

VIBRATION TESTING OF RAILROAD TANK CAR SPECIMENS

**J. E. Harris
W. E. Pierce**

Prepared by

**COMPUTER SCIENCES CORPORATION
ENGINEERING LABORATORY
NATIONAL SPACE TECHNOLOGY LABORATORIES
NSTL STATION, MISSISSIPPI 39529**



**APRIL 1981
FINAL REPORT**

Document is available to the U.S. public through the
National Technical Information Service
Springfield, Virginia 22161

Prepared for

**U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Office of Research and Development
Washington D.C. 20590**

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Vibration Testing of Railroad Tank Car Specimens		5. Report Date April 1981	6. Performing Organization Code
7. Author (s) Harris, J.E. and Pierce, W.E.		8. Performing Organization Report No.	
9. Performing Organization Name and Address Computer Sciences Corporation Engineering Laboratory National Space Technology Laboratories NSTL Station, MS 39529		10. Work Unit No. (TRAIS)	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Railroad Administration Office of Research and Development Washington, D.C. 20590		13. Type of Report and Period Covered Final Report December 1980-April 1981	
14. Sponsoring Agency Code			
15. Supplementary Notes			
16. Abstract Vibration tests of fireproof coatings were performed on test specimens measuring 4 feet square. Specimens were simulations of railroad tank car side-wall panels. Samples of fireproof coatings from three different manufacturers were tested. The vibration test consisted of application of a prescribed vibration spectrum perpendicular to the test panels, determination of natural resonances within the test frequency range, and examination of the test specimens for deterioration or failure of the coatings. Each panel was continuously vibrated during seven 12-minute duration long-sweeps, stepping from 10 Hz. at 0.5 G's to 200 Hz. at 1.5 G's. All six panels were tested (two from each manufacturer). No observable defects were noted on any of the six specimens. It is concluded that within the limits of the tests performed, all six panels performed satisfactorily.			
17. Key Words Tank Car Fireproof Coatings Vibration Test Coatings Tank Car Coatings Fireproof Coatings		18. Distribution Statement This document is available to the U. S. Public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 58	22. Price

TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
1. SCOPE	1
2. BACKGROUND	1
3. TEST CONFIGURATION	1
4. TEST SPECIMENS	2
5. TEST SPECIMEN HOLDING FRAME	2
6. SHAKER TO TEST SPECIMEN FRAME ADAPTER	3
7. SHAKER AND TEST INSTRUMENTATION	3
8. TEST PROCEDURES	3
9. TEST CONCLUSIONS	3
APPENDIX A - ITTRI TEST PLAN CORRESPONDENCE	
APPENDIX B - TEST EQUIPMENT SPECIFICATIONS	
APPENDIX C - FIXTURE DESIGN COMMENTS	

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
Figure 1	PHYSICAL CHARACTERISTICS FOR COATED PANEL "A"	6
Figure 2	PHYSICAL CHARACTERISTICS FOR COATED PANEL "B"	7
Figure 3	PHYSICAL CHARACTERISTICS FOR COATED PANEL "C"	8
Figure 4	PHYSICAL CHARACTERISTICS FOR COATED PANEL "D"	9
Figure 5	PHYSICAL CHARACTERISTICS FOR COATED PANEL "E"	10
Figure 6	PHYSICAL CHARACTERISTICS FOR COATED PANEL "F"	11
Figure 7	PHYSICAL CHARACTERISTICS FOR UNCOATED (BARE) PANEL	12
Figure 8	TEST SPECIMEN HOLDING FRAME	13
Figure 9	SECTION THROUGH TEST SPECIMEN HOLDING FRAME	14
Figure 10	TEST EQUIPMENT SET-UP	15
Figure 11	VIBRATION TEST CURVE	16
Figure 12-17	TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980	17-22
Figure 18	TEST SPECIMEN PANEL "A" (TSI, INC.) RECEIVING INSPECTION	23
Figure 19	TEST SPECIMEN PANEL "B" (TSI, INC.) RECEIVING INSPECTION	24
Figure 20	TEST SPECIMEN PANEL "C" (AVCO) RECEIVING INSPECTION	25
Figure 21	TEST SPECIMEN PANEL "D" (AVCO) RECEIVING INSPECTION	26
Figure 22	TEST SPECIMEN PANEL "E" (DeSOTO, INC.) RECEIVING INSPECTION	27
Figure 23	TEST SPECIMEN PANEL "F" (DeSOTO, INC.) RECEIVING INSPECTION	28
Figure 24	UNHOLTZ-DICKIE CORPORATION MODEL 56 SHAKER AND RIGID ADAPTER FRAME PRIOR TO ROTATION INTO THE TESTING POSITION	29
Figure 25	UNHOLTZ-DICKIE CORPORATION MODEL 1019 AUTOMATIC VIBRATION EXCITER CONTROL CABINET	30
Figure 26	RIGID ALUMINUM ADAPTER FRAME	31
Figure 27	TEST SPECIMEN HOLDING FRAME ASSEMBLY MOUNTED ON MATERIAL HANDLING FIXTURE PRIOR TO INSTALLATION ON RIGID ALUMINUM ADAPTER FRAME	32
Figure 28	REAR VIEW OF TEST ASSEMBLY - ACCELEROMETER LEADS ARE SEEN TAPED TO RIGID ALUMINUM ADAPTER FRAME. SPECIMEN HOLDING FRAME ATTACHING HARDWARE CAN BE SEEN.	33

LIST OF FIGURES (CONTINUED)

<u>FIGURE</u>		<u>PAGE</u>
Figure 29	FOUR-INCH THICK FIBERGLASS BATT MOUNTED IN TEST FRAME	34
Figure 30	TEST SPECIMEN PANEL "E" READY FOR TESTING	35
Figure 31	CLOSE-UP OF TEST SPECIMEN MOUNTING AND 4 ⁰ RAMP	36
Figure 32	TEST SPECIMEN PANEL "A" AFTER TESTING SEQUENCE	37
Figure 33	CLOSE-UP OF ACCELEROMETER MOUNTED ON TEST SPECIMEN PANEL "A"	38

LIST OF TABLES

Table 1	PANEL RESONANCE	5
---------	-----------------	---

1. SCOPE

This report describes the effort undertaken by the National Space Technology Laboratories (NSTL) Engineering Laboratory (EL) to perform vibration tests on simulated Railroad Tank Car Specimens. The work described includes the location and acquisition of test equipment, design and fabrication of test fixtures, handling equipment, assembly of test specimens and the performance of the required testing in an extremely compressed time frame.

2. BACKGROUND

The effort described herein was in support of the Department of Transportation, Federal Railroad Administration research program with the 105 Tank Car. Part of this program required the performance of vibration tests on a matrix of coated tank car specimens.

The ARRADCOM Resident Operations Office (AROO) at NSTL was tasked to perform the vibration tests at the NSTL Engineering Laboratory. A portion of this effort was completed in August 1980 at NSTL under a separate work request. Designs and test fixtures developed during the earlier effort were incorporated into the effort described in this report.

The tests described herein were initiated by a Technical Work Request (TWR) issued by AROO to the NSTL/EL Mechanical Engineering Branch on 10 December 1980. Variations of the tank car coated test plates were tested in accordance with a test plan prepared by Dr. M. Johnson of the IIT Research Institute (IITRI). (Reference Appendix A.)

3. TEST CONFIGURATION

Test specimen panels were assembled to simulate railroad tank cars coated with fireproofing materials.

The test configuration was developed to apply a mechanical vibration excitation force perpendicular to the surface of each 4-foot square test specimen panel. In order to accomplish this purpose, for ease of handling, and to stay within the capacity of the vibration test equipment, special test fixtures were devised and utilized during the test. The hardware used for the tests is listed below:

1. Unholtz-Dickie Corp. Dynamic Shaker and Controller (reference Appendix B)
2. Rigid aluminum fixture to adapt the U-D Shaker's armature to the test specimen holding frame assembly
3. Test specimen holding frame assembly
4. Four-foot square test specimen panels, insulation inserts, and 0.75-inch backing plate

5. Accelerometers and instrumentation.

Each specimen tested represented a simulated tank car sidewall consisting of three layers. The first or outermost layer was one of seven 4-foot square test specimen panels. The 4-foot square test specimen panel consisted of a 0.125-inch steel plate uniformly coated with the fireproof material undergoing testing. The second or middle layer of the simulated tank car sidewall was one of four insulation inserts. Insulation inserts were of two types of material with two thicknesses of each type:

- Fiberglass
 - 1-inch
 - 4-inch
- Urethane foam
 - 2-inch
 - 4-inch

The third or innermost layer was a 0.75-inch steel backing plate. Thus, the simulated tank car sidewall tested consisted of a 4-foot square coated panel, an insulation insert, and a 0.75-inch steel backing plate.

4. TEST SPECIMENS

The test specimens were received at NSTL/EL on 23 December 1980. They were unpacked, marked for identification and inspected for defects and dimensional accuracy.

Six coated panels and one uncoated (bare) panel were delivered. The six coated panels consisted of two panels from each of three fireproof coating manufacturers/applicators. The coating materials on all test specimens had been applied in a manner which allowed the coating to extend beyond the edges of the steel backing plates. This material was trimmed until the edge of the coating coincided with the edge of the steel backing plate. The test specimens' dimensions were verified and recorded (reference Figures 1 through 7).

5. TEST SPECIMEN HOLDING FRAME

The holding frame for the test specimens utilized in these tests was fabricated to simulate a frame described in Union Tank Car Company Drawing Number X5865. The latter frame was modified to strengthen the test specimen retention method and to reduce the set up time for each test configuration.

The test specimen was retained in the frame using twelve 1.50-inch by 0.25-inch aluminum angle brackets (reference Figure 8), as opposed to the original four corner pin-retainers.

A single 4-foot square baseplate was fabricated from 0.75-inch steel and mounted on the shaker adapter frame assembly. The corner support blocks between the test specimen and the baseplate were changed from single 4-inch blocks to two stacked 2-inch blocks retained with bolts through the holding frame side-plates (reference Figure 9). This approach allowed a single holding frame to be used for all tests with both 2-inch and 4-inch insulation thickness.

6. SHAKER TO TEST SPECIMEN FRAME ADAPTER

A welded 6061-T6 aluminum alloy frame was fabricated to adapt the shaker armature to the test specimen frame assembly (reference Figure 24). This frame was attached to the shaker armature with thirteen each 0.375-inch high tensile strength socket head-cap screws and to the test specimen holding frame with twenty-eight each 0.5-inch diameter high tensile strength flat-head splined bolts and self-locking nuts.

7. SHAKER AND TEST INSTRUMENTATION

As shown in Figure 10, Unholtz-Dickie Corporation Model 56 Dynamic Shaker and Model 1019 Automatic Vibration Exciter Control were used to vibrate the test panels. The output frequency of the shaker controller was monitored with a Hewlett-Packard Model 5245L electronic counter. Two Endevco Model 2226 accelerometers were used to monitor the test panel and the test specimen holding frame base plate. The accelerometers were mounted in the geometric center of each plate. An Endevco Model 2017AM1314/2629A Charge Amplifier was used to power the accelerometers. The accelerometer outputs were monitored with a Tektronix Model 422 Dual-Trace Oscilloscope and a Hewlett-Packard Model 3440A/3445A Digital Voltmeter.

The test specimen holding frame base plate accelerometer output was displayed on one channel of the oscilloscope while the test panel accelerometer output was displayed on the other oscilloscope channel and on the digital voltmeter.

8. TEST PROCEDURES

All test panels were vibrated in accordance with the schedule shown in Figure 11. The vibrations were of a sinusoidal nature and were applied in a plane perpendicular to the plane of the test panel. The excitation frequency was varied from 10 Hz to 200 Hz and back to 10 Hz in 12 minutes. The sweep time varied logarithmically with the amplitude/frequency relationship shown in Figure 11. This process was repeated several times. The panel under test was inspected after each test cycle for signs of damage. The insulation inserts were also inspected after each test for signs of deterioration. The results of these tests are summarized in Table 1.

9. TEST CONCLUSIONS

The purpose of the test was to determine whether the fireproof coatings applied to the panels simulating tank car outer sidewalls would fail mechanically under vibration.

There were no signs of cracking, crazing, delamination, spalling, loss of adhesion, tearing, or any other visually observable defects, either before or after the vibration test. In addition, there was no noticeable deterioration in any of the insulation inserts.

As noted in the vibration test curve (reference Figure 11), each panel was continuously vibrated during the seven 12-minute duration sweeps from 10 Hz and 0.5 G's to 200 Hz and 1.5 G's. Each panel received a minimum cumulative test time of 84 minutes.

All test panels satisfactorily passed the test sequence described in this report. Panel resonances noted during sweep tests are delineated in Table 1. If more than one resonance was noted, the one with the higher amplitude was designated as major, while the lower amplitude resonance was designated as minor. None of the resonances noted were of an amplitude or sharpness which would indicate susceptibility to destruction if subjected to extended periods of vibration at those resonant frequencies.

TABLE 1. PANEL RESONANCE

Coated Panel Identification	Backing Insulation Type And Thickness, Inches	Major Resonance, Hz*	Minor Resonance, Hz*
Bare	4-inch fiberglass	138-142 Hz	35-47 Hz 78 Hz 110-123 Hz
A	4-inch fiberglass	- **	- **
A	2-inch urethane foam	103-109 Hz	- **
B	4-inch urethane foam	102-111 Hz	48 Hz 55 Hz 67 Hz 138 Hz
C	4-inch fiberglass	100-110 Hz 158-163 Hz	25 Hz 52-53 Hz
C	2-inch fiberglass	101-105 Hz	52-54 Hz
D	4-inch urethane foam	150-152 Hz	75 Hz
E	4-inch fiberglass	162-165 Hz	- **
E	2-inch urethane foam	102-111 Hz	150 Hz 188 Hz
F	4-inch urethane foam	- **	- **

Notes: * Resonance frequencies obtained by observation of accelerometer output on digital voltmeter (Sample rate: 1.0 ± 0.25 seconds)

** A dash (-) is used to indicate that there were no observed resonant points.

Manufacturer: TSI, Inc.

Color: White

Weight: 97.5 Pounds

Coating Thickness: Avg. 0.119 inches

Total Average Panel Thickness: 0.239 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. A regular square pattern of small holes (0.06-0.09 inch diameter) was impressed into the coating.

COATED PANEL "A"

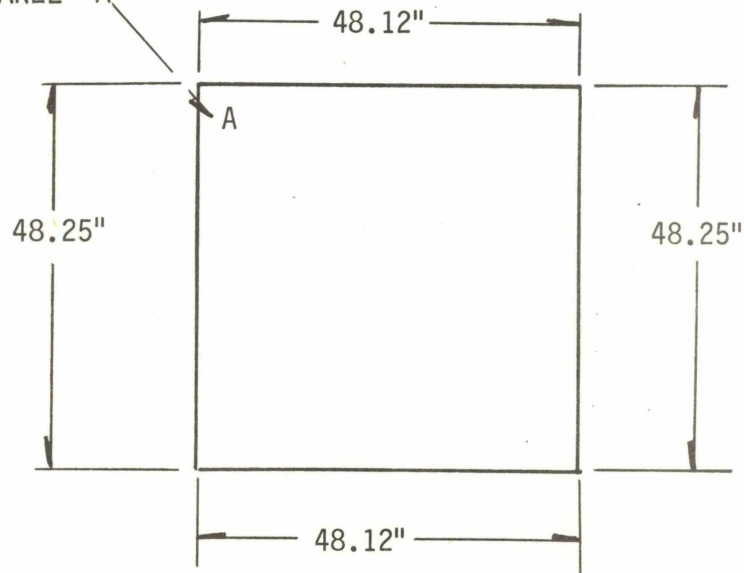


FIGURE 1. PHYSICAL CHARACTERISTICS FOR COATED PANEL "A"

Manufacturer: TSI, Inc.

Color: White

Weight: 96.5 Pounds

Coating Thickness: Avg. 0.136 inches

Total Average Panel Thickness: 0.256 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. A regular, square pattern of small holes (0.06-0.09 inch diameter) was impressed into the coating.

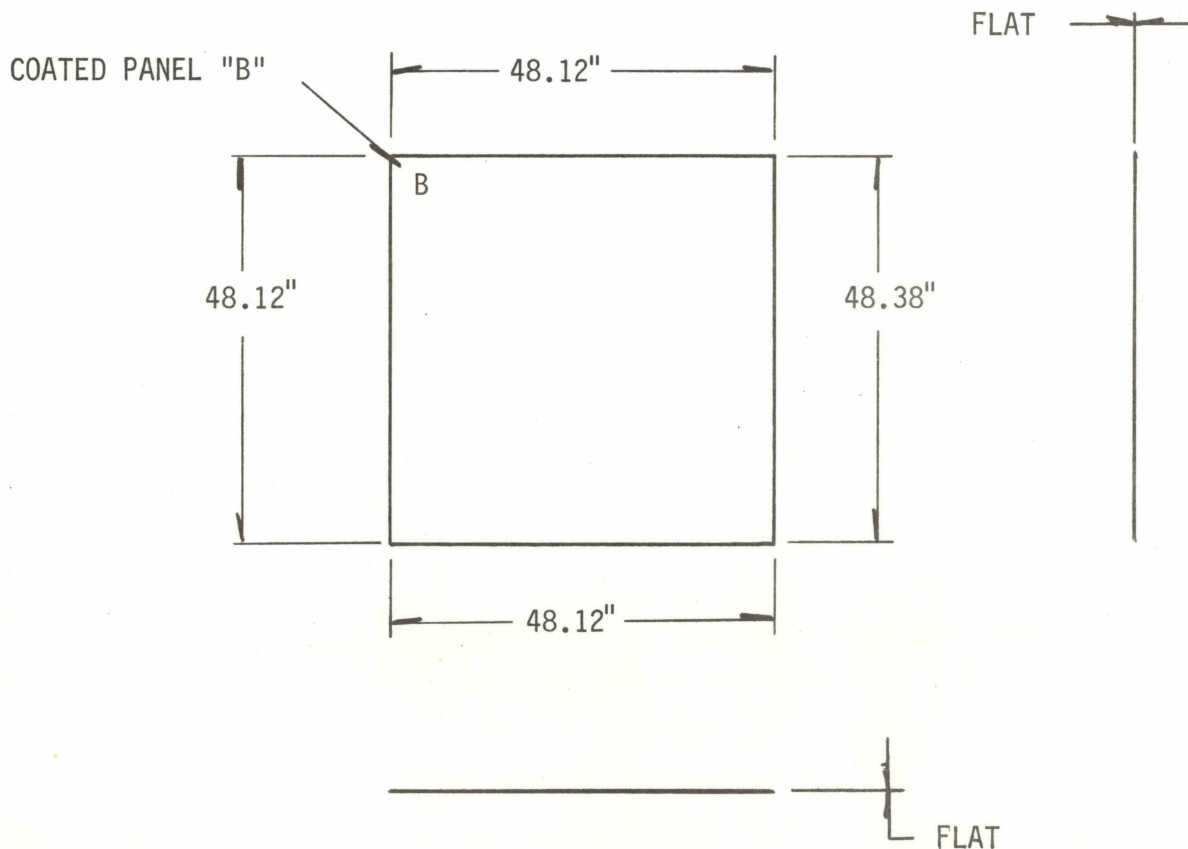


FIGURE 2. PHYSICAL CHARACTERISTICS FOR COATED PANEL "B"

Manufacturer: AVCO

Color: Yellow

Weight: 95.5 Pounds

Coating Thickness: Avg. 0.162 inches

Total Average Panel Thickness: 0.282 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. No surface irregularities were noted.

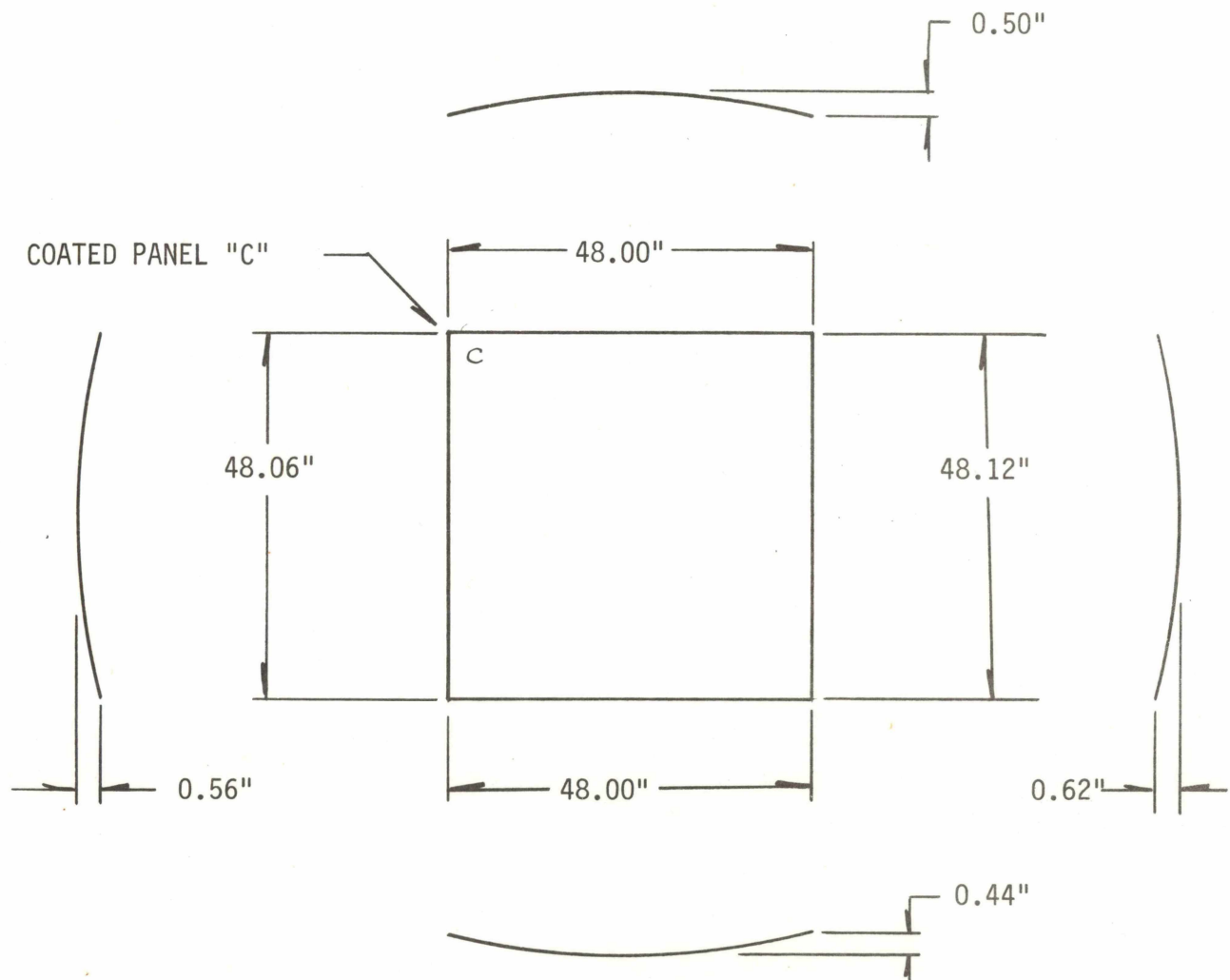


FIGURE 3. PHYSICAL CHARACTERISTICS FOR COATED PANEL "C"

Manufacturer: AVCO

Color: Yellow

Weight: 96.5 Pounds

Coating Thickness: Avg. 0.162 inches

Total Average Panel Thickness: 0.282 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. No surface irregularities were noted.

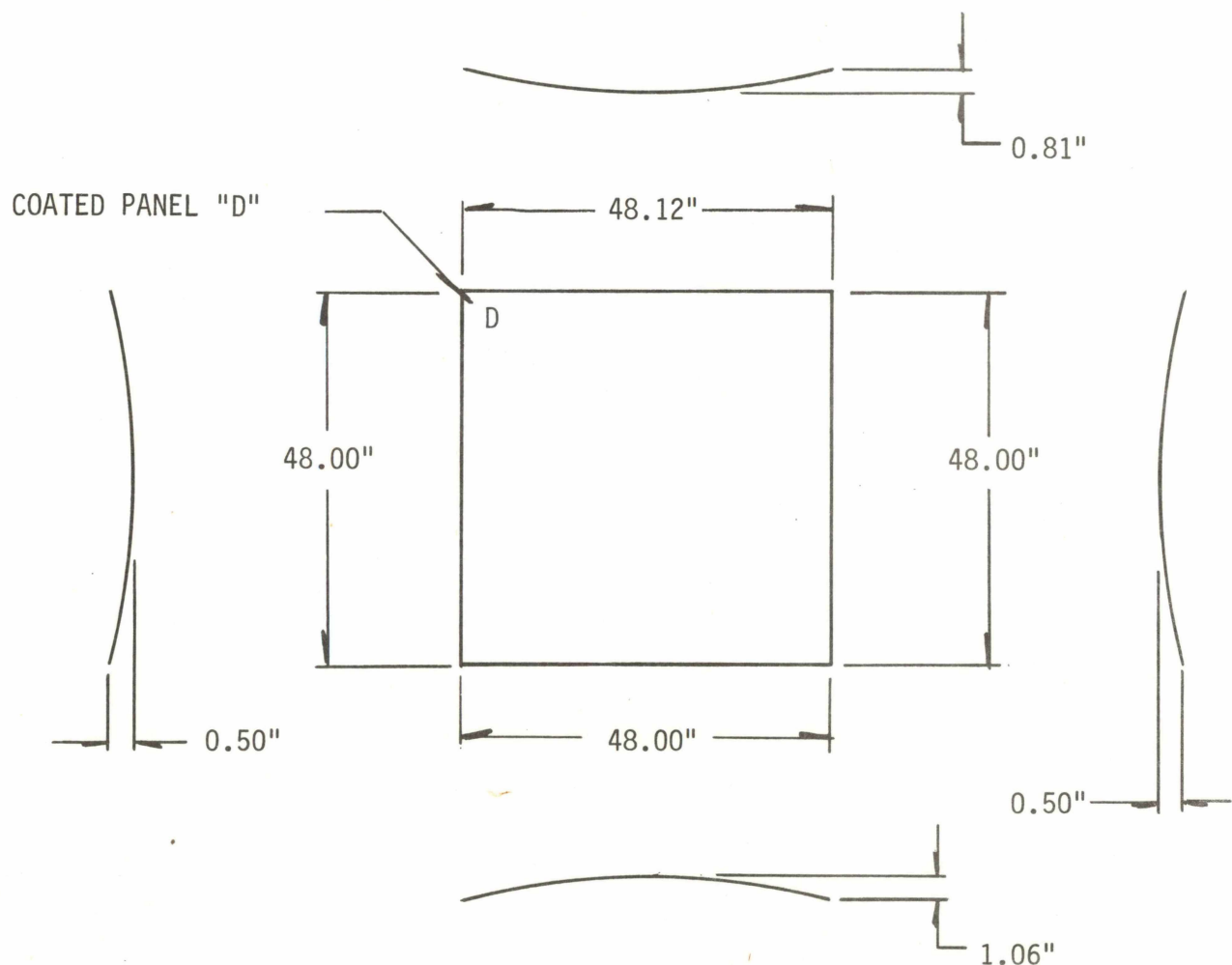


FIGURE 4. PHYSICAL CHARACTERISTICS FOR COATED PANEL "D"

Manufacturer: DeSoto, Inc.

Color: Yellow over painted in gloss black

Weight: 94.75 Pounds

Coating Thickness: Avg. 0.257 inches

Total Average Panel Thickness: 0.377 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. Random areas of the panels would impress with fingernail pressure. A number of small diameter (0.06-0.09 inch) holes were present.

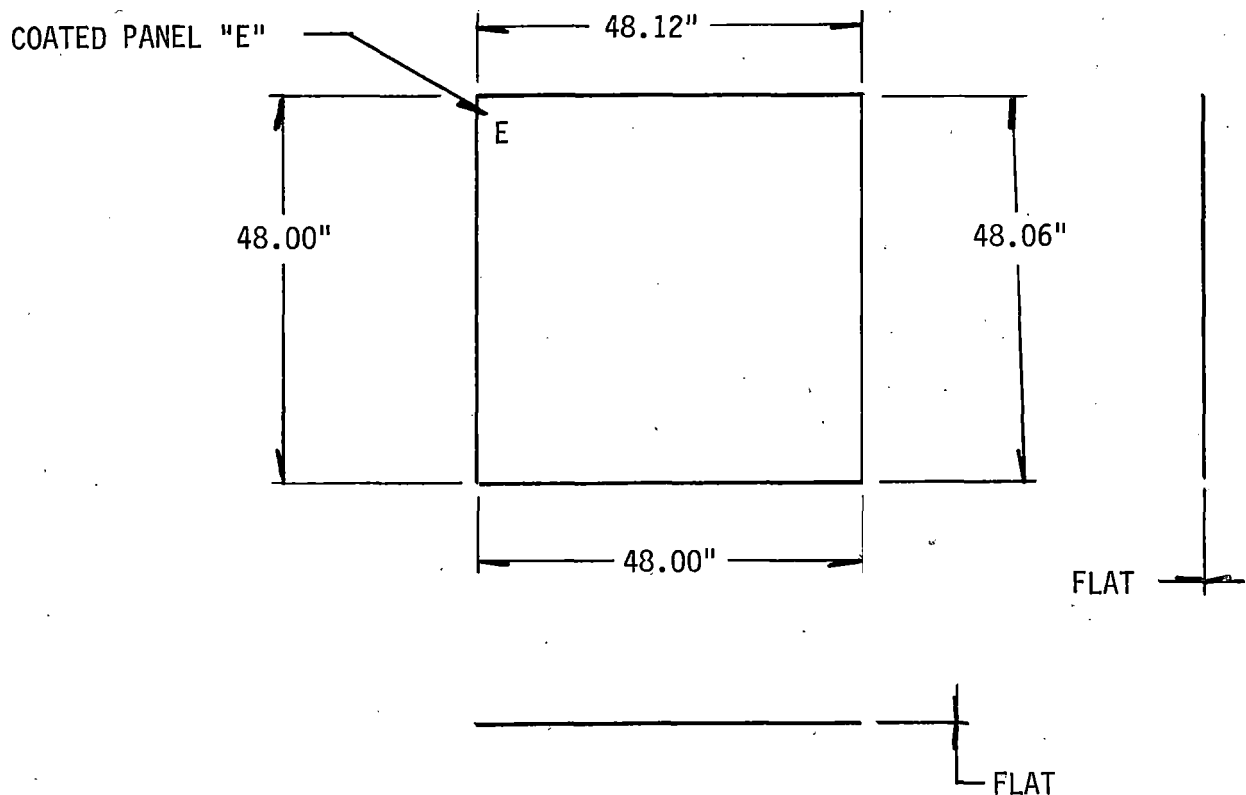


FIGURE 5. PHYSICAL CHARACTERISTICS FOR COATED PANEL "E"

Manufacturer: DeSoto, Inc.

Color: Yellow over painted in gloss black

Weight: 94.0 Pounds

Coating Thickness: Avg. 0.225 inches

Total Average Panel Thickness: 0.345 inches (Coating + Steel Plate)

- Notes:
1. Coating thickness measurements were taken 1.00 ± 0.12 inches in from the edges of the panel (five places/side - 20 places/panel).
 2. Panel identification letter was applied for photo and data control on the coated side of the panel.
 3. Random areas of the panels would impress with fingernail pressure. A number of random small diameter (0.06-0.09 inch) holes were present.

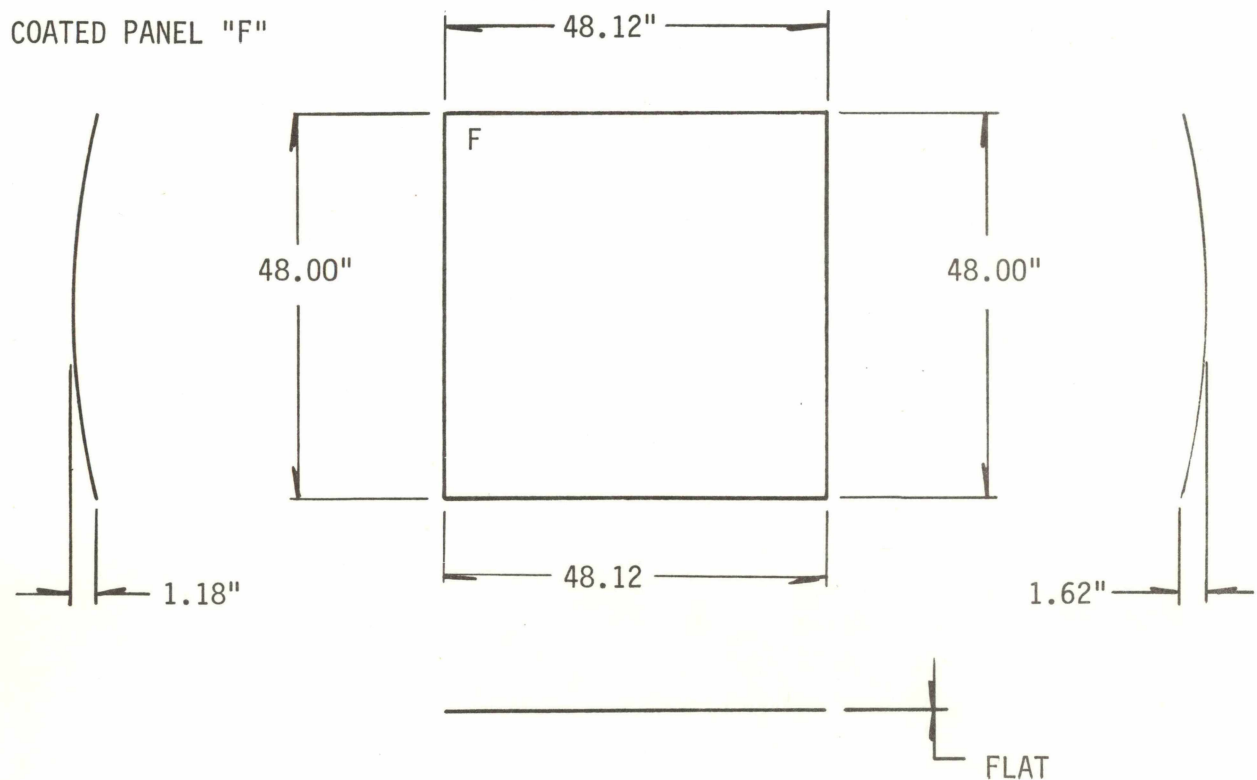


FIGURE 6. PHYSICAL CHARACTERISTICS FOR COATED PANEL "F"

Manufacturer: N/A

Color: N/A

Weight: 82.75 Pounds

Thickness: Avg. 0.126 inches

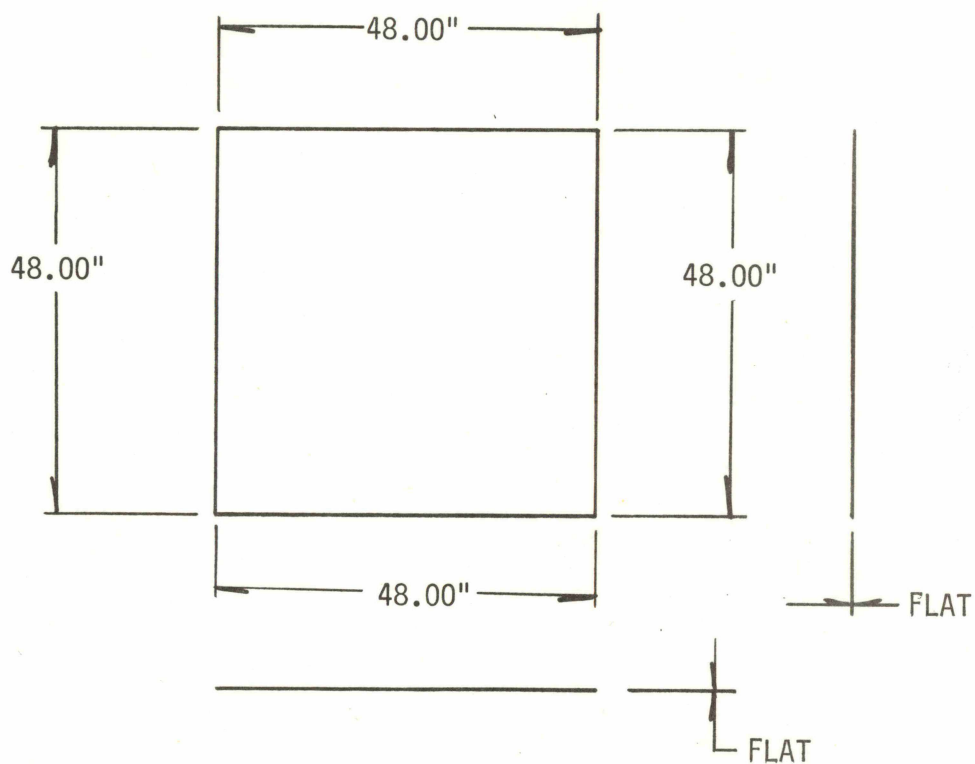


FIGURE 7. PHYSICAL CHARACTERISTICS FOR UNCOATED (BARE) PANEL

Notes: Item 1: 1.50 X 1.50 X 0.25 inch aluminum angle test panel retainer.
Twelve per panel.

Item 2: Test Panel

Item 3: Accelerometer attached to test panel with adhesive.

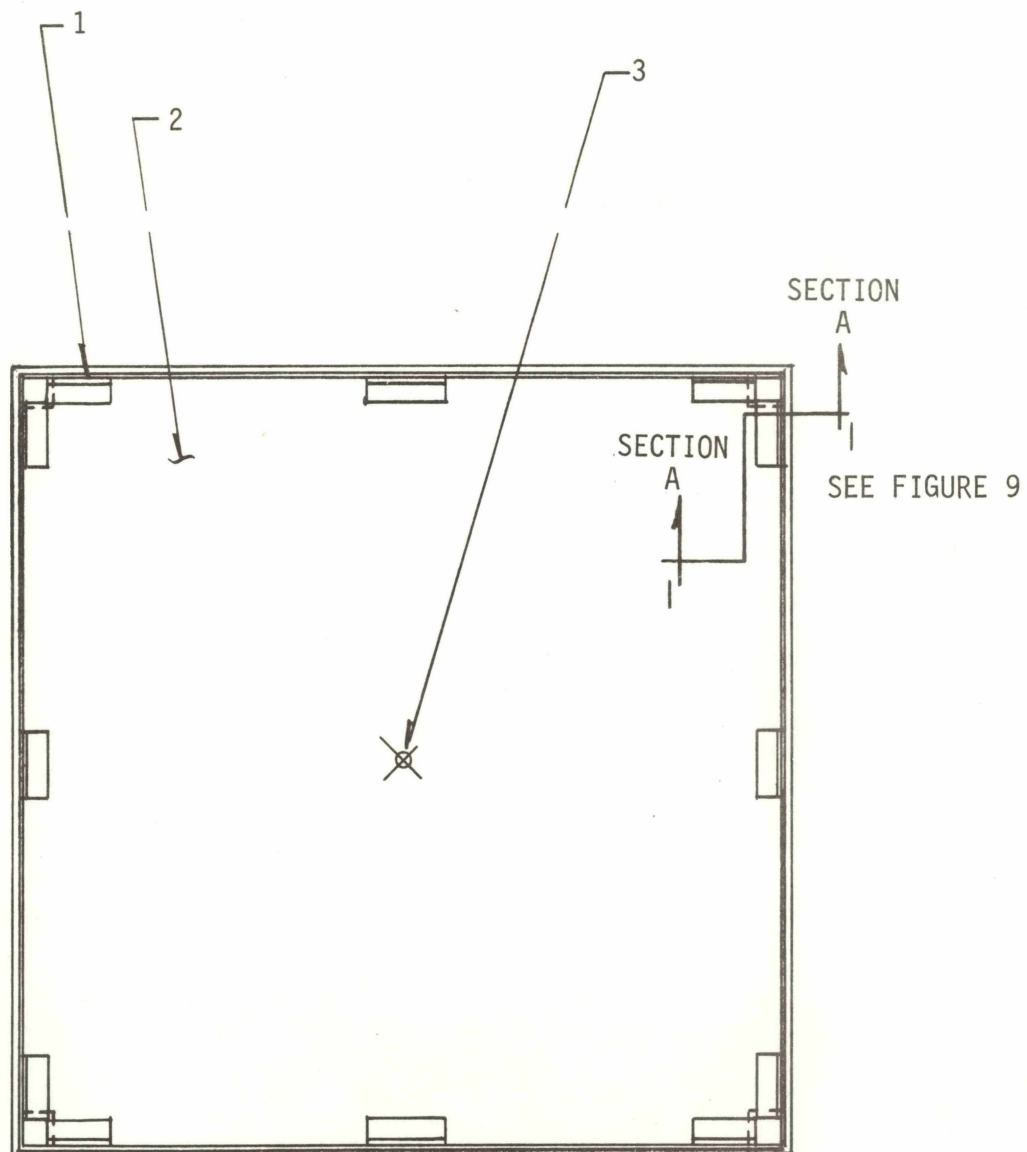


FIGURE 8. TEST SPECIMEN HOLDING FRAME

Note: Leather padding used to fill gaps between the aluminum angle and the test panels.

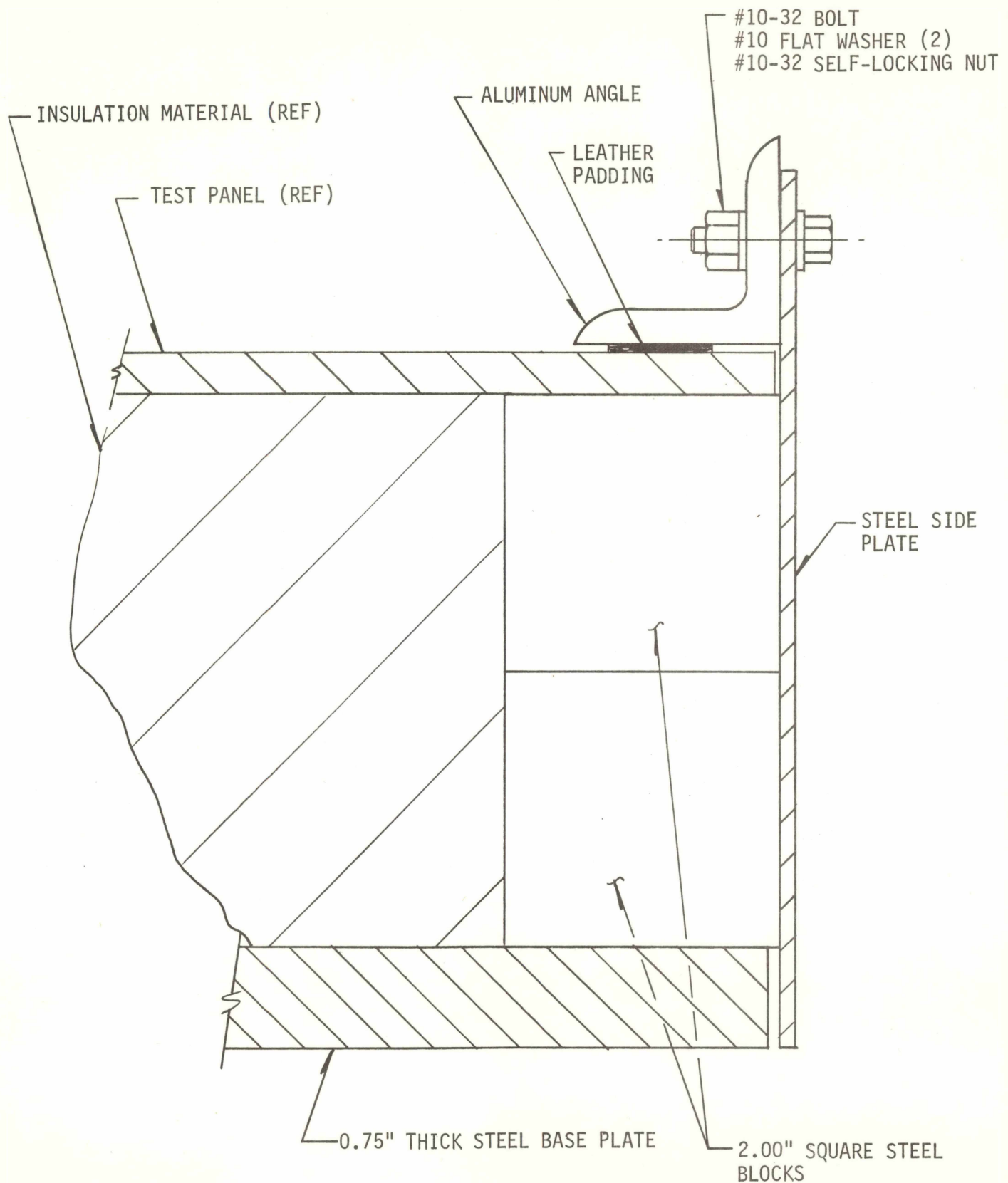


FIGURE 9. SECTION THROUGH TEST SPECIMEN HOLDING FRAME

Item	Description
1	Dynamic Shaker, Unholtz-Dickie Corp. Model 56
2	Automatic Vibration Exciter Control, Unholtz-Dickie Corp. Model 1019
3	Electronic Counter, Hewlett-Packard, Model 5245L
4 & 5	Accelerometer, Endevco, Model 2226
6	Charge Amplifier, Endevco, Model 2710AM13&14/2629A
7	Oscilloscope, Tektronix, Model 422
8	Digital Voltmeter 10, Hewlett-Packard, Model 3440A/3445A

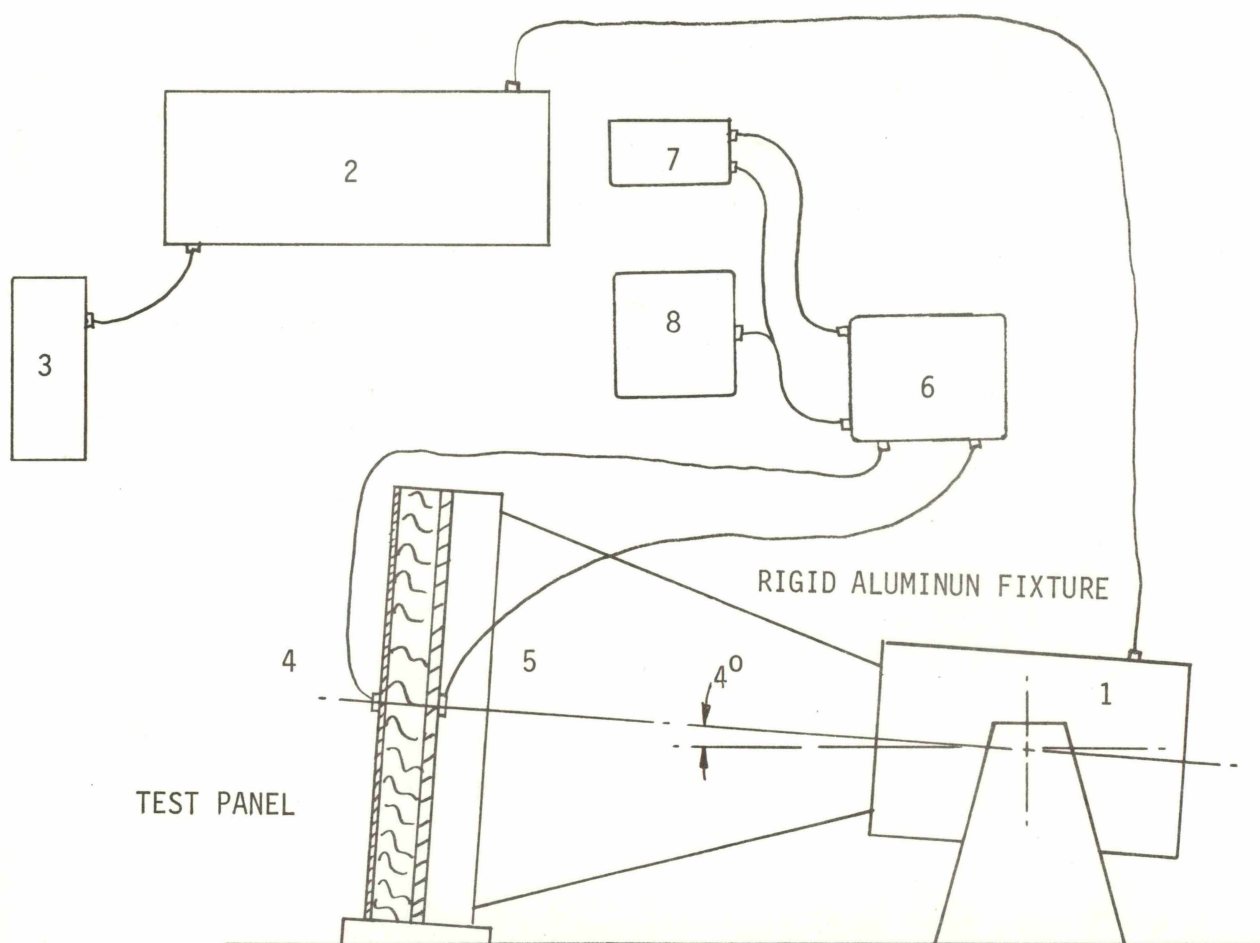


FIGURE 10. TEST EQUIPMENT SET-UP

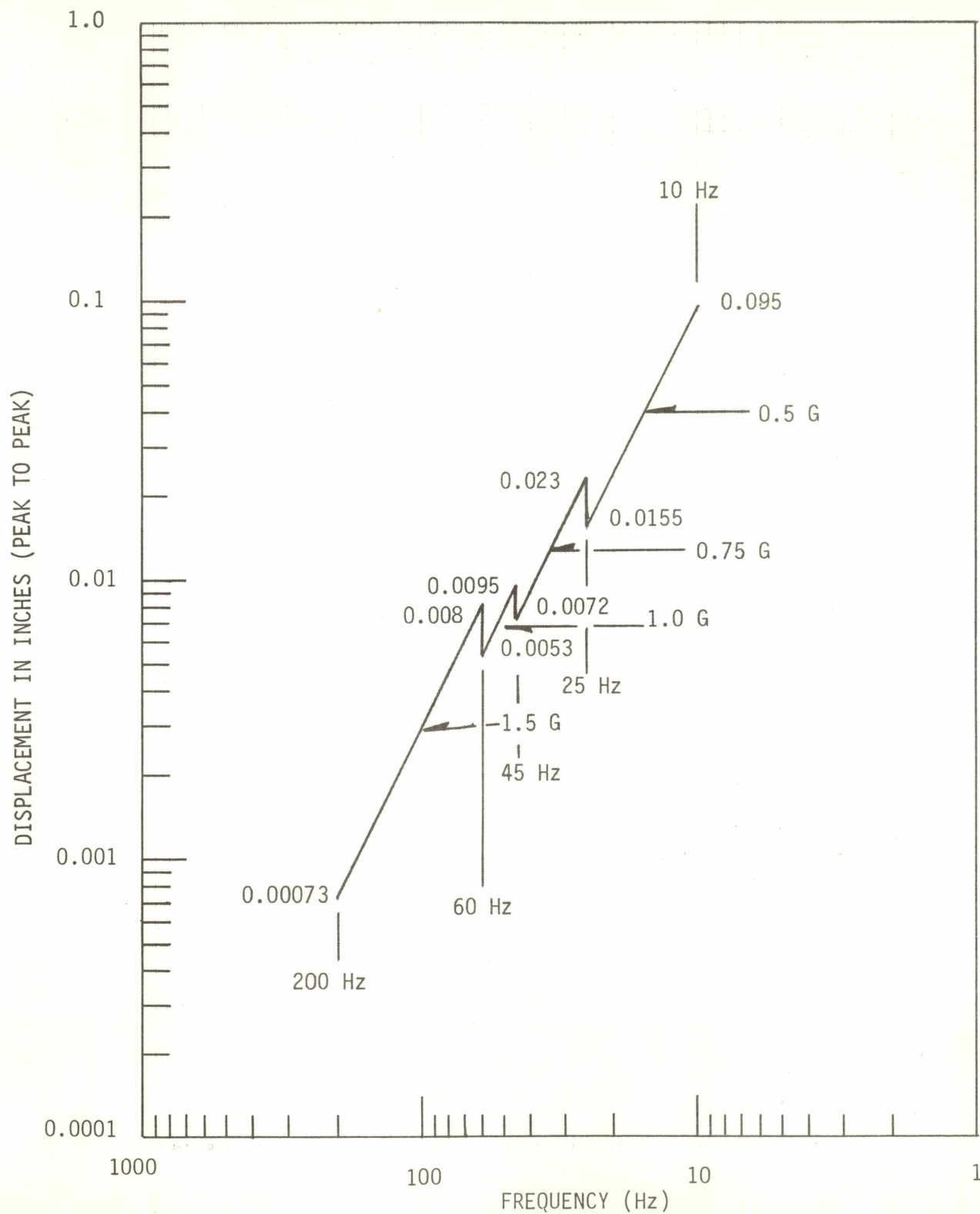


FIGURE 11. VIBRATION TEST CURVE



FIGURE 12. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.

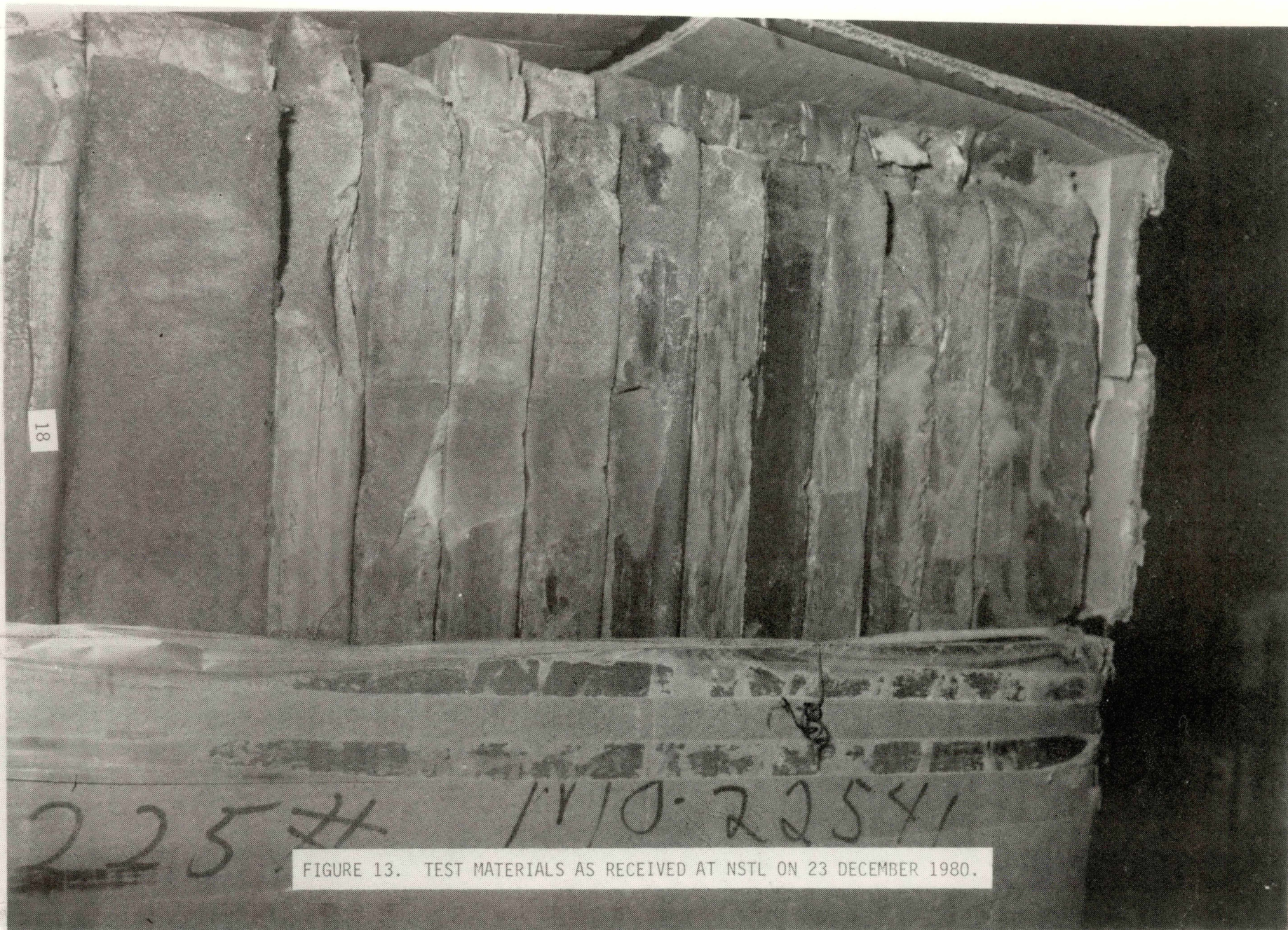


FIGURE 13. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.

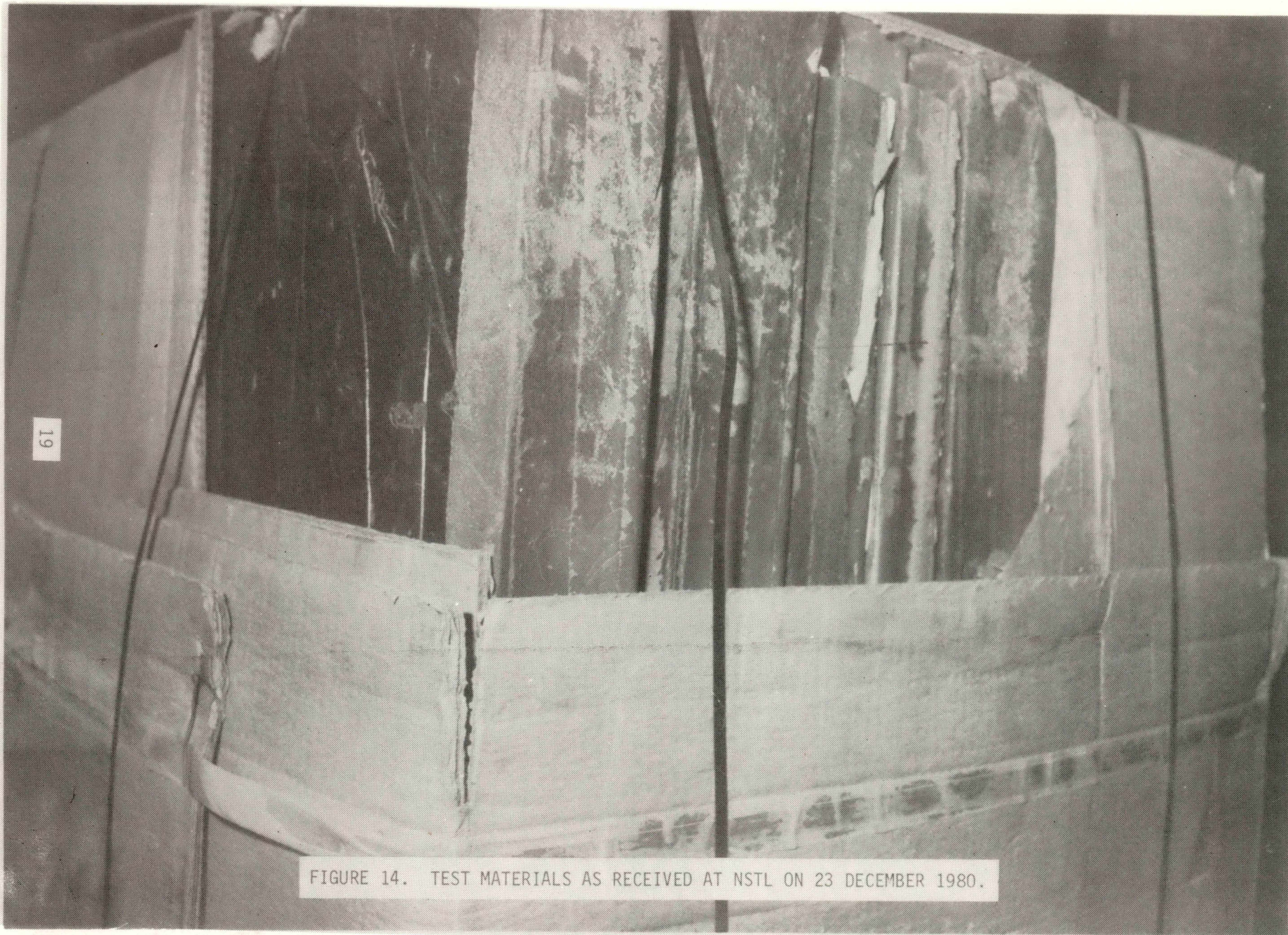


FIGURE 14. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.



FIGURE 15. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.

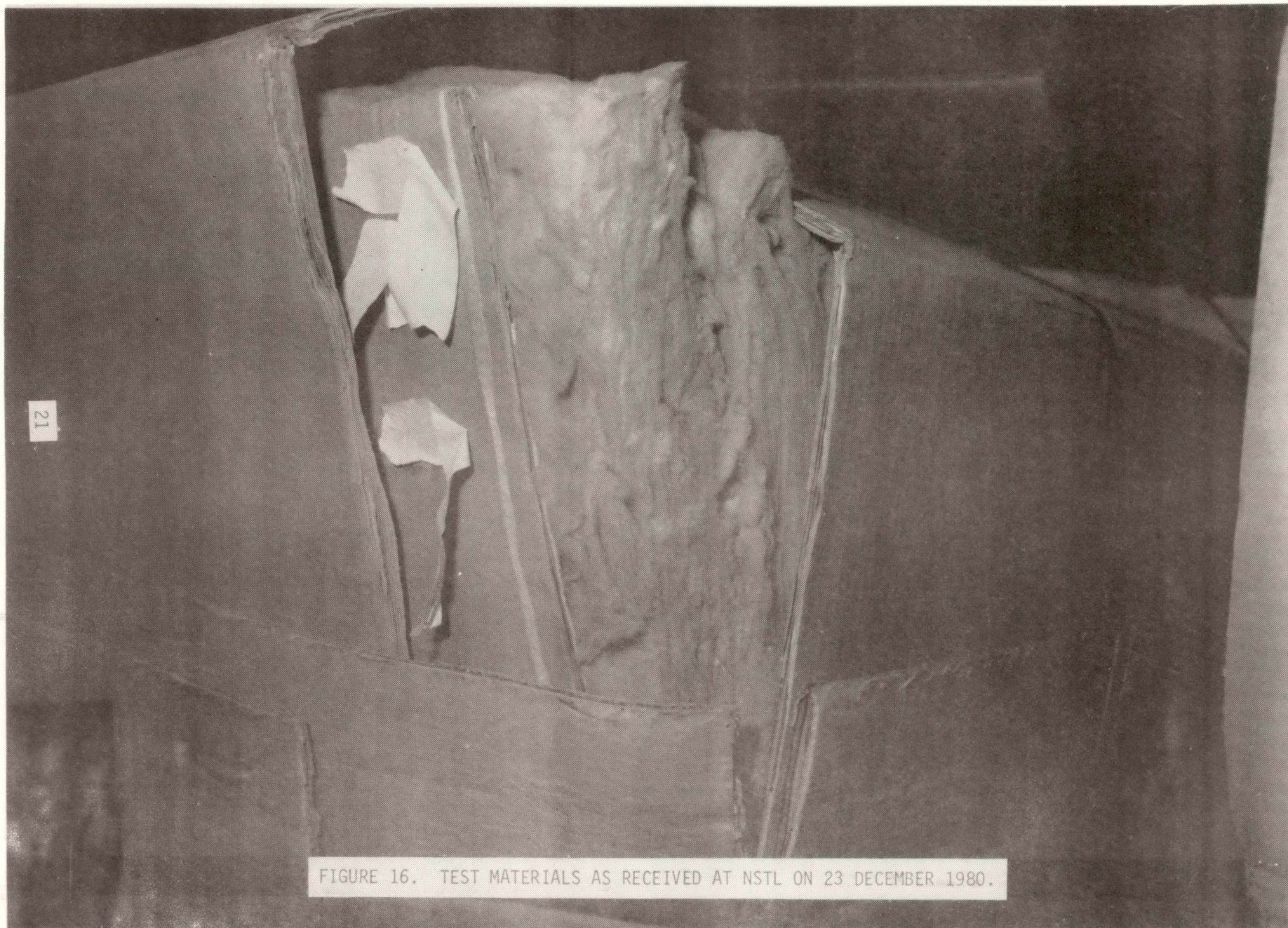


FIGURE 16. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.



FIGURE 17. TEST MATERIALS AS RECEIVED AT NSTL ON 23 DECEMBER 1980.

105

23

FIGURE 18. TEST SPECIMEN PANEL "A" (TSI,



, INC.) RECEIVING INSPECTION.

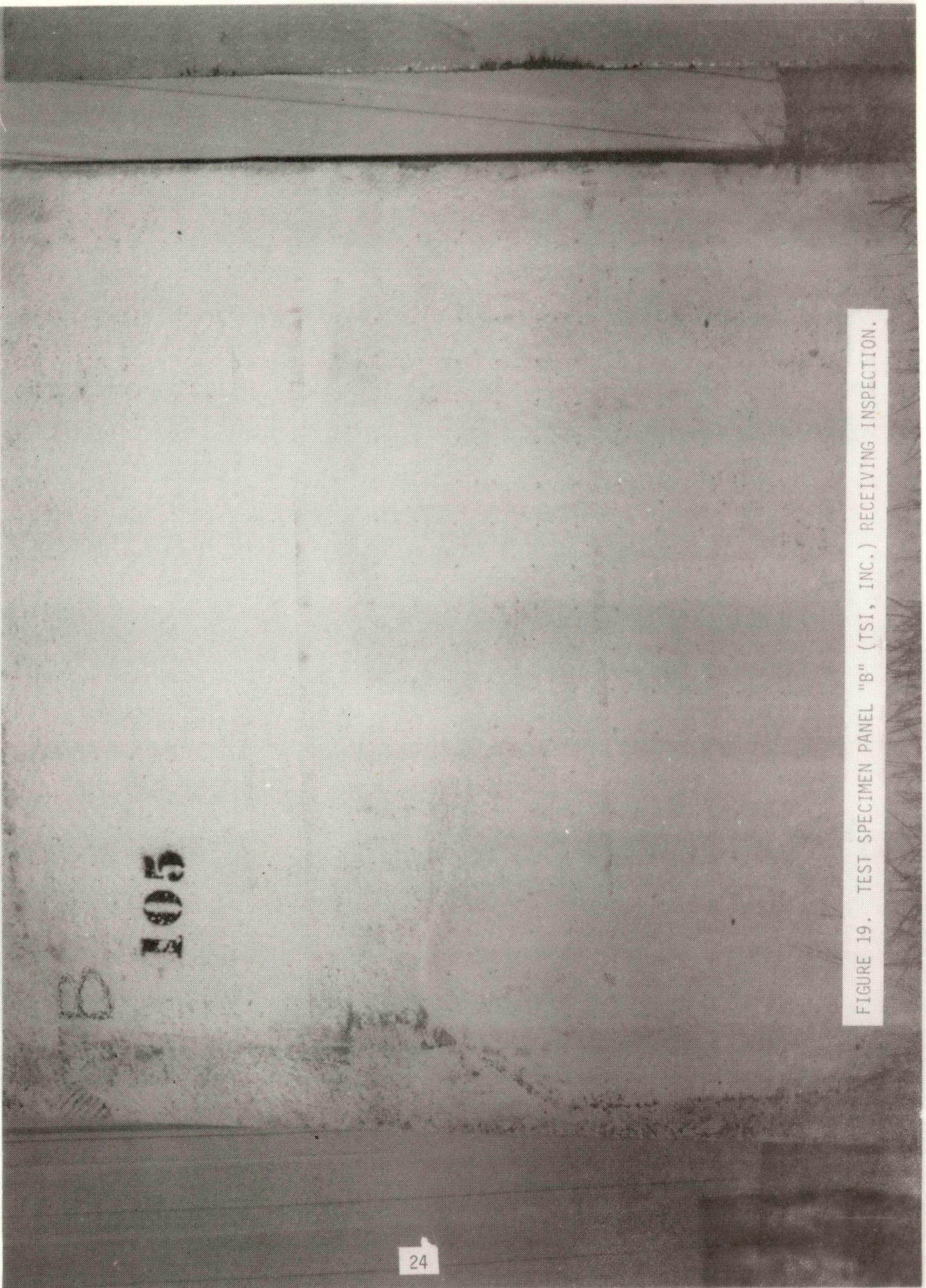


FIGURE 19. TEST SPECIMEN PANEL "B" (TSI, INC.) RECEIVING INSPECTION.

FIGURE 20. TEST SPECIMEN PANEL "C" (AVCO) RECEIVING INSPECTION.

A

26

FIGURE 21. TEST SPECIMEN PANEL "D" (AVCO) RECEIVING INSPECTION.

FIGURE 22. TEST SPECIMEN PANEL "E" (DESOTO, INC.) RECEIVING INSPECTION.

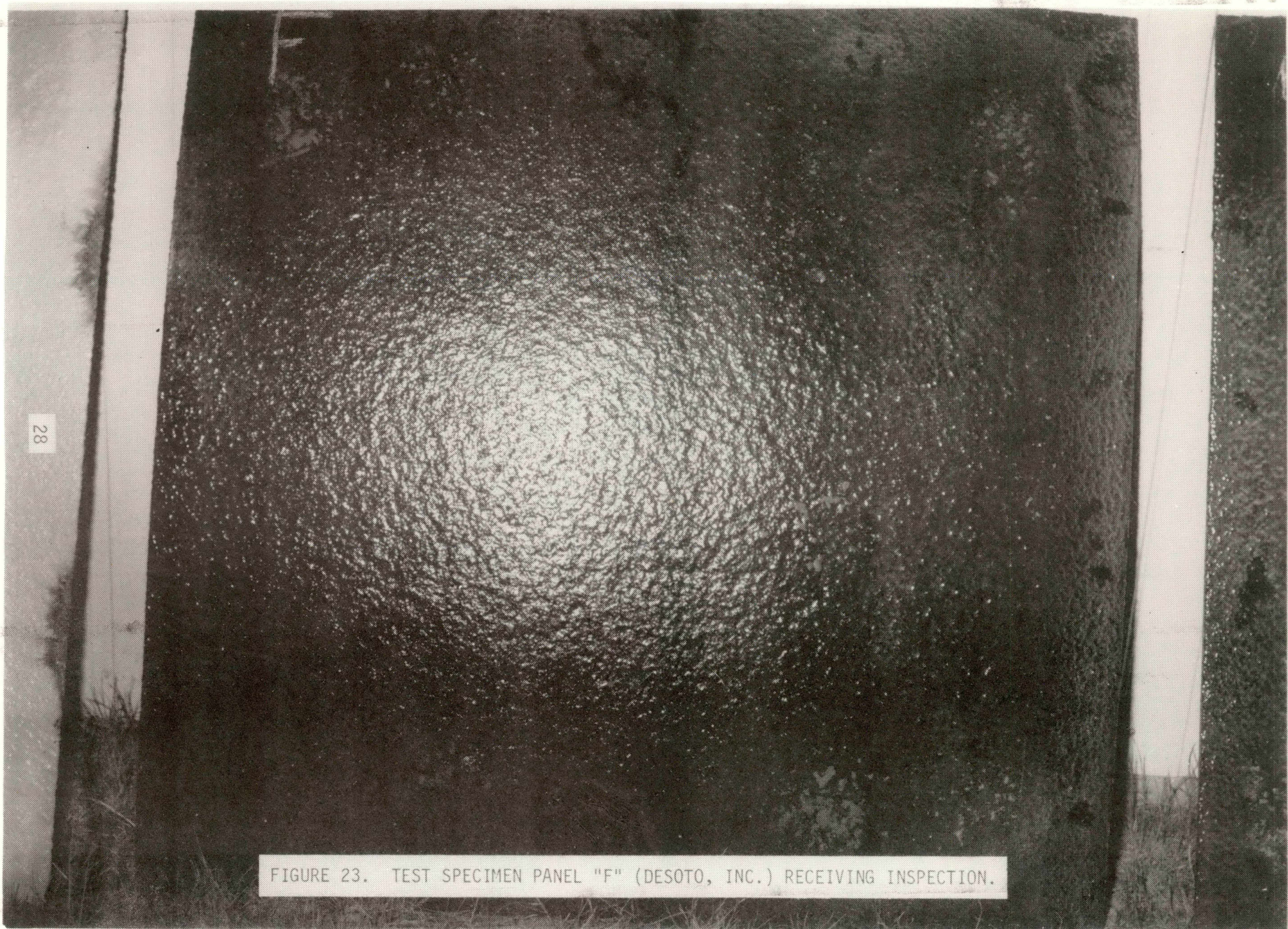


FIGURE 23. TEST SPECIMEN PANEL "F" (DESOTO, INC.) RECEIVING INSPECTION.

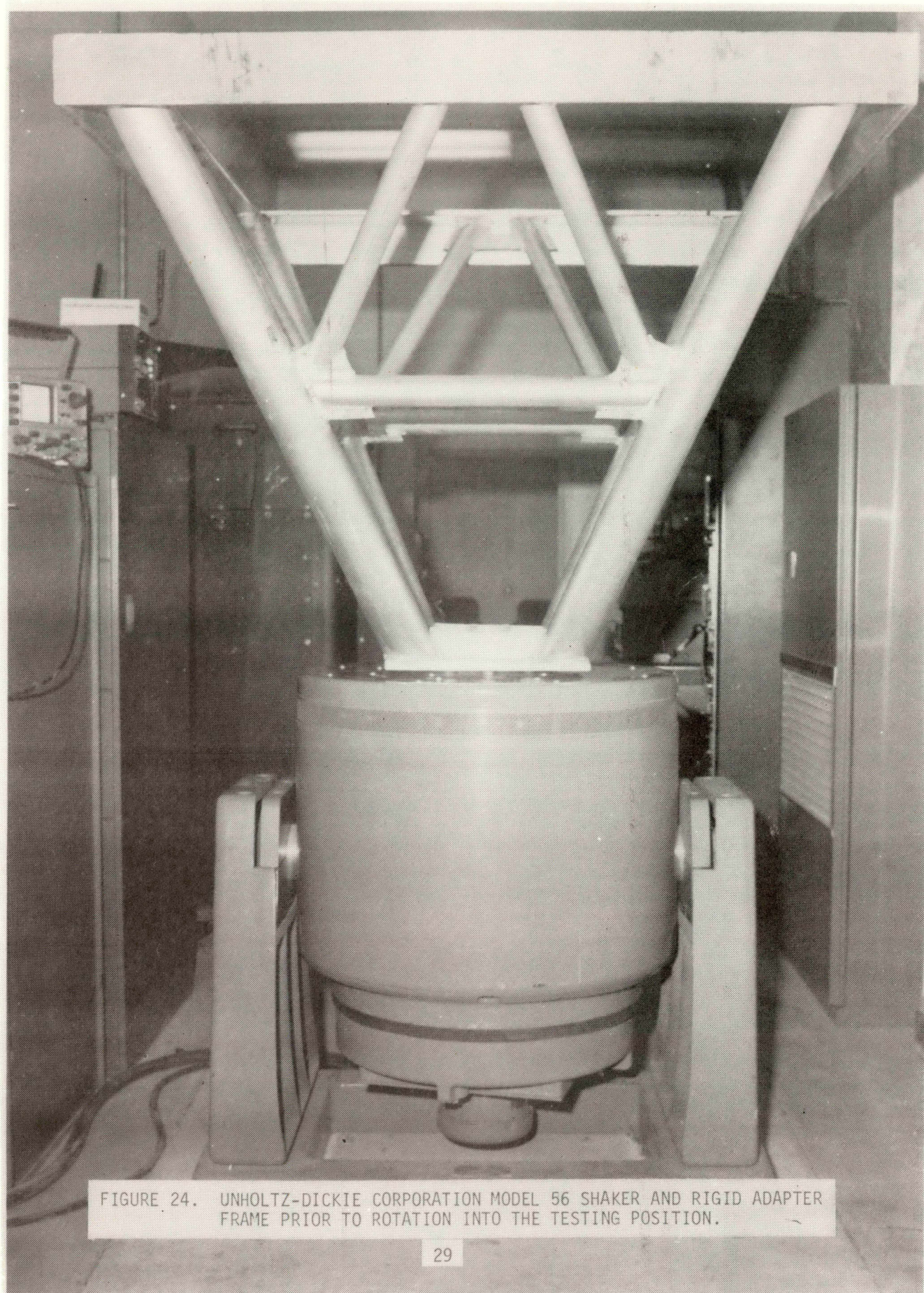


FIGURE 24. UNHOLTZ-DICKIE CORPORATION MODEL 56 SHAKER AND RIGID ADAPTER FRAME PRIOR TO ROTATION INTO THE TESTING POSITION.

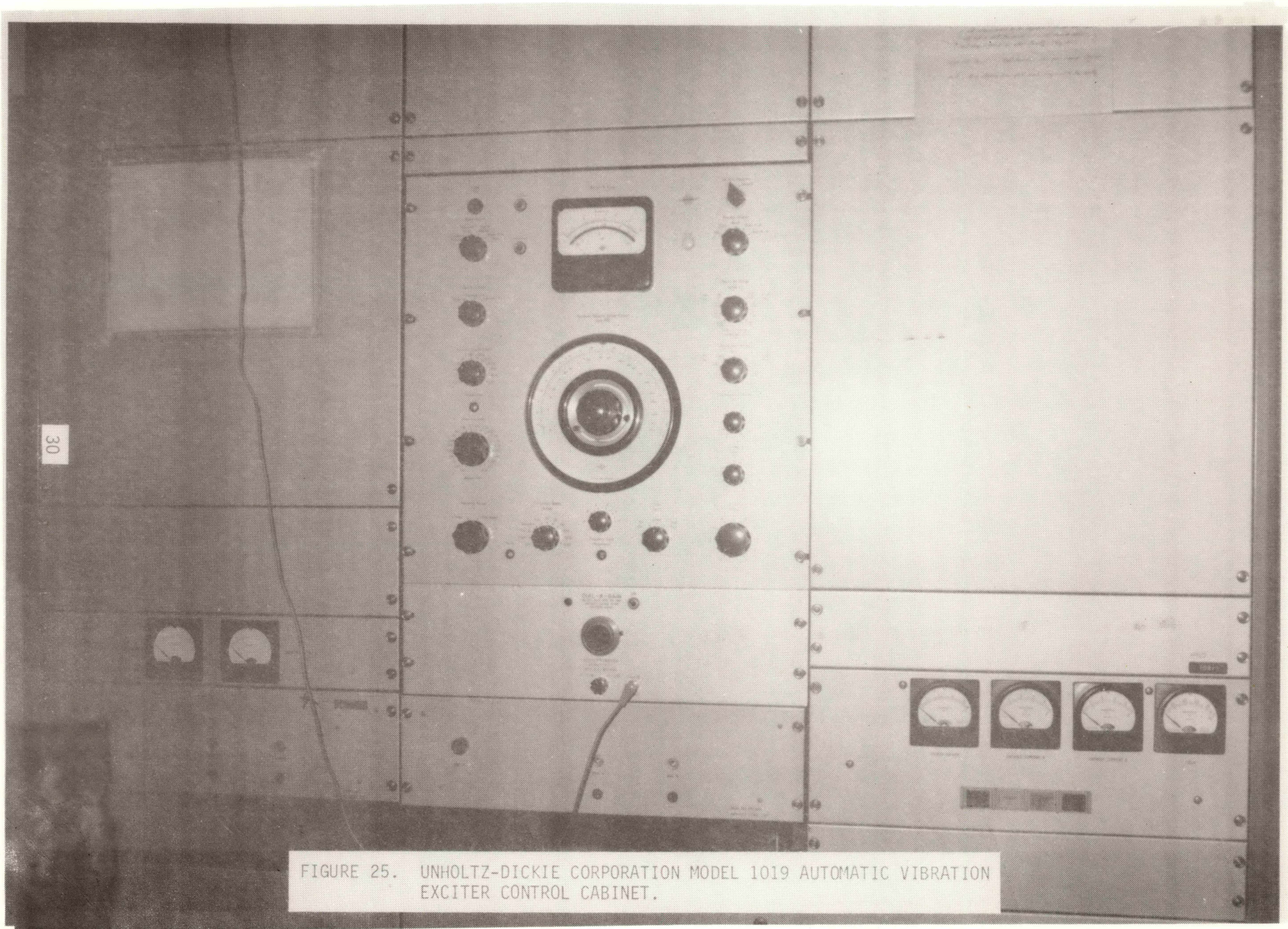


FIGURE 25. UNHOLTZ-DICKIE CORPORATION MODEL 1019 AUTOMATIC VIBRATION EXCITER CONTROL CABINET.

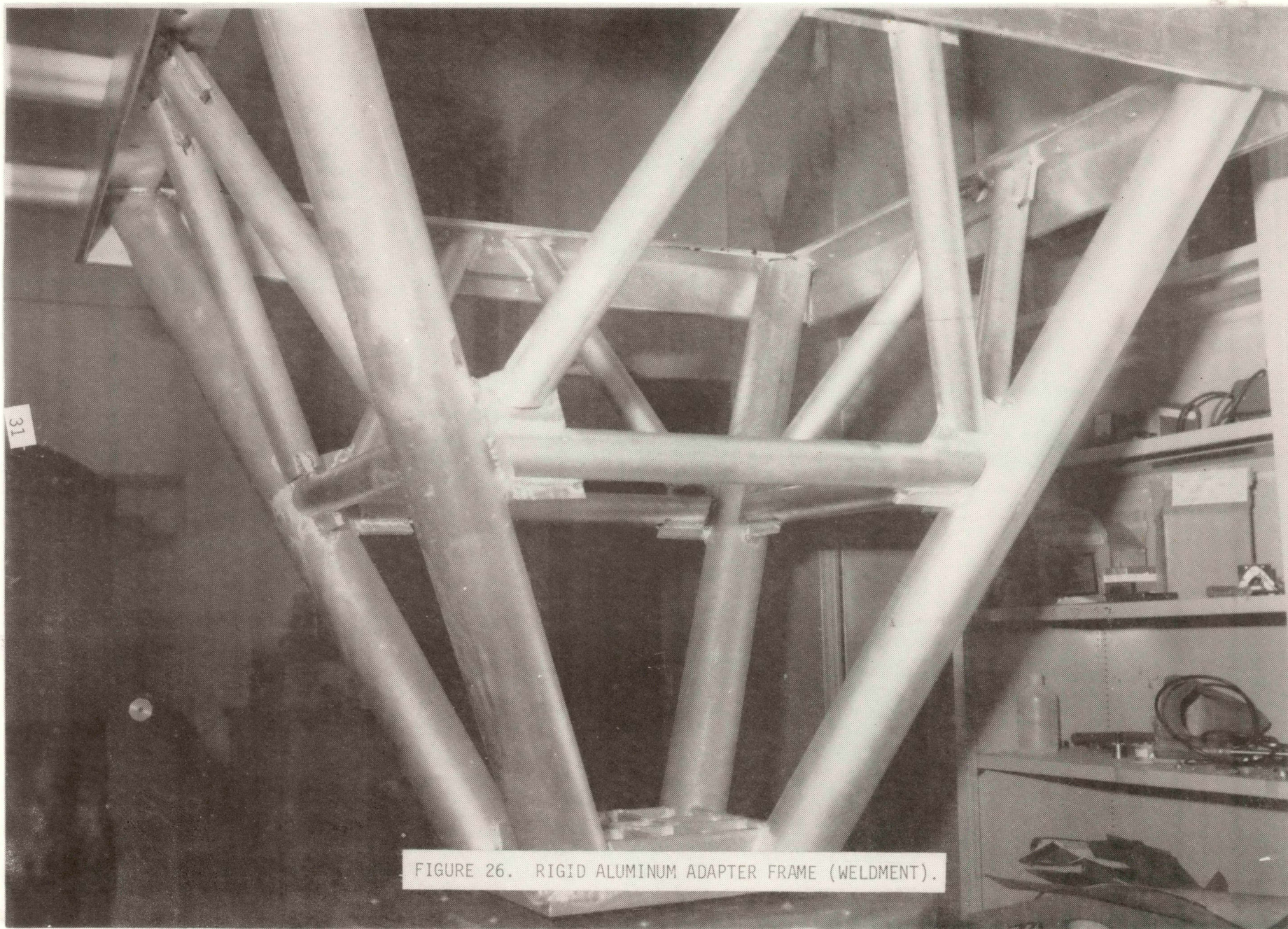


FIGURE 26. RIGID ALUMINUM ADAPTER FRAME (WELDMENT).

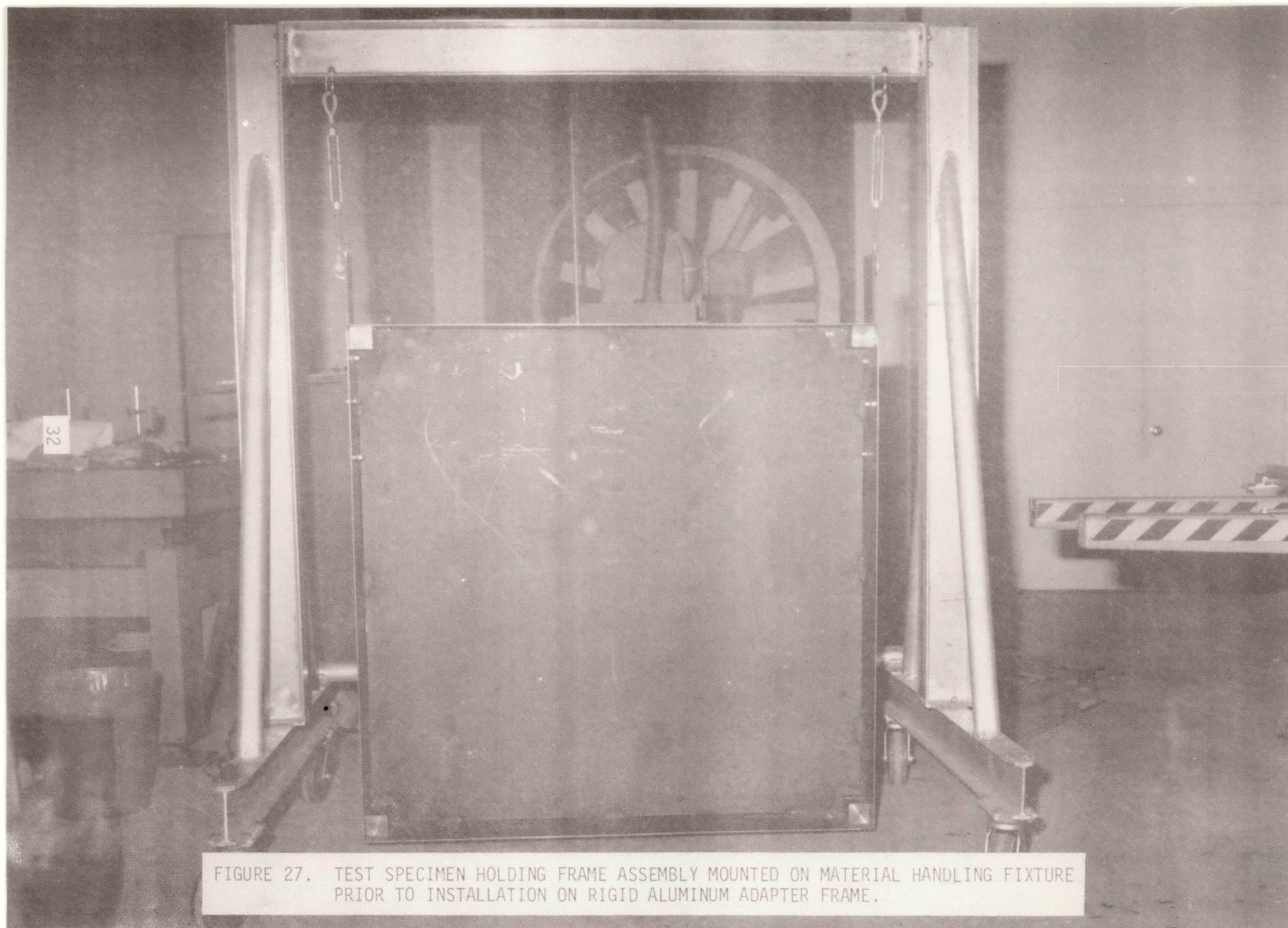


FIGURE 27. TEST SPECIMEN HOLDING FRAME ASSEMBLY MOUNTED ON MATERIAL HANDLING FIXTURE PRIOR TO INSTALLATION ON RIGID ALUMINUM ADAPTER FRAME.

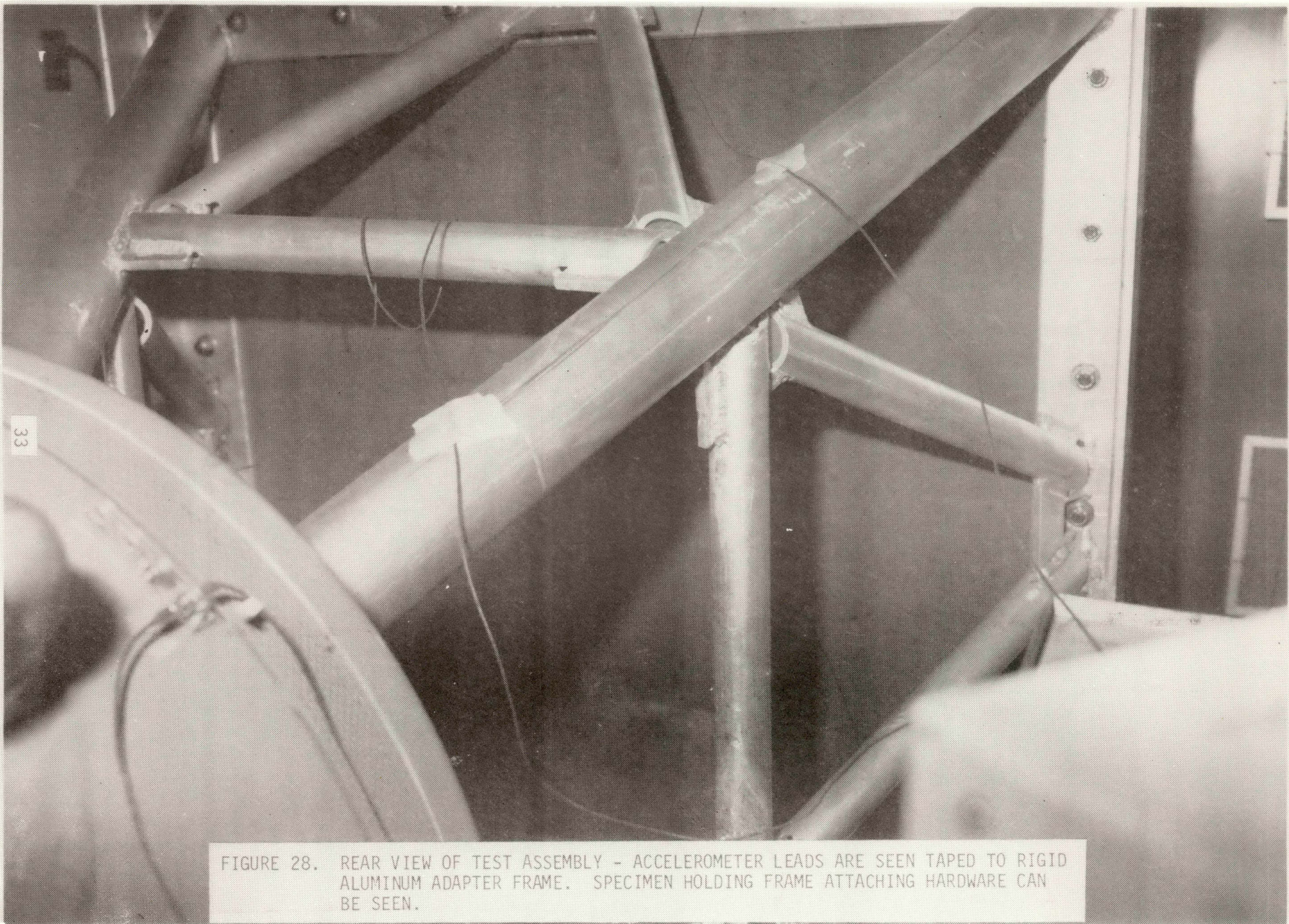


FIGURE 28. REAR VIEW OF TEST ASSEMBLY - ACCELEROMETER LEADS ARE SEEN TAPED TO RIGID ALUMINUM ADAPTER FRAME. SPECIMEN HOLDING FRAME ATTACHING HARDWARE CAN BE SEEN.

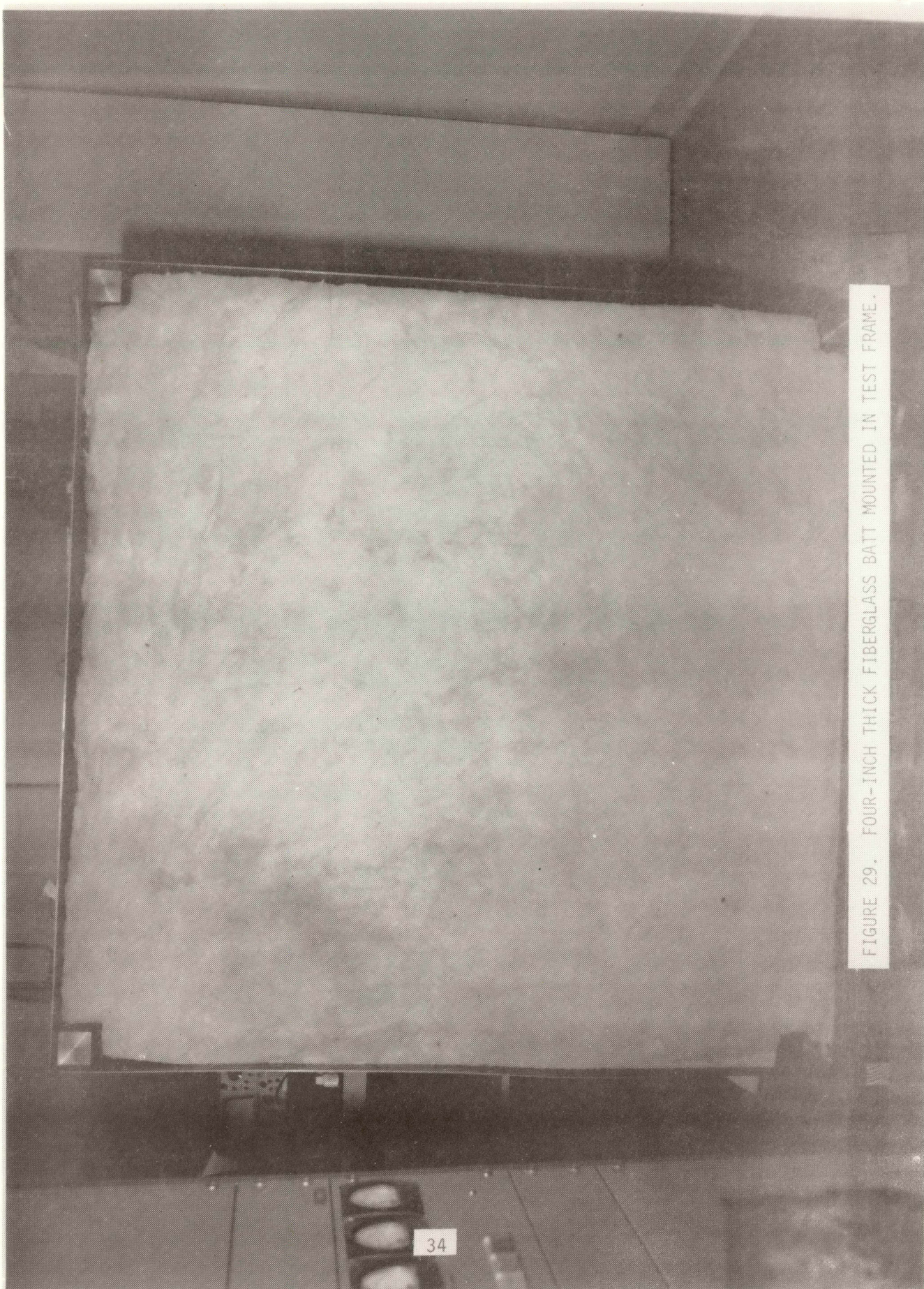
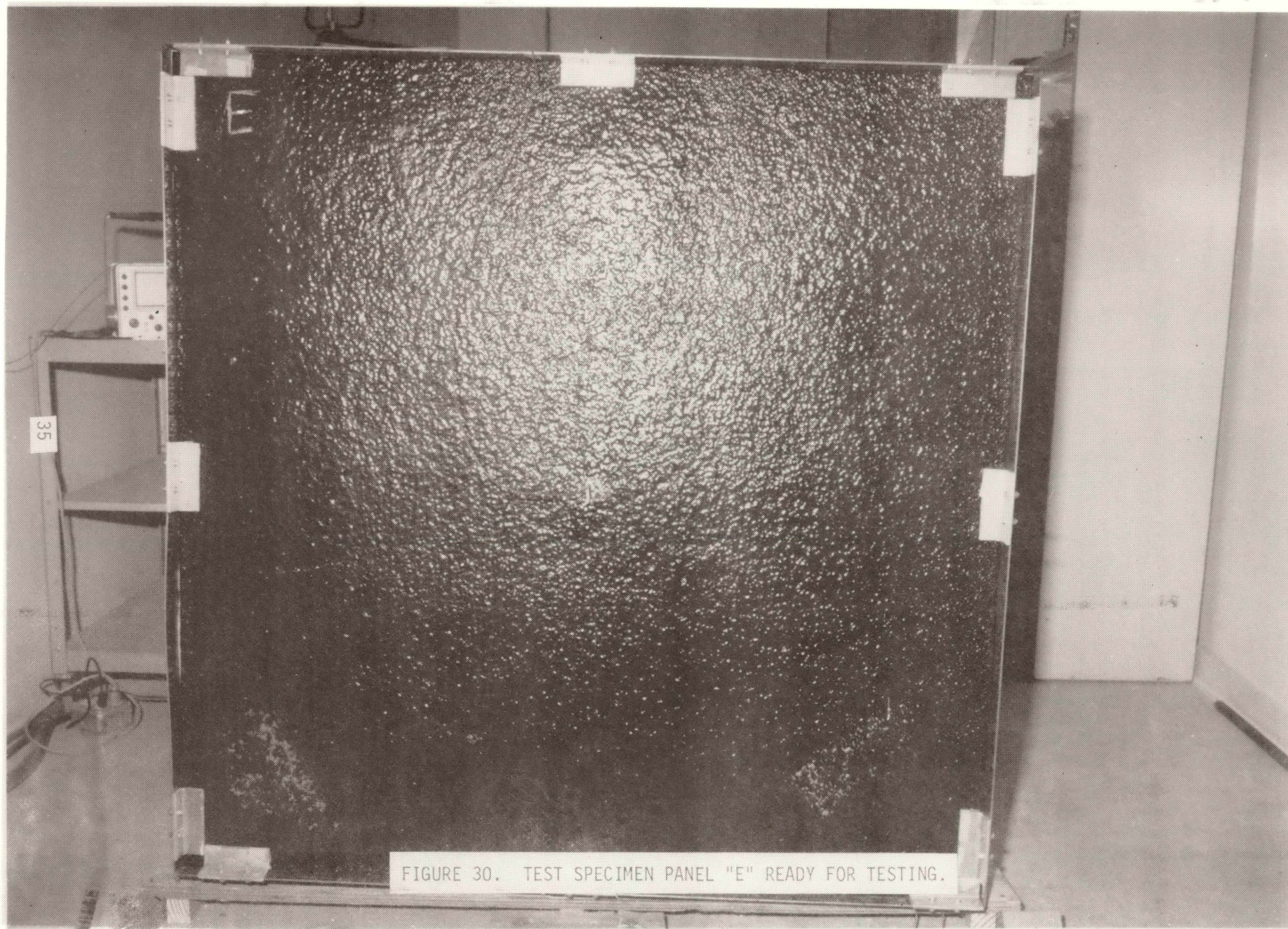


FIGURE 29. FOUR-INCH THICK FIBERGLASS BATT MOUNTED IN TEST FRAME.



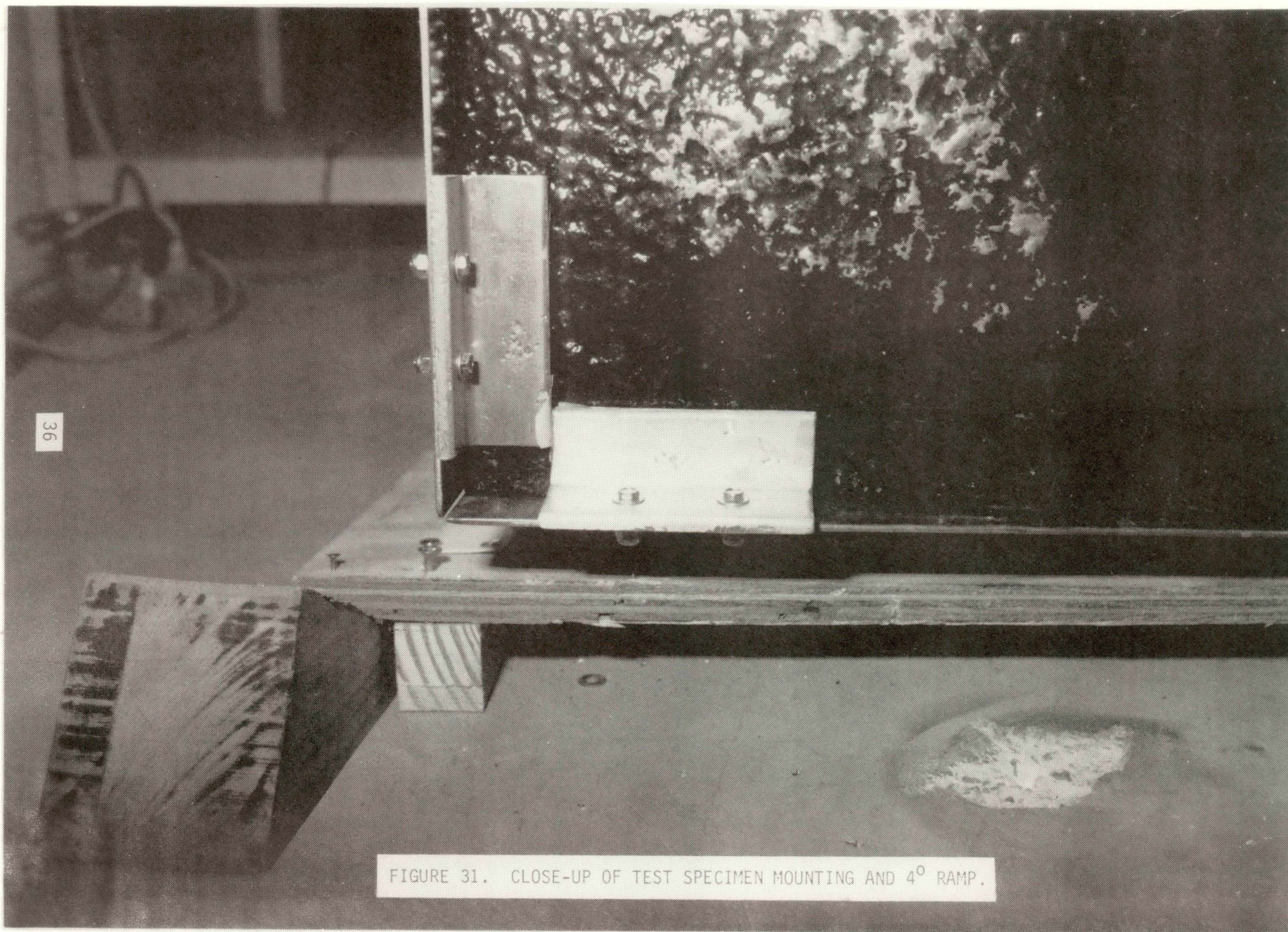


FIGURE 31. CLOSE-UP OF TEST SPECIMEN MOUNTING AND 4° RAMP.

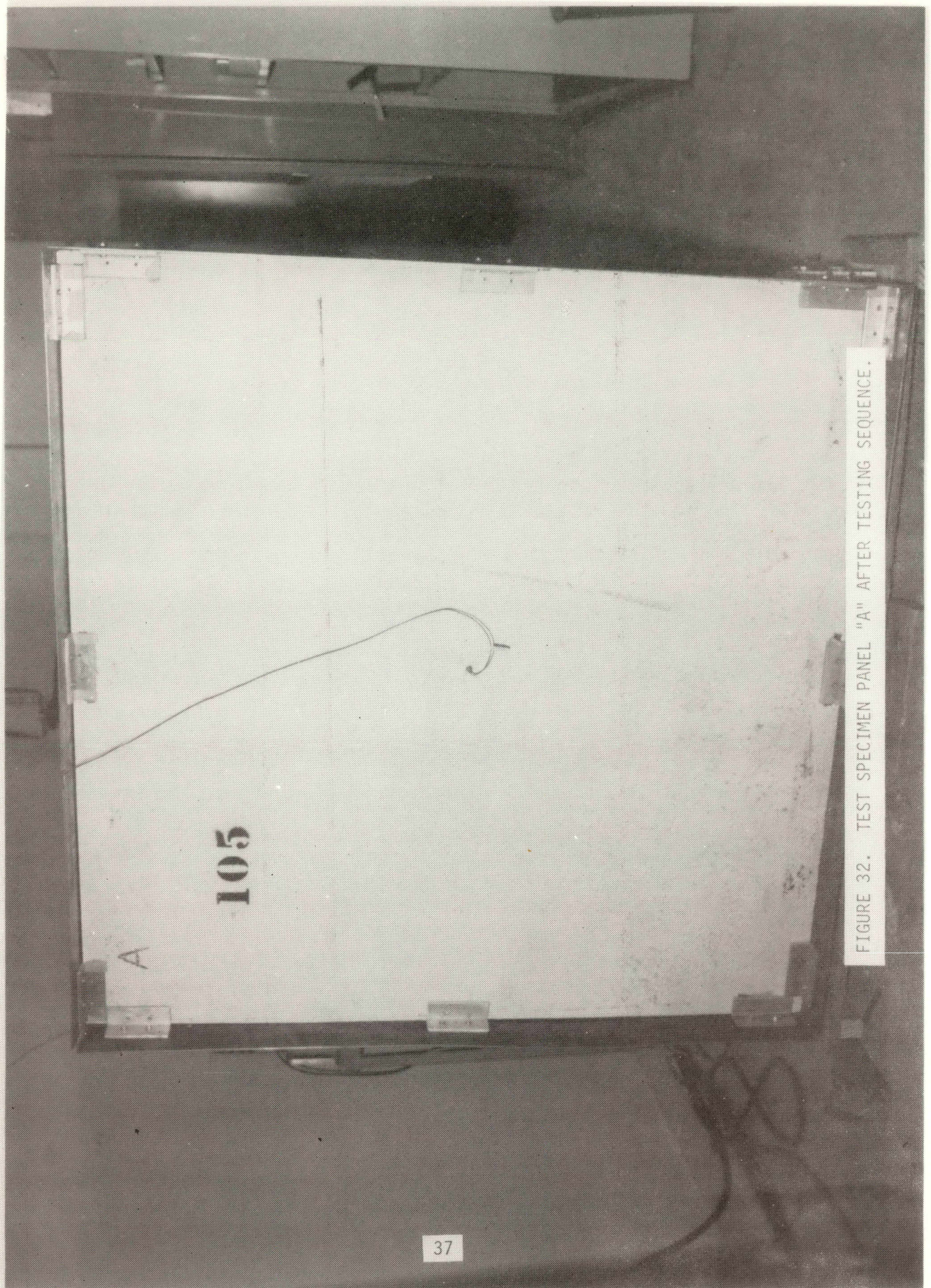


FIGURE 32. TEST SPECIMEN PANEL "A" AFTER TESTING SEQUENCE.

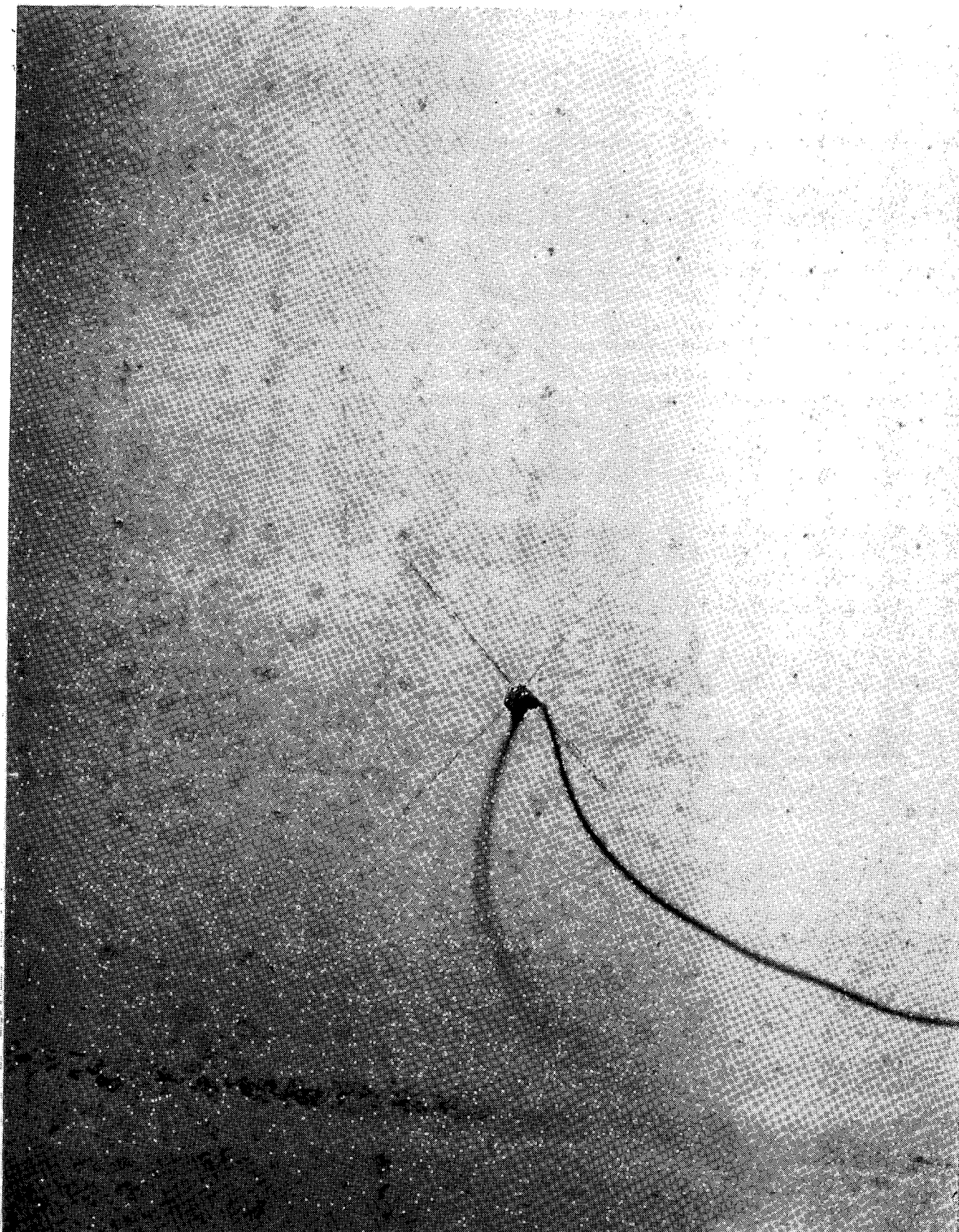
A black and white photograph showing a close-up of an accelerometer mounted on a test specimen. The accelerometer is a small, dark, rectangular component with a circular base, mounted on a light-colored, textured surface. A thin, dark wire extends from the base of the accelerometer, curving downwards and to the right. The background is a light-colored, textured surface, possibly a piece of paper or a test panel, with some faint, dark lines visible. The overall image has a grainy, halftone appearance.

FIGURE 33. CLOSE-UP OF ACCELEROMETER MOUNTED ON TEST SPECIMEN (PANEL "A").

APPENDIX A: IITRI TEST PLAN CORRESPONDENCE



IIT Research Institute
10 West 35 Street, Chicago, Illinois 60616
312/567-4000

May 20, 1980

Mr. Donald Chenevert
Computer Sciences Corporation
Building 1100, TLR 225
NSTL Station, Mississippi 39529

Subject: Preliminary Information for Vibration Tests of
Insulated Tank Car Specimens

Dear Mr. Chenevert:

We have reviewed possible requirements for vibration tests which are to be performed on representative specimens of prototype insulation systems for type 105 tank cars. A tentative test plan is summarized in this letter. It is based on a review of the vibration data which was obtained on type 112 and 114 tank cars during tests at the Transportation Test Center (TTC). The test plan is also based on a review of the vibration section of MIL-STD-810C. This appears to be an appropriate reference for establishing guidelines for the test requirements. The vibration levels established in this standard are for equipment transported as cargo in rail vehicles. The standard appears to be a conservative representation of the actual railroad operating environment. The vibration levels also appear to be within the capabilities of the test equipment which is presently available at NSTL.

1. Purpose

The purpose of the vibration tests is to determine if a thin chemical coating applied to the jacket of a conventional insulation system used on type 105 tank cars will give satisfactory performance in the normal railroad service environment. It is desired that any shortcomings in the ability of the coating to adhere to the jacket will be revealed by the tests. The vibration tests will be one phase in the qualification of such materials. Additional testing is planned with full scale tank cars at the TTC.

2. Test Specimens

The tests are to be conducted on four by four foot specimens of representative tank car construction. These specimens consist of a base plate, which represents the wall of the tank, a 2 - 4 inch thick layer of insulation, and an 11 guage jacket which would be applied over the insulation material. These specimens would be sent to various coating manufacturers who would apply additional

insulation on the outside of the jacket. This layer would normally be approximately $\frac{1}{4}$ inch or less. The completed specimens would be then shipped to NSTL for the tests.

3. Apparatus

The vibration tests would be conducted on an Unholtz-Dickie vibration test machine system, Model Number 454H. This equipment reportedly has a maximum 1600 pound force capability and a frequency range up to 4,000 Hz.

4. Mounting Techniques

The test specimens shall be attached either directly to the vibration excitor or table by means of a rigid fixture capable of transmitting the specified vibrational conditions. Precautions shall be taken in the establishment of mechanical interfaces to minimize the introduction of extraneous responses in the test set up. The test load will be distributed as uniformly as possible over the test specimen in order to minimize the effects of unbalanced loads.

5. Sinusoidal Vibration Tests

The vibration shall be applied perpendicular to the face of the test specimen. The base plate of the sample shall be mounted against the vibration table. The vibratory acceleration levels specified by the test curve shall be maintained at the test specimen mounting points. The test specimen shall be vibrated in accordance with the test level and frequency range specified in Figure 1. The vibration frequency shall be swept from 5 to 200 and back to 5 Hz in 12 minutes. The sweep time shall vary logarithmically as indicated in Figure 2. The total test time will be 84 minutes.

During the frequency sweep, the presence of any resonant frequencies shall be noted.

6. Instrumentation

The maximum acceleration level shall be monitored on both the vibration table and the top surface of the jacket. This will provide a means for verifying the desired input to the specimen and for noting the presence of resonant conditions.

7. Inspection

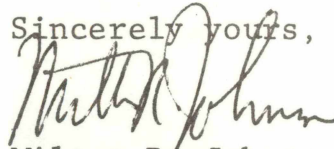
During the test period, changes in the apparent condition of the test specimen and the coating shall be noted. Following the cyclic test period, the coated surface shall be examined carefully

for cracks or separations from the steel jacket. Any deficiencies shall be documented by preparing sketches showing their location and the nature of the deficiency. Photographs shall also be obtained of the defects.

Conclusion

The above information presents a preliminary recommendation for the test requirements. I will call you in a few days to discuss these recommendations.

Sincerely yours,



Milton R. Johnson
Senior Engineering Advisor
Transportation Research Division

MRJ/se

cc: Dr. C. Anderson - BRL
Mr. M.O. Johnson - Micro-Tec

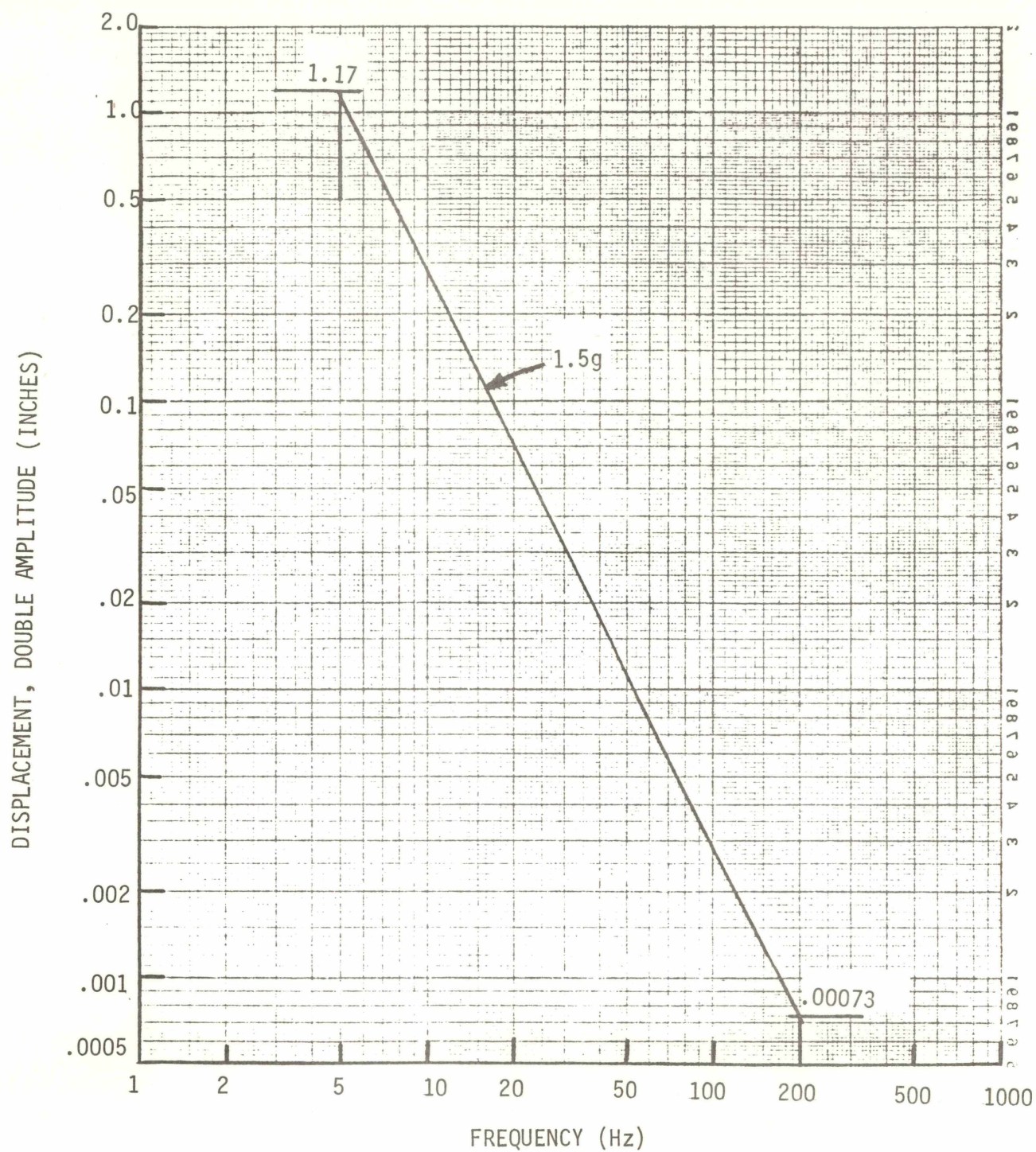


FIGURE A-1 VIBRATION TEST CURVE

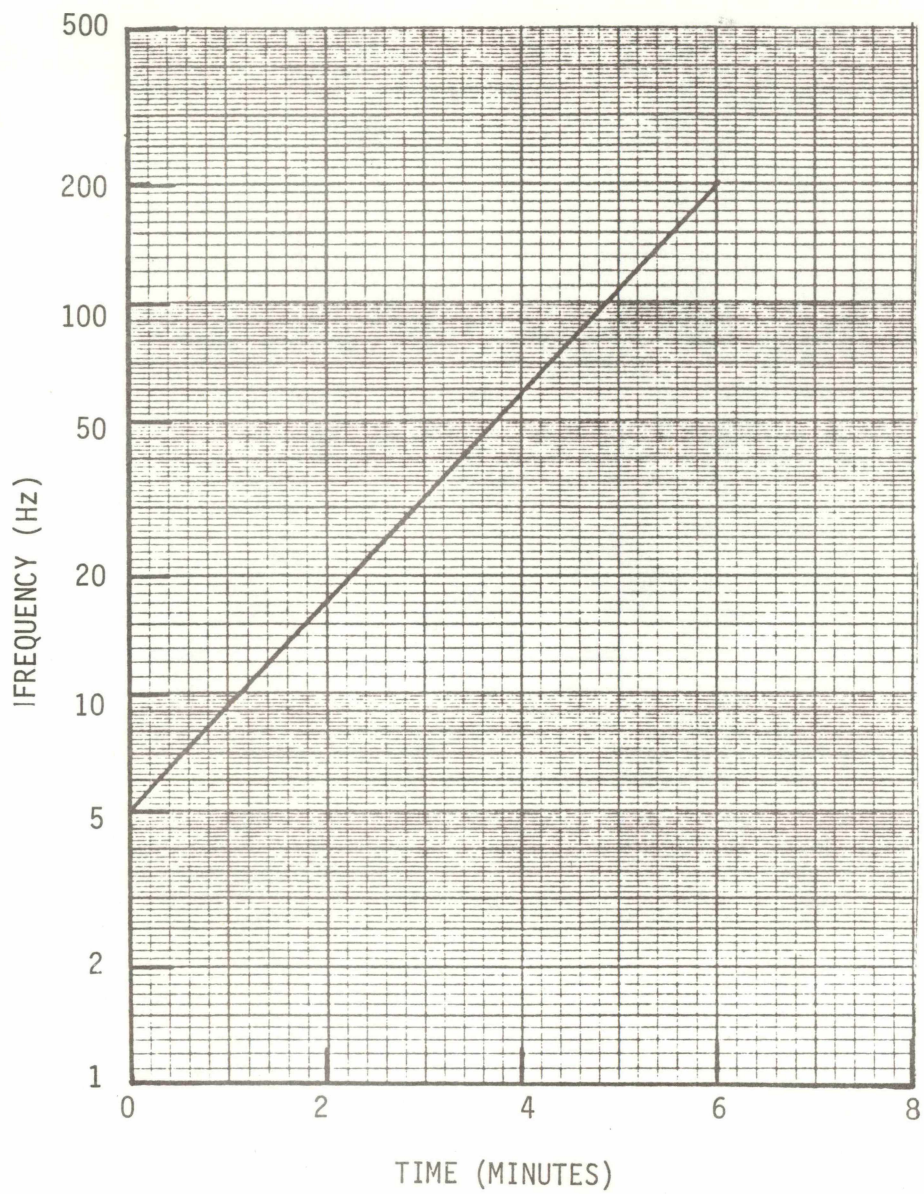


FIGURE A-2 LOGARITHMIC SWEEP OF VIBRATION FREQUENCIES



IIT Research Institute
10 West 35 Street, Chicago, Illinois 60616
312/567-4000

June 5, 1980

Mr. Donald Chenevert
Computer Sciences Corporation
Building 1100, TLR225
NSTL Station, Mississippi 39529

Subject: Additional Information for Vibration
Tests of Insulated Tank Car Specimens (T6016)

Dear Mr. Chenevert:

This information supplements the material in our letter of May 20, 1980. It represents a summary of things we have discussed over the telephone as well as some additional information I have gained from discussions with Mr. David Dancer at the FRA and Dr. Charles Anderson at BRL.

1. Additional Restraint for Jackets

The problem of jacket restraint within the test frame has been discussed several times. It would seem that the use of roll pins at each corner of the test frame would not provide sufficient restraint to hold the jacket against the insulation during the vibration test. It is likely that the vibration of the specimen would cause excessive movement of the jacket and perhaps even cause it to come loose from the roll pin restraint. Therefore, it is recommended that consideration be given to the construction of a simple 4 x 4 ft. restraint frame which can slip down inside the test frame providing support for the jacket on all four edges. This supplementary restraint frame would then be attached to the test frame by the roll pins. One possibility would be the use of 1 or 1½ inch angle for the construction of the additional restraint frame. A better appreciation for the behavior of the assembly during the vibration test and the possible need for additional restraint can be obtained when the materials are delivered to NSTL.

2. Mounting of Base Plate

Attention has been given to the manner of mounting the base plate to the vibration test platform. There would appear to be no problem with drilling and tapping holes in the base plate for the attachment of mounting bolts.

3. Vibration Measurements on Jacket

The preliminary instrumentation plan called for the acceleration level to be monitored on the top surface of the jacket. The easiest way to make this measurement would be to attach an accelerometer directly to the jacket. This would involve drilling a small hole in the jacket to allow the use of a mounting screw. Since there is the possibility that these insulation samples may be subsequently subjected to a torch test, it would be desirable to avoid drilling holes in the jacket plates. Therefore, if feasible, it would be preferable to monitor the vibration level of the jacket with a noncontacting probe. If this is impractical then a use of a small mounting hole will probably be acceptable.

4. Number of Base Plates and Frames

It is not yet certain how many base plates and frames will be sent to NSTL for the tests. There is some likelihood that only two base plates will be submitted, one 5/8 inch thick and the other 3/4 inch thick. If only two base plates are submitted, the frames will have to be switched on the plates once during the tests. The specimen drawing states that the frame is to be attached to the base plate by a tack weld around the edge of the plate.

The test schedule will call for examining the behavior of 4 different jacket plates with each type of insulation. It is our understanding that 2 samples of each insulation material will be submitted. This will permit changing out the insulation after 2 jacket tests are conducted.

5. Schedule

We understand that some difficulties have been encountered in pouring the foamed insulation samples for these tests. Another attempt is to be made tomorrow to make these insulation samples. The base plates, frames, and jackets have been fabricated. All of the base plates, frames, uncoated jackets and insulation samples, with the exception of the cork sample, will be sent to NSTL in one shipment. It is estimated that this shipment would not reach NSTL before the week of June 16. The cork insulation system has been delayed. It will be shipped separately when available. The cork will have to be cut to fit the test frame at NSTL.

It is intended that the jackets will be sent to the 3 companies which will provide insulating coatings by the end of this week. Another 2 to 3 weeks is anticipated for the coatings to be completed and for the jackets then to be sent directly to NSTL.

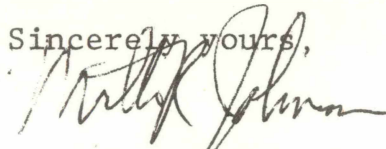
6. Inspection

One additional item should be included in the inspection plan.

Following each test the insulation material should be examined for signs of deterioration.

The information in this letter is intended to supplement our previous discussions. If you have any questions please call. Also, please let me know if you hear anything more about the delivery schedule for the test samples.

Sincerely yours,

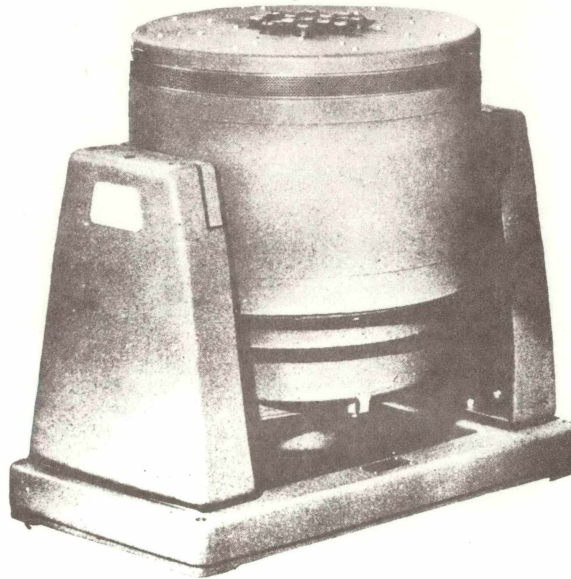
A handwritten signature in dark ink, appearing to read 'Milton R. Johnson', written over the typed name.

Milton R. Johnson
Senior Engineering Advisor
Transportation Research Division

MRJ/se

UNHOLTZ - DICKIE CORPORATION

vibration generation systems and measurement instruments



NEW 200 SHAKER SERIES FRAME SIZE
1200 TO 2200 POUNDS FORCE

- New Interchangeable Armatures
- Choice of 13 lb. or 20 lb. Armature
- Choice of Air or Water Cooled Field
- Massive Shaker Body minimizes Shaker Motion
- Most rugged Armature and Suspension. 2 year warranty on these items
- 1¼" stroke allows heavy unsupported loads
- Unmatched low cross axis motion

This standard 200 Frame Size Shaker gives various force and 'g' levels depending on the model chosen. Most of the shaker parts are easily interchanged. The most important options are the weight of the moving element, the choice of water or air cooled field coils and the choice of an integral or remotely located blower. A low cost, lower performance shaker with the Model 56 designation is also offered using this same 200 Frame Size.

The new lightweight armatures (PH Type Shaker designation) are designed for the latest high 'g' level test specifications. Up to 9 pound payload can be tested at 100 g.

MODEL 200 SPECIFICATIONS

Force Rating: 1200 - 2200 pounds vector sine

Frequency Range: 5 - 4000 cps; operable to higher frequencies

Stroke: 1¼ inch peak to peak

Overtravel Protection: Limit switch with 1/8" energy absorbing cushions

Axial Resonance: 3200 cps minimum

Moving Assembly Weight: 20 lbs.

Shaker Type PH 13 lbs.

Shaker Weight: 2900 lbs.

Suspension Stiffness: 600 lb./in.

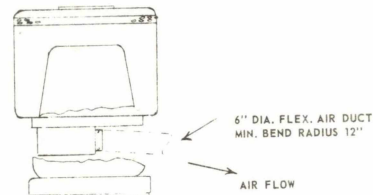
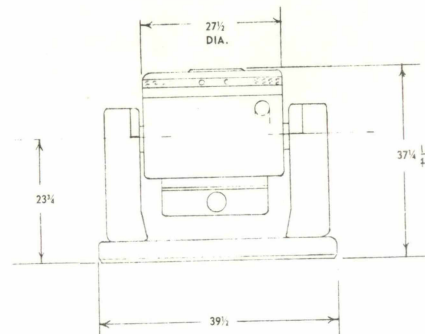
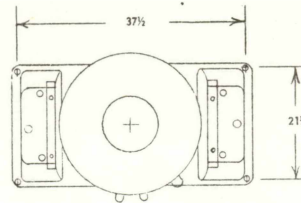
Shaker Type PH 300 lb./in.

Stray Magnetic Field: Less than 20 gauss 5/8" above table with full field. Less than 5 gauss with optional degauss coil.

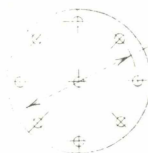
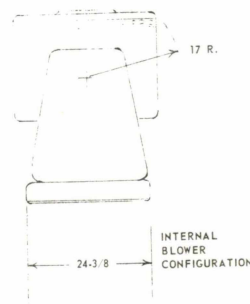
Motion Monitor: Accelerometer under center insert; Easily removable from the table top

Cooling: All models have air cooled driver coils. Choice of remote blower and duct (Type H designation). Model 206 and 56 have air cooled field coils. Model 200 has field cooled by ordinary clean tap water, thermostatically controlled, 2 gpm at 80°F max. All Field coils have overtemperature protection.

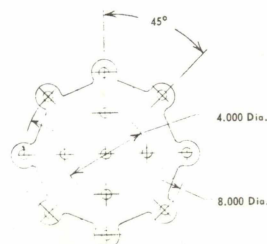
Trunnion: Full 360° rotation with locking at any angle. Vibration isolation in trunnion with isolation lockout independent of rotation locking. Trunnion suspension frequency less than 12 cps.



TYPE H SHAKER - REMOTE BLOWER CONFIGURATION



HOLE PATTERN
3/8 - 16 NC THDS
NINE HOLES
13 POUND ARMATURE
TYPE PH SHAKER



HOLE PATTERN
3/8 - 16 NC THDS
THIRTEEN HOLES
20 POUND ARMATURE

UNHOLTZ-DICKIE CORPORATION

2994 Whitney Avenue, Hamden, Connecticut,

Area Code 203 288-3358

Bull. S-4-65-1M
Printed U.S.A.

B-3

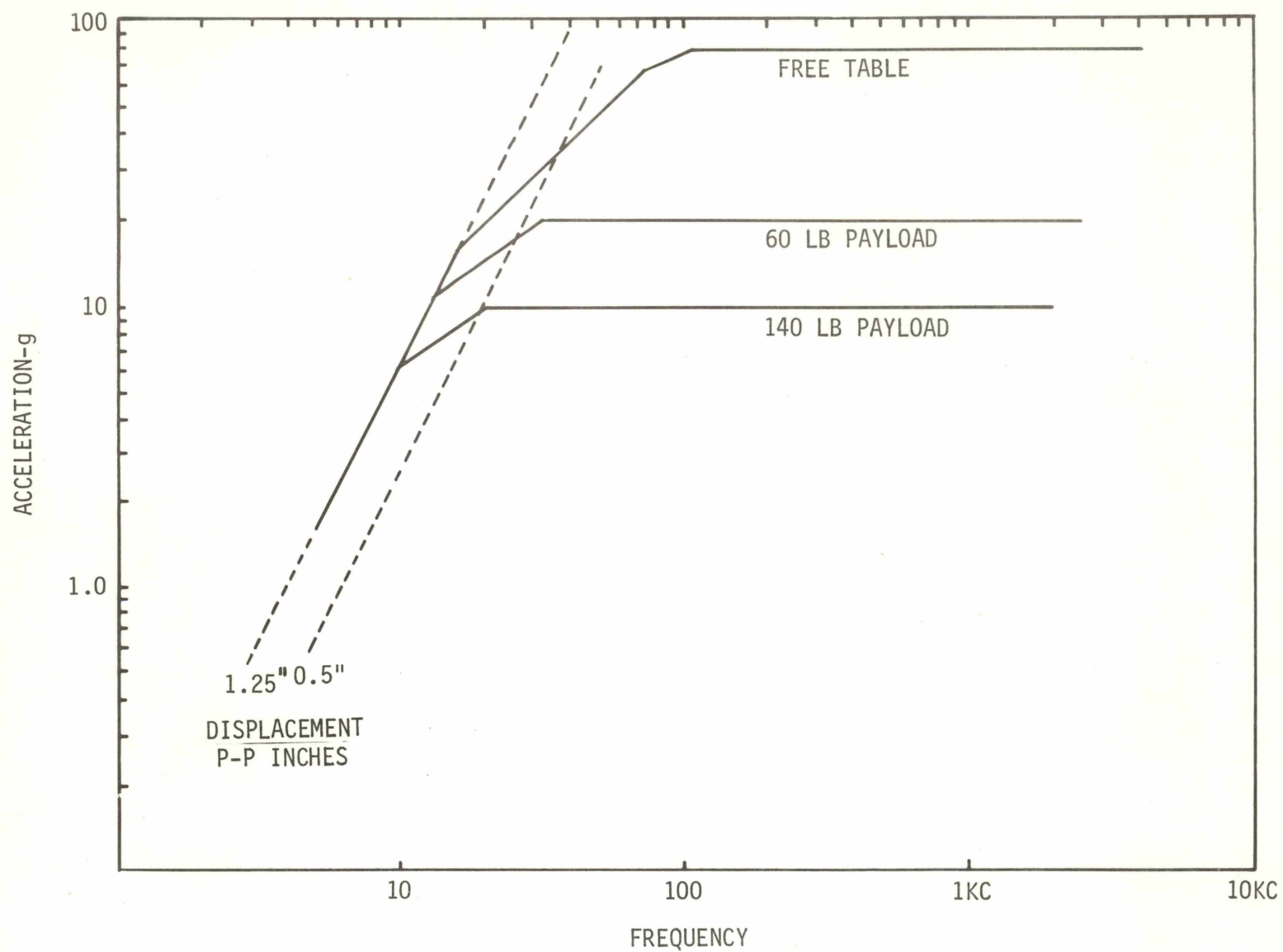


FIGURE B-1. UNHOLTZ-DICKIE CORPORATION RATED PERFORMANCE SYSTEM M4-5411.
(1600 LBS FORCE - 20 LB TABLE - MODEL 56 SHAKER)

APPENDIX C: FIXTURE DESIGN COMMENTS

Vibration test fixtures come in such a large variety of sizes and shapes that it is difficult to give general statements that can be useful for a particular design. However in working with our customers who are newcomers to the field of vibration, we have found a common problem which we feel warrants pointing out. Customers with long experience in fixture designs and applications will of course be aware of the problem to be discussed here and will have overcome it.

Many newcomers to approach fixture design from the viewpoint of static strength and stiffness. The fixture and load weight are estimated and multiplied by the 'g' level of the test. This yields the force transmitted. This force is usually quite modest in terms of static strengths so that the designer then proceeds to clamp the specimen to the fixture and the fixture to the shaker table with a few bolts and clamping sections which are entirely adequate to cope with these low static forces. This approach fails to account for the dynamic conditions that occur at the higher frequencies encountered in most vibration tests.

Usually when a fixture is designed with only static loads in mind, a very severe major resonance occurs within the frequency range of the test. The clamping and bolting arrangement, while adequate statically, turns out to be very soft or compliant when analyzed dynamically. In other words the mass of the test item and fixture is resonant on the soft springs consisting of the clamping arrangement to the shaker table.

There are at least two major objections to this resonant condition. The first is that the test item does not receive the correct 'g' level as controlled by the accelerometer in the shaker table. Due to the resonance, the 'g' level at the test item can be many times higher than the shaker 'g' read on the meter. This results in severe overtesting, sometimes damaging the specimen.

The second is that due to the resonance, there usually occurs a frequency where extremely high amplifier power is required to maintain constant 'g' at the shaker table. This can be observed by noting when the driver ammeter swings full to the maximum and pegs the needle. This results in severe overdrive, high distortion, shortened tube life, and blown fuses.

The cure is to design fixtures with the dynamic problems in mind. In practice, this means making the clamps and hold down bolts stiff relative to the masses involved, so that the resonance of the spring-mass system is as high as possible, preferably above the operating frequency.

A second cure is to control from an accelerometer located up on the fixture or test item. This is usually less convenient, for the accelerometer must be moved each time the fixtures are shifted on and off the table. It is sometimes the only solution, as for example, if the test item is so large that the resonance cannot be pushed above the operating frequency.

The following section describes some typical static fixture designs we have encountered, and the recommended changes to make them dynamically satisfactory.

Case I

The test items were small electrical components clamped to rectangular aluminum plates 5" x 5" x 1/2". These plates were then mounted on the fixture which was bolted permanently to the shaker table. The first design for the fixture was a welded box structure of 3/8" thick welded aluminum plates as in Fig. 1. It was impossible to run the tests because of the severe resonance below 1000 cps, and g levels on the test items were over 10 times as great as measured by the shaker accelerometer. The solution was the redesigned fixture shown in Fig. 2. This fixture was solid cube of magnesium, with drilled holes to remove weight. Also more of the hold down bolts into the shaker table were utilized. The resonance for this new fixture was moved up over 2 Kc and no testing difficulties were found.

Case II

In this test the specimen fitted into a cubical aluminum fixture. The fixture then was fastened at four points to a 1/4 inch thick aluminum adapter plate. The adapter plate was fastened at four other points to the shaker table. This adapter plate was in effect a very soft spring and a severe resonance occurred. Two solutions were possible. The fixture could be redesigned to bolt directly to the shaker table, using more than four bolts if possible. The second was to redesign the adapter plate. It was made of magnesium, about 1" thick. It was tied to the shaker table using all 13 holddown bolts available on that shaker. Additional bolts were added from the fixture to the plate. Figs. 3 and 4 show the before and after for this case.

Summary

Some of the points brought out by the above cases are:

1. Use as many of the hold down bolts to the shaker as possible.
2. Use magnesium instead of aluminum. Magnesium weight is about 65% of aluminum. Plate thickness can be made much thicker and stiffer with magnesium.

3. Avoid thin plates that can act as leaf springs, instead use solid, smaller fixtures. Weight can often be kept down by honeycombing with drilled holes, without affecting stiffness.
4. Use a minimum of joints or mating members. The omission of an intervening adapter plate almost always increases stiffness.
5. Two flat mating surfaces can be helped by a layer of silicone grease on the mating surfaces. This grease results in an adhesive action similar to the oil on Johanson gage blocks. This is particularly effective at high frequencies.
6. Use as many bolts, as possible, spaced as close as possible in bolting specimen to fixture, and fixture to adapter plates.
7. The fixture weight should not be the maximum allowed by the system performance. By making the static weight somewhat less, it allows for the higher dynamic loads that occur around resonance frequencies.

Several of the following references are helpful on vibration theory and dynamics of structures. Some give formula for stiffness of plates, beams etc. which are useful in fixture design.

1. "Handbook of Shock and Vibration"; Harris McGraw Hill
2. "Mechanical Vibrations"; Den Hartog 3rd Ed. McGraw Hill
3. "Mechanical Vibrations"; Thomson, Prentice Hall
4. "Vibration and Shock Isolation"; Crede; Wiley

POOR DESIGN

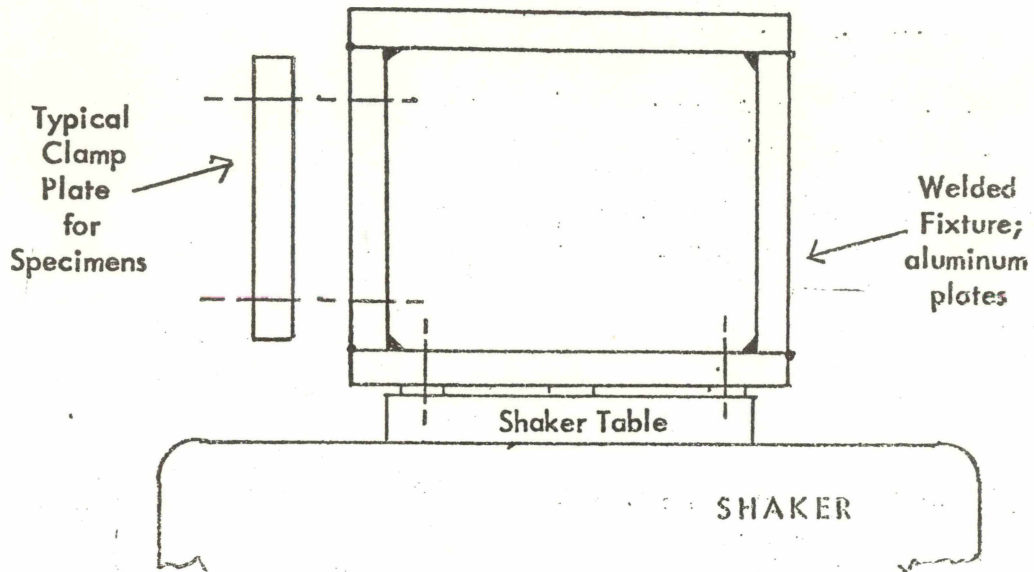


FIG. 1

REDESIGNED

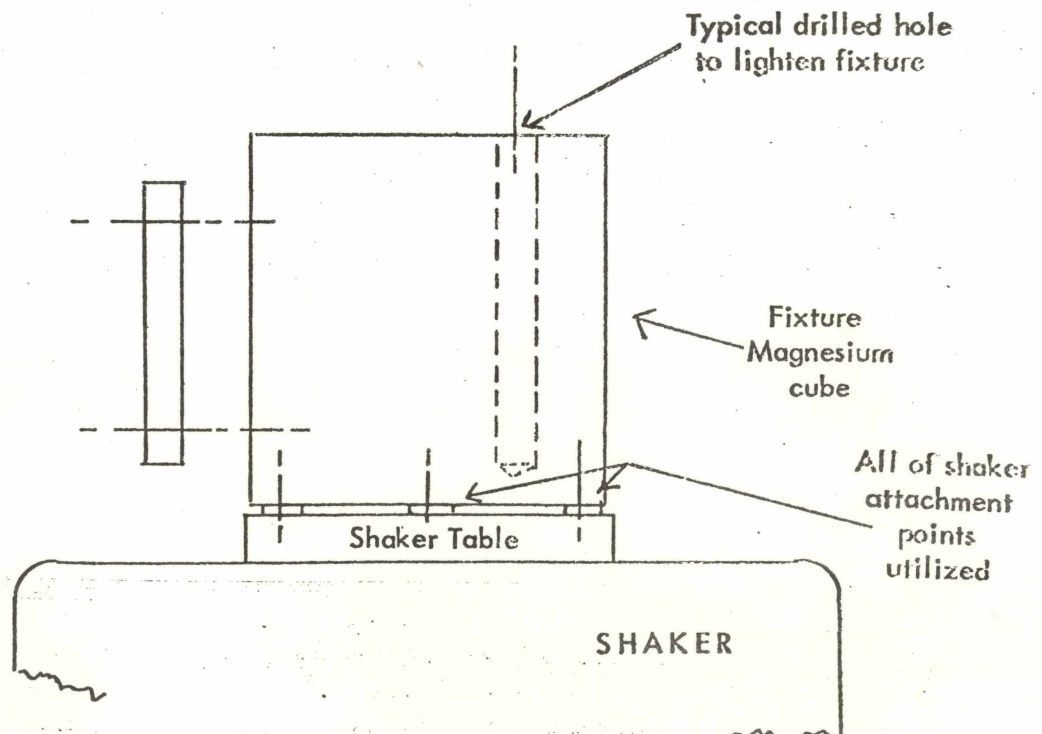


FIG. 2

POOR DESIGN

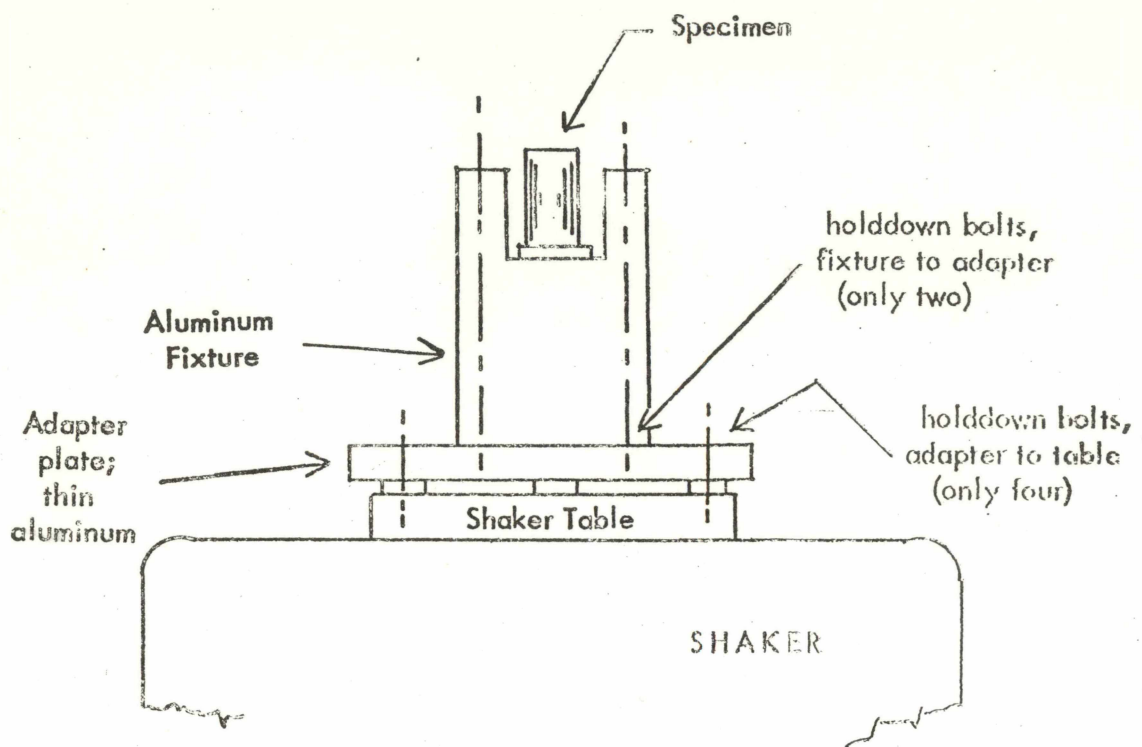


FIG. 3

REDESIGNED

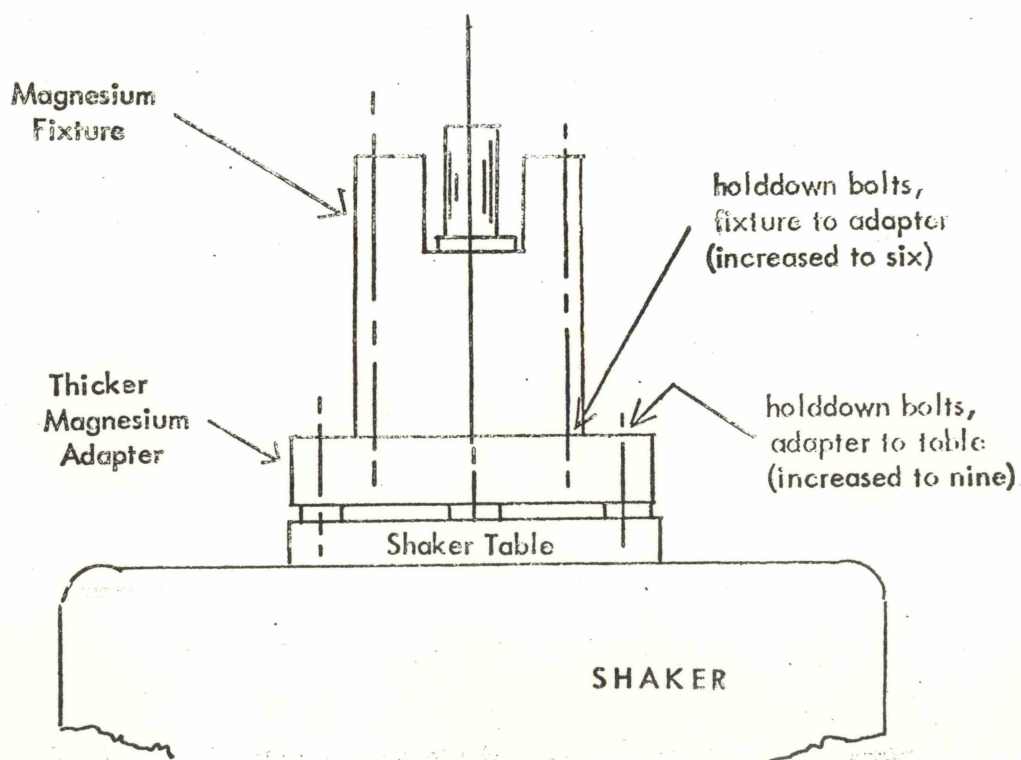


FIG. 4

PROPERTY OF FRA
RESEARCH & DEVELOPMENT
LIBRARY

Vibration Testing of Railroad Tank Car Specimens
(Final Report), JE Harris, WE Pierce, 1981-14-
HazMat

Vibration Testing of Railroad Tank Car Specimens
(Final Report), JE Harris, WE Pierce, 1981-14-
HazMat