

## Index to Tables in English Units

TABLE A-1E	Atomic or Molecular Weights and Critical Properties of Selected Elements and Compounds	807
TABLE A-2E	Properties of Saturated Water (Liquid–Vapor): Temperature Table	808
TABLE A-3E	Properties of Saturated Water (Liquid–Vapor): Pressure Table	810
TABLE A-4E	Properties of Superheated Water Vapor	812
TABLE A-5E	Properties of Compressed Liquid Water	818
TABLE A-6E	Properties of Saturated Water (Solid–Vapor): Temperature Table	819
TABLE A-7E	Properties of Saturated Refrigerant 22 (Liquid–Vapor): Temperature Table	820
TABLE A-8E	Properties of Saturated Refrigerant 22 (Liquid–Vapor): Pressure Table	821
TABLE A-9E	Properties of Superheated Refrigerant 22 Vapor	822
TABLE A-10E	Properties of Saturated Refrigerant 134a (Liquid–Vapor): Temperature Table	826
TABLE A-11E	Properties of Saturated Refrigerant 134a (Liquid–Vapor): Pressure Table	827
TABLE A-12E	Properties of Superheated Refrigerant 134a Vapor	828
TABLE A-13E	Properties of Saturated Ammonia (Liquid–Vapor): Temperature Table	831
TABLE A-14E	Properties of Saturated Ammonia (Liquid–Vapor): Pressure Table	832
TABLE A-15E	Properties of Superheated Ammonia Vapor	833
TABLE A-16E	Properties of Saturated Propane (Liquid–Vapor): Temperature Table	837
TABLE A-17E	Properties of Saturated Propane (Liquid–Vapor): Pressure Table	838
TABLE A-18E	Properties of Superheated Propane Vapor	839
TABLE A-19E	Properties of Selected Solids and Liquids: $c_p$ , $\rho$ , and $\kappa$	843
TABLE A-20E	Ideal Gas Specific Heats of Some Common Gases	844
TABLE A-21E	Variation of $\bar{c}_p$ with Temperature for Selected Ideal Gases	845
TABLE A-22E	Ideal Gas Properties of Air	846
TABLE A-23E	Ideal Gas Properties of Selected Gases	848
TABLE A-24E	Constants for the van der Waals, Redlich–Kwong, and Benedict–Webb–Rubin Equations of State	852
TABLE A-25E	Thermochemical Properties of Selected Substances at 537°R and 1 atm.	853

**TABLE A-1E** Atomic or Molecular Weights and Critical Properties of Some Selected Elements and Compounds

Substance	Chemical Formula	$M$ (lb/lbmol)	$T_c$ (°R)	$P_c$ (atm)	$Z_c = \frac{P_c v_c}{RT_c}$
Acetylene	C <sub>2</sub> H <sub>2</sub>	26.04	556	62	0.274
Air (equivalent)	—	28.97	239	37.2	0.284
Ammonia	NH <sub>3</sub>	17.03	730	111.3	0.242
Argon	Ar	39.94	272	47.97	0.290
Benzene	C <sub>6</sub> H <sub>6</sub>	78.11	1013	48.7	0.274
Butane	C <sub>4</sub> H <sub>10</sub>	58.12	765	37.5	0.274
Carbon	C	12.01	—	—	—
Carbon dioxide	CO <sub>2</sub>	44.01	548	72.9	0.276
Carbon monoxide	CO	28.01	239	34.5	0.294
Copper	Cu	63.54	—	—	—
Ethane	C <sub>2</sub> H <sub>6</sub>	30.07	549	48.2	0.285
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH	46.07	929	63.0	0.249
Ethylene	C <sub>2</sub> H <sub>4</sub>	28.05	510	50.5	0.270
Helium	He	4.003	9.33	2.26	0.300
Hydrogen	H <sub>2</sub>	2.016	59.8	12.8	0.304
Methane	CH <sub>4</sub>	16.04	344	45.8	0.290
Methyl alcohol	CH <sub>3</sub> OH	32.04	924	78.5	0.220
Nitrogen	N <sub>2</sub>	28.01	227	33.5	0.291
Octane	C <sub>8</sub> H <sub>18</sub>	114.22	1025	24.6	0.258
Oxygen	O <sub>2</sub>	32.00	278	49.8	0.290
Propane	C <sub>3</sub> H <sub>8</sub>	44.09	666	42.1	0.276
Propylene	C <sub>3</sub> H <sub>6</sub>	42.08	657	45.6	0.276
Refrigerant 12	CCl <sub>2</sub> F <sub>2</sub>	120.92	693	40.6	0.278
Refrigerant 22	CHClF <sub>2</sub>	86.48	665	49.1	0.267
Refrigerant 134a	CF <sub>3</sub> CH <sub>2</sub> F	102.03	673	40.2	0.260
Sulfur dioxide	SO <sub>2</sub>	64.06	775	77.7	0.268
Water	H <sub>2</sub> O	18.02	1165	218.0	0.233

Sources: Adapted from *International Critical Tables* and L. C. Nelson and E. F. Obert, Generalized Compressibility Charts, *Chem. Eng.*, 617: 203 (1954).

TABLE A-2E Properties of Saturated Water (Liquid-Vapor): Temperature Table

Temp. °F	Press. lbf/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
32	0.0886	0.01602	3305	-.01	1021.2	-.01	1075.4	1075.4	-.00003	2.1870	32
35	0.0999	0.01602	2948	2.99	1022.2	3.00	1073.7	1076.7	0.00607	2.1764	35
40	0.1217	0.01602	2445	8.02	1023.9	8.02	1070.9	1078.9	0.01617	2.1592	40
45	0.1475	0.01602	2037	13.04	1025.5	13.04	1068.1	1081.1	0.02618	2.1423	45
50	0.1780	0.01602	1704	18.06	1027.2	18.06	1065.2	1083.3	0.03607	2.1259	50
52	0.1917	0.01603	1589	20.06	1027.8	20.07	1064.1	1084.2	0.04000	2.1195	52
54	0.2064	0.01603	1482	22.07	1028.5	22.07	1063.0	1085.1	0.04391	2.1131	54
56	0.2219	0.01603	1383	24.08	1029.1	24.08	1061.9	1085.9	0.04781	2.1068	56
58	0.2386	0.01603	1292	26.08	1029.8	26.08	1060.7	1086.8	0.05159	2.1005	58
60	0.2563	0.01604	1207	28.08	1030.4	28.08	1059.6	1087.7	0.05555	2.0943	60
62	0.2751	0.01604	1129	30.09	1031.1	30.09	1058.5	1088.6	0.05940	2.0882	62
64	0.2952	0.01604	1056	32.09	1031.8	32.09	1057.3	1089.4	0.06323	2.0821	64
66	0.3165	0.01604	988.4	34.09	1032.4	34.09	1056.2	1090.3	0.06704	2.0761	66
68	0.3391	0.01605	925.8	36.09	1033.1	36.09	1055.1	1091.2	0.07084	2.0701	68
70	0.3632	0.01605	867.7	38.09	1033.7	38.09	1054.0	1092.0	0.07463	2.0642	70
72	0.3887	0.01606	813.7	40.09	1034.4	40.09	1052.8	1092.9	0.07839	2.0584	72
74	0.4158	0.01606	763.5	42.09	1035.0	42.09	1051.7	1093.8	0.08215	2.0526	74
76	0.4446	0.01606	716.8	44.09	1035.7	44.09	1050.6	1094.7	0.08589	2.0469	76
78	0.4750	0.01607	673.3	46.09	1036.3	46.09	1049.4	1095.5	0.08961	2.0412	78
80	0.5073	0.01607	632.8	48.08	1037.0	48.09	1048.3	1096.4	0.09332	2.0356	80
82	0.5414	0.01608	595.0	50.08	1037.6	50.08	1047.2	1097.3	0.09701	2.0300	82
84	0.5776	0.01608	559.8	52.08	1038.3	52.08	1046.0	1098.1	0.1007	2.0245	84
86	0.6158	0.01609	527.0	54.08	1038.9	54.08	1044.9	1099.0	0.1044	2.0190	86
88	0.6562	0.01609	496.3	56.07	1039.6	56.07	1043.8	1099.9	0.1080	2.0136	88
90	0.6988	0.01610	467.7	58.07	1040.2	58.07	1042.7	1100.7	0.1117	2.0083	90
92	0.7439	0.01611	440.9	60.06	1040.9	60.06	1041.5	1101.6	0.1153	2.0030	92
94	0.7914	0.01611	415.9	62.06	1041.5	62.06	1040.4	1102.4	0.1189	1.9977	94
96	0.8416	0.01612	392.4	64.05	1041.2	64.06	1039.2	1103.3	0.1225	1.9925	96
98	0.8945	0.01612	370.5	66.05	1042.8	66.05	1038.1	1104.2	0.1261	1.9874	98
100	0.9503	0.01613	350.0	68.04	1043.5	68.05	1037.0	1105.0	0.1296	1.9822	100
110	1.276	0.01617	265.1	78.02	1046.7	78.02	1031.3	1109.3	0.1473	1.9574	110
120	1.695	0.01621	203.0	87.99	1049.9	88.00	1025.5	1113.5	0.1647	1.9336	120
130	2.225	0.01625	157.2	97.97	1053.0	97.98	1019.8	1117.8	0.1817	1.9109	130
140	2.892	0.01629	122.9	107.95	1056.2	107.96	1014.0	1121.9	0.1985	1.8892	140
150	3.722	0.01634	97.0	117.95	1059.3	117.96	1008.1	1126.1	0.2150	1.8684	150
160	4.745	0.01640	77.2	127.94	1062.3	127.96	1002.2	1130.1	0.2313	1.8484	160
170	5.996	0.01645	62.0	137.95	1065.4	137.97	996.2	1134.2	0.2473	1.8293	170
180	7.515	0.01651	50.2	147.97	1068.3	147.99	990.2	1138.2	0.2631	1.8109	180
190	9.343	0.01657	41.0	158.00	1071.3	158.03	984.1	1142.1	0.2787	1.7932	190
200	11.529	0.01663	33.6	168.04	1074.2	168.07	977.9	1145.9	0.2940	1.7762	200

H<sub>2</sub>O

TABLE A-2E (Continued)

Temp. °F	Press. lbf/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid <i>v<sub>f</sub></i>	Sat. Vapor <i>v<sub>g</sub></i>	Sat. Liquid <i>u<sub>f</sub></i>	Sat. Vapor <i>u<sub>g</sub></i>	Sat. Liquid <i>h<sub>f</sub></i>	Evap. <i>h<sub>fg</sub></i>	Sat. Vapor <i>h<sub>g</sub></i>	Sat. Liquid <i>s<sub>f</sub></i>	Sat. Vapor <i>s<sub>g</sub></i>	
210	14.13	0.01670	27.82	178.1	1077.0	178.1	971.6	1149.7	0.3091	1.7599	210
212	14.70	0.01672	26.80	180.1	1077.6	180.2	970.3	1150.5	0.3121	1.7567	212
220	17.19	0.01677	23.15	188.2	1079.8	188.2	965.3	1153.5	0.3241	1.7441	220
230	20.78	0.01685	19.39	198.3	1082.6	198.3	958.8	1157.1	0.3388	1.7289	230
240	24.97	0.01692	16.33	208.4	1085.3	208.4	952.3	1160.7	0.3534	1.7143	240
250	29.82	0.01700	13.83	218.5	1087.9	218.6	945.6	1164.2	0.3677	1.7001	250
260	35.42	0.01708	11.77	228.6	1090.5	228.8	938.8	1167.6	0.3819	1.6864	260
270	41.85	0.01717	10.07	238.8	1093.0	239.0	932.0	1170.9	0.3960	1.6731	270
280	49.18	0.01726	8.65	249.0	1095.4	249.2	924.9	1174.1	0.4099	1.6602	280
290	57.53	0.01735	7.47	259.3	1097.7	259.4	917.8	1177.2	0.4236	1.6477	290
300	66.98	0.01745	6.472	269.5	1100.0	269.7	910.4	1180.2	0.4372	1.6356	300
310	77.64	0.01755	5.632	279.8	1102.1	280.1	903.0	1183.0	0.4507	1.6238	310
320	89.60	0.01765	4.919	290.1	1104.2	290.4	895.3	1185.8	0.4640	1.6123	320
330	103.00	0.01776	4.312	300.5	1106.2	300.8	887.5	1188.4	0.4772	1.6010	330
340	117.93	0.01787	3.792	310.9	1108.0	311.3	879.5	1190.8	0.4903	1.5901	340
350	134.53	0.01799	3.346	321.4	1109.8	321.8	871.3	1193.1	0.5033	1.5793	350
360	152.92	0.01811	2.961	331.8	1111.4	332.4	862.9	1195.2	0.5162	1.5688	360
370	173.23	0.01823	2.628	342.4	1112.9	343.0	854.2	1197.2	0.5289	1.5585	370
380	195.60	0.01836	2.339	353.0	1114.3	353.6	845.4	1199.0	0.5416	1.5483	380
390	220.2	0.01850	2.087	363.6	1115.6	364.3	836.2	1200.6	0.5542	1.5383	390
400	247.1	0.01864	1.866	374.3	1116.6	375.1	826.8	1202.0	0.5667	1.5284	400
410	276.5	0.01878	1.673	385.0	1117.6	386.0	817.2	1203.1	0.5792	1.5187	410
420	308.5	0.01894	1.502	395.8	1118.3	396.9	807.2	1204.1	0.5915	1.5091	420
430	343.3	0.01909	1.352	406.7	1118.9	407.9	796.9	1204.8	0.6038	1.4995	430
440	381.2	0.01926	1.219	417.6	1119.3	419.0	786.3	1205.3	0.6161	1.4900	440
450	422.1	0.01943	1.1011	428.6	1119.5	430.2	775.4	1205.6	0.6282	1.4806	450
460	466.3	0.01961	0.9961	439.7	1119.6	441.4	764.1	1205.5	0.6404	1.4712	460
470	514.1	0.01980	0.9025	450.9	1119.4	452.8	752.4	1205.2	0.6525	1.4618	470
480	565.5	0.02000	0.8187	462.2	1118.9	464.3	740.3	1204.6	0.6646	1.4524	480
490	620.7	0.02021	0.7436	473.6	1118.3	475.9	727.8	1203.7	0.6767	1.4430	490
500	680.0	0.02043	0.6761	485.1	1117.4	487.7	714.8	1202.5	0.6888	1.4335	500
520	811.4	0.02091	0.5605	508.5	1114.8	511.7	687.3	1198.9	0.7130	1.4145	520
540	961.5	0.02145	0.4658	532.6	1111.0	536.4	657.5	1193.8	0.7374	1.3950	540
560	1131.8	0.02207	0.3877	548.4	1105.8	562.0	625.0	1187.0	0.7620	1.3749	560
580	1324.3	0.02278	0.3225	583.1	1098.9	588.6	589.3	1178.0	0.7872	1.3540	580
600	1541.0	0.02363	0.2677	609.9	1090.0	616.7	549.7	1166.4	0.8130	1.3317	600
620	1784.4	0.02465	0.2209	638.3	1078.5	646.4	505.0	1151.4	0.8398	1.3075	620
640	2057.1	0.02593	0.1805	668.7	1063.2	678.6	453.4	1131.9	0.8681	1.2803	640
660	2362	0.02767	0.1446	702.3	1042.3	714.4	391.1	1105.5	0.8990	1.2483	660
680	2705	0.03032	0.1113	741.7	1011.0	756.9	309.8	1066.7	0.9350	1.2068	680
700	3090	0.03666	0.0744	801.7	947.7	822.7	167.5	990.2	0.9902	1.1346	700
705.4	3204	0.05053	0.05053	872.6	872.6	902.5	0	902.5	1.0580	1.0580	705.4

Source: Tables A-2E through A-6E are extracted from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables*, Wiley, New York, 1969.

H<sub>2</sub>O

TABLE A-3E Properties of Saturated Water (Liquid-Vapor): Pressure Table

Press. lbf/in. <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R			Press. lbf/in. <sup>2</sup>
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Evap. $s_{fg}$	Sat. Vapor $s_g$	
0.4	72.84	0.01606	792.0	40.94	1034.7	40.94	1052.3	1093.3	0.0800	1.9760	2.0559	0.4
0.6	85.19	0.01609	540.0	53.26	1038.7	53.27	1045.4	1098.6	0.1029	1.9184	2.0213	0.6
0.8	94.35	0.01611	411.7	62.41	1041.7	62.41	1040.2	1102.6	0.1195	1.8773	1.9968	0.8
1.0	101.70	0.01614	333.6	69.74	1044.0	69.74	1036.0	1105.8	0.1327	1.8453	1.9779	1.0
1.2	107.88	0.01616	280.9	75.90	1046.0	75.90	1032.5	1108.4	0.1436	1.8190	1.9626	1.2
1.5	115.65	0.01619	227.7	83.65	1048.5	83.65	1028.0	1111.7	0.1571	1.7867	1.9438	1.5
2.0	126.04	0.01623	173.75	94.02	1051.8	94.02	1022.1	1116.1	0.1750	1.7448	1.9198	2.0
3.0	141.43	0.01630	118.72	109.38	1056.6	109.39	1013.1	1122.5	0.2009	1.6852	1.8861	3.0
4.0	152.93	0.01636	90.64	120.88	1060.2	120.89	1006.4	1127.3	0.2198	1.6426	1.8624	4.0
5.0	162.21	0.01641	73.53	130.15	1063.0	130.17	1000.9	1131.0	0.2349	1.6093	1.8441	5.0
6.0	170.03	0.01645	61.98	137.98	1065.4	138.00	996.2	1134.2	0.2474	1.5819	1.8292	6.0
7.0	176.82	0.01649	53.65	144.78	1067.4	144.80	992.1	1136.9	0.2581	1.5585	1.8167	7.0
8.0	182.84	0.01653	47.35	150.81	1069.2	150.84	988.4	1139.3	0.2675	1.5383	1.8058	8.0
9.0	188.26	0.01656	42.41	156.25	1070.8	156.27	985.1	1141.4	0.2760	1.5203	1.7963	9.0
10	193.19	0.01659	38.42	161.20	1072.2	161.23	982.1	1143.3	0.2836	1.5041	1.7877	10
14.696	211.99	0.01672	26.80	180.10	1077.6	180.15	970.4	1150.5	0.3121	1.4446	1.7567	14.696
15	213.03	0.01672	26.29	181.14	1077.9	181.19	969.7	1150.9	0.3137	1.4414	1.7551	15
20	227.96	0.01683	20.09	196.19	1082.0	196.26	960.1	1156.4	0.3358	1.3962	1.7320	20
25	240.08	0.01692	16.31	208.44	1085.3	208.52	952.2	1160.7	0.3535	1.3607	1.7142	25
30	250.34	0.01700	13.75	218.84	1088.0	218.93	945.4	1164.3	0.3682	1.3314	1.6996	30
35	259.30	0.01708	11.90	227.93	1090.3	228.04	939.3	1167.4	0.3809	1.3064	1.6873	35
40	267.26	0.01715	10.50	236.03	1092.3	236.16	933.8	1170.0	0.3921	1.2845	1.6767	40
45	274.46	0.01721	9.40	243.37	1094.0	243.51	928.8	1172.3	0.4022	1.2651	1.6673	45
50	281.03	0.01727	8.52	250.08	1095.6	250.24	924.2	1174.4	0.4113	1.2476	1.6589	50
55	287.10	0.01733	7.79	256.28	1097.0	256.46	919.9	1176.3	0.4196	1.2317	1.6513	55
60	292.73	0.01738	7.177	262.1	1098.3	262.2	915.8	1178.0	0.4273	1.2170	1.6443	60
65	298.00	0.01743	6.647	267.5	1099.5	267.7	911.9	1179.6	0.4345	1.2035	1.6380	65
70	302.96	0.01748	6.209	272.6	1100.6	272.8	908.3	1181.0	0.4412	1.1909	1.6321	70
75	307.63	0.01752	5.818	277.4	1101.6	277.6	904.8	1182.4	0.4475	1.1790	1.6265	75
80	312.07	0.01757	5.474	282.0	1102.6	282.2	901.4	1183.6	0.4534	1.1679	1.6213	80
85	316.29	0.01761	5.170	286.3	1103.5	286.6	898.2	1184.8	0.4591	1.1574	1.6165	85
90	320.31	0.01766	4.898	290.5	1104.3	290.8	895.1	1185.9	0.4644	1.1475	1.6119	90
95	324.16	0.01770	4.654	294.5	1105.0	294.8	892.1	1186.9	0.4695	1.1380	1.6075	95
100	327.86	0.01774	4.434	298.3	1105.8	298.6	889.2	1187.8	0.4744	1.1290	1.6034	100
110	334.82	0.01781	4.051	305.5	1107.1	305.9	883.7	1189.6	0.4836	1.1122	1.5958	110
120	341.30	0.01789	3.730	312.3	1108.3	312.7	878.5	1191.1	0.4920	1.0966	1.5886	120
130	347.37	0.01796	3.457	318.6	1109.4	319.0	873.5	1192.5	0.4999	1.0822	1.5821	130
140	353.08	0.01802	3.221	324.6	1110.3	325.1	868.7	1193.8	0.5073	1.0688	1.5761	140
150	358.48	0.01809	3.016	330.2	1111.2	330.8	864.2	1194.9	0.5142	1.0562	1.5704	150
160	363.60	0.01815	2.836	335.6	1112.0	336.2	859.8	1196.0	0.5208	1.0443	1.5651	160

H<sub>2</sub>O

TABLE A-3E (Continued)

Press. lbf/in. <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R			Press. lbf/in. <sup>2</sup>
		Sat. Liquid <i>v<sub>f</sub></i>	Sat. Vapor <i>v<sub>g</sub></i>	Sat. Liquid <i>u<sub>f</sub></i>	Sat. Vapor <i>u<sub>g</sub></i>	Sat. Liquid <i>h<sub>f</sub></i>	Evap. <i>h<sub>fg</sub></i>	Sat. Vapor <i>h<sub>g</sub></i>	Sat. Liquid <i>s<sub>f</sub></i>	Evap. <i>s<sub>fg</sub></i>	Sat. Vapor <i>s<sub>g</sub></i>	
170	368.47	0.01821	2.676	340.8	1112.7	341.3	855.6	1196.9	0.5270	1.0330	1.5600	170
180	373.13	0.01827	2.553	345.7	1113.4	346.3	851.5	1197.8	0.5329	1.0223	1.5552	180
190	377.59	0.01833	2.405	350.4	1114.0	351.0	847.5	1198.6	0.5386	1.0122	1.5508	190
200	381.86	0.01839	2.289	354.9	1114.6	355.6	843.7	1199.3	0.5440	1.0025	1.5465	200
250	401.04	0.01865	1.845	375.4	1116.7	376.2	825.8	1202.1	0.5680	0.9594	1.5274	250
300	417.43	0.01890	1.544	393.0	1118.2	394.1	809.8	1203.9	0.5883	0.9232	1.5115	300
350	431.82	0.01912	1.327	408.7	1119.0	409.9	795.0	1204.9	0.6060	0.8917	1.4977	350
400	444.70	0.01934	1.162	422.8	1119.5	424.2	781.2	1205.5	0.6218	0.8638	1.4856	400
450	456.39	0.01955	1.033	435.7	1119.6	437.4	768.2	1205.6	0.6360	0.8385	1.4745	450
500	467.13	0.01975	0.928	447.7	1119.4	449.5	755.8	1205.3	0.6490	0.8154	1.4644	500
550	477.07	0.01994	0.842	458.9	1119.1	460.9	743.9	1204.8	0.6611	0.7941	1.4451	550
600	486.33	0.02013	0.770	469.4	1118.6	471.7	732.4	1204.1	0.6723	0.7742	1.4464	600
700	503.23	0.02051	0.656	488.9	1117.0	491.5	710.5	1202.0	0.6927	0.7378	1.4305	700
800	518.36	0.02087	0.569	506.6	1115.0	509.7	689.6	1199.3	0.7110	0.7050	1.4160	800
900	532.12	0.02123	0.501	523.0	1112.6	526.6	669.5	1196.0	0.7277	0.6750	1.4027	900
1000	544.75	0.02159	0.446	538.4	1109.9	542.4	650.0	1192.4	0.7432	0.6471	1.3903	1000
1100	556.45	0.02195	0.401	552.9	1106.8	557.4	631.0	1188.3	0.7576	0.6209	1.3786	1100
1200	567.37	0.02232	0.362	566.7	1103.5	571.7	612.3	1183.9	0.7712	0.5961	1.3673	1200
1300	577.60	0.02269	0.330	579.9	1099.8	585.4	593.8	1179.2	0.7841	0.5724	1.3565	1300
1400	587.25	0.02307	0.302	592.7	1096.0	598.6	575.5	1174.1	0.7964	0.5497	1.3461	1400
1500	596.39	0.02346	0.277	605.0	1091.8	611.5	557.2	1168.7	0.8082	0.5276	1.3359	1500
1600	605.06	0.02386	0.255	616.9	1087.4	624.0	538.9	1162.9	0.8196	0.5062	1.3258	1600
1700	613.32	0.02428	0.236	628.6	1082.7	636.2	520.6	1156.9	0.8307	0.4852	1.3159	1700
1800	621.21	0.02472	0.218	640.0	1077.7	648.3	502.1	1150.4	0.8414	0.4645	1.3060	1800
1900	628.76	0.02517	0.203	651.3	1072.3	660.1	483.4	1143.5	0.8519	0.4441	1.2961	1900
2000	636.00	0.02565	0.188	662.4	1066.6	671.9	464.4	1136.3	0.8623	0.4238	1.2861	2000
2250	652.90	0.02698	0.157	689.9	1050.6	701.1	414.8	1115.9	0.8876	0.3728	1.2604	2250
2500	668.31	0.02860	0.131	717.7	1031.0	730.9	360.5	1091.4	0.9131	0.3196	1.2327	2500
2750	682.46	0.03077	0.107	747.3	1005.9	763.0	297.4	1060.4	0.9401	0.2604	1.2005	2750
3000	695.52	0.03431	0.084	783.4	968.8	802.5	213.0	1015.5	0.9732	0.1843	1.1575	3000
3203.6	705.44	0.05053	0.0505	872.6	872.6	902.5	0	902.5	1.0580	0	1.0580	3203.6

H<sub>2</sub>O

TABLE A-4E Properties of Superheated Water Vapor

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 1 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 101.7^\circ\text{F}$ )					$p = 5 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 162.2^\circ\text{F}$ )			
Sat.	333.6	1044.0	1105.8	1.9779	73.53	1063.0	1131.0	1.8441
150	362.6	1060.4	1127.5	2.0151				
200	392.5	1077.5	1150.1	2.0508	78.15	1076.0	1148.6	1.8715
250	422.4	1094.7	1172.8	2.0839	84.21	1093.8	1171.7	1.9052
300	452.3	1112.0	1195.7	2.1150	90.24	1111.3	1194.8	1.9367
400	511.9	1147.0	1241.8	2.1720	102.24	1146.6	1241.2	1.9941
500	571.5	1182.8	1288.5	2.2235	114.20	1182.5	1288.2	2.0458
600	631.1	1219.3	1336.1	2.2706	126.15	1219.1	1335.8	2.0930
700	690.7	1256.7	1384.5	2.3142	138.08	1256.5	1384.3	2.1367
800	750.3	1294.4	1433.7	2.3550	150.01	1294.7	1433.5	2.1775
900	809.9	1333.9	1483.8	2.3932	161.94	1333.8	1483.7	2.2158
1000	869.5	1373.9	1534.8	2.4294	173.86	1373.9	1534.7	2.2520
$p = 10 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 193.2^\circ\text{F}$ )					$p = 14.7 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 212.0^\circ\text{F}$ )			
Sat.	38.42	1072.2	1143.3	1.7877	26.80	1077.6	1150.5	1.7567
200	38.85	1074.7	1146.6	1.7927				
250	41.95	1092.6	1170.2	1.8272	28.42	1091.5	1168.8	1.7832
300	44.99	1110.4	1193.7	1.8592	30.52	1109.6	1192.6	1.8157
400	51.03	1146.1	1240.5	1.9171	34.67	1145.6	1239.9	1.8741
500	57.04	1182.2	1287.7	1.9690	38.77	1181.8	1287.3	1.9263
600	63.03	1218.9	1335.5	2.0164	42.86	1218.6	1335.2	1.9737
700	69.01	1256.3	1384.0	2.0601	46.93	1256.1	1383.8	2.0175
800	74.98	1294.6	1433.3	2.1009	51.00	1294.4	1433.1	2.0584
900	80.95	1333.7	1483.5	2.1393	55.07	1333.6	1483.4	2.0967
1000	86.91	1373.8	1534.6	2.1755	59.13	1373.7	1534.5	2.1330
1100	92.88	1414.7	1586.6	2.2099	63.19	1414.6	1586.4	2.1674
$p = 20 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 228.0^\circ\text{F}$ )					$p = 40 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 267.3^\circ\text{F}$ )			
Sat.	20.09	1082.0	1156.4	1.7320	10.50	1093.3	1170.0	1.6767
250	20.79	1090.3	1167.2	1.7475				
300	22.36	1108.7	1191.5	1.7805	11.04	1105.1	1186.8	1.6993
350	23.90	1126.9	1215.4	1.8110	11.84	1124.2	1211.8	1.7312
400	25.43	1145.1	1239.2	1.8395	12.62	1143.0	1236.4	1.7606
500	28.46	1181.5	1286.8	1.8919	14.16	1180.1	1284.9	1.8140
600	31.47	1218.4	1334.8	1.9395	15.69	1217.3	1333.4	1.8621
700	34.47	1255.9	1383.5	1.9834	17.20	1255.1	1382.4	1.9063
800	37.46	1294.3	1432.9	2.0243	18.70	1293.7	1432.1	1.9474
900	40.45	1333.5	1483.2	2.0627	20.20	1333.0	1482.5	1.9859
1000	43.44	1373.5	1534.3	2.0989	21.70	1373.1	1533.8	2.0223
1100	46.42	1414.5	1586.3	2.1334	23.20	1414.2	1585.9	2.0568

H<sub>2</sub>O

TABLE A-4E (Continued)

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R
<i>p</i> = 60 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 292.7°F)					<i>p</i> = 80 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 312.1°F)			
Sat.	7.17	1098.3	1178.0	1.6444	5.47	1102.6	1183.6	1.6214
300	7.26	1101.3	1181.9	1.6496				
350	7.82	1121.4	1208.2	1.6830	5.80	1118.5	1204.3	1.6476
400	8.35	1140.8	1233.5	1.7134	6.22	1138.5	1230.6	1.6790
500	9.40	1178.6	1283.0	1.7678	7.02	1177.2	1281.1	1.7346
600	10.43	1216.3	1332.1	1.8165	7.79	1215.3	1330.7	1.7838
700	11.44	1254.4	1381.4	1.8609	8.56	1253.6	1380.3	1.8285
800	12.45	1293.0	1431.2	1.9022	9.32	1292.4	1430.4	1.8700
900	13.45	1332.5	1481.8	1.9408	10.08	1332.0	1481.2	1.9087
1000	14.45	1372.7	1533.2	1.9773	10.83	1372.3	1532.6	1.9453
1100	15.45	1413.8	1585.4	2.0119	11.58	1413.5	1584.9	1.9799
1200	16.45	1455.8	1638.5	2.0448	12.33	1455.5	1638.1	2.0130
<i>p</i> = 100 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 327.8°F)					<i>p</i> = 120 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 341.3°F)			
Sat.	4.434	1105.8	1187.8	1.6034	3.730	1108.3	1191.1	1.5886
350	4.592	1115.4	1200.4	1.6191	3.783	1112.2	1196.2	1.5950
400	4.934	1136.2	1227.5	1.6517	4.079	1133.8	1224.4	1.6288
450	5.265	1156.2	1253.6	1.6812	4.360	1154.3	1251.2	1.6590
500	5.587	1175.7	1279.1	1.7085	4.633	1174.2	1277.1	1.6868
600	6.216	1214.2	1329.3	1.7582	5.164	1213.2	1327.8	1.7371
700	6.834	1252.8	1379.2	1.8033	5.682	1252.0	1378.2	1.7825
800	7.445	1291.8	1429.6	1.8449	6.195	1291.2	1428.7	1.8243
900	8.053	1331.5	1480.5	1.8838	6.703	1330.9	1479.8	1.8633
1000	8.657	1371.9	1532.1	1.9204	7.208	1371.5	1531.5	1.9000
1100	9.260	1413.1	1584.5	1.9551	7.711	1412.8	1584.0	1.9348
1200	9.861	1455.2	1637.7	1.9882	8.213	1454.9	1637.3	1.9679
<i>p</i> = 140 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 353.1°F)					<i>p</i> = 160 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 363.6°F)			
Sat.	3.221	1110.3	1193.8	1.5761	2.836	1112.0	1196.0	1.5651
400	3.466	1131.4	1221.2	1.6088	3.007	1128.8	1217.8	1.5911
450	3.713	1152.4	1248.6	1.6399	3.228	1150.5	1246.1	1.6230
500	3.952	1172.7	1275.1	1.6682	3.440	1171.2	1273.0	1.6518
550	4.184	1192.5	1300.9	1.6945	3.646	1191.3	1299.2	1.6785
600	4.412	1212.1	1326.4	1.7191	3.848	1211.1	1325.0	1.7034
700	4.860	1251.2	1377.1	1.7648	4.243	1250.4	1376.0	1.7494
800	5.301	1290.5	1427.9	1.8068	4.631	1289.9	1427.0	1.7916
900	5.739	1330.4	1479.1	1.8459	5.015	1329.9	1478.4	1.8308
1000	6.173	1371.0	1531.0	1.8827	5.397	1370.6	1530.4	1.8677
1100	6.605	1412.4	1583.6	1.9176	5.776	1412.1	1583.1	1.9026
1200	7.036	1454.6	1636.9	1.9507	6.154	1454.3	1636.5	1.9358

H<sub>2</sub>O

H<sub>2</sub>O

TABLE A-4E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 180 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 373.1^\circ\text{F}$ )					$p = 200 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 381.8^\circ\text{F}$ )			
Sat.	2.533	1113.4	1197.8	1.5553	2.289	1114.6	1199.3	1.5464
400	2.648	1126.2	1214.4	1.5749	2.361	1123.5	1210.8	1.5600
450	2.850	1148.5	1243.4	1.6078	2.548	1146.4	1240.7	1.5938
500	3.042	1169.6	1270.9	1.6372	2.724	1168.0	1268.8	1.6239
550	3.228	1190.0	1297.5	1.6642	2.893	1188.7	1295.7	1.6512
600	3.409	1210.0	1323.5	1.6893	3.058	1208.9	1322.1	1.6767
700	3.763	1249.6	1374.9	1.7357	3.379	1248.8	1373.8	1.7234
800	4.110	1289.3	1426.2	1.7781	3.693	1288.6	1425.3	1.7660
900	4.453	1329.4	1477.7	1.8174	4.003	1328.9	1477.1	1.8055
1000	4.793	1370.2	1529.8	1.8545	4.310	1369.8	1529.3	1.8425
1100	5.131	1411.7	1582.6	1.8894	4.615	1411.4	1582.2	1.8776
1200	5.467	1454.0	1636.1	1.9227	4.918	1453.7	1635.7	1.9109
$p = 250 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 401.0^\circ\text{F}$ )					$p = 300 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 417.4^\circ\text{F}$ )			
Sat.	1.845	1116.7	1202.1	1.5274	1.544	1118.2	1203.9	1.5115
450	2.002	1141.1	1233.7	1.5632	1.636	1135.4	1226.2	1.5365
500	2.150	1163.8	1263.3	1.5948	1.766	1159.5	1257.5	1.5701
550	2.290	1185.3	1291.3	1.6233	1.888	1181.9	1286.7	1.5997
600	2.426	1206.1	1318.3	1.6494	2.004	1203.2	1314.5	1.6266
700	2.688	1246.7	1371.1	1.6970	2.227	1244.0	1368.3	1.6751
800	2.943	1287.0	1423.2	1.7301	2.442	1285.4	1421.0	1.7187
900	3.193	1327.6	1475.3	1.7799	2.653	1326.3	1473.6	1.7589
1000	3.440	1368.7	1527.9	1.8172	2.860	1367.7	1526.5	1.7964
1100	3.685	1410.5	1581.0	1.8524	3.066	1409.6	1579.8	1.8317
1200	3.929	1453.0	1634.8	1.8858	3.270	1452.2	1633.8	1.8653
1300	4.172	1496.3	1689.3	1.9177	3.473	1495.6	1688.4	1.8973
$p = 350 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 431.8^\circ\text{F}$ )					$p = 400 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 444.7^\circ\text{F}$ )			
Sat.	1.327	1119.0	1204.9	1.4978	1.162	1119.5	1205.5	1.4856
450	1.373	1129.2	1218.2	1.5125	1.175	1122.6	1209.5	1.4901
500	1.491	1154.9	1251.5	1.5482	1.284	1150.1	1245.2	1.5282
550	1.600	1178.3	1281.9	1.5790	1.383	1174.6	1277.0	1.5605
600	1.703	1200.3	1310.6	1.6068	1.476	1197.3	1306.6	1.5892
700	1.898	1242.5	1365.4	1.6562	1.650	1240.4	1362.5	1.6397
800	2.085	1283.8	1418.8	1.7004	1.816	1282.1	1416.6	1.6844
900	2.267	1325.0	1471.8	1.7409	1.978	1323.7	1470.1	1.7252
1000	2.446	1366.6	1525.0	1.7787	2.136	1365.5	1523.6	1.7632
1100	2.624	1408.7	1578.6	1.8142	2.292	1407.8	1577.4	1.7989
1200	2.799	1451.5	1632.8	1.8478	2.446	1450.7	1621.8	1.8327
1300	2.974	1495.0	1687.6	1.8799	2.599	1494.3	1686.8	1.8648

TABLE A-4E (Continued)

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	
<i>p</i> = 450 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 456.4°F)					<i>p</i> = 500 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 467.1°F)				
Sat.	1.033	1119.6	1205.6	1.4746	0.928	1119.4	1205.3	1.4645	
500	1.123	1145.1	1238.5	1.5097	0.992	1139.7	1231.5	1.4923	
550	1.215	1170.7	1271.9	1.5436	1.079	1166.7	1266.6	1.5279	
600	1.300	1194.3	1302.5	1.5732	1.158	1191.1	1298.3	1.5585	
700	1.458	1238.2	1359.6	1.6248	1.304	1236.0	1356.7	1.6112	
800	1.608	1280.5	1414.4	1.6701	1.441	1278.8	1412.1	1.6571	
900	1.752	1322.4	1468.3	1.7113	1.572	1321.0	1466.5	1.6987	
1000	1.894	1364.4	1522.2	1.7495	1.701	1363.3	1520.7	1.7371	
1100	2.034	1406.9	1576.3	1.7853	1.827	1406.0	1575.1	1.7731	
1200	2.172	1450.0	1630.8	1.8192	1.952	1449.2	1629.8	1.8072	
1300	2.308	1493.7	1685.9	1.8515	2.075	1493.1	1685.1	1.8395	
1400	2.444	1538.1	1741.7	1.8823	2.198	1537.6	1741.0	1.8704	
<i>p</i> = 600 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 486.3°F)					<i>p</i> = 700 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 503.2°F)				
Sat.	0.770	1118.6	1204.1	1.4464	0.656	1117.0	1202.0	1.4305	
500	0.795	1128.0	1216.2	1.4592	0.728	1149.0	1243.2	1.4723	
550	0.875	1158.2	1255.4	1.4990	0.793	1177.5	1280.2	1.5081	
600	0.946	1184.5	1289.5	1.5320	0.907	1226.9	1344.4	1.5661	
700	1.073	1231.5	1350.6	1.5872	1.011	1272.0	1402.9	1.6145	
800	1.190	1275.4	1407.6	1.6343	1.109	1315.6	1459.3	1.6576	
900	1.302	1318.4	1462.9	1.6766	1.204	1358.9	1514.9	1.6970	
1000	1.411	1361.2	1517.8	1.7155	1.296	1402.4	1570.2	1.7337	
1100	1.517	1404.2	1572.7	1.7519	1.387	1446.2	1625.8	1.7682	
1200	1.622	1447.7	1627.8	1.7861	1.476	1490.4	1681.7	1.8009	
1300	1.726	1491.7	1683.4	1.8186	1.565	1535.3	1738.1	1.8321	
1400	1.829	1536.5	1739.5	1.8497					
<i>p</i> = 800 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 518.3°F)					<i>p</i> = 900 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 532.1°F)				
Sat.	0.569	1115.0	1199.3	1.4160	0.501	1112.6	1196.0	1.4027	
550	0.615	1138.8	1229.9	1.4469	0.527	1127.5	1215.2	1.4219	
600	0.677	1170.1	1270.4	1.4861	0.587	1162.2	1260.0	1.4652	
650	0.732	1197.2	1305.6	1.5186	0.639	1191.1	1297.5	1.4999	
700	0.783	1222.1	1338.0	1.5471	0.686	1217.1	1331.4	1.5297	
800	0.876	1268.5	1398.2	1.5969	0.772	1264.9	1393.4	1.5810	
900	0.964	1312.9	1455.6	1.6408	0.851	1310.1	1451.9	1.6257	
1000	1.048	1356.7	1511.9	1.6807	0.927	1354.5	1508.9	1.6662	
1100	1.130	1400.5	1567.8	1.7178	1.001	1398.7	1565.4	1.7036	
1200	1.210	1444.6	1623.8	1.7526	1.073	1443.0	1621.7	1.7386	
1300	1.289	1489.1	1680.0	1.7854	1.144	1487.8	1687.3	1.7717	
1400	1.367	1534.2	1736.6	1.8167	1.214	1533.0	1735.1	1.8031	

H<sub>2</sub>O

H<sub>2</sub>O

TABLE A-4E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 1000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 544.7^\circ\text{F}$ )					$p = 1200 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 567.4^\circ\text{F}$ )			
Sat.	0.446	1109.0	1192.4	1.3903	0.362	1103.5	1183.9	1.3673
600	0.514	1153.7	1248.8	1.4450	0.402	1134.4	1223.6	1.4054
650	0.564	1184.7	1289.1	1.4822	0.450	1170.9	1270.8	1.4490
700	0.608	1212.0	1324.6	1.5135	0.491	1201.3	1310.2	1.4837
800	0.688	1261.2	1388.5	1.5665	0.562	1253.7	1378.4	1.5402
900	0.761	1307.3	1448.1	1.6120	0.626	1301.5	1440.4	1.5876
1000	0.831	1352.2	1505.9	1.6530	0.685	1347.5	1499.7	1.6297
1100	0.898	1396.8	1562.9	1.6908	0.743	1393.0	1557.9	1.6682
1200	0.963	1441.5	1619.7	1.7261	0.798	1438.3	1615.5	1.7040
1300	1.027	1486.5	1676.5	1.7593	0.853	1483.8	1673.1	1.7377
1400	1.091	1531.9	1733.7	1.7909	0.906	1529.6	1730.7	1.7696
1600	1.215	1624.4	1849.3	1.8499	1.011	1622.6	1847.1	1.8290
$p = 1400 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 587.2^\circ\text{F}$ )					$p = 1600 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 605.1^\circ\text{F}$ )			
Sat.	0.302	1096.0	1174.1	1.3461	0.255	1087.4	1162.9	1.3258
600	0.318	1110.9	1193.1	1.3641	0.303	1137.8	1227.4	1.3852
650	0.367	1155.5	1250.5	1.4171	0.342	1177.0	1278.1	1.4299
700	0.406	1189.6	1294.8	1.4562	0.403	1237.7	1357.0	1.4953
800	0.471	1245.8	1367.9	1.5168	0.466	1289.5	1424.4	1.5468
900	0.529	1295.6	1432.5	1.5661	0.504	1338.0	1487.1	1.5913
1000	0.582	1342.8	1493.5	1.6094	0.549	1385.2	1547.7	1.6315
1100	0.632	1389.1	1552.8	1.6487	0.592	1431.8	1607.1	1.6684
1200	0.681	1435.1	1611.4	1.6851	0.634	1478.3	1666.1	1.7029
1300	0.728	1481.1	1669.6	1.7192	0.675	1524.9	1724.8	1.7354
1400	0.774	1527.2	1727.8	1.7513	0.755	1619.0	1842.6	1.7955
1600	0.865	1620.8	1844.8	1.8111				
$p = 1800 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 621.2^\circ\text{F}$ )					$p = 2000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 636.0^\circ\text{F}$ )			
Sat.	0.218	1077.7	1150.4	1.3060	0.188	1066.6	1136.3	1.2861
650	0.251	1117.0	1200.4	1.3517	0.206	1091.1	1167.2	1.3141
700	0.291	1163.1	1259.9	1.4042	0.249	1147.7	1239.8	1.3782
750	0.322	1198.6	1305.9	1.4430	0.280	1187.3	1291.1	1.4216
800	0.350	1229.1	1345.7	1.4753	0.307	1220.1	1333.8	1.4562
900	0.399	1283.2	1416.1	1.5291	0.353	1276.8	1407.6	1.5126
1000	0.443	1333.1	1480.7	1.5749	0.395	1328.1	1474.1	1.5598
1100	0.484	1381.2	1542.5	1.6159	0.433	1377.2	1537.2	1.6017
1200	0.524	1428.5	1602.9	1.6534	0.469	1425.2	1598.6	1.6398
1300	0.561	1475.5	1662.5	1.6883	0.503	1472.7	1659.0	1.6751
1400	0.598	1522.5	1721.8	1.7211	0.537	1520.2	1718.8	1.7082
1600	0.670	1617.2	1840.4	1.7817	0.602	1615.4	1838.2	1.7692

TABLE A-4E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 2500 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 668.3^\circ\text{F}$ )					$p = 3000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 695.5^\circ\text{F}$ )			
Sat.	0.1306	1031.0	1091.4	1.2327	0.0840	968.8	1015.5	1.1575
700	0.1684	1098.7	1176.6	1.3073	0.0977	1003.9	1058.1	1.1944
750	0.2030	1155.2	1249.1	1.3686	0.1483	1114.7	1197.1	1.3122
800	0.2291	1195.7	1301.7	1.4112	0.1757	1167.6	1265.2	1.3675
900	0.2712	1259.9	1385.4	1.4752	0.2160	1241.8	1361.7	1.4414
1000	0.3069	1315.2	1457.2	1.5262	0.2485	1301.7	1439.6	1.4967
1100	0.3393	1366.8	1523.8	1.5704	0.2772	1356.2	1510.1	1.5434
1200	0.3696	1416.7	1587.7	1.6101	0.3086	1408.0	1576.6	1.5848
1300	0.3984	1465.7	1650.0	1.6465	0.3285	1458.5	1640.9	1.6224
1400	0.4261	1514.2	1711.3	1.6804	0.3524	1508.1	1703.7	1.6571
1500	0.4531	1562.5	1772.1	1.7123	0.3754	1557.3	1765.7	1.6896
1600	0.4795	1610.8	1832.6	1.7424	0.3978	1606.3	1827.1	1.7201
$p = 3500 \text{ lbf/in.}^2$					$p = 4000 \text{ lbf/in.}^2$			
650	0.0249	663.5	679.7	0.8630	0.0245	657.7	675.8	0.8574
700	0.0306	759.5	779.3	0.9506	0.0287	742.1	763.4	0.9345
750	0.1046	1058.4	1126.1	1.2440	0.0633	960.7	1007.5	1.1395
800	0.1363	1134.7	1223.0	1.3226	0.1052	1095.0	1172.9	1.2740
900	0.1763	1222.4	1336.5	1.4096	0.1462	1201.5	1309.7	1.3789
1000	0.2066	1287.6	1421.4	1.4699	0.1752	1272.9	1402.6	1.4449
1100	0.2328	1345.2	1496.0	1.5193	0.1995	1333.9	1481.6	1.4973
1200	0.2566	1399.2	1565.3	1.5624	0.2213	1390.1	1553.9	1.5423
1300	0.2787	1451.1	1631.7	1.6012	0.2414	1443.7	1622.4	1.5823
1400	0.2997	1501.9	1696.1	1.6368	0.2603	1495.7	1688.4	1.6188
1500	0.3199	1552.0	1759.2	1.6699	0.2784	1546.7	1752.8	1.6526
1600	0.3395	1601.7	1831.6	1.7010	0.2959	1597.1	1816.1	1.6841
$p = 4400 \text{ lbf/in.}^2$					$p = 4800 \text{ lbf/in.}^2$			
650	0.0242	653.6	673.3	0.8535	0.0237	649.8	671.0	0.8499
700	0.0278	732.7	755.3	0.9257	0.0271	725.1	749.1	0.9187
750	0.0415	870.8	904.6	1.0513	0.0352	832.6	863.9	1.0154
800	0.0844	1056.5	1125.3	1.2306	0.0668	1011.2	1070.5	1.1827
900	0.1270	1183.7	1287.1	1.3548	0.1109	1164.8	1263.4	1.3310
1000	0.1552	1260.8	1387.2	1.4260	0.1385	1248.3	1317.4	1.4078
1100	0.1784	1324.7	1469.9	1.4809	0.1608	1315.3	1458.1	1.4653
1200	0.1989	1382.8	1544.7	1.5274	0.1802	1375.4	1535.4	1.5133
1300	0.2176	1437.7	1614.9	1.5685	0.1979	1431.7	1607.4	1.5555
1400	0.2352	1490.7	1682.3	1.6057	0.2143	1485.7	1676.1	1.5934
1500	0.2520	1542.7	1747.6	1.6399	0.2300	1538.2	1742.5	1.6282
1600	0.2681	1593.4	1811.7	1.6718	0.2450	1589.8	1807.4	1.6605

H<sub>2</sub>O

TABLE A-5E Properties of Compressed Liquid Water

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 500 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 467.1^\circ\text{F}$ )					$p = 1000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 544.7^\circ\text{F}$ )			
32	0.015994	0.00	1.49	0.00000	0.015967	0.03	2.99	0.00005
50	0.015998	18.02	19.50	0.03599	0.015972	17.99	20.94	0.03592
100	0.016106	67.87	69.36	0.12932	0.016082	67.70	70.68	0.12901
150	0.016318	117.66	119.17	0.21457	0.016293	117.38	120.40	0.21410
200	0.016608	167.65	169.19	0.29341	0.016580	167.26	170.32	0.29281
300	0.017416	268.92	270.53	0.43641	0.017379	268.24	271.46	0.43552
400	0.018608	373.68	375.40	0.56604	0.018550	372.55	375.98	0.56472
Sat.	0.019748	447.70	449.53	0.64904	0.021591	538.39	542.38	0.74320
$p = 1500 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 596.4^\circ\text{F}$ )					$p = 2000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 636.0^\circ\text{F}$ )			
32	0.015939	0.05	4.47	0.00007	0.015912	0.06	5.95	0.00008
50	0.015946	17.95	22.38	0.03584	0.015920	17.91	23.81	0.03575
100	0.016058	67.53	71.99	0.12870	0.016034	67.37	73.30	0.12839
150	0.016268	117.10	121.62	0.21364	0.016244	116.83	122.84	0.21318
200	0.016554	166.87	171.46	0.29221	0.016527	166.49	172.60	0.29162
300	0.017343	267.58	272.39	0.43463	0.017308	266.93	273.33	0.43376
400	0.018493	371.45	376.59	0.56343	0.018439	370.38	377.21	0.56216
500	0.02024	481.8	487.4	0.6853	0.02014	479.8	487.3	0.6832
Sat.	0.02346	605.0	611.5	0.8082	0.02565	662.4	671.9	0.8623
$p = 3000 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 695.5^\circ\text{F}$ )					$p = 4000 \text{ lbf/in.}^2$			
32	0.015859	0.09	8.90	0.00009	0.015807	0.10	11.80	0.00005
50	0.015870	17.84	26.65	0.03555	0.015821	17.76	29.47	0.03534
100	0.015987	67.04	75.91	0.12777	0.015942	66.72	78.52	0.12714
150	0.016196	116.30	125.29	0.21226	0.016150	115.77	127.73	0.21136
200	0.016476	165.74	174.89	0.29046	0.016425	165.02	177.18	0.28931
300	0.017240	265.66	275.23	0.43205	0.017174	264.43	277.15	0.43038
400	0.018334	368.32	378.50	0.55970	0.018235	366.35	379.85	0.55734
500	0.019944	476.2	487.3	0.6794	0.019766	472.9	487.5	0.6758
Sat.	0.034310	783.5	802.5	0.9732				

H<sub>2</sub>O

TABLE A-6E Properties of Saturated Water (Solid-Vapor): Temperature Table

Temp. °F	Press. lbf/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb			Enthalpy Btu/lb			Entropy Btu/lb · °R		
		Sat. Solid $v_i$	Sat. Vapor $v_g \times 10^{-3}$	Sat. Solid $u_i$	Subl. $u_{ig}$	Sat. Vapor $u_g$	Sat. Solid $h_i$	Subl. $h_{ig}$	Sat. Vapor $h_g$	Sat. Solid $s_i$	Subl. $s_{ig}$	Sat. Vapor $s_g$
32.018	.0887	.01747	3.302	-143.34	1164.6	1021.2	-143.34	1218.7	1075.4	-.292	2.479	2.187
32	.0886	.01747	3.305	-143.35	1164.6	1021.2	-143.35	1218.7	1075.4	-.292	2.479	2.187
30	.0808	.01747	3.607	-144.35	1164.9	1020.5	-144.35	1218.9	1074.5	-.294	2.489	2.195
25	.0641	.01746	4.506	-146.84	1165.7	1018.9	-146.84	1219.1	1072.3	-.299	2.515	2.216
20	.0505	.01745	5.655	-149.31	1166.5	1017.2	-149.31	1219.4	1070.1	-.304	2.542	2.238
15	.0396	.01745	7.13	-151.75	1167.3	1015.5	-151.75	1219.7	1067.9	-.309	2.569	2.260
10	.0309	.01744	9.04	-154.17	1168.1	1013.9	-154.17	1219.9	1065.7	-.314	2.597	2.283
5	.0240	.01743	11.52	-156.56	1168.8	1012.2	-156.56	1220.1	1063.5	-.320	2.626	2.306
0	.0185	.01743	14.77	-158.93	1169.5	1010.6	-158.93	1220.2	1061.2	-.325	2.655	2.330
-5	.0142	.01742	19.03	-161.27	1170.2	1008.9	-161.27	1220.3	1059.0	-.330	2.684	2.354
-10	.0109	.01741	24.66	-163.59	1170.9	1007.3	-163.59	1220.4	1056.8	-.335	2.714	2.379
-15	.0082	.01740	32.2	-165.89	1171.5	1005.6	-165.89	1220.5	1054.6	-.340	2.745	2.405
-20	.0062	.01740	42.2	-168.16	1172.1	1003.9	-168.16	1220.6	1052.4	-.345	2.776	2.431
-25	.0046	.01739	55.7	-170.40	1172.7	1002.3	-170.40	1220.6	1050.2	-.351	2.808	2.457
-30	.0035	.01738	74.1	-172.63	1173.2	1000.6	-172.63	1220.6	1048.0	-.356	2.841	2.485
-35	.0026	.01737	99.2	-174.82	1173.8	998.9	-174.82	1220.6	1045.8	-.361	2.874	2.513
-40	.0019	.01737	133.8	-177.00	1174.3	997.3	-177.00	1220.6	1043.6	-.366	2.908	2.542

H<sub>2</sub>O

TABLE A-7E Properties of Saturated Refrigerant 22 (Liquid-Vapor): Temperature Table

Temp. °F	Press. lbf/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
-80	4.781	0.01090	9.6984	-10.30	87.24	-10.29	106.11	95.82	-0.0257	0.2538	-80
-60	8.834	0.01113	5.4744	-5.20	89.16	-5.18	103.30	98.12	-0.0126	0.2458	-60
-55	10.187	0.01120	4.7933	-3.91	89.64	-3.89	102.58	98.68	-0.0094	0.2441	-55
-50	11.701	0.01126	4.2123	-2.62	90.12	-2.60	101.84	99.24	-0.0063	0.2424	-50
-45	13.387	0.01132	3.7147	-1.33	90.59	-1.30	101.10	99.80	-0.0031	0.2407	-45
-40	15.261	0.01139	3.2869	-0.03	91.07	0.00	100.35	100.35	0.0000	0.2391	-40
-35	17.335	0.01145	2.9176	1.27	91.54	1.31	99.59	100.90	0.0031	0.2376	-35
-30	19.624	0.01152	2.5976	2.58	92.00	2.62	98.82	101.44	0.0061	0.2361	-30
-25	22.142	0.01159	2.3195	3.89	92.47	3.94	98.04	101.98	0.0092	0.2347	-25
-20	24.906	0.01166	2.0768	5.21	92.93	5.26	97.24	102.50	0.0122	0.2334	-20
-15	27.931	0.01173	1.8644	6.53	93.38	6.59	96.43	103.03	0.0152	0.2321	-15
-10	31.233	0.01181	1.6780	7.86	93.84	7.93	95.61	103.54	0.0182	0.2308	-10
-5	34.829	0.01188	1.5138	9.19	94.28	9.27	94.78	104.05	0.0211	0.2296	-5
0	38.734	0.01196	1.3688	10.53	94.73	10.62	93.93	104.55	0.0240	0.2284	0
5	42.967	0.01204	1.2404	11.88	95.17	11.97	93.06	105.04	0.0270	0.2272	5
10	47.545	0.01212	1.1264	13.23	95.60	13.33	92.18	105.52	0.0298	0.2261	10
15	52.486	0.01220	1.0248	14.58	96.03	14.70	91.29	105.99	0.0327	0.2250	15
20	57.808	0.01229	0.9342	15.95	96.45	16.08	90.38	106.45	0.0356	0.2240	20
25	63.529	0.01237	0.8531	17.31	96.87	17.46	89.45	106.90	0.0384	0.2230	25
30	69.668	0.01246	0.7804	18.69	97.28	18.85	88.50	107.35	0.0412	0.2220	30
35	76.245	0.01255	0.7150	20.07	97.68	20.25	87.53	107.78	0.0441	0.2210	35
40	83.278	0.01265	0.6561	21.46	98.08	21.66	86.54	108.20	0.0468	0.2200	40
45	90.787	0.01275	0.6029	22.86	98.47	23.07	85.53	108.60	0.0496	0.2191	45
50	98.792	0.01285	0.5548	24.27	98.84	24.50	84.49	108.99	0.0524	0.2182	50
55	107.31	0.01295	0.5112	25.68	99.22	25.94	83.44	109.37	0.0552	0.2173	55
60	116.37	0.01306	0.4716	27.10	99.58	27.38	82.36	109.74	0.0579	0.2164	60
65	125.98	0.01317	0.4355	28.53	99.93	28.84	81.25	110.09	0.0607	0.2155	65
70	136.18	0.01328	0.4027	29.98	100.27	30.31	80.11	110.42	0.0634	0.2147	70
75	146.97	0.01340	0.3726	31.43	100.60	31.79	78.95	110.74	0.0661	0.2138	75
80	158.38	0.01352	0.3452	32.89	100.92	33.29	77.75	111.04	0.0689	0.2130	80
85	170.44	0.01365	0.3200	34.36	101.22	34.80	76.53	111.32	0.0716	0.2121	85
90	183.16	0.01378	0.2969	35.85	101.51	36.32	75.26	111.58	0.0743	0.2113	90
95	196.57	0.01392	0.2756	37.35	101.79	37.86	73.96	111.82	0.0771	0.2104	95
100	210.69	0.01407	0.2560	38.86	102.05	39.41	72.63	112.04	0.0798	0.2095	100
105	225.54	0.01422	0.2379	40.39	102.29	40.99	71.24	112.23	0.0825	0.2087	105
110	241.15	0.01438	0.2212	41.94	102.52	42.58	69.82	112.40	0.0852	0.2078	110
115	257.55	0.01455	0.2058	43.50	102.72	44.19	68.34	112.53	0.0880	0.2069	115
120	274.75	0.01472	0.1914	45.08	102.90	45.83	66.81	112.64	0.0907	0.2060	120
140	352.17	0.01555	0.1433	51.62	103.36	52.64	60.06	112.70	0.1019	0.2021	140

Source: Tables A-7E through A-9E are calculated based on equations from A. Kamei and S. W. Beyerlein, "A Fundamental Equation for Chlorodifluoromethane (R-22)," *Fluid Phase Equilibria*, Vol. 80, No. 11, 1992, pp. 71-86.

TABLE A-8E Properties of Saturated Refrigerant 22 (Liquid-Vapor): Pressure Table

Press. lbf/in. <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Press. lbf/in. <sup>2</sup>
		Sat. Liquid <i>v<sub>f</sub></i>	Sat. Vapor <i>v<sub>g</sub></i>	Sat. Liquid <i>u<sub>f</sub></i>	Sat. Vapor <i>u<sub>g</sub></i>	Sat. Liquid <i>h<sub>f</sub></i>	Evap. <i>h<sub>fg</sub></i>	Sat. Vapor <i>h<sub>g</sub></i>	Sat. Liquid <i>s<sub>f</sub></i>	Sat. Vapor <i>s<sub>g</sub></i>	
5	-78.62	0.01091	9.3014	-9.95	87.37	-9.93	105.92	95.98	-0.0248	0.2532	5
10	-55.66	0.01119	4.8769	-4.08	89.58	-4.06	102.67	98.61	-0.0098	0.2443	10
15	-40.67	0.01138	3.3402	-0.21	91.00	-0.17	100.45	100.28	-0.0004	0.2393	15
20	-29.22	0.01153	2.5518	2.78	92.07	2.83	98.70	101.52	0.0066	0.2359	20
25	-19.84	0.01166	2.0695	5.25	92.94	5.31	97.22	102.52	0.0123	0.2333	25
30	-11.82	0.01178	1.7430	7.38	93.67	7.44	95.91	103.35	0.0171	0.2313	30
35	-4.77	0.01189	1.5068	9.25	94.30	9.33	94.74	104.07	0.0212	0.2295	35
40	1.54	0.01198	1.3277	10.94	94.86	11.03	93.66	104.70	0.0249	0.2280	40
45	7.27	0.01207	1.1870	12.49	95.37	12.59	92.67	105.26	0.0283	0.2267	45
50	12.53	0.01216	1.0735	13.91	95.82	14.03	91.73	105.76	0.0313	0.2256	50
55	17.41	0.01224	0.9799	15.24	96.23	15.36	90.85	106.21	0.0341	0.2245	55
60	21.96	0.01232	0.9014	16.48	96.62	16.62	90.01	106.63	0.0367	0.2236	60
65	26.23	0.01239	0.8345	17.65	96.97	17.80	89.21	107.01	0.0391	0.2227	65
70	30.26	0.01247	0.7768	18.76	97.30	18.92	88.45	107.37	0.0414	0.2219	70
75	34.08	0.01254	0.7265	19.82	97.61	19.99	87.71	107.70	0.0435	0.2212	75
80	37.71	0.01260	0.6823	20.83	97.90	21.01	86.99	108.00	0.0456	0.2205	80
85	41.18	0.01267	0.6431	21.79	98.17	21.99	86.30	108.29	0.0475	0.2198	85
90	44.49	0.01274	0.6081	22.72	98.43	22.93	85.63	108.56	0.0494	0.2192	90
95	47.67	0.01280	0.5766	23.61	98.67	23.84	84.98	108.81	0.0511	0.2186	95
100	50.73	0.01286	0.5482	24.47	98.90	24.71	84.34	109.05	0.0528	0.2181	100
110	56.52	0.01298	0.4988	26.11	99.33	26.37	83.11	109.49	0.0560	0.2170	110
120	61.92	0.01310	0.4573	27.65	99.71	27.94	81.93	109.88	0.0590	0.2161	120
130	67.00	0.01321	0.4220	29.11	100.07	29.43	80.80	110.22	0.0618	0.2152	130
140	71.80	0.01332	0.3915	30.50	100.39	30.84	79.70	110.54	0.0644	0.2144	140
150	76.36	0.01343	0.3649	31.82	100.69	32.20	78.63	110.82	0.0669	0.2136	150
160	80.69	0.01354	0.3416	33.09	100.96	33.49	77.59	111.08	0.0693	0.2128	160
170	84.82	0.01365	0.3208	34.31	101.21	34.74	76.57	111.31	0.0715	0.2121	170
180	88.78	0.01375	0.3023	35.49	101.44	35.95	75.57	111.52	0.0737	0.2115	180
190	92.58	0.01386	0.2857	36.62	101.66	37.11	74.60	111.71	0.0757	0.2108	190
200	96.24	0.01396	0.2706	37.72	101.86	38.24	73.64	111.88	0.0777	0.2102	200
225	104.82	0.01422	0.2386	40.34	102.28	40.93	71.29	112.22	0.0824	0.2087	225
250	112.73	0.01447	0.2126	42.79	102.63	43.46	69.02	112.47	0.0867	0.2073	250
275	120.07	0.01473	0.1912	45.10	102.91	45.85	66.79	112.64	0.0908	0.2060	275
300	126.94	0.01499	0.1732	47.30	103.11	48.14	64.60	112.73	0.0946	0.2047	300
325	133.39	0.01525	0.1577	49.42	103.26	50.33	62.42	112.75	0.0982	0.2034	325
350	139.49	0.01552	0.1444	51.45	103.35	52.46	60.25	112.71	0.1016	0.2022	350

R-22

TABLE A-9E Properties of Superheated Refrigerant 22 Vapor

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 5 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -78.62^\circ\text{F}$ )					$p = 10 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -55.66^\circ\text{F}$ )			
Sat.	9.3014	87.37	95.98	0.2532	4.8769	89.58	98.61	0.2443
-70	9.5244	88.31	97.13	0.2562				
-60	9.7823	89.43	98.48	0.2596				
-50	10.0391	90.55	99.84	0.2630	4.9522	90.23	99.40	0.2462
-40	10.2952	91.69	101.22	0.2663	5.0846	91.39	100.81	0.2496
-30	10.5506	92.84	102.61	0.2696	5.2163	92.57	102.23	0.2530
-20	10.8054	94.01	104.01	0.2728	5.3472	93.75	103.65	0.2563
-10	11.0596	95.19	105.43	0.2760	5.4775	94.95	105.09	0.2595
0	11.3133	96.39	106.87	0.2791	5.6073	96.16	106.55	0.2627
10	11.5666	97.60	108.31	0.2822	5.7366	97.39	108.01	0.2658
20	11.8195	98.83	109.77	0.2853	5.8655	98.63	109.49	0.2690
30	12.0720	100.07	111.25	0.2884	5.9941	99.88	110.98	0.2720
40	12.3242	101.33	112.74	0.2914	6.1223	101.15	112.49	0.2751
$p = 15 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -40.67^\circ\text{F}$ )					$p = 20 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -29.22^\circ\text{F}$ )			
Sat.	3.3402	91.00	100.28	0.2393	2.5518	92.07	101.52	0.2359
-40	3.3463	91.08	100.38	0.2396				
-30	3.4370	92.28	101.83	0.2430				
-20	3.5268	93.49	103.28	0.2463	2.6158	93.21	102.90	0.2391
-10	3.6160	94.70	104.75	0.2496	2.6846	94.45	104.39	0.2424
0	3.7046	95.93	106.22	0.2529	2.7528	95.69	105.89	0.2457
10	3.7927	97.17	107.71	0.2561	2.8204	96.95	107.39	0.2490
20	3.8804	98.43	109.20	0.2592	2.8875	98.22	108.91	0.2522
30	3.9677	99.69	110.71	0.2623	2.9542	99.49	110.43	0.2553
40	4.0546	100.97	112.23	0.2654	3.0205	100.78	111.97	0.2584
50	4.1412	102.26	113.76	0.2684	3.0865	102.09	113.52	0.2615
60	4.2275	103.57	115.31	0.2714	3.1522	103.40	115.08	0.2645
70	4.3136	104.89	116.87	0.2744	3.2176	104.73	116.65	0.2675
$p = 25 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -19.84^\circ\text{F}$ )					$p = 30 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -11.82^\circ\text{F}$ )			
Sat.	2.0695	92.94	102.52	0.2333	1.7430	93.67	103.35	0.2313
-10	2.1252	94.18	104.02	0.2367	1.7518	93.91	103.64	0.2319
0	2.1812	95.45	105.54	0.2400	1.7997	95.19	105.19	0.2353
10	2.2365	96.72	107.07	0.2433	1.8470	96.48	106.74	0.2386
20	2.2914	98.00	108.61	0.2466	1.8937	97.78	108.30	0.2419
30	2.3458	99.29	110.15	0.2498	1.9400	99.09	109.86	0.2451
40	2.3998	100.59	111.70	0.2529	1.9858	100.40	111.43	0.2483
50	2.4535	101.91	113.27	0.2560	2.0313	101.73	113.01	0.2514
60	2.5068	103.23	114.84	0.2590	2.0764	103.06	114.60	0.2545
70	2.5599	104.57	116.42	0.2621	2.1213	104.41	116.19	0.2576
80	2.6127	105.92	118.01	0.2650	2.1659	105.77	117.80	0.2606
90	2.6654	107.28	119.62	0.2680	2.2103	107.13	119.41	0.2635
100	2.7178	108.65	121.24	0.2709	2.2545	108.52	121.04	0.2665

R-22

TABLE A-9E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 40 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 1.54^\circ\text{F}$ )				$p = 50 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 12.53^\circ\text{F}$ )				
Sat.	1.3277	94.86	104.70	0.2280	1.0735	95.82	105.76	0.2256
10	1.3593	95.99	106.06	0.2310				
20	1.3960	97.33	107.67	0.2343	1.0965	96.85	107.00	0.2282
30	1.4321	98.66	109.27	0.2376	1.1268	98.22	108.65	0.2316
40	1.4678	100.01	110.88	0.2409	1.1565	99.59	110.30	0.2349
50	1.5032	101.35	112.49	0.2441	1.1858	100.97	111.95	0.2382
60	1.5381	102.71	114.10	0.2472	1.2147	102.35	113.60	0.2414
70	1.5728	104.08	115.73	0.2503	1.2433	103.74	115.25	0.2445
80	1.6071	105.45	117.36	0.2534	1.2716	105.13	116.90	0.2476
90	1.6413	106.84	118.99	0.2564	1.2996	106.53	118.57	0.2507
100	1.6752	108.23	120.64	0.2593	1.3274	107.95	120.24	0.2537
110	1.7089	109.64	122.30	0.2623	1.3549	109.37	121.91	0.2567
120	1.7424	111.06	123.97	0.2652	1.3823	110.80	123.60	0.2596
$p = 60 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 21.96^\circ\text{F}$ )				$p = 70 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 30.26^\circ\text{F}$ )				
Sat.	0.9014	96.62	106.63	0.2236	0.7768	97.30	107.37	0.2219
30	0.9226	97.75	108.00	0.2264				
40	0.9485	99.16	109.70	0.2298	0.7994	98.71	109.07	0.2254
50	0.9739	100.57	111.39	0.2332	0.8221	100.15	110.81	0.2288
60	0.9988	101.98	113.07	0.2365	0.8443	101.59	112.53	0.2321
70	1.0234	103.39	114.76	0.2397	0.8660	103.03	114.25	0.2354
80	1.0476	104.80	116.44	0.2428	0.8874	104.46	115.97	0.2386
90	1.0716	106.22	118.13	0.2459	0.9086	105.90	117.68	0.2418
100	1.0953	107.65	119.82	0.2490	0.9294	107.35	119.40	0.2449
110	1.1188	109.09	121.52	0.2520	0.9500	108.80	121.12	0.2479
120	1.1421	110.53	123.22	0.2549	0.9704	110.26	122.84	0.2509
130	1.1653	111.99	124.93	0.2579	0.9907	111.73	124.57	0.2539
140	1.1883	113.45	126.65	0.2608	1.0107	113.21	126.31	0.2568
$p = 80 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 37.71^\circ\text{F}$ )				$p = 90 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 44.49^\circ\text{F}$ )				
Sat.	0.6823	97.90	108.00	0.2205	0.6081	98.43	108.56	0.2192
40	0.6871	98.24	108.42	0.2213				
50	0.7079	99.72	110.20	0.2248	0.6186	99.26	109.57	0.2212
60	0.7280	101.19	111.97	0.2283	0.6373	100.77	111.39	0.2247
70	0.7478	102.65	113.73	0.2316	0.6555	102.27	113.19	0.2282
80	0.7671	104.11	115.48	0.2349	0.6733	103.76	114.98	0.2315
90	0.7861	105.58	117.22	0.2381	0.6907	105.24	116.75	0.2348
100	0.8048	107.04	118.97	0.2412	0.7078	106.73	118.52	0.2380
110	0.8233	108.51	120.71	0.2443	0.7246	108.22	120.29	0.2411
120	0.8416	109.99	122.45	0.2474	0.7412	109.71	122.06	0.2442
130	0.8596	111.47	124.20	0.2504	0.7576	111.20	123.83	0.2472
140	0.8775	112.96	125.96	0.2533	0.7739	112.71	125.60	0.2502
150	0.8953	114.46	127.72	0.2562	0.7899	114.22	127.38	0.2531

TABLE A-9E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 100 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 50.73^\circ\text{F}$ )					$p = 120 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 61.92^\circ\text{F}$ )			
Sat.	0.5482	98.90	109.05	0.2181	0.4573	99.71	109.88	0.2161
60	0.5645	100.33	110.79	0.2214				
80	0.5980	103.38	114.46	0.2284	0.4846	102.60	113.37	0.2227
100	0.6300	106.40	118.07	0.2349	0.5130	105.73	117.13	0.2295
120	0.6609	109.42	121.66	0.2412	0.5400	108.83	120.83	0.2360
140	0.6908	112.45	125.24	0.2473	0.5661	111.92	124.50	0.2422
160	0.7201	115.50	128.83	0.2532	0.5914	115.02	128.16	0.2482
180	0.7489	118.58	132.45	0.2589	0.6161	118.15	131.84	0.2541
200	0.7771	121.69	136.08	0.2645	0.6404	121.30	135.53	0.2597
220	0.8051	124.84	139.75	0.2700	0.6642	124.48	139.24	0.2653
240	0.8327	128.04	143.45	0.2754	0.6878	127.69	142.98	0.2707
260	0.8600	131.27	147.19	0.2806	0.7110	130.95	146.75	0.2760
280	0.8871	134.54	150.97	0.2858	0.7340	134.24	150.55	0.2812
300	0.9140	137.85	154.78	0.2909	0.7568	137.57	154.39	0.2863
$p = 140 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 71.80^\circ\text{F}$ )					$p = 160 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 80.69^\circ\text{F}$ )			
Sat.	0.3915	100.39	110.54	0.2144	0.3416	100.96	111.08	0.2128
80	0.4028	101.76	112.20	0.2175				
100	0.4289	105.02	116.14	0.2246	0.3653	104.26	115.08	0.2201
120	0.4534	108.21	119.96	0.2313	0.3881	107.56	119.06	0.2271
140	0.4768	111.37	123.73	0.2377	0.4095	110.81	122.94	0.2337
160	0.4993	114.53	127.48	0.2439	0.4301	114.03	126.77	0.2400
180	0.5212	117.70	131.21	0.2498	0.4499	117.25	130.57	0.2460
200	0.5426	120.89	134.96	0.2556	0.4692	120.47	134.37	0.2518
220	0.5636	124.10	138.71	0.2612	0.4880	123.72	138.18	0.2575
240	0.5842	127.35	142.49	0.2666	0.5065	126.99	142.00	0.2631
260	0.6045	130.62	146.30	0.2720	0.5246	130.30	145.84	0.2685
280	0.6246	133.94	150.13	0.2773	0.5425	133.63	149.70	0.2738
300	0.6445	137.29	154.00	0.2824	0.5602	137.00	153.60	0.2790
320	0.6642	140.68	157.89	0.2875	0.5777	140.41	157.62	0.2841
$p = 180 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 88.78^\circ\text{F}$ )					$p = 200 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 96.24^\circ\text{F}$ )			
Sat.	0.3023	101.44	111.52	0.2115	0.2706	101.86	111.88	0.2102
100	0.3154	103.44	113.95	0.2159	0.2748	102.56	112.73	0.2117
120	0.3369	106.88	118.11	0.2231	0.2957	106.15	117.10	0.2194
140	0.3570	110.21	122.11	0.2299	0.3148	109.59	121.25	0.2264
160	0.3761	113.50	126.04	0.2364	0.3327	112.96	125.28	0.2330
180	0.3943	116.78	129.92	0.2425	0.3497	116.29	129.25	0.2393
200	0.4120	120.05	133.78	0.2485	0.3661	119.61	133.17	0.2454
220	0.4292	123.33	137.64	0.2542	0.3820	122.94	137.08	0.2512
240	0.4459	126.64	141.50	0.2598	0.3975	126.27	140.99	0.2569
260	0.4624	129.96	145.38	0.2653	0.4126	129.63	144.91	0.2624
280	0.4786	133.32	149.28	0.2706	0.4275	133.01	148.84	0.2678
300	0.4946	136.71	153.20	0.2759	0.4422	136.42	152.79	0.2731
320	0.5104	140.13	157.15	0.2810	0.4566	139.86	156.77	0.2782
340	0.5260	143.59	161.12	0.2860	0.4709	143.33	160.77	0.2833

TABLE A-9E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R				
$p = 225 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 104.82^\circ\text{F}$ )								$p = 250 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 112.73^\circ\text{F}$ )				
Sat.	0.2386	102.28	112.22	0.2087	0.2126	102.63	112.47	0.2073	0.2198	104.10	114.27	0.2104
120	0.2539	105.17	115.75	0.2149	0.2378	107.90	118.91	0.2183	0.2540	111.51	123.27	0.2255
140	0.2722	108.78	120.12	0.2223	0.2690	115.02	127.48	0.2321	0.2833	118.48	131.59	0.2385
160	0.2891	112.26	124.30	0.2291	0.2969	121.91	135.66	0.2445	0.3101	125.33	139.69	0.2504
180	0.3050	115.67	128.38	0.2356	0.3229	128.76	143.71	0.2560	0.3354	132.21	147.73	0.2616
200	0.3202	119.06	132.40	0.2418	0.3476	135.67	151.76	0.2669	0.3596	139.16	155.81	0.2722
220	0.3348	122.43	136.38	0.2477	0.3715	142.67	159.87	0.2773	0.3831	146.22	163.95	0.2824
240	0.3490	125.81	140.35	0.2535								
260	0.3628	129.20	144.32	0.2591								
280	0.3764	132.61	148.29	0.2645								
300	0.3896	136.05	152.28	0.2699								
320	0.4027	139.51	156.29	0.2751								
340	0.4156	143.00	160.32	0.2802								
360	0.4284	146.33	164.38	0.2852								
$p = 275 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 120.07^\circ\text{F}$ )								$p = 300 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 126.94^\circ\text{F}$ )				
Sat.	0.1912	102.91	112.64	0.2060	0.1732	103.11	112.73	0.2047	0.1849	105.93	116.20	0.2105
140	0.2092	106.96	117.61	0.2144	0.2006	109.89	121.04	0.2185	0.2146	133.64	125.56	0.2257
160	0.2250	110.73	122.19	0.2219	0.2276	117.26	129.91	0.2324	0.2399	120.83	134.15	0.2387
180	0.2395	144.35	126.54	0.2288	0.2516	124.35	138.33	0.2447	0.2629	127.87	142.47	0.2506
200	0.2530	117.88	130.77	0.2353	0.2739	131.38	146.59	0.2562	0.2845	134.90	150.71	0.2617
220	0.2659	121.38	134.91	0.2415	0.2949	138.44	154.83	0.2671	0.3051	142.00	158.95	0.2723
240	0.2782	124.85	139.02	0.2475	0.3152	145.58	163.09	0.2774				
260	0.2902	128.32	143.10	0.2532								
280	0.3018	131.80	147.17	0.2588								
300	0.3132	135.29	151.24	0.2642								
320	0.3243	138.80	155.32	0.2695								
340	0.3353	142.34	159.41	0.2747								
360	0.3461	145.90	163.53	0.2798								
$p = 325 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 133.39^\circ\text{F}$ )								$p = 350 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 139.49^\circ\text{F}$ )				
Sat.	0.1577	103.26	112.75	0.2034	0.1444	103.35	112.71	0.2022	0.1448	103.48	112.86	0.2024
140	0.1637	104.78	114.63	0.2066	0.1605	107.90	118.30	0.2113	0.1747	112.06	123.38	0.2194
160	0.1796	109.00	119.81	0.2151	0.1874	115.95	128.10	0.2267	0.1987	119.65	132.53	0.2333
180	0.1934	112.89	124.53	0.2226	0.2095	123.31	136.89	0.2396	0.2199	126.93	141.18	0.2457
200	0.2061	116.62	129.02	0.2295	0.2297	130.52	145.41	0.2514	0.2393	134.12	149.62	0.2571
220	0.2179	120.26	133.37	0.2360	0.2486	137.71	153.82	0.2626	0.2486	137.71	153.82	0.2626
240	0.2291	123.84	137.63	0.2422	0.2577	141.32	158.02	0.2679	0.2577	141.32	158.02	0.2679
260	0.2398	127.40	141.83	0.2481	0.2666	144.95	162.23	0.2730	0.2666	144.95	162.23	0.2730
280	0.2501	130.96	146.01	0.2538	0.2754	148.59	166.43	0.2781	0.2754	148.59	166.43	0.2781
300	0.2602	134.51	150.17	0.2593								
320	0.2700	138.08	154.33	0.2647								
340	0.2796	141.66	158.49	0.2700								
360	0.2891	145.26	162.66	0.2752								
380	0.2983	148.89	166.85	0.2802								

R-22

TABLE A-10E Properties of Saturated Refrigerant 134a (Liquid-Vapor): Temperature Table

Temp. °F	Press. lbf/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
-40	7.490	0.01130	5.7173	-0.02	87.90	0.00	95.82	95.82	0.0000	0.2283	-40
-30	9.920	0.01143	4.3911	2.81	89.26	2.83	94.49	97.32	0.0067	0.2266	-30
-20	12.949	0.01156	3.4173	5.69	90.62	5.71	93.10	98.81	0.0133	0.2250	-20
-15	14.718	0.01163	3.0286	7.14	91.30	7.17	92.38	99.55	0.0166	0.2243	-15
-10	16.674	0.01170	2.6918	8.61	91.98	8.65	91.64	100.29	0.0199	0.2236	-10
-5	18.831	0.01178	2.3992	10.09	92.66	10.13	90.89	101.02	0.0231	0.2230	-5
0	21.203	0.01185	2.1440	11.58	93.33	11.63	90.12	101.75	0.0264	0.2224	0
5	23.805	0.01193	1.9208	13.09	94.01	13.14	89.33	102.47	0.0296	0.2219	5
10	26.651	0.01200	1.7251	14.60	94.68	14.66	88.53	103.19	0.0329	0.2214	10
15	29.756	0.01208	1.5529	16.13	95.35	16.20	87.71	103.90	0.0361	0.2209	15
20	33.137	0.01216	1.4009	17.67	96.02	17.74	86.87	104.61	0.0393	0.2205	20
25	36.809	0.01225	1.2666	19.22	96.69	19.30	86.02	105.32	0.0426	0.2200	25
30	40.788	0.01233	1.1474	20.78	97.35	20.87	85.14	106.01	0.0458	0.2196	30
40	49.738	0.01251	0.9470	23.94	98.67	24.05	83.34	107.39	0.0522	0.2189	40
50	60.125	0.01270	0.7871	27.14	99.98	27.28	81.46	108.74	0.0585	0.2183	50
60	72.092	0.01290	0.6584	30.39	101.27	30.56	79.49	110.05	0.0648	0.2178	60
70	85.788	0.01311	0.5538	33.68	102.54	33.89	77.44	111.33	0.0711	0.2173	70
80	101.37	0.01334	0.4682	37.02	103.78	37.27	75.29	112.56	0.0774	0.2169	80
85	109.92	0.01346	0.4312	38.72	104.39	38.99	74.17	113.16	0.0805	0.2167	85
90	118.99	0.01358	0.3975	40.42	105.00	40.72	73.03	113.75	0.0836	0.2165	90
95	128.62	0.01371	0.3668	42.14	105.60	42.47	71.86	114.33	0.0867	0.2163	95
100	138.83	0.01385	0.3388	43.87	106.18	44.23	70.66	114.89	0.0898	0.2161	100
105	149.63	0.01399	0.3131	45.62	106.76	46.01	69.42	115.43	0.0930	0.2159	105
110	161.04	0.01414	0.2896	47.39	107.33	47.81	68.15	115.96	0.0961	0.2157	110
115	173.10	0.01429	0.2680	49.17	107.88	49.63	66.84	116.47	0.0992	0.2155	115
120	185.82	0.01445	0.2481	50.97	108.42	51.47	65.48	116.95	0.1023	0.2153	120
140	243.86	0.01520	0.1827	58.39	110.41	59.08	59.57	118.65	0.1150	0.2143	140
160	314.63	0.01617	0.1341	66.26	111.97	67.20	52.58	119.78	0.1280	0.2128	160
180	400.22	0.01758	0.0964	74.83	112.77	76.13	43.78	119.91	0.1417	0.2101	180
200	503.52	0.02014	0.0647	84.90	111.66	86.77	30.92	117.69	0.1575	0.2044	200
210	563.51	0.02329	0.0476	91.84	108.48	94.27	19.18	113.45	0.1684	0.1971	210

Source: Tables A-10E through A-12E are calculated based on equations from D. P. Wilson and R. S. Basu, "Thermodynamic Properties of a New Stratospherically Safe Working Fluid—Refrigerant 134a," *ASHRAE Trans.*, Vol. 94, Pt. 2, 1988, pp. 2095–2118.

TABLE A-11E Properties of Saturated Refrigerant 134a (Liquid-Vapor): Pressure Table

Press. lbf/in. <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Press. lbf/in. <sup>2</sup>
		Sat. Liquid <i>v<sub>f</sub></i>	Sat. Vapor <i>v<sub>g</sub></i>	Sat. Liquid <i>u<sub>f</sub></i>	Sat. Vapor <i>u<sub>g</sub></i>	Sat. Liquid <i>h<sub>f</sub></i>	Evap. <i>h<sub>fg</sub></i>	Sat. Vapor <i>h<sub>g</sub></i>	Sat. Liquid <i>s<sub>f</sub></i>	Sat. Vapor <i>s<sub>g</sub></i>	
5	-53.48	0.01113	8.3508	-3.74	86.07	-3.73	97.53	93.79	-0.0090	0.2311	5
10	-29.71	0.01143	4.3581	2.89	89.30	2.91	94.45	97.37	0.0068	0.2265	10
15	-14.25	0.01164	2.9747	7.36	91.40	7.40	92.27	99.66	0.0171	0.2242	15
20	-2.48	0.01181	2.2661	10.84	93.00	10.89	90.50	101.39	0.0248	0.2227	20
30	15.38	0.01209	1.5408	16.24	95.40	16.31	87.65	103.96	0.0364	0.2209	30
40	29.04	0.01232	1.1692	20.48	97.23	20.57	85.31	105.88	0.0452	0.2197	40
50	40.27	0.01252	0.9422	24.02	98.71	24.14	83.29	107.43	0.0523	0.2189	50
60	49.89	0.01270	0.7887	27.10	99.96	27.24	81.48	108.72	0.0584	0.2183	60
70	58.35	0.01286	0.6778	29.85	101.05	30.01	79.82	109.83	0.0638	0.2179	70
80	65.93	0.01302	0.5938	32.33	102.02	32.53	78.28	110.81	0.0686	0.2175	80
90	72.83	0.01317	0.5278	34.62	102.89	34.84	76.84	111.68	0.0729	0.2172	90
100	79.17	0.01332	0.4747	36.75	103.68	36.99	75.47	112.46	0.0768	0.2169	100
120	90.54	0.01360	0.3941	40.61	105.06	40.91	72.91	113.82	0.0839	0.2165	120
140	100.56	0.01386	0.3358	44.07	106.25	44.43	70.52	114.95	0.0902	0.2161	140
160	109.56	0.01412	0.2916	47.23	107.28	47.65	68.26	115.91	0.0958	0.2157	160
180	117.74	0.01438	0.2569	50.16	108.18	50.64	66.10	116.74	0.1009	0.2154	180
200	125.28	0.01463	0.2288	52.90	108.98	53.44	64.01	117.44	0.1057	0.2151	200
220	132.27	0.01489	0.2056	55.48	109.68	56.09	61.96	118.05	0.1101	0.2147	220
240	138.79	0.01515	0.1861	57.93	110.30	58.61	59.96	118.56	0.1142	0.2144	240
260	144.92	0.01541	0.1695	60.28	110.84	61.02	57.97	118.99	0.1181	0.2140	260
280	150.70	0.01568	0.1550	62.53	111.31	63.34	56.00	119.35	0.1219	0.2136	280
300	156.17	0.01596	0.1424	64.71	111.72	65.59	54.03	119.62	0.1254	0.2132	300
350	168.72	0.01671	0.1166	69.88	112.45	70.97	49.03	120.00	0.1338	0.2118	350
400	179.95	0.01758	0.0965	74.81	112.77	76.11	43.80	119.91	0.1417	0.2102	400
450	190.12	0.01863	0.0800	79.63	112.60	81.18	38.08	119.26	0.1493	0.2079	450
500	199.38	0.02002	0.0657	84.54	111.76	86.39	31.44	117.83	0.1570	0.2047	500

R-134a

TABLE A-12E Properties of Superheated Refrigerant 134a Vapor

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 10 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -29.71^\circ\text{F}$ )					$p = 15 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -14.25^\circ\text{F}$ )			
Sat.	4.3581	89.30	97.37	0.2265	2.9747	91.40	99.66	0.2242
-20	4.4718	90.89	99.17	0.2307				
0	4.7026	94.24	102.94	0.2391	3.0893	93.84	102.42	0.2303
20	4.9297	97.67	106.79	0.2472	3.2468	97.33	106.34	0.2386
40	5.1539	101.19	110.72	0.2553	3.4012	100.89	110.33	0.2468
60	5.3758	104.80	114.74	0.2632	3.5533	104.54	114.40	0.2548
80	5.5959	108.50	118.85	0.2709	3.7034	108.28	118.56	0.2626
100	5.8145	112.29	123.05	0.2786	3.8520	112.10	122.79	0.2703
120	6.0318	116.18	127.34	0.2861	3.9993	116.01	127.11	0.2779
140	6.2482	120.16	131.72	0.2935	4.1456	120.00	131.51	0.2854
160	6.4638	124.23	136.19	0.3009	4.2911	124.09	136.00	0.2927
180	6.6786	128.38	140.74	0.3081	4.4359	128.26	140.57	0.3000
200	6.8929	132.63	145.39	0.3152	4.5801	132.52	145.23	0.3072
$p = 20 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -2.48^\circ\text{F}$ )					$p = 30 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 15.38^\circ\text{F}$ )			
Sat.	2.2661	93.00	101.39	0.2227	1.5408	95.40	103.96	0.2209
0	2.2816	93.43	101.88	0.2238				
20	2.4046	96.98	105.88	0.2323	1.5611	96.26	104.92	0.2229
40	2.5244	100.59	109.94	0.2406	1.6465	99.98	109.12	0.2315
60	2.6416	104.28	114.06	0.2487	1.7293	103.75	113.35	0.2398
80	2.7569	108.05	118.25	0.2566	1.8098	107.59	117.63	0.2478
100	2.8705	111.90	122.52	0.2644	1.8887	111.49	121.98	0.2558
120	2.9829	115.83	126.87	0.2720	1.9662	115.47	126.39	0.2635
140	3.0942	119.85	131.30	0.2795	2.0426	119.53	130.87	0.2711
160	3.2047	123.95	135.81	0.2869	2.1181	123.66	135.42	0.2786
180	3.3144	128.13	140.40	0.2922	2.1929	127.88	140.05	0.2859
200	3.4236	132.40	145.07	0.3014	2.2671	132.17	144.76	0.2932
220	3.5323	136.76	149.83	0.3085	2.3407	136.55	149.54	0.3003
$p = 40 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 29.04^\circ\text{F}$ )					$p = 50 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 40.27^\circ\text{F}$ )			
Sat.	1.1692	97.23	105.88	0.2197	0.9422	98.71	107.43	0.2189
40	1.2065	99.33	108.26	0.2245				
60	1.2723	103.20	112.62	0.2331	0.9974	102.62	111.85	0.2276
80	1.3357	107.11	117.00	0.2414	1.0508	106.62	116.34	0.2361
100	1.3973	111.08	121.42	0.2494	1.1022	110.65	120.85	0.2443
120	1.4575	115.11	125.90	0.2573	1.1520	114.74	125.39	0.2523
140	1.5165	119.21	130.43	0.2650	1.2007	118.88	129.99	0.2601
160	1.5746	123.38	135.03	0.2725	1.2484	123.08	134.64	0.2677
180	1.6319	127.62	139.70	0.2799	1.2953	127.36	139.34	0.2752
200	1.6887	131.94	144.44	0.2872	1.3415	131.71	144.12	0.2825
220	1.7449	136.34	149.25	0.2944	1.3873	136.12	148.96	0.2897
240	1.8006	140.81	154.14	0.3015	1.4326	140.61	153.87	0.2969
260	1.8561	145.36	159.10	0.3085	1.4775	145.18	158.85	0.3039
280	1.9112	149.98	164.13	0.3154	1.5221	149.82	163.90	0.3108

R-134a

TABLE A-12E (Continued)

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R
<i>p</i> = 60 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 49.89°F)				<i>p</i> = 70 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 58.35°F)				
Sat.	0.7887	99.96	108.72	0.2183	0.6778	101.05	109.83	0.2179
60	0.8135	102.03	111.06	0.2229	0.6814	101.40	110.23	0.2186
80	0.8604	106.11	115.66	0.2316	0.7239	105.58	114.96	0.2276
100	0.9051	110.21	120.26	0.2399	0.7640	109.76	119.66	0.2361
120	0.9482	114.35	124.88	0.2480	0.8023	113.96	124.36	0.2444
140	0.9900	118.54	129.53	0.2559	0.8393	118.20	129.07	0.2524
160	1.0308	122.79	134.23	0.2636	0.8752	122.49	133.82	0.2601
180	1.0707	127.10	138.98	0.2712	0.9103	126.83	138.62	0.2678
200	1.1100	131.47	143.79	0.2786	0.9446	131.23	143.46	0.2752
220	1.1488	135.91	148.66	0.2859	0.9784	135.69	148.36	0.2825
240	1.1871	140.42	153.60	0.2930	1.0118	140.22	153.33	0.2897
260	1.2251	145.00	158.60	0.3001	1.0448	144.82	158.35	0.2968
280	1.2627	149.65	163.67	0.3070	1.0774	149.48	163.44	0.3038
300	1.3001	154.38	168.81	0.3139	1.1098	154.22	168.60	0.3107
<i>p</i> = 80 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 65.93°F)				<i>p</i> = 90 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 72.83°F)				
Sat.	0.5938	102.02	110.81	0.2175	0.5278	102.89	111.68	0.2172
80	0.6211	105.03	114.23	0.2239	0.5408	104.46	113.47	0.2205
100	0.6579	109.30	119.04	0.2327	0.5751	108.82	118.39	0.2295
120	0.6927	113.56	123.82	0.2411	0.6073	113.15	123.27	0.2380
140	0.7261	117.85	128.60	0.2492	0.6380	117.50	128.12	0.2463
160	0.7584	122.18	133.41	0.2570	0.6675	121.87	132.98	0.2542
180	0.7898	126.55	138.25	0.2647	0.6961	126.28	137.87	0.2620
200	0.8205	130.98	143.13	0.2722	0.7239	130.73	142.79	0.2696
220	0.8506	135.47	148.06	0.2796	0.7512	135.25	147.76	0.2770
240	0.8803	140.02	153.05	0.2868	0.7779	139.82	152.77	0.2843
260	0.9095	144.63	158.10	0.2940	0.8043	144.45	157.84	0.2914
280	0.9384	149.32	163.21	0.3010	0.8303	149.15	162.97	0.2984
300	0.9671	154.06	168.38	0.3079	0.8561	153.91	168.16	0.3054
320	0.9955	158.88	173.62	0.3147	0.8816	158.73	173.42	0.3122
<i>p</i> = 100 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 79.17°F)				<i>p</i> = 120 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 90.54°F)				
Sat.	0.4747	103.68	112.46	0.2169	0.3941	105.06	113.82	0.2165
80	0.4761	103.87	112.68	0.2173				
100	0.5086	108.32	117.73	0.2265	0.4080	107.26	116.32	0.2210
120	0.5388	112.73	122.70	0.2352	0.4355	111.84	121.52	0.2301
140	0.5674	117.13	127.63	0.2436	0.4610	116.37	126.61	0.2387
160	0.5947	121.55	132.55	0.2517	0.4852	120.89	131.66	0.2470
180	0.6210	125.99	137.49	0.2595	0.5082	125.42	136.70	0.2550
200	0.6466	130.48	142.45	0.2671	0.5305	129.97	141.75	0.2628
220	0.6716	135.02	147.45	0.2746	0.5520	134.56	146.82	0.2704
240	0.6960	139.61	152.49	0.2819	0.5731	139.20	151.92	0.2778
260	0.7201	144.26	157.59	0.2891	0.5937	143.89	157.07	0.2850
280	0.7438	148.98	162.74	0.2962	0.6140	148.63	162.26	0.2921
300	0.7672	153.75	167.95	0.3031	0.6339	153.43	167.51	0.2991
320	0.7904	158.59	173.21	0.3099	0.6537	158.29	172.81	0.3060

R-134a

TABLE A-12E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	
$p = 140 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 100.56^\circ\text{F}$ )					$p = 160 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 109.55^\circ\text{F}$ )				
Sat.	0.3358	106.25	114.95	0.2161	0.2916	107.28	115.91	0.2157	
120	0.3610	110.90	120.25	0.2254	0.3044	109.88	118.89	0.2209	
140	0.3846	115.58	125.54	0.2344	0.3269	114.73	124.41	0.2303	
160	0.4066	120.21	130.74	0.2429	0.3474	119.49	129.78	0.2391	
180	0.4274	124.82	135.89	0.2511	0.3666	124.20	135.06	0.2475	
200	0.4474	129.44	141.03	0.2590	0.3849	128.90	140.29	0.2555	
220	0.4666	134.09	146.18	0.2667	0.4023	133.61	145.52	0.2633	
240	0.4852	138.77	151.34	0.2742	0.4192	138.34	150.75	0.2709	
260	0.5034	143.50	156.54	0.2815	0.4356	143.11	156.00	0.2783	
280	0.5212	148.28	161.78	0.2887	0.4516	147.92	161.29	0.2856	
300	0.5387	153.11	167.06	0.2957	0.4672	152.78	166.61	0.2927	
320	0.5559	157.99	172.39	0.3026	0.4826	157.69	171.98	0.2996	
340	0.5730	162.93	177.78	0.3094	0.4978	162.65	177.39	0.3065	
360	0.5898	167.93	183.21	0.3162	0.5128	167.67	182.85	0.3132	
$p = 180 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 117.74^\circ\text{F}$ )					$p = 200 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 125.28^\circ\text{F}$ )				
Sat.	0.2569	108.18	116.74	0.2154	0.2288	108.98	117.44	0.2151	
120	0.2595	108.77	117.41	0.2166					
140	0.2814	113.83	123.21	0.2264	0.2446	112.87	121.92	0.2226	
160	0.3011	118.74	128.77	0.2355	0.2636	117.94	127.70	0.2321	
180	0.3191	123.56	134.19	0.2441	0.2809	122.88	133.28	0.2410	
200	0.3361	128.34	139.53	0.2524	0.2970	127.76	138.75	0.2494	
220	0.3523	133.11	144.84	0.2603	0.3121	132.60	144.15	0.2575	
240	0.3678	137.90	150.15	0.2680	0.3266	137.44	149.53	0.2653	
260	0.3828	142.71	155.46	0.2755	0.3405	142.30	154.90	0.2728	
280	0.3974	147.55	160.79	0.2828	0.3540	147.18	160.28	0.2802	
300	0.4116	152.44	166.15	0.2899	0.3671	152.10	165.69	0.2874	
320	0.4256	157.38	171.55	0.2969	0.3799	157.07	171.13	0.2945	
340	0.4393	162.36	177.00	0.3038	0.3926	162.07	176.60	0.3014	
360	0.4529	167.40	182.49	0.3106	0.4050	167.13	182.12	0.3082	
$p = 300 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 156.17^\circ\text{F}$ )					$p = 400 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 179.95^\circ\text{F}$ )				
Sat.	0.1424	111.72	119.62	0.2132	0.0965	112.77	119.91	0.2102	
160	0.1462	112.95	121.07	0.2155					
180	0.1633	118.93	128.00	0.2265	0.0965	112.79	119.93	0.2102	
200	0.1777	124.47	134.34	0.2363	0.1143	120.14	128.60	0.2235	
220	0.1905	129.79	140.36	0.2453	0.1275	126.35	135.79	0.2343	
240	0.2021	134.99	146.21	0.2537	0.1386	132.12	142.38	0.2438	
260	0.2130	140.12	151.95	0.2618	0.1484	137.65	148.64	0.2527	
280	0.2234	145.23	157.63	0.2696	0.1575	143.06	154.72	0.2610	
300	0.2333	150.33	163.28	0.2772	0.1660	148.39	160.67	0.2689	
320	0.2428	155.44	168.92	0.2845	0.1740	153.69	166.57	0.2766	
340	0.2521	160.57	174.56	0.2916	0.1816	158.97	172.42	0.2840	
360	0.2611	165.74	180.23	0.2986	0.1890	164.26	178.26	0.2912	
380	0.2699	170.94	185.92	0.3055	0.1962	169.57	184.09	0.2983	
400	0.2786	176.18	191.64	0.3122	0.2032	174.90	189.94	0.3051	

TABLE A-13E Properties of Saturated Ammonia (Liquid-Vapor): Temperature Table

Temp. °F	Press. lb/in. <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
-60	5.548	0.02278	44.7537	-21.005	543.61	-20.97	610.56	589.58	-0.0512	1.4765	-60
-55	6.536	0.02288	38.3991	-15.765	545.11	-15.73	607.31	591.58	-0.0381	1.4627	-55
-50	7.664	0.02299	33.0880	-10.525	546.59	-10.49	604.04	593.54	-0.0253	1.4492	-50
-45	8.949	0.02310	28.6284	-5.295	548.04	-5.25	600.72	595.48	-0.0126	1.4361	-45
-40	10.405	0.02322	24.8672	-0.045	549.46	0.00	597.37	597.37	0.0000	1.4235	-40
-35	12.049	0.02333	21.6812	5.20	550.86	5.26	593.98	599.24	0.0124	1.4111	-35
-30	13.899	0.02345	18.9715	10.46	552.24	10.52	590.54	601.06	0.0247	1.3992	-30
-25	15.972	0.02357	16.6577	15.73	553.59	15.80	587.05	602.85	0.0369	1.3875	-25
-20	18.290	0.02369	14.6744	21.01	554.91	21.09	583.51	604.61	0.0490	1.3762	-20
-15	20.871	0.02381	12.9682	26.31	556.20	26.40	579.92	606.32	0.0610	1.3652	-15
-10	23.738	0.02393	11.4951	31.63	557.46	31.73	576.26	607.99	0.0729	1.3544	-10
-5	26.912	0.02406	10.2190	36.96	558.70	37.08	572.54	609.62	0.0847	1.3440	-5
0	30.416	0.02419	9.1100	42.32	559.91	42.45	568.76	611.22	0.0964	1.3338	0
5	34.275	0.02432	8.1430	47.69	561.08	47.85	564.92	612.76	0.1080	1.3238	5
10	38.512	0.02446	7.2974	53.09	562.23	53.27	561.00	614.27	0.1196	1.3141	10
15	43.153	0.02460	6.5556	58.52	563.34	58.72	557.01	615.73	0.1311	1.3046	15
20	48.224	0.02474	5.9032	63.97	564.43	64.19	552.95	617.14	0.1425	1.2953	20
25	53.752	0.02488	5.3278	69.43	565.48	69.68	548.82	618.51	0.1539	1.2862	25
30	59.765	0.02503	4.8188	74.93	566.49	75.20	544.62	619.82	0.1651	1.2774	30
35	66.291	0.02517	4.3675	80.44	567.48	80.75	540.34	621.09	0.1764	1.2687	35
40	73.359	0.02533	3.9664	85.98	568.42	86.33	535.97	622.30	0.1875	1.2602	40
45	81.000	0.02548	3.6090	91.55	569.33	91.93	531.54	623.46	0.1986	1.2518	45
50	89.242	0.02564	3.2897	97.13	570.21	97.55	527.02	624.57	0.2096	1.2436	50
55	98.118	0.02581	3.0040	102.73	571.04	103.20	522.42	625.62	0.2205	1.2356	55
60	107.66	0.02597	2.7476	108.35	571.83	108.87	517.74	626.61	0.2314	1.2277	60
65	117.90	0.02614	2.5171	113.99	572.59	114.56	512.97	627.54	0.2422	1.2199	65
70	128.87	0.02632	2.3095	119.65	573.29	120.28	508.12	628.40	0.2530	1.2123	70
75	140.60	0.02650	2.1220	125.33	573.95	126.02	503.18	629.20	0.2636	1.2048	75
80	153.13	0.02668	1.9524	131.02	574.57	131.78	498.15	629.93	0.2742	1.1973	80
85	166.50	0.02687	1.7988	136.73	575.13	137.56	493.03	630.59	0.2848	1.1900	85
90	180.73	0.02707	1.6593	142.46	575.65	143.37	487.81	631.18	0.2953	1.1827	90
95	195.87	0.02727	1.5324	148.21	576.10	149.20	482.49	631.68	0.3057	1.1756	95
100	211.96	0.02747	1.4168	153.98	576.51	155.05	477.06	632.11	0.3161	1.1685	100
105	229.02	0.02768	1.3113	159.76	576.85	160.94	471.52	632.46	0.3264	1.1614	105
110	247.10	0.02790	1.2149	165.58	577.13	166.85	465.86	632.71	0.3366	1.1544	110
115	266.24	0.02813	1.1266	171.41	577.34	172.80	460.08	632.88	0.3469	1.1475	115
120	286.47	0.02836	1.0456	177.28	577.48	178.79	454.16	632.95	0.3570	1.1405	120

Ammonia

Source: Tables A-13E through A-15E are calculated based on equations from L. Haar and J. S. Gallagher, "Thermodynamic Properties of Ammonia," *J. Phys. Chem. Reference Data*, Vol. 7, 1978, pp. 635-792.

TABLE A-14E Properties of Saturated Ammonia (Liquid-Vapor): Pressure Table

Press. lbf/in. <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Press. lbf/in. <sup>2</sup>
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
5	-63.10	0.02271	49.320	-24.24	542.67	-24.22	612.56	588.33	-0.0593	1.4853	5
6	-57.63	0.02283	41.594	-18.51	544.32	-18.49	609.02	590.54	-0.0450	1.4699	6
7	-52.86	0.02293	36.014	-13.52	545.74	-13.49	605.92	592.42	-0.0326	1.4569	7
8	-48.63	0.02302	31.790	-9.09	546.98	-9.06	603.13	594.08	-0.0218	1.4456	8
9	-44.81	0.02311	28.477	-5.09	548.09	-5.05	600.60	595.55	-0.0121	1.4357	9
10	-41.33	0.02319	25.807	-1.44	549.09	-1.40	598.27	596.87	-0.0033	1.4268	10
12	-35.14	0.02333	21.764	5.06	550.82	5.11	594.08	599.18	0.0121	1.4115	12
14	-29.74	0.02345	18.843	10.73	552.31	10.79	590.36	601.16	0.0254	1.3986	14
16	-24.94	0.02357	16.631	15.80	553.60	15.87	587.01	602.88	0.0371	1.3874	16
18	-20.60	0.02367	14.896	20.38	554.75	20.46	583.94	604.40	0.0476	1.3775	18
20	-16.63	0.02377	13.497	24.58	555.78	24.67	581.10	605.76	0.0571	1.3687	20
25	-7.95	0.02399	10.950	33.81	557.97	33.92	574.75	608.67	0.0777	1.3501	25
30	-0.57	0.02418	9.229	41.71	559.77	41.84	569.20	611.04	0.0951	1.3349	30
35	5.89	0.02435	7.984	48.65	561.29	48.81	564.22	613.03	0.1101	1.3221	35
40	11.65	0.02450	7.041	54.89	562.60	55.07	559.69	614.76	0.1234	1.3109	40
45	16.87	0.02465	6.302	60.56	563.75	60.76	555.50	616.26	0.1354	1.3011	45
50	21.65	0.02478	5.705	65.77	564.78	66.00	551.59	617.60	0.1463	1.2923	50
55	26.07	0.02491	5.213	70.61	565.70	70.86	547.93	618.79	0.1563	1.2843	55
60	30.19	0.02503	4.801	75.13	566.53	75.41	544.46	619.87	0.1656	1.2770	60
65	34.04	0.02515	4.450	79.39	567.29	79.69	541.16	620.85	0.1742	1.2703	65
70	37.67	0.02526	4.1473	83.40	567.99	83.73	538.01	621.74	0.1823	1.2641	70
75	41.11	0.02536	3.8837	87.21	568.63	87.57	535.00	622.56	0.1900	1.2583	75
80	44.37	0.02546	3.6520	90.84	569.22	91.22	532.10	623.32	0.1972	1.2529	80
85	47.47	0.02556	3.4466	94.30	569.77	94.71	529.31	624.02	0.2040	1.2478	85
90	50.44	0.02566	3.2632	97.62	570.28	98.05	526.62	624.66	0.2106	1.2429	90
100	56.01	0.02584	2.9497	103.87	571.21	104.35	521.48	625.82	0.2227	1.2340	100
110	61.17	0.02601	2.6913	109.68	572.01	110.20	516.63	626.83	0.2340	1.2259	110
120	65.98	0.02618	2.4745	115.11	572.73	115.69	512.02	627.71	0.2443	1.2184	120
130	70.50	0.02634	2.2899	120.21	573.36	120.85	507.64	628.48	0.2540	1.2115	130
140	74.75	0.02649	2.1309	125.04	573.92	125.73	503.43	629.16	0.2631	1.2051	140
150	78.78	0.02664	1.9923	129.63	574.42	130.37	499.39	629.76	0.2717	1.1991	150
175	88.02	0.02699	1.7128	140.19	575.45	141.07	489.89	630.95	0.2911	1.1856	175
200	96.31	0.02732	1.5010	149.72	576.21	150.73	481.07	631.80	0.3084	1.1737	200
225	103.85	0.02764	1.3348	158.43	576.77	159.58	472.80	632.38	0.3240	1.1630	225
250	110.78	0.02794	1.2007	166.48	577.16	167.77	464.97	632.74	0.3382	1.1533	250
275	117.20	0.02823	1.0901	173.99	577.41	175.43	457.49	632.92	0.3513	1.1444	275
300	123.20	0.02851	0.9974	181.05	577.54	182.63	450.31	632.94	0.3635	1.1361	300

TABLE A-15E Properties of Superheated Ammonia Vapor

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R
<i>p</i> = 6 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -57.63°F)				<i>p</i> = 8 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -48.63°F)				
Sat.	41.594	544.32	590.54	1.4699	31.790	546.98	594.08	1.4456
-50	42.435	547.22	594.37	1.4793				
-40	43.533	551.03	599.40	1.4915	32.511	550.32	598.49	1.4562
-30	44.627	554.84	604.42	1.5033	33.342	554.19	603.58	1.4682
-20	45.715	558.66	609.45	1.5149	34.169	558.06	608.68	1.4799
-10	46.800	562.47	614.47	1.5261	34.992	561.93	613.76	1.4914
0	47.882	566.29	619.49	1.5372	35.811	565.79	618.84	1.5025
10	48.960	570.12	624.51	1.5480	36.627	569.66	623.91	1.5135
20	50.035	573.95	629.54	1.5586	37.440	573.52	628.99	1.5241
30	51.108	577.78	634.57	1.5690	38.250	577.40	634.06	1.5346
40	52.179	581.63	639.60	1.5791	39.058	581.27	639.13	1.5449
50	53.247	585.49	644.64	1.5891	39.865	585.16	644.21	1.5549
60	54.314	589.35	649.70	1.5990	40.669	589.05	649.29	1.5648
<i>p</i> = 10 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -41.33°F)				<i>p</i> = 12 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -35.14°F)				
Sat.	25.807	549.09	596.87	1.4268	21.764	550.82	599.18	1.4115
-40	25.897	549.61	597.56	1.4284				
-30	26.571	553.54	602.74	1.4406	22.056	552.87	601.88	1.4178
-20	27.241	557.46	607.90	1.4525	22.621	556.85	607.12	1.4298
-10	27.906	561.37	613.05	1.4641	23.182	560.82	612.33	1.4416
0	28.568	565.29	618.19	1.4754	23.739	564.78	617.53	1.4530
10	29.227	569.19	623.31	1.4864	24.293	568.73	622.71	1.4642
20	29.882	573.10	628.43	1.4972	24.843	572.67	627.88	1.4750
30	30.535	577.01	633.55	1.5078	25.392	576.61	633.03	1.4857
40	31.186	580.91	638.66	1.5181	25.937	580.55	638.19	1.4961
50	31.835	584.82	643.77	1.5282	26.481	584.49	643.33	1.5063
60	32.482	588.74	648.89	1.5382	27.023	588.43	648.48	1.5163
70	33.127	592.66	654.01	1.5479	27.564	592.38	653.63	1.5261
<i>p</i> = 14 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -29.74°F)				<i>p</i> = 16 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -24.94°F)				
Sat.	18.843	552.31	601.16	1.3986	16.631	553.60	602.88	1.3874
-20	19.321	556.24	606.33	1.4105	16.845	555.62	605.53	1.3935
-10	19.807	560.26	611.61	1.4223	17.275	559.69	610.88	1.4055
0	20.289	564.27	616.86	1.4339	17.701	563.75	616.19	1.4172
10	20.768	568.26	622.10	1.4452	18.124	567.79	621.48	1.4286
20	21.244	572.24	627.31	1.4562	18.544	571.81	626.75	1.4397
30	21.717	576.22	632.52	1.4669	18.961	575.82	632.00	1.4505
40	22.188	580.19	637.71	1.4774	19.376	579.82	637.23	1.4611
50	22.657	584.16	642.89	1.4877	19.789	583.82	642.45	1.4714
60	23.124	588.12	648.07	1.4977	20.200	587.81	647.66	1.4815
70	23.590	592.09	653.25	1.5076	20.609	591.80	652.86	1.4915
80	24.054	596.07	658.42	1.5173	21.017	595.80	658.07	1.5012
90	24.517	600.04	663.60	1.5268	21.424	599.80	663.27	1.5107

Ammonia

TABLE A-15E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 18 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -20.60^\circ\text{F}$ )					$p = 20 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -16.63^\circ\text{F}$ )			
Sat.	14.896	554.75	604.40	1.3775	13.497	555.78	605.76	1.3687
-20	14.919	555.00	604.72	1.3783				
-10	15.306	559.13	610.14	1.3905	13.730	558.55	609.40	1.3769
0	15.688	563.23	615.52	1.4023	14.078	562.70	614.84	1.3888
10	16.068	567.31	620.87	1.4138	14.422	566.83	620.24	1.4005
20	16.444	571.37	626.18	1.4250	14.764	570.94	625.61	1.4118
30	16.818	575.42	631.47	1.4359	15.103	575.02	630.95	1.4228
40	17.189	579.46	636.75	1.4466	15.439	579.09	636.26	1.4335
50	17.558	583.48	642.00	1.4570	15.773	583.14	641.55	1.4440
60	17.925	587.50	647.25	1.4672	16.105	587.19	646.83	1.4543
70	18.291	591.52	652.48	1.4772	16.436	591.23	652.10	1.4643
80	18.655	595.53	657.71	1.4869	16.765	595.26	657.35	1.4741
90	19.018	599.55	662.94	1.4965	17.094	599.30	662.60	1.4838
$p = 30 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = -0.57^\circ\text{F}$ )					$p = 40 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 11.65^\circ\text{F}$ )			
Sat.	9.2286	559.77	611.04	1.3349	7.0414	562.60	614.76	1.3109
0	9.2425	560.02	611.36	1.3356				
10	9.4834	564.38	617.07	1.3479				
20	9.7209	568.70	622.70	1.3598	7.1965	566.39	619.69	1.3213
30	9.9554	572.97	628.28	1.3713	7.3795	570.86	625.52	1.3333
40	10.187	577.21	633.80	1.3824	7.5597	575.28	631.28	1.3450
50	10.417	581.42	639.28	1.3933	7.7376	579.65	636.96	1.3562
60	10.645	585.60	644.73	1.4039	7.9134	583.97	642.58	1.3672
70	10.871	589.76	650.15	1.4142	8.0874	588.26	648.16	1.3778
80	11.096	593.90	655.54	1.4243	8.2598	592.52	653.69	1.3881
90	11.319	598.04	660.91	1.4342	8.4308	596.75	659.20	1.3982
100	11.541	602.16	666.27	1.4438	8.6006	600.97	664.67	1.4081
110	11.762	606.28	671.62	1.4533	8.7694	605.17	670.12	1.4178
$p = 50 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 21.65^\circ\text{F}$ )					$p = 60 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 30.19^\circ\text{F}$ )			
Sat.	5.7049	564.78	617.60	1.2923	4.8009	566.53	619.87	1.2770
40	5.9815	573.30	628.68	1.3149	4.9278	571.25	626.00	1.2894
60	6.2733	582.31	640.39	1.3379	5.1788	580.60	638.14	1.3133
80	6.5574	591.10	651.82	1.3595	5.4218	589.66	649.90	1.3355
100	6.8358	599.75	663.04	1.3799	5.6587	598.52	661.39	1.3564
120	7.1097	608.30	674.13	1.3993	5.8910	607.23	672.68	1.3762
140	7.3802	616.80	685.13	1.4180	6.1198	615.86	683.85	1.3951
160	7.6480	625.28	696.09	1.4360	6.3458	624.44	694.95	1.4133
200	8.1776	642.27	717.99	1.4702	6.7916	641.59	717.05	1.4479
240	8.7016	659.44	740.00	1.5026	7.2318	658.87	739.21	1.4805
280	9.2218	676.88	762.26	1.5336	7.6679	676.38	761.58	1.5116
320	9.7391	694.65	784.82	1.5633	8.1013	694.21	784.22	1.5414
360	10.254	712.79	807.73	1.5919	8.5325	712.40	807.20	1.5702

TABLE A-15E (Continued)

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R
<i>p</i> = 70 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 37.67°F)					<i>p</i> = 80 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 44.37°F)			
Sat.	4.1473	567.99	621.74	1.2641	3.6520	569.22	623.32	1.2529
40	4.1739	569.15	623.25	1.2671				
60	4.3962	578.85	635.84	1.2918	3.8084	577.06	633.48	1.2727
80	4.6100	588.19	647.95	1.3147	4.0006	586.69	645.95	1.2963
100	4.8175	597.26	659.70	1.3361	4.1862	595.98	657.99	1.3182
120	5.0202	606.14	671.22	1.3563	4.3668	605.04	669.73	1.3388
140	5.2193	614.91	682.56	1.3756	4.5436	613.94	681.25	1.3583
160	5.4154	623.60	693.79	1.3940	4.7175	622.74	692.63	1.3770
200	5.8015	640.91	716.11	1.4289	5.0589	640.22	715.16	1.4122
240	6.1818	658.29	738.42	1.4617	5.3942	657.71	737.62	1.4453
280	6.5580	675.89	760.89	1.4929	5.7256	675.39	760.20	1.4767
320	6.9314	693.78	783.62	1.5229	6.0540	693.34	783.02	1.5067
360	7.3026	712.02	806.67	1.5517	6.3802	711.63	806.15	1.5357
400	7.6721	730.63	830.08	1.5796	6.7047	730.29	829.61	1.5636
<i>p</i> = 90 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 50.44°F)					<i>p</i> = 100 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 56.01°F)			
Sat.	3.2632	570.28	624.66	1.2429	2.9497	571.21	625.82	1.2340
60	3.3504	575.22	631.05	1.2553	2.9832	573.32	628.56	1.2393
80	3.5261	585.15	643.91	1.2796	3.1460	583.58	641.83	1.2644
100	3.6948	594.68	656.26	1.3021	3.3014	593.35	654.49	1.2874
120	3.8584	603.92	668.22	1.3231	3.4513	602.79	666.70	1.3088
140	4.0180	612.97	679.93	1.3430	3.5972	611.98	678.59	1.3290
160	4.1746	621.88	691.45	1.3619	3.7401	621.01	690.27	1.3481
200	4.4812	639.52	714.20	1.3974	4.0189	638.82	713.24	1.3841
240	4.7817	657.13	736.82	1.4307	4.2916	656.54	736.01	1.4176
280	5.0781	674.89	759.52	1.4623	4.5600	674.39	758.82	1.4493
320	5.3715	692.90	782.42	1.4924	4.8255	692.47	781.82	1.4796
360	5.6628	711.24	805.62	1.5214	5.0888	710.86	805.09	1.5087
400	5.9522	729.95	829.14	1.5495	5.3503	729.60	828.68	1.5368
<i>p</i> = 110 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 61.17°F)					<i>p</i> = 120 lbf/in. <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 65.98°F)			
Sat.	2.6913	572.01	626.83	1.2259	2.4745	572.73	627.71	1.2184
80	2.8344	581.97	639.71	1.2502	2.5744	580.33	637.53	1.2369
100	2.9791	592.00	652.69	1.2738	2.7102	590.63	650.85	1.2611
120	3.1181	601.63	665.14	1.2957	2.8401	600.46	663.57	1.2834
140	3.2528	610.98	677.24	1.3162	2.9657	609.97	675.86	1.3043
160	3.3844	620.13	689.07	1.3356	3.0879	619.24	687.86	1.3240
200	3.6406	638.11	712.27	1.3719	3.3254	637.40	711.29	1.3606
240	3.8905	655.96	735.20	1.4056	3.5563	655.36	734.39	1.3946
280	4.1362	673.88	758.13	1.4375	3.7829	673.37	757.43	1.4266
320	4.3788	692.02	781.22	1.4679	4.0065	691.58	780.61	1.4572
360	4.6192	710.47	804.56	1.4971	4.2278	710.08	804.02	1.4864
400	4.8578	729.26	828.21	1.5252	4.4473	728.92	827.74	1.5147

Ammonia

TABLE A-15E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 130 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 70.50^\circ\text{F}$ )					$p = 140 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 74.75^\circ\text{F}$ )			
Sat.	2.2899	573.36	628.48	1.2115	2.1309	573.92	629.16	1.2051
80	2.3539	578.64	635.30	1.2243	2.1633	576.80	632.89	1.2119
100	2.4824	589.23	648.98	1.2492	2.2868	587.79	647.08	1.2379
120	2.6048	599.27	661.97	1.2720	2.4004	597.85	660.08	1.2604
140	2.7226	608.94	674.48	1.2932	2.5140	607.90	673.07	1.2828
160	2.8370	618.34	686.64	1.3132	2.6204	617.34	685.27	1.3025
180	2.9488	627.57	698.55	1.3321	2.7268	626.77	697.46	1.3222
200	3.0585	636.69	710.31	1.3502	2.8289	635.93	709.27	1.3401
240	3.2734	654.77	733.57	1.3844	3.0304	654.17	732.73	1.3747
280	3.4840	672.87	756.73	1.4166	3.2274	672.38	756.04	1.4071
320	3.6915	691.14	780.00	1.4472	3.4212	690.73	779.42	1.4379
360	3.8966	709.69	803.49	1.4766	3.6126	709.34	802.99	1.4674
400	4.1000	728.57	827.27	1.5049	3.8022	728.27	826.84	1.4958
$p = 150 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 78.78^\circ\text{F}$ )					$p = 200 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 96.31^\circ\text{F}$ )			
Sat.	1.9923	574.42	629.76	1.1991	1.5010	576.21	631.80	1.1737
100	2.1170	586.33	645.13	1.2271	1.5190	578.52	634.77	1.1790
140	2.3332	606.84	671.65	1.2729	1.6984	601.34	664.24	1.2299
180	2.5343	625.95	696.35	1.3128	1.8599	621.77	690.65	1.2726
220	2.7268	644.43	720.17	1.3489	2.0114	641.07	715.57	1.3104
260	2.9137	662.70	743.63	1.3825	2.1569	659.90	739.78	1.3450
300	3.0968	681.02	767.04	1.4141	2.2984	678.62	763.74	1.3774
340	3.2773	699.54	790.57	1.4443	2.4371	697.44	787.70	1.4081
380	3.4558	718.35	814.34	1.4733	2.5736	716.50	811.81	1.4375
420	3.6325	737.50	838.39	1.5013	2.7085	735.86	836.17	1.4659
460	3.8079	757.01	862.78	1.5284	2.8420	755.57	860.82	1.4933
500	3.9821	776.91	887.51	1.5548	2.9742	775.65	885.80	1.5199
540	4.1553	797.19	912.60	1.5804	3.1054	796.10	911.11	1.5457
580	4.3275	817.85	938.05	1.6053	3.2357	816.94	936.77	1.5709
$p = 250 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 110.78^\circ\text{F}$ )					$p = 300 \text{ lbf/in.}^2$ ( $T_{\text{sat}} = 123.20^\circ\text{F}$ )			
Sat.	1.2007	577.16	632.74	1.1533	0.9974	577.54	632.94	1.1361
140	1.3150	595.40	656.28	1.1936	1.0568	588.94	647.65	1.1610
180	1.4539	617.38	684.69	1.2395	1.1822	612.75	678.42	1.2107
220	1.5816	637.61	710.82	1.2791	1.2944	634.01	705.91	1.2524
260	1.7025	657.03	735.85	1.3149	1.3992	654.09	731.82	1.2895
300	1.8191	676.17	760.39	1.3481	1.4994	673.69	756.98	1.3235
340	1.9328	695.32	784.79	1.3794	1.5965	693.16	781.85	1.3554
380	2.0443	714.63	809.27	1.4093	1.6913	712.74	806.70	1.3857
420	2.1540	734.22	833.93	1.4380	1.7843	732.55	831.67	1.4148
460	2.2624	754.12	858.85	1.4657	1.8759	752.66	856.87	1.4428
500	2.3695	774.38	884.07	1.4925	1.9663	773.10	882.33	1.4699
540	2.4755	795.01	909.61	1.5186	2.0556	793.90	908.09	1.4962
580	2.5807	816.01	935.47	1.5440	2.1440	815.07	934.17	1.5218

TABLE A-16E Properties of Saturated Propane (Liquid-Vapor): Temperature Table

Temp. °F	Press. lbf/in <sup>2</sup>	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Temp. °F
		Sat. Liquid <i>v<sub>f</sub></i>	Sat. Vapor <i>v<sub>g</sub></i>	Sat. Liquid <i>u<sub>f</sub></i>	Sat. Vapor <i>u<sub>g</sub></i>	Sat. Liquid <i>h<sub>f</sub></i>	Evap. <i>h<sub>fg</sub></i>	Sat. Vapor <i>h<sub>g</sub></i>	Sat. Liquid <i>s<sub>f</sub></i>	Sat. Vapor <i>s<sub>g</sub></i>	
-140	0.6053	0.02505	128.00	-51.33	139.22	-51.33	204.9	153.6	-0.139	0.501	-140
-120	1.394	0.02551	58.88	-41.44	143.95	-41.43	200.6	159.1	-0.109	0.481	-120
-100	2.888	0.02601	29.93	-31.34	148.80	-31.33	196.1	164.8	-0.080	0.465	-100
-80	5.485	0.02653	16.52	-21.16	153.73	-21.13	191.6	170.5	-0.053	0.452	-80
-60	9.688	0.02708	9.75	-10.73	158.74	-10.68	186.9	176.2	-0.026	0.441	-60
-40	16.1	0.02767	6.08	-0.08	163.80	0.00	181.9	181.9	0.000	0.433	-40
-20	25.4	0.02831	3.98	10.81	168.88	10.94	176.6	187.6	0.025	0.427	-20
0	38.4	0.02901	2.70	21.98	174.01	22.19	171.0	193.2	0.050	0.422	0
10	46.5	0.02939	2.25	27.69	176.61	27.94	168.0	196.0	0.063	0.420	10
20	55.8	0.02978	1.89	33.47	179.15	33.78	164.9	198.7	0.074	0.418	20
30	66.5	0.03020	1.598	39.34	181.71	39.71	161.7	201.4	0.087	0.417	30
40	78.6	0.03063	1.359	45.30	184.30	45.75	158.3	204.1	0.099	0.415	40
50	92.3	0.03110	1.161	51.36	186.74	51.89	154.7	206.6	0.111	0.414	50
60	107.7	0.03160	0.9969	57.53	189.30	58.16	151.0	209.2	0.123	0.413	60
70	124.9	0.03213	0.8593	63.81	191.71	64.55	147.0	211.6	0.135	0.412	70
80	144.0	0.03270	0.7433	70.20	194.16	71.07	142.9	214.0	0.147	0.411	80
90	165.2	0.03332	0.6447	76.72	196.46	77.74	138.4	216.2	0.159	0.410	90
100	188.6	0.03399	0.5605	83.38	198.71	84.56	133.7	218.3	0.171	0.410	100
110	214.3	0.03473	0.4881	90.19	200.91	91.56	128.7	220.3	0.183	0.409	110
120	242.5	0.03555	0.4254	97.16	202.98	98.76	123.3	222.1	0.195	0.408	120
130	273.3	0.03646	0.3707	104.33	204.92	106.17	117.5	223.7	0.207	0.406	130
140	306.9	0.03749	0.3228	111.70	206.64	113.83	111.1	225.0	0.220	0.405	140
150	343.5	0.03867	0.2804	119.33	208.05	121.79	104.1	225.9	0.233	0.403	150
160	383.3	0.04006	0.2426	127.27	209.16	130.11	96.3	226.4	0.246	0.401	160
170	426.5	0.04176	0.2085	135.60	209.81	138.90	87.4	226.3	0.259	0.398	170
180	473.4	0.04392	0.1771	144.50	209.76	148.35	76.9	225.3	0.273	0.394	180
190	524.3	0.04696	0.1470	154.38	208.51	158.94	63.8	222.8	0.289	0.387	190
200	579.7	0.05246	0.1148	166.65	204.16	172.28	44.2	216.5	0.309	0.376	200
206.1	616.1	0.07265	0.07265	186.99	186.99	195.27	0.0	195.27	0.343	0.343	206.1

Propane

TABLE A-17E Properties of Saturated Propane (Liquid-Vapor): Pressure Table

Press. lbf/in <sup>2</sup>	Temp. °F	Specific Volume ft <sup>3</sup> /lb		Internal Energy Btu/lb		Enthalpy Btu/lb			Entropy Btu/lb · °R		Press. lbf/in <sup>2</sup>
		Sat. Liquid $v_f$	Sat. Vapor $v_g$	Sat. Liquid $u_f$	Sat. Vapor $u_g$	Sat. Liquid $h_f$	Evap. $h_{fg}$	Sat. Vapor $h_g$	Sat. Liquid $s_f$	Sat. Vapor $s_g$	
0.75	-135.1	0.02516	104.8	-48.93	140.36	-48.93	203.8	154.9	-0.132	0.496	0.75
1.5	-118.1	0.02556	54.99	-40.44	144.40	-40.43	200.1	159.7	-0.106	0.479	1.5
3	-98.9	0.02603	28.9	-30.84	149.06	-30.83	196.0	165.1	-0.079	0.464	3
5	-83.0	0.02644	18.00	-22.75	152.96	-22.73	192.4	169.6	-0.057	0.454	5
7.5	-69.3	0.02682	12.36	-15.60	156.40	-15.56	189.1	173.6	-0.038	0.446	7.5
10	-58.8	0.02711	9.468	-10.10	159.04	-10.05	186.6	176.6	-0.024	0.441	10
20	-30.7	0.02796	4.971	4.93	166.18	5.03	179.5	184.6	0.012	0.430	20
30	-12.1	0.02858	3.402	15.15	170.93	15.31	174.5	189.8	0.035	0.425	30
40	2.1	0.02909	2.594	23.19	174.60	23.41	170.4	193.8	0.053	0.422	40
50	13.9	0.02954	2.099	29.96	177.63	30.23	166.8	197.1	0.067	0.419	50
60	24.1	0.02995	1.764	35.86	180.23	36.19	163.6	199.8	0.079	0.418	60
70	33.0	0.03033	1.520	41.14	182.50	41.53	160.6	202.2	0.090	0.416	70
80	41.1	0.03068	1.336	45.95	184.57	46.40	157.9	204.3	0.100	0.415	80
90	48.4	0.03102	1.190	50.38	186.36	50.90	155.3	206.2	0.109	0.414	90
100	55.1	0.03135	1.073	54.52	188.07	55.10	152.8	207.9	0.117	0.414	100
120	67.2	0.03198	0.8945	62.08	191.07	62.79	148.1	210.9	0.131	0.412	120
140	78.0	0.03258	0.7650	68.91	193.68	69.75	143.7	213.5	0.144	0.412	140
160	87.6	0.03317	0.6665	75.17	195.97	76.15	139.5	215.7	0.156	0.411	160
180	96.5	0.03375	0.5890	80.99	197.97	82.12	135.5	217.6	0.166	0.410	180
200	104.6	0.03432	0.5261	86.46	199.77	87.73	131.4	219.2	0.176	0.409	200
220	112.1	0.03489	0.4741	91.64	201.37	93.06	127.6	220.7	0.185	0.408	220
240	119.2	0.03547	0.4303	96.56	202.76	98.14	123.7	221.9	0.194	0.408	240
260	125.8	0.03606	0.3928	101.29	204.07	103.0	120.0	223.0	0.202	0.407	260
280	132.1	0.03666	0.3604	105.83	205.27	107.7	116.1	223.9	0.210	0.406	280
300	138.0	0.03727	0.3319	110.21	206.27	112.3	112.4	224.7	0.217	0.405	300
320	143.7	0.03790	0.3067	114.47	207.17	116.7	108.6	225.3	0.224	0.404	320
340	149.1	0.03855	0.2842	118.60	207.96	121.0	104.7	225.8	0.231	0.403	340
360	154.2	0.03923	0.2639	122.66	208.58	125.3	100.9	226.2	0.238	0.402	360
380	159.2	0.03994	0.2455	126.61	209.07	129.4	97.0	226.4	0.245	0.401	380
400	164.0	0.04069	0.2287	130.51	209.47	133.5	93.0	226.5	0.251	0.400	400
450	175.1	0.04278	0.1921	140.07	209.87	143.6	82.2	225.9	0.266	0.396	450
500	185.3	0.04538	0.1610	149.61	209.27	153.8	70.4	224.2	0.282	0.391	500
600	203.4	0.05659	0.1003	172.85	200.27	179.1	32.2	211.4	0.319	0.367	600
616.1	206.1	0.07265	0.07265	186.99	186.99	195.3	0.0	195.3	0.343	0.343	616.1

Propane

TABLE A-18E Properties of Superheated Propane

<i>T</i> °F	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R	<i>v</i> ft <sup>3</sup> /lb	<i>u</i> Btu/lb	<i>h</i> Btu/lb	<i>s</i> Btu/lb · °R
<i>p</i> = 0.75 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -135.1°F)					<i>p</i> = 1.5 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -118.1°F)			
Sat.	104.8	140.4	154.9	0.496	54.99	144.4	159.7	0.479
-130	106.5	141.6	156.4	0.501				
-110	113.1	146.6	162.3	0.518	56.33	146.5	162.1	0.486
-90	119.6	151.8	168.4	0.535	59.63	151.7	168.2	0.503
-70	126.1	157.2	174.7	0.551	62.92	157.1	174.5	0.520
-50	132.7	162.7	181.2	0.568	66.20	162.6	181.0	0.536
-30	139.2	168.6	187.9	0.584	69.47	168.4	187.7	0.552
-10	145.7	174.4	194.7	0.599	72.74	174.4	194.6	0.568
10	152.2	180.7	201.9	0.615	76.01	180.7	201.8	0.583
30	158.7	187.1	209.2	0.630	79.27	187.1	209.1	0.599
50	165.2	193.8	216.8	0.645	82.53	193.8	216.7	0.614
70	171.7	200.7	224.6	0.660	85.79	200.7	224.5	0.629
90	178.2	207.8	232.6	0.675	89.04	207.8	232.5	0.644
<i>p</i> = 5.0 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -83.0°F)					<i>p</i> = 10.0 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -58.8°F)			
Sat.	18.00	153.0	169.6	0.454	9.468	159.0	176.6	0.441
-80	18.15	153.8	170.6	0.456				
-60	19.17	159.4	177.1	0.473				
-40	20.17	165.1	183.8	0.489	9.957	80.9	99.3	1.388
-20	21.17	171.1	190.7	0.505	10.47	86.9	106.3	1.405
0	22.17	177.2	197.7	0.521	10.98	93.1	113.4	1.421
20	23.16	183.5	205.0	0.536	11.49	99.5	120.8	1.436
40	24.15	190.1	212.5	0.552	11.99	106.1	128.3	1.452
60	25.14	196.9	220.2	0.567	12.49	113.0	136.1	1.467
80	26.13	204.0	228.2	0.582	12.99	120.0	144.1	1.482
100	27.11	211.3	236.4	0.597	13.49	127.3	152.3	1.497
120	28.09	218.8	244.8	0.611	13.99	134.9	160.7	1.512
140	29.07	226.5	253.4	0.626	14.48	142.6	169.4	1.526
<i>p</i> = 20.0 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = -30.7°F)					<i>p</i> = 40.0 lbf/in <sup>2</sup> ( <i>T</i> <sub>sat</sub> = 2.1°F)			
Sat.	4.971	166.2	184.6	0.430	2.594	174.6	193.8	0.422
-20	5.117	169.5	188.5	0.439				
0	5.385	175.8	195.8	0.455				
20	5.648	182.4	203.3	0.471	2.723	180.6	200.8	0.436
40	5.909	189.1	211.0	0.487	2.864	187.6	208.8	0.453
60	6.167	195.9	218.8	0.502	3.002	194.6	216.9	0.469
80	6.424	203.1	226.9	0.518	3.137	201.8	225.1	0.484
100	6.678	210.5	235.2	0.533	3.271	209.4	233.6	0.500
120	6.932	218.0	243.7	0.548	3.403	217.0	242.2	0.515
140	7.184	225.8	252.4	0.562	3.534	224.9	251.1	0.530
160	7.435	233.9	261.4	0.577	3.664	232.9	260.1	0.545
180	7.685	242.1	270.6	0.592	3.793	241.3	269.4	0.559
200	7.935	250.6	280.0	0.606	3.921	249.8	278.9	0.574

Propane

TABLE A-18E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 60.0 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 24.1^\circ\text{F}$ )					$p = 80.0 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 41.1^\circ\text{F}$ )			
Sat.	1.764	180.2	199.8	0.418	1.336	184.6	204.3	0.415
30	1.794	182.4	202.3	0.384				
50	1.894	189.5	210.6	0.400	1.372	187.9	208.2	0.423
70	1.992	196.9	219.0	0.417	1.450	195.4	216.9	0.440
90	2.087	204.4	227.6	0.432	1.526	203.1	225.7	0.456
110	2.179	212.1	236.3	0.448	1.599	210.9	234.6	0.472
130	2.271	220.0	245.2	0.463	1.671	218.8	243.6	0.487
150	2.361	228.0	254.2	0.478	1.741	227.0	252.8	0.503
170	2.450	236.3	263.5	0.493	1.810	235.4	262.2	0.518
190	2.539	244.8	273.0	0.508	1.879	244.0	271.8	0.533
210	2.626	253.5	282.7	0.523	1.946	252.7	281.5	0.548
230	2.713	262.3	292.5	0.537	2.013	261.7	291.5	0.562
250	2.800	271.6	302.7	0.552	2.079	270.9	301.7	0.577
$p = 100 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 55.1^\circ\text{F}$ )					$p = 120 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 67.2^\circ\text{F}$ )			
Sat.	1.073	188.1	207.9	0.414	0.8945	191.1	210.9	0.412
60	1.090	189.9	210.1	0.418				
80	1.156	197.8	219.2	0.435	0.9323	196.2	216.9	0.424
100	1.219	205.7	228.3	0.452	0.9887	204.3	226.3	0.441
120	1.280	213.7	237.4	0.468	1.043	212.5	235.7	0.457
140	1.340	221.9	246.7	0.483	1.094	220.8	245.1	0.473
160	1.398	230.2	256.1	0.499	1.145	229.2	254.7	0.489
180	1.454	238.8	265.7	0.514	1.194	237.9	264.4	0.504
200	1.510	247.5	275.5	0.529	1.242	246.7	274.3	0.520
220	1.566	256.4	285.4	0.544	1.289	255.6	284.3	0.534
240	1.620	265.6	295.6	0.559	1.336	264.8	294.5	0.549
260	1.674	274.9	305.9	0.573	1.382	274.2	304.9	0.564
280	1.728	284.4	316.4	0.588	1.427	283.8	315.5	0.579
$p = 140 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 78.0^\circ\text{F}$ )					$p = 160 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 87.6^\circ\text{F}$ )			
Sat.	0.7650	193.7	213.5	0.412	0.6665	196.0	215.7	0.411
80	0.7705	213.3	214.5	0.413				
100	0.8227	222.9	224.2	0.431	0.6968	201.2	221.9	0.422
120	0.8718	232.4	233.8	0.448	0.7427	209.9	231.9	0.439
140	0.9185	242.1	243.5	0.464	0.7859	218.4	241.7	0.456
160	0.9635	251.7	253.2	0.480	0.8272	227.2	251.7	0.472
180	1.007	261.4	263.0	0.496	0.8669	235.9	261.6	0.488
200	1.050	271.4	273.0	0.511	0.9054	244.9	271.7	0.504
220	1.091	281.5	283.2	0.526	0.9430	254.0	282.0	0.519
240	1.132	291.7	293.5	0.541	0.9797	263.4	292.4	0.534
260	1.173	302.1	303.9	0.556	1.016	272.8	302.9	0.549
280	1.213	312.7	314.6	0.571	1.051	282.6	313.7	0.564
300	1.252	323.6	325.5	0.585	1.087	292.4	324.6	0.578

TABLE A-18E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 180 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 96.5^\circ\text{F}$ )					$p = 200 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 104.6^\circ\text{F}$ )			
Sat.	0.5890	198.0	217.6	0.410	0.5261	199.8	219.2	0.409
100	0.5972	199.6	219.5	0.413				
120	0.6413	208.4	229.8	0.431	0.5591	206.8	227.5	0.424
140	0.6821	217.1	239.9	0.449	0.5983	215.8	238.0	0.441
160	0.7206	226.1	250.1	0.465	0.6349	224.9	248.4	0.458
180	0.7574	234.9	260.2	0.481	0.6694	233.9	258.7	0.475
200	0.7928	244.0	270.4	0.497	0.7025	243.1	269.1	0.491
220	0.8273	253.2	280.8	0.513	0.7345	252.4	279.6	0.506
240	0.8609	262.6	291.3	0.528	0.7656	261.7	290.1	0.522
260	0.8938	272.1	301.9	0.543	0.7960	271.4	300.9	0.537
280	0.9261	281.8	312.7	0.558	0.8257	281.1	311.7	0.552
300	0.9579	291.8	323.7	0.572	0.8549	291.1	322.8	0.567
320	0.9894	301.9	334.9	0.587	0.8837	301.3	334.0	0.581
$p = 220 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 112.1^\circ\text{F}$ )					$p = 240 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 119.2^\circ\text{F}$ )			
Sat.	0.4741	201.4	220.7	0.408	0.4303	202.8	221.9	0.408
120	0.4906	205.1	225.1	0.416	0.4321	203.2	222.4	0.409
140	0.5290	214.4	236.0	0.435	0.4704	212.9	233.8	0.428
160	0.5642	223.6	246.6	0.452	0.5048	222.4	244.8	0.446
180	0.5971	232.9	257.2	0.469	0.5365	231.6	255.5	0.463
200	0.6284	242.1	267.7	0.485	0.5664	241.1	266.3	0.480
220	0.6585	251.5	278.3	0.501	0.5949	250.5	277.0	0.496
240	0.6875	261.0	289.0	0.516	0.6223	260.1	287.8	0.511
260	0.7158	270.6	299.8	0.532	0.6490	269.8	298.7	0.527
280	0.7435	280.5	310.8	0.547	0.6749	279.8	309.8	0.542
300	0.7706	290.5	321.9	0.561	0.7002	289.8	320.9	0.557
320	0.7972	300.6	333.1	0.576	0.7251	300.1	332.3	0.571
340	0.8235	311.0	344.6	0.591	0.7496	310.5	343.8	0.586
$p = 260 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 125.8^\circ\text{F}$ )					$p = 280 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 132.1^\circ\text{F}$ )			
Sat.	0.3928	204.1	223.0	0.407	0.3604	205.3	223.9	0.406
130	0.4012	206.3	225.6	0.411				
150	0.4374	216.1	237.2	0.431	0.3932	214.5	234.9	0.424
170	0.4697	225.8	248.4	0.449	0.4253	224.4	246.5	0.443
190	0.4995	235.2	259.3	0.466	0.4544	234.1	257.7	0.461
210	0.5275	244.8	270.2	0.482	0.4815	243.8	268.8	0.477
230	0.5541	254.4	281.1	0.498	0.5072	253.5	279.8	0.494
250	0.5798	264.2	292.1	0.514	0.5317	263.3	290.9	0.510
270	0.6046	274.1	303.2	0.530	0.5553	273.3	302.1	0.525
290	0.6288	284.0	314.3	0.545	0.5783	283.4	313.4	0.540
310	0.6524	294.3	325.7	0.560	0.6007	293.5	324.7	0.555
330	0.6756	304.7	337.2	0.574	0.6226	304.0	336.3	0.570
350	0.6984	315.2	348.8	0.589	0.6441	314.6	348.0	0.585

Propane

TABLE A-18E (Continued)

$T$ °F	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R	$v$ ft <sup>3</sup> /lb	$u$ Btu/lb	$h$ Btu/lb	$s$ Btu/lb · °R
$p = 320 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 143.7^\circ\text{F}$ )					$p = 360 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 154.2^\circ\text{F}$ )			
Sat.	0.3067	207.2	225.3	0.404	0.2639	208.6	226.2	0.402
150	0.3187	210.7	229.6	0.412				
170	0.3517	221.4	242.3	0.432	0.2920	217.9	237.4	0.420
190	0.3803	231.7	254.2	0.450	0.3213	228.8	250.2	0.440
210	0.4063	241.6	265.7	0.468	0.3469	239.3	262.4	0.459
230	0.4304	251.6	277.1	0.485	0.3702	249.5	274.2	0.476
250	0.4533	261.6	288.5	0.501	0.3919	259.8	285.9	0.493
270	0.4751	271.7	299.9	0.517	0.4124	270.1	297.6	0.509
290	0.4961	281.9	311.3	0.532	0.4320	280.4	309.2	0.525
310	0.5165	292.3	322.9	0.548	0.4510	290.8	320.9	0.540
330	0.5364	302.7	334.5	0.563	0.4693	301.4	332.7	0.556
350	0.5559	313.4	346.3	0.577	0.4872	312.2	344.7	0.570
370	0.5750	324.2	358.3	0.592	0.5047	323.0	356.7	0.585
$p = 400 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 164.0^\circ\text{F}$ )					$p = 450 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 175.1^\circ\text{F}$ )			
Sat.	0.2287	209.5	226.5	0.400	0.1921	209.9	225.9	0.396
170	0.2406	213.6	231.4	0.408				
190	0.2725	225.6	245.8	0.430	0.2205	220.7	239.1	0.416
210	0.2985	236.7	258.8	0.450	0.2486	233.0	253.7	0.439
230	0.3215	247.4	271.2	0.468	0.2719	244.3	267.0	0.458
250	0.3424	257.8	283.2	0.485	0.2925	255.2	279.6	0.476
270	0.3620	268.3	295.1	0.502	0.3113	266.0	292.0	0.493
290	0.3806	278.8	307.0	0.518	0.3290	276.8	304.2	0.510
310	0.3984	289.4	318.9	0.534	0.3457	287.6	316.4	0.526
330	0.4156	300.1	330.9	0.549	0.3617	298.4	328.5	0.542
350	0.4322	311.0	343.0	0.564	0.3772	309.4	340.8	0.557
370	0.4484	321.9	355.1	0.579	0.3922	320.4	353.1	0.572
390	0.4643	333.1	367.5	0.594	0.4068	331.7	365.6	0.587
$p = 500 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 185.3^\circ\text{F}$ )					$p = 600 \text{ lbf/in}^2$ ( $T_{\text{sat}} = 203.4^\circ\text{F}$ )			
Sat.	0.1610	209.3	224.2	0.391	0.1003	200.3	211.4	0.367
190	0.1727	213.8	229.8	0.399				
210	0.2066	228.6	247.7	0.426	0.1307	214.3	228.8	0.394
230	0.2312	240.9	262.3	0.448	0.1661	232.2	250.7	0.426
250	0.2519	252.4	275.7	0.467	0.1892	245.8	266.8	0.449
270	0.2704	263.6	288.6	0.485	0.2080	258.1	281.2	0.469
290	0.2874	274.6	301.2	0.502	0.2245	269.8	294.8	0.487
310	0.3034	285.6	313.7	0.519	0.2396	281.4	308.0	0.505
330	0.3186	296.6	326.1	0.534	0.2536	292.8	321.0	0.521
350	0.3331	307.7	338.6	0.550	0.2669	304.2	333.9	0.538
370	0.3471	318.9	351.0	0.565	0.2796	315.7	346.8	0.553
390	0.3607	330.2	363.6	0.580	0.2917	327.3	359.7	0.569
410	0.3740	341.7	376.3	0.595	0.3035	338.9	372.6	0.584

TABLE A-19E Properties of Selected Solids and Liquids:  $c_p$ ,  $\rho$ , and  $\kappa$ 

Substance	Specific Heat, $c_p$ (Btu/lb · °R)	Density, $\rho$ (lb/ft <sup>3</sup> )	Thermal Conductivity, $\kappa$ (Btu/h · ft · °R)
<b>Selected Solids, 540°R</b>			
Aluminum	0.216	169	137
Coal, anthracite	0.301	84.3	0.15
Copper	0.092	557	232
Granite	0.185	164	1.61
Iron	0.107	491	46.4
Lead	0.031	705	20.4
Sand	0.191	94.9	0.16
Silver	0.056	656	248
Soil	0.439	128	0.30
Steel (AISI 302)	0.115	503	8.7
Tin	0.054	456	38.5
<b>Building Materials, 540°R</b>			
Brick, common	0.199	120	0.42
Concrete (stone mix)	0.210	144	0.81
Glass, plate	0.179	156	0.81
Hardboard, siding	0.279	40	0.054
Limestone	0.193	145	1.24
Plywood	0.291	34	0.069
Softwoods (fir, pine)	0.330	31.8	0.069
<b>Insulating Materials, 540°R</b>			
Blanket (glass fiber)	—	1.0	0.027
Cork	0.43	7.5	0.023
Duct liner (glass fiber, coated)	0.199	2.0	0.022
Polystyrene (extruded)	0.289	3.4	0.016
Vermiculite fill (flakes)	0.199	5.0	0.039
<b>Saturated Liquids</b>			
Ammonia, 540°R	1.151	37.5	0.269
Mercury, 540°R	0.033	845	4.94
Refrigerant 22, 540°R	0.303	74.0	0.049
Refrigerant 134a, 540°R	0.343	75.0	0.047
Unused Engine Oil, 540°R	0.456	55.2	0.084
Water, 495°R	1.006	62.42	0.332
540°R	0.998	62.23	0.354
585°R	0.999	61.61	0.373
630°R	1.002	60.79	0.386
675°R	1.008	59.76	0.394
720°R	1.017	58.55	0.398

Source: Drawn from several sources, these data are only representative. Values can vary depending on temperature, purity, moisture content, and other factors.

TABLE A-20E Ideal Gas Specific Heats of Some Common Gases (Btu/lb · °R)

Temp. °F	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	Temp. °F
	Air			Nitrogen, N <sub>2</sub>			Oxygen, O <sub>2</sub>			
40	0.240	0.171	1.401	0.248	0.177	1.400	0.219	0.156	1.397	40
100	0.240	0.172	1.400	0.248	0.178	1.399	0.220	0.158	1.394	100
200	0.241	0.173	1.397	0.249	0.178	1.398	0.223	0.161	1.387	200
300	0.243	0.174	1.394	0.250	0.179	1.396	0.226	0.164	1.378	300
400	0.245	0.176	1.389	0.251	0.180	1.393	0.230	0.168	1.368	400
500	0.248	0.179	1.383	0.254	0.183	1.388	0.235	0.173	1.360	500
600	0.250	0.182	1.377	0.256	0.185	1.383	0.239	0.177	1.352	600
700	0.254	0.185	1.371	0.260	0.189	1.377	0.242	0.181	1.344	700
800	0.257	0.188	1.365	0.262	0.191	1.371	0.246	0.184	1.337	800
900	0.259	0.191	1.358	0.265	0.194	1.364	0.249	0.187	1.331	900
1000	0.263	0.195	1.353	0.269	0.198	1.359	0.252	0.190	1.326	1000
1500	0.276	0.208	1.330	0.283	0.212	1.334	0.263	0.201	1.309	1500
2000	0.286	0.217	1.312	0.293	0.222	1.319	0.270	0.208	1.298	2000
Temp. °F	Carbon Dioxide, CO <sub>2</sub>			Carbon Monoxide, CO			Hydrogen, H <sub>2</sub>			Temp. °F
	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	$c_p$	$c_v$	$k$	
40	0.195	0.150	1.300	0.248	0.177	1.400	3.397	2.412	1.409	40
100	0.205	0.160	1.283	0.249	0.178	1.399	3.426	2.441	1.404	100
200	0.217	0.172	1.262	0.249	0.179	1.397	3.451	2.466	1.399	200
300	0.229	0.184	1.246	0.251	0.180	1.394	3.461	2.476	1.398	300
400	0.239	0.193	1.233	0.253	0.182	1.389	3.466	2.480	1.397	400
500	0.247	0.202	1.223	0.256	0.185	1.384	3.469	2.484	1.397	500
600	0.255	0.210	1.215	0.259	0.188	1.377	3.473	2.488	1.396	600
700	0.262	0.217	1.208	0.262	0.191	1.371	3.477	2.492	1.395	700
800	0.269	0.224	1.202	0.266	0.195	1.364	3.494	2.509	1.393	800
900	0.275	0.230	1.197	0.269	0.198	1.357	3.502	2.519	1.392	900
1000	0.280	0.235	1.192	0.273	0.202	1.351	3.513	2.528	1.390	1000
1500	0.298	0.253	1.178	0.287	0.216	1.328	3.618	2.633	1.374	1500
2000	0.312	0.267	1.169	0.297	0.226	1.314	3.758	2.773	1.355	2000

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

TABLE A-21E Variation of  $\bar{c}_p$  with Temperature for Selected Ideal Gases

$$\frac{\bar{c}_p}{R} = \alpha + \beta T + \gamma T^2 + \delta T^3 + \epsilon T^4$$

$T$  is in  $^{\circ}\text{R}$ , equations valid from 540 to 1800  $^{\circ}\text{R}$

Gas	$\alpha$	$\beta \times 10^3$	$\gamma \times 10^6$	$\delta \times 10^9$	$\epsilon \times 10^{12}$
CO	3.710	-0.899	1.140	-0.348	0.0228
CO <sub>2</sub>	2.401	4.853	-2.039	0.343	0
H <sub>2</sub>	3.057	1.487	-1.793	0.947	-0.1726
H <sub>2</sub> O	4.070	-0.616	1.281	-0.508	0.0769
O <sub>2</sub>	3.626	-1.043	2.178	-1.160	0.2053
N <sub>2</sub>	3.675	-0.671	0.717	-0.108	-0.0215
Air	3.653	-0.7428	1.017	-0.328	0.02632
NH <sub>3</sub>	3.591	0.274	2.576	-1.437	0.2601
NO	4.046	-1.899	2.464	-1.048	0.1517
NO <sub>2</sub>	3.459	1.147	2.064	-1.639	0.3448
SO <sub>2</sub>	3.267	2.958	0.211	-0.906	0.2438
SO <sub>3</sub>	2.578	8.087	-2.832	-0.136	0.1878
CH <sub>4</sub>	3.826	-2.211	7.580	-3.898	0.6633
C <sub>2</sub> H <sub>2</sub>	1.410	10.587	-7.562	2.811	-0.3939
C <sub>2</sub> H <sub>4</sub>	1.426	6.324	2.466	-2.787	0.6429
Monatomic gases <sup>a</sup>	2.5	0	0	0	0

<sup>a</sup>For monatomic gases, such as He, Ne, and Ar,  $\bar{c}_p$  is constant over a wide temperature range and is very nearly equal to  $5/2 R$ .

Source: Adapted from K. Wark, *Thermodynamics*, 4th ed., McGraw-Hill, New York, 1983, as based on NASA SP-273, U.S. Government Printing Office, Washington, DC, 1971.

TABLE A-22E Ideal Gas Properties of Air

$T(^{\circ}\text{R}), h$ and $u(\text{Btu/lb}), s^{\circ}(\text{Btu/lb} \cdot ^{\circ}\text{R})$											
$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0^1$		$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0$	
				$p_r$	$v_r$					$p_r$	$v_r$
360	85.97	61.29	0.50369	0.3363	396.6	940	226.11	161.68	0.73509	9.834	35.41
380	90.75	64.70	0.51663	0.4061	346.6	960	231.06	165.26	0.74030	10.61	33.52
400	95.53	68.11	0.52890	0.4858	305.0	980	236.02	168.83	0.74540	11.43	31.76
420	100.32	71.52	0.54058	0.5760	270.1	1000	240.98	172.43	0.75042	12.30	30.12
440	105.11	74.93	0.55172	0.6776	240.6	1040	250.95	179.66	0.76019	14.18	27.17
460	109.90	78.36	0.56235	0.7913	215.33	1080	260.97	186.93	0.76964	16.28	24.58
480	114.69	81.77	0.57255	0.9182	193.65	1120	271.03	194.25	0.77880	18.60	22.30
500	119.48	85.20	0.58233	1.0590	174.90	1160	281.14	201.63	0.78767	21.18	20.29
520	124.27	88.62	0.59172	1.2147	158.58	1200	291.30	209.05	0.79628	24.01	18.51
537	128.34	91.53	0.59945	1.3593	146.34	1240	301.52	216.53	0.80466	27.13	16.93
540	129.06	92.04	0.60078	1.3860	144.32	1280	311.79	224.05	0.81280	30.55	15.52
560	133.86	95.47	0.60950	1.5742	131.78	1320	322.11	231.63	0.82075	34.31	14.25
580	138.66	98.90	0.61793	1.7800	120.70	1360	332.48	239.25	0.82848	38.41	13.12
600	143.47	102.34	0.62607	2.005	110.88	1400	342.90	246.93	0.83604	42.88	12.10
620	148.28	105.78	0.63395	2.249	102.12	1440	353.37	254.66	0.84341	47.75	11.17
640	153.09	109.21	0.64159	2.514	94.30	1480	363.89	262.44	0.85062	53.04	10.34
660	157.92	112.67	0.64902	2.801	87.27	1520	374.47	270.26	0.85767	58.78	9.578
680	162.73	116.12	0.65621	3.111	80.96	1560	385.08	278.13	0.86456	65.00	8.890
700	167.56	119.58	0.66321	3.446	75.25	1600	395.74	286.06	0.87130	71.73	8.263
720	172.39	123.04	0.67002	3.806	70.07	1650	409.13	296.03	0.87954	80.89	7.556
740	177.23	126.51	0.67665	4.193	65.38	1700	422.59	306.06	0.88758	90.95	6.924
760	182.08	129.99	0.68312	4.607	61.10	1750	436.12	316.16	0.89542	101.98	6.357
780	186.94	133.47	0.68942	5.051	57.20	1800	449.71	326.32	0.90308	114.0	5.847
800	191.81	136.97	0.69558	5.526	53.63	1850	463.37	336.55	0.91056	127.2	5.388
820	196.69	140.47	0.70160	6.033	50.35	1900	477.09	346.85	0.91788	141.5	4.974
840	201.56	143.98	0.70747	6.573	47.34	1950	490.88	357.20	0.92504	157.1	4.598
860	206.46	147.50	0.71323	7.149	44.57	2000	504.71	367.61	0.93205	174.0	4.258
880	211.35	151.02	0.71886	7.761	42.01	2050	518.61	378.08	0.93891	192.3	3.949
900	216.26	154.57	0.72438	8.411	39.64	2100	532.55	388.60	0.94564	212.1	3.667
920	221.18	158.12	0.72979	9.102	37.44	2150	546.54	399.17	0.95222	233.5	3.410

1.  $p_r$  and  $v_r$  data for use with Eqs. 6.43 and 6.44, respectively.

TABLE A-22E (Continued)

Table A-22E

$T(^{\circ}\text{R}), h$ and $u(\text{Btu}/\text{lb}), s^{\circ}(\text{Btu}/\text{lb} \cdot ^{\circ}\text{R})$											
$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0^1$		$T$	$h$	$u$	$s^{\circ}$	when $\Delta s = 0$	
				$p_r$	$v_r$					$p_r$	$v_r$
2200	560.59	409.78	0.95868	256.6	3.176	3700	998.11	744.48	1.10991	2330	.5882
2250	574.69	420.46	0.96501	281.4	2.961	3750	1013.1	756.04	1.11393	2471	.5621
2300	588.82	431.16	0.97123	308.1	2.765	3800	1028.1	767.60	1.11791	2618	.5376
2350	603.00	441.91	0.97732	336.8	2.585	3850	1043.1	779.19	1.12183	2773	.5143
2400	617.22	452.70	0.98331	367.6	2.419	3900	1058.1	790.80	1.12571	2934	.4923
2450	631.48	463.54	0.98919	400.5	2.266	3950	1073.2	802.43	1.12955	3103	.4715
2500	645.78	474.40	0.99497	435.7	2.125	4000	1088.3	814.06	1.13334	3280	.4518
2550	660.12	485.31	1.00064	473.3	1.996	4050	1103.4	825.72	1.13709	3464	.4331
2600	674.49	496.26	1.00623	513.5	1.876	4100	1118.5	837.40	1.14079	3656	.4154
2650	688.90	507.25	1.01172	556.3	1.765	4150	1133.6	849.09	1.14446	3858	.3985
2700	703.35	518.26	1.01712	601.9	1.662	4200	1148.7	860.81	1.14809	4067	.3826
2750	717.83	529.31	1.02244	650.4	1.566	4300	1179.0	884.28	1.15522	4513	.3529
2800	732.33	540.40	1.02767	702.0	1.478	4400	1209.4	907.81	1.16221	4997	.3262
2850	746.88	551.52	1.03282	756.7	1.395	4500	1239.9	931.39	1.16905	5521	.3019
2900	761.45	562.66	1.03788	814.8	1.318	4600	1270.4	955.04	1.17575	6089	.2799
2950	776.05	573.84	1.04288	876.4	1.247	4700	1300.9	978.73	1.18232	6701	.2598
3000	790.68	585.04	1.04779	941.4	1.180	4800	1331.5	1002.5	1.18876	7362	.2415
3050	805.34	596.28	1.05264	1011	1.118	4900	1362.2	1026.3	1.19508	8073	.2248
3100	820.03	607.53	1.05741	1083	1.060	5000	1392.9	1050.1	1.20129	8837	.2096
3150	834.75	618.82	1.06212	1161	1.006	5100	1423.6	1074.0	1.20738	9658	.1956
3200	849.48	630.12	1.06676	1242	0.9546	5200	1454.4	1098.0	1.21336	10539	.1828
3250	864.24	641.46	1.07134	1328	0.9069	5300	1485.3	1122.0	1.21923	11481	.1710
3300	879.02	652.81	1.07585	1418	0.8621						
3350	893.83	664.20	1.08031	1513	0.8202						
3400	908.66	675.60	1.08470	1613	0.7807						
3450	923.52	687.04	1.08904	1719	0.7436						
3500	938.40	698.48	1.09332	1829	0.7087						
3550	953.30	709.95	1.09755	1946	0.6759						
3600	968.21	721.44	1.10172	2068	0.6449						
3650	983.15	732.95	1.10584	2196	0.6157						

Table A-23E

TABLE A-23E Ideal Gas Properties of Selected Gases

T	Carbon Dioxide, CO <sub>2</sub> ( $\bar{h}_f^\circ = -169,300$ Btu/lbmol)			Carbon Monoxide, CO ( $\bar{h}_f^\circ = -47,540$ Btu/lbmol)			Water Vapor, H <sub>2</sub> O ( $\bar{h}_f^\circ = -104,040$ Btu/lbmol)			Oxygen, O <sub>2</sub> ( $\bar{h}_f^\circ = 0$ Btu/lbmol)			Nitrogen, N <sub>2</sub> ( $\bar{h}_f^\circ = 0$ Btu/lbmol)		
	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$
300	2108.2	1512.4	46.353	2081.9	1486.1	43.223	2367.6	1771.8	40.439	2073.5	1477.8	44.927	2082.0	1486.2	41.695
320	2256.6	1621.1	46.832	2220.9	1585.4	43.672	2526.8	1891.3	40.952	2212.6	1577.1	45.375	2221.0	1585.5	42.143
340	2407.3	1732.1	47.289	2359.9	1684.7	44.093	2686.0	2010.8	41.435	2351.7	1676.5	45.797	2360.0	1684.4	42.564
360	2560.5	1845.6	47.728	2498.8	1783.9	44.490	2845.1	2130.2	41.889	2490.8	1775.9	46.195	2498.9	1784.0	42.962
380	2716.4	1961.8	48.148	2637.9	1883.3	44.866	3004.4	2249.8	42.320	2630.0	1875.3	46.571	2638.0	1883.4	43.337
400	2874.7	2080.4	48.555	2776.9	1982.6	45.223	3163.8	2369.4	42.728	2769.1	1974.8	46.927	2777.0	1982.6	43.694
420	3035.7	2201.7	48.947	2916.0	2081.9	45.563	3323.2	2489.1	43.117	2908.3	2074.3	47.267	2916.1	2082.0	44.034
440	3199.4	2325.6	49.329	3055.0	2181.2	45.886	3482.7	2608.9	43.487	3047.5	2173.8	47.591	3055.1	2181.3	44.357
460	3365.7	2452.2	49.698	3194.0	2280.5	46.194	3642.3	2728.8	43.841	3186.9	2273.4	47.900	3194.1	2280.6	44.665
480	3534.7	2581.5	50.058	3333.0	2379.8	46.491	3802.0	2848.8	44.182	3326.5	2373.3	48.198	3333.1	2379.9	44.962
500	3706.2	2713.3	50.408	3472.1	2479.2	46.775	3962.0	2969.1	44.508	3466.2	2473.2	48.483	3472.2	2479.3	45.246
520	3880.3	2847.7	50.750	3611.2	2578.6	47.048	4122.0	3089.4	44.821	3606.1	2573.4	48.757	3611.3	2578.6	45.519
537	4027.5	2963.8	51.032	3725.1	2663.1	47.272	4258.0	3191.9	45.079	3725.1	2658.7	48.982	3729.5	2663.1	45.743
540	4056.8	2984.4	51.082	3750.3	2677.9	47.310	4282.4	3210.0	45.124	3746.2	2673.8	49.021	3750.3	2678.0	45.781
560	4235.8	3123.7	51.408	3889.5	2777.4	47.563	4442.8	3330.7	45.415	3886.6	2774.5	49.276	3889.5	2777.4	46.034
580	4417.2	3265.4	51.726	4028.7	2876.9	47.807	4603.7	3451.9	45.696	4027.3	2875.5	49.522	4028.7	2876.9	46.278
600	4600.9	3409.4	52.038	4168.0	2976.5	48.044	4764.7	3573.2	45.970	4168.3	2976.8	49.762	4167.9	2976.4	46.514
620	4786.6	3555.6	52.343	4307.4	3076.2	48.272	4926.1	3694.9	46.235	4309.7	3078.4	49.993	4307.1	3075.9	46.742
640	4974.9	3704.0	52.641	4446.9	3175.9	48.494	5087.8	3816.8	46.492	4451.4	3180.4	50.218	4446.4	3175.5	46.964
660	5165.2	3854.6	52.934	4586.6	3275.8	48.709	5250.0	3939.3	46.741	4593.5	3282.9	50.437	4585.8	3275.2	47.178
680	5357.6	4007.2	53.225	4726.2	3375.8	48.917	5412.5	4062.1	46.984	4736.2	3385.8	50.650	4725.3	3374.9	47.386
700	5552.0	4161.9	53.503	4866.0	3475.9	49.120	5575.4	4185.3	47.219	4879.3	3489.2	50.858	4864.9	3474.8	47.588
720	5748.4	4318.6	53.780	5006.1	3576.3	49.317	5738.8	4309.0	47.450	5022.9	3593.1	51.059	5004.5	3574.7	47.785
740	5946.8	4477.3	54.051	5146.4	3676.9	49.509	5902.6	4433.1	47.673	5167.0	3697.4	51.257	5144.3	3674.7	47.977
760	6147.0	4637.9	54.319	5286.8	3777.5	49.697	6066.9	4557.6	47.893	5311.4	3802.2	51.450	5284.1	3774.9	48.164
780	6349.1	4800.1	54.582	5427.4	3878.4	49.880	6231.7	4682.7	48.106	5456.4	3907.5	51.638	5424.2	3875.2	48.345
800	6552.9	4964.2	54.839	5568.2	3979.5	50.058	6396.9	4808.2	48.316	5602.0	4013.3	51.821	5564.4	3975.7	48.522
820	6758.3	5129.9	55.093	5709.4	4081.0	50.232	6562.6	4934.2	48.520	5748.1	4119.7	52.002	5704.7	4076.3	48.696
840	6965.7	5297.6	55.343	5850.7	4182.6	50.402	6728.9	5060.8	48.721	5894.8	4226.6	52.179	5845.3	4177.1	48.865
860	7174.7	5466.9	55.589	5992.3	4284.5	50.569	6895.6	5187.8	48.916	6041.9	4334.1	52.352	5985.9	4278.1	49.031
880	7385.3	5637.7	55.831	6134.2	4386.6	50.732	7062.9	5315.3	49.109	6189.6	4442.0	52.522	6126.9	4379.4	49.193
900	7597.6	5810.3	56.070	6276.4	4489.1	50.892	7230.9	5443.6	49.298	6337.9	4550.6	52.688	6268.1	4480.8	49.352
920	7811.4	5984.4	56.305	6419.0	4592.0	51.048	7399.4	5572.4	49.483	6486.7	4659.7	52.852	6409.6	4582.6	49.507
940	8026.8	6160.1	56.536	6561.7	4695.0	51.202	7568.4	5701.7	49.665	6636.1	4769.4	53.012	6551.2	4684.5	49.659
960	8243.8	6337.4	56.765	6704.9	4798.5	51.353	7738.0	5831.6	49.843	6786.0	4879.5	53.170	6693.1	4786.7	49.808
980	8462.2	6516.1	56.990	6848.4	4902.3	51.501	7908.2	5962.0	50.019	6936.4	4990.3	53.326	6835.4	4889.3	49.955
1000	8682.1	6696.2	57.212	6992.2	5006.3	51.646	8078.9	6093.0	50.191	7087.5	5101.6	53.477	6977.9	4992.0	50.099
1020	8903.4	6877.8	57.432	7136.4	5110.8	51.788	8250.4	6224.8	50.360	7238.9	5213.3	53.628	7120.7	5095.1	50.241
1040	9126.2	7060.9	57.647	7281.0	5215.7	51.929	8422.4	6357.1	50.528	7391.0	5325.7	53.775	7263.8	5198.5	50.380
1060	9350.3	7245.3	57.861	7425.9	5320.9	52.067	8595.0	6490.0	50.693	7543.6	5438.6	53.921	7407.2	5302.2	50.516

T	Carbon Dioxide, CO <sub>2</sub> ( $\bar{h}_f^{\circ} = -169,300$ Btu/lbmol)			Carbon Monoxide, CO ( $\bar{h}_f^{\circ} = -47,540$ Btu/lbmol)			Water Vapor, H <sub>2</sub> O ( $\bar{h}_f^{\circ} = -104,040$ Btu/lbmol)			Oxygen, O <sub>2</sub> ( $\bar{h}_f^{\circ} = 0$ Btu/lbmol)			Nitrogen, N <sub>2</sub> ( $\bar{h}_f^{\circ} = 0$ Btu/lbmol)		
	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$
1080	9575.8	7431.1	58.072	7571.1	5426.4	52.203	8768.2	6623.5	50.854	7696.8	5552.1	54.064	7551.0	5406.2	50.651
1100	9802.6	7618.1	58.281	7716.8	5532.3	52.337	8942.0	6757.5	51.013	7850.4	5665.9	54.204	7695.0	5510.5	50.783
1120	10030.6	7806.4	58.485	7862.9	5638.7	52.468	9116.4	6892.2	51.171	8004.5	5780.3	54.343	7839.3	5615.2	50.912
1140	10260.1	7996.2	58.689	8009.2	5745.4	52.598	9291.4	7027.5	51.325	8159.1	5895.2	54.480	7984.0	5720.1	51.040
1160	10490.6	8187.0	58.889	8156.1	5851.5	52.726	9467.1	7163.5	51.478	8314.2	6010.6	54.614	8129.0	5825.4	51.167
1180	10722.3	8379.0	59.088	8303.3	5960.0	52.852	9643.4	7300.1	51.630	8469.8	6126.5	54.748	8274.4	5931.0	51.291
1200	10955.3	8572.3	59.283	8450.8	6067.8	52.976	9820.4	7437.4	51.777	8625.8	6242.8	54.879	8420.0	6037.0	51.413
1220	11189.4	8766.6	59.477	8598.8	6176.0	53.098	9998.0	7575.2	51.925	8782.4	6359.6	55.008	8566.1	6143.4	51.534
1240	11424.6	8962.1	59.668	8747.2	6284.7	53.218	10176.1	7713.6	52.070	8939.4	6476.9	55.136	8712.6	6250.1	51.653
1260	11661.0	9158.8	59.858	8896.0	6393.8	53.337	10354.9	7852.7	52.212	9096.7	6594.5	55.262	8859.3	6357.2	51.771
1280	11898.4	9356.5	60.044	9045.0	6503.1	53.455	10534.4	7992.5	52.354	9254.6	6712.7	55.386	9006.4	6464.5	51.887
1300	12136.9	9555.3	60.229	9194.6	6613.0	53.571	10714.5	8132.9	52.494	9412.9	6831.3	55.508	9153.9	6572.3	51.001
1320	12376.4	9755.0	60.412	9344.6	6723.2	53.685	10895.3	8274.0	52.631	9571.6	6950.2	55.630	9301.8	6680.4	52.114
1340	12617.0	9955.9	60.593	9494.8	6833.7	53.799	11076.6	8415.5	52.768	9730.7	7069.6	55.750	9450.0	6788.9	52.225
1360	12858.5	10157.7	60.772	9645.5	6944.7	53.910	11258.7	8557.9	52.903	9890.2	7189.4	55.867	9598.6	6897.8	52.335
1380	13101.0	10360.5	60.949	9796.6	7056.1	54.021	11441.4	8700.9	53.037	10050.1	7309.6	55.984	9747.5	7007.0	52.444
1400	13344.7	10564.5	61.124	9948.1	7167.9	54.129	11624.8	8844.6	53.168	10210.4	7430.1	56.099	9896.9	7116.7	52.551
1420	13589.1	10769.2	61.298	10100.0	7280.1	54.237	11808.8	8988.9	53.299	10371.0	7551.1	56.213	10046.6	7226.7	52.658
1440	13834.5	10974.8	61.469	10252.2	7392.6	54.344	11993.4	9133.8	53.428	10532.0	7672.4	56.326	10196.6	7337.0	52.763
1460	14080.8	11181.4	61.639	10404.8	7505.4	54.448	12178.8	9279.4	53.556	10693.3	7793.9	56.437	10347.0	7447.6	52.867
1480	14328.0	11388.9	61.800	10557.8	7618.7	54.522	12364.8	9425.7	53.682	10855.1	7916.0	56.547	10497.8	7558.7	52.969
1500	14576.0	11597.2	61.974	10711.1	7732.3	54.665	12551.4	9572.7	53.808	11017.1	8038.3	56.656	10648.0	7670.1	53.071
1520	14824.9	11806.4	62.138	10864.9	7846.4	54.757	12738.8	9720.3	53.932	11179.6	8161.1	56.763	10800.4	7781.9	53.171
1540	15074.7	12016.5	62.302	11019.0	7960.8	54.858	12926.8	9868.6	54.055	11342.4	8284.2	56.869	10952.2	7893.9	53.271
1560	15325.3	12227.3	62.464	11173.4	8075.4	54.958	13115.6	10017.6	54.117	11505.4	8407.4	56.975	11104.3	8006.4	53.369
1580	15576.7	12439.0	62.624	11328.2	8190.5	55.056	13305.0	10167.3	54.298	11668.8	8531.1	57.079	11256.9	8119.2	53.465
1600	15829.0	12651.6	62.783	11483.4	8306.0	55.154	13494.4	10317.6	54.418	11832.5	8655.1	57.182	11409.7	8232.3	53.561
1620	16081.9	12864.8	62.939	11638.9	8421.8	55.251	13685.7	10468.6	54.535	11996.6	8779.5	57.284	11562.8	8345.7	53.656
1640	16335.7	13078.9	63.095	11794.7	8537.9	55.347	13877.0	10620.2	54.653	12160.9	8904.1	57.385	11716.4	8459.6	53.751
1660	16590.2	13293.7	63.250	11950.9	8654.4	55.411	14069.2	10772.7	54.770	12325.5	9029.0	57.484	11870.2	8573.6	53.844
1680	16845.5	13509.2	63.403	12107.5	8771.2	55.535	14261.9	10925.6	54.886	12490.4	9154.1	57.582	12024.3	8688.1	53.936
1700	17101.4	13725.4	63.555	12264.3	8888.3	55.628	14455.4	11079.4	54.999	12655.6	9279.6	57.680	12178.9	8802.9	54.028
1720	17358.1	13942.4	63.704	12421.4	9005.7	55.720	14649.5	11233.8	55.113	12821.1	9405.4	57.777	12333.7	8918.0	54.118
1740	17615.5	14160.1	63.853	12579.0	9123.6	55.811	14844.3	11388.9	55.226	12986.9	9531.5	57.873	12488.8	9033.4	54.208
1760	17873.5	14378.4	64.001	12736.7	9241.6	55.900	15039.8	11544.7	55.339	13153.0	9657.9	57.968	12644.3	9149.2	54.297
1780	18132.2	14597.4	64.147	12894.9	9360.0	55.990	15236.1	11701.2	55.449	13319.2	9784.4	58.062	12800.2	9265.3	54.385
1800	18391.5	14816.9	64.292	13053.2	9478.6	56.078	15433.0	11858.4	55.559	13485.8	9911.2	58.155	12956.3	9381.7	54.472
1820	18651.5	15037.2	64.435	13212.0	9597.7	56.166	15630.6	12016.3	55.668	13652.5	10038.2	58.247	13112.7	9498.4	54.559
1840	18912.2	15258.2	64.578	13371.0	9717.0	56.253	15828.7	12174.7	55.777	13819.6	10165.6	58.339	13269.5	9615.5	54.645
1860	19173.4	15479.7	64.719	13530.2	9836.5	56.339	16027.6	12333.9	55.884	13986.8	10293.1	58.428	13426.5	9732.8	54.729

Table A-23E

TABLE A-23E (Continued)

T	Carbon Dioxide, CO <sub>2</sub> ( $\bar{h}_f^\circ = -169,300$ Btu/lbmol)			Carbon Monoxide, CO ( $\bar{h}_f^\circ = -47,540$ Btu/lbmol)			Water Vapor, H <sub>2</sub> O ( $\bar{h}_f^\circ = -104,040$ Btu/lbmol)			Oxygen, O <sub>2</sub> ( $\bar{h}_f^\circ = 0$ Btu/lbmol)			Nitrogen, N <sub>2</sub> ( $\bar{h}_f^\circ = 0$ Btu/lbmol)		
	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$	$\bar{h}$	$\bar{u}$	$\bar{s}^\circ$
1900	19,698	15,925	64.999	13,850	10,077	56.509	16,428	12,654	56.097	14,322	10,549	58.607	13,742	9,968	54.896
1940	20,224	16,372	65.272	14,170	10,318	56.677	16,830	12,977	56.307	14,658	10,806	58.782	14,058	10,205	55.061
1980	20,753	16,821	65.543	14,492	10,560	56.841	17,235	13,303	56.514	14,995	11,063	58.954	14,375	10,443	55.223
2020	21,284	17,273	65.809	14,815	10,803	57.007	17,643	13,632	56.719	15,333	11,321	59.123	14,694	10,682	55.383
2060	21,818	17,727	66.069	15,139	11,048	57.161	18,054	13,963	56.920	15,672	11,581	59.289	15,013	10,923	55.540
2100	22,353	18,182	66.327	15,463	11,293	57.317	18,467	14,297	57.119	16,011	11,841	59.451	15,334	11,164	55.694
2140	22,890	18,640	66.581	15,789	11,539	57.470	18,883	14,633	57.315	16,351	12,101	59.612	15,656	11,406	55.846
2180	23,429	19,101	66.830	16,116	11,787	57.621	19,301	14,972	57.509	16,692	12,363	59.770	15,978	11,649	55.995
2220	23,970	19,561	67.076	16,443	12,035	57.770	19,722	15,313	57.701	17,036	12,625	59.926	16,302	11,893	56.141
2260	24,512	20,024	67.319	16,772	12,284	57.917	20,145	15,657	57.889	17,376	12,888	60.077	16,626	12,138	56.286
2300	25,056	20,489	67.557	17,101	12,534	58.062	20,571	16,003	58.077	17,719	13,151	60.228	16,951	12,384	56.429
2340	25,602	20,955	67.792	17,431	12,784	58.204	20,999	16,352	58.261	18,062	13,416	60.376	17,277	12,630	56.570
2380	26,150	21,423	68.025	17,762	13,035	58.344	21,429	16,703	58.445	18,407	13,680	60.522	17,604	12,878	56.708
2420	26,699	21,893	68.253	18,093	13,287	58.482	21,862	17,057	58.625	18,752	13,946	60.666	17,932	13,126	56.845
2460	27,249	22,364	68.479	18,426	13,541	58.619	22,298	17,413	58.803	19,097	14,212	60.808	18,260	13,375	56.980
2500	27,801	22,837	68.702	18,759	13,794	58.754	22,735	17,771	58.980	19,443	14,479	60.946	18,590	13,625	57.112
2540	28,355	23,310	68.921	19,093	14,048	58.885	23,175	18,131	59.155	19,790	14,746	61.084	18,919	13,875	57.243
2580	28,910	23,786	69.138	19,427	14,303	59.016	23,618	18,494	59.328	20,138	15,014	61.220	19,250	14,127	57.372
2620	29,465	24,262	69.352	19,762	14,559	59.145	24,062	18,859	59.500	20,485	15,282	61.354	19,582	14,379	57.499
2660	30,023	24,740	69.563	20,098	14,815	59.272	24,508	19,226	59.669	20,834	15,551	61.486	19,914	14,631	57.625
2700	30,581	25,220	69.771	20,434	15,072	59.398	24,957	19,595	59.837	21,183	15,821	61.616	20,246	14,885	57.750
2740	31,141	25,701	69.977	20,771	15,330	59.521	25,408	19,967	60.003	21,533	16,091	61.744	20,580	15,139	57.872
2780	31,702	26,181	70.181	21,108	15,588	59.644	25,861	20,340	60.167	21,883	16,362	61.871	20,914	15,393	57.993
2820	32,264	26,664	70.382	21,446	15,846	59.765	26,316	20,715	60.330	22,232	16,633	61.996	21,248	15,648	58.113
2860	32,827	27,148	70.580	21,785	16,105	59.884	26,773	21,093	60.490	22,584	16,905	62.120	21,584	15,905	58.231
2900	33,392	27,633	70.776	22,124	16,365	60.002	27,231	21,472	60.650	22,936	17,177	62.242	21,920	16,161	58.348
2940	33,957	28,118	70.970	22,463	16,625	60.118	27,692	21,853	60.809	23,288	17,450	62.363	22,256	16,417	58.463
2980	34,523	28,605	71.160	22,803	16,885	60.232	28,154	22,237	60.965	23,641	17,723	62.483	22,593	16,675	58.576
3020	35,090	29,093	71.350	23,144	17,146	60.346	28,619	22,621	61.120	23,994	17,997	62.599	22,930	16,933	58.688
3060	35,659	29,582	71.537	23,485	17,408	60.458	29,085	23,085	61.274	24,348	18,271	62.716	23,268	17,192	58.800
3100	36,228	30,072	71.722	23,826	17,670	60.569	29,553	23,397	61.426	24,703	18,546	62.831	23,607	17,451	58.910
3140	36,798	30,562	71.904	24,168	17,932	60.679	30,023	23,787	61.577	25,057	18,822	62.945	23,946	17,710	59.019
3180	37,369	31,054	72.085	24,510	18,195	60.787	30,494	24,179	61.727	25,413	19,098	63.057	24,285	17,970	59.126
3220	37,941	31,546	72.264	24,853	18,458	60.894	30,967	24,572	61.874	25,769	19,374	63.169	24,625	18,231	59.232
3260	38,513	32,039	72.441	25,196	18,722	61.000	31,442	24,968	62.022	26,175	19,651	63.279	24,965	18,491	59.338
3300	39,087	32,533	72.616	25,539	18,986	61.105	31,918	25,365	62.167	26,412	19,928	63.386	25,306	18,753	59.442
3340	39,661	33,028	72.788	25,883	19,250	61.209	32,396	25,763	62.312	26,839	20,206	63.494	25,647	19,014	59.544
3380	40,236	33,524	72.960	26,227	19,515	61.311	32,876	26,164	62.454	27,197	20,485	63.601	25,989	19,277	59.646
3420	40,812	34,020	73.129	26,572	19,780	61.412	33,357	26,565	62.597	27,555	20,763	63.706	26,331	19,539	59.747
3460	41,388	34,517	73.297	26,917	20,045	61.513	33,839	26,968	62.738	27,914	21,043	63.811	26,673	19,802	59.846

$T(^{\circ}R), \bar{h}$  and  $\bar{u}$ (Btu/lbmol),  $\bar{s}^{\circ}$ (Btu/lbmol  $\cdot^{\circ}R$ )

T	Carbon Dioxide, CO <sub>2</sub> ( $\bar{h}_f^{\circ} = -169,300$ Btu/lbmol)			Carbon Monoxide, CO ( $\bar{h}_f^{\circ} = -47,540$ Btu/lbmol)			Water Vapor, H <sub>2</sub> O ( $\bar{h}_f^{\circ} = -104,040$ Btu/lbmol)			Oxygen, O <sub>2</sub> ( $\bar{h}_f^{\circ} = 0$ Btu/lbmol)			Nitrogen, N <sub>2</sub> ( $\bar{h}_f^{\circ} = 0$ Btu/lbmol)			T
	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	$\bar{h}$	$\bar{u}$	$\bar{s}^{\circ}$	
3500	41,965	35,015	73.462	27,262	20,311	61.612	34,324	27,373	62.875	28,273	21,323	63.914	27,016	20,065	59.944	3500
3540	42,543	35,513	73.627	27,608	20,576	61.710	34,809	27,779	63.015	28,633	21,603	64.016	27,359	20,329	60.041	3540
3580	43,121	36,012	73.789	27,954	20,844	61.807	35,296	28,187	63.153	28,994	21,884	64.114	27,703	20,593	60.138	3580
3620	43,701	36,512	73.951	28,300	21,111	61.903	35,785	28,596	63.288	29,354	22,165	64.217	28,046	20,858	60.234	3620
3660	44,280	37,012	74.110	28,647	21,378	61.998	36,274	29,006	63.423	29,716	22,447	64.316	28,391	21,122	60.328	3660
3700	44,861	37,513	74.267	28,994	21,646	62.093	36,765	29,418	63.557	30,078	22,730	64.415	28,735	21,387	60.422	3700
3740	45,442	38,014	74.423	29,341	21,914	62.186	37,258	29,831	63.690	30,440	23,013	64.512	29,080	21,653	60.515	3740
3780	46,023	38,517	74.578	29,688	22,182	62.279	37,752	30,245	63.821	30,803	23,296	64.609	29,425	21,919	60.607	3780
3820	46,605	39,019	74.732	30,036	22,450	62.370	38,247	30,661	63.952	31,166	23,580	64.704	29,771	22,185	60.698	3820
3860	47,188	39,522	74.884	30,384	22,719	62.461	38,743	31,077	64.082	31,529	23,864	64.800	30,117	22,451	60.788	3860
3900	47,771	40,026	75.033	30,733	22,988	61.511	39,240	31,495	64.210	31,894	24,149	64.893	30,463	22,718	60.877	3900
3940	48,355	40,531	75.182	31,082	23,257	62.640	39,739	31,915	64.338	32,258	24,434	64.986	30,809	22,985	60.966	3940
3980	48,939	41,035	75.330	31,431	23,527	62.728	40,239	32,335	64.465	32,623	24,720	65.078	31,156	23,252	61.053	3980
4020	49,524	41,541	75.477	31,780	23,797	62.816	40,740	32,757	64.591	32,989	25,006	65.169	31,503	23,520	61.139	4020
4060	50,109	42,047	75.622	32,129	24,067	62.902	41,242	33,179	64.715	33,355	25,292	65.260	31,850	23,788	61.225	4060
4100	50,695	42,553	75.765	32,479	24,337	62.988	41,745	33,603	64.839	33,722	25,580	65.350	32,198	24,056	61.310	4100
4140	51,282	43,060	75.907	32,829	24,608	63.072	42,250	34,028	64.962	34,089	25,867	64.439	32,546	24,324	61.395	4140
4180	51,868	43,568	76.048	33,179	24,878	63.156	42,755	34,454	65.084	34,456	26,155	65.527	32,894	24,593	61.479	4180
4220	52,456	44,075	76.188	33,530	25,149	63.240	43,267	34,881	65.204	34,824	26,444	65.615	33,242	24,862	61.562	4220
4260	53,044	44,584	76.327	33,880	25,421	63.323	43,769	35,310	65.325	35,192	26,733	65.702	33,591	25,131	61.644	4260
4300	53,632	45,093	76.464	34,231	25,692	63.405	44,278	35,739	65.444	35,561	27,022	65.788	33,940	25,401	61.726	4300
4340	54,221	45,602	76.601	34,582	25,934	63.486	44,788	36,169	65.563	35,930	27,312	65.873	34,289	25,670	61.806	4340
4380	54,810	46,112	76.736	34,934	26,235	63.567	45,298	36,600	65.680	36,300	27,602	65.958	34,638	25,940	61.887	4380
4420	55,400	46,622	76.870	35,285	26,508	63.647	45,810	37,032	65.797	36,670	27,823	66.042	34,988	26,210	61.966	4420
4460	55,990	47,133	77.003	35,637	26,780	63.726	46,322	37,465	65.913	37,041	28,184	66.125	35,338	26,481	62.045	4460
4500	56,581	47,645	77.135	35,989	27,052	63.805	46,836	37,900	66.028	37,412	28,475	66.208	35,688	26,751	62.123	4500
4540	57,172	48,156	77.266	36,341	27,325	63.883	47,350	38,334	66.142	37,783	28,768	66.290	36,038	27,022	62.201	4540
4580	57,764	48,668	77.395	36,693	27,598	63.960	47,866	38,770	66.255	38,155	29,060	66.372	36,389	27,293	62.278	4580
4620	58,356	49,181	77.521	37,046	27,871	64.036	48,382	39,207	66.368	38,528	29,353	66.453	36,739	27,565	62.354	4620
4660	58,948	49,694	77.652	37,398	28,144	64.113	48,899	39,645	66.480	38,900	29,646	66.533	37,090	27,836	62.429	4660
4700	59,541	50,208	77.779	37,751	28,417	64.188	49,417	40,083	66.591	39,274	29,940	66.613	37,441	28,108	62.504	4700
4740	60,134	50,721	77.905	38,104	28,691	64.263	49,936	40,523	66.701	39,647	30,234	66.691	37,792	28,379	62.578	4740
4780	60,728	51,236	78.029	38,457	28,965	64.337	50,455	40,963	66.811	40,021	30,529	66.770	38,144	28,651	62.652	4780
4820	61,322	51,750	78.153	38,811	29,239	64.411	50,976	41,404	66.920	40,396	30,824	66.848	38,495	28,924	62.725	4820
4860	61,916	52,265	78.276	39,164	29,513	64.484	51,497	41,856	67.028	40,771	31,120	66.925	38,847	29,196	62.798	4860
4900	62,511	52,781	78.398	39,518	29,787	64.556	52,019	42,288	67.135	41,146	31,415	67.003	39,199	29,468	62.870	4900
5000	64,000	54,071	78.698	40,403	30,473	64.735	53,327	43,398	67.401	42,086	32,157	67.193	40,080	30,151	63.049	5000
5100	65,491	55,363	78.994	41,289	31,161	64.910	54,640	44,512	67.662	43,021	32,901	67.380	40,962	30,834	63.223	5100
5200	66,984	56,658	79.284	42,176	31,849	65.082	55,957	45,631	67.918	43,974	33,648	67.562	41,844	31,518	63.395	5200
5300	68,471	57,954	79.569	43,063	32,538	65.252	57,279	46,754	68.172	44,922	34,397	67.743	42,728	32,203	63.563	5300

Table A-23E

TABLE A-24E Constants for the van der Waals, Redlich-Kwong, and Benedict-Webb-Rubin Equations of State

1. van der Waals and Redlich-Kwong: Constants for pressure in atm, specific volume in ft<sup>3</sup>/lbmol, and temperature in °R

Substance	van der Waals		Redlich-Kwong	
	atm $\left(\frac{\text{ft}^3}{\text{lbmol}}\right)^2$	$\frac{b}{\text{ft}^3/\text{lbmol}}$	atm $\left(\frac{\text{ft}^3}{\text{lbmol}}\right)^2 (\text{°R})^{1/2}$	$\frac{b}{\text{ft}^3/\text{lbmol}}$
Air	345	0.586	5,409	0.4064
Butane (C <sub>4</sub> H <sub>10</sub> )	3,509	1.862	98,349	1.2903
Carbon dioxide (CO <sub>2</sub> )	926	0.686	21,972	0.4755
Carbon monoxide (CO)	372	0.632	5,832	0.4382
Methane (CH <sub>4</sub> )	581	0.685	10,919	0.4751
Nitrogen (N <sub>2</sub> )	346	0.618	5,280	0.4286
Oxygen (O <sub>2</sub> )	349	0.509	5,896	0.3531
Propane (C <sub>3</sub> H <sub>8</sub> )	2,369	1.444	61,952	1.0006
Refrigerant 12	2,660	1.558	70,951	1.0796
Sulfur dioxide (SO <sub>2</sub> )	1,738	0.910	49,032	0.6309
Water (H <sub>2</sub> O)	1,400	0.488	48,418	0.3380

Source: Calculated from critical data.

2. Benedict-Webb-Rubin: Constants for pressure in atm, specific volume in ft<sup>3</sup>/lbmol, and temperature in °R

Substance	<i>a</i>	<i>A</i>	<i>b</i>	<i>B</i>	<i>c</i>	<i>C</i>	<i>α</i>	<i>γ</i>
C <sub>4</sub> H <sub>10</sub>	7736.7	2587.6	10.26	1.9921	4.214 × 10 <sup>9</sup>	8.254 × 10 <sup>8</sup>	4.527	8.724
CO <sub>2</sub>	562.3	702.4	1.850	0.7995	1.987 × 10 <sup>8</sup>	1.152 × 10 <sup>8</sup>	0.348	1.384
CO	150.6	344.1	0.675	0.8737	1.385 × 10 <sup>7</sup>	7.118 × 10 <sup>6</sup>	0.555	1.540
CH <sub>4</sub>	203.0	476.0	0.867	0.6824	3.389 × 10 <sup>7</sup>	1.876 × 10 <sup>7</sup>	0.511	1.540
N <sub>2</sub>	103.2	270.4	0.597	0.6526	9.700 × 10 <sup>6</sup>	6.700 × 10 <sup>6</sup>	0.523	1.360

Source: H. W. Cooper and J. C. Goldfrank, *Hydrocarbon Processing*, 46 (12): 141 (1967).

TABLE A-25E Thermochemical Properties of Selected Substances at 537°R and 1 atm

Substance	Formula	Molar Mass, <i>M</i> (lb/lbmol)	Enthalpy of Formation, $\bar{h}_f^\circ$ (Btu/lbmol)	Gibbs Function of Formation, $\bar{g}_f^\circ$ (Btu/lbmol)	Absolute Entropy, $\bar{s}^\circ$ (Btu/lbmol · °R)	Heating Values	
						Higher, HHV (Btu/lb)	Lower, LHV (Btu/lb)
Carbon	C(s)	12.01	0	0	1.36	14,100	14,100
Hydrogen	H <sub>2</sub> (g)	2.016	0	0	31.19	61,000	51,610
Nitrogen	N <sub>2</sub> (g)	28.01	0	0	45.74	—	—
Oxygen	O <sub>2</sub> (g)	32.00	0	0	48.98	—	—
Carbon monoxide	CO(g)	28.01	-47,540	-59,010	47.27	—	—
Carbon dioxide	CO <sub>2</sub> (g)	44.01	-169,300	-169,680	51.03	—	—
Water	H <sub>2</sub> O(g)	18.02	-104,040	-98,350	45.08	—	—
Water	H <sub>2</sub> O(l)	18.02	-122,970	-102,040	16.71	—	—
Hydrogen peroxide	H <sub>2</sub> O <sub>2</sub> (g)	34.02	-58,640	-45,430	55.60	—	—
Ammonia	NH <sub>3</sub> (g)	17.03	-19,750	-7,140	45.97	—	—
Oxygen	O(g)	16.00	107,210	99,710	38.47	—	—
Hydrogen	H(g)	1.008	93,780	87,460	27.39	—	—
Nitrogen	N(g)	14.01	203,340	195,970	36.61	—	—
Hydroxyl	OH(g)	17.01	16,790	14,750	43.92	—	—
Methane	CH <sub>4</sub> (g)	16.04	-32,210	-21,860	44.49	23,880	21,520
Acetylene	C <sub>2</sub> H <sub>2</sub> (g)	26.04	97,540	87,990	48.00	21,470	20,740
Ethylene	C <sub>2</sub> H <sub>4</sub> (g)	28.05	22,490	29,306	52.54	21,640	20,290
Ethane	C <sub>2</sub> H <sub>6</sub> (g)	30.07	-36,420	-14,150	54.85	22,320	20,430
Propylene	C <sub>3</sub> H <sub>6</sub> (g)	42.08	8,790	26,980	63.80	21,050	19,700
Propane	C <sub>3</sub> H <sub>8</sub> (g)	44.09	-44,680	-10,105	64.51	21,660	19,950
Butane	C <sub>4</sub> H <sub>10</sub> (g)	58.12	-54,270	-6,760	74.11	21,300	19,670
Pentane	C <sub>5</sub> H <sub>12</sub> (g)	72.15	-62,960	-3,530	83.21	21,090	19,510
Octane	C <sub>8</sub> H <sub>18</sub> (g)	114.22	-89,680	7,110	111.55	20,760	19,270
Octane	C <sub>8</sub> H <sub>18</sub> (l)	114.22	-107,530	2,840	86.23	20,610	19,110
Benzene	C <sub>6</sub> H <sub>6</sub> (g)	78.11	35,680	55,780	64.34	18,180	17,460
Methyl alcohol	CH <sub>3</sub> OH(g)	32.04	-86,540	-69,700	57.29	10,260	9,080
Methyl alcohol	CH <sub>3</sub> OH(l)	32.04	-102,670	-71,570	30.30	9,760	8,570
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH(g)	46.07	-101,230	-72,520	67.54	13,160	11,930
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH(l)	46.07	-119,470	75,240	38.40	12,760	11,530

Source: Based on JANAF Thermochemical Tables, NSRDS-NBS-37, 1971; *Selected Values of Chemical Thermodynamic Properties*, NBS Tech. Note 270-3, 1968; and *API Research Project 44*, Carnegie Press, 1953. Heating values calculated.