PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – December 2015

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)

A suite of offices is to be air conditioned. The following determinations have been made:

- Outside design 95°F dB, 82°F wb
- Inside design 78°F dB, 53% RH
- Room sensible heat gain 150,000 Btu/hr
- Room latent heat gain 30,000 Btu/hr
- Ventilation (outside air) required 2,000 cfm

A four row coil with a by pass factor (BPF) of 0.10 will be used.

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 total air conditioning load for the room.
e. Calculate the total refrigeration capacity
f. Comment on the effect of coil bypass

PROBLEM 2. (20 POINTS)

An air conditioning system operating on the winter heating cycle, is required to maintain inside conditions of 20°CdB (dry bulb), 50% RH (relative humidity), when the outdoor design conditions are 0°CdB, practically at saturation. The sensible heat loss from the building is 65 kW, and the latent heat loss is 12kW. The building will be heated using a heater and a steam humidifier. The mass ratio of outside air to the mixed air is 0.35. The supply air temperature is 40°CdB. The steam humidifier uses saturated steam at 1.8 bar.

a. Identify each characteristic point on the diagram,
b. Draw the operating cycle on the psychrometric chart provided, and show for each significant point its dry bulb temperature and relative humidity.
c. Determine the supply air conditions and quantity.
d. Calculate the rating of the heater.
e. Calculate the mass flow rate of steam.

PROBLEM 3 (20 POINTS).

a. 10 points.

Each person in a room is assumed to be producing CO₂ at an average rate of 0.005 l/sec. and air with a CO₂ concentration of 260 ppm is being supplied to the room at a rate of 3.2 m³/sec.

It is desired to keep the concentration of CO₂ in the space below 1000 ppm. Assuming complete mixing how many persons could occupy the room and not exceed the desired CO₂ level.
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.

Using the recommended limits of comfort, comment on the comfort of the group.

The MRT is 78°F. Suppose the group is moving around (light activity) instead of sitting. What is your conclusion about their comfort level?

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 equal friction method to select duct sizes for the small duct system shown below.

Data:
- the velocity in section AB is limited to 1000 FPM.
- total pressure loss across each diffuser is 0.02 in. w.g. at the given flow rates.

Calculate the total pressure loss that the fan must supply at A. Give duct sizes in diameter and as well as equivalent rectangular dimensions.
PROBLEM 5. (20 POINTS)

A wall is constructed of: 4 in. face brick, pressed fiber board sheathing \((k = 0.44 \text{ Btu-in./ft}^2\cdot\text{hr}\cdot\text{o}^\circ\text{F})\), 3.5 in. air space, 0.5 in. lightweight gypsum plaster on 0.5 in plaster board.

When the inside air temperature is 70°F and the outside temperature is -15°F, how thick must be the sheathing in order to prevent water pipes from freezing?
Comment on moisture flow through wall structures and proper installation of vapour barriers.

PROBLEM 6. (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 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 undercooling 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 \((\text{cm}^3)\) which is single acting and runs at 250 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 on ground water heat pumps.

PROBLEM 7. (20 POINTS)

You are involved in selecting the revamping and modernizing of heating and cooling system for a campus of a big university 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 20-story office building with floor dimensions 150 ft x 200 ft and a height of 240 ft has curtain walls with windows that are fixed and airtight. The window wall ratio is 0.8. 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 $150 \text{ ft}^2$ of gross floor area) making an average of four entrances or exits per 10 hours. The indoor and outdoor temperatures are $75^\circ F$ and $20^\circ F$, 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 20.

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