PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS -December 2007

98-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. Candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the first inside left hand sheet of the first examination workbook.

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 R-134a are attached.

PROBLEM 1. (20 POINTS)

An air conditioning system operating on the winter heating cycle, is required to maintain inside conditions of 68°F dry bulb, 48.5°F dew point, when the heating load is 350,000 Btu/hr (all sensible).

The system airflow is 10050 CFM (ft^3/min), of which 3400 CFM is brought from outside for ventilation. Outside conditions are 35°F dry bulb, 60% relative humidity.
The heating and humidification system consists of a preheater, a spray cabinet and a main heater. The main heater is rated at 500,000 Btu/hr.

a. Make a diagram of the system; identify each characteristic point on the diagram, and show for each significant point its dry bulb temperature and relative humidity.
b. Draw the operating cycle on the psychrometric chart provided.
c. Calculate the Btu/hr rating of the preheater.
d. Calculate the adiabatic efficiency of the spray cabinet, and the quantity of make-up water required in the operation of the spray cabinet.

PROBLEM 2. (20 POINTS)

A space is to be maintained at 24°C and 50% relative humidity. The total cooling load is 30 kW of which 70% is sensible heat. Ventilation air at 410 L/s is required on a day when the outside conditions are 34°C and 55% relative humidity. Assume that the building is at sea level elevation, and that the supply air temperature is 14°C. Ignore the duct heat transfer and the fan air temperature rise.

a. Make a diagram 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 (kW), apparatus dew point, coil by-pass factor.
e. Calculate grand sensible heat factor (GSHF) required for operation on this specific day.

PROBLEM 3. (20 POINTS)

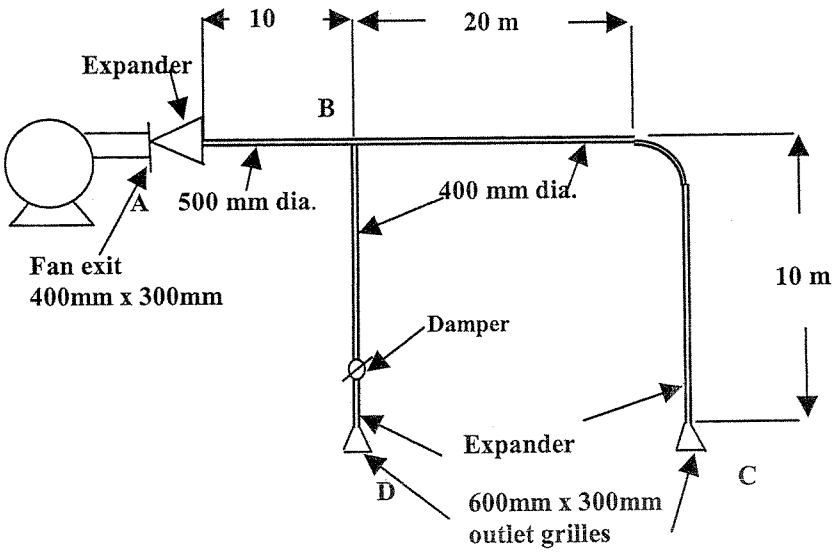
Estimate the indoor-outdoor pressure differential for the first and twentieth floors of a 20-story office building with plan dimensions of 150 ft x 40 ft and 10 ft floor height.
The structure has fixed windows and is of conventional curtain wall construction.
There are double vestibule-type doors on all four sides. Under winter conditions a 35 mph wind blows normal to one of the long dimensions.

Consider only wind and stack effect. The indoor-outdoor temperature difference is 60°F.

PROBLEM 4. (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**
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 5. (20 POINTS)

Sketch an induced draft counter-flow cooling tower, showing how it may be regulated to control the operation of a refrigeration plant.

A cooling tower operating in atmospheric conditions of 65°F db (dry bulb), 57°F wb (wet bulb), cools 3800 lb/min of water from 100°F through a range of up to 30°F. The air is assumed to leave the top of the tower at 90°F db, 95% RH.

a. **Calculate the enthalpy, specific volume and relative humidity of the air entering the tower.**
b. **Find the air volumetric flow at the tower inlet (ft^3/min)**
c. **Find the evaporative loss (%).**
d. **Find the make-up water required, taking into account that some moisture is gained by the cooling air and also that there is a drift of 0.3% of the total water flow**

PROBLEM 6. (20 POINTS)

a. 10 points

A large office space has an average occupancy of 20 people from 8:00 a.m. to 5:00 PM. 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 1.5 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 550,000 Btu/hr. Furnace efficiency is 80% and fuel heating value is 1000 Btu/ft^3.

PROBLEM 7. (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 100,000 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.**

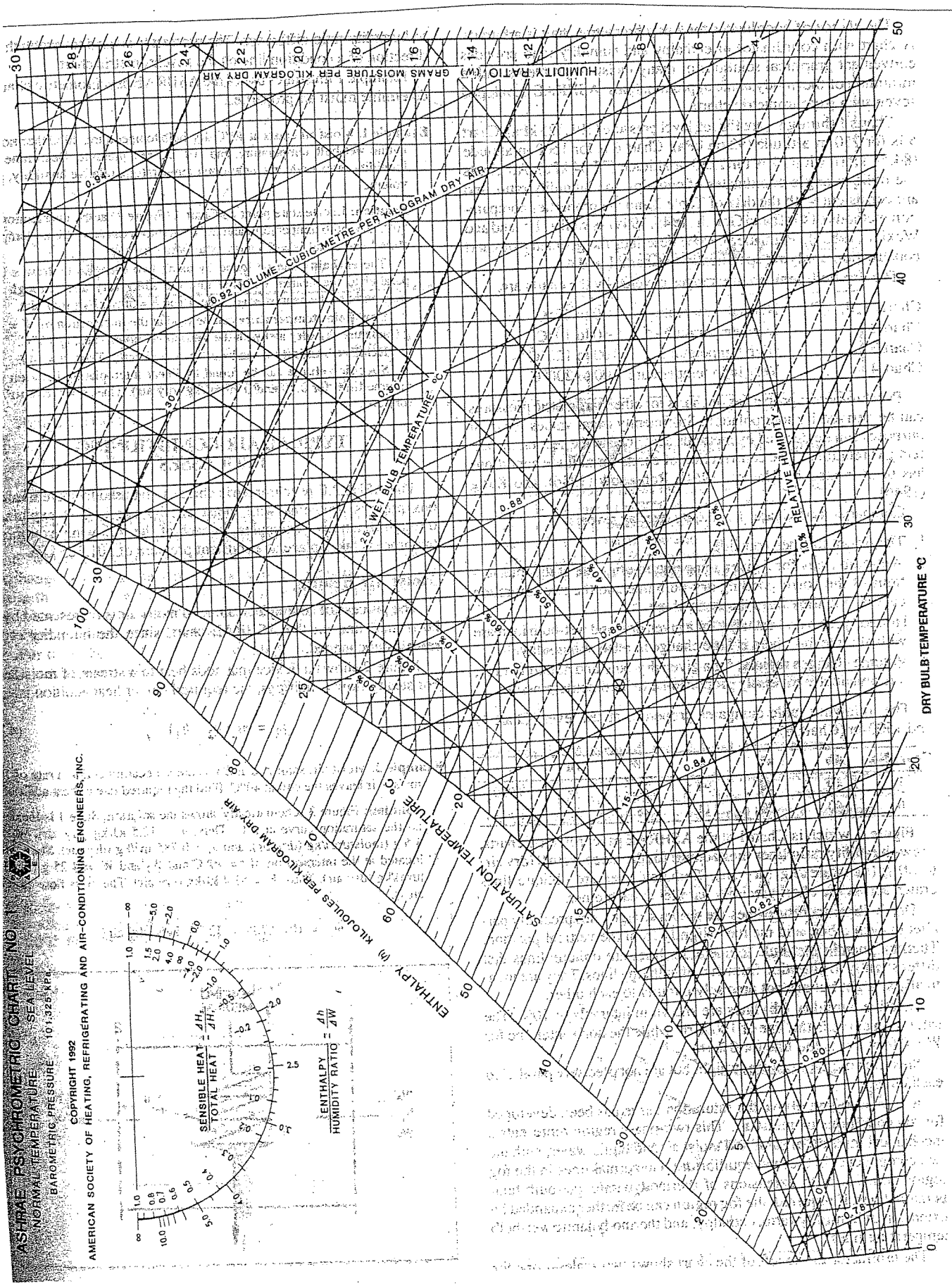
Comment about ground-source heat pumps usage. Comment on environmental impacts and economics.

PROBLEM 8. (20 POINTS)

A small dental office, 30 ft by 100 ft, located in downtown Ottawa, Ontario, has design heating and cooling loads of 240,000 Btu/hr and 85,000 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. Estimate the annual cooling and heating energy requirements and 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*	*$0.30/m^3*
	Oil	*$ 0.85/liter*
	Electricity	*$0.09/kWh*


ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
HUMIDITY RATIO (W) GRAMS MOISTURE PER KILOGRAM DRY AIR
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
WET BULB TEMPERATURE °C
RELATIVE HUMIDITY
SATURATION TEMPERATURE °C
ENTHALPY (h) KILOJOULES PER KILOGRAM DRY AIR
DRY BULB TEMPERATURE °C
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔH
ENTHALPY / HUMIDITY RATIO = Δh / ΔW

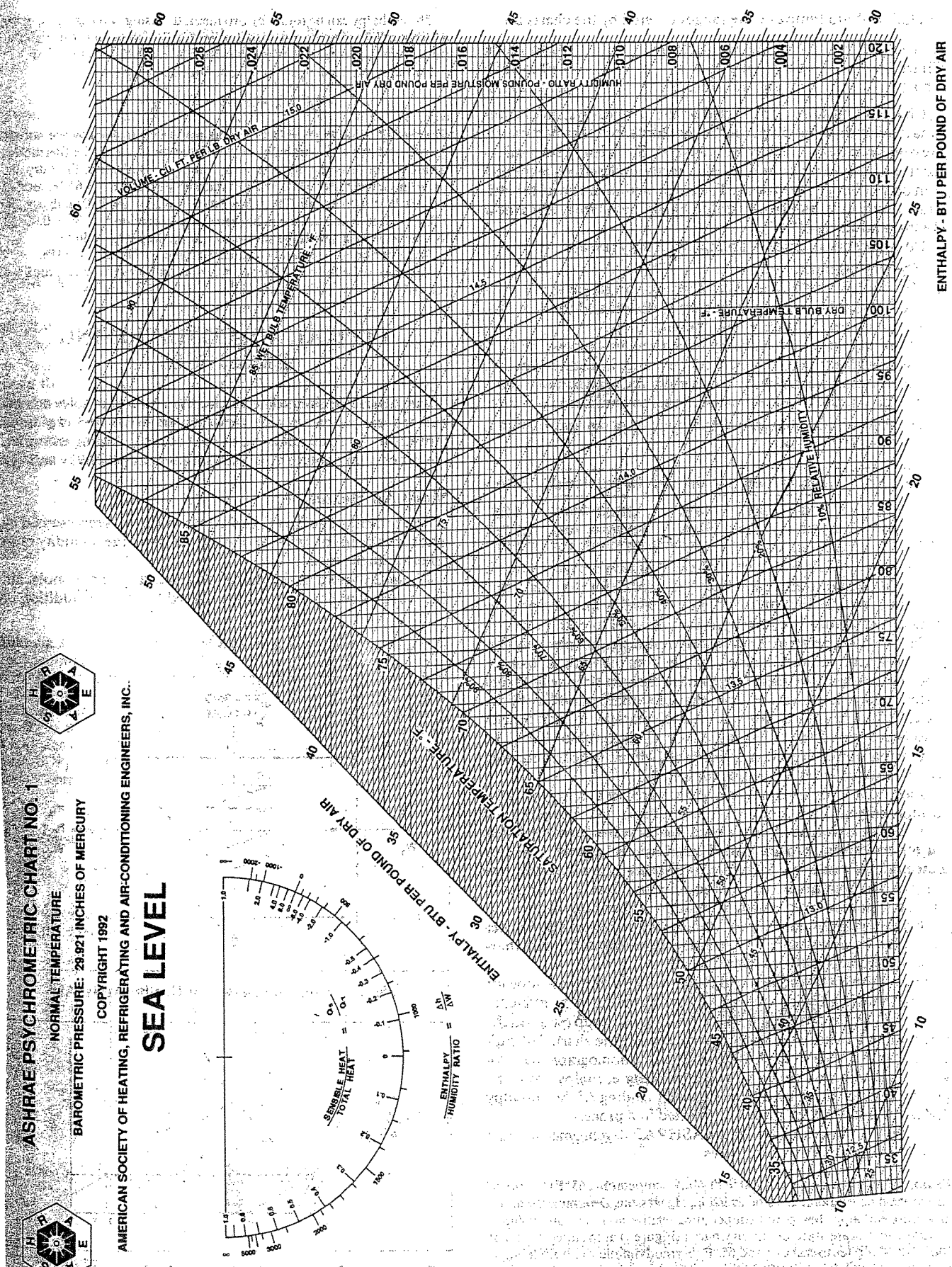

Fig. 1 ASHRAE Psychrometric Chart No. 1

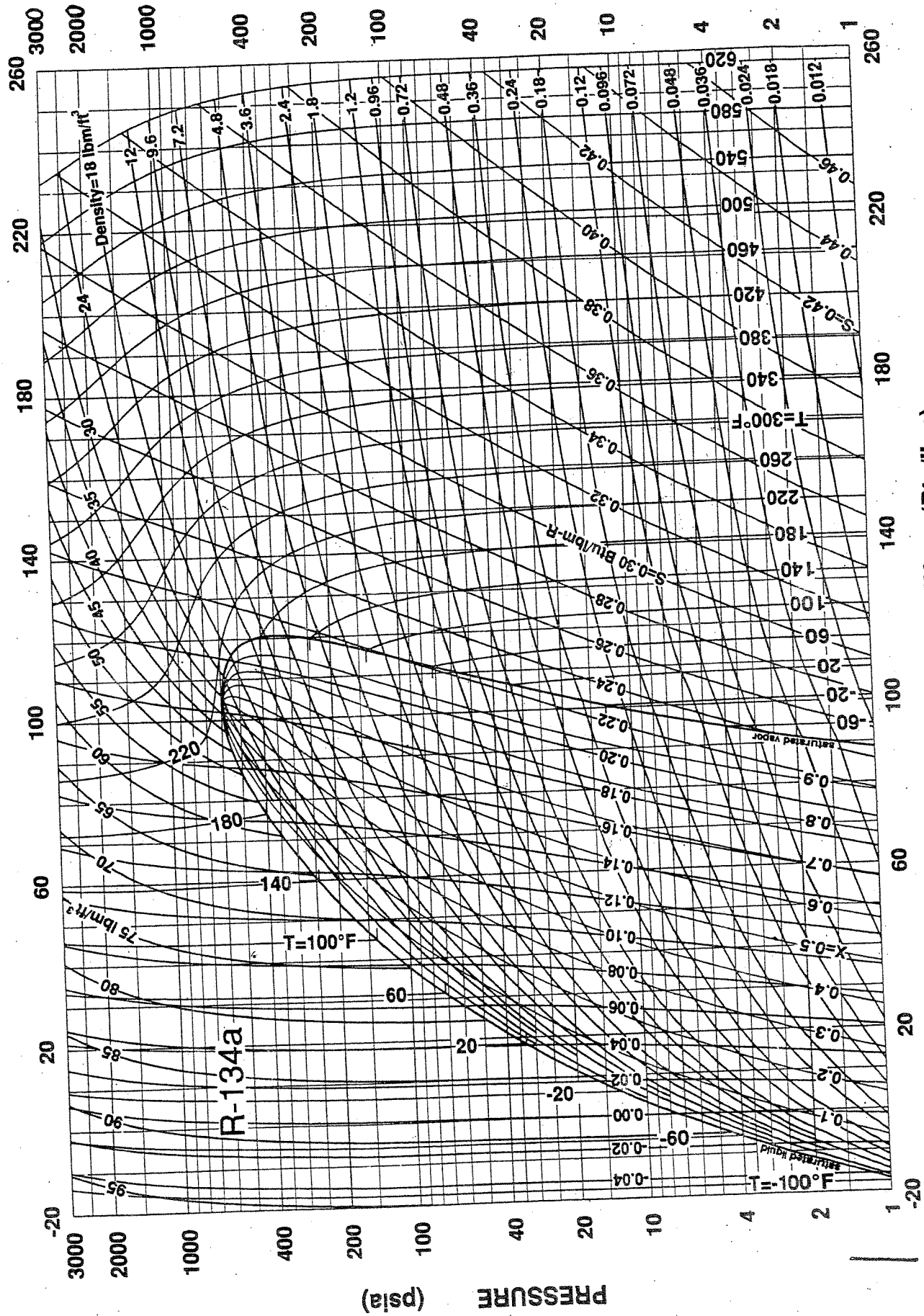

Fig. 14 Pressure-Enthalpy Diagram for Refrigerant 134a