PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS –December 09

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 single duct constant volume air handling system with local reheat is delivering for 2 zones.
The thermostat setting is: 72°F for heating
78°F for cooling
The design loads (Btu/hr) are:

Zone	Heating (winter)	Cooling (summer)
1	48,000	24,000
2	56,000	50,000

For this system the supply air (S/A) temperature is 55°F all-year round.

Sketch the system identifying each equipment.

a)

1. **Determine required zone air flow rates and the capacity of AHU.**
2. **Calculate the reheat required for each zone and the temperature of the reheated air for each zone.**

b) **On a day at a certain time, the intermediate conditions (off-design conditions) are given below:**

Zone	Heating load (Btu/hr)	Cooling load (Btu/hr)
1	24,000	-
2	-	30,000

1. **Without discriminator control, calculate the reheat required for each zone.**
2. **With discriminator control, calculate the reheat required for each zone and the amount of savings.**

Assume that both heating and cooling loads are dominated by sensible heat.

PROBLEM 2. (20 POINTS)

A building has a total heating load of 240,000 Btu/hr. The sensible heat factor for the space is 0.8, and the space is to be maintained at 72°F and 30% relative humidity.
Outdoor air at 40°F and 20% relative humidity in the amount of 1200cfm is required for ventilation. Air is supplied to the space at 120°F.
Water vapour at atmospheric pressure is used to humidify the air.

a. **Sketch the system.**
b. **Find the conditions and the amount of air supplied to the space**
c. **Calculate the temperature rise of air in the heating coil (furnace)**
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 (furnace).**

PROBLEM 3. (20 POINTS)

Part A. (10 points)

Each person in a room is assumed to be producing CO_2 at an average rate of 0.005 l/sec. and air with a CO_2 concentration of 260 ppm is being supplied to the room at a rate of 3.2 m^3/sec. it is desired to keep the concentration of CO_2 in the space below 1000 ppm. Assuming complete mixing how many persons could occupy the room and not exceed the desired CO_2 level.

Part B. (10 points)

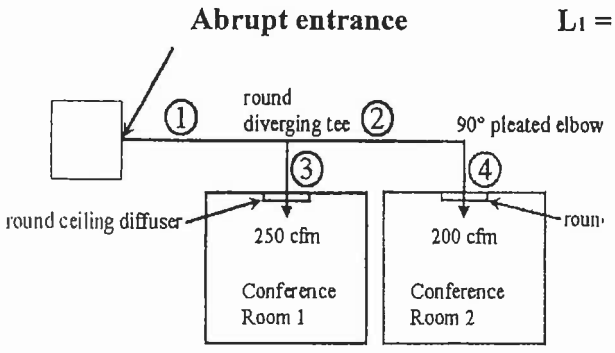
A mixed group of men and women occupy a space maintained at 70°F db and 64°F wb. All are lightly clothed, with sedentary activity.

a. **Using the recommended limits of comfort , comment on the comfort of the group.**
b. **The MRT is 78°F. Suppose the group is moving around (light activity) instead of sitting. What is your conclusion about their comfort.**
c. **Suppose that the group is composed of retired people (65 years of age or more) playing cards. What is their comfort level? It will be necessary to change room conditions to ensure their comfort?**

PROBLEM 4. (20 POINTS)

Use a design pressure loss of 0.08 in. wg per 100 ft to design the ductwork of a conference centre, as shown below.
(a) Using the equal friction method, determine the diameters (*in.*) of the ducts. The duct sizes must conform to the standard sizes.
(b) Determine the total pressure loss and noise criterion (NC) number of each round ceiling diffuser.
(c) Determine the total pressure loss of each run of ducts (in. wg) from plenum to each diffuser outlet, including diffuser loss.
(d) Is damper necessary for balancing the system? If yes, where should it be placed?

Note: Beware of the limiting air velocities in the ducts and the NC numbers of diffusers for acceptable noise level.



PROBLEM 5. (20 POINTS)

Part A. (6 points)
Describe a situation where the heat gain to the space is:

a. greater that the cooling load at a given time
b. less than the cooling load at a given time
c. equal to the cooling load at a given time

Part B. (7 points)
Describe the operation of a VAV system. Explain the advantages and the disadvantages.

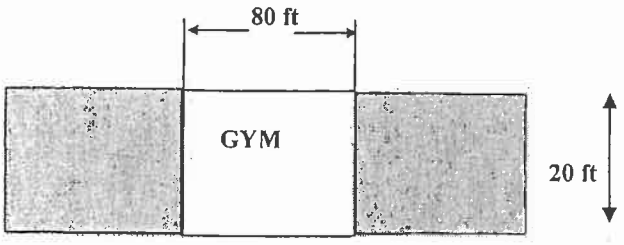
Part C (7 points)
Describe how building systems can be improved, in order to achieve more sustainability.

PROBLEM 6. (20 POINTS)

A high school gym in Ottawa, Ontario, has two exposed walls and measures 80 ft long, 40 ft wide and has a ceiling height of 20 ft. The gym is on the second floor of a three-story building, and is not mechanical ventilated. The gym is surrounded by conditioned space (see schematic below). Each of the exposed walls contains 15 windows. The windows are double-hung (both upper and lower halves operable), wood framed, single glazed, non-weather-stripped, average fit, and each measures 3 ft wide by 5 ft tall. The window frame-wall joint is caulked. One of the exposed walls faces prevailing wind direction. The pressure difference between the outside and inside is estimated to be 0.2 in water (outside pressure is greater). The wall construction is as follows:

- 4 in. face brick
- 12 in. concrete block (sand and aggregate)
- 4 in fibreglass board insulation
- vapour barrier (plastic film)
- ½ in plaster board

a. Indicate the indoor and outdoor design conditions. Justify your selection.
b. Calculate the heat loss from the gym. Assume that there is no heat transfer between the gym and conditioned spaces.



PROBLEM 7. (20 POINTS)

Part A. 15 points

A house is heated with an air heat pump using R134a as the working fluid. On a particular day when the outside temperature is 5°C, the house requires a heat transfer rate of 15 kW to maintain an inside temperature of 20°C.

Specify appropriate evaporator and condenser pressures for this cycle. Let the refrigerant to be saturated at evaporator exit and saturated liquid at condenser exit. If you want to consider other conditions please specify.

Calculate:

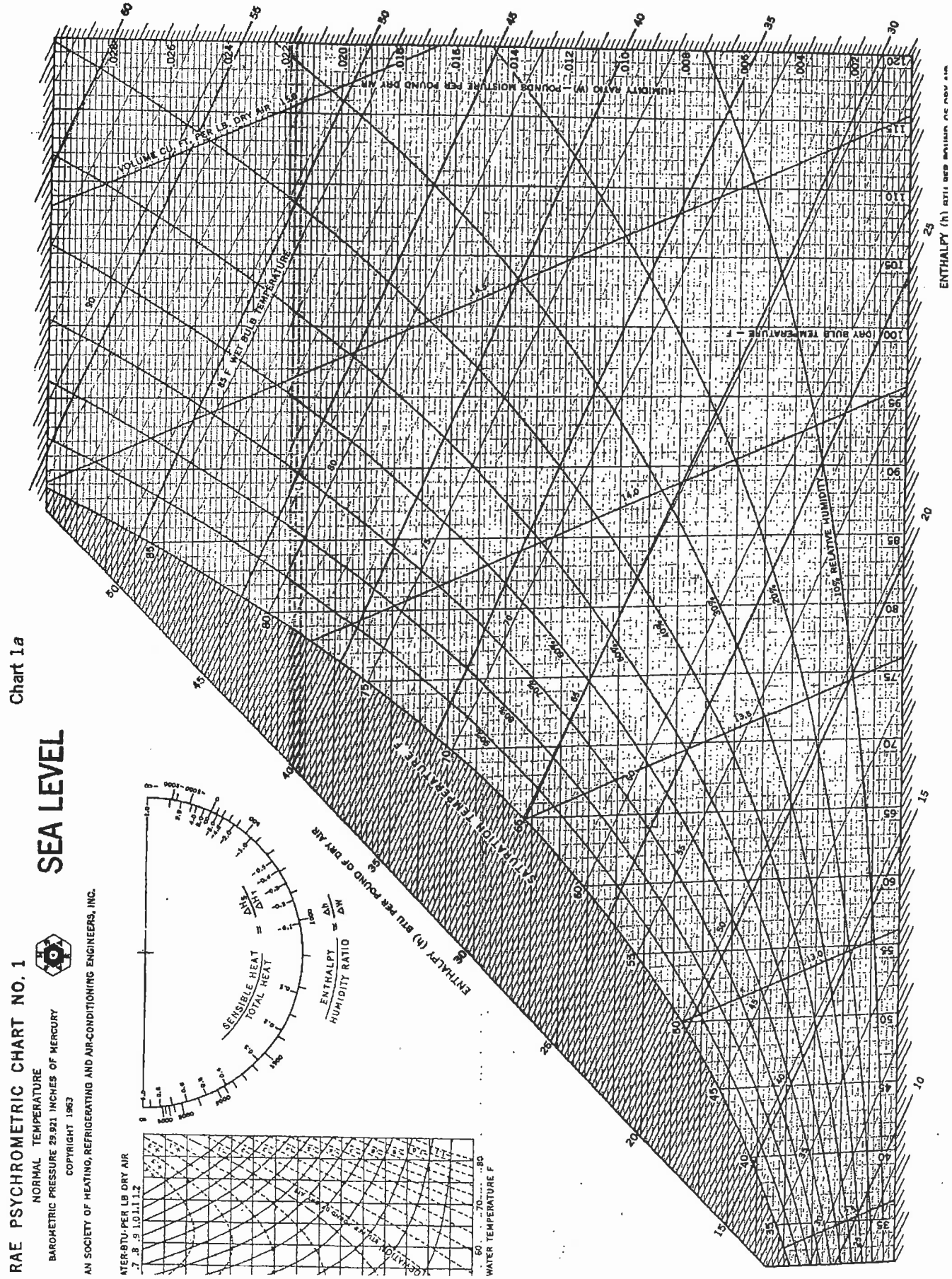
- **mass flow of refrigerant.**
- **compressor power**
- **coefficient of performance**

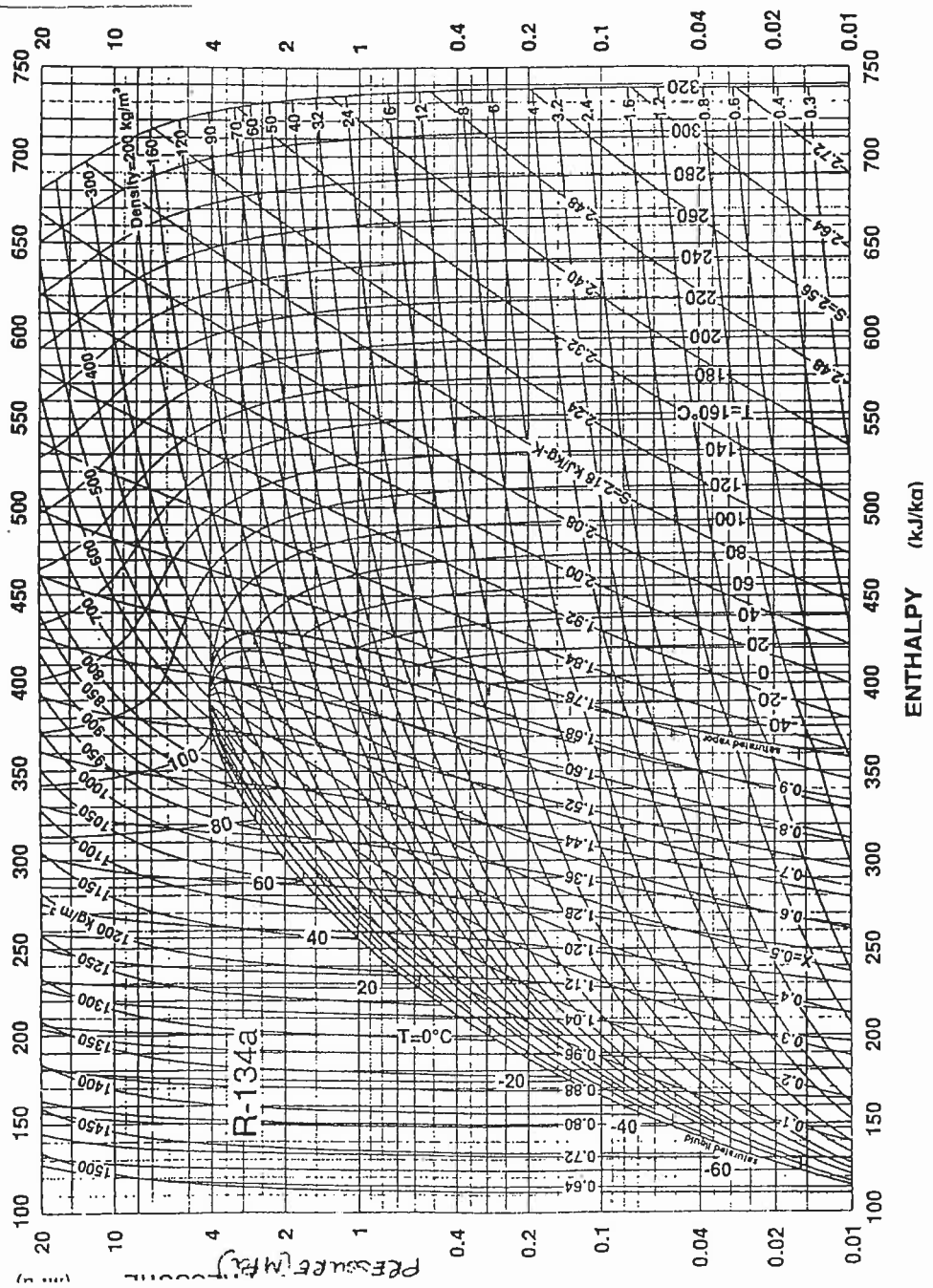
Part B. 5 points

Comment on advantages and disadvantages of air heat pumps.

PROBLEM 8. (20 POINTS)

A small commercial building is located in Vancouver, BC.
Using the degree-day method estimate the quantity of natural gas required to heat it. Select the design conditions. The computed heat load is 250,000 Btu/hr. Assume an efficiency factor of 85%.
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 4.5 cents per mcf (million cubic feet), 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 in view of environmental concerns.


RAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
AN 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
WET BULB TEMPERATURE
VOLUME CU. FT. PER LB. DRY AIR
RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
WATER-BTU-PER LB DRY AIR
WATER TEMPERATURE F


R-134a
T=0°C
ENTHALPY (kJ/kg)
Saturated vapor
Saturated liquid