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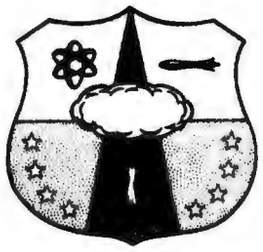
WING I, LER SINGLE ISOLATOR SHOCK TESTS

INTERIM REPORT

Frank T. Krek



AIR FORCE SPECIAL WEAPONS CENTER
Air Force Systems Command
Kirtland Air Force Base
New Mexico

TECHNICAL REPORT NO. AFSWC-TR-69-20

November 1969

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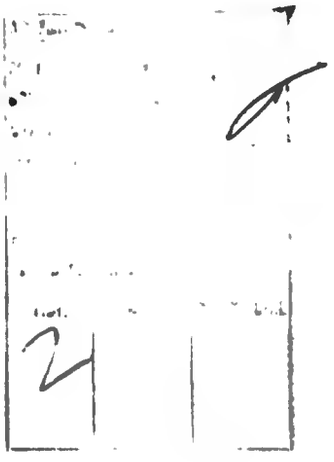

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FOREWORD

This research was performed under Program Element 1.12.13.F, Project 133BCR, and was funded by the Space and Missile Systems Organization (SAMSO). Inclusive dates of research were March 1968 through April 1969. This report was submitted 11 August 1969 by the Air Force Special Weapons Center Test Director, Mr. Frank T. Krek (SWVIC).

Information in this report is embargoed under the Department of State ITIARs. This report may be released to foreign governments by departments or agencies of the US Government subject to approval of AFSWC (SWVIC), Kirtland AFB, NM, 87117.

This technical report has been reviewed and is approved.

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ABSTRACT

(Distribution Limitation Statement No. 2)

The summary data and results of tests performed on Minuteman Wing I Launcher Equipment Room (LER) Shock Isolators are presented in this report. The testing was performed by the Air Force Special Weapons Center at the request of Space and Missile Systems Organization (SAMSO). Single isolator displacement tests and single isolator shock tests were performed. The tests were conducted to determine the threshold of failure and the mode of failure for the LER isolator as a result of a shock loading condition or any other loading. The test results indicated a need for a number of improvements in the original design. Test data summary results, notation of observations made during testing, and other pertinent information are presented.

CONTENTS

ILLUSTRATIONS

SECTION I

INTRODUCTION

1. GENERAL

In summary, the data and the results of an investigation conducted on Minuteman Wing I Launcher Equipment Room (LER) Types I, III, and IV shock isolators are presented in this report. The authority for this work is contained in AF Form 111 for Project 133BTA4H, entitled Minuteman II and III, dated 26 March 1968. This authority was issued by Headquarters, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico. The project has since been changed to 133BCR.

2. PURPOSE

This investigation primarily conducted a series of tests that evaluated the three types of individual shock isolator's ability to survive the test input requirements.

SECTION II

TEST SPECIMEN

1. ORIGIN

The LER isolators used in these tests were delivered from the Wing I, Malmstrom AFB, Great Falls, Montana, site. The isolators were delivered after replacement isolators were furnished during a force modernization shutdown period.

2. ISOLATOR DESCRIPTION

Figure 1 shows the basic arrangement of the spring isolator assemblies. All isolators are approximately 11 feet long and they differ only in size of spring and housing parts. The following information was taken from representative field drawings:

a. The spring in Type I isolator is formed with 23/32-inch diameter wire, has 16 total coils (13 active coils of 3-25/32 inches mean diameter), has a free length of 21 inches, and has a designed spring rate of 500 lb/in.

b. The Type III isolator contains two springs which are nested. The inner spring is formed with 31/32-inch diameter wire, has 14-1/8 total coils (11-1/8 active coils of 4-25/32 inches mean diameter), and has a free length of 22 inches. The outer spring is formed with 1-1/8-inch wire, has 9-1/8 total coils (6-1/8 active coils of 7-1/8 inches mean diameter), and has a free length of 22 inches. The combined spring system has a designed spring rate of 1903 lb/in.

c. The spring in the Type IV isolator is formed with 29/32-inch diameter wire, has 13-3/16 total coils (10-3/16 active coils of 4-27/32 inches mean diameter), has a free length of 20 inches, and has a designed spring rate of 770 lb/in.

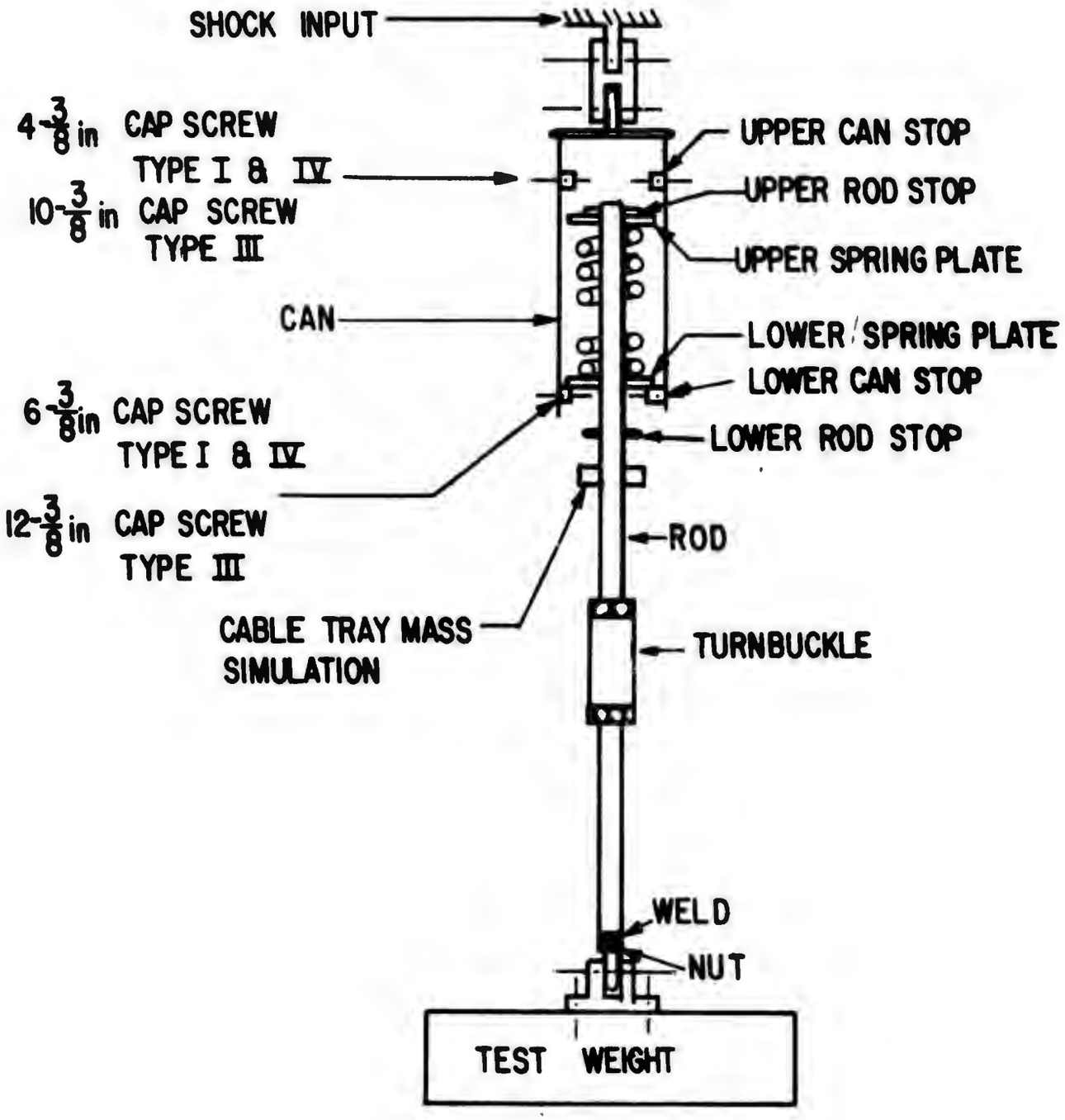


Figure 1. Wing I, LER Isolator Assembly in Test Configuration

SECTION III

TEST PROCEDURE

The LER isolators were tested in accordance with the Air Force Special Weapons Center (SWTEE) Program Plan as delineated in reference 1, dated May 1968 and revised July 1968.

1. TEST REQUIREMENTS

The program plan was followed with minor modifications as required during the testing period. The plan called for the following characteristics of the isolators to be investigated:

a. Spring rate test--to determine the stiffness of the isolator assembly.

b. Twang test--to determine isolator damping as well as individual isolator characteristics such as natural frequency and internal impacting.

c. Shock test--to determine the dynamic characteristics and mechanical strength of the isolators when subjected to shock input loading while operating both, below and above the solid height of the isolator springs.

2. INSTRUMENTATION AND TEST SETUP

The instrumentation, which was typical for all isolators, is shown in figure 2. The instrumentation locations are given in figure 3. Other illustrations of typical LER isolator instrumentation are shown in figures 4, 5, 6, and 7. Also shown in figures 4 and 7 is a detail of the Cable Tray mass simulation located at the rod top. Figure 8 shows the spring rate test setup. Figure 9 shows the remote air-operated quick release used for releasing the simulated mass during the twang test.

3. SHOCK TESTS

The shock input to the isolator ceiling attach point was provided by the Air Force Special Weapons Center Seismic Impulse Facility. The shock impacts were applied to the isolators in a pure vertical, pure horizontal, or a combined vertical and horizontal direction. The input pulses were consistent with the values specified in the test matrix, reference 2. The isolators were subjected to the five different tests identified below:

a. Incremental vertical (I.V.)

b. Incremental horizontal (I.H.)

c. Constant displacement with variable velocity (CD,V)

d. Constant velocity with variable displacement (CV,D)

e. Combined vertical and horizontal (comb)

Reference 2 gives the approximate values of displacement and velocity for these input pulses and reference 3 gives the tolerances for these values.

The inputs were applied until isolator failure occurred or until the maximum input values were reached. The isolator spring solid height for each isolator was achieved before isolator failure or before testing was stopped.

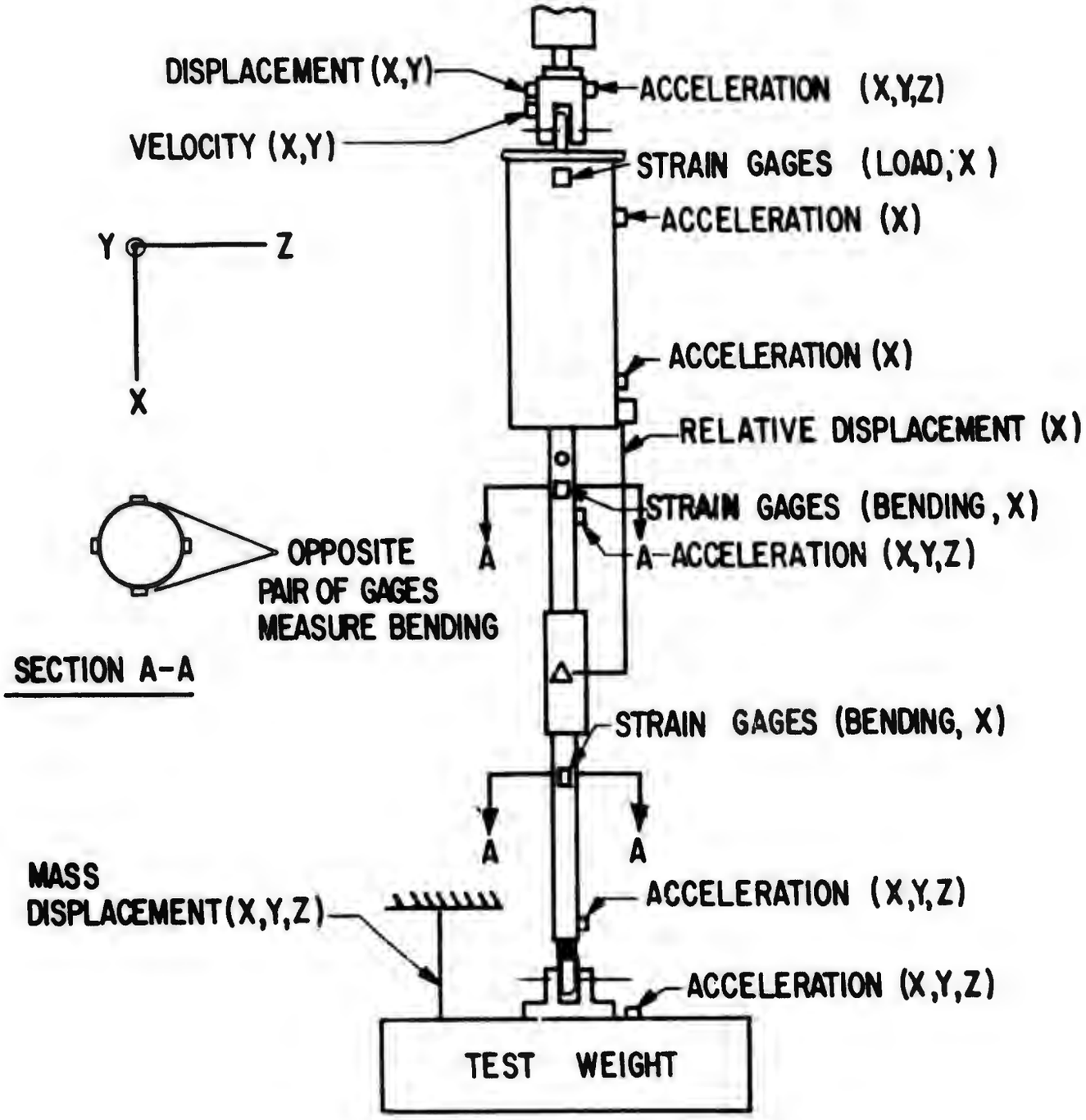


Figure 2. Instrumentation--Typical LER Isolators

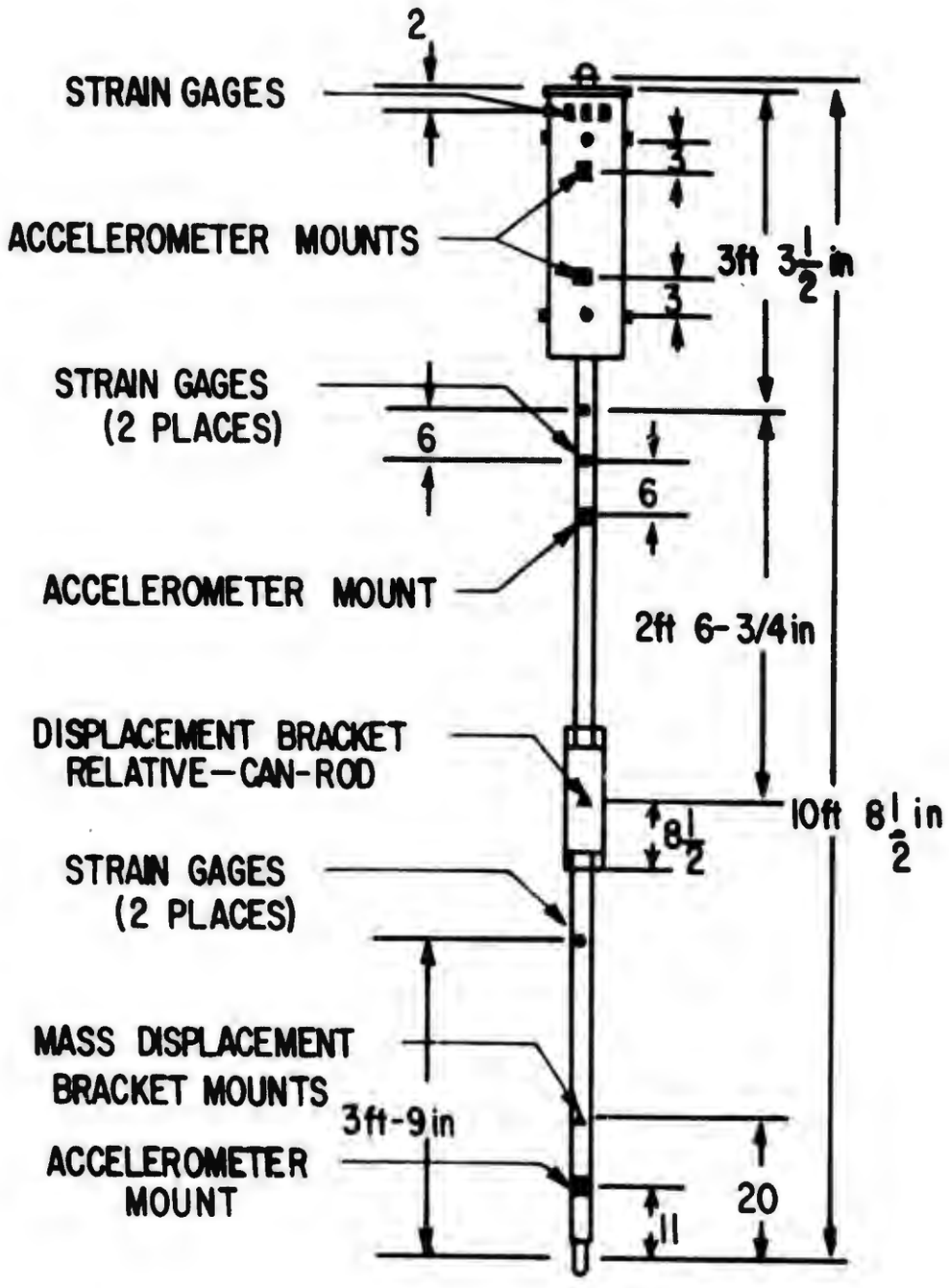


Figure 3. Instrumentation Locations--Typical for All Isolators

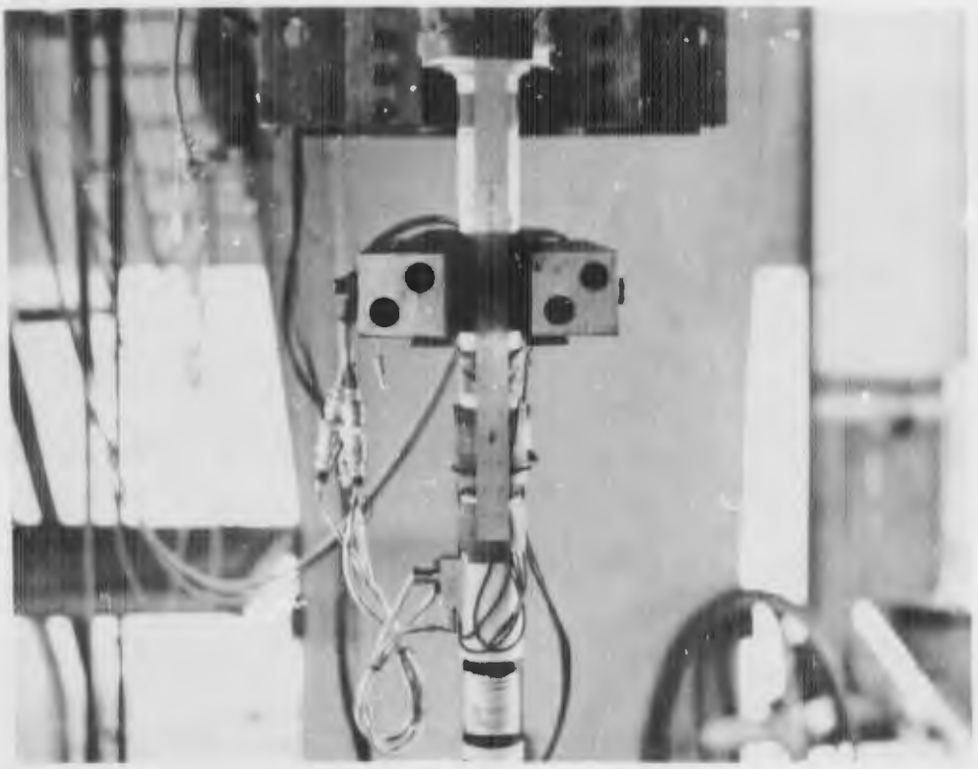


Figure 4. Instrumentation--Strain Gage and Accelerometer Installation at Upper Rod Location

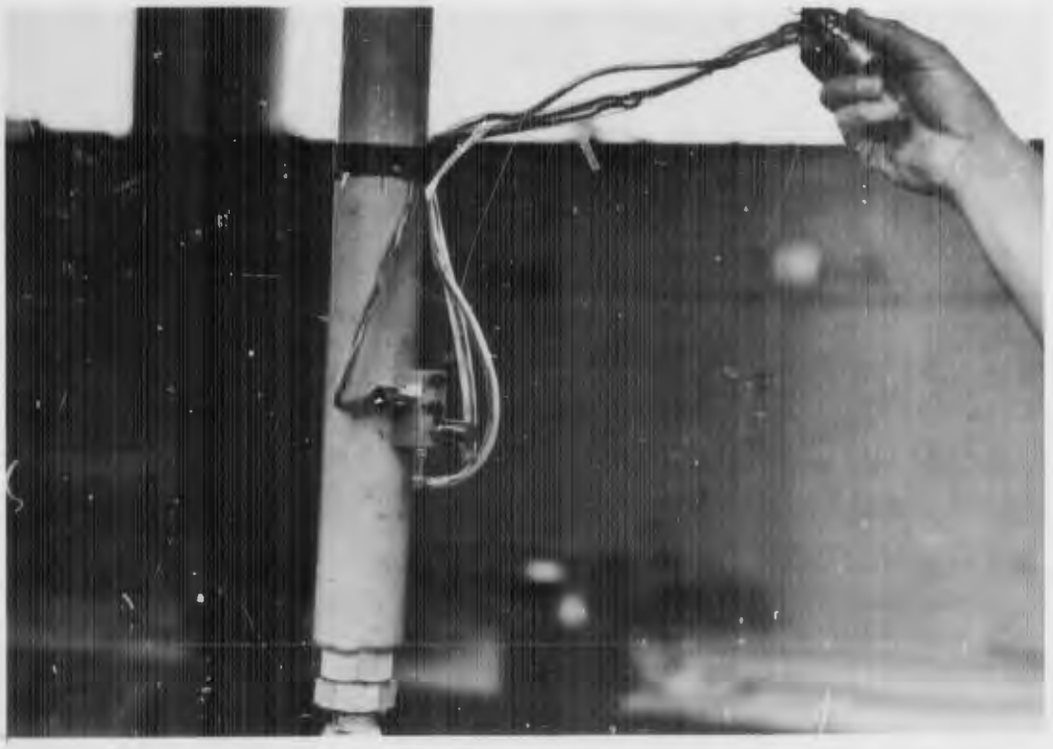


Figure 5. Instrumentation--Accelerometer Installation at Lower Rod Location

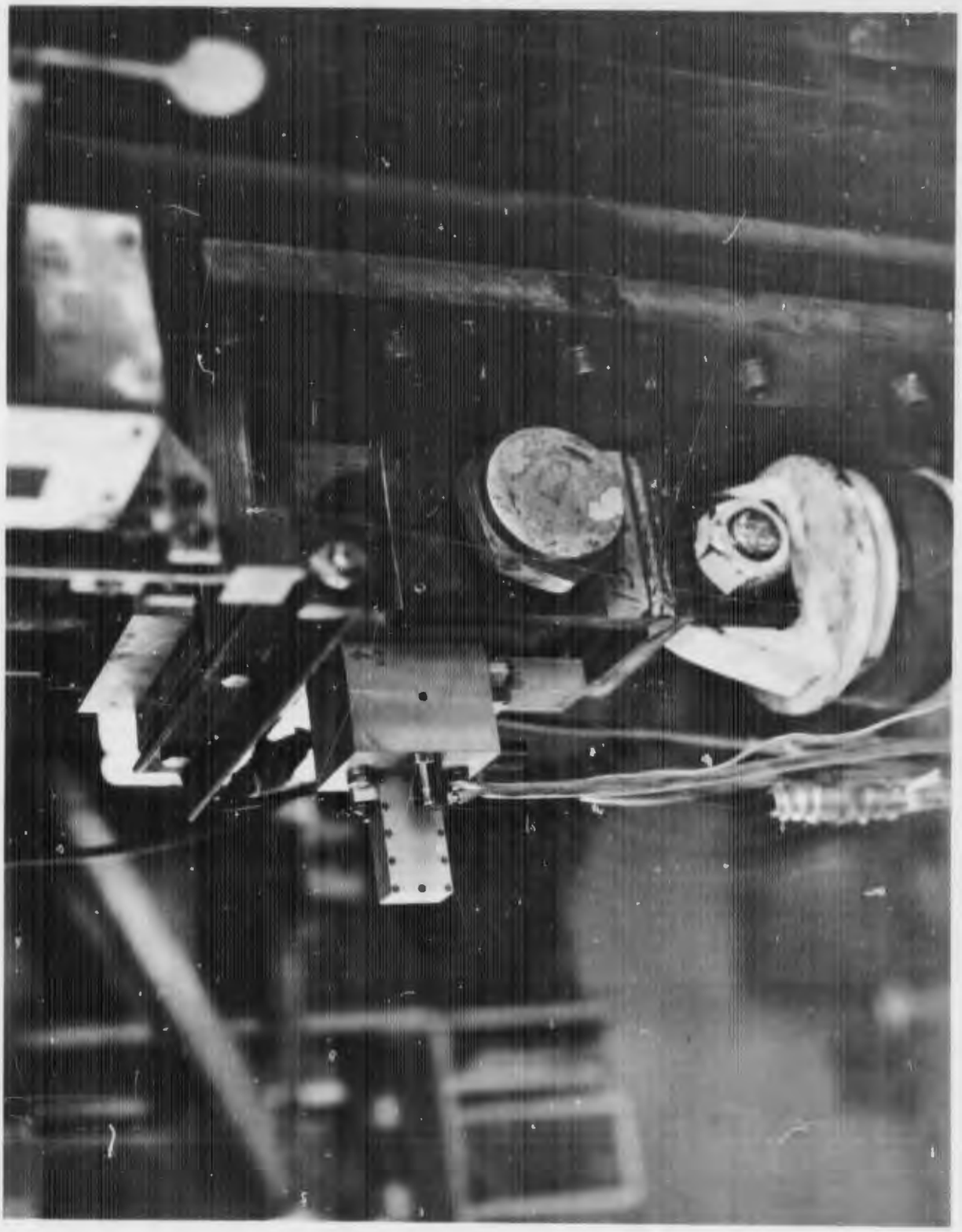


Figure 6. Instrumentation--Accelerometer Installation at the Shock Input Location

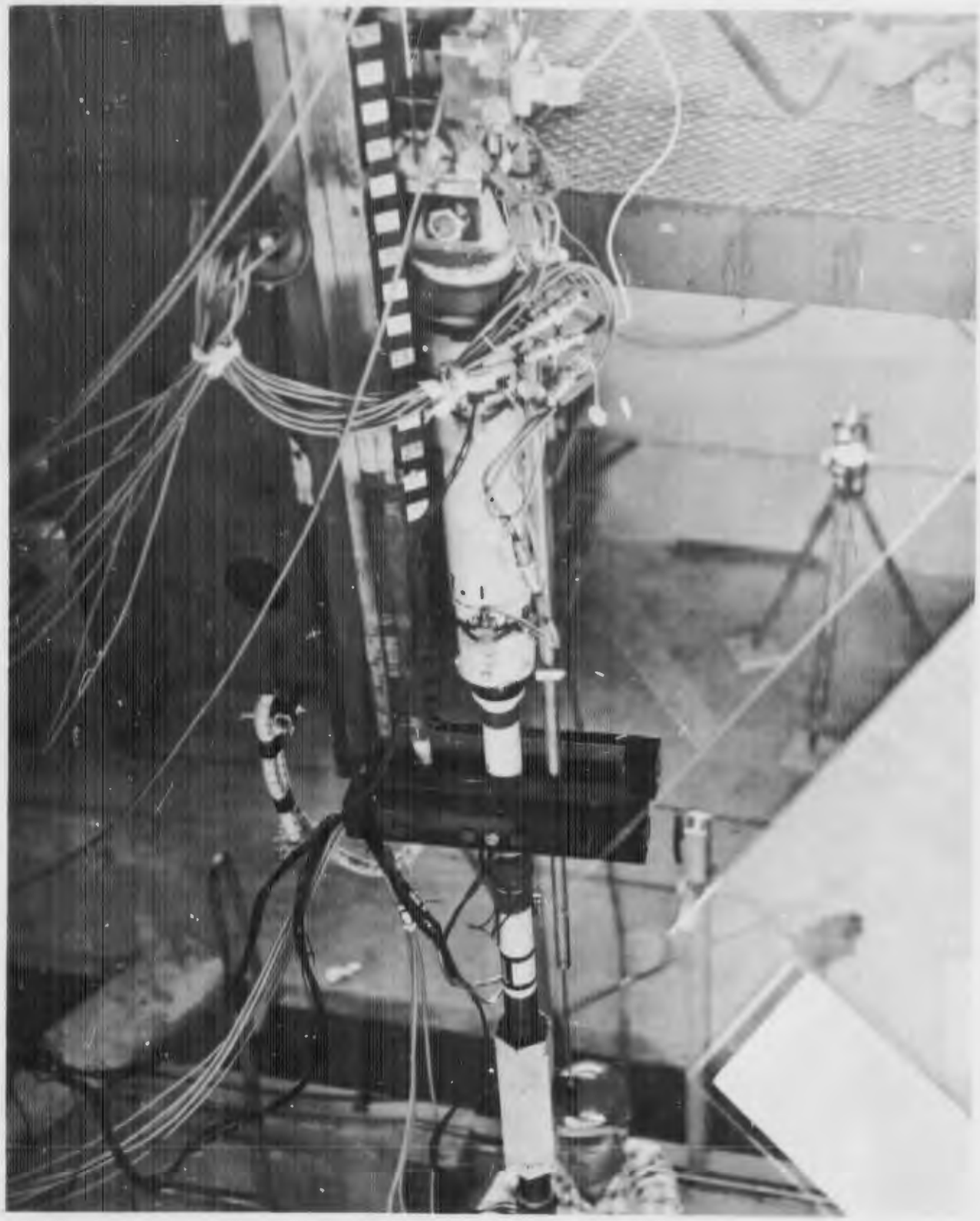


Figure 7. Instrumentation--General View Upper Portion of Isolator

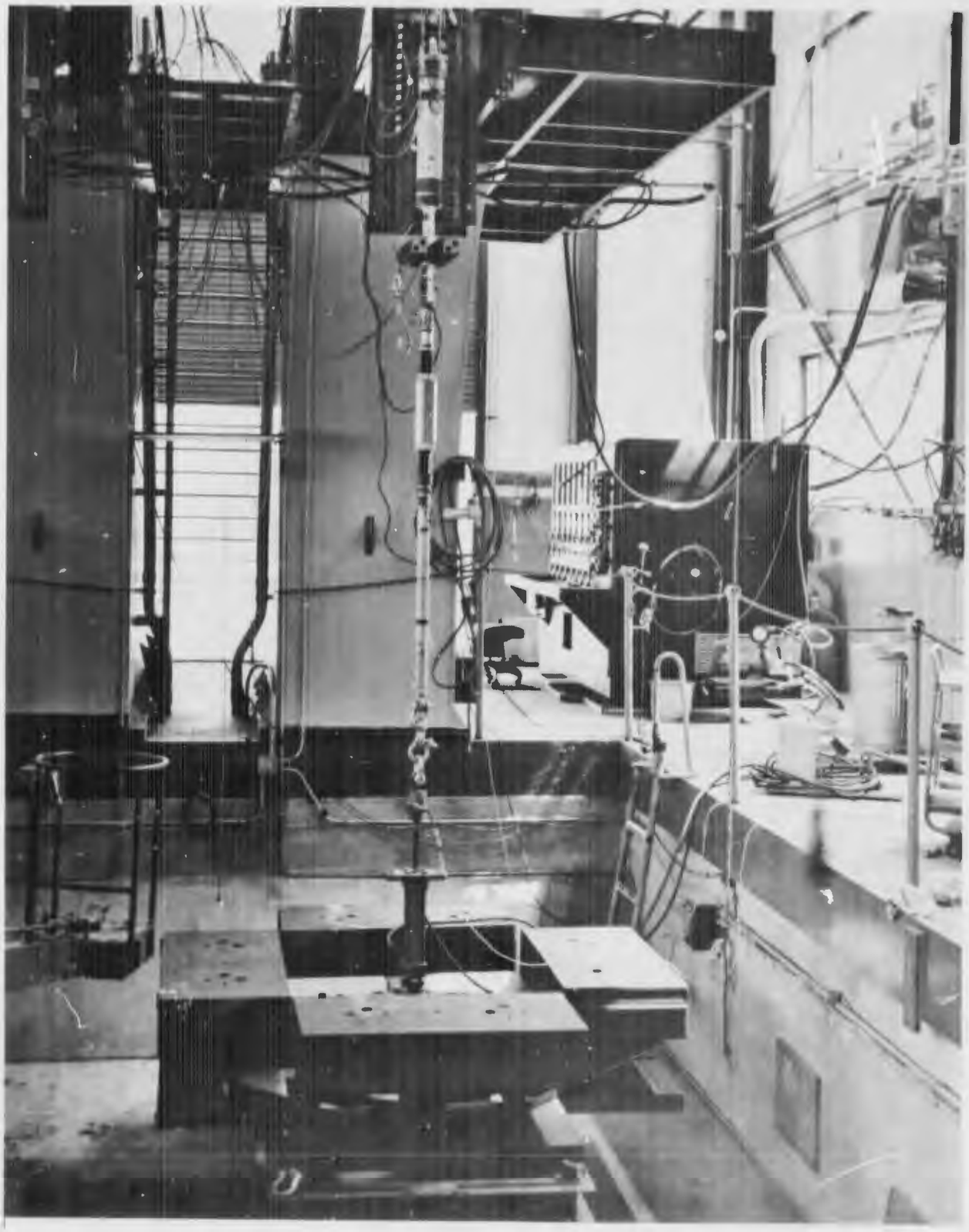


Figure 8. Test Setup--Spring Rate Test

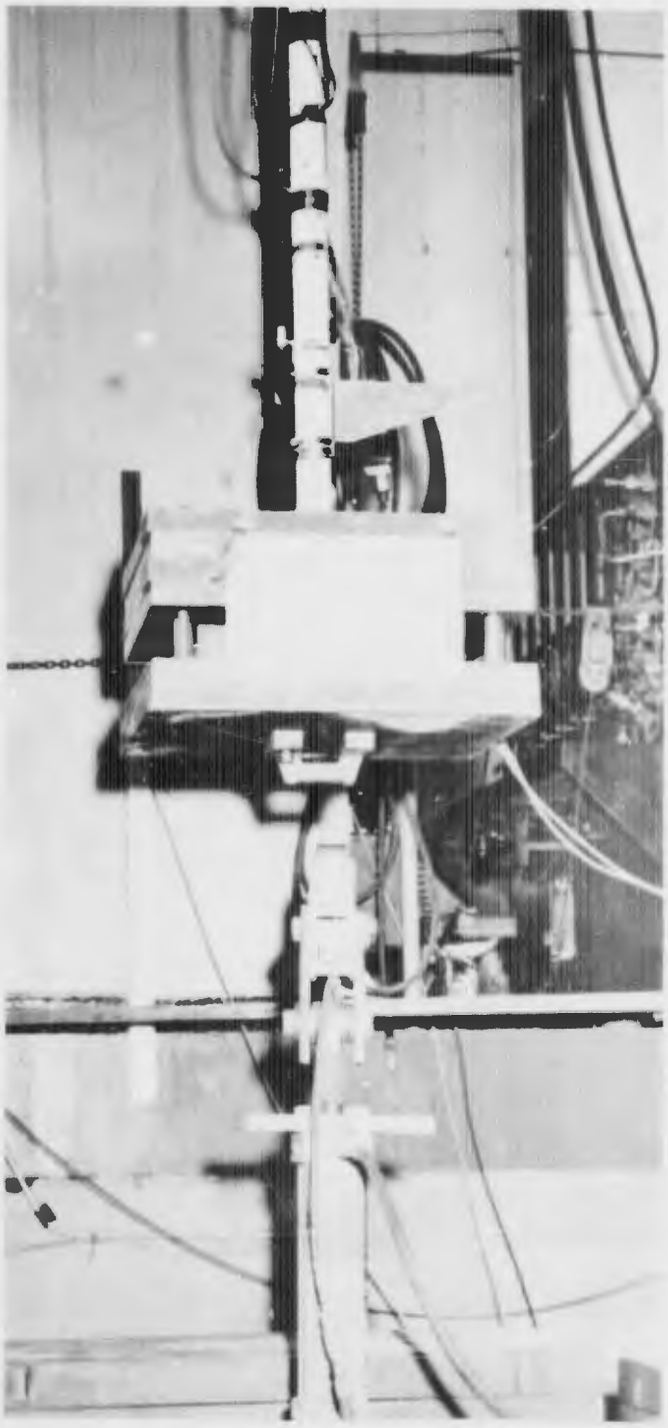


Figure 9. Quick Release Method--Twang Test

SECTION IV

TEST RESULTS

1. TEST LOG

A test log, which includes the reference run number or shot number, date, configuration, and test condition, is represented in Appendix I.

2. ISOLATOR TEST HISTORY

The individual test history and test results for each LER isolator are included in Appendix II.

3. POST-TEST INSPECTION

The post-test inspection results for each individual LER isolator are shown in Appendix III.

4. POST-TEST AND FAILURE ILLUSTRATIONS

Figures 10 and 11 show views of Type I, S/N 26 isolator after incremental vertical shock testing. This was the first isolator to undergo shock testing. Figure 11 illustrates the permanent set in the spring.

Figures 12 and 13 show the general condition of Type IV, S/N 1 isolator after incremental vertical shock testing. No failure or permanent damage was apparent. However, internal impacting at the upper can stop was noted as shown in figure 13.

Figure 14 shows a typical Type III isolator failure. The isolator rod-end bearing proved to be the weakest "link" on all Type III isolators. Figure 15 shows the Type III rod-end bearing failure and damage to the lower can stop cap screws.

Figure 16 shows a close-up view of a typical Type I isolator failure. The six cap screws, which attached the lower can stop, failed in shear. Figure 17 shows Type I, S/N 3 isolator test configuration after a secondary failure of the shock cord (bungee cord). No damage occurred to the isolator components as a result of the secondary failure. Figure 18 shows another view of a typical Type I isolator failure. The isolator rod is restrained by the shock cord during this failure.

Failures to Type IV isolators were identical to Type I failures. Figure 19 shows a typical Type IV cap screw shear failure at the lower can stop.

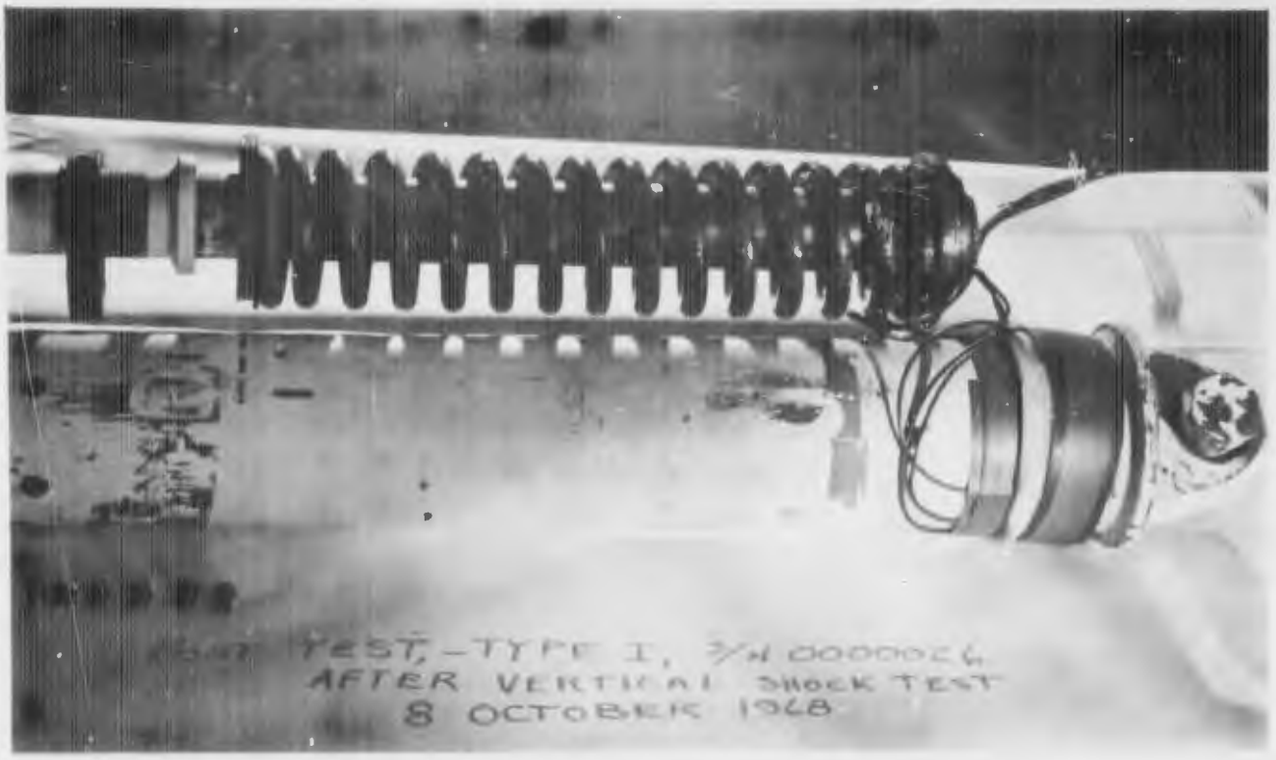


Figure 10. Type I, S/N 26, Post-Test Inspection of Spring Assembly

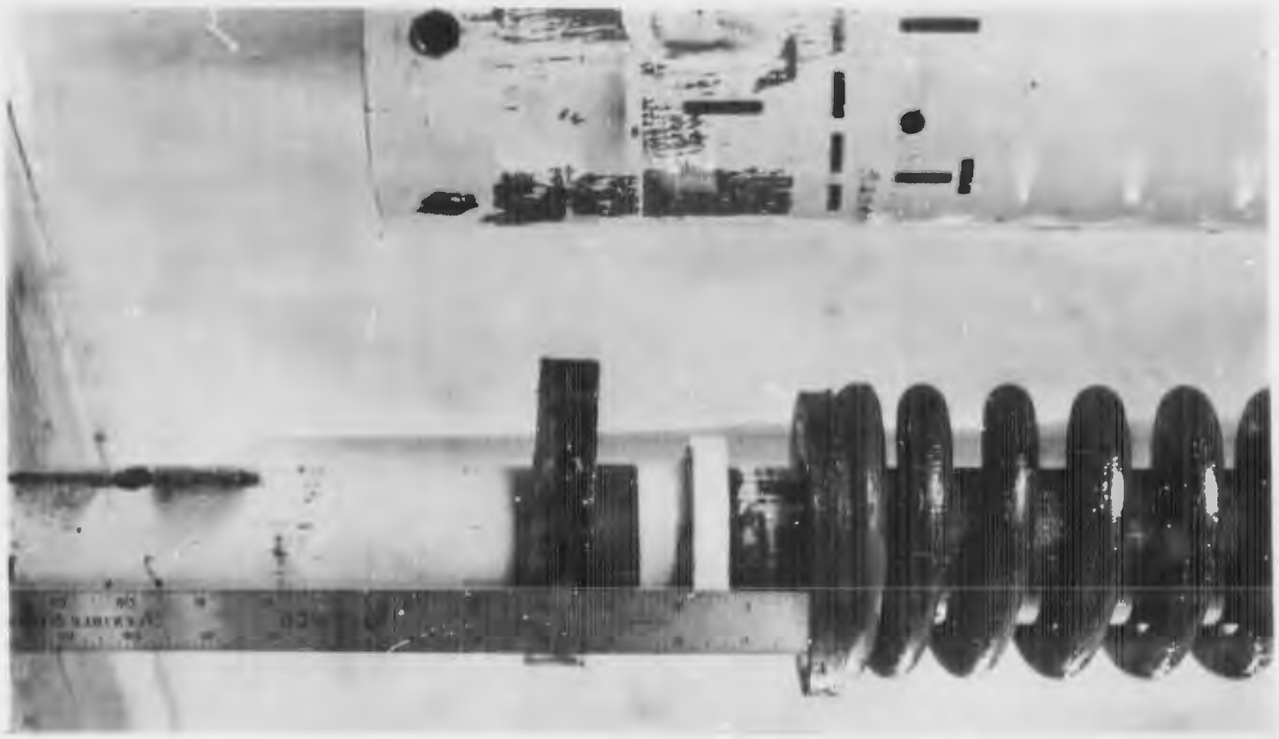


Figure 11. Type I, S/N 26, Close-Up of Permanent Set in Spring after Testing

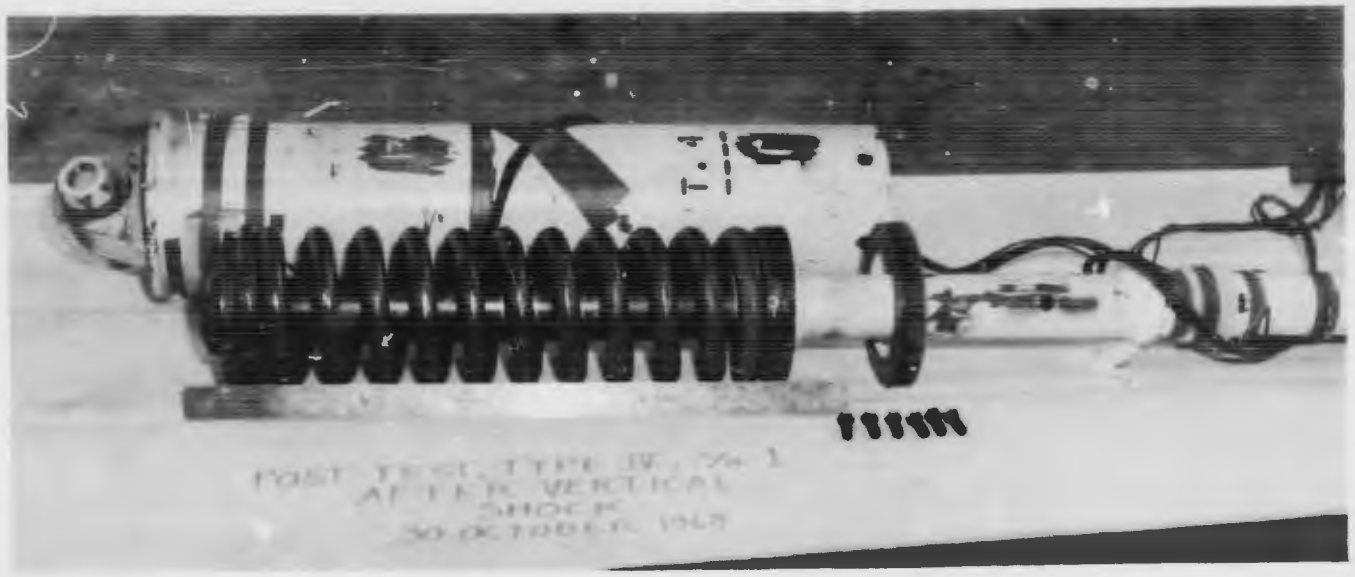


Figure 12. Type IV, S/N 1, Post-Test Inspection of Spring Assembly

Figure 13. Type IV, S/N 1, Close-Up of "Clang-Bang" Effect on Upper Can Stop

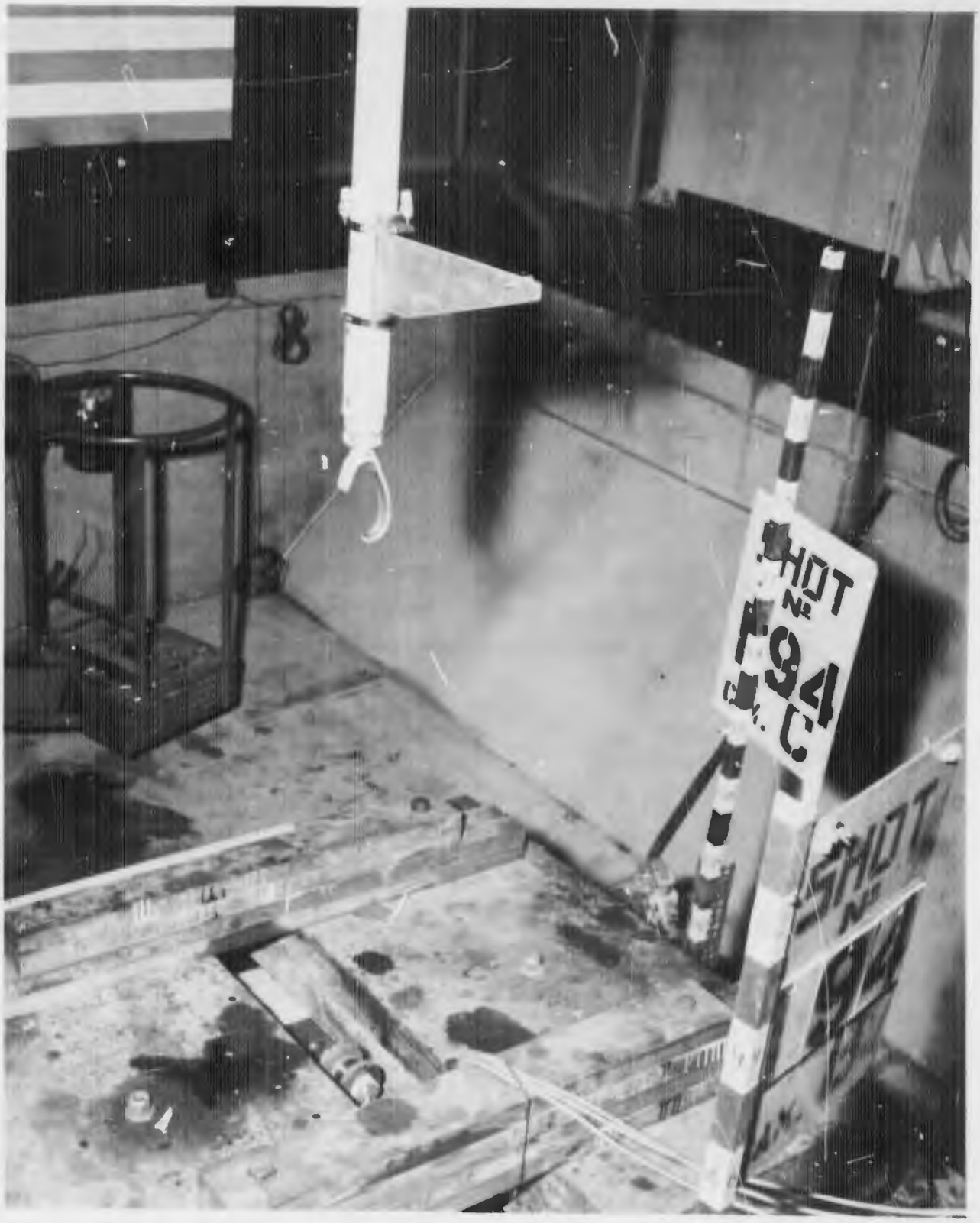


Figure 14. Typical Type III Test Failure

Figure 15. Type III, S/N 23, Test Failures

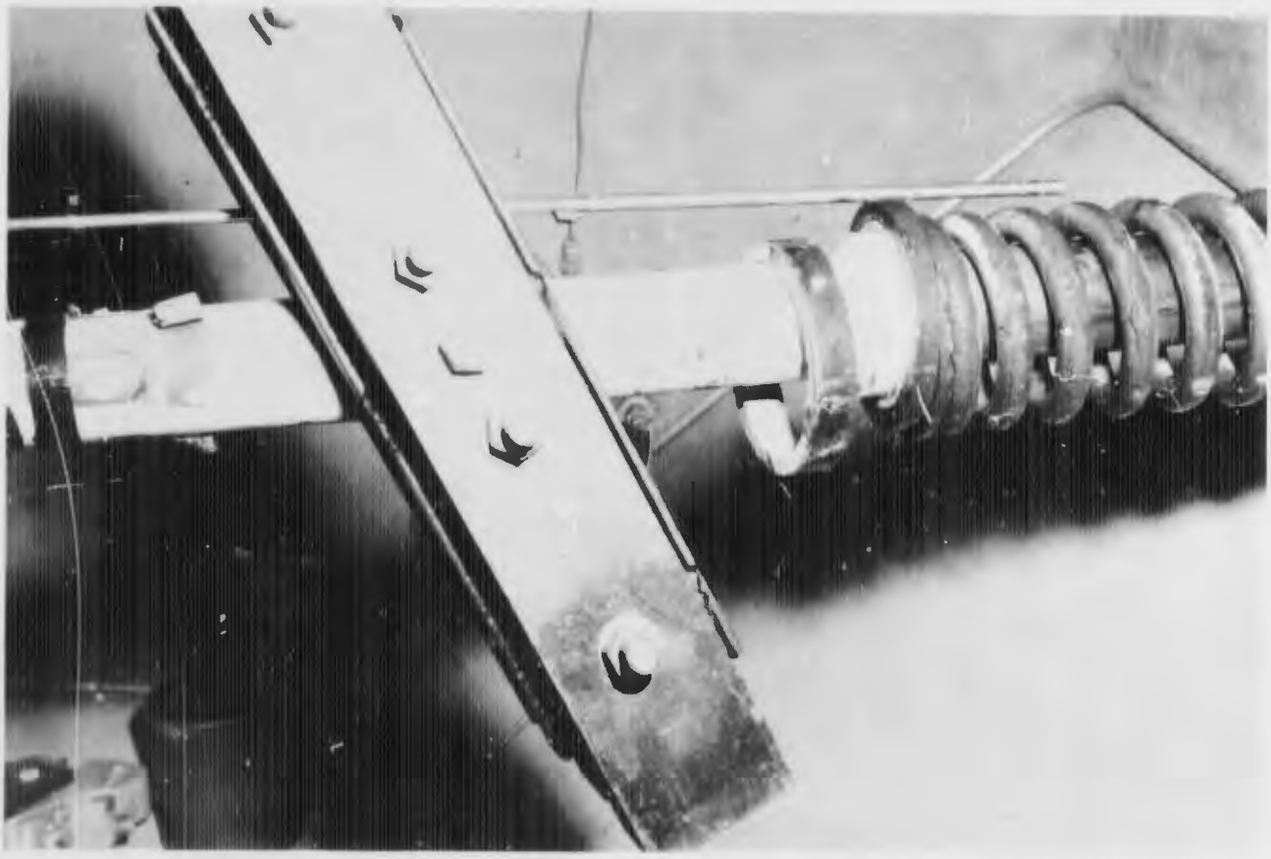


Figure 16. Typical Type I Failure--Cap Screw Shear Failure at Lower Can Stop

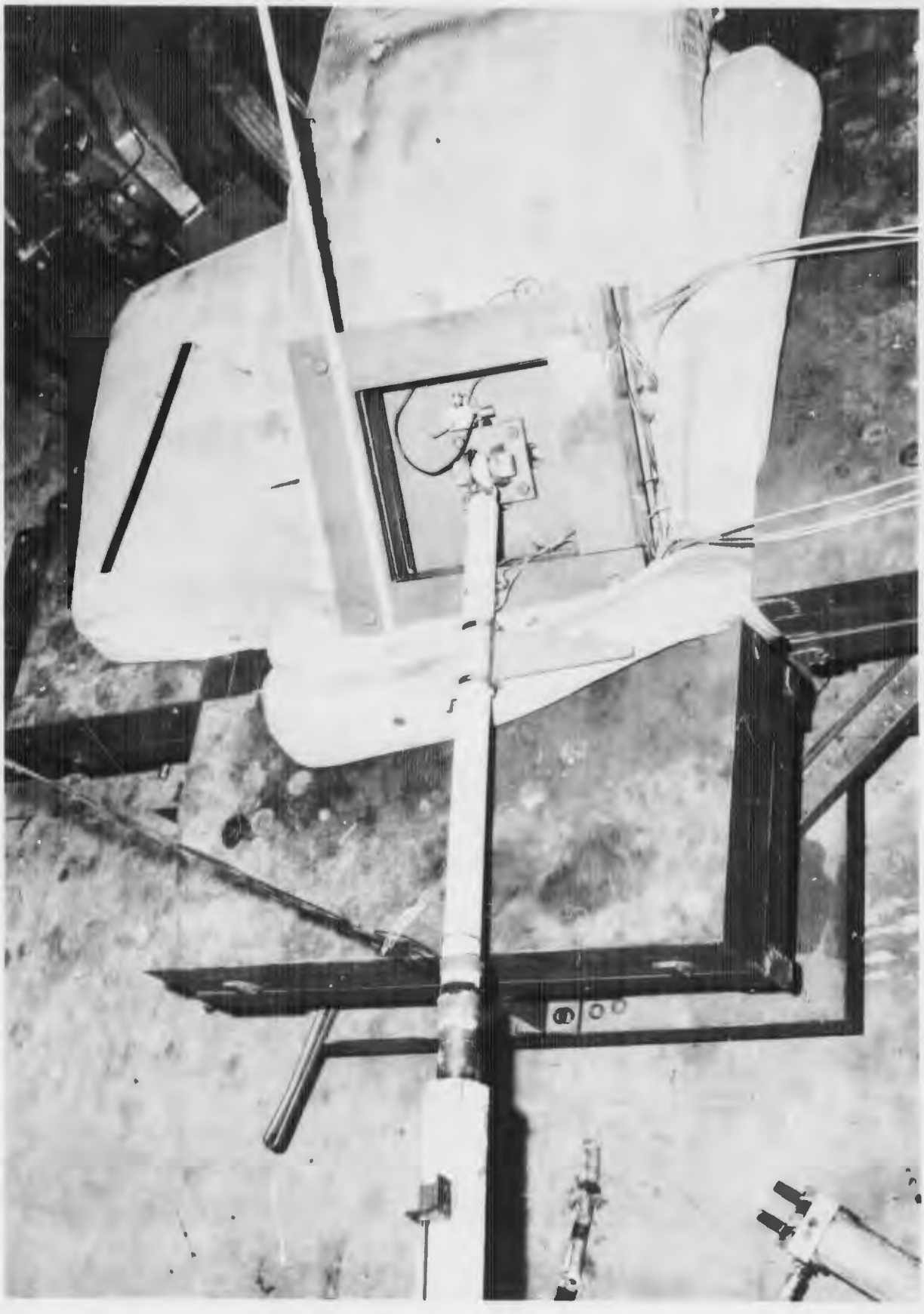


Figure 17. Type I, S/N 3, Test Configuration after Isolator Failure--Secondary Failure of Shock Cord

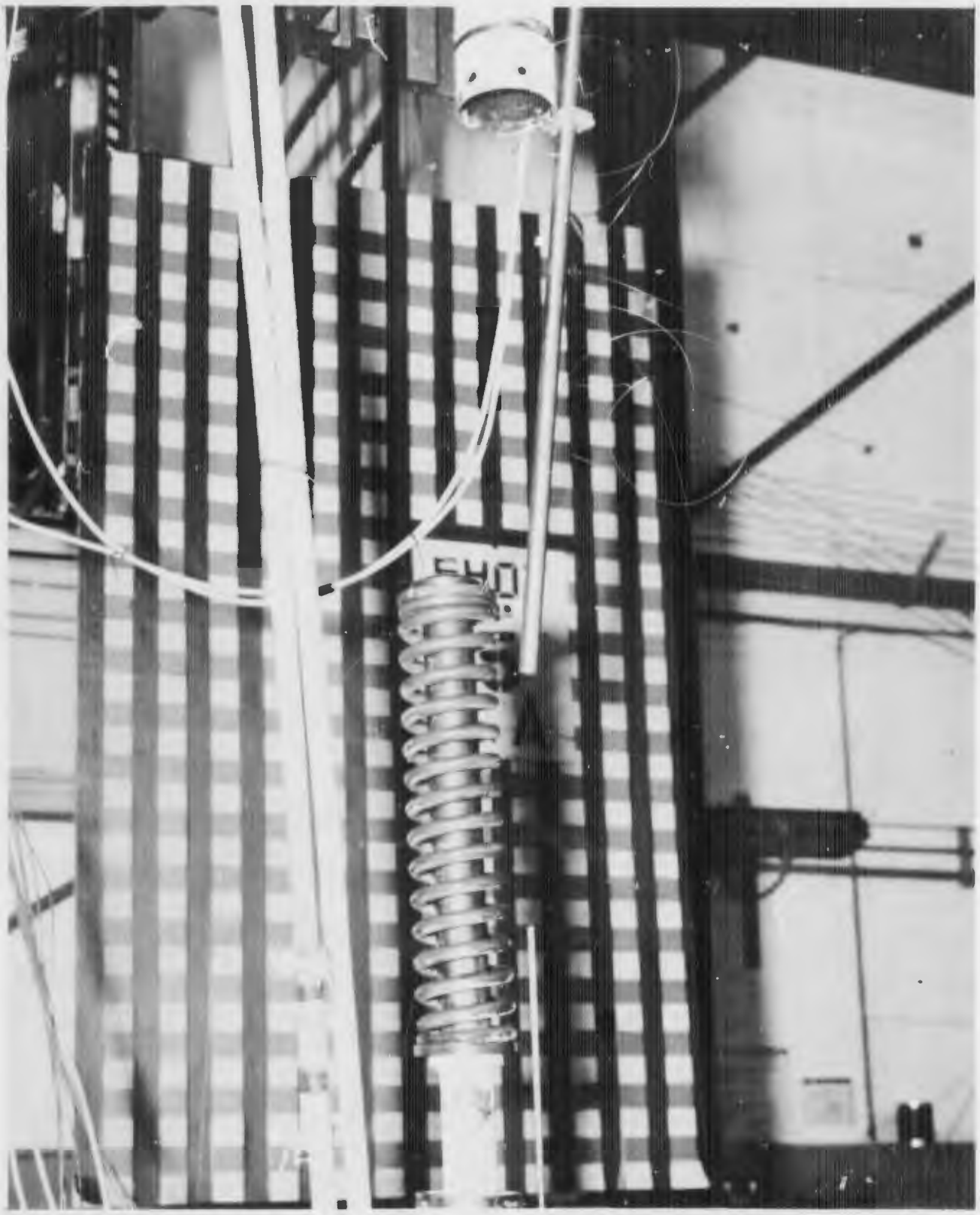


Figure 18. Typical Type I Failure at Lower Can Stop--Restrained by Shock Cord

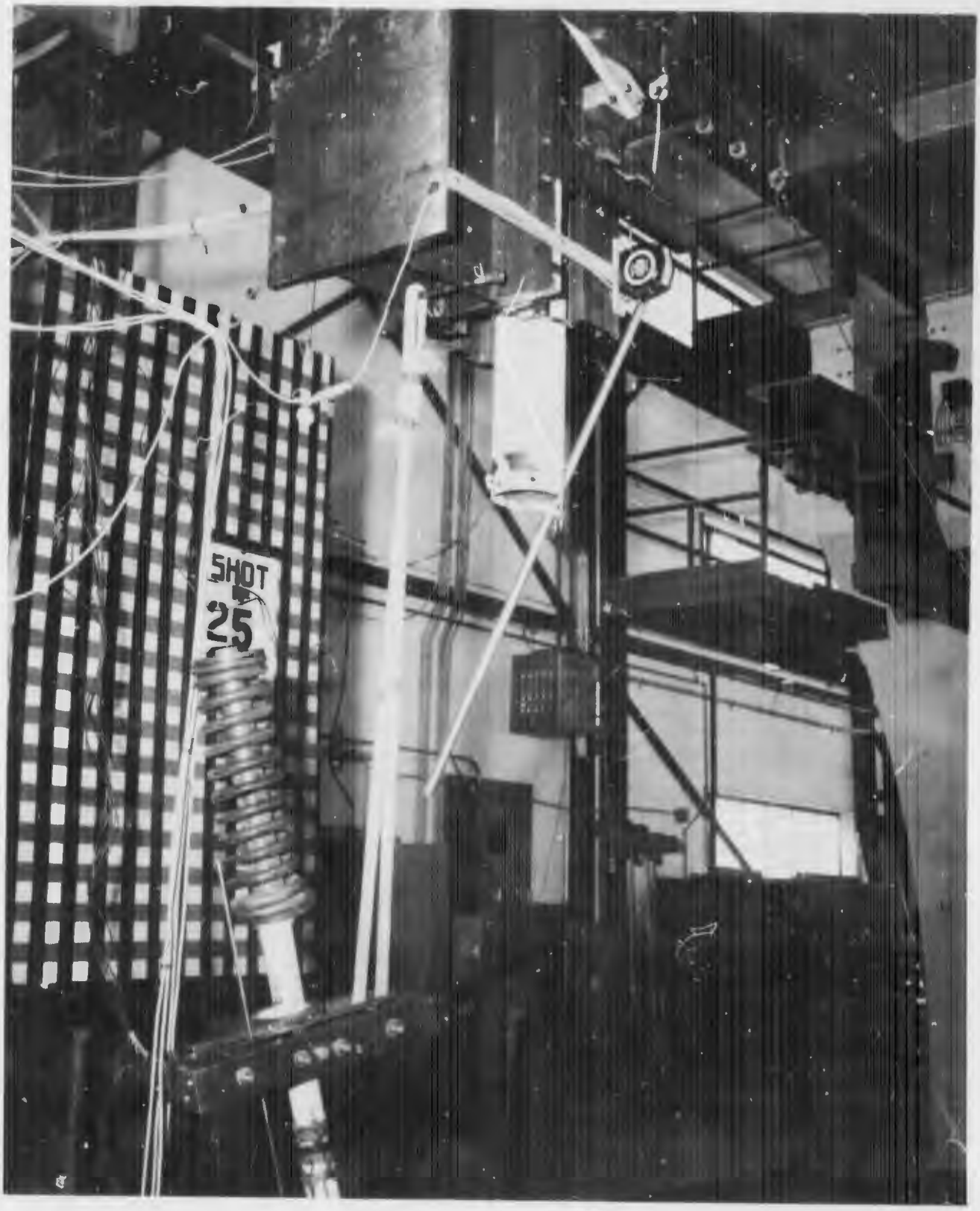


Figure 19. Typical Type IV Failure--Cap Screw Shear Failure at Lower Can Stop

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

a. All test requirements were met and the test results showed conclusively that different modes of failure do occur during a shock input to the LER Shock Isolators.

b. All failures occurred during the hard spring (spring solid height) mode of shock input.

c. Failures occurred in two areas: (1) the lower rod-end bearing, and (2) the cap screws which attach the lower can stop to the spring can. Both of these failures had been anticipated. The cap screw shear failure occurred on the Type I and Type IV isolators, while the lower rod-end bearing failure occurred on the Type III isolators.

d. Test success criteria was obtained with the acquisition of sufficient test data to satisfy the test requirements.

2. RECOMMENDATIONS

a. It is recommended that the joint between the cap screws and the lower can stop be redesigned and made stronger. The redesign should include an increased shear-tensile area in the cap screws as well as stronger cap screws.

b. It is recommended that the lower rod-end bearing be redesigned and made stronger, structurally.

c. It is recommended that the isolators be refurbished at the two failure areas, and the higher mode shock testing be repeated to prove isolator survival.

APPENDIX I

TEST LOG

Run no. or shot no.	Date	Configuration	Test condition
Spring rate No. 1	20 Aug 68	Type I S/N 0000026	Incremental static pulls to 7-1/2 inches total
Spring rate No. 2	21 Aug 68	Type I S/N 0000026	Incremental static pulls to 7-1/2 inches total
Twang test No. 1	6 Sep 68	Type I S/N 0000026	3-1/4-inch pull-down then released
Twang test No. 2	10 Sep 68	Type I S/N 0000026	3-1/4-inch pull-down then released
Shot 172	1 Oct 68	Type I S/N 0000026	Incremental vertical V1
Shot 173	1 Oct 68	Type I S/N 0000026	Incremental vertical V3
Shot 174	1 Oct 68	Type I S/N 0000026	Incremental vertical V5
Twang test No. 3	2 Oct 68	Type I S/N 0000026	4-1/2-inch pull-down then released
Twang test No. 4	2 Oct 68	Type I S/N 0000026	5-3/4-inch pull-down then released
Shot 175	2 Oct 68	Type I S/N 0000026	Incremental vertical V7.5
Shot 176	3 Oct 68	Type I S/N 0000026	Incremental vertical V8
Shot 177	3 Oct 68	Type I S/N 0000026	Incremental vertical V12
Shot 178	4 Oct 68	Type I S/N 0000026	Incremental vertical V12.75
Shot 179	4 Oct 68	Type I S/N 0000026	Incremental vertical V16
Spring rate No. 1	16 Oct 58	Type IV S/N 1	Incremental static pulls to 6 inches total
Spring rate No. 2	17 Oct 68	Type IV S/N 1	Incremental static pulls to 6 inches total

Run no. or shot no.	Date	Configuration	Test condition
Shot 216	15 Jan 69	Type III S/N 1	Incremental horizontal H3
Shot 217	15 Jan 69	Type III S/N 1	Incremental horizontal H4.5
Shot 229	24 Jan 69	Type III S/N 1	CD, V- V3, VV1
Shot 230	24 Jan 69	Type III S/N 1	CD, V- V3, VV2
Shot 231	27 Jan 69	Type III S/N 1	CD, V- V3, VV2
Shot 232	27 Jan 69	Type III S/N 1	CD, V- V3, VV3
Shot 233	28 Jan 69	Type III S/N 1	CD, V- V5.75, VV1
Shot 234	28 Jan 69	Type III S/N 1	CD, V- V5.75, VV2
Shot 235	28 Jan 69	Type III S/N 1	CD, V- V5.75, VV3
Shot 236	29 Jan 69	Type III S/N 1	CD, V- V9.5, VV1 with solid height stop
Shot 237	29 Jan 69	Type III S/N 1	CD, V- V9.5, VV2 with solid height stop; isolator failed
Spring rate No. 1	3 Feb 69	Type III S/N 3	Incremental static pull to 6 inches total
Twang test No. 1	6 Feb 69	Type III S/N 3	4-inch pull-down then released
Shot 238	7 Feb 69	Type III S/N 3	CV, D- V100, V2.3
Shot 239	7 Feb 69	Type III S/N 3	CV, D- V100, V4.5
Shot 240	10 Feb 69	Type III S/N 3	CV, D- V100, V7
Shot 241	11 Feb 69	Type III S/N 3	CV, D- V100, V7

Run no. or shot no.	Date	Configuration	Test condition
Shot 242	11 Feb 69	Type III S/N 3	CV, D- V200, V5.5
Shot 243	11 Feb 69	Type III S/N 3	CV, D- V200, V7
Shot 244	12 Feb 69	Type III S/N 3	CV, D- V100, V10 with solid height stop; isolator failed
Spring rate No. 1	24 Feb 69	Type III S/N 2	Incremental static pull to 6 inches total
Twang test No. 1	26 Feb 69	Type III S/N 2	4-1/16-inch pull-down then released
Shot 252	27 Feb 69	Type III S/N 2	Combined--H2, V2
Shot 253	27 Feb 69	Type III S/N 2	Combined--H3, V3.5
Shot 254	27 Feb 69	Type III S/N 2	Combined--H3, V5
Shot 255	27 Feb 69	Type III S/N 2	Combined--H3, V5
Shot 256	28 Feb 69	Type III S/N 2	Combined--H3, V5
Shot 257	28 Feb 69	Type III S/N 2	Combined--H3, V7
Shot 258	28 Feb 69	Type III S/N 2	Combined--H4.5, V10 with solid height stop on V10; isolator failed
Shot 267	12 Mar 69	Type I S/N 3	CD, V- V5, VV1
Shot 268	12 Mar 69	Type I S/N 3	CD, V- V5, VV2
Shot 269	12 Mar 69	Type I S/N 3	CD, V- V5, VV3
Shot 270	12 Mar 69	Type I S/N 3	CD, V- V9.5, VV1 with solid height stop
Shot 271	13 Mar 69	Type I S/N 3	CD, V- V9.5, VV2 with solid height stop

Run no. or shot no.	Date	Configuration	Test condition
Shot 272	13 Mar 69	Type I S/N 3	CD, V- V9.5, VV3 with solid height stop; isolator failed
Spring rate No. 1	17 Mar 69	Type I S/N 4	Incremental static pull to 4 inches total
Twang test No. 1	18 Mar 69	Type I S/N 4	3-13/16-inch pull-down then released
Shot 273	19 Mar 69	Type I S/N 4	CV, D- V100, V2.3
Shot 274	19 Mar 69	Type I S/N 4	CV, D- V100, V6.5
Shot 275	19 Mar 69	Type I S/N 4	CV, D- V100, V9.75 with solid height stop; isolator failed
Spring rate No. 1	21 Mar 69	Type I S/N 2	Incremental static pull to 4 inches total
Twang test No. 1	24 Mar 69	Type I S/N 2	3-3/16-inch pull-down then released
Shot 276	24 Mar 69	Type I S/N 2	Combined--H2, V3
Shot 277	24 Mar 69	Type I S/N 2	Combined--H2, V5
Shot 278	25 Mar 69	Type I S/N 2	Combined--H3, V7.5
Shot 279	25 Mar 69	Type I S/N 2	Combined--H3, V9.75 with solid height stop on V9.75
Shot 280	25 Mar 69	Type I S/N 2	Combined--H3, V9.75 with solid height stop on V9.75; isolator failed
Shot 281	2 Apr 69	Type IV S/N 4	CD, V- V5, VV1
Shot 282	2 Apr 69	Type IV S/N 4	CD, V- V5, VV2
Shot 283	2 Apr 69	Type IV S/N 4	CD, V- V5, VV3
Shot 284	2 Apr 69	Type IV S/N 4	CV, D- V100, V2.3

Run no. or shot no.	Date	Configuration	Test condition
Shot 285	3 Apr 69	Type IV S/N 4	CV, D- V100, V6
Shot 286	3 Apr 69	Type IV S/N 4	CV, D- V200, V7
Shot 287	4 Apr 69	Type IV S/N 4	CV, D- V200, V7
Shot 288	4 Apr 69	Type IV S/N 4	Combined--H2, V3
Shot 289	7 Apr 69	Type IV S/N 4	Combined--H2, V3
Shot 290	7 Apr 69	Type IV S/N 4	Combined--H2, V5
Shot 291	7 Apr 69	Type IV S/N 4	Combined--H3, V7.5
Shot 292	8 Apr 69	Type IV S/N 4	CD, V- V9, VV1
Shot 293	8 Apr 69	Type IV S/N 4	CD, V- V9, VV2
Shot 294	8 Apr 69	Type IV S/N 4	CD, V- V9, VV3
Shot 295	8 Apr 69	Type IV S/N 4	CV, D- V100, V9.25 with solid height stop
Shot 296	8 Apr 69	Type IV S/N 4	CV, D- V200, V9.25 with solid height stop
Shot 297	8 Apr 69	Type IV S/N 4	Combined--H3, V9.25 with solid height stop on V9.25
Shot 298	9 Apr 69	Type IV S/N 4	Combined--H3, V9.25 with solid height stop on V9.25
Shot 299	9 Apr 69	Type IV S/N 4	CD, V- V11.5, VV1 with solid height stop; isolator failed
Spring rate No. 1	10 Apr 69	Type IV S/N 3	Incremental static pull to 4 inches total
Twang test No. 1	11 Apr 69	Type IV S/N 3	2-5/8-inch pull-down then released

Run no. or shot no.	Date	Configuration	Test condition
Shot 300	11 Apr 69	Type IV S/N 3	CD, V- V9, VV2
Shot 301	14 Apr 69	Type IV S/N 3	CV, D- V200, V9.25 with solid height stop; isolator failed
Spring rate No. 1	17 Apr 69	Type IV S/N 2	Incremental static pull to 4 inches total
Twang test No. 1	17 Apr 69	Type IV S/N 2	2-3/8-inch pull-down then released
Shot 302	17 Apr 69	Type IV S/N 2	CD, V- V9, VV2
Shot 303	17 Apr 69	Type IV S/N 2	CV, D- V200, V9.25 with solid height stop
Shot 304	17 Apr 69	Type IV S/N 2	CD, V- V11.5, VV2 with solid height stop; isolator failed

APPENDIX II

ISOLATOR TEST HISTORY

ISOLATOR:	Type I
SERIAL NO:	S/N 0000026
TEST WEIGHT:	1140 lb
TEST HISTORY:	Spring rate - K = 500 lb/in
	Twang test - f = 1.89 cps
SHOCK:	Incremental vertical--6 tests (V1, V3, V5, V7.5, V8, and V12) plus 2 higher level shocks (V12.75 and V16)
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--None
FAILURE RUN:	None--six incremental vertical tests was extent of testing
DETERIORATION DURING TESTS:	1-1/8 inches--permanent set in spring after twang test No. 2
	19/32 inch--additional permanent set after seventh incremental vertical test (V12.75)
	1/32 inch--additional permanent set after last incremental vertical test (V16)
TEST ARTICLE OR TEST ANOMALIES:	Erroneous "can strain" data obtained during spring rate test No. 1 necessitated repeat of test.
	Additional twang tests were conducted to check out instrumentation and obtain the "clang-bang" mode of isolator excitation.
	Solid height shock actuator stops not installed for the incremental shock tests.
	The shock test matrix, reference 2, was not available for shock tests. Criteria followed was preliminary information obtained before issuance of above document.
ADDITIONAL DATA:	None

ISOLATOR:	Type I
SERIAL NO:	S/N 2
TEST WEIGHT:	1140 lb
TEST HISTORY:	Spring rate - K = 467 lb/in
	Twang test - f = 2.00 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--five tests (H2, V3; H2, V5; H3, V7.5; H3, V9.75; H3, V9.75)
FAILURE RUN:	Fifth combined horizontal/vertical (H3, V 9.75) shock test. A solid height shock actuator stop was used on the vertical actuator during the failure run.
DESCRIPTION OF FAILURE:	The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear through the thread area.
DETERIORATION DURING TESTS:	1/16 inch--permanent set in spring after third combined horizontal/vertical test (H3, V7.5)
	3/16 inch--additional permanent set after fourth combined horizontal/vertical test (H3, V9.75)
TEST ARTICLE OR TEST ANOMALIES:	The combined horizontal/vertical (H3, V9.75) test was repeated because of a low velocity input from the vertical actuator on the initial test. Spring solid height was not obtained during the initial test. Failure was not anticipated on the repeat run, therefore the isolator accelerometers were not removed. Three accelerometers, two on the rod bottom location and one on the rod top location, were lost on the failure run.
ADDITIONAL DATA:	A solid height shock actuator stop was installed for the vertical actuator on the last two tests (H3, V9.75).

ISOLATOR:	Type I
SERIAL NO:	S/N 3
TEST WEIGHT:	1140 lb
TEST HISTORY:	Spring rate - K = 510 lb/in
	Twang test - f = 1.87 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--three tests (H2, H3, H4.5)
	Constant displacement with variable velocity--six tests (V5, VV1; V5, VV2; V5, VV3; V9.5, VV1; V9.5, VV2, V9.5, VV3)
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--None
FAILURE RUN:	Sixth variable velocity (V9.5, VV3) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	The six 3/8-16 cap screws, which attach the lower retainer ring to the spring can (lower can stop), failed in shear through the thread area.
DETERIORATION DURING TESTS:	13/16 inch--permanent set in spring after the spring rate test
	1/32 inch--additional permanent set after third incremental horizontal test (H4.5)
	1/32 inch--additional permanent set after first variable velocity test (V5, VV1)
	1/32 inch--additional permanent set after second variable velocity test (V5, VV2)
	11/16 inch--additional permanent set after fourth variable velocity test (V9.5, VV1)
	3/32 inch--additional permanent set after fifth variable velocity test (V9.5, VV2)
	The six lower can stop cap screws showed indications of movement and were displaced by approximately 1/64 inch after the fourth variable velocity test (V9.5, VV1). Additional displacement was noted after the fifth variable velocity test (V9.5, VV2).
TEST ARTICLE OR TEST ANOMALIES:	None

ADDITIONAL DATA: The cross-axis (A-MT-Z1) mass accelerometer was out during the three incremental horizontal tests (H2, H3, H4.5).

The spring solid height was obtained during the first two cycles on both the fourth and fifth variable velocity tests (V9.5, VV1; V9.5, VV2).

ISOLATOR:	Type I
SERIAL NO:	S/N 4
TEST WEIGHT:	1140 lb
TEST HISTORY:	Spring rate - K = 473 lb/in
	Twang test - f = 1.88 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--three tests (V100, V2.3; V100, V6.5; V100, V9.75)
	Combined horizontal/vertical--None
FAILURE RUN:	Third variable displacement (V100, V9.75) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear through the thread area.
DETERIORATION DURING TESTS:	1/16 inch--permanent set in spring after the twang test.
	1/16 inch--additional permanent set after second variable displacement test (V100, V6.5).
TEST ARTICLE OR TEST ANOMALIES:	Failure was not anticipated on the very first solid height run at the lower velocity, therefore the isolator accelerometers were not removed. Two accelerometers, located at the rod bottom were lost on the failure run.
ADDITIONAL DATA:	A solid height shock actuator stop was installed only for the last shock test (V100, V9.75).

ISOLATOR:	Type III
SERIAL NO:	S/N 0000023
TEST WEIGHT:	5830 lb
TEST HISTORY:	Spring rate - K = 1808 lb/in
	Twang test - f = 1.67 cps
SHOCK:	Incremental vertical--seven tests (V2, V3.5, V5, V5, V7, V10, V10)
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--None
FAILURE RUN:	Seventh incremental vertical (V10) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	Failed the rod-end bearing.
DETERIORATION DURING TESTS:	3/16 inch--permanent set in spring after the spring rate test
	1/8 inch--additional permanent set after twang test
	1/8 inch--additional permanent set after fifth incremental vertical test (V7)
	1/8 inch--additional permanent set after sixth incremental vertical test (V10)
	Noted severe paint chipping around the upper and lower can stop cap screws. The chipping indicates significant stop movement during the "clang-bang" mode of isolator excitation.
TEST ARTICLE OR TEST ANOMALIES:	A jammed explosive bolt washer caused an actuator malfunction during the third incremental vertical run. The run was repeated.
ADDITIONAL DATA:	All accelerometers, except the input and test mass locations, were removed for the solid height (V10) runs.
	The mass vertical measuring accelerometer was lost during the failure run.

ISOLATOR:	Type III
SERIAL NO:	S/N 1
TEST WEIGHT:	5830 lb
TEST HISTORY:	Spring rate - K = 1905 lb/in
	Twang test - f = 1.75 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--three tests (H2, H3, H4.5)
	Constant displacement with variable velocity--nine tests (V3, VV1; V3, VV2; V3, VV2; V3, VV3; V5.75, VV1; V5.75, VV2; V5.75, VV3; V9.5, VV1; V9.5, VV2)
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--None
FAILURE RUN:	Ninth variable velocity (V9.5, VV2) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	Failed the rod-end bearing.
DETERIORATION DURING TESTS:	1/16 inch--permanent set in spring after first twang test
	1/8 inch--additional permanent set after eighth variable velocity test (V9.5, VV1)
TEST ARTICLE OR TEST ANOMALIES:	The twang test was repeated due to loss of the vertical measuring accelerometer on the initial twang test. The replacement accelerometer was lost on the repeat test.
	The variable velocity (V3, VV2) shock test was repeated due to bad oscillations and a delayed deceleration phase on the initial test
ADDITIONAL DATA:	A solid height shock actuator stop was installed for the last two shock tests (V9.5, VV1; V9.5, VV2).
	The spring solid height was obtained during the last two shock tests (V9.5, VV1; V9.5, VV2).
	All accelerometers, except the input and test mass locations, were removed for the last test.

ISOLATOR:	Type III
SERIAL NO:	S/N 2
TEST WEIGHT:	5830 lb
TEST HISTORY:	Spring rate - K = 2075 lb/in
	Twang test - f = 1.77 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--seven tests (H2, V2; H3, V3.5; H3, V5; H3, V5; H3, V5; H3, V7, H4.5, V10)
FAILURE RUN:	Seventh combined horizontal/vertical (H4.5, V10) shock test. A solid height shock actuator stop was used on the vertical actuator during the failure run.
DESCRIPTION OF FAILURE:	Failed the rod-end bearing.
DETERIORATION DURING TESTS:	1/16 inch--permanent set in spring after the twang test
	1/4 inch--additional permanent set after sixth combined horizontal/vertical test (H3, V7)
	Noted strain on rod-end bearing after the sixth combined horizontal/vertical test (H3, V7)
TEST ARTICLE OR TEST ANOMALIES:	High internal friction caused by oversize upper spring plate and oversize outer compression spring rubbing against can inner wall.
	The combined horizontal/vertical (H3, V5) was repeated two times due to a malfunctioned explosive bolt at the horizontal actuator on the first attempt and a malfunctioned explosive bolt at the vertical actuator on the second attempt.
ADDITIONAL DATA:	A solid height shock actuator stop was installed for the vertical actuator on the last test (H4.5, V10) only.
	All accelerometers, except the input and the test mass locations, were removed for the last test.

ISOLATOR:	Type III
SERIAL NO:	S/N 3
TEST WEIGHT:	5830 lb
TEST HISTORY:	Spring rate - K = 1925 lb/in
	Twang test - f = 1.71 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--seven tests (V100, V2.3; V100, V4.5; V100, V7; V100, V7; V200, V5.5; V200, V7; V100, V10)
	Combined horizontal/vertical--None
FAILURE RUN:	Seventh variable displacement (V100, V10) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	Failed the rod-end bearing.
DETERIORATION DURING TESTS:	1/32 inch--permanent set in spring after spring rate test
	1/16 inch--additional permanent set after second twang test
	1/16 inch--additional permanent set after second variable displacement test (V100, V4.5)
	1/16 inch--additional permanent set after third variable displacement test (V100, V7)
	1/16 inch--additional permanent set after fourth variable displacement test (V100, V7)
	Noted strain on rod-end bearing after fifth variable displacement test (200, V5.5). Additional strain was noted on the very next test and last test before failure occurred (V200, V7).
TEST ARTICLE OR TEST ANOMALIES:	The twang test was repeated to verify high-magnitude and high-frequency acceleration recorded readings taken at the can-top location. These readings were recorded on an oscilloscope trace.
	The variable displacement (V100, V7) shock test was repeated because of a low velocity input on the initial test

ADDITIONAL DATA: A solid height shock actuator stop was installed for the last shock test (V100, V10) only.

The spring solid height was obtained during the fourth (V100, V7) and sixth (V200, V7) shock tests.

All accelerometers, except the input and test mass locations, were removed for the last test.

The order of magnitude for the parallel oscilloscope acceleration readings at the can-top location was approximately 2-1/2 times that of the standard recording. The frequency range was in the order of 5,000 to 10,000 cps.

ISOLATOR:	Type IV
SERIAL NO:	S/N 1
TEST WEIGHT:	1055 lb
TEST HISTORY:	Spring rate - K = 770 lb/in
	Twang test - f = 2.53 cps
SHOCK:	Incremental vertical--seven tests (V3, V3, V5, V7.5, V9, V12, V12) plus two higher level shocks (V13, V15)
	Incremental horizontal--None
	Constant displacement with variable velocity--None
	Constant velocity with variable displacement--None
	Combined horizontal/vertical--None
FAILURE RUN:	None--seven incremental vertical tests was the extent of testing.
DETERIORATION DURING TESTS:	3/16 inch--permanent set in spring after sixth incremental vertical test (first V12)
TEST ARTICLE OR TEST ANOMALIES:	Erroneous "can strain" data obtained during spring rate test No. 1. Two 50 percent load cycles (third pull-down) were conducted to exercise the strain gages before spring rate test No. 2.
	Mass displacement data dropout occurred during twang test No. 1; the test was repeated.
ADDITIONAL DATA:	An additional spring rate test was performed on the isolator to obtain the spring solid height. A distance of 8-1/16 inches to solid height was obtained. Measurement was between the mating surfaces of the lower spring plate and the lower rod stop. New load calibrations were obtained for the strain location on the can from this test.
	Solid height shock actuator stops were installed for the last three (V12, V13, V15) shock tests.

ISOLATOR:	Type IV
SERIAL NO:	S/N 2
TEST WEIGHT:	1055 lb
TEST HISTORY:	Spring rate - K = 767 lb/in
	Twang test - f = 2.60 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--two tests (V9, VV2; V11.5, VV2)
	Constant velocity with variable displacement--one test (V200, V9.25)
	Combined horizontal/vertical--None
FAILURE RUN:	Second constant displacement (V11.5, VV2) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear through the thread area.
DETERIORATION DURING TESTS:	1/16 inch--permanent set in spring after the twang test
	3/16 inch--additional permanent set after first variable velocity test (V9, VV2)
	1/16 inch--additional permanent set after the variable displacement test (V200, V9.25)
TEST ARTICLE OR TEST ANOMALIES:	None
ADDITIONAL DATA:	A solid height shock actuator stop was used for the last two shock tests (V200, V9.25; V11.5, VV2).
	Only the input and the test mass accelerometers were used during the twang and shock tests.
	The spring solid height was obtained during the first cycle of both shock tests (V9, VV2; V200, V9.25).

ISOLATOR:	Type IV
SERIAL NO:	S/N 3
TEST WEIGHT:	1055 lb
TEST HISTORY:	Spring rate - K = 753 lb/in
	Twang test - f = 2.53 cps
SHOCK:	Incremental vertical--None
	Incremental horizontal--None
	Constant displacement with variable velocity--one test (V9, VV2)
	Constant velocity with variable displacement--one test (V200, V9.25)
	Combined horizontal/vertical--None
FAILURE RUN:	First constant velocity (V200, V9.25) shock test. A solid height shock actuator stop was used during the failure run.
DESCRIPTION OF FAILURE:	The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear through the thread area.
DETERIORATION DURING TESTS:	1/4 inch--Permanent set in spring after first constant displacement test (V9, VV2)
TEST ARTICLE OR TEST ANOMALIES:	None
ADDITIONAL DATA:	A solid height shock actuator stop was used for both of the shock tests (V9, VV2; V200, V9.25).
	Only the input and the test mass accelerometers were used during the twang and shock tests.
	The spring solid height was obtained during the first cycle of the variable velocity test (V9, VV2).

ISOLATOR: Type IV

SERIAL NO: S/N 4

TEST WEIGHT: 1055 lb

TEST HISTORY: Spring rate - K = 794 lb/in

Twang test - f = 2.44 cps

SHOCK: Incremental vertical--None

Incremental horizontal--three tests (H2, H3, H4.5)

Constant displacement with variable velocity--seven tests (V5, VV1; V5, VV2; V5, VV3; V9, VV1; V9, VV2; V9, VV3; V11.5, VV1)

Constant velocity with variable displacement--six tests (V100, V2.3; V100, V6; V200, V7; V200, V7; V100, V9.25; V200, V9.25)

Combined horizontal/vertical--six tests (H2, V3; H2, V3; H2, V5; H3, V7.5; H3, V9.25; H3, V9.25)

FAILURE RUN: Seventh variable velocity (V11.5, VV1) shock test. A solid height shock actuator stop was used during the failure run.

DESCRIPTION OF FAILURE: The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear through the thread area.

DETERIORATION DURING TESTS: 1/16 inch--permanent set in spring after third variable velocity test (V5, VV3)

1/16 inch--additional permanent set after third variable displacement test (V200, V7)

1/16 inch--additional permanent set after fourth variable velocity test (V9, VV1)

Noted paint chipping around lower can stop cap screws after fifth variable velocity test (V9, VV2)

TEST ARTICLE OR TEST ANOMALIES: Some data channels were not recorded during the initial twang test due to dirty heads on the tape recorder. The twang test was repeated.

The variable displacement (V200, V7) shock test was repeated due to an error on initial total stroke setup of 8 inches instead of 7 inches.

The combined horizontal/vertical (H2, V3) shock test was repeated due to an error on initial horizontal total stroke setup of 3 inches instead of 2 inches.

The combined horizontal/vertical (H3, V9.25) shock test was repeated due to an explosive bolt misfire on the horizontal actuator.

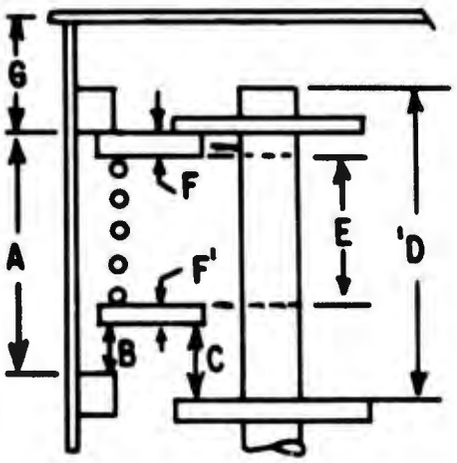
ADDITIONAL DATA: A solid height shock actuator stop was installed in the vertical actuator for tests which had a vertical stroke of 9.25 inches or above.

The spring solid height was obtained during the last seven shock tests (V9, VV2; V9, VV3; V100, V9.25; V200, V9.25; H3, V9.25; H3, V9.25; V11.5, VV1).

All accelerometers, except the input and test mass locations, were removed for the last five tests (V100, V9.25; V200, V9.25; H3, V9.25; H3, V9.25; V11.5, VV1).

APPENDIX III

LER ISOLATOR DIMENSIONS



Post-test inspection or as otherwise noted.

Sym-bol	Type I Serial No. 26	Type I Serial No. 2	Type I Serial No. 3	Type I Serial No. 4	Type III Serial No. 23	Type III Serial No. 1	Type III Serial No. 2	Type III Serial No. 3	Type IV Serial No. 1	Type IV Serial No. 2	Type IV Serial No. 3	Type IV Serial No. 4
A	$21\frac{13}{16}$	$21\frac{11}{16}$	$21\frac{11}{16}$	$21\frac{3}{4}$	$23\frac{1}{8}$	23	$23\frac{3}{16}$	$23\frac{1}{8}$	$20\frac{13}{16}$	$20\frac{13}{16}$	$20\frac{13}{16}$	$20\frac{13}{16}$
B 1>	---	$\frac{3}{8}$	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$
B 2>	$1\frac{11}{16}$	N.A. fail	N.A. fail	N.A. fail	$\frac{11}{16}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	N.A. fail	N.A. fail	N.A. fail
B 3>	$1\frac{1}{4}$	0	$\frac{3}{4}$	0	0	0	0	0	0	0	0	0
C 4>	4	$1\frac{13}{16}$	$2\frac{5}{16}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{9}{16}$	1	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$
5>	---	---	---	---	---	---	---	---	$8\frac{1}{16}$	---	---	---
D	$22\frac{1}{16}$	$22\frac{1}{8}$	$22\frac{1}{16}$	$22\frac{3}{16}$	$23\frac{3}{8}$	$22\frac{9}{16}$	$23\frac{3}{8}$	$23\frac{5}{16}$	$21\frac{1}{8}$	$21\frac{3}{16}$	$21\frac{3}{16}$	$21\frac{1}{4}$
E	$19\frac{1}{32}$	$20\frac{5}{16}$	$19\frac{1}{2}$	$20\frac{5}{16}$	21	21	21	21	$19\frac{1}{4}$	$19\frac{5}{16}$	$19\frac{1}{4}$	$19\frac{5}{16}$
F	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
F'	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
G	$6\frac{3}{16}$	$6\frac{3}{16}$	$6\frac{3}{16}$	$6\frac{3}{16}$	$5\frac{1}{16}$	$5\frac{1}{8}$	$5\frac{1}{16}$	$5\frac{1}{16}$	$6\frac{5}{16}$	$6\frac{5}{16}$	$6\frac{3}{8}$	$6\frac{5}{16}$
Outer N 6>	15	16	16	16	9	9	9	9	13	13	13	13
Inner	---	---	---	---	14	14	14	14	---	---	---	---

1) Pretest measurement

2) Post-test measurement

3) Measured with isolator unloaded

4) Measured with isolator loaded with test mass

5) Measured with spring compressed to solid height

6) Number of coils (including partial coils)

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13. ABSTRACT

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The summary data and results of tests performed on Minuteman Wing I Launcher Equipment Room (LER) Shock Isolators are presented in this report. The testing was performed by the Air Force Special Weapons Center at the request of Space and Missile Systems Organization (SAMSO). Single isolator displacement tests and single isolator shock tests were performed. The tests were conducted to determine the threshold of failure and the mode of failure for the LER isolator as the result of a shock loading condition or any other loading. The test results indicated a need for a number of improvements in the original design. Test data summary results, notation of observations made during testing, and other pertinent information are presented.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Minuteman Launcher Equipment Room						
Shock testing						
Seismic impulse facility						
Static characteristics						
Dynamic characteristics						

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