UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2016/2017

December 2016 / January 2017

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

Duration : 3 hours
Masa : 3 jam

Please check that this paper contains **SEVEN(7)** printed pages, **EIGHT(8)** pages Appendix and **FIVE(5)** questions before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **TUJUH(7)** mukasurat beserta **LAPAN(8)** mukasurat Lampiran dan **LIMA(5)** soalan yang bercetak sebelum anda memulakan peperiksaan.]*

Appendix/*Lampiran:*

1.	Saturated R134a	[1 **page**/*mukasurat*]
2.	Superheated R134a	[2 **pages**/mukasurat]
3.	Saturated water	[2 **pages**/*mukasurat*]
4.	Lithium bromide in solution % by mass	[1 **page**/mukasurat]
5.	Enthalpy of LiBr-water solution	[1 **page**/mukasurat]
6.	Psychrometric Chart	[1 **page**/mukasurat]

INSTRUCTIONS : Answer **ALL** questions.

*[**ARAHAN** : Jawab **SEMUA** 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 :
Provided: Thermodynamic Properties Booklet
Dibekalkan: Buku Sifat-Sifat Termodinamik

Q1. [a] As an engineer, you are assigned to design a refrigeration system using vapour compression cycle and refrigerant R134a that able to cool down to 4°C. The system will be installed at a place with the outdoor temperature at 12°C in spring, 45°C in summer, 25°C in fall and 6°C in winter.

(i) What is the maximum pressure at the low pressure side (evaporator) and minimum pressure at the high pressure side (condenser) of the refrigeration system? Justify your answer.

Sebagai seorang jurutera, anda diminta untuk mereka sebuah sistem penyejukan dengan menggunakan kitar pemampatam wap dan bahan penyejuk R134a yang mampu menyejuk sehingga 4°C. Sistem ini akan dipasang di tempat yang mempunyai suhu luar 12°C semasa musim bunga, 45°C semasa musim panas, 25°C semasa musim gugur dan 6°C semasa musim sejuk.

(i) Apakah tekanan maksimum di sebelah tekanan rendah (penyejat) dan tekanan minimum di sebelah tekanan tinggi (kondenser) dalam sistem penyejukan ini? Wajarkan jawapan anda.

If the COP of the refrigeration system in summer is 2.8, energy consumption by the compressor is 25 kW, and the compressor efficiency is 90%, calculate:

Jika COP sistem penyejukan ini ialah 2.8 semasa musim panas, penggunaan kuasa oleh pemampat ialah 25 kW, dan kecekapan pemampat ialah 90%, kirakan:

(ii) refrigerating effect,
kesan penyejukan,

(iii) refrigerating capacity, and
keupayaan penyejukan, dan

(iv) refrigerant mass flow rate.
kadar aliran jisim bahan penyejuk.

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

[b] With the aid of a diagram, explain how a multi-pressure low temperature refrigeration system works. Use dry ice making process as the example.

Dengan bantuan gambar rajah, terangkan bagaimana sistem penyejukan suhu rendah berperingkat berfungsi. Gunakan proses pembuatan ais kering sebagai contoh.

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

Q2. [a] The generator, condenser, evaporator and absorber of a LiBr-H_2O vapour absorption system operate at the temperatures of 95°C, 45°C, 5°C, and 35°C , respectively. Calculate:

Penjana, penyejat, pemeluwap dan penyerap sebuah sistem penyerapan wap LiBr-H_2O beroperasi pada 95°C, 45°C, 5°C dan 35°C masing-masing. Kirakan:

(i) the LiBr-H_2O concentration at the generator and absorber,
kepekatan LiBr-H_2O dalam penjana dan penyerap,

(ii) the solution mass flow rate to condenser and absorber, when the mass flow rate of the pump is 0.85 kg/s, and
kadar aliran jisim campuran ke condenser dan penyejat, apabila kadar aliran jisim pam ialah 0.85 kg/s dan

(iii) the coefficient of performance of the system.
pekali prestasi sistem.

(**70 marks**/*markah)*

[b] With the aid of diagram, explain the working principle of a magnetic refrigeration system.

Dengan bantuan rajah, terangkan prinsip kerja sistem penyejukan magnet.

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

Q3. [a] An air cooler was used in a room at 33°C and relative humidity of 60%. If the efficiency of the air cooler is 85%, calculate:

Sebuah penyejuk udara digunakan dalam bilik bersuhu 33℃ dan kelembapan relatif 60%. Jika kecekapan penyejuk udara ialah 85%, kirakan:

(i) The air temperature, and
suhu udara, dan

(ii) The air relative humidity at the outlet of air cooler.
kelembapan relatif udara di alur keluar sistem gabungan ini.

Propose an air cooler with an additional system to improve the cooling (output) temperature. Compare the performance of the proposed system and the existing system.

Cadangkan sebuah penyejuk udara dengan sistem tambah untuk memperbaiki suhu penyejukan (keluaran). Bandingkan prestasi sistem yang dicadangkan dan sistem sedia ada.

(**50 marks**/*markah)*

[b] An engineer is required to design an air conditioning system of an office consisting of five executive rooms, a meeting room, a pantry, a store cum printing room, two common water closets, a reception space and a cubicle for up to 12 clerks. Given that the overall dimension of the office is 120 feet long and 60 feet wide, sketch a conceptual layout and justify the type of air conditioning system for each area.

Seorang jurutera diminta mereka bentuk sistem penyaman udara sebuah pejabat yang mempunyai lima bilik eksekutif, sebuah bilik mesyuarat, sebuah pantri, sebuah stor merangkap bilik cetak, dua bilik air bersama, sebuah ruang tamu serta sebuah kubikel bagi maksima 12 kerani. Diberi bahawa dimensi keseluruhan pejabat tersebut ialah 120 kaki panjang dan 60 kaki lebar, lakarkan sebuah susun atur konseptual dan wajarkan jenis sistem penyaman udara bagi setiap kawasan.

(50 marks/*markah***)**

Q4. [a] Define thermal comfort and briefly describe the factors that engineers can control it.

Takrifkan keselesaan termal dan jelaskan dengan ringkas faktor-faktor di mana jurutera-jurutera boleh mengawalnya.

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

...5/-

[b] **A seminar room is to be designed for air conditioning as follows:**
Designed condition: 20°C, w = 0.0075
Outside air condition: 30°C, 80% Relative Humidity
Sensible Cooling Load = 20kW
Latent Cooling Load = 5.0kW
Supplied air contains 30% outside fresh air (30% ventilation air)
Supplied air temperature 15°C
Cooler efficiency 80% (contact factor).

Sebuah bilik seminar direka bentuk bagi penyamanan udara seperti berikut:
Keadaan rekabentuk: 20°C, w = 0.0075
Keadaan udara luar: 30°C, 80% Kelembapan Bandingan
Beban Pendinginan Deria = 20kW
Beban Pendinginan Terlakur = 5.0kW
Udara yang disalur mengandungi 30% udara segar luar (30% udara aliran)
Suhu udara disalur 15°C
Keberkesanan pendingin 80% (faktor sesentuh).

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

(i) **Mass flow rate of the supply air, m_a.**
Kadar aliran jisim udara disalur, m_a.

(ii) **Temperature of the air after the cooling coil.**
Suhu udara selepas gegelung pendingin.

(iii) **Refrigeration capacity (cooling coil load).**
Kapasiti penyejukan (beban gegelung pendingin).

(iv) **Heating capacity (ducting load).**
Kapasiti pemanasan (beban kolong).

(50 marks/*markah***)**

[c] **Discuss <u>FOUR (4)</u> different functions of air conditioning control system. Explain briefly how a building automation system can help control air conditioning effectively.**

Bincangkan <u>EMPAT (4)</u> fungsi sistem kawalan penyaman udara. Terangkan dengan ringkas bagaimana sistem automasi bangunan dapat mengawal penyaman udara dengan berkesan.

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

Q5. [a] Discuss the importance of indoor air quality and propose a few solutions to improve it.

Bincangkan kepentingan kualiti udara dalaman dan cadangkan beberapa penyelesaian bagi memperbaikinya.

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

[b] A large house has a number of electrical appliances as in Table Q5(b.i). An electricity tariff is shown in Table Q5(b.ii). Calculate the average monthly electricity bill for the house.

The house owner plans to save the electricity bills by changing all the lights to the LED type and the air conditioning units to the inverter type as well as refrigerators with 5-star Energy Efficient Rating (EER). An LED light bulb consumes only 6W for the equivalent fluorescent light and costs RM12 each. On average, each new air conditioning unit consumes 65% less power than the current unit. The new air conditioning unit costs RM1800 each while the owner sells the old unit back at RM600 each. The old refrigerators are sold at RM300 each whereas the new refrigerators cost RM1500 each, but they consume 50% less electricity than the old ones. If other factors remain the same, calculate the new expected electricity bill for the house. Estimate the payback period as a result of the savings from the new electricity bills.

Sebuah rumah besar mempunyai peralatan elektrik seperti Jadual S5(b.i). Tarif elektrik ditunjukkan dalam Jadual S5(b.ii). Kirakan purata bil elektrik bulanan rumah tersebut.

Tuan rumah tersebut bercadang untuk menjimatkan bil elektrik dengan menukar setiap lampu kepada jenis LED manakala alat pendingin udara kepada jenis pengalih dan peti sejuk dengan kadar keberkesanan tenaga (EER) 5-bintang. Sebuah mentol LED menggunakan hanya 6W bagi kuasa yang sama oleh lampu kalimantang dan berharga RM12 seunit. Secara purata, setiap alat penyaman udara menggunakan 65% kurang kuasa berbanding unit sedia ada. Alat penyaman udara baharu berharga RM1800 setiap satu manakala tuan rumah menjual semula unit lama pada harga RM600 seunit. Peti sejuk lama dijual pada harga RM300 sebuah manakala peti sejuk baharu berharga RM1500 setiap satu, tetapi ia menggunakan 50% kurang elektrik berbanding dengan yang lama. Jika semua faktor lain kekal sama, kirakan anggaran bil elektrik yang baharu bagi rumah tersebut. Anggarkan tempoh bayaran balik pelaburan tersebut hasil daripada penjimatan bil elektrik yang baharu.

(50 marks/*markah***)**

...7/-

Table Q5(b.i)
Jadual S5(b.i)

Item/ *Peralatan*	**Quantity/** *Bilangan*	**Average W/unit/** *Purata W/unit*	**Usage/day (hour)/** *Penggunaan/hari (jam)*
Lights/ *lampu*	250	60	4
Air conditioner/ *Alat pendingin udara*	10	1000	3
Refrigerator/ *Peti sejuk*	3	500	24
Television/ *Televisyen*	5	100	6
Washing machine/ *Mesin basuh*	2	500	1
Others/ *Lain-lain*	Various/ *pelbagai*	3000 (lump total/ *jumlah semua*)	2

Table Q5(b.ii)
Jadual S5(b.ii)

Electricity used/ *Penggunaan elektrik* ***(kWh)***	**Tariff rates/** *kadar tarif* ***(sen/kWh)***
1 – 200	21.80
201 – 300	33.40
301 – 600	51.60
601 – 900	54.60
> 900	57.10

[c] **Discuss how awareness on energy efficient rating (EER) system would influence the consumer's choice in new electrical appliances. Predict their reaction with the escalating electricity tariff that we currently practise in Malaysia.**

Bincangkan bagaimana kesedaran terhadap sistem penarafan keberkesanan tenaga (EER) dapat mempengaruhi pilihan pengguna dalam pembelian peralatan elektrik baharu. Ramalkan bagaimana reaksi mereka terhadap tarif elektrik menaik sebagaimana yang diamalkan di Malaysia.

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

-oooOooo-

APPENDIX 1

LAMPIRAN 1

Saturated R134a

Temp	Pressure	enthalpy (kJ/kg)			entropy (kJ/kg.K)		
deg C	kPa	hf	hfg	hg	sf	sfg	sg
-40	51.2	0.00	225.86	225.86	0.0000	0.9687	0.9687
-36	62.9	5.04	223.35	228.39	0.0214	0.9418	0.9632
-32	76.7	10.10	220.82	230.92	0.0425	0.9157	0.9582
-28	92.7	15.20	218.23	233.43	0.0634	0.8902	0.9536
-26	101.7	17.76	216.92	234.68	0.0738	0.8777	0.9515
-24	111.3	20.33	215.60	235.93	0.0841	0.8653	0.9495
-22	121.7	22.91	214.26	237.17	0.0944	0.8531	0.9476
-20	132.7	25.49	212.92	238.41	0.1046	0.8411	0.9457
-18	144.6	28.09	211.55	239.64	0.1148	0.8292	0.9440
-16	157.3	30.69	210.18	240.87	0.1249	0.8174	0.9423
-14	170.8	33.30	208.79	242.09	0.1350	0.8057	0.9407
-12	185.2	35.92	207.39	243.31	0.1451	0.7941	0.9392
-10	200.6	38.55	205.97	244.52	0.1550	0.7827	0.9377
-8	216.9	41.19	204.53	245.72	0.1650	0.7714	0.9364
-6	234.3	43.84	203.08	246.92	0.1749	0.7602	0.9351
-4	252.7	46.50	201.61	248.11	0.1848	0.7490	0.9338
-2	272.2	49.17	200.12	249.29	0.1946	0.7380	0.9326
0	292.8	51.86	198.60	250.46	0.2044	0.7271	0.9315
2	314.6	54.55	197.07	251.62	0.2142	0.7162	0.9304
4	337.7	57.25	195.53	252.78	0.2239	0.7055	0.9294
6	362.0	59.97	193.95	253.92	0.2336	0.6948	0.9284
8	387.6	62.69	192.36	255.05	0.2432	0.6842	0.9274
12	443.0	68.19	189.11	257.29	0.2625	0.6632	0.9256
16	504.3	73.73	185.74	259.47	0.2816	0.6424	0.9240
20	571.7	79.32	182.28	261.60	0.3006	0.6218	0.9224
24	645.8	84.98	178.70	263.68	0.3196	0.6014	0.9210
26	685.4	87.83	176.87	264.70	0.3290	0.5912	0.9203
28	726.9	90.70	175.00	265.69	0.3385	0.5811	0.9196
30	770.2	93.58	173.09	266.67	0.3479	0.5710	0.9189
32	815.4	96.48	171.16	267.64	0.3573	0.5609	0.9182
34	862.6	99.40	169.18	268.58	0.3667	0.5508	0.9175
36	911.9	102.33	167.17	269.50	0.3761	0.5407	0.9168
38	963.2	105.29	165.12	270.41	0.3855	0.5307	0.9162
40	1016.6	108.27	163.01	271.28	0.3949	0.5206	0.9155
42	1072.2	111.26	160.88	272.14	0.4043	0.5105	0.9147
44	1130.1	114.28	158.69	272.97	0.4136	0.5004	0.9140
48	1252.9	120.39	154.16	274.55	0.4324	0.4800	0.9125
52	1385.4	126.60	149.41	276.01	0.4513	0.4595	0.9108
56	1528.2	132.92	144.40	277.32	0.4702	0.4387	0.9089
60	1681.8	139.36	139.13	278.49	0.4892	0.4176	0.9068
70	2116.8	156.14	124.37	280.51	0.5376	0.3624	0.9000
80	2633.2	174.25	106.42	280.67	0.5880	0.3014	0.8894
90	3244.2	194.78	82.49	277.27	0.6434	0.2272	0.8706
100	3972.4	225.15	34.39	259.54	0.7232	0.0921	0.8153
101.06	4059.1	241.49	0.00	241.49	0.7665	0.0000	0.7665

Saturated water

SATURATED STEAM - TEMPERATURE TABLE

		Spec. vol. m^3=kg		Int. Ener. kJ/kg		Enthalpy kJ/kg		Entropy kJ=(kg°K)	
T °C	P bar	Sat. liq. v_f X1000	Sat. vap. v_g	Sat. liq. u_f	Sat. vap. u_g	Sat. liq. h_f	Sat. vap. h_g	Sat. liq. s_f	Sat. vap. s_g
0.01	0.0061	1.0002	206.1	0.01	2376	0.01	2501	0	9.156
4	0.0081	1.0001	157.2	16.79	2381	16.79	2509	0.061	9.051
5	0.0087	1.0001	147.1	21.00	2383	21	2511	0.0762	9.026
6	0.0093	1.0001	137.7	25.21	2384	25.21	2512	0.0912	9.000
8	0.0107	1.0001	120.9	33.61	2387	33.61	2516	0.1212	8.950
10	0.0123	1.0001	106.4	42.01	2389	42.01	2520	0.151	8.901
11	0.0131	1.0007	99.86	46.19	2391	46.19	2522	0.1658	8.876
12	0.0140	1.0007	93.79	50.40	2392	50.4	2523	0.1806	8.852
13	0.0150	1.0007	88.13	54.59	2393	54.59	2525	0.1953	8.828
14	0.0160	1.0007	82.85	58.80	2394	58.8	2527	0.2099	8.805
15	0.0170	1.0007	77.93	62.99	2396	62.99	2529	0.2245	8.781
16	0.0182	1.0013	73.34	67.17	2397	67.17	2531	0.239	8.758
17	0.0194	1.0013	69.05	71.36	2399	71.36	2533	0.2535	8.735
18	0.0206	1.0013	65.04	75.57	2400	75.57	2534	0.2679	8.712
19	0.0220	1.0013	61.30	79.76	2401	79.76	2536	0.2823	8.690
20	0.0234	1.002	57.79	83.94	2403	83.94	2538	0.2966	8.667
21	0.0249	1.002	54.52	88.13	2404	88.13	2540	0.3108	8.645
22	0.0264	1.002	51.45	92.32	2406	92.32	2542	0.3251	8.623
23	0.0281	1.0026	48.58	96.50	2407	96.5	2544	0.3392	8.601
24	0.0298	1.0026	45.89	100.7	2409	100.7	2545	0.3533	8.579
25	0.0317	1.0032	43.36	104.9	2410	104.9	2547	0.3673	8.558
26	0.0336	1.0032	41.00	109.0	2411	109.0	2549	0.3814	8.537
27	0.0357	1.0032	38.78	113.2	2412	113.2	2551	0.3953	8.515
28	0.0378	1.0038	36.69	117.4	2414	117.4	2553	0.4093	8.495
29	0.0401	1.0038	34.73	121.6	2415	121.6	2554	0.4231	8.474
30	0.0425	1.0045	32.90	125.8	2416	125.8	2556	0.4369	8.453
31	0.0450	1.0045	31.17	130.0	2418	130.0	2558	0.4507	8.433
32	0.0476	1.0051	29.54	134.1	2419	134.1	2560	0.4644	8.413
33	0.0503	1.0051	28.01	138.3	2421	138.3	2562	0.478	8.393
34	0.0532	1.0057	26.57	142.5	2422	142.5	2563	0.4917	8.373
35	0.0563	1.0057	25.22	146.7	2423	146.7	2565	0.5053	8.353
36	0.0595	1.0063	23.94	150.8	2425	150.8	2567	0.5188	8.333
38	0.0663	1.007	21.60	159.2	2427	159.2	2571	0.5457	8.295
40	0.0738	1.0076	19.52	167.5	2430	167.5	2574	0.5725	8.257
45	0.0959	1.010	15.26	188.4	2437	188.4	2583	0.6386	8.165
50	0.1235	1.012	12.03	209.3	2443	209.3	2592	0.7037	8.076
55	0.1576	1.015	9.569	230.2	2450	230.2	2601	0.7679	7.991
60	0.1994	1.017	7.671	251.1	2457	251.1	2610	0.8311	7.910
65	0.2503	1.020	6.197	272.0	2463	272.0	2618	0.8934	7.831
70	0.3119	1.023	5.042	293.0	2470	293.0	2627	0.9549	7.755
75	0.3858	1.026	4.131	313.9	2476	313.9	2635	1.016	7.682
80	0.4739	1.029	3.407	334.8	2482	334.9	2644	1.075	7.612

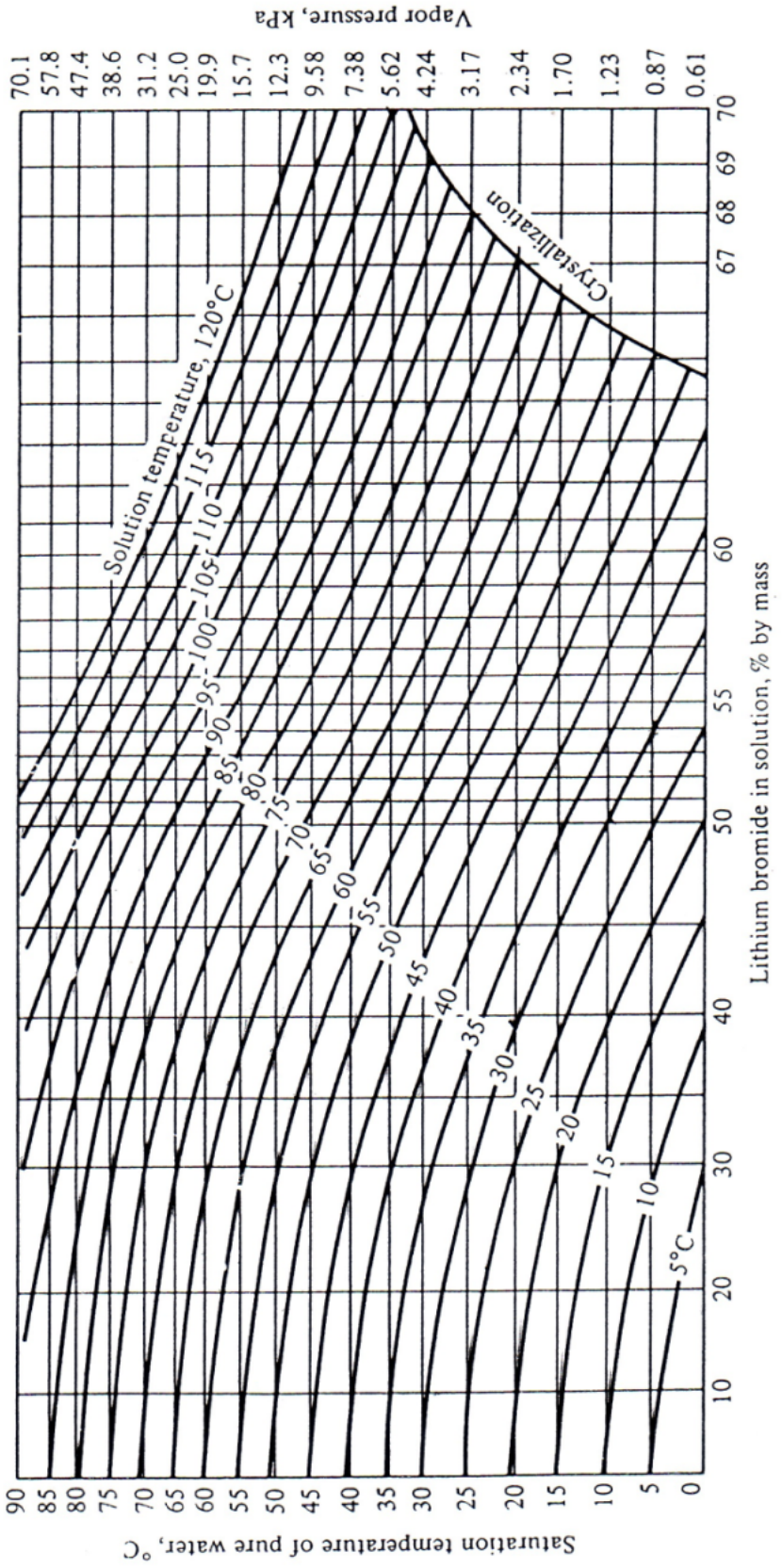
SATURATED STEAM - TEMPERATURE TABLE (Continued)

		Spec. vol. m^3=kg		Int. Ener. kJ/kg		Enthalpy kJ/kg		Entropy kJ=(kg°K)	
T °C	P bar	Sat. liq. v_f X1000	Sat. vap. v_g	Sat. liq. u_f	Sat. vap. u_g	Sat. liq. h_f	Sat. vap. h_g	Sat. liq. s_f	Sat. vap. s_g
85	0.5783	1.033	2.828	355.8	2488	355.9	2652	1.134	7.544
90	0.7013	1.036	2.361	376.8	2494	376.9	2660	1.193	7.479
95	0.8455	1.039	1.982	397.9	2501	398.0	2668	1.250	7.416
100	1.013	1.044	1.673	418.9	2507	419.0	2676	1.307	7.355
110	1.433	1.052	1.21	461.1	2518	461.3	2691	1.418	7.239
120	1.985	1.060	0.892	503.5	2529	503.7	2706	1.528	7.130
130	2.701	1.069	0.669	546.0	2540	546.3	2720	1.634	7.027
140	3.613	1.080	0.509	588.7	2550	589.1	2734	1.739	6.930
150	4.758	1.091	0.393	631.7	2559	632.2	2746	1.842	6.838
160	6.178	1.102	0.307	674.9	2568	675.5	2758	1.943	6.750
170	7.916	1.114	0.243	718.3	2576	719.2	2769	2.042	6.666
180	10.02	1.127	0.194	762.1	2584	763.2	2778	2.140	6.586
190	12.54	1.141	0.157	806.2	2589	807.6	2786	2.236	6.508
200	15.54	1.156	0.127	850.6	2596	852.4	2793	2.331	6.432
210	19.06	1.172	0.104	895.5	2600	897.8	2798	2.425	6.358
220	23.18	1.190	0.086	940.8	2603	943.6	2802	2.518	6.286
230	27.95	1.209	0.072	986.7	2603	990.1	2804	2.610	6.215
240	33.44	1.229	0.06	1033	2603	1037.3	2804	2.702	6.144
250	39.73	1.251	0.05	1080	2603	1085.3	2802	2.793	6.073
260	46.88	1.275	0.042	1128	2600	1134.4	2797	2.884	6.002
270	54.98	1.302	0.036	1177	2592	1184.5	2790	2.975	5.930
280	64.11	1.332	0.03	1227	2587	1236.0	2780	3.067	5.857
290	74.36	1.365	0.026	1279	2573	1289.0	2766	3.159	5.782
300	85.81	1.403	0.022	1332	2560	1344.0	2749	3.253	5.704
320	112.7	1.499	0.015	1445	2531	1461.5	2700	3.448	5.536
340	145.9	1.638	0.011	1570	2462	1594.1	2622	3.659	5.336
360	186.5	1.893	0.007	1725	2351	1760.5	2481	3.915	5.053
374.14	220.9	3.155	0.003155	2030	2030	2099.3	2099	4.430	4.430

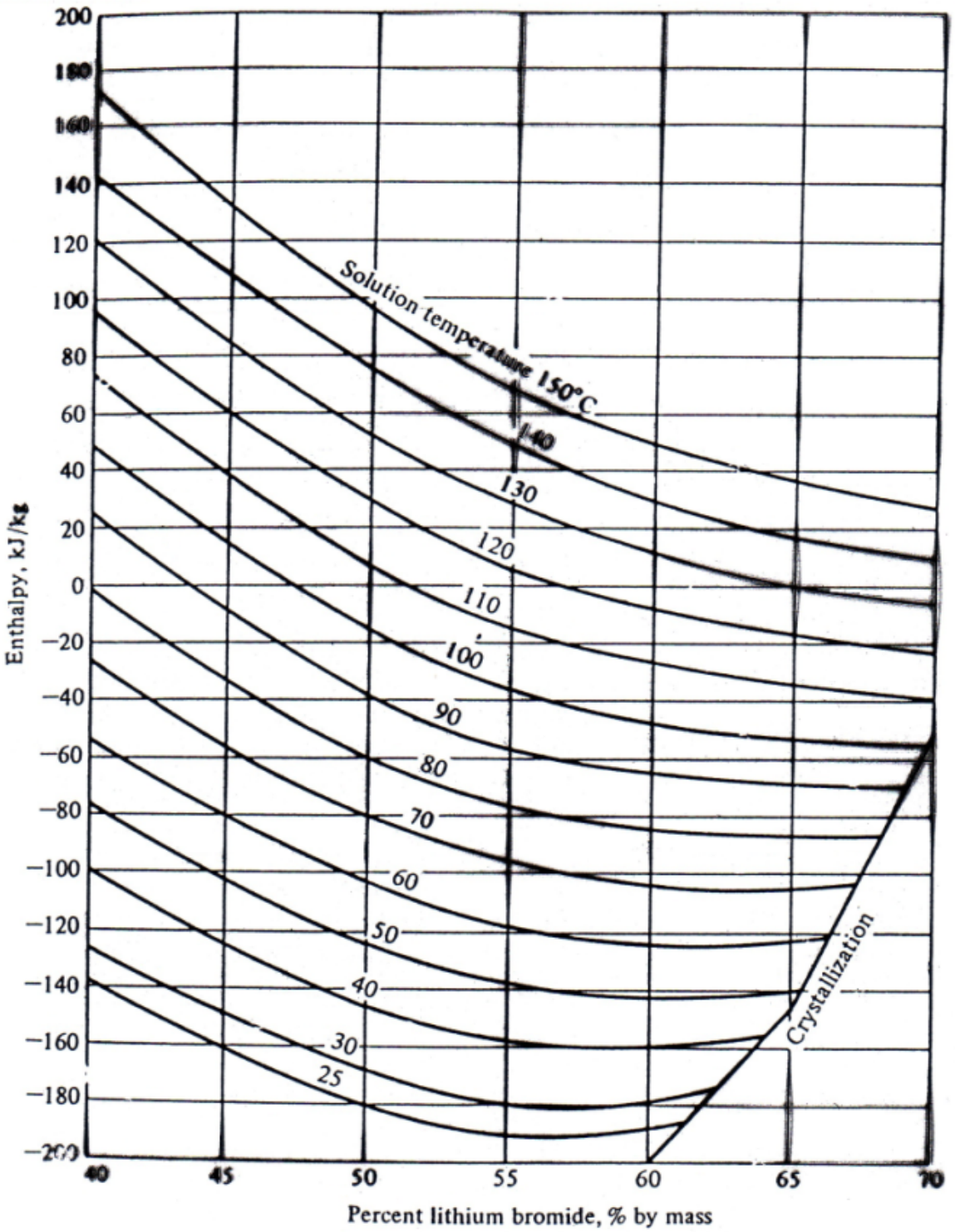
APPENDIX 4

LAMPIRAN 4

Lithium bromide in solution % by mass



Enthalpy of LiBr-water solutions



Psychrometric Chart

APPENDIX 2
LAMPIRAN 2

[EME 431]

Superheated R134a

APPENDIX 2
LAMPIRAN 2

[EME 431]

Superheated R134a

R134a - TetraFlouroEthane Superheated Properties

	P=0.06 MPa (-36.9 C)				P=0.10 MPa -26.4 C)				P=0.14 MPa (-18.8 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.3112	209.1	227.8	0.964	0.1926	215.2	234.5	0.952				
-20	0.3361	220.6	240.8	1.018	0.1984	219.7	239.5	0.972	0.1402	219.6	239.2	0.945
-10	0.3505	227.6	248.6	1.048	0.2074	226.8	247.5	1.003	0.1461	225.9	246.4	0.972
0	0.3648	234.7	256.5	1.077	0.2163	234.0	255.6	1.033	0.1526	233.2	254.6	1.003
10	0.3789	241.9	264.7	1.107	0.2251	241.3	263.8	1.063	0.1591	240.7	262.9	1.033
20	0.3930	249.4	272.9	1.135	0.2337	248.8	272.2	1.092	0.1654	248.2	271.4	1.062
30	0.4071	257.0	281.4	1.164	0.2423	256.5	280.7	1.120	0.1717	255.9	280.0	1.091
40	0.4210	264.7	290.0	1.192	0.2509	264.3	289.3	1.149	0.1780	263.8	288.7	1.120
50	0.4350	272.6	298.7	1.219	0.2594	272.2	298.2	1.176	0.1841	271.8	297.6	1.147
60	0.4488	280.7	307.7	1.246	0.2678	280.4	307.1	1.204	0.1903	280.0	306.6	1.175
70	0.4627	289.0	316.8	1.273	0.2763	288.6	316.3	1.231	0.1964	288.3	315.8	1.202
80	0.4765	297.4	326.0	1.300	0.2847	297.1	325.6	1.257	0.2024	296.8	325.1	1.229
90	0.4903	306.0	335.4	1.326	0.2930	305.7	335.0	1.284	0.2085	305.4	334.6	1.255
100	0.5041	314.8	345.0	1.352	0.3014	314.5	344.6	1.310	0.2145	314.2	344.2	1.282

	P=0.18 MPa (-12.7 C)				P=0.20 MPa (-10.1 C)				P=0.24 MPa (-5.4 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.1104	223.0	242.9	0.940	0.0999	224.5	244.5	0.938	0.0839	227.2	247.3	0.935
-10	0.1119	225.0	245.2	0.948								
0	0.1172	232.5	253.6	0.980	0.1048	232.1	253.1	0.970	0.0862	231.3	252.0	0.952
10	0.1224	240.0	262.0	1.010	0.1096	239.7	261.6	1.001	0.0903	239.0	260.7	0.983
20	0.1275	247.6	270.6	1.040	0.1142	247.4	270.2	1.030	0.0942	246.8	269.4	1.013
30	0.1325	255.4	279.3	1.069	0.1187	255.2	278.9	1.060	0.0981	254.6	278.2	1.043
40	0.1374	263.3	288.1	1.098	0.1232	263.1	287.7	1.088	0.1019	262.6	287.1	1.072
50	0.1423	271.4	297.0	1.126	0.1277	271.2	296.7	1.116	0.1057	270.7	296.1	1.100
60	0.1472	279.6	306.1	1.153	0.1321	279.4	305.8	1.144	0.1094	279.0	305.2	1.128
70	0.1520	287.9	315.3	1.181	0.1364	287.7	315.0	1.171	0.1131	287.4	314.5	1.156
80	0.1567	296.4	324.6	1.207	0.1407	296.3	324.4	1.198	0.1168	295.9	323.9	1.183
90	0.1615	305.1	334.1	1.234	0.1451	304.9	333.9	1.225	0.1204	304.6	333.5	1.209
100	0.1662	313.9	343.8	1.260	0.1493	313.7	343.6	1.251	0.1240	313.5	343.2	1.236

	P=0.28 MPa (-1.2 C)				P=0.32 MPa (2.5 C)				P=0.40 MPa (8.9 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.0724	229.5	249.7	0.932	0.0636	231.5	251.9	0.930	0.0512	235.1	255.6	0.927
10	0.0765	238.3	259.7	0.968	0.0661	237.5	258.7	0.954	0.0515	236.0	256.6	0.931
20	0.0800	246.1	268.5	0.999	0.0693	245.5	267.7	0.986	0.0542	244.2	265.9	0.963
30	0.0834	254.1	277.4	1.029	0.0723	253.5	276.7	1.016	0.0568	252.4	275.1	0.994
40	0.0867	262.1	286.4	1.058	0.0753	261.6	285.7	1.045	0.0593	260.6	284.3	1.024
50	0.0900	270.3	295.5	1.086	0.0782	269.8	294.9	1.074	0.0617	268.9	293.6	1.053
60	0.0932	278.6	304.7	1.114	0.0811	278.2	304.1	1.102	0.0641	277.3	303.0	1.081
70	0.0964	287.0	314.0	1.142	0.0839	286.6	313.5	1.130	0.0664	285.9	312.4	1.109
80	0.0996	295.6	323.5	1.169	0.0868	295.2	323.0	1.157	0.0687	294.5	322.0	1.137
90	0.1028	304.3	333.1	1.196	0.0895	304.0	332.6	1.184	0.0710	303.3	331.7	1.164
100	0.1059	313.2	342.8	1.222	0.0923	312.9	342.4	1.211	0.0733	312.3	341.6	1.191
110	0.1090	322.2	352.7	1.248	0.0950	321.9	352.3	1.237	0.0755	321.3	351.5	1.217
120	0.1121	331.3	362.7	1.274	0.0977	331.1	362.4	1.263	0.0777	330.6	361.6	1.243

	P=0.50 MPa (15.7 C)				P=0.60 MPa (21.6 C)				P=0.70 MPa (26.7 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.0411	238.8	259.3	0.924	0.0343	241.9	262.4	0.922	0.0294	244.5	265.1	0.920
20	0.0421	242.4	263.5	0.938								
30	0.0443	250.8	273.0	0.970	0.0360	249.2	270.8	0.950	0.0300	247.5	268.5	0.931
40	0.0465	259.3	282.5	1.001	0.0379	257.9	280.6	0.982	0.0317	256.4	278.6	0.964
50	0.0485	267.7	292.0	1.031	0.0397	266.5	290.3	1.012	0.0333	265.2	288.5	0.995
60	0.0505	276.3	301.5	1.060	0.0414	275.2	300.0	1.042	0.0349	274.0	298.4	1.026
70	0.0524	284.9	311.1	1.088	0.0431	283.9	309.7	1.071	0.0364	282.9	308.3	1.055
80	0.0543	293.6	320.8	1.116	0.0447	292.7	319.6	1.099	0.0378	291.8	318.3	1.084
90	0.0562	302.5	330.6	1.144	0.0463	301.7	329.5	1.126	0.0393	300.8	328.3	1.111
100	0.0581	311.5	340.5	1.171	0.0479	310.7	339.5	1.154	0.0406	310.0	338.4	1.139
110	0.0599	320.6	350.6	1.197	0.0495	319.9	349.6	1.180	0.0420	319.2	348.6	1.166
120	0.0617	329.9	360.7	1.223	0.0510	329.2	359.8	1.207	0.0434	328.6	358.9	1.192
130	0.0635	339.3	371.0	1.249	0.0525	338.7	370.2	1.233	0.0447	338.0	369.3	1.219
140	0.0653	348.8	381.5	1.275	0.0540	348.3	380.7	1.258	0.0460	347.7	379.9	1.244

	P=0.80 MPa (31.3 C)				P=0.90 MPa (35.5 C)				P=1.00 MPa (39.4 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.0256	246.8	267.3	0.918	0.0227	248.9	269.3	0.917	0.0203	250.7	271.0	0.916
40	0.0270	254.8	276.5	0.948	0.0234	253.1	274.2	0.933	0.0204	251.3	271.7	0.918
50	0.0285	263.9	286.7	0.980	0.0248	262.4	284.8	0.966	0.0218	260.9	282.7	0.953
60	0.0300	272.8	296.8	1.011	0.0261	271.6	295.1	0.998	0.0231	270.3	293.4	0.985
70	0.0313	281.8	306.9	1.041	0.0274	280.7	305.4	1.028	0.0243	279.6	303.9	1.016
80	0.0327	290.8	317.0	1.070	0.0286	289.9	315.6	1.057	0.0254	288.9	314.3	1.046
90	0.0339	300.0	327.1	1.098	0.0298	299.1	325.9	1.086	0.0265	298.2	324.7	1.075
100	0.0352	309.2	337.3	1.126	0.0310	308.3	336.2	1.114	0.0276	307.5	335.1	1.103
110	0.0364	318.5	347.6	1.153	0.0321	317.7	346.6	1.141	0.0286	316.9	345.5	1.131
120	0.0376	327.9	358.0	1.180	0.0332	327.2	357.0	1.168	0.0296	326.5	356.1	1.158
130	0.0388	337.4	368.5	1.206	0.0342	336.8	367.6	1.195	0.0306	336.1	366.7	1.185
140	0.0400	347.1	379.1	1.232	0.0353	346.5	378.2	1.221	0.0316	345.9	377.4	1.211
150	0.0411	356.9	389.8	1.258	0.0363	356.3	389.0	1.247	0.0325	355.7	388.2	1.237
160	0.0423	366.8	400.6	1.283	0.0374	366.2	399.9	1.272	0.0335	365.7	399.2	1.262

	P=1.2 MPa (46.3 C)				P=1.4 MPa (52.4 C)				P=1.6 MPa (57.9 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.0167	253.8	273.9	0.913	0.0141	256.4	276.2	0.911	0.0121	258.5	277.9	0.908
50	0.0172	257.6	278.3	0.927								
60	0.0184	267.6	289.6	0.961	0.0150	264.5	285.5	0.939	0.0124	260.9	280.7	0.916
70	0.0195	277.2	300.6	0.994	0.0161	274.6	297.1	0.973	0.0134	271.8	293.3	0.954
80	0.0205	286.8	311.4	1.025	0.0170	284.5	308.3	1.006	0.0144	282.1	305.1	0.987
90	0.0215	296.3	322.1	1.055	0.0179	294.3	319.4	1.036	0.0152	292.2	316.5	1.019
100	0.0224	305.8	332.7	1.084	0.0188	304.0	330.3	1.066	0.0160	302.1	327.8	1.050
110	0.0233	315.4	343.4	1.112	0.0196	313.8	341.2	1.095	0.0168	312.1	338.9	1.080
120	0.0242	325.0	354.1	1.139	0.0204	323.6	352.1	1.123	0.0175	322.0	350.0	1.108
130	0.0251	334.8	364.9	1.166	0.0212	333.4	363.0	1.150	0.0182	332.0	361.1	1.136
140	0.0259	344.6	375.7	1.193	0.0219	343.4	374.0	1.177	0.0189	342.1	372.3	1.163
150	0.0268	354.6	386.7	1.219	0.0226	353.4	385.1	1.204	0.0195	352.2	383.5	1.190
160	0.0276	364.6	397.7	1.245	0.0234	363.5	396.2	1.230	0.0202	362.4	394.7	1.216
170	0.0284	374.8	408.8	1.270	0.0241	373.8	407.4	1.255	0.0208	372.7	406.0	1.242
180	0.0292	385.1	420.1	1.295	0.0248	384.1	418.8	1.281	0.0215	383.1	417.4	1.268

(Source of data: NIST Chemistry WebBook Accessed: May 2007)

	P=1.8 MPa (62.9 C)				P=2.0 MPa (67.5 C)			
Temp	volume	energy	enthalpy	entropy	volume	energy	enthalpy	entropy
Deg C	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg.K)
Sat.	0.0106	408.4	427.4	1.701	0.0093	409.7	428.3	1.698
70	0.0113	416.7	437.1	1.729	0.0096	412.9	432.1	1.709
80	0.0123	427.6	449.7	1.766	0.0105	424.7	445.8	1.748
90	0.0131	438.1	461.6	1.799	0.0114	435.7	458.4	1.783
100	0.0139	448.3	473.3	1.831	0.0121	446.2	470.5	1.816
110	0.0146	458.5	484.7	1.861	0.0128	456.6	482.2	1.847
120	0.0152	468.6	496.0	1.890	0.0134	466.9	493.8	1.877
130	0.0159	478.7	507.3	1.918	0.0141	477.2	505.3	1.906
140	0.0165	488.9	518.6	1.946	0.0146	487.5	516.8	1.934
150	0.0171	499.1	529.9	1.973	0.0152	497.8	528.2	1.961
160	0.0177	509.4	541.3	2.000	0.0158	508.2	539.7	1.988
170	0.0183	519.8	552.7	2.026	0.0163	518.7	551.3	2.015
180	0.0189	530.3	564.3	2.051	0.0168	529.2	562.9	2.041

(Source of data: NIST Chemistry WebBook Accessed: Oct 2010)