PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – December 2016

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 department store designed for 75°F dB (dry bulb) temperature and 50% relative humidity, has a calculated cooling load of 450,000 Btu/hr sensible heat and 120,000 Btu/hr latent heat Ventilation air of 30% of total air (by mass) is required on a day when outside air conditions are 90°F dB and 60% relative humidity.

After leaving the room, some of the air exhausts to the outside and the remainder mixes with the ventilation air and then passes through a filter, fan, and the cooling coil.

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 air supply rate.
e. Calculate the capacity of the coil (kW).
f. Find apparatus dew point.
g. Find coil by-pass factor.

Assume sea level conditions, and neglect the effects of duct heat transfer and fan air temperature rise.

PROBLEM 2. (20 POINTS)

A space heating system has a furnace, a humidifier and a preheater.
Outdoor air enters the preheating coil at -14°C and essentially 0 percent relative humidity. The outdoor air is then heated to 16°C and mixed with the return air. Then it is heated and humidified to 40°C and 30% relative humidity for supply to the space. 25% (by mass) of supply air is outside air, required for proper ventilation. The building has a total heating load of 145 kW. The sensible heat factor for the space is 0.8, and the space is to be maintained at 20°C and 30% relative humidity. Saturated steam at 1.2 bar is used for humidification.

a. Sketch the system and draw the cycle on the psychrometric chart.
b. Identify each significant point, on the diagram and psychrometric chart, and note for each of these points its dry bulb and wet bulb temperature.
c. Find the conditions and the amount of air supplied to the space
d. Calculate the temperature rise of air in the heating coil (furnace).
e. Calculate the amount of water vapour required.
f. Calculate the capacity of the heating coil (furnace) and of the preheater.

PROBLEM 3. (20 POINTS)

A small office, 50 ft by 100 ft, located in downtown Toronto, Ontario, has design heating and cooling loads of 280,000 Btu/hr and 125,000 Btu/hr, respectively. Design conditions of 75°F inside and -5°F outside were used for winter while 78°F inside and 91°F outside were used for summer. The average interior heat gain during the winter has been estimated at 8 kW.

The owner is considering the following systems:

a. Electric baseboard heaters and a high efficiency air conditioner
b. A gas furnace and the same air conditioner

Estimate the annual cooling and heating energy requirements using the degree day method and the corresponding energy cost, if the price of natural gas is 4.00 $/thousands cubic feet, and the price of electricity is 0.10$/kWh. Neglect the cost of initial installation.

Do you have any recommendations, in order to reduce the costs?

PROBLEM 4. (20 POINTS)

On a particular day when the outside temperature is 4°C, a house requires a heat transfer rate of 16kW to maintain the inside temperature of 20°C. A vapour-compression heat pump with refrigerant R 22 as working fluid is used to provide the necessary heating.

Specify the appropriate evaporator and condenser pressure of the cycle for this purpose. Let the refrigerant be saturated vapour at the evaporator exit and saturated liquid at the condenser exit.

Calculate:

a. The mass flow of the refrigerant in kg/min
b. The compressor power in kW
c. The coefficient of performance

PROBLEM 5. (20 POINTS)

Explain succinctly (about half page each explanation) the following concepts. Each explanation is 4 points

a. Self sustainable dwelling
b. LEED certification
c. Cogeneration and trigeneration
d. Carbon footprint
e. Sick building syndrome

PROBLEM 6. (20 POINTS)

a. 15 points

A 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 5mm on the outside wall.
In one room of the house the external wall is 4 m by 2.5 m and contains a window 1.8 m by 1.2 m of 1.5mm 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 $0.16 m^2K/W$. Neglect all end effects, and neglect radiation.

b. 5 points

Explain moisture flow through walls. Discuss vapour barriers, their role and installation.

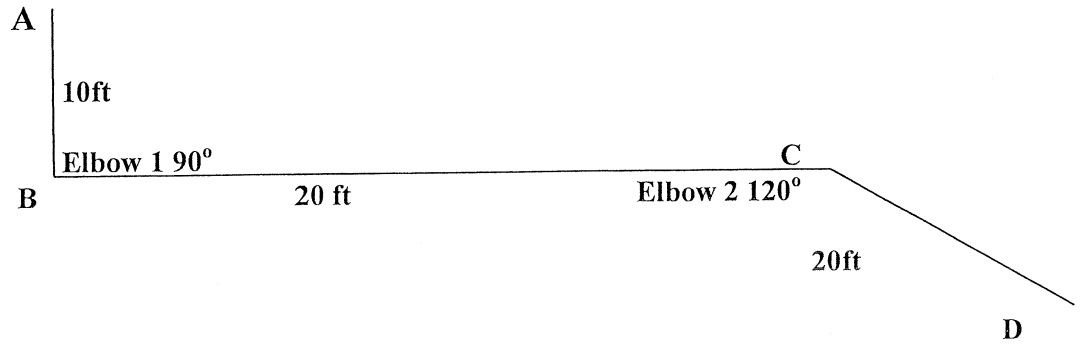
PROBLEM 7. (20 POINTS)

a. 10 points

A duct system designed for 1000cfm of air has a 16" diameter round duct entering a fan and a 10" diameter round duct leaving the fan. Required pressures in the system are –0.15 in. wg at the fan inlet and +0.30 in. wg at the fan discharge to create the pressure difference for the air flow.
Draw the fan arrangement and find the energy required in feet of air and horse power

b. 10 points

Find the pressure loss between points A and D for the 12" x 12"duct shown schematically below. Air at standard conditions is being supplied to the rate of 2000 cfm in galvanized duct of average construction. Elbow nr 1 and nr 2 have centreline radii of 13" and 24", respectively.



PROBLEM 8. (20 POINTS)

A room is located at the middle floor of a multi-storey office building in Ottawa, Ontario. The room is to be maintained at 75°F in summer. It has an exterior all-glass wall facing east is 8 ft high and 20 ft wide, with no internal shading. The glass is double pane (1/2" air space) insulating glass with heat absorbing outer pane and clear inner pane. The other three walls, the floor and the suspended ceiling are all interior surfaces with no heat loss or gain. The room is occupied by six office workers (light physical work) from 8:00 to 18:00. There are a total of 6 fluorescent lighting fixtures in the room, each with two 40-watt tubes. The lights are turned on continuously from 8:00 to 18:00.

Determine the cooling load for the room at hour 15:00 in July due to people, lights and the glass wall. State clearly your assumptions. (I.e. wind, partition, room mass, etc.)

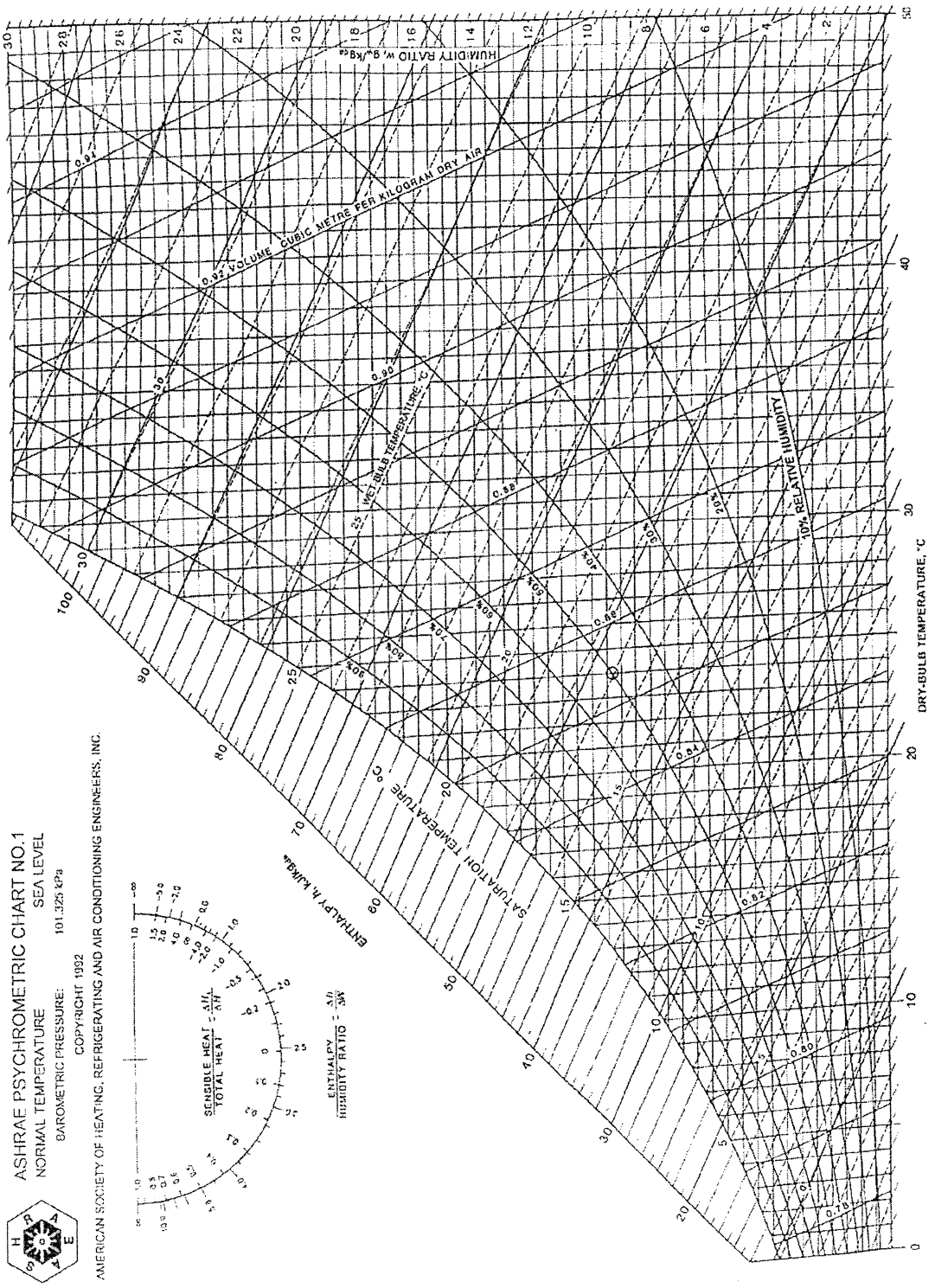
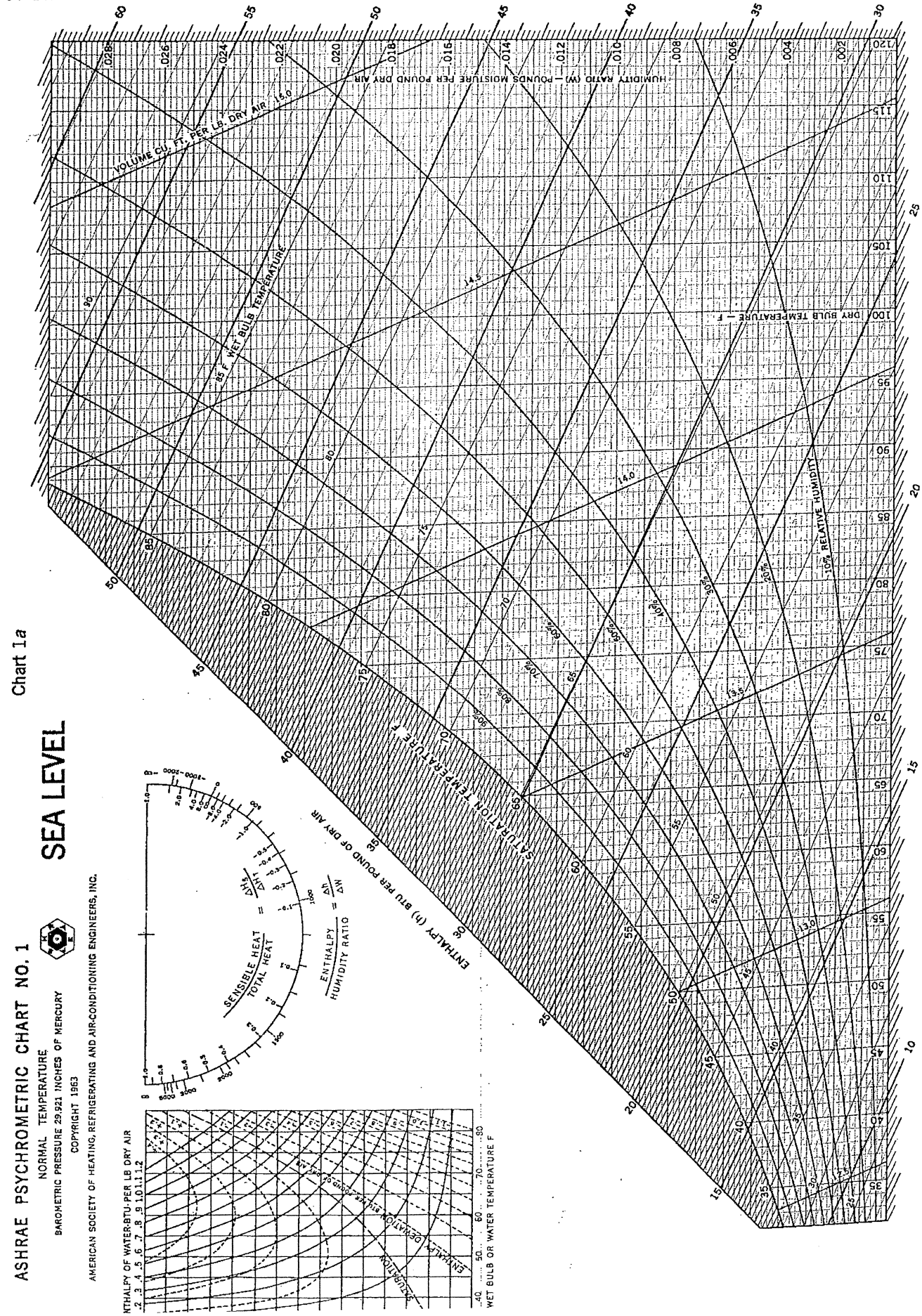
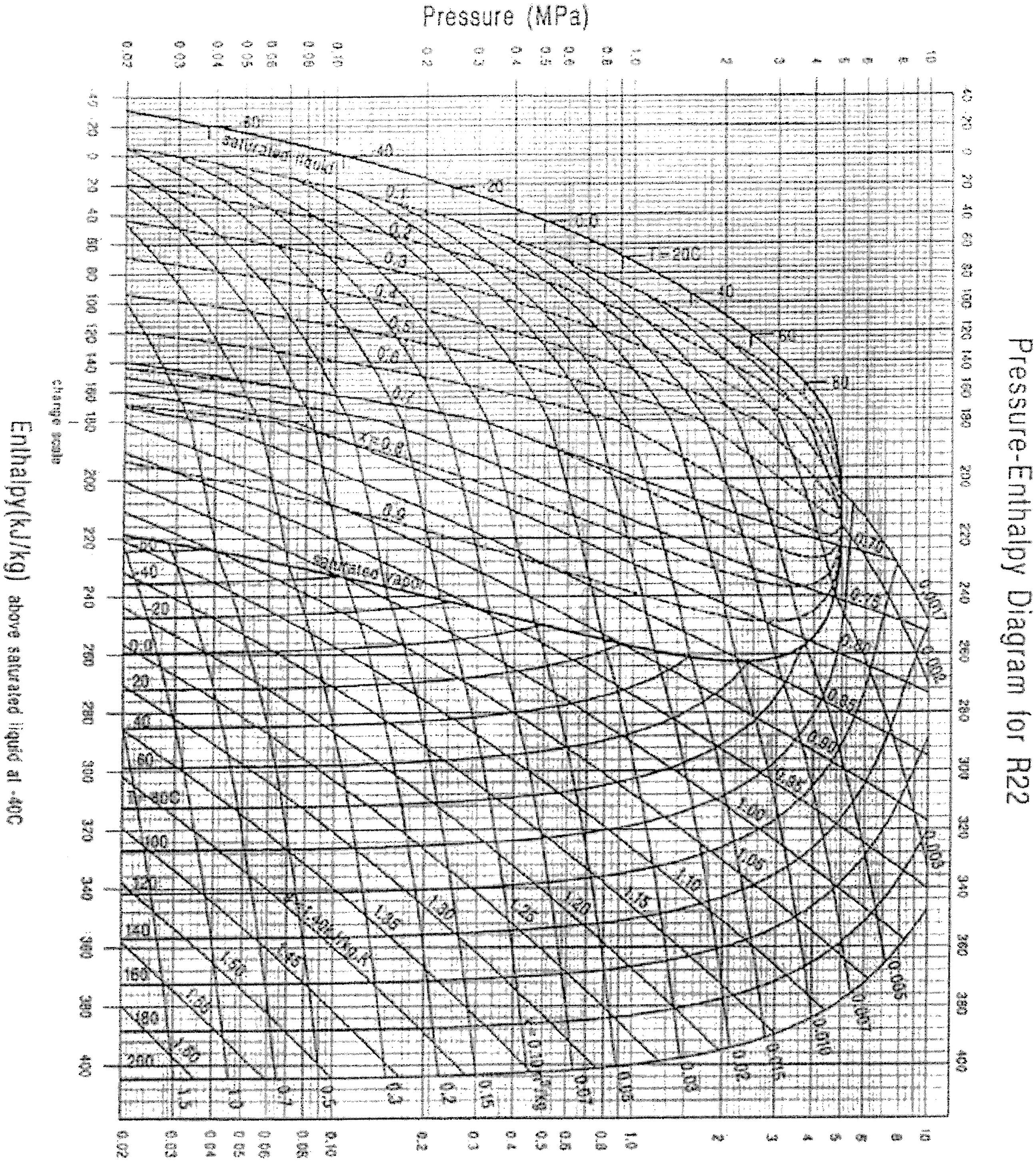


Fig. 1 ASHRAE Psychrometric Chart No. 1


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 - F
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
ENTHALPY (h) BTU PER POUND OF DRY AIR
ENTHALPY (h) BTU PER POUND OF DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
65 F WET BULB TEMPERATURE
RELATIVE HUMIDITY
SATURATION TEMPERATURE - F
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
ENTHALPY OF WATER-BTU-PER LB DRY AIR
WET BULB OR WATER TEMPERATURE F
SATURATION
ENTHALPY DEVIATION
MOISTURE DEVIATION


Pressure (MPa)
Pressure-Enthalpy Diagram for R22
Enthalpy(kJ/kg) above saturated liquid at -40C
saturated liquid
saturated vapor