



ELIZADE UNIVERSITY, ILARA-MOKIN,
ONDO STATE, NIGERIA

DEPARTMENT OF MECHANICAL ENGINEERING

FIRST SEMESTER EXAMINATIONS
2019/2020 ACADEMIC SESSION

COURSE: MEE 411 – Applied Thermodynamics I (2 Units)
CLASS: 400 Level Mechanical & Automotive Engineering
TIME ALLOWED: 2 Hours: 15 Min.
INSTRUCTIONS Answer Question 1 and any other three (3) Questions.
Date: February, 2020

Question 1 (18 Marks)

- What is the importance of thermodynamic relations?
- State the four (4) Maxwell relations.
- Given that $dg = Vdp - SdT$. Show that:
 - $\left(\frac{ds}{dp}\right)_T = -\left(\frac{dv}{dT}\right)_P$
 - Verify the validity of (i) above for steam at 200 °C and 400 kPa.
- What does Joule-Thomson coefficient represent?
 - Given that Joule-Thomson coefficient is $\mu_{JT} = \frac{1}{c_p} \left[T \left(\frac{\partial v}{\partial T}\right)_P - V \right]$. Estimate μ_{JT} for steam at 400 °C and 0.8 MPa

Question 2 (14 Marks)

- State Amagat's law of additive volumes and Dalton's law of additive pressures
- Consider a gas mixture that consist of 3 kg of O₂, 7 kg of N₂ and 13 kg of CH₄. Determine:
 - Mass fraction of each component,
 - The mole fraction of each component, and
 - The average molar mass and gas constant of the mixture.

Question 3 (14 Marks)

- Define the following:
 - Dew point temperature
 - Wet-bulb temperature
 - Dry-bulb temperature

- The dry- and the wet-bulb temperatures of atmospheric air at 1 atm (101.325 kPa) pressure are measured with a sling psychrometer and determined to be 30 and 20 °C, respectively. Determine:
 - The specific humidity
 - The relative humidity

Question 4 (14 Marks)

- Briefly discuss the four (4) major air-conditioning processes.
 - State the three (3) factors on which the comfort of human body depends
- Consider a room that contains air at 1 atm, 40 °C and 50 percent relative humidity. Use psychrometric chart to determine:
 - The specific humidity
 - The enthalpy (in KJ/Kg dry air)
 - The wet-bulb temperature
 - The dew point temperature, and
 - The specific volume of the air (in m³/kg dry air)

Question 5 (14 Marks)

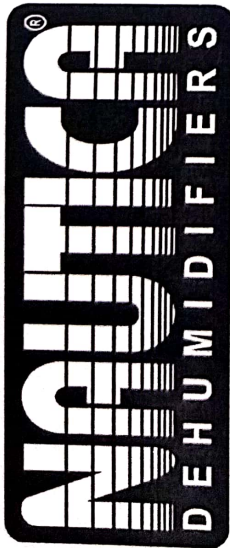
- Outside air at 10 °C and 70 percent relative humidity is heated to 25 °C. Calculate the rate of heat transfer needed if the incoming volume flow rate is 40 m³/min. (Assume P=100 kPa)
- Saturated air leaving the cooling section of an air-conditioning system at 14 °C at a rate of 40 m³/min is mixed adiabatically with the outside air at 32 °C and 60 % relative humidity at a rate of 15 m³/min. Assuming that the mixing process occurs at a pressure of 1 atm, determine the specific humidity and relative humidity of the mixture.

Question 6 (14 Marks)

- With the aid of a diagram, describe the working principle of a forced-draft cooling tower.
- Cooling water leaves the condenser of a power plant and enters a wet cooling tower at 35 °C at a rate of 90 kg/s. The water is cooled to 20 °C in the cooling tower by air that enters the tower at 1 atm, 15 °C, and 60 percent relative humidity and leaves saturated at 30 °C. Neglecting the power input to the fan, determine:
 - The volume flow rate of air into the cooling tower.
 - The mass flow rate of the required make up water.

$$\left[\text{Hint: } \dot{m}_a = \frac{\dot{m}_3(h_3 - h_4)}{(h_2 - h_1) - (\omega_2 - \omega_1)} \right]$$

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**PSYCHROMETRIC
CHART**

Normal Temperature
SI Units

SEA LEVEL

BAROMETRIC PRESSURE: 101.325 kPa

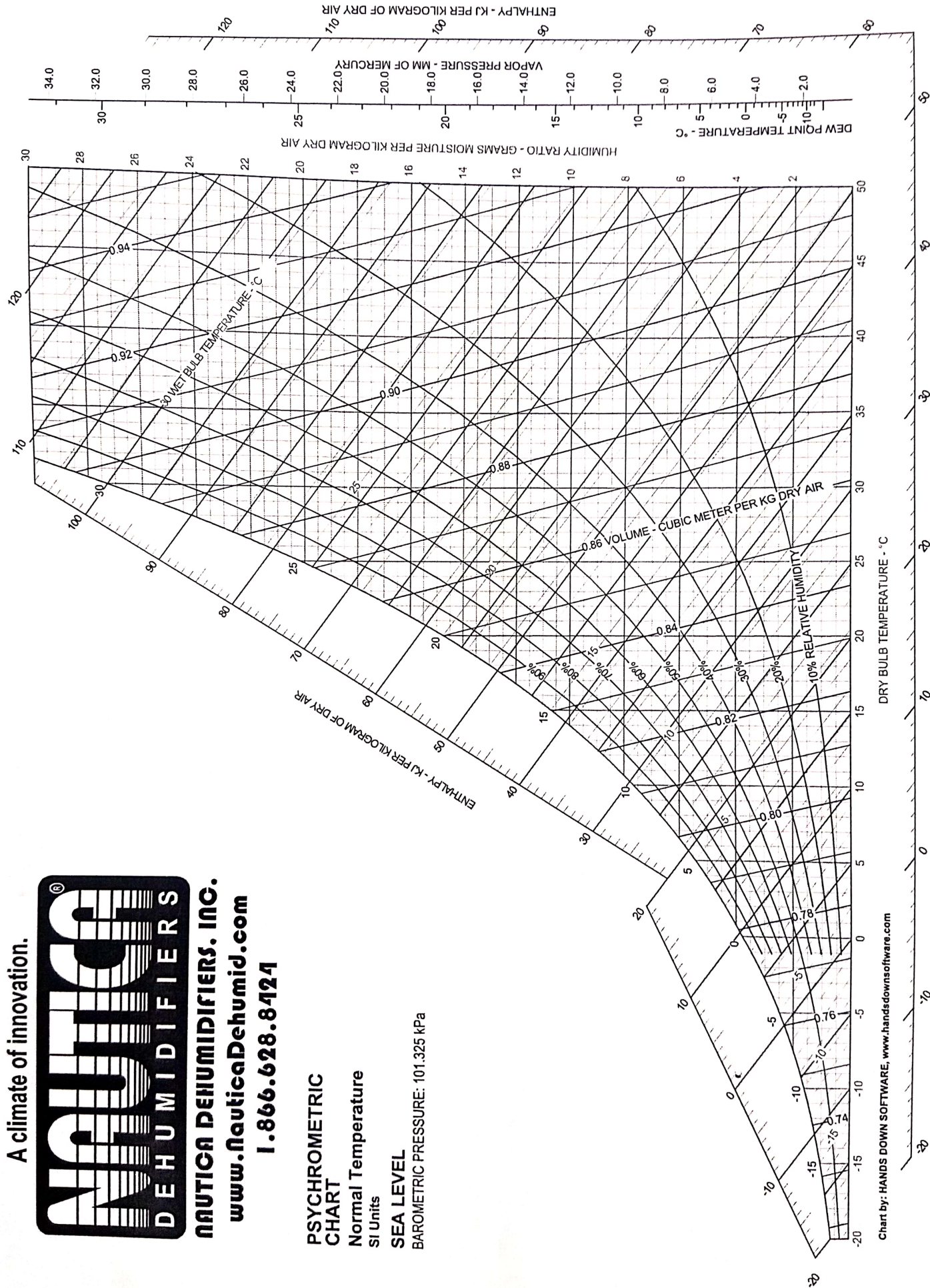


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

TABLE A-4

Saturated water—Temperature table

Temp., T °C	Sat. press., P_{sat} kPa	Specific volume, m^3/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302

TABLE A-6

Superheated water

T °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
$P = 0.01 \text{ MPa (45.81}^\circ\text{C)}^*$				$P = 0.05 \text{ MPa (81.32}^\circ\text{C)}^*$				$P = 0.10 \text{ MPa (99.61}^\circ\text{C)}^*$				
Sat.†	14.670	2437.2	2583.9	8.1488	3.2403	2483.2	2645.2	7.5931	1.6941	2505.6	2675.0	7.3589
50	14.867	2443.3	2592.0	8.1741					1.6959	2506.2	2675.8	7.3611
100	17.196	2515.5	2687.5	8.4489	3.4187	2511.5	2682.4	7.6953	1.9367	2582.9	2776.6	7.6148
150	19.513	2587.9	2783.0	8.6893	3.8897	2585.7	2780.2	7.9413	2.1724	2658.2	2875.5	7.8356
200	21.826	2661.4	2879.6	8.9049	4.3562	2660.0	2877.8	8.1592	2.4062	2733.9	2974.5	8.0346
250	24.136	2736.1	2977.5	9.1015	4.8206	2735.1	2976.2	8.3568	2.6389	2810.7	3074.5	8.2172
300	26.446	2812.3	3076.7	9.2827	5.2841	2811.6	3075.8	8.5387	3.1027	2968.3	3278.6	8.5452
400	31.063	2969.3	3280.0	9.6094	6.2094	2968.9	3279.3	8.8659	3.5655	3132.2	3488.7	8.8362
500	35.680	3132.9	3489.7	9.8998	7.1338	3132.6	3489.3	9.1566	4.0279	3302.8	3705.6	9.0999
600	40.296	3303.3	3706.3	10.1631	8.0577	3303.1	3706.0	9.4201	4.4900	3480.4	3929.4	9.3424
700	44.911	3480.8	3929.9	10.4056	8.9813	3480.6	3929.7	9.6626	4.9519	3665.0	4160.2	9.5682
800	49.527	3665.4	4160.6	10.6312	9.9047	3665.2	4160.4	9.8883	5.4137	3856.7	4398.0	9.7800
900	54.143	3856.9	4398.3	10.8429	10.8280	3856.8	4398.2	10.1000	5.8755	4055.0	4642.6	9.9800
1000	58.758	4055.3	4642.8	11.0429	11.7513	4055.2	4642.7	10.3000	6.3372	4259.8	4893.6	10.1698
1100	63.373	4260.0	4893.8	11.2326	12.6745	4259.9	4893.7	10.4897	6.7988	4470.7	5150.6	10.3504
1200	67.989	4470.9	5150.8	11.4132	13.5977	4470.8	5150.7	10.6704	7.2605	4687.2	5413.3	10.5229
1300	72.604	4687.4	5413.4	11.5857	14.5209	4687.3	5413.3	10.8429				
$P = 0.20 \text{ MPa (120.21}^\circ\text{C)}^*$				$P = 0.30 \text{ MPa (133.52}^\circ\text{C)}^*$				$P = 0.40 \text{ MPa (143.61}^\circ\text{C)}^*$				
Sat.	0.88578	2529.1	2706.3	7.1270	0.60582	2543.2	2724.9	6.9917	0.46242	2553.1	2738.1	6.8955
150	0.95986	2577.1	2769.1	7.2810	0.63402	2571.0	2761.2	7.0792	0.47088	2564.4	2752.8	6.9306
200	1.08049	2654.6	2870.7	7.5081	0.71643	2651.0	2865.9	7.3132	0.53434	2647.2	2860.9	7.1723
250	1.19890	2731.4	2971.2	7.7100	0.79645	2728.9	2967.9	7.5180	0.59520	2726.4	2964.5	7.3804
300	1.31623	2808.8	3072.1	7.8941	0.87535	2807.0	3069.6	7.7037	0.65489	2805.1	3067.1	7.5677
400	1.54934	2967.2	3277.0	8.2236	1.03155	2966.0	3275.5	8.0347	0.77265	2964.9	3273.9	7.9003
500	1.78142	3131.4	3487.7	8.5153	1.18672	3130.6	3486.6	8.3271	0.88936	3129.8	3485.5	8.1933
600	2.01302	3302.2	3704.8	8.7793	1.34139	3301.6	3704.0	8.5915	1.00558	3301.0	3703.3	8.4580
700	2.24434	3479.9	3928.8	9.0221	1.49580	3479.5	3928.2	8.8345	1.12152	3479.0	3927.6	8.7012
800	2.47550	3664.7	4159.8	9.2479	1.65004	3664.3	4159.3	9.0605	1.23730	3663.9	4158.9	8.9274
900	2.70656	3856.3	4397.7	9.4598	1.80417	3856.0	4397.3	9.2725	1.35298	3855.7	4396.9	9.1394
1000	2.93755	4054.8	4642.3	9.6599	1.95824	4054.5	4642.0	9.4726	1.46859	4054.3	4641.7	9.3396
1100	3.16848	4259.6	4893.3	9.8497	2.11226	4259.4	4893.1	9.6624	1.58414	4259.2	4892.9	9.5295
1200	3.39938	4470.5	5150.4	10.0304	2.26624	4470.3	5150.2	9.8431	1.69966	4470.2	5150.0	9.7102
1300	3.63026	4687.1	5413.1	10.2029	2.42019	4686.9	5413.0	10.0157	1.81516	4686.7	5412.8	9.8828
$P = 0.50 \text{ MPa (151.83}^\circ\text{C)}^*$				$P = 0.60 \text{ MPa (158.83}^\circ\text{C)}^*$				$P = 0.80 \text{ MPa (170.41}^\circ\text{C)}^*$				
Sat.	0.37483	2560.7	2748.1	6.8207	0.31560	2566.8	2756.2	6.7593	0.24035	2576.0	2768.3	6.6616
200	0.42503	2643.3	2855.8	7.0610	0.35212	2639.4	2850.6	6.9683	0.26088	2631.1	2839.8	6.8177
250	0.47443	2723.8	2961.0	7.2725	0.39390	2721.2	2957.6	7.1833	0.29321	2715.9	2950.4	7.0402
300	0.52261	2803.3	3064.6	7.4614	0.43442	2801.4	3062.0	7.3740	0.32416	2797.5	3056.9	7.2345
350	0.57015	2883.0	3168.1	7.6346	0.47428	2881.6	3166.1	7.5481	0.35442	2878.6	3162.2	7.4107
400	0.61731	2963.7	3272.4	7.7956	0.51374	2962.5	3270.8	7.7097	0.38429	2960.2	3267.7	7.5735
500	0.71095	3129.0	3484.5	8.0893	0.59200	3128.2	3483.4	8.0041	0.44332	3126.6	3481.3	7.8692
600	0.80409	3300.4	3702.5	8.3544	0.66976	3299.8	3701.7	8.2695	0.50186	3298.7	3700.1	8.1354
700	0.89696	3478.6	3927.0	8.5978	0.74725	3478.1	3926.4	8.5132	0.56011	3477.2	3925.3	8.3794
800	0.98966	3663.6	4158.4	8.8240	0.82457	3663.2	4157.9	8.7395	0.61820	3662.5	4157.0	8.6061
900	1.08227	3855.4	4396.6	9.0362	0.90179	3855.1	4396.2	8.9518	0.67619	3854.5	4395.5	8.8185
1000	1.17480	4054.0	4641.4	9.2364	0.97893	4053.8	4641.1	9.1521	0.73411	4053.3	4640.5	9.0189
1100	1.26728	4259.0	4892.6	9.4263	1.05603	4258.8	4892.4	9.3420	0.79197	4258.3	4891.9	9.2090
1200	1.35972	4470.0	5149.8	9.6071	1.13309	4469.8	5149.6	9.5229	0.84980	4469.4	5149.3	9.3898
1300	1.45214	4686.6	5412.6	9.7797	1.21012	4686.4	5412.5	9.6955	0.90761	4686.1	5412.2	9.5625

*The temperature in parentheses is the saturation temperature at the specified pressure.

† Properties of saturated vapor at the specified pressure.