

# NATIONAL EXAMINATIONS – May 2016

BS-10, Thermodynamics

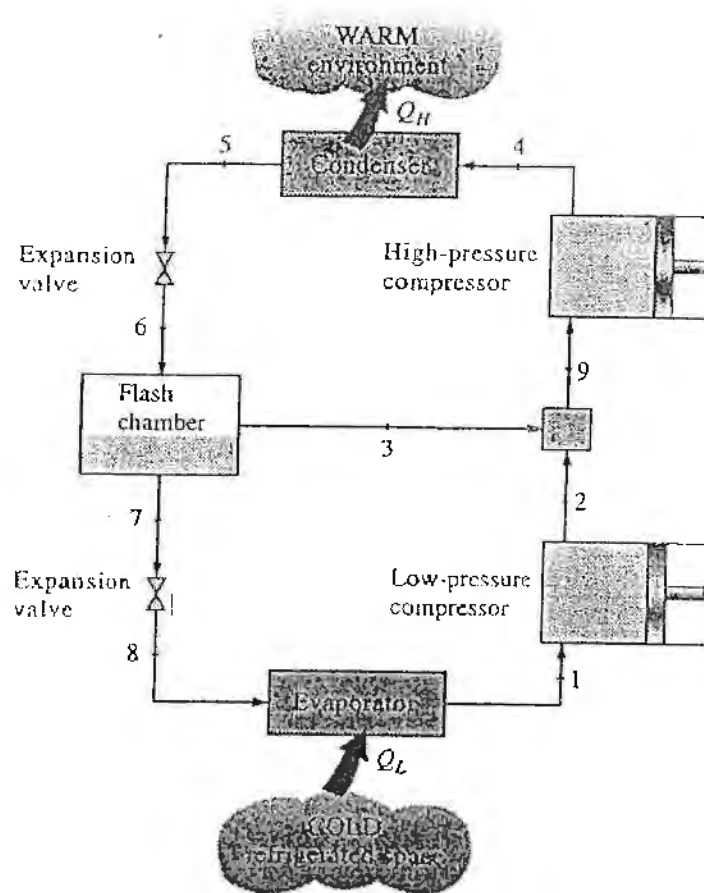
3 Hours Duration

## NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.
  2. Any one of the approved Casio or Sharp calculator models is permitted. This is a "Closed-Book" examination with one 8.5×11 inch sheet of notes (both sides) allowed.
  3. Property tables and charts are provided where necessary. **Interpolation is not necessary. The closest tabular value may be used.**
  4. The **two** questions from part "A" plus **four** questions from part "B" (a total of **six** questions) constitutes a complete paper. Unless clearly indicated otherwise by you, only the first two questions from part "A" and the first four questions from part "B" that you answered will be marked.
  5. The mark associated with each question is specified.
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**PART A. DO ONLY TWO OF QUESTIONS 1, 2, or 3**  
(Each question is worth 20 marks)

1. Water is the working fluid in a vapor power cycle with reheat. Superheated vapor enters the first turbine stage at 8 MPa, 480°C and expands to 0.7 MPa. Then, it is reheated to 480°C before entering the second turbine stage, where it expands to the condenser pressure of 8 kPa. The mass flow rate of steam entering the first turbine stage is  $2.63 \times 10^5$  kg/h. Each turbine stage operates with an isentropic efficiency of 88%. The pump operates with an isentropic efficiency of 80%. Sketch the cycle on a T-s diagram with respect to saturation lines. Determine
- the rate of the heat input to the working fluid, in kW,
  - the rate of the heat rejected from the working fluid, in kW
  - the net power output, in kW, and
  - the thermal efficiency.
2. Consider a regenerative gas turbine with a two-stage air compressor that operates at steady state, compressing  $10 \text{ m}^3/\text{min}$  of air from 100 kPa and 300 K to 1 MPa. An intercooler between the two stages cools the air to 300 K at a constant pressure of 300 kPa. Each compressor stage has an isentropic efficiency of 85%. The turbine inlet temperature is 1300 K and the turbine has an isentropic efficiency of 87%. The regenerator effectiveness is 80%. Show the cycle on a T-s diagram. Accounting for the variation of specific heats with temperature, calculate
- the power required to run the compressor in kW,
  - the thermal efficiency,
  - the rate of heat addition in kW, and
  - the net power developed in kW.
3. A two-state compression refrigeration system as shown in the figure operates with R-134a between the pressure limits of 1 and 0.14 MPa. The refrigerant leaves the condenser as saturated liquid and is throttled to a flash chamber operating at 0.5 MPa. The refrigerant leaving the low-pressure compressor at 0.5 MPa is mixed with the saturated vapor from the flash chamber and the mixture is then compressed to the condenser pressure by the high-pressure compressor, and the liquid is throttled to the evaporator pressure. The mass flow rate of the refrigerant through the condenser is 0.25 kg/s. Assuming the refrigerant leaves the evaporator as saturated vapor and both compressors are isentropic,
- sketch the cycle on a T-s diagram with respect to saturation lines,
  - determine the amount of heat removed from the refrigerated space, in kW,
  - determine the power input to refrigeration system, in kW, and
  - determine the coefficient of performance.



**PART B. DO ONLY FOUR OF QUESTIONS 4, 5, 6, 7, 8 or 9**  
(Each question is worth **15 marks**)

4. An ideal Otto cycle with air as the working fluid has a compression ratio of 8. The minimum and maximum temperatures in the cycle are 310 and 1600 K. Accounting for the variation of specific heats with temperature, determine
- the amount of heat transferred to air during the heat addition process, in kJ/kg,
  - the net work output of the cycle, in kJ/kg, and
  - the thermal efficiency.
5. A mixture of 80% of  $N_2$  and 20% of  $CO_2$  gases (by mole numbers) is compressed isentropically in a compressor. The mixture enters the compressor at 100 kPa and 1000 K and leaves at 500 kPa. Assume constant specific heats at room temperature. Treat the mixture as an ideal gas. Determine the work input to the compressor per unit mass of the mixture.

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6. One kilogram of moist air initially at a pressure of 1 atm has a dry bulb temperature of 20°C and a relative humidity of 60 percent and is contained in a closed rigid vessel. Determine the heat transfer to the moist air that is required to increase the dry bulb temperature to 50°C. Calculate the final pressure and final relative humidity of the mixture.
7. Steam at 1.0 MPa and 320°C with a mass flow rate of 10 kg/s enters an insulated turbine operating at steady state and exits at 20 kPa. If the work developed by the turbine is measured as 630 kJ/kg, determine
- the isentropic efficiency of the turbine,
  - the exit temperature,
  - the quality at the exit if a two-phase liquid-vapor mixture exits, and
  - whether the process is a reversible process.
8. A piston-cylinder assembly contains a two-phase liquid-vapor mixture of H<sub>2</sub>O initially at 500 kPa with a quality of 98%. Expansion occurs to a state where the pressure is 150 kPa. During the process, the pressure and specific volume are related by  $p v = \text{constant}$ . Determine
- the work per unit mass, in kJ/kg, and
  - heat transfer per unit mass, in kJ/kg.
9. An insulated vessel is divided into two compartments connected by a valve. Initially, one compartment contains steam at 1.0 MPa, 500°C, and the other is evacuated. The valve is opened and the steam is allowed to fill the entire volume, achieving the final pressure of 0.1 MPa. Determine
- the final temperature, in °C,
  - the percentage of the vessel volume initially occupied by the steam, and
  - the amount of entropy produced, in kJ/kgK.

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**TABLE A.1**  
Molar mass, gas constant, and critical-point properties

Substance	Formula	Molar mass kg/kmol	$R$ kJ/(kg · K)*	Temperature K	Pressure MPa	Volume m <sup>3</sup> /kmol
Ammonia	NH <sub>3</sub>	17.03	0.4882	405.5	11.28	0.0724
Argon	Ar	39.948	0.2001	151	4.86	0.0749
Bromine	Br <sub>2</sub>	159.808	0.0520	584	10.34	0.1355
Carbon dioxide	CO <sub>2</sub>	44.01	0.1889	304.2	7.39	0.0943
Carbon monoxide	CO	28.011	0.2968	133	3.50	0.0930
Chlorine	Cl <sub>2</sub>	70.906	0.1173	417	7.71	0.1242
Deuterium (normal)	D <sub>2</sub>	4.00	2.0785	38.4	1.66	—
Helium	He	4.003	2.0769	5.3	0.23	0.0578
Hydrogen (normal)	H <sub>2</sub>	2.016	4.1240	33.3	1.30	0.0649
Krypton	Kr	83.80	0.09921	209.4	5.50	0.0924
Neon	Ne	20.183	0.4119	44.5	2.73	0.0417
Nitrogen	N <sub>2</sub>	28.013	0.2968	126.2	3.39	0.0899
Nitrous oxide	N <sub>2</sub> O	44.013	0.1889	309.7	7.27	0.0961
Oxygen	O <sub>2</sub>	31.999	0.2598	154.8	5.08	0.0780
Sulfur dioxide	SO <sub>2</sub>	64.063	0.1298	430.7	7.88	0.1217
Water	H <sub>2</sub> O	18.015	0.4615	647.3	22.09	0.0560
Xenon	Xe	131.30	0.06332	289.8	5.88	0.1186
Benzene	C <sub>6</sub> H <sub>6</sub>	78.115	0.1064	562	4.92	0.2603
<i>n</i> -Butane	C <sub>4</sub> H <sub>10</sub>	58.124	0.1430	425.2	3.80	0.2547
Carbon tetrachloride	CCl <sub>4</sub>	153.82	0.05405	556.4	4.56	0.2759
Chloroform	CHCl <sub>3</sub>	119.38	0.06964	536.6	5.47	0.2403
Dichlorodifluoromethane (R-12)	CCl <sub>2</sub> F <sub>2</sub>	120.91	0.06876	384.7	4.01	0.2179
Dichlorofluoromethane	CHCl <sub>2</sub> F	102.92	0.08078	451.7	5.17	0.1973
Ethane	C <sub>2</sub> H <sub>6</sub>	30.070	0.2765	305.5	4.88	0.1480
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH	46.07	0.1805	516	6.38	0.1673
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.054	0.2964	282.4	5.12	0.1242
<i>n</i> -Hexane	C <sub>6</sub> H <sub>14</sub>	86.178	0.09647	507.9	3.03	0.3677
Methane	CH <sub>4</sub>	16.043	0.5102	191.1	4.64	0.0993
Methyl alcohol	CH <sub>3</sub> OH	32.042	0.2595	513.2	7.95	0.1180
Methyl chloride	CH <sub>3</sub> Cl	50.488	0.1647	416.3	6.68	0.1430
Propane	C <sub>3</sub> H <sub>8</sub>	44.097	0.1885	370	4.26	0.1998
Propene	C <sub>3</sub> H <sub>6</sub>	42.081	0.1976	365	4.62	0.1810
Propyne	C <sub>3</sub> H <sub>4</sub>	40.065	0.2075	401	5.35	—
Trichlorofluoromethane	CCl <sub>3</sub> F	137.37	0.06052	471.2	4.38	0.2478
Air	—	28.97	0.2870	—	—	—

\*The unit kJ/(kg · K) is equivalent to kPa · m<sup>3</sup>/(kg · K). The gas constant is calculated from  $R = R_u/M$ , where  $R_u = 8.314$  kJ/(kmol · K) and  $M$  is the molar mass.

Source: Gordon J. Van Wylan and Richard E. Sonntag, *Fundamentals of Classical Thermodynamics, English/SI Version*, 3d ed., Wiley, New York, 1986, p. 605, table A.6SI. Originally published in K. A. Kobe and R. E. Lynn, Jr., *Chemical Review*, vol. 52, pp. 117–236, 1953.

TABLE A-4

Saturated water—Temperature table

Temp., T, °C	Sat. press., P <sub>sat</sub> , kPa	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/(kg·K)		
		Sat. liquid, v <sub>f</sub>	Sat. vapor, v <sub>g</sub>	Sat. liquid, u <sub>f</sub>	Evap., u <sub>fg</sub>	Sat. vapor, u <sub>g</sub>	Sat. liquid, h <sub>f</sub>	Evap., h <sub>fg</sub>	Sat. vapor, h <sub>g</sub>	Sat. liquid, s <sub>f</sub>	Evap., s <sub>fg</sub>	Sat. vapor, s <sub>g</sub>
0.01	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.3	2501.4	0.000	9.1562	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9008
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2304.9	2409.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5580
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8470	8.3531
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7553
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.98	2270.2	2668.1	1.2500	6.1659	7.4159
<b>Sat. press., MPa</b>												
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	418.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2397
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.2321	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.4756	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.8925	4.7153	6.7076
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1398	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698



TABLE A-4

Saturated water—Temperature table (Concluded)

Temp., T°C	Sat. press., P <sub>sat</sub> MPa	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/(kg·K)		
		Sat. liquid, v <sub>f</sub>	Sat. vapor, v <sub>g</sub>	Sat. liquid, u <sub>f</sub>	Evap., u <sub>fg</sub>	Sat. vapor, u <sub>g</sub>	Sat. liquid, h <sub>f</sub>	Evap., h <sub>fg</sub>	Sat. vapor, h <sub>g</sub>	Sat. liquid, s <sub>f</sub>	Evap., s <sub>fg</sub>	Sat. vapor, s <sub>g</sub>
200	1.5538	0.001157	0.13736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1859.5	2802.1	2.5178	3.7683	6.2861
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.9	2804.0	2.6099	3.6047	6.2146
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1781
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730
255	4.319	0.001263	0.04598	1104.28	1596.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301
275	5.942	0.001317	0.03279	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1365.4	2738.7	3.3010	2.3633	5.6643
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230
315	10.547	0.001472	0.016867	1415.5	1121.1	2536.6	1431.0	1283.5	2714.5	3.3982	2.1821	5.5804
320	11.274	0.001499	0.015488	1444.6	1080.9	2525.5	1461.5	1238.8	2700.1	3.4480	2.0882	5.5362
330	12.845	0.001561	0.012996	1505.3	993.7	2498.9	1525.3	1140.6	2665.9	3.5507	1.8909	5.4417
340	14.506	0.001638	0.010797	1570.3	894.3	2464.6	1594.2	1027.9	2622.0	3.6594	1.6763	5.3357
350	16.513	0.001740	0.008813	1641.9	776.6	2418.4	1670.6	893.4	2563.9	3.7777	1.4335	5.2112
360	18.651	0.001893	0.006945	1725.2	626.3	2351.5	1760.5	720.3	2481.0	3.9147	1.1379	5.0528
370	21.03	0.002213	0.004925	1844.0	384.5	2228.5	1890.5	441.8	2332.1	4.1106	0.6865	4.7971
374.14	22.09	0.003155	0.003155	2029.8	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

Source: Tables A-4 through A-8 are adapted from Gordon J. Van Wylen and Richard E. Sonntag, *Fundamentals of Classical Thermodynamics*, English/SI Version, 3rd ed. (New York: John Wiley & Sons, 1986), pp. 635-651. Originally published in Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore, *Steam Tables*, SI Units (New York: John Wiley & Sons, 1978).

TABLE A-5

Saturated water—Pressure table

Press., kPa	Specific volume, m <sup>3</sup> /kg			Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/(kg·K)		
	Sat. temp., T <sub>sat</sub> , °C	Sat. liquid, v <sub>f</sub>	Sat. vapor, v <sub>g</sub>	Sat. liquid, u <sub>f</sub>	Evap., u <sub>fg</sub>	Sat. vapor, u <sub>g</sub>	Sat. liquid, h <sub>f</sub>	Evap., h <sub>fg</sub>	Sat. vapor, h <sub>g</sub>	Sat. liquid, s <sub>f</sub>	Evap., s <sub>fg</sub>	Sat. vapor, s <sub>g</sub>
0.0113	0.01	0.001000	206.14	0.00	2375.3	2375.3	0.01	2501.3	2501.4	0.0000	8.1562	8.1562
1.0	6.98	0.001000	120.21	20.30	2355.7	2385.0	29.30	2484.9	2514.2	0.1059	8.8637	8.9750
1.5	13.03	0.001001	87.98	54.71	2338.6	2393.3	54.71	2470.6	2525.3	0.1957	8.6322	8.8279
2.0	17.50	0.001001	67.00	73.48	2326.0	2399.5	73.48	2460.0	2533.5	0.2507	8.4629	8.7237
2.5	21.08	0.001002	54.25	88.48	2315.9	2404.4	88.49	2451.6	2540.0	0.3120	8.3311	8.6432
3.0	24.08	0.001003	45.67	101.04	2307.5	2408.5	101.05	2444.5	2545.5	0.3545	8.2231	8.5776
4.0	28.96	0.001004	34.80	121.45	2293.7	2415.2	121.46	2432.9	2554.4	0.4226	8.0520	8.4746
5.0	32.88	0.001005	28.19	137.81	2282.7	2420.5	137.82	2423.7	2561.5	0.4764	7.9167	8.3951
7.5	40.29	0.001008	19.24	168.78	2261.7	2430.5	168.79	2406.0	2574.8	0.5764	7.6750	8.2516
10	45.81	0.001010	14.67	191.82	2248.1	2437.9	191.83	2392.8	2584.7	0.6493	7.5009	8.1502
15	53.97	0.001014	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	0.7549	7.2536	8.0085
20	60.06	0.001017	7.649	251.38	2205.4	2458.7	251.40	2358.3	2609.7	0.8320	7.0768	7.9085
25	64.97	0.001020	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	0.8931	6.9363	7.8314
30	69.10	0.001022	5.229	289.20	2179.2	2469.4	289.23	2336.1	2625.3	0.9439	6.8247	7.7686
40	75.87	0.001027	3.993	317.53	2159.5	2477.0	317.58	2319.2	2636.8	1.0259	6.6441	7.6700
50	81.33	0.001030	3.240	340.44	2143.4	2483.9	340.49	2305.4	2645.9	1.0910	6.6020	7.5939
75	91.78	0.001037	2.217	384.31	2112.4	2496.7	384.38	2278.6	2663.0	1.2130	6.2434	7.4584
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.6	1.3026	6.0568	7.3684
0.125	105.89	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.8	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5708	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.4	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6716	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2648	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9176
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.83	0.001088	0.4140	622.77	1934.8	2557.6	623.26	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9608	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	655.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.58	2086.3	2756.8	1.9312	4.8298	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001108	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.76	0.001112	0.2550	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.8	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6626
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.1	2773.9	2.0948	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17763	780.09	1806.3	2586.4	781.34	2000.4	2817.7	2.1792	4.3744	6.5538
1.20	187.89	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.6	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953

TABLE A-5

Saturated water—Pressure table (Concluded)

Press., P, MPa	Sat. temp., $T_{sat}$ , °C	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, $s_g$
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1957.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1714.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2088	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141
11	318.15	0.001489	0.015987	1433.7	1096.0	2529.8	1450.1	1255.5	2705.6	3.4295	2.1233	5.5527
12	324.75	0.001527	0.014263	1473.0	1040.7	2513.7	1491.3	1193.3	2684.9	3.4962	1.9962	5.4924
13	330.93	0.001567	0.012780	1511.1	985.0	2496.1	1531.5	1130.7	2662.2	3.5606	1.8718	5.4323
14	336.75	0.001611	0.011485	1548.6	928.2	2476.8	1571.1	1065.5	2637.6	3.6232	1.7485	5.3717
15	342.24	0.001658	0.010337	1585.6	869.8	2455.5	1610.5	1000.0	2610.5	3.6848	1.6249	5.3098
16	347.44	0.001711	0.009306	1622.7	809.0	2431.7	1650.1	930.6	2580.6	3.7461	1.4994	5.2455
17	352.37	0.001770	0.008364	1660.2	744.8	2405.0	1690.3	858.9	2547.2	3.8079	1.3698	5.1777
18	357.06	0.001840	0.007489	1698.9	675.4	2374.3	1732.0	777.1	2509.1	3.8715	1.2329	5.1044
19	361.54	0.001924	0.006657	1739.9	598.1	2338.1	1776.5	688.0	2464.5	3.9388	1.0839	5.0228
20	365.81	0.002036	0.005834	1785.6	507.5	2293.0	1826.3	583.4	2409.7	4.0139	0.9130	4.9289
21	369.89	0.002207	0.004952	1842.1	388.5	2230.6	1888.4	446.2	2334.6	4.1075	0.6938	4.8013
22	373.80	0.002742	0.003568	1961.9	125.2	2087.1	2022.2	143.4	2165.6	4.3110	0.2216	4.5327
22.09	374.14	0.003155	0.003155	2029.6	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

TABLE A-6

Superheated water<sup>1</sup>

T °C	P = 0.01 MPa (45.81°C)*				P = 0.05 MPa (61.33°C)				P = 0.10 MPa (99.63°C)			
	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
Sat. <sup>†</sup>	14.674	2437.9	2584.7	8.1502	3.240	2483.9	2645.9	7.5939	1.6940	2506.1	2675.5	7.3594
50	14.869	2443.9	2592.6	8.1749								
100	17.196	2515.5	2687.5	8.4478	3.418	2511.6	2632.5	7.8947	1.6958	2506.7	2675.2	7.3614
150	19.512	2587.9	2783.0	8.6882	3.059	2585.6	2780.1	7.9401	1.9364	2582.8	2775.4	7.6134
200	21.825	2661.3	2879.5	8.9038	4.356	2659.9	2877.7	8.1580	2.172	2658.1	2875.3	7.6343
250	24.136	2736.0	2977.3	9.1002	4.820	2735.0	2976.0	8.3556	2.406	2733.7	2974.3	8.0333
300	26.445	2812.1	3076.5	9.2813	5.264	2811.3	3075.5	8.5373	2.639	2810.4	3074.3	8.2158
400	31.063	2968.9	3279.6	9.6077	6.209	2968.5	3278.9	8.8642	3.103	2967.9	3278.2	8.5435
500	35.879	3132.3	3489.1	9.8978	7.134	3132.0	3488.7	9.1546	3.565	3131.6	3488.1	8.8342
600	40.295	3302.5	3705.4	10.1608	8.057	3302.2	3705.1	9.4178	4.028	3301.9	3704.4	9.0976
700	44.911	3479.6	3928.7	10.4028	8.981	3479.4	3928.5	9.6599	4.490	3479.2	3928.2	9.3398
800	49.526	3663.8	4159.0	10.6281	9.904	3663.6	4158.9	9.8852	4.952	3663.6	4158.6	9.5652
900	54.141	3855.0	4396.4	10.8396	10.828	3854.9	4396.3	10.0987	5.414	3854.8	4396.1	9.7767
1000	58.757	4053.0	4640.6	11.0393	11.751	4052.9	4640.5	10.2964	5.875	4052.8	4640.3	9.9704
1100	63.372	4257.5	4891.2	11.2287	12.674	4257.4	4891.1	10.4859	6.337	4257.3	4891.0	10.1659
1200	67.987	4467.9	5147.8	11.4091	13.597	4467.8	5147.7	10.6662	6.799	4467.7	5147.6	10.3463
1300	72.602	4683.7	5409.7	11.5811	14.521	4683.6	5409.6	10.8382	7.260	4683.5	5409.5	10.5183
	P = 0.20 MPa (120.23°C)				P = 0.30 MPa (133.05°C)				P = 0.40 MPa (143.63°C)			
Sat.	0.8657	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.8	2730.6	6.8959
150	0.8596	2576.9	2768.6	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2504.5	2752.8	6.9289
200	1.0803	2654.4	2870.5	7.5060	0.7163	2650.7	2865.8	7.3115	0.5342	2648.8	2860.5	7.1706
250	1.1986	2731.2	2971.0	7.7088	0.7964	2728.7	2967.6	7.5165	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.6	3066.8	7.5662
400	1.5493	2966.7	3278.8	8.2218	1.0315	2965.6	3275.0	8.0330	0.7720	2964.4	3273.4	7.8985
500	1.7614	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0184	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6887
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2372	3662.4	4167.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2602	1.3529	3853.9	4396.1	9.1392
1000	2.937	4052.5	4640.0	9.6563	1.9591	4052.3	4639.7	9.4690	1.4605	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8388	1.6996	4467.0	5146.8	9.7090
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780
	P = 0.50 MPa (151.86°C)				P = 0.60 MPa (158.85°C)				P = 0.80 MPa (170.43°C)			
Sat.	0.3749	2561.2	2748.7	6.8213	0.3157	2567.4	2756.6	6.7600	0.2404	2576.8	2789.1	6.6028
200	0.4249	2642.9	2855.4	7.0592	0.3520	2638.9	2850.1	6.6665	0.2608	2630.6	2839.3	6.8159
250	0.4744	2723.5	2960.7	7.2709	0.3936	2720.9	2957.2	7.1816	0.2931	2715.5	2950.0	7.0384
300	0.5226	2802.9	3064.2	7.4599	0.4344	2801.0	3061.6	7.3724	0.3241	2797.2	3056.5	7.2328
350	0.6701	2882.6	3167.7	7.6329	0.4742	2881.2	3165.7	7.5484	0.3544	2878.2	3161.7	7.4089
400	0.6173	2953.2	3271.9	7.7938	0.5137	2962.1	3270.3	7.7079	0.3843	2959.7	3267.1	7.5718
500	0.7109	3128.4	3483.9	8.0873	0.5920	3127.6	3482.8	8.0021	0.4433	3126.0	3460.6	7.8673
600	0.8041	3299.8	3701.7	7.3522	0.6697	3209.1	3700.9	8.2674	0.5018	3297.9	3699.4	8.1333
700	0.8969	3477.5	3925.9	8.5952	0.7472	3477.0	3925.3	8.5107	0.5601	3476.2	3924.2	8.3770
800	0.9896	3662.1	4156.9	8.8211	0.8245	3661.8	4156.5	8.7367	0.6181	3661.1	4156.6	8.6033
900	1.0822	3853.8	4394.7	9.0329	0.9017	3853.4	4394.4	8.9486	0.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	0.9788	4051.5	4638.8	9.1485	0.7340	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	0.7919	4255.6	4889.1	9.2050
1200	1.3596	4466.8	5146.6	9.6029	1.1330	4466.5	5146.3	9.5185	0.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	0.9076	4681.8	5407.9	9.5575

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

<sup>†</sup>Properties of saturated vapor at the specified pressure.

TABLE A-6

Superheated water (Continued)

T °C	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
<b>P = 1.00 MPa (179.91°C)</b>				<b>P = 1.20 MPa (187.99°C)</b>				<b>P = 1.40 MPa (195.07°C)</b>				
Sat.	0.19444	2503.6	2778.1	6.5865	0.16333	2588.8	2784.8	6.5239	0.14084	2592.8	2790.0	6.4693
200	0.2060	2621.9	2827.9	6.6940	0.16930	2612.9	2815.9	6.5990	0.14302	2603.1	2803.3	6.4976
250	0.2327	2709.9	2942.6	6.9247	0.19234	2704.2	2935.0	6.8294	0.16350	2698.3	2927.2	6.7467
300	0.2579	2793.2	3051.2	7.1229	0.2138	2709.2	3045.8	7.0317	0.18228	2785.2	3040.4	6.9534
350	0.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	0.2003	2868.2	3149.5	7.1360
400	0.3068	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026
500	0.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027
600	0.4011	3296.8	3697.9	8.0290	0.3339	3295.8	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710
700	0.4478	3475.3	3923.1	8.2731	0.3729	3474.4	3922.0	8.1891	0.3195	3473.6	3920.8	8.1160
800	0.4943	3660.4	4154.7	8.4998	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431
900	0.5407	3852.2	4392.8	8.7118	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5558
1000	0.5871	4050.5	4637.6	8.9119	0.4892	4050.0	4637.0	8.8274	0.4192	4049.5	4636.4	8.7559
1100	0.6335	4255.1	4888.6	9.1017	0.5278	4254.6	4888.0	9.0172	0.4524	4254.1	4887.5	8.9457
1200	0.6798	4465.6	5145.4	9.2822	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262
1300	0.7261	4681.3	5407.4	9.4543	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984
<b>P = 1.60 MPa (201.41°C)</b>				<b>P = 1.80 MPa (207.15°C)</b>				<b>P = 2.00 MPa (212.42°C)</b>				
Sat.	0.12380	2596.0	2794.0	6.4218	0.11042	2598.4	2797.1	6.3794	0.09063	2600.3	2799.5	6.3409
225	0.13287	2644.7	2857.3	6.5518	0.11673	2636.6	2846.7	6.4808	0.10377	2628.3	2835.8	6.4147
250	0.14184	2692.3	2918.2	6.6732	0.12497	2686.0	2911.0	6.6066	0.11144	2679.6	2902.5	6.5453
300	0.15862	2781.1	3034.8	6.8944	0.14021	2776.9	3029.2	6.8226	0.12547	2772.6	3023.5	6.7684
350	0.17456	2868.1	3145.4	7.0694	0.15457	2863.0	3141.2	7.0100	0.13857	2859.8	3137.0	6.9563
400	0.19005	2950.1	3254.2	7.2374	0.16847	2947.7	3250.9	7.1794	0.15120	2945.2	3247.6	7.1271
500	0.2203	3119.5	3472.0	7.5390	0.19550	3117.9	3469.8	7.4825	0.17568	3116.2	3467.6	7.4317
600	0.2500	3293.3	3693.2	7.8090	0.2220	3292.1	3691.7	7.7523	0.19960	3290.9	3690.1	7.7024
700	0.2794	3472.7	3918.7	8.0535	0.2482	3471.8	3918.5	7.9983	0.2232	3470.9	3917.4	7.9487
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.8	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4366	0.2700	3849.3	4389.4	8.3895
1000	0.3668	4040.0	4635.8	8.6939	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.6901
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7600
1200	0.4246	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1329
<b>P = 2.50 MPa (223.99°C)</b>				<b>P = 3.00 MPa (233.90°C)</b>				<b>P = 3.50 MPa (242.60°C)</b>				
Sat.	0.07998	2603.1	2803.1	6.2575	0.06668	2604.1	2804.2	6.1669	0.05707	2603.7	2803.4	6.1253
225	0.08027	2605.6	2806.3	6.2639					0.06872	2623.7	2829.2	6.1749
250	0.08700	2662.6	2880.1	6.4065	0.07058	2644.0	2855.8	6.2872	0.06842	2738.0	2877.5	6.4461
300	0.09890	2761.6	3008.8	6.6438	0.08114	2750.1	2993.5	6.5390	0.07678	2835.3	3104.0	6.6579
350	0.10978	2851.9	3126.3	6.8403	0.09053	2843.7	3115.3	6.7428	0.08453	2926.4	3222.3	6.8405
400	0.12010	2939.1	3239.3	7.0148	0.09936	2932.6	3230.9	6.9212	0.09196	3015.3	3337.2	7.0052
450	0.13014	3025.6	3350.8	7.1746	0.10787	3020.4	3344.0	7.0834	0.09918	3103.0	3450.9	7.1572
500	0.13993	3112.1	3462.1	7.3234	0.11619	3108.0	3455.5	7.2336	0.11324	3282.1	3678.4	7.4339
600	0.15930	3288.0	3688.3	7.5960	0.13243	3285.0	3682.3	7.5085	0.12699	3464.3	3908.8	7.6837
700	0.17832	3468.7	3914.5	7.8435	0.14838	3466.5	3911.7	7.7571	0.14056	3651.8	4143.7	7.9134
800	0.19716	3655.3	4148.2	8.0720	0.16414	3653.5	4145.9	7.9852	0.15402	3845.0	4384.1	8.1276
900	0.21590	3847.9	4387.6	8.2853	0.17990	3846.5	4385.9	8.1999	0.16743	4044.1	4630.1	8.3288
1000	0.2346	4046.7	4633.1	8.4861	0.19541	4045.4	4631.6	8.4003	0.18060	4249.2	4891.9	8.5192
1100	0.2532	4251.5	4884.8	8.6762	0.21098	4250.3	4883.3	8.5912	0.19415	4459.8	5139.3	8.7000
1200	0.2718	4462.1	5141.7	8.8569	0.22652	4460.9	5140.5	8.7720	0.20749	4675.5	5401.7	8.8723
1300	0.2905	4677.8	5404.0	9.0291	0.24206	4676.8	5402.8	8.9442				



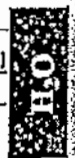
TABLE A-6

Superheated water (Continued)

T °C	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
P = 4.0 MPa (250.40°C)				P = 4.5 MPa (257.49°C)				P = 5.0 MPa (263.99°C)				
Sat.	0.04978	2602.3	2801.4	5.0701	0.04406	2600.1	2798.3	6.0199	0.03944	2597.1	2794.3	5.9734
275	0.05457	2667.9	2886.2	6.2285	0.04730	2650.3	2863.2	6.1401	0.04141	2631.3	2838.3	6.0544
300	0.05884	2725.3	2950.7	6.3615	0.05135	2712.0	2943.1	6.2828	0.04532	2698.0	2924.5	6.2084
350	0.06645	2826.7	3092.5	6.5821	0.05940	2817.8	3080.6	6.5131	0.05194	2806.7	3068.4	6.4493
400	0.07341	2919.9	3213.6	7.7690	0.06475	2913.3	3204.7	6.7047	0.05781	2906.6	3195.7	6.6459
450	0.08002	3010.2	3330.3	6.9363	0.07074	3005.0	3323.3	6.8746	0.06330	2999.7	3316.2	6.8188
500	0.08643	3099.5	3445.3	7.0901	0.07651	3095.3	3439.6	7.0301	0.06857	3091.0	3433.8	6.9759
600	0.09885	3278.1	3674.4	7.3688	0.08765	3276.0	3670.5	7.3110	0.07869	3273.0	3666.5	7.2589
700	0.11095	3462.1	3905.9	7.6198	0.09847	3459.9	3903.0	7.5631	0.08849	3457.6	3900.1	7.5122
800	0.12287	3650.0	4141.5	7.8502	0.10911	3648.3	4139.3	7.7942	0.09911	3646.6	4137.1	7.7440
900	0.13469	3843.0	4382.3	8.0647	0.11965	3842.2	4380.6	8.0091	0.10782	3840.7	4378.6	7.9593
1000	0.14645	4042.9	4628.7	8.2662	0.13013	4041.8	4627.2	8.2106	0.11707	4040.4	4625.7	8.1612
1100	0.15817	4248.0	4880.6	8.4567	0.14056	4246.9	4879.3	8.4015	0.12648	4245.6	4878.0	8.3520
1200	0.16987	4458.6	5138.1	8.6376	0.15098	4457.5	5138.9	8.5825	0.13587	4456.3	5135.7	8.5331
1300	0.18156	4674.3	5400.5	8.8100	0.16139	4673.1	5399.4	8.7649	0.14526	4672.0	5399.2	8.7055
P = 6.0 MPa (276.64°C)				P = 7.0 MPa (285.88°C)				P = 8.0 MPa (293.06°C)				
Sat.	0.03244	2589.7	2784.3	5.8892	0.02737	2580.5	2772.1	6.8133	0.02352	2569.6	2758.0	5.7432
300	0.03616	2667.2	2884.2	6.0674	0.02947	2632.2	2838.4	6.9305	0.02426	2590.9	2785.0	5.7906
350	0.04223	2789.6	3043.0	6.3335	0.03524	2769.4	3016.0	6.2263	0.02995	2747.7	2987.3	6.1301
400	0.04739	2892.9	3177.2	6.5409	0.03993	2878.6	3158.1	6.4478	0.03432	2863.8	3138.3	6.3834
450	0.05214	2988.9	3301.8	6.7193	0.04416	2978.0	3287.1	6.6327	0.03817	2966.7	3272.0	6.6551
500	0.05685	3082.2	3422.2	6.8803	0.04814	3073.4	3410.3	6.7975	0.04175	3064.3	3398.3	6.7240
550	0.06101	3174.6	3540.8	7.0288	0.05195	3167.2	3530.9	6.9486	0.04516	3159.8	3521.0	6.8778
600	0.06525	3266.9	3658.4	7.1677	0.05565	3260.7	3650.3	7.0894	0.04845	3254.4	3642.0	7.0206
700	0.07352	3453.1	3894.2	7.4234	0.06283	3448.5	3888.3	7.3476	0.05481	3443.9	3882.4	7.2812
800	0.08160	3643.1	4132.7	7.6568	0.06981	3639.5	4128.2	7.5822	0.06097	3638.0	4123.8	7.5170
900	0.08958	3837.8	4375.3	7.8727	0.07669	3835.0	4371.8	7.7931	0.06702	3832.1	4368.3	7.7351
1000	0.09749	4037.8	4622.7	8.0751	0.08350	4035.3	4619.8	8.0020	0.07301	4032.8	4616.9	7.9384
1100	0.10530	4243.3	4875.4	8.2661	0.09027	4240.9	4872.9	8.1933	0.07896	4238.6	4870.3	8.1300
1200	0.11321	4454.0	5133.3	8.4474	0.09703	4451.7	5130.9	8.3747	0.08480	4449.5	5128.5	8.3115
1300	0.12106	4669.6	5396.0	8.6199	0.10377	4667.3	5393.7	8.5475	0.09080	4665.0	5391.5	8.4842
P = 9.0 MPa (303.40°C)				P = 10.0 MPa (311.06°C)				P = 12.0 MPa (327.89°C)				
Sat.	0.02048	2557.6	2742.1	5.6772	0.018026	2544.4	2724.7	5.8141	0.013495	2505.1	2673.8	5.4624
325	0.02327	2646.6	2856.0	5.8712	0.018961	2610.4	2809.1	5.7568	0.016126	2624.6	2826.2	5.7118
350	0.02580	2724.4	2950.6	6.0361	0.02242	2699.2	2923.4	5.8443	0.02000	2789.3	3039.3	6.0417
400	0.02893	2848.4	3117.8	6.2854	0.02641	2832.4	3096.5	6.2120	0.02299	2912.5	3189.8	6.2719
450	0.03350	2955.2	3256.6	6.4944	0.02975	2943.4	3240.9	6.4180	0.02560	3021.7	3341.8	6.4616
500	0.03877	3055.2	3386.1	6.6576	0.03279	3045.8	3373.7	6.5966	0.02801	3125.0	3476.2	6.6290
550	0.03987	3152.2	3511.0	6.8142	0.03564	3144.6	3500.9	6.7561	0.03029	3225.4	3604.0	6.7810
600	0.04285	3248.1	3633.7	6.9589	0.03837	3241.7	3626.3	6.9029	0.03248	3324.4	3730.4	6.9219
650	0.04574	3343.6	3755.3	7.0943	0.04101	3338.2	3748.2	7.0396	0.03460	3422.9	3855.3	7.0530
700	0.04857	3439.3	3876.5	7.2221	0.04358	3434.7	3870.5	7.1687	0.03689	3520.0	4103.6	7.2965
800	0.05409	3632.5	4119.3	7.4596	0.04859	3628.9	4114.8	7.4077	0.04267	3819.1	4352.5	7.5182
900	0.05950	3829.2	4364.8	7.6783	0.05349	3826.3	4361.2	7.6272	0.04658	4021.6	4603.8	7.7237
1000	0.06485	4030.3	4614.0	7.8821	0.05832	4027.8	4611.0	7.8315	0.05045	4228.2	4853.8	7.9165
1100	0.07016	4236.3	4867.7	8.0740	0.06312	4234.0	4865.1	8.0237	0.05430	4439.3	5118.0	8.0937
1200	0.07544	4447.2	5126.2	8.2556	0.06789	4444.9	5123.8	8.2055	0.05813	4654.8	5381.4	8.2717
1300	0.08072	4662.7	5389.2	8.4284	0.07265	4660.5	5387.0	8.3783				

TABLE A-6

Superheated water (Concluded)



T °C	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
P = 15.0 MPa (342.24°C)				P = 17.5 MPa (354.75°C)				P = 20.0 MPa (365.81°C)				
Sat.	0.010337	2455.5	2610.5	5.3090	0.007920	2390.2	2520.0	5.1419	0.005834	2293.0	2409.7	4.9269
350	0.011470	2520.4	2692.4	5.4421								
400	0.015649	2740.7	2975.5	5.8811	0.012447	2685.0	2902.9	5.7213	0.009942	2619.3	2818.1	5.5540
450	0.018445	2879.5	3158.2	6.1404	0.015174	2844.2	3109.7	6.0184	0.012695	2808.2	3060.1	5.9017
500	0.02060	2998.6	3308.6	6.3443	0.017358	2970.3	3274.1	6.2383	0.014768	2942.9	3238.2	6.1401
550	0.02293	3104.7	3448.6	6.5199	0.019288	3083.9	3421.4	6.4230	0.016555	3062.4	3393.5	6.3348
600	0.02491	3208.6	3582.3	6.6776	0.02106	3191.5	3560.1	6.5866	0.018178	3174.0	3537.6	6.5048
650	0.02680	3310.3	3712.3	6.8224	0.02274	3296.0	3683.9	6.7357	0.019693	3281.4	3675.3	6.6582
700	0.02861	3410.9	3840.1	6.9572	0.02434	3398.7	3824.6	6.8736	0.02113	3386.4	3809.0	6.7993
800	0.03210	3610.9	4092.4	7.2040	0.02738	3601.8	4081.1	7.1244	0.02385	3592.7	4069.7	7.0544
900	0.03546	3811.9	4343.8	7.4279	0.03031	3804.7	4335.1	7.3507	0.02645	3797.5	4326.4	7.2830
1000	0.03675	4015.4	4506.6	7.6349	0.03316	4009.3	4589.5	7.5589	0.02897	4003.1	4582.5	7.4925
1100	0.04200	4222.8	4852.6	7.8283	0.03597	4216.9	4846.4	7.7531	0.03145	4211.3	4840.2	7.6874
1200	0.04523	4433.8	5112.3	8.0108	0.03876	4428.3	5106.6	7.9360	0.03391	4422.8	5101.0	7.8707
1300	0.04645	4649.1	5378.0	8.1840	0.04154	4643.5	5370.5	8.1093	0.03636	4638.0	5365.1	8.0442
P = 25.0 MPa				P = 30.0 MPa				P = 35.0 MPa				
375	0.0019731	1798.7	1848.0	4.0320	0.0017892	1737.8	1791.5	3.8305	0.0017003	1702.9	1762.4	3.8722
400	0.006004	2430.1	2590.2	5.1418	0.002790	2067.4	2151.1	4.4728	0.002100	1914.1	1987.6	4.2125
425	0.007881	2609.2	2806.3	5.4723	0.005303	2455.1	2614.2	5.1604	0.003420	2253.4	2373.4	4.7747
450	0.009162	2720.7	2949.7	5.6744	0.006735	2619.3	2821.4	5.4424	0.004961	2499.7	2672.4	5.1962
500	0.011123	2884.3	3182.4	5.9592	0.008678	2820.7	3091.1	5.7905	0.006927	2751.9	2994.4	5.6282
550	0.012724	3017.5	3335.6	6.1765	0.010168	2970.3	3275.4	6.0342	0.008345	2921.0	3213.0	5.9028
600	0.014137	3137.9	3491.4	6.3602	0.011448	3100.5	3443.9	6.2331	0.009527	3082.0	3395.5	6.1179
650	0.015433	3251.6	3637.4	6.5229	0.012596	3221.0	3598.9	6.4058	0.010575	3189.8	3559.9	6.3010
700	0.016646	3361.3	3777.5	6.6707	0.013681	3335.8	3745.6	6.5606	0.011533	3309.8	3713.5	6.4831
800	0.018912	3574.3	4047.1	6.9345	0.015623	3555.5	4024.2	6.8332	0.013278	3536.7	4001.5	6.7450
900	0.021045	3783.0	4309.1	7.1680	0.017448	3768.5	4291.9	7.0718	0.014883	3754.0	4274.9	6.9366
1000	0.02310	3990.9	4568.5	7.3802	0.019198	3978.8	4554.7	7.2867	0.016410	3968.7	4541.1	7.2064
1100	0.02512	4200.2	4828.2	7.5765	0.020903	4189.2	4818.3	7.4845	0.017895	4178.3	4804.6	7.4037
1200	0.02711	4412.0	5089.9	7.7605	0.022589	4401.3	5079.0	7.6892	0.019380	4390.7	5068.3	7.5910
1300	0.02910	4626.9	5354.4	7.9342	0.024266	4616.0	5344.0	7.8432	0.020816	4605.1	5333.6	7.7653
P = 40.0 MPa				P = 50.0 MPa				P = 60.0 MPa				
375	0.0016407	1677.1	1742.8	3.8290	0.0015594	1638.6	1716.6	3.7639	0.0015028	1603.4	1699.5	3.7141
400	0.0019077	1854.6	1930.9	4.1135	0.0017309	1788.1	1874.6	4.0031	0.0016335	1745.4	1843.4	3.9318
425	0.002532	2098.9	2198.1	4.5026	0.002007	1859.7	2090.0	4.2734	0.0018165	1892.7	2001.7	4.1626
450	0.003693	2365.1	2512.0	4.9459	0.002406	2159.8	2284.0	4.5884	0.002085	2053.9	2179.0	4.4121
500	0.005622	2678.4	2903.3	5.4700	0.003892	2525.5	2720.1	5.1726	0.002956	2390.8	2567.9	4.9321
550	0.006984	2869.7	3149.1	5.7785	0.005118	2763.8	3019.5	5.5405	0.003956	2658.6	2896.2	5.3441
600	0.008094	3022.6	3348.4	6.0144	0.006112	2942.0	3247.8	5.8178	0.004834	2861.1	3151.2	5.6452
650	0.009063	3158.0	3520.8	6.2054	0.006900	3093.5	3441.8	6.0342	0.005595	3020.8	3364.5	5.8829
700	0.009941	3283.8	3681.2	6.3750	0.007727	3230.5	3618.8	6.2189	0.006272	3177.2	3553.5	6.0824
800	0.011523	3517.8	3978.7	6.6882	0.009076	3479.8	3933.8	6.5290	0.007459	3441.5	3899.1	6.4109
900	0.012962	3739.4	4257.9	6.9150	0.010283	3710.3	4224.4	6.7882	0.008508	3681.0	4191.5	6.6905
1000	0.014324	3954.6	4527.6	7.1356	0.011411	3930.5	4501.1	7.0148	0.009480	3908.4	4475.2	6.9127
1100	0.015642	4187.4	4793.1	7.3364	0.012496	4145.7	4770.5	7.2184	0.010409	4124.1	4748.6	7.1195
1200	0.016940	4380.1	5057.7	7.5224	0.013561	4359.1	5037.2	7.4058	0.011317	4338.2	5017.2	7.3083
1300	0.018229	4594.3	5323.5	7.6969	0.014616	4572.8	5303.6	7.5808	0.012215	4551.4	5284.3	7.4837





TABLE A-11

Saturated refrigerant-134a—Temperature table

Temp., T °C	Press., P <sub>sat</sub> MPa	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg		Enthalpy, kJ/kg			Entropy, kJ/(kg·K)	
		Sat. liquid, v <sub>f</sub>	Sat. vapor, v <sub>g</sub>	Sat. liquid, u <sub>f</sub>	Sat. vapor, u <sub>g</sub>	Sat. liquid, h <sub>f</sub>	Evap., h <sub>fg</sub>	Sat. vapor, h <sub>g</sub>	Sat. liquid, s <sub>f</sub>	Sat. vapor, s <sub>g</sub>
-40	0.05164	0.0007055	0.3569	-0.04	204.45	0.00	222.88	222.88	0.0000	0.9560
-36	0.06332	0.0007113	0.2947	4.68	206.73	4.73	220.67	225.40	0.0201	0.9506
-32	0.07704	0.0007172	0.2451	9.47	209.01	9.52	218.37	227.90	0.0401	0.9456
-28	0.09305	0.0007233	0.2052	14.31	211.29	14.37	216.01	230.38	0.0600	0.9411
-26	0.10199	0.0007265	0.1882	16.75	212.43	16.82	214.80	231.62	0.0699	0.9390
-24	0.11160	0.0007296	0.1728	19.21	213.57	19.29	213.57	232.85	0.0798	0.9370
-22	0.12192	0.0007328	0.1590	21.68	214.70	21.77	212.32	234.08	0.0897	0.9351
-20	0.13299	0.0007361	0.1464	24.17	215.84	24.26	211.05	235.31	0.0996	0.9332
-18	0.14483	0.0007395	0.1350	26.67	216.97	26.77	209.76	236.53	0.1094	0.9315
-16	0.15748	0.0007428	0.1247	29.18	218.10	29.30	208.45	237.74	0.1192	0.9298
-12	0.18540	0.0007498	0.1068	34.25	220.36	34.39	205.77	240.15	0.1388	0.9267
-8	0.21704	0.0007569	0.0919	39.38	222.60	39.54	203.00	242.54	0.1583	0.9239
-4	0.25274	0.0007644	0.0794	44.56	224.84	44.75	200.15	244.90	0.1777	0.9213
0	0.29282	0.0007721	0.0689	49.79	227.06	50.02	197.21	247.23	0.1970	0.9190
4	0.33765	0.0007801	0.0600	55.08	229.27	55.35	194.19	249.53	0.2162	0.9169
8	0.38756	0.0007884	0.0525	60.43	231.46	60.73	191.07	251.80	0.2354	0.9150
12	0.44294	0.0007971	0.0460	65.83	233.63	66.18	187.85	254.03	0.2545	0.9132
16	0.50416	0.0008062	0.0405	71.29	235.78	71.69	184.52	256.22	0.2735	0.9116
20	0.57160	0.0008157	0.0358	76.80	237.91	77.26	181.09	258.35	0.2924	0.9102
24	0.64566	0.0008257	0.0317	82.37	240.01	82.90	177.55	260.45	0.3113	0.9089
26	0.68530	0.0008309	0.0298	85.18	241.05	85.75	175.73	261.48	0.3208	0.9082
28	0.72675	0.0008362	0.0281	88.00	242.08	88.61	173.89	262.50	0.3302	0.9076
30	0.77006	0.0008417	0.0265	90.84	243.10	91.49	172.00	263.50	0.3396	0.9070
32	0.81528	0.0008473	0.0250	93.70	244.12	94.39	170.09	264.48	0.3490	0.9064
34	0.86247	0.0008530	0.0236	96.58	245.12	97.31	168.14	265.45	0.3584	0.9058
36	0.91168	0.0008590	0.0223	99.47	246.11	100.25	166.15	266.40	0.3678	0.9053
38	0.96298	0.0008651	0.0210	102.38	247.09	103.21	164.12	267.33	0.3772	0.9047
40	1.0164	0.0008714	0.0199	105.30	248.06	106.19	162.05	268.24	0.3866	0.9041
42	1.0720	0.0008780	0.0188	108.25	249.02	109.19	159.94	269.14	0.3960	0.9035
44	1.1299	0.0008847	0.0177	111.22	249.96	112.22	157.79	270.01	0.4054	0.9030
46	1.2526	0.0008989	0.0159	117.22	251.79	118.35	153.33	271.68	0.4243	0.9017
52	1.3851	0.0009142	0.0142	123.31	253.55	124.58	148.66	273.24	0.4432	0.9004
56	1.5278	0.0009308	0.0127	129.51	255.23	130.93	143.75	274.68	0.4622	0.8990
60	1.6813	0.0009488	0.0114	135.82	256.81	137.42	138.57	275.99	0.4814	0.8973
70	2.1162	0.0010027	0.0086	152.22	260.15	154.34	124.08	278.43	0.5302	0.8918
80	2.6324	0.0010766	0.0064	169.88	262.14	172.71	106.41	279.12	0.5814	0.8827
90	3.2435	0.0011949	0.0046	189.82	261.34	193.69	82.63	276.32	0.6380	0.8655
100	3.9742	0.0015443	0.0027	218.60	248.49	224.74	34.40	259.13	0.7196	0.8117

Source for Tables A-8 through A-10: M. J. Moran and H. N. Shapiro, *Fundamentals of Engineering Thermodynamics*, 2nd ed. (New York: John Wiley & Sons, 1992), pp. 710–15. Originally based on equations from D. P. Wilson and R. S. Basu, "Thermodynamic Properties of a New Stratospherically Safe Working Fluid—Refrigerant-134a," *ASHRAE Trans.* 94, Pt. 2 (1988), pp. 2085–116. Used with permission.

TABLE A-12

Saturated refrigerant-134a—Pressure table

Press., MPa	Temp., $T_{\text{sat}}$ , °C	Specific volume, $\text{m}^3/\text{kg}$		Internal energy, kJ/kg		Enthalpy, kJ/kg			Entropy, kJ/(kg · K)	
		Sat. liquid, $v_f$	Sat. vapor, $v_g$	Sat. liquid, $u_f$	Sat. vapor, $u_g$	Sat. liquid, $h_f$	Evap., $h_{fg}$	Sat. vapor, $h_g$	Sat. liquid, $s_f$	Sat. vapor, $s_g$
0.06	-37.07	0.0007097	0.3100	3.41	206.12	3.46	221.27	224.72	0.0147	0.9520
0.08	-31.21	0.0007184	0.2366	10.41	209.46	10.47	217.92	228.39	0.0440	0.9447
0.10	-26.43	0.0007258	0.1917	16.22	212.18	16.29	215.06	231.35	0.0678	0.9385
0.12	-22.36	0.0007323	0.1614	21.23	214.50	21.32	212.54	233.86	0.0879	0.9354
0.14	-18.80	0.0007381	0.1395	25.66	216.52	25.77	210.27	236.04	0.1055	0.9322
0.16	-15.62	0.0007435	0.1229	29.66	218.32	29.78	208.18	237.97	0.1211	0.9295
0.18	-12.73	0.0007485	0.1098	33.31	219.94	33.45	206.26	239.71	0.1352	0.9273
0.20	-10.09	0.0007532	0.0993	36.69	221.43	36.84	204.46	241.30	0.1481	0.9253
0.24	-5.37	0.0007618	0.0834	42.77	224.07	42.95	201.14	244.09	0.1710	0.9222
0.28	-1.23	0.0007697	0.0719	48.18	226.38	48.39	198.13	246.52	0.1911	0.9197
0.32	2.48	0.0007770	0.0632	53.06	228.43	53.31	195.35	248.66	0.2089	0.9177
0.36	5.84	0.0007839	0.0564	57.54	230.28	57.82	192.76	250.58	0.2251	0.9160
0.4	8.93	0.0007904	0.0509	61.69	231.97	62.00	190.32	252.32	0.2399	0.9145
0.5	15.74	0.0008056	0.0409	70.93	235.64	71.33	184.74	256.07	0.2723	0.9117
0.6	21.58	0.0008196	0.0341	78.99	238.74	79.48	179.71	259.19	0.2999	0.9097
0.7	26.72	0.0008328	0.0292	86.19	241.42	86.78	175.07	261.85	0.3242	0.9080
0.8	31.33	0.0008454	0.0255	92.75	243.78	93.42	170.73	264.15	0.3459	0.9066
0.9	35.53	0.0008576	0.0226	98.79	245.88	99.56	166.62	266.18	0.3656	0.9054
1.0	39.39	0.0008695	0.0202	104.42	247.77	105.29	162.68	267.87	0.3838	0.9043
1.2	46.32	0.0008928	0.0166	114.69	251.03	115.76	155.23	270.99	0.4164	0.9023
1.4	52.43	0.0009159	0.0140	123.98	253.74	125.26	148.14	273.40	0.4453	0.9003
1.6	57.92	0.0009392	0.0121	132.52	256.00	134.02	141.31	275.33	0.4714	0.8982
1.8	62.91	0.0009631	0.0105	140.49	257.88	142.22	134.60	276.83	0.4954	0.8959
2.0	67.49	0.0009878	0.0093	148.02	259.41	149.99	127.95	277.94	0.5178	0.8934
2.5	77.59	0.0010562	0.0069	165.48	261.84	168.12	111.06	279.17	0.5687	0.8854
3.0	86.22	0.0011416	0.0053	181.88	262.16	185.30	92.71	278.01	0.6156	0.8735

R-134a

TABLE A-13

Superheated refrigerant-134a

$T$ °C	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/(kg·K)	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/(kg·K)	$v$ m <sup>3</sup> /kg	$u$ kJ/kg	$h$ kJ/kg	$s$ kJ/(kg·K)
$P = 0.06 \text{ MPa } (T_{\text{sat}} = -37.07^\circ\text{C})$				$P = 0.10 \text{ MPa } (T_{\text{sat}} = -26.43^\circ\text{C})$				$P = 0.14 \text{ MPa } (T_{\text{sat}} = -18.80^\circ\text{C})$				
Sat.	0.31003	206.12	224.72	0.9520	0.19170	212.18	231.35	0.9395	0.13945	216.52	238.04	0.9322
-20	0.33536	217.86	237.98	1.0062	0.19770	216.77	236.54	0.9602				
-10	0.34992	224.97	245.96	1.0371	0.20606	224.01	244.70	0.9918	0.14549	223.03	243.40	0.9606
0	0.36433	232.24	254.10	1.0676	0.21587	231.41	252.99	1.0227	0.15219	230.55	251.86	0.9922
10	0.37851	239.69	262.41	1.0973	0.22473	238.96	261.43	1.0531	0.15075	238.21	260.43	1.0230
20	0.39279	247.32	270.89	1.1267	0.23349	246.87	270.02	1.0829	0.16520	246.01	269.13	1.0532
30	0.40688	255.12	279.53	1.1557	0.24216	254.54	278.76	1.1122	0.17155	253.96	277.97	1.0828
40	0.42091	263.10	288.35	1.1844	0.25076	262.58	287.66	1.1411	0.17783	262.06	286.96	1.1120
50	0.43487	271.25	297.34	1.2126	0.25930	270.79	296.72	1.1696	0.18404	270.32	296.09	1.1407
60	0.44879	279.58	306.51	1.2405	0.26779	279.16	305.94	1.1977	0.19020	278.74	305.37	1.1690
70	0.46266	288.08	315.84	1.2681	0.27623	287.70	315.32	1.2254	0.19633	287.32	314.80	1.1969
80	0.47650	296.75	325.34	1.2954	0.28464	296.40	324.87	1.2528	0.20241	296.06	324.39	1.2244
90	0.49031	305.58	335.00	1.3224	0.29302	305.27	334.57	1.2799	0.20846	304.95	334.14	1.2516
100									0.21449	314.01	344.04	1.2785
$P = 0.18 \text{ MPa } (T_{\text{sat}} = -12.73^\circ\text{C})$				$P = 0.20 \text{ MPa } (T_{\text{sat}} = -10.09^\circ\text{C})$				$P = 0.24 \text{ MPa } (T_{\text{sat}} = -5.37^\circ\text{C})$				
Sat.	0.10983	219.94	239.71	0.9273	0.09933	221.43	241.30	0.9253	0.06343	224.07	244.09	0.9222
-10	0.11135	222.02	242.08	0.9362	0.09939	221.50	241.38	0.9256				
0	0.11678	229.67	250.69	0.9684	0.10438	229.23	250.10	0.9582	0.06574	228.31	248.89	0.9399
10	0.12207	237.44	259.41	0.9998	0.10922	237.05	258.89	0.9898	0.06993	236.26	257.84	0.9721
20	0.12723	245.33	268.23	1.0304	0.11394	244.89	267.78	1.0206	0.09339	244.30	266.85	1.0034
30	0.13230	253.36	277.17	1.0604	0.11856	253.06	278.77	1.0508	0.09784	252.45	275.95	1.0339
40	0.13730	261.53	286.24	1.0898	0.12311	261.26	285.88	1.0804	0.10181	260.72	285.16	1.0637
50	0.14222	269.85	295.46	1.1187	0.12758	269.61	295.12	1.1094	0.10562	269.12	294.47	1.0930
60	0.14710	278.31	304.79	1.1472	0.13201	278.10	304.50	1.1380	0.10937	277.67	303.91	1.1218
70	0.15193	286.83	314.28	1.1753	0.13639	286.74	314.02	1.1681	0.11307	286.35	313.49	1.1501
80	0.15672	295.71	323.82	1.2030	0.14073	295.53	323.68	1.1939	0.11674	295.18	323.19	1.1780
90	0.16148	304.63	333.70	1.2303	0.14504	304.47	333.48	1.2212	0.12037	304.15	333.04	1.2055
100	0.16622	313.72	343.63	1.2573	0.14932	313.57	343.43	1.2483	0.12398	313.27	343.03	1.2326
$P = 0.28 \text{ MPa } (T_{\text{sat}} = -1.23^\circ\text{C})$				$P = 0.32 \text{ MPa } (T_{\text{sat}} = 2.48^\circ\text{C})$				$P = 0.40 \text{ MPa } (T_{\text{sat}} = 8.93^\circ\text{C})$				
Sat.	0.07193	226.38	246.52	0.9197	0.06322	228.43	248.66	0.9177	0.05089	231.97	252.32	0.9145
0	0.07240	227.37	247.64	0.9238								
10	0.07813	235.44	256.76	0.9566	0.06576	234.61	255.65	0.9427	0.05119	232.87	253.35	0.9182
20	0.07972	243.59	265.91	0.9883	0.06901	242.87	264.95	0.9749	0.05397	241.37	262.96	0.9515
30	0.08320	251.83	275.12	1.0192	0.07214	251.19	274.28	1.0062	0.05662	249.89	272.54	0.9937
40	0.08660	260.17	284.42	1.0494	0.07518	259.61	283.67	1.0367	0.05917	258.47	282.14	1.0148
50	0.08992	268.64	293.81	1.0789	0.07815	268.14	293.15	1.0665	0.06164	267.13	291.79	1.0452
60	0.09319	277.23	303.32	1.1079	0.08106	276.79	302.72	1.0957	0.06405	275.89	301.51	1.0748
70	0.09641	285.86	312.95	1.1364	0.08392	285.58	312.41	1.1243	0.06641	284.75	311.32	1.1038
80	0.09960	294.82	322.71	1.1644	0.08674	294.46	322.22	1.1525	0.06873	293.73	321.23	1.1322
90	0.10275	303.83	332.60	1.1920	0.08953	303.50	332.15	1.1802	0.07102	302.84	331.25	1.1602
100	0.10587	312.98	342.62	1.2193	0.09229	312.68	342.21	1.1076	0.07327	312.07	341.38	1.1878
110	0.10897	322.27	352.78	1.2461	0.09503	322.00	352.40	1.2345	0.07550	321.44	351.64	1.2149
120	0.11205	331.71	363.08	1.2727	0.09774	331.45	362.73	1.2611	0.07771	330.94	362.03	1.2417
130									0.07991	340.58	372.54	1.2681
140									0.08208	350.35	383.16	1.2941

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TABLE A-13

Superheated refrigerant-134a (Concluded)

T °C	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
<b>P = 0.50 MPa (T<sub>sat</sub> = 15.74°C)</b>				<b>P = 0.60 MPa (T<sub>sat</sub> = 21.58°C)</b>				<b>P = 0.70 MPa (T<sub>sat</sub> = 26.72°C)</b>				
Sat.	0.04066	253.64	256.07	0.9117	0.03408	238.74	259.19	0.9097	0.02918	241.42	261.85	0.9060
20	0.04188	239.40	260.34	0.9264								
30	0.04416	248.20	270.28	0.9597	0.03581	246.41	267.69	0.9388	0.02979	244.51	265.37	0.9197
40	0.04633	256.99	280.16	0.9918	0.03774	255.45	278.09	0.9719	0.03157	253.83	275.93	0.9539
50	0.04842	265.83	290.04	1.0229	0.03958	264.48	288.23	1.0037	0.03324	263.08	286.35	0.9867
60	0.05043	274.73	299.95	1.0531	0.04134	273.54	298.35	1.0346	0.03482	272.31	296.69	1.0182
70	0.05240	283.72	309.92	1.0825	0.04304	282.66	308.48	1.0645	0.03634	281.57	307.01	1.0487
80	0.05432	292.80	319.96	1.1114	0.04469	291.86	318.67	1.0938	0.03781	290.88	317.35	1.0784
90	0.05620	302.00	330.10	1.1397	0.04631	301.14	328.93	1.1225	0.03924	300.27	327.74	1.1074
100	0.05805	311.31	340.33	1.1675	0.04790	310.53	339.27	1.1505	0.04084	309.74	338.19	1.1358
110	0.05988	320.74	350.68	1.1949	0.04946	320.03	349.70	1.1781	0.04201	319.31	348.71	1.1637
120	0.06168	330.30	361.14	1.2218	0.05099	320.64	360.24	1.2053	0.04335	328.98	359.33	1.1910
130	0.06347	339.98	371.72	1.2484	0.05251	339.38	370.88	1.2320	0.04468	338.76	370.04	1.2179
140	0.06524	349.79	382.42	1.2746	0.05402	349.23	381.64	1.2584	0.04599	348.68	380.86	1.2444
150					0.05550	359.21	392.52	1.2844	0.04729	358.68	391.79	1.2706
160					0.05698	369.32	403.51	1.3100	0.04857	368.82	402.82	1.2963
<b>P = 0.80 MPa (T<sub>sat</sub> = 31.33°C)</b>				<b>P = 0.90 MPa (T<sub>sat</sub> = 36.83°C)</b>				<b>P = 1.00 MPa (T<sub>sat</sub> = 39.33°C)</b>				
Sat.	0.02547	243.78	264.15	0.9066	0.02255	245.88	268.18	0.9054	0.02020	247.77	267.97	0.9043
40	0.02691	252.18	273.66	0.9374	0.02325	250.32	271.25	0.9217	0.02029	248.39	268.68	0.9066
50	0.02846	261.62	284.39	0.9711	0.02472	260.09	282.34	0.9568	0.02171	258.48	280.19	0.9429
60	0.02992	271.04	294.98	1.0034	0.02609	269.72	293.21	0.9897	0.02301	268.35	291.36	0.9768
70	0.03131	280.45	305.50	1.0345	0.02738	279.30	303.94	1.0214	0.02423	278.11	302.34	1.0093
80	0.03264	289.89	316.00	1.0647	0.02861	288.87	314.62	1.0521	0.02538	287.82	313.20	1.0405
90	0.03393	299.37	326.52	1.0940	0.02980	298.46	325.28	1.0819	0.02649	297.53	324.01	1.0707
100	0.03518	308.93	337.08	1.1227	0.03095	308.11	335.96	1.1109	0.02755	307.27	334.82	1.1000
110	0.03642	318.57	347.71	1.1508	0.03207	317.82	346.68	1.1392	0.02858	317.06	345.65	1.1286
120	0.03762	328.31	358.40	1.1784	0.03316	327.62	357.47	1.1670	0.02959	326.83	356.52	1.1567
130	0.03881	338.14	369.19	1.2055	0.03423	337.52	368.33	1.1943	0.03058	336.68	367.46	1.1841
140	0.03997	348.09	380.07	1.2321	0.03529	347.51	379.27	1.2211	0.03154	346.62	378.46	1.2111
150	0.04113	358.15	391.05	1.2584	0.03633	357.61	390.31	1.2475	0.03250	356.66	389.56	1.2376
160	0.04227	368.32	402.14	1.2843	0.03738	367.82	401.44	1.2735	0.03344	367.31	400.74	1.2638
170	0.04340	378.61	413.33	1.3096	0.03838	378.14	412.68	1.2992	0.03436	377.68	412.02	1.2895
180	0.04452	389.02	424.63	1.3351	0.03939	388.57	424.02	1.3245	0.03528	388.12	423.40	1.3149
<b>P = 1.20 MPa (T<sub>sat</sub> = 46.32°C)</b>				<b>P = 1.40 MPa (T<sub>sat</sub> = 52.43°C)</b>				<b>P = 1.60 MPa (T<sub>sat</sub> = 57.92°C)</b>				
Sat.	0.01683	251.03	270.99	0.9023	0.01405	253.74	273.40	0.9003	0.01208	256.00	275.33	0.8982
50	0.01712	254.98	276.52	0.9164								
60	0.01835	265.42	287.44	0.9527	0.01495	262.17	283.10	0.9297	0.01233	258.48	278.20	0.9089
70	0.01947	276.59	298.96	0.9908	0.01603	272.87	295.31	0.9658	0.01340	269.89	291.33	0.9457
80	0.02051	288.62	310.24	1.0192	0.01701	283.29	307.19	0.9997	0.01435	280.78	303.74	0.9813
90	0.02150	299.59	321.39	1.0503	0.01792	293.55	318.63	1.0319	0.01521	291.39	315.72	1.0148
100	0.02244	309.54	332.47	1.0804	0.01878	303.73	330.02	1.0626	0.01601	301.84	327.46	1.0467
110	0.02335	319.50	343.52	1.1096	0.01960	313.89	341.32	1.0927	0.01677	312.20	339.04	1.0773
120	0.02423	329.51	354.58	1.1381	0.02039	324.05	352.59	1.1218	0.01750	322.53	350.53	1.1069
130	0.02508	339.58	365.68	1.1660	0.02115	334.25	363.86	1.1501	0.01820	332.87	361.99	1.1357
140	0.02592	349.73	376.83	1.1933	0.02189	344.50	375.15	1.1777	0.01887	343.24	373.44	1.1638
150	0.02674	359.95	388.04	1.2201	0.02262	354.82	386.49	1.2048	0.01953	353.66	384.91	1.1912
160	0.02754	369.27	399.33	1.2465	0.02333	365.22	397.89	1.2315	0.02017	364.15	396.43	1.2181
170	0.02834	378.69	410.70	1.2724	0.02403	375.71	409.36	1.2576	0.02080	374.71	407.99	1.2445
180	0.02912	387.21	422.16	1.2980	0.02472	386.29	420.90	1.2834	0.02142	385.35	419.62	1.2704
190					0.02541	396.96	432.53	1.3088	0.02203	396.08	431.33	1.2960
200					0.02608	407.73	444.24	1.3338	0.02263	406.90	443.11	1.3212

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TABLE A-14 Ideal Gas Specific Heats of Some Common Gases (kJ/kg · K)

Temp. K	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	Temp. K
	Air			Nitrogen, $N_2$			Oxygen, $O_2$			
250	1.003	0.716	1.401	1.039	0.742	1.400	0.913	0.653	1.398	250
300	1.005	0.718	1.400	1.039	0.743	1.400	0.918	0.658	1.395	300
350	1.008	0.721	1.398	1.041	0.744	1.399	0.928	0.668	1.389	350
400	1.013	0.726	1.395	1.044	0.747	1.397	0.941	0.681	1.382	400
450	1.020	0.733	1.391	1.049	0.752	1.395	0.956	0.696	1.373	450
500	1.029	0.742	1.387	1.056	0.759	1.391	0.972	0.712	1.365	500
550	1.040	0.753	1.381	1.065	0.768	1.387	0.988	0.728	1.358	550
600	1.051	0.764	1.376	1.075	0.778	1.382	1.003	0.743	1.350	600
650	1.063	0.776	1.370	1.086	0.789	1.376	1.017	0.758	1.343	650
700	1.075	0.788	1.364	1.098	0.801	1.371	1.031	0.771	1.337	700
750	1.087	0.800	1.359	1.110	0.813	1.365	1.043	0.785	1.332	750
800	1.099	0.812	1.354	1.121	0.825	1.360	1.054	0.794	1.327	800
900	1.121	0.834	1.344	1.145	0.849	1.349	1.074	0.814	1.319	900
1000	1.142	0.855	1.336	1.167	0.870	1.341	1.090	0.830	1.313	1000

Temp. K	Carbon dioxide, $CO_2$			Carbon monoxide, $CO$			Hydrogen, $H_2$			Temp. K
	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	
250	0.791	0.602	1.314	1.039	0.743	1.400	14.051	9.827	1.416	250
300	0.846	0.657	1.288	1.040	0.744	1.399	14.307	10.183	1.405	300
350	0.895	0.706	1.268	1.043	0.746	1.398	14.427	10.303	1.400	350
400	0.939	0.750	1.252	1.047	0.751	1.395	14.876	10.352	1.398	400
450	0.978	0.790	1.239	1.054	0.757	1.392	14.501	10.377	1.398	450
500	1.014	0.825	1.229	1.063	0.767	1.387	14.513	10.389	1.397	500
550	1.046	0.857	1.220	1.075	0.778	1.382	14.530	10.405	1.396	550
600	1.075	0.886	1.213	1.087	0.790	1.376	14.546	10.422	1.396	600
650	1.102	0.913	1.207	1.100	0.803	1.370	14.571	10.447	1.395	650
700	1.126	0.937	1.202	1.113	0.816	1.364	14.604	10.480	1.394	700
750	1.148	0.959	1.197	1.126	0.829	1.358	14.645	10.521	1.392	750
800	1.169	0.980	1.193	1.139	0.842	1.353	14.695	10.570	1.390	800
900	1.204	1.015	1.186	1.163	0.866	1.343	14.822	10.698	1.385	900
1000	1.234	1.045	1.181	1.185	0.888	1.335	14.983	10.859	1.380	1000

Source: Adapted from K. Wark, *Thermodynamics, 4th ed.*, McGraw-Hill, New York, 1983, as based on "Tables of Thermal Properties of Gases," NBS Circular 564, 1955.

Table A-14

TABLE A-17 Ideal Gas Properties of Nitrogen, N<sub>2</sub>T(K),  $\bar{h}$  and  $\bar{u}$ (kJ/kmol),  $\bar{s}^\circ$ (kJ/kmol · K) $[\bar{h}_f^\circ = 0 \text{ kJ/kmol}]$ 

T	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	T	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$
0	0	0	0	600	17,563	12,574	212.066
220	6,391	4,562	182.639	610	17,864	12,792	212.564
230	6,683	4,770	183.938	620	18,166	13,011	213.055
240	6,975	4,979	185.180	630	18,468	13,230	213.541
250	7,266	5,188	186.370	640	18,772	13,450	214.018
260	7,558	5,396	187.514	650	19,075	13,671	214.489
270	7,849	5,604	188.614	660	19,380	13,892	214.954
280	8,141	5,813	189.673	670	19,685	14,114	215.413
290	8,432	6,021	190.695	680	19,991	14,337	215.866
298	8,669	6,190	191.502	690	20,297	14,560	216.314
300	8,723	6,229	191.682	700	20,604	14,784	216.756
310	9,014	6,437	192.638	710	20,912	15,008	217.192
320	9,306	6,645	193.562	720	21,220	15,234	217.624
330	9,597	6,853	194.459	730	21,529	15,460	218.059
340	9,888	7,061	195.328	740	21,839	15,686	218.472
350	10,180	7,270	196.173	750	22,149	15,913	218.889
360	10,471	7,478	196.995	760	22,460	16,141	219.301
370	10,763	7,687	197.794	770	22,772	16,370	219.709
380	11,055	7,895	198.572	780	23,085	16,599	220.113
390	11,347	8,104	199.331	790	23,398	16,830	220.512
400	11,640	8,314	200.071	800	23,714	17,061	220.907
410	11,932	8,523	200.794	810	24,027	17,292	221.298
420	12,225	8,733	201.499	820	24,342	17,524	221.684
430	12,518	8,943	202.189	830	24,658	17,757	222.067
440	12,811	9,153	202.863	840	24,974	17,990	222.447
450	13,105	9,363	203.523	850	25,292	18,224	222.822
460	13,399	9,574	204.170	860	25,610	18,459	223.194
470	13,693	9,786	204.803	870	25,928	18,695	223.562
480	13,988	9,997	205.424	880	26,248	18,931	223.927
490	14,285	10,210	206.033	890	26,568	19,168	224.288
500	14,581	10,423	206.630	900	26,890	19,407	224.647
510	14,876	10,635	207.216	910	27,210	19,644	225.002
520	15,172	10,848	207.792	920	27,532	19,883	225.353
530	15,469	11,062	208.358	930	27,854	20,122	225.701
540	15,766	11,277	208.914	940	28,178	20,362	226.047
550	16,064	11,492	209.461	950	28,501	20,603	226.389
560	16,363	11,707	209.999	960	28,826	20,844	226.728
570	16,662	11,923	210.528	970	29,151	21,086	227.064
580	16,962	12,139	211.049	980	29,476	21,328	227.398
590	17,262	12,356	211.562	990	29,803	21,571	227.728

N<sub>2</sub>

TABLE A-18 Ideal Gas Properties of Oxygen, O<sub>2</sub>O<sub>2</sub> $T(K)$ ,  $\bar{h}$  and  $\bar{u}$ (kJ/kmol),  $\bar{s}^\circ$ (kJ/kmol · K) $\{\bar{h}_f^\circ = 0 \text{ kJ/kmol}\}$ 

$T$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$T$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$
0	0	0	0	600	17,929	12,940	226.346
220	6,404	4,575	196.171	610	18,250	13,178	226.877
230	6,694	4,782	197.461	620	18,572	13,417	227.400
240	6,984	4,989	198.696	630	18,895	13,657	227.918
250	7,275	5,197	199.885	640	19,219	13,898	228.429
260	7,566	5,405	201.027	650	19,544	14,140	228.932
270	7,858	5,613	202.128	660	19,870	14,383	229.430
280	8,150	5,822	203.191	670	20,197	14,626	229.920
290	8,443	6,032	204.218	680	20,524	14,871	230.405
298	8,682	6,203	205.033	690	20,854	15,116	230.885
300	8,736	6,242	205.213	700	21,184	15,364	231.358
310	9,030	6,453	206.177	710	21,514	15,611	231.827
320	9,325	6,664	207.112	720	21,845	15,859	232.291
330	9,620	6,877	208.020	730	22,177	16,107	232.748
340	9,916	7,090	208.904	740	22,510	16,357	233.201
350	10,213	7,303	209.765	750	22,844	16,607	233.649
360	10,511	7,518	210.604	760	23,178	16,859	234.091
370	10,809	7,733	211.423	770	23,513	17,111	234.528
380	11,109	7,949	212.222	780	23,850	17,364	234.960
390	11,409	8,166	213.002	790	24,186	17,618	235.387
400	11,711	8,384	213.765	800	24,523	17,872	235.810
410	12,012	8,603	214.510	810	24,861	18,126	236.230
420	12,314	8,822	215.241	820	25,199	18,382	236.644
430	12,618	9,043	215.955	830	25,537	18,637	237.055
440	12,923	9,264	216.656	840	25,877	18,893	237.462
450	13,228	9,487	217.342	850	26,218	19,150	237.864
460	13,535	9,710	218.016	860	26,559	19,408	238.264
470	13,842	9,935	218.676	870	26,899	19,666	238.660
480	14,151	10,160	219.326	880	27,242	19,925	239.051
490	14,460	10,386	219.963	890	27,584	20,185	239.439
500	14,770	10,614	220.589	900	27,928	20,445	239.823
510	15,082	10,842	221.206	910	28,272	20,706	240.203
520	15,395	11,071	221.812	920	28,616	20,967	240.580
530	15,708	11,301	222.409	930	28,960	21,228	240.953
540	16,022	11,533	222.997	940	29,306	21,491	241.323
550	16,338	11,765	223.576	950	29,652	21,754	241.689
560	16,654	11,998	224.146	960	29,999	22,017	242.052
570	16,971	12,232	224.708	970	30,345	22,280	242.411
580	17,290	12,467	225.262	980	30,692	22,544	242.768
590	17,609	12,703	225.808	990	31,041	22,809	243.120

TABLE A-19 Ideal Gas Properties of Water Vapor, H<sub>2</sub>O

$T(K)$ ,  $\bar{h}$  and  $\bar{u}(kJ/kmol)$ ,  $\bar{s}^\circ(kJ/kmol \cdot K)$

$[\bar{h}_f^\circ = -241,820 \text{ kJ/kmol}]$

T	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	T	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$
0	0	0	0	600	20,402	15,413	212.920
220	7,295	5,466	178.576	610	20,765	15,693	213.529
230	7,628	5,715	180.054	620	21,130	15,975	214.122
240	7,961	5,965	181.471	630	21,495	16,257	214.707
250	8,294	6,215	182.831	640	21,862	16,541	215.285
260	8,627	6,466	184.139	650	22,230	16,826	215.856
270	8,961	6,716	185.399	660	22,600	17,112	216.419
280	9,295	6,968	186.616	670	22,970	17,399	216.976
290	9,631	7,219	187.791	680	23,342	17,688	217.527
298	9,904	7,425	188.720	690	23,714	17,978	218.071
300	9,966	7,472	188.928	700	24,088	18,268	218.610
310	10,302	7,725	190.030	710	24,464	18,561	219.142
320	10,639	7,978	191.098	720	24,840	18,854	219.668
330	10,976	8,232	192.136	730	25,218	19,148	220.189
340	11,314	8,487	193.144	740	25,597	19,444	220.707
350	11,652	8,742	194.125	750	25,977	19,741	221.215
360	11,992	8,998	195.081	760	26,358	20,039	221.720
370	12,331	9,255	196.012	770	26,741	20,339	222.221
380	12,672	9,513	196.920	780	27,125	20,639	222.717
390	13,014	9,771	197.807	790	27,510	20,941	223.207
400	13,356	10,030	198.673	800	27,896	21,245	223.693
410	13,699	10,290	199.521	810	28,284	21,549	224.174
420	14,043	10,551	200.350	820	28,672	21,855	224.651
430	14,388	10,813	201.160	830	29,062	22,162	225.123
440	14,734	11,075	201.955	840	29,454	22,470	225.592
450	15,080	11,339	202.734	850	29,846	22,779	226.057
460	15,428	11,603	203.497	860	30,240	23,090	226.517
470	15,777	11,869	204.247	870	30,635	23,402	226.973
480	16,126	12,135	204.982	880	31,032	23,715	227.426
490	16,477	12,403	205.705	890	31,429	24,029	227.875
500	16,828	12,671	206.413	900	31,828	24,345	228.321
510	17,181	12,940	207.112	910	32,228	24,662	228.763
520	17,534	13,211	207.799	920	32,629	24,980	229.202
530	17,889	13,482	208.475	930	33,032	25,300	229.637
540	18,245	13,755	209.139	940	33,436	25,621	230.070
550	18,601	14,028	209.795	950	33,841	25,943	230.499
560	18,959	14,303	210.440	960	34,247	26,265	230.924
570	19,318	14,579	211.075	970	34,653	26,588	231.347
580	19,678	14,856	211.702	980	35,061	26,913	231.767
590	20,039	15,134	212.320	990	35,472	27,240	232.184

H<sub>2</sub>O



TABLE A-22 Ideal Gas Properties of Air

T(K), h and u(kJ/kg), s°(kJ/kg·K)											
T	h	$p_r$	u	$u_r$	$s^\circ$	T	h	$p_r$	u	$u_r$	$s^\circ$
200	199.97	0.3363	142.56	1707.	1.29559	450	451.80	5.775	322.62	223.6	2.11161
210	209.97	0.3987	149.69	1512.	1.34444	460	462.02	6.245	329.97	211.4	2.13407
220	219.97	0.4690	156.82	1346.	1.39105	470	472.24	6.742	337.32	200.1	2.15604
230	230.02	0.5477	164.00	1205.	1.43557	480	482.49	7.268	344.70	189.5	2.17760
240	240.02	0.6355	171.13	1084.	1.47824	490	492.74	7.824	352.08	179.7	2.19876
250	250.05	0.7329	178.28	979.	1.51917	500	503.02	8.411	359.49	170.6	2.21952
260	260.09	0.8405	185.45	887.8	1.55848	510	513.32	9.031	366.92	162.1	2.23993
270	270.11	0.9590	192.60	808.0	1.59634	520	523.63	9.684	374.36	154.1	2.25997
280	280.13	1.0889	199.75	738.0	1.63279	530	533.98	10.37	381.84	146.7	2.27967
285	285.14	1.1584	203.33	706.1	1.65055	540	544.35	11.10	389.34	139.7	2.29906
290	290.16	1.2311	206.91	676.1	1.66802	550	554.74	11.86	396.86	133.1	2.31809
295	295.17	1.3068	210.49	647.9	1.68515	560	565.17	12.66	404.42	127.0	2.33685
300	300.19	1.3860	214.07	621.2	1.70203	570	575.59	13.50	411.97	121.2	2.35531
305	305.22	1.4686	217.67	596.0	1.71865	580	586.04	14.38	419.55	115.7	2.37348
310	310.24	1.5546	221.25	572.3	1.73498	590	596.52	15.31	427.15	110.6	2.39140
315	315.27	1.6442	224.85	549.8	1.75106	600	607.02	16.28	434.78	105.8	2.40902
320	320.29	1.7375	228.42	528.6	1.76690	610	617.53	17.30	442.42	101.2	2.42644
325	325.31	1.8345	232.02	508.4	1.78249	620	628.07	18.36	450.09	96.92	2.44356
330	330.34	1.9352	235.61	489.4	1.79783	630	638.63	19.44	457.78	92.84	2.46048
340	340.42	2.149	242.82	454.1	1.82790	640	649.22	20.64	465.50	88.99	2.47716
350	350.49	2.379	250.02	422.2	1.85708	650	659.84	21.86	473.25	85.34	2.49364
360	360.58	2.626	257.24	393.4	1.88543	660	670.47	23.13	481.01	81.89	2.50985
370	370.67	2.892	264.46	367.2	1.91313	670	681.14	24.46	488.81	78.61	2.52589
380	380.77	3.176	271.69	343.4	1.94001	680	691.82	25.85	496.62	75.50	2.54175
390	390.88	3.481	278.93	321.5	1.96633	690	702.52	27.29	504.45	72.56	2.55731
400	400.98	3.806	286.16	301.6	1.99194	700	713.27	28.80	512.33	69.76	2.57277
410	411.12	4.153	293.43	283.3	2.01699	710	724.04	30.38	520.23	67.07	2.58810
420	421.26	4.522	300.69	266.6	2.04142	720	734.82	32.02	528.14	64.53	2.60319
430	431.43	4.915	307.99	251.1	2.06533	730	745.62	33.72	536.07	62.13	2.61803
440	441.61	5.332	315.30	236.8	2.08870	740	756.44	35.50	544.02	59.82	2.63280

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TABLE A-22 (Continued)

T(K), h and v(kJ/kg), s°(kJ/kg·K)											
T	h	p <sub>r</sub>	v	v <sub>r</sub>	s°	T	h	p <sub>r</sub>	v	v <sub>r</sub>	s°
750	767.29	37.35	551.99	57.63	2.64737	1300	1395.97	330.9	1022.82	11.275	3.27345
760	778.18	39.27	560.01	55.54	2.66176	1320	1419.76	352.5	1040.88	10.747	3.29160
770	789.11	41.31	568.07	53.39	2.67595	1340	1443.60	375.3	1058.94	10.247	3.30959
780	800.03	43.35	576.12	51.64	2.69013	1360	1467.49	399.1	1077.10	9.780	3.32724
790	810.99	45.55	584.21	49.86	2.70400	1380	1491.44	424.2	1095.26	9.337	3.34474
800	821.95	47.75	592.30	48.08	2.71787	1400	1515.42	450.5	1113.52	8.919	3.36200
820	843.98	52.59	608.59	44.84	2.74504	1420	1539.44	478.0	1131.77	8.526	3.37901
840	866.08	57.60	624.95	41.85	2.77170	1440	1563.51	506.9	1150.13	8.153	3.39586
860	888.27	63.09	641.40	39.12	2.79783	1460	1587.63	537.1	1168.49	7.801	3.41247
880	910.56	68.98	657.95	36.61	2.82344	1480	1611.79	568.8	1186.95	7.468	3.42892
900	932.93	75.29	674.58	34.31	2.84856	1500	1635.97	601.9	1205.41	7.152	3.44516
920	955.38	82.05	691.28	32.18	2.87324	1520	1660.23	636.5	1223.87	6.854	3.46120
940	977.92	89.28	708.08	30.22	2.89748	1540	1684.51	672.8	1242.43	6.569	3.47712
960	1000.55	97.00	725.02	28.40	2.92128	1560	1708.82	710.5	1260.99	6.301	3.49276
980	1023.25	105.2	741.98	26.73	2.94468	1580	1733.17	750.0	1279.65	6.046	3.50829
1000	1046.04	114.0	758.94	25.17	2.96770	1600	1757.57	791.2	1298.30	5.804	3.52364
1020	1068.89	123.4	776.10	23.72	2.99034	1620	1782.00	834.1	1316.96	5.574	3.53879
1040	1091.85	133.3	793.36	22.39	3.01260	1640	1806.46	878.9	1335.72	5.355	3.55381
1060	1114.86	143.9	810.62	21.14	3.03449	1660	1830.96	925.6	1354.48	5.147	3.56867
1080	1137.89	155.2	827.88	19.98	3.05608	1680	1855.50	974.2	1373.24	4.949	3.58335
1100	1161.07	167.1	845.33	18.896	3.07732	1700	1880.1	1025	1392.7	4.761	3.5979
1120	1184.28	179.7	862.79	17.886	3.09825	1750	1941.6	1161	1439.8	4.328	3.6336
1140	1207.57	193.1	880.35	16.946	3.11883	1800	2003.3	1310	1487.2	3.944	3.6684
1160	1230.92	207.2	897.91	16.064	3.13916	1850	2065.3	1475	1534.9	3.601	3.7023
1180	1254.34	222.2	915.57	15.241	3.15916	1900	2127.4	1655	1582.6	3.295	3.7354
1200	1277.79	238.0	933.33	14.470	3.17888	1950	2189.7	1852	1630.6	3.022	3.7677
1220	1301.31	254.7	951.09	13.747	3.19834	2000	2252.1	2068	1678.7	2.776	3.7994
1240	1324.93	272.3	968.95	13.069	3.21751	2050	2314.6	2303	1726.8	2.555	3.8303
1260	1348.55	290.8	986.90	12.435	3.23638	2100	2377.4	2559	1775.3	2.356	3.8605
1280	1372.24	310.4	1004.76	11.835	3.25510	2150	2440.3	2837	1823.8	2.175	3.8901
						2200	2503.2	3138	1872.4	2.012	3.9191
						2250	2566.4	3464	1921.3	1.864	3.9474

Source: Adapted from K. Wark, *Thermodynamics*, 4th ed., McGraw-Hill, New York, 1963, as based on J. H. Keenan and J. Kaye, *Gas Tables*, Wiley, New York, 1945.

Psychrometric Chart for 1 atm (SI units)

