INHIBITED SHAPED CHARGE LAUNCHER TESTING OF SPACECRAFT SHIELD DESIGNS

Prepared by

Donald J. Grosch
Southwest Research Institute

FINAL REPORT
Contract No. NAS8-40634
SwRI Project No. 06-7698

Prepared for

NATIONAL AERONAUTICS and SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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APPROVED:

Charles E. Anderson, Jr., Ph.D., Director
Engineering Dynamics Department
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### Inhibited Shaped Charge Launcher Testing of Spacecraft Shield Designs

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**Abstract**

This report describes a test program in which several orbital debris shield designs were impact tested using the inhibited shaped charge launcher facility at Southwest Research Institute. This facility enables researchers to study the impact of one-gram aluminum projectiles on various shielding designs at velocities above 11 km/s. A total of twenty tests were conducted on targets provided by NASA-MSFC. This report discusses in detail the shield design, the projectile parameters and the test configuration used for each test. A brief discussion of the target damage is provided, as the detailed analysis of the target response will be done by NASA-MSFC.

**Subject Terms**

spacecraft shielding, inhibited shaped charge, hypervelocity impact, orbital debris, and SwRI

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EXECUTIVE SUMMARY

This report describes a test program in which several orbital debris shield designs were impact tested using the inhibited shaped charge launcher facility at Southwest Research Institute. This facility enables researchers to study the impact of one-gram aluminum projectiles on various shielding designs at velocities above 11 km/s. A total of twenty tests were conducted on targets provided by NASA-MSFC. This report discusses in detail the shield design, the projectile parameters and the test configuration used for each test. A brief discussion of the target damage is provided, as the detailed analysis of the target response will be done by NASA-MSFC.
1.0 INTRODUCTION

This report describes a test program in which several orbital debris shield designs were impact tested using the inhibited shaped charge launcher (ISCL) facility at Southwest Research Institute (SwRI). The ISCL facility enables researchers to study the impact of one-gram projectiles on various shield designs at velocities above 11 km/s. A total of twenty tests were conducted on targets provided by NASA-MSFC.

2.0 BACKGROUND

The basis for the ISCL is a metal-lined explosive cavity, referred to as a shaped charge. This device generates a long, plastically-deforming jet of material that travels at high speeds. Shaped charges, which have great penetrating capabilities, have been used for many years in anti-armor warheads and as oil well perforators.

The ISCL isolates the high-speed jet tip of the shaped charge through the use of an inhibitor. The inhibitor is placed within the cavity of the shaped charge. It allows the jet tip to develop as usual but prevents the remainder of the jet from forming. The isolated jet tip is the projectile used to simulate space debris.

The concept of an inhibited shaped charge launcher was first examined in the early 1960's. A re-examination of this concept began in 1987, when NASA-JSC funded SwRI to develop an explosive launcher for simulation of orbital impacts. Since then, several programs have been conducted by SwRI (one funded internally by SwRI, one by DNA, and the remainder by NASA) to refine the explosive launcher concept.

To utilize the explosive launcher in an environment that simulates the conditions in space, an evacuated hypervelocity launcher facility was designed and fabricated at SwRI. This facility increased the usefulness of the ISCL as a testing instrument by providing the means for conducting impact tests within a vacuum. It was designed to hold targets of various sizes and configurations so that different shield concepts could be tested.

3.0 TEST PROCEDURES

All tests were performed within the SwRI inhibited shaped charge launcher facility (Figure 1). Reduced pressures between 4 and 6 Torr were used in the target chamber.

An aluminum (1100-O) lined shaped charge with a 30° included angle was used for each test. Octol 70/30 was cast upon the aluminum liner to form the charge. The charge was initiated using an explosive bridge-wire detonator (EBW) and a precision initiation coupler (PIC). An OFHC copper inhibitor was used for each test to inhibit the formation of the shaped charge jet. (The reader is referred to Reference 1 for a detailed description of the ISCL concept.) Figure 2 shows a shaped charge with an inhibitor placed inside the aluminum liner.
Flash x-ray (FXR) equipment was positioned to take radiographs of the projectile and debris cloud at various positions in the target chamber. Kodak direct exposure film (DEF) was used for all tests. The projectile geometry was measured from these radiographs and its velocity was calculated based on its position on the radiographs and the time at which the FXRs were taken.

The ISCL was configured to provide three (3) orthogonal views. The first FXR station used an HP 180 kV system with standard x-ray heads. The standard heads at this station produced low quality images of the projectiles, as the low-density aluminum projectiles do not absorb a large amount of this wavelength of x-ray. The image quality was enhanced during this program by placing an NDT-9 intensifier screen behind the film (intensifier screens are not required with the DEF film). This initial FXR station was used to determine the position-in-time and the integrity of the projectile.

The second and third FXR stations used HP 300 kV systems with soft x-ray heads. These soft heads create x-rays which are readily absorbed by the low-density aluminum material. Thus, a much clearer image of the projectile was produced with this type of system. The first soft FXR station was positioned to produce a radiograph of the projectile before it impacted the target. The projectile geometry and position-in-time were measured from this radiograph. The second soft FXR station, which was only used for the zero-degree obliquity tests, was positioned between the wall plate and the witness pack to provide a view of the post-impact debris cloud.

The FXR pulsers for each orthogonal view are triggered by time delay using Hewlett Packard (HP) Model 43114A digital delay generators. The delay generators are activated by the signal sent from the Reynolds FS-10 firing module to the detonator. Delay times were calculated prior to each test based on the position of the x-ray heads and the anticipated projectile velocity. Figure 3 shows the orientation for the pre-impact FXR stations.

![Figure 3. FXR Stations 1 and 2 Orientation.](image)

During some tests, the third FXR station pulser was triggered using a make-screen. A make-screen consists of two pieces of aluminum-foil separated by a piece of mylar. A 700 volt potential is placed across the foils. However, since the Mylar is non-conductive, the current cannot flow from one foil to the other. Therefore, electronically the make-screen appears as an open switch. When a metallic object penetrates the screen, the switch is closed and the current flows from one foil to the other. This flow of current (or closing of the switch) can be detected...
and recorded by electronic monitoring equipment and the signal can be used to trigger devices such as the FXR equipment. For certain tests, a make-screen was positioned such that the leading particle behind the target wall would penetrate it and trigger the behind-wall FXR station. Since it does not rely on a calculated delay time, such a setup insured that this FXR station would be triggered at the proper time.

Photographs (35mm) were taken before and after each test to show the target configuration using Kodak ASA-200 color film. Additional photographs were taken of the front and back faces of each individual target plate after they had been impacted. These photographs have been sent to the technical monitor at MSFC.

Data sheets were filled out during the conduct of each. Information recorded on these sheets includes test date and number, inhibitor geometry, x-ray delay times and distances, and vacuum pressure. Copies of these data sheets are provided in this report as Appendix A.

Post test information is also included on these data sheets. This type of information includes the projectile geometry, orientation, mass, and velocity. This information is acquired by examining the radiographs on a back-lit digitizing table. Values such as geometry, orientation, and velocity are provided directly using a software program called FILM developed at SwRI. This program allows immediate measurements of the projectile data using simple, yet extremely accurate, calibration techniques that are implemented with the ISCL. (The reader is referred to Ref. 2 for more information on this calibration system).

A summary of the projectile geometry measurements is provided in Table 3 (see Appendix B). In this table, a total angle (pitch and yaw) is provided with a quadrant value. This quadrant is the location in which the projectile is angled towards. The quadrant numbering system is that of the standard Cartesian coordinate system and is taken looking at the impact surface of the target from the charge (Quadrant 1 being in the upper right-hand corner with numbers increasing counter-clockwise). When a target was tested at other than $0^\circ$ obliquity, the target was first positioned on a level surface and then rotated clockwise (looking down on the target) to achieve the proper angle. When this was done, quadrants 1 and 4 were closer to the charge than quadrants 2 and 3.

Since the ISCL projectile is not a sphere or a perfect rod, some estimations are made when determining its mass. To provide the best possible estimate of projectile mass, the projectile for each test was analyzed individually. The assumptions made and the analysis done for each test is provided as Appendix C of this report. In most cases, values for the projectile inner diameter, outer diameter, length, L/D ratio, and total inclination angle (yaw and pitch) are provided based on the projectile shape.

4.0 TEST RESULTS

Testing began on 22 February 1996. The test matrix originally prepared by MSFC was followed until we had a failure of the shaped charge device on Test 7698-14. During this test, the RP-87 detonator fired as usual, but failed to detonate the PIC. This resulted in a large portion of
the Octol charge being damaged. Although the aluminum liner was not damaged, the charge itself could no longer be used for an ISCL test.

The supplier of the PIC was contacted in an attempt to determine the cause of the failure. The company stood by their original response that the RP-87 detonator was sufficient to detonate their PIC. Since SwRI had successfully used this detonator / PIC combination 28 times before, we agreed with their response and continued testing.

During the next two tests (Tests 7698-15 and 7698-16), the detonation train of the ISCL worked successfully. However, during Test 7698-17, the PIC again did not detonate. The program was stopped until a solution could be determined. After several discussions with the PIC manufacturer, we decided to implement a more powerful detonator. It was decided that since the detonation train worked most of the time, but not all the time, that our detonator must be at the threshold of working with that PIC design.

Several very fortunate situations simultaneously occurred that allowed the two failed tests to be repeated. First, the liners were not damaged by the PIC failures. Second, SwRI had another set of liners being prepared to be explosively loaded at the time of the failures. Third, NASA-JSC had a few extra ISCL charges in storage at SwRI that they loaned to NASA-MSFC so the test series could be completed.

Testing resumed on 12 March 1996 with Test 7698-18. The final five tests (Tests 7698-18 through 7698-22) were completed in two days. Table 1 provides detailed information
about the targets that were impacted during this test program. Figures 4 through 7 show several types of targets that were tested. The nomenclature for the targets is that the initial plate is the “face plate,” followed by either a fabric layer (consisting of Nextel and Kevlar) or an MLI layer (which consists of several layers of multi-layer insulation), the second plate is the “wall plate,” which is followed by the witness pack.

Table 1. Target Descriptions

<table>
<thead>
<tr>
<th>TARGET NAME</th>
<th>ABBREVIATION</th>
<th>TARGET DESCRIPTION</th>
</tr>
</thead>
</table>
| Witness Pack (For ALL Tests) | NONE | 6" Space
| | | 0.020" Al Plate
| | | 2" Space
| | | 0.020" Al Plate
| | | 2" Space
| | | 0.020" Al Plate
| U.S. LAB | L0 | 0.032" Al 6061-T6
| | and | 1.500" Space
| | L45 | 20 Layers MLI
| | and | 1.500" Space
| | L65 | 0.125" Al 2219-T87
| | | Witness Pack
| U.S. LAB | L45F | 0.050" Al 6061-T6
| | | 2.250" Space
| | | 20 Layers MLI
| | | 2.250" Space
| | | 0.188" Al 2219-T87
| | | Witness Pack
| U.S. LAB ENHANCED | LE0 | 0.050" Al 6061-T6
| | and | 1.500" Space
| | LE45 | 4 Layers NEXTEL
| | | 4 Layers KEVLAR
| | | 1.500" Space
| | | 0.125" Al 2219-T87
| | | Witness Pack
| U.S. LAB ENHANCED | LE0.8 | 0.063" Al 6061-T6
| | and | 1.800" Space
| | LE45.8 | 5 Layers NEXTEL
| | | 5 Layers KEVLAR
| | | 1.800" Space
| | | 0.150" Al 2219-T87
| | | Witness Pack
| U.S. LAB ENDCONE | LEC0 | 0.032" Al 6061-T6
| | and | 1.000" Space
| | LEC45 | 20 Layers MLI
| | | 4.810" Space
| | | 0.125" Al 2219-T87
| | | Witness Pack
<table>
<thead>
<tr>
<th>TARGET NAME</th>
<th>ABBREVIATION</th>
<th>TARGET DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. LAB ENDcone F</td>
<td>LEC0F</td>
<td>0.050&quot; Al 6061-T6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.500&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 Layers MLI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.220&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.188&quot; Al 2219-T87</td>
</tr>
<tr>
<td></td>
<td>LEC45F</td>
<td>Witness Pack</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JEM</td>
<td>JEM0</td>
<td>0.032&quot; Al 6061-T6</td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>1.500&quot; Space</td>
</tr>
<tr>
<td></td>
<td>JEM45</td>
<td>20 Layers MLI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.500&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.080&quot; Al 2219-T87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Witness Pack</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JEM</td>
<td>JEM45F</td>
<td>0.050&quot; Al 6061-T6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.250&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 Layers MLI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.250&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.125&quot; Al 2219-T87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Witness Pack</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S. LAB REAR WALL</td>
<td>LRW0</td>
<td>0.032&quot; Al 6061-T6</td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>1.500&quot; Space</td>
</tr>
<tr>
<td></td>
<td>LRW45</td>
<td>20 Layers MLI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.500&quot; Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.125&quot; Al 5456</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Witness Pack</td>
</tr>
</tbody>
</table>

NOTE: Space values given are approximate. The addition of the two space values is the true distance between the front of the face plate and the rear of the wall plate.

General target damage measurements were made by SwRI subsequent to the tests. These measurements include a rough sketch of the holes in both the face plates and the wall plates for each test. Rough measurements, taken with a tape measure, are provided on these sketches and in Table 2, which is a brief summary of each test. These sketches and measurements are provided as Appendix C.

MSFC also requested that specific measurements be recorded for the wall plate holes. To make these measurements, the wall plate of interest was positioned onto a piece of gridded paper. The hole in the plate was traced onto the paper keeping the pencil perpendicular to the paper and in contact with the side of the hole. Any cracks that might occur near the impact hole were also traced and their lengths recorded. Finally, the longest distance between any two cracks was recorded as the tip-to-tip crack length. The tip-to-tip crack length values for each applicable test are provided in Table 4 of Appendix D, as are copies of the hole sketches. The detailed analysis of the target plates will be done by MSFC. The target materials were shipped back to the MSFC technical monitor shortly after the conclusion of the test program. Following are brief descriptions of each test.
<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>MASS (g)</th>
<th>VELOCITY (km/s)</th>
<th>TARGET</th>
<th>WALL DAMAGE (TIP-TO-TIP LENGTH)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7698-1</td>
<td>1.35</td>
<td>11.68</td>
<td>L0</td>
<td>1&quot; Dia. Hole (2.7&quot;)</td>
<td>Cookie-cut hole. Very symmetric debris pattern.</td>
</tr>
<tr>
<td>7698-2</td>
<td>1.12</td>
<td>11.38</td>
<td>LEC0</td>
<td>3.5&quot; to 4.3&quot; Dia. Hole (5.7&quot;)</td>
<td>Slightly &quot;C&quot; shaped projectile.</td>
</tr>
<tr>
<td>7698-3</td>
<td>0.99</td>
<td>11.64</td>
<td>LE0</td>
<td>3&quot; to 4&quot; Dia. Hole (11&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-4</td>
<td>0.94</td>
<td>11.37</td>
<td>L45</td>
<td>4.5&quot; to 7&quot; Dia. Hole (7.5&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-5</td>
<td>1.03</td>
<td>11.77</td>
<td>JEM0</td>
<td>4.5&quot; to 5&quot; Dia. Hole (8.3&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-6</td>
<td>0.84</td>
<td>11.37</td>
<td>LRW0</td>
<td>4.5&quot; Dia. Hole (5.3&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-7</td>
<td>0.99</td>
<td>11.37</td>
<td>LEC45</td>
<td>4.7&quot; to 6.3&quot; Dia. Hole (3.6&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-8</td>
<td>0.82</td>
<td>11.40</td>
<td>LE45</td>
<td>No Penetration (-)</td>
<td>Poorly Formed Small Projectile</td>
</tr>
<tr>
<td>7698-9</td>
<td>0.97</td>
<td>11.42</td>
<td>JEM45</td>
<td>4&quot; to 6.3&quot; Dia. Hole (13&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-10</td>
<td>1.42</td>
<td>11.35</td>
<td>LRW45</td>
<td>1.5&quot; Dia. Hole (3.5&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-11</td>
<td>1.28</td>
<td>11.47</td>
<td>LEC0F</td>
<td>0.5&quot; to 1.25&quot; Hole (3.1&quot;)</td>
<td>Typical (but longer than usual) projectile. Near the Ballistic Limit.</td>
</tr>
<tr>
<td>7698-12</td>
<td>0.76</td>
<td>11.45</td>
<td>LE0.8</td>
<td>No Penetration (-)</td>
<td>Poorly Formed Small Projectile</td>
</tr>
<tr>
<td>7698-13</td>
<td>1.04</td>
<td>11.51</td>
<td>L45F</td>
<td>0.625&quot; Dia. Hole (0.8&quot;)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-14</td>
<td>-</td>
<td>-</td>
<td>LE0.8</td>
<td>-</td>
<td>Detonator Went, PIC Did Not</td>
</tr>
<tr>
<td>7698-15</td>
<td>-</td>
<td>-</td>
<td>LE0.8</td>
<td>-</td>
<td>Projectile Hit Stripper #2 -- Bad Shot</td>
</tr>
<tr>
<td>7698-16</td>
<td>1.09</td>
<td>11.51</td>
<td>LE45</td>
<td>No Penetration (-)</td>
<td>Odd Projectile, Had a Flat Impact due to Mass on Side</td>
</tr>
<tr>
<td>TEST NO.</td>
<td>MASS (g)</td>
<td>VELOCITY (km/s)</td>
<td>TARGET</td>
<td>WALL DAMAGE (TIP-TO-TIP LENGTH)</td>
<td>COMMENTS</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>-----------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>7698-17</td>
<td>-</td>
<td>-</td>
<td>L65</td>
<td>-</td>
<td>Detonator Went, PIC Did Not</td>
</tr>
<tr>
<td>7698-18</td>
<td>0.97</td>
<td>11.30</td>
<td>L65</td>
<td>No Penetration (-)</td>
<td>Typical projectile.</td>
</tr>
<tr>
<td>7698-19</td>
<td>1.11</td>
<td>11.32</td>
<td>L450.8</td>
<td>0.75” to 2” Dia. Hole (4.8”)</td>
<td>Used an 0.050” 6061-T6 Face Sheet.</td>
</tr>
<tr>
<td>7698-20</td>
<td>1.23</td>
<td>11.38</td>
<td>L45</td>
<td>2.75” to 1.25” Dia. Hole (6”)</td>
<td>Projectile is an Open Cylinder (cross section is “C” shaped)</td>
</tr>
<tr>
<td>7698-21</td>
<td>-</td>
<td>-</td>
<td>LE0.8</td>
<td>1.5” to 3.5” Dia. Hole (7”)</td>
<td>Equipment Failure - No Pre-Impact Radiographs. Based on target, assume a fairly lethal projectile (high L/D, flying straight).</td>
</tr>
<tr>
<td>7698-22</td>
<td>0.98</td>
<td>11.36</td>
<td>JEM45F</td>
<td>0.5” to 1” Dia. Hole (6.8”)</td>
<td>Projectile is not completely closed along axial length. About 1/3 of perimeter is opened (somewhat “C” shaped).</td>
</tr>
</tbody>
</table>
**TEST 7698-1**

This test resulted in a slightly larger than average (1.35 gram) projectile. An elliptical hole, roughly 15.2 by 10.2 cm (6 by 4 inches), was produced in the face sheet. This hole was jagged and the plate petalled in several places. The MLI layer was shredded, as was the case in each test in which the material was used. A 2.5 cm (1 inch) diameter hole was produced in the wall of the target. This was a “cookie-cut” hole, as there were no petals. A large hole resulted in the first two witness plates and the third witness plate was severely deformed with many small holes.

The third FXR station for this test was configured to be triggered using a make-screen. However, although the screen was working prior to test, during the evacuation of the target chamber it malfunctioned. Therefore, the station was triggered using a calculated time delay. A very nice post-impact debris pattern was captured during this test. Contact-prints of these radiographs are shown in Appendix E. Note that the make-screen is visible in each radiograph.

**TEST 7698-2**

The projectile for this test was cylindrically shaped with about one-fifth of the perimeter missing (shaped like the letter “C”). Its mass was right at the average value of 1.12 grams. The hole in the face plate had a diameter from about 8.9 to 10.7 cm (3.5 to 4.2 inches) with one large petal that extended to about 10.6 cm (4.2 inches) from the estimated impact point. The hole in the wall plate was typically 3.1 cm (1.2 inches) in diameter with one petal widening the hole to 5.6 cm (2.2 inches) wide. Witness Plate 1 had a roughly 15.2 cm (6 inch) hole with several smaller holes around it. Plate 2 had several holes and Plate 3 had only a few holes. The behind-wall plate radiographs reveal a very concentrated debris pattern.

**TEST 7698-3**

The projectile in this test has a slightly longer L/D ratio than average (2.3), but is about the average mass (.99 grams). The hole in the face plate is about 7.6 cm (3 inches) in diameter and extends to about 10.6 cm (4.2 inches) at two petal locations. The wall plate has a jagged hole that varies between 8.9 and 12.7 cm (3.5 and 5.0 inches) in diameter and up to 19.1 cm (7.5 inches) at a petal. All three witness plates had multiple small holes and rearward deformation.

**TEST 7698-4**

This was the first 45° obliquity test. The aim point for this and all oblique-impact tests was 5.1 cm (2 inches) forward horizontally from the center of the wall plate. This modification of the impact point insured that all plates would be impacted during the high-obliquity tests. As for all oblique impacts, the third (behind-wall) FXR station was not used for this test.

The projectile for Test 7698-4 had an L/D of 1.98 and a mass of 0.94 grams. The face plate had a roughly 11.4 cm (4.5 inch) hole that extended to as much as 17.8 cm (7 inches) at one
point. The wall plate had a roughly 6.4 cm (2.5 inch) diameter hole, and cracks ran left and right 10.2 and 6.4 cm (4 and 2.5 inches) respectively. Cracks that extended to the edge of the plate ran up and down such that the plate was cut in two. Damage on the witness plates decreased from many small holes on the front plate to only a few on the third plate.

**TEST 7698-5**

Test 7698-5 was a 0° obliquity shot. It produced a very jagged hole in the face plate with diameter values that varied from 11.4 to 17.0 cm (4.5 to 6.7 inches). The wall plate had a nominally 6.4 cm (2.5 inch) diameter hole with several petals that extended the hole size up to 12.7 cm (5 inches) long. The first witness plate has a 6.4 cm (8 inch) diameter hole and a large deflection. Plate #2 was fractured into two pieces with a large hole and deflection. The third witness plate is largely deformed and has several small holes in it. The behind-wall radiographs show a dispersed debris pattern.

**TEST 7698-6**

A relatively small (.84 gram) projectile was produced during this test. It resulted in a jagged face plate hole that was up to 11.4 cm (4.5 inches) in diameter. The wall had a 7.6 cm (3 inch) diameter hole with a single petal that extended the radius to 6.8 cm (2.7 inches). Witness Plate #1 had a large hole and deformation which decreased in Plate #2. Plate #3 had only a few small holes. The behind-wall radiographs show a debris cloud consisting of mainly small particles.

**TEST 7698-7**

This test was another 45° shot. A low L/D (1.15) projectile with a mass of 0.99 grams was produced. The face plate hole was about 11.9 cm (4.7 inches) in diameter and the longest petal extended the hole radius to 15.7 cm (6.2 inches). The hole in the wall plate was around 3.8 cm (1.5 inches) in diameter with no petalling. Damage was minimal to Witness Plate #1 and Plate #2 was not damaged.

**TEST 7698-8**

This test produced a projectile that was not well formed. It appeared to be a cylinder that consisted of only about half of the cylinder wall. Although a poor shape, it had a substantial mass (0.82 grams). The projectile produced an elliptical hole in the face plate that measured 6.4 by 10.2 cm (2.5 by 4.0 inches). The wall plate was not penetrated but was bulged a few centimeters.

**TEST 7698-9**

The projectile for Test 7698-9 produced a very jagged hole which resulted in large petal formation in the face plate. The diameter varied from 10.2 to 15.7 cm (4.0 to 6.2 inches). A large amount of damage was also done to the wall plate, which was broken in two pieces by the
impact. The approximate hole size of the wall plate was 15.2 cm (6 inches). A central hole was produced in all three witness plates. The damage decreases from many small holes in Witness Plate #1 to only a few small holes in Plate #3.

**TEST 7698-10**

A larger than average projectile (1.42 grams) was produced during this test. The face sheet had an almost rectangularly-shaped hole with a minor diameter of 6.4 cm (2.5 inches) and a major diameter of 14.0 cm (5.5 inches). The wall plate had a 3.8 cm (1.5 inch) diameter hole with no petals. Witness Plate #1 had a large 12.7 cm (5 inch) diameter hole in it. This damage decreased to multiple small holes by Plate #2 and only a few small holes by Plate #3.

**TEST 7698-11**

A high L/D ratio (3.4) projectile was produced during this test. It produced a hole with a 8.9 to 10.7 cm (3.5 to 4.2 inch) diameter in the face sheet. The damage to the wall plate suggests the test was very near the ballistic limit of the material. It appears that the small hole in the plate was caused by spalling of the rear surface of the plate, not by penetration. The hole, which is really a small crack, is about 1.3 cm (0.5 inches) wide by about 3.0 cm (1.2 inches) long. The resulting debris on the back side of the wall plate produced only small holes in the initial witness plate and only two small impacts on the second plate.

**TEST 7698-12**

A poorly-formed, low-mass (0.76 grams) projectile was produced during this test and resulted in no penetration of the target wall plate. The projectile formed a roughly 5.1 cm (2 inch) diameter hole in the face plate with no petalling. About a 2.5 cm (1 inch) bulge resulted at the impact point on the wall.

**TEST 7698-13**

A very nice projectile was produced during Test 7698-13. It produced a hole in the face plate that varied between 8.1 and 11.4 cm (3.2 and 4.5 inches) in diameter and had three large petals. A “cookie-cut” hole approximately 1.5 cm (0.6 inches) in diameter resulted in the wall plate. Witness plate damage decreased from about nine small holes in the initial plate to two small holes in the third.

**TEST 7698-14**

During this test, the detonator fired while the PIC did not. The result was that the charge could not be fired.

**TEST 7698-15**

The projectile formed during this test did not fly straight and it impacted the second stripper plate. The impact occurred approximately 1.3 cm (0.5 inches) from the edge of the
stripper hole. The result of this near miss was that a large amount of steel spall (from the stripper plate) and projectile material impacted and destroyed the target.

**TEST 7698-16**

The projectile produced during this test was not typical. It appears that the projectile opened up severely and resembled a flat plat more than a hollow cylinder. The mass of 1.09 grams was still present, it was just in a non-typical form. The projectile created a 8.1 to 10.2 cm (3.2 to 4.0 inch) diameter hole in the face plate and only a 2.0 cm (0.8 inch) high bulge in the wall plate.

**TEST 7698-17**

Again, the detonator fired and the PIC did not. No shot occurred.

**TEST 7698-18**

This was the only 65° obliquity test performed during this program. A typically shaped projectile was produced but did not penetrate the wall plate. It did produce a jagged hole in the face plate that measured between 15.2 and 17.8 cm (6 and 7 inches) in diameter with one crack that ran to the bottom edge of the plate.

**TEST 7698-19**

Another very nice projectile was produced during this test. It produced a highly-petalled hole in the face plate. Hole diameters varied from 7.6 to 11.4 cm (3.0 to 4.5 inches). A “cookie-cut” hole resulted in the wall plate. Its measured about 2.0 by 5.1 cm (0.8 by 2.0 inches). The test resulted in a large number of small holes in Witness Plate #1. The number of small holes decreased greatly by Plate #2 and only one hole was created in Witness Plate #3.

**TEST 7698-20**

The projectile for this test appeared to be an opened-up cylinder whose cross-section looked like the letter “C”. It produced a jagged hole in the face plate that measured about 11.4 cm (4.5 inches) in diameter. The hole diameter increased to 15.7 cm (6.2 inches) at two locations where petals occurred. The wall plate had a hole with a nominal diameter of 4.3 cm (1.7 inches) that petalled in two places. The petalling of the wall plate increased the hole diameter to 6.9 cm (2.7 inches) at one point. All three witness plates had a main hole that was approximately 1.3 cm (0.5 inches) in diameter. Plate #1 had approximately 40 smaller holes that decreased to 5 by Plate #3.

**TEST 7698-21**

Due to a malfunction of the X-ray equipment, we did not get an image of the projectile during this test. Only the third FXR station triggered properly and produced a nice image of the behind wall debris pattern. The hole in the face plate was nominally 7.6 cm (3 inches) in
diameter and had only a small amount of petalling. The hole in the wall plate was 3.8 cm (1.5 inches) in diameter and had a single petal that extended the hole size to 8.9 cm (3.5 inches). Four long cracks ran from the hole in the wall plate. Witness plate damage was typical, with a large number of small holes in Plate #1 that reduced to a few small holes by Plate #3.

**TEST 7698-22**

The 0.98 gram projectile produced during the final test produced a 10.2 cm (4 inch) diameter hole in the face plate. One large and several small petals occurred in this plate. The wall plate had a "cookie-cut" hole with four large cracks running from it. The hole was about 1.3 by 2.5 cm (0.5 by 1.0 inches). The first and second witness plates had about eight small holes and one 1.0 cm (0.4 inch) diameter hole through them. The third witness plate only had a single 0.5 cm (0.2 inch) diameter hole.

**5.0 SUMMARY**

A total of twenty ISCL tests were performed on shield designs provided by NASA-MSFC. Flash x-rays were used to image the ISCL projectile before impact for projectile velocity and geometry measurements. In some tests, flash x-rays were used to image the behind-wall debris pattern. The average projectile mass was 1.05 grams and the average velocity was 11.45 km/s. Basic measurements of hole size and shape were made and are included in this report. Detailed analysis of the targets will be done by NASA-MSFC.

**6.0 ACKNOWLEDGMENTS**

SwRI would like to thank Ms. Jeanne Crews of NASA-JSC for her help in this program. She loaned us the initial twenty ISCL charges so that the program would not be delayed (there is a long lead time for procuring the ISCL charges). She also loaned us an additional two charges after the PIC failure tests. This generosity allowed us to complete the program in approximately 1/2 the estimated time.

**7.0 REFERENCES**


2. "Improved Photogrammetry at SwRI," by D. J. Grosch and J. P. Riegel, III, presented at the 44th Aeroballistics Range Association Meeting, Munich, Germany, September 1993.
APPENDIX A

Test Data Sheets
### INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

**TEST NUMBER** 7698-1  
**DATE** 2-22-96 (10:50 AM)  
**Sunny & 85°F**

**ISCL TEST NO.** 130

---

**EXPLOSIVE**

- **CHARGE NUMBER** 6  
- **CHARGE WEIGHT** 657.6 (grams)  
- **DETONATOR TYPE** RP-80

**INHIBITOR**

- **OVERALL HEIGHT** 1.759 (in)  
- **INNER DIAMETER** 0.469 (in)

**FXRs**

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<th>DELAY TIME</th>
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<td>127</td>
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<tr>
<td>#2:</td>
<td>300 soft</td>
<td>57</td>
<td>153</td>
</tr>
<tr>
<td>#3:</td>
<td>300 soft</td>
<td>77</td>
<td>217 msec</td>
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**VACUUM PRESSURE** 4½ (torr)

**TARGET DESCRIPTION** MSFC L0 (US Lab, 1/3 Scale, @ 0°)

---

**COMMENTS**

- Face Plate: LARGE Perforated Hole (≈6" Ø)  
- Wall Plate: Cookie-Cut Hole (≈1" Ø)  
- Witness: Severe Damage
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-2                DATE 2-22-96
ISCL TEST NO. 131

EXPLOSIVE

CHARGE NUMBER 41
CHARGE WEIGHT 62.9 b (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.468 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC SAME (in)
DELAY TIME SAME (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC SAME (in)
DELAY TIME SAME (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC SAME (in)

VACUUM PRESSURE 4/2 (torr)

TARGET DESCRIPTION MSFC LECO
- 6 GAP IN TARGET 10/4" FROM STRIPER #2

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

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<tr>
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<th>DATE</th>
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<tr>
<td>ISCL TEST NO.</td>
<td>132</td>
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<td>Hot &amp; Sunny</td>
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EXPLOSIVE

<table>
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<th>CHARGE NUMBER</th>
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<tbody>
<tr>
<td>CHARGE WEIGHT</td>
<td>656.5 (grams)</td>
</tr>
<tr>
<td>DETONATOR TYPE</td>
<td>RP-87</td>
</tr>
</tbody>
</table>

INHIBITOR

| OVERALL HEIGHT | 1.759 (in) |
| INNER DIAMETER | 2.4 (in) |

FXRs

| HEAD #1: SIZE | 150 (kV) |
| DISTANCE FBOC | 11 (in) |
| DELAY TIME | 11 (usec) |
| HEAD #2: SIZE | 300 soft (kV) |
| DISTANCE FBOC | 11 (in) |
| DELAY TIME | 11 (usec) |
| HEAD #3: SIZE | 300 soft (kV) |
| DISTANCE FBOC | 11 (in) |
| DELAY TIME | 04 Make = 210 (usec) |

VACUUM PRESSURE | 4 (torr) |

TARGET DESCRIPTION | MSFC LEO |

COMMENTS

Big hole in Face Plate, Big hole in Fabric, Large Petalled holes in wall, appear that fabric contributed to petals, all 3 witness plates perforated with small holes & bent around.
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-4 DATE 2-26-96
ISCL TEST NO. 133

EXPLOSIVE

CHARGE NUMBER 4
CHARGE WEIGHT 65.1 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.469 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

VACUUM PRESSURE 5 (torr)

TARGET DESCRIPTION

MSFC L-45

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-5  DATE 2-26-96

ISCL TEST NO. 134

EXPLOSIVE

CHARGE NUMBER 43
CHARGE WEIGHT 657.0 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.459 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 210 (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION JEM 0

COMMENTS Use wooden frame (3/4" plywood) to support
Cube as used styrofoam, it always had problems
Screen didn't work!
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-6 DATE 2-26-96
ISCL TEST NO. 135

EXPLOSIVE

CHARGE NUMBER 249
CHARGE WEIGHT 651.3 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1,26.7 (in)
INNER DIAMETER 3.148 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME Make Size E 201.77 (usec)

VACUUM PRESSURE 4/2 (torr)

TARGET DESCRIPTION MQFC LNW9

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-7   DATE 2-27-96
ISCL TEST NO. 1316

EXPLOSIVE
CHARGE NUMBER 18
CHARGE WEIGHT 659.5 (grams)
DETONATOR TYPE RP-87

INHIBITOR
OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.468 (in)

FXRs
HEAD #1: SIZE 150 (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION MSFC 47 LEC 45

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-8   DATE 2-27-76
ISCL TEST NO. 37

EXPLOSIVE

CHARGE NUMBER 15
CHARGE WEIGHT 659.2 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.469 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC
DELAY TIME

VACUUM PRESSURE 4.5 (torr)
TARGET DESCRIPTION MSFC LE45

COMMENTS

Do NOT penetrate wall (only a bulge)
- Poor looking projectile, looks more like a flat plate hitting edge-on than a cylinder.
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-1
ISCL TEST NO. 138

DATE 2-28-96

EXPLOSIVE
CHARGE NUMBER 49
CHARGE WEIGHT 655.7 (grams)
DETONATOR TYPE RP-87

INHIBITOR
OVERALL HEIGHT 1.759 (in)
INNER DIAMETER 0.468 (in)

FXRs
HEAD #1: SIZE 150 (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC 11 (in)
DELAY TIME 11 (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC X (in)
DELAY TIME X (usec)

VACUUM PRESSURE 4/3 (torr)

TARGET DESCRIPTION MSFC JEM 45

COMMENTS
## INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

**TEST NUMBER** 7698 - 10  
**ISCL TEST NO.** 17  
**DATE** 2-28-96

### EXPLOSIVE

- **CHARGE NUMBER** 32
- **CHARGE WEIGHT** 3.7  
  grams
- **DETONATOR TYPE** RP-87

### INHIBITOR

- **OVERALL HEIGHT** 1.75  
  in
- **INNER DIAMETER** 0.457  
  in

### FXRs

- **HEAD #1:**
  - **SIZE** 150  
    (kV)
  - **DISTANCE FBOC** 11  
    (in)
  - **DELAY TIME** 11  
    (usec)
- **HEAD #2:**
  - **SIZE** 300 soft  
    (kV)
  - **DISTANCE FBOC** 1
  - **DELAY TIME** 11  
    (usec)
- **HEAD #3:**
  - **SIZE** 300 soft  
    (kV)
  - **DISTANCE FBOC**
  - **DELAY TIME**

### VACUUM PRESSURE

- **4.5 - 5**  
  (torr)

### TARGET DESCRIPTION

- **MSFC**  
  **LRW 45**

### COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-11  DATE 3-2-76
ISCL TEST NO. 140  50°F, Cloudy, 4:25 AM

EXPLOSIVE

CHARGE NUMBER
CHARGE WEIGHT 633.3 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)
INNER DIAMETER 0.457 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME 210 \rightarrow 266 usec (usec)

VACUUM PRESSURE 5/2 torr

TARGET DESCRIPTION LECOF

COMMENTS

Very near the Ballistic Limit. Small Hits.

Mostly caused by "spelling"

A few hits on the wall instead of the target.
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-12  DATE 3-4-76
ISCL TEST NO. 141

EXPLOSIVE

CHARGE NUMBER 2
CHARGE WEIGHT 637.2 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 17-5/16 (in)
INNER DIAMETER 2-9/16 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION MSFC LEO 8

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-5
ISCL TEST NO. 142

DATE

EXPLOSIVE

CHARGE NUMBER

CHARGE WEIGHT (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT (in)

INNER DIAMETER (in)

FXRs

HEAD #1:

SIZE 150 (kV)

DISTANCE FBOC (in)

DELAY TIME (usec)

HEAD #2:

SIZE 300 soft (kV)

DISTANCE FBOC (in)

DELAY TIME (usec)

HEAD #3:

SIZE 300 soft (kV)

DISTANCE FBOC (in)

DELAY TIME (usec)

VACUUM PRESSURE (torr)

TARGET DESCRIPTION

COMMENTS
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-14 DATE 3-5-96
ISCL TEST NO. 14B 143

EXPLOSIVE

CHARGE NUMBER 16
CHARGE WEIGHT 655.6 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1,750 (in)
INNER DIAMETER 0.468 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME MAKE SURE (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION MSFC LEO 8

COMMENTS

DET NENT Pico Diron OCTOC Broken UP
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-15 DATE 3-5-76
ISCL TEST NO. 144

EXPLOSIVE

CHARGE NUMBER 3
CHARGE WEIGHT 6.5 grams
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)
INNER DIAMETER 0.68 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME Make Scan (usec)

VACUUM PRESSURE 4/2 (torr)

TARGET DESCRIPTION M5Fc LE0.8 (Report #41)

COMMENTS

Project: Spec. #2
Target 1 Free 2 SC: 30.0 C 30.0
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-16  DATE 3-8-73
ISCL TEST NO. 1-5

EXPLOSIVE

CHARGE NUMBER ____________________
CHARGE WEIGHT ____________________ (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT ____________________ (in)
INNER DIAMETER ____________________ (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC ____________________ (in)
DELAY TIME ____________________ (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC ____________________ (in)
DELAY TIME ____________________ (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC ____________________ (in)
DELAY TIME ____________________ (usec)

VACUUM PRESSURE 4.5 (torr)

TARGET DESCRIPTION MSFC LE 45

COMMENTS NO PEN
## INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

### EXPLOSIVE
- **Charge Number**: 23
- **Charge Weight**: 2.58 grams
- **Detonator Type**: RP-87

### INHIBITOR
- **Overall Height**: 1.750 in
- **Inner Diameter**: 0.105 in

### FXRs

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<td>#2</td>
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</tr>
<tr>
<td>#3</td>
<td>300 soft</td>
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### Vacuum Pressure
- **41/2** torr

### Target Description
- **MSFC L65**

### Comments
- Det Wnt
- Pic Didn't
- Oct 12 Broken Up
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-8
ISCL TEST NO. 47

DATE 3-12-76

EXPLOSIVE

CHARGE NUMBER 25
CHARGE WEIGHT 658.5 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.749 (in)
INNER DIAMETER 0.468 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC ________ (in)
DELAY TIME ________ (usec)

HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC ________ (in)
DELAY TIME ________ (usec)

HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC ________ (in)
DELAY TIME ________ (usec)

VACUUM PRESSURE 4/2 (torr)

TARGET DESCRIPTION MSFC L-65

COMMENTS

NO PEN
1ST TEST WITH RP-80 Det.
# INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>7698 - 19</th>
<th>DATE</th>
<th>3-12-76</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISCL TEST NO.</td>
<td>148</td>
<td></td>
<td></td>
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## Explosive

- **Charge Number**: 45
- **Charge Weight**: 6.590 (grams)
- **Detonator Type**: RP-87

## Inhibitor

- **Overall Height**: 1.750 (in)
- **Inner Diameter**: 0.468 (in)

## FXRs

<table>
<thead>
<tr>
<th>HEAD #1:</th>
<th>SIZE: 150 (kV)</th>
<th>DISTANCE FBOC: 11 (in)</th>
<th>DELAY TIME: 11 (usec)</th>
</tr>
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<tbody>
<tr>
<td>HEAD #2:</td>
<td>SIZE: 300 soft (kV)</td>
<td>DISTANCE FBOC: 11 (in)</td>
<td>DELAY TIME: 11 (usec)</td>
</tr>
<tr>
<td>HEAD #3:</td>
<td>SIZE: 300 soft (kV)</td>
<td>DISTANCE FBOC: 11 (in)</td>
<td>DELAY TIME: 11 (usec)</td>
</tr>
</tbody>
</table>

## Vacuum Pressure

- **Vacuum Pressure**: 4 1/2 (torr)

## Target Description

- **Target**: MSFC L45.8
  - (with a 0.050 front face)

## Comments

- \[ \left( \frac{0.050}{6061.73} \right) 1.8 \text{ gap } [2.0 \text{ MIL}] 1.8 \text{ gap } [0.150 \text{ 229}] \]
## INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

**TEST NUMBER** 7698-20  
**DATE** 3-12-76

**ISCL TEST NO.** 149  
**DATE** Sunny 70°

## EXPLOSIVE

<table>
<thead>
<tr>
<th>Charge Number</th>
<th>Charge Weight (grams)</th>
<th>Detonator Type</th>
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<tbody>
<tr>
<td>17</td>
<td>653.0</td>
<td>RP-87</td>
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## INHIBITOR

<table>
<thead>
<tr>
<th>Overall Height</th>
<th>Inner Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.750</td>
<td>0.468</td>
</tr>
</tbody>
</table>

## FXRs

### HEAD #1:

<table>
<thead>
<tr>
<th>Size</th>
<th>150 (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance FBOC</td>
<td>11 (in)</td>
</tr>
<tr>
<td>Delay Time</td>
<td>11 (usec)</td>
</tr>
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### HEAD #2:

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<tr>
<th>Size</th>
<th>300 soft (kV)</th>
</tr>
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<tbody>
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<td>Distance FBOC</td>
<td>11 (in)</td>
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<tr>
<td>Delay Time</td>
<td>11 (usec)</td>
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### HEAD #3:

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<td>Distance FBOC</td>
<td></td>
</tr>
<tr>
<td>Delay Time</td>
<td></td>
</tr>
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## Vacuum Pressure

| 4 1/2 (torr) |

## Target Description

| MSFC L45 |

## Comments
EXPLOSIVE

CHARGE NUMBER 13
CHARGE WEIGHT 658.0 (grams)
DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)
INNER DIAMETER 0.468 (in)

FXRs

HEAD #1: SIZE 150 (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)
HEAD #2: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME (usec)
HEAD #3: SIZE 300 soft (kV)
DISTANCE FBOC (in)
DELAY TIME 222.7 (usec)

VACUUM PRESSURE 4/12 (torr)
TARGET DESCRIPTION MSFC LEO 8

COMMENTS

DID NOT DUMP.
INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-22  DATE 3-13-96
ISCL TEST NO. 151

EXPLOSIVE
CHARGE NUMBER ____________________________
CHARGE WEIGHT ___________________________ (grams)
DETONATOR TYPE __ RP-87 ________________

INHIBITOR
OVERALL HEIGHT ___________________________ (in)
INNER DIAMETER __________________________ (in)

FXRs

<table>
<thead>
<tr>
<th>HEAD</th>
<th>SIZE</th>
<th>DISTANCE FBOC</th>
<th>DELAY TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>300 soft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td>300 soft</td>
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VACUUM PRESSURE 492 (torr)

TARGET DESCRIPTION MSFC JEM 45F

COMMENTS
APPENDIX B

Projectile Geometry Measurements
Table 3. Projectile Geometry Measurements

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>MASS (g)</th>
<th>VELOCITY (km/s)</th>
<th>DIAMETER (cm)</th>
<th>L/D</th>
<th>TOTAL ANGLE (°) (QUADRANT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7698-1</td>
<td>1.35</td>
<td>11.68</td>
<td>0.871</td>
<td>1.4</td>
<td>26 (2)</td>
</tr>
<tr>
<td>7698-2</td>
<td>1.12</td>
<td>11.38</td>
<td>1.011</td>
<td>1.1</td>
<td>31 (2)</td>
</tr>
<tr>
<td>7698-3</td>
<td>0.99</td>
<td>11.64</td>
<td>0.623</td>
<td>2.3</td>
<td>40 (1)</td>
</tr>
<tr>
<td>7698-4</td>
<td>0.94</td>
<td>11.37</td>
<td>0.665</td>
<td>2.0</td>
<td>30 (2)</td>
</tr>
<tr>
<td>7698-5</td>
<td>1.03</td>
<td>11.77</td>
<td>0.696</td>
<td>1.9</td>
<td>54 (3)</td>
</tr>
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<td>7698-6</td>
<td>0.84</td>
<td>11.37</td>
<td>0.739</td>
<td>1.5</td>
<td>50 (2)</td>
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<tr>
<td>7698-7</td>
<td>0.99</td>
<td>11.37</td>
<td>0.820</td>
<td>1.2</td>
<td>33 (1)</td>
</tr>
<tr>
<td>7698-8</td>
<td>0.82</td>
<td>11.40</td>
<td>—</td>
<td>—</td>
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<tr>
<td>7698-9</td>
<td>0.97</td>
<td>11.42</td>
<td>0.831</td>
<td>1.1</td>
<td>61 (2)</td>
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<tr>
<td>7698-10</td>
<td>1.42</td>
<td>11.35</td>
<td>0.693</td>
<td>2.6</td>
<td>36 (1)</td>
</tr>
<tr>
<td>7698-11</td>
<td>1.28</td>
<td>11.47</td>
<td>0.602</td>
<td>3.4</td>
<td>7 (1)</td>
</tr>
<tr>
<td>7698-12</td>
<td>0.76</td>
<td>11.45</td>
<td>0.762</td>
<td>1</td>
<td>—</td>
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<tr>
<td>7698-13</td>
<td>1.04</td>
<td>11.51</td>
<td>0.742</td>
<td>1.3</td>
<td>27 (4)</td>
</tr>
<tr>
<td>7698-14</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
</tr>
<tr>
<td>7698-15</td>
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<td>—</td>
</tr>
<tr>
<td>7698-16</td>
<td>1.09</td>
<td>11.51</td>
<td>1.102</td>
<td>1</td>
<td>75 (4)</td>
</tr>
<tr>
<td>7698-17</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7698-18</td>
<td>0.97</td>
<td>11.30</td>
<td>0.813</td>
<td>1.3</td>
<td>15 (4)</td>
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<tr>
<td>7698-19</td>
<td>1.11</td>
<td>11.32</td>
<td>0.716</td>
<td>2.0</td>
<td>15 (2)</td>
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<td>7698-20</td>
<td>1.23</td>
<td>11.38</td>
<td>1.392</td>
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<td>—</td>
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<tr>
<td>7698-21</td>
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<td>7698-22</td>
<td>0.98</td>
<td>11.36</td>
<td>0.947</td>
<td>1.3</td>
<td>29 (1)</td>
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</table>
# ISCL Projectile Data

<table>
<thead>
<tr>
<th>Test Number</th>
<th>7698-1</th>
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</table>

<table>
<thead>
<tr>
<th>View</th>
<th>Outer Diameter (in)</th>
<th>Length (in)</th>
<th>Wall Thickness (in)</th>
<th>Velocity (km/s)</th>
<th>Yaw (view 3) (deg)</th>
<th>Pitch (view 4) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.400</td>
<td>0.483</td>
<td>0.072</td>
<td>11.66</td>
<td>-10.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.305</td>
<td></td>
<td>0.074</td>
<td>11.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.408</td>
<td></td>
<td>0.062</td>
<td>11.68</td>
<td>+24.1</td>
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</tr>
<tr>
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<td>0.258</td>
<td></td>
<td>0.069</td>
<td>11.70</td>
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<td></td>
</tr>
</tbody>
</table>

Average Outer Diameter (in) 0.343

Average Thickness (in) 0.075

Inner Diameter (in) 0.193

Length (in) 0.483

L/D 1.4

Total Angle (deg) 25.8 (Quadrant #) 2

Mass (g) 1.35

Average Velocity (km/s) 11.68

**Notes:**

YAW: (+) is Right

PITCH: (+) is Up

Density: 2.7 g/cc

Quadrant: Looking at Impact Surface

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>2</th>
<th>1</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
</table>
## ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) (deg)</th>
<th>PITCH (view 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.521</td>
<td>0.434</td>
<td>0.076</td>
<td>11.38</td>
<td>-30.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.275</td>
<td></td>
<td>0.065</td>
<td>11.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>0.073</td>
<td>11.39</td>
<td>+8.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>0.068</td>
<td>11.38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **AVERAGE OUTER DIAMETER (in)**: 0.398
- **AVERAGE THICKNESS (in)**: 0.071
- **INNER DIAMETER (in)**: 0.256
- **LENGTH (in)**: 0.434
- **L/D**: 1.1
- **TOTAL ANGLE (deg)**: 30.7 (Quadrant #): 2
- **MASS (g)**: 1.12
- **AVERAGE VELOCITY (km/s)**: 11.38

### NOTES:
- **YAW**: (+) is RIGHT
- **PITCH**: (+) is UP
- **DENSITY**: 2.7 g/cc
- **QUADRANT**: Looking at Impact Surface

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
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</table>
# ISCL PROJECTILE DATA

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<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) PITCH (view 4) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.260</td>
<td>0.560</td>
<td>0.084, 0.086</td>
<td>11.65</td>
<td>+0</td>
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<tr>
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<td>2.239</td>
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<td>0.074</td>
<td>11.63</td>
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<td>4</td>
<td>2.245</td>
<td></td>
<td>0.076</td>
<td>11.64</td>
<td>+39.7</td>
</tr>
<tr>
<td></td>
<td>2.243</td>
<td></td>
<td>0.066, 0.060</td>
<td>11.64</td>
<td></td>
</tr>
</tbody>
</table>

**AVERAGE OUTER DIAMETER (in)**: 0.246

**AVERAGE THICKNESS (in)**: 0.074

**INNER DIAMETER (in)**: 0.098

**LENGTH (in)**: 0.560

**L/D**: 2.3

**TOTAL ANGLE (deg)**: 39.7 (Quadrant #): 1

**MASS (g)**: 0.99

**AVERAGE VELOCITY (km/s)**: 11.64

**NOTES**:  
**Yaw**: (+) is Right  
**Pitch**: (+) is Up  
**Density**: 2.7 g/cc  
**Quadrant**: Looking at Impact Surface

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>2</th>
<th>1</th>
<th>3</th>
<th>4</th>
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### ISCL PROJECTILE DATA

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<th>7698-4</th>
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<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
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<tr>
<td>3</td>
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<td>0.298</td>
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<td>4</td>
<td>0.206</td>
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<tr>
<td></td>
<td>0.232</td>
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</table>

AVERAGE OUTER DIAMETER (in) 0.262
AVERAGE THICKNESS (in) 0.078
INNER DIAMETER (in) 0.129
LENGTH (in) 0.518
L/D 1.98
TOTAL ANGLE (deg) 29.9 (Quadrant #) 2
MASS (g) 0.94
AVERAGE VELOCITY (km/s) 11.37

**NOTES:**

- YAW: (+) is RIGHT
- PITCH: (+) is UP
- DENSITY: 2.7 g/cc
- QUADRANT: Looking at Impact Surface

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>3</th>
<th>4</th>
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## ISCL PROJECTILE DATA

<table>
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<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) (deg)</th>
<th>PITCH (view 4)</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11.74</td>
<td>-24.5</td>
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</tr>
<tr>
<td>4</td>
<td>0.276</td>
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<td>0.074</td>
<td>11.76</td>
<td>-52.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.280, 0.267</td>
<td></td>
<td>0.068</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AVERAGE OUTER DIAMETER (in) __0.274__

AVERAGE THICKNESS (in) __0.071__

INNER DIAMETER (in) __0.132__

LENGTH (in) __0.515__

L/D __1.88__

TOTAL ANGLE (deg) __54.3__ (Quadrant #) __3__

MASS (g) __1.03__

AVERAGE VELOCITY (km/s) __11.77__

**NOTES:**
- YAW: (+) is RIGHT
- PITCH: (+) is UP
- DENSITY: 2.7 g/cc
- QUADRANT: Looking at Impact Surface

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>2</th>
<th>1</th>
</tr>
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<tbody>
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## ISCL PROJECTILE DATA

<table>
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<th>TEST NUMBER</th>
<th>7698-6</th>
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<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
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<tr>
<td>3</td>
<td>0.244</td>
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<tr>
<td>4</td>
<td>0.330</td>
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</tbody>
</table>

AVERAGE OUTER DIAMETER (in) \[ 0.291 \]
AVERAGE THICKNESS (in) \[ 0.069 \]
INNER DIAMETER (in) \[ 0.153 \]
LENGTH (in) \[ 0.446 \]
L/D \[ 1.53 \]
TOTAL ANGLE (deg) \[ 50.1 \] (Quadrant #) \[ 2 \]
MASS (g) \[ 0.84 \]
AVERAGE VELOCITY (km/s) \[ 11.37 \]

NOTES:
- YAW: (+) is RIGHT
- PITCH: (+) is UP
- DENSITY: 2.7 g/cc
- QUADRANT: Looking at Impact Surface

| QUADRANT | 3 | 4 |
## ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.328</td>
<td>0.372</td>
<td>0.058</td>
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<td>+32.2</td>
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<tr>
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<td>0.322</td>
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<td>0.074</td>
<td>11.36</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.320</td>
<td>-</td>
<td>0.061</td>
<td>11.35</td>
<td>+10.5</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td></td>
<td>-</td>
<td>11.37</td>
<td></td>
</tr>
</tbody>
</table>

AVERAGE OUTER DIAMETER (in) 0.323

AVERAGE THICKNESS (in) 0.064

INNER DIAMETER (in) 0.195

LENGTH (in) 0.372

L/D 1.15

TOTAL ANGLE (deg) 33.3 (Quadrant #) 1

MASS (g) 0.99

AVERAGE VELOCITY (km/s) 11.37

NOTES:

YAW: (+) is RIGHT

PITCH: (+) is UP

DENSITY: 2.7 g/cc

QUADRANT: Looking at Impact Surface
ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) (deg)</th>
<th>PITCH (view 4) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>0.071</td>
<td>11.46</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>0.064</td>
<td>11.44</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

AVERAGE OUTER DIAMETER (in)_________
AVERAGE THICKNESS (in)_________
INNER DIAMETER (in)_________
LENGTH (in)_________
L/D_________
TOTAL ANGLE (deg)_________ (Quadrant #)_________
MASS (g)_________ 0.82
AVERAGE VELOCITY (km/s)_________ 11.41

NOTES: YAW: (+) is RIGHT
PITCH: (+) is UP
DENSITY: 2.7 g/cc
QUADRANT: Looking at Impact Surface

Broken Projectile
# ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>7698 - 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.274</td>
</tr>
<tr>
<td></td>
<td>0.370</td>
</tr>
<tr>
<td>4</td>
<td>—</td>
</tr>
</tbody>
</table>

- **AVERAGE OUTER DIAMETER (in)**: 0.327
- **AVERAGE THICKNESS (in)**: 0.064
- **INNER DIAMETER (in)**: 0.199
- **LENGTH (in)**: 0.365
- **L/D**: 1.12
- **TOTAL ANGLE (deg)**: 60.7 (Quadrant #) 2
- **MASS (g)**: 0.97
- **AVERAGE VELOCITY (km/s)**: 11.42

**NOTES:**
- **YAW**: (+) is RIGHT
- **PITCH**: (+) is UP
- **DENSITY**: 2.7 g/cc
- **QUADRANT**: Looking at Impact Surface

<table>
<thead>
<tr>
<th>QUADRANT</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
</tr>
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</table>
# ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
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</tr>
</thead>
<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.335</td>
</tr>
<tr>
<td></td>
<td>-</td>
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<tr>
<td>4</td>
<td>0.273, 273</td>
</tr>
<tr>
<td></td>
<td>0.252, 258</td>
</tr>
</tbody>
</table>

AVERAGE OUTER DIAMETER (in) 0.273
AVERAGE THICKNESS (in) 0.072
INNER DIAMETER (in) 0.129
LENGTH (in) 0.707
L/D 2.59
TOTAL ANGLE (deg) (Quadrant #)
MASS (g) 1.42
AVERAGE VELOCITY (km/s) 11.35

NOTES: YAW: (+) is RIGHT
PITCH: (+) is UP
DENSITY: 2.7 g/cc
QUADRANT: Looking at Impact Surface

| 2 | 1 |
| 3 | 4 |
## ISCL Projectile Data

<table>
<thead>
<tr>
<th>Test Number</th>
<th>7698-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>View</td>
<td>Outer Diameter (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.232</td>
</tr>
<tr>
<td></td>
<td>0.197</td>
</tr>
<tr>
<td>4</td>
<td>0.286</td>
</tr>
<tr>
<td></td>
<td>0.231</td>
</tr>
</tbody>
</table>

Average Outer Diameter (in) 0.237
Average Thickness (in) 0.067
Inner Diameter (in) 0.103
Length (in) 0.809
L/D 3.41
Total Angle (deg) 7.2 (Quadrant #) 1
Mass (g) 1.28
Average Velocity (km/s) 11.47

Notes:
- Yaw: (+) is RIGHT
- Pitch: (+) is UP
- Density: 2.7 g/cc
- Quadrant: Looking at Impact Surface
### ISCL Projectile Data

<table>
<thead>
<tr>
<th>Test Number</th>
<th>7698-12</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>View</th>
<th>Average Outer Diameter (in)</th>
<th>Average Thickness (in)</th>
<th>Inner Diameter (in)</th>
<th>Length (in)</th>
<th>L/D</th>
<th>Total Angle (deg) (Quadrant #)</th>
<th>Mass (g)</th>
<th>Average Velocity (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.76</td>
<td>11.53</td>
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<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.48</td>
</tr>
</tbody>
</table>

**Notes:**

- **YAW:** (+) is Right
- **Pitch:** (+) is Up
- **Density:** 2.7 g/cc
- **Quadrant:** Looking at Impact Surface

- Broken Projectile
### ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>VIEW</th>
<th>OUTER DIAMETER (in)</th>
<th>LENGTH (in)</th>
<th>WALL THICKNESS (in)</th>
<th>VELOCITY (km/s)</th>
<th>YAW (view 3) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.294</td>
<td>-</td>
<td>0.068</td>
<td>11.50</td>
<td>+12.8</td>
</tr>
<tr>
<td></td>
<td>0.297</td>
<td></td>
<td>0.072</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.299</td>
<td>0.392</td>
<td>0.072</td>
<td>11.51</td>
<td>-24.2</td>
</tr>
<tr>
<td></td>
<td>0.308</td>
<td></td>
<td>0.064</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **AVG OUTER DIAMETER (in):** 0.292
- **AVG THICKNESS (in):** 0.069
- **INNER DIAMETER (in):** 0.154
- **LENGTH (in):** 0.392
- **L/D:** 1.34
- **TOTAL ANGLE (deg):** 26.7 (Quadrant #) 4
- **MASS (g):** 1.04
- **AVG VELOCITY (km/s):** 11.50

**NOTES:**
- **YAW:** (+) is RIGHT
- **PITCH:** (+) is UP
- **DENSITY:** 2.7 g/cc
- **QUADRANT:** Looking at Impact Surface

<table>
<thead>
<tr>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
### ISCL Projectile Data

<table>
<thead>
<tr>
<th>View</th>
<th>Outer Diameter (in)</th>
<th>Length (in)</th>
<th>Wall Thickness (in)</th>
<th>Velocity (km/s)</th>
<th>Yaw (view 3)</th>
<th>Pitch (view 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>11.5</td>
<td></td>
<td>11.5</td>
</tr>
</tbody>
</table>

**Average Outer Diameter (in):**

**Average Thickness (in):**

**Inner Diameter (in):**

**Length (in):**

**L/D:**

**Total Angle (deg):**

**Mass (g):** 1.09

**Average Velocity (km/s):** 11.5

**Notes:**
- **Yaw:** (+) is right
- **Pitch:** (+) is up
- **Density:** 2.7 g/cc
- **Quadrant:** Looking at impact surface

![Broken Projectile]
# ISCL Projectile Data

<table>
<thead>
<tr>
<th>Test Number</th>
<th>7698-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>View</td>
<td>Length (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.424</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

- **Average Outer Diameter (in)**: 0.320
- **Average Thickness (in)**: 0.065
- **Inner Diameter (in)**: 0.191
- **Length (in)**: 0.424
- **L/D**: 1.33
- **Total Angle (deg)**: 14.7 (Quadrant #) 4
- **Mass (g)**: 0.97
- **Average Velocity (km/s)**: 11.30

**Notes:**
- **Yaw**: (+) is RIGHT
- **Pitch**: (+) is UP
- **Density**: 2.7 g/cc
- **Quadrant**: Looking at Impact Surface
  - 2
  - 3
  - 4
## ISCL Projectile Data

<table>
<thead>
<tr>
<th>Test Number</th>
<th>7698-19</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>View</th>
<th>Outer Diameter (in)</th>
<th>Length (in)</th>
<th>Wall Thickness (in)</th>
<th>Velocity (km/s)</th>
<th>Yaw (View 3)</th>
<th>Pitch (View 4) (deg)</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>0.285</td>
<td>-</td>
<td>0.064</td>
<td>11.27</td>
<td>-8.7</td>
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<tr>
<td></td>
<td>0.220</td>
<td></td>
<td>0.063</td>
<td></td>
<td></td>
<td></td>
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<td>0.284</td>
<td>0.580</td>
<td>0.077</td>
<td>11.35</td>
<td>+12.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.298</td>
<td></td>
<td>0.060</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Average Outer Diameter (in):** 0.282
- **Average Thickness (in):** 0.066
- **Inner Diameter (in):** 0.150
- **Length (in):** 0.580
- **L/D:** 1.99
- **Total Angle (deg):** 15.1 (Quadrant #2)
- **Mass (g):** 11.11
- **Average Velocity (km/s):** 11.32

**Notes:**
- **Yaw:** (+) is RIGHT
- **Pitch:** (+) is UP
- **Density:** 2.7 g/cc
- **Quadrant:** Looking at Impact Surface

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
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</tbody>
</table>
# ISCL Projectile Data

<table>
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<tr>
<th>TEST NUMBER</th>
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<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.548</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

**Average Outer Diameter (in):** 0.548

**Average Thickness (in):** 0.080

**Inner Diameter (in):** 0.388

**Length (in):** 0.473

**L/D:** 0.86

**Total Angle (deg):** 22.8 (Quadrant #) 4

**Mass (g):** 1.23

**Average Velocity (km/s):** 11.38

**Notes:**
- **Yaw:** (+) is RIGHT
- **Pitch:** (+) is UP
- **Density:** 2.7 g/cc
- **Quadrant:** Looking at Impact Surface

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
## ISCL PROJECTILE DATA

<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>7698-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIEW</td>
<td>OUTER DIAMETER (in)</td>
</tr>
<tr>
<td>3</td>
<td>0.410</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
</tr>
</tbody>
</table>

### Average Values
- **Average Outer Diameter (in)**: 0.373
- **Average Thickness (in)**: 0.071
- **Inner Diameter (in)**: 0.231
- **Length (in)**: 0.493
- **L/D**: 1.32
- **Total Angle (deg)**: 29.0 (Quadrant #1)
- **Mass (g)**: 0.98
- **Average Velocity (km/s)**: 11.36

### Notes:
- **Yaw**: (+) is RIGHT
- **Pitch**: (+) is UP
- **Density**: 2.7 g/cc
- **Quadrant**: Looking at Impact Surface

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Count</th>
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<tbody>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
APPENDIX C

General Target Damage Measurements
Volucin = 11.65 m/s (high est.?)

Walls:
#1 - Destroyed
#2 - Hurt - Bad
#3 - Damaged
7678 -- LECO

Velocity = 11.38 km/s (est)

FACE

3 1/2''

1/2''

2 3/4''

3/4'' long

1/2'' long

1/4'' long

2 1/4'' long

2 1/2'' long

WIT #1

4'' hole & a lot of trash

WIT #2

1 large hole (1''Ø), several small holes & trash

WIT #3

3 1/4'' hole
TARGET LEO

Velocity = 11.64 km/s (est.)

FACE

WALL

Witness all 3
Hand Multiple
Small to Medium
(¼” ø to 1” ø)
Size hits.
All 3 were
Deformed (Ber).

Petal 3” High
Petals 2” High
Petal 3½” High
Petal 4”

3”
3½”
1½”

7½”
4”
7678 - 4

Wall

Split in two

4½" long crack

2½" long crack

1½" hole

WITNESS

Damage described: From many small (½") holes on Plate #1 to only a few small ones (<¼") on Plate #2.
With a #2 bit, drill 3 in. Deeper in #1., several small ones at 3 in. (May have to go another 1/2 in. for screen unit.)
WITNESS #1

Mostly A 24-22 g. aluminum, 1/32" .0003

2. only very thin think (< 1/16"")

3. no scrape
THROUGH Hole x 3-3 1/4
FACE

WALL

Witness 81 4'-5" x 10' with multiple holes, all over

42 1'-7 3/4" holes pattern reduced to only small holes by Chart 2:
Witness #1
Very little deformation
Several small holes

#2 2 impacts, no penetration
Witness: #1 Has 2 - 3/4" w/det 3 = 2 cement blocks
   1 - 1-1/4" load 3 x 1 gal. 3/4" rain
   = 3 in. in window
BAD CHANGE
Prove that \( S^m \cong \mathbb{R}^m \).
WILL - HM REM - 3½ Buce
BAD CHANGE
FACE

WALL

Witness: Savage Hole Pattern (x 100-150) Decrease 75

A few Dents & only 1 Hole is by #3
FACE

WALL

All 3 internal plates have numerous small holes
JEM 45 E

WALL

WITNESS

#1 8 - 1/8" or Smaller Holes 1 - 3/8" Ø Holes

#2 Same

#3 1 - 1/4" Ø 1 Hole
APPENDIX D

MSFC Wall Hole Size Measurements
Table 4. MSFC Hole Size Measurements

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>TIP-TO-TIP CRACK LENGTH (cm)</th>
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<tbody>
<tr>
<td>7698-1</td>
<td>6.86</td>
</tr>
<tr>
<td>7698-2</td>
<td>14.48</td>
</tr>
<tr>
<td>7698-3</td>
<td>27.94</td>
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<td>7698-4</td>
<td>19.05</td>
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<td>13.46</td>
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<tr>
<td>7698-7</td>
<td>9.14</td>
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<tr>
<td>7698-8</td>
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<tr>
<td>7698-9</td>
<td>33.02</td>
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<tr>
<td>7698-10</td>
<td>8.89</td>
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<td>15.24</td>
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<td>7698-21</td>
<td>17.78</td>
</tr>
<tr>
<td>7698-22</td>
<td>17.15</td>
</tr>
</tbody>
</table>
\[ L_{TT} = 3.6" \]
BAD SHOT.

NO HOLE.

1/4" BURGE.
7698-11

LECOF

\[ l_{TT} (A-B) = 3\frac{1}{8}'' \] (indicative times)
76.98 - 12
BAD (Small, Dis-Formed) Projectile

1 - 1 1/2 " Bulge
7698 - 13
L45E

\[ L_{IT} = \frac{1}{16}'' \]
7698-14 - NO DET
7698-15 - H + STRIPES
7698-16 - NO PEN
7698-17 - NO DET
7698-18 - NO PEN
CE = 7
DF = 6 3/4
BE = 6
AD = 6 1/2
BD = 6 1/2
APPENDIX E

Radiographic Images
Figure 8. Projectile for Test 7698-1 (View 3 and 4).

Figure 9. Projectile for Test 7698-2 (View 3 and 4).

Figure 10. Projectile for Test 7698-3 (View 3 and 4).
Figure 11. Projectile for Test 7698-4 (View 3 and 4).

Figure 12. Projectile for Test 7698-5 (View 3 and 4).

Figure 13. Projectile for Test 7698-6 (View 3 and 4).
Figure 14. Projectile for Test 7698-7 (View 3 and 4).

Figure 15. Projectile for Test 7698-8 (View 3 and 4).

Figure 16. Projectile for Test 7698-9 (View 3 and 4).
Figure 17. Projectile for Test 7698-10 (View 3 and 4).

Figure 18. Projectile for Test 7698-11 (View 3 and 4).

Figure 19. Projectile for Test 7698-12 (View 3 and 4).
Figure 20. Projectile for Test 7698-13 (View 3 and 4).

Figure 21. Projectile for Test 7698-16 (View 3 and 4).

Figure 22. Projectile for Test 7698-18 (View 3 and 4).
Figure 23. Projectile for Test 7698-19 (View 3 and 4).

Figure 24. Projectile for Test 7698-20 (View 3 and 4).

Figure 25. Projectile for Test 7698-22 (View 3 and 4).
Figure 26. Behind Wall Debris Pattern for Test 7698-1 (Horizontal View).
Figure 27. Behind Wall Debris Pattern for Test 7698-1 (Vertical View).
Figure 28. Behind Wall Debris Pattern for Test 7698-2 (Horizontal View).

Figure 29. Behind Wall Debris Pattern for Test 7698-2 (Vertical View).
Figure 30. Behind Wall Debris Pattern for Test 7698-5 (Horizontal View).

Figure 31. Behind Wall Debris Pattern for Test 7698-5 (Vertical View).
Figure 32. Behind Wall Debris Pattern for Test 7698-6 (Horizontal View).

Figure 33. Behind Wall Debris Pattern for Test 7698-6 (Vertical View).
Figure 34. Behind Wall Debris Pattern for Test 7698-11 (Horizontal View).

Figure 35. Behind Wall Debris Pattern for Test 7698-11 (Vertical View).
Figure 36. Behind Wall Debris Pattern for Test 7698-21 (Horizontal View).
Figure 37. Behind Wall Debris Pattern for Test 7698-21 (Vertical View).
Appendix F

Test Summary for

Final Report 06-7139

dated October 1995
The work reported on in this test report (06-7698) is a continuation of work performed during SwRI Project Number 06-7139. Therefore, correlation of the data between these programs is essential. During the previous program, projectile mass calculations were made using a technique which has since been modified. Therefore, to insure that the data in this current work correlates properly with the data reported in the October 1995 report, the projectile masses from the 06-7139 report have been recalculated using the new calculation procedure. The following table reflects these changes.

Also, during the conduct of the 06-7139 experiments, are-calibration of the flash x-ray system occurred between Tests 7139-9 and 7139-10. It has since been determined, based on the extremely low velocity values measured during Tests 7139-10 through 7139-15, that this calibration was inaccurate. Therefore, the velocity values have been adjusted based on the average ISCL velocity. The procedure used to adjust the values is given below:

Average Velocity of "Slow" Projectiles: 10.69 km/s

Known Average ISCL Velocity: 11.28 km/s

Adjusted Value = ["slow" velocity - 10.69] + 11.28

Example: Test 7139-10:

Adjusted Velocity = [10.60 - 10.69] + 11.28 = 11.19 km/s
<table>
<thead>
<tr>
<th>Test Number</th>
<th>Test Date</th>
<th>Projectile Mass (g)</th>
<th>Projectile Velocity (km/s)</th>
<th>Target: Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>7139-1</td>
<td>5-2-95</td>
<td>1.24</td>
<td>N/M</td>
<td>U.S. Lab Whipple (0/)</td>
<td>Shield had a 1-1/2&quot; diameter hole, Wall had a 1&quot; diameter hole. All three witness plates were perforated.</td>
</tr>
<tr>
<td>7139-2</td>
<td>5-2-95</td>
<td>1.30</td>
<td>11.14</td>
<td>Russian Whipple Shield (0/)</td>
<td>Shield had a 3&quot; diameter hole, Wall had a 6&quot; (post petal) diameter hole, and Plate #3 had a full waffle-square removed. All three witness plates were perforated.</td>
</tr>
<tr>
<td>7139-3</td>
<td>5-3-95</td>
<td>1.30</td>
<td>11.16</td>
<td>ESA Cylinder (0/)</td>
<td>Shield had a 1-1/2&quot; diameter hole, Wall had a 1-1/4&quot; diameter hole, and Plate #3 had a 1-3/4&quot; diameter hole. All three witness plates were perforated.</td>
</tr>
<tr>
<td>7139-4</td>
<td>5-3-95</td>
<td>-</td>
<td>-</td>
<td>Enhanced Lab #1 (0/)</td>
<td>Projectile hit stripper plate. No data.</td>
</tr>
<tr>
<td>7139-5</td>
<td>8-24-95</td>
<td>0.94</td>
<td>11.20</td>
<td>U.S. Lab Whipple (65/)</td>
<td>Shield had a 4&quot; by 2&quot; hole. MLI was destroyed. Material came off shield normal to its surface and missed wall. No witness damage.</td>
</tr>
<tr>
<td>7139-6</td>
<td>8-25-95</td>
<td>1.06</td>
<td>11.18</td>
<td>ESA Cylinder (65/)</td>
<td>Shield had a 1-3/4&quot; by 3&quot; hole. Wall #1 had a narrow slit 2-1/4&quot; long with several cracks forming. Wall #2 had not cracks or holes. No witness damage.</td>
</tr>
<tr>
<td>7139-7</td>
<td>8-25-95</td>
<td>-</td>
<td>-</td>
<td>Jem Whipple (0/)</td>
<td>Projectile hit stripper plate. No data.</td>
</tr>
<tr>
<td>7139-8</td>
<td>8-28-95</td>
<td>1.11</td>
<td>N/M</td>
<td>Jem Whipple (65/)</td>
<td>Shield had a jagged hole with major diameter of 3-1/2&quot;. MLI was destroyed. Wall had no cracks or holes. No witness damage.</td>
</tr>
<tr>
<td>Test Number</td>
<td>Test Date</td>
<td>Projectile Mass (g)</td>
<td>Projectile Velocity (km/s)</td>
<td>Target Description</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------</td>
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</tr>
<tr>
<td>7139-9</td>
<td>8-28-95</td>
<td>0.88</td>
<td>N/M</td>
<td>Enhanced Lab #2 (0/)</td>
<td>Shield had a hole with major diameter of 2-1/2&quot;. Wall had a large, jagged hole with major diameter up to 5-1/2&quot; and cracks up to 6&quot; long. Large amount of pettaling of wall plate. All witness plates perforated.</td>
</tr>
<tr>
<td>7139-10</td>
<td>8-28-95</td>
<td>1.00</td>
<td>11.19*</td>
<td>Enhanced Lab #1 (0/)</td>
<td>Shield had a 3-1/2&quot; diameter hole. The Nextel layer had a 3&quot; diameter hole. The Kevlar layer had a 5&quot; diameter hole. The wall had a jagged hole with diameter up to 8-1/2&quot; with several cracks (one running to the plate edge). All witness plates perforated.</td>
</tr>
<tr>
<td>7139-11</td>
<td>8-29-95</td>
<td>1.20</td>
<td>11.26*</td>
<td>Enhanced Lab #1 (65/)</td>
<td>Shield had a 3-1/2&quot; diameter hole. Nextel and Kevlar layers both had 3&quot; to 4&quot; diameter holes. Wall had no holes but bulged 1&quot;. No witness damage.</td>
</tr>
<tr>
<td>7139-12</td>
<td>8-30-95</td>
<td>0.58 (est)</td>
<td>11.67*</td>
<td>Enhanced Russian (0/)</td>
<td>Projectile broke up. Shield had a 3&quot; diameter hole. Nextel and Kevlar layers had 3&quot; diameter holes. Wall had a hole up to 7-1/2&quot; diameter.</td>
</tr>
<tr>
<td>7139-13</td>
<td>8-31-95</td>
<td>1.11</td>
<td>11.27*</td>
<td>U.S. Lab Whipple (45/)</td>
<td>Shield had a 4-3/4&quot; by 2-1/2&quot; diameter hole. Wall had only one small hole (1/2&quot; diameter). Witness 1 had a few small perforations, Witness 2 and 3 were not damaged.</td>
</tr>
<tr>
<td>7139-14</td>
<td>8-31-95</td>
<td>1.07 (est)</td>
<td>N/M</td>
<td>Russian Enhanced with Clamped Fabric (0/)</td>
<td>Shield had a 2-1/2&quot; diameter hole. Nextel and Kevlar layers had 2&quot; to 3&quot; diameter holes. Wall had a hole up to 7-1/2&quot; diameter. Witness 1 had a 4&quot; diameter hole. Witness 2 and 3 had 2&quot; to 3&quot; diameter holes.</td>
</tr>
<tr>
<td>Test Number</td>
<td>Test Date</td>
<td>Mass (g)</td>
<td>Velocity (km/s)</td>
<td>Comments</td>
<td></td>
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<td>-------------</td>
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<td></td>
</tr>
<tr>
<td>Test 1</td>
<td>11.0.15</td>
<td>1.0.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td>9.5.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 3</td>
<td>7.13.9.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>