# PROFESSIONAL ENGINEERS OF ONTARIO

## ANNUAL EXAMINATIONS – May 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 zone in a building has a sensible load of 20.5 kW and a latent load of 8.8 kW. The zone is to be maintained at 24°C and 50% relative humidity (RH), with an air supply to the room of 1.8 kg/s at 14°C and 60% relative humidity. The outside design conditions are 28°C and 70% relative humidity.
The plant consists of a mixing chamber for re-circulated and outside fresh air, a cooling coil supplied with chilled water, a heating coil and supply fan. The ratio of re-circulated air to fresh air is 3:1; the cooling coil has an apparatus dew point of 5°C, and the refrigeration unit supplying the chilled water has an overall coefficient of performance of 2. Neglect all friction losses and fan and pump work. Assume sea level conditions.

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 energy input.
f. Calculate the required energy input if the energy to the heating coil is supplied from the refrigeration plant condenser cooling water.

## PROBLEM 2. (20 POINTS)

An air conditioning system operating on the winter heating cycle, is required to maintain inside conditions of 68°FdB (dry bulb), 50% RH (relative humidity), when the outdoor design conditions are 32°FdB and 10% RH. The sensible heat loss from the building is 220,000 Btu/hr, and the latent heat loss is 45,000 Btu/hr. The building will be heated using a heater and a steam humidifier. The mass ratio of outside air to the mixed air is 0.45. The supply air temperature is 100°FdB. The steam humidifier uses saturated steam at 20 psia.

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 (lb/hr)
d. Calculate the Btu/hr rating of the heater.
e. Calculate the mass flow rate of steam.

## PROBLEM 3 (20 POINTS).

A centrifugal fan operating at 2400 rpm delivers 20,000 cfm of air through 32 inch diameter duct against a static pressure of 4.8 in. $H_2O$.
The air is at 40°F. The barometric pressure is 29.0 in. Hg.

a. Calculate the power, if the efficiency is 70%.
b. If the fan size, gas density, and duct system remains the same, calculate the power required if the fan is operated at 3200rpm.
c. Explain the effect of air density on the flow rate, developed head and horsepower.

## PROBLEM 4. (20 POINTS)

### *a. 10 points*

**Indoor air quality is one of the major concerns in HVAC industry today.**
**Please describe in a maximum of two pages 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.**

### *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 50 $\mu g/m^3$, what outdoor airflow is needed to satisfy the required (recommended by standard) conditions in the building.**

## PROBLEM 5. (20 POINTS)

**The wall of a house consists of two 125mm thick brick walls with an inner cavity. The inside wall has a 10 mm coating of plaster and there is cement rendering of 5 mm on the outside wall. In one room of the house the external wall is 4 m x 2.5 m, and contains a window of 1.8 m x 1.2 m of 1.5mm thick glass. The heat transfer coefficients for the inside and outside surfaces of the wall and window are 8.5 and 31 $W/m^2K$, respectively. The thermal conductivities of brick, plaster, cement and glass are 0.43, 0.14, 0.86, and 0.76 W/m K, respectively.**

**Calculate the proportion of the total heat transfer which is due to the heat loss through the window. Assume that the resistance of the air cavity is 0.15 $m^2K/W$. Neglect all end effects, and neglect radiation.**

## PROBLEM 6. (20 POINTS)

**A small size induced (forced draft) cooling tower is designed to cool 6 liters of water per second, with the inlet temperature of 45°C. The motor driven fan induces 9 $m^3/s$ of air through the tower and the power absorbed is 4.75 kW. The air entering the tower is at 18°C, and has a relative humidity of 60%. The air leaving the tower can be assumed to be saturated and its temperature 26°C.**

**Show a diagram of the cooling tower.**
**Calculate the final temperature of the amount of cooling water make-up required per second.**
**Assume that pressure remains constant throughout the tower at 1.013 bar.**

## PROBLEM 7. (20 POINTS)

**A small commercial building located in Toronto, Ontario has a heating load of 75 kW sensible and 12 kW latent. Design conditions are 22°C and -20°C. The structure is heated with natural gas warm-air furnace, with an efficiency of 85%.**

**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 3.56. The compressor/motor has an efficiency of 82%.**

**Draw a schematic as 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 environmental impact for each solution.**

## PROBLEM 8. (20 POINTS)

### a. 15 points

**An ideal R134a chiller operates with a condensing temperature of 125°F and an evaporator temperature of 35°F. If the cooling rate is 20 tons, what are the refrigerant flow rate, condenser pressure, evaporator pressure, and COP?**

**Compare the COP with that of a Carnot refrigeration cycle operating between the same condensing and evaporating temperatures.**

### b. 5 points

**What are the primary environmental concerns related to the use of refrigerants.**

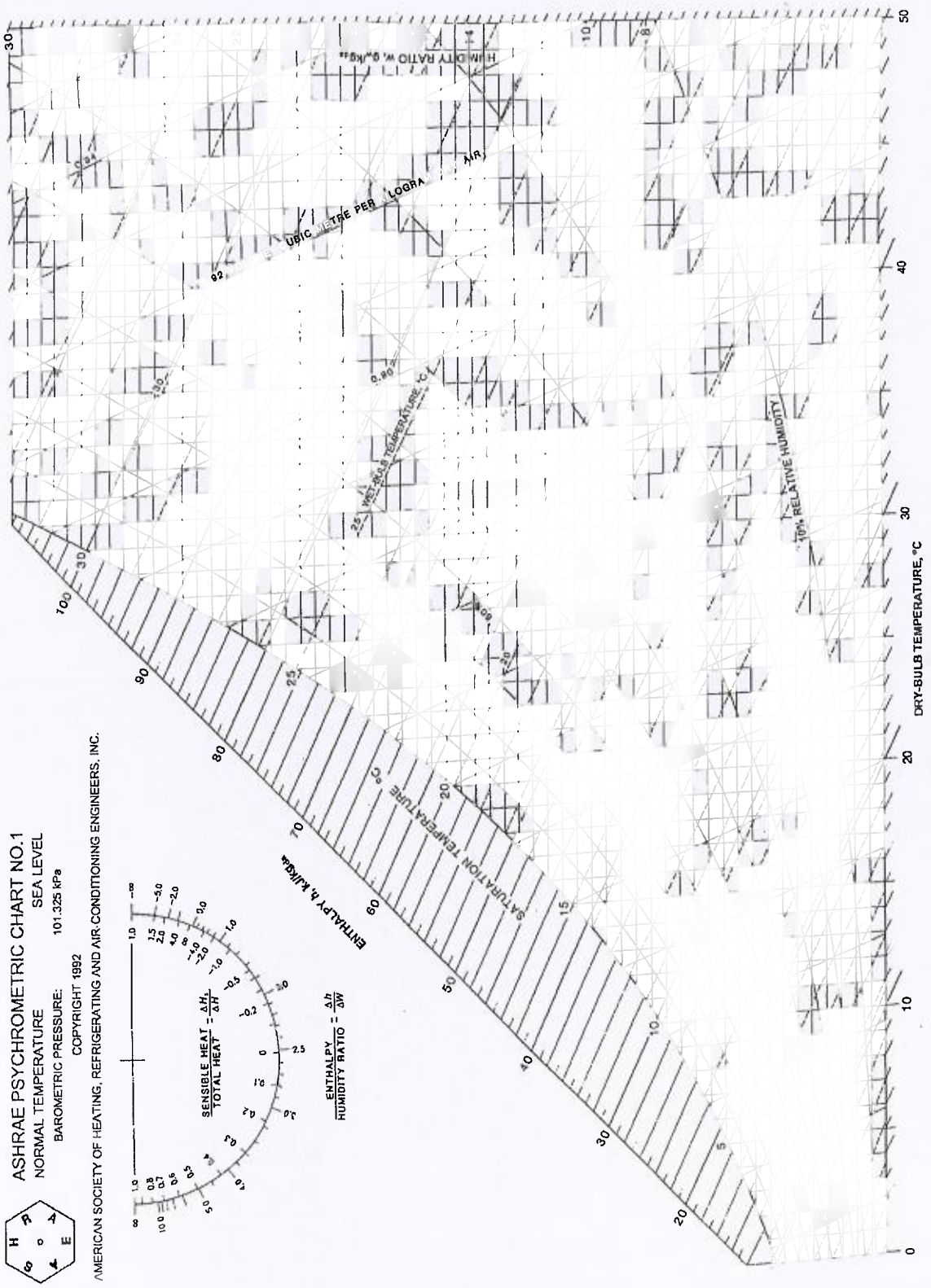
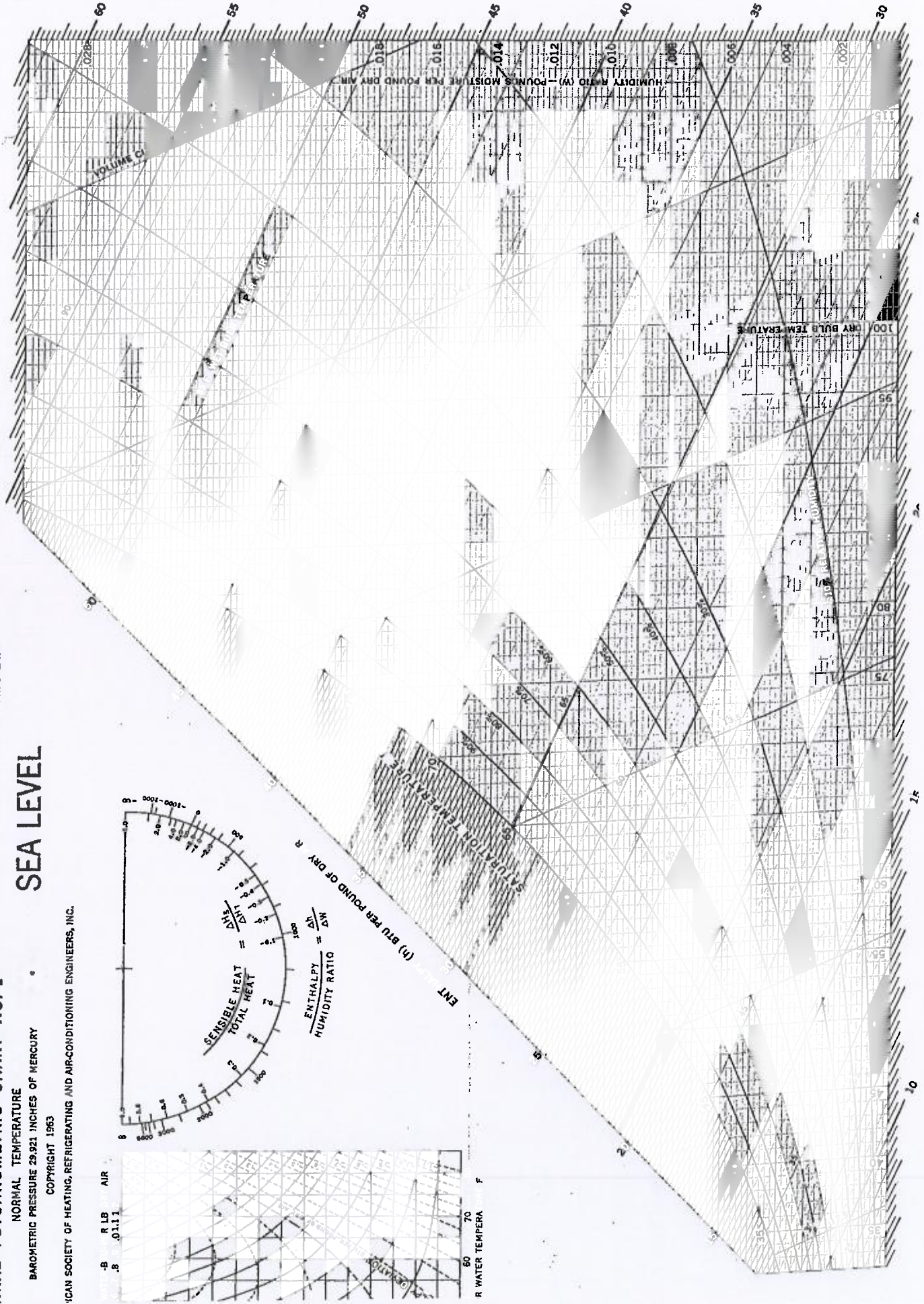
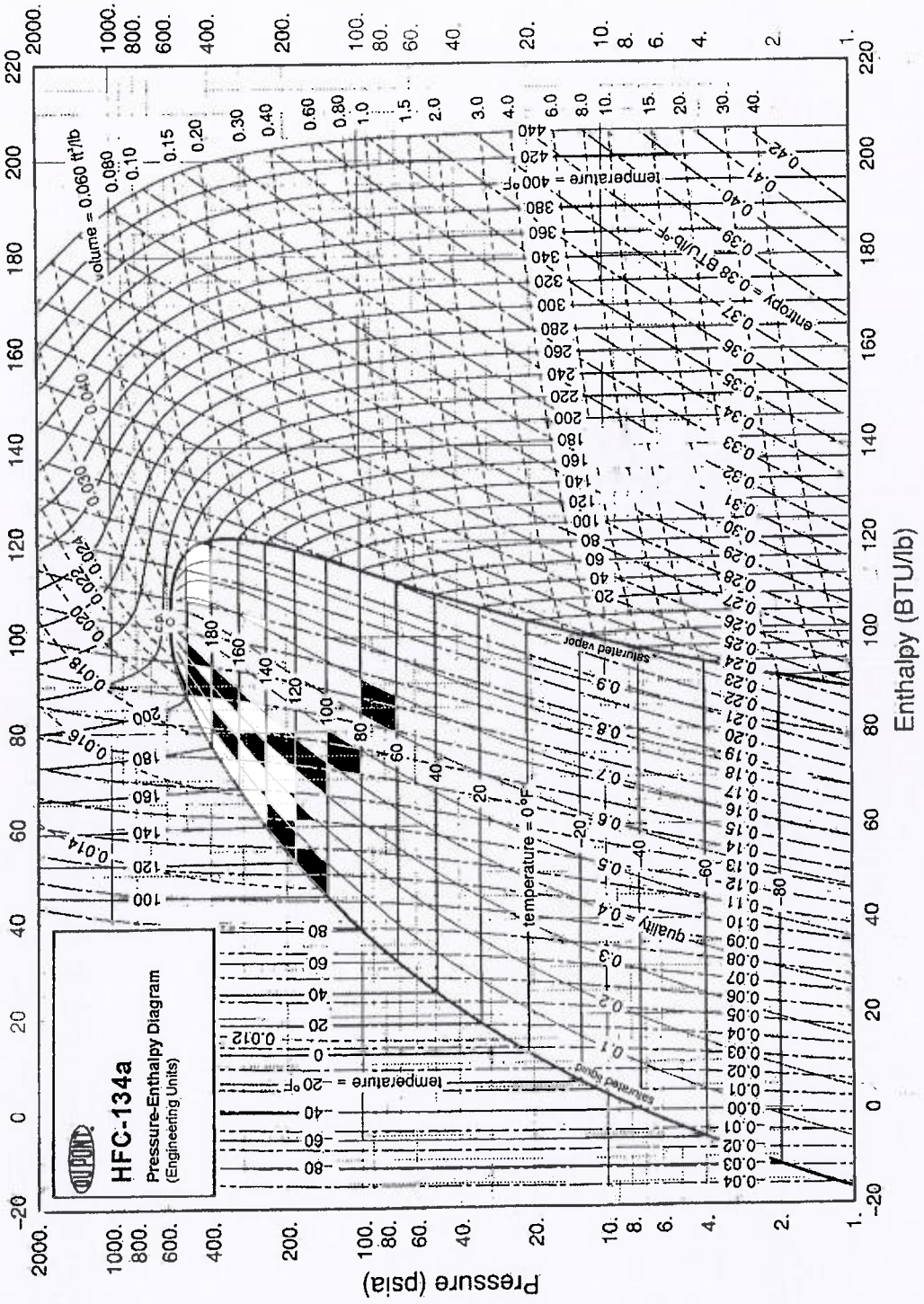



Fig. 1 ASHRAE Psychrometric Chart No. 1


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
Chart 1a
DRY BULB TEMPERATURE
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
SATURATION TEMPERATURE
ENTHALPY (h) BTU PER POUND OF DRY AIR
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
VOLUME CU FT PER LB DRY AIR
R WATER TEMPERA 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
temperature = −20 °F
saturated vapor
saturated liquid