

Level : B. Tech.
Year : II
Time : 2 hrs. 30 mins.

Course : ENVE 204
Semester : I
F. M. : 55

SECTION "B"

Answer ALL the questions. The data or information not given in the questions should be assumed properly.

- The flow of mass in a device depends upon gas pressure and temperature. For a given pressure p and temperature T , mass flow rate through the device is given by $m = 0.0644 p / (T)^{0.5}$ where m is in lb/min, p is in psia and T is in °R.

(a) What is the unit of the constant 0.0644? [3]

(b) What will be the new value of the constant, now given as 0.0644, if the variables in the equation are to be substituted with SI units and m is calculated in SI units. [4]
- Calcium sulfate is reacted with carbon in the form of coke containing 6 percent ash (which is infusible). The composition of the fusion mass is: CaSO₄: 11.1%; CaS: 72.8%; C: 13.9%; Ash: 2.2%. The reaction is $\text{CaSO}_4 + 4\text{C} \rightarrow \text{CaS} + 4\text{CO}$. The molecular weights of CaSO₄ and CaS are 136.14 and 72.14 respectively. Calculate the following:

(a) the limiting reactant [3]

(b) the percentage of excess reactant [2]

(c) the degree of completion of the reaction [3]
- A solution, composed of 40% of contaminant **A**, 20% of contaminant **B**, and 40% of water, is fed at the rate of 200 kg/hr into a separator that produces one stream at the rate of 120 kg/hr with the composition of 85% **A**, 10% **B**, and 5% water, and a second stream of unknown composition. Calculate the following using mass balance diagram:

(a) the composition (in %) of the three compounds in the unknown stream, [6]

(b) the flow rates of the three compounds (in kg/hr) in the unknown stream. [2]
- The experimental data for the exit Orsat gas analysis from the combustion of a hydrocarbon oil in a furnace are: CO₂: 12.3 %; CO: 4.8 %; H₂: 1.2 %; O₂: 1.6%; and the remainder is N₂.

(a) Calculate all the unknowns in the material balance. [6]

(b) What is the required oxygen? [3]
- Clearly explain the importance of single-pass conversion and overall conversion in material balances having recycle streams. [4]
- The composition of a gas mixture is: CO₂: 15%, CH₄: 40% and C₂H₄: 45%. The mass of 40.2 lb of this mixture has to be filled in a container. The maximum pressure inside the container should not exceed 2200 psig when the temperature is 175 °F. Calculate the volume of the container required by Kay's method. [7]

Use $R = 10.73 \text{ (psia)(ft}^3\text{)/(lb mol)(}^\circ\text{R)} = 0.7302 \text{ (atm)(ft}^3\text{)/(lb mol)(}^\circ\text{R)}$. For CO₂, $p_c = 72.9 \text{ atm}$ and $T_c = 304.2 \text{ K}$. For CH₄, $p_c = 45.8 \text{ atm}$ and $T_c = 190.7 \text{ K}$. For C₂H₄, $p_c = 50.5 \text{ atm}$ and $T_c = 283.1$.

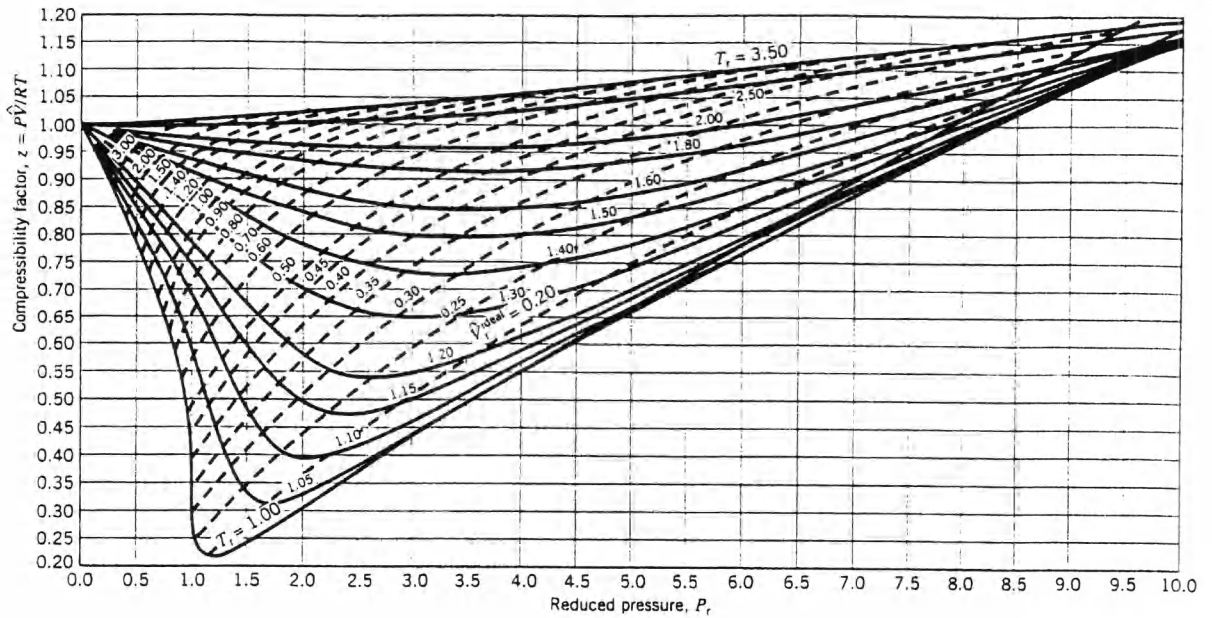


Figure for Q.6: Generalized compressibility chart.

7. During a certain day in a city, the ambient temperature is 93 °F, relative humidity is 83%, and the barometric pressure is 14.588 psia.
- Find the molar humidity. [3]
 - Find the humidity using weight basis. [2]
 - Find the dew point. [1]
8. In an aeration system, an air blower supplies 182 gmol of air/min to the aerator. The blower uses 1.4 kW. The inlet gas flow rate is 3.02 m³/min at a temperature of 305 K. Determine the final temperature of the gas assuming the process is adiabatic, and that the blower is 100% efficient. [6]

CONVERSION FACTORS

VOLUME EQUIVALENTS

	in. ³	ft. ³	U.S. gal	liters	m ³
in. ³	1	5.787×10^{-4}	4.329×10^{-3}	1.639×10^{-2}	1.639×10^{-5}
ft. ³	1.728×10^3	1	7.481	28.32	2.832×10^{-2}
U.S. gal	2.31×10^2	0.1337	1	3.785	3.785×10^{-3}
liters	61.03	3.531×10^{-2}	0.2642	1	1.000×10^{-3}
m ³	6.102×10^4	35.31	264.2	1000	1

MASS EQUIVALENTS

	avoir oz	pounds	grains	grams
avoir oz	1	6.25×10^{-2}	4.375×10^2	28.35
pounds	16	1	7×10^3	4.536×10^2
grains	2.286×10^{-3}	1.429×10^{-4}	1	6.48×10^{-2}
grams	3.527×10^{-2}	2.20×10^{-3}	15.432	1

LINEAR MEASURE EQUIVALENTS

	meter	inch	foot	mile
meter	1	39.37	3.2808	6.214×10^{-4}
inch	2.54×10^{-2}	1	8.333×10^{-2}	1.58×10^{-5}
foot	0.3048	12	1	1.8939×10^{-4}
mile	1.61×10^3	6.336×10^4	5280	1

HEAT, ENERGY, OR WORK EQUIVALENTS

	(ft)(lb _f)	kWh	(hp)(hr)	Btu	calorie*	joule
(ft)(lb _f)	1	3.766×10^{-7}	5.0505×10^{-7}	1.285×10^{-3}	0.3241	1.356
kWh	2.655×10^6	1	1.341	3.4128×10^3	8.6057×10^5	3.6×10^6
(hp)(hr)	1.98×10^6	0.7455	1	2.545×10^3	6.4162×10^5	2.6845×10^6
Btu	7.7816×10^2	2.930×10^{-4}	3.930×10^{-4}	1	2.52×10^2	1.055×10^3
calorie*	3.086	1.162×10^{-6}	1.558×10^{-6}	3.97×10^{-3}	1	4.184
joule	0.7376	2.773×10^{-7}	3.725×10^{-7}	9.484×10^{-4}	0.2390	1

*The thermochemical calorie = 4.184 J.

PRESSURE EQUIVALENTS

	mm Hg	in. Hg	bar	atm	kPa	psia
mm Hg	1	3.937×10^{-3}	1.333×10^{-3}	1.316×10^{-3}	0.1333	1.934×10^{-2}
in. Hg	25.40	1	3.386×10^1	3.342×10^{-2}	3.386	0.4912
bar	750.06	29.53	1	0.9869	100.0	14.51
atm	760.0	29.92	1.013	1	101.3	14.696
kPa	7.502	0.2954	1.000×10^{-2}	9.872×10^{-3}	1	0.1451
psia	51.71	2.036	6.893×10^{-2}	6.805×10^{-2}	6.893	1

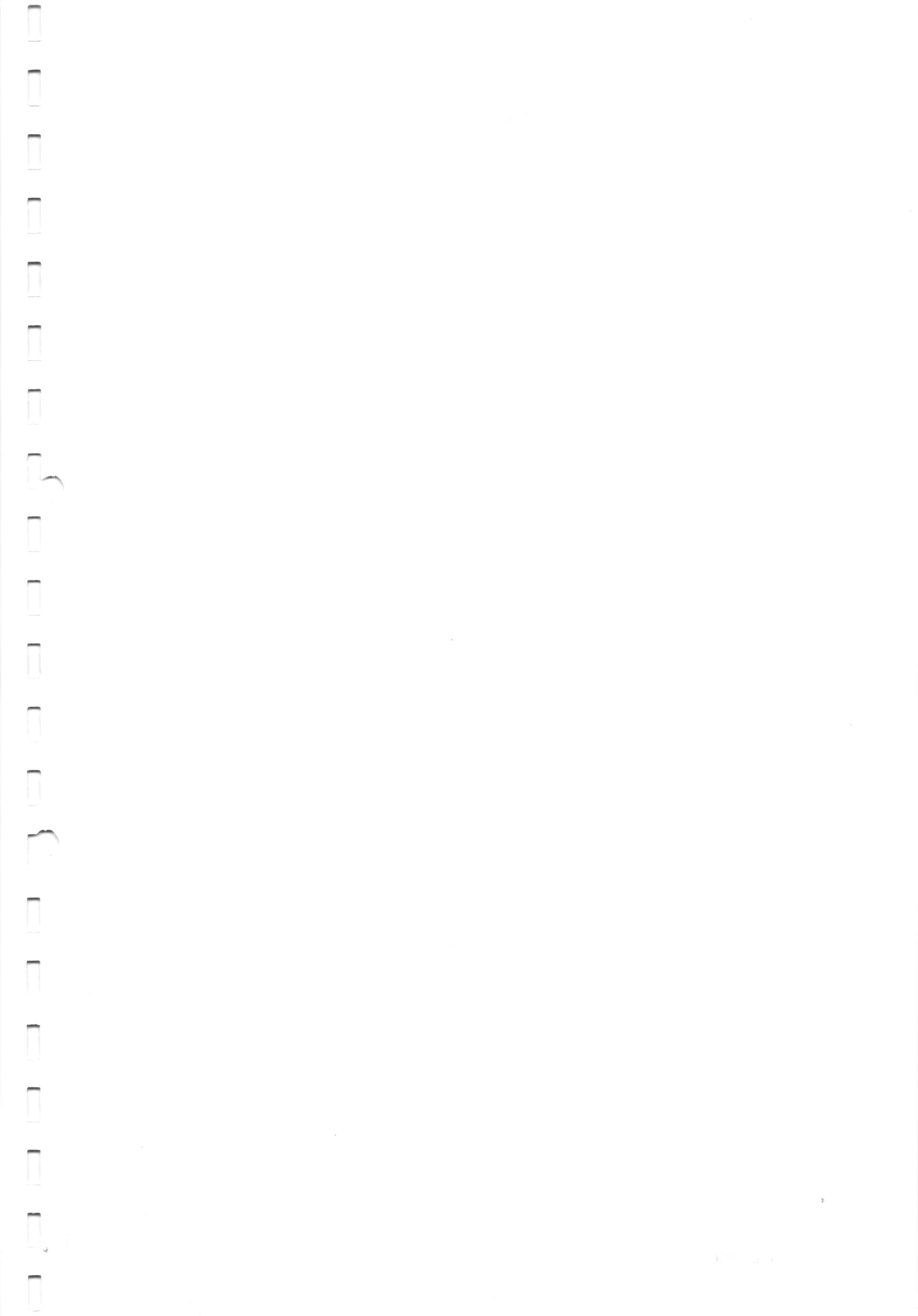


Table 1. Properties of Saturated Water and Steam (Temperature)

Temp. °F	Pressure psia	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Temp. °F
		v _L	v _V	h _L	h _V	s _L	s _V	
32	0.08865	0.016022	3302.0	-0.018	1075.2	0.0000	2.1868	32
35	0.09998	0.016020	2945.5	3.004	1076.5	0.0061	2.1762	35
40	0.12173	0.016020	2443.4	8.032	1078.7	0.0162	2.1590	40
45	0.14757	0.016021	2035.6	13.052	1080.9	0.0262	2.1421	45
50	0.17813	0.016024	1702.9	18.066	1083.1	0.0361	2.1257	50
55	0.21414	0.016029	1430.3	23.074	1085.3	0.0459	2.1097	55
60	0.25639	0.016035	1206.1	28.079	1087.4	0.0555	2.0941	60
65	0.30579	0.016043	1020.8	33.080	1089.6	0.0651	2.0788	65
70	0.36334	0.016052	867.19	38.078	1091.8	0.0746	2.0640	70
75	0.43015	0.016062	739.30	43.074	1094.0	0.0840	2.0495	75
80	0.50744	0.016074	632.44	48.069	1096.1	0.0933	2.0353	80
85	0.59656	0.016086	542.84	53.062	1098.3	0.1025	2.0215	85
90	0.69899	0.016100	467.45	58.054	1100.4	0.1116	2.0080	90
95	0.81636	0.016115	403.79	63.046	1102.6	0.1207	1.9948	95
100	0.95044	0.016131	349.87	68.037	1104.7	0.1296	1.9819	100
105	1.1032	0.016148	304.05	73.028	1106.9	0.1385	1.9693	105
110	1.2766	0.016166	264.99	78.019	1109.0	0.1473	1.9570	110
115	1.4730	0.016185	231.60	83.010	1111.1	0.1560	1.9450	115
120	1.6949	0.016205	202.96	88.002	1113.2	0.1647	1.9333	120
125	1.9449	0.016225	178.34	92.994	1115.3	0.1732	1.9218	125
130	2.2258	0.016247	157.10	97.987	1117.4	0.1817	1.9106	130
135	2.5407	0.016269	138.74	102.98	1119.5	0.1902	1.8996	135
140	2.8929	0.016293	122.82	107.98	1121.6	0.1985	1.8888	140
145	3.2858	0.016317	108.99	112.97	1123.7	0.2068	1.8783	145
150	3.7231	0.016342	96.934	117.97	1125.7	0.2151	1.8680	150
155	4.2089	0.016367	86.405	122.97	1127.8	0.2232	1.8580	155
160	4.7472	0.016394	77.186	127.98	1129.8	0.2313	1.8481	160
165	5.3426	0.016421	69.097	132.98	1131.9	0.2394	1.8384	165
170	5.9998	0.016449	61.982	137.99	1133.9	0.2474	1.8290	170
175	6.7237	0.016478	55.710	143.00	1135.9	0.2553	1.8197	175
180	7.5196	0.016507	50.171	148.01	1137.9	0.2631	1.8106	180
185	8.3930	0.016538	45.267	153.03	1139.9	0.2709	1.8017	185
190	9.3497	0.016569	40.918	158.05	1141.8	0.2787	1.7930	190
195	10.396	0.016601	37.053	163.07	1143.8	0.2864	1.7844	195
200	11.538	0.016633	33.611	168.10	1145.7	0.2940	1.7760	200
205	12.782	0.016667	30.540	173.13	1147.6	0.3016	1.7678	205
210	14.136	0.016701	27.796	178.17	1149.5	0.3092	1.7597	210
215	15.606	0.016736	25.339	183.20	1151.4	0.3167	1.7517	215
220	17.201	0.016771	23.135	188.25	1153.3	0.3241	1.7440	220
225	18.928	0.016808	21.155	193.30	1155.1	0.3315	1.7363	225
230	20.795	0.016845	19.373	198.35	1157.0	0.3388	1.7288	230
235	22.811	0.016883	17.766	203.41	1158.8	0.3461	1.7214	235
240	24.985	0.016921	16.316	208.47	1160.5	0.3534	1.7141	240
245	27.326	0.016961	15.004	213.54	1162.3	0.3606	1.7070	245
250	29.843	0.017001	13.816	218.62	1164.0	0.3678	1.7000	250

Table 1. Properties of Saturated Water and Steam (Temperature)

Temp. °F	Pressure psia	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Temp. °F
		v _L	v _V	h _L	h _V	s _L	s _V	
255	32.546	0.017042	12.739	223.70	1165.7	0.3749	1.6930	255
260	35.445	0.017084	11.760	228.79	1167.4	0.3820	1.6862	260
265	38.551	0.017127	10.870	233.88	1169.1	0.3890	1.6796	265
270	41.874	0.017170	10.059	238.99	1170.7	0.3960	1.6730	270
275	45.426	0.017214	9.3196	244.10	1172.3	0.4030	1.6665	275
280	49.218	0.017259	8.6442	249.21	1173.9	0.4099	1.6601	280
285	53.261	0.017305	8.0265	254.34	1175.5	0.4168	1.6538	285
290	57.567	0.017352	7.4610	259.47	1177.0	0.4236	1.6476	290
295	62.150	0.017400	6.9425	264.61	1178.5	0.4305	1.6414	295
300	67.021	0.017449	6.4666	269.76	1180.0	0.4372	1.6354	300
305	72.193	0.017498	6.0293	274.91	1181.4	0.4440	1.6294	305
310	77.680	0.017548	5.6270	280.08	1182.8	0.4507	1.6235	310
315	83.496	0.017600	5.2564	285.26	1184.2	0.4574	1.6177	315
320	89.654	0.017652	4.9148	290.44	1185.5	0.4640	1.6120	320
325	96.168	0.017705	4.5994	295.64	1186.8	0.4706	1.6063	325
330	103.05	0.017760	4.3079	300.85	1188.0	0.4772	1.6007	330
335	110.32	0.017815	4.0384	306.07	1189.3	0.4838	1.5952	335
340	118.00	0.017871	3.7888	311.30	1190.5	0.4903	1.5897	340
345	126.08	0.017929	3.5574	316.54	1191.6	0.4968	1.5843	345
350	134.60	0.017987	3.3428	321.79	1192.7	0.5033	1.5789	350
355	143.57	0.018047	3.1435	327.06	1193.8	0.5097	1.5736	355
360	153.00	0.018108	2.9582	332.34	1194.8	0.5162	1.5684	360
365	162.92	0.018170	2.7859	337.63	1195.8	0.5226	1.5632	365
370	173.33	0.018233	2.6254	342.94	1196.7	0.5289	1.5580	370
375	184.25	0.018297	2.4758	348.26	1197.6	0.5353	1.5529	375
380	195.71	0.018363	2.3363	353.59	1198.5	0.5416	1.5478	380
385	207.72	0.018430	2.2061	358.94	1199.3	0.5479	1.5428	385
390	220.29	0.018498	2.0843	364.31	1200.1	0.5542	1.5378	390
395	233.45	0.018568	1.9705	369.70	1200.8	0.5605	1.5329	395
400	247.22	0.018639	1.8640	375.10	1201.5	0.5667	1.5280	400
405	261.61	0.018711	1.7643	380.52	1202.1	0.5729	1.5231	405
410	276.64	0.018785	1.6708	385.95	1202.6	0.5791	1.5182	410
415	292.34	0.018861	1.5830	391.41	1203.2	0.5853	1.5134	415
420	308.71	0.018938	1.5007	396.89	1203.6	0.5915	1.5086	420
425	325.79	0.019016	1.4234	402.38	1204.0	0.5977	1.5038	425
430	343.59	0.019097	1.3507	407.90	1204.4	0.6038	1.4991	430
435	362.13	0.019179	1.2822	413.44	1204.7	0.6100	1.4943	435
440	381.44	0.019263	1.2179	419.01	1204.9	0.6161	1.4896	440
445	401.53	0.019349	1.1572	424.59	1205.1	0.6222	1.4849	445
450	422.42	0.019437	1.1000	430.20	1205.2	0.6283	1.4802	450
455	444.14	0.019527	1.0461	435.84	1205.2	0.6344	1.4755	455
460	466.71	0.019619	0.9952	441.50	1205.2	0.6405	1.4709	460
465	490.15	0.019713	0.9471	447.19	1205.1	0.6466	1.4662	465
470	514.48	0.019810	0.9016	452.91	1204.9	0.6526	1.4615	470
475	539.73	0.019908	0.8586	458.66	1204.7	0.6587	1.4569	475

Table 1. Properties of Saturated Water and Steam (Temperature)

Temp. °F	Pressure psia	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Temp. °F
		v _L	v _V	h _L	h _V	s _L	s _V	
480	565.92	0.02001	0.8180	464.44	1204.4	0.6648	1.4522	480
485	593.07	0.02011	0.7795	470.25	1204.0	0.6708	1.4475	485
490	621.20	0.02022	0.7430	476.10	1203.5	0.6769	1.4429	490
495	650.35	0.02033	0.7084	481.97	1203.0	0.6829	1.4382	495
500	680.53	0.02044	0.6756	487.89	1202.3	0.6890	1.4335	500
505	711.77	0.02056	0.6445	493.84	1201.6	0.6951	1.4288	505
510	744.09	0.02068	0.6149	499.83	1200.8	0.7011	1.4241	510
515	777.52	0.02080	0.5868	505.86	1199.9	0.7072	1.4193	515
520	812.08	0.02092	0.5601	511.93	1198.9	0.7133	1.4145	520
525	847.81	0.02105	0.5347	518.05	1197.9	0.7194	1.4098	525
530	884.73	0.02118	0.5105	524.21	1196.7	0.7255	1.4049	530
535	922.85	0.02132	0.4875	530.42	1195.4	0.7316	1.4001	535
540	962.23	0.02146	0.4656	536.69	1194.0	0.7377	1.3952	540
545	1002.9	0.02161	0.4446	543.00	1192.5	0.7438	1.3903	545
550	1044.8	0.02176	0.4247	549.37	1190.8	0.7500	1.3853	550
555	1088.1	0.02192	0.4056	555.80	1189.1	0.7562	1.3803	555
560	1132.7	0.02208	0.3875	562.29	1187.2	0.7624	1.3752	560
565	1178.7	0.02225	0.3701	568.85	1185.2	0.7686	1.3701	565
570	1226.2	0.02242	0.3535	575.48	1183.0	0.7749	1.3649	570
575	1275.1	0.02260	0.3376	582.18	1180.7	0.7812	1.3596	575
580	1325.4	0.02279	0.3223	588.95	1178.2	0.7875	1.3543	580
585	1377.3	0.02299	0.3077	595.81	1175.6	0.7939	1.3489	585
590	1430.8	0.02319	0.2938	602.75	1172.8	0.8003	1.3433	590
595	1485.8	0.02341	0.2803	609.79	1169.8	0.8067	1.3377	595
600	1542.5	0.02363	0.2675	616.93	1166.6	0.8133	1.3320	600
605	1600.8	0.02387	0.2551	624.17	1163.2	0.8198	1.3261	605
610	1660.8	0.02411	0.2432	631.53	1159.6	0.8265	1.3202	610
615	1722.6	0.02437	0.2317	639.01	1155.7	0.8332	1.3140	615
620	1786.1	0.02465	0.2207	646.62	1151.6	0.8400	1.3077	620
625	1851.5	0.02494	0.2101	654.38	1147.2	0.8469	1.3012	625
630	1918.8	0.02525	0.1998	662.30	1142.5	0.8539	1.2945	630
635	1988.0	0.02558	0.1899	670.40	1137.4	0.8610	1.2876	635
640	2059.2	0.02593	0.1802	678.69	1132.0	0.8683	1.2804	640
645	2132.4	0.02631	0.1709	687.21	1126.1	0.8757	1.2729	645
650	2207.7	0.02672	0.1618	695.99	1119.7	0.8833	1.2651	650
655	2285.2	0.02717	0.1530	705.06	1112.8	0.8911	1.2569	655
660	2364.8	0.02766	0.1444	714.47	1105.3	0.8991	1.2482	660
665	2446.8	0.02821	0.1359	724.30	1097.2	0.9075	1.2390	665
670	2531.2	0.02883	0.1276	734.63	1088.1	0.9163	1.2292	670
675	2618.0	0.02953	0.1194	745.57	1078.0	0.9255	1.2185	675
680	2707.3	0.03035	0.1112	757.30	1066.6	0.9354	1.2068	680
685	2799.3	0.03133	0.1030	770.10	1053.5	0.9462	1.1937	685
690	2894.2	0.03256	0.09444	784.45	1037.9	0.9582	1.1786	690
695	2991.9	0.03422	0.08531	801.35	1018.3	0.9723	1.1602	695
700	3092.9	0.03683	0.07466	823.64	990.64	0.9910	1.1350	700
705	3197.9	0.04662	0.05338	882.44	913.89	1.0409	1.0679	705
T _c	3200.1	0.04975	0.04975	897.48	897.48	1.0538	1.0538	T _c

T_c = 705.1028 °F

Table 2. Properties of Saturated Water and Steam (Pressure)

Pressure psia	Temp. °F	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Pressure psia
		v _L	v _V	h _L	h _V	s _L	s _V	
0.1	35.00	0.016020	2945.0	3.009	1076.5	0.0061	2.1762	0.1
0.2	53.13	0.016027	1525.9	21.204	1084.4	0.0422	2.1156	0.2
0.3	64.45	0.016042	1039.4	32.532	1089.4	0.0641	2.0805	0.3
0.5	79.55	0.016073	641.32	47.618	1095.9	0.0925	2.0366	0.5
0.7	90.05	0.016100	466.81	58.100	1100.4	0.1117	2.0079	0.7
1.0	101.69	0.016137	333.51	69.728	1105.4	0.1326	1.9776	1.0
1.5	115.64	0.016187	227.68	83.650	1111.4	0.1571	1.9435	1.5
2.0	126.03	0.016230	173.72	94.019	1115.8	0.1750	1.9195	2.0
3.0	141.42	0.016299	118.70	109.39	1122.2	0.2009	1.8858	3.0
4.0	152.91	0.016356	90.628	120.89	1126.9	0.2198	1.8621	4.0
6	170.00	0.016449	61.979	137.99	1133.9	0.2474	1.8290	6
8	182.81	0.016524	47.345	150.83	1139.0	0.2675	1.8056	8
10	193.16	0.016589	38.423	161.22	1143.1	0.2836	1.7875	10
12	201.91	0.016646	32.398	170.02	1146.4	0.2969	1.7728	12
14	209.52	0.016697	28.048	177.68	1149.4	0.3084	1.7605	14
16	216.27	0.016745	24.755	184.49	1151.9	0.3186	1.7497	16
18	222.36	0.016788	22.173	190.63	1154.2	0.3276	1.7403	18
20	227.92	0.016829	20.092	196.25	1156.2	0.3358	1.7319	20
25	240.03	0.016922	16.306	208.51	1160.5	0.3534	1.7141	25
30	250.30	0.017003	13.748	218.93	1164.1	0.3682	1.6995	30
35	259.25	0.017078	11.900	228.03	1167.2	0.3809	1.6873	35
40	267.22	0.017146	10.500	236.15	1169.8	0.3921	1.6766	40
45	274.42	0.017209	9.4023	243.50	1172.2	0.4022	1.6672	45
50	280.99	0.017268	8.5171	250.23	1174.2	0.4113	1.6588	50
55	287.06	0.017325	7.7878	256.45	1176.1	0.4196	1.6512	55
60	292.69	0.017378	7.1762	262.24	1177.8	0.4273	1.6443	60
65	297.96	0.017429	6.6557	267.66	1179.4	0.4345	1.6378	65
70	302.92	0.017477	6.2071	272.76	1180.8	0.4412	1.6319	70
75	307.59	0.017524	5.8164	277.59	1182.1	0.4475	1.6264	75
80	312.03	0.017569	5.4730	282.18	1183.3	0.4534	1.6212	80
85	316.25	0.017613	5.1686	286.55	1184.5	0.4590	1.6163	85
90	320.27	0.017655	4.8969	290.73	1185.6	0.4644	1.6117	90
95	324.12	0.017696	4.6528	294.73	1186.6	0.4695	1.6073	95
100	327.82	0.017736	4.4324	298.57	1187.5	0.4744	1.6032	100
110	334.78	0.017813	4.0496	305.84	1189.2	0.4835	1.5954	110
120	341.26	0.017886	3.7286	312.62	1190.7	0.4920	1.5883	120
130	347.33	0.017956	3.4554	318.98	1192.1	0.4998	1.5818	130
140	353.04	0.018023	3.2199	324.99	1193.4	0.5072	1.5757	140
150	358.43	0.018089	3.0148	330.68	1194.5	0.5141	1.5700	150
160	363.55	0.018152	2.8345	336.10	1195.5	0.5207	1.5647	160
170	368.43	0.018213	2.6746	341.27	1196.5	0.5269	1.5596	170
180	373.08	0.018272	2.5320	346.21	1197.3	0.5328	1.5549	180
190	377.54	0.018330	2.4038	350.96	1198.1	0.5385	1.5503	190
200	381.81	0.018387	2.2880	355.53	1198.8	0.5439	1.5460	200
210	385.92	0.018442	2.1829	359.94	1199.5	0.5491	1.5419	210

Table 2. Properties of Saturated Water and Steam (Pressure)

Pressure psia	Temp. °F	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Pressure psia
		v _L	v _V	h _L	h _V	s _L	s _V	
220	389.89	0.018496	2.0870	364.19	1200.1	0.5541	1.5379	220
230	393.71	0.018549	1.9992	368.30	1200.6	0.5588	1.5342	230
240	397.41	0.018601	1.9184	372.29	1201.1	0.5635	1.5305	240
250	400.98	0.018653	1.8439	376.16	1201.6	0.5679	1.5270	250
260	404.45	0.018703	1.7749	379.92	1202.0	0.5723	1.5236	260
270	407.82	0.018753	1.7108	383.58	1202.4	0.5764	1.5203	270
280	411.09	0.018801	1.6512	387.14	1202.8	0.5805	1.5172	280
290	414.27	0.018849	1.5955	390.61	1203.1	0.5844	1.5141	290
300	417.37	0.018897	1.5434	394.00	1203.4	0.5883	1.5111	300
320	423.33	0.018990	1.4487	400.54	1203.9	0.5956	1.5054	320
340	429.01	0.019081	1.3647	406.81	1204.3	0.6026	1.5000	340
360	434.43	0.019170	1.2898	412.82	1204.6	0.6093	1.4949	360
380	439.63	0.019257	1.2224	418.60	1204.9	0.6156	1.4900	380
400	444.63	0.019343	1.1616	424.18	1205.0	0.6217	1.4853	400
420	449.43	0.019427	1.1064	429.56	1205.1	0.6276	1.4807	420
440	454.06	0.019510	1.0560	434.78	1205.2	0.6333	1.4764	440
460	458.53	0.019592	1.0098	439.84	1205.2	0.6387	1.4722	460
480	462.86	0.019672	0.9673	444.75	1205.1	0.6440	1.4682	480
500	467.05	0.019752	0.9282	449.53	1205.0	0.6490	1.4643	500
520	471.11	0.019831	0.8919	454.19	1204.9	0.6540	1.4605	520
540	475.05	0.019909	0.8582	458.72	1204.7	0.6588	1.4568	540
560	478.89	0.019987	0.8268	463.15	1204.4	0.6634	1.4532	560
580	482.62	0.02006	0.7976	467.48	1204.2	0.6679	1.4498	580
600	486.25	0.02014	0.7702	471.71	1203.9	0.6723	1.4464	600
620	489.79	0.02022	0.7445	475.85	1203.5	0.6766	1.4430	620
640	493.24	0.02029	0.7203	479.91	1203.2	0.6808	1.4398	640
660	496.62	0.02037	0.6976	483.88	1202.8	0.6849	1.4367	660
680	499.91	0.02044	0.6761	487.79	1202.4	0.6889	1.4336	680
700	503.14	0.02051	0.6559	491.62	1201.9	0.6928	1.4305	700
720	506.29	0.02059	0.6367	495.38	1201.4	0.6966	1.4276	720
740	509.38	0.02066	0.6185	499.08	1200.9	0.7004	1.4246	740
760	512.40	0.02073	0.6012	502.72	1200.4	0.7040	1.4218	760
780	515.36	0.02081	0.5848	506.30	1199.9	0.7076	1.4190	780
800	518.27	0.02088	0.5692	509.83	1199.3	0.7112	1.4162	800
820	521.12	0.02095	0.5543	513.30	1198.7	0.7146	1.4135	820
840	523.92	0.02102	0.5401	516.73	1198.1	0.7181	1.4108	840
860	526.67	0.02110	0.5265	520.10	1197.5	0.7214	1.4082	860
880	529.37	0.02117	0.5135	523.43	1196.8	0.7247	1.4056	880
900	532.02	0.02124	0.5011	526.72	1196.2	0.7279	1.4030	900
920	534.63	0.02131	0.4892	529.96	1195.5	0.7311	1.4005	920
940	537.20	0.02138	0.4777	533.17	1194.8	0.7343	1.3980	940
960	539.72	0.02146	0.4667	536.34	1194.1	0.7374	1.3955	960
980	542.21	0.02153	0.4562	539.47	1193.3	0.7404	1.3930	980
1000	544.65	0.02160	0.4461	542.56	1192.6	0.7434	1.3906	1000
1050	550.61	0.02178	0.4223	550.15	1190.6	0.7507	1.3847	1050

Table 2. Properties of Saturated Water and Steam (Pressure)

Pressure psia	Temp. °F	Volume, ft ³ /lb _m		Enthalpy, Btu/lb _m		Entropy, Btu/(lb _m ·°R)		Pressure psia
		v _L	v _V	h _L	h _V	s _L	s _V	
1100	556.35	0.02196	0.4006	557.55	1188.6	0.7578	1.3789	1100
1150	561.90	0.02214	0.3808	564.77	1186.4	0.7647	1.3733	1150
1200	567.26	0.02233	0.3625	571.84	1184.2	0.7714	1.3677	1200
1250	572.46	0.02251	0.3456	578.76	1181.9	0.7780	1.3623	1250
1300	577.50	0.02270	0.3299	585.55	1179.5	0.7843	1.3570	1300
1350	582.39	0.02288	0.3153	592.21	1177.0	0.7905	1.3517	1350
1400	587.14	0.02307	0.3017	598.77	1174.4	0.7966	1.3465	1400
1450	591.76	0.02327	0.2890	605.23	1171.8	0.8025	1.3414	1450
1500	596.27	0.02346	0.2770	611.59	1169.0	0.8084	1.3363	1500
1550	600.66	0.02366	0.2658	617.87	1166.2	0.8141	1.3312	1550
1600	604.93	0.02386	0.2553	624.07	1163.3	0.8197	1.3262	1600
1650	609.11	0.02407	0.2453	630.21	1160.3	0.8253	1.3212	1650
1700	613.19	0.02428	0.2358	636.28	1157.2	0.8307	1.3163	1700
1750	617.18	0.02449	0.2269	642.30	1154.0	0.8361	1.3113	1750
1800	621.07	0.02471	0.2184	648.27	1150.7	0.8415	1.3063	1800
1850	624.89	0.02493	0.2103	654.20	1147.3	0.8467	1.3014	1850
1900	628.62	0.02516	0.2026	660.09	1143.8	0.8519	1.2964	1900
1950	632.27	0.02539	0.1952	665.96	1140.2	0.8571	1.2914	1950
2000	635.85	0.02563	0.1882	671.80	1136.5	0.8622	1.2864	2000
2050	639.36	0.02588	0.1814	677.62	1132.7	0.8673	1.2814	2050
2100	642.81	0.02614	0.1750	683.44	1128.7	0.8724	1.2763	2100
2150	646.18	0.02640	0.1687	689.26	1124.6	0.8774	1.2711	2150
2200	649.50	0.02668	0.1627	695.09	1120.4	0.8825	1.2659	2200
2250	652.75	0.02696	0.1569	700.93	1116.0	0.8875	1.2606	2250
2300	655.94	0.02726	0.1514	706.80	1111.5	0.8926	1.2553	2300
2350	659.08	0.02757	0.1459	712.71	1106.8	0.8976	1.2498	2350
2400	662.16	0.02789	0.1407	718.67	1101.9	0.9027	1.2443	2400
2450	665.19	0.02823	0.1356	724.69	1096.8	0.9078	1.2387	2450
2500	668.17	0.02859	0.1307	730.78	1091.5	0.9130	1.2329	2500
2550	671.10	0.02897	0.1258	736.97	1086.0	0.9183	1.2269	2550
2600	673.98	0.02938	0.1211	743.27	1080.2	0.9236	1.2208	2600
2650	676.81	0.02981	0.1165	749.71	1074.1	0.9290	1.2144	2650
2700	679.60	0.03028	0.1119	756.32	1067.6	0.9346	1.2078	2700
2750	682.34	0.03078	0.1074	763.13	1060.7	0.9403	1.2009	2750
2800	685.03	0.03134	0.1029	770.20	1053.4	0.9462	1.1936	2800
2850	687.69	0.03195	0.09843	777.59	1045.5	0.9524	1.1859	2850
2900	690.30	0.03264	0.09391	785.39	1036.8	0.9590	1.1776	2900
2950	692.88	0.03344	0.08930	793.75	1027.3	0.9660	1.1686	2950
3000	695.41	0.03438	0.08453	802.90	1016.5	0.9736	1.1585	3000
3050	697.90	0.03554	0.07945	813.22	1003.8	0.9823	1.1469	3050
3100	700.35	0.03708	0.07381	825.57	988.14	0.9926	1.1328	3100
3150	702.75	0.03947	0.06686	842.34	966.17	1.0068	1.1133	3150
3200	705.10	0.04897	0.05052	893.85	901.07	1.0507	1.0569	3200
p_c	705.1028	0.04975	0.04975	897.48	897.48	1.0538	1.0538	p_c

p_c = 3200.11 psia

TABLE A-17

Ideal-gas properties of air

<i>T</i> K	<i>h</i> kJ/kg	<i>P_r</i>	<i>u</i> kJ/kg	<i>v_r</i>	<i>s°</i> kJ/kg · K	<i>T</i> K	<i>h</i> kJ/kg	<i>P_r</i>	<i>u</i> kJ/kg	<i>v_r</i>	<i>s°</i> kJ/kg · K
200	199.97	0.3363	142.56	1707.0	1.29559	580	586.04	14.38	419.55	115.7	2.37348
210	209.97	0.3987	149.69	1512.0	1.34444	590	596.52	15.31	427.15	110.6	2.39140
220	219.97	0.4690	156.82	1346.0	1.39105	600	607.02	16.28	434.78	105.8	2.40902
230	230.02	0.5477	164.00	1205.0	1.43557	610	617.53	17.30	442.42	101.2	2.42644
240	240.02	0.6355	171.13	1084.0	1.47824	620	628.07	18.36	450.09	96.92	2.44356
250	250.05	0.7329	178.28	979.0	1.51917	630	638.63	19.84	457.78	92.84	2.46048
260	260.09	0.8405	185.45	887.8	1.55848	640	649.22	20.64	465.50	88.99	2.47716
270	270.11	0.9590	192.60	808.0	1.59634	650	659.84	21.86	473.25	85.34	2.49364
280	280.13	1.0889	199.75	738.0	1.63279	660	670.47	23.13	481.01	81.89	2.50985
285	285.14	1.1584	203.33	706.1	1.65055	670	681.14	24.46	488.81	78.61	2.52589
290	290.16	1.2311	206.91	676.1	1.66802	680	691.82	25.85	496.62	75.50	2.54175
295	295.17	1.3068	210.49	647.9	1.68515	690	702.52	27.29	504.45	72.56	2.55731
298	298.18	1.3543	212.64	631.9	1.69528	700	713.27	28.80	512.33	69.76	2.57277
300	300.19	1.3860	214.07	621.2	1.70203	710	724.04	30.38	520.23	67.07	2.58810
305	305.22	1.4686	217.67	596.0	1.71865	720	734.82	32.02	528.14	64.53	2.60319
310	310.24	1.5546	221.25	572.3	1.73498	730	745.62	33.72	536.07	62.13	2.61803
315	315.27	1.6442	224.85	549.8	1.75106	740	756.44	35.50	544.02	59.82	2.63280
320	320.29	1.7375	228.42	528.6	1.76690	750	767.29	37.35	551.99	57.63	2.64737
325	325.31	1.8345	232.02	508.4	1.78249	760	778.18	39.27	560.01	55.54	2.66176
330	330.34	1.9352	235.61	489.4	1.79783	780	800.03	43.35	576.12	51.64	2.69013
340	340.42	2.149	242.82	454.1	1.82790	800	821.95	47.75	592.30	48.08	2.71787
350	350.49	2.379	250.02	422.2	1.85708	820	843.98	52.59	608.59	44.84	2.74504
360	360.58	2.626	257.24	393.4	1.88543	840	866.08	57.60	624.95	41.85	2.77170
370	370.67	2.892	264.46	367.2	1.91313	860	888.27	63.09	641.40	39.12	2.79783
380	380.77	3.176	271.69	343.4	1.94001	880	910.56	68.98	657.95	36.61	2.82344
390	390.88	3.481	278.93	321.5	1.96633	900	932.93	75.29	674.58	34.31	2.84856
400	400.98	3.806	286.16	301.6	1.99194	920	955.38	82.05	691.28	32.18	2.87324
410	411.12	4.153	293.43	283.3	2.01699	940	977.92	89.28	708.08	30.22	2.89748
420	421.26	4.522	300.69	266.6	2.04142	960	1000.55	97.00	725.02	28.40	2.92128
430	431.43	4.915	307.99	251.1	2.06533	980	1023.25	105.2	741.98	26.73	2.94468
440	441.61	5.332	315.30	236.8	2.08870	1000	1046.04	114.0	758.94	25.17	2.96770
450	451.80	5.775	322.62	223.6	2.11161	1020	1068.89	123.4	776.10	23.72	2.99034
460	462.02	6.245	329.97	211.4	2.13407	1040	1091.85	133.3	793.36	23.29	3.01260
470	472.24	6.742	337.32	200.1	2.15604	1060	1114.86	143.9	810.62	21.14	3.03449
480	482.49	7.268	344.70	189.5	2.17760	1080	1137.89	155.2	827.88	19.98	3.05608
490	492.74	7.824	352.08	179.7	2.19876	1100	1161.07	167.1	845.33	18.896	3.07732
500	503.02	8.411	359.49	170.6	2.21952	1120	1184.28	179.7	862.79	17.886	3.09825
510	513.32	9.031	366.92	162.1	2.23993	1140	1207.57	193.1	880.35	16.946	3.11883
520	523.63	9.684	374.36	154.1	2.25997	1160	1230.92	207.2	897.91	16.064	3.13916
530	533.98	10.37	381.84	146.7	2.27967	1180	1254.34	222.2	915.57	15.241	3.15916
540	544.35	11.10	389.34	139.7	2.29906	1200	1277.79	238.0	933.33	14.470	3.17888
550	555.74	11.86	396.86	133.1	2.31809	1220	1301.31	254.7	951.09	13.747	3.19834
560	565.17	12.66	404.42	127.0	2.33685	1240	1324.93	272.3	968.95	13.069	3.21751
570	575.59	13.50	411.97	121.2	2.35531						



TABLE A-17

Ideal-gas properties of air (*Concluded*)

<i>T</i> K	<i>h</i> kJ/kg	<i>P_r</i>	<i>u</i> kJ/kg	<i>v_r</i>	<i>s°</i> kJ/kg · K	<i>T</i> K	<i>h</i> kJ/kg	<i>P_r</i>	<i>u</i> kJ/kg	<i>v_r</i>	<i>s°</i> kJ/kg · K
1260	1348.55	290.8	986.90	12.435	3.23638	1600	1757.57	791.2	1298.30	5.804	3.52364
1280	1372.24	310.4	1004.76	11.835	3.25510	1620	1782.00	834.1	1316.96	5.574	3.53879
1300	1395.97	330.9	1022.82	11.275	3.27345	1640	1806.46	878.9	1335.72	5.355	3.55381
1320	1419.76	352.5	1040.88	10.747	3.29160	1660	1830.96	925.6	1354.48	5.147	3.56867
1340	1443.60	375.3	1058.94	10.247	3.30959	1680	1855.50	974.2	1373.24	4.949	3.58335
1360	1467.49	399.1	1077.10	9.780	3.32724	1700	1880.1	1025	1392.7	4.761	3.5979
1380	1491.44	424.2	1095.26	9.337	3.34474	1750	1941.6	1161	1439.8	4.328	3.6336
1400	1515.42	450.5	1113.52	8.919	3.36200	1800	2003.3	1310	1487.2	3.994	3.6684
1420	1539.44	478.0	1131.77	8.526	3.37901	1850	2065.3	1475	1534.9	3.601	3.7023
1440	1563.51	506.9	1150.13	8.153	3.39586	1900	2127.4	1655	1582.6	3.295	3.7354
1460	1587.63	537.1	1168.49	7.801	3.41247	1950	2189.7	1852	1630.6	3.022	3.7677
1480	1611.79	568.8	1186.95	7.468	3.42892	2000	2252.1	2068	1678.7	2.776	3.7994
1500	1635.97	601.9	1205.41	7.152	3.44516	2050	2314.6	2303	1726.8	2.555	3.8303
1520	1660.23	636.5	1223.87	6.854	3.46120	2100	2377.7	2559	1775.3	2.356	3.8605
1540	1684.51	672.8	1242.43	6.569	3.47712	2150	2440.3	2837	1823.8	2.175	3.8901
1560	1708.82	710.5	1260.99	6.301	3.49276	2200	2503.2	3138	1872.4	2.012	3.9191
1580	1733.17	750.0	1279.65	6.046	3.50829	2250	2566.4	3464	1921.3	1.864	3.9474

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

Source: Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 785–86, table A-5. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1948).

