

PROPERTY TABLES AND CHARTS (ENGLISH UNITS)

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TABLE A-1E

Molar mass, gas constant, and critical-point properties

Substance	Formula	Molar mass, M lbm/lbmol	Gas constant, R		Critical-point properties		
			Btu/ lbm·R*	psia·ft ³ / lbm·R*	Temperature, R	Pressure, psia	Volume, ft ³ /lbmol
Air	—	28.97	0.06855	0.3704	238.5	547	1.41
Ammonia	NH ₃	17.03	0.1166	0.6301	729.8	1636	1.16
Argon	Ar	39.948	0.04971	0.2686	272	705	1.20
Benzene	C ₆ H ₆	78.115	0.02542	0.1374	1012	714	4.17
Bromine	Br ₂	159.808	0.01243	0.06714	1052	1500	2.17
n-Butane	C ₄ H ₁₀	58.124	0.03417	0.1846	765.2	551	4.08
Carbon dioxide	CO ₂	44.01	0.04513	0.2438	547.5	1071	1.51
Carbon monoxide	CO	28.011	0.07090	0.3831	240	507	1.49
Carbon tetrachloride	CCl ₄	153.82	0.01291	0.06976	1001.5	661	4.42
Chlorine	Cl ₂	70.906	0.02801	0.1517	751	1120	1.99
Chloroform	CHCl ₃	119.38	0.01664	0.08988	965.8	794	3.85
Dichlorodifluoromethane (R-12)	CCl ₂ F ₂	120.91	0.01643	0.08874	692.4	582	3.49
Dichlorofluoromethane (R-21)	CHCl ₂ F	102.92	0.01930	0.1043	813.0	749	3.16
Ethane	C ₂ H ₆	30.020	0.06616	0.3574	549.8	708	2.37
Ethyl alcohol	C ₂ H ₅ OH	46.07	0.04311	0.2329	929.0	926	2.68
Ethylene	C ₂ H ₄	28.054	0.07079	0.3825	508.3	742	1.99
Helium	He	4.003	0.4961	2.6809	9.5	33.2	0.926
n-Hexane	C ₆ H ₁₄	86.178	0.02305	0.1245	914.2	439	5.89
Hydrogen (normal)	H ₂	2.016	0.9851	5.3224	59.9	188.1	1.04
Krypton	Kr	83.80	0.02370	0.1280	376.9	798	1.48
Methane	CH ₄	16.043	0.1238	0.6688	343.9	673	1.59
Methyl alcohol	CH ₃ OH	32.042	0.06198	0.3349	923.7	1154	1.89
Methyl chloride	CH ₃ Cl	50.488	0.03934	0.2125	749.3	968	2.29
Neon	Ne	20.183	0.09840	0.5316	80.1	395	0.668
Nitrogen	N ₂	28.013	0.07090	0.3830	227.1	492	1.44
Nitrous oxide	N ₂ O	44.013	0.04512	0.2438	557.4	1054	1.54
Oxygen	O ₂	31.999	0.06206	0.3353	278.6	736	1.25
Propane	C ₃ H ₈	44.097	0.04504	0.2433	665.9	617	3.20
Propylene	C ₃ H ₆	42.081	0.04719	0.2550	656.9	670	2.90
Sulfur dioxide	SO ₂	64.063	0.03100	1.1675	775.2	1143	1.95
Tetrafluoroethane (R-134a)	CF ₃ CH ₂ F	102.03	0.01946	0.1052	673.6	588.7	3.19
Trichlorofluoromethane (R-11)	CCl ₃ F	137.37	0.01446	0.07811	848.1	635	3.97
Water	H ₂ O	18.015	0.1102	0.5956	1164.8	3200	0.90
Xenon	Xe	131.30	0.01513	0.08172	521.55	852	1.90

*Calculated from $R = R_u/M$, where $R_u = 1.98588$ Btu/lbmol·R = 10.7316 psia·ft³/lbmol·R and M is the molar mass.Source of Data: K. A. Kobe and R. E. Lynn, Jr., *Chemical Review* 52 (1953), pp. 117–236, and ASHRAE, *Handbook of Fundamentals* (Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1993), pp. 16.4 and 36.1.

TABLE A-2E

Ideal-gas specific heats of various common gases
(a) At 80°F

Gas	Formula	Gas constant, R Btu/lbm·R	c_p Btu/lbm·R	c_v Btu/lbm·R	k
Air	—	0.06855	0.240	0.171	1.400
Argon	Ar	0.04971	0.1253	0.0756	1.667
Butane	C ₄ H ₁₀	0.03424	0.415	0.381	1.09
Carbon dioxide	CO ₂	0.04513	0.203	0.158	1.285
Carbon monoxide	CO	0.07090	0.249	0.178	1.399
Ethane	C ₂ H ₆	0.06616	0.427	0.361	1.183
Ethylene	C ₂ H ₄	0.07079	0.411	0.340	1.208
Helium	He	0.4961	1.25	0.753	1.667
Hydrogen	H ₂	0.9851	3.43	2.44	1.404
Methane	CH ₄	0.1238	0.532	0.403	1.32
Neon	Ne	0.09840	0.246	0.1477	1.667
Nitrogen	N ₂	0.07090	0.248	0.177	1.400
Octane	C ₈ H ₁₈	0.01742	0.409	0.392	1.044
Oxygen	O ₂	0.06206	0.219	0.157	1.395
Propane	C ₃ H ₈	0.04504	0.407	0.362	1.124
Steam	H ₂ O	0.1102	0.445	0.335	1.329

Source of Data: Gordon J. Van Wylen and Richard E. Sonntag, *Fundamentals of Classical Thermodynamics*, English/SI Version, 3rd ed. (New York: John Wiley & Sons, 1986), p. 687, Table A-8E.

TABLE A-2E

Ideal-gas specific heats of various common gases (*Continued*)

(b) At various temperatures

Temp., °F	c_p Btu/lbm·R	c_v Btu/lbm·R	k	c_p Btu/lbm·R	c_v Btu/lbm·R	k	c_p Btu/lbm·R	c_v Btu/lbm·R	k
<i>Air</i>				<i>Carbon dioxide, CO₂</i>			<i>Carbon monoxide, CO</i>		
40	0.240	0.171	1.401	0.195	0.150	1.300	0.248	0.177	1.400
100	0.240	0.172	1.400	0.205	0.160	1.283	0.249	0.178	1.399
200	0.241	0.173	1.397	0.217	0.172	1.262	0.249	0.179	1.397
300	0.243	0.174	1.394	0.229	0.184	1.246	0.251	0.180	1.394
400	0.245	0.176	1.389	0.239	0.193	1.233	0.253	0.182	1.389
500	0.248	0.179	1.383	0.247	0.202	1.223	0.256	0.185	1.384
600	0.250	0.182	1.377	0.255	0.210	1.215	0.259	0.188	1.377
700	0.254	0.185	1.371	0.262	0.217	1.208	0.262	0.191	1.371
800	0.257	0.188	1.365	0.269	0.224	1.202	0.266	0.195	1.364
900	0.259	0.191	1.358	0.275	0.230	1.197	0.269	0.198	1.357
1000	0.263	0.195	1.353	0.280	0.235	1.192	0.273	0.202	1.351
1500	0.276	0.208	1.330	0.298	0.253	1.178	0.287	0.216	1.328
2000	0.286	0.217	1.312	0.312	0.267	1.169	0.297	0.226	1.314
<i>Hydrogen, H₂</i>				<i>Nitrogen, N₂</i>			<i>Oxygen, O₂</i>		
40	3.397	2.412	1.409	0.248	0.177	1.400	0.219	0.156	1.397
100	3.426	2.441	1.404	0.248	0.178	1.399	0.220	0.158	1.394
200	3.451	2.466	1.399	0.249	0.178	1.398	0.223	0.161	1.387
300	3.461	2.476	1.398	0.250	0.179	1.396	0.226	0.164	1.378
400	3.466	2.480	1.397	0.251	0.180	1.393	0.230	0.168	1.368
500	3.469	2.484	1.397	0.254	0.183	1.388	0.235	0.173	1.360
600	3.473	2.488	1.396	0.256	0.185	1.383	0.239	0.177	1.352
700	3.477	2.492	1.395	0.260	0.189	1.377	0.242	0.181	1.344
800	3.494	2.509	1.393	0.262	0.191	1.371	0.246	0.184	1.337
900	3.502	2.519	1.392	0.265	0.194	1.364	0.249	0.187	1.331
1000	3.513	2.528	1.390	0.269	0.198	1.359	0.252	0.190	1.326
1500	3.618	2.633	1.374	0.283	0.212	1.334	0.263	0.201	1.309
2000	3.758	2.773	1.355	0.293	0.222	1.319	0.270	0.208	1.298

Note: The unit Btu/lbm·R is equivalent to Btu/lbm·°F.

Source of Data: Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), p. 830, Table A-4. Originally published in *Tables of Properties of Gases*, NBS Circular 564, 1955.

TABLE A-2E

Ideal-gas specific heats of various common gases (*Concluded*)
(c) As a function of temperature

$\bar{c}_p = a + bT + cT^2 + dT^3$ (T in R, c_p in Btu/lbmol·R)							% error	
Substance	Formula	a	b	c	d	Temperature range, R	Max.	Avg.
Nitrogen	N ₂	6.903	-0.02085×10^{-2}	0.05957×10^{-5}	-0.1176×10^{-9}	491-3240	0.59	0.34
Oxygen	O ₂	6.085	0.2017×10^{-2}	-0.05275×10^{-5}	0.05372×10^{-9}	491-3240	1.19	0.28
Air	—	6.713	0.02609×10^{-2}	0.03540×10^{-5}	-0.08052×10^{-9}	491-3240	0.72	0.33
Hydrogen	H ₂	6.952	-0.02542×10^{-2}	0.02952×10^{-5}	-0.03565×10^{-9}	491-3240	1.02	0.26
Carbon monoxide	CO	6.726	0.02222×10^{-2}	0.03960×10^{-5}	-0.09100×10^{-9}	491-3240	0.89	0.37
Carbon dioxide	CO ₂	5.316	0.79361×10^{-2}	-0.2581×10^{-5}	0.3059×10^{-9}	491-3240	0.67	0.22
Water vapor	H ₂ O	7.700	0.02552×10^{-2}	0.07781×10^{-5}	-0.1472×10^{-9}	491-3240	0.53	0.24
Nitric oxide	NO	7.008	-0.01247×10^{-2}	0.07185×10^{-5}	-0.1715×10^{-9}	491-2700	0.97	0.36
Nitrous oxide	N ₂ O	5.758	0.7780×10^{-2}	-0.2596×10^{-5}	0.4331×10^{-9}	491-2700	0.59	0.26
Nitrogen dioxide	NO ₂	5.48	0.7583×10^{-2}	-0.260×10^{-5}	0.322×10^{-9}	491-2700	0.46	0.18
Ammonia	NH ₃	6.5846	0.34028×10^{-2}	0.073034×10^{-5}	-0.27402×10^{-9}	491-2700	0.91	0.36
Sulfur	S ₂	6.499	0.2943×10^{-2}	-0.1200×10^{-5}	0.1632×10^{-9}	491-3240	0.99	0.38
Sulfur dioxide	SO ₂	6.157	0.7689×10^{-2}	-0.2810×10^{-5}	0.3527×10^{-9}	491-3240	0.45	0.24
Sulfur trioxide	SO ₃	3.918	1.935×10^{-2}	-0.8256×10^{-5}	1.328×10^{-9}	491-2340	0.29	0.13
Acetylene	C ₂ H ₂	5.21	1.2227×10^{-2}	-0.4812×10^{-5}	0.7457×10^{-9}	491-2700	1.46	0.59
Benzene	C ₆ H ₆	-8.650	6.4322×10^{-2}	-2.327×10^{-5}	3.179×10^{-9}	491-2700	0.34	0.20
Methanol	CH ₄ O	4.55	1.214×10^{-2}	-0.0898×10^{-5}	-0.329×10^{-9}	491-1800	0.18	0.08
Ethanol	C ₂ H ₆ O	4.75	2.781×10^{-2}	-0.7651×10^{-5}	0.821×10^{-9}	491-2700	0.40	0.22
Hydrogen chloride	HCl	7.244	-0.1011×10^{-2}	0.09783×10^{-5}	-0.1776×10^{-9}	491-2740	0.22	0.08
Methane	CH ₄	4.750	0.6666×10^{-2}	0.09352×10^{-5}	-0.4510×10^{-9}	491-2740	1.33	0.57
Ethane	C ₂ H ₆	1.648	2.291×10^{-2}	-0.4722×10^{-5}	0.2984×10^{-9}	491-2740	0.83	0.28
Propane	C ₃ H ₈	-0.966	4.044×10^{-2}	-1.159×10^{-5}	1.300×10^{-9}	491-2740	0.40	0.12
<i>n</i> -Butane	C ₄ H ₁₀	0.945	4.929×10^{-2}	-1.352×10^{-5}	1.433×10^{-9}	491-2740	0.54	0.24
<i>i</i> -Butane	C ₄ H ₁₀	-1.890	5.520×10^{-2}	-1.696×10^{-5}	2.044×10^{-9}	491-2740	0.25	0.13
<i>n</i> -Pentane	C ₅ H ₁₂	1.618	6.028×10^{-2}	-1.656×10^{-5}	1.732×10^{-9}	491-2740	0.56	0.21
<i>n</i> -Hexane	C ₆ H ₁₄	1.657	7.328×10^{-2}	-2.112×10^{-5}	2.363×10^{-9}	491-2740	0.72	0.20
Ethylene	C ₂ H ₄	0.944	2.075×10^{-2}	-0.6151×10^{-5}	0.7326×10^{-9}	491-2740	0.54	0.13
Propylene	C ₃ H ₆	0.753	3.162×10^{-2}	-0.8981×10^{-5}	1.008×10^{-9}	491-2740	0.73	0.17

Source of Data: B.G. Kyle, *Chemical and Process Thermodynamics*, 3rd ed. (Upper Saddle River, NJ: Prentice Hall, 2000).

TABLE A-3E

Properties of common liquids, solids, and foods
(a) Liquids

Substance	Boiling data at 1 atm		Freezing data		Liquid properties		
	Normal boiling point, °F	Latent heat of vaporization, h_{fg} Btu/lbm	Freezing point, °F	Latent heat of fusion, h_{if} Btu/lbm	Temperature, °F	Density, ρ lbm/ft ³	Specific heat, c_p Btu/lbm·R
Ammonia	-27.9	24.54	-107.9	138.6	-27.9 0 40 80	42.6 41.3 39.5 37.5	1.06 1.083 1.103 1.135
Argon	-302.6	69.5	-308.7	12.0	-302.6	87.0	0.272
Benzene	176.4	169.4	41.9	54.2	68	54.9	0.411
Brine (20% sodium chloride by mass)	219.0	—	0.7	—	68	71.8	0.743
<i>n</i> -Butane	31.1	165.6	-217.3	34.5	31.1	37.5	0.552
Carbon dioxide	-109.2*	99.6 (at 32°F)	-69.8	—	32	57.8	0.583
Ethanol	172.8	360.5	-173.6	46.9	77	48.9	0.588
Ethyl alcohol	173.5	368	-248.8	46.4	68	49.3	0.678
Ethylene glycol	388.6	344.0	12.6	77.9	68	69.2	0.678
Glycerine	355.8	419	66.0	86.3	68	78.7	0.554
Helium	-452.1	9.80	—	—	-452.1	9.13	5.45
Hydrogen	-423.0	191.7	-434.5	25.6	-423.0	4.41	2.39
Isobutane	10.9	157.8	-255.5	45.5	10.9	37.1	0.545
Kerosene	399-559	108	-12.8	—	68	51.2	0.478
Mercury	674.1	126.7	-38.0	4.90	77	847	0.033
Methane	-258.7	219.6	296.0	25.1	-258.7 -160	26.4 20.0	0.834 1.074
Methanol	148.1	473	-143.9	42.7	77	49.1	0.609
Nitrogen	-320.4	85.4	-346.0	10.9	-320.4 -260	50.5 38.2	0.492 0.643
Octane	256.6	131.7	-71.5	77.9	68	43.9	0.502
Oil (light)	—	—	—	—	77	56.8	0.430
Oxygen	-297.3	91.5	-361.8	5.9	-297.3	71.2	0.408
Petroleum	—	99-165	—	—	68	40.0	0.478
Propane	-43.7	184.0	-305.8	34.4	-43.7 32 100	36.3 33.0 29.4	0.538 0.604 0.673
Refrigerant-134a	-15.0	93.3	-141.9	—	-40 -15 32 90	88.5 86.0 80.9 73.6	0.283 0.294 0.318 0.348
Water	212	970.1	32	143.5	32 90 150 212	62.4 62.1 61.2 59.8	1.01 1.00 1.00 1.01

*Sublimation temperature. (At pressures below the triple-point pressure of 75.1 psia, carbon dioxide exists as a solid or gas. Also, the freezing-point temperature of carbon dioxide is the triple-point temperature of -69.8°F.)

TABLE A-3E

Properties of common liquids, solids, and foods (*Concluded*)
 (b) Solids (values are for room temperature unless indicated otherwise)

Substance	Density, ρ lbm/ft ³	Specific heat, c_p Btu/lbm·R	Substance	Density, ρ lbm/ft ³	Specific heat, c_p Btu/lbm·R
Metals			Nonmetals		
Aluminum			Asphalt	132	0.220
−100°F		0.192	Brick, common	120	0.189
32°F		0.212	Brick, fireclay (500°C)	144	0.229
100°F	170	0.218	Concrete	144	0.156
200°F		0.224	Clay	62.4	0.220
300°F		0.229	Diamond	151	0.147
400°F		0.235	Glass, window	169	0.191
500°F		0.240	Glass, pyrex	139	0.200
Bronze (76% Cu, 2% Zn, 2% Al)	517	0.0955	Graphite	156	0.170
Brass, yellow (65% Cu, 35% Zn)	519	0.0955	Granite	169	0.243
Copper			Gypsum or plaster board	50	0.260
−60°F		0.0862	Ice		
0°F		0.0893	−50°F		0.424
100°F	555	0.0925	0°F		0.471
200°F		0.0938	20°F		0.491
390°F		0.0963	32°F	57.5	0.502
Iron	490	0.107	Limestone	103	0.217
Lead	705	0.030	Marble 162	0.210	
Magnesium	108	0.239	Plywood (Douglas fir)	34.0	
Nickel	555	0.105	Rubber (hard)	68.7	
Silver	655	0.056	Rubber (soft)	71.8	
Steel, mild	489	0.119	Sand	94.9	
Tungsten	1211	0.031	Stone	93.6	
			Woods, hard (maple, oak, etc.)	45.0	
			Woods, soft (fir, pine, etc.)	32.0	

(c) Foods

Food	Water content, % (mass)	Freezing point, °F	Specific heat, Btu/lbm·R		Latent heat of fusion, Btu/lbm	Food	Water content, % (mass)	Freezing point, °F	Specific heat, Btu/lbm·R		Latent heat of fusion, Btu/lbm
			Above freezing	Below freezing					Above freezing	Below freezing	
Apples	84	30	0.873	0.453	121	Lettuce	95	32	0.961	0.487	136
Bananas	75	31	0.801	0.426	108	Milk, whole	88	31	0.905	0.465	126
Beef round	67	—	0.737	0.402	96	Oranges	87	31	0.897	0.462	125
Broccoli	90	31	0.921	0.471	129	Potatoes	78	31	0.825	0.435	112
Butter	16	—	—	0.249	23	Salmon fish	64	28	0.713	0.393	92
Cheese, Swiss	39	14	0.513	0.318	56	Shrimp	83	28	0.865	0.450	119
Cherries	80	29	0.841	0.441	115	Spinach	93	31	0.945	0.481	134
Chicken	74	27	0.793	0.423	106	Strawberries	90	31	0.921	0.471	129
Corn, sweet	74	31	0.793	0.423	106	Tomatoes, ripe	94	31	0.953	0.484	135
Eggs, whole	74	31	0.793	0.423	106	Turkey	64	—	0.713	0.393	92
Ice cream	63	22	0.705	0.390	90	Watermelon	93	31	0.945	0.481	134

Source of Data: Values are obtained from various handbooks and other sources or are calculated. Water content and freezing-point data of foods are from ASHRAE, *Handbook of Fundamentals*, I-P version (Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1993), Chap. 30, Table 1. Freezing point is the temperature at which freezing starts for fruits and vegetables, and the average freezing temperature for other foods.

TABLE A-4E

Saturated water—Temperature table

Temp., $T^{\circ}\text{F}$	Sat. press., P_{sat} psia	Specific volume, ft^3/lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, $\text{Btu}/\text{lbm}\cdot\text{R}$		
		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
32.018	0.08871	0.01602	3299.9	0.000	1021.0	1021.0	0.000	1075.2	1075.2	0.00000	2.18672	2.1867
35	0.09998	0.01602	2945.7	3.004	1019.0	1022.0	3.004	1073.5	1076.5	0.00609	2.17011	2.1762
40	0.12173	0.01602	2443.6	8.032	1015.6	1023.7	8.032	1070.7	1078.7	0.01620	2.14271	2.1589
45	0.14756	0.01602	2035.8	13.05	1012.2	1025.3	13.05	1067.8	1080.9	0.02620	2.11587	2.1421
50	0.17812	0.01602	1703.1	18.07	1008.9	1026.9	18.07	1065.0	1083.1	0.03609	2.08956	2.1256
55	0.21413	0.01603	1430.4	23.07	1005.5	1028.6	23.07	1062.2	1085.3	0.04586	2.06377	2.1096
60	0.25638	0.01604	1206.1	28.08	1002.1	1030.2	28.08	1059.4	1087.4	0.05554	2.03847	2.0940
65	0.30578	0.01604	1020.8	33.08	998.76	1031.8	33.08	1056.5	1089.6	0.06511	2.01366	2.0788
70	0.36334	0.01605	867.18	38.08	995.39	1033.5	38.08	1053.7	1091.8	0.07459	1.98931	2.0639
75	0.43016	0.01606	739.27	43.07	992.02	1035.1	43.07	1050.9	1093.9	0.08398	1.96541	2.0494
80	0.50745	0.01607	632.41	48.06	988.65	1036.7	48.07	1048.0	1096.1	0.09328	1.94196	2.0352
85	0.59659	0.01609	542.80	53.06	985.28	1038.3	53.06	1045.2	1098.3	0.10248	1.91892	2.0214
90	0.69904	0.01610	467.40	58.05	981.90	1040.0	58.05	1042.4	1100.4	0.11161	1.89630	2.0079
95	0.81643	0.01612	403.74	63.04	978.52	1041.6	63.04	1039.5	1102.6	0.12065	1.87408	1.9947
100	0.95052	0.01613	349.83	68.03	975.14	1043.2	68.03	1036.7	1104.7	0.12961	1.85225	1.9819
110	1.2767	0.01617	264.96	78.01	968.36	1046.4	78.02	1031.0	1109.0	0.14728	1.80970	1.9570
120	1.6951	0.01620	202.94	88.00	961.56	1049.6	88.00	1025.2	1113.2	0.16466	1.76856	1.9332
130	2.2260	0.01625	157.09	97.99	954.73	1052.7	97.99	1019.4	1117.4	0.18174	1.72877	1.9105
140	2.8931	0.01629	122.81	107.98	947.87	1055.9	107.99	1013.6	1121.6	0.19855	1.69024	1.8888
150	3.7234	0.01634	96.929	117.98	940.98	1059.0	117.99	1007.8	1125.7	0.21508	1.65291	1.8680
160	4.7474	0.01639	77.185	127.98	934.05	1062.0	128.00	1001.8	1129.8	0.23136	1.61670	1.8481
170	5.9999	0.01645	61.982	138.00	927.08	1065.1	138.02	995.88	1133.9	0.24739	1.58155	1.8289
180	7.5197	0.01651	50.172	148.02	920.06	1068.1	148.04	989.85	1137.9	0.26318	1.54741	1.8106
190	9.3497	0.01657	40.920	158.05	912.99	1071.0	158.08	983.76	1141.8	0.27874	1.51421	1.7930
200	11.538	0.01663	33.613	168.10	905.87	1074.0	168.13	977.60	1145.7	0.29409	1.48191	1.7760
210	14.136	0.01670	27.798	178.15	898.68	1076.8	178.20	971.35	1149.5	0.30922	1.45046	1.7597
212	14.709	0.01671	26.782	180.16	897.24	1077.4	180.21	970.09	1150.3	0.31222	1.44427	1.7565
220	17.201	0.01677	23.136	188.22	891.43	1079.6	188.28	965.02	1153.3	0.32414	1.41980	1.7439
230	20.795	0.01684	19.374	198.31	884.10	1082.4	198.37	958.59	1157.0	0.33887	1.38989	1.7288
240	24.985	0.01692	16.316	208.41	876.70	1085.1	208.49	952.06	1160.5	0.35342	1.36069	1.7141
250	29.844	0.01700	13.816	218.54	869.21	1087.7	218.63	945.41	1164.0	0.36779	1.33216	1.6999
260	35.447	0.01708	11.760	228.68	861.62	1090.3	228.79	938.65	1167.4	0.38198	1.30425	1.6862
270	41.877	0.01717	10.059	238.85	853.94	1092.8	238.98	931.76	1170.7	0.39601	1.27694	1.6730
280	49.222	0.01726	8.6439	249.04	846.16	1095.2	249.20	924.74	1173.9	0.40989	1.25018	1.6601
290	57.573	0.01735	7.4607	259.26	838.27	1097.5	259.45	917.57	1177.0	0.42361	1.22393	1.6475
300	67.028	0.01745	6.4663	269.51	830.25	1099.8	269.73	910.24	1180.0	0.43720	1.19818	1.6354
310	77.691	0.01755	5.6266	279.79	822.11	1101.9	280.05	902.75	1182.8	0.45065	1.17289	1.6235
320	89.667	0.01765	4.9144	290.11	813.84	1104.0	290.40	895.09	1185.5	0.46396	1.14802	1.6120
330	103.07	0.01776	4.3076	300.46	805.43	1105.9	300.80	887.25	1188.1	0.47716	1.12355	1.6007
340	118.02	0.01787	3.7885	310.85	796.87	1107.7	311.24	879.22	1190.5	0.49024	1.09945	1.5897
350	134.63	0.01799	3.3425	321.29	788.16	1109.4	321.73	870.98	1192.7	0.50321	1.07570	1.5789
360	153.03	0.01811	2.9580	331.76	779.28	1111.0	332.28	862.53	1194.8	0.51607	1.05227	1.5683
370	173.36	0.01823	2.6252	342.29	770.23	1112.5	342.88	853.86	1196.7	0.52884	1.02914	1.5580
380	195.74	0.01836	2.3361	352.87	761.00	1113.9	353.53	844.96	1198.5	0.54152	1.00628	1.5478
390	220.33	0.01850	2.0842	363.50	751.58	1115.1	364.25	835.81	1200.1	0.55411	0.98366	1.5378

TABLE A-4E

Saturated water—Temperature table (Concluded)

Temp., $T^{\circ}\text{F}$	Sat. press., P_{sat} psia	Specific volume, ft^3/lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, $\text{Btu}/\text{lbm}\cdot\text{R}$		
		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
400	247.26	0.01864	1.8639	374.19	741.97	1116.2	375.04	826.39	1201.4	0.56663	0.96127	1.5279
410	276.69	0.01878	1.6706	384.94	732.14	1117.1	385.90	816.71	1202.6	0.57907	0.93908	1.5182
420	308.76	0.01894	1.5006	395.76	722.08	1117.8	396.84	806.74	1203.6	0.59145	0.91707	1.5085
430	343.64	0.01910	1.3505	406.65	711.80	1118.4	407.86	796.46	1204.3	0.60377	0.89522	1.4990
440	381.49	0.01926	1.2178	417.61	701.26	1118.9	418.97	785.87	1204.8	0.61603	0.87349	1.4895
450	422.47	0.01944	1.0999	428.66	690.47	1119.1	430.18	774.94	1205.1	0.62826	0.85187	1.4801
460	466.75	0.01962	0.99510	439.79	679.39	1119.2	441.48	763.65	1205.1	0.64044	0.83033	1.4708
470	514.52	0.01981	0.90158	451.01	668.02	1119.0	452.90	751.98	1204.9	0.65260	0.80885	1.4615
480	565.96	0.02001	0.81794	462.34	656.34	1118.7	464.43	739.91	1204.3	0.66474	0.78739	1.4521
490	621.24	0.02022	0.74296	473.77	644.32	1118.1	476.09	727.40	1203.5	0.67686	0.76594	1.4428
500	680.56	0.02044	0.67558	485.32	631.94	1117.3	487.89	714.44	1202.3	0.68899	0.74445	1.4334
510	744.11	0.02067	0.61489	496.99	619.17	1116.2	499.84	700.99	1200.8	0.70112	0.72290	1.4240
520	812.11	0.02092	0.56009	508.80	605.99	1114.8	511.94	687.01	1199.0	0.71327	0.70126	1.4145
530	884.74	0.02118	0.51051	520.76	592.35	1113.1	524.23	672.47	1196.7	0.72546	0.67947	1.4049
540	962.24	0.02146	0.46553	532.88	578.23	1111.1	536.70	657.31	1194.0	0.73770	0.65751	1.3952
550	1044.8	0.02176	0.42465	545.18	563.58	1108.8	549.39	641.47	1190.9	0.75000	0.63532	1.3853
560	1132.7	0.02207	0.38740	557.68	548.33	1106.0	562.31	624.91	1187.2	0.76238	0.61284	1.3752
570	1226.2	0.02242	0.35339	570.40	532.45	1102.8	575.49	607.55	1183.0	0.77486	0.59003	1.3649
580	1325.5	0.02279	0.32225	583.37	515.84	1099.2	588.95	589.29	1178.2	0.78748	0.56679	1.3543
590	1430.8	0.02319	0.29367	596.61	498.43	1095.0	602.75	570.04	1172.8	0.80026	0.54306	1.3433
600	1542.5	0.02362	0.26737	610.18	480.10	1090.3	616.92	549.67	1166.6	0.81323	0.51871	1.3319
610	1660.9	0.02411	0.24309	624.11	460.73	1084.8	631.52	528.03	1159.5	0.82645	0.49363	1.3201
620	1786.2	0.02464	0.22061	638.47	440.14	1078.6	646.62	504.92	1151.5	0.83998	0.46765	1.3076
630	1918.9	0.02524	0.19972	653.35	418.12	1071.5	662.32	480.07	1142.4	0.85389	0.44056	1.2944
640	2059.3	0.02593	0.18019	668.86	394.36	1063.2	678.74	453.14	1131.9	0.86828	0.41206	1.2803
650	2207.8	0.02673	0.16184	685.16	368.44	1053.6	696.08	423.65	1119.7	0.88332	0.38177	1.2651
660	2364.9	0.02767	0.14444	702.48	339.74	1042.2	714.59	390.84	1105.4	0.89922	0.34906	1.2483
670	2531.2	0.02884	0.12774	721.23	307.22	1028.5	734.74	353.54	1088.3	0.91636	0.31296	1.2293
680	2707.3	0.03035	0.11134	742.11	269.00	1011.1	757.32	309.57	1066.9	0.93541	0.27163	1.2070
690	2894.1	0.03255	0.09451	766.81	220.77	987.6	784.24	253.96	1038.2	0.95797	0.22089	1.1789
700	3093.0	0.03670	0.07482	801.75	146.50	948.3	822.76	168.32	991.1	0.99023	0.14514	1.1354
705.10	3200.1	0.04975	0.04975	866.61	0	866.6	896.07	0	896.1	1.05257	0	1.0526

Source of Data: Tables A-4E through A-8E are generated using the Engineering Equation Solver (EES) software developed by S. A. Klein and F. L. Alvarado. The routine used in calculations is the highly accurate Steam_IAPWS, which incorporates the 1995 Formulation for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use, issued by The International Association for the Properties of Water and Steam (IAPWS). This formulation replaces the 1984 formulation of Haar, Gallagher, and Kell (NBS/NRC Steam Tables, Hemisphere Publishing Co., 1984), which is also available in EES as the routine STEAM. The new formulation is based on the correlations of Saul and Wagner (J. Phys. Chem. Ref. Data, 16, 893, 1987) with modifications to adjust to the International Temperature Scale of 1990. The modifications are described by Wagner and Pruss (J. Phys. Chem. Ref. Data, 22, 783, 1993). The properties of ice are based on Hyland and Wexler, "Formulations for the Thermodynamic Properties of the Saturated Phases of H_2O from 173.15 K to 473.15 K," *ASHRAE Trans.*, Part 2A, Paper 2793, 1983.

TABLE A-5E

Saturated water—Pressure table

Press., <i>P</i> psia	Sat. temp., <i>T</i> _{sat} °F	Specific volume, ft ³ /lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, Btu/lbm·R		
		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	101.69	0.01614	333.49	69.72	973.99	1043.7	69.72	1035.7	1105.4	0.13262	1.84495	1.9776
2	126.02	0.01623	173.71	94.02	957.45	1051.5	94.02	1021.7	1115.8	0.17499	1.74444	1.9194
3	141.41	0.01630	118.70	109.39	946.90	1056.3	109.40	1012.8	1122.2	0.20090	1.68489	1.8858
4	152.91	0.01636	90.629	120.89	938.97	1059.9	120.90	1006.0	1126.9	0.21985	1.64225	1.8621
5	162.18	0.01641	73.525	130.17	932.53	1062.7	130.18	1000.5	1130.7	0.23488	1.60894	1.8438
6	170.00	0.01645	61.982	138.00	927.08	1065.1	138.02	995.88	1133.9	0.24739	1.58155	1.8289
8	182.81	0.01652	47.347	150.83	918.08	1068.9	150.86	988.15	1139.0	0.26757	1.53800	1.8056
10	193.16	0.01659	38.425	161.22	910.75	1072.0	161.25	981.82	1143.1	0.28362	1.50391	1.7875
14.696	211.95	0.01671	26.805	180.12	897.27	1077.4	180.16	970.12	1150.3	0.31215	1.44441	1.7566
15	212.99	0.01672	26.297	181.16	896.52	1077.7	181.21	969.47	1150.7	0.31370	1.44441	1.7549
20	227.92	0.01683	20.093	196.21	885.63	1081.8	196.27	959.93	1156.2	0.33582	1.39606	1.7319
25	240.03	0.01692	16.307	208.45	876.67	1085.1	208.52	952.03	1160.6	0.35347	1.36060	1.7141
30	250.30	0.01700	13.749	218.84	868.98	1087.8	218.93	945.21	1164.1	0.36821	1.33132	1.6995
35	259.25	0.01708	11.901	227.92	862.19	1090.1	228.03	939.16	1167.2	0.38093	1.30632	1.6872
40	267.22	0.01715	10.501	236.02	856.09	1092.1	236.14	933.69	1169.8	0.39213	1.28448	1.6766
45	274.41	0.01721	9.4028	243.34	850.52	1093.9	243.49	928.68	1172.2	0.40216	1.26506	1.6672
50	280.99	0.01727	8.5175	250.05	845.39	1095.4	250.21	924.03	1174.2	0.41125	1.24756	1.6588
55	287.05	0.01732	7.7882	256.25	840.61	1096.9	256.42	919.70	1176.1	0.41958	1.23162	1.6512
60	292.69	0.01738	7.1766	262.01	836.13	1098.1	262.20	915.61	1177.8	0.42728	1.21697	1.6442
65	297.95	0.01743	6.6560	267.41	831.90	1099.3	267.62	911.75	1179.4	0.43443	1.20341	1.6378
70	302.91	0.01748	6.2075	272.50	827.90	1100.4	272.72	908.08	1180.8	0.44112	1.19078	1.6319
75	307.59	0.01752	5.8167	277.31	824.09	1101.4	277.55	904.58	1182.1	0.44741	1.17895	1.6264
80	312.02	0.01757	5.4733	281.87	820.45	1102.3	282.13	901.22	1183.4	0.45335	1.16783	1.6212
85	316.24	0.01761	5.1689	286.22	816.97	1103.2	286.50	898.00	1184.5	0.45897	1.15732	1.6163
90	320.26	0.01765	4.8972	290.38	813.62	1104.0	290.67	894.89	1185.6	0.46431	1.14737	1.6117
95	324.11	0.01770	4.6532	294.36	810.40	1104.8	294.67	891.89	1186.6	0.46941	1.13791	1.6073
100	327.81	0.01774	4.4327	298.19	807.29	1105.5	298.51	888.99	1187.5	0.47427	1.12888	1.6032
110	334.77	0.01781	4.0410	305.41	801.37	1106.8	305.78	883.44	1189.2	0.48341	1.11201	1.5954
120	341.25	0.01789	3.7289	312.16	795.79	1107.9	312.55	878.20	1190.8	0.49187	1.09646	1.5883
130	347.32	0.01796	3.4557	318.48	790.51	1109.0	318.92	873.21	1192.1	0.49974	1.08204	1.5818
140	353.03	0.01802	3.2202	324.45	785.49	1109.9	324.92	868.45	1193.4	0.50711	1.06858	1.5757
150	358.42	0.01809	3.0150	330.11	780.69	1110.8	330.61	863.88	1194.5	0.51405	1.05595	1.5700
160	363.54	0.01815	2.8347	335.49	776.10	1111.6	336.02	859.49	1195.5	0.52061	1.04405	1.5647
170	368.41	0.01821	2.6749	340.62	771.68	1112.3	341.19	855.25	1196.4	0.52682	1.03279	1.5596
180	373.07	0.01827	2.5322	345.53	767.42	1113.0	346.14	851.16	1197.3	0.53274	1.02210	1.5548
190	377.52	0.01833	2.4040	350.24	763.31	1113.6	350.89	847.19	1198.1	0.53839	1.01191	1.5503
200	381.80	0.01839	2.2882	354.78	759.32	1114.1	355.46	843.33	1198.8	0.54379	1.00219	1.5460
250	400.97	0.01865	1.8440	375.23	741.02	1116.3	376.09	825.47	1201.6	0.56784	0.95912	1.5270
300	417.35	0.01890	1.5435	392.89	724.77	1117.7	393.94	809.41	1203.3	0.58818	0.92289	1.5111
350	431.74	0.01912	1.3263	408.55	709.98	1118.5	409.79	794.65	1204.4	0.60590	0.89143	1.4973
400	444.62	0.01934	1.1617	422.70	696.31	1119.0	424.13	780.87	1205.0	0.62168	0.86350	1.4852
450	456.31	0.01955	1.0324	435.67	683.52	1119.2	437.30	767.86	1205.2	0.63595	0.83828	1.4742
500	467.04	0.01975	0.92819	447.68	671.42	1119.1	449.51	755.48	1205.0	0.64900	0.81521	1.4642
550	476.97	0.01995	0.84228	458.90	659.91	1118.8	460.93	743.60	1204.5	0.66107	0.79388	1.4550
600	486.24	0.02014	0.77020	469.46	648.88	1118.3	471.70	732.15	1203.9	0.67231	0.77400	1.4463
700	503.13	0.02051	0.65589	488.96	627.98	1116.9	491.62	710.29	1201.9	0.69279	0.73771	1.4305
800	518.27	0.02087	0.56920	506.74	608.30	1115.0	509.83	689.48	1199.3	0.71117	0.70502	1.4162

TABLE A-5E

Saturated water—Pressure table (*Concluded*)

Press., <i>P</i> psia	Sat. temp., T_{sat} °F	Specific volume, ft ³ /lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, Btu/lbm·R		
		Sat. liquid, ν_f	Sat. vapor, ν_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
900	532.02	0.02124	0.50107	523.19	589.54	1112.7	526.73	669.46	1196.2	0.72793	0.67505	1.4030
1000	544.65	0.02159	0.44604	538.58	571.49	1110.1	542.57	650.03	1192.6	0.74341	0.64722	1.3906
1200	567.26	0.02232	0.36241	566.89	536.87	1103.8	571.85	612.39	1184.2	0.77143	0.59632	1.3677
1400	587.14	0.02307	0.30161	592.79	503.50	1096.3	598.76	575.66	1174.4	0.79658	0.54991	1.3465
1600	604.93	0.02386	0.25516	616.99	470.69	1087.7	624.06	539.18	1163.2	0.81972	0.50645	1.3262
1800	621.07	0.02470	0.21831	640.03	437.86	1077.9	648.26	502.35	1150.6	0.84144	0.46482	1.3063
2000	635.85	0.02563	0.18815	662.33	404.46	1066.8	671.82	464.60	1136.4	0.86224	0.42409	1.2863
2500	668.17	0.02860	0.13076	717.67	313.53	1031.2	730.90	360.79	1091.7	0.91311	0.31988	1.2330
3000	695.41	0.03433	0.08460	783.39	186.41	969.8	802.45	214.32	1016.8	0.97321	0.18554	1.1587
3200.1	705.10	0.04975	0.04975	866.61	0	866.6	896.07	0	896.1	1.05257	0	1.0526

TABLE A-6E

Superheated water

<i>T</i> °F	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R
<i>P</i> = 1.0 psia (101.69°F)*					<i>P</i> = 5.0 psia (162.18°F)				<i>P</i> = 10 psia (193.16°F)			
Sat. [†]	333.49	1043.7	1105.4	1.9776	73.525	1062.7	1130.7	1.8438	38.425	1072.0	1143.1	1.7875
200	392.53	1077.5	1150.1	2.0509	78.153	1076.2	1148.5	1.8716	38.849	1074.5	1146.4	1.7926
240	416.44	1091.2	1168.3	2.0777	83.009	1090.3	1167.1	1.8989	41.326	1089.1	1165.5	1.8207
280	440.33	1105.0	1186.5	2.1030	87.838	1104.3	1185.6	1.9246	43.774	1103.4	1184.4	1.8469
320	464.20	1118.9	1204.8	2.1271	92.650	1118.4	1204.1	1.9490	46.205	1117.6	1203.1	1.8716
360	488.07	1132.9	1223.3	2.1502	97.452	1132.5	1222.6	1.9722	48.624	1131.9	1221.8	1.8950
400	511.92	1147.1	1241.8	2.1722	102.25	1146.7	1241.3	1.9944	51.035	1146.2	1240.6	1.9174
440	535.77	1161.3	1260.4	2.1934	107.03	1160.9	1260.0	2.0156	53.441	1160.5	1259.4	1.9388
500	571.54	1182.8	1288.6	2.2237	114.21	1182.6	1288.2	2.0461	57.041	1182.2	1287.8	1.9693
600	631.14	1219.4	1336.2	2.2709	126.15	1219.2	1335.9	2.0933	63.029	1219.0	1335.6	2.0167
700	690.73	1256.8	1384.6	2.3146	138.09	1256.7	1384.4	2.1371	69.007	1256.5	1384.2	2.0605
800	750.31	1295.1	1433.9	2.3553	150.02	1294.9	1433.7	2.1778	74.980	1294.8	1433.5	2.1013
1000	869.47	1374.2	1535.1	2.4299	173.86	1374.2	1535.0	2.2524	86.913	1374.1	1534.9	2.1760
1200	988.62	1457.1	1640.0	2.4972	197.70	1457.0	1640.0	2.3198	98.840	1457.0	1639.9	2.2433
1400	1107.8	1543.7	1748.7	2.5590	221.54	1543.7	1748.7	2.3816	110.762	1543.6	1748.6	2.3052
<i>P</i> = 15 psia (212.99°F)					<i>P</i> = 20 psia (227.92°F)				<i>P</i> = 40 psia (267.22°F)			
Sat.	26.297	1077.7	1150.7	1.7549	20.093	1081.8	1156.2	1.7319	10.501	1092.1	1169.8	1.6766
240	27.429	1087.8	1163.9	1.7742	20.478	1086.5	1162.3	1.7406				
280	29.085	1102.4	1183.2	1.8010	21.739	1101.4	1181.9	1.7679	10.713	1097.3	1176.6	1.6858
320	30.722	1116.9	1202.2	1.8260	22.980	1116.1	1201.2	1.7933	11.363	1112.9	1197.1	1.7128
360	32.348	1131.3	1221.1	1.8496	24.209	1130.7	1220.2	1.8171	11.999	1128.1	1216.9	1.7376
400	33.965	1145.7	1239.9	1.8721	25.429	1145.1	1239.3	1.8398	12.625	1143.1	1236.5	1.7610
440	35.576	1160.1	1258.8	1.8936	26.644	1159.7	1258.3	1.8614	13.244	1157.9	1256.0	1.7831
500	37.986	1181.9	1287.3	1.9243	28.458	1181.6	1286.9	1.8922	14.165	1180.2	1285.0	1.8143
600	41.988	1218.7	1335.3	1.9718	31.467	1218.5	1334.9	1.9398	15.686	1217.5	1333.6	1.8625
700	45.981	1256.3	1383.9	2.0156	34.467	1256.1	1383.7	1.9837	17.197	1255.3	1382.6	1.9067
800	49.967	1294.6	1433.3	2.0565	37.461	1294.5	1433.1	2.0247	18.702	1293.9	1432.3	1.9478
1000	57.930	1374.0	1534.8	2.1312	43.438	1373.8	1534.6	2.0994	21.700	1373.4	1534.1	2.0227
1200	65.885	1456.9	1639.8	2.1986	49.407	1456.8	1639.7	2.1668	24.691	1456.5	1639.3	2.0902
1400	73.836	1543.6	1748.5	2.2604	55.373	1543.5	1748.4	2.2287	27.678	1543.3	1748.1	2.1522
1600	81.784	1634.0	1861.0	2.3178	61.335	1633.9	1860.9	2.2861	30.662	1633.7	1860.7	2.2096
<i>P</i> = 60 psia (292.69°F)					<i>P</i> = 80 psia (312.02°F)				<i>P</i> = 100 psia (327.81°F)			
Sat.	7.1766	1098.1	1177.8	1.6442	5.4733	1102.3	1183.4	1.6212	4.4327	1105.5	1187.5	1.6032
320	7.4863	1109.6	1192.7	1.6636	5.5440	1105.9	1187.9	1.6271				
360	7.9259	1125.5	1213.5	1.6897	5.8876	1122.7	1209.9	1.6545	4.6628	1119.8	1206.1	1.6263
400	8.3548	1140.9	1233.7	1.7138	6.2187	1138.7	1230.8	1.6794	4.9359	1136.4	1227.8	1.6521
440	8.7766	1156.1	1253.6	1.7364	6.5420	1154.3	1251.2	1.7026	5.2006	1152.4	1248.7	1.6759
500	9.4005	1178.8	1283.1	1.7682	7.0177	1177.3	1281.2	1.7350	5.5876	1175.9	1279.3	1.7088
600	10.4256	1216.5	1332.2	1.8168	7.7951	1215.4	1330.8	1.7841	6.2167	1214.4	1329.4	1.7586
700	11.4401	1254.5	1381.6	1.8613	8.5616	1253.8	1380.5	1.8289	6.8344	1253.0	1379.5	1.8037
800	12.4484	1293.3	1431.5	1.9026	9.3218	1292.6	1430.6	1.8704	7.4457	1292.0	1429.8	1.8453
1000	14.4543	1373.0	1533.5	1.9777	10.8313	1372.6	1532.9	1.9457	8.6575	1372.2	1532.4	1.9208
1200	16.4525	1456.2	1638.9	2.0454	12.3331	1455.9	1638.5	2.0135	9.8615	1455.6	1638.1	1.9887
1400	18.4464	1543.0	1747.8	2.1073	13.8306	1542.8	1747.5	2.0755	11.0612	1542.6	1747.2	2.0508
1600	20.438	1633.5	1860.5	2.1648	15.3257	1633.3	1860.2	2.1330	12.2584	1633.2	1860.0	2.1083
1800	22.428	1727.6	1976.6	2.2187	16.8192	1727.5	1976.5	2.1869	13.4541	1727.3	1976.3	2.1622
2000	24.417	1825.2	2096.3	2.2694	18.3117	1825.0	2096.1	2.2376	14.6487	1824.9	2096.0	2.2130

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

† Properties of saturated vapor at the specified pressure.

TABLE A-6E

Superheated water (*Concluded*)

<i>T</i> °F	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R
<i>P</i> = 120 psia (341.25°F)					<i>P</i> = 140 psia (353.03°F)				<i>P</i> = 160 psia (363.54°F)			
Sat.	3.7289	1107.9	1190.8	1.5883	3.2202	1109.9	1193.4	1.5757	2.8347	1111.6	1195.5	1.5647
360	3.8446	1116.7	1202.1	1.6023	3.2584	1113.4	1197.8	1.5811				
400	4.0799	1134.0	1224.6	1.6292	3.4676	1131.5	1221.4	1.6092	3.0076	1129.0	1218.0	1.5914
450	4.3613	1154.5	1251.4	1.6594	3.7147	1152.6	1248.9	1.6403	3.2293	1150.7	1246.3	1.6234
500	4.6340	1174.4	1277.3	1.6872	3.9525	1172.9	1275.3	1.6686	3.4412	1171.4	1273.2	1.6522
550	4.9010	1193.9	1302.8	1.7131	4.1845	1192.7	1301.1	1.6948	3.6469	1191.4	1299.4	1.6788
600	5.1642	1213.4	1328.0	1.7375	4.4124	1212.3	1326.6	1.7195	3.8484	1211.3	1325.2	1.7037
700	5.6829	1252.2	1378.4	1.7829	4.8604	1251.4	1377.3	1.7652	4.2434	1250.6	1376.3	1.7498
800	6.1950	1291.4	1429.0	1.8247	5.3017	1290.8	1428.1	1.8072	4.6316	1290.2	1427.3	1.7920
1000	7.2083	1371.7	1531.8	1.9005	6.1732	1371.3	1531.3	1.8832	5.3968	1370.9	1530.7	1.8682
1200	8.2137	1455.3	1637.7	1.9684	7.0367	1455.0	1637.3	1.9512	6.1540	1454.7	1636.9	1.9363
1400	9.2149	1542.3	1746.9	2.0305	7.8961	1542.1	1746.6	2.0134	6.9070	1541.8	1746.3	1.9986
1600	10.2135	1633.0	1859.8	2.0881	8.7529	1632.8	1859.5	2.0711	7.6574	1632.6	1859.3	2.0563
1800	11.2106	1727.2	1976.1	2.1420	9.6082	1727.0	1975.9	2.1250	8.4063	1726.9	1975.7	2.1102
2000	12.2067	1824.8	2095.8	2.1928	10.4624	1824.6	2095.7	2.1758	9.1542	1824.5	2095.5	2.1610
<i>P</i> = 180 psia (373.07°F)					<i>P</i> = 200 psia (381.80°F)				<i>P</i> = 225 psia (391.80°F)			
Sat.	2.5322	1113.0	1197.3	1.5548	2.2882	1114.1	1198.8	1.5460	2.0423	1115.3	1200.3	1.5360
400	2.6490	1126.3	1214.5	1.5752	2.3615	1123.5	1210.9	1.5602	2.0728	1119.7	1206.0	1.5427
450	2.8514	1148.7	1243.7	1.6082	2.5488	1146.7	1241.0	1.5943	2.2457	1144.1	1237.6	1.5783
500	3.0433	1169.8	1271.2	1.6376	2.7247	1168.2	1269.0	1.6243	2.4059	1166.2	1266.3	1.6091
550	3.2286	1190.2	1297.7	1.6646	2.8939	1188.9	1296.0	1.6516	2.5590	1187.2	1293.8	1.6370
600	3.4097	1210.2	1323.8	1.6897	3.0586	1209.1	1322.3	1.6771	2.7075	1207.7	1320.5	1.6628
700	3.7635	1249.8	1375.2	1.7361	3.3796	1249.0	1374.1	1.7238	2.9956	1248.0	1372.7	1.7099
800	4.1104	1289.5	1426.5	1.7785	3.6934	1288.9	1425.6	1.7664	3.2765	1288.1	1424.5	1.7528
900	4.4531	1329.7	1478.0	1.8179	4.0031	1329.2	1477.3	1.8059	3.5530	1328.5	1476.5	1.7925
1000	4.7929	1370.5	1530.1	1.8549	4.3099	1370.1	1529.6	1.8430	3.8268	1369.5	1528.9	1.8296
1200	5.4674	1454.3	1636.5	1.9231	4.9182	1454.0	1636.1	1.9113	4.3689	1453.6	1635.6	1.8981
1400	6.1377	1541.6	1746.0	1.9855	5.5222	1541.4	1745.7	1.9737	4.9068	1541.1	1745.4	1.9606
1600	6.8054	1632.4	1859.1	2.0432	6.1238	1632.2	1858.8	2.0315	5.4422	1632.0	1858.6	2.0184
1800	7.4716	1726.7	1975.6	2.0971	6.7238	1726.5	1975.4	2.0855	5.9760	1726.4	1975.2	2.0724
2000	8.1367	1824.4	2095.4	2.1479	7.3227	1824.3	2095.3	2.1363	6.5087	1824.1	2095.1	2.1232
<i>P</i> = 250 psia (400.97°F)					<i>P</i> = 275 psia (409.45°F)				<i>P</i> = 300 psia (417.35°F)			
Sat.	1.8440	1116.3	1201.6	1.5270	1.6806	1117.0	1202.6	1.5187	1.5435	1117.7	1203.3	1.5111
450	2.0027	1141.3	1234.0	1.5636	1.8034	1138.5	1230.3	1.5499	1.6369	1135.6	1226.4	1.5369
500	2.1506	1164.1	1263.6	1.5953	1.9415	1162.0	1260.8	1.5825	1.7670	1159.8	1257.9	1.5706
550	2.2910	1185.6	1291.5	1.6237	2.0715	1183.9	1289.3	1.6115	1.8885	1182.1	1287.0	1.6001
600	2.4264	1206.3	1318.6	1.6499	2.1964	1204.9	1316.7	1.6380	2.0046	1203.5	1314.8	1.6270
650	2.5586	1226.8	1345.1	1.6743	2.3179	1225.6	1343.5	1.6627	2.1172	1224.4	1341.9	1.6520
700	2.6883	1247.0	1371.4	1.6974	2.4369	1246.0	1370.0	1.6860	2.2273	1244.9	1368.6	1.6755
800	2.9429	1287.3	1423.5	1.7406	2.6699	1286.5	1422.4	1.7294	2.4424	1285.7	1421.3	1.7192
900	3.1930	1327.9	1475.6	1.7804	2.8984	1327.3	1474.8	1.7694	2.6529	1326.6	1473.9	1.7593
1000	3.4403	1369.0	1528.2	1.8177	3.1241	1368.5	1527.4	1.8068	2.8605	1367.9	1526.7	1.7968
1200	3.9295	1453.3	1635.0	1.8863	3.5700	1452.9	1634.5	1.8755	3.2704	1452.5	1634.0	1.8657
1400	4.4144	1540.8	1745.0	1.9488	4.0116	1540.5	1744.6	1.9381	3.6759	1540.2	1744.2	1.9284
1600	4.8969	1631.7	1858.3	2.0066	4.4507	1631.5	1858.0	1.9960	4.0789	1631.3	1857.7	1.9863
1800	5.3777	1726.2	1974.9	2.0607	4.8882	1726.0	1974.7	2.0501	4.4803	1725.8	1974.5	2.0404
2000	5.8575	1823.9	2094.9	2.1116	5.3247	1823.8	2094.7	2.1010	4.8807	1823.6	2094.6	2.0913

TABLE A-6E

Superheated water (Continued)

<i>T</i> °F	<i>v</i> ft³/lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft³/lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft³/lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R		
<i>P</i> = 350 psia (431.74°F)					<i>P</i> = 400 psia (444.62°F)					<i>P</i> = 450 psia (456.31°F)				
Sat.	1.3263	1118.5	1204.4	1.4973	1.1617	1119.0	1205.0	1.4852	1.0324	1119.2	1205.2	1.4742		
450	1.3739	1129.3	1218.3	1.5128	1.1747	1122.5	1209.4	1.4901						
500	1.4921	1155.2	1251.9	1.5487	1.2851	1150.4	1245.6	1.5288	1.1233	1145.4	1238.9	1.5103		
550	1.6004	1178.6	1282.2	1.5795	1.3840	1174.9	1277.3	1.5610	1.2152	1171.1	1272.3	1.5441		
600	1.7030	1200.6	1310.9	1.6073	1.4765	1197.6	1306.9	1.5897	1.3001	1194.6	1302.8	1.5737		
650	1.8018	1221.9	1338.6	1.6328	1.5650	1219.4	1335.3	1.6158	1.3807	1216.9	1331.9	1.6005		
700	1.8979	1242.8	1365.8	1.6567	1.6507	1240.7	1362.9	1.6401	1.4584	1238.5	1360.0	1.6253		
800	2.0848	1284.1	1419.1	1.7009	1.8166	1282.5	1417.0	1.6849	1.6080	1280.8	1414.7	1.6706		
900	2.2671	1325.3	1472.2	1.7414	1.9777	1324.0	1470.4	1.7257	1.7526	1322.7	1468.6	1.7117		
1000	2.4464	1366.9	1525.3	1.7791	2.1358	1365.8	1523.9	1.7636	1.8942	1364.7	1522.4	1.7499		
1200	2.7996	1451.7	1633.0	1.8483	2.4465	1450.9	1632.0	1.8331	2.1718	1450.1	1631.0	1.8196		
1400	3.1484	1539.6	1743.5	1.9111	2.7527	1539.0	1742.7	1.8960	2.4450	1538.4	1742.0	1.8827		
1600	3.4947	1630.8	1857.1	1.9691	3.0565	1630.3	1856.5	1.9541	2.7157	1629.8	1856.0	1.9409		
1800	3.8394	1725.4	1974.0	2.0233	3.3586	1725.0	1973.6	2.0084	2.9847	1724.6	1973.2	1.9952		
2000	4.1830	1823.3	2094.2	2.0742	3.6597	1823.0	2093.9	2.0594	3.2527	1822.6	2093.5	2.0462		
<i>P</i> = 500 psia (467.04°F)					<i>P</i> = 600 psia (486.24°F)					<i>P</i> = 700 psia (503.13°F)				
Sat.	0.92815	1119.1	1205.0	1.4642	0.77020	1118.3	1203.9	1.4463	0.65589	1116.9	1201.9	1.4305		
500	0.99304	1140.1	1231.9	1.4928	0.79526	1128.2	1216.5	1.4596						
550	1.07974	1167.1	1267.0	1.5284	0.87542	1158.7	1255.9	1.4996	0.72799	1149.5	1243.8	1.4730		
600	1.15876	1191.4	1298.6	1.5590	0.94605	1184.9	1289.9	1.5325	0.79332	1177.9	1280.7	1.5087		
650	1.23312	1214.3	1328.4	1.5865	1.01133	1209.0	1321.3	1.5614	0.85242	1203.4	1313.8	1.5393		
700	1.30440	1236.4	1357.0	1.6117	1.07316	1231.9	1351.0	1.5877	0.90769	1227.2	1344.8	1.5666		
800	1.44097	1279.2	1412.5	1.6576	1.19038	1275.8	1408.0	1.6348	1.01125	1272.4	1403.4	1.6150		
900	1.57252	1321.4	1466.9	1.6992	1.30230	1318.7	1463.3	1.6771	1.10921	1316.0	1459.7	1.6581		
1000	1.70094	1363.6	1521.0	1.7376	1.41097	1361.4	1518.1	1.7160	1.20381	1359.2	1515.2	1.6974		
1100	1.82726	1406.2	1575.3	1.7735	1.51749	1404.4	1572.9	1.7522	1.29621	1402.5	1570.4	1.7341		
1200	1.95211	1449.4	1630.0	1.8075	1.62252	1447.8	1627.9	1.7865	1.38709	1446.2	1625.9	1.7685		
1400	2.1988	1537.8	1741.2	1.8708	1.82957	1536.6	1739.7	1.8501	1.56580	1535.4	1738.2	1.8324		
1600	2.4430	1629.4	1855.4	1.9291	2.0340	1628.4	1854.2	1.9085	1.74192	1627.5	1853.1	1.8911		
1800	2.6856	1724.2	1972.7	1.9834	2.2369	1723.4	1971.8	1.9630	1.91643	1722.7	1970.9	1.9457		
2000	2.9271	1822.3	2093.1	2.0345	2.4387	1821.7	2092.4	2.0141	2.08987	1821.0	2091.7	1.9969		
<i>P</i> = 800 psia (518.27°F)					<i>P</i> = 1000 psia (544.65°F)					<i>P</i> = 1250 psia (572.45°F)				
Sat.	0.56920	1115.0	1199.3	1.4162	0.44604	1110.1	1192.6	1.3906	0.34549	1102.0	1181.9	1.3623		
550	0.61586	1139.4	1230.5	1.4476	0.45375	1115.2	1199.2	1.3972						
600	0.67799	1170.5	1270.9	1.4866	0.51431	1154.1	1249.3	1.4457	0.37894	1129.5	1217.2	1.3961		
650	0.73279	1197.6	1306.0	1.5191	0.56411	1185.1	1289.5	1.4827	0.42703	1167.5	1266.3	1.4414		
700	0.78330	1222.4	1338.4	1.5476	0.60844	1212.4	1325.0	1.5140	0.46735	1198.7	1306.8	1.4771		
750	0.83102	1246.0	1369.1	1.5735	0.64944	1237.6	1357.8	1.5418	0.50344	1226.4	1342.9	1.5076		
800	0.87678	1268.9	1398.7	1.5975	0.68821	1261.7	1389.0	1.5670	0.53687	1252.2	1376.4	1.5347		
900	0.96434	1313.3	1456.0	1.6413	0.76136	1307.7	1448.6	1.6126	0.59876	1300.5	1439.0	1.5826		
1000	1.04841	1357.0	1512.2	1.6812	0.83078	1352.5	1506.2	1.6535	0.65656	1346.7	1498.6	1.6249		
1100	1.13024	1400.7	1568.0	1.7181	0.89783	1396.9	1563.1	1.6911	0.71184	1392.2	1556.8	1.6635		
1200	1.21051	1444.6	1623.8	1.7528	0.96327	1441.4	1619.7	1.7263	0.76545	1437.4	1614.5	1.6993		
1400	1.36797	1534.2	1736.7	1.8170	1.09101	1531.8	1733.7	1.7911	0.86944	1528.7	1729.8	1.7649		
1600	1.52283	1626.5	1851.9	1.8759	1.21610	1624.6	1849.6	1.8504	0.97072	1622.2	1846.7	1.8246		
1800	1.67606	1721.9	1970.0	1.9306	1.33956	1720.3	1968.2	1.9053	1.07036	1718.4	1966.0	1.8799		
2000	1.82823	1820.4	2091.0	1.9819	1.46194	1819.1	2089.6	1.9568	1.16892	1817.5	2087.9	1.9315		

TABLE A-6E

Superheated water (*Concluded*)

<i>T</i> °F	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R
<i>P</i> = 1500 psia (596.26°F)					<i>P</i> = 1750 psia (617.17°F)				<i>P</i> = 2000 psia (635.85°F)			
Sat.	0.27695	1092.1	1169.0	1.3362	0.22681	1080.5	1153.9	1.3112	0.18815	1066.8	1136.4	1.2863
600	0.28189	1097.2	1175.4	1.3423								
650	0.33310	1147.2	1239.7	1.4016	0.26292	1122.8	1207.9	1.3607	0.20586	1091.4	1167.6	1.3146
700	0.37198	1183.6	1286.9	1.4433	0.30252	1166.8	1264.7	1.4108	0.24894	1147.6	1239.8	1.3783
750	0.40535	1214.4	1326.9	1.4771	0.33455	1201.5	1309.8	1.4489	0.28074	1187.4	1291.3	1.4218
800	0.43550	1242.2	1363.1	1.5064	0.36266	1231.7	1349.1	1.4807	0.30763	1220.5	1334.3	1.4567
850	0.46356	1268.2	1396.9	1.5328	0.38835	1259.3	1385.1	1.5088	0.33169	1250.0	1372.8	1.4867
900	0.49015	1293.1	1429.2	1.5569	0.41238	1285.4	1419.0	1.5341	0.35390	1277.5	1408.5	1.5134
1000	0.54031	1340.9	1490.8	1.6007	0.45719	1334.9	1482.9	1.5796	0.39479	1328.7	1474.9	1.5606
1100	0.58781	1387.3	1550.5	1.6402	0.49917	1382.4	1544.1	1.6201	0.43266	1377.5	1537.6	1.6021
1200	0.63355	1433.3	1609.2	1.6767	0.53932	1429.2	1603.9	1.6572	0.46864	1425.1	1598.5	1.6400
1400	0.72172	1525.7	1726.0	1.7432	0.61621	1522.6	1722.1	1.7245	0.53708	1519.5	1718.3	1.7081
1600	0.80714	1619.8	1843.8	1.8033	0.69031	1617.4	1840.9	1.7852	0.60269	1615.0	1838.0	1.7693
1800	0.89090	1716.4	1963.7	1.8589	0.76273	1714.5	1961.5	1.8410	0.66660	1712.5	1959.2	1.8255
2000	0.97358	1815.9	2086.1	1.9108	0.83406	1814.2	2084.3	1.8931	0.72942	1812.6	2082.6	1.8778
<i>P</i> = 2500 psia (668.17°F)					<i>P</i> = 3000 psia (695.41°F)				<i>P</i> = 3500 psia			
Sat.	0.13076	1031.2	1091.7	1.2330	0.08460	969.8	1016.8	1.1587				
650									0.02492	663.7	679.9	0.8632
700	0.16849	1098.4	1176.3	1.3072	0.09838	1005.3	1059.9	1.1960	0.03065	760.0	779.9	0.9511
750	0.20327	1154.9	1249.0	1.3686	0.14840	1114.1	1196.5	1.3118	0.10460	1057.6	1125.4	1.2434
800	0.22949	1195.9	1302.0	1.4116	0.17601	1167.5	1265.3	1.3676	0.13639	1134.3	1222.6	1.3224
850	0.25174	1230.1	1346.6	1.4463	0.19771	1208.2	1317.9	1.4086	0.15847	1183.8	1286.5	1.3721
900	0.27165	1260.7	1386.4	1.4761	0.21640	1242.8	1362.9	1.4423	0.17659	1223.4	1337.8	1.4106
950	0.29001	1289.1	1423.3	1.5028	0.23321	1273.9	1403.3	1.4716	0.19245	1257.8	1382.4	1.4428
1000	0.30726	1316.1	1458.2	1.5271	0.24876	1302.8	1440.9	1.4978	0.20687	1289.0	1423.0	1.4711
1100	0.33949	1367.3	1524.4	1.5710	0.27732	1356.8	1510.8	1.5441	0.23289	1346.1	1496.9	1.5201
1200	0.36966	1416.6	1587.6	1.6103	0.30367	1408.0	1576.6	1.5850	0.25654	1399.3	1565.4	1.5627
1400	0.42631	1513.3	1710.5	1.6802	0.35249	1507.0	1702.7	1.6567	0.29978	1500.7	1694.8	1.6364
1600	0.48004	1610.1	1832.2	1.7424	0.39830	1605.3	1826.4	1.7199	0.33994	1600.4	1820.5	1.7006
1800	0.53205	1708.6	1954.8	1.7991	0.44237	1704.7	1950.3	1.7773	0.37833	1700.8	1945.8	1.7586
2000	0.58295	1809.4	2079.1	1.8518	0.48532	1806.1	2075.6	1.8304	0.41561	1802.9	2072.1	1.8121
<i>P</i> = 4000 psia					<i>P</i> = 5000 psia				<i>P</i> = 6000 psia			
650	0.02448	657.9	676.1	0.8577	0.02379	648.3	670.3	0.8485	0.02325	640.3	666.1	0.8408
700	0.02871	742.3	763.6	0.9347	0.02678	721.8	746.6	0.9156	0.02564	708.1	736.5	0.9028
750	0.06370	962.1	1009.2	1.1410	0.03373	821.8	853.0	1.0054	0.02981	788.7	821.8	0.9747
800	0.10520	1094.2	1172.1	1.2734	0.05937	986.9	1041.8	1.1581	0.03949	897.1	941.0	1.0711
850	0.12848	1156.7	1251.8	1.3355	0.08551	1092.4	1171.5	1.2593	0.05815	1018.6	1083.1	1.1819
900	0.14647	1202.5	1310.9	1.3799	0.10390	1155.9	1252.1	1.3198	0.07584	1103.5	1187.7	1.2603
950	0.16176	1240.7	1360.5	1.4157	0.11863	1203.9	1313.6	1.3643	0.09010	1163.7	1263.7	1.3153
1000	0.17538	1274.6	1404.4	1.4463	0.13128	1244.0	1365.5	1.4004	0.10208	1211.4	1324.7	1.3578
1100	0.19957	1335.1	1482.8	1.4983	0.15298	1312.2	1453.8	1.4590	0.12211	1288.4	1424.0	1.4237
1200	0.22121	1390.3	1554.1	1.5426	0.17185	1372.1	1531.1	1.5070	0.13911	1353.4	1507.8	1.4758
1300	0.24128	1443.0	1621.6	1.5821	0.18902	1427.8	1602.7	1.5490	0.15434	1412.5	1583.8	1.5203
1400	0.26028	1494.3	1687.0	1.6182	0.20508	1481.4	1671.1	1.5868	0.16841	1468.4	1655.4	1.5598
1600	0.29620	1595.5	1814.7	1.6835	0.23505	1585.6	1803.1	1.6542	0.19438	1575.7	1791.5	1.6294
1800	0.33033	1696.8	1941.4	1.7422	0.26320	1689.0	1932.5	1.7142	0.21853	1681.1	1923.7	1.6907
2000	0.36335	1799.7	2068.6	1.7961	0.29023	1793.2	2061.7	1.7689	0.24155	1786.7	2054.9	1.7463

TABLE A-7E

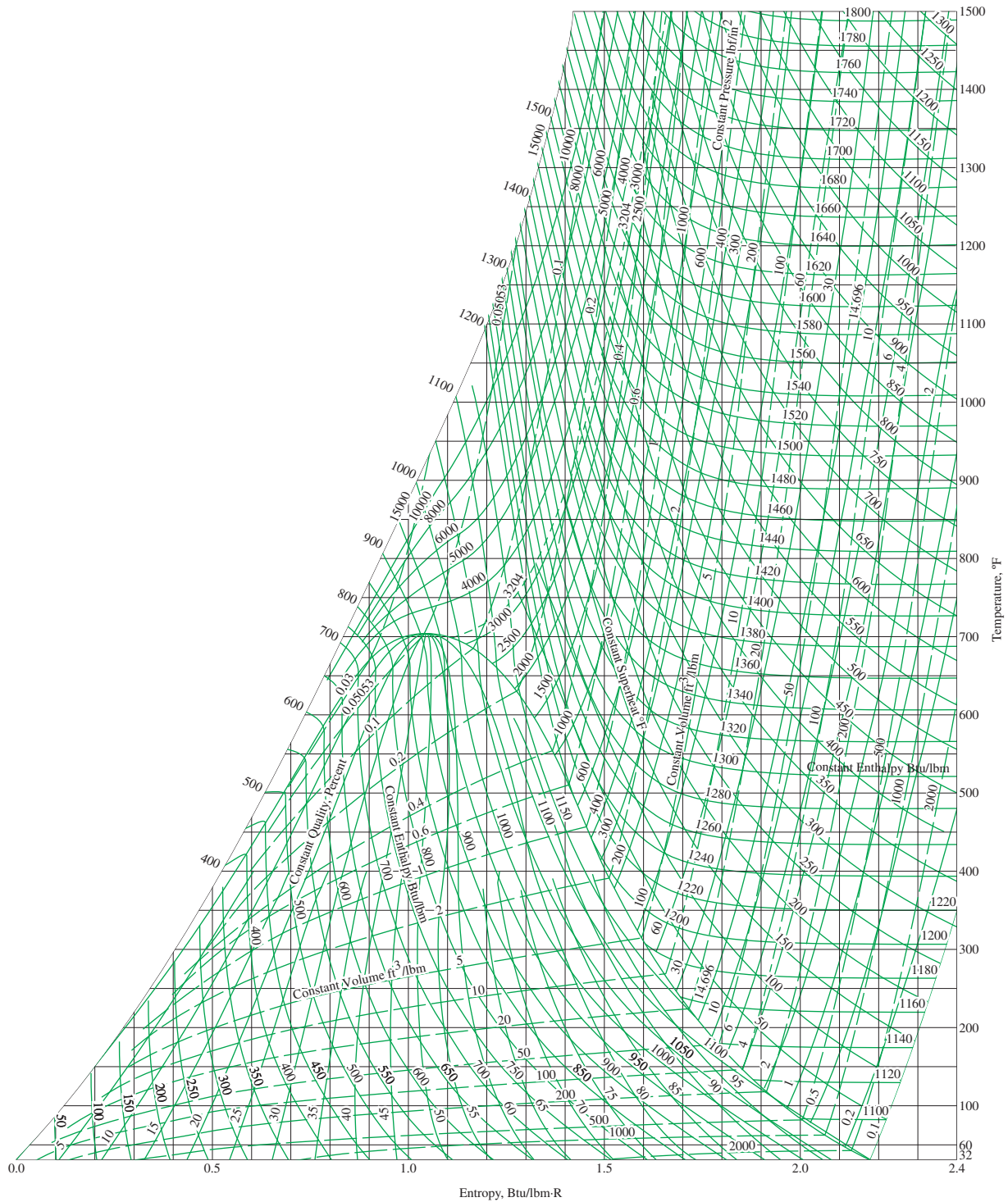
Compressed liquid water

<i>T</i> °F	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R	<i>v</i> ft ³ /lbm	<i>u</i> Btu/lbm	<i>h</i> Btu/lbm	<i>s</i> Btu/lbm·R		
<i>P</i> = 500 psia (467.04°F)					<i>P</i> = 1000 psia (544.65°F)					<i>P</i> = 1500 psia (596.26°F)				
Sat.	0.019750	447.68	449.51	0.64900	0.021595	538.58	542.57	0.74341	0.023456	605.07	611.58	0.80836		
32	0.015994	0.01	1.49	0.00001	0.015966	0.03	2.99	0.00005	0.015939	0.05	4.48	0.00008		
50	0.015998	18.03	19.51	0.03601	0.015972	17.99	20.95	0.03593	0.015946	17.95	22.38	0.03584		
100	0.016107	67.86	69.35	0.12930	0.016083	67.69	70.67	0.12899	0.016059	67.53	71.98	0.12869		
150	0.016317	117.70	119.21	0.21462	0.016292	117.42	120.43	0.21416	0.016267	117.14	121.66	0.21369		
200	0.016607	167.70	169.24	0.29349	0.016580	167.31	170.38	0.29289	0.016553	166.92	171.52	0.29229		
250	0.016972	218.04	219.61	0.36708	0.016941	217.51	220.65	0.36634	0.016911	217.00	221.69	0.36560		
300	0.017417	268.92	270.53	0.43641	0.017380	268.24	271.46	0.43551	0.017345	267.57	272.39	0.43463		
350	0.017954	320.64	322.30	0.50240	0.017910	319.77	323.08	0.50132	0.017866	318.91	323.87	0.50025		
400	0.018609	373.61	375.33	0.56595	0.018552	372.48	375.91	0.56463	0.018496	371.37	376.51	0.56333		
450	0.019425	428.44	430.24	0.62802	0.019347	426.93	430.51	0.62635	0.019271	425.47	430.82	0.62472		
500					0.020368	484.03	487.80	0.68764	0.020258	482.01	487.63	0.68550		
550									0.021595	542.50	548.50	0.74731		
<i>P</i> = 2000 psia (635.85°F)					<i>P</i> = 3000 psia (695.41°F)					<i>P</i> = 5000 psia				
Sat.	0.025634	662.33	671.82	0.86224	0.034335	783.39	802.45	0.97321						
32	0.015912	0.07	5.96	0.00010	0.015859	0.10	8.90	0.00011	0.015756	0.13	14.71	0.00002		
50	0.015921	17.91	23.80	0.03574	0.015870	17.83	26.64	0.03554	0.015773	17.65	32.25	0.03505		
100	0.016035	67.36	73.30	0.12838	0.015988	67.04	75.91	0.12776	0.015897	66.41	81.12	0.12652		
200	0.016527	166.54	172.66	0.29170	0.016475	165.79	174.94	0.29053	0.016375	164.36	179.51	0.28824		
300	0.017310	266.92	273.33	0.43376	0.017242	265.65	275.22	0.43204	0.017112	263.24	279.07	0.42874		
400	0.018442	370.30	377.12	0.56205	0.018338	368.22	378.41	0.55959	0.018145	364.35	381.14	0.55492		
450	0.019199	424.06	431.16	0.62314	0.019062	421.36	431.94	0.62010	0.018812	416.40	433.80	0.61445		
500	0.020154	480.08	487.54	0.68346	0.019960	476.45	487.53	0.67958	0.019620	469.94	488.10	0.67254		
560	0.021739	552.21	560.26	0.75692	0.021405	546.59	558.47	0.75126	0.020862	537.08	556.38	0.74154		
600	0.023317	605.77	614.40	0.80898	0.022759	597.42	610.06	0.80086	0.021943	584.42	604.72	0.78803		
640					0.024765	654.52	668.27	0.85476	0.023358	634.95	656.56	0.83603		
680					0.028821	728.63	744.64	0.92288	0.025366	690.67	714.14	0.88745		
700									0.026777	721.78	746.56	0.91564		

TABLE A-8E

Saturated ice—water vapor

Temp., T °F	Sat. press., P_{sat} psia	Specific volume, ft ³ /lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, Btu/lbm·R		
		Sat. ice, v_i	Sat. vapor, v_g	Sat. ice, u_i	Subl., u_{ig}	Sat. vapor, u_g	Sat. ice, h_i	Subl., h_{ig}	Sat. vapor, h_g	Sat. ice, s_i	Subl., s_{ig}	Sat. vapor, s_g
32.018	0.08871	0.01747	3299.6	-143.34	1164.2	1020.9	-143.34	1218.3	1075.0	-0.29146	2.4779	2.1864
32	0.08864	0.01747	3302.6	-143.35	1164.2	1020.9	-143.35	1218.4	1075.0	-0.29148	2.4779	2.1865
30	0.08086	0.01747	3605.8	-144.35	1164.6	1020.2	-144.35	1218.5	1074.2	-0.29353	2.4883	2.1948
25	0.06405	0.01746	4505.8	-146.85	1165.4	1018.6	-146.85	1218.8	1072.0	-0.29865	2.5146	2.2160
20	0.05049	0.01746	5657.6	-149.32	1166.2	1016.9	-149.32	1219.1	1069.8	-0.30377	2.5414	2.2376
15	0.03960	0.01745	7138.9	-151.76	1167.0	1015.2	-151.76	1219.3	1067.6	-0.30889	2.5687	2.2598
10	0.03089	0.01744	9054.0	-154.18	1167.8	1013.6	-154.18	1219.5	1065.4	-0.31401	2.5965	2.2825
5	0.02397	0.01743	11,543	-156.57	1168.5	1011.9	-156.57	1219.7	1063.1	-0.31913	2.6248	2.3057
0	0.01850	0.01743	14,797	-158.94	1169.2	1010.3	-158.94	1219.9	1060.9	-0.32426	2.6537	2.3295
-5	0.01420	0.01742	19,075	-161.28	1169.9	1008.6	-161.28	1220.0	1058.7	-0.32938	2.6832	2.3538
-10	0.01083	0.01741	24,731	-163.60	1170.6	1007.0	-163.60	1220.1	1056.5	-0.33451	2.7133	2.3788
-15	0.00821	0.01740	32,257	-165.90	1171.2	1005.3	-165.90	1220.2	1054.3	-0.33964	2.7440	2.4044
-20	0.00619	0.01740	42,335	-168.16	1171.8	1003.6	-168.16	1220.3	1052.1	-0.34478	2.7754	2.4306
-25	0.00463	0.01739	55,917	-170.41	1172.4	1002.0	-170.41	1220.3	1049.9	-0.34991	2.8074	2.4575
-30	0.00344	0.01738	74,345	-172.63	1173.0	1000.3	-172.63	1220.3	1047.7	-0.35505	2.8401	2.4850
-35	0.00254	0.01738	99,526	-174.83	1173.5	998.7	-174.83	1220.3	1045.5	-0.36019	2.8735	2.5133
-40	0.00186	0.01737	134,182	-177.00	1174.0	997.0	-177.00	1220.3	1043.3	-0.36534	2.9076	2.5423

**FIGURE A-9E**

T-s diagram for water.

Source of Data: Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore. Steam Tables (New York: John Wiley & Sons, 1969)

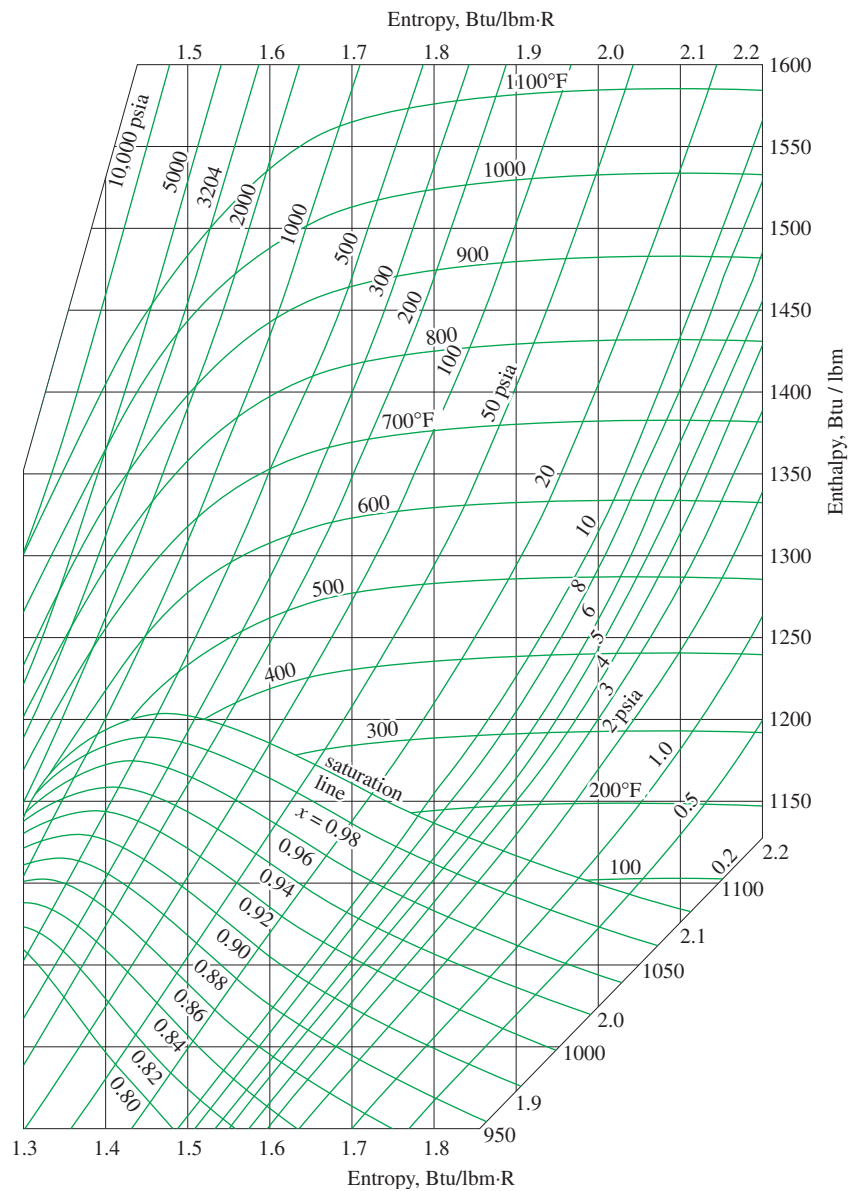


FIGURE A-10E

Mollier diagram for water.

Source of Data: Joseph H. Keenan, Frederick G. Keyes, Philip G. Hill, and Joan G. Moore. Steam Tables (New York: John Wiley & Sons, 1969)

TABLE A-11E

Saturated refrigerant-134a—Temperature table

Temp., T °F	Sat. press., P_{sat} psia	Specific volume, ft^3/lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, $\text{Btu}/\text{lbm}\cdot\text{R}$		
		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
-40	7.432	0.01130	5.7769	-0.016	89.174	89.16	0.000	97.104	97.10	0.00000	0.23136	0.23136
-35	8.581	0.01136	5.0489	1.483	88.360	89.84	1.501	96.360	97.86	0.00355	0.22689	0.23044
-30	9.869	0.01143	4.4286	2.987	87.542	90.53	3.008	95.608	98.62	0.00707	0.22250	0.22957
-25	11.306	0.01149	3.8980	4.497	86.717	91.21	4.522	94.849	99.37	0.01057	0.21819	0.22876
-20	12.906	0.01156	3.4424	6.014	85.887	91.90	6.041	94.080	100.12	0.01404	0.21396	0.22800
-15	14.680	0.01163	3.0495	7.536	85.050	92.59	7.568	93.303	100.87	0.01748	0.20981	0.22729
-10	16.642	0.01170	2.7097	9.065	84.206	93.27	9.102	92.515	101.62	0.02090	0.20572	0.22662
-5	18.806	0.01178	2.4146	10.601	83.355	93.96	10.642	91.717	102.36	0.02430	0.20171	0.22600
0	21.185	0.01185	2.1575	12.143	82.496	94.64	12.190	90.907	103.10	0.02767	0.19775	0.22542
5	23.793	0.01193	1.9328	13.693	81.628	95.32	13.745	90.085	103.83	0.03103	0.19385	0.22488
10	26.646	0.01200	1.7358	15.249	80.751	96.00	15.308	89.251	104.56	0.03436	0.19001	0.22437
15	29.759	0.01208	1.5625	16.813	79.865	96.68	16.879	88.403	105.28	0.03767	0.18623	0.22390
20	33.147	0.01216	1.4097	18.384	78.969	97.35	18.459	87.541	106.00	0.04097	0.18249	0.22345
25	36.826	0.01225	1.2746	19.963	78.062	98.03	20.047	86.665	106.71	0.04424	0.17880	0.22304
30	40.813	0.01233	1.1548	21.550	77.144	98.69	21.643	85.772	107.42	0.04750	0.17515	0.22265
35	45.124	0.01242	1.0482	23.145	76.214	99.36	23.249	84.863	108.11	0.05074	0.17154	0.22228
40	49.776	0.01251	0.95323	24.749	75.272	100.02	24.864	83.937	108.80	0.05397	0.16797	0.22194
45	54.787	0.01261	0.86837	26.361	74.317	100.68	26.489	82.993	109.48	0.05718	0.16443	0.22162
50	60.175	0.01270	0.79236	27.983	73.347	101.33	28.124	82.029	110.15	0.06038	0.16093	0.22131
55	65.957	0.01280	0.72414	29.614	72.363	101.98	29.770	81.046	110.82	0.06357	0.15746	0.22103
60	72.152	0.01290	0.66277	31.254	71.364	102.62	31.426	80.041	111.47	0.06674	0.15401	0.22075
65	78.780	0.01301	0.60744	32.904	70.348	103.25	33.094	79.014	112.11	0.06991	0.15058	0.22049
70	85.858	0.01311	0.55746	34.565	69.315	103.88	34.773	77.964	112.74	0.07306	0.14718	0.22024
75	93.408	0.01323	0.51222	36.237	68.264	104.50	36.465	76.889	113.35	0.07621	0.14379	0.22000
80	101.45	0.01334	0.47119	37.920	67.193	105.11	38.170	75.788	113.96	0.07934	0.14042	0.21976
85	110.00	0.01346	0.43391	39.614	66.102	105.72	39.888	74.660	114.55	0.08247	0.13706	0.21953
90	119.08	0.01359	0.39997	41.321	64.989	106.31	41.620	73.503	115.12	0.08560	0.13371	0.21931
95	128.72	0.01372	0.36902	43.041	63.852	106.89	43.367	72.315	115.68	0.08872	0.13036	0.21908
100	138.93	0.01386	0.34074	44.774	62.690	107.46	45.130	71.094	116.22	0.09183	0.12702	0.21885
105	149.73	0.01400	0.31486	46.521	61.501	108.02	46.909	69.838	116.75	0.09495	0.12367	0.21862
110	161.16	0.01415	0.29113	48.284	60.284	108.57	48.706	68.544	117.25	0.09806	0.12031	0.21838
115	173.23	0.01430	0.26933	50.063	59.035	109.10	50.521	67.210	117.73	0.10118	0.11694	0.21813
120	185.96	0.01446	0.24928	51.858	57.753	109.61	52.356	65.833	118.19	0.10430	0.11356	0.21786
130	213.53	0.01482	0.21373	55.505	55.075	110.58	56.091	62.935	119.03	0.11056	0.10672	0.21728
140	244.06	0.01522	0.18331	59.237	52.221	111.46	59.925	59.813	119.74	0.11686	0.09973	0.21660
150	277.79	0.01567	0.15707	63.070	49.151	112.22	63.875	56.419	120.29	0.12324	0.09253	0.21577
160	314.94	0.01619	0.13423	67.022	45.811	112.83	67.965	52.690	120.66	0.12971	0.08502	0.21473
170	355.80	0.01682	0.11413	71.139	42.101	113.24	72.246	48.509	120.75	0.13637	0.07703	0.21340
180	400.66	0.01759	0.09619	75.464	37.893	113.36	76.768	43.721	120.49	0.14327	0.06834	0.21161
190	449.90	0.01861	0.07982	80.093	32.929	113.02	81.642	38.025	119.67	0.15057	0.05852	0.20909
200	504.00	0.02010	0.06441	85.297	26.629	111.93	87.172	30.761	117.93	0.15872	0.04662	0.20534
210	563.76	0.02309	0.04722	91.993	16.498	108.49	94.402	19.015	113.42	0.16924	0.02839	0.19763

Source of Data: Tables A-11E through A-13E are generated using the Engineering Equation Solver (EES) software developed by S. A. Klein and F. L. Alvarado. The routine used in calculations is the R134a, which is based on the fundamental equation of state developed by R. Tillner-Roth and H.D. Baehr, "An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for temperatures from 170 K to 455 K and pressures up to 70 MPa," *J. Phys. Chem. Ref. Data*, Vol. 23, No. 5, 1994. The enthalpy and entropy values of saturated liquid are set to zero at -40°C (and -40°F).

TABLE A-12E

Saturated refrigerant-134a—Pressure table

Sat. Press., <i>P</i> psia	Sat. temp., <i>T</i> _{sat} °F	Specific volume, ft ³ /lbm		Internal energy, Btu/lbm			Enthalpy, Btu/lbm			Entropy, Btu/lbm·R		
		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
5	-53.09	0.01113	8.3740	-3.914	91.283	87.37	-3.903	99.021	95.12	-0.00944	0.24353	0.23409
10	-29.52	0.01143	4.3740	3.132	87.463	90.59	3.153	95.536	98.69	0.00741	0.22208	0.22949
15	-14.15	0.01164	2.9882	7.796	84.907	92.70	7.828	93.170	101.00	0.01806	0.20911	0.22717
20	-2.43	0.01181	2.2781	11.393	82.915	94.31	11.436	91.302	102.74	0.02603	0.19967	0.22570
25	7.17	0.01196	1.8442	14.367	81.249	95.62	14.422	89.725	104.15	0.03247	0.19218	0.22465
30	15.37	0.01209	1.5506	16.929	79.799	96.73	16.996	88.340	105.34	0.03792	0.18595	0.22386
35	22.57	0.01221	1.3382	19.195	78.504	97.70	19.274	87.093	106.37	0.04265	0.18058	0.22324
40	29.01	0.01232	1.1773	21.236	77.326	98.56	21.327	85.950	107.28	0.04686	0.17586	0.22272
45	34.86	0.01242	1.0510	23.101	76.240	99.34	23.205	84.889	108.09	0.05065	0.17164	0.22229
50	40.23	0.01252	0.94909	24.824	75.228	100.05	24.939	83.894	108.83	0.05412	0.16780	0.22192
55	45.20	0.01261	0.86509	26.428	74.277	100.70	26.556	82.954	109.51	0.05732	0.16429	0.22160
60	49.84	0.01270	0.79462	27.932	73.378	101.31	28.073	82.060	110.13	0.06028	0.16104	0.22132
65	54.20	0.01278	0.73462	29.351	72.523	101.87	29.505	81.205	110.71	0.06306	0.15801	0.22107
70	58.30	0.01287	0.68290	30.696	71.705	102.40	30.862	80.385	111.25	0.06567	0.15518	0.22084
75	62.19	0.01295	0.63784	31.975	70.921	102.90	32.155	79.594	111.75	0.06813	0.15251	0.22064
80	65.89	0.01303	0.59822	33.198	70.167	103.36	33.391	78.830	112.22	0.07047	0.14998	0.22045
85	69.41	0.01310	0.56309	34.369	69.438	103.81	34.575	78.089	112.66	0.07269	0.14758	0.22027
90	72.78	0.01318	0.53173	35.494	68.733	104.23	35.713	77.369	113.08	0.07481	0.14529	0.22011
95	76.02	0.01325	0.50356	36.577	68.048	104.63	36.810	76.668	113.48	0.07684	0.14311	0.21995
100	79.12	0.01332	0.47811	37.623	67.383	105.01	37.870	75.984	113.85	0.07879	0.14101	0.21981
110	85.00	0.01346	0.43390	39.614	66.102	105.72	39.888	74.660	114.55	0.08247	0.13706	0.21953
120	90.49	0.01360	0.39681	41.489	64.878	106.37	41.791	73.388	115.18	0.08590	0.13338	0.21928
130	95.64	0.01374	0.36523	43.263	63.704	106.97	43.594	72.159	115.75	0.08912	0.12993	0.21905
140	100.51	0.01387	0.33800	44.951	62.570	107.52	45.311	70.967	116.28	0.09215	0.12668	0.21883
150	105.12	0.01400	0.31426	46.563	61.473	108.04	46.952	69.807	116.76	0.09502	0.12359	0.21861
160	109.50	0.01413	0.29339	48.109	60.406	108.51	48.527	68.674	117.20	0.09776	0.12064	0.21840
170	113.69	0.01426	0.27487	49.595	59.366	108.96	50.043	67.564	117.61	0.10036	0.11783	0.21819
180	117.69	0.01439	0.25833	51.027	58.349	109.38	51.507	66.475	117.98	0.10286	0.11513	0.21799
190	121.53	0.01452	0.24346	52.412	57.353	109.76	52.922	65.402	118.32	0.10526	0.11252	0.21778
200	125.22	0.01464	0.23001	53.753	56.375	110.13	54.295	64.345	118.64	0.10757	0.11000	0.21757
220	132.21	0.01490	0.20662	56.321	54.462	110.78	56.927	62.267	119.19	0.11195	0.10519	0.21714
240	138.73	0.01516	0.18694	58.757	52.596	111.35	59.430	60.225	119.65	0.11606	0.10063	0.21669
260	144.85	0.01543	0.17012	61.082	50.763	111.84	61.824	58.205	120.03	0.11994	0.09627	0.21622
280	150.62	0.01570	0.15555	63.313	48.951	112.26	64.126	56.197	120.32	0.12364	0.09207	0.21571
300	156.09	0.01598	0.14279	65.460	47.154	112.61	66.347	54.195	120.54	0.12717	0.08800	0.21517
350	168.64	0.01672	0.11673	70.567	42.632	113.20	71.651	49.109	120.76	0.13545	0.07815	0.21360
400	179.86	0.01758	0.09643	75.401	37.957	113.36	76.702	43.794	120.50	0.14317	0.06847	0.21164
450	190.02	0.01860	0.07979	80.112	32.909	113.02	81.662	38.003	119.67	0.15060	0.05849	0.20909
500	199.29	0.01997	0.06533	84.900	27.096	112.00	86.748	31.292	118.04	0.15810	0.04748	0.20558

TABLE A-13E

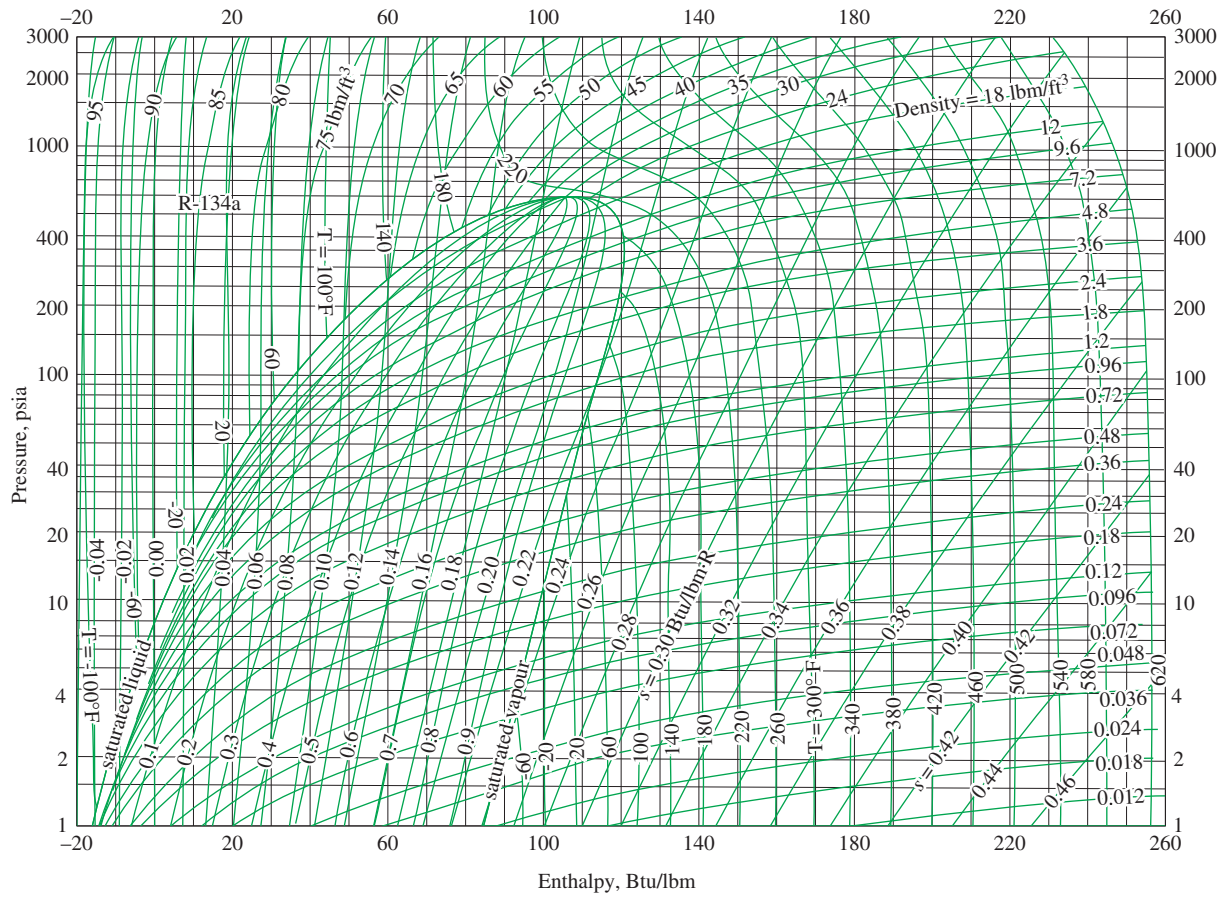
Superheated refrigerant-134a

T °F	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R
$P = 10 \text{ psia } (T_{\text{sat}} = -29.52^\circ\text{F})$					$P = 15 \text{ psia } (T_{\text{sat}} = -14.15^\circ\text{F})$				$P = 20 \text{ psia } (T_{\text{sat}} = -2.43^\circ\text{F})$			
Sat.	4.3740	90.59	98.69	0.22949	2.9882	92.70	101.00	0.22717	2.2781	94.31	102.74	0.22570
-20	4.4856	92.14	100.44	0.23351								
0	4.7135	95.42	104.14	0.24175	3.1001	95.08	103.69	0.23312	2.2922	94.73	103.21	0.22673
20	4.9380	98.77	107.91	0.24978	3.2551	98.49	107.52	0.24129	2.4130	98.19	107.12	0.23506
40	5.1600	102.21	111.76	0.25763	3.4074	101.96	111.42	0.24924	2.5306	101.71	111.07	0.24313
60	5.3802	105.73	115.68	0.26533	3.5577	105.51	115.38	0.25702	2.6461	105.29	115.08	0.25099
80	5.5989	109.33	119.69	0.27290	3.7064	109.14	119.42	0.26465	2.7600	108.94	119.15	0.25868
100	5.8165	113.02	123.78	0.28035	3.8540	112.85	123.54	0.27214	2.8726	112.67	123.30	0.26623
120	6.0331	116.80	127.96	0.28768	4.0006	116.64	127.75	0.27952	2.9842	116.48	127.53	0.27364
140	6.2490	120.66	132.23	0.29492	4.1464	120.52	132.03	0.28678	3.0950	120.38	131.83	0.28094
160	6.4642	124.62	136.58	0.30205	4.2915	124.49	136.40	0.29395	3.2051	124.35	136.22	0.28814
180	6.6789	128.66	141.01	0.30910	4.4361	128.53	140.85	0.30102	3.3146	128.41	140.68	0.29523
200	6.8930	132.78	145.54	0.31606	4.5802	132.67	145.38	0.30800	3.4237	132.56	145.23	0.30223
220	7.1068	136.99	150.14	0.32293	4.7239	136.89	150.00	0.31489	3.5324	136.78	149.86	0.30914
$P = 30 \text{ psia } (T_{\text{sat}} = 15.37^\circ\text{F})$					$P = 40 \text{ psia } (T_{\text{sat}} = 29.01^\circ\text{F})$				$P = 50 \text{ psia } (T_{\text{sat}} = 40.23^\circ\text{F})$			
Sat.	1.5506	96.73	105.34	0.22386	1.1773	98.56	107.28	0.22272	0.9491	100.05	108.83	0.22192
20	1.5691	97.56	106.27	0.22583								
40	1.6528	101.18	110.35	0.23416	1.2126	100.61	109.59	0.22740				
60	1.7338	104.83	114.45	0.24220	1.2768	104.35	113.80	0.23567	1.0019	103.85	113.12	0.23033
80	1.8130	108.54	118.60	0.25003	1.3389	108.12	118.03	0.24365	1.0540	107.69	117.44	0.23849
100	1.8908	112.31	122.81	0.25769	1.3995	111.94	122.30	0.25142	1.1043	111.56	121.78	0.24639
120	1.9675	116.16	127.08	0.26519	1.4588	115.83	126.63	0.25902	1.1534	115.49	126.16	0.25408
140	2.0434	120.08	131.43	0.27256	1.5173	119.79	131.02	0.26646	1.2015	119.48	130.60	0.26160
160	2.1185	124.09	135.85	0.27981	1.5750	123.82	135.47	0.27377	1.2488	123.54	135.09	0.26898
180	2.1931	128.17	140.34	0.28695	1.6321	127.92	140.00	0.28096	1.2955	127.67	139.66	0.27622
200	2.2671	132.33	144.92	0.29399	1.6887	132.10	144.60	0.28805	1.3416	131.87	144.29	0.28335
220	2.3408	136.58	149.57	0.30094	1.7449	136.37	149.28	0.29503	1.3873	136.15	148.99	0.29037
240	2.4141	140.90	154.30	0.30780	1.8007	140.70	154.03	0.30192	1.4326	140.51	153.76	0.29730
260	2.4871	145.30	159.11	0.31458	1.8562	145.12	158.86	0.30873	1.4776	144.94	158.61	0.30413
280	2.5598	149.79	164.00	0.32128	1.9114	149.62	163.77	0.31545	1.5223	149.45	163.53	0.31087
$P = 60 \text{ psia } (T_{\text{sat}} = 49.84^\circ\text{F})$					$P = 70 \text{ psia } (T_{\text{sat}} = 58.30^\circ\text{F})$				$P = 80 \text{ psia } (T_{\text{sat}} = 65.89^\circ\text{F})$			
Sat.	0.7946	101.31	110.13	0.22132	0.6829	102.40	111.25	0.22084	0.5982	103.36	112.22	0.22045
60	0.8179	103.31	112.39	0.22572	0.6857	102.74	111.62	0.22157				
80	0.8636	107.24	116.82	0.23408	0.7271	106.77	116.18	0.23018	0.6243	106.27	115.51	0.22663
100	0.9072	111.17	121.24	0.24212	0.7662	110.77	120.69	0.23838	0.6601	110.35	120.12	0.23501
120	0.9495	115.14	125.69	0.24992	0.8037	114.79	125.20	0.24630	0.6941	114.43	124.70	0.24305
140	0.9908	119.17	130.17	0.25753	0.8401	118.86	129.74	0.25399	0.7270	118.53	129.29	0.25084
160	1.0312	123.26	134.71	0.26497	0.8756	122.98	134.32	0.26151	0.7589	122.69	133.92	0.25843
180	1.0709	127.42	139.31	0.27227	0.9105	127.16	138.95	0.26886	0.7900	126.89	138.59	0.26585
200	1.1101	131.64	143.97	0.27945	0.9447	131.40	143.64	0.27608	0.8206	131.17	143.31	0.27312
220	1.1489	135.94	148.69	0.28651	0.9785	135.72	148.40	0.28318	0.8507	135.50	148.09	0.28026
240	1.1872	140.31	153.49	0.29346	1.0118	140.11	153.22	0.29017	0.8803	139.91	152.94	0.28728
260	1.2252	144.76	158.36	0.30032	1.0449	144.57	158.10	0.29706	0.9096	144.38	157.85	0.29420
280	1.2629	149.28	163.30	0.30709	1.0776	149.10	163.06	0.30386	0.9386	148.93	162.82	0.30102
300	1.3004	153.88	168.31	0.31378	1.1101	153.71	168.09	0.31057	0.9674	153.55	167.87	0.30775
320	1.3377	158.55	173.40	0.32039	1.1424	158.40	173.20	0.31720	0.9959	158.25	172.99	0.31440

TABLE A-13E

Superheated refrigerant-134a (Concluded)

T °F	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R	v ft ³ /lbm	u Btu/lbm	h Btu/lbm	s Btu/lbm·R
$P = 90 \text{ psia } (T_{\text{sat}} = 72.78^\circ\text{F})$					$P = 100 \text{ psia } (T_{\text{sat}} = 79.12^\circ\text{F})$				$P = 120 \text{ psia } (T_{\text{sat}} = 90.49^\circ\text{F})$			
Sat.	0.53173	104.23	113.08	0.22011	0.47811	105.01	113.85	0.21981	0.39681	106.37	115.18	0.21928
80	0.54388	105.75	114.81	0.22332	0.47906	105.19	114.06	0.22018				
100	0.57729	109.91	119.53	0.23191	0.51076	109.46	118.91	0.22902	0.41013	108.49	117.59	0.22364
120	0.60874	114.05	124.19	0.24009	0.54022	113.66	123.66	0.23735	0.43692	112.85	122.55	0.23234
140	0.63885	118.20	128.84	0.24799	0.56821	117.86	128.38	0.24535	0.46190	117.16	127.42	0.24059
160	0.66796	122.39	133.51	0.25565	0.59513	122.09	133.10	0.25310	0.48563	121.47	132.25	0.24853
180	0.69629	126.63	138.22	0.26313	0.62122	126.36	137.85	0.26065	0.50844	125.80	137.09	0.25621
200	0.72399	130.92	142.98	0.27045	0.64667	130.68	142.64	0.26802	0.53054	130.18	141.96	0.26370
220	0.75119	135.28	147.79	0.27763	0.67158	135.05	147.48	0.27525	0.55206	134.60	146.86	0.27102
240	0.77796	139.70	152.66	0.28469	0.69605	139.50	152.38	0.28234	0.57312	139.08	151.80	0.27819
260	0.80437	144.19	157.59	0.29164	0.72016	144.00	157.33	0.28932	0.59379	143.62	156.80	0.28523
280	0.83048	148.75	162.58	0.29849	0.74396	148.58	162.34	0.29620	0.61413	148.22	161.86	0.29216
300	0.85633	153.39	167.65	0.30524	0.76749	153.22	167.42	0.30297	0.63420	152.89	166.97	0.29898
320	0.88195	158.09	172.78	0.31191	0.79079	157.94	172.57	0.30966	0.65402	157.62	172.15	0.30571
$P = 140 \text{ psia } (T_{\text{sat}} = 100.51^\circ\text{F})$					$P = 160 \text{ psia } (T_{\text{sat}} = 109.50^\circ\text{F})$				$P = 180 \text{ psia } (T_{\text{sat}} = 117.69^\circ\text{F})$			
Sat.	0.33800	107.52	116.28	0.21883	0.29339	108.51	117.20	0.21840	0.25833	109.38	117.98	0.21799
120	0.36243	111.97	121.36	0.22775	0.30578	111.01	120.07	0.22339	0.26083	109.95	118.64	0.21912
140	0.38551	116.42	126.40	0.23630	0.32774	115.63	125.33	0.23232	0.28231	114.78	124.18	0.22852
160	0.40711	120.82	131.37	0.24444	0.34790	120.14	130.44	0.24070	0.30154	119.43	129.47	0.23720
180	0.42766	125.23	136.31	0.25229	0.36686	124.63	135.49	0.24872	0.31936	124.01	134.65	0.24542
200	0.44743	129.66	141.25	0.25990	0.38494	129.13	140.52	0.25647	0.33619	128.58	139.77	0.25332
220	0.46657	134.13	146.22	0.26731	0.40234	133.65	145.56	0.26399	0.35228	133.16	144.89	0.26095
240	0.48522	138.65	151.22	0.27457	0.41921	138.21	150.62	0.27133	0.36779	137.76	150.01	0.26838
260	0.50345	143.22	156.26	0.28168	0.43564	142.82	155.72	0.27851	0.38284	142.41	155.16	0.27564
280	0.52134	147.85	161.36	0.28866	0.45171	147.48	160.86	0.28555	0.39751	147.11	160.35	0.28275
300	0.53895	152.55	166.51	0.29553	0.46748	152.21	166.05	0.29248	0.41186	151.86	165.58	0.28972
320	0.55630	157.31	171.72	0.30230	0.48299	156.99	171.29	0.29929	0.42594	156.67	170.85	0.29658
340	0.57345	162.14	176.99	0.30898	0.49828	161.84	176.59	0.30600	0.43980	161.53	176.18	0.30333
360	0.59041	167.03	182.33	0.31557	0.51338	166.75	181.95	0.31262	0.45347	166.47	181.57	0.30998
$P = 200 \text{ psia } (T_{\text{sat}} = 125.22^\circ\text{F})$					$P = 300 \text{ psia } (T_{\text{sat}} = 156.09^\circ\text{F})$				$P = 400 \text{ psia } (T_{\text{sat}} = 179.86^\circ\text{F})$			
Sat.	0.23001	110.13	118.64	0.21757	0.14279	112.61	120.54	0.21517	0.09643	113.36	120.50	0.21164
140	0.24541	113.86	122.94	0.22483								
160	0.26412	118.67	128.44	0.23386	0.14656	113.82	121.96	0.21747				
180	0.28115	123.36	133.77	0.24231	0.16355	119.53	128.61	0.22803	0.09658	113.42	120.56	0.21174
200	0.29704	128.01	139.00	0.25037	0.17776	124.79	134.66	0.23734	0.11440	120.53	128.99	0.22473
220	0.31212	132.65	144.20	0.25813	0.19044	129.86	140.43	0.24596	0.12746	126.45	135.88	0.23502
240	0.32658	137.31	149.39	0.26566	0.20211	134.83	146.05	0.25412	0.13853	131.96	142.21	0.24420
260	0.34054	141.99	154.60	0.27300	0.21306	139.77	151.60	0.26193	0.14844	137.27	148.26	0.25272
280	0.35410	146.73	159.83	0.28017	0.22347	144.71	157.11	0.26949	0.15756	142.48	154.15	0.26079
300	0.36733	151.50	165.10	0.28720	0.23346	149.66	162.62	0.27683	0.16611	147.65	159.95	0.26853
320	0.38029	156.34	170.41	0.29410	0.24310	154.63	168.13	0.28399	0.17423	152.81	165.71	0.27601
340	0.39300	161.23	175.77	0.30089	0.25246	159.65	173.66	0.29100	0.18201	157.97	171.45	0.28328
360	0.40552	166.18	181.19	0.30758	0.26159	164.71	179.23	0.29788	0.18951	163.16	177.19	0.29037

**FIGURE A-14E**

P-h diagram for refrigerant-134a.

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TABLE A-16E

Properties of the atmosphere at high altitude

Altitude, ft	Temperature, °F	Pressure, psia	Gravity, g, ft/s ²	Speed of sound, ft/s	Density, lbm/ft ³	Viscosity μ , lbm/ft·s	Thermal conductivity, Btu/h·ft·R
0	59.00	14.7	32.174	1116	0.07647	1.202×10^{-5}	0.0146
500	57.22	14.4	32.173	1115	0.07536	1.199×10^{-5}	0.0146
1000	55.43	14.2	32.171	1113	0.07426	1.196×10^{-5}	0.0146
1500	53.65	13.9	32.169	1111	0.07317	1.193×10^{-5}	0.0145
2000	51.87	13.7	32.168	1109	0.07210	1.190×10^{-5}	0.0145
2500	50.09	13.4	32.166	1107	0.07104	1.186×10^{-5}	0.0144
3000	48.30	13.2	32.165	1105	0.06998	1.183×10^{-5}	0.0144
3500	46.52	12.9	32.163	1103	0.06985	1.180×10^{-5}	0.0143
4000	44.74	12.7	32.162	1101	0.06792	1.177×10^{-5}	0.0143
4500	42.96	12.5	32.160	1099	0.06690	1.173×10^{-5}	0.0142
5000	41.17	12.2	32.159	1097	0.06590	1.170×10^{-5}	0.0142
5500	39.39	12.0	32.157	1095	0.06491	1.167×10^{-5}	0.0141
6000	37.61	11.8	32.156	1093	0.06393	1.164×10^{-5}	0.0141
6500	35.83	11.6	32.154	1091	0.06296	1.160×10^{-5}	0.0141
7000	34.05	11.3	32.152	1089	0.06200	1.157×10^{-5}	0.0140
7500	32.26	11.1	32.151	1087	0.06105	1.154×10^{-5}	0.0140
8000	30.48	10.9	32.149	1085	0.06012	1.150×10^{-5}	0.0139
8500	28.70	10.7	32.148	1083	0.05919	1.147×10^{-5}	0.0139
9000	26.92	10.5	32.146	1081	0.05828	1.144×10^{-5}	0.0138
9500	25.14	10.3	32.145	1079	0.05738	1.140×10^{-5}	0.0138
10,000	23.36	10.1	32.145	1077	0.05648	1.137×10^{-5}	0.0137
11,000	19.79	9.72	32.140	1073	0.05473	1.130×10^{-5}	0.0136
12,000	16.23	9.34	32.137	1069	0.05302	1.124×10^{-5}	0.0136
13,000	12.67	8.99	32.134	1065	0.05135	1.117×10^{-5}	0.0135
14,000	9.12	8.63	32.131	1061	0.04973	1.110×10^{-5}	0.0134
15,000	5.55	8.29	32.128	1057	0.04814	1.104×10^{-5}	0.0133
16,000	+1.99	7.97	32.125	1053	0.04659	1.097×10^{-5}	0.0132
17,000	-1.58	7.65	32.122	1049	0.04508	1.090×10^{-5}	0.0132
18,000	-5.14	7.34	32.119	1045	0.04361	1.083×10^{-5}	0.0130
19,000	-8.70	7.05	32.115	1041	0.04217	1.076×10^{-5}	0.0129
20,000	-12.2	6.76	32.112	1037	0.04077	1.070×10^{-5}	0.0128
22,000	-19.4	6.21	32.106	1029	0.03808	1.056×10^{-5}	0.0126
24,000	-26.5	5.70	32.100	1020	0.03553	1.042×10^{-5}	0.0124
26,000	-33.6	5.22	32.094	1012	0.03311	1.028×10^{-5}	0.0122
28,000	-40.7	4.78	32.088	1003	0.03082	1.014×10^{-5}	0.0121
30,000	-47.8	4.37	32.082	995	0.02866	1.000×10^{-5}	0.0119
32,000	-54.9	3.99	32.08	987	0.02661	0.986×10^{-5}	0.0117
34,000	-62.0	3.63	32.07	978	0.02468	0.971×10^{-5}	0.0115
36,000	-69.2	3.30	32.06	969	0.02285	0.956×10^{-5}	0.0113
38,000	-69.7	3.05	32.06	968	0.02079	0.955×10^{-5}	0.0113
40,000	-69.7	2.73	32.05	968	0.01890	0.955×10^{-5}	0.0113
45,000	-69.7	2.148	32.04	968	0.01487	0.955×10^{-5}	0.0113
50,000	-69.7	1.691	32.02	968	0.01171	0.955×10^{-5}	0.0113
55,000	-69.7	1.332	32.00	968	0.00922	0.955×10^{-5}	0.0113
60,000	-69.7	1.048	31.99	968	0.00726	0.955×10^{-5}	0.0113

Source of Data: U.S. Standard Atmosphere Supplements, U.S. Government Printing Office, 1966. Based on year-round mean conditions at 45° latitude and varies with the time of the year and the weather patterns. The conditions at sea level ($z = 0$) are taken to be $P = 14.696$ psia, $T = 59^\circ\text{F}$, $\rho = 0.076474$ lbm/ft³, $g = 32.1741$ ft/s².

TABLE A-17E

Ideal-gas properties of air

T R	h Btu/lbm	P_r	u Btu/lbm	v_r	s° Btu/lbm·R	T R	h Btu/lbm	P_r	u Btu/lbm	v_r	s° Btu/lbm·R
360	85.97	0.3363	61.29	396.6	0.50369	1600	395.74	71.13	286.06	8.263	0.87130
380	90.75	0.4061	64.70	346.6	0.51663	1650	409.13	80.89	296.03	7.556	0.87954
400	95.53	0.4858	68.11	305.0	0.52890	1700	422.59	90.95	306.06	6.924	0.88758
420	100.32	0.5760	71.52	270.1	0.54058	1750	436.12	101.98	316.16	6.357	0.89542
440	105.11	0.6776	74.93	240.6	0.55172	1800	449.71	114.0	326.32	5.847	0.90308
460	109.90	0.7913	78.36	215.33	0.56235	1850	463.37	127.2	336.55	5.388	0.91056
480	114.69	0.9182	81.77	193.65	0.57255	1900	477.09	141.5	346.85	4.974	0.91788
500	119.48	1.0590	85.20	174.90	0.58233	1950	490.88	157.1	357.20	4.598	0.92504
520	124.27	1.2147	88.62	158.58	0.59173	2000	504.71	174.0	367.61	4.258	0.93205
537	128.10	1.3593	91.53	146.34	0.59945	2050	518.71	192.3	378.08	3.949	0.93891
540	129.06	1.3860	92.04	144.32	0.60078	2100	532.55	212.1	388.60	3.667	0.94564
560	133.86	1.5742	95.47	131.78	0.60950	2150	546.54	223.5	399.17	3.410	0.95222
580	138.66	1.7800	98.90	120.70	0.61793	2200	560.59	256.6	409.78	3.176	0.95919
600	143.47	2.005	102.34	110.88	0.62607	2250	574.69	281.4	420.46	2.961	0.96501
620	148.28	2.249	105.78	102.12	0.63395	2300	588.82	308.1	431.16	2.765	0.97123
640	153.09	2.514	109.21	94.30	0.64159	2350	603.00	336.8	441.91	2.585	0.97732
660	157.92	2.801	112.67	87.27	0.64902	2400	617.22	367.6	452.70	2.419	0.98331
680	162.73	3.111	116.12	80.96	0.65621	2450	631.48	400.5	463.54	2.266	0.98919
700	167.56	3.446	119.58	75.25	0.66321	2500	645.78	435.7	474.40	2.125	0.99497
720	172.39	3.806	123.04	70.07	0.67002	2550	660.12	473.3	485.31	1.996	1.00064
740	177.23	4.193	126.51	65.38	0.67665	2600	674.49	513.5	496.26	1.876	1.00623
760	182.08	4.607	129.99	61.10	0.68312	2650	688.90	556.3	507.25	1.765	1.01172
780	186.94	5.051	133.47	57.20	0.68942	2700	703.35	601.9	518.26	1.662	1.01712
800	191.81	5.526	136.97	53.63	0.69558	2750	717.83	650.4	529.31	1.566	1.02244
820	196.69	6.033	140.47	50.35	0.70160	2800	732.33	702.0	540.40	1.478	1.02767
840	201.56	6.573	143.98	47.34	0.70747	2850	746.88	756.7	551.52	1.395	1.03282
860	206.46	7.149	147.50	44.57	0.71323	2900	761.45	814.8	562.66	1.318	1.03788
880	211.35	7.761	151.02	42.01	0.71886	2950	776.05	876.4	573.84	1.247	1.04288
900	216.26	8.411	154.57	39.64	0.72438	3000	790.68	941.4	585.04	1.180	1.04779
920	221.18	9.102	158.12	37.44	0.72979	3050	805.34	1011	596.28	1.118	1.05264
940	226.11	9.834	161.68	35.41	0.73509	3100	820.03	1083	607.53	1.060	1.05741
960	231.06	10.61	165.26	33.52	0.74030	3150	834.75	1161	618.82	1.006	1.06212
980	236.02	11.43	168.83	31.76	0.74540	3200	849.48	1242	630.12	0.955	1.06676
1000	240.98	12.30	172.43	30.12	0.75042	3250	864.24	1328	641.46	0.907	1.07134
1040	250.95	14.18	179.66	27.17	0.76019	3300	879.02	1418	652.81	0.8621	1.07585
1080	260.97	16.28	186.93	24.58	0.76964	3350	893.83	1513	664.20	0.8202	1.08031
1120	271.03	18.60	194.25	22.30	0.77880	3400	908.66	1613	675.60	0.7807	1.08470
1160	281.14	21.18	201.63	20.29	0.78767	3450	923.52	1719	687.04	0.7436	1.08904
1200	291.30	24.01	209.05	18.51	0.79628	3500	938.40	1829	698.48	0.7087	1.09332
1240	301.52	27.13	216.53	16.93	0.80466	3550	953.30	1946	709.95	0.6759	1.09755
1280	311.79	30.55	224.05	15.52	0.81280	3600	968.21	2068	721.44	0.6449	1.10172
1320	322.11	34.31	231.63	14.25	0.82075	3650	983.15	2196	732.95	0.6157	1.10584
1360	332.48	38.41	239.25	13.12	0.82848	3700	998.11	2330	744.48	0.5882	1.10991
1400	342.90	42.88	246.93	12.10	0.83604	3750	1013.1	2471	756.04	0.5621	1.11393
1440	353.37	47.75	254.66	11.17	0.84341	3800	1028.1	2618	767.60	0.5376	1.11791
1480	363.89	53.04	262.44	10.34	0.85062	3850	1043.1	2773	779.19	0.5143	1.12183
1520	374.47	58.78	270.26	9.578	0.85767	3900	1058.1	2934	790.80	0.4923	1.12571
1560	385.08	65.00	278.13	8.890	0.86456	3950	1073.2	3103	802.43	0.4715	1.12955

TABLE A-17E

Ideal-gas properties of air (*Concluded*)

T R	h Btu/lbm	P_r	u Btu/lbm	v_r	s° Btu/lbm·R	T R	h Btu/lbm	P_r	u Btu/lbm	v_r	s° Btu/lbm·R
4000	1088.3	3280	814.06	0.4518	1.13334	4600	1270.4	6089	955.04	0.2799	1.17575
4050	1103.4	3464	825.72	0.4331	1.13709	4700	1300.9	6701	978.73	0.2598	1.18232
4100	1118.5	3656	837.40	0.4154	1.14079	4800	1331.5	7362	1002.5	0.2415	1.18876
4150	1133.6	3858	849.09	0.3985	1.14446	4900	1362.2	8073	1026.3	0.2248	1.19508
4200	1148.7	4067	860.81	0.3826	1.14809	5000	1392.9	8837	1050.1	0.2096	1.20129
4300	1179.0	4513	884.28	0.3529	1.15522	5100	1423.6	9658	1074.0	0.1956	1.20738
4400	1209.4	4997	907.81	0.3262	1.16221	5200	1454.4	10,539	1098.0	0.1828	1.21336
4500	1239.9	5521	931.39	0.3019	1.16905	5300	1485.3	11,481	1122.0	0.1710	1.2192

Note: The properties P_r (relative pressure) and v_r (relative specific volume) are dimensionless quantities used in the analysis of isentropic processes, and should not be confused with the properties pressure and specific volume.

Source of Data: Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 832–33, Table A–5. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1948).

TABLE A-18E

Ideal-gas properties of nitrogen, N_2

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,082.0	1,486.2	41.695	1080	7,551.0	5,406.2	50.651
320	2,221.0	1,585.5	42.143	1100	7,695.0	5,510.5	50.783
340	2,360.0	1,684.4	42.564	1120	7,839.3	5,615.2	50.912
360	2,498.9	1,784.0	42.962	1140	7,984.0	5,720.1	51.040
380	2,638.0	1,883.4	43.337	1160	8,129.0	5,825.4	51.167
400	2,777.0	1,982.6	43.694	1180	8,274.4	5,931.0	51.291
420	2,916.1	2,082.0	44.034	1200	8,420.0	6,037.0	51.143
440	3,055.1	2,181.3	44.357	1220	8,566.1	6,143.4	51.534
460	3,194.1	2,280.6	44.665	1240	8,712.6	6,250.1	51.653
480	3,333.1	2,379.9	44.962	1260	8,859.3	6,357.2	51.771
500	3,472.2	2,479.3	45.246	1280	9,006.4	6,464.5	51.887
520	3,611.3	2,578.6	45.519	1300	9,153.9	6,572.3	51.001
537	3,729.5	2,663.1	45.743	1320	9,301.8	6,680.4	52.114
540	3,750.3	2,678.0	45.781	1340	9,450.0	6,788.9	52.225
560	3,889.5	2,777.4	46.034	1360	9,598.6	6,897.8	52.335
580	4,028.7	2,876.9	46.278	1380	9,747.5	7,007.0	52.444
600	4,167.9	2,976.4	46.514	1400	9,896.9	7,116.7	52.551
620	4,307.1	3,075.9	46.742	1420	10,046.6	7,226.7	52.658
640	4,446.4	3,175.5	46.964	1440	10,196.6	7,337.0	52.763
660	4,585.8	3,275.2	47.178	1460	10,347.0	7,447.6	52.867
680	4,725.3	3,374.9	47.386	1480	10,497.8	7,558.7	52.969
700	4,864.9	3,474.8	47.588	1500	10,648.0	7,670.1	53.071
720	5,004.5	3,574.7	47.785	1520	10,800.4	7,781.9	53.171
740	5,144.3	3,674.7	47.977	1540	10,952.2	7,893.9	53.271
760	5,284.1	3,774.9	48.164	1560	11,104.3	8,006.4	53.369
780	5,424.2	3,875.2	48.345	1580	11,256.9	8,119.2	53.465
800	5,564.4	3,975.7	48.522	1600	11,409.7	8,232.3	53.561
820	5,704.7	4,076.3	48.696	1620	11,562.8	8,345.7	53.656
840	5,845.3	4,177.1	48.865	1640	11,716.4	8,459.6	53.751
860	5,985.9	4,278.1	49.031	1660	11,870.2	8,573.6	53.844
880	6,126.9	4,379.4	49.193	1680	12,024.3	8,688.1	53.936
900	6,268.1	4,480.8	49.352	1700	12,178.9	8,802.9	54.028
920	6,409.6	4,582.6	49.507	1720	12,333.7	8,918.0	54.118
940	6,551.2	4,684.5	49.659	1740	12,488.8	9,033.4	54.208
960	6,693.1	4,786.7	49.808	1760	12,644.3	9,149.2	54.297
980	6,835.4	4,889.3	49.955	1780	12,800.2	9,265.3	54.385
1000	6,977.9	4,992.0	50.099	1800	12,956.3	9,381.7	54.472
1020	7,120.7	5,095.1	50.241	1820	13,112.7	9,498.4	54.559
1040	7,263.8	5,198.5	50.380	1840	13,269.5	9,615.5	54.645
1060	7,407.2	5,302.2	50.516	1860	13,426.5	9,732.8	54.729

TABLE A-18E

Ideal-gas properties of nitrogen, N_2 (Concluded)

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
1900	13,742	9,968	54.896	3500	27,016	20,065	59.944
1940	14,058	10,205	55.061	3540	27,359	20,329	60.041
1980	14,375	10,443	55.223	3580	27,703	20,593	60.138
2020	14,694	10,682	55.383	3620	28,046	20,858	60.234
2060	15,013	10,923	55.540	3660	28,391	21,122	60.328
2100	15,334	11,164	55.694	3700	28,735	21,387	60.422
2140	15,656	11,406	55.846	3740	29,080	21,653	60.515
2180	15,978	11,649	55.995	3780	29,425	21,919	60.607
2220	16,302	11,893	56.141	3820	29,771	22,185	60.698
2260	16,626	12,138	56.286	3860	30,117	22,451	60.788
2300	16,951	12,384	56.429	3900	30,463	22,718	60.877
2340	17,277	12,630	56.570	3940	30,809	22,985	60.966
2380	17,604	12,878	56.708	3980	31,156	23,252	61.053
2420	17,932	13,126	56.845	4020	31,503	23,520	61.139
2460	18,260	13,375	56.980	4060	31,850	23,788	61.225
2500	18,590	13,625	57.112	4100	32,198	24,056	61.310
2540	18,919	13,875	57.243	4140	32,546	24,324	61.395
2580	19,250	14,127	57.372	4180	32,894	24,593	61.479
2620	19,582	14,379	57.499	4220	33,242	24,862	61.562
2660	19,914	14,631	57.625	4260	33,591	25,131	61.644
2700	20,246	14,885	57.750	4300	33,940	25,401	61.726
2740	20,580	15,139	57.872	4340	34,289	25,670	61.806
2780	20,914	15,393	57.993	4380	34,638	25,940	61.887
2820	21,248	15,648	58.113	4420	34,988	26,210	61.966
2860	21,584	15,905	58.231	4460	35,338	26,481	62.045
2900	21,920	16,161	58.348	4500	35,688	26,751	62.123
2940	22,256	16,417	58.463	4540	36,038	27,022	62.201
2980	22,593	16,675	58.576	4580	36,389	27,293	62.278
3020	22,930	16,933	58.688	4620	36,739	27,565	62.354
3060	23,268	17,192	58.800	4660	37,090	27,836	62.429
3100	23,607	17,451	58.910	4700	37,441	28,108	62.504
3140	23,946	17,710	59.019	4740	37,792	28,379	62.578
3180	24,285	17,970	59.126	4780	38,144	28,651	62.652
3220	24,625	18,231	59.232	4820	38,495	28,924	62.725
3260	24,965	18,491	59.338	4860	38,847	29,196	62.798
3300	25,306	18,753	59.442	4900	39,199	29,468	62.870
3340	25,647	19,014	59.544	5000	40,080	30,151	63.049
3380	25,989	19,277	59.646	5100	40,962	30,834	63.223
3420	26,331	19,539	59.747	5200	41,844	31,518	63.395
3460	26,673	19,802	59.846	5300	42,728	32,203	63.563

Source of Data: Tables A-18E through A-23E are adapted from Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 834–44. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1945).

TABLE A-19E

Ideal-gas properties of oxygen, O_2

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,073.5	1,477.8	44.927	1080	7,696.8	5,552.1	54.064
320	2,212.6	1,577.1	45.375	1100	7,850.4	5,665.9	54.204
340	2,351.7	1,676.5	45.797	1120	8,004.5	5,780.3	54.343
360	2,490.8	1,775.9	46.195	1140	8,159.1	5,895.2	54.480
380	2,630.0	1,875.3	46.571	1160	8,314.2	6,010.6	54.614
400	2,769.1	1,974.8	46.927	1180	8,469.8	6,126.5	54.748
420	2,908.3	2,074.3	47.267	1200	8,625.8	6,242.8	54.879
440	3,047.5	2,173.8	47.591	1220	8,782.4	6,359.6	55.008
460	3,186.9	2,273.4	47.900	1240	8,939.4	6,476.9	55.136
480	3,326.5	2,373.3	48.198	1260	9,096.7	6,594.5	55.262
500	3,466.2	2,473.2	48.483	1280	9,254.6	6,712.7	55.386
520	3,606.1	2,573.4	48.757	1300	9,412.9	6,831.3	55.508
537	3,725.1	2,658.7	48.982	1320	9,571.9	6,950.2	55.630
540	3,746.2	2,673.8	49.021	1340	9,730.7	7,069.6	55.750
560	3,886.6	2,774.5	49.276	1360	9,890.2	7,189.4	55.867
580	4,027.3	2,875.5	49.522	1380	10,050.1	7,309.6	55.984
600	4,168.3	2,976.8	49.762	1400	10,210.4	7,430.1	56.099
620	4,309.7	3,078.4	49.993	1420	10,371.0	7,551.1	56.213
640	4,451.4	3,180.4	50.218	1440	10,532.0	7,672.4	56.326
660	4,593.5	3,282.9	50.437	1460	10,693.3	7,793.9	56.437
680	4,736.2	3,385.8	50.650	1480	10,855.1	7,916.0	56.547
700	4,879.3	3,489.2	50.858	1500	11,017.1	8,038.3	56.656
720	5,022.9	3,593.1	51.059	1520	11,179.6	8,161.1	56.763
740	5,167.0	3,697.4	51.257	1540	11,342.4	8,284.2	56.869
760	5,311.4	3,802.4	51.450	1560	11,505.4	8,407.4	56.975
780	5,456.4	3,907.5	51.638	1580	11,668.8	8,531.1	57.079
800	5,602.0	4,013.3	51.821	1600	11,832.5	8,655.1	57.182
820	5,748.1	4,119.7	52.002	1620	11,996.6	8,779.5	57.284
840	5,894.8	4,226.6	52.179	1640	12,160.9	8,904.1	57.385
860	6,041.9	4,334.1	52.352	1660	12,325.5	9,029.0	57.484
880	6,189.6	4,442.0	52.522	1680	12,490.4	9,154.1	57.582
900	6,337.9	4,550.6	52.688	1700	12,655.6	9,279.6	57.680
920	6,486.7	4,659.7	52.852	1720	12,821.1	9,405.4	57.777
940	6,636.1	4,769.4	53.012	1740	12,986.9	9,531.5	57.873
960	6,786.0	4,879.5	53.170	1760	13,153.0	9,657.9	57.968
980	6,936.4	4,990.3	53.326	1780	13,319.2	9,784.4	58.062
1000	7,087.5	5,101.6	53.477	1800	13,485.8	9,911.2	58.155
1020	7,238.9	5,213.3	53.628	1820	13,652.5	10,038.2	58.247
1040	7,391.0	5,325.7	53.775	1840	13,819.6	10,165.6	58.339
1060	7,543.6	5,438.6	53.921	1860	13,986.8	10,293.1	58.428

TABLE A-19E

Ideal-gas properties of oxygen, O_2 (Concluded)

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
1900	14,322	10,549	58.607	3500	28,273	21,323	63.914
1940	14,658	10,806	58.782	3540	28,633	21,603	64.016
1980	14,995	11,063	58.954	3580	28,994	21,884	64.114
2020	15,333	11,321	59.123	3620	29,354	22,165	64.217
2060	15,672	11,581	59.289	3660	29,716	22,447	64.316
2100	16,011	11,841	59.451	3700	30,078	22,730	64.415
2140	16,351	12,101	59.612	3740	30,440	23,013	64.512
2180	16,692	12,363	59.770	3780	30,803	23,296	64.609
2220	17,036	12,625	59.926	3820	31,166	23,580	64.704
2260	17,376	12,888	60.077	3860	31,529	23,864	64.800
2300	17,719	13,151	60.228	3900	31,894	24,149	64.893
2340	18,062	13,416	60.376	3940	32,258	24,434	64.986
2380	18,407	13,680	60.522	3980	32,623	24,720	65.078
2420	18,572	13,946	60.666	4020	32,989	25,006	65.169
2460	19,097	14,212	60.808	4060	33,355	25,292	65.260
2500	19,443	14,479	60.946	4100	33,722	25,580	65.350
2540	19,790	14,746	61.084	4140	34,089	25,867	64.439
2580	20,138	15,014	61.220	4180	34,456	26,155	65.527
2620	20,485	15,282	61.354	4220	34,824	26,144	65.615
2660	20,834	15,551	61.486	4260	35,192	26,733	65.702
2700	21,183	15,821	61.616	4300	35,561	27,022	65.788
2740	21,533	16,091	61.744	4340	35,930	27,312	65.873
2780	21,883	16,362	61.871	4380	36,300	27,602	65.958
2820	22,232	16,633	61.996	4420	36,670	27,823	66.042
2860	22,584	16,905	62.120	4460	37,041	28,184	66.125
2900	22,936	17,177	62.242	4500	37,412	28,475	66.208
2940	23,288	17,450	62.363	4540	37,783	28,768	66.290
2980	23,641	17,723	62.483	4580	38,155	29,060	66.372
3020	23,994	17,997	62.599	4620	38,528	29,353	66.453
3060	24,348	18,271	62.716	4660	38,900	29,646	66.533
3100	24,703	18,546	62.831	4700	39,274	29,940	66.613
3140	25,057	18,822	62.945	4740	39,647	30,234	66.691
3180	25,413	19,098	63.057	4780	40,021	30,529	66.770
3220	25,769	19,374	63.169	4820	40,396	30,824	66.848
3260	26,175	19,651	63.279	4860	40,771	31,120	66.925
3300	26,412	19,928	63.386	4900	41,146	31,415	67.003
3340	26,839	20,206	63.494	5000	42,086	32,157	67.193
3380	27,197	20,485	63.601	5100	43,021	32,901	67.380
3420	27,555	20,763	63.706	5200	43,974	33,648	67.562
3460	27,914	21,043	63.811	5300	44,922	34,397	67.743

TABLE A-20E

Ideal-gas properties of carbon dioxide, CO₂

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,108.2	1,512.4	46.353	1080	9,575.8	7,431.1	58.072
320	2,256.6	1,621.1	46.832	1100	9,802.6	7,618.1	58.281
340	2,407.3	1,732.1	47.289	1120	10,030.6	7,806.4	58.485
360	2,560.5	1,845.6	47.728	1140	10,260.1	7,996.2	58.689
380	2,716.4	1,961.8	48.148	1160	10,490.6	8,187.0	58.889
400	2,874.7	2,080.4	48.555	1180	10,722.3	8,379.0	59.088
420	3,035.7	2,201.7	48.947	1200	10,955.3	8,572.3	59.283
440	3,199.4	2,325.6	49.329	1220	11,189.4	8,766.6	59.477
460	3,365.7	2,452.2	49.698	1240	11,424.6	8,962.1	59.668
480	3,534.7	2,581.5	50.058	1260	11,661.0	9,158.8	59.858
500	3,706.2	2,713.3	50.408	1280	11,898.4	9,356.5	60.044
520	3,880.3	2,847.7	50.750	1300	12,136.9	9,555.3	60.229
537	4,027.5	2,963.8	51.032	1320	12,376.4	9,755.0	60.412
540	4,056.8	2,984.4	51.082	1340	12,617.0	9,955.9	60.593
560	4,235.8	3,123.7	51.408	1360	12,858.5	10,157.7	60.772
580	4,417.2	3,265.4	51.726	1380	13,101.0	10,360.5	60.949
600	4,600.9	3,409.4	52.038	1400	13,344.7	10,564.5	61.124
620	4,786.6	3,555.6	52.343	1420	13,589.1	10,769.2	61.298
640	4,974.9	3,704.0	52.641	1440	13,834.5	10,974.8	61.469
660	5,165.2	3,854.6	52.934	1460	14,080.8	11,181.4	61.639
680	5,357.6	4,007.2	53.225	1480	14,328.0	11,388.9	61.800
700	5,552.0	4,161.9	53.503	1500	14,576.0	11,597.2	61.974
720	5,748.4	4,318.6	53.780	1520	14,824.9	11,806.4	62.138
740	5,946.8	4,477.3	54.051	1540	15,074.7	12,016.5	62.302
760	6,147.0	4,637.9	54.319	1560	15,325.3	12,227.3	62.464
780	6,349.1	4,800.1	54.582	1580	15,576.7	12,439.0	62.624
800	6,552.9	4,964.2	54.839	1600	15,829.0	12,651.6	62.783
820	6,758.3	5,129.9	55.093	1620	16,081.9	12,864.8	62.939
840	6,965.7	5,297.6	55.343	1640	16,335.7	13,078.9	63.095
860	7,174.7	5,466.9	55.589	1660	16,590.2	13,293.7	63.250
880	7,385.3	5,637.7	55.831	1680	16,845.5	13,509.2	63.403
900	7,597.6	5,810.3	56.070	1700	17,101.4	13,725.4	63.555
920	7,811.4	5,984.4	56.305	1720	17,358.1	13,942.4	63.704
940	8,026.8	6,160.1	56.536	1740	17,615.5	14,160.1	63.853
960	8,243.8	6,337.4	56.765	1760	17,873.5	14,378.4	64.001
980	8,462.2	6,516.1	56.990	1780	18,132.2	14,597.4	64.147
1000	8,682.1	6,696.2	57.212	1800	18,391.5	14,816.9	64.292
1020	8,903.4	6,877.8	57.432	1820	18,651.5	15,037.2	64.435
1040	9,126.2	7,060.9	57.647	1840	18,912.2	15,258.2	64.578
1060	9,350.3	7,245.3	57.861	1860	19,173.4	15,479.7	64.719

TABLE A-20E

Ideal-gas properties of carbon dioxide, CO₂ (Concluded)

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
1900	19,698	15,925	64.999	3500	41,965	35,015	73.462
1940	20,224	16,372	65.272	3540	42,543	35,513	73.627
1980	20,753	16,821	65.543	3580	43,121	36,012	73.789
2020	21,284	17,273	65.809	3620	43,701	36,512	73.951
2060	21,818	17,727	66.069	3660	44,280	37,012	74.110
2100	22,353	18,182	66.327	3700	44,861	37,513	74.267
2140	22,890	18,640	66.581	3740	45,442	38,014	74.423
2180	23,429	19,101	66.830	3780	46,023	38,517	74.578
2220	23,970	19,561	67.076	3820	46,605	39,019	74.732
2260	24,512	20,024	67.319	3860	47,188	39,522	74.884
2300	25,056	20,489	67.557	3900	47,771	40,026	75.033
2340	25,602	20,955	67.792	3940	48,355	40,531	75.182
2380	26,150	21,423	68.025	3980	48,939	41,035	75.330
2420	26,699	21,893	68.253	4020	49,524	41,541	75.477
2460	27,249	22,364	68.479	4060	50,109	42,047	75.622
2500	27,801	22,837	68.702	4100	50,695	42,553	75.765
2540	28,355	23,310	68.921	4140	51,282	43,060	75.907
2580	28,910	23,786	69.138	4180	51,868	43,568	76.048
2620	29,465	24,262	69.352	4220	52,456	44,075	76.188
2660	30,023	24,740	69.563	4260	53,044	44,584	76.327
2700	30,581	25,220	69.771	4300	53,632	45,093	76.464
2740	31,141	25,701	69.977	4340	54,221	45,602	76.601
2780	31,702	26,181	70.181	4380	54,810	46,112	76.736
2820	32,264	26,664	70.382	4420	55,400	46,622	76.870
2860	32,827	27,148	70.580	4460	55,990	47,133	77.003
2900	33,392	27,633	70.776	4500	56,581	47,645	77.135
2940	33,957	28,118	70.970	4540	57,172	48,156	77.266
2980	34,523	28,605	71.160	4580	57,764	48,668	77.395
3020	35,090	29,093	71.350	4620	58,356	49,181	77.581
3060	35,659	29,582	71.537	4660	58,948	49,694	77.652
3100	36,228	30,072	71.722	4700	59,541	50,208	77.779
3140	36,798	30,562	71.904	4740	60,134	50,721	77.905
3180	37,369	31,054	72.085	4780	60,728	51,236	78.029
3220	37,941	31,546	72.264	4820	61,322	51,750	78.153
3260	38,513	32,039	72.441	4860	61,916	52,265	78.276
3300	39,087	32,533	72.616	4900	62,511	52,781	78.398
3340	39,661	33,028	72.788	5000	64,000	54,071	78.698
3380	40,236	33,524	72.960	5100	65,491	55,363	78.994
3420	40,812	34,020	73.129	5200	66,984	56,658	79.284
3460	41,388	34,517	73.297	5300	68,471	57,954	79.569

TABLE A-21E

Ideal-gas properties of carbon monoxide, CO

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,081.9	1,486.1	43.223	1080	7,571.1	5,426.4	52.203
320	2,220.9	1,585.4	43.672	1100	7,716.8	5,532.3	52.337
340	2,359.9	1,684.7	44.093	1120	7,862.9	5,638.7	52.468
360	2,498.8	1,783.9	44.490	1140	8,009.2	5,745.4	52.598
380	2,637.9	1,883.3	44.866	1160	8,156.1	5,851.5	52.726
400	2,776.9	1,982.6	45.223	1180	8,303.3	5,960.0	52.852
420	2,916.0	2,081.9	45.563	1200	8,450.8	6,067.8	52.976
440	3,055.0	2,181.2	45.886	1220	8,598.8	6,176.0	53.098
460	3,194.0	2,280.5	46.194	1240	8,747.2	6,284.7	53.218
480	3,333.0	2,379.8	46.491	1260	8,896.0	6,393.8	53.337
500	3,472.1	2,479.2	46.775	1280	9,045.0	6,503.1	53.455
520	3,611.2	2,578.6	47.048	1300	9,194.6	6,613.0	53.571
537	3,725.1	2,663.1	47.272	1320	9,344.6	6,723.2	53.685
540	3,750.3	2,677.9	47.310	1340	9,494.8	6,833.7	53.799
560	3,889.5	2,777.4	47.563	1360	9,645.5	6,944.7	53.910
580	4,028.7	2,876.9	47.807	1380	9,796.6	7,056.1	54.021
600	4,168.0	2,976.5	48.044	1400	9,948.1	7,167.9	54.129
620	4,307.4	3,076.2	48.272	1420	10,100.0	7,280.1	54.237
640	4,446.9	3,175.9	48.494	1440	10,252.2	7,392.6	54.344
660	4,586.6	3,275.8	48.709	1460	10,404.8	7,505.4	54.448
680	4,726.2	3,375.8	48.917	1480	10,557.8	7,618.7	54.522
700	4,886.0	3,475.9	49.120	1500	10,711.1	7,732.3	54.665
720	5,006.1	3,576.3	49.317	1520	10,864.9	7,846.4	54.757
740	5,146.4	3,676.9	49.509	1540	11,019.0	7,960.8	54.858
760	5,286.8	3,777.5	49.697	1560	11,173.4	8,075.4	54.958
780	5,427.4	3,878.4	49.880	1580	11,328.2	8,190.5	55.056
800	5,568.2	3,979.5	50.058	1600	11,483.4	8,306.0	55.154
820	5,709.4	4,081.0	50.232	1620	11,638.9	8,421.8	55.251
840	5,850.7	4,182.6	50.402	1640	11,794.7	8,537.9	55.347
860	5,992.3	4,284.5	50.569	1660	11,950.9	8,654.4	55.411
880	6,134.2	4,386.6	50.732	1680	12,107.5	8,771.2	55.535
900	6,276.4	4,489.1	50.892	1700	12,264.3	8,888.3	55.628
920	6,419.0	4,592.0	51.048	1720	12,421.4	9,005.7	55.720
940	6,561.7	4,695.0	51.202	1740	12,579.0	9,123.6	55.811
960	6,704.9	4,798.5	51.353	1760	12,736.7	9,241.6	55.900
980	6,848.4	4,902.3	51.501	1780	12,894.9	9,360.0	55.990
1000	6,992.2	5,006.3	51.646	1800	13,053.2	9,478.6	56.078
1020	7,136.4	5,110.8	51.788	1820	13,212.0	9,597.7	56.166
1040	7,281.0	5,215.7	51.929	1840	13,371.0	9,717.0	56.253
1060	7,425.9	5,320.9	52.067	1860	13,530.2	9,836.5	56.339

TABLE A-21E

Ideal-gas properties of carbon monoxide, CO (*Concluded*)

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
1900	13,850	10,077	56.509	3500	27,262	20,311	61.612
1940	14,170	10,318	56.677	3540	27,608	20,576	61.710
1980	14,492	10,560	56.841	3580	27,954	20,844	61.807
2020	14,815	10,803	57.007	3620	28,300	21,111	61.903
2060	15,139	11,048	57.161	3660	28,647	21,378	61.998
2100	15,463	11,293	57.317	3700	28,994	21,646	62.093
2140	15,789	11,539	57.470	3740	29,341	21,914	62.186
2180	16,116	11,787	57.621	3780	29,688	22,182	62.279
2220	16,443	12,035	57.770	3820	30,036	22,450	62.370
2260	16,722	12,284	57.917	3860	30,384	22,719	62.461
2300	17,101	12,534	58.062	3900	30,733	22,988	62.511
2340	17,431	12,784	58.204	3940	31,082	23,257	62.640
2380	17,762	13,035	58.344	3980	31,431	23,527	62.728
2420	18,093	13,287	58.482	4020	31,780	23,797	62.816
2460	18,426	13,541	58.619	4060	32,129	24,067	62.902
2500	18,759	13,794	58.754	4100	32,479	24,337	62.988
2540	19,093	14,048	58.885	4140	32,829	24,608	63.072
2580	19,427	14,303	59.016	4180	33,179	24,878	63.156
2620	19,762	14,559	59.145	4220	33,530	25,149	63.240
2660	20,098	14,815	59.272	4260	33,880	25,421	63.323
2700	20,434	15,072	59.398	4300	34,231	25,692	63.405
2740	20,771	15,330	59.521	4340	34,582	25,934	63.486
2780	21,108	15,588	59.644	4380	34,934	26,235	63.567
2820	21,446	15,846	59.765	4420	35,285	26,508	63.647
2860	21,785	16,105	59.884	4460	35,637	26,780	63.726
2900	22,124	16,365	60.002	4500	35,989	27,052	63.805
2940	22,463	16,625	60.118	4540	36,341	27,325	63.883
2980	22,803	16,885	60.232	4580	36,693	27,598	63.960
3020	23,144	17,146	60.346	4620	37,046	27,871	64.036
3060	23,485	17,408	60.458	4660	37,398	28,144	64.113
3100	23,826	17,670	60.569	4700	37,751	28,417	64.188
3140	24,168	17,932	60.679	4740	38,104	28,691	64.263
3180	24,510	18,195	60.787	4780	38,457	28,965	64.337
3220	24,853	18,458	60.894	4820	38,811	29,239	64.411
3260	25,196	18,722	61.000	4860	39,164	29,513	64.484
3300	25,539	18,986	61.105	4900	39,518	29,787	64.556
3340	25,883	19,250	61.209	5000	40,403	30,473	64.735
3380	26,227	19,515	61.311	5100	41,289	31,161	64.910
3420	26,572	19,780	61.412	5200	42,176	31,849	65.082
3460	26,917	20,045	61.513	5300	43,063	32,538	65.252

TABLE A-22E

Ideal-gas properties of hydrogen, H_2

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,063.5	1,467.7	27.337	1400	9,673.8	6,893.6	37.883
320	2,189.4	1,553.9	27.742	1500	10,381.5	7,402.7	38.372
340	2,317.2	1,642.0	28.130	1600	11,092.5	7,915.1	38.830
360	2,446.8	1,731.9	28.501	1700	11,807.4	8,431.4	39.264
380	2,577.8	1,823.2	28.856	1800	12,526.8	8,952.2	39.675
400	2,710.2	1,915.8	29.195	1900	13,250.9	9,477.8	40.067
420	2,843.7	2,009.6	29.520	2000	13,980.1	10,008.4	40.441
440	2,978.1	2,104.3	29.833	2100	14,714.5	10,544.2	40.799
460	3,113.5	2,200.0	30.133	2200	15,454.4	11,085.5	41.143
480	3,249.4	2,296.2	30.424	2300	16,199.8	11,632.3	41.475
500	3,386.1	2,393.2	30.703	2400	16,950.6	12,184.5	41.794
520	3,523.2	2,490.6	30.972	2500	17,707.3	12,742.6	42.104
537	3,640.3	2,573.9	31.194	2600	18,469.7	13,306.4	42.403
540	3,660.9	2,588.5	31.232	2700	19,237.8	13,876.0	42.692
560	3,798.8	2,686.7	31.482	2800	20,011.8	14,451.4	42.973
580	3,937.1	2,785.3	31.724	2900	20,791.5	15,032.5	43.247
600	4,075.6	2,884.1	31.959	3000	21,576.9	15,619.3	43.514
620	4,214.3	2,983.1	32.187	3100	22,367.7	16,211.5	43.773
640	4,353.1	3,082.1	32.407	3200	23,164.1	16,809.3	44.026
660	4,492.1	3,181.4	32.621	3300	23,965.5	17,412.1	44.273
680	4,631.1	3,280.7	32.829	3400	24,771.9	18,019.9	44.513
700	4,770.2	3,380.1	33.031	3500	25,582.9	18,632.4	44.748
720	4,909.5	3,479.6	33.226	3600	26,398.5	19,249.4	44.978
740	5,048.8	3,579.2	33.417	3700	27,218.5	19,870.8	45.203
760	5,188.1	3,678.8	33.603	3800	28,042.8	20,496.5	45.423
780	5,327.6	3,778.6	33.784	3900	28,871.1	21,126.2	45.638
800	5,467.1	3,878.4	33.961	4000	29,703.5	21,760.0	45.849
820	5,606.7	3,978.3	34.134	4100	30,539.8	22,397.7	46.056
840	5,746.3	4,078.2	34.302	4200	31,379.8	23,039.2	46.257
860	5,885.9	4,178.0	34.466	4300	32,223.5	23,684.3	46.456
880	6,025.6	4,278.0	34.627	4400	33,070.9	24,333.1	46.651
900	6,165.3	4,378.0	34.784	4500	33,921.6	24,985.2	46.842
920	6,305.1	4,478.1	34.938	4600	34,775.7	25,640.7	47.030
940	6,444.9	4,578.1	35.087	4700	35,633.0	26,299.4	47.215
960	6,584.7	4,678.3	35.235	4800	36,493.4	26,961.2	47.396
980	6,724.6	4,778.4	35.379	4900	35,356.9	27,626.1	47.574
1000	6,864.5	4,878.6	35.520	5000	38,223.3	28,294.0	47.749
1100	7,564.6	5,380.1	36.188	5100	39,092.8	28,964.9	47.921
1200	8,265.8	5,882.8	36.798	5200	39,965.1	29,638.6	48.090
1300	8,968.7	6,387.1	37.360	5300	40,840.2	30,315.1	48.257

TABLE A-23E

Ideal-gas properties of water vapor, H₂O

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
300	2,367.6	1,771.8	40.439	1080	8,768.2	6,623.5	50.854
320	2,526.8	1,891.3	40.952	1100	8,942.0	6,757.5	51.013
340	2,686.0	2,010.8	41.435	1120	9,116.4	6,892.2	51.171
360	2,845.1	2,130.2	41.889	1140	9,291.4	7,027.5	51.325
380	3,004.4	2,249.8	42.320	1160	9,467.1	7,163.5	51.478
400	3,163.8	2,369.4	42.728	1180	9,643.4	7,300.1	51.360
420	3,323.2	2,489.1	43.117	1200	9,820.4	7,437.4	51.777
440	3,482.7	2,608.9	43.487	1220	9,998.0	7,575.2	51.925
460	3,642.3	2,728.8	43.841	1240	10,176.1	7,713.6	52.070
480	3,802.0	2,848.8	44.182	1260	10,354.9	7,852.7	52.212
500	3,962.0	2,969.1	44.508	1280	10,534.4	7,992.5	52.354
520	4,122.0	3,089.4	44.821	1300	10,714.5	8,132.9	52.494
537	4,258.0	3,191.9	45.079	1320	10,895.3	8,274.0	52.631
540	4,282.4	3,210.0	45.124	1340	11,076.6	8,415.5	52.768
560	4,442.8	3,330.7	45.415	1360	11,258.7	8,557.9	52.903
580	4,603.7	3,451.9	45.696	1380	11,441.4	8,700.9	53.037
600	4,764.7	3,573.2	45.970	1400	11,624.8	8,844.6	53.168
620	4,926.1	3,694.9	46.235	1420	11,808.8	8,988.9	53.299
640	5,087.8	3,816.8	46.492	1440	11,993.4	9,133.8	53.428
660	5,250.0	3,939.3	46.741	1460	12,178.8	9,279.4	53.556
680	5,412.5	4,062.1	46.984	1480	12,364.8	9,425.7	53.682
700	5,575.4	4,185.3	47.219	1500	12,551.4	9,572.7	53.808
720	5,738.8	4,309.0	47.450	1520	12,738.8	9,720.3	53.932
740	5,902.6	4,433.1	47.673	1540	12,926.8	9,868.6	54.055
760	6,066.9	4,557.6	47.893	1560	13,115.6	10,017.6	54.117
780	6,231.7	4,682.7	48.106	1580	13,305.0	10,167.3	54.298
800	6,396.9	4,808.2	48.316	1600	13,494.4	10,317.6	54.418
820	6,562.6	4,934.2	48.520	1620	13,685.7	10,468.6	54.535
840	6,728.9	5,060.8	48.721	1640	13,877.0	10,620.2	54.653
860	6,895.6	5,187.8	48.916	1660	14,069.2	10,772.7	54.770
880	7,062.9	5,315.3	49.109	1680	14,261.9	10,925.6	54.886
900	7,230.9	5,443.6	49.298	1700	14,455.4	11,079.4	54.999
920	7,399.4	5,572.4	49.483	1720	14,649.5	11,233.8	55.113
940	7,568.4	5,701.7	49.665	1740	14,844.3	11,388.9	55.226
960	7,738.0	5,831.6	49.843	1760	15,039.8	11,544.7	55.339
980	7,908.2	5,962.0	50.019	1780	15,236.1	11,701.2	55.449
1000	8,078.2	6,093.0	50.191	1800	15,433.0	11,858.4	55.559
1020	8,250.4	6,224.8	50.360	1820	15,630.6	12,016.3	55.668
1040	8,422.4	6,357.1	50.528	1840	15,828.7	12,174.7	55.777
1060	8,595.0	6,490.0	50.693	1860	16,027.6	12,333.9	55.884

TABLE A-23E

Ideal-gas properties of water vapor, H_2O (Continued)

T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R	T R	$\bar{h}$ Btu/lbmol	$\bar{u}$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
1900	16,428	12,654	56.097	3500	34,324	27,373	62.876
1940	16,830	12,977	56.307	3540	34,809	27,779	63.015
1980	17,235	13,303	56.514	3580	35,296	28,187	63.153
2020	17,643	13,632	56.719	3620	35,785	28,596	63.288
2060	18,054	13,963	56.920	3660	36,274	29,006	63.423
2100	18,467	14,297	57.119	3700	36,765	29,418	63.557
2140	18,883	14,633	57.315	3740	37,258	29,831	63.690
2180	19,301	14,972	57.509	3780	37,752	30,245	63.821
2220	19,722	15,313	57.701	3820	38,247	30,661	63.952
2260	20,145	15,657	57.889	3860	38,743	31,077	64.082
2300	20,571	16,003	58.077	3900	39,240	31,495	64.210
2340	20,999	16,352	58.261	3940	39,739	31,915	64.338
2380	21,429	16,703	58.445	3980	40,239	32,335	64.465
2420	21,862	17,057	58.625	4020	40,740	32,757	64.591
2460	22,298	17,413	58.803	4060	41,242	33,179	64.715
2500	22,735	17,771	58.980	4100	41,745	33,603	64.839
2540	23,175	18,131	59.155	4140	42,250	34,028	64.962
2580	23,618	18,494	59.328	4180	42,755	34,454	65.084
2620	24,062	18,859	59.500	4220	43,267	34,881	65.204
2660	24,508	19,226	59.669	4260	43,769	35,310	65.325
2700	24,957	19,595	59.837	4300	44,278	35,739	65.444
2740	25,408	19,967	60.003	4340	44,788	36,169	65.563
2780	25,861	20,340	60.167	4380	45,298	36,600	65.680
2820	26,316	20,715	60.330	4420	45,810	37,032	65.797
2860	26,773	21,093	60.490	4460	46,322	37,465	65.913
2900	27,231	21,472	60.650	4500	46,836	37,900	66.028
2940	27,692	21,853	60.809	4540	47,350	38,334	66.142
2980	28,154	22,237	60.965	4580	47,866	38,770	66.255
3020	28,619	22,621	61.120	4620	48,382	39,207	66.368
3060	29,085	23,085	61.274	4660	48,899	39,645	66.480
3100	29,553	23,397	61.426	4700	49,417	40,083	66.591
3140	30,023	23,787	61.577	4740	49,936	40,523	66.701
3180	30,494	24,179	61.727	4780	50,455	40,963	66.811
3220	30,967	24,572	61.874	4820	50,976	41,404	66.920
3260	31,442	24,968	62.022	4860	51,497	41,856	67.028
3300	31,918	25,365	62.167	4900	52,019	42,288	67.135
3340	32,396	25,763	62.312	5000	53,327	43,398	67.401
3380	32,876	26,164	62.454	5100	54,640	44,512	67.662
3420	33,357	26,565	62.597	5200	55,957	45,631	67.918
3460	33,839	26,968	62.738	5300	57,279	46,754	68.172

TABLE A-26E

Enthalpy of formation, Gibbs function of formation, and absolute entropy at 77°F, 1 atm

Substance	Formula	$\bar{h}_f^\circ$ Btu/lbmol	$\bar{g}_f^\circ$ Btu/lbmol	$\bar{s}^\circ$ Btu/lbmol·R
Carbon	C(s)	0	0	1.36
Hydrogen	H ₂ (g)	0	0	31.21
Nitrogen	N ₂ (g)	0	0	45.77
Oxygen	O ₂ (g)	0	0	49.00
Carbon monoxide	CO(g)	-47,540	-59,010	47.21
Carbon dioxide	CO ₂ (g)	-169,300	-169,680	51.07
Water vapor	H ₂ O(g)	-104,040	-98,350	45.11
Water	H ₂ O(l)	-122,970	-102,040	16.71
Hydrogen peroxide	H ₂ O ₂ (g)	-58,640	-45,430	55.60
Ammonia	NH ₃ (g)	-19,750	-7,140	45.97
Methane	CH ₄ (g)	-32,210	-21,860	44.49
Acetylene	C ₂ H ₂ (g)	+97,540	+87,990	48.00
Ethylene	C ₂ H ₄ (g)	+22,490	+29,306	52.54
Ethane	C ₂ H ₆ (g)	-36,420	-14,150	54.85
Propylene	C ₃ H ₆ (g)	+8,790	+26,980	63.80
Propane	C ₃ H ₈ (g)	-44,680	-10,105	64.51
n-Butane	C ₄ H ₁₀ (g)	-54,270	-6,760	74.11
n-Octane	C ₈ H ₁₈ (g)	-89,680	+7,110	111.55
n-Octane	C ₈ H ₁₈ (l)	-107,530	+2,840	86.23
n-Dodecane	C ₁₂ H ₂₆ (g)	-125,190	+21,570	148.86
Benzene	C ₆ H ₆ (g)	+35,680	+55,780	64.34
Methyl alcohol	CH ₃ OH(g)	-86,540	-69,700	57.29
Methyl alcohol	CH ₃ OH(l)	-102,670	-71,570	30.30
Ethyl alcohol	C ₂ H ₅ OH(g)	-101,230	-72,520	67.54
Ethyl alcohol	C ₂ H ₅ OH(l)	-119,470	-75,240	38.40
Oxygen	O(g)	+107,210	+99,710	38.47
Hydrogen	H(g)	+93,780	+87,460	27.39
Nitrogen	N(g)	+203,340	+195,970	36.61
Hydroxyl	OH(g)	+16,790	+14,750	43.92

Source of Data: From JANAF, *Thermochemical Tables* (Midland, MI: Dow Chemical Co., 1971), *Selected Values of Chemical Thermodynamic Properties*, NBS Technical Note 270-3, 1968; and *API Research Project 44* (Carnegie Press, 1953).

TABLE A-27E

Properties of some common fuels and hydrocarbons

Fuel (phase)	Formula	Molar mass, lbm/lbmol	Density, ¹ lbm/ft ³	Enthalpy of vaporization, ² Btu/lbm	Specific heat, ¹ c_p , Btu/lbm·°F	Higher heating value, ³ Btu/lbm	Lower heating value, ³ Btu/lbm
Carbon (s)	C	12.011	125	—	0.169	14,100	14,100
Hydrogen (g)	H ₂	2.016	—	—	3.44	60,970	51,600
Carbon monoxide (g)	CO	28.013	—	—	0.251	4,340	4,340
Methane (g)	CH ₄	16.043	—	219	0.525	23,880	21,520
Methanol (ℓ)	CH ₄ O	32.042	49.3	502	0.604	9,740	8,570
Acetylene (g)	C ₂ H ₂	26.038	—	—	0.404	21,490	20,760
Ethane (g)	C ₂ H ₆	30.070	—	74	0.418	22,320	20,430
Ethanol (ℓ)	C ₂ H ₆ O	46.069	49.3	395	0.583	12,760	11,530
Propane (ℓ)	C ₃ H ₈	44.097	31.2	144	0.662	21,640	19,930
Butane (ℓ)	C ₄ H ₁₀	58.123	36.1	156	0.578	21,130	19,510
1-Pentene (ℓ)	C ₅ H ₁₀	70.134	40.0	156	0.525	20,540	19,190
Isopentane (ℓ)	C ₅ H ₁₂	72.150	39.1	—	0.554	20,890	19,310
Benzene (ℓ)	C ₆ H ₆	78.114	54.7	186	0.411	17,970	17,240
Hexene (ℓ)	C ₆ H ₁₂	84.161	42.0	169	0.439	20,430	19,090
Hexane (ℓ)	C ₆ H ₁₄	86.177	41.2	157	0.542	20,770	19,240
Toluene (ℓ)	C ₇ H ₈	92.141	54.1	177	0.408	18,230	17,420
Heptane (ℓ)	C ₇ H ₁₆	100.204	42.7	157	0.535	20,680	19,180
Octane (ℓ)	C ₈ H ₁₈	114.231	43.9	156	0.533	20,590	19,100
Decane (ℓ)	C ₁₀ H ₂₂	142.285	45.6	155	0.528	20,490	19,020
Gasoline (ℓ)	C _n H _{1.87n}	100–110	45–49	151	0.57	20,300	18,900
Light diesel (ℓ)	C _n H _{1.8n}	170	49–52	116	0.53	19,800	18,600
Heavy diesel (ℓ)	C _n H _{1.7n}	200	51–55	99	0.45	19,600	18,400
Natural gas (g)	C _n H _{3.8n} N _{0.1n}	18	—	—	0.48	21,500	19,400

¹At 1 atm and 68°F.²At 77°F for liquid fuels, and 1 atm and normal boiling temperature for gaseous fuels.³At 77°F. Multiply by molar mass to obtain heating values in Btu/lbmol.



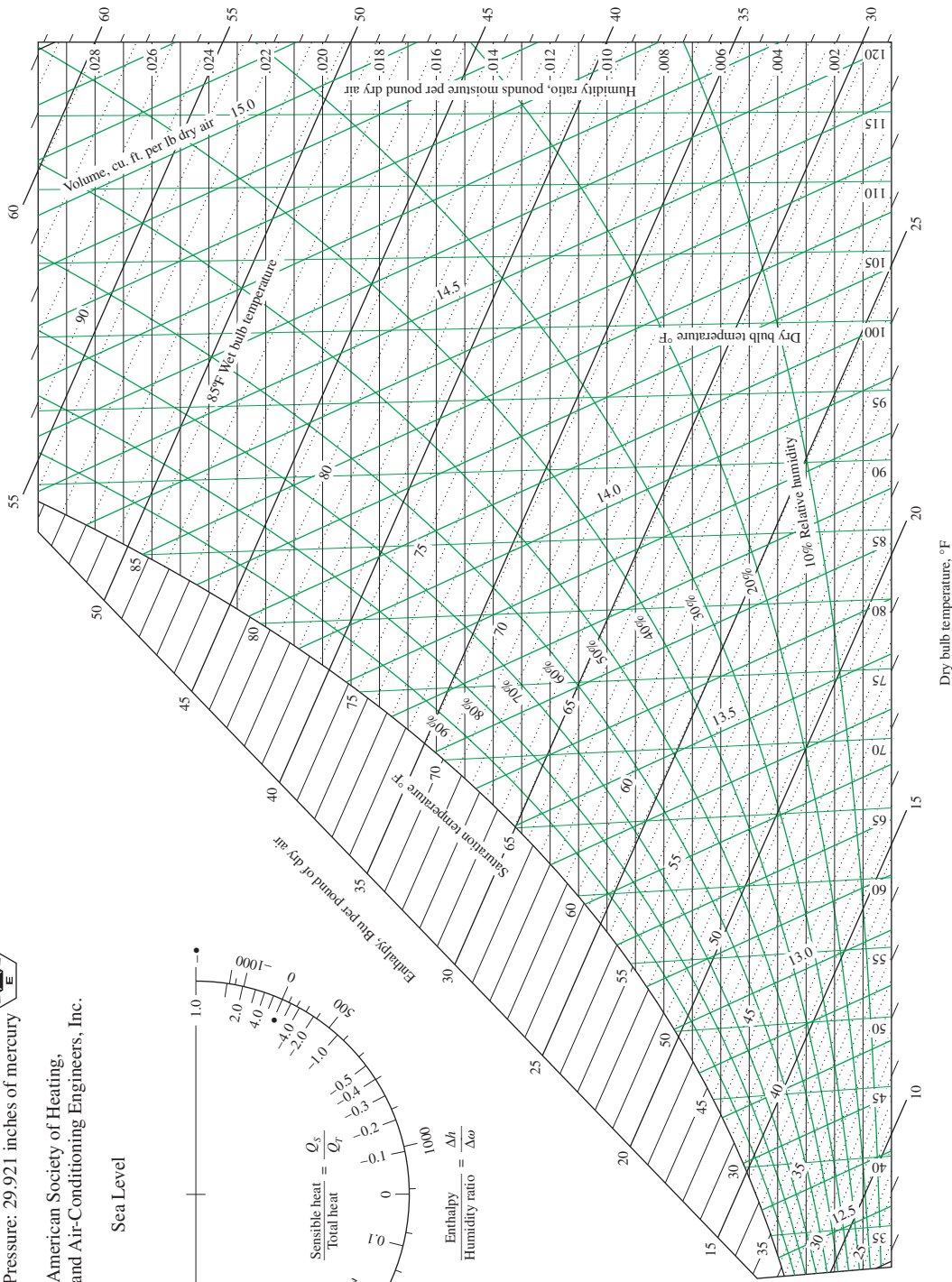
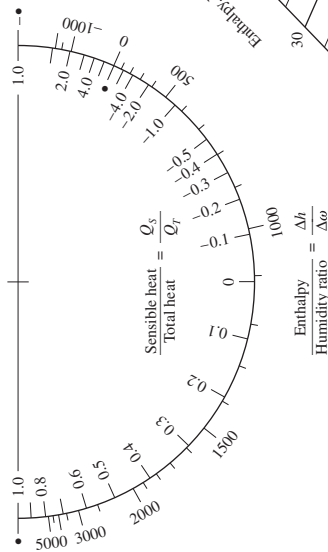
ASHRAE Psychrometric Chart No. 1

Normal Temperature

Barometric Pressure: 29.921 inches of mercury

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Sea Level



Prepared by Center for Applied Thermodynamic Studies, University of Idaho.

FIGURE A-31E

Psychrometric chart at 1 atm total pressure.

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