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INHIBITED SHAPED CHARGE LAUNCHER TESTING OF SPACECRAFT SHIELD DESIGNS

Prepared by

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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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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.

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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.

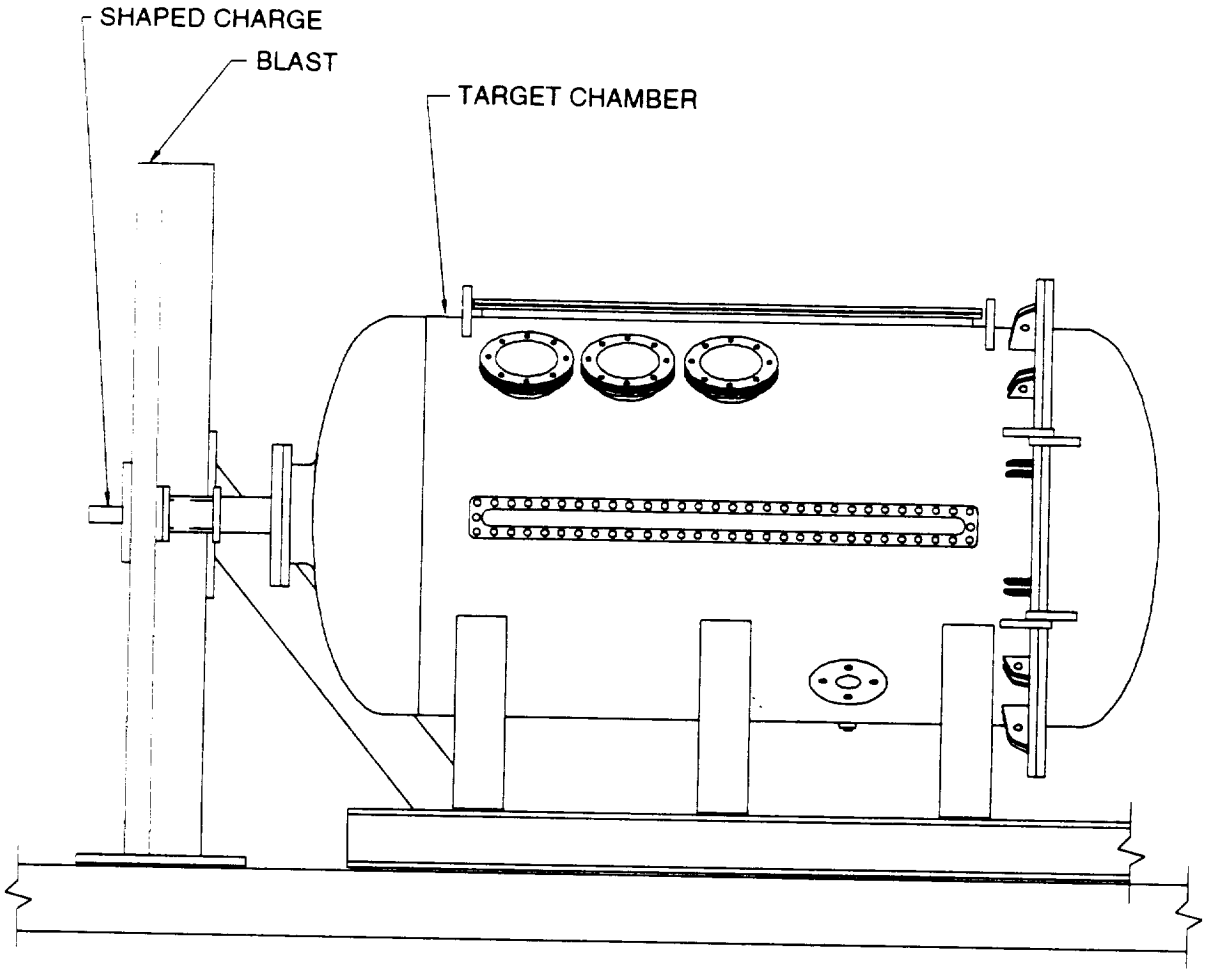


Figure 1. The SwRI ISCL Facility.

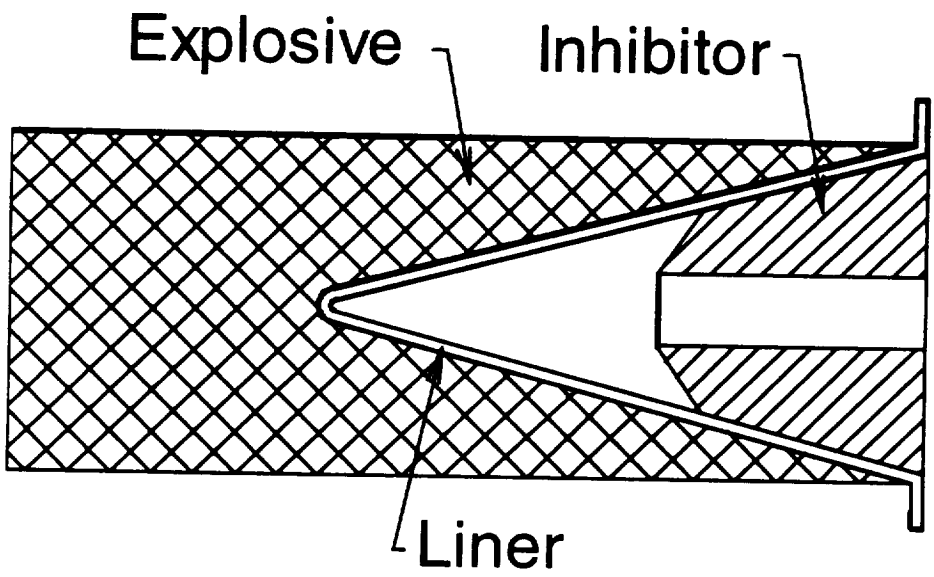


Figure 2. Shaped Charge with Inhibitor.

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.

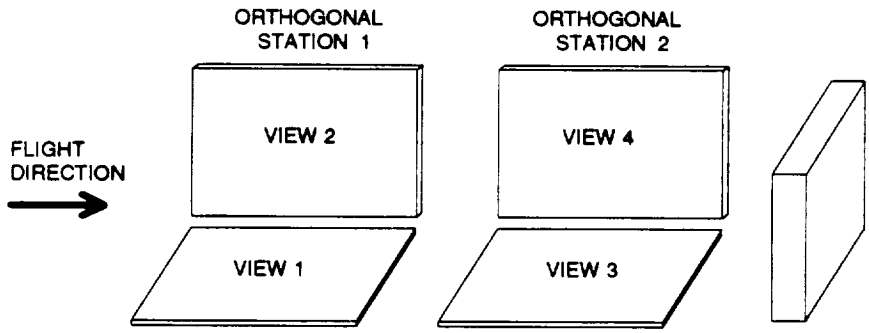


Figure 3. FXR Stations 1 and 2 Orientation.

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° 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.

Figure 4. U.S. Lab at 0° (LO).

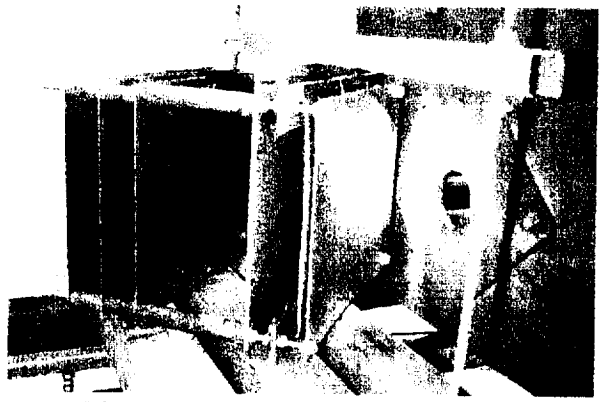


Figure 5. U.S. Lab at 45° (L45).

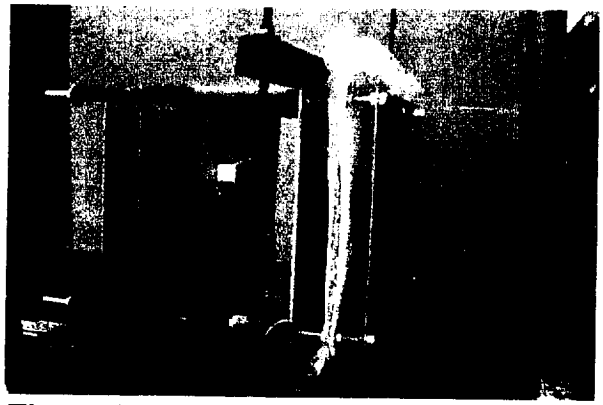


Figure 6. U.S. Lab Enhanced at 0° (LEO).

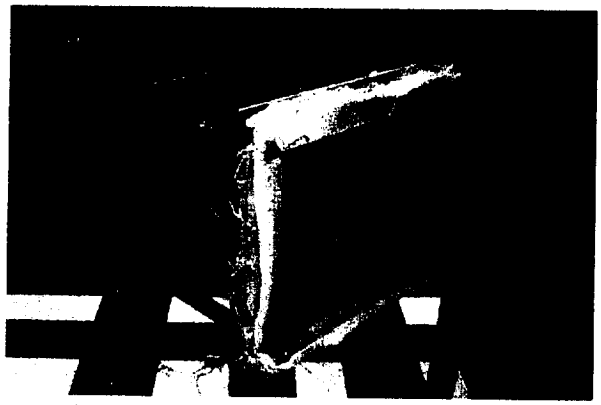


Figure 7. U.S. Lab Enhanced at 45°

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

TARGET NAME	ABREVIATION	TARGET DESCRIPTION
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 2/3 Scale 0°, 45°, and 65° Obliquity	L0 and L45 and L65	0.032" Al 6061-T6 1.500" Space 20 Layers MLI 1.500" Space 0.125" Al 2219-T87 Witness Pack
U.S. LAB Full Scale 45° Obliquity	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 2/3 Scale 0° and 45° Obliquity	LE0 and LE45	0.050" Al 6061-T6 1.500" Space 4 Layers NEXTEL 4 Layers KEVLAR 1.500" Space 0.125" Al 2219-T87 Witness Pack
U.S. LAB ENHANCED 0.8 Scale 0° and 45° Obliquity	LE0.8 and LE45.8	0.063" Al 6061-T6 1.800" Space 5 Layers NEXTEL 5 Layers KEVLAR 1.800" Space 0.150" Al 2219-T87 Witness Pack
U.S. LAB ENDCONE 2/3 Scale 0° and 45° Obliquity	LEC0 and LEC45	0.032" Al 6061-T6 1.000" Space 20 Layers MLI 4.810" Space 0.125" Al 2219-T87 Witness Pack

TARGET NAME	ABREVIATION	TARGET DESCRIPTION
U.S. LAB ENDCONE Full Scale 0° and 45° Obliquity	LEC0F and LEC45F	0.050" Al 6061-T6 1.500" Space 20 Layers MLI 7.220" Space 0.188" Al 2219-T87 Witness Pack
JEM 2/3 Scale 0° and 45° Obliquity	JEM0 and JEM45	0.032" Al 6061-T6 1.500" Space 20 Layers MLI 1.500" Space 0.080" Al 2219-T87 Witness Pack
JEM Full Scale 45° Obliquity	JEM45F	0.050" Al 6061-T6 2.250" Space 20 Layers MLI 2.250" Space 0.125" Al 2219-T87 Witness Pack
U.S. LAB REAR WALL 2/3 Scale 0° and 45° Obliquity	LRW0 and LRW45	0.032" Al 6061-T6 1.500" Space 20 Layers MLI 1.500" Space 0.125" Al 5456 Witness Pack

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 2. Test Summary

TEST NO.	MASS (g)	VELOCITY (km/s)	TARGET	WALL DAMAGE (TIP-TO-TIP LENGTH)	COMMENTS
7698-1	1.35	11.68	L0	1" Dia. Hole (2.7")	Cookie-cut hole. Very symmetric debris pattern.
7698-2	1.12	11.38	LEC0	3.5" to 4.3" Dia. Hole (5.7")	Slightly "C" shaped projectile.
7698-3	0.99	11.64	LE0	3" to 4" Dia. Hole (11")	Typical projectile.
7698-4	0.94	11.37	L45	4.5" to 7" Dia. Hole (7.5")	Typical projectile.
7698-5	1.03	11.77	JEM0	4.5" to 5" Dia. Hole (8.3")	Typical projectile.
7698-6	0.84	11.37	LRW0	4.5" Dia. Hole (5.3")	Typical projectile.
7698-7	0.99	11.37	LEC45	4.7" to 6.3" Dia. Hole (3.6")	Typical projectile.
7698-8	0.82	11.40	LE45	No Penetration (-)	Poorly Formed Small Projectile
7698-9	0.97	11.42	JEM45	4" to 6.3" Dia. Hole (13")	Typical projectile.
7698-10	1.42	11.35	LRW45	1.5" Dia. Hole (3.5")	Typical projectile.
7698-11	1.28	11.47	LEC0F	0.5" to 1.25" Hole (3.1")	Typical (but longer than usual) projectile. Near the Ballistic Limit.
7698-12	0.76	11.45	LE0.8	No Penetration (-)	Poorly Formed Small Projectile
7698-13	1.04	11.51	L45F	0.625" Dia. Hole (0.8")	Typical projectile.
7698-14	-	-	LE0.8	- (-)	Detonator Went, PIC Did Not
7698-15	-	-	LE0.8	- (-)	Projectile Hit Stripper #2 -- Bad Shot
7698-16	1.09	11.51	LE45	No Penetration (-)	Odd Projectile, Had a Flat Impact due to Mass on Side

TEST NO.	MASS (g)	VELOCITY (km/s)	TARGET	WALL DAMAGE (TIP-TO-TIP LENGTH)	COMMENTS
7698-17	-	-	L65	- (-)	Detonator Went, PIC Did Not
7698-18	0.97	11.30	L65	No Penetration (-)	Typical projectile.
7698-19	1.11	11.32	L450.8	0.75" to 2" Dia. Hole (4.8")	Used an 0.050" 6061-T6 Face Sheet.
7698-20	1.23	11.38	L45	2.75" to 1.25" Dia. Hole (6")	Projectile is an Open Cylinder (cross section is "C" shaped)
7698-21	-	-	LE0.8	1.5" to 3.5" Dia. Hole (7")	Equipment Failure - No Pre-Impact Radiographs. Based on target, assume a fairly lethal projectile (high L/D, flying straight).
7698-22	0.98	11.36	JEM45F	0.5" to 1" Dia. Hole (6.8")	Projectile is not completely closed along axial length. About 1/3 of perimeter is opened (somewhat "C" shaped).

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 8.9 cm (3.5 inches) and 10.2 cm (4 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 an 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

1. "Development of an Inhibited Explosive Hypervelocity Launcher," by D. Grosch, J. Walker, S. Mullin, and R. Tullos, Final Report, SwRI Project No. 06-3513, July 1991.

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)

ISCL TEST NO. 130 Sunny & 85°F

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

HEAD #1: SIZE 150 (kV)

DISTANCE FBOC 46 (in)

DELAY TIME 127 (usec)

HEAD #2: SIZE 300 soft (kV)

DISTANCE FBOC 57 (in)

DELAY TIME 153 (usec)

Δ 26 μsec

HEAD #3: SIZE 300 soft (kV)

DISTANCE FBOC 77 (in)

DELAY TIME 217 μsec (usec)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LO (US LAB, 2/3 Scale, @ 0°)

COMMENTS - Face Plate: Large Pettaled 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 62-9.6 (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)

205.2 Msec → DELAY TIME Trigger of Make Surface (usec) 1" in front of Wit #1

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LECO

6 GAP IN TARGET 10¼" From Stripper #2

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-3 DATE 2-23-96

ISCL TEST NO. 132 Hot & Sunny

EXPLOSIVE

CHARGE NUMBER 49

CHARGE WEIGHT 656.5 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)

INNER DIAMETER 2.469 (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 Off Make = 210 (usec)

DID NOT FIRE

VACUUM PRESSURE 4 (torr)

TARGET DESCRIPTION MSFC LEO

COMMENTS Big hole in Face Plate, Big hole in Fabric, Large Petalled hole in Wall. appears that fabric contributed to petals all 3 witness plates perforated with small holes & Bent rearward.

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-4 DATE 2-26-96

ISCL TEST NO. 133

COPY : 55°

EXPLOSIVE

CHARGE NUMBER # 41

CHARGE WEIGHT 6[illegible] (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)

INNER DIAMETER [illegible].69 (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)

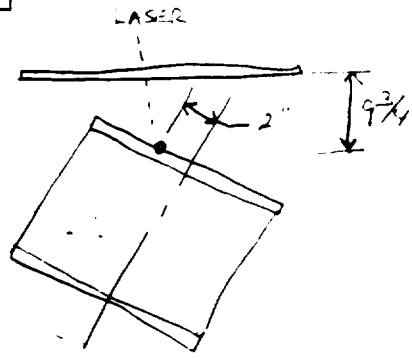
DON'T USE [illegible] TARGET ANGLE

VACUUM PRESSURE 5 (torr)

TARGET DESCRIPTION MSFC L45

AIM POINT IS 2" FROM CENTER OF TARGET

CENTER OF TARGET IS [illegible] FROM STARTER



COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-5 DATE 2-26-96

ISCL TEST NO. 134

EXPLOSIVE

CHARGE NUMBER [illegible] 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 " (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 ~~[illegible]~~ @ 210 (usec)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION JEMO

COMMENTS USE WOODEN FRAME (3/4" PLYWOOD) TO SUPPORT MYLAR SCREEN (WHEN WE 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 #9

CHARGE WEIGHT 652.3 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.767 (in)

INNER DIAMETER 2.48" (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 @ 201.1 + 7 μsec (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION MSFC LEND

COMMENTS AGAIN - A [illegible] →

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-7 DATE 2-27-96

ISCL TEST NO. 136

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 " (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)

NOT USED

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC #7 LEC45

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 8 DATE 2-27-96

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 (in)~~

~~DELAY TIME (usec)~~

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LE45

COMMENTS DID 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 - 9 DATE 2-28-96

ISCL TEST NO. 138

EXPLOSIVE

CHARGE NUMBER #9

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 " (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 4½ (torr)

TARGET DESCRIPTION MSFC JEM 45

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 10 DATE 2-28-96

ISCL TEST NO. 13 Cloudy 50°

EXPLOSIVE

CHARGE NUMBER 32

CHARGE WEIGHT 57.8 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.759 (in)

INNER DIAMETER 0.467 (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 (in)

DELAY TIME (usec)

VACUUM PRESSURE 4½ - 5 (torr)

TARGET DESCRIPTION MSFC LRW 45

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 11 DATE 3-2-96

ISCL TEST NO. 142 50°F, Cloudy, 4:25 am

EXPLOSIVE

CHARGE NUMBER [illegible]

CHARGE WEIGHT [illegible] (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT [illegible] (in)

INNER DIAMETER [illegible] (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~~ → 266 off Mark screen (usec)

VACUUM PRESSURE 5 1/2 (torr)

TARGET DESCRIPTION LECOF

COMMENTS Very near the Ballistic Limit. Small Hole(s). Four Lines Focus. Mostly Caused by Spalling of the wall instead of Penetration

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-12 DATE 3-4-92

ISCL TEST NO. 141

EXPLOSIVE

CHARGE NUMBER #2

CHARGE WEIGHT 357.2 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.59 (in)

INNER DIAMETER [illegible] (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 MAIN SCRN (usec)

NO IMAGE (NO PEN OF WALL)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LEO.8

COMMENTS NO WALL PROTECTION

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 5 DATE 3-[illegible]

ISCL TEST NO. 142

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 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 _____ (usec)

VACUUM PRESSURE 4 1/2 (torr)

TARGET DESCRIPTION MSFC L45F

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-14 DATE 3-5-96

ISCL TEST NO. 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 SCRN (usec)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LEO.8

COMMENTS

DET WENT
PIC DIDN'T
OCTOL BROKEN UP

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - ~~[illegible]~~ 15 DATE 3-5-96

ISCL TEST NO. ~~[illegible]~~ 144

EXPLOSIVE

CHARGE NUMBER #3

CHARGE WEIGHT 63.5 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)

INNER DIAMETER 0.408 (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 Screen (usec)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LE 0.8 (Repeat #14)

COMMENTS Projectile Hit Strap #2

Target / Face [illegible] [illegible] [illegible] [illegible] [illegible]

Wall [illegible] [illegible] [illegible]

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-19 DATE 3-5-[illegible]

ISCL TEST NO. [illegible]

EXPLOSIVE

CHARGE NUMBER _____

CHARGE WEIGHT _____ (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT [illegible] (in)

INNER DIAMETER [illegible] (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 4½ (torr)

TARGET DESCRIPTION MSFC LE 45

COMMENTS NO PEN

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-17 DATE [illegible]

ISCL TEST NO. [illegible]

EXPLOSIVE

CHARGE NUMBER 23

CHARGE WEIGHT 2.5.8 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)

INNER DIAMETER 0.505 (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 4½ (torr)

TARGET DESCRIPTION MSFC L65

COMMENTS

Det Went
PIC DIDN'T
OCTOL Broken UP

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 8 DATE 3-12-96

ISCL TEST NO. 47 Sunny & 71°

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 1/2 (torr)

TARGET DESCRIPTION MSFC L-65

COMMENTS

NO PEN

- 1ST TEST WITH RP-80 Det.

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-19 DATE 3-12-96

ISCL TEST NO. 148 Sunny & 70°

EXPLOSIVE

CHARGE NUMBER 45

CHARGE WEIGHT 659.0 (grams)

DETONATOR TYPE RP-87

INHIBITOR

OVERALL HEIGHT 1.750 (in)

INNER DIAMETER 0.468 (in)

FXRs

HEAD #1: SIZE 150 (kV)

DISTANCE FBOC 11 (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 4½ (torr)

TARGET DESCRIPTION MSFC L45.8
(WITH A 0.050" FRONT FACE)

COMMENTS [.050 6061-T6] 1.8 GAP [20 MLI] 1.8 GAP [.150 2219]

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698-20 DATE 3-12-96

ISCL TEST NO. 149 Sunny 70°

EXPLOSIVE

CHARGE NUMBER 17

CHARGE WEIGHT 655.0 (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 (usec)

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC L45

COMMENTS

INHIBITED SHAPED CHARGE LAUNCHER DATA SHEET

TEST NUMBER 7698 - 21 DATE 3-13-96

ISCL TEST NO. 150

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)

DID NOT DUMP!

VACUUM PRESSURE 4½ (torr)

TARGET DESCRIPTION MSFC LEO.8

COMMENTS

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

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 4½ (torr)

TARGET DESCRIPTION MSFC JEM 45F

COMMENTS

APPENDIX B

Projectile Geometry Measurements

Table 3. Projectile Geometry Measurements

TEST NO.	MASS (g)	VELOCITY (km/s)	DIAMETER (cm)	L/D	TOTAL ANGLE (°) (QUADRANT)
7698-1	1.35	11.68	0.871	1.4	26 (2)
7698-2	1.12	11.38	1.011	1.1	31 (2)
7698-3	0.99	11.64	0.623	2.3	40 (1)
7698-4	0.94	11.37	0.665	2.0	30 (2)
7698-5	1.03	11.77	0.696	1.9	54 (3)
7698-6	0.84	11.37	0.739	1.5	50 (2)
7698-7	0.99	11.37	0.820	1.2	33 (1)
7698-8	0.82	11.40	—	—	—
7698-9	0.97	11.42	0.831	1.1	61 (2)
7698-10	1.42	11.35	0.693	2.6	36 (1)
7698-11	1.28	11.47	0.602	3.4	7 (1)
7698-12	0.76	11.45	0.762	1	—
7698-13	1.04	11.51	0.742	1.3	27 (4)
7698-14	—	—	—	—	—
7698-15	—	—	—	—	—
7698-16	1.09	11.51	1.102	1	75 (4)
7698-17	—	—	—	—	—
7698-18	0.97	11.30	0.813	1.3	15 (4)
7698-19	1.11	11.32	0.716	2.0	15 (2)
7698-20	1.23	11.38	1.392	0.9	—
7698-21	—	—	—	—	—
7698-22	0.98	11.36	0.947	1.3	29 (1)

ISCL PROJECTILE DATA

TEST NUMBER	7698-1				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.400	.483	.092	11.66	-10.4
	.305		.074, .071	11.64	
4	.408	—	.062 .081	11.68	+24.1
	.258		.069	11.70	

AVERAGE OUTER DIAMETER (in) 0.343

AVERAGE THICKNESS (in) 0.075

INNER DIAMETER (in) 0.193

LENGTH (in) 0.483

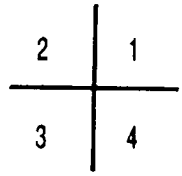
L/D 1.4

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



ISCL PROJECTILE DATA

TEST NUMBER	7698 - 2				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	0.521	0.434	.076	11.38	-30.0
	0.275		.065	11.36	
4	—	—	.073	11.39	+8.0
	—		.068	11.38	

AVERAGE OUTER DIAMETER (in) 0.398

AVERAGE THICKNESS (in) 0.071

INNER DIAMETER (in) 0.256

LENGTH (in) 0.434

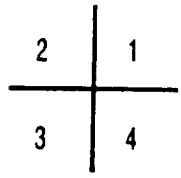
L/D 1.1

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



ISCL PROJECTILE DATA

TEST NUMBER	7698 - 3

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.260	—	.084, .086	11.65	+0
	.239		.074	11.63	
4	.240	0.560	.076	11.64	+39.7
	.243		.066, .060	11.64	

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7698-4				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.270	—	.079	11.40	-19.5
	.298		.079	11.33	
4	.206	—	.093	11.38	+24.4
	.232		.061	—	

AVERAGE OUTER DIAMETER (in) 0.262

AVERAGE THICKNESS (in) 0.078

INNER DIAMETER (in) 0.129

LENGTH (in) 0.518

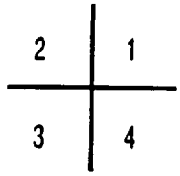
L/D 1.98

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



ISCL PROJECTILE DATA

TEST NUMBER	7698-5

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	—	—	-	11.74	-24.5
	—		-	11.80	
4	.276	—	.074	11.76	-52.7
	.280, .267		.068	-	

AVERAGE OUTER DIAMETER (in) 0.274

AVERAGE THICKNESS (in) 0.071

INNER DIAMETER (in) 0.132

LENGTH (in) 0.515

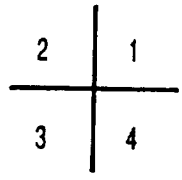
L/D 1.88

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



ISCL PROJECTILE DATA

TEST NUMBER	7698-6				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.264	.389	.075	11.36	-48.6
	.271		.065	11.39	
4	.330	—	.066	11.37	+20.9
	.298		—	—	

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7698-7

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.328	.372	.058	11.38	+32.2
	.322		.074	11.36	
4	.320	—	.061	11.35	+10.5
	-		—	11.37	

AVERAGE OUTER DIAMETER (in) 0.323

AVERAGE THICKNESS (in) 0.064

INNER DIAMETER (in) 0.195

LENGTH (in) 0.372

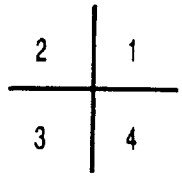
L/D 1.15

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

TEST NUMBER	7698 - 8				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	–	–	0.071	11.46	–
	–		–	11.36	
4	–	–	0.064	11.44	–
	–		–	11.36	

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

2	1
3	4

BROKEN PROJECTILE

ISCL PROJECTILE DATA

TEST NUMBER	7698 - 9				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.284	.365	.051, .061	11.42	-60.3
	.370		.081, .063	11.47	
4	–	–	–	11.37	+16.9
	–		–	–	

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7698-10				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.335	—	.083	11.34	+35.9
	—		.075	11.34	
4	.273, .242	0.455	.060, .080	11.36	+4.81
	.256, .258		.064	—	

AVERAGE OUTER DIAMETER (in) 0.273

AVERAGE THICKNESS (in) 0.072

INNER DIAMETER (in) 0.129

LENGTH (in) 0.707

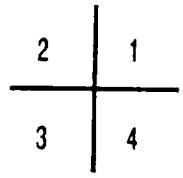
L/D 2.59

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



ISCL PROJECTILE DATA

TEST NUMBER	7698-11

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.232	.847	.068	11.46	+5.51
	.197		.057	11.49	
4	.286	.771	.074	11.48	+4.65
	.231		.069	11.46	

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7698-12				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	—	—	—	11.53	—
	—		—	11.40	
4	—	—	—	11.48	—
	—		—	11.39	

AVERAGE OUTER DIAMETER (in) —

AVERAGE THICKNESS (in) —

INNER DIAMETER (in) —

LENGTH (in) —

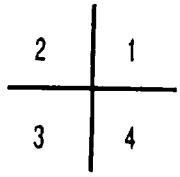
L/D —

TOTAL ANGLE (deg) — (Quadrant #) —

MASS (g) 0.76

AVERAGE VELOCITY (km/s) 11.45

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



Broken Projectile

ISCL PROJECTILE DATA

TEST NUMBER	7698-13

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.294	—	.068	11.50	+12.8
	.267		.072		
4	.299	.392	.072	11.51	−24.2
	.308		.064		

AVERAGE OUTER DIAMETER (in) 0.292

AVERAGE 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

AVERAGE VELOCITY (km/s) 11.50

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7691 - 16				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3): PITCH (view 4) (deg)
3	-	-	-	11.51	-
	-		-		
4	-	-	-	11.52	-
	-		-	11.51	

AVERAGE OUTER DIAMETER (in) -

AVERAGE THICKNESS (in) -

INNER DIAMETER (in) -

LENGTH (in) -

L/D -

TOTAL ANGLE (deg) - (Quadrant #) -

MASS (g) 1.09

AVERAGE VELOCITY (km/s) 11.51

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

2	1
3	4

Broken Projectile

ISCL PROJECTILE DATA

TEST NUMBER	7698-18				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.352	0.424	.062	11.25	+10.5
	.312		.078	11.22	
4	.268	—	.063	11.36	-10.5
	.348		.056	11.35	

AVERAGE OUTER DIAMETER (in) 0.320

AVERAGE THICKNESS (in) 0.065

INNER DIAMETER (in) 0.191

LENGTH (in) 0.424

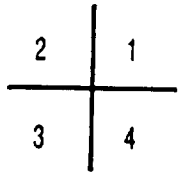
L/D 1.33

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



ISCL PROJECTILE DATA

TEST NUMBER	7698-19				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.285	—	.064	11.29	−8.7
	.220		.063	—	
4	.324	0.560	.077	11.35	+12.5
	.298		.060	—	

AVERAGE OUTER DIAMETER (in) 0.282

AVERAGE THICKNESS (in) 0.066

INNER DIAMETER (in) 0.150

LENGTH (in) 0.560

L/D 1.99

TOTAL ANGLE (deg) 15.1 (Quadrant #) 2

MASS (g) 1.11

AVERAGE VELOCITY (km/s) 11.32

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7698 - 20

VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	0.548	0.473	.080	11.31	+13.8
	–		–	–	
4	–	–	–	11.46	-18.9
	–		–	–	

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

2	1
3	4

ISCL PROJECTILE DATA

TEST NUMBER	7693 - 22				
VIEW	OUTER DIAMETER (in)	LENGTH (in)	WALL THICKNESS (in)	VELOCITY (km/s)	YAW (view 3) PITCH (view 4) (deg)
3	.410	.493	.071	11.38	+28.6
	.330		–	–	
4	–	–	–	11.35	+5.8
	–		–	–	

AVERAGE OUTER DIAMETER (in) 0.373

AVERAGE THICKNESS (in) .071

INNER DIAMETER (in) 0.231

LENGTH (in) 0.493

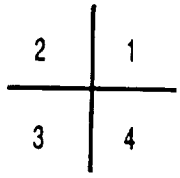
L/D 1.32

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



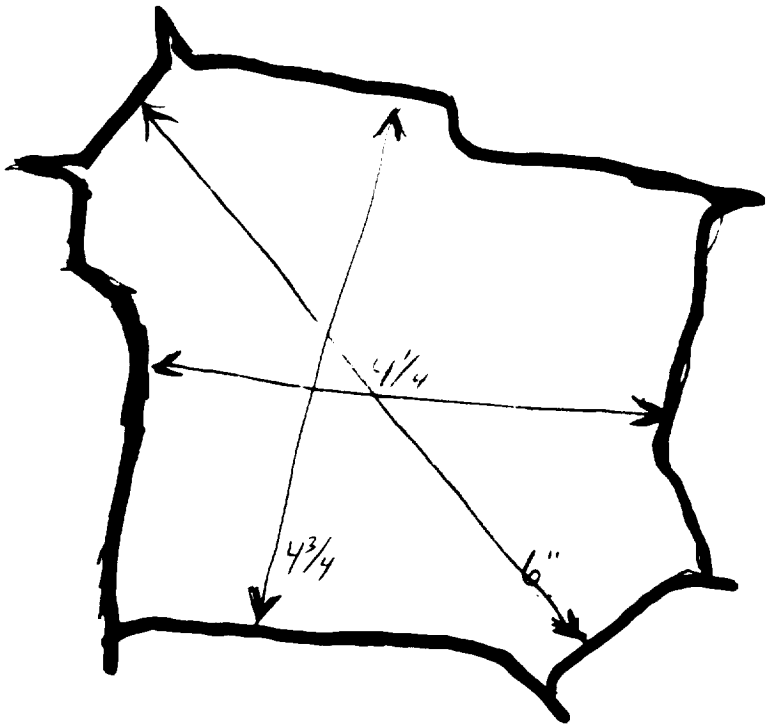
APPENDIX C

General Target Damage Measurements

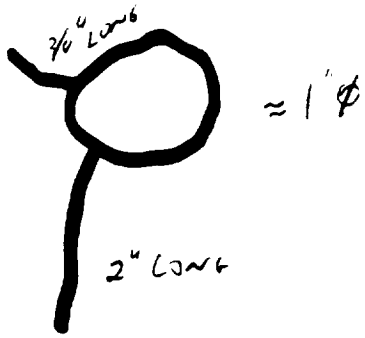
LC

VELOCITY = 11.68 m/s (highest?)

FACE



WALL



WINDOWS

1 - DESTROYED

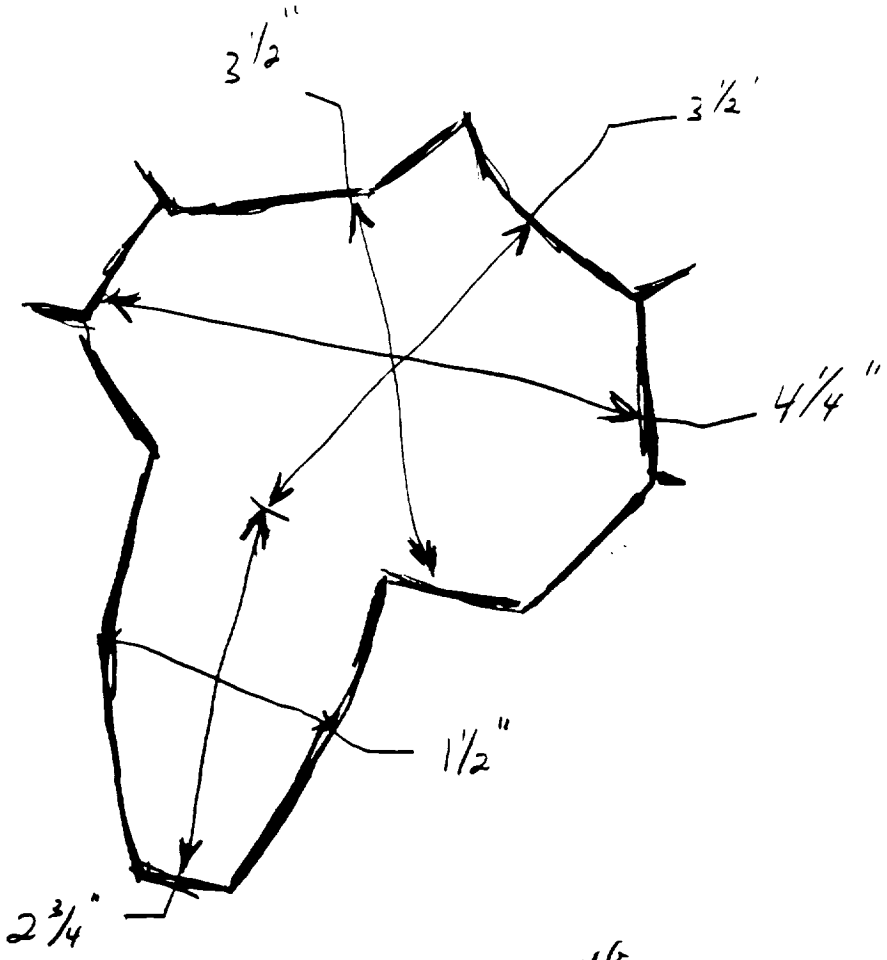
2 - HURT BAD

3 - DAMAGED

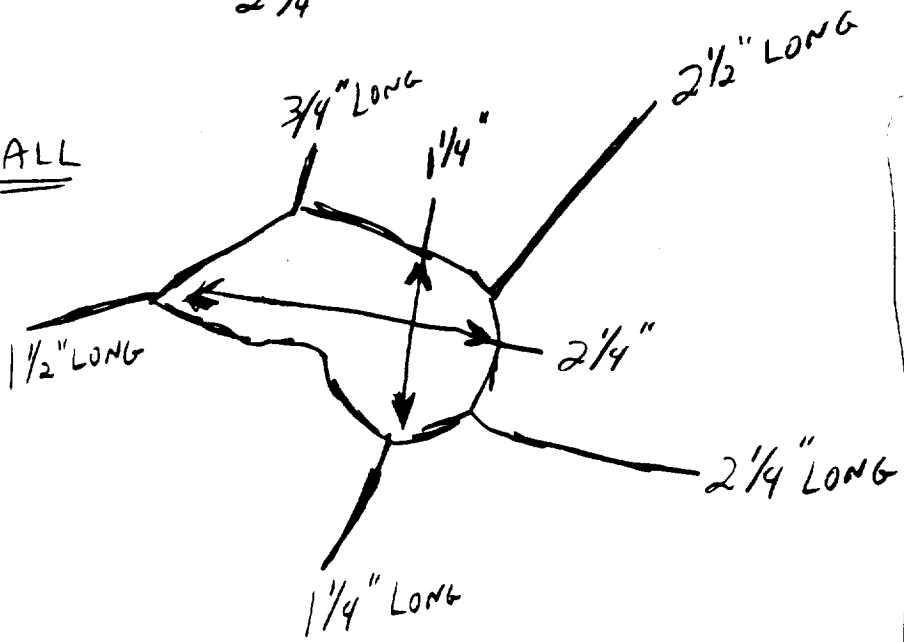
7095 - ≈ LECO

velocity = 11.38 km/s (est)

FACE



WALL



WITNESS #1
4" Ø HOLE & A LOT OF TRASH

WIT #2 1 LARGE HOLE (1" Ø), SEVERAL SMALL & TRASH

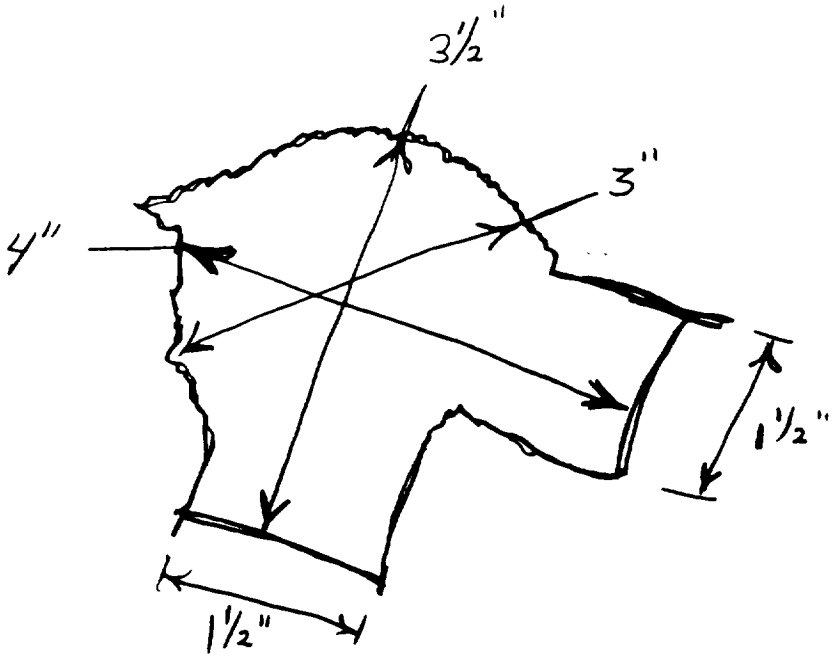
WIT #3 3/4" Ø HOLE

TARGET LEO

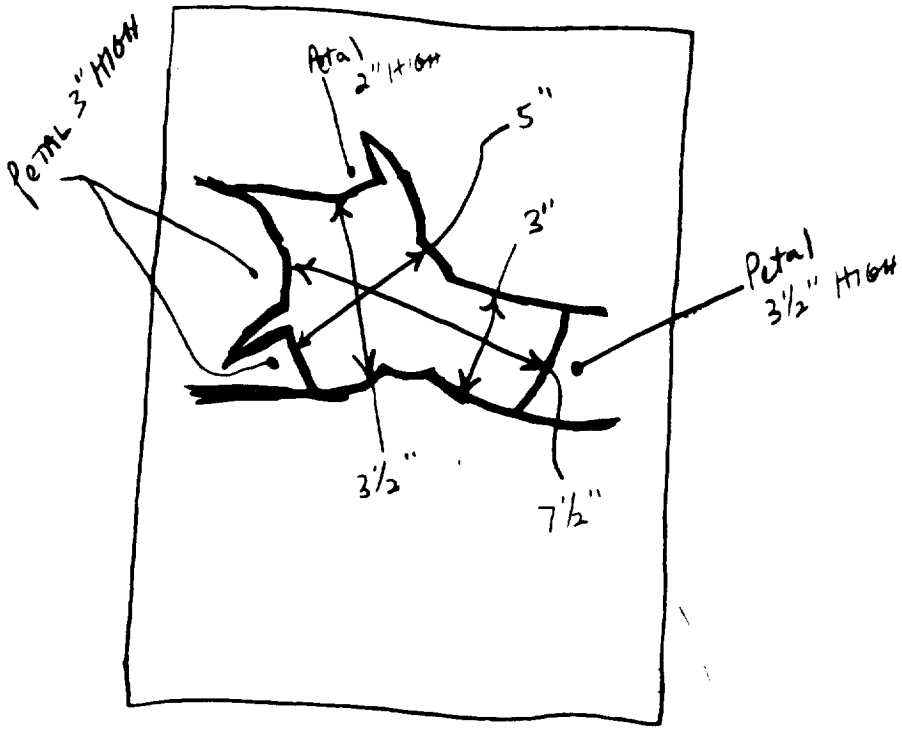
7698-3

Velocity = 11.64 km/s (est.)

FACE



WALL

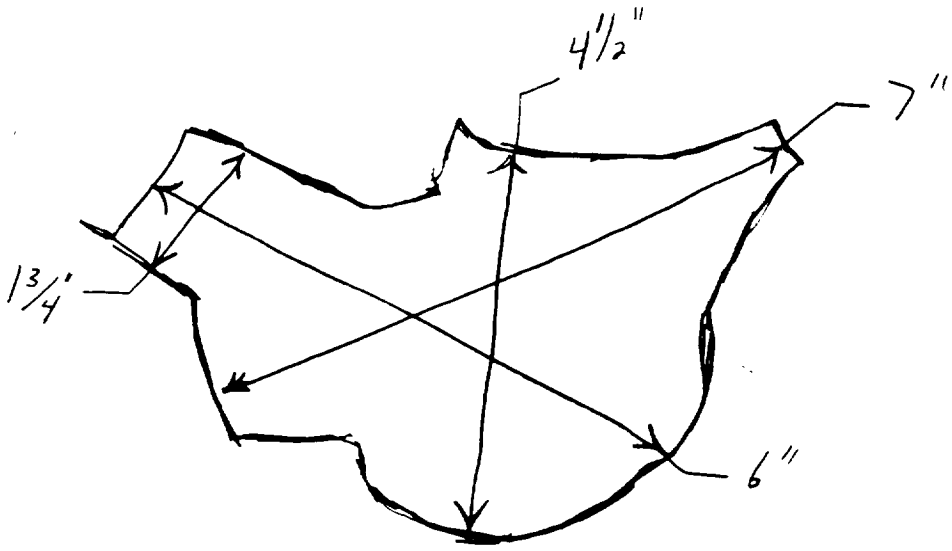


WITNESS all 3 had MULTIPLE SMALL to MEDIUM (¼"Ø to 1"Ø) SIZE HOLES. All 3 were DEFORMED (BENT).

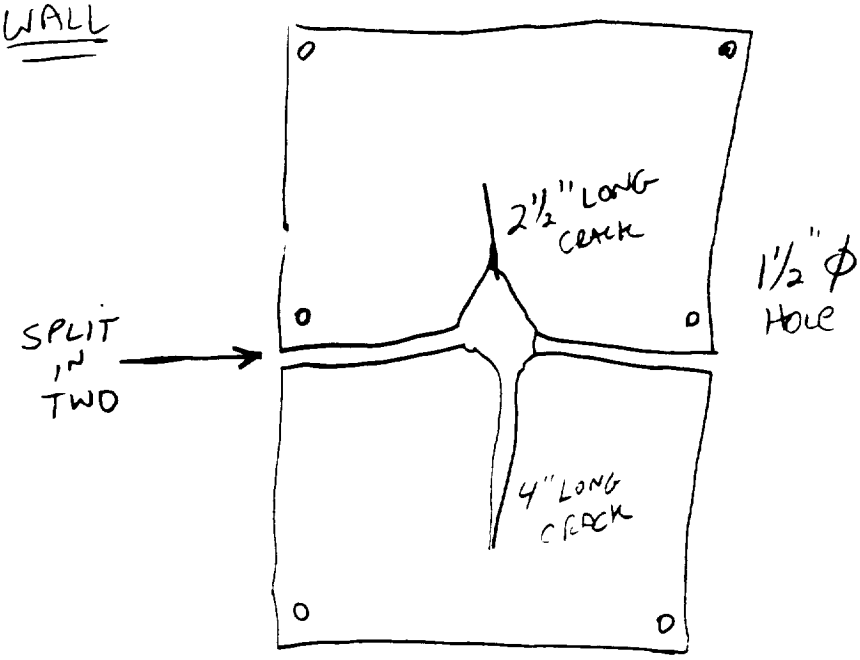
7698-4
L45

Joint = 11.38

FAF



WALL



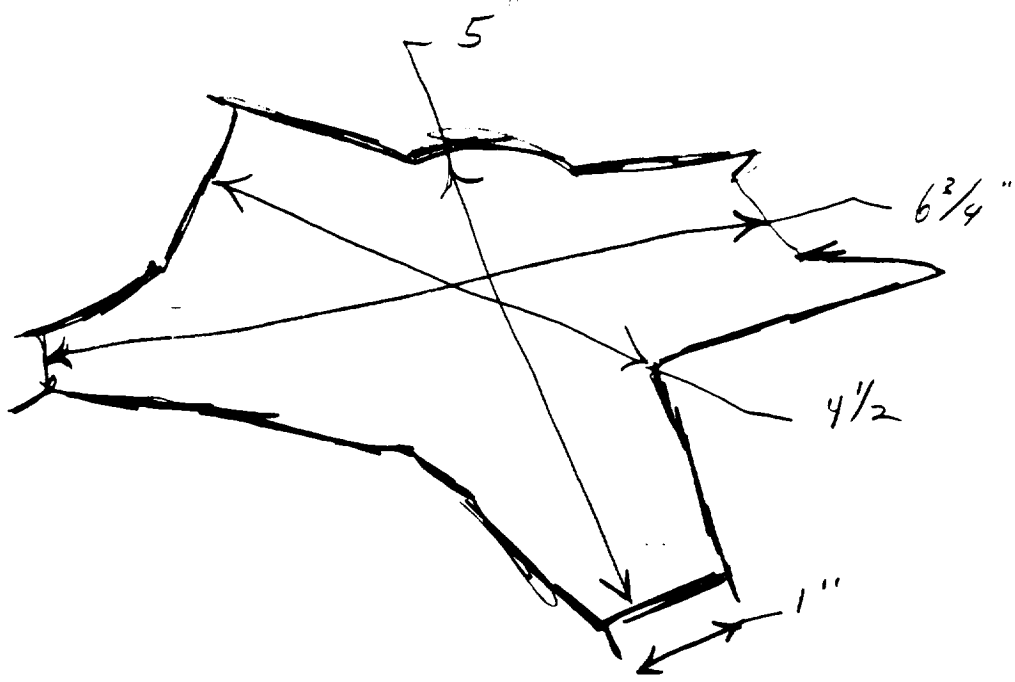
WITNESS

DAMAGE DECREASES FROM MANY SMALL (¼") HOLES ON PLANE ⊥ TO ONLY A FEW SMALL HOLES (< ¼" ϕ) ON FACE

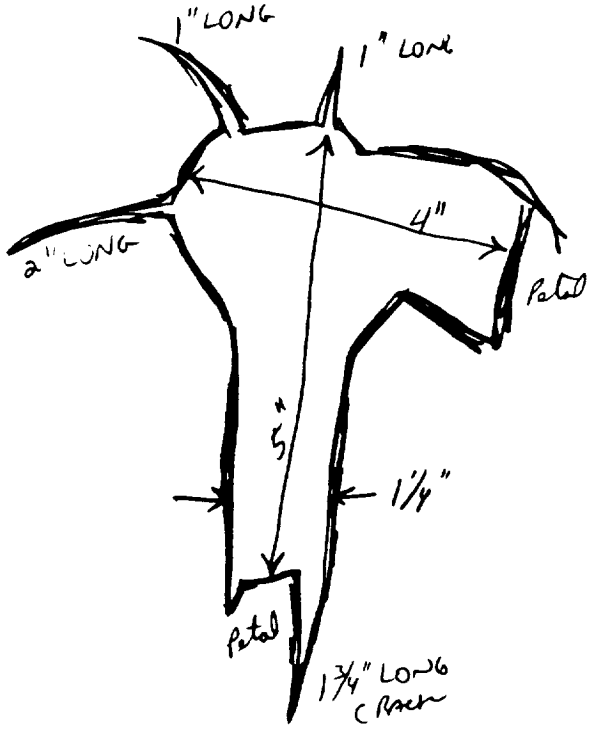
Velocity 11.77

7678-5
JFM 0

FACE



WALL

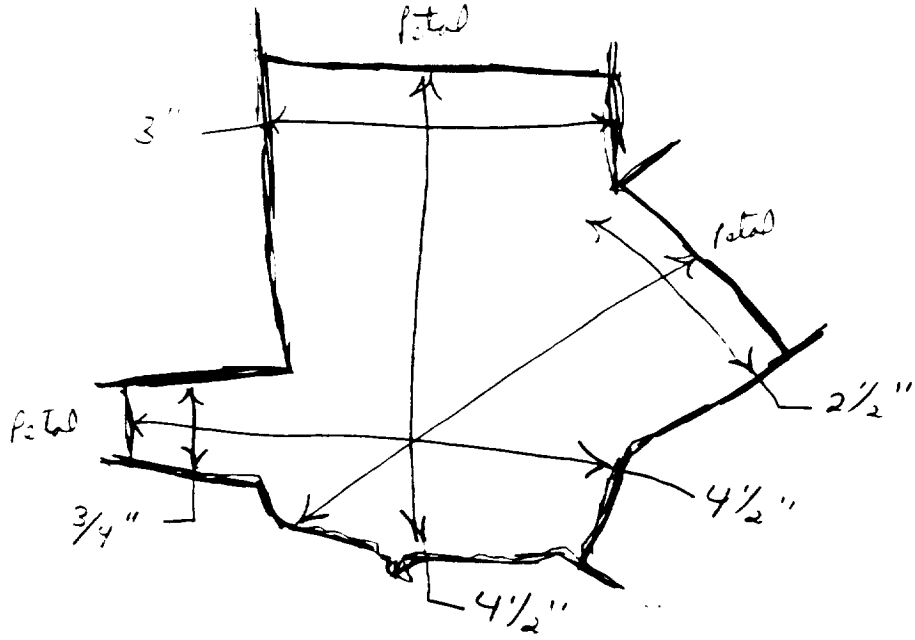


WITNESS #1 HAS A 8' ϕ HOLE & LARGE CORE
#2 IS CUT IN HALF WITH LARGE HOLE & BEAD
#3 HAS SEVERAL HOLES & LARGE BEND

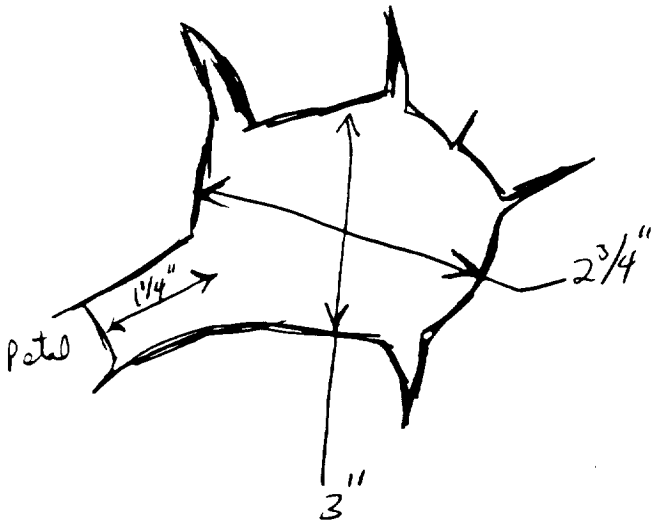
1/8 - 6

- 10

- FINE



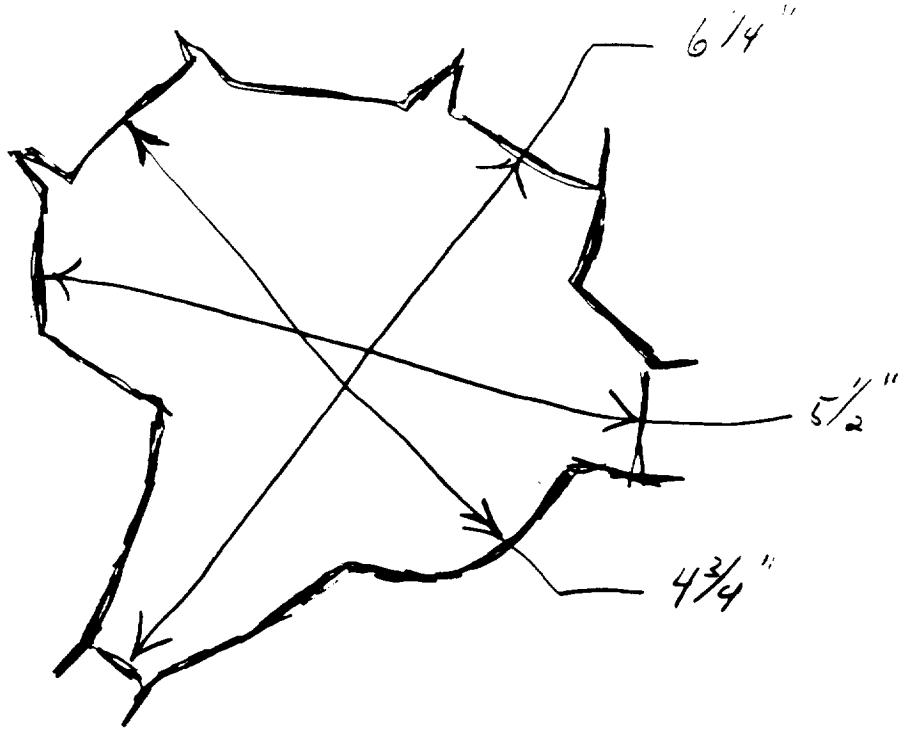
WALL



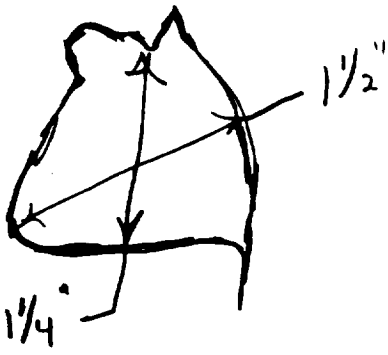
WITH [illegible] 1. Decreasing In #2, Several Small [illegible] #3 (May [illegible] Make Screen [illegible])

LEC 45

FAR F



WALL



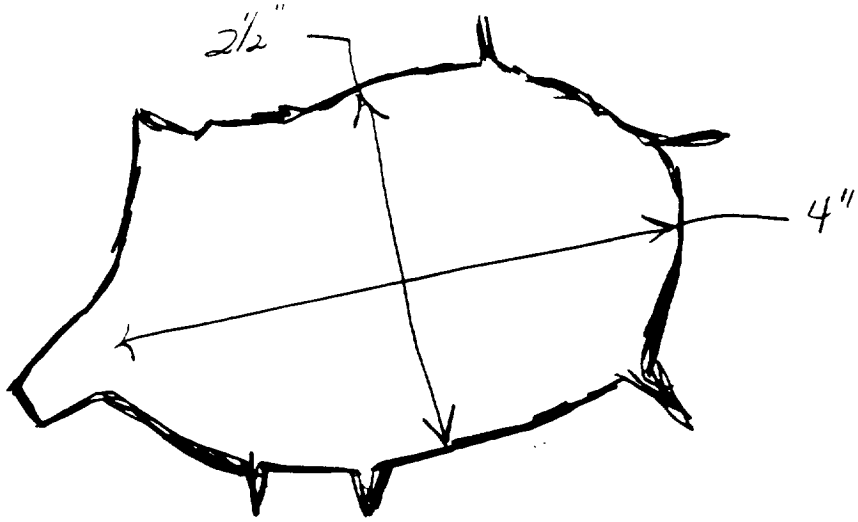
WITNESS #1 MOSTLY A FEW OF ALUMINUM, VERY FEW HOLES

#2 ONLY VERY FEW HOLES (< 1/4" ⌀)

#3 NO WITNESS

LE-15

FACE

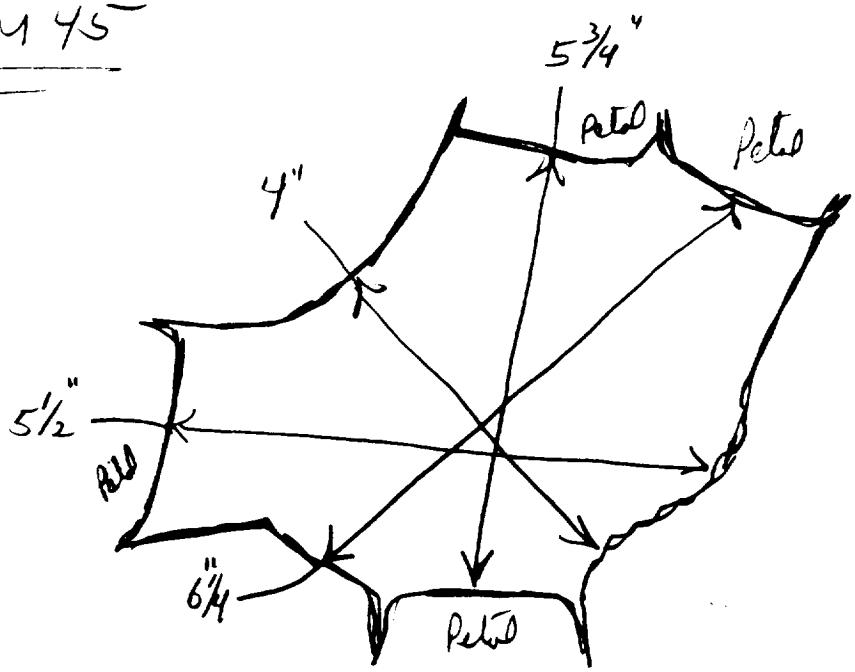


FABRIC LAYERS THROUGH HOLE ≈ 2"-3" Dia

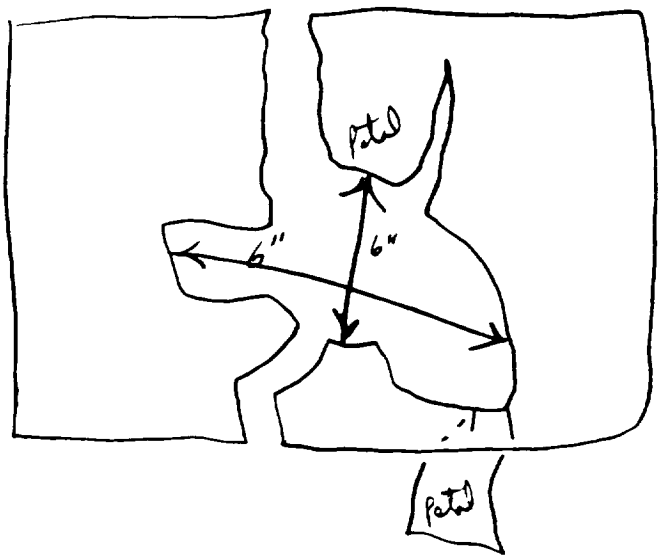
7698-9

JEM 45

FACE



WALL



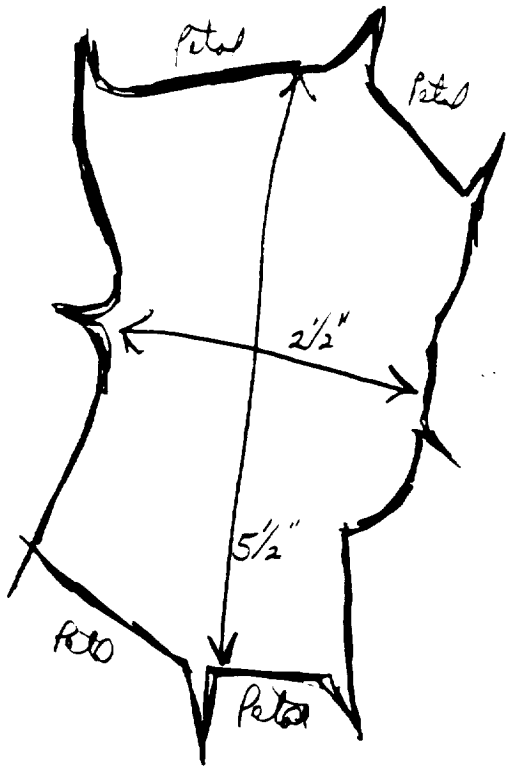
Witness #1 MULTIPLE SMALL, 1 Large (1½" x 3/4") hole

#2 Large hole in larger (1½" x 1¼"), many small holes

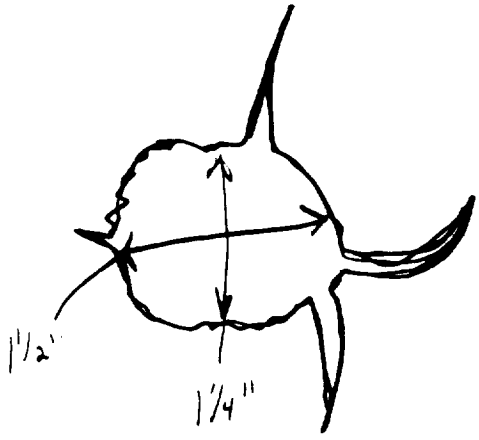
#3 Single hole ¾ x ⅜"

7078-10

FACE



WALL

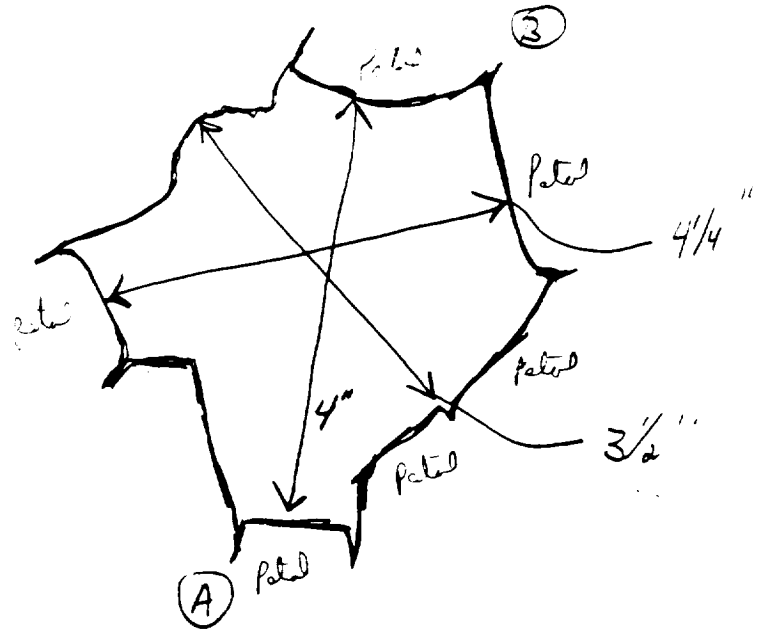


WITNESS #1 4-5" Ø HOLE WITH MULTIPLE HOLES all over

#2 & #3 Hole pattern reduces to only small holes by slot #

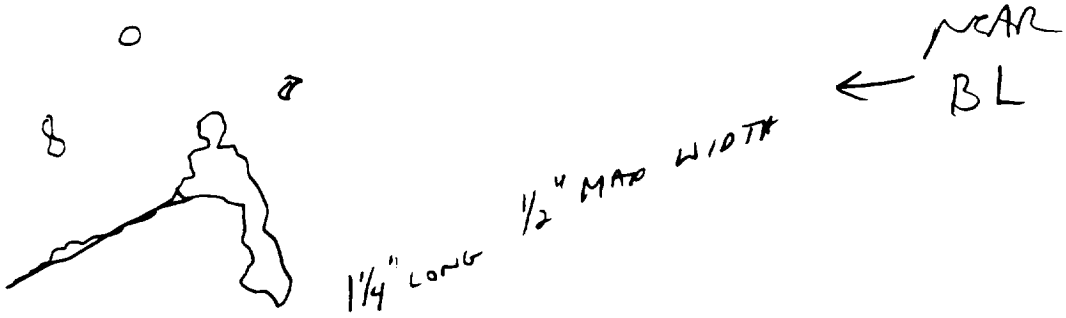
Tc F-11

LE COF



TOT = 4 3/4"

WALL

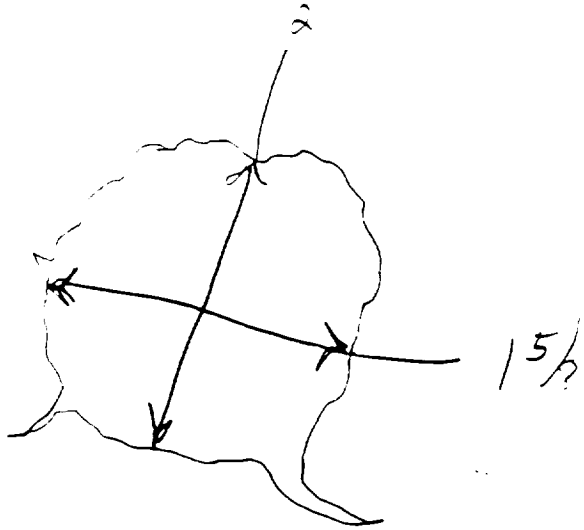


WITNESS #1 Very Little Deformation
Several Small Marks

#2 2 IMPACTS, NO PENETRATION

LEO. 7

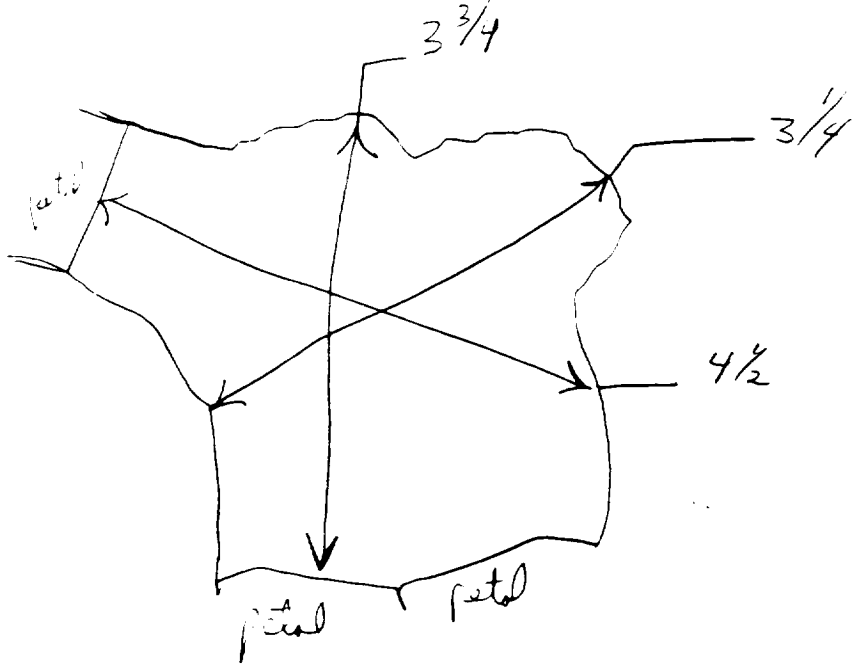
FATE



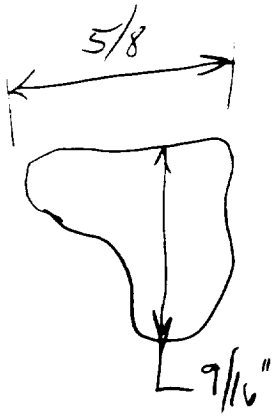
WALL NO DAMAGE

1-1¼ BULGE

WINDOWS NO DAMAGE



WALL



WITNESS - #1 HAS 2 - 3/4 Ø holes = ? smaller holes
= " " 1 - 1/4 = 1 Ø holes = 1 Ø 3/4 holes
= 3 holes

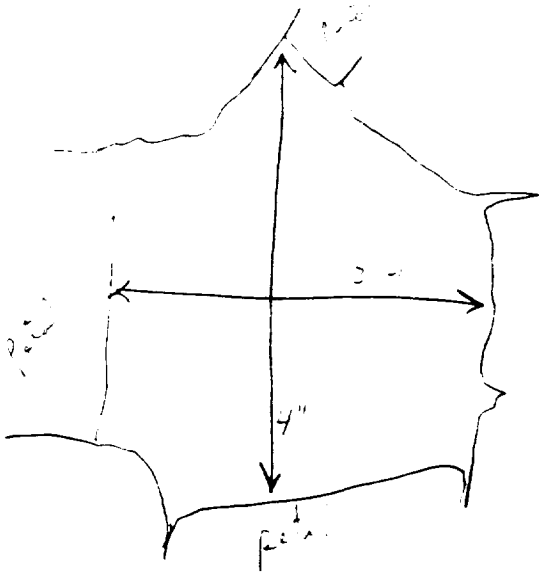
7618-14

BAL CHANGE

7698-15

Prison Study #2

LEFT



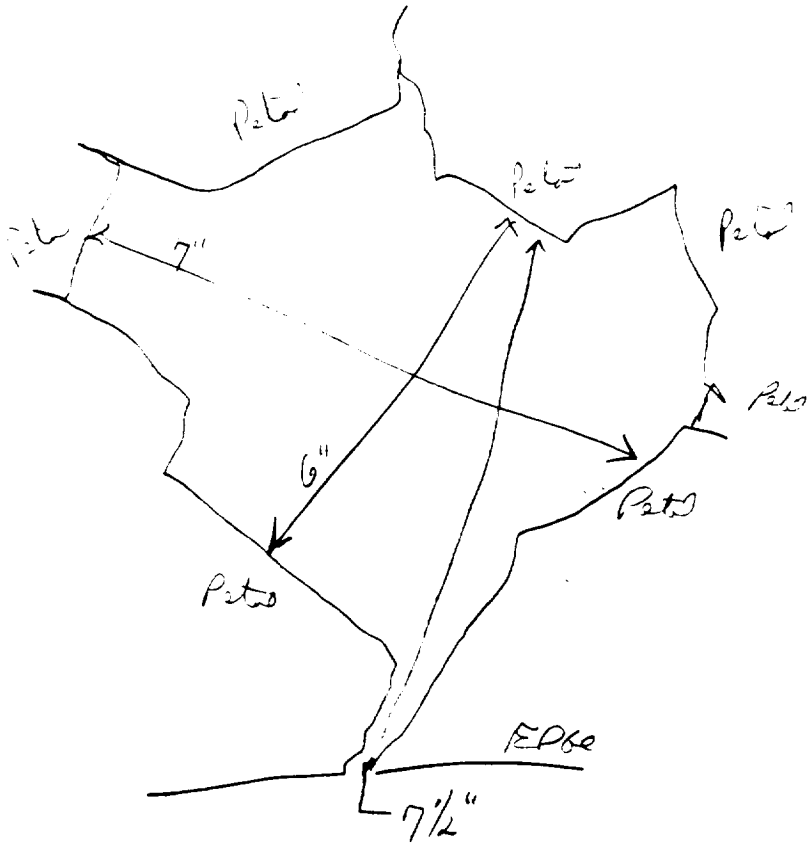
WALL — NO PEN — 3/4 BULGE

7698-17

BAD CHARGE

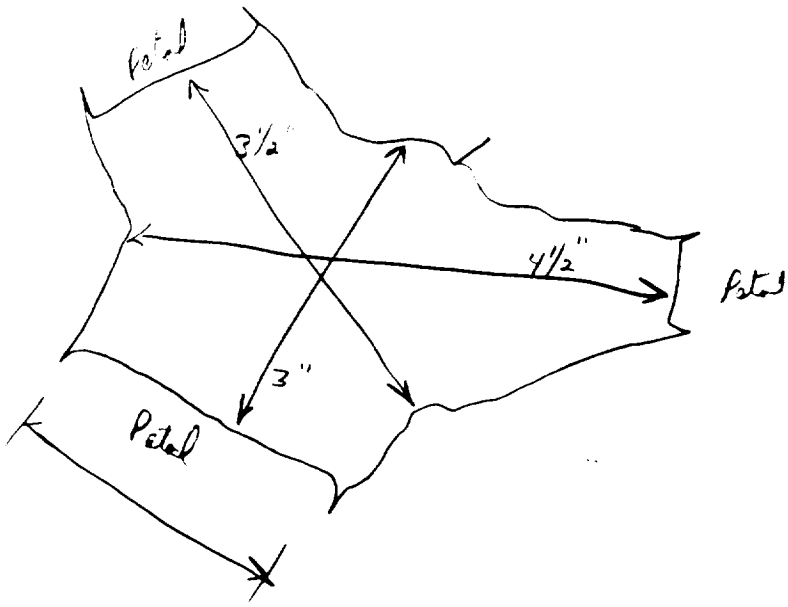
L-65

FACE

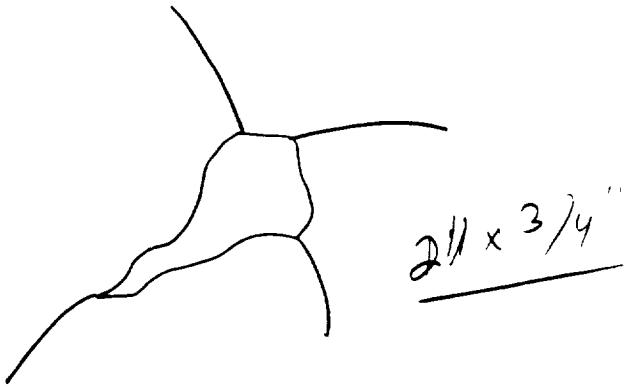


L45.8

FACE



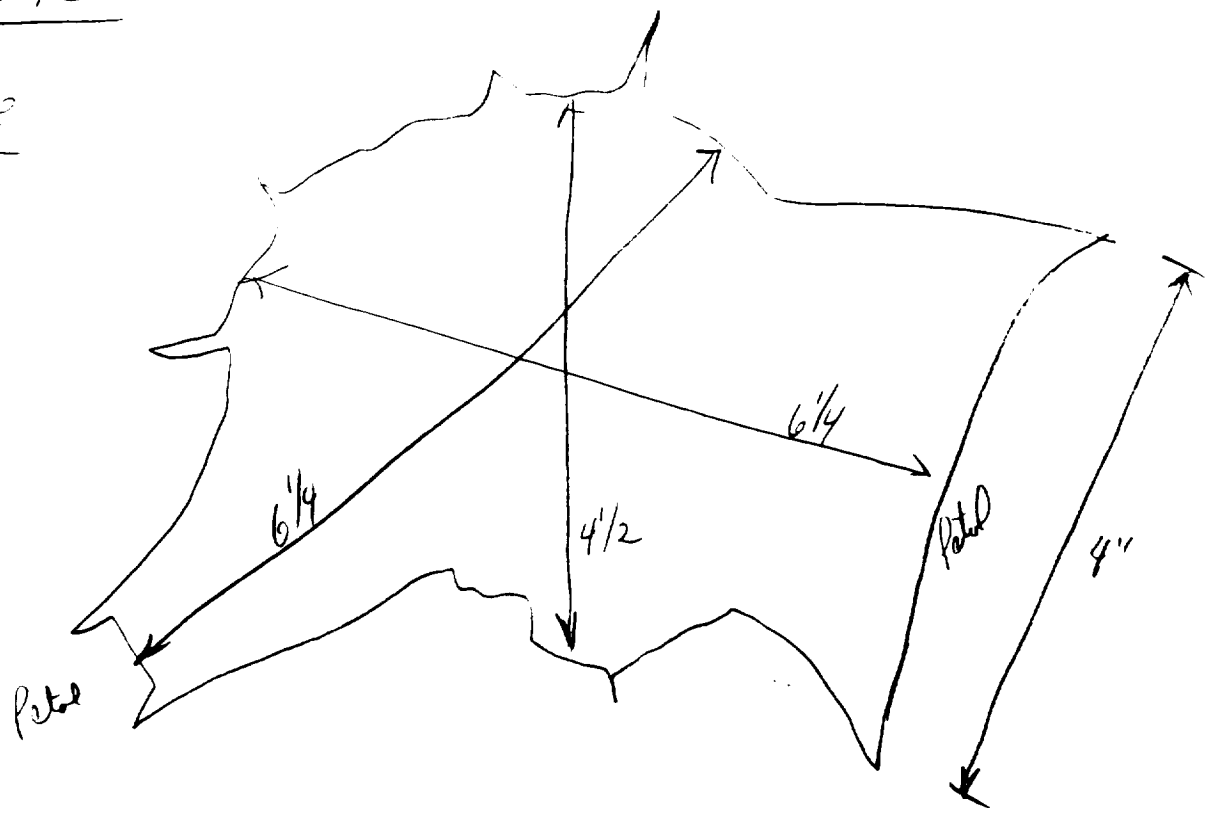
WALL

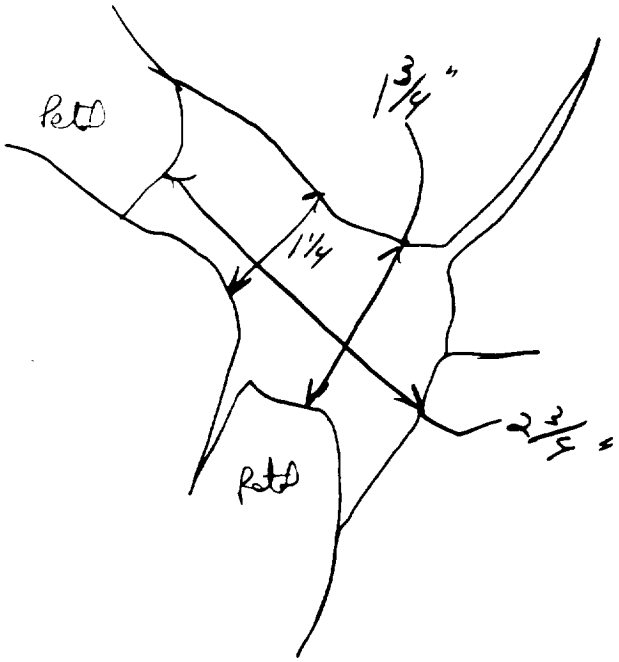


WITNESS Same Hub Pattern (≈ 100-150) Decrease to A Few Dents & Only 1 Hole is #3

L45

FACE

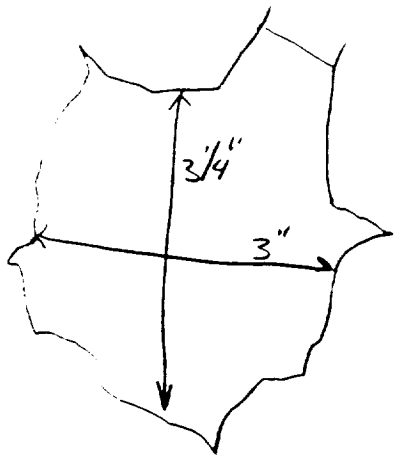




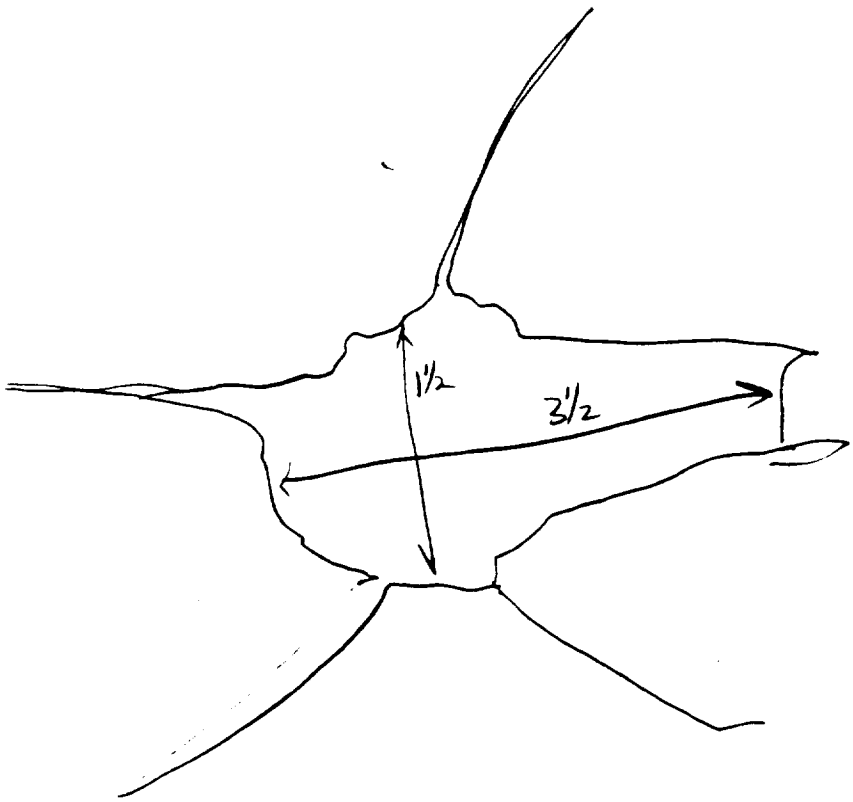
WITNESS Holes in #1 — (5 - 1/4 - 40 Small - 1-1/2"
Replace w/ 1 Large (1/4 x 1/2) & 5 Smaller ones in #3

LF 0.8

FACE



WALL

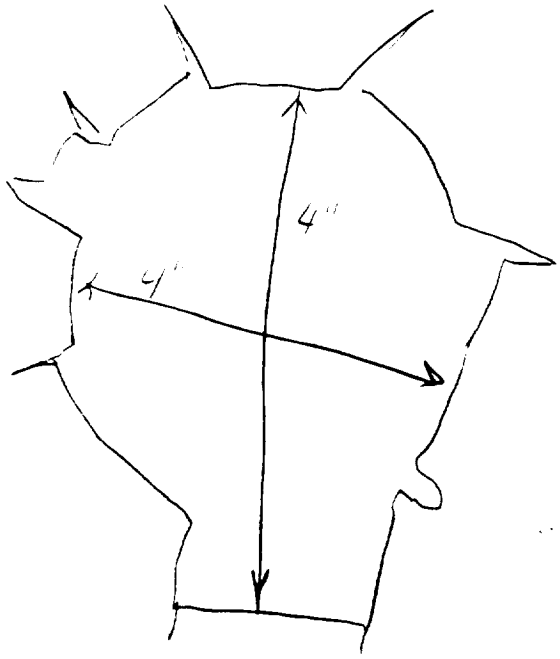


all 3 bottom plates have numerous small holes

-378-12

JEM 45-F

FACE



WAX

1" LONG x ½" HIGH

WITNESS #1 8 - 1/8" OR SMALLER HOLES 1 - 3/8" Ø HOLE

#2 SAME

#3 1 - 1/4" Ø HOLE

APPENDIX D

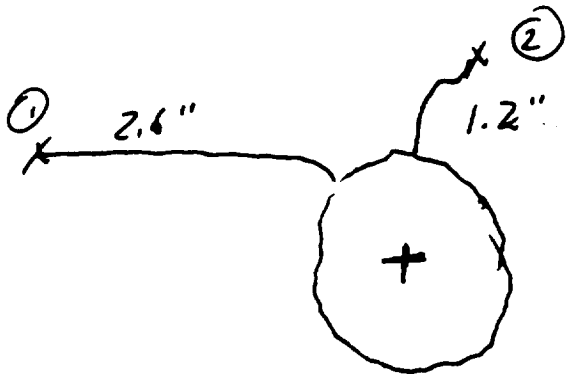
MSFC Wall Hole Size Measurements

Table 4. MSFC Hole Size Measurements

TEST NO.	TIP-TO-TIP CRACK LENGTH (cm)
7698-1	6.86
7698-2	14.48
7698-3	27.94
7698-4	19.05
7698-5	21.08
7698-6	13.46
7698-7	9.14
7698-8	N/A
7698-9	33.02
7698-10	8.89
7698-11	7.94
7698-12	N/A
7698-13	1.75
7698-14	N/A
7698-15	N/A
7698-16	N/A
7698-17	N/A
7698-18	N/A
7698-19	12.07
7698-20	15.24
7698-21	17.78
7698-22	17.15

7698-1

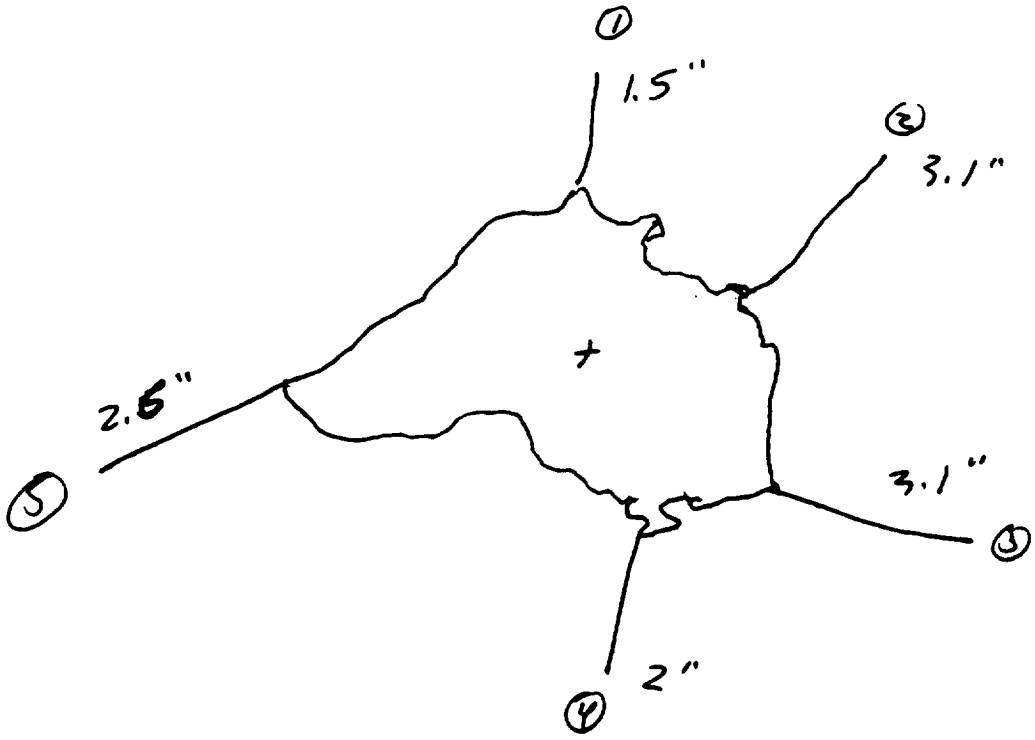
.125" LO



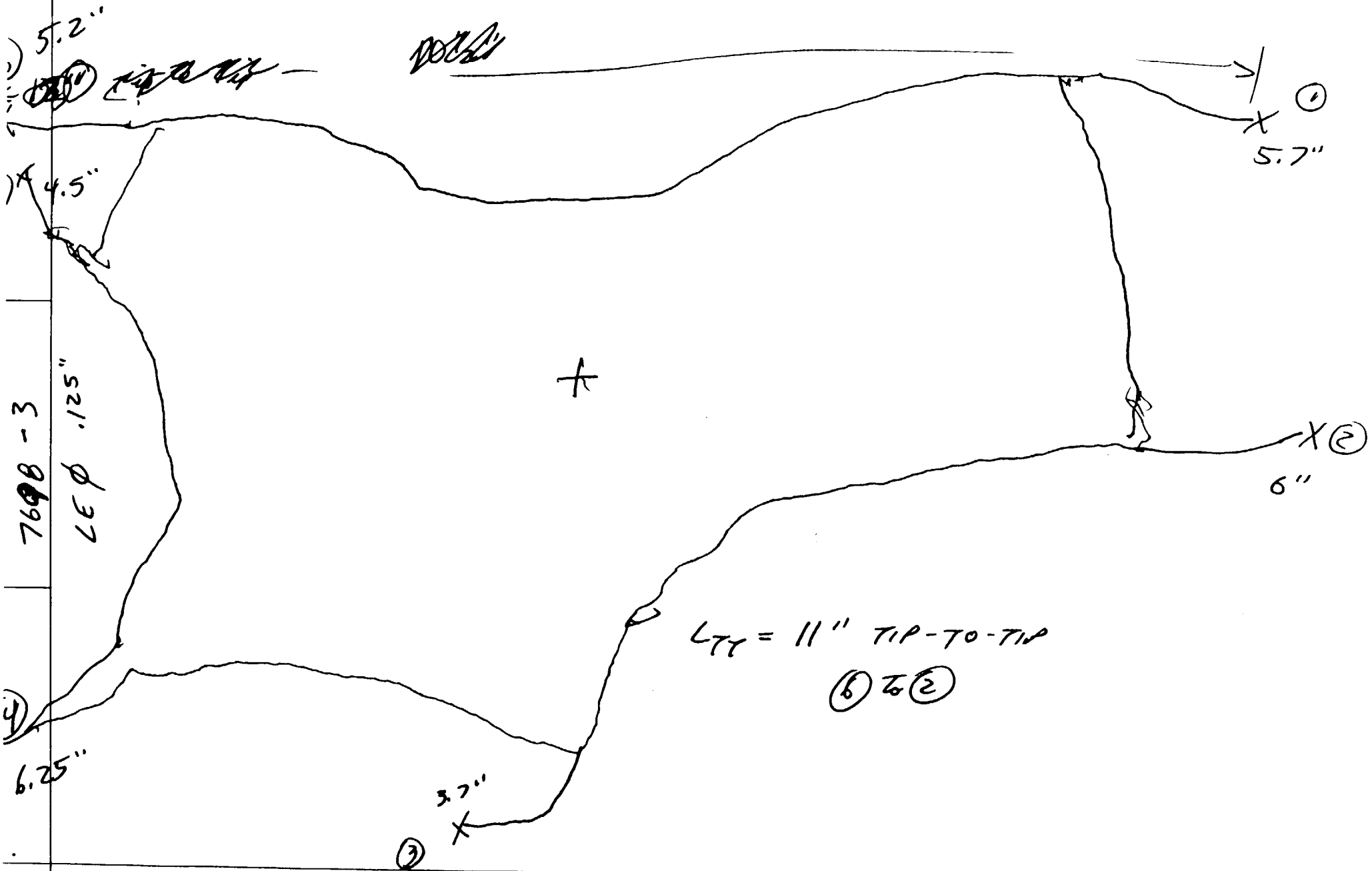
$L_{TT} = 2.7''$

7685-C

ECO



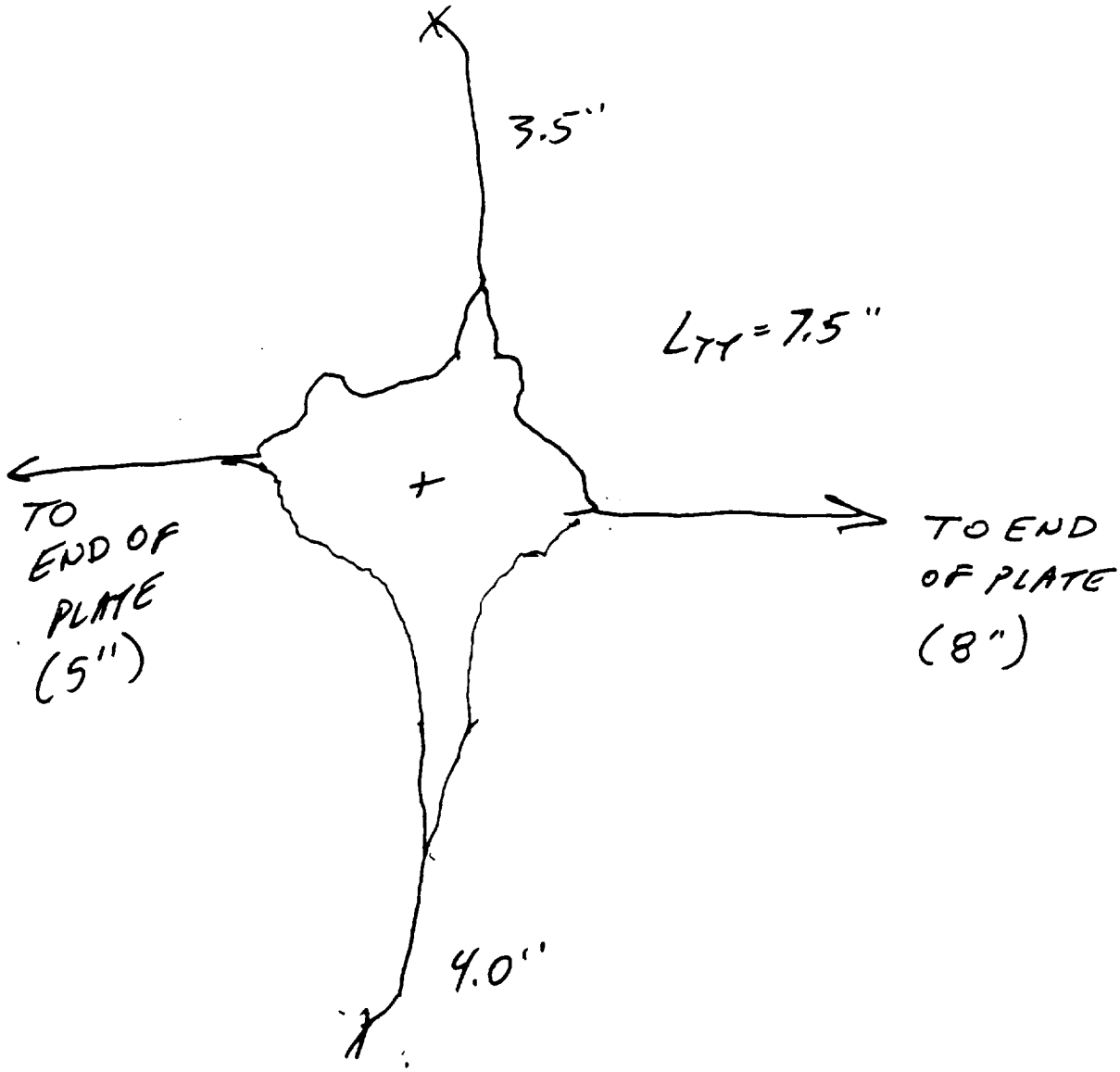
L_{TT} = 5.7" (⑤ to ③)


5.2"
4.5"
5.7"
6"
7698-3
LE Ø .125"
L_{TT} = 11" TIP-TO-TIP
6.25"
3.7"
1
2
3
4

7698-4

.125" 2219

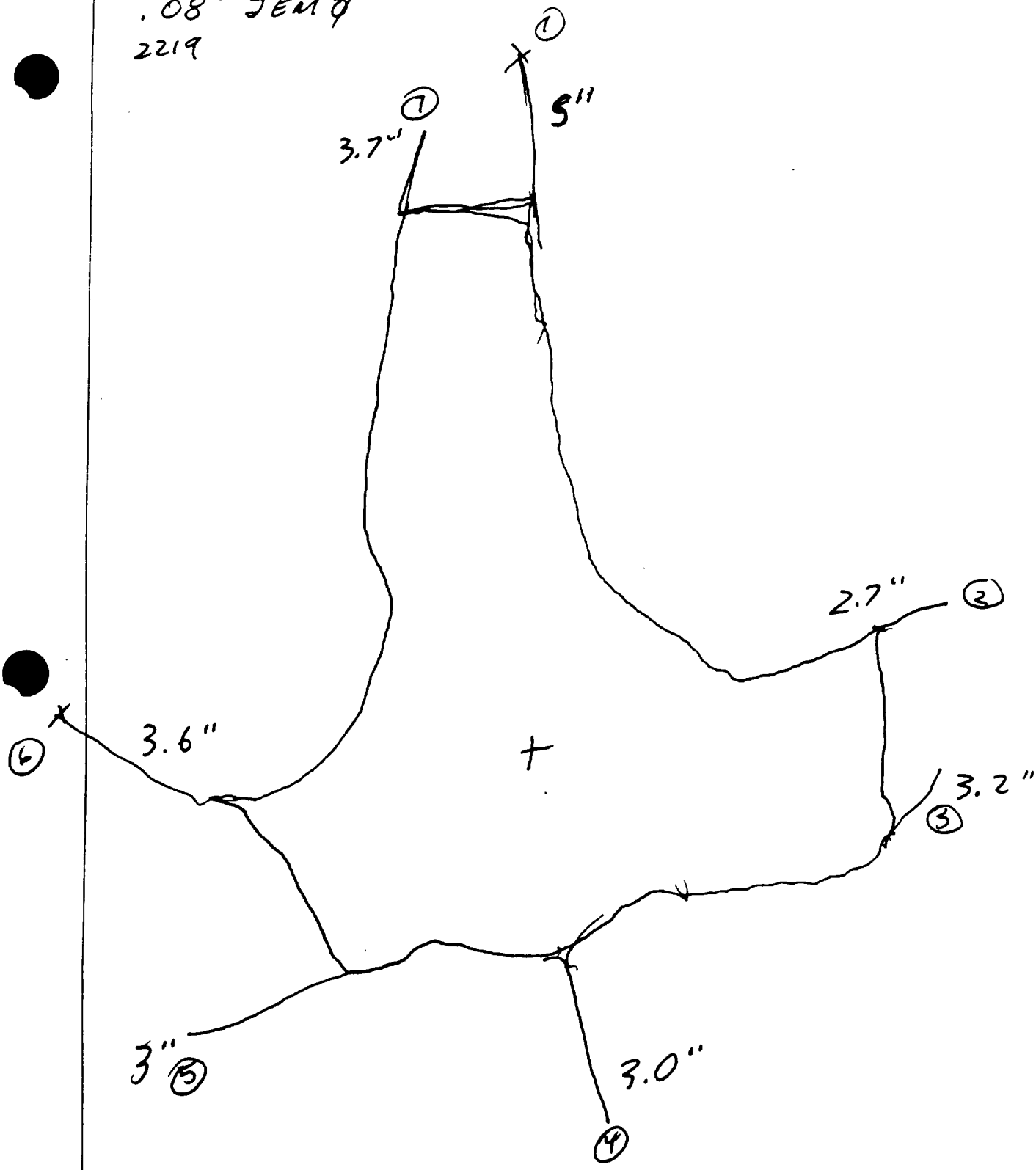
L45



7648-5

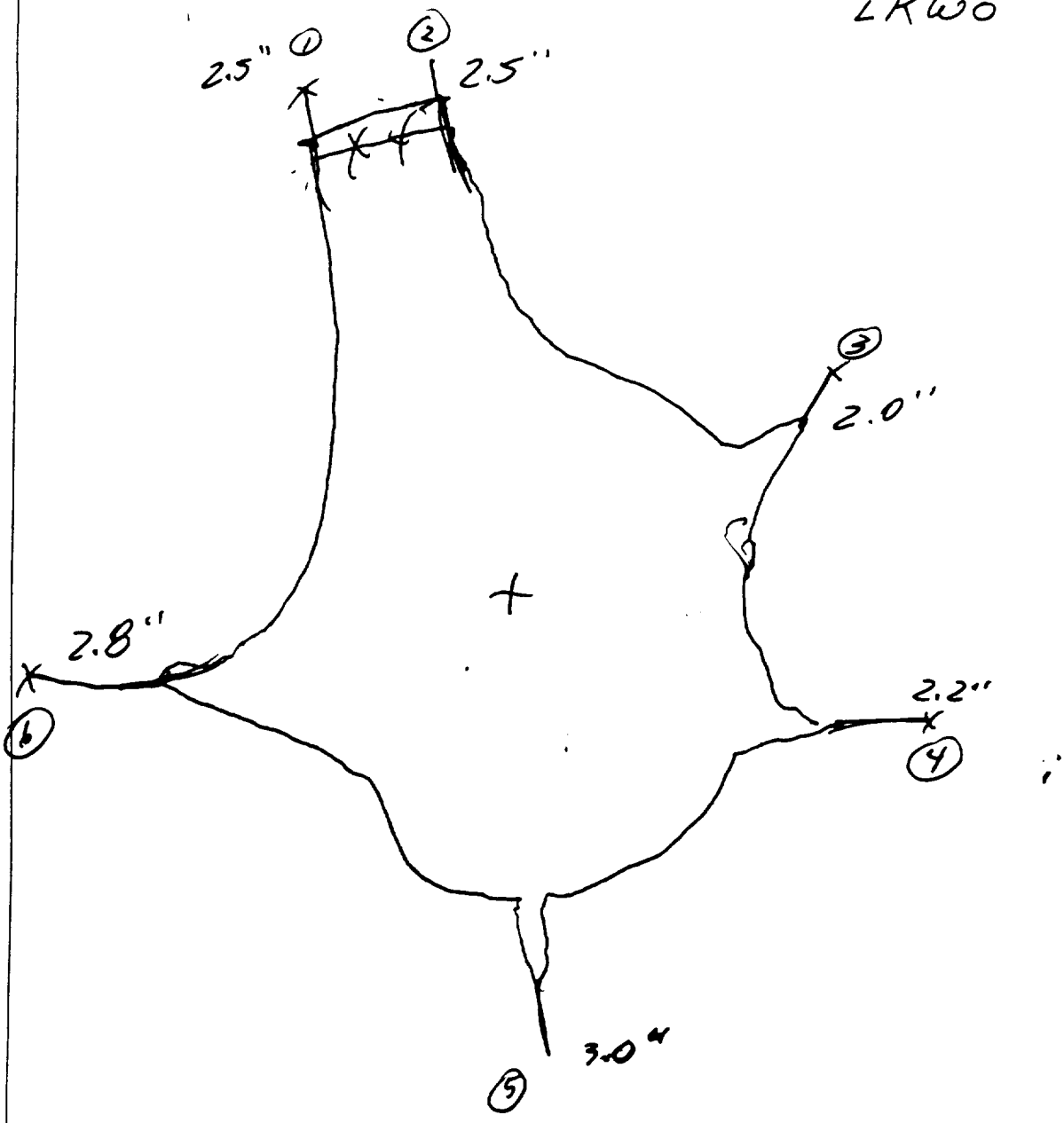
.08" JEM Q

2219



$L_{TT} = 8.3"$

76x1-6
.125" 5456
LRWO

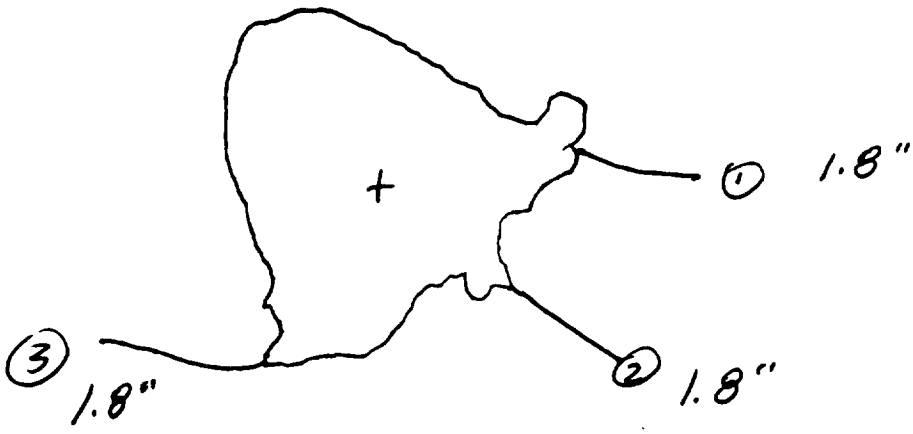


$L_{TT} = 5.3"$

7698-7

.125" 2219

CEC 45



$L_{TT} = 3.6"$

76 18-8

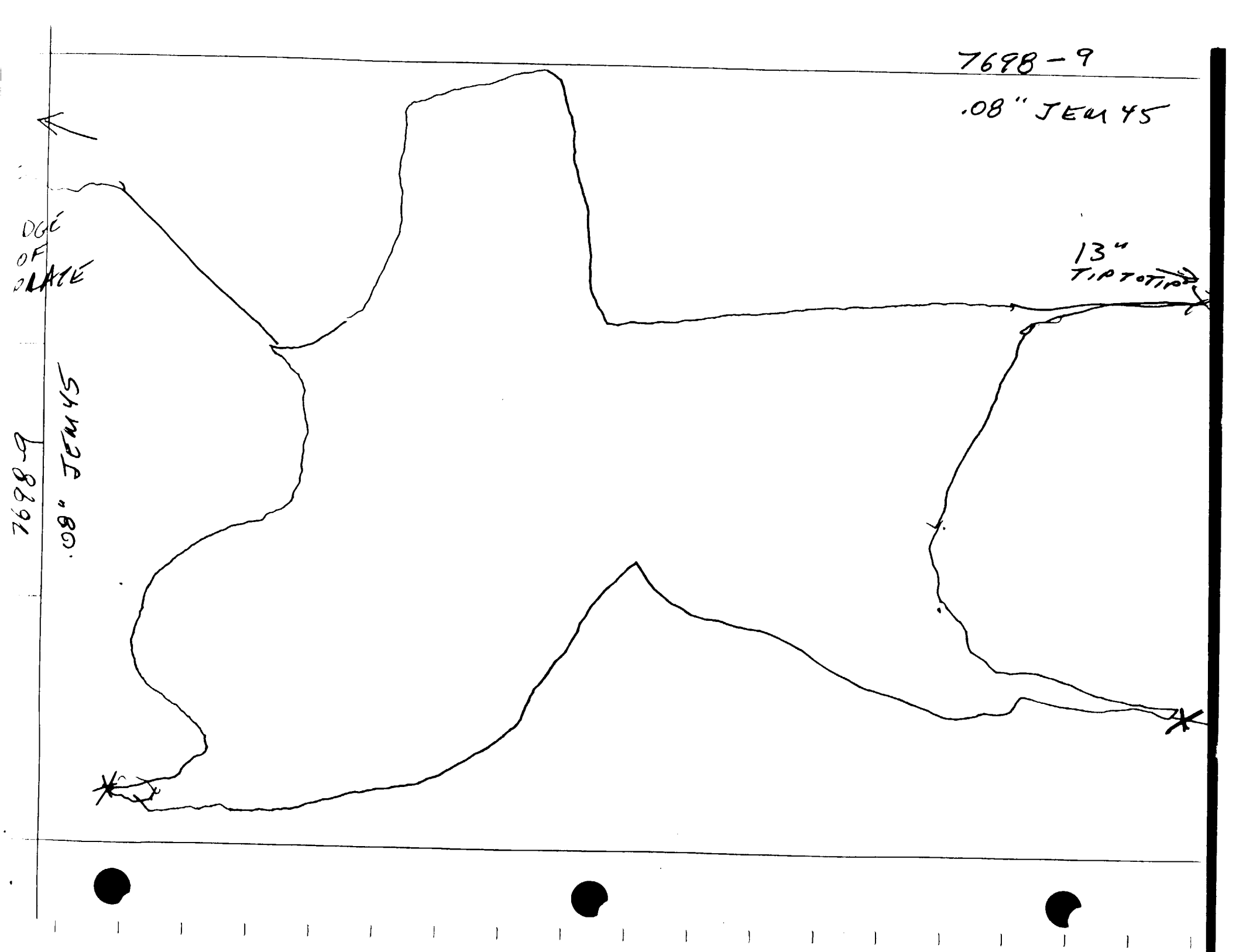
.125" 2219

LE45

BAD SHOT.

NO HOLE.

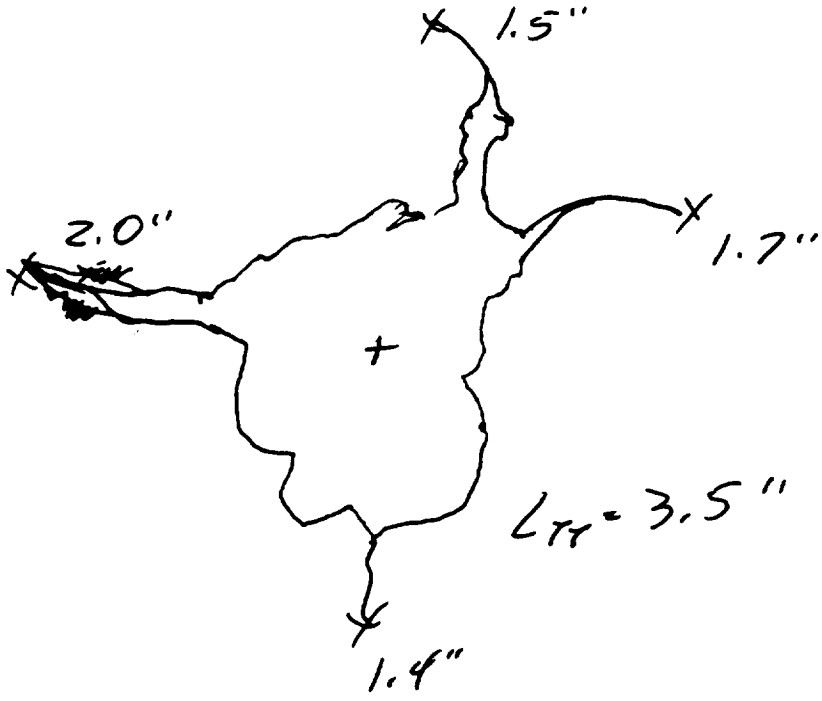
.1" BULGE.


7698-9
.08" JEM 45
EDGE OF PLATE
13" TIP TO TIP
.08" JEM 45
7698-9

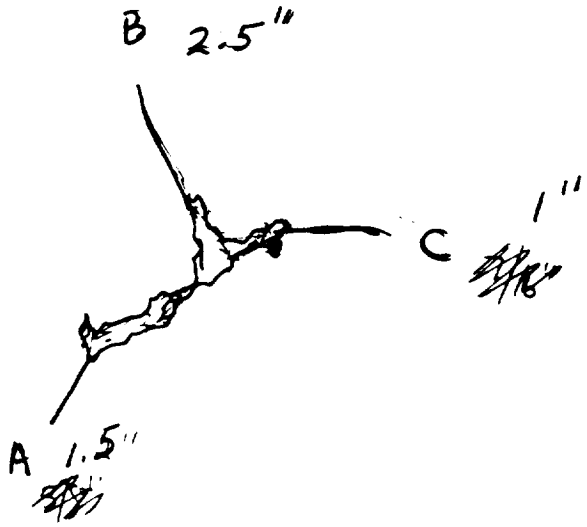
7618-10

.125" 5456

LRW 45



7698-11
LECOF



LTT (A-B) - 3/8" (HAIRLINE CRACKS)

7698-12

BAD (SMALL, DIS-FORMED) PROJECTILE

1-1½" BULDGE

7698 - 13
L45F

$L_{TT} = 11/16''$

7698-14 - NO DET

7698-15 - H + STRIPS

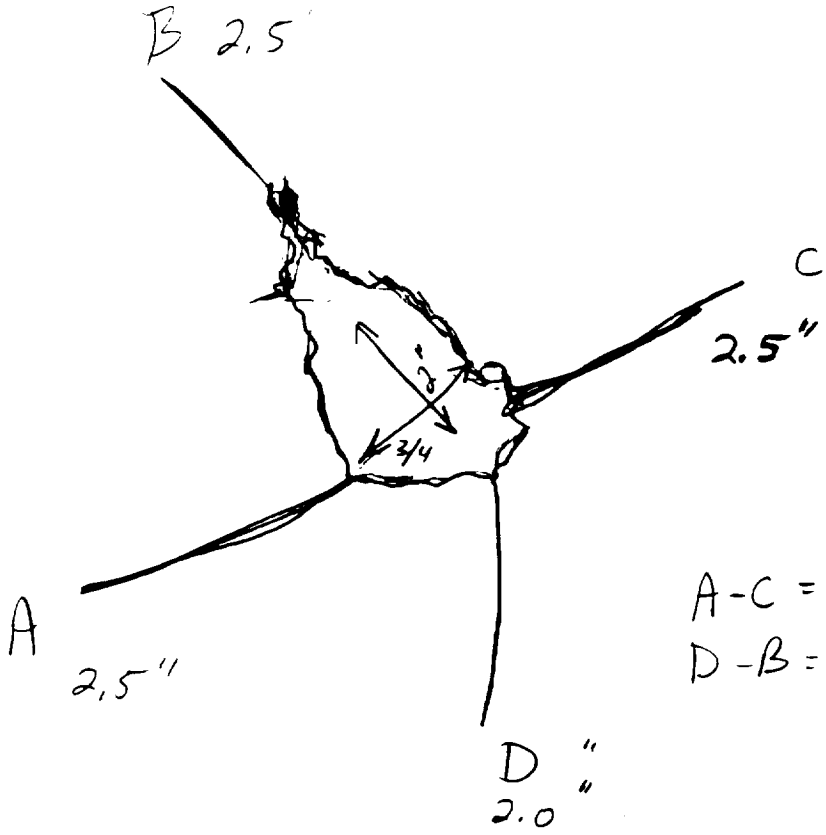
7698-16 - NO PEN

7698-17 - NO DET

7698-18 - NO PEN

7698-19

L450.8

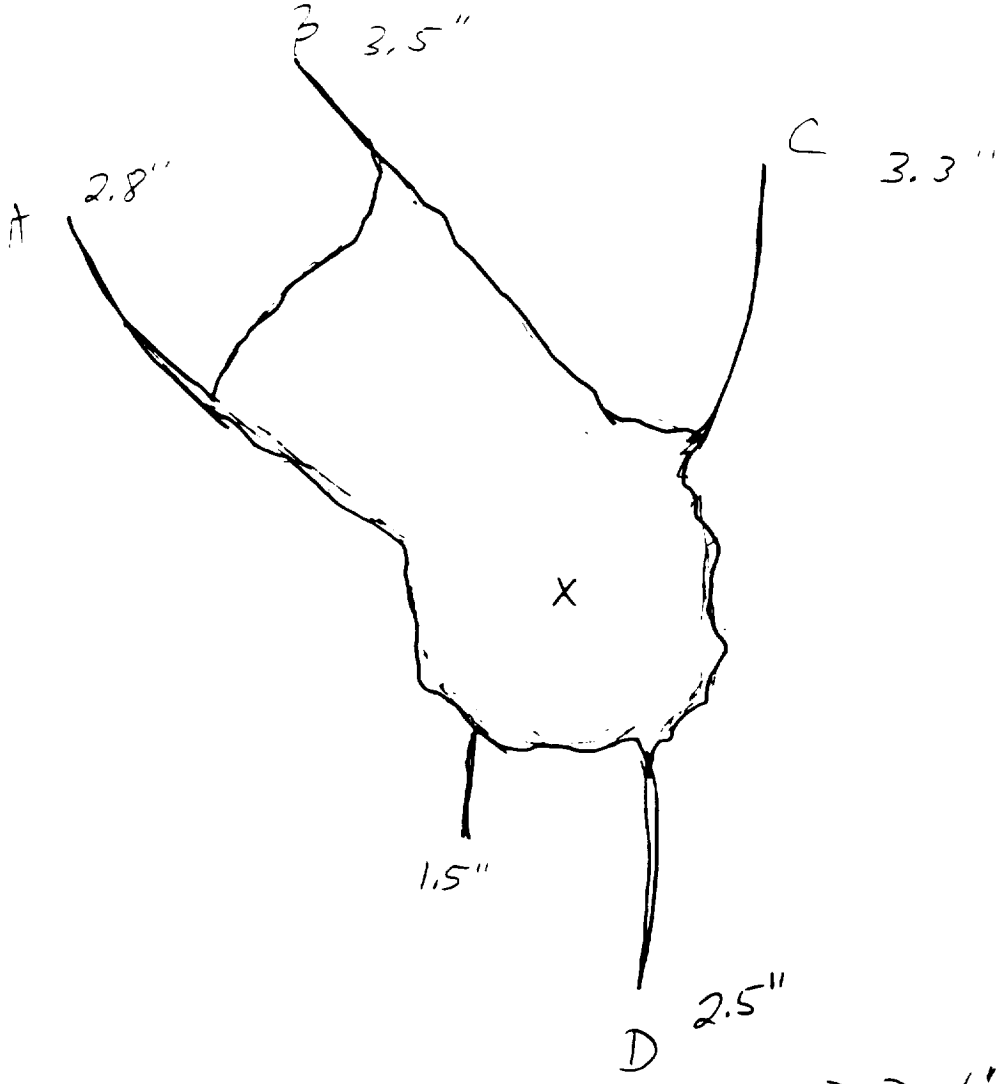


A-C = 4 3/4

D-B = 4 1/2

7698-20

L45



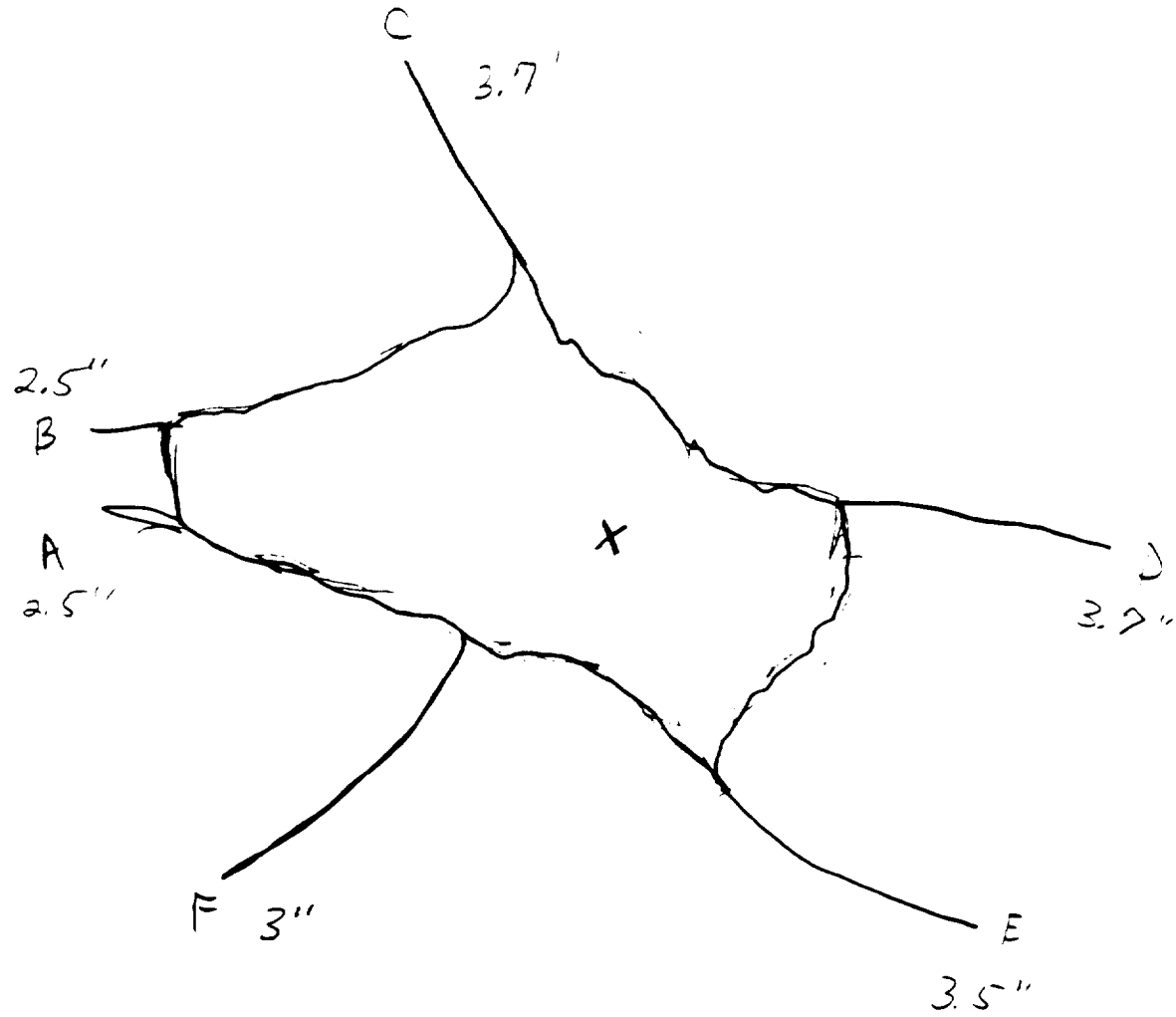
B-D = 6'

A-C = 4¼

C-D = 5½

7698-21

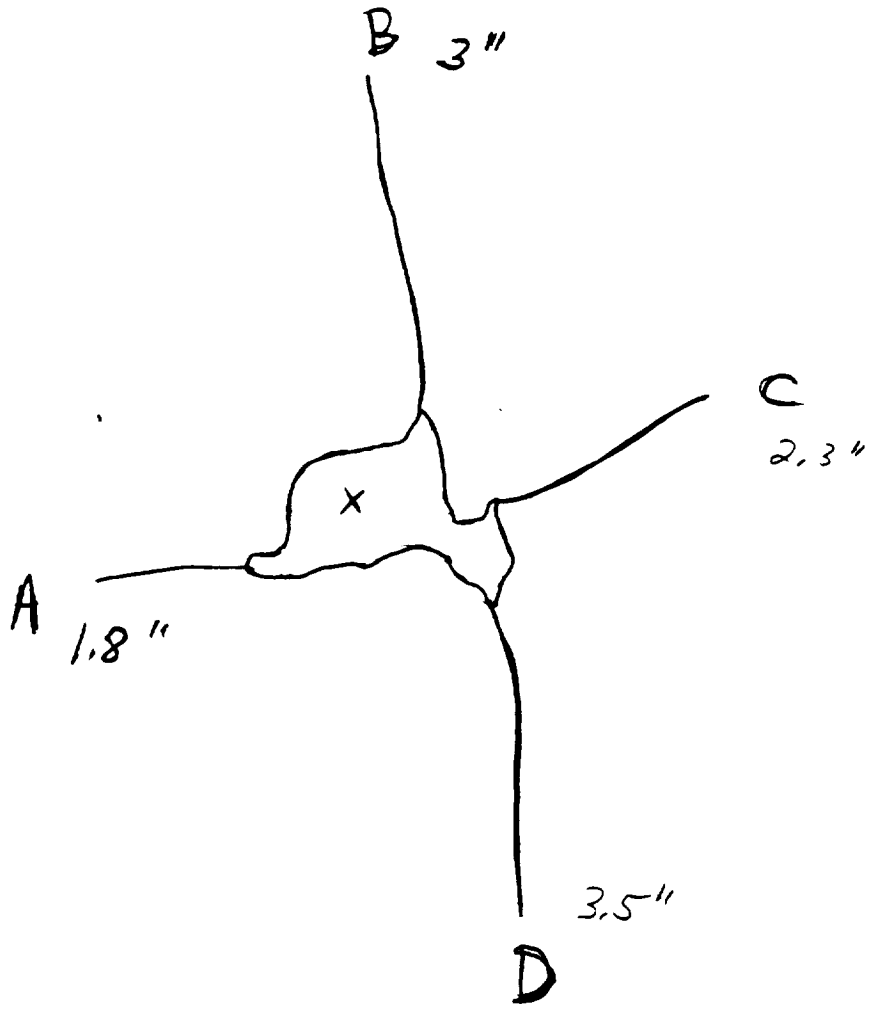
LE0.8



CE = 7
DF = 6 3/4
BE = 6
AD = 6 1/2
BD = 6 1/2

7698-22

JEM 45F



BD - 6 3/4

AC - 4

APPENDIX E

Radiographic Images

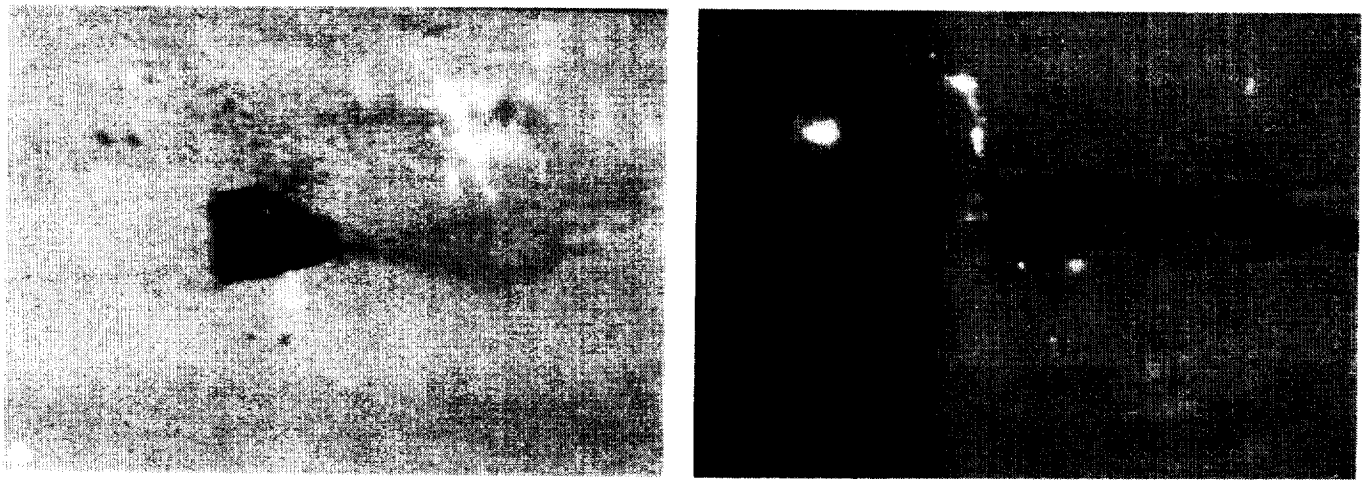


Figure 8. Projectile for Test 7698-1 (View 3 and 4).

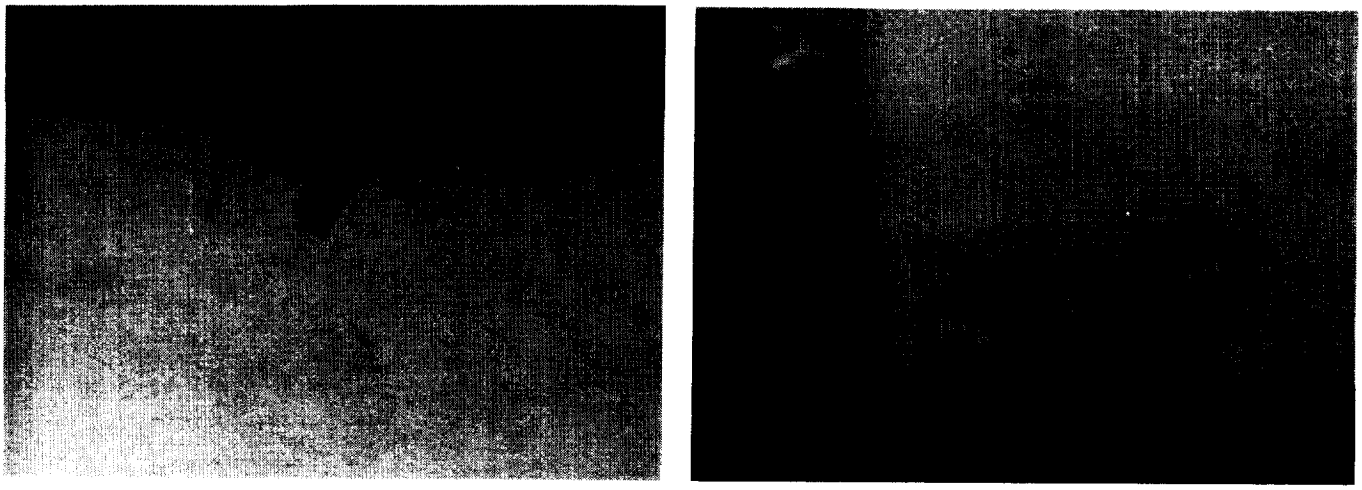


Figure 9. Projectile for Test 7698-2 (View 3 and 4).

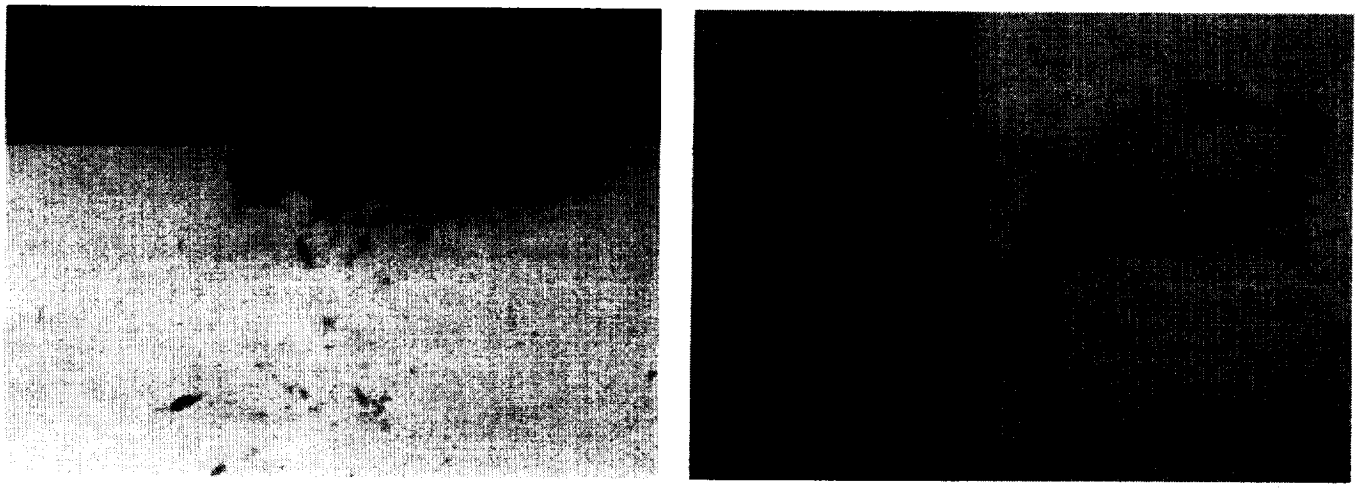


Figure 10. Projectile for Test 7698-3 (View 3 and 4).

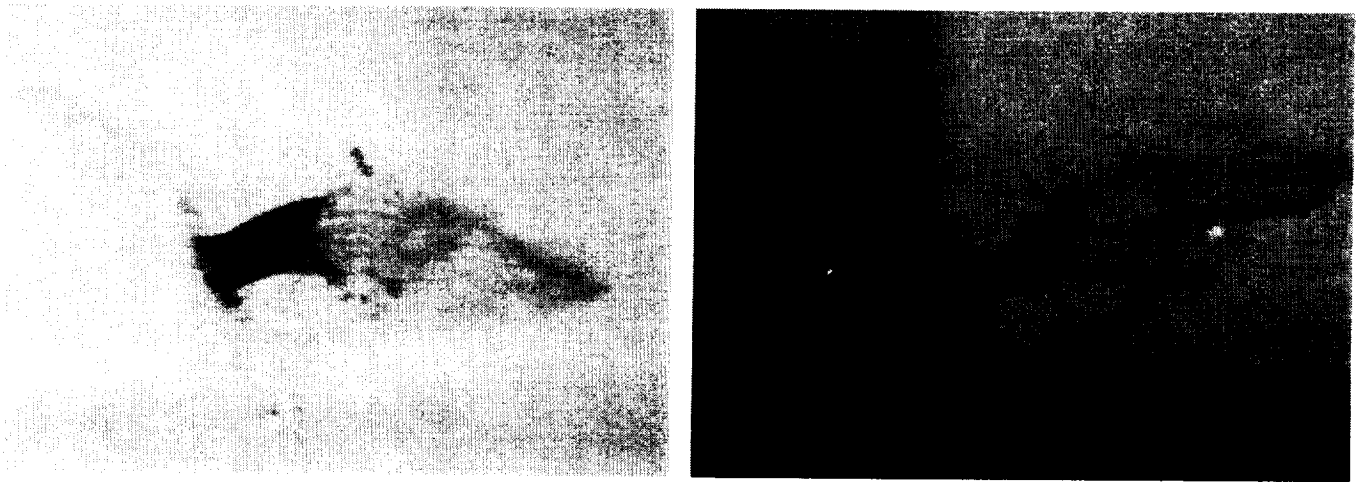


Figure 11. Projectile for Test 7698-4 (View 3 and 4).

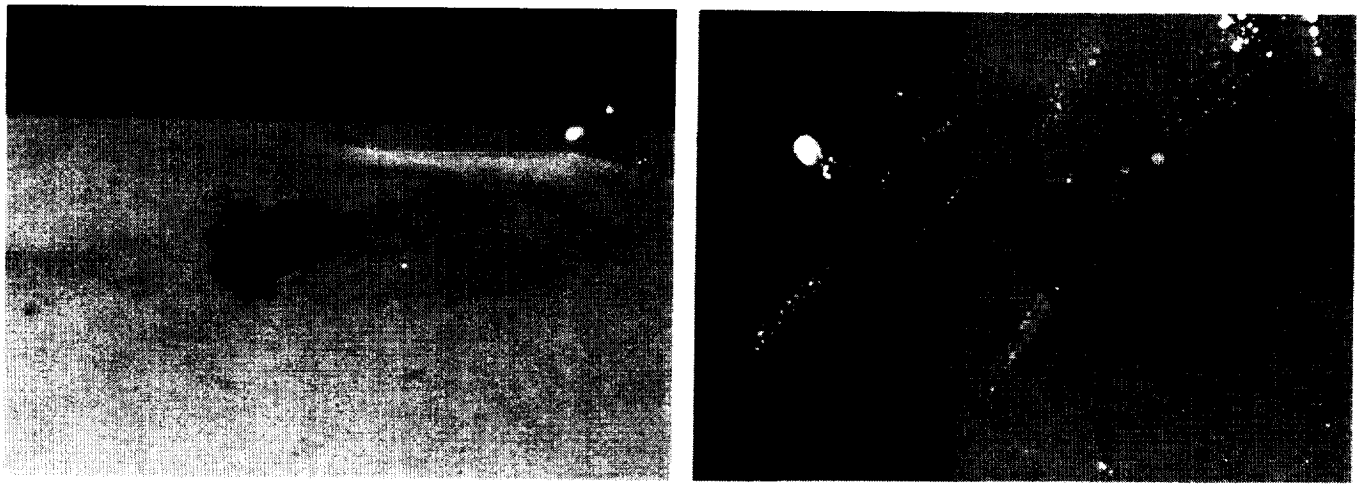


Figure 12. Projectile for Test 7698-5 (View 3 and 4).

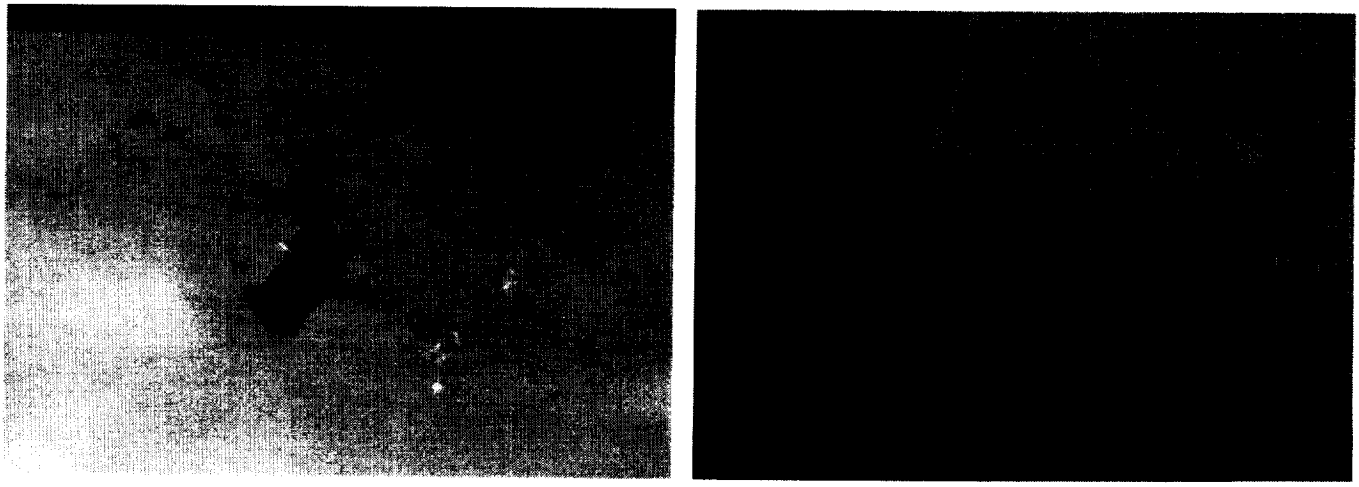


Figure 13. Projectile for Test 7698-6 (View 3 and 4).

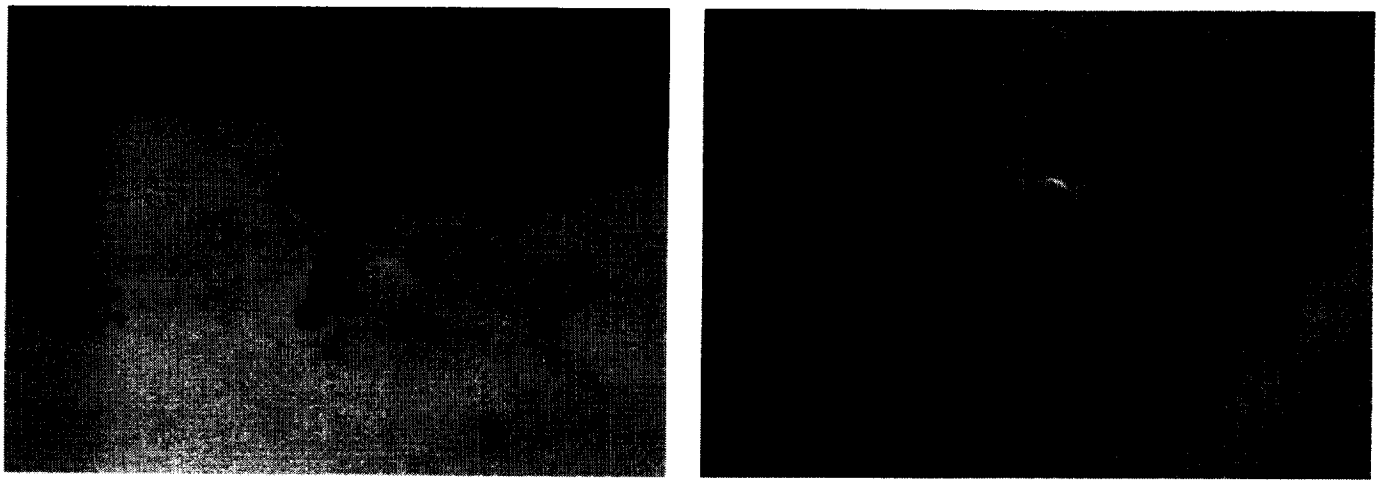


Figure 14. Projectile for Test 7698-7 (View 3 and 4).

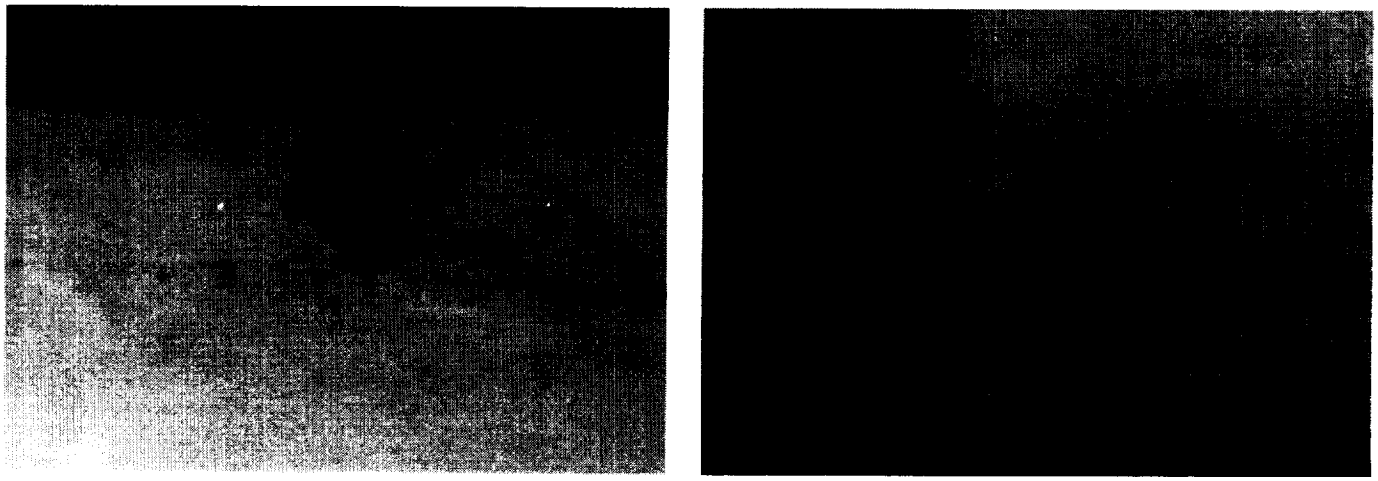


Figure 15. Projectile for Test 7698-8 (View 3 and 4).

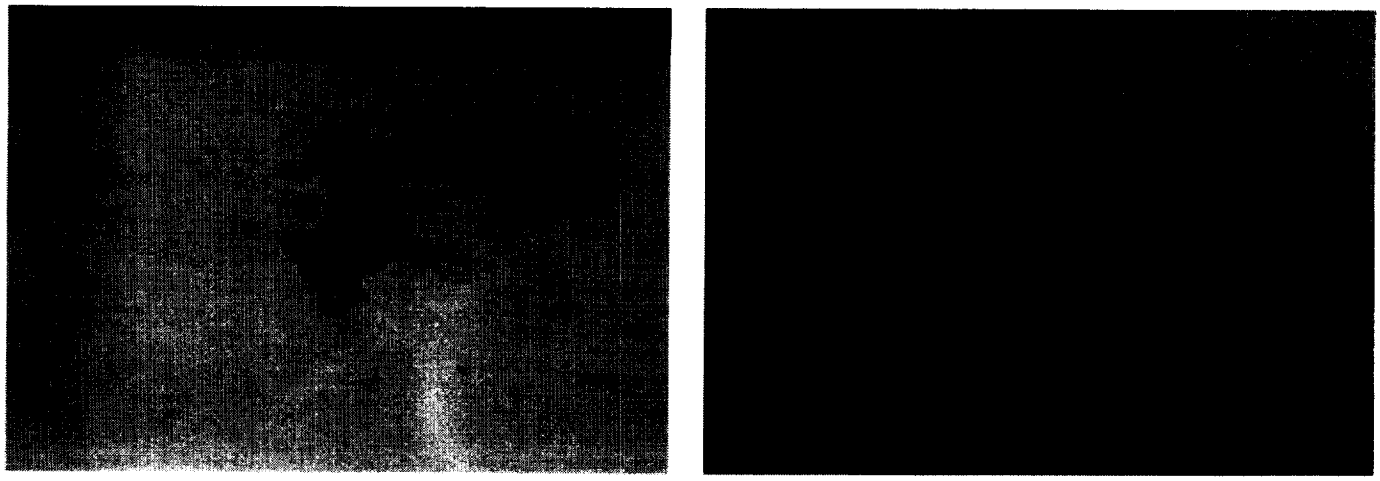


Figure 16. Projectile for Test 7698-9 (View 3 and 4).

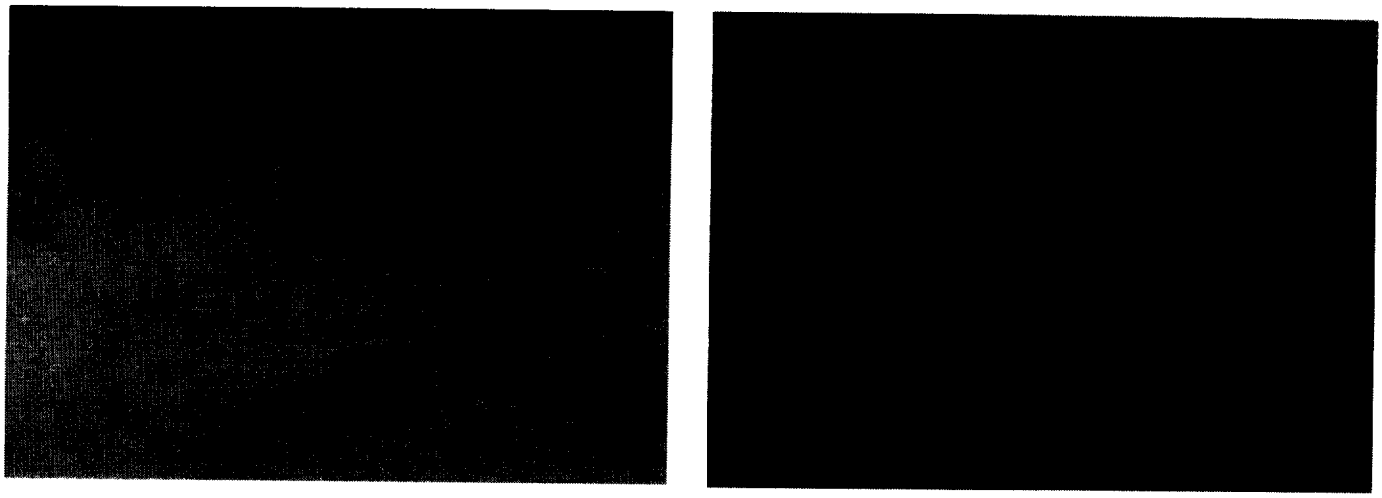


Figure 17. Projectile for Test 7698-10 (View 3 and 4).

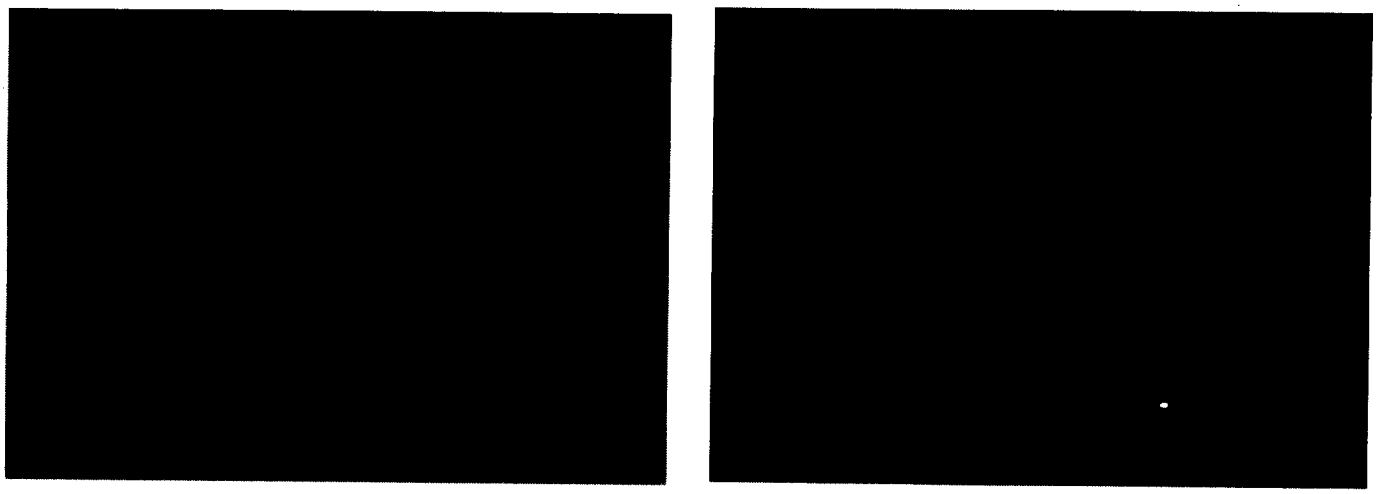


Figure 18. Projectile for Test 7698-11 (View 3 and 4).

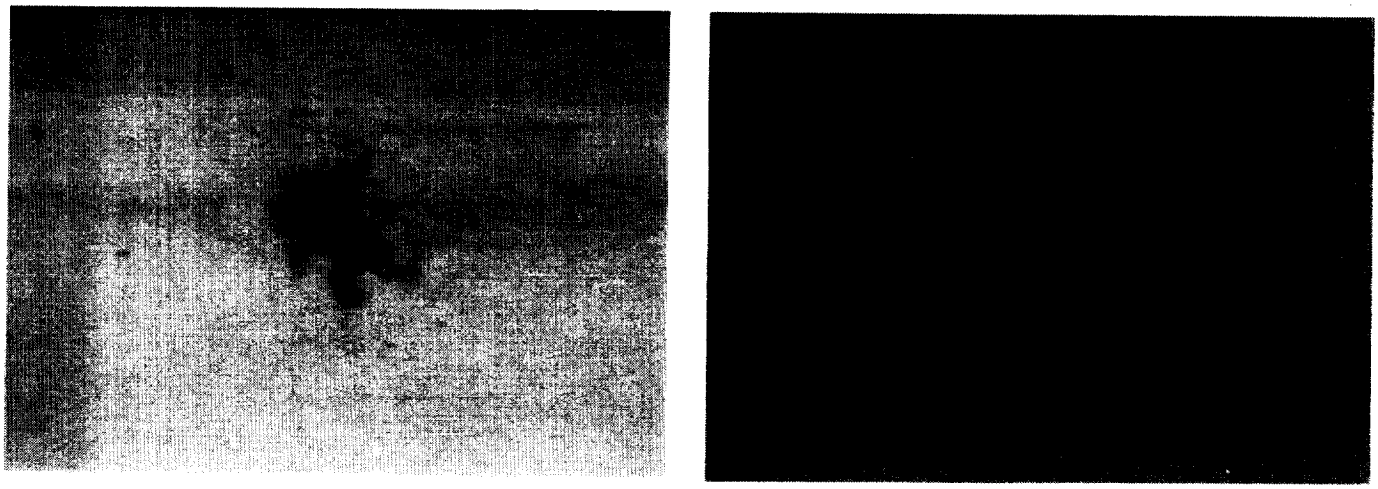


Figure 19. Projectile for Test 7698-12 (View 3 and 4).

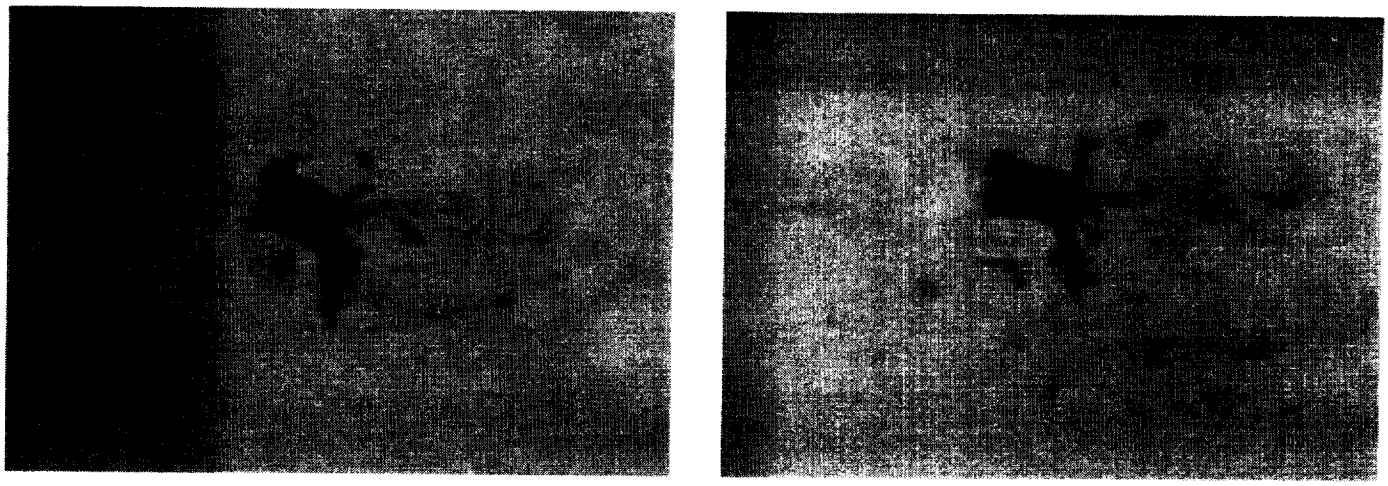


Figure 20. Projectile for Test 7698-13 (View 3 and 4).

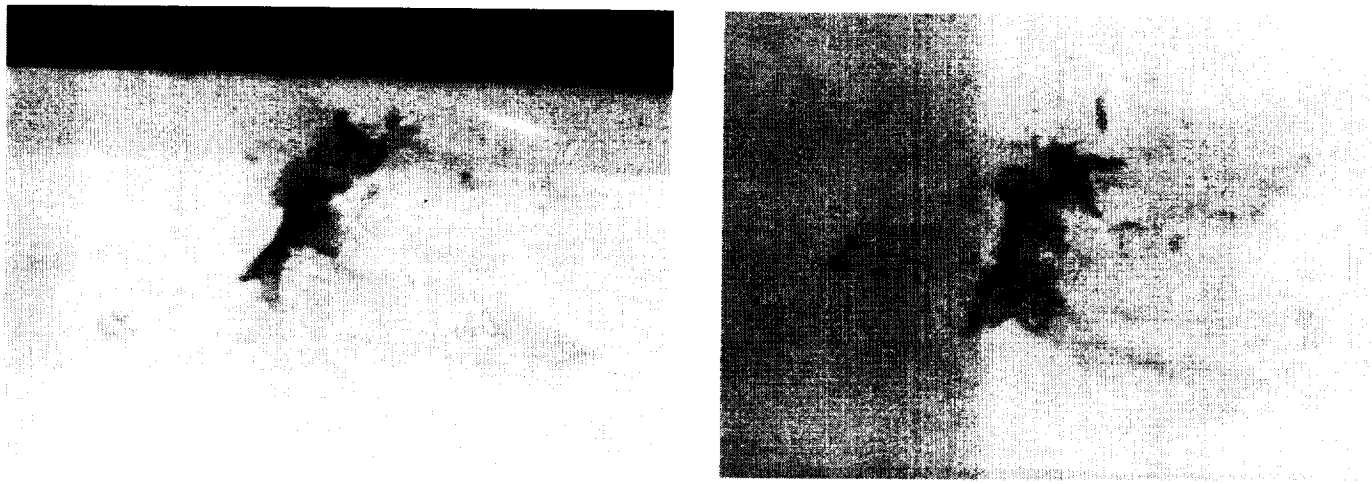


Figure 21. Projectile for Test 7698-16 (View 3 and 4).

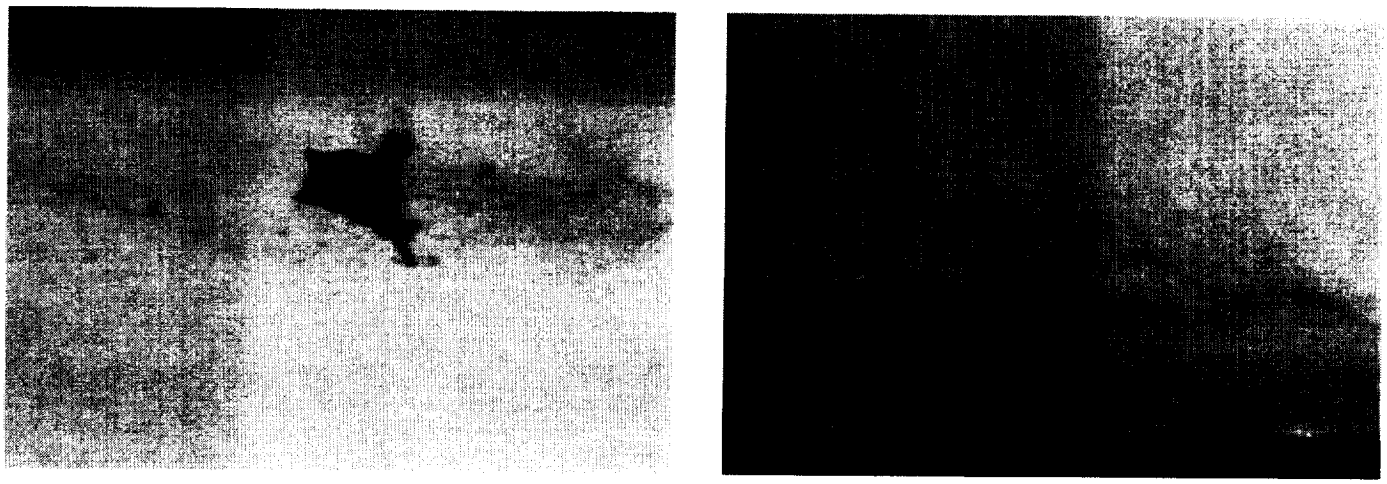


Figure 22. Projectile for Test 7698-18 (View 3 and 4).

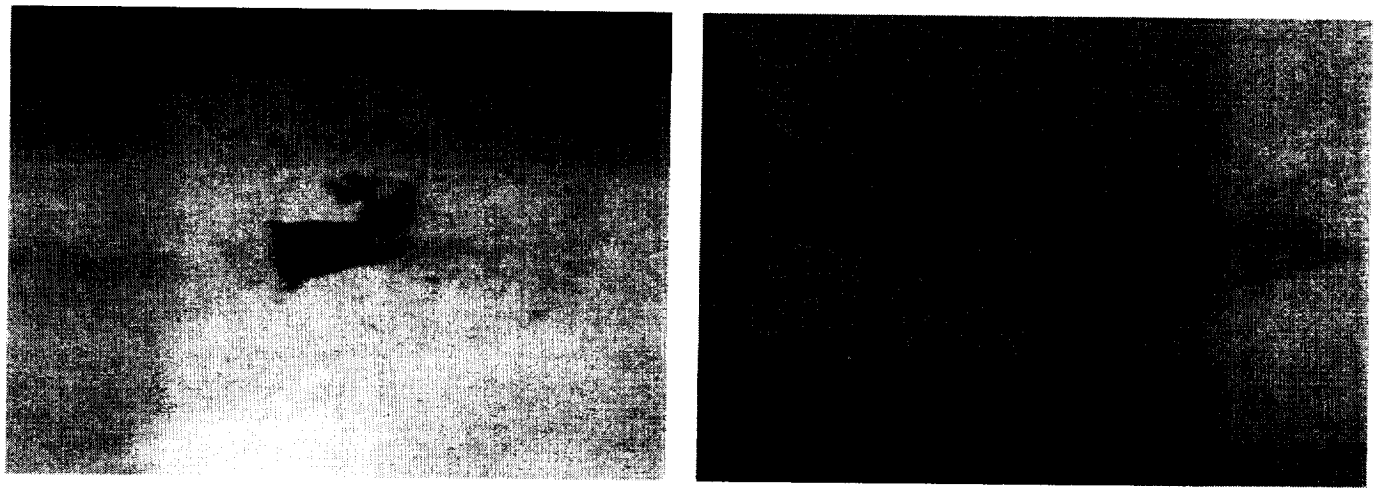


Figure 23. Projectile for Test 7698-19 (View 3 and 4).

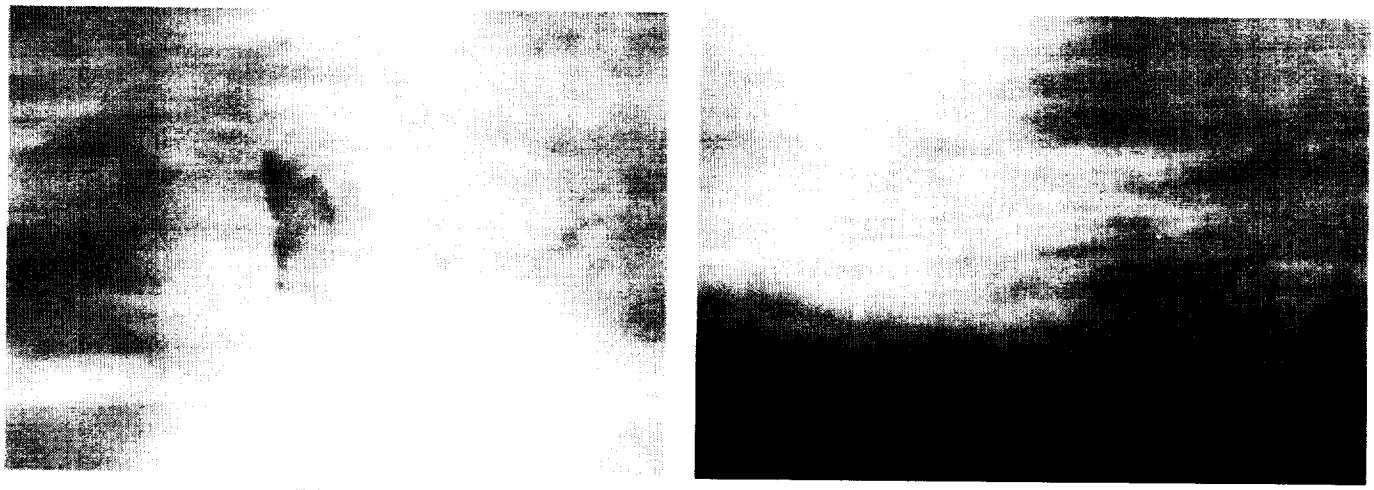


Figure 24. Projectile for Test 7698-20 (View 3 and 4).

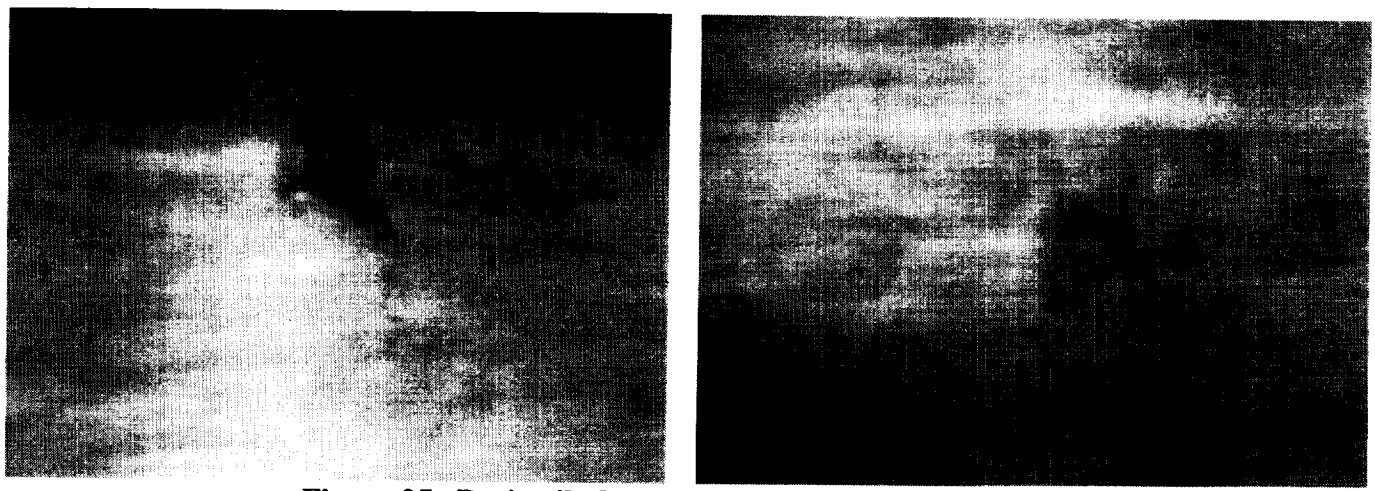


Figure 25. Projectile for Test 7698-22 (View 3 and 4).

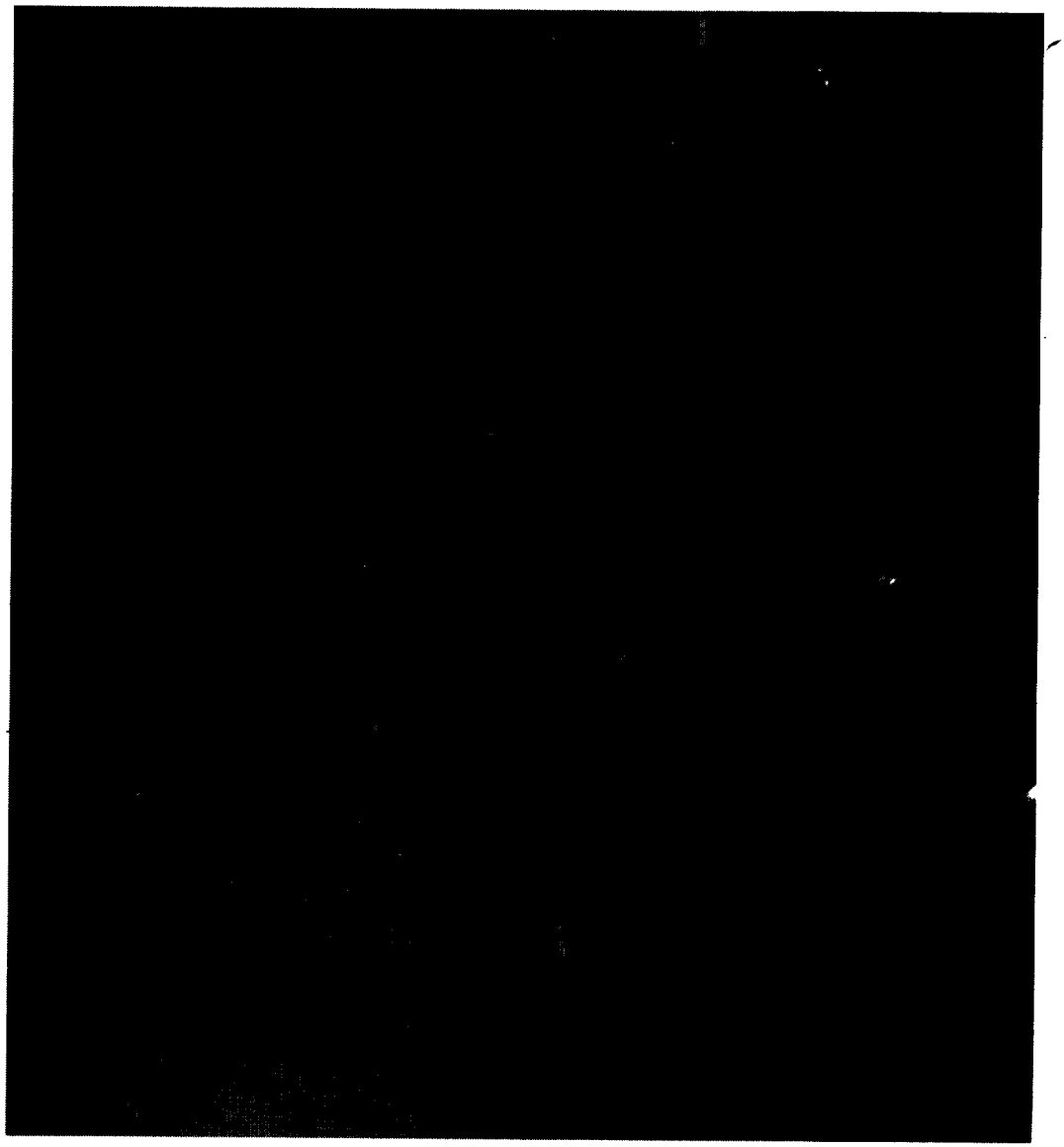


Figure 26. Behind Wall Debris Pattern for Test 7698-1 (Horizontal View).

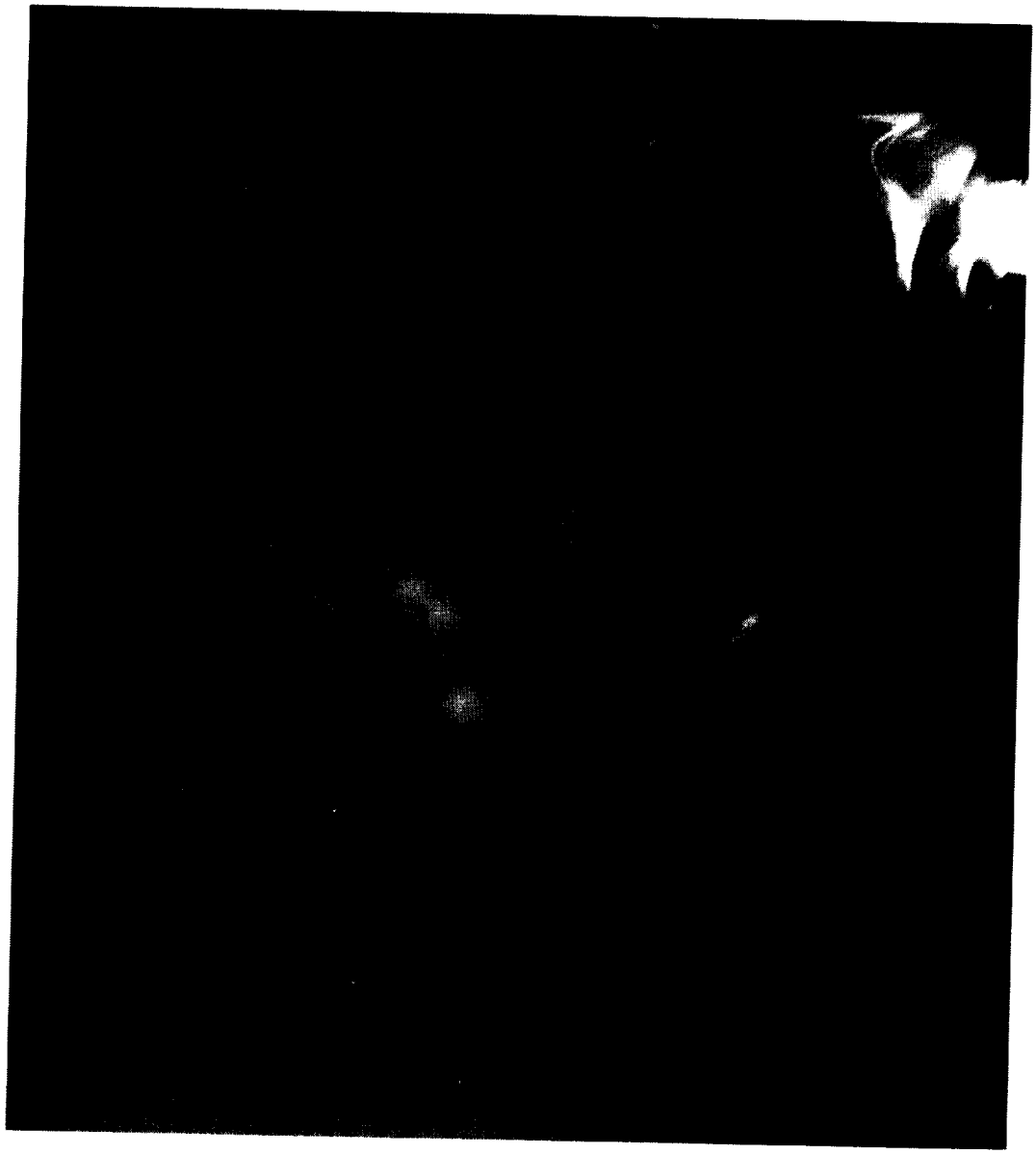


Figure 27. Behind Wall Debris Pattern for Test 7698-1 (Vertical View).

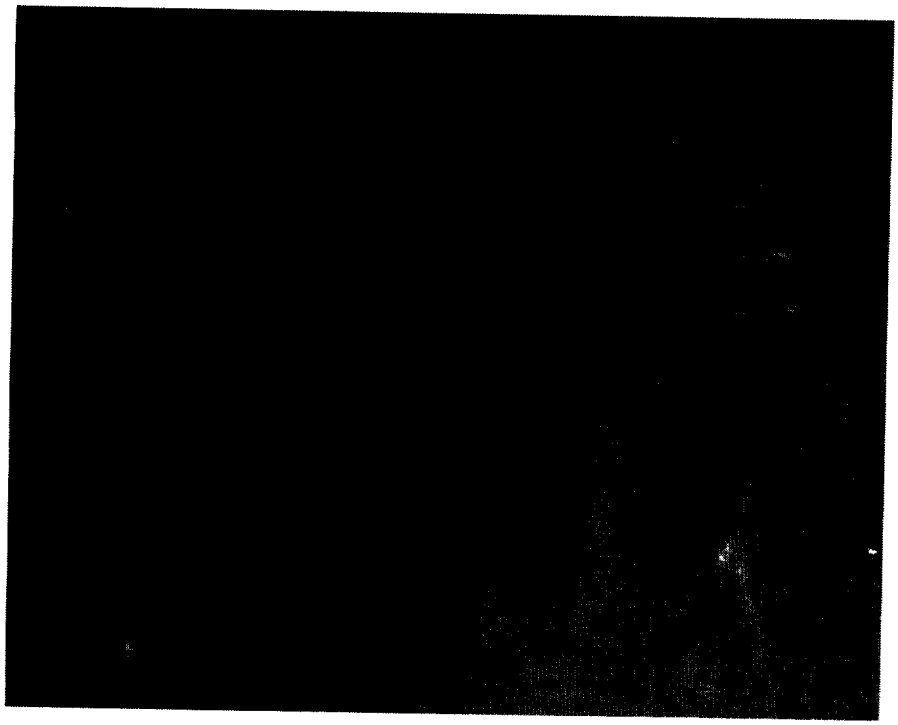


Figure 28. Behind Wall Debris Pattern for Test 7698-2 (Horizontal View).

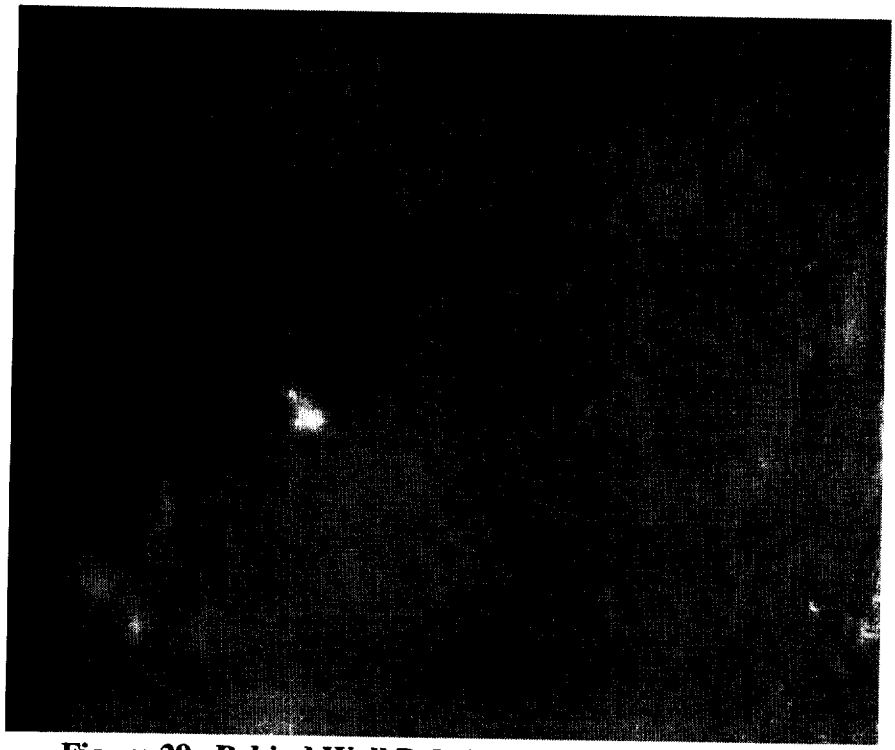


Figure 29. Behind Wall Debris Pattern for Test 7698-2 (Vertical View).

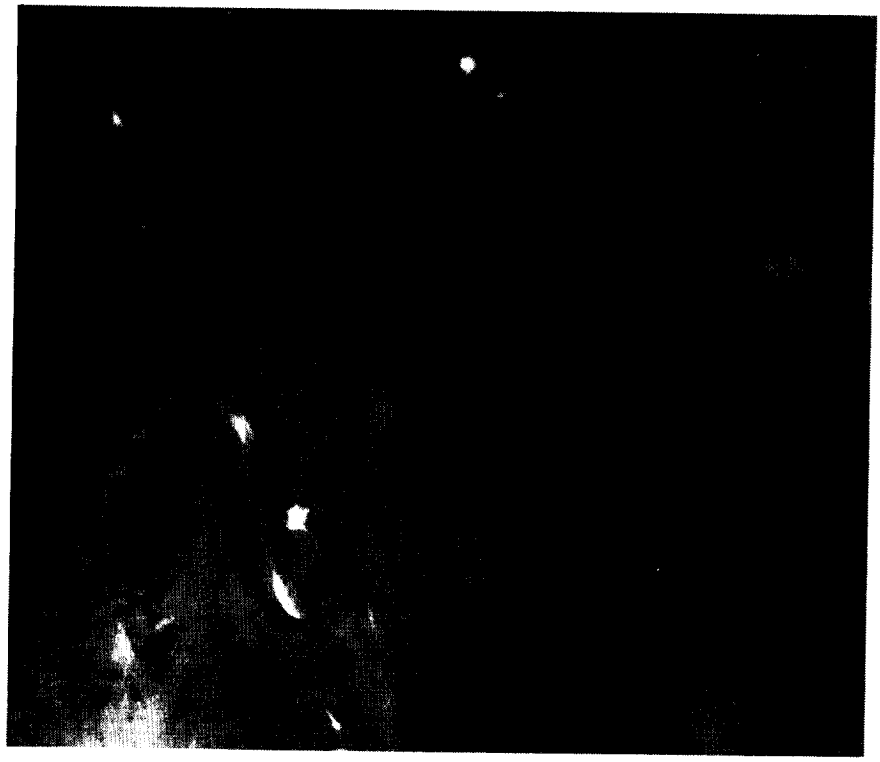


Figure 30. Behind Wall Debris Pattern for Test 7698-5 (Horizontal View).

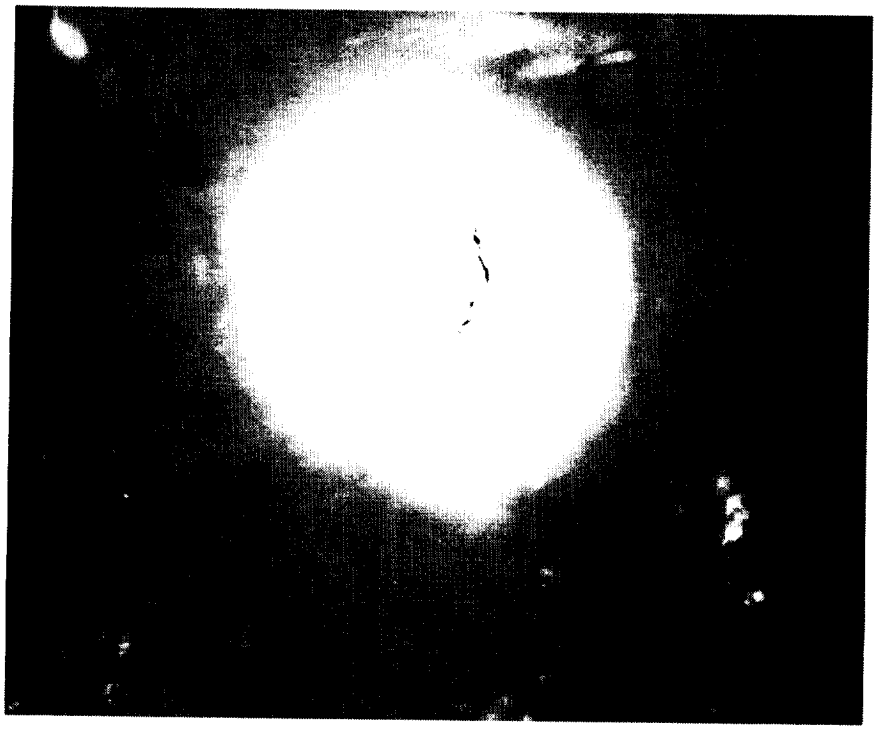


Figure 31. Behind Wall Debris Pattern for Test 7698-5 (Vertical View).

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

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

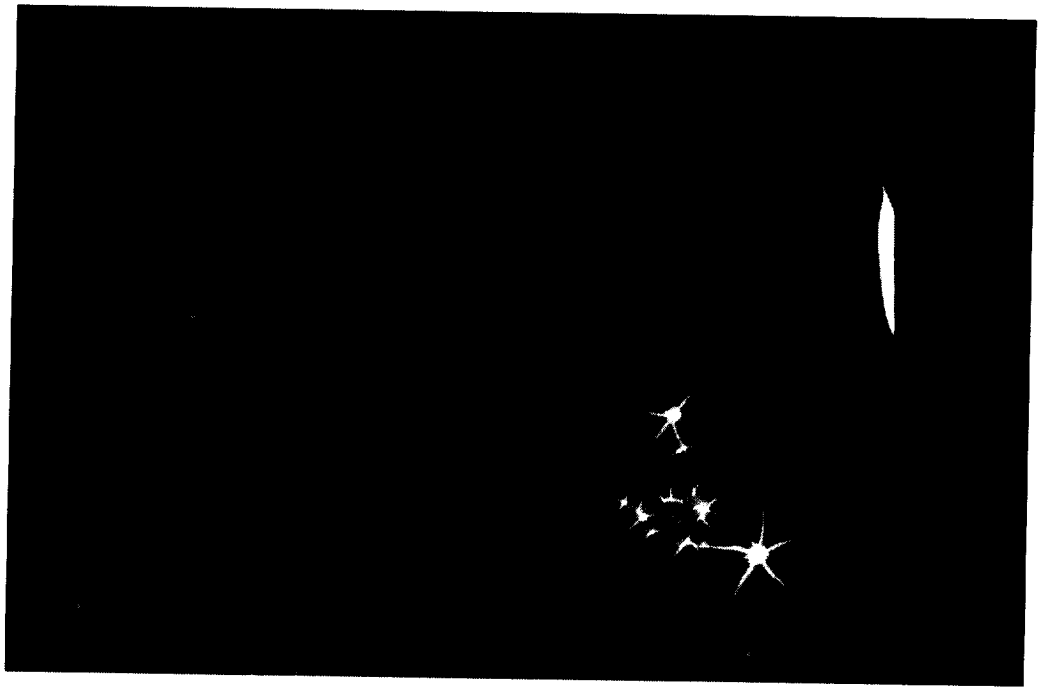


Figure 34. Behind Wall Debris Pattern for Test 7698-11 (Horizontal View).

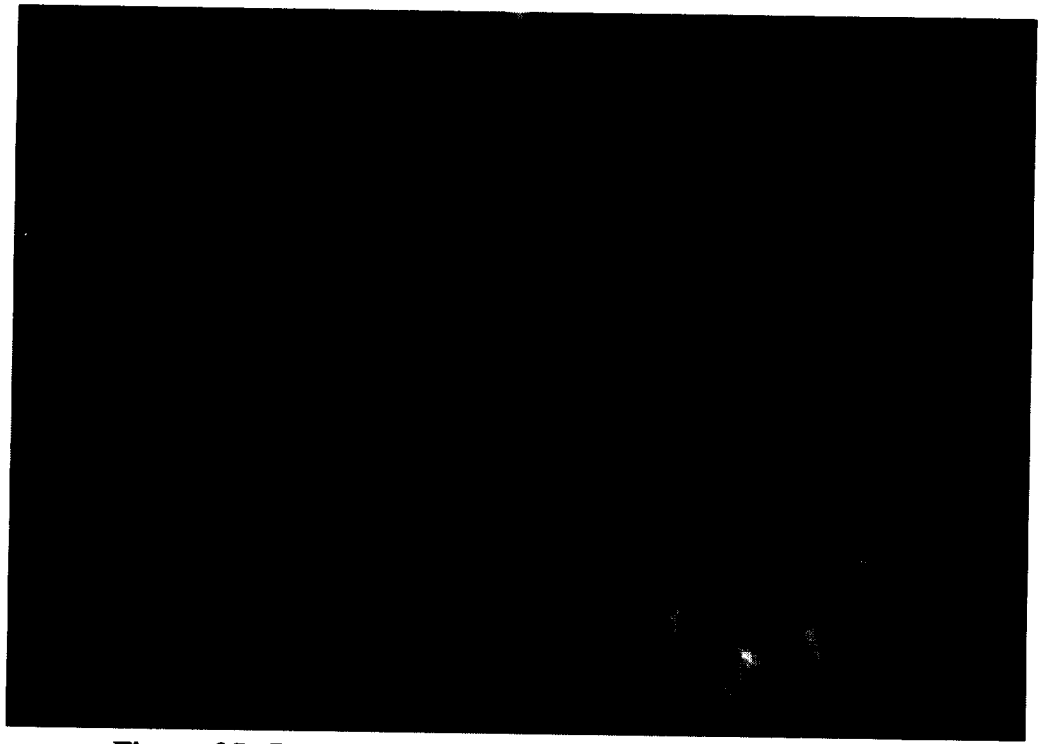


Figure 35. Behind Wall Debris Pattern for Test 7698-11 (Vertical View).

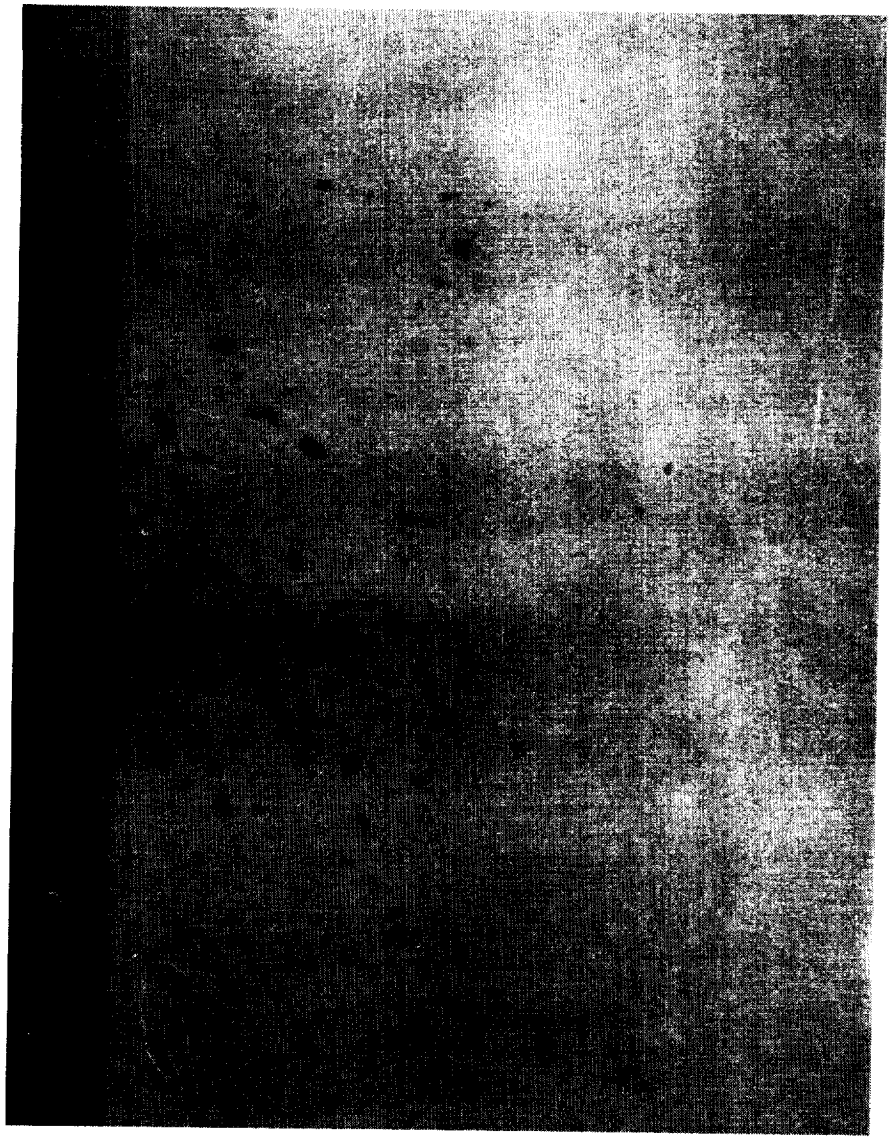


Figure 36. Behind Wall Debris Pattern for Test 7698-21 (Horizontal View).

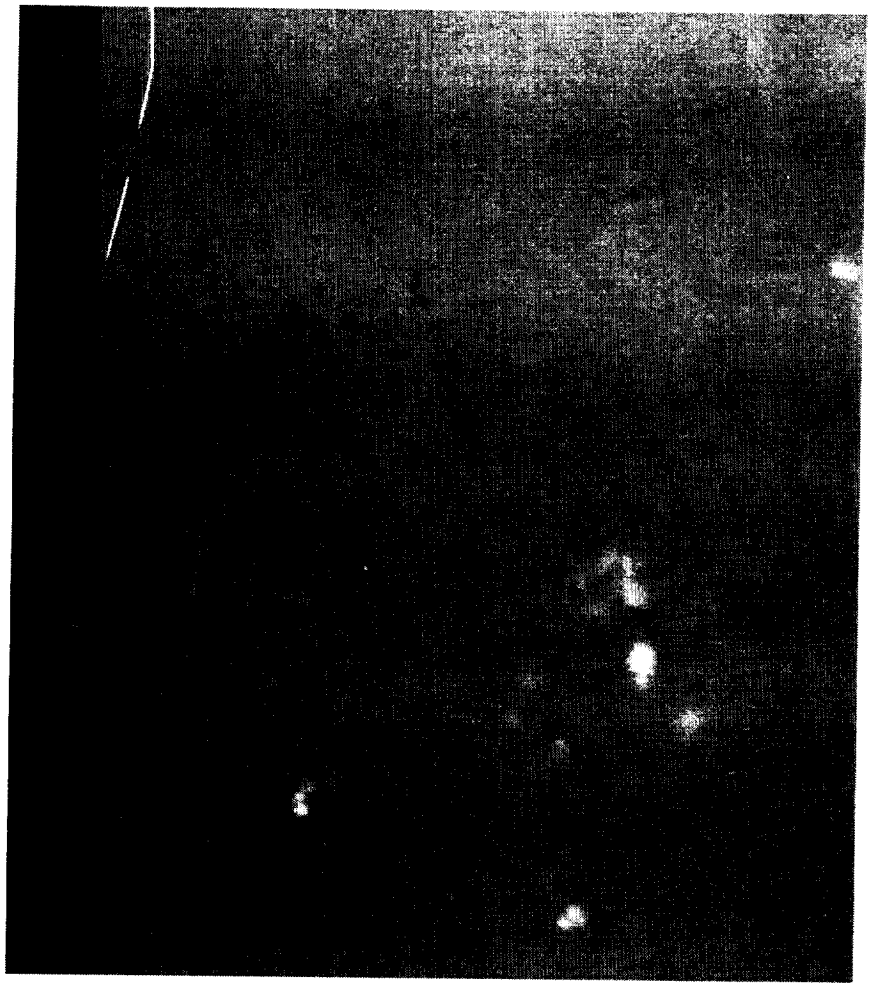


Figure 37. Behind Wall Debris Pattern for Test 7698-21 (Vertical View).

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 No. 2. Test Summary					
Test Number	Test Date	Projectile Mass (g)	Projectile Velocity (km/s)	Target Description	Comments
7139-1	5-2-95	1.24	N/M	U.S. Lab Whipple (0/)	Shield had a 1-1/2" diameter hole, Wall had a 1" diameter hole. All three witness plates were perforated.
7139-2	5-2-95	1.30	11.14	Russian Whipple Shield (0/)	Shield had a 3" diameter hole, Wall had a 6" (post petal) diameter hole, and Plate #3 had a full waffle-square removed. All three witness plates were perforated.
7139-3	5-3-95	1.30	11.16	ESA Cylinder (0/)	Shield had a 1-1/2" diameter hole, Wall had a 1-1/4" diameter hole, and Plate #3 had a 1-3/4" diameter hole. All three witness plates were perforated.
7139-4	5-3-95	-	-	Enhanced Lab #1 (0/)	Projectile hit stripper plate. No data.
7139-5	8-24-95	0.94	11.20	U.S. Lab Whipple (65/)	Shield had a 4" by 2" hole. MLI was destroyed. Material came off shield normal to its surface and missed wall. No witness damage.
7139-6	8-25-95	1.06	11.18	ESA Cylinder (65/)	Shield had a 1-3/4" by 3" hole. Wall #1 had a narrow slit 2-1/4" long with several cracks forming. Wall #2 had not cracks or holes. No witness damage.
7139-7	8-25-95	-	-	Jem Whipple (0/)	Projectile hit stripper plate. No data.
7139-8	8-28-95	1.11	N/M	Jem Whipple (65/)	Shield had a jagged hole with major diameter of 3-1/2". MLI was destroyed. Wall had no cracks or holes. No witness damage.

Table No. 2. Test Summary

Test Number	Test Date	Projectile Mass (g)	Projectile Velocity (km/s)	Target Description	Comments
7139-9	8-28-95	0.88	N/M	Enhanced Lab #2 (0/)	Shield had a hole with major diameter of 2-1/2". Wall had a large, jagged hole with major diameter up to 5-1/2" and cracks up to 6" long. Large amount of pettaling of wall plate. All witness plates perforated.
7139-10	8-28-95	1.00	11.19*	Enhanced Lab #1 (0/)	Shield had a 3-1/2" diameter hole. The Nextel layer had a 3" diameter hole. The Kevlar layer had a 5" diameter hole. The wall had a jagged hole with diameter up to 8-1/2" with several cracks (one running to the plate edge). All witness plates perforated.
7139-11	8-29-95	1.20	11.26*	Enhanced Lab #1 (65/)	Shield had a 3-1/2" diameter hole. Nextel and Kevlar layers both had 3" to 4" diameter holes. Wall had no holes but bulged 1". No witness damage.
7139-12	8-30-95	0.58 (est)	11.67*	Enhanced Russian (0/)	Projectile broke up. Shield had a 3" diameter hole. Nextel and Kevlar layers had 3" diameter holes. Wall had a hole up to 7-1/2" diameter.
7139-13	8-31-95	1.11	11.27*	U.S. Lab Whipple (45/)	Shield had a 4-3/4" by 2-1/2" diameter hole. Wall had only one small hole (1/2" diameter). Witness 1 had a few small perforations, Witness 2 and 3 were not damaged.
7139-14	8-31-95	1.07 (est)	N/M	Russian Enhanced with Clamped Fabric (0/)	Shield had a 2-1/2" diameter hole. Nextel and Kevlar layers had 2" to 3" diameter holes. Wall had a hole up to 7-1/2" diameter. Witness 1 had a 4" diameter hole. Witness 2 and 3 had 2" to 3" diameter holes.

Table No. 2. Test Summary					
Test Number	Test Date	Projectile Mass (g)	Projectile Velocity (km/s)	Target Description	Comments
7139-15	9-5-95	0.95	11.01*	Enhanced Lab #1 with Clamped Fabric (45/)	Shield had a 3" diameter hole. The Nextel and Kevlar layers had 4" diameter holes. The wall had a hole up to 5" diameter and several cracks (one extending to the plate edge).