NATIONAL EXAMS – December 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)

An air conditioning system is designed to maintain a room at 20°C dB (dry-bulb) and 50%RH, (relative humidity) with an air supply to the room of 1.8 kg/s at 14°C dB and 60%RH.
The design outside air conditions are 27°C dB and 70%RH.
The system consists of a mixing chamber for re-circulated and fresh air, a cooling coil supplied with chilled water, heating coil and supply fan. The ratio of re-circulated air to fresh air is 3; 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 losses and fan and pump work.

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. **Calculate the total air conditioning load for the room**
e. **Calculate the total required 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)

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 250,000 Btu/hr (all sensible).
The system airflow is 7250 CFM (ft^3/min), of which 2400 CFM is brought from outside for ventilation. Outside conditions are 30°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 360,000 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 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 23°C db (dry bulb), 17°C wb (wet bulb), cooling 15 kg/s of water from 27°C to 21°C. The air is assumed to leave the top of the tower at 25°C saturated with water. Fan air power input is 5kW.

a. **Find the air mass flow induced by the fan for the given cooling duty.**
b. **Find the evaporative loss (%).**
c. **Find the make-up water required, taking into account that some moisture is gained by the cooling air.**

PROBLEM 4. (20 POINTS)

A cold storage plant is used to cool 9000 litres of milk per hour from 27°C to 4°C.The heat gain of the plant is estimated at 3600kJ/min.
The refrigerant is ammonia and the temperature required in the evaporator is -6°C. The compressor delivery pressure is 10.34bar and the condenser liquid is undercooled to 24°C before throttling.
The plant has a brine circulating system and the rise in temperature of the brine is to be limited to 3°C.
The vapour is dry saturated at evaporator outlet, and the compression process is isentropic.

a) **Sketch the system.**
b) **Draw the refrigeration cycle on the *p-h* diagram provided.**
c) **Calculate:**
   - **The power input required in kW, taking the mechanical efficiency of the compressor as 90%.**
   - **The swept volume of each cylinder of the twin-cylinder, single acting compressor, with a volumetric efficiency of 85% and a rotational speed of 200 rpm.**
   - **The rate of brine circulation in liter/sec.**

Milk : specific heat 3.77 kJ/kg.K **density 1030kg/m^3**
Brine :specific heat 2.93kJ/kgK **density 1190kg/m^3**

PROBLEM 5. (20 POINTS)

a. 10 points

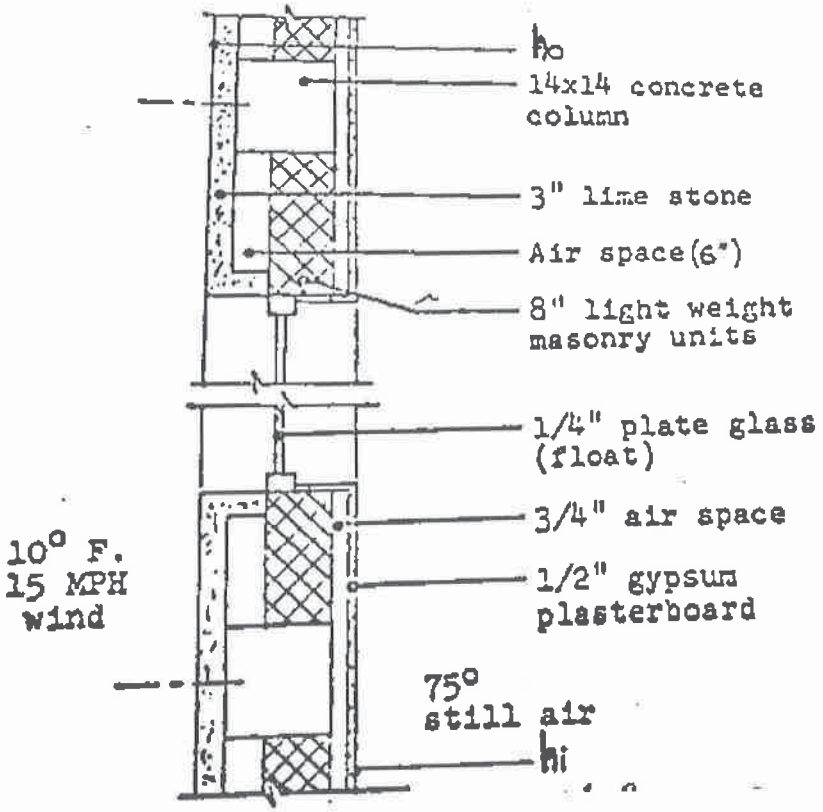
What is LEED certification. Explain

b. 10 points

Indoor air quality is one of the major concerns in HVAC industry today.
Please describe in a maximum of one page what are the factors influencing the indoor air quality, and what measures are to be taken in order to provide an acceptable indoor air quality. In your discussion make reference to standards and codes required in maintaining an acceptable indoor air quality.

PROBLEM 6. (20 POINTS)

Calculate the U factor for the wall shown below.
Assume that the window (glass is 40%) of the wall surface.



PROBLEM 7. (20 POINTS)

Select a centrifugal fan from the table below for a system requiring 12,000 cfm at a static pressure of 1.25 in w.g.

Calculate:

a. **The rotating speed**
b. **The power required**

Plot the fan performance curves at this speed.
Plot the system curve.

Table 6.1 Sample Performance Table for a Centrifugal Fan

		1/4sp		3/8sp		1/2sp		5/8sp		3/4sp		7/8sp		1 sp		1-1/4sp		1-1/2sp	
C F M	VEL	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
7448	800	245	.46	275	.62	304	.80	331	.99	360	1.20								
8379	900	262	.55	287	.73	314	.91	340	1.12	365	1.34	389	1.57						
9310	1000	280	.68	303	.87	327	1.07	361	1.27	374	1.49	396	1.73	418	2.00				
10241	1100	300	.82	321	1.03	341	1.23	363	1.45	385	1.68	438	1.92	427	2.19	466	2.75		
11172	1200	319	.97	339	1.21	358	1.43	376	1.66	397	1.90	417	2.14	436	2.40	474	2.97	510	3.59
12103	1300	339	1.15	358	1.40	376	1.65	393	1.89	410	2.15	429	2.40	448	2.67	483	3.22	518	3.87
13034	1400	359	1.36	377	1.62	394	1.89	411	2.16	427	2.42	442	2.69	460	2.97	494	3.54	527	4.17
13965	1500	380	1.58	396	1.86	413	2.16	428	2.43	444	2.72	459	3.01	473	3.30	506	3.89	537	4.51
14896	1600	401	1.84	416	2.13	432	2.44	447	2.76	462	3.08	478	3.39	490	3.66	518	4.27	549	4.92
15827	1700	423	2.13	436	2.43	451	2.75	486	3.09	479	3.41	493	3.72	507	4.05	632	4.69	551	5.37
16758	1800	444	2.45	467	2.77	471	3.10	485	3.45	496	3.79	511	4.14	524	4.47	549	5.15	574	5.86
17688	1900	468	2.80	479	3.16	491	3.49	505	3.86	517	4.20	530	4.59	542	4.96	557	5.67	589	6.38
18620	2000	488	3.20	600	3.65	511	3.90	524	4.28	537	4.67	549	5.08	550	5.43	584	6.19	608	6.92
20492	2200	532	4.01	543	4.47	554	4.87	584	5.26	576	5.68	587	6.08	599	6.54	620	7.39	641	8.18
22344	2400	576	5.14	587	6.58	597	6.00	606	6.41	616	6.86	627	7.31	637	7.75	658	8.70	677	9.63
24205	2600	621	6.39	631	6.85	640	7.30	649	7.76	658	8.23	657	8.71	677	9.19	695	10.18	715	11.18
26068	2800	666	7.83	675	8.31	684	8.81	692	9.28	701	9.20	709	10.30	717	10.60	738	11.87	753	12.90
27930	3000	711	9.45	719	9.97	728	10.53	736	11.05	744	11.58	752	12.12	759	12.63	775	13.72	792	14.85
29792	3200	766	11.34	764	11.89	772	12.46	789	13.03	787	13.56	795	14.18	802	14.71	816	15.85	832	17.04
31654	3400	801	13.44	809	14.05	816	14.81	824	15.24	831	15.82	838	16.41	845	17.02	859	16.25	872	19.45

Source: Reprinted by permission from *Cook Centrifugal Plug Fan*, Loren Cook Co., Springfield, MO., 1989.
Note: INTAKE AREA = 9.72 ft^2. WHEEL DIAMETER = 40$\frac{1}{4}$.
TIP SPEED FPM = 10.537 × RPM MAXIMUM BHP = 31.14 $\left[\frac{\text{RPM}}{1000}\right]^3$.
BHP does not include drive loss, underlines indicate maximum static efficiencies, VEL is inlet flow velocity in ft/min, blank spaces are conditions of surging.

PROBLEM 8. (20 POINTS)

An R-2000standard house is located in Ottawa and has a calculated heat loss of 10kW with indoor and outdoor design temperatures of 22°C and -25°C, respectively.
The furnace is of energy efficient type and its energy efficiency factor is 0.85. The heating value of natural gas is 37 MJ/m^3

a. **Estimate the annual amount of natural gas required to heat the house.**
b. **What will be the savings if the indoor temperature is set back by 4°Cto 18°C for 7 hours (11:00pm-6:00am) every day.**

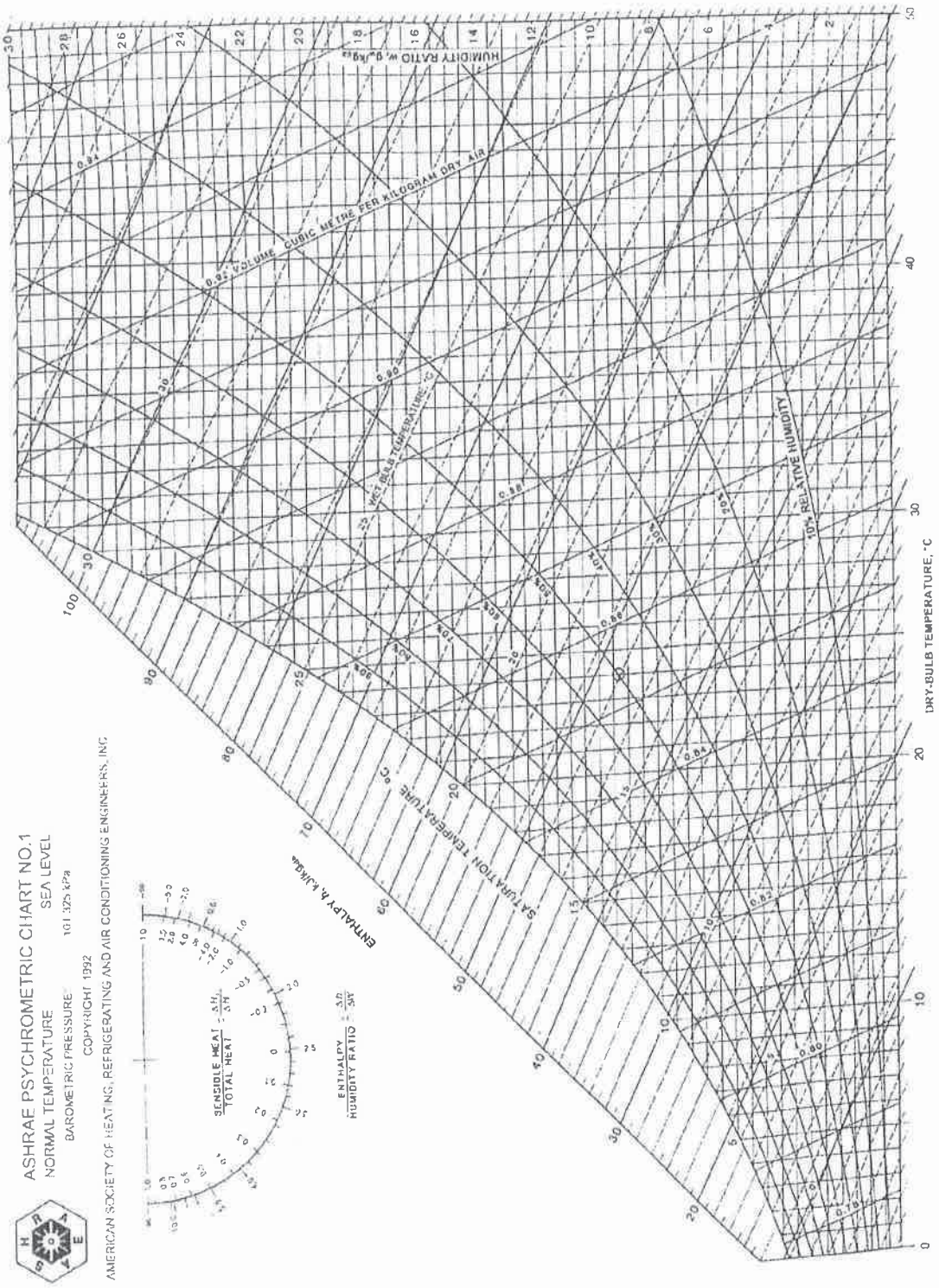
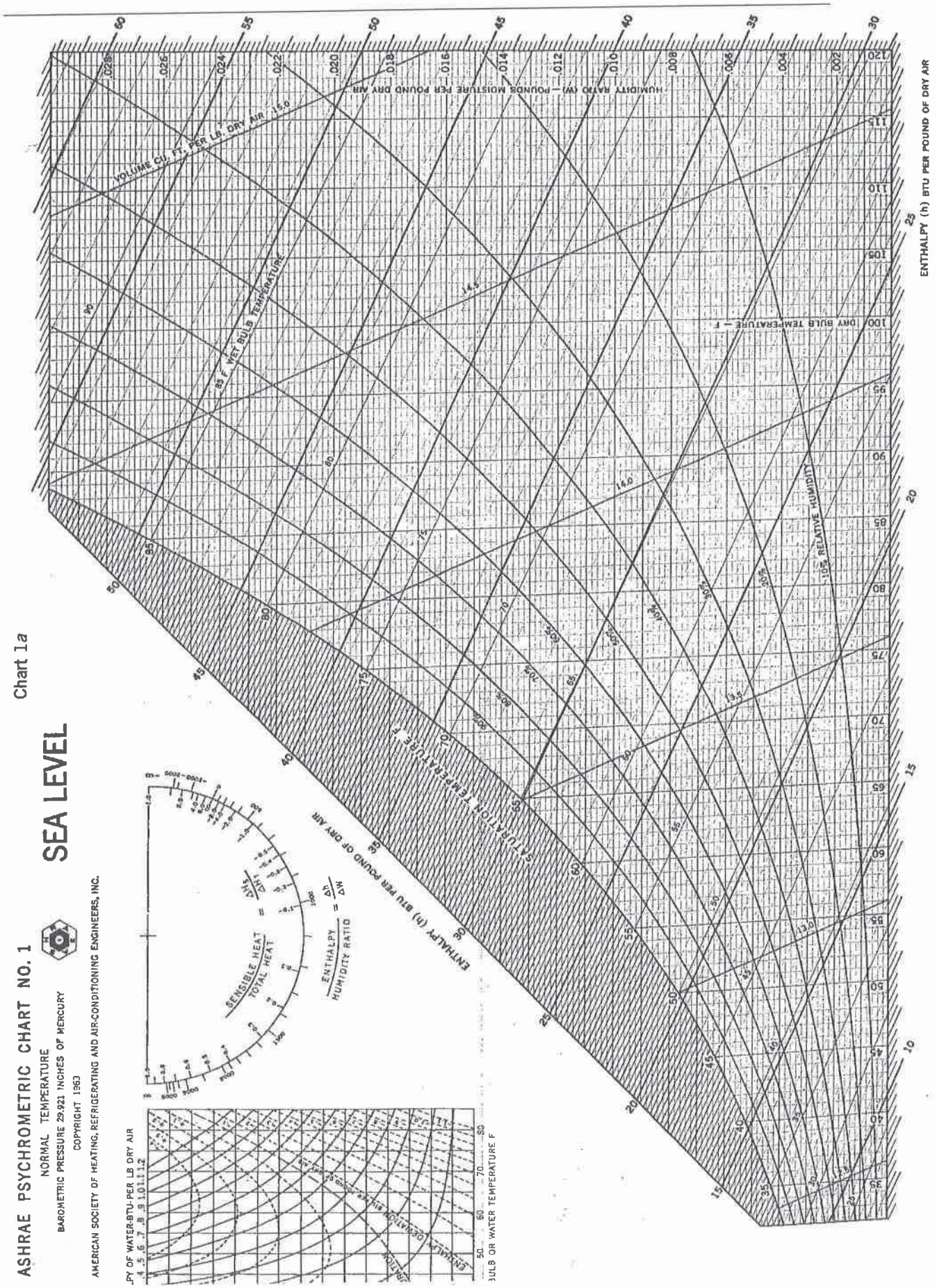


Fig. 1 ASHRAE Psychrometric Chart No. 1


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
ENTHALPY (h) BTU PER POUND OF DRY AIR
VOLUME CU. FT. PER LB. DRY AIR
85° F. WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
PY OF WATER-BTU-PER LB DRY AIR
ULB OR WATER TEMPERATURE F

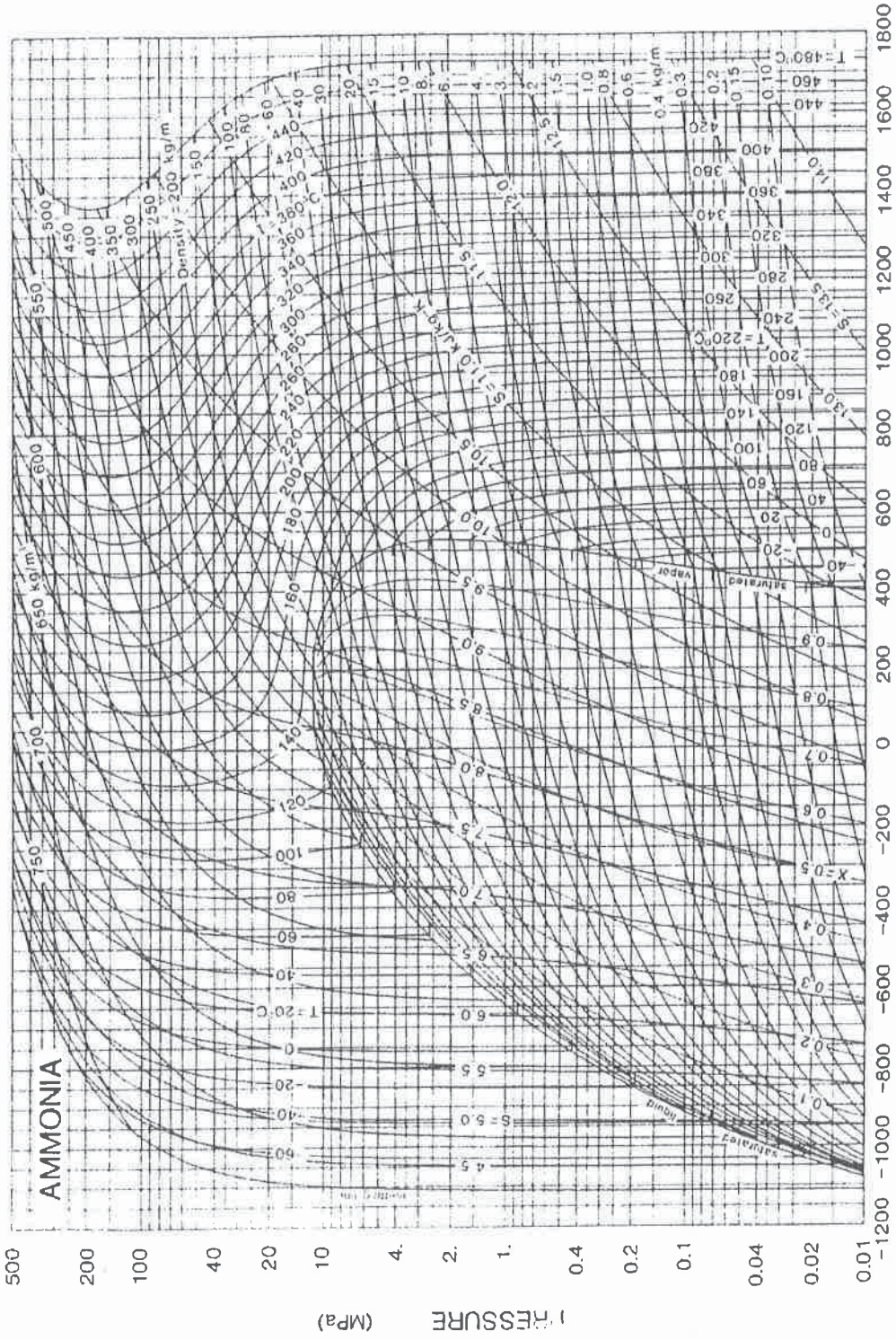


Fig. 21 Pressure-Enthalpy Diagram for Refrigerant 717 (Ammonia)
Note: The reference states for enthalpy and entropy differ from those in the table.