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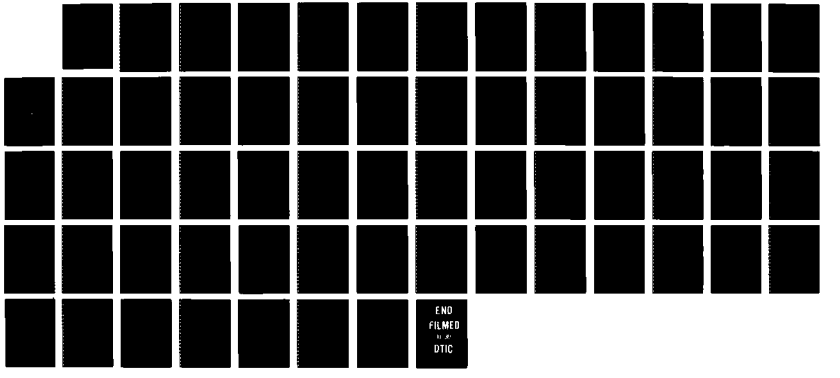

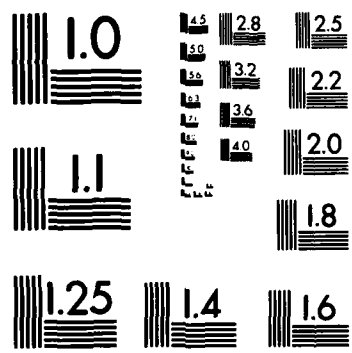

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CHARACTERIZATION OF COMBUSTION PRODUCTS OF MILITARY PROPELLANTS

FINAL REPORT

Volume II

by

Alan Snelson
Paul Ase
Warren Bock
Ronald Butler

March 1983

Supported by:

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IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

Contracting Officer's Technical Representatives:

Dr. William H. Dennis, Jr.
CPT James W. Carroll
MAJ David L. Parmer
U.S. Army Medical Bioengineering Research and Development Laboratory
Fort Detrick, Frederick, Maryland 21701-5010

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16. SUPPLEMENTARY NOTATION This is Volume II of a two-volume final report. It contains data on the results of a literature search and an example of theoretical computations on propellant (over)

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
06	21	
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18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Propellant combustion products; major, minor, and trace species. Experimental laboratory and field studies. (over)

16. (Continued)

combustion products. Volume I contains the main findings of the theoretical, laboratory, and field studies devoted to the characterization of combustion products of military propellants.

18. (Continued)

Simulated propellant combustor. M16 rifle. XM2 Fighting Vehicle, M198 howitzer, and MLRS. Theoretical product distribution calculations.

FOREWORD

IIT Research Institute is pleased to submit this two-volume document as the final report on the "Characterization of Combustion Products from Military Propellants." The study was sponsored by the U.S. Army Medical Bioengineering Research and Development Laboratory under Contract DAMD17-80-C-0019. The program started in February 1980 and the experimental phases ended in October 1982. The report contains much new information on the nature and amounts of combustion products formed in propellant systems not heretofore available.

We would like to acknowledge the enthusiasm and support received from Dr. William Dennis and Captain James W. Carroll of the U.S. Army Medical Bioengineering Research and Development Laboratory during the course of the program. The kind assistance of Dr. Eli Freedman, of the Interior Ballistics Division, Ballistics Research Laboratory, Aberdeen Proving Grounds, in providing theoretical performance calculations on the M6 propellant is also appreciated.

Citation of commercial organizations and trade names in this report does not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

Respectfully submitted,
IIT RESEARCH INSTITUTE

Alan Snelson
Science Advisor
Chemistry Research

Approved

Demetrios J. Moschandreas
Director
Chemistry and Chemical Engineering Department

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APPENDIX I

SUMMARY OF PROPELLANT COMBUSTION PRODUCT DATA OBTAINED IN THE LITERATURE SEARCH

SUMMARY OF PROPELLANT COMBUSTION PRODUCT DATA FROM LITERATURE SEARCH

1. Detonation Calculations (Special Technical Report No. 13)

Department of the Army, Edgewood Arsenal
Contract DA-18-035-AMC-122(A), 1967. AD822301.

This report is largely concerned with the origins of muzzle flash. The propellants listed in Table 1 were considered.

TABLE 1. CALCULATION INPUT PARAMETERS FOR PURE EXPLOSIVES

Chemical Name	Formula	Formula Weight	Oxygen Balance[a]	Crystal Density, g/cc	Heat of Formation	
					kcal/mol	kcal/g
Pentaerythitol tetranitrate (PETN)	$C_5H_8N_4O_{12}$	316.2	-10.0	1.77	-125.0	-0.395
Cyclotrimethylenetrinitramine (RDX)	$C_3H_6N_6O_6$	222.1	-22.0	1.80	+14.71	+0.066
Cyclotetramethylenetetranitramine (HMX)	$C_4H_8N_8O_8$	296.2	-22.0	1.90	+17.93	+0.061
Trinitrotoluene (TNT)	$C_7H_5N_3O_6$	227.1	-74.0	1.64	-17.81	-0.078
Ammonium perchlorate (AP)	NH_4ClO_4	117.5	+34.1[b]	1.95	-69.42	-0.591
Ammonium nitrate (AN)	NH_4NO_3	80.0	+20.0	1.73	-87.27	-1.091

[a] Oxygen balance $= -\frac{1600}{\text{formula wt}}\left[2\text{ C atoms} + \frac{H}{2}\text{ atom} - \text{O atom}\right]$.

[b] Assuming Cl atoms form HCl.

Theoretical product compositions were calculated using two models (LASL and SRI). Typical results are shown in Table 2. In one case the calculated combustion product compositions were compared with some experimental values obtained by the author. No details of the experimental methods were given. The results are shown in Table 3.

TABLE 2. CALCULATED PRODUCT COMPOSITIONS
[Mole%]

Product	HMX, ρ_o = 1.6 g/cc		TNT, ρ_o = 1.6 g/cc		TNT, ρ_o = 1.6 g/cc		RDX, ρ_o = 1.6 g/cc	
	LASL	SRI	LASL	SRI	LASL	SRI	LASL	SRI
CO_2	15.9	17.8	14.3	13.4	11.4	17.1	16.5	18.0
CO	1.5	2.6	2.1	1.3	9.5	7.7	0.2	1.0
CH_4	--	1.4	--	2.7	--	3.2	--	0.8
C(s)	15.9	14.2	46.7	44.1	42.8	40.2	16.5	14.4
H_2O	33.3	30.6	22.7	17.7	22.4	16.6	33.3	31.3
H_2	--	--	--	--	0.2	0.3	--	--
NH_3	--	1.2	--	0.7	--	0.7	--	0.9
N_2	33.3	32.2	13.6	14.1	13.6	14.3	33.3	33.7

TABLE 3. COMPARISON OF CALCULATED AND EXPERIMENTAL EXPANDED PRODUCT COMPOSITIONS FOR PETN

Product	Experimental		Calculated for Detonation State		Calculated for BKW Isentrope at 1500-1800K
	Confined	Unconfined			
ρ_o (g/cc)	1.74	1.74	1.77	1.00	1.74
Products (mole/mole PETN)					
CO_2	3.39	3.50	3.95	3.04	4.0-4.1
CO	1.69	1.56	0.096	0.96	0.5-0.6
CH_4	0.003	<0.0002	<0.0002	0.0002	0.3-0.4
C(s)	None	None	0.951	None	None
H_2O	3.50	3.45	4.00	3.94	3.2-3.3
H_2	0.45	0.51	<0.0002	0.050	0.02-0.05
NH_3	0.037	<0.0002	<0.0002	0.004	0.04-0.06
N_2	2.00	2.00	2.00	1.99+	2.0

2. Solid Propellant Combustion Gas Analysis Using a Micrometer Technique

U.S. Air Force, Edwards Air Force Base
Contract AFRPL-TR-69-53, 1969. AD851089.

The combustion products from two composite formulations containing 16% Al, 68% NH_4ClO_4, and 16% unspecified binder and 15% Al, 30% NH_4ClO_4, and 55% unspecified binder, were determined experimentally. A small micro-combustor shown in Figure 1 was vented into a large chamber at reduced pressure (250 mm Hg) containing either argon or air. The contained effluents were then analyzed directly by a mass spectrometer within a period of 30 s. Typical results are shown in Tables 4 and 5.

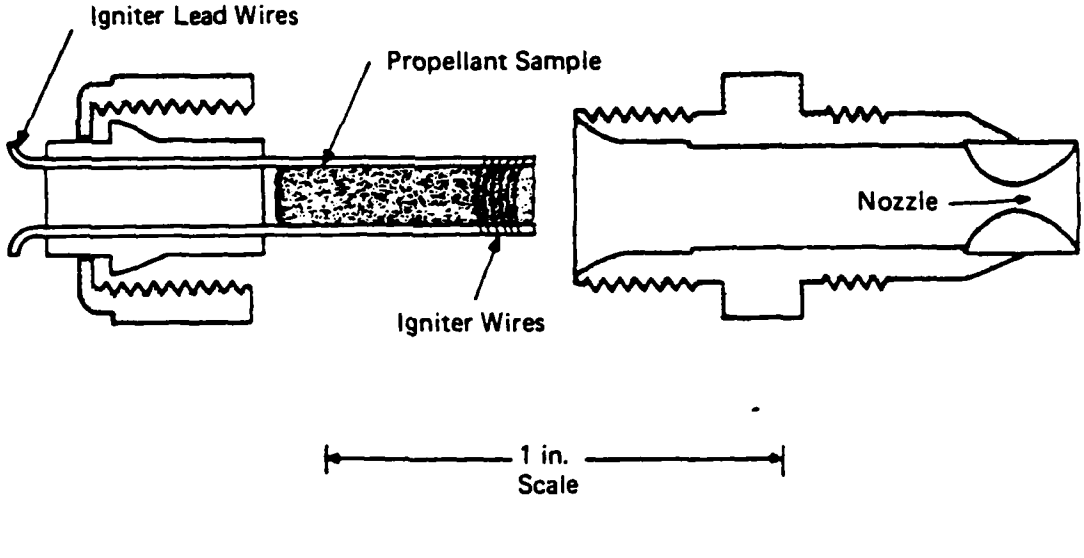

Figure 1. Micromotor design.

TABLE 4. COMPOSITE PROPELLANT FIRED IN ARGON
[Composition in Mole%]

Species	Run No.						Average	Thermo-dynamic Prediction
	10197A	10197B	10207A	10207B	11027A	11027B		
NH_3	13.7	13.0	19.7	20.0	11.5	11.7	14.7	--
H_2O	30.8	22.3	36.9	21.9	12.8	29.6	25.3	19.2
CO	20.1	31.5	15.7	24.2	41.8	20.9	25.3	40.6
N_2	7.2	11.6	5.7	10.0	14.6	7.0	9.2	12.9
HCl	27.1	20.0	20.9	22.4	15.9	29.2	23.8	24.4
CO_2	1.1	1.6	1.0	1.4	3.3	1.6	1.7	3.0

TABLE 5. MODIFIED DOUBLE-BASE PROPELLANT FIRED IN AIR AND ARGON
[Composition in Mole%]

Species	Air	Argon	Thermodynamic Prediction
NH_3	2.7	14.4	--
H_2O	28.4	17.9	22.5
CO	9.3	33.8	47.2
N_2	33.9	17.8	14.3
NO	2.2	3.6	--
HCl	5.2	10.4	10.1
CO_2	18.4	7.1	5.9

In Figure 2 a graph of the combustion product decay in the holding chamber as a function of time is presented. The decay of the species was attributed to reaction of the gases or adsorption on the walls of the chamber.

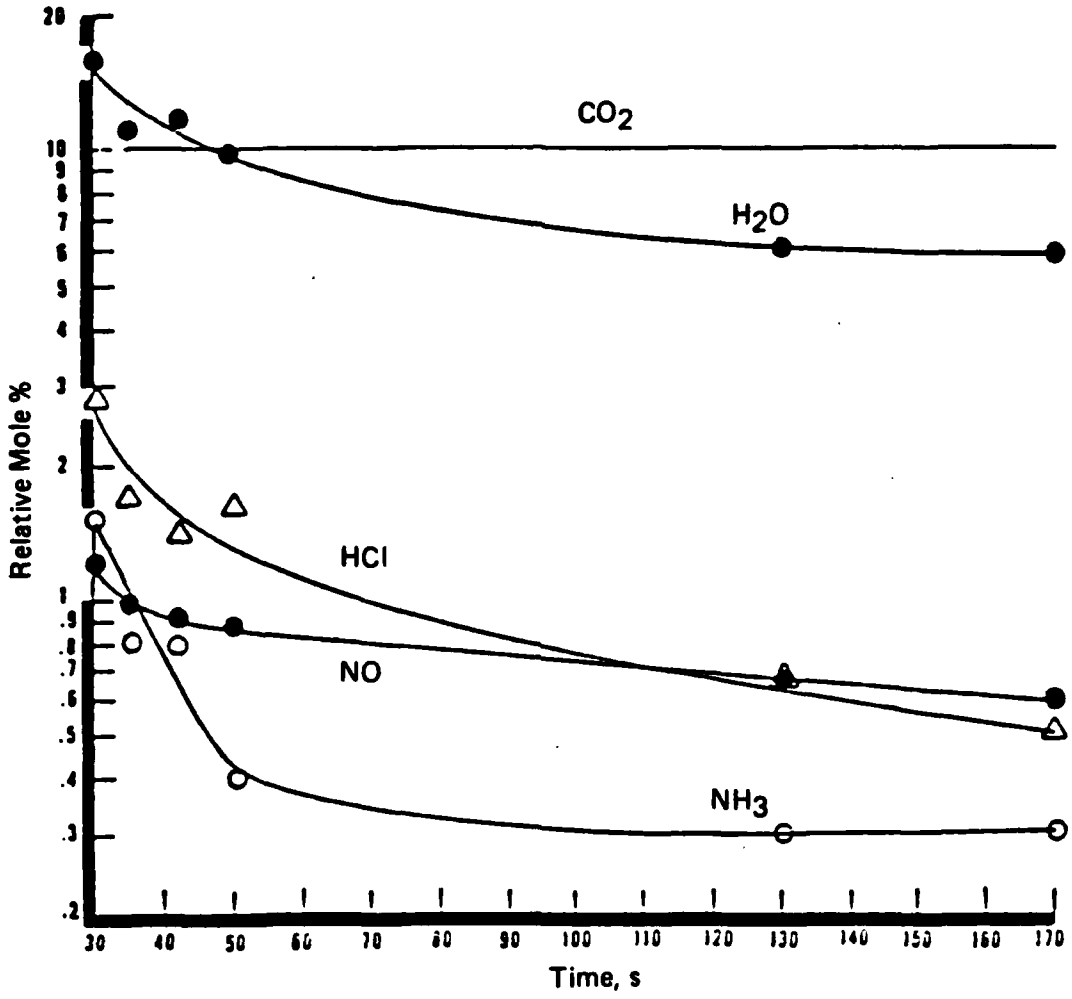

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Figure 2. Combustion products decay in air diluent.

3. **The Composition of the Exhaust Products of Military Weapons--A Comparison of Calculated and Experimental Results**

Joint USAARL-USAFA Report, USAFA Report R-1968 1970. AD 871485.

The three propellant systems shown in Table 6 were the subject of the investigation described in the project title. An initial literature search, presumably made in the literature prior to 1970, revealed no relevant data on the systems below. Experimental arrangements for sampling gun and rocket propellant system effluents were constructed as indicated in Figures 3 and 4. Chemical analyses were also made by mass spectrometry on the collected species. Aerosols were collected, but it is not clear if they were chemically analyzed.

TABLE 6. PROPELLANT AND WEAPON SYSTEMS

Weapon	7.62mm Machine Gun	Caliber .50 Machine Gun	2.75 in. FFAR
Ammunition	Cartridge, 7.62mm, NATO	Cartridge, Caliber .50,	--
Ball	M80	M33	--
Propellant	WC846	WC860	N-5
Charge Weight	2.92 g	15.99 g	2.68 kg

	Component, %		
	WC846	WC860	N-5
Nitrocellulose	82.61[a]	80.54[a]	49.7
% Nitrogen	13.12	13.15	12.6
Nitroglycerine	9.86[a]	8.79[a]	35.2
Diphenylamine	0.97[a]	0.94[a]	--
Dinitrotoluene	0.57[a]	--	--
Graphite	0.2	0.2	--
Moisture	0.62	1.13	--
Volatiles	0.37	0.37	--
Dibutylphthalate	5.07[a]	8.11[a]	--
Diethylphthalate	--	--	10.5
2-Nitrodiphenylamine	--	--	2.0
Wax	--	--	0.2
Sodium sulfate	0.07[a]	0.12[a]	--
Calcium carbonate	0.62[a]	0.49[a]	--
Potassium nitrate	--	0.73[a]	--
Lead salicylate	--	--	1.3
Lead 2-ethylhexoate	--	--	1.1

[a]Reported on a volatile-free basis.

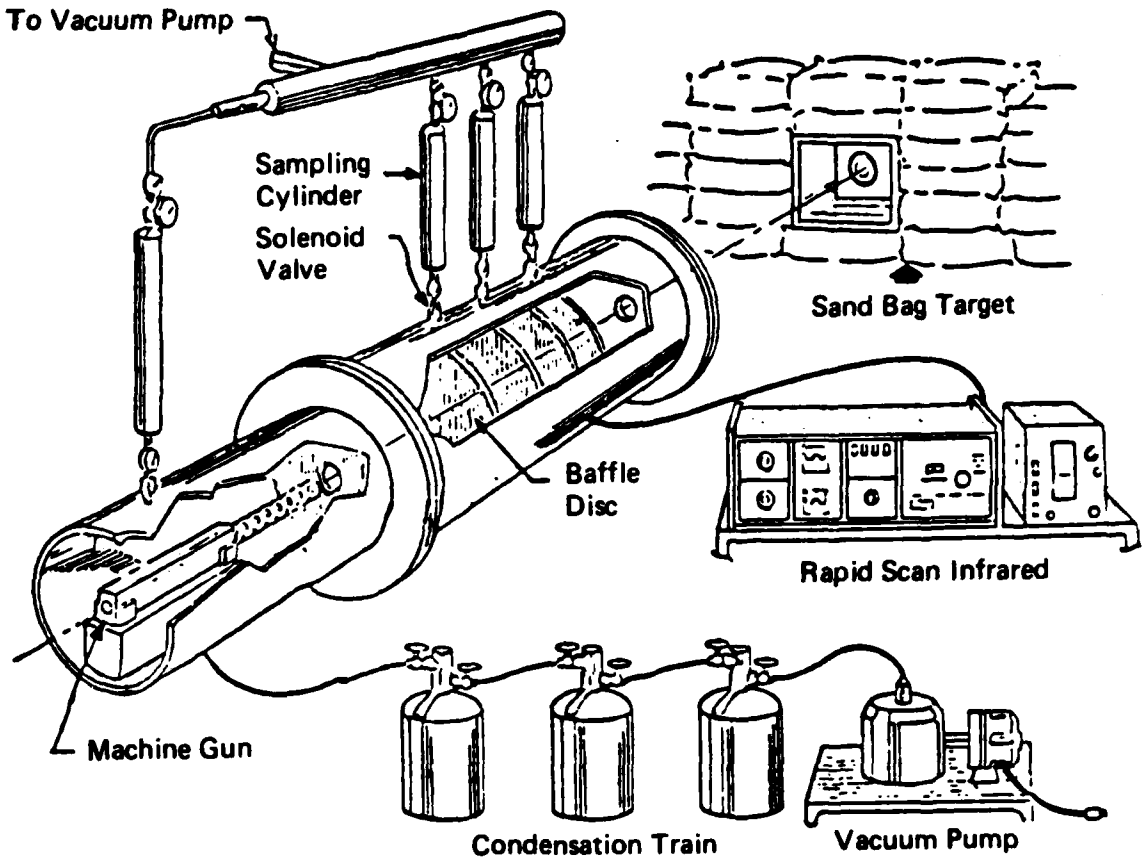

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Figure 3. Gun exhaust sampling apparatus and test stand.

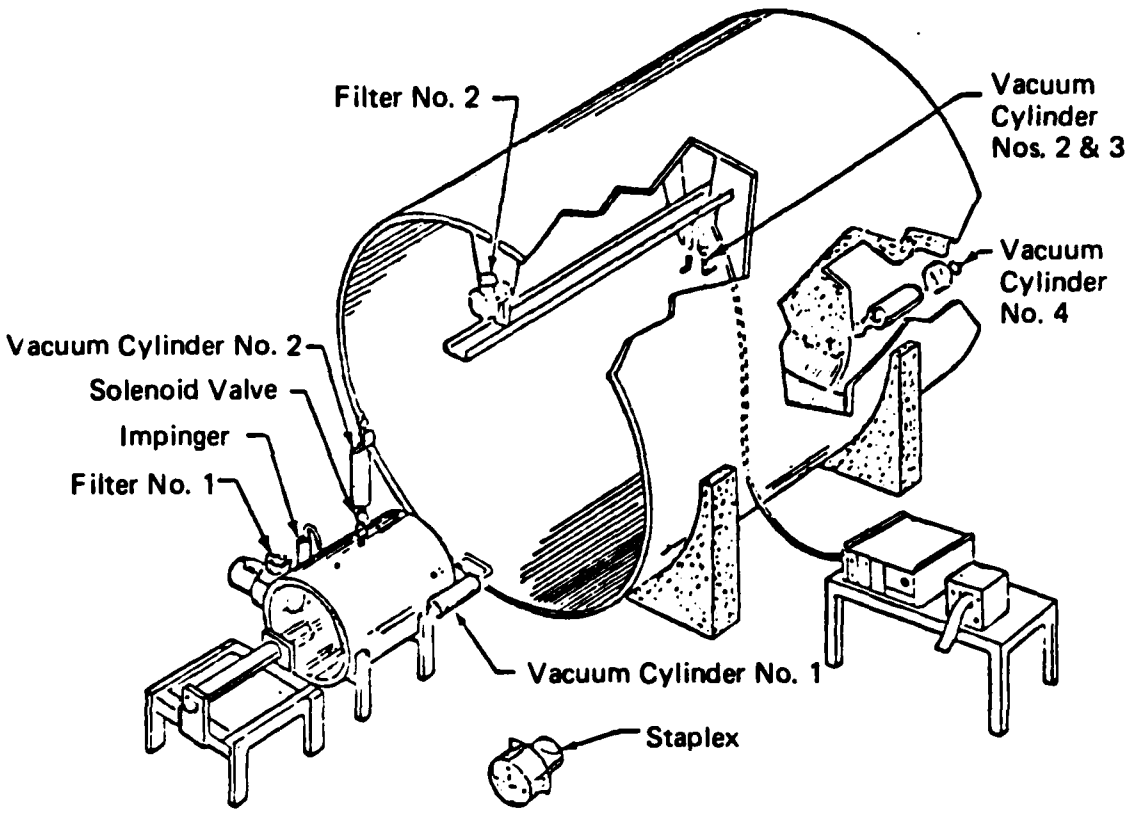

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Figure 4. Rocket exhaust sampling apparatus and test stand.

The specific computer program used in the theoretical equilibrium calculations was not identified. The data base was the then existing JANNAF tables. To simplify the calculation, the primer compositions, added stabilizers, or smoke suppressants were not included in the computation.

The results from the study are essentially summarized by the data presented in Tables 7 through 14. In Table 15, the chemical species introduced into the computer computation are presented. It is at once apparent that a number of the species found experimentally, SCO, CH_3CHO, and C_6H_6 were not included in the computer data base.

TABLE 7. COMPARISON OF RECONCILED COMPUTER AND EXPERIMENTAL RESULTS FOR SELECTED EXHAUST COMPONENTS OF THE 2.75 in. ROCKET USING N-5 PROPELLANT
[Mole Fractions]

Component	Calculated Pressure, psi					Experimental	
	1,200	1,000	500	100	14.7	Mean	Maximum
CO	0.83E-00	0.83E-00	0.81E-00	0.76E-00	0.65E-00	0.21E-00	0.57E-00
CO_2	0.16E-00	0.16E-00	0.18E-00	0.23E-00	0.34E-00	0.52E-00	0.70E-00
CH_4	0.73E-06	0.80E-06	0.13E-05	0.16E-05	0.37E-02	0.60E-02	0.26E-01
NH_3	0.51E-04	0.31E-04	0.26E-04	0.24E-04	0.41E-04	0.70E-02	0.11E-01
NO_2	Exponents range from -10 (1200 psi) to -26 (14.7 psi)					None detected	
HCN	0.19E-04	0.16E-04	0.94E-05	0.30E-05	0.11E-05	0.30E-02	0.38E-02

TABLE 8. COMPARISON OF RECONCILED COMPUTER AND EXPERIMENTAL RESULTS FOR SELECTED EXHAUST COMPONENTS OF THE 7.62mm MACHINE GUN USING WC846 PROPELLANT
[Mole Fractions]

Component	Calculated Pressure, psi						Experimental	
	50,000	25,000	10,000	5,000	1,000	14.7	Mean	Maximum
CO	0.83E-00	0.80E-00	0.78E-00	0.74E-00	0.63E-00	0.28E-00	0.66E-00	0.81E-00
CO_2	0.18E-00	0.20E-00	0.22E-00	0.25E-00	0.34E-02	0.68E-00	0.26E-00	0.42E-00
CH_4	0.91E-03	0.14E-02	0.35E-02	0.84E-02	0.39E-01	0.46E-01	0.10E-01	0.15E-01
NH_3	0.12E-02	0.98E-03	0.83E-03	0.76E-03	0.51E-03	0.11E-03	0.38E-02	0.10E-01
NO_2	Exponents range from -11 (50,000 psi) to -30 (14.7 psi)						0.20E-02	0.48E-02
HCN	0.65E-03	0.36E-03	0.18E-03	0.10E-03	0.25E-04	0.23E-06	0.55E-03	0.10E-02

TABLE 9. COMPARISON OF RECONCILED COMPUTER AND EXPERIMENTAL RESULTS FOR SELECTED EXHAUST COMPONENTS OF THE CALIBER .50 MACHINE GUN USING WC860 PROPELLANT
[Mole Fractions]

Component	Calculated Pressure, psi						Experimental	
	50,000	25,000	10,000	5,000	1,000	14.7	Mean	Maximum
CO	0.83E-00	0.82E-00	0.78E-00	0.73E-00	0.60E-00	0.26E-00	0.65E-00	0.85E-00
CO_2	0.15E-00	0.17E-00	0.21E-00	0.24E-00	0.24E-00	0.67E-00	0.27E-00	0.59E-00
CH_4	0.68E-02	0.11E-01	0.23E-01	0.37E-02	0.67E-01	0.55E-01	0.65E-02	0.93E-02
NH_3	0.21E-02	0.17E-02	0.13E-02	0.11E-02	0.56E-03	0.12E-03	0.28E-02	0.80E-02
NO_2	Exponents range from -12 (50000 psi) to -30 (14.7 psi)						0.20E-03	0.50E-03
HCN	0.10E-02	0.55E-03	0.24E-03	0.13E-03	0.25E-04	0.20E-06	0.28E-03	0.88E-03

TABLE 10. SPECIES PREDICTED BY COMPUTATION BUT NOT DETECTED BY CHEMICAL EXPERIMENTS[a]

Component[b]	Formula	Typical Mole Fraction Predicted	Pressure Used for Calculation, psi	Propellant
Hydrogen	H_2	0.26 E-00	14.7	N-5
Carbon, monatomic	C	0.97 E-17	10,000	WC846
Water	H_2O	0.94 E-01	14.7	N-5
Nitrogen	N_2	0.11 E-00	14.7	N-5
Oxygen	O_2	0.15 E-11	10,000	WC846
Nitric oxide	NO	0.36 E-08	10,000	WC846
Methylidyne	CH	0.19 E-14	10,000	WC846
Methylene	CH_2	0.81 E-08	10,000	WC846
Methyl	CH_3	0.19 E-05	10,000	WC846
Imidogen	NH	0.18 E-09	10,000	WC846
Amidogen	NH_2	0.62 E-07	10,000	WC846
Cyanogen	C_2H_2	0.13 E-09	10,000	WC846
Hydroxyl	OH	0.22 E-06	10,000	WC846

[a]Specific examples of typical results given for illustration.

[b]Gaseous state.

TABLE 11. COMPONENTS REPORTED BY CHEMICAL ANALYSIS BUT NOT PREDICTED IN THE COMPUTATION RESULTS

Component	Typical Mole Fraction	Weapon
Cyanogen	0.50 E-03	All
Carbonyl sulfide	0.10 E-03	Both machine guns
Benzene	0.10 E-04	7.62 mm machine gun
Acetaldehyde	0.50 E-03	Caliber .50 machine gun
Hydrogen chloride	Trace	Rocket plume only
Sulfur dioxide	Trace	Rocket plume only
Copper and lead	50 mg/m^3 of air	Both machine guns

TABLE 12. PROJECT WEST DATA, CALIBER .50 MACHINE GUN

Run	LOC Code	Inst Code	Total Sample Press.	CO Partial Press.	CO_2		CH_4		NH_3		NO_2		HCN		C≡N		CH_3CHO		SCO		C_6H_6		C_2H_2	
					P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R
2	MUZ1	IR	68	45	18	400	0.6	13	0.15	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	MUZ1	IR	71	45	20	430	0.5	10	0.30	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	MUZ1	IR	93	32	55	1700	0.5	14	0.15	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	MUZ1	IR	180	14	170	12000	--	--	--	--	0.09	7	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ	102	--	~10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	MUZ	102	--	~80	--	--	--	--	~1	~13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	140	98	36	370	1.1	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ1	M	160	120	24	200	1.2	10	0.41	4	--	--	0.14	1	0.01	0.1	--	--	--	--	--	--	0.7	0.6
7	MUZ1	IR	150	99	38	380	1.4	14	0.45	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	IR	180	130	48	380	1.5	12	0.75	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	120	83	32	380	1.1	13	0.36	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	240	160	45	290	0.7	5	0.41	4	--	--	0.04	0.3	0.08	0.5	1.5	10	0.03	0.1	--	--	0.07	0.4
8	MUZ1	IR	92	65	23	360	0.8	12	0.51	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	IR	150	110	40	380	1.3	12	0.90	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	100	73	26	350	0.8	10	0.80	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ	102	--	~200	--	--	--	--	~2	~10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9	MUZ3	M	45	38	6	170	0.2	6	0.03	0.8	--	--	0.1	0.4	--	--	0.01	0.4	--	--	--	--	0.02	0.6
	MUZ	102	--	300	--	--	--	~2	~7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10	RCV	IR	15	6	1000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	270	210	60	280	2.5	12	0.2	1	--	--	0.01	0.05	0.03	0.2	0.14	0.5	0.02	0.1	--	--	0.14	0.5
11	RCV	IR	19	8	5	690	0.09	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	110	88	20	230	0.14	2	0.02	0.2	--	--	0.007	0.07	0.003	0.04	0.007	0.04	--	--	--	--	0.0	0.2
	RCV	102	--	~10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	RCV	IR	26	14	9	640	0.09	7	0.03	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	80	62	18	280	0.34	5	0.03	0.5	--	--	0.03	0.5	0.01	0.2	0.03	0.5	0.007	0.1	--	--	0.04	0.7
14	RCV	IR	28	14	11	790	0.03	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 13. PROJECT MEST DATA, 7.62mm MACHINE GUN

Run	LOC Code	Inst Code	Total Sample Press.	CO Partial Press.	CO_2 P	CO_2 R	CH_4 P	CH_4 R	NH_3 P	NH_3 R	NO_2 P	NO_2 R	HCN P	HCN R	C≡N P	C≡N R	CH_3CHO P	CH_3CHO R	SCO P	SCO R	C_6H_6 P	C_6H_6 R	C_2H_2 P	C_2H_2 R
15	MUZ1	IR	25	5.4	18	3300	--	--	--	--	0.12	22	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	IR	27	3.6	22	6100	0.3	8	--	--	0.09	25	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	19	5.7	13	2300	0.03	5	--	--	0.06	11	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	8.4	1.8	4	2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	MUZ1	IR	6	4.5	2	330	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	9.6	5.7	4	680	0.06	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	49	30	12	400	0.66	22	0.33	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	49	34	7	220	0.48	15	0.07	2	--	--	0.052		0.01	0.3	0.06	2	0.002	--	0.04	0.001	0.02	0.05	2
17	MUZ1	IR	170	96	52	540	2.3	23	0.15	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	44	21	13	610	0.4	19	0.27	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	170	130	33	270	1.4	12	0.07	0.6	--	--	0.03	0.3	0.03	0.3	--	--	0.003	0.03	0.002	0.02	0.05	0.4
	MUZ	102	--	~200	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	MUZ1	IR	180	120	42	360	2.1	16	0.48	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	66	36	17	460	0.8	21	0.51	14	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ	102	--	~100	--	--	--	--	1	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	MUZ5	IR	130	90	30	330	1.5	17	0.33	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	75	45	20	430	0.8	17	0.45	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	92	52	24	460	0.8	16	0.70	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	102	--	~30	--	--	--	--	1	33	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	MUZ1	IR	170	110	40	350	2.2	20	0.33	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	110	80	26	330	1.6	20	0.12	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	56	34	15	430	0.8	22	0.57	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	31	20	8	410	0.4	19	0.27	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	M	140	110	29	260	1.3	11	0.20	2	--	--	0.07	0.7	0.14	1.4	--	--	0.03	0.3	--	--	0.07	0.7
	RCV	M	--	63	18	290	1.1	17	0.14	2	--	--	0.07	1.2	0.14	2.0	--	--	0.05	0.8	--	--	0.07	1.3
	RCV	102	--	~30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
21	MUZ1	IR	300	200	75	360	1.9	9	0.30	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ5	IR	130	84	36	430	0.9	11	0.18	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	24	13	8	580	0.12	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	IR	20	13	8	600	0.09	7	~0.01	~2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	MUZ3	M	210	170	35	220	1.4	9	0.14	0.08	--	--	0.11	0.7	0.03	0.20	--	--	--	--	--	--	--	--
	RCV	M	35	27	8	270	0.5	19	0.27	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	RCV	102	--	~20		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 14. PROJECT WEST DATA, 2.75 In. ROCKET (FFAR)

Run	LOC Code	Inst Code	Total Sample Press.	CO Partial Press.	CO_2		CH_4		NH_3		NO_2		HCN		C≡N		CH_3CHO		SCO		C_6H_6		C_2H_2	
					P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R	P	R
25	TANK	IR	15	2.4	10	4300	0.03	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	13	1.1	6	5900	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	20	1.5	12	7900	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	TANK	IR	43	4.0	29	7400	0.04	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	56	7.0	39	5600	0.93	135	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	TANK	IR	18	5.3	8	1400	0.08	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	23	5.1	11	2200	0.09	18	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--
	TANK	IR	40	8.4	22	2700	0.03	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PROBE	M	32	16	14	880	0.07	6	--	--	--	--	0.03	2	--	--	--	--	--	--	--	-0.03	--	2
	TANK	102	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	TANK	IR	21	4	13	3200	0.07	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	20	3.9	11	3300	0.06	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	49	7.2	31	4300	0.11	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PROBE	M	61	27	31	1200	0.54	20	0.007	2	--	--	0.11	4	0.07	3	--	--	--	--	--	--	0.14	5
29	TANK	IR	34	7.3	17	2300	0.15	20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	40	7.0	23	3400	0.09	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PROBE	IR	59	20	29	1500	0.33	17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	M	37	15	14	930	0.65	42	0.41	25	--	--	0.14	10	--	--	--	--	--	--	--	--	0.14	10
	TANK	102	--	~6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30	TANK	IR	28	9.3	12	1300	0.15	16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	41	10	21	2100	0.15	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PROBE	IR	29	14	10	730	0.19	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	43	17	16	930	0.17	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	102	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31	TANK	IR	29	9.7	13	1400	0.15	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	37	11	19	1700	0.13	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	PROBE	IR	120	55	51	930	0.47	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	IR	50	13	27	2200	0.15	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	102	--	~6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	TANK	M	91	52	24	450	2.4	47	0.27	5	--	--	0.20	3	0.06	1	--	--	--	--	--	--	--	--

TABLE 15. CHEMICAL SPECIES USED IN THEORETICAL PERFORMANCE CALCULATIONS

Formula	Species	Formula	Species
C	Carbon, monatomic	H_2	Hydrogen, diatomic (reference state, gaseous)
C_2	Carbon, diatomic	H_2O	Water
C_3	Carbon, trimeric	HCN	Hydrogen cyanide
CH	Methylidyne	N	Nitrogen, diatomic
CH_2	Methylene	N_2	Nitrogen, diatomic
CH_3	Methyl	NH	Imidogen
CH_4	Methane	NH_2	Amidogen
C_2H_2	Acetylene	NH_3	Ammonia
C_2N_2	Cyanogen	NO	Nitric oxide
CO	Carbon monoxide	NO_2	Nitrogen dioxide
CO_2	Carbon dioxide	O	Oxygen, monatomic
C(S)	Carbon (reference state, graphite)	O_2	Oxygen, diatomic
H	Hydrogen, monatomic	OH	Hydroxyl

4. Analysis of Exhaust Gases from the XM-19 Rifle--An Application of Gas Chromatography/Mass Spectrometry

USA Ballistic Research Laboratories, Aberdeen Proving Grounds
ROT E Project No. IJ563607D013, 1973. AD 910937.

The above chemical analytical technique was used to determine the composition of gases resulting from firing the XM-19 rifle with the XM-645 flechette round and the results compared with theoretical performance calculations. The experimental sampling arrangement was similar to that used in the previous study with the rifle mounted in a suitable stand. Gas samples were withdrawn from the enclosure area, after firing a number of rounds, in evacuated glass flasks. In addition, some cryogenic trapping procedures were also used. No attempt to collect aerosol samples was made.

Theoretical product calculations were made with a code named Blake--a modification of the Tiger code developed by SRI for BRL. The modifications were made by Dr. E. Freedman of BRL. The chemical species included in the calculation are given in Table 16 and the propellant composition in Table 17. Typical results from the program are presented in Table 18.

TABLE 16. LIST OF CHEMICAL SPECIES INCLUDED IN THERMODYNAMIC CALCULATIONS[a]

CO	S
H_2O	O_2
H_2	C_2H_2
N_2	C_2H_4
CO_2	CNCN
KOH	OH
H_2S	CN
NH_3	HS
HCN	SO
K	CH_3
CH_2O	H
COS	KO
NO	O
SO_2	N
CH_4	C

[a]All species in gaseous state, except C, a solid.

TABLE 17. NOMINAL COMPOSITION OF X-2374.13 PROPELLANT AND PISTON PRIMER

Propellant	Weight	Component	Wt%	% of Total Weight[a]
X-2374.13	1.3 g	Nitrocellulose	85.0	82.6
		Nitroglycerine	9.4	9.1
		Diphenylamine	0.9	.88
		Dinitrotoluene	0.7	.68
		Dibutyl phthalate	2.8	2.7
		Potassium sulfate	0.5	.48
		Moisture and volatiles	0.7	.68
Piston Primer	0.037 g	Lead styphnate	37 ±5	1.02
		Tetracene	4 ±1	.11
		Barium nitrate	32 ±5	.89
		Antimony sulfide	15 ±2	.41
		Aluminum powder	7 ±1	.19
		PETN	5 ±1	.14
Total[b]	**1.337 g**			**100%**

[a]Percent component weight of total charge; propellant and primer.

[b]Total weight of propellant and primer.

TABLE 18. COMPARISON OF EXPERIMENTAL AND CALCULATED PRODUCT CONCENTRATIONS FOR X-2374.13 PROPELLANT[a]

Species	Calculated	Measured	Species	Calculated	Measured
CO	1000	(1000)	C_2H_2	2.86×10^{-5}	>1[b]
H_2O	476	dnm[c]	C_2H_4	3.80×10^{-5}	
H_2	389		CNCN	1.57×10^{-8}	.25
N_2	289	dnm	OH	5.97×10^{-4}	
CO_2	364	380	CN	1.45×10^{-8}	
KOH	3.34		HS	3.73×10^{-3}	
H_2S	1.65		SO	8.27×10^{-5}	
NH_3	3.66×10^{-1}	dnm	CH_3	2.28×10^{-4}	
HCN	3.69×10^{-2}	dnm	H	1.01×10^{-2}	
K	1.97×10^{-1}		KO	8.43×10^{-7}	
CH_2O	1.98×10^{-2}		O	1.28×10^{-8}	
COS	1.18×10^{-1}	.25	N	3.10×10^{-10}	
NO	1.08×10^{-5}	dnm	C_3H_4	(NI)[d]	<.1
SO_2	3.35×10^{-4}		C_3H_6	(NI)	.1
CH_4	3.56×10^{-1}	1	C_3H_8	(NI)	<.1
S	8.29×10^{-6}		C_2H_6	(NI)	dnm
O_2	7.27×10^{-9}	dnm			

[a]Values are normalized to CO; [(Concentration of component/concentration of CO) x 10^3]

[b]Measured value includes both C_2H_2 and C_2H_4.

[c]Detected, but did not quantify

[d]Not included in these calculations.

5. Reduced-Smoke Solid Propellant Combustion Products Analysis--Development of a Micromotor Combustor Technique

U.S. Air Force, Edwards Air Force Base
Job Order No. 573010CN, 1976. AD A032152.

A small motor was developed to burn a few grams of the rocket propellant given in Table 19 at pressures from 200-1500 psi with subsequent analysis of nine condensable gases by gas chromatography and mass spectrometry. For the former technique, gas samples of the combustion effluents were collected in evacuated glass flasks or metal cylinders. In the latter technique, a water-cooled probe was used to sample directly into the mass spectrometer from the motor exit nozzle. Typical analytical data are shown in Tables 20 and 21 where the results of theoretical calculations are also given for comparison. No details of the theoretical computations were given.

TABLE 19. ROCKET PROPELLANT COMPOSITION

Ingredient	Wt%
Binder	12.5
Ammonium perchlorate	85.0
Zirconium carbide	0.5
Graphite	1.0
Aluminum oxide	0.5
Ferric fluoride	0.5

TABLE 20. COMBINED ANALYTICAL DATA
[Reduced-Smoke Propellant, Combustion Gas Composition]

Species	Mass Spectral Mean	Gas Chromatographic Mean	Combined Mean	Theoretical Data
H_2	20.1	20.1	20.1	16.1
N_2	53.4	21.6	21.6	23.2
CO		31.2	31.2	33.2
CO_2	26.0	26.9	26.5	27.6
CH_4	0.19	0.13	0.16	--
C_2H_2	0.15	0.06	0.11	--
O_2	0.23	--	0.23	0.21
Ratio				
CO/CO_2			1.177	1.202
N_2/CO_2			0.815	0.841
H_2/CO_2			0.758	0.583

TABLE 21. HIGH PRESSURE COMBUSTION GAS CORRELATION

Species	High, 1500 psi	Average, 350-1000 psi	Theoretical, 500-1500 psi
H_2	22.0	20.1	16.1
N_2	20.3	21.6	23.2
CO	33.1	31.2	33.2
CO_2	24.2	26.5	27.6
CH_4	0.16	0.16	--
C_2H_2	--	0.11	--
O_2	0.14	0.23	0.21
Ratio			
CO/CO_2	1.37	1.18	1.20
N_2/CO_2	0.84	0.82	0.84
H_2/CO_2	0.91	0.76	0.58

6. **Summary of Airborne Chlorine and Hydrogen Chloride Gas Measurements for August 10 and September 6, 1977, Voyager Launches at Air Force Eastern Test Range, Florida**

NASA Technical Memorandum 78673, 1978.

This program presents the results of an airborne sampling program in the wakes of Titan rockets. Measurements were made from about 2 min after launch to as long as 4-1/2 h after launch. All sampling was at an altitude of 500-1500 m at distances out to 100 km from the launch pad. Maximum observed hydrogen chloride concentrations for both launches was ≈25-30 ppm occurring 2-6 min after launch. Maxima in the chlorine concentration at 40-55 ppb occurred in the same time frame. Details of the analytical techniques were given. In addition, the exhaust product composition from a Titan rocket was given. This is shown in Table 22.

TABLE 22. EXHAUST PRODUCT COMPOSITION

Species	Formula	Mass Fraction Afterburned Plume[a]	Nominal Conc. in Stabilized Ground Cloud[b]
Aluminum oxide	Al_2O_3	30.4	1000-3000 μg/m³
Carbon monoxide	CO	.1	<1 ppm
Hydrogen chloride	HCl	20.4	5-40 ppm
Water vapor	H_2O	31.9	--[c]
Carbon dioxide	CO_2	48.0	Ambient Values
Chlorine	Cl_2	2.3	--[d]
Nitrogen oxide	NO	1.2	200-800 ppb
Others	--	0.6	--[c]

[a]Includes only that entrained air combusted in afterburning; total mass fraction is greater than 100% as reference mass for calculation is exhaust effluents from the motors.

[b]Range of nominal concentrations measured in earlier Titan III monitoring programs (Refs. 2-6 of NASA TM-78673).

[c]Not measured in monitoring program.

[d]Not measured in previous monitoring program.

7. **Toxicological and Recalcitrant Properties of a Proposed Propellant Ingredient, Triaminoguanidine Nitrate (TAGN) Analysis of the Deflagration By-Products of a TAGN-Based Propellant**

U.S. Air Force, Eglin Air Force Base, Florida
Report No. AFATL-TR-76-161, 1976. AD A041050.

The propellant formulations listed in Table 23 were subject to combustion in closed bombs at terminal pressures in the range of 11,500 to 31,000 psi, and the combustion products were analyzed by gas chromatography. The results are presented in Table 24.

TABLE 23. FORMULATIONS OF THE VARIOUS PROPELLANTS USED IN THIS STUDY

Propellant	Chemical Composition	% Total*
Hercules' GAU-8 Extract	Nitrocellulose (NC)	82.30
	Nitroglycerine (NG)	9.37
	Dibutyl phthalate (DBP)	4.17
	Diphenylamine (DPA)	0.54
	Potassium nitrate (KNO_3)	0.56
	Hercote $C_{5.142}H_{8.75}O_{1.838}$	3.06
Rocketdyne's RGP-150	Nitrocellulose (NC)	19.00
	Triaminoguanidine nitrate (TAGN)	45.00
	Cyclotetramethylenetetranitramine (HMX)	30.00
	Isodecyl pelargonate (IDP)	5.00
	Resorcinol	1.00
M-10	Nitrocellulose (NC)	97.40
	Diphenylamine (DPA)	1.00
	Graphite glaze	0.10
	Carbon black	0.50
	Potassium sulfate (K_2SO_4)	1.00
Triple Base	Nitrocellulose (NC)	28.04
	Nitroglycerine (NG)	20.12
	Ethylcellulose (EC)	1.00
	Potassium sulfate (K_2SO_4)	0.25
	Nitroguanidine (NQ)	50.59
WC870	Nitrocellulose (NC)	80.23
	Nitroglycerine (NG)	9.66
	Diphenylamine (DPA)	1.06
	Potassium nitrate (KNO_3)	0.50
	Dibutylphthalate (DBP)	7.38
	Potassium sulfate (K_2SO_4)	0.38
	Dinitrotoluene (DNT)	0.52
	Calcium carbonate ($CaCO_3$)	0.05
	Sodium sulfate (Na_2SO_4)	0.12
	Graphite	0.10

*Among product batches, it is common to have minor variations in constituent percentages.

TABLE 24. PERCENTAGES OF GASES PRODUCED WHEN SELECTED PROPELLANTS WERE BURNED UNDER HIGH AND LOW PRESSURES

Propellant	Pressure, psi	H_2	N_2	O_2	N_2O	CO	CO_2	CH_4	C_2H_4	H_2O
RGP-150	Atm	--	84.0	8.7	--	--	5.8	--	--	1.5
RGP-150	13,000	0.2	42.2	tr	--	40.0	6.4	4.6	--	6.6
RGP-150	31,000	0.3	41.3	0.1	--	31.4	10.0	12.7	--	4.2
GAU-8 Extract	Atm	--	43.5	7.4	--	5.8	28.9	tr	--	14.4
GAU-8 Extract	11,500	0.3	15.3	0.3	--	50.9	14.8	2.3	--	16.1
GAU-8 Extract	28,000	0.3	12.7	--	--	42.0	20.8	7.1	--	17.1
M-10	Atm	--	51.0	15.7	--	1.6	22.2	--	--	9.5
M-10	13,000	0.4	16.2	--	--	57.7	20.4	1.3	--	4.0
M-10	30,000	0.2	15.6	--	--	40.9	30.2	3.2	--	9.9
WC870	Atm	--	60.6	5.1	--	4.0	20.2	--	--	10.1
WC870	12,000	0.3	16.2	--	--	60.6	16.3	2.4	--	4.2
WC870	27,000	0.2	16.6	0.3	--	49.0	25.4	4.9	--	3.6
Triple Base	Atm	--	62.9	17.5	tr	5.5	4.1	--	2.6	7.4
Triple Base	13,000	tr	37.8	--	--	38.7	12.5	2.0	--	9.0
Triple Base	27,000	tr	35.9	--	--	38.9	14.2	2.1	--	8.9

APPENDIX II

THEORETICAL COMBUSTION PRODUCT CALCULATIONS FOR THE WC844 PROPELLANT ASSUMING EQUILIBRIUM AND FROZEN COMPOSITIONS DURING EXPANSION AT INITIAL PRODUCT PRESSURES OF 20,000, 30,000, 40,000, 50,000, AND 60,000 psi

TABLE 25. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2) [10,000 psi]

PC = 10000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C	6.00000	H	7.36400	N	2.63580	O	10.27200	0.951500	-164700.000	S	298.15	0.0
FUEL	C	1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C	12.00000	H	11.00000	N	1.00000			0.007500	27900.000	S	298.15	0.0
FUEL	C	18.00000	H	14.00000	O	4.00000			0.030000	-200000.000	S	298.15	0.0
FUEL	NA	2.00000	S	1.00000	O	4.00000			0.005000	-326300.000	S	298.15	0.0
FUEL	CA	1.00000	C	1.00000	O	3.00000			0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL = 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7966	1.0021	1.0087	1.1238	1.3420	33.855	84.726	198.73	586.57
P, ATM	680.46	378.74	679.03	674.58	605.48	507.06	20.099	8.0313	3.4240	1.1601
T, DEG K	2376.2	2122.6	2375.2	2372.2	2323.7	2245.8	1218.2	1071.1	990.2	917.6
RHO, G/CC	8.5083-2	5.3017-2	8.4940-2	8.4489-2	7.7420-2	6.7084-2	4.9387-3	2.2834-3	1.0794-3	4.0767-4
H, CAL/G	-594.6	-701.9	-595.0	-596.3	-616.9	-650.0	-1089.3	-1173.2	-1242.0	-1320.7
S, CAL/(G)(K)	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593
M, MOL WT	24.380	24.381	24.380	24.380	24.380	24.381	24.562	24.989	25.614	26.461
(DLV/DLP)T	-1.00046	-1.00037	-1.00046	-1.00046	-1.00043	-1.00040	-1.01060	-1.03436	-1.09871	-1.08867
(DLV/DLT)P	1.0031	1.0022	1.0031	1.0031	1.0028	1.0025	1.1333	1.4968	2.7932	2.7198
CP, CAL/(G)(K)	0.4285	0.4209	0.4284	0.4283	0.4266	0.4241	0.5559	0.9989	2.9946	2.9814
GAMMA (S)	1.2360	1.2409	1.2360	1.2361	1.2372	1.2388	1.2141	1.1682	1.1153	1.1082
SON VEL,M/SEC	1000.8	947.7	1000.6	1000.0	990.2	974.0	707.6	645.2	598.7	565.3
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.876	3.410	3.887	4.361
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4502	4502	4502	4502	4502	4502	4502	4502	4502
CF		0.691	0.043	0.087	0.315	0.496	1.483	1.604	1.696	1.796
IVAC LB-SEC/LB		174.5	1402.3	705.7	230.9	184.1	228.1	240.9	251.4	263.3
ISP, LB-SEC/LB		96.6	6.0	12.1	44.1	69.4	207.5	224.4	237.3	251.4

TABLE 25. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[10,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01615	0.05233
CH2O	0.00003	0.00002	0.00002	0.00002	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000
CH4	0.00001	0.00002	0.00001	0.00001	0.00002	0.00002	0.00270	0.01128	0.01557	0.01304
CO	0.45184	0.44553	0.45182	0.45175	0.45068	0.44883	0.38563	0.35424	0.30994	0.24382
COS	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00003	0.00004	0.00004	0.00003
CO2	0.10986	0.11614	0.10989	0.10995	0.11101	0.11284	0.17613	0.20841	0.23706	0.26668
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00013	0.00045	0.00050	0.00050
CAO(S)	0.00026	0.00044	0.00026	0.00026	0.00032	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00022	0.00017	0.00011	0.0	0.0	0.0	0.0
CAS(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00036	0.00004	0.0	0.0
H	0.00020	0.00007	0.00020	0.00020	0.00016	0.00012	0.00000	0.0	0.0	0.0
HCN	0.00005	0.00003	0.00005	0.00005	0.00004	0.00004	0.00000	0.00000	0.00000	0.00000
HCO	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.0
H2	0.13588	0.14222	0.13590	0.13596	0.13704	0.13890	0.19559	0.20298	0.20293	0.20386
H2O	0.18956	0.18348	0.18954	0.18948	0.18848	0.18671	0.12793	0.10882	0.10309	0.10560
H2S	0.00072	0.00075	0.00072	0.00072	0.00072	0.00073	0.00048	0.00079	0.00084	0.00085
NH3	0.00014	0.00011	0.00014	0.00014	0.00013	0.00012	0.00010	0.00009	0.00007	0.00004
N2	0.10930	0.10931	0.10930	0.10930	0.10930	0.10930	0.11005	0.11197	0.11292	0.11238
NA	0.00038	0.00039	0.00038	0.00038	0.00038	0.00038	0.00000	0.00000	0.0	0.0
NACN	0.00001	0.00002	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.0	0.0
NAH	0.00003	0.00002	0.00003	0.00003	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00129	0.00128	0.00129	0.00129	0.00129	0.00129	0.00000	0.00000	0.00000	0.0
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00088	0.00089	0.00088
NA2CO3(L)	0.0	0.0	0.0	0.0	0.0	0.0	0.00086	0.0	0.0	0.0
OH	0.00005	0.00001	0.00005	0.00005	0.00004	0.00002	0.0	0.0	0.0	0.0
SH	0.00003	0.00002	0.00003	0.00003	0.00003	0.00002	0.00000	0.0	0.0	0.0
SO	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.0	0.0	0.0	0.0
SO2	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.0	0.0	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)
CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2	H2SO4(L)
H2SO4	N	NCO	NH	NH2	NO	NO2	NO3	N2H4	N2O
N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)	NAOH(L)
NAO2(S)	NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)
NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3	S(S)
S(L)	S	SN	SO3	S2	S2O	S8			

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 26. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2) [20,000 psi]

PC = 20000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C	6.00000	H	7.36400	N	2.63580	O	10.27200	0.951500	-164700.000	S	298.15	0.0
FUEL	C	1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C	12.00000	H	11.00000	N	1.00000			0.007500	27900.000	S	298.15	0.0
FUEL	C	18.00000	H	14.00000	O	4.00000			0.030000	-200000.000	S	298.15	0.0
FUEL	NA	2.00000	S	1.00000	O	4.00000			0.005000	-326300.000	S	298.15	0.0
FUEL	CA	1.00000	C	1.00000	O	3.00000			0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7966	1.0021	1.0087	1.1238	1.3420	33.466	83.230	194.90	577.89
P, ATM	1360.91	757.49	1358.05	1349.15	1210.95	1014.12	40.666	16.351	6.9826	2.3550
T, DEG K	2377.3	2123.5	2376.3	2373.3	2324.7	2246.8	1241.0	1103.0	1023.4	945.4
RHO, G/CC	1.7016-1	1.0603-1	1.6987-1	1.6897-1	1.5483-1	1.3416-1	9.8815-3	4.5656-3	2.1561-3	8.1343-4
H, CAL/G	-594.6	-701.9	-595.0	-596.3	-616.9	-650.0	-1088.9	-1173.5	-1243.5	-1324.1
S, CAL/(G)(K)	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028
M, MOL WT	24.390	24.390	24.390	24.390	24.390	24.390	24.744	25.271	25.931	26.795
(DLV/DLP)T	-1.00082	-1.00077	-1.00083	-1.00082	-1.00080	-1.00077	-1.02076	-1.04356	-1.09915	-1.08892
(DLV/DLT)P	1.0041	1.0043	1.0041	1.0041	1.0040	1.0040	1.2602	1.6183	2.7326	2.6623
CP, CAL/(G)(K)	0.4282	0.4217	0.4282	0.4281	0.4265	0.4243	0.6813	1.1149	2.7852	2.7785
GAMMA (S)	1.2361	1.2408	1.2362	1.2362	1.2373	1.2388	1.1997	1.1644	1.1190	1.1114
SON VEL,M/SEC	1000.9	947.7	1000.7	1000.1	990.2	974.1	707.3	650.0	605.9	571.0
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.876	3.386	3.846	4.327
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4502	4502	4502	4502	4502	4502	4502	4502	4502
CF		0.691	0.043	0.087	0.315	0.496	1.482	1.604	1.698	1.801
IVAC LB-SEC/LB		174.5	1401.8	705.8	230.9	184.1	228.3	241.3	252.0	264.1
ISP, LB-SEC/LB		96.6	6.0	12.1	44.1	69.4	207.4	224.4	237.6	251.9

TABLE 26. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[20,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02113	0.05814
CH2O	0.00005	0.00003	0.00005	0.00005	0.00005	0.00004	0.00000	0.00000	0.00000	0.00000
CH4	0.00006	0.00008	0.00006	0.00006	0.00006	0.00007	0.00621	0.01699	0.01929	0.01630
CO	0.45178	0.44547	0.45176	0.45169	0.45062	0.44878	0.38435	0.35221	0.30397	0.23753
COS	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00005	0.00005	0.00004	0.00003
CO2	0.11001	0.11627	0.11003	0.11010	0.11115	0.11298	0.17769	0.21114	0.23851	0.26757
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00049	0.00050	0.00051	0.00050
CAO(S)	0.00026	0.00044	0.00026	0.00026	0.00032	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00022	0.00017	0.00011	0.0	0.0	0.0	0.0
H	0.00014	0.00005	0.00014	0.00014	0.00012	0.00008	0.00000	0.0	0.0	0.0
HCN	0.00009	0.00006	0.00009	0.00009	0.00008	0.00007	0.00001	0.00000	0.00000	0.00000
HCO	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.00000	0.00000	0.00000	0.00000
H2	0.13562	0.14197	0.13565	0.13571	0.13679	0.13865	0.18709	0.18888	0.18840	0.18930
H2O	0.18959	0.18349	0.18957	0.18951	0.18850	0.18673	0.13140	0.11516	0.11258	0.11574
H2S	0.00073	0.00076	0.00073	0.00073	0.00074	0.00074	0.00082	0.00084	0.00085	0.00085
NH3	0.00027	0.00022	0.00027	0.00027	0.00026	0.00024	0.00018	0.00014	0.00010	0.00006
N2	0.10924	0.10927	0.10924	0.10924	0.10925	0.10926	0.11083	0.11320	0.11372	0.11308
NA	0.00028	0.00029	0.00028	0.00028	0.00028	0.00029	0.00000	0.00000	0.0	0.0
NACN	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00000	0.00000	0.0	0.0
NAH	0.00003	0.00002	0.00003	0.00003	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00137	0.00136	0.00137	0.00137	0.00137	0.00136	0.00000	0.00000	0.00000	0.0
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00089	0.00089	0.00089
NA2CO3(L)	0.0	0.0	0.0	0.0	0.0	0.0	0.00087	0.0	0.0	0.0
OH	0.00004	0.00001	0.00003	0.00003	0.00003	0.00002	0.0	0.0	0.0	0.0
SH	0.00002	0.00001	0.00002	0.00002	0.00002	0.00002	0.00000	0.00000	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)
CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2
H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2	NO3	N2H4
N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)
NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)
NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3
S(S)	S(L)	S	SN	SO	SO2	SO3	S2	S2O	S8

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 27. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2)
[30,000 psi]

PC = 30000.0 PSIA

	CHEMICAL FORMULA						WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200			0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000						0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000				0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000				0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000				0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000				0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7964	1.0021	1.0087	1.1239	1.3419	33.186	82.382	192.83	573.30
P, ATM	2041.37	1136.36	2037.08	2023.72	1816.39	1521.24	61.513	24.779	10.586	3.5608
T, DEG K	2378.2	2124.5	2377.2	2374.2	2325.6	2247.7	1258.6	1123.1	1043.6	962.1
RHO, G/CC	2.5525-1	1.5906-1	2.5482-1	2.5346-1	2.3225-1	2.0125-1	1.4824-2	6.8452-3	3.2308-3	1.2181-3
H, CAL/G	-594.6	-701.9	-595.0	-596.3	-616.9	-650.0	-1088.8	-1174.0	-1244.8	-1326.5
S, CAL/(G)(K)	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698
M, MOL WT	24.401	24.400	24.400	24.401	24.400	24.400	24.888	25.459	26.135	27.007
(DLV/DLP)T	-1.00132	-1.00133	-1.00132	-1.00132	-1.00130	-1.00129	-1.02802	-1.04872	-1.09900	-1.08868
(DLV/DLT)P	1.0062	1.0075	1.0062	1.0062	1.0063	1.0066	1.3472	0.0	2.6921	2.6233
CP, CAL/(G)(K)	0.4289	0.4274	0.4288	0.4287	0.4279	0.4255	0.7624	0.0	2.6620	2.6582
GAMMA (S)	1.2360	1.2406	1.2360	1.2361	1.2371	1.2386	1.1934	0.9535	1.1211	1.1133
SON VEL,M/SEC	1000.8	947.7	1000.6	1000.0	990.1	974.0	708.4	591.4	610.1	574.3
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.871	3.723	3.823	4.310
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4502	4502	4502	4502	4502	4502	4502	4502	4502
CF		0.691	0.043	0.087	0.315	0.496	1.482	1.605	1.700	1.803
IVAC LB-SEC/LB		174.5	1403.4	705.8	230.9	184.1	228.5	241.5	252.4	264.6
ISP, LB-SEC/LB		96.6	6.0	12.1	44.1	69.4	207.4	224.5	237.9	252.4

TABLE 27. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[30,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02422	0.06166
CH2O	0.00007	0.00005	0.00007	0.00007	0.00007	0.00006	0.00000	0.00000	0.00000	0.00000
CH4	0.00013	0.00018	0.00013	0.00013	0.00014	0.00015	0.00912	0.02081	0.02170	0.01843
CO	0.45165	0.44534	0.45163	0.45156	0.45050	0.44865	0.38288	0.35041	0.29988	0.23337
COS	0.00010	0.00009	0.00010	0.00010	0.00009	0.00009	0.00006	0.00005	0.00005	0.00004
CO2	0.11021	0.11647	0.11023	0.11029	0.11134	0.11317	0.17955	0.21343	0.23983	0.26847
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00050	0.00051	0.00051	0.00051
CAO(S)	0.00026	0.00044	0.00026	0.00026	0.00032	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00022	0.00017	0.00011	0.0	0.0	0.0	0.0
H	0.00012	0.00004	0.00012	0.00011	0.00010	0.00007	0.00000	0.0	0.0	0.0
HCN	0.00014	0.00008	0.00014	0.00014	0.00012	0.00011	0.00001	0.00000	0.00000	0.00000
HCO	0.00002	0.00001	0.00002	0.00002	0.00001	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00003	0.00001	0.00003	0.00003	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000
H2	0.13531	0.14164	0.13533	0.13540	0.13648	0.13834	0.18030	0.17986	0.17950	0.18039
H2O	0.18964	0.18354	0.18962	0.18956	0.18855	0.18677	0.13421	0.11899	0.11821	0.12177
H2S	0.00074	0.00076	0.00074	0.00074	0.00074	0.00075	0.00082	0.00084	0.00085	0.00086
NH3	0.00040	0.00034	0.00040	0.00040	0.00039	0.00037	0.00023	0.00018	0.00012	0.00007
N2	0.10919	0.10923	0.10919	0.10919	0.10920	0.10921	0.11144	0.11402	0.11424	0.11354
NA	0.00023	0.00024	0.00023	0.00024	0.00024	0.00024	0.00000	0.00000	0.0	0.0
NACN	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00000	0.00000	0.00000	0.0
NAH	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00140	0.00139	0.00140	0.00140	0.00140	0.00140	0.00000	0.00000	0.00000	0.00000
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00074	0.00090	0.00089
NA2CO3(L)	0.0	0.0	0.0	0.0	0.0	0.0	0.00087	0.00015	0.0	0.0
OH	0.00003	0.00001	0.00003	0.00003	0.00002	0.00001	0.0	0.0	0.0	0.0
SH	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.00000	0.00000	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)
CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2
H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2	NO3	N2H4
N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)
NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)
NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3
S(S)	S(L)	S	SN	SO	SO2	SO3	S2	S2O	S8

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 28. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2)
[40,000 psi]

PC = 40000.0 PSIA

	CHEMICAL FORMULA						WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200			0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000						0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000				0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000				0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000				0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000				0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7962	1.0021	1.0087	1.1238	1.3418	32.975	81.833	191.46	570.27
P, ATM	2721.83	1515.28	2716.10	2698.32	2421.99	2028.44	82.542	33.261	14.216	4.7729
T, DEG K	2379.2	2125.6	2378.2	2375.2	2326.6	2248.7	1272.8	1137.8	1058.2	974.2
RHO, G/CC	3.4035-1	2.1208-1	3.3977-1	3.3797-1	3.0969-1	2.6835-1	1.9764-2	9.1215-3	4.3038-3	1.6220-3
H, CAL/G	-594.6	-701.9	-595.0	-596.3	-616.9	-650.0	-1088.8	-1174.6	-1245.9	-1328.3
S, CAL/(G)(K)	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463
M, MOL WT	24.412	24.412	24.412	24.412	24.411	24.411	25.007	25.605	26.288	27.166
(DLV/DLP)T	-1.00192	-1.00203	-1.00192	-1.00191	-1.00190	-1.00191	-1.03312	-1.05198	-1.09869	-1.08830
(DLV/DLT)P	1.0090	1.0118	1.0090	1.0090	1.0093	1.0100	1.4067	1.7192	2.6609	2.5930
CP, CAL/(G)(K)	0.4300	0.4258	0.4300	0.4299	0.4287	0.4271	0.8152	1.1948	2.5744	2.5722
GAMMA (S)	1.2359	1.2402	1.2358	1.2359	1.2369	1.2384	1.1901	1.1628	1.1226	1.1147
SON VEL,M/SEC	1000.7	947.6	1000.5	999.9	990.0	973.9	709.7	655.5	613.0	576.5
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.866	3.361	3.809	4.298
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4502	4502	4502	4502	4502	4502	4502	4502	4502
CF		0.690	0.043	0.087	0.315	0.496	1.482	1.605	1.701	1.806
IVAC LB-SEC/LB		174.5	1401.4	705.8	230.9	184.1	228.6	241.8	252.7	264.9
ISP, LB-SEC/LB		96.6	6.0	12.1	44.1	69.4	207.4	224.7	238.1	252.7

TABLE 28. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[40,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02650	0.06423
CH2O	0.00010	0.00006	0.00010	0.00010	0.00009	0.00008	0.00001	0.00000	0.00000	0.00000
CH4	0.00023	0.00032	0.00023	0.00023	0.00024	0.00027	0.01152	0.02377	0.02351	0.02004
CO	0.45147	0.44517	0.45145	0.45139	0.45033	0.44848	0.38152	0.34874	0.29666	0.23017
COS	0.00010	0.00009	0.00010	0.00010	0.00010	0.00009	0.00006	0.00005	0.00005	0.00004
CO2	0.11044	0.11670	0.11046	0.11052	0.11157	0.11339	0.18122	0.21548	0.24099	0.26931
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00050	0.00051	0.00051	0.00051
CAO(S)	0.00026	0.00044	0.00026	0.00026	0.00032	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00023	0.00017	0.00011	0.0	0.0	0.0	0.0
H	0.00010	0.00003	0.00010	0.00010	0.00008	0.00006	0.00000	0.0	0.0	0.0
HCN	0.00018	0.00011	0.00018	0.00018	0.00016	0.00014	0.00001	0.00000	0.00000	0.00000
HCO	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00004	0.00002	0.00004	0.00004	0.00003	0.00003	0.00000	0.00000	0.00000	0.00000
H2	0.13495	0.14124	0.13497	0.13504	0.13612	0.13797	0.17482	0.17312	0.17302	0.17391
H2O	0.18969	0.18362	0.18967	0.18962	0.18861	0.18683	0.13640	0.12169	0.12223	0.12607
H2S	0.00074	0.00076	0.00074	0.00074	0.00075	0.00075	0.00082	0.00085	0.00085	0.00086
NH3	0.00054	0.00044	0.00054	0.00053	0.00051	0.00048	0.00028	0.00021	0.00014	0.00009
N2	0.10914	0.10921	0.10914	0.10914	0.10915	0.10917	0.11195	0.11466	0.11463	0.11389
NA	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021	0.00000	0.00000	0.0	0.0
NACN	0.00006	0.00007	0.00006	0.00006	0.00006	0.00006	0.00000	0.00000	0.00000	0.0
NAH	0.00004	0.00003	0.00004	0.00004	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00141	0.00140	0.00141	0.00141	0.00141	0.00141	0.00000	0.00000	0.00000	0.00000
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00090	0.00089
NA2CO3(L)	0.0	0.0	0.0	0.0	0.0	0.0	0.00088	0.00090	0.0	0.0
OH	0.00003	0.00001	0.00003	0.00002	0.00002	0.00001	0.0	0.0	0.0	0.0
SH	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.00000	0.00000	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)
CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2
H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2	NO3	N2H4
N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)
NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)
NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3
S(S)	S(L)	S	SN	SO	SO2	SO3	S2	S2O	S8

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 29. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2) [50,000 psi]

PC = 50000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C	6.00000	H	7.36400	N	2.63580	O	10.27200	0.951500	-164700.000	S	298.15	0.0
FUEL	C	1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C	12.00000	H	11.00000	N	1.00000			0.007500	27900.000	S	298.15	0.0
FUEL	C	18.00000	H	14.00000	O	4.00000			0.030000	-200000.000	S	298.15	0.0
FUEL	NA	2.00000	S	1.00000	O	4.00000			0.005000	-326300.000	S	298.15	0.0
FUEL	CA	1.00000	C	1.00000	O	3.00000			0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL = 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7960	1.0021	1.0087	1.1238	1.3418	32.810	81.400	190.45	568.06
P, ATM	3402.28	1894.40	3395.17	3372.92	3027.59	2535.70	103.70	41.797	17.865	5.9893
T, DEG K	2380.2	2127.0	2379.3	2376.3	2327.7	2249.9	1284.6	1149.7	1069.7	983.7
RHO, G/CC	4.2545-1	2.6511-1	4.2474-1	4.2249-1	3.8713-1	3.3545-1	2.4702-2	1.1396-2	5.3754-3	2.0252-3
H, CAL/G	-594.6	-701.8	-595.0	-596.3	-616.9	-649.9	-1088.9	-1175.1	-1246.9	-1329.9
S, CAL/(G)(K)	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282
M, MOL WT	24.424	24.425	24.424	24.424	24.423	24.423	25.108	25.722	26.411	27.294
(DLV/DLP)T	-1.00260	-1.00285	-1.00261	-1.00260	-1.00260	-1.00264	-1.03690	-1.05417	-1.09833	-1.08789
(DLV/DLT)P	1.0124	1.0170	1.0124	1.0124	1.0129	1.0141	1.4498	1.7432	2.6354	2.5680
CP, CAL/(G)(K)	0.4316	0.4286	0.4316	0.4315	0.4305	0.4292	0.8520	1.2097	2.5065	2.5052
GAMMA (S)	1.2355	1.2399	1.2355	1.2356	1.2366	1.2381	1.1881	1.1627	1.1238	1.1158
SON VEL,M/SEC	1000.5	947.5	1000.3	999.7	989.9	973.8	710.9	657.3	615.2	578.2
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.861	3.353	3.798	4.290
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4503	4503	4503	4503	4503	4503	4503	4503	4503
CF		0.690	0.043	0.087	0.315	0.496	1.482	1.606	1.702	1.807
IVAC LB-SEC/LB		174.5	1402.3	705.9	230.9	184.1	228.7	242.0	252.9	265.3
ISP, LB-SEC/LB		96.6	6.0	12.1	44.1	69.4	207.4	224.8	238.3	252.9

TABLE 29. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[50,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02834	0.06626
CH2O	0.00012	0.00007	0.00012	0.00012	0.00011	0.00010	0.00001	0.00000	0.00000	0.00000
CH3	0.00001	0.00000	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.0	0.0
CH4	0.00035	0.00049	0.00035	0.00036	0.00037	0.00041	0.01357	0.02614	0.02496	0.02134
CO	0.45127	0.44495	0.45125	0.45118	0.45012	0.44828	0.38028	0.34734	0.29396	0.22753
COS	0.00010	0.00009	0.00010	0.00010	0.00010	0.00009	0.00006	0.00006	0.00005	0.00004
CO2	0.11071	0.11698	0.11073	0.11079	0.11183	0.11366	0.18274	0.21718	0.24204	0.27008
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00050	0.00051	0.00051	0.00051
CAO(S)	0.00025	0.00044	0.00026	0.00026	0.00031	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00023	0.00017	0.00011	0.0	0.0	0.0	0.0
H	0.00009	0.00003	0.00009	0.00009	0.00007	0.00005	0.00000	0.0	0.0	0.0
HCN	0.00022	0.00014	0.00022	0.00022	0.00020	0.00018	0.00001	0.00001	0.00000	0.00000
HCO	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00004	0.00002	0.00004	0.00004	0.00004	0.00003	0.00000	0.00000	0.00000	0.00000
H2	0.13455	0.14078	0.13457	0.13463	0.13571	0.13755	0.17025	0.16781	0.16793	0.16880
H2O	0.18976	0.18371	0.18974	0.18968	0.18868	0.18691	0.13817	0.12379	0.12535	0.12941
H2S	0.00074	0.00076	0.00074	0.00074	0.00075	0.00075	0.00082	0.00085	0.00085	0.00086
NH3	0.00067	0.00055	0.00067	0.00066	0.00064	0.00060	0.00032	0.00024	0.00016	0.00010
N2	0.10909	0.10919	0.10909	0.10909	0.10911	0.10914	0.11238	0.11517	0.11494	0.11417
NA	0.00018	0.00019	0.00018	0.00018	0.00019	0.00019	0.00000	0.00000	0.0	0.0
NACN	0.00008	0.00009	0.00008	0.00008	0.00008	0.00008	0.00000	0.00000	0.00000	0.0
NAH	0.00004	0.00003	0.00004	0.00004	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00142	0.00141	0.00142	0.00142	0.00142	0.00141	0.00000	0.00000	0.00000	0.00000
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00090	0.00090
NA2CO3(L)	0.0	0.0	0.0	0.0	0.0	0.0	0.00088	0.00090	0.0	0.0
OH	0.00002	0.00001	0.00002	0.00002	0.00002	0.00001	0.0	0.0	0.0	0.0
SH	0.00002	0.00001	0.00002	0.00002	0.00001	0.00001	0.00000	0.00000	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CN	CNN	CN2	CS	CS2	C2	C2H
C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4	C5
CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)	CAS(S)
CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2	H2SO4(L)
H2SO4	N	NCO	NH	NH2	NO	NO2	NO3	N2H4	N2O
N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)	NAOH(L)
NAO2(S)	NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)
NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3	S(S)
S(L)	S	SN	SO	SO2	SO3	S2	S2O	S8	

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 30. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 1 of 2)
[60,000 psi]

PC = 60000.0 PSIA

	CHEMICAL FORMULA							WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200				0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000					0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000					0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000					0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000					0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.7916	1.0021	1.0087	1.1237	1.3412	32.689	81.092	189.73	566.56
P, ATM	4082.74	2278.77	4074.16	4047.48	3633.43	3044.06	124.90	50.347	21.519	7.2062
T, DEG K	2381.4	2130.4	2380.4	2377.5	2329.0	2251.3	1294.6	1159.5	1079.2	991.5
RHO, G/CC	5.1057-1	3.1864-1	5.0970-1	5.0700-1	4.6460-1	4.0267-1	2.9626-2	1.3664-2	6.4435-3	2.4271-3
H, CAL/G	-594.6	-701.4	-595.0	-596.3	-616.9	-649.9	-1089.0	-1175.7	-1247.8	-1331.3
S, CAL/(G)(K)	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134
M, MOL WT	24.437	24.443	24.437	24.437	24.436	24.436	25.197	25.821	26.516	27.401
(DLV/DLP)T	-1.00337	-1.00529	-1.00337	-1.00337	-1.00338	-1.00346	-1.03984	-1.05577	-1.09795	-1.08747
(DLV/DLT)P	1.0163	1.0430	1.0164	1.0164	1.0172	1.0188	1.4825	1.7601	2.6136	2.5465
CP, CAL/(G)(K)	0.4335	0.4538	0.4335	0.4334	0.4326	0.4317	0.8789	1.2186	2.4511	2.4503
GAMMA (S)	1.2352	1.2340	1.2352	1.2353	1.2363	1.2377	1.1868	1.1626	1.1247	1.1166
SON VEL,M/SEC	1000.4	945.6	1000.2	999.6	989.8	973.7	712.0	658.8	616.9	579.6
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.857	3.347	3.790	4.284
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4504	4504	4504	4504	4504	4504	4504	4504	4504
CF		0.689	0.043	0.087	0.315	0.495	1.482	1.606	1.703	1.808
IVAC LB-SEC/LB		174.6	1403.1	706.1	231.0	184.2	228.8	242.1	253.2	265.5
ISP, LB-SEC/LB		96.4	6.0	12.1	44.1	69.4	207.4	224.9	238.4	253.2

TABLE 30. THEORETICAL ROCKET PERFORMANCE ASSUMING EQUILIBRIUM COMPOSITION DURING EXPANSION (page 2 of 2)
[60,000 psi]

MOLE FRACTIONS

C(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02991	0.06796
CH2O	0.00015	0.00009	0.00015	0.00015	0.00013	0.00011	0.00001	0.00000	0.00000	0.00000
CH3	0.00001	0.00000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.0	0.0
CH4	0.00050	0.00069	0.00050	0.00050	0.00053	0.00058	0.01535	0.02815	0.02617	0.02243
CO	0.45103	0.44477	0.45101	0.45095	0.44989	0.44805	0.37911	0.34606	0.29160	0.22525
COS	0.00010	0.00009	0.00010	0.00010	0.00010	0.00009	0.00006	0.00006	0.00005	0.00004
CO2	0.11100	0.11719	0.11102	0.11108	0.11212	0.11395	0.18414	0.21872	0.24299	0.27080
CACO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.00050	0.00052	0.00051	0.00051
CAO(S)	0.00025	0.00044	0.00025	0.00026	0.00031	0.00038	0.0	0.0	0.0	0.0
CAO2H2	0.00023	0.00005	0.00023	0.00023	0.00017	0.00011	0.0	0.0	0.0	0.0
H	0.00008	0.00003	0.00008	0.00008	0.00007	0.00005	0.00000	0.0	0.0	0.0
HCN	0.00027	0.00016	0.00027	0.00027	0.00024	0.00021	0.00001	0.00001	0.00000	0.00000
HCO	0.00003	0.00001	0.00003	0.00003	0.00002	0.00001	0.0	0.0	0.0	0.0
HNCO	0.00005	0.00003	0.00005	0.00005	0.00005	0.00004	0.00000	0.00000	0.00000	0.00000
H2	0.13410	0.14030	0.13412	0.13419	0.13526	0.13708	0.16633	0.16339	0.16372	0.16458
H2O	0.18984	0.18390	0.18982	0.18976	0.18876	0.18700	0.13964	0.12547	0.12791	0.13215
H2S	0.00075	0.00076	0.00075	0.00075	0.00075	0.00075	0.00082	0.00085	0.00086	0.00086
NH2	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	0.0	0.0	0.0	0.0
NH3	0.00079	0.00066	0.00079	0.00079	0.00076	0.00072	0.00036	0.00026	0.00018	0.00011
N2	0.10905	0.10919	0.10905	0.10906	0.10908	0.10911	0.11275	0.11560	0.11520	0.11441
NA	0.00017	0.00016	0.00017	0.00017	0.00017	0.00017	0.00000	0.00000	0.0	0.0
NACN	0.00009	0.00009	0.00009	0.00009	0.00009	0.00010	0.00000	0.00000	0.00000	0.0
NAH	0.00004	0.00002	0.00004	0.00004	0.00003	0.00003	0.0	0.0	0.0	0.0
NAOH	0.00142	0.00126	0.00142	0.00142	0.00142	0.00142	0.00000	0.00000	0.00000	0.00000
NA2CO3(S)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00090	0.00090
NA2CO3(L)	0.0	0.00009	0.0	0.0	0.0	0.0	0.00088	0.00091	0.0	0.0
OH	0.00002	0.00000	0.00002	0.00002	0.00002	0.00001	0.0	0.0	0.0	0.0
SH	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.0	0.0

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C	CH	CH2	CN	CNN	CN2	CS	CS2	C2	C2H
C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4	C5
CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CAO(L)	CAO	CAOH	CAO2H2(S)	CAS(S)
CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)	H2O2	H2SO4(L)
H2SO4	N	NCO	NH	NO	NO2	NO3	N2H4	N2O	N2O4
N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)	NAOH(L)	NAO2(S)
NA2	NA2CO3(S)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2
NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O	O2	O3	S(S)	S(L)
S	SN	SO	SO2	SO3	S2	S2O	S8		

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 31. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2)
[10,000 psi]

PC = 10000.0 PSIA

	CHEMICAL FORMULA					WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200		0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000					0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000			0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000			0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000			0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000			0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8011	1.0021	1.0088	1.1244	1.3436	36.112	97.734	259.84	937.99
P, ATM	680.46	377.81	679.02	674.55	605.19	506.46	18.843	6.9623	2.6188	0.7254
T, DEG K	2376.2	2115.8	2375.2	2372.1	2322.2	2242.2	1130.4	902.2	715.5	519.8
RHO, G/CC	8.5083-2	5.3054-2	8.4939-2	8.4489-2	7.7432-2	6.7110-2	4.9527-3	2.2929-3	1.0874-3	4.1470-4
H, CAL/G	-594.6	-702.2	-595.0	-596.3	-617.0	-650.2	-1088.5	-1170.7	-1234.9	-1299.1
S, CAL/(G)(K)	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593	2.1593
M, MOL WT	24.380	24.380	24.380	24.380	24.380	24.380	24.380	24.380	24.380	24.380
CP, CAL/(G)(K)	0.4163	0.4101	0.4163	0.4162	0.4151	0.4133	0.3679	0.3518	0.3362	0.3195
GAMMA (S)	1.2435	1.2480	1.2435	1.2435	1.2443	1.2457	1.2846	1.3016	1.3200	1.3426
SON VEL,M/SEC	1003.8	949.0	1003.6	1003.0	992.7	976.0	703.7	632.8	567.5	487.8
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.889	3.470	4.079	4.977
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4493	4493	4493	4493	4493	4493	4493	4493	4493
CF		0.693	0.043	0.087	0.317	0.498	1.485	1.603	1.690	1.773
IVAC LB-SEC/LB		174.3	1399.7	704.3	230.5	183.9	226.7	238.2	246.8	255.0
ISP, LB-SEC/LB		96.8	6.0	12.2	44.2	69.5	207.3	223.9	236.1	247.6

TABLE 31. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[10,000 psi]

MOLE FRACTIONS

CH2O	0.00003	CH4	0.00001	CO	0.45184	COS	0.00009
CO2	0.10986	CAO(S)	0.00026	CAO2H2	0.00023	H	0.00020
HCN	0.00005	HCO	0.00001	HNCO	0.00001	H2	0.13588
H2O	0.18956	H2S	0.00072	NH3	0.00014	N2	0.10930
NA	0.00038	NACN	0.00001	NAH	0.00003	NAOH	0.00129
OH	0.00005	SH	0.00003	SO	0.00001	SO2	0.00001

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2
C2	C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2
C4	C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO
CAOH	CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)
H2O(L)	H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2
NO3	N2H4	N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)
NAO	NAOH(S)	NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)
NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)
NA2SO4	O	O2	O3	S(S)	S(L)	S	SN	SO3	S2
S2O	S8								

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 32. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2) [20,000 psi]

PC = 20000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200					0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000								0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000						0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000						0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000						0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000						0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8010	1.0021	1.0088	1.1244	1.3436	36.097	97.680	259.65	937.13
P, ATM	1360.91	755.65	1358.01	1349.07	1210.37	1012.92	37.701	13.932	5.2413	1.4522
T, DEG K	2377.3	2117.0	2376.3	2373.2	2323.3	2243.3	1131.5	903.2	716.5	520.6
RHO, G/CC	1.7016-1	1.0610-1	1.6987-1	1.6897-1	1.5485-1	1.3421-1	9.9040-3	4.5851-3	2.1745-3	8.2921-4
H, CAL/G	-594.6	-702.2	-595.0	-596.3	-617.0	-650.2	-1088.6	-1170.8	-1235.1	-1299.3
S, CAL/(G)(K)	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028	2.1028
M, MOL WT	24.390	24.390	24.390	24.390	24.390	24.390	24.390	24.390	24.390	24.390
CP, CAL/(G)(K)	0.4163	0.4102	0.4163	0.4162	0.4152	0.4133	0.3680	0.3519	0.3363	0.3195
GAMMA (S)	1.2433	1.2479	1.2433	1.2434	1.2442	1.2455	1.2844	1.3013	1.3198	1.3423
SON VEL,M/SEC	1003.8	949.0	1003.6	1002.9	992.6	975.9	703.8	633.0	567.7	488.1
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.889	3.469	4.078	4.976
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4493	4493	4493	4493	4493	4493	4493	4493	4493
CF		0.693	0.043	0.087	0.316	0.498	1.485	1.603	1.690	1.773
IVAC LB-SEC/LB		174.3	1399.6	704.3	230.5	183.9	226.7	238.2	246.8	255.1
ISP, LB-SEC/LB		96.8	6.0	12.2	44.2	69.5	207.3	223.9	236.1	247.6

TABLE 32. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[20,000 psi]

MOLE FRACTIONS

CH2O	0.00005	CH4	0.00006	CO	0.45178	COS	0.00009
CO2	0.11001	CAO(S)	0.00026	CAO2H2	0.00023	H	0.00014
HCN	0.00009	HCO	0.00001	HNCO	0.00002	H2	0.13562
H2O	0.18959	H2S	0.00073	NH3	0.00027	N2	0.10924
NA	0.00028	NACN	0.00003	NAH	0.00003	NAOH	0.00137
OH	0.00004	SH	0.00002				

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2
C2	C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2
C4	C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO
CAOH	CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)
H2O(L)	H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2
NO3	N2H4	N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)
NAO	NAOH(S)	NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)
NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)
NA2SO4	O	O2	O3	S(S)	S(L)	S	SN	SO	SO2
SO3	S2	S2O	S8						

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 33. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2)
[30,000 psi]

PC = 30000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C	6.00000	H	7.36400	N	2.63580	O	10.27200	0.951500	-164700.000	S	298.15	0.0
FUEL	C	1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C	12.00000	H	11.00000	N	1.00000			0.007500	27900.000	S	298.15	0.0
FUEL	C	18.00000	H	14.00000	O	4.00000			0.030000	-200000.000	S	298.15	0.0
FUEL	NA	2.00000	S	1.00000	O	4.00000			0.005000	-326300.000	S	298.15	0.0
FUEL	CA	1.00000	C	1.00000	O	3.00000			0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8009	1.0021	1.0088	1.1244	1.3435	36.083	97.626	259.47	936.29
P, ATM	2041.37	1133.54	2037.01	2023.61	1815.57	1519.43	56.575	20.910	7.8675	2.1803
T, DEG K	2378.2	2117.9	2377.2	2374.1	2324.2	2244.3	1132.5	904.2	717.4	521.3
RHO, G/CC	2.5525-1	1.5915-1	2.5481-1	2.5346-1	2.3229-1	2.0132-1	1.4855-2	6.8770-3	3.2613-3	1.2436-3
H, CAL/G	-594.6	-702.2	-595.0	-596.3	-617.0	-650.1	-1088.6	-1170.9	-1235.2	-1299.5
S, CAL/(G)(K)	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698	2.0698
M, MOL WT	24.401	24.401	24.401	24.401	24.401	24.401	24.401	24.401	24.401	24.401
CP, CAL/(G)(K)	0.4164	0.4102	0.4164	0.4163	0.4152	0.4134	0.3681	0.3519	0.3363	0.3195
GAMMA (S)	1.2431	1.2477	1.2432	1.2432	1.2440	1.2453	1.2841	1.3011	1.3195	1.3421
SON VEL,M/SEC	1003.7	948.9	1003.5	1002.9	992.6	975.9	703.9	633.1	567.9	488.3
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.888	3.469	4.077	4.974
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4493	4493	4493	4493	4493	4493	4493	4493	4493
CF		0.693	0.043	0.087	0.316	0.498	1.485	1.603	1.690	1.773
IVAC LB-SEC/LB		174.3	1400.6	704.3	230.5	183.9	226.7	238.2	246.9	255.1
ISP, LB-SEC/LB		96.8	6.0	12.2	44.2	69.5	207.3	223.9	236.1	247.7

TABLE 33. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[30,000 psi]

MOLE FRACTIONS

CH2O	0.00007	CH4	0.00013	CO	0.45165	COS	0.00010
CO2	0.11021	CAO(S)	0.00026	CAO2H2	0.00023	H	0.00012
HCN	0.00014	HCO	0.00002	HNCO	0.00003	H2	0.13531
H2O	0.18964	H2S	0.00074	NH3	0.00040	N2	0.10919
NA	0.00023	NACN	0.00005	NAH	0.00003	NAOH	0.00140
OH	0.00003	SH	0.00002				

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2
C2	C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2
C4	C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO
CAOH	CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)
H2O(L)	H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2
NO3	N2H4	N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)
NAO	NAOH(S)	NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)
NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)
NA2SO4	O	O2	O3	S(S)	S(L)	S	SN	SO	SO2
SO3	S2	S2O	S8						

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 34. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2)
[40,000 psi]

PC = 40000.0 PSIA

	CHEMICAL FORMULA								WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200					0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000								0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000						0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000						0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000						0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000						0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8008	1.0021	1.0088	1.1243	1.3435	36.066	97.566	259.27	935.37
P, ATM	2721.83	1511.48	2716.03	2698.15	2420.81	2025.96	75.468	27.897	10.498	2.9099
T, DEG K	2379.2	2119.0	2378.2	2375.1	2325.2	2245.3	1133.6	905.2	718.3	522.1
RHO, G/CC	3.4035-1	2.1221-1	3.3977-1	3.3797-1	3.0973-1	2.6844-1	1.9806-2	9.1685-3	4.3480-3	1.6580-3
H, CAL/G	-594.6	-702.2	-595.0	-596.3	-617.0	-650.1	-1088.6	-1171.0	-1235.3	-1299.6
S, CAL/(G)(K)	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463	2.0463
M, MOL WT	24.412	24.412	24.412	24.412	24.412	24.412	24.412	24.412	24.412	24.412
CP, CAL/(G)(K)	0.4164	0.4103	0.4164	0.4163	0.4153	0.4134	0.3681	0.3520	0.3364	0.3195
GAMMA (S)	1.2430	1.2475	1.2430	1.2430	1.2438	1.2452	1.2839	1.3008	1.3192	1.3419
SON VEL,M/SEC	1003.6	948.9	1003.4	1002.8	992.5	975.8	704.1	633.3	568.1	488.5
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.888	3.468	4.076	4.972
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4494	4494	4494	4494	4494	4494	4494	4494	4494
CF		0.693	0.043	0.087	0.316	0.498	1.485	1.603	1.691	1.773
IVAC LB-SEC/LB		174.3	1400.3	704.3	230.5	183.9	226.7	238.3	246.9	255.2
ISP, LB-SEC/LB		96.8	6.0	12.2	44.2	69.5	207.3	223.9	236.1	247.7

TABLE 34. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[40,000 psi]

MOLE FRACTIONS

CH2O	0.00010	CH4	0.00023	CO	0.45147	COS	0.00010
CO2	0.11044	CAO(S)	0.00026	CAO2H2	0.00023	H	0.00010
HCN	0.00018	HCO	0.00002	HNCO	0.00004	H2	0.13495
H2O	0.18969	H2S	0.00074	NH3	0.00054	N2	0.10914
NA	0.00021	NACN	0.00006	NAH	0.00004	NAOH	0.00141
OH	0.00003	SH	0.00002				

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CH3	CN	CNN	CN2	CS	CS2
C2	C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2
C4	C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO
CAOH	CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)
H2O(L)	H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2
NO3	N2H4	N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)
NAO	NAOH(S)	NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)
NA2O(S)	NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)
NA2SO4	O	O2	O3	S(S)	S(L)	S	SN	SO	SO2
SO3	S2	S2O	S8						

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 35. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2)
[50,000 psi]

PC = 50000.0 PSIA

	CHEMICAL FORMULA						WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200			0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000						0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000				0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000				0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000				0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000				0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8006	1.0021	1.0088	1.1243	1.3434	36.048	97.500	259.04	934.36
P, ATM	3402.28	1889.50	3395.06	3372.73	3026.06	2532.56	94.382	34.895	13.134	3.6413
T, DEG K	2380.2	2120.1	2379.2	2376.2	2326.3	2246.4	1134.8	906.3	719.4	523.0
RHO, G/CC	4.2545-1	2.6527-1	4.2473-1	4.2248-1	3.8719-1	3.3557-1	2.4756-2	1.1460-2	5.4344-3	2.0721-3
H, CAL/G	-594.6	-702.1	-595.0	-596.3	-617.0	-650.1	-1088.7	-1171.0	-1235.4	-1299.8
S, CAL/(G)(K)	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282	2.0282
M, MOL WT	24.424	24.424	24.424	24.424	24.424	24.424	24.424	24.424	24.424	24.424
CP, CAL/(G)(K)	0.4165	0.4103	0.4165	0.4164	0.4153	0.4135	0.3682	0.3521	0.3364	0.3195
GAMMA (S)	1.2428	1.2473	1.2428	1.2428	1.2436	1.2450	1.2836	1.3005	1.3190	1.3416
SON VEL,M/SEC	1003.5	948.8	1003.3	1002.7	992.4	975.7	704.2	633.5	568.3	488.7
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.888	3.467	4.075	4.970
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4494	4494	4494	4494	4494	4494	4494	4494	4494
CF		0.693	0.043	0.087	0.316	0.498	1.485	1.604	1.691	1.774
IVAC LB-SEC/LB		174.3	1399.6	704.5	230.5	183.9	226.7	238.3	246.9	255.2
ISP, LB-SEC/LB		96.8	6.0	12.1	44.2	69.5	207.3	224.0	236.1	247.7

TABLE 35. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[50,000 psi]

MOLE FRACTIONS

CH2O	0.00012	CH3	0.00001	CH4	0.00035	CO	0.45127
COS	0.00010	CO2	0.11071	CAO(S)	0.00025	CAO2H2	0.00023
H	0.00009	HCN	0.00022	HCO	0.00002	HNCO	0.00004
H2	0.13455	H2O	0.18976	H2S	0.00074	NH3	0.00067
N2	0.10909	NA	0.00018	NACN	0.00008	NAH	0.00004
NAOH	0.00142	OH	0.00002	SH	0.00002		

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO	CAOH
CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)
H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NH2	NO	NO2	NO3
N2H4	N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO
NAOH(S)	NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)	NA2O(S)
NA2O(L)	NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4
O	O2	O3	S(S)	S(L)	S	SN	SO	SO2	SO3
S2	S2O	S8							

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

TABLE 36. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 1 of 2)
[60,000 psi]

PC = 60000.0 PSIA

	CHEMICAL FORMULA							WT FRACTION (SEE NOTE)	ENERGY CAL/MOL	STATE	TEMP DEG K	DENSITY G/CC
FUEL	C 6.00000	H 7.36400	N 2.63580	O 10.27200				0.951500	-164700.000	S	298.15	0.0
FUEL	C 1.00000							0.004000	0.0	S	298.15	0.0
FUEL	C 12.00000	H 11.00000	N 1.00000					0.007500	27900.000	S	298.15	0.0
FUEL	C 18.00000	H 14.00000	O 4.00000					0.030000	-200000.000	S	298.15	0.0
FUEL	NA 2.00000	S 1.00000	O 4.00000					0.005000	-326300.000	S	298.15	0.0
FUEL	CA 1.00000	C 1.00000	O 3.00000					0.002000	-287900.000	S	298.15	0.0

O/F= 0.0 PERCENT FUEL= 100.0000 EQUIVALENCE RATIO= 1.6846 PHI= 0.0 REACTANT DENSITY= 0.0

	CHAMBER	THROAT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT	EXIT
PC/P	1.0000	1.8005	1.0021	1.0088	1.1243	1.3434	36.029	97.432	258.81	933.30
P, ATM	4082.74	2267.54	4074.02	4047.23	3631.30	3039.16	113.32	41.904	15.775	4.3745
T, DEG K	2381.4	2121.3	2380.4	2377.3	2327.5	2247.6	1136.1	907.6	720.5	524.0
RHO, G/CC	5.1057-1	3.1833-1	5.0969-1	5.0699-1	4.6464-1	4.0269-1	2.9704-2	1.3750-2	6.5202-3	2.4861-3
H, CAL/G	-594.6	-702.1	-595.0	-596.3	-617.0	-650.1	-1088.7	-1171.1	-1235.6	-1300.0
S, CAL/(G)(K)	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134	2.0134
M, MOL WT	24.437	24.437	24.437	24.437	24.437	24.437	24.437	24.437	24.437	24.437
CP, CAL/(G)(K)	0.4165	0.4104	0.4165	0.4165	0.4154	0.4136	0.3683	0.3522	0.3365	0.3196
GAMMA (S)	1.2426	1.2471	1.2426	1.2426	1.2434	1.2448	1.2834	1.3002	1.3186	1.3413
SON VEL,M/SEC	1003.4	948.7	1003.2	1002.6	992.3	975.6	704.3	633.6	568.6	489.0
MACH NUMBER	0.0	1.000	0.059	0.119	0.437	0.699	2.887	3.466	4.073	4.968
AE/AT		1.0000	10.000	5.0000	1.5000	1.1000	5.0000	10.000	20.000	50.000
CSTAR, FT/SEC		4494	4494	4494	4494	4494	4494	4494	4494	4494
CF		0.693	0.043	0.087	0.316	0.498	1.485	1.604	1.691	1.774
IVAC LB-SEC/LB		174.3	1399.1	704.6	230.5	183.9	226.7	238.3	247.0	255.2
ISP, LB-SEC/LB		96.7	6.0	12.1	44.2	69.5	207.4	224.0	236.2	247.8

TABLE 36. THEORETICAL ROCKET PERFORMANCE ASSUMING FROZEN COMPOSITION DURING EXPANSION (page 2 of 2)
[60,000 psi]

MOLE FRACTIONS

CH2O	0.00015	CH3	0.00001	CH4	0.00050	CO	0.45103
COS	0.00010	CO2	0.11100	CAO(S)	0.00025	CAO2H2	0.00023
H	0.00008	HCN	0.00027	HCO	0.00003	HNCO	0.00005
H2	0.13410	H2O	0.18984	H2S	0.00075	NH2	0.00001
NH3	0.00079	N2	0.10905	NA	0.00017	NACN	0.00009
NAH	0.00004	NAOH	0.00142	OH	0.00002	SH	0.00001

ADDITIONAL PRODUCTS WHICH WERE CONSIDERED BUT WHOSE MOLE FRACTIONS WERE LESS THAN 0.50000E-05 FOR ALL ASSIGNED CONDITIONS

C(S)	C	CH	CH2	CN	CNN	CN2	CS	CS2	C2
C2H	C2H2	C2H4	C2H6	C2N	C2N2	C2O	C3	C3O2	C4
C5	CA(S)	CA(S)	CA(L)	CA	CACO3(S)	CACO3(S)	CAO(L)	CAO	CAOH
CAO2H2(S)	CAS(S)	CASO4(S)	CA2	HNO	HNO2	HNO3	HO2	H2O(S)	H2O(L)
H2O2	H2SO4(L)	H2SO4	N	NCO	NH	NO	NO2	NO3	N2H4
N2O	N2O4	N2O5	N3	NA(S)	NA(L)	NACN(S)	NACN(L)	NAO	NAOH(S)
NAOH(L)	NAO2(S)	NA2	NA2CO3(S)	NA2CO3(S)	NA2CO3(L)	NA2C2N2	NA2O(S)	NA2O(S)	NA2O(L)
NA2O	NA2O2(S)	NA2O2(S)	NA2O2H2	NA2SO4(S)	NA2SO4(S)	NA2SO4(S)	NA2SO4(L)	NA2SO4	O
O2	O3	S(S)	S(L)	S	SN	SO	SO2	SO3	S2
S2O	S8								

NOTE. WEIGHT FRACTION OF FUEL IN TOTAL FUELS AND OF OXIDANT IN TOTAL OXIDANTS

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