PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS - MAY 2003

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, p-h diagram for the refrigerant, and pressure drop tables for some fittings are attached.**

PROBLEM 1 (20 POINTS)

A winter heating system is used to maintain a building at 21°C and 30% RH. The heating load is 150kW.

Outside air enters a preheat coil at -14°C and essentially 0 percent relative humidity. The outdoor air is heated to 10°C and then mixed with the return air. The mixed air is then heated and humidified to 40°C and 30% RH and is supplied to the space. Saturated steam at 2.0 psig is used for humidifying. Outdoor air is 25% by mass.

a. **Draw a sketch of the system and draw the various processes on the psychometric chart. Identify each significant point, on the diagram and psychrometric chart, and note for each of these points its characteristics.**
b. **Determine the supply air quantity.**
c. **Calculate the heat transfer rate for each coil**

PROBLEM 2 (20 POINTS)

Estimate the indoor-outdoor pressure differential for the first and twentieth floors of a 20-story office building with plan dimensions of 120 ft x 30 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 25 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 3 (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.**

Comment about ground-source heat pumps.

PROBLEM 4 (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 25°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 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 5 (20 POINTS)

A test on a fan running at 1000 r.p.m provided the data characteristics shown below. The fan has a two-speed motor so it can also run at 1800 r.p.m.
This fan is used for air flow in a duct which has a resistance of 38.1 mm of water at a flow rate of 1.42 m^3/s. For some process a filter is added which has a resistance of 12.7 mm of water at a flow rate of 1.42 m^3/s and in this case the fan will be running at the higher speed.

Volume flow rate (m^3/s)	*0.5*	*1.0*	*1.5*	*2.0*	*2.5*	*3.0*
Pressure (mm water)	46	52	53	48	37	19
Power consumption(kW)	0.80	1.10	1.40	1.70	2.05	2.60

Calculate:

- a. **The volume rate of air delivered when the filter is fitted**
- b. **The power required under these conditions**
- c. **The fan efficiency at the operating point**
- d. **The resistance required to be put in series with the system to reduce the flow rate by 0.47 m^3/s**

PROBLEM 6 (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 3000 lb/min of water from 100°F through a range of 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 7 (20 POINTS)

A small commercial building located in Toronto, Ontario has a heating load of 70 kW sensible and 12 kW. 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 3.6. The compressor/motor has an efficiency of 82%.

Draw a schematic as how an air to air the 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 in good engineering practice, considering environmental implication for each solution.

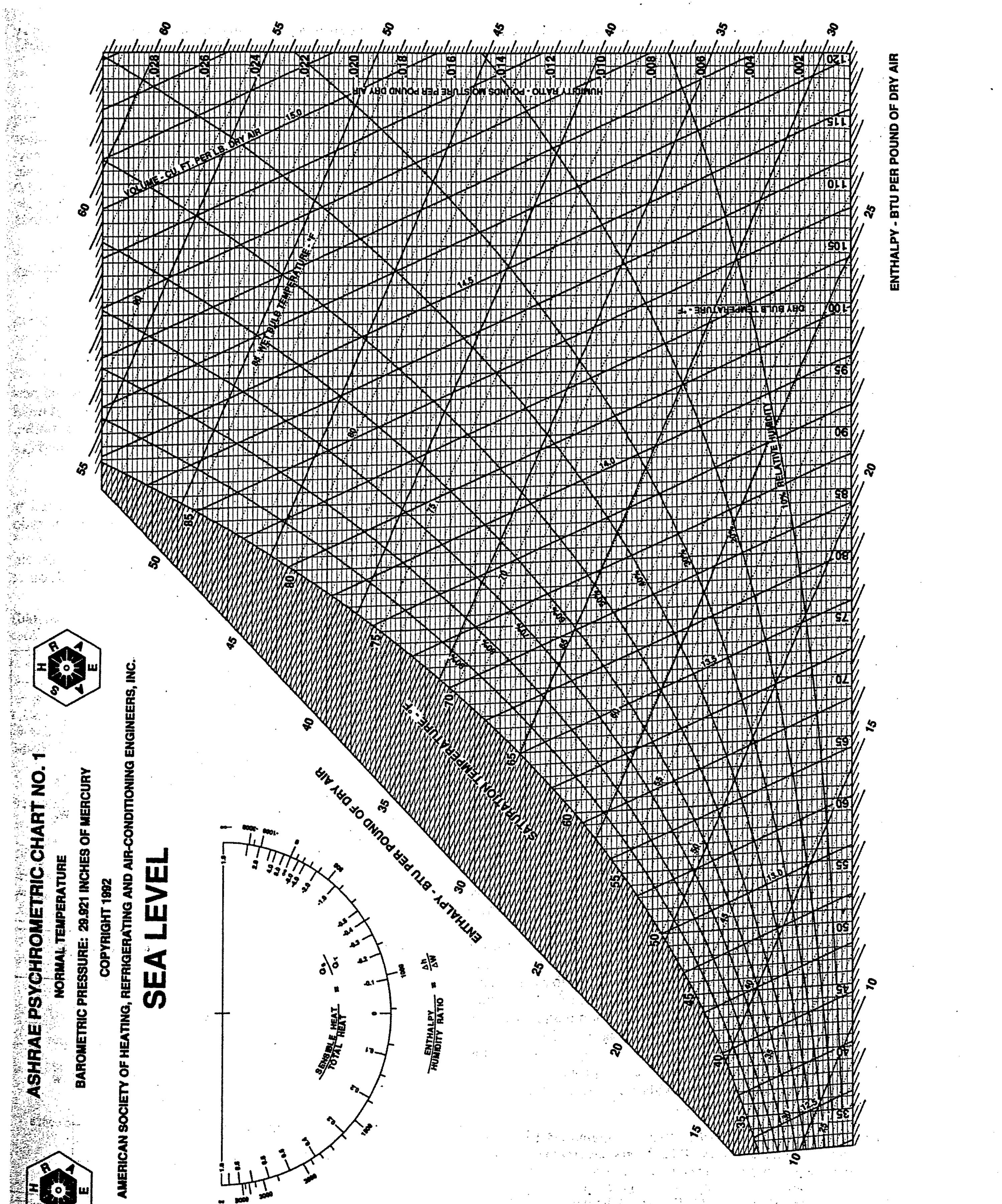
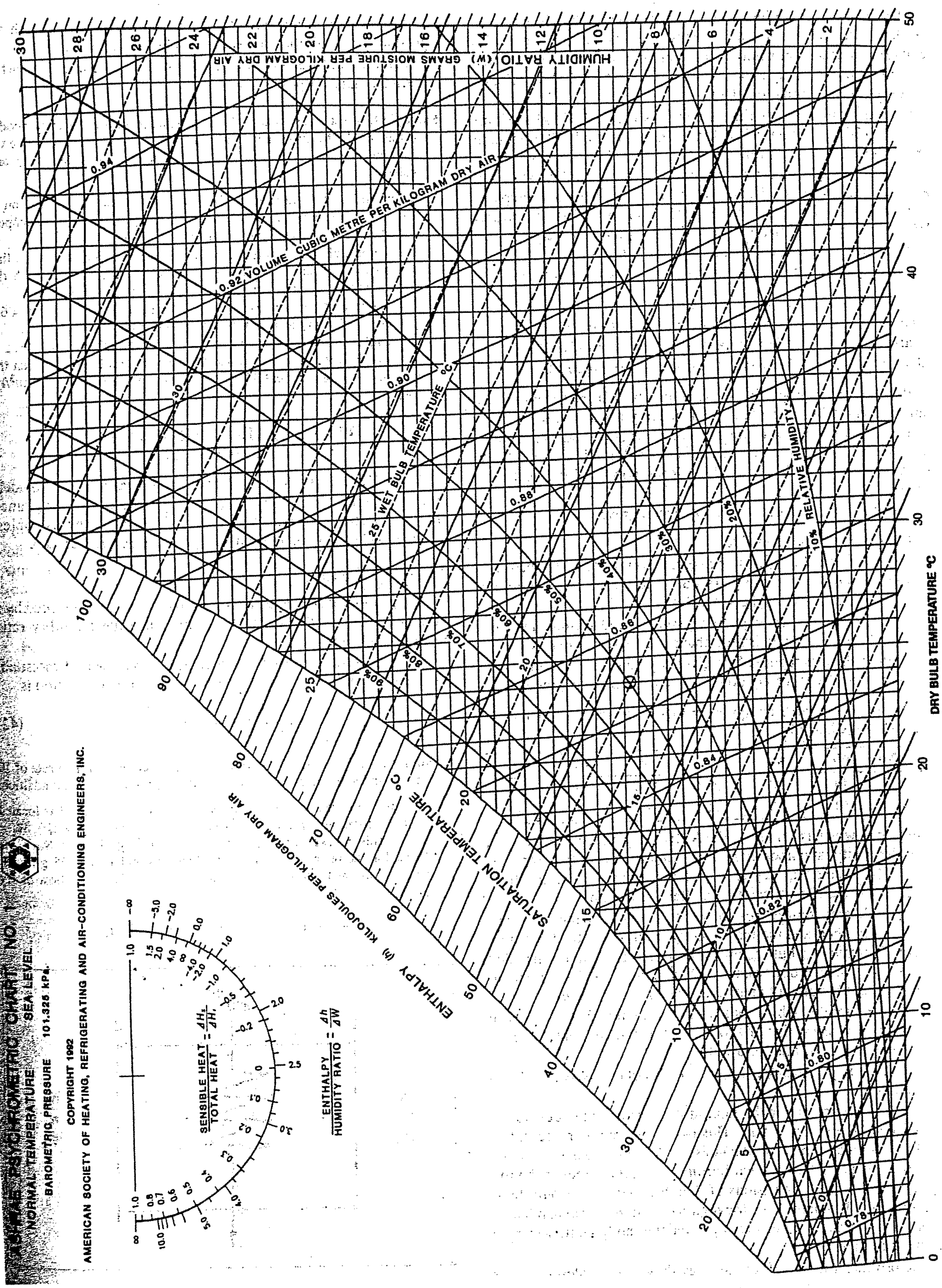


Fig. 1 ASHRAE Psychrometric Chart No. 1


PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE 101.325 kPa
COPYRIGHT 1992
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 / ΔHt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW

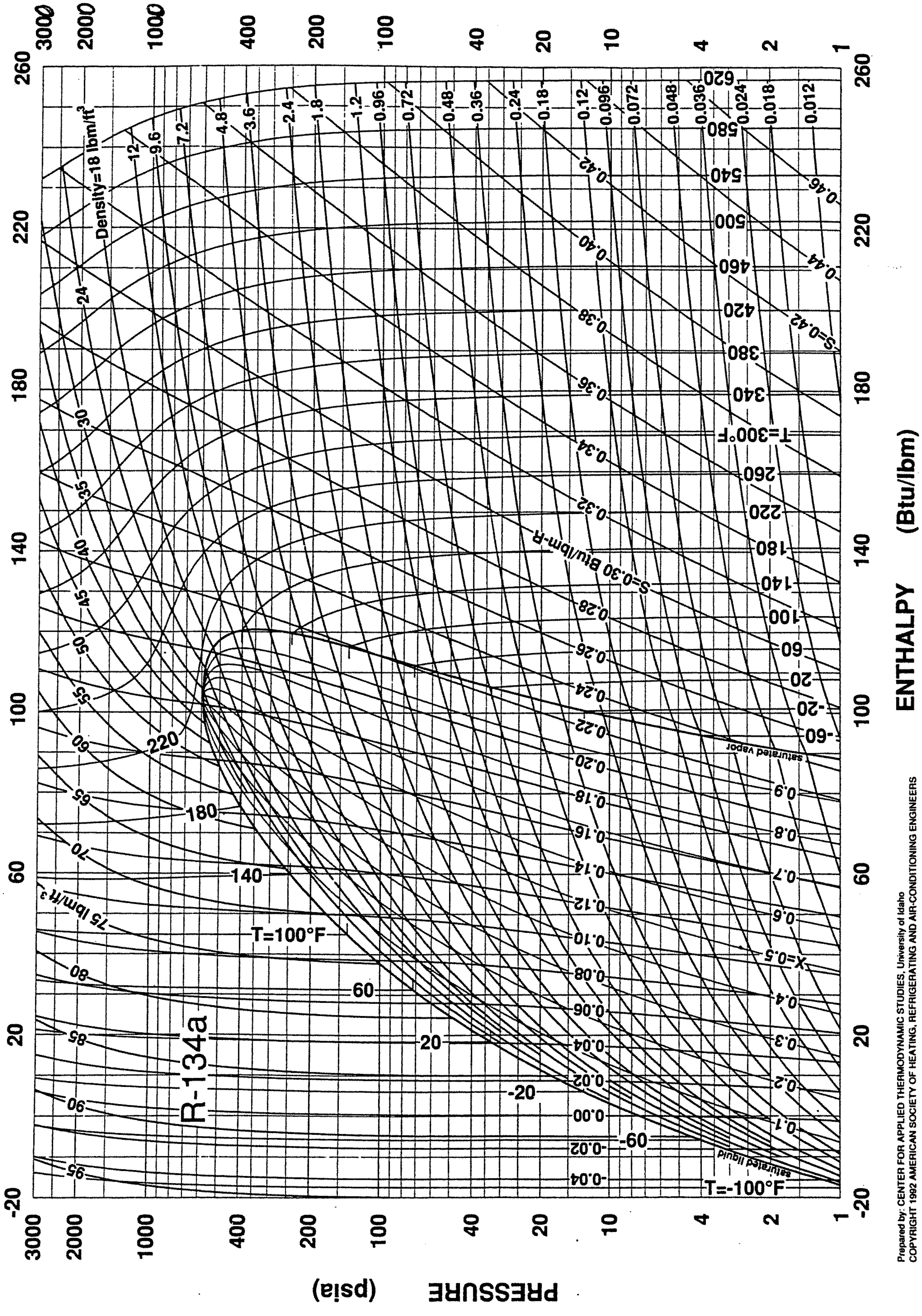


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Fig. 14 Pressure-Enthalpy Diagram for Refrigerant 134a