NATIONAL EXAMINATIONS – December 2018

16-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.**

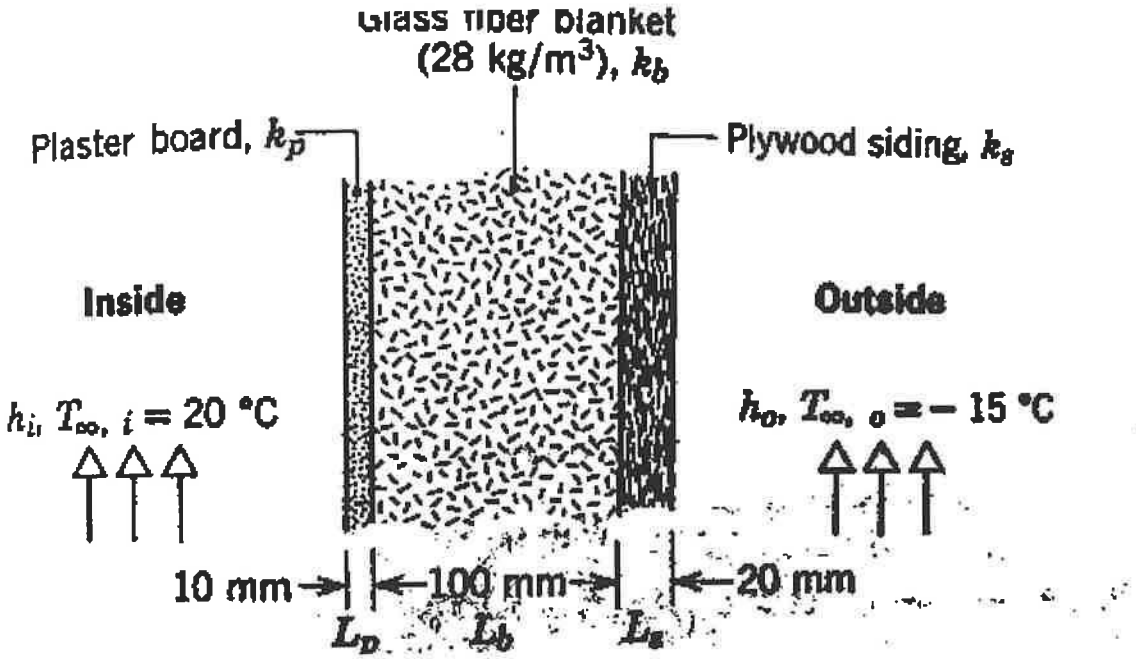
6. **Problem one is 30 points, and problem 2 is 10 points, the rest are all 20 points each. Indicate which five questions are to be graded on the cover of the first examination workbook.**

7. **Psychrometric charts and the p-h diagram for the refrigerant are attached.**

PROBLEM 1. (30 POINTS)

A house has a composite wall of plywood siding 20mm thick on the outside, fibreglass insulation 100mm thick (density 28kg/m^3), and inside plaster board of 10mm thick. On a cold winter day with an outside temperature of -15°C, the outside convection coefficient is h_o=60W/m^{2}K, and the inside convection coefficient is h_i=30W/m^{2}K. The inside temperature is 20°C. The total wall surface is 350m^2.

a. **Determine a symbolic expression for the total thermal resistance of the wall, including inside and outside convection coefficients for the described conditions.**
b. **Determine the total heat loss through the wall.**
c. **If the wind is blowing violently, rising h_o to 300W/m^{2}K. Determine the percentage increase in heat loss.**
d. **What is the controlling resistance that determine the amount of heat flow through the wall?**



PROBLEM 2. (10 POINTS)

A space in an industrial building has a winter sensible heat loss of 200,000Btu/hr and a negligible latent heat load. The space is to be maintained at precisely 75°F dry bulb, and 50%RH. Due to the nature of the process, 100% outside air is required for ventilation. The outside air conditions can be taken as saturated at 20°F. The amount of air for ventilation is 7000 scfm (standard cubic feet per minute) and the air is to be preheated, humidified with an adiabatic saturator to the desired humidity, and then reheated. The temperature of the adiabatic saturator is to be maintained to 60°F dry bulb.

a. **Draw a diagram of the system.**
b. **Determine the temperature of the air entering the space to be heated**
c. **Draw the operating cycle on the psychrometric chart provided and 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 heat supplied to the preheat coil Btu/hr.
e. Calculate the heat supplied to the reheat coil Btu/hr.
f. Calculate the amount of water required for humidification, gpm.

PROBLEM 3. (20 POINTS)

A zone in a building has a sensible load of 22.5 kW and a latent load of 9.8 kW. The zone is to be maintained at 24°C and 50% relative humidity (RH), with an air supply to the room of 2.0 kg/s at 13°C and 60% relative humidity. The outside design conditions are 27°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 4. (20 POINTS)

A food storage plant requires a refrigeration system of 12-ton capacity at an evaporator temperature of 20°F and a condenser temperature of 90°F. The refrigerant R-134a is subcooled 9°F before entering the expansion valve, the vapour is superheated 9°F before leaving the evaporator. Compression of the refrigerant is isentropic. The volumetric efficiency of the compressor is 70%. A two cylinder vertical compressor with stroke equal 1.5 times the bore is used and operates at 900rpm.

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 bore and the stroke of the compressor.

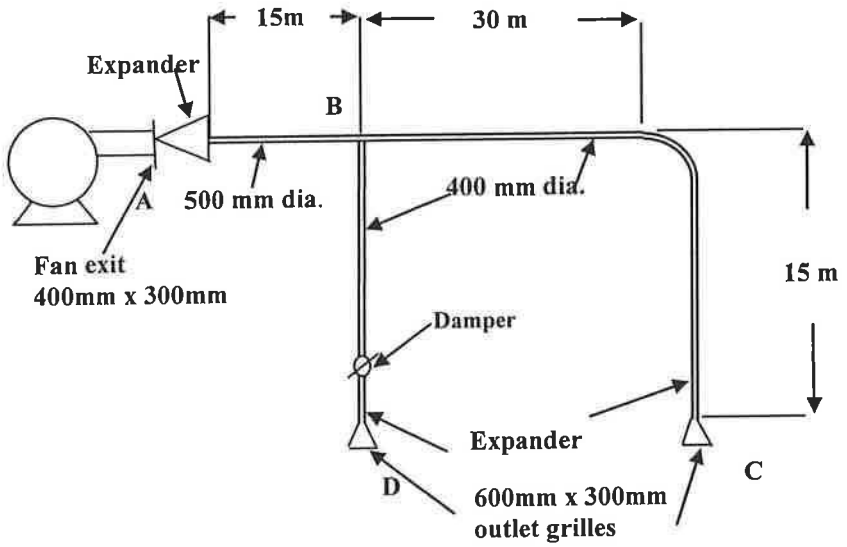
PROBLEM 5. (20 POINTS)

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 with the dimensions of 12 ft high and 20 ft wide, 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 5 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.)

PROBLEM 6. (20 POINTS)

The layout of a ductwork system is shown below. The centrifugal fan takes air at atmospheric pressure and supplies it through two branches which discharge to atmosphere.
Using the data provided below and duct friction charts, calculate the total air flow rate handled by the fan and the flow rates from the two outlets:

a. When the damper is fully open.
b. When both outlets are delivering equal flow rates after adjustment of the damper.



Data:
Velocity pressure factors:
Bend: 0.3
Branch : flow to main: 0.2 (applied to downstream velocity pressure)
flow to branch:0.5(applied to velocity pressure in off-take)
Discharge grill: 0.4
Expander: 0.25(applied to maximum velocity)
Damper (fully open): 0.2
Fan characteristic: $P_t = 200 - 12V^2$ (V is volumetric flow)

PROBLEM 7. (20 POINTS)

a. **10 points**

Please describe on not more then two pages which are the modern methods for designing energy efficient high rise office buildings. (i.e. passive heating/cooling, natural ventilation, electrical consumption, etc).

b. **10 points**

Explain succinctly what a LEED certified building is.

PROBLEM 8. (20 POINTS)

A small office, 40 ft by 120 ft, located in downtown Toronto, Ontario, has design heating and cooling loads of 280,000 Btu/hr and 95,000 Btu/hr, respectively.

Design conditions of 75°F inside and -5°F outside are used for winter, while 78°F inside and 90°F outside are used for summer. Estimate the annual cooling and heating energy requirements.
Estimate the corresponding energy cost, if:

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

Price:	*Natural gas*	*$ 0.10/ m^3*
	Heating Oil	*$ 3.25/gallon*
	Electricity average	*$ 0.11/kWh*

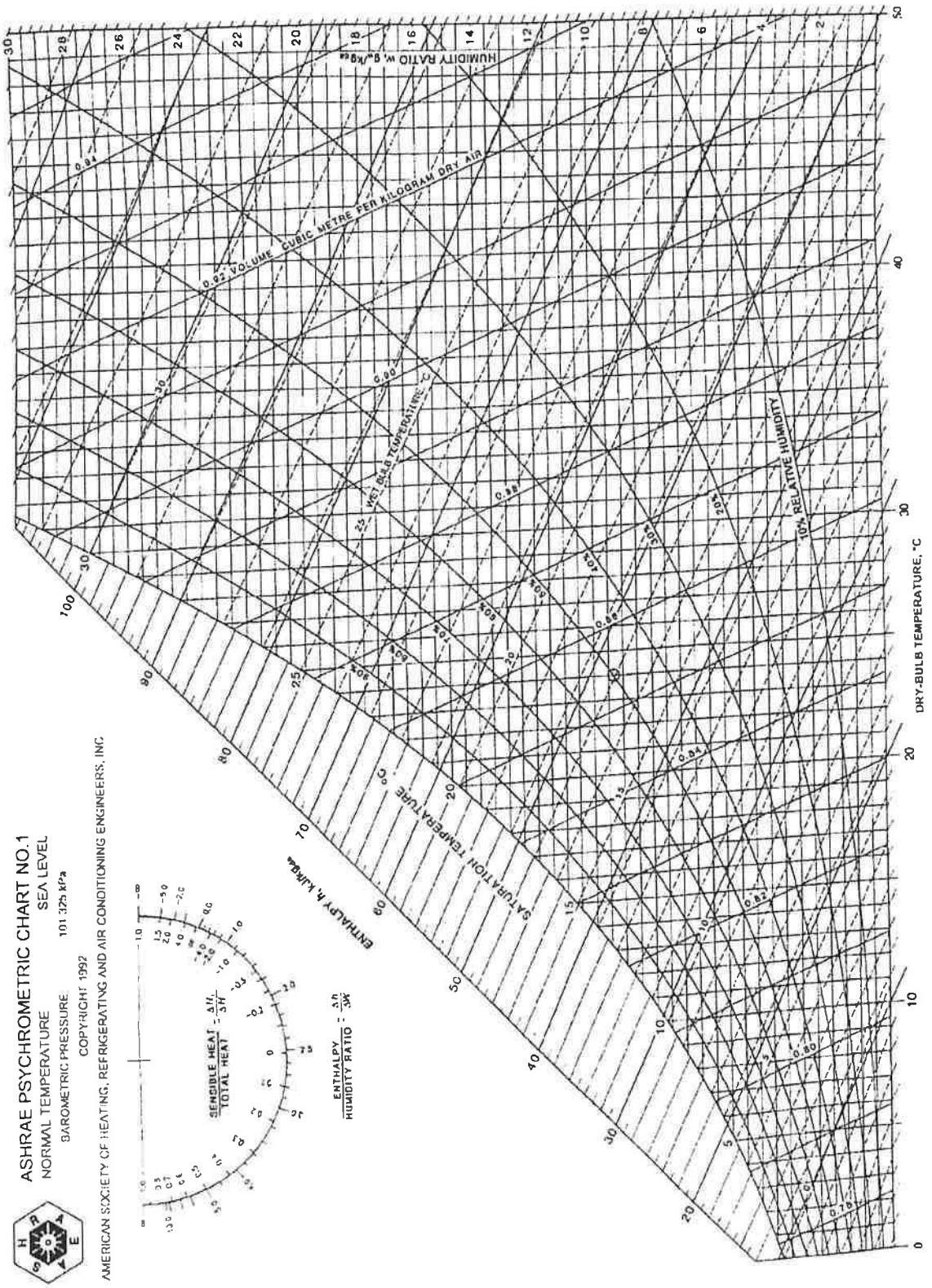
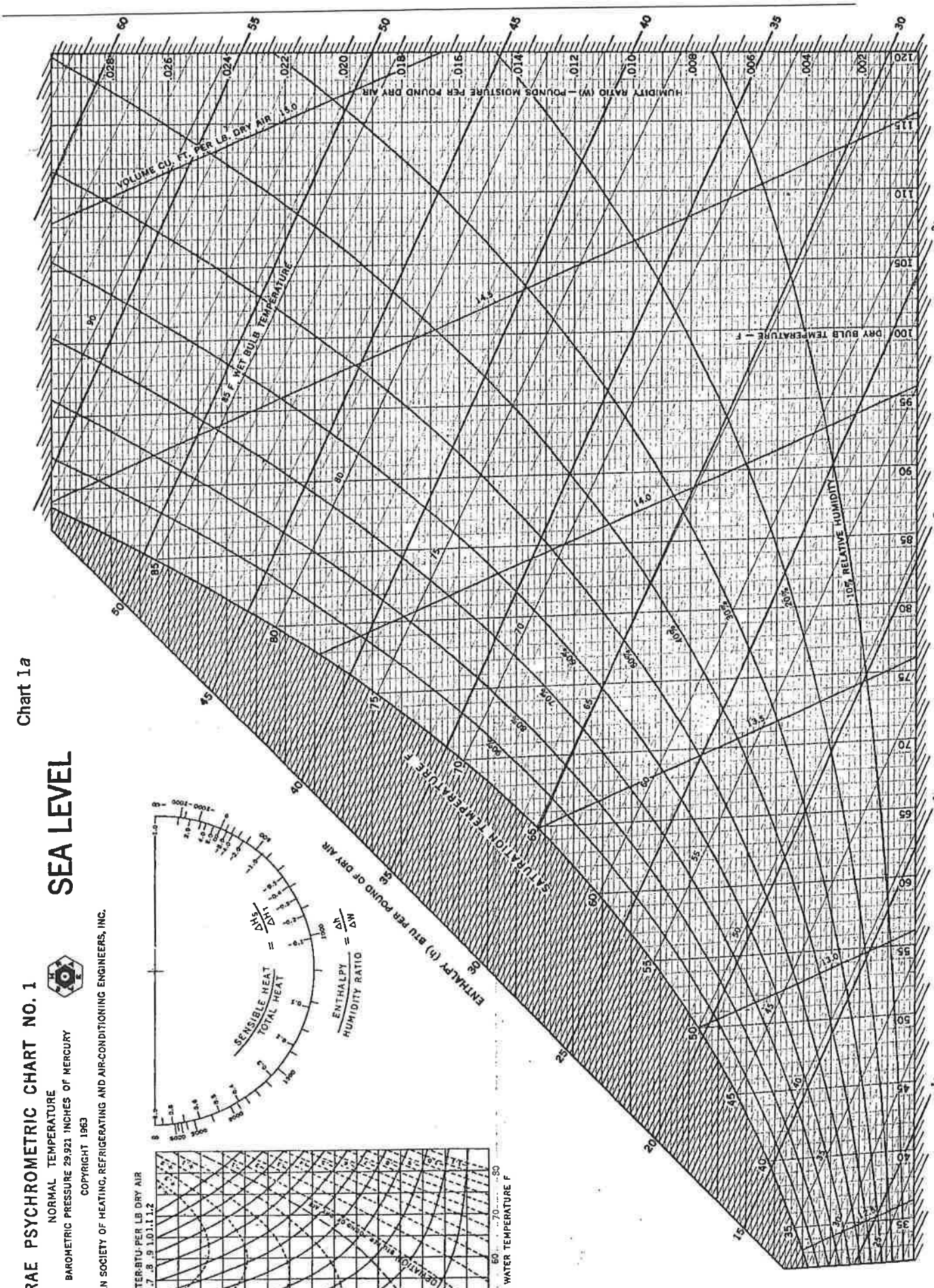
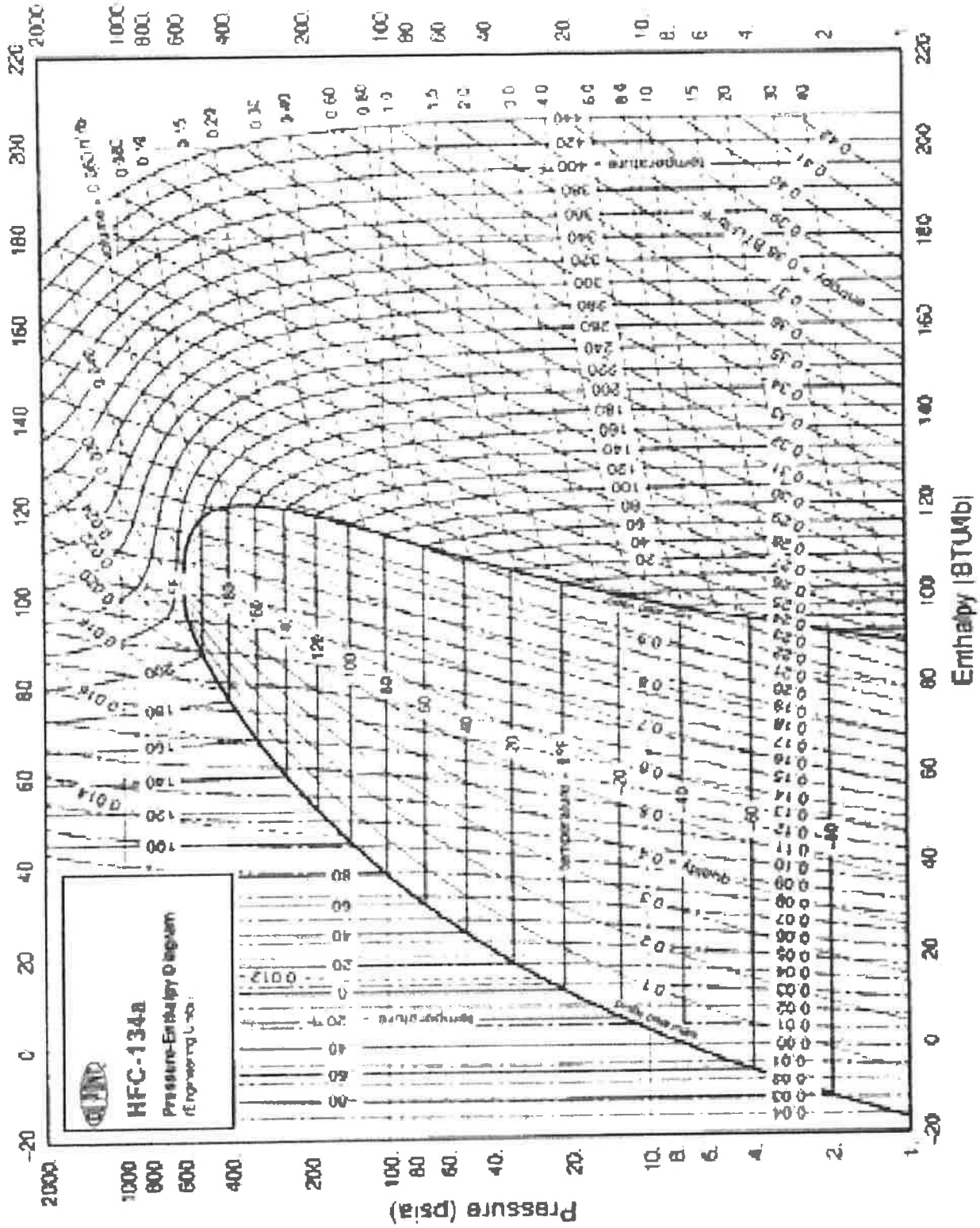


Fig. 1 ASHRAE Psychrometric Chart No. 1


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
SATURATION TEMPERATURE — F
VOLUME CU. FT. PER LB. DRY AIR
85° F. WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT = ΔHs/ΔH
ENTHALPY / HUMIDITY RATIO = Δh/ΔW
OF WATER-BTU PER LB DRY AIR
OR WATER TEMPERATURE F


HFC-134a
Pressure-Enthalpy Diagram
Pressure (psia)
Enthalpy (BTU/lb)