FINAL REPORT

FOR THE

NASA RELOAD PROGRAM

Submitted To:

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER, AL 35812

Submitted Under:

NASA CONTRACT NO: NAS8-38668

Submitted By:

ATLANTIC RESEARCH CORPORATION
PROPULSION DIVISION
5945 WELLINGTON ROAD
GAINESVILLE, VA 22065

APRIL 1993
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</tr>
</tbody>
</table>
1.0 INTRODUCTION AND SUMMARY

Atlantic Research Corporation (ARC) contracted with NASA to manufacture and deliver thirteen small scale Solid Rocket Motors (SRM). These motors, containing five distinct propellant formulations, will be used for plume induced radiation studies. The information contained herein summarizes and documents the program accomplishments and results.

Several modifications were made to the scope of work during the course of the program. The effort was on hold from late 1991 through August, 1992 while propellant formulation changes were developed. Modifications to the baseline program were completed in late-August and Modification No. 6 was received by ARC on September 14, 1992. The modifications include changes to the propellant formulation and the nozzle design.

The required motor deliveries were completed in late-December, 1992. However, ARC agreed to perform an additional mix and cast effort at no cost to NASA and another motor was delivered in March, 1993.

2.0 ACTIVITIES

The initial program required refurbishment of NASA supplied hardware and the loading of fourteen motors with a specified propellant formulation. One motor was to be static tested as a demonstration or qualification unit. It was subsequently discovered that the motor cases and forward closures had been insulated with material containing asbestos. As a result of asbestos disposal issues, new cases and closures were purchased along with the required canted nozzles.

Prior to the initiation of propellant casting, NASA developed a need for motors containing a number of different propellant formulations in lieu of the original
single formulation. The nozzle design was also changed from canted to axisymmetric.

A Propellant Mix Plan (Attachment 1) and a Motor/Propellant Matrix (Attachment 2) were developed utilizing five distinct propellant formulations to meet the new requirements. Since Maximum Expected Operating Pressure (MEOP) was of major concern, the formulation for Motor #5 was selected for the demonstration test. This formulation was expected to yield the highest burn rate. Propellant checkout mixes were conducted to verify that burn rate and MEOP could be controlled within contract limits. The schedule by which the work was performed is included as Attachment 3.

Following a successful checkout mix and associated Rohm and Haas (R&H) testing, the demonstration motor was successfully tested on November 6, 1992. NASA representatives witnessed the test of motor SOSM-00. In addition to the thrust/pressure/time data measured by ARC, we assisted NASA personnel with the measurement of plume infrared radiation data. NASA provided instrumentation and ARC collected and recorded data.

Analysis of the R&H results yields maximum pressure predictions for the corresponding full scale motor. As can be seen from the analysis of Rohm and Haas 05 and 06, Motor #2 could experience peak pressures up to 750 psi which is approximately 4% above the allowable maximum pressure. Our structural analysis of the motor components indicated a factor of safety of 4 at this maximum pressure. Based upon the structural analysis, a deviation (Attachment 14) was issued granting relief from the 720 psi MEOP requirement.

Test data for each mix and the demonstration motor are included as Attachments 4 through 11. These data reports are keyed to the Propellant Mix Plan. The first propellant checkout mix (Mix #1) yielded results so close to requirements for the test motor that a second mix (Mix #2) was not needed. Therefore, there were no Rohm and Haas Motors 03 and 04.
X-ray results for Motor #6, the PBAN Motor, indicated the presence of two voids which rendered the motor unacceptable. Recognizing the importance of the PBAN motor to the planned NASA test program, ARC elected to perform an additional mix and cast at no cost to NASA. The effort was successful and the new motor was designated SOSM-14 PBAN/16.0. Motor #6 was subsequently scrapped at ARC.

3.0 SHIPMENTS

The 13 canted nozzles originally purchased for use on the program and the spent motors containing asbestos were shipped to NASA on October 30, 1992.

Motors 1 through 5 and 7 through 13 were shipped on December 28, 1992. The replacement for Motor #6, SOSM-14 PBAN/16.0, was shipped on March 8, 1993.

Copies of the DD Form 250 and the ARC Packing Lists for these shipments are included as Attachment 15.
PROPELLANT MIX PLAN
NASA Reload

Task Description

1. Mix #1: Formulation 5 in 60-qt Hobart
   Cast R&H-01 & -02
   Perform physicals, strands, & bond tests

2. Assemble and fire R&H-01 & -02
   Reduce data
   Adjust burn rate and physicals (AR)

3. Mix #2: Formulation 5 in 60-qt Hobart
   Cast R&H-03 & -04
   Perform physicals, strands, & bond tests

4. Assemble and fire R&H-03 & -04
   Reduce data

5. Mix #3: Formulation 5 in 140-qt Hobart
   Cast R&H-05 & -06
   Cast SOSM-00 for test
   Perform physicals, strands, & bond tests

6. Assemble and fire R&H-05 & -06
   Assemble and fire SOSM-00
   Reduce data SCSM-00

7. Mix #4: Formulation 2 in 140-qt Hobart
   Cast SOSM-02 and R&H-07 & 08
   Perform physicals, strands, & bond tests
   Assemble and fire R&H-07 & 08
   Deliver SOSM-02

8. Mix #5: Formulation 1 in 140-qt Hobart
   Cast SOSM-01 and R&H-09 & 10
   Perform physicals, strands, & bond tests
   Assemble and fire R&H-09 & 10
   Deliver SOSM-01

9. Mix #6: Formulations 3,9,10,11,12,13 in 150-gal Hbrt.
   Cast SOSM-03,09,10,11,12,13 & R&H-11 & 12
   Perform physicals, strands, & bond tests
   Assemble and fire R&H-11 & 12
   Deliver SOSM-03,09,10,11,12,13

Notes

Checkout highest rb ASRM variation first

Checkout lowest rb

Interpolate based on formulations 5 & 2

ATTACHMENT 1
## PROPELLANT MIX PLAN CONTINUED

**NASA Reload**

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10. Mix #7:</strong> Formulation 4 in 150-gal Hobart Cast SOSM-04,05,07,08 and R&amp;H-13 &amp; 14</td>
<td></td>
</tr>
<tr>
<td>Perform physicals, strands, &amp; bond tests</td>
<td></td>
</tr>
<tr>
<td>Assemble and fire R&amp;H-13 &amp; 14</td>
<td></td>
</tr>
<tr>
<td>Deliver SOSM-04,05,07,08</td>
<td></td>
</tr>
<tr>
<td><strong>11. Mix #8:</strong> Formulation 6 in 140-qt Hobart Cast SOSM-06 and R&amp;H-15 &amp; 16</td>
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<tr>
<td>Perform physicals, strands, &amp; bond tests</td>
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</tr>
<tr>
<td>Assemble and fire R&amp;H-15 &amp; 16</td>
<td></td>
</tr>
<tr>
<td>Deliver SOSM-06</td>
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</tr>
<tr>
<td>Motor #</td>
<td>Binder Type</td>
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<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>HTPB</td>
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<td>2</td>
<td>HTPB</td>
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<tr>
<td>3</td>
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<td>11</td>
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</tr>
<tr>
<td>13</td>
<td>HTPB</td>
</tr>
<tr>
<td>Task Name</td>
<td>Duration (Mth)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------</td>
</tr>
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<td>ESTABLISH BUDGETS, ORDER MATL</td>
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<tr>
<td>FORMULATION #5</td>
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<tr>
<td>RSH 1&amp;2</td>
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<tr>
<td>RSH 3&amp;4</td>
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<tr>
<td>DEMO MTR #00 RSH 8&amp;6</td>
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</tr>
<tr>
<td>MTR #2 RSH 7&amp;8</td>
<td>1</td>
</tr>
<tr>
<td>FORMULATION #1 RSH 8A10</td>
<td>1</td>
</tr>
<tr>
<td>FORMULATION #2 RSH 8C10</td>
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<tr>
<td>FORMULATION MOTOR</td>
<td>3</td>
</tr>
<tr>
<td>MTR #4, #5, #12 RSH 11612</td>
<td>3</td>
</tr>
<tr>
<td>MTR #4, #5, #12 RSH 11614</td>
<td>12.2</td>
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<td>MONTHLY REPORTS</td>
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<td>SEPTEMBER</td>
<td>0</td>
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<tr>
<td>OCTOBER</td>
<td>0</td>
</tr>
<tr>
<td>NOVEMBER</td>
<td>0</td>
</tr>
<tr>
<td>DECEMBER</td>
<td>0</td>
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</table>
INTRODUCTION

On October 13, 1992 two Rohm and Haas motors (F/N's 02447 and 02448) were fired from NASA Reload Mix 1. This mix was an 86% solids, 16% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. This was designated formulation 5 on the motor/propellant matrix. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02447 used an eroding nozzle throat made from Durez. Firing number 02448 used a non-eroding, ATJ graphite throat. The burning rate exponent while the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02447, the burning rate exponent was determined to be 0.445. Based on the analysis of F/N 02448, the burning rate was determined to be 0.415 inches/second at 669 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.02295 P_c^{0.445} \]
TEST DATA REPORT
NASA RELOAD R/H

FIRING NOS: 02447-02448
FIRING DATE: OCTOBER 13, 1992
MOTOR NOS: 15, JGB109

RB DATA

PRODUCT ASSURANCE APPROVAL: N/A 10/15/92

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GAINESVILLE, VA 22055

PROPULSION TEST GROUP
OCTOBER 14, 1992

SPECIFICATION: N/A
DATA REDUCTION: J.K.
ENGINEERING APPROVAL: 1/14/92
TEST DATA SUMMARY

Firing Number 02447
Date Tested 13-Oct-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 57.00 Deg. F
Rel Humidity 60.00 %
Barometer 29.95 inHg

TIME VALUES
(seconds)

Ignition Delay (0 - 10%) 0.0525
Action Time (10% - 10%) 2.4000
Total Time (0 - 0) 2.4781

INTEGRALS

<table>
<thead>
<tr>
<th>CHN ID</th>
<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
<th>ACTION</th>
<th>BURN</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 PRESS-A (PSIA)</td>
<td>1724.5</td>
<td>1722.6</td>
<td>1709.9</td>
<td>717.8</td>
<td>726.0</td>
<td>872.0</td>
</tr>
<tr>
<td>01 PRESS-B (PSIA)</td>
<td>1727.5</td>
<td>1725.5</td>
<td>1712.5</td>
<td>719.0</td>
<td>727.1</td>
<td>872.3</td>
</tr>
<tr>
<td>02 THRUST-A (LBF)</td>
<td>2655.5</td>
<td>2654.2</td>
<td>2634.8</td>
<td>1105.9</td>
<td>1118.7</td>
<td>1266.3</td>
</tr>
<tr>
<td>03 THRUST-B (LBF)</td>
<td>2674.4</td>
<td>2673.0</td>
<td>2653.4</td>
<td>1113.8</td>
<td>1126.6</td>
<td>1269.8</td>
</tr>
</tbody>
</table>

Observed Burn Rate = 0.4161 ln/sec. B 726.0 psia
Specific Impulse = 234.1590 lbf-s/ft-lb
Action / Burn Time = 1.0190
**TEST INFORMATION SHEET**

**PROGRAM NAME:** NASA Reload

**ACCT. NO.:** 38-6464-NE-1000

**MOTOR NO.:** 15

**GRAIN NO.:** N96-W3-T

**PURPOSE OF TEST:** Burn Rate (Q+H)

**DAREZ Nozzle Insert**

---

**MOTOR ASSEMBLY**

<table>
<thead>
<tr>
<th>Assy. Drawing No.</th>
<th>Motor: DAREZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle:</td>
<td>DAREZ</td>
</tr>
<tr>
<td>DT = 1.102</td>
<td></td>
</tr>
<tr>
<td>Insulation:</td>
<td></td>
</tr>
<tr>
<td>Other Components:</td>
<td></td>
</tr>
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**GRAIN PREPARATION**

<table>
<thead>
<tr>
<th>End Preparation:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhibiting:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonding:</td>
<td></td>
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</table>

**IGNITER**

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Igniter Charge: 20 g</td>
</tr>
<tr>
<td></td>
<td>Housing or Container: 10 g</td>
</tr>
</tbody>
</table>

**PROPELLANT DATA**

| Motor Weight Before Firing: 87.0 Lbs |
| Motor Weight After Firing:    |
| Inhibited Grain Weight: 513.483 gr |
| Wet, Propellant Weight:       |
| Grain I.D. 4.057, 4.055, 4.052, 4.057 |
| Grain O.D. 4.016, 4.015, 4.013, 4.016 |
| Web:                          |
| Grain Length: 11.790, 11.795 |
| D_t: Before: 1.020 |
| After:                       |
| D_e: Before: 3.540 |
| After:                       |

**TEST PLAN AND EXPECTED PERFORMANCE**

<table>
<thead>
<tr>
<th>Conditioning Temp.</th>
<th>70 °F</th>
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<tbody>
<tr>
<td>Equilibrium Time:</td>
<td>7 Hrs</td>
</tr>
<tr>
<td>Other Conditioning: Supply Temperature Cycling Instrument Sheet</td>
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</tr>
<tr>
<td>Instrumentation Required</td>
<td>3 - Sec</td>
</tr>
<tr>
<td>Expected Value</td>
<td>7000 Lb</td>
</tr>
<tr>
<td>2 Thrust</td>
<td>1000 m/s</td>
</tr>
<tr>
<td>2 Pressure Temp</td>
<td>Supply Location</td>
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**Other Instructions or Comments:**

---

**SIGNATURE**

**PRODUCT ASSURANCE**

**PROGRT:**

In 90X6 @ 1320 ± 75 ° 10-12-92 WAY
**TEST DATA SUMMARY**

<table>
<thead>
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<th>Channel</th>
<th>Total Action</th>
<th>Burn Action</th>
<th>Maximum</th>
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<td>00 PRESS-A (PSIA)</td>
<td>1644.8</td>
<td>1663.4</td>
<td>1645.9</td>
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<td>01 PRESS-B (PSIA)</td>
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<td>1646.7</td>
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<td>02 THRUST-A (LBF)</td>
<td>2603.1</td>
<td>2602.3</td>
<td>2577.9</td>
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<tr>
<td>03 THRUST-B (LBF)</td>
<td>2618.6</td>
<td>2617.7</td>
<td>2593.1</td>
</tr>
</tbody>
</table>

- Ignition Delay (0 - 10%) = 0.0333 seconds
- Ignition Rise (10% - 75%) = 0.0352 seconds
- Action Time (10% - 10%) = 2.4640 seconds
- Burn Time (10% - 98%) = 2.5197 seconds
- Observed Burn Rate = 0.4073 in/sec
- Specific Impulse = 229.5882 lbf-sec/lb
- Action / Burn Time = 1.0226
**TEST INFORMATION SHEET**

**PROGRAM NAME:** NASA Reload  
**ACCT. NO.:** 38-6464-450-1000  
**MOTOR NO.:** 5GR-103  
**GRAIN NO.:** B0963-T  
**PURPOSE OF TEST:** Burn Rate (R+H)  
**AT J Nozzle Insert**

### MOTOR ASSEMBLY

<table>
<thead>
<tr>
<th>Assy. Drawing No.</th>
<th>Motor:</th>
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</thead>
<tbody>
<tr>
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<td>AT J</td>
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<table>
<thead>
<tr>
<th>Assy. Drawing No.</th>
<th>Nozzle:</th>
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<tbody>
<tr>
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<table>
<thead>
<tr>
<th>Assy. Drawing No.</th>
<th>Nozzle:</th>
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### IGNITER

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<tr>
<th>Assy. Drawing No.</th>
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<table>
<thead>
<tr>
<th>Igniter Charge:</th>
<th>20g 2.0</th>
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<td>Housing or Container:</td>
<td>10g 2.0</td>
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### TEST PLAN AND EXPECTED PERFORMANCE

<table>
<thead>
<tr>
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<th>70.0°F</th>
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<td>Other Conditioning:</td>
<td>Supply Temperature Cycling Instrument Sheet</td>
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<tr>
<td>Instrumentation Required</td>
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</tr>
<tr>
<td>Expected Max. Value</td>
<td>1000 lb</td>
</tr>
<tr>
<td>2 Thrust</td>
<td>650 lb</td>
</tr>
<tr>
<td>2 Pressure</td>
<td>650 psi</td>
</tr>
<tr>
<td>Temp</td>
<td>Supply Location:</td>
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### GRAIN PREPARATION

<table>
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<table>
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<table>
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<th>Bonding:</th>
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### PROPELLANT DATA

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<td>Motor Weight After Firing:</td>
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<td>Inhibited Grain Weight:</td>
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<tr>
<td>Propellant Weight:</td>
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<tr>
<td>Grain 1.0:</td>
<td>4.045, 4.647, 4.652</td>
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<tr>
<td>Grain 0.0:</td>
<td>4.045, 4.647, 4.652</td>
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<tr>
<td>Web:</td>
<td>1192.16, 1192.16, 1192.01</td>
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<td>Grain Length:</td>
<td>1.783, 1.783</td>
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<tr>
<td>D1: Before:</td>
<td>1.181</td>
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<td>D1: After:</td>
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<td>D2: Before:</td>
<td>3.524</td>
</tr>
<tr>
<td>D2: After:</td>
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</tbody>
</table>

**Signature:**

Harry T. Price  
PROG:  
F.U. Box 1210  
1320 175th  
10-10-52  
With
NASA RELOAD

Ballistic Analysis

of

ROHM and HAAS Motors

05 and 06

INTRODUCTION

On November 3, 1992 two Rohm and Haas motors (F/N's 02478 and 02479) were fired from NASA Reload Mix 3. This mix was an 86% solids, 16% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. This was designated formulation 5 on the motor/propellant matrix and was identical to Mix 1. Due to an operator error, the thrust data on F/N 02479 was not properly acquired. No meaningful data can be acquired from this firing since the thrust data is critical to the analysis of this motor. The data from the remaining motor is sufficient to determine the acceptability of this batch.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate. Firing number 02478 used a non-eroding, ATJ graphite throat. The non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02478, the burning rate was determined to be 0.383 inches/second at 565 psi. Using these results, and the burning rate exponent of 0.445 obtained from Mix 1, the burning rate equation for this mix is:

\[ r = 0.02283 \cdot P_c^{0.445} \]

This is 0.52% lower than Mix 1 and is within the acceptable range.

ATTACHMENT 5
TEST DATA REPORT

NASA RELOAD R/H

FIRING NOS: 02476-02479
FIRING DATE: NOVEMBER 3, 1992
MOTOR NOS: RASM-5, RASM-14

RB DATA

PRODUCT ASSURANCE APPROVAL: N/A 11/1/92

AR

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GRANVILLE, VA 22065

PROPELLION TEST GROUP
NOVEMBER 3, 1992

SPECIFICATION: [Signature]
DATA REDUCTION: [Signature]
ENGINEERING APPROVAL: [Signature]

DISCREPANIES NOTED:

Thrust clipped on the 02479 - op temp
rpm = left Joy. step card on a push

.................................................................
TEST DATA SUMMARY

Test ID: MASARELOAD/F
Acct No. 38-6454-M6-1000
Motor No. AASH-5
Grain No. BU9681-T
Pro. Wgt. 5225.6001 grams
Web 0.9940 in.

DATE TESTED: 3-Nov-92

Ignition Delay (0 - 10%) 0.0309
Ignition Rise (10% - 75%) 0.0640
Action Time (10% - 10%) 2.6600
Burn Time (10% - TAN) 2.6400
Total Time (0 - 0) 2.7449

INTEGRALS

<table>
<thead>
<tr>
<th>CHN ID</th>
<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 PRESS-1 (PSI)</td>
<td>1536.1</td>
<td>1524.5</td>
<td>572.2</td>
</tr>
<tr>
<td>01 PRESS-2 (PSI)</td>
<td>1534.7</td>
<td>1533.5</td>
<td>570.9</td>
</tr>
<tr>
<td>02 THRUST-1 (LBF)</td>
<td>2611.6</td>
<td>2592.2</td>
<td>971.9</td>
</tr>
<tr>
<td>03 THRUST-2 (LBF)</td>
<td>2614.1</td>
<td>2613.3</td>
<td>972.9</td>
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</table>

AVERAGES

<table>
<thead>
<tr>
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<th>ACTION</th>
<th>BURN</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 PRESS-1 (PSI)</td>
<td>572.2</td>
<td>577.5</td>
</tr>
<tr>
<td>01 PRESS-2 (PSI)</td>
<td>570.9</td>
<td>576.3</td>
</tr>
<tr>
<td>02 THRUST-1 (LBF)</td>
<td>971.9</td>
<td>981.9</td>
</tr>
<tr>
<td>03 THRUST-2 (LBF)</td>
<td>972.9</td>
<td>982.9</td>
</tr>
</tbody>
</table>

Observed Burn Rate = 0.3765 in/sec. 0 577.5 psia
Specific Impulse = 226.6741 lbf-s/lbm
Action / Burn Time = 1.0174
**TEST INFORMATION SHEET**

**PROGRAM NAME:** NASA RECORD

**ACCT. NO.** 38-676-4-MG-1000

**MOTOR NO.** AASm-5

**GRAIN NO.** A09681-T

**PURPOSE OF TEST** R + H

---

**ATJ INSERT**

---

**MOTOR ASSEMBLY**

Assy. Drawing No.: ____________
Motor: ____________
Nozzle: ____________
Insulation: ____________
Other Components: ____________

---

**IGNITER**

Assy. Drawing No.: ____________
Squibs: ____________
Igniter Charge: ____________
Housing or Container: ____________

---

**GRAIN PREPARATION**

End Preparation: ____________
Inhibiting: ____________
Bonding: ____________

---

**PROPELLANT DATA**

Motor Weight Before Firing: 89.6 lbs
Motor Weight After Firing: ____________
Inhibited Grain Weight: ____________
Wt. Propellant Weight: ____________
Grain I.D. ____________
Grain O.D. ____________
Web ____________
Grain Length ____________
Dq Before: ____________
After: ____________
Dq Before: ____________
After: ____________

---

**TEST PLAN AND EXPECTED PERFORMANCE**

Conditioning Temp. 70°F
Equilibrium Time: 4 hrs
Other Conditioning: Supply Temperature Cycling Instrument Sheet

Instrumentation Required

<table>
<thead>
<tr>
<th>3 sec</th>
<th>2 Thrust</th>
<th>2 Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 lb</td>
<td>100 psi</td>
<td></td>
</tr>
</tbody>
</table>

Supply Location Data

Other Instructions or Comments: ____________

---

**SIGNATURE**

PRODUCT ASSURANCE: ____________
PROGRAM: ____________
TEST: ____________
ENGINEERING: ____________

---

*Signature*

10-29-92

**PROJECT MANAGER:** ____________

**DATE:** 10-29-92
**SIGNATURE:** ____________

**NOT REQ**
TEST DATA SUMMARY

Test ID : NASARELOAD/M
Acct No. 58-6444-166-1000
Motor No. 14
Grain No. 6096817
Pro. Wgt. 5162.3999 grams
Web 0.9845 in.

Firing Number 02479
Date Tested 3-Nov-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 64.00 Deg. F
Rel Humidity 68.00 %
Barometer 29.83 inHg

TIME VALUES
(seconds)

Ignition Delay (0 - 10%) 0.0289
Action Time (10% - 10%) 2.5440
Total Time (0 - 0) 2.5989

Ignition Rise (10% - 75%) 0.0360
Burn Time (10% - 95%) 2.6440

INTEGRALS

ACTION BURN ACTION BURN MAXIMUM

CHN ID TOTAL ACTION BURN ACTION BURN MAXIMUM
00 PRESS-1 (PSIA) 1630.9 1629.3 1597.4 640.5 653.6 762.3
01 PRESS-2 (PSIA) 1629.0 1627.5 1595.8 639.7 652.9 761.1
02 THRUST-1 (LBF) 2442.4 2441.3 2389.4 959.6 977.7 997.0
03 THRUST-2 (LBF) 2448.9 2447.6 2395.4 962.1 980.1 998.7

Observed Burn Rate = 0.4028 in/sec. 0 653.6 psia
Specific Impulse = 214.6023 lbf-s/lbm
Action / Burn Time = 1.0409
TEST INFORMATION SHEET

PROGRAM NAME: NASA RELOAD
ACCT. NO. 38-6464-NC-1000
MOTOR NO. AASM-14
GRAIN NO. B09681-T
PURPOSE OF TEST L&A

PROPULSION TEST SPEC. NO. GTP9606
SCHEDULE DATE: 10-29-92
DELIVER EXPENDED MOTOR TO: Bldg 97
DISTRIBUTE DATA TO:
R. Schubert, M. Arington
X-RAY REVIEW: ACCEPTABLE: 
UNACCEPTABLE:

Durex Throat

MOTOR ASSEMBLY
Assy. Drawing No.
Motor:
Nozzle: Durex
Insulation:
Other Components:

IGNITER
Assy. Drawing No.
Squibbs:
Igniter Charge: 240~250 mbar
Housing or Container:

PROPELLANT DATA
Motor Weight Before Firing: 98.4 lbs
Motor Weight After Firing: 88.4 lbs
Inhibited Grain Weight: 5162.4 g
Propellant Weight: 5162.4 g
Grain I.D. 4.091
Grain O.D. 6.010
Web:
Grain Length: 11.304
D1: Before: 1.196
After: 1.196
D2: Before: 3.500
After: 3.500

TEST PLAN AND EXPECTED PERFORMANCE
Conditioning Temp: 70°F
Equilibrium Time: 24 hrs
Other Conditioning: Supply Temperature Cycling Instrument Sheet
Instrumentation Expected Max. Required
Required Value 3 sec
lb 1000 lb
2 Thrust 1000
2 Pressure Temp
Supply Location D

Other Instructions or Comments:

Signature: 11-3-92
Harry E. Price 10/27/92
PRODUCT ASSURANCE
NOT REQ.
ENGINEERING

Full unit in Box 6 @ 70°F on 11-2-92 at 14:15 WSD
INTRODUCTION

On November 6, 1992 a full scale motor from NASA Reload Mix 3 was fired (F/N 80956). This mix was an 86% solids, 16% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. This was designated formulation 5 on the motor/propellant matrix and was identical to Mix 1.

The motor operation closely matched expectations with no performance or data acquisition anomalies.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor operating performance. The results of this analysis are summarized in Table 1.

The propellant burning rate was determined to be 0.426 inches/second at 655 psia. Assuming that the burning rate exponent is unchanged from Mix 1 at 0.445, then the burning rate equation for this motor is calculated to be:

\[ r = 0.02378 P_{c}^{0.445} \text{ inches/second} \]

This is 4.1% higher than the burning rate determined in the Rohm and Haas firing for this mix. This is typical for this type of propellant.

CONCLUSIONS AND RECOMMENDATIONS

The maximum pressure observed of 720 psia precisely equaled the requirement. Because of this, it is recommended that the iron oxide content of the propellant be decreased from 0.5% to 0.25% in all future mixes. This will allow some margin on the maximum pressure requirement in subsequent firings.
Table 1. Ballistic Performance Summary

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burn Time, seconds</strong></td>
<td>5.087</td>
</tr>
<tr>
<td><strong>Action Time, seconds</strong></td>
<td>5.539</td>
</tr>
<tr>
<td><strong>Burn Time Average Pressure, psia</strong></td>
<td>654.6</td>
</tr>
<tr>
<td><strong>Action Time Average Pressure, psia</strong></td>
<td>634.2</td>
</tr>
<tr>
<td><strong>Maximum Pressure, psia</strong></td>
<td>720.0</td>
</tr>
<tr>
<td><strong>Burn Time Average Thrust, 1bf</strong></td>
<td>4451</td>
</tr>
<tr>
<td><strong>Action Time Average Thrust, 1bf</strong></td>
<td>4302</td>
</tr>
<tr>
<td><strong>Maximum Thrust, 1bf</strong></td>
<td>5677</td>
</tr>
<tr>
<td><strong>Nozzle Throat Efficiency</strong></td>
<td>0.998</td>
</tr>
<tr>
<td><strong>Thrust Efficiency</strong></td>
<td>0.956</td>
</tr>
<tr>
<td><strong>Total Pressure Integral, psia-sec</strong></td>
<td>3515</td>
</tr>
<tr>
<td><strong>Total Impulse, 1bf-sec</strong></td>
<td>23839</td>
</tr>
<tr>
<td><strong>Propellant Weight, 1bm</strong></td>
<td>100.7</td>
</tr>
<tr>
<td><strong>Delivered Specific Impulse, 1bf-sec/1bm</strong></td>
<td>236.7</td>
</tr>
</tbody>
</table>
TEST DATA REPORT

NASA RELOAD

FIRING NO: 80956
FIRING DATE: NOVEMBER 6, 1992
MOTOR NO: 505M-00

LOT ACCEPTANCE TEST

PRODUCT ASSURANCE APPROVAL:

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GRINESVILLE, VA 22065

PROPULSION TEST GROUP
NOVEMBER 6, 1992

SPECIFICATION: M75-270

DATA REDUCTION:

ENGINEERING APPROVAL:
### TEST DATA SUMMARY

Test ID: NASA RELOAD  
Account No.: 36-6464-M6-2888  
Motor No.: S06-M8  
Grain No.: B9601-T  
Propellant Weight: 106.699997  
Web: 8.88888

| Firing Number | 88956  
|---------------|-----------------  
| Date Tested   | 6-NOV-92  
| Conditioning Temp. | 70.0  
| Ambient Temp.  | 45.0  
| Relative Humidity | 58.0  
| Barometer      | 30.85 |

### TIME VALUES

- Ignition Delay Time: 0.8112 sec.  
- Burn Time: 5.2488 sec.  
- Action Time: 5.6530 sec.  
- Total Time: 5.7480 sec.

### SUMMARY BY CHANNEL

<table>
<thead>
<tr>
<th>Channel</th>
<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
<th>AVERAGE</th>
<th>MAXIMUM</th>
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<tr>
<td>1</td>
<td>THRUST-A</td>
<td>23911.9</td>
<td>23897.9</td>
<td>23224.6</td>
<td>4393.7</td>
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<tr>
<td>2</td>
<td>THRUST-B</td>
<td>23915.3</td>
<td>23941.5</td>
<td>23229.2</td>
<td>4393.7</td>
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<tr>
<td>3</td>
<td>PRESS-A</td>
<td>3527.9</td>
<td>3823.9</td>
<td>3416.8</td>
<td>634.4</td>
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</table>

### SENSOR TYPE AVERAGES

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<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
<th>AVERAGE</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Cell</td>
<td>23913.6</td>
<td>23899.7</td>
<td>23226.4</td>
<td>4393.7</td>
<td>4425.1</td>
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<tr>
<td>Pressure (PR)</td>
<td>3527.9</td>
<td>3823.9</td>
<td>3416.8</td>
<td>634.4</td>
<td>651.0</td>
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<table>
<thead>
<tr>
<th>Units</th>
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<tbody>
<tr>
<td>Lbf</td>
<td></td>
</tr>
<tr>
<td>Ps</td>
<td></td>
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</tbody>
</table>


PROGRAM NAME: NASA RELOAD
ACCT. NO. 36-6444-NC-2000
MOTOR NO. S05M-00
GRAIN NO. B09681-T / DM-15
PURPOSE OF TEST LAT

PROPULSION TEST SPEC. NO. MTS-270
SCHEDULE DATE: 11-6-92
DELIVER EXPENDED MOTOR TO: Bldg 97
DISTRIBUTE DATA TO: G Price
X-RAY REVIEW: ACCEPTABLE: X UNACCEPTABLE: 

MOTOR ASSEMBLY
Assy. Drawing No. A0327901-002 A
Motor: 
Nozzle: H7501 A
Insulation:
Other Components:

IGNITER
Assy. Drawing No. B14249-01-01
Squirbs: RESISTANCE 5-54
Igniter Charge: 2-71
Housing or Container:

GRAIN PREPARATION
End Preparation:
Inhibiting:
Iodizing:

PROPELLANT DATA
Motor Weight Before Firing: 319.8 lb
Motor Weight After Firing:
Inhibited Grain Weight: 
Wp: Propellant Weight: 100.7
Grain I.D.:
Grain O.D.:
Web:
Grain Length:
D1: Before: 2.3996
D2: After: 
D1: Before: 6.558

CONDITIONING Temp. 70°F
Equilibrium Time: 24 Hrs
Other Conditioning: Supply Temperature Cycling Instrument Sheet

INSTRUMENTATION Required 5.5-sec
Expected Max. Value
Thrust 4500 lb
Pressure 700 psi
Supply Location U

OTHER INSTRUCTIONS OR COMMENTS

CURRENT RqR 1500 psi

SIGNATURE TEST
11/6/92
NASA RELOAD

Ballistic Analysis

of

ROHM and HAAS Motors

07 and 08

INTRODUCTION

On December 3, 1992 two Rohm and Haas motors (F/N's 02527 and 02528) were fired from NASA Reload Batch B09722-T. This mix was an 88% solids, 17.5% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. From this batch, full scale Motor #2 was also cast. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02527 used an eroding nozzle throat made from Durez. Firing number 02528 used a non-eroding, ATJ graphite throat. The burning rate exponent with the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02527, the burning rate exponent was determined to be 0.4305. Based on the analysis of F/N 02528, the burning rate was determined to be 0.394 inches/second at 598 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.02513 \ P_c^{0.4305} \]

Full scale motor maximum pressure was calculated by comparing burning rates, exponents and propellant thermochemical properties to the mix 3 full scale motor. This was done using a mass balance equation, with a 3.8% scale factor applied to the subscale burning rate. This value was required to calibrate the calculation to the actual mix 3 full scale motor. The calculated full scale maximum pressure for batch B09722-T is 750 psi which is above the requirement of 720 psi.
TEST DATA REPORT
NASA RELOAD R/H

FIRING NOS: 02527-02528
FIRING DATE: DECEMBER 3, 1992
MOTOR NOS: RSHM-2.88

RB DATA: 809722T

PRODUCT ASSURANCE APPROVAL: 

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GAINESVILLE, VA 22065

PROPULSION TEST GROUP
DECEMBER 3, 1992

SPECIFICATION: 
DATA REDUCTION: 
ENGINEERING APPROVAL: 
TEST DATA SUMMARY

Test ID: NASA RELOAD R/H
Acct No. 38-6454-651-1000
Motor No. AASM-2
Grain No. A0972B1
Prop. Wgt. 5288.5999 grams
Web. 0.9960 in.

Firing Number 02527
Date Tested 3-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 41.00 Deg. F
Rel Humidity 35.00 %
Barometer 29.90 inHg

TIME VALUES
(seconds)

Ignition Delay (0 - 10%) 0.0387
Action Time (10% - 10%) 2.5200
Burn Time (10% - 90%) 2.4480
Total Time (0 - 90%) 2.5867

INTGRALS

<table>
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<tr>
<th>CHNL ID</th>
<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
<th>ACTION</th>
<th>BURN</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 PRESS-1 (PSIA)</td>
<td>1630.1</td>
<td>1628.3</td>
<td>1608.2</td>
<td>646.2</td>
<td>656.9</td>
<td>786.7</td>
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<tr>
<td>01 PRESS-2 (PSIA)</td>
<td>1629.2</td>
<td>1627.3</td>
<td>1607.3</td>
<td>645.8</td>
<td>656.6</td>
<td>787.3</td>
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<tr>
<td>02 THRUST-1 (LBF)</td>
<td>2714.4</td>
<td>2712.9</td>
<td>2679.6</td>
<td>1076.6</td>
<td>1094.6</td>
<td>1282.5</td>
</tr>
<tr>
<td>03 THRUST-2 (LBF)</td>
<td>2717.2</td>
<td>2715.6</td>
<td>2682.2</td>
<td>1077.6</td>
<td>1095.7</td>
<td>1284.6</td>
</tr>
</tbody>
</table>

Observed Burn Rate = 0.4069 in/sec. & 656.9 psia
Specific Impulse = 232.8006 lbf-s/lbm
Action / Burn Time = 1.0294
## TEST INFORMATION SHEET

**Program Name:** NASA RELOAD

**Account No.:** 38-4464-NG-1000

**Motor No.:** AASM-2

**Grain No.:** B09.227-T-AASM 2

**Purpose of Test:** R+H

---

### MOTOR ASSEMBLY

<table>
<thead>
<tr>
<th>Assy. Drawing No.:</th>
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</thead>
<tbody>
<tr>
<td>Nozzle:</td>
</tr>
<tr>
<td>Insulation:</td>
</tr>
<tr>
<td>Other Components:</td>
</tr>
</tbody>
</table>

---

### IGNITER

| Assy. Drawing No.: |
| Squib: |

**Igniter Charge:**
- 20 g 20 Pallets
- 10 g 20 Granules

**Housed in or Container:**
- [Blank]

---

### GRAIN PREPARATION

**End Preparation:**
- [Blank]

**Inhibiting:**
- [Blank]

**Toning:**
- [Blank]

---

### PROPELLANT DATA

**Motor Weight Before Firing:** 858.14

**Motor Weight After Firing:**
- [No data]

**Inhibited Grain Weight:**
- [No data]

**Propellant Weight:**
- 11.66

**Grain I.D.:**
- 4.009
- 4.033
- 4.035

**Grain O.D.:**
- 6.060
- 6.081
- 6.085

**Web:**
- 0.996

**Grain Length:**
- 14.321

**Q1 Before:**
- 1440 ft

**Q1 After:**
- 1470 ft

**Q2:**
- Before: 3.505

---

### TEST PLAN AND EXPECTED PERFORMANCE

**Conditioning Temp:** 70°F

**Equilibrium Time:** 72 Hrs

**Other Conditioning:** Supply Temperature Cycling Instrument Sheet

**Instrumentation Required:**
- 1 lb

**Expected Max.:**
- Value
- 1 sec

**Thrust:**
- 1000 lb

**Pressure Temp.:**
- 6000 psi

**Supply Location D:**
- [Blank]

---

**Other Instructions or Comments:**
- [Blank]

---

**Signature:**

**Proving Assurance:**

**Program:**

**Test:**
- [Blank]

**W.O.D.:**
- [Blank]
**TEST DATA SUMMARY**

- **Firing Number**: 02528
- **Date Tested**: 3-Dec-92
- **Cond. Temp.**: 70.00 Deg. F
- **Ambient Temp.**: 41.00 Deg. F
- **Rel Humidity**: 35.00 %
- **Barometer**: 29.90 inHg

**TIME VALUES**

- **Ignition Delay (0 - 10%)**: 0.0989
- **Ignition Rise (10% - 75%)**: 0.0300
- **Action Time (10% - 10%)**: 2.5780
- **Burn Time (10% - 75%)**: 2.5360
- **Total Time (0 - 0)**: 2.7069

**INTEGRALS**

<table>
<thead>
<tr>
<th>CHN ID</th>
<th>TOTAL</th>
<th>ACTION</th>
<th>BURN</th>
<th>ACTION</th>
<th>BURN</th>
<th>MAXIMUM</th>
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<tbody>
<tr>
<td>00 PRESS-1 (PSIA)</td>
<td>1528.4</td>
<td>1526.8</td>
<td>1515.3</td>
<td>592.2</td>
<td>597.5</td>
<td>618.2</td>
</tr>
<tr>
<td>01 PRESS-2 (PSIA)</td>
<td>1527.7</td>
<td>1526.1</td>
<td>1514.6</td>
<td>592.0</td>
<td>597.3</td>
<td>617.4</td>
</tr>
<tr>
<td>02 THRUST-1 (LBF)</td>
<td>2652.2</td>
<td>2651.1</td>
<td>2633.8</td>
<td>1028.4</td>
<td>1038.6</td>
<td>1188.0</td>
</tr>
<tr>
<td>03 THRUST-2 (LBF)</td>
<td>2648.4</td>
<td>2646.9</td>
<td>2629.8</td>
<td>1026.7</td>
<td>1037.0</td>
<td>1188.5</td>
</tr>
</tbody>
</table>

- **Observed Burn Rate** = 0.3904 in/sec
- **Specific Impulse** = 229.0377 lbf·s/lbm
- **Action / Burn Time** = 1.0166

---

**Graphical Data**

- Time (seconds) vs Force (psia)
- Force (psia) range: 2000 to 1400
- Time range: 0.000 to 2.5000 seconds
# TEST INFORMATION SHEET

**Program Name:** NASA RELOAD  
**Account No.:** 38-6464-NL-1000  
**Motor No.:** 88  
**Grain No.:** B09722-T-88  
**Purpose of Test:** K+T

**Propulsion Test Spec. No.:** GTP 9606  
**Schedule Date:** 12-3-92  
**Delivered Expended Motor To:** Bldg 97  
**C. Harrold, G. Price**  
**R. Schuster, M. Braggton**  
**Distribute Data To:**

**X-Ray Review:** Acceptable  
**Unacceptable:**

---

## MOTOR ASSEMBLY

**Assy. Drawing No.:**

**Motor:**

**Nozzle:** ATJ

**Insulation:**

**Other Components:**

---

## IGNITER

**Assy. Drawing No.:**

**Spills:** Atlas match

**Igniter Charge:** 20.0 g 27 Pellets

**Housing or Container:**

---

## PROPELLANT DATA

**Motor Weight Before Firing:** 896.4 lb

**Motor Weight After Firing:**

**Inhibited Grain Weight:**

**Grain I.D.:** 4.032 4.034 4.036

**Grain O.D.:** 6.012 6.014 6.015

**Web:** 990

**Grain Length:** 11.526

**Dₐ Before:** 1.584

**Dₐ After:** 1.580

**Dₑ Before:** 3.5068

**Dₑ After:**

---

**Conditioning Temp.:** 70 °F

**Equilibrium Time:** 4 hr

**Other Conditioning:** Supply "Temperature Cycling Instrument Sheet"

**Instrumentation Required:**

**Expected Max. Value:** 5 sec

**1 Thrust:** 1000 lb

**2 Pressure:** 1000 psi

**Supply Location D:**

---

**Other Instructions or Comments:**

---

**Signature:**

**Not Read**

**Engineering:**
INTRODUCTION

On December 17, 1992 two Rohm and Haas motors (F/N's 02583 and 02582) were fired from NASA Reload Batch B09749-T. This mix was an 88% solids, 21.5% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. From this batch, full scale Motor #1 was also cast. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02583 used an eroding nozzle throat made from Durez. Firing number 02582 used a non-eroding, ATJ graphite throat. The burning rate exponent with the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02583, the burning rate exponent was determined to be 0.4326. Based on the analysis of F/N 02582, the burning rate was determined to be 0.3583 inches/second at 546 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.02345 \ P_c^{0.4326} \]

Full scale motor maximum pressure was calculated by comparing burning rates, exponents and propellant thermochemical properties to the mix 3 full scale motor. This was done using a mass balance equation, with a 3.8% scale factor applied to the subscale burning rate. This value was required to calibrate the calculation to the actual mix 3 full scale motor. The calculated full scale maximum pressure for batch B09749-T is 693 psi which is below the requirement of 720 psi. This batch should yield acceptable performance in full scale motors.
TEST DATA REPORT

NASA RELOAD R/H

FIRING NO: 02582 - 02583
FIRING DATE: DECEMBER 17, 1992

STATIC TESTS

PRODUCT ASSURANCE APPROVAL:

ATLANTIC RESEARCH CORP.
5945 KELLINGTON HULD
GAINESVILLE, FL 32605

PROPULSION TEST GROUP
DECEMBER 17, 1992

SPECIFICATION:

DATA REDUCTION: FACILITY

ENGINEERING APPROVAL:
Test ID: NASA RELOAD R/H

Acct No. 38-6464-W6-1000
Motor No. RTY108
Grain No. B09749-T
Pro. Wgt. 5311.6001 grams
Web 0.9850 in.

Test Data Summary
Firing Number 02582
Date Tested 17-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 48.00 Deg. F
Rel Humidity 100.00 %
Barometer 30.10 inHg

Time Values (seconds)
Ignition Delay (0 - 10%) 0.0340
Action Time (10% - 10%) 2.8296
Total Time (0 - 0) 2.8899

Integrals

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Averages

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Observed Burn Rate = 0.3553 in/sec. @ 544.7 psia
Specific Impulse = 224.4685 lbf-s/lbm
Action / Burn Time = 1.0208
**TEST INFORMATION SHEET**

**PROGRAM NAME:** NASA RECORD

**ACCT. NO.** 38-6764-NX-1000

**MOTOR NO.** R.T.Y 108

**GRAIN NO.** 809749-T

**PURPOSE OF TEST** R & H

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<tr>
<td>DELIVER EXPLODED MOTOR TO:</td>
<td>Bldg 97</td>
</tr>
<tr>
<td>c.Harrad, c.Price</td>
<td></td>
</tr>
<tr>
<td>c.Schubert, Maxington</td>
<td></td>
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</table>

**X-RAY REVIEW:** ACCEPTABLE: ✔ |

**I N S T R U M E N T A T I O N**

**Conditioning Temp.** 70.°F

**Other Conditioning:** Supply Temperature Cycling Instrument Sheet

**Thrust**

**Pressure**

**Temperature**

**Other Instructions or Comments:**

---

**ASSEMBLY**

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**I G N I T E R**

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**G R A I N P R E P A R A T I O N**

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**P R O P E L L A N T D A T A**

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<th>Motor Weight Before Firing: 39.5 lbs</th>
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<th>Motor Weight After Firing:</th>
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<table>
<thead>
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<th>Inhibited Grain Weight:</th>
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<table>
<thead>
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<th>Vp: Propellant Weight:</th>
</tr>
</thead>
</table>

| Grain I.O.  |
| 4.056 |
| 4.057 |
| 4.058 |

| Grain O.D.  |
| 6.034 |
| 6.015 |
| 6.027 |

| Web:  |
| 198.5 |

| Grain Length: |
| 11.322 |
| 11.325 |

| D1: Before:  |
| 1.217 |
| 1.224 |

| D2: After:   |
| 1.321 |
| 1.325 |

| D3: Before:  |
| 1.321 |
| 1.325 |

---

**SIGNATURE**

**Test**

**ENGINEERING**

בטא.
Test ID: NASA RELOAD R/M
Motor No. 10
Grain No. 809749-T
Pro. Wgt. 5347.8999 grams
Web 0.9980 in.

Ignition Delay (0 - 10%) 0.0304
Action Time (10% - 100%) 2.7668
Total Time (0 - 100%) 2.8024

INTEGRALS

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AVERAGES

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<td>2655.4</td>
<td>1117.3</td>
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</table>

Observed Burn Rate = 0.3751 in/sec. @ 612.2 psi
Specific Impulse = 228.5288 lbf-s/lbm
Action / Burn Time = 1.0325
NASA RELOAD

Ballistic Analysis

of

ROHM and HAAS Motors

11 and 12

INTRODUCTION

On December 4, 1992 two Rohm and Haas motors (F/N’s 02530 and 02529) were fired from NASA Reload Batch 3457. This mix was an 88% solids, 19% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. From this batch, full scale motors 3, 9, 10, 11, 12, and 13 were also cast. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02530 used an eroding nozzle throat made from Durez. Firing number 02529 used a non-eroding, ATJ graphite throat. The burning rate exponent with the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02530, the burning rate exponent was determined to be 0.431. Based on the analysis of F/N 02529, the burning rate was determined to be 0.381 inches/second at 587 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.02441 \text{ Pc}^{0.431} \]

Full scale motor maximum pressure was calculated by comparing burning rates, exponents and propellant thermochemical properties to the mix 3 full scale motor. This was done using a mass balance equation, with a 3.8% scale factor applied to the subscale burning rate. This value was required to calibrate the calculation to the actual mix 3 full scale motor. The calculated full scale maximum pressure for batch 3457 is 717 psi which is below the requirement of 720 psi. This batch should yield acceptable performance in full scale motors.
TEST DATA REPORT
NASA RELOAD R/H

FIRING NOS: 02529-02530
FIRING DATE: DECEMBER 4, 1992
MOTOR NOS: 18, 101

RB DATA

PRODUCT ASSURANCE APPROVAL: [Signature]

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GAINESVILLE, VA 22065

PROPULSION TEST GROUP
DECEMBER 4, 1992

SPECIFICATION: [Signature]

DATA REDUCTION: [Signature]

ENGINEERING APPROVAL: [Signature]
TEST DATA SUMMARY

Test ID: NASA RELOAD R/W
Acct No. 38-6464-k6-1000
Motor No. 18
Grain No. 3457
Pro. Wgt. 5329.7002 grams
Web 1.0030 In.

Firing No. 02529
Date Tested 4-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 34.00 Deg. F
Rel Humidity 35.00 %
Barometer 29.90 lnHg

Ignition Delay (0 - 10%) 0.0521
Ignition Rise (10% - 75%) 3.3193
Action Time (10% - 10%) 2.6460
Burn Time (10% - 10%) 2.6136
Total Time (0 - 0) 3.3715

INTEGRALS

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<th>BURN</th>
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<th>BURN</th>
<th>MAXIMUM</th>
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Observed Burn Rate = 0.3838 in/sec. B 590.4 psia
Specific Impulse = 231.2790 lbf-sec/lbm
Action / Burn Time = 1.0124
## Test Information Sheet

**Program Name:** NASA RELOAD  
**Account No.:** 38-6464-N6-1000  
**Motor No.:** 18  
**Grain No.:** 3.457-18  
**Purpose of Test:** RTH

### Motor Assembly

- **Assy. Drawing No.:** ATJ  
- **Motor:**  
- **Nozzle:** ATJ  
- **Insulation:**  
- **Other Components:**

### Igniter

- **Assy. Drawing No.:** Atlas match  
- **Igniter Charge:**  
- **10 g. R.C. Granules**  
- **Housing or Container:**

### ProPELLANT DATA

- **Motor Weight Before Firing:** 89.4 lbm  
- **Motor Weight After Firing:**  
- **Inhibited Grain Weight:**  
- **Wp Propellant Weight:** 11.750  
- **Grain L.O.D.:** 4.041  
- **Grain O.D.:** 6.032  
- **Web:** 99.5  
- **Grain Length:** 11.320  
- **Dp Before:** 3.499  
- **Dp After:**

### Conditioning Temp.

- **Equilibrium Time:** 4 hrs  
- **Other Conditioning:** Supply Temperature Cycling Instrument Sheet

### Instrumentation Required

- **Expected Max. Value:**  
- **3 sec:** 1,000 psig  
- **Pressure Temp:**

### Other Instructions or Comments:

- **Testing in Box B @ 1/30 +60° 12-3-92 with**

---

**Test Information Sheet**

**SCHEDULE DATE:** 12-4-92  
**DELIVER EXPENDED MOTOR TO:** Bldg 97  
**DISTRIBUTE DATA TO:** C. Harrod, C. Price  
**X-RAY REVIEW:** ACCEPTABLE  
**NOT ACCEPTABLE:**

**Signature:**

**Test:** Not ReO  
**Engineering Date:** 12-4-92
TEST DATA SUMMARY

Test ID: NASA RELoad R/N
Acct No. 38-6454-M6-1000
Motor No. 101
Grain No. 3457
Pro. Wgt. 5349.7002 grams
Web 1.0000 in.

Firing Number 02530
Date Tested 4-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 34.00 Deg. F
Rel. Humidity 35.00%
Barometer 29.90 inHg

TIME VALUES
(seconds)

Ignition Delay (0 - 10%) 0.0349
Action Time (10% - 10%) 2.5928
Total Time (0 - 0) 2.6473

INTEGRALS

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Observed Burn Rate = 0.3907 in/sec. B 640.9 psia
Specific Impulse = 234.5561 lbf-s/lbm
Action / Burn Time = 1.0131
**Propulsion Test Spec. No.**

GTP 9606

**Schedule Date:**

12-4-92

**Deliver Expended Motor To:**

Bldg 97

Mrs. Price

**Distribute Data To:**

C. Schubert

M. Vaystrom

**X-Ray Review:**

Acceptable: [ ]

Unacceptable: [ ]

---

**Motor Assembly**

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<td>Nozzle:</td>
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<td>Insulation:</td>
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<td>Other Components:</td>
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**Propellant Data**

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<td>Motor Weight After Firing:</td>
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<td>V, Propellant Weight:</td>
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<td>Grain O.D.</td>
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<td>Web:</td>
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<td>D1: Before:</td>
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**Ignitor Charge:**

20.0 g 20 Calct.

10 g 3 C Granules

**Housing or Container:**

---

**Test Plan and Expected Performance**

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<th>Condition</th>
<th>Temp.</th>
<th>Equilibration Time</th>
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**Instrumentation Required**

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<tr>
<td>g Th my</td>
<td>3 Sec</td>
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</table>

**Supply Location**

1000 ps

**Other Instructions or Comments:**

---

**Signature**

[Signature]

**Test**

Not Re-Q

**Engineering**

[Signature]

**Program**

Nasa P.E. Load

**Acct. No.**

38-6464-NE-1000

**Motor No.**

101

**Grain No.4th**

3x57-101

**Purpose of Test**

R & H

**Program Assurance**

23-92

Harry L. Piir 1/3/92

In Box 6 @ 1130 +60° 12-3-92 Wty.
NASA RELOAD

Ballistic Analysis

of

ROHM and HAAS Motors

13 and 14

INTRODUCTION

On December 17, 1992 two Rohm and Haas motors (F/N's 02586 and 02587) were fired from NASA Reload Batch 3467. This mix was an 86% solids, 16% aluminum, HTPB formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. From this batch, full scale Motors 4, 5, 7 and 8 were also cast. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02586 used an eroding nozzle throat made from Durez. Firing number 02587 used a non-eroding, ATJ graphite throat. The burning rate exponent with the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02586, the burning rate exponent was determined to be 0.4163. Based on the analysis of F/N 02587, the burning rate was determined to be 0.3292 inches/second at 497 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.02483 \cdot P_c^{0.4163} \]

Full scale motor maximum pressure was calculated by comparing burning rates, exponents and propellant thermochemical properties to the mix 3 full scale motor. This was done using a mass balance equation, with a 3.8% scale factor applied to the subscale burning rate. This value was required to calibrate the calculation to the actual mix 3 full scale motor. The calculated full scale maximum pressure for batch 3467 is 596 psi which is below the requirement of 720 psi. This batch should yield acceptable performance in full scale motors.
TEST DATA REPORT
NASA RELOAD R/H

FIRING NO: 02586-02587
FIRING DATE: DECEMBER 17, 1992

STATIC TESTS

PRODUCT ASSURANCE APPROVAL:

ATLANTIC RESEARCH CORP
5945 WELLINGTON ROAD
GAINESVILLE, VA 22065

PROPULSION TEST GROUP
DECEMBER 17, 1992

SPECIFICATION:
DATA REDUCTION:
ENGINEERING APPROVAL:
MOTOR 110.3

FILING NO. 02586 17-Dec-92

PRESS-1 — PRESS-2 — THRUST-1 — THRUST-2 —

TEST DATA SUMMARY

Test ID: NASA RELOAD R/H
Act No. 36-6464-K6-1000
Motor No. 3
Grain No. 3467
Proc. Wgt. 515.2002 grams
Web 0.9990 in.

TIME VALUES
(seconds)

Ignition Delay (0 - 10%) 0.0305
Action Time (10% - 10%) 2.9557
Burn Time (10% - 90%) 0.0396

INTEGRALS

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<th>BURN</th>
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<td>1634.6</td>
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Observed Burn Rate = 0.3400 in/sec. 8 557.7 psia
Specific Impulse = 227.1721 lbf-s/lbm
Action / Burn Time = 1.0161
### TEST INFORMATION SHEET

**Program Name:** NASA RELOAD  
**Account No.:** 38-6467-NL-1000  
**Motor No.:** 3  
**Grain No.:** 3447  
**Purpose of Test:** R + H

| **Propulsion Test Spec. No.:** GTP 9606  
**Schedule Date:** 12-17-92  
**Deliver Exposed Motor To:** Bldg 97  
**C. Harford, O. Price, C. Schubert, M. Youngman**  
**X-Ray Review:** Acceptable  |

| **Motor Assembly**  
**Assy. Drawing No.:**  
**Hole:**  
**Insulation:**  
**Other Components:**  |
| **Igniter**  
**Assy. Drawing No.:**  
**Squibs:** Atlas match  
**Igniter Charge:** 20.0 g 2.0 cell  
**Gransules:**  
**Housing or Container:**  |

| **Grain Preparation**  
**End Preparation:**  
**Inhibiting:**  
**Finishing:**  |

| **Propellant Data**  
**Motor Weight Before Firing:** 88.54 lb  
**Motor Weight After Firing:**  
**Inhibited Grain Weight:**  
**Propellant Weight:**  
**Grain I.D.:** 4.033  
**Grain O.D.:** 5.010  
**Web:**  
**Grain Length:** 11.312  
**D1 Before:** 4.558  
**D1 After:** 4.558  
**D2 Before:** 7.536  
**D2 After:**  |

| **Test Plan and Expected Performance**  
**Conditioning Temp:** 70°F  
**Equilibrium Time:** 4 Hrs  
**Other Conditioning:** Supply Temperature Cycling Instrument Sheet  
**Instrumentation Required:**  
**Expected Meas. Value:**  
**3 Thrust:** 1000 lb  
**3 Pressure Temp:** 1000 psi  
**Supply Location:**  
**Other Instructions or Comments:** |

---

**Signature**

---

**Not Req.**

---

**Engineering**
Test ID: NASA Reload R/H
Actn No. 32-6-66-6-1000
Motor No. MMC-B
Grain No. 3407
Prop Wgt. 5167.2996 grams
Web 0.9999 in.

Firing Number 02587
Date Tested 17-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 48.00 Deg. F
Rel Humidity 100.00%
Barometer 30.10 inHg

Time Values (seconds)
Ignition Delay (0 - 10%) 0.0774
Action Time (10% - 10%) 3.1177
Total Time (0 - 0) 3.2238

Data Summary

Test ID: NASA Reload R/H
Actn No. 32-6-66-6-1000
Motor No. MMC-B
Grain No. 3407
Prop Wgt. 5167.2996 grams
Web 0.9999 in.

Firing Number 02587
Date Tested 17-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 48.00 Deg. F
Rel Humidity 100.00%
Barometer 30.10 inHg

Average

Observed Burn Rate = 0.3261 in/sec. 8 495.5 psia
Specific Impulse = 219.3088 lbf-s/lbm
Action / Burn Time = 1.0176

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</table>

Observed Burn Rate = 0.3261 in/sec. 8 495.5 psia
Specific Impulse = 219.3088 lbf-s/lbm
Action / Burn Time = 1.0176

Firing Number 02587
Date Tested 17-Dec-92
Cond. Temp. 70.00 Deg. F
Ambient Temp. 48.00 Deg. F
Rel Humidity 100.00%
Barometer 30.10 inHg

Average
**TEST INFORMATION SHEET**

**PROGRAM NAME:** NASA RELAY

**ACCOUNT NO.:** 38-6764-NG-1000

**MOTOR NO.:** MNC-8

**OFFSET NO.:** 3.967

**PURPOSE OF TEST:** R+H

---

**MOTOR ASSEMBLY**

- Assy. Drawing No.: 
- Motor:
- Nozzle:

- Insulation:
- Other Components:

---

**IGNITER**

- Assy. Drawing No.: Atlas match
- Igniter Charge: 80.0 g 2.0 gallets 10 g 2.0 grams
- Housing or Container:

---

**GRAIN PREPARATION**

- End Preparation:
- Inhibiting:
- Inhibiting:

---

**PROPPELLANT DATA**

- Motor Weight Before Firing:
- Motor Weight After Firing:
- Inhibited Grain Weight:
- V₁, Propellant Weight:
- Grain I.D.:
- Grain O.D.:
- Web:
- Grain Length:
- D₁: Before: 1.2405
- After: 
- D₉: Before: 3.999
- After: 

---

**TEST PLAN AND EXPECTED PERFORMANCE**

- Conditioning Temp.: 70 °F
- Equilibrium Time: 72 Hrs
- Other Conditioning: Supply Temperature Cycling Instrument Sheet

- Instrumentation Required:
- Expected Max. Value:
- 3 lbs
- 1000 psi
- Supply Location:

---

**Other Instructions or Comments:**

---

**SIGNATURE**

- Project Assurance: 
- Program: 
- Date: 12/15/97
NASA RELOAD

Ballistic Analysis of
ROHM and HAAS Motors (PBAN Mix 2)

INTRODUCTION

On February 18, 1993 two Rohm and Haas motors (F/N’s 02724 and 02725) were fired from NASA Reload Batch 3502. This mix was an 86% solids, 16% aluminum, PBAN formulation with a bi-modal (200/20 micron) AP distribution in a 70/30 ratio. From this batch, full scale motor DM-06 was also cast. There were no anomalies noted in the firings.

ANALYSIS RESULTS

The firing data was processed using the standard firing analysis code to determine the motor burning rate and burning rate exponent. Firing number 02725 used an eroding nozzle throat made from Durez. Firing number 02724 used a non-eroding, ATJ graphite throat. The eroding throat firing provides an accurate assessment of the burning rate exponent while the non-eroding throat provides an accurate burning rate value at the motor average operating pressure.

Based on the analysis of F/N 02725, the burning rate exponent was determined to be 0.3401. Based on the analysis of F/N 02724, the burning rate was determined to be 0.361 inches/second at 550 psi. Using these results, the burning rate equation for this mix is:

\[ r = 0.04222 \, P_c^{0.3401} \]

Full scale motor maximum pressure was calculated by comparing burning rates, exponents and propellant thermochemical properties to the mix 2 full scale motor. This was done using a mass balance equation, with a 3.8% scale factor applied to the subscale burning rate. This value was required to calibrate the calculation to the actual mix 2 full scale motor. The calculated full scale maximum pressure for batch 3502 is 652 psi which is below the requirement of 720 psi. This batch should yield acceptable performance in full scale motors.
TEST DATA REPORT

NASA RELOAD R/H

Firing No. : 02724-02725
Firing Date : 18-FEB-1993
Motor No. : 30,RTY-111

RS DATA

PRODUCT ASSURANCE APPROVAL : N/A

ATLANTIC RESEARCH CORPORATION
5945 Wellington Road
Gainesville, VA 22065

February 19, 1993

SPECIFICATION: ........................................
DATA REDUCTION: ..........................................
ENGINEERING APPROVAL: ..........................
Firing Number 02724
Date Tested 18-Feb-93
Cond. Temp. 70.00 Deg. F
Ambient Temp. 28.00 Deg. F
Rel Humidity 65.00 %
Barometer 29.78 inHg

Ignition Delay (0 - 10%) 0.0349
Ignition Rise (10% - 75%) 0.0196
Action Time (10% - 10%) 2.8338
Burn Time (10% - 75%) 2.8168
Total Time (0 - 0) 2.9385

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Observed Burn Rate = 0.3566 in/sec. @ 548.0 psia
Specific Impulse = 228.6732 lbf-s/lbm
Action / Burn Time = 1.0060
PROGRAM NAME: NASA Reload
ACCT. NO. 38-646-4-NG-1000
MOTOR NO. 30
CHASSIS NO. 3502
PURPOSE OF TEST R Y H

MOTOR ASSEMBLY

Assy. Drawing No. Try
Motor: ATJ
Nozzle: ATJ
Insulation: 
Other Components: 

GRAIN PREPARATION

End Preparation: 
Inhibiting: 
Bonding:

PROPELLANT DATA

Motor Weight Before Firing: 89.2 lbs
Motor Weight After Firing: 
Inhibited Grain Weight: 
W., Propellant Weight: 
Grain I.D.: 4.027
Grain O.D.: 6.045
Web: 0.045
Grain Length: 11.300
D, Before: 1.24 D, After: 
D, Before: 3.492

TEST INFORMATION SHEET

PROPULSION TEST SPEC. NO. GTP 9600
SCHEDULE DATE: 2-12-93
DELIVER EXPENDED MOTOR TO: JDG 97
DISTRIBUTE DATA TO: 
X-RAY REVIEW: ACCEPTABLE: 
UNACCEPTABLE: 

IGNITION

Assy. Drawing No. Atlas March
Squibs: 
Igniter Charge: 20 g 20 Pellets
Housing or Container: 

TEST PLAN AND EXPECTED PERFORMANCE

Conditioning Temp. 70°F
Equilibrium Time: 4 hrs
Other Conditioning: Supply Temperature Cycling Instrument Sheet
Instrumentation Required 
Expected Max. Value 
T, Thrust 3 sec
P, Pressure 1000 psi
Supply Location Dial

Other Instructions or Comments:

SIGNATURE

PRODUCT ASSURANCE
2.16.93

PRODUCT
7.16.93

TEST
Not Req.

ENGINEERING
**TEST DATA SUMMARY**

**Firing Number:** 02725  
**Date Test:** 18-Feb-93

**Test ID:** NASA RELADO  
**Actn No.:** 39-6464-66-1000  
**Motor No.:** RHY-111  
**Grain No.:** 3802

**Pro Wgt.:** 5545.6206 grams  
**Web:** 0.9940 in.

**Time Values (seconds):**

- Ignition Delay (0 - 10%) = 0.0769
- Ignition Rise (10% - 75%) = 0.0224
- Action Time (10% - 100%) = 2.7926
- Burn Time (100% - 10%) = 2.6938
- Total Time (0 - 0) = 2.8973

**Integrals:**

| CEN | ID | TOTAL ACTION BURN ACTION BURN MAXIMUM |
|-----|----|------------------|--|--|---------|
| 00  | PRESS-1 (PSIA) | 1666.1 1666.5 | 1660.6 | 605.0 | 613.6 | 607.9 |
| 01  | PRESS-2 (PSIA) | 1672.5 1670.8 | 1654.9 | 607.0 | 613.0 | 607.9 |
| 02  | THRUST-1 (LBF) | 2695.6 2693.9 | 2667.9 | 978.7 | 991.8 | 1267.6 |
| 03  | THRUST-2 (LBF) | 2665.3 2663.9 | 2638.5 | 967.8 | 980.6 | 1254.9 |

**Observed Burn Rate =** 0.3694 in/sec  
**Specific Impulse =** 220.4824 lbf-s/1bm  
**Action / Burn Time =** 1.0228
TEST INFORMATION SHEET

PROGRAM NAME: NASA RECORD

ACCT. NO. 38-6767-NG-1000
MOTOR NO. RTY 111

DENG No. 3502

PURPOSE OF TEST R+H

DUKEX

MOTOR ASSEMBLY

Assy. Drawing No.
Motor:
Nozzle:

Insulation:
Other Components:

IGNITER

Assy. Drawing No.
Spurs:

Igniter Charge:
20.0 g 2.0 Alls
10.0 C Grenades

Housing or Container:

PROPELLANT DATA

Motor Weight Before Firing:
Motor Weight After Firing:
Inhibited Grain Weight:
V. Propellant Weight:
Grain I.D.:
Grain O.D.:
Web:
Grain Length:
D1: Before:
After:
D2: Before:
After:

TEST PLAN AND EXPECTED PERFORMANCE

Conditioning Temp. 70°F
Equilibrium Time: 6 hrs
Other Conditioning: Supply Temperature Cycling Instrument Sheet

Instrumentation Required Value

Expected Max. Thrust 3 lb/s
Pressure 1000 lb/s
Temp. 70000 psi
Supply Location D

Other Instructions or Comments:

Signature

PRODUCT ASSURANCE

2.16.93

PROGRESS

DATE

HARRY'S LIST

3/6/93

SIGNATURE

TEST

ENG ING:

NOT RD
## MOTOR INFORMATION CHART

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<th>BATCH #</th>
<th>MIX DATE</th>
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ATTACHMENT 12
## PROPELLANT COMPOSITION

**MOTOR #00 (DEMO MOTOR)**

**SERIAL # SOSM-00 HTPB/16.0**

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# PROPELLANT COMPOSITION

**MOTOR #1**

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**ATTACHMENT 5**
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## PROPELLANT COMPOSITION

**MOTOR #3,9,10,11,12,13**

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<td>SOSM-13</td>
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</tr>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>8.937</td>
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<td>DOA</td>
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<tr>
<td>0.150</td>
<td>DOA</td>
<td>FE203</td>
</tr>
<tr>
<td>2.000</td>
<td>DOA</td>
<td>AL</td>
</tr>
<tr>
<td>0.200</td>
<td>DOA</td>
<td>MGO</td>
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<tr>
<td>19.000</td>
<td>DOA</td>
<td>AP200</td>
</tr>
<tr>
<td>0.025</td>
<td>DOA</td>
<td>AP20</td>
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<tr>
<td>0.025</td>
<td>DOA</td>
<td>IPDI</td>
</tr>
<tr>
<td>0.025</td>
<td>DOA</td>
<td>TPB</td>
</tr>
<tr>
<td>100%</td>
<td>DOA</td>
<td>MALEIC ANHYDRIDE</td>
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# PROPELLANT COMPOSITION

**MOTOR #4, 5, 7, 8**

<table>
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<table>
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<td>DOA</td>
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<td>0.025</td>
<td>TPB</td>
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<tr>
<td>100%</td>
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## PROPELLANT COMPOSITION

**MOTOR # 14**

**SERIAL # SOSM-14 PBAN/16.0**

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<tr>
<td>11.980</td>
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<td>1.820</td>
<td>DER 331</td>
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<td>0.200</td>
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<td>16.000</td>
<td>AL</td>
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<td>21.000</td>
<td>AP20</td>
</tr>
<tr>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
**DEVIATION APPROVAL REQUEST SHEET 1 OF 1**

1. **FOR:** 
   - Deviation
   - Summary of Minor Nonconformances

2. **FROM CONTRACTOR:**
   - Atlantic Research Corporation

3. **CONTRACT NUMBER:**
   - NASE-33663

4. **REQUEST NUMBER:**
   - ARC-1

5. **NOMENCLATURE:**
   - Strap-On Solid Motor

6. **NUMBER:**
   - 3

7. **REVISION:**
   - 8

8. **DATE:**
   - 12/23/92

9. **NONCONFORMANCE:**
   - [ ] Minor
   - [ ] Major

10. **MRB ACTION NO.:**
    - "-

11. **SERIAL NUMBER(S):**
    - SOSM-02 HTPB/17.5

12. **LOT NUMBER:**
    - "-

13. **QUANTITY:**
    - 1

14. **SUPPLIER OR SUBCONTRACTOR (GIVE NAME AND ADDRESS):**
    - "-

15. **SPECIFIED REQUIREMENTS:**
    - Refurbishment Specification 1.
    - Maximum Expected Operating Pressure (MEOP) = 720 psia

16. **DESCRIPTION OF DEPARTURE FROM REQUIREMENTS:**
    - Predicted MEOP for SOSM-02 = 750 psia

17. **REASON FOR REQUEST AND/OR CORRECTIVE ACTION TAKEN:**
    - Calculated MEOP does not affect test series objectives or test firing safety due to margin in factor of safety (approx. 4.0 for primary failure mode)

18. **REMARKS:**
    - No other motors exceed MEOP requirement

19. **CONTRACTOR CERTIFICATION:**
    - The contractor hereby certifies that the above described deviation is a departure from the contractual requirements in the quantities and/or conditions as stated above.

    -[ ] No cost adjustment
    - [ ] Cost adjustment (explain)

20. **GOVERNMENT QUALITY ASSURANCE REPRESENTATIVE COMMENTS:**

21. **MSFC REVIEW:**

<table>
<thead>
<tr>
<th>ORGANIZATION SYMBOL</th>
<th>REPRESENTATIVE</th>
<th>CONCURRENCE</th>
<th>NON-CONCURRENCE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP-20</td>
<td>Mark D'Angelo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP-72</td>
<td>Rosalyn Patrick</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>EP-24</td>
<td>Christina Shepherd</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22. **CONTRACTING OFFICER'S REPRESENTATIVE OR OTHER DULY DELEGATED AUTHORITY:**

   - [ ] Disapproval (Recommended)
   - [ ] Approval (Recommended) (With) (Without) Price Adjustment
   - [ ] Subject to Conditions Stated on MSFC Form 1

23. **CONTRACTING OFFICER:**

   - [ ] Approved
   - [ ] Disapproved

**MSFC Form #41 (Rev. May 1992) 9 COPY #4 CONTRACTOR'S RECORD**

**ATTACHMENT 14**
MATERIAL INSPECTION AND RECEIVING REPORT

ARCO001  300CT92  233923  Net 30

Atlantic Research Corporation
5945 Wellington Road
Gainesville, Virginia 22065

DCMAO Baltimore
Attention: Chesapeake
200 Towsontown Blvd., West
Towson, MD 21204-5299

Financial Management Office
George C. Marshall Space Flight Center, NAS
Marshall Space Flight Center, AL 35812

STOCK/PART NO. DESCRIPTION

<table>
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<tr>
<th>ITEM NO.</th>
<th>QUANTITY</th>
<th>UNIT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
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<tbody>
<tr>
<td>1</td>
<td>Motor Case</td>
<td>13 ea</td>
<td>NSP</td>
<td>NSP</td>
</tr>
<tr>
<td>2</td>
<td>Nozzle Insert A032704-100</td>
<td>13 ea</td>
<td>NSP</td>
<td>NSP</td>
</tr>
<tr>
<td>3</td>
<td>Retaining Ring B14236-03-01</td>
<td>13 ea</td>
<td>NSP</td>
<td>NSP</td>
</tr>
</tbody>
</table>

CONTRACT QUALITY ASSURANCE

Acceptance of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

RECEIVER'S USE

Quantities shown in column 17 were received in apparent good condition except as noted.

Packing List 233923

DD Form 250, DEC91

ATTACHMENT 15
**PACKING LIST**

No. 233923

**DATE SHIPPED**
10/30/92

<table>
<thead>
<tr>
<th>CUSTOMER ORDER NO.</th>
<th>BILL OF LADING NO.</th>
<th>NUMBER OF CARTONS IN THIS SHIPMENT</th>
<th>SHIPPING CHARGES:</th>
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<tbody>
<tr>
<td>NAS8-38668</td>
<td>233923</td>
<td>3 W/B</td>
<td>PREPAID</td>
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</table>

<table>
<thead>
<tr>
<th>GOVT. CONTRACT NO.</th>
<th>INSURE FOR</th>
<th>WEIGHT</th>
<th>CUBE</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5000 # ESTIMATED</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>ARC ORDER NO.</th>
<th>SHIP VIA</th>
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<tbody>
<tr>
<td>38-6464-N7-0000</td>
<td>ROADWAY EXPRESS</td>
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**METHOD TRADEMARK AFFIXED**

- [ ] LABEL
- [ ] TAG
- [ ] ENGRAVE
- [ ] CAST
- [ ] OTHER

**TRADMARK APPLIED TO**

- [ ] PRODUCT
- [ ] CONTAINER
- [ ] OTHER

**VERIFIED BY:** [Signature]

**DATE:** [Signature]

**NUMBER OF CARTONS IN THIS SHIPMENT:** 3

**WEIGHT:** 5000 # ESTIMATED

**CUBE:**

<table>
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<tr>
<th>CONTR. ITEM</th>
<th>QUANTITY ORDERED</th>
<th>QUANTITY SHIPPED</th>
<th>BACK ORDERED</th>
<th>ARC PART NUMBER</th>
<th>DESCRIPTION</th>
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<tr>
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<td>A0327004-100</td>
<td>MOTOR CASE</td>
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<td>B14236-03-01</td>
<td>NOZZLE INSERT</td>
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<td>RETAINING RING</td>
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**CUSTOMER FURNISHED**

**MATERIAL BEING RETURNED**

**METHOD TRADEMARK AFFIXED**

- [ ] LABEL
- [ ] TAG
- [ ] ENGRAVE
- [ ] CAST
- [ ] OTHER

**TRADMARK APPLIED TO**

- [ ] PRODUCT
- [ ] CONTAINER
- [ ] OTHER

**VERIFIED BY:** [Signature]

**DATE:** [Signature]
**MATERIAL INSPECTION AND RECEIVING REPORT**

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
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<tr>
<td>FSCM 95335 MFR P/N: A0327001-002 REV. A</td>
<td>MOTOR ASSEMBLY</td>
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<td>EA.</td>
<td>NSP</td>
<td>NSP</td>
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<tr>
<td>S/N: S0SM-01-BTPB-21.5, S0SM-02-BTPB-17.5, S0SM-03-BTPB-19.0, S0SM-04-BTPB-16.0, S0SM-05-BTPB-16.0, S0SM-06-BTPB-16.0, S0SM-07-BTPB-19.0, S0SM-08-BTPB-19.0, S0SM-09-BTPB-19.0, S0SM-10-BTPB-19.0, S0SM-11-BTPB-19.0, S0SM-12-BTPB-19.0, S0SM-13-BTPB-19.0</td>
<td>ROCKET MOTOR, UN0186, EXPLOSIVE 1.3C</td>
<td>12</td>
<td>EA.</td>
<td>NSP</td>
<td>NSP</td>
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<tr>
<td>MFR P/N: 17411-1 CARTRIDGE, IGNITER CARTRIDGES, POWER DEVICE, UN0323</td>
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</tr>
</tbody>
</table>

**CONTRACT QUALITY ASSURANCE**

* A. ORIGIN: Acceptance of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

* B. DESTINATION: Acceptance of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

**RECEIVER'S USE**

Quantities shown in column 17 were received in apparent good condition except as noted.

* If quantity received by the Government is the same as quantity shipped, indicate by (v)

**PACKING LIST NO.** 234039

**DD Form 250, DEC 91**

*Previous editions are obsolete.*
<table>
<thead>
<tr>
<th>ITEM NO</th>
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<th>QUANTITY</th>
<th>UNIT</th>
<th>UNIT PRICE</th>
<th>AMOUNT</th>
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<tr>
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<td>PROPELLANT SAMPLES</td>
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<td>PROPELLANT EXPLOSIVE, SOLID, CLASS &quot;B&quot; EXPLOSIVE</td>
<td></td>
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<td></td>
</tr>
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Packing List

No. 234039

DATE SHIPPED: 92DEC23E
RFS#RNP010

TRANSPORTATION OFFICER
EXPLOSIVES STORAGE & DEMOLITIONS BRANCH
BLDG. 8700
REDSTONE ARSENAL, SUPPORT ACTIVITY
REDSTONE, ALABAMA 35898-5330

CUSTOMER ORDER NO. BILL OF LADING NO. NUMBER OF CARTONS IN THIS SHIPMENT

COMM B/L INSURE FOR WEIGHT

NAS8-38668 4685.0 LBS.

ARC ORDER NO. SHIP VIA CUBE

38-6464-N7-1000 MOTOR FREIGHT 148.09 CU. FT.

SHIPPING CHARGES: PREPAID COLLECT

FOB: SHIPPING POINT DESTINATION

CONTR. ITEM

QUANTITY ORDERED QUANTITY SHIPPED BACK ORDERED ARC PART NUMBER DESCRIPTION

28 EA. SEE ATTACHED DD FORM 250 FOR ALL INFORMATION REQUIRED (ARC0002)

TOTAL NET EXPLOSIVE WT. 1290.0 LBS.

METHOD TRADEMARK AFFIXED LABEL TAG ENGRAVE CAST OTHER

TRADEMARK APPLIED TO PRODUCT CONTAINER OTHER

XXX SHIPMENT OF END ITEM

MATERIAL FURNISHED FOR FURTHER PROCESSING ON P.O. NO.

MATERIAL RETURNED FOR REPLACEMENT

MATERIAL RETURNED FOR FULL CREDIT ON P.O. NO.

MATERIAL RETURNED FOR REPAIR ON P.O. NO. OTHER SPECIFY
MATERIAL INSPECTION AND RECEIVING REPORT

ARCO003  93MAR03  TEN  B NET 30

ATLANTIC RESEARCH CORPORATION
5945 WELLINGTON ROAD
GAINESVILLE, VIRGINIA 22065

TRANSPORTATION OFFICER
EXPLOSIVES STORAGE & DEMOLITIONS BRANCH
BLDG 8700, REDSTONE ARSENAL SUPPORT ACTIVITY
REDSTONE, ALABAMA 35898-5330

<table>
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<th>QUANTITY</th>
<th>UNIT</th>
<th>UNIT PRICE</th>
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<tr>
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<td>MOTOR ASSEMBLY (P-BAN) S/N: SOSM-14-PBAN-16.0 ROCKET MOTOR, UN0186, EXPLOSIVE 1.3C MFR P/N: 17411-1 CARTRIDGE, IGNITER CARTRIDGES, POWER DEVICE, UN0323</td>
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<td>EA.</td>
<td>NSP</td>
<td>NSP</td>
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<td></td>
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<td>PROPELLANT EXPLOSIVE, SOLID, CLASS &quot;B&quot; EXPLOSIVE SHIPPED IN 3 W/B GROSS WT 440.0 LBS.</td>
<td>1</td>
<td>EA.</td>
<td>NSP</td>
<td>NSP</td>
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</table>

A. ORIGIN

□ CONFORM To CONTENTS AND QUANTITIES SHIPPED

□ ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION

□ QUALITY ASSURANCE

□ ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION AND THEY CONFORM TO CONTRACT, EXCEPT AS NOTED HEREIN OR ON SUPPORTING DOCUMENTS

□ LOCATION

□ DATE

□ SIGNATURE OF AUTHORIZED PERSON

□ CONTRACT QUALITY ASSURANCE

□ DATE

□ SIGNATURE OF AUTHORIZED PERSON

□ DESTINATION

□ CONFORM TO CONTENTS AND QUANTITIES SHIPPED

□ ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION

□ QUALITY ASSURANCE

□ ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION AND THEY CONFORM TO CONTRACT, EXCEPT AS NOTED HEREIN OR ON SUPPORTING DOCUMENTS

□ LOCATION

□ DATE

□ SIGNATURE OF AUTHORIZED PERSON

□ CONTRACT QUALITY ASSURANCE

□ DATE

□ SIGNATURE OF AUTHORIZED PERSON

□ RECEIVER'S USE

□ QUANTITIES SHOWN IN COLUMN 17 WERE RECEIVED IN APPARENT GOOD CONDITION EXCEPT AS NOTED

□ DATE RECEIVED

□ SIGNATURE OF AUTHORIZED PERSON

□ PAYMENT WILL BE MADE BY

□ FINANCIAL MANAGEMENT OFFICE

□ George C. Marshall Space Flight Center, NASA

□ MARSHALL SPACE FLIGHT CENTER, AL. 35812

□ PAYMENT WILL BE MADE TO

□ W31P4Q

□ TRANSPORTATION OFFICER

□ EXPLOSIVES STORAGE & DEMOLITIONS BRANCH

□ BLDG 8700, REDSTONE ARSENAL SUPPORT ACTIVITY

□ REDSTONE, ALABAMA 35898-5330

□ SAME AS BLOCK 9

□ MESSAGE

□ ATTN: GARRETT WHALAN

□ ATTN: GEORGE C. MARSHALL SPACE FLIGHT CENTER, NASA

□ ATTN: MARSHALL SPACE FLIGHT CENTER, AL., 35812

□ SIGNED

□ DATE

□ SIGNATURE OF AUTHORIZED PERSON

□ CONTRACTOR USE ONLY

38-6464-N7-1000

PACKING LIST NO. 236359

DD Form 250, DEC91

Previous editions are obsolete.

"U.S. GOVERNMENT PRINTING OFFICE"
Atlantic Research Corporation
a subsidiary of Sequa Corporation

SHIP TO:
TRANSPORTATION OFFICER
EXPLOSIVES STORAGE AND DEMOLITIONS BRANCH
BLDG. 8700
REDSTONE SUPPORT ACTIVITY
REDSTONE ARSENAL, ALABAMA 35898-5330
ATTN: GARRETT WHALAN

DATE SHIPPED:
93MAR08E
RFSRFWP021

PACKING LIST
No. 236359

<table>
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<tr>
<th>CUSTOMER ORDER NO</th>
<th>BILL OF LADING NO</th>
<th>NUMBER OF CARTONS IN THIS SHIPMENT</th>
<th>SHIPPING CHARGES:</th>
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</thead>
<tbody>
<tr>
<td>GOVT CONTRACT NO</td>
<td>INSURED FOR</td>
<td>3 W/B</td>
<td>PREPAID COLLECT</td>
</tr>
<tr>
<td>NASB-3866B</td>
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</tr>
<tr>
<td>ARC ORDER NO</td>
<td>SHIP VIA</td>
<td>440.0 LBS.</td>
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</tr>
<tr>
<td>38-6464-N7-1000</td>
<td>MOTOR FREIGHT</td>
<td>10.40 CU. FT.</td>
<td></td>
</tr>
</tbody>
</table>

3 EA.

SEE ATTACHED DD FORM 250 FOR ALL INFORMATION REQUIRED (ARC0003)
Atlantic Research Corporation (ARC) contracted with NASA to manufacture and deliver thirteen small scale Solid Rocket Motors (SRM). These motors, containing five distinct propellant formulations, will be used for plume induced radiation studies. The information contained herein summarizes and documents the program accomplishments and results.

Several modifications were made to the scope of work during the course of the program. The effort was on hold from late 1991 through August 1992 while propellant formulation changes were developed. Modifications to the baseline program were completed in late-August and Modification No. 6 was received by ARC on September 14, 1992. The modifications include changes to the propellant formulation and the nozzle design. The required motor deliveries were completed in late-Dec. 1992. ARC agreed to perform an additional mix & cast effort at no cost to NASA & another motor was delivered in March 1993.