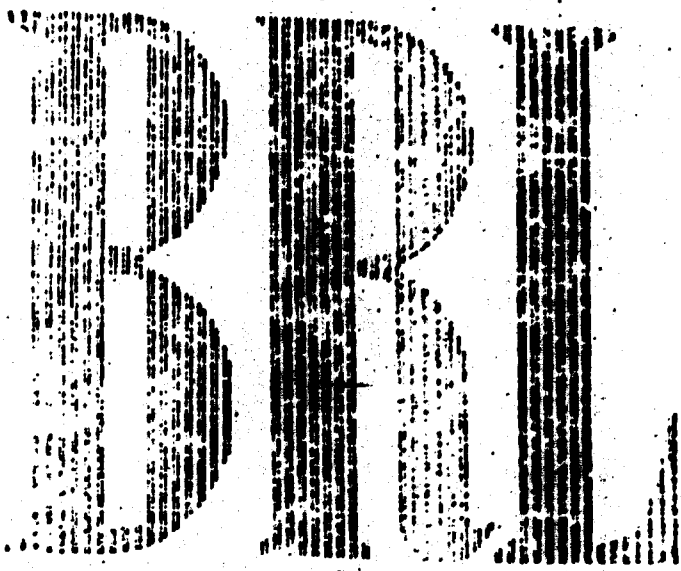


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MARCH 1961

TABLES OF COMPUTED THERMODYNAMIC PROPERTIES
OF
MILITARY GUN PROPELLANTS

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ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1338

IGPaer/KIBryson/ram
Aberdeen Proving Ground, Md.
March 1961

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MILITARY GUN PROPELLANTS

ABSTRACT

Thermodynamic properties of all commonly used military gun propellants plus some experimental propellants are presented in tabular and graphical form. For the military propellants, these properties are given over a loading density ranging from 0.05 to 0.4 gm/cc. Comparisons are made between the propellants on the basis of "force" and isochoric flame temperature. The tables and data presented herein can be used for gun design computations.

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I INTRODUCTION

Within the past two years a general program for the computation of ballistic trajectories inside of a gun⁽¹⁾ has been set up at these laboratories on the high speed digital computer, CRDVAC. A portion of the input data required for this program is thermodynamic properties of the combustion products such as; flame temperature, force, covolume, and specific heat ratio.

Tables which have been used in the past as a source of this information have been compiled either from obsolete thermodynamic data, or computed using various simplifying assumptions. In addition, these tables have given the thermodynamic properties for a single density of loading for the gun (usually 0.2 gm/cc) whereas most guns operate over a wide range of loading densities. Since the thermodynamic properties of the propellant gases vary with loading density, it would be useful to compute the properties of all the common military propellants over the range of loading densities normally encountered in gun firings.

In the following report, the thermodynamic properties for all the common military propellants and some experimental propellants are given. For the military propellants (with the exception of M7 and M20) these properties are given over a loading density range from 0.05 to 0.4 gm/cc. In addition the thermodynamic properties of three other types of propellants are examined:

- (1) Nitrocellulose at varying percentages of nitration.
- (2) M1 propellant contaminated with varying percentages of water and/or ethyl alcohol.
- (3) Double base propellant with varying proportions of nitrocellulose and nitroglycerine.

To carry out the extensive computations required for the preparation of this report, a digital computer program designed to

compute the thermodynamic properties of gun propellants was used on the ORDVAC. This program was initially formulated by Brinkley⁽²⁾ and revised by Leser⁽³⁾ and has been used by the authors for about 1/2 year. The computer program as devised by Leser has been revised by one of the authors (Baer) so that the flame temperature of the propellant can be computed together with the thermodynamic properties at the flame temperature. This revised computer program is the one now in current use.

II COMPUTATIONAL RESULTS

The data in this report have been organized in the following manner:

- (1) Tables listing propellant composition and important thermodynamic properties.
- (2) Tables of input thermodynamic data used in the program.
- (3) Figures presenting in graphical form some of the particular thermodynamic properties of military propellants.
- (4) An appendix presenting the detailed computed data for all propellants considered.

For ease in locating a particular piece of detailed information in the appendix, a table of contents appears at the beginning of that section.

In Table I, composition and thermodynamic data at the flame temperature are given for 16 military propellants. In Table II, data are given for 7 experimental propellants. In Table III data are given for M1 propellant contaminated with water and/or ethyl alcohol and for nitrocellulose propellants with varying degrees of nitration. In Table IV data are given for experimental double base propellants.

Tables I through IV have been arranged in a format similar to that of the Picatinny tables⁽⁴⁾ with the following differences;

(1) For each propellant in Tables I, II, and III percentage compositions are given; the composition under the column marked "S" (for specification) is the composition as given in the Picatinny tables. The composition under the column marked "B" (for Brinkley) is a normalized composition used in computing the thermodynamic properties of the propellant. The difference between the two compositions is due to two factors: (1) percentages listed in the Picatinny tables added up to values greater than 100%, and so had to be normalized to a percentage composition; (2) in some propellants inorganic salts, such as potassium sulfate, potassium perchlorate, etc. had been added. Since the Brinkley code does not have provision for the inclusion of these salts, they were normalized out of the composition.

It is believed that, with the exception of M7, the omission of these salts will not appreciably change the thermodynamic results.

(2) Data in Tables I, II, and III are reported at a density of loading of 0.2 gm/cc. Data in Table IV are reported for densities of loading of both 0.1 and 0.15. The difference in the densities of loading between Table IV and the other three tables is that the data in Table IV were computed in the support of an experimental program for the measurement of propellant gas temperatures in a closed bomb.

(3) The propellant Force "P" in all four tables was computed at the loading density shown. This was done to give a direct comparison between the force values for the military propellants and the experimental propellants.

It is of interest to compare the force and flame temperatures for these propellants. In Table V, military and experimental propellants are listed in order of decreasing force; in Table VI in order of decreasing adiabatic flame temperature. It will be noted that for some propellants there is a difference between the force

rating and the flame temperature rating. The special propellants of Tables III and IV were not included in this rating in order to avoid confusion.

The thermodynamic data in Table I are given for a standard loading density of 0.2 gm/cc. To examine the variation with loading density of the thermodynamic properties at the flame temperature, the thermodynamic properties for all the military propellants (with the exception of M7 and M26) were computed for five loading densities: 0.05, 0.1, 0.2, 0.3, 0.4. This range was chosen to account for most of the gun pressure range (1000 - 100,000 psi). Table VII gives these thermodynamic properties for the above loading densities.

One of the results which can be derived from the Brinkley thermodynamic computations is the covolume correction. This correction appears in the Helmholtz - Abel equation of state for propellant gas as follows:

$$P(V - \eta) = nRT_0 = F \quad (1)$$

Since the volume term in equation (1) is the reciprocal of the loading density, equation (1) can be written as follows:

$$P\left(\frac{1}{\rho} - \eta\right) = F \quad (2)$$

Expanding and rearranging (2) we obtain:

$$\frac{P}{\rho} = F + \eta P \quad (3)$$

Equation (3) can be represented as a linear plot of P/ρ vs P in which the slope is the covolume η , and the intercept with $P = 0$, the propellant force, F . When P/ρ vs P is plotted from the Brinkley computations, the resulting plot is not linear, the data points falling on a smooth curve. For this reason, the covolume correction will vary with the constant volume chamber pressure P . To determine this variation a cubic equation in pressure, P , was fitted by least squares to the data of P/ρ vs P , giving the following relation:

$$P/\rho = F_1 + a_1 P + a_2 P^2 + a_3 P^3 \quad (4)$$

The covolume is the first derivative of equation (3) thus:

$$\gamma = a_1 + 2a_2 P + 3a_3 P^2 \quad (5)$$

In equation (5) a_1 is the linear covolume term. In Table VIII the value of the coefficients F_1 , a_1 , $2a_2$, and $3a_3$ are listed for the military propellants. In Table VII, for each military propellant, the covolume correction is given for each density of loading.

In Table VII is also given the intercept propellant force F_1 and a force computed from the relation:

$$F = nRT_v \quad (6)$$

The force F is tabulated for each propellant and for each density of loading.

The intercept force F_1 can be used to compute the pressure developed by burning the propellant in an adiabatic closed bomb at a loading density ρ . The pressure developed can be computed by solving the cubic equation:

$$\rho a_3 P^3 + \rho a_2 P^2 + (\rho a_1 - 1)P + \rho F_1 = 0 \quad (7)$$

Since the value for the coefficient a_3 is quite small, little error will be made at low loading densities if one drops the cubic term, in which case solution to the resulting quadratic equation can be obtained by normal algebraic methods. Complex algebraic solutions exist for the cubic equation, one method being listed in the Chemical Rubber Handbook. (5)

A number of military guns, especially those of the howitzer class, can be approximated by a simple gun model. In this model, it is assumed that the projectile does not move to any appreciable extent while the propellant is burning. After the propellant is burned, the projectile is accelerated by the expanding hot gases. It is of interest in interior ballistics to show the relation between gas pressure and temperature while the combustion gases are undergoing an isentropic expansion behind the projectile. A

pressure-entropy diagram is one way in which this process can be illustrated; therefore, pressure-entropy diagrams have been plotted from the results of the Brinkley computation on the military propellants. These plots are shown in Fig. 1 - 14.

These figures are a graphical representation of the relationship between gas density, temperature, pressure, and entropy for the combustion gases of each of the military propellants. The dotted line labeled T_A represents the flame temperature of the propellants.

These figures can be used to predict the gas temperature in a gun, provided that the pressures are known. For example, suppose M1 propellant at a density of loading of 0.3 gm/cc is burned in a gun chamber and burnout of the propellant occurs before the projectile moves to any appreciable extent. On Fig. 1, the pressure-entropy diagram for M1 propellant, the intersection of the density of loading line $\rho = .3$ with the isochoric flame temperature line T_A is the condition in the chamber at burnout of the propellant. Under these conditions $T_A = 2440^\circ\text{K}$, the pressure $P = 60,700$ psi. (this could be checked against the experimental pressure), and the entropy $S = 2.122$ cal/gm $^\circ\text{K}$. If one assumes that motion of the projectile causes isentropic expansion of the gas; then one can determine the temperature of the gas at any point along the gun tube provided the pressure at that point is known. For example, assume that muzzle pressure of the gun has been found to be 5,000 psi. Then dropping down the entropy line at 2.122 until the 5,000 psi pressure line is reached, one finds that the gas temperature is 1540°K .

In closed chamber firings, the relationship between pressure and temperature is generally unknown because of heat loss from the chamber. From these figures the temperature of the propellant gas can be predicted, knowing the loading density and the experimental pressure; since the gas temperature will be the intersection of the pressure line with the gas density line.

Other types of diagrams can be plotted from the thermodynamic data obtained from the Brinkley computations, but in lieu of plotting more diagrams the thermodynamic data is presented in the appendix for each propellant. In addition to the thermodynamic data, there are presented the equilibrium combustion gas composition at a particular gas density and temperature. The range of gas temperatures presented in these tables depends upon the range of gas temperatures presented in the pressure-entropy figures. For high gas densities the temperature range is narrow and for low gas densities, the temperature range is wide. Further details on these tables is presented in the appendix.

III MISCELLANEOUS COMPUTATIONS

It is of interest to the manufacturer and user of military propellants to determine the effect of water and/or ethyl alcohol on the thermodynamic properties (particularly the flame temperature and force) of the propellant. The propellant chosen for this investigation was M1 at a loading density of 0.2 g/cc. The first portion of Table III gives the propellant composition and a summary of the propellants thermodynamic properties. The format for this table is the same as that used in Tables I and II. The propellant composition column headed by the letter "S" is the standard composition showing the amount of alcohol and/or water added. The composition column headed by the letter "B" is the normalized propellant composition used in the Brinkley computations. In this table amounts of water or ethyl alcohol added to the propellant were varied from 0 - 6%. In one propellant a 3% - 3% mix of ethyl alcohol - water was added to determine the effect of a mixture. A plot of the flame temperature vs percentage water or ethyl alcohol added is shown in Fig. 16. This figure can be used to estimate the effect on flame temperature of alcohol - water mixtures, which can be made by assuming that the drop in flame temperature due to water

can be added to the drop due to alcohol. On the graph this estimate can be made by measuring the temperature drop due to the addition of water with dividers and then spacing off this distance below the flame temperature due to the alcohol addition. For low (less than 1%) percentages of alcohol and water, this method will give values within 3% of the computed value. For higher percentages, the error is greater, for instance a 3% - 3% mixture gives an estimated value of 2171°K, the computed value being 2192°K. Detailed tables for these propellants are presented in the appendix.

In the latter portion of Table III are shown the composition and thermodynamic properties of pure nitrocellulose propellants where nitrogen content varies from 12.6% to 13.2%. The detailed computational results are given in the appendix.

Recently, at this laboratory, flame temperature studies were made on a series of double-base propellants in which the nitro-glycerine concentration was varied from 0% to 20%. In Table IV, the computed composition and thermodynamic properties for these experimental double base propellants are given for two loading densities, 0.10 and 0.15 gm/cc. As would be expected, the flame temperature and the propellant force increase as the nitro-glycerine content increases. Detailed computations on these propellants are given in the appendix.

In all of the computations, the combustion products have been assumed to behave as real gases. It is of interest to see what would happen to the thermodynamic properties of the propellant, if this assumption were not made; e.g., assume the combustion products behave as ideal gases. In the Brinkley code this is done by setting the virial coefficients equal to zero. In the appendix are listed the thermodynamic properties for M1 propellant at a density of loading of 0.2 gm/cc. Comparison of thermodynamic properties at the flame temperature gives the following results:

M1 Propellant

$$\rho = 0.2 \text{ gm/cc}$$

	Real Gas	Ideal Gas
Flame Temp. °K	2433	2427
γ	1.264	1.263
Mol. wt.	22.13	22.10
P psi	35,019	26,494

From the above, the only significant difference in results is in the constant volume combustion pressure, the ideal gas combustion pressure being 24.35% lower than the real gas combustion pressure.

THERMODYNAMIC DATA

Thermodynamic data used in these computations are presented in Tables IX through Table XII. Table IX shows the atomic composition and heat of formation of military and experimental propellants. These data, together with the loading density, are all that are needed for propellant input to the Brinkley program. In Table X the atomic composition and heats of formations are given for the special propellants, that is, the M1 propellant containing various concentrations of water and ethyl alcohol, and the experimental double base propellants. Table XI shows the atomic composition and heats of formation for the propellant reactants. Included in this table is the source of the thermodynamic data used to compute the heats of formation of the reactants.

It was assumed in computing the heats of formation of the propellants considered in this report that the total heat of formation was the sum of the proportional heats of formations of the individual reactants. Thus heats of polymerization, or any heat released by chemical reaction between the propellant reactants prior to burning, were not considered.

The heats of formation of the propellant combustion products are given in Table XII, and in Table XIII, a correction factor to correct

the value of the internal energy of the combustion products from a level of 0°K (the level being used in the Brinkley calculations) to a level of 298°K, the temperature level of the heats of formation of the propellant reactants. Tables of internal energies, chemical potential, specific heats, and virial correction for each of the combustion products are presented in Leser's report⁽³⁾ and will not be repeated here.

V DISCUSSION

This report presents thermodynamic data regarding the combustion properties of military gun propellants, plus some data concerning experimental propellants. These data must be regarded as tentative, pending revisions in the thermodynamic data used in the computations. In future revisions, both the ideal gas thermodynamic properties, and the real gas virial corrections of the combustion products will be replaced. In addition, the thermodynamic code will be set up in such a way as to account for the presence of the inorganic salts used in the propellants.

In Leser's report⁽³⁾ one serious error occurred which, until located and corrected, markedly influenced the shape of the pressure-entropy diagram. This error was in the sign of the correction to the activity coefficient for gas imperfection. The correct equation is [eq. (11) in Leser's report]:

$$+ \log \gamma_1 = \frac{(B + nB_1) \rho}{r_0} + \frac{(nC + n^2 C_1/2) \rho^2}{M_0^2}$$

The ideal gas thermodynamic data and the real gas virial data for ammonia had discontinuities and irregularities when plotted as a function of temperature. In Fig. 15, the effects of these irregularities upon the combustion gas composition for M-1 at 0.2 gm/cc loading is shown. Since the proportion of ammonia in

the combustion products is very minor, any changes in the ammonia data would not be expected to change the overall thermodynamic properties of the propellant to any great extent. A severe error in the chemical potential for ammonia at 1700°K was corrected in the process of these computations and is not present in the results.

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TABLE
Formulas and Calculated Thermochemical

PROPELLANT SPECIFICATION	M1 JAN P-309		M1A1		M2 JAN P-323		M5 JAN P-323		M6 JAN P-309		M7 JAN P-659		M8 JAN P-38
	B	S	B	S	B	S	B	S	B	S	B	S	B
Nitrocellulose	83.13	85.00	83.17	84.50	76.80	77.45	81.26	81.95	84.96	87.00	58.71	54.60	52.60
% Nitrogen	13.15	13.15	12.6	12.6	13.25	13.25	13.25	13.25	13.15	13.15	13.15	13.15	13.25
Nitrogl. cerine					19.54	19.50	14.87	15.00			38.17	43.00	43.47
Barium Nitrate						1.40		1.40					
Potassium Nitrate						0.75		0.75					
Lead Carbonate													
Nitroguanidine													
Dinitrotoluene	9.78	10.00	9.84	10.00					9.77	10.00			
Dibutylphthalate	4.89	5.00	4.45	4.50					2.93	3.00			
Diphenylamine	0.98	1.00	0.98	1.00					0.98	1.00			
2-Nitrodiphenylamine													
Ethyl Centralite					0.59	0.60	0.59	0.60			0.97	0.90	0.61
Graphite					0.30	0.30	0.30	0.30					
Eryolite													
Ethyl Alcohol	0.73	0.75	0.98	1.00	2.28	2.30	2.28	2.30	0.58	0.90	0.86	0.80	0.40
Water	0.49	0.50	0.59	0.60	0.69	0.70	0.69	0.70	0.49	0.50			
Carbon Black											1.29	1.20	
Diethylphthalate													3.03
Potassium Sulfate													
Fin													
Potassium Perchlorate												7.80	
Isochoric Flame Temp., °K, T _v	2433		2258		3372		3294		2584		3686		3757
Force, ft - lb/lb, F	305,846		288,475		378,639		367,146		317,820		391,146		396,73
Gas Volume, moles/cm, a	.04906		.04562		.03947		.04018		.04418		.03847		.03841
Ratio of Specific Heats, γ	1.264		1.270		1.222		1.225		1.258		1.214		1.211
Isobaric Flame Temp., °K, T _p	1925		1778		2759		2689		2053		3056		3102
Evolume, in ³ /lb., a	31.08		31.71		29.67		29.61		30.99		--		30.26
Specific Gravity	1.57		1.56		1.65		1.65		1.51		--		--
Loading Density, gm/cc	0.2		0.2		0.2		0.2		0.2		0.2		0.2

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TABLE I
Calculated Thermochemical Values for Military Propellants

M7 JAN P-659		M8 JAN F-281		M9 MIL P-20306		M10 PA FD-123		M12 JAN P-528		M14 JAN P-309		M15 MIL P-682A		M17 MIL FD-688A		M18 FA FD-26A		M26 PA FD-329		DMR JAN P-733		
B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	
23.71	54.00	52.60	52.15	59.33	57.75	96.93	93.00	89.63	97.70	88.02	90.00	20.00	20.00	21.98	22.00	79.60	80.00	67.22	67.25	89.92	100.00	
13.15	13.15	13.25	13.25	13.25	13.25	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	
23.17	43.00	43.47	43.00	40.40	40.40							19.00	19.00	21.48	21.50	9.95	10.00	24.99	25.00			
																				0.75		
				1.25		1.50														0.70		
												54.70	54.70	54.65	54.70							
								7.34	8.00	7.82	8.00										7.19	8.00
										1.96	2.00					8.96	9.00					
						0.99	1.00	0.73	0.80	0.98	1.00					1.00	1.00				0.63	0.70
0.97	0.70	0.61	0.64	0.76	0.75							6.00	6.00	1.50	1.50			6.00	6.00			
						0.10	0.10											0.30	0.30			
												0.30	0.30									
0.86	0.80	0.40	0.40	0.51	0.50	1.48	1.50	1.38	1.50	0.98	1.00	0.30	0.30	0.30	0.30	0.50	0.50	1.20	1.20	1.15	1.50	
						0.49	0.50	0.92	1.00	0.25	0.25			0.10	0.10			0.30	0.30	0.90	1.00	
1.29	1.20																					
		3.03	3.00																			
							1.00														1.00	
	7.80																					
3666		3757		3940		3034		2838		2724		2543		2974		2552		3032		2677		
391,146		326,755		396,340		246,180		326,320		320,140		326,855		359,483		330,625		361,638		337,687		
.02447		.02441		.03700		.04129		.04333		.04330		.04637		.04347		.04444		.04222		.04222		
.214		1.211		1.207		1.235		1.244		1.252		1.260		1.241		1.256		1.231		1.243		
3030		3102		3181		2457		2297		2176		2020		2396		2063		2498		2315		
-		30.23		30.64		29.69		29.92		30.24		30.15		29.92		30.53		-		29.69		
-		-		-		1.67		-		1.61		1.66		1.67		-		1.62		-		
.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		0.2		

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TABLE II

Formulae and Calculated Thermochemical Values for Experiments

Propellant Specification	T 20		T 25 PA PD-329		T 29		T 31				
	B	S	B	S	B	S	B		S		
Nitrocellulose	19.94	20.00	73.21	73.25	45.95	46.00	29.79	24.83	30.00	25.00	30.00
$\frac{1}{2}$ Nitrogen	13.15	13.15	13.15	13.15	13.15	13.15	12.20	13.35	12.20	13.35	12.20
Nitroglycerine	12.96	13.00	19.99	20.00	21.48	21.50	42.70		43.00		
Barium Nitrate				0.75							
Potassium Nitrate				0.70							
Lead Carbonate		1.00									
Nitroguanidine	59.82	60.00			30.67	30.70					
Dinitrotoluene											
Dibutylphthalate	4.00	5.00									
Diphenylamine											
2-Nitrodiphenylamine											
Ethyl Centralite	2.00	2.00	5.00	5.00	1.50	1.50	1.99		2.00		
Graphite			0.30	0.30	0.10	0.10					
Cryolite						0.30					
Ethyl Alcohol	0.30	0.30	1.20	1.20	0.30	0.30	0.50		0.50		
Water			0.30	0.30							
Carbon Black							0.20		0.20		
Diethylphthalate											
Potassium Sulfate											
Pin											
Isochoric Flame Temp., °K, T_v	2325		3090		3215		3688				
Force, Ft - lb/lb, F	307,484		358,113		370,235		392,299				
Gas Volume, moles/lbm, η	.04733		.04171		.04147		.03867				
Ratio of Specific Heats, γ	1.268		1.237		1.232		1.213				
Isobaric Flame Temp., °K, T_p	1934		2498		2610		3040				
Specific Gravity	1.66		1.62		1.66		1.62				
Loading Density, g/cc	0.2		0.2		0.2		0.2				



TABLE II

Related Thermochemical Values for Experimental Propellants

T 29		T 31				T 32				T 33				T 34	
B	S	B		S		B		S		B		S		B	S
5.95	46.00	29.79	24.83	30.00	25.00	30.80	25.67	30.95	25.80	21.19	35.27	21.30	35.45	20.00	20.00
5.15	13.15	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.20	13.35	12.00	12.60
1.48	21.50	42.70		45.00		34.83		35.00		34.83		35.00		19.00	19.00
0.67	30.70													54.70	54.70
														4.00	4.00
														2.00	2.00
1.50	1.50	1.99	2.00	7.91	7.95	7.91	7.95	7.91	7.95	7.91	7.95	7.91	7.95		
0.10	0.10														
	0.30														0.30
0.30	0.30	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.30	0.30
		0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30		
3215		3688				3087				3135				2571	
370,255		390,297				304,529				368,149				309,028	
.04147		.03067				.04249				.04226				.04595	
1.232		1.213				1.240				1.238				1.257	
2.10		3040				2490				2532				2045	
1.00		1.02				1.02				1.02				1.65	
0.2		0.2				0.2				0.2				0.2	

1

TAN
Formulae and Calculated Thermod

Propellant	M 1 0-0		M 1 2-0		M 1 4-0		M 1 6-0		M 1 0-3	
	B	S	B	S	B	S	B	S	B	S
Nitrocellulose	84.18	85.00	82.52	85.00	80.95	85.00	79.43	85.00	82.52	85.00
% Nitrogen	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15
Dinitrotoluene	9.20	10.00	9.71	10.00	9.52	10.00	9.35	10.00	9.71	10.00
Dibutylphthalate	4.95	5.00	4.85	5.00	4.76	5.00	4.67	5.00	4.85	5.00
Diphenylamine	0.99	1.00	0.97	1.00	0.95	1.00	0.93	1.00	0.97	1.00
Ethyl Alcohol			1.94	2.00	3.81	4.00	5.61	6.00		
Water									1.94	2.00
Isochoric Flame Temp., °K, F _v	2510		2362		2234		2127		2429	
Force, ft - lb/lb., F	312,220		301,113		290,393		280,379		303,304	
Gas Volume, moles/gm, η	.04664		.04562		.04627		.04646		.04680	
Ratio of Specific Heats, γ	1.263		1.263		1.272		1.274		1.262	
Adiabatic Flame Temp., K, F _p	1987		1863		1756		1670		1925	
Loading Density, gm/cc	0.2		0.2		0.2		0.2		0.2	

2

TABLE III
 Related Thermodynamic Values for Special Propellants

	M 1 0-3		M 1 0-4		M 1 0-6		M 1 3-3		NC 12.6	NC 12.8	NC 13.0	NC 13.1	NC 13.15	NC 13.2
	B	S	B	S	B	S	B	S						
00	82.52	85.00	80.95	85.00	79.43	85.00	79.43	85.00	100.00	100.00	100.00	100.00	100.00	100.00
15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	13.15	12.6	12.8	13.0	13.1	13.15	13.2
00	9.71	10.00	9.52	10.00	9.35	10.00	9.35	10.00						
00	4.85	5.00	4.76	5.00	4.67	5.00	4.67	5.00						
00	0.97	1.00	0.95	1.00	0.93	1.00	0.93	1.00						
00							2.80	3.00						
	1.94	2.00	3.81	4.00	5.61	6.00	2.80	3.00						
	2429		2352		2280		2192		3060	3145	3230	3272	3292	3317
	303,304		291,974		287,024		283,406		344,001	349,924	355,681	358,413	359,032	361,411
	.04480		.04497		.04511		.04509		.04046	.04006	.03967	.03947	.03957	.03928
	1.262		1.264		1.265		1.269		1.232	1.230	1.227	1.226	1.225	1.224
	1925		1861		1805		1727		2484	2557	2632	2669	2657	2710
	0.2		0.2		0.2		0.2		0.2	0.2	0.2	0.2	0.2	0.2

TABIE IV
Formulas and Calculated Thermodynamic Values for Experimental Double - Base Propellants

Propellant	0% NC		5% NC		10% NC		15% NC		20% NC	
	100% NC		95% NC		90% NC		85% NC		80% NC	
Nitrocellulose	100.00		95.00		90.00		85.00		80.00	
% Nitrogen	13.15		13.15		13.15		13.15		13.15	
Nitroglycerine	0		5.00		10.00		15.00		20.00	
Isobaric Flame Temp., °K, T ₁	3247	3255	3336	3347	3420	3434	3493	3516	3570	3592
Pressure, P _c - lb/in ² , P	320, 365	355, 605	362, 235	362, 692	366, 874	367, 967	371, 925	373, 294	376, 282	377, 949
Gas Volume, v _g /gm, γ	0.9945	0.9938	0.9910	0.9904	0.9890	0.9872	0.9852	0.9832	0.9828	0.9825
Ratio of Specific Heats, γ	1.226	1.226	1.225	1.225	1.220	1.220	1.216	1.217	1.215	1.214
Isobaric Flame Temp., °K, T ₂	2648	2656	2727	2737	2602	2615	2575	2589	2598	2598
Loading Density, gm/cc	0.10	0.15	0.20	0.15	0.10	0.15	0.10	0.15	0.10	0.15

TABLE V

Military and Experimental Propellants in
order of Decreasing Force

Propellant	Force @ $\rho = 0.2$ ft.- lb. ft.
1. M9	396,840
2. M8	396,735
3. T31	391,299
4. M7	391,146
5. M2	372,639
6. T29	370,235
7. T33	368,149
8. M5	367,146
9. T32	364,529
10. M26	361,638
11. M17	359,483
12. T25	358,113
13. M10	346,180
14. IMR	337,687
15. M12	336,390
16. T34	329,028
17. M15	328,855
18. M14	328,140
19. M18	320,655
20. M6	317,830
21. T20	307,488
22. M1	305,846
23. M1A1	288,475

TABLE VI

Military and Experimental Propellants in
order of Decreasing Adiabatic Flame Temperature

Propellant		Adiabatic Flame Temperature, $T_v @ p = 0.2$ $^{\circ}K$
1.	M9	3840
2.	M3	3757
3.	T31	3688
4.	M7	3686
5.	M2	3372
6.	M5	3294
7.	T29	3215
8.	T33	3135
9.	M26	3092
10.	T25	3090
11.	T32	3087
12.	M10	3034
13.	M17	2974
14.	IMR	2877
15.	M12	2858
16.	M14	2724
17.	M18	2591
18.	M6	2583
19.	T34	2571
20.	M15	2545
21.	M1	2433
22.	T20	2325
23.	M1A1	2258

TABLE VII
 Variation of the Thermodynamic Properties of Military Propellants with Loading Density

Propellant	Loading Density (lb/cc)	γ	ρ (g/cc)	E (cal/g)	P (psi)	S_V (cal/g-°K)	Z	S (cal/g-°K)	H_F (cal/g)	K (lb/mole)	\ln^3/lb	F_1 (ft-lb/lb)	F (ft-lb/lb)
M0	.05	2433	625.7	7,073	.3434	1.265	2.319	1174	22.065	36.656	304,895	307,616	
	.1	2407	624.7	15,166	.3450	1.265	2.250	1173	22.090	34.242		305,835	
	.2	2353	624.1	35,019	.3486	1.264	2.174	1170	22.190	31.084		305,846	
	.3	2359	625.4	60,660	.3531	1.265	2.123	1167	22.414	27.670		305,496	
M0A	.05	2237	578.1	6,564	.3431	1.271	2.081	1163	22.803	24.438		304,884	
	.1	2212	577.0	14,205	.3450	1.271	2.319	1182	21.631			287,708	
	.2	2231	574.5	32,118	.3494	1.270	2.247	1151	21.682	34.861		288,005	
	.3	2317	572.6	57,660	.3550	1.269	2.170	1148	21.920	31.707		288,475	
M2	.05	3323	590.8	8,499	.3551	1.268	2.117	1146	22.368	28.201		288,876	
	.1	3354	585.6	18,284	.3566	1.224	2.307	1510	24.925	34.861		289,055	
	.2	3376	587.7	41,725	.3591	1.224	2.247	1515	25.011	33.176		369,248	
	.3	3573	587.1	71,639	.3637	1.223	2.181	1517	25.084	29.665		371,255	
M5	.05	3251	924.5	109,058	.3643	1.226	2.101	1514	25.156	24.078		372,867	
	.1	3260	925.1	27,957	.3545	1.227	2.307	1493	24.762	34.601		372,477	
	.2	3294	929.2	51,125	.3584	1.225	2.246	1496	24.832	32.999		364,505	
	.3	3254	925.7	70,957	.3620	1.226	2.136	1497	24.891	29.689		366,951	
M6	.05	2572	623.8	7,243	.3443	1.229	2.100	1194	24.954	26.381		367,146	
	.1	2582	623.0	15,726	.3457	1.227	2.307	1493	24.762	34.601		367,226	
	.2	2583	620.1	36,210	.3489	1.225	2.246	1497	24.832	32.999		366,736	
	.3	2768	627.1	62,444	.3525	1.226	2.136	1494	24.926	26.381		367,226	
M8	.05	3051	1039.1	6,940	.3443	1.229	2.100	1194	24.954	26.381		367,226	
	.1	3066	1033.3	19,282	.3457	1.227	2.307	1493	24.762	34.601		367,226	
	.2	3077	1027.6	44,334	.3489	1.225	2.246	1497	24.832	32.999		367,226	
	.3	3176	1029.5	76,500	.3525	1.226	2.136	1494	24.926	26.381		367,226	
M5	.05	3707	1096.3	6,502	.3519	1.212	2.095	1577	26.218	24.906		366,736	
	.1	3717	1111.0	19,284	.3541	1.215	2.275	1573	25.911	37.841		387,131	
	.2	3640	1129.2	44,291	.3571	1.210	2.219	1591	25.371	35.371		392,559	
	.3	3669	1136.4	76,427	.3593	1.207	2.158	1606	26.455	30.636		396,840	

TABLE VII
(Continued)

Variation of the Thermodynamic Properties of Military Propellants with Loading Density.

Propellant	Loading Density gm/cc	T _v °K	E cal/gm	F psi	C _v cal/gm - %	γ	S cal/gm - %	H _f cal/gm	N lb/role	V _v in ³ /lb	P _i ft-lb/lb	F ft-lb/lb
ML0	.05	3019	832.7	7,947	.3499	1.235	2.297	1425	24,274	34,172	345,579	344,890
	.1	3028	833.6	16,970	.3512	1.235	2.235	1427	24,327	32,756		345,725
	.2	3034	832.5	38,916	.3517	1.235	2.167	1425	24,358	29,590		346,180
	.3	3034	829.7	66,894	.3504	1.236	2.121	1422	24,385	26,544		345,955
ML2	.4	3029	826.5	101,803	.3593	1.239	2.084	1419	24,410	25,807		345,212
	.05	2849	774.2	7,744	.3479	1.244	2.308	1342	23,574	34,336	324,697	335,820
	.1	2854	774.1	16,560	.3492	1.244	2.244	1342	23,536	32,949		336,227
	.2	2858	771.9	37,981	.3500	1.244	2.173	1340	23,524	29,917		336,190
ML4	.3	2856	769.8	65,360	.3519	1.245	2.125	1337	23,657	26,729		335,945
	.4	2851	765.1	99,615	.3581	1.249	2.087	1333	23,708	23,829		335,083
	.05	2718	725.2	7,571	.3451	1.252	2.311	1269	23,044	34,723	326,990	327,773
	.1	2722	727.7	16,201	.3464	1.252	2.246	1269	23,061	33,226		328,132
ML5	.2	2724	725.3	37,230	.3493	1.253	2.174	1266	23,094	30,249		328,140
	.3	2722	722.0	64,191	.3524	1.257	2.125	1263	23,116	26,959		327,583
	.4	2720	716.2	97,996	.3559	1.261	2.085	1259	23,247	23,990		326,569
	.05	2559	694.5	7,591	.3573	1.261	2.352	996.5	21,475	34,510	327,976	328,726
ML7	.1	2542	693.9	15,278	.3590	1.261	2.322	995.9	21,497	33,157		328,956
	.2	2545	692.8	37,293	.3626	1.260	2.244	993.6	21,564	30,155		328,955
	.3	2548	689.3	64,261	.3666	1.260	2.192	991.3	21,700	26,912		328,177
	.4	2554	686.7	98,013	.3714	1.262	2.149	988.7	21,955	23,807		327,011
ML8	.05	2360	832.4	6,245	.3592	1.242	2.371	1151	22,934	33,193	337,160	338,367
	.1	2969	833.3	17,591	.3606	1.242	2.306	1152	22,965	31,637		339,146
	.2	2974	832.3	40,116	.3635	1.241	2.234	1151	23,003	28,915		339,483
	.3	2975	830.1	68,656	.3665	1.242	2.186	1149	23,045	25,918		339,090
ML9	.4	2965	827.2	101,358	.3697	1.244	2.147	1146	23,098	23,284		338,167
	.05	2586	694.0	7,405	.3487	1.256	2.332	1251	22,436	33,016	319,599	320,405
	.1	2589	693.1	15,556	.3504	1.256	2.264	1250	22,457	31,627		320,686
	.2	2591	690.4	36,499	.3534	1.256	2.190	1247	22,500	30,544		320,655
ML9	.3	2592	686.3	63,041	.3570	1.258	2.140	1244	22,571	27,236		320,102
	.4	2595	682.9	96,288	.3611	1.260	2.099	1240	22,764	24,120		319,129
	.05	2667	730.3	7,773	.3480	1.245	2.366	1345	23,637	34,314	335,931	336,937
	.1	2673	730.2	16,630	.3495	1.245	2.295	1346	23,659	32,925		337,506
ML9	.2	2677	728.1	38,112	.3521	1.245	2.245	1346	23,686	29,856		337,687
	.3	2675	725.1	65,174	.3550	1.244	2.196	1343	23,721	26,702		337,252
	.4	2670	711.3	99,926	.3581	1.248	2.087	1339	23,769	23,821		336,551

TABLE VIII

Covolume Correction for Military Propellants

Propellant	$\frac{F}{\text{in} - \text{lb}}$	a_1 in^3/lb	$2a_2$	$3a_3$
M1	3,658,720	36.956	-1.8768×10^{-4}	5.7114×10^{-10}
M1A1	3,442,820	37.518	-1.9386×10^{-4}	5.5963×10^{-10}
M2	4,403,320	36.450	-1.9319×10^{-4}	7.3135×10^{-10}
M5	4,348,670	36.109	-1.8528×10^{-4}	6.7349×10^{-10}
M6	3,802,480	36.386	-1.7970×10^{-4}	5.4313×10^{-10}
M8	4,611,070	39.247	-2.5110×10^{-4}	10.9872×10^{-10}
M9	4,584,460	40.127	-2.6753×10^{-4}	12.0317×10^{-10}
M10	4,122,950	35.492	-1.7028×10^{-4}	5.4562×10^{-10}
M12	4,016,360	35.620	-1.6973×10^{-4}	5.1602×10^{-10}
M14	3,923,160	36.015	-1.7451×10^{-4}	5.2861×10^{-10}
M15	3,935,710	35.755	-1.6748×10^{-4}	4.6486×10^{-10}
M17	4,285,920	34.460	-1.5753×10^{-4}	4.8182×10^{-10}
M18	3,835,190	36.295	-1.7658×10^{-4}	5.2136×10^{-10}
IMR	4,031,170	35.603	-1.6969×10^{-4}	5.1829×10^{-10}

$$P/\Delta = F + a_1 P + a_2 P^2 + a_3 P^3$$

$$\eta = a_1 + 2a_2 P + 3a_3 P^2$$

TABLE IX

Atomic Composition and Heat of Formation of
Military and Experimental Propellants

Propellant	C	H	O	N	$\Delta H F$ cal/gm
	gm - atoms/gm $\times 10^3$				
M1	2535	3102	3370	894	538
M1A1	2577	3237	3357	862	574
M2	2049	2837	3669	986	559
M5	2085	2855	3655	970	568
M6	2467	3015	3412	911	538
M7	1965	2565	3683	1063	483
M8	1911	2609	3720	1075	475
M9	1844	2527	3751	1091	477
M10	2214	2854	3606	916	593
M12	2309	2922	3522	927	568
M14	2406	2940	3456	918	541
M15	1597	3532	2565	2586	302
M17	1395	3301	2718	2662	319
M18	2440	3145	3446	885	557
M26	2224	2951	3515	1006	504
DMR	2301	2912	3527	927	568
T20	1599	3690	2479	2672	323
T25	2223	2890	3532	989	521
T31	1929	2663	3697	1072	491
T32	2244	2966	3476	1032	474
T33	2230	2936	3480	1040	466
T34	1572	3524	2614	2552	331

TABLE X

Atomic Composition and Heats of Formation of Special Propellants

Propellant		C	H	O	N	$\Delta H F$ cal/gm
		gm - atoms / gm $\times 10^5$				
MI	0-0	2534	2990	3368	905	516
MI	2-0	2568	3184	3344	887	533
MI	4-0	2602	3371	3322	870	549
MI	6-0	2635	3552	3307	854	565
MI	0-2	2484	3146	3410	887	579
MI	0-4	2437	3298	3451	870	639
MI	0-6	2391	3444	3490	854	697
MI	3-5	2513	3497	3395	854	631
5% NG	95% NC	2096	2602	3674	958	575
10% NG	90% NC	2055	2581	3689	977	564
15% NG	85% NC	2015	2560	3705	996	553
20% NG	80% NC	1974	2539	3720	1015	541

TABLE XI
Atomic Composition and Heat of Formation
of Propellant Reactants

Reactant	% N	C H O N				ΔH_f cal/gm	Source
		gm - atom/gm x 10 ⁵					
Nitrocellulose	12.2	2250	2879	3617	871	641	1
	12.6	2203	2772	3635	899	612	1
	12.8	2179	2718	3643	914	598	1
	13.0	2155	2664	3652	928	584	1
	13.1	2143	2637	3656	935	577	1
	13.25	2137	2623	3659	939	574	1*
	13.2	2131	2610	3661	942	569	1
	13.25	2125	2596	3662	946	564	1*
	13.35	2113	2564	3667	953	558	1*
Nitroglycerine		1321	2202	3963	1321	349	1
Nitroguanidine		961	3844	1922	3844	207	4
Dinitrotoluene		3843	3294	2196	1098	15	1
Dibutylphthalate		5748	7904	1437		679	1
Diphenylamine		7092	6501		591	-210	1
2-Nitrodiphenylamine		5601	4668	934	934	-136	6
Ethyl Centralite		6339	7458	373	746	55	4
Graphite		8326				0	3
Ethyl Alcohol		4343	13030	2172		1393	4
Water (1)			11101	5551		3741	5
Carbon Black		8326				0	3
Diethylphthalate		5400	6300	1800		681	2

THERMOCHEMICAL DATA SOURCE

- (1) Hunt. "Internal Ballistics", page 217, Philosophical Library, New York 1951.
- (1*) Ibid: Data obtained by interpolation.
- (2) Ibid: Heat for formation data obtained by extrapolation from those of di-
amylphthalate and dibutylphthalate.
- (3) Computed data.
- (4) Corner, J. "Theory of the Interior Ballistics of Guns", page 94, John Wiley
& Sons, Inc., New York 1950.
- (5) "Handbook of Chemistry and Physics", 38th ed., page 1698, Chemical Rubber
Publishing Company, Cleveland, Ohio, 1956.
- (6) Computed from data on structural features.

TABLE XII

Heats of Formation of Propellant Combustion Products

Product	ΔH_f at 298°K cal/mole
CO ₂	94,052
CO	26,416
H ₂	0
H ₂ O (g)	57,798
H ₂	0
O ₂	0
O	-59,159
OH	-10,060
H	-52,089
NO	-21,600
N	-85,565
NH ₃	11,040
CH ₄	17,889

TABLE XIII

Internal Energy Correction ($\Delta E_{298} + \Delta_f E_o^0$) for
Propellant Combustion Products

Product	$\Delta E_{298} + \Delta_f E_o^0$ cal/mole
CO ₂	-92,323
CO	-25,723
H ₂	1,431
H ₂ O (g)	-55,329
N ₂	1,480
O ₂	1,482
O	59,601
OH	11,514
H	52,309
NO	23,079
N	86,009
NH ₃	7,545
CH ₄	-14,166

FIG. 1.
PRESSURE - ENTROPY DIAGRAM
FOR
MI PROPELLANT

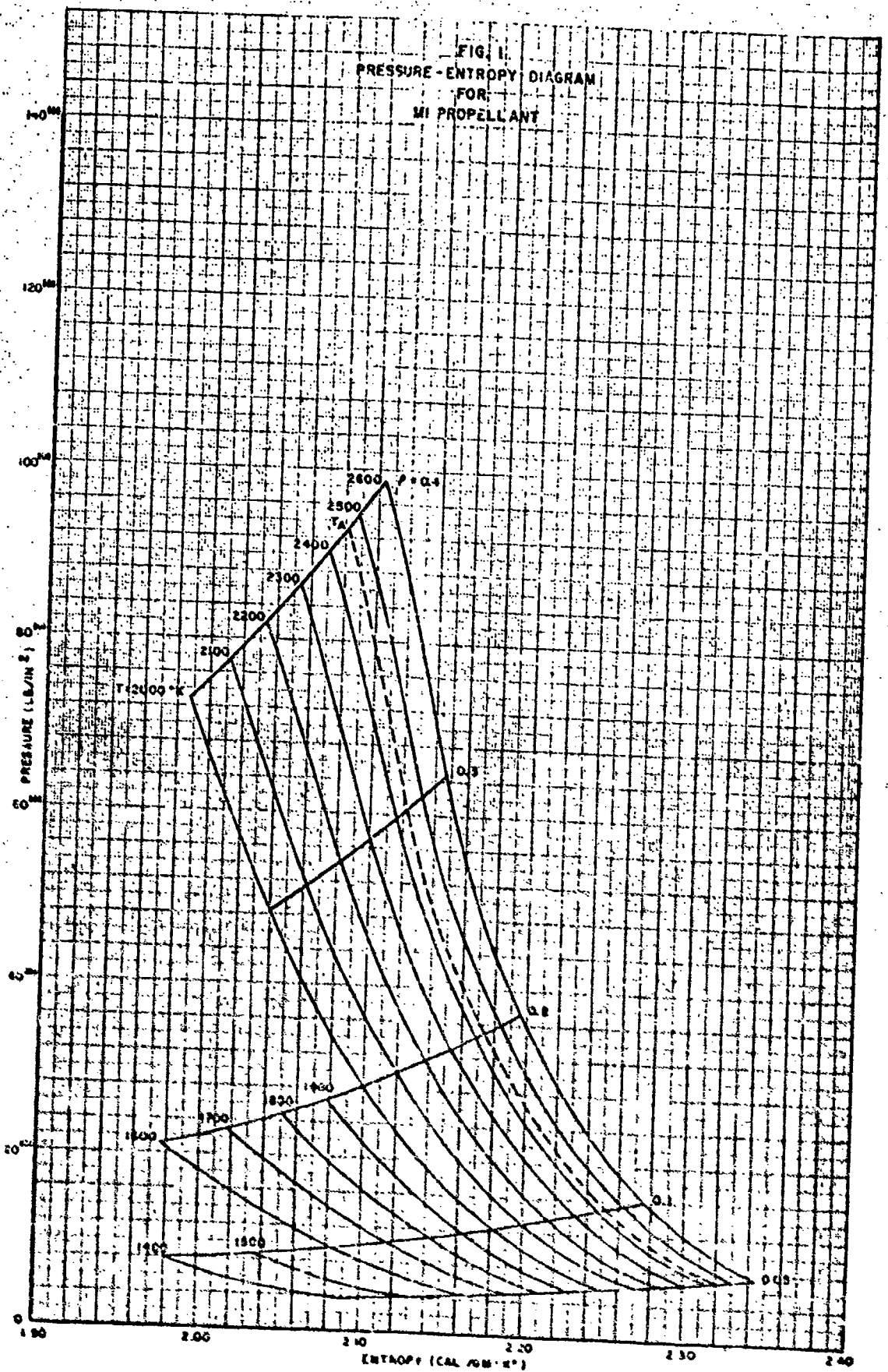
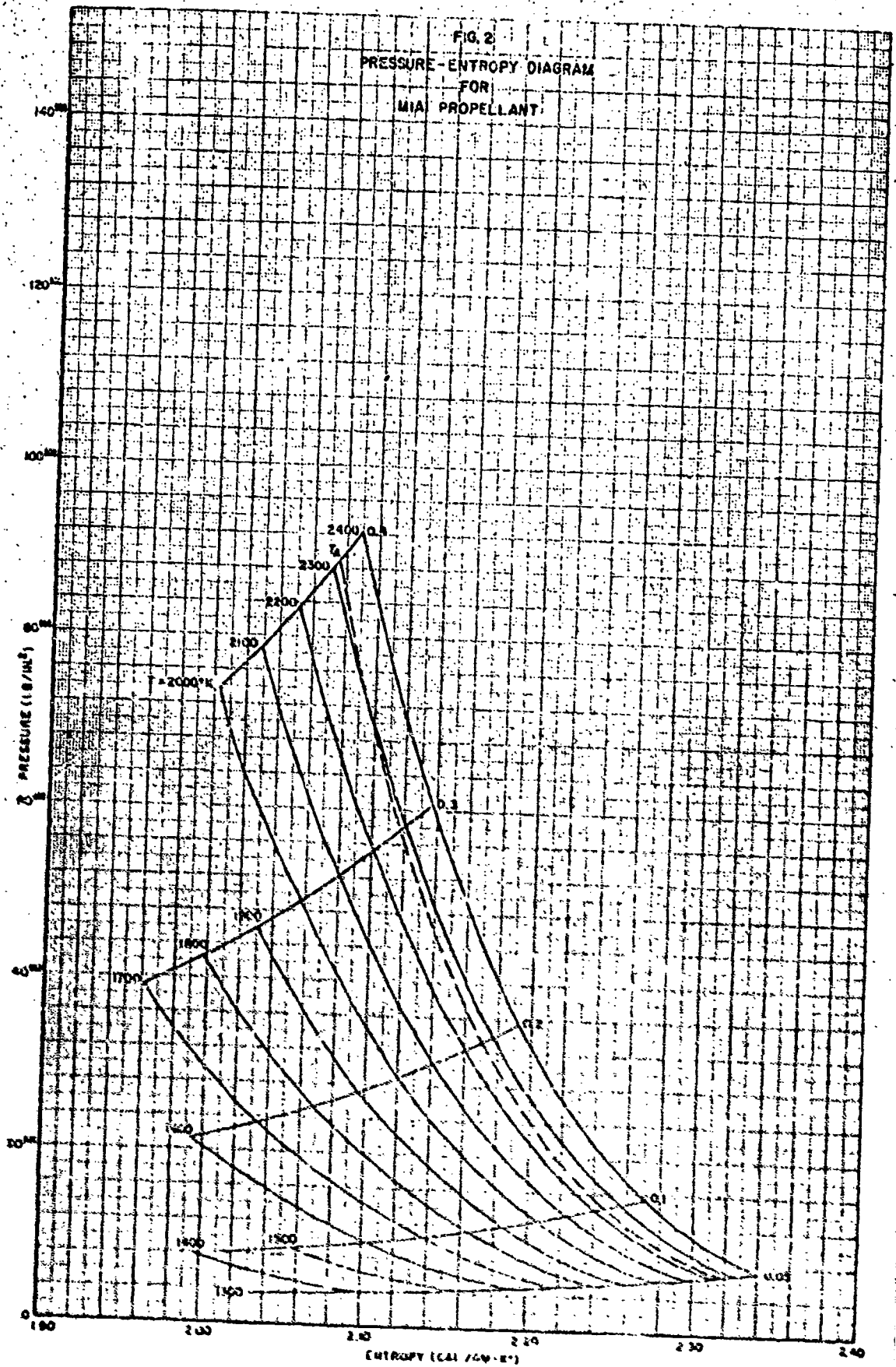


FIG. 2
 PRESSURE-ENTROPY DIAGRAM
 FOR
 MIA PROPPELLANT



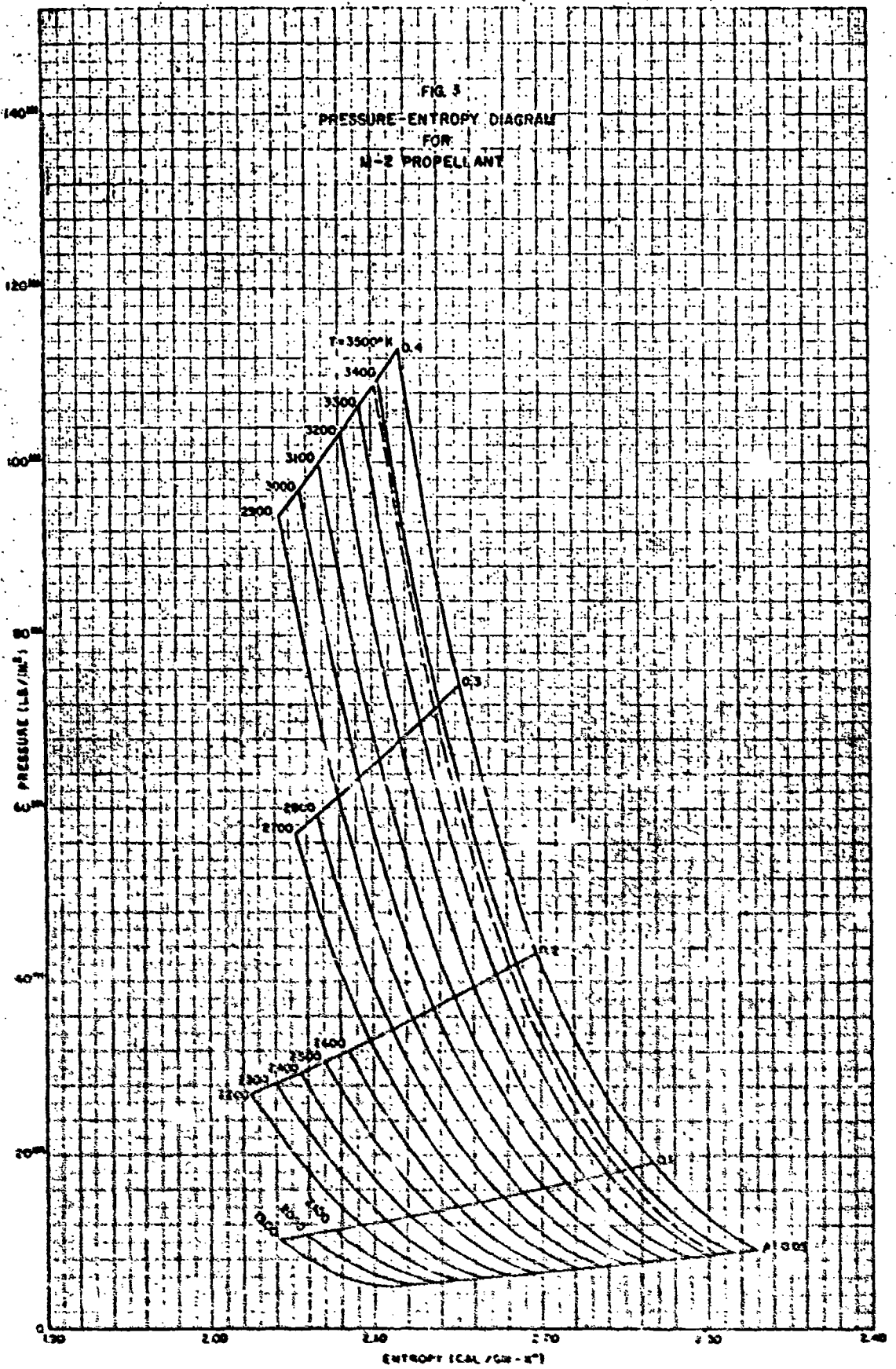


FIG. 4
 PRESSURE-ENTROPY DIAGRAM
 FOR
 M-5 PROPELLANT

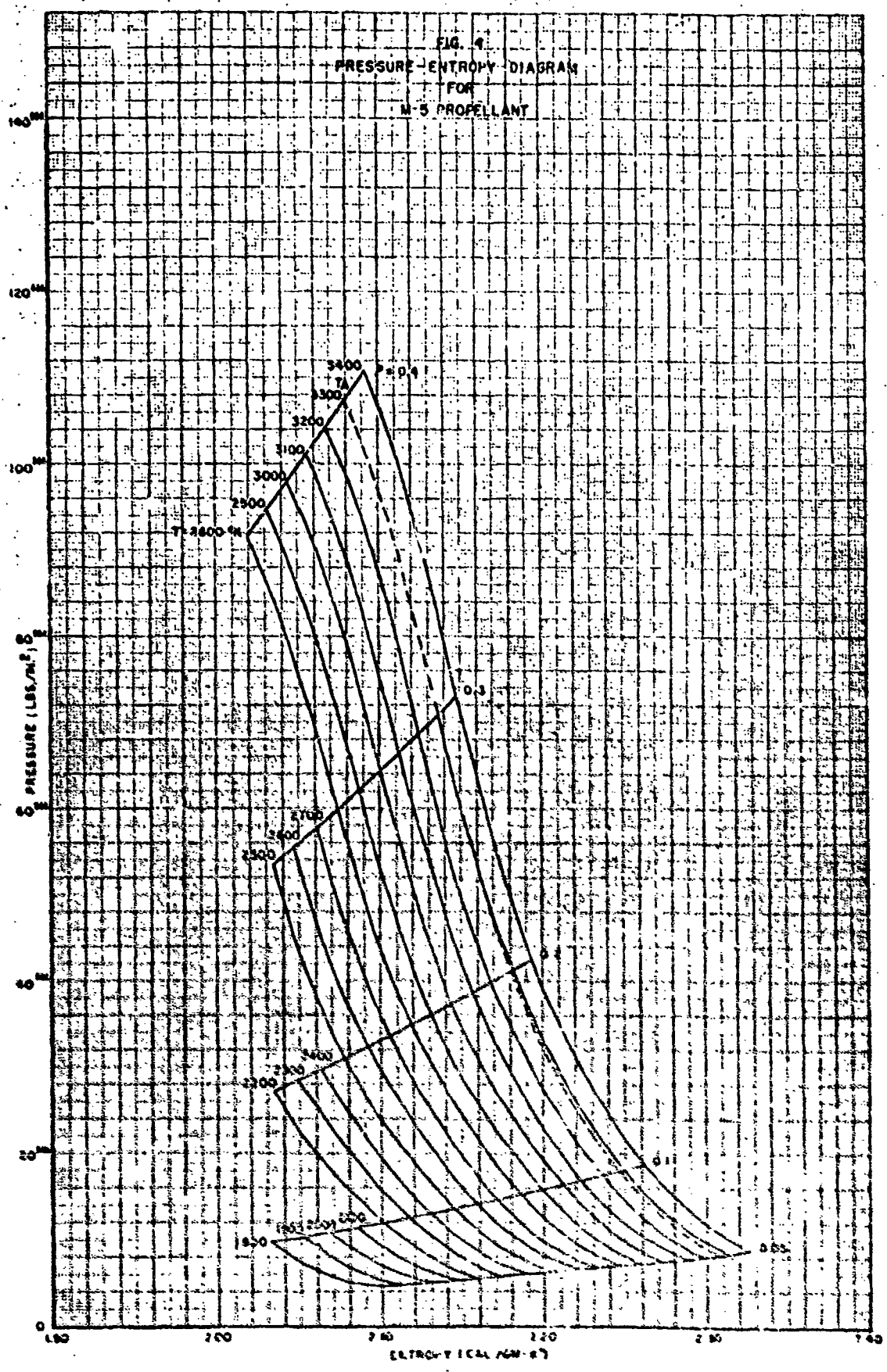


FIG. 5
PRESSURE-ENTROPY DIAGRAM
FOR
M-6 PROPELLANT

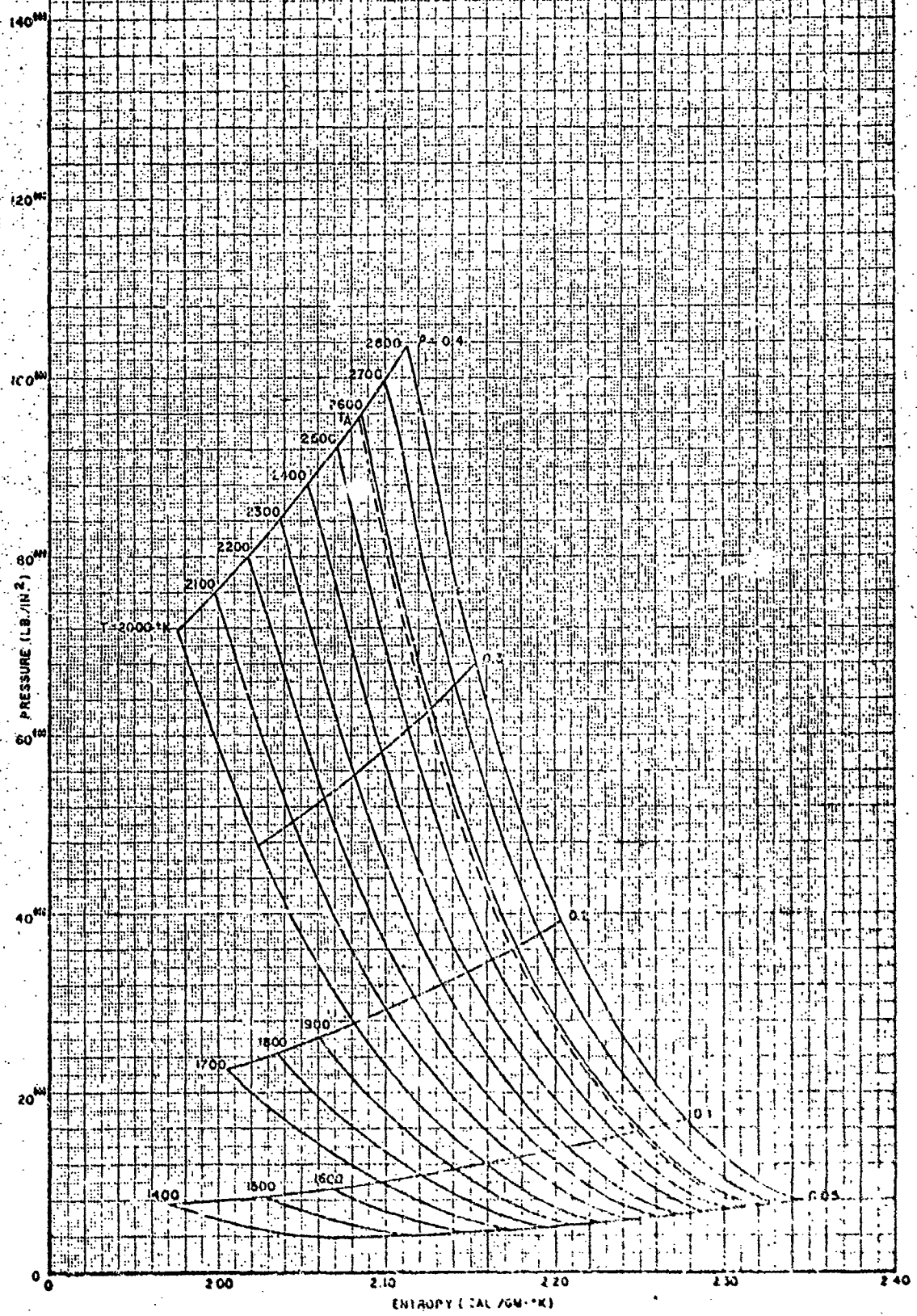


FIG 6
 PRESSURE-ENTROPY DIAGRAM
 FOR
 M-3 PROPELLANT

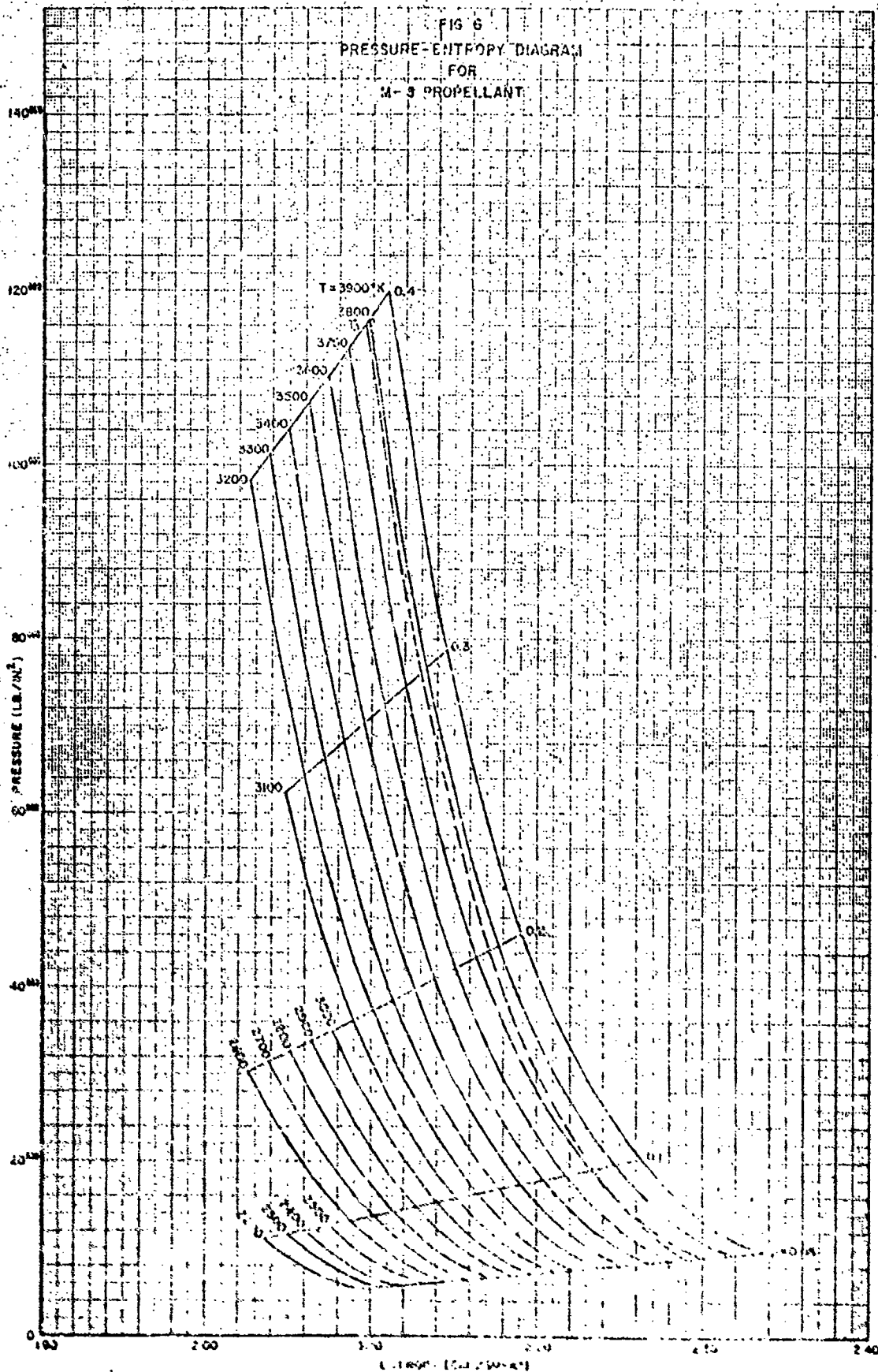


FIG. 7
 PRESSURE-ENTROPY DIAGRAM
 FOR
 M-9 PROPELLANT

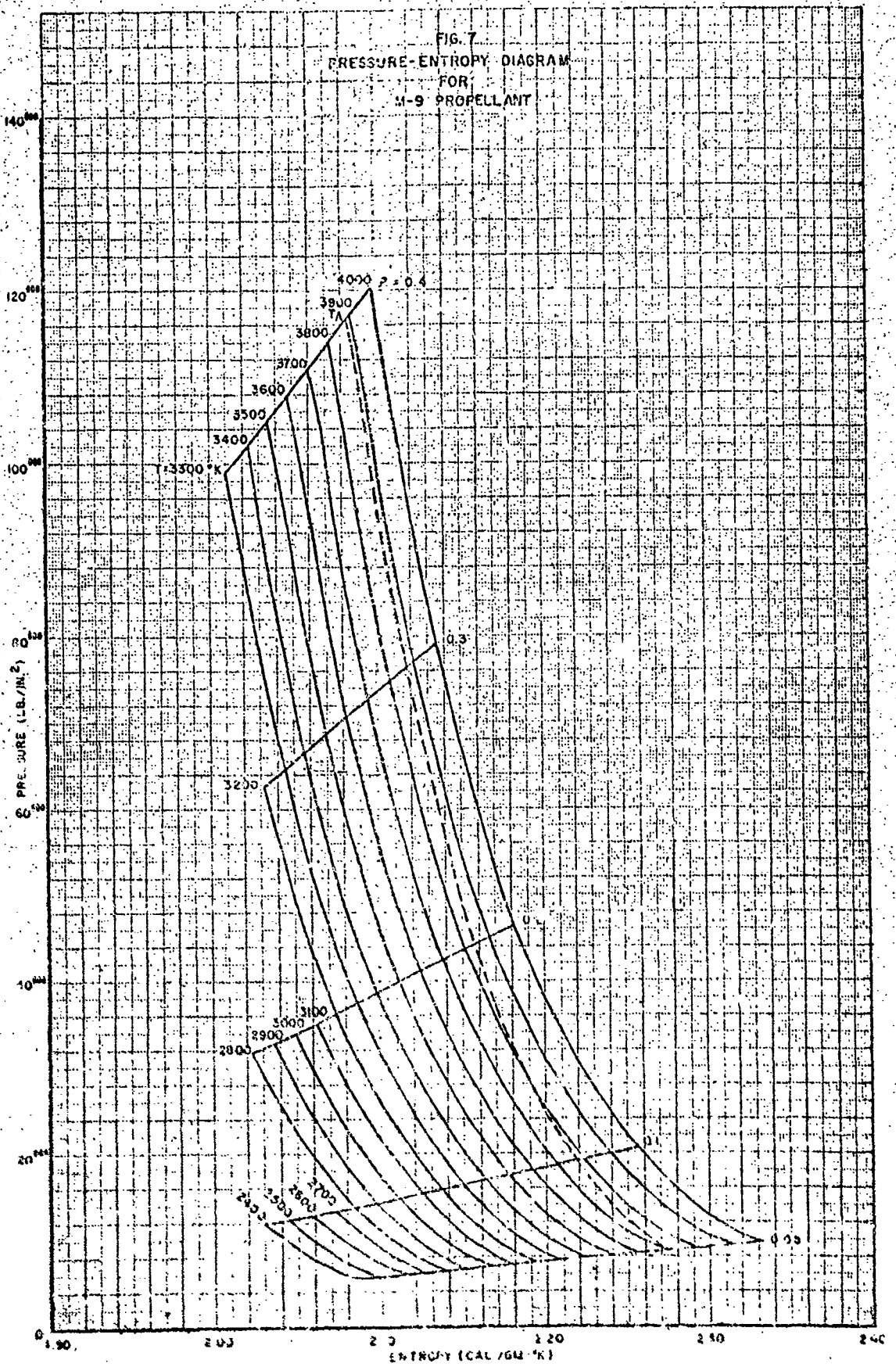


FIG. 6
 PRESSURE-ENTROPY DIAGRAM
 FOR
 M-10 PROPELLANT

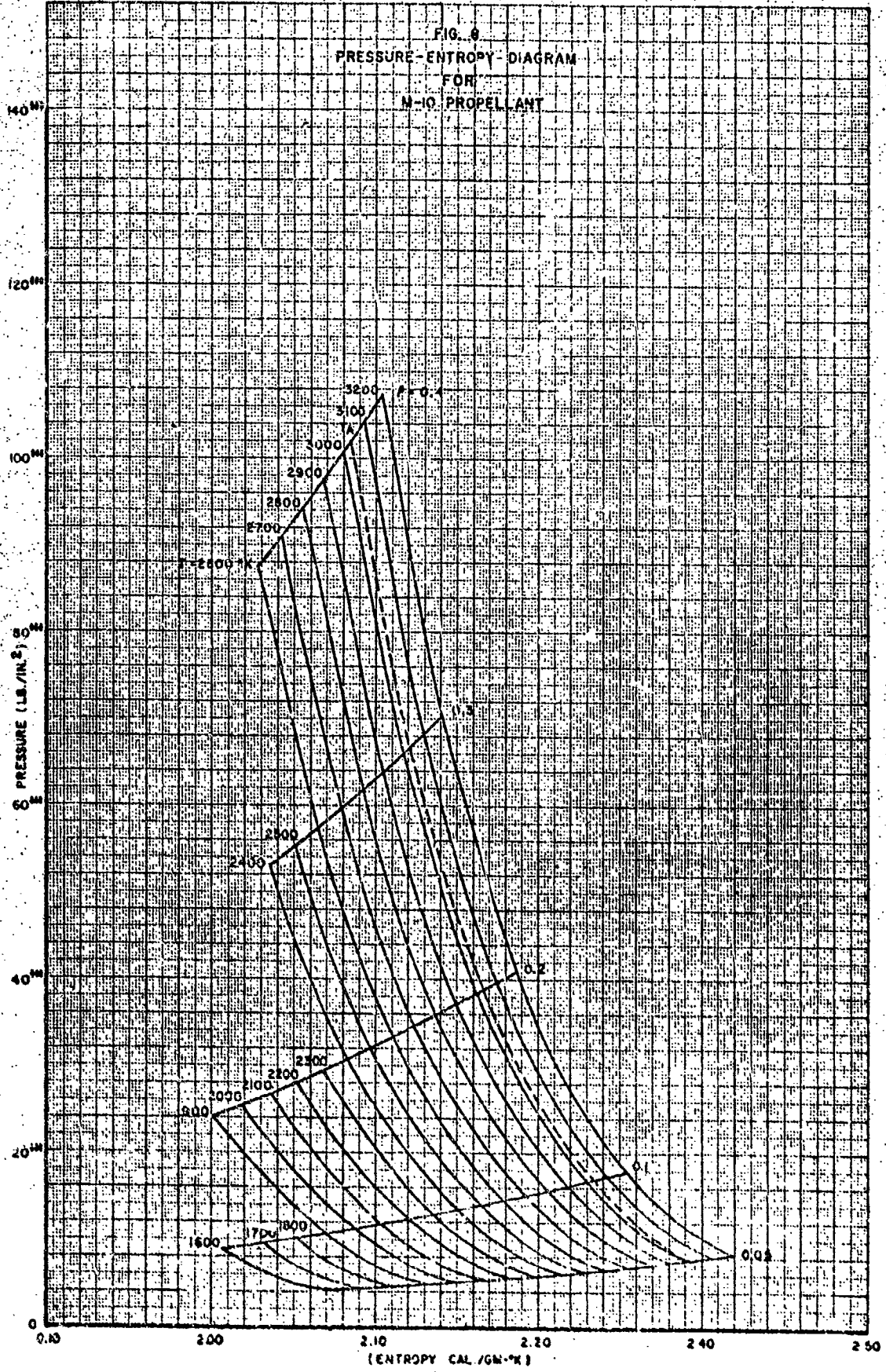


FIG 9
PRESSURE-ENTROPY DIAGRAM
FOR
M-12 PROPELLANT

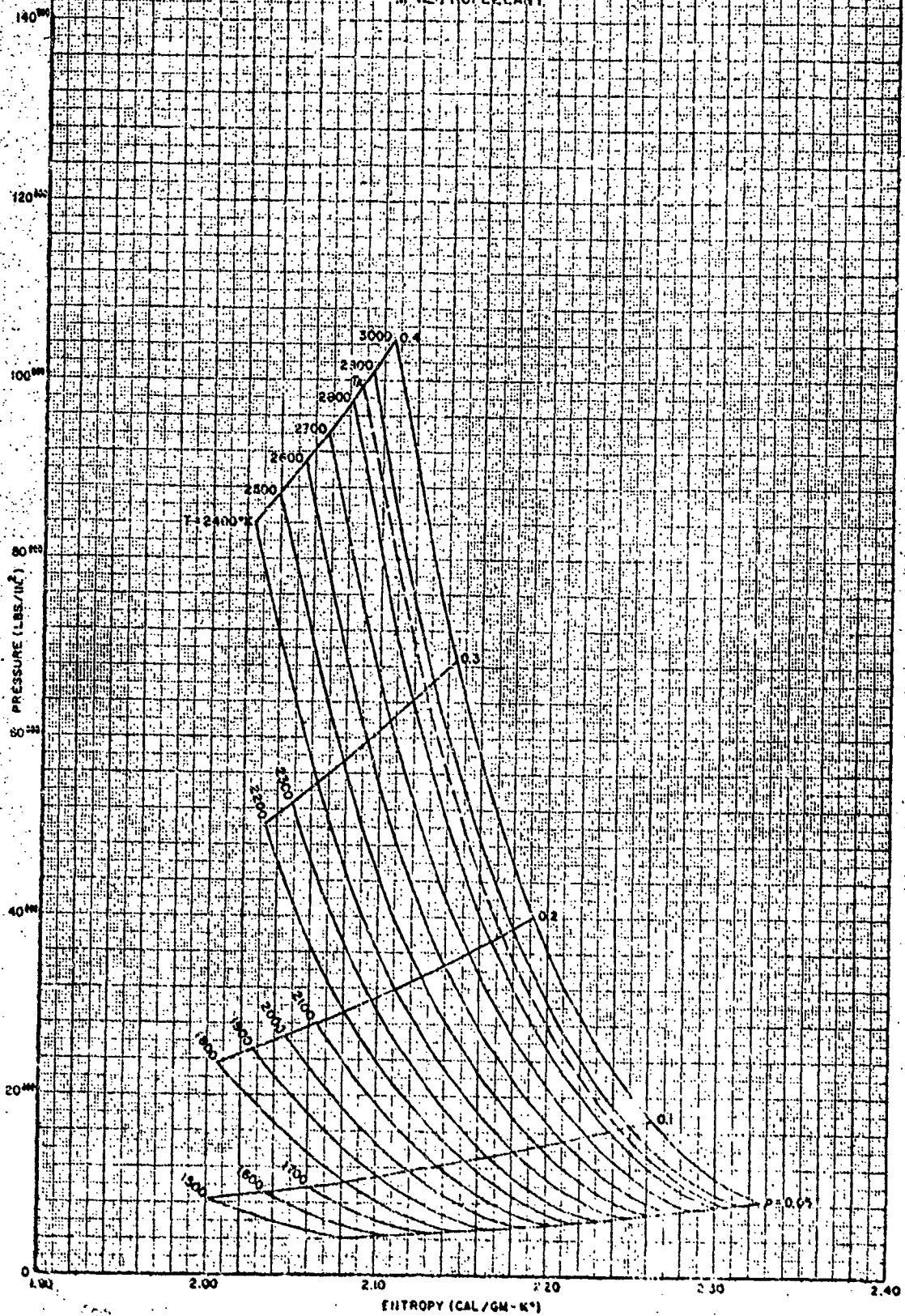


FIG. 10
PRESSURE-ENTROPY DIAGRAM
FOR
M-14 PROPELLANT

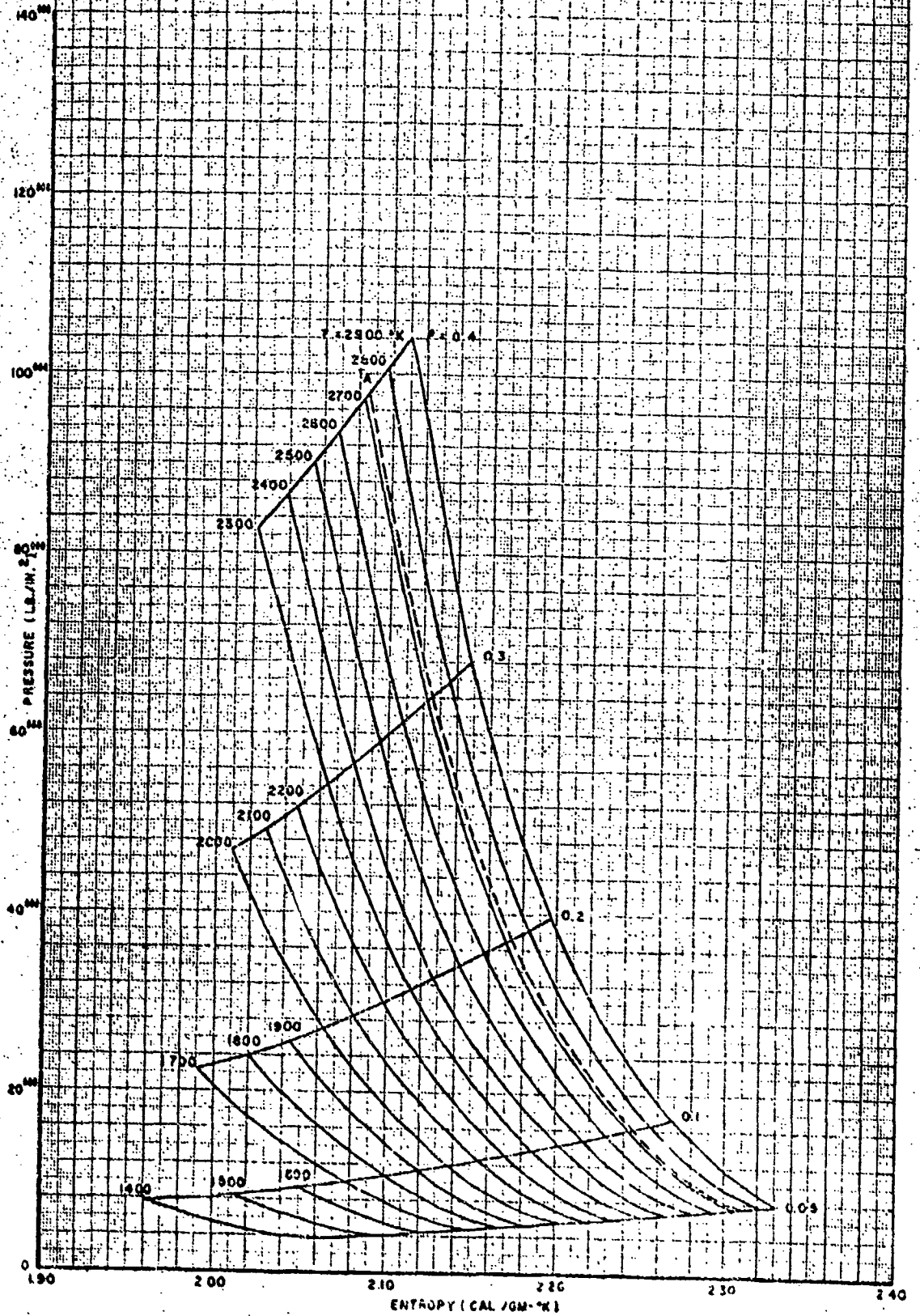


FIG. II
PRESSURE-ENTROPY DIAGRAM
FOR
M-15 PROPELLANT

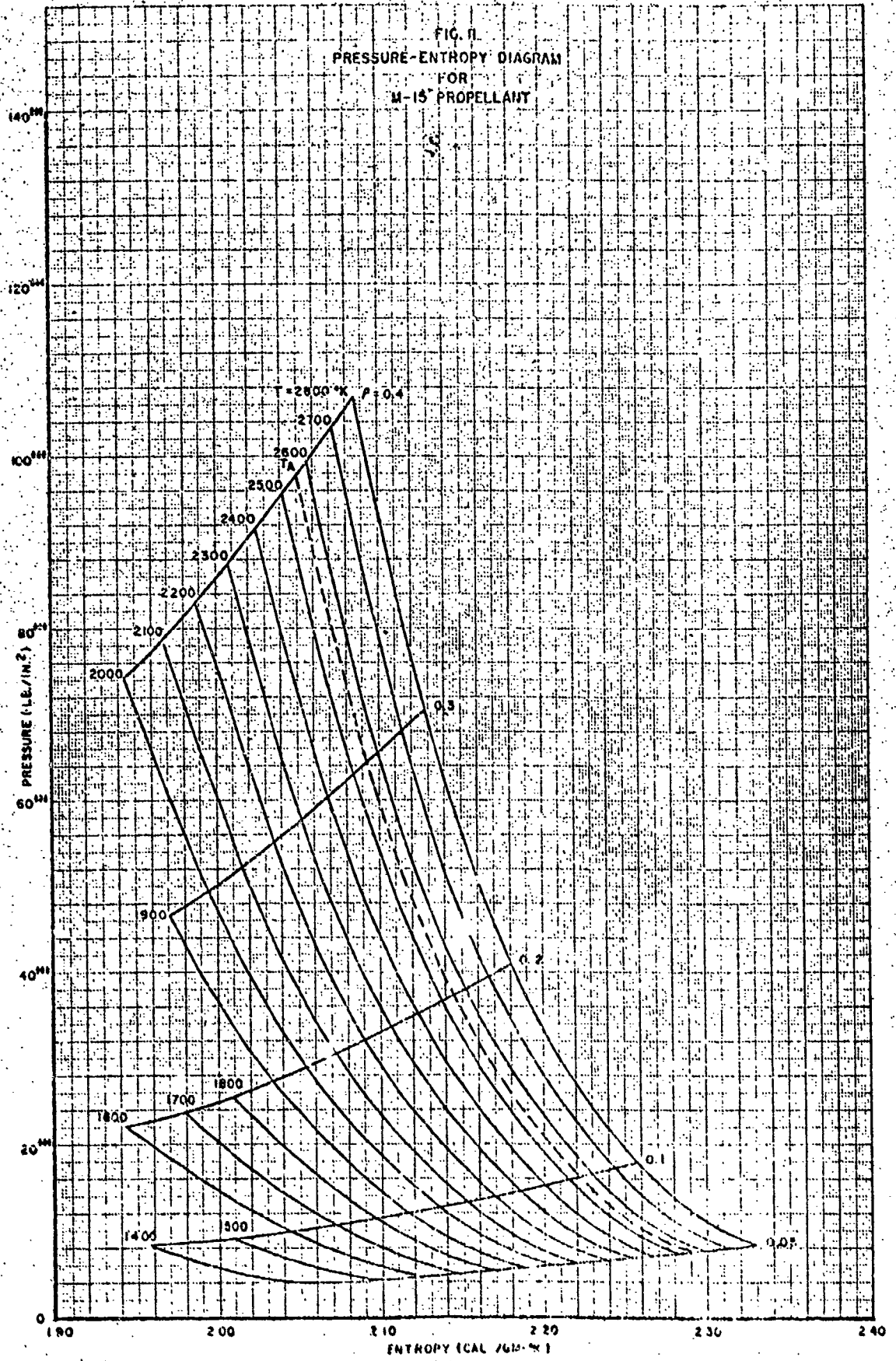


FIG. 12
PRESSURE-ENTROPY DIAGRAM
FOR
M-17 PROPELLANT

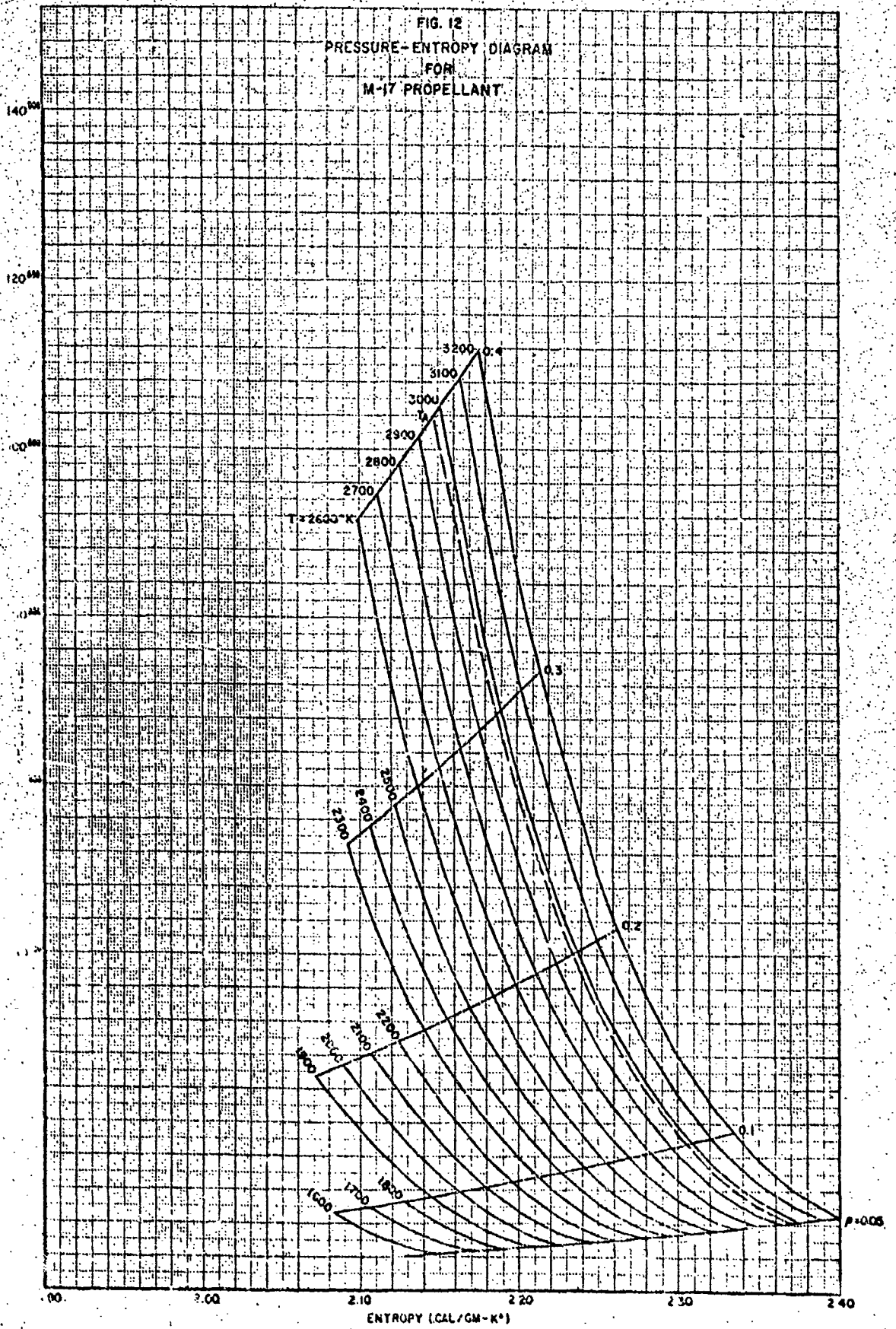


FIG. 13
PRESSURE-ENTROPY DIAGRAM
FOR
M-18 PROPELLANT

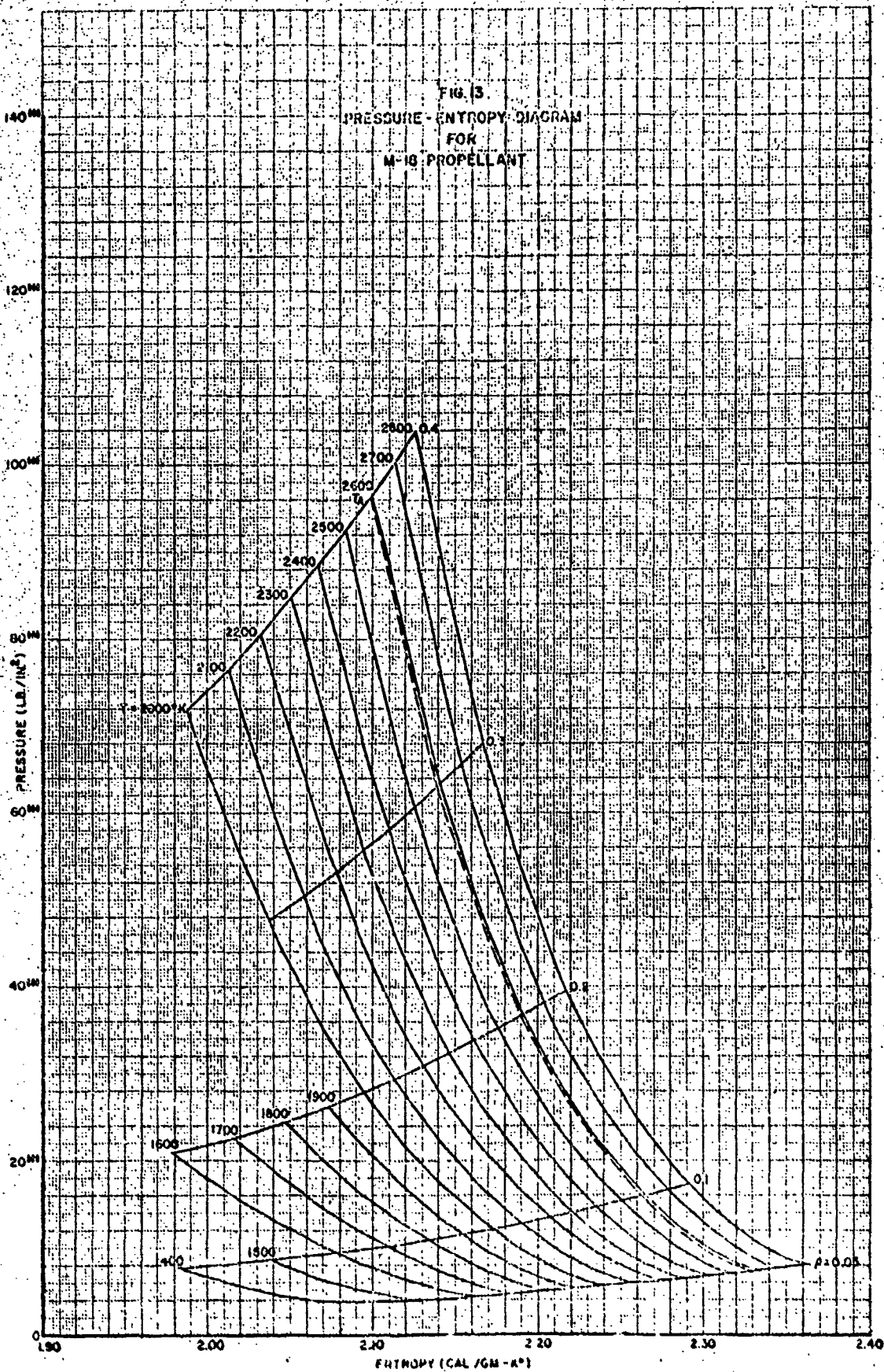


FIG. 14
 PRESSURE-ENTROPY DIAGRAM
 FOR
 IMR PROPELLANT

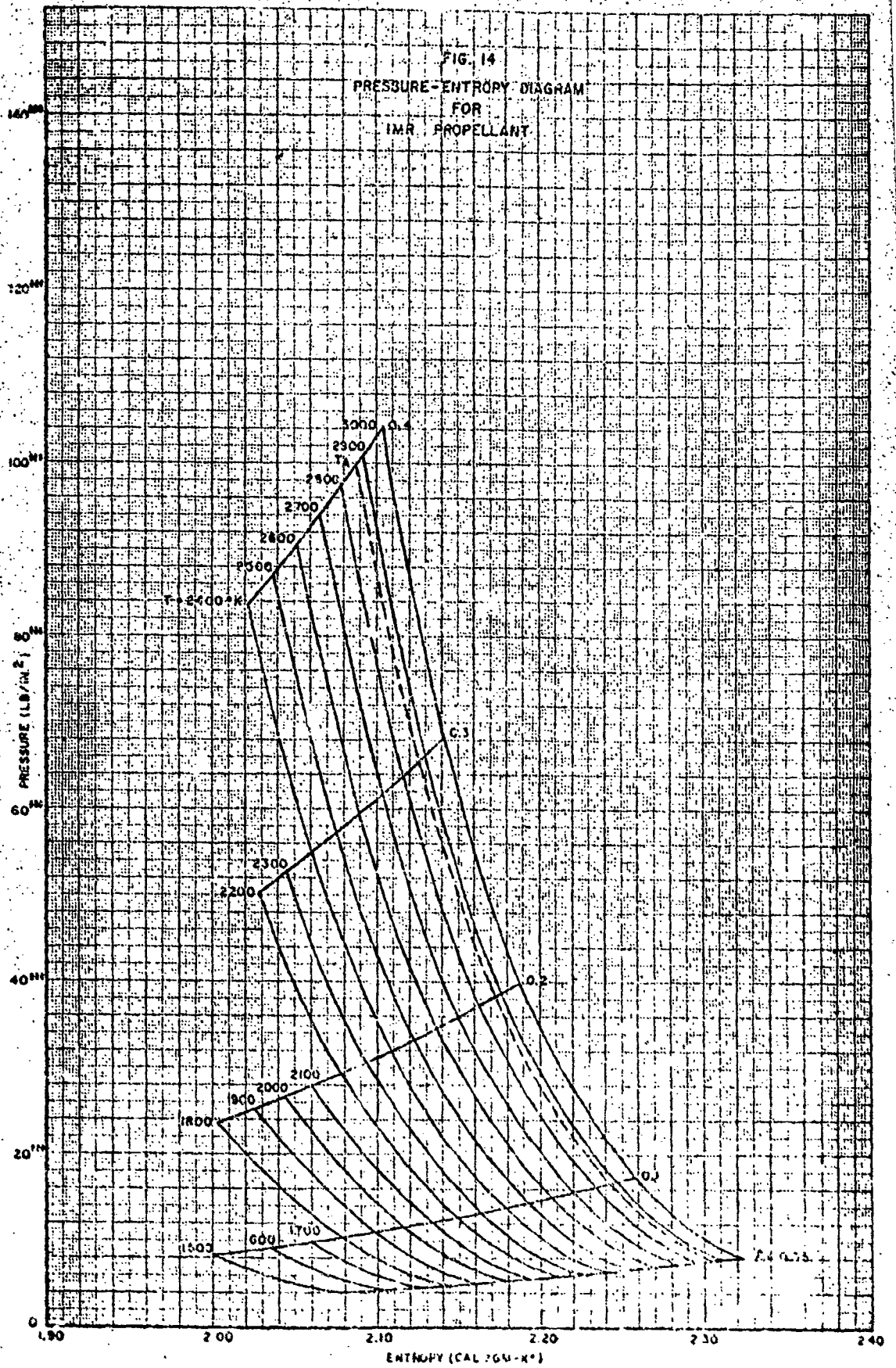


FIG. 15 - COMBUSTION GAS COMBUSTION-TEMPERATURE
 DIAGRAM FOR NI PROPELLANT
 $\Delta = 0.2 \text{ GM./C.C.}$

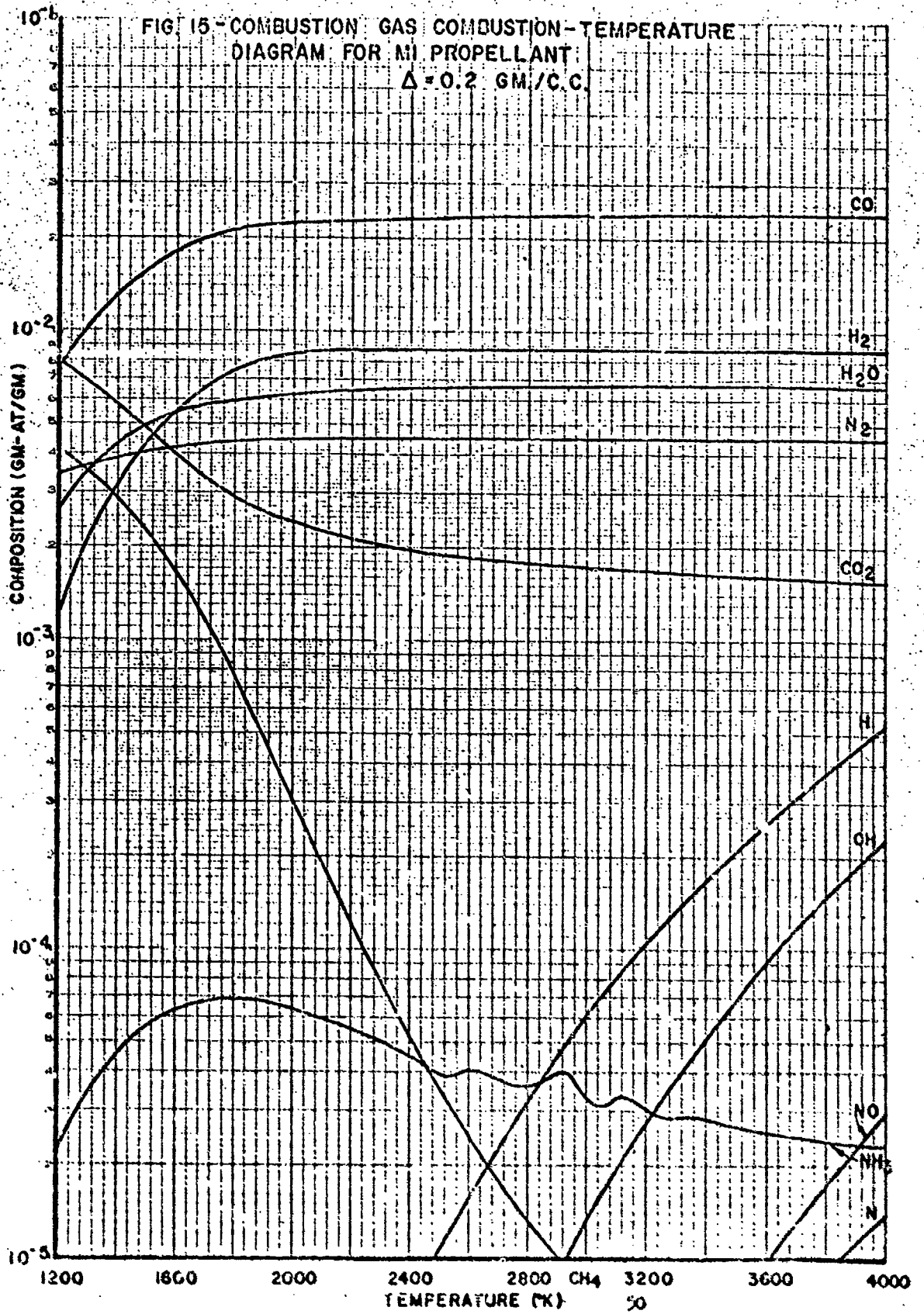
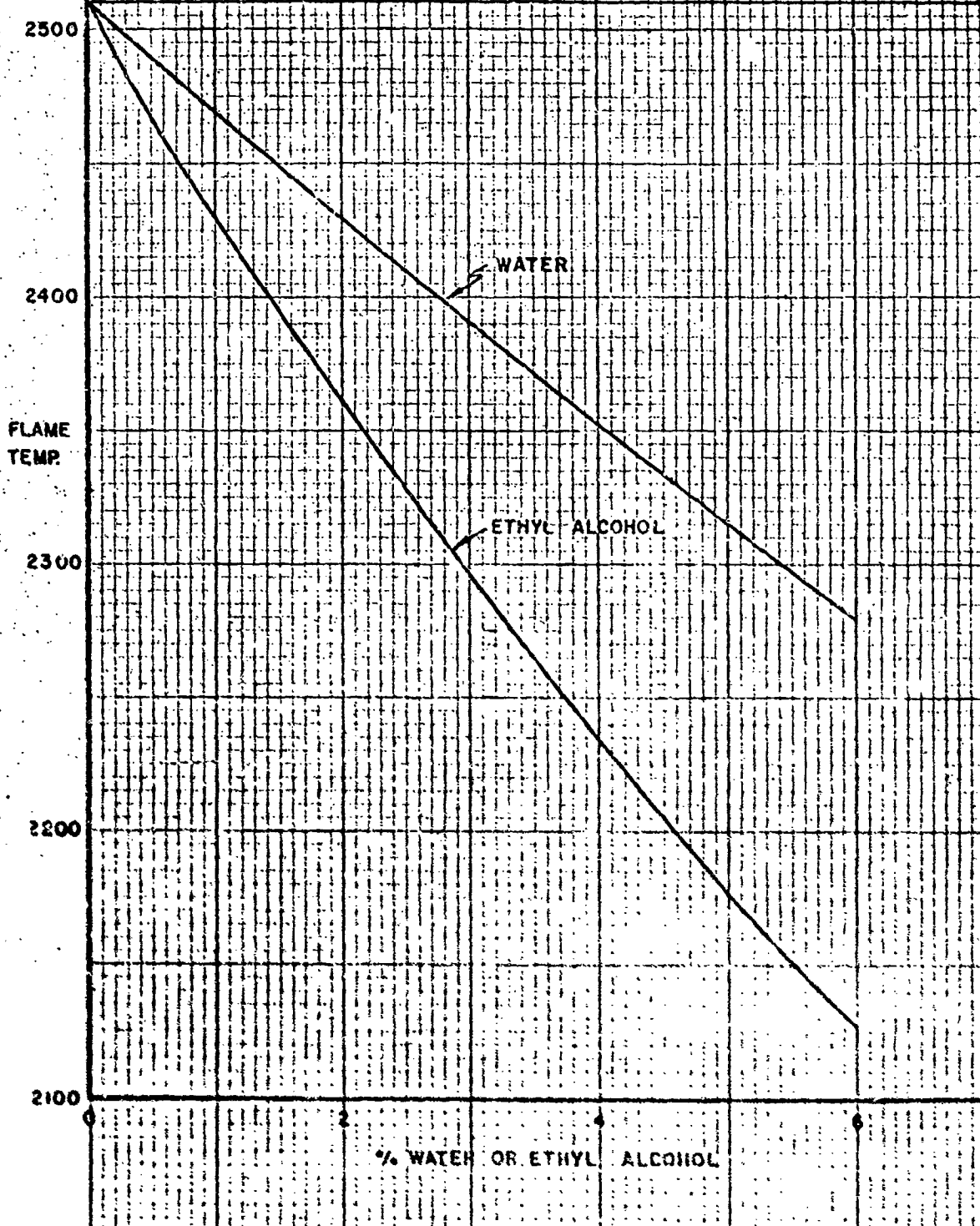


FIG. 16 - VARIATION OF FLAME TEMPERATURE OF MI PROPELLANT WITH ADDED WATER OR ETHYL ALCOHOL



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	PAGE
12.6% NC	260
12.8% NC	263
13.0% NC	266
13.1% NC	269
13.15% NC	272
13.2% NC	275
0% NG 100% NC	278
5% NG 95% NC	282
10% NG 90% NC	286
15% NG 85% NC	290
20% NG 80% NC	294
NI Ideal Gas	298

USE OF TABLES

In the following tables thermodynamic properties and combustion gas composition are listed for all the propellants which appear in Tables I through IV. In the thermodynamic properties and combustion gas composition tables, the type of propellant, for instance M1, appears in the upper left of the title block. In the upper right of the title block is given the loading density (gas density); for instance, 0.05 gm/cc.

In the row following TEMP. °K are combustion gas temperatures at which the combustion gas thermodynamic properties and composition was computed. These temperatures are listed starting at a temperature considerably below the flame temperature, and increase in 100 °K intervals until a temperature is reached which is usually about 200 °K above the flame temperature. The last temperature in this listing is the flame temperature.

In the column below each temperature are the combustion gas thermodynamic properties and composition at a temperature and gas density (loading density). The thermodynamic properties are as follows:

- MOL.WT. - Average molecular weight - gm/gm - mole
- P - Pressure - psi
- E - Energy content - cal/gm
- CV - Specific heat at constant volume - cal/gm - °K
- γ - Ratio of specific heats
- S - Entropy - cal/gm - °K
- E - Internal energy - cal/gm
- HF - Heat of formation - cal/gm

The thermodynamic values are complete for all temperatures listed, except the flame temperature. In the flame temperature column the value for energy content was not computed, thus a blank space appears for this value.

Below the table of thermodynamic properties are listed the combustion gas composition. The gas species are: CO, CO₂, H₂, H₂O, N₂, O₂, O, OH, H, NO, H, NH₃, and CH₄. The units of composition are gm - moles/gm.

In the gas composition tables a number of blanks appear. The presence of blanks means that the computed concentration of a particular specie was less than 1×10^{-7} gm - moles/gm for the temperature and gas density shown.

COMPUTATION OF PROPELLANT FLAME TEMPERATURE

In Leser's report⁽³⁾ no provision was made in the code for the computation of the propellant's flame temperature. The following describes the method used in the revised code so that the flame temperature of the propellant could be computed.

In Hunt⁽⁶⁾ a method is given by which the flame temperature of a propellant may be computed. In this reference the flame temperature is defined as the temperature at which the internal energy of the combustion gases is equal to the heat of reaction of the propellant. This can be represented as:

$$\Delta HF - E = 0 \quad (1A)$$

where:

ΔHF = HF prod - HF prop. = heat of reaction of propellant

E = internal energy of combustion gas at flame temperature - cal/gm

HF prod = heat of formation of combustion gases - cal/gm

HF prop = heat of formation of propellant - cal/gm

The heat of formation of the propellant is given for each propellant, and as such is read into the program as a constant. The base temperature used to compute heats of formation is 25°C (298°K). For some propellants heats of formation were given at 300°K. The difference in heats of formations between the two temperatures was assumed to be negligible.

The heat of formation of the combustion gases is a function of the combustion gas composition, so it has to be computed at each trial temperature for which combustion gas composition is known.

The function used is:

$$HF \text{ prod} = \sum_{i=1}^s n_i (\Delta H_{f,i}) \quad (i = 1, 2, \dots, s) \quad (2A)$$

where: n_i = number of moles of i-th combustion product - moles/gm
 $(\Delta H_f)_i$ = heat of formation of i-th combustion product-cal/mole

The heats of formation of the combustion products are given in Table XII.

In the original Brinkley code, an energy content "e" is computed which is defined as the energy of the combustion gases at temperature T, relative to the elements at 0°K. Since the internal energy of the gases "E" is defined as the amount of energy required to raise the combustion gases from some datum temperature (in this case 25°C) to some temperature T; it is apparent that a correction factor must be used to convert the compute energy content "e" to the internal energy "E". This conversion is made by means of the following relation:

$$E = e + \sum_{i=1}^S n_i (\Delta E_{298} + \Delta_f E_o^0)_i \quad (3A)$$

where: ΔE_{298} = change in internal energy of i-th combustion product from 0°K to 298°K - cal/mole

$\Delta_f E_o^0$ = heat of formation of i-th combustion product from the elements at 0°K - cal/mole

Tables of these values for all the combustion products is found in NBS Circular 500. In Table XIII, the correction factor is listed for each of the combustion products.

To determine the flame temperature, the computer program computes E, HF prod, ΔHF , and $\Delta HF-E$ for a temperature range which has been previously chosen so as to be several hundred of degrees above and below the estimated flame temperature - upon completion of this portion of the problem, the computer checks back until it reaches a set of temperatures in which the difference $\Delta HF-E$ has changed from a positive value to a negative value. Using a 3 point Lagrangian interpolation formulae on values of the difference at three temperature steps; two of which are positive and one negative, a temperature value is found in which this

difference is zero. This temperature is the flame temperature. In addition, the interpolation ratio are used to compute thermodynamic and gas composition values at the flame temperature. When this portion of the program is completed, the values are printed out and the program is stopped.

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.9128	23.3860	22.6442	22.3219	22.1874	22.1288	22.1016
P	3820	4232	4592	4919	5227	5528	5825
e	- 905.10	- 833.26	- 780.16	- 737.89	- 700.54	- 665.09	- 630.36
CV	.321872	.322073	.323716	.326174	.328913	.331561	.334139
γ	1.27553	1.28220	1.28376	1.28238	1.27980	1.27702	1.27429
S	2.08456	2.13417	2.16849	2.19414	2.21549	2.23465	2.25245
E	231.75	299.87	349.32	385.24	424.72	456.69	492.19
HF	1190.15	1187.34	1184.35	1182.00	1180.21	1178.76	1177.56
CO	.0180938	.0201852	.0213654	.0219844	.0223258	.0225413	.0226927
CO2	.0045150	.0038149	.0033761	.0030934	.0028944	.0027410	.0026178
H2	.0074627	.0068747	.0065770	.0063187	.0061438	.0059986	.0059103
H2O	.0045860	.0049135	.0051426	.0053282	.0054862	.0056221	.0057375
N2	.0041937	.0043289	.0044008	.0044341	.0044489	.0044560	.0044596
O2							
O							
OH							
H							
NO							
N							
NH3	.0000246	.0000244	.0000218	.0000187	.0000159	.0000136	.0000116
CH4	.0012441	.0006191	.0002777	.0001213	.0000552	.0000266	.0000139

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2424.76
MOL. WT.	22.0875	22.0791	22.0726	22.0658	22.0597	22.0525	22.0652
P	6120	6414	6707	7001	7294	7587	7073
c	595.80	561.19	526.51	491.67	456.34	420.78	
CV	336594	358841	340885	342911	344663	345327	343371
γ	1.27166	1.26924	1.26725	1.26526	1.26353	1.26192	1.26481
S	2.26931	2.28540	2.30062	2.31503	2.33008	2.34402	2.31868
E	525.79	559.34	593.12	627.22	661.42	695.90	635.68
HF	1176.51	1175.56	1174.65	1173.92	1172.80	1171.75	1172.68
CO	.0226101	.0229099	.0229876	.0230397	.0231202	.0231747	.0230979
CO2	.0025147	.0024268	.0023506	.0023028	.0022271	.0021771	.0022867
H2	.0096293	.0095526	.0094826	.0094371	.0093650	.0093193	.0094215
H2O	.0098371	.0099293	.0099984	.0100456	.0100620	.0100696	.01002816
N2	.0044617	.0044631	.0044642	.0044651	.0044654	.0044659	.0044654
O2							
C							
OH	.0000002	.0000004	.0000008	.0000015	.0000028	.0000047	.0000018
H	.0000032	.0000057	.0000095	.0000152	.0000235	.0000351	.0000170
H2O				.0000001	.0000001	.0000003	.0000001
N						.0000001	.0000001
NH3	.0000104	.0000094	.0000085	.0000078	.0000065	.0000067	.0000075
CH4	.0000078	.0000047	.0000028	.0000019	.0000012	.0000009	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	27.4087	25.2166	23.8163	22.9919	22.5506	22.3261	22.2149
P	7762	8696	9567	10365	11097	11784	12444
e	- 962.68	- 879.17	- 811.15	- 756.29	- 710.90	- 671.00	- 633.99
CV	.329428	.328576	.328713	.329800	.331624	.333703	.336014
γ	1.26679	1.27510	1.27982	1.28128	1.28034	1.27824	1.27560
S	1.98580	2.03840	2.08236	2.11564	2.14159	2.16316	2.18213
E	171.36	253.45	318.55	370.49	413.56	451.70	487.40
HF	1185.93	1185.75	1183.65	1181.23	1179.18	1177.57	1176.33
CO	.0156101	.0181758	.0200587	.0212588	.0219889	.0224181	.0226754
CO2	.0050579	.0041828	.0035589	.0031364	.0028557	.0026008	.0025203
H2	.0052114	.0067711	.0079959	.0087912	.0092068	.0093786	.0094220
H2O	.0045055	.0049767	.0052750	.0054761	.0056289	.0057567	.0058640
H2	.0039929	.0041613	.0042821	.0043596	.0044040	.0044280	.0044409
O2							
O							
OH							
H							
NO							
N							
NH3	.0000341	.0000366	.0000393	.0000372	.0000337	.0000299	.0000263
CH4	.0020728	.0013501	.0007982	.0004341	.0002265	.0001179	.0000640
				.0000001	.0000003	.0000006	.0000001
							.0000012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2427.84
MOL. WT.	22.1572	22.1257	22.1056	22.0929	22.0809	22.0733	22.0895
P	13090	13729	14361	14991	15619	16247	15166
e	- 598.20	- 562.89	- 527.84	- 492.81	- 457.38	- 421.86	
CV	.338369	.340524	.342468	.344481	.346202	.347812	.344990
γ	1.27272	1.26998	1.26783	1.26553	1.26352	1.26163	1.26494
S	2.19959	2.21599	2.23158	2.24588	2.26097	2.27491	2.25000
E	522.12	556.50	590.71	625.11	659.56	694.20	634.70
HF	1175.29	1174.39	1173.56	1172.93	1171.97	1171.09	1172.70
CO	.0228459	.0229683	.0230652	.0231248	.0232092	.0232642	.0231458
CO2	.0024103	.0023202	.0022434	.0021956	.0021211	.0020723	.0021776
H2	.0094082	.0093691	.0093230	.0092917	.0092302	.0091840	.0092777
H2O	.0059572	.0060386	.0061104	.0061554	.0062283	.0062753	.0061729
N2	.0044481	.0044525	.0044554	.0044575	.0044601	.0044605	.0044582
O2							
C							
OH	.0000001	.0000003	.0000006	.0000011	.0000019	.0000033	.0000013
H	.0000022	.0000039	.0000065	.0000105	.0000162	.0000241	.0000119
NO							
N							
NH3	.0000235	.0000212	.0000193	.0000176	.0000147	.0000153	.0000170
CH4	.0000365	.0000221	.0000136	.0000090	.0000060	.0000042	.0000080

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.2

TEMP. °K	1600.00	1700.00	1500.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	26.0921	24.7193	23.7653	23.1294	22.7350	22.4956	22.3533
P	21040	23028	24925	26717	28401	30005	31552
e	- 866.13	- 799.78	- 742.23	- 691.84	- 647.56	- 606.67	- 568.47
CV	335003	327923	326305	335247	340549	342752	344593
γ	1.27251	1.27529	1.27040	1.27651	1.27488	1.27245	1.26980
S	1.97687	2.01711	2.05001	2.07717	2.09993	2.11975	2.13760
E	260.79	325.15	380.47	428.72	471.49	510.93	548.33
HF	1179.54	1178.34	1176.63	1175.02	1173.67	1172.56	1171.65
CO	.0177594	.0194573	.0207807	.0217003	.0223046	.0226996	.0229576
CO2	.0039037	.0033095	.0028795	.0025726	.0023638	.0022143	.0021038
H2	.0034587	.0069253	.0079867	.0080166	.0084192	.0086532	.0087742
H2O	.0054180	.0057264	.0059266	.0060541	.0061616	.0062414	.0063105
N2	.0040783	.0041885	.0042720	.0043317	.0043715	.0043970	.0044133
O2							
OH							
H	.0000001	.0000001	.0000002	.0000004	.0000007	.0000014	.0000025
N							
H3	.0000631	.0000678	.0000688	.0000668	.0000628	.0000584	.0000539
CH4	.0016445	.0011468	.0007618	.0004825	.0003008	.0001876	.0001200

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2433.47
MOL. WT.	22.2603	22.2060	22.1634	22.1703	22.1904
P	33052	34529	35989	37423	35019
e	- 531.45	- 495.19	- 458.89	- 477.41	
CV	346176	348074	349666	349689	348641
γ	1.26780	1.26527	1.26301	1.26295	1.26448
S	2.15407	2.16889	2.16434	2.18076	2.17399
E	584.49	620.17	555.65	637.14	632.07
HF	1170.85	1170.31	1169.52	1169.52	1170.07
CO	.0231429	.0232518	.0233686	.0233604	.0232900
CO2	.0020151	.0019617	.0018860	.0018875	.0019389
H2	.0088376	.0088716	.0088627	.0088529	.0088734
H2O	.0063724	.0064109	.0064771	.0064770	.0064300
H	.0044247	.0044320	.0044359	.0044385	.0044346
O					
OH	.0000004	.0000007	.0000013	.0000013	.0000009
H	.0000042	.0000068	.0000106	.0000104	.0000080
NO			.0000001	.0000001	
N					
NH3	.0000498	.0000459	.0000386	.0000401	.0000439
CH4	.0000761	.0000514	.0000345	.0000372	.0000449

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 0.3

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOLE WT.	23.6512	23.1453	22.6348	22.6075	22.4654	22.3533	22.2917
ρ	48500	51331	54177	56911	59560	62157	64688
c _v	368.03	621.76	578.86	558.32	499.62	461.43	424.12
γ	1.2732	1.348321	1.34959	1.350805	1.352446	1.353788	1.355014
E	2.09937	1.27147	1.26944	1.26804	1.26573	1.26359	1.26141
HF	448.58	2.06185	2.08177	2.09982	2.11568	2.13191	2.14656
	1170.50	493.32	535.12	574.72	612.30	650.26	686.84
		1169.44	1168.54	1167.73	1167.21	1166.54	1165.34
CO	.0215689	.0222144	.0226715	.0230184	.0232333	.0234292	.0235475
CO ₂	.0222016	.0220605	.0219128	.0217966	.0217267	.0216418	.0215834
H ₂	.070069	.074796	.078097	.080525	.082101	.083355	.084298
H ₂ O	.0864523	.0865028	.0866240	.0866753	.0867050	.0867221	.0867939
O ₂	.0342090	.0343123	.0343438	.0343631	.0343347	.0344023	.0344066
H	.0000001	.0000001	.0000002	.0000003	.0000006	.0000010	.0000016
NO	.0000000	.0000010	.0000018	.0000031	.0000050	.0000078	.0000117
N ₂	.0000045	.0001027	.0000989	.0000943	.0000889	.0000801	.0000754
CH ₄	.0006738	.0004720	.0003303	.0002245	.0001586	.0001105	.0000793

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0.3

TEMP. °K	2442.89
MOL. WT.	22.4138
P	60680
CV	.353058
γ	1.26479
S	2.12259
E	628.94
HF	1166.94
CO	.0233156
CO ₂	.5016921
H ₂	.0082584
H ₂ O	.0067262
H ₂	.0043921
O	.0000008
OH	.5017061
H	
NO	
N	
NH ₃	.0000845
CM ₄	.0001358

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1
0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.6242	24.0172	23.5613	23.1899	22.9343	22.7189	22.5871
P	72824	77477	81992	86372	90598	94745	98725
e	- 640.36	- 640.26	- 393.71	- 549.46	- 507.69	- 466.75	- 427.36
CV	553171	354577	355412	356574	357713	358721	359620
γ	1.27515	1.27154	1.26994	1.26928	1.26718	1.26542	1.26348
z	1.58761	2.01196	2.03363	2.05355	2.07050	2.08784	2.10333
z	422.73	471.51	517.14	560.43	601.57	641.64	680.42
MF	1166.57	1169.73	1164.90	1164.23	1163.75	1162.22	1162.51
CO	.0207222	.0219260	.0221551	.0226418	.0229876	.0232951	.0235003
CO2	.0021947	.0019465	.0017620	.0016131	.0015190	.0014179	.0013550
H2	.0055555	.0061311	.0065631	.0069630	.0072588	.0074923	.0076892
H2O	.0067803	.0068618	.0069493	.0070592	.0071928	.0073498	.0075289
H2	.0041569	.0042078	.0042487	.0042856	.0043099	.0043395	.0043641
O2							
N							
OH	.0000001	.0000001	.0000001	.0000003	.0000005	.0000009	.0000013
H	.0000007	.0000007	.0000013	.0000023	.0000037	.0000059	.0000089
HO							
H2O2	.0001473	.0001517	.0001526	.0001517	.0001476	.0001295	.0001181
CH4	.0000723	.0000824	.0000824	.0000682	.0000592	.0000461	.0000343

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 0.4

TEMP. °K	2459.04
MOL. WT.	22.8025
P	93055
e	
CV	352347
γ	1.26612
S	2.08072
E	625.44
HF	1163.44
CO	.0231755
CO2	.0014605
H2	.0074040
H2O	.0070473
N2	.0043270
O2	
C	
OH	.0000007
H	.0000049
NO	
N	
NH3	.0001387
CH4	.0002962

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MIAI 0.05

TEMP. °K	1300.00	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00
MO. WT.	27.5009	24.8770	23.2038	22.3473	21.9495	21.7764	21.6992
P	3406	3865	4295	4674	5016	5356	5645
c	- 984.55	- 889.90	- 813.00	- 756.67	- 711.83	- 673.03	- 636.75
CV	32055	32023	325984	327347	326328	322300	334942
γ	1.26507	1.27483	1.28256	1.28514	1.28442	1.28217	1.27952
z	2.03173	2.10179	2.15442	2.19126	2.21347	2.24065	2.26020
z	132.50	225.27	290.92	349.89	391.01	425.58	463.55
HF	1107.44	1108.66	1105.15	1161.58	1150.92	1157.00	1155.54

CO	332472	3122864	3205411	3213773	3225965	3229862	3232212
CO2	3022800	3142832	3035607	3031025	3028107	3026109	3024608
H2	3057262	3077070	3093114	3122206	3106038	3107266	3106929
H2O	3039314	3044584	3047342	3049328	3050952	3052371	3053617
O2	3035074	3140347	3041464	3042209	3042667	3042851	3042939
H							
OH							
H							
NO							
N							
CH3	3000225	3000255	3000259	3000237	3000206	3000177	3000153
CH4	3023170	3014511	3007675	3003643	3001655	3000770	3000371

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

		M1A1				0.05	
TEMP. °K		2000.00	2100.00	2200.00	2300.00	2400.00	2236.97
MOL. WT.		21.6633	21.6448	21.6341	21.6262	21.6197	21.6308
P		5949	6252	6533	6852	7152	6664
c		- 501.47	- 566.47	- 531.47	- 496.42	- 461.21	
CV		.337542	.340032	.342320	.344410	.346475	.343115
γ		1.27683	1.27420	1.27177	1.26976	1.26775	1.27098
γ		2.27835	2.29542	2.31169	2.32728	2.34162	2.31753
E		497.43	531.40	565.47	599.65	634.14	578.10
HF		1154.36	1153.34	1152.42	1151.55	1150.84	1152.10
CO		.0233767	.0234965	.0235904	.0236694	.0237195	.0236214
CO2		.0023424	.0022443	.0021613	.0020896	.0020447	.0021355
H2		.0106376	.0105707	.0105036	.0104410	.0104000	.0104799
H2O		.0054686	.0055612	.0056416	.0057116	.0057557	.0056687
N2		.0042985	.0043011	.0043027	.0043040	.0043050	.0043033
O2							
O							
OH		.0000001	.0000002	.0000004	.0000007	.0000014	.0000005
H		.0000018	.0000034	.0000059	.0000100	.0000160	.0000073
HO						.0000001	
H+3		.0000135	.0000118	.0000106	.0000097	.0000089	.0000102
CH4		.0000199	.0000112	.0000067	.0000041	.0000027	.0000056

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

H1A1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	27.5102	25.2149	23.7017	22.7679	22.2398	21.9577	21.8132
P	7836	8796	9702	10539	11308	12026	12709
e	- 550.66	- 864.41	- 792.91	- 734.56	- 686.29	- 644.39	- 606.10
CV	.333955	.332000	.332940	.333779	.335397	.337343	.339594
γ	1.26524	1.27404	1.27950	.28161	1.28160	1.27998	1.27760
S	1.99496	2.05457	2.10077	2.13618	2.16378	2.18642	2.20606
H	162.18	246.66	314.69	369.58	415.10	455.00	491.86
HF	1165.03	1164.38	1161.79	1156.90	1156.49	1154.67	1153.32
CO	.0156802	.0183255	.0203072	.0216609	.0225031	.0230067	.0233051
CO2	.0048500	.0039659	.0033278	.0028898	.0025978	.0023977	.0022568
H2	.0052540	.0069654	.0082499	.0093247	.0098953	.0101761	.0102866
H2O	.0043761	.0048233	.0050953	.0052683	.0053961	.0055046	.0055952
N2	.0038031	.0039706	.0040951	.0041793	.0042305	.0042595	.0042755
O2							
OH							
H							
NO							
N							
H3	.0000345	.0000398	.0000415	.0000402	.0000371	.0000334	.0000297
CH4	.0023122	.0015680	.0009743	.0005582	.0003044	.0001635	.0000906

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

MIAL

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2241.94
MOL. WT.	21.7370	21.6952	21.6686	21.6524	21.6822
P	13276	14033	14680	15326	14305
•	- 569.44	- 533.51	- 457.95	- 462.46	
• V	• 341935	• 344099	• 346077	• 348117	• 344951
Y	1.27485	1.27217	1.27004	1.26775	1.27121
S	2.22593	2.24063	2.25645	2.27091	2.24737
E	527.40	562.40	597.13	631.99	577.00
MF	1152.25	1151.35	1150.53	1149.92	1151.00
CO	• 234963	• 0236281	• 0237294	• 0237910	• 0236743
CO2	• 0021488	• 0020620	• 0019669	• 0019434	• 0020297
H2	• 0103121	• 0102974	• 0102680	• 0102465	• 0102868
H2O	• 0056815	• 0057552	• 0058207	• 0058619	• 0057837
H2	• 0042645	• 0042895	• 0042936	• 0042961	• 0042917
O2					
OH	• 0000001	• 0000003	• 0000005	• 0000010	• 0000004
H	• 0000023	• 0000041	• 0000066	• 0000110	• 0000051
NO					
N					
NH3	• 0000266	• 0000241	• 0000220	• 0000202	• 0000232
CH4	• 0000524	• 0000320	• 0000197	• 0000131	• 0000259

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

G.2

MIA)

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	26.1605	24.7067	23.6661	22.9445	22.4763	22.1795	21.9972
P	21273	23324	25298	27176	28944	30626	32240
e	- 852.58	- 783.76	- 723.48	- 670.42	- 623.58	- 580.89	- 541.00
CV	.342780	.342625	.343030	.343684	.345014	.346807	.348475
γ	1.27071	1.27412	1.27584	1.27630	1.27542	1.27342	1.27109
S	1.99147	2.03321	2.06767	2.09633	2.12035	2.14115	2.15965
E	253.13	319.59	377.26	427.90	472.62	514.01	552.75
HF	1158.45	1156.94	1154.95	1152.97	1151.34	1150.03	1149.00
CO	.0178356	.0196316	.0210147	.0220341	.0227293	.0231985	.0235044
CO2	.0037071	.0031082	.0026698	.0023538	.0021373	.0019825	.0018701
H2	.0055866	.0067531	.0077431	.0085105	.0090416	.0093802	.0095775
H2O	.0052645	.0055513	.0057279	.0058410	.0059164	.0059776	.0060322
H2	.0038852	.0039959	.0040823	.0041469	.0041919	.0042221	.0042418
O2							
OH							
H							
NO							
N							
HM3	.0000649	.0000709	.0000732	.0000726	.0000694	.0000654	.0000610
CH4	.0018816	.0013638	.0009433	.0006242	.0004047	.0002604	.0001705
		.0000001	.0000002	.0000004	.0000008	.0000015	.0000026

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MIAI

TEMP. °K	2300.00	2400.00	2257.85
MOL. WT.	21.8747	21.8024	21.9196
P	33758	35324	33148
e	- 502.79	- 465.67	.349418
CV	.250096	.351961	1.26959
Z	1.26928	1.26691	2.16969
S	2.17609	2.19186	574.47
F	590.00	626.49	1148.47
MF	1148.12	1147.53	
CO	.0237256	.0238564	.0236423
CO2	.0017808	.0017273	.0018157
H2	.0096586	.0097686	.0096563
H2O	.0060823	.0061134	.0060617
N2	.0042559	.0042650	.0042506
O2			
O	.0000004	.0000007	.0000003
OH	.0000044	.0000072	.0000036
H			
NO			
N			
NH3	.0000568	.0000527	.0000586
CH4	.0001100	.0000751	.0001321

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MIAI

C.3

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MOL. WT.	26.4458	25.1875	24.2183	23.5031	22.9793	22.6096	22.3255
p	39162	42570	45914	49140	52252	55239	58115
e	623.75	759.52	701.03	648.26	599.72	554.79	512.35
CV	350522	350664	350758	351570	352961	354056	355246
γ	1.27016	1.27169	1.27264	1.27252	1.27122	1.26964	1.26856
S	1.96139	1.99810	2.02967	2.05673	2.08038	2.10125	2.12014
E	276.45	338.83	395.29	446.25	493.19	536.80	578.09
HF	1152.82	1151.65	1150.20	1148.82	1147.55	1146.46	1145.43

CO	.0180604	.0195927	.0208357	.0217857	.0225073	.0230345	.0234469
CO2	.0032781	.0027539	.0023568	.0020736	.0018654	.0017134	.0015934
H2	.0048390	.0057873	.0066534	.0073842	.0079671	.0083995	.0087366
H2O	.0057327	.0059976	.0061649	.0062601	.0063197	.0063617	.0063951
H2	.0038491	.0039404	.0040164	.0040768	.0041237	.0041590	.0041873
O							
OH							
H							
NO		.0000001	.0000002	.0000005	.0000010	.0000019	.0000032
N							
NH3	.0000949	.0001044	.0001107	.0001128	.0001126	.0001101	.0001065
CH4	.0019591	.0015258	.0011529	.0008537	.0006204	.0004488	.0003145

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MIA1 0.3

TEMP. °K.		2400.00	2284.01
MOL. WT.		22.1469	22.3683
P		60882	57660
C		472.17	
CV		356771	355044
Z		1.26658	1.26870
S		2.13061	2.11724
F		617.51	571.63
HF		1144.63	1145.63
CO		.0237111	.0233879
CO2		.0015203	.0016106
H2		.0089683	.0086900
H2O		.0064119	.0063903
N2		.0042072	.0041832
O2			
OH		.0000005	.0000003
H		.0000052	.0000030
H2O			
N			
H+3		.0001014	.0001071
CH4		.0002271	.0003337

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1A1 0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2316.90
MU. WT.	24.6501	23.9830	23.4773	23.0482	22.7427	22.9887
P	73824	78666	83374	87968	92401	98728
e	- 673.62	- 621.75	- 573.18	- 526.91	- 483.55	
CV	.358356	.359719	.360416	.361411	.362601	.361599
γ	1.27170	1.27039	1.26917	1.26859	1.26707	1.26659
S	2.00291	2.02618	2.05074	2.07133	2.08925	2.07453
E	418.07	468.55	515.68	561.00	603.74	568.37
MF	1145.31	1144.32	1143.40	1142.50	1141.87	1142.37
CO	.208012	.0216472	.0223153	.0226872	.0232908	.0229664
CO2	.0020304	.0017815	.0015954	.0014440	.0013472	.0014240
H2	.0057490	.0063961	.0069429	.0074374	.0078173	.0075091
H2O	.0065732	.0066558	.0067046	.0067339	.0067412	.0067366
O2	.0039579	.0040097	.0040523	.0040899	.0041190	.0040953
OH						
H	.0000001	.0000001	.0000001	.0000003	.0000005	.0000003
NO	.0000004	.0000007	.0000013	.0000023	.0000035	.0000026
N						
NH3	.0001561	.0001631	.0001664	.0001679	.0001654	.0001676
CH4	.0012996	.0010333	.0008159	.0006246	.0004848	.0005976

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2

0.05

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	25.2475	25.2450	25.2430	25.2405	25.2380	25.2339	25.2277
P	4601	5057	5313	5568	5823	6079	6334
•	-1030.71	- 946.49	- 962.12	- 927.59	- 892.92	- 858.07	- 822.67
CV	331264	333977	336530	338816	340851	342900	344647
γ	1.24575	1.24299	1.24042	1.23812	1.23625	1.23453	1.23268
g	2.10092	2.11648	2.13525	2.15132	2.16674	2.18118	2.19603
g	452.57	485.34	510.44	551.85	585.43	619.45	653.55
MF	1541.89	1540.45	1539.18	1538.05	1536.96	1536.14	1534.85
CO	.0139957	.0141438	.0142710	.0142816	.0144731	.0145403	.0146393
CO2	.0004979	.0063513	.0062250	.0061156	.0060201	.0059597	.0058632
H2	.004731	.0043285	.0042053	.0041943	.0039986	.0039377	.0038410
H2O	.0097504	.0098553	.0099756	.0100891	.0101842	.0102439	.0103387
O2	.0049289	.0049295	.0049300	.0049304	.0049307	.0049312	.0049318
OH	.0000001	.0000002	.0000005	.0000011	.0000022	.0000041	.0000074
H	.0000006	.0000012	.0000021	.0000037	.0000062	.0000099	.0000151
N	.0000043	.0000036	.0000031	.0000027	.0000024	.0000022	.0000021
CH4	.0000009	.0000004	.0000002	.0000001	.0000001	.0000003	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M2

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MCL. WT.	25.2153	25.2068	25.1892	25.1651	25.1316	25.0871	25.0283
P	5590	6847	7104	7363	7623	7885	8149
•	787.01	750.90	714.13	676.58	638.03	598.26	556.92
CV	346282	347762	349246	350557	351800	352918	353960
γ	1.23117	1.22989	1.22862	1.22750	1.22653	1.22573	1.22503
S	2.21002	2.22365	2.23702	2.25019	2.26320	2.27629	2.28941
E	689.03	722.70	757.65	793.28	829.11	865.35	902.10
HF	1533.67	1532.30	1530.61	1528.53	1525.84	1522.33	1517.75

CO	.0147072	.0147699	.0148284	.0148869	.0149424	.0150024	.0150689
CO2	.0057987	.0057411	.0056896	.0056431	.0055993	.0055575	.0055151
H2	.0037799	.0037169	.0036680	.0036239	.0035864	.0035532	.0035204
H2O	.0104500	.0104523	.0104551	.0104587	.0104632	.0104670	.0104700
H2	.0049323	.0049331	.0049340	.0049349	.0049363	.0049377	.0049393
O2	.0000001	.0000001	.0000003	.0000006	.0000013	.0000025	.0000045
OH	.0000126	.0000001	.0000003	.0000006	.0000012	.0000023	.0000042
H	.0000224	.0000207	.0000328	.0000502	.0000747	.0001081	.0001520
NO	.0000012	.0000323	.0000452	.0000622	.0000836	.0001102	.0001430
N	.0000001	.0000021	.0000037	.0000062	.0000099	.0000154	.0000233
NH3	.0000001	.0000002	.0000003	.0000005	.0000009	.0000014	.0000021
CH4	.0000018	.0000017	.0000015	.0000017	.0000014	.0000014	.0000012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M2

TEMP. °K	3300.00	3400.00	3500.00	3330.26
MOL. WT.	24.9519	24.8541	24.7304	24.9247
P	8417	8089	8937	8498
Q	- 513.68	- 468.15	- 419.87	
CV	354875	355703	356455	355130
γ	1.22451	1.22417	1.22404	1.22439
ρ	2.30271	2.31650	2.33029	2.30679
E	939.39	977.27	1015.83	950.78
HF	1511.89	1504.31	1494.67	1509.78
CO	.0151449	.0152345	.0153423	.0151705
CO2	.0054756	.0054215	.0052652	.0054563
H2	.0035120	.0035037	.0035043	.0035093
H2O	.0105605	.0105370	.0104978	.0105249
N2	.0049409	.0049426	.0049443	.0049414
O2	.0000000	.0000135	.0000219	.0000094
O	.0000074	.0000125	.0000203	.0000087
OH	.0002166	.0002644	.0003766	.0002311
H	.0001627	.0002304	.0002871	.0001962
NO	.0000342	.0000489	.0000683	.0000382
N	.0000052	.0000047	.0000067	.0000036
HO2	.0000012	.0000012	.0000011	.0000012
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.1

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	25.2620	25.2546	25.2503	25.2471	25.2440	25.2404	25.2352
P	11208	10756	10304	9851	9396	8943	8487
e	-1032.77	-988.59	-943.90	-899.25	-854.57	-809.72	-764.26
CV	1332062	1335375	1337977	1340246	1342189	1344265	1345999
γ	1.25567	1.24731	1.24409	1.24122	1.23905	1.23668	1.23463
ρ	4.064054	2.55819	2.07502	2.09114	2.10657	2.12101	2.13585
L	446.98	432.02	415.33	548.00	582.59	616.72	650.92
MF	1540.36	1539.02	1537.83	1536.77	1535.78	1535.06	1533.90

CO	0.000000	0.0142793	0.0145953	0.0145032	0.0145979	0.0146583	0.0147550
CO2	0.000000	0.0064197	0.0060970	0.0059909	0.0059977	0.0058368	0.0057444
H2	0.000000	0.0041805	0.0040677	0.0039639	0.0038719	0.0038137	0.0037202
H2O	0.000000	0.0098854	0.0101063	0.0102189	0.0103057	0.0103641	0.0104576
H	0.000000	0.0049264	0.0049274	0.0049281	0.0049287	0.0049293	0.0049301
O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HF	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Cl	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

1/2

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	25.2294	25.2204	25.2081	25.1919	25.1692	25.1378	25.1074
P	14333	14579	15127	15675	16226	16779	17336
e	- 768.63	- 753.00	- 716.64	- 679.71	- 642.04	- 603.55	- 562.94
CV	347574	345995	350473	351806	352984	354086	355154
γ	1.23278	1.25126	1.22965	1.22820	1.22694	1.22587	1.22481
S	2.14979	2.16331	2.17654	2.18950	2.20226	2.21487	2.22744
E	655.45	720.18	755.25	790.59	826.28	862.26	898.65
HF	1532.91	1531.81	1530.53	1528.95	1527.00	1524.50	1521.51

CO	.0148202	.0148600	.0149348	.0149803	.0150377	.0150888	.0151433
CO2	.0056816	.0056254	.0055736	.0055308	.0054820	.0054503	.0054123
H2	.0026569	.0026013	.0025525	.0025091	.0024724	.0024417	.0024146
H2O	.0105182	.0105707	.0106146	.0106502	.0106788	.0106982	.0107093
N2	.0049505	.0049311	.0049318	.0049323	.0049336	.0049344	.0049355
O2	.0000001	.0000001	.0000001	.0000003	.0000006	.0000012	.0000021
OH	.0000088	.0000001	.0000001	.0000003	.0000005	.0000011	.0000020
H	.0000153	.0000145	.0000230	.0000353	.0000525	.0000761	.0001077
NO	.0000008	.0000220	.0000309	.0000424	.0000570	.0000751	.0000973
N	.0000001	.0000015	.0000026	.0000043	.0000069	.0000108	.0000163
NH3	.0000039	.0000001	.0000002	.0000004	.0000006	.0000010	.0000015
CH4	.0000001	.0000035	.0000034	.0000037	.0000030	.0000030	.0000027

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M2

TEMP. °K	3300.00	3400.00	3500.00	3354.16
MOL. WT.	25.0453	24.9788	24.8949	25.0111
P	17898	18464	19029	18204
e	- 523.02	- 480.55	- 436.23	
CV	.356098	.556931	.357703	.356557
γ	1.22397	1.22328	1.22277	1.22357
S	2.24002	2.25270	2.26554	2.24698
E	935.46	972.70	1010.40	955.57
HF	1517.23	1512.04	1505.49	1514.57
CO	.0152028	.0152704	.0153491	.0152384
CO2	.0053742	.0053340	.0052900	.0053527
H2	.0032941	.0033797	.0033723	.0033855
H2O	.0107107	.0107017	.0106810	.0107071
N2	.0049065	.0049374	.0049381	.0049370
O2	.0000035	.0000064	.0000105	.0000051
O	.0000036	.0000061	.0000099	.0000048
OH	.0001488	.0002015	.0002677	.0001759
H	.0001243	.0001565	.0001947	.0001411
NO	.0000240	.0000345	.0000483	.0000293
N	.0000022	.0000053	.0000047	.0000028
NH3	.0000026	.0000025	.0000024	.0000026
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MZ 0.2

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	25.2645	25.2581	25.2532	25.2469	25.2426	25.2356	25.2266
P	27080	28325	29574	30814	32056	33300	34544
e	931.75	896.93	861.90	826.40	790.79	755.04	718.61
CV	343251	345009	347149	348858	350210	351569	353068
T	1.24536	1.24282	1.23978	1.23716	1.23483	1.23303	1.23092
S	2.02473	2.04024	2.05476	2.06967	2.08364	2.09714	2.11031
Z	543.37	577.32	611.75	646.26	681.03	715.90	751.15
HF	1533.72	1532.85	1532.25	1531.27	1530.44	1529.57	1528.58

CO	.0147799	.0148723	.0149302	.0150231	.0150840	.0151399	.0151904
CO2	.0057047	.0056161	.0055608	.0054709	.0054120	.0053591	.0053123
H2	.0030592	.0035763	.0035243	.0034384	.0033797	.0033285	.0032835
H2O	.0104958	.0105846	.0106345	.0107297	.0107869	.0108374	.0108802
N2	.0049223	.0049237	.0049248	.0049264	.0049266	.0049274	.0049282
O2							
O							
OH	.0000005	.0000011	.0000020	.0000036	.0000061	.0000101	.0000160
H	.0000016	.0000027	.0000043	.0000067	.0000099	.0000142	.0000200
NO							
N				.0000001	.0000006	.0000010	.0000018
NH3	.0000142	.0000125	.0000113	.0000092	.0000093	.0000091	.0000080
CH4	.0000030	.0000017	.0000011	.0000007	.0000005	.0000003	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M2

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	25.2163	25.1987	25.1782	25.1504	25.1152	25.0705	25.0140
P	35788	37036	38286	39540	40800	42065	43329
e	682.10	644.95	607.21	568.65	529.17	488.64	446.92
CV	354375	355464	356507	357587	358506	359306	360204
γ	1.22903	1.22738	1.22599	1.22453	1.22325	1.22220	1.22129
S	2.12317	2.12578	2.14814	2.16037	2.17251	2.18460	2.19668
E	786.60	822.40	858.34	894.67	931.32	968.26	1005.50
HF	1527.39	1526.00	1524.23	1522.00	1519.19	1515.54	1511.20
CO	.0152961	.0152826	.0152263	.0153718	.0154194	.0154717	.0155307
CO2	.0022709	.0052316	.0051963	.0051621	.0051289	.0050949	.0050592
H2	.0032424	.0032088	.0031767	.0031335	.0031325	.0031165	.0031056
H2O	.0105148	.0109454	.0109675	.0109230	.0109909	.0109911	.0109828
N2	.0049281	.0049297	.0049302	.0049312	.0049318	.0049322	.0049325
O2	.0000001	.0000003	.0000005	.0000009	.0000017	.0000028	.0000047
O	.0000001	.0000003	.0000005	.0000009	.0000017	.0000028	.0000046
OH	.0000240	.0000367	.0000535	.0000755	.0001040	.0001420	.0001891
H	.0000274	.0000365	.0000485	.0000628	.0000802	.0001009	.0001254
HO	.0000030	.0000048	.0000075	.0000114	.0000165	.0000242	.0000340
H	.0000003	.0000004	.0000007	.0000011	.0000016	.0000023	.0000033
NH3	.0000087	.0000071	.0000070	.0000064	.0000061	.0000060	.0000056
CN4	.0000002	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.2

TEMP. °K	3371.58
MOL. WT.	25.0842
P	41705
e	
CV	.359091
γ	1.22248
S	2.18117
E	957.73
HF	1516.73
CO	.0154564
CO2	.0051047
H2	.0031207
H2O	.0109919
N2	.0049321
O2	.0000024
O	.0000024
OH	.0001305
H	.0000947
NO	.0000219
N	.0000021
NH3	.0000060
CH4	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

O.3

M2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	25.2456	25.2415	25.2342	25.2180	25.2019	25.1793	25.1513
P	57278	59397	61512	63635	65755	67821	70010
e	- 755.02	- 719.28	- 652.61	- 645.43	- 607.92	- 569.65	- 530.64
CV	.594344	.555869	.357149	.358139	.359113	.260196	.361081
γ	1.23562	1.23315	1.23092	1.22902	1.22741	1.22565	1.22410
S	2.05298	2.06619	2.07505	2.09165	2.10393	2.11607	2.12805
E	712.37	747.89	783.56	819.62	855.69	892.18	928.93
HF	1526.61	1525.79	1524.79	1523.69	1522.26	1520.49	1518.25

CO	.0154556	.0154866	.0155273	.0155711	.0156100	.0156507	.0156923
CO2	.0050521	.0050097	.0049721	.0049349	.0049027	.0048713	.0048412
H2	.0030118	.0029713	.0029330	.0029042	.0028767	.0028541	.0028351
H2O	.0111417	.0111820	.0112157	.0112444	.0112656	.0112823	.0112919
N2	.0049228	.0049257	.0049232	.0049255	.0049259	.0049270	.0049276
O2			.0000001	.0000002	.0000003	.0000005	.0000010
O			.0000001	.0000002	.0000003	.0000006	.0000010
OH	.0000081	.0000129	.0000199	.0000297	.0000432	.0000612	.0000849
H	.0000104	.0000145	.0000199	.0000268	.0000353	.0000458	.0000584
HO	.0000008	.0000015	.0000024	.0000039	.0000061	.0000093	.0000137
N	.0000001	.0000001	.0000002	.0000003	.0000006	.0000009	.0000013
NH3	.0000153	.0000143	.0000158	.0000126	.0000125	.0000113	.0000108
CH4	.0000009	.0000007	.0000005	.0000004	.0000003	.0000002	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.3

TEMP. °K	3400.00	3500.00	3376.39
MOL. WT.	25.1162	25.0716	25.1251
P	72142	74286	71639
e	- 490.83	- 450.12	
CV	.361813	.362752	.361655
γ	1.22281	1.22164	1.22309
S	2.13993	2.15172	2.13714
E	965.90	1002.05	957.15
HF	1515.43	1511.91	1516.15

CO	.0157372	.0157872	.0157263
CO2	.0046107	.0047789	.0048179
H2	.0028195	.0028067	.0028229
H2O	.0112950	.0112912	.0112949
N2	.0049279	.0049281	.0049273
O2	.0000017	.0000028	.0000015
O	.0000017	.0000029	.0000015
OH	.0001155	.0001540	.0001076
H	.0000735	.0000914	.0000697
NO	.0000197	.0000278	.0000182
N	.0000019	.0000027	.0000017
NH3	.0000105	.0000099	.0000106
CH4	.0000001	.0000001	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.4

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	25.2526	25.2557	25.2220	25.2019	25.1780	25.1484	25.1106
P	53884	97085	100275	103470	106665	109857	113060
e	- 681.76	- 644.45	- 506.96	- 568.74	- 529.88	- 490.36	- 450.16
CV	360126	361012	361914	362996	363640	364493	365465
γ	1.23467	1.23256	1.23076	1.22876	1.22699	1.22551	1.22414
S	2.04357	2.05620	2.06847	2.08059	2.09253	2.10431	2.11595
E	781.28	917.69	853.95	890.69	927.64	964.76	1001.98
HF	1521.65	1520.76	1519.55	1518.07	1516.19	1513.81	1510.85
CO	.0158462	.0158884	.0159233	.0159605	.0159977	.0160375	.0160819
CO2	.0046452	.0046100	.0045809	.0045520	.0045247	.0044970	.0044681
H2	.0025926	.0025683	.0025442	.0025249	.0025085	.0024949	.0024854
H2O	.0115385	.0115688	.0115883	.0116046	.0116143	.0116181	.0116163
N2	.0049170	.0049204	.0049208	.0049222	.0049229	.0049231	.0049234
O2	.0000001	.0000001	.0000002	.0000004	.0000007	.0000011	.0000019
C	.0000001	.0000001	.0000002	.0000004	.0000007	.0000012	.0000020
CH	.0000171	.0000255	.0000371	.0000528	.0000735	.0000998	.0001333
H	.0001150	.0001202	.0001267	.0001346	.0001441	.0001556	.0001691
NO	.0000021	.0000034	.0000053	.0000081	.0000120	.0000173	.0000244
N	.0000003	.0000003	.0000005	.0000007	.0000011	.0000016	.0000023
NH3	.0000249	.0000199	.0000197	.0000178	.0000169	.0000165	.0000156
CH4	.0000011	.0000008	.0000006	.0000005	.0000004	.0000003	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M2 0.4

TEMP. °K 3374.96

MOL. WT.
 P 25.1564
 C 109058
 CV .364348
 T 1.22585
 S 2.10138
 E 955.45
 HF 1514.45

CO	.0160273
CO2	.0045040
H2	.0024980
H2O	.0116177
N2	.0049231
O2	.0000010
O	.0000001
OH	.0000926
H	.0000525
NO	.0000159
N	.0000015
NH3	.0000156
CH4	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

M5

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOL. WT.	25.0205	25.0154	25.0125	25.0104	25.0081	25.0052	25.0008
P	4589	4848	5106	5364	5622	5880	6138
e	-1042.63	-1008.41	-974.17	-939.79	-905.24	-870.56	-835.72
CV	326374	333929	333929	336472	338750	340780	342825
γ	1.25100	1.24767	1.24511	1.24252	1.24021	1.23834	1.23642
S	2.09214	2.11064	2.12821	2.14499	2.16106	2.17648	2.19090
E	420.37	452.91	485.69	518.77	552.15	585.74	619.77
HF	1521.35	1519.67	1518.21	1516.92	1515.75	1514.66	1513.86
CO	.0144879	.0146378	.0147885	.0149179	.0150301	.0151286	.0151921
CO2	.0063910	.0062149	.0060658	.0059376	.0058264	.0057292	.0056678
H2O	.0049493	.0047766	.0046323	.0045053	.0043946	.0042974	.0042355
H2	.0053127	.0094691	.0096582	.0097666	.0098777	.0099746	.0100356
O2	.0048475	.0046485	.0044891	.0043496	.0042500	.00418504	.00414510
OH	.0000001	.0000001	.0000002	.0000005	.0000010	.0000021	.0000039
H	.0000003	.0000006	.0000012	.0000022	.0000039	.0000064	.0000102
H2O	.0000058	.0000048	.0000040	.0000034	.0000030	.0000027	.0000024
CH4	.0000026	.0000012	.0000006	.0000003	.0000002	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	24.9950	24.9868	24.9747	24.9576	24.9345	24.9023	24.8599
P	6396	6654	6913	7173	7433	7695	7960
c	- 699.33	- 764.06	- 828.59	- 891.87	- 954.39	- 1015.95	- 1076.33
CV	344266	346198	347696	349159	350501	351717	352839
γ	1.23477	1.23325	1.23194	1.23068	1.22955	1.22857	1.22776
z	2.20570	2.2.973	2.23337	2.24672	2.25987	2.27290	2.28588
z	693.63	688.29	723.00	758.06	793.45	829.23	865.40
HF	1512.52	1511.34	1509.97	1508.32	1506.24	1503.60	1500.19
CO	.0192926	.0153016	.0154251	.0154842	.0155409	.0155983	.0156574
CO2	.0255696	.0255040	.0254456	.0253930	.0253465	.0253027	.0252614
H2	.041309	.040704	.040116	.039621	.039146	.038759	.038432
H2O	.161321	.161947	.162482	.162923	.163271	.163591	.163883
N2	.0048515	.0048521	.0048528	.0048538	.0048547	.0048562	.0048576
O2			.000001	.000003	.000005	.000011	.000020
O		.000001	.000001	.000003	.000006	.000011	.000021
OH	.0000009	.000119	.000195	.000309	.000474	.000704	.001020
H	.000015	.000232	.000335	.000471	.000646	.000869	.001146
HNO	.000000	.000011	.000019	.000033	.000056	.000089	.000139
N		.000001	.000002	.000003	.000005	.000009	.000014
HNO3	.0000020	.0000020	.0000018	.0000017	.0000019	.0000015	.0000015
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M5

TEMP. °K	3200.00	3300.00	3400.00	3260.58
MOL. WT.	24.8039	24.7516	24.6395	24.7622
P	8226	6496	8770	9389
e	- 535.23	- 432.33	- 447.20	
CV	1.33883	1.354814	1.355657	1.354465
γ	1.22704	1.22650	1.22613	1.22609
S	2.29592	2.31213	2.32555	2.30690
E	502.06	939.23	976.96	924.51
HF	1495.79	1490.11	1462.84	1492.51
CO	.0157222	.0157953	.0158805	.0157654
CO2	.0052202	.0051777	.0051316	.0051546
H2	.0038148	.0037574	.0037658	.0038041
H2O	.0107701	.0103625	.0103443	.0103700
H2	.0046595	.0046610	.0048627	.0048603
O2	.0000037	.0000066	.0000111	.0000053
OH	.0000038	.0000067	.0000113	.0000054
H	.001440	.0011988	.002686	.0001751
HC	.001486	.001895	.002394	.0001727
N	.000210	.0000358	.0000441	.0000266
HN3	.0000021	.0000032	.0000046	.0000027
CH4	.0000014	.0000013	.0000013	.0000013

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M5

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOL. WT.	25.0516	25.0328	25.0238	25.0187	25.0151	25.0118	25.0081
P	9752	10311	10865	11418	11970	12520	13072
e	-1045.10	-1010.40	-976.03	-941.51	-906.85	-872.16	-837.31
CV	32929	332657	335934	337923	340184	342122	344193
γ	1.23045	1.22260	1.24930	1.24608	1.24321	1.24103	1.23866
S	2.33357	2.04766	2.06735	2.08419	2.10031	2.11575	2.13018
E	440.20	449.28	462.36	515.67	549.24	582.92	617.04
HF	1519.02	1516.58	1516.73	1515.53	1514.44	1513.44	1512.71
CO	.0145713	.0177643	.0149165	.0150447	.0151548	.0152514	.0153129
CO2	.0002540	.0000770	.0059311	.0058062	.0056982	.0056033	.0055435
HE	.0047760	.0046238	.0044830	.0043652	.0042599	.0041665	.0041073
H2O	.0094490	.0096255	.0097715	.0098965	.0100047	.0100995	.0101590
N2	.0048410	.0048440	.0048457	.0048468	.0048476	.0048483	.0048488
O2							
OH		.0000001	.0000001	.0000003	.0000007	.0000014	.0000027
H		.0000004	.0000008	.0000015	.0000026	.0000044	.0000070
NO						.0000001	.0000002
H3	.0000126	.0000134	.0000067	.0000075	.0000066	.0000058	.0000052
CH4	.0000116	.0000052	.0000026	.0000014	.0000008	.0000005	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	25.0000	24.9971	24.9884	24.9764	24.9608	24.9379	24.9089
P	13021	14172	14723	15274	15825	16385	16943
Q	- 801.99	- 790.43	- 730.51	- 694.28	- 657.41	- 619.81	- 581.42
R	1.23172	1.23493	1.23813	1.24133	1.24453	1.24773	1.25093
S	1.23062	1.23476	1.23824	1.24162	1.24500	1.24838	1.25176
T	2.14003	2.15897	2.17248	2.18570	2.19864	2.21138	2.22395
U	691.23	685.75	720.46	755.50	790.81	826.47	862.39
HF	1511.54	1510.54	1509.44	1508.16	1506.60	1504.93	1502.25

CO	1.194-14	0.194778	0.199386	0.199942	0.156460	0.156973	0.157484
CO2	0.054473	0.053854	0.053253	0.052757	0.052264	0.051784	0.051498
H2	0.040122	0.039477	0.038855	0.038410	0.037964	0.037587	0.037259
H2O	0.110945	0.109361	0.107808	0.106410	0.105117	0.104461	0.105021
N2	0.048-97	0.048351	0.048557	0.048515	0.048519	0.048523	0.048542
O2			0.000001	0.000001	0.000002	0.000003	0.000010
OH	0.000147	0.000089	0.000187	0.000217	0.000233	0.000245	0.000278
H	0.001107	0.001159	0.001229	0.001301	0.001381	0.001471	0.001571
NO	0.000104	0.000107	0.000113	0.000113	0.000119	0.000122	0.000127
HNO		0.000001	0.000001	0.000001	0.000004	0.000006	0.000010
HCN	0.000043	0.000043	0.000040	0.000038	0.000034	0.000033	0.000033
CN	0.000002	0.000001	0.000001	0.000001	0.000002	0.000003	0.000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M5

TEMP. °K	3200.00	3300.00	3400.00	3280.01
MOL. WT.	24.8704	24.8209	24.7582	24.8317
P	17505	18070	18641	17957
e	- 541.98	- 501.28	- 459.11	
CV	.355080	.256021	.356875	.355844
γ	1.22678	1.22590	1.22519	1.22606
S	2.23647	2.24899	2.26157	2.24649
E	898.72	935.44	972.58	928.07
HF	1499.15	1495.21	1490.22	1496.07

CO	.0158020	.0158599	.0159248	.0158479
CO2	.0051124	.0050753	.0050369	.0050827
H2	.0036985	.0036766	.0036605	.0035805
H2O	.0105146	.0105175	.0105101	.0105177
N2	.0048554	.0048565	.0048574	.0048563
O2	.0000017	.0000031	.0000052	.0000028
O	.0000019	.0000032	.0000055	.0000029
OH	.0001015	.0001404	.0001901	.0001318
H	.0001013	.0001294	.0001629	.0001233
NO	.0000147	.0000216	.0000310	.0000201
N	.0000015	.0000022	.0000033	.0000021
NH3	.0000030	.0000029	.0000028	.0000029
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M5

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MCL. WT.	25.0355	25.0220	25.0225	25.0156	25.0113	25.0042	24.9954
P	27362	28619	29860	31131	32325	33540	34809
e	- 909.25	- 874.40	- 839.36	- 803.85	- 768.24	- 732.51	- 696.29
CV	343202	344954	347086	348788	350237	351495	352991
γ	1.24718	1.24464	1.24162	1.23901	1.23668	1.23482	1.23277
S	2.03329	2.04280	2.05332	2.07324	2.09220	2.10571	2.11858
E	543.70	577.67	612.10	646.54	681.27	716.23	751.46
HF	1511.28	1510.41	1509.81	1508.81	1507.97	1507.10	1506.12
CO	0.154370	0.155324	0.155721	0.156872	0.157494	0.158064	0.158579
CO2	0.054043	0.053157	0.052572	0.051654	0.051053	0.050554	0.050038
H2	0.039453	0.038599	0.038073	0.037204	0.036607	0.036115	0.035623
H2O	0.102957	0.103664	0.104429	0.105346	0.106330	0.107448	0.108687
N2	0.048410	0.048426	0.048438	0.048456	0.048459	0.048465	0.048474
O2							
CH	0.000005	0.000010	0.000019	0.000034	0.000058	0.000095	0.000151
F	0.000017	0.000028	0.000045	0.000069	0.000103	0.000149	0.000209
NO		0.000001	0.000001	0.000003	0.000005	0.000009	0.000016
NH3	0.000158	0.000140	0.000126	0.000103	0.000104	0.000096	0.000092
CH4	0.000040	0.000023	0.000015	0.000010	0.000006	0.000005	0.000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M5

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3293.74
MOL. WT.	24.9856	24.9684	24.9487	24.9221	24.8886	24.8464	24.8909
e	36150	37409	38670	39935	41205	42480	41125
CV	- 659.68	- 622.52	- 584.86	- 546.40	- 507.07	- 466.76	358285
γ	1.23057	1.22923	1.22753	1.22637	1.22509	1.22402	1.22517
ε	2.13172	2.14421	2.15664	2.16884	2.18094	2.19296	2.18018
HF	786.88	822.66	858.57	894.85	931.44	968.31	929.14
	1504.93	1503.57	1501.83	1499.67	1496.95	1493.54	1497.14

CO	.0159941	.0159511	.0159947	.0160399	.0160866	.0161373	.0160836
CO2	.0049618	.0049221	.0048867	.0048527	.0048200	.0047872	.0048220
H2	.0035204	.0034861	.0034550	.0034290	.0034073	.0033898	.0034085
H2O	.0107243	.0107561	.0107750	.0107958	.0108049	.0108064	.0108046
N2	.0048473	.0048491	.0048497	.0048507	.0048515	.0048520	.0048514
O2	.0000001	.0000002	.0000004	.0000008	.0000013	.0000023	.0000013
OH	.0000001	.0000002	.0000005	.0000009	.0000015	.0000025	.0000015
H	.0000232	.0000346	.0000502	.0000712	.0000986	.0001338	.0000967
HCO	.0000265	.0000383	.0000505	.0000655	.0000836	.0001052	.0000824
HCN	.0000027	.0000043	.0000067	.0000102	.0000151	.0000217	.0000147
NH3	.0000003	.0000004	.0000007	.0000010	.0000016	.0000023	.0000015
CH4	.0000100	.0000080	.0000079	.0000072	.0000069	.0000067	.0000069
	.0000002	.0000002	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

G.3

M5

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00
MOL. WT.	25.0221	25.0273	25.0196	25.0116	25.0048	24.9885	24.9730
ρ	53588	55726	57866	60004	62136	64273	66416
ε	- 904.56	- 768.75	- 732.93	- 696.60	- 659.96	- 622.82	- 585.37
CV	.351663	.353187	.354277	.355798	.357076	.358066	.359042
γ	1.24201	1.23936	1.23740	1.23492	1.23270	1.23090	1.22919
S	2.03357	2.04763	2.06115	2.07436	2.08722	2.09980	2.11206
E	642.57	677.65	712.73	748.24	783.88	819.94	855.97
HF	1505.47	1504.74	1504.01	1503.20	1502.20	1501.13	1499.73
CO	.0160026	.0160614	.0161155	.0161636	.0162049	.0162496	.0162886
CO2	.0048413	.0047855	.0047350	.0046907	.0046525	.0046148	.0045824
H2	.0033795	.0033258	.0032793	.0032381	.0031993	.0031657	.0031414
H2O	.0166951	.0109103	.0109592	.0110036	.0110332	.0110621	.0110873
H2	.0048398	.0048400	.0048414	.0048424	.0048417	.0048444	.0048449
O2					.0000001	.0000001	.0000002
OH					.0000001	.0000001	.0000003
H					.0000197	.0000260	.0000405
NO					.0000206	.0000285	.0000369
N					.0000022	.0000035	.0000055
NO2					.0000002	.0000003	.0000006
CH4	.0000186	.0000189	.0000175	.0000162	.0000179	.0000143	.0000142
CH2	.0000027	.0000018	.0000013	.0000010	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5 0.3

TEMP. °K	3200.00	3300.00	3400.00	3296.75
MOL. WT.	24.9512	24.9246	24.8914	24.9255
P	68560	70707	72855	70637
e	- 547.19	- 508.31	- 468.67	
CV	360126	361014	361753	360988
γ	1.22743	1.22587	1.22458	1.22592
S	2.12417	2.13612	2.14794	2.13573
E	892.43	929.13	966.03	927.93
HF	1498.01	1495.85	1493.14	1495.93
CO	.0163292	.0163701	.0164137	.0163688
CO2	.0045510	.0045213	.0044916	.0045222
H2	.0031182	.0030985	.0030820	.0030990
H2O	.0111050	.0111156	.0111198	.0111154
H2	.0048461	.0048468	.0048472	.0048468
O2	.0000004	.0000008	.0000014	.0000008
O	.0000005	.0000009	.0000016	.0000009
OH	.0000576	.0000800	.0001087	.0000792
H	.0000479	.0000611	.0000769	.0000606
HC	.0000083	.0000122	.0000176	.0000121
N	.0000008	.0000017	.0000019	.0000013
NH3	.0000129	.0000123	.0000120	.0000123
CH4	.0000003	.0000003	.0000002	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M5

TEMP. °K	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00
MOL. WT.	25.0501	25.0253	25.0078	24.9945	24.9749	24.9520	24.9241
P	516.05	948.16	960.45	1012.60	1044.81	1077.01	1109.17
e	- 633.72	- 556.94	- 521.60	- 505.23	- 546.03	- 507.34	- 467.98
CV	3588.05	3550.57	3600.41	3618.45	3625.25	3637.70	3644.29
γ	1.23689	1.23639	1.23430	1.23251	1.23390	1.22872	1.22725
z	2.03852	2.05143	2.06405	2.07631	2.08840	2.10030	2.11204
z	745.71	751.62	816.02	854.27	890.57	927.65	964.95
M*	1499.77	1493.95	1458.04	1496.86	1495.44	1492.63	1491.34
CO	0104780	0165346	0165781	0166132	0166506	0166873	0167260
CO2	0043474	0043133	0042776	0042463	0042192	0041923	0041654
H2	0028781	0028433	0028192	0027945	0027749	0027580	0027437
H2O	0113412	0113396	0114014	0114217	0114391	0114497	0114545
O2	0048239	0048346	0048285	0048389	0048436	0048414	0048417
N2			0000001	0000002	0000003	0000005	0000009
NO			0000001	0000002	0000004	0000006	0000011
H			0000240	0000349	0000486	0000689	0000936
OH			0000212	0000280	0000363	0000463	0000583
HO2			0000000	0000048	0000072	0000107	0000154
H2O2			0000000	0000005	0000007	0000011	0000016
CH4			0000228	0000227	0000225	0000195	0000190
CH3			0000000	0000009	0000007	0000007	0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M5

TEMP. °K 3294.20

MOL. WT. 24.9535

P 1.07514

• CV 363728

7 22882

S 2.03961

E 925.74

HF 1493.74

CO 0.166852

CO2 0.041938

H2 0.027589

H2O 0.114493

N2 0.048414

O2 0.033335

OH 0.000006

H 0.000677

NC 0.000457

N 0.000104

NH3 0.000011

CH4 0.000195

0.000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6 0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.8862	23.5691	22.9875	22.7549	22.6624	22.6230	22.6047
P	3774	4162	4500	4810	5106	5397	5686
e	943.18	877.03	820.51	788.86	752.78	717.93	683.55
CV	319027	319685	321737	324436	327277	329958	332539
γ	1.27542	1.28066	1.28489	1.27849	1.27557	1.27264	1.26987
S	2.06964	2.11553	2.14669	2.17074	2.19137	2.21020	2.22783
E	241.47	305.04	350.86	388.30	422.60	455.92	489.03
MF	1238.43	1236.65	1234.32	1232.25	1230.51	1229.03	1227.76

CO	0.175974	0.194123	0.203940	0.209035	0.211996	0.214004	0.215503
CO2	0.043455	0.042789	0.038625	0.035875	0.033849	0.032235	0.030915
H2	0.072906	0.064016	0.038450	0.029319	0.0268743	0.0257749	0.0246709
H2O	0.050435	0.054176	0.056256	0.059013	0.060799	0.062314	0.063593
NO	0.043258	0.044460	0.045036	0.045232	0.045387	0.045437	0.045464
N2							
O2							
HF							
SO							
Si							
Cl							
Br							
I							
Na							
K							
Ca							
Mg							
Al							
Fe							
Cu							
Zn							
Pb							
B							
Li							
Ag							
Au							
Sn							
Pt							
Bi							
Mn							
Ni							
Cr							
V							
Ti							
Zr							
Hf							
Mo							
W							
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Ir							
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Ta							
Sb							
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Se							
As							
Ge							
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U							
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Cm							
Bk							
Cf							
Es							
Fm							
Md							
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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	22.5950	22.5889	22.5838	22.5787	22.5721	22.5650	22.5548
P	5574	6261	6547	6833	7119	7406	7693
e	- 645.21	- 614.79	- 580.27	- 545.59	- 510.42	- 475.02	- 439.22
CV	334966	337214	339222	341239	342965	344602	346123
7	1.26724	1.26484	1.26288	1.26090	1.25919	1.25759	1.25621
S	2.24458	2.26058	2.27593	2.29010	2.30506	2.31894	2.33246
E	522.23	555.03	589.17	625.08	657.05	691.35	725.88
HF	1226.63	1225.61	1224.64	1223.87	1222.69	1221.58	1220.32

CO	.0216712	.0217725	.0218598	.0219158	.0220033	.0220627	.0221173
CO2	.0029757	.0028837	.0028002	.0027476	.0026641	.0026088	.0025599
H2	.0095727	.0084836	.0084036	.0083521	.0082691	.0082110	.0081591
H2O	.0064692	.0065644	.0066473	.0066995	.0067825	.0068365	.0068835
N2	.0045475	.0045490	.0045499	.0045507	.0045518	.0045523	.0045534
O							
OH	.0000002	.0000005	.0000010	.0000018	.0000033	.0000055	.0000092
H	.0000030	.0000053	.0000089	.0000143	.0000221	.0000330	.0000477
H2O2				.0000001	.0000002	.0000003	.0000006
H3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000001	.0000002
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M6

TEMP. °K	2600.00	2578.09
MOL. WT.	22.5413	22.5666
P	7961	7343
e	- 402.90	
CV	.347593	.344251
γ	1.25485	1.25793
S	2.34566	2.31599
E	760.69	683.91
HF	1218.81	1221.81
CO	.0221674	.0220521
CO2	.0025172	.0026185
H2	.0081121	.0022216
H2O	.0069231	.0068272
H2	.0045546	.0045523
O2		
OH	.000001	.000050
H	.000045	.0000303
H2O	.0000673	.0000073
H	.000011	.0000001
H2O	.0000003	.0000054
H2	.0000000	.0000000
CH4		

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6
O.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	27.1818	25.1455	23.9149	23.2447	22.9140	22.7560	22.6806
P	7691	8592	9418	10167	10855	11510	12144
Q	- 996.26	- 916.44	- 852.92	- 802.37	- 760.14	- 722.19	- 686.29
CV	326142	375.02	325967	327466	329586	331842	334243
γ	1.26816	1.27560	1.27911	1.27932	1.27746	1.27480	1.27188
S	1.96974	2.02481	2.06587	2.09654	2.12068	2.14119	2.15960
E	193.76	263.53	325.09	373.45	413.82	450.23	484.89
MF	1232.68	1233.60	1232.38	1230.61	1228.95	1227.51	1226.51
CO	.0152663	.0177033	.0193929	.0204299	.0210242	.0213735	.0215922
CO2	.0054415	.0045819	.0039808	.0035801	.0033122	.0031206	.0029777
H2	.0052017	.0066136	.0076150	.0081768	.0084092	.0084626	.0084374
H2O	.0047407	.0054523	.0057912	.0060300	.0062134	.0063640	.0064820
N2	.0041336	.0042967	.0044067	.0044715	.0045058	.0045234	.0045325
O							
OH							
H							
NO							
N							
HMS	.0000335	.0000372	.0000365	.0000235	.0000295	.0000257	.0000224
CH4	.0017714	.0012815	.0005918	.0002985	.0001470	.0000737	.0000391
				.0000001	.0000003	.0000006	.0000001
							.0000011

PROPERTY, THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION.

0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
h ₀ , kJ/kg	22,000.22	23,000.00	22,000.74	22,598.2	22,988.7	23,582.1	24,176.4
h, kJ/kg	12,761.1	13,389.1	14,003.1	14,617.1	15,231.1	15,845.1	16,459.1
s ⁰ , kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
s, kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
h ₀ , kJ/kg	22,000.22	23,000.00	22,000.74	22,598.2	22,988.7	23,582.1	24,176.4
h, kJ/kg	12,761.1	13,389.1	14,003.1	14,617.1	15,231.1	15,845.1	16,459.1
s ⁰ , kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
s, kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
h ₀ , kJ/kg	22,000.22	23,000.00	22,000.74	22,598.2	22,988.7	23,582.1	24,176.4
h, kJ/kg	12,761.1	13,389.1	14,003.1	14,617.1	15,231.1	15,845.1	16,459.1
s ⁰ , kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
s, kJ/kg·K	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M6

TEMP. °K	2800.00	2581.14
MJL. WT.	22.5630	22.5853
P	17067	15725
CV	- 404.50	.345737
Z	1.25441	1.25799
S	2.27802	2.24895
E	758.98	683.00
HF	1218.59	1221.00
CO	.0222663	.0221565
CO2	.0024054	.0025029
H2O	.0079930	.0080913
H2	.0070562	.0065428
O2	.0045495	.0045472
OH	.0000101	.0000059
H	.0000463	.0000211
N2	.0000007	.0000002
N	.0000002	.0000001
NO	.0000112	.0000123
CH4	.0000013	.0000026

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

O.2

M6

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MOL. WT.	24.6747	23.9508	23.3369	23.0395	22.9692	22.7722	22.7103
P	22705	24532	26187	27770	29288	30763	32201
Q	- 638.35	- 734.29	- 737.39	- 695.78	- 637.10	- 620.06	- 584.04
CV	334713	335540	336683	338447	340560	342461	344132
γ	1.27389	1.27615	1.27509	1.27292	1.26994	1.26694	1.26473
S	2.00363	2.03493	2.05986	2.08120	2.10006	2.11726	2.13220
E	333.96	386.44	431.82	472.21	509.85	546.01	581.24
HF	1225.22	1225.14	1223.94	1222.89	1221.97	1221.15	1220.40
CO	.0190005	.0201874	.0209666	.0214549	.0217673	.0219727	.0221235
CO2	.0036732	.0052590	.0029664	.0027681	.0026240	.0025146	.0024246
H2	.0062949	.0069823	.0074264	.0076726	.0077886	.0078289	.0078337
H2O	.0062505	.0064848	.0066542	.0067784	.0068796	.0069650	.0070402
O2	.0043243	.0043994	.0044497	.0044810	.0045001	.0045120	.0045201
O							
OH							
H	.0000001	.0000002	.0000004	.0000007	.0000013	.0000024	.0000035
NO							
NO2							
CO3	.0000639	.0000629	.0000593	.0000544	.0000496	.0000452	.0000414
CH4	.0008880	.0005513	.0003275	.0001936	.0001160	.0000722	.0000448

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

0.2

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2583.46
MOL. WT.	22.6745	22.6452	22.6309	22.6164	22.6039	22.5323
p	32626	35038	36441	37845	39245	36210
e	- 348.43	- 512.62	- 476.94	- 441.19	- 405.11	
CV	346088	347702	349155	350467	351933	348926
γ	1.26203	1.25966	1.25743	1.25560	1.25356	1.25779
γ	2.17787	2.16309	2.17710	2.19059	2.20371	2.17486
z	616.30	651.27	686.18	721.16	756.38	680.41
H _f	1219.87	1219.05	1218.29	1217.53	1216.68	1218.41
CO	.0222125	.0223197	.0223856	.0224433	.0224920	.0223776
CO ₂	.0023659	.0022886	.0022365	.0021906	.0021511	.0022451
H ₂	.0076224	.0077928	.0077570	.0077254	.0076941	.0077627
H ₂ O	.0070570	.0071636	.0072115	.0072547	.0072917	.0072056
H ₂	.0045253	.0045314	.0045322	.0045347	.0045366	.0045324
O ₂						
O						
OH	.0000009	.0000016	.0000027	.0000044	.0000059	.0000025
H	.0000064	.0000100	.0000149	.0000216	.0000304	.0000140
NO		.0000001	.0000002	.0000003	.0000005	.0000001
N ₂				.0000001	.0000002	.0000002
N ₂ O				.0000001	.0000002	.0000001
CH ₄				.0000001	.0000002	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.5957	23.3445	23.1025	22.8416	22.8450	22.7687	22.7300
ρ	47459	50252	52931	55508	58026	60499	62929
e	- 711.06	- 667.48	- 625.85	- 588.25	- 550.94	- 513.83	- 477.31
CV	343664	345408	346885	348206	350010	351453	352720
γ	1.77295	1.27052	1.26789	1.26608	1.26338	1.26094	1.25858
W	2.02421	2.04544	2.06431	2.08150	2.09680	2.11255	2.12690
E	453.23	495.65	535.65	573.51	611.35	646.76	682.60
HF	1219.80	1216.05	1217.38	1216.74	1216.32	1215.68	1215.02
CO	.0210003	.0219379	.0219055	.0221724	.0223330	.0224906	.0225838
CO2	.0026065	.0024124	.0022715	.0021602	.0020938	.0020071	.0019536
H2	.0065478	.0066759	.0070792	.0072114	.0072918	.0073203	.0073227
H2O	.0070252	.0071925	.0072766	.0073482	.0073916	.0074635	.0075055
OH	.0043926	.0044348	.0044598	.0044783	.0044905	.0045038	.0045065
O	.0000001	.0000001	.0000002	.0000004	.0000007	.0000012	.0000021
CH	.0000010	.0000010	.0000017	.0000029	.0000047	.0000074	.0000110
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HT	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HT*	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH*	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M6

TEMP. °K	2700.00	2800.00	2584.61
MOL. WT.	22.6971	22.6735	22.7336
P	65352	67758	6255A
e	- 441.01	- 404.50	.352536
CV	.353656	.355253	1.25894
γ	1.25669	1.25440	2.12478
S	2.14060	2.15388	677.12
E	718.29	754.10	1215.12
HF	1214.42	1213.75	
CO	.0226999	.0227189	.0225736
CO2	.0019074	.0018690	.0019597
H2O	.0073217	.0073117	.0073240
H2	.0075448	.0075783	.0075009
O2	.0045117	.0045155	.0045067
OH	.0000035	.0000055	.0000020
H	.0000160	.0000227	.0000104
NO	.0000002	.0000002	.0000001
N	.0000001	.0000001	.0000001
NH3	.0000004	.0000074	.0000653
CH4	.0000327	.0000250	.0000471

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

%

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
100. WT.	24.9359	24.9199	25.0410	25.2594	25.5779	26.0000
e	710.99	791.99	893.79	1022.94	1189.94	1390.00
C _v	549.434	601.06	677.34	785.47	932.47	1120.00
γ	1.27402	1.35999	1.52079	1.8385	2.3079	3.06324
z	1.97527	1.97168	1.96903	1.96793	1.96743	1.96747
z	450.60	1.99849	2.01809	2.03773	2.05737	2.07707
H _f	1214.67	477.99	921.19	1501.94	2201.94	3001.94
CO ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CO	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂ O	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
O ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N ₂	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6

G.4

TEMP. °K 2700.00 2800.00 2587.79

MOL. WT.

P	22.8528	22.8046	22.9300
e	99874	103565	95678
CV	- 441.03	- 402.77	
7	.357756	.359121	.256710
S	1.25562	1.25720	1.26172
E	2.09571	2.11328	2.08387
HF	714.66	751.42	673.30
	1210.77	1210.25	1211.50

CO
CO2
H2
H2O
O2
O
OH
H
NO
N
NH3
CH4

CO	.0226115	.0225961	.0226511
CO2	.0016215	.0015614	.0016774
H2	.0067971	.0068251	.0067395
H2O	.0076499	.0078791	.0075124
O2	.0044733	.0044804	.0044635
O			
OH	.0000029	.0000046	.0000017
H	.0000124	.0000175	.0000061
NO	.0000002	.0000003	.0000001
N	.0000001	.0000001	
NH3	.0001064	.0001016	.0001105
CH4	.0000034	.0000045	.0001163

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.2

M7

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	26.3047	26.2450	26.1777	26.0884	25.9776	25.8434	25.6826
P	38935	40151	41379	42620	43878	45158	46435
e	- 591.44	- 550.78	- 508.65	- 464.57	- 418.44	- 367.65	- 316.91
CV	.352206	.352954	.353779	.354625	.355358	.356036	.354763
γ	1.21750	1.21649	1.21564	1.21475	1.21401	1.21345	1.21486
S	2.11557	2.12770	2.13990	2.15231	2.16497	2.17794	2.19112
E	916.18	952.76	989.70	1027.23	1065.17	1103.96	1142.57
HF	1565.36	1561.34	1556.19	1549.71	1541.59	1531.69	1519.67
CO	.0132601	.0133350	.0134088	.0134923	.0135950	.0137142	.0138573
CO2	.0064501	.0063921	.0063492	.0062995	.0062389	.0061711	.0060962
H2	.0021196	.0021088	.0021017	.0021012	.0021055	.0021234	.0021452
H2O	.0126421	.0126399	.0126283	.0126031	.0125712	.0125247	.0124660
H2	.0032162	.0031900	.0031566	.0031146	.0030632	.0030034	.0029360
O2	.0000015	.0000059	.0000097	.0000154	.0000238	.0000354	.0000510
O	.0000024	.0000040	.0000066	.0000105	.0000162	.0000244	.0000359
OH	.0001231	.0001570	.0002223	.0002905	.0003734	.0004712	.0005874
H	.0000058	.0000328	.0001030	.000266	.000543	.0011864	.0022237
H2	.0000251	.0000361	.0000506	.0000695	.0000935	.0001250	.0001628
N	.0000016	.0000024	.0000034	.0000048	.0000066	.0000089	.0000119
NO	.0000035	.0000034	.0000032	.0000031	.0000030	.0000030	.0000030

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M7

TEMP. °K 3686.01

MOL. WT. 25.9945

P 43701

Cv 355289

7 1.21511

E 2.19310

MF 1059.63

1542.83

- CO2 0.135794
- CO 0.062481
- H2O 0.021046
- H2 0.005782
- OH 0.053134
- O2 0.002224
- O 0.000153
- NO 0.003008
- NO2 0.000151
- N2 0.000898
- N 0.000063
- H2O2 0.000030
- CH4 0.000030

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MO

0.05

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	26.6364	26.6321	26.6253	26.6156	26.6010	26.5797
P	5511	5754	5996	6239	6482	6726
Q	-562.56	-947.94	-912.97	-877.67	-841.85	-805.23
CV	.337164	.339185	.340924	.342540	.344018	.345455
γ	1.22053	1.22497	1.22936	1.23189	1.23065	1.21943
S	2.10176	2.11610	2.12070	2.12454	2.12806	2.17136
E	578.04	611.74	645.55	679.74	714.21	749.06
HF	1618.73	1618.21	1617.06	1615.96	1614.62	1612.91
CO	.015242	.016064	.016895	.017472	.018013	.018536
CO2	.0075609	.0075102	.0074296	.0073754	.0073265	.0072618
H2	.0028117	.0025609	.0024806	.0024271	.0023803	.0023400
H2O	.0104309	.0104803	.0105564	.0106081	.0106495	.0106821
O2	.0053756	.0053766	.0053765	.0053770	.0053777	.0053785
N2	.0000000	.0000001	.0000001	.0000001	.0000002	.0000008
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MB
0.05

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	26.5497	26.5072	26.4491	26.3703	26.2658	26.1294	25.9549
P	6972	7219	7469	7723	7980	8244	8515
e	- 767.76	- 729.01	- 688.69	- 646.34	- 601.45	- 553.47	- 501.78
CV	346763	347955	349001	349974	350906	351520	352130
γ	1.21857	1.21746	1.21675	1.21616	1.21579	1.21564	1.21576
S	2.18452	2.19766	2.21087	2.22431	2.23812	2.25244	2.26742
E	784.29	820.00	856.21	893.07	930.63	969.01	1008.27
MF	1610.65	1607.63	1503.57	1598.12	1590.88	1581.36	1569.06
CO	.0119068	.0119644	.0120295	.0121076	.0122038	.0123247	.0124771
CO2	.0072355	.0071972	.0071531	.0071037	.0070456	.0069749	.0068873
H2	.0023050	.0022774	.0022550	.0022408	.0022342	.0022372	.0022518
H2O	.0107000	.0107205	.0107251	.0107182	.0106983	.0106639	.0106129
N2	.0033793	.0033804	.0033814	.0033826	.0033837	.0033850	.0033866
O2	.0000017	.0000033	.0000064	.0000117	.0000204	.0000341	.0000545
C	.0000010	.0000020	.0000037	.0000066	.0000118	.0000198	.0000321
CH	.0000640	.0000952	.0001378	.0001944	.0002677	.0003607	.0004757
H	.0000496	.0000666	.0000876	.0001139	.0001457	.0001842	.0002303
NO	.0000103	.0000166	.0000252	.0000389	.0000570	.0000811	.0001124
N	.0000066	.0000099	.0000014	.0000022	.0000033	.0000049	.0000070
OH	.0000009	.0000007	.0000007	.0000007	.0000006	.0000006	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M6 0.05

TEMP. °K	3600.00	3700.00	3800.00	3900.00	3650.52
MOL. WT.	25.7370	25.4711	25.1570	24.7941	25.6094
P	8794	9085	9337	9702	8940
e	- 443.77	- 535.03	- 319.06	- 248.09	
CV	.352634	.352989	.353197	.352830	.352834
γ	1.21610	1.21675	1.21771	1.21948	1.21639
z	2.28319	2.29986	2.31741	2.33585	2.29148
S	1048.50	1089.54	1131.66	1174.15	1069.12
MF	1553.43	1533.91	1510.28	1482.06	1544.12
CO	.0126674	.0129038	.0131821	.0135102	.0127603
CO2	.0067728	.0066437	.0064870	.0063024	.0067143
H2	.0022800	.0023220	.0023841	.0024628	.0022993
H2O	.0105434	.0104553	.0103421	.0102071	.0105015
H2	.0053865	.0053510	.0053945	.0053990	.0053897
O2	.0000638	.0001236	.0001748	.0002378	.0001024
O	.0000501	.0000759	.0001112	.0001583	.0000621
OH	.0006148	.0007798	.0009700	.0011861	.0006945
H	.0002855	.0003511	.0004292	.0005215	.0003172
NO	.0001516	.0001999	.0002565	.0003219	.0001748
N	.0000598	.0000135	.0000164	.0000246	.0000116
NH3	.0000006	.0000000	.0000006	.0000006	.0000006
CH4					

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

TEMP. °K	2300.00	2200.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	26.6405	26.6429	26.6372	26.6320	26.6253	26.6151	26.6004
P	11723	11206	12241	12757	13275	13794	14314
Q	-984.20	-1016.47	-949.83	-914.92	-879.76	-844.28	-808.19
CV	338474	336541	340522	342250	343810	345215	346669
γ	1.22998	1.23213	1.22766	1.22564	1.22382	1.22233	1.22076
z	2.03469	2.02747	2.03904	2.07361	2.08740	2.10080	2.11392
E	575.26	541.88	609.04	642.94	677.17	711.60	746.40
MF	1618.03	1618.88	1617.40	1616.39	1615.49	1614.44	1613.15
CO	.0116489	.0115702	.0116951	.0117794	.0118342	.0118849	.0119327
CO2	.0074047	.0075425	.0074157	.0073372	.0072849	.0072378	.0071953
H2	.0025137	.0025910	.0024650	.0023873	.0023254	.0022900	.0022507
H2O	.0105267	.0104492	.0105749	.0106517	.0107009	.0107428	.0107770
O2	.0053745	.0053741	.0053749	.0053755	.0053758	.0053763	.0053769
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000019	.0000010	.0000036	.0000066	.0000112	.0000185	.0000294
MO	.0000024	.0000021	.0000054	.0000082	.0000122	.0000175	.0000246
NH	.0000002	.0000001	.0000004	.0000007	.0000014	.0000025	.0000044
H	.0000028	.0000032	.0000025	.0000020	.0000021	.0000021	.0000022
OH	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MB

0.1

TEMP. °K	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00
MOL. WT.	26.5800	26.5500	26.5113	26.4581	26.3875	26.2964	26.1791
P	14855	13259	15885	16418	16955	17500	18054
CV	- 771.77	- 733.75	- 695.06	- 654.94	- 613.10	- 569.18	- 522.76
Z	347573	349121	350193	351199	352074	352836	353565
W	1.21936	1.21814	1.21713	1.21617	1.21540	1.21483	1.21447
L	2.12063	2.11928	2.11727	2.11500	2.11276	2.11097	2.20442
MF	781.50	816.99	852.83	889.17	926.05	963.48	1001.55
	1611.49	1607.55	1600.51	1602.76	1597.84	1591.42	1583.16

CO	011977	0120282	0120804	0121402	0122107	0122965	0124023
CO2	0071577	0071577	0070797	0070392	0069542	0069418	0068790
H2O	0021678	0021678	0021644	0021453	0021342	0021285	0021312
H2	0033332	0033332	0108341	0108366	0108293	0108114	0107813
O2	0053773	0053782	0053707	0053793	0053795	0053797	0052797
N2	0000000	0000016	0000031	0000055	0000058	0000165	0000270
NO	0000000	0000000	0000000	0000000	0000000	0000000	0000159
H	0000000	0000000	0000000	0000000	0000000	0000000	0000159
OH	0000000	0000000	0000000	0000000	0000000	0000000	0000159
H2O2	0000000	0000000	0000000	0000000	0000000	0000000	0000159
HF	0000000	0000000	0000000	0000000	0000000	0000000	0000159
Cl	0000000	0000000	0000000	0000000	0000000	0000000	0000159
Br	0000000	0000000	0000000	0000000	0000000	0000000	0000159
I	0000000	0000000	0000000	0000000	0000000	0000000	0000159
Ar	0000000	0000000	0000000	0000000	0000000	0000000	0000159
Ne	0000000	0000000	0000000	0000000	0000000	0000000	0000159
He	0000000	0000000	0000000	0000000	0000000	0000000	0000159
CH4	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C2H6	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C3H8	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C4H10	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C5H12	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C6H14	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C7H16	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C8H18	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C9H20	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C10H22	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C11H24	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C12H26	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C13H28	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C14H30	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C15H32	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C16H34	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C17H36	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C18H38	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C19H40	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C20H42	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C21H44	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C22H46	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C23H48	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C24H50	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C25H52	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C26H54	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C27H56	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C28H58	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C29H60	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C30H62	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C31H64	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C32H66	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C33H68	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C34H70	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C35H72	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C36H74	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C37H76	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C38H78	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C39H80	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C40H82	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C41H84	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C42H86	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C43H88	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C44H90	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C45H92	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C46H94	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C47H96	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C48H98	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C49H100	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C50H102	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C51H104	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C52H106	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C53H108	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C54H110	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C55H112	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C56H114	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C57H116	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C58H118	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C59H120	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C60H122	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C61H124	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C62H126	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C63H128	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C64H130	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C65H132	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C66H134	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C67H136	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C68H138	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C69H140	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C70H142	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C71H144	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C72H146	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C73H148	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C74H150	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C75H152	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C76H154	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C77H156	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C78H158	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C79H160	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C80H162	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C81H164	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C82H166	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C83H168	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C84H170	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C85H172	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C86H174	0000000	0000000	0000000	0000000	0000000	0000000	0000159
C87H176	0000000	00					

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MS
0.1

TEMP. °K	3000.00	3700.00	3800.00	3900.00	3708.47
MOL. WT.	26.3317	25.8496	25.6308	25.3724	25.8326
P	13621	19202	19800	20416	19252
e	- 473.32	- 420.55	- 353.84	- 303.49	
CV	.354245	.354759	.355227	.354628	.354840
γ	1.21421	1.21417	1.21438	1.21578	1.21418
S	2.21654	2.23232	2.24791	2.26358	2.23407
E	1040.40	1079.90	1120.41	1161.21	1083.29
HF	1572.68	1559.52	1543.48	1524.11	1558.29
CO	.0125329	.0126957	.0128862	.0131191	.0127108
CO2	.0066029	.0067081	.0065982	.0064663	.0066994
H2	.0021428	.0021654	.0021989	.0022466	.0021657
H2O	.0107578	.0106811	.0106050	.0105125	.0106754
N2	.0053794	.0053790	.0053785	.0053781	.0053789
O2	.0000422	.0000638	.0000926	.0001298	.0000659
U	.0000250	.0000383	.0000568	.0000819	.0000396
HF	.0004423	.0005649	.0007085	.0008745	.0005762
H	.0001911	.0002338	.0002840	.0003429	.0002377
HO	.0001101	.0001466	.0001907	.0002428	.0001501
H	.0000609	.0000995	.0000129	.0000173	.0000098
CH4	.0000012	.0000012	.0000012	.0000012	.0000012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M8

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	26.0353	26.0274	26.0177	26.0043	26.9837	26.9573	26.9214
P	30313	31496	32679	33864	35052	36243	37440
c	- 687.35	- 846.97	- 811.05	- 774.64	- 737.57	- 699.83	- 561.06
CV	346312	347765	349243	350526	351597	352611	353651
γ	1.22639	1.22458	1.22255	1.22063	1.21901	1.21765	1.21623
S	2.02457	2.03792	2.05098	2.06375	2.07631	2.08868	2.10098
E	672.62	707.38	742.32	777.51	813.04	848.78	884.95
MF	1613.71	1612.85	1611.92	1610.70	1609.19	1607.20	1604.62
CO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
O2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MB

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	26.4744	26.4134	26.3552	26.2968	26.1147	25.9666	25.7894
P	38642	39855	41079	42319	43577	44858	46161
e	- 621.10	- 579.75	- 536.77	- 491.66	- 444.28	- 394.04	- 341.62
CV	354525	355273	356096	356946	357685	358311	356953
γ	1.21501	1.21402	1.21319	1.21233	1.21163	1.21112	1.21263
S	2.11326	2.12559	2.13804	2.15073	2.16374	2.17709	2.19071
E	921.51	958.48	995.85	1033.86	1072.34	1111.71	1150.93
HF	1601.26	1596.92	1591.36	1584.33	1575.52	1564.74	1551.67

CO	.1123503	.0124150	.0124862	.0125794	.0126923	.0128246	.0129836
CO2	.0066231	.0067826	.0067358	.0066807	.0066128	.0065355	.0064426
H2	.0019331	.0019234	.0019193	.0019212	.0019285	.0019466	.0019731
H2O	.0110522	.0110451	.0110294	.0110039	.0109693	.0109201	.0108586
N2	.0053761	.0051757	.0053750	.0053737	.0053719	.0053695	.0053665
O2	.0000045	.0000077	.0000126	.0000199	.0000306	.0000454	.0000651
O	.0000027	.0000046	.0000075	.0000120	.0000184	.0000276	.0000403
OH	.0001339	.0001816	.0002416	.0003155	.0004052	.0005114	.0006358
H	.0000629	.0000791	.0000984	.0001212	.0001477	.0001786	.0002148
HCO	.0000287	.0000413	.0000579	.0000794	.0001067	.0001400	.0001803
H2O2	.0000016	.0000024	.0000034	.0000048	.0000067	.0000090	.0000121
HT3	.0000030	.0000035	.0000048	.0000067	.0000096	.0000136	.0000196
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MB

TEMP. °K 3756.96

MOL. WT. 26.9333
44304

CV .358056
γ 1.21132
S 2.17130
E 1094.64
HF 1569.64

TEMP. °K

MOL. WT.

P
e
CV
γ
S
E
HF

.0127650
.0065700
.0019373
.0009422
.0005705
.0000385
.0000233
.0004635
.0001646
.0001248
.0000079
.0000026

CO
CO2
H2
H2O
H2
O2
O
OH
H
HO
N
NH3
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M8

TEMP. °K	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00
MOL. WT.	26.5804	26.5518	26.5148	26.4669	26.4054	26.3281	26.2320
P	62317	64348	66385	68428	70485	72559	74651
e	- 701.42	- 663.05	- 623.74	- 583.52	- 541.67	- 498.24	- 453.00
CV	.355244	.356293	.357148	.357839	.358714	.359681	.360538
γ	1.21934	1.21761	1.21609	1.21483	1.21371	1.21246	1.21136
z	2.04652	2.05868	2.07076	2.08261	2.09487	2.10709	2.11950
E	846.17	882.46	919.07	955.99	993.19	1031.01	1069.20
MF	1606.16	1604.10	1601.42	1597.56	1593.56	1587.99	1581.01

CO	.0124569	.0124976	.0125427	.0125951	.0126575	.0127323	.0128244
CO2	.0066782	.0066479	.0066162	.0065810	.0065410	.0064943	.0064374
H2	.0017443	.0017271	.0017135	.0017034	.0016976	.0016966	.0016994
H2O	.0112674	.0112769	.0112799	.0112767	.0112665	.0112485	.0112233
N2	.0053735	.0053738	.0053736	.0053730	.0053720	.0053704	.0053681
O2	.0000000	.0000015	.0000028	.0000047	.0000078	.0000125	.0000193
S	.0000005	.0000010	.0000017	.0000029	.0000047	.0000075	.0000117
OH	.0000534	.0000780	.0001090	.0001480	.0001973	.0002583	.0003327
H	.0000274	.0000355	.0000452	.0000569	.0000707	.0000870	.0001059
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M8

TEMP. °K	3800.00	3900.00	3777.91
MOL. WT.	26.1152	23.9749	26.1429
P	76770	78909	76300
Q	- 405.39	- 356.49	.361130
CV	.361284	.359034	1.21061
γ	1.21042	1.21230	2.12933
S	2.13215	2.14485	1099.51
E	1168.19	1146.63	1574.51
HF	1572.47	1562.12	
CO	.0129317	.0130599	.0129065
CO2	.0063732	.0062971	.0063881
H2	.0017108	.0017293	.0017075
H2O	.0111859	.0111981	.0111953
H2	.0052651	.0053612	.0053658
O2	.0000288	.0000418	.0000265
O	.0000175	.0000257	.0000161
OH	.0004213	.0005256	.0004004
H	.0001280	.0001536	.0001229
NO	.0001178	.0001524	.0001110
..	.0000072	.0000097	.0000068
NH3	.0000044	.0000044	.0000044
CH4			

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MS 0.4

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	26.5723	26.5409	26.5006	26.4407	26.3834	26.3022	25.2035
P	98317	101380	104446	107524	110617	113727	116864
e	- 663.04	- 623.95	- 583.94	- 542.93	- 500.31	- 456.14	- 409.89
CV	.359159	.359983	.360608	.361521	.362590	.363546	.364385
γ	1.22094	1.21913	1.21771	1.21636	1.21479	1.21336	1.21209
S	2.02475	2.03675	2.04868	2.06055	2.07253	2.08465	2.09693
E	881.11	917.91	954.95	992.17	1030.01	1068.18	1107.10
HF	1602.73	1600.45	1597.51	1593.76	1589.03	1583.08	1575.82
CO	.0127190	.0127588	.0128049	.0128597	.0129252	.0130057	.0130992
CO2	.0064190	.0063906	.0063591	.0063231	.0062813	.0062304	.0061751
H2	.0014920	.0014900	.0014707	.0014650	.0014632	.0014643	.0014725
H2O	.0115126	.0115162	.0115144	.0115070	.0114928	.0114727	.0114422
N2	.0053713	.0053710	.0053703	.0053692	.0053674	.0053648	.0053613
O2	.0000011	.0000019	.0000033	.0000055	.0000089	.0000138	.0000207
C	.0000007	.0000012	.0000020	.0000033	.0000053	.0000083	.0000125
OH	.0000676	.0000942	.0001281	.0001711	.0002244	.0002896	.0003675
H	.0000264	.0000336	.0000423	.0000526	.0000647	.0000788	.0000951
NO	.0000143	.0000212	.0000306	.0000431	.0000594	.0000803	.0001041
N	.0000007	.0000011	.0000016	.0000023	.0000033	.0000045	.0000061
H+3	.0000082	.0000076	.0000076	.0000072	.0000069	.0000065	.0000065
CH4	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

48 C=4

TEMP. °A	3900.00	3786.59
MOL. WT.	20.0846	26.2177
P	120016	116444
e	- 363.02	
G:	.351165	.354351
γ	1.21446	1.21225
S	2.10910	2.09528
E	1145.06	1101.87
TE	1597.00	1576.57

CO	.132103	.0130859
CO2	.061059	.0061812
H2	.0014669	.0014710
H2O	.0114022	.0114469
H2	.003906	.0039519
O2	.000302	.0003197
O	.001153	.000118
OH	.004596	.0003563
H	.001141	.000328
NO	.0001377	.0001024
N	.0001082	.000059
N2	.0000065	.0000065

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.05

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	27.3586	27.3513	27.3404	27.3239	27.2995	27.2644	27.2140
P	5598	5834	6071	6308	6546	6786	7028
e	-1003.52	-968.43	933.15	-897.30	-860.59	-822.79	-783.55
CV	338637	340390	342012	343493	344928	346228	347385
Z	1.21964	1.21805	1.21660	1.21538	1.21419	1.21316	1.21230
S	2.03455	2.05947	2.11330	2.12684	2.14018	2.15344	2.16674
E	610.12	643.95	678.15	712.65	747.55	782.90	818.78
HF	1672.17	1671.11	1670.04	1668.69	1666.91	1664.49	1661.16
CO	.0100107	.0100854	.0101345	.0101835	.0102324	.0102845	.0103439
CO2	.0084371	.0082669	.0082194	.0082760	.0082354	.0081952	.0081529
H2	.0019984	.0019290	.0018831	.0018433	.0018094	.0017811	.0017588
H2O	.0106343	.0107014	.0107424	.0107777	.0108038	.0108216	.0108304
O2	.0054566	.0054570	.0054575	.0054580	.0054587	.0054593	.0054601
O		.0000001	.0000002	.0000006	.0000013	.0000028	.0000057
OH		.0000103	.0000001	.0000003	.0000006	.0000013	.0000026
H	.0000070	.0000107	.0000184	.0000303	.0000480	.0000736	.0001095
NO	.0000007	.0000014	.0000026	.0000047	.0000082	.0000136	.0000219
N		.0000001	.0000001	.0000002	.0000003	.0000006	.0000009
CH4		.0000007	.0000007	.0000006	.0000006	.0000006	.0000005

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.05

TEMP. °K	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00
MOL. WT.	27.1440	27.0478	26.9186	26.7489	26.5317	26.2616	25.9355
P	7273	7521	7776	8037	8307	8588	8880
e	- 742.44	- 698.88	- 652.25	- 601.87	- 547.06	- 487.22	- 421.99
CV	348425	345359	350137	350772	351280	351658	351864
γ	1.21165	1.21114	1.21088	1.21089	1.21120	1.21179	1.21272
S	2.18022	2.19404	2.20838	2.22342	2.23930	2.25615	2.27405
E	855.27	892.51	930.63	969.74	1009.90	1051.17	1093.34
HF	1656.58	1650.33	1641.91	1630.75	1616.26	1597.87	1575.04
CO	.0104192	.0105051	.0106206	.0107701	.0109616	.0112020	.0114956
CO2	.0091054	.0080484	.0079774	.0078868	.0077716	.0076272	.0074487
H2	.0017430	.0017344	.0017348	.0017456	.0017691	.0018073	.0018604
H2O	.0198285	.0198161	.0197903	.0197500	.0196932	.0196181	.0195246
N2	.0054609	.0054617	.0054625	.0054636	.0054653	.0054677	.0054712
O2	.0000110	.0000199	.0000345	.0000571	.0000901	.0001359	.0001964
O	.0000049	.0000089	.0000154	.0000257	.0000413	.0000639	.0000958
OH	.0001583	.0002230	.0003066	.0004120	.0005414	.0006967	.0008790
H	.0000772	.0001002	.0001285	.0001628	.0002044	.0002546	.0003149
HO	.0000340	.0000512	.0000747	.0001057	.0001455	.0001947	.0002536
H	.0000014	.0000022	.0000033	.0000049	.0000070	.0000099	.0000137
H2O2	.0000005	.0000004	.0000004	.0000004	.0000004	.0000004	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

MS

TEMP. °K	3800.00	3900.00	4000.00	3706.95
MOL. WT.	25.5165	25.1269	24.6529	25.9109
P	9186	9506	9840	8901
e	- 351.18	- 275.18	- 193.96	
CV	.351909	.351360	.351145	.351873
γ	1.21400	1.21608	1.21811	1.21280
S	2.29289	2.31263	2.33315	2.27532
C	1336.52	1175.87	1223.67	1096.30
MF	1547.09	1515.45	1478.27	1573.30
CO	.0118448	.0122453	.0126946	.0115209
CO2	.0072424	.0070043	.0067392	.0074352
H2	.0019534	.0020231	.0021310	.0018648
H2O	.0104371	.0102693	.0101062	.0105173
H2	.0054751	.0054824	.0054904	.0054715
O2	.0002711	.0003598	.0004613	.0002011
O	.0001338	.0001952	.0002571	.0000934
CH	.0010870	.0013211	.0015789	.0008925
H	.0003875	.0004742	.0005773	.0003195
NO	.0003217	.0003968	.0004838	.0002581
N	.0000186	.0000249	.0000329	.0000140
NH3	.0000004	.0000005	.0000005	.0000004
CH4				

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.1

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	27.3632	27.2578	27.3504	27.3369	27.3221	27.2984	27.2641
P	11907	12410	12915	13421	13928	14437	14943
e	-1005.50	-970.53	-935.45	-897.95	-855.80	-825.87	-788.53
CV	33971	34174	34328	34469	34614	34747	34858
Z	1.2225	1.2205	1.2186	1.2172	1.2157	1.2142	1.2131
S	2.0224	2.0438	2.0576	2.0710	2.0841	2.0971	2.1097
E	657.43	641.53	675.56	710.01	744.84	780.01	815.60
HF	1671.55	1670.61	1669.74	1668.71	1667.39	1665.65	1663.32
CO	.0103685	.0101583	.0102063	.0102515	.0102950	.0103393	.0103875
CO2	.0095579	.0092598	.0092443	.0092030	.0091651	.0091289	.0090923
H2O	.0115161	.0118511	.0118067	.0117680	.0117347	.0117062	.0116828
H2	.0107140	.0107799	.0108217	.0108567	.0108846	.0109054	.0109195
O2	.0054557	.0054562	.0054555	.0054559	.0054574	.0054577	.0054582
N2			.0000001	.0000003	.0000006	.0000014	.0000027
HT			.0000001	.0000001	.0000003	.0000006	.0000013
H	.0000042	.0000075	.0000129	.0000213	.0000338	.0000518	.0000772
NO	.0000048	.0000073	.0000107	.0000154	.0000216	.0000295	.0000396
OH	.0000005	.0000010	.0000018	.0000032	.0000058	.0000095	.0000155
HO			.0000001	.0000001	.0000002	.0000004	.0000006
CH4	.0000017	.0000014	.0000014	.0000013	.0000012	.0000013	.0000010

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.1

M9

TEMP. °K	3800.00	3900.00	4000.00	3777.39
MO. WT.	26.1275	25.8126	25.4545	26.1920
R	19341	19962	20606	19204
•	- 403.35	- 393.79	- 269.56	
CV	354174	353450	353460	354121
γ	1.21031	1.21196	1.21313	1.21019
z	1.22273	2.23955	2.25703	2.21902
z	1.23148	1.69.24	1.297.73	1.14.00
MF	1.950.11	1.903.82	1.937.34	1.971.00

•	142544	147256	1520978	1513755
•	2074431	2072686	2070676	2074795
•	1017403	1014000	1018712	1017329
•	1006610	1005957	1004510	1006618
•	1004055	1004054	1004560	10054356
•	1001400	1001000	1000710	1001389
•	1001700	1001333	1001000	1001000
•	1001111	1000841	1001000	1000830
•	1000634	1000370	1000370	10002123
•	1000244	1000076	1000076	10000309
•	1000030	1000074	10000250	10000122
•	1000000	1000000	1000000	1000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9 0.2

TEMP. °K	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00
MOL. WT.	27.3400	27.3243	27.3007	27.2693	27.2263	27.1692	27.0943
P	31804	32961	34122	35287	36459	37639	38829
e	- 867.10	- 820.60	- 792.37	- 755.33	- 716.08	- 675.44	- 633.10
CV	348732	350015	351085	352093	353118	353977	354691
T	1.21765	1.21580	1.21419	1.21284	1.21146	1.21028	1.20923
S	2.02273	2.03553	2.04814	2.06060	2.07305	2.08554	2.09817
E	742.74	775.97	811.56	847.47	883.72	920.50	957.78
HF	1666.58	1565.52	1663.70	1651.51	1558.62	1654.80	1645.79

CO	.0104519	.0104891	.0105289	.0105716	.0106211	.0106800	.0107524
CO2	.0060022	.0079703	.0079385	.0079065	.0078715	.0079321	.0077852
H2	.0015679	.0015411	.0015188	.0015003	.0014859	.0014759	.0014703
H2O	.0110540	.0110752	.0110918	.0111013	.0111048	.0111011	.0110897
H2	.0054557	.0054557	.0054562	.0054562	.0054560	.0054554	.0054543
O2	.0000003	.0000006	.0000012	.0000024	.0000044	.0000078	.0000133
O	.0000001	.0000005	.0000006	.0000011	.0000020	.0000036	.0000061
OH	.0000236	.0000363	.0000541	.0000786	.0001112	.0001539	.0002085
H	.0000138	.0000188	.0000252	.0000332	.0000430	.0000548	.0000691
H2	.0000041	.0000068	.0000109	.0000171	.0000259	.0000382	.0000547
N	.0000002	.0000003	.0000005	.0000007	.0000011	.0000016	.0000024
NH3	.0000027	.0000000	.0000024	.0000023	.0000021	.0000020	.0000020

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION:

0.2

M9

TEMP. °K	3500.00	3600.00	3700.00	3800.00	3900.00	4000.00	
MOL. WT.	26.9975	26.8749	26.7223	26.5574	26.3174	26.0611	3839.60
p	40034	41259	42506	43780	45079	46415	26.4547
c	508.78	541.91	592.27	639.23	689.72	724.15	44291
CV	355409	355256	350916	357447	356123	356249	357133
γ	1.21258	1.20761	1.20125	1.20689	1.20854	1.20995	1.20729
S	2.11101	2.12420	2.13781	2.15189	2.16633	2.18142	2.15756
H	955.55	1024.09	1079.22	1113.29	1152.23	1194.26	1129.15
HF	1043.31	1035.23	1624.55	1611.91	1596.49	1572.14	1606.15

CO ₂	0.000024	0.009544	0.010950	0.012627	0.014545	0.017729	0.013382
CO	0.077284	0.075587	0.075712	0.074684	0.073547	0.071986	0.074221
H ₂	0.001704	0.014769	0.014895	0.015124	0.015444	0.015664	0.015239
H ₂ O	0.000000	0.010404	0.010019	0.009495	0.008652	0.008079	0.009256
H	0.004321	0.004595	0.004478	0.004445	0.004407	0.004366	0.004430
O	0.000000	0.000343	0.000500	0.000764	0.001079	0.001472	0.000879
N ₂	0.000000	0.000106	0.000240	0.000357	0.000516	0.000731	0.000415
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000106	0.000291	0.000521	0.000712	0.000880	0.000634
NO ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000047	0.000139	0.000273	0.000411	0.000522	0.000199
H ₂ O ⁺	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CO ⁺	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CO ₂ ⁺	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO ⁺	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO ₂ ⁺	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HF	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	0.000015	0.000018	0.000018	0.000016	0.000016	0.000019	0.000018

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MS 0.3

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	27.2101	27.2153	27.1566	27.0807	26.9845	26.8643	26.7179
P	82715	54716	56723	58746	70790	72857	74555
e	- 718.75	- 676.90	- 637.71	- 595.01	- 550.18	- 503.13	- 453.34
CV	355801	356645	357316	358155	359069	359862	360526
γ	1.21297	1.21148	1.21024	1.20917	1.20799	1.20698	1.20616
S	1.03162	2.04387	2.05614	2.06851	2.08111	2.09402	2.10724
E	81.17	917.95	955.12	992.65	1030.87	1069.59	1109.17
MF	1658.72	1655.57	1651.7	1646.57	1640.04	1631.79	1621.69
CO	.007770	.0108260	.0108856	.0109590	.0110498	.0111635	.0112989
CO2	.0077041	.0076703	.0076307	.0075852	.0075255	.0074533	.0073688
H2	.012373	.012572	.012904	.012860	.012902	.012967	.013115
H2O	.012399	.0112691	.0112822	.0112889	.0112472	.0112187	.0111790
N2	.0054542	.0054534	.0054521	.0054502	.0054476	.0054441	.0054397
O2	.000027	.000049	.000063	.0000137	.0000218	.0000335	.0000497
OH	.000013	.000022	.000038	.000062	.000099	.000153	.000229
H	.0000308	.0001252	.0001699	.0002203	.0002958	.0003803	.0004805
HNO	.0000215	.0000317	.0000494	.0000614	.0000757	.0000923	.0001119
N	.0000009	.0000013	.0000015	.0000028	.0000050	.0000181	.0001551
NH3	.0000036	.0000034	.0000033	.0000032	.0000030	.0000053	.0000072
CH4						.0000030	.0000029

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M9

TEMP. °F	3900.00	4000.00	3869.45
MOL. WT.	26.5424	26.3357	26.5992
P	77079	79244	76427
e	- 401.61	- 346.67	
CV	.358261	.358588	.359282
7	1.20811	1.20810	1.20720
5	2.12063	2.12450	2.11652
E	1149.31	1198.61	1126.40
HF	1609.40	1594.71	1613.40
CO	.0114622	.0115567	.0114092
CO ₂	.0072071	.0071460	.0073001
H ₂ O	.0123333	.0123327	.0123239
H ₂	.0111292	.0110691	.0111455
O ₂	.0054266	.0054265	.0054262
N ₂	.0000711	.0000989	.0000640
HT	.0000334	.0000475	.0000299
HT	.0000979	.0000731	.0000601
H ₂	.0001347	.0001613	.0001274
H ₂ O	.0001594	.0002516	.0001850
H ₂	.0000097	.0000128	.0000089
H ₂	.0000029	.0000030	.0000029

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M9

0.4

TEMP. °K	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00	3900.00
MOL. WT.	27.2436	27.1944	27.1303	27.0491	26.9475	26.8234	26.6741
P	98980	101593	105022	108070	111139	114241	117359
e	- 575.74	- 639.07	- 597.15	- 553.34	- 507.61	- 459.47	- 410.29
CV	359541	360154	361036	362057	362953	363719	364526
Z	1.21468	1.21320	1.21190	1.21039	1.20903	1.20786	1.20682
E	2.01050	2.02262	2.03475	2.04707	2.05960	2.07239	2.08517
W	916.60	954.05	991.56	1029.74	1068.39	1107.82	1146.40
W	1855.04	1951.95	2047.59	2142.03	2235.11	2326.39	2415.59
CO	.0109931	.0110451	.0111091	.0111881	.0112869	.0114048	.0115467
CO2	.0074935	.0074984	.0074162	.0073650	.0073011	.0072351	.0071863
H2	.0011109	.0011044	.0011013	.0011019	.0011056	.0011160	.0011324
H2O	.0114759	.0114750	.0114645	.0114476	.0114249	.0113926	.0113516
H2	.0054515	.0054500	.0054479	.0054450	.0054410	.0054360	.0054270
O2	.0000025	.0000059	.0000098	.0000157	.0000244	.0000363	.0000525
O	.0000016	.0000027	.0000044	.0000070	.0000103	.0000164	.0000240
OH	.0001080	.0001469	.0001959	.0002567	.0003306	.0004191	.0005230
H	.0000290	.0000365	.0000454	.0000558	.0000681	.0000825	.0000992
H2O	.0000264	.0000340	.0000426	.0000529	.0000657	.0000806	.0000985
H	.0000001	.0000010	.0000023	.0000035	.0000045	.0000061	.0000081
CH4	.0000001	.0000004	.0000007	.0000009	.0000013	.0000017	.0000023

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MIO 0.05

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	24.4944	24.4374	24.4165	24.4075	24.4030	24.3992	24.3973
P	4174	4444	4711	4977	5242	5507	5772
e	-1036.74	-1001.59	-967.23	-933.08	-898.96	-864.73	-830.54
CV	.320555	.323640	.326716	.329503	.332142	.334629	.336865
γ	1.26488	1.26125	1.25779	1.25469	1.25192	1.24934	1.24700
S	2.07361	2.09493	2.11456	2.13302	2.15052	2.16723	2.18321
E	354.11	387.13	419.56	452.02	484.54	517.03	550.79
HF	1447.77	1445.67	1443.76	1442.07	1440.60	1439.34	1438.11
CO	.0160392	.0163491	.0165792	.0167654	.0169197	.0170522	.0171659
CO2	.0060210	.0057595	.0055467	.0053676	.0052165	.0050867	.0049739
H2	.0062453	.0060555	.0058689	.0057006	.0055546	.0054271	.0053152
H2O	.0079074	.0081625	.0083734	.0085520	.0087030	.0088233	.0089457
N2	.0045652	.0045718	.0045746	.0045760	.0045769	.0045777	.0045781
O2							
OH							
H	.0000001	.0000001	.0000003	.0000001	.0000002	.0000004	.0000006
NO				.0000007	.0000013	.0000024	.0000042
N							
NH3	.0000114	.0000090	.0000073	.0000060	.0000051	.0000044	.0000039
CH4	.0000360	.0000134	.0000055	.0000025	.0000013	.0000007	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.05

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MCL. WT.	24.3942	24.3901	24.3841	24.3764	24.3651	24.3496	24.3288
P	6036	6300	6564	6829	7095	7361	7628
e	- 795.84	- 761.19	- 725.99	- 690.57	- 654.74	- 618.32	- 581.22
CV	.338264	.340876	.342586	.344196	.345680	.347125	.348457
γ	1.24211	1.24218	1.24153	1.24000	1.23869	1.23740	1.23624
S	2.19656	2.21284	2.22768	2.24158	2.25510	2.26834	2.28136
E	584.19	618.00	651.87	686.10	720.58	755.38	790.48
HF	1437.01	1436.17	1434.85	1433.66	1432.32	1430.71	1428.73
CC	.0172660	.0173302	.0174327	.0175027	.0175668	.0176261	.0176823
CO2	.0048753	.0048129	.0047133	.0046469	.0045878	.0045357	.0044890
H2	.0052169	.0051540	.0050539	.0049858	.0049253	.0048719	.0048241
H2O	.0090441	.0091060	.0092045	.0092686	.0093238	.0093699	.0094069
N2	.0045785	.0045790	.0045796	.0045802	.0045811	.0045820	.0045829
O2	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017	.0000017
CO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NH3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

MIG

TEMP. °K	2000.00	3100.00	3200.00	3018.97
MOL. WT.	24.3000	24.3000	24.2142	24.2936
P	7896	5165	8438	7947
c	-543.26	-524.27	464.00	
CV	3495.19	3507.96	3518.55	3498.90
γ	1.23924	1.23439	1.23363	1.23506
S	1.29423	2.30700	2.31979	2.29666
E	525.95	861.76	897.99	832.71
HF	426.26	1423.11	1419.10	1425.71
	0177382	0177943	0176543	0177488
	0044462	0044071	0043594	0044385
	0047828	0047662	0047163	0047756
	0043556	0044542	0044632	0044399
	0044945	0045860	0045878	0045848
	0000006	0000011	0000020	0000007
	0000008	0000016	0000028	0000009
	0000078	0000036	0001181	0000621
	0000965	0001273	0001652	0001018
	0000064	0000100	0001150	0000070
	0000008	0000013	0000000	0000009
	0000001	0000021	0000001	0000020

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10
0.1

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MOL. WT.	24.4028	24.3987	24.3930	24.3875	24.3792	24.3681	24.3542
P	12867	13432	13996	14560	15126	15692	16259
e	- 797.24	- 727.40	- 692.09	- 656.51	- 620.44	- 583.89	- 546.86
CV	342227	343946	345499	346909	348273	349594	350876
Z	1.34741	1.24302	1.24116	1.23963	1.23801	1.23655	1.23517
S	2.12629	2.16542	2.17927	2.19273	2.20562	2.21865	2.23165
E	581.53	649.42	695.72	733.02	763.02	788.05	810.05
MF	1435.72	1433.81	1432.60	1431.71	1430.46	1428.96	1427.26
CO	.0173524	.0174955	.0175502	.0176237	.0176853	.0177414	.0177931
CO2	.0047441	.0046852	.0046355	.0045906	.0045438	.0044918	.0044365
H2	.0050777	.0050182	.0049621	.0049093	.0048592	.0048118	.0047604
H2O	.0191742	.0192343	.0192920	.0193452	.0193940	.0194371	.0194755
N2	.0143757	.0143764	.0143774	.0143777	.0143785	.0143792	.0143797
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Cl2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Cl	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Br2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Br	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
I2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
I	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
SO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
SO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
SiO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
SiO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Al2O3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
AlO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Al	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
FeO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Fe	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
MgO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Mg	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CaO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Ca	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Na2O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Na	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
K2O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
K	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Li2O	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Li	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.I

M10

TEMP. °C 3000.00 3100.00 3200.00 3028.46

MOLE WT.
 P 24.3324 24.3078 24.2741 24.3266
 • 15225 17299 17974 16990
 CV - 545.68 - 505.78 - 465.05 351185
 7 355962 251970 353047 1.23474
 S 1.23527 1.22417 1.23210 2.23180
 E 2.23125 2.24367 2.25599 832.56
 HF 823.45 857.27 895.13 1426.56
 1427.16 1422.26

CO	178442	178932	179429	178989
CO2	543249	642578	642528	643125
H2O	646612	646258	645937	646500
H2	25076	395907	395503	395791
O2	64313	643129	643129	643129
N2	1403	1403	1403	1403
NO	1403	1403	1403	1403
NO2	1403	1403	1403	1403
HF	1403	1403	1403	1403
CH4	1403	1403	1403	1403
C2H2	1403	1403	1403	1403
C2H4	1403	1403	1403	1403
C2H6	1403	1403	1403	1403
C3H8	1403	1403	1403	1403
C4H10	1403	1403	1403	1403
C4H8	1403	1403	1403	1403
C4H6	1403	1403	1403	1403
C6H6	1403	1403	1403	1403
C6H12	1403	1403	1403	1403
C6H14	1403	1403	1403	1403
C6H18	1403	1403	1403	1403
C6H20	1403	1403	1403	1403
C6H22	1403	1403	1403	1403
C6H24	1403	1403	1403	1403
C6H26	1403	1403	1403	1403
C6H28	1403	1403	1403	1403
C6H30	1403	1403	1403	1403
C6H32	1403	1403	1403	1403
C6H34	1403	1403	1403	1403
C6H36	1403	1403	1403	1403
C6H38	1403	1403	1403	1403
C6H40	1403	1403	1403	1403
C6H42	1403	1403	1403	1403
C6H44	1403	1403	1403	1403
C6H46	1403	1403	1403	1403
C6H48	1403	1403	1403	1403
C6H50	1403	1403	1403	1403
C6H52	1403	1403	1403	1403
C6H54	1403	1403	1403	1403
C6H56	1403	1403	1403	1403
C6H58	1403	1403	1403	1403
C6H60	1403	1403	1403	1403
C6H62	1403	1403	1403	1403
C6H64	1403	1403	1403	1403
C6H66	1403	1403	1403	1403
C6H68	1403	1403	1403	1403
C6H70	1403	1403	1403	1403
C6H72	1403	1403	1403	1403
C6H74	1403	1403	1403	1403
C6H76	1403	1403	1403	1403
C6H78	1403	1403	1403	1403
C6H80	1403	1403	1403	1403
C6H82	1403	1403	1403	1403
C6H84	1403	1403	1403	1403
C6H86	1403	1403	1403	1403
C6H88	1403	1403	1403	1403
C6H90	1403	1403	1403	1403
C6H92	1403	1403	1403	1403
C6H94	1403	1403	1403	1403
C6H96	1403	1403	1403	1403
C6H98	1403	1403	1403	1403
C6H100	1403	1403	1403	1403

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10

0.2

TEMP. °F.	190	200	2100	2200	2300	2400	2500
MOL. WT.	24.4976	24.4976	24.4609	24.4409	24.4260	24.4196	24.4105
P	25542	25542	26859	28166	29455	30752	32037
CV	747.17	904.29	109.02	133.94	179.15	205.23	228.57
γ	1.33232	1.33649	1.339212	1.341371	1.343094	1.345175	1.346836
S	1.20730	1.2605	1.25654	1.25298	1.25046	1.24748	1.24492
E	2.03019	2.01060	2.03581	2.05212	2.06761	2.08201	2.09695
TF	3.13	474.01	508.30	542.46	576.38	610.69	645.05
	1436.17	1435.11	1434.26	1433.35	1432.49	1431.89	1430.89

CO ₂	.0172331	.0172934	.0174513	.0175747	.0176732	.0177422	.0178416
CO	.0049310	.0047719	.0046435	.0045303	.0044425	.0043842	.0042903
H ₂ O	.0089905	.0049915	.0049089	.0048256	.0047464	.0046962	.0046101
H ₂	.0089905	.0091490	.0092743	.0093803	.0094735	.0095315	.0095625
O ₂	.0045478	.0045569	.0045621	.0045654	.0045677	.0045694	.0045717
OH							
H	.0000001	.0000001	.0000002	.0000004	.0000008	.0000015	.0000028
NO	.0000006	.0000006	.0000011	.0000019	.0000031	.0000050	.0000077
N ₂						.0000001	.0000002
CH ₄	.0000320	.0000274	.0000259	.0000211	.0000188	.0000170	.0000135
	.0000572	.0000294	.0000161	.0000094	.0000055	.0000036	.0000023

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10 0.2

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
Hum. HT.	24.4026	24.3381	24.2674	24.1908	24.1093	24.0243	23.9363
P	33222	34013	34806	35601	36398	37187	37978
CV	0.93.49	0.97.42	0.24.94	0.22.01	0.19.07	0.16.14	0.13.21
γ	0.34072	0.34515	0.34958	0.35401	0.35844	0.36287	0.36730
β	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ε	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
MF	0.77.00	7.4.9	7.49.21	7.64.48	7.79.75	7.95.02	8.10.29
	1430.00	1429.19	1428.28	1427.09	1425.60	1424.10	1422.21
CO	0.179116	0.179049	0.178982	0.178915	0.178848	0.178781	0.178714
CO ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H ₂ O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
O ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH ₄	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M10

3034.41

TEMP. °K

24.3584
38516

MOLE WT.

e
CV
N
E
HF

353742
1.32467
2.1567
312.29
1.135.29

0.01261
0.040315
0.043639
0.09540
0.45763
0.01001
0.00002
0.000523
0.000472
0.000036
0.00005
0.00007
0.000004

O₂
CO₂
H₂
H₂O
H₂
O₂
O₂
O₂
H₂
H₂
NH₃
CH₄

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MIO 0.5

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	24.4548	24.4571	24.4258	24.4202	24.4110	24.4050	24.3980
P	52969	55184	57377	59572	61764	63947	66145
CV	- 704.92	- 729.21	- 695.53	- 657.87	- 621.76	- 585.38	- 548.51
Z	1.348357	1.349962	1.351269	1.352356	1.353844	1.355109	1.356094
S	1.25056	1.24763	1.24502	1.24306	1.24061	1.23849	1.23652
E	2.03602	2.05110	2.06511	2.07857	2.09170	2.10447	2.11695
HF	666.25	641.14	676.08	711.02	746.35	781.75	817.62
	1428.12	1427.50	1426.57	1425.86	1425.08	1424.11	1423.12
CO	.0180614	.0151643	.0182275	.0192851	.0183354	.0183774	.0184236
CO2	.0040420	.0039510	.0038933	.0038415	.0037961	.0037575	.0037194
H2	.0000114	.0000140	.0000176	.0000225	.0000281	.0000347	.0000425
H2O	.0000710	.0000622	.0000516	.0000387	.0000247	.0000117	.0000000
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
...	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
T	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
...	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NH3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

	TEMP. °K	3100.00	3200.00	3023.77
MIC				
MOL. WT.		24.3740	24.3540	24.3829
P		58233	70529	66884
e		511.40	- 473.65	
CV		357072	356150	356425
γ		1.23490	1.23314	1.23594
S		2.12911	2.14108	2.12109
E		853.41	889.60	829.71
MF		1421.82	1420.26	1422.71
CO		.0184622	.0185025	.0184315
CO2		.0036374	.0036570	.0036379
H2		.0040040	.0039801	.0040235
H2O		.0102031	.0102226	.0101835
N2		.0045699	.0045710	.0045699
O2		.0000001	.0000002	.0000001
O		.0000002	.0000004	.0000001
OH		.0000330	.0000465	.0000259
H		.0000417	.0000540	.0000348
NO		.0000038	.0000058	.0000029
N		.0000005	.0000008	.0000004
NH3		.0000002	.0000003	.0000019
CH4		.0000011	.0000008	.0000013

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M10 0.4

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	24.4665	24.4518	24.4398	24.4349	24.4145	24.4019	24.3829
P	87656	90974	94262	97568	100392	104172	107471
e	- 692.68	- 656.79	- 620.42	- 583.83	- 546.89	- 509.71	- 471.95
CV	351436	355400	356907	358142	359016	359919	360990
γ	1.24923	1.24717	1.24443	1.24194	1.23968	1.23809	1.23609
S	2.02819	2.04174	2.05496	2.06779	2.08039	2.09249	2.10446
E	672.95	706.26	743.97	779.66	815.54	851.97	888.44
HF	1422.56	1421.99	1421.25	1420.50	1419.74	1418.63	1417.39
CO	.0185712	.0186306	.0186905	.0187189	.0187659	.0188119	.0188389
CO2	.0035269	.0034773	.0034347	.0034001	.0033632	.0033341	.0033058
H2	.0057777	.0037425	.0037096	.0036740	.0036535	.0036287	.0036098
H2O	.0038066	.0104791	.0104696	.0104989	.0105394	.0105792	.0105747
H2	.0045516	.0045546	.0045568	.0045549	.0045605	.0045611	.0045625
O2							
N2							
OH	.0000052	.0000093	.0000084	.0000130	.0000119	.0000081	.0000002
H	.0000064	.0000093	.0000130	.0000179	.0000194	.0000283	.0000401
NO	.0000002	.0000004	.0000058	.0000012	.0000021	.0000319	.0000414
N	.0000001	.0000001	.0000001	.0000002	.0000003	.0000033	.0000049
H4S	.0000436	.0000452	.0000377	.0000417	.0000003	.0000365	.0000007
CH4	.0000107	.0000075	.0000056	.0000041	.0000334	.0000333	.0000301
							.0000019

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M10

TEMP. °K 3029.13

MOL. WT. 24.4101
 P 101843
 CV .359276
 γ 1.23933
 S 2.08391
 E 826.46
 MF 1419.46

CO .0187775
 CO2 .0032545
 H2 .0036468
 H2O .0105411
 N2 .0045612
 O2 .0000001
 O .0000017
 OH .0000262
 NO .0000024
 N .0000003
 NH3 .0000025
 CH4 .0000029

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

W12

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	24.1754	25.5091	25.7006	25.6617	25.6453	25.6374	25.6328
ρ	4.012	4.310	4.594	4.871	5.147	5.421	5.695
Cv	3.17542	3.20769	3.23854	3.26860	3.29813	3.32727	3.35606
γ	1.27179	1.27179	1.26833	1.26519	1.26214	1.25933	1.25671
β	2.07654	2.13540	2.12743	2.14721	2.15333	2.16335	2.20011
β ₁	3.1409	3.53067	3.67095	4.00080	4.53053	4.96029	5.29026
β ₂	1.56152	1.95709	1.95769	1.95355	1.95401	1.95279	1.95152
C ₁	0.17010	0.17330	0.18190	0.184462	0.186267	0.187908	0.189208
C ₂	0.54033	0.54097	0.546225	0.546104	0.544344	0.542569	0.541604
C ₃	0.72834	0.73203	0.73700	0.73977	0.73838	0.737465	0.7366248
C ₄	0.67475	0.676644	0.678144	0.679202	0.679949	0.680497	0.6809670
C ₅	0.43767	0.436094	0.446210	0.446259	0.446283	0.446296	0.446305
C ₆							
C ₇							
C ₈							
C ₉							
C ₁₀							
C ₁₁							
C ₁₂							
C ₁₃							
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C ₁₆							
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C ₁₈							
C ₁₉							
C ₂₀							
C ₂₁							
C ₂₂							
C ₂₃							
C ₂₄							
C ₂₅							
C ₂₆							
C ₂₇							
C ₂₈							
C ₂₉							
C ₃₀							
C ₃₁							
C ₃₂							
C ₃₃							
C ₃₄							
C ₃₅							
C ₃₆							
C ₃₇							
C ₃₈							
C ₃₉							
C ₄₀							
C ₄₁							
C ₄₂							
C ₄₃							
C ₄₄							
C ₄₅							
C ₄₆							
C ₄₇							
C ₄₈							
C ₄₉							
C ₅₀							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.05

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.6290	23.6257	23.6215	23.6154	23.6080	23.5974	23.5829
P	5969	6242	6515	6788	7061	7335	7610
e	- 741.90	- 706.99	- 672.34	- 637.15	- 601.74	- 565.93	- 529.57
CV	336926	338927	340935	342945	344262	345755	347207
γ	1.25435	1.25245	1.25047	1.24850	1.24721	1.24590	1.24455
ρ	2.21011	2.23145	2.24509	2.26057	2.27446	2.28798	2.30120
E	552.95	585.90	619.76	655.67	687.90	722.38	757.16
HF	1355.99	1349.29	1346.47	1347.17	1346.00	1344.67	1343.10

CV	• 0190329	• 0191904	• 0191932	• 0192526	• 0193006	• 0194228	• 0194800
CO2	• 0040509	• 0029552	• 0038947	• 0037982	• 0037340	• 0036771	• 0036270
H2	• 0065177	• 0064229	• 0063621	• 0062655	• 0061988	• 0061396	• 0060869
H2O	• 0080765	• 0081719	• 0082320	• 0083277	• 0083901	• 0084442	• 0084895
H2	• 0046315	• 0046318	• 0046324	• 0046333	• 0046338	• 0046347	• 0046359
O2							• 0000001
O							• 0000001
NH	• 0000007	• 0000014	• 0000026	• 0000046	• 0000079	• 0000130	• 0000205
H	• 0000047	• 0000078	• 0000125	• 0000192	• 0000287	• 0000414	• 0000563
HO		• 0000001	• 0000001	• 0000003	• 0000006	• 0000010	• 0000018
H73						• 0000002	• 0000002
CH4	• 0000053	• 0000048	• 0000043	• 0000026	• 0000037	• 0000034	• 0000032
	• 0000009	• 0000005	• 0000003	• 0000002	• 0000002	• 0000001	• 0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

v.05

TEMP. °K	2900.00	3000.00	2843.74
MOL. WT.	23.5640	23.5977	23.5742
ρ	7886	8163	7744
e	- 452.58	- 454.79	
CV	34551	34570	347876
γ	1.24340	1.24236	1.24299
β	2.31415	2.32699	2.30755
ϵ	792.21	827.61	774.21
HF	1341.17	1329.80	1342.21

CO	0195337	0195809	0195066
CO2	0035825	0035424	0036046
H2	0060389	0059973	0060629
H2O	0085264	0085557	0085088
N2	0046366	0046367	0046367
O2	0000002	0000003	0000001
OH	0000003	0000006	0000002
H	000314	0001457	0000254
H2O2	0000000	0001061	0000684
NO	0000029	0000047	0000023
NO2	0000005	0000008	0000004
HNO3	0000036	0000029	0000033
CH4	0000001	0000001	0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.1

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	25.1161	24.2924	23.9229	23.7676	23.7004	23.6696	23.6539
P	8364	9090	9747	10366	10959	11561	12151
e	-1016.90	-962.94	-920.18	-882.51	-846.97	-812.07	-777.46
CV	322257	323716	325029	328659	331193	333726	335209
γ	1.27427	1.27470	1.27245	1.25913	1.26572	1.26248	1.25930
S	1.99568	2.03417	2.06010	2.08163	2.10089	2.11874	2.13562
E	284.81	237.60	379.02	415.14	449.30	482.79	516.23
HF	1356.49	1356.51	1355.35	1353.89	1352.46	1351.18	1350.01
CO	.0161825	.0174133	.0180901	.0184751	.0187240	.0189007	.0190397
CO2	.0056041	.0050797	.0047332	.0044889	.0043006	.0041512	.0040256
H2	.0061499	.0066581	.0068024	.0067697	.0066739	.0065666	.0064618
H2O	.0067612	.0071549	.0074383	.0076550	.0078333	.0079783	.0081019
O2	.0044780	.0045554	.0045928	.0046098	.0046180	.0046223	.0046248
O							
OH							
H							
NO							
N							
CH3	.0000330	.0000296	.0000252	.0000212	.0000179	.0000153	.0000134
CH4	.0000552	.0000742	.0001190	.0000532	.0000251	.0000128	.0000070

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.1

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MJL. WT.	23.6448	23.6362	23.6329	23.6263	23.6208	23.6126	23.6021
P	12739	13322	13907	14489	15073	15657	16242
e	- 742.84	- 708.26	- 673.55	- 638.37	- 603.06	- 567.49	- 531.46
CV	.338408	.340322	.342347	.344040	.345501	.347024	.348484
γ	1.25644	1.25425	1.25189	1.24985	1.24799	1.24644	1.24481
S	2.15172	2.16710	2.18136	2.19625	2.21010	2.22353	2.23663
E	549.79	583.39	617.35	651.40	685.71	720.22	755.03
HF	1348.96	1347.97	1347.26	1346.11	1345.12	1344.06	1342.84
CO	.0191946	.0192555	.0193162	.0194147	.0194804	.0195402	.0195946
CO2	.0039181	.0038241	.0037649	.0036701	.0036074	.0035517	.0035027
H2	.0063652	.0062775	.0062214	.0061298	.0060662	.0060101	.0059601
H2O	.0082036	.0083022	.0083610	.0084553	.0085166	.0085703	.0086160
H2	.0046264	.0046276	.0046266	.0046301	.0046304	.0046313	.0046322
O2							
N	.000005	.0000010	.0000018	.0000032	.0000055	.0000091	.0000001
NH	.0000032	.0000054	.0000086	.0000132	.0000196	.0000284	.0000400
NO			.0000001	.0000002	.0000004	.0000007	.0000012
NH3	.0000119	.0000106	.0000097	.0000080	.0000061	.0000041	.0000022
CH4	.0000041	.0000025	.0000016	.0000010	.0000008	.0000076	.0000072
							.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.1

TEMP. °K	2900.00	3000.00	2854.47
MOL. WT.	23.5895	23.5701	23.5955
P	16827	17415	16560
e	- 494.97	- 457.87	
CV	349818	351010	349226
γ	1.24333	1.24203	1.24398
ε	2.24944	2.25201	2.24364
E	770.04	825.40	774.07
HF	1341.39	1339.65	1342.07

CO	.0196441	.0196931	.0196222
CO2	.0034255	.0034201	.0034784
H2	.0059139	.0058754	.0059345
H2O	.0085538	.0086859	.0086376
N2	.0046326	.0046346	.0046525
O2	.0000001	.0000001	.0000001
O	.0000001	.0000003	.0000001
OH	.0000220	.0000329	.0000182
H	.0000550	.0000740	.0000477
HO	.0000020	.0000032	.0000016
H+	.0000004	.0000006	.0000003
OH+	.0000000	.0000005	.0000005
CH4	.0000000	.0000002	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
MOLE WT.	24.2259	23.9517	23.8156	23.7450	23.7063	23.6820	23.6673
P	23555	25047	26462	27844	29209	30552	31854
•	- 955.74	- 354.29	- 216.82	- 780.58	- 745.14	- 710.07	- 675.00
CV	1.33231	1.24852	1.22755	1.22951	1.24124	1.25356	1.26589
γ	1.27243	1.26957	1.26620	1.26245	1.25899	1.25556	1.25264
z	2.00912	2.02703	2.04620	2.06357	2.08039	2.09600	2.11042
z	397.30	437.00	474.17	509.38	544.05	578.28	612.77
WF	1348.25	1348.07	1347.21	1346.32	1345.47	1344.55	1344.08
CO ₂	0.62729	0.67500	0.719044	0.75825	0.794059	0.828209	0.861902
H ₂ O	0.342681	0.374374	0.403636	0.431277	0.457187	0.481249	0.504669
CO	0.039319	0.060647	0.080760	0.100386	0.119518	0.138198	0.156579
H ₂	0.0074256	0.011908	0.0162831	0.020668	0.025106	0.0296014	0.0341579
N ₂	0.065521	0.045609	0.045568	0.046059	0.046115	0.046153	0.046183
Ar	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
He	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000485	0.000430	0.000376	0.000323	0.000297	0.000267	0.000245
NO	0.000273	0.000235	0.000165	0.0000974	0.000023	0.0000134	0.000008

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

412

6.2

Temp. (°F)	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3097.57
Temp. (°F)	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	3097.57
Pressure (psia)	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000
Enthalpy (Btu/lb)	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
Entropy (Btu/lb-°R)	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000
Specific Heat (Btu/lb-°R)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Volume (ft³/lb)	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
Density (lb/ft³)	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000
Speed of Sound (ft/s)	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
Equilibrium Composition

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

MIC

Temp. °C	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
ρ	35.8361	28.7710	23.7537	20.7020	18.0593	15.8733	13.9659
μ	5.337	52672	54952	57275	59554	61829	64092
γ	1.47872	1.4160	1.3590	1.3073	1.2591	1.2144	1.1729
7	1.76104	1.2944	1.2507	1.2533	1.25084	1.24889	1.24645
8	2.1183	2.1470	2.1650	2.1772	2.1910	2.2050	2.2185
9	33.11	373.70	300.10	245.30	198.50	153.61	109.04
10	124.420	1341.55	1340.15	1339.43	1338.73	1338.05	1337.32
11	116250	117500	118750	119999	121250	122500	123750
12	116250	117500	118750	119999	121250	122500	123750
13	116250	117500	118750	119999	121250	122500	123750
14	116250	117500	118750	119999	121250	122500	123750
15	116250	117500	118750	119999	121250	122500	123750
16	116250	117500	118750	119999	121250	122500	123750
17	116250	117500	118750	119999	121250	122500	123750
18	116250	117500	118750	119999	121250	122500	123750
19	116250	117500	118750	119999	121250	122500	123750
20	116250	117500	118750	119999	121250	122500	123750

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.3

TEMP. °K	2900.00	3000.00	2855.82
MOL. WT.	23.6553	23.6555	23.6574
P	66355	68631	65360
e	495.58	458.69	
CV	355465	356465	354933
γ	1.24428	1.24242	1.24522
S	2.13143	2.14392	2.12584
E	784.47	820.45	768.82
HF	1336.38	1335.47	1336.82
CO	.0202151	.0202624	.0201980
CO2	.0028518	.0028153	.0028672
H2	.0052521	.0052302	.0052694
H2O	.0092600	.0092938	.0092471
N2	.0046116	.0046169	.0046127
O2			
O	.0000001	.0000001	
OH	.0000122	.0000182	.0000101
H	.0000266	.0000359	.0000232
NO	.0000011	.0000017	.0000009
N	.0000002	.0000003	.0000002
NH3	.0000382	.0000307	.0000358
CH4	.0000048	.0000037	.0000355

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

N12

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
Q ₁₂	23.8541	23.7594	23.7601	23.7331	23.7134	23.7057	23.6783
P	64016	67524	69482	74437	7872	101271	134716
CV	- 670.64	- 637.62	- 605.16	- 560.56	- 530.43	- 493.61	- 456.64
γ	0.32440	0.33517	0.35007	0.37070	0.37450	0.35561	0.35957
z	0.133	1.15738	1.22407	1.25000	1.25000	1.24754	1.24554
z	0.85	2.03927	2.00302	2.00709	2.00038	2.00934	2.10501
z	0.65	0.34.20	0.75.15	710.11	745.76	782.34	819.32
z	0.65	1335.13	1334.57	1324.06	1335.47	1332.64	1332.00
CO	0.201306	0.202769	0.203034	0.204522	0.204923	0.205336	0.205856
CO2	0.027812	0.026354	0.026260	0.025775	0.025352	0.025017	0.024650
H ₂ O	0.049372	0.049301	0.049358	0.049820	0.049709	0.049401	0.048312
H ₂	0.093214	0.094415	0.094923	0.095326	0.095769	0.096062	0.096510
O ₂	0.043725	0.043856	0.043673	0.043524	0.043560	0.043592	0.043519
NO	0.000000	0.000015	0.000026	0.000042	0.000067	0.000105	0.000154
NO2	0.000000	0.000049	0.000073	0.000109	0.000149	0.000205	0.000277
H ₂	0.000000	0.000001	0.000002	0.000003	0.000005	0.000009	0.000014
H ₂ O	0.000780	0.000652	0.000679	0.000622	0.000587	0.000552	0.000525
C ₂ H ₄	0.000036	0.0000423	0.0000294	0.0000211	0.0000159	0.0000116	0.0000090

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M12 0.4

TEMP. °K	2851.14
MOL. WT.	23.7080
P	99615
e	.358110
γ	1.24871
S	2.08721
E	765.08
HF	1332.08
CO	.0205154
CO2	.0025170
H2	.0048563
H2O	.0095944
N2	.0045954
O2	.0000000
OH	.0000000
H	.0000000
NO	.0000000
H2	.0000000
NH3	.0000608
CH4	.0000136

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
WGL. WT.	24.3225	23.8069	23.3614	23.1944	23.1304	23.1034	23.0905
P	3727	4092	4411	4707	4994	5277	5559
e	- 982.58	- 921.88	- 877.09	- 839.29	- 804.02	- 769.56	- 735.41
CV	316749	317875	320277	323152	326060	328759	331341
γ	1.27475	1.27815	1.27720	1.27447	1.27133	1.26833	1.26559
S	2.05473	2.09664	2.12556	2.14850	2.16806	2.18727	2.20420
E	250.00	329.01	351.54	357.26	420.73	453.61	486.43
MF	1266.62	1265.80	1225.63	1231.36	1250.10	1278.56	1277.22

CO ₂	0169602	0186000	0194166	0198487	0201168	0203103	0204611
CO	0053676	007582	0043646	0040936	0038872	0037192	0035800
H ₂	0070002	0078931	0051359	0081095	0079880	0076698	0077485
H ₂ O	0044314	0055591	0061940	0064274	006197	0067822	0069191
O ₂	0044049	0045074	0045522	0045701	0045776	0045812	0045832
CH ₄							
NO			0000001	0000002	0000004	0000008	0000001
OH							0000015
HNS	0000225	0000203	0000171	0000141	0000117	0000099	0000085
CH*	0007780	0003227	0001255	0000504	0000218	0000102	0000052

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION:

M14 0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	23.0839	23.0792	23.0749	23.0703	23.0640	23.0569	23.0465
P	5840	6121	6400	6680	6960	7240	7521
e	- 701.23	- 666.93	- 632.53	- 597.98	- 562.91	- 527.62	- 491.95
CV	.333781	.325994	.317990	.309984	.301690	.293306	.284804
γ	1.26292	1.26054	1.25800	1.25564	1.25495	1.25337	1.25201
S	2.22147	2.23742	2.25272	2.26686	2.28174	2.29559	2.30905
E	519.42	552.64	586.02	619.77	653.59	687.74	722.12
MF	1276.03	1274.95	1273.93	1273.13	1271.89	1270.76	1269.47

CO	.0205858	.0206918	.0207840	.0208432	.0209364	.0209998	.0210580
CO2	.0034613	.0033589	.0032696	.0032132	.0031235	.0030639	.0030112
H2	.0076384	.0075403	.0074520	.0073969	.0073072	.0072450	.0071855
H2O	.0070370	.0071389	.0072279	.0072840	.0073751	.0074312	.0074818
O2	.0045844	.0045652	.0045860	.0045806	.0045877	.0045882	.0045892
O							
OH	.0000003	.0000006	.0000011	.0000021	.0000038	.0000065	.0000106
H	.0000029	.0000050	.0000084	.0000135	.0000208	.0000310	.0000448
NO			.0000001	.0000001	.0000002	.0000004	.0000008
N						.0000001	.0000002
H3	.0000074	.0000066	.0000060	.0000054	.0000045	.0000046	.0000043
CH4	.0000029	.0000017	.0000010	.0000007	.0000004	.0000002	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M14

TEMP. °K	2800.00	2900.00	2717.64
MOLE WT.	23.0327	23.0151	23.0443
5	7802	8084	7571
6	- 455.74	- 418.93	
CV	346255	347604	345063
7	1.25509	1.24947	1.25177
8	2.32222	2.33514	2.31143
9	756.80	751.73	728.22
MF	1267.95	1266.06	1269.22

10	3533114	3211615	3210678
11	3022650	3029242	3030026
12	3071396	3070935	3071809
13	3073241	3075589	3074597
14	3045903	3045903	3045654
15	3000000	3000000	3000000
16	3000000	3000000	3000000
17	3000000	3000000	3000000
18	3000000	3000000	3000000
19	3000000	3000000	3000000
20	3000000	3000000	3000000
21	3000000	3000000	3000000
22	3000000	3000000	3000000
23	3000000	3000000	3000000
24	3000000	3000000	3000000
25	3000000	3000000	3000000
26	3000000	3000000	3000000
27	3000000	3000000	3000000
28	3000000	3000000	3000000
29	3000000	3000000	3000000
30	3000000	3000000	3000000
31	3000000	3000000	3000000
32	3000000	3000000	3000000
33	3000000	3000000	3000000
34	3000000	3000000	3000000
35	3000000	3000000	3000000
36	3000000	3000000	3000000
37	3000000	3000000	3000000
38	3000000	3000000	3000000
39	3000000	3000000	3000000
40	3000000	3000000	3000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

O.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	27.0086	25.1391	24.0797	23.5483	23.3049	23.1943	23.1429
P	7419	8484	9266	9972	10626	11253	11866
Q	-1030.87	-955.03	-896.01	-849.73	-809.43	-772.82	-737.63
CV	.323387	.323023	.323893	.325736	.328091	.330471	.332930
γ	1.26907	1.27579	1.27772	1.27681	1.27423	1.27118	1.26808
S	1.95889	2.01143	2.04938	2.07776	2.10051	2.12029	2.13834
E	195.94	272.57	330.39	375.45	413.61	446.76	482.70
HF	1279.62	1281.71	1281.15	1279.77	1278.23	1276.89	1275.67
CO	.0149022	.0171961	.0196917	.0195618	.0200501	.0203454	.0205400
CO2	.0058311	.0049954	.0044235	.0040463	.0037899	.0036007	.0034551
H2O	.0051602	.0064021	.0071875	.0075430	.0076431	.0076163	.0075465
N2	.0053726	.0059166	.0062849	.0065488	.0067514	.0069164	.0070513
O2	.0042250	.0043789	.0044755	.0045278	.0045535	.0045662	.0045728
C							
OH							
H							
NO							
N							
H2							
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	23.1168	23.1023	23.0925	23.0855	23.0776	23.0717	23.0633
P	12474	13078	13677	14277	14875	15473	16072
Q	- 702.89	- 668.26	- 633.72	- 599.09	- 564.00	- 528.80	- 493.23
CV	325354	327523	329492	341435	343120	344684	346116
γ	1.26458	1.26214	1.25996	1.25762	1.25560	1.25373	1.25216
z	2.15226	2.17195	2.18674	2.20092	2.21582	2.22963	2.24302
z	516.33	549.96	583.57	617.92	651.51	685.76	720.20
RF	1274.58	1273.54	1272.66	1271.98	1270.90	1269.95	1269.92
W	0.000042	0.000097	0.000095	0.000090	0.000099	0.001112	0.001167
W	0.000051	0.000036	0.000045	0.000087	0.000016	0.0029437	0.0028921
W	0.000042	0.000025	0.000038	0.000054	0.000036	0.0000150	0.000035
W	0.000023	0.000054	0.000023	0.000055	0.000045	0.000075	0.000012
W	0.000045	0.000078	0.000085	0.000081	0.000086	0.000089	0.000085
W	0.000002	0.000004	0.000008	0.000015	0.000026	0.000045	0.000074
W	0.000022	0.000035	0.000058	0.000093	0.000143	0.000213	0.000308
W	0.0000120	0.000025	0.000058	0.000091	0.000143	0.000213	0.000308
W	0.0000196	0.000048	0.000124	0.000312	0.000810	0.002104	0.005097
W	0.0000134	0.000038	0.000098	0.000232	0.000521	0.001314	0.003010

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M14

TEMP. °K	2800.00	2900.00	2721.62
MOL. WT.	23.0530	23.0413	23.0613
P	16671	17271	16201
e	- 457.43	- 421.10	
CV	.347572	.348911	.346428
γ	1.25053	1.24903	1.25181
S	2.25607	2.26882	2.24587
E	754.92	789.83	727.62
HF	1267.75	1266.34	1268.68
CO	.0212183	.0212643	.0211790
CO2	.0028469	.0028073	.0028818
H2	.0070170	.0069730	.0070530
H2O	.0076438	.0076790	.0076111
N2	.0045660	.0045862	.0045852
O2			
C	.0000001	.0000001	
OH	.0000117	.0000180	.0000082
H	.0000434	.0000597	.0000332
NO	.0000009	.0000015	.0000006
N	.0000002	.0000004	.0000001
NH3	.0000092	.0000103	.0000096
CH4	.0000008	.0000006	.0000010

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14 0.2

TEMP. °K	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00
MCL. WT.	24.7025	24.0097	23.6072	23.3890	23.2700	23.2042	23.1628
P	22374	24073	25661	27160	28609	30028	31418
•	- 878.35	- 827.76	- 783.87	- 744.46	- 707.24	- 671.12	- 635.74
CV	.332139	.333271	.334702	.336684	.338943	.340932	.342619
7	1.27580	1.27513	1.27321	1.27045	1.26708	1.26383	1.26150
S	1.99510	2.01902	2.04273	2.06294	2.08109	2.09786	2.11362
E	341.65	391.16	435.87	472.25	508.54	543.61	578.39
HF	1274.38	1273.72	1272.80	1271.90	1271.04	1270.23	1269.46
CO	.0185102	.0195245	.0201694	.0205628	.0208150	.0209860	.0211160
CO2	.0040049	.0030691	.0033938	.0032001	.0030668	.0029578	.0028662
H2	.0000134	.0000279	.0000114	.0000501	.0000999	.0000567	.0000245
H2O	.0007948	.0070132	.0072136	.0075443	.0074584	.0075540	.0076276
H2	.0044357	.0044706	.0045111	.0045349	.0045489	.0045574	.0045632
O	.0000001	.0000002	.0000003	.0000001	.0000001	.0000003	.0000005
OH				.0000007	.0000013	.0000022	.0000038
H							
N2							
N							
CH4	.0000591	.0000563	.0000517	.0000463	.0000417	.0000376	.0000341
CH	.0006737	.0005911	.0002167	.0001236	.0000718	.0000437	.0000267

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14 0.2

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	2723.62
MOL. WT.	23.1387	23.1179	23.1079	23.0966	23.0860	23.0782	23.0940
P	32801	34173	35540	36907	38274	39636	37230
ρ	- 600.54	- 565.05	- 529.61	- 494.07	- 458.17	- 421.99	
CV	344010	346232	347673	348958	350416	351725	349287
γ	1.25869	1.25625	1.25399	1.25217	1.25011	1.24822	1.25175
S	2.12804	2.14311	2.15702	2.17043	2.18349	2.19619	2.17355
L	613.03	647.64	682.29	717.05	752.04	787.14	725.27
MF	1266.92	1268.04	1267.26	1266.47	1265.59	1264.52	1266.27
CO	.0211936	.0212966	.0213609	.0214184	.0214681	.0215102	.0214308
CO2	.0028102	.0027240	.0026665	.0026192	.0025719	.0025395	.0026085
H2	.0069012	.0068418	.0067951	.0067545	.0067139	.0066769	.0067453
H2O	.0076896	.0077736	.0078265	.0078739	.0079113	.0079472	.0078841
O2	.0045670	.0045717	.0045722	.0045742	.0045758	.0045749	.0045746
O							
OH	.0000010	.0000018	.0000031	.0000051	.0000071	.0000124	.0000057
H	.0000061	.0000093	.0000139	.0000202	.0000282	.0000392	.0000221
NO	.0000001	.0000001	.0000002	.0000004	.0000006	.0000010	.0000004
N							
NO2	.0000012	.00000259	.0000047	.0000081	.0000128	.0000203	.0000091
CH4	.0000176	.0000116	.0000081	.0000058	.0000044	.0000032	.0000244

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14 0.3

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.3094	23.5946	23.4274	23.3104	23.2516	23.1996	23.1753
P	46551	49187	51726	54179	56595	58972	61323
• CV	- 755.56	- 714.34	- 675.51	- 638.34	- 601.97	- 565.58	- 529.56
γ	1.27193	1.26889	1.26576	1.26303	1.26066	1.25803	1.25557
S	2.03906	2.02915	2.04718	2.06374	2.07866	2.09410	2.10824
E	656.95	497.32	535.40	571.98	607.91	643.59	678.93
MF	1267.29	1266.72	1266.13	1265.54	1265.15	1264.48	1263.81
CO	.0233425	.0207798	.0210696	.0212304	.0214040	.0215378	.0216167
CO2	.0029698	.0026075	.0026743	.0025676	.0025040	.0024154	.0023603
H2O	.0065401	.0062423	.0063476	.0064008	.0064300	.0064149	.0063918
H2	.0076501	.0077747	.0078730	.0079368	.0080079	.0080892	.0081377
O2	.0044711	.0044939	.0045190	.0045325	.0045414	.0045514	.0045550
N2	.0000001	.0000001	.0000002	.0000004	.0000008	.0000014	.0000025
NO	.0000005	.0000009	.0000016	.0000028	.0000045	.0000069	.0000105
N	.0000017	.0000064	.0000070	.00000652	.00000601	.00000503	.00000519
CH4	.0003185	.0002009	.0001291	.0000817	.0000550	.0000367	.0000256

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M:4

TEMP. °K	2700.00	2800.00	2900.00	2722.18
MOL. WT.	23.1524	23.1353	23.1268	23.1491
P	626.71	560.59	623.29	641.91
Q	- 452.06	- 457.47	- 421.13	
CV	1.757129	1.353575	1.354842	1.352421
7	1.25304	1.2529	1.24911	1.25315
8	2.12180	2.13496	2.14772	2.12475
E	714.15	745.68	785.10	722.04
HF	1263.19	1262.49	1261.58	1263.04
CO	.0216826	.0217080	.0217602	.0216969
CO2	.0023121	.0022711	.0022371	.0023023
H2O	.003709	.0063470	.0062149	.0063658
H2	.0081822	.0082159	.0082484	.0081912
O2	.0045503	.0045593	.0045578	.0045577
N2				
OH				
NO	.0000041	.0000064	.0000099	.0000045
NO2	.0000150	.0000212	.0000291	.0000162
H	.0000003	.0000005	.0000008	.0000003
O	.0000001	.0000001	.0000002	.0000001
H2O2	.0000084	.0000048	.0000051	.0000077
CF4	.0000185	.0000140	.0000103	.0000173

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
%O ₂	23.5977	23.4643	23.3561	23.3005	23.2542	23.2219	23.2068
%N ₂	82026	86402	90097	93705	97298	100858	104365
%H ₂ O	-	-	-	-	-	-	-
%CO ₂	0.4206	0.4206	0.4206	0.4206	0.4206	0.4206	0.4206
%CO	0.25097	0.25097	0.25097	0.25097	0.25097	0.25097	0.25097
%H ₂	0.22212	0.22212	0.22212	0.22212	0.22212	0.22212	0.22212
%HF	0.3129	0.3129	0.3129	0.3129	0.3129	0.3129	0.3129
%H ₂	1251.01	1260.79	1260.35	1259.79	1259.33	1258.79	1257.98
%O ₂	0.21923	0.21923	0.21923	0.21923	0.21923	0.21923	0.21923
%N ₂	0.019504	0.019504	0.019504	0.019504	0.019504	0.019504	0.019504
%H ₂ O	0.059041	0.059041	0.059041	0.059041	0.059041	0.059041	0.059041
%CO ₂	0.035437	0.035437	0.035437	0.035437	0.035437	0.035437	0.035437
%CO	0.045341	0.045341	0.045341	0.045341	0.045341	0.045341	0.045341
%H ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%HF	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%H ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%O ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%N ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%H ₂ O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%CO ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%CO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%H ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
%HF	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M14

0.4

TEMP. °K 2719.53

MOL. WT. 23.2468
 P 97996
 CV 355912
 γ 1.25658
 Z 2.08492
 S 718.23
 HF 1259.23

CO 0219590
 CO2 0019626
 H2 0059051
 H2O 0085161
 O2 0045301

CH 0000037
 C 0000124
 NO 0000009
 NH3 0010001
 NH2 0000834
 CH4 0000440

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	23.1320	22.1911	21.7645	21.6230	21.5551	21.5250	21.5100
P	4908	4392	4754	5053	5362	5667	5970
e	681.76	622.05	576.42	527.40	480.91	435.27	390.90
CV	327467	329448	332374	335654	338924	341972	344878
γ	1.28506	1.28726	1.28560	1.28273	1.27908	1.27617	1.27520
S	2.15371	2.19495	2.22443	2.24800	2.26894	2.28820	2.30635
E	273.24	325.43	366.53	402.81	437.47	471.71	505.97
HF	1019.11	1012.38	1008.20	1005.60	1002.82	1002.46	1001.35

CO	.0111399	.0123807	.0130564	.0133925	.0136126	.0137685	.0138672
CO2	.0034576	.0029832	.0026772	.0024634	.0022901	.0021704	.0020934
H2	.0086974	.0097218	.0101114	.0101853	.0101424	.0100652	.0099642
H2O	.0056601	.0062867	.0070770	.0072443	.0073885	.0075119	.0076159
N2	.0124327	.0126955	.0128161	.0128697	.0128923	.0129034	.0129095
O2							
OH							
H							
NO							
N							
H2O3	.000520	.000473	.000401	.000335	.000262	.000204	.000151
CH4	.0007924	.0007459	.000675	.000583	.000472	.000359	.000239
CH2							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.05

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	21.5014	21.4955	21.4904	21.4851	21.4777	21.4710	21.4606
P	6272	6573	6874	7174	7475	7776	8078
e	- 394.47	- 358.88	- 329.13	- 287.16	- 250.67	- 213.88	- 176.85
CV	.347631	.350123	.352373	.354599	.356554	.358384	.360074
γ	1.27339	1.26785	1.26575	1.26363	1.26179	1.26008	1.25861
S	2.32363	2.34018	2.35607	2.37100	2.38528	2.40071	2.41476
E	540.43	375.13	610.03	645.32	680.72	716.41	752.33
HF	1000.40	999.33	998.25	997.95	996.90	995.81	994.31

CO	.0139835	.0140642	.0141333	.0141776	.0142464	.0142923	.0142344
CO2	.0019733	.0018964	.0018200	.0017583	.0017225	.0016793	.0016413
H2	.0095076	.0092362	.0097761	.0097364	.0096731	.0096267	.0095865
H2O	.0077045	.0077811	.0078473	.0078886	.0079540	.0079958	.0080317
H2	.0129133	.0129160	.0129183	.0129204	.0129237	.0129253	.0129253
O2							
CH	.0000003	.0000005	.0000011	.0000020	.0000036	.0000060	.0000099
H	.0000033	.0000058	.0000097	.0000155	.0000239	.0000357	.0000516
NO			.0000001	.0000002	.0000003	.0000006	.0000011
N					.0000001	.0000002	.0000003
NH3	.0000085	.0000166	.0000151	.0000138	.0000116	.0000125	.0000112
CH4	.0000039	.0000024	.0000015	.0000010	.0000007	.0000005	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.05

TEMP. °K 2600.00 2538.66

MOL. WT.
 P 21.4470 21.4751
 8360 7591
 e - 138.82
 CV .361717 .357276
 γ 1.25718 1.26111
 S 2.42852 2.39196
 E 768.54 694.48
 HF .992.91 996.48

CO .0143727 .0142669
 CO2 .0016081 .0017031
 H2 .0095499 .0095531
 H2O .0080614 .0079730
 N2 .0125324 .0125245
 O .0000001
 OH .0000156
 H .0000731
 .0000019
 .0000000
 .0000000
 .0000107
 .0000003
 CH3 .0000000
 CH4 .0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15

0.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.9542	23.4199	22.5028	22.0070	21.7617	21.6422	21.5829
P	8201	9098	9927	10687	11395	12073	12734
e	- 727.98	- 655.57	- 595.54	- 548.81	- 507.37	- 469.22	- 432.58
CV	.353752	.334617	.336245	.338559	.341263	.343956	.346719
γ	1.27984	1.28406	1.28523	1.28391	1.28115	1.27904	1.27486
S	2.05473	2.10469	2.14262	2.17176	2.19543	2.21605	2.23484
E	232.15	296.33	348.46	392.02	430.64	466.94	502.29
HF	1022.81	1015.77	1009.94	1005.89	1003.26	1001.53	1000.29
CO	.0055672	.0112763	.0124227	.0131224	.0135288	.0137761	.0139362
CO2	.0037209	.0031141	.0026945	.0024116	.0022162	.0020717	.0019616
H2	.0064662	.0079242	.0089197	.0094616	.0096908	.0097571	.0097521
H2O	.0067763	.0070563	.0072460	.0073935	.0075202	.0076321	.0077275
N2	.0119605	.0123408	.0125926	.0127330	.0128141	.0128535	.0128745
O2							
OH							
H							
HO							
H							
CH3	.0000791	.0000823	.0000783	.0000705	.0000618	.0000539	.0000471
CH4	.0015153	.0009027	.0004844	.0002425	.0001201	.0000610	.0000329

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M.S

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	21.5512	21.5528	21.5201	21.5108	21.5000	21.4945	21.4852
P	13367	14037	14681	15326	15969	16611	17254
e	- 396.45	- 360.44	- 324.49	- 288.38	- 251.84	- 215.13	- 178.10
CV	349451	351886	354032	356266	358193	359964	361577
γ	1.27164	1.26871	1.26640	1.26392	1.26177	1.25977	1.25812
S	2.25247	2.26921	2.28520	2.30019	2.31549	2.32989	2.34388
E	537.41	572.58	607.75	643.25	678.69	714.72	750.74
HF	999.51	998.45	997.71	997.12	996.22	995.34	994.35
CO	.0140917	.0141410	.0142149	.0142610	.0143303	.0143747	.0144153
CO2	.0018718	.0017967	.0017319	.0016916	.0016279	.0015865	.0015499
H2	.0097178	.0096735	.0096283	.0095994	.0095478	.0095058	.0094714
H2O	.0076100	.0075817	.0075445	.0075839	.0080473	.0082871	.0081223
O2	.0123866	.0128942	.0128597	.0129039	.0129097	.0129107	.0129142
O							
HT	.0000002	.0000004	.0000007	.0000014	.0000025	.0000042	.0000068
H	.0000023	.0000040	.0000066	.0000107	.0000165	.0000246	.0000357
N							
N2							
CH4	.0000420	.0000378	.0000344	.0000313	.0000284	.0000271	.0000259
	.0000168	.0000114	.0000070	.0000037	.0000031	.0000032	.0000016

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.1

TEMP. °K 2800.00 2541.83

MOL. WT. 21.4744 21.4970
 P 17898 16256
 e - 140.60
 CV .363226 .358953
 T 1.25641 1.26091
 S 2.35750 2.32162
 E 787.05 693.85
 HF 993.17 995.85

CO	.0144516	.0143519
CO2	.0015180	.0016078
H2	.0094397	.0095290
H2O	.0081517	.0080669
O2	.0129177	.0129107
O		
OH	.0000109	.0000031
H	.0000504	.0000196
NO	.0000012	.0000003
N	.0000004	.0000001
NH2	.0000243	.0000260
CH4	.0000012	.0000007

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.2

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	24.1709	23.2046	22.5588	22.1518	21.9123	21.7725	21.6904
P	21912	23846	25680	27406	29039	30614	32150
e	- 640.60	- 561.07	- 529.13	- 483.17	- 441.56	- 402.36	- 364.42
CV	.344280	.345489	.347122	.348868	.351120	.353661	.355867
Z	1.28048	1.28077	1.27966	1.27782	1.27519	1.27191	1.26875
S	2.04128	2.07737	2.10704	2.13188	2.15321	2.17234	2.18997
E	308.54	362.26	409.67	452.37	491.81	529.57	566.45
HF	1012.41	1007.38	1003.39	1000.48	998.54	997.19	996.20

CO	.0111920	.0122089	.0130057	.0135294	.0138774	.0140966	.0142433
CO2	.0027730	.0023767	.0020966	.0018984	.0017623	.0016611	.0015827
H2	.0065206	.0075068	.0082313	.0087026	.0089740	.0091153	.0091800
H2O	.0075451	.0077141	.0078303	.0079199	.0079913	.0080562	.0081144
N2	.0121185	.0123685	.0125475	.0126673	.0127422	.0127883	.0128172
O2							
O							
OH							
H							
NO							
N							
AMS	.0001392	.0001415	.0001370	.0001282	.0001172	.0001070	.0000978
CH4	.0011666	.0007782	.0004320	.0002865	.0001708	.0001034	.0000651

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2544.92
MOL. WT.	21.6563	21.6030	21.5717	21.5607	21.5454	21.5322	21.5643
P	32655	35147	36632	38098	39569	41036	37293
e	- 327.28	- 250.37	- 253.21	- 216.17	- 179.00	- 141.44	
CV	357752	359955	361794	363425	364871	366518	362552
γ	1.26041	1.26355	1.26106	1.25872	1.25666	1.25479	1.25999
Z	2.25020	2.22163	2.23738	2.25152	2.26595	2.27960	2.24403
Z	602.73	635.06	675.46	711.75	748.17	784.86	691.77
MF	995.35	994.64	994.11	993.37	992.63	991.77	993.77
CO	.0145527	.0144152	.0144991	.0145466	.0145895	.0146256	.0145245
CO2	.0015173	.0014775	.0014170	.0013792	.0013454	.0013164	.0013972
H2	.0092384	.0092246	.0092150	.0091899	.0091740	.0091558	.0092055
H2O	.0081673	.0082007	.0082564	.0082919	.0083236	.0083503	.0082765
H2	.0126375	.0126508	.0126657	.0126686	.0126754	.0126808	.0126693
O2							
O							
OH	.0000009	.0000009	.0000017	.0000028	.0000046	.0000073	.0000021
H	.0000070	.0000070	.0000079	.0000163	.0000236	.0000334	.0000131
NO	.0000001	.0000001	.0000001	.0000003	.0000005	.0000008	.0000002
N				.0000001	.0000001	.0000003	.0000001
HFC	.0000598	.0000220	.0000094	.0000079	.0000073	.0000064	.0000086
GM	.0000409	.0000275	.0000180	.0000131	.0000096	.0000073	.0000157

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.3

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MP	22.5777	22.5502	22.2266	22.0276	21.8552	21.7975	21.7200
P	46442	49452	52335	55119	57809	60442	63047
e	- 555.57	- 490.46	- 412.70	- 371.42	- 331.85	- 293.27	- 254.79
CV	.354705	.356487	.358775	.360615	.362167	.364250	.365928
γ	1.27014	1.27432	1.27150	1.26867	1.26671	1.26383	1.26130
S	2.07008	2.09425	2.11508	2.13477	2.15238	2.16842	2.18450
E	432.17	470.32	517.90	557.05	595.99	633.83	671.55
HF	999.98	997.39	995.47	994.09	993.01	992.33	991.65
CO	.0130349	.0139669	.0139421	.0141994	.0143904	.0145065	.0146227
CO2	.0017647	.0015917	.0014663	.0013741	.0013002	.0012559	.0011953
H2	.0072358	.0077721	.0081443	.0083867	.0085539	.0086615	.0087332
H2O	.0082537	.0082927	.0083397	.0083795	.0084176	.0084414	.0084909
N2	.0123534	.0125207	.0126112	.0126741	.0127210	.0127529	.0127880
O2							
OH							
H							
NO							
NO2							
CO*							
H*							
CH*							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M15

TEMP. °K	2600.00	2700.00	2800.00	2547.63
MOL. WT.	21.6839	21.6552	21.6306	21.6996
P	65577	68115	70632	64261
e	- 216.91	- 179.15	- 141.15	
CV	367372	368622	370250	366645
γ	1.25834	1.25697	1.25466	1.26012
S	2.19939	2.21363	2.22745	2.19173
E	708.55	745.75	783.03	689.30
HF	990.69	990.27	989.57	991.30
CO	.0146882	.0147441	.0147873	.0146602
CO2	.0011594	.0011274	.0011008	.0011752
H2	.0087470	.0087674	.0087747	.0087468
H2O	.0085140	.0085411	.0085634	.0085054
N2	.0127944	.0128087	.0128190	.0127945
O2				
O				
OH	.0000024	.0000056	.0000057	.0000017
H	.0000122	.0000177	.0000251	.0000099
NO	.0000002	.0000003	.0000006	.0000001
N	.0000001	.0000001	.0000002	
NH3	.0001441	.0001354	.0001290	.0001376
CH4	.0000041	.0000035	.0000250	.0000523

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MLE							
MOL. WT.	23.3559	22.7114	22.5872	22.3516	22.1582	22.0040	21.9311
P	74227	78656	83319	87612	91775	95894	99807
R	- 474.23	- 427.30	- 382.45	- 339.76	- 298.70	- 258.12	- 218.73
CV	362453	364635	366138	367392	369291	370737	371029
γ	1.2706	1.2760	1.2820	1.2876	1.2931	1.2981	1.26043
S	2.04364	2.06822	2.08765	2.10666	2.12375	2.14063	2.15618
H	457.50	502.42	545.23	586.30	626.30	666.03	704.41
Hf	996.27	994.02	992.29	990.85	989.93	989.21	988.27
CO	0.147397	0.146340	0.145449	0.144548	0.143648	0.142747	0.141846
CO2	0.009500	0.009870	0.010522	0.011060	0.011522	0.011970	0.012400
H2	0.0081181	0.008342	0.008410	0.008479	0.008540	0.008602	0.008664
H2O	0.0087412	0.0087915	0.0088426	0.0088926	0.0089426	0.0089926	0.0090426
O2	0.0126675	0.0126524	0.0125897	0.0125336	0.0124775	0.0124214	0.0123653
N2	0.000011	0.000011	0.000011	0.000011	0.000011	0.000011	0.000011
NO	0.000062	0.000062	0.000062	0.000062	0.000062	0.000062	0.000062
HF	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Cl2	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
Br2	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
I2	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001
CH4	0.002432	0.002432	0.002432	0.002432	0.002432	0.002432	0.002432
C2H6	0.001564	0.001564	0.001564	0.001564	0.001564	0.001564	0.001564

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M15 0.4

TEMP. °K	2700.00	2800.00	2553.52
MOL. WT.			
P	21.8607	21.8112	21.9554
e	102729	107591	98013
CV	-	141.00	371405
γ	1.372972	1.374532	1.26154
β	1.25668	1.25627	2.14914
ε	2.17094	2.18498	686.73
MF	742.60	785.80	988.73
	957.05	967.03	
CO	1148292	1148850	1146995
CO2	119175	1138910	1100538
H2O	1082217	1082543	1080921
H2	1087575	1087736	1087402
O2	1126546	1127140	1126662
OH			
H	1000030	1000047	1000014
NO	1000136	1000195	1000078
N2	1000003	1000005	1000001
N	1000001	1000002	
HNO3	1102422	1002322	1002440
CH4	1000850	1000665	1001317

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

0.05

TEMP. °F	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
CP	13.2107	25.0941	23.0533	23.0368	23.0288	23.0242	23.0209
	4.128	4420	4705	4987	5268	5549	5829
CV	776.65	741.33	706.52	671.72	636.98	602.20	567.25
γ	323752	327474	331103	334503	337583	340493	343240
γ	1.27322	1.27417	1.27505	1.26628	1.25294	1.23995	1.22716
γ	2.12695	2.13086	2.13226	2.12219	2.21093	2.22877	2.24582
γ	326.32	362.84	396.15	429.25	462.55	496.09	529.94
γ	1173.35	1170.91	1168.90	1167.21	1165.77	1164.53	1163.43
CG	0.000000	0.004439	0.0102393	0.0194276	0.0305820	0.0407100	0.048192
CO2	0.000000	0.0035011	0.0036846	0.0035073	0.0033560	0.0032324	0.0031247
H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C3H	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C3H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C3H4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C3H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C4H	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C4H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C4H4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C4H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

M17

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MCL. WT.	23.0180	23.0145	23.0104	23.0039	22.9965	22.9853	22.9701
P	6109	6389	6669	6949	7229	7510	7792
e	- 352.10	- 498.78	- 461.24	- 425.15	- 388.77	- 351.82	- 314.44
CV	.345696	.347885	.350077	.351975	.353740	.355354	.356939
γ	1.25466	1.25263	1.25055	1.24875	1.24710	1.24572	1.24434
S	2.26217	2.27788	2.29271	2.30774	2.32201	2.33591	2.34955
E	564.08	598.44	633.20	668.07	703.27	738.71	774.46
HF	1162.42	1161.47	1160.69	1159.48	1158.30	1156.91	1155.19

CO	.0109134	.0109957	.0110464	.0111221	.0111886	.0112432	.0112875
CO2	.0030317	.0029505	.0028992	.0028175	.0027633	.0027150	.0026724
H2	.0062901	.0062098	.0061587	.0060777	.0060218	.0059730	.0059301
H2O	.0101934	.0102744	.0103252	.0104057	.0104573	.0105013	.0105370
N2	.0130015	.0130028	.0130042	.0130065	.0130081	.0130110	.0130146
O2						.0000001	.0000001
OH	.0000009	.0000016	.0000033	.0000059	.0000100	.0000164	.0000259
H	.0000046	.0000077	.0000123	.0000190	.0000283	.0000409	.0000577
H2O	.0000001	.0000002	.0000003	.0000006	.0000012	.0000022	.0000037
H3	.0000004	.0000076	.0000069	.0000001	.0000002	.0000003	.0000005
CH4	.0000004	.0000002	.0000001	.0000001	.0000001	.0000001	.0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17 0.05

TEMP. °K	2900.00	3000.00	3100.00	3200.00	2960.32
MOL. WT.	22.9503	22.9217	22.8857	22.8386	22.9341
P	8074	8358	8644	8932	8245
e	- 276.20	- 227.01	- 196.70	- 154.99	
CV	.358396	.355712	.360945	.362106	.359208
γ	1.24311	1.24206	1.24117	1.24037	1.24246
S	2.36290	2.37625	2.38946	2.40269	2.37099
H	810.48	846.86	883.23	920.57	892.38
HF	1152.99	1150.20	1146.59	1141.97	1151.38

CO	.0113315	.0113753	.0114181	.0114632	.0113580
CO2	.0026344	.0025994	.0025675	.0025369	.0026129
H2	.0058514	.0058605	.0058339	.0058138	.0058718
H2O	.0105642	.0105858	.0105532	.0105925	.0105770
O2	.0130184	.0130250	.0130331	.0130413	.0130221
N2	.0000002	.0000005	.0000009	.0000017	.0000004
H	.0000004	.0000008	.0000014	.0000026	.0000006
OH	.0000395	.0000586	.0000846	.0001192	.0000503
H	.0000794	.0001070	.0001414	.0001837	.0000953
HO	.0000062	.0000099	.0000153	.0000230	.0000083
N	.0000009	.0000014	.0000022	.0000035	.0000012
H3	.0000056	.0000047	.0000047	.0000045	.0000054
CH4					

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

O.

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	23.3118	23.1538	23.0914	23.0621	23.0472	23.0386	23.0327
P	9340	9974	10590	11197	11798	12398	12998
c	- 748.87	- 710.61	- 674.51	- 639.15	- 604.07	- 568.90	- 533.59
CV	.329826	.333072	.336276	.339195	.342068	.344859	.347292
T	1.27916	1.27492	1.27060	1.26672	1.26321	1.25981	1.25680
S	2.08181	2.10500	2.12561	2.14472	2.16272	2.17988	2.19630
E	354.47	390.58	424.98	458.93	492.85	526.98	561.37
HF	1169.32	1167.31	1165.67	1164.29	1163.13	1162.11	1161.19
CO	.0099325	.0102874	.0105184	.0106890	.0108212	.0109308	.0110236
CO2	.0038097	.0035689	.0033839	.0032332	.0031102	.0030056	.0029155
H2	.0066440	.0066297	.0065592	.0064314	.0063299	.0062370	.0061538
H2O	.0094474	.0096649	.0098417	.0099897	.0101121	.0102167	.0103070
N2	.0128989	.0129467	.0129682	.0129791	.0129854	.0129893	.0129921
O							
OH							
H	.0000001		.0000002	.0000005	.0000001	.0000003	.0000006
NO					.0000010	.0000018	.0000032
N							
NH3	.0000492	.0000405	.0000336	.0000283	.0000242	.0000212	.0000188
CH4	.0001150	.0000475	.0000210	.0000100	.0000051	.0000028	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
WT	23.0278	23.0231	23.0163	23.0113	23.0027	22.9916	22.9789
P	13554	14192	14788	15385	15982	16580	17178
e	- 420.22	- 422.65	- 420.58	- 390.31	- 353.74	- 316.84	- 279.00
CV	349375	351594	353474	355172	356699	358296	359743
γ	1.25449	1.25198	1.24981	1.24784	1.24625	1.24456	1.24303
S	2.21203	2.22067	2.24190	2.25613	2.26993	2.28342	2.29663
E	555.86	630.77	665.80	701.10	736.58	772.38	808.27
HF	1160.33	1159.67	1158.63	1157.67	1156.58	1155.28	1153.66
CO2	0.113009	0.111565	0.112365	0.112927	0.113423	0.113870	0.114273
H2O	0.028305	0.027867	0.027059	0.026544	0.026075	0.025662	0.025298
CO	0.000752	0.000322	0.000565	0.000928	0.001568	0.002181	0.002779
O2	0.109861	0.104356	0.105151	0.105656	0.106097	0.106464	0.106750
N2	0.1129544	0.1129964	0.1129956	0.1130056	0.1130031	0.1130059	0.1130079
H	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
H2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
C2H6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M17

TEMP. °K	3000.00	3100.00	3200.00	2960.74
MOL. WT.	22.9573	22.9225	22.8999	22.9650
P	17780	18382	18989	17591
Q	- 240.63	- 201.52	- 161.37	
CV	361.074	362.221	363.401	360.536
γ	1.24172	1.24055	1.23950	1.24211
S	2.10964	2.32246	2.33520	2.30560
H	844.72	881.27	918.15	833.33
HF	1151.67	1149.11	1145.87	1152.33
CO	.0114675	.0115055	.0115441	.0114551
CO2	.0024959	.0024659	.0024374	.0025063
H2	.0057495	.0057229	.0057024	.0057573
H2O	.0106988	.0107123	.0107205	.0106919
O2	.0230138	.0130186	.0130254	.0130115
O	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000012	.0000003
H2O	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000
N2	.0000000	.0000000	.0000000	.0000000
NH3	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M17

TEMP. °K	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
MOL. WT.	23.1975	23.1346	23.1003	23.0802	23.0663	23.0565	23.0474
P	23462	23862	28246	29621	30983	32347	33703
•	- 644.15	- 607.76	- 571.78	- 535.91	- 500.26	- 464.38	- 428.07
CV	.342667	.345416	.348282	.350557	.352574	.354801	.356643
γ	1.27599	1.26598	1.26282	1.25915	1.25658	1.25345	1.25077
S	2.07083	2.08950	2.10706	2.12374	2.13900	2.15457	2.16970
E	450.65	485.96	521.02	555.09	590.99	626.33	661.79
HF	1160.27	1159.86	1158.97	1158.19	1157.45	1156.92	1156.09
CO	.0108742	.0110432	.0111656	.0112008	.0112500	.0114017	.0114823
CO2	.0029640	.0028385	.0027303	.0026504	.0025752	.0025283	.0024520
H2	.0255632	.0059298	.0058772	.0058199	.0057633	.0057282	.0056664
H2O	.0102627	.0103815	.0104612	.0105663	.0106414	.0106883	.0107658
N2	.0129204	.0129427	.0129559	.0129645	.0129707	.0129753	.0129820
O2							
OH		.0000001	.0000002	.0000004	.0000008	.0000016	.0000026
H		.0000005	.0000012	.0000021	.0000035	.0000056	.0000086
NO					.0000001	.0000001	.0000003
N							
NH3	.0000097	.0000004	.0000032	.0000474	.0000427	.0000389	.0000322
CH4	.0000052	.00000279	.0000156	.0000054	.0000057	.0000037	.0000025

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M17

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
Wt.	23.0402	23.0518	23.0225	23.0161	22.9964	22.9796	22.9554
2	35055	36409	37763	39111	40471	41826	43188
6	- 391.66	- 322.15	- 318.14	- 280.79	- 242.79	- 204.39	- 165.18
CV	358204	359549	361166	362587	363749	364888	366073
7	1.24837	1.24656	1.24442	1.24249	1.24087	1.23948	1.23800
3	2.18358	2.19777	2.21125	2.22435	2.23721	2.24980	2.26224
E	697.39	732.09	769.14	805.28	841.90	878.50	915.47
MF	1155.30	1154.48	1153.53	1152.32	1150.95	1149.17	1146.96
CO	.0115323	.0115796	.0116211	.0116561	.0116945	.0117270	.0117604
CO2	.0024242	.0023604	.0023220	.0022892	.0022569	.0022256	.0022037
H2	.0056183	.0055792	.0055441	.0055069	.0054862	.0054617	.0054441
H2O	.0108114	.0108537	.0108891	.0109157	.0109424	.0109590	.0109709
N2	.0129326	.0129859	.0129669	.0129584	.0129961	.0129993	.0130052
O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HNO3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M17

TEMP. °K	2973.96
MOL. WT.	23.0029
P	40116
CV	.353472
Y	1.24126
S	2.23389
E	832.32
MF	1:51.32
CO	.0116842
CO2	.0022652
H2	.0054900
H2O	.0109355
N2	.0129933
O2	.0000000
O	.0000001
OH	.0000255
H	.0000449
HO	.0000141
H ₂	.0000006
CH3	.0000289
CH4	.0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17

0.3

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00
MOL. WT.	23.1343	23.1125	23.0867	23.0827	23.0709	23.0601	23.0580
P	53123	52429	57774	60071	62373	64670	66946
Q	- 501.01	- 465.24	- 428.50	- 391.82	- 355.14	- 317.97	- 280.60
CV	.35521	.358254	.360053	.361474	.362630	.364268	.365663
7	1.25886	1.25536	1.25236	1.24969	1.24779	1.24533	1.24310
8	2.09108	2.10626	2.12157	2.13596	2.14981	2.16353	2.17646
E	586.23	622.16	658.23	694.22	730.24	766.64	802.99
MF	.153.99	.1153.58	.1152.92	.1152.24	.1151.59	.1150.83	.1149.81
CO	.0116792	.0116677	.0117511	.0117995	.0118452	.0118846	.0119146
CO2	.0022827	.0022374	.0021651	.0021210	.0020803	.0020451	.0020166
H2	.0053718	.0053564	.0053162	.0052765	.0052475	.0052202	.0051845
H2O	.0159267	.0107716	.0110456	.0110872	.0111270	.0111602	.0111825
O2	.0129321	.0127418	.0129546	.0129555	.0129609	.0129652	.0129621
OH	.0000007	.0000012	.0000022	.0000038	.0000062	.0000098	.0000150
H	.0000026	.0000042	.0000064	.0000096	.0000135	.0000195	.0000289
NO	.0000001	.0000001	.0000002	.0000004	.0000008	.0000013	.0000022
N	.0000016	.0000044	.00000618	.0000091	.0000131	.0000192	.0000284
CH4	.0000178	.0000118	.0000079	.00000634	.00000589	.00000557	.00000620
				.0000054	.0000039	.0000029	.0000022

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M17

TEMP. °K	3000.00	3100.00	3200.00	2973.31
MOL. WT.	23.0344	23.0209	22.9990	23.0439
P	69256	71545	73845	62636
e	- 242.55	- 204.34	- 165.38	
CV	.366705	.367769	.368950	.366462
γ	1.24150	1.23973	1.23800	1.24174
S	2.18934	2.20186	2.21421	2.18592
E	840.03	676.81	914.05	830.07
MF	1148.81	1147.39	1145.69	1149.07

CO	.0119531	.0119819	.0120125	.0119420
CO2	.0019856	.0019613	.0019376	.0019941
H2	.0051751	.0051535	.0051418	.0051749
H2O	.0112109	.0112266	.0112358	.0112027
N2	.0129740	.0129766	.0129634	.0129591
O2		.0000001	.0000002	
O		.0000002	.0000003	
OH	.0000224	.0013324	.0000458	.0000202
H	.0000363	.0000479	.0000623	.0000335
NO	.0000035	.0000055	.0000083	.0000031
NO2	.0000006	.0000009	.0000014	.0000005
HNO3	.0000500	.0000502	.0000457	.0000551
CH4	.0000017	.0000013	.0000011	.0000018

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M17 0.4

TEMP. °K	2600.00	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00
MOL. WT.	23.1519	23.1311	23.1152	23.1170	23.0948	23.0725	23.0493
P	83366	94772	98250	101622	105141	108566	112015
Q	- 390.23	- 354.22	- 316.76	- 279.26	- 240.94	- 202.72	- 163.76
CV	.370949	.365958	.367619	.368990	.369900	.370884	.372057
T	1.22566	1.25007	1.24795	1.24548	1.24357	1.24187	1.23994
Z	2.12823	2.11120	2.12488	2.12807	2.15103	2.16355	2.17590
L	708.37	727.82	764.66	801.25	838.64	875.88	913.47
MF	1154.75	1148.15	1147.59	1146.67	1145.97	1144.81	1143.46
CO	.0114573	.0121124	.0121576	.0121830	.0122242	.0122500	.0122793
CO2	.0024306	.0017832	.0017509	.0017271	.0016968	.0016756	.0016539
H2	.0054363	.0048657	.0048496	.0048158	.0048224	.0048061	.0048020
H2O	.0107700	.0114140	.0114445	.0114611	.0114921	.0115058	.0115197
N2	.0129157	.0129228	.0129255	.0129235	.0129471	.0129446	.0129536
O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH3	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M17

TEMP. °K	2969.24
MOL. WT.	23.0984
	104559
CV	.369071
Y	1.24409
S	2.14707
F	827.16
HF	.146.26
CO	.0177098
CO2	.0117068
H2	.0049159
H2O	.011811
O2	.0109337
N2	.0000000
OH	.0000107
H	.0000000
HC	.0000000
HNO3	.0000000
CON	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18 0.05

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	24.6969	23.4045	22.8413	22.6178	22.5294	22.4917	22.4742
P	3798	4187	4525	4836	5134	5427	5717
e	- 968.04	- 901.66	- 852.99	- 813.07	- 776.62	- 741.39	- 706.50
CV	.322546	.323500	.325455	.328244	.331162	.333908	.336554
γ	1.27463	1.27945	1.27947	1.27719	1.27420	1.27123	1.26845
S	2.08233	2.12819	2.15964	2.18386	2.20459	2.22373	2.24157
E	244.31	308.56	354.75	392.44	427.07	460.75	484.23
HF	1267.30	1265.99	1263.83	1261.79	1259.03	1258.51	1257.20
CO	.0171900	.0190314	.0200020	.0205087	.0208070	.0210117	.0211657
CO2	.0050935	.0044242	.0040046	.0037229	.0035141	.0033472	.0032103
H2	.0075249	.0086208	.0090475	.0091162	.0090490	.0089410	.0088312
H2O	.0054743	.0059661	.0061486	.0063736	.0065602	.0067181	.0068512
N2	.0042062	.0043218	.0043765	.0043998	.0044098	.0044145	.0044171
O2							
OH							
H							
NO							
N							
HM3	.0002245	.000231	.0000198	.0000166	.0000139	.0000118	.0000101
CH4	.0009775	.0004388	.0001808	.0000750	.0000332	.0000157	.0000081

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

H18

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MOL. WT.	22.4646	22.4587	22.4539	22.4487	22.4422	22.4351	22.4248
P	6006	6295	6583	6871	7158	7447	7735
ρ	- 671.53	- 636.98	- 602.02	- 566.92	- 531.29	- 495.43	- 459.17
CV	335063	341346	343409	345468	347236	348911	350466
γ	1.26577	1.26395	1.26137	1.25937	1.25765	1.25604	1.25465
U	2.23553	2.27474	2.29028	2.30464	2.31977	2.33384	2.34752
E	527.52	561.54	595.98	629.88	664.27	698.99	733.95
HF	1256.13	1334.97	1413.97	1493.18	1571.95	1650.82	1729.53
CO	0.212914	0.213982	0.214856	0.215425	0.216342	0.216957	0.217521
CO2	0.002043	0.002946	0.002979	0.002952	0.0027566	0.0027092	0.0026505
H2	0.007284	0.0086354	0.008522	0.0084986	0.0084124	0.0083522	0.0082983
H2O	0.004656	0.0070644	0.0071506	0.0072048	0.0072913	0.0073472	0.0073959
O2	0.0044185	0.0044195	0.0044205	0.0044213	0.0044224	0.0044229	0.0044239
OH	0.000002	0.000005	0.000010	0.000019	0.000033	0.000056	0.000096
H	0.000031	0.000054	0.000090	0.000145	0.000223	0.000333	0.000482
N2	0.000009	0.000030	0.000072	0.000166	0.000355	0.000657	0.001155
CH4	0.000045	0.000027	0.000016	0.000011	0.000007	0.000005	0.000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18 0.05

TEMP. °K		2800.00	2585.63
MOL. WT.		22.4112	22.4362
P		8025	7405
e		-422.37	
c _v		351972	345575
γ		1.25528	1.25526
5		2.35091	2.33188
E		769.20	653.08
HF		1247.99	1250.98
CO		.0218040	.0216897
CO2		.0026141	.0027156
H2		.0082501	.0083592
H2O		.0074370	.0073410
N2		.0044251	.0044229
O2		.0000001	
OH		.0000154	.0000055
H		.0000679	.0000315
NO		.0000011	.0000003
N		.0000003	.0000001
NH3		.0000050	.0000056
CH4		.0000003	.0000005

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18 0.1

TEMP. °K	1400.00	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00
MOL. WT.	26.9772	24.9566	23.7445	23.0908	22.7712	22.6194	22.5472
P	7736	8642	9472	1023	10914	11571	12207
e	-1021.48	-941.00	-877.12	-826.34	-793.87	-745.61	-709.93
CV	329716	329129	329642	331264	333471	335798	338269
γ	1.26755	1.27495	1.27828	1.27832	1.27653	1.27359	1.27361
S	1.96181	2.03734	2.07862	2.13943	2.19370	2.15438	2.17299
E	185.44	250.37	28.72	377.53	418.22	454.97	464.95
HF	1260.50	162.77	1261.29	1259.85	1258.27	1256.86	1255.65
CO	.0179177	.0173591	.0190357	.0200629	.0206504	.0209983	.0212175
CO2	.0055724	.0047101	.0041066	.0037032	.0034318	.0032393	.0030895
H2	.0053884	.0066137	.0078163	.0083653	.0085839	.0086267	.0085940
H2O	.0053699	.0059007	.0062549	.0065057	.0066982	.0068559	.0069853
N2	.0040186	.0041773	.0042835	.0043456	.0043782	.0043945	.0044036
O2							
OH							
H				.0000001	.0000003	.0000006	.0000001
HO							
N							
M13	.0000352	.0000383	.0000374	.0000341	.0000299	.0000260	.0000227
C44	.0017561	.0010705	.0005806	.0002936	.0001424	.0000711	.0000377

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18
0.1

TEMP. °K	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00
MO. WT.	22.5104	22.4901	22.4769	22.4679	22.4586	22.4522	22.4434
P	12835	13459	14076	14654	15309	15925	16541
e	- 673.78	- 635.46	- 603.30	- 568.07	- 532.40	- 496.61	- 460.55
CV	340736	342958	344925	346987	348732	350391	351838
γ	1.26754	1.26477	1.26250	1.26015	1.25810	1.25620	1.25460
z	2.19532	2.20674	2.22238	2.23680	2.25195	2.26599	2.27960
E	524.45	533.75	543.03	552.28	562.19	572.03	582.01
HF	1254.56	1253.61	1252.70	1252.03	1250.97	1250.03	1249.01

CO	.0213729	.0214919	.0215901	.0216514	.0217432	.0218027	.0218587
CO2	.0029705	.0026709	.0027849	.0027311	.0026460	.0025900	.0025405
H2O	.0085327	.0084636	.0083956	.0083514	.0082744	.0082188	.0081701
N2	.0070959	.0071913	.0072745	.0073274	.0074117	.0074663	.0075143
O2	.0044085	.0044115	.0044137	.0044153	.0044174	.0044177	.0044189
H	.0000002	.0000004	.0000007	.0000014	.0000024	.0000042	.0000066
CH	.0000021	.0000037	.0000062	.0000099	.0000153	.0000228	.0000331
NO				.0000001	.0000001	.0000002	.0000004
N	.0000201	.0000180	.0000165	.0000149	.0000124	.0000108	.0000091
CH4	.0000212	.0000127	.0000077	.0000051	.0000034	.0000023	.0000017

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

M18

TEMP. °K 2900.00 2588.85

MOL. WT. 22.4329 22.4528
 P 17158 15856
 • - 424.06
 CV .353349 .350177
 7 1.25295 1.25641
 S 2.29287 2.26448
 E 767.37 693.13
 MF 1247.83 1250.13

CO .0219750 .0217524
 CO2 .0024972 .0025942
 H2 .0081258 .0082245
 H2O .0075552 .0074617
 N2 .0044201 .0044178

O .0000108 .0000039
 OH .0000467 .0000219
 NO .0000008 .0000002
 N .0000002 .0000001
 NH3 .0000113 .0000126
 CH4 .0000013 .0000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18 0.2

TEMP. °K	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00	2200.00
MOL. WT.	25.7326	24.4947	23.6835	23.1815	22.9930	22.7288	22.6355
P	20910	22828	24633	26323	27910	29433	30914
CV	- 925.95	- 862.20	- 807.78	- 760.60	- 718.70	- 679.70	- 642.30
γ	.338304	.358517	.339415	.340625	.342470	.344670	.346635
S	1.27311	1.27522	1.27536	1.27417	1.27190	1.26883	1.26576
E	1.57752	2.01620	2.04730	2.07279	2.09428	2.11329	2.13066
HF	274.42	337.38	390.51	436.35	477.11	515.13	551.67
	1254.69	1254.66	1253.68	1252.66	1251.92	1251.04	1250.24
CO	.0170650	.0167043	.0192555	.0205276	.0211099	.0214185	.0216224
CO2	.0043513	.0037752	.0053565	.0050525	.0025625	.0027165	.0026050
H2	.0055340	.0054675	.0071525	.0075853	.0078252	.0079334	.0079674
H2O	.0063748	.0057320	.0069774	.0071556	.0072863	.0073925	.0074819
H2	.0041011	.0042030	.0042756	.0043239	.0043539	.0043721	.0043834
O							
OH							
H	.0000001	.0000002	.0000002	.0000004	.0000001	.0000001	.0000002
NO					.0000007	.0000014	.0000024
N							
NO2	.0000632	.0000656	.0000643	.0000604	.0000552	.0000503	.0000458
CH4	.0013413	.0008773	.0005409	.0003192	.0001878	.0001122	.0000696

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

H2B C.2

TEMP. °K	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00	2591.34
MOL. WT.	22.5762	22.5418	22.5135	22.4997	22.4855	22.4732	22.4732
P	32359	33791	35210	36621	38032	39440	22.5003
CV	- 605.90	- 569.68	- 533.64	- 497.52	- 461.33	- 424.79	36499
T	348342	350360	352018	353502	354836	356342	353381
S	1.26353	1.26078	1.25836	1.25611	1.25428	1.25222	1.25630
E	2.14687	2.15162	2.17701	2.19119	2.20485	2.21813	2.19001
HF	587.28	622.75	656.13	693.47	728.87	764.53	690.41
	1249.49	1248.96	1248.12	1247.35	1246.57	1245.70	1247.41
CO	.0217729	.0218619	.0219706	.0220376	.0220964	.0221463	.0220335
CO2	.0025129	.0024569	.0023731	.0023193	.0022720	.0022311	.0023228
H2	.0079674	.0079631	.0079199	.0078818	.0078484	.0078155	.0078849
H2O	.0075605	.0076093	.0076890	.0077388	.0077836	.0078223	.0078355
N2	.0043912	.0043963	.0044022	.0044030	.0044054	.0044073	.0044051
O							
OH	.0000005	.0000009	.0000017	.0000028	.0000047	.0000074	.0000027
H	.0000040	.0000065	.0000100	.0000150	.0000218	.0000307	.0000145
NO			.0000001	.0000002	.0000003	.0000005	.0000002
N					.0000001	.0000001	.0000001
NH3	.0000418	.0000384	.0000320	.0000331	.0000309	.0000293	.0000327
CH4	.0000432	.0000288	.0000191	.0000133	.0000096	.0000073	.0000137

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M18

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	23.5223	23.1797	22.9547	22.7992	22.7061	22.6326	22.5555
P	47698	50300	53167	55772	58300	60783	63224
ρ	- 733.83	- 689.94	- 646.98	- 610.05	- 572.37	- 534.66	- 497.52
CV	347671	349513	351061	352412	354290	355783	357078
Z	1.27207	1.26954	1.26682	1.26497	1.26220	1.25971	1.25733
S	2.03711	2.05850	2.07752	2.09485	2.11032	2.12623	2.14074
E	457.85	500.91	541.12	579.25	616.59	653.42	689.67
HF	1247.57	1246.76	1246.16	1245.57	1245.19	1244.56	1243.90
CO	.020685	.0212202	.0215809	.0218458	.0220037	.0221605	.0222532
CO2	.002617	.0024867	.0023448	.0022324	.0021654	.0020769	.0020222
H2	.0066928	.0070143	.0072116	.0073374	.0074135	.0074374	.0074367
H2O	.0074225	.0077158	.0078046	.0078802	.0079267	.0079011	.00780450
N2	.0042739	.0043038	.0043328	.0043504	.0043622	.0043752	.0043776
O2							
OH	.0000001	.0000001	.0000002	.0000004	.0000007	.0000013	.0000023
H	.0000005	.0000010	.0000017	.0000030	.0000048	.0000074	.0000111
NO						.0000001	.0000001
H3	.0000053	.0000011	.0000057	.0000081	.0000745	.0000628	.0000652
CH4	.0004554	.0003033	.0002019	.0001315	.0000902	.0000612	.0000432

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

M18

TEMP. °K	2700.00	2800.00	2592.43
MOL. WT.	22.5409	22.5409	22.5971
P	65658	68077	63041
Q	- 424.26	- 424.26	356987
CV	358230	359710	1.25750
T	1.25544	1.25311	2.13959
S	2.15460	2.16804	686.95
E	725.77	762.02	1243.95
HF	1263.29	1262.61	
CO	.0223292	.0223885	.0222483
CO2	.0019750	.0015355	.0020252
H2	.0074333	.0074214	.0074376
H2O	.0030860	.0091208	.0080428
N2	.0043327	.0043864	.0043777
O2			
OH	.0000037	.0000059	.0000022
H	.000162	.0000229	.0000105
NO	.0000002	.0000004	.0000001
N	.0000001	.0000001	
NH3	.0000010	.0000059	.0000045
CH4	.0000015	.0000020	.0000042

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M18

0.4

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.3026	23.8479	23.4808	23.1987	23.0154	22.8650	22.7817
P	72340	76477	80757	84880	88875	92783	96566
Q	- 752.54	- 704.03	- 659.32	- 617.12	- 576.97	- 537.41	- 499.02
CV	.353433	.355097	.356241	.357242	.358901	.360145	.361176
γ	.27316	1.27095	1.26867	1.26737	1.26482	1.26252	1.26021
z	1.98757	2.01136	2.03212	2.05091	2.06743	2.08418	2.09927
ε	434.92	492.28	526.39	568.02	607.83	646.91	684.67
MF	1242.12	1241.80	1241.44	1241.05	1240.82	1240.44	1239.87
CO	.000872	.0207975	.0213199	.0217326	.0219966	.0222386	.0223854
CO2	.0025449	.0022996	.0021195	.0019759	.0018882	.0017867	.0017255
H2	.0054105	.0058636	.0062041	.0064735	.0066599	.0067861	.0068503
H2O	.0070990	.0090342	.0081323	.0082108	.0082565	.0083287	.0083660
H2	.0041780	.0042234	.0042582	.0042865	.0043069	.0043299	.0043352
U2							
O							
OH	.0000001	.0000001	.0000002	.0000003	.0000006	.0000011	.0000019
H	.0000007	.0000007	.0000013	.0000022	.0000036	.0000057	.0000085
NO							
N							
NH3	.0001386	.0001390	.0001363	.0001320	.0001259	.0001085	.0001138
CH4	.0007879	.0005743	.0004164	.0002918	.0002108	.0001495	.0001091

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

M18

TEMP. °K	2700.00	2800.00	2595.23
MOL. WT.	22.7142	22.6678	22.7843
P	100323	104030	96388
•	- 461.27	- 423.54	
CV	362118	363514	361133
7	1.25840	1.25594	1.26032
5	2.11352	2.12724	2.09858
HF	721.94	759.13	682.90
	1235.43	1238.52	1239.50
CO	.022504	.0225841	.0223802
CO2	.0016743	.0016337	.0017275
H2	.0068994	.0069249	.0068465
H2O	.0024028	.0024336	.0023650
O2	.0043449	.0043517	.0043352
O3			
OH	.000031	.000049	.000012
H	.000125	.000177	.000084
N2	.000032	.000033	.000001
N	.000001	.000001	
NH3	.000174	.0001825	.0001130
CH4	.0000802	.0000620	.0001091

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION.

M26

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.8097	23.6006	23.7927	23.7758	23.7594	23.7369	23.7099
P	35542	36861	38178	39501	40824	42150	43481
Q	- 590.70	- 554.56	- 516.10	- 481.11	- 443.74	- 405.69	- 366.93
CV	351183	352669	353984	355087	356157	357260	358211
γ	1.24475	1.24265	1.24075	1.23911	1.23769	1.23622	1.23451
S	2.15014	2.14325	2.13706	2.13161	2.12685	2.12292	2.11887
E	718.48	753.67	788.99	824.71	860.49	896.62	932.58
MF	1366.52	1365.58	1364.44	1363.15	1361.61	1359.70	1357.33
CO	.0187182	.0167702	.0186153	.0138623	.0189035	.0189454	.0189505
CO2	.0035113	.0034640	.0034229	.0033541	.0033507	.0033195	.0032910
H2	.0053178	.0052727	.0052292	.0051966	.0051642	.0051372	.0051133
H2O	.0093883	.0094531	.0094693	.0095031	.0095275	.0095474	.0095593
H2	.0050168	.0050201	.0050195	.0050226	.0050235	.0050253	.0050268
O2				.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000001	.0000001	.0000003	.0000005	.0000009
H	.0000000	.0000000	.0000168	.0000250	.0000352	.0000519	.0000711
OH	.0000000	.0000253	.0000348	.0000468	.0000618	.0000812	.0001024
HO	.0000000	.0000000	.0000016	.0000026	.0000041	.0000061	.0000090
H2O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000168	.0000187	.0000150	.0000151	.0000137	.0000131
CH2	.0000000	.0000000	.0000011	.0000009	.0000007	.0000005	.0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

426

TEMP. IN 3092.33

MOL. WT. 23.7406
40722

CV 3560.76
7 1.22779
8 2.199 2
9 857.75
10 1361.75

11 1189.16
12 1037.53
13 1051.667
14 1195.262
15 1111.35
16 1111.35
17 1111.35
18 1111.35
19 1111.35
20 1111.35
21 1111.35
22 1111.35
23 1111.35
24 1111.35
25 1111.35
26 1111.35
27 1111.35
28 1111.35
29 1111.35
30 1111.35

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

0.05

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	24.1524	23.8632	23.7636	23.7266	23.7110	23.7035	23.6991
P	4001	4298	4581	4857	5132	5405	5678
e	- 997.05	- 956.26	- 920.06	- 885.34	- 851.05	- 816.88	- 782.63
CV	.317765	.320625	.323723	.326734	.329485	.332102	.334570
γ	1.27354	1.27126	1.26797	1.26461	1.26154	1.25875	1.25613
S	2.07614	2.10249	2.12444	2.14428	2.15281	2.18034	2.19705
E	314.88	353.65	387.78	420.63	453.27	486.00	518.97
HF	136	1366.16	1364.15	1362.30	1360.66	1359.23	1357.96

CO	.0170710	.0176987	.0180566	.0183021	.0184921	.0186462	.0187765
CO2	.0055291	.0051620	.0048945	.0046823	.0045058	.0043579	.0042310
H2	.0072054	.0072258	.0070944	.0069329	.0067775	.0066391	.0065167
H2O	.0068064	.0071240	.0075748	.0075812	.0077556	.0079028	.0080295
O2	.0045822	.0046116	.0046227	.0046274	.0046297	.0046310	.0046318
O							
OH							
H	.0000001	.0000001	.0000001	.0000003	.0000001	.0000001	.0000003
NO					.0000007	.0000014	.0000027
N							
HMS	.0000176	.0000143	.0000115	.0000094	.0000079	.0000067	.0000059
CM4	.0001917	.0000589	.0000265	.0000112	.0000052	.0000026	.0000014

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

1.0

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
CP	23.6922	23.6911	23.6879	23.6819	23.6744	23.6637	23.6501
CV	748.25	713.75	679.11	642.53	608.53	572.74	536.95
γ	1.25278	1.25180	1.24991	1.24723	1.24403	1.24035	1.23619
ρ	2.21314	2.22823	2.24261	2.25674	2.27127	2.28488	2.29710
μ	551.12	585.61	619.42	653.30	687.52	721.93	756.74
MF	1356.83	1355.73	1354.90	1353.60	1352.43	1351.10	1349.52
CO	0.166589	0.139867	0.1190497	0.1011496	0.092177	0.082801	0.073575
CO2	0.241212	0.240251	0.239643	0.238675	0.238030	0.237458	0.236943
H2	0.006171	0.003197	0.002327	0.001555	0.000887	0.000294	0.000753
H2O	0.581374	0.592392	0.598295	0.602916	0.608442	0.613584	0.618323
N2	0.040326	0.041531	0.042637	0.043645	0.0446331	0.045630	0.0466373
OH	0.000007	0.000014	0.000026	0.000047	0.000080	0.000132	0.000213
H	0.000047	0.000178	0.000124	0.000191	0.000284	0.000411	0.000575
O	0.000001	0.000001	0.000002	0.000003	0.000006	0.000011	0.000018
H2O2	0.000052	0.000047	0.000042	0.000035	0.000036	0.000032	0.000031
NO	0.000008	0.000005	0.000003	0.000002	0.000001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.05

1MR

TEMP. °K	2900.00	3000.00	2867.22
MOL. WT.	23.6302	23.6037	23.6369
P	7863	8139	7773
c	- 499.40	- 461.61	.347984
CV	.348411	.349638	1.24322
Z	1.24285	1.24182	2.30685
S	2.31108	2.32389	780.27
E	791.79	827.18	1348.27
HF	1347.59	1345.21	
CO	.0192915	.0194449	.0193742
CO2	.0036509	.0036104	.0036649
H2	.0059285	.0058869	.0059437
H2O	.0085909	.0085202	.0085797
N2	.0046380	.0045399	.0046377
O2	.0000002	.0000003	.0000001
O	.0000003	.0000006	.0000002
OH	.0000320	.0000475	.0000280
H	.0000795	.0001070	.0000718
NO	.0000030	.0000048	.0000025
N	.0000005	.0000008	.0000004
NH3	.0000035	.0000028	.0000033
CH4	.0000001		.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR
C.1

TEMP. °K	1500.00	1600.00	1700.00	1800.00	1900.00	2000.00	2100.00
MOL. WT.	25.1341	24.3309	23.9755	23.8274	23.7635	23.7342	23.7192
P	8347	9067	9720	10336	10936	11526	12114
e	-1021.70	-968.93	-926.54	-889.06	-853.51	-818.76	-784.18
CV	321498	323512	325864	328514	331046	333593	336077
T	1.27412	1.27438	1.27201	1.26564	1.26521	1.26196	1.25875
S	1.99762	2.03172	2.05743	2.07885	2.09806	2.11589	2.13275
E	285.79	338.09	379.09	415.02	449.08	482.52	515.52
HF	1362.93	1362.97	1361.81	1360.35	1358.91	1357.62	1356.46
CO	.0160972	.0173016	.0179611	.0183376	.0185828	.0187580	.0188965
CO2	.0056546	.0051455	.0048022	.0045593	.0043713	.0042218	.0040960
H2	.0061070	.0065882	.0067141	.0066717	.0065710	.0064611	.0063549
H2O	.0068204	.0072149	.0074988	.0077171	.0078950	.0080405	.0081648
N2	.0044842	.0045597	.0045956	.0046119	.0046198	.0046239	.0046263
O2							
OH							
H							
NO							
N							
NH3	.0000326	.0000291	.0000247	.0000207	.0000175	.0000149	.0000130
CH4	.0005807	.0002611	.0001125	.0000500	.0000236	.0000120	.0000066

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.7105	23.7042	23.6990	23.6925	23.6871	23.6789	23.6683
P	12700	13282	13865	14446	15027	15610	16193
e	- 749.58	- 715.02	- 680.33	- 645.17	- 609.87	- 574.30	- 539.25
CV	338276	342088	342212	343905	345464	346884	348341
γ	1.25591	1.25372	1.25137	1.24934	1.24747	1.24592	1.24425
S	2.14884	2.16422	2.17847	2.19335	2.20720	2.22062	2.23372
E	549.45	323.04	617.00	651.01	685.31	719.81	754.62
MF	1355.40	1554.41	1353.09	1352.54	1351.55	1350.48	1349.26

CO	.0190113	.0191103	.0191730	.0192718	.0193377	.0193979	.0194524
CO2	.0035822	.0038939	.0038344	.0037393	.0036763	.0036203	.0035711
H2	.0062273	.0061653	.0061124	.0060202	.0059553	.0059000	.0058455
H2O	.0062716	.0063656	.0064246	.0065192	.0065802	.0066348	.0066857
O2	.0046279	.0046251	.0046300	.0046314	.0046317	.0046326	.0046336
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H2O2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

1MR

TEMP. °K	2900.00	3000.00	2873.24
MOL. WT.	23.6556	23.6361	23.6592
P	16776	17363	16620
Q	- 511.61	- 464.72	
CV	349674	350864	349330
Y	1.24281	1.24151	1.24319
S	2.24652	2.25909	2.24312
E	789.60	824.95	780.22
HF	1347.80	1340.07	1348.22
CO	.0195121	.0195513	.0194893
CO2	.0035276	.0034880	.0035387
H2	.0058034	.0057648	.0058155
H2O	.0087185	.0087507	.0087052
O2	.0046339	.0046359	.0046339
N2	.0000001	.0000001	.0000001
CH4	.0000001	.0000001	.0000001
HCN	.0000224	.0000333	.0000201
NO	.0000545	.0000734	.0000509
NO2	.0000021	.0000033	.0000018
N2O	.0000004	.0000006	.0000003
HNO	.0000078	.0000063	.0000075
CH2	.0000003	.0000002	.0000003

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

IMR 0.2

TEMP. °K	1800.00	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00
WGT. WT.	24.2662	24.0042	23.8735	23.8057	23.7690	23.7460	23.7320
P	23502	24975	26381	27758	29117	30455	31793
Q	- 901.11	- 860.66	- 823.30	- 787.33	- 751.85	- 716.62	- 681.73
CV	.332237	.334669	.336930	.339377	.341475	.343187	.345237
γ	1.27221	1.26920	1.26578	1.26201	1.25854	1.25609	1.25319
S	2.50270	2.502455	2.50369	2.506125	2.507774	2.509334	2.510774
ε	396.21	437.71	474.05	509.15	543.76	577.94	612.40
HF	1355.51	1354.55	1353.66	1352.77	1351.92	1351.09	1350.52

CO	.0181044	.0186414	.0189313	.0191255	.0192664	.0193758	.0194483
CO2	.0043525	.0041045	.0039311	.0037968	.0036878	.0035939	.0035359
H2	.0058793	.0059776	.0059802	.0059376	.0058778	.0058137	.0057722
H2O	.0079877	.0081931	.0083458	.0084699	.0085740	.0086632	.0087219
N2	.0045565	.0045842	.0045995	.0046082	.0046135	.0046172	.0046197
O2							
OH							
H	.0000001	.0000003	.0000006	.0000012	.0000021	.0000035	.0000050
HO							.0000001
H3	.0000476	.0000420	.0000367	.0000324	.0000289	.0000260	.0000235
CH4	.0002245	.0001165	.0000623	.0000349	.0000208	.0000125	.0000082

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

1MR

TEMP. °K	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00	2876.53
MOL. WT.	23.7186	23.7121	23.7033	23.6941	23.6863	23.6695	23.6880
P	33119	34445	35772	37099	38422	39753	38112
e	- 646.35	- 610.90	- 575.34	- 539.37	- 502.09	- 466.50	-
CV	348366	348325	349593	351051	352354	353463	352073
7	1.25065	1.24835	1.24655	1.24447	1.24257	1.24094	1.24300
5	2.12274	2.13665	2.15008	2.16316	2.17589	2.18835	2.17293
E	646.87	681.49	716.21	751.25	786.41	821.97	778.14
HF	1349.57	1348.74	1347.91	1346.98	1345.86	1344.65	1346.14
CO	.0195502	.0196147	.0196733	.0197250	.0197698	.0198164	.0197599
CO2	.0034439	.0033842	.0033309	.0032843	.0032438	.0032058	.0032528
H2	.0056947	.0056384	.0055895	.0055454	.0055023	.0054704	.0055123
H2O	.0028135	.0028713	.0029231	.0029673	.0029903	.0030038	.0029956
H2	.0046230	.0046234	.0046248	.0046250	.0046255	.0046285	.0046258
O2						.0000001	
O					.0000001	.0000001	.0000001
OH	.0000023	.0000039	.0000064	.0000101	.0000155	.0000231	.0000141
H	.0000055	.0000127	.0000184	.0000259	.0000356	.0000460	.0000331
N2		.0000003	.0000015	.0000028	.0000044	.0000062	.0000042
N			.0000011	.0000022	.0000033	.0000044	.0000027
NO			.0000015	.0000031	.0000045	.0000056	.0000037
CH4	.0000053	.0000036	.0000025	.0000017	.0000011	.0000007	.0000016

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR 0.3

TEMP. °K	2200.00	2300.00	2400.00	2500.00	2600.00	2700.00	2800.00
MOL. WT.	23.8918	23.8302	23.7949	23.7548	23.7519	23.7378	23.7261
P	50180	52503	54814	57093	59360	61627	63890
e	- 754.51	- 718.26	- 682.55	- 646.58	- 610.77	- 575.00	- 538.64
CV	345051	345516	348567	350150	351453	352555	354030
γ	1.26146	1.25904	1.25579	1.25296	1.25040	1.24845	1.24604
ε	2.02941	2.04546	2.06016	2.07539	2.08945	2.10295	2.11610
E	537.11	572.45	607.77	642.97	678.07	713.16	748.56
HF	1347.66	1347.04	1346.62	1345.87	1345.17	1344.49	1343.74
CO	.0194533	.0196479	.0197384	.0198529	.0199213	.0199823	.0200340
CO2	.0033603	.0032599	.0031952	.0031080	.0030508	.0029998	.0029557
H2	.0052839	.0053654	.0053510	.0052981	.0052545	.0052170	.0051816
H2O	.0089106	.0090030	.0090594	.0091488	.0092029	.0092522	.0092939
O2	.0045689	.0045974	.0046030	.0046098	.0046105	.0046131	.0046151
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.3

1.1R

TEMP. °K	2500.00	3000.00	2874.82
HOL. WT.	23.7159	23.7033	23.7209
P	66140	68438	65574
CV	- 502.48	- 465.61	.355000
Z	.24359	.356294	1.24437
SE	2.12287	2.14135	2.12569
TF	1942.60	819.92	775.06
		1341.89	1343.00
CO	.020757	.0201228	.0200661
CO2	.0029187	.0028820	.0029274
H2	.0051431	.0051205	.0051531
H2O	.0093261	.0093600	.0093189
O2	.0046136	.0046187	.0046143
OH		.0000001	.0000112
NO	.0000124	.0000165	.0000244
AM3	.0000264	.0000355	.0000010
CH4	.0000011	.0000018	.0000002
	.0000002	.0000003	.0000000
	.0000370	.0000297	.0000355
	.0000044	.0000034	.0000048

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

1MR

0.4

TEMP. °K	2400.00	2500.00	2600.00	2700.00	2800.00	2900.00	3000.00
MOL. WT.	23.9084	23.8471	23.8197	23.7941	23.7753	23.7680	23.7413
P	83752	87241	90685	94126	97549	100937	104369
g	- 683.25	- 646.38	- 609.57	- 573.82	- 537.31	- 500.71	- 463.57
CV	.352243	.353720	.354866	.355785	.357261	.358491	.359367
7	1.25497	1.25699	1.25427	1.25226	1.24958	1.24713	1.24511
S	2.02131	2.03691	2.05121	2.06486	2.07814	2.09100	2.10356
E	602.63	638.95	674.75	710.37	746.28	782.04	818.51
HF	1247.10	1341.59	1341.01	1340.49	1339.90	1339.07	1338.42
CO	.0200025	.0201875	.0202300	.0203004	.0203566	.0203977	.0204492
CO2	.0028462	.0027505	.0026935	.0026431	.0026008	.0025671	.0025305
H2	.0045446	.0048301	.0048072	.0047872	.0047647	.0047332	.0047235
H2O	.0094175	.0095080	.0095591	.0096066	.0096462	.0096738	.0097086
H2	.0045766	.0045888	.0045956	.0045953	.0045987	.0045960	.0046044
O2							
O							
OH	.0000008	.0000015	.0000026	.0000043	.0000068	.0000105	.0000157
H	.0000031	.0000048	.0000072	.0000105	.0000148	.0000203	.0000274
H		.0000001	.0000002	.0000003	.0000006	.0000009	.0000015
N				.0000001	.0000001	.0000002	.0000003
NH3	.0000756	.0000630	.0000647	.0000601	.0000566	.0000530	.0000507
CH4	.0000590	.0000591	.0000271	.0000194	.0000146	.0000107	.0000089

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.4

1stR

TEMP. °K	2870.64
MOL. WT.	23.7650
P	99526
CV	358149
Y	1.24784
Z	2.58719
E	771.024
WF	1339.34
CO	.0203670
CO2	.0021762
H2O	.047435
H2	.0096668
O2	.0045575
O	
OH	.0000993
H	.000195
H2O	.0000008
H	.0000002
H2O	.0000650
CH4	.0000118

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

T20

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	21.5229	21.3361	21.2195	21.1413	21.0934	21.0508	21.0345
P	29820	31483	33094	34665	36216	37756	39272
g	- 384.92	- 343.74	- 304.41	- 266.17	- 228.43	- 190.58	- 152.94
CV	.355758	.358186	.360321	.362217	.364402	.366253	.367923
Z	1.27657	1.27372	1.27085	1.26866	1.26593	1.26353	1.26122
Y	2.17969	2.19978	2.21806	2.23507	2.25075	2.26658	2.28196
E	445.91	535.39	573.06	610.24	647.28	684.35	721.20
MF	946.67	944.84	943.57	942.59	941.94	941.18	940.42

CO	.0140216	.0142891	.0144654	.0145936	.0146700	.0147546	.0148033
CO2	.0014770	.0013788	.0013044	.0012438	.0012071	.0011532	.0011197
H2	.0095679	.0102426	.0103646	.0104690	.0105196	.0105420	.0105323
H2O	.0074595	.0074985	.0075382	.0075766	.0076011	.0076486	.0076752
H2	.0130977	.0131623	.0132037	.0132327	.0132521	.0132735	.0132769
O2							
OH							
H	.0000008	.0000001	.0000002	.0000004	.0000008	.0000014	.0000024
HO	.0000008	.0000015	.0000028	.0000047	.0000075	.0000116	.0000174
H							
NO							
N							
NO2	.0001421	.0001316	.0001215	.0001123	.0001038	.0000877	.0000910
CH4	.0002625	.0001642	.0001058	.0000676	.0000439	.0000313	.0000222

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

T20

TEMP. °K 2324.69

MOL. WT. 21.1267
35050

CV 362730
7 1.26833
S 2.23937
E 615.40
MF 942.40

CO₂ 0146172
CO 0012325
H₂O 0106847
H₂ 0075839
OH 0122254

NO 0000025
O₂ 0000053

N₂ 0001162
CH₄ 0001607

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T25 0.2

TEMP. °K	2700.00	2500.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	24.0255	24.0176	24.0096	23.9928	23.9762	23.9534	23.9259
ρ	35201	36508	37813	39124	40434	41749	43067
e	- 526.69	- 573.71	- 534.39	- 497.57	- 452.34	- 422.43	- 383.81
CV	• 345657	• 352130	• 352430	• 353523	• 354580	• 355670	• 356609
γ	• 24378	1.24169	1.23980	1.23816	1.23675	1.23527	1.23398
S	2.13890	2.15199	2.16473	2.17721	2.18940	2.20143	2.21330
E	7.5.37	750.40	785.57	821.14	856.77	892.74	928.96
MF	1379.05	1378.10	1376.97	1375.72	1374.13	1372.21	1369.82

CO	• 0185341	• 0185861	• 0186315	• 0186785	• 0187201	• 0187623	• 0188043
CO2	• 0036956	• 0036481	• 0026068	• 0035678	• 0035341	• 0035025	• 0034735
H2	• 0050215	• 0049763	• 0049327	• 0048995	• 0048670	• 0048398	• 0048160
H2O	• 0093642	• 0094340	• 0094703	• 0095041	• 0095288	• 0095483	• 0095603
N2	• 0045369	• 0045360	• 0045376	• 0045404	• 0045412	• 0045425	• 0045443
O2				• 0000001	• 0000002	• 0000003	• 0000005
OH				• 0000002	• 0000003	• 0000005	• 0000009
H	• 0000071	• 0000113	• 0000173	• 0000257	• 0000373	• 0000529	• 0000732
NO	• 0000174	• 0000246	• 0000337	• 0000454	• 0000600	• 0000778	• 0000994
NO2	• 0000006	• 0000010	• 0000017	• 0000027	• 0000042	• 0000064	• 0000095
HCl	• 0000001	• 0000002	• 0000003	• 0000004	• 0000007	• 0000011	• 0000016
CH4	• 0000162	• 0000152	• 0000170	• 0000136	• 0000136	• 0000124	• 0000118
	• 0000017	• 0000013	• 0000009	• 0000007	• 0000006	• 0000004	• 0000004

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

125

TEMP. °K 3090.28

MOL. WT. 23.9778
P 49307

CV 354479
Y 1.23687
S 2.18623
E 853.30
HF 1374.30

CO 0157163
CO2 0035571
H2 0048701
H2O 0095269
O2 0049412
O 0000001
J 0000003
OH 0000361
H 0000584
NO 0000041
N 0000007
NH3 0000135
CH4 0000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

129

TEMP. °K	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00	3400.00
mol. wt.	24.1692	24.1608	24.1624	24.1436	24.1176	24.0853	24.0451
D	35925	37216	38510	39805	41104	42409	43718
g	- 501.83	- 494.55	- 427.15	- 385.33	- 350.65	- 311.10	- 270.54
CV	354705	356047	357153	358224	359336	360287	361117
γ	1.20619	1.23629	1.23407	1.23326	1.23185	1.23055	1.22949
S	2.12238	2.15827	2.18093	2.19335	2.20360	2.21176	2.22988
H	715.19	790.73	826.67	862.67	899.05	935.70	972.60
HF	13.585	1317.64	1516.22	1314.40	1312.12	1309.24	1305.61

CO ₂	.0131250	.0135707	.0132144	.0132536	.0132942	.0133354	.0133794
CO	.0036416	.0036030	.0035657	.0035230	.0035015	.0034716	.0034417
H ₂	.0040883	.0040450	.0040162	.0039862	.0039655	.0039479	.0039341
H ₂ O	.0109421	.0109450	.0109746	.0109946	.0110089	.0110151	.0110134
H ₂	.0045107	.0055108	.0052097	.005280	.0052264	.0052297	.0052332
O ₂	.0000001	.0000001	.0000002	.0000003	.0000006	.0000010	.0000016
H	.0000001	.0000001	.0000002	.0000004	.0000008	.0000013	.0000022
OH	.0000044	.0000222	.0000350	.0000478	.0000677	.0000937	.0001270
H ₂ O	.0002224	.0003507	.0004413	.000546	.000708	.000964	.0001139
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
N ₂	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH ₄	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

729 3.2

TEMP. OK 3215.49

MOLE WT. 24.1150
 P 0.1356

CV 385454
 7 1.25102
 5 2.28749
 4 904.71
 HF 1511.71

CO₂ 0.1356
 CO 0.1356
 H₂O 0.1356
 H₂ 0.1356
 O₂ 0.1356
 O 0.1356
 H₂ 0.1356
 H 0.1356
 C 0.1356
 O 0.1356
 H 0.1356
 C 0.1356

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

131

0.2

TEMP. °K	3200.00	3300.00	3400.00	3500.00	3600.00	3700.00	3800.00
MOL. WT.	26.2280	26.1838	26.1267	26.0537	25.9622	25.8487	25.7112
P	37857	39072	40294	41528	42776	44042	45330
C	- 641.71	- 601.85	- 560.68	- 517.98	- 473.26	- 426.41	- 376.84
CV	354627	355514	356270	357110	357984	358751	359410
γ	1.21788	1.21665	1.21564	1.21479	1.21390	1.21316	1.21261
S	2.11555	2.12620	2.13848	2.15085	2.16343	2.17629	2.18947
E	867.21	723.80	560.76	998.10	1036.06	1074.45	1113.70
MF	1587.69	1584.43	1580.28	1574.97	1568.27	1559.89	1549.67

CO	.0126416	.0120590	.0129537	.0130249	.0131103	.0132154	.0133374
CO2	.0094693	.0064555	.0064148	.0063707	.0062195	.0062570	.0061670
H2	.0021533	.0021374	.0021264	.0021209	.0021215	.0021273	.0021440
H2O	.0111126	.0111147	.0110947	.0110947	.0110705	.0110373	.0109892
O2	.0059652	.0053603	.0053601	.0053597	.0053587	.0053573	.0053553
N2	.0000021	.0000037	.0000065	.0000104	.0000165	.0000254	.0000377
OH	.0000014	.0000025	.0000042	.0000069	.0000109	.0000168	.0000252
H	.0000425	.0001261	.0001738	.0002312	.0003021	.0003882	.0004904
H2O	.0000016	.0000061	.0000082	.0001035	.0001274	.0001552	.0001677
H	.0000017	.00000261	.00000375	.00000526	.00000722	.00000971	.00001277
HO	.0000011	.0000016	.0000024	.0000034	.0000048	.0000067	.0000090
H3	.0000007	.0000005	.00000035	.00000033	.00000031	.00000031	.00000030
CH4							

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

111 0.2

TEMP. °K	3900.00	3688.37
MOL. WT.	25.5466	25.8631
P	46639	43894
Q	325.25	358662
CV	256.37	1.21324
γ	1.21438	2.17472
ε	2.20287	1069.96
MF	1152.77	1560.96
	1537.26	
CO	0.154337	0.152021
CO2	0.061034	0.062649
H2	0.121692	0.021263
H2O	0.05286	0.110417
O2	0.053527	0.053575
O	0.000543	0.000292
OH	0.000368	0.000160
H	0.0006103	0.003773
N	0.002253	0.001512
NO	0.001647	0.000939
N2	0.000121	0.000064
NO2	0.000030	0.000031

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

732

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.5956	23.5667	23.5682	23.5510	23.5350	23.5130	23.4862
P	35930	37264	38597	39924	41269	42609	43952
e	- 017.95	- 579.67	- 486.56	- 449.41	- 412.06	- 374.07	- 335.43
CV	349500	351077	353575	354983	356059	357167	358123
Z	1.24850	1.24669	1.24271	1.24108	1.23967	1.23817	1.23687
S	2.14171	2.13531	2.13431	2.13583	2.20906	2.22111	2.23200
E	061.15	046.17	785.40	625.12	660.98	696.95	733.31
MF	1335.64	1333.01	1332.95	1331.73	1330.17	1328.50	1325.96
CO	0051335	0051920	0052889	0053353	0053755	0054195	0054560
CO2	0032660	0032331	0031462	0031104	0030773	0030478	0030203
H2	0057465	0055580	0050133	0055823	0055593	0055239	0055002
H2O	0090239	0080754	0071583	0091890	0092130	0092324	0092449
O2	0051452	0051469	0051462	0051517	0051526	0051547	0051561
N2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
H	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CH	0000000	0000000	0000000	0000000	0000000	0000000	0000000
OH	0000000	0000000	0000000	0000000	0000000	0000000	0000000
HF	0000000	0000000	0000000	0000000	0000000	0000000	0000000
Cl	0000000	0000000	0000000	0000000	0000000	0000000	0000000
Br	0000000	0000000	0000000	0000000	0000000	0000000	0000000
I	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CF	0000000	0000000	0000000	0000000	0000000	0000000	0000000
Cl2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
Br2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
I2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CH4	0000000	0000000	0000000	0000000	0000000	0000000	0000000
C2H6	0000000	0000000	0000000	0000000	0000000	0000000	0000000
C2H4	0000000	0000000	0000000	0000000	0000000	0000000	0000000
C2H2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CH3	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CH2	0000000	0000000	0000000	0000000	0000000	0000000	0000000
CH	0000000	0000000	0000000	0000000	0000000	0000000	0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

T32

TEMP. °K 3087.43

MOL. WT. 23.5369
P 41101

CV 355926
Y 1.23982
S 2.20754
E 856.39
HF 1330.39

CO .0193709
CO2 .0030817
H2 .0055544
H2O .0052104
N2 .0051526
O2 .0000001
O .0000002
OH .0000323
H .0000619
NO .0000035
N .0000007
NH3 .0000168
CH4 .0000009

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T33

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
MOL. WT.	23.7178	23.7087	23.7010	23.6839	23.6677	23.6455	23.6190
P	35709	37034	38356	39685	41012	42344	43680
e	- 568.68	- 332.63	- 496.26	- 459.37	- 422.10	- 384.17	- 345.55
CV	.350371	.351850	.353161	.354263	.355332	.356433	.357384
γ	1.24596	1.24388	1.24193	1.24035	1.23893	1.23745	1.23615
S	2.15213	2.16524	2.17801	2.19050	2.20271	2.21474	2.22662
E	717.36	753.47	787.70	823.35	859.04	895.07	931.33
HF	1343.15	1342.22	1341.09	1339.86	1338.30	1336.41	1334.07

CO	.0189452	.0189967	.0190411	.0190876	.0191282	.0191693	.0192099
CO2	.0033489	.0033023	.0032620	.0032238	.0031911	.0031606	.0031327
H2	.0054378	.0054457	.0054056	.0053689	.0053369	.0053103	.0052866
H2O	.0091443	.0091883	.0092240	.0092574	.0092818	.0093013	.0093136
N	.0051893	.0051906	.0051901	.0051934	.0051943	.0051963	.0051979
O2				.0000001	.0000001	.0000002	.0000004
O			.0000001	.0000001	.0000003	.0000005	.0000008
OH	.0000066	.0000105	.0000161	.0000239	.0000347	.0000491	.0000681
H	.0000162	.0000257	.0000353	.0000475	.0000626	.0000815	.0001041
HO	.0000005	.0000009	.0000015	.0000025	.0000039	.0000058	.0000086
H+	.0000001	.0000002	.0000003	.0000004	.0000007	.0000011	.0000016
NH3	.0000190	.0000182	.0000172	.0000161	.0000151	.0000147	.0000142
CH4	.0000123	.0000117	.0000113	.0000112	.0000112	.0000112	.0000112

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T33

0.2

TEMP. °K 3.35.17

MOL. WT. 25.6606
P 41460

CV 3557.5
Y 1.23841
S 2.20696
E 871.67
HF 1337.67

CO 0191426
CO2 0031801
H2 0053269
H2O 0092832
N2 0051949
O2 0000002
O 0000003
OH 0000394
F 0000690
NO 0000045
H 0000008
NH3 0000158
CH4 0000007

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

T34 0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.0481	21.9344	21.8683	21.8249	21.7979	21.7716	21.7627
P	28720	30257	31763	33242	34712	36174	37622
e	- 478.22	- 439.68	- 402.15	- 365.28	- 328.51	- 291.44	- 254.43
CV	350996	353633	355899	357794	360032	361886	363513
γ	1.27339	1.27037	1.26706	1.26465	1.26172	1.25917	1.25681
S	2.14065	2.16547	2.18292	2.19932	2.21460	2.23010	2.24463
H	492.21	529.48	566.07	602.14	638.36	674.67	710.93
HF	1035.92	1034.75	1033.87	1033.11	1032.56	1031.85	1031.13

CO	.0135221	.0137191	.0138529	.0139548	.0140162	.0140966	.0141443
CO2	.0019374	.0018351	.0017544	.0016864	.0016448	.0015806	.0015402
H2	.0085231	.0086137	.0086453	.0086502	.0086521	.0086288	.0085971
H2O	.0085255	.0085052	.0084719	.0084315	.0083789	.0083319	.0082889
N2	.0126028	.0126405	.0126641	.0126805	.0126916	.0127053	.0127067
O	.0000001	.0000001	.0000003	.0000006	.0000010	.0000018	.0000031
OH	.0000005	.0000014	.0000025	.0000042	.0000068	.0000106	.0000158
H	.0001065	.0000970	.0000882	.0000806	.0000740	.0000621	.0000501
CH4	.0001317	.0000784	.0000488	.0000305	.0000204	.0000137	.0000096

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

134 0.2

TEMP. °K	2700.00	2800.00	2570.73
MOL. WT.	21.7493	21.7372	21.7625
P	39074	40522	37200
•	- 217.29	- 179.74	
CV	• 364545	• 366597	• 363060
γ	1.25497	1.25286	1.25748
S	2.25565	2.27231	2.24048
E	747.31	783.98	700.32
HF	1030.36	1029.49	1031.32
CO	• 0141879	• 0142250	• 0141337
CO2	• 0015041	• 0014729	• 0015495
H2	• 0085750	• 0085523	• 0086072
H2O	• 0089033	• 0089324	• 0088607
H2	• 0127126	• 0127173	• 0127075
O2			
O			
OH	• 0000051	• 0000061	• 0000027
H	• 0000229	• 0000323	• 0000141
H3	• 0000005	• 0000009	• 0000002
N	• 0000001	• 0000003	• 0000001
NH2	• 0000000	• 0000070	• 0000021
CH4	• 0000070	• 0000054	• 0000106

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
ADL. WT.	22.9256	22.7064	22.5771	22.4933	22.4445	22.4260	22.4260
P	28098	29669	31160	32662	34116	35555	36932
Q	- 650.98	- 641.18	- 575.49	- 537.00	- 501.29	- 465.44	- 429.83
CV	337476	335648	341163	342810	344091	346262	347732
Y	1.27473	1.27237	1.26963	1.26750	1.26592	1.26274	1.26150
Z	2.05223	2.04902	2.04243	2.03894	2.03275	2.02622	2.01821
E	52.00	537.23	543.98	579.57	614.79	649.82	684.74
MF	13.56	1172.47	1171.61	1173.53	1173.29	1169.50	1169.77
CO	0.22222	0.21760	0.22953	0.230793	0.231613	0.232035	0.233329
CO2	0.24357	0.22890	0.22180	0.220921	0.220391	0.219931	0.219410
H2	0.280675	0.282053	0.283674	0.284006	0.284299	0.284421	0.284500
H2O	0.362583	0.361425	0.362119	0.362794	0.363196	0.363375	0.364297
O2	0.044344	0.044382	0.044731	0.044835	0.044972	0.044975	0.044985
O	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N2	0.000007	0.000014	0.000025	0.000041	0.000067	0.000103	0.000134
N	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M1 O-O

TEMP. °K 2510.32

MOL. WT. 22.4031
P 35703

CV 345617
Z 1.26251
S 2.16972
E 653.42
HF 1169.42

CO 0.279026
CO2 0.501558
H2 0.084100
H2O 0.5563920
O2 0.3044575

CH 0.000014
N 0.000108
NO 0.000001
NH3 0.0000355
CH4 0.0000285

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 2-0

G.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.5559	22.2620	22.0684	21.8626	21.6531	21.5434	21.5317
D	25317	32433	32054	32630	35146	36643	39121
CV	820.75	576.50	536.96	501.00	464.19	427.40	390.57
7	343575	343173	346847	346465	352322	351899	353367
5	1.27558	1.27352	1.27112	1.26932	1.26692	1.26475	1.26262
6	2.11403	2.11345	2.11299	2.11198	2.11043	2.10859	2.10689
HF	471.57	512.34	550.74	587.70	623.94	659.50	695.57
	1147.01	1145.70	1144.09	1143.81	1143.22	1142.43	1141.08
CO	.0226712	.0231205	.0234242	.0236365	.0237652	.0238919	.0239685
CO2	.0021487	.0019959	.0018642	.0017957	.0017427	.0016702	.0016243
H2	.0588948	.0092162	.0094011	.0095128	.0095769	.0095932	.0095932
H2O	.0058550	.0059179	.0058739	.0060251	.0060569	.0061153	.0061316
O2	.043190	.0043401	.0043667	.0043826	.0043916	.0044011	.0044030
OH							
H	.0000005	.0000001	.0000002	.0000004	.0000007	.0000012	.0000020
N		.0000015	.0000026	.0000044	.0000071	.0000110	.0000165
N2						.0000031	.0000050
CH2	.0000685	.0000645	.0000601	.0000559	.0000518	.0000437	.0000354
CH4	.0003563	.0002478	.0001617	.0001040	.0000709	.0000481	.0000330

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

202

MI 2-0

TEMP. °K 2362.44

MI. WT. 41.9199
34560

CO 349699
Y 1.2678E
S 2.17047
E 612.41
FE 1147.41

CO2 1237275
H2O 1017589
H2 1195931
O2 1160472
N2 1342385

CO 1001005
H2O 1001000

CO 1001005
H2O 1001000

TEMP. °K

MI. WT.

CO
Y
S
E
FE

CO2
H2O
H2
O2
N2
CO
H2
O
N

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 4-0

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.2590	21.9008	21.6731	21.5157	21.4208	21.3491	21.3000
P	28476	31240	32927	34551	36132	37691	39199
e	- 593.16	- 543.24	- 506.77	- 467.19	- 429.05	- 391.21	- 357.48
CV	349268	350926	352471	354066	355673	357437	359481
γ	1.27566	1.27415	1.27219	1.27062	1.26944	1.26842	1.26752
z	2.14549	2.16354	2.18165	2.19927	2.21435	2.22696	2.23713
E	473.63	513.59	550.76	586.20	620.58	653.04	683.62
MF	1122.16	1120.55	1119.27	1118.23	1117.54	1116.71	1116.72
CO	.025779	.025792	.025840	.025934	.026030	.026130	.026234
CO2	.001913	.001751	.001640	.001546	.001462	.001389	.001327
H2	.0596266	.013076	.0103710	.0085649	.0072629	.0062703	.0055219
H2O	.0550575	.0056748	.0057101	.0057644	.0058252	.0058913	.0059619
O2	.0042044	.0042408	.0042651	.0042829	.0042947	.0043066	.0043184
OH	.0000001	.0000001	.0000002	.0000003	.0000006	.0000012	.0000024
H	.0000008	.0000015	.0000027	.0000046	.0000075	.0000119	.0000184
NH3	.0000775	.0000741	.0000699	.0000656	.0000612	.0000570	.0000539
CH4	.0005302	.0003527	.0002370	.0001560	.0001079	.0000742	.0000529

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

MI 4-0 0.2

MI 4-0

TEMP. °K 2239.71

MOL. WT. 21.6129

P 33491

CV 353004

γ 1.27152

β 2.19777

ϵ 569.95

MF 1116.90

CO 0.239596

CO2 0.016113

H2 0.0104653

H2O 0.0057218

NO 0.0042718

O2 0.0000000

N2 0.0000000

NO 0.0000000

MF 0.0000000

MI 0.0000000

MI 0.0000000

MI 0.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

6-2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
Wt.	22.0340	21.6096	21.3284	21.1271	21.0027	20.9074	20.8523
P	31.80	31.94	33.716	35.423	37.075	38.699	40.287
CV	567.99	520.59	476.52	435.41	395.86	356.83	319.33
γ	1.25170	1.30671	1.35890	1.40933	1.45839	1.50510	1.54987
Z	1.27532	1.27429	1.27279	1.27151	1.27059	1.26970	1.26883
E	2.16499	2.16810	2.20842	2.22688	2.24304	2.25764	2.27070
HF	475.01	520.00	582.08	632.10	640.70	670.73	690.00
	1095.01	1095.97	1095.41	1094.10	1093.24	1092.31	1091.10

CO	0.29122	0.29797	0.24400	0.24082	0.24670	0.24827	0.24937
CO2	0.01724	0.01564	0.01473	0.01350	0.01328	0.01308	0.01288
H2	0.10355	0.11555	0.11260	0.10954	0.10733	0.10578	0.10453
H2O	0.54171	0.56423	0.55437	0.54553	0.53907	0.53403	0.52950
O2	0.04122	0.04194	0.04197	0.04188	0.04183	0.04178	0.04173
N2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HF	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HCl	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
OH	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

PROPERTIES, THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

3.2

NO. 6-C

TEMP. °K 2126.53

Wt. % H₂ 21.5228
32.419

CO 35.7072
CO₂ 1.07325
H₂O 1.19575
N₂ 33.1952
O₂ 1.96652

H₂ 0.236577
CO 0.05263
CO₂ 0.0332
H₂O 0.034311
N₂ 0.037133

O₂ 0.000000
H₂ 0.000000

H₂ 0.000000
CO 0.000000
CO₂ 0.000000
H₂O 0.000000
N₂ 0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 C-2

O.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.7692	22.5677	22.4514	22.3765	22.3331	22.2982	22.2809
P	28256	29772	31287	32761	34217	35659	37099
e	- 684.54	- 644.44	- 606.56	- 569.80	- 533.61	- 497.24	- 461.14
CV	342319	344393	346272	347953	349924	351556	353038
γ	1.27940	1.27062	1.26775	1.26562	1.26297	1.26062	1.25840
S	2.12005	2.11952	2.13715	2.15351	2.16851	2.18376	2.19795
E	475.21	514.01	551.04	586.58	622.62	658.11	693.49
E-F	1215.14	1214.18	1213.55	1212.59	1212.06	1211.25	1210.49
CO	.0216921	.0220429	.0222723	.0224328	.0225368	.0226491	.0227176
CO2	.0026073	.0024592	.0023480	.0022573	.0022025	.0021225	.0020714
H2	.0081866	.0083557	.0084306	.0084599	.0084752	.0084458	.0084167
H2O	.0067819	.0069765	.0069570	.0070282	.0070725	.0071451	.0071919
O2	.0043517	.0043735	.0043872	.0043966	.0044027	.0044096	.0044137
OH							
H	.0000007	.0000001	.0000002	.0000004	.0000008	.0000015	.0000020
N2		.0000014	.0000025	.0000042	.0000067	.0000104	.0000155
N						.0000021	.0000034
H2E	.0000550	.0000548	.0000503	.0000462	.0000425	.0000356	.0000365
CH4	.0002411	.0001470	.0000926	.0000580	.0000389	.0000260	.0000182

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MI 0-2

TEMP. °K 2428.80

MOL. WT. 22.3221
P 34634

CV 350429
Y 1.26226
S 2.17270
E 652.85
HF 1211.85

CO 0225677
CO2 0021821
H2 0084655
H2O 0070906
N2 0044346

O2 0000013
OH 0000076

NO 0000408
HTE 0000345

TEMP. °K

MOL. WT.
P

CV
Y
S
E
HF

CO
CO2
H2
H2O
N2
O2
OH
H
NO
HTE
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

Mi O-4

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.6201	22.4365	22.3310	22.2634	22.2242	22.1923	22.1767
P	28310	29871	31385	32859	34318	35763	37197
e	- 716.22	- 676.19	- 637.96	- 600.89	- 564.28	- 527.48	- 490.24
CV	.347551	.349209	.351186	.352917	.354973	.356667	.358184
γ	1.27197	1.26901	1.26601	1.26382	1.26198	1.25987	1.25641
S	2.11432	2.13383	2.15158	2.16809	2.18309	2.19871	2.21380
E	481.42	520.44	557.78	594.08	630.14	666.38	701.94
HF	1254.75	1253.87	1253.07	1252.32	1251.79	1250.96	1250.19
CO	.0211193	.0214539	.0216739	.0218350	.0219299	.0220425	.0221715
CO2	.0027601	.0026109	.0024576	.0024046	.0023482	.0022946	.0022412
H2	.0062902	.0084345	.0084917	.0095077	.0085129	.0084775	.0084434
H2O	.0074857	.0075900	.0076772	.0077540	.0078017	.0078302	.0078491
H2	.0042716	.0042917	.0043042	.0043129	.0043186	.0043252	.0043320
O	.0000001	.0000001	.0000002	.0000005	.0000009	.0000016	.0000024
N	.0000007	.0000014	.0000025	.0000042	.0000067	.0000104	.0000153
NH3	.0000601	.0000550	.0000503	.0000461	.0000423	.0000394	.0000366
CH4	.0002196	.0001327	.0000831	.0000518	.0000347	.0000231	.0000162

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

M1 C-4

2352.43

TEMP. °K

22.2394
33626

MOL. WT.
P

.353955
1.26245
2.17614
613.02
1257.02

CV
7
9
E
HE

.0218928
.0023705
.0085117
.0077826
.0043163

CO
CO2
H2
H2O
H2
O2

.0000007
.0000054

O
OH
H
HO

.0000440
.0000411

N
NH2
CH4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

O.2

M1 C-6

TEMP. °A	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
TEMP. °A	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
LOG. P	22.4837	22.3153	22.2192	22.1579	22.1222	22.0929	22.0787
LOG. P	28403	29960	31473	32948	34410	35857	37295
LOG. P	- 747.01	- 706.85	- 668.36	- 630.93	- 593.90	- 556.65	- 519.52
CV	351503	353842	355911	357688	359826	361577	363129
Y	1.27003	1.26750	1.26436	1.26214	1.25932	1.25685	1.25456
Z	2.12760	2.14759	2.16526	2.18193	2.19713	2.21292	2.22749
E	487.33	526.37	564.21	600.35	637.33	673.72	710.03
TF	1292.96	1292.14	1291.37	1290.63	1290.10	1289.25	1288.46
CO	2.5659	2.6887	2.8074	2.9259	3.0464	3.1693	3.2958
CO2	3.0790	3.2745	3.4634	3.6457	3.8218	3.9915	4.1546
H2	3.083734	3.084954	3.085368	3.085411	3.085394	3.084970	3.084585
H2O	3.081759	3.082696	3.083826	3.084643	3.085149	3.085577	3.086092
O2	3.041964	3.042150	3.042266	3.042346	3.042399	3.042461	3.042509
N2	3.000001	3.000001	3.000003	3.000005	3.000010	3.000018	3.000031
H	3.000007	3.000014	3.000025	3.000042	3.000067	3.000104	3.000150
OH	3.000003	3.000000	3.000000	3.000000	3.000000	3.000000	3.000000
HO	3.000003	3.000000	3.000000	3.000000	3.000000	3.000000	3.000000
H2O2	3.000003	3.000000	3.000000	3.000000	3.000000	3.000000	3.000000
CO	3.000003	3.000000	3.000000	3.000000	3.000000	3.000000	3.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

MI 0-6

TEMP. °K 2280.47

MOL. WT. 32.62

CV 357363

7 25251

3 217876

HF 191.77

1191.77

0.212274

0.255568

0.085431

0.054492

0.042333

0.000005

0.000003

0.000066

0.000009

TEMP. °K

MOL. WT.

CV

7

3

HF

CO₂

CO

H₂O

H₂

O₂

N₂

H₂

H₂O

CH₄

PELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

M1 3-3 0.2

TEMP. °A	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	22.1450	21.8615	21.6887	21.5734	21.5054	21.4526	21.4612
P	29314	31012	22642	34217	35761	37286	38768
Q	- 654.24	- 610.87	- 570.27	- 531.35	- 492.44	- 455.60	- 474.04
C _v	.352900	.354857	.356651	.358347	.360036	.362013	.362044
γ	1.27393	1.27174	1.26928	1.26740	1.26492	1.26268	1.26261
S	2.14870	2.16583	2.18669	2.20602	2.22150	2.23761	2.23389
E	482.54	524.54	564.07	602.08	638.37	676.37	657.94
MF	1.74.12	1.92.95	1.92.00	1.91.17	1.90.60	1.89.80	1.89.80

CO ₂	.0221172	.0224749	.0227762	.0229920	.0231210	.0232512	.0232400
CO	.0222544	.021977	.0215825	.0218976	.0218555	.0217591	.0217605
H ₂ O	.054711	.0597557	.079874	.079997	.0801639	.0801785	.0801648
O ₂	.0567443	.0566632	.0569270	.0569642	.0570194	.0570850	.0570832
N ₂	.0541927	.0541831	.0542022	.0542158	.0542242	.0542343	.0542325
H ₂	.0000001	.0000001	.0000002	.0000004	.0000008	.0000013	.0000013
NO	.0000013	.0000015	.0000027	.0000045	.0000073	.0000114	.0000111
OH	.0000742	.0000697	.0000645	.0000602	.0000558	.0000471	.0000466
GM4	.0003923	.0002507	.0001633	.0001049	.0000715	.0000485	.0000522

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

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PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12.6% NC

0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
MOL. WT.	24.8397	24.8108	24.7950	24.7846	24.7776	24.7696	24.7650
P	25154	26447	27724	29005	30280	31545	32812
e	- 930.81	- 895.90	- 861.10	- 826.54	- 791.82	- 756.66	- 721.44
CV	.334945	.337107	.339659	.341372	.343427	.345087	.346507
γ	1.25562	1.25460	1.25101	1.24851	1.24554	1.24297	1.24067
E	2.00244	2.01947	2.03565	2.05104	2.06537	2.08020	2.09402
HF	471.90	505.82	539.71	573.39	607.50	641.66	676.05
	1459.27	1458.30	1457.39	1456.52	1455.92	1454.93	1454.10
CO	.0168453	.0169931	.0171101	.0172098	.0172717	.0173691	.0174323
CO2	.0051301	.0050052	.0049001	.0048078	.0047504	.0046576	.0045969
H2	.0045700	.0044792	.0043923	.0043110	.0042596	.0041730	.0041130
H2O	.0091902	.0093133	.0094178	.0095098	.0095670	.0096598	.0097190
N2	.0044765	.0044637	.0044483	.0044353	.0044266	.0044186	.0044138
O2							
OH	.0000001	.0000002	.0000004	.0000009	.0000016	.0000029	.0000050
H	.0000006	.0000010	.0000018	.0000030	.0000048	.0000073	.0000109
NO					.0000001	.0000002	.0000004
...							
H3	.0000236	.0000235	.0000232	.0000230	.0000226	.0000221	.0000218
CH4	.0000217	.0000217	.0000216	.0000215	.0000214	.0000213	.0000212

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

12.6% NC

	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
TEMP. PK	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
VOL. WT.	24.7579	24.7493	24.7403	24.7297	24.7057	24.6813	24.6510
P	34280	35348	36616	37888	39161	40438	41719
e	- 686.28	- 650.29	- 614.13	- 577.45	- 540.34	- 502.49	- 463.87
CV	347747	349202	350481	351554	352586	353652	354564
γ	1.25887	1.23678	1.23490	1.23326	1.23186	1.23040	1.22912
z	2.15737	2.12038	2.13307	2.14550	2.15755	2.16966	2.18153
z	710.94	745.37	780.39	815.75	851.23	887.05	923.15
MF	1453.24	1452.25	1451.14	1449.84	1448.21	1446.21	1443.71
	0175422	0175422	0175854	0176354	0176794	0177223	0177670
	0054946	0044946	004522	0045130	0043791	0043451	0043141
	0162140	0162140	0039709	0039362	0039040	0038768	0038535
	0036103	0036103	0098529	0098458	0099100	0099284	0099394
	0044906	0044906	0044904	0044923	0044939	0044940	0044948
			0000001	0000001	0000003	0000005	0000009
			0000001	0000002	0000004	0000007	0000012
	0000131	0000220	0000200	0000299	0000414	0000615	0000852
	0000220	0000220	0000303	0000407	0000537	0000696	0000888
	0000207	0000213	0000221	0000304	0000453	0000680	0000118
	0000201	0000204	0000205	0000304	0000453	0000680	0000915
	0000111	0000104	0000116	0000092	0000092	0000084	0000080
	0000103	0000006	0000004	0000003	0000003	0000002	0000002

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

12.6% A.C

TEMP. °K	3400.00	3500.00	3059.66
NO. HT.	24.6131	24.5655	24.7122
e	43034	44297	38647
CV	- 424.38	- 383.91	.352175
γ	.355375	.256274	1.23240
W _g	1.22504	1.22710	2.15278
W _g	2.33331	2.20554	336.91
W _g	9.59.49	998.08	1448.91
W _g	1440.59	1435.79	

0.00	.0178569	.0176616	
0.00	.0042529	.0043916	
0.00	.0038183	.0039166	
0.00	.0099392	.0099013	
0.00	.0049611	.0044528	
0.00	.000025	.000002	
0.00	.000034	.000003	
0.00	.001540	.000075	
0.00	.001399	.000048	
0.00	.003238	.000044	
0.00	.000032	.000005	
0.00	.000074	.000009	
0.00	.000000	.000000	
0.00	.000000	.000000	

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12.8% NC 0.2

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
6	25.0950	25.0715	25.0581	25.0493	25.0432	25.0359	25.0315
6	24269	26145	27416	28673	29934	31185	32439
6	- 547.28	- 512.61	- 477.99	- 443.59	- 409.01	- 373.98	- 338.58
7	33920	336395	336543	340253	342309	343953	345305
7	25713	22530	1.24951	1.24700	1.24403	1.24147	1.23917
7	69003	2.00785	2.02395	2.03927	2.05355	2.06831	2.08209
7	473.47	504.14	537.84	571.38	605.36	639.39	673.67
7	1474.21	1473.23	1472.32	1471.46	1470.85	1469.88	1469.05
6	3333	0164532	0166057	0167023	0167624	0168577	0169199
6	33344	0052706	0053537	0054079	0055027	0049913	0048715
6	33355	0013334	0013733	0013977	00139462	00138500	00138006
6	33363	0093551	0094653	0095593	0096153	0097065	0097652
6	333544	0045575	0045595	0045616	0045629	0045647	0045649
6	33365	0000002	0000004	0000009	0000017	0000030	0000052
6	333655	0000010	0000017	0000029	0000049	0000079	0000104
6	333214	0000185	0000162	0000144	0000125	0000105	0000107
6	3330165	0000091	0000052	0000031	0000020	0000013	0000008

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

12. ex NC

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
NO. NT.	25.0159	25.0159	25.0066	24.9899	24.9713	24.9461	24.9146
P	34548	34548	36253	37461	38721	39985	41253
ρ	- 567.96	- 567.96	- 533.50	- 505.23	- 478.20	- 452.51	- 428.93
C _v	345195	348043	349314	350379	351403	352457	353360
γ	1.23529	1.23341	1.23178	1.23178	1.23038	1.22892	1.22765
ε	2.10837	2.10837	2.12102	2.13341	2.14554	2.15752	2.16939
W _g	742.77	742.77	777.68	812.93	848.31	884.03	920.04
W _g	1467.24	1467.24	1466.10	1464.79	1463.15	1461.11	1458.56

CO ₂	.0170230	.0170738	.0171204	.0171633	.0172074	.0172527	.0172974
CO	.0047708	.0047239	.0046897	.0046550	.0046219	.0045903	.0045593
H ₂	.0037027	.0036605	.0036260	.0035945	.0035679	.0035453	.0035279
H ₂ O	.0095607	.0095965	.0096287	.0096521	.0096797	.0097099	.0097474
O ₂	.0045665	.0045663	.0045681	.0045686	.0045697	.0045704	.0045704
N ₂	.0000001	.0000001	.0000002	.0000003	.0000006	.0000011	.0000017
OH	.0000001	.0000001	.0000002	.0000004	.0000009	.0000015	.0000023
H	.0000137	.0000210	.0000310	.0000454	.0000643	.0000892	.0001252
H ₂ O	.0000212	.0000290	.0000390	.0000515	.0000667	.0000852	.0001130
NO	.0000014	.0000023	.0000037	.0000058	.0000088	.0000130	.0000190
NO ₂	.0000002	.0000005	.0000004	.0000007	.0000010	.0000015	.0000021
CO ₂	.0000093	.0000103	.0000082	.0000082	.0000074	.0000071	.0000071
CO	.0000004	.0000003	.0000002	.0000002	.0000002	.0000002	.0000002

ACCELERANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION.

0.2

12.50°C

	3400°C	3500°C	3144.64
1	27.8731	24.8253	24.9508
2	43.226	43.317	39287
3	43.3339	43.333	331872
4	43.3339	43.3334	332973
5	43.3339	43.3363	333593
6	43.3339	43.3330	334426
7	43.3339	43.3333	334328
8	43.3339	43.3333	334328
9	43.3339	43.3333	334328
10	43.3339	43.3333	334328
11	43.3339	43.3333	334328
12	43.3339	43.3333	334328
13	43.3339	43.3333	334328
14	43.3339	43.3333	334328
15	43.3339	43.3333	334328
16	43.3339	43.3333	334328
17	43.3339	43.3333	334328
18	43.3339	43.3333	334328
19	43.3339	43.3333	334328
20	43.3339	43.3333	334328
21	43.3339	43.3333	334328
22	43.3339	43.3333	334328
23	43.3339	43.3333	334328
24	43.3339	43.3333	334328
25	43.3339	43.3333	334328
26	43.3339	43.3333	334328
27	43.3339	43.3333	334328
28	43.3339	43.3333	334328
29	43.3339	43.3333	334328
30	43.3339	43.3333	334328
31	43.3339	43.3333	334328
32	43.3339	43.3333	334328
33	43.3339	43.3333	334328
34	43.3339	43.3333	334328
35	43.3339	43.3333	334328
36	43.3339	43.3333	334328
37	43.3339	43.3333	334328
38	43.3339	43.3333	334328
39	43.3339	43.3333	334328
40	43.3339	43.3333	334328
41	43.3339	43.3333	334328
42	43.3339	43.3333	334328
43	43.3339	43.3333	334328
44	43.3339	43.3333	334328
45	43.3339	43.3333	334328
46	43.3339	43.3333	334328
47	43.3339	43.3333	334328
48	43.3339	43.3333	334328
49	43.3339	43.3333	334328
50	43.3339	43.3333	334328
51	43.3339	43.3333	334328
52	43.3339	43.3333	334328
53	43.3339	43.3333	334328
54	43.3339	43.3333	334328
55	43.3339	43.3333	334328
56	43.3339	43.3333	334328
57	43.3339	43.3333	334328
58	43.3339	43.3333	334328
59	43.3339	43.3333	334328
60	43.3339	43.3333	334328
61	43.3339	43.3333	334328
62	43.3339	43.3333	334328
63	43.3339	43.3333	334328
64	43.3339	43.3333	334328
65	43.3339	43.3333	334328
66	43.3339	43.3333	334328
67	43.3339	43.3333	334328
68	43.3339	43.3333	334328
69	43.3339	43.3333	334328
70	43.3339	43.3333	334328
71	43.3339	43.3333	334328
72	43.3339	43.3333	334328
73	43.3339	43.3333	334328
74	43.3339	43.3333	334328
75	43.3339	43.3333	334328
76	43.3339	43.3333	334328
77	43.3339	43.3333	334328
78	43.3339	43.3333	334328
79	43.3339	43.3333	334328
80	43.3339	43.3333	334328
81	43.3339	43.3333	334328
82	43.3339	43.3333	334328
83	43.3339	43.3333	334328
84	43.3339	43.3333	334328
85	43.3339	43.3333	334328
86	43.3339	43.3333	334328
87	43.3339	43.3333	334328
88	43.3339	43.3333	334328
89	43.3339	43.3333	334328
90	43.3339	43.3333	334328
91	43.3339	43.3333	334328
92	43.3339	43.3333	334328
93	43.3339	43.3333	334328
94	43.3339	43.3333	334328
95	43.3339	43.3333	334328
96	43.3339	43.3333	334328
97	43.3339	43.3333	334328
98	43.3339	43.3333	334328
99	43.3339	43.3333	334328
100	43.3339	43.3333	334328

PROPELLANT THERMODYNAMIC PROPERTIES AND COMPOSITION GAS COMPOSITION

0.2

13.0% NC

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
CP	25.2618	25.3424	25.3315	25.2241	24.9589	30.824	32.064
P	24520	25941	27096	28339	29589	30824	32064
Q	- 364.47	- 930.02	- 895.52	- 861.31	- 826.36	- 791.97	- 756.98
CV	332755	335222	337469	339173	341220	342859	344265
Y	1.25152	1.25152	1.24792	1.24542	1.24245	1.23989	1.23759
Z	1.97524	1.95955	2.01197	2.02722	2.04147	2.05616	2.06989
W	489.03	502.49	536.03	569.43	603.28	637.20	671.37
HF	1485.87	1488.89	1487.99	1487.13	1486.54	1485.57	1484.75
CP	0.163868	0.163868	0.163868	0.163868	0.163868	0.163868	0.163868
CP	0.051663	0.051663	0.051663	0.051663	0.051663	0.051663	0.051663
CP	0.034980	0.034980	0.034980	0.034980	0.034980	0.034980	0.034980
CP	0.098002	0.098002	0.098002	0.098002	0.098002	0.098002	0.098002
CP	0.046357	0.046357	0.046357	0.046357	0.046357	0.046357	0.046357
CP	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005
CP	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100
CP	0.000009	0.000009	0.000009	0.000009	0.000009	0.000009	0.000009
CP	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

13.02 NC

TEMP. °K 3400.00 3500.00 3230.36

MOLE WT.
 O 25.1460 25.0958 25.2110
 N 42046 43315 39911
 - 46110 42051
 CO 332988 351596
 H 22505 1.22697
 S 2.16677 2.14875
 F 953.25 892.02
 Cl 1475.86 1476.02

CO 0.57656 0.166223 0.166846
 CO2 0.34250 0.048228 0.049100
 H2 0.032306 0.032176 0.032632
 H2O 0.100103 0.100042 0.100029
 O2 0.046412 0.046415 0.046404
 N2 0.000022 0.000036 0.000039
 H 0.000025 0.000040 0.000010
 Cl 0.000268 0.001690 0.000746
 S 0.00026 0.001274 0.000589
 O 0.000206 0.000250 0.000109
 H2O 0.000022 0.000032 0.000012
 Cl 0.000061 0.000058 0.000064
 S 0.000001 0.000001 0.000001

PROPERTY THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

12.12 NC

TEMP. °K	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
h _f	25.4502	25.4767	25.4688	25.4620	25.4559	25.4505	25.4462
h _g	24435	25691	26940	28176	29416	30647	31881
s _f	572.95	585.25	594.20	600.00	603.02	604.79	605.85
s _g	3323.0	3347.98	33694	338645	34088	342124	342727
h _o	35.77	325073	1.24714	1.24483	1.24168	1.23910	1.23680
s _o	97.325	99500	0.00559	2.02122	3.02544	2.05011	2.03334
h _o	488.31	504.58	513.14	516.48	502.28	480.14	450.23
s _o	97.324	196.55	452.07	1494.82	1494.23	1493.26	1492.48
h _o	1155.5	1157.24	1158.60	1159.09	1159.671	1160.357	1161.103
h _o	1155.5	1157.040	1158.048	1158.474	1158.830	1159.275	1159.705
h _o	1155.5	1157.175	1158.258	1158.478	1158.4966	1158.120	1157.943
h _o	1155.5	1157.203	1158.253	1158.6130	1158.6673	1158.550	1158.120
h _o	1155.5	1157.655	1158.6674	1159.658	1160.6598	1161.6713	1162.6713
h _o	1155.5	1160.002	1160.005	1160.0010	1160.0018	1160.0033	1160.0050
h _o	1155.5	1160.009	1160.016	1160.027	1160.043	1160.066	1160.093
h _o	1155.5	1160.015	1160.023	1160.031	1160.041	1160.053	1160.068
h _o	1155.5	1160.015	1160.0137	1160.0121	1160.0109	1160.0088	1160.0059
h _o	1155.5	1160.0114	1160.0035	1160.0020	1160.0013	1160.0008	1160.0005

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.2

TEMP. °K	1700.00	1800.00	1900.00	2000.00	3000.00	3100.00	3200.00	3300.00
TEMP. °K	1700.00	1800.00	1900.00	2000.00	3000.00	3100.00	3200.00	3300.00
M.W.	25.4352	25.4306	25.4207	25.4038	25.3841	25.3575	25.3245	25.3245
P	32115	34350	35585	36824	38064	39309	40558	40558
C _v	735.75	675.26	659.25	622.91	585.99	546.28	509.73	509.73
γ	1.44751	1.346385	1.247642	1.148697	1.049708	0.950747	0.851635	0.851635
S	2.22522	1.22294	1.22107	1.22544	1.22805	1.22661	1.22534	1.22534
E _g	2.17705	2.08927	2.10257	2.11492	2.12702	2.13897	2.15082	2.15082
H _f	774.67	733.05	773.81	608.92	544.15	673.74	915.63	915.63
H _g	1491.81	1490.66	1489.52	1488.23	1486.52	1484.45	1481.79	1481.79
CH ₂	0.161725	0.162259	0.162685	0.163111	0.163538	0.164011	0.164473	0.164473
CH	0.150641	0.152185	0.151779	0.151395	0.151051	0.150720	0.150401	0.150401
H ₂	0.033037	0.032592	0.032186	0.031851	0.031559	0.031295	0.031061	0.031061
H	0.058015	0.057904	0.059383	0.059689	0.059909	0.060079	0.060257	0.060357
O ₂	0.1543723	0.1540719	0.1546724	0.1546744	0.1546749	0.1546754	0.1546763	0.1546763
O	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
N	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CO	0.000000	0.000146	0.000220	0.000335	0.000487	0.000663	0.000858	0.000958
CO ₂	0.000000	0.000159	0.000272	0.000366	0.000482	0.000625	0.000797	0.000915
H ₂ O	0.000000	0.000116	0.000227	0.000343	0.000467	0.000602	0.000757	0.000835
H ₂ O ₂	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH ₄	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

TEMP. °C	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00	2600.00
NO. AT.	25.5098	25.5532	25.5458	25.5372	25.5323	25.5260	25.5217
P	74362	25611	26855	28089	29324	30552	31782
Q	777.48	749.49	706.67	674.71	640.30	605.56	570.56
W	321.949	311.517	306.661	302.302	300.003	342037	343435
Y	1.25433	1.23020	1.24671	1.24419	1.24123	1.23567	1.23037
Z	1.97008	1.96678	2.00275	2.01796	2.02217	2.04682	2.06051
ME	407.94	521.24	334.0	507.97	501.74	635.57	669.00
MF	1511.77	1500.73	1499.83	1490.59	1482.40	1497.44	1496.64
CO	.0154420	.0155695	.0150742	.0157650	.0158219	.0159129	.0159724
CO2	.0058925	.0057839	.0056655	.0055938	.0055447	.0054568	.0053993
H2O	.0037375	.0036401	.0035512	.0034793	.0034195	.0033354	.0032781
H2	.0093162	.0094350	.0095321	.0096190	.0096729	.0097600	.0098166
O2	.0040822	.0046650	.0046898	.0046852	.0046892	.0046907	.0046909
H	.0000001	.0000002	.0000005	.0000010	.0000018	.0000033	.0000057
NO	.0000005	.0000009	.0000016	.0000027	.0000043	.0000065	.0000097
OH	.0000000	.0000000	.0000000	.0000001	.0000001	.0000003	.0000005
HO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C2H6	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.15% NC

0.2

TEMP. °K	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	2500.00
MOL. WT.	25.5149	25.5062	25.4962	25.4791	25.4693	25.4625	25.4525
0	32013	34244	35475	36711	37948	39185	40422
4	- 735.02	- 700.42	- 664.24	- 627.22	- 590.22	- 553.22	- 514.67
CV	344062	346009	347347	348402	349410	350448	351333
7	1.23458	1.23251	1.23004	1.22902	1.22763	1.22645	1.22491
9	2.07374	2.07205	2.06924	2.06615	2.06266	2.05878	2.05447
E	702.25	733.60	773.14	809.21	843.42	877.00	914.86
MF	1495.80	1494.95	1493.71	1492.28	1490.70	1488.59	1485.93
CO	0.02271	0.02769	0.031212	0.034266	0.036992	0.039359	0.041359
CO2	0.03476	0.03319	0.031615	0.0292233	0.026890	0.024590	0.022333
H2O	0.02278	0.03335	0.031453	0.031101	0.030802	0.030549	0.030333
H2	0.07865	0.07377	0.069720	0.0669720	0.0646942	0.062333	0.060000
O2	0.04070	0.03001	0.026000	0.023002	0.020004	0.017000	0.014000
N2	0.01149	0.01149	0.01149	0.01149	0.01149	0.01149	0.01149
H	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
OH	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
NO2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
HNO3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CH4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

2/4

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

13.15% NC

0.2

TEMP. °K	3400.00	3500.00	3292.47
MOL. WT.	25.3555	25.3012	25.4013
ρ	4168	42945	40341
e	-	-	-
C_V	352112	352973	351272
γ	1.22387	1.22298	1.22501
S	2.15590	2.17104	2.14658
E	951.01	987.44	912.15
H_f	1482.55	1478.40	1486.15
CO2	.0163508	.0164080	.0152964
CO	.0050813	.0050571	.0051263
H2	.0030167	.0030045	.0030353
H2O	.0100185	.0100119	.0100175
CH4	.0046958	.0046960	.0046955
OH	.0000025	.0000041	.0000014
O2	.0000025	.0000043	.0000015
NO	.0000014	.0000015	.0000015
NO2	.0000001	.0000001	.0000001
NC	.0000001	.0000001	.0000001
HCN	.0000001	.0000001	.0000001
HTS	.0000001	.0000001	.0000001
CH4	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.2

13.2% NC

TEMP. °F.	2700.00	2800.00	2900.00	3000.00	3100.00	3200.00	3300.00
ρ	25.5825	25.5748	25.5647	25.5475	25.5275	25.5064	25.4661
e	32920	34149	35377	36609	37842	39081	40327
Cv	- 740.14	- 704.07	- 668.90	- 632.41	- 595.51	- 557.82	- 519.27
γ	1.23417	1.23347	1.23253	1.23132	1.22979	1.22793	1.22483
Σ	2.07175	2.08568	2.09624	2.10857	2.12066	2.13261	2.14446
ΣE	793.32	757.84	722.58	687.61	642.80	598.36	554.01
ΣE	1455.76	1498.61	1497.67	1496.34	1494.65	1492.54	1489.93
CO ₂	.0158927	.0159418	.0159863	.0160315	.0160741	.0161155	.0161651
CO	.0014245	.0013791	.0013385	.0013009	.0012627	.0012296	.0012011
H ₂ O	.0031600	.0031160	.0030762	.0030431	.0030135	.0029895	.0029705
H ₂	.0098708	.0098123	.0097461	.0096755	.0096073	.0095328	.0094533
O ₂	.0017073	.0017030	.0017079	.0017093	.0017098	.0017106	.0017111
N ₂	.0000001	.0000001	.0000001	.0000002	.0000005	.0000009	.0000013
ΣE	.0000394	.0000001	.0000001	.0000003	.0000009	.0000035	.0000093
H ₂	.0000135	.0000155	.0000230	.0000343	.0000498	.0000706	.0000979
H ₂ O	.0000010	.0000017	.0000026	.0000037	.0000047	.0000051	.0000079
CO ₂	.0000001	.0000002	.0000002	.0000004	.0000007	.0000010	.0000013
CO	.0000077	.0000072	.0000065	.0000064	.0000063	.0000057	.0000053
CH ₄	.0000003	.0000002	.0000002	.0000001	.0000001	.0000001	.0000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0-2

15.25 NC

TEMP. °K	3400.00	3500.00	3317.01
MOL. WT.	25.4226	25.3675	25.4554
D	41571	42828	40535
e	- 475.74	- 439.07	
CV	333553	352710	351216
γ	1.22348	1.22257	1.22434
ε	2.15526	2.15504	2.14647
SE	550.35	526.76	520.34
TE	1496.40	1482.27	1489.24

CO	0.62162	0.152739	0.161734
CO2	0.951687	0.951341	0.951960
H2	0.025537	0.029386	0.029644
H2O	0.00216	0.00143	0.00215
O2	0.047114	0.047116	0.047112
N2	0.000026	0.000043	0.000017
H	0.000027	0.000044	0.000018
O	0.000029	0.000070	0.000032
OH	0.000960	0.001215	0.000811
NO	0.000227	0.000323	0.000169
HNO	0.000023	0.000052	0.000016
H2O2	0.000054	0.000051	0.000054
CH4	0.000001	0.000001	0.000001

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

CH NS 100% HC

0.1

TEMP. °C	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
ΔU ₀ AT.	25.4484	25.4290	25.2810	25.3308	25.2668	25.1860	25.0859
D	16567	16614	17165	17720	18279	18846	19421
e	625.24	587.62	548.96	509.37	467.73	424.66	375.47
CV	145957	147020	148046	148947	149764	150564	151341
γ	1.2280	1.2276	1.2266	1.2257	1.2250	1.2245	1.2240
S	2.1773	2.1896	2.2019	2.2142	2.2265	2.2390	2.2517
E	811.75	846.98	882.60	918.30	955.01	991.86	1029.27
F	1493.35	1490.98	1487.97	1484.12	1479.22	1473.05	1465.35

CO	0159512	0159810	0160341	0160920	0161576	0162339	0163237
CO2	0054713	0054339	0053972	0053606	0053221	0052802	0052335
H2	0033651	0033315	0033050	0032837	0032677	0032562	0032557
H2O	0097154	0097348	0097463	0097485	0097410	0097225	0096917
N2	0046973	0046960	0046950	0046998	0047005	0047010	0047015
O2	0000000	0000000	0000019	0000033	0000057	0000092	0000147
OH	0000000	0000011	0000019	0000034	0000057	0000093	0000145
H	0000485	0000703	0000995	0001376	0001864	0002476	0003231
H2O	0000560	0000738	0000957	0001221	0001598	0002012	0002552
NO	0000664	0000899	0001350	0001822	0002317	0002844	0003409
NH3	0000000	0000009	0000015	0000022	0000032	0000046	0000069
CH4	0000000	0000025	0000025	0000024	0000024	0000022	0000021

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

C.1

0% NG 100% NC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3247.24
MOL. WT.	24.9630	24.8152	24.6395	24.4338	25.3587
P	20006	20604	21215	21843	17426
e	- 332.03	- 281.58	- 228.55	- 172.08	
CV	.352027	.352619	.352266	.352656	.348488
γ	1.22375	1.22362	1.22460	1.22503	1.22618
S	2.26478	2.27818	2.29195	2.30625	2.20772
E	1067.07	1105.78	1144.62	1184.18	899.56
HF	1455.77	1444.15	1430.08	1413.29	1486.26
CO	.0164329	.0165560	.0167078	.0168841	.0160608
CO2	.0051771	.0051163	.0050437	.0049587	.0053799
H2O	.0032594	.0032760	.0033017	.0033388	.0032942
H2	.0096493	.0095883	.0095123	.0094189	.0097486
O2	.0047015	.0047010	.0047003	.0046992	.0046994
NO	.0000226	.0000326	.0000465	.0000680	.0000025
OH	.0000226	.0000342	.0000499	.0000712	.0000025
CH	.0004146	.0005230	.0006500	.0007958	.0001163
H	.0002663	.0003457	.0004141	.0004927	.0001076
HCN	.0000518	.0001076	.0001389	.0001761	.0000181
CH2	.0000089	.0000121	.0000161	.0000212	.0000018
CH4	.0000021	.0000020	.0000020	.0000021	.0000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

OR NG 2001 NC 0.25

TEMP. °F.	5000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
CP	25.4670	25.4436	25.4123	25.3723	25.3214	25.2575	25.1773
e	25739	26611	27456	28367	29253	30146	31041
Cv	325.95	335.30	345.27	350.123	35927	36809	37651
γ	1.2278	1.2275	1.22628	1.22520	1.22430	1.22355	1.22291
Σ	2.13927	2.15204	2.16410	2.17609	2.18809	2.20011	2.21211
HF	609.61	545.00	660.55	916.43	952.64	989.19	1025.61
	1403.11	1491.27	1488.72	1485.62	1481.69	1476.76	1471.81
CO	0.160425	0.160863	0.161358	0.161866	0.162431	0.163075	0.163793
CO2	0.039225	0.039305	0.039263	0.0392454	0.0392134	0.0391765	0.0391349
H2O	0.022421	0.022412	0.022400	0.0223855	0.022365	0.0223399	0.0223091
H2	0.058358	0.058013	0.058754	0.058817	0.058797	0.058668	0.058531
O2	0.43554	0.43550	0.43699	0.436975	0.436975	0.436982	0.436988
N2	0.000000	0.000000	0.000012	0.000021	0.000036	0.000053	0.000071
NO	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
OH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

OX NS IOCS NC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3255.40
MOL. WT.	25.0604	24.9650	24.8230	24.6534	25.3912
P	31966	32897	33842	34807	27974
e	- 342.81	- 295.31	- 245.97	- 195.69	
CV	353373	354047	353326	352796	349741
γ	1.22217	1.22171	1.22275	1.22284	1.22566
β	2.22466	2.23727	2.25009	2.26533	2.17075
β ₁	1.905.84	1.91.65	1.93.98	1.97.88	950.39
β ₂	1.463.05	1.455.65	1.442.73	1.429.45	1.487.09
CO	0165713	0165722	0166922	0168332	0161636
CO ₂	0050378	0050378	0049787	0049098	0052634
H ₂	0031383	0031363	0031565	0031827	0031725
H ₂ O	0099153	0097694	0097097	0096356	0098789
NO	0046978	0046970	0046956	0046938	0046972
O ₂	0001144	0002216	0003114	0004445	0000016
N ₂	0001145	0002222	0003326	0004467	0000017
H ₂ O	0034000	0043000	0053000	0065557	0000972
NO	0022233	002693	003221	003825	0000955
O ₂	0000672	0009884	001145	001459	0000151
N ₂	0000072	0000098	0000131	0000173	0000015
CO ₂	0000034	0000033	0000033	0000033	0000040

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

5% NG 95% MC C.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOL. WT.	25.7211	25.6901	25.6488	25.5953	25.5269	25.4401	25.3321
P	15889	15431	16976	17526	18091	18643	19215
c	- 650.15	- 612.40	- 573.55	- 535.40	- 491.70	- 448.14	- 402.32
CV	345376	347135	348156	349049	349855	350640	351398
Z	1.22640	1.22535	1.22434	1.22349	1.22282	1.22233	1.22189
S	2.16886	2.17925	2.19158	2.20392	2.21637	2.22899	2.24183
E	811.64	846.93	882.62	918.73	955.26	992.27	1029.87
HF	1513.44	1516.00	1512.88	1508.67	1503.73	1497.25	1489.13
CO	.0151558	.0152059	.0152640	.0153239	.0153927	.0154738	.0155703
CO2	.0058352	.0057977	.0057605	.0057226	.0056819	.0056368	.0055852
H2	.0030652	.0030351	.0030100	.0029952	.0029762	.0029688	.0029688
H2O	.0095086	.0095265	.0095364	.0095369	.0095274	.0095067	.0094735
N2	.0047929	.0047956	.0047945	.0047952	.0047957	.0047961	.0047961
O2	.0000007	.0000013	.0000024	.0000042	.0000071	.0000116	.0000184
OH	.0000006	.0000012	.0000022	.0000038	.0000064	.0000104	.0000165
CH	.0000516	.0000752	.0001063	.0001470	.0001991	.0002644	.0003448
H	.0000535	.0000705	.0000913	.0001165	.0001467	.0001825	.0002246
NO	.0000072	.0000112	.0000170	.0000250	.0000358	.0000502	.0000688
N	.0000006	.0000010	.0000015	.0000022	.0000032	.0000046	.0000065
NH3	.0000024	.0000024	.0000022	.0000021	.0000021	.0000020	.0000019
CH4							

REFRELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

50 MG 95% HC 0.1

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3336.07
MOLE WT.	25.1994	25.0395	24.8493	24.6269	25.5724
ρ	.9797	20393	21003	21631	17725
ρ ₀	354.04	- 302.61	- 248.39	- 190.50	
γ	1.35059	1.35262	1.352224	1.352571	1.349251
γ ₀	1.22169	1.22159	1.22252	1.22313	1.22323
γ _∞	1.22113	1.22082	1.22825	1.229756	2.20840
γ _∞	1.06711	1.06689	1.14603	1.18501	931.65
γ _∞	1.47F.50	1.466.50	1.451.64	1.432.79	1507.15
0.02	0.000000	0.000000	0.000000	0.000000	0.000000
0.04	0.000000	0.000000	0.000000	0.000000	0.000000
0.06	0.000000	0.000000	0.000000	0.000000	0.000000
0.08	0.000000	0.000000	0.000000	0.000000	0.000000
0.10	0.000000	0.000000	0.000000	0.000000	0.000000
0.12	0.000000	0.000000	0.000000	0.000000	0.000000
0.14	0.000000	0.000000	0.000000	0.000000	0.000000
0.16	0.000000	0.000000	0.000000	0.000000	0.000000
0.18	0.000000	0.000000	0.000000	0.000000	0.000000
0.20	0.000000	0.000000	0.000000	0.000000	0.000000
0.22	0.000000	0.000000	0.000000	0.000000	0.000000
0.24	0.000000	0.000000	0.000000	0.000000	0.000000
0.26	0.000000	0.000000	0.000000	0.000000	0.000000
0.28	0.000000	0.000000	0.000000	0.000000	0.000000
0.30	0.000000	0.000000	0.000000	0.000000	0.000000
0.32	0.000000	0.000000	0.000000	0.000000	0.000000
0.34	0.000000	0.000000	0.000000	0.000000	0.000000
0.36	0.000000	0.000000	0.000000	0.000000	0.000000
0.38	0.000000	0.000000	0.000000	0.000000	0.000000
0.40	0.000000	0.000000	0.000000	0.000000	0.000000
0.42	0.000000	0.000000	0.000000	0.000000	0.000000
0.44	0.000000	0.000000	0.000000	0.000000	0.000000
0.46	0.000000	0.000000	0.000000	0.000000	0.000000
0.48	0.000000	0.000000	0.000000	0.000000	0.000000
0.50	0.000000	0.000000	0.000000	0.000000	0.000000
0.52	0.000000	0.000000	0.000000	0.000000	0.000000
0.54	0.000000	0.000000	0.000000	0.000000	0.000000
0.56	0.000000	0.000000	0.000000	0.000000	0.000000
0.58	0.000000	0.000000	0.000000	0.000000	0.000000
0.60	0.000000	0.000000	0.000000	0.000000	0.000000
0.62	0.000000	0.000000	0.000000	0.000000	0.000000
0.64	0.000000	0.000000	0.000000	0.000000	0.000000
0.66	0.000000	0.000000	0.000000	0.000000	0.000000
0.68	0.000000	0.000000	0.000000	0.000000	0.000000
0.70	0.000000	0.000000	0.000000	0.000000	0.000000
0.72	0.000000	0.000000	0.000000	0.000000	0.000000
0.74	0.000000	0.000000	0.000000	0.000000	0.000000
0.76	0.000000	0.000000	0.000000	0.000000	0.000000
0.78	0.000000	0.000000	0.000000	0.000000	0.000000
0.80	0.000000	0.000000	0.000000	0.000000	0.000000
0.82	0.000000	0.000000	0.000000	0.000000	0.000000
0.84	0.000000	0.000000	0.000000	0.000000	0.000000
0.86	0.000000	0.000000	0.000000	0.000000	0.000000
0.88	0.000000	0.000000	0.000000	0.000000	0.000000
0.90	0.000000	0.000000	0.000000	0.000000	0.000000
0.92	0.000000	0.000000	0.000000	0.000000	0.000000
0.94	0.000000	0.000000	0.000000	0.000000	0.000000
0.96	0.000000	0.000000	0.000000	0.000000	0.000000
0.98	0.000000	0.000000	0.000000	0.000000	0.000000
1.00	0.000000	0.000000	0.000000	0.000000	0.000000

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

5% NO 95% C 0.15

TEMP, °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
h ₀ , kJ	25.7390	25.7143	25.6812	25.6366	25.5843	25.5156	25.4300
e	25449	26312	27160	28052	28930	29817	30715
CV	- 651.96	- 614.73	- 576.36	- 537.34	- 496.88	- 454.97	- 411.22
T	347272	348307	349338	350229	351022	351847	352680
S	1.22557	1.22533	1.22408	1.22301	1.22212	1.22140	1.22066
Z	2.12575	2.14199	2.15410	2.16616	2.17323	2.19037	2.20269
E	0.09.65	0.44.83	0.80.51	0.916.47	0.952.79	0.989.47	1.026.69
HF	1516.28	1516.28	1513.75	1510.51	1506.41	1501.23	1494.76
CO	0.022029	0.015216	0.0103600	0.007026	0.004709	0.003045	0.002017
CO2	0.057217	0.056561	0.055513	0.054122	0.052800	0.0515388	0.050365
H2	0.029492	0.029195	0.028948	0.028746	0.028591	0.028493	0.028455
H2O	0.02285	0.020622	0.010612	0.009660	0.008623	0.007493	0.006298
N2	0.047912	0.047316	0.04723	0.047930	0.047932	0.047934	0.047931
O2	0.00104	0.00098	0.000915	0.000926	0.0009045	0.000874	0.000817
OH	0.00004	0.000038	0.000014	0.000024	0.000041	0.000067	0.000107
H	0.000421	0.000311	0.000265	0.000198	0.0001624	0.000161	0.0002824
NO	0.000418	0.000551	0.000713	0.000910	0.001145	0.001424	0.001750
N	0.000099	0.000091	0.000138	0.000203	0.000292	0.000409	0.000563
HF	0.000005	0.000008	0.000012	0.000018	0.000026	0.000038	0.000053
CH4	0.000041	0.000039	0.000036	0.000034	0.000033	0.000032	0.000030

PHYSICAL PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

958 10

3500.00	4000.00	3546.77
25.746	27.8678	25.6148
3349	34490	28462
- 233.95	- 233.95	
333.12	333746	350612
22.71	3309	322237
24.33	2.25406	337.80
44.33	1.51.25	933.41
146.12	145.99	1505.71
3500.00	4000.00	3546.77
25.746	27.8678	25.6148
3349	34490	28462
- 233.95	- 233.95	
333.12	333746	350612
22.71	3309	322237
24.33	2.25406	337.80
44.33	1.51.25	933.41
146.12	145.99	1505.71
3500.00	4000.00	3546.77
25.746	27.8678	25.6148
3349	34490	28462
- 233.95	- 233.95	
333.12	333746	350612
22.71	3309	322237
24.33	2.25406	337.80
44.33	1.51.25	933.41
146.12	145.99	1505.71
3500.00	4000.00	3546.77
25.746	27.8678	25.6148
3349	34490	28462
- 233.95	- 233.95	
333.12	333746	350612
22.71	3309	322237
24.33	2.25406	337.80
44.33	1.51.25	933.41
146.12	145.99	1505.71
3500.00	4000.00	3546.77
25.746	27.8678	25.6148
3349	34490	28462
- 233.95	- 233.95	
333.12	333746	350612
22.71	3309	322237
24.33	2.25406	337.80
44.33	1.51.25	933.41
146.12	145.99	1505.71

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

102 HG 90% NC 0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOL. WT.	25.9964	25.9659	25.9215	25.8642	25.7906	25.6970	25.5801
D	15711	16248	16788	17333	17884	18443	19011
CV	- 675.08	- 637.17	- 598.12	- 557.67	- 515.54	- 471.42	- 424.87
Z	346225	347281	348297	349183	349976	350745	351481
S	1.22409	1.22305	1.22205	1.22122	1.22058	1.22011	1.21972
E	2.15623	2.16864	2.18104	2.19348	2.20605	2.21883	2.23194
MF	511.53	646.99	822.77	918.95	955.67	992.86	1030.09
	1543.66	1541.14	1537.89	1533.69	1528.30	1521.43	1512.76

CO	.0143735	.0144249	.0144792	.0145414	.0146140	.0147006	.0148049
CO2	.0142140	.0061760	.0061388	.0060994	.0060563	.0060073	.0059503
H2O	.0027825	.0027540	.0027306	.0027127	.0027007	.0026955	.0026982
H2	.0028607	.0031025	.0031109	.0031095	.0030979	.0030879	.0030851
O2	.0048885	.0048693	.0048489	.0048265	.0047998	.0047650	.0047235
N2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HCN	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
NO	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
OH	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
HF	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Cl	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
Br	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
I	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
CH4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C2H6	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C2H4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C2H2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C2H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C3H8	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C3H6	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C3H4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C3H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H10	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H8	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H6	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C4H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H12	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H10	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H8	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H6	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H4	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H2	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
C5H	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000

STELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

26.16 90% HC 0.1

TEMP. °C.	3700.00	3800.00	3900.00	4000.00	3419.95
CP	25.1159	25.2622	25.0556	24.8145	25.7736
CP	18.951	20.186	20.795	21.422	21.7995
CP	375.66	- 313.10	- 267.52	- 208.09	
CP	312.14	352.64	352.199	352.498	350.131
CP	2.2193	2.2155	1.22064	1.22124	1.22247
CP	2.24179	2.22543	2.27386	2.28991	2.28358
CP	1.69	1.73.28	1.47.76	1.18.02	962.05
CP	141.84	148.91	1472.85	1453.62	1527.05
CP	1.52	1.50.827	1.52630	1.54753	1.56921
CP	1.48.12	1.53324	1.557082	1.555976	1.560470
CP	1.47.70	1.527313	1.527650	1.529113	1.526991
CP	1.48.03	1.522271	1.519414	1.5097409	1.510943
CP	1.48.34	1.524289	1.504865	1.5043872	1.5048509
CP	1.48.65	1.521522	1.500745	1.5011933	1.5000099
CP	1.48.96	1.520425	1.500019	1.5000879	1.5000079
CP	1.49.27	1.525933	1.507350	1.508985	1.5082254
CP	1.49.58	1.531441	1.509757	1.504528	1.5091462
CP	1.50.29	1.536949	1.509175	1.502211	1.5080435
CP	1.50.60	1.542457	1.508164	1.500217	1.5070035
CP	1.50.91	1.547965	1.507026	1.500016	1.5060015

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

FOR THE 90% TIC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3433.79
Wt. %	25.5786	25.4326	25.2676	25.0733	25.8284
P	31268	32210	33149	34011	28928
B	397.97	- 338.78	- 287.38	- 232.66	
CO	1.53499	1.54121	1.55322	1.55715	1.551422
Y	1.21797	1.21760	1.21870	1.21809	1.21767
Z	2.22271	2.21878	2.23213	2.24598	2.17234
W	1.65113	1.63151	1.62247	1.61156	1.61148
HF	15.0032	1499.91	1487.28	1472.19	1529.48
CO ₂	0.49494	0.152098	0.056733	0.0193802	0.0147068
CO	0.08133	0.057620	0.026720	0.0095834	0.0059483
H ₂ O	0.25521	0.25973	0.26209	0.26544	0.25849
H ₂	0.01521	0.01513	0.015053	0.0149554	0.0148243
O ₂	0.48269	0.48854	0.49237	0.494209	0.486885
N ₂	0.02229	0.022340	0.022491	0.022688	0.022606
NO	0.00185	0.002278	0.001407	0.000581	0.000055
H	0.001873	0.004692	0.005066	0.007463	0.0091916
O	0.00129	0.002451	0.002937	0.003497	0.0031174
H ₂ O	0.001856	0.001129	0.001457	0.001848	0.002372
CO ₂	0.000074	0.000100	0.000134	0.000176	0.000230
CO	0.000026	0.000025	0.000025	0.000025	0.000029

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

15% H₂ 85% HC

0.1

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
MOL. WT.	25.2814	26.2463	26.1992	26.1376	26.0579	25.9563	25.8289
P	15535	16056	16602	17142	17689	18244	18810
Q	- 700.04	- 661.87	- 622.65	- 581.84	- 539.23	- 494.46	- 447.07
CV	146405	347458	348469	349347	350125	350876	351588
γ	1.22175	1.22073	1.21974	1.21893	1.21832	1.21789	1.21754
S	2.14536	2.15784	2.17051	2.18286	2.19558	2.20855	2.22189
E	811.72	847.15	863.05	879.40	896.26	913.66	931.75
H _F	1568.99	1566.39	1562.99	1558.57	1552.87	1545.57	1536.25
CO	.1135725	.0136254	.0136800	.0137449	.0138219	.0139150	.0140283
CO ₂	.0066076	.0065702	.0065317	.0064906	.0064446	.0063912	.0063275
H ₂	.0125147	.0124881	.0124666	.0124507	.0124408	.0124361	.0124338
H ₂ O	.0102455	.0102638	.0102699	.0102663	.0102526	.0102272	.0101868
O ₂	.049841	.049846	.049835	.049856	.049858	.049858	.049854
N ₂	.000011	.000021	.000028	.000067	.000113	.000185	.000291
H ₂ O	.000008	.000015	.000027	.000048	.000080	.000131	.000206
H	.000052	.000059	.0001214	.0001679	.0002272	.0003014	.0003925
H ₂	.000084	.000060	.0000827	.0001055	.0001329	.0001655	.0002035
H	.000053	.000044	.0000518	.0000631	.0000861	.0001144	.0001581
H ₂ O	.000006	.000010	.000015	.000023	.000033	.000047	.000066
CH ₄	.000018	.000018	.000017	.000016	.000016	.000015	.000014

PROPELLANT THERMODYNAMIC PROPERTIES AND COMEUSTION GAS COMPOSITION

0.1

15% NO 65% IC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3498.51
h _o	25.6716	25.6422	25.2556	24.9946	25.99580
s _o	19383	19922	20591	21223	18256
h _f	-356.78	-342.94	-285.95	-224.70	
h _g	352.89	352.57	352.130	352.432	350.855
h _l	317.40	312.747	312.165	312.1939	312.1790
h _v	242.57	242.57	242.64	242.032	242.0935
h _g	177.38	177.00	174.85	175.49	175.10
h _l	524.81	511.71	493.63	473.29	454.70
h _o	24.4167	24.3337	24.5273	24.7661	24.39134
s _o	2262.47	2261.634	2260.521	2259.269	2263.920
h _f	2245.00	2248.37	2252.17	2257.26	2243.81
h _g	2113.79	2100.680	2098.22	2098.795	2102.277
h _l	1498.47	1498.37	1498.25	1498.12	1498.58
h _v	1004.44	1001.651	1000.924	1000.273	1000.184
h _g	903.19	900.471	899.691	899.579	899.300
h _l	552.25	552.219	552.622	552.959	552.902
h _v	357.88	353.114	353.626	354.035	354.169
h _g	111.78	111.540	111.872	112.277	112.0641
h _l	111.78	111.124	110.165	109.247	108.0047
h _v	111.78	111.114	110.0014	108.9014	107.5015

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

15% I.C 65% H.C

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
TEMP. °K	26.3152	26.2723	26.2348	26.1859	26.1229	26.0425	25.9418
ρ	24676	25725	26575	27432	28295	29169	30055
c _v	702.13	664.62	626.07	586.33	545.15	502.25	457.20
γ	1.347604	1.346033	1.345658	1.345235	1.344811	1.344389	1.343967
γ ₂	1.22200	1.22097	1.21991	1.21886	1.21777	1.21673	1.21569
γ ₃	2.111359	2.11028	2.10921	2.10813	2.10702	2.10593	2.10483
γ ₄	843.02	843.02	843.02	843.02	843.02	843.02	843.02
γ ₅	1565.0	1565.88	1564.14	1560.60	1556.04	1550.25	1542.94
CC	19560	193718	1917617	1898173	1878820	1859569	1840511
CC ₂	305507	304717	303936	303156	302376	301593	300807
CC ₃	302400	302342	302285	302228	302171	302114	302057
CC ₄	303303	303377	303451	303523	303596	303668	303740
CC ₅	304307	304451	304595	304737	304879	305021	305163
CC ₆	305307	305513	305719	305924	306129	306334	306539
CC ₇	306307	306575	306843	307111	307379	307646	307914
CC ₈	307307	307635	307963	308291	308619	308947	309275
CC ₉	308307	308675	309043	309411	309779	310147	310515
CC ₁₀	309307	309715	310123	310531	310939	311347	311755
CC ₁₁	310307	310755	311203	311651	312099	312547	312995
CC ₁₂	311307	311805	312303	312801	313299	313797	314295
CC ₁₃	312307	312845	313383	313921	314459	314997	315535
CC ₁₄	313307	313895	314483	315071	315659	316247	316835
CC ₁₅	314307	314935	315563	316191	316819	317447	318075
CC ₁₆	315307	315975	316643	317311	317979	318647	319315
CC ₁₇	316307	317015	317723	318431	319139	319847	320555
CC ₁₈	317307	318055	318803	319551	320299	321047	321795
CC ₁₉	318307	319105	319903	320701	321499	322297	323095
CC ₂₀	319307	320145	320983	321821	322659	323497	324335

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.15

15% NG 85% NC

TEMP. °K	3700.00	3800.00	3900.00	4000.00	3516.12
MOL. WT.	25.8172	25.6664	25.4863	25.2748	25.0277
P	30950	31875	32812	33773	2931:
Q	- 410.02	- 359.80	- 307.16	- 251.00	
CV	.352502	.354192	.353351	.353700	.352238
γ	1.21586	1.21554	1.21678	1.21709	1.21692
β	2.19609	2.20543	2.22310	2.23792	2.17246
ε	1066.24	1125.21	1144.20	1184.04	996.58
MF	1522.80	1522.65	1509.12	1492.95	1549.18
CO	.0141647	.0142969	.0144560	.0146442	.0139726
CO2	.0061961	.0061235	.0060265	.0059338	.0063056
H2O	.0022342	.0023521	.0023789	.0024160	.0023271
H2	.0102951	.0102409	.0101733	.0100907	.0103571
CH4	.0049312	.0049794	.0049771	.0049743	.0049832
C2H2	.0002288	.0000428	.0000614	.0000957	.0000128
C2H4	.0000208	.0000312	.0000456	.0000549	.0000092
CH	.0004133	.0005214	.0006461	.0007956	.0002578
H	.0001929	.0002353	.0002800	.0003339	.0001331
NO	.0000072	.0001277	.0001645	.0002080	.0000556
OH	.0000074	.0000101	.0000135	.0000178	.0000041
HF	.0000022	.0000022	.0000022	.0000022	.0000024

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

20% MG 80% NC O.I

TEMP. °A	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
P	26.5701	26.5325	26.4818	26.4151	26.3283	26.2172	26.0777
ρ	15359	15826	16416	16952	17495	18047	18611
C _v	- 725.01	- 686.73	- 647.12	- 605.90	- 562.72	- 517.20	- 468.83
γ	346615	347665	348670	349538	350301	351031	351715
ΔH _f	1.21940	1.21829	1.21742	1.21652	1.21605	1.21566	1.21537
ΔH _c	2.13429	2.14683	2.15940	2.17207	2.18496	2.19815	2.21177
ΔH _o	811.51	847.45	883.46	919.57	957.03	994.68	1033.77
ΔH _g	1554.45	1591.73	1588.17	1582.50	1577.43	1569.64	1559.75
CO ₂	0.27372	0.315086	0.428665	0.5129350	0.6130172	0.7131181	0.8132421
H ₂ O	0.72157	0.764782	0.809385	0.866958	0.928463	0.9967875	0.067166
CO	0.022618	0.022372	0.022178	0.022041	0.021966	0.021965	0.022049
H ₂	0.033470	0.033097	0.032436	0.0314078	0.0301917	0.028639	0.0268220
O ₂	0.050796	0.049801	0.048805	0.047808	0.046807	0.045805	0.044799
N ₂	0.001104	0.001026	0.000948	0.000865	0.000774	0.000675	0.000569
NO	0.001104	0.001026	0.000948	0.000865	0.000774	0.000675	0.000569
NO ₂	0.000634	0.000591	0.000531	0.000465	0.000391	0.000319	0.000233
H ₂	0.000450	0.000419	0.000379	0.000334	0.000282	0.000224	0.000168
CO	0.00126	0.001164	0.001078	0.001001	0.000926	0.000851	0.000777
CO ₂	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106
CO	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106
CO ₂	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106	0.000106

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

0.1

20% VC 80% IC

TEMP. °C	3700.00	3800.00	3900.00	4000.00	3570.40
CP	25.0051	25.6973	25.4512	25.1058	26.1222
CV	10.86	19.751	20.92	21.024	18.443
W	0.5733	-1.3623	-	240.19	
W	0.3522	0.3527	0.3521	0.3523	0.3515
W	0.2152	0.2154	0.2177	0.2175	0.2154
W	0.2219	0.2405	0.2528	0.2718	0.2075
W	0.2701	0.2207	0.1523	0.1914	0.2162
W	0.1473	0.2212	0.1518	0.1923	0.1562

W	0.1335	0.1379	0.1379	0.1403	0.1320
W	0.0608	0.0626	0.0640	0.0626	0.0673
W	0.0201	0.0225	0.0229	0.0235	0.0220
W	0.0100	0.0104	0.0107	0.0112	0.0133
W	0.0079	0.0077	0.0076	0.0075	0.0080
W	0.0051	0.0045	0.0048	0.0049	0.0050
W	0.0035	0.0032	0.0031	0.0030	0.0030
W	0.0026	0.0025	0.0025	0.0025	0.0025
W	0.0022	0.0022	0.0022	0.0022	0.0022
W	0.0019	0.0019	0.0019	0.0019	0.0019
W	0.0015	0.0015	0.0015	0.0015	0.0015
W	0.0012	0.0012	0.0012	0.0012	0.0012

PROPELLANT THERMODYNAMIC PROPERTIES AND COMPOSITION GAS COMPOSITION

20% H₂ 30% N₂

C.15

TEMP. °K	3000.00	3100.00	3200.00	3300.00	3400.00	3500.00	3600.00
1	26.5847	26.5598	26.5349	26.4667	26.3982	26.3104	26.2131
2	24293	25432	26270	27125	27982	28850	29731
3	727.24	681.37	635.79	590.79	545.09	498.64	452.37
4	1478.18	1248.47	1028.67	808.74	588.99	369.284	149.49
5	2.470	1.8154	1.2734	0.8390	0.5193	0.21403	0.07141
6	2.20001	1.6171	1.12293	0.71630	0.41967	0.21025	0.07133
7	575.37	343.20	212.14	135.24	84.18	51.43	29.26
8	1174.27	1792.30	2550.49	3455.75	4581.92	5974.73	7665.51
9	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
10	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
11	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
12	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
13	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
14	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
15	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
16	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
17	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
18	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
19	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
20	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
21	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
22	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
23	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
24	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
25	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
26	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
27	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
28	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
29	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44
30	11294.0	11219.24	11144.48	11069.72	10994.96	10920.20	10845.44

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

20E 1G 82X HC 0.15

TEMP. °C	1700.00	1800.00	1900.00	4000.00	3592.24
Wt. %	26.6634	25.8479	25.7000	25.4591	26.2096
g	30229	31545	32482	33444	29662
CV	355725	355021	326.16	268.39	
Y	21574	354275	353394	355093	352099
Z	21574	21461	21461	21522	1.21424
W	26703	26703	26703	2.22871	2.17211
U	26703	266.44	266.29	1.86.32	1026.29
V	26703	26703	26703	1512.12	1567.50
W	26703	26703	26703		
X	26703	26703	26703		
Y	26703	26703	26703		
Z	26703	26703	26703		
W	26703	26703	26703		
V	26703	26703	26703		
U	26703	26703	26703		
T	26703	26703	26703		
S	26703	26703	26703		
R	26703	26703	26703		
Q	26703	26703	26703		
P	26703	26703	26703		
O	26703	26703	26703		
N	26703	26703	26703		
M	26703	26703	26703		
L	26703	26703	26703		
K	26703	26703	26703		
J	26703	26703	26703		
I	26703	26703	26703		
H	26703	26703	26703		
G	26703	26703	26703		
F	26703	26703	26703		
E	26703	26703	26703		
D	26703	26703	26703		
C	26703	26703	26703		
B	26703	26703	26703		
A	26703	26703	26703		

PROPELLANT THERMODYNAMIC PROPERTIES AND COMBUSTION GAS COMPOSITION

IDEAL GAS

0.2

TEMP. °C	1900.00	2000.00	2100.00	2200.00	2300.00	2400.00	2500.00
u ₀ kJ	224063	224267	224847	225290	225619	225838	225963
D	2149	2167	2184	2199	2213	2225	2235
h	2170	2187	2203	2218	2232	2244	2254
h ₀	2170	2187	2203	2218	2232	2244	2254
h ₀	2170	2187	2203	2218	2232	2244	2254
h ₀	2170	2187	2203	2218	2232	2244	2254
h ₀	2170	2187	2203	2218	2232	2244	2254
h ₀	2170	2187	2203	2218	2232	2244	2254

h ₀	22786	22817	22852	22889	22928	22968	22999
h ₀	22817	22852	22889	22928	22968	22999	23030
h ₀	22852	22889	22928	22968	22999	23030	23061
h ₀	22889	22928	22968	22999	23030	23061	23092
h ₀	22928	22968	22999	23030	23061	23092	23123
h ₀	22968	22999	23030	23061	23092	23123	23154
h ₀	22999	23030	23061	23092	23123	23154	23185
h ₀	23030	23061	23092	23123	23154	23185	23216

MECHANICAL PROPERTIES AND COMBUSTION GAS COMPOSITION

IDEAL GAS 0.2

Pressure (psi)	Temperature (°F)	Volume (cc)	Weight (g)	Composition
1500	1000	3000.00	3000.00	...
1000	1000	3000.00	3000.00	...
500	1000	3000.00	3000.00	...
1500	1500	3000.00	3000.00	...
1000	1500	3000.00	3000.00	...
500	1500	3000.00	3000.00	...

Pressure (psi)	Temperature (°F)	Volume (cc)	Weight (g)	Composition
1500	1000	3000.00	3000.00	...
1000	1000	3000.00	3000.00	...
500	1000	3000.00	3000.00	...
1500	1500	3000.00	3000.00	...
1000	1500	3000.00	3000.00	...
500	1500	3000.00	3000.00	...

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