First Semester Examination
2019/2020 Academic Session

December 2019 / January 2020

EME 431 – Refrigeration & Air Conditioning
[Penyejukan & Penyamanan Udara]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **SIXTEEN** **[16]** printed pages including appendix before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **ENAM BELAS** **[16]** mukasurat bercetak beserta lampiran sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

Answer Questions In **English** OR **Bahasa Malaysia**.
*[Jawab soalan dalam **Bahasa Inggeris** ATAU **Bahasa Malaysia**.]*

Answer to each question must begin from a new page.
[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

Note: Psychrometric Chart, Mass Concentration-Enthalpy Diagram, Properties Tables and Pressure Drop in Ducting Diagram are provided in the Appendix.

Carta Psikrometrik, gambarajah jisim kepekatan-entalpi, jadual-jadual sifat dan gambarajah kejatuhan tekanan di dalam saluran dibekalkan dalam lampiran.

1. **[a] List FIVE (5) applications for each process:**

Senaraikan LIMA (5) applikasi untuk setiap proses:

(i) refrigeration;
penyejukan;

(10 marks/*markah***)**

(ii) air conditioning.
penyaman udara.

(10 marks/*markah***)**

[b] As an engineer, you are assigned to design a freezer for cold storage using vapour compression cycle and refrigerant R410a that operates with condensing temperature of 35°C and evaporator temperature of -30°C. If the mass flow rate of the refrigerant is 0.35 kg/s.

Sebagai seorang jurutera, anda diberi tugas mereka bentuk sebuah penyejuk beku dengan menggunakan kitar pemampatam wap dan bahan penyejuk R410a yang beroperasi dengan suhu condenser 35℃ dan suhu penyejat -30℃. Jika kadar aliran jisim penyejuk ialah 0.35kg/s.

Calculate:
Kirakan:

(i) refrigerating effect.
kesan penyejukan.

(ii) refrigeration capacity.
kapasiti penyejukan.

(iii) power required by compressor.
kuasa yang diperlukan oleh pemampat.

(iv) coefficient of performance (COP) of the system.
pekali prestasi sistem.

(80 marks/*markah***)**

2. [a] Explain the phenomenon of passive daytime radiative cooling.

Terangkan fenomena penyejukan menyinar pasif siang hari.

(20 marks/*markah***)**

[b] An ammonia-aqua vapour absorption freezer is used to store fish from ocean. The temperature of the generator, condenser, evaporator and absorber is 100°C, 35°C, -10°C and 30°C, respectively. The power of pump is 50 kW and the rated mass flow rate is 0.75 kg/s.

Sebuah penyejuk beku sistem penyerapan wap ammonia-akua digunakan untuk menyimpan ikan dari laut. Suhu penjana, kondenser, penyejat dan penyerap masing-masing ialah 100°C, 35°C, -10°C dan 30°C. Kuasa pam ialah 50 kW dan kadar aliran jisim dicatat ialah 0.75 kg/s.

Calculate:
Kirakan:

(i) The pressure at the condenser and evaporator.
Tekanan minimum di condenser dan penyejat.
(10 marks/*markah***)**

(ii) The refrigerant concentration at the generator and absorber.
Kepekatan bahan penyejuk di penjana dan penyerap.
(10 marks/*markah***)**

(iii) The mass flow rate entering condenser and absorber,
Kadar aliran jisim yang masuk ke condenser dan penyejat,
(20 marks/*markah***)**

(iv) Refrigeration capacity.
Kapasiti penyejukan. **(10 marks/***markah***)**

(v) Power required by generator.
Kuasa yang perlu oleh penjana. **(20 marks/***markah***)**

(vi) The coefficient of performance (COP) of the system without pump.
Pekali prestasi sistem tanpa pam.
(10 marks/*markah***)**

3. [a] As an engineer, you are given the following requirements by a client to design a cooling system for:

Sebagai seorang jurutera, anda diberi syarat-syarat berikut oleh pelanggan untuk mereka bentuk sebuah sistem penyejuk untuk:

- **large shaded semi-outdoor area with the size of football field;**
  kawasan separuh luaran terlindung yang besar bersaiz padang bola sepak:
- **able to reduce temperature to below 30°C (when the outdoor temperature is 35°C and relative humidity of 50-60%); and.**
  mampu mengurangkan suhu ke bawah 30℃ (semasa suhu luaran ialah 35℃ dan kelembapan relative ialah 50-60%), dan.
- **low setup cost and energy consumption (compared to air conditioning system).**
  kos persediaan rendah dan kegunaan tenaga rendah (berbanding dengan sistem penghawa dingin).

(i) With the aid of a diagram, explain the operation of your cooling system.
Dengan bantuan gambar rajah, terangkan operasi sistem penyejuk anda.

(15 marks/*markah***)**

(ii) What is the achievable minimum cooling temperature?
Apakah suhu penyejukan minima yang boleh dicapai?

(10 marks/*markah***)**

(iii) If the efficiency of the designed machine is 80%, what is the temperature and relative humidity of the output air?
Jika kecekapan mesin yang direka ialah 80%, apakah suhu dan kelembapan relative udara di keluaran?

(25 marks/*markah***)**

[b] With the aid of diagrams describe the different components functions of a typical central air conditioning system in Malaysia.

Dengan bantuan gambarajah, menggambarkan fungsi komponen yang berbeza dari sistem penghawa dingin pusat khas di Malaysia.

(30 marks/*markah***)**

[c] Define thermal comfort and briefly discuss <u>FOUR (4)</u> factors that engineers can control it.

Takrifkan keselesaan termal dan bincangkan dengan ringkas <u>EMPAT (4)</u> faktor-faktor di mana jurutera-jurutera boleh mengawalnya.

(20 marks/*markah***)**

4. [a] An air conditioning plant is designed to maintain a lecture room at temperature 26ºC and relative humidity 40%. The outside air is at a temperature of 30ºC and relative humidity of 80%. The cooling load of the room is 15 kW sensible heat gain and 5 kW latent heat gain. The fresh air supply is 50% by mass. Temperature of the cold air to the room is 16°C. Assuming that the cooling coil efficiency is 80% and neglect the effect of the fan.

Sebuah loji penyamanan udara direkabentuk untuk mengekalkan sebuah bilik kuliah pada suhu 26°C dan kelembapan relatif 40%. Suhu udara luar adalah 30°C dan kelembapan relatif 80%. Beban penyejukan bilik adalah 15 kW haba deria dan 5kW haba tambah pelakuran. Pembekalan udara segar adalah 50% jisim udara. Suhu udara sejuk masuk adalah 16°C. Andaikan kecekapan gelung penyejukan adalah 80% dan abaikan kesan kipas.

Using a psychrometric chart, calculate:
Dengan menggunakan carta psikrometri, kirakan:

(i) Actual mass flow rate of the supply air to the room.
Kadar aliran jisim sebenar udara bekalan ke bilik.

(20 marks/*markah***)**

(ii) Refrigeration capacity (cooling coil load in TR).
Kapasiti penyejukan (beban gegelung pendingin dalam TR).

(20 marks/*markah***)**

(iii) Heating capacity (kW) of the reheater.
Kapasiti haba penghaba semula (kW). **(10 marks**/*markah***)**

(iv) Compare the difference between the room load and cooling coil load values (in kW) and evaluate <u>ONE (1)</u> method to reduce this difference.

Bandingkan perbezaan antara beban bilik dan nilai beban gegelung penyejukan (dalam kW) dan nilaikan <u>SATU (1)</u> kaedah untuk mengurangkan perbezaan ini.

(20 marks/*markah***)**

[b] Name <u>FOUR (4)</u> different air ducts configurations in the all air systems. With the aid of schematic drawing, briefly discuss <u>ONE (1)</u> of it.

Namakan <u>EMPAT (4)</u> konfigurasi saluran udara yang berlainan dalam semua sistem udara. Dengan bantuan lukisan skematik, bincangkan secara ringkas <u>SATU (1)</u> daripadanya.

(30 marks/*markah***)**

5. [a] A supermarket of 40m x 40m floor area and 5 m height is designed to accommodate maximum capacity of 200 people. The main entrance is a glass door of 4m x 3m facing North. Overall heat transfer coefficient for walls U= 0.64W/m^{2}K, roof U= 0.52W/m^{2}K and glass door 4 W/m^{2}K. Make all the necessary assumptions and consider the following values at the peak load.

Sebuah pasar raya 40m x 40m kawasan lantai dan ketinggian 5 m direka untuk menampung kapasiti maksimum 200 orang. Pintu masuk utama ialah pintu kaca 4m x 3m yang menghadap ke utara. Pakej pemindahan haba secara keseluruhan untuk dinding U = 0.64W / m^{2}K, bumbung U = 0.52W / m^{2}K dan pintu kaca 4 W / m^{2}K. Andaikan yang perlu dan pertimbangkan nilai berikut pada beban puncak

- **Maximum (CLTD)c for the roof is 26 and the walls/glass door is 8.**
  Maksimum (CLTD)c untuk bumbung ialah 26 dan untuk dinding / pintu kaca adalah 8.

- **Maximum SHGF= 315 W/m^2 for the door glass with no shading.**
  Maksimum SHGF = 315W/m^2 untuk pintu kaca tanpa teduhan.

- **Equipment: fridges/freezers, display TVs, etc.**
  Peralatan pejabat: peti sejuk / freezer, memaparkan TV , dsb.

- **Lighting requirement 45 W/ m^2 of floor area (Flourescent lamps).**
  Keperluan pencahayaan 45 W/m^2 ruang lantai (Pendarfluor lampu).

Calculate the peak heat gain in supermarket.
Kira puncak kenaikan haba di pasar raya.

(70 marks/*markah*)

[b] For the supermarket in question 5[a], if the air supply through the main duct is 10 m^3/s at 16°C and 50% relative humidity and air velocity of 16 m/s.

Untuk pasar raya dalam soalan 5[a], jika bekalan udara melalui saluran utamanya adalah 10 m^3/s pada suhu 16°C dan 50% Kelembapan Bandingan dan halaju udara ialah 16 m/s.

(i) Calculate the reference value of friction losses in Pa/m in the main duct.
Kirakan nilai rujukan kehilangan geseran di Pa/m dalam saluran utamanya

.**(10 marks**/*markah***)**

(ii) If air is distributed to the supermarket through ten secondary ducts, use the Equal Friction Method to calculate air velocity (m/s) and diameter (m) for each duct.

Sekiranya udara diedarkan ke pasar raya melalui sepuluh saluran sekunder, gunakan Kaedah Geseran Bersama untuk mengira halaju udara (m/s) dan diameter (m) untuk setiap saluran.

(20 marks/*markah***)**

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Appendix A
Lampiran A

R410a Saturation Table

Freon™ 410A Refrigerant

Table 1. Freon™ 410A Saturation Properties—Temperature Table (continued)

Temp [°C]	Pressure [kPa]		Volume [m³/kg]		Density [kg/m³]		Enthalpy [kJ/kg]			Entropy [kJ/(kg)(K)]		Temp [°C]
	Liquid p_f	Vapor p_g	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid H_f	Latent H_{fg}	Vapor H_g	Liquid S_f	Vapor S_g	
−40	176.2	175.8	0.0008	0.1419	1325.7	7.045	141.1	265.9	407.1	0.7666	1.9072	−40
−39	184.3	183.8	0.0008	0.1360	1322.3	7.352	142.5	265.0	407.6	0.7727	1.9045	−39
−38	192.7	192.2	0.0008	0.1304	1318.9	7.669	144.0	264.1	408.0	0.7787	1.9017	−38
−37	201.3	200.8	0.0008	0.1251	1315.5	7.996	145.4	263.1	408.5	0.7847	1.8990	−37
−36	210.3	209.8	0.0008	0.1200	1312.1	8.335	146.8	262.2	408.9	0.7908	1.8963	−36
−35	219.6	219.0	0.0008	0.1151	1308.6	8.685	148.2	261.2	409.4	0.7968	1.8936	−35
−34	229.2	228.6	0.0008	0.1105	1305.2	9.046	149.6	260.2	409.8	0.8028	1.8910	−34
−33	239.1	238.4	0.0008	0.1062	1301.7	9.419	151.0	259.3	410.3	0.8088	1.8884	−33
−32	249.3	248.6	0.0008	0.1020	1298.2	9.805	152.4	258.3	410.7	0.8148	1.8858	−32
−31	259.9	259.2	0.0008	0.0980	1294.7	10.202	153.9	257.3	411.2	0.8207	1.8832	−31
−30	270.8	270.1	0.0008	0.0942	1291.2	10.613	155.3	256.3	411.6	0.8267	1.8807	−30
−29	282.1	281.3	0.0008	0.0906	1287.6	11.036	156.7	255.3	412.0	0.8326	1.8782	−29
−28	293.7	292.9	0.0008	0.0872	1284.1	11.473	158.2	254.3	412.5	0.8385	1.8757	−28
−27	305.7	304.9	0.0008	0.0839	1280.5	11.923	159.6	253.3	412.9	0.8445	1.8733	−27
−26	318.1	317.2	0.0008	0.0807	1276.9	12.388	161.1	252.2	413.3	0.8504	1.8709	−26
−25	330.9	329.9	0.0008	0.0777	1273.3	12.866	162.5	251.2	413.7	0.8562	1.8685	−25
−24	344.0	343.0	0.0008	0.0749	1269.7	13.360	164.0	250.1	414.1	0.8621	1.8661	−24
−23	357.6	356.6	0.0008	0.0721	1266.0	13.868	165.4	249.1	414.5	0.8680	1.8638	−23
−22	371.5	370.5	0.0008	0.0695	1262.3	14.391	166.9	248.0	414.9	0.8738	1.8614	−22
−21	385.9	384.8	0.0008	0.0670	1258.7	14.931	168.4	247.0	415.3	0.8797	1.8591	−21
−20	400.7	399.5	0.0008	0.0646	1255.0	15.486	169.8	245.9	415.7	0.8855	1.8569	−20
−19	415.9	414.7	0.0008	0.0623	1251.3	16.058	171.3	244.8	416.1	0.8913	1.8546	−19
−18	431.6	430.3	0.0008	0.0601	1247.5	16.647	172.8	243.7	416.5	0.8971	1.8523	−18
−17	447.7	446.4	0.0008	0.0580	1243.8	17.253	174.3	242.6	416.9	0.9029	1.8501	−17
−16	464.3	462.9	0.0008	0.0559	1240.0	17.877	175.7	241.5	417.2	0.9087	1.8479	−16
−15	481.3	479.9	0.0008	0.0540	1236.2	18.519	177.2	240.4	417.6	0.9145	1.8457	−15
−14	498.9	497.4	0.0008	0.0521	1232.4	19.179	178.7	239.3	418.0	0.9203	1.8436	−14
−13	516.9	515.3	0.0008	0.0504	1228.6	19.859	180.2	238.1	418.3	0.9260	1.8414	−13
−12	535.4	533.7	0.0008	0.0486	1224.7	20.558	181.7	237.0	418.7	0.9318	1.8393	−12
−11	554.4	552.7	0.0008	0.0470	1220.8	21.276	183.2	235.8	419.1	0.9375	1.8372	−11
−10	573.9	572.1	0.0008	0.0454	1216.9	22.016	184.7	234.7	419.4	0.9432	1.8351	−10
−9	593.9	592.1	0.0008	0.0439	1213.0	22.776	186.2	233.5	419.7	0.9489	1.8330	−9
−8	614.4	612.6	0.0008	0.0425	1209.1	23.558	187.7	232.3	420.1	0.9547	1.8309	−8
−7	635.5	633.6	0.0008	0.0411	1205.1	24.361	189.3	231.1	420.4	0.9604	1.8288	−7
−6	657.2	655.1	0.0008	0.0397	1201.1	25.187	190.8	229.9	420.7	0.9660	1.8268	−6
−5	679.3	677.3	0.0008	0.0384	1197.1	26.036	192.3	228.7	421.0	0.9717	1.8247	−5
−4	702.1	699.9	0.0008	0.0372	1193.1	26.909	193.8	227.5	421.4	0.9774	1.8227	−4
−3	725.4	723.2	0.0008	0.0360	1189.0	27.806	195.4	226.3	421.7	0.9830	1.8207	−3
−2	749.3	747.0	0.0008	0.0348	1184.9	28.728	196.9	225.1	422.0	0.9887	1.8187	−2
−1	773.9	771.4	0.0009	0.0337	1180.8	29.675	198.5	223.8	422.3	0.9943	1.8167	−1
0	799.0	796.5	0.0009	0.0326	1176.7	30.649	200.0	222.5	422.5	1.0000	1.8147	0
1	824.7	822.1	0.0009	0.0316	1172.5	31.649	201.6	221.3	422.8	1.0056	1.8128	1
2	851.0	848.4	0.0009	0.0306	1168.3	32.676	203.1	220.0	423.1	1.0112	1.8108	2
3	878.0	875.3	0.0009	0.0297	1164.1	33.732	204.7	218.7	423.4	1.0168	1.8088	3
4	905.6	902.8	0.0009	0.0287	1159.8	34.817	206.2	217.4	423.6	1.0225	1.8069	4
5	933.9	931.0	0.0009	0.0278	1155.5	35.931	207.8	216.1	423.9	1.0281	1.8049	5
6	962.9	959.8	0.0009	0.0270	1151.2	37.076	209.4	214.8	424.1	1.0337	1.8030	6
7	992.5	989.3	0.0009	0.0261	1146.9	38.252	211.0	213.4	424.4	1.0392	1.8011	7
8	1022.8	1019.5	0.0009	0.0253	1142.5	39.461	212.6	212.1	424.6	1.0448	1.7991	8
9	1053.8	1050.4	0.0009	0.0246	1138.1	40.702	214.1	210.7	424.9	1.0504	1.7972	9
10	1085.5	1082.0	0.0009	0.0238	1133.7	41.977	215.7	209.3	425.1	1.0560	1.7953	10
11	1117.9	1114.3	0.0009	0.0231	1129.2	43.288	217.3	207.9	425.3	1.0616	1.7934	11
12	1151.0	1147.3	0.0009	0.0224	1124.7	44.634	219.0	206.5	425.5	1.0671	1.7914	12
13	1184.9	1181.1	0.0009	0.0217	1120.1	46.017	220.6	205.1	425.7	1.0727	1.7895	13
14	1219.5	1215.6	0.0009	0.0211	1115.6	47.437	222.2	203.7	425.9	1.0783	1.7876	14
15	1254.9	1250.8	0.0009	0.0205	1110.9	48.897	223.8	202.2	426.1	1.0838	1.7857	15
16	1291.0	1286.9	0.0009	0.0198	1106.3	50.398	225.4	200.8	426.2	1.0894	1.7838	16
17	1328.0	1323.7	0.0009	0.0193	1101.6	51.939	227.1	199.3	426.4	1.0949	1.7818	17
18	1365.7	1361.3	0.0009	0.0187	1096.9	53.523	228.7	197.8	426.5	1.1005	1.7799	18
19	1404.2	1399.6	0.0009	0.0181	1092.1	55.152	230.4	196.3	426.7	1.1060	1.7780	19

R410a Saturation Table (cont.)

Freon™ 410A Refrigerant

Table 1. Freon™ 410A Saturation Properties—Temperature Table (continued)

Temp [°C]	Pressure [kPa]		Volume [m³/kg]		Density [kg/m³]		Enthalpy [kJ/kg]			Entropy [kJ/(kg)(K)]		Temp [°C]
	Liquid p_f	Vapor p_g	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid H_f	Latent H_{fg}	Vapor H_g	Liquid S_f	Vapor S_g	
20	1443.6	1438.8	0.0009	0.0176	1087.2	56.825	232.0	194.8	426.8	1.1116	1.7760	20
21	1483.7	1478.9	0.0009	0.0171	1082.4	58.545	233.7	193.2	426.9	1.1172	1.7741	21
22	1524.7	1519.7	0.0009	0.0166	1077.5	60.314	235.4	191.7	427.1	1.1227	1.7721	22
23	1566.6	1561.4	0.0009	0.0161	1072.5	62.132	237.1	190.1	427.2	1.1283	1.7702	23
24	1609.3	1604.0	0.0009	0.0156	1067.5	64.001	238.7	188.5	427.3	1.1338	1.7682	24
25	1652.9	1647.4	0.0009	0.0152	1062.4	65.924	240.4	186.9	427.3	1.1394	1.7662	25
26	1697.3	1691.7	0.0010	0.0147	1057.3	67.901	242.1	185.3	427.4	1.1450	1.7643	26
27	1742.7	1736.9	0.0010	0.0143	1052.1	69.935	243.9	183.6	427.5	1.1506	1.7623	27
28	1788.9	1783.0	0.0010	0.0139	1046.9	72.028	245.6	181.9	427.5	1.1562	1.7603	28
29	1836.1	1830.0	0.0010	0.0135	1041.6	74.181	247.3	180.2	427.5	1.1618	1.7582	29
30	1884.2	1877.9	0.0010	0.0131	1036.3	76.398	249.1	178.5	427.6	1.1674	1.7562	30
31	1933.3	1926.8	0.0010	0.0127	1030.9	78.679	250.8	176.8	427.6	1.1730	1.7541	31
32	1983.3	1976.6	0.0010	0.0123	1025.4	81.028	252.6	175.0	427.6	1.1786	1.7521	32
33	2034.3	2027.4	0.0010	0.0120	1019.9	83.447	254.3	173.2	427.5	1.1843	1.7500	33
34	2086.3	2079.2	0.0010	0.0116	1014.2	85.939	256.1	171.4	427.5	1.1899	1.7479	34
35	2139.2	2132.0	0.0010	0.0113	1008.6	88.506	257.9	169.5	427.5	1.1956	1.7458	35
36	2193.2	2185.7	0.0010	0.0110	1002.8	91.151	259.7	167.7	427.4	1.2013	1.7436	36
37	2248.1	2240.5	0.0010	0.0107	996.9	93.879	261.5	165.8	427.3	1.2070	1.7414	37
38	2304.2	2296.3	0.0010	0.0103	991.0	96.691	263.4	163.8	427.2	1.2127	1.7392	38
39	2361.2	2353.2	0.0010	0.0100	985.0	99.592	265.2	161.9	427.1	1.2185	1.7370	39
40	2419.3	2411.1	0.0010	0.0098	978.9	102.585	267.1	159.9	427.0	1.2243	1.7348	40
41	2478.5	2470.1	0.0010	0.0095	972.7	105.674	269.0	157.8	426.8	1.2301	1.7325	41
42	2538.8	2530.2	0.0010	0.0092	966.4	108.864	270.9	155.8	426.7	1.2359	1.7302	42
43	2600.1	2591.3	0.0010	0.0089	960.0	112.159	272.8	153.7	426.5	1.2418	1.7278	43
44	2662.6	2653.6	0.0011	0.0087	953.4	115.564	274.8	151.5	426.3	1.2477	1.7255	44
45	2726.1	2717.0	0.0011	0.0084	946.8	119.085	276.7	149.3	426.0	1.2537	1.7230	45
46	2790.9	2781.6	0.0011	0.0082	940.0	122.727	278.7	147.1	425.8	1.2597	1.7206	46
47	2856.7	2847.3	0.0011	0.0079	933.1	126.497	280.7	144.8	425.5	1.2658	1.7181	47
48	2923.8	2914.2	0.0011	0.0077	926.0	130.402	282.7	142.5	425.2	1.2719	1.7156	48
49	2991.9	2982.2	0.0011	0.0074	918.8	134.448	284.8	140.1	424.9	1.2781	1.7130	49
50	3061.3	3051.5	0.0011	0.0072	911.4	138.645	286.9	137.7	424.6	1.2843	1.7104	50
51	3131.9	3122.0	0.0011	0.0070	903.9	143.001	289.0	135.2	424.2	1.2906	1.7077	51
52	3203.7	3193.7	0.0011	0.0068	896.1	147.527	291.2	132.6	423.8	1.2971	1.7050	52
53	3276.7	3266.6	0.0011	0.0066	888.2	152.235	293.4	130.0	423.4	1.3036	1.7022	53
54	3351.0	3340.9	0.0011	0.0064	880.0	157.139	295.6	127.3	423.0	1.3102	1.6994	54
55	3426.5	3416.3	0.0012	0.0062	871.5	162.252	297.9	124.6	422.5	1.3169	1.6965	55
56	3503.3	3493.1	0.0012	0.0060	862.8	167.594	300.3	121.7	422.0	1.3238	1.6935	56
57	3581.3	3571.2	0.0012	0.0058	853.8	173.187	302.7	118.7	421.4	1.3308	1.6904	57
58	3660.7	3650.7	0.0012	0.0056	844.5	179.056	305.1	115.7	420.8	1.3380	1.6873	58
59	3741.3	3731.5	0.0012	0.0054	834.8	185.232	307.7	112.5	420.2	1.3453	1.6841	59
60	3823.3	3813.6	0.0012	0.0052	824.7	191.757	310.3	109.2	419.5	1.3529	1.6808	60
61	3906.6	3897.1	0.0012	0.0050	814.1	198.680	313.0	105.8	418.8	1.3608	1.6773	61
62	3991.2	3982.0	0.0013	0.0049	802.9	206.069	315.9	102.2	418.1	1.3689	1.6738	62
63	4077.2	4068.4	0.0013	0.0047	791.1	214.014	318.8	98.4	417.2	1.3774	1.6700	63
64	4164.5	4156.1	0.0013	0.0045	778.5	222.641	322.0	94.3	416.3	1.3863	1.6661	64
65	4253.2	4245.4	0.0013	0.0043	765.0	232.131	325.3	90.0	415.3	1.3958	1.6620	65
66	4343.3	4336.1	0.0013	0.0041	750.3	242.755	328.8	85.3	414.2	1.4059	1.6575	66
67	4434.7	4428.2	0.0014	0.0039	734.2	254.940	332.7	80.3	412.9	1.4168	1.6527	67
68	4527.6	4521.9	0.0014	0.0037	716.0	269.366	336.9	74.6	411.5	1.4289	1.6476	68
69	4621.8	4617.2	0.0014	0.0035	694.9	287.059	341.7	68.4	410.1	1.4425	1.6424	69
70	4717.5	4713.9	0.0015	0.0032	669.1	308.947	347.3	61.6	408.9	1.4586	1.6380	70

Appendix B
Lampiran B

R410a Superheated Table

Freon™ 410A Refrigerant

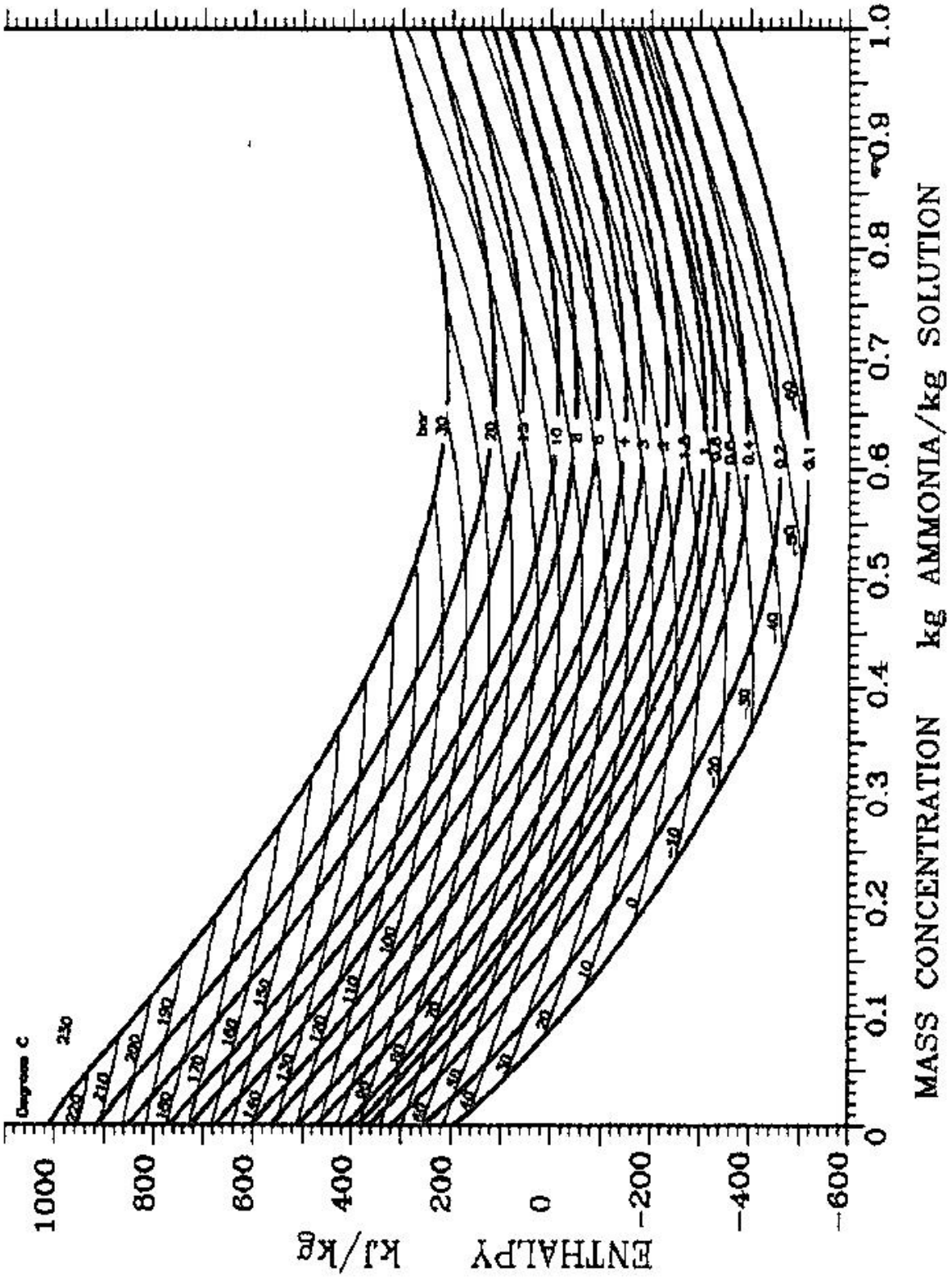
Table 2. Freon™ 410A Superheated Vapor—Constant Pressure Table (continued)

V = Volume in m^3/kg H = Enthalpy in kJ/kg S = Entropy in kJ/(kg)(K) Saturation Properties in Light Blue

Absolute Pressure [kPa]													
Temp [°C]	1900.0			2000.0			2200.0			2400.0			Temp [°C]
	30.45 °C			32.46 °C			36.26 °C			39.81 °C			
	V	H	S	V	H	S	V	H	S	V	H	S	
	0.0129	427.6	1.7553	0.0122	427.6	1.7511	0.0109	427.4	1.7430	0.0098	427.0	1.7352	
35	0.0136	434.4	1.7776	0.0125	431.5	1.7641							35
40	0.0142	441.4	1.8003	0.0132	438.9	1.7879	0.0114	433.5	1.7627	0.0098	427.3	1.7363	40
45	0.0148	448.1	1.8214	0.0138	445.9	1.8099	0.0120	441.1	1.7868	0.0105	435.8	1.7632	45
50	0.0154	454.5	1.8414	0.0143	452.5	1.8305	0.0126	448.2	1.8090	0.0110	443.6	1.7874	50
55	0.0159	460.7	1.8603	0.0149	458.8	1.8500	0.0131	455.0	1.8297	0.0116	450.8	1.8096	55
60	0.0164	466.7	1.8785	0.0154	465.0	1.8686	0.0136	461.4	1.8493	0.0120	457.7	1.8305	60
65	0.0169	472.5	1.8960	0.0158	471.0	1.8865	0.0140	467.7	1.8680	0.0125	464.3	1.8501	65
70	0.0174	478.3	1.9128	0.0163	476.8	1.9037	0.0145	473.8	1.8859	0.0129	470.7	1.8688	70
75	0.0178	484.0	1.9292	0.0167	482.6	1.9203	0.0149	479.8	1.9032	0.0134	476.9	1.8867	75
80	0.0183	489.5	1.9451	0.0172	488.3	1.9365	0.0153	485.6	1.9199	0.0137	482.9	1.9040	80
85	0.0187	495.1	1.9607	0.0176	493.9	1.9522	0.0157	491.4	1.9360	0.0141	488.8	1.9206	85
90	0.0191	500.5	1.9758	0.0180	499.4	1.9676	0.0161	497.1	1.9518	0.0145	494.7	1.9368	90
95	0.0195	506.0	1.9907	0.0184	504.9	1.9826	0.0165	502.7	1.9671	0.0149	500.4	1.9525	95
100	0.0199	511.3	2.0052	0.0188	510.3	1.9973	0.0169	508.2	1.9821	0.0152	506.1	1.9679	100
105	0.0203	516.7	2.0195	0.0192	515.7	2.0117	0.0172	513.8	1.9968	0.0156	511.7	1.9828	105
110	0.0207	522.1	2.0335	0.0196	521.1	2.0259	0.0176	519.2	2.0112	0.0159	517.3	1.9975	110
115	0.0211	527.4	2.0474	0.0199	526.5	2.0398	0.0179	524.7	2.0254	0.0162	522.9	2.0119	115
120	0.0215	532.7	2.0610	0.0203	531.9	2.0535	0.0183	530.1	2.0393	0.0166	528.4	2.0260	120
125	0.0219	538.0	2.0744	0.0207	537.2	2.0670	0.0186	535.6	2.0530	0.0169	533.9	2.0399	125
130	0.0223	543.3	2.0877	0.0210	542.6	2.0804	0.0189	541.0	2.0665	0.0172	539.4	2.0536	130
135	0.0226	548.7	2.1008	0.0214	547.9	2.0935	0.0193	546.4	2.0799	0.0175	544.8	2.0671	135
140	0.0230	554.0	2.1137	0.0218	553.2	2.1066	0.0196	551.8	2.0930	0.0178	550.3	2.0804	140
145	0.0234	559.3	2.1265	0.0221	558.6	2.1194	0.0199	557.2	2.1060	0.0181	555.7	2.0935	145
150	0.0237	564.6	2.1392	0.0225	563.9	2.1321	0.0202	562.6	2.1188	0.0184	561.2	2.1065	150
155	0.0241	570.0	2.1517	0.0228	569.3	2.1447	0.0206	568.0	2.1315	0.0187	566.6	2.1193	155
160	0.0244	575.3	2.1642	0.0231	574.7	2.1572	0.0209	573.4	2.1441	0.0190	572.1	2.1319	160
165	0.0248	580.7	2.1765	0.0235	580.1	2.1696	0.0212	578.8	2.1566	0.0193	577.6	2.1445	165
170	0.0251	586.0	2.1887	0.0238	585.5	2.1818	0.0215	584.2	2.1689	0.0196	583.0	2.1569	170
175	0.0255	591.4	2.2008	0.0242	590.9	2.1939	0.0218	589.7	2.1811	0.0199	588.5	2.1692	175
180	0.0258	596.9	2.2128	0.0245	596.3	2.2060	0.0221	595.2	2.1932	0.0202	594.0	2.1814	180
185	0.0262	602.3	2.2247	0.0248	601.7	2.2179	0.0224	600.6	2.2052	0.0205	599.5	2.1935	185
190							0.0227	606.1	2.2171	0.0207	605.0	2.2054	190

Appendix C
Lampiran C

NH3-Aqua Mass Concentration-Enthalpy Diagram



Appendix D
Lampiran D

NH3 Properties Table

TABLE A-13

Properties of Saturated Ammonia (Liquid–Vapor): Temperature Table

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

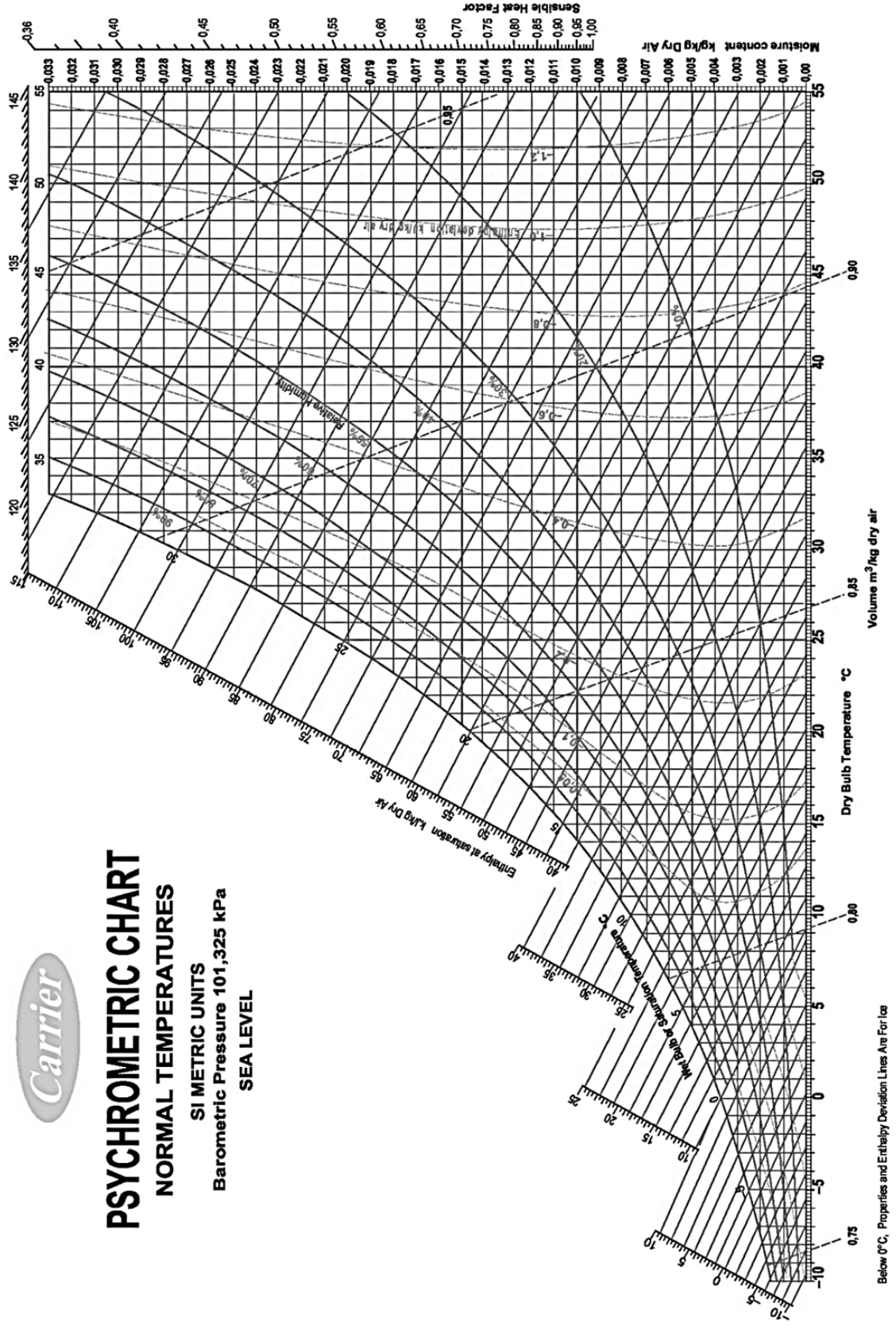
Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Temp. °C
−8	3.1532	1.5400	0.3874	142.60	1310.78	143.09	1289.86	1432.95	0.5734	5.4380	−8
−6	3.4134	1.5464	0.3595	151.74	1312.57	152.26	1283.02	1435.28	0.6077	5.4103	−6
−4	3.6901	1.5528	0.3340	160.88	1314.32	161.46	1276.10	1437.56	0.6418	5.3831	−4
−2	3.9842	1.5594	0.3106	170.07	1316.04	170.69	1269.08	1439.78	0.6759	5.3562	−2
0	4.2962	1.5660	0.2892	179.29	1317.71	179.96	1261.97	1441.94	0.7097	5.3298	0
2	4.6270	1.5727	0.2695	188.53	1319.34	189.26	1254.77	1444.03	0.7435	5.3038	2
4	4.9773	1.5796	0.2514	197.80	1320.92	198.59	1247.48	1446.07	0.7770	5.2781	4
6	5.3479	1.5866	0.2348	207.10	1322.47	207.95	1240.09	1448.04	0.8105	5.2529	6
8	5.7395	1.5936	0.2195	216.42	1323.96	217.34	1232.61	1449.94	0.8438	5.2279	8
10	6.1529	1.6008	0.2054	225.77	1325.42	226.75	1225.03	1451.78	0.8769	5.2033	10
12	6.5890	1.6081	0.1923	235.14	1326.82	236.20	1217.35	1453.55	0.9099	5.1791	12
16	7.5324	1.6231	0.1691	253.95	1329.48	255.18	1201.70	1456.87	0.9755	5.1314	16
20	8.5762	1.6386	0.1492	272.86	1331.94	274.26	1185.64	1459.90	1.0404	5.0849	20
24	9.7274	1.6547	0.1320	291.84	1334.19	293.45	1169.16	1462.61	1.1048	5.0394	24
28	10.993	1.6714	0.1172	310.92	1336.20	312.75	1152.24	1465.00	1.1686	4.9948	28
32	12.380	1.6887	0.1043	330.07	1337.97	332.17	1134.87	1467.03	1.2319	4.9509	32
36	13.896	1.7068	0.0930	349.32	1339.47	351.69	1117.00	1468.70	1.2946	4.9078	36
40	15.549	1.7256	0.0831	368.67	1340.70	371.35	1098.62	1469.97	1.3569	4.8652	40
45	17.819	1.7503	0.0725	393.01	1341.81	396.13	1074.84	1470.96	1.4341	4.8125	45
50	20.331	1.7765	0.0634	417.56	1342.42	421.17	1050.09	1471.26	1.5109	4.7604	50

NH3 Properties Table (cont.)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 12.0 bar = 1.20 MPa (T_{sat} = 30.94°C)				p = 14.0 bar = 1.40 MPa (T_{sat} = 36.26°C)			
Sat.	0.10751	1337.52	1466.53	4.9625	0.09231	1339.56	1468.79	4.9050
40	0.11287	1359.73	1495.18	5.0553	0.09432	1349.29	1481.33	4.9453
60	0.12378	1404.54	1553.07	5.2347	0.10423	1396.97	1542.89	5.1360
80	0.13387	1445.91	1606.56	5.3906	0.11324	1440.06	1598.59	5.2984
100	0.14347	1485.55	1657.71	5.5315	0.12172	1480.79	1651.20	5.4433
120	0.15275	1524.41	1707.71	5.6620	0.12986	1520.41	1702.21	5.5765
140	0.16181	1563.09	1757.26	5.7850	0.13777	1559.63	1752.52	5.7013
160	0.17072	1601.95	1806.81	5.9021	0.14552	1598.92	1802.65	5.8198
180	0.17950	1641.23	1856.63	6.0145	0.15315	1638.53	1852.94	5.9333
200	0.18819	1681.05	1906.87	6.1230	0.16068	1678.64	1903.59	6.0427
220	0.19680	1721.50	1957.66	6.2282	0.16813	1719.35	1954.73	6.1485
240	0.20534	1762.63	2009.04	6.3303	0.17551	1760.72	2006.43	6.2513
260	0.21382	1804.48	2061.06	6.4297	0.18283	1802.78	2058.75	6.3513
280	0.22225	1847.04	2113.74	6.5267	0.19010	1845.55	2111.69	6.4488
	p = 16.0 bar = 1.60 MPa (T_{sat} = 41.03°C)				p = 18.0 bar = 1.80 MPa (T_{sat} = 45.38°C)			
Sat.	0.08079	1340.97	1470.23	4.8542	0.07174	1341.88	1471.01	4.8086
60	0.08951	1389.06	1532.28	5.0461	0.07801	1380.77	1521.19	4.9627
80	0.09774	1434.02	1590.40	5.2156	0.08565	1427.79	1581.97	5.1399
100	0.10539	1475.93	1644.56	5.3648	0.09267	1470.97	1637.78	5.2937
120	0.11268	1516.34	1696.64	5.5008	0.09931	1512.22	1690.98	5.4326
140	0.11974	1556.14	1747.72	5.6276	0.10570	1552.61	1742.88	5.5614

Appendix E
Lampiran E

Psychrometric chart



Appendix F
Lampiran F

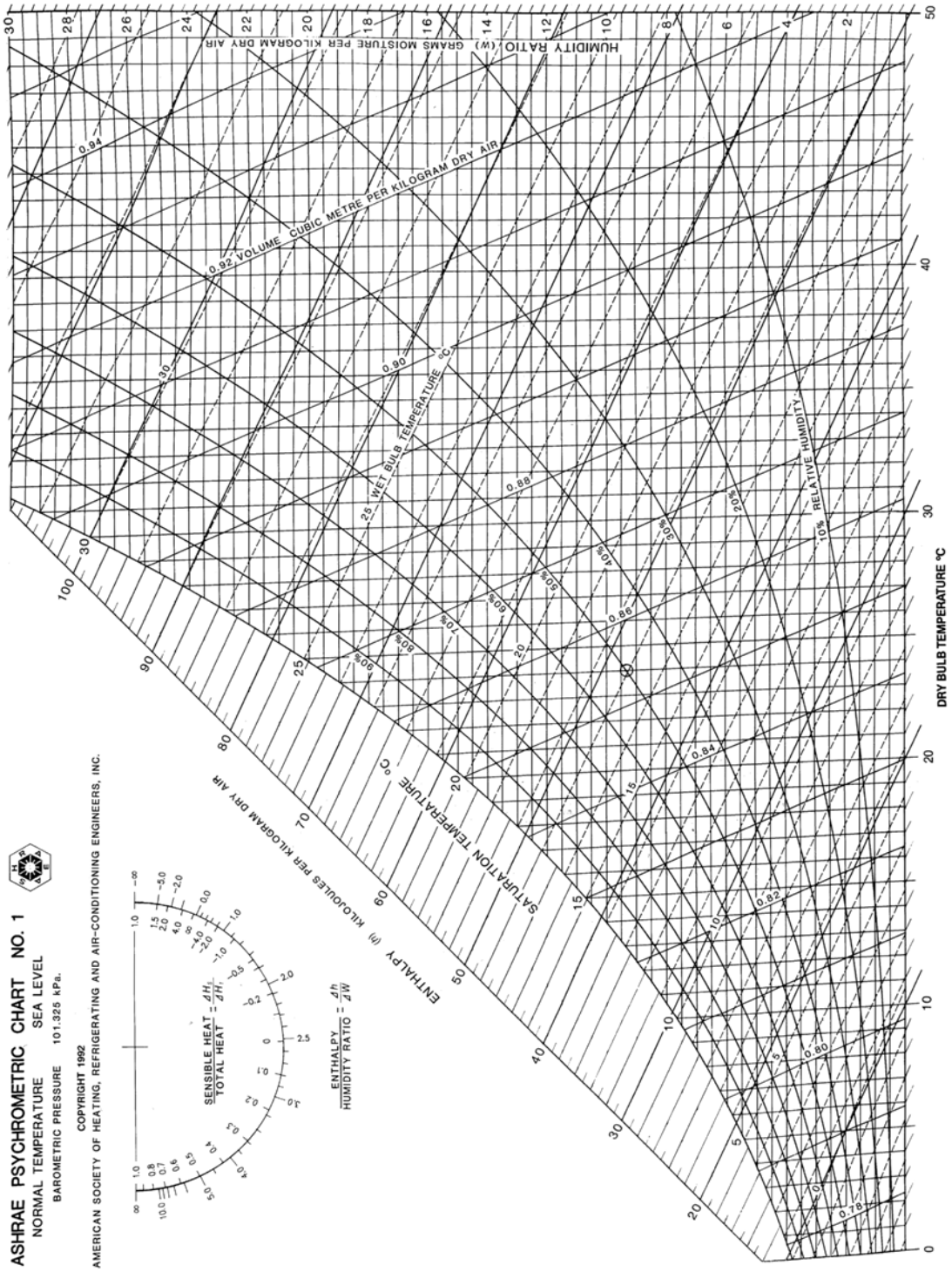


Fig. 1 ASHRAE Psychrometric Chart No. 1

Appendix G
Lampiran G