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# SHUTTLE/AGENA STUDY

FINAL REPORT

PREPARED FOR
THE NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER • HOUSTON, TEXAS

CONTRACT NAS9-11949

LMSC
SPACE SYSTEMS
DIVISION

## ANNEX C

## SPACE SHUTTLE CANDIDATE INSULATOR/PROPELLANT COMPATIBILITY TEST PROGRAM

LOCKHEED MISSILES & SPACE COMPANY, INC.
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SUNNYVALE, CALIFORNIA

# SHUTTLE/AGENA STUDY FINAL REPORT

## Annex C
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Submitted to the
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

LOCKHEED MISSILES & SPACE COMPANY, INC.
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# FOREWORD

Annex C contains supplemental data pertinent to the Shuttle/Agena Study Final Report. Although not required under Contract NAS9-11949, this preliminary information on the compatibility of candidate shuttle insulator material with earth-storable propellants should prove helpful in any evaluation of Agena capabilities for the proposed space tug missions. It is therefore included as a useful adjunct to the Final Report.

Annex C

# SPACE SHUTTLE CANDIDATE INSULATOR/PROPELLANT COMPATIBILITY TEST PROGRAM

It is recognized that some of the Agena space tug propellants could be absorbed by the space shuttle orbiter vehicle's reentry thermal insulation material during an emergency orbital propellant dump. A preliminary test program has been completed with the objective of determining the compatibility of two space shuttle candidate insulation samples with earth-storable propellants. The candidate insulation materials selected were SLA 561 (furnished by NASA) and LI 1500 (furnished by LMSC).

The test program involved nine 2 by 2 by 1 inch samples of each type of material. One sample was not tested and was utilized as a control sample. The propellant combinations used were inhibited red fuming nitric acid (IRFNA); a mixture of IRFNA and nitrogen tetroxide, $N_2O_4$; and unsymmetrical dimethyl hydrazine (UDMH). The test setup is shown in Figs. 1 through 3; pre- and post-test photos of the test samples are shown in Figs. 4 through 8.

Two propellant exposure procedures were followed:

1. The specimens were placed in a vacuum chamber that was then evacuated to less than 10 microns. Propellant vapor was slowly injected into the chamber and held for approximately 2 hours.
2. The specimens were placed in an open-mouth container. Liquid propellant was admitted to the container at atmospheric conditions (approximately 60°F and 13.7 psia) and held for 2 hours.

Following exposure to propellants, all specimens were placed in an aluminum foil container and heated to 850°F for 5 minutes.

All specimens were weighed and a thermal conductivity index was determined before and after testing. Determination of an accurate, one-direction thermal conductivity value, using the standard equation

$$k = \frac{QL}{A\Delta T}$$

was not possible because the area-to-thickness ratio, A/L, was too small and sample edge heat losses could not be accounted for in the testing setup. Therefore, a thermal "conductivity index" was established in an attempt to evaluate possible degradation of sample chemical conductivity after propellant exposure and thermal conditioning. This conductivity index was calculated from the following equation:

$$\text{conductivity index} = \frac{\text{power input}}{\text{temperature differential}}$$

No conclusion as to actual thermal conductivity change can be drawn from the conductivity index values (see Table C-1) because of the measurement inaccuracies involved. However, it does appear that the thermal characteristics of the SLA 561 samples sustained a change; the thermal characteristics of the LI 1500 samples were apparently unchanged.

It is recommended that samples at least 12 by 12 inches in size be used for any future test programs of this type.

Table C-1

SPACE SHUTTLE INSULATION COMPATIBILITY TEST DATA

a. LI 1500 (Furnished by LMSC)

| Sample No. | Pre-Exposure Weight (grams) | Post-Exposure Weight (grams) | Pre-Exposure Cond Index | Post-Exposure Cond Index | Propellant | Procedure* | Propellant Exposure Visual Inspection | Heat Cycle** Visual Inspection |
|---|---|---|---|---|---|---|---|---|
| 1 | 16.9 | 16.0 | 0.011 | 0.011 | IRFNA | 1 | No change observed | No change observed |
| 2 | 16.0 | 15.1 | 0.012 | 0.011 | IRFNA | 1 | No change observed | No change observed |
| 3 | 16.0 | 16.1 | 0.011 | 0.011 | HDA | 1 | No change observed | Limited brownish spotting |
| 4 | 15.9 | 15.9 | 0.011 | 0.012 | HDA | 1 | No change observed | Limited brownish spotting |
| 5 | 17.3 | 17.5 | 0.011 | 0.011 | UDMH | 1 | Sample had yellowish tint | Yellow tint disappeared |
| 6 | 16.4 | 15.7 | 0.011 | 0.011 | IRFNA | 2 | Sample soaked up acid; no damage | No damage; vaporizing acid could be seen during heating; slight brown discoloration |
| 7 | 16.0 | 16.1 | 0.010 | 0.011 | HDA | 2 | Same as above | Same as above |
| 8 | 16.4 | 17.5 | 0.011 | 0.011 | UDMH | 2 | Sample soaked up UDMH; no damage | No damage; UDMH burned during heating but went out after heat off; some slight discoloration |

*Procedure 1: Specimen installed in vacuum chamber that was evacuated to less than 10 microns. Propellant vapors slowly injected into chamber and held for approximately 2 hours.

Procedure 2: Specimen put in an open-mouth container. Liquid propellant at atmospheric conditions (approximately 60°F and 13.7 psia) admitted to container and held for 2 hours.

**Heat Cycle: Specimen installed in aluminum foil container and heated to 850°F for 5 minutes.

Table C-1 (cont)

b. SLA 561 (Furnished by NASA)

| Sample No. | Pre-Exposure Weight (grams) | Post-Exposure Weight (grams) | Pre-Exposure Cond Index | Post-Exposure Cond Index | Propellant | Procedure* | Propellant Exposure Visual Inspection | Heat Cycle** Visual Inspection |
|---|---|---|---|---|---|---|---|---|
| 1 | 13.9 | 6.8 | 0.011 | 0.012 | IRFNA | 1 | No change observed | Self-ignited during heating; outer surface burned black |
| 2 | 14.8 | 8.4 | 0.011 | 0.012 | IRFNA | 1 | No change observed | Same as above |
| 3 | 13.8 | 7.8 | 0.018 | 0.019 | HDA | 1 | No change observed | Same as above |
| 4 | 14.0 | 8.5 | 0.018 | 0.018 | HDA | 1 | No change observed | Same as above |
| 5 | 14.3 | 10.0 | 0.011 | 0.012 | UDMH | 1 | No change observed | Self-ignited at less than 500°F; temperature exceeded 850°F due to UDMH burning; sample black and cracked |
| 6 | 14.0 | -- | 0.012 | -- | IRFNA | 2 | Outer surfaces of sample disintegrated. Sample loaded up with acid and was too corrosive to handle. Therefore, post-exposure weight and heat cycle deleted. | -- |
| 7 | 14.4 | -- | 0.011 | -- | HDA | 2 | Same as above | -- |
| 8 | 14.8 | 10.0 | 0.011 | 0.012 | UDMH | 2 | No visual change but sample soaked up a lot of UDMH | Self-ignited at less than 500°F; temperature exceeded 850°F due to UDMH burning; sample black and cracked |

*Procedure 1: Specimen installed in vacuum chamber that was evacuated to less than 10 microns. Propellant vapors slowly injected into chamber and held for approximately 2 hours.

Procedure 2: Specimen put in an open-mouth container. Liquid propellant at atmospheric conditions (approximately 60°F and 13.7 psia) admitted to container and held for 2 hours.

**Heat Cycle: Specimen installed in aluminum foil container and heated to 850°F for 5 minutes.

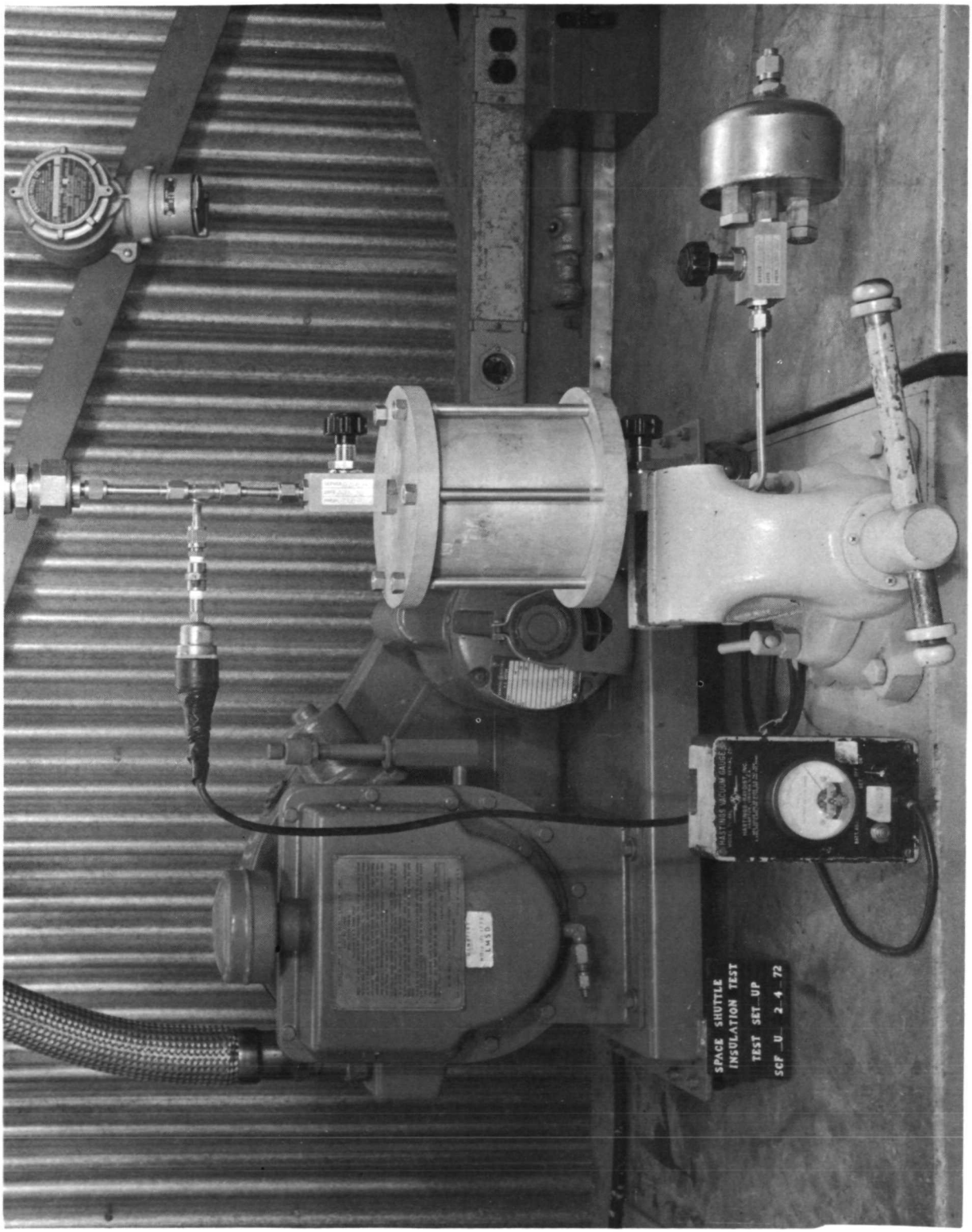


Fig. 1 Vacuum Chamber Setup

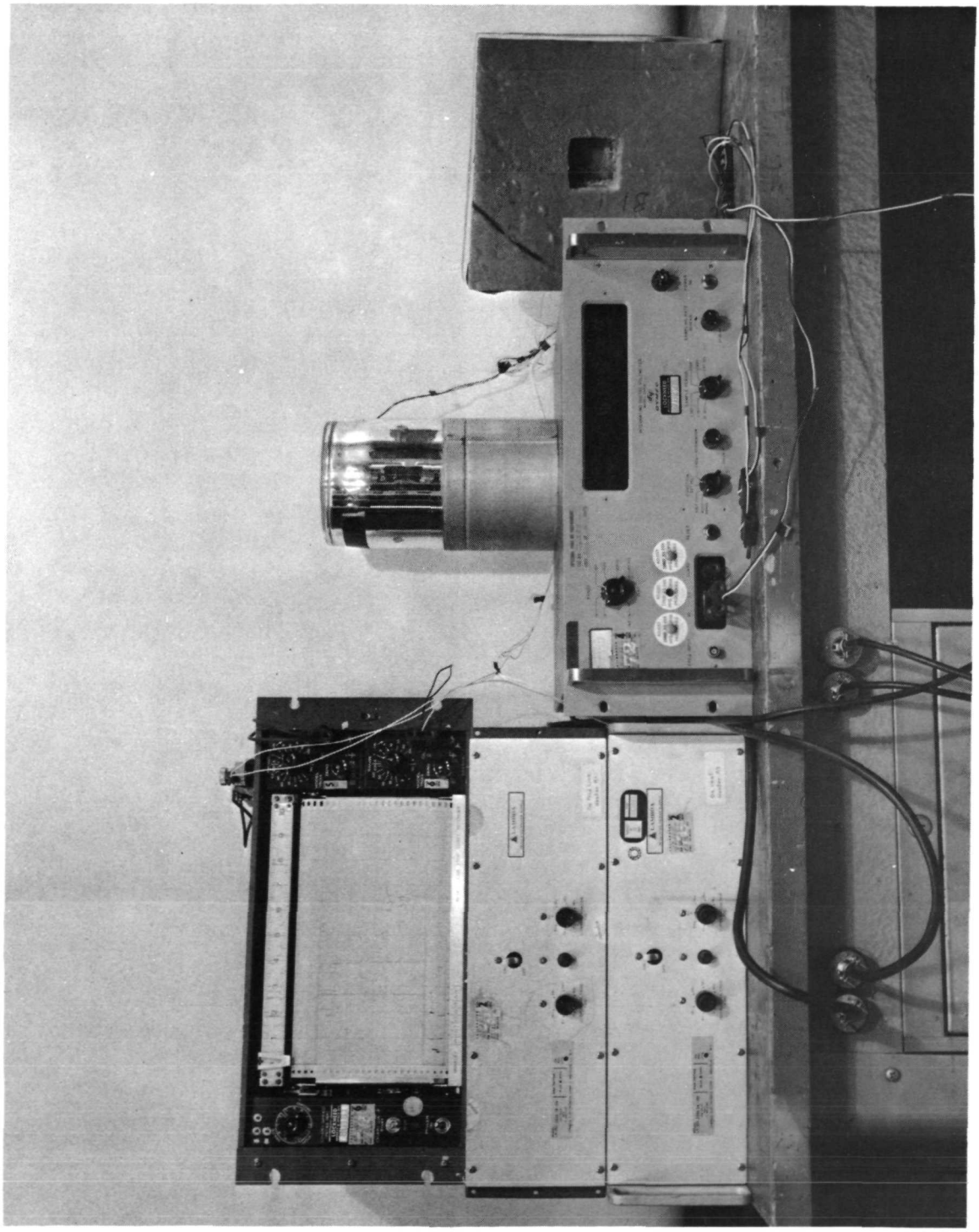

Fig. 2 Thermal Conductivity Measurement Setup

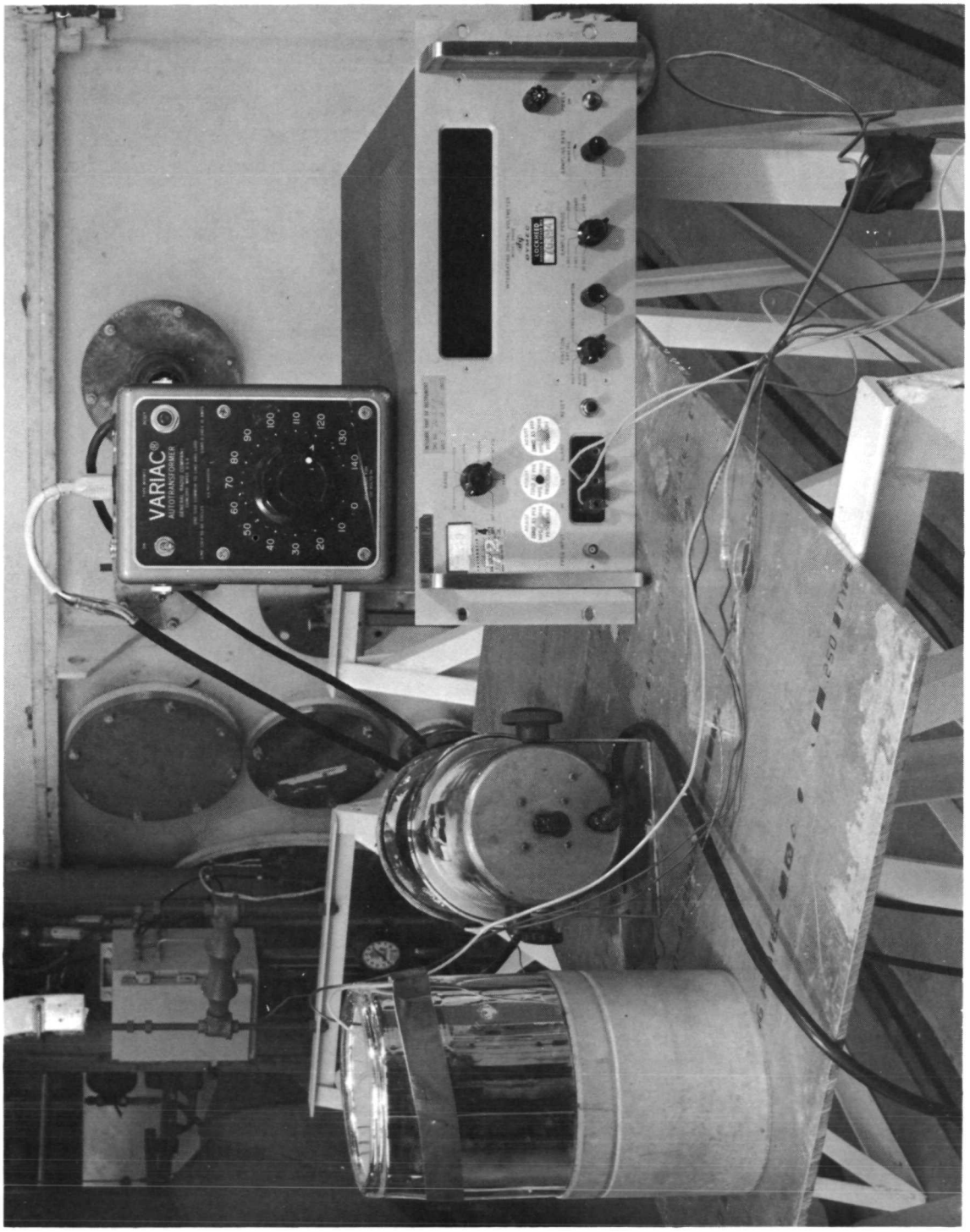


Fig. 3 Heat Environment Test Setup

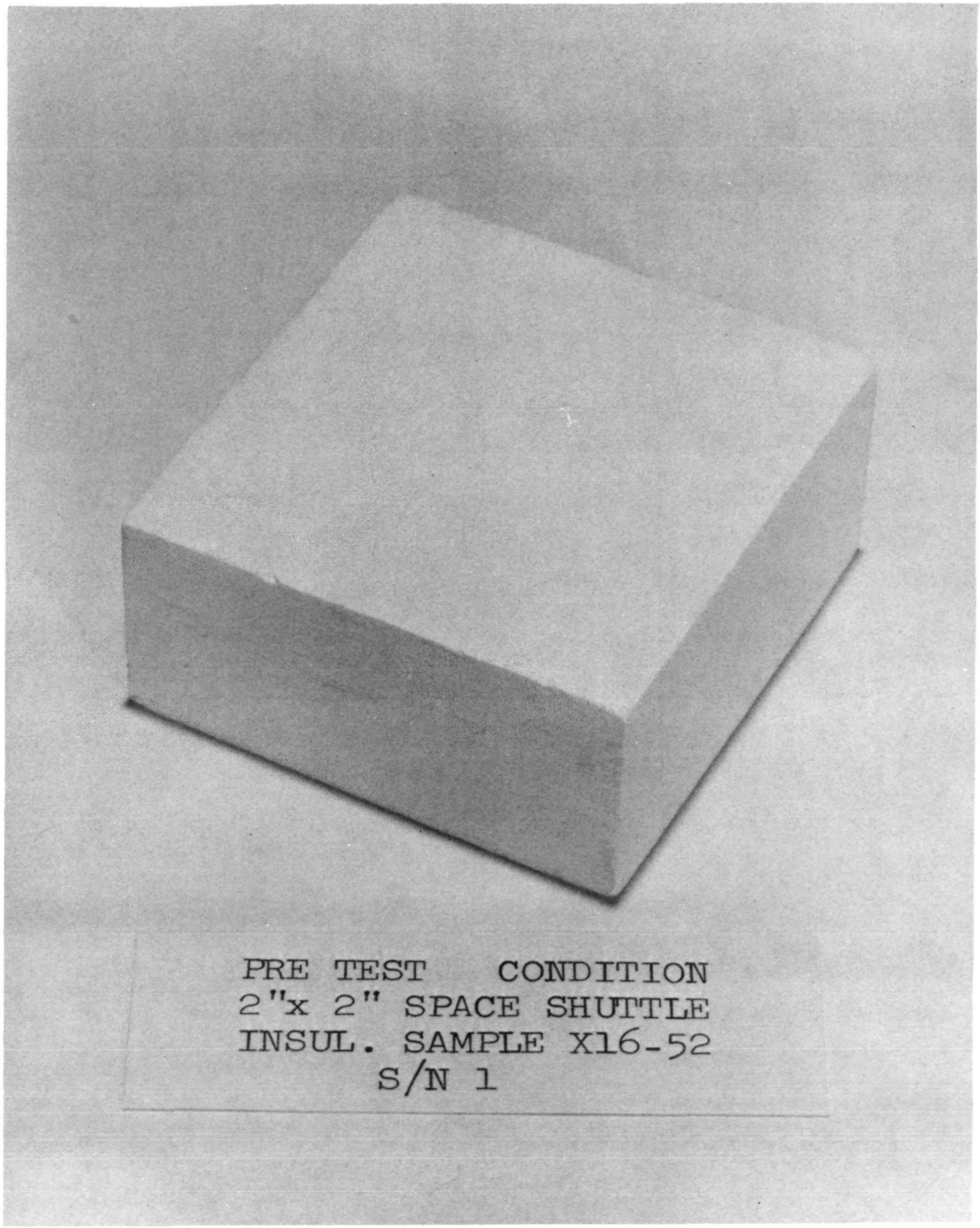


Fig. 4 LI 1500 Sample 1 (Pretest)

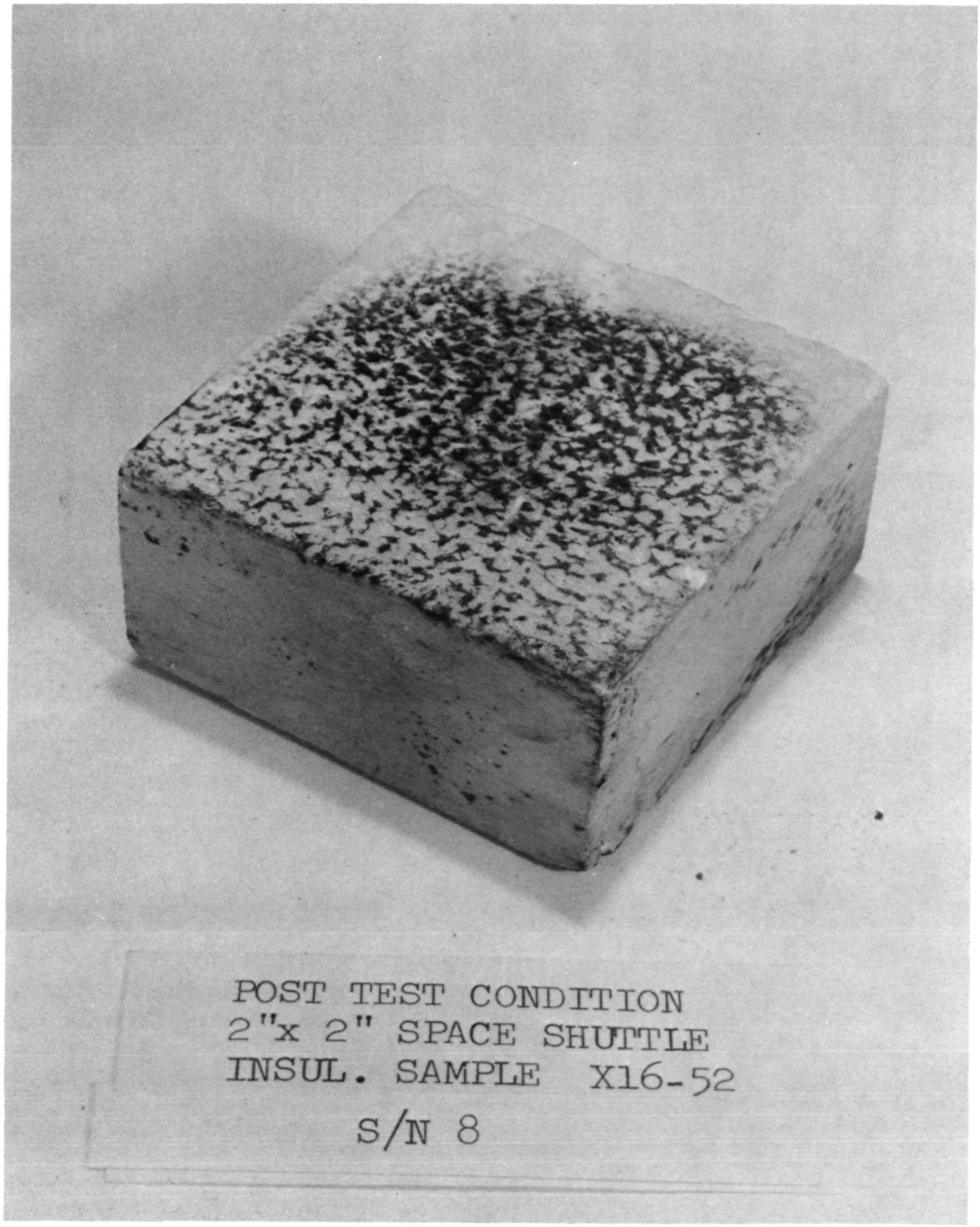


Fig. 5 LI 1500 Sample 8 (Post-Test)

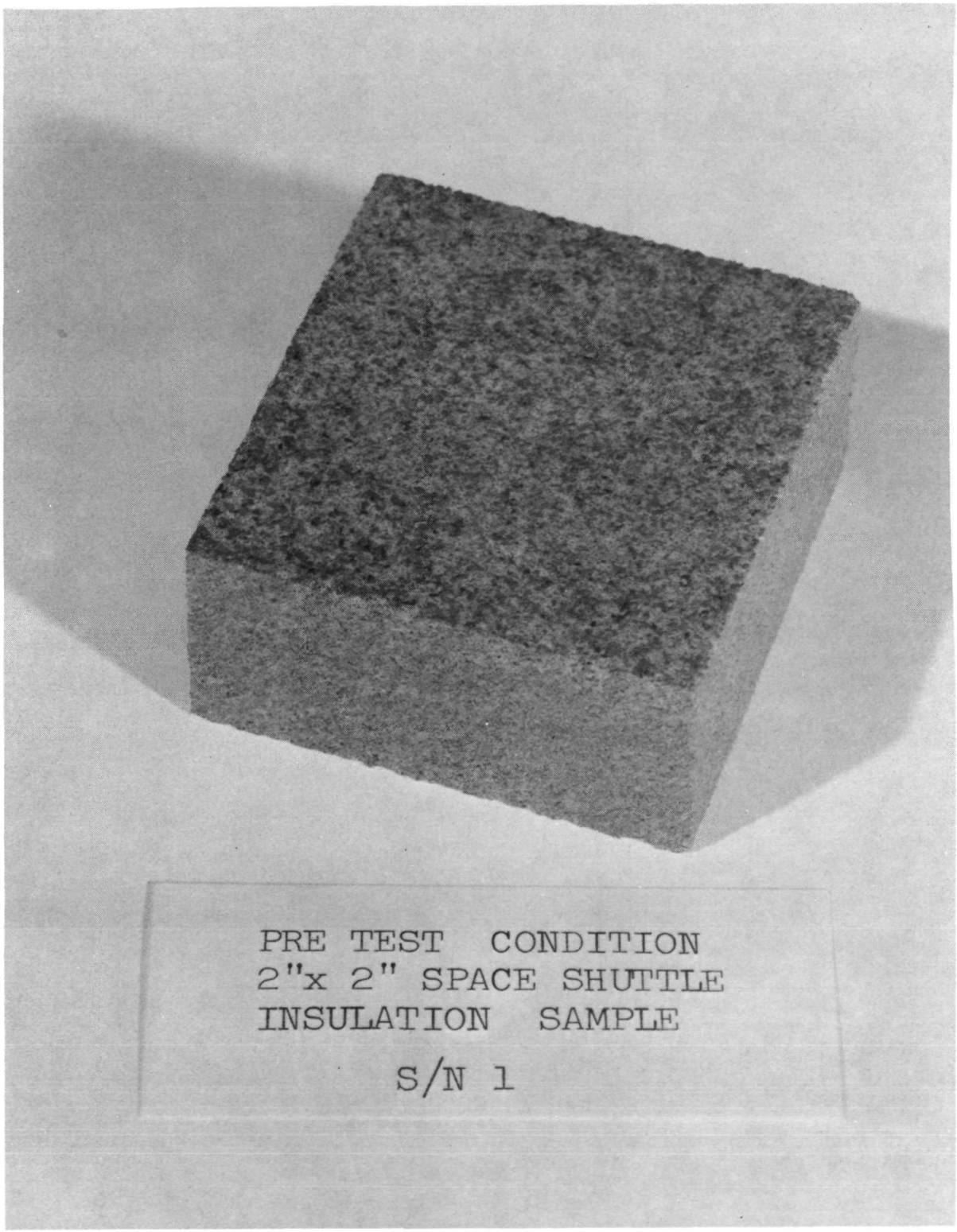


Fig. 6 SLA 561 Sample 1 (Pretest)

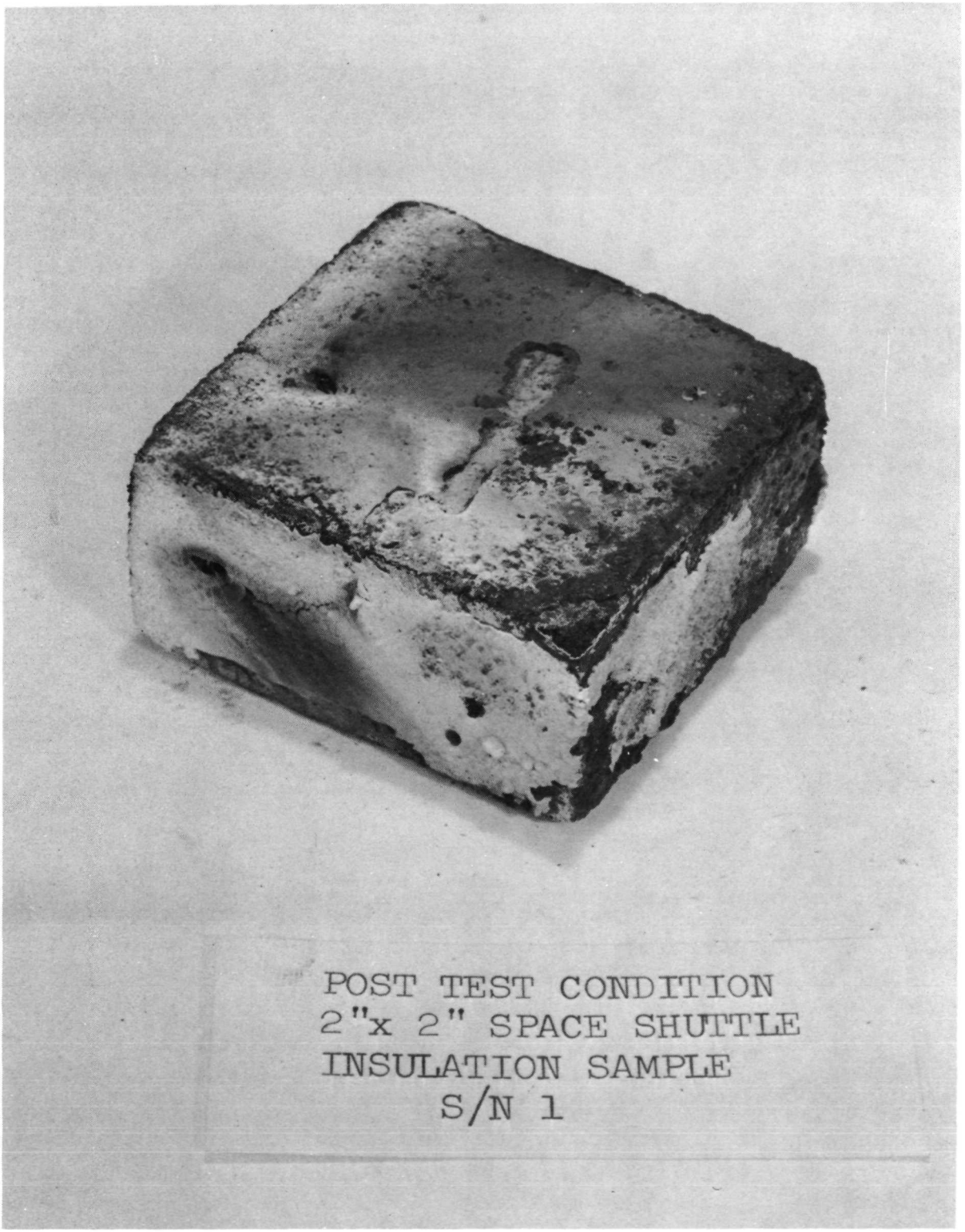


Fig. 7 SLA 561 Sample 1 (Post-Test)


Fig. 8 SLA 561 Sample 3 (Post-Test)

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