



<u>PROGRAM</u>	: NATIONAL DIPLOMA) <i>ENGINEERING: MECHANICAL</i>
<u>SUBJECT</u>	: STEAM PLANT
<u>CODE</u>	: SMP 301
<u>DATE</u>	: SUMMER SSA EXAMINATION 2015 7 DECEMBER 2015
<u>DURATION</u>	: (SESSION 2) 11:30 - 14:30
<u>WEIGHT</u>	:
<u>TOTAL MARKS</u>	: 108 = 100%
<u>MAXIMUM MARKS</u>	: 100
<u>ASSESSOR</u>	: ASSESSOR: Mr. E. BAKAYA-KYAHURWA
<u>MODERATOR</u>	: MODERATOR: Mr. Kobus Van Tonder
<u>NUMBER OF PAGES</u>	: PAGES: 2 excluding the cover page.
<u>INSTRUCTIONS</u>	: ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED.
1. This paper contains 5 questions 2. PLEASE ANSWER ALL QUESTIONS 3. Make sure that you understand what the question requires before attempting it. 4. Any additional examination material is to be placed in the answer book and must indicate clearly the question number, and Student number. 5. Draw proper sketches where required with all relevant information Answers without calculations will not be considered. Answers without units will not be considered. All answers to be to the 4th decimal point. Number all answer according to the numbering in question paper.	
<u>REQUIREMENTS</u>	: h-s Chart for steam, Thermodynamic Property Tables

QUESTION 1

Dry saturated steam is supplied to the high pressure turbine in a nuclear plant at 6 MPa. Under part load conditions this is throttled by a control valve to 3 MPa before entering the turbine. It then expands in the turbine to a pressure of 0.6 MPa before reheating. The steam temperature after reheating is 300°C and it is then expanded in the low pressure turbine to 0.004 MPa. Under these conditions the steam flow through the turbine is 600 kg/s. Assuming a turbine internal efficiency of 80% for both the high and low pressure turbines, determine the power output. Also determine the terminal conditions as defined below.

Terminal conditions (temperature and moisture content) of steam at the following points.

- 1.1.1 Inlet of the high pressure turbine (4)
- 1.1.2 Exit of the high pressure turbine (4)
- 1.1.3 Exit of the low pressure turbine (4)

[12]

QUESTION 2

- 2.1 A wall with an area of 25 m² is made up of four layers. On the inside is plaster 15 mm thick, then there is brick 100 mm thick, then there is insulation 60 mm thick and finally brick 100 mm thick. The values of k for plaster, brick, and insulation are 0.1, 0.6 and 0.09 W/mK respectively. The inner surface of the wall is at 18°C and the outer is -2°C. Calculate the

- 2.1.1 heat loss through the wall and (10)
- 2.1.2 the temperature at the interface between the plaster and the brick. (3)

- 2.2 A steel pipe 120 mm inside diameter has a wall 10 mm thick. It is covered with insulation 20 mm thick. The thermal conductivity of the steel is 60 W/mK and for the insulation 0.09 W/mK. The pipe carries steam at 150 °C and the outer surface temperature of the insulation is 0°C. Determine:

- 2.2.1 the heat lost per meter length of pipe (8)
- 2.2.2 the temperature at the pipe's outer surface. (3)

[24]

QUESTION 3

- 3.1 Moist air at 101.3 kPa and 25°C is cooled to 18°C by passing it over water at 18°C. It emerges saturated at 18°C and 101.3 kPa. Assuming that there is no net water absorbed or lost determine the: relative humidity and the specific humidity before cooling. (8)
- 3.2 A centrifugal compressor has a pressure ratio of 4:1 with an isentropic efficiency of 80% when running at 15000 rpm and inducing air at 293 K. Curved vanes at the inlet give the air a prewhirl of 25° to the axial direction at all radii. The tip diameter of the eye of the impeller is 250 mm. The absolute velocity at inlet is 150 m/s and the impeller diameter is 600 mm. Calculate the slip factor (14)

[22]

QUESTION 4

A wet cooling tower is to cool 200 kg/s of cooling water from 49.5°C to 29°C at a location where the atmospheric pressure is 90 kPa. Atmospheric air enters the tower at 13°C and 70 % relative humidity and leaves at 31°C with a relative humidity of 90 %. Neglecting the power input to the fan, determine:

- a) the mass flow rate of the required make-up water. (11)
 - b) the volume flow rate of air into the cooling tower. (5)
- [16]**

QUESTION 5

Following data refer to the velocity compounded impulse turbine with two rows of moving blades:

Steam supply: 60 bar, 500°C

Speed of rotation: 3600 rpm

Mean radius of blades: 60 cm

Steam supply: 6 kg/s

Blade speed to steam velocity ratio: 0.2

Nozzle efficiency: 90%

Nozzle angle: 20°

Exit angles: 25°, 25° and 40° for first moving, fixed and second moving blades respectively

Blade velocity coefficient: 0.85 for all blades

Disc friction and Windage loss: 15kW.

Draw to scale the velocity diagrams of the two stages and determine all the velocities and angles not stated: (15)

- 5.1 pressure at entry to the stage (10)
- 5.2 net power output (4)
- 5.3 diagram efficiency (3)
- 5.4 stage efficiency (2)

[34]

TOTAL = 108

Properties of Water and Saturated Steam

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m³/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg.K	kJ/kg.K
1,0	7,0	129,20	29	2 485	2 514	0,106	8,977
1,5	13,0	87,98	55	2 471	2 526	0,196	8,829
2,0	17,5	67,01	74	2 460	2 534	0,261	8,725
2,5	21,1	54,26	89	2 452	2 541	0,312	8,644
3,0	24,1	45,67	101	2 445	2 546	0,354	8,579
3,5	26,7	39,48	112	2 439	2 551	0,391	8,523
4,0	29,0	34,80	121	2 433	2 554	0,423	8,476
4,5	31,0	31,14	130	2 428	2 558	0,451	8,434
5,0	32,9	28,19	138	2 424	2 562	0,476	8,396
5,5	34,6	25,77	145	2 420	2 565	0,500	8,362
6,0	36,2	23,74	152	2 416	2 568	0,521	8,331
6,5	37,7	22,02	158	2 413	2 571	0,541	8,303
7,0	39,0	20,53	163	2 410	2 573	0,559	8,277
7,5	40,3	19,24	169	2 406	2 575	0,576	8,252
8,0	41,6	18,10	174	2 403	2 577	0,593	8,230
8,5	42,7	17,10	179	2 401	2 580	0,608	8,208
9,0	43,8	16,20	183	2 398	2 581	0,622	8,188
9,5	44,8	15,40	188	2 395	2 583	0,636	8,169
10	45,8	14,67	192	2 393	2 585	0,649	8,151
11	47,7	13,42	200	2 388	2 588	0,674	8,118
12	49,5	12,36	207	2 384	2 591	0,696	8,087
13	51,1	11,47	214	2 380	2 594	0,717	8,059
14	52,6	10,69	220	2 377	2 597	0,737	8,033
15	54,0	10,02	226	2 373	2 599	0,755	8,009
16	55,3	9,433	232	2 370	2 602	0,772	7,987
17	56,6	8,911	237	2 367	2 604	0,788	7,966
18	57,8	8,445	242	2 364	2 606	0,804	7,946
19	59,0	8,027	247	2 361	2 608	0,818	7,927
20	60,1	7,650	252	2 358	2 610	0,832	7,909
21	61,1	7,307	256	2 356	2 612	0,845	7,893
22	62,2	6,995	260	2 353	2 613	0,858	7,876
23	63,1	6,709	264	2 351	2 615	0,870	7,861
24	64,1	6,447	268	2 349	2 617	0,882	7,846
25	65,0	6,204	272	2 346	2 618	0,893	7,832
26	65,9	5,980	276	2 344	2 620	0,904	7,819
27	66,7	5,772	279	2 342	2 621	0,915	7,806
28	67,6	5,579	283	2 340	2 623	0,925	7,793
29	68,3	5,398	286	2 338	2 624	0,935	7,781
30	69,1	5,229	289	2 336	2 625	0,944	7,770

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m³/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg.K	kJ/kg.K
32	70.6	4.922	296	2 332	2 628	0.962	7.747
34	72.0	4.650	302	2 329	2 631	0.960	7.727
36	73.4	4.408	307	2 326	2 633	0.956	7.707
38	74.7	4.190	313	2 322	2 635	1.011	7.688
40	75.9	3.993	318	2 319	2 637	1.026	7.671
45	78.7	3.575	330	2 312	2 642	1.060	7.631
50	81.4	3.240	341	2 305	2 646	1.091	7.595
55	83.7	2.964	351	2 299	2 650	1.119	7.562
60	86.0	2.732	360	2 294	2 654	1.145	7.533
65	88.0	2.535	369	2 288	2 657	1.170	7.506
70	90.0	2.365	377	2 283	2 660	1.192	7.480
75	91.8	2.217	385	2 279	2 664	1.213	7.457
80	93.5	2.087	392	2 274	2 666	1.233	7.435
85	95.2	1.972	399	2 270	2 669	1.252	7.415
90	96.7	1.869	405	2 266	2 671	1.270	7.395
95	98.2	1.777	412	2 262	2 674	1.287	7.377
100	99.6	1.694	418	2 258	2 676	1.303	7.360
110	102.3	1.549	429	2 251	2 680	1.333	7.328
120	104.8	1.428	439	2 244	2 683	1.361	7.300
130	107.1	1.325	449	2 238	2 687	1.387	7.272
140	109.3	1.236	458	2 232	2 690	1.411	7.247
150	111.4	1.159	467	2 226	2 693	1.434	7.223
160	113.3	1.091	475	2 221	2 696	1.455	7.202
170	115.2	1.031	483	2 216	2 699	1.475	7.181
180	116.9	0.977 2	491	2 211	2 702	1.494	7.162
190	118.6	0.929 0	498	2 206	2 704	1.513	7.144
200	120.2	0.885 4	505	2 202	2 707	1.530	7.127
210	121.8	0.845 9	511	2 197	2 708	1.547	7.111
220	123.3	0.809 8	518	2 193	2 711	1.563	7.095
230	124.7	0.776 8	524	2 189	2 713	1.578	7.080
240	126.1	0.746 5	530	2 185	2 715	1.593	7.066
250	127.4	0.718 4	535	2 181	2 716	1.607	7.052
260	128.7	0.692 5	541	2 177	2 718	1.621	7.039
270	130.0	0.668 4	546	2 174	2 720	1.634	7.026
280	131.2	0.646 0	551	2 170	2 721	1.647	7.014
290	132.4	0.625 1	557	2 167	2 724	1.660	7.002
300	133.5	0.605 6	561	2 163	2 724	1.672	6.991
310	134.7	0.587 2	566	2 160	2 726	1.683	6.980
320	135.8	0.570 0	571	2 157	2 728	1.695	6.969
330	136.8	0.553 8	576	2 154	2 730	1.706	6.959
340	137.9	0.538 5	580	2 150	2 730	1.717	6.949
350	138.9	0.524 0	584	2 147	2 731	1.727	6.939
360	139.9	0.510 3	589	2 144	2 733	1.738	6.930
370	140.8	0.497 4	593	2 141	2 734	1.748	6.921

p	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m³/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg.K	kJ/kg.K
380	141.8	0.485 1	597	2 139	2 736	1.757	6.912
390	142.7	0.473 4	601	2 136	2 737	1.767	6.903
400	143.6	0.462 2	605	2 133	2 738	1.776	6.894
410	144.5	0.451 6	609	2 130	2 739	1.786	6.886
420	145.4	0.441 5	612	2 128	2 740	1.795	6.878
430	146.3	0.431 8	616	2 125	2 741	1.803	6.870
440	147.1	0.422 6	620	2 122	2 742	1.812	6.862
450	147.9	0.413 8	624	2 120	2 744	1.820	6.855
460	148.7	0.405 3	627	2 117	2 744	1.829	6.847
470	149.5	0.397 2	630	2 115	2 745	1.837	6.840
480	150.3	0.389 4	634	2 112	2 746	1.845	6.833
490	151.1	0.381 9	637	2 110	2 747	1.853	6.826
500	151.8	0.374 7	640	2 107	2 747	1.860	6.819
520	153.3	0.361 1	647	2 103	2 750	1.875	6.806
540	154.8	0.348 5	653	2 098	2 751	1.890	6.793
560	156.2	0.336 7	659	2 094	2 753	1.904	6.781
580	157.5	0.325 7	665	2 089	2 754	1.918	6.769
600	158.8	0.315 5	670	2 085	2 755	1.931	6.758
620	160.1	0.305 9	676	2 081	2 757	1.944	6.746
640	161.4	0.296 8	682	2 077	2 759	1.956	6.736
660	162.6	0.288 3	687	2 073	2 760	1.968	6.725
680	163.8	0.280 3	692	2 069	2 761	1.980	6.715
700	165.0	0.272 7	697	2 065	2 762	1.992	6.705
720	166.1	0.265 5	702	2 061	2 763	2.003	6.696
740	167.2	0.258 7	707	2 057	2 764	2.014	6.686
760	168.3	0.252 2	712	2 054	2 766	2.025	6.677
780	169.4	0.246 1	717	2 050	2 767	2.035	6.668
800	170.4	0.240 3	721	2 047	2 768	2.046	6.660
820	171.4	0.234 7	725	2 043	2 768	2.056	6.651
840	172.5	0.229 4	730	2 040	2 770	2.066	6.643
860	173.4	0.224 3	734	2 036	2 770	2.075	6.635
880	174.4	0.219 5	739	2 033	2 772	2.085	6.627
900	175.4	0.214 8	743	2 030	2 773	2.094	6.619
920	176.3	0.210 4	747	2 026	2 773	2.103	6.612
940	177.2	0.206 1	751	2 023	2 774	2.112	6.604
960	178.1	0.202 0	755	2 020	2 775	2.121	6.597
980	179.0	0.198 1	759	2 017	2 776	2.130	6.590
1 000	179.9	0.194 3	763	2 014	2 777	2.138	6.583
1 050	182.0	0.185 5	772	2 006	2 778	2.159	6.566
1 100	184.1	0.177 4	781	1 999	2 780	2.179	6.550
1 150	186.1	0.170 0	790	1 991	2 781	2.198	6.534
1 200	188.0	0.163 2	798	1 984	2 782	2.216	6.519
1 250	189.8	0.156 9	807	1 977	2 784	2.234	6.505
1 300	191.6	0.151 1	815	1 971	2 786	2.251	6.491

p kPa	t_s °C	v_g m³/kg	h_f kJ/kg	h_g kJ/kg	h_g kJ/kg	s_f kJ/kg·K	s_g kJ/kg·K
1 350	193.4	0.145 7	823	1 964	2 787	2,268	6,478
1 400	195.0	0.140 7	830	1 958	2 788	2,284	6,465
1 450	196.7	0.136 0	838	1 951	2 789	2,299	6,453
1 500	198.3	0.131 7	845	1 945	2 790	2,315	6,441
1 550	199.9	0.127 5	852	1 939	2 791	2,330	6,429
1 600	201.4	0.123 7	859	1 933	2 792	2,344	6,418
1 650	202.9	0.120 1	865	1 927	2 792	2,358	6,407
1 700	204.3	0.116 6	872	1 922	2 794	2,371	6,396
1 750	205.7	0.113 4	878	1 916	2 794	2,385	6,385
1 800	207.1	0.110 3	885	1 910	2 795	2,398	6,375
1 850	208.6	0.107 4	891	1 905	2 796	2,410	6,365
1 900	209.8	0.104 7	897	1 899	2 796	2,423	6,355
1 950	211.1	0.102 0	903	1 894	2 797	2,435	6,346
2 000	212.4	0.099 54	908	1 889	2 797	2,447	6,337
2 050	213.6	0.097 16	914	1 883	2 797	2,459	6,328
2 100	214.9	0.094 89	920	1 878	2 798	2,470	6,319
2 150	216.1	0.092 72	926	1 873	2 799	2,481	6,310
2 200	217.2	0.090 65	931	1 868	2 799	2,492	6,302
2 250	218.4	0.088 67	936	1 863	2 799	2,503	6,293
2 300	219.6	0.086 77	942	1 858	2 800	2,514	6,285
2 350	220.7	0.084 95	947	1 853	2 800	2,524	6,277
2 400	221.8	0.083 20	952	1 849	2 801	2,534	6,269
2 450	222.9	0.081 52	957	1 844	2 801	2,544	6,261
2 500	223.9	0.079 91	962	1 839	2 801	2,554	6,254
2 550	225.0	0.078 35	967	1 834	2 801	2,564	6,246
2 600	226.0	0.076 86	972	1 830	2 802	2,574	6,239
2 650	227.1	0.075 41	977	1 825	2 802	2,583	6,232
2 700	228.1	0.074 02	981	1 821	2 802	2,592	6,224
2 750	229.1	0.072 68	986	1 816	2 802	2,602	6,217
2 800	230.1	0.071 39	991	1 811	2 802	2,611	6,210
2 850	231.0	0.070 14	995	1 807	2 802	2,620	6,204
2 900	232.0	0.068 93	1 000	1 802	2 802	2,628	6,197
2 950	232.9	0.067 76	1 004	1 798	2 802	2,637	6,190
3 000	233.8	0.066 63	1 008	1 794	2 802	2,646	6,184
3 100	235.7	0.064 47	1 017	1 785	2 802	2,662	6,171
3 200	237.5	0.062 44	1 025	1 777	2 802	2,679	6,159
3 300	239.2	0.060 53	1 034	1 768	2 802	2,695	6,146
3 400	240.9	0.058 73	1 042	1 760	2 802	2,710	6,134
3 500	242.5	0.057 03	1 050	1 752	2 802	2,725	6,123
3 600	244.2	0.055 41	1 058	1 744	2 802	2,740	6,112
3 700	245.8	0.053 89	1 065	1 736	2 801	2,755	6,100
3 800	247.3	0.052 44	1 073	1 728	2 801	2,769	6,090
3 900	248.8	0.051 06	1 080	1 721	2 801	2,783	6,079
4 000	250.3	0.049 75	1 087	1 713	2 800	2,797	6,069

p kPa	t_s °C	v_g m³/kg	h_f kJ/kg	h_g kJ/kg	h_g kJ/kg	s_f kJ/kg·K	s_g kJ/kg·K
4 100	251.8	0.048 50	1 095	1 705	2 800	2,810	6,058
4 200	253.2	0.047 31	1 102	1 698	2 800	2,823	6,048
4 300	254.7	0.046 17	1 109	1 690	2 799	2,836	6,038
4 400	256.1	0.045 08	1 115	1 683	2 798	2,849	6,029
4 500	257.4	0.044 04	1 122	1 676	2 798	2,861	6,019
4 600	258.8	0.043 04	1 129	1 668	2 797	2,874	6,010
4 700	260.1	0.042 08	1 135	1 661	2 796	2,886	6,000
4 800	261.4	0.041 16	1 142	1 654	2 796	2,897	5,991
4 900	262.7	0.040 28	1 148	1 647	2 795	2,909	5,982
5 000	263.9	0.039 43	1 155	1 640	2 795	2,921	5,974
5 100	265.2	0.038 61	1 161	1 633	2 794	2,932	5,965
5 200	266.4	0.037 82	1 167	1 626	2 793	2,943	5,956
5 300	267.6	0.037 07	1 173	1 619	2 792	2,954	5,948
5 400	268.8	0.036 33	1 179	1 612	2 791	2,965	5,939
5 500	269.9	0.035 63	1 185	1 605	2 790	2,976	5,931
5 600	271.1	0.034 95	1 191	1 598	2 789	2,986	5,923
5 700	272.2	0.034 29	1 197	1 591	2 788	2,997	5,915
5 800	273.4	0.033 65	1 202	1 585	2 787	3,007	5,907
5 900	274.5	0.033 03	1 208	1 578	2 786	3,017	5,899
6 000	275.6	0.032 44	1 214	1 571	2 785	3,027	5,891
6 200	277.7	0.031 30	1 225	1 558	2 783	3,047	5,875
6 400	279.8	0.030 23	1 236	1 545	2 781	3,066	5,860
6 600	281.8	0.029 22	1 247	1 532	2 779	3,085	5,845
6 800	283.8	0.028 27	1 257	1 519	2 776	3,104	5,831
7 000	285.8	0.027 37	1 267	1 506	2 773	3,122	5,816
7 200	287.7	0.026 52	1 278	1 493	2 771	3,140	5,802
7 400	289.6	0.025 72	1 288	1 481	2 769	3,157	5,788
7 600	291.4	0.024 95	1 298	1 468	2 766	3,174	5,774
7 800	293.2	0.024 22	1 307	1 455	2 762	3,191	5,761
8 000	295.0	0.023 53	1 317	1 443	2 760	3,208	5,747
8 200	296.7	0.022 86	1 327	1 430	2 757	3,224	5,734
8 400	298.4	0.022 23	1 336	1 418	2 754	3,240	5,721
8 600	300.1	0.021 63	1 345	1 406	2 751	3,256	5,708
8 800	301.7	0.021 05	1 355	1 393	2 748	3,271	5,695
9 000	303.3	0.020 50	1 364	1 381	2 745	3,287	5,682
9 200	304.9	0.019 96	1 373	1 369	2 742	3,302	5,669
9 400	306.4	0.019 45	1 382	1 356	2 738	3,317	5,657
9 600	308.0	0.018 97	1 391	1 344	2 735	3,332	5,644
9 800	309.5	0.018 49	1 399	1 332	2 731	3,346	5,632
10 000	311.0	0.018 04	1 408	1 320	2 728	3,361	5,620
10 400	313.4	0.017 18	1 425	1 295	2 720	3,389	5,596
10 800	316.7	0.016 39	1 442	1 271	2 713	3,417	5,572
11 200	319.4	0.015 64	1 459	1 247	2 706	3,444	5,548
11 600	322.1	0.014 94	1 475	1 222	2 697	3,471	5,524

Properties of Superheated Steam

P kPa	t_s °C	v_g m³/kg	h_f kJ/kg	h_{fg} kJ/kg	h_g kJ/kg	s_f kJ/kg·K	s_g kJ/kg·K
12 000	324.7	0.014 28	1 492	1 197	2 689	3.497	5.600
12 400	327.2	0.013 66	1 508	1 173	2 681	3.523	5.477
12 800	329.6	0.013 08	1 524	1 148	2 672	3.549	5.453
13 200	332.0	0.012 52	1 540	1 122	2 662	3.574	5.429
13 600	334.4	0.012 00	1 556	1 097	2 653	3.599	5.405
14 000	336.6	0.011 50	1 572	1 071	2 643	3.624	5.380
14 400	338.9	0.011 02	1 587	1 044	2 631	3.648	5.356
14 800	341.1	0.010 56	1 603	1 018	2 621	3.674	5.331
15 200	343.2	0.010 12	1 619	990	2 609	3.698	5.305
15 600	345.3	0.009 707	1 635	963	2 598	3.723	5.279
16 000	347.3	0.009 308	1 651	934	2 585	3.747	5.253
16 400	349.3	0.008 925	1 667	906	2 573	3.772	5.227
16 800	351.3	0.008 553	1 683	876	2 559	3.797	5.199
17 200	353.2	0.008 191	1 700	844	2 544	3.824	5.171
17 600	355.1	0.007 839	1 718	812	2 530	3.850	5.143
18 000	357.0	0.007 498	1 735	779	2 514	3.877	5.113
18 400	358.8	0.007 165	1 752	745	2 497	3.903	5.082
18 800	360.6	0.006 839	1 770	710	2 480	3.929	5.050
19 200	362.3	0.006 517	1 788	673	2 461	3.957	5.016
19 600	364.0	0.006 198	1 807	634	2 441	3.985	4.980
20 000	365.7	0.005 877	1 827	592	2 419	4.015	4.941

P kPa		t_{sup}									
		50°	100°	150°	200°	250°	300°	400°	500°		
1	v_{sup} h_{sup} s_{sup}	149.1 2 595 8.241	172.2 2 689 9.512	195.3 2 784 9.751	218.4 2 880 9.966	241.4 2 978 10.163	264.5 3 077 10.344	310.7 3 280 10.670	356.8 3 489 10.980		
5	v_{sup} h_{sup} s_{sup}	29.78 2 594 8.496	34.42 2 688 8.768	39.04 2 784 9.008	43.66 2 880 9.223	48.28 2 978 9.420	52.90 3 077 9.601	62.13 3 280 9.927	71.36 3 489 10.217		
10	v_{sup} h_{sup} s_{sup}	14.87 2 592 8.173	17.20 2 688 8.447	19.51 2 783 8.688	21.83 2 880 8.903	24.14 2 977 9.100	26.45 3 077 9.281	31.06 3 280 9.607	35.68 3 489 9.987		
50	v_{sup} h_{sup} s_{sup}		3.420 2 683 7.694	3.890 2 780 7.940	4.356 2 878 8.158	4.821 2 976 8.355	5.284 3 076 8.537	6.209 3 279 8.864	7.134 3 489 9.154		
75	v_{sup} h_{sup} s_{sup}		2.271 2 680 7.500	2.568 2 779 7.750	2.901 2 877 7.969	3.211 2 975 8.167	3.521 3 075 8.349	4.136 3 279 8.676	4.765 3 489 8.967		
100	v_{sup} h_{sup} s_{sup}		1.696 2 676 7.36	1.937 2 777 7.614	2.173 2 876 7.834	2.406 2 975 8.033	2.639 3 075 8.215	3.103 3 278 8.543	3.505 3 488 8.834		
150	v_{sup} h_{sup} s_{sup}			1.286 2 773 7.420	1.445 2 873 7.643	1.601 2 973 7.843	1.757 3 073 8.027	2.067 3 277 8.355	2.376 3 488 8.646		
200	v_{sup} h_{sup} s_{sup}			0.960 2 2 770 7.280	1.081 2 871 7.507	1.199 2 971 7.708	1.316 3 072 7.892	1.549 3 277 8.221	1.781 3 487 8.513		
300	v_{sup} h_{sup} s_{sup}			0.634 2 2 762 7.078	0.716 6 2 866 7.312	0.796 5 2 968 7.517	0.875 4 3 070 7.702	1.031 3 275 8.032	1.187 3 486 8.324		
400	v_{sup} h_{sup} s_{sup}			0.471 2 753 6.929	0.534 5 2 862 7.172	0.595 3 2 965 7.379	0.654 9 3 067 7.566	0.772 5 3 274 7.898	0.889 3 3 485 8.191		

p kPa	t _{sup}										
	200°	250°	300°	350°	400°	450°	500°	600°	700°	800°	900°
500	V _{sup}	0,425 2	0,474 5	0,522 6	0,570 1	0,617 2	0,664 1	0,710 8	0,757 4	0,804	0,851
	h _{sup}	2 857	2 962	3 065	3 168	3 272	3 377	3 484	3 592	3 702	3 811
	S _{sup}	7,060	7,271	7,460	7,633	7,793	7,944	8,087	8,224	8,351	8,479
600	V _{sup}	0,352 2	0,394	0,434 4	0,474 3	0,513 6	0,552 8	0,591 9	0,630 7	0,669 7	0,708 7
	h _{sup}	2 851	2 958	3 062	3 166	3 270	3 376	3 483	3 591	3 701	3 811
	S _{sup}	6,968	7,182	7,373	7,546	7,707	7,858	8,001	8,138	8,267	8,396
700	V _{sup}	0,300 1	0,336 4	0,371 4	0,405 8	0,439 7	0,473 4	0,506 9	0,539 7	0,573 7	0,607 7
	h _{sup}	2 846	2 955	3 060	3 164	3 269	3 374	3 482	3 590	3 700	3 810
	S _{sup}	6,888	7,106	7,298	7,473	7,634	7,786	7,929	8,066	8,195	8,324
800	V _{sup}	0,281	0,293 3	0,324 2	0,354 4	0,384 2	0,413 8	0,443 2	0,472 6	0,501 8	0,531 0
	h _{sup}	2 840	2 951	3 057	3 162	3 267	3 373	3 481	3 589	3 699	3 809
	S _{sup}	6,817	7,040	7,233	7,409	7,571	7,723	7,866	8,003	8,132	8,261
900	V _{sup}	0,230 5	0,259 7	0,287 4	0,314 4	0,341	0,367 4	0,393 7	0,419 8	0,445 8	0,471 8
	h _{sup}	2 835	2 948	3 055	3 160	3 266	3 372	3 480	3 588	3 696	3 804
	S _{sup}	6,753	6,980	7,176	7,352	7,515	7,667	7,811	7,948	8,085	8,222
1 000	V _{sup}	0,206 1	0,232 8	0,258	0,282 5	0,306 5	0,330 3	0,354	0,378	0,401	0,425
	h _{sup}	2 829	2 944	3 052	3 158	3 264	3 370	3 478	3 586	3 694	3 802
	S _{sup}	6,695	6,926	7,124	7,301	7,464	7,617	7,761	7,898	8,035	8,172
1 500	V _{sup}	0,132 4	0,152	0,169 7	0,186 5	0,202 9	0,219 1	0,235 1	0,251 1	0,266 7	0,282 3
	h _{sup}	2 796	2 925	3 039	3 148	3 256	3 364	3 473	3 582	3 691	3 800
	S _{sup}	6,452	6,711	6,919	7,102	7,268	7,423	7,569	7,707	7,844	7,981
2 000	V _{sup}	0,111 5	0,125 5	0,138 6	0,151 1	0,163 4	0,175 6	0,187 8	0,199 9	0,211 9	0,223 9
	h _{sup}	2 904	3 025	3 138	3 248	3 357	3 467	3 577	3 687	3 797	3 907
	S _{sup}	6,547	6,768	6,957	7,126	7,283	7,431	7,570	7,709	7,848	7,987
3 000	V _{sup}	0,070 6	0,081 2	0,090 5	0,099 3	0,107 8	0,116 1	0,124 4	0,132 6	0,140 8	0,149 0
	h _{sup}	2 858	2 995	3 117	3 231	3 343	3 455	3 567	3 679	3 791	3 903
	S _{sup}	6,289	6,541	6,744	6,921	7,082	7,233	7,375	7,517	7,659	7,801
4 000	V _{sup}	0,058 8	0,066 4	0,072 3	0,077 3	0,082 3	0,087 3	0,092 3	0,097 3	0,102 3	0,107 3
	h _{sup}	2 963	3 094	3 214	3 324	3 434	3 544	3 654	3 764	3 874	3 984
	S _{sup}	6,364	6,584	6,769	6,935	7,089	7,233	7,375	7,517	7,659	7,801
5 000	V _{sup}	0,045 3	0,051 9	0,057 8	0,063 2	0,068 5	0,073 8	0,079 1	0,084 4	0,089 7	0,095 0
	h _{sup}	2 927	3 070	3 196	3 316	3 436	3 556	3 676	3 796	3 916	4 036
	S _{sup}	6,212	6,451	6,646	6,818	6,975	7,129	7,283	7,437	7,591	7,745
6 000	V _{sup}	0,038 2	0,042 2	0,047 3	0,052 1	0,056 8	0,061 5	0,066 2	0,070 9	0,075 6	0,080 3
	h _{sup}	2 887	3 045	3 177	3 301	3 421	3 541	3 661	3 781	3 901	4 021
	S _{sup}	6,071	6,336	6,541	6,719	6,879	7,039	7,199	7,359	7,519	7,679
7 000	V _{sup}	0,029 5	0,031 8	0,033 9	0,035 8	0,037 7	0,039 6	0,041 5	0,043 4	0,045 3	0,047 2
	h _{sup}	2 841	3 018	3 158	3 287	3 416	3 545	3 674	3 803	3 932	4 061
	S _{sup}	5,934	6,231	6,448	6,632	6,803	6,964	7,125	7,286	7,447	7,608

p kPa	t _{sup}										
	350°	375°	400°	425°	450°	500°	600°	700°	800°	900°	1 000°
8 000	V _{sup}	0,029 94	0,032 2	0,034 28	0,036 25	0,038 12	0,041 7	0,045 76	0,049 76	0,053 76	0,057 76
	h _{sup}	2 990	3 067	3 139	3 207	3 272	3 338	3 404	3 470	3 536	3 602
	S _{sup}	6,133	6,255	6,364	6,463	6,555	6,643	6,731	6,819	6,907	6,995
9 000	V _{sup}	0,025 78	0,027 94	0,029 91	0,031 73	0,033 46	0,035 73	0,038 76	0,041 76	0,044 76	0,047 76
	h _{sup}	2 959	3 042	3 118	3 189	3 256	3 323	3 390	3 457	3 524	3 591
	S _{sup}	6,039	6,171	6,286	6,390	6,484	6,577	6,670	6,763	6,856	6,949
10 000	V _{sup}	0,022 41	0,024 53	0,026 39	0,028 12	0,029 72	0,031 73	0,033 76	0,035 76	0,037 76	0,039 76
	h _{sup}	2 926	3 017	3 097	3 172	3 241	3 313	3 384	3 455	3 526	3 597
	S _{sup}	5,947	6,091	6,213	6,321	6,419	6,516	6,613	6,710	6,807	6,904
11 000	V _{sup}	0,019 6	0,021 69	0,023 5	0,025 14	0,026 66	0,028 49	0,030 65	0,032 76	0,034 87	0,036 98
	h _{sup}	2 889	2 989	3 075	3 153	3 225	3 300	3 374	3 448	3 522	3 596
	S _{sup}	5,856	6,014	6,143	6,257	6,358	6,459	6,559	6,659	6,759	6,859
12 000	V _{sup}	0,017 19	0,019 31	0,021 07	0,022 65	0,024 1	0,025 77	0,027 59	0,029 41	0,031 23	0,033 05
	h _{sup}	2 849	2 960	3 052	3 134	3 209	3 284	3 358	3 432	3 506	3 580
	S _{sup}	5,762	5,937	6,076	6,195	6,301	6,407	6,513	6,619	6,725	6,831
13 000	V _{sup}	0,015 09	0,017 28	0,019 01	0,020 53	0,021 93	0,023 47	0,025 19	0,026 91	0,028 63	0,030 35
	h _{sup}	2 804	2 929	3 028	3 114	3 192	3 266	3 340	3 414	3 488	3 562
	S _{sup}	5,664	5,862	6,011	6,136	6,246	6,356	6,466	6,576	6,686	6,796
14 000	V _{sup}	0,013 21	0,015 48	0,017 22	0,018 72	0,020 06	0,021 5	0,023 29	0,025 03	0,026 77	0,028 51
	h _{sup}	2 753	2 886	3 003	3 093	3 175	3 252	3 326	3 399	3 473	3 547
	S _{sup}	5,559	5,784	5,946	6,079	6,193	6,307	6,421	6,535	6,649	6,763
15 000	V _{sup}	0,011 46	0,013 91	0,015 66	0,017 14	0,018 44	0,019 78	0,021 12	0,022 46	0,023 80	0,025 14
	h _{sup}	2 693	2 861	2 977	3 073	3 157	3 239	3 321	3 403	3 485	3 567
	S _{sup}	5,443	5,707	5,883	6,023	6,142	6,261	6,380	6,499	6,618	6,737
16 000	V _{sup}	0,009 76	0,012 48	0,014 27	0,015 73	0,017 02	0,018 28	0,019 54	0,020 80	0,022 06	0,023 32
	h _{sup}	2 617	2 821	2 948	3 051	3 139	3 225	3 311	3 397	3 483	3 569
	S _{sup}	5,304	5,626	5,820	5,968	6,093	6,219	6,345	6,471	6,597	6,723
17 000	V _{sup}	0,008 17	0,011 17	0,013 03	0,014 49	0,015 76	0,017 06	0,018 36	0,019 66	0,020 96	0,022 26
	h _{sup}	2 578	2 778	2 920	3 028	3 121	3 207	3 293	3 379	3 465	3 551
	S _{sup}	5,141	5,541	5,756	5,914	6,044	6,170	6,296	6,422	6,548	6,674
18 000	V _{sup}	0,006 97	0,009 97	0,011 91	0,013 38	0,014 63	0,015 88	0,017 13	0,018 38	0,019 63	0,020 88
	h _{sup}	2 543	2 729	2 888	3 004	3 102	3 188	3 274	3 360	3 446	3 532
	S _{sup}	5,009	5,449	5,691	5,861	5,997	6,123	6,249	6,375	6,501	6,627
19 000	V _{sup}	0,005 82	0,008 82	0,010 89	0,012 36	0,013 62	0,014 87	0,016 12	0,017 37	0,018 62	0,019 87
	h _{sup}	2 509	2 674	2 855	2 980	3 082	3 168	3 254	3 340	3 426	3 512
	S _{sup}	4,875	5,346	5,625	5,807	5,950	6,076	6,202	6,328	6,454	6,580
20 000	V _{sup}	0,004 60	0,007 60	0,009 95	0,011 47	0,012 7	0,013 92	0,015 17	0,016 42	0,017 67	0,018 92
	h _{sup}	2 465	2 605	2 819	2 955	3 062	3 148	3 234	3 320	3 406	3 492
	S _{sup}	4,741	5,228	5,556	5,753	5,904	6,030	6,156	6,282	6,408	6,534

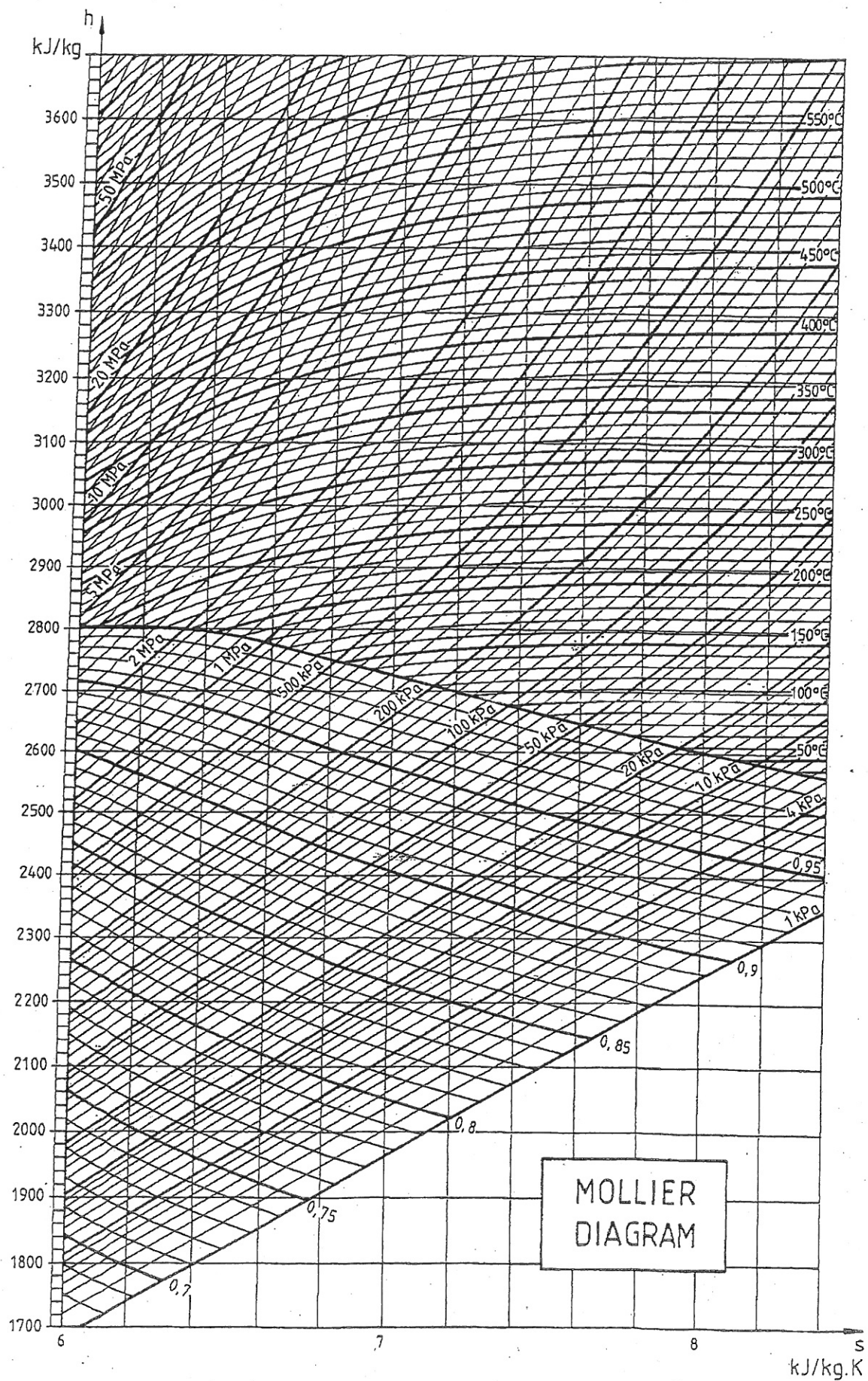


TABLE A-5

Saturated water—Pressure table

Press., <i>P</i> kPa	Sat. temp., <i>T</i> _{sat} °C	Specific volume, m ³ /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, <i>v</i> _f	Sat. vapor, <i>v</i> _g	Sat. liquid, <i>u</i> _f	Evap., <i>u</i> _{fg}	Sat. vapor, <i>u</i> _g	Sat. liquid, <i>h</i> _f	Evap., <i>h</i> _{fg}	Sat. vapor, <i>h</i> _g	Sat. liquid, <i>s</i> _f	Evap., <i>s</i> _{fg}	Sat. vapor, <i>s</i> _g
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2405.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207
300	133.52	0.001073	0.60582	561.11	1982.1	2543.2	561.43	2163.5	2724.9	1.6717	5.3200	6.9917
325	136.27	0.001076	0.56199	572.84	1973.1	2545.9	573.19	2155.4	2728.6	1.7005	5.2645	6.9650
350	138.86	0.001079	0.52422	583.89	1964.6	2548.5	584.26	2147.7	2732.0	1.7274	5.2128	6.9402
375	141.30	0.001081	0.49133	594.32	1956.6	2550.9	594.73	2140.4	2735.1	1.7526	5.1645	6.9171
400	143.61	0.001084	0.46242	604.22	1948.9	2553.1	604.66	2133.4	2738.1	1.7765	5.1191	6.8955
450	147.90	0.001088	0.41392	622.65	1934.5	2557.1	623.14	2120.3	2743.4	1.8205	5.0356	6.8561
500	151.83	0.001093	0.37483	639.54	1921.2	2560.7	640.09	2108.0	2748.1	1.8604	4.9603	6.8207
550	155.46	0.001097	0.34261	655.16	1908.8	2563.9	655.77	2096.6	2752.4	1.8970	4.8916	6.7886
600	158.83	0.001101	0.31560	669.72	1897.1	2566.8	670.38	2085.8	2756.2	1.9308	4.8285	6.7593
650	161.98	0.001104	0.29260	683.37	1886.1	2569.4	684.08	2075.5	2759.6	1.9623	4.7699	6.7322
700	164.95	0.001108	0.27278	696.23	1875.6	2571.8	697.00	2065.8	2762.8	1.9918	4.7153	6.7071
750	167.75	0.001111	0.25552	708.40	1865.6	2574.0	709.24	2056.4	2765.7	2.0195	4.6642	6.6837

Saturated Water and Steam

t [°C]	p_s [bar]	v_g [m³/kg]	h_f	h_{fg} [kJ/kg]	h_g	s_f	s_{fg} [kJ/kg K]	s_g
0.01	0.006112	206.1	0*	2500.8	2500.8	0†	9.155	9.155
1	0.006566	192.6	4.2	2498.3	2502.5	0.015	9.113	9.128
2	0.007054	179.9	8.4	2495.9	2504.3	0.031	9.071	9.102
3	0.007575	168.2	12.6	2493.6	2506.2	0.046	9.030	9.076
4	0.008129	157.3	16.8	2491.3	2508.1	0.061	8.989	9.050
5	0.008719	147.1	21.0	2488.9	2509.9	0.076	8.948	9.024
6	0.009346	137.8	25.2	2486.6	2511.8	0.091	8.908	8.999
7	0.01001	129.1	29.4	2484.3	2513.7	0.106	8.868	8.974
8	0.01072	121.0	33.6	2481.9	2515.5	0.121	8.828	8.949
9	0.01147	113.4	37.8	2479.6	2517.4	0.136	8.788	8.924
10	0.01227	106.4	42.0	2477.2	2519.2	0.151	8.749	8.900
11	0.01312	99.90	46.2	2474.9	2521.1	0.166	8.710	8.876
12	0.01401	93.83	50.4	2472.5	2522.9	0.180	8.671	8.851
13	0.01497	88.17	54.6	2470.2	2524.8	0.195	8.633	8.828
14	0.01597	82.89	58.8	2467.8	2526.6	0.210	8.594	8.804
15	0.01704	77.97	62.9	2465.5	2528.4	0.224	8.556	8.780
16	0.01817	73.38	67.1	2463.1	2530.2	0.239	8.518	8.757
17	0.01936	69.09	71.3	2460.8	2532.1	0.253	8.481	8.734
18	0.02063	65.08	75.5	2458.4	2533.9	0.268	8.444	8.712
19	0.02196	61.34	79.7	2456.0	2535.7	0.282	8.407	8.689
20	0.02337	57.84	83.9	2453.7	2537.6	0.296	8.370	8.666
21	0.02486	54.56	88.0	2451.4	2539.4	0.310	8.334	8.644
22	0.02642	51.49	92.2	2449.0	2541.2	0.325	8.297	8.622
23	0.02808	48.62	96.4	2446.6	2543.0	0.339	8.261	8.600
24	0.02982	45.92	100.6	2444.2	2544.8	0.353	8.226	8.579
25	0.03166	43.40	104.8	2441.8	2546.6	0.367	8.190	8.557
26	0.03360	41.03	108.9	2439.5	2548.4	0.381	8.155	8.536
27	0.03564	38.81	113.1	2437.2	2550.3	0.395	8.120	8.515
28	0.03778	36.73	117.3	2434.8	2552.1	0.409	8.085	8.494
29	0.04004	34.77	121.5	2432.4	2553.9	0.423	8.050	8.473
30	0.04242	32.93	125.7	2430.0	2555.7	0.436	8.016	8.452
32	0.04754	29.57	134.0	2425.3	2559.3	0.464	7.948	8.412
34	0.05318	26.60	142.4	2420.5	2562.9	0.491	7.881	8.372
36	0.05940	23.97	150.7	2415.8	2566.5	0.518	7.814	8.332
38	0.06624	21.63	159.1	2411.0	2570.1	0.545	7.749	8.294
40	0.07375	19.55	167.5	2406.2	2573.7	0.572	7.684	8.256
42	0.08198	17.69	175.8	2401.4	2577.2	0.599	7.620	8.219
44	0.09100	16.03	184.2	2396.6	2580.8	0.625	7.557	8.182
46	0.1009	14.56	192.5	2391.8	2584.3	0.651	7.494	8.145
48	0.1116	13.23	200.9	2387.0	2587.9	0.678	7.433	8.111
50	0.1233	12.04	209.3	2382.1	2591.4	0.704	7.371	8.075
55	0.1574	9.578	230.2	2370.1	2600.3	0.768	7.223	7.991
60	0.1992	7.678	251.1	2357.9	2609.0	0.831	7.078	7.909
65	0.2501	6.201	272.0	2345.7	2617.7	0.893	6.937	7.830
70	0.3116	5.045	293.0	2333.3	2626.3	0.955	6.800	7.755
75	0.3855	4.133	313.9	2320.8	2634.7	1.015	6.666	7.681
80	0.4736	3.408	334.9	2308.3	2643.2	1.075	6.536	7.611
85	0.5780	2.828	355.9	2295.6	2651.5	1.134	6.410	7.544
90	0.7011	2.361	376.9	2282.8	2659.7	1.192	6.286	7.478
95	0.8453	1.982	398.0	2269.8	2667.8	1.250	6.166	7.416
100	1.01325	1.673	419.1	2256.7	2675.8	1.307	6.048	7.355

† u and s are chosen to be zero for saturated liquid at the triple point.

Note: values of v_f can be found on p. 10.

CIBSE PSYCHROMETRIC CHART

BASED ON A BAROMETRIC
PRESSURE OF 101.325 kPa

