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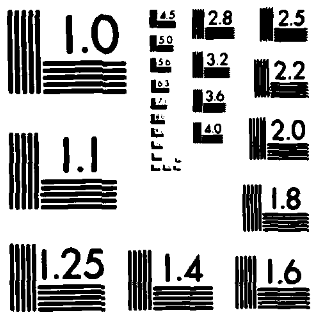

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TECHNICAL REPORT ARAED-TR-86029

PROPELLANT CONTAINERS AND EXPULSION CHARGES FOR M483A1 AND M509 PROJECTILES

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18. SUPPLEMENTARY NOTES

This project was initiated in 1980 by the Large Caliber Weapon Systems Laboratory, Energetic Materials Division, ARDC.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M10 propellant	M6 propellant	Ball powder
Propellant costs	Expulsion charge	Propellant container
Moisture protection	Hygroscopicity	Celcon acrylic cloth
Polyethylene	Temperature cycling	High moisture conditions

(continued)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This investigation was conducted to develop a suitable propellant candidate to replace the M10 propellant expulsion charge for the M483A1/M509A1 projectiles in order to gain cost advantages, improved safety characteristics, longer shelf life, and the elimination of manufacturing and loading problems caused by the undesirable hygroscopic characteristics of M10. This report describes the selection of a replacement propellant and the tests undertaken to indicate its suitability, extrusion characteristics, ballistic performance,
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Block 19. Key Words (Continued)

Relative quickness	Relative force	Ballistic performance
Closed ogive	Malfunction	Flake diameter
Web thickness	Shelf life	Instability
Static firing	Pressure	Ignition delay

Block 20. Abstract (Continued)

and the effects of temperature and different charge weights on ballistic performance. In addition, details are given demonstrating the need for the redesign of the propelling charge container based on tests involving exposure to extreme temperature and high humidity cycles and the effect on the ballistic performance of M10 propellant following exposure to these severe environmental conditions.

SUMMARY

Phase I

In an attempt to verify the suitability of M6 propellant as a replacement for M10 in the propellant expulsion charge for the M483/M509 projectiles, four extrusions of 0.049 inch diameter M6 propellant were prepared having web thicknesses of 0.007, 0.009, 0.010 and 0.011 inch. These trial extrusions were compared in closed bomb tests with standard M10 propellant of 0.035 inch diameter and 0.012 inch web thickness. The relative quickness and relative force results obtained for the four extrusions of M6 and the standard M10 propellant are shown in table 1. Static firing tests were conducted at -65°F, ambient, and +160°F, using the M6 propellant extrusion that came closest to matching the relative quickness (RQ) and relative force (RF) values of the standard M10 propellant, which was also used as the standard of reference for the sealed ogive static firing tests. A total of 76 static firings were conducted over the temperature range from -65°F to 160°F. The static tests program was essentially designed to ascertain:

1. The effect of the various conditioning temperatures on the expulsion charges.

2. The effect of varying the charge weight on the ballistic performance of the propellant.

3. The ballistic performance characteristics of the M6 propellant and how they compare with those of M10 propellant.

4. The feasibility of replacing M10 propellant with M6 based on comparatively favorable ballistic performance characteristics without decreasing the total energy of the system.

A total of 76 static firings were conducted: 25 using M6 propellant and 51 using M10 propellant. The M6 tests included 9 firings conducted at -65°F, 8 firings at ambient, and 8 firings at 160°F. The M10 tests included 14 firings conducted at -65°F, 27 firings at ambient, and 10 firings at -60°F. There was only one static test malfunction in this phase of the program. This malfunction occurred when a 58 g charge of M10 propellant misfired at -65°F.

Phase II

The celcon/acrylic bags had a history of a high failure rate in the areas adjacent to the seal when subjected to the three-psi air test. A program was initiated to determine the effect that these bag imperfections had on the propellant powder. Five loaded bags containing M10 composition--three of which had deliberately made imperfections--were exposed to 95% relative humidity at 25°C prior to static firing. The results of this hygroscopicity test are shown in table 13. The static firing results for these conditioned charges are shown in

table 14. The JAN Cycle Test was conducted on three different types of loaded propellant containers including the celcon/acrylic bag to determine the comparative degrees of container permeability. Some of the containers had deliberately made imperfections in order to determine the effects of moisture and temperature extremes on the M10 propellant. This was determined by sealed ogive static firings at weekly intervals following completion of the JAN Cycle Test. These tests demonstrated that the celcon/acrylic bags were unsatisfactory with regards to moisture resistance and powder protection as demonstrated by their higher hygroscopicity values as compared to those obtained for the plastic bags. The high moisture content was directly responsible for the low pressure values, the long ignition delay periods, and the greater number of malfunctions, as shown in table 15.

This report does not intend to convey the impression that the plastic container is completely satisfactory, but only that in comparison with the cloth bag, it has proven to be less hygroscopic, thus offering greater protection to the propellant. This greater degree of protection is responsible for the static firing results that are closer to the acceptable range with the occurrence of a smaller number of malfunctions.

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INTRODUCTION

This report discusses a program that is primarily concerned with the modification of the existing propellant expulsion charge for the M483/M509 projectiles by either changing the grain dimensions of M10 to a larger diameter, 0.049 inch from 0.035 inch, or replacing the M10 with M6 propellant. The former approach would result in a cost savings of $0.87 per pound, and the latter would result in an additional cost savings of $0.45 per pound with the additional advantages of safety and increased shelf life.* In view of the desirable cost and safety characteristics associated with M6 propellant, the latter approach was selected as the preferable alternative. It is anticipated that this propellant expulsion charge modification will provide the specified advantages without adversely affecting item functioning, safety, or reliability.

The secondary consideration is concerned with the redesign or replacement of the celcon/acrylic propellant charge bag used for containing the expulsion charge. During the initial production start-up, this bag had a high failure rate in the areas adjacent to the seal when subjected to the 3 psi air test. Although there are still problems associated with the celcon/acrylic bag, subsequent production experienced a normal reject rate. Since it was recognized that the cloth bag was water resistant and not waterproof, it was considered desirable to evaluate the effects of exposure to high humidity in the event that the projectile in which the charge assembly is sealed fails to keep the bag free from moisture. In view of this area of concern, the scope of this secondary objective was expanded to determine the ability of the celcon/acrylic and plastic containers to withstand the effects of temperature cycling and high moisture conditions, and their ultimate effect on the functioning of the propellant after exposure to these various environments.

Original development work that was conducted on the expulsion charge for the M483A1/M509 projectiles used the M10 propellant formulation. In the interest of cost reduction, it was proposed that a study be made of the feasibility of replacing the M10 propellant with M6 propellant, which was to be manufactured and processed at the US Army Armament Research, Development and Engineering Center (ARDEC) (formerly ARRADCOM). In addition to the favorable cost features, the M6 propellant was considered to have the advantages of safety and increased shelf life.

It was recognized at the beginning of the program that the M6 had a lower output and bulk density than the standard M10. Therefore, the compensation of the reduction in total energy of the charge and the loadability of the propellant were considered to be two major problems that should be overcome. It was determined that a 10% additional charge weight would be required; therefore, aluminum expulsion charge cups were procured having an overall length of 3.865-0.020 inch in lieu of 3.365-0.020 inch version. The increased volume permitted the charge weight to be increased from 51 g to 58 g.

*Costs computed in 1984 dollars.

The celcon/acrylic propellant charge bag for the expulsion charge for the M483A1/M509 projectiles had an approximate 90% failure rate when subjected to a 3 psi air test as indicated by the presence of air bubbles in the water tank when tested by Iowa Army Ammunition Plant (IAAP) personnel. The discontinuities appeared to be in the area adjacent to the seal and not the seal itself. The bags that did pass the air test usually failed upon retesting after being bent, folded, or twisted. To compound the problem further, the methods for sealing and testing the bags lacked standardization. Iowa Army Ammunition Plant sealed the bags ultrasonically and tested them for waterproofness by subjecting the bags to 3 psi air pressure while submerging them in a water tank. The load plants, Kansas Army Ammunition Plant (KAAP) and Lone Star Army Ammunition Plant (LSAAP), on the other hand, heat-sealed the bags and tested them for leakage in a vacuum chamber. Corrective measures that were applied included increasing the adhesive between the acrylic cloth and the acetal in an attempt to improve the sealing characteristics of the modified laminate, in addition to increasing the delamination, cracking, and rupture resistant qualities of the material when subjected to rough handling, pressure, and ultrasonic waves. When bags were fabricated with the new laminate, however, the increased quantity of adhesive was instrumental in "gumming up" the horn on the ultrasonic sealer. The modified bags did not offer any improvement over the bags using the original material since more than 50% of the test samples failed to pass the waterproof test. Alternate designs of the bag were also tested, which included eliminating the double fold that the bag was subjected to prior to inserting the metal eyelet, increasing the unfolded bags length and inserting the eyelet in the portion beyond the seal, changing the double fold design to a single fold, and stitching a rectangular tab of cloth that extended beyond the length of the unfolded bag for the purpose of inserting the eyelet. These modifications helped to decrease the seal failure rate, but the bags still remained fragile in the area adjacent to the seal.

EXPERIMENTAL PROCEDURE

1. M6 Propellant Manufacture - Propellant and Explosives Section Manufacturing Procedure 4-1 for the Manufacture of Clean Burning Ignition Powder.

2. Hygroscopicity Preparation - Five loaded expulsion charge bags [celcon/acrylic containing M10 flake propellant (RAD-LOT 77R-069829)] were sent to Energetic Materials Division (EMD) for the purpose of determining the hygroscopicity at 95% R.H. and 25°C. Samples were kept in humidity chambers and weighed at 24 hour intervals until equilibrium was attained. Deliberate imperfections were made by making pinhole perforations in two of the bags and a 0.5-inch opening in one. The bags were again put in the humidity chamber and the weighing procedure was repeated.

Hygroscopicity Procedure - MIL-STD 283 was Method No. 503.1.3.

3. JAN Cycle Test Preparation and Test - Nineteen celcon/acrylic loaded bags and 19 polyethylene loaded bags, making a total of 38 bags, each type containing 51 g of M10 propellant, were submitted to EMD, Chemistry Branch for the following work:

a. The celcon/acrylic bags were numbered 1 through 19.

b. The polyethylene bags were numbered 1a through 19a.

c. The weight of each bag was recorded.

d. Deliberate imperfections were made in some of the bags and were arranged in the following order:

Bag	No. of Holes	Bag	No. of Holes
1 and 1A	None	10 and 10A	None
2 and 2A	1	11 and 11A	None
3 and 3A	5	12and 12A	1
4 and 4A	None	13 and 13A	1
5 and 5A	1	14 and 14A	3
6 and 6A	5	15 and 15A	3
7 and 7A	None	16 and 16A	5
8 and 8A	1	17 and 17A	5
9 and 9A	5	18 and 18A	7
		19 and 19A	7

e. The bags were then put in a desiccator and carefully transported to TSEF, Bldg 3109 for the JAN cycle test.

In addition to the 38 loaded bags, four empty bags, two celcon/acrylic and two polyethylene, were submitted to the Anal Chem Section for the purpose of performing a hygroscopicity test. The bags were exposed to 95% R.H. at ambient temperature until equilibrium was reached. The hygroscopicity results of these empty bags are shown below:

Hygroscopicity Results for Empty Bags

Bag	Initial weight, g	Final weight, g	Weight increase, g	Increase (%)
Celcon/Acrylic				
1st Bag	5.4551	5.4602	0.0051	0.09
2nd Bag	5.4250	5.4289	0.0039	0.07
Polyethylene				
1st Bag	5.0656	5.0659	0.0003	0.006
2nd Bag	4.9603	4.9603	0.0000	0

f. At Bldg 3109, weighings were made immediately prior to the JAN Cycle Test. Bags were removed from the chamber at weekly intervals, reweighed, and sent to the test station at ARDEC for static firing according to the following schedule:

(1) At the end of week 1 - Bags 1, 1A, 2, 2A, 3, and 3A were removed from the conditioning chamber, weighed, and sent to the test station (Bldg. 1501) for firing.

(2) At the end of week 2 - Bags 4, 4A, 5, 5A, 6, and 6A were treated in the same manner as described in para. (1).

(3) At the end of week 3 - Bags 7, 7A, 8, 8A, 9, and 9A were treated in the same manner as described in para. (1).

(4) At the end of week 4 - the remaining bags followed the same procedure as described in para. (1).

The temperature-humidity conditions conformed to those described in SPEC MIL-STD-331-A - Test No. 105.

4. Chemical Compositions and Total Volatiles - MIL-STD-652C.

5. Relative quickness (RQ) and relative force (RF) - MIL-STD-286B, Method 801-1.

6. Grain Dimensions - MIL-STD-652C.

7. Closed Ogive Tests - The M483 closed ogive pressure test fixture is shown in figure 1. The tests were conducted in the heavy duty test stand by the personnel of the Energetics Test Section.

Detonator used - M-70

Fuze used - M577

Gages - A 10KGP BLH gage and a T-18 copper ball gage, internal. The copper ball gage was used for back up pressure; it is not considered as accurate as the BLH gage.

RESULTS

Table 1 gives the RQ and RF test results obtained for the four extrusions of M6 propellant produced at ARDEC and the standard M10 propellant produced at Radford Army Ammunition Plant (RAAP), Lot No. KN-79A. The table clearly illustrates that the M6 propellant having the nominal dimensions of 0.049-inch diameter and 0.007-inch web thickness (Lot No. 1B-8923-1) came closest to the closed bomb test values that were obtained for the standard M10 propellant having 0.035-inch diameter and 0.012-inch web thickness.

Results of the static firing tests of the selected lot of M6 propellant are given in table 2 and the static firing results of the standard M10 propellant are in table 3. Tables 4 through 6 present the firing results of M6 propellant in grouped data form for purposes of clarification and to facilitate performance comparisons. Tables 7through 10 present the firing results of M10 propellant in grouped data form for the same reasons. A summary of the firing tests (table 11) shows the performance of the M6 propellant charge in comparison with the M10 propellant charge. The tests were conducted between the temperature limits of -65°F and +160°F which yielded the the average values.

Table 12 is a further refinement of the firing tests which compares the overall performance of the M6 propellant charge with the M10 propellant charge. This table combines all of the values for each parameter, ignoring temperature and charge weight differences.

Table 13 shows the results of the hygroscopicity test on five celcon/acrylic bags containing 51 g of M10. Three of the five bags had known imperfections. The results show that the bag with the smallest opening area had the greatest increase in weight.

Table 14 presents the static firing results for the five celcon/acrylic bags loaded with 51 g of M10 propellant following their exposure to 95% R.H. at 25°C. These are the same expulsion charges shown in table 13.

Table 15 shows the comparative hygroscopicity results obtained for M10 propellant contained in celcon/acrylic and polyethylene bags following exposure to the conditions produced in the JAN Cycle Test for periods ranging from 1 to 4 weeks. The table also compares the ballistic performance results of the M10 propellant contained in both types of bags following exposure to the JAN Cycle Test in increments up to 4 weeks. The first 3 weekly increments contain three bags of each type: having no holes, one hole, and five holes. The fourth and final increment contains ten bags of each type: having no holes, one hole, three holes, five holes, and seven holes. A summary of the effects of the JAN Cycle Test on M10 propellant contained in celcon/acrylic and polyethylene bags showing the average increase in charge weight due to hygroscopicity and the subsequent effect on the performance of the propellant when tested statically is shown in table 16.

Table 17 shows the effects of the JAN Cycle Test on five high density polyethylene containers loaded with 51 g of M10 propellant. Both the weight change and the ballistic results following 28 days of exposure are tabulated.

Table 18 gives the chemical composition of the two propellant formulations, M6 and M10.

DISCUSSION OF RESULTS

A comparison of the RQ and RF results (table 1) indicates that the M6 propellant prepared at ARDEC having the nominal dimensions of 0.049-inch diameter and 0.007-inch web thickness came closest to approximating the values obtained for the standard M10 propellant having 0.035-inch diameter and 0.012-inch thickness. A study of the values (table 19) shows that the actual dimensions of the flakes differed considerably from the nominal dimensions. Specifically, the lot of M6 (IB 8293-1) coming closest to the standard M10 values had an average web thickness of 0.0136 inch in lieu of 0.007 inch and an average diameter of 0.055 inch in lieu of 0.049 inch. Problems were encountered in both the manufacture and the measurement of the M6 propellant. The manufacturing problem was due to the relatively small size of each lot (10 lbs). When this type of propellant is made at RAAP, it is made in large quantities which permits a large amount of waste during the cutting operations. Several passes are made which allow for accurate cutter adjustment in order to obtain the desired length. Since the propellant that was manufactured and processed at ARDEC was not in sufficient quantity to allow this "zeroing in" technique, the web sizes obtained for each extrusion were larger than desired. Since the flakes of propellant became distorted while drying, accurate measurements were difficult to obtain. The important factors to note are that the dimensions of the M6 propellant flake that came closest to matching the performance of M10 are known, and it is possible to manufacture M6 at a lower cost than M10.

The results of the chemical analysis of the M6 flake propellant manufactured at ARDEC are shown in table 20. They indicate that the nominal requirements specified in (MIL-STD-652D) were met.

Table 2 is the master result table that covers all of the M6 static test results, and table 3 is the master result table that covers all of the M10 static firings that were connected with the first phase of the program. Tables 4, 5 and 6 present the M6 static test results in grouped data form that combines the firings having the same charge weight in order to facilitate visual comparison and analysis of the measured parameters at the three test temperatures. Tables 7 through 10 present the M10 static test results in grouped data form. A study of table 11 which compares M6 and M10 average performance values for each parameter reveals that M6 propellant very closely approximates the performance of the M10 propellant.

Table 12 is a further refinement of the firing tests summary (table 11) which compares the performance of the M6 propellant charge with the M10 propellant charge. An analysis of table 12, which presents the mean average value for each parameter indicates that with the exception of ignition delay, both propellants are quite similar based on the performance parameters measured. Although the results shown in this table are derived from the combined values obtained from the firings at each temperature and charge weight, they do form a basis for a visual comparison of the ballistic characteristics of the two propellant formulations.

Table 13 shows the effects of high humidity conditions on the celcon/acrylic expulsion charge bags containing M10 propellant; bags 1, 2, and 3 having attained maximum hygroscopicity values after 124 hours were kept at ambient conditions for 24 hours. After losing some of the moisture they had gained, they were treated as follows:

1. Deliberate imperfections were made.

   a. Four pinhole perforations were made in bag 1.

   b. Ten pinhole perforations were made in bag 2.

   c. The seal on bag 3 was ripped creating an 0.5-inch opening.

The bags were again placed in the humidity chambers and then weighed every 24 hours until equilibrium was reached. The results obtained for the sealed bags indicated that the percentage weight gain was fairly consistent, and, in each case, the maximum moisture requirement of 1.20%, specified in (MIL-P-48099A), was exceeded. The second part of the experiment shows that the bag with the least perforations (bag no. 1) had the largest weight gain following the second exposure in the humidity chamber. This phenomenon indicated that the moisture was trapped inside the bag.

Using the same bags (table 14) that were previously tested to determine their ability to protect the M10 propellant in a high humidity environment (table 13), a second test was conducted to determine the effect of moisture on the performance of the M10 propellant expulsion charge prior to the alteration of bag integrity and afterward. The results indicate that the deliberate imperfections had little or no effect on the pressure or ignition delay results. Bag no. 1, which contained the most moisture (1.96%), equalled or exceeded the pressure results obtained for the two good bags (rounds 94 and 95). The ignition delay equalled that obtained for rounds 92 and 93. In both of these rounds, bag integrity had been altered; however, it was half of that obtained for round 94 (no bag imperfections), but was over eight times as great as that obtained for round 95 (no bag imperfections). A comparison of these results with those obtained for dry M10 propellant in table 7 points out the following:

	Temperature	Charge wt, g	Average Max. pressure, psi	Average Ignition delay, ms
Dry M10	Amb	51	6889	13.3
Wet M10	Amb	51	6740	255.5

1. Moisture contents up to 2% have an insignificant effect on the performance of the M10 propellant with respect to pressure since the average pressure results only suffered a 2.2% reduction.

2. Moisture contents up to 2% do affect the performance of the M10 propellant with respect to ignition delay as evidenced by a 1917% increase in delay time.

Table 15 compares the ability of the celcon/acrylic and plastic containers, loaded with 51 g of M10 propellant to withstand the combined effects of temperature cycling and high moisture conditions over periods ranging from 7 to 28 days. The subsequent effect on the ballistic performance of the propellant in both types of containers is also shown. A summary of these values is presented in table 16. An analysis of the hygroscopicity values indicated that the cloth bags are more hygroscopic than the plastic ones. A comparison of the values obtained for both types of bags having no perforations reveals the following:

1. For both types of bags, the weight gain is a function of exposure time. The cloth bags had an 8% average increase in weight the first week, 14% after the second week, 17% after the third week, and 25% after the fourth week. Although the plastic containers only had a 4% average weight increase over the four week period, each weekly increment showed a progressive increase over the previous week.

2. The polyethylene bag resisted the effects of the JAN Cycle Test better than the celcon/acrylic type. This was evidenced by the fact that the hygroscopicity for the celcon/acrylic bag, was 548% greater than that obtained for the polyethylene bag after the 28 day exposure period.

A comparison of the values obtained for both types of bags having perforations revealed the following:

1. The average weight increase of 17% for the polyethylene bag versus 28% for the celcon/acrylic bag after 28 days of exposure to temperature and humidity extremes indicates that the plastic bag is better with respect to weight gain resistance.

2. The table also illustrates that both bags having five holes increased their moisture content dramatically by the end of the third week; each bag exceeded a 30% increase in weight. There is no apparent explanation for this phenomenon.

An analysis of the closed ogive results indicated the following:

1. The powder contained in the cloth bags suffered 11 malfunctions out of 19 firings compared to 4 out of 19 for the propellant in the plastic bags.

2. Out of the five bags of each type having no perforations, four malfunctions occurred when the cloth bags were used while there were no malfunctions when the propellant contained in the plastic bags was statically tested.

3. The average maximum pressure of 6151 psi obtained for wet M10 in the plastic bag compared more favorably with the average value of 6889 psi obtained for dry M10 (table 7) than the average value of 4440 psi obtained for wet M10 in the cloth bag. The standard deviation value of 90 for the plastic bags versus 1818 for the cloth bags indicated a much narrower spread of values for the plastic bag.

4. The average ignition delay and standard deviation values for the plastic bag were more acceptable than those obtained for the cloth bag. The hygroscopicity and static firing results clearly indicated that the polyethylene bag provided greater protection of the propellant against the effects of temperature cycling and high moisture conditions.

Five high density polyethylene cylinders (table 17), equipped with tight fitting tops, were filled with 51 g of M10 flake propellant and exposed to the JAN Cycle Test and, subsequently, statically fired. The purpose of the test was to ascertain if the moisture protective characteristics of the hard plastic cup were superior to the other two containers. The results are inconclusive because the plastic covers blew off four of the five cups during the JAN Cycle Test and some of the propellant had spilled out.

CONCLUSIONS

Based on the results obtained for M6 Propellant when tested in the closed bomb, its performance over the required temperature range when statically tested in the closed ogive, and its relatively low cost, the M6 Propellant has demonstrated its eligibility to be considered as a candidate to be used as the expulsion charge for the M483/M509 projectiles.

In the event the bags containing the expulsion charge are exposed to the environment either by inadequate protection by the projectile or by separation from it, the hygroscopicity and static firing results indicate that the polyethylene bag provides greater protection to the propellant against the effects of temperature cycling and high moisture conditions than the celcon/acrylic type.

RECOMMENDATIONS

A more thorough investigation of the propellant expulsion charge should be initiated to determine the cause of the wide variations in the ignition delay values.

Some of the problems associated with M10 are:

a. Reported indications of shelf life problems.

b. Reported incidents of chemical instability.

c. It is relatively expensive.

d. It is comparatively hygroscopic which causes manufacturing and loading problems.

Therefore, it is recommended that an engineering study be undertaken to demonstrate that ball powder, which presently costs about 30% less than M10, be used as an alternate to M10 propellant. Based on the findings of this investigation, M6 could serve as an interim replacement for M10. Since M6 is only 20% cheaper than M10, it should be noted that M6 can not successfully compete with ball powder in cost effectiveness.

Efforts should be directed towards the replacement of the celcon/acrylic bag with a plastic container that is capable of providing protection for the powder charge from severe environmental exposure in addition to meeting all the TDP requirements that the current assembly meets.

Table 1. Comparison of relative quickness (RQ) and relative force (RF) values of four lots of M6 propellant with standard M10 propellant

Closed Bomb Test Results[a]

Powder	Lot	Diameter (in.)	Web (in.)	Relative quickness (%)			Relative force (%)		
M10[b] Comparison	RN-79A	0.035	0.012	1.000	1.000	1.000	1.000	1.000	1.000
M6[c] Under Test	1B-8923-1	0.049	0.007	0.998	0.994	1.046	0.951	0.959	0.969
	1B-8923-2	0.049	0.009	0.843	0.813	0.835	0.961	0.954	0.964
	1B-8923-3	0.049	0.010	0.811	0.841	0.788	0.947	0.950	0.943
	1B-8923-4	0.049	0.011	0.704	.731	0.725	0.937	0.950	0.973
Temp, °C				21	-40	60	21	-40	60

[a]Tests were conducted in a 200 cm3 closed bomb at 0.1 gm/cm3 loading density, and the pressure range was from 4000 psi to 12000 psi.

[b]The standard M10 flake propellant (Lot KN-79A) was manufactured at RAAP, Radford, VA.

[c]The M6 flake propellant was prepared at ARDEC, Dover, NJ.

[d]The pressure range for this test was from 4000 psi to 12000 psi.

Table 2. Sealed ogive static test results of M6 propellant

Round	Condition temperature (°F)	Charge weight (g)	Ignition delay (ms)	Average maximum pressure (psi)	Average pressure (psi)	Action time (ms)	Part integral ∫Pdt
227	AMB	53	200.0	6980	3320	29.6	98.27
229	AMB	53	1.0	7150	3180	31.9	101.41
230	AMB	53	155.0	7090	3070	35.9	110.14
231	AMB	58	0.1	8510	3650	29.0	105.83
232	AMB	58	0.6	8305	3140	39.4	123.71
233	AMB	53	0.7	7560	3230	32.3	104.31
234	AMB	53	181.0	7045	2990	40.3	120.32
235	AMB	58	1.0	8115	3580	30.3	108.41
236	AMB	58	1.0	8100	3530	32.5	114.69
237	160	53	1.3	7405	3080	34.7	107.02
238	160	58	0.8	8140	3630	28.5	103.54
239	160	53	1.0	7580	3230	30.6	98.69
240	160	58	0.6	8485	3390	32.3	106.93
241	160	53	0.7	7820	3790	22.7	86.10
242	160	58	0.6	8610	3600	28.4	102.19
243	160	53	0.6	7880	3280	32.5	106.69
244	160	58	0.5	8785	3530	30.9	109.22
245	-65	53	271.0	6715	2800	35.5	99.57
246	-65	58	12.2	7410	3170	34.2	108.40
247	-65	53	13.8	7075	2940	32.1	94.52
248	-65	58	0.7	7670	3700	31.1	114.92
249	-65	53	21.1	6330	2870	36.3	104.13
250	-65	58	9.9	7215	3170	32.1	101.61
251	-65	53	414.0	6790	2920	36.3	105.98
252	-65	58	0.9	8075	3450	35.6	122.96

Table 3. Sealed ogive static test results of M10 propellant

Ambient Temperature

Round	Charge weight (g)	Ignition delay (ms)	Average maximum pressure (psi)	Average pressure (psi)	Action time (ms)	Pt integral ∫Pdt (psi-sec)
46	51	4.0	7200	2900	35.0	101.4
47	51	1.5	6500	2600	36.7	95.5
48	51	24.0	6800	2630	35.8	94.2
49	51	3.0	7000	2831	28.7	81.3
50	51	9.0	7000	2765	33.1	91.5
51	51	19.0	6500	2540	31.8	80.9
53	51	16.0	6800	2510	37.0	92.9
54	51	5.0	7000	LOST		LOST
57	51	14.0	7000	2790	41.0	114.4
58	51	5.0	7000	2950	35.2	103.8
60	51	11.0	6800	2700	29.0	78.2
61	51	25.0	6800	2640	34.1	90.0
62	51	13.0	6800	2570	34.7	89.1
88	51	13.0	7000	3140	31.3	98.1
98	51	3.0	7100	2800	34.4	96.3
115	58	0.8	8620	3670	33.6	123.5
122	58	0.6	8580	3750	27.3	102.5
129	58	53.0	8290	3660	32.1	117.4
135	58	2.5	8430	3480	36.5	126.9
141	58	0.8	8430	3440	34.5	118.8
147	58	26.0	8380	2830	44.0	124.4
149	58	26.0	8210	3670	23.5	86.3
151	58	18.0	8415	3470	30.8	106.9
154	58	0.8	8700	3320	35.0	116.3
160	58	0.6	8670	3530	35.5	125.2
226	51	15.9	7260	3200	32.3	103.4
228	51	45.0	6550	2776	33.9	93.9

Temperature at +160°F

Round	Charge weight (g)	Ignition delay (ms)	Average maximum pressure (psi)	Average pressure (psi)	Action time (ms)	Pt integral ∫Pdt (psi-sec)
259	51	4.0	7630	3360	28.3	95.0
260	58	17.0	8730	3640	24.9	90.7
261	51	10.0	7505	3470	29.7	103.1
262	58	21.0	8745	3800	27.7	105.2
263	51	18.0	7505	3180	33.4	106.3
264	58	11.0	8810	4210	21.7	91.4
265	51	5.0	7535	3140	31.1	97.6
266	58	36.0	8680	3810	26.6	101.4
267	51	2.4	7675	3480	31.1	108.3
268	58	25.0	8650	4670	19.6	91.6

Table 3. (Cont)

Round	Charge weight (g)	Ignition delay (ms)	Average maximum pressure (psi)	Average pressure (psi)	Action time (ms)	Pt integral ∫Pdt (psi-sec)
			Temperature at -65°F			
283	51	205	6130	2770	33.2	92.0
284	58	942	3700	1760	7.2	13.7
285	58	300	7390	3670	27.3	100.3
286	51	56	6610	3060	34.9	106.9
287	58	351	7840	3600	30.2	108.6
288	51	124	6280	2830	42.0	119.0
289	51	398	6[illegible]65	2620	39.1	102.4
290	58	293	7750	3270	39.9	130.6
291	51	398	6315	2770	33.5	92.9
292	58	381	7070	3220	33.1	103.4
295	58	93	7145			
298	58	Failed to ignite, cup shattered - misfire				
299	58	317	7090			
300	58	435	7185	2730	46.7	127.5

Table 4. M6 closed ogive static test results

Grouped Data Using A 53 g Charge Weight

-65°F			Ambient			+160°F		
Round no.	Average maximum pressure (psi)	Ignition delay (ms)	Round no.	Average maximum pressure (psi)	Ignition delay (ms)	Round no.	Average maximum pressure (psi)	Ignition delay (ms)
245	6715	271.0	227	6980	200.0	237	7405	1.3
247	7075	13.8	229	7150	1.0	239	7580	1.0
249	6330	21.1	230	7090	155.0	241	7820	0.7
251	6790	414.0	233	7560	0.7	243	7880	0.6
			234	7045	181.0			
Avg max press mean values	6727 psi			7165 psi			7671 psi	
Ignition delay mean values	179.9 ms			107.5 ms			0.9 ms	

Table 5. M6 closed ogive static test results of M6 propellant grouped data using a 58 g charge weight

-65°F			Ambient			+160°F		
Round no.	Average maximum pressure (psi)	Ignition delay (ms)	Round no.	Average maximum pressure (psi)	Ignition delay (ms)	Round no.	Average maximum pressure (psi)	Ignition delay (ms)
246	7410	12.2	231	8510	0.1	238	8140	0.8
248	7670	0.7	232	8305	0.6	240	8485	0.6
250	7215	9.9	235	8115	1.0	242	8610	0.6
252	8075	0.9	236	8100	1.0	244	8785	0.5

	-65°F	Ambient	+160°F
Avg max press mean values	7592 psi	8258 psi	8504 psi
Ignition delay mean values	5.9 ms	0.7 ms	0.6 ms

Table 6. M6 closed ogive static tests showing additional parameters

Grouped Data Using a 53 g and 58 g Charge Weight

-65°F				Ambient				+160°F			
Round	Action time (ms)	Average pressure (psi)	∫Pdt (psi-sec)	Round	Action time (ms)	Average pressure (psi)	∫Pdt (psi-sec)	Round	Action time (ms)	Average pressure (psi)	∫Pdt (psi-sec)
					53 g Charge Weight						
245	35.5	2800	99.57	227	29.6	3320	98.27	237	34.7	3080	107.02
247	32.1	2940	94.52	229	31.9	3180	101.41	239	30.6	3230	98.69
251	36.3	2920	105.98	230	35.9	3070	110.14	241	22.7	3790	86.10
249	36.3	2870	104.13	234	40.3	2990	120.32	243	32.5	3280	106.69
				233	32.3	3230	104.31				
Mean values	35.0	2883	101.0		34.0	3154	107.0		30.0	3345	100.0
					58 g Charge weight						
246	34.2	3170	108.40	231	29.0	3650	105.83	238	28.5	3630	103.54
248	31.1	3700	114.92	232	39.4	3140	123.71	240	32.3	3390	106.93
250	32.1	3170	101.61	235	30.3	3580	108.41	242	28.4	3600	102.19
252	35.6	3450	122.96	236	32.5	3530	114.69	244	30.9	3530	109.22
Mean values	33.0	3373	112.0		33.0	3475	111.0		30.0	3538	105.0

Table 7. Closed ogive static test results of M10 propellant - grouped data using a 51 g charge weight

-65°F			Ambient			+160°F		
Round	Average maximum pressure (psi)	Ignition delay (ms)	Round	Average maximum pressure (psi)	Ignition delay (ms)	Round	Average maximum pressure (psi)	Ignition delay (ms)
283	6130	205	46	7200	4	259	7630	4
286	6610	56	47	6500	65	261	7505	10
288	6280	124	48	6800	24	263	7505	18
289	6165	398	49	7000	3	265	7535	5
291	6315	358	50	7000	9	267	7675	2.4
			51	6500	19			
			53	6800	16			
			54	7000	5			
			57	7000	14			
			58	7000	5			
			60	6800	14			
			61	6800	25			
			62	6800	13			
			88	7000	13			
			98	7100	3			
			226	7260	15.9			
			228	6550	45			
Avg max press mean values		6300 psi		6889 psi			7550 psi	
Ignition delay mean values		288 ms		13.3 ms			7.6 ms	

Table 8. Closed ogive static test results of M10 propellant - grouped data using a 58 g charge weight

-65°F			Ambient			+160°F		
Round	Average maximum pressure (psi)	Ignition delay (ms)	Round	Average maximum pressure (psi)	Ignition delay (ms)	Round	Average maximum pressure (psi)	Ignition delay (ms)
284*	3700	942	115	8620	0.8	260	8730	17
285	7390	300	122	8580	0.6	262	8745	21
287	7840	351	129	8290	53.0	264	8810	11
292	7070	381	135	8430	2.5	266	8680	36
290	7750	293	141	8430	0.8	268	8650	25
295	7145	93	147	8380	27.0			
298	Misfire - propellant failed to ignite. Cup shattered. Fuze went out.		149	8210	26.0			
299	7090	317	151	8415	18.0			
300	7185	435	154	8700	0.8			
			160	8670	0.6			
Avg max press Mean values		7532 psi		8473 psi			8723 psi	
Ignition delay Mean values		443 ms		13.0 ms			22 ms	

*Base plug of fuze blew out.

Table 9. Closed ogive static tests of M10 propellant - grouped data using a 51 g charge weight showing additional parameters

Round	Action time (ms)	Average pressure (psi)	∫Pdt (psi-sec)
		Temperature at -65°F	
283	33.2	2770	92.0
286	34.9	3060	106.9
288	42.0	2830	119.0
289	39.1	2620	102.4
291	33.5	2770	92.9
Mean Values:			
	36.5	2810	103
		At Ambient Temperature	
46	35.0	2900	101.4
47	36.7	2600	95.5
48	35.8	2630	94.2
49	28.7	2831	81.3
50	33.1	2765	91.5
51	31.8	2540	80.9
53	37.0	2510	92.9
54	Lost	Lost	Lost
57	41.0	2790	114.4
58	35.2	2950	103.8
60	29.0	2700	78.2
61	34.1	2640	90.0
62	34.7	2570	89.1
88	31.3	3140	98.1
98	34.4	2800	96.3
226	32.3	3200	103.4
228	33.9	2776	93.9
Mean Values:			
	34.0	2709	94.0
		Temperature at +160°F	
259	28.3	3360	95.0
261	29.7	3470	103.1
263	33.4	3180	106.3
265	31.1	3140	97.6
267	31.1	3480	108.3
Mean Values:			
	30.7	3326	102

Table 10. Closed ogive static tests of M10 propellant - grouped data using a 58 g charge weight showing additional parameters

Round	Action time (ms)	Average pressure (psi)	$\int Pdt$ (psi-sec)
		Temperature at -65°F	
284	7.2	1760	13.7
285	27.3	3670	100.3
287	30.3	3600	108.6
292	33.1	3220	103.4
290	39.9	3270	130.6
295	----------Not recorded----------		
298	----------Misfire----------		
299	----------Not Recorded----------		
300	46.7	2730	127.5
Mean Values:	30.8	3042	97.0
		At Ambient Temperature	
115	33.6	3670	123.5
122	27.3	3750	102.5
129	32.1	3660	117.4
135	36.5	3480	126.9
141	34.5	3440	118.8
147	44.0	2830	124.4
149	23.5	3670	86.3
151	30.8	3470	106.9
154	35.0	3320	116.3
Mean Values:	33.0	3476	114.0
		Temperature at +160°F	
260	24.9	3640	90.7
262	27.7	3800	105.2
264	21.7	4210	91.4
266	26.6	3810	101.4
268	19.6	4670	91.6
Mean Values:	24.0	4026	96.0

Table 11. Summary of firing tests showing the comparative performance of M6 and M10 propellant charges

	Standard M10 propellant						M6 propellant					
Temperature, °F	-65		Ambient		+160		-65		Ambient		+160	
Charge weight, g	51	58	51	58	51	58	53	58	53	58	53	58
No. of rounds	5	8*	17	10	5	5	4	4	5	4	4	4
Max. Pressure, psi	6300	7352	6889	8473	7550	8723	6727	7592	7165	8258	7671	8504
Std Deviation	189	1414	224	195	81	61	307	361	229	192	219	272
Avg Pressure, psi	2810	3042	2709	3476	3326	4026	2883	3373	3154	3475	3345	3538
Std Deviation	160	711	210	280	206	417	62	255	130	228	308	107
Ignition Delay, ms	228	443	13.3	13.0	7.6	22	180	5.9	108	0.7	0.9	0.6
Std Deviation	147	251	10.9	17.8	6.3	9.3	196	6.0	101	0.4	0.3	0.1
Act. Time, 10% to 10%, ms	36.5	30.8	34.0	33.0	30.7	24.1	35.1	33.2	34.0	32.8	30.1	30.0
Std Deviation	3.8	13.0	3.1	5.9	1.9	3.4	2.0	2.0	4.2	4.6	5.2	1.9
∫Pdt, psi-sec	103	97	94	114	102	96	101	112	107	111	100	105
Std Deviation	11.1	42	9.3	13.1	5.1	6.8	5.1	9.1	8.7	8.3	9.8	3.2

*Nine rounds were actually fired; one round malfunctioned.

Table 12. Comparison of M6 and M10 showing the mean average value of each parameter determined by closed ogive static testing

Propellant	M10	M6
Mean average Maximum pressure, psi	7547	7652
Mean std-dev	361	263
Mean average Average pressure, psi	3231	3294
Mean std-dev	330	181
Mean average Ignition delay	121	49.3
Mean std-dev	73	50
Mean average Action time	32.3	32.5
Mean std-dev	5.2	3.3
Mean Average $\int Pdt$	101	106
Mean std-dev	14.5	7.3

Table 13. Hygroscopicity of bags containing M10 propellant

Bag number	Sealed bags (hygroscopicity, %)	Bags with imperfections (weight gain, %)
1	1.78	0.18
2	1.85	0.08
3	1.84	0.03
4	1.77	-
5	1.86	-

NOTE: Conditions were 95% R.H. and 25°C temperature.

Table 14. Static firing results of M10 contained in celcon/acrylic bags following exposure to 95% R.H. at 25°C

Round no.	Bag no.	Bag condition	Peak pressure, psig BLH	Peak pressure, psig copper ball	Ignition delay, ms
91	1	4 pin holes	6700	6700	250
92	2	10 pin holes	7000	6600	250
93	3	1/4" tear in bag[a]	6800	6600	250
94	4	Good bag[b]	6500	6200	500
95	5	Good bag[b]	6700	6600	29
Mean Values:			6740		255

[a]Bag was dropped in loading room at Rocket Test Station and approximately one gram of the 51-g charge weight was lost prior to firing.

[b]No deliberate imperfections.

Test Data:

Charge weight - 51 g
Temperature - ambient

Table 15. Effects of JAN Cycle Test on M10 Propellant contained in celcon/acrylic and polyethylene bags with respect to weight gain and ballistic performance

Jan Cycle Test							Closed Ogive Test			
			Weight							
Week	Bag No.[a]	No. of Holes	Before test	After test	Weight gain (g)	Weight gain (%)	Round	Avg max pressure (psig)	Ignition delay (ms)	Comments
1	1	None	55.691	60.200	4.509	8.10	170	5825	368	
	1A	None	55.543	56.615	1.072	1.93	169	6130	210	
	2	1	55.912	60.085	4.173	7.46	171	6185	392	
	2A	1	55.589	58.578	2.989	5.38	167	6455	-	
	3	5	55.774	60.490	4.716	8.46	172	5825	326	
	3A	5	55.654	57.610	1.956	3.51	168	6095	136	
2	4	None	55.966	63.630	7.664	13.69	177	Misfire		
	4A	None	55.508	57.040	1.532	2.76	173	6235		
	5	1	55.798	62.798	6.582	11.80	176	5865	1453	
	5A	1	55.581	57.610	2.029	3.65	178	6490	258	
	6	5	55.395	61.440	6.045	10.91	174	5880	513	
	6A	5	55.494	60.090	4.596	8.28	175	6055	290	
3	7	None	55.799	65.275	9.476	16.98	183	Misfire		
	7A	None	55.505	57.425	1.920	3.46	184	6035	744	
	8	1	55.464	63.030	7.566	13.64	181	4830	59200	Hangfire
	8A	1	55.594	57.485	1.891	3.40	180	6475	108	
	9	5	56.006	74.450	18.444	32.93	179	Misfire		
	9A	5	55.616	73.110	17.494	31.45	182	432	10600	Low order-blew out cup base
4	10	None	55.515	69.565	14.040	25.29	197	Misfire		
	10A	None	55.619	57.920	2.301	4.14	198	6250	559	
	11	None	55.992	69.555	13.563	24.22	199	Misfire		Fuze and cup intact
	11A	None	55.644	58.075	2.431	4.34	200	6105	561	

[a]Celcon/Acrylic bags were numbered 1 through 19; polyethylene bags were numbered 1A through 19A.

Table 15. continued

			Jan Cycle Test				Closed Ogive Test			
			Weight							
Week	Bag No.[a]	No. of Holes	Before test	After test	Weight gain (g)	Weight gain (%)	Round	Avg max pressure (psig)	Ignition delay (ms)	Comments
	12	1	56.097	68.235	12.138	21.63	201	Misfire		Fuze and cup intact
	12A	1	55.615	58.340	2.725	4.89	202	6015	392	
	13	1	56.010	69.877	13.867	23.75	203[b]	2555	1580	
	13A	3	55.685	58.450	2.765	4.73	204	6670	419	
	14	3	55.552	77.675	22.123	39.82	191	Misfire		Fuze and cup intact
	14A	3	55.428	66.705	11.277	20.34	192	Misfire		Fuze and cup intact
	15	3	56.138	73.100	16.962	30.21	188	Misfire		
	15A	3	55.597	58.804	3.207	5.77	187	6375		Cup base out only
	16	5	55.966	71.860	15.894	28.40	195	1820	1020	
	16A	5	55.634	51.000	5.366	2.65	196	6195	1230	
	17	5	56.092	65.478	9.386	16.73	185	Misfire		Cup intact
	17A	5	55.562	72.085	16.523	29.73	186	2335	362	Cup base out only
	18	7	55.138	76.225	21.087	38.24	193	Misfire		Fuze and cup intact
	18A	7	55.684	75.400	19.716	35.40	194	Misfire		Fuze and cup intact
	19	7	56.203	71.180	14.977	26.64	189[c]	2565	1260	
	19A	7	55.946	71.450	15.504	27.71	190	Misfire		

[a]Celcon/Acrylic bags were numbered 1 through 19; polyethylene bags were numbered 1A through 19A.

[b]First peak after ignition delay of 1580 ms was 2555 psig, followed 80 ms later by second peak of 2485 psig.

[c]First peak after ignition delay of 1260 ms was 835 psig, followed by second 114 ms later peak of 2695 psig.

Table 16. Summary of the effects of the JAN Cycle Test on M10 propellant contained in celcon/acrylic and polyethylene bags showing the average increase in charge weight due to hygroscopicity and the subsequent effect on the performance of the propellant when tested statically

	Celcon/acrylic bag		Polyethylene bag	
Bag condition	No perforations	Perforations	No perforations	Perforations
Number of bags and rounds	5	14	5	14
Average Hygroscopicity, %	17.66	22.26	3.33	13.85
Standard Deviation	7.22	10.94	0.99	12.18
Average weight gain (%):				
After 1 week	8.10(1)	7.96(2)	1.93(1)	4.44(2)
After 2 weeks	13.69(1)	11.35(2)	2.76(1)	5.96(2)
After 3 weeks	16.98(1)	23.28(2)	3.46(1)	17.42(2)
After 4 weeks	24.76(2)	28.30(8)	4.24(2)	17.26(8)
Avg max. pressure, psi	4 malfunctions	4440[a]	6151	5916[b]
Standard deviation	-	1818	90	1276
Avg ignition delay, ms	4 malfunctions	936[c]	518	387[d]
Standard deviation	-	525	223	333

NOTE: (No.) indicates number of bags tested.

[a]Based on eight firings; the remaining six were misfires.

[b]Based on ten firings; the remaining four were malfunctions consisting of three misfires and one hangfire.

[c]Based on seven firings; the remaining seven were malfunctions consisting of six misfires and one hangfire.

[d]Based on nine firings; the remaining five rounds consisted of four malfunctions and one nonrecording.

Table 17. Effects of JAN Cycle Test on M10 flake propellant contained in plastic cups with respect to change in charge weight and ballistic performance

	JAN Cycle Test				Closed Ogive Test			
	Weight							
Bag	Pre test weighing	Post test weighing	Weight change (g)	Weight change (%)	Round	Maximum pressure (psig)	Ignition delay (ms)	Comments
1	63.823	64.232	0.409	0.64	333	6875	0.76	
2	63.873	53.645	-10.228	-16.01	336	Misfire		High order-fuze burned hole in cups.
3	63.935	56.496	-7.439	-11.63	337	Misfire		High order-fuze burned hole in cups.
4	63.866	64.875	1.009	1.56	335	5295	425	
5	63.887	64.728	0.841	1.32	334	5580	572	

Note 1 - Cover blew off Nos. 2 through 5 during test.
Note 2 - Container Nos. 2 and 3 tipped over and lost propellant during JAN cycle test.
Note 3 - Charge weight - 51 g.
Note 4 - Firing temp-ambient.
Note 5 - Fuze M577, no copper ball gage.

Table 18. Chemical composition of M6 and M10 propellant

Composition	M6	M10
Nitrocellulose, Type I, Grade C (13.15% N), %	87.00 ± 2.00	98.00 ± 1.00
Dinitrotoluene, %	10.00 ± 2.00	
Potassium Sulfate, %	---	1.00 ± 0.30
Diphenylamine, %1.00 ± $^{0.20}_{0.10}$*	1.00 ± $^{0.20}_{0.10}$	1.00 ± 0.30
Dibutylphthalate, %	3.00 ± 1.00	
Graphite (glaze added), maximum	---	0.25
Moisture, maximum	0.80	1.20
Moisture, minimum	0.40	0.50
Total volatiles, maximum	(see fig. 3)	

*Added basis.

Table 19. Actual measurements of M6 flake propellant*

Lot IB-8923	Lot PI-E	Nominal diameter (in.)	Nominal web thickness (in.)	Grain dimensions: Web thickness (in.)	Grain dimensions: Thickness variation (%)	Grain dimensions: Diameter (in.)	Grain dimensions: Diameter variation (%)
1	15	0.049	0.007	0.0136	13.02	0.0550	2.18
2	16	0.049	0.009	0.0145	10.60	0.0558	2.09
3	17	0.049	0.010	0.0155	9.68	0.0543	3.19
4	18	0.049	0.011	0.0153	8.73	0.0553	2.96

*Manufactured at ARDEC, Dover, NJ.

Table 20. Chemical analysis of M6 flake propellant*

Component	Results (%)	Nominal (%)
Nitrocellulose (13.15% N)	87.02	87.00 ± 2.00
Dinitrotoluene	9.66	10.00 ± 2.00
Dibutylphthalate	3.32	3.00 ± 1.00
Diphenylamine (Added)	1.15	$1.00 \pm {}^{0.20}_{0.10}$
Total Volatiles	0.63	(See fig. 3)

*Manufactured at ARDEC, Dover, NJ.

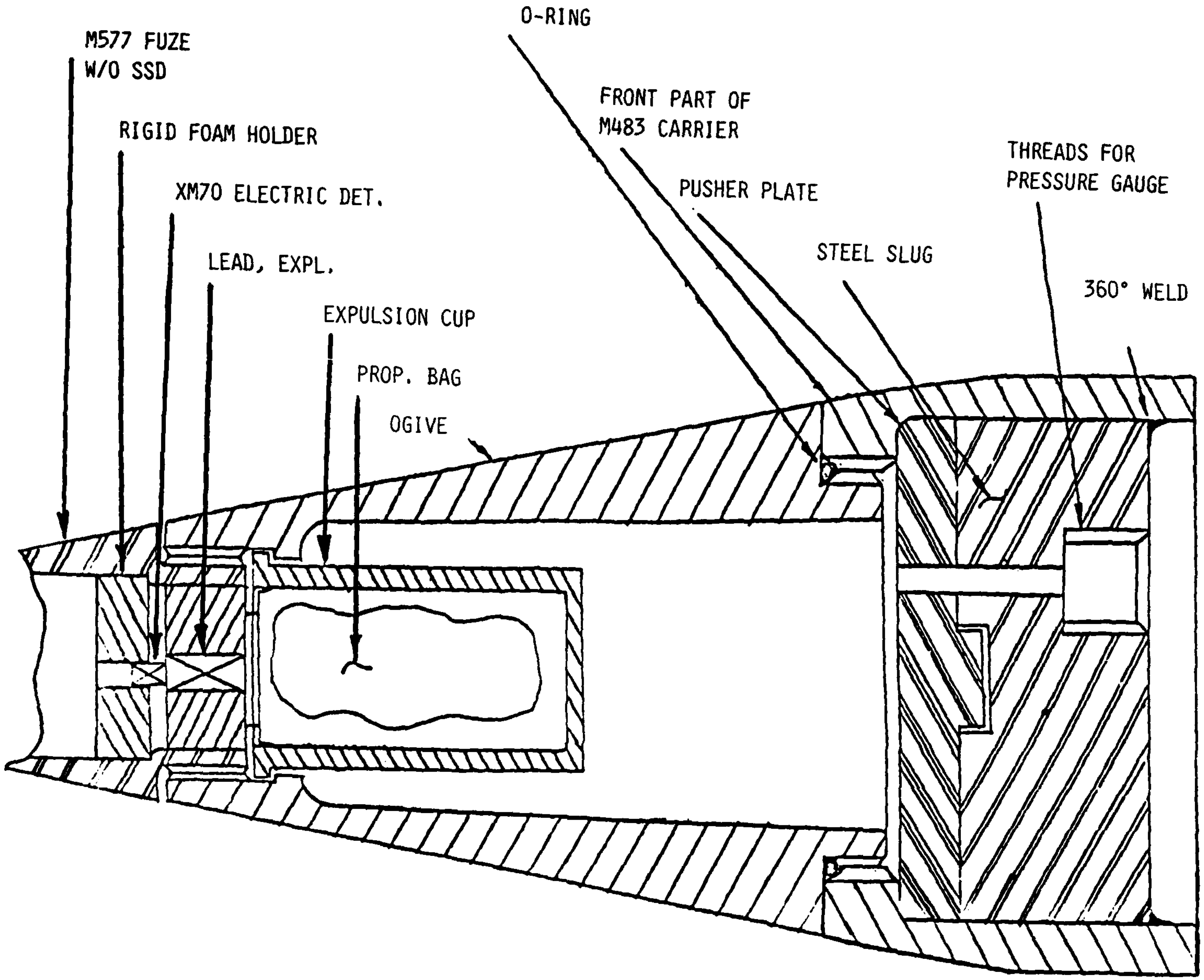

Figure 1. Closed ogive pressure test fixture

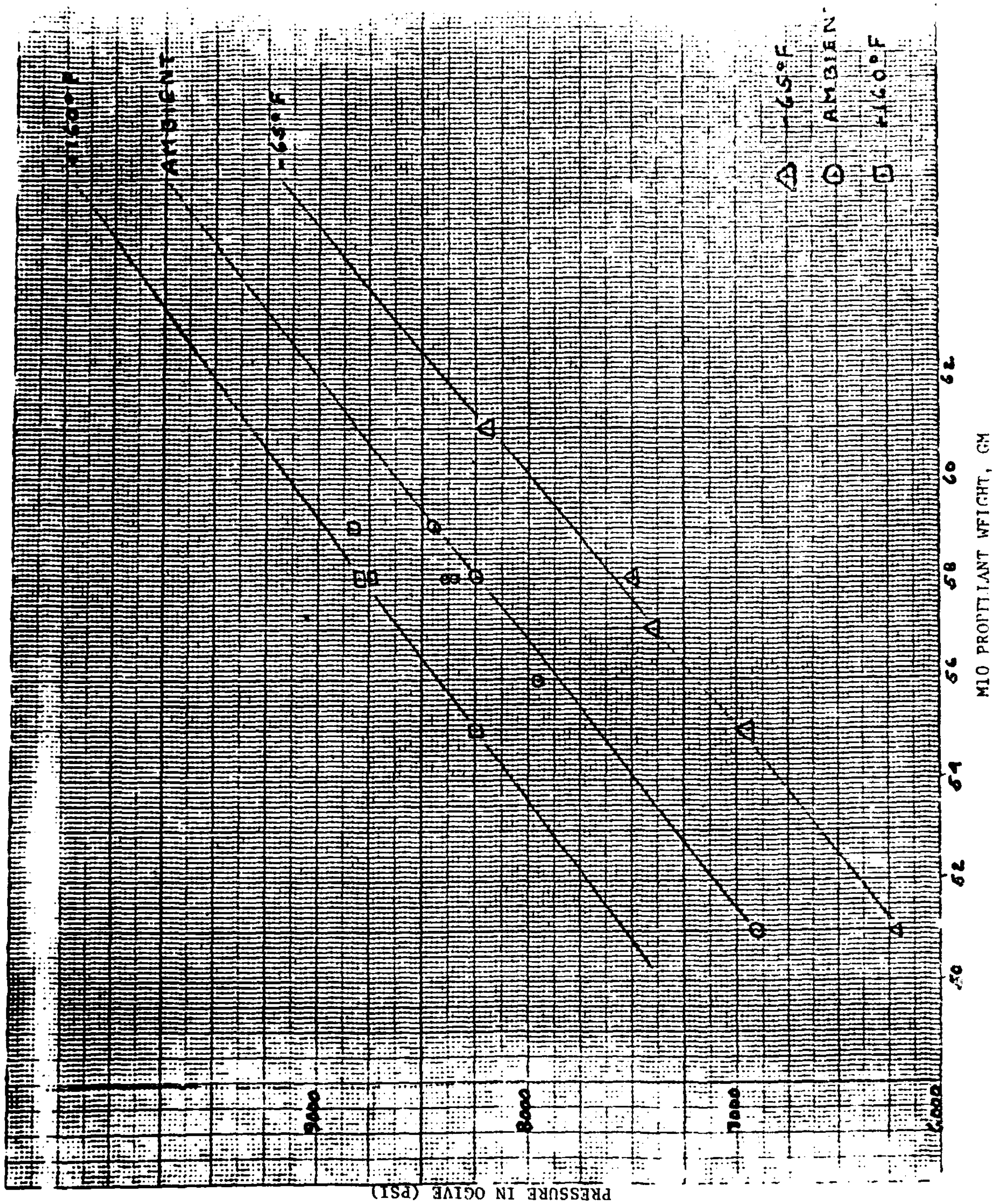

Figure 2. M483A1 closed ogive test - pressure versus propellant weight

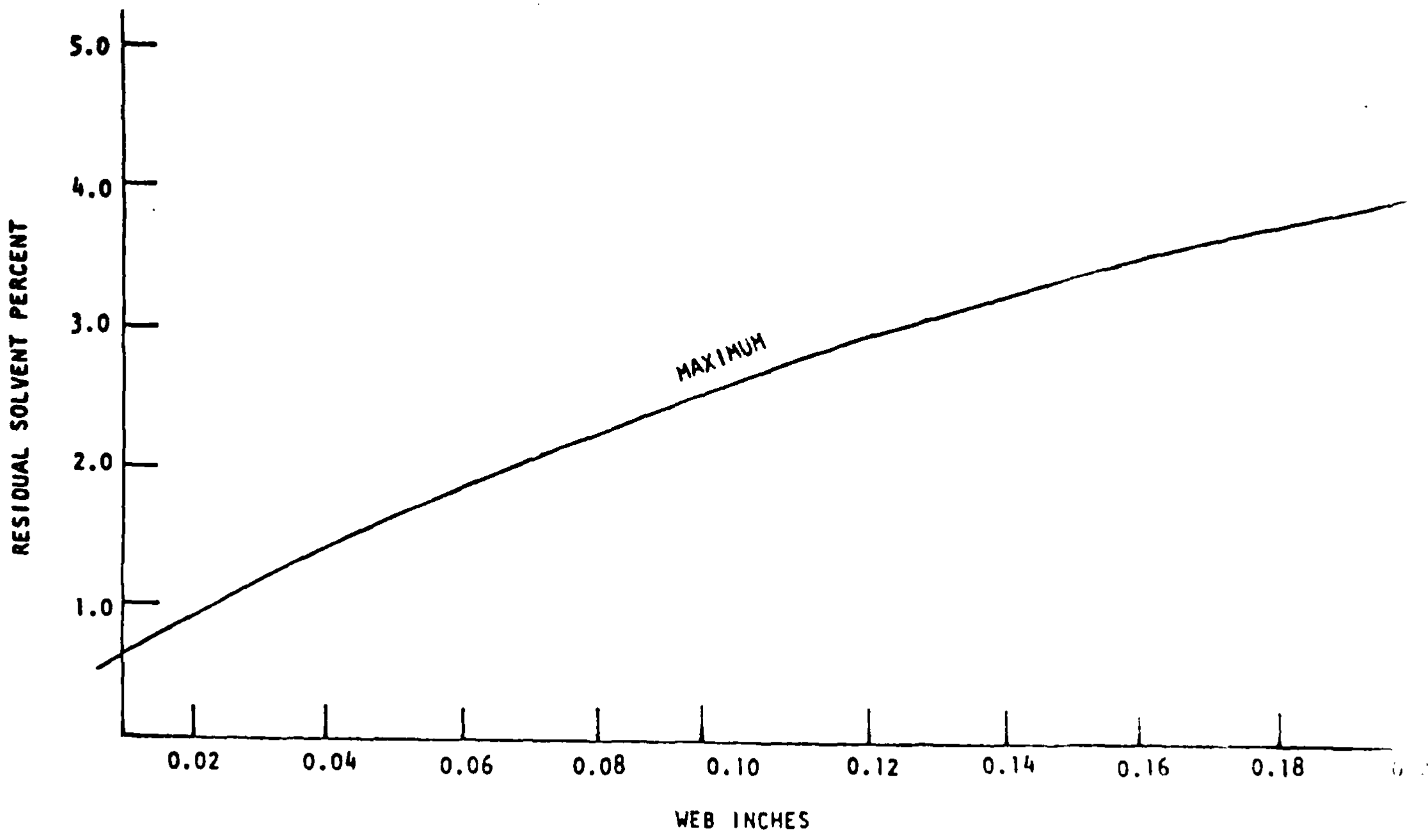

Figure 3. Curve for residual solvent in cannon propellant powder, M1, and M6 - volatile solvent = total volatiles - total moisture

SOURCES

1. DF, DRDAR-LCU-E, dtd 22 Aug 78, to Sel Mun Sys, subject, Propellant for Propulsion Charge M483 Projectile.

2. DF, DRDAR-LCU-SS, dtd 6 Sep 78, to C, Expl & Pyro Appl Br, subject, Propellant for Propulsion Charge M483 Projectile.

3. DF, DRDAR-LCU-E, dtd 31 Oct 78, to Sec Mun Sys Br, subject, Propellant for Propulsion Charge M483 Projectile.

4. M483 Sealed Ogive (Wet Powder Test), ARRADCOM Firing Record 3783, 21 May 79.

5. M483 Sealed Ogive Test, ARRADCOM Firing Procedure Report, Test Project No. 451-78, 26 July 79.

6. M483 Sealed Ogive Test, ARRADCOM Firing Procedure Report, Test Project: RH Test - Orange Plastic Cups, 16 Nov 79.

7. Arthur R. Lusardi, - Improvement of M483A1 Projectile Propulsion Charge Bag, Trip Report, 28 Dec 78.

8. Hygroscopicity Determination of M10 Propellant, ARRADCOM, EMD Report No. EMD MP 0379, 31 Jan 79.

9. Composition - Total Volatiles and Grain Dimension Determination of M6 Flake Propellant, ARRADCOM EMD Report No. 382-79, 30 Mar 79.

10. RQ and RF Determinations for M6 Lots 1B-8923 -1,2-3-4, ARRADCOM IGN and Comb Br Report, 22 Jun 79.

11. Recorded Weighings of M483A1 Projectile Propellant for JAN Cycle Tests, ARRADCOM, Explosive Test Section, 25 Oct 79.

12. Composition Analysis of M10 Propellant, ARRADCOM EMD Report No. EMD MD-21-80, 31 Mar 80.

13. DF, DRDAR-LCU, dtd 24 Oct 79, subject, M10 Propellant.

APPENDIX

SEQUEL TO THE FINDINGS IN THIS REPORT WITH RESPECT TO THE EXPULSION CHARGE CONTAINER FOR THE M483A1/M509 PROJECTILE

At the time that the work described in this report was nearing completion, a new high density polyethylene expulsion charge container was being examined as a possible replacement for the celcon/acrylic cloth bag and the soft polyethylene bag. As shown in this report, these hard plastic containers had their caps pop off during temperature cycling. These same containers were also responsible for misfires during the closed ogive static tests and failed to survive the 40 foot drop test. In addition to these drawbacks the container was subject to cracking at low temperature.

Because of these problems, the expulsion cup was redesigned. The material of the cup was changed from a high density polyethylene to a medium density polyethylene. The seal on the cup was changed in an attempt to improve the survivability characteristics following the drop test and JAN CYCLE TEST. Thirty closed ogive static tests were conducted using this type of container; there were two failures out of the 30 tested. Problems were also still occurring during the drop test; the cups were continuing to crack and their tops were still popping off.

The expulsion cup was again redesigned. Ribs were added to the outside of the cup in order to add strength and support to the cup so that it could survive the drop test. Previous designs allowed the cup to move inside the aluminum expulsion cup; during drop tests the plastic cup would collide with the inside wall of the aluminum cup and shatter. The material of the cup was changed to a low density polyethylene and improvements were made to the cup seal. Twelve closed ogive tests were conducted without any malfunctions.

The final design evolved following further testing of the same polethylene cup described above. The final version that is currently being used is a high density polyethylene cup having external reinforcing ribs. An aluminum foil cover is heat sealed onto the cup and the cup is sealed in place. The foil provides a positive seal for the container and protection for the cup's contents. The cup's cap is a snap on type equipped with a pull tab.

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