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Unidynamics Phoenix, inc.
PHOENIX, ARIZONA

(NASA-CR-161703) DEVELOPMENT, QUALIFICATION, AND DELIVERY OF A HYDROGEN BURNOFF IGNITER Final Report (Unidynamics/Phoenix) 37 p HC A03/MF A01 CSCL 21B

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24 March 1981

Unidynamics Phoenix, inc.

phoenix, arizona

UNIDYNAMICS DOCUMENT NO. DTR-149

FINAL REPORT ON DEVELOPMENT, QUALIFICATION, AND DELIVERY OF A HYDROGEN BURNOFF IGNITER

(NASA Contract No. NAS8-34195)

(Unidynamics Account No. C35-780)

Prepared For:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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TABLE OF CONTENTS

INTRODUCTION

Under Marshall Space Flight Center Contract NAS8-34195, Unidynamics/Phoenix, Inc. desiged, fabricated, and qualified the hydrogen burn-off igniter illustrated on the next page to MSFC-SPEC-541. This item is a pyrotechnic device used to burn off excess hydrogen gas near the Space Shuttle Main Engine (SSME) nozzle.

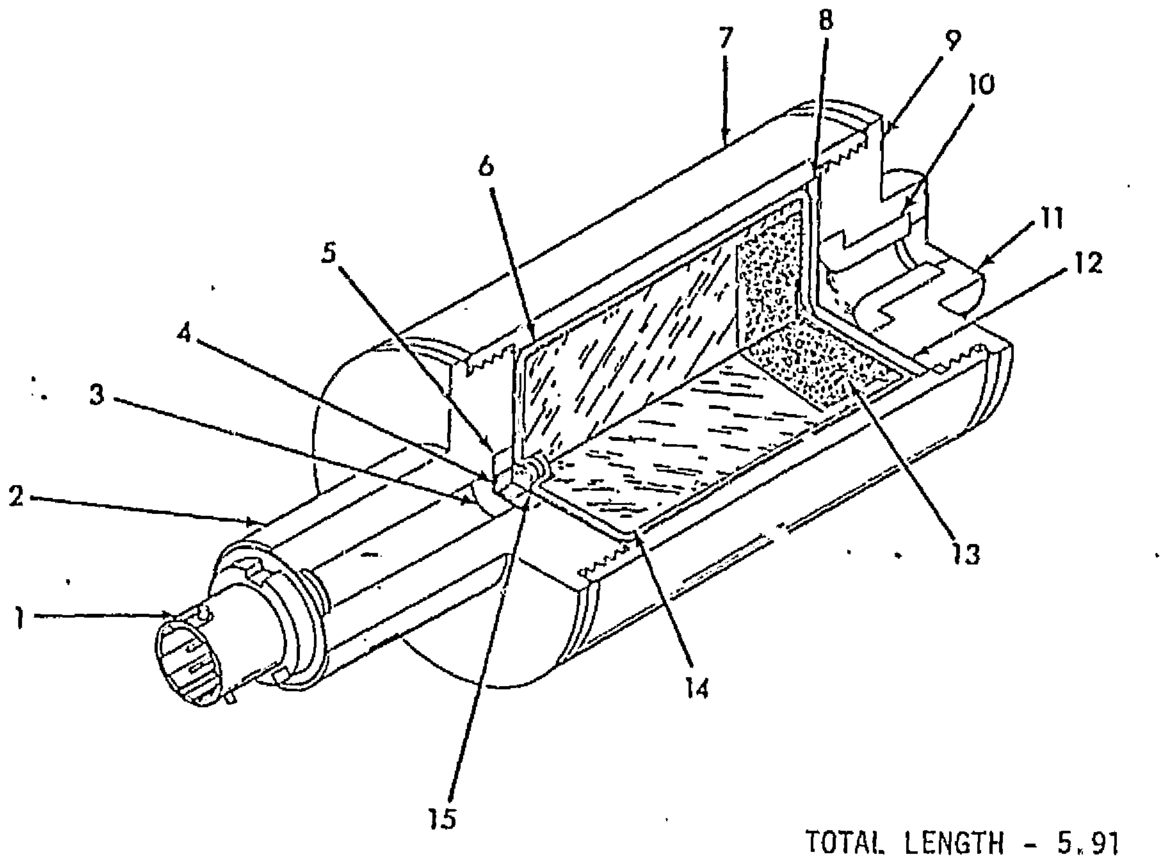
As set forth in the statement of work, the program was to be completed in four phases:

- Phase I - Material Study and Prototype Design
- Phase II - Prototype Fabrication, Development Testing, and Final Design
- Phase III - Fabrication
- Phase IV - Qualification Testing

MSFC-SPEC-541 specified that the burnoff igniter was to have a function time of 8 $\pm$ 2 seconds, a minimum three-foot flame length at maximum output, and hot particles projected 15 feet when fired directly into or perpendicular to a 34.5-knot wind. The three-foot flame requirement was considered to be of questionable importance, since the hot particles are the media for igniting the hydrogen. Flame temperature was to be greater than 1500°F. As shown by the qualification report*, all of these specifications were met.

Additional details are provided in subsequent sections.

*Unidynamics Document No. 51-1151-QTR-03.



TOTAL LENGTH - 5.91
DIAMETER - 2.00 Ø

LEGEND

1 - NSI
2 - ADAPTER
3 - ALUMINUM FOIL
4 - 107-PPR-02 (LOOSE LOAD)
5 - TRANSFER PELLET
6 - FITCO
7 - CASE
8 - PAD
9 - NOZZLE HOUSING
10 - NOZZLE
11 - WELDED CLOSURE DISK
12 - PAPER DISK
13 - GRAIN
14 - INHIBITOR
15 - ALUMINUM FOIL

51-1151
HYDROGEN BURNOFF IGNITER

PHASE I - MATERIAL STUDY

Since it was deemed desirable to eliminate all corrosive halides from the combustion products of the hydrogen burnoff igniter, the most promising propellant composition was a composite of potassium nitrate, a hydrocarbon fuel-binder, a high-combustion-temperature metal powder of appropriate particle size, and necessary ballistic additives to enhance ignition or modify burn rates.

Potassium nitrate was selected as the best candidate because of its relatively non-hygroscopic nature and established history of use in halogen-free propellants and ignition materials. It was felt, however, that the most widely used solid propellant oxidizers, such as ammonium perchlorate, should not be eliminated from this program even though they do produce small amounts of corrosive halides in the combustion process. Therefore, the potassium nitrate formulations and the ammonium perchlorate formulations were evaluated simultaneously.

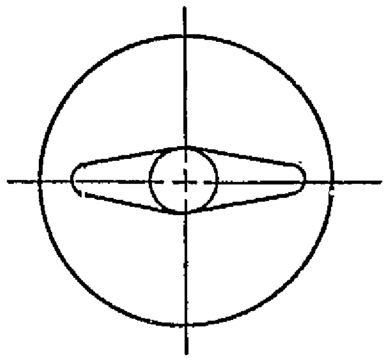
The oxidizer/fuel binder/ballistic additive combination functions as a propellant base to generate a controlled mass flow of hot gases to form a high velocity jet in the exit plume of the nozzle. This flow of high temperature, high velocity gases contains a flux of entrained burning particles of the metal fuel additive. These particles are ejected into the plume while still burning and continue on their respective flight paths for distances which are determined principally by their initial velocity, particle sizes, burning rates in air and the effects of wind velocities.

The NASA requirements of 8.0 $\pm$ 2 seconds burn time, spark projection of 15 feet minimum when fired directly into or perpendicular to a 34.5-knot wind, and particle temperature of 1500°F were all met under this program. Total cartridge burn time was controlled by grain web thickness, length of grain and nozzle opening. Several nozzle opening diameters and shapes were evaluated during the program in an effort to control the particle plume. The nozzle shaping configurations proved to be ineffective due primarily to the fact that the resulting nozzle opening was relatively small. Two of the tested nozzle configurations are illustrated on the next page.

Since it was still desirable to be able to reduce or eliminate errant sparks which traveled above the 28-inch height as measured from the centerline of the unit, a spark deflector which could easily be attached to the nozzle was designed. This deflector effectively controlled the errant sparks.

A series of small laboratory-size batches of propellants using various metals for the sparks were blended as a means of quickly evaluating spark characteristics. Zirconium, aluminum, iron and magnesium were evaluated. Zirconium proved to be the best candidate. Essentially two particle-size zirconiums were evaluated; the finer particles produced undesirable anomalies. Coarser grade zirconium, approximately 400-micron, produced good spark characteristics and was selected for the final design.

The computer analysis reproduced on the following pages was conducted for the final propellant system. The potassium nitrate and the ammonium perchlorate compositions evaluated during Phase I are discussed more thoroughly in the following sections.



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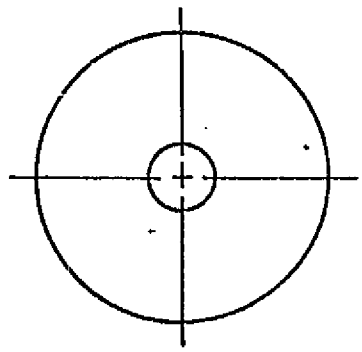

STRAIGHT

NOZZLE CONFIGURATIONS

CH3 M004 10/23/80

	DH	COMPOSITION
AMMONIUM PERCHLORATE (AP)	-602	1CL 4H 1N 4O
HTPB (SINCLAIR)	13	103H 73C 1O
ZIRCONIUM	0	1ZR
FERRIC OXIDE (ANHYDROUS)*	-1230	3O 2FE

INGRED. DENSITIES (RHO) ARE

.0704 .0332 .2311 .1818

INPUT PRESSURES (ATM)

3.4 1.0

INGRED.WTS.&TOTAL/ GRAM ATOMS/ CHAMBER/ EXHAUST RESULTS/PERFORMANCE

58.00000 18.00000 23.50000 .50000 100.00000

3.834792 H 1.318447 C .493630 N 2.001970 O .493630 CL
.006262 FE .257619 ZR

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
2674.	4354.	3.40	50.00	-35.30	229.08	1.2448	3.773	.901

1.49990 H2	1.29865 CO	.47018 HCL	.25681 ZRO2$
.24677 N2	.14845 H2O	.06615 H	.01972 CO2
.01458 CL	.00353 FECL2	.00257 FE	.00162 HO
7.3E-04 ZRCL2	1.2E-04 FECL	5.5E-05 ZRCL3	5.4E-05 NO
[illegible]	1.8E-05 FEO	1.7E-05 CNH	8.6E-06 CHO
7.4E-06 NH3	7.2E-06 CL2	4.2E-06 ZRO2	3.6E-06 ZRCL4
1.9E-06 O2	1.6E-06 NH	1.0E-06 CH2O	

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
2190.	3482.	1.00	14.70	-57.50	229.08	1.2499	3.738	.268

1.52693 H2	1.29474 CO	.47894 HCL	.25758 ZRO2$
.24680 N2	.14454 H2O	.02365 CO2	.01263 H
5.8E-03 FECL2	2.9E-03 CL	3.8E-04 FE	1.6E-04 HO
2.0E-05 FECL	1.3E-05 ZRCL2	5.3E-06 CNH	3.9E-06 NH3
3.1E-06 NO	2.9E-06 ZRCL3	1.1E-06 FEO	1.1E-06 CL2
1.0E-06 CHO			

IMPULSE	IS EX	T*	P*	CF	ISP*	OPT EX	D-ISP	A*M.	EX T
137.7	1.2494	2378.	1.89	.970		1.19	259.2	2.83896	2094.
139.0	1.1959	2449.	1.92	.962	179.0	1.20	261.7	2.89089	2190.

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OF POOR QUALITY

CH3 MOD4 10/23/80

	DH	COMPOSITION			
AMMONIUM PERCHLORATE (AP)	-602	1CL	4H	1N	4O
HTPB (SINCLAIR)	13	103H	73C	1O	
ZIRCONIUM	0	1ZR			
FERRIC OXIDE (ANHYDROUS)*	-1230	3O	2FE		

INGRED. DENSITIES (RHO) ARE

.0704 .0332 .2311 .1818

INPUT PRESSURES (ATM)

17.0 1.0

INGRED.WTS.&TOTAL/ GRAM ATOMS/ CHAMBER/ EXHAUST RESULTS/PERFORMANCE

58.00000 18.00000 23.50000 .50000 100.00000

3.834792 H 1.318447 C .493630 N 2.001970 O .493630 CL
.006262 FE .257619 ZR

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
2730.	4454.	17.01	250.00	-39.30	217.04	1.2427	3.753	4.531

1.51178 H2	1.29885 CO	.47263 HCL	.25637 ZRO2$
.24673 N2	.15040 H2O	.03653 H	.01945 CO2
8.0E-03 CL	5.1E-03 FECL2	1.1E-03 ZRCL2	1.0E-03 FE
9.5E-04 HO	1.5E-04 ZRCL3	9.8E-05 FECL	8.3E-05 CNH
[illegible]	3.3E-05 NO	2.2E-05 CHO	2.0E-05 ZRCL4
1.5E-05 O	8.7E-06 CL2	7.6E-06 FEO	5.1E-06 CH2O
3.0E-06 FECL3	2.2E-06 NH	1.7E-06 ZRO2	

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
1593.	2409.	1.00	14.70	-80.16	217.04	1.2632	3.729	.268

1.54510 H2	1.28168 CO	.48109 HCL	.25760 ZRO2$
.24680 N2	.13162 H2O	.03671 CO2	.00624 FECL2
1.2E-04 H	3.0E-05 CL	1.2E-05 NH3	6.6E-06 CNH
3.9E-06 CH4	1.3E-06 FECL3		

IMPULSE	IS EX	T*	P*	CF	ISP*	OPT EX	D-ISP	A*M.	EX T
195.8	1.2540	2422.	9.42	1.373		3.04	368.6	.57053	1538.
197.6	1.2226	2463.	9.53	1.371	179.5	3.07	371.9	.57664	1593.

```
CH3 MOD4   10/23/80

                                          DH    COMPOSITION

AMMONIUM PERCHLORATE (AP)               -602    1CL   4H   1N   4O
HTPB (SINCLAIR)                           13  103H   73C    1O
ZIRCONIUM                                  0    1ZR
FERRIC OXIDE (ANHYDROUS)*              -1230    3O   2FE

INGRED. DENSITIES (RHO) ARE
    .0704     .0332     .2311     .1818

INPUT PRESSURES (ATM)
   34.0    1.0

INGRED.WTS.&TOTAL/-GRAM ATOMS/ CHAMBER/ EXHAUST RESULTS/PERFORMANCE

58.00000  18.00000  23.50000    .50000 100.00000

3.834792 H    1.318447 C     .493630 N    2.001970 O     .493630 CL
 .006262 FE    .257619 ZR

T(K)  T(F)  P(ATM)   P(PSI) ENTHALPY  ENTROPY   CP/CV   GAS    RT/V
2747. 4485.  34.01   500.00   -35.30   211.88  1.2420  3.747   9.078

 1.51520 H2       1.29880 CO        .47322 HCL       .25616 ZRO2$
  .24668 N2        .15121 H2O       .02749 H         .01940 CO2
 6.0E-03 CL       5.5E-03 FECL2    1.2E-03 ZRCL2    7.3E-04 HO
 6.1E-04 FE       2.3E-04 ZRCL3    1.7E-04 CNH      8.1E-05 FECL
 7.1E-05 NH3      4.0E-05 ZRCL4    3.3E-05 CHO      2.6E-05 NO
 1.0E-05 CH2O     9.1E-06 CL2      8.5E-06 O        4.7E-06 FEO
 4.6E-06 FECL3    3.0E-06 CH4      2.4E-06 NH       1.0E-06 ZRO2

T(K)  T(F)  P(ATM)   P(PSI) ENTHALPY  ENTROPY   CP/CV   GAS    RT/V
1389. 2041.   1.00    14.70   -87.84   211.88  1.2666  3.729    .268

 1.55494 H2       1.27163 CO        .48111 HCL       .25760 ZRO2$
  .24679 N2        .12168 H2O       .04670 CO2       .00624 FECL2
 5.3E-05 CH4      2.3E-05 NH3      1.0E-05 H        7.8E-06 CNH
 2.6E-06 CL       1.5E-06 FECL3

IMPULSE  IS EX     T*      P*     CF    ISP*  OPT EX D-ISP   A*M.    EX T

 212.2  1.2529  2438.  18.86  1.484           4.89  399.5  .28608  1348.
 213.9  1.2400  2455.  18.94  1.491  179.4    4.97  402.5  .28684  1389.
```

CH3 MOD4 10/23/80

	DH	COMPOSITION			
AMMONIUM PERCHLORATE (AP)	-602	1CL	4H	1N	4O
HTPB (SINCLAIR)	13	103H	73C	1O	
ZIRCONIUM	0	1ZR			
FERRIC OXIDE (ANHYDROUS)*	-1230	3O	2FE		

INGRED. DENSITIES (RHO) ARE

.0704 .0332 .2311 .1818

INPUT PRESSURES (ATM)

68.0 1.0

INGRED,WTS,&TOTAL/-GRAM ATOMS/ CHAMBER/ EXHAUST RESULTS/PERFORMANCE

58.00000 18.00000 23.50000 .50000 100.00000

3.834792 H 1.318447 C .493630 N 2.001970 O .493630 CL
.006262 FE .257619 ZR

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
2760.	4508.	68.02	1000.00	-35.30	206.72	1.2415	3.742	18.180

1.51760 H2	1.29861 CO	.47355 HCL	.25592 ZRO2$
.24656 N2	.15206 H2O	.02038 H	.01939 CO2
5.8E-03 FECL2	4.4E-0[illegible] CL	1.3E-03 ZRCL2	5.5E-04 HO
3.5E-04 FE	[illegible] ZRCL3	3.3E-04 CNH	1.4E-04 NH3
8.1E-05 ZRCL4	[illegible] FECL	4.8E-05 CHO	2.1E-05 CH2O
2.0E-05 NO	1.1E-05 CH4	9.5E-06 CL2	6.8E-06 FECL3
4.7E-06 O	2.7E-06 FEO	2.6E-06 NH	

T(K)	T(F)	P(ATM)	P(PSI)	ENTHALPY	ENTROPY	CP/CV	GAS	RT/V
1203.	1706.	1.00	14.70	-94.52	206.72	1.2737	3.727	.268

1.56664 H2	1.25499 CO	.48111 HCL	.25760 ZRO2$
.24678 N2	.10750 H2O	.06211 CO2	.00623 FECL2
1.3E-03 CH4	5.0E-05 NH3	9.7E-06 CNH	1.7E-06 FECL3

IMPULSE	IS EX	T*	P*	CF	ISP*	OPT EX	D-ISP	A*M.	EX T
225.5	1.2558	2447.	37.68	1.578		7.98	424.5	.14294	1168.
227.0	1.2449	2460.	37.81	1.584	179.5	8.11	427.3	.14332	1203.

POTASSIUM NITRATE COMPSITIONS EVALUATED IN PHASE I

Table I summarizes this series of evaluations, and the individual compositions are discussed below.

Test No. 1 involved the following composition:

- 64.0% Potassium Nitrate
- 11.4% Hydroxyl-Terminated Polybutadiene (HTPB)
- 14.0% Zirconium (30-44 Micron)
- 6.0% Boron
- 2.5% Dimethyl Diisocyanate (DDI-1410)
- 2.0% Ferric Oxide
- 0.1% Antioxidant (CAO-14)

This composition was pressed into a pellet at 1500 psi. The pellet was then inhibited with a mixture of Epon 828 (50 percent) and Versamid 140 (50 percent). When fired, the propellant overpressurized in the test unit using a nozzle diameter of 0.200-inch (K_n49). The nozzle asssembly was expelled.

Test No. 2 used the following composition:

- 56.0% Potassium Nitrate
- 20.0% Powdered Sugar, commercial grade
- 16.0% Zirconium (-200/+325)
- 6.0% Polyester Resin
- 2.0% Ferric Oxide

This composition was pressed into a pellet at 10,000 psi and inhibited with a mixture of 50 percent Epon 828 and 50 percent Versamid 140. Overpressurization occurred in the test unit using a nozzle diameter of 0.200-inch (K_n49). The nozzle was expelled.

TABLE I - POTASSIUM NITRATE PROPELLANT TESTS

Test No.	Grain Comp.	Grain Length (Inches)	Grain Diameter (Inches)	Ignition Loose Load	Ignition Pellet	Nozzle I.D. (Inches)	Nozzle Config.	Kn	Closure Disk Thk (Inches)	FITCO Dia. (Inches)	Burn Time (sec)	Spark Dist. (Feet)	Flame Length (Feet)	COMMENTS
1	EL48832'	---	1.40	50 mg	1g w/1g buttered	0.200	(1)	49	0.002	0.030	----	----	----	Expelled nozzle assembly
2	EL48837	---	----	50 mg	460mg w/1g buttered	0.200	(1)	49	0.001	0.030	----	----	----	Expelled nozzle assembly
8	EL48843	1.030	1.344	50 mg	1g buttered	0.200	(2)	45	0.001	0.030	23.35	----	----	Stable--few sparks
10	EL48843	1.032	1.344	50 mg	1g buttered	0.200	(2)	45	0.001	0.030	22.78	----	----	Stable--few sparks
27	EL48857	1.170	1.40	50 mg	1g buttered	0.200	(2)	49	0.001	0.055	6.89	40-45'	1-2'	Stable--good sparks
30	EL48857	1.174	1.40	50 mg	1g buttered	0.150	(2)	87	0.001	0.055	3.45	45-50'	1-2'	Stable--good sparks
33	EL48861	1.90	1.397	50 mg	1g buttered	0.150	(2)	87	0.001	0.055	----	----	----	Expelled nozzle assembly
34	EL48861	1.48	1.398	50 mg	1g buttered	0.189	(2)	55	0.001	0.055	7.20	bunker*		Stable--good sparks
35	EL48861	1.51	1.396	50 mg	1 g	0.189	(2)	55	0.001	0.055	----	----	----	Expelled nozzle assembly
38	EL48861	1.402	1.345	50 mg	400 mg	0.250	(2)	29	0.001	0.055	10.60	bunker*		Stable--good sparks
40	EL48861	1.430	1.345	50 mg	400 mg	0.250	(2)	29	0.001	0.055	10.60	25-30'	1-2'	Stable--good sparks
41	EL48861	1.451	1.346	50 mg	400 mg	0.250	(2)	29	0.001	0.055	10.60	25-30'	1-2'	Stable--good sparks
42	EL48861	1.450	1.344	25 mg	400 mg	0.238	(2)	32	0.001	0.055	10.50	bunker*		Stable--good sparks
43	EL48861	1.450	1.345	25 mg	400 mg	0.238	(2)	32	0.001	0.055	10.60	bunker*		Stable--good sparks
45	EL48861	1.400	1.342	25 mg	400 mg	0.250	(2)	29	0.001	0.055	10.30	15-20'	1-2'	40 mph wind--6-10' spark deflection
46	EL48861	1.401	1.3[illegible]	25 mg	400 mg	0.250	(2)	29	0.001	0.055	10.36	15-20'	1-2'	42 mph wind--6-12' spark deflection
50	EL48861	1.447	1.344	25 mg	400 mg	0.250	(2)	29	0.001	0.055	10.60	15-25'	1-2'	38 mph wind--6-10' spark deflection
52	EL48861	1.400	1.342	25 mg	400 mg	0.250	(2)	29	0.001	0.055	10.00	20-25'	1-2'	20 mph wind--2-6' spark deflection
53	EL48861	1.480	1.342	25 mg	400 mg	0.250	(2)	29	0.001	0.055	10.90	20-25'	1-2'	20 mph wind --2-6' spark deflection
54	EL48861	1.100	1.350	25 mg	400 mg	0.221	(2)	29	0.001	0.055	7.57	bunker*		Stable--good sparks

NOTES: 1. ⊂○⊃ SHAPED NOZZLE OPENING.
2. ○ ROUND NOZZLE OPENING.
3. ALL GRAINS WERE INHIBITED WITH 50 PERCENT EPON 828, 50 PERCENT Versamid 40.
4. ALL IGNITION MATERIAL WAS 107-PPR-02.

*BUNKER - UNDERGROUND TEST BAY.

Tests 8 and 10 employed the following composition:

- 54.0% Potassium Nitrate (15.4-micron)
- 24.0% Powdered Sugar, commercial grade
- 14.0% Zirconium (Type I, Class 1)(approximately 400 micron)
- 8.0% Flucrel

Test Unit No. 8 was fabricated using a 0.200-inch diameter nozzle, (K_n45), and it burned for 23.35 seconds. The burn was stable, but spark output and projection were poor. Number 10 also had a 0.200-inch diameter nozzle (K_n45). This unit also produced poor sparks. Burn time was 22.78 seconds.

Tests 27 and 30 used the following composition:

- 41.39% Potassium Nitrate (15.4 Micron)
- 31.03% Zirconium (Type I, Class 1)(approximately 400 micron)
- 8.62% Magnesium
- 8.62% Powdered Sugar, commercial grade
- 8.62% Fluorel (10% solution in MEK)
- 1.72% Boron

The propellant was pressed at 10,000 psi and then inhibited using a mixture of 50 percent Epon 828 and 50 percent Versamid 140. Test Unit No. 27 had a 0.200-inch diameter nozzle (K_n49). A stable burn with good spark output was sustained for 6.89 seconds. Test Unit No. 30 had a 0.150-inch diameter nozzle (K_n87). A 3.45-second stable burn produced good spark output.

A total of 14 tests were conducted using the following propellant composition:

41.0% Potassium Nitrate
30.0% Zirconium (Type I, Class 1)(approximately 400 micron)
9.0% Magnesium
9.0% Powdered Sugar, commercial grade, with 3.0% cornstarch
9.0% Fluorel
2.0% Boron

All propellants in this series were inhibited using a mixture of 50 percent Epon 828 and 50 percent Versamid 140. Test No. 33 had a 0.150-inch diameter nozzle, (K_n 87), and the nozzle assembly was expelled during functioning.

Test Units 34 and 35 had 0.189-inch diameter nozzles. Test No. 34 had a 7.2-second burn with good spark output. The nozzle expelled on Unit 35 during functioning. As a result of the expulsion of nozzles, a brief analysis of the cause was conducted. It was felt that the reuse of hardware more than twice resulted in thread fatique, thus causing the nozzle housing to blow out. This problem was eliminated when new hardware was used exclusively for testing.

Tests 38, 40, 41, 45, 46, 50, 52, and 53 were conducted as above but with 0.250-inch diameter nozzles. All units produced good sparks with stable burns for the durations as listed below:

Unit No.	Burn Time (seconds)	Unit No.	Burn Time (seconds)
38	10.6	46	10.3
40	10.6	50	10.6
41	10.6	52	10.0
45	10.3	53	10.9

On October 24, 1980, Unidynamics conducted a series of tests for MSFC and Rockwell International. The tests were conducted in cross winds of 40 miles per hour and 20 miles per hour to evaluate the effects of the wind upon the sparks. Basically, the units performed very well under the effects of the wind. Units 45, 46, 50, 52 and 53 of the above group were fired into a cross wind with the following results:

Unit No.	Cross Wind Velocity	Spark Deflection
45	40 mph	6 to 10 feet
46	42 mph	6 to 12 feet
50	38 mph	8 to 10 feet
52	20 mph	2 to 6 feet
53	20 mph	2 to 10 feet

Although the cross wind did deflect the sparks, a significant number passed through a target placed seven feet away. Spar' projection was in excess of 15 feet.

Test Units 42 and 43 using the same propellant composition had 0.238-inch diameter nozzles and produced stable burns with good spark output. Test Unit. No. 42 had a burn time of 10.5 seconds, and Unit No. 43 burned for 10.6 seconds.

Test Unit No. 54 using the same propellant composition had a 0.221-inch diameter nozzle. It produced good spark output and burned for 7.57 seconds.

Although the potassium nitrate units performed well under the wind conditions, Unidynamics also tested the ammonium perchlorate compositions under the same conditions. Both compositions performed well with the potassium nitrate producing more smoke.

Since it was felt that the small amount of corrosive halides given off by the ammonium perchlorate compositions were insignificant, a decision was made to concentrate on the more widely used ammonium perchlorate system. In addition to the potassium nitrate compositions, one unit was fabricated (Test No. 28) using the following composition:

60.0%	47-PPR-01	
	42.0%	Magnesium Powder
	21.0%	Halon
	6.5%	Fluorel
	3.5%	Red Lead Oxide
	27.0%	Tetranitrocarbazole
40.0%	Zirconium (Type I, Class 1)	

This unit had a 0.125-inch diameter nozzle (K_n125). Burn time was 3.91 seconds. The burn was stable but with poor spark output.

AMMONIUM PERCHLORATE COMPOSITIONS EVALUATED IN PHASE I

Table II summarizes this series of evaluations, and the individual compositions are discussed below.

The ammonium perchlorate compositions evaluated were formulated using a bi-modal particle distribution of ammonium perchlorate, and a ground ammonium perchlorate system. Nozzle diameter variations were also evaluated. Test No. 3 had the following composition:

- 32.0% Ammonium Perchlorate
- 32.0% Ammonium Perchlorate (approximately 11 micron)
- 13.1% R-45M
- 19.0% Zirconium (-200/325 mesh)
- 2.8% DDI-1410
- 1.0% Ferric Oxide
- 0.1% CHO-14

This mixture was readily castable and burned vigorously with good sparks. However, Unit No. 3 with a 0.200-inch nozzle (K_n 49) expelled the nozzle. This phenomena was attributed to the multiple uses of the hardware causing structural fatique.

Test No. 4 had the following composition:

- 32.0% Ammonium Perchlorate
- 32.0% Ammonium Perchlorate (approximately 11 micron)
- 13.1% R-45M
- 12.0% Aluminum (Reynolds No. 40 - 30 ± 5 micron)
- 7.0% Aluminum (Reynolds No. 1-842)
- 2.8% DDI-1410
- 1.0% Ferric Oxide
- 0.1% CAO-14

TABLE II - AMMONIUM PERCHLORATE MIX PROPELLANT TESTS

Test No.	Grain Comp.	Grain Length (Inches)	Grain Diameter (Inches)	Ignition Loose Load	Ignition Pellet	Nozzle I.D. (Inches)	Nozzle Config.	Kn	Closure Disk Thk (Inches)	FITCO Dia. (Inches)	Burn Time (sec)	Spark Dist (ft)	Flame Length (Feet)	COMMENTS
3	EL48834	1.31		50 mg	1g buttered	0.200	(2)	49	0.001	0.030	----	----	----	
4	EL48831	1.30	1.395	50 mg	1g buttered	0.200	(2)	49	0.001	0.030	2.0	----	----	Stable burn--poor sparks
5	EL48839	0.950	1.334	50 mg	1g buttered	0.202	(2)	44	0.001	0.030	18.41	----	----	Stable burn--good sparks
6	EL48838	----	1.337	50 mg	1g buttered	0.200	(2)	44	0.001	0.030	30.0+	----	----	Chuffed (few sparks)
7	EL48838	1.150	1.336	50 mg	1g buttered	0.200	(2)	44	0.001	0.030	30.0	----	----	Chuffed (few sparks)
9	EL48841	1.20	1.358	50 mg	1g buttered	0.200	(2)	46	0.001	0.030	18.82	----	----	Chuffed good sparks
11	EL48841	1.19	1.335	50 mg	1g buttered	0.200	(2)	45	0.001	0.030	19.6	50'	1-2'	Stable---good sparks
12	EL48839	1.18	1.350	50 mg	1g buttered	0.200	(2)	45	0.001	0.030	21.27	30-35'	1-2'	Stable---good sparks
13	EL48839	1.08	1.350	50 mg	1g buttered	0.150	(1)	81	0.001	0.030	13.9	----	----	Stable---good sparks
14	EL48841	1.18	1.335	50 mg	1g buttered	0.150	(1)	79	0.001	0.030	7.3	----	----	Stable---good sparks
15	EL48841	1.13	1.335	50 mg	1g buttered	0.150	(1)	79	0.001	0.010	2.99	50'+	1-2"	Stable---good sparks
16	EL48839	1.15	1.350	50 mg	1g buttered	0.150	(1)	79	0.001	0.030	12.9	40-50'	1-2'	Stable---good sparks
17	EL48846	1.18	1.350	50 mg	1g buttered	0.200	(1)	46	0.001	0.030	19.9	35-40'	1'-1'6"	Stable---good sparks
18	EL48846	1.18	1.350	50 mg	1g buttered	0.150	(1)	81	0.001	0.030	11.74	50'	1-2'	Stable---good sparks
19	EL48846	1.18	1.350	50 mg	1g buttered	0.200	(1)	46	0.001	0.030	19.35	35-40'	1'-1'6"	Stable---good sparks
20	EL48846	1.20	1.350	50 mg	1g buttered	0.150	(1)	81	0.001	0.030	9.5	50'+	1-2'	Chuffed--good sparks
21	EL48852	0.70	1.350	50 mg	1g buttered	0.150	(2)	81	0.001	0.055	10.66	bunker*		Chuffed--deflection shield (4")
22	EL48852	0.70	1.350	50 mg	1g buttered	0.150	(2)	81	0.001	0.055	11.4	25-30'	1'-1'6"	Chuffed--deflection shield (4")
23	EL48852	0.70	1.340	50 mg	1g buttered	0.150	(1)	81	0.001	0.055	10.3	30'35'	1-2'	Chuffed
24	EL48852	0.70	1.340	50 mg	1g buttered	0.150	(1)	81	0.001	0.055	10.46	30-35'	1'-1'6"	Chuffed
25	EL48852	0.70	1.340	50 mg	1g buttered	0.150	(1)	81	0.001	0.055	9.9	25-40'	1'-1'6"	Deflection shield 1" long
26	EL48855	1.10	1.40	50 mg	1g buttered	0.150	(2)	81	0.001	0.055	21.2	25-30'	1'-0'	Fluttered--weak sparks
29	EL48858	1.12	1.340*	50 mg	1g buttered	0.200	(2)	46	0.001	0.055	1.8	50'+	2-3'	Stable---good sparks
31	EL48858	1.16	1.340*	50 mg	1g buttered	0.250	(2)	29	0.001	0.055	8.1	40-50'	1-2'	Stable---weak sparks
32	EL48858	1.202	1.354*	50 mg	1g buttered	0.221	(2)	37	0.001	0.055	---	40-50'	1-2'	
36	EL48865	1.20	1.353	50 mg	400 mg	0.125	(2)	117	0.001	0.055	3.52	bunker*		Stable---good sparks
37	EL48865	1.18	1.355	50 mg	400 mg	0.125	(2)	117	0.001	0.055	4.25	bunker*		Stable---good sparks
39	EL48858	1.50	1.353	50 mg	400 mg	0.234	(2)	33	0.001	0.055	11.31	bunker*		Stable---good sparks
44	EL48858	1.10	1.345*	25 mg	400 mg	0.234	(2)	33	0.001	0.055	8.2	bunker*		Stable---good sparks
47	EL48858	1.10	1.370*	25 mg	400 mg	0.234	(2)	33	0.001	0.055	8.3	15-20'	1-2'	40 mph wind 8 to 12 feet
51	EL48358	1.100	1.370*	25 mg	400 mg	0.234	(2)	23	0.001	0.055	8.87	15-20'	1-2'	50 mph wind 8 to 15 feet

NOTES: 1. SHAPED NOZZLE OPENING.
2. ROUND NOZZLE OPENING.
3. ALL GRAINS WERE INHIBITED WITH 50 PERCENT EPON 828, 50 PERCENT VERSAMID140.
4. ALL IGNITION MATERIAL WAS 107-PPR-02.

*BUNKER - UNDERGROUND TEST BAY.

TABLE II - AMMONIUM PERCHLORATE MIX PROPELLANT TESTS

Test No.	Grain Comp.	Grain Length (Inches)	Grain Diameter (Inches)	Ignition Loose Load	Ignition Pellet	Nozzle I.D. (Inches)	Nozzle Config.	Kn	Closure Disk Thk (Inches)	PITCO Dia. (Inches)	Burn Time (sec)	Spark Dist (ft)	Flame Length (Feet)	COMMENTS
55	EL48864	1.102	1.349	25 mg	400 mg	0.201	(2)	45	0.002	0.055	6.27	bunker		Stable--good sparks
56	EL48864	1.100	1.350	25 mg	400 mg	0.150	(2)	81	0.002	0.055	3.10	bunker		Stable--good sparks
57	EL48865	1.101	1.349	25 mg	400 mg	0.221	(2)	37	0.002	0.055	8.41	25-30'	1-1'6"	Stable--good sparks
58	EL48865	1.10	1.350	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.33	30-35'	1-2'	Stable--good sparks
59	EL48865	1.102	1.350	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.74	30-35'	1-2'	Stable--good sparks
60	EL48865	1.102	1.352	25 mg	400 mg	0.221	(2)	37	0.002	0.055	8.02	25-30'	1-2'	Stable--good sparks
61	EL48865	2.402	1.351	25 mg	400 mg	0.161	(2)	70	0.002	0.055	8.82	40-50'	1-2'	Stable--good sparks
62	EL48865	2.401	1.348	25 mg	400 mg	0.161	(2)	70	0.002	0.055	8.45	45-50'	1-2'	Stable--good sparks
63	EL48865	1.101	1.348	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.96	40-50'	1-2'	Stable--good sparks
64	EL48865	2.361	1.350	25 mg	400 mg	0.161	(2)	70	0.002	0.055	2.44	50-60'	2-3'	Inhibitor breakdown
65	EL48863	1.105	1.348	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.98	30-35'	1-2'	Stable--good sparks
66	EL48863	1.100	1.351	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.88	30-35'	1-2'	Stable--good sparks
67	EL48868	1.101	1.345	25 mg	400 mg	0.221	(2)	37	0.002	0.055	7.74	30-35'	1-2'	Stable--good sparks

NOTES: 1. ◯◯ SHAPED NOZZLE OPENING.
2. ◯ ROUND NOZZLE OPENING.
3. ALL GRAINS WERE INHIBITED WITH 50 PERCENT EPON 828, 50 PERCENT VERSAMID140.
4. ALL IGNITION MATERIAL WAS 107-PPR-02.

*BUNKER - UNDERGROUND TEST BAY.

This composition was readily castable, and stable burning, but spark output was poor. The unit had a 0.200-inch diameter nozzle and burned for 2.0 seconds. Since the sparks produced were poor, aluminum was eliminated from further development activitiy.

Test Numbers 5, 12, 13, and 16 featured the following composition:

- 29.0% Ammonium Perchlorate
- 29.0% Ammonium Perchlorate (approximately 11 micron)
- 24.0% Zirconium (Type I, Class 1)
- 14.8% R-45M
- 3.2% DDI-1410

This composition was readily castable. Unit No. 5 had a 0.200-inch diameter nozzle (K_n44) and produced a stable burn and good sparks for 18.41 seconds. Test Unit No. 12 also had a 0.200-inch diameter nozzle (K_n45), and its burn time was 21.27 seconds with good stability and output. Test Unit 13 had a 0.150-inch diameter nozzle (K_n81), and its burn time was 13.9 seconds. Test Unit 16 had a 0.150-inch diameter nozzle (K_n79) and a burn time of 12.9 seconds. Both units produced good sparks with a stable burn.

Tests 6 and 7 evaluated the following composition:

- 58.0% Ammonium Perchlorate, ground approximately 11 micron)
- 24.0% Zirconium (-200/+325 mesh)
- 14.8% R-45M
- 3.2% DDI-1410

Both units had 0.200-inch diameter nozzles (K_n44), and both had burn times of 30 seconds plus. However, the units chuffed during burn, and few sparks were produced.

Tests 9, 11, 14, and 15 were conducted with units incorporating the following propellant composition:

- 32.0% Ammonium Perchlorate
- 32.0% Ammonium Perchlorate (11 micron)
- 20.0% Zirconium (Type I, Class 1)
- 13.2% R-45M
- 2.8% DDI-1410

Unit No. 9, with a 0.200-inch diameter nozzle (K_n46), had a burn time of 18.82 seconds. It chuffed during burn, but spark output was good. Unit No. 11 also had a 0.200-inch diameter nozzle (K_n45), and it burned for 19.6 seconds. The spark output was good and the burn was stable.

Test Units 14 and 15 had 0.150-inch diameter nozzles (K_n79). Unit No. 14 had a burn time of 7.30 seconds, and Unit No. 15 had a burn time of 2.99 seconds. Both units burned stably with good spark output.

The following propellant mix was used in Tests 17, 18, 19 and 20:

- 24.0% Ammonium Perchlorate
- 40.0% Ammonium Perchlorate (11 micron)
- 20.0% Zirconium (Type I, Class 1)
- 13.2% R-45M
- 2.8% DDI-1410

Units 17 and 19 had 0.200-inch diameter nozzles (K_n46) and produced burn times of 19.90 and 19.35 seconds, respectively. Both units had stable burns with good spark output. Unit No. 18 had a 0.150-inch diameter nozzle (K_n 81) and burned stably for 11.74 seconds with good spark output.

Unit No. 19 had a 0.150-inch diameter nozzle (K_n81) and produced a burn time of 9.50 seconds. This unit chuffed, but spark output was good.

The following propellant composition was used for Tests 21, 22, 23, 24, and 25:

- 29.0% Ammonium Perchlorate
- 29.0% Ammonium Perchlorate (11 micron)
- 24.0% Zirconium (Type I, Class 1) (approximately 400 micron)
- 14.7% R-45M
- 3.2% DDI-1410
- 0.1% CAO-14

All five units had 0.150-inch diameter nozzles (K_n81). With the exception of Test No. 25, all units chuffed for approximately two seconds after ignition and then burned stably for the remainder of function. This indicated slight nozzle plugging. Unit No. 25 had a stable burn throughout. All units had good spark output, and burn times were 10.66, 11.40, 10.30, 10.46, and 9.90 seconds, respectively.

Units 21 and 22 incorporated a four-inch long deflector shield made from 0.010-inch thick stainless steel. This produced no significant deflection in the spark pattern, because the 0.010-inch thick stainless steel shield would not withstand the heat. Unit 25 had a one-inch long deflector shield made from 0.010-inch stainless steel. It also proved ineffective. A thicker walled deflector was later fabricated which did significantly reduce the errant sparks.

At this point in the program, the bi-modal particle size distribution of ammonium perchlorate was discontinued in favor of the ground perchlorate for burn rate enhancement.

Considerable effort was expended in selection of the proper propellant composition, inhibitor material, nozzle configuration and the addition of a small amount of ferric oxide to act as a burn rate catalyst. The final propellant composition developed for this program was designated CH_3 MOD 4 and has the following ingredients:

- 58.0% Ammonium Perchlorate, (ground approximately 12 micron)
- 23.5% Zirconium, Type I, Class 1
- 14.8% Hydroxy-terminated Polybutadiene
- 3.2% DDI-1410 Catalyst
- 0.5% Ferric Oxide

The final nozzle diameter was 0.221-inch, (K_n 37). All tests produced stable burns and good spark projection. Additional discussion of burn characteristics is provided in the next section.

A total of 10 units were fabricated and shipped to Santa Susana Field Laboratory and NSTL.

PHASE II - PROTOTYPE FABRICATION AND DEVELOPMENT TESTING, AND FINAL DESIGN

This phase encompassed preparation of final drawings, the acceptance test procedure, RIOS, and manufacturing process procedures. The documents were presented to MSFC in a design review meeting on November 10 and 11, 1980. Recommended changes were incorporated and these documents were submitted for final approval on November 19, 1980. Final approval was granted on November 24, 1980.

As specified in MSFC-SPEC-541, the NSI igniter cartridge fifty-percent fire point tests were conducted on November 11. Twenty units functioned at a distance of 2.23 inches, which is an increase of one inch above normal. No further tests were conducted, since all units functioned.

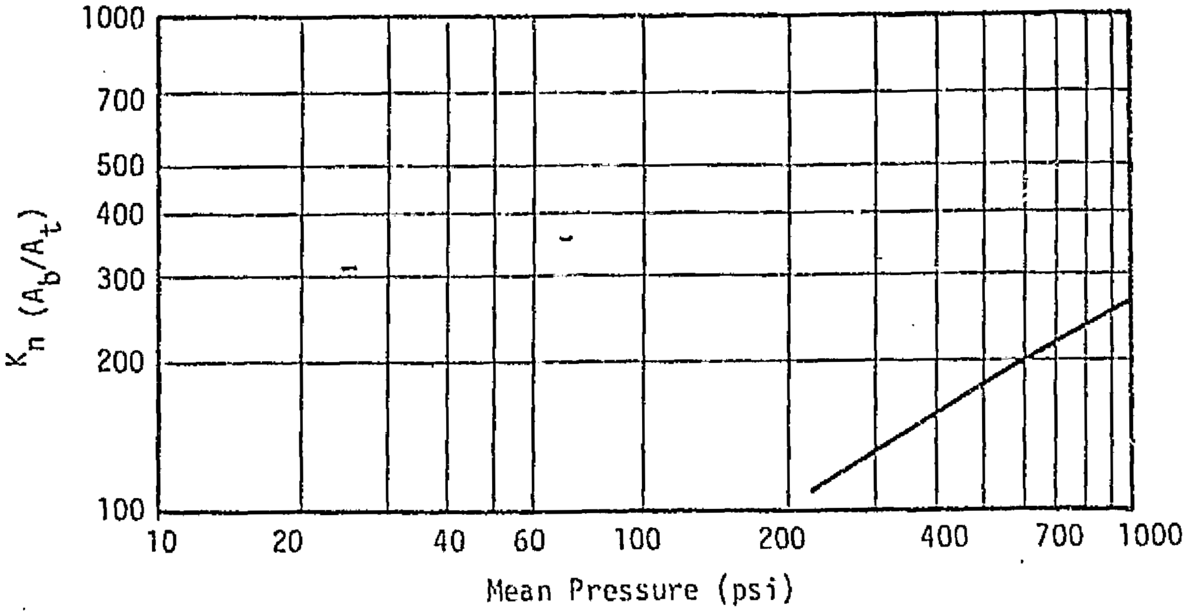
K_n motor testing was conducted on November 25. Internal/external burning centrally perforated grains with both ends inhibited were tested in the 30-3738 K_n motor. Results are tabulated below and shown graphically on the next page.

Test No.	Grain OD x ID x Length (inches)	K_n	Max. Pressure (psig)	P (psig)	Action Time (sec)	Burn Rate (in/sec)
1	0.935 x 0.250 x 0.904	193	728	583	0.345	0.50
2	0.945 x 0.250 x 0.505	109	312	224	0.461	0.38
3	0.922 x 0.375 x 1.103	258	1230	963	0.242	0.57

Strand burning rate tests were also conducted on November 19. The propellant strands were inhibited with two coats of 50/50 Epon 828/Versamid 140 with two percent carbon black added.

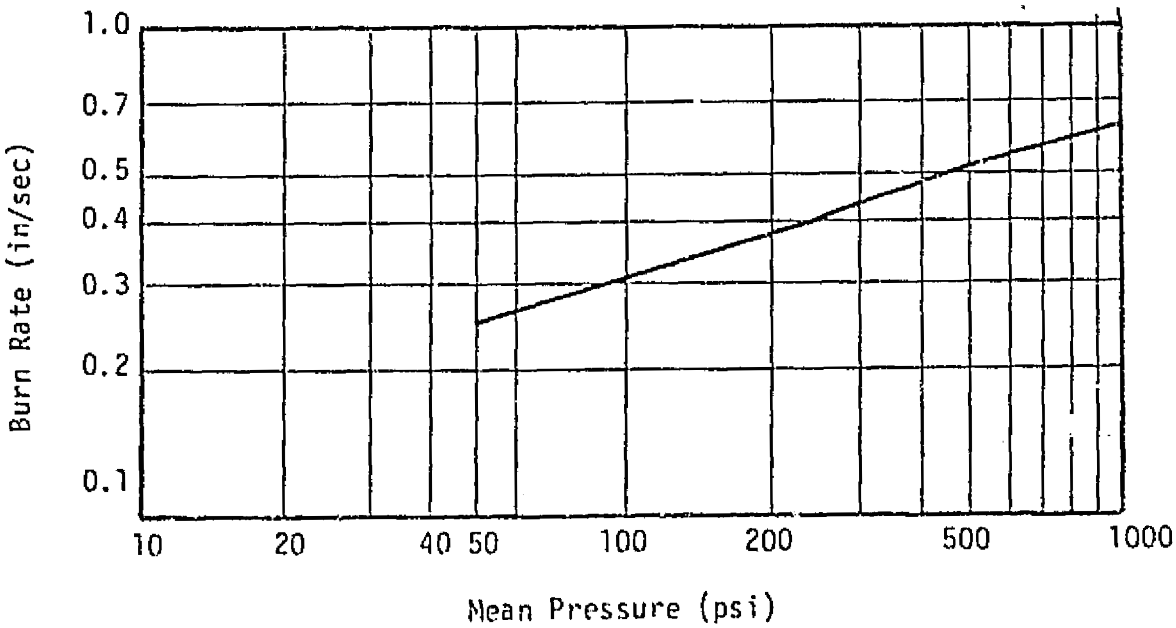
PROPELLANT COMPOSITION - CH_3 MOD 4

PROPELLANT LOT NO. - EL48868



K_n VERSUS MEAN PRESSURE

Pressure	K_n
224	109
583	193
963	258



BURN RATE VERSUS PRESSURE

50 psi - 0.25 in/sec

250 psi - 0.40 in/sec

500 psi - 0.51 in/sec

1000 psi - 0.61 in/sec

Strands were burned under nitrogen in the low pressure bomb. Results are tabulated below and shown graphically on the previous page.

Pressure (psig)	Length (in)	Time (sec)	Rate (in/second)	
1,000	1.90	3.157	0.602	>0.61
1,000	1.90	3.094	0.614	
500	1.93	3.688	0.523	
500	2.00	4.137	0.483	>0.51
500	2.00	3.802	0.526	
250	2.00	5.147	0.389	>0.40
250	2.00	4.891	0.409	
50	1.95	7.208	0.271	>0.25
50	1.90	8.052	0.236	

One lot of 28 igniter cartridges were fabricated in December 1980 using accepted process procedures. Before pre-qualification testing the lot was subjected to the 100-percent acceptance tests described below and outlined by the table on the next page.

Visual Mechanical. Each NSI igniter cartridge was inspected for conformance to workmanship, dimensional, and marking requirements of Drawing 51-1151, Revision A. Five units (S/N 111, 112, 114, 125, and 129) failed this test. Units 111 and 114 had a small crack in the adapter. Units 112, 125, and 129 had a small crack in the nozzle housing. These cracks would cause the units to fail the leak tests. MSFC gave approval to use these units in test. Six additional units had voids or blow holes in the weld area which could not be sealed. These units were also approved for test by MSFC since the leaks would not affect performance.

Unit S/N	Grain S/N	NSI S/N	Visual/ Mechanical	NSI Flight Cert.	NSI Staking Verif.	Gross Leak Test(1)		Helium Leak Test	X-Ray	B/W ohms Resistance	Insulation Resistance 50VDC	DISPOSITION Qual	Shipment
109 NSI 1864	109	1864	P	X	X	F	F	F	X	0.990	P	X	NA
110 NSI 1867	110	1867	P	X	X	F	P	P	X	0.989	P	NA	X
111 NSI 1868	111	1868	(2)	X	X	F (2)	—	F	X	0.994	P	X	NA
112 NSI 1869	112	1869	(3)	X	X	F (3)	—	F	X	0.975	P	X	NA
113 NSI 1870	113	1870	P	X	X	P	—	P	X	0.997	P	NA	X
114 NSI 1871	114	1871	(2)	X	X	F	F	F	X	0.992	P	X	NA
115 NSI 1872	115	1872	P	X	X	F	P	P	X	0.999	P	NA	X
116 NSI 1873	116	1873	P	X	X	F	P	P	X	0.988	P	NA	X
117 NSI 1875	117	1875	P	X	X	P	—	P	X	0.993	P	(4)	—
118 NSI 1876	118	1876	P	X	X	P	—	P	X	0.991	P	NA	X
118 NSI 1895	119	1895	P	X	X	P	—	P	X	0.980	P	NA	X
120 NSI 1878	120	1878	P	X	X	F	P	P	X	0.973	P	NA	X
121 NSI 1879	121	1879	P	X	X	P	—	P	X	0.995	P	NA	X
122 NSI 1880	122	1880	P	X	X	P	—	P	X	1.005	P	NA	X
123 NSI 1881	123	1881	P	X	X	F (6)	F	F	X	0.985	P	X	NA
124 NSI 1882	124	1882	P	X	X	F (6)	F	F	X	0.998	P	X	NA
125 NSI 1883	125	1883	(3)	X	X	F (3)	—	F	X	1.003	P	X	NA
126 NSI 1886	126	1886	P	X	X	F	P	P	X	1.004	P	(4)	—
127 NSI 1887	127	1887	P	X	X	F (6)	F	F	X	0.990	P	X	NA
128 --- ---	128	---	---	---	---	---	---	---	---	---	---	Scrap (5)	---
129 NSI 1889	129	1889	(3)	X	X	F (3)	---	F	X	0.986	P	X	NA
130 NSI 1890	130	1890	P	X	X	F (6)	F	F	X	0.997	P	X	NA
131 NSI 1891	131	1891	P	X	X	F	P	P	X	1.000	P	NA	X
132 NSI 1892	132	1892	P	X	X	P	---	P	X	0.996	P	NA	X
133 NSI 1893	133	1893	P	X	X	P		P	X	1.004	P	NA	X
134 NSI 1888	134	1888	P	X	X	F	F	F	X	0.983	P	X	NA
135 NSI 1895	135	1895	GRAIN ACCEPTANCE TEST			---	---	---	---	1.002	---	---	---
136 NSI 1896	136	1896	GRAIN ACCEPTANCE TEST			---	---	---	---	0.985	---	---	---

1 If units failed the gross leak test the first time they were rewelded then retested. Units that failed the second time were used in Mini-Qual Testing.

2 Adapter Crack

3 Nozzle Housing crack

4 Unit passed all test - carried over into next lot

5 Inhibiter cracked during machining

6. Weld Leak

NSI Flight Certification. Verification was made that each cartridge was listed by serial number and lot number in the NASA Flight Certification Document (P/N SEB 261-0000-1).

NSI Staking Verification. Verification was made that all units were welded to the initiator adapter for hermetic sealing per NASA/JSC Drawing SED 261-0000-1.

Leak Tests. Maximum allowable leakage was 1×10^{-6} cc per second of helium measured at one atmosphere differential pressure and at ambient temperature. Twenty-five igniter cartridges were subjected to the gross leak check per Paragraph 4.1.4.2 of Unidynamics' Document 51-1151-ATP-01. Eleven units failed. These units were used as the eleven test units in the pre-qualification series. The same group of 25 units was also subjected to the helium leak test per Paragraph 4.1.4.3. of Unidynamics' Document 51-1151-ATP-01. The eleven units that failed the gross leak also failed the helium leak. (See Visual/Mechanical paragraph.)

Radiograph Inspection. Each igniter cartridge was X-rayed for evidence of visual defects, missing components, cracks, and voids. None were found.

Bridgewire Resistance. All units were within the specified resistance of 0.95 to 1.15 ohms.

Insulation Resistance. All units passed an insulation resistance test measured between the shorted bridgewire circuit and the igniter body. Resistance was greater than two megohms (25 microamperes) at 50 VDC. The eleven units designated for prequalification testing passed the 125 microamperes (2 megohms minimum) at 250 VDC except for S/N 123 (NSI S/N 1887) and 129 (NSI S/N 1889) which failed. MSFC authorized use of the units for testing.

Prequalification Testing. Two, S/N 135 and 136, of the original lot of 28 units were used by Unidynamics in grain acceptance tests. Recorded burn times were 8.20 and 8.00 seconds, respectively.

As outlined in the flow chart and table of results on the next two pages, four units (S/N 114, 123, 125, and 129) were functioned at ambient temperature with no wind. Results were satisfactory as outlined below:

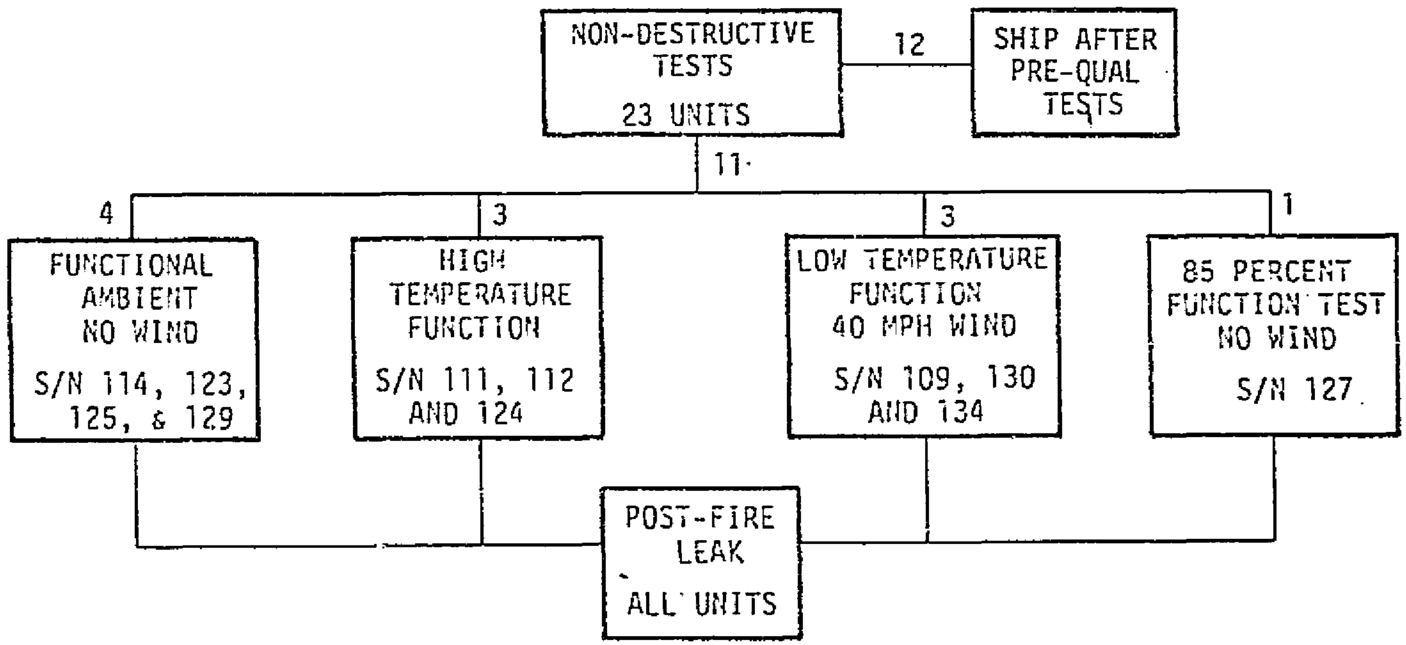
S/N	Burn Time (seconds)
114	7.96
123	7.84
125	8.31
129	7.95

Spark Pro ection was in excess of 15 feet.

Three units (S/N 111, 112, and 124) were functioned at high temperature (+150°F) with a 40-mile-per-hour cross wind. Results were satisfactory as outlined below:

S/N	Burn Time (seconds)
111	7.39
112	7.17
124	7.17

Spark projection was in excess of 15 feet.



PRE-QUALIFICATION TESTS

BLI 7 -QU :FI IOI EST SU

P=Passed F=Failed

Unit S/N	Grain S/N	NSI S/N	Insul. Resist. 250 VDC	FUNCTIONAL TEST			Burn Time(sec)	15 Ft. Particle Projection	Post Fire Leak	Wind Velocity
				Ambient Temp.	Low Temp. +20	High Temp.+150				
109 NSI 1864	109	1864	P	---	X	---	8.26	X	P	40 mph
111 NSI 1868	111	1868	P	---	---	X	7.39	X	F	40 mph
112 NSI 1869	112	1869	P	---	---	X	7.17	X	F	40 mph
114 NSI 1871	114	1871	P	X	---	---	7.96	X	F	----
123 NSI 1881	123	1881	F	X	---	---	7.84	X	F	----
124 NSI 1882	124	1882	P	---	---	X	7.17	X	F	40 mph
125 NSI 1883	125	1883	P	X	---	---	8.31	X	F	----
127 NSI 1887	127	1887	P	X	---	---	5.67 (1)	X	P	----
129 NSI 1889	129	1889	F	X	---	---	7.95	X	F	----
130 NSI 1890	130	1890	F	---	X	---	8.37	X	P	40 mph
134 NSI 1888	134	1888	P	---	X	---	8.39	X	F	40 mph
135 NSI 1895	135	1895	---	X	---	---	8.20	X	---	----
136 NSI 1896	136	1896	---	X	---	---	8.00	X	---	----

1. 85% Load Test Unit (Grain length reduced 15 percent)

Three units (S/N 109, 130, and 134) were functioned at low tempera'ure (+20°F) with a 40-mile-per-hour cross wind. Results were satisfactory as outlined below:

S/N	Burn Time (seconds)
109	8.23
130	8.37
134	8.39

Spark projection was in excess of 15 feet.

Eighty-five Percent Load Test. One unit, S/N 127, was manufactured with an 85 percent nominal output charge to verify that it would still perform within specifications. Burn time was 5.67 seconds, and spark projection was in excess of 15 feet. This unit passed the post-fire leak test.

All pre-qualification units functioned properly, producing high density sparks. In units tested under 40-mile-per-hour winds, sparks drifted approximately 10 feet; however, a significant number of sparks were not affected by the wind and traveled through the center of the target area placed 15 feet from the unit.

During these tests a deflector was installed on the nozzle of the igniter in an attempt to eliminate the errant sparks which traveled above the 28-inch height desired at the 15-foot distance. The deflector was successful in eliminating these sparks. On December 15 approval was given to proceed with design, fabrication, and shipment of six deflectors.

After pre-qualification was completed, twelve units were shipped.

PHASE III - FABRICATION AND QUALIFICATION TESTING

A total of 46 units were fabricated in accordance with Unidynamics' Drawing 51-1151 and Unidynamics' Manufacturing Procedures (51-1151, Revision B). Of these, 21 were to go into lot qualification and 20 units were for shipment. The qualification report is Unidynamics' Document Number 51-1151-QTR-03. Twenty-four units were shipped after qualification testing.

For convenient reference, qualification results are outlined on the next page.

TABLE V QUALIFICATION TEST RESULTS

Unit S/N	Grain S/N	NSI S/N	Salt Fog	Auto Ignition	Vibration Test	Thermal Shock	Drop Test	Gross Leak Test	Helium Leak Test	Insul. Resist. 250 VDC	Functional Test: Low Temp. +20°F	Functional Test: High Temp. +150°F	Functional Test: Ambient	Burn Time (sec)	15 Feet Particle Projection	Post Fire Leak	Proof Press	Burst Press
143 NSI 1903	143	1903	---	X (1)	---	---	---	---	---	Pass	---	---	X	7.61	X	---	---	---
144 NSI 1904	144	1904	---	---	X	---	---	Pass	Pass	Pass	---	X	---	6.61	X	Pass	---	---
146 NSI 1906	146	1906	X	---	X	X	---	Pass	Pass	Pass	X	---	---	7.93	X	Pass	---	---
148 NSI 1908	148	1908	---	---	X	X	---	Pass	Pass	Pass	---	X	---	6.70	X	Pass	---	---
149 NSI 1909	149	1909	---	---	X	---	---	Pass	Pass	Pass	---	X	---	6.90	X	Pass	---	---
152 NSI 1912	152	1912	---	---	X	---	---	Pass	Pass	Pass	---	X	---	6.8(	X	Pass	---	---
153 NSI 1913	153	1913	---	---	---	---	---	---	---	Pass	---	X	---	7.11	X	Pass	---	---
159 NSI 1919	159	1919	---	---	---	---	X (2)	---	---	Pass	X	---	---	7.93	X	Fail	---	---
162 NSI 1925	162	1925	---	---	---	---	X (2)	---	---	Pass	X	---	---	6.02	X	Fail	---	
163 NSI 1926	163	1926	---	---	---	---	X (3)	---	---	Pass	---	---	---	---	---	---	---	---
165 NSI 1928	165	1928	---	---	---	---	X (2)	---	---	Pass	X	---	---	6.88	X	Pass	---	---
166 NSI 1929	166	1929	X	---	---	X	---	Pass	Pass	Pass	X	---	---	8.07	X	Pass	---	---
167 NSI 1930	167	1930	---	---	X	X	---	Pass	Pass	Pass	---	X	---	6.89	X	Pass	---	---
171 NSI 1934	171	1934	---	---	---	---	---	---	---	Pass	---	---	X (5)	6.14	X	---	---	---
173 NSI 1937	173	1937	---	X (1)	---	---	---	---	---	Pass	---	---	X	8.09	X	---	---	---
175 NSI 1939	175	1939	X	---	X	X	---	Pass	Pass	Pass	X	---	---	7.77	X	Pass	---	---
176 NSI 1940	176	1940	---	---	X (6)	---	---	---	---	Pass	---	X	---	6.88	X	---	---	---
177 NSI 1941	177	1941	---	---	X	---	---	Pass	Pass	Fail (4)	---	X	---	6.99	X	Pass	---	---
178 NSI 1942	178	1942	---	---	---	---	---	---	---	Pass	---	X	---	6.60	X	Pass	---	---
136 NSI 1896	136	1896	X	---	X	X	---	Pass	Pass	Pass	---	X	---	7.23	X	Pass	Pass	Pass
117 NSI 1875	117	1875	X	---	---	X	---	Pass	Pass	Pass	X	---	---	8.30	X	Pass	---	---
126 NSI 1886	126	1886	X	---	X	X	---	Pass	Pass	Pass	---	X	---	7.24	X	Pass	Pass	Pass

1. Autoignition test units were fired for Rockwell on 1-9-81. Autoignition requirements were fulfilled by presentation of data.
2. Eight-foot drop test unit.
3. Forty-foot drop test unit.
4. GFM failed -- continued with qual.
5. 85% load test.
6. Extra unit in qual.

CONCLUSIONS

The P/N 51-1151 NSI Igniter Cartridge has met all of the requirements of MSFC-SPEC-541.