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AFSWC-TR-70-2, Vol. I

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STATIC AND SHOCK TESTING OF WING I, LER SHOCK ISOLATORS

Volume I

Test Requirements, Test Procedures, and Test Results

Frank T. Krek

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

TECHNICAL REPORT NO. AFSWC-TR-70-2, Vol. I

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FOREWORD

[illegible] n was performed under Program Element [illegible] by the Space and Missile Systems Organization (SAMSO) [illegible] were May 1969 through August 1969. [illegible], the Air Force Special Weapons Center [illegible]

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ABSTRACT

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Tests were performed on Minuteman Wing I Launcher Equipment Room (LER) Shock Isolators. Isolator component static tests, single isolator stiffness tests, single isolator ultimate static tests, and single isolator shock tests were performed. These tests determined the isolator mechanical stiffness, the isolator mechanical impedance and evaluated the use of damping collars on shock isolators for high-frequency shock attenuation. All test objectives were met.

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SECTION I

INTRODUCTION

1. GENERAL

This report presents data and test results of an investigation that was conducted on Minuteman Wing I Launcher Equipment Room (LER) Types I, III and IV shock isolators. The authority for this effort is contained in AF Form 111 for Project 133B4H, entitled Minuteman II and III, dated 12 May 1969. This authority was issued by Headquarters, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico.

The investigation was requested by the Space and Missile Systems Organization (SAMSO/SMQNM) in a memorandum, "Wing I LER Single Isolator Shock Tests, Supplemental Test Program," dated 22 April 1969. Volume II, Isolators Dynamic Shock Test Data Traces, will be published at a later date.

2. PURPOSE

The purpose of this investigation was primarily a series of static and dynamics tests to determine structural integrity and to evaluate the performance of three types of individual shock isolators. A secondary purpose was to evaluate the effects of damping collars on the performance of shock isolators for high-frequency shock attenuation.

3. SCOPE

The scope of this test program included fabrication of test fixtures to support component and isolator static testing, static testing and dynamic shock testing. The testing program consisted of the following:

a. Isolator component testing--to determine mechanical characteristics of shock isolator components.

b. Isolator stiffness tests--to determine stiffness characteristics of the shock isolators.

c. Isolator ultimate static strength tests--to determine the ultimate static strength of the shock isolators.

d. High-frequency shock attenuation test--to evaluate the effects of damping collars on high-frequency shock attenuation during a dynamic shock input pulse to the shock isolator.

e. Provide input and output data for determinating isolator mechanical impendence--The data is to be provided from the Linear, Clang-Bang and Hard-Spring modes of dynamic shock input pulses. These modes are defined as follows:

(1) Linear Mode (input displacement is insufficient to cause a clang-bang noise in the spring housing).

(2) Clang-Bang Mode (the upper and lower spring plates are excited to hit at both ends of the spring housing and at the upper and lower rod stops).

(3) Hard-Spring Mode (spring is compressed to solid height).

SECTION II

TEST SPECIMEN

1. ORIGIN

The LER isolators used in this test program were obtained from the Wing I site, Malmstrom AFB, Great Falls, Montana. The isolators were obtained after replacement isolators were furnished during a Force Modernization shutdown period.

2. ISOLATOR DESCRIPTION

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

a. The spring in a Type I isolator has the following characteristics:

(1) 23/32 in diameter wire

(2) 13 active coils

(3) 3-25/32 in mean coil diameter

(4) 16 total coils

(5) 21 in free length

(6) Designed spring rate of 500 lb/in

b. The Type III isolator contains two springs which are nested. The inner spring has the following characteristics:

(1) 31/32 in diameter wire

(2) 11-1/8 active coils

(3) 4-25/32 in mean coil diameter

(4) 14-1/8 total coils

(5) 22 in free length

(6) Designed spring rate of 953 lb/in

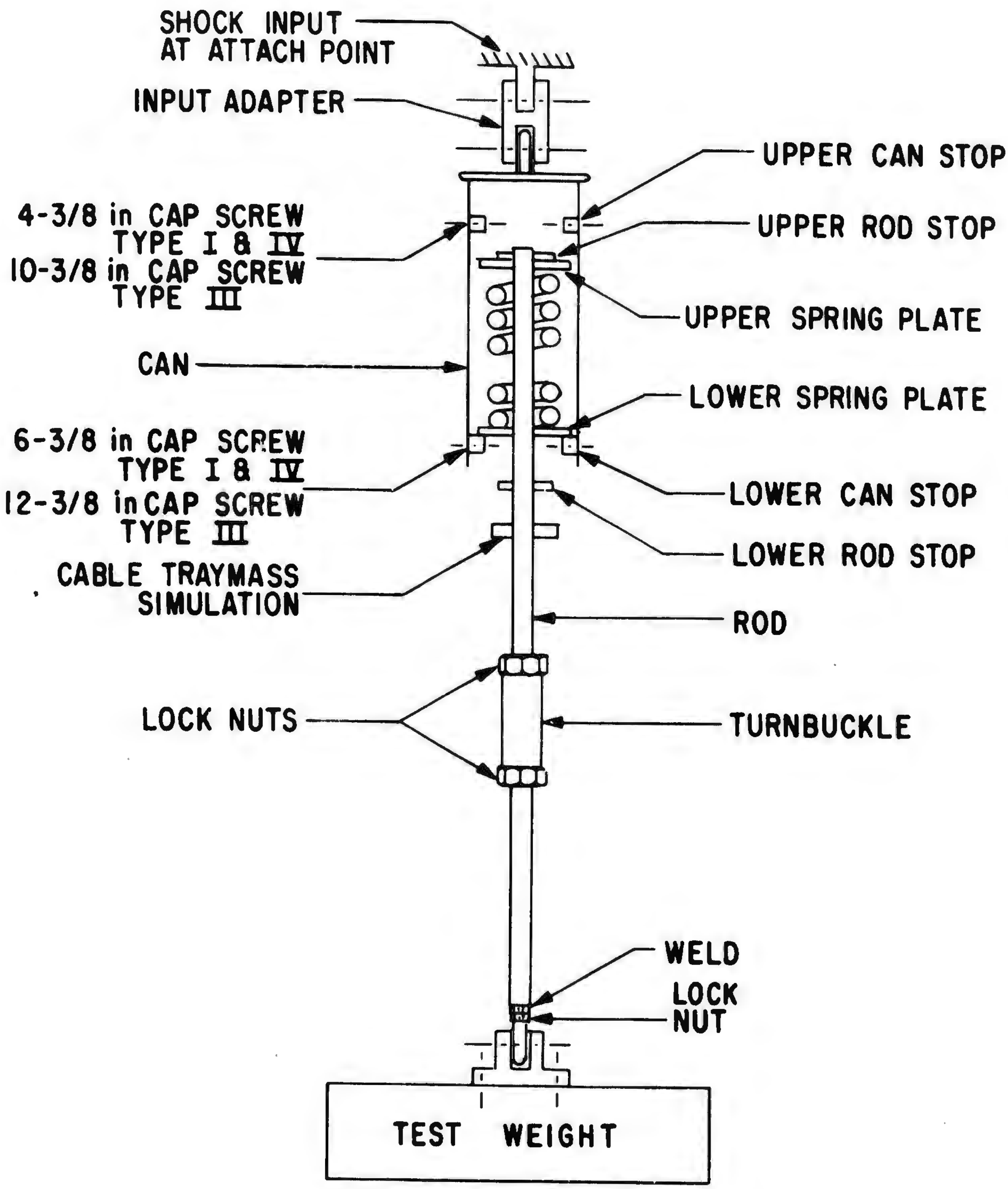


Figure 1. Wing I LER Isolator Assembly
in Test Configuration

The outer spring has the following characteristics:

(1) 1-1/8 in diameter wire

(2) 6-1/8 active coils

(3) 7-1/8 in mean coil diameter

(4) 9-1/8 total coils

(5) 22 in free length

(6) Designed spring rate of 950 lb/in

c. The spring in a Type IV isolator has the following characteristics:

(1) 29/32 in diameter wire

(2) 10-3/16 active coils

(3) 4-27/32 in mean coil diameter

(4) 13-3/16 total coils

(5) 20 in free length

(6) Designed spring rate of 770 lb/in

SECTION III

REQUIREMENTS

The Wing I LER isolators were tested in accordance with the Test Plan and Requirements Document (Ref. 1), dated 7 May 1969 and revised 15 May 1969.

The Air Force has a requirement to increase the scope of the Wing I, LER Single Isolator Shock Test Program. The initial testing is reported under AFSWC-TR-69-20, "Wing I, LER Single Isolator Shock Tests Interim Report." The additional testing is required to provide vital information relevant to a study program to determine requirements for upgrading the hardness level of the MINUTEMAN Weapon System.

In general, the test plan called for the following characteristics of the Wing I LER isolators to be investigated:

a. Isolator component structural integrity.

b. Isolator stiffness.

c. Isolator ultimate strength.

d. Isolator mechanical impendence.

e. Isolator high-frequency shock attenuation capabilities.

SECTION IV

TEST PROCEDURES

1. PRE-TEST ISOLATOR INSPECTION

After the initial shock test program, the isolators were disassembled for a dimensional check of all the internal components from the isolator can-spring assembly. This post-test inspection served as part of the pre-test inspection for the supplemental test program.

The additional pre-test inspection of the isolators consisted of:

a. Noting the previous type of failure or failures.

b. Noting any defects and the quality of workmanship (in particular the welds on the isolator).

c. Measurements of the thickness of the spring cans in the area of the attachment of the lower can stop to the spring can.

d. Measuring the contact distance of the assembled spring between the upper and lower spring plates.

e. Measurements of the coil spring wire diameter and noting the number of coils.

f. Noting whether the original lower can stop cap screw threads were in the shearing plane between the spring can and lower can stop.

2. ISOLATOR REFURBISHMENT

Isolator refurbishment was required because most of the available isolators failed during the initial shock testing program. Failures occurred in two areas: (1) the lower rod end spherical bearing and (2) the cap screws which attach the lower can stop to the spring can.

After the pre-test isolator inspection, each isolator was refurbished during reassembly by removing existing upper and lower can stop can screws and replacing them with new original strength cap screws or with new higher strength cap screws. All Type III isolators were refurbished with new high strength rod end spherical bearings. Some Type I and Type IV isolators were also refurbished with the new high strength rod end spherical bearings for applicable tests.

The original cap screws had a tensile strength (Rockwell Hardness Tester) that averaged 103,000 psi for Type I, 120,000 psi for Type III and 132,000 psi for Type IV. The new cap screws of the original type (Grade 5) had a tensile strength of 125,000 psi and the new higher strength cap screws (Grade 8) had a tensile strength of 150,000 psi. The new cap screws were procured with a 1/4-inch shoulder length. The screws were installed such that the shearing plane between the spring can and lower can stop (cap screw failure location) would occur in this shoulder. This increased the shearing area over the former cap screws which had no shoulder length.

The original rod end spherical bearings failed consistently on the Type III isolators during the initial dynamic shock testing program. The original rod end spherical bearings were fabricated from ordinary structural steel having a yield strength range of 38,000-45,000 psi and a tensile strength range of 69,000-80,000 psi (Ref. 2). The new high-strength rod end bearings were fabricated from high-strength steel having a tensile strength in the range of 100,000 -150,000 psi.

3. ISOLATOR COMPONENT STATIC TESTING

Isolator component static testing was conducted on all 12 available isolators (4 each of Type I, Type III, and Type IV). All component testing was conducted with the new original strength cap screw installation (when applicable). The torque values used on these cap screws was 30 ft-lbs as recommended by the cap screw manufacturer. The maximum applied load for isolator component testing was 10,000 pounds for Type I and IV and 20,000 pounds for Type III isolators.

a. Spring Can--Lower Can Stop Static Test

The spring can was attached to a static test frame as shown in figure 2. A fixture to simulate the lower spring plate contacting the lower can stop was fabricated to produce the same loading condition as encountered by the spring can from the spring assembly. The force was applied to the fixture through a hydraulic cylinder and controlled by a load cell installed between the fixture and cylinder. Displacement was measured with dial indicators having a sensitivity of 0.001 inch. Two dial indicator readings were taken at the bottom surface of the lower can stop to measure the gross movement. An indicator was affixed to the isolator spherical bearing ceiling attach point to measure test frame movement. The difference between these two displacements resulted in the net spring can--lower can stop movement. The test setup shown in figure 2 is typical for both

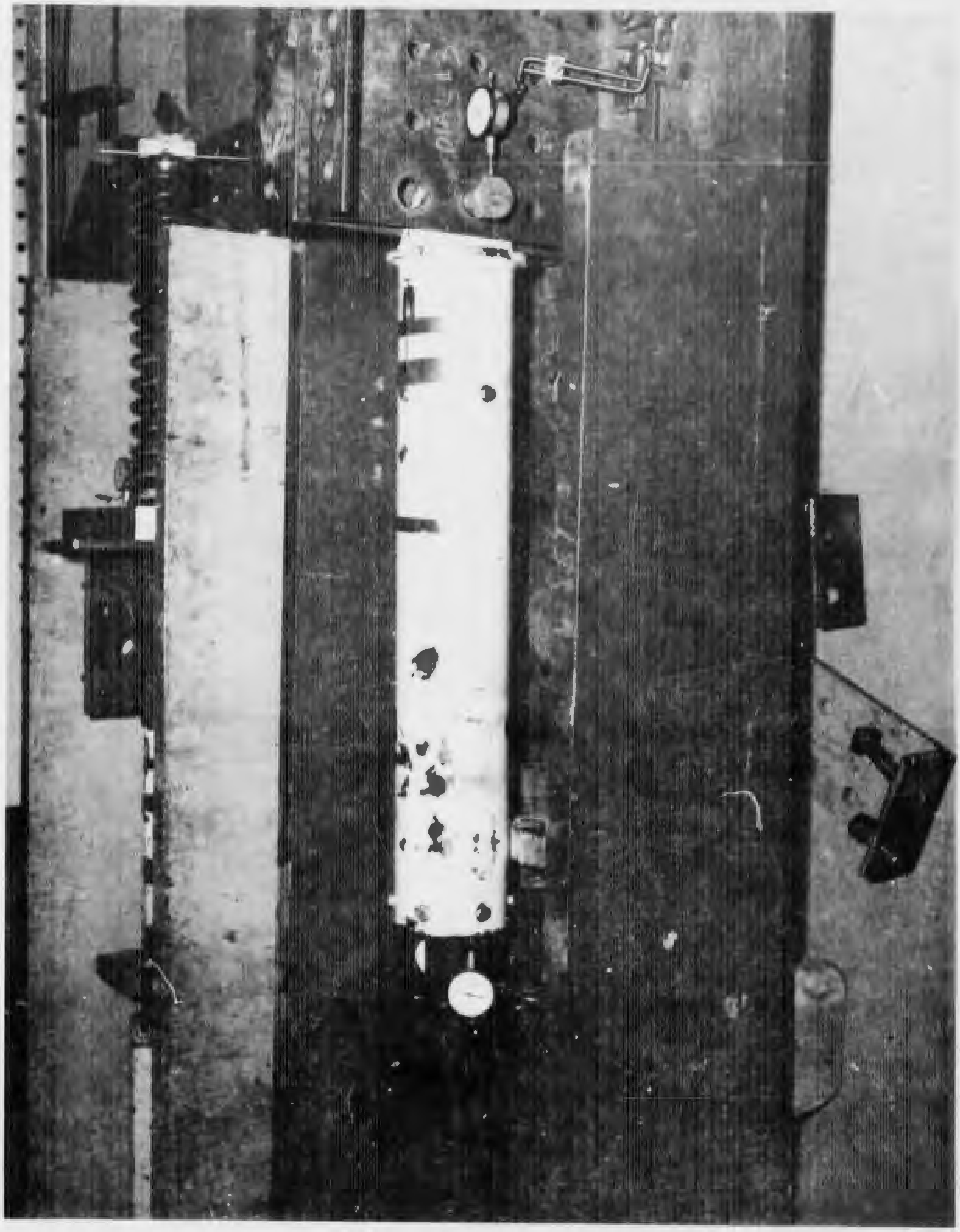


Figure 2. Spring Can Static Test Setup—Typical Type I and Type IV

Type I and Type IV isolators. The spring can was subjected to three load cycles to 20 percent (2,000 pounds) of maximum load prior to testing. Displacement readings were taken during incremental loads up to the maximum of 10,000 pounds. The 10,000-pound maximum load was repeated for each isolator.

The Type III isolator spring can testing was conducted in a different manner than the Type I and Type IV. A completely different fixture and arrangement was needed to simulate loading on the lower spring plate from the nested spring design. A tandem pull fixture was fabricated to produce the loading conditions on the lower can stop from the two springs. The inner and outer spring loads were applied through hydraulic cylinders and controlled by load cells as shown in the overall view of figure 3. A detail of deflection measurement method is shown in figure 4. The same method used for obtaining net spring can movement for the Types I and IV isolators was used for the Type III isolator. The spring can was subjected to three load cycles of 1000 pounds on both outer and inner contact areas prior to testing. In simulating the inner and outer spring loading on the lower can stop, both loads were applied simultaneously and incremently until a load of approximately 8300 pounds was obtained. At this load the solid height condition was theoretically obtained on the inner spring. In order to simulate actual spring assembly conditions, the 8300 pounds was maintained on the outer contact area and the inner load was increased incremently (simulate loading beyond spring solid height) until the maximum total load of 20,000 pounds was obtained. Each Type III isolator was subjected to one 20,000 pound load test.

b. Spring and Spring Plate Test

The isolator rod and spring assembly was used for conducting the load-displacement test. The assembly was secured and firmly fixed in the test frame. Figure 5 shows an overall view of a typical test setup for the Type I and IV isolators. Figure 6 shows a close-up view of the fixturing required for the test. The force was applied to the rod and spring assembly through a hydraulic cylinder and monitored by a load cell installed in series with the rod end and cylinder. This arrangement is shown in detail in figure 7. Gross displacements were measured with a pointer along a scale until the spring solid height was obtained. A dial indicator measurement was used on displacements beyond the spring solid height. Two dial indicator readings were taken to measure test frame movement (see figure 6). The difference between the gross displacement measurement and the test fixture frame resulted in the net isolator rod and spring assembly displacement. Figure 8 shows an overall test setup for the Type III test.

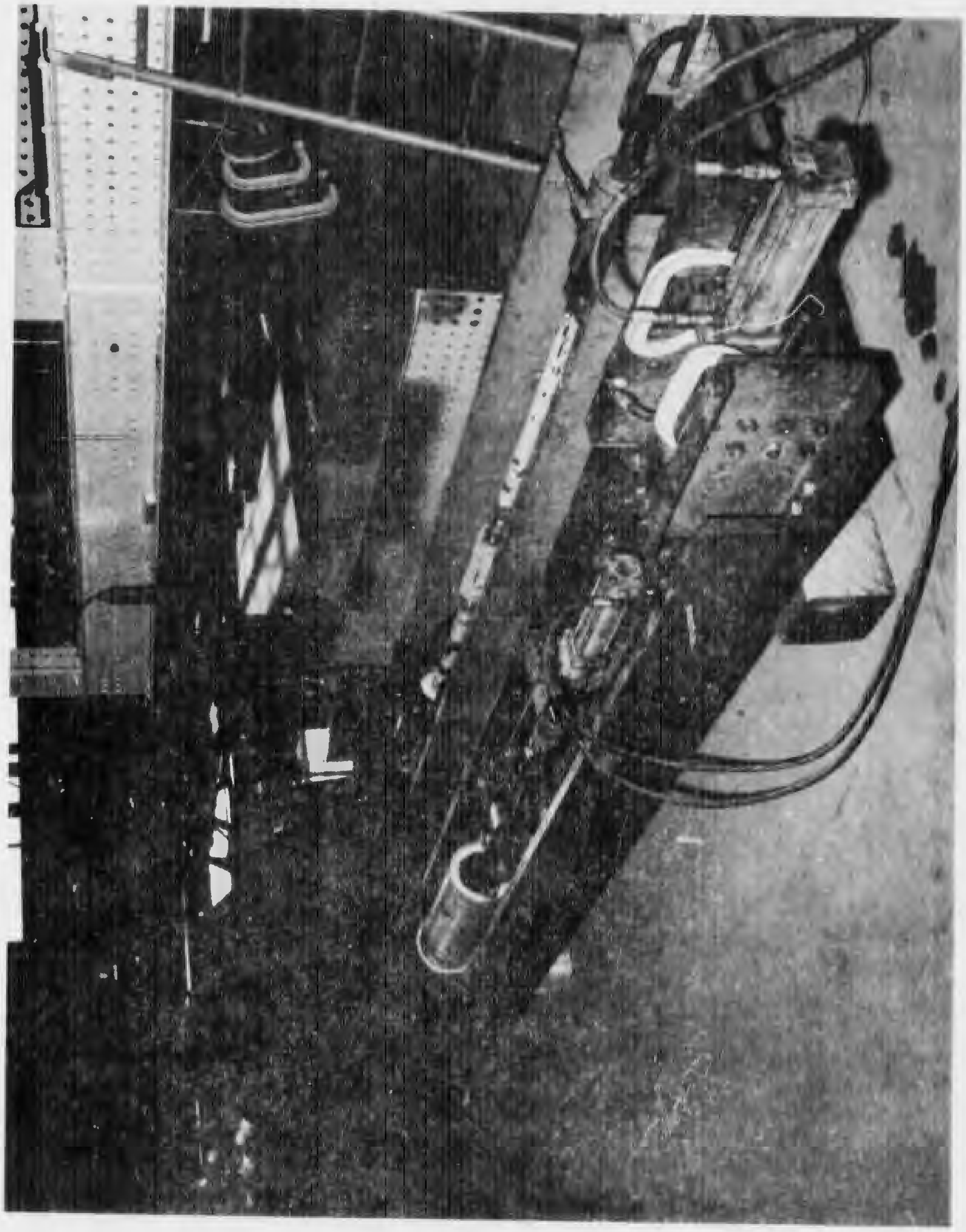


Figure 3. Overall--Spring Can Test for Type III Isolator

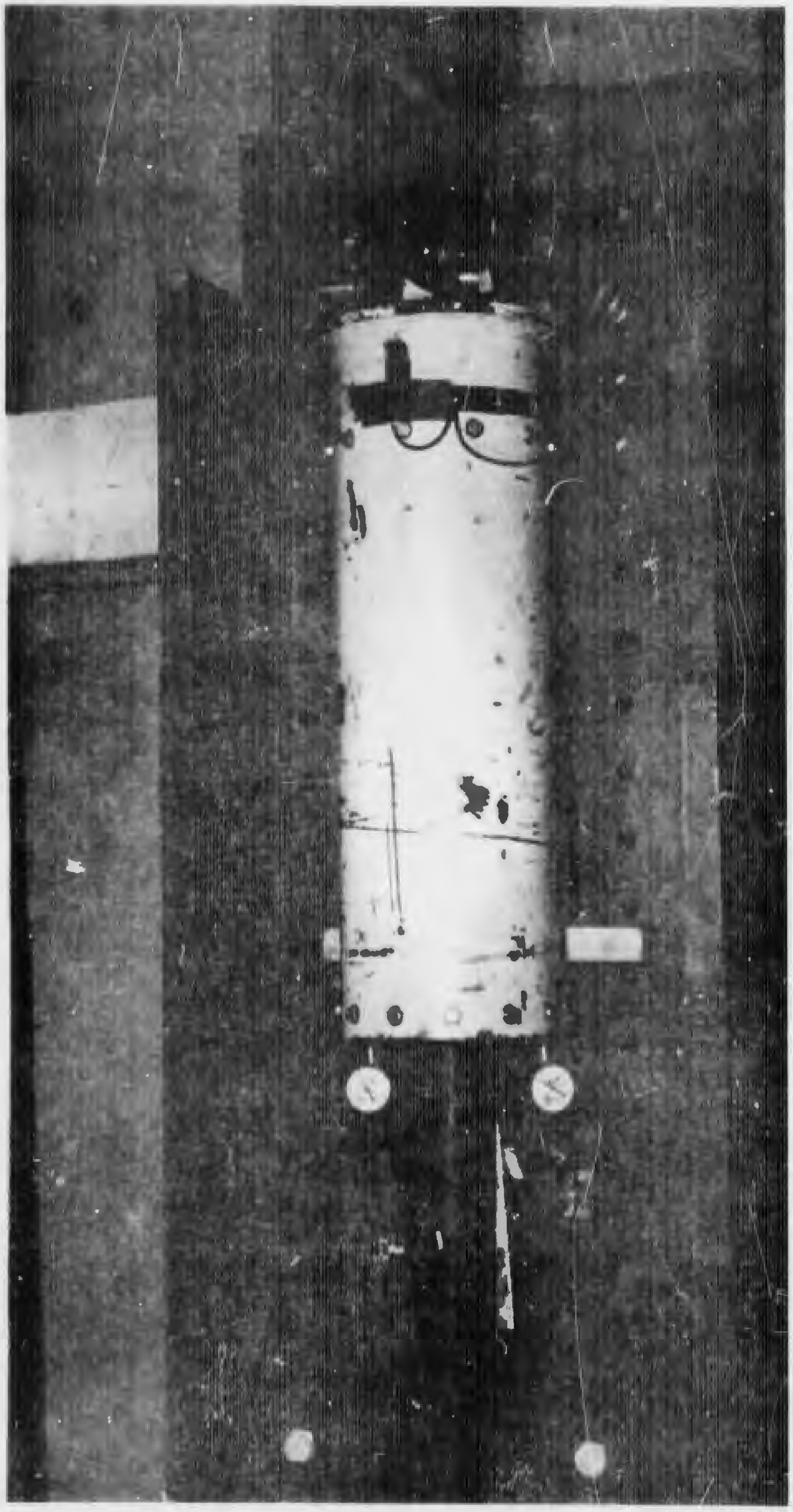


Figure 4. Closeup--Spring Can Test for Type III Isolator

Figure 5. Spring and Spring Plate Test Setup
Typical Type I and Type IV

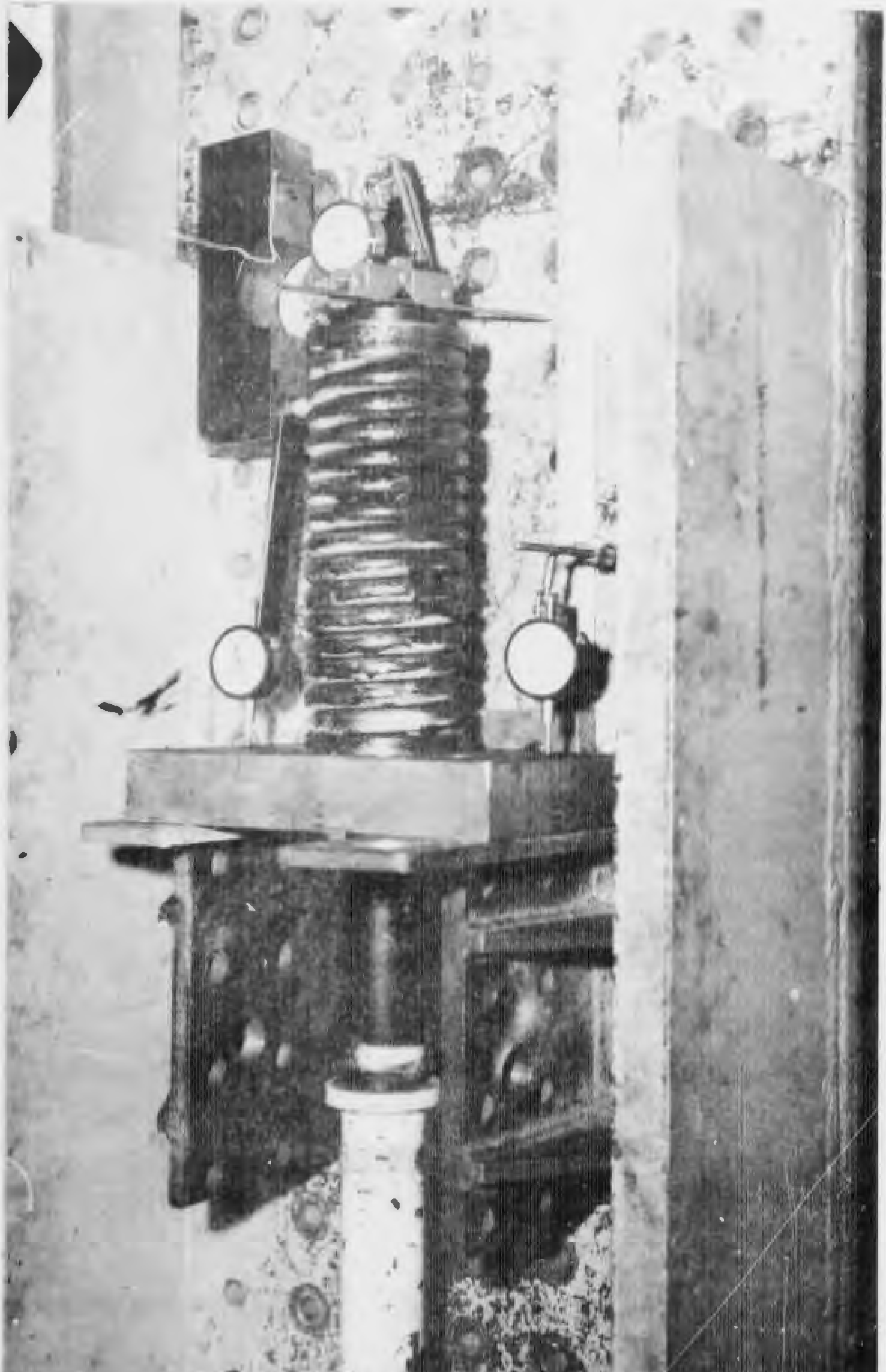


Figure 6. Closeup of Spring and Spring Plate Test Type I and Type IV

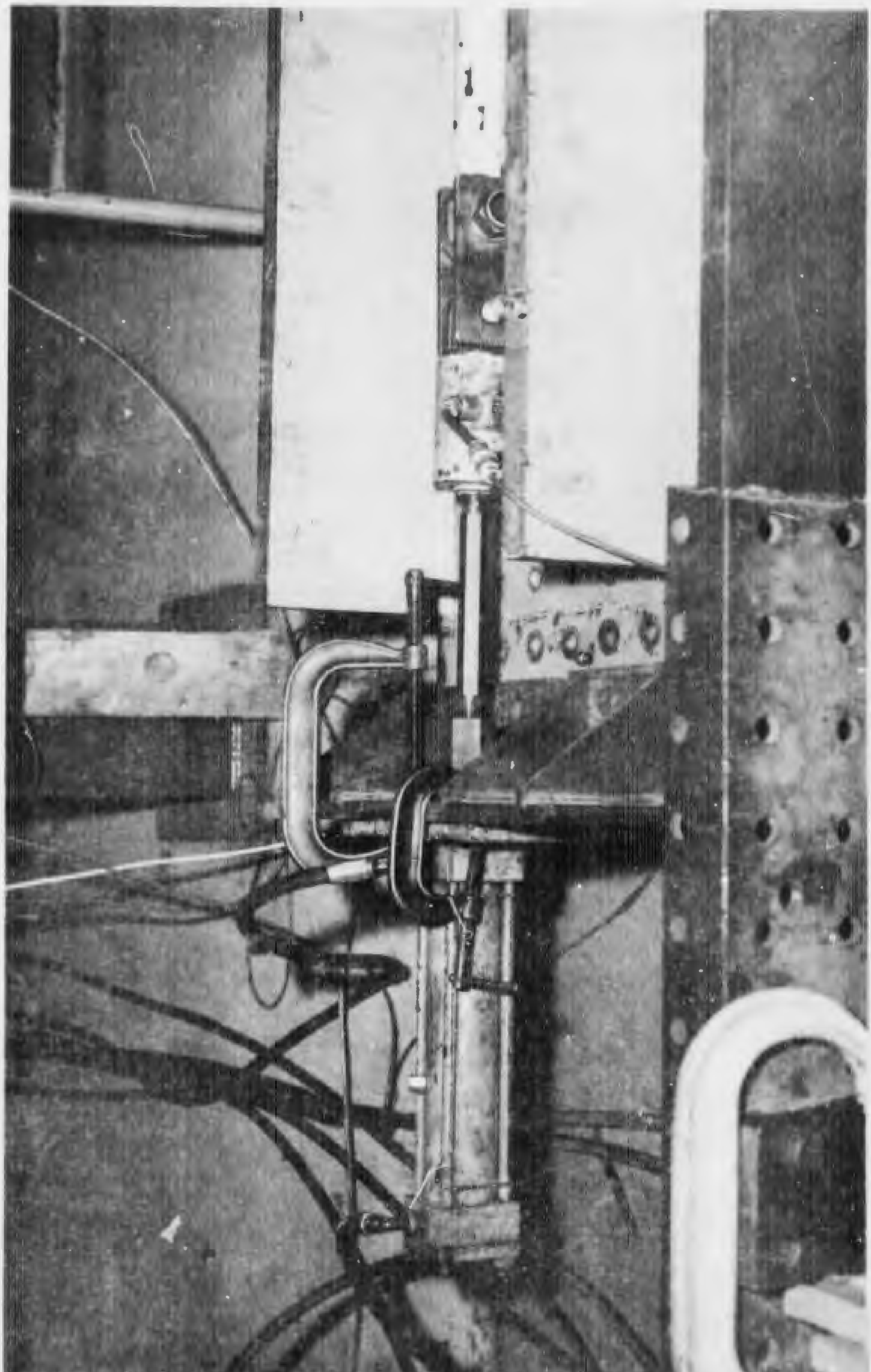


Figure 7. Spring and Spring Plate Test Loading Configuration

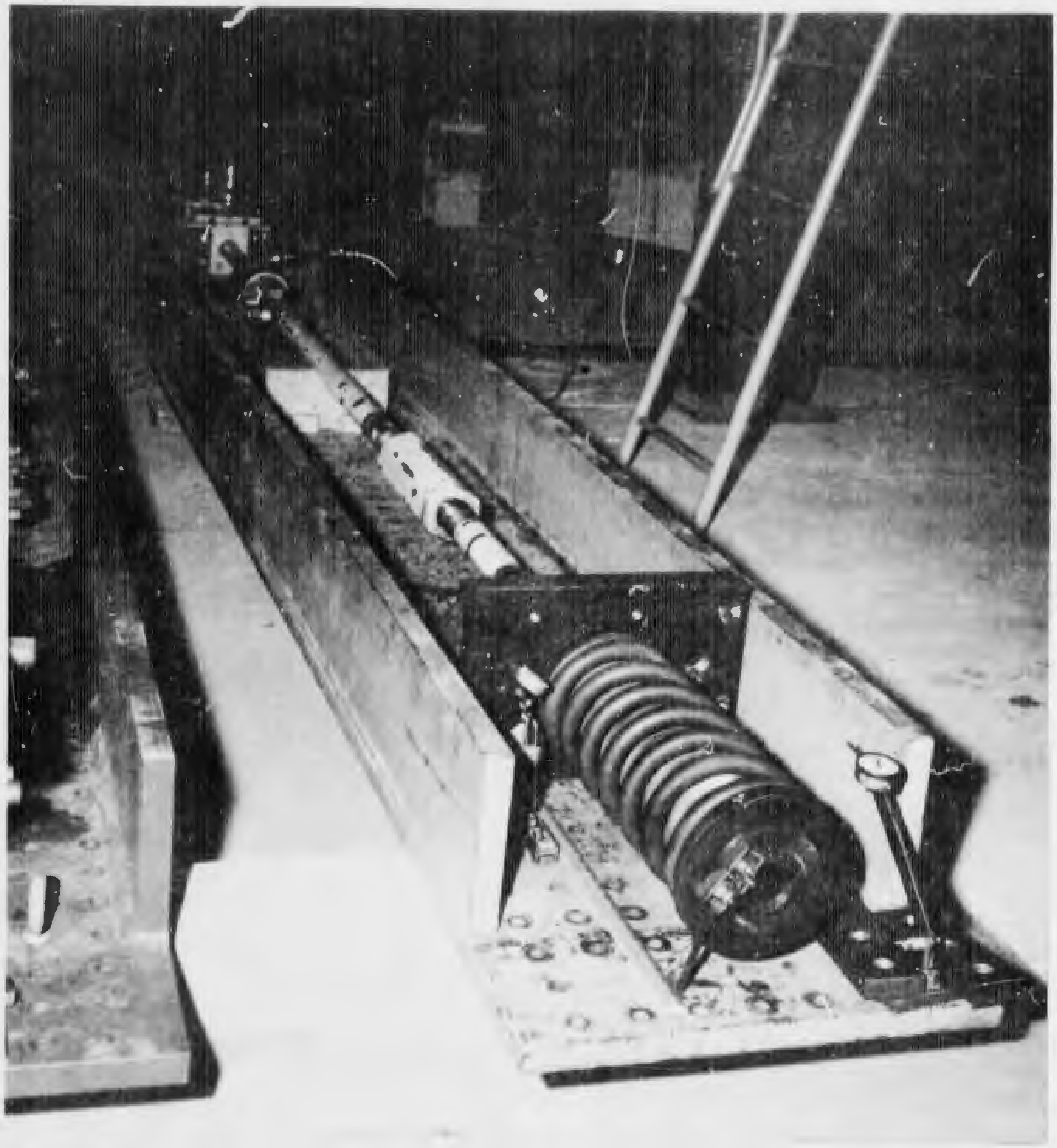


Figure 8. Test Setup
Type III Spring and Spring Plate Test

The Type I and Type IV isolator rod and spring assembly was subjected to three load cycles to 30 percent (3000 pounds) of maximum load prior to testing Loads were applied in increments until the maximum load of 10,000 pounds was obtained. The 10,000-pound maximum load was repeated for each isolator. The same procedure for testing was used on the Type III isolator rod and spring assembly with the exception that the three load cycles prior to testing were 50 percent (10,000 pounds) of maximum load and the maximum load applied was 20,000 pounds instead of 10,000 pounds. The 20,000-pound maximum load was repeated for each Type III isolator except Serial Number 1.

c. Isolator Hanger Rod Test

The isolator hanger rod test was conducted to determine elongation (stretch) over the total length of the isolator rod. The test setup is shown in figure 9. The load was applied, as in the preceding two tests, through a hydraulic cylinder and monitored by a load cell. A reaction fixture block was installed between the upper rod stop and upper spring plate for restraining the upper end of the rod during the pull test. A detail of this installation and the method used for measuring test fixture movements are shown in figure 10. A dial indicator was affixed to the isolator rod end, as shown in figure 11, to measure the gross hanger rod movement. The difference between these two displacements resulted in the net hanger rod elongation.

The Type I and Type IV isolator hanger rods were subjected to three load cycles of 50 percent (5000 pound) maximum loading prior to testing. Test loading was applied in increments until the maximum load of 10,000 pounds was obtained. The test run up to 10,000 pound load was repeated for each isolator. Procedures for testing the Type III isolator were the same with the exception that the three exercise cycles prior to testing were 50 percent (10,000 pounds) of maximum load and the maximum load applied was 20,000 pounds. The 20,000 pound maximum load was repeated for each Type III isolator.

4. ISOLATOR STIFFNESS TEST

The isolators were assembled and refurbished with new original cap screws and new high strength rod end spherical bearings for the stiffness (load-displacement) test on a complete isolator. The isolator was firmly secured into the same test fixture as was used for the component testing. Figure 12 shows a typical test setup used for all the isolators. The force was applied at the

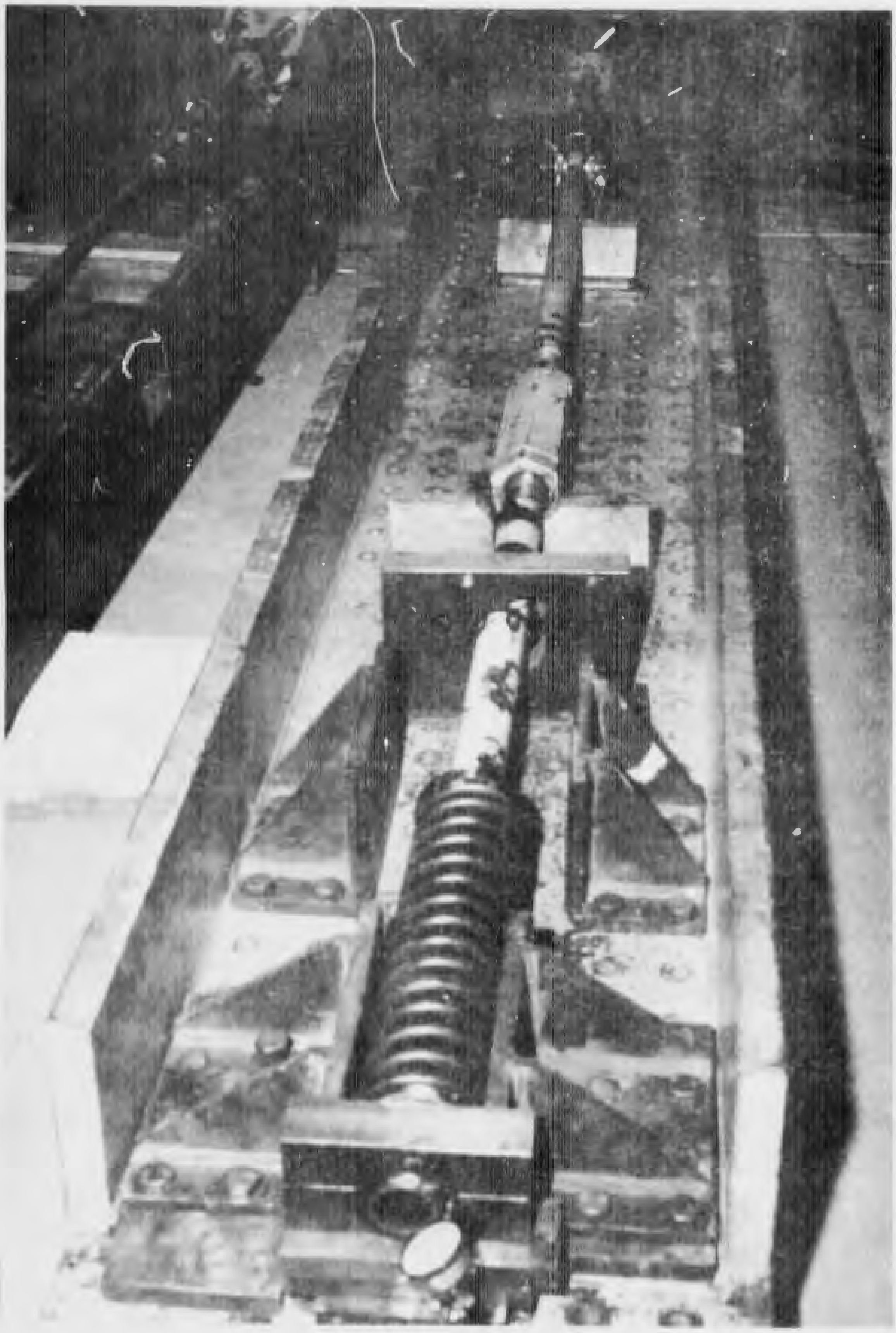


Figure 9. Test Setup--Hanger Rod Test

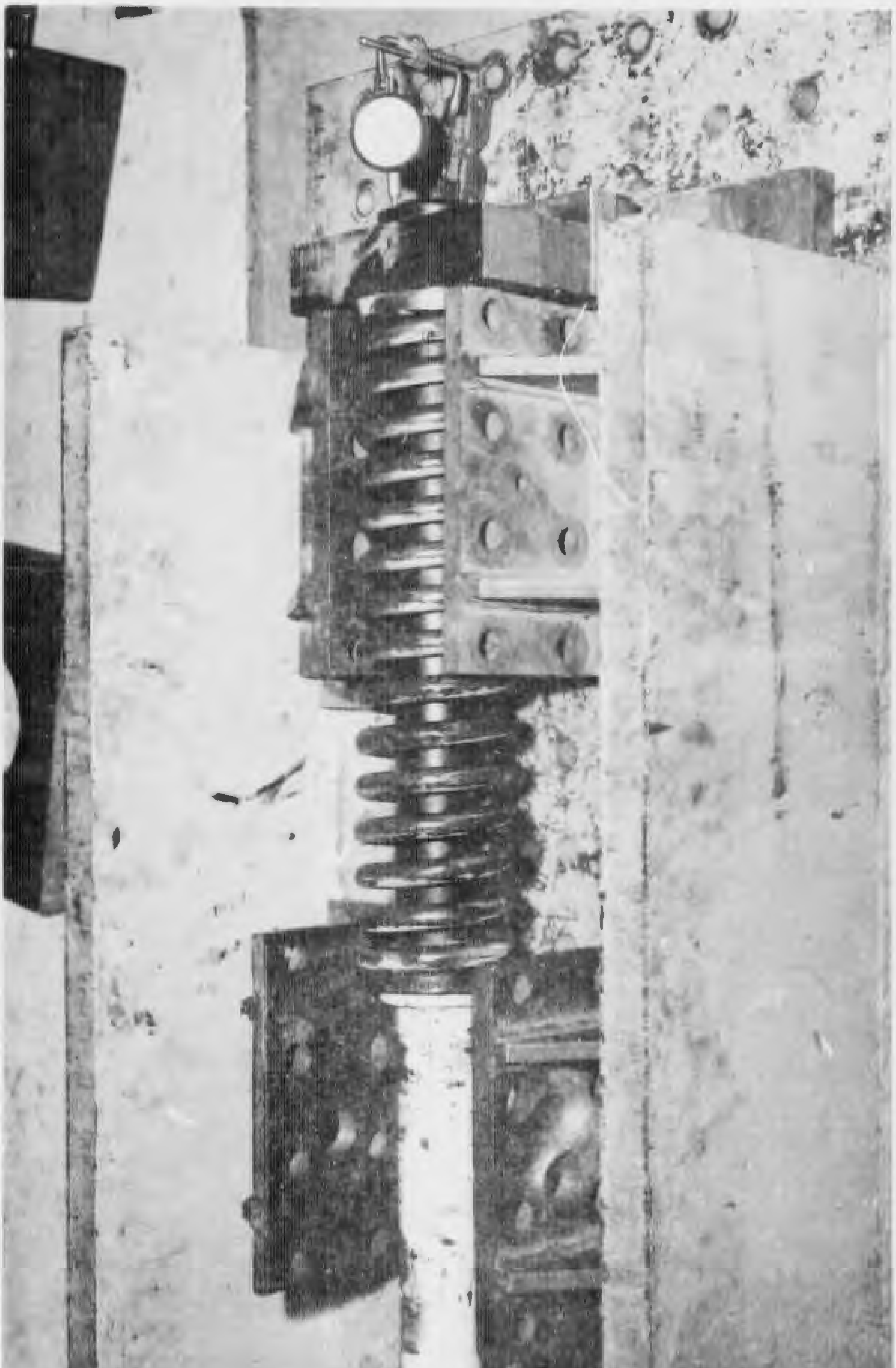


Figure 10. Closeup--Hanger Rod Test

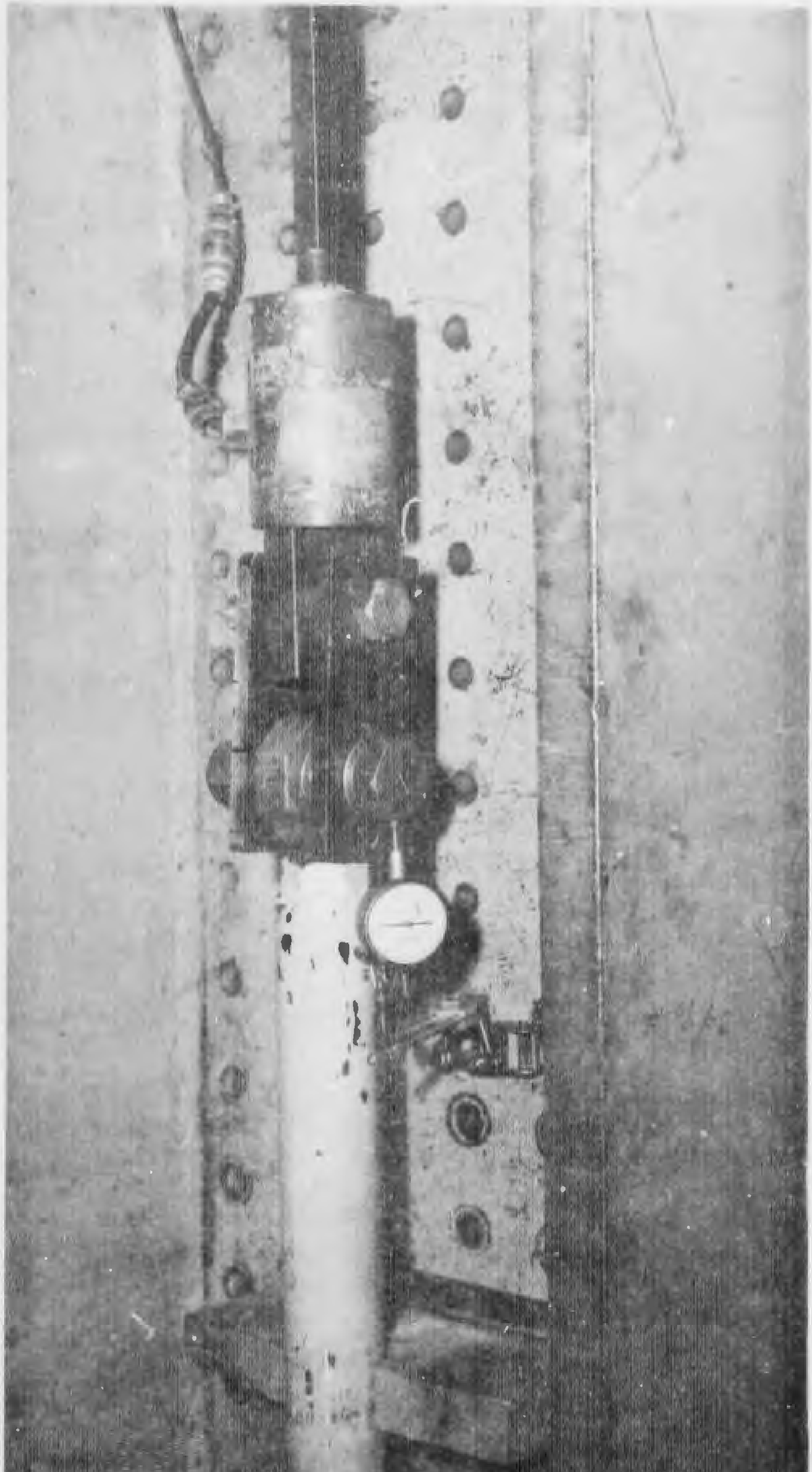


Figure 11. Lower Measurement--Hanger Rod Test

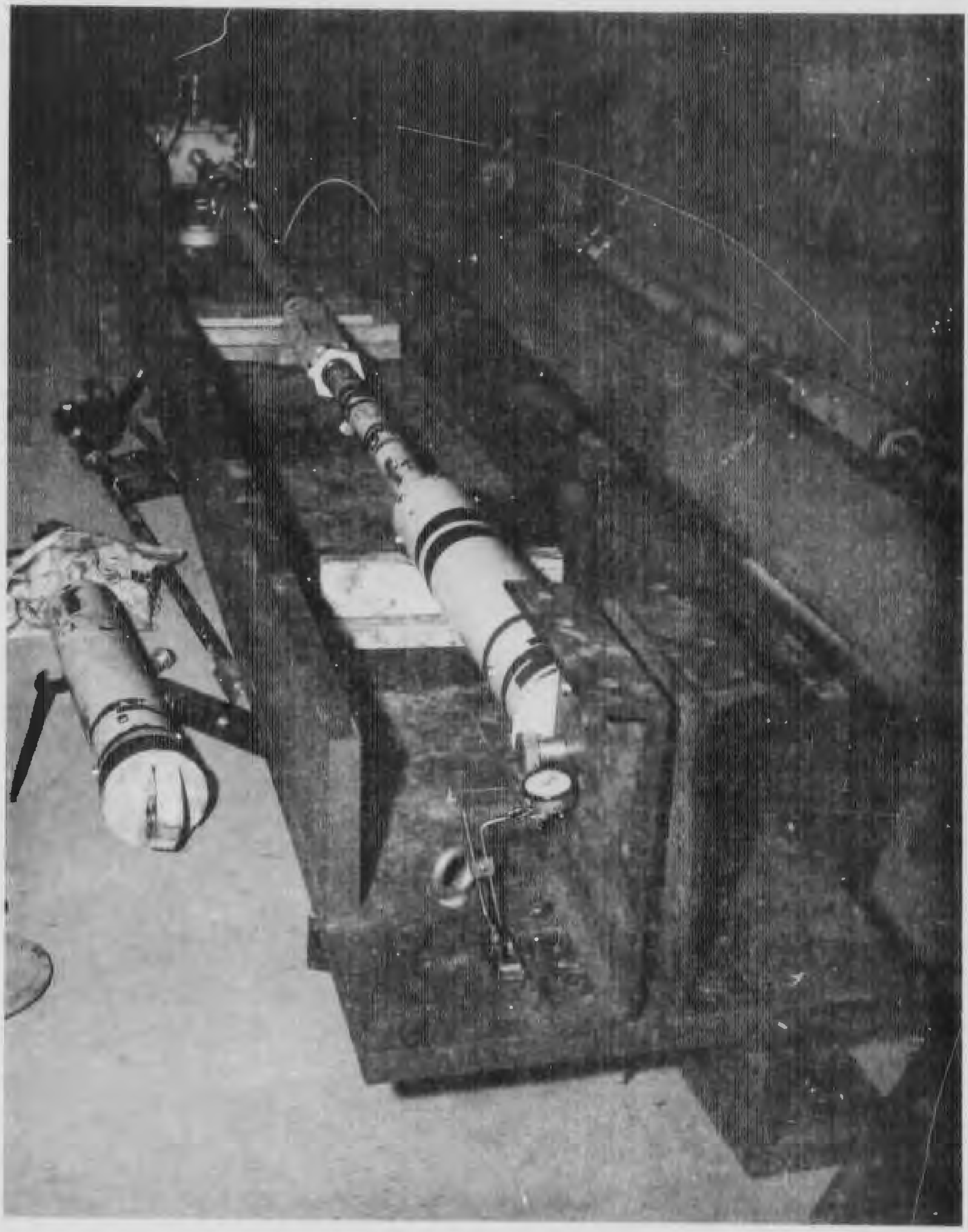


Figure 12. Test Setup--Isolator Stiffness Test

isolator rod bottom through a hydraulic cylinder and monitored by a load cell as shown in figure 13. Figure 13 also shows the method used for measuring isolator movement. Gross displacement was measured with a pointer along a scale until the spring solid height was obtained. A dial indicator measurement was used on displacement beyond the spring solid height. A dial reading was taken at the isolator ceiling attach point, as shown in figure 14, to measure the test frame movement. The difference between the gross displacement measurement and the test fixture frame gave the net isolator displacement.

The Type I and IV isolators were subjected to three load cycles of 30 percent (3000 pounds) maximum load prior to installing the instrumentation and testing. Incremental loads were applied until the maximum load of 10,000 pounds was obtained. Three additional load cycles up to 10,000 pounds were made to determine if any permanent set took place. The load increments for the three cycles on the Type I isolator were 5,000, 7,000, and 10,000 pounds. The load increments on the Type IV isolator were 7,000, 8,500, and 10,000 pounds.

The same procedure was used for the testing of the Type III isolators with the exception that the three load cycles prior to testing were 50 percent (10,000 pounds) of a 20,000 pound maximum load and the three additional load cycle increments for determining permanent set were 16,000, 18,000, and 20,000 pounds.

Tests were conducted on all the Type I and Type IV isolators (4 each) and on only three of the Type III. High internal friction between the spring assembly and spring can inner wall prevented the testing of Serial Number 2, Type III isolator.

5. ISOLATOR ULTIMATE STIFFNESS TEST

Three isolators, one of each Type I, III, and IV, were prepared for the ultimate stiffness test. All three isolators were refurbished with new original strength cap screws. The Type III isolator was refurbished with a new high-strength rod end spherical bearing, while the Type I and Type IV isolators were initially furnished with the original rod end bearings. These were later replaced with the new higher strength rod end bearings for further testing.

The isolator was firmly secured in the standard test frame as shown in figure 15. The test frame was reinforced to withstand the higher loads of isolator failure. Figure 16 shows the reinforced attachment used at the upper end of the

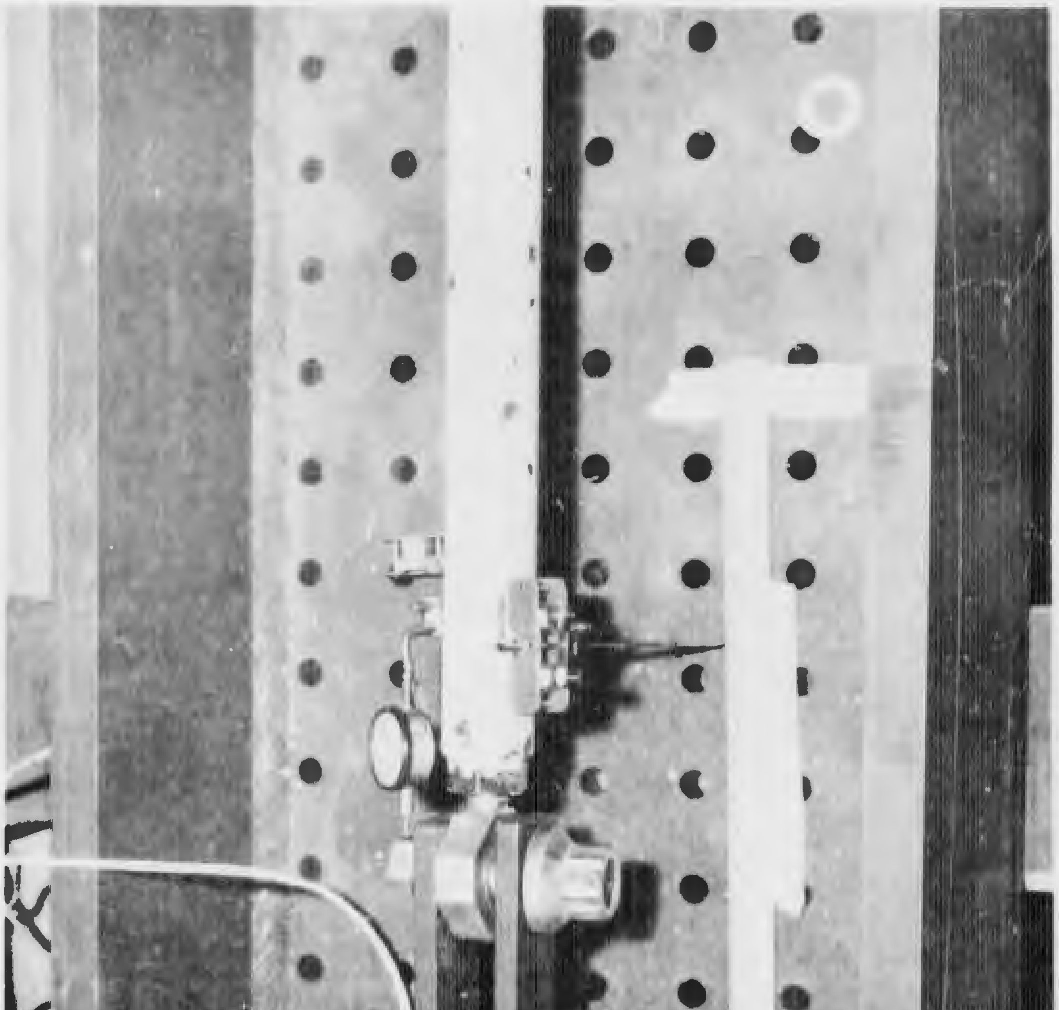


Figure 13. Isolator Loading and Isolator Displacement Reading

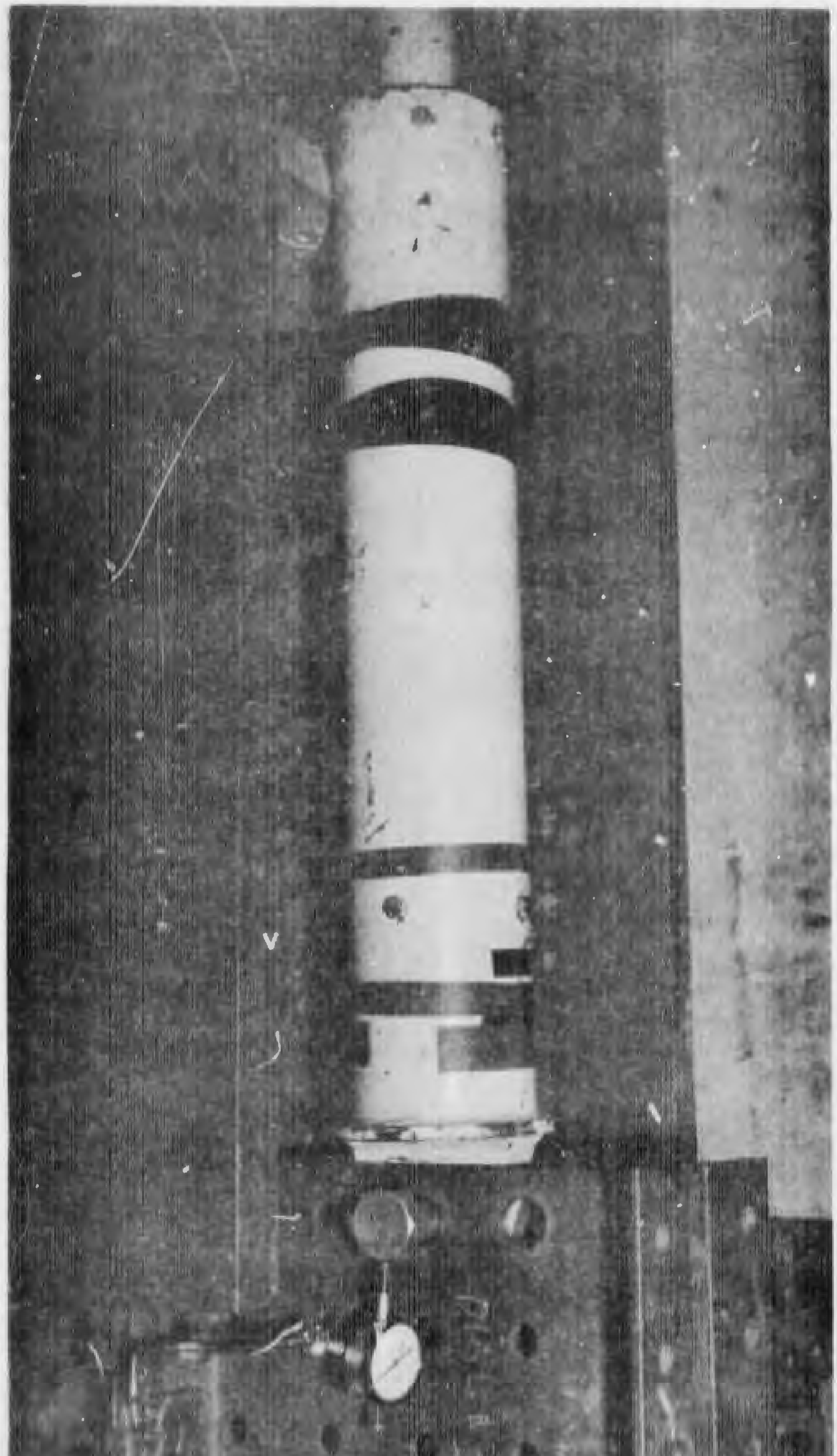


Figure 14. Ceiling Attachment--Isolator Stiffness Test

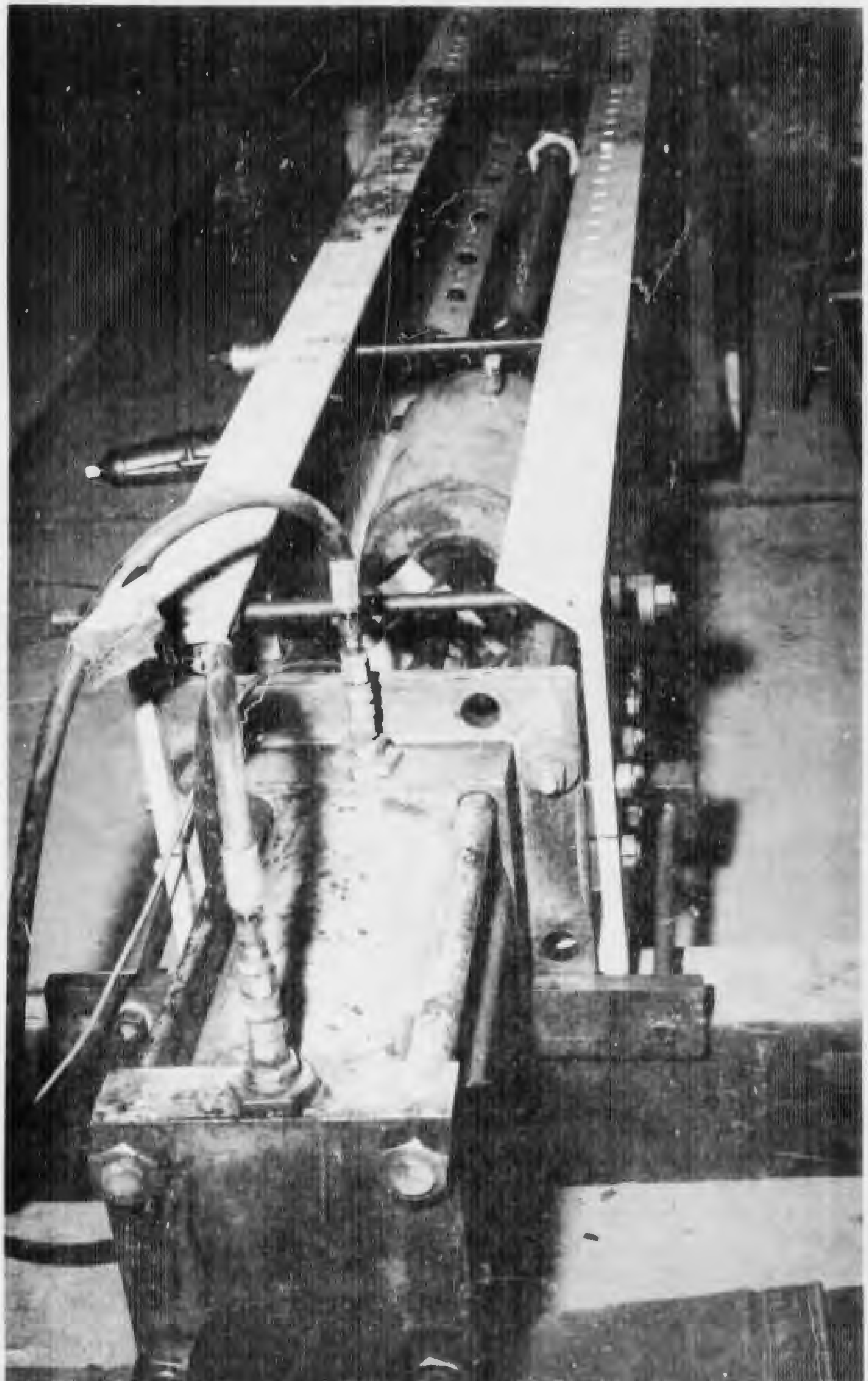


Figure 15. Test Setup--Isolator Ultimate Stiffness Test

Figure 16. Upper Isolator Attachment--Ultimate Stiffness Test

isolator. The force was applied at the isolator rod bottom through a large hydraulic cylinder and controlled by a 100,000-pound load cell as shown in figure 15. Test failure load, taken from the load cell reading, was the only data taken for these tests. The isolator load was applied at a slow steady rate until failure occurred.

After initial failure of the original rod end spherical bearing on the Types I and IV isolators, testing was continued with the new high strength rod end bearing to determine a secondary mode of static failure.

6. ISOLATOR DYNAMIC (SHOCK) TESTS

Three isolators, one of each Type I, III, and IV, were prepared for the dynamic tests. Type I and IV isolators were refurbished with the new higher strength cap screws (Grade 8, 150,000 psi tensile strength) and the original rod end spherical bearings. The cap screws were installed with 45 ft-lbs of torque, as recommended by the cap screw manufacturer. The Type III isolator was refurbished with new original strength cap screws and a new high strength rod end spherical bearing.

The shock input to the isolator ceiling attach point was provided by the Air Force Special Weapons Center Seismic Impulse Facility. The isolator was secured to one of the shock actuators at the facility. Figure 17 shows a typical test setup used for all the isolators. This particular view shows a light mass isolator test setup. As noted earlier, the shock tests were conducted to determine isolator mechanical impedance and to evaluate high frequency shock attenuation by using specially fabricated damping collars installed on the isolated rod. Figure 18 shows a general view of the isolator rod area without collars and figure 19 shows a typical isolator rod collar installation. A detail of the collar installation at the lower rod is shown in figure 20 and figure 21 shows a detail of the upper rod installation.

Shock tests were performed on one each of a Type I, III, and IV isolator. Twenty shock tests per isolator type (a total of sixty shock tests) were scheduled. The schedule called for four shock tests with collars installed and sixteen without collars. The tests were conducted in accordance with the test and configuration matrix shown in table I. The test input conditions and test mass configurations, as applied to the test matrix in table I, are called out in tables II and III.

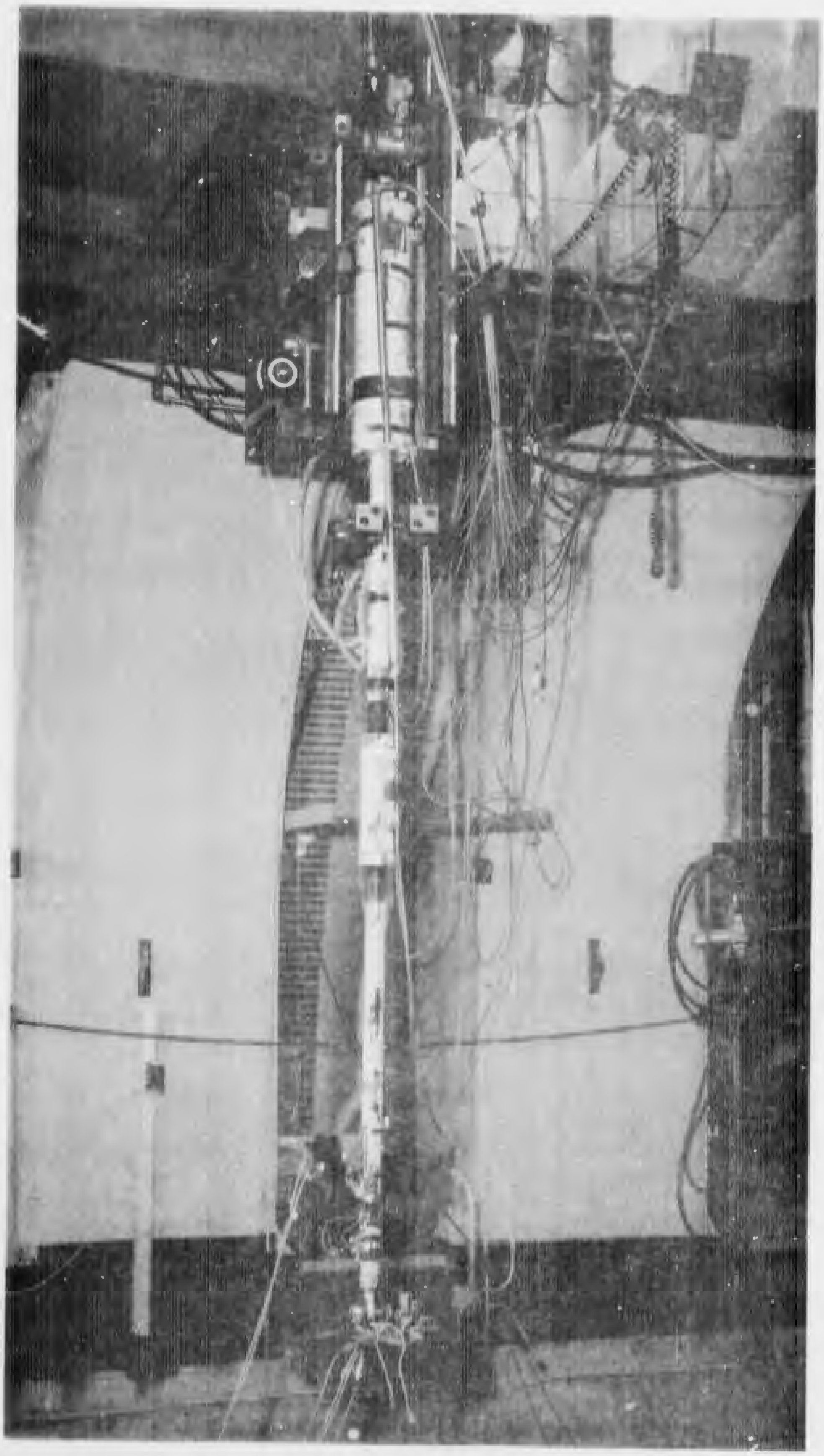


Figure 17. Typical Isolator Shock Test Setup with Light Mass

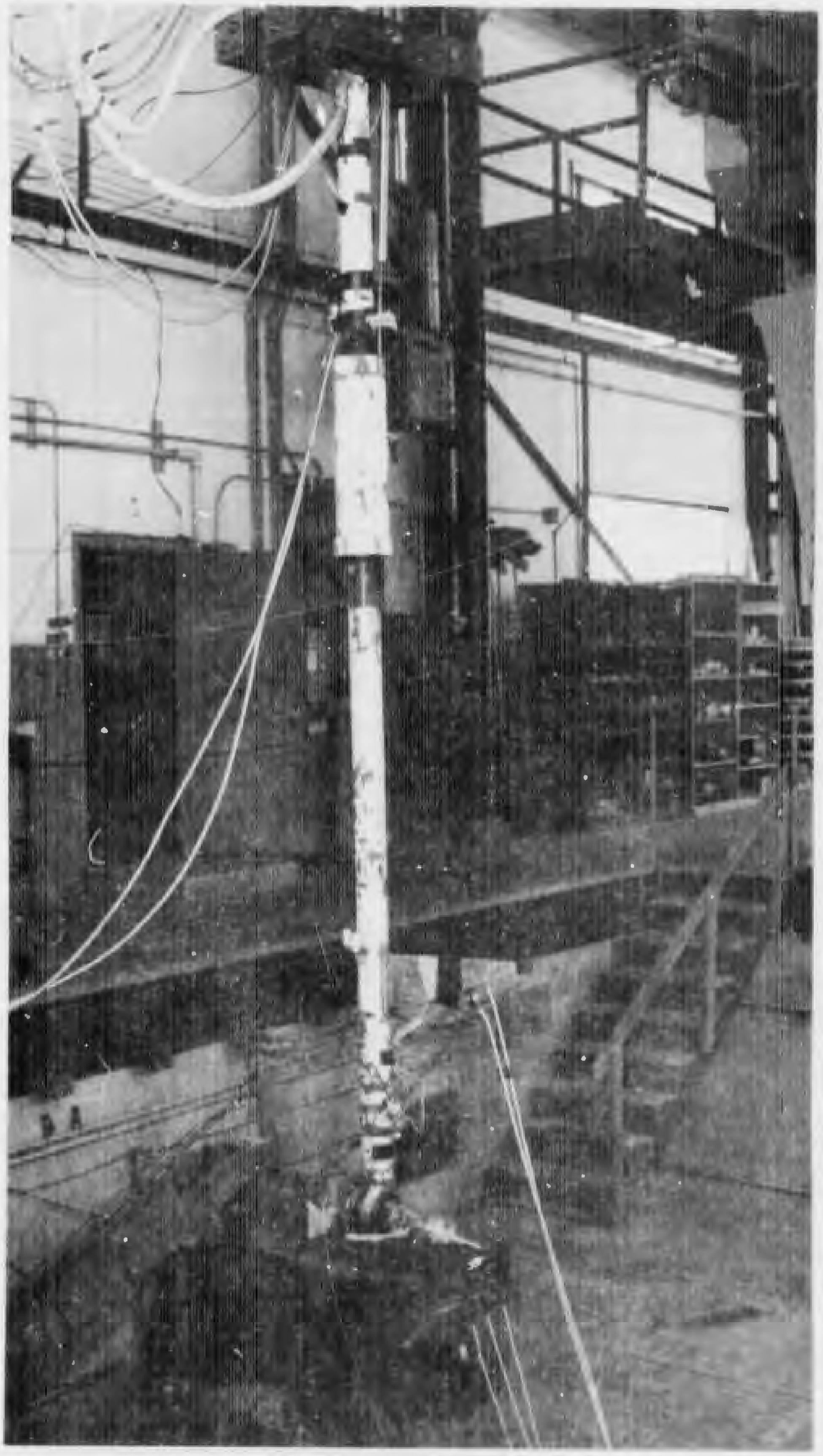


Figure 18. Isolator Rod--Without Collars

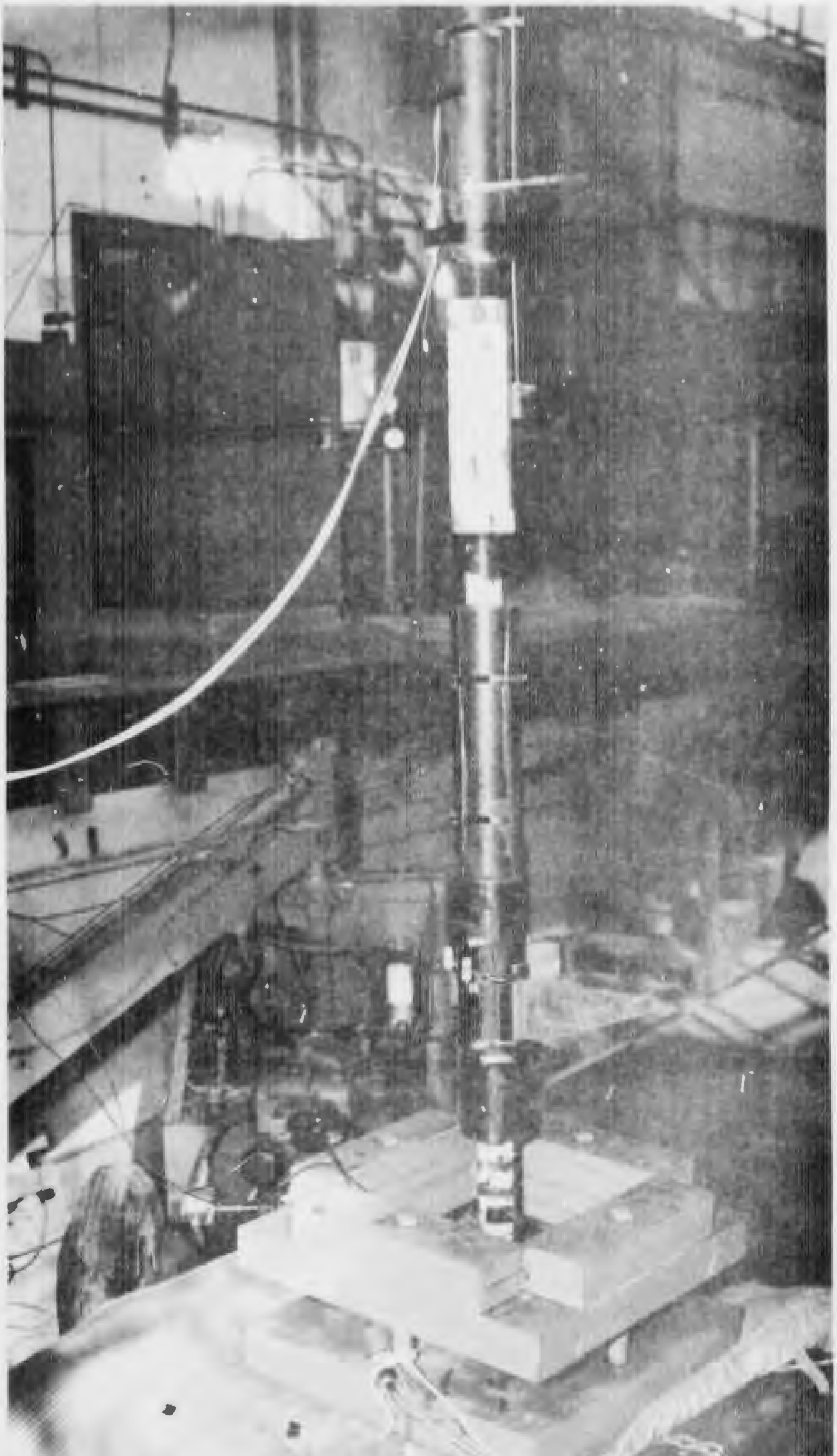


Figure 19. Isolator Rod--Collar Installation

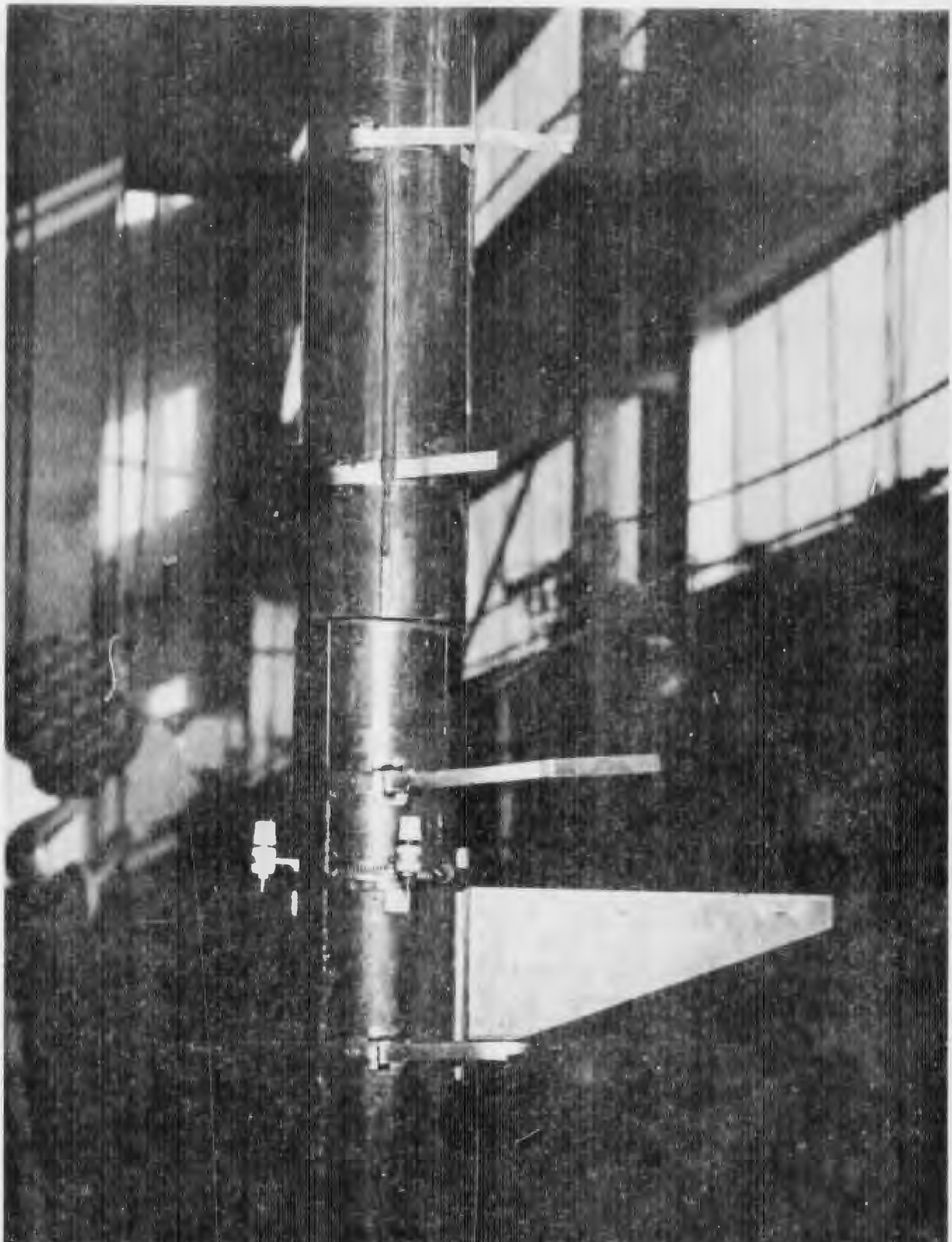


Figure 20. Collar Installation--Lower Rod

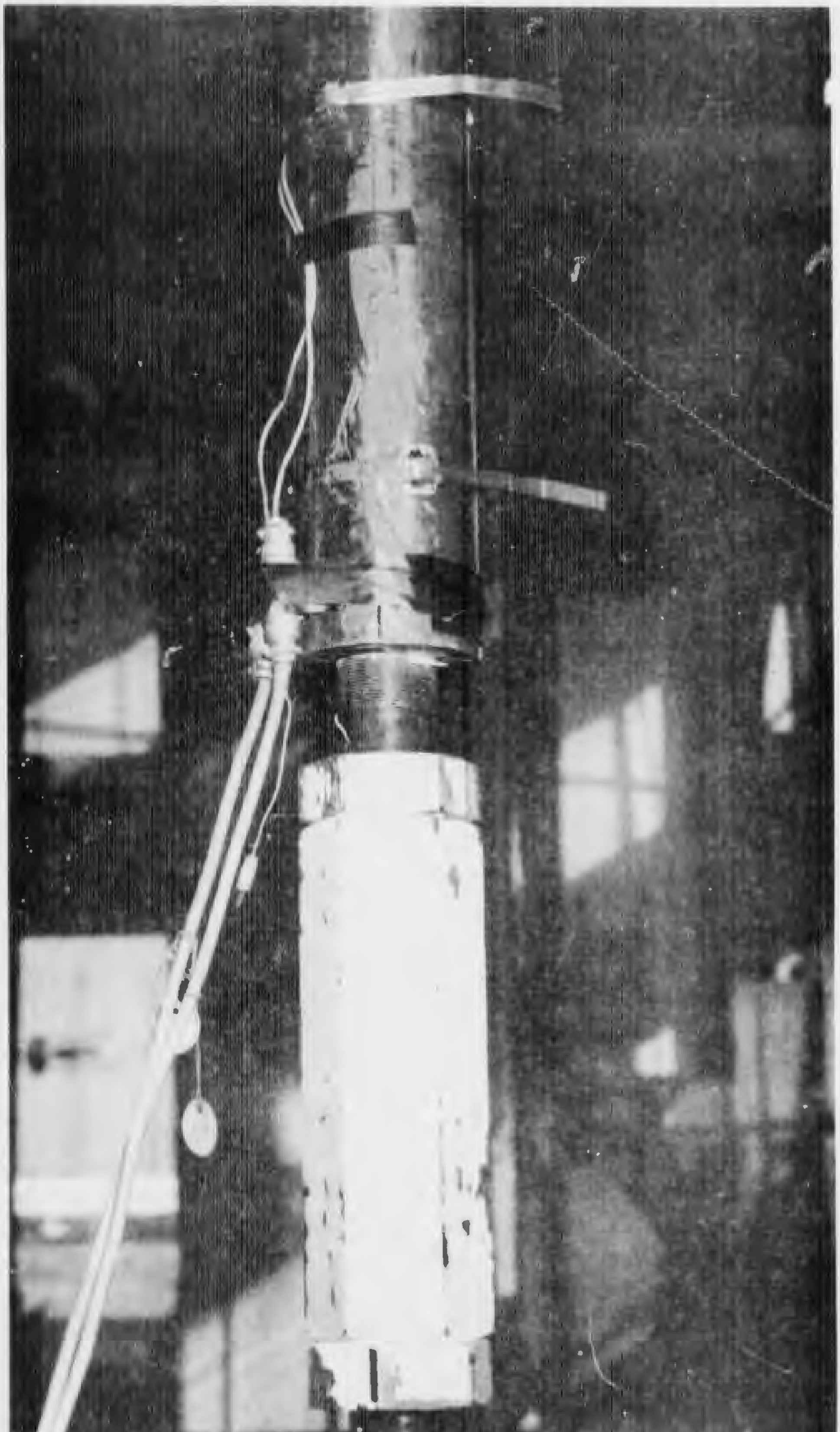


Figure 21. Collar Installation--Upper Rod

Table I

TEST AND CONFIGURATION MATRIX (EACH ISOLATOR TYPE)

TEST RUN	INPUT[1] CONDITION	MODE	DAMPING COLLAR CONFIGURATION		MASS CONFIGURATION[2]		
			Absent	Installed	Heavy Mass	Medium Mass	Light Mass
1	A	Linear	X		X		
2	A	↕	X		X		
3	A	↕	X			X	
4	A	↕	X				X
5	A	Linear		X	X		
6	B	Clang-Bang	X		X		
7	B	↕	X		X		
8	B	↕	X			X	
9	B	↕	X				X
10	B	Clang-Bang		X	X		
11	C	Hard Spring	X		X		
12	C	↕	X		X		
13	C	↕	X			X	
14	C	↕	X				X
15	C	↕		X	X		
16	D	↕	X		X		
17	D	↕	X		X		
18	D	↕	X			X	
19	D	↕	X				X
20	D	Hard Spring		X	X		

[1] See Table II
[2] See Table III

Table II

INPUT CONDITION

INPUT CONDITION	TYPE I			TYPE III			TYPE IV		
	Disp	Vel	Rise Time	Dist	Vel	Rise Time	Dist	Vel	Rise Time
A	3.00	60	16×10^{-3}	3.5	65	17×10^{-3}	3.00	60	16×10^{-3}
B	7.50	145	26×10^{-3}	5.0	100	25×10^{-3}	7.50	145	26×10^{-3}
C	9.75	185	26×10^{-3}	7.0	135	26×10^{-3}	9.25	175	26×10^{-3}
D	12.00	230	26×10^{-3}	10.0	190	26×10^{-3}	12.00	230	26×10^{-3}

Table III

MASS DESCRIPTION

MASS SIZE	TYPE I	TYPE III	TYPE IV
Heavy Mass	1140 lbs	5830 lbs	1055 lbs
Medium Mass	620 lbs	1140 lbs	620 lbs
Light Mass	200 lbs	200 lbs	200 lbs

Tolerances:
- Displacement ± 1/4 inch
- Velocity (Peak) ± 20 percent (in/sec)
- Rise Time ± 20 percent (sec)
- Masses ± 20 percent (lbs)

The primary data desired during the shock tests were a record of the input pulse and the response of the isolator due to this input. The responses from the isolator were accelerations, loads, relative displacements and displacements along the isolator spring can, upper rod, lower rod, rod bottom and the test mass. The input data and isolator response data were obtained from instrumentation sensors located on the Seismic Impulse Facility actuator and isolator as indicated in figure 22. The data requirements called out in table IV identify the data obtained from each of the shock tests. A detailed instrumentation plan for the shock testing portion of the test program is delineated in Appendix I.

Incremental 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 shock testing was terminated.

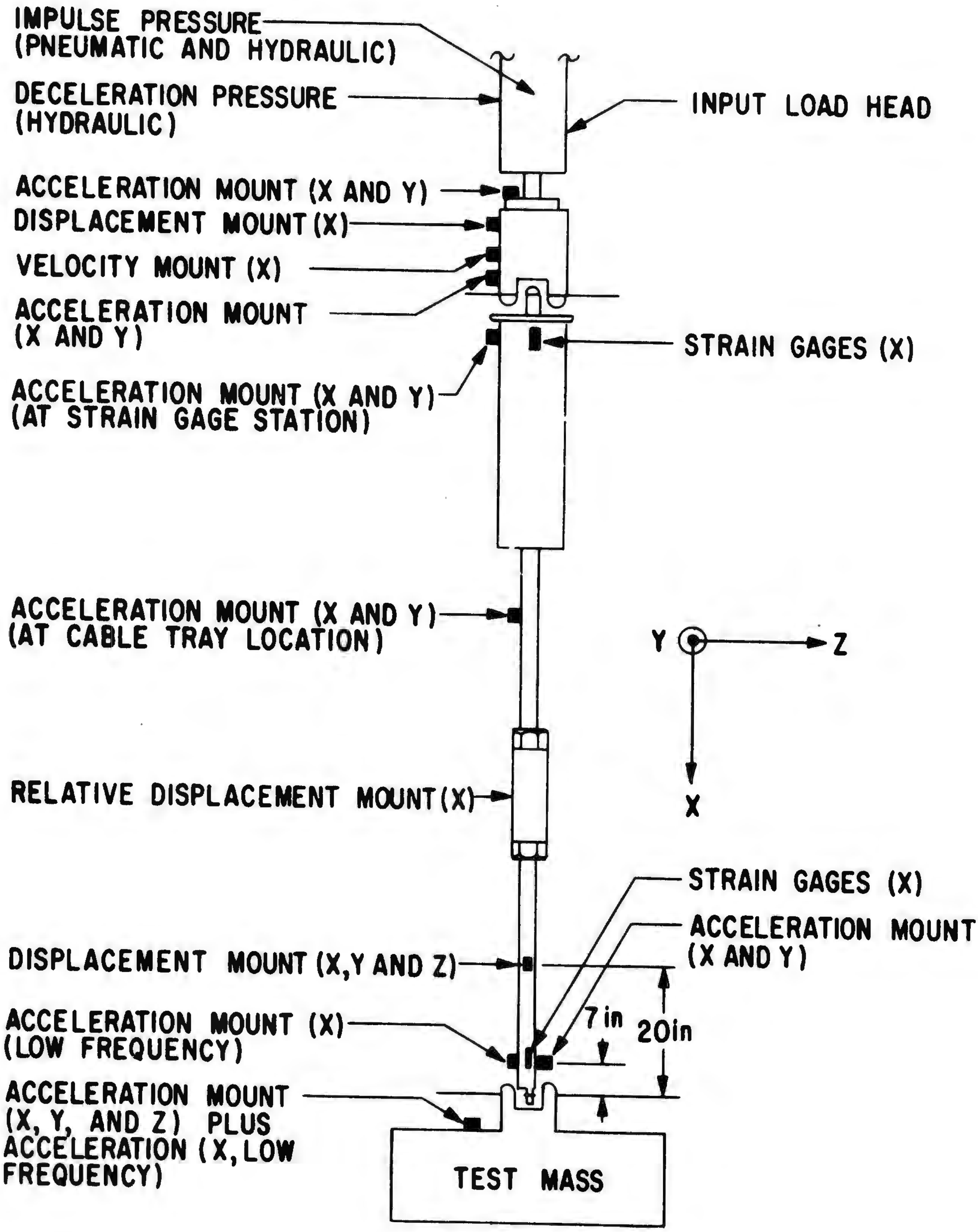


Figure 22. Typical Instrumentation for LER Isolator

Table IV

DATA REQUIREMENTS

Measurement	Data to be Determined	Freq Resp (Hz)	Range
Displacement	1. Displacement inputs to isolator attach point	0-300	± 20 in vert ± 20 in vert
	2. Relative displacement between isolator can and isolator rod	0-300	± 10 in vert
	3. Relative displacement between simulated mass and ground	0-2 0-2 0-2	± 20 in vert ± 10 in horz ± 10 in cross
Strain	1. Isolator can, top (maybe a load cell)	0-2000	± 3000 μ in/in
	2. Isolator rod bottom (axial load cell) (Strain data to be presented in force units)	0-2000	± 3000 μ in/in
Velocity	1. Velocity inputs to isolator attach points	0-400	± 250 in/sec vert
Pressure	1. Impulse pressure (pneumatic)	0-600	0-3000 psi
	2. Impulse pressure (hydraulic)	0-600	0-3000 psi
	3. Deceleration pressure (hydraulic)	0-600	0-3000 psi

Table IV (Cont'd)

Measurement	Data to be Determined	Freq Resp (Hz)	Range
Acceleration	1. Facility acceleration inputs to isolator attach points	0-400	± 100 g vert
		0-400	± 100 g horz
	2. Acceleration outputs from the simulated mass	0-2000	± 250 g vert
		0-2000	± 250 g horz
		0-600	± 250 g cross
	3. Acceleration inputs to isolator attach point (on actuator rod)	0-2000	± 2500 g vert
		0-2000	± 2500 g horz
	4. Isolator can, top	0-2000	± 2500 g vert
		0-2000	± 2500 g horz
	5. Isolator rod, top	0-2000	± 2500 g vert
		0-2000	± 2500 g horz
	6. Isolator rod, bottom	0-2000	± 2500 g vert
		0-2000	± 2500 g horz
	Isolator rod bottom low frequency	0-400	± 100 g vert

SECTION V

TEST RESULTS AND DISCUSSION

1. PRE-TEST ISOLATOR INSPECTION

As noted in the test procedure, a post-test inspection was made on the internal components of each isolator can-spring assembly after the initial shock test program. This post-test,inspection, presented in Table V, serves as a pre-test inspection. The additional pre-test inspection results for each LER isolator are included in Appendix II.

2. ISOLATOR COMPONENT STATIC TESTING

a. Spring Can--Lower Can Stop Static Test

As noted in the test procedures section, the load application for the Type III isolators was different from that used on the Type I and Type IV isolators. The load-displacement results for the four each Type I, Type III and Type IV isolators are represented by tables VI, VII and VIII. The static testing on all the isolators proved uneventful and no type of failure was observed. The tests indicated some permanent set took place. All the tests showed that the lower can stop was permanently displaced with respect to the spring can after testing.

b. Spring and Spring Plate Test

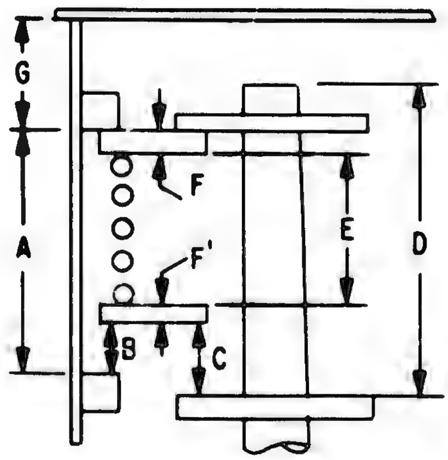
The load-displacement results for each individual isolator (four each Type I, Type III and Type IV) are given in tables IX, X and XI. No failures were observed during the isolator spring and spring plate static testing and no post-test damage was noted as the result of loading each rod-spring assembly beyond the spring solid height.

c. Isolator Hanger Rod Test

Tables XII, XIII and XIV give the results of static tests conducted on the isolator hanger rods. The tests indicated that permanent set, as the result of isolator rod static testing, was negligible for all isolator rods. No failures occurred and no damage to the isolator rod was evident.

Table V

INITIAL SHOCK TESTING



LER Isolator Dimensions

Post-Test Inspection or as Otherwise Noted

Symbol	Type I				Type III				Type IV			
	Serial No.				Serial No.				Serial No.			
	26	2	3	4	23	1	2	3	1	2	3	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
C (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	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$
C (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	$6\frac{3}{16}$	$6\frac{3}{16}$	$6\frac{3}{16}$	$6\frac{3}{16}$	$5\frac{1}{16}$	$5\frac{1}{8}$	$5\frac{1}{16}$	$5\frac{1}{16}$	$6\frac{5}{16}$	$6\frac{5}{16}$	$6\frac{3}{8}$	$6\frac{5}{16}$
N (6) Outer	15	16	16	16	9	9	9	9	13	13	13	13
N (6) Inner	---	---	---	---	14	14	14	14	---	---	---	---

Table V (cont'd)

1 Pre-test 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)

Table VI

SPRING CAN STATIC TEST--TYPE I ISOLATOR

Load (lbs)	Deflection (inch)			
	S/N 2	S/N 3	S/N 4	S/N 26
500	0	0	0	0
1,000	0.001	0	0.002	0.001
2,000	0.005	0.006	0.007	0.002
3,000	0.008	0.011	0.010	0.005
4,000	0.013	0.015	0.015	0.010
5,000	0.017	0.021	0.019	0.013
6,000	0.023	0.028	0.025	0.018
7,000	0.028	0.034	0.029	0.023
8,000	0.034	0.041	0.035	0.028
9,000	0.039	0.049	0.048	0.038
10,000	0.046	0.056	0.052	0.045
5,000	0.032	0.040	0.036	0.031
500	0.012	0.015	0.011	0.016
2,000	0.016	0.020	0.020	0.018
4,000	0.024	0.030	0.029	0.024
6,000	0.032	0.039	0.037	0.031
8,000	0.040	0.048	0.047	0.038
10,000	0.048	0.057	0.054	0.046
6,000	0.036	0.045	0.039	0.035
500	0.013	0.016	0.017	0.015
0	---	0.012	0.012	0.001

NOTE: Three cycles to 2,000 pounds prior to test.

Table VII

SPRING CAN STATIC TEST--TYPE III ISOLATOR

Load (lbs)			Deflection (inch)			
Outer	Inner	Total	S/N 1	S/N 2	S/N 3	S/N 23
300	600	900	0	0	0	0
2,100	2,200	4,300	0.015	0.012	0.014	0.013
4,100	4,200	8,300	0.034	0.036	0.030	0.029
6,200	6,200	12,400	0.046	0.055	0.049	0.050
8,300	8,400	16,700	0.058	0.072	0.066	0.068
8,300	9,200	17,500	0.055	0.075	0.069	0.072
8,300	10,000	18,300	0.055	0.077	0.070	0.076
8,300	11,700	20,000	0.058	0.082	0.080	0.083
300	600	900	-0.020	0.020	0.014	0.023
0	0	0	---	0.016	0.010	0.018

NOTE: Three cycles to 1,000 pounds on both outer and inner contact areas prior to test.

Table VIII

SPRING CAN STATIC TEST--TYPE IV ISOLATOR

Three Cycles to 2,000 pounds Prior to Test

Load (lbs)	Deflection (inch)			
	S/N 1	S/N 2	S/N 3	S/N 4
500	0	0	0	0
1,000	0.001	0	0.002	0
2,000	0.004	0.001	0.006	0.004
3,000	0.010	0.006	0.010	0.010
4,000	0.013	0.017	0.015	0.013
5,000	0.020	0.025	0.022	0.020
6,000	0.028	0.033	0.030	0.030
7,000	0.041	0.038	0.040	0.030
8,000	0.053	0.047	0.048	0.032
9,000	0.057	0.051	0.058	0.037
10,000	0.062	0.056	0.066	0.045
5,000	0.045	0.045	0.050	0.028
500	0.025	0.029	0.031	0.008
2,000	0.029	0.029	0.034	0.013
4,000	0.037	0.035	0.042	0.019
6,000	0.045	0.042	0.050	0.027
8,000	0.056	0.049	0.059	0.036
10,000	0.063	0.056	0.068	0.044
6,000	0.051	0.047	0.054	0.032
500	0.026	0.026	0.031	0.010
0	0.018	---	0.025	---

Table IX

SPRING AND SPRING PLATE STATIC TEST--TYPE I ISOLATOR

Three Cycles to 3,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 2	S/N 3	S/N 4	S/N 26
500	0	0	0	0
1,000	1.000	0.937	0.999	0.968
2,000	3.188	2.905	3.121	2.936
3,000	5.312	4.810	5.276	4.872
4,000	7.625	6.716	7.494	6.651
Solid Height	9.249 @ ~ 4,900 lbs	7.558 @ ~ 4,500 lbs	8.898 @ ~ 5,000 lbs	7.111 @ ~ 4,400 lbs
5,000	9.256	7.599	8.898	7.133
6,000	9.287	7.618	8.924	7.152
7,000	9.295	7.626	8.932	7.161
8,000	9.302	7.632	8.935	7.169
9,000	9.310	7.637	8.942	7.175
10,000	9.310	7.641	8.946	7.182
6,000	9.288	7.636	8.933	7.152
500	0.810	0.500	0.592	---
2,000	3.188	3.373	3.683	---
Solid Height	8.529 @ ~ 4,700 lbs	7.596 @ ~ 5,000 lbs	8.929 @ ~ 5,000 lbs	7.144 @ ~ 5,000 lbs
6,000	8.591	7.604	8.939	7.149
8,000	8.602	7.615	8.959	7.173
10,000	8.612	7.621	8.967	7.179
6,000	8.593	7.614	8.952	7.161
500	0.154	0.530	0.560	0.154
0	-0.811	-0.530	-0.374	-0.810

Table X

SPRING AND SPRING PLATE STATIC TEST--TYPE III ISOLATOR

Three Cycles to 10,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 1	S/N 2	S/N 3	S/N 23
1,000	0	0	0	0
2,000	0.499	0.561	0.499	0.562
4,000	1.497	1.623	1.560	1.686
6,000	2.557	2.685	2.622	2.809
8,000	3.554	3.746	3.745	3.933
10,000	4.740	4.776	4.744	5.057
12,000	5.737	5.744	5.743	6.180
14,000	6.673	6.742	6.740	7.241
16,000	7.482	7.616	7.677	7.833
Solid Height	7.597 @ ~ 16,600 lbs	7.896 @ ~ 17,600 lbs	---	---
18,000	7.715	7.931	7.988	7.869
20,000	7.802	7.968	8.051	7.890
10,000	---	4.930	4.865	5.148
1,000	0.053	0.124	0.059	0.030
4,000	---	1.623	1.648	1.686
8,000	---	3.746	3.774	3.929
12,000	---	5.743	5.834	6.180
16,000	---	7.553	7.675	7.834
Solid Height	---	7.786 @ ~ 17,600 lbs	7.943 @ ~ 17,600 lbs	---
20,000	---	7.848	8.019	7.892
12,000	---	5.804	5.863	6.211
1,000	---	0.001	0.059	0.062
0	-0.125	-0.220	-0.083	-0.264

Table XI

SPRING AND SPRING PLATE STATIC TEST--TYPE IV ISOLATOR

Three Cycles to 3,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 1	S/N 2	S/N 3	S/N 4
500	0	0	0	0
1,000	0.655	0.375	0.656	0.625
2,000	2.029	1.749	1.999	1.936
3,000	3.372	3.061	3.373	3.216
4,000	4.621	4.341	4.686	4.496
5,000	5.839	5.621	5.997	5.777
6,000	7.057	6.902	7.340	7.058
Solid Height	7.712 @ ~ 6,800 lbs	7.401 @ ~ 6,500 lbs	7.902 @ ~ 6,500 lbs	7.682 @ ~ 6,700 lbs
7,000	7.735	7.506	8.033	7.684
8,000	7.832	7.545	8.076	7.707
9,000	7.842	7.568	8.089	7.722
10,000	7.853	7.586	8.096	7.736
7,000	7.808	7.526	8.050	7.722
500	0.062	0.029	0.311	0.281
2,000	2.091	1.811	2.342	2.249
4,000	4.715	4.402	5.028	4.840
6,000	7.150	6.964	7.526	7.213
Solid Height	7.712 @ ~ 6,800 lbs	7.401 @ ~ 6,500 lbs	7.933 @ ~ 6,500 lbs	7.743 @ ~ 6,500 lbs
8,000	7.803	7.524	8.074	7.788
10,000	7.826	7.563	8.092	7.818
7,000	7.765	7.509	8.043	7.779
500	0	0.029	0.374	0.375
0	-0.376	-0.375	-0.228	-0.313

Table XII

HANGER ROD STATIC TEST--TYPE I ISOLATOR

Three Cycles to 5,000 pounds Prior to Test

Load (lbs)	Deflection (inch)			
	S/N 2	S/N 3	S/N 4	S/N 26
500	0	0	0	0
1,000	0.001	0.009	0.003	0.008
2,000	0.008	0.020	0.006	0.015
3,000	0.012	0.028	0.010	0.019
4,000	0.016	0.034	0.016	0.024
5,000	0.019	0.040	0.021	0.029
6,000	0.023	0.045	0.024	0.033
7,000	0.028	0.048	0.030	0.037
8,000	0.033	0.053	0.036	0.041
9,000	0.034	0.056	0.040	0.044
10,000	0.040	0.060	0.042	0.046
5,000	0.021	0.038	0.026	0.028
500	0	0	0.003	0
2,000	0.009	0.020	0.008	0.015
4,000	0.019	0.033	0.017	0.027
6,000	0.027	0.044	0.026	0.037
8,000	0.033	0.051	0.034	0.942
10,000	0.039	0.060	0.042	0.048
6,000	0.024	0.043	0.029	0.035
500	0	0	0.002	0.004
0	0	0	0	0.002

Table XIII

HANGER ROD STATIC TEST--TYPE III ISOLATOR

Three Cycles to 10,000 pounds Prior to Test

Load (lbs)	Deflection (inch)			
	S/N 1	S/N 2	S/N 3	S/N 23
1,000	0 @ 600 lbs	0	0	0
2,000	0.009	0.004	0.007	0.009
4,000	0.025	0.014	0.017	0.009
6,000	0.030	0.022	0.026	0.028
8,000	0.038	0.030	0.034	0.035
10,000	0.043	0.038	0.041	0.042
12,000	0.051	0.046	0.048	0.048
14,000	0.059	0.055	0.054	0.054
16,000	0.066	0.062	0.061	0.061
18,000	0.073	0.070	0.067	0.067
20,000	0.081	0.077	0.075	0.073
10,000	0.066 @ 16,000 lbs	0.038	0.039	0.040
1,000	0 @ 600 lbs	0	-0.004	0
4,000	0.028 @ 6,000 lbs	0.011	0.018	0.021
8,000	0.042 @ 10,000 lbs	0.030	0.034	0.037
12,000	0.056 @ 14,000 lbs	0.047	0.048	0.049
16,000	0.063	0.063	0.061	0.061
20,000	0.078	0.078	0.075	0.073
12,000	---	0.048	0.046	0.047
1,000	-0.003 @ 600 lbs	0	-0.004	0.002
0	-0.016	-0.007	---	---

Table XIV

HANGER ROD STATIC TEST--TYPE IV ISOLATOR

Three Cycles to 5,000 pounds Prior to Test

Load (lbs)	Deflection (inch)			
	S/N 1	S/N 2	S/N 3	S/N 4
500	0	0	0	0
1,000	0.006	0.004	0.008	0.003
2,000	0.013	0.013	0.014	0.007
3,000	0.016	0.021	0.018	0.008
4,000	0.019	0.027	0.020	0.010
5,000	0.022	0.032	0.024	0.014
6,000	0.024	0.034	0.025	0.017
7,000	0.029	0.036	0.030	0.019
8,000	0.033	0.039	0.034	0.021
9,000	0.036	0.043	0.040	0.024
10,000	0.040	0.046	0.044	0.027
5,000	0.018	0.018	0.019	0.009
500	0.002	0	0	0
2,000	0.009	0.012	0.017	0.007
4,000	0.018	0.024	0.029	0.013
6,000	0.020	0.032	0.037	0.016
8,000	0.025	0.040	0.042	0.023
10,000	0.030	0.048	0.050	0.028
6,000	0.016	0.027	0.035	0.014
500	0	0	0.002	0
0	---	---	0	---

3. ISOLATOR STIFFNESS TEST

A load-displacement test was conducted on 11 completely assembled isolators (four each Type I, three each Type III, and four each Type IV). As noted in the test procedures, Serial Number 2 of the Type III isolator had internal friction. The load-displacement results of isolator stiffness tests are tabulated in tables XV, XVI, and XVII. The three additional load cycles in the spring solid height region did not produce any isolator failure or create any visual isolator damage. The data show the approximate solid height for the assembled Type IV ranged: 8.000 to 8.307 inches, Type III 8.103 to 8.280 inches (three isolators) and Type I 9.425 to 9.473 inches (two isolators only). The two Type I isolators, Serial Numbers 3 and 26, did not have compressed springs in the assembled no load condition (see table V inspection record).

4. ISOLATOR ULTIMATE STIFFNESS TEST

An isolator ultimate stiffness test was conducted on three completely assembled isolators (one of each Type I, III, and IV). No data, other than the failure load, were recorded during the tests.

The initial failure on the Type I, Serial Number 2 isolator occurred at the original spherical rod end bearing. The rod end bearing, shown in figure 23, failed at a tensile load of 34,300 pounds.

The rod end bearing was replaced with the new high-strength spherical rod end bearing and testing was continued to determine a secondary mode of failure. A tensile load of 48,400 pounds was obtained when a definite indication of yielding occurred. The load was returned to zero in order to make an inspection. Figure 24 shows that severe yielding was taking place in the spring can at the lower can stop and cap screw junction. The isolator was reloaded and failure occurred at the same junction at a tensile load of 47,400 pounds. The failure is attributed to a combination of cap screw shear or bending and spring can material failure. Failure of the spring can is shown in figure 25.

Failure of the Type III, Serial Number 1 isolator occurred in the weld area at the rod bottom where the spherical rod bottom attaching nut is welded to the rod bottom. Figure 26 shows a detail of the Type III isolator failure. Slight bending was noted on the 1-1/4-inch bolt that attaches the platform weight to the isolator through the spherical rod end bearing.

Table XV

ISOLATOR STIFFNESS STATIC TEST--TYPE I ISOLATOR

Three Cycles to 3,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 2	S/N 3	S/N 4	S/N 26
500	0	0	0	0
1,000	0.875	1.031	1.031	1.094
2,000	2.969	3.094	3.156	3.094
3,000	5.094	5.094	5.656	5.030
4,000	7.311	6.938	7.531	6.901
Solid Height	8.581 @ ~ 4,800 lbs	7.188 @ ~ 4,500 lbs	8.500 @ ~ 4,800 lbs	7.123 @ ~ 4,500 lbs
5,000	8.622	7.206	8.512	7.145
6,000	8.655	7.231	8.556	7.175
7,000	8.681	7.249	8.578	7.200
8,000	8.699	7.267	8.598	7.218
9,000	8.715	7.287	8.616	7.233
10,000	8.729	7.303	8.635	7.247
5,000	8.634	7.241	8.571	7.188
7,000	8.699	7.268	8.597	7.215
10,000	8.732	7.304	8.638	7.247
5,000	8.636	7.242	8.574	7.189
7,000	8.703	7.269	8.600	7.217
10,000	8.733	7.306	8.634	7.249
5,000	8.643	7.244	8.575	7.190
7,000	8.704	7.270	8.602	7.219
10,000	8.723	7.307	8.640	7.250
500	0.437	0.155	0.156	0.090
0	-0.844	-0.031	-0.973	-1.161

Table XVI

ISOLATOR STIFFNESS STATIC TEST--TYPE III ISOLATOR

Three Cycles to 10,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 1	S/N 2	S/N 3	S/N 23
1,000	0	No Test Conducted--Isolator Internal Friction	0	0
2,000	0.500		0.500	0.500
4,000	1.531		1.563	1.625
6,000	2.499		2.563	2.624
8,000	3.499		3.594	3.686
10,000	4.467		4.624	4.810
12,000	5.435		5.592	5.809
14,000	6.370		6.560	6.870
16,000	7.305		7.557	7.742
Solid Height	~ 17,400 lbs		~ 17,800 lbs	~ 17,600 lbs
18,000	7.924		8.041	7.870
20,000	8.032		8.145	7.900
16,000	7.407		7.654	7.779
18,000	7.926		8.054	7.877
20,000	8.020		8.149	7.901
16,000	7.418		7.652	7.788
18,000	7.925		8.067	7.877
20,000	8.020		8.151	7.899
16,000	7.414		7.659	7.788
18,000	7.936		8.065	7.878
20,000	8.021		8.153	7.900
1,000	0.091		0.032	0.059
0	-0.225		-0.062	-0.410

Table XVII

ISOLATOR STIFFNESS STATIC TEST--TYPE IV ISOLATOR

Three Cycles to 3,000 pounds Prior to Test

Load (lbs)	Deflection (inches)			
	S/N 1	S/N 2	S/N 3	S/N 4
500	0	0	0	0
1,000	0.719	0.563	0.719	0.656
2,000	2.031	1.875	2.062	1.969
3,000	3.406	3.188	3.468	3.250
4,000	4.688	4.531	4.842	4.563
5,000	5.906	5.813	6.154	5.844
6,000	7.156	7.188	7.403	7.000
Solid Height	7.719 @ ~ 6,500 lbs	7.843 @ ~ 6,500 lbs	7.778 @ ~ 6,500 lbs	7.406 @ ~ 6,500 lbs
7,000	7.857	8.183	7.823	7.466
8,000	7.903	8.248	7.855	7.504
9,000	7.925	8.280	7.875	7.545
10,000	7.942	8.305	7.890	7.586
7,000	7.893	8.233	7.846	7.506
8,500	7.925	8.270	7.873	7.542
10,000	7.945	8.308	7.892	7.590
7,000	7.895	8.242	7.847	7.513
8,500	7.926	8.283	7.874	7.547
10,000	7.946	8.311	7.892	7.594
7,000	7.897	8.240	7.848	7.524
8,500	7.928	8.285	7.874	7.550
10,000	7.948	8.312	7.893	7.596
500	0.065	0.311	0.122	0.031
0	-0.341	-0.033	-0.529	-0.594

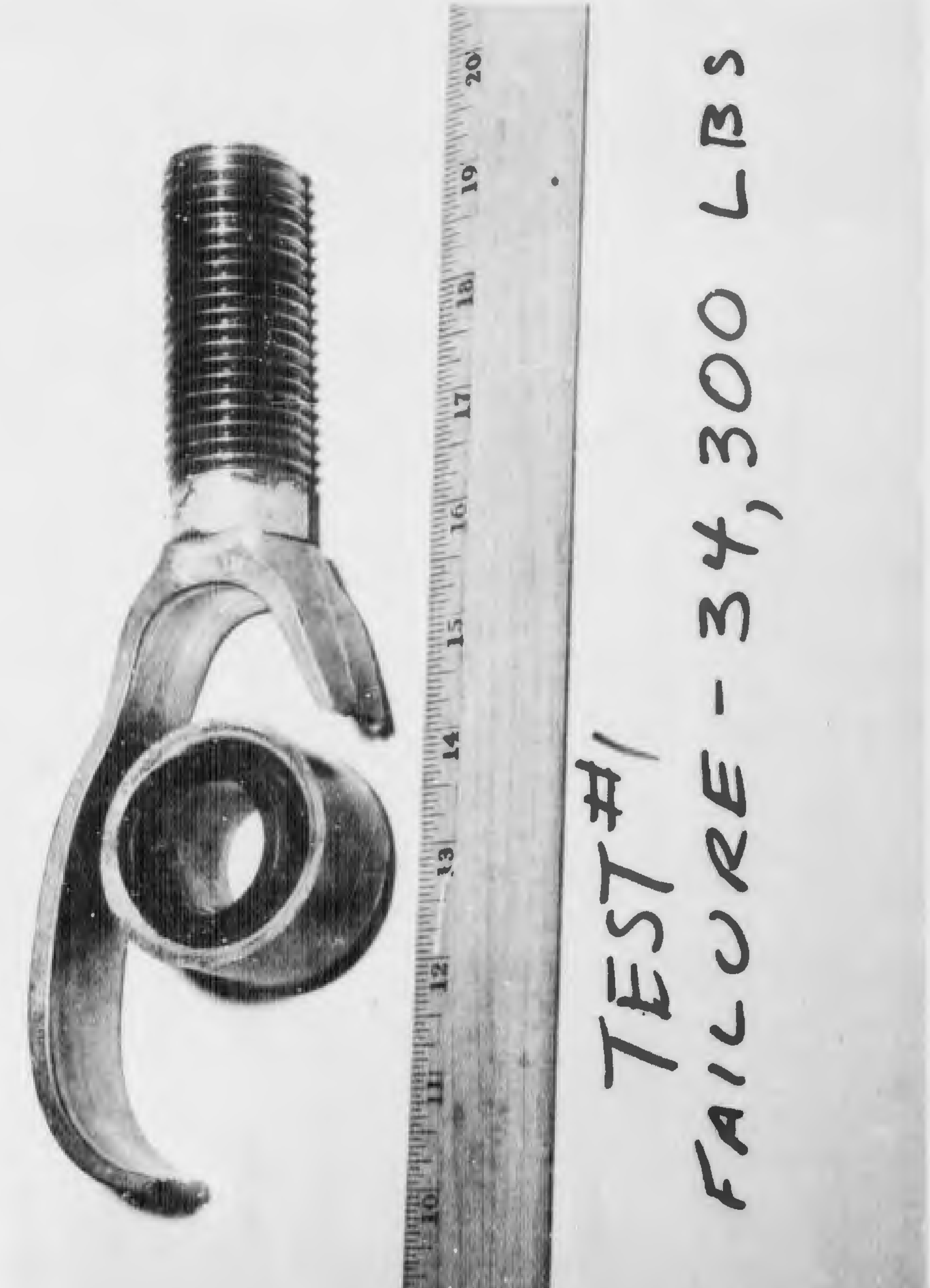


Figure 23. Type I, S/N 2 Ultimate Stiffness Initial Failure

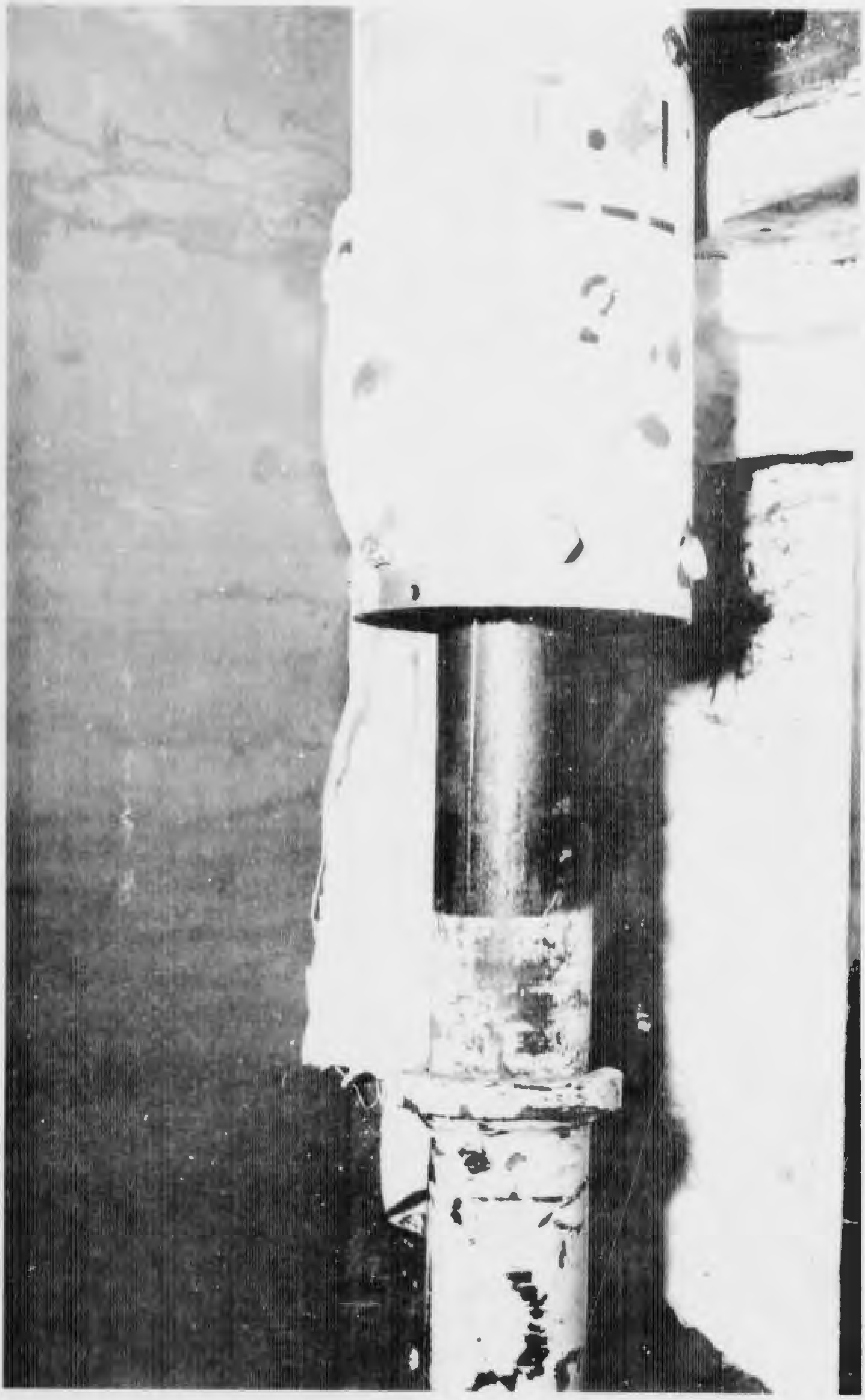


Figure 24. Type I, S/N 2 Spring Can Yielding Ultimate Stiffness Test

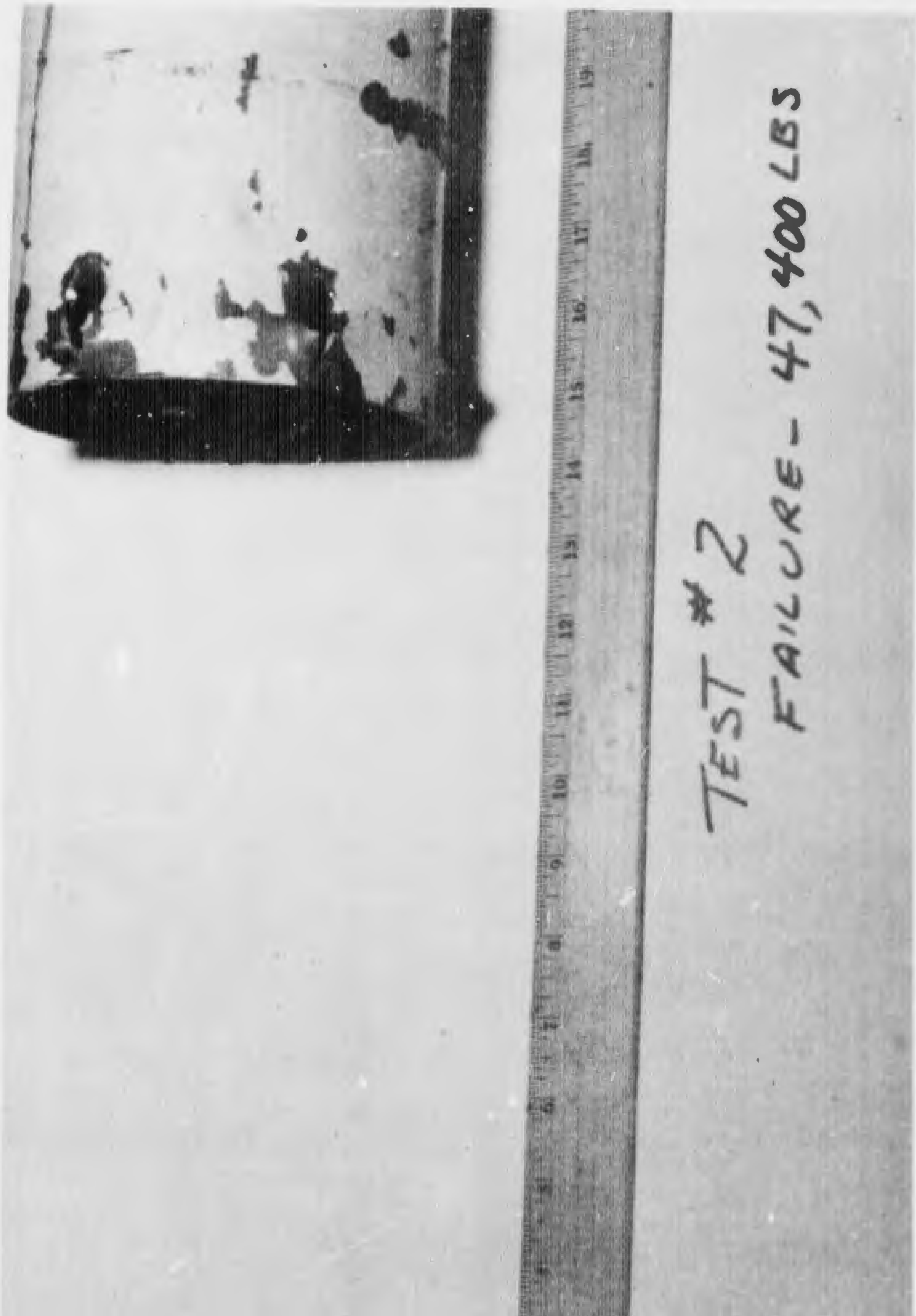


Figure 25. Type I, S/N 2 Ultimate Stiffness Secondary Failure

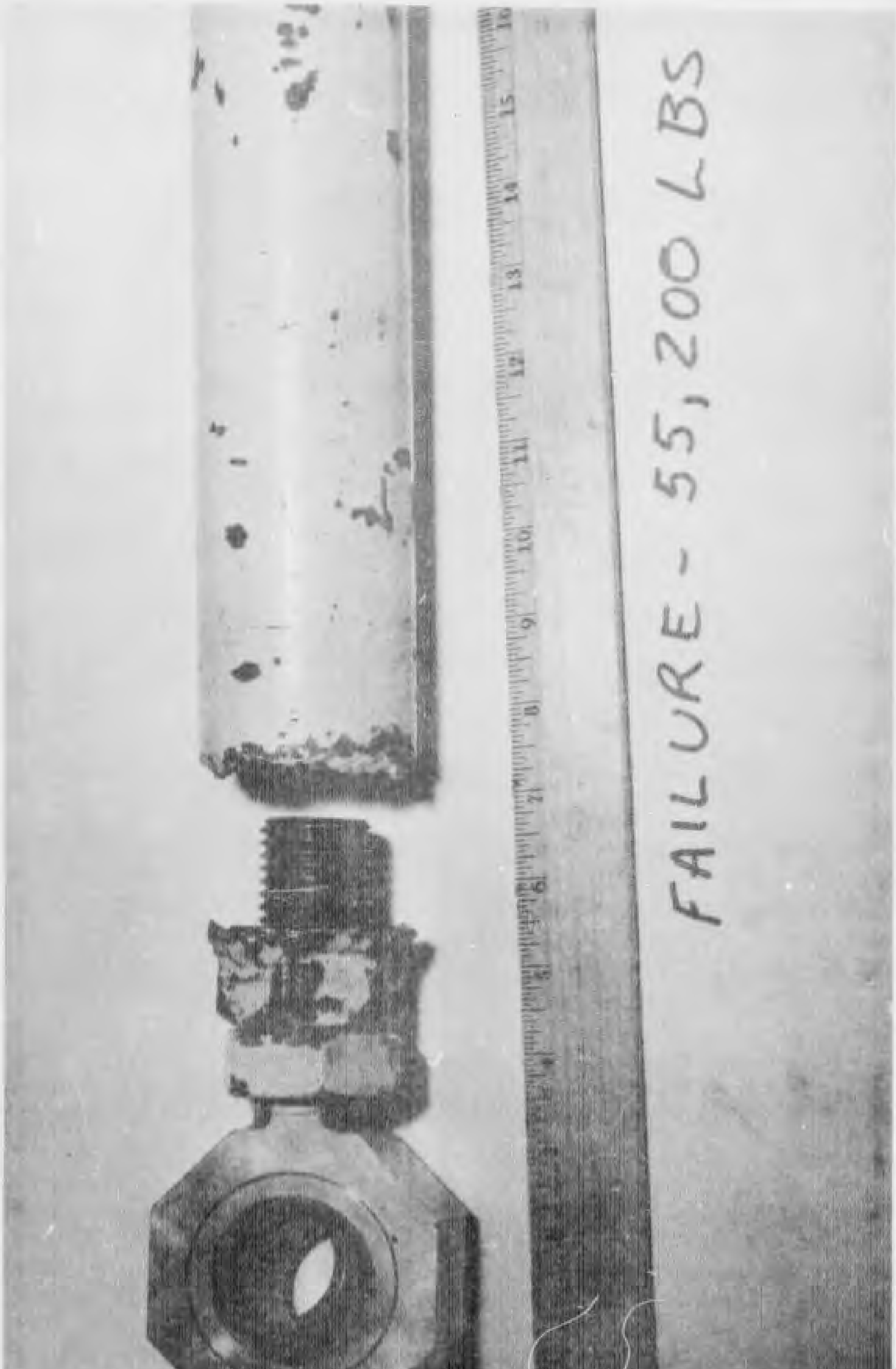


Figure 26. Type III, S/N 1 Ultimate Stiffness Failure

As on the Type I, Serial Number 2 isolator; the initial failure on the Type IV, Serial Number 1 isolator occurred at the original rod end bearing. The failure, shown in figure 27, was somewhat similar to the Type I failure in that the failure of the rod end was typical of a normal tensile failure after extensive bending, stretching and localized necking. The Type IV failure occurred at a tensile load of 34,600 pounds compared to 34,300 pounds for the Type 1. The rod end bearing was replaced with the new high-strength rod end spherical bearing and the secondary mode of failure occurred at the junction between the spring can and the lower can stop. The failure occurred at a tensile load of 44,600 pounds where the six cap screws at that joint failed in shear (see figure 27).

5. ISOLATOR DYNAMIC (SHOCK) TESTS

A series of shock input tests was conducted on three isolators (one of each Type I, III, and IV) to simulate service of the LER (Launcher Equipment Room) Isolator System. During the course of testing, the dynamic (shock) tests were identified by a "Shot" number. The "Shot" numbering system is consistent with the chronological number of shock tests conducted at the Seismic Impulse Facility. The "Shots" ran consecutively from number 305 through 364 for the testing of the three isolators and are identified by test mode and configuration in table XVIII.

Of prime importance for success of the dynamic shock testing was to provide an accurate input pulse to the isolator ceiling attached point by the Seismic Impulse Facility. The correlation of the shock input pulse and the data obtained from measuring this input for all the "Shots" is tabulated in tables, XIX, XX, and XXI The input data as well as the isolator response data were obtained electronically and recorded on instrumentation magnetic tape as delineated in the Instrumentation Plan, Appendix A. The test shot input data represented in the above tables are measured values from raw oscillograph traces which were obtained by "playback" from the instrumentation magnetic tape. Each reduced value was computed from the oscillograph raw data by multiplying the transducer stimulus by the ratio of the trace deflection, at the time point of interest, to the calibration trace deflection. The measured velocities are peak velocities and the rise time signifies time to reach the peak velocity. The displacement measurements were taken at any time after the completion of the input stroke.

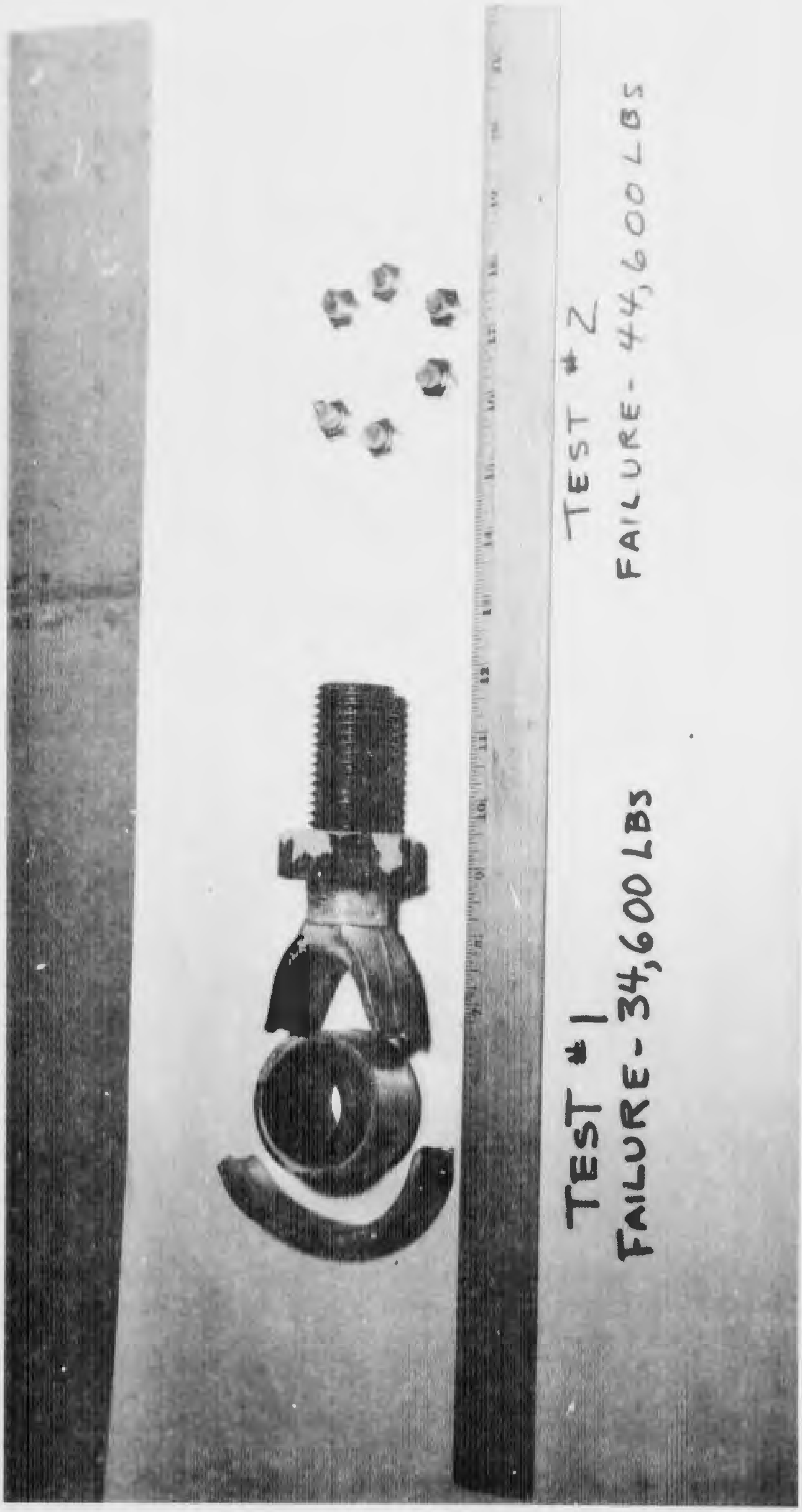


Figure 27. Type IV, S/N 1 Ultimate Stiffness Failures

Table XVIII

TEST AND CONFIGURATION MATRIX (ISOLATOR IDENTIFICATION)

Shot No.	Input[1] Condition	Mode	Damping Collar Configuration		Mass Configuration[2]			Isolator	
			Absent	Installed	Heavy Mass	Medium Mass	Light Mass	Type	S/N
305	A	Linear	X		X			III	3
306	A	Linear	X		X			III	3
307	B	Clang-Bang	X		X			III	3
308	B	Clang-Bang	X		X			III	3
309	B	Clang-Bang	X				X	III	3
310	A	Linear	X				X	III	3
311	B	Clang-Bang	X				X	III	3
312	B	Clang-Bang		X	X			III	3
313	A	Linear		X	X			III	3
314	A	Linear		X	X			III	3
315	C	Hard Spring		X	X			III	3
316	C	Hard Spring	X		X			III	3
317	C	Hard Spring	X		X			III	3
318	C	Hard Spring	X				X	III	3
319	C	Hard Spring	X			X		III	3
320	B	Clang-Bang	X			X		III	3
321	A	Linear	X			X		III	3
322	D	Hard Spring		X	X			III	3
323	D	Hard Spring	X		X			III	3

Table XVIII (Cont'd)

Shot No.	Input[1] Condition	Mode	Damping Collar Configuration		Mass Configuration[2]			Isolator	
			Absent	Installed	Heavy Mass	Medium Mass	Light Mass	Type	S/N
324	A	Linear	X				X	I	4
325	B	Clang-Bang	X				X	I	4
326	B	Clang-Bang	X			X		I	4
327	A	Linear	X			X		I	4
328	A	Lirear	X		X			I	4
329	A	Linear	X		X			I	4
330	B	Clang-Bang	X		X			I	4
331	B	Clang-Bang	X		X			I	4
332	B	Clang-Bang		X	X			I	4
333	B	Clang-Bang		X	X			I	4
334	A	Linear		X	X			I	4
335	C	Hard Spring		X	X			I	4
336	C	Hard Spring	X		X			I	4
337	C	Hard Spring	X		X			I	4
338	C	Hard Spring	X				X	I	4
339	C	Hard Spring	X			X		I	4
340	D	Hard Spring		X	X			I	4
341	D	Hard Spring	X		X			I	4
342	D	Hard Spring	X		X			I	4
343	D	Hard Spring	X			X		I	4
344	D	Hard Spring	X				X	I	4

Table XVIII (Cont'd)

Shot No.	Input[1] Condition	Mode	Damping Collar Configuration		Mass Configuration[2]			Isolator	
			Absent	Installed	Heavy Mass	Medium Mass	Light Mass	Type	S/N
345	A	Linear	X				X	IV	4
346	B	Clang-Bang	X				X	IV	4
347	B	Clang-Bang	X			X		IV	4
348	A	Linear	X			X		IV	4
349	A	Linear	X		X			IV	4
350	A	Linear	X		X			IV	4
351	B	Clang-Bang	X		X			IV	4
352	B	Clang-Bang	X		X			IV	4
353	B	Clang-Bang		X	X			IV	4
354	A	Linear		X	X			IV	4
355	C	Hard Spring		X	X			IV	4
356	C	Hard Spring	X		X			IV	4
357	C	Hard Spring	X		X			IV	4
358	C	Hard Spring	X				X	IV	4
359	C	Hard Spring	X			X		IV	4
360	D	Hard Spring		X	X			IV	4
361	D	Hard Spring	X		X			IV	4
362	D	Hard Spring	X		X			IV	4
363	D	Hard Spring	X			X		IV	4
364	D	Hard Spring	X				X	IV	4

1 See Table II 2 See Table III

Table XIX

SHOCK INPUT VERSUS TEST RESULTS FOR TYPE I, S/N 4 ISOLATOR

Input Condition	Shot Criteria[1]			Shot No.	Test Shot Results		
	Disp	Vel	Rise Time		Disp	Vel	Rise Time
A	3.00	60	16×10^{-3}	324	3.0	60	14×10^{-3}
B	7.50	145	26×10^{-3}	325	7.5	145	27×10^{-3}
B	7.50	145	26×10^{-3}	326	7.5	140	27×10^{-3}
A	3.00	60	16×10^{-3}	327	3.0	60	17×10^{-3}
A	3.00	60	16×10^{-3}	328	3.0	60	16×10^{-3}
A	3.00	60	16×10^{-3}	329	3.0	58	16×10^{-3}
B	7.50	145	26×10^{-3}	330	7.3	145	26×10^{-3}
B	7.50	145	26×10^{-3}	331	7.4	144	26×10^{-3}
B	7.50	145	26×10^{-3}	332	7.3	145	26×10^{-3}
B	7.50	145	26×10^{-3}	333	7.4	147	27×10^{-3}
A	3.00	60	16×10^{-3}	334	3.0	60	14×10^{-3}
C	9.75	185	26×10^{-3}	335	9.6	182	22×10^{-3}
C	9.75	185	26×10^{-3}	336	9.6	190	27×10^{-3}
C	9.75	185	26×10^{-3}	337	9.7	188	28×10^{-3}
C	9.75	185	26×10^{-3}	338	9.6	195	27×10^{-3}
C	9.75	185	26×10^{-3}	339	9.7	180	30×10^{-3}
D	12.00	230	26×10^{-3}	340	12.0	260	23×10^{-3}
D	12.00	230	26×10^{-3}	341	12.0	250	23×10^{-3}
D	12.00	230	26×10^{-3}	342	12.0	250	23×10^{-3}
D	12.00	230	26×10^{-3}	343	12.0	265	23×10^{-3}
D	12.00	230	26×10^{-3}	344	12.0	260	23×10^{-3}

[1] See Table II Tolerances

Table XX

SHOCK INPUT VERSUS TEST RESULTS FOR TYPE III, S/N 3 ISOLATOR

Input Condition	Shot Criteria[1]			Shot No.	Test Shot Results		
	Disp	Vel	Rise Time		Disp	Vel	Rise Time
A	3.5	65	17×10^{-3}	305	3.6	66	16×10^{-3}
A	3.5	65	17×10^{-3}	306	3.6	70	15×10^{-3}
B	5.0	100	25×10^{-3}	307	5.2	100	23×10^{-3}
B	5.0	100	25×10^{-3}	308	5.2	100	25×10^{-3}
B	5.0	100	25×10^{-3}	309	5.0	100	23×10^{-3}
A	3.5	65	17×10^{-3}	310	3.6	64	16×10^{-3}
B	5.0	100	25×10^{-3}	311	5.0	96	23×10^{-3}
B	5.0	100	25×10^{-3}	312	5.0	108	23×10^{-3}
A	3.5	65	17×10^{-3}	313	3.7	69	15×10^{-3}
A	3.5	65	17×10^{-3}	314	3.6	65	15×10^{-3}
C	7.0	135	26×10^{-3}	315	7.1	112	24×10^{-3}
C	7.0	135	26×10^{-3}	316	7.1	121	26×10^{-3}
C	7.0	135	26×10^{-3}	317	7.1	120	26×10^{-3}
C	7.0	135	26×10^{-3}	318	6.9	117	27×10^{-3}
C	7.0	135	26×10^{-3}	319	7.0	118	25×10^{-3}
B	5.0	100	26×10^{-3}	320	5.2	112	25×10^{-3}
A	3.5	65	17×10^{-3}	321	3.5	63	14×10^{-3}
D	10.0	190	26×10^{-3}	322	10.0	205	27×10^{-3}
D	10.0	190	26×10^{-3}	323	10.0	200	27×10^{-3}

[1] See Table II Tolerances

Table XXI

SHOCK INPUT VERSUS TEST RESULTS FOR TYPE IV, S/N 4 ISOLATOR

Input Condition	Shot Criteria[1]			Shot No.	Test Shot Results		
	Disp	Vel	Rise Time		Disp	Vel	Rise Time
A	3.00	60	16×10^{-3}	345	3.0	60	13×10^{-3}
B	7.50	145	26×10^{-3}	346	7.5	148	27×10^{-3}
B	7.50	145	26×10^{-3}	347	7.5	145	28×10^{-3}
A	3.00	60	16×10^{-3}	348	3.0	58	13×10^{-3}
A	3.00	60	16×10^{-3}	349	3.0	58	13×10^{-3}
A	3.00	60	16×10^{-3}	350	3.1	63	13×10^{-3}
B	7.50	145	26×10^{-3}	351	7.4	145	23×10^{-3}
B	7.50	145	26×10^{-3}	352	7.5	142	28×10^{-3}
B	7.50	145	26×10^{-3}	353	7.4	140	27×10^{-3}
A	3.00	60	16×10^{-3}	354	3.0	60	13×10^{-3}
C	9.25	175	26×10^{-3}	355	9.3	184	26×10^{-3}
C	9.25	175	26×10^{-3}	356	9.3	190	29×10^{-3}
C	9.25	175	26×10^{-3}	357	9.3	183	27×10^{-3}
C	9.25	175	26×10^{-3}	358	9.4	188	28×10^{-3}
C	9.25	175	26×10^{-3}	359	9.4	186	25×10^{-3}
D	12.00	230	26×10^{-3}	360	12.3	236	24×10^{-3}
D	12.00	230	26×10^{-3}	361	12.2	230	26×10^{-3}
D	12.00	230	26×10^{-3}	362	12.2	235	24×10^{-3}
D	12.00	230	26×10^{-3}	363	12.0	230	26×10^{-3}
D	12.00	230	26×10^{-3}	364	12.2	230	24×10^{-3}

[1] See Table II Tolerances

The test inputs were applied according to the test and matrix configuration of table I. All conditions of the matrix were met for the Type I and IV isolators without any appreciable damage that would incapacitate the isolator. The Type III isolator failed before all the test conditions were met. The failure incapacitated the isolator and terminated the sequence. Figure 28 shows that yielding was definitely taking place at the original spherical rod end bearing on the Type I, Serial Number 4 isolator. Yielding was first noted at "Shot" Number 335 (see table XIX, Test Shot Results). Continued yielding was noted during tests conducted with the heavy mass.

Failure on the Type III, Serial Number 3 isolator occurred in the weld area at the junction where the rod bottom attaching nut is welded to the rod bottom. The failure occurred during the second hard spring "D" input condition with the heavy mass (Shot 323, table XX). Weld cracks around the junction were noted on the preceding shock test (Shot 322). Figure 29 shows a detail of the Type III isolator failure. A post-test inspection of the isolator was made after detachment from the Seismic Impulse Facility actuator. The inspection revealed that additional cracks occurred at the welded junction between the top spherical bearing lug and spring can top plate. Figures 30 and 31 show a detail of the crack area around the junction.

The failure on the Type IV, Serial Number 4 isolator was similar to the Type I failure. Failure occurred at the original rod end bearing. Yielding in the rod end bearing was first noted after "Shot" 360 (see table XXI, Test Shot Results) and continued during the tests conducted with the heavy mass. Figure 32 shows the condition of rod end bearing after the completion of the shock tests.

6. ISOLATOR SHOCK TEST HISTORY

The individual isolator test history and test result notations for the three isolators subjected to shock testing are included in Appendix III. Summarizations of previous test histories and test results for each of the isolators are also included.

7. ISOLATOR DYNAMIC (SHOCK) TEST DATA TRACES

Volume II will include oscillograph traces and data plots illustrating typical data obtained from test facility inputs and isolator responses as the result of the inputs. The data will include typical runs for each of the three isolators.

Figure 28. Type I, S/N 4 Dynamic Shock Test Isolator Yielding

Figure 29. Type III, S/N 3 Dynamic Shock Test Failure

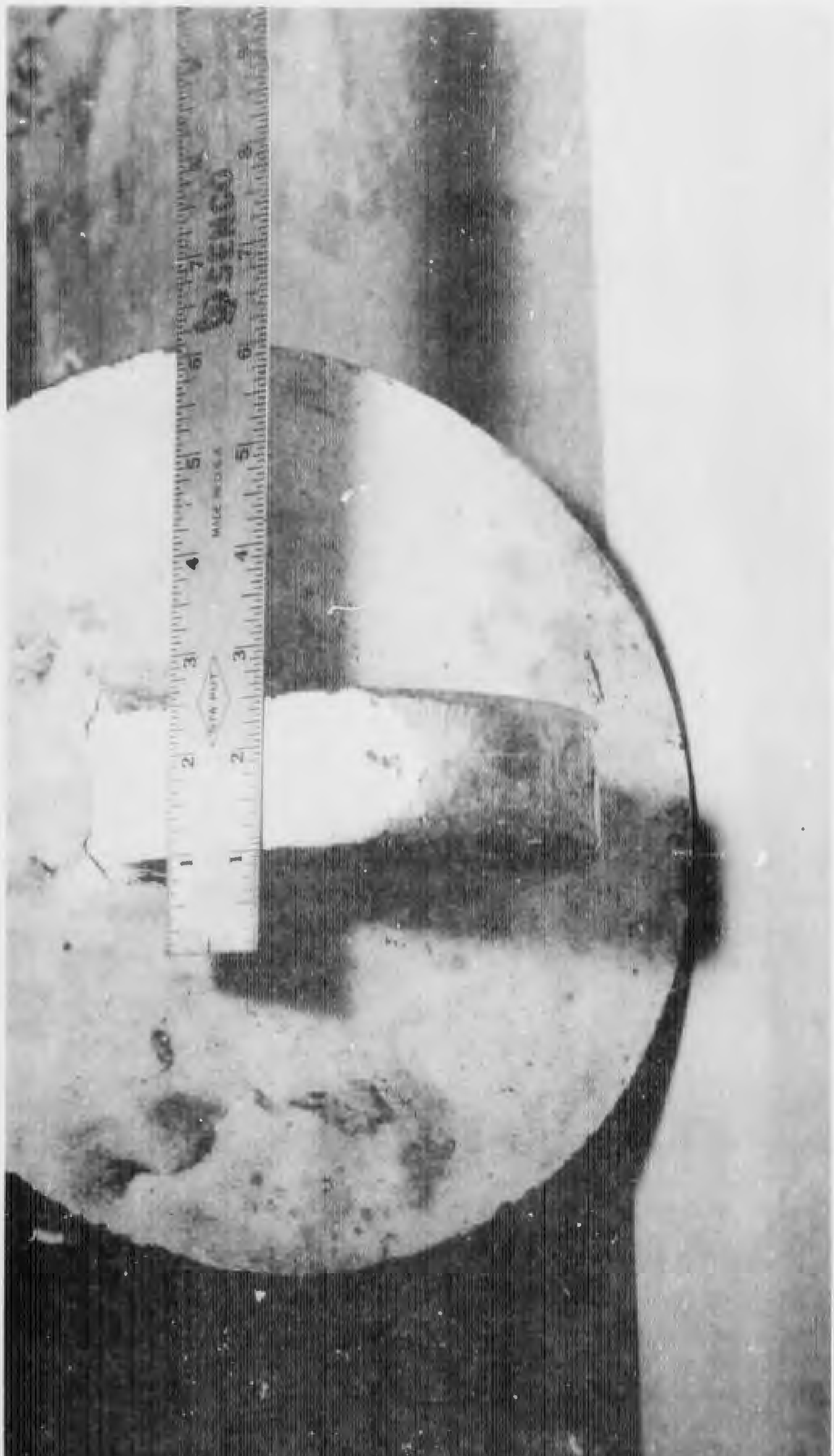


Figure 30. Type III, S/N 3 Dynamic Shock Test Isolator Yielding

Figure 31. Type III, S/N 3 Dynamic Shock Test Isolator Yielding

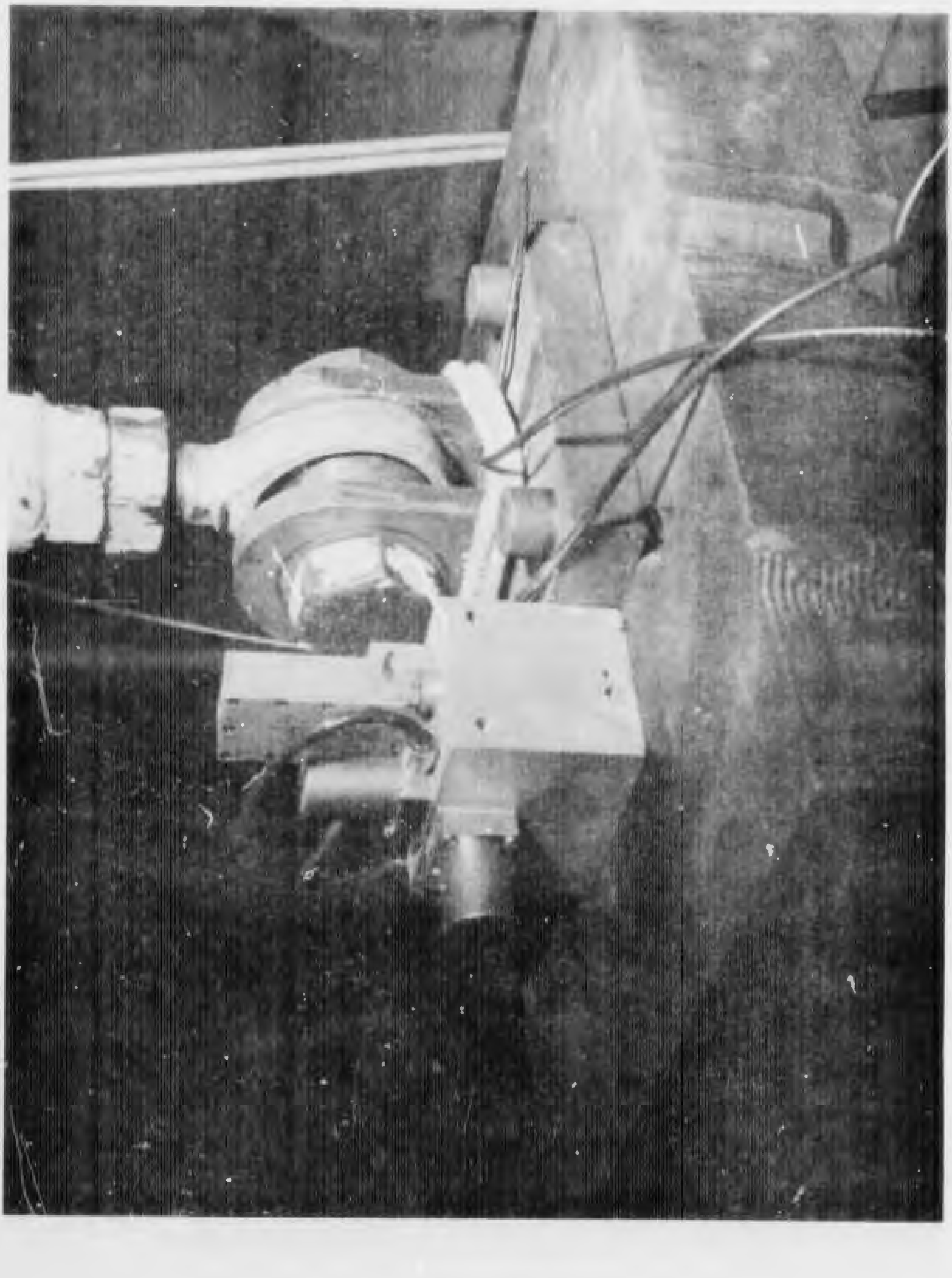


Figure 32. Type IV, S/N 4 Dynamic Shock Test Isolator Yielding

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

a. All test program requirements were met and no failures occurred prior to overtest.

b. When overtested, the test results showed that different failures occur to the LER Shock Isolators, whether it be a static load condition or a dynamic (shock) input condition.

c. Failures occurred in three areas, (1) the lower rod end spherical bearing, (2) the joint between the cap screws and the lower can stop and (3) at the weld area where the rod bottom bearing nut is attached to the rod bottom. The lower rod end spherical bearing and cap screw joint failures were repeated results of previous isolator dynamic (shock) tests. However, isolator refurbishment of these two areas definitely increased the ultimate dynamic strength of the isolators.

d. The ultimate strength of the isolators, after refurbishment, is approximately 34,450 pounds for the Type I and Type IV isolators and approximately 55,200 pounds for the Type III isolator. These values are based on the results of static tensile pull tests.

e. The installation of damping collars on LER shock isolator rods showed a definite improvement to the shock isolation system. The use of the collars attenuated the high frequency vibrations and decreased the magnitude of these vibrations along the rod and test mass.

f. Test program success criteria were obtained with the acquisition of sufficient test data to satisfy the test requirements.

2. RECOMMENDATIONS

a. It is recommended that the existing rod end spherical bearing on the Type I and Type IV isolators be replaced with the new higher strength rod end bearing. The new bearing will increase the ultimate static load strength from approximately 34,450 pounds to 46,000 pounds. The 46,000-pound ultimate strength represents the approximate static force at which the joint between the cap screws and the lower can stop will fail and the lower can stop will fail when refurbished with new cap screws as noted in the test procedure.

b. It is recommended that the installation of damping collars be considered in the overall evaluation study if reducing the source of high frequency is required.

APPENDIX I

INSTRUMENTATION PLAN

1. INSTRUMENTATION

Data monitored during the dynamic (shock) tests were

a. Velocity, displacement, acceleration (two axes) and pressure versus time for the shock input.

b. Loads, relative displacement, and accelerations (two axes) versus time along the LER isolator.

c. Displacement (three axes) and acceleration (three axes) versus time for the platform simulated mass.

d. The shock-test starting-time reference was indicated through a relay switch in the programer. A time code generator provided a time basis throughout the test run.

The input velocity was monitored with a generator output transducer operated from a rack and pinion arrangement. The input displacement was measured with both a potentiometer transducer operated from the above rack and pinion arrangement and also a rod-type linear variable displacement transducer (LVDT). Hydraulic and pneumatic pressures at the input pulse were measured by strain gage pressure transducers. Accelerations at the input, the isolator and the platform simulated mass were monitored by means of piezoresistive and strain gage accelerometers. The platform simulated mass motion was monitored in longitudinal, vertical and transverse modes by reel potentiometer displacement transducers. The starting times were accurately determined by the relay switch circuit which provided a timing blip.

Data from the various transducers were routed through carrier-type amplifiers, bridge balance or voltage divider systems and were then impressed on a fourteen track magnetic tape recorder by the use of voltage controlled oscillators. The resulting data tapes were then reduced into "quick look" oscillograph records or reduced and programed utilizing digitizing and computer equipment. The "quick look" oscillograph records provided a means for checking input data and other selected channel locations before proceeding to the next test run. Figures 33, 34, 35, 36, 37, 38, and 39 give schematics showing the instrumentation, the instrumentation recording systems and the general location of the transducers.

2. CALIBRATION OF INSTRUMENTATION

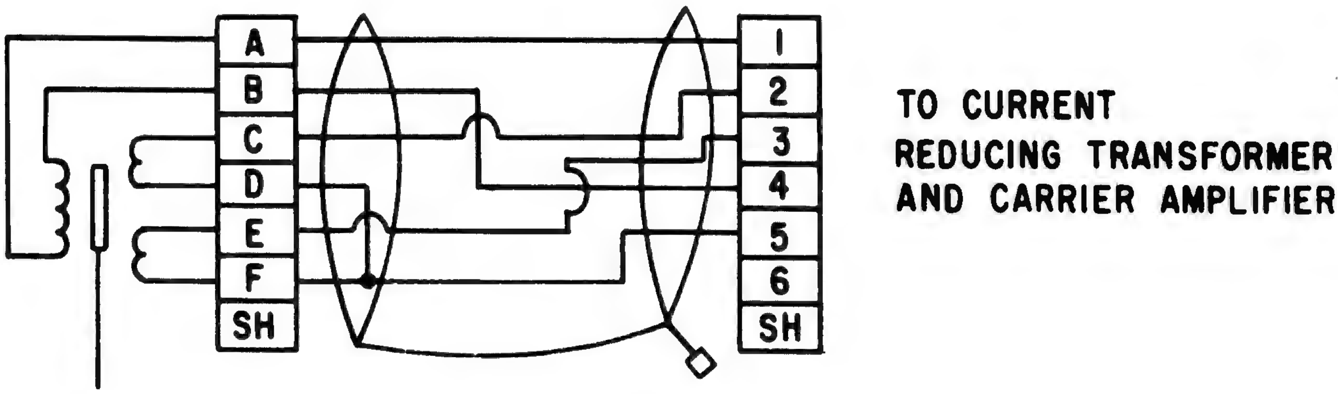
a. In general, calibration of the Wing I, LER Shock Isolator test instrumentation was accomplished by comparison against laboratory standards during test set up and by simulation prior to each test.

b. Input (Actuator Crosshead) Displacement: Both the linear variable displacement transducer (LVDT) and the potentiometer transducer calibrations were accomplished by physically displacing the moving element through a known distance and tabulating the resulting readings. Linearity was assured by dividing full-scale travel into equal increments. The results were plotted and the deviation from best straight line response was determined. Prior to each test run, a synthetic calibration was used with a substitute voltage signal. This voltage was introduced during the original physical calibration to provide a known voltage matched displacement. The figure 40 schematic shows the method used for applying a voltage signal as a calibration source and the calibration method used for both the potentiometer and LVDT displacement transducer.

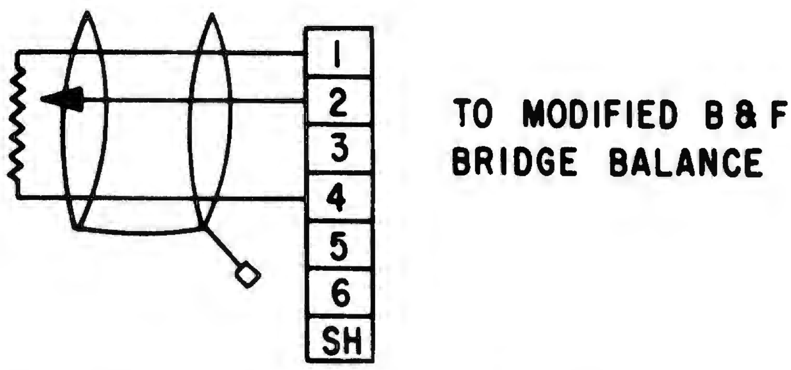
c. Platform Simulated Mass Displacement: The simulated mass displacements for the three axes were measured with potentiometer "reel" transducers. The calibration method, shown in the upper view of figure 40, was accomplished in the same manner as the input potentiometer displacement transducer.

d. Isolator Can-Rod Relative Displacement: A linear variable displacement transducer (LVDT) was used to measure the isolator can-rod relative displacement. The LVDT calibration method is shown in the lower view of figure 40.

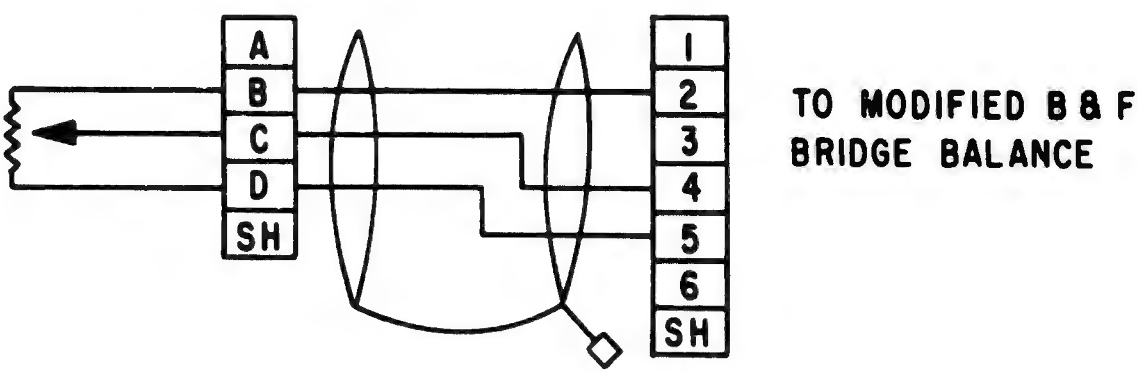
e. Input (Actuator Crosshead) Velocity: The velocity (generator output type) transducer was calibrated by measuring the output signals generated by introducing variable speeds to the input shaft. Linearity was assured by incremental speeds at the input. Prior to each test run, a substitute voltage signal was used to produce a synthetic calibration. The voltage was introduced during the original calibration to provide a known voltage matched velocity. Figure 41 shows the method used for calibrating and applying the voltage signal as a calibration source.



COLLINS LVDT



RESEARCH INC. POTENTIOMETER



THE BOEING CO. POTENTIOMETER

Figure 33. Displacement Transducer Wiring

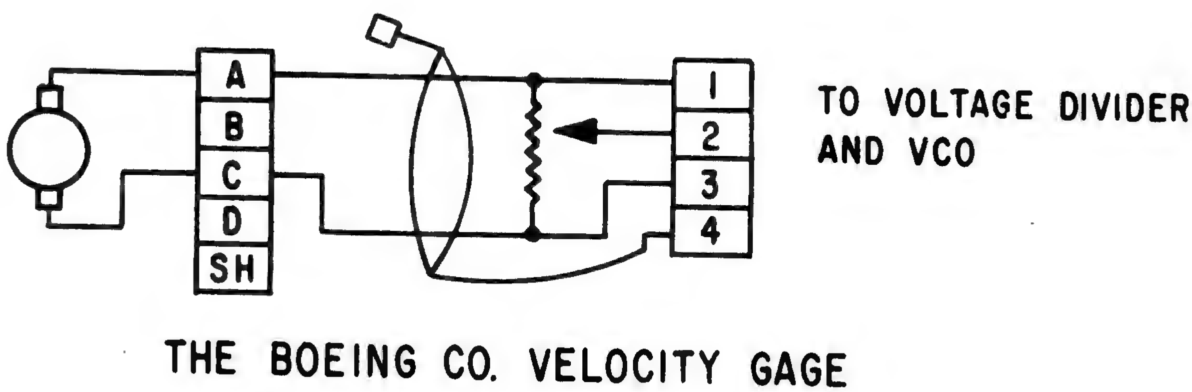


Figure 34. Velocity Transducer Wiring

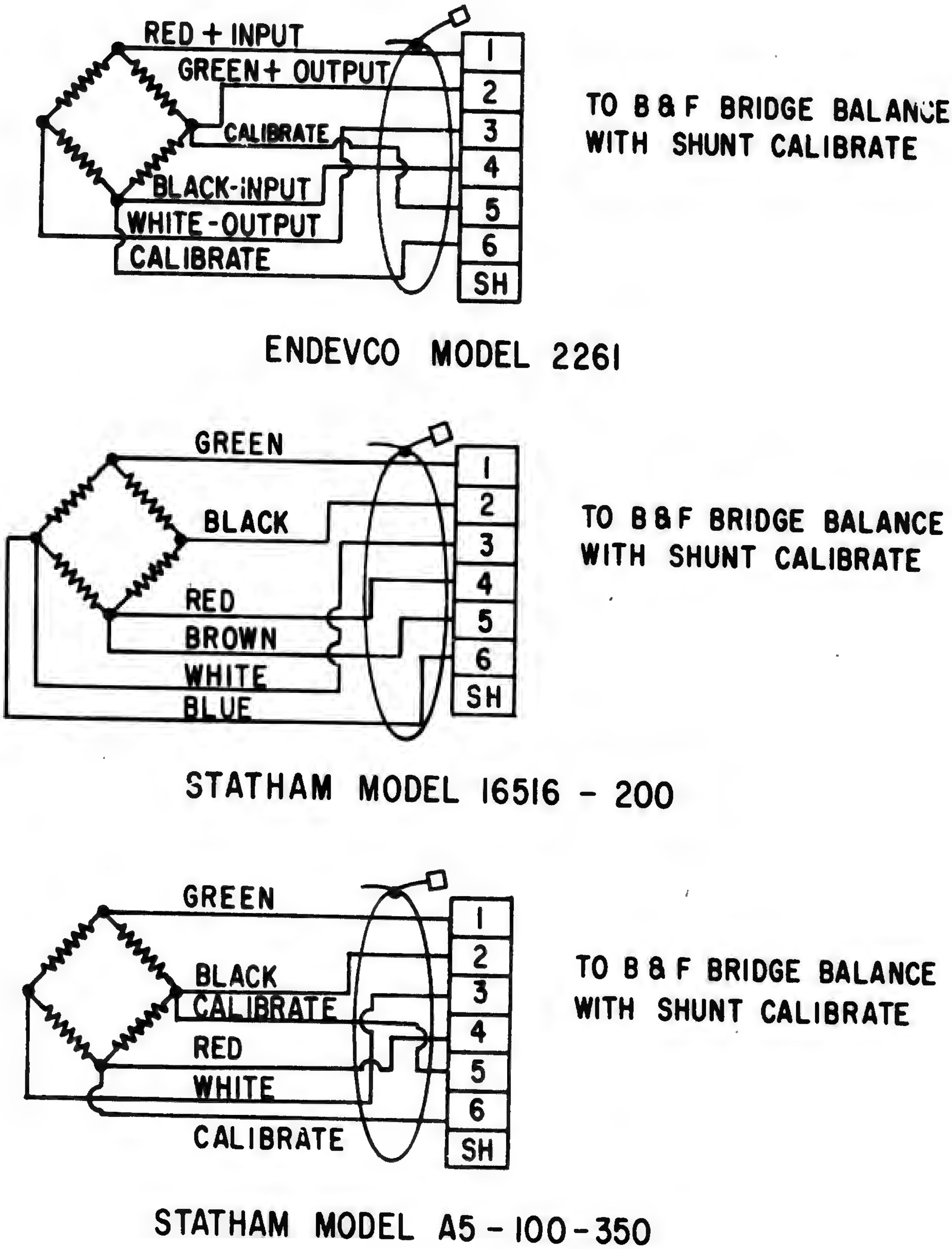


Figure 35. Accelerometer Transducer Wiring

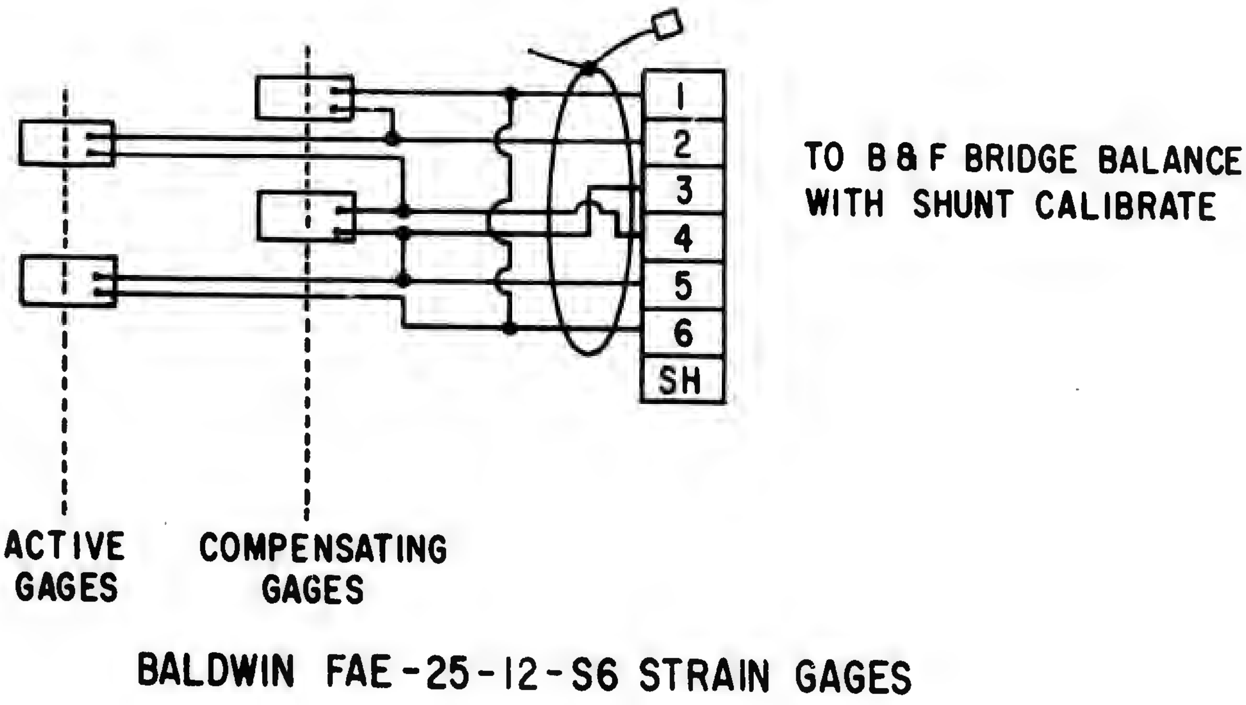
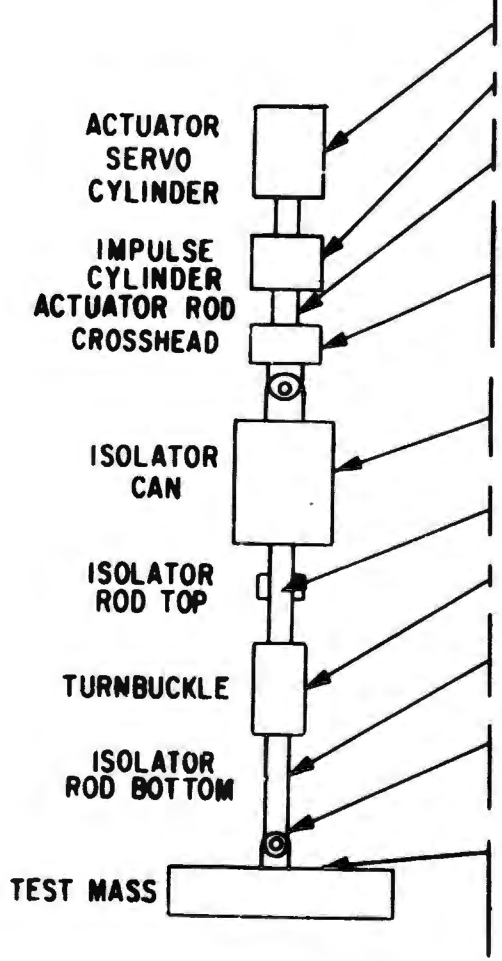


Figure 36. Isolator Can and Rod (Strain)
Load Wiring



Designation	Measurement	Transducer model number	Manufacturer	Range
P-RH-XO	Servo Pressure	111-34-P	Norwood	3000 psi
P-IH-XO	Servo Pressure	111-34-P	Norwood	3000 psi
P-IG-XO	Impulse Pressure	111-34-P	Norwood	3000 psi
A-AR-X3	Actuator Acceleration	2261M3	Endevco	±2500 g
A-AR-Y3	Actuator Acceleration	2261M3	Endevco	±2500 g
A-XH-X3	Input Acceleration	A5-100-350	Statham	±100 g
A-XH-Y3	Input Acceleration	A5-100-350	Statham	±100 g
D-XH-X4	Input Displacement	LMT-17910	Collins	±20 in
D-XH-X2	Input Displacement	---	Boeing	±20 in
V-XH-X2	Input Velocity	---	Boeing	±250 in/sec
L-CT-X1	Can Load	FAE-25-12-S6	Baldwin	±3000μ in/in
A-CT-X2	Can Acceleration	2261M3	Endevco	±2500 g
A-CT-Y2	Can Acceleration	2261M3	Endevco	±2500 g
A-RT-X2	Rod Top Acceleration	2261M3	Endevco	±2500 g
A-RT-Y2	Rod Top Acceleration	2261M3	Endevco	±2500 g
D-RB-X3	Relative Displacement	LMT-17910	Collins	±10 in
L-RB-X1	Rod Bottom Load	FAE-25-12-S6	Baldwin	±3000μ in/in
A-RB-X2	Rod Bottom Acceleration	2261M3	Endevco	±2500 g
A-RB-Y2	Rod Bottom Acceleration	2261M3	Endevco	±2500 g
D-MT-X4	Mass Displacement	4040	Research Inc	±20 in
D-MT-Y1	Mass Displacement	4040	Research Inc	±10 in
D-MT-Z2	Mass Displacement	4040	Research Inc	±10 in
A-MT-XO	Mass Acceleration	A5-100-350	Statham	±100 g
A-MT-X2	Mass Acceleration	16516-200	Statham	±250 g
A-MT-Y2	Mass Acceleration	16516-200	Statham	±250 g
A-MT-Z2	Mass Acceleration	16516-200	Statham	±250 g
T-BF-XO	Event Start	---	Fire Switch	---
IRIG "B" AC	Time	6190-679	Astro Data	---

Figure 37. Instrumentation Schematic

Transducer	Location	Direction	Orientation
A-Acceleration	RH-Retard Hydraulic	X-Vertical	0-Center
D-Displacement	IH-Impulse Hydraulic	Y-Horizontal	1-0°
L-Load	IG-Impulse Gas	Z-Lateral	2-90°
P-Pressure	AR-Actuator Rod		3-180°
T-Time	XH-Crosshead		4-270°
V-Velocity	CT-Can Top		
	CB-Can Bottom		
	RT-Rod Top		
	RB-Rod Bottom		
	MT-Mass Top		
	BF-Bolt Fire		

(1-0° and 3-180°: Horizontal; 2-90° and 4-270°: Lateral)

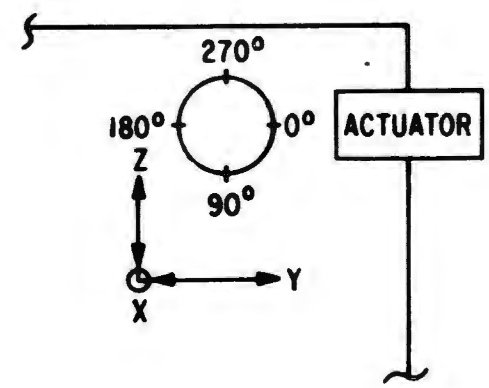


Figure 37 (cont'd). Instrumentation Schematic

FR 1400 AMPEX MAGNETIC TAPE RECORDER

TRACK	22 K	30 K	40 K	70 K	108 K
1	D-MT-X4	A-XH-X3	P-IG-XO	A-AR-X3	
2	D-MT-Y1	A-XH-Y3		A-AR-Y3	
3	D-MT-Z2	V-XH-X2	P-IH-XO	A-CT-X2	
4	D-XH-X4	A-MT-XO	P-RH-XO	A-MT-X2	
5				A-MT-Y2	
6	D-RB-X3	D-XH-X2	A-MT-Z2	A-CT-Y2	
7				A-RT-X2	
8				A-RT-Y2	
9				L-CT-X1	
10				A-RB-X2	
11				A-RB-Y2	
12				L-RB-X1	
13					IRIG "B" AC
14					T-BF-XO

Figure 38. Instrumentation Recording

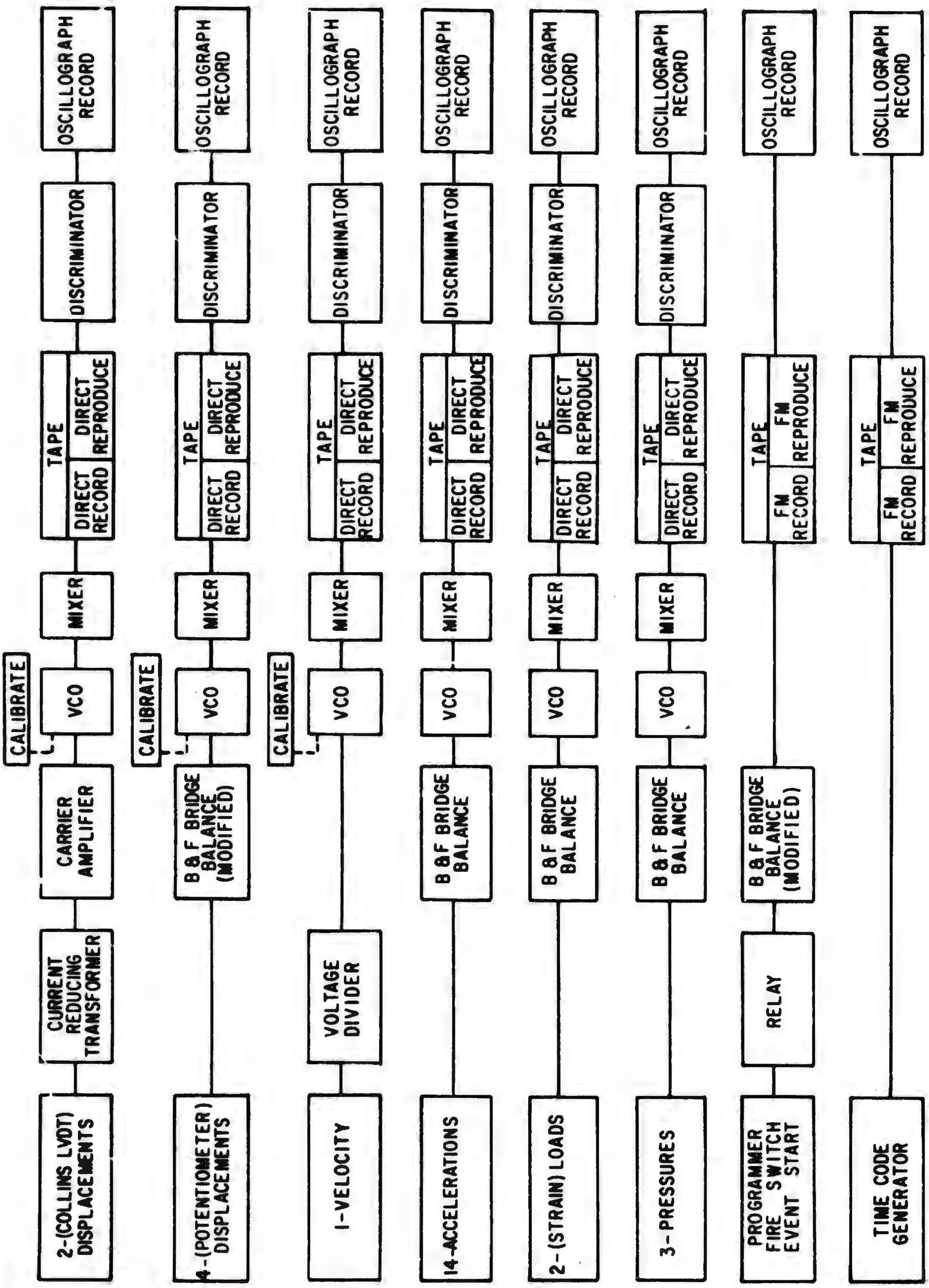
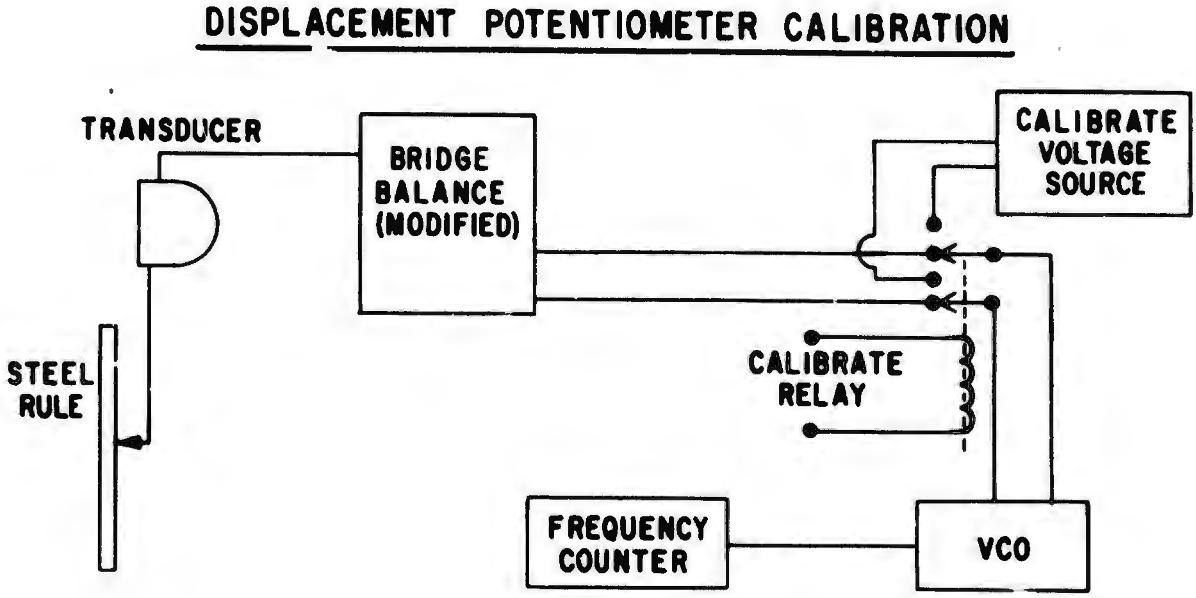


Figure 39. Instrumentation Recording System



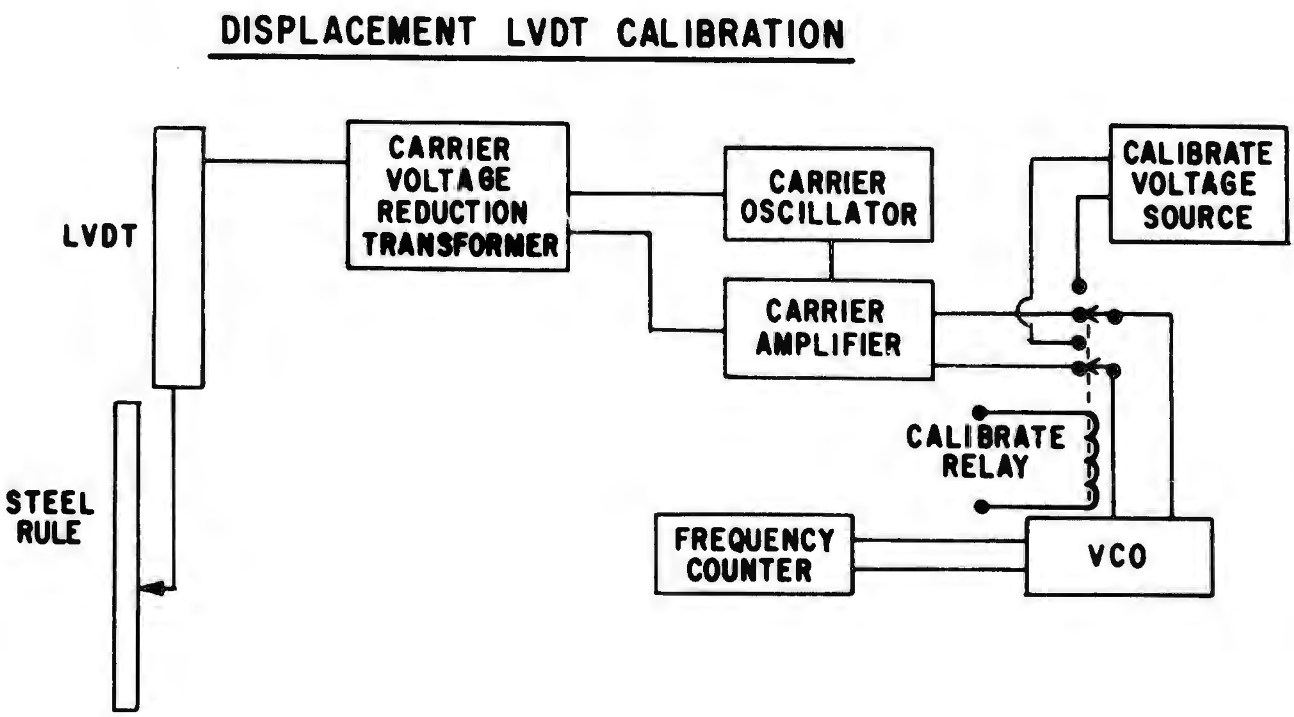


Figure 40. Input Displacement Calibrations

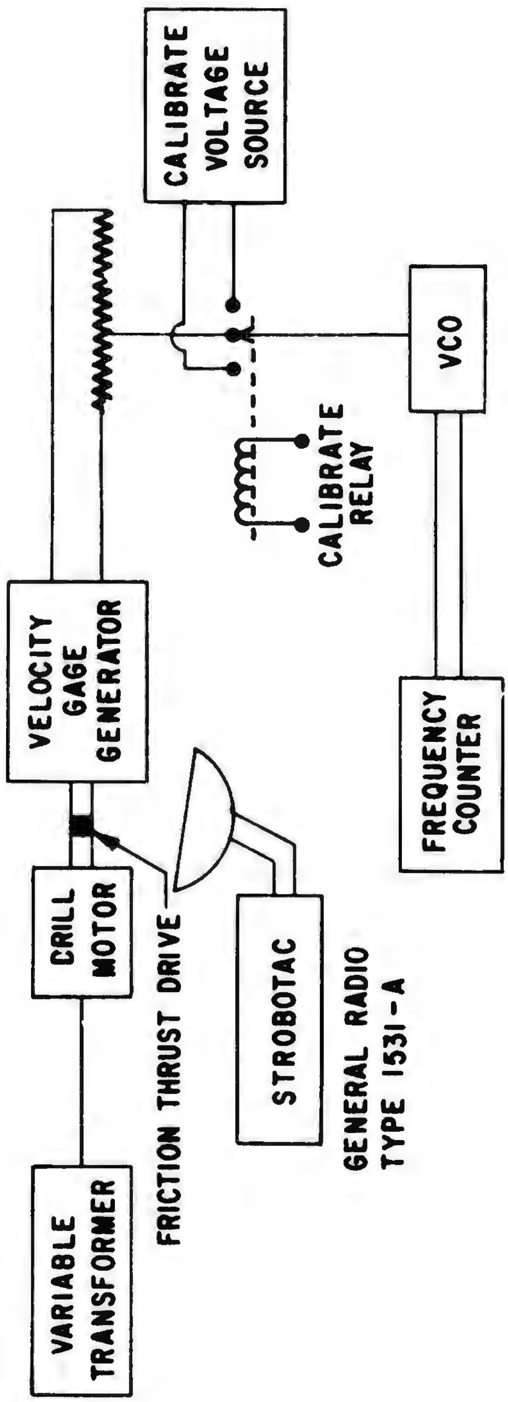


Figure 41. Velocity Gage Calibration

f. Acceleration: The accelerometers were mounted on a Schaevitz Rotary Accelerator with a revolution counter and subjected to known increments of accelerating loads. The results were recorded and plotted to check for linearity. In addition, the bridge balance unit is provided with a precision resistor bridged across one active arm of the accelerometer bridge, as shunt calibration, to provide a simulated calibration for use prior to each test run. Two accelerometers were calibrated simultaneously as shown in the figure 42 schematic. The results of resistive and physical calibrations were compared to established scale factors for resistive calibrations.

g. Isolator Loads: Both the isolator can load and the isolator rod bottom load calibrations were accomplished by physically loading the isolator with a hydraulic cylinder to known loads (as indicated from a load cell) and tabulating the resulting readings. The results were recorded and plotted to check for linearity. As shown in figure 43, the bridge balance unit is provided with a precision resistor (shunt calibrate) bridged across one active arm of the two-arm strain gage bridge to provide a simulated calibration prior to each test run.

h. Input Actuator Pressures: The input source pressure transducers were connected to an air supply pressure source as shown in figure 44. Pressure was applied in equal increments until the maximum anticipated pressure was obtained. Bridging resistors in the bridge balance unit were also used to provide simulated calibrations. Results of pressure calibration and resistive substitution were plotted to determine linearity and scale factor. The simulated calibration signals were then used prior to each test run.

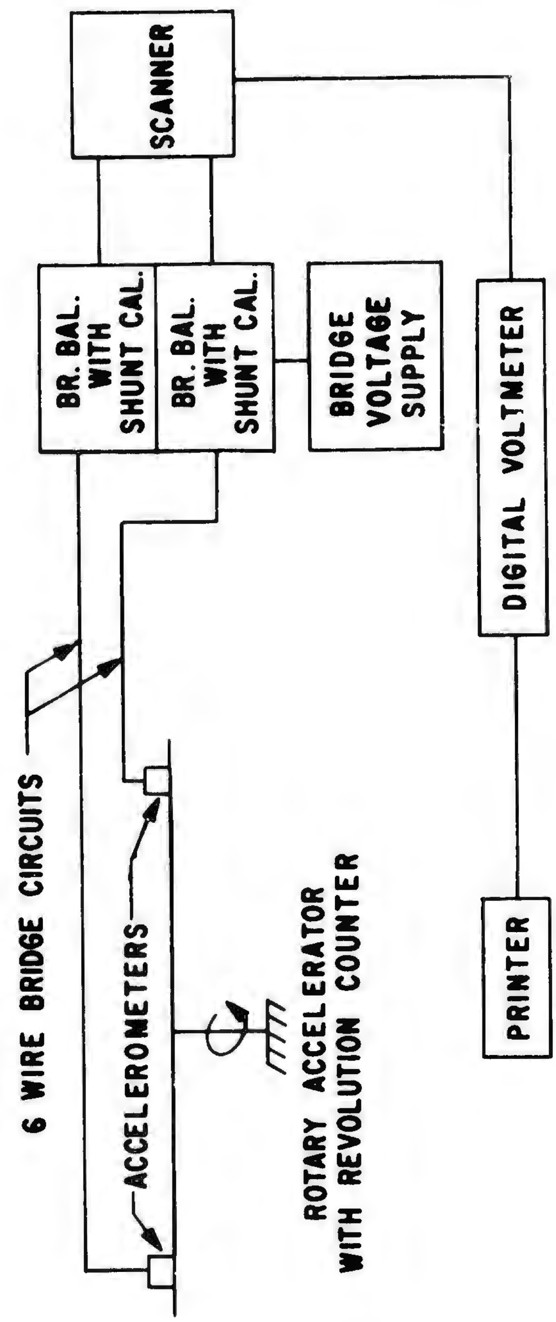


Figure 42. Accelerometer Calibration

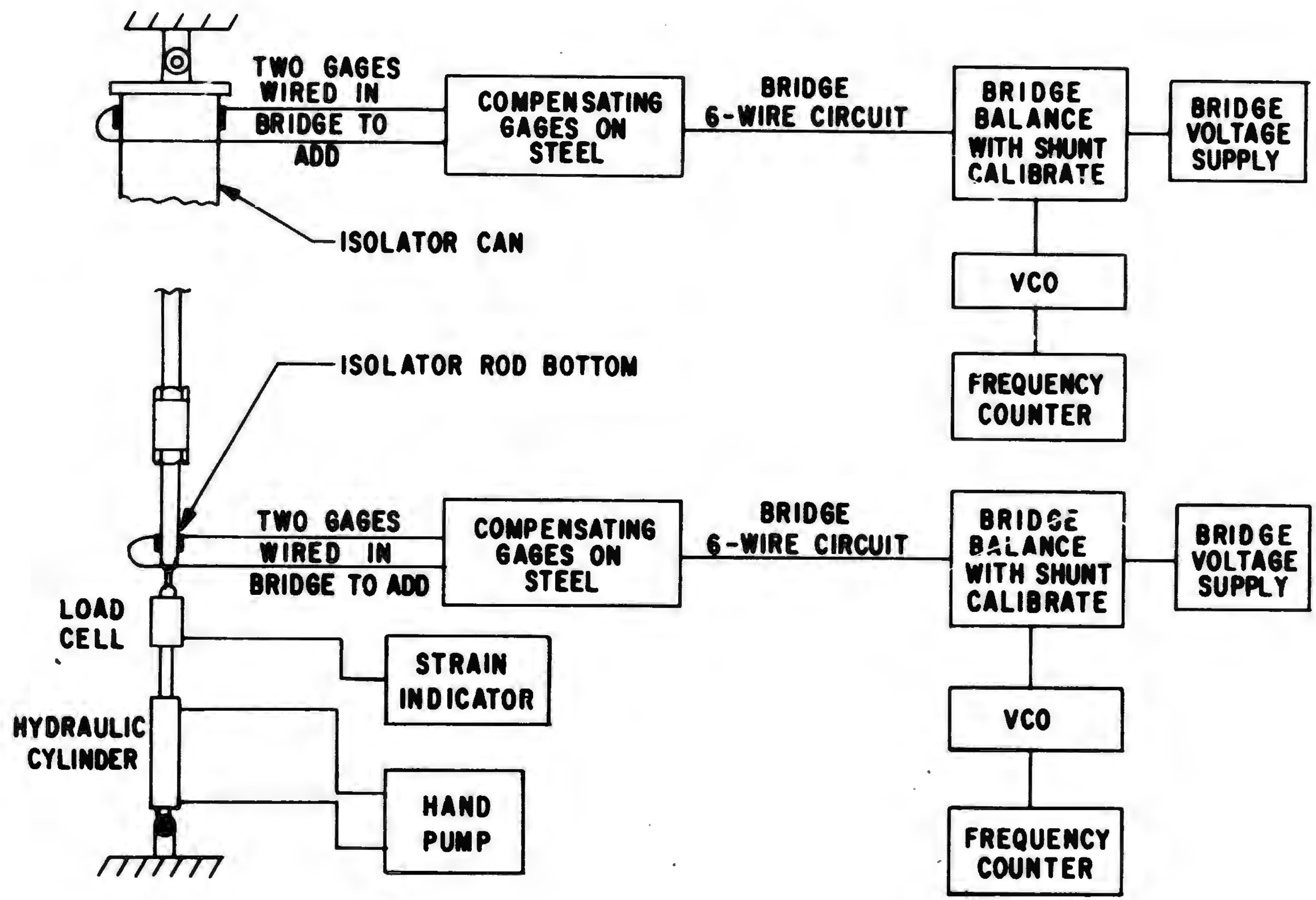


Figure 43. Isolator Load Calibration

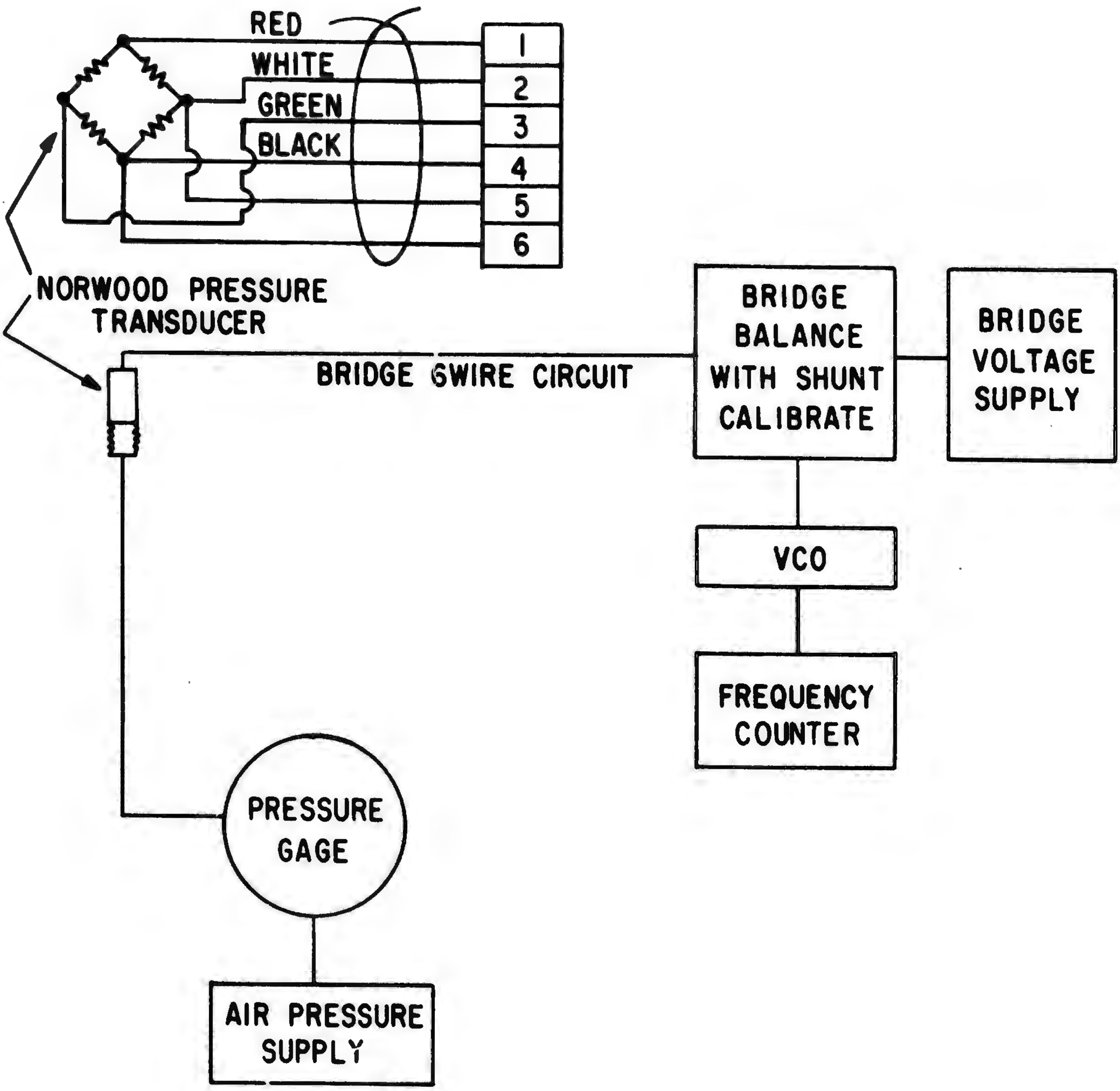


Figure 44. Pressure Calibration

APPENDIX II

PRE-TEST ISOLATOR INSPECTION

Isolator Identification, Type: I Serial No. 2

1. Previous type of failure: Sheared six screws at lower can stop.
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good--Marginal
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.150 in
   b. Below holes at lower retainer ring attachment 0.145 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 0
6. Coil spring wire diameter 0.711 in
7. Number of coils:
   a. Complete 14
   b. Total 16

Isolator Identification, Type: I Serial No. 3

1. Previous type of failure: Sheared six screws at lower can stop.
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good--Marginal
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.138 in
   b. Below holes at lower retainer ring attachment 0.142 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 3/4 in
6. Coil spring wire diameter 0.717 in
7. Number of coils:
   a. Complete 14
   b. Total 16

Isolator Identification, Type: I Serial No. 4

1. Previous type of failure: Sheared six screws at lower can stop.
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.139 in
   b. Below holes at lower retainer ring attachment 0.145 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 0
6. Coil spring wire diameter 0.708 in
7. Number of coils:
   a. Complete 14
   b. Total 16

Isolator Identification, Type: I Serial No. 26

1. Previous type of failure: None
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.132 in
   b. Below holes at lower retainer ring attachment 0.134 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 1-5/32 in
6. Coil spring wire diameter 0.713 in
7. Number of coils:
   a. Complete 14
   b. Total 16

Isolator Identification, Type: III Serial No. 1

1. Previous type of failure: Lower rod-end spherical bearing failed.
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Marginal
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.206 in
   b. Below holes at lower retainer ring attachment 0.206 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 0
6. Coil spring wire diameter, Inner--0.961 in, Outer--1.115 in
7. Number of coils:
   a. Outer--Complete 8 Total 9
   b. Inner--Complete 12 Total 14

Isolator Identification, Type: III Serial No. 2

1. Previous type of failure: Lower rod-end spherical bearing failed.*

2. Weld workmanship on isolator:

   a. Top hanger to can top Good

   b. Can top to can cylinder Good

   c. Upper rod stop to rod Good

   d. Lower rod stop to rod Good

   e. Hex nut to lower end of rod Good

3. Spring can thickness:

   a. Between bolt holes at lower retainer ring attachment 0.209 in

   b. Below holes at lower retainer ring attachment 0.208 in

4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes

5. Contact distance between assembled spring and upper and lower spring plates 0

6. Coil spring wire diameter, Inner--0.063 in, Outer--1.125 in

7. Number of coils:

   a. Outer--Complete 8 Total 9

   b. Inner--Complete 12 Total 14

---

* Bad isolator. Upper spring plate and outer spring (near center) interfering with can inner wall.

Isolator Identification, Type: III Serial No. 3

1. Previous type of failure: Lower rod-end spherical bearing failed.

2. Weld workmanship on isolator:

   a. Top hanger to can top Good

   b. Can top to can cylinder Good

   c. Upper rod stop to rod Marginal

   d. Lower rod stop to rod Good

   e. Hex nut to lower end of rod Good

3. Spring can thickness:

   a. Between bolt holes at lower retainer ring attachment 0.231 in

   b. Below holes at lower retainer ring attachment 0.233 in

4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes

5. Contact distance between assembled spring and upper and lower spring plates 0

6. Coil spring wire diameter, Inner--0.960 in, Outer--1.122 in

7. Number of coils:

   a. Outer--Complete 8 Total 9

   b. Inner--Complete 12 Total 14

Isolator Identification, Type: III Serial No. 23

1. Previous type of failure: Lower rod-end spherical bearing failed.

2. Weld workmanship on isolator:

   a. Top hanger to can top Marginal

   b. Can top to can cylinder Good

   c. Upper rod stop to rod Marginal

   d. Lower rod stop to rod Good

   e. Hex nut to lower end of rod Good

3. Spring can thickness:

   a. Between bolt holes at lower retainer ring attachment 0.191 in

   b. Below holes at lower retainer ring attachment 0.222 in

4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes

5. Contact distance between assembled spring and upper and lower spring plates 0

6. Coil spring wire diameter, Inner--0.955 in, Outer--1.106 in

7. Number of coils:

   a. Outer--Complete 8 Total 9

   b. Inner--Complete 12 Total 14

Isolator Identification, Type: IV Serial No. 1

1. Previous type of failure: None
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good--Marginal
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.210 in
   b. Below holes at lower retainer ring attachment 0.203 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 0
6. Coil spring wire diameter 0.900 in
7. Number of coils:
   a. Complete 12
   b. Total 13

Isolator Identification, Type: IV Serial No. 2

1. Previous type of failure: Sheared six screws at lower can stop.
2. Weld workmanship on isolator:
   a. Top hanger to can top Good
   b. Can top to can cylinder Good
   c. Upper rod stop to rod Good
   d. Lower rod stop to rod Good
   e. Hex nut to lower end of rod Good
3. Spring can thickness:
   a. Between bolt holes at lower retainer ring attachment 0.209 in
   b. Below holes at lower retainer ring attachment 0.206 in
4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes
5. Contact distance between assembled spring and upper and lower spring plates 0
6. Coil spring wire diameter 0.897 in
7. Number of coils:
   a. Complete 12
   b. Total 13

Isolator Identification, Type: IV Serial No. 3

1. Previous type of failure: ____

2. Weld workmanship on isolator:

   a. Top hanger to can top Good

   b. Can top to can cylinder Good

   c. Upper rod stop to rod Good

   d. Lower rod stop to rod Good

   e. Hex nut to lower end of rod Good

3. Spring can thickness:

   a. Between bolt holes at lower retainer ring attachment 0.212 in

   b. Below holes at lower retainer ring attachment 0.209 in

4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes

5. Contact distance between assembled spring and upper and lower spring plates 0

6. Coil spring wire diameter 0.903 in

7. Number of coils:

   a. Complete 12

   b. Total 13

Isolator Identification, Type: IV Serial No. 4

1. Previous type of failure: Sheared six screws at lower can stop.

2. Weld workmanship on isolator:

   a. Top hanger to can top Good

   b. Can top to can cylinder Good

   c. Upper rod stop to rod Good

   d. Lower rod stop to rod Good

   e. Hex nut to lower end of rod Good

3. Spring can thickness:

   a. Between bolt holes at lower retainer ring attachment 0.211 in

   b. Below holes at lower retainer ring attachment 0.205 in

4. Spring can and lower retainer ring cap screw threads are in the shearing plane. (YES or NO) Yes

5. Contact distance between assembled spring and upper and lower spring plates 0

6. Coil spring wire diameter 0.898 in

7. Number of coils:

   a. Complete 12

   b. Total 13

APPENDIX III

ISOLATOR SHOCK TEST HISTORY

ISOLATOR: Type I

SERIAL NUMBER: 4

TEST WEIGHT: 200, 620, and 1,140 pounds

SPRING RATE: K = 473 lb/in (previous test)

TWANG TEST: f = 1.88 cps (previous test)

TEST HISTORY: Previous Shock Tests

Constant Velocity with Variable Displacement--three tests.

Present Shock Tests

Incremental Vertical--21 tests as indicated in table I, Test and Configuration Matrix.

FAILURE RUN: Failed on the third Variable Displacement Shock Test in the previous series of tests. No failure occurred during the second series of tests.

DESCRIPTION OF FAILURES: The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear during the initial series of tests. No failure occurred during the latter series of tests.

DETERIORATION DURING TEST: 1/8 inch--permanent set in spring during the previous series of tests.

5/32 inch--permanent set in spring during second series of tests.

Gross yielding occurred in the lower spherical rod-end bearing between the body and the bearing race. This continual yielding occurred during the last ten tests in the second series of tests. The total elongation in the yield area was approximately 7/16 inch.

ADDITIONAL DATA: (These additional data pertain to the second series of shock tests.) A solid height shock actuator stop was installed for all "Hard Spring" modes of input. These are indicated by Input Condition C and D of table I, Test and Configuration Matrix.

The spring solid height was obtained during shock Input Condition D with all the test masses.

ISOLATOR: Type III

SERIAL NUMBER: 3

TEST WEIGHT: 200, 1,140, and 5,830 pounds

SPRING RATE: K = 1,925 lb/in (previous test)

TWANG TEST: f = 1.71 cps (previous test)

TEST HISTORY: Previous Shock Tests

Constant Velocity with Variable Displacement--seven tests

Present Shock Tests

Incremental Vertical--19 tests as indicated in table I, Test and Configuration Matrix.

FAILURE RUNS: Failed on the seventh Variable Displacement Shock Test in the previous series of tests.

Failure occurred during the second test of Input Condition D in the second series of tests. Both of the Input Condition D tests were conducted with the heavy test mass.

DESCRIPTION OF FAILURES: Failure during the previous series of tests occurred at the lower spherical rod-end bearing between the body and the bearing race.

Failure during the second series of tests occurred at the welded junction between the rod bottom and the lower spherical rod-end bearing nut.

DETERIORATION DURING TESTS: 9/32 inch--permanent set in spring during initial series of tests.

7/32 inch--permanent set in spring during second series of tests.

Yielding occurred at the welded junction between the rod bottom and the lower spherical rod-end bearing nut during the test preceding the failure run. Both the yielding and the failure occurred during the second series of tests with the heavy test mass.

ADDITIONAL DATA: (These additional data pertain to the second series of shock tests.) A solid height shock actuator stop was installed for all "Hard Spring" modes of input. These are indicated by Input Condition C and D of table I, Test and Configuration Matrix.

The spring solid height was not obtained during shock Input Condition C or D.

ISOLATOR: Type IV

SERIAL NUMBER: 4

TEST WEIGHT: 200, 620, and 1,055 pounds

SPRING RATE: K = 794 lb/in (previous test)

TWANG TEST: f = 2.44 cps (previous test)

TEST HISTORY: Previous Shock Tests

Incremental Horizontal--three tests.

Constant Displacement with Variable Velocity--seven tests.

Constant Velocity with Variable Displacement--six tests.

Combined Horizontal/Vertical--six tests.

Present Shock Tests

Incremental Vertical--20 tests as indicated in table I, Test and Configuration Matrix.

FAILURE RUN: Failed on the seventh Variable Velocity Shock test in the previous series of tests. No failure occurred during the second series of tests.

DESCRIPTION OF FAILURES: The six 3/8-16 cap screws, which attach the lower can stop to the spring can, failed in shear during the initial series of tests. No failure occurred during the latter series of tests.

DETERIORATION DURING TEST: 3/16 inch--permanent set in spring during the previous series of tests.

3/16 inch--permanent set in spring during second series of tests.

Gross yielding occurred in the lower spherical rod-end bearing between the body and the bearing race. This continual yielding occurred during the last five tests in the second series of tests. The total elongation in the yield area was approximately 9/16 inch.

ADDITIONAL DATA: (These additional data pertain to the second series of shock tests.) A solid height shock actuator stop was installed for all "Hard Spring" modes of input. These are indicated by Input Condition C and D of table I, Test and Configuration Matrix.

The spring solid height was obtained during shock Input Condition C with a heavy mass only, while the solid height was obtained during Input Condition D with all the test masses.

REFERENCES

1. Franklin, R. W., Test Plan and Requirements Document for Wing I, LER Single Isolator Shock Tests Supplemental Test Program, Attachment to TRW 10C 69.6153.3.8-017, 7 May 1969, Revised 15 May 1969.

2. Freeman, R. L., Failure Analysis: LER Isolator Lower Rod End Bearing (Minuteman Wing I), TRW 10C 69-4320.3-40, 10 February 1969.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Special Weapons Center (SWVIC) Kirtland Air Force Base, New Mexico 87117	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

STATIC AND SHOCK TESTING OF WING I, LER SHOCK ISOLATORS, Volume I
Test Requirements, Test Procedures, and Test Results

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

May 1969 through August 1969

5. AUTHOR(S) (First name, middle initial, last name)

Frank T. Krek

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1970	114	2

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) AFSWC-TR-70-2, Vol. I
b. PROJECT NO. 133B4H c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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13. ABSTRACT

(Distribution Limitation Statement No. 2)

Tests were performed on Minuteman Wing I Launcher Equipment Room (LER) Shock Isolators. Isolator component static tests, single isolator stiffness tests, single isolator ultimate static tests, and single isolator shock tests were performed. These tests determined the isolator mechanical stiffness, the isolator mechanical impedance and evaluated the use of damping collars on shock isolators for high-frequency shock attenuation. All test objectives were met.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
LER shock isolator						
Minuteman Launcher Equipment Room						
Static testing--static characteristics						
Shock testing--dynamic characteristics						
Seismic impulse facility						
High frequency shock attenuation						

AFSC-HOLLOMAN AFB, NMEX