PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – December 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 summer air conditioning system for a clothing store is being designed. The following information is available:

Outside design	100°F DB, 78°F WB
Inside design	75°F DB, 50% RH
Sensible load:	
Room sensible heat	265,000 Btu/hr
Sensible heat from outside air	90,500 Btu/hr
Total sensible-heat load	355,500 Btu/hr
Latent load:	
Room latent heat	71,500 Btu/hr
Latent heat from outside air	102,500 Btu/hr
Total latent-heat load	174,000 Btu/hr
Outside air to meet the ventilation standard	3,500 cfm

Duct heat gains have been included in the determination of the internal heat load.

A direct expansion cooling coil with a by pass factor (BPF) rated at 0.084 will be used.

Analyze the problem on a psychrometric chart and determine the following:

a. The sensible heat factor SHF
b. The room apparatus dew point
c. Temperature of air leaving the coil
d. Total air quantity required, in cfm
e. Temperature of mixed air entering the coil
f. Coil apparatus dew point
g. Moisture removal, in pounds/hr
h. Tons of refrigeration required

PROBLEM 2. (20 POINTS)

A space is air conditioned in winter by a system consisting of filter, heating coil, a fan and a humidifier. The space has a total heating load of 30 kW and a sensible heat ratio SHR = 0.6 on a day when the space temperature and relative humidity are maintained at 21°C DB and 50 %RH, respectively, and the outside temperature and humidity are 10°C DB and 10% RH, respectively. The system uses 60% return air and 40% outside air (based on mass flow rates of dry air). Supply air is provided to the space at a rate of 7000 kg/hr. The saturated steam of the humidifier is at 120°C.

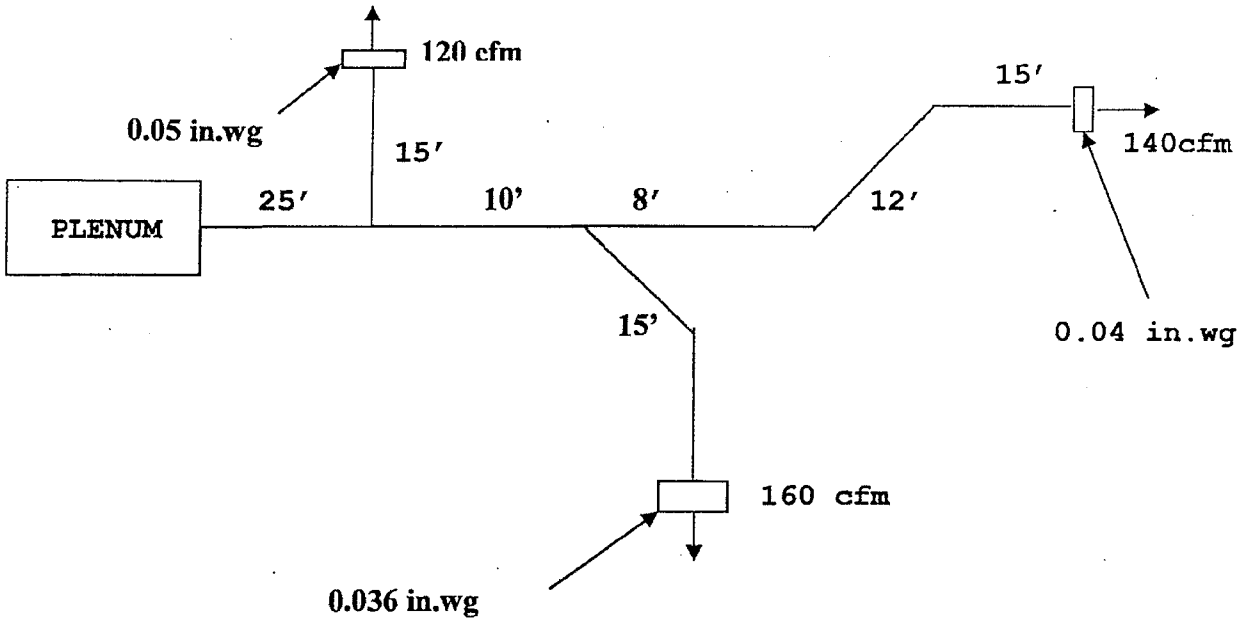
a. Draw a diagram of the system.
b. Draw the operating cycle on the psychrometric chart provided.
c. Identify each significant point, on the diagram and chart.
e. Calculate the rate of the heat addition by the heating coil.
f. Calculate the rate of the moisture addition by the humidifier.

PROBLEM 3 (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 0.13 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 4. (20 POINTS)

a. 10 points

A large office space has an average occupancy of 20 people from 8:00 a.m. to 5:00 p.m. Lighting is 2.5 W/ft^2 recessed, unvented fluorescent fixtures from 8:00 a.m. to 6:00 p.m. Computers, photocopiers, fax machines, etc. create a heat gain of 1.8 W/ft^2. Calculate the sensible and latent heat gain at 4:00 p.m. for the space, assuming a floor area of 4000 ft^2.

b. 10 points

Using the degree-day method, estimate the quantity of natural gas required to heat a building in Ottawa, Ontario. Design conditions are 70 °F inside and -12 °F outside. The heating load is 350,000 Btu/hr. Furnace efficiency is 80% and fuel heating value is 1000 Btu/ft^3.

PROBLEM 5. (20 POINTS)

a. 15 points

An office has one external wall 5 m long, containing a window of area $4m^2$; the width of the office from the window to the wall adjacent to the corridor is 4m, and the ceiling height is 3m. There are similar offices above, below and on either side. The temperature in the corridor is 16 °C, the temperature in the room is 20°C, and the external design temperature is -1°C. If the heat transfer coefficients for the external wall, window and internal wall are 1 W/m^2K, 5.6 W/m^2K, and 2.7 W/m^2K, respectively, and an air change rate of one per hour is required for ventilation, calculate the heat input to the room.

b. 5 points.

Comment on moisture flow through wall structures and proper installation of vapour barriers.

PROBLEM 6 (20 POINTS).

An old hospital has an air conditioning system dating from the early 1970. The system is using Freon-12 (R12), and has a electric chiller plant.

Due to expansion, as well as the maintenance of the system, discussions are about changing the system.

(a) Comment about the refrigerants available to be used now, in a new system.
(b) What system(s) you will recommend that will be environmentally acceptable for the next 30 years?
(c) Comment about COP's of different systems.
(d) What is district heating?
(e) Comment on the winter heating if district heating is used.
(f) If the system is not changed what are the methods to be used to maintain the existing plant?
(g) What are the ozone depletion potential of different refrigerants recommended.

PROBLEM 7. (20 POINTS)

A 20-story office building with floor dimensions 60 ft x 120 ft and a height of 220 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 120-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 70°F and 20°F, and the wind is parallel to the 60-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.

PROBLEM 8. (20 POINTS)

A heat pump using refrigerant R134a heats a house by using underground water at 45°F as the heat source. The house is losing heat at a rate of 70,000 Btu/hr. The refrigerant enters the compressor at 30 psia and 20°F and leaves it at 120 psia and 140°F. The refrigerant leaves the condenser at 90°F. Determine:

a. **The power input to the heat pump,**
b. **The rate of heat absorption from the water,**
c. **COP and Carnot COP**
d. **Compare the (a) with heating by using an electric resistance heater.**
e. **Comment about ground source heat pumps.**

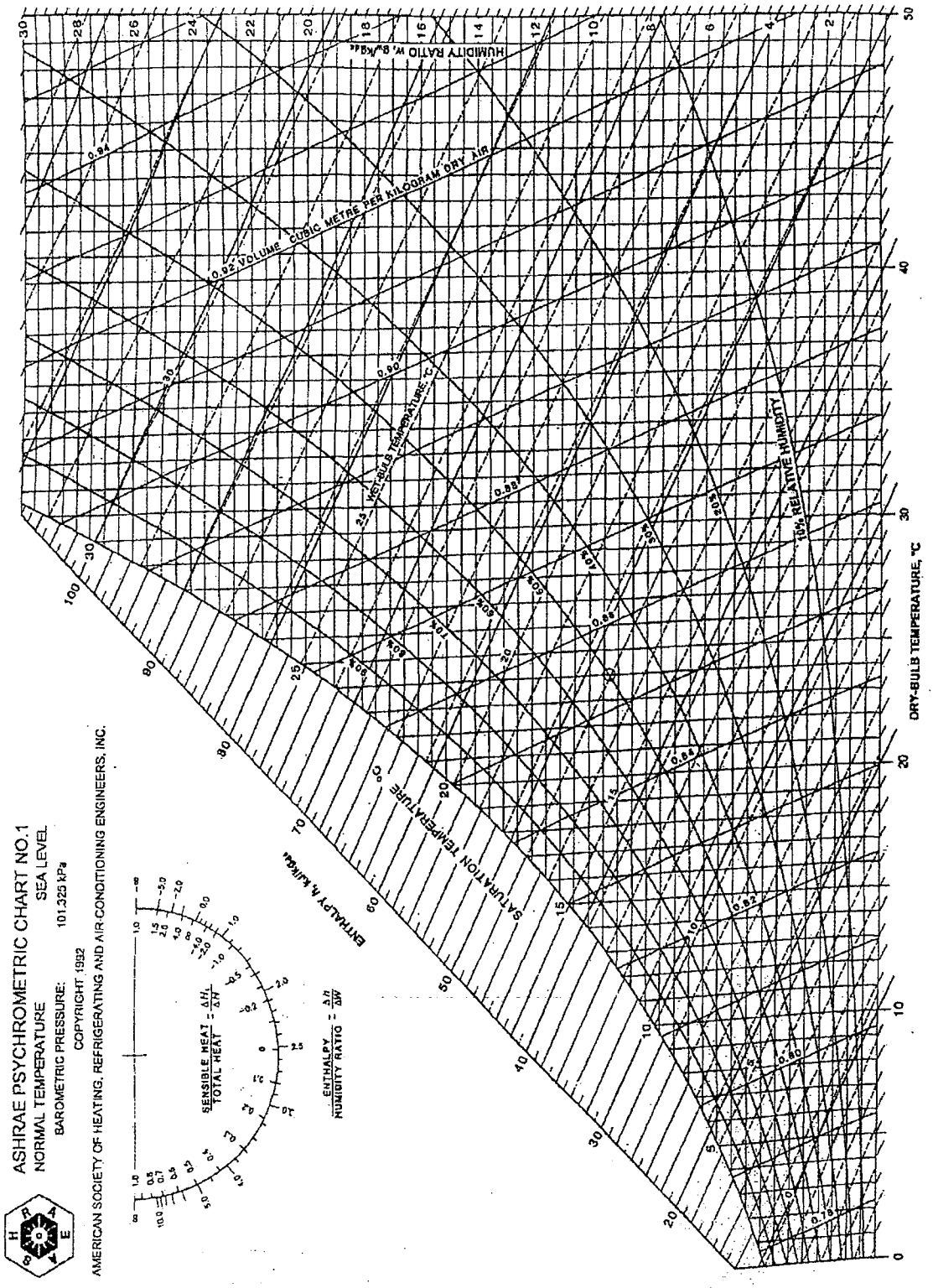
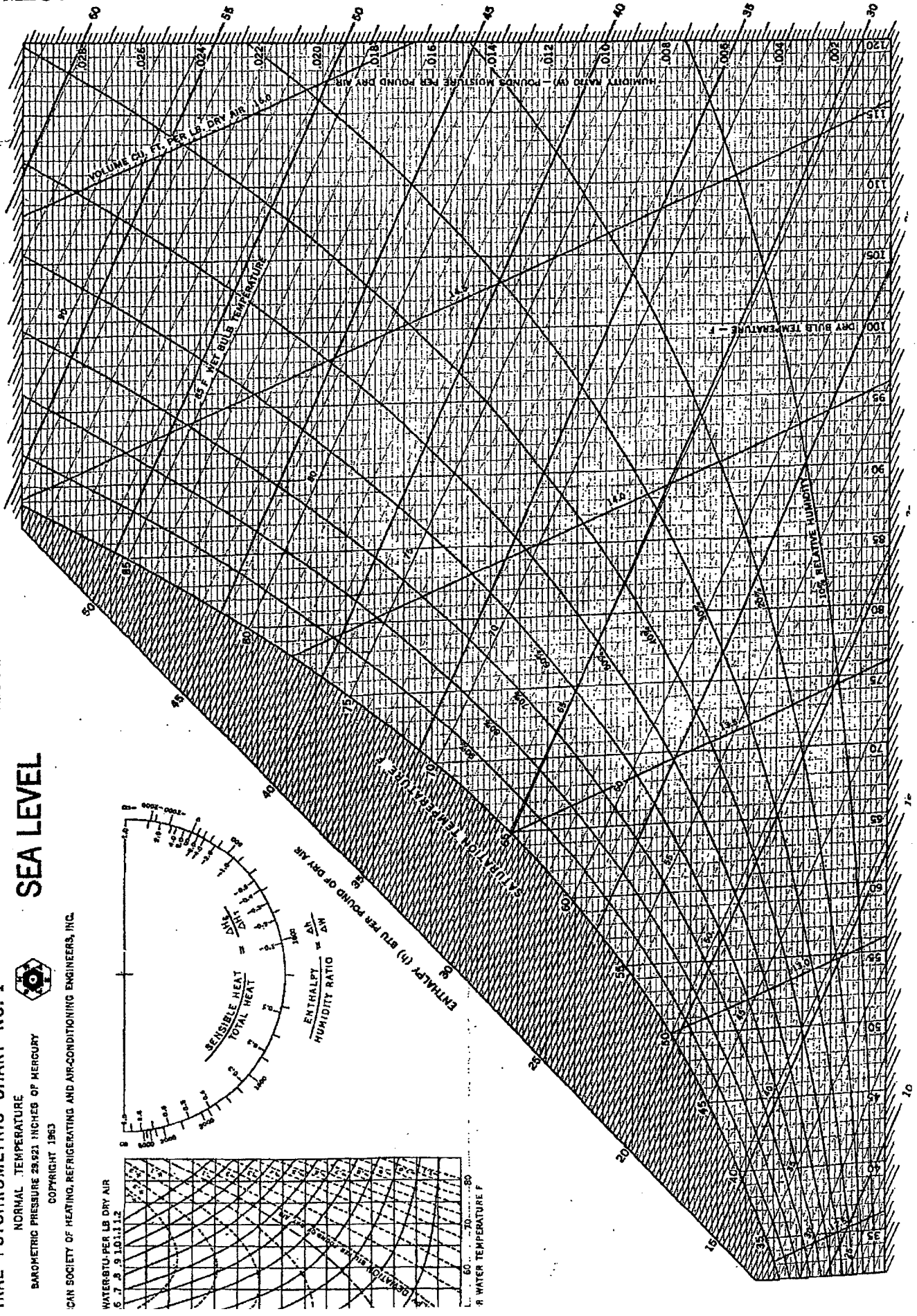
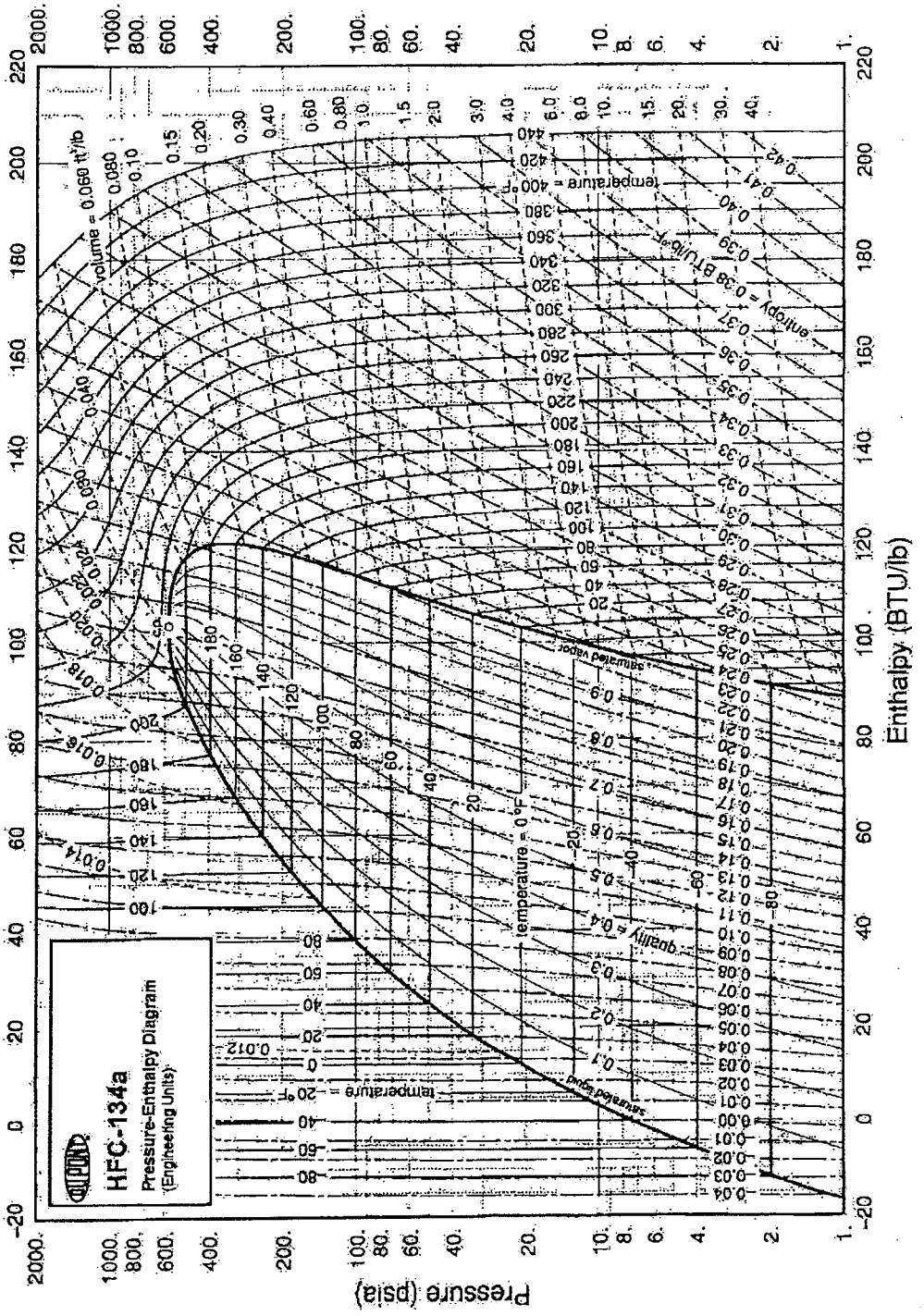


Fig. 1 ASHRAE Psychrometric Chart No. 1


ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
SEA LEVEL
Chart 1a
DRY BULB TEMPERATURE — F
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
ENTHALPY — BTU PER POUND OF DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
65 F WET BULB TEMPERATURE
100% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
WATER-BTU-PER LB DRY AIR
WATER TEMPERATURE F


HFC-134a
Pressure-Enthalpy Diagram
(Engineering Units)
Pressure (psia)
Enthalpy (BTU/lb)
Volume = 0.060 ft³/lb
Temperature = 400°F
Temperature = 0°F
Temperature = -20°F
Saturated Vapor
Saturated Liquid
Quality = 0.4