/kg·K
S=0.96 kJ/kg·K
S=0.88 kJ/kg·K
S=0.80 kJ/kg·K
S=0.72 kJ/kg·K
S=0.64 kJ/kg·K
Saturated vapor
Saturated liquid
X=0.5