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REVIEW OF AVAILABLE DATA ON THE HEAT CAPACITY OF SOME COMMON GASES

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and

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ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

A Review of Available Data on the Heat Capacity of Some Common Gases.

by

I.H.Ring* and F.W.David*

R.A.E. Ref: Gas/3100/3200/159

SUMMARY

This report compares the values of the heat capacities of some common gases, as derived from well known sources, and tabulates the most reliable values of specific heat at constant pressure and total heat. These values are presented in a form useful for calculations on combustion at relatively low temperatures, i.e. temperatures at which the effects of dissociation can be neglected.

The effect of pressure on the heat capacity has been calculated according to the most reliable data available.

The investigation covers the following gases over a range of temperatures from 0° to 3000°C., and a range of pressures from 0 to 500 lb./in.^{2}, except in the case of steam, where it was extended to 1000 lb./in.^{2} for temperatures below 1000°C: steam (H_2O), hydrogen (H_2), nitrogen (N_2), oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2), air, nitric oxide (NO) and nitrous oxide (N_2O).

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1 Introduction

The specific heats of many gases at high temperatures have been thoroughly investigated in recent years, but there is a wide discepancy in the figures quoted in many reference books and reports.

This report endeavours to list the values of specific heats and enthalpies of the common gases, as derived from well known sources, and to tabulate the most reliable values in a form useful for calculations on combustion at relatively low temperatures, e.g. with hydrogen peroxide as oxidizer. Further, the effect of pressure on the specific heats and enthalpies has been calculated according to the most reliable data available, and is also tabulated.

This investigation has been limited to the temperature range from 0° to 3000°C., the upper limit being chosen as the extreme temperature at which it might be possible to neglect the effects of dissociation, particularly at pressures such as occur in rocket combustion chambers. For the thermodynamic properties of gases at higher temperatures, reference should be made to the collection of data made by Beeton[23].

The gases treated below are steam (H_2O), hydrogen (H_2), nitrogen (N_2), oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2), air, nitric oxide (NO) and nitrous oxide (N_2O).

2 Steam (H_2O)

For the purpose of comparing the values given by various authors of the specific and total heats of steam, the total heat from 0° to t°C. has, in each case, been calculated for the range from 0° to 3000°C. The basic data is variously quoted for the ideal gaseous state (P = 0) and for P = 1 atmosphere. These cannot be compared directly as the heat content of the water up to 100°C. and the latent heat, as well as the effect of the change of pressure, are included in the latter. Comparison may be made approximately however, between the total heats from 100° to t°C. found by difference.

Table 1 shows the total heats for steam from 0° to t°C., derived from readily available sources. It is arranged in three parts:

(a) That derived from data referring to the ideal gaseous state (P = 0).

(b) That derived from data referring to a pressure of 1 atm.

(c) That derived from data referring to a pressure of 300 lb./in.^{2} absolute, which was chosen arbitrarily as a typical combusion chamber pressure.

The most reliable data is based on the work of Gordon[12], who calculated the thermodynamic properties of steam in the ideal gaseous state from spectroscopic data. In a recent paper, Wagman, Kilpatrick, Taylor, Pitzer and Rossini[17] have applied a small additive correction, as given by Wilson[18], to Gordon's values, and these corrected figures are those recommended for use. Other authors, notably Justi[1], Spiers[2], Hutte[7] and Lewis and von Elbe[15] quote Gordon's figures without making the corrections, and the values of Schmidt[9], from an unknown source, agree very closely with the latter group.

The effect of pressure on the heat capacity of steam is best indicated by the work of Koch(16), who tabulated the total heat from 0°C. over a range of temperatures from 10°C. to 550°C. for pressures up to 300 kg/cm^2.

The influence of pressure is expressed by his formula:

$$\Delta H = \frac{-5.76603\,P}{(T/100)^{2.82}} - P^3 \left[\frac{531.77465}{(T/100)^{14}} + \frac{3.86669 \times 10^{14}}{(T/100)^{31.6}} \right]$$

from which is derived

$$\Delta K_p = \frac{0.162602\,P}{(T/100)^{3.82}} + P^3 \left[\frac{74.448458}{(T/100)^{15}} + \frac{1.221874 \times 10^{14}}{(T/100)^{32.6}} \right]$$

where ΔH = increment of total heat due to change of pressure from 0 to P lb./in.^{2} absolute.

ΔK_p = increment of specific heat at constant pressure due to change of pressure from 0 to P lb./in.^{2} absolute.

T = temperature °K.

The figures of Wagman et al., having been chosen as the most reliable for the ideal gas, have been retabulated in Table 2, (Specific heat at constant pressure) and in Table 3(Total heat from 0°C). The corrections due to changes of pressure, and the latent heat, both derived from Koch's formulae and table, have been applied, and the resultant tables show the figures for the pressures 0, 14.7, 100, 200, 300, 500 and 1000 lb./in.^{2} absolute. Over 1000°C., the pressure correction is very small and is therefore expressed as an increment to be added for each 100 lb./in.^{2} increase in pressure above 1 atmosphere, up to 500 lb./in.^{2}.

The variation of K_p with pressure, over the low temperature range, as shown in Table 2, is plotted in Fig.1.

Comparison of the chosen figures of Table 3 with those at 14.7 and 300 lb./in.^{2} of Table 1, shows that the values derived from Callendar(4), Schüle(5) and Partington and Shilling(6), give good agreement up to 500°C, while at higher temperatures the discrepancies are large. The values derived from the older sources, Stodola(3) (Entropy Chart No. II) and International Critical Tables(8), are unreliable throughout. The figures issued in the data sheets of Walter Werke(10)(11) show reasonable agreement up to 1000°C. but large variations above that temperature.

It should be noted that Spiers(2) gives values of the specific heat at constant pressure for P = 1 atm., claiming that their accuracy is sufficiently good for the range from 1 to 10 atm., and also below 1 atm. In the case of H_2O, Koch's figures show this to be incorrect below temperatures of about 600°C., where, as is seen in Fig.1, pressure has a large effect on K_p. This is confirmed by Callendar.

3 The Permanent Gases

The gases H_2, N_2, O_2, CO, CO_2, air, NO and N_2O are here grouped together because the method of treating them has been substantially the same. In all cases, the values of the true specific heats at constant pressure have been found from the best available source and tabulated in Table 4.

Values of total heat are quoted in the form we require, by both Justi[1] and Spiers[2], but their points do not always lie on smooth curves and are therefore open to some doubt. The curves of Kp_o (K_p for the ideal gaseous state, i.e. $P = 0$) have therefore, been successively integrated to obtain the values of the total heat from 0° to t°C., and these are tabulated in Table 5.

With small differences, due probably to the varying accuracy of converting figures from the same source to different units, the figures given by the following authors for all the gases with the exception of CO_2, air and N_2O, result in the same values of total heat: Justi[1], Spiers[2], Hutte[7], Penning and Whiffin[13], Pike[14], Lewis and von Elbe[15] and Wagman et al[17].

Other authors, such as Stodola[3], Schüle[5] and Partington and Shilling[6], and International Critical Tables[8], quote figures which are based on older data, are therefore unreliable, and are here neglected.

The effect of pressure on the heat capacity of the gases has been calculated according to the method of Justi[1], and is expressed in the tables as increments (ΔH_{100} and ΔK_{p100}) to be added to the value for $P = 0$, for every 100 lb./in.^{2} of pressure. These corrections are valid for pressures up to 500 lb./in.^{2} absolute, and where no values are stated, are negligibly small.

3.1 Hydrogen (H_2)

The most reliable figures for the specific heat of H_2 are based on the spectroscopic measurements of Davis and Johnston[19], which served as the common source for the authors above. The values of Schmidt[20] and Walter Werke[21] agree below 1000°C., but over this temperature are consistently low.

3.2 Nitrogen (N_2)

Johnston and Davis[22] provide the source for the values of the true specific heats of N_2, in the ideal gaseous state. The values given by Schmidt[20] and Walter Werke[21] agree very well over the entire range from 0° to 3000°C.

3.3 Oxygen (O_2)

The values given by Johnston and Walker[23] are the basis for the figures of the authors quoted above, and the figures of Refs. (20) and (21) are in good agreement.

3.4 Carbon monoxide (CO)

All the authors referred to above have used the values of Johnston and Davis[22], and Schmidt[20] and Walter Werke[21] agree with these closely. The actual values adopted in this report, are taken from

Justi[1], but it is noted that his value of the specific heat at constant pressure at 2500°C. does not lie on the smooth curve through the other points. This value has, therefore, been corrected.

3.5 Carbon dioxide (CO_2)

The values of the specific heats adopted for CO_2 are derived from Wagmen et al[17]. They are based on the statistical calculations of Kassel[24], with a small additive correction for rotational stretching, as given by Wilson[18]. Lewis and von Elbe[15], Pike[14], and Fenning and Whiffin[13], quote these same values, but Justi[1], Spiers[2], Hutte[7], Schmidt[20] and Walter Werke[21] give figures which correspond closely to one another, but are somewhat lower than Wagmans' at the higher temperatures.

It should be noted that the accuracy of the figures for CO_2 above 1500°C. is seriously reduced, and there is no justification in the data available, for quoting the specific heats to more than two figures.

3.6 Air

Ellenwood, Kulik and Gay[25] quote, for the specific heat of dry air, figures attributed to H.L.Johnston who calculated the values from spectrographic data. Benser, Wilcox and Voit[26] have taken these figures and smoothed them to an empirical curve given by:

$$K_p = 0.2445 - 3.9708 \times 10^{-5}.T + 8.9359 \times 10^{-8}.T^2$$

for temperature from 200° to 633°K; and

$$K_p = 0.2413 + 1.0886 \times 10^{-3}\sqrt{1.8T - 976}$$

for temperatures from 633° to 3056°K.

The values of the specific heat found from this curve have been adopted in this report, and the total heats have been derived in the usual way by successive integration.

Justi[1], Spiers[2], Hutte[7], Schmidt[20] and Keenan and Kaye[28] quote figures for the heat capacity of air, but their figures, although corresponding closely to one another, differ widely from those adopted here, which represent the latest N.A.C.A. data.

3.7 Nitric oxide (NO)

The work of Johnston and Chapman[27] provides the source for the values of specific heats and enthalpies quoted by Justi[1], Fenning and Whiffin[13], Pike[14], and Lewis and von Elbe[15]. No other author amongst those referred to, considers this gas.

3.8 Nitrous oxide (N_2O)

Kassel[24] derived figures for N_2O up to a temperature of 1500°K. These values have been quoted by Hutte[7] and Fenning and Whiffin[13]. Justi[1], however, has considered Kassel's results in conjunction with theoretical data, and has produced values for the specific heat and enthalpy up to 3000°C. These are slightly lower than Kassel's values. Justi's figures for the total heat from 0°C., however, do not all lie on a smooth curve, so his values of the specific heat have been integrated to obtain the total heat values adopted in this report.

4 The Specific Heat Difference, $K_p - K_v$

The values of the specific heat differences for the ideal gaseous state, derived from R = 1.987 CHU/lb.mole. (Ref.(17)), are presented in Table 6(a).

H_2O deviates substantially from the ideal relationship at low temperatures and high pressures as shown in Table 6(b).

5 Conclusions

The values of the specific and total heats of certain gases, as quoted in many reference books and reports, show wide discrepancies. This is particularly so in the case of steam.

The values set out in Tables 2, 3, 4 and 5 of this report are derived from the most reliable data available, and can be used as a basis for future combustion calculations, provided the effect of dissociation can be neglected.

The effect of pressure on the heat capacity of gases is, in general, very small, except in the case of steam at temperatures below 1000°C.

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Attached: Tables 1 - 6
Figure 1

Circulation:

D.S.R.(A)	
A.D.S.R.(Gen.)	
D.Eng.R.D.	
D.D.Eng.R.D.	
C.T.A./D.E.R.D.	
A.D./R.D.E.1	
A.D./R.D.E(R)	Action
D.D.T.E.	
A.D./R.D.E.(F)	
R.T.P./T.I.B.	200+1
A.D./T.E.(D)	
N.G.T.E. Pyestock	
A.R.D. Fort Halstead	
G.P.E. Westcott (Mr.Elstub)	
Armstrong Siddeley Motors Ltd.	
De Havilland	
Director, R.A.E.	
D.D.R.A.E.	
Mat./Chem. Dept.	
Controlled Weapons Dept.	
Aero. Dept.	
Library	2
SD/A, P, PA, PB, AF	
C.S.A.R. A.R.D. Woolwich	
A.R.D. Woolwich (Dr.Masterman)	
R.G.P.F. Waltham Abbey	
R.G.P.F. Waltham Abbey (Mr.L.A.Wiseman)	
C.E.A.D. Fort Halstead	

H_2O - COMPARISON OF TOTAL HEATS FROM 0° TO t°C, DERIVED FROM VARIOUS SOURCES.
ALL VALUES IN CHU/LB.

t°C	WAGMAN ET AL. (17) P=0	JUSTI (1) P=0	HUTTE (7) P=0	SCHMIDT (9) P=0	SPIERS (2) P=0	CALLENDAR (4) P=14.7	SCHULE (5) P=14.7	WOHL/SCHULE (5) P=14.7	PARTINGTON AND SHILLING (6) P=14.7	STODOLA (3) P=14.7	I.C.T. (8) P=14.7	WALTER (10) P=14.7	WALTER (11) P=14.7	CALLENDAR (4) P=300	SCHULE (5) P=300
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	44.7	44.57	44.6	44.6	44.5	639.4	639.4	639.1	639.1	-	-	-	-	-	-
200	90.4	90.14	90.1	90.1	90.1	686.9	687.5	684.8	687.9	-	-	684.4	-	-	-
300	137.5	136.9	136.9	136.8	137.0	734.4	735.3	731.5	735.9	-	-	730.9	-	721.4	723.0
400	186.0	185.2	185.2	185.1	185.1	783.1	783.4	-	783.8	-	-	777.2	-	773.2	776.3
500	236.1	235.1	235.1	235.0	235.1	-	832.6	830.1	832.2	761	-	828.9	835	827.2	828.8
600	287.8	286.4	286.4	286.5	286.6			-	880.9	-	-	881.4	-		
700	341.2	339.6	339.6	339.7	339.6			-	930.8	-	-	937.5	-		
800	396.4	394.8	394.8	394.5	395.1			-	981.6	-	-	990.6	-		
900	453.2	451.6	451.6	451.2	451.2			1046.1	1034.0	-	-	1049.4	-		
1000	511.6	509.5	509.5	509.4	510.0			-	1088.6	1012	978.6	1108.8	1108		
1100	571.6	569.1	569.1	568.9	569.3			-	1144.1	-	-	1168.0	-		
1200	633.0	628.5	629.5	629.5	630.0			-	1202.0	-	-	1230.8	-		
1300	695.8	691.3	691.3	691.6	690.6			1284.3	1262.7	-	-	1296.9	-		
1400	759.9	755.4	755.4	754.7	755.9			-	1326.1	-	-	1364.8	-		
1500	825.1	819.3	819.3	818.9	819.0			-	1392.2	1302	1219.0	1434.1	1430		
1600	891.3	-	-	884.5	883.7			-	1461.9	-	-	1507.8	-		
1700	958.5	-	-	950.6	951.7			1543.8	1534.8	-	-	1586.2	-		
1800	1026.6	-	-	1018.1	1018.8			-	1608.5	-	-	1667.2	-		
1900	1086.6	-	-	1086.6	1087.2			-	1688.7	-	-	1748.7	-		
2000	1165.3	1155.0	1155.0	1156.8	1154.4			-	1770.8	1651	1529.3	1865.8	1860		
2100	1236	-	-	1225.8	1225.6			1813.8	1854.1	-	-	1972.8			
2200	1307	-	-	1298.8	1294.5			-	1944.2	-	-	2091.2			
2300	1379	-	-	1366.2	1367.6			-	2036.2	-	-	2218.0			
2400	1451	-	-	1437.6	1436.2			-	-	-	-	2354.0			
2500	1523	1508	1508	1508.8	1508.3			2089.0	-	2133	1920.8	2501.0			
2600	1596	-	-	1581.3	1581.6					-	-	2655.0			
2700	1670	-	-	1653.2	1652.4					-	-	2816.5			
2800	1744	-	-	1725.1	1727.6					-	-	2991			
2900	1818	-	-	1797.4	1800.3					-	-	-			
3000	1853	1870	1870	1869.6	1869.6					2694	2401.4	-			

Table 2

H_2O - True Specific Heat at Constant Pressure for Pressures From 0 to 1000 lb./in.^{2} Absolute

$t^\circ C$	K_p CHU/lb./°C.						
	P = 0 lb./in.^{2}	14.7	100	200	300	500	1000
0	0.443						
15	0.444						
100	0.451	0.557					
200	0.463	0.469	0.524	0.692			
300	0.478	0.481	0.499	0.522	0.549	0.625	1.024
400	0.493	0.495	0.504	0.516	0.527	0.552	0.633
500	0.509	0.510	0.516	0.522	0.529	0.542	0.579
600	0.526	0.527	0.530	0.534	0.538	0.547	0.568
700	0.543	0.543	0.546	0.548	0.551	0.557	0.570
800	0.560	0.560	0.562	0.564	0.566	0.570	0.579
900	0.577	0.577	0.578	0.580	0.581	0.584	0.591
1000	0.592	0.592	0.593	0.594	0.595	0.597	0.602

$t^\circ C$	P = 0 lb./in.^{2}	14.7	ΔK_{p100} - Specific heat gradient per 100 lb./in.^{2} pressure difference, valid between 14.7 and 500 lb./in.^{2} abs.
1100	0.607	0.607	+ 0.001
1200	0.621	0.621	+ 0.001
1300	0.634	0.634	0
1400	0.646	0.646	0
1500	0.658	0.658	0
1600	0.667	0.667	0
1700	0.677	0.677	0
1800	0.685	0.685	0
1900	0.693	0.693	0
2000	0.701	0.701	0
2100	0.71	0.71	0
2200	0.71	0.71	0
2300	0.72	0.72	0
2400	0.72	0.72	0
2500	0.73	0.73	0
2600	0.73	0.73	0
2700	0.74	0.74	0
2800	0.74	0.74	0
2900	0.74	0.74	0
3000	0.75	0.75	0

Table 3

H_2O - Total Heat From 0^{c} to $t^{o}C$ for Pressures

From 0 to 1000 lb./in.^{2} Absolute

$t^{o}C.$	H_o^t CHU/lb.						
	P = 0 lb./in.^{2}	14.7	100	200	300	500	1000
0	0	0	0	0	0	0	0
15	-	15.1	15.2	15.4	15.5	15.8	16.6
100	44.7	639.1	100.1	100.3	100.4	100.6	101.3
200	90.4	686.8	673.8	668.3	203.5	203.6	204.0
300	137.5	734.3	730.4	726.1	721.2	711.4	678.2
400	186.0	783.0	780.4	777.7	774.6	769.1	754.6
500	236.1	833.2	831.4	829.6	827.3	823.7	814.5
600	287.8	885.0	883.6	882.3	880.6	878.0	871.6
700	341.2	938.5	937.4	936.4	935.0	933.1	928.4
800	396.4	993.7	992.8	992.1	990.9	989.4	985.9
900	453.2	1050.5	1049.7	1049.2	1043.1	1047.0	1044.2
1000	511.6	1108.9	1108.3	1107.8	1106.9	1106.0	1103.8
			ΔH_{100} - Heat gradient per 100 lb./in.^{2} pressure difference, valid between 14.7 and 500 lb./in.^{2} abs.				
1100	571.6	1168.9	- 0.5				
1200	633.0	1230.4	- 0.5				
1300	695.8	1293.2	- 0.4				
1400	759.9	1357.3	- 0.4				
1500	825.1	1422.5	- 0.3				
1600	891.3	1488.7	- 0.3				
1700	958.5	1555.9	- 0.3				
1800	1026.6	1624.0	- 0.3				
1900	1095.6	1692.0	- 0.3				
2000	1165.3	1762.7	- 0.2				
2100	1236	1833	- 0.2				
2200	1307	1904	- 0.2				
2300	1379	1976	- 0.2				
2400	1451	2048	- 0.2				
2500	1523	2121	- 0.2				
2600	1596	2194	- 0.2				
2700	1670	2267	- 0.2				
2800	1744	2341	- 0.2				
2900	1818	2415	- 0.2				
3000	1893	2490	- 0.2				

TABLE. 4.

TRUE SPECIFIC HEAT AT CONSTANT PRESS. FOR THE IDEAL GAS ($P=0$), & CORREC^{N} FOR PRESSURES UP TO 500 LB/IN^2 ABSOLUTE

ALL VALUES IN CHU/ LB/°C

t°C	H_2		N_2		O_2		CO		CO_2		AIR		NO		N_2O	
	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$	K_{p_0}	$\Delta K_{p_{100}}$
0	3.40	.002	.248	.0036	.218	.0041	.249	.0041	.196	.0150	.240	.0036	.239	.0035	.203	.0150
15	3.41	.002	.248	.0031	.219	.0035	.249	.0035	.200	.0127	.240	.0031	.238	.0030	.207	.0127
100	3.45	.001	.249	.0014	.223	.0016	.250	.0016	.219	.0059	.242	.0014	.238	.0014	.228	.0059
200	3.46	.001	.251	.0007	.230	.0008	.253	.0008	.238	.0029	.245	.0007	.242	.0007	.245	.0029
300	3.46		.256	.0004	.238	.0004	.258	.0004	.254	.0016	.251	.0004	.247	.0004	.259	.0016
400	3.48		.261	.0002	.245	.0003	.264	.0003	.266	.0010	.258	.0002	.254	.0002	.270	.0010
500	3.50		.267	.0002	.251	.0002	.270	.0002	.277	.0007	.263	.0002	.260	.0002	.281	.0007
600	3.53		.272	.0001	.256	.0001	.277	.0001	.286	.0005	.268	.0001	.265	.0001	.290	.0005
700	3.57		.278	.0001	.260	.0001	.282	.0001	.294	.0003	.271	.0001	.270	.0001	.297	.0003
800	3.61		.283		.263		.287		.300	.0002	.275		.274		.302	.0002
900	3.66		.287		.266		.291		.305	.0002	.278		.277		.306	.0002
1000	3.71		.291		.268		.294		.310	.0001	.281		.280		.310	.0001
1100	3.77		.294		.271		.298		.314	.0001	.283		.283		.313	.0001
1200	3.82		.297		.273		.300		.317		.286		.285		.316	
1300	3.87		.299		.275		.303		.320		.288		.287		.318	
1400	3.92		.301		.276		.305		.323		.290		.289		.320	
1500	3.96		.303		.278		.306		.325		.293		.290		.322	
1600	4.01		.305		.280		.308		.33		.295		.291		.324	
1700	4.05		.306		.281		.309		.33		.297		.292		.325	
1800	4.08		.308		.283		.310		.33		.299		.293		.326	
1800	4.12		.309		.285		.312		.33		.300		.294		.327	
2000	4.16		.310		.287		.313		.33		.302		.295		.328	
2100	4.19		.312		.289		.314		.33		.304		.296		.329	
2200	4.22		.312		.290		.314		.34		.305		.296		.330	
2300	4.25		.313		.292		.315		.34		.307		.297		.330	
2400	4.28		.314		.293		.316		.34		.309		.298		.331	
2500	4.31		.315		.295		.317		.34		.310		.298		.331	
2600	4.33		.316		.296		.317		.34		.312		.299		.332	
2700	4.36		.316		.297		.318		.34		.313		.299		.332	
2800	4.38		.317		.298		.318		.34		.315		.300		.332	
2900	4.41		.318		.300		.319		.34		.316		.300		.333	
3000	4.43		.318		.301		.319		.34		.318		.300		.333	

TABLE. 5.

TOTAL HEAT FROM 0°C TO t°C FOR THE IDEAL GAS (p·0) AND CORRECTION FOR PRESSURES UP TO 500 LB/IN.² ABSOLUTE.
ALL VALUES IN CHU/LB.

t°C	H_2		N_2		O_2		CO.		CO_2		AIR		NO		N_2O	
	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}	$H_{p=0}$	ΔH_{100}
0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	51·1		3·7	·05	3·3	·06	3·7	·06	3·0	·21	3·6	·05	3·6	·05	3·1	·21
100	342·8		24·9	·23	22·0	·26	24·9	·26	20·7	·95	24·1	·23	23·8	·22	21·6	·95
200	688·2		49·9	·33	44·7	·37	50·0	·38	43·6	1·36	48·5	·33	47·8	·32	45·3	1·36
300	1034		75·2	·38	68·1	·43	75·6	·44	68·2	1·58	73·3	·38	72·2	·37	70·5	1·58
400	1381		101·0	·41	92·2	·47	101·6	·47	94·2	1·71	98·7	·42	97·2	·40	96·9	1·71
500	1730		127·4	·43	117·0	·49	128·3	·49	121·4	1·79	124·8	·43	122·9	·42	124·4	1·79
600	2081		154·4	·44	142·3	·50	155·7	·51	149·5	1·84	151·3	·45	149·2	·43	152·9	1·84
700	2436		181·9	·45	168·0	·51	183·6	·52	178·5	1·88	178·3	·46	175·9	·44	182·2	1·88
800	2785		208·9	·46	194·2	·52	212·1	·53	208·2	1·91	205·6	·47	203·1	·45	212·2	1·91
900	3158		238·4	·47	220·6	·53	241·0	·53	238·4	1·93	233·2	·47	230·7	·45	242·6	1·93
1000	3527		267·3	·47	247·3	·53	270·3	·54	269·2	1·95	261·2	·47	258·5	·46	273·4	1·95
1100	3901		296·5	·47	274·3	·53	299·9	·54	300·4	1·96	289·4	·48	286·7	·46	304·6	1·96
1200	4280		326·1	·48	301·4	·54	329·8	·54	331·9	1·97	317·8	·48	315·1	·46	336·0	1·97
1300	4664		355·8	·48	328·8	·54	358·9	·55	363·8	1·98	346·5	·48	343·7	·46	367·7	1·98
1400	5054		385·9	·48	356·4	·54	390·2	·55	396·0	1·99	375·5	·48	372·4	·46	399·7	1·99
1500	5448		416·1	·48	384·1	·54	420·8	·55	428·4	1·99	404·6	·49	401·3	·47	431·8	1·99
1600	5846		446·5	·48	412·0	·55	451·5	·55	461	2·0	434·0	·49	430·4	·47	464·1	2·00
1700	6249		477·0	·48	440·0	·55	482·3	·55	494	2·0	463·5	·49	459·6	·47	496·5	2·00
1800	6656		507·7	·48	468·3	·55	513·3	·55	527	2·0	493·3	·49	488·8	·47	529·1	2·01
1900	7067		538·6	·48	496·7	·55	544·4	·55	560	2·0	523·2	·49	518·2	·47	561·8	2·01
2000	7481		569·6	·48	525·3	·55	575·6	·55	593	2·0	553·3	·49	547·6	·47	594·5	2·01
2100	7898		600·7	·49	554·0	·55	607·0	·56	627	2·0	583·6	·49	577·2	·47	627·4	2·02
2200	8319		631·9	·49	583·0	·55	638·4	·56	660	2·0	614·1	·49	606·8	·47	660·3	2·02
2300	8743		663·2	·49	612·1	·55	669·8	·56	694	2·0	644·7	·49	636·4	·47	693·3	2·02
2400	9169		694·6	·49	641·3	·55	701·4	·56	728	2·0	675·5	·49	666·2	·47	726·3	2·02
2500	9599		726·0	·49	670·7	·55	733·0	·56	762	2·0	706·4	·49	686·0	·47	759·4	2·02
2600	10031		757·6	·49	700·2	·55	764·7	·56	796	2·0	737·5	·49	725·8	·47	792·6	2·02
2700	10465		789·2	·49	729·8	·55	796·5	·56	830	2·0	768·8	·49	755·7	·47	825·8	2·02
2800	10902		820·8	·49	759·6	·55	828·3	·56	864	2·0	800·2	·49	785·6	·47	859·0	2·03
2900	11342		852·5	·49	789·5	·55	860·1	·56	898	2·0	831·7	·49	815·6	·47	892·2	2·03
3000	11783		884·3	·49	819·5	·55	892·0	·56	932	2·0	863·4	·49	845·6	·47	925·5	2·03

TABLE 5

Table 6

The Specific Heat Difference, $K_p - K_v$

(a) For the ideal gaseous state.

Gas	Molecular Weight	$R = K_p - K_v$ CHU/lb./°C.
H_2O	18.016	0.1103
H_2	2.016	0.985
N_2	28.02	0.0709
O_2	32.00	0.0621
CO	28.01	0.0709
CO_2	44.01	0.0451
Air	28.96	0.0686
NO	30.01	0.0662
N_2O	44.02	0.0451

(b) H_2O - for the non-ideal gaseous state.

t°C.	$K_p - K_v$*					
	P = 14.7 lb./in.^{2}	100	200	300	500	1000
100	0.0862	Liquid State				
200		0.0972	0.0575			
300			0.1063	0.0956	0.0652	0.0319
400	Ideal Gaseous State				0.1049	0.0738
500						0.1054

* Derived from Ref. (16), using

$$K_p - K_v = A.T. \left(\frac{\partial P}{\partial T}\right)_V \cdot \left(\frac{\partial V}{\partial T}\right)_P .$$

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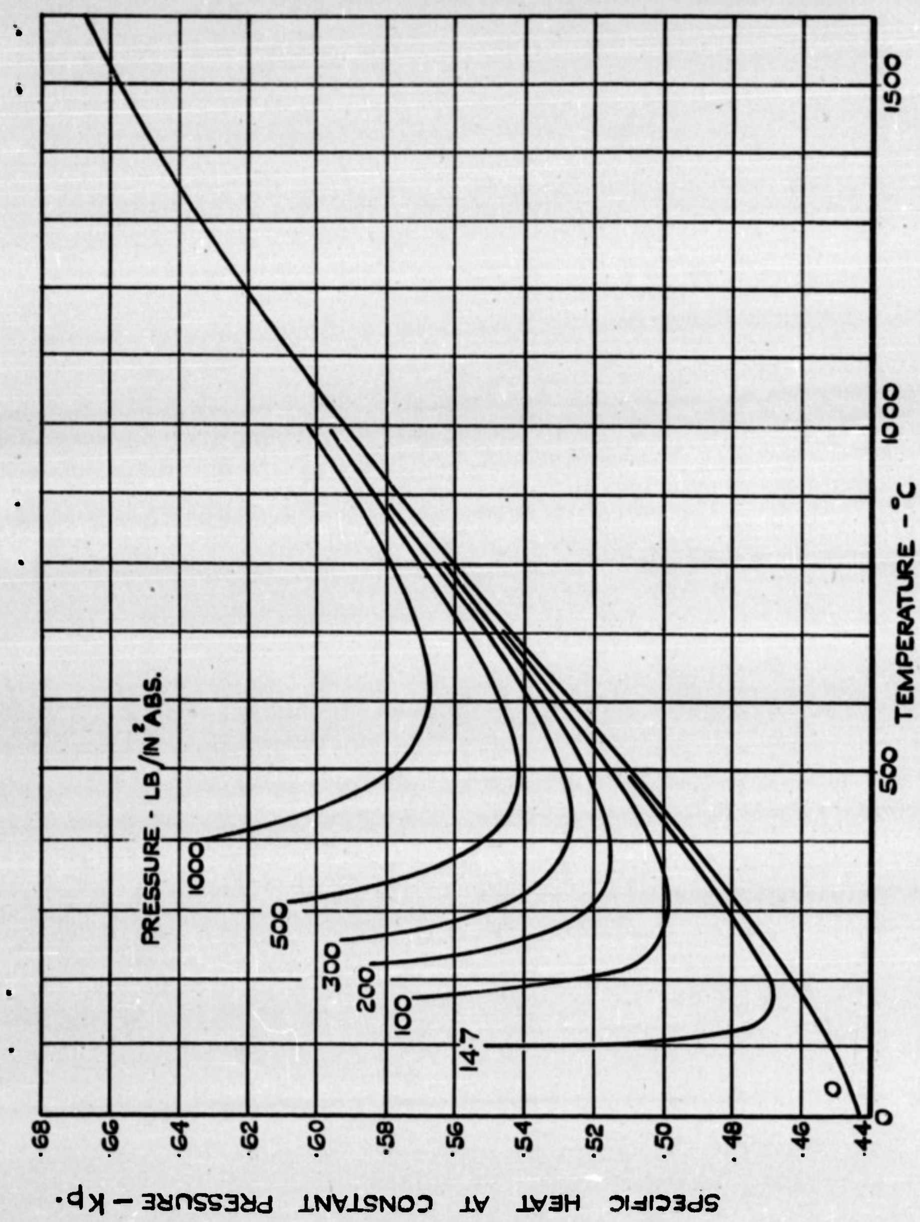
FIG. 1.



H_2O- TRUE SPECIFIC HEAT AT CONSTANT PRESSURE.

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