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ROHM & HAAS COMPANY

REDSTONE ARSENAL RESEARCH DIVISION

HUNTSVILLE, ALABAMA

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FINAL REPORT - EVALUATION OF PROPELLANT/LINER SYSTEM OF MAULER (U)

ORDNANCE CORPS, DEPARTMENT OF THE ARMY

CONFIDENTIAL

ROHM & HAAS COMPANY

REDSTONE ARSENAL RESEARCH DIVISION
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FINAL REPORT - EVALUATION OF PROPELLANT/LINER SYSTEM OF MAULER (U)

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ABSTRACT

An investigation to evaluate the current liner system of Mauler (butyl/PL-1), and to compare it with the 42RPD/PL-1 liner system used in the Missile A program, indicated that the current system was satisfactory and that it compared favorably with the 42RPD/PL-1 system.

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FINAL REPORT - EVALUATION OF PROPELLANT/LINER SYSTEM OF MAULER

1. INTRODUCTION

This investigation was conducted to evaluate the current propellant/liner system and to investigate the parameters affecting the liner bond in the Mauler motor.

Specific objectives of the program were

1. to develop processing techniques for small scale manufacture of LPC-1003 (RH-P-226) propellant composition.

2. To conduct casebond tests at low temperatures and to conduct cycling tests from 140°F to 10°F above the propellant low temperature failure point, using strain evaluation cylinders.

3. To conduct surveillance tests at 140°F and at ambient (magazine storage), using sealed evaluation cylinders.

4. To evaluate the thermal stability of the propellant/liner system, using the adiabatic calorimeter and cube cracking tests.

This item was later eliminated as unnecessary. Since the thermal stability could be evaluated in conjunction with the high temperature surveillance tests.

5. To compare the ballistic performance of six 6C5-11.4 static test motors loaded with LPC-1003 by Lockheed Propulsion Company with six similar motors loaded with RH-P-112 by Rohm & Haas Company. All motors were test fired by Rohm & Haas Company.

2. CONCLUSIONS

1. Processing techniques were developed for the small scale manufacture of LPC-1003 and LPC-1003A propellant compositions of a quality comparable to that produced by Lockheed Propulsion Company for use in the Mauler.

2. Casebonding of compositions LPC-1003 and -1003A to PL-1 liner on both 42RPD and SMR-81-11 (butyl) insulating liner substrates was adequate over the temperature range of -40°F to

140°F and for six cycles over the same temperature extremes in 2SM-7.5 strain evaluation cylinders.

3. The same liner systems with LPC-1003 and LPC-1003A propellant compositions in 2SM-7.5 evaluation cylinders are good for at least ten months at 140°F.

4. The thermal stability of these propellant compositions was also adequate for at least ten months at 140°F, except when the propellant was not separated from the steel case with either 42RPD or SMR-81-11 (butyl) insulating liners. The type of substrate appeared to have an effect on thermal stability of the propellant at the liner interface and should be investigated further.

5. A set of six 6C5-11.4 static test motors loaded with LPC-1003 were test fired alternately with six similar motors loaded with RH-P-112 composition. One motor containing LPC-1003 was not fired because of a severe case bond failure. The reproducibility of the LPC-1003 rounds was not as good as usually obtained with this test motor. A σ of 0.39% on specific impulse was obtained as compared to a normal value of about 0.25%.

3. DISCUSSION

3.1 Processing Techniques

To provide the propellant for this program, a process for the small scale manufacture of the Mauler propellant was developed by modifying the standard plastisol process. Two of the Lockheed Propulsion Company propellants were made (Table I).

Table I

Plastisol Propellant Compositions

Ingredient	RH-P-112	LPC-1003	LPC-1003A
"Fluid Ball" powder[1]	16.67%	16	16
Triethyleneglycol dinitrate	37.33	33	33
Aluminum	15.00[2]	18[2]	18[3]
Ammonium Perchlorate	30.00[4]	32[5]	32[5]
Resorcinol	1.00	1	0.5
Ethyl Centralite			0.5
Slurry Viscosity - cp.	4000	50,000	50,000

A check showed that the Lockheed Propulsion Company raw material specifications were essentially identical to the Rohm & Haas specifications.

Because of the small particle size of the ammonium perchlorate used to obtain the required burning rate, the slurry viscosity of the Mauler propellant was higher than that of most other plastisol compositions such as RH-P-112. This relatively high slurry viscosity caused some mixing problems initially. The primary mixing problem encountered was short pot life because of a temperature increase during mixing. (Table II)

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[1]Olin Mathieson Type B powder

[2]Alcoa 140, particle size 7 micron

[3]Reynolds 1-131, particle size 10 micron; also used Valley H-10 with a particle size of 10 microns

[4]Particle size, 55 microns, coated with 1% TCP

[5]Particle size, 20 microns, coated with 1% TCP

Table II

Temperature Distribution in 10-Gal. Turbine Mixer for LPC-1003[1]

Batch No.	Cooling Water Temp. - °F	Prop. Temp. Near Wall - °F	Prop. Temp. at Agitator - °F
25	75	79	90
27	66	72	79

There is essentially no temperature gradient across the mixer with RH-P-112 composition.

The solution to this problem of short pot life adopted for this program was to limit the batch size to fifty pounds in a nominal 100-pound mixer. For efficient mixing of this propellant, refrigerated cooling water is required.

The mechanical properties reproducibility of the LPC-1003 propellant made by Rohm & Haas is shown in Table III. Similar results were obtained for LPC-1003A. The density results demonstrate that deaeration was adequate.

Table III

Mechanical Properties Reproducibility of LPC-1003

Composition	Tensile Strength at 77°F - psi		Elongation at 77°F - %		Density-gm/cc Range
	Mean	Std. devia.	Mean	Std. devia.	
LPC-1003	77.8	3.2	13.2	0.53	1.695-1.705
RH-P-112	56.9	4.55	18.5	1.57	1.655-1.665

A comparison of the mechanical properties of LPC-1003A propellant made by Rohm & Haas and by Lockheed Propulsion is shown in Table IV. The tests were made by Rohm & Haas. These results indicate a real difference between the propellants from the two sources. However previous studies have shown that the moisture content of the propellant has a strong effect on the tensile

[1]After incorporation of all ingredients.

strength of the propellant. To determine if moisture was the cause of the difference in tensile strengths, the propellant was tested again after storage at 0% relative humidity for 35 days. The results (Table V) indicate no difference in mechanical properties of the propellant from the two sources.

Table IV

Comparison of Mechanical Properties of LPC-1003A Propellant From Rohm & Haas and From Lockheed Propulsion Company

Temperature - °F	Max. Stress, psi/Strain @ Max. Stress, % Rohm & Haas	LPC
164	48.0/17.0	51.6/14.4
140	51.0/16.2	60.9/16.8
77	80.4/13.1	92.9/12.9
50	115/12.6	133/13.5
-12	335/8.0	415/8.9
-36	578/7.5	782/5.5

Table V

Comparison of Mechanical Properties of LPC-1003A Propellant From Rohm & Haas and From Lockheed Propulsion Company

Propellant Conditioned at 0% Relative Humidity for 35 Days

Temperature - °F	Max. Stress, psi/Strain @ Max. Stress, % Rohm & Haas	LPC
138	69.2/14.4	72.8/13.5
113	82.5/13.9	85.2/13.8
77	116/13.6	118/13.3
40	169/12.7	185/13.7
0	322/10.9	355/11.0
-32	650/9.1	810/9.1

3.2 Casebond Tests

One of the objectives of this contract was to evaluate the effectiveness of the "present liner system" used in Mauler, the

SMR-81-11[1] butyl liner. At the same time tests were made with 42RPD[2] insulating liner as a comparison. The 42RPD system was successfully used in the Missile A with a similar plastisol propellant composition. Both insulating liners had a thin spray coat (1 to 2 mils) of PL-1 bonding liner.

Initial bond strengths between the PL-1 liner and the SMR 81-11 insulation were inadequate. The poor bonding was attributed to inadequate cross-linking in the PL-1 liner. To overcome this problem, the concentration of toluene diisocyanate (TDI) cross-linker was doubled. The higher TDI concentration was required to compensate for the higher water content in the PL-1 made at this location, since the humidity is generally higher in north Alabama than in the dry area of southern California. Lockheed Propulsion Company (then Grand Central Rocket Company) had no trouble with the original PL-1 composition at that location. Water degrades the TDI and reduces the cross-linking in the liner.

To establish the strain level at failure of LPC-1003 propellant several strain evaluation cylinders (SEC's) were cast with LPC-1003 propellant with different web thicknesses. A cylindrical perforation was used (Fig. 1). This configuration was designated the 2C1-7.5 SEC. The code designation is described as follows:

1. The first number is the inside diameter of the SEC in inches.
2. The letter designates the perforation (C = cylindrical, SM = slotted tube).
3. The number following the "C" is the inside diameter of the propellant in inches.
4. The number following the dash is the length of the SEC in inches.

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[1]Stoner Rubber Company, Anaheim, California

[2]Raybestos-Manhattan, Inc., Manheim, Pennsylvania

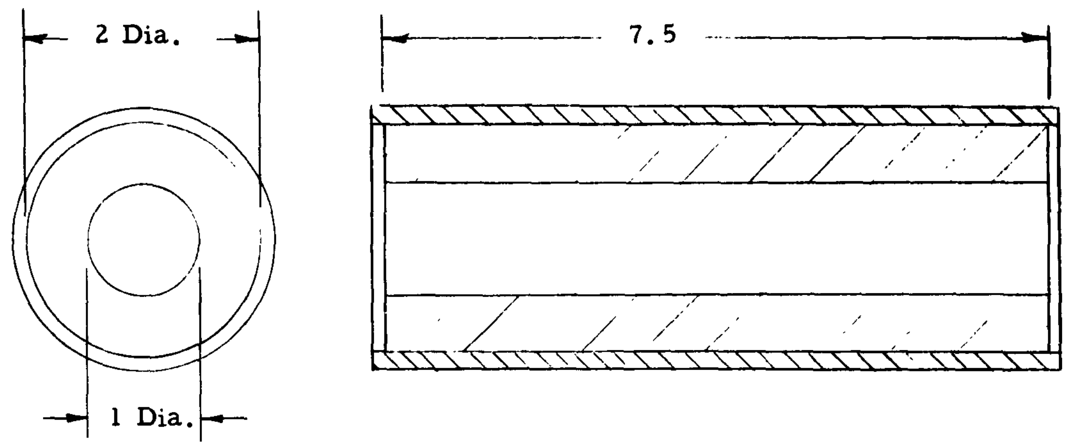


Fig. 1. Configuration of 2C1-7.5 Strain Evaluation Cylinder

Obviously the thicker the web, the higher the strain on the internal surface as the propellant is cooled. Using different web thicknesses, the failure curve was established over a temperature range of -50°F to 80°F. Failure was found to occur at strains of 6 - 8% over this temperature range.

Based on the Mauler web thickness and the cylindrical perforation, failure occurred at approximately 40°F. Using the slotted tube evaluation cylinders (2SM - 7.5) which were designed to simulate the actual Mauler propellant configuration, strains were appreciably reduced, such that the propellant failure did not occur until below -50°F. One 2SM cylinder with 42RPD insulation and PL-1 liner was cooled to -83°F overnight with no apparent failure in the propellant or case bond. The same propellant composition which failed at 40°F in the cylindrical configuration did not fail at -50°F in the slotted tube configuration. The cylindrical configuration test was considered to be too severe to determine the propellant capability in the Mauler geometry.

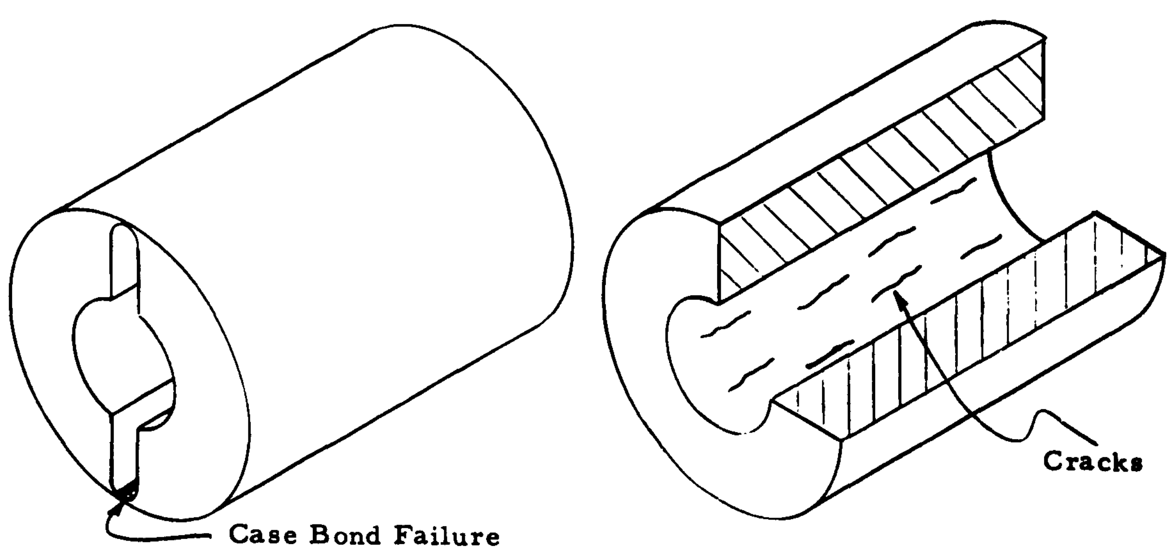
LPC-1003 on both 42RPD and SMR-81-11 (butyl) insulating liner with PL-1 bonding liner was shown to be adequate in terms of propellant physical properties and case bonding to a temperature lower than -40°F.

3.3 Tempc ·ature Cycling

Following the establishment of a low temperature limit of at least -50°F for the propellant in the slotted SEC's, the same cylinders were subjected to temperature cycling over the range of -40°F to 140°F at one week inte~vals.

Additional SEC's with cylindrical perforations and cast with LPC-1003A were prepared with various web thicknesses. A similar failure curve was established as for composition LPC-1003. Based on these test results, the 2C0.75 - 7.5 geometry was selected for cycling between 0°F and 140°F at one week intervals, because failure would not occur at the lower cycling limits. Both the 42RPD and butyl liner were used in two sets of SEC's, one for cycling and one for storage at 140°F.

The slotted tube samples withstood six cycles and failed on the seventh, while the cylindrical samples failed on the sixth as shown in Fig. 2.



2SM-7.5 Configuration 2C0.75-7.5 Configuration

Fig. 2. Failures Due To Temperature Cycling

The failures in the slotted tube configuration all occurred as small case bond failures at the bottom of the slots. It is believed that moisture was responsible for the failures, since each time the sample was removed from the cold box for inspection, a layer of frost formed on the propellant. After repeated cycles the propellant appeared softer to the touch and the failures were detected. A water analysis of the propellant indicated up to 0.6% water, which is approximately three times the normal water content, and water is known to have a detrimental effect on plastisol propellants.

3.4 High Temperature Storage

Ten evaluation cylinders of each the butyl/PL-1 and 42RPD/PL-1 liner systems were stored at 140°F. Both LPC-1003 and LPC-1003A were investigated.

All five of the butyl lined cylinders containing LPC 1003A contained bond failures after four months storage at 140°F. Another set of samples made in the same way exceeded ten months storage at the same conditions. Failures between plastisol propellant and PL-1 liner have never occurred unless the surface of the PL-1 was contaminated with oil, grease or mold release. Since the failures in four samples were very small and did not propagate, surface contamination at the ends of the cylinders, perhaps by fingerprints or mold release from the casting fixtures, is strongly suspected. All failures were small case bond failures at the ends of the grains. One cylinder had a larger failure which doubled in size over a one month period. However, no PL-1 could be found in the failed area. It is possible that the surface of the butyl which is normally shiny did not get completely covered with the PL-1 spray. This conclusion is partially supported by data from Lockheed Propulsion Company where they found the bond of LPC-1003 to butyl was fairly good initially, but degradation with aging was not well known. The available information indicates that this failure was the result of incomplete PL-1 coverage.

Only one failure occurred in the set of cylinders insulated with 42RPD after ten months storage, and this failure occurred between the propellant and the steel case, where the 42RPD did not cover the entire length of the cylinder. The failure was limited to the steel/propellant interface. No failure was evident in the 42RPD insulated portion of the cylinder.

Apparently either liner system should be satisfactory with LPC-1003 or LPC-1003A propellant for at least ten months storage at 140°F, provided the insulating liner is properly coated with the PL-1 bonding liner.

3.5 Thermal Stability

There was no indication of any degradation of the propellant itself, during the ten months storage at 140°F, except where the propellant was in direct contact with the steel case. In the one sample where the bond failed between the propellant and steel, the propellant took on a pink color. Apparently the substrate has an effect on the thermal stability of LPC-1003 propellant composition. There was no indication of propellant change in the insulated region, either with butyl or 42RPD. An investigation into the cause of the propellant degradation was not within the scope of this contract. However, further studies on the effect of substrate on propellant would probably be advantageous and profitable.

3.6 Ballistic Performance of LPC-1003

Six standard 6C5-11.4 static test motors were bonded with LPC-1003 propellant by Lockheed Propulsion Company for ballistic evaluation. The motors were alternately fired with similar motors loaded with RH-P-112 composition as a control. One motor with LPC-1003 exhibited a case bond failure. Data from this round are not included. The data from the remaining five rounds are presented in Table VI with the data from the six control rounds.

Table VI

Evaluation of LPC-1003 in 6C5-11.4 Motors

Composition	K_m	r_b (in/sec)	$\bar{P}_b$ (psia)	$\bar{P}_a$ (psia)	I^0_{1000} lb_f-sec/lb_m	σ (%)
LPC-1003	127.2	0.89	1013	969	246.3	0.39
RH-P-112$_{cb}$	162.3	0.65	938	904	245.5	0.24

The reproducibility of the r· unds containing LPC-1003 propellant was not as good as normally experienced in this test motor as evidenced by the somewhat larger value of σ on specific impulse.

Initial distribution of this report was made in accordance with the Joint Army-Navy-Air Force mailing lists for Solid Propellant and Liquid Propellant technical information plus approved supplements