9210-128
Reference booklet

Sample

Mollier Chart - Metric

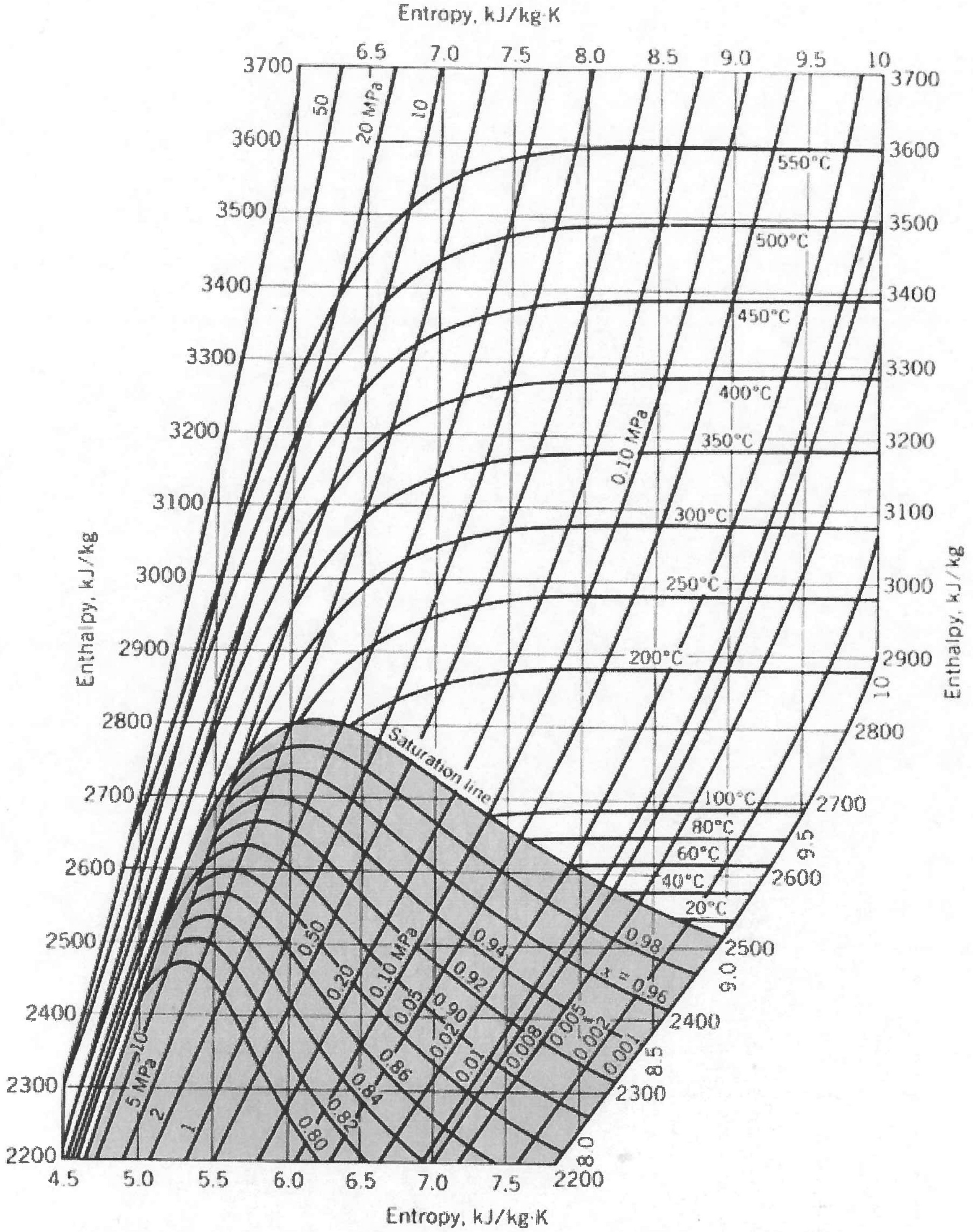
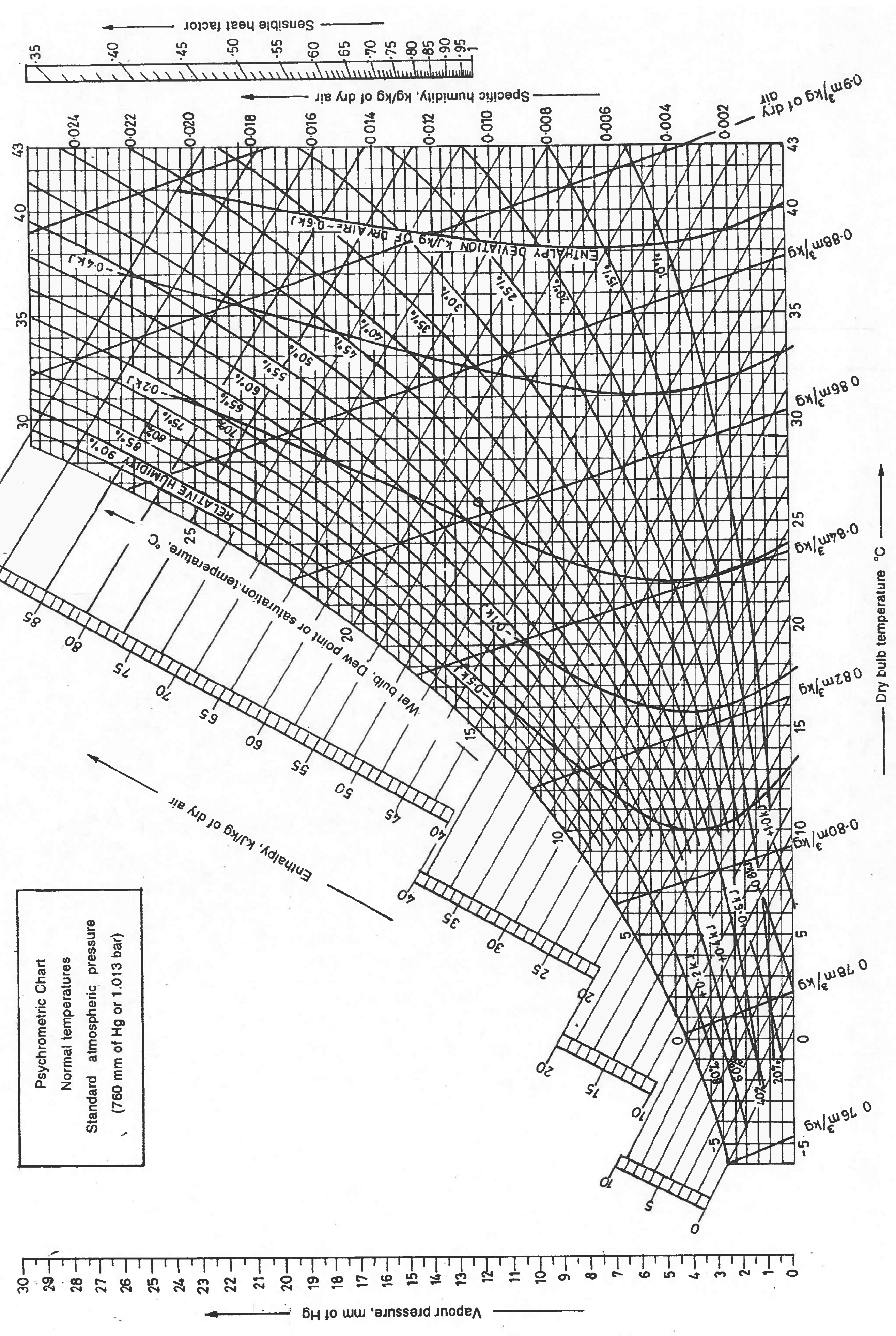


Figure A-8 Enthalpy–entropy diagram for water (SI units). *Source:* J. B. Jones and G. A. Hawkins, *Engineering Thermodynamics*, 2nd ed., Wiley, New York, 1986.

CHART 6



See next page

Thermodynamic and Transport Properties of Fluids

SI Units

arranged by

G. F. C. Rogers and Y. R. Mayhew

Third Edition

OXFORD
BASIL BLACKWELL
1981

NOTATION AND UNITS

a	m/s	– velocity of sound
c_p, c_v	kJ/kg K	– specific heat (at constant p, constant v)
G	kJ/kmol	– molar Gibbs function
h	kJ/kg	– specific enthalpy
H	kJ/kmol	– molar enthalpy
ΔH_0	kJ	– molar enthalpy of reaction ($H_{prod} - H_{react}$)
k	kW/m K	– thermal conductivity
K	(atm units)	– dissociation constant
M	kg/kmol	– molar mass
p	bar	– absolute pressure
Pr		– Prandtl number, $c_p \mu/k$
R	kJ/kg K	– specific gas constant
R_0	kJ/kmol K	– universal gas constant
s	kJ/kg K	– specific entropy
S	kJ/kmol K	– molar entropy
t	°C	– Celsius temperature
T	K	– absolute temperature
u	kJ/kg	– specific internal energy
U	kJ/kmol	– molar internal energy
v	m^3/kg	– specific volume
z	m	– geometric altitude above sea level
γ		– ratio of specific heats, c_p/c_v
λ	m	– mean free path
μ	kg/m s = N s/m^2	– dynamic viscosity
ν	m^2/s	– kinematic viscosity, μ/ρ
ρ	kg/m^3	– density

Subscripts and Superscripts

a – refers to a property at standard atmospheric pressure
f – refers to a property of the saturated liquid
g – refers to a property of the saturated vapour
fg – refers to the change of phase at constant p
i – refers to the property of the saturated solid
s – refers to the saturation state

Saturated Water and Steam

t [°C]	p_s [bar]	v_g [m³/kg]	h_f [kJ/kg]	h_{fg} [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_{fg} [kJ/kg K]	s_g [kJ/kg K]
0.01	0.006112	206.1	0*	2500.8	2500.8	0†	9.155	9.155
1	0.006566	192.6	4.2	2498.3	2502.5	0.015	9.113	9.128
2	0.007054	179.9	8.4	2495.9	2504.3	0.031	9.071	9.102
3	0.007575	168.2	12.6	2493.6	2506.2	0.046	9.030	9.076
4	0.008129	157.3	16.8	2491.3	2508.1	0.061	8.989	9.050
5	0.008719	147.1	21.0	2488.9	2509.9	0.076	8.948	9.024
6	0.009346	137.8	25.2	2486.6	2511.8	0.091	8.908	8.999
7	0.01001	129.1	29.4	2484.3	2513.7	0.106	8.868	8.974
8	0.01072	121.0	33.6	2481.9	2515.5	0.121	8.828	8.949
9	0.01147	113.4	37.8	2479.6	2517.4	0.136	8.788	8.924
10	0.01227	106.4	42.0	2477.2	2519.2	0.151	8.749	8.900
11	0.01312	99.90	46.2	2474.9	2521.1	0.166	8.710	8.876
12	0.01401	93.83	50.4	2472.5	2522.9	0.180	8.671	8.851
13	0.01497	88.17	54.6	2470.2	2524.8	0.195	8.633	8.828
14	0.01597	82.89	58.8	2467.8	2526.6	0.210	8.594	8.804
15	0.01704	77.97	62.9	2465.5	2528.4	0.224	8.556	8.780
16	0.01817	73.38	67.1	2463.1	2530.2	0.239	8.518	8.757
17	0.01936	69.09	71.3	2460.8	2532.1	0.253	8.481	8.734
18	0.02063	65.08	75.5	2458.4	2533.9	0.268	8.444	8.712
19	0.02196	61.34	79.7	2456.0	2535.7	0.282	8.407	8.689
20	0.02337	57.84	83.9	2453.7	2537.6	0.296	8.370	8.666
21	0.02486	54.56	88.0	2451.4	2539.4	0.310	8.334	8.644
22	0.02642	51.49	92.2	2449.0	2541.2	0.325	8.297	8.622
23	0.02808	48.62	96.4	2446.6	2543.0	0.339	8.261	8.600
24	0.02982	45.92	100.6	2444.2	2544.8	0.353	8.226	8.579
25	0.03166	43.40	104.8	2441.8	2546.6	0.367	8.190	8.557
26	0.03360	41.03	108.9	2439.5	2548.4	0.381	8.155	8.536
27	0.03564	38.81	113.1	2437.2	2550.3	0.395	8.120	8.515
28	0.03778	36.73	117.3	2434.8	2552.1	0.409	8.085	8.494
29	0.04004	34.77	121.5	2432.4	2553.9	0.423	8.050	8.473
30	0.04242	32.93	125.7	2430.0	2555.7	0.436	8.016	8.452
32	0.04754	29.57	134.0	2425.3	2559.3	0.464	7.948	8.412
34	0.05318	26.60	142.4	2420.5	2562.9	0.491	7.881	8.372
36	0.05940	23.97	150.7	2415.8	2566.5	0.518	7.814	8.332
38	0.06624	21.63	159.1	2411.0	2570.1	0.545	7.749	8.294
40	0.07375	19.55	167.5	2406.2	2573.7	0.572	7.684	8.256
42	0.08198	17.69	175.8	2401.4	2577.2	0.599	7.620	8.219
44	0.09100	16.03	184.2	2396.6	2580.8	0.625	7.557	8.182
46	0.1009	14.56	192.5	2391.8	2584.3	0.651	7.494	8.145
48	0.1116	13.23	200.9	2387.0	2587.9	0.678	7.433	8.111
50	0.1233	12.04	209.3	2382.1	2591.4	0.704	7.371	8.075
55	0.1574	9.578	230.2	2370.1	2600.3	0.768	7.223	7.991
60	0.1992	7.678	251.1	2357.9	2609.0	0.831	7.078	7.909
65	0.2501	6.201	272.0	2345.7	2617.7	0.893	6.937	7.830
70	0.3116	5.045	293.0	2333.3	2626.3	0.955	6.800	7.755
75	0.3855	4.133	313.9	2320.8	2634.7	1.015	6.666	7.681
80	0.4736	3.408	334.9	2308.3	2643.2	1.075	6.536	7.611
85	0.5780	2.828	355.9	2295.6	2651.5	1.134	6.410	7.544
90	0.7011	2.361	376.9	2282.8	2659.7	1.192	6.286	7.478
95	0.8453	1.982	398.0	2269.8	2667.8	1.250	6.166	7.416
100	1.01325	1.673	419.1	2256.7	2675.8	1.307	6.048	7.355

† u and s are chosen to be zero for saturated liquid at the triple point.

Note: values of v_f can be found on p. 10.

p [bar]	t_s [°C]	v_g [m³/kg]	u_f [kJ/kg]	u_g [kJ/kg]	h_f [kJ/kg]	h_{fg} [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_{fg} [kJ/kg K]	s_g [kJ/kg K]
0.006112	0.01	206.1	0†	2375	0*	2501	2501	0†	9.155	9.155
0.010	7.0	129.2	29	2385	29	2485	2514	0.106	8.868	8.974
0.015	13.0	87.98	55	2393	55	2470	2525	0.196	8.631	8.827
0.020	17.5	67.01	73	2399	73	2460	2533	0.261	8.462	8.723
0.025	21.1	54.26	88	2403	88	2451	2539	0.312	8.330	8.642
0.030	24.1	45.67	101	2408	101	2444	2545	0.354	8.222	8.576
0.035	26.7	39.48	112	2412	112	2438	2550	0.391	8.130	8.521
0.040	29.0	34.80	121	2415	121	2433	2554	0.422	8.051	8.473
0.045	31.0	31.14	130	2418	130	2428	2558	0.451	7.980	8.431
0.050	32.9	28.20	138	2420	138	2423	2561	0.476	7.918	8.394
0.055	34.6	25.77	145	2422	145	2419	2564	0.500	7.860	8.360
0.060	36.2	23.74	152	2425	152	2415	2567	0.521	7.808	8.329
0.065	37.7	22.02	158	2427	158	2412	2570	0.541	7.760	8.301
0.070	39.0	20.53	163	2428	163	2409	2572	0.559	7.715	8.274
0.075	40.3	19.24	169	2430	169	2405	2574	0.576	7.674	8.250
0.080	41.5	18.10	174	2432	174	2402	2576	0.593	7.634	8.227
0.085	42.7	17.10	179	2434	179	2400	2579	0.608	7.598	8.206
0.090	43.8	16.20	183	2435	183	2397	2580	0.622	7.564	8.186
0.095	44.8	15.40	188	2436	188	2394	2582	0.636	7.531	8.167
0.100	45.8	14.67	192	2437	192	2392	2584	0.649	7.500	8.149
0.12	49.4	12.36	207	2442	207	2383	2590	0.696	7.389	8.085
0.14	52.6	10.69	220	2446	220	2376	2596	0.737	7.294	8.031
0.16	55.3	9.432	232	2450	232	2369	2601	0.772	7.213	7.985
0.18	57.8	8.444	242	2453	242	2363	2605	0.804	7.140	7.944
0.20	60.1	7.648	251	2456	251	2358	2609	0.832	7.075	7.907
0.22	62.2	6.994	260	2459	260	2353	2613	0.858	7.016	7.874
0.24	64.1	6.445	268	2461	268	2348	2616	0.882	6.962	7.844
0.26	65.9	5.979	276	2464	276	2343	2619	0.904	6.913	7.817
0.28	67.5	5.578	283	2466	283	2339	2622	0.925	6.866	7.791
0.30	69.1	5.228	289	2468	289	2336	2625	0.944	6.823	7.767
0.32	70.6	4.921	295	2470	295	2332	2627	0.962	6.783	7.745
0.34	72.0	4.649	302	2472	302	2328	2630	0.980	6.745	7.725
0.36	73.4	4.407	307	2473	307	2325	2632	0.996	6.709	7.705
0.38	74.7	4.189	312	2475	312	2322	2634	1.011	6.675	7.686
0.40	75.9	3.992	318	2476	318	2318	2636	1.026	6.643	7.669
0.42	77.1	3.814	323	2478	323	2315	2638	1.040	6.612	7.652
0.44	78.2	3.651	327	2479	327	2313	2640	1.054	6.582	7.636
0.46	79.3	3.502	332	2481	332	2310	2642	1.067	6.554	7.621
0.48	80.3	3.366	336	2482	336	2308	2644	1.079	6.528	7.607
0.50	81.3	3.239	340	2483	340	2305	2645	1.091	6.502	7.593
0.55	83.7	2.964	351	2486	351	2298	2649	1.119	6.442	7.561
0.60	86.0	2.731	360	2489	360	2293	2653	1.145	6.386	7.531
0.65	88.0	2.535	369	2492	369	2288	2657	1.169	6.335	7.504
0.70	90.0	2.364	377	2494	377	2283	2660	1.192	6.286	7.478
0.75	91.8	2.217	384	2496	384	2278	2662	1.213	6.243	7.456
0.80	93.5	2.087	392	2498	392	2273	2665	1.233	6.201	7.434
0.85	95.2	1.972	399	2500	399	2269	2668	1.252	6.162	7.414
0.90	96.7	1.869	405	2502	405	2266	2671	1.270	6.124	7.394
0.95	98.2	1.777	411	2504	411	2262	2673	1.287	6.089	7.376
1.00	99.6	1.694	417	2506	417	2258	2675	1.303	6.056	7.359

$$* \quad \frac{h_f}{[\mathrm{kJ/kg}]} = \frac{p v_f}{[\mathrm{kJ/kg}]} = \frac{p}{[\mathrm{bar}]} \times \frac{10^5[\mathrm{N}]}{[\mathrm{m}^2]} \times \frac{v_f}{[\mathrm{m}^3/\mathrm{kg}]} \times \left[\frac{\mathrm{m}^3}{\mathrm{kg}}\right] \times \frac{[\mathrm{kJ}]}{10^3[\mathrm{N\,m}]} \times \frac{1}{[\mathrm{kJ/kg}]}$$

$$= \frac{p}{[\mathrm{bar}]} \times \frac{v_f}{[\mathrm{m}^3/\mathrm{kg}]} \times 10^2 = 0.006112 \times 0.0010002 \times 10^2 = 0.0006112$$

See next page

Saturated Water and Steam

p [bar]	t_s [°C]	v_g [m³/kg]	u_f [kJ/kg]	u_g	h_f [kJ/kg]	h_{fg}	h_g	s_f [kJ/kg K]	s_{fg}	s_g
1.0	99.6	1.694	417	2506	417	2258	2675	1.303	6.056	7.359
1.1	102.3	1.549	429	2510	429	2251	2680	1.333	5.994	7.327
1.2	104.8	1.428	439	2512	439	2244	2683	1.361	5.937	7.298
1.3	107.1	1.325	449	2515	449	2238	2687	1.387	5.884	7.271
1.4	109.3	1.236	458	2517	458	2232	2690	1.411	5.835	7.246
1.5	111.4	1.159	467	2519	467	2226	2693	1.434	5.789	7.223
1.6	113.3	1.091	475	2521	475	2221	2696	1.455	5.747	7.202
1.7	115.2	1.031	483	2524	483	2216	2699	1.475	5.707	7.182
1.8	116.9	0.9774	491	2526	491	2211	2702	1.494	5.669	7.163
1.9	118.6	0.9292	498	2528	498	2206	2704	1.513	5.632	7.145
2.0	120.2	0.8856	505	2530	505	2202	2707	1.530	5.597	7.127
2.1	121.8	0.8461	511	2531	511	2198	2709	1.547	5.564	7.111
2.2	123.3	0.8100	518	2533	518	2193	2711	1.563	5.533	7.096
2.3	124.7	0.7770	524	2534	524	2189	2713	1.578	5.503	7.081
2.4	126.1	0.7466	530	2536	530	2185	2715	1.593	5.474	7.067
2.5	127.4	0.7186	535	2537	535	2182	2717	1.607	5.446	7.053
2.6	128.7	0.6927	541	2539	541	2178	2719	1.621	5.419	7.040
2.7	130.0	0.6686	546	2540	546	2174	2720	1.634	5.393	7.027
2.8	131.2	0.6462	551	2541	551	2171	2722	1.647	5.368	7.015
2.9	132.4	0.6253	556	2543	556	2168	2724	1.660	5.344	7.004
3.0	133.5	0.6057	561	2544	561	2164	2725	1.672	5.321	6.993
3.5	138.9	0.5241	584	2549	584	2148	2732	1.727	5.214	6.941
4.0	143.6	0.4623	605	2554	605	2134	2739	1.776	5.121	6.897
4.5	147.9	0.4139	623	2558	623	2121	2744	1.820	5.037	6.857
5.0	151.8	0.3748	639	2562	640	2109	2749	1.860	4.962	6.822
5.5	155.5	0.3427	655	2565	656	2097	2753	1.897	4.893	6.790
6	158.8	0.3156	669	2568	670	2087	2757	1.931	4.830	6.761
7	165.0	0.2728	696	2573	697	2067	2764	1.992	4.717	6.709
8	170.4	0.2403	720	2577	721	2048	2769	2.046	4.617	6.663
9	175.4	0.2149	742	2581	743	2031	2774	2.094	4.529	[illegible]
10	179.9	0.1944	762	2584	763	2015	2778	2.138	4.448	6.586
11	184.1	0.1774	780	2586	781	2000	2781	2.179	4.375	6.554
12	188.0	0.1632	797	2588	798	1986	2784	2.216	4.307	6.523
13	191.6	0.1512	813	2590	815	1972	2787	2.251	4.244	6.495
14	195.0	0.1408	828	2593	830	1960	2790	2.284	4.185	6.469
15	198.3	0.1317	843	2595	845	1947	2792	2.315	4.130	6.445
16	201.4	0.1237	857	2596	859	1935	2794	2.344	4.078	6.422
17	204.3	0.1167	870	2597	872	1923	2795	2.372	4.028	6.400
18	207.1	0.1104	883	2598	885	1912	2797	2.398	3.981	6.379
19	209.8	0.1047	895	2599	897	1901	2798	2.423	3.936	6.359
20	212.4	0.09957	907	2600	909	1890	2799	2.447	3.893	6.340
22	217.2	0.09069	928	2601	931	1870	2801	2.492	3.813	6.305
24	221.8	0.08323	949	2602	952	1850	2802	2.534	3.738	6.272
26	226.0	0.07689	969	2603	972	1831	2803	2.574	3.668	6.242
28	230.0	0.07142	988	2603	991	1812	2803	2.611	3.602	6.213
30	233.8	0.06665	1004	2603	1008	1795	2803	2.645	3.541	6.186
32	237.4	0.06246	1021	2603	1025	1778	2803	2.679	3.482	6.161
34	240.9	0.05875	1038	2603	1042	1761	2803	2.710	3.426	6.136
36	244.2	0.05544	1054	2602	1058	1744	2802	2.740	3.373	6.113
38	247.3	0.05246	1068	2602	1073	1729	2802	2.769	3.322	6.091
40	250.3	0.04977	1082	2602	1087	1714	2801	2.797	3.273	6.070

p [bar]	t_s [°C]	v_g [m^3/kg]	u_f [kJ/kg]	u_g	h_f [kJ/kg]	h_{fg}	h_g	s_f [kJ/kg K]	s_{fg}	s_g
40	250.3	0.04977	1082	2602	1087	1714	2801	2.797	3.273	6.070
42	253.2	0.04732	1097	2601	1102	1698	2800	2.823	3,226	6.049
44	256.0	0.04509	1109	2600	1115	1683	2798	2.849	3.180	6.029
46	258.8	0.04305	1123	2599	1129	1668	2797	2.874	3.136	6.010
48	261.4	0.04117	1136	2598	1142	1654	2796	2.897	3.094	5.991
50	263.9	0.03944	1149	2597	1155	1639	2794	2.921	3.052	5.973
55	269.9	0.03563	1178	2594	1185	1605	2790	2.976	2.955	5.931
60	275.6	0.03244	1206	2590	1214	1570	2784	3.027	2.863	5.890
65	280.8	0.02972	1232	2586	1241	1538	2779	3.076	2.775	5.851
70	285.8	0.02737	1258	2581	1267	1505	2772	3.122	2.692	5.814
75	290.5	0.02532	1283	2576	1293	1473	2766	3.166	2.613	5.779
80	295.0	0.02352	1306	2570	1317	1441	2758	3.207	2.537	5.744
85	299.2	0.02192	1329	2565	1341	1410	2751	3.248	2.463	5.711
90	303.3	0.02048	1351	2559	1364	1379	2743	3.286	2.393	5.679
95	307.2	0.01919	1372	2552	1386	1348	2734	3.324	2.323	5.647
100	311.0	0.01802	1393	2545	1408	1317	2725	3.360	2.255	5.615
105	314.6	0.01696	1414	2537	1429	1286	2715	3.395	2.189	5.584
110	318.0	0.01598	1434	2529	1450	1255	2705	3.430	2.123	5.553
115	321.4	0.01508	1454	2522	1471	1224	2695	3.463	2.060	5.523
120	324.6	0.01426	1473	2514	1491	1194	2685	3.496	1.997	5.493
125	327.8	0.01349	1492	2505	1511	1163	2674	3.529	1.934	5.463
130	330.8	0.01278	1511	2496	1531	1131	2662	3.561	1.872	5.433
135	333.8	0.01211	1530	2487	1551	1099	2650	3.592	1.811	5.403
140	336.6	0.01149	1548	2477	1571	1067	2638	3.623	1.750	5.373
145	339.4	0.01090	1567	2467	1591	1034	2625	3.654	1.689	5.343
150	342.1	0.01035	1585	2456	1610	1001	2611	3.685	1.627	5.312
155	344.8	0.00982	1604	2445	1630	967	2597	3.715	1.565	5.280
160	347.3	0.00932	1623	2433	1650	932	2582	3.746	1.502	5.248
165	349.8	0.00884	1641	2420	1670	895	2565	3.777	1.437	5.214
170	352.3	0.00838	1660	2406	1690	858	2548	3.808	1.373	5.181
175	354.6	0.00794	1679	2391	1711	819	2530	3.839	1.305	5.144
180	357.0	0.00751	1699	2375	1732	778	2510	3.872	1.236	5.108
185	359.2	0.00709	1719	2358	1754	735	2489	3.905	1.163	5.068
190	361.4	0.00668	1740	2339	1777	689	2466	3.941	1.086	5.027
195	363.6	0.00627	1762	2318	1801	639	2440	3.977	1.004	4.981
200	365.7	0.00585	1786	2294	1827	584	2411	4.014	0.914	4.928
202	366.5	0.00569	1796	2283	1838	560	2398	4.031	0.875	4.906
204	367.4	0.00552	1806	2271	1849	535	2384	4.049	0.835	4.884
206	368.2	0.00534	1817	2259	1861	508	2369	4.067	0.792	4.859
208	369.0	0.00517	1829	2245	1874	479	2353	4.087	0.745	4.832
210	369.8	0.00498	1842	2231	1889	447	2336	4.108	0.695	4.803
212	370.6	0.00479	1856	2214	1904	412	2316	4.131	0.640	4.771
214	371.4	0.00458	1871	2196	1921	373	2294	4.157	0.579	4.736
216	372.1	0.00436	1888	2174	1940	328	2268	4.186	0.508	4.694
218	372.9	0.00409	1911	2146	1965	270	2235	4.224	0.417	4.641
220	373.7	0.00368	1949	2097	2008	170	2178	4.289	0.263	4.552
221.2	374.15	0.00317	2014	2014	2084	0	2084	4.406	0.000	4.406

Superheated Steam

p/[bar] (t_s/[°C])			t/[°C] 50	100	150	200	250	300	400	500
0		v								
	$u=h-RT$	u	2446	2517	2589	2662	2737	2812	2969	3132
		h	2595	2689	2784	2880	2978	3077	3280	3489
		s								
	v_g 206.1	v	243.9	281.7	319.5	357.3	395.0	432.8	508.3	583.8
0.006112	u_g 2375	u	2446	2517	2589	2662	2737	2812	2969	3132
(0.01)	h_g 2501	h	2595	2689	2784	2880	2978	3077	3280	3489
	s_g 9.155	s	9.468	9.739	9.978	10.193	10.390	10.571	10.897	11.187
	v_g 129.2	v	149.1	172.2	195.3	218.4	241.4	264.5	310.7	356.8
0.01	u_g 2385	u	2446	2517	2589	2662	2737	2812	2969	3132
(7.0)	h_g 2514	h	2595	2689	2784	2880	2978	3077	3280	3489
	s_g 8.974	s	9.241	9.512	9.751	9.966	10.163	10.344	10.670	10.960
	v_g 28.20	v	29.78	34.42	39.04	43.66	48.28	52.90	62.13	71.36
0.05	u_g 2420	u	2445	2516	2589	2662	2737	2812	2969	3132
(32.9)	h_g 2561	h	2594	2688	2784	2880	2978	3077	3280	3489
	s_g 8.394	s	8.496	8.768	9.008	9.223	9.420	9.601	9.927	10.217
	v_g 14.67	v	14.87	17.20	19.51	21.83	24.14	26.45	31.06	35.68
0.1	u_g 2437	u	2443	2516	2588	2662	2736	2812	2969	3132
(45.8)	h_g 2584	h	2592	2688	2783	2880	2977	3077	3280	3489
	s_g 8.149	s	8.173	8.447	8.688	8.903	9.100	9.281	9.607	9.897
	v_g 3.239	v		3.420	3.890	4.356	4.821	5.284	6.209	7.134
0.5	u_g 2483	u		2512	2585	2660	2735	2812	2969	3132
(81.3)	h_g 2645	h		2683	2780	2878	2976	3076	3279	3489
	s_g 7.593	s		7.694	7.940	8.158	8.355	8.537	8.864	9.154
	v_g 2.217	v		2.271	2.588	2.901	3.211	3.521	4.138	4.755
0.75	u_g 2496	u		2510	2585	2659	2734	2811	2969	3132
(91.8)	h_g 2662	h		2680	2779	2877	2975	3075	3279	3489
	s_g 7.456	s		7.500	7.750	7.969	8.167	8.349	8.676	8.967
	v_g 1.694	v		1.696	1.937	2.173	2.406	2.639	3.103	3.565
1	u_g 2506	u		2506	2583	2659	2734	2811	2968	3131
(99.6)	h_g 2675	h		2676	2777	2876	2975	3075	3278	3488
	s_g 7.359	s		7.360	7.614	7.834	8.033	8.215	8.543	8.834
	v_g 1.673	v			1.912	2.145	2.375	2.604	3.062	3.519
1.01325	u_g 2506	u			2583	2659	2734	2811	2968	3131
(100.0)	h_g 2676	h			2777	2876	2975	3075	3278	3488
	s_g 7.355	s			7.608	7.828	8.027	8.209	8.537	8.828
	v_g 1.159	v			1.286	1.445	1.601	1.757	2.067	2.376
1.5	u_g 2519	u			2580	2656	2733	2809	2967	3131
(111.4)	h_g 2693	h			2773	2873	2973	3073	3277	3488
	s_g 7.223	s			7.420	7.643	7.843	8.027	8.355	8.646
	v_g 0.8856	v			0.9602	1.081	1.199	1.316	1.549	1.781
2	u_g 2530	u			2578	2655	2731	2809	2967	3131
(120.2)	h_g 2707	h			2770	2871	2971	3072	3277	3487
	s_g 7.127	s			7.280	7.507	7.708	7.892	8.221	8.513
	v_g 0.6057	v			0.6342	0.7166	0.7965	0.8754	1.031	1.187
3	u_g 2544	u			2572	2651	2729	2807	2966	3130
(133.5)	h_g 2725	h			2762	2866	2968	3070	3275	3486
	s_g 6.993	s			7.078	7.312	7.517	7.702	8.032	8.324
	v_g 0.4623	v			0.4710	0.5345	0.5953	0.6549	0.7725	0.8893
4	u_g 2554	u			2565	2648	2727	2805	2965	3129
(143.6)	h_g 2739	h			2753	2862	2965	3067	3274	3485
	s_g 6.897	s			6.929	7.172	7.379	7.566	7.898	8.191

p/[bar] (t_s/[°C])			t / [°C]	200	250	300	350	400	450	500	600
5 (151.8)	v_g	0.3748	v	0.4252	0.4745	0.5226	0.5701	0.6172	0.6641	0.7108	0.8040
	u_g	2562	u	2644	2725	2804	2883	2963	3045	3129	3300
	h_g	2749	h	2857	2962	3065	3168	3272	3377	3484	3702
	s_g	6.822	s	7.060	7.271	7.460	7.633	7.793	7.944	8.087	8.351
6 (158.8)	v_g	0.3156	v	0.3522	0.3940	0.4344	0.4743	0.5136	0.5528	0.5919	0.6697
	u_g	2568	u	2640	2722	2801	2881	2962	3044	3128	3299
	h_g	2757	h	2851	2958	3062	3166	3270	3376	3483	3701
	s_g	6.761	s	6.968	7.182	7.373	7.546	7.707	7.858	8.001	8.267
7 (165.0)	v_g	0.2728	v	0.3001	0.3364	0.3714	0.4058	0.4397	0.4734	0.5069	0.5737
	u_g	2573	u	2636	2720	2800	2880	2961	3043	3127	3298
	h_g	2764	h	2846	2955	3060	3164	3269	3374	3482	3700
	s_g	6.709	s	6.888	7.106	7.298	7.473	7.634	7.786	7.929	8.195
8 (170.4)	v_g	0.2403	v	0.2610	0.2933	0.3242	0.3544	0.3842	0.4138	0.4432	0.5018
	u_g	2577	u	2631	2716	2798	2878	2960	3042	3126	3298
	h_g	2769	h	2840	2951	3057	3162	3267	3373	3481	3699
	s_g	6.663	s	6.817	7.040	7.233	7.409	7.571	7.723	7.866	8.132
9 (175.4)	v_g	0.2149	v	0.2305	0.2597	0.2874	0.3144	0.3410	0.3674	0.3937	0.4458
	u_g	2581	u	2628	2714	2796	2877	2959	3041	3126	3298
	h_g	2774	h	2835	2948	3055	3160	3266	3372	3480	3699
	s_g	6.623	s	6.753	6.980	7.176	7.352	7.515	7.667	7.811	8.077
10 (179.9)	v_g	0.1944	v	0.2061	0.2328	0.2580	0.2825	0.3065	0.3303	0.3540	0.4010
	u_g	2584	u	2623	2711	2794	2875	2957	3040	3124	3297
	h_g	2778	h	2829	2944	3052	3158	3264	3370	3478	3698
	s_g	6.586	s	6.695	6.926	7.124	7.301	7.464	7.617	7.761	8.028
15 (198.3)	v_g	0.1317	v	0.1324	0.1520	0.1697	0.1865	0.2029	0.2191	0.2351	0.2667
	u_g	2595	u	2597	2697	2784	2868	2952	3035	3120	3294
	h_g	2792	h	2796	2925	3039	3148	3256	3364	3473	3694
	s_g	6.445	s	6.452	6.711	6.919	7.102	7.268	7.423	7.569	7.838
20 (212.4)	v_g	0.0996	v		0.1115	0.1255	0.1386	0.1511	0.1634	0.1756	0.1995
	u_g	2600	u		2681	2774	2861	2946	3030	3116	3291
	h_g	2799	h		2904	3025	3138	3248	3357	3467	3690
	s_g	6.340	s		6.547	6.768	6.957	7.126	7.283	7.431	7.701
30 (233.8)	v_g	0.0666	v		0.0706	0.0812	0.0905	0.0993	0.1078	0.1161	0.1324
	u_g	2603	u		2646	2751	2845	2933	3020	3108	3285
	h_g	2803	h		2858	2995	3117	3231	3343	3456	3682
	s_g	6.186	s		6.289	6.541	6.744	6.921	7.082	7.233	7.507
40 (250.3)	v_g	0.0498	v			0.0588	0.0664	0.0733	0.0800	0.0864	0.0988
	u_g	2602	u			2728	2828	2921	3010	3099	3279
	h_g	2801	h			2963	3094	3214	3330	3445	3674
	s_g	6.070	s			6.364	6.584	6.769	6.935	7.089	7.368
50 (263.9)	v_g	0.0394	v			0.0453	0.0519	0.0578	0.0632	0.0685	0.0786
	u_g	2597	u			2700	2810	2907	3000	3090	3273
	h_g	2794	h			2927	3070	3196	3316	3433	3666
	s_g	5.973	s			6.212	6.451	6.646	6.818	6.975	7.258
60 (275.6)	v_g	0.0324	v			0.0362	0.0422	0.0473	0.0521	0.0566	0.0652
	u_g	2590	u			2670	2792	2893	2988	3081	3266
	h_g	2784	h			2887	3045	3177	3301	3421	3657
	s_g	5.890	s			6.071	6.336	6.541	6.719	6.879	7.166
70 (285.8)	v_g	0.0274	v			0.0295	0.0352	0.0399	0.0441	0.0481	0.0556
	u_g	2581	u			2634	2772	2879	2978	3073	3260
	h_g	2772	h			2841	3018	3158	3287	3410	3649
	s_g	5.814	s			5.934	6.231	6.448	6.632	6.796	7.088

See next page

Superheated Steam

p/[bar] (t_s/[°C])		t/[°C]	350	375	400	425	450	500	600	700
80	v_g 0.02352	$v \times 10^2$	2.994	3.220	3.428	3.625	3.812	4.170	4.839	5.476
(295.0)	h_g 2758	h	2990	3067	3139	3207	3272	3398	3641	3881
	s_g 5.744	s	6.133	6.255	6.364	6.463	6.555	6.723	7.019	7.279
90	v_g 0.02048	$v \times 10^2$	2.578	2.794	2.991	3.173	3.346	3.673	4.279	4.852
(303.3)	h_g 2743	h	2959	3042	3118	3189	3256	3385	3633	3874
	s_g 5.679	s	6.039	6.171	6.286	6.390	6.484	6.657	6.958	7.220
100	v_g 0.01802	$v \times 10^2$	2.241	2.453	2.639	2.812	2.972	3.275	3.831	4.353
(311.0)	h_g 2725	h	2926	3017	3097	3172	3241	3373	3624	3868
	s_g 5.615	s	5.947	6.091	6.213	6.321	6.419	6.596	6.902	7.166
110	v_g 0.01598	$v \times 10^2$	1.960	2.169	2.350	2.514	2.666	2.949	3.465	3.945
(318.0)	h_g 2705	h	2889	2989	3075	3153	3225	3360	3616	3862
	s_g 5.553	s	5.856	6.014	6.143	6.257	6.358	6.539	6.850	7.117
120	v_g 0.01426	$v \times 10^2$	1.719	1.931	2.107	2.265	2.410	2.677	3.159	3.605
(324.6)	h_g 2685	h	2849	2960	3052	3134	3209	3348	3607	3856
	s_g 5.493	s	5.762	5.937	6.076	6.195	6.301	6.487	6.802	7.072
130	v_g 0.01278	$v \times 10^2$	1.509	1.726	1.901	2.053	2.193	2.447	2.901	3.318
(330.8)	h_g 2662	h	2804	2929	3028	3114	3192	3335	3599	3850
	s_g 5.433	s	5.664	5.862	6.011	6.136	6.246	6.437	6.758	7.030
140	v_g 0.01149	$v \times 10^2$	1.321	1.548	1.722	1.872	2.006	2.250	2.679	3.071
(336.6)	h_g 2638	h	2753	2896	3003	3093	3175	3322	3590	3843
	s_g 5.373	s	5.559	5.784	5.946	6.079	6.193	6.390	6.716	6.991
150	v_g 0.01035	$v \times 10^2$	1.146	1.391	1.566	1.714	1.844	2.078	2.487	2.857
(342.1)	h_g 2611	h	2693	2861	2977	3073	3157	3309	3581	3837
	s_g 5.312	s	5.443	5.707	5.883	6.023	6.142	6.345	6.677	6.954
160	v_g 0.00932	$v \times 10^2$	0.976	1.248	1.427	1.573	1.702	1.928	2.319	2.670
(347.3)	h_g 2582	h	2617	2821	2949	3051	3139	3295	3573	3831
	s_g 5.248	s	5.304	5.626	5.820	5.968	6.093	6.301	6.639	6.919
170	v_g 0.00838	$v \times 10^2$		1.117	1.303	1.449	1.576	1.796	2.171	2.506
(352.3)	h_g 2548	h		2778	2920	3028	3121	3281	3564	3825
	s_g 5.181	s		5.541	5.756	5.914	6.044	6.260	6.603	6.886
180	v_g 0.00751	$v \times 10^2$		0.997	1.191	1.338	1.463	1.678	2.039	2.359
(357.0)	h_g 2510	h		2729	2888	3004	3102	3268	3555	3818
	s_g 5.108	s		5.449	5.691	5.861	5.997	6.219	6.569	6.855
190	v_g 0.00668	$v \times 10^2$		0.882	1.089	1.238	1.362	1.572	1.921	2.228
(361.4)	h_g 2466	h		2674	2855	2980	3082	3254	3546	3812
	s_g 5.027	s		5.348	5.625	5.807	5.950	6.180	6.536	6.825
200	v_g 0.00585	$v \times 10^2$		0.768	0.995	1.147	1.270	1.477	1.815	2.110
(365.7)	h_g 2411	h		2605	2819	2955	3062	3239	3537	3806
	s_g 4.928	s		5.228	5.556	5.753	5.904	6.142	6.505	6.796
210	v_g 0.00498	$v \times 10^2$		0.650	0.908	1.064	1.187	1.390	1.719	2.003
(369.8)	h_g 2336	h		2500	2781	2928	3041	3225	3528	3799
	s_g 4.803	s		5.050	5.484	5.699	5.859	6.105	6.474	6.768
220	v_g 0.00368	$v \times 10^2$		0.450	0.825	0.987	1.111	1.312	1.632	1.906
(373.7)	h_g 2178	h		2300	2738	2900	3020	3210	3519	3793
	s_g 4.552	s		4.725	5.409	5.645	5.813	6.068	6.444	6.742
221.2	v_c 0.00317	$v \times 10^2$	0.163	0.351	0.816	0.978	1.103	1.303	1.622	1.895
(374.15)	h_c 2084	h	1637	2139	2733	2896	3017	3208	3518	3792
	s_c 4.406	s	3.708	4.490	5.398	5.638	5.807	6.064	6.441	6.739

Linear interpolation is not accurate near the critical point.

p [bar]	t [°C]	350	375	400	425	450	500	600	700	800
225	$v \times 10^2$	0.163	0.249	0.786	0.951	1.076	1.275	1.591	1.861	2.109
	h	1635	1980	2716	2885	3009	3203	3514	3790	4055
	s	3.704	4.470	5.369	5.616	5.790	6.050	6.430	6.729	6.988
250	$v \times 10^2$	0.160	0.198	0.601	0.789	0.917	1.113	1.412	1.662	1.890
	h	1625	1850	2580	2807	2951	3165	3491	3774	4043
	s	3.682	4.026	5.142	5.474	5.677	5.962	6.361	6.667	6.931
275	$v \times 10^2$	0.158	0.187	0.419	0.650	0.786	0.980	1.265	1.500	1.710
	h	1617	1814	2382	2718	2890	3125	3468	3758	4032
	s	3.662	3.985	4.828	5.320	5.562	5.878	6.296	6.610	6.878
300	$v \times 10^2$	0.155	0.180	0.282	0.530	0.674	0.868	1.143	1.364	1.561
	h	1610	1791	2157	2614	2823	3084	3445	3742	4020
	s	3.645	3.933	4.482	5.157	5.444	5.795	6.234	6.557	6.829
350	$v \times 10^2$	0.152	0.171	0.211	0.343	0.496	0.693	0.952	1.152	1.327
	h	1599	1762	1992	2375	2673	2998	3397	3709	3997
	s	3.614	3.875	4.219	4.776	5.197	5.633	6.120	6.459	6.741
400	$v \times 10^2$	0.149	0.164	0.191	0.255	0.369	0.562	0.809	0.993	1.152
	h	1590	1743	1935	2203	2514	2906	3348	3677	3974
	s	3.588	3.832	4.119	4.510	4.947	5.474	6.014	6.371	6.662
450	$v \times 10^2$	0.146	0.160	0.181	0.219	0.291	0.463	0.698	0.870	1.016
	h	1583	1729	1901	2115	2380	2813	3299	3644	3951
	s	3.565	3.797	4.056	4.368	4.740	5.320	5.914	6.290	6.590
500	$v \times 10^2$	0.144	0.156	0.173	0.201	0.249	0.388	0.611	0.772	0.908
	h	1577	1717	1879	2064	2288	2722	3249	3612	3928
	s	3.544	3.768	4.009	4.279	4.594	5.176	5.821	6.214	6.524
550	$v \times 10^2$	0.143	0.153	0.168	0.190	0.224	0.334	0.540	0.693	0.820
	h	1572	1709	1862	2030	2227	2641	3200	3579	3905
	s	3.525	3.742	3.971	4.218	4.494	5.047	5.731	6.144	6.462
600	$v \times 10^2$	0.141	0.151	0.164	0.182	0.209	0.295	0.483	0.627	0.747
	h	1568	1702	1848	2005	2184	2571	3152	3548	3883
	s	3.506	3.718	3.939	4.168	4.419	4.937	5.648	6.077	6.405
650	$v \times 10^2$	0.139	0.148	0.160	0.176	0.198	0.267	0.436	0.572	0.685
	h	1565	1696	1837	1986	2151	2514	3106	3517	3860
	s	3.489	3.697	3.910	4.128	4.360	4.845	5.568	6.014	6.352
700	$v \times 10^2$	0.138	0.146	0.157	0.171	0.189	0.247	0.397	0.526	0.633
	h	1561	1691	1829	1971	2127	2468	3062	3486	3839
	s	3.473	3.678	3.886	4.093	4.312	4.769	5.494	5.955	6.300
750	$v \times 10^2$	0.137	0.145	0.154	0.167	0.183	0.231	0.365	0.486	0.587
	h	1559	1687	1821	1958	2107	2431	3021	3456	3817
	s	3.459	3.659	3.863	4.064	4.272	4.705	5.425	5.899	6.252
800	$v \times 10^2$	0.136	0.143	0.152	0.163	0.178	0.219	0.338	0.452	0.548
	h	1557	1684	1815	1948	2091	2400	2983	3428	3797
	s	3.444	3.642	3.842	4.037	4.237	4.651	5.361	5.845	6.206
900	$v \times 10^2$	0.133	0.140	0.148	0.158	0.169	0.202	0.296	0.396	0.484
	h	1554	1678	1805	1932	2066	2353	2916	3373	3756
	s	3.418	3.612	3.805	3.991	4.179	4.563	5.248	5.746	6.120
1000	$v \times 10^2$	0.131	0.138	0.145	0.153	0.163	0.189	0.267	0.354	0.434
	h	1552	1674	1798	1920	2048	2319	2860	3324	3718
	s	3.394	3.584	3.773	3.951	4.131	4.493	5.153	5.656	6.042

See next page

Saturated Water and Steam

t [°C]	p_s [bar]	v_f 10^{-2}[m³/kg]	c_{pf} [kJ/kg K]	c_{pg} [kJ/kg K]	μ_f 10^{-6}[kg/m s]	μ_g 10^{-6}[kg/m s]	k_f 10^{-6}[kW/m K]	k_g 10^{-6}[kW/m K]	$(Pr)_f$	$(Pr)_g$
0.01	0.006112	0.10002	4.210	1.86	1752	8.49	569	16.3	12.96	0.97
5	0.008719	0.10001	4.204	1.86	1501	8.66	578	16.7	10.92	0.96
10	0.01227	0.10003	4.193	1.86	1300	8.83	587	17.1	9.29	0.96
15	0.01704	0.10010	4.186	1.87	1136	9.00	595	17.5	7.99	0.96
20	0.02337	0.10018	4.183	1.87	1002	9.18	603	17.9	6.95	0.96
25	0.03166	0.10030	4.181	1.88	890	9.35	611	18.3	6.09	0.96
30	0.04242	0.10044	4.179	1.88	797	9.52	618	18.7	5.39	0.96
35	0.05622	0.10060	4.178	1.88	718	9.70	625	19.1	4.80	0.96
40	0.07375	0.10079	4.179	1.89	651	9.87	632	19.5	4.30	0.96
45	0.09582	0.10099	4.181	1.89	594	10.0	638	19.9	3.89	0.95
50	0.1233	0.1012	4.182	1.90	544	10.2	643	20.4	3.54	0.95
55	0.1574	0.1015	4.183	1.90	501	10.4	648	20.8	3.23	0.95
60	0.1992	0.1017	4.185	1.91	463	10.6	653	21.2	2.97	0.95
65	0.2501	0.1020	4.188	1.92	430	10.7	658	21.6	2.74	0.95
70	0.3116	0.1023	4.191	1.93	400	10.9	662	22.0	2.53	0.96
75	0.3855	0.1026	4.194	1.94	374	11.1	666	22.5	2.36	0.96
80	0.4736	0.1029	4.198	1.95	351	11.3	670	22.9	2.20	0.96
85	0.5780	0.1032	4.203	1.96	330	11.4	673	23.3	2.06	0.96
90	0.7011	0.1036	4.208	1.97	311	11.6	676	23.8	1.94	0.96
95	0.8453	0.1040	4.213	1.99	294	11.8	678	24.3	1.83	0.97
100	1.01325	0.1044	4.219	2.01	279	12.0	681	24.8	1.73	0.97
105	1.208	0.1048	4.226	2.03	265	12.2	683	25.3	1.64	0.98
110	1.433	0.1052	4.233	2.05	252	12.4	684	25.8	1.56	0.99
115	1.691	0.1056	4.240	2.07	241	12.6	686	26.3	1.49	0.99
120	1.985	0.1060	4.248	2.09	230	12.8	687	26.8	1.42	1.00
125	2.321	0.1065	4.26	2.12	220	13.0	687	27.3	1.36	1.01
130	2.701	0.1070	4.27	2.15	211	13.2	688	27.8	1.31	1.02
135	3.131	0.1075	4.28	2.18	203	13.4	688	28.3	1.26	1.03
140	3.614	0.1080	4.29	2.21	195	13.5	688	28.8	1.22	1.04
145	4.155	0.1085	4.30	2.25	188	13.7	687	29.4	1.18	1.05
150	4.760	0.1091	4.32	2.29	181	13.9	687	30.0	1.14	1.07
160	6.181	0.1102	4.35	2.38	169	14.2	684	31.3	1.07	1.09
170	7.920	0.1114	4.38	2.49	159	14.6	681	32.6	1.02	1.12
180	10.03	0.1128	4.42	2.62	149	15.0	676	34.1	0.97	1.15
190	12.55	0.1142	4.46	2.76	141	15.3	671	35.7	0.94	1.18
200	15.55	0.1157	4.51	2.91	134	15.7	665	37.5	0.91	1.22
210	19.08	0.1173	4.56	3.07	127	16.0	657	39.4	0.88	1.25
220	23.20	0.1190	4.63	3.25	121	16.3	648	41.5	0.86	1.28
230	27.98	0.1209	4.70	3.45	116	16.7	639	43.9	0.85	1.31
240	33.48	0.1229	4.78	3.68	111	17.1	628	46.5	0.84	1.35
250	39.78	0.1251	4.87	3.94	107	17.5	616	49.5	0.85	1.39
260	46.94	0.1276	4.98	4.22	103	17.9	603	52.8	0.85	1.43
270	55.05	0.1302	5.10	4.55	99	18.3	589	56.6	0.86	1.47
280	64.19	0.1332	5.24	4.98	96	18.8	574	61.0	0.88	1.53
290	74.45	0.1366	5.42	5.46	93	19.3	558	66.0	0.90	1.60
300	85.92	0.1404	5.65	6.18	90	19.8	541	72.0	0.94	1.70
320	112.9	0.1499								
340	146.1	0.1639								
360	186.7	0.1894								
370	210.5	0.2225								
374.15	221.2	0.317								

The values for saturated water can be used with good accuracy above saturation pressure. The values for saturated steam can be used with only moderate accuracy below saturation pressure at temperatures greater than 200 °C.

General Information for H_2O

Triple point: Thermodynamic temperature (by definition) = 273.16 K ≙ 0.01 °C ≙ 491.688 R ≙ 32.018 °F
(hence 0 °C ≙ 273.15 K, 0 °F ≙ 459.67 R, 32 °F ≙ 491.67 R)
Gas constant: $R = R_0/M = 8.3144/18.015 = 0.4615$ kJ/kg K

Compressed Water

	t/[°C]	0.01	100	200	250	300	350	374.15
p/[bar] (t_s/[°C])	p_s	0.006112	1.01325	15.55	39.78	85.92	165.4	221.2
	$v_f \times 10^2$	0.1000	0.1044	0.1157	0.1251	0.1404	0.1741	0.317
	h_f	0	419	852	1086	1345	1671	2084
	s_f	0	1.307	2.331	2.793	3.255	3.779	4.430
100 (311.0)	$(v-v_f) \times 10^2$	−0.0005	−0.0006	−0.0009	−0.0011	−0.0007		
	$(h-h_f)$	+10	+7	+4	0	−2		
	$(s-s_f)$	0.000	−0.008	−0.013	−0.014	−0.007		
221.2 (374.15)	$(v-v_f) \times 10^2$	−0.0011	−0.0012	−0.0020	−0.0029	−0.0051	−0.0107	0
	$(h-h_f)$	+22	+17	+9	+1	−12	−34	0
	$(s-s_f)$	+0.001	−0.017	−0.031	−0.040	−0.053	−0.071	0
500	$(v-v_f) \times 10^2$	−0.0023	−0.0024	−0.0042	−0.0064	−0.0117	−0.0298	−0.161
	$(h-h_f)$	+49	+38	+23	+8	−21	−94	−369
	$(s-s_f)$	0.000	−0.037	−0.068	−0.091	−0.134	−0.235	−0.670
1000	$(v-v_f) \times 10^2$	−0.0044	−0.0044	−0.0075	−0.0111	−0.0191	−0.0427	−0.180
	$(h-h_f)$	+96	+76	+51	+28	−17	−119	−415
	$(s-s_f)$	−0.007	−0.070	−0.124	−0.164	−0.235	−0.385	−0.853

Saturated Ice and Steam

t [°C]	p_s [bar]	v_i 10^{-2}[m³/kg]	v_g [m³/kg]	u_i [kJ/kg]	u_g [kJ/kg]	h_i [kJ/kg]	h_g [kJ/kg]	s_i [kJ/kg K]	s_g [kJ/kg K]
0.01	0.006112	0.1091	206.1	−333.5	2374.7	−333.5	2500.8	−1.221	9.155
−10	0.002598	0.1089	467.5	−354.2	2360.8	−354.2	2482.2	−1.298	9.481
−20	0.001038	0.1087	1125	−374.1	2346.8	−374.1	2463.6	−1.375	9.835
−30	0.0003809	0.1086	2946	−393.3	2332.9	−393.3	2445.1	−1.452	10.221
−40	0.0001288	0.1084	8354	−411.8	2319.0	−411.8	2426.6	−1.530	10.644

Isentropic Expansion of Steam—Approximate Relations

Wet equilibrium expansion:

pv^n = constant, with $n \approx 1.135$ for steam initially dry saturated

Superheated and supersaturated expansion:

pv^n = constant and $p/T^{n/(n-1)}$ = constant, with $n \approx 1.3$

$$\text{Enthalpy drop } \frac{(h_2 - h_1)}{[\text{kJ/kg}]} = \left(\frac{h_1}{[\text{kJ/kg}]} - 1943\right)\left[\left(\frac{p_2}{p_1}\right)^{(n-1)/n} - 1\right]$$

Specific volume of supersaturated steam:

$$\frac{p}{[\text{bar}]} \times \frac{v}{[\text{m}^3/\text{kg}]} \times 10^2 = \frac{0.3}{1.3}\left(\frac{h}{[\text{kJ/kg}]} - 1943\right)$$

See next page

Ammonia – NH_3 (Refrigerant 717)

Saturation Values							Superheat $(t-t_s)$ 50 K		Superheat $(t-t_s)$ 100 K	
t [°C]	p_s [bar]	v_g [m³/kg]	h_f [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_g [kJ/kg K]	h [kJ/kg]	s [kJ/kg K]	h [kJ/kg]	s [kJ/kg K]
−50	0.4089	2.625	−44.4	1373.3	−0.194	6.159	1479.8	6.592	1585.9	6.948
−45	0.5454	2.005	−22.3	1381.6	−0.096	6.057	1489.3	6.486	1596.1	6.839
−40	0.7177	1.552	0	1390.0	0	5.962	1498.6	6.387	1606.3	6.736
−35	0.9322	1.216	22.3	1397.9	0.095	5.872	1507.9	6.293	1616.3	6.639
−30	1.196	0.9633	44.7	1405.6	0.188	5.785	1517.0	6.203	1626.3	6.547
−28	1.317	0.8809	53.6	1408.5	0.224	5.751	1520.7	6.169	1630.3	6.512
−26	1.447	0.8058	62.6	1411.4	0.261	5.718	1524.3	6.135	1634.2	6.477
−24	1.588	0.7389	71.7	1414.3	0.297	5.686	1527.9	6.103	1638.2	6.444
−22	1.740	0.6783	80.8	1417.3	0.333	5.655	1531.4	6.071	1642.2	6.411
−20	1.902	0.6237	89.8	1420.0	0.368	5.623	1534.8	6.039	1646.0	6.379
−18	2.077	0.5743	98.8	1422.7	0.404	5.593	1538.2	6.008	1650.0	6.347
−16	2.265	0.5296	107.9	1425.3	0.440	5.563	1541.7	5.978	1653.8	6.316
−14	2.465	0.4890	117.0	1427.9	0.475	5.533	1545.1	5.948	1657.7	6.286
−12	2.680	0.4521	126.2	1430.5	0.510	5.504	1548.5	5.919	1661.5	6.256
−10	2.908	0.4185	135.4	1433.0	0.544	5.475	1551.7	5.891	1665.3	6.227
− 8	3.153	0.3879	144.5	1435.3	0.579	5.447	1554.9	5.863	1669.0	6.199
− 6	3.413	0.3599	153.6	1437.6	0.613	5.419	1558.2	5.836	1672.8	6.171
− 4	3.691	0.3344	162.8	1439.9	0.647	5.392	1561.4	5.808	1676.4	6.143
− 2	3.983	0.3110	172.0	1442.2	0.681	5.365	1564.6	5.782	1680.1	6.116
0	4.295	0.2895	181.2	1444.4	0.715	5.340	1567.8	5.756	1683.9	6.090
2	4.625	0.2699	190.4	1446.5	0.749	5.314	1570.9	5.731	1687.5	6.065
4	4.975	0.2517	199.7	1448.5	0.782	5.288	1574.0	5.706	1691.2	6.040
6	5.346	0.2351	209.1	1450.6	0.816	5.263	1577.0	5.682	1694.9	6.015
8	5.736	0.2198	218.5	1452.5	0.849	5.238	1580.1	5.658	1698.4	5.991
10	6.149	0.2056	227.8	1454.3	0.881	5.213	1583.1	5.634	1702.2	5.967
12	6.585	0.1926	237.2	1456.1	0.914	5.189	1586.0	5.611	1705.7	5.943
14	7.045	0.1805	246.6	1457.8	0.947	5.165	1588.9	5.588	1709.1	5.920
16	7.529	0.1693	256.0	1459.5	0.979	5.141	1591.7	5.565	1712.5	5.898
18	8.035	0.1590	265.5	1461.1	1.012	5.118	1594.4	5.543	1715.9	5.876
20	8.570	0.1494	275.1	1462.6	1.044	5.095	1597.2	5.521	1719.3	5.854
22	9.134	0.1405	284.6	1463.9	1.076	5.072	1600.0	5.499	1722.8	5.832
24	9.722	0.1322	294.1	1465.2	1.108	5.049	1602.7	5.478	1726.3	5.811
26	10.34	0.1245	303.7	1466.5	1.140	5.027	1605.3	5.458	1729.6	5.790
28	10.99	0.1173	313.4	1467.8	1.172	5.005	1608.0	5.437	1732.7	5.770
30	11.67	0.1106	323.1	1468.9	1.204	4.984	1610.5	5.417	1735.9	5.750
32	12.37	0.1044	332.8	1469.9	1.235	4.962	1613.0	5.397	1739.3	5.731
34	13.11	0.0986	342.5	1470.8	1.267	4.940	1615.4	5.378	1742.6	5.711
36	13.89	0.0931	352.3	1471.8	1.298	4.919	1617.8	5.358	1745.7	5.692
38	14.70	0.0880	362.1	1472.6	1.329	4.898	1620.1	5.340	1748.7	5.674
40	15.54	0.0833	371.9	1473.3	1.360	4.877	1622.4	5.321	1751.9	5.655
42	16.42	0.0788	381.8	1473.8	1.391	4.856	1624.6	5.302	1755.0	5.637
44	17.34	0.0746	391.8	1474.2	1.422	4.835	1626.8	5.284	1758.0	5.619
46	18.30	0.0706	401.8	1474.5	1.453	4.814	1629.0	5.266	1761.0	5.602
48	19.29	0.0670	411.9	1474.7	1.484	4.793	1631.1	5.248	1764.0	5.584
50	20.33	0.0635	421.9	1474.7	1.515	4.773	1633.1	5.230	1766.8	5.567

Critical point $t_c = 132.4$ °C, $p_c = 113.0$ bar.
Molar mass $M = 17.030$ kg/kmol; further properties of the liquid are given on p. 15.

Dichlorodifluoromethane – CF_2Cl_2 (Refrigerant 12)

Saturation Values							Superheat $(t-t_s)$ 15 K		Superheat $(t-t_s)$ 30 K	
t [°C]	p_s [bar]	v_g [m³/kg]	h_f [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_g [kJ/kg K]	h [kJ/kg]	s [kJ/kg K]	h [kJ/kg]	s [kJ/kg K]
−100	0.0118	10.100	−51.84	142.00	−0.2567	0.8628	148.89	0.9019	156.10	0.9428
− 95	0.0181	6.585	−47.56	144.22	−0.2323	0.8442	151.23	0.8830	158.55	0.9195
− 90	0.0284	4.416	−43.28	146.46	−0.2086	0.8274	153.59	0.8649	161.02	0.9010
− 85	0.0424	3.037	−39.00	148.73	−0.1856	0.8122	155.98	0.8493	163.52	0.8851
− 80	0.0617	2.138	−34.72	151.02	−0.1631	0.7985	158.39	0.8351	166.04	0.8706
− 75	0.0879	1.538	−30.43	153.32	−0.1412	0.7861	160.82	0.8226	168.57	0.8578
− 70	0.1227	1.127	−26.13	155.63	−0.1198	0.7749	163.26	0.8110	171.12	0.8459
− 65	0.1680	0.8412	−21.81	157.96	−0.0988	0.7649	165.70	0.8008	173.68	0.8355
− 60	0.2262	0.6379	−17.49	160.29	−0.0783	0.7558	168.15	0.7915	176.26	0.8259
− 55	0.2998	0.4910	−13.14	162.62	−0.0582	0.7475	170.60	0.7830	178.84	0.8172
− 50	0.3915	0.3831	− 8.78	164.95	−0.0384	0.7401	173.07	0.7753	181.43	0.8093
− 45	0.5044	0.3027	− 4.40	167.28	−0.0190	0.7335	175.54	0.7685	184.01	0.8023
− 40	0.6417	0.2419	0	169.60	0	0.7274	178.00	0.7623	186.60	0.7959
− 35	0.8071	0.1954	4.42	171.90	0.0187	0.7219	180.45	0.7568	189.18	0.7902
− 30	1.004	0.1594	8.86	174.20	0.0371	0.7170	182.90	0.7517	191.76	0.7851
− 25	1.237	0.1312	13.33	176.48	0.0552	0.7127	185.33	0.7473	194.33	0.7805
− 20	1.509	0.1088	17.82	178.73	0.0731	0.7087	187.75	0.7432	196.89	0.7764
− 15	1.826	0.0910	22.33	180.97	0.0906	0.7051	190.15	0.7397	199.44	0.7728
− 10	2.191	0.0766	26.87	183.19	0.1080	0.7020	192.53	0.7365	201.97	0.7695
− 5	2.610	0.0650	31.45	185.38	0.1251	0.6991	194.90	0.7336	204.49	0.7666
0	3.086	0.0554	36.05	187.53	0.1420	0.6966	197.25	0.7311	206.99	0.7641
5	3.626	0.0475	40.69	189.66	0.1587	0.6943	199.56	0.7289	209.47	0.7618
10	4.233	0.0409	45.37	191.74	0.1752	0.6921	201.85	0.7268	211.92	0.7598
15	4.914	0.0354	50.10	193.78	0.1915	0.6901	204.10	0.7251	214.35	0.7580
20	5.673	0.0308	54.87	195.78	0.2078	0.6885	206.32	0.7235	216.75	0.7565
25	6.516	0.0269	59.70	197.73	0.2239	0.6869	208.50	0.7220	219.11	0.7552
30	7.449	0.0235	64.59	199.62	0.2399	0.6853	210.63	0.7208	221.44	0.7540
35	8.477	0.0206	69.55	201.45	0.2559	0.6839	212.72	0.7196	223.73	0.7529
40	9.607	0.0182	74.59	203.20	0.2718	0.6825	214.76	0.7185	225.98	0.7519
45	10.84	0.0160	79.71	204.87	0.2877	0.6811	216.74	0.7175	228.18	0.7511
50	12.19	0.0142	84.94	206.45	0.3037	0.6797	218.64	0.7166	230.33	0.7503
55	13.66	0.0125	90.27	207.92	0.3197	0.6782	220.48	0.7156	232.42	0.7496
60	15.26	0.0111	95.74	209.26	0.3358	0.6765	222.23	0.7146	234.45	0.7490
65	16.99	0.00985	101.36	210.46	0.3521	0.6747	223.89	0.7136	236.42	0.7484
70	18.86	0.00873	107.15	211.48	0.3686	0.6726	225.45	0.7125	238.32	0.7477
75	20.88	0.00772	113.15	212.29	0.3854	0.6702	226.89	0.7113	240.13	0.7470
80	23.05	0.00682	119.39	212.83	0.4027	0.6673	228.21	0.7099	241.86	0.7463
85	25.38	0.00601	125.93	213.04	0.4204	0.6636	229.39	0.7084	243.50	0.7455
90	27.89	0.00526	132.84	212.80	0.4389	0.6591	230.43	0.7067	245.03	0.7445
95	30.57	0.00456	140.23	211.94	0.4583	0.6531	231.30	0.7047	246.47	0.7435
100	33.44	0.00390	148.32	210.12	0.4793	0.6449	231.93	0.7023	247.80	0.7424
105	36.51	0.00324	157.52	206.57	0.5028	0.6325	232.22	0.6994	248.97	0.7412
110	39.79	0.00246	169.55	197.99	0.5334	0.6076	232.47	0.6964	250.10	0.7399
112	41.15	0.00179	183.43	183.43	0.5690	0.5690	232.80	0.6958	250.58	0.7394

Molar mass M = 120.91 kg/kmol; further properties of the liquid are given on p. 15.

Mercury – Hg

p [bar]	t_s [°C]	v_g [m³/kg]	h_f [kJ/kg]	h_{fg} [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_{fg} [kJ/kg K]	s_g [kJ/kg K]
0.0006	109.2	259.6	15.13	297.20	312.33	0.0466	0.7774	0.8240
0.0007	112.3	224.3	15.55	297.14	312.69	0.0477	0.7709	0.8186
0.0008	115.0	197.7	15.93	297.09	313.02	0.0487	0.7654	0.8141
0.0009	117.5	176.8	16.27	297.04	313.31	0.0496	0.7604	0.8100
0.0010	119.7	160.1	16.58	297.00	313.58	0.0503	0.7560	0.8063
0.002	134.9	83.18	18.67	296.71	315.38	0.0556	0.7271	0.7827
0.004	151.5	43.29	20.93	296.40	317.33	0.0610	0.6981	0.7591
0.006	161.8	29.57	22.33	296.21	318.54	0.0643	0.6811	0.7454
0.008	169.4	22.57	23.37	296.06	319.43	0.0666	0.6690	0.7356
0.010	175.5	18.31	24.21	295.95	320.16	0.0685	0.6596	0.7281
0.02	195.6	9.570	26.94	295.57	322.51	0.0744	0.6305	0.7049
0.04	217.7	5.013	29.92	295.15	325.07	0.0806	0.6013	0.6819
0.06	231.6	3.438	31.81	294.89	326.70	0.0843	0.5842	0.6685
0.08	242.0	2.632	33.21	294.70	327.91	0.0870	0.5721	0.6591
0.10	250.3	2.140	34.33	294.54	328.87	0.0892	0.5627	0.6519
0.2	278.1	1.128	38.05	294.02	332.07	0.0961	0.5334	0.6295
0.4	309.1	0.5942	42.21	293.43	335.64	0.1034	0.5039	0.6073
0.6	329.0	0.4113	44.85	293.06	337.91	0.1078	0.4869	0.5947
0.8	343.9	0.3163	46.84	292.78	339.62	0.1110	0.4745	0.5855
1	356.1	0.2581	48.45	292.55	341.00	0.1136	0.4649	0.5785
2	397.1	0.1377	53.87	291.77	345.64	0.1218	0.4353	0.5571
3	423.8	0.09551	57.38	291.27	348.65	0.1268	0.4179	0.5447
4	444.1	0.07378	60.03	290.89	350.92	0.1305	0.4056	0.5361
5	460.7	0.06044	62.20	290.58	352.78	0.1334	0.3960	0.5294
6	474.9	0.05137	64.06	290.31	354.37	0.1359	0.3881	0.5240
7	487.3	0.04479	65.66	290.08	355.74	0.1380	0.3815	0.5195
8	498.4	0.03978	67.11	289.87	356.98	0.1398	0.3757	0.5155
9	508.5	0.03584	68.42	289.68	358.10	0.1415	0.3706	0.5121
10	517.8	0.03266	69.61	289.50	359.11	0.1429	0.3660	0.5089
12	534.4	0.02781	71.75	289.19	360.94	0.1455	0.3581	0.5036
14	549.0	0.02429	73.63	288.92	362.55	0.1478	0.3514	0.4992
16	562.0	0.02161	75.37	288.67	364.04	0.1498	0.3456	0.4954
18	574.0	0.01949	76.83	288.45	365.28	0.1515	0.3405	0.4920
20	584.9	0.01778	78.23	288.24	366.47	0.1531	0.3359	0.4890
22	595.1	0.01637	79.54	288.05	367.59	0.1546	0.3318	0.4864
24	604.6	0.01518	80.75	287.87	368.62	0.1559	0.3280	0.4839
26	613.5	0.01416	81.89	287.70	369.59	0.1571	0.3245	0.4816
28	622.0	0.01329	82.96	287.54	370.50	0.1583	0.3212	0.4795
30	630.0	0.01252	83.97	287.39	371.36	0.1594	0.3182	0.4776
35	648.5	0.01096	86.33	287.04	373.37	0.1619	0.3115	0.4734
40	665.1	0.00978	88.43	286.73	375.16	0.1641	0.3056	0.4697
45	680.3	0.00885	90.35	286.44	376.79	0.1660	0.3004	0.4664
50	694.4	0.00809	92.11	286.18	378.29	0.1678	0.2958	0.4636
55	707.4	0.00746	93.76	285.93	379.69	0.1694	0.2916	0.4610
60	719.7	0.00693	95.30	285.70	381.00	0.1709	0.2878	0.4587
65	731.3	0.00648	96.75	285.48	382.23	0.1723	0.2842	0.4565
70	742.3	0.00609	98.12	285.28	383.40	0.1736	0.2809	0.4545
75	752.7	0.00575	99.42	285.08	384.50	0.1748	0.2779	0.4527

h_f and s_f are zero at 0 °C. Molar mass $M = 200.59$ kg/kmol; for superheated vapour $c_p = 0.1036$ kJ/kg K; further properties of the liquid are given on p. 15.

	$T/[\mathrm{K}]$	250	300	400	500	600	800	1000
Ammonia (NH_3)	c_p	4.52	4.75	6.91	—	—	—	—
sat. liquid	ρ	669	600	346	—	—	—	—
t.p. = 195.4 K	$\mu \times 10^6$	245	141	38	—	—	—	—
M = 17.030 kg/kmol	$k \times 10^6$	592	477	207	—	—	—	—
R–12 (CF_2Cl_2)	c_p	0.902	0.980	—	—	—	—	—
sat. liquid	ρ	1468	1304	—	—	—	—	—
t.p. = 115.3 K	$\mu \times 10^6$	336	213	—	—	—	—	—
M = 120.91 kg/kmol	$k \times 10^6$	86.8	68.6	—	—	—	—	—
Lead (Pb)-Bismuth	c_p	—	—	0.146	0.146	0.146	0.146	0.146
(Bi) 44.5%–55.5%	ρ	—	—	10570	10450	10330	10090	9840
eutectic liquid	$\mu \times 10^6$	—	—	3360	2340	1840	1330	1100
m.p. 397 K	k	—	—	0.0109	0.0120	0.0129	0.0150	0.0170
Mercury (Hg)	c_p	0.141	0.139	0.137	0.137	0.137	0.138	—
liquid	ρ	13650	13530	13290	13050	12840	12420	—
m.p. = 234.3 K	$\mu \times 10^6$	1880	1520	1190	1010	890	780	—
M = 200.59 kg/kmol	k	0.0075	0.0081	0.0094	0.0107	0.0128	0.0137	—
Potassium (K)	c_p	—	0.710	0.805	0.786	0.772	0.768	0.775
liquid	ρ	—	860	812	789	766	721	675
m.p. 336.8 K	$\mu \times 10^6$	solid	solid	417	319	258	179	133
M = 39.098 kg/kmol	k	—	0.099	0.0465	0.0454	0.0425	0.0337	0.0278
Sodium (Na)	c_p	1.179	1.224	1.369	1.315	1.277	1.273	1.277
liquid	ρ	977	967	921	897	872	823	774
m.p. 370.5 K	$\mu \times 10^6$	solid	solid	610	420	320	230	180
M = 22.990 kg/kmol	k	0.135	0.135	0.086	0.080	0.074	0.063	0.059
Sodium-Potassium	c_p	—	0.977	0.929	0.904	0.886	0.871	0.882
22%–78%	ρ	—	869	845	821	797	749	700
eutectic liquid	$\mu \times 10^6$	solid	780	467	348	277	193	146
m.p. 262 K	k	—	0.0222	0.0236	0.0249	0.0262	0.0287	0.0312
Argon (Ar)	c_p	0,5203	0.5203	0.5203	0.5203	0.5203	0.5203	0.5203
1 atm	ρ	1.947	1.623	1.217	0.974	0.811	0.609	0.487
M = 39.948 kg/kmol	$\mu \times 10^6$	19.74	22.94	28.67	33.75	38.38	46.71	54.21
	$k \times 10^6$	15.15	17.66	22.27	26.41	30.16	36.83	42.66
Carbon dioxide (CO_2)	c_p	0.791	0.846	0.939	1.014	1.075	1.169	1.234
1 atm	ρ	2.145	1.788	1.341	1.073	0.894	0.670	0.536
M = 44.010 kg/kmol	$\mu \times 10^6$	12.60	14.99	19.46	23.67	27.32	33.81	39.51
	$k \times 10^6$	12.90	16.61	24.75	32.74	40.40	54.64	67.52
Helium (He)	c_p	5.193	5.193	5.193	5.193	5.193	5.193	5.193
1 atm	ρ	0.1951	0.1626	0.1220	0.0976	0.0813	0.0610	0.0488
M = 4.003 kg/kmol	$\mu \times 10^6$	18.40	20.80	25.23	29.30	33.12	40.19	46.70
	$k \times 10^6$	134.0	149.8	177.9	202.6	224.7	—	—
Hydrogen (H_2)	c_p	14.05	14.31	14.48	14.51	14.55	14.69	14.98
1 atm	ρ	0.0983	0.0819	0.0614	0.0491	0.0409	0.0307	0.0246
M = 2.016 kg/kmol	$\mu \times 10^6$	7.92	8.96	10.87	12.64	14.29	17.34	20.13
	$k \times 10^6$	156.1	181.7	228.1	271.8	314.7	402.2	—
Steam (H_2O)	c_p	1.855	1.864	1.901	1.954	2.015	2.147	2.288
low pressures	$\mu \times 10^6$	—	9.42	13.2	17.3	21.3	29.5	37.6
M = 18.015 kg/kmol	$k \times 10^6$	—	18.8	26.6	35.7	46.3	70.8	97.9

The properties c_p, μ and k (and ρ for liquids) do not vary much with pressure: see also footnote on p.16.

Dry Air at Low Pressure

T [K]	c_p [kJ/kg K]	c_v [kJ/kg K]	γ	μ 10^{-5}[kg/m s]	k 10^{-5}[kW/m K]	Pr	at 1 atm ρ [kg/m³]	at 1 atm ν 10^{-5}[m²/s]
175	1.0023	0.7152	1.401	1.182	1.593	0.744	2.017	0.586
200	1.0025	0.7154	1.401	1.329	1.809	0.736	1.765	0.753
225	1.0027	0.7156	1.401	1.467	2.020	0.728	1.569	0.935
250	1.0031	0.7160	1.401	1.599	2.227	0.720	1.412	1.132
275	1.0038	0.7167	1.401	1.725	2.428	0.713	1.284	1.343
300	1.0049	0.7178	1.400	1.846	2.624	0.707	1.177	1.568
325	1.0063	0.7192	1.400	1.962	2.816	0.701	1.086	1.807
350	1.0082	0.7211	1.398	2.075	3.003	0.697	1.009	2.056
375	1.0106	0.7235	1.397	2.181	3.186	0.692	0.9413	2.317
400	1.0135	0.7264	1.395	2.286	3.365	0.688	0.8824	2.591
450	1.0206	0.7335	1.391	2.485	3.710	0.684	0.7844	3.168
500	1.0295	0.7424	1.387	2.670	4.041	0.680	0.7060	3.782
550	1.0398	0.7527	1.381	2.849	4.357	0.680	0.6418	4.439
600	1.0511	0.7640	1.376	3.017	4.661	0.680	0.5883	5.128
650	1.0629	0.7758	1.370	3.178	4.954	0.682	0.5430	5.853
700	1.0750	0.7879	1.364	3.332	5.236	0.684	0.5043	6.607
750	1.0870	0.7999	1.359	3.482	5.509	0.687	0.4706	7.399
800	1.0987	0.8116	1.354	3.624	5.774	0.690	0.4412	8.214
850	1.1101	0.8230	1.349	3.763	6.030	0.693	0.4153	9.061
900	1.1209	0.8338	1.344	3.897	6.276	0.696	0.3922	9.936
950	1.1313	0.8442	1.340	4.026	6.520	0.699	0.3716	10.83
1000	1.1411	0.8540	1.336	4.153	6.754	0.702	0.3530	11.76
1050	1.1502	0.8631	1.333	4.276	6.985	0.704	0.3362	12.72
1100	1.1589	0.8718	1.329	4.396	7.209	0.707	0.3209	13.70
1150	1.1670	0.8799	1.326	4.511	7.427	0.709	0.3069	14.70
1200	1.1746	0.8875	1.323	4.626	7.640	0.711	0.2941	15.73
1250	1.1817	0.8946	1.321	4.736	7.849	0.713	0.2824	16.77
1300	1.1884	0.9013	1.319	4.846	8.054	0.715	0.2715	17.85
1350	1.1946	0.9075	1.316	4.952	8.253	0.717	0.2615	18.94
1400	1.2005	0.9134	1.314	5.057	8.450	0.719	0.2521	20.06
1500	1.2112	0.9241	1.311	5.264	8.831	0.722	0.2353	22.36
1600	1.2207	0.9336	1.308	5.457	9.199	0.724	0.2206	24.74
1700	1.2293	0.9422	1.305	5.646	9.554	0.726	0.2076	27.20
1800	1.2370	0.9499	1.302	5.829	9.899	0.728	0.1961	29.72
1900	1.2440	0.9569	1.300	6.008	10.233	0.730	0.1858	32.34
2000	1.2505	0.9634	1.298	—	—	—	0.1765	—
2100	1.2564	0.9693	1.296	—	—	—	0.1681	—
2200	1.2619	0.9748	1.295	—	—	—	0.1604	—
2300	1.2669	0.9798	1.293	—	—	—	0.1535	—
2400	1.2717	0.9846	1.292	—	—	—	0.1471	—
2500	1.2762	0.9891	1.290	—	—	—	0.1412	—
2600	1.2803	0.9932	1.289	—	—	—	0.1358	—
2700	1.2843	0.9972	1.288	—	—	—	0.1307	—
2800	1.2881	1.0010	1.287	—	—	—	0.1261	—
2900	1.2916	1.0045	1.286	—	—	—	0.1217	—
3000	1.2949	1.0078	1.285	—	—	—	0.1177	—

The values for air can also be used with reasonable accuracy for CO, N_2 and O_2.

The values of the thermodynamic properties c_v and c_p on pp. 16 and 17 are those at zero pressure. The values for the gases are quite accurate over a wide range of pressure, but those for the vapours increase appreciably with pressure.

The transport properties μ and k for air are accurate over a wide range of pressure, except at such low pressures that the mean free path of the molecules is comparable to the distance between the solid surfaces containing the gas.

At high temperatures (>1500 K for air) dissociation becomes appreciable and pressure is a significant variable for both gases and vapours: the values on pp. 16 and 17 apply only to undissociated states.

T/[K]	CO_2	CO	H_2	N_2	O_2	H_2O	CH_4	C_2H_4	C_2H_6
175	0.709	1.039	13.12	1.039	0.910	1.850	2.083	1.241	
200	0.735	1.039	13.53	1.039	0.910	1.851	2.087	1.260	
225	0.763	1.039	13.83	1.039	0.911	1.852	2.121	1.316	
250	0.791	1.039	14.05	1.039	0.913	1.855	2.156	1.380	1.535
275	0.819	1.040	14.20	1.039	0.915	1.859	2.191	1.453	1.651
300	0.846	1.040	14.31	1.040	0.918	1.864	2.226	1.535	1.766
325	0.871	1.041	14.38	1.040	0.923	1.871	2.293	1.621	1.878
350	0.895	1.043	14.43	1.041	0.928	1.880	2.365	1.709	1.987
375	0.918	1.045	14.46	1.042	0.934	1.890	2.442	1.799	2.095
400	0.939	1.048	14.48	1.044	0.941	1.901	2.525	1.891	2.199
450	0.978	1.054	14.50	1.049	0.956	1.926	2.703	2.063	2.402
500	1.014	1.064	14.51	1.056	0.972	1.954	2.889	2.227	2.596
550	1.046	1.075	14.53	1.065	0.988	1.984	3.074	2.378	2.782
600	1.075	1.087	14.55	1.075	1.003	2.015	3.256	2.519	2.958
650	1.102	1.100	14.57	1.086	1.017	2.047	3.432	2.649	3.126
700	1.126	1.113	14.60	1.098	1.031	2.080	3.602	2.770	3.286
750	1.148	1.126	14.65	1.110	1.043	2.113	3.766	2.883	3.438
800	1.168	1.139	14.71	1.122	1.054	2.147	3.923	2.989	3.581
850	1.187	1.151	14.77	1.134	1.065	2.182	4.072	3.088	3.717
900	1.204	1.163	14.83	1.146	1.074	2.217	4.214	3.180	3.846
950	1.220	1.174	14.90	1.157	1.082	2.252	4.348	3.266	
1000	1.234	1.185	14.98	1.167	1.090	2.288	4.475	3.347	
1050	1.247	1.194	15.06	1.177	1.097	2.323	4.595	3.423	
1100	1.259	1.203	15.15	1.187	1.103	2.358	4.708	3.494	
1150	1.270	1.212	15.25	1.196	1.109	2.392	4.814	3.561	
1200	1.280	1.220	15.34	1.204	1.115	2.425			
1250	1.290	1.227	15.44	1.212	1.120	2.458			
1300	1.298	1.234	15.54	1.219	1.125	2.490			
1350	1.306	1.240	15.65	1.226	1.130	2.521			
1400	1.313	1.246	15.77	1.232	1.134	2.552			
1500	1.326	1.257	16.02	1.244	1.143	2.609			
1600	1.338	1.267	16.23	1.254	1.151	2.662			
1700	1.348	1.275	16.44	1.263	1.158	2.711			
1800	1.356	1.282	16.64	1.271	1.166	2.756			
1900	1.364	1.288	16.83	1.278	1.173	2.798			
2000	1.371	1.294	17.01	1.284	1.181	2.836			
2100	1.377	1.299	17.18	1.290	1.188	2.872			
2200	1.383	1.304	17.35	1.295	1.195	2.904			
2300	1.388	1.308	17.50	1.300	1.202	2.934			
2400	1.393	1.311	17.65	1.304	1.209	2.962			
2500	1.397	1.315	17.80	1.307	1.216	2.987			
2600	1.401	1.318	17.93	1.311	1.223	3.011			
2700	1.404	1.321	18.06	1.314	1.230	3.033			
2800	1.408	1.324	18.17	1.317	1.236	3.053			
2900	1.411	1.326	18.28	1.320	1.243	3.072			
3000	1.414	1.329	18.39	1.323	1.249	3.090			
3500	1.427	1.339	18.91	1.333	1.276	3.163			
4000	1.437	1.346	19.39	1.342	1.299	3.217			
4500	1.446	1.353	19.83	1.349	1.316	3.258			
5000	1.455	1.359	20.23	1.355	1.328	3.292			
5500	1.465	1.365	20.61	1.362	1.337	3.322			
6000	1.476	1.370	20.96	1.369	1.344	3.350			

T/[K]	C_6H_6	C_8H_{18}
250	0.850	1.308
275	0.957	1.484
300	1.060	1.656
325	1.160	1.825
350	1.255	1.979
375	1.347	2.109
400	1.435	2.218
450	1.600	2.403
500	1.752	2.608
550	1.891	2.774
600	2.018	2.924
650	2.134	3.121
700	2.239	3.232
750	2.335	3.349
800	2.422	3.465
850	2.500	3.582
900	2.571	3.673

The specific heats of atomic H, N and O are given with adequate accuracy by $c_p = 2.5\ R_0/M$ where M is the molar mass of the *atomic* species.

See next page

International Standard Atmosphere

z [m]	p [bar]	T [K]	ρ/ρ_0	ν 10^{-5}[m²/s]	k 10^{-5}[kW/m K]	a [m/s]	λ 10^{-8}[m]
−2500	1.3521	304.4	1.2631	1.207	2.661	349.8	5.251
−2000	1.2778	301.2	1.2067	1.253	2.636	347.9	5.497
−1500	1.2070	297.9	1.1522	1.301	2.611	346.0	5.757
−1000	1.1393	294.7	1.0996	1.352	2.585	344.1	6.032
− 500	1.0748	291.4	1.0489	1.405	2.560	342.2	6.324
0	1.01325	288.15	1.0000	1.461	2.534	340.3	6.633
500	0.9546	284.9	0.9529	1.520	2.509	338.4	6.961
1000	0.8988	281.7	0.9075	1.581	2.483	336.4	7.309
1500	0.8456	278.4	0.8638	1.646	2.457	334.5	7.679
2000	0.7950	275.2	0.8217	1.715	2.431	332.5	8.072
2500	0.7469	271.9	0.7812	1.787	2.405	330.6	8.491
3000	0.7012	268.7	0.7423	1.863	2.379	328.6	8.936
3500	0.6578	265.4	0.7048	1.943	2.353	326.6	9.411
4000	0.6166	262.2	0.6689	2.028	2.327	324.6	9.917
4500	0.5775	258.9	0.6343	2.117	2.301	322.6	10.46
5000	0.5405	255.7	0.6012	2.211	2.275	320.5	11.03
5500	0.5054	252.4	0.5694	2.311	2.248	318.5	11.65
6000	0.4722	249.2	0.5389	2.416	2.222	316.5	12.31
6500	0.4408	245.9	0.5096	2.528	2.195	314.4	13.02
7000	0.4111	242.7	0.4817	2.646	2.169	312.3	13.77
7500	0.3830	239.5	0.4549	2.771	2.142	310.2	14.58
8000	0.3565	236.2	0.4292	2.904	2.115	308.1	15.45
8500	0.3315	233.0	0.4047	3.046	2.088	306.0	16.39
9000	0.3080	229.7	0.3813	3.196	2.061	303.8	17.40
9500	0.2858	226.5	0.3589	3.355	2.034	301.7	18.48
10000	0.2650	223.3	0.3376	3.525	2.007	299.5	19.65
10500	0.2454	220.0	0.3172	3.706	1.980	297.4	20.91
11000	0.2270	216.8	0.2978	3.899	1.953	295.2	22.27
11500	0.2098	216.7	0.2755	4.213	1.952	295.1	24.08
12000	0.1940	216.7	0.2546	4.557	1.952	295.1	26.05
12500	0.1793	216.7	0.2354	4.930	1.952	295.1	28.18
13000	0.1658	216.7	0.2176	5.333	1.952	295.1	30.48
13500	0.1533	216.7	0.2012	5.768	1.952	295.1	32.97
14000	0.1417	216.7	0.1860	6.239	1.952	295.1	35.66
14500	0.1310	216.7	0.1720	6.749	1.952	295.1	38.57
15000	0.1211	216.7	0.1590	7.300	1.952	295.1	41.72
15500	0.1120	216.7	0.1470	7.895	1.952	295.1	45.13
16000	0.1035	216.7	0.1359	8.540	1.952	295.1	48.81
16500	0.09572	216.7	0.1256	9.237	1.952	295.1	52.79
17000	0.08850	216.7	0.1162	9.990	1.952	295.1	57.10
17500	0.08182	216.7	0.1074	10.805	1.952	295.1	61.76
18000	0.07565	216.7	0.09930	11.686	1.952	295.1	66.79
18500	0.06995	216.7	0.09182	12.639	1.952	295.1	72.24
19000	0.06467	216.7	0.08489	13.670	1.952	295.1	78.13
19500	0.05980	216.7	0.07850	14.784	1.952	295.1	84.50
20000	0.05529	216.7	0.07258	15.989	1.952	295.1	91.39
22000	0.04047	218.6	0.05266	22.201	1.968	296.4	126.0
24000	0.02972	220.6	0.03832	30.743	1.985	297.7	173.1
26000	0.02188	222.5	0.02797	42.439	2.001	299.1	237.2
28000	0.01616	224.5	0.02047	58.405	2.018	300.4	324.0
30000	0.01197	226.5	0.01503	80.134	2.034	301.7	441.3
32000	0.00889	228.5	0.01107	109.62	2.051	303.0	599.4

Density at sea level $\rho_0 = 1.2250$ kg/m³

SI – British Conversion Factors

The International System of Units (HMSO, 1977) may be consulted for the definitions of SI units, and *British Standard* 350 for comprehensive tables of conversion factors.

Exact values are printed in **bold type.**

Mass: $\mathbf{1\ kg} = \dfrac{\mathbf{1}}{\mathbf{0.453\,592\,37}}\ \text{lb} = 2.205\ \text{lb}$

Length: $1\ \text{m} = \dfrac{\mathbf{1}}{\mathbf{0.3048}}\ \text{ft} = 3.281\ \text{ft}$

Volume: $1\ \text{m}^3 = 10^3\ \text{dm}^3\ \text{(litre)} = 35.31\ \text{ft}^3 = 220.0\ \text{UK gal}$

Time: $1\ \text{s} = \dfrac{\mathbf{1}}{\mathbf{60}}\ \text{min} = \dfrac{\mathbf{1}}{\mathbf{3600}}\ \text{h}$

Temperature unit: $1\ \text{K} = \mathbf{1.8}\ \text{R}$ (see p. 11 for definitions of units and scales)

Force: $1\ \text{N (or kg m/s}^2) = \mathbf{10^5}\ \text{dyn} = \dfrac{\mathbf{1}}{\mathbf{9.806\,65}}\ \text{kgf}$

$$= 7.233\ \text{pdl} = \frac{7.233}{32.174}\ \text{or}\ 0.2248\ \text{lbf}$$

Pressure p: $1\ \text{bar} = \mathbf{10^5}\ \text{N/m}^2\ \text{(or Pa)} = 14.50\ \text{lbf/in}^2 = 750\ \text{mmHg} = 10.20\ \text{mH}_2\text{O}$

Specific volume v: $1\ \text{m}^3/\text{kg} = 16.02\ \text{ft}^3/\text{lb}$

Density ρ: $1\ \text{kg/m}^3 = 0.062\,43\ \text{lb/ft}^3$

Energy: $1\ \text{kJ} = \mathbf{10^3}\ \text{N m} = \dfrac{\mathbf{1}}{\mathbf{4.1868}}\ \text{kcal}_{\text{IT}} = 0.9478\ \text{Btu} = 737.6\ \text{ft lbf}$

Power: $1\ \text{kW} = \mathbf{1}\ \text{kJ/s} = \dfrac{\mathbf{10^3}}{\mathbf{9.806\,65}}\ \text{kgf m/s} = \dfrac{\mathbf{10^3}}{\mathbf{9.806\,65 \times 75}}\ \text{metric hp}$

$$= 737.6\ \text{ft lbf/s} = \frac{737.6}{\mathbf{550}}\ \text{or}\ \frac{1}{0.7457}\ \text{British hp} = 3412\ \text{Btu/h}$$

Specific energy etc. (u, h): $1\ \text{kJ/kg} = \dfrac{\mathbf{1}}{\mathbf{2.326}}\ \text{Btu/lb} = 0.4299\ \text{Btu/lb}$

Specific heat etc. (c, R, s): $1\ \text{kJ/kg K} = \dfrac{\mathbf{1}}{\mathbf{4.1868}}\ \text{Btu/lb R} = 0.2388\ \text{Btu/lb R}$

Thermal conductivity k: $1\ \text{kW/m K} = 577.8\ \text{Btu/ft h R}$

Heat transfer coefficient: $1\ \text{kW/m}^2\ \text{K} = 176.1\ \text{Btu/ft}^2\ \text{h R}$

Dynamic viscosity μ: $1\ \text{kg/m s} = \mathbf{1}\text{N s/m}^2 = 1\ \text{Pa s} = \mathbf{10}\ \text{dyn s/cm}^2\ \text{(or poise)}$
$= 2419\ \text{lb/ft h} = 18.67 \times 10^{-5}\ \text{pdl h/ft}^2$

Kinematic viscosity ν: $1\ \text{m}^2/\text{s} = \mathbf{10^4}\ \text{cm}^2/\text{s (or stokes)} = 38\,750\ \text{ft}^2/\text{h}$

See next page

General Information

Standard acceleration: $g_n = 9.806\,65 \text{ m/s}^2 = 32.1740 \text{ ft/s}^2$

Standard atmospheric pressure: 1 atm = **1.013 25** bar

$= 760 \text{ mmHg} = 10.33 \text{ mH}_2\text{O} = 1.0332 \text{ kgf/cm}^2$
$= 29.92 \text{ inHg} = 33.90 \text{ ftH}_2\text{O} = 14.696 \text{ lbf/in}^2$

Molar (universal) gas constant: $R_0 = 8.3144$ kJ/kmol K†
= 1.986 Btu/lb-mol R = 1545 ft lbf/lb-mol R

1 kmol occupies 22.41 m^3 at 1 atm and 0 °C
1 lb-mol occupies 359.0 ft^3 at 1 atm and 32 °F

Composition of air:

	vol. analysis	grav. analysis
Nitrogen (N_2 – 28.013 kg/kmol)	0.7809	0.7553
Oxygen (O_2 – 31.999 kg/kmol)	0.2095	0.2314
Argon (Ar – 39.948 kg/kmol)	0.0093	0.0128
Carbon dioxide (CO_2 – 44.010 kg/kmol)	0.0003	0.0005

Molar mass $M = 28.96$ kg/kmol
Specific gas constant $R = 0.2871$ kJ/kg K
= 0.068 56 Btu/lb R = 53.35 ft lbf/lb R

See p. 16 for other properties

For approximate calculations with air:

	vol. analysis	grav. analysis
N_2 – 28 kg/kmol	0.79	0.767
O_2 – 32 kg/kmol	0.21	0.233
N_2/O_2	3.76	3.29

Molar mass M = 29 kg/kmol
Specific gas constant R = 0.287 kJ/kg K
= 0.0685 Btu/lb R = 53.3 ft lbf/lb R
$c_p = 1.005$ kJ/kg K = 0.240 Btu/lb R
$c_v = 0.718$ kJ/kg K = 0.1715 Btu/lb R
$c_p/c_v = \gamma = 1.40$

The Stefan-Boltzmann constant:

$$\sigma = 56.7 \times 10^{-12} \text{ kW/m}^2 \text{ K}^4 = 0.171 \times 10^{-8} \text{ Btu/ft}^2 \text{ h R}^4$$

† The kilomole (kmol) is the amount of substance of a system which contains as many elementary entities as there are atoms in 12 kg of carbon 12.
The elementary entities must be specified, but for problems involving mixtures of gases and combustion they will be molecules or atoms.

FOR USE WITH THESE TABLES

Enthalpy-Entropy Diagram for Steam

Pressure-Enthalpy Diagram for Refrigerant 12
(Dichlorodifluoromethane, CF_2Cl_2)

Pressure-Enthalpy Diagram for Ammonia
(Refrigant 717, NH_3)

Prepared by D. C. Hickson *and* F. R. Taylor

Diagram for Temperature Rise v. *Fuel/Air Ratio for Combustion of a Gas Turbine Fuel*

Prepared by G. F. C. Rogers and Y. R. Mayhew

BASIL BLACKWELL