

PROFESSIONAL ENGINEERS OF ONTARIO
ANNUAL EXAMINATIONS – December 2012
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. 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. 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 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 2. (20 POINTS)

A space in an industrial building has a winter sensible heat loss of 200,000 Btu/h and a negligible latent heat load. The space is to be maintained at 75°F and 50% RH. Due to the nature of the process, 100% outside air is required for ventilation. The outdoor air conditions can be taken as saturated at 20°F. The amount of ventilation air is 7000 scfm and the air is to be preheated, humidified with an adiabatic saturator to the desired humidity, and then reheated. Temperature from the adiabatic saturator is to be maintained at 60°F DB.

Draw a diagram of the system.

Draw the operating cycle on the psychrometric chart provided.

Determine the following:

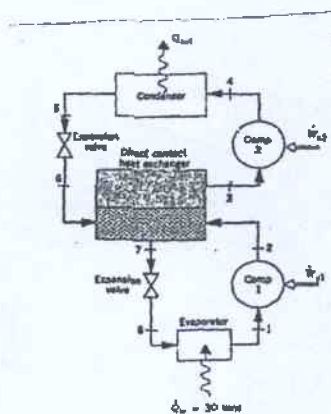
- temperature of air entering the space to be heated, °F
- heat supplied to the preheat coil, Btu/h
- heat supplied to the reheat coil, Btu/h
- amount of water required for humidification, gpm

PROBLEM 3 (20 POINTS).

Ammonia is the working fluid in a two stage refrigeration system. The system uses a direct contact heat exchanger to achieve intercooling. The evaporator has a refrigeration capacity of 30 tons and produces -20°F saturated vapour at its exit. In the first compressor stage the refrigerant is compressed to 80 psi, which is the pressure in the direct contact heat exchanger. Saturated vapour at 80 psi enters the second compressor stage and is compressed to 250 psi. Each compressor has an isentropic efficiency of 85%. there are no significant pressure drops as the refrigerant passes through the heat exchanger. Saturated liquid enters each expansion valve.

Calculate:

- the ratio of mass flow rates between the second stage to first stage
- the power input to each compressor stage, in horse power
- the coefficient of performance



PROBLEM 4. (20 POINTS)

A small office, located in downtown Ottawa, Ontario, has design heating and cooling loads of 250,000 Btu/hr and 95,000 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	\$0.075 /m ³
	Oil	\$1.22 /liter
	Electricity	\$0.07/kWh

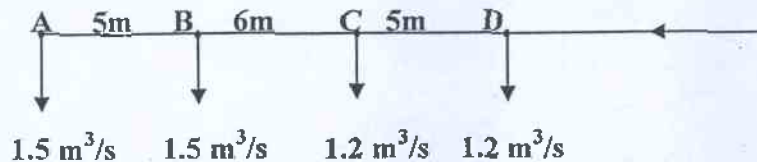
PROBLEM 5 (20 POINTS).

a. 5 points

Explain in a few sentences, the principles of equal friction, balanced-capacity method, and static regain method used in duct design. Summarize their advantages and disadvantages.

b. 15 points

Calculate the diameters of sections AB, BC and CD of the duct system shown below. Assume a velocity of 6 m/s in section AB, and size sections BC and CD using static regain method. All ducts are circular. The pressure loss factor for the main duct at each junction may be taken as 0.1, applied to the velocity pressure in the main downstream of the branch.



PROBLEM 6 (20 POINTS).

A small size induced (forced draft) cooling tower is designed to cool 5.5 liters of water per second, the inlet temperature of which is 44°C. The motor driven fan induces 9 m³/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. 10 points

How many people could occupy a room where the concentration level of carbon dioxide CO₂ is to be kept below 1000 ppm, if air with a concentration of 250 ppmCO₂ is being supplied to the room at a rate of 5000 cfm (cubic feet per minute). State your assumptions.

b. 5 points

Explain the ASHRAE comfort chart and the perception of thermal comfort.

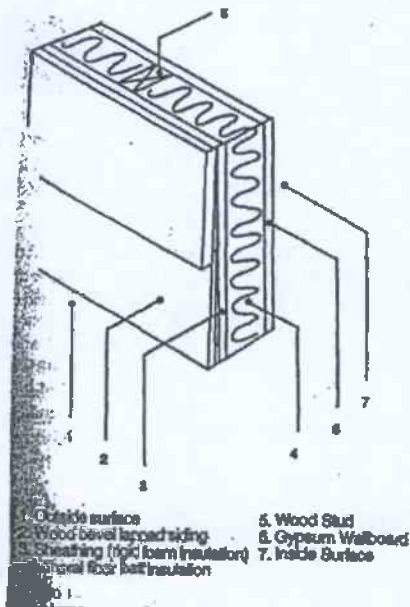
c. 5 points

It is proposed that in order to save energy in summer, for large office building using chilled water cooling systems, to increase the temperature of the water circulating in the system. Comment on feasibility of this method and how it will affect the comfort conditions in the building.

PROBLEM 8. (20 POINTS)

a. 15 points

Calculate the U factor of a 2 by 4 stud wall shown below. The studs are at 16 in distance. There is 3.5 in mineral fibre batt insulation (R-13) in the stud space. The inside finish is 0.5 in. gypsum wallboard; the outside is finished with rigid foam insulating sheathing (R-4) and 0.5 in. by 8 in. wood bevel lapped siding. The insulated cavity occupies approximately 75% of the transmission area; the studs, plates and sills occupy 21% and the headers occupy 4%.



b. 5 points

In a condominium in Toronto, Ontario an owner is complaining of mold on an outside wall. The wall is in a "solarium" a room with large windows. An inspection confirmed the mold existence. The wall is concrete and the inspector found that there is no insulation, as that room was supposed to be a balcony, and was enclosed later by the builder that sold the apartment with a "solarium". Indicate how the problem can be remediated.

Comment on moisture flow in an enclosed environment.

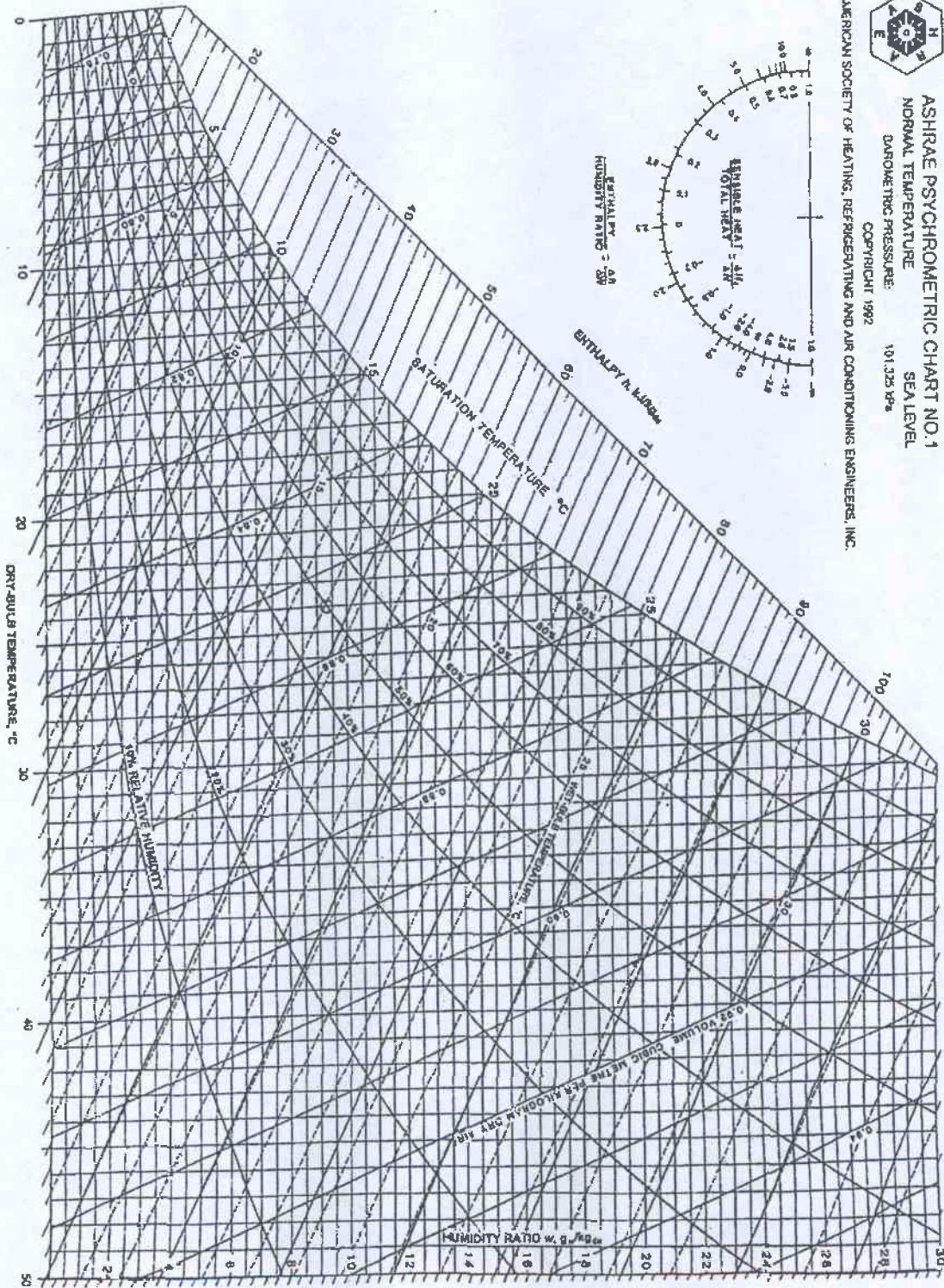


Fig. 1 ASHRAE Psychrometric Chart No. 1

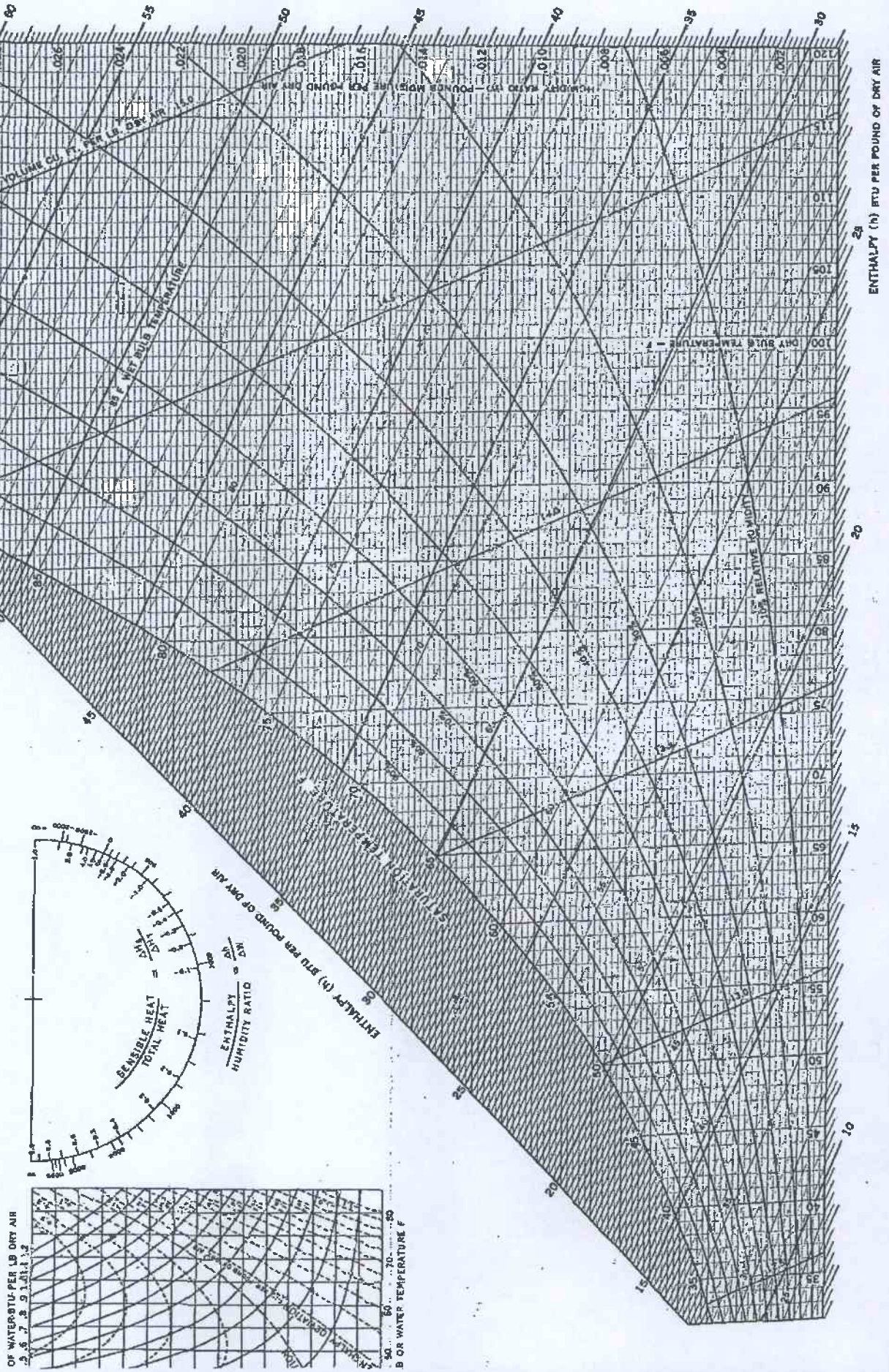
ASHRAE PSYCHROMETRIC CHART NO. 1
 NORMAL TEMPERATURE
 SEA LEVEL
 BAROMETRIC PRESSURE: 101.325 kPa
 COPYRIGHT 1992
 AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, INC.

Chart 1a

ASHRAE PSYCHROMETRIC CHART NO. 1
 NORMAL TEMPERATURE
 BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
 COPYRIGHT 1983
 AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.



SEA LEVEL



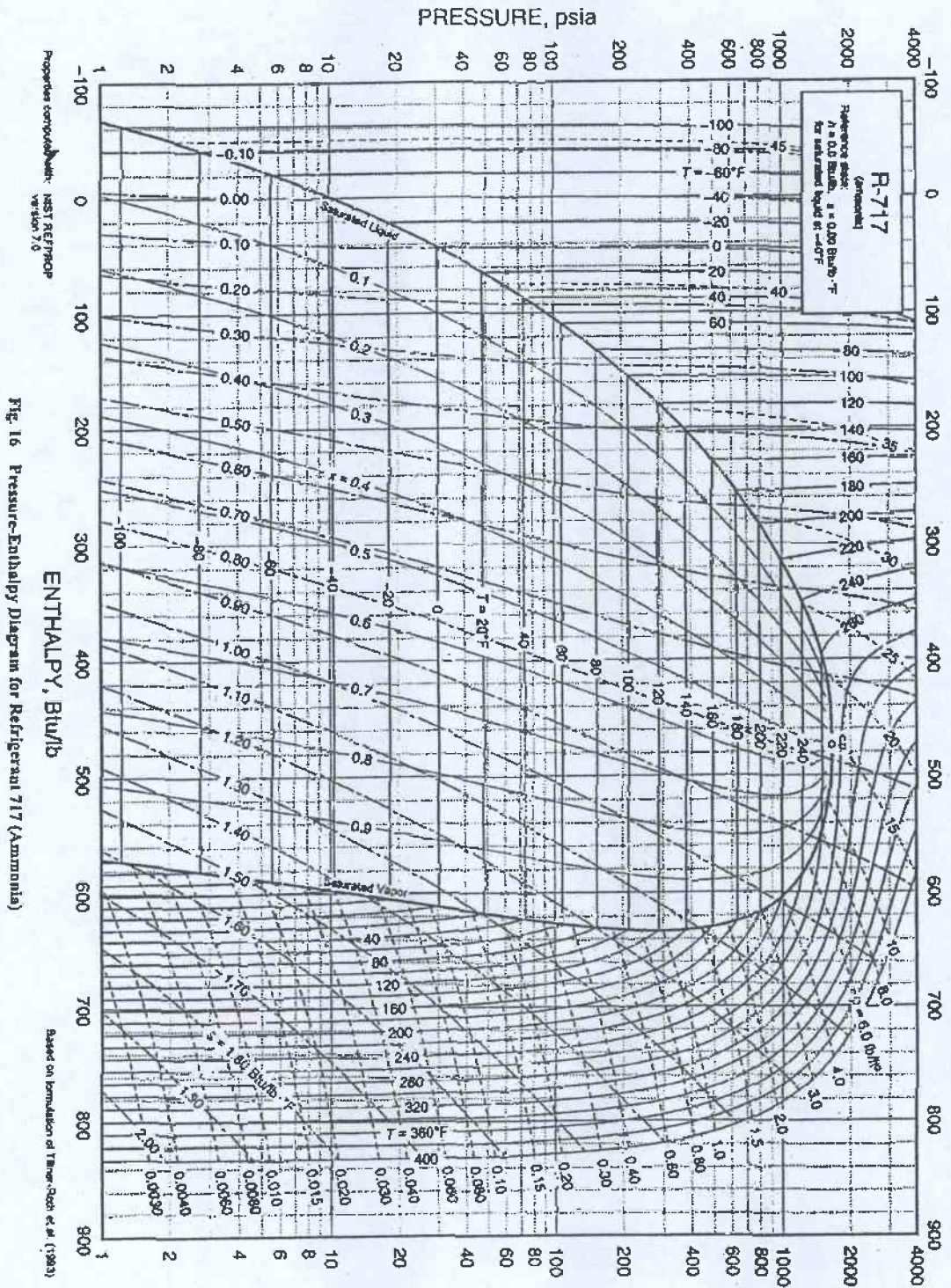


Fig. 16 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)