PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – May 2014

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 space is to be maintained at 78°F db and 50% relative humidity. The total cooling load is 250,000 Btu/h, the sensible portion of the load is 220,000 Btu/h. Indoor air quality considerations require 14,000 cfm of outdoor air. The outdoor conditions are 95°Fdb and 75°Fwb. Assume that the building is at sea level elevation. For simplicity ignore the duct heat transfer and the fan air temperature rise.

a. **Make a sketch of the system, identifying each characteristic point.**
b. **Draw the operating cycle on the psychrometric chart provided and show for each significant point its dry bulb temperature and relative humidity.**
c. **Calculate the air supply rate.**
d. **Calculate the capacity of the coil Btu/h, apparatus dew point, coil by-pass factor.**
e. **Calculate grand sensible heat factor (GSHF) required for operation on this specific day.**

PROBLEM 2. (20 POINTS)

A winter heating and humidifying system uses twenty five (25%) percent outdoor air by mass, for ventilation purposes. 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:

- the heating load is 75 kW all sensible.
- design conditions are 21°C dB (dry bulb), 30% RH.
- outside air -12°C, and essentially percent relative humidity.
- the supply temperature is 40°C.

a. **Make 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 mass flow**
e. **Calculate the Btu/hr 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 3 (20 POINTS).

A test on a fan running at 1000 r.p.m gave the characteristics shown below. The fan has a two-speed motor so it can also run at 1500 r.p.m.
The fan is used for air flow in a duct which has a resistance of 38.1 mm of water at a flow rate of 1.42 m^3/s . For some process a filter is used which has a resistance of 12.7 mm of water at a flow rate of 1.42 m^3/s and in this case the fan is run at the higher speed.

Volume flow rate (m^3/s)	*0.5*	*1.0*	*1.5*	*2.0*	*2.5*	*3.0*
Pressure (mm water)	46	52	53	48	37	19
Power consumption(kW)	0.80	1.10	1.40	1.70	2.05	2.60

Calculate:

a. **the volume rate of air delivered when the filter is fitted**
b. **the power required under this conditions**
c. **the fan efficiency at the operating point**
d. **the resistance required to be put in series with the system to reduce the flow rate by 0.47 m^3/s**

PROBLEM 4. (20 POINTS)

A small commercial building located in Regina, Saskatchewan has a heating load of 350,000 Btu/hr sensible and 45,000 Btu/hr latent. Design conditions are 70°F inside and -29°F outside. The owner has to decide between two heating options:

- warm air furnace using natural gas (efficiency 80%).
- electric resistance heating elements (efficiency of 100%).

The heating value of natural gas is 1000 Btu/std ft^3 (standard cubic feet).

Using the degree day method, and knowing that the price of natural gas is $3311.00/ million cubic feet, and the price of electricity is 0.10$/kWh, compare the annual heating costs. Neglect the cost of initial installation.

A contractor 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 3.92. The compressor/motor has an efficiency of 82%. How much will be the yearly heating cost with the heat pump?

Comment on your results. What are the environmental impacts of each alternative? Comment on the fact that the power plant that produces electricity uses coal as the fuel, and has an overall efficiency of 38%.

PROBLEM 5. (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 -12 °C. The roof area is 244 m^2 and $U_{roof} = 2.7\ W/m^{2o}K$. The ceiling area is 203 m^2 and $U_{ceiling} = 0.30\ W/m^2\,^oK$. Inside design temperature is 22 °C.
Determine the ceiling heat loss W and compare to the loss if there had been no ventilation.

PROBLEM 6 (20 POINTS).

a. 10 points

Describe the method of calculating the summer heating load.

b. 10 points.

A wall is constructed of 4 in. face brick, pressed fiber board sheathing (k = 0.44 Btu-in./ft^2-hr-$^\circ$F), 3.5 in. air space , and 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 7. (20 POINTS)

a. 10 points

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

b. 10 points

Indoor air quality is one of the major concerns in HVAC industry today.
Describe succinctly what are the factors influencing the indoor air quality, and what measures are to be taken in order to provide an acceptable indoor air quality. In your discussion make reference to standards and codes required in maintaining an acceptable indoor air quality, the ASHRAE comfort chart and the perception of thermal comfort.

PROBLEM 8. (20 POINTS)

A home heating system uses an air heat pump with R-134a as the refrigerant. The maximum heating load results when the temperature of 1000 ft^3/min of inside home circulation air is raised 45°F.

The refrigerant R-134a, enters the compressor at 30 psia dry saturated, and leaves it at 160 psia, there is no undercooling in the condenser. Consider isentropic efficiency of the compressor as 0.9.

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

a. **Calculate the coefficient of performance COP.**
b. **Calculate the mass flow of the refrigerant**
c. **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.**
d. **Describe the limitations of this system. If you must use this system in Ottawa, Ontario, what you suggest to be done.**

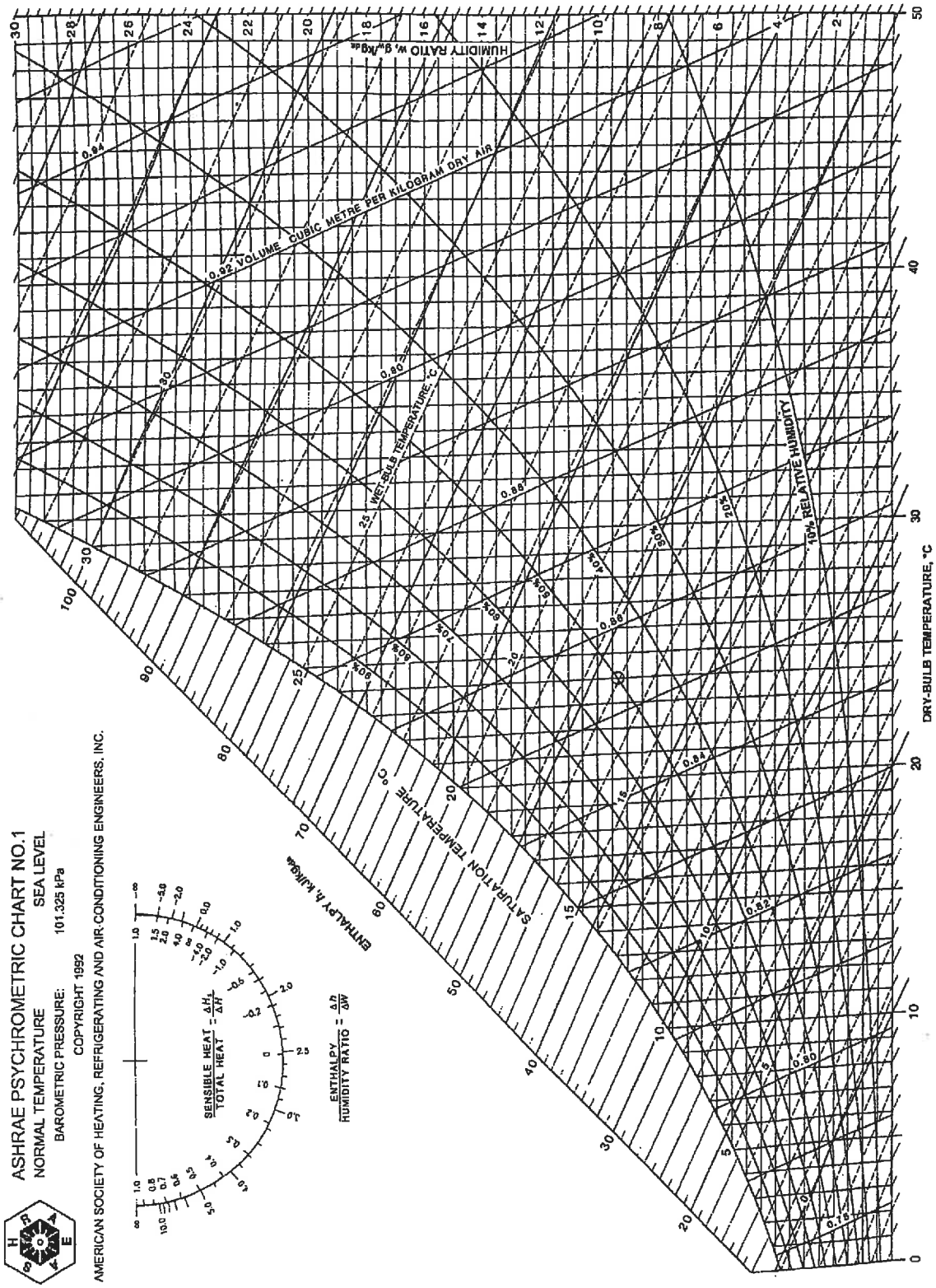
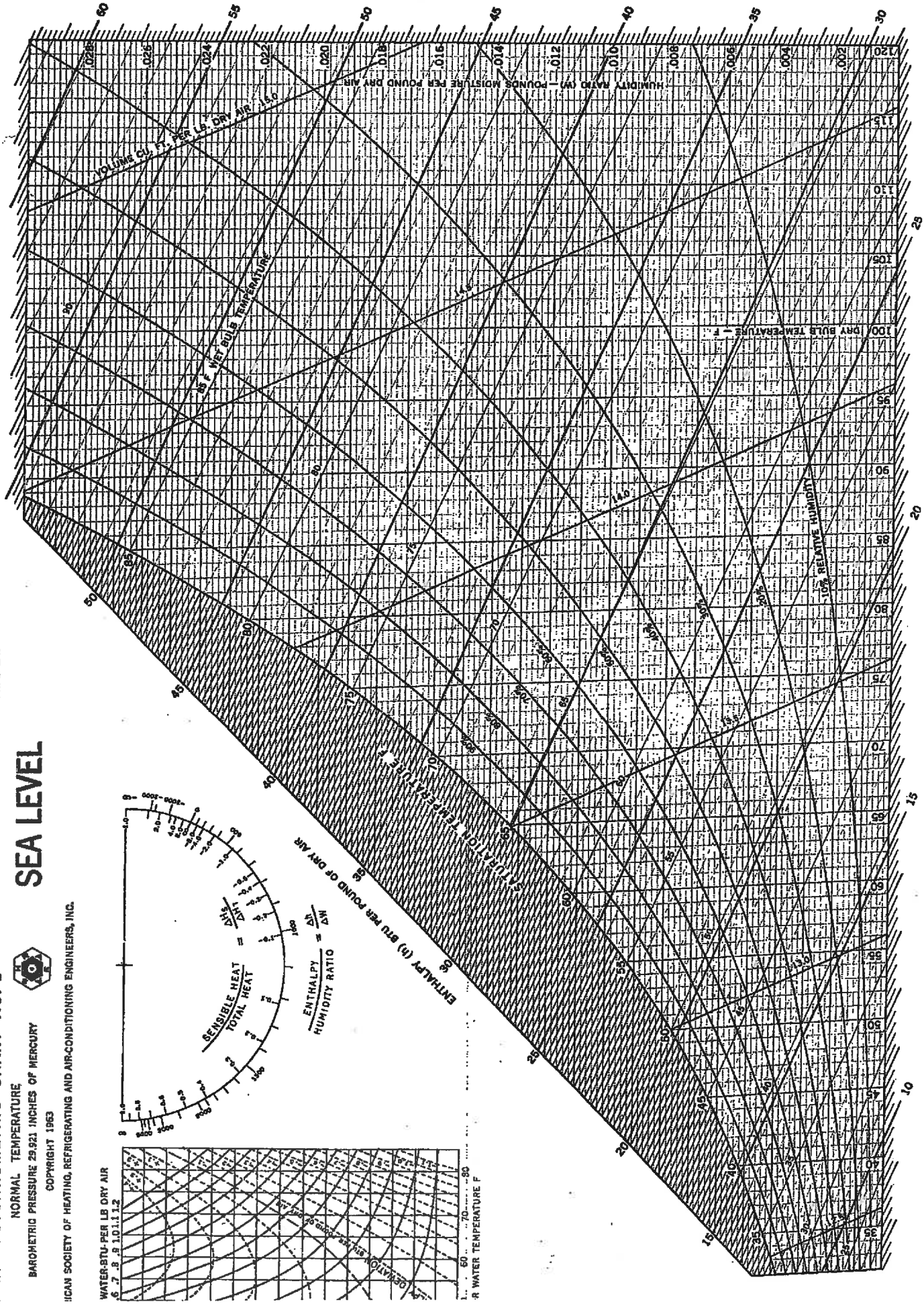
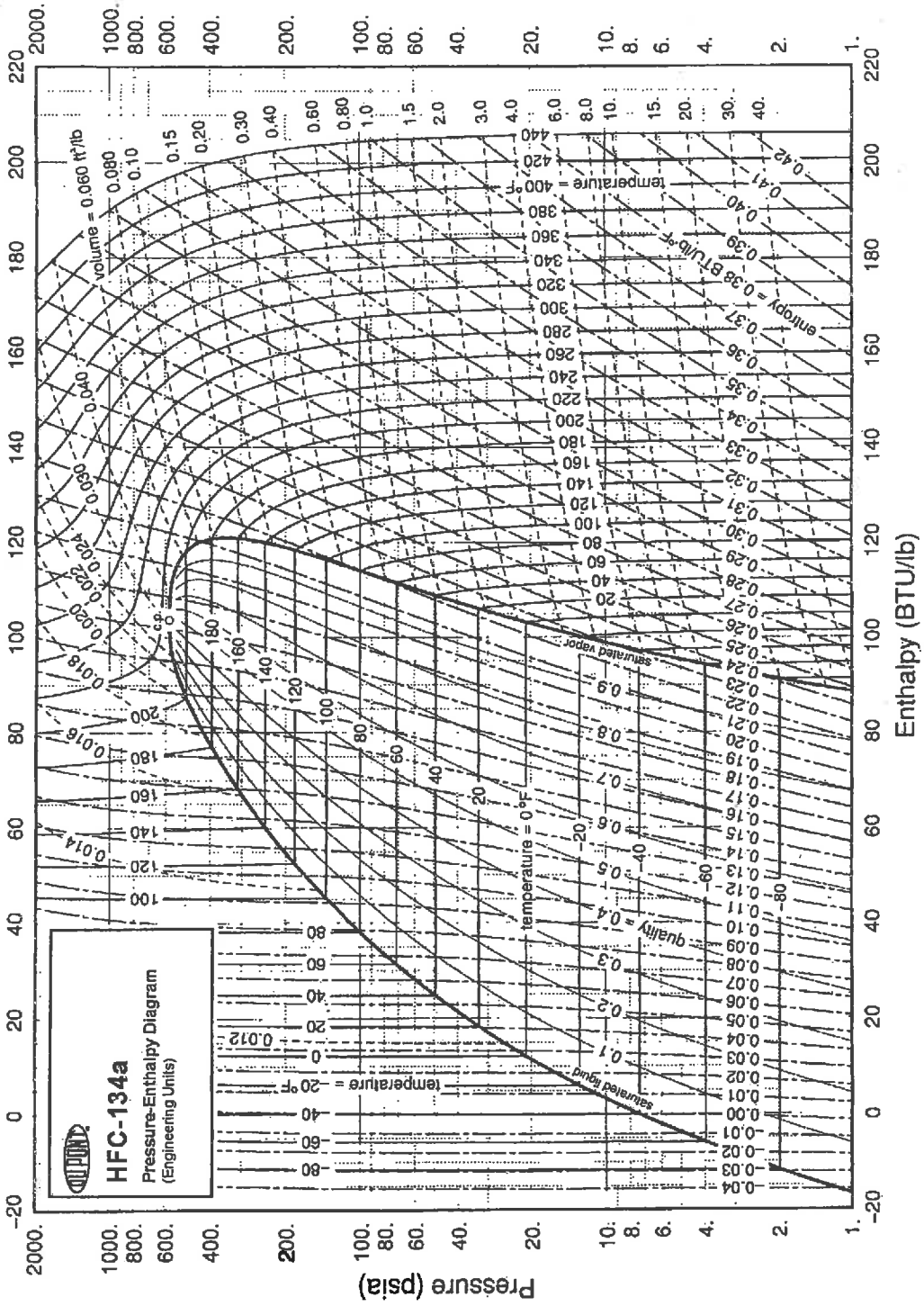


Fig. 1 ASHRAE Psychrometric Chart No. 1


HRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
ICAN 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
VOLUME CU. FT. PER LB. DRY AIR
45 F WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
WATER-BTU-PER LB DRY AIR
R WATER TEMPERATURE F


HFC-134a
Pressure-Enthalpy Diagram
(Engineering Units)
Pressure (psia)
Enthalpy (BTU/lb)
volume = 0.060 ft³/lb
temperature = 400°F
entropy = 0.38 BTU/lb-°F
temperature = 0°F
quality = 0.4
saturated vapor
saturated liquid
temperature = −20°F