UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 2006/2007

Oktober/November 2006

EMH 372E/3 - Penyejukan & Penyamanan Udara

Masa : 3 jam

ARAHAN KEPADA CALON :

Sila pastikan bahawa kertas soalan ini mengandungi **LIMA** (5) mukasurat dan **LIMA** (5) soalan yang bercetak serta **TIGA BELAS (13)** helaian lampiran sebelum anda memulakan peperiksaan.

Sila jawab **SEMUA** soalan.

Semua soalan perlu dijawab dalam **Bahasa Malaysia** atau **Bahasa Inggeris**.

Lampiran :

1. Table A4(a) - Maximum Solar Heat Gain Factor (w/m²) For Sunlit Glass, North Latitudes [1 mukasurat]
2. Table A8 - Cooling Load Temperature Differences For Calculating Cooling Load From Sunlit Walls [1 mukasurat]
3. Table A9 - Cooling Load Temperature Differences (CLTD) For Callculating Cooling Load From Flat Roofs [1 mukasurat]
4. Table A10(a) - CLTD Correction For Latitude and Month Applied To Walls and Roofs, North Latitudes [1 mukasurat]
5. Table A10(b) - Cooling Load Temperature Differences (CLTD) For Conduction Through Glass [1 mukasurat]
6. Table A11 - Shading Coefficients For Single Glass and Insulating Glass[a] [1 mukasurat]
7. Table A18 - Rates of Heat Gains From Occupants in Conditioned Spaces [1 mukasurat]
8. Appendix - Table A-1 (Water: Properties of Liquid and Saturated Vapor) [1 mukasurat]
9. Appendix - Table A-3 (Ammonia: Properties of Liquid and Saturated Vapor[3] [1 mukasurat]
10. Appendix - Figure A-1 (Pressure – Enthalpy Diagram of Superheated Ammonia Vapour) [1 mukasurat]
11. Appendix - Figure 17-5 (Temperature Pressure Concentration Diagram of Saturated LiBr-water Solutions, Developed From Data in Ref. 1) [1 mukasurat]
12. Appendix - Figure 17-8 (Enthalpy of LiBr-water Solutions; Data From Ref. L) [1 mukasurat]
13. Appendix - Figure 12-4 (Psychrometry Chart For Normal Temperature) [1 mukasurat]

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

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S1. (a) Nyatakan empat pengklasan bahan penyejuk dan terangkan 5 sifat bahan penyejuk dengan contoh.

State four classification of refrigerants and explain 5 properties of refrigerants with examples.

(30 markah)

(b) Sebuah sistem pelbagai tahap menghasilkan 200kW muatan penyejukan pada suhu penyejat -10°C. Sistem tersebut menggunakan 2 pemampat dan satu penyejat. Ammonia digunakan sebagai bahan penyejuk. Suhu pemeluwap adalah 30°C.

i) Lakarkan lukisan skima dan kitar tersebut pada gambarajah p-h
ii) Kuasa yang diperlukan oleh pemampat dan
iii) Pekali prestasi kitar
iv) Tentukan peratus perubahan dalam pekali prestasi dan keperluan kuasa diantara proses mampatan satu tahap dan dua tahap.

A multi-pressure system produces 200 kW refrigeration capacity at an evaporator temperature of -10°C. The system uses 2 compressors and single evaporator. The refrigerant used is Ammonia. The condenser temperature is 30°C.

i) Sketch the schematic drawing of the system and the cycle on P-h diagram
ii) Determine the power required by the compressors and
iii) Determine the coefficient of performance of the cycle.
iv) Determine the percentage change in the COP and the power requirement between the single stage and 2 stage compression process.

(70 markah)

S2. Sebuah sistem penyerapan menggunakan Li-Br-air dengan data berikut:

- **Suhu penyerap 40°C**
- **Suhu penjana 90°C**
- **Suhu Pemeluwap 40°C**
- **Suhu penyejat 10°C**
- **Kadar alir larutan penyerap 1.5 kg/s**

(a) Lakarkan dan terangkan operasi sistem penyejukan penyerapan wap.

(b) Tentukan pekali prestasi dan bandingkan dengan pekali prestasi unggul.

A vapour absorption refrigeration system uses Li-Br water with the following data:

- *Absorber temperature = 40°C*
- *Generator temperature = 90°C*
- *Condenser temperature = 40°C*
- *Evaporator temperature = 10°C*
- *Flow rate of absorber solution = 1.5 kg/s*

a) *Sketch and explain the operation of a vapour absorption refrigeration cycle.*

b) *Determine the coefficient of performance and compare with the ideal coefficient of performance.*

(100 markah)

S3. Dengan bantuan gambarajah, terangkan TIGA (3) sistem penyamanan udara yang digunakan.

With the aid of diagrams describe THREE (3) types of air-conditioning system used.

(100 markah)

S4. Lakaran sebuah pasaraya ditunjuk pada Rajah S5. Berikut adalah maklumat yang diberikan:

(a) Bumbung 100mm konkrik dengan 50mm penebat, gypsum papan siling U = 0.5112W/m^2 K

(b) Dinding kumpulan B; U=0.643W/m^2/K

(c) Tingkap depan 6mm cermin, 3m tinggi, tanpa lindung; U = 5.68 W/m^{2}K

(d) Pintu 10mm cermin lutsinar; U = 2.21W/m^{2}K

(e) Penghuni 60 orang

(f) Lampu 9 W/m^2 daripada luas lantai menggunakan lampu flourescent

(g) Pasaraya buka mulai 10 pagi hingga 8malam.

(h) Suhu luar 30°C, RH 80%

(i) Latitud 5° Utara

(j) Ventilasi: kadar alir udara 7.5 liters/s se orang

(k) Abaikan kesan lantai.

Tentukan beban penyejukan pasaraya bagi keadaan dalam pasaraya 22°C dan RH 50%.

A sketch of a supermarket is shown in Figure Q5. The following are the detail:

(a) Roof 100mm concrete with 50mm insulation, gypsum board ceiling $U = 0.5112 W/m^2K$

(b) Walls group B; $U = 0.643 W/m^2/K$

(c) Front window is 6mm single heat absorbing glass, 3m high, not shaded $U = 5.68 W/m^2 K$

(d) Doors are 10mm single clear glass, $U = 2.21 W/m^2K$

(e) Occupancy 60 people

(f) Lighting 9 W/m^2 of floor area using flourescent fixtures

(g) Supermarket open from 10 am to 8pm.

(h) Ambient temperature 30°C, RH 80%

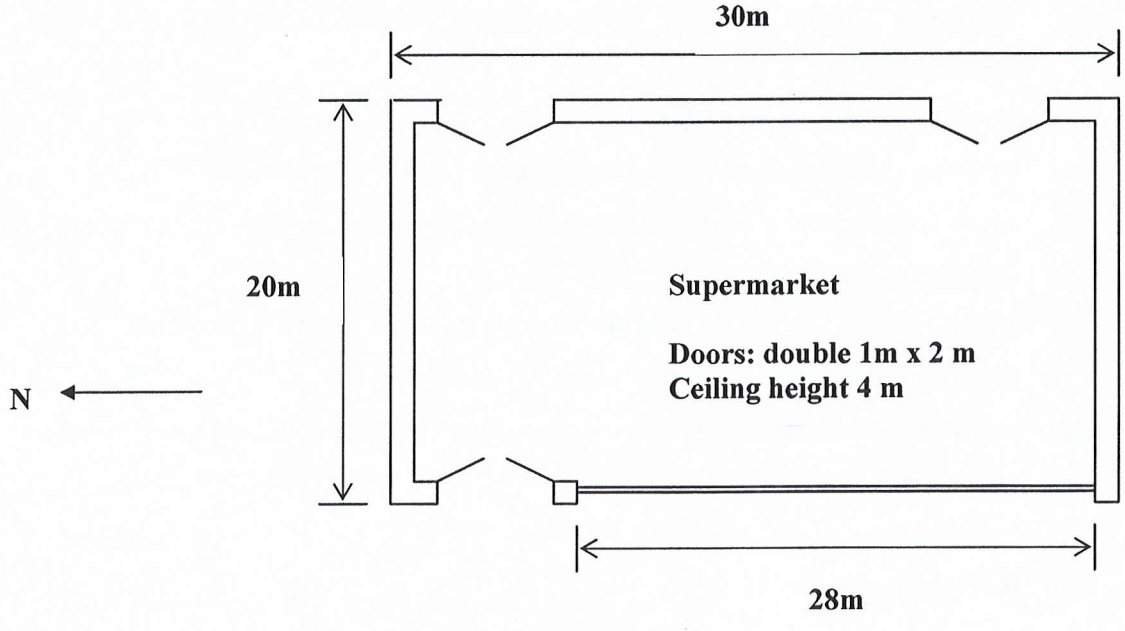
(i) The latitude is 5°N

(j) Ventilation, volume flow rate of air 7.5 liters/s per person

(k) Neglect floor

Determine the cooling load of the supermarket to be air-conditioned with 22°C and RH 50%.

(100 markah)



Rajah S5
Figure Q5

S5. Sebuah loji penyamanan udara direkabentuk untuk mengekalkan sebuah bilik pada suhu 20°C dan kelembapan relatif 55%. Suhu udara luar adalah 30°C dan kelembapan relatif 80%. Beban penyejukan bilik adalah 21.6 kW haba deria dan 3.6kW haba tambah pelakuran. Pembekalan udara segar adalah satu pertiga jisim udara. Suhu udara masuk adalah 15°C.

Andaikan kecekapan gelung penyejukan adalah 80% dan abaikan kesan kipas, kirakan:

a) Kadar alir bekalan udara
b) Kapasiti penyejukan gelung penyejukan
c) Kapasiti haba pemanas semula
d) Amaun air terpeluwap yang dibuang

Plot proses tersebut di atas carta psikrometri yang dibekalkan.

An air conditioning plant is designed to maintain a room at temperature 20°C and relative humidity 55%. The outside air is at a temperature of 30°C and relative humidity of 80%. The cooling load of the room is 21.6 kW with sensible heat gain and 3.6 kW latent heat gain. The refresh air supply is one-third by mass. Temperature of supply air is 15°C.

Assuming that the cooling coil efficiency is 80% and neglecting the effect of the fan, calculate:

a) Mass flow rate of the supply air
b) Refrigeration capacity of the cooling coil
c) Heating capacity of the reheater
d) Amount of condensate removed

Plot the process on the psychometric chart.

(100 markah)

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TABLE A4(a) Maximum solar heat gain factor (W/m^2) for sunlit glass, north latitudes

0°N Lat										
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan.	107	107	278	558	738	801	741	574	372	934
Feb.	114	123	416	647	773	779	663	445	211	965
Mar.	120	274	536	704	746	704	536	274	120	956
Apr.	224	423	609	707	697	581	372	120	117	896
May	357	517	640	688	634	486	252	117	117	836
June	407	546	650	669	603	441	208	117	117	805
July	363	517	634	672	615	470	243	120	120	820
Aug.	237	423	590	681	669	552	353	123	120	871
Sep.	126	265	514	672	729	672	514	265	126	924
Oct.	117	126	407	628	745	751	637	426	208	943
Nov.	110	110	278	552	726	789	726	565	369	924
Dec.	107	107	224	517	713	798	757	618	435	909

4°N Lat										
	N	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SWW	S	HOR
Jan.	104	104	249	536	722	795	514	609	445	902
Feb.	110	110	388	628	764	782	678	480	278	550
Mar.	120	243	514	691	764	716	558	303	136	953
Apr.	174	394	596	704	704	599	398	136	120	905
May	293	486	631	694	650	508	281	120	120	858
June	347	517	637	678	618	464	230	120	120	830
July	303	486	622	678	631	492	268	123	120	842
Aug.	186	391	581	678	675	571	379	133	126	880
Sep.	123	237	492	659	729	681	536	293	139	924
Oct.	114	114	379	609	738	754	653	467	271	928
Nov.	107	107	249	530	713	782	732	599	439	896
Dec.	104	104	196	495	697	789	764	650	505	874

Adapted by permission from *ASHRAE Fundamentals*, 1989, Table 34.

(Contd.)

TABLE A8 Cooling load temperature differences for calculating cooling load from sunlit walls

	Solar time, h																								Hours of maximum CLTD	Hours of Minimum CLTD	Hours of Maximum CLTD	Difference CLTD
	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400				
Group B Walls																												
N	8	8	8	7	7	6	6	6	5	5	5	5	5	5	5	6	6	7	7	8	8	8	8	8	24	5	8	3
NE	11	10	10	9	9	8	7	7	7	7	8	8	9	9	10	10	11	11	11	12	12	12	11	11	21	7	12	5
E	13	13	12	11	10	10	9	8	8	9	9	10	12	13	13	14	14	15	15	15	15	15	14	14	20	8	15	7
SE	13	12	12	11	10	10	9	8	8	8	8	9	10	11	12	13	14	14	14	14	14	14	14	14	21	8	14	6
S	12	11	11	10	9	9	8	7	7	6	6	6	6	7	8	9	10	11	11	12	12	12	12	12	23	6	12	6
SW	15	15	14	13	13	12	11	10	9	9	8	8	7	7	8	9	10	11	13	14	15	15	16	16	24	7	16	9
W	16	16	15	14	14	13	12	11	10	9	9	8	8	8	8	8	9	11	12	14	15	16	16	17	24	8	17	9
NW	13	12	12	11	11	10	9	9	8	7	7	7	6	6	7	7	8	8	9	11	12	13	13	13	24	6	13	7
Group C Walls																												
N	9	8	–	7	6	5	5	4	4	4	4	4	5	5	6	6	7	8	9	9	9	10	9	9	22	4	10	6
NE	10	10	9	8	7	6	6	6	6	7	8	10	10	11	12	12	12	13	13	13	13	12	12	11	20	6	13	7
E	13	12	11	10	9	8	7	7	8	9	11	13	14	15	16	16	17	17	16	16	16	16	15	14	18	7	17	10
SE	13	12	11	10	9	8	7	6	7	7	9	10	12	14	15	16	16	16	16	16	16	16	15	14	19	6	16	10
S	12	11	10	9	8	7	6	6	5	5	5	5	6	8	9	11	12	13	14	14	14	14	13	12	20	5	14	9
SW	16	15	14	12	11	10	9	8	7	7	6	6	6	7	8	10	12	14	16	18	18	18	18	17	22	6	18	12
W	17	16	15	14	12	11	10	9	8	7	7	7	7	7	8	9	11	13	16	18	19	20	19	18	22	7	20	13
NW	14	13	12	11	10	9	8	7	6	6	5	5	6	6	6	7	9	10	12	14	15	15	15	15	22	5	15	10
Group D Walls																												
N	8	7	7	6	5	4	3	3	3	3	4	4	5	6	6	7	8	9	10	11	11	10	10	9	21	3	11	8
NE	9	8	7	6	5	5	4	4	6	8	10	11	12	13	13	13	14	14	14	13	13	12	11	10	19	4	14	10
E	11	10	8	7	6	5	5	5	7	10	13	15	17	18	18	18	18	18	17	17	16	15	13	12	16	5	18	13
SE	11	10	9	7	6	5	5	5	5	7	10	12	14	16	17	18	18	18	17	17	16	15	14	12	17	5	18	13
S	11	10	8	7	6	5	4	4	3	3	4	5	7	9	11	13	15	16	16	16	15	14	13	12	19	3	16	13
SW	15	14	12	10	9	8	6	5	5	4	4	5	5	7	9	12	15	18	20	21	21	20	19	17	21	4	21	17
W	17	15	13	12	10	9	7	6	5	5	5	5	6	6	8	10	13	17	20	22	23	22	21	19	21	5	23	18
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6	7	8	10	12	15	17	18	17	16	15	22	4	18	14
Group E Walls																												
N	7	6	5	4	3	2	2	2	3	3	4	5	6	7	8	10	10	11	12	12	11	10	9	8	20	2	12	10
NE	7	6	5	4	3	2	3	5	8	11	13	14	14	14	14	14	15	14	14	13	12	11	9	8	16	2	15	13
E	8	7	6	5	4	3	3	6	10	15	18	20	21	21	20	19	18	18		17	15	14	12	11	9	13	3	21
18																												
SE	8	7	6	5	4	3	3	4	7	10	14	17	19	20	20	20	19	18	17	16	14	13	11	10	15	3	20	17
S	8	7	6	5	4	3	2	2	2	3	5	7	10	14	16	18	19	18	17	16	14	13	11	10	17	2	19	17
SW	12	10	8	7	6	4	4	3	3	3	4	5	7	10	14	18	21	24	25	24	22	19	17	14	19	3	25	22
W	14	12	10	8	6	5	4	3	3	3	4	4	5	6	8	11	15	20	24	27	27	25	22	19	16	20	3	27	24
NW	11	9	8	6	5	4	3	3	3	3	4	5	6	7	9	11	14	18	21	21	20	18	15	13	20	3	21	18

[1/2] Adapted by permission from *ASHRAE Fundamentals*, 1989, Table 31. *(Contd.)*

TABLE A9 Cooling load temperature differences (CLTD) for calculating cooling load from flat roofs

Roof no.	Description of construction	Mass, kg/m²	U-value W/m².°C	Solar time 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Hours of maximum CLTD	Minimum CLTD	Maximum CLTD	Difference CLTD
Without Suspended Ceiling																															
1	Steel sheet with 25 mm (or 50 mm) insulation	34 (39)	1.209 (0.704)	0	−1	−2	−2	−3	−2	3	11	19	27	34	40	43	44	43	39	33	25	17	10	7	5	3	1	14	−3	44	47
2	25 mm wood with 25 mm insulation	39	0.965	3	2	0	−1	−2	−2	−1	2	8	15	22	29	35	39	41	41	39	35	29	21	15	11	8	5	16	−2	41	43
3	100 mm l.w. concrete	88	1.209	5	3	1	0	−1	−2	−2	1	5	11	18	25	31	36	39	40	40	37	32	25	19	14	10	7	16	−2	40	42
4	50 mm h.w. concrete with 25 mm (or 50 mm) ins.	142	1.170 (0.693)	7	5	3	2	0	−1	0	2	6	11	17	23	28	33	36	37	37	34	30	25	20	16	12	10	16	−1	37	38
5	25 mm wood with 50 mm insulation	44	0.619	2	0	−2	−3	−4	4	−4	−2	3	9	15	22	27	32	35	36	35	32	27	20	14	10	6	3	16	−4	36	40
6	150 mm l.w. concrete	117	0.897	12	10	7	5	3	2	1	0	2	4	8	13	18	24	29	33	35	36	35	32	28	24	19	16	18	0	36	36
7	60 mm wood with 25 mm insulation	63	0.738	16	13	11	9	7	6	4	3	4	5	8	11	15	19	23	27	29	31	31	30	27	25	22	19	19	3	31	28
8	200 mm l.w. concrete	151	0.715	20	17	14	12	10	8	6	5	4	4	5	7	11	14	18	22	25	28	30	30	29	27	25	22	20	4	30	26
9	100 mm h.w. concrete with 25 mm (or 50 mm) ins.	254 (254)	1.136 (0.681)	14	12	10	8	7	5	4	4	6	8	11	15	18	22	25	28	29	30	29	27	24	21	19	16	18	4	30	26
10	60 mm wood will 50 mm insulation	63	0.528	18	15	13	11	9	8	6	5	5	5	7	10	13	17	21	24	27	28	29	29	27	25	23	20	19	5	29	24
11	Roof terrace system	366	0.602	19	17	15	14	12	11	9	8	7	8	8	10	12	15	18	20	22	24	25	26	25	24	22	21	20	7	26	19
12	150 mm h.w. concrete with 25 mm (or 50 mm) ins.	366 (366)	(1.090) (0.664)	18	16	14	12	11	10	9	8	8	9	10	12	15	17	20	22	24	25	25	25	24	22	20	19	19	8	25	17
13	100 mm wood with 25 mm (or 50 mm) insulation	83 (88)	0.602 (0.443)	21	20	18	17	15	14	13	11	10	9	9	9	10	12	14	16	18	20	22	23	24	24	23	22	22	9	24	15
With Suspended Ceiling																															
1	Steel Sheet with 25 mm (or 50 mm) insulation	44 (49)	0.761 (0.522)	1	0	−1	−2	−3	−3	0	5	13	20	28	35	40	43	43	41	37	31	23	15	10	7	5	3	15	−3	43	46
2	25 mm wood with 25 mm insulation	49	0.653	11	8	6	5	3	2	1	2	4	7	12	17	22	27	31	33	35	34	32	28	24	20	17	14	17	1	35	34
3	100 mm l.w. concrete	97	0.761	10	8	6	4	2	1	0	0	2	6	10	16	21	27	31	34	36	36	34	30	26	21	17	13	17	0	36	36
4	50 mm h.w. concrete with 25 mm insulation	146	0.744	16	14	13	11	10	8	7	7	8	9	11	14	17	19	22	24	25	26	26	25	23	21	20	18	18	7	26	19
5	25 mm wood with 50 mm insulation	49	0.471	14	11	9	7	5	4	3	3	4	6	10	14	18	23	27	30	31	32	31	29	26	22	19	16	18	3	32	30
6	150 mm l.w. concrete	127	0.619	18	15	13	11	9	7	6	4	4	4	6	9	12	16	20	24	27	29	30	30	28	26	23	20	20	4	30	26
7	60 mm wood with 25 mm insulation	73	0.545	19	18	16	14	13	12	10	9	8	8	9	10	12	14	17	19	21	23	24	25	24	23	22	21	20	8	25	17
8	200 mm l.w. concrete	161	0.528	22	20	18	16	15	13	11	10	9	8	8	8	9	11	14	16	19	21	23	25	25	25	24	23	20	8	25	17
9	100 mm h.w. concrete with 25 mm (or 50 mm) ins.	259 (264)	0.727 (0.511)	17	16	15	14	13	13	12	11	11	11	12	13	15	16	18	19	20	21	21	21	21	20	19	18	19	11	21	10
10	60 mm wood with 50 mm insulation	73	0.409	19	18	17	16	14	13	12	11	10	10	10	11	12	14	16	18	19	21	22	23	23	22	22	21	21	10	23	13
11	Roof terrace system	376	0.466	17	16	16	15	15	14	13	13	13	12	12	13	13	14	15	16	16	17	18	18	19	18	18	18	21	12	19	7
12	150 mm h.w. concrete with 25 mm (or 50 mm) ins.	376	0.710	16	16	15	15	14	13	13	12	12	12	12	13	14	15	16	17	18	18	19	19	19	18	18	18	20	12	19	7
13	100 mm wood with 25 mm (or 50 mm) insulation	93 (97)	0.465 (0.363)	20	19	19	18	17	16	15	14	14	13	12	12	12	12	13	14	15	16	18	19	20	20	20	20	23	12	20	8

Adapted by permission from *ASHRAE Fundamentals*, 1989, Table 29.

TABLE A10(a) CLTD correction for latitude and month applied to walls and roofs, north latitudes

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	HOR
0	Dec	–1.6	–2.7	–2.7	–2.7	–1.1	0.0	1.6	3.3	5.0	–0.5
	Jan/Nov	–1.6	–2.7	–2.2	–2.2	–0.5	0.0	1.1	2.2	3.8	–0.5
	Feb/Oct	–1.6	–1.1	–1.1	–1.1	–0.5	–0.5	0.0	–0.5	–3.8	0.0
	Mar/Sept	–1.6	0.0	0.5	–0.5	–0.5	–1.6	–1.6	–2.7	–4.4	0.0
	Apr/Aug	2.7	2.2	1.6	0.0	–1.1	–2.7	–3.3	–4.4	–4.4	–1.1
	May/Jul	5.5	3.8	2.7	0.0	–1.6	–3.8	–4.4	–5.0	–4.4	–2.2
	Jun	6.6	5.0	2.7	0.0	–1.6	–3.8	–5.0	–5.5	–4.4	–2.7
8	Dec	–2.2	–3.3	–3.3	–3.3	–1.6	0.0	2.2	4.4	6.6	–2.7
	Jan/Nov	–1.6	–2.7	–3.3	–2.7	–1.1	0.0	1.6	3.3	5.5	–2.2
	Feb/Oct	–1.6	–2.2	–1.6	–1.6	–0.5	–0.5	0.5	1.1	2.2	–0.5
	Mar/Sept	–1.6	–1.1	–0.5	–0.5	–0.5	–1.1	–1.1	–1.6	–2.2	0.0
	Apr/Aug	1.1	1.1	1.1	0.0	–0.5	–2.2	–2.7	–3.8	–3.8	–0.5
	May/Jul	3.8	2.7	2.2	0.0	–1.1	–2.7	–3.8	–5.0	–3.8	–1.1
	Jun	5.0	3.3	2.2	0.0	–1.1	–3.3	–4.4	–5.0	–3.8	–1.1
16	Dec	–2.2	–3.3	–4.4	–4.4	–2.2	–0.5	2.2	5.0	7.2	–5.0
	Jan/Nov	–2.2	–3.3	–3.8	–3.8	–2.2	–0.5	2.2	4.4	6.6	–3.8
	Feb/Oct	–1.6	–2.7	–2.7	–2.2	–1.1	0.0	1.1	2.7	3.8	–2.2
	Mar/Sept	–1.6	–1.6	–1.1	–1.1	–0.5	–0.5	0.0	0.0	0.0	–0.5
	Apr/Aug	–0.5	0.0	–0.5	–0.5	–0.5	–1.6	–1.6	–2.7	–3.3	0.0
	May/Jul	2.2	1.6	1.6	0.0	–0.5	–2.2	–2.7	–3.8	–3.8	0.0
	Jun	3.3	2.2	2.2	0.5	–0.5	–2.2	–3.3	–4.4	–3.8	0.0
24	Dec	–2.7	–3.8	–5.0	–5.5	–3.8	–1.6	1.6	5.0	7.2	–7.2
	Jan/Nov	–2.2	–3.3	–4.4	–5.0	–3.3	–1.6	1.6	5.0	7.2	–6.1
	Feb/Oct	–2.2	–2.7	–3.3	–3.3	–1.6	–0.5	1.6	3.8	5.5	–3.8
	Mar/Sept	–1.6	–2.2	–1.6	–1.6	–0.5	–0.5	0.5	1.1	2.2	–1.6
	Apr/Aug	–1.1	–0.5	0.0	–0.5	–0.5	–1.1	–0.5	–1.1	–1.6	0.0
	May/Jul	0.5	1.1	1.1	0.0	0.0	–1.6	–1.6	–2.7	–3.3	0.5
	Jun	1.6	1.6	1.6	0.5	0.0	–1.6	–2.2	–3.3	–3.3	0.5
32	Dec	–2.7	–3.8	–5.5	–6.1	–4.4	–2.7	1.1	5.0	6.6	–9.4
	Jan/Nov	–2.7	–3.8	–5.0	–6.1	–4.4	–2.2	1.1	5.0	6.6	–8.3
	Feb/Oct	–2.2	–3.3	–3.8	–4.4	–2.2	–1.1	2.2	4.4	6.1	–5.5
	Mar/Sept	–1.6	–2.2	–2.2	–2.2	1.1	–0.5	1.6	2.7	3.8	–2.7
	Apr/Aug	–1.1	–1.1	–0.5	–1.1	0.0	–0.5	0.0	0.5	0.5	–0.5
	May/Jul	0.5	0.5	0.5	0.0	0.0	–0.5	–0.5	–1.6	–1.6	0.5
	Jun	0.5	1.1	1.1	0.5	0.0	–1.1	–1.1	–2.2	–2.2	1.1

Adapted by permission from *ASHRAE Fundamentals*, 1989, Table 32.

(*Contd.*)

TABLE A10(b) Cooling load temperture differences (CLTD) for conduction through glass

Solar time, h	CLTD, °C	Solar time, h	CLTD, °C
0100	1	1300	7
0200	0	1400	7
0300	−1	1500	8
0400	−1	1600	8
0500	−1	1700	7
0600	−1	1800	7
0700	−1	1900	6
0800	0	2000	4
0900	1	2100	3
1000	2	2200	2
1100	4	2300	2
1200	5	2400	1

TABLE A11 Shading coefficients for single glass and insulating glass[a]

Type of glass	Nominal thickness[b]	Solar trans.[b]	Shading coefficient	
			$h_0 = 22.7$	$h_0 = 7.0$
A. Single Glass				
Clear	3 mm	0.86	1.00	1.00
	6 mm	0.78	0.94	0.95
	10 mm	0.72	0.90	0.92
	13 mm	0.67	0.87	0.88
Heat absorbing	3 mm	0.64	0.83	0.85
	6 mm	0.46	0.69	0.73
	10 mm	0.33	0.60	0.64
	13 mm	0.24	0.53	0.58
B. Insulating Glass				
Clear out, Clear in	3 mm[c]	0.71[e]	0.88	0.88
Clear out, Clear in	6 mm	0.61	0.81	0.82
Heat absorbing[d] Out, Clear in	6 mm	0.36	0.55	0.58

[a]Refers to factory-fabricated units with 5-, 6-, or 13 mm airspace or to prime windows plus storm sash.
[b]Refer to manufacturer's literature for values.
[c]Thickness of each pane of glass, not thickness of assembled unit.
[d]Refers to gray, bronze, and green tinted heat-absorbing float glass.
[e]Combined transmittance for assembled unit.

Adapted by permission from *ASHRAE Fundamentals*, 1989, Table 20.

TABLE A18 Rates of heat gains from occupants in conditioned spaces

Degree of activity	Typical application	Total heat gain (W)	Total heat adjusted (W)	Sensible heat (W)	Latent heat (W)
Moderately active office work	Office, Hotels, Apartments	140	130	75	55
Standing, Light work; Walking	Departmental store, Retail store	160	130	75	55
Walking, Standing	Drug store, Bank	160	145	75	70
Light bench work	Factory	235	220	80	140
Walking 3 mph; light machine work	Factory	295	295	110	185
Heavy work	Factory	440	425	170	255
Athletics	Gymnasium	585	525	210	315

APPENDIX

Table A-1 Water: properties of liquid and saturated vapor

t, °C	Saturation pressure, kPa	Specific volume, m^3/kg		Enthalpy, kJ/kg		Entropy, kJ/kg · K	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
0	0.6108	0.0010002	206.3	-0.04	2501.6	-0.0002	9.1577
2	0.7055	0.0010001	179.9	8.39	2505.2	0.0306	9.1047
4	0.8129	0.0010000	157.3	16.80	2508.9	0.0611	9.0526
6	0.9345	0.0010000	137.8	25.21	2512.6	0.0913	9.0015
8	1.0720	0.0010001	121.0	33.60	2516.2	0.1213	8.9513
10	1.2270	0.0010003	106.4	41.99	2519.9	0.1510	8.9020
12	1.4014	0.0010004	93.84	50.38	2523.6	0.1805	8.8536
14	1.5973	0.0010007	82.90	58.75	2527.2	0.2098	8.8060
16	1.8168	0.0010010	73.38	67.13	2530.9	0.2388	8.7593
18	2.062	0.0010013	65.09	75.50	2534.5	0.2677	8.7135
20	2.337	0.0010017	57.84	83.86	2538.2	0.2963	8.6684
22	2.642	0.0010022	51.49	92.23	2541.8	0.3247	8.6241
24	2.982	0.0010026	45.93	100.59	2545.5	0.3530	8.5806
26	3.360	0.0010032	41.03	108.95	2549.1	0.3810	8.5379
28	3.778	0.0010037	36.73	117.31	2552.7	0.4088	8.4959
30	4.241	0.0010043	32.93	125.66	2556.4	0.4365	8.4546
32	4.753	0.0010049	29.57	134.02	2560.0	0.4640	8.4140
34	5.318	0.0010056	26.60	142.38	2563.6	0.4913	8.3740
36	5.940	0.0010063	23.97	150.74	2567.2	0.5184	8.3348
38	6.624	0.0010070	21.63	159.09	2570.8	0.5453	8.2962
40	7.375	0.0010078	19.55	167.45	2574.4	0.5721	8.2583
42	8.198	0.0010086	17.69	175.31	2577.9	0.5987	8.2209
44	9.100	0.0010094	16.04	184.17	2581.5	0.6252	8.1842
46	10.086	0.0010103	14.56	192.53	2585.1	0.6514	8.1481

Table A-1 (continued)

t, °C	Saturation pressure, kPa	Specific volume, m^3/kg		Enthalpy, kJ/kg		Entropy, kJ/kg · K	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
48	11.162	0.0010112	13.23	200.89	2588.6	0.6776	8.1125
50	12.335	0.0010121	12.05	209.26	2592.2	0.7035	8.0776
52	13.613	0.0010131	10.98	217.62	2595.7	0.7293	8.0432
54	15.002	0.0010140	10.02	225.98	2599.2	0.7550	8.0093
56	16.511	0.0010150	9.159	234.35	2602.7	0.7804	7.9759
58	18.147	0.0010161	8.381	242.72	2606.2	0.8058	7.9431
60	19.920	0.0010171	7.679	251.09	2609.7	0.8310	7.9108
62	21.84	0.0010182	7.044	259.46	2613.2	0.8560	7.8790
64	23.91	0.0010193	6.469	267.84	2616.6	0.8809	7.8477
66	26.15	0.0010205	5.948	276.21	2620.1	0.9057	7.8168
68	28.56	0.0010217	5.476	284.59	2623.5	0.9303	7.7864
70	31.16	0.0010228	5.046	292.97	2626.9	0.9548	7.7565
72	33.96	0.0010241	4.646	301.35	2630.3	0.9792	7.7270
74	36.96	0.0010253	4.300	309.74	2633.7	1.0034	7.6979
76	40.19	0.0010266	3.976	318.13	2637.1	1.0275	7.6693
78	43.65	0.0010279	3.680	326.52	2640.4	1.0514	7.6410
80	47.36	0.0010292	3.409	334.92	2643.8	1.0753	7.6132
82	51.33	0.0010305	3.162	343.31	2647.1	1.0990	7.5850
84	55.57	0.0010319	2.935	351.71	2650.4	1.1225	7.5588
86	60.11	0.0010333	2.727	360.12	2653.6	1.1460	7.5321
88	64.95	0.0010347	2.536	368.53	2656.9	1.1693	7.5058
90	70.11	0.0010361	2.361	376.94	2660.1	1.1925	7.4799
92	75.61	0.0010376	2.200	385.36	2663.4	1.2156	7.4543
94	81.46	0.0010391	2.052	393.78	2666.6	1.2386	7.4291
96	87.69	0.0010406	1.915	402.20	2669.7	1.2615	7.4042
98	94.30	0.0010421	1.789	410.63	2672.9	1.2842	7.3796
100	101.33	0.0010437	1.673	419.06	2676.0	1.3069	7.3554
102	108.78	0.0010453	1.566	427.50	2679.1	1.3294	7.3315
104	116.68	0.0010469	1.466	435.95	2682.2	1.3518	7.3078
106	125.04	0.0010485	1.374	444.40	2685.3	1.3742	7.2845
108	133.90	0.0010502	1.289	452.85	2688.3	1.3964	7.2615
110	143.26	0.0010519	1.210	461.32	2691.3	1.4185	7.2388
112	153.16	0.0010536	1.137	469.78	2694.3	1.4405	7.2164
114	163.62	0.0010553	1.069	478.26	2697.2	1.4624	7.1942
116	174.65	0.0010571	1.005	486.74	2700.2	1.4842	7.1723
118	186.28	0.0010588	0.9463	495.23	2703.1	1.5060	7.1507
120	198.54	0.0010606	0.8915	503.72	2706.0	1.5276	7.1293

Source: Abstracted by permission from Ref. 1.

Table A-3 Ammonia: properties of liquid and saturated vapor[3]

		Enthalpy, kJ/kg		Entropy, kJ/kg · K		Specific volume, L/kg	
t, °C	P, kPa	h_f	h_g	s_f	s_g	v_f	v_g
-60	21.99	-69.5330	1373.19	-0.10909	6.6592	1.4010	4685.08
-55	30.29	-47.5062	1382.01	-0.00717	6.5454	1.4126	3474.22
-50	41.03	-25.4342	1390.64	0.09264	6.4382	1.4245	2616.51
-45	54.74	-3.3020	1399.07	0.19049	6.3369	1.4367	1998.91
-40	72.01	18.9024	1407.26	0.28651	6.2410	1.4493	1547.36
-35	93.49	41.1883	1415.20	0.38082	6.1501	1.4623	1212.49
-30	119.90	63.5629	1422.86	0.47351	6.0636	1.4757	960.867
-28	132.02	72.5387	1425.84	0.51015	6.0302	1.4811	878.100
-26	145.11	81.5300	1428.76	0.54655	5.9974	1.4867	803.761
-24	159.22	90.5370	1431.64	0.58272	5.9652	1.4923	736.868
-22	174.41	99.5600	1434.46	0.61865	5.9336	1.4980	676.570
-20	190.74	108.599	1437.23	0.65436	5.9025	1.5037	622.122
-18	208.26	117.656	1439.94	0.68984	5.8720	1.5096	572.875
-16	227.04	126.729	1442.60	0.72511	5.8420	1.5155	528.257
-14	247.14	135.820	1445.20	0.76016	5.8125	1.5215	487.769
-12	268.63	144.929	1447.74	0.79501	5.7835	1.5276	450.971
-10	291.57	154.056	1450.22	0.82965	5.7550	1.5338	417.477
-9	303.60	158.628	1451.44	0.84690	5.7409	1.5369	401.860
-8	316.02	163.204	1452.64	0.86410	5.7269	1.5400	386.944
-7	328.84	167.785	1453.83	0.88125	5.7131	1.5432	372.692
-6	342.07	172.371	1455.00	0.89835	5.6993	1.5464	359.071
-5	355.71	176.962	1456.15	0.91541	5.6856	1.5496	346.046
-4	369.77	181.559	1457.29	0.93242	5.6721	1.5528	333.589
-3	384.26	186.161	1458.42	0.94938	5.6586	1.5561	321.670
-2	399.20	190.768	1459.53	0.96630	5.6453	1.5594	310.263
-1	414.58	195.381	1460.62	0.98317	5.6320	1.5627	299.340
0	430.43	200.000	1461.70	1.00000	5.6189	1.5660	288.880
1	446.74	204.625	1462.76	1.01679	5.6058	1.5694	278.858
2	463.53	209.256	1463.80	1.03354	5.5929	1.5727	269.253
3	480.81	213.892	1464.83	1.05024	5.5800	1.5762	260.046
4	498.59	218.535	1465.84	1.06691	5.5672	1.5796	251.216
5	516.87	223.185	1466.84	1.08353	5.5545	1.5831	242.745
6	535.67	227.841	1467.82	1.10012	5.5419	1.5866	234.618
7	555.00	232.503	1468.78	1.11667	5.5294	1.5901	226.817
8	574.87	237.172	1469.72	1.13317	5.5170	1.5936	219.326
9	595.28	241.848	1470.64	1.14964	5.5046	1.5972	212.132
10	616.25	246.531	1471.57	1.16607	5.4924	1.6008	205.221
11	637.78	251.221	1472.46	1.18246	5.4802	1.6045	198.580
12	659.89	255.918	1473.34	1.19882	5.4681	1.6081	192.196
13	682.59	260.622	1474.20	1.21515	5.4561	1.6118	186.058
14	705.88	265.334	1475.05	1.23144	5.4441	1.6156	180.154
15	729.79	270.053	1475.88	1.24769	5.4322	1.6193	174.475
16	754.31	274.779	1476.69	1.26391	5.4204	1.6231	169.009
17	779.46	279.513	1477.48	1.28010	1.4087	1.6269	163.748
18	805.25	284.255	1478.25	1.29626	5.3971	1.6308	158.683
19	831.69	289.005	1479.01	1.31238	5.3855	1.6347	153.804
20	858.79	293.762	1479.75	1.32847	5.3740	1.6386	149.106

Table A-3 (continued)

		Enthalpy, kJ/kg		Entropy, kJ/kg · K		Specific volume, L/kg	
t, °C	P, kPa	h_f	h_g	s_f	s_g	v_f	v_g
21	886.57	298.527	1480.48	1.34452	5.3626	1.6426	144.578
22	915.03	303.300	1481.18	1.36055	5.3512	1.6466	140.214
23	944.18	308.081	1481.87	1.37654	5.3399	1.6507	136.006
24	974.03	312.870	1482.53	1.39250	5.3286	1.6547	131.950
25	1004.6	317.667	1483.18	1.40843	5.3175	1.6588	128.037
26	1035.9	322.471	1483.81	1.42433	5.3063	1.6630	124.261
27	1068.0	327.284	1484.42	1.44020	5.2953	1.6672	120.619
28	1100.7	332.104	1485.01	1.45604	5.2843	1.6714	117.103
29	1134.3	336.933	1485.59	1.47185	5.2733	1.6757	113.708
30	1168.6	341.769	1486.14	1.48762	5.2624	1.6800	110.430
31	1203.7	346.614	1486.67	1.50337	5.2516	1.6844	107.263
32	1239.6	351.466	1487.18	1.51908	5.2408	1.6888	104.205
33	1276.3	356.326	1487.66	1.53477	5.2300	1.6932	101.248
34	1313.9	361.195	1488.13	1.55042	5.2193	1.6977	98.3913
35	1352.2	366.072	1488.57	1.56605	5.2086	1.7023	95.6290
36	1391.5	370.957	1488.99	1.58165	5.1980	1.7069	92.9579
37	1431.5	375.851	1489.39	1.59722	5.1874	1.7115	90.3743
38	1472.4	380.754	1489.76	1.61276	5.1768	1.7162	87.8748
39	1514.3	385.666	1490.10	1.62828	5.1663	1.7209	85.4561
40	1557.0	390.587	1490.42	1.64377	5.1558	1.7257	83.1150
41	1600.6	395.519	1490.71	1.65924	5.1453	1.7305	80.8484
42	1645.1	400.462	1490.98	1.67470	5.1349	1.7354	78.6536
43	1690.6	405.416	1491.21	1.69013	5.1244	1.7404	76.5276
44	1737.0	410.382	1491.41	1.70554	5.1140	1.7454	74.4678
45	1784.3	415.362	1491.58	1.72095	5.1036	1.7504	72.4716
46	1832.6	420.358	1491.72	1.73635	5.0932	1.7555	70.5365
47	1881.9	425.369	1491.83	1.75174	5.0827	1.7607	68.6602
48	1932.2	430.399	1491.88	1.76714	5.0723	1.7659	66.8403
49	1983.5	435.450	1491.91	1.78255	5.0618	1.7712	65.0746
50	2035.9	440.523	1491.89	1.79798	5.0514	1.7766	63.3608
51	2089.2	445.623	1491.83	1.81343	5.0409	1.7820	61.6971
52	2143.6	450.751	1491.73	1.82891	5.0303	1.7875	60.0813
53	2199.1	455.913	1491.58	1.84445	5.0198	1.7931	58.5114
54	2255.6	461.112	1491.38	1.86004	5.0092	1.7987	56.9855
55	2313.2	466.353	1491.12	1.87571	4.9985	1.8044	55.5019

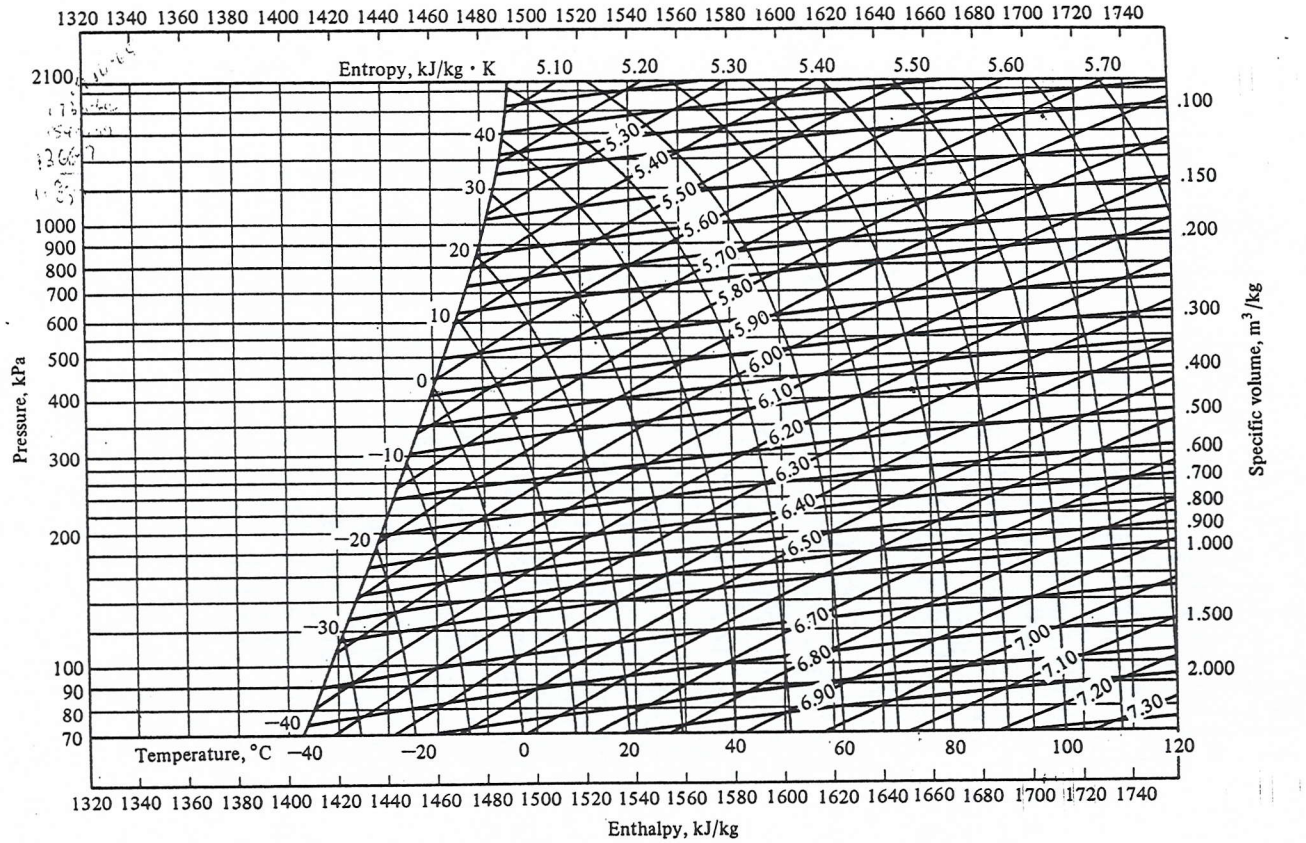


Figure A-1 Pressure-enthalpy diagram of superheated ammonia vapor. *(Prepared for this book by the Technical University of Denmark from Data in Ref. 8.)*

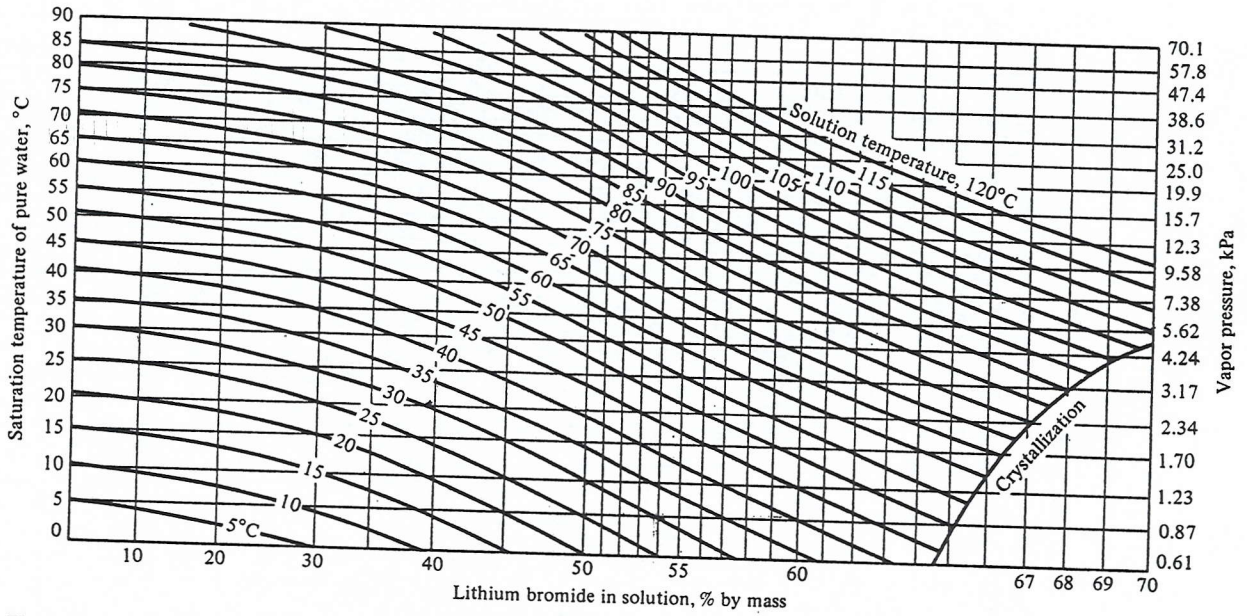


Figure 17-5 Temperature-pressure-concentration diagram of saturated LiBr–water solutions, developed from data in Ref. 1.

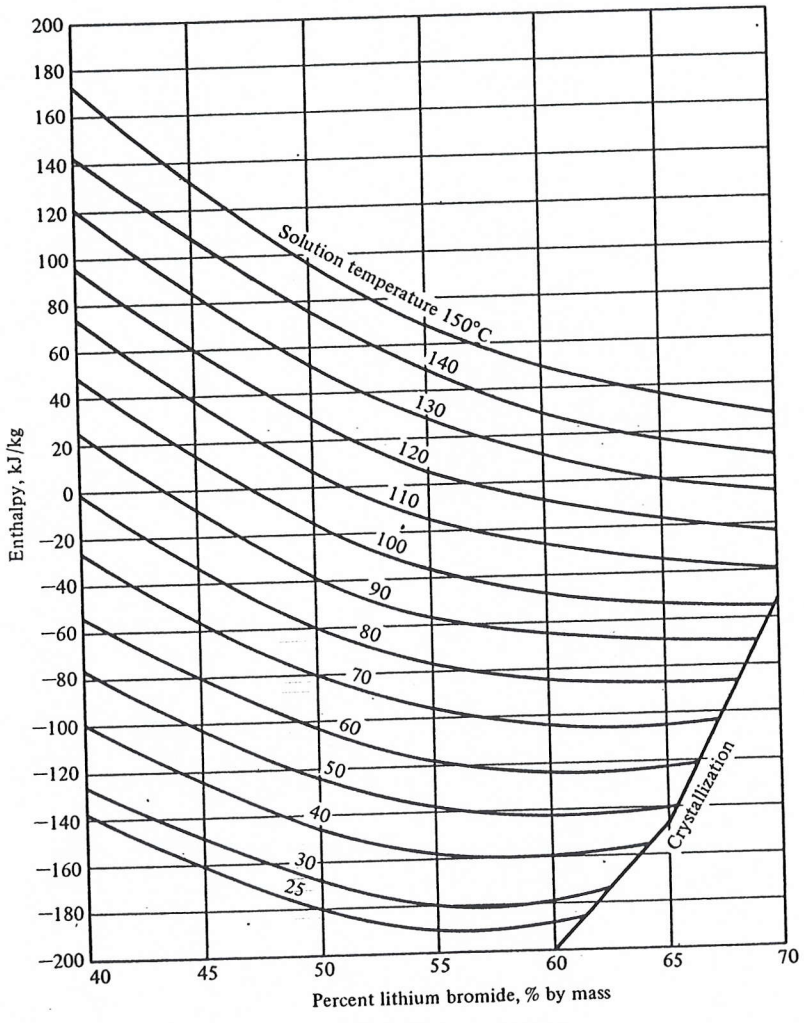
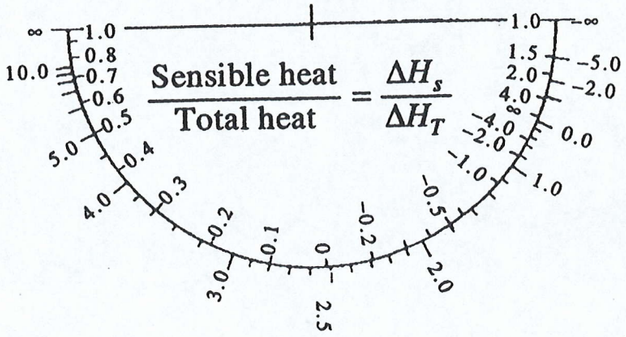


Figure 17-8 Enthalpy of LiBr–water solutions; data from Ref. 1.

ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE SEA LEVEL

BAROMETRIC PRESSURE 101.325 kPa



$$\frac{\text{Sensible heat}}{\text{Total heat}} = \frac{\Delta H_s}{\Delta H_T}$$

$$\frac{\text{Enthalpy}}{\text{Humidity ratio}} = \frac{\Delta h}{\Delta w}$$

FIGURE 12.4 Psychrometry chart for normal temperature.