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TECHNICAL REPORT RL-80-5

DEVELOPMENT AND TESTING OF AN
ICE PROTECTION TECHNIQUE FOR THE
2.75 INCH ROCKET SYSTEM

Donald E. Davis
Ground Equipment and Missile Structures Directorate
US Army Missile Laboratory

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U.S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35809

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) ✓ The 2.75 Inch Rocket System requires a means of protection from ice and environmental debris. A program was successfully pursued that produced one solution to this problem. The Environmental Protection device has to (1) break out when a rocket is fired and (2) withstand rocket blast in order to provide protection to the remaining rounds. A series of plastic domes met these requirements.		

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I. INTRODUCTION

In January, 1979, the 2.75 Inch Rocket Project Office request that the Ground Equipment and Missile Structures Directorate (GEMSD) explore methods of closing the ends of the launcher tubes. This is to exclude ice as well as other environmental debris. Each closure is to breakout individually, leaving the remaining tubes protected. The resulting structure is called the Environmental Protection Device (EPD).

II. GENERAL APPROACH

Although the techniques developed during this task may be used on the Light Weight Launchers (XM-260 and XM-261) the decision was made to use the M-200 launcher as a test-bed. This was based on the known reliability, and ease of modification of this launcher. Sample EPD sections were bolted on the front face and rockets were fired past or through them. This arrangement worked very well for testing.

One of the chief design considerations is the size of the fragments produced when a rocket breaks out of a tube. Initial analysis indicated that flat closures strong enough to withstand the 250 psi design overpressure,* would be too thick. The fragments would be too large to be acceptable.

A dome over each tube requires less material (i.e., thinner) than a flat cover. Several concepts of this approach were considered. Two schemes were pursued to hardware and tests. Even though both are domes, the main difference is material.

III. PLASTIC ENVIRONMENTAL PROTECTION DEVICE -EPD-P

The EPD-P, as tested, is a one piece plate with spherical section domes vacuum molded in place. One dome is centered over each tube opening. The plate is held in place with a bulkhead. This allows each rocket to breakout of its dome individually. The remaining tubes are still closed.

*The overpressure from MK-66 rocket is predicted to be 190 psi.

The dome is treated as a spherical section pressure vessel that withstands external pressure. The thickness of the dome is defined by:

$$t = \frac{P'r^2}{.365E} \quad \text{where}$$

t = Thickness of dome.

P' = Maximum pressure expected. If pressure exceeds the dome elastic limits then it will collapse.

r = Spherical radius of the dome.

E = Modulus of elasticity.

Note: The higher the elastic modulus, the thinner the material.

Polystyrene has the highest elastic modulus, $E=3 \times 10^6$ of commercially available plastics. It also has the lowest elongation before rupture, approximately 10 percent. This fact is important when considering the breakout characteristics.

Polystyrene also lends itself readily to vacuum forming methods. For these reasons, polystyrene was chosen as the plate material.

Exact thickness is determined by an iterative process that chooses a radius r and computes the thickness. The available material thickness must be considered.

For any dome configuration, the final dome thickness (t_f) is the product of the original material thickness (t_o) times the ratio of the original plate area (A_o) to the final formed (A_f).

$$t_f = \frac{t_o A_o}{A_f}$$

Uniformity is controlled by the original material thickness.

When the test article was formed, the blank plate was held over the mold. Both were baked at 300°F for ten minutes and then, vacuum applied. The mold and sample was then cooled for 15 minutes to prevent warpage.

The test article covered the seven center tubes of the M-200 A1, Figure 2. Figure 3 shows the EPD in more detail.

1 is the flat plate, 2 is where a dome has been formed. The aluminum retaining bulkhead is bolted onto the launcher bulkhead 6. The dome is aligned with the tube 5. Line 4 shows the launcher body.

IV. CERAMIC ENVIRONMENTAL PROTECTION DEVICE -EPD-C

The EPD-C was a dome of slip cast fused silica. The dome thickness is a function of time in the casting process. The theoretically required thickness was too thin to handle. The cast pieces were somewhat thicker to allow for handling.

The ceramic was chosen because it has a fairly good compressive strength important with a dome and will shatter when hit. This was an attempt to keep the size of debris at a minimum.

The samples were mounted between two aluminum plates, cut out to clear the tubes of the M-200 A1. The center tube was the only one covered in tests, Figure 1.

V. TESTS

A. Testing of the EPD-C

Four samples were tested. The first two were subjected to four round ripples fired past the EPD sample. They caved in. The third sample was subjected to a similar ripple and cracked. (Figure 4) The fourth sample was somewhat thicker. Again a ripple was fired past the sample. Several places had spalling and the surface was chipped.

Failure appears to come from two possible sources. The first is the sudden pressure rise caused by the rocket exiting the adjacent launch tube. While the sample is designed to withstand the overpressure, the sudden pressure rise is analogous to an impact. The second source is debris from the rocket, i.e., wire, unburned and burning propellant and ignitor pieces. These generate a real impact. Ceramic materials do not resist impact very well.

Based on these results, the EPD-C concept was dropped from further consideration.



Figure 1. EPD-C mounted on M-200 Al, ready for test.

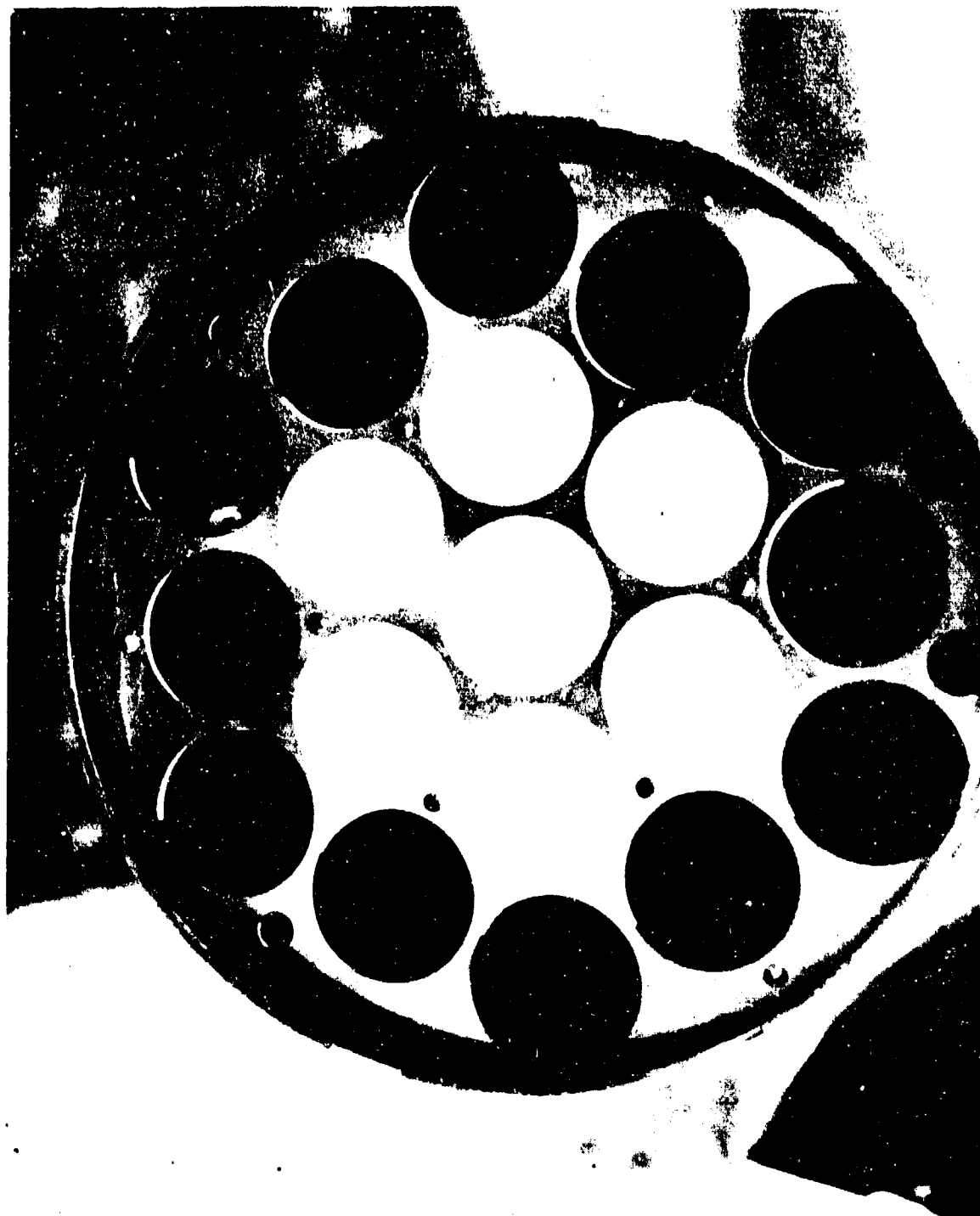


Figure 2. EPD-P mounted on M-200 ready for testing.

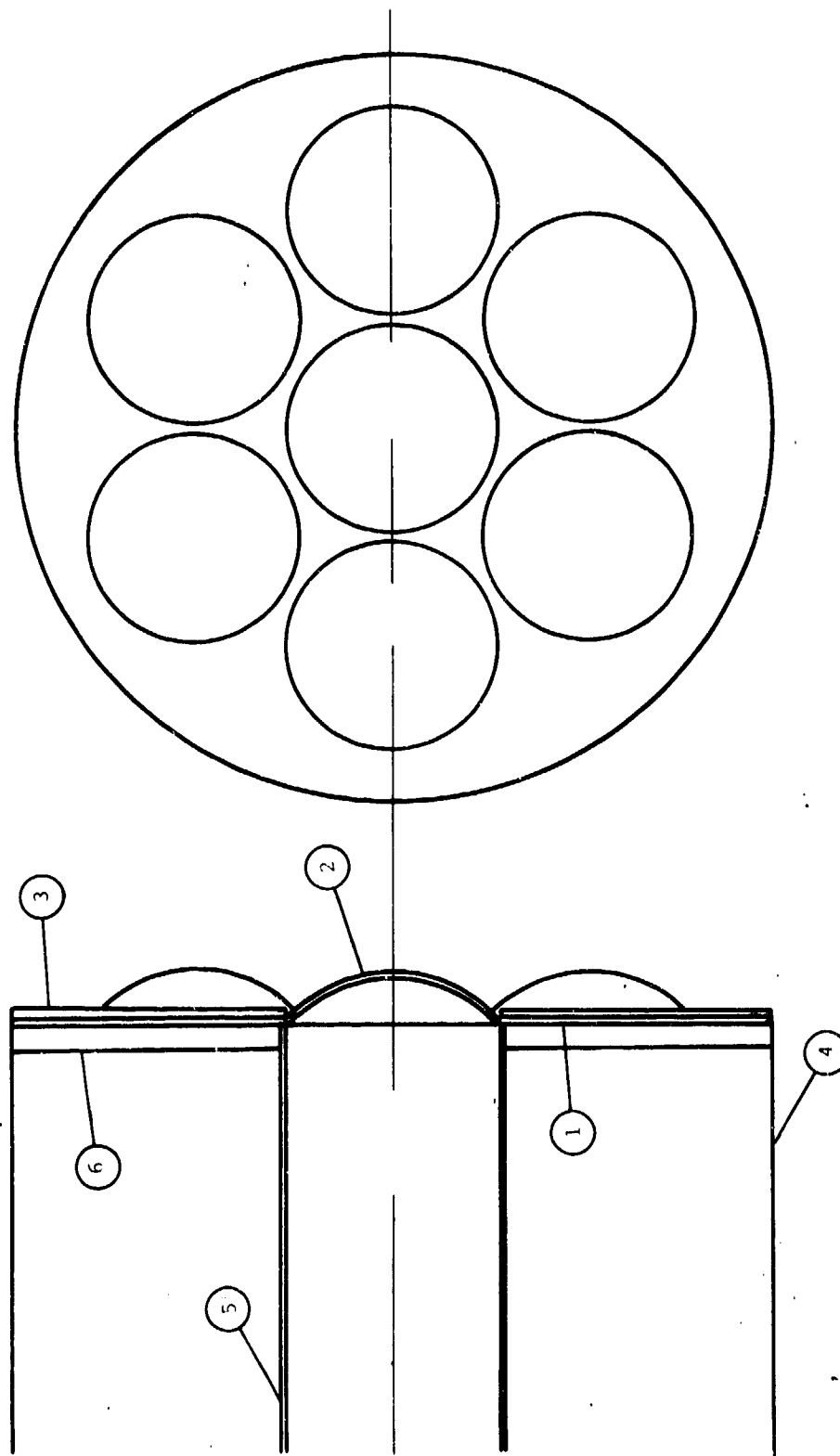


Figure 3. EDP layout.



Figure 4. EPD-C showing failed pieces.

Figure 4 is typical of the failure generated with the EPD-C.

B. EPD-P Testing

Several EPD-P samples were tested. Some were subjected to multiple firings. Tests were conducted with both MK-40 and MK-66 rockets. In all cases, the individual domes withstood the rocket overpressure.

The samples were subjected to a series of ripple firings that built up in duration. Table 1 shows the number of rockets test fired with the EPD-P samples. Except where noted, all rockets are MK-40's.

Test 4 was the first severe test of the concept. As succeeding rockets in a ripple are fired, there is some pressure build up (rising to a level after 3 or 4 rounds and then holding) and a heat build up. These could have caused the EPD to collapse. The concept was demonstrated to be valid.

Test 7 was another severe test. Five MK-40 rockets were rippled, to build heat and pressure, and then an MK-66 followed, in the ripple sequence. The MK-66 has a much higher blast pressure than the MK-40. In previous EPD efforts, the MK-66 rocket blast has caused tube covers to fail. (Note: MK-66's are currently in very short supply as it is still under development.) Figure 5 is EPD-P after test 7.

Test 10 was a 6 round ripple of MK-66's. It was felt that the overpressure generated by the ripple would be as severe as an EPD would ever have to withstand.

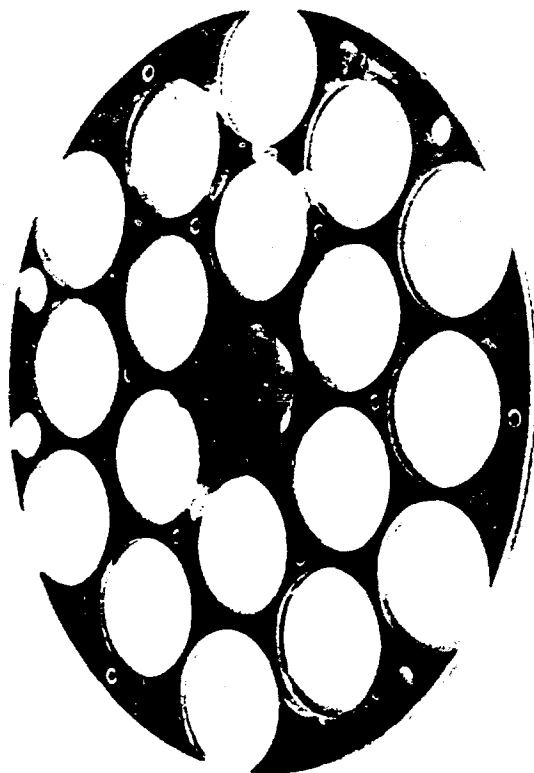
Several fragments of the EPD's were recovered after testing. These averaged 2.6 grams in weight. This compares with 5.7 grams for the fin retainer and firing contact on the MK-40. (The fin retainer usually becomes foreign object debris (FOD) when the rocket is fired.) From this, it can be concluded that the polystyrene breaks up satisfactorily when the rocket breaks out.

VI. CONCLUSIONS

The original goal was to develop an EPD concept that would:

TABLE 1. EPD-P TESTS

Test No.	EPD Sample	Rockets Fired	Notes
1.	1	1	Fired past EPD-P
2.	1	6	Ripple fired past EPD-P
3.	1	11	Ripple fired past EPD-P. One tube malfunctioned
4.	1	17	Ripple fired through EPD-P. Center tube not loaded, One tube malfunctioned.
5.	2	1	Fired through center tube.
6.	3	15	Ripple fired past and through EPD. Center 3 tubes not fired. One tube malfunctioned.
7.	4	6	Ripple fired five MK-40's, followed by one MK-66, fired through EPD around center tube.
8.	5	1	Fired past EPD.
9.	5	1	MK-66 fired past EPD.
10.	5	6	MK-66 rockets ripple fired around center tube.
11.	5	6	MK-40 rockets ripple fired around center tube.



ENVIRONMENTAL PROTECTION
DEVICE (EPD)
FOR M260/261 LT WGT LAU.
AFTER FIRING 6 ROUND
RIPPLE OF 5 MK40/1 MK66 MTR

Figure 5. EPD-P after test 7.

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- Withstand the rocket overpressure generated by both the MK-40 and MK-66 rockets.

- Breakout and break up easily. The domed plate formed from polystyrene meets these criteria.

No testing was done with ice on the test samples. Such tests should be performed on a final design, which this never was intended to be. What we did here was to generate a concept and prove out a piece of technology. This test is intended to point out one way to solve the problem of ice protection.

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