# PROFESSIONAL ENGINEERS OF ONTARIO

## ANNUAL EXAMINATIONS – May 2017

## 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. **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 winter heating and humidifying system uses equal volumes of recirculated room air and outside air. The mixed flow is preheated, then is passed through an adiabatic spray cabinet, then is re-heated and supplied to the room. The following conditions apply:**

**- room heating load is 58 kW all sensible.**
**- room design conditions 20°C dB (dry bulb), 15°C wB (wet bulb).**
**- outside air 7°C dB, 4°C dew point.**
**- supply temperature to the room is 40°C**

**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 characteristics.**
**d. Find the total system air mass flow.**
**e. Calculate the kW rating of the preheater and reheater.**
**f. 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 to be maintained at 25°C dB (dry bulb) temperature and 18°C wB (wet bulb) has a rate of sensible-heat gain of 25 kW and a rate of moisture gain of 20 kg/hr. Moist air enters the space at a dry-bulb temperature of 15°C.**
**Outdoor air at 35°C dB temperature and 25°C wB is supplied for ventilation purposes at a rate of 400 l/s (litres per second) of standard air.**
**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, a cooling coil and a fan.**

**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 conditions of the air entering the cooling coil (dB and wB).**
**e. Calculate the capacity of the coil (kW), apparatus dew point, coil by-pass factor.**
**f. Calculate room sensible heat factor (SHF), and grand sensible heat factor (GSHF).**

## PROBLEM 3. (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 functions in atmospheric conditions of 70°F db (dry bulb), 55°F wb (wet bulb), cools 3200 lb/min of water from 105°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 4. (20 POINTS)

**An ammonia two-stage vapour compression refrigeration plant operates with a condenser pressure of 12 bar, a flash chamber pressure of 5 bar and an evaporator pressure of 2 bar. Saturated liquid leaves the condenser and after being throttled to 5 bar the saturated liquid and saturated vapour are separated in the flash chamber. The saturated vapour is then mixed with the superheated vapour from the LP (low pressure) compressor discharge before it enters the HP (high pressure) compressor, while the saturated liquid is throttled down to the evaporator pressure. The vapour leaving the evaporator is at -16°C. Each stage of the compressor has an isentropic efficiency of 90%.**

a) **Sketch the system.**
b) **Draw the cycle on the *p-h* diagram provided.**
c) **Calculate:**
- **the mass fraction of the vapour leaving the flash chamber;**
- **the coefficient of performance of the plant;**
- **the mass flow of the refrigerant through the condenser when the refrigeration load is 450 kW**

## PROBLEM 5. (20 POINTS)

### a. 5 points

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

### b. 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**

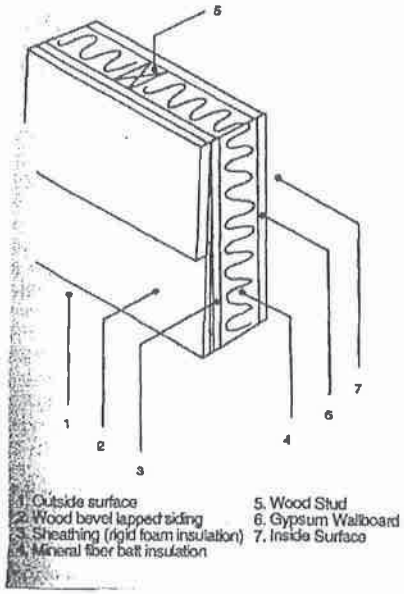
## c. 10 points

**Explain the concept of cogeneration and how it can be use in an University campus. Explain all your assumptions.**

# PROBLEM 6. (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%.**

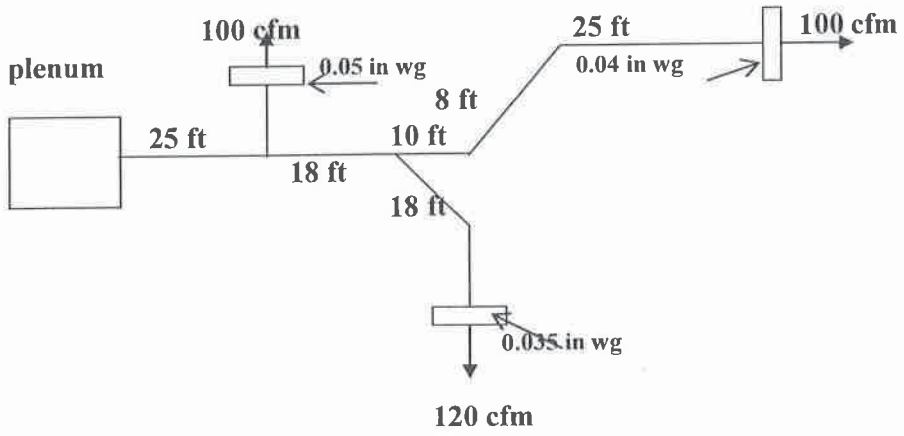



## b. 5 points

**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.**

## PROBLEM 7. (20 POINTS)

**Select the round duct sizes for the duct system shown in the figure below, using equal-friction method. A total pressure of 0.15 in. wg. is available at the plenum.**
**State all your assumptions.**




## PROBLEM 8. (20 POINTS)

### a. 10 points

**A large office space has an average occupancy of 25 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 Toronto, Ontario. Design conditions are 70 °F inside and -12 °F outside. The heating load is 450,000 Btu/hr. Furnace efficiency is 80% and fuel heating value is 1000 Btu/ft$^3$.**

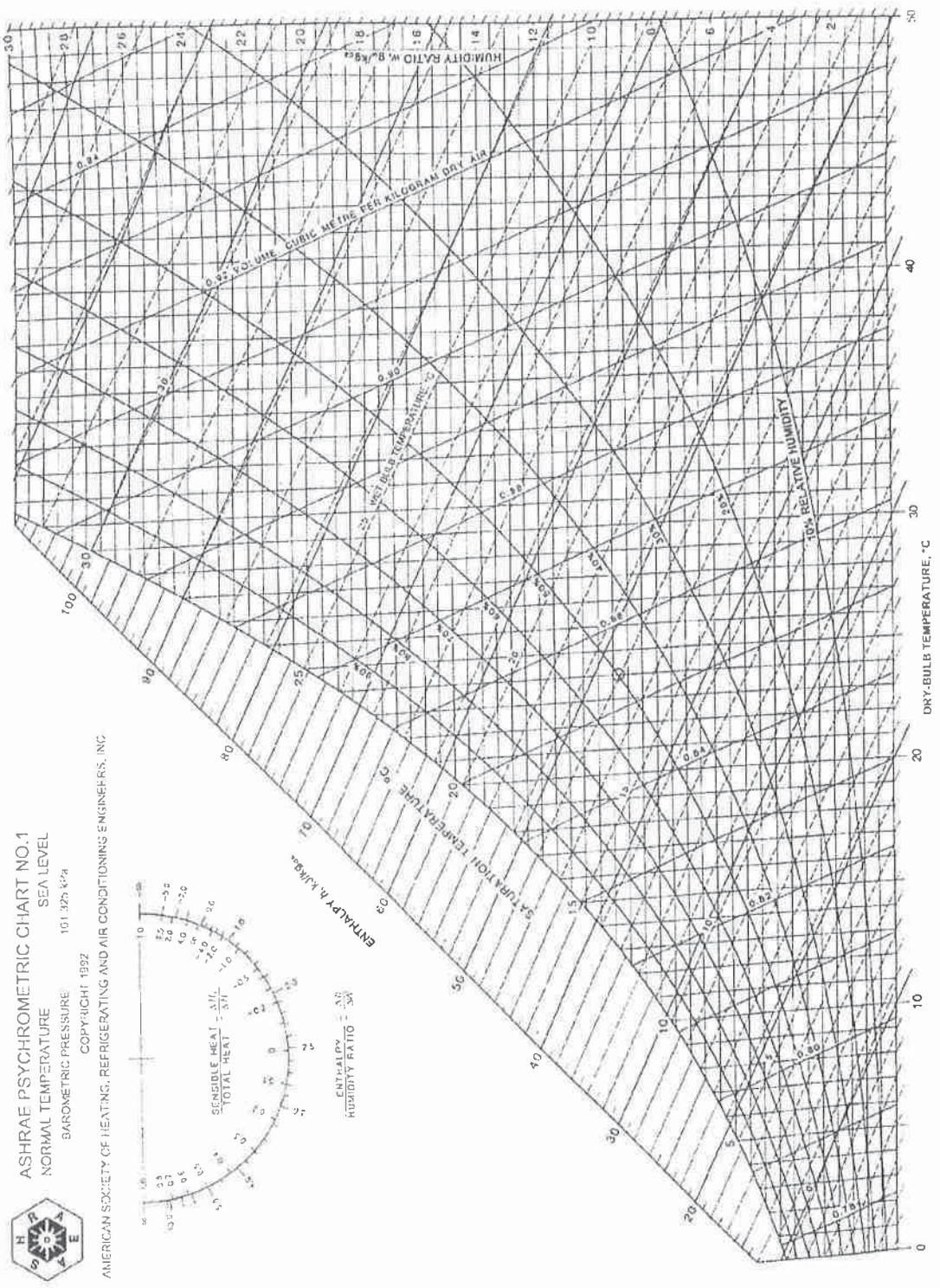
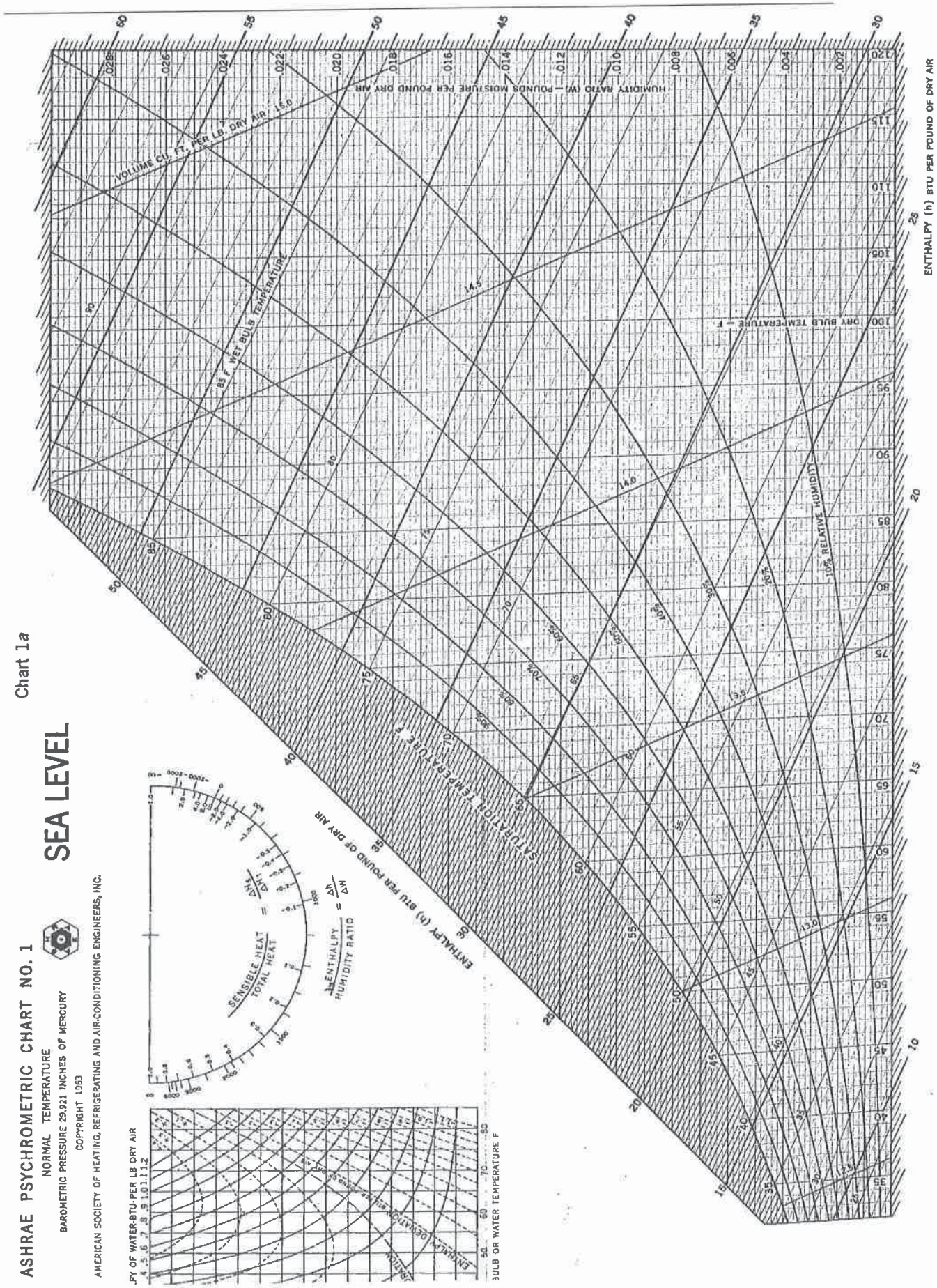



Fig. 1 ASHRAE Psychrometric Chart No. 1


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
HUMIDITY RATIO (W) — POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE — F
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
20%
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
ENTHALPY DEVIATION
PY OF WATER-BTU-PER LB DRY AIR
ULB OR WATER TEMPERATURE F

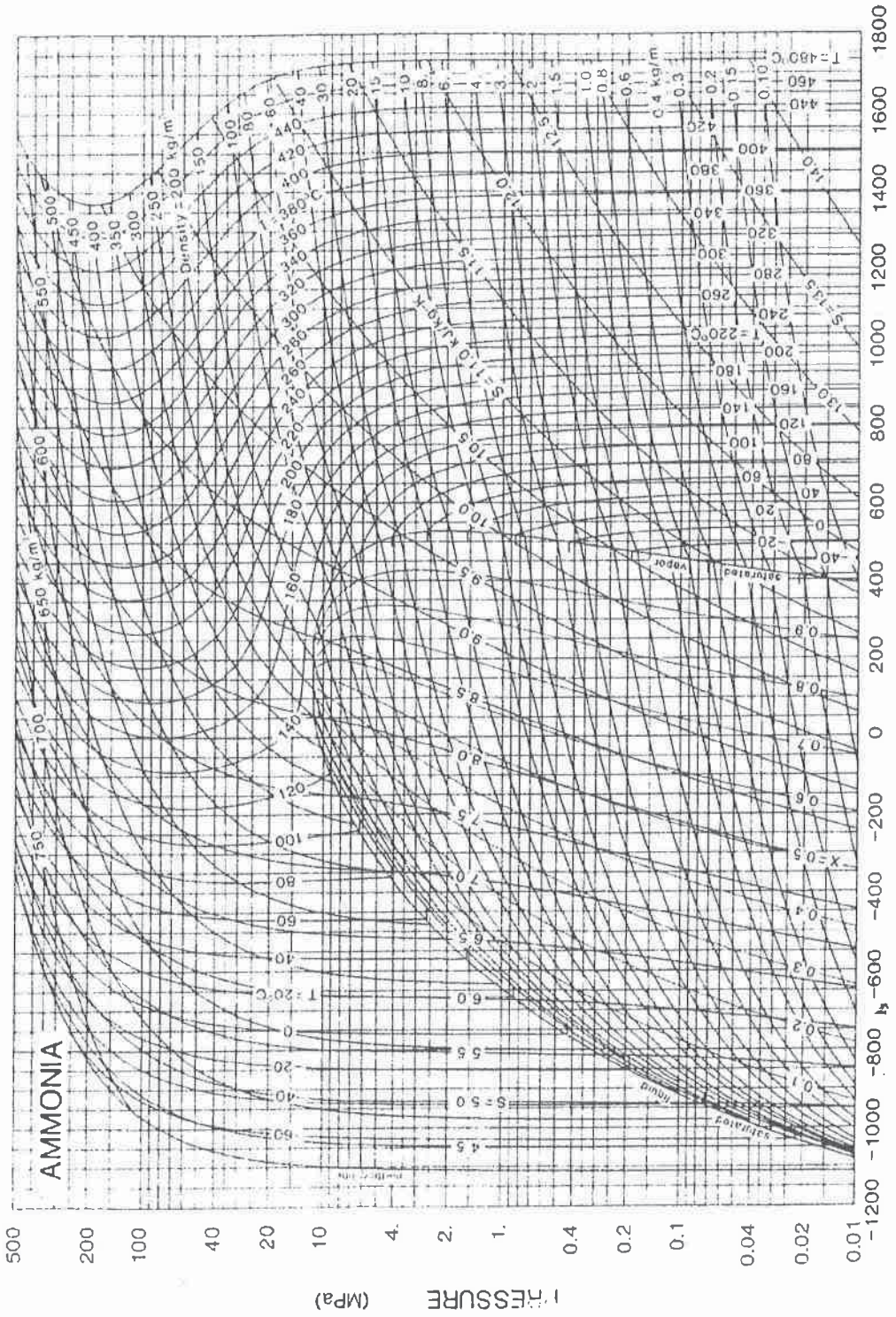



Fig. 21 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)
Note: The tabulated values for enthalpy and entropy differ from those in the table