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SNAP-27 FRAGMENT IMPACT TESTS

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SNAP-27 FRAGMENT IMPACT TESTS (U)

R. E. Berry, 9512
Sandia Laboratories, Albuquerque

June 1969

Approved by: A. J. Clark, Jr.
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ABSTRACT (U)

The SNAP-27 graphite lunar module fuel cask (GLFC) with the fuel capsule assembly (FCA) within was subjected to fragment impacts at various velocities; the fragments simulated are those expected from an explosive abort of the S-IVB stage of the Saturn V launch vehicle. The fuel capsule assembly survived most fragment impacts. However, either high velocity lightweight fragments or massive low velocity fragments can cause simulated radioisotope fuel release.

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The cutoff date for information in this report is May 1969.

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SUMMARY

The SNAP-27 graphite lunar module fuel cask (GLFC) with the fuel capsule assembly (FCA) within was subjected to fragment impacts at various velocities. The fragments simulated those expected from an explosive abort of the S-IVB stage of the Saturn V launch vehicle. There were 13 tests performed, with 9 impacts on the end of the test assemblies and 4 impacts on the side of the test assemblies. The fragments used for the tests were either aluminum sheet (0.063 x 16 x 18 inches) or an electronic component box (12 x 15 x 7.5 inches).

Impacting the end of the test assembly with flat fragments at velocities up to 3200 feet per second did not cause fuel release. Impacting the end of the test assembly with edge fragments resulted in:

1. No penetration at 1830 feet per second with the graphite primary thermal shield and the Bendix pressure plate in place,

2. Clad penetration at 1865 feet per second without the graphite primary thermal shield and the Bendix pressure plate in place, and

3. Clad and liner penetration at 2800 feet per second with the graphite primary thermal shield in place followed by the release of a large quantity of fuel.

Impacting the side of the test assembly with a flat fragment at 1040 feet per second caused cracking of the beryllium secondary thermal shield, but the thermal protection was not removed. Some delayed fuel release can be expected when the secondary thermal shield is damaged sufficiently to expose the FCA to the fireball. Impacting the side of the test assembly with an edge fragment at 1920 feet per second did not cause any damage. Impacting the side of the test assembly with an electronic box (33 pounds) at 680 feet per second caused rupture of both halves of the FCA and gross fuel release.

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SNAP-27 FRAGMENT IMPACT TESTS

Introduction and Test Program Justification

The SNAP-27 fuel capsule assembly (FCA) within the graphite LM fuel cask (GLFC) may be subjected to high velocity fragments in the event of an explosive launch vehicle abort. An explosion of the S-IVB stage of the Saturn V launch vehicle could provide fragments from the hydrogen tank upper dome and perhaps from the instrument unit. Most of these fragments would be pieces of aluminum 0.063-inch thick and might have velocities in the range of 100 to 3000 feet per second. The fragment size distribution and the velocity distribution have been estimated, but the penetration of the GLFC/FCA by these sheet metal fragments cannot readily be calculated. The complexity of the system and the lack of information about the penetration characteristics of metal fragments into complex structures make calculations difficult and the answers questionable. Therefore, this test program was devised to determine experimentally the penetration velocity of a single-size fragment into various configurations of the GLFC/FCA. The fragment selected was 0.063 x 16 x 18 inches. The GLFC/FCA test assemblies were impacted by flat and edge fragments. The various GLFC/FCA test assemblies are described in detail in the Test Assembly Description section. Briefly, the GLFC/FCA test assemblies impacted on the forward end included three configurations: (1) the FCA in the secondary thermal shield assembly (STS); (2) the FCA in the STS and the graphite primary thermal shield; and (3) the FCA in the STS and the graphite primary thermal shield with a Bendix pressure plate over the graphite. The Bendix pressure plate is a titanium cap over the forward graphite dome and is a part of the support structure used to mount the GLFC on the lunar module (LM).

One test was performed which simulated an explosion external to the launch vehicle skin. The fragment was an electronic box (33 pounds) from the instrument unit (Guidance Section of the Saturn V launch vehicle).

The design of the test program and the performance of the testing was a joint effort between the General Electric Co. and Sandia Laboratories. The design and performance of the testing was divided such that it was considered assured that all inputs would result in data outputs that would meet the several requirements of GE and Sandia. The data outputs were established such that the fragment penetration analysis being performed would be substantiated. The tests were performed at Sandia because the facilities were readily available. General Electric designed and fabricated the GLFC/FCA test assemblies. Since sufficient actual components were not available for the GLFC/FCA assemblies for the end impact tests, simulated components fabricated from stainless steel were supplied. Analyses of the structures indicated that the impact responses of the simulated assemblies were similar to those of the actual components.

Test Assembly Description

The most desirable GLFC/FCA assembly for test purposes would be a flight quality assembly suitably mounted in a flight quality Bendix structure, but the time scales, availability, and cost did not allow flight quality component acquisition. The flight configuration for the GLFC/FCA assembly is shown in Figure 1, and the GLFC/FCA mounted in the Bendix support structure is illustrated in Figure 2.

The limited availability of actual components greatly influenced the GLFC/FCA test assemblies. Bendix support structures were unavailable, and the beryllium secondary thermal shields and the graphite primary thermal shield components were in limited supply.

All tests were performed without the Bendix support structure. All tests were performed with actual FCA's, either complete or one-half complete. All side impact tests were performed with complete FCA's and complete beryllium STS assemblies. All end impact tests were performed with one-half FCA's, titanium thermal covers, and simulated STS's. When used on the end impact tests, the graphite primary thermal shields were actual hardware.

The end impact test assembly is illustrated in Figure 3. This illustration includes all hardware available for use, but the Bendix pressure plate and the graphite primary thermal shield end cap were used on a limited number of tests. The Bendix pressure plate was used on two tests. The graphite primary thermal shield end cap was used on four tests.

The side impact test assembly is illustrated in Figure 4. This illustration shows the stainless steel mounting structure as well as the beryllium secondary thermal shield and the fuel capsule assembly.

Description of Sleds and Tracks

The tests were performed by mounting the GLFC/FCA test assemblies on a rocket-driven sled and impacting the assemblies into a fixed aluminum fragment mounted above the track. The track is 5000 feet long and is equipped with a water brake to permit recovery of the sled.

The sleds used were a dual rail sled for velocities up to 2000 feet per second and a monorail sled for velocities greater than 2000 feet per second. Figure 5 shows the dual rail sled, and Figure 6 shows the monorail sled. Both sleds use a water scoop as the braking device; the dual rail sled uses a scoop between the rails, and the monorail sled uses a scoop on top of the rail. The latter unit has polyethylene tubes filled with water laid on top of the track for braking.

The SNAP-27 GLFC/FCA test assembly shown mounted on the sled and wrapped in insulation for heating purposes was impacted into either edge or flat fragments mounted above the track (Figures 7 and 8). The insulation was removed just prior to rocket motor ignition, allowing fragment impact into the bare test assembly.

Instrumentation

The instrumentation was designed to give two pieces of information, the temperature of the test hardware at rocket ignition and the velocity of the sled at target impact. These data were collected with a Brown recorder for the GLFC/FCA test assembly temperatures and with a combination of track electronic instrumentation and image motion cameras for the sled velocity. Additional photo coverage recorded GLFC/FCA test assembly conditions before and after target impact.

Test Criterion and Tests Performed

The test criterion was to determine the threshold velocity at which fuel would be released due to either a flat fragment impact, an edge fragment impact, or an electronic box impact. This criterion was applicable to the GLFC/FCA test assembly impacted on the end as well as the assembly impacted on the side. However, the lack of GLFC/FCA test assemblies for side impact prevented a complete experimental evaluation of this mode of impact. Impacting the sides of the GLFC/FCA assembly is considered the low probability case and, therefore, had a low priority for extensive testing.

The test program was designed as a series effect program (see "Fragment Impact on GLFC Test Plan" in the Appendix). The series effect technique was the complete evaluation of a test prior to establishing the requirements for the next test. This approach resulted in the performance of 13 tests.

Nine GLFC/FCA test assemblies were impacted on the end. Two tests carried two GLFC/FCA test assemblies, one on either side of the dual rail sled. The intent when testing two GLFC/FCA test assemblies was to assure identical test conditions for both the flat and edge fragment impact.

Four side impact tests were performed on the GLFC/FCA test assembly. One GLFC/FCA test assembly was impacted with a flat fragment, two with an edge fragment, and one with an electronic box.

Test Results

The results of the 13 tests performed are summarized in Table I. An understanding of the velocities which caused penetration under the described test conditions can be obtained from this table. There was no penetration through the end of the GLFC/FCA test assembly with a flat fragment through 3200 feet per second. There was penetration through the end of the test assembly at 1865 feet per second with an edge fragment, but the test assembly did not have the graphite primary thermal shield end cap or the Bendix pressure plate (Test 3). The GE postmortem analysis of the test assembly revealed that there was no fuel released

and the liner was not ruptured. Installing the graphite primary thermal shield end cap over the end of the GLFC/FCA test assembly prevented penetration by the edge fragment at 1830 feet per second (Test 5). However, the graphite did not prevent penetration at 2800 feet per second (Test 10). The edge fragment passed completely through the one-half fuel capsule assembly, ripping the liner its full length.

Two tests on end impact GLFC/FCA test assemblies were performed (Tests 5 and 11) using a Bendix pressure plate over the graphite primary thermal shield end cap. The first test (Test 5) impacted an edge fragment at 1830 feet per second. No penetration was experienced, and the damage to the titanium thermal cover was reduced. Note that the Bendix pressure plate on Test 3 was 5 inches in diameter, the size requested by the AEC for flight hardware. The request was denied by NASA, and the pressure plate on flight quality hardware is 2.5 inches in diameter. Penetration resistance was increased by installing the Bendix pressure plate, but insufficient tests were performed to permit a complete evaluation. In the second test (Test 11), a flat fragment was impacted at 2800 feet per second. The Bendix pressure plate was lost prior to target impact. No penetration was experienced.

The final test was performed by impacting an electronic box mounted on a cooling plate into the side of the STS/FCA at 680 feet per second. The impact point was the top corner of the box, and the line of travel was from this top corner diagonally through the box to a bottom corner. The electronic box mounted on the cooling plate was suspended inside a catch container and the space behind the electronic box was filled with polystyrene foam plastic. The plastic was installed to stop the STS/FCA and to prevent secondary impact damage to the STS/FCA assembly.

The impact occurred on the corner of the box as desired, but the remainder of the desired conditions were not met. The electronic box broke the beryllium secondary thermal shield into many pieces and the fuel capsule at the midsection weld into its two halves. The fuel capsule halves went through the cooling plate, the polystyrene foam plastic, and the rear of the catch container and impacted the sled and then the ground. Both halves of the fuel capsule were breached with holes ranging from 1.5 to 4 square inches in size. It is impossible to determine when the rupture of the fuel capsule halves occurred. It could have occurred at initial impact, at catch container impact, at sled impact, or at final ground impact.

Although direct (immediate) fuel release occurred on only two tests (Tests 10 and 13), there were several tests which would be classified as potential delayed release of fuel. Tests 3, 4, 9, and 11 show damage to the thermal cover which probably would expose part of the FCA to the fireball, and quite possibly the FCA would melt sufficiently to release some of the fuel.

The damage to each test item is illustrated in Figures 9 through 47. Also shown are the sleds used to carry the hardware, the method for suspending the fragments and the appearance of some fragments after impact.

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Summary of SNAP-27

Sled Number	Test Number	Impact Orientation: Test Assembly	Impact Orientation: Fragment	Graphite Primary Thermal Shield	Bendix Pressure Plate	Velocity (fps): Required	Velocity (fps): Actual	Capsule Center (1250 req'd)
1	1	End*	Edge	No	No	1000	1025	1160
	2	End	Flat	No	No			1160
2	3	End	Edge	No	No	2000	1865	1190
	4	End	Flat	No	No			1200
3	5	End	Edge	Yes	Yes†	2000	1830	1240
4	6	Side**	Edge	No	No	1000	970	1165
5	7	Side	Flat	No	No	1000	1040	1410
6	8	End	Flat	No	No	3000	3200	1210
7	9	End	Edge	Yes	No	2000	1820	1270
8	10	End	Edge	Yes	No	3000	2800	1310
9	11	End	Flat	Yes††	Yes††	3000	2800	1240
10	12	Side	Edge	No	No	2000	1920	--
11	13	Side	+	No	No	700	680	--

*GLFC/FCA test assembly (end impact) consists of (Figure 1): (1) titanium thermal cover, (2 (3) simulated forward capsule support, and (4) simulated one-half secondary thermal shield;

**GLFC/FCA test assembly (side impact) consists of (Figure 2): (1) complete fuel capsule ass shield; impact surface is the side of the beryllium secondary thermal shield.

†Bendix pressure plate was 5 inches in diameter.

††Bendix pressure plate was 2-1/2 inches in diameter and graphite was Supertemp.

+Instrument unit box (12 x 15 x 7-1/2 inches) weighed 33 pounds and was mounted on cooling p 30 pounds; beryllium secondary thermal shield impacted on corner of box, with line of trave corner.

++Sled failed; left track and was destroyed; photo coverage was the only data available on fu

TABLE I

27 Fragment Impact Tests

	Unit Temperature (°F)			
'd)	Capsule Edge	Titanium Thermal Cover	Beryllium Secondary Thermal Shield	Results
	1150	1040	--	Thermal cover dent about 0.5 inch deep; minimum damage.
	1170	1070		No visible damage.
	1200	1110	--	Capsule clad penetrated; aluminum fragment filled hole.
	1185	1130		Thermal cover cracked; capsule deformed.
	1240	1140	--	Bendix pressure plate bent; graphite penetrated; thermal cover dented.
	1160	1110	OD - 1240 Center, ID - 1260 Aft, ID - 1190	No apparent damage.
	--	--	Mid. - 1260	Beryllium cracked but remained intact.
	1210	1170	--	Thermal cover flattened; capsule slightly mushroomed; thermal cover screw heads popped off.++
	1265	1210	--	Thermal cover dented about 0.5 inch deep; capsule dented and mushroomed; thermal cover screw heads popped off.
	1295	1255	--	Capsule penetrated; 0.3-inch-wide gap; inner liner sliced full length of half capsule.
	1245	1200	--	Thermal cover flattened and screw heads popped off; Bendix pressure plate lost before fragment impact.
	1150	--	850	No apparent damage to the beryllium secondary thermal shield.
	1150	--	850	Beryllium destroyed; capsule broken in half and cracked at closure welds; both capsule halves ruptured.

(2) one-half fuel capsule assembly,
d; impact surface is the titanium thermal cover.

ss. nbly, and (2) complete secondary thermal

; plate (30 x 30 x 1 inch) which weighed
ıvel from top corner diagonally to the bottom

fuel capsule damage.

Conclusions and Recommendations

Aluminum sheet metal fragments (16 x 18 x 0.063 inch) can penetrate the SNAP-27 fuel capsule assembly through the GLFC components when the FCA is impacted by an edge fragment and when sufficient velocity is present; the configuration of the test assembly has an effect on the velocity. The GLFC/FCA test assembly with bare titanium thermal cover was penetrated by an edge fragment at about 2000 feet per second; when graphite was added to the assembly, a velocity of about 3000 feet per second was required for penetration. Insufficient test hardware was available to determine the penetration velocity with the Bendix pressure plate present.

No penetration was observed when a flat fragment was impacted into the end of GLFC/FCA test assemblies at velocities up to 3200 feet per second. Insufficient impacts were performed on the side of the GLFC/FCA test assemblies to establish the penetration velocity for either edge or flat fragments.

One test was performed using an electronic box from the Instrument Unit of the Saturn V launch vehicle Guidance Section. The box ruptured both halves of the fuel capsule assembly, and a large percentage of the fuel was released from each half of the FCA.

Further testing would be necessary to refine the gross velocity values listed above for penetration through the end of the GLFC/FCA test assemblies.

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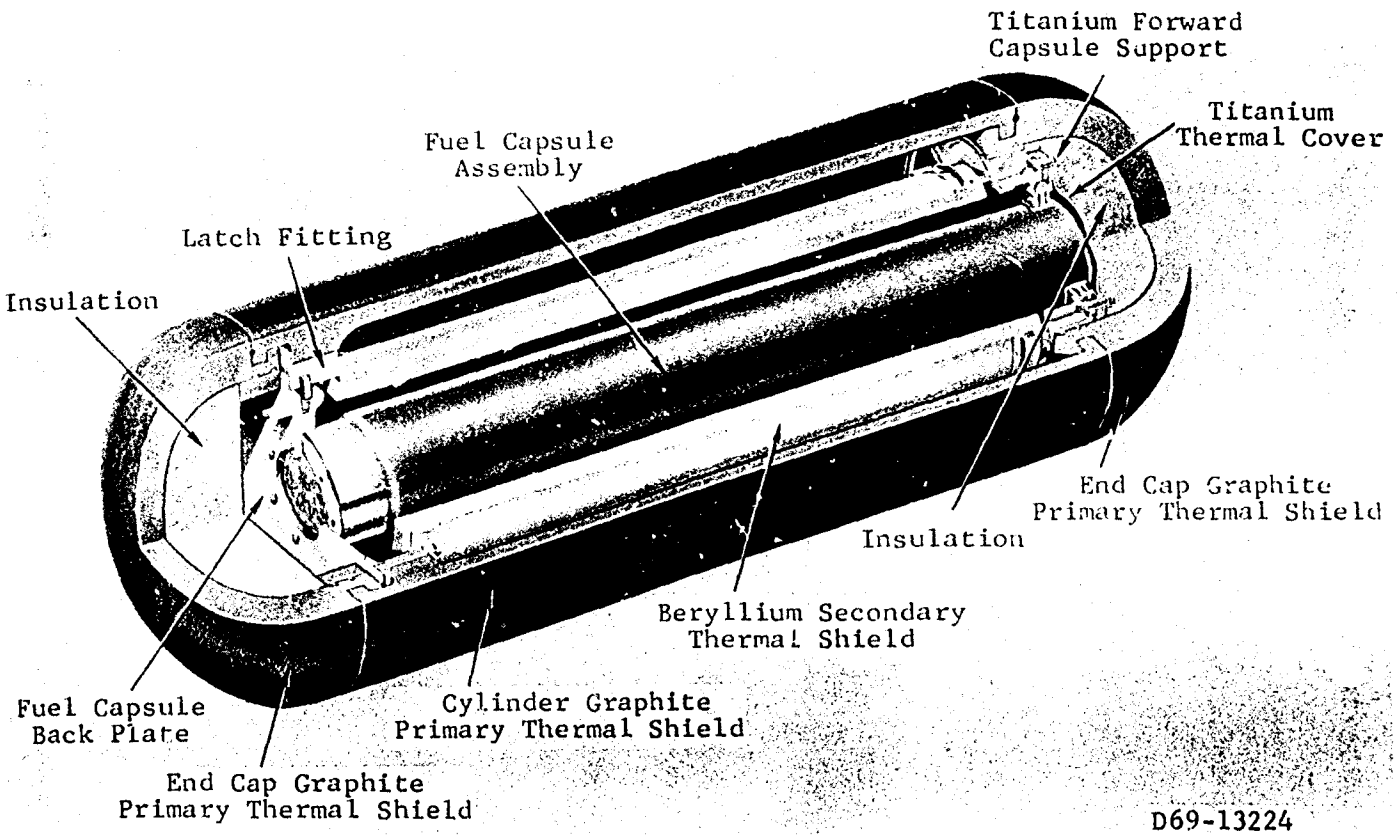

Figure 1. SNAP-27 graphite LM fuel cask with beryllium secondary thermal shield incorporated

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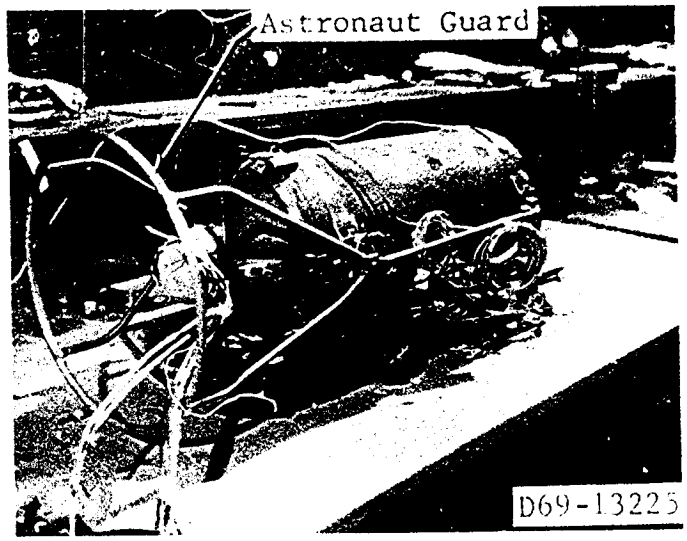
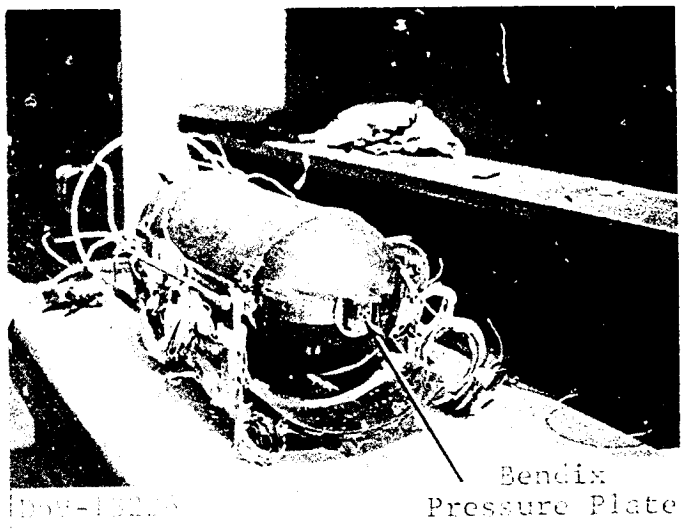


a.



b.

Figure 2. Bendix support structure with SNAP-27 GLFC/FCA

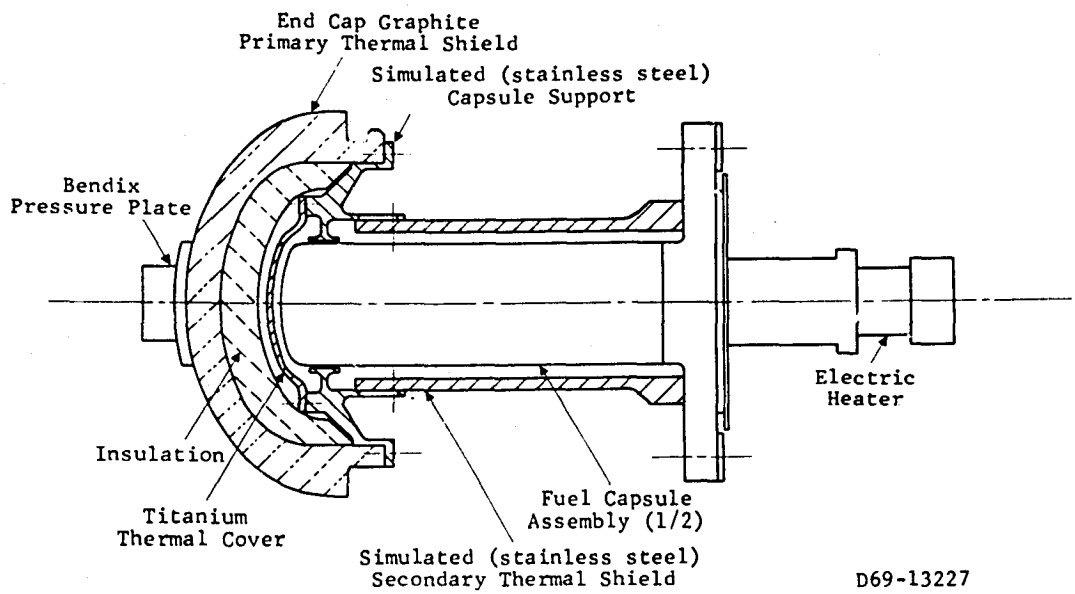


Figure 3. SNAP-27 GLFC/FCA test assembly (end impact)

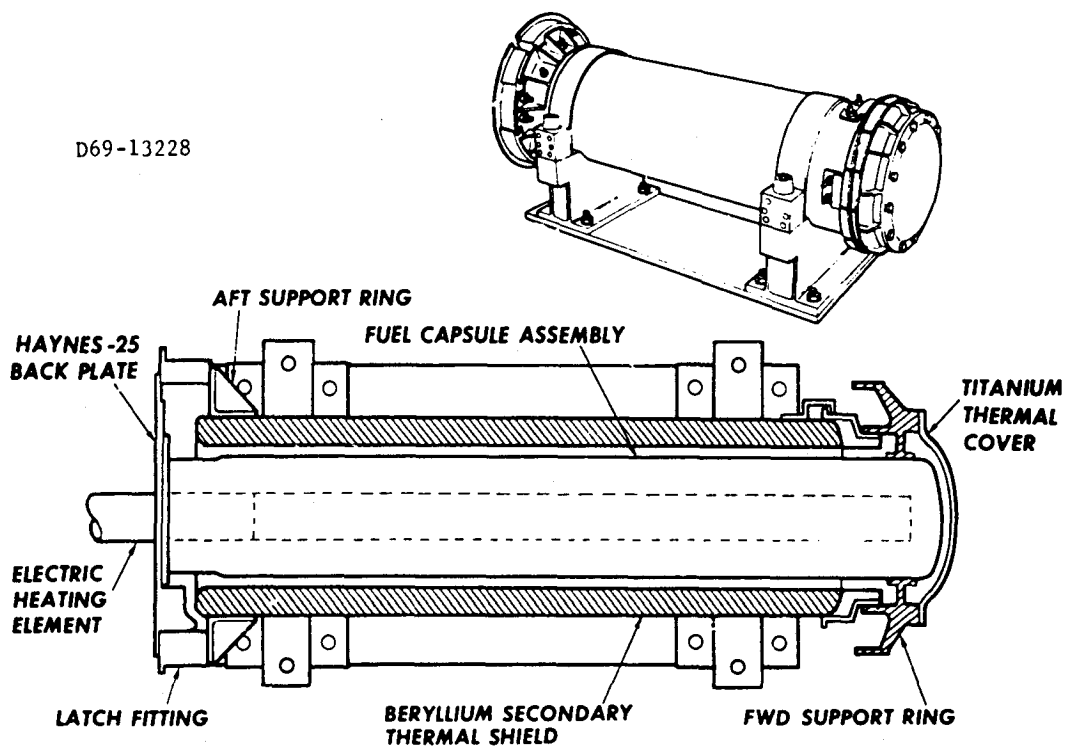
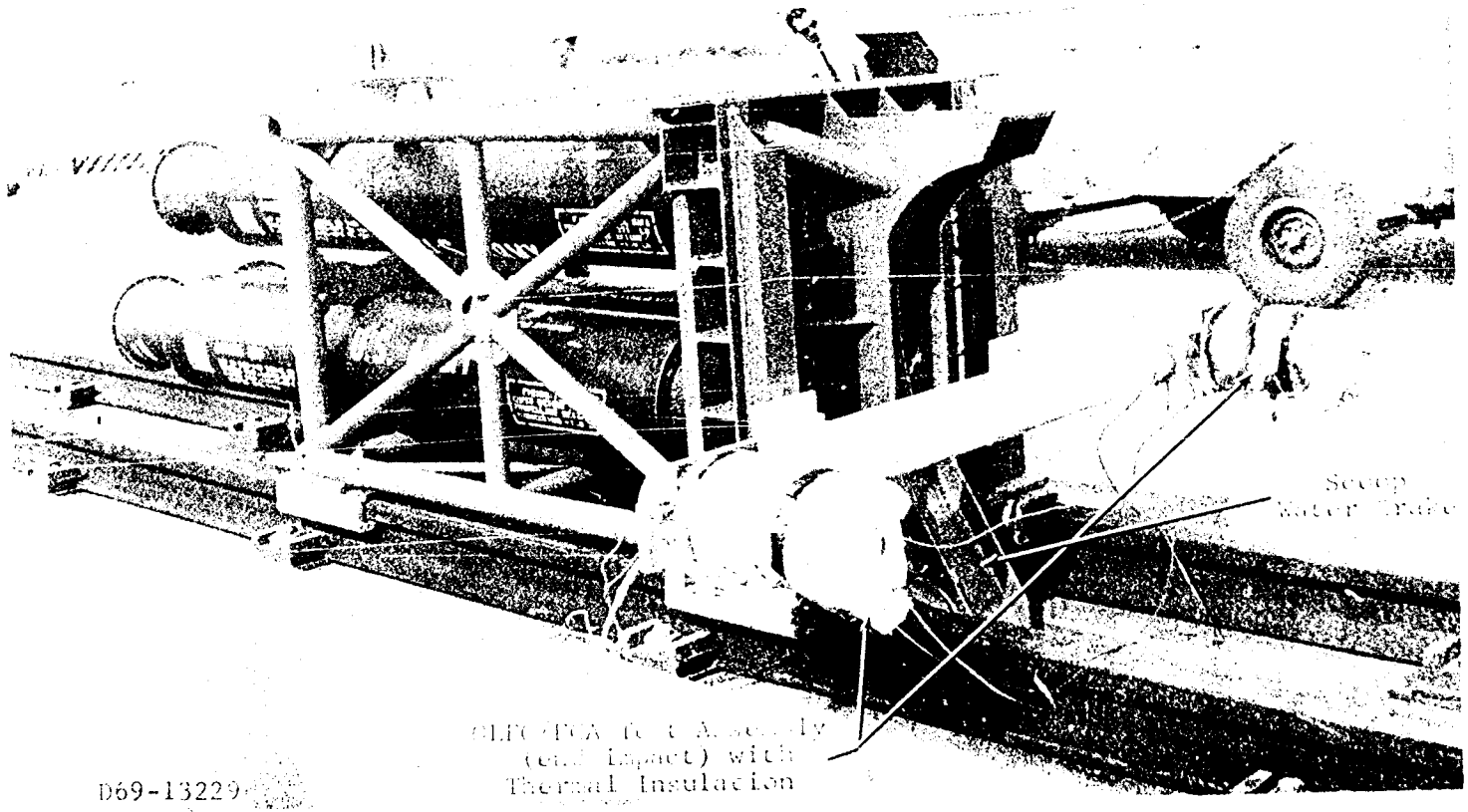
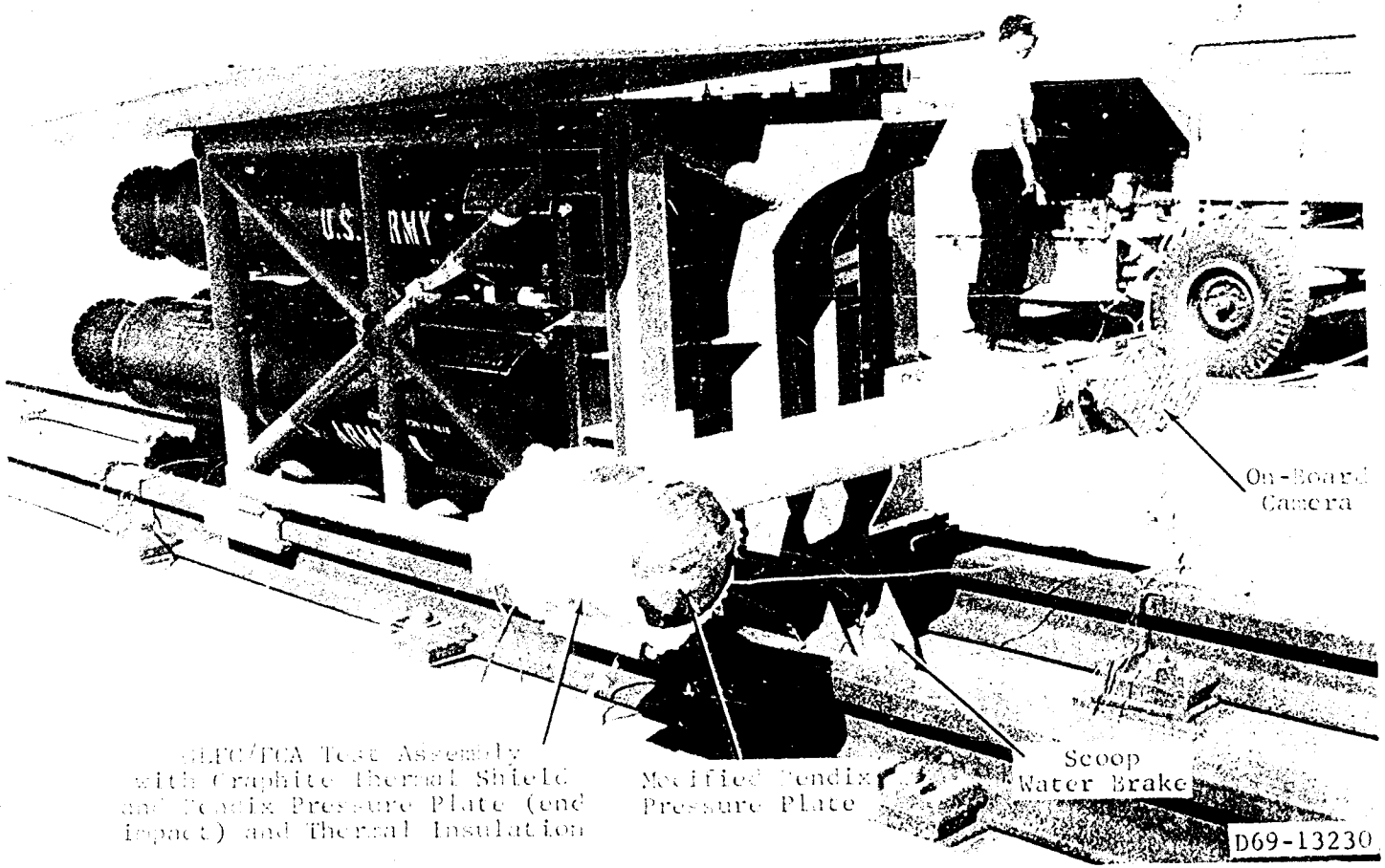


Figure 4. SNAP-27 GLFC/FCA test assembly (side impact)



a.

Figure 5. Dual rail sled



b.

Figure 5. (continued)

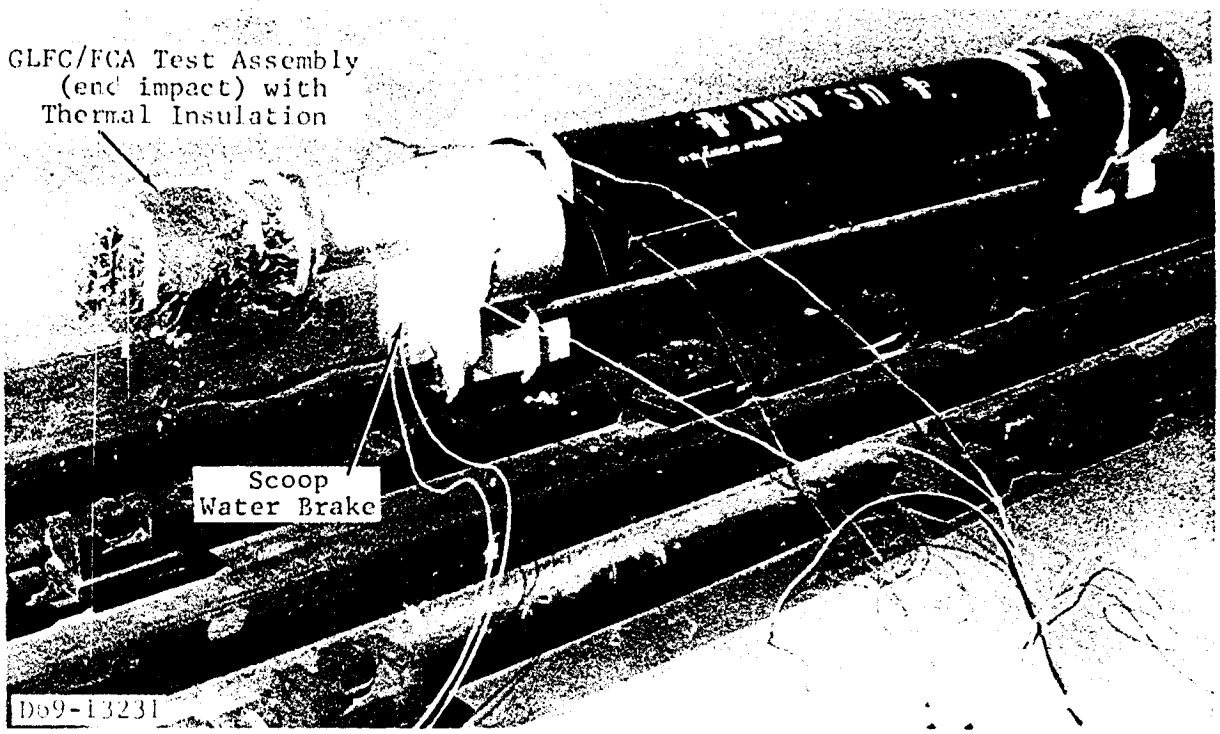


Figure 6. Monorail sled

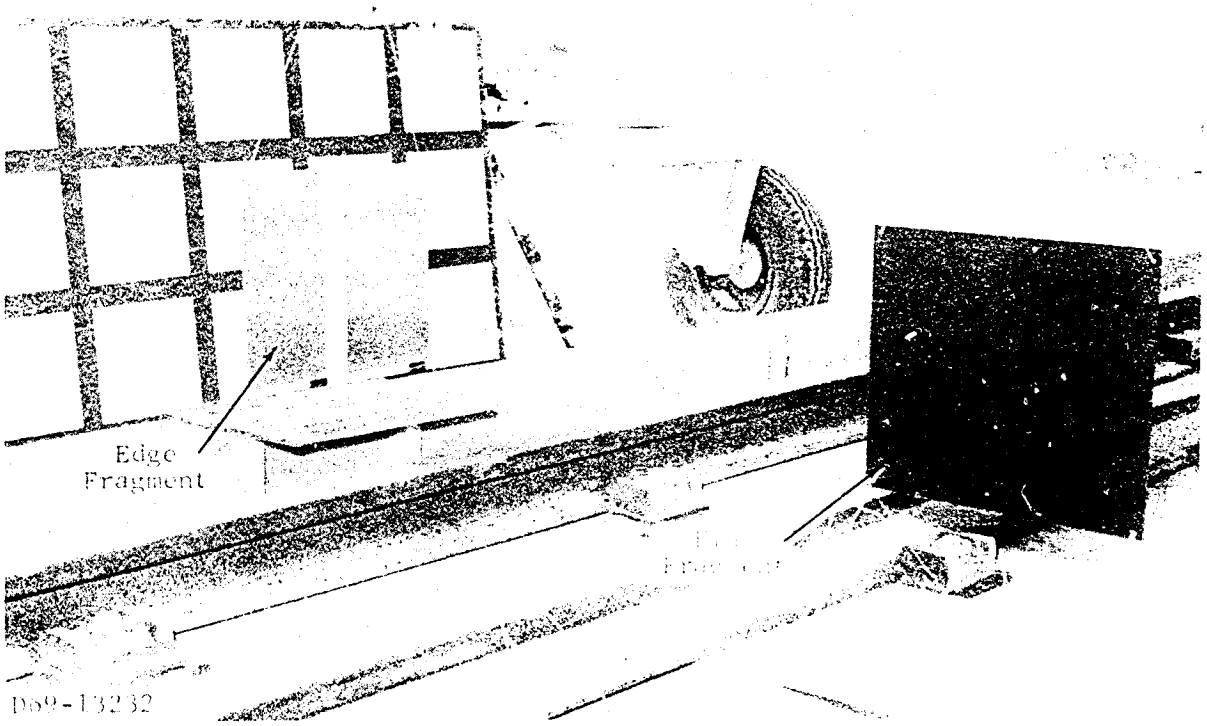
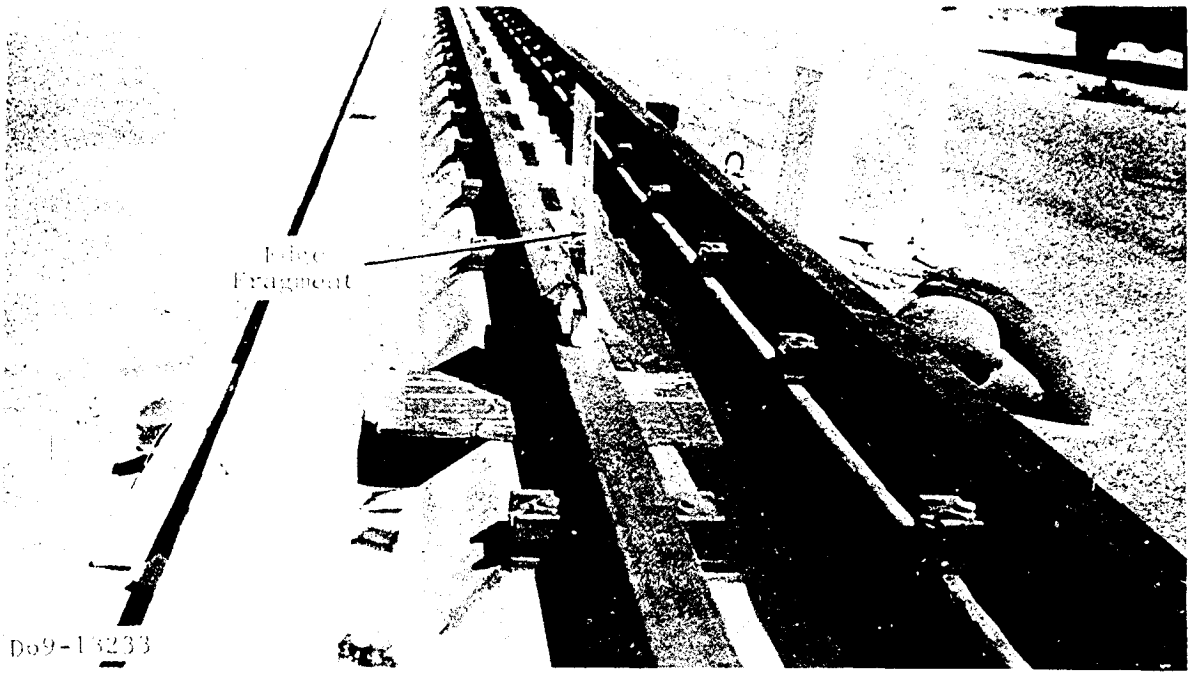
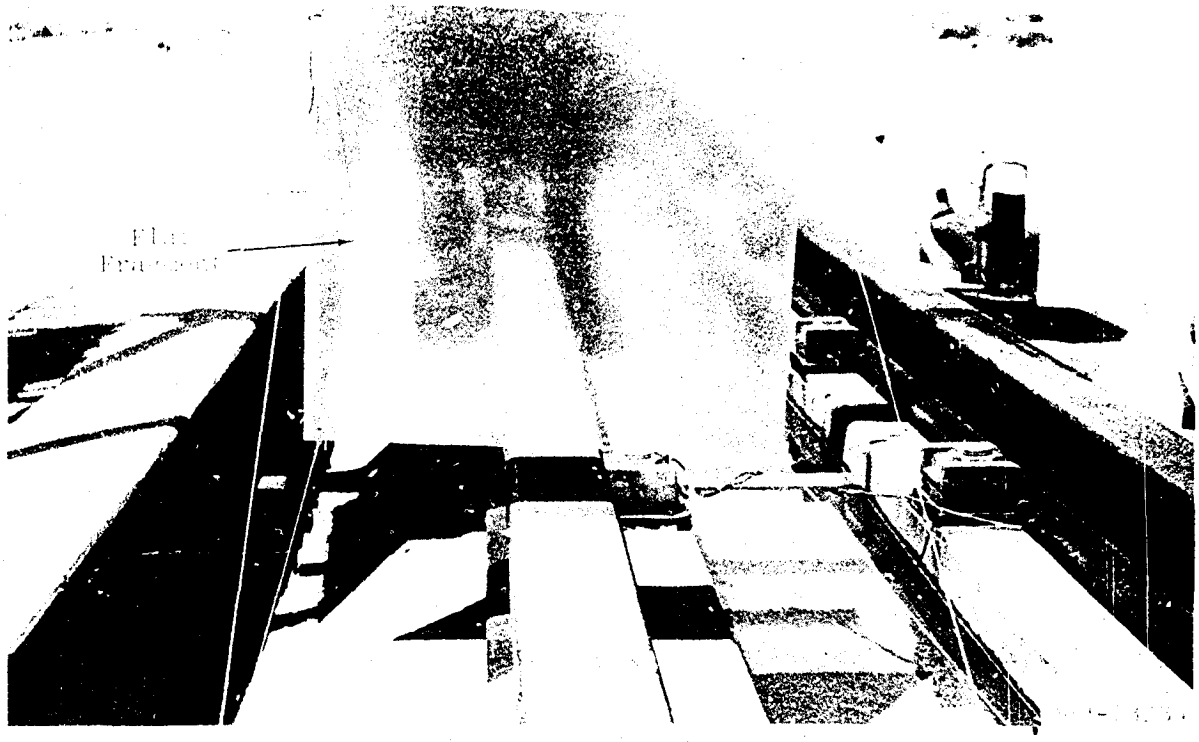


Figure 7. Fragment mounting along track (dual rail sled)

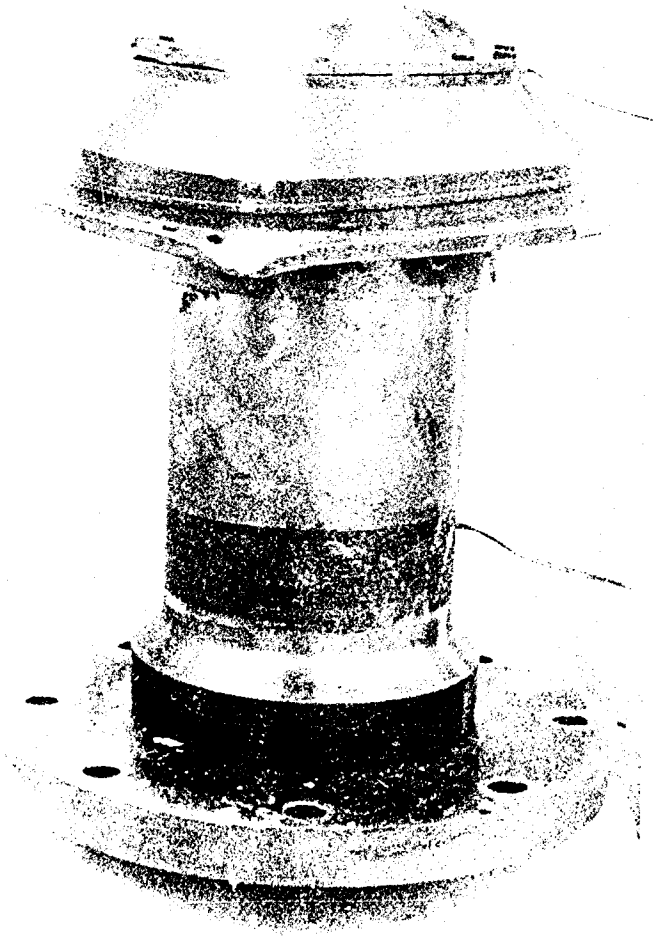


a.



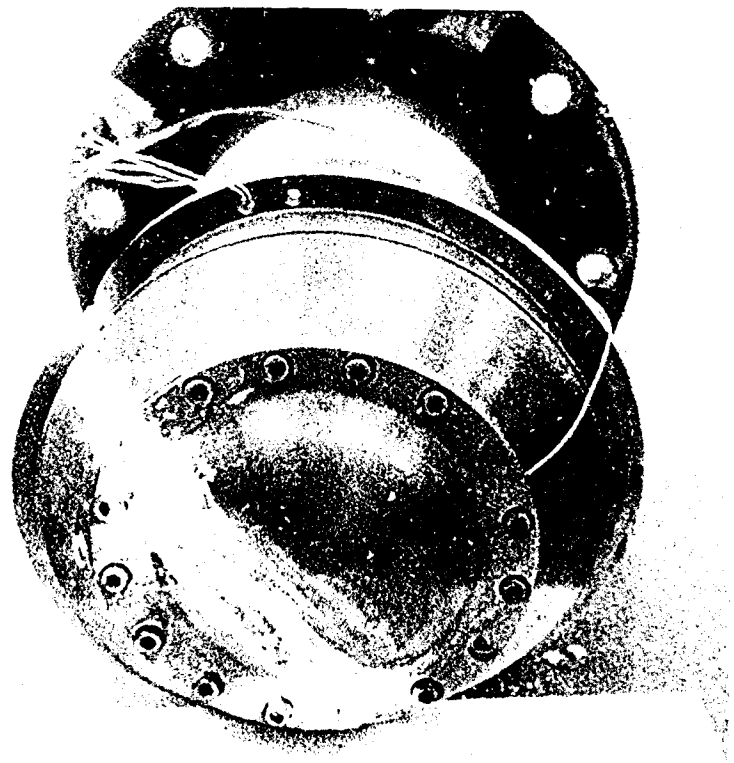
b.

Figure 8. Fragment mounting along track (monorail sled)



EDGE ON

a.



EDGE ON

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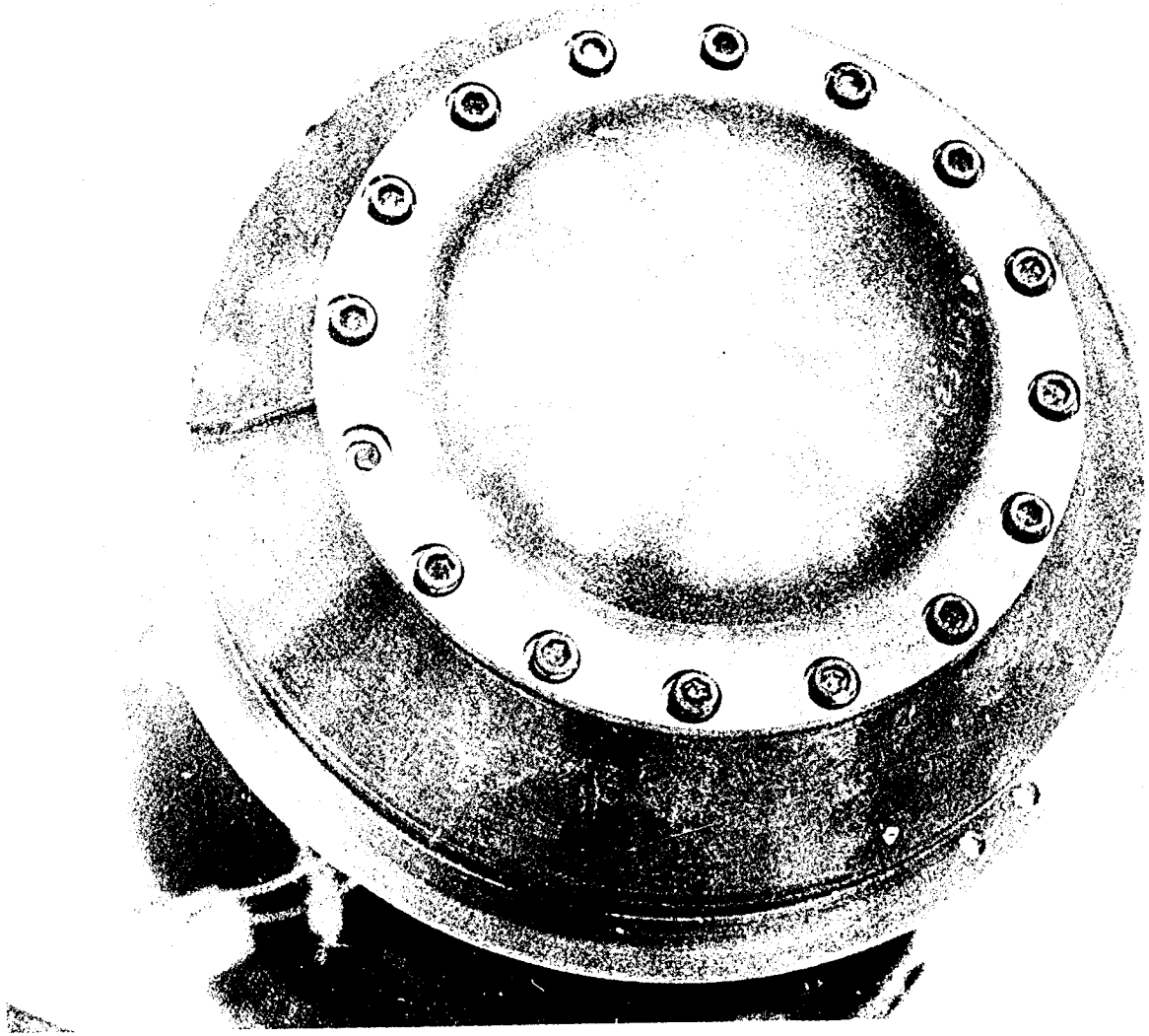
b.

Figure 9. Test 1--GLFC/FCA test assembly (end impact); edge fragment impact; velocity 1025 fps

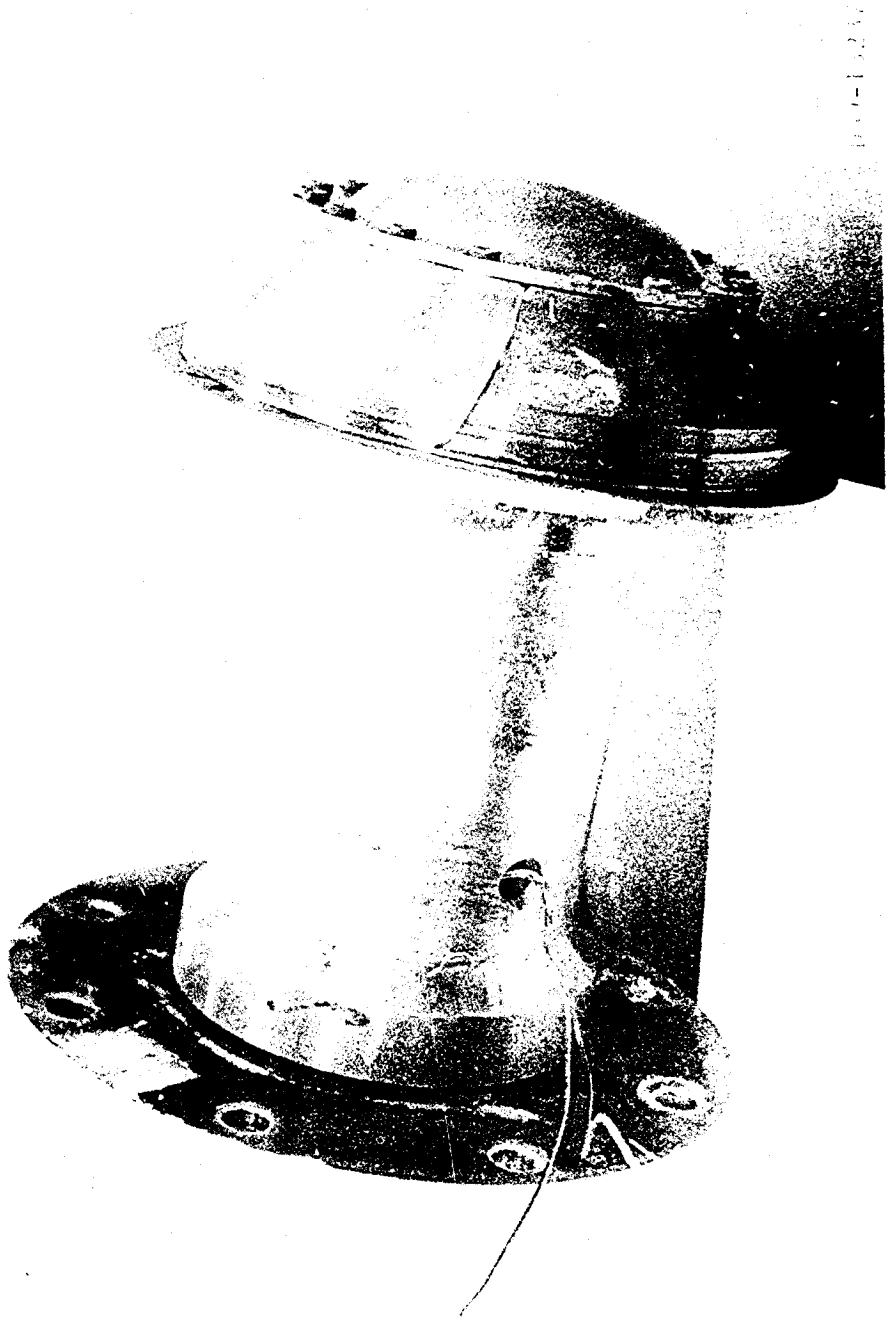
[redacted]



a. Flat fragment impact

Figure 10. Test 2--GLFC/FCA test assembly (end impact); velocity 1025 fps

[redacted]

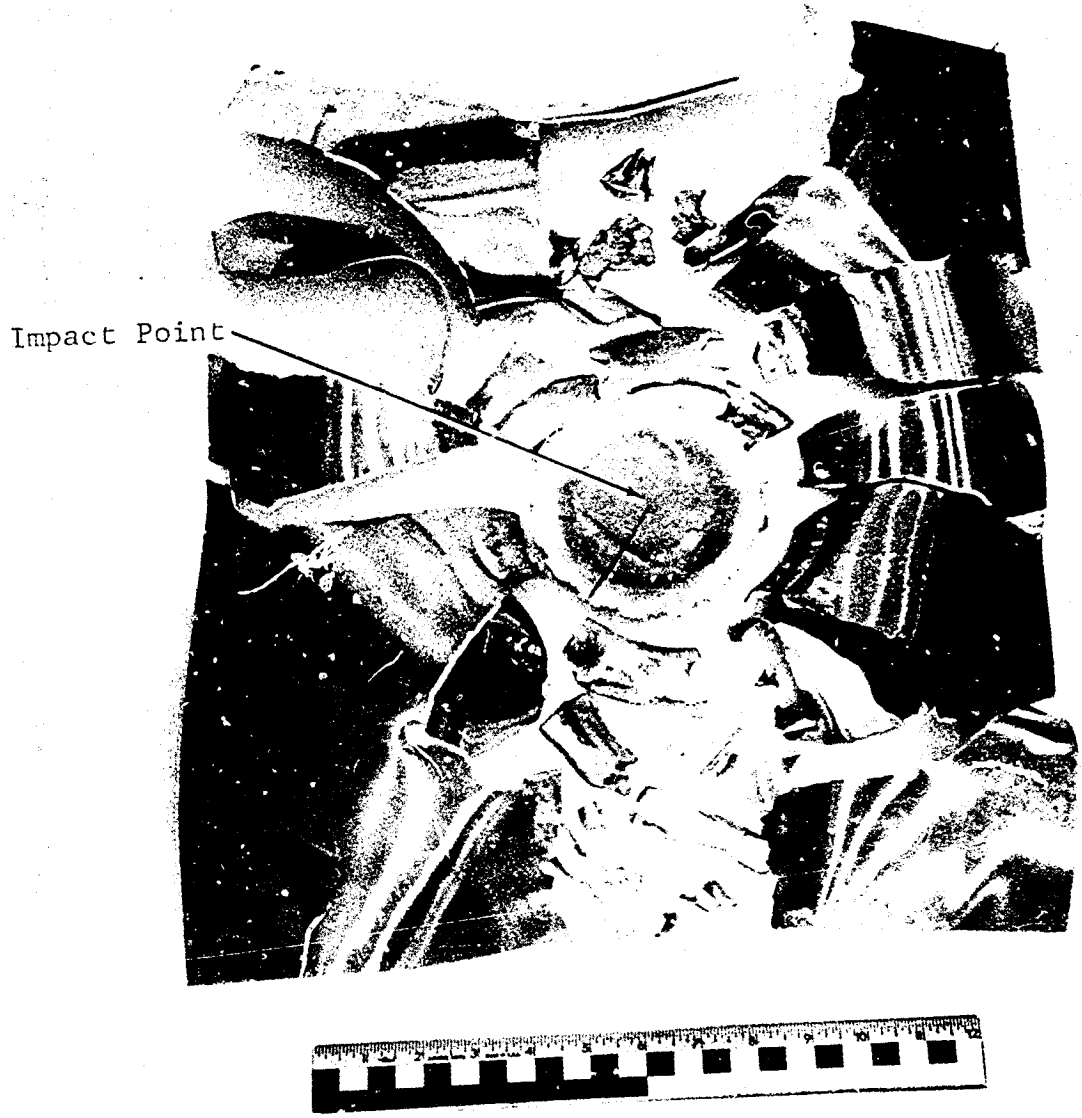


b. Flat fragment impact

Figure 10. (continued)

a. Edge fragment impact

Figure 11. Tests 1 and 2--fragments impacted into GLFC/FCA test assembly (end impact); velocity 1025 fps



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b. Flat fragment impact

Figure 11. (continued)

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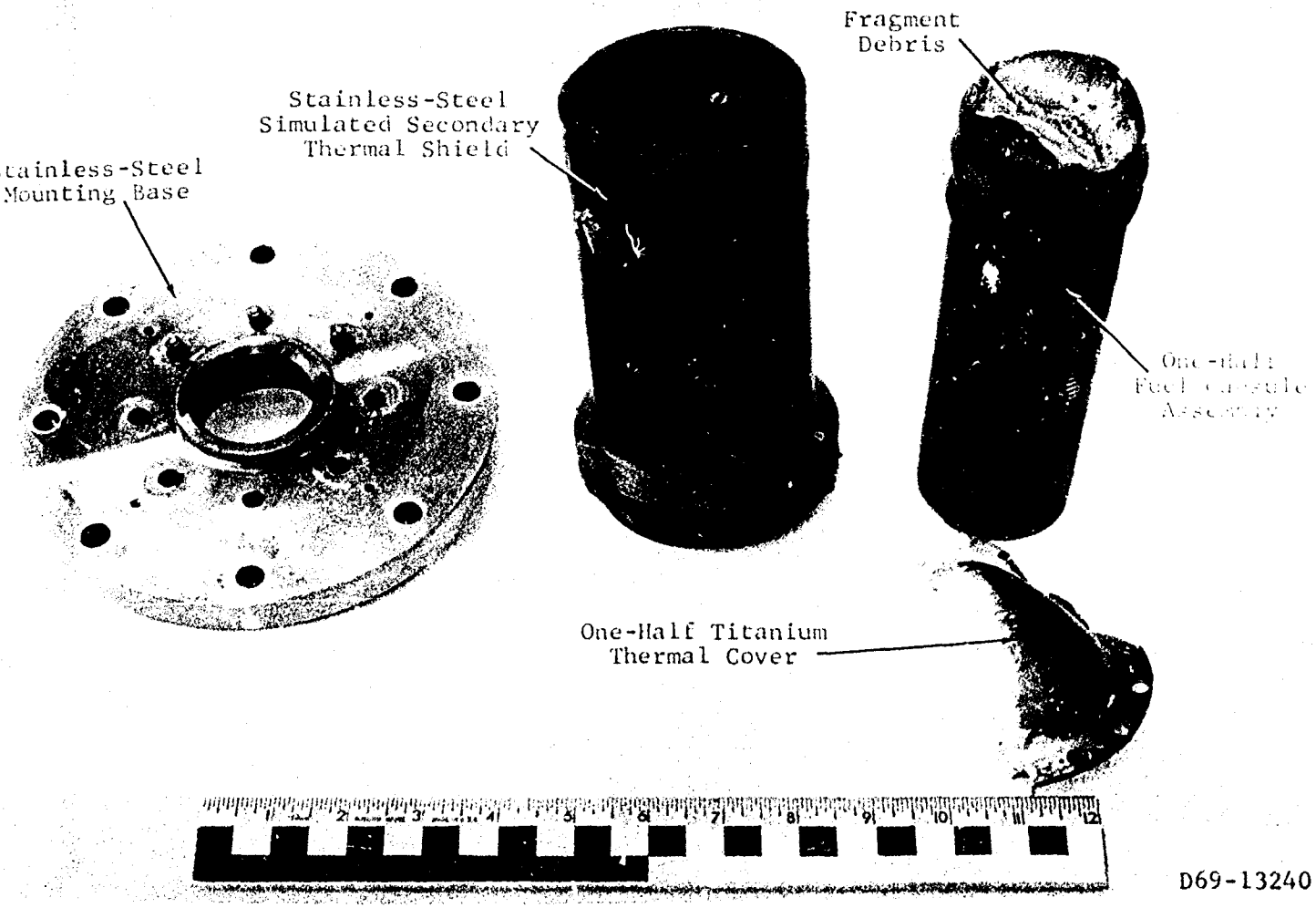

a.

Figure 12. Test 3--GLFC/FCA test assembly (end impact); edge fragment impact; velocity 1865 fps

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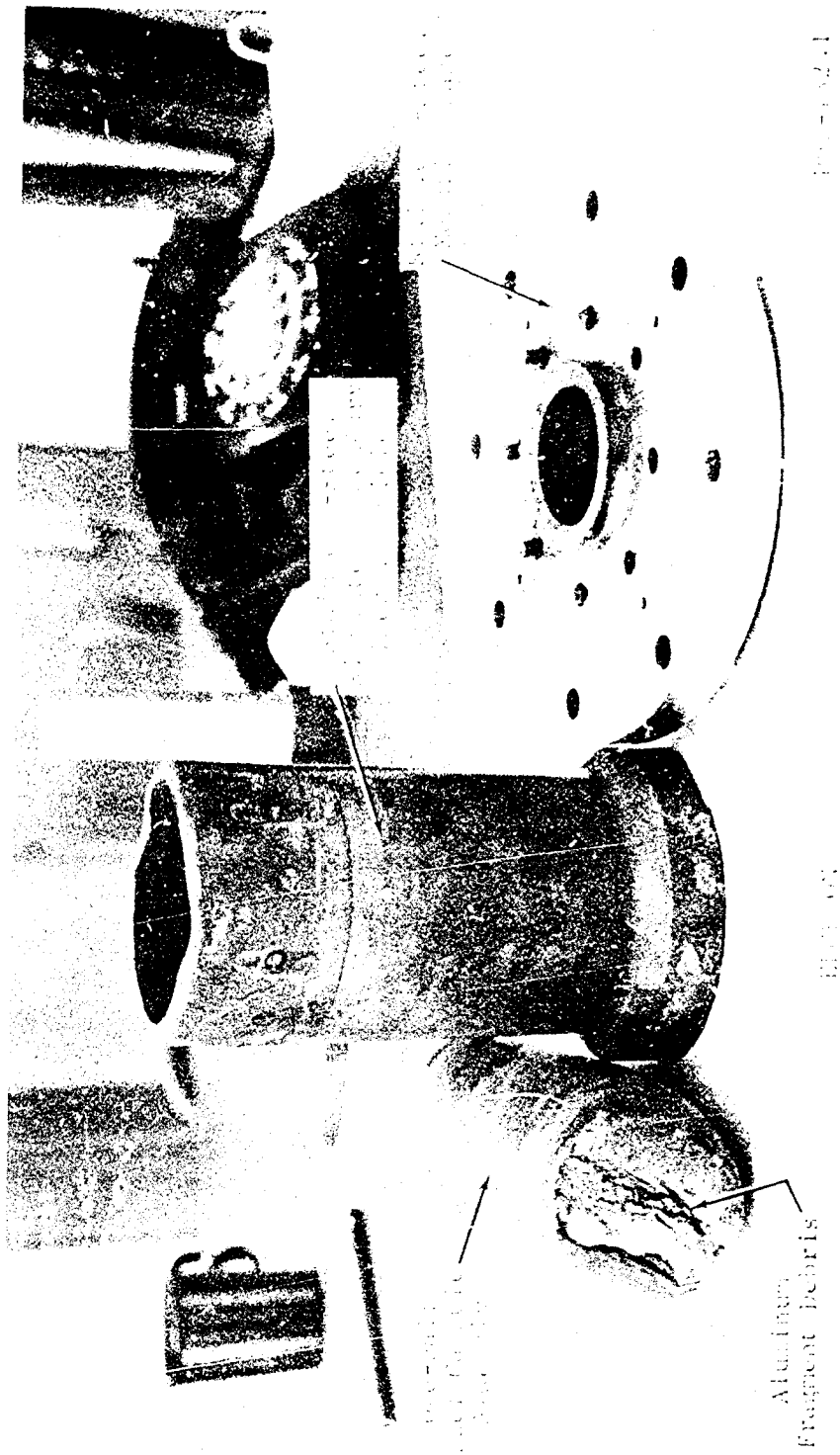
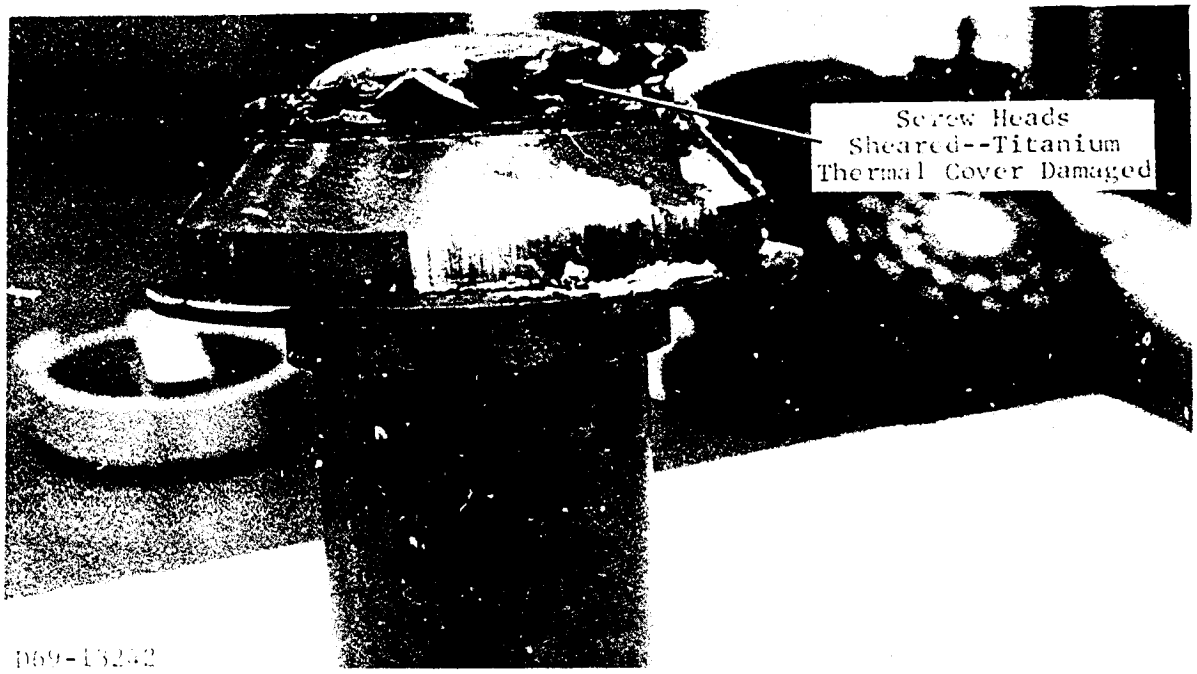


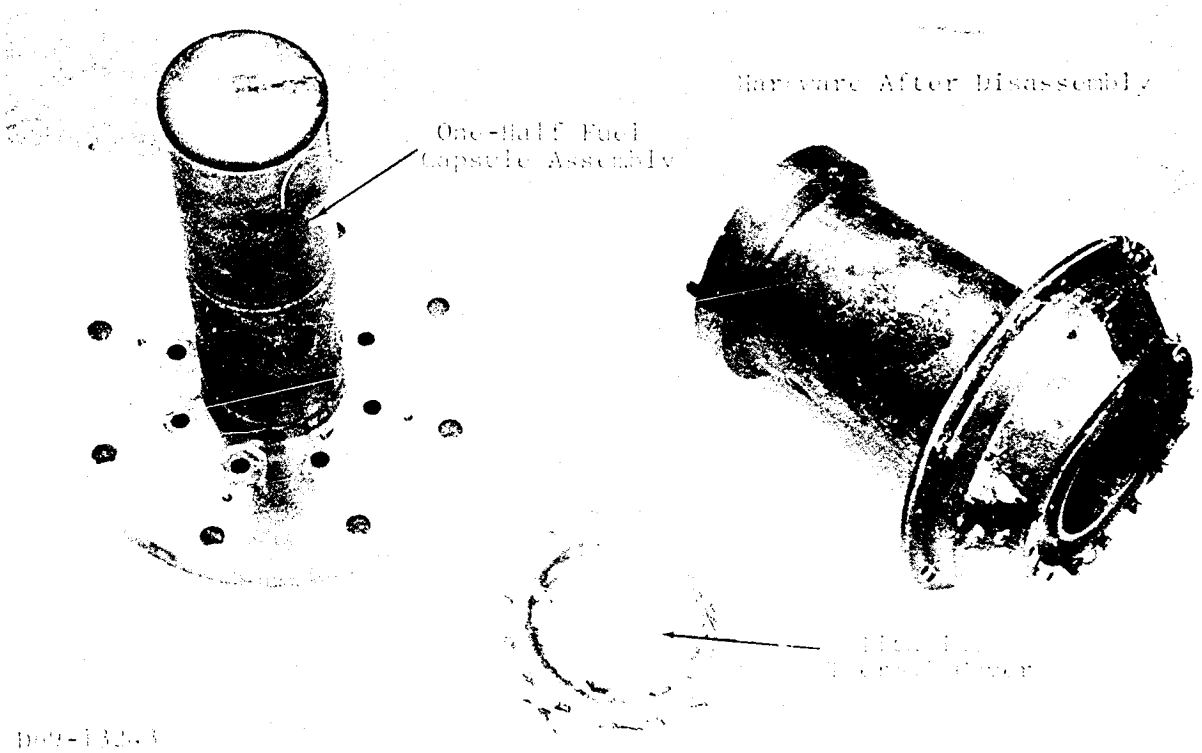
b.

Figure 12. (continued)

[redacted]

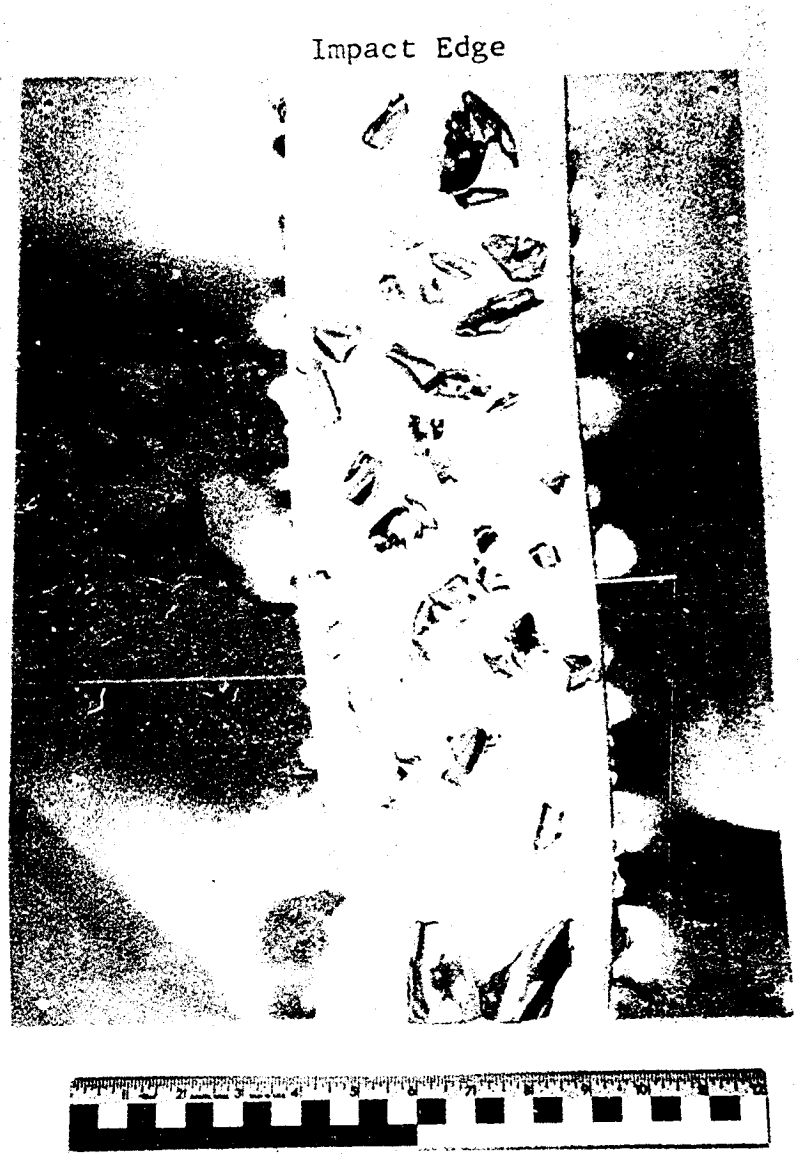


a.



b.

Figure 13. Test 4--GLFC/FCA test assembly (end impact); flat fragment impact; velocity 1865 fps



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a. Edge fragment impact

Figure 14. Tests 3 and 4--fragments impacted into GLFC/FCA test assembly (end impact); velocity 1865 fps

b. Flat fragment impact

Figure 14. (continued)

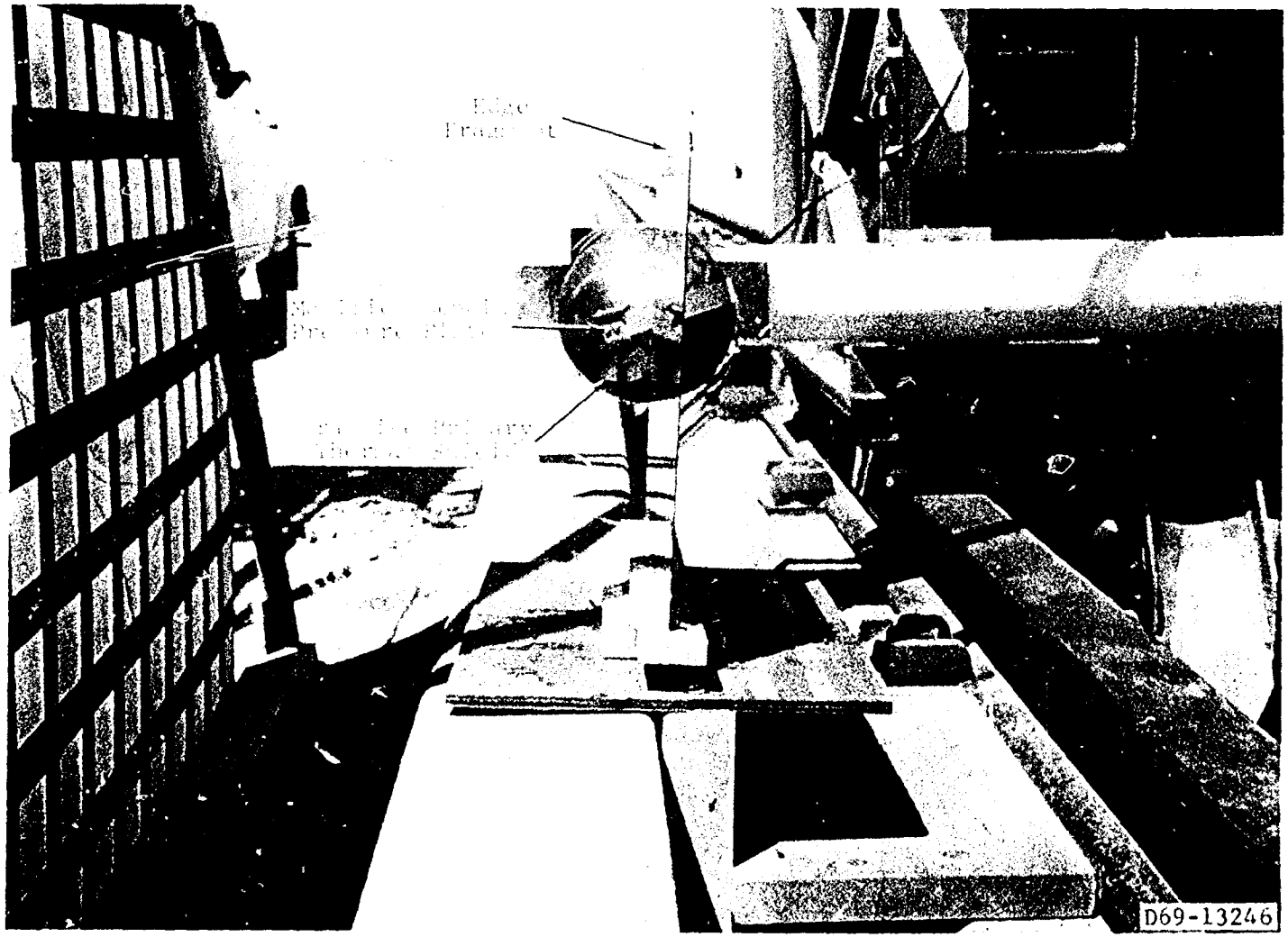
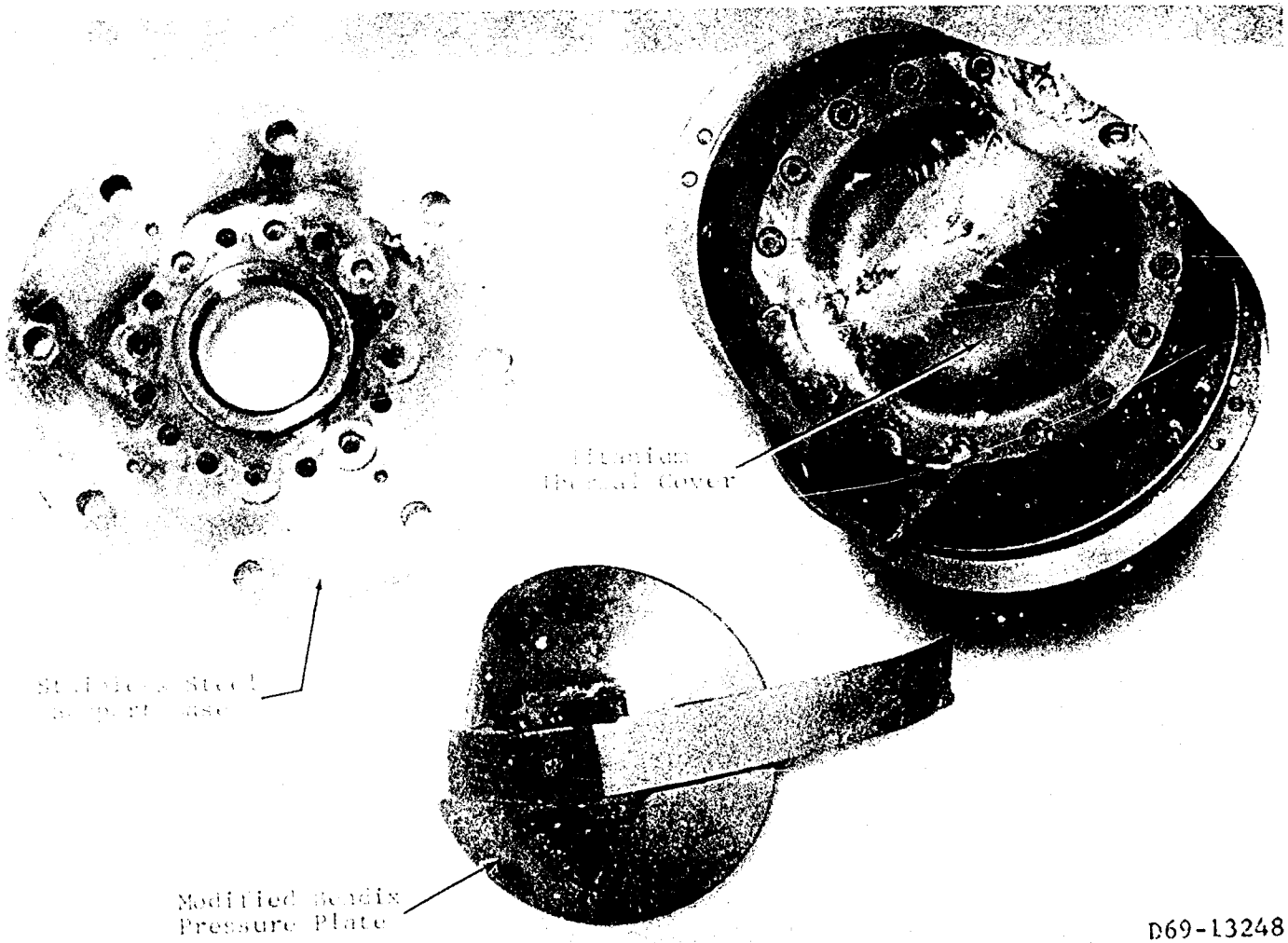


Figure 15. Test 5--GLFC/FCA test assembly (end impact) with graphite primary thermal shield and modified Bendix pressure plate; edge fragment; velocity 1830 fps

a.

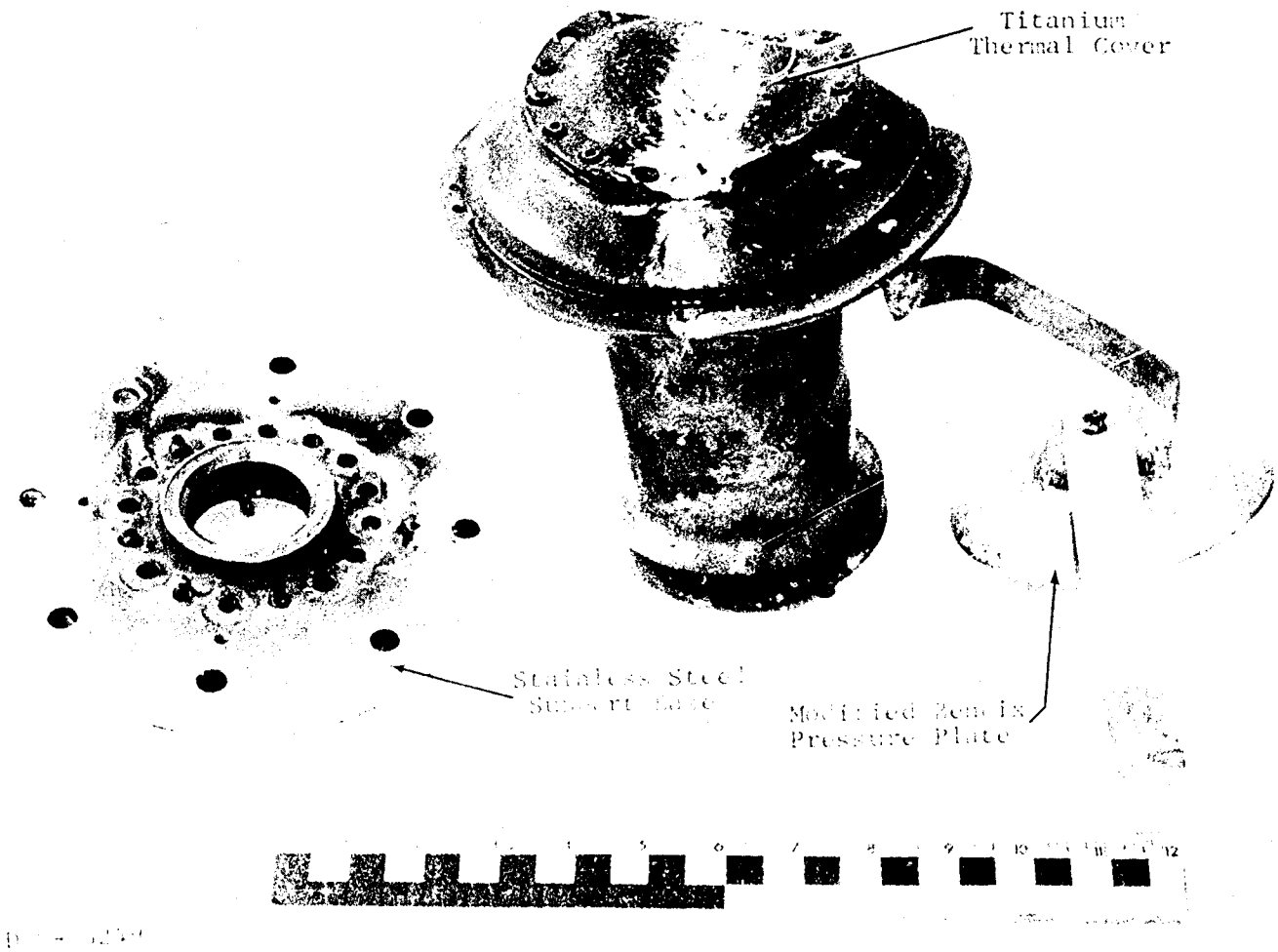
Figure 16. Test 5--GLFC/FCA test assembly (end impact) with graphite primary thermal shield and modified Bendix pressure plate; edge fragment impact; velocity 1830 fps



b.

Figure 16. (continued)

UNCLASSIFIED



c.

Figure 16. (continued)

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[redacted]

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Figure 17. Test 5--GLFC/FCA test assembly (end impact); edge fragment impact; velocity 1830 fps

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[redacted]

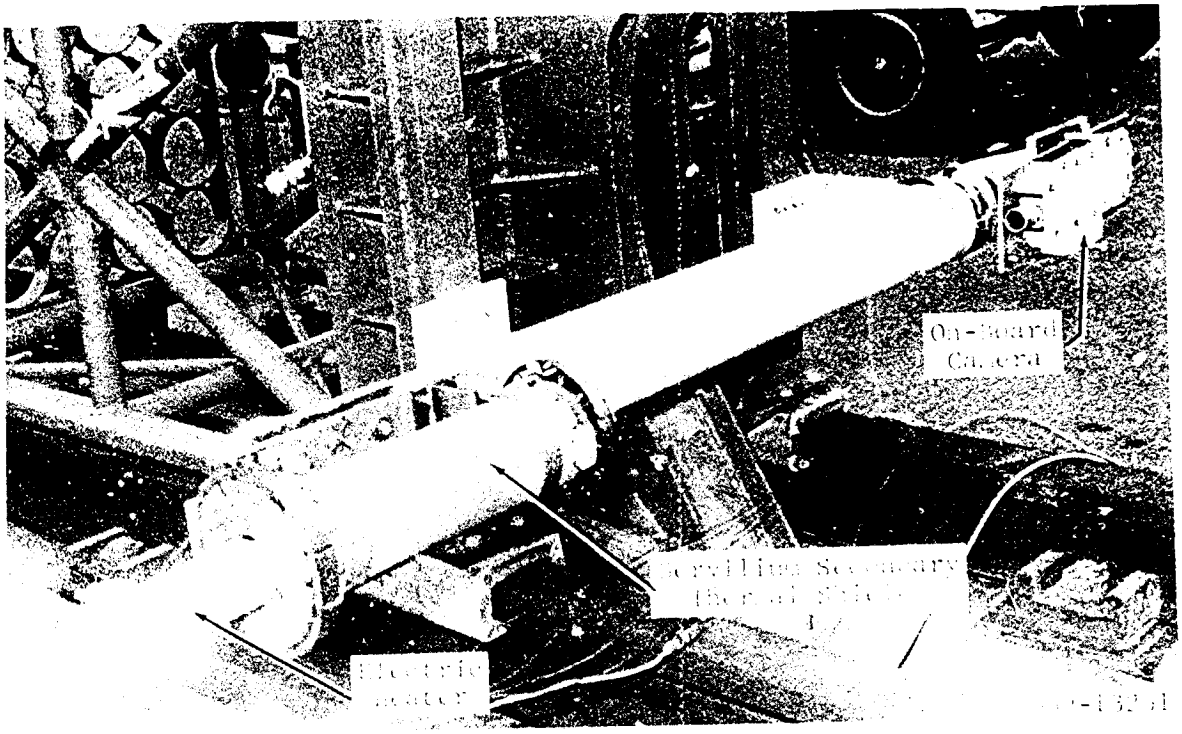

Figure 18. Test 6--GLFC/FCA test assembly (side impact); edge fragment; velocity 970 fps

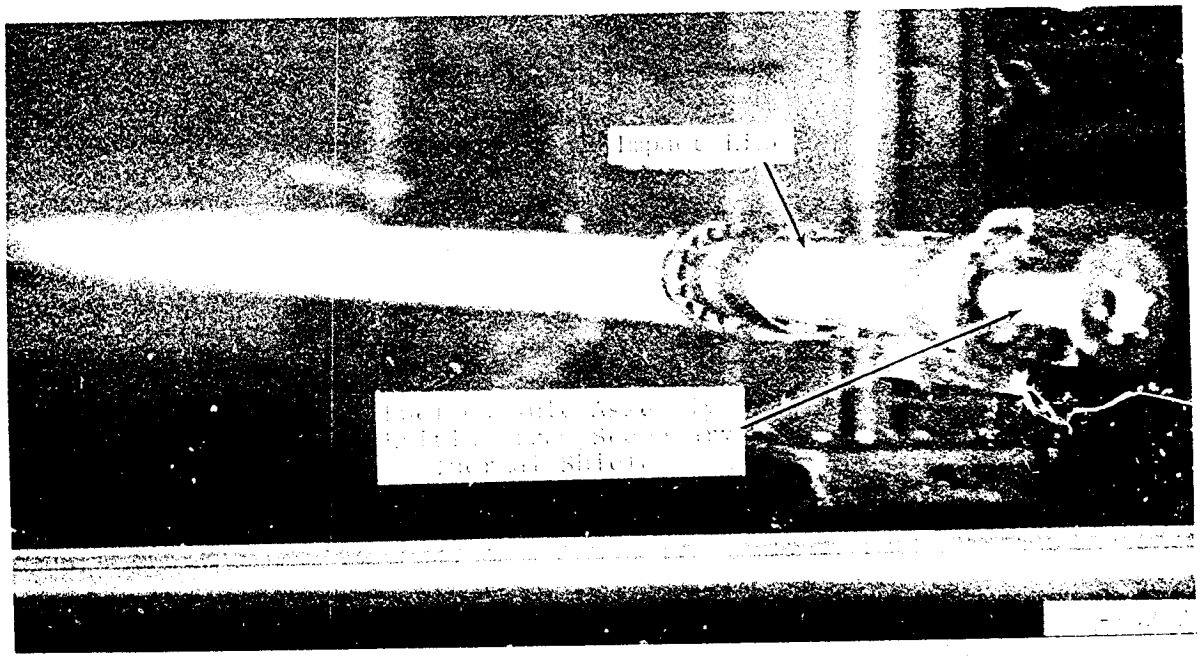

Figure 19. Test 6--GLFC/FCA test assembly (side impact) at impact plus 100 feet; edge fragment impact; velocity 970 fps

[redacted]

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Figure 20. Test 6--edge fragment impacted into GLFC/FCA test assembly (side impact); velocity 970 fps

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[redacted]

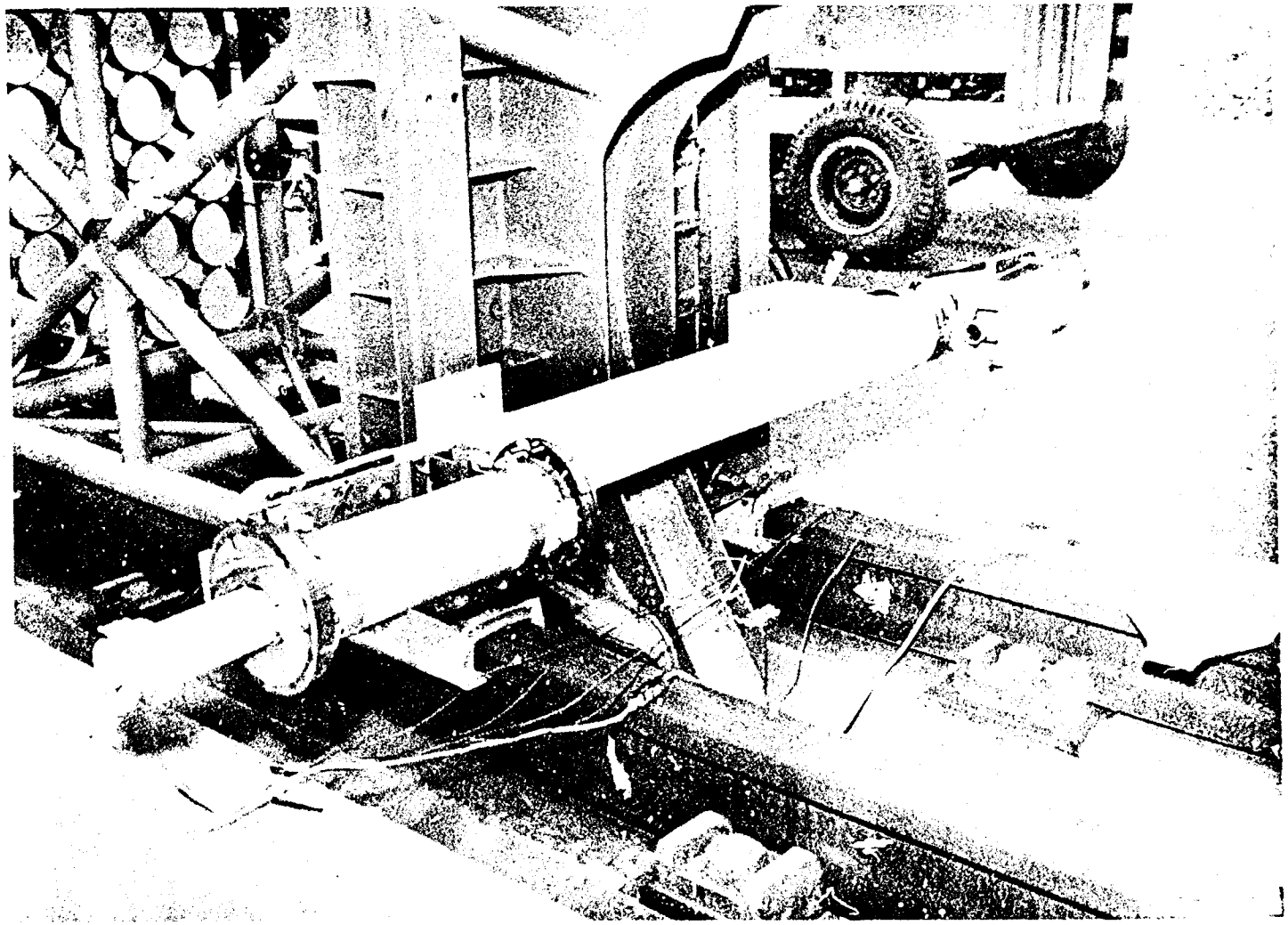


Figure 21. Test 7--GLFC/FCA test assembly (side impact); flat fragment impact; velocity 1040 fps

[redacted]

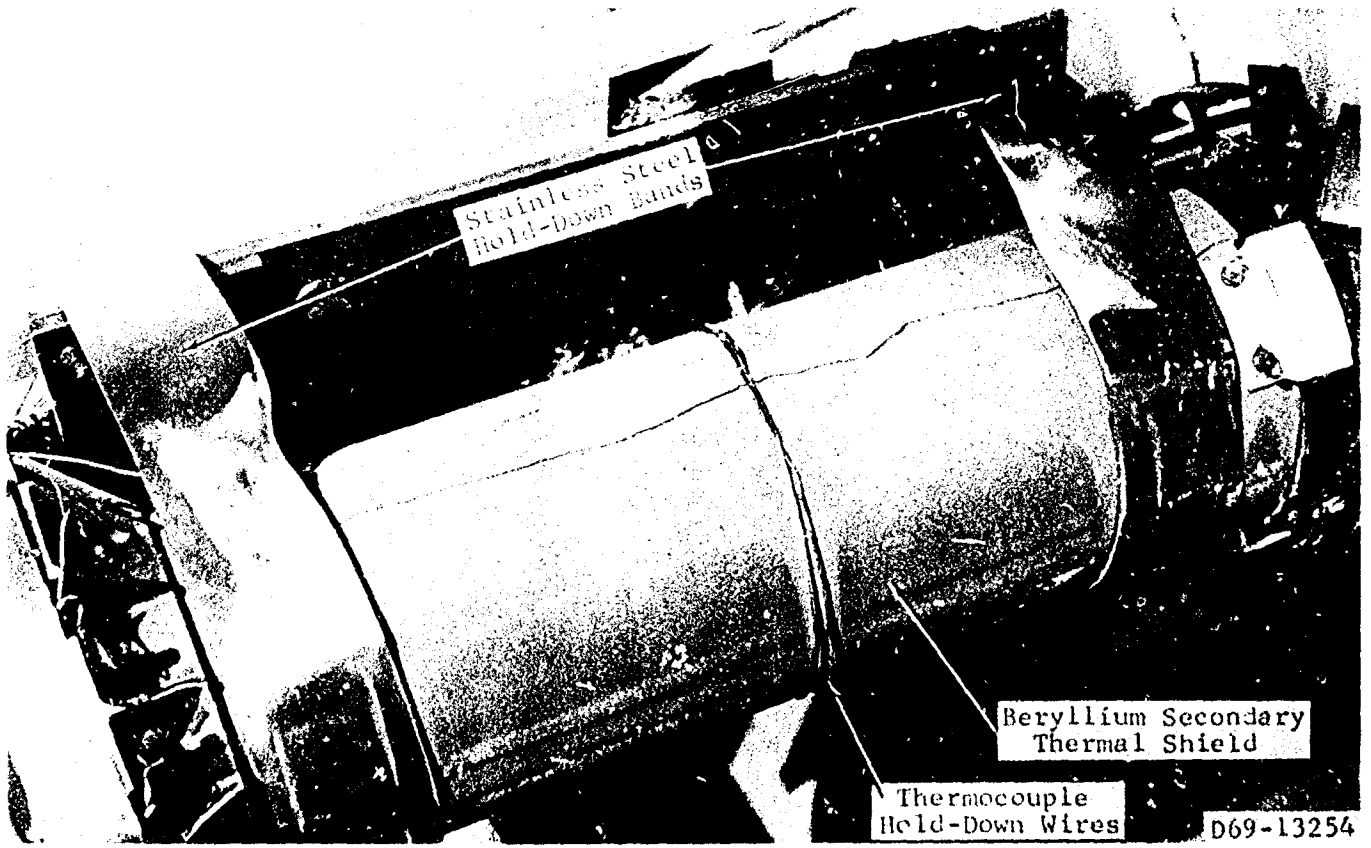


Figure 22. Test 7--GLFC/FCA test assembly (side impact); flat fragment impact; velocity 1040 fps

[redacted]

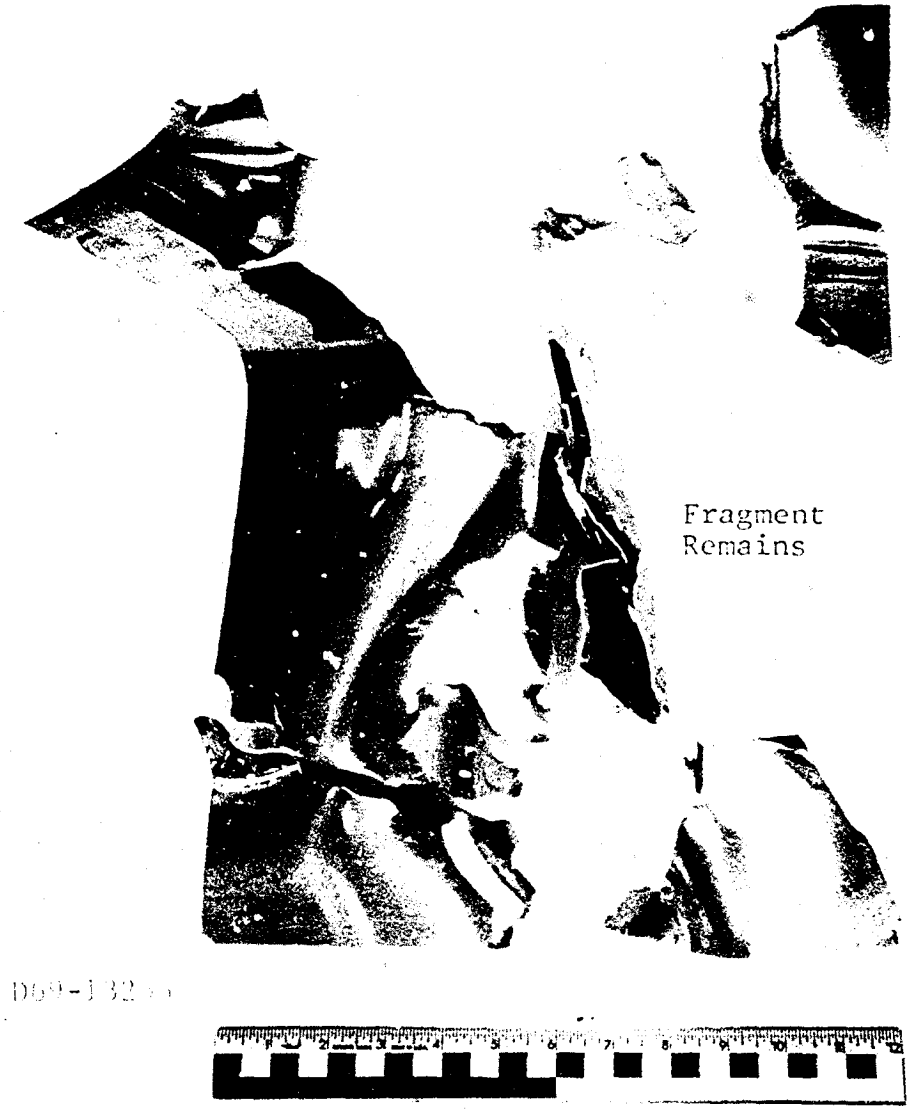
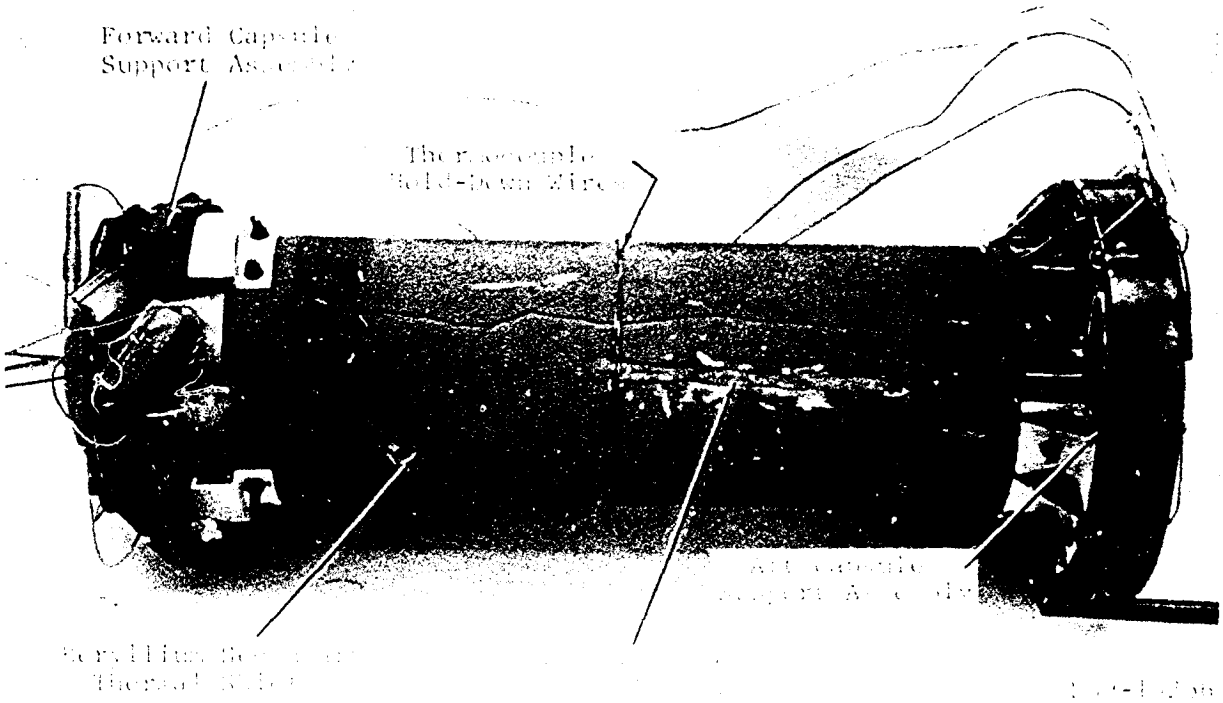


Figure 23. Test 7--GLFC/FCA test assembly (side impact); flat fragment impact; velocity 1040 fps



a.

b.

Figure 24. Test 7--GLFC/FCA test assembly (side impact); flat fragment impact; velocity 1040 fps

UNCLASSIFIED

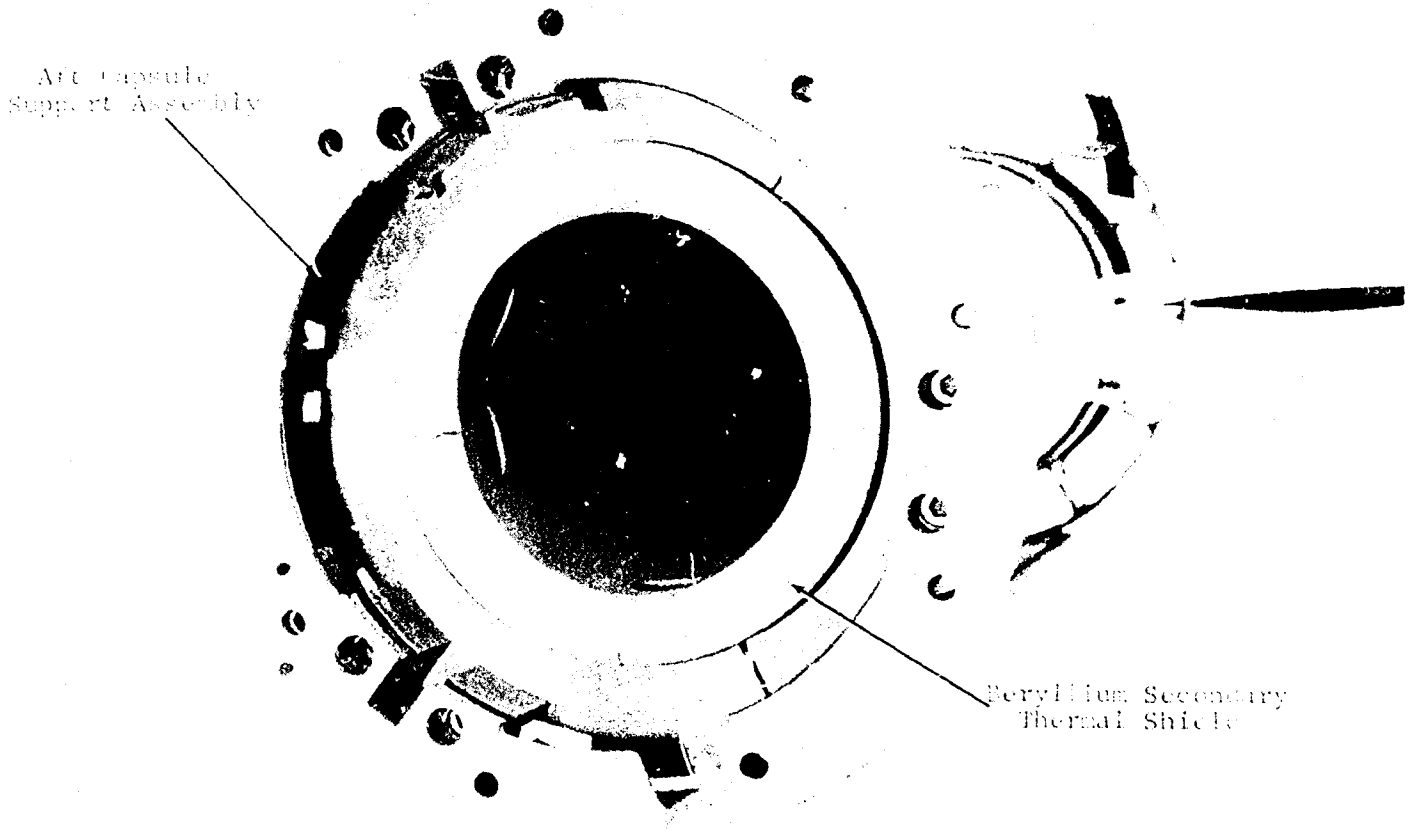


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Figure 25. Test 7--GLFC/FCA test assembly (side impact); flat fragment impact; velocity 1040 fps

UNCLASSIFIED

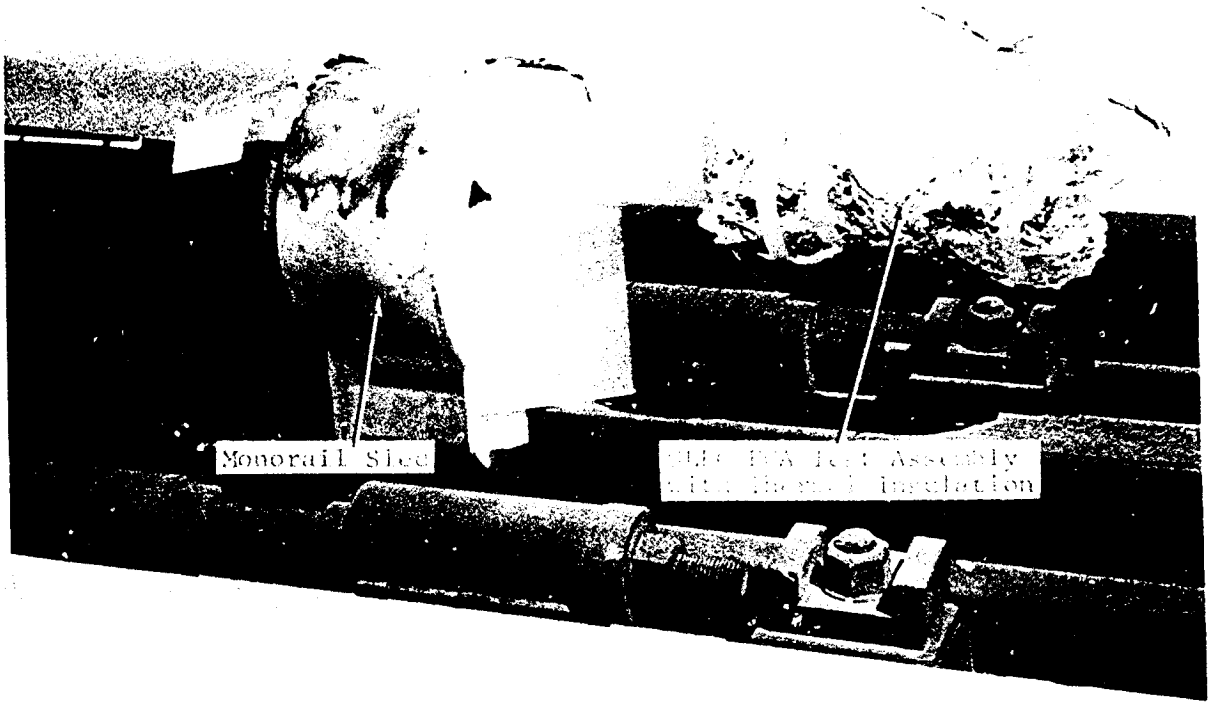


Figure 26. Test 8--GLFC/FCA test assembly (end impact); flat fragment impact; velocity 3200 fps

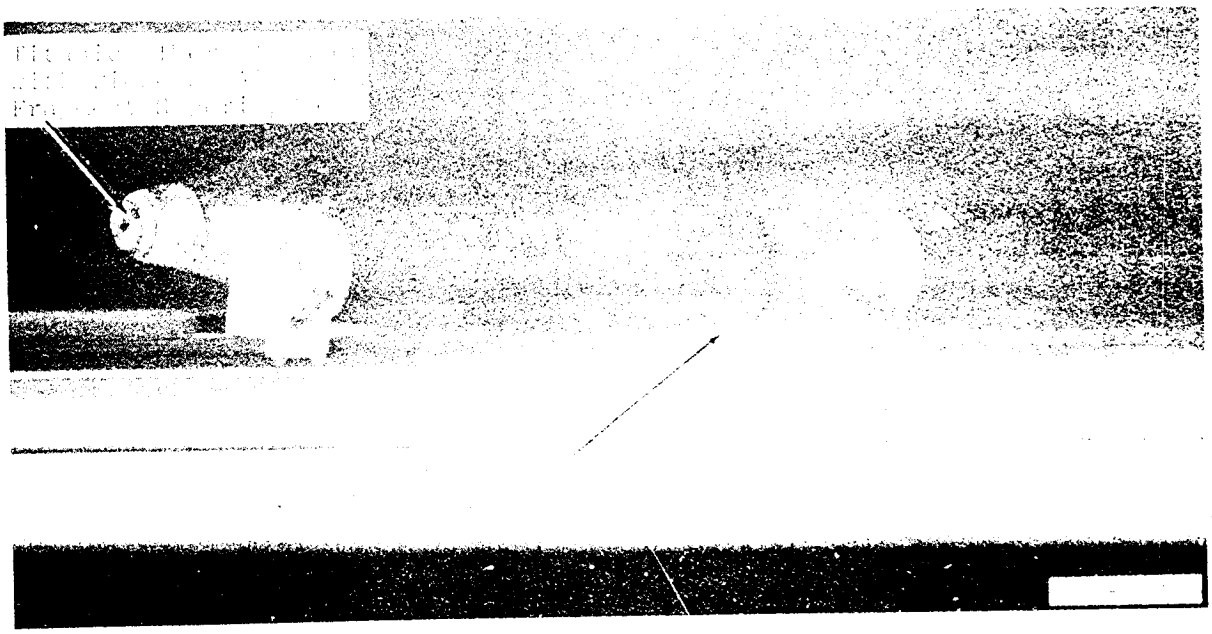
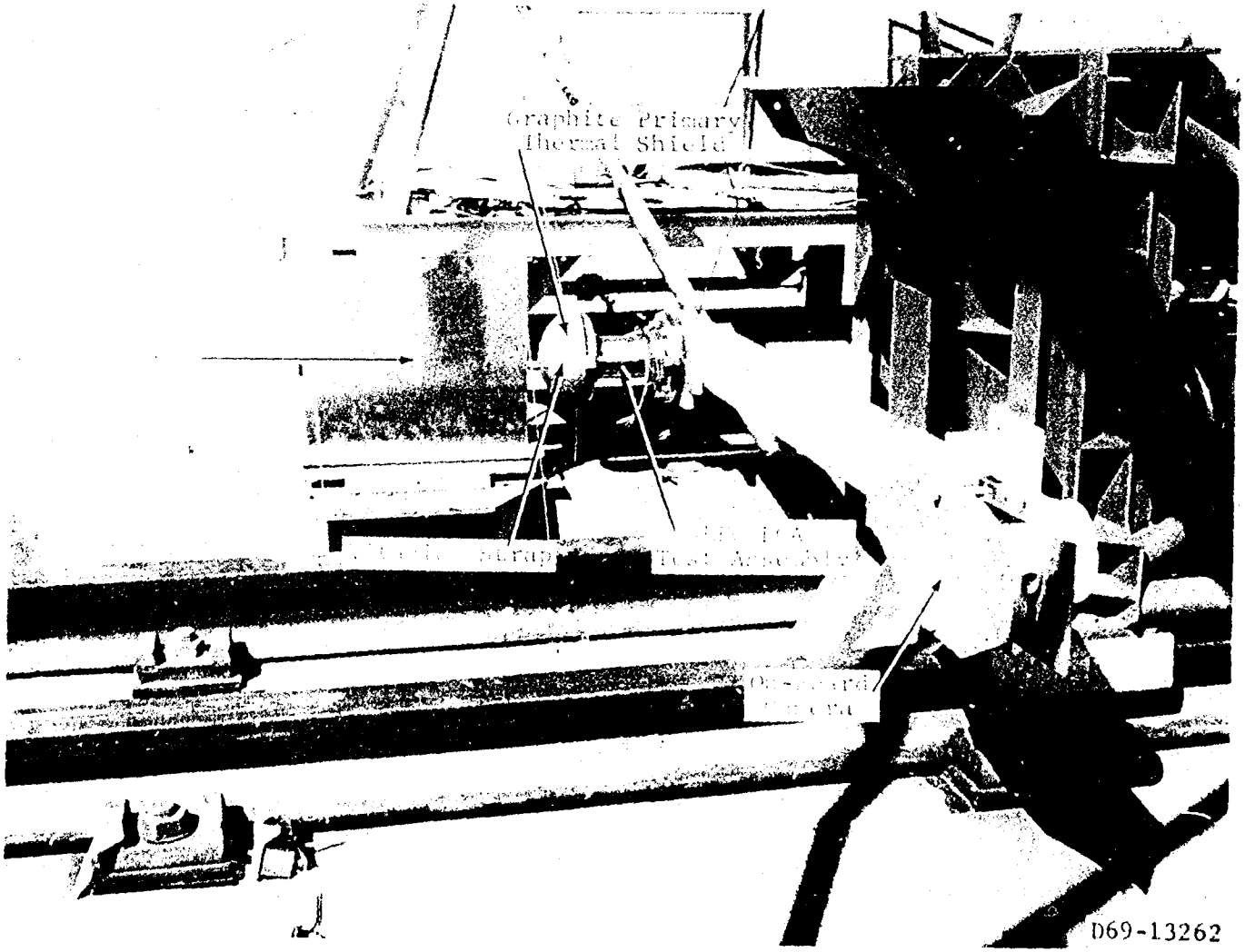


Figure 27. Test 8--GLFC/FCA test assembly (end impact); flat fragment impact; velocity 3200 fps

a.

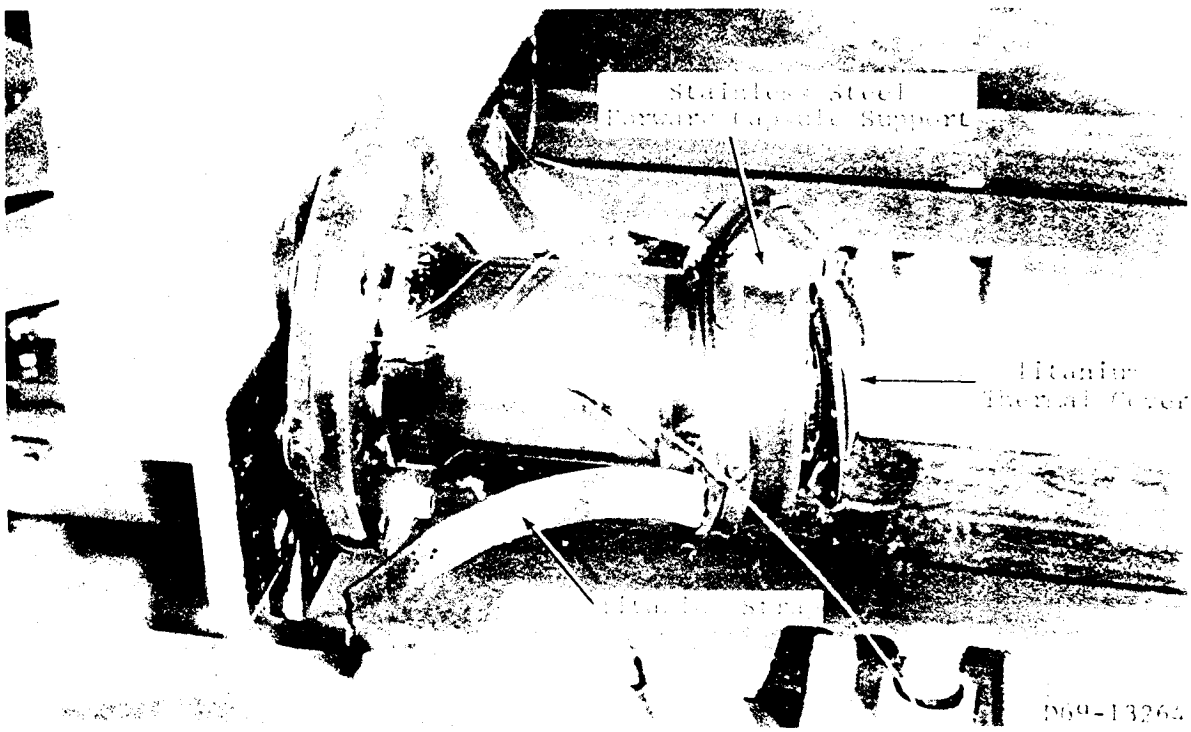
Figure 28. Test 9--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment impact; velocity 1820 fps



b.

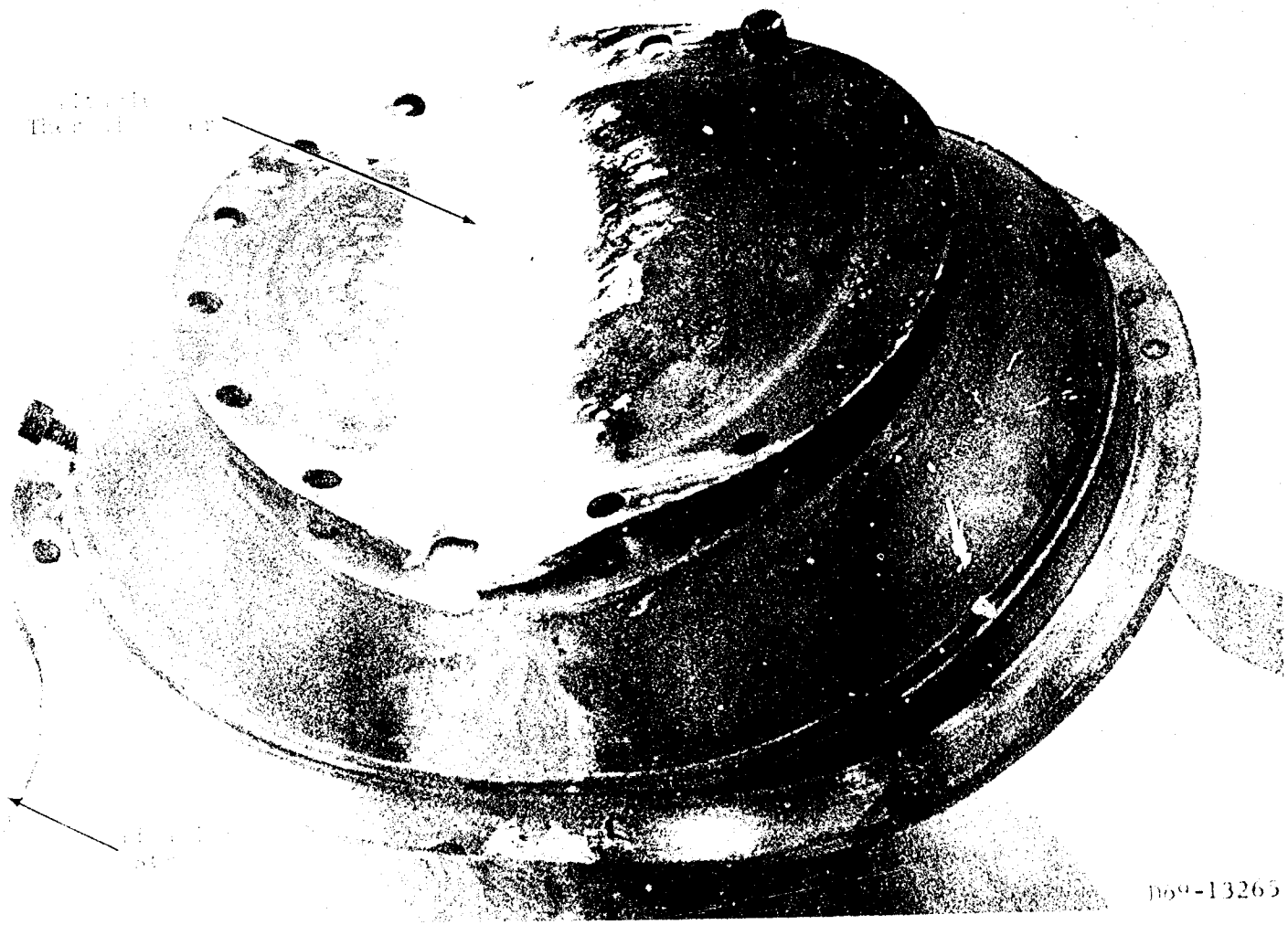
Figure 28. (continued)

a.



b.

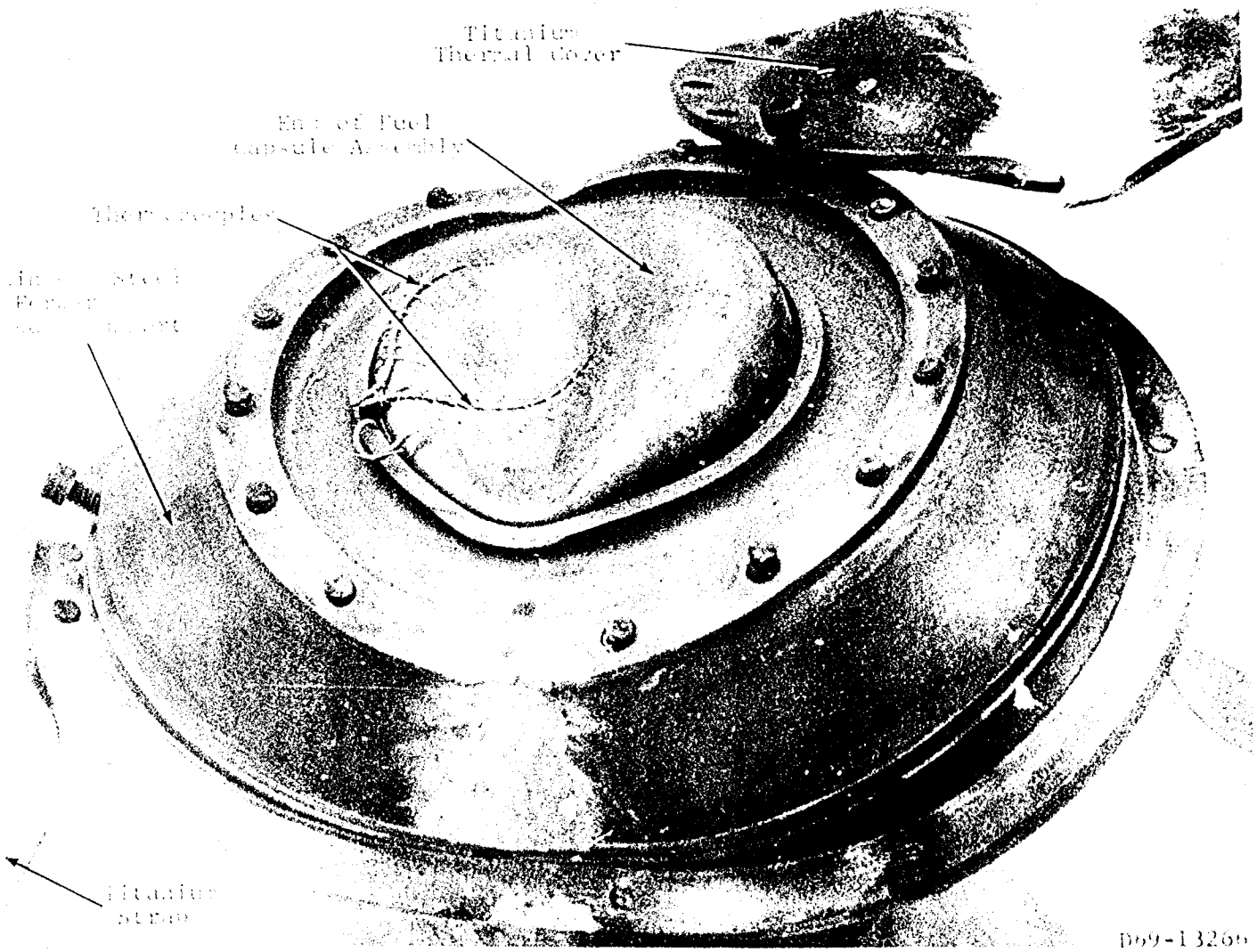
Figure 29. Test 9--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment impact; velocity 1820 fps



a.

Figure 30. Test 9--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment impact; velocity 1820 fps

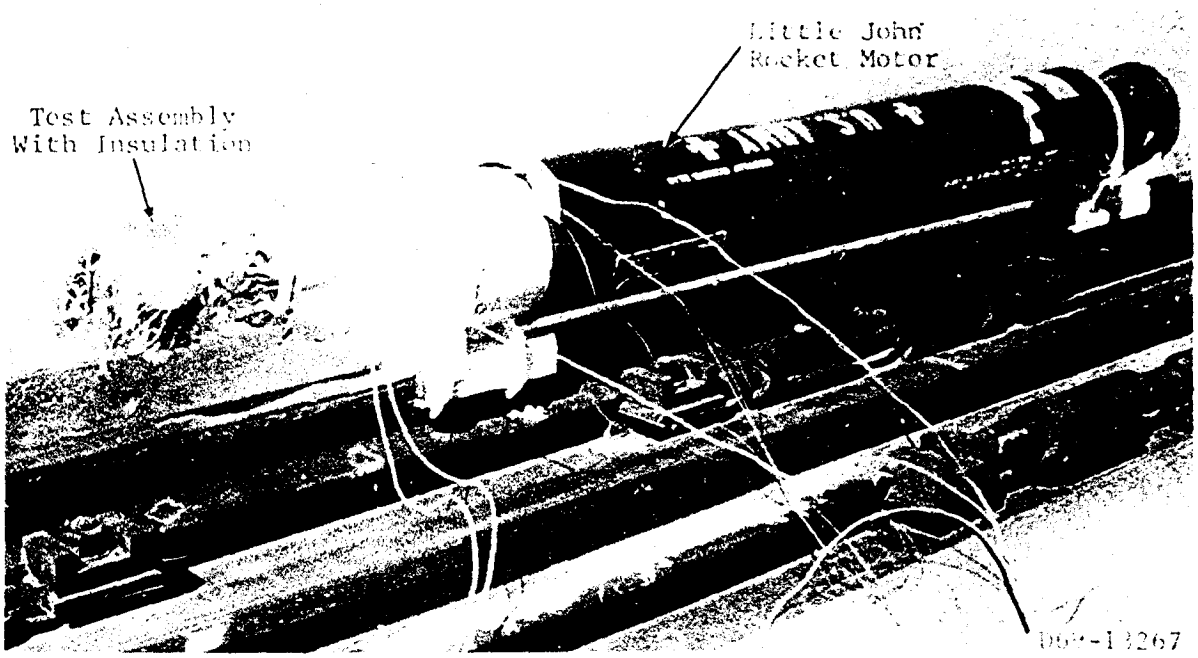
UNCLASSIFIED



b.

Figure 30. (continued)

UNCLASSIFIED



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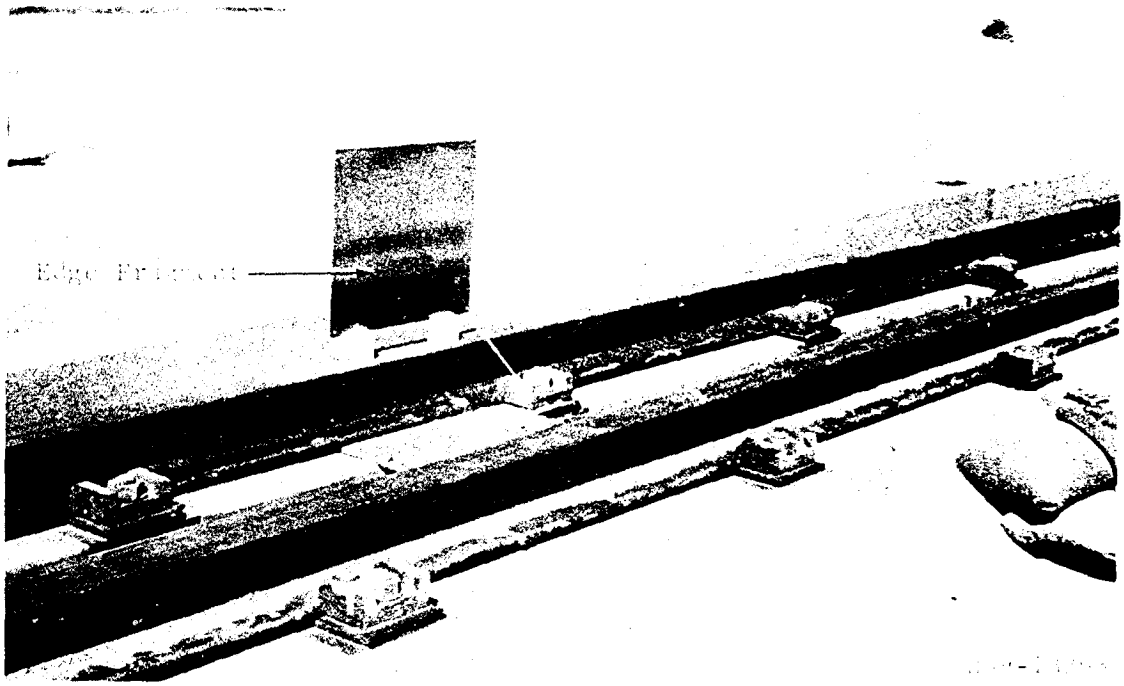


b.

Figure 31. Test 10--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment; velocity 2800 fps

Figure 32. Test 10--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment impact; velocity 2800 fps

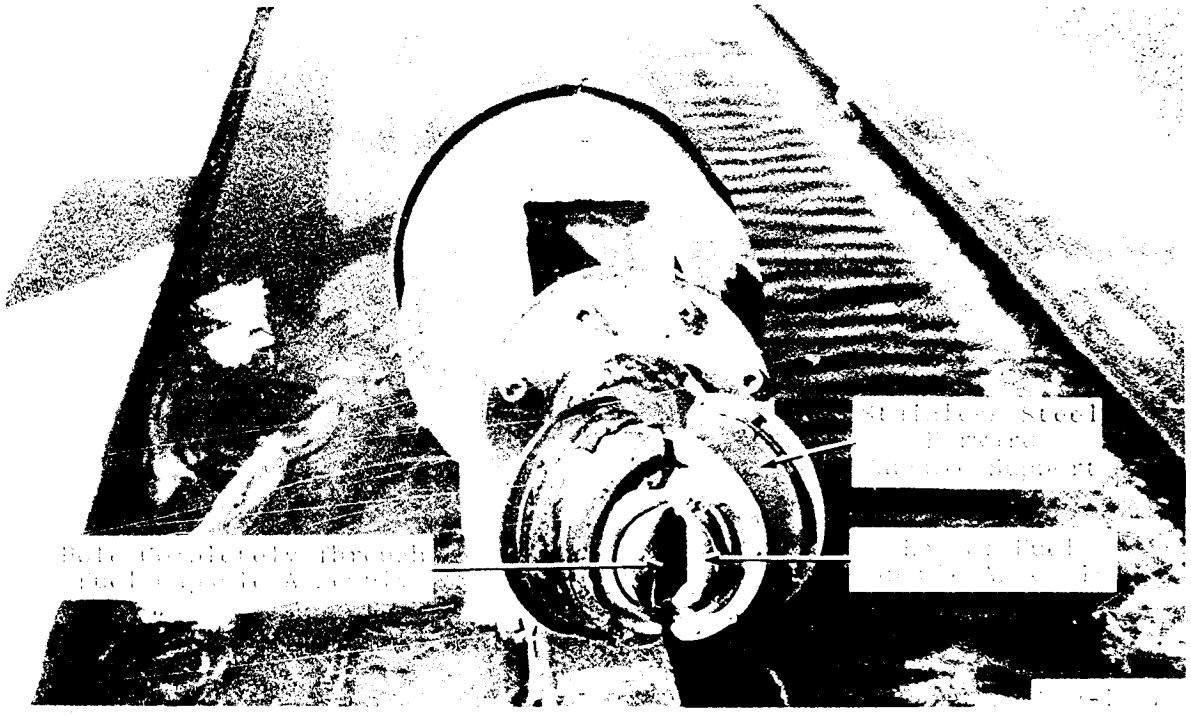


Figure 33. Test 10--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; edge fragment impact; velocity 2800 fps

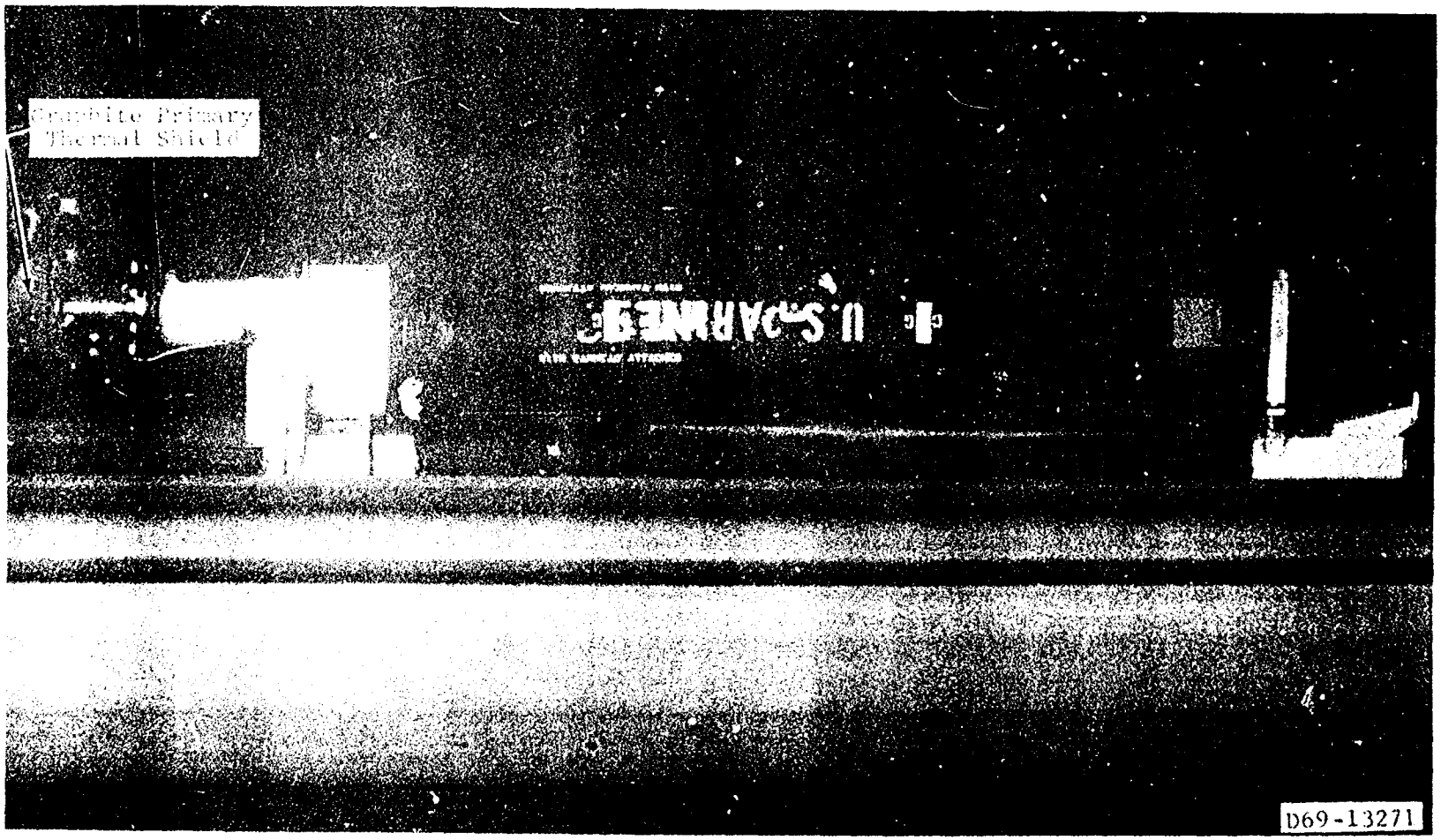
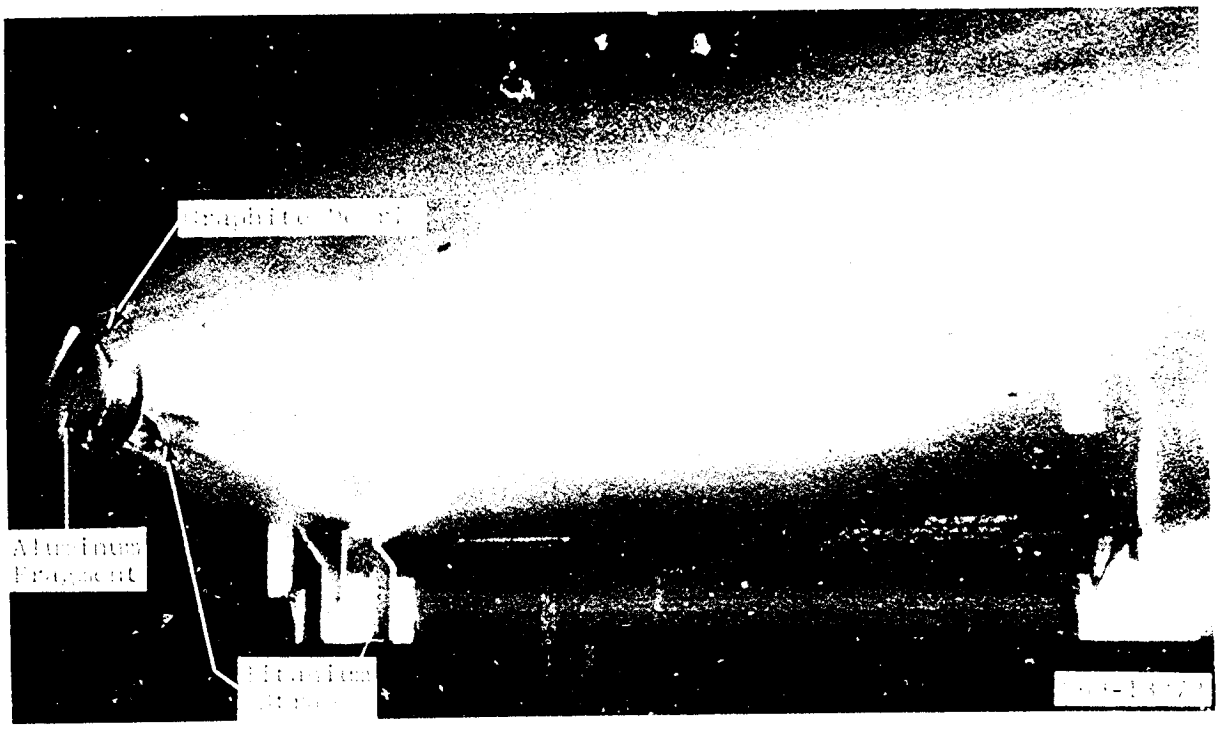


Figure 34. Test 11--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; flat fragmentimpact; velocity 2800 fps; prior to fragment impact



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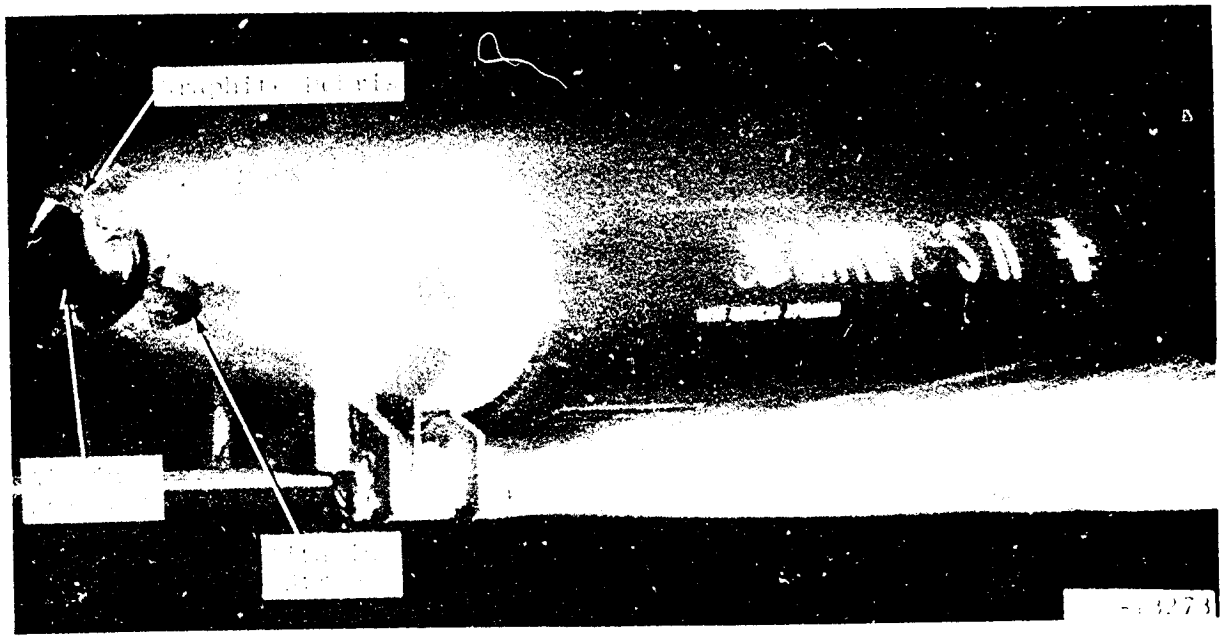
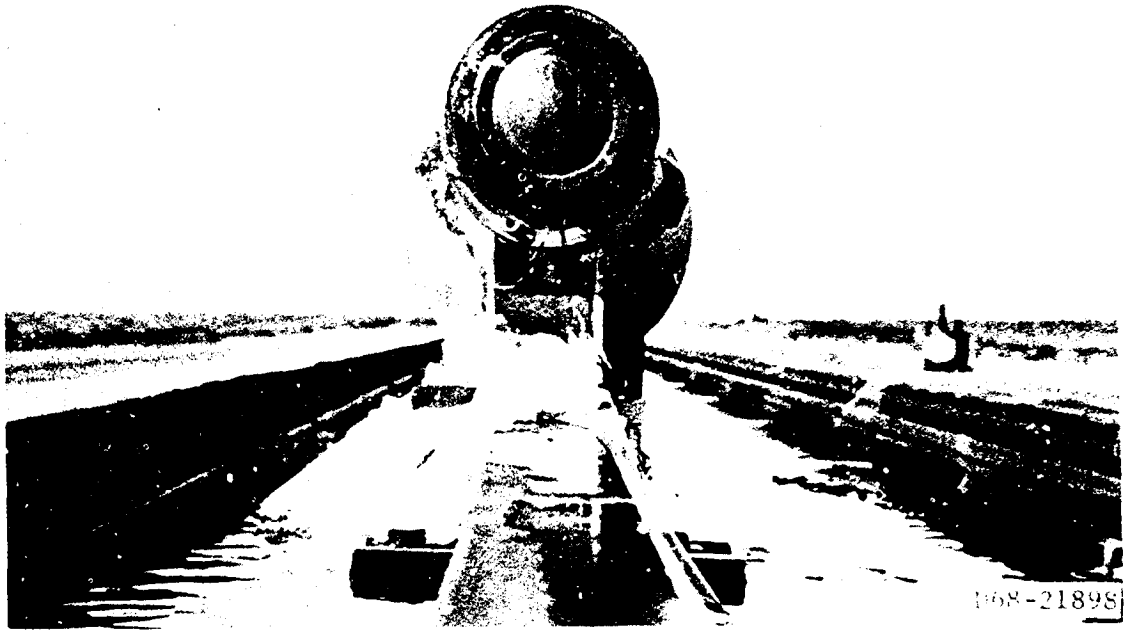


b.

Figure 35. Test 11--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; flat fragment impact: velocity 2800 fps; after fragment impact.



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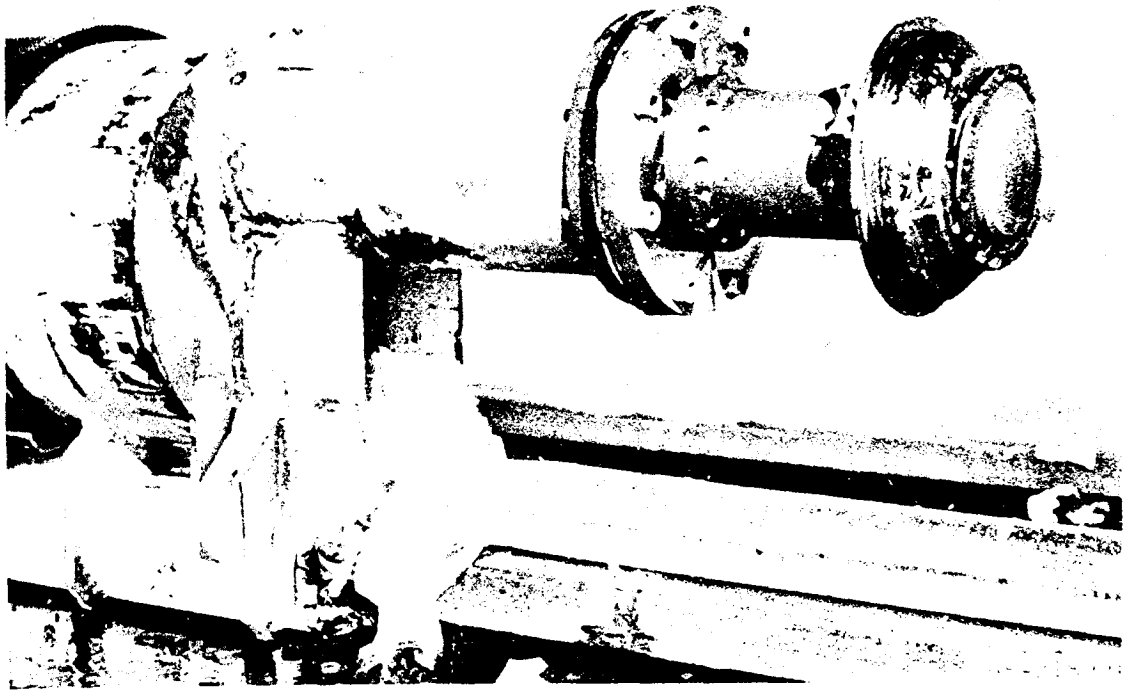

b.

Figure 36. Test 11--GLFC/FCA test assembly (end impact) with graphite primary thermal shield; flat fragment impact; velocity 280 fps

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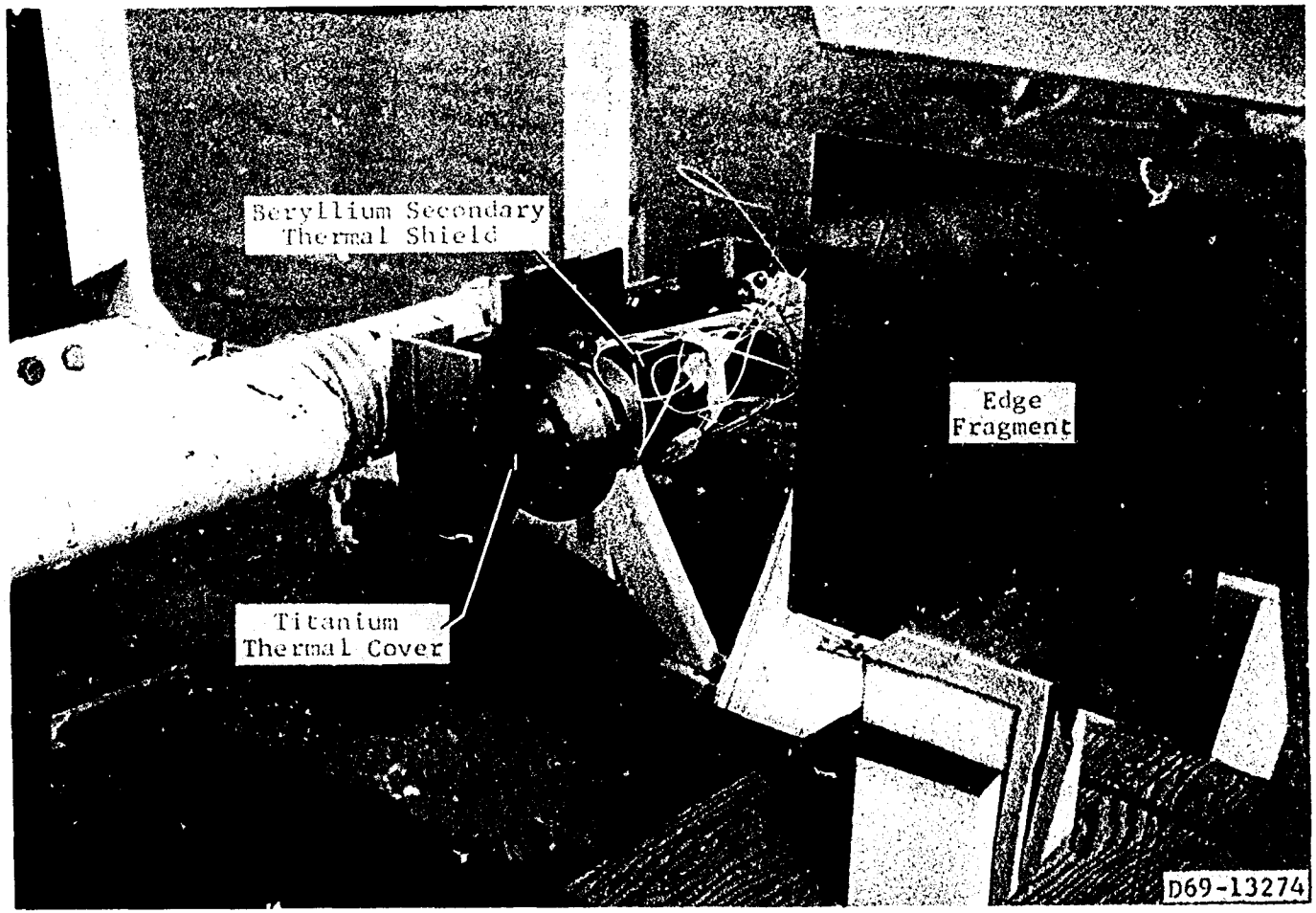

Figure 37. Test 12--GLFC/FCA test assembly (side impact); edge fragment; velocity 1920 fps

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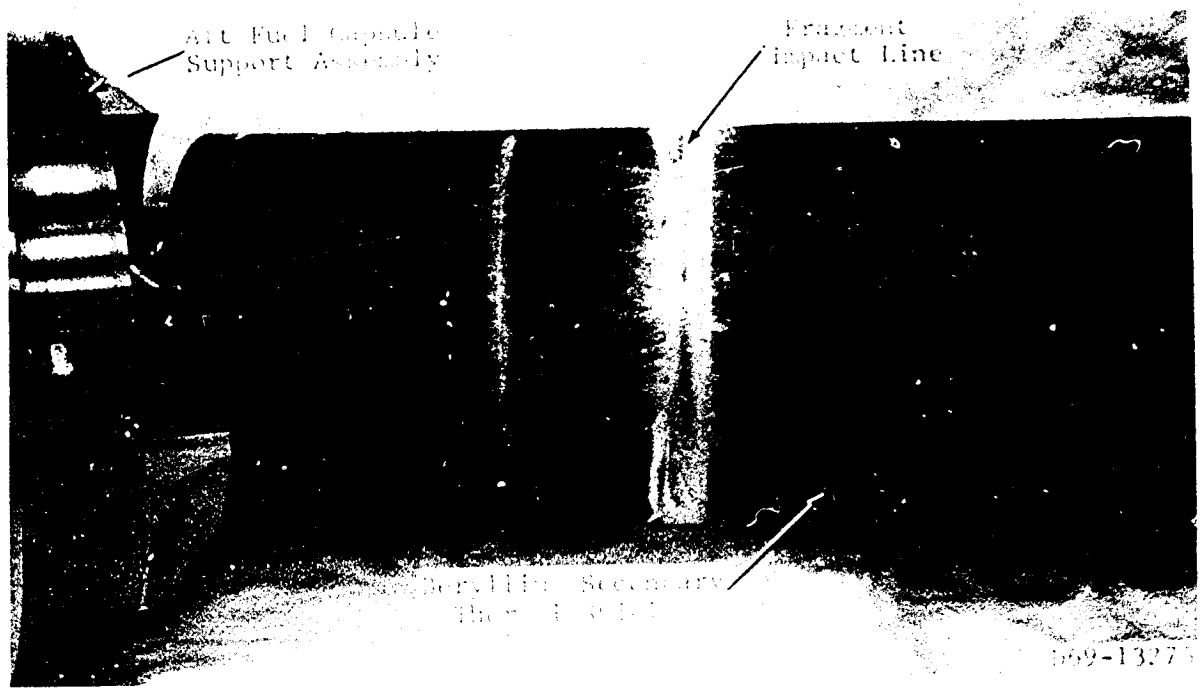
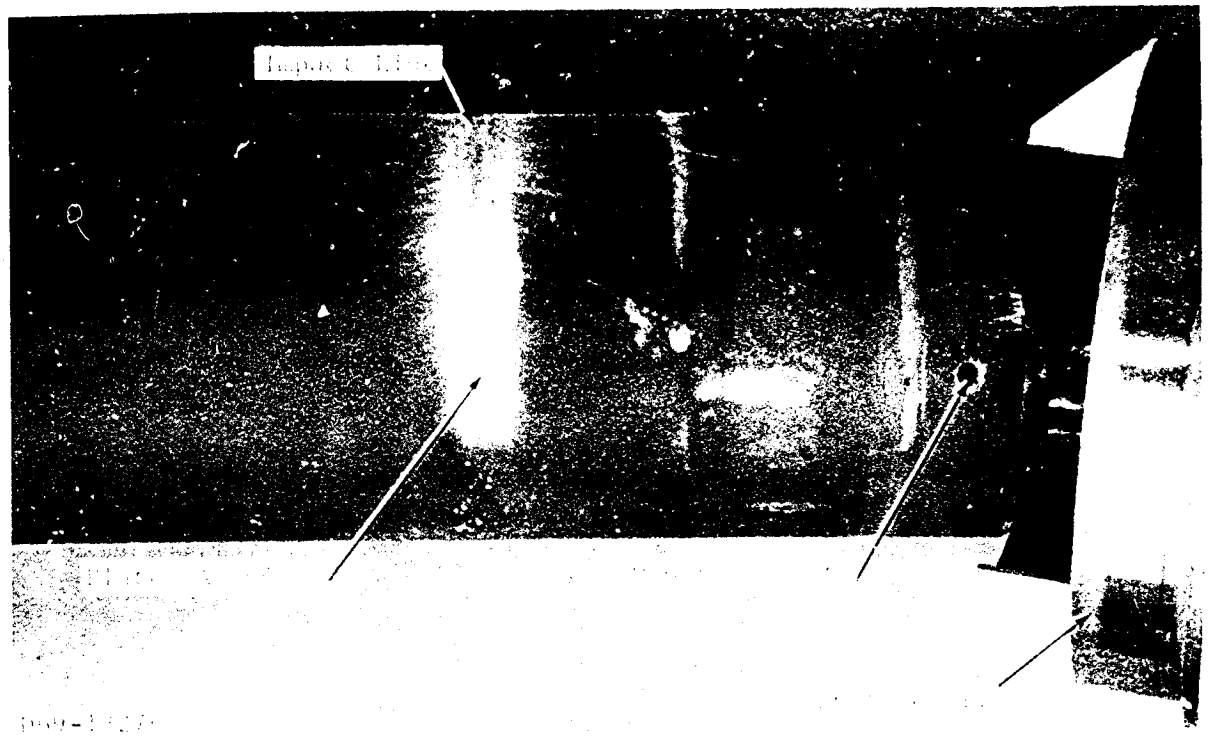


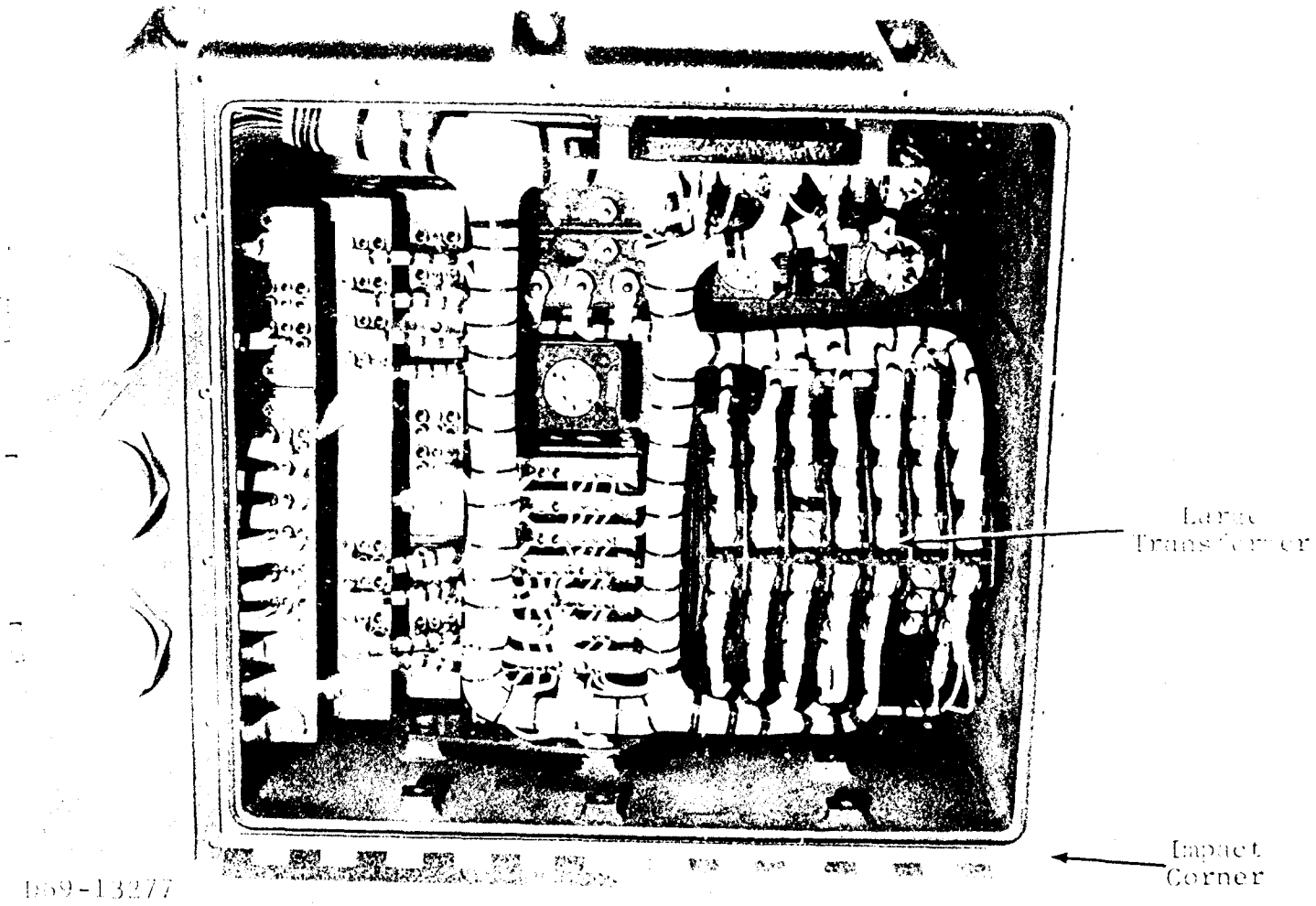
a.



b.

Figure 38. Test 12--GLFC/FCA test assembly (side impact); edge fragment; velocity 1920 fps

UNCLASSIFIED



a.

Figure 39. Test 13--electronic box mounted on cooling plate; impacted GLFC/FCA test assembly (side impact) at 680 fps

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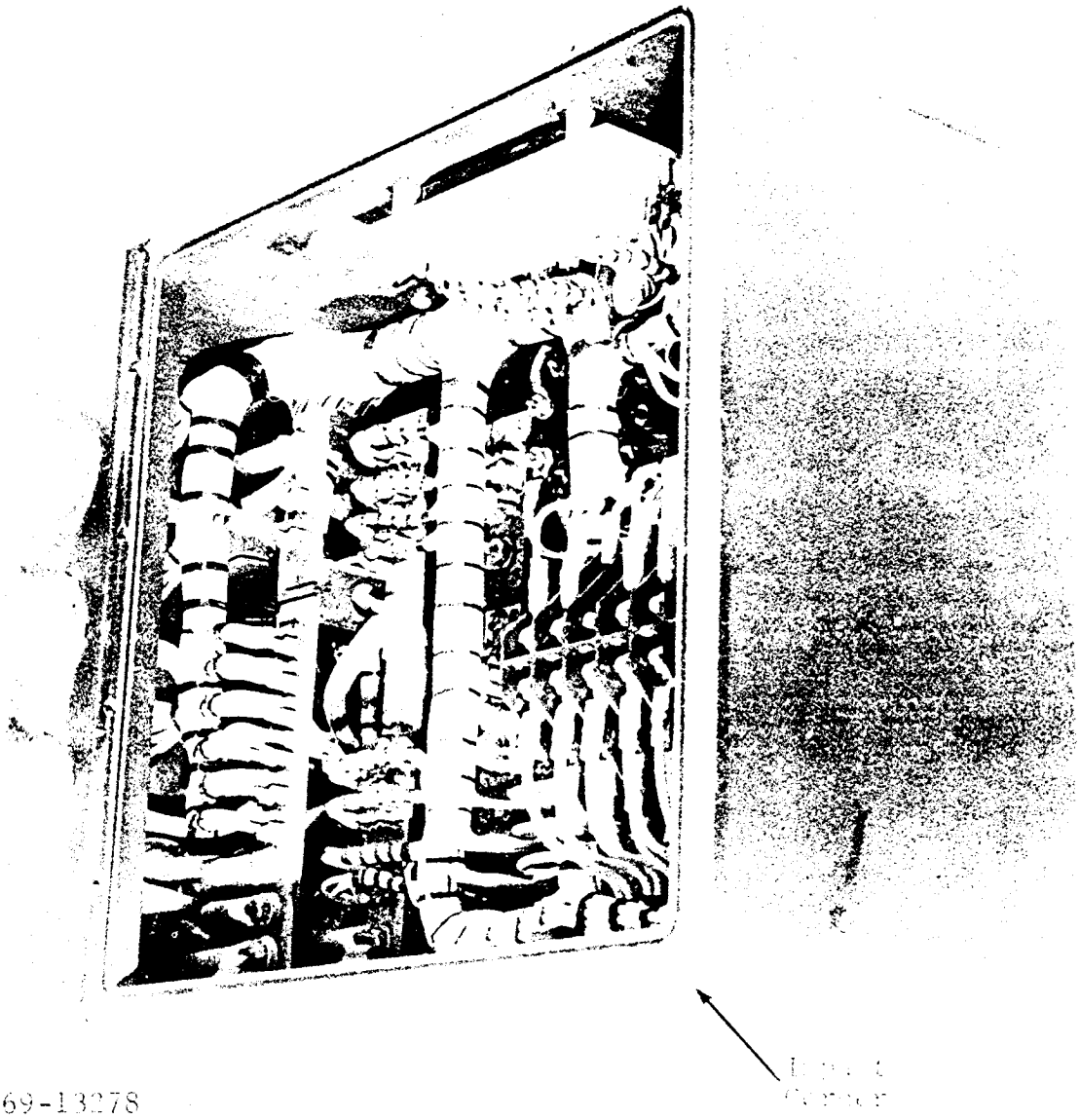
[redacted]



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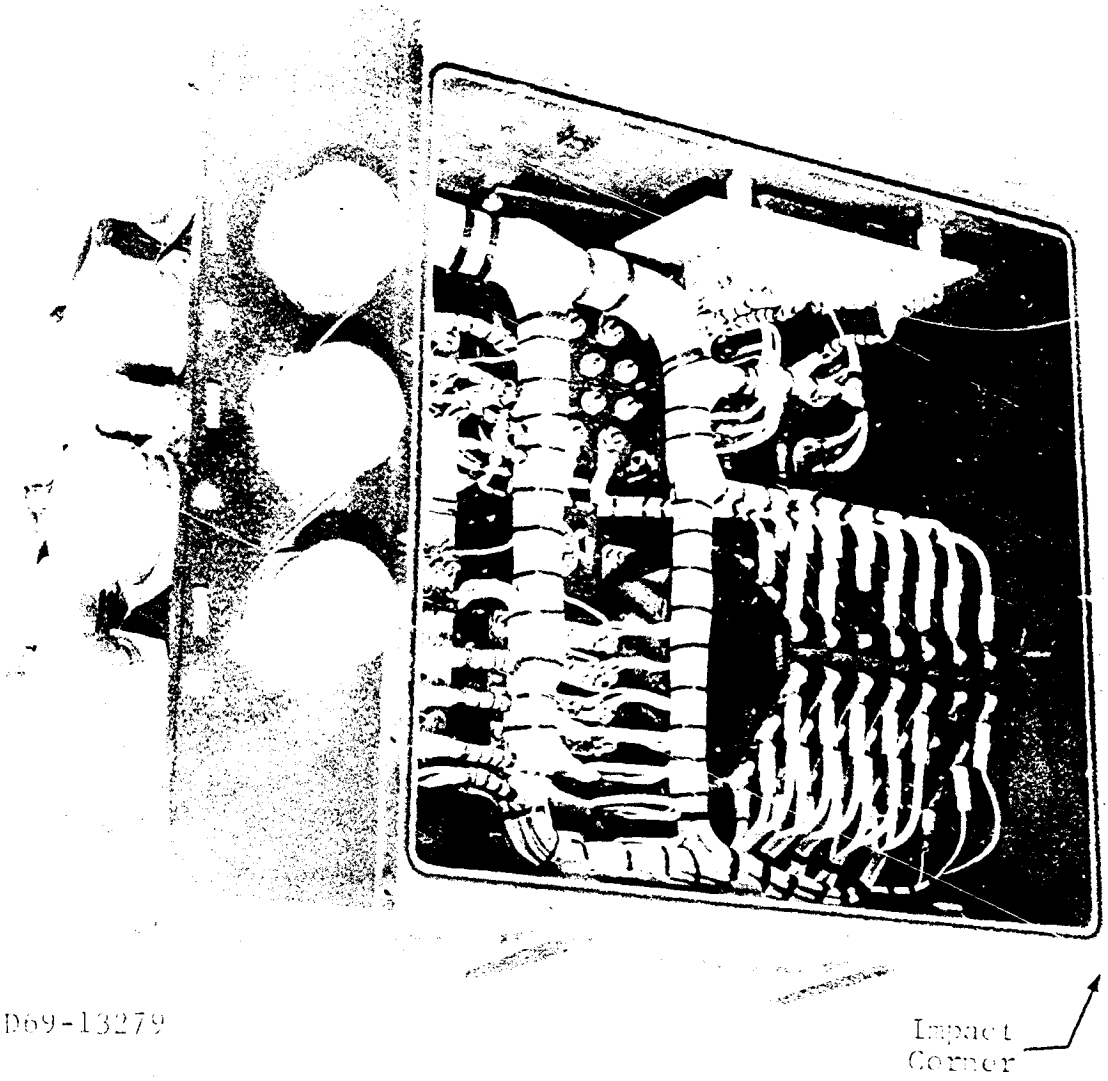
b.

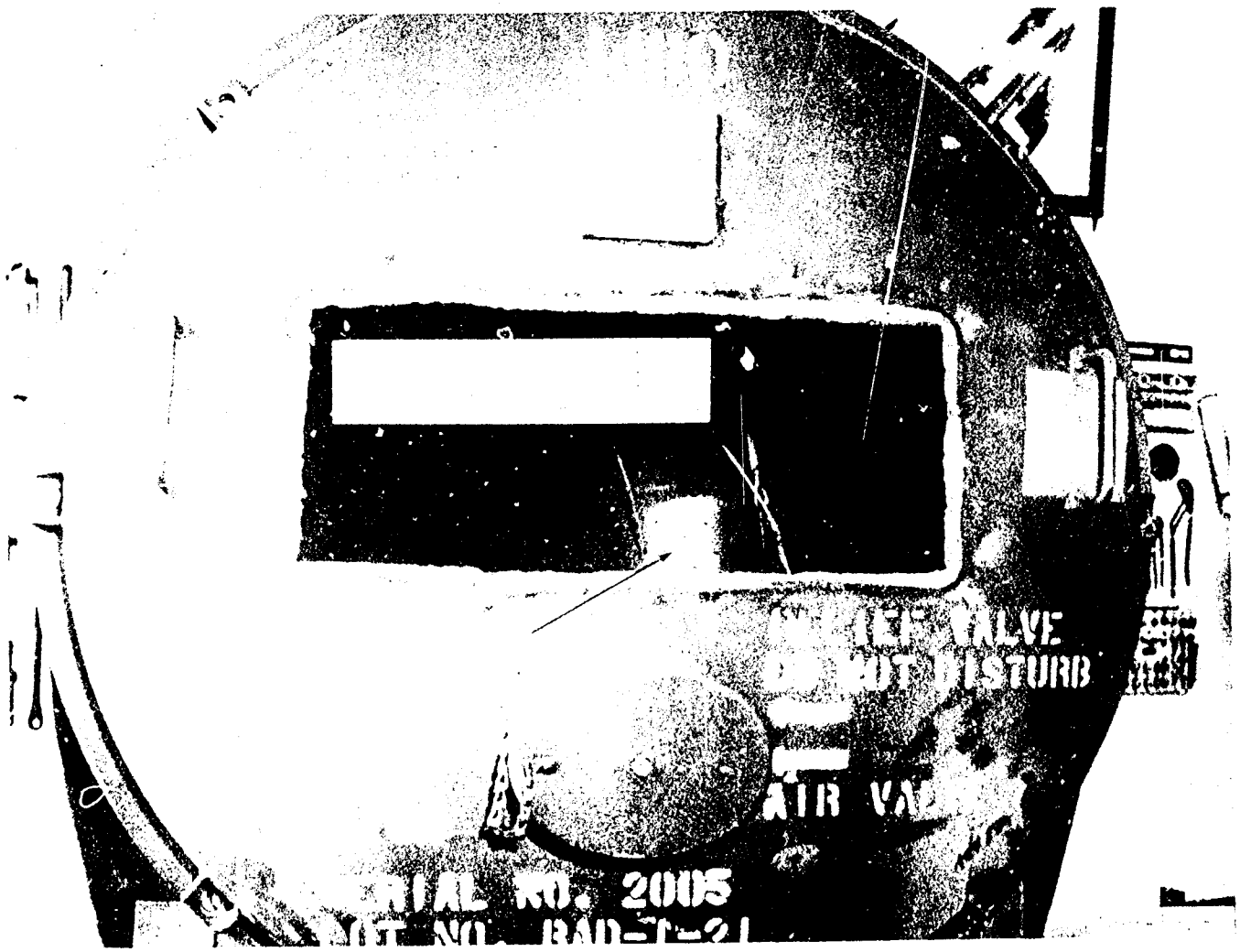
Figure 39. (continued)

[redacted]



c.

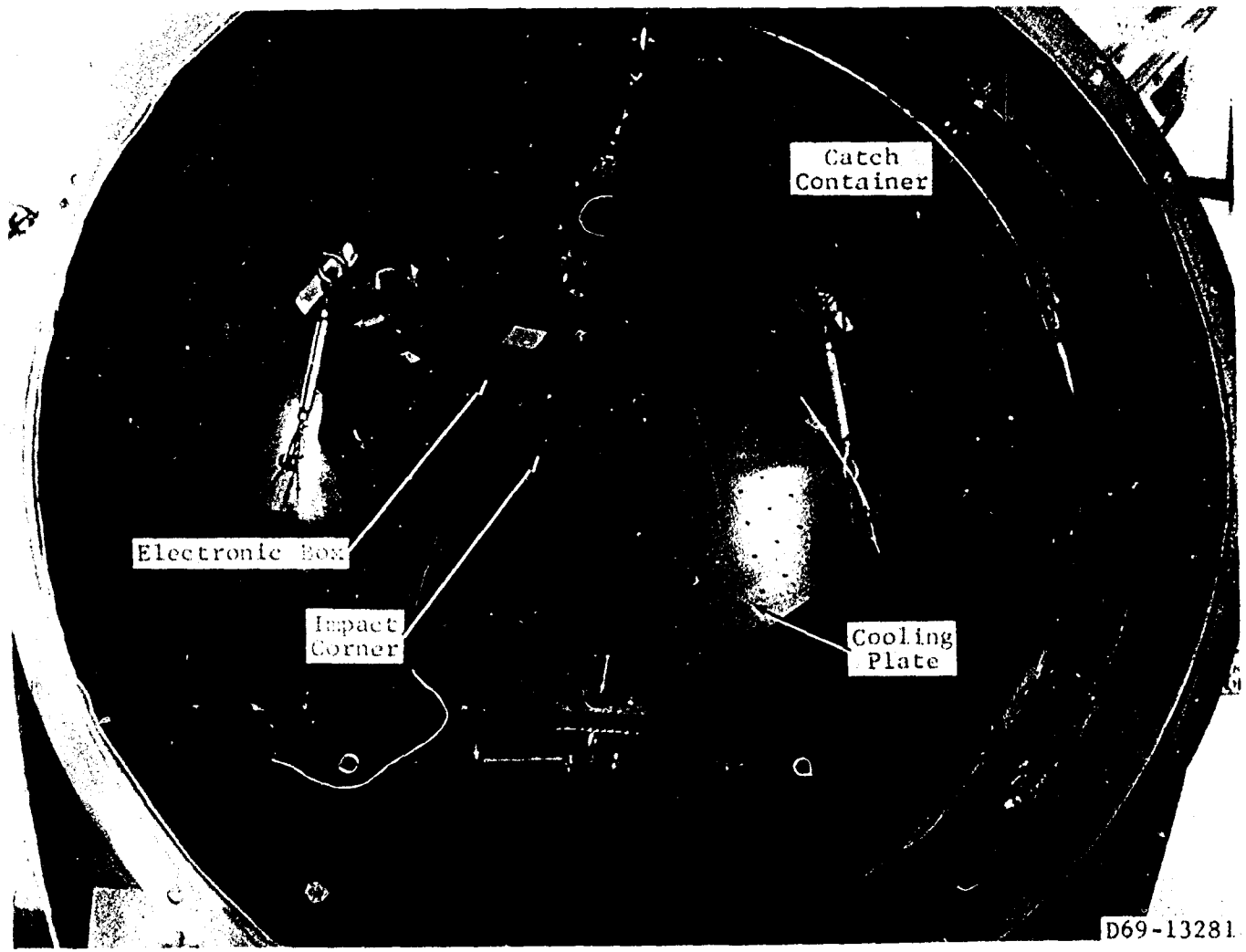
Figure 39. (continued)



a.

Figure 40. Catch container for GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps

[redacted]
UNCLASSIFIED



b.

Figure 40. (continued)

[redacted]
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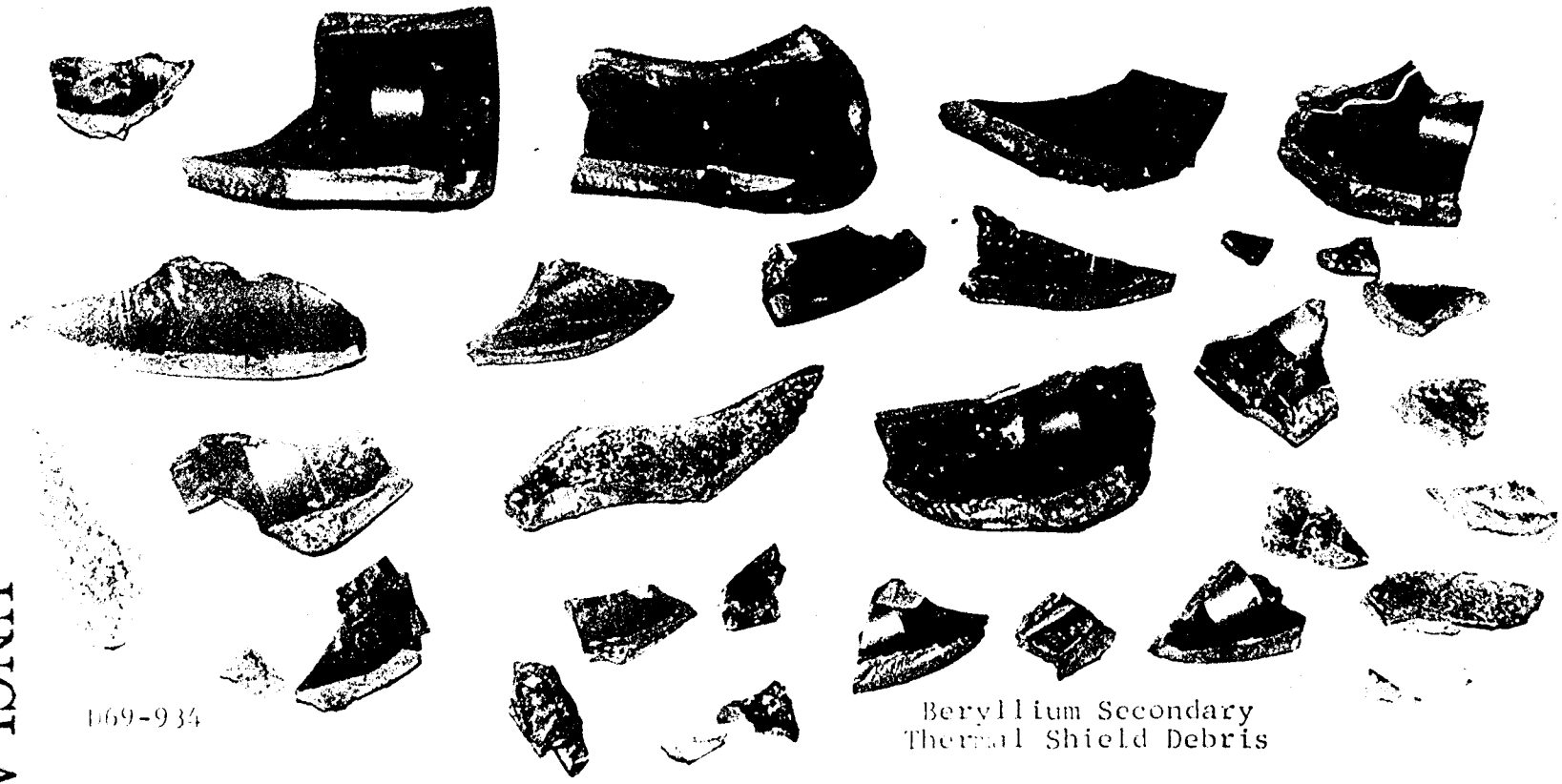
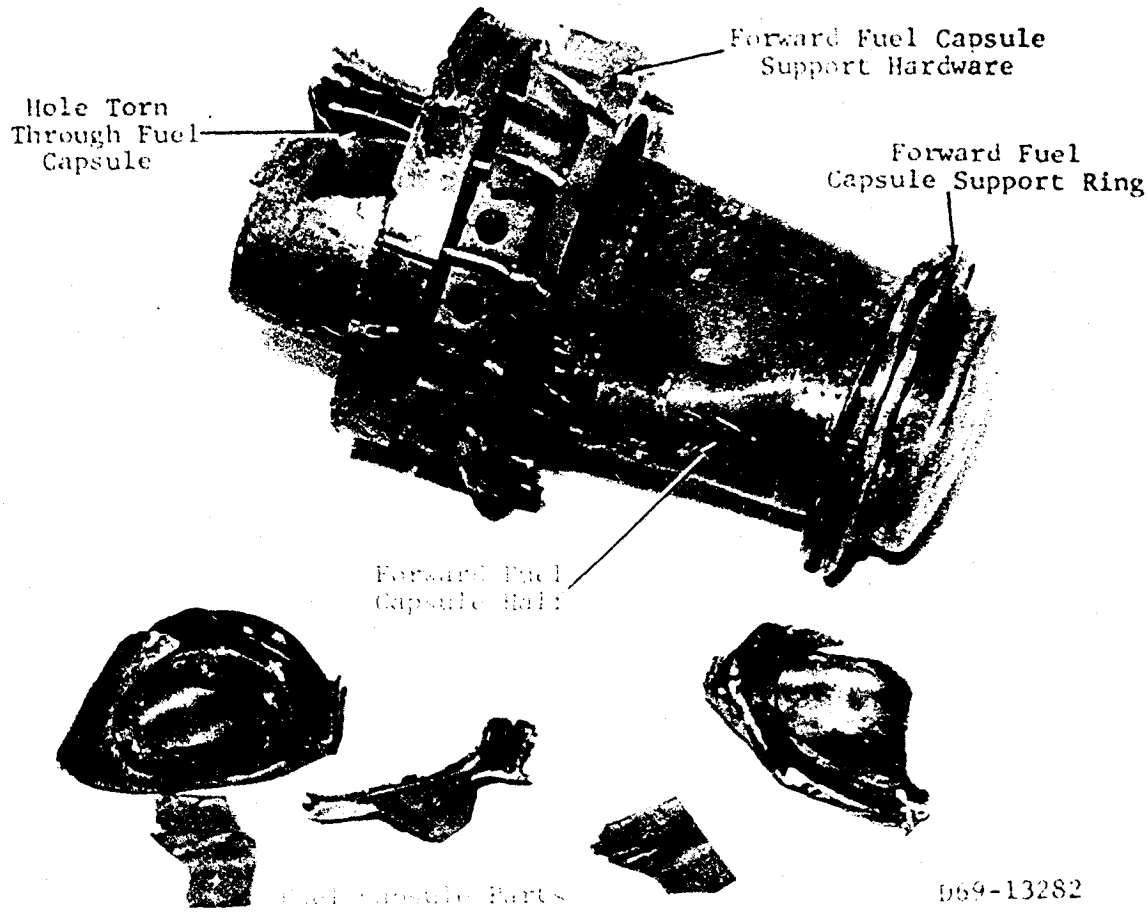
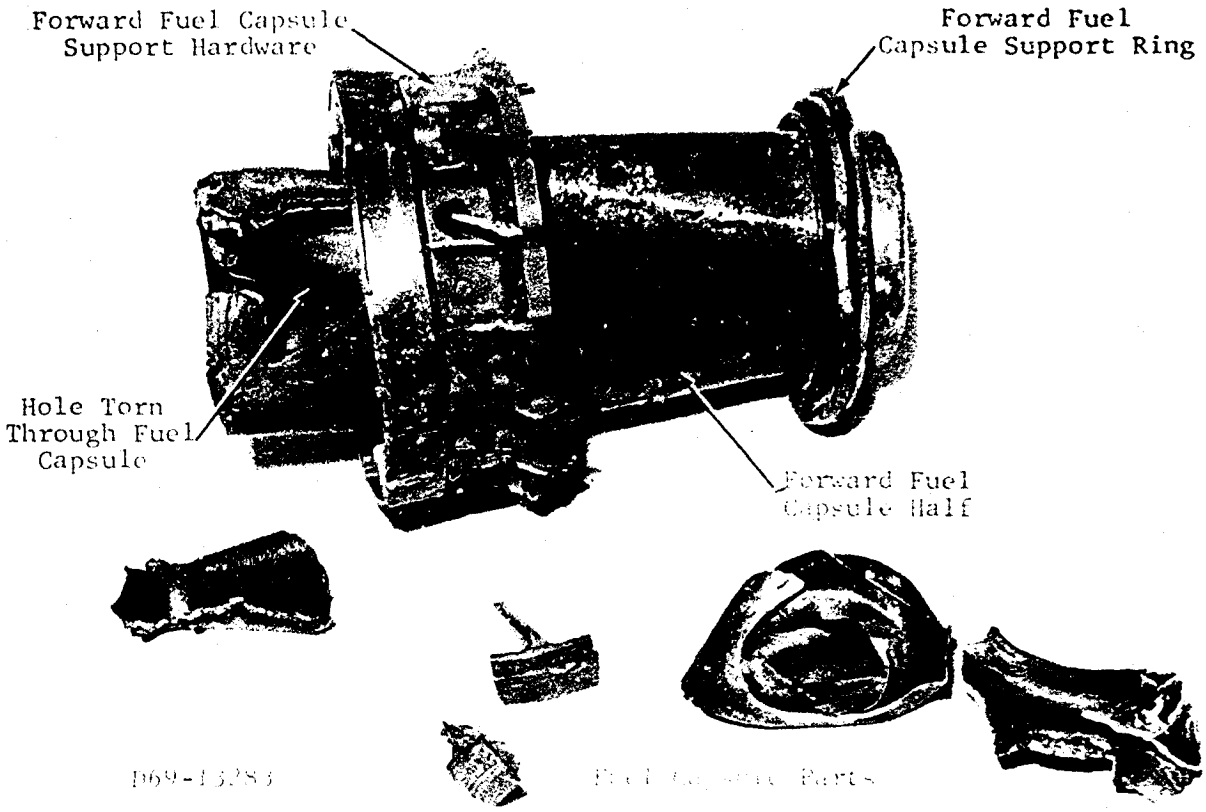


Figure 41. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps



a.

Figure 42. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps



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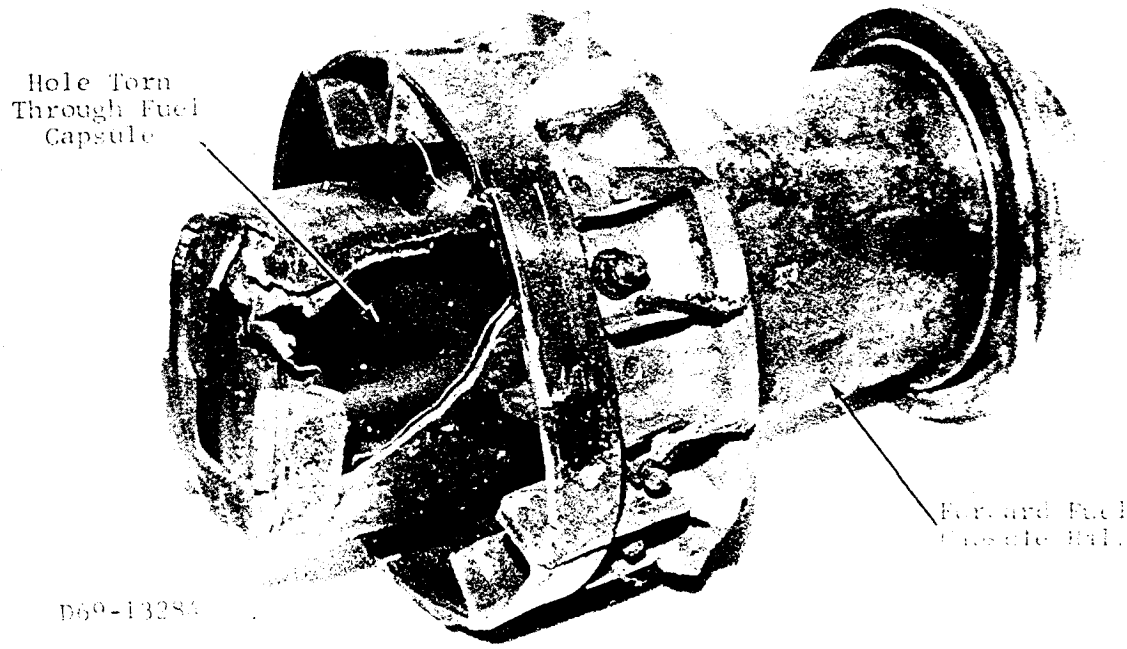
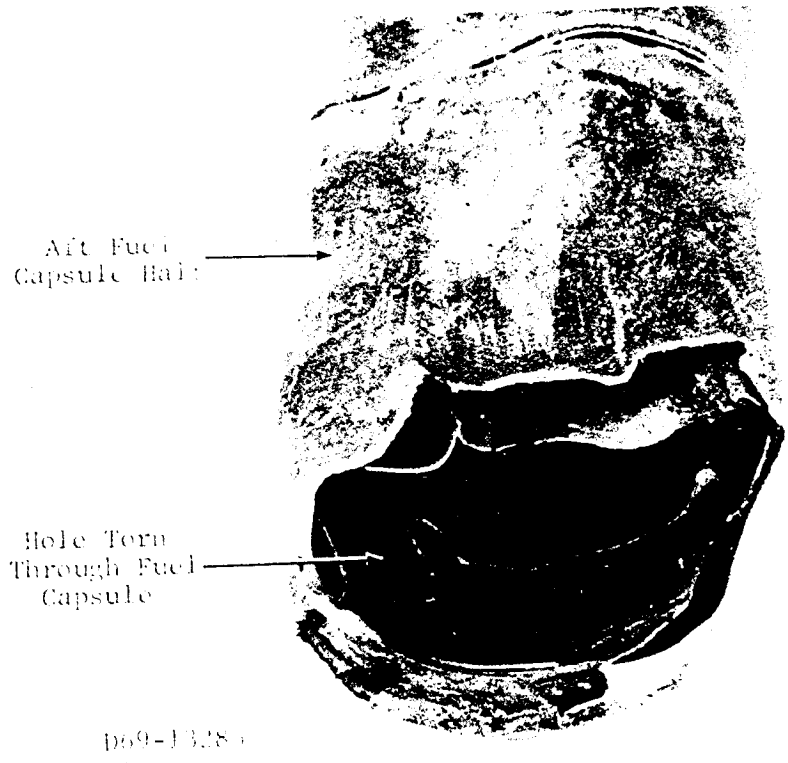
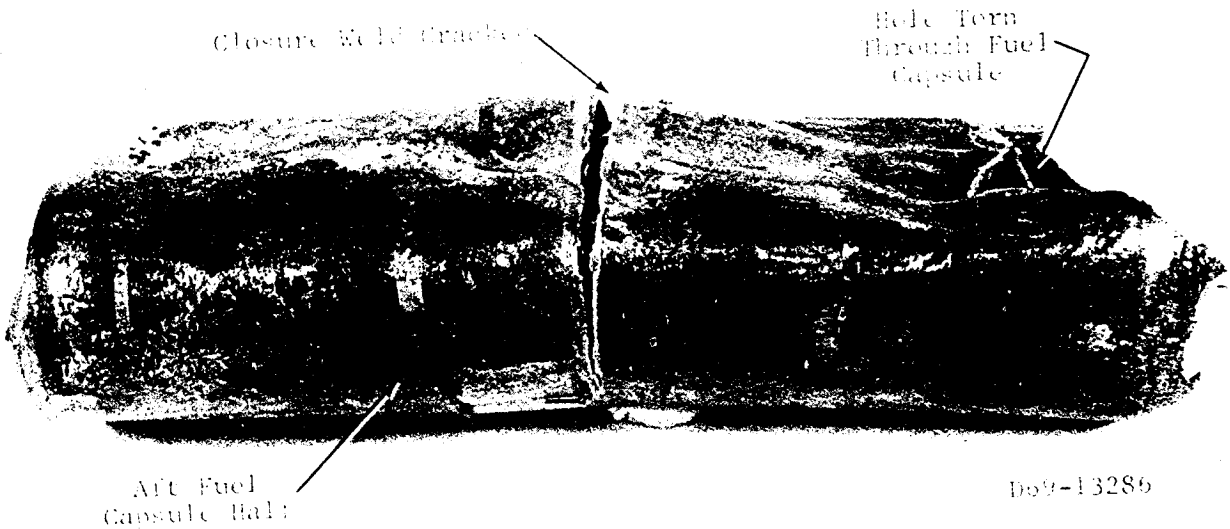


c.

Figure 42. (continued)

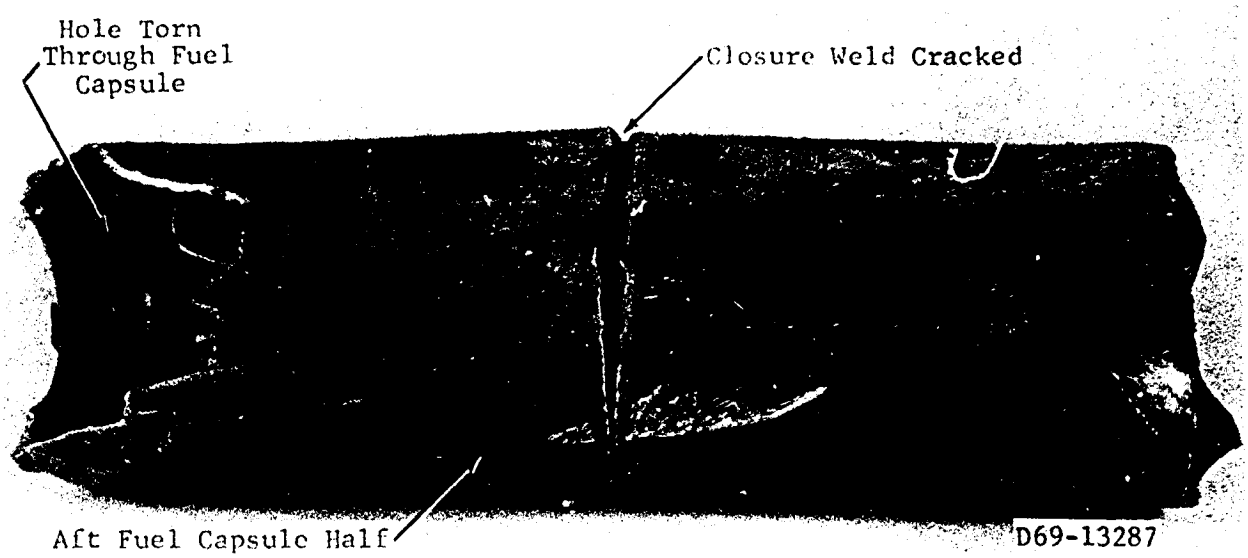


a.

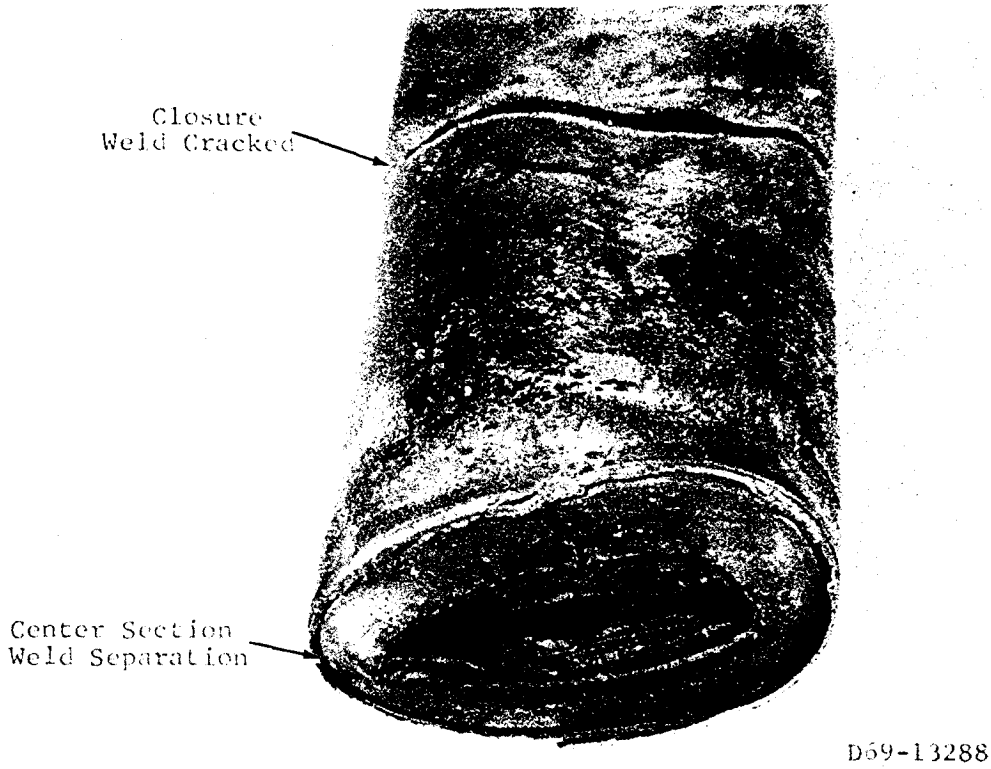


b.

Figure 43. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps



c.



d.

Figure 43. (continued)

D69-935 Fuel Capsule Support Hardware

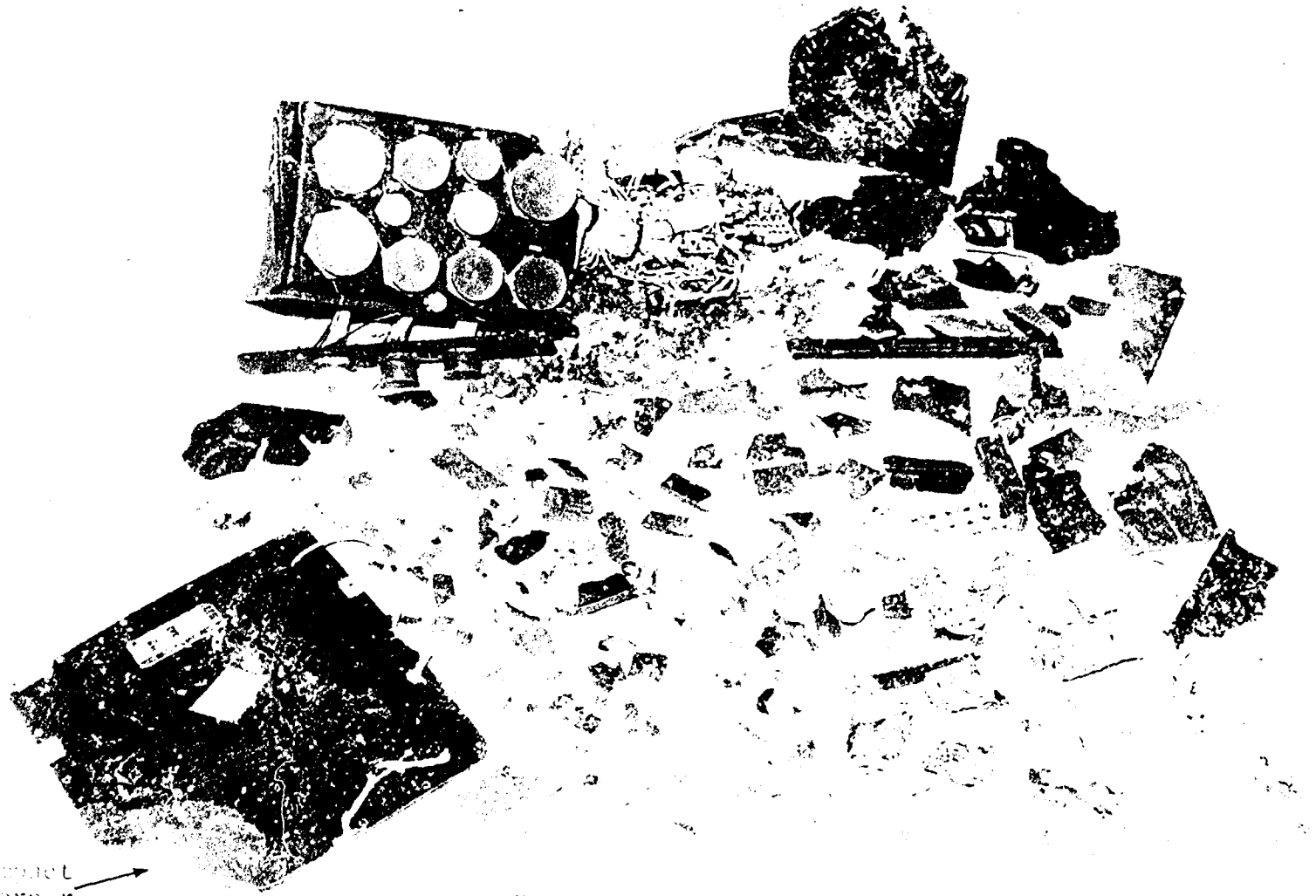
Figure 44. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps

Debris From Power Distribution Box

a.

Figure 45. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps

[redacted] UNCLASSIFIED



Power Distribution Box

D69-13290

b.

Figure 45. (continued)

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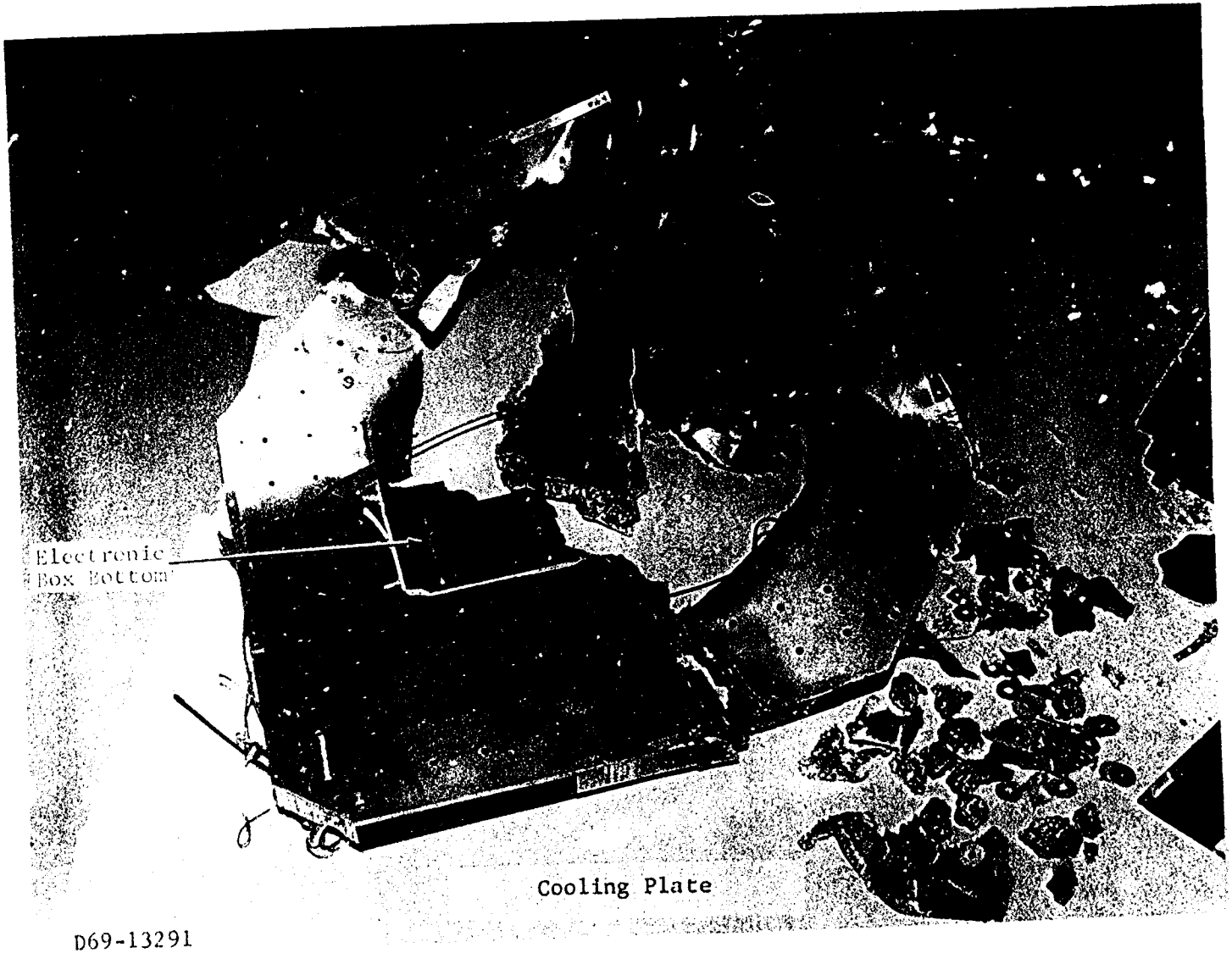


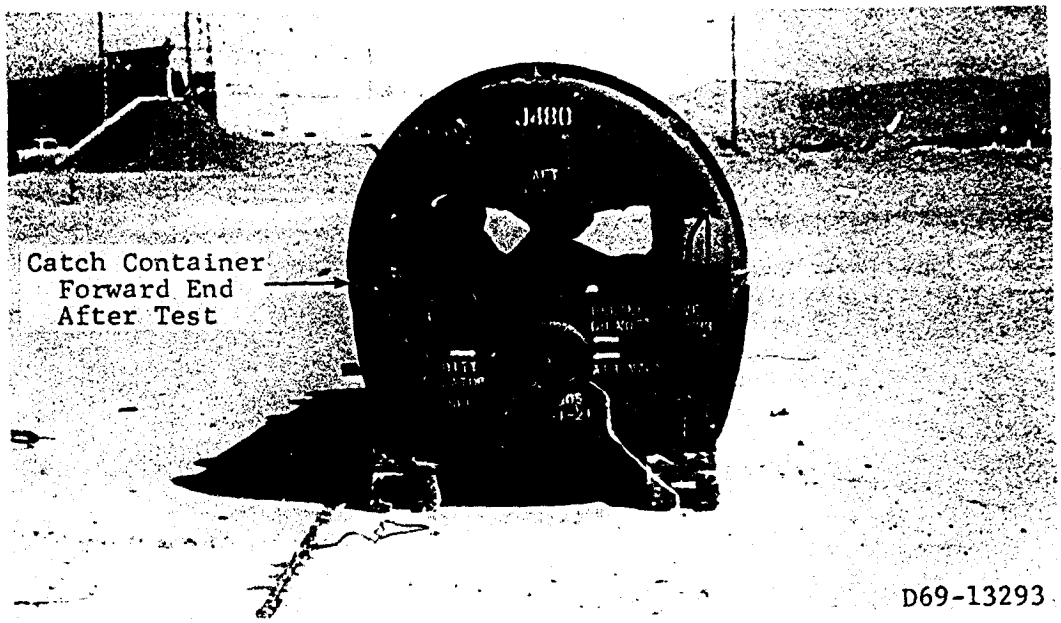
D69-13291

Figure 46. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps

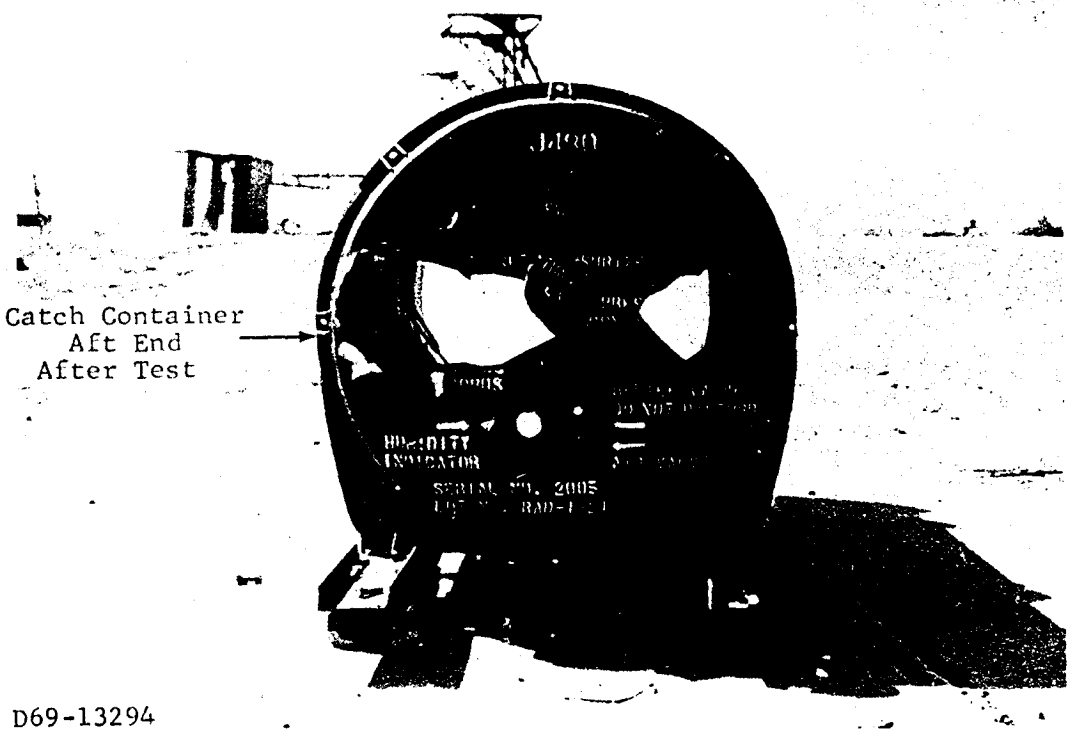
Cooling Plate

b.

Figure 46. (continued)



a.



b.

Figure 47. Test 13--GLFC/FCA test assembly; side impact into electronic box; velocity 680 fps

APPENDIX

Fragment Impact on GLFC Test Plan

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COPY

FRAGMENT IMPACT ON GLFC
TEST PLAN

Prepared by
R. E. Berry, SC - 9512

Approved by
T. Bradshaw, GE

July 22, 1968

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FRAGMENT IMPACT INTO GLFC TEST PLAN

The penetration of the SNAP 27 fuel capsule assembly by fragments created during an explosion causes release of the radioactive fuel into the fireball. The fireball vaporizes a percentage of the fuel and creates a significant health hazard.

More experimental information is needed to enable analysis of the penetration characteristics of the SNAP 27 fuel capsule. This test series is designed to provide sufficient information to permit establishing a penetration velocity for a specific fragment size.

The testing has been designed to provide information about the dynamic shear properties of heated beryllium, titanium and Haynes; to provide the penetration velocity of a fragment impacting edge on to the end of the GLFC and impacting the side of the GLFC; and finally to provide the penetration velocity or damage estimate when fragments impact flat against the end and the side of the GLFC.

The test matrix shown later in this plan calls for nine (9) sled tests for hardware planning purposes. There is a firm requirement for tests 1 and 6; other tests will be run depending on the results of the previous test. Evaluation of test 1 will result in either test 2 or 3 and not both. Evaluation of test 6 will result in either test 7 or 8 or 9 and not all of them.

TEST OBJECTIVES

1. Determine the dynamic shear properties of beryllium, titanium, and Haynes heated to about 1000°F.

2. Determine the penetration velocity through the titanium thermal cover and Haynes capsule, with and without the graphite heat shield. (Edge impact).

3. Determine the damage to the titanium thermal cover and Haynes capsule, with and without the graphite heat shield as a function of velocity. (Flat impact).

4. Determine the penetration velocity through the beryllium heat shield and the Haynes capsule. (Edge impact).

5. Determine the damage to the beryllium heat shield and the Haynes capsule as a function of velocity. (Flat impact).

All of the above tests will be performed with the test item heated to approximately the correct temperature expected at the time of a launch pad abort.

Test Set Up and Instrumentation

Objective 1:

A heated (approx. 1000°F) beryllium, titanium or Haynes plate will be rigidly supported around its entire circumference (12 inch diameter).

Five 1/2 inch diameter by approximately 4 inch long aluminum cylinders will be fired into the heated beryllium plate such that a 3 inch edge distance is maintained.

The velocity will be calculated for the first shot. If penetration occurs the velocity will be reduced. It is desired to have two penetrations and one no penetration shot at nearly the same velocity.

The velocity will be measured before impact by two independent methods and after penetration by one method.

The temperature of the plate will be measured continuously during the test.

If the beryllium plate cracks, the Project Engineer will decide if further testing is necessary. Other materials are not expected to crack.

The penetration holes will be flattened and smoothed. The hole will be plugged (snug fit) with a bolt and large washers on both sides.

Camera coverage is necessary to determine orientation at impact.

Two calibration shots using aluminum cylinders on an aluminum plate are necessary to evaluate the instrumentation system.

Objective 2: Objective 3:

These two objectives will be accomplished at the same time by mounting two sets of hardware on the sled and impacting one set with edge on aluminum plates (16x18x.063"). The impact edge will have a beveled edge (approx. 52°). The other set of hardware will be impacted with a flat plate (16"x18"x.063").

The test hardware must be heated to have the temperature at impact near that expected while mounted within a GLFC on the Saturn launch vehicle.

Camera coverage is desired to show the orientation of the plates at impact and the damage immediately after impact.

Sled velocity must be measured by two independent techniques at the time of fragment impact.

Objective 4: Objective 5:

These two objectives will also be accomplished simultaneously by mounting two beryllium heat shields on the sled and impacting one with a flat plate (16"x18"x.063) made of aluminum and the other with a similar plate edge on. The edge will be beveled to approximately 52°.

The beryllium heat shield and capsule will be heated to have the temperature at impact near that expected while mounted within a GLFC on the Saturn launch vehicle.

Camera coverage is desired to show the orientation of the plates at impact and the damage immediately after impact.

Sled velocity must be measured by two independent techniques at the time of fragment impact.

Data Requirements

Velocity at impact.

Velocity after impact for Objective 1.

Temperatue of Test items Titanium - approx. 1100°F
Beryllium - approx. 900°F
Haynes - approx. 1200°F

Damage evaluation after impact.

Test Matrix (Sled)

	VELOCITY	FRAGMENT ORIENTATION	GLFC HARDWARE ORIENTATION	REMARKS
Test 1	1000 fps	Edge On Flat	End On	(Titanium, Graphite, Haynes)
	If penetration occurs perform Test 2			
	If no penetration occurs perform Test 3			
Test 2	500 fps	Edge On Flat	End On	(Titanium, Graphite, Haynes)
	If penetration occurs perform Test 4			
	If no penetration occurs end testing			
Test 3	2000 fps	Edge On Flat	End On	(Titanium, Graphite, Haynes)
	If penetration occurs, end testing			
	If no penetration occurs, perform Test 4			
Test 4&5	3000 fps	Edge On Flat	End On	(Titanium, Haynes, Graphite)
Test 6	2000 fps	Edge On Flat	Side On	(Beryllium, Haynes)
	If penetration occurs perform Test 7			
	If no penetration occurs perform Test 8			
Test 7	1000 fps	Edge On Flat	Side On	(Beryllium, Haynes)
Test 8&9	3000 fps	Edge On Flat	Side On	(Beryllium, Haynes)

Test Matrix (Gun)

TEST NO.	VEL.	PLATE MATERIAL	PROJECTILE
A	800 fps	Be	1/2"Dx6" AL
B	1500	Be	1/2"Dx2" AL
C	TBD	Ti	1/2"xT: AL
D	TBD	Haynes	1/2"xTBD AL

TBD = To Be Determined.

Test Schedule

Preliminary planning schedule which will be modified as firm delivery information is received from General Electric.

Gun Tests

A & B	week of 7-22-68
D	week of 7-29-68
C	week of 7-29-68 if titanium can be acquired

Sled Tests

1	August 5
2	August 7
3	August 9
4	Open
5	Open
6	August 14
7	August 16
8	Open
9	Open

Data will be available to both GE and Sandia upon completion of a test.

General Electric will have Test Engineers present at each test and will participate in the damage evaluation for the selection of the next test.

NOTE: The Bendix mounting hardware may provide additional penetration protection and therefore will be installed on some of the test items. Procurement is proceeding and the Test Project Engineers (GE and Sandia) will determine the tests which will carry the Bendix mounting hardware.

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