NASA TECHNICAL MEMORANDUM

NASA TM X-2965

NASA TM X-2965

EFFECTS OF SIMULATED SPACE ENVIRONMENT ON SKYLAB PARASOL MATERIAL

by Wayne S. Slemp

Langley Research Center
Hampton, Va. 23665

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MAY 1974

1. Report No. NASA TM X-2965	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EFFECTS OF SIMULATED SPACE ENVIRONMENT ON SKYLAB PARASOL MATERIAL		5. Report Date May 1974
		6. Performing Organization Code
7. Author(s) Wayne S. Slemp		8. Performing Organization Report No. L-9344
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23665		10. Work Unit No. 502-21-27-01
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A material consisting of ripstop nylon bonded to the Mylar side of aluminized Mylar film was used to construct the first Skylab parasol. The mechanical properties of elongation and tensile strength and the radiative properties of solar absorptance and thermal emittance were measured before and after exposure to simulated solar radiation at intensities of 1.0 and 3.5 solar constants for exposure times as long as 947 hours or 3316 equivalent solar hours. The accelerated testing indicated more severe degradation than was experienced in the real-time test (1 solar constant). The results predicted that this material could have given satisfactory performance throughout the planned lifetime of the Skylab workshop.

17. Key Words (Suggested by Author(s))		18. Distribution Statement	
Simulated solar radiation Polymeric material Elongation Tensile strength Solar absorptance		Unclassified – Unlimited STAR Category 18	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 19	22. Price* $3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

EFFECTS OF SIMULATED SPACE ENVIRONMENT
ON SKYLAB PARASOL MATERIAL

By Wayne S. Slemp
Langley Research Center

SUMMARY

A series of tests have been conducted to evaluate the effects of the space environment on the ripstop nylon bonded to the Mylar side of the aluminized Mylar film used for the first Skylab parasol. These tests included exposure of the samples in high vacuum to simulated solar radiation at intensities of 1.0 and 3.5 solar constants for exposure times as long as 3316 equivalent solar hours. The mechanical properties of elongation and tensile strength and the radiative properties of solar absorptance and thermal emittance were measured for the exposed samples and compared to the respective values for the unirradiated material. The results indicated that the accelerated testing predicted more severe degradation than would be experienced if the tests had been conducted in real-time conditions. Even with the severe degradation rate experienced in the 3.5 solar constant test, the material retained over 55 percent of its original tensile strength and elongation, and had only a 10-percent increase in its ratio of solar absorptance to thermal emittance after 3316 equivalent solar hours of exposure.

INTRODUCTION

The loss of the meteoroid shield and its thermal control surface from the orbital workshop of Skylab I caused the workshop to experience an excessively high equilibrum temperature. To alleviate this thermal control problem, a parasol, constructed at the Johnson Space Center, was deployed by the first Skylab crew. This parasol shaded the damaged area of the workshop from direct solar radiation and thus lowered the workshop temperature to about 298 K (76.7° F).

The parasol was constructed of a laminated material consisting of an orange ripstop nylon bonded to the Mylar side of aluminized Mylar film. This material was deployed over the orbital workshop with the orange nylon side facing the sun.

At the request of the Johnson Space Center, a series of simulated solar radiation tests was conducted by the Langley Research Center to determine if this parasol material would satisfactorily perform its function for approximately 7 months (about 3000 hours of solar irradiation), corresponding to the estimated lifetime of the Skylab workshop. Both mechanical and radiative properties were measured after exposure to a simulated space radiation environment and compared to the same properties of the unexposed material.

Another series of tests was also included in this program to check the validity of using highly accelerated testing to evaluate this material.

Values are given in both SI and U.S. Customary Units. The measurements and calculations were made in U.S. Customary Units.

MATERIAL

The material, supplied by the Johnson Space Center, was a laminate consisting of an orange ripstop nylon 37 g/m^2 (1.1 oz/yd^2) bonded to the Mylar side of 0.013 mm (1/2 mil) aluminized Mylar film using polyester adhesive. The thickness of the vapor-deposited aluminum was approximately 1200 Å (1 Å = 10^{-10} m). The total thickness was 0.081 mm (3.2 mils) and weight was 54 g/m^2 (1.6 oz/yd^2). Figure 1 is a photomicrograph showing the weave of the ripstop nylon at $\times 5$ magnification. The weave is sufficiently open, as shown by the dark lines, to allow the solar radiation to penetrate through the adhesive and Mylar to the vapor-deposited aluminum over a high percentage of the material's surface. This allows the solar radiation to damage the adhesive and Mylar.

APPARATUS AND TEST PROCEDURE

Simulated Space Environment System

The system used to expose the test samples to a simulated space environment of high vacuum and solar radiation is shown in figure 2. Two solar simulators and high vacuum chambers with identical construction were used to conduct the irradiation portion of this test program. Each of these simulators used three 2500-watt xenon arc lamps as the radiation source. These simulators are optically filtered to give a spectral output which approximates the solar spectrum. In table I this spectral output is shown for wavelength bands from 0.22 to 2.7 μm and compared to the U.S. Naval Research Laboratory (NRL) solar energy spectrum. This table was developed by the manufacturer of the solar simulators. The lamps and optics in each simulator were thoroughly inspected prior to this study, but because of time and equipment constraints, the spectral output was not checked. There is no reason to suspect a substantial change in the spectral output of these simulators from that listed in table I.

The typical uniformity of the 26.7-cm-diameter (10.5-in.) simulator beam is given in figure 3. The beam has good uniformity for this diameter. Although this uniformity was determined earlier, it was checked at five points just prior to sample irradiation (fig. 4). This figure shows that there was little deviation from the earlier data. The simulators are constructed so that each of the three lamps can be operated separately to vary the intensity of radiation incident on the test samples from 0.5 to 3.5 equivalent solar constants. A solar constant is defined as the irradiance of the solar radiation incident on a finite body 1 astronomical unit from the Sun. The intensity of the radiation incident on the test sample is determined by use of a National Bureau of Standards secondary-calibrated radiometer which reads directly in mW/cm^2. One solar constant was assumed to be 135.3 mW/cm^2 (1.940 $cal/min\text{-}cm^2$) (ref. 1).

Each vacuum chamber was evacuated by a mechanical roughing pump and an oil diffusion pump to a pressure between 1.3 mPa (8.96 psi) and 13 μPa (0.0896 psi). Chevron baffles cooled by liquid nitrogen were used between the pumps and the chamber to prevent possible contamination of the samples with diffusion pump oil. The vacuum chambers have a 30.5-cm-diameter (12-in.) window of ultraviolet-grade Suprasil II quartz, which transmits the simulated solar radiation to the test sample. The samples were mounted vertically in the vacuum chamber on a water-cooled copper plate as shown in figure 5. An aluminum frame (fig. 6) was used to hold the samples in place during irradiation and allows only 6.45 cm^2 (1 in^2) of each sample to be exposed to the simulated solar radiation. A high-thermal conductivity, low-outgassing thermal grease was used between the samples and the water-cooled plate to assure good temperature control of the test samples. The samples were maintained at 355 ± 5 K (180 ± 9° F), the predicted temperature of the parasol in orbit, by regulation of the cooling water flow to the sample mounting plate. Three thermocouples were attached to the back of the sample mounting plate as shown in figure 7 and the output of these thermocouples was monitored continuously by a type of potentiometer strip chart recorder calibrated over the required temperature range.

Identical samples were installed in each vacuum chamber. One set was irradiated at an intensity of 3.5 solar constants while the other set was irradiated at 1 solar constant. Specimens exposed to 3.5 solar constants for 196 hours (686 equivalent solar hours) were compared to specimens exposed to 1 solar constant for 686 hours. These data were used to check the validity of the accelerated testing.

Mechanical Property Tests

The mechanical properties (elongation and tensile strength) were measured on a commercially available power-driven testing machine with a constant rate-of-jaw separation. This testing machine is autographic giving a linear chart with the inches of jaw separation on one axis and the applied tension as the other axis of the chart coordinates.

The initial tests were conducted with pneumatic actuated grips. However, analysis of the data suggested that these grips were allowing the samples to slip, giving high values of elongation. In discussing this problem with the manufacturer of the testing machine, it was found that these grips are faced with an asbestos impregnated material, similar to standard automotive brake shoes, so that these grips can be used at elevated temperature. As the grips are used, the faces tend to become smooth and can allow the test sample to slip. In order to continue using these grips, the faces must be roughened or replaced. Mechanical grips were then installed and all mechanical property data reported in table II were produced with these mechanical grips. It should also be noted that all samples failed in the middle of the gage length thus indicating that sample failure was not initiated by the grips.

In order that these tests could be compared directly to earlier data generated by the Johnson Space Center, the following parameters were used in conducting these tests:

Sample width, cm (in.)	2.54 (1)
Sample irradiated area, cm^2 (in^2)	6.45 (1)
Gage length, cm (in.)	2.92 (1.15)
Cross-head speed, cm/sec (in/sec)	0.84 (0.33)

The fabric was pulled in the warp direction.

Radiative Property Tests

The radiative properties which determine the equilibrium temperature of a body in space are its solar absorptance (α_S) and thermal emittance (ϵ_T) (ref. 2). The measurement of these properties for the side of the material facing the Sun with respect to the equivalent solar hours of irradiation was a requirement for this test program.

The solar absorptance was calculated from spectral reflectance measurements using a digital computer as described in reference 3. The spectral reflectance measurements are made by using the spectroreflectometer shown in figure 8. This spectroreflectometer is a dual-beam ratio-recording instrument equipped with an absolute-measurement-type integrating sphere. The sphere is constructed to allow center mounting of a test sample and provides absolute reflectance measurements (does not require a reference standard). The interior of the sphere was coated with an opaque coating of barium sulfate which has proven more durable than the conventional magnesium oxide coating while still providing the diffuse, highly reflective wall coating required for these measurements. The spectroreflectometer was equipped with tungsten and xenon arc sources and with a photomultiplier and lead sulfide detectors to allow efficient operation over the wavelength range from 0.22 μm to 2.65 μm.

A portable total normal emittance $(\epsilon_{t,n})$ apparatus, whose principle of operation is described in reference 4, was used to measure the thermal emittance of the test samples.

RESULTS AND DISCUSSION

The results of the mechanical property tests on both the irradiated and unirradiated parasol material are shown in table II. The material which was irradiated at 3.5 solar constants for 3316 equivalent solar hours (ESH) had a decrease in the percent-elongation from 34.5 to 19.4 (a 44-percent decrease) while the tensile strength decreased from 253.2 N (56.9 lb) to 150.9 N (33.9 lb) (a 40-percent loss).

The ratio of solar absorptance (α_s) to total normal emittance $(\epsilon_{t,n})$ decreased from 0.59 at 0 ESH to 0.56 at 686 ESH, but then showed an increase to 0.65 after 3316 ESH of irradiation. This was approximately a 10-percent increase in $\alpha_s/\epsilon_{t,n}$ from 0 ESH to 3316 ESH. The orange ripstop nylon changed to a gold color during the first 200 ESH of irradiation and this gold color became darker as the ESH of exposure increased. The spectral reflectance of this material prior to irradiation and at 686 and 3316 ESH of irradiation is shown in figure 9. The change in slope of the absorption edge at approximately 0.6 μm accounts for the slight decrease in the solar absorptance at 686 ESH although the material shows a decrease in reflectance from 0.6 to 2.6 μm. The 3316 ESH curve shows a marked decrease in reflectance from 0.6 to 1.3 μm thus accounting for its increase in solar absorptance.

At 686 ESH of exposure a set of samples was removed from the 3.5 solar constant accelerated test to be compared with the test samples exposed at 1 solar constant. These data, also shown in table II, indicate that the 3.5 solar constant test is much more severe than the 1 solar constant test. The accelerated test samples had a 39-percent decrease in elongation and a 38-percent decrease in tensile strength (virtually the same as those exposed for 3316 ESH), while the samples exposed to 1 solar constant for an equivalent period of time showed only a 19-percent decrease in elongation and a 22-percent decrease in tensile strength. The solar absorptance and thermal emittance are virtually the same for each condition. Figure 10 shows the slight difference in the reflectance from the 0.8- to 1.5-μm absorption edge. Although the radiation properties show little difference between the 1 and 3.5 solar-constant tests, these mechanical property data cast some doubt on the validity of using highly accelerated tests to evaluate this material.

Figure 11 presents typical distance curves as a function of force for the parasol material as obtained from the mechanical property testing machine. The significance in presenting these curves is found by observing the shape of the curve after the maximum force is obtained. In the before-irradiation tests (fig. 11(a)) after the ripstop nylon is broken, the Mylar imparts some residual strength to the laminate. After exposure to simulated solar radiation (figs. 11(b) and (c)), the residual strength is substantially reduced or essentially zero. The weave of the ripstop nylon is relatively open and a large percentage of the adhesive and Mylar is exposed directly to the radiation. The loss in residual strength is therefore attributed to the embrittlement of the Mylar from exposure to the simulated solar radiation. After approximately 1000 hours of solar radiation all the strength of this laminated material is derived from the ripstop nylon.

Two of the samples (686 ESH (for the discolored samples) in table II) in the accelerated test had released slightly from the water-cooled mounting plate. They exhibited some black discoloration along with the characteristic dark gold color. These samples were measured to see how this overheating, due to loss of thermal contact to the cooled substrate, would influence their properties. The 15.1-percent elongation and 134.4-N (30.2-lb) tensile strength (average of the two samples) were substantially lower than the respective values obtained in the 686 ESH accelerated test. The solar absorptance (α_s) was 0.662 and the total normal emittance $(\epsilon_{t,n})$ was 0.863 for an $\alpha_s/\epsilon_{t,n}$ of 0.77, much higher than the value obtained for even the 3316 ESH test. Thus it is important in tests of this type to have good thermal conductivity between the samples and the temperature-controlling substrate.

CONCLUDING REMARKS

A series of tests have been conducted to evaluate the effects of the space environment on the ripstop nylon bonded to the Mylar side of the aluminized Mylar film used for the first Skylab parasol. The accelerated testing predicted more severe degradation than would be experienced if the tests had been conducted in real-time conditions. Even with the severe degradation rate experienced in the 3.5 solar constant test, the material retained over 55 percent of its original tensile strength and elongation, and had only a 10-percent increase in its ratio of solar absorptance to thermal emittance after 3316 equivalent solar hours of exposure. Since only gross embrittlement and/or optical darkening would result in failure of this parasol, these results indicate that the material could have given satisfactory performance throughout the planned lifetime of the Skylab workshop.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., February 8, 1974.

REFERENCES

1. Thekaekara, M. P.: Proposed Standard Values of the Solar Constant and the Solar Spectrum. J. Environ. Sci., vol. XIII, no. five, Sept./Oct. 1970, pp. 6-9.
2. Van Vliet, Robert M.: Passive Temperature Control in the Space Environment. Macmillan Co., c.1965.
3. Progar, Donald J.; and Wade, William R.: Vacuum and Ultraviolet-Radiation Effects on Binders and Pigments for Spacecraft Thermal-Control Coatings. NASA TN D-6546, 1971.
4. Nelson, K. E.; Luedke, E. E.; and Bevans, J. T.: A Device for the Rapid Measurement of Total Emittance. J. Spacecraft & Rockets, vol. 3, no. 5, May 1966, pp. 758-760.

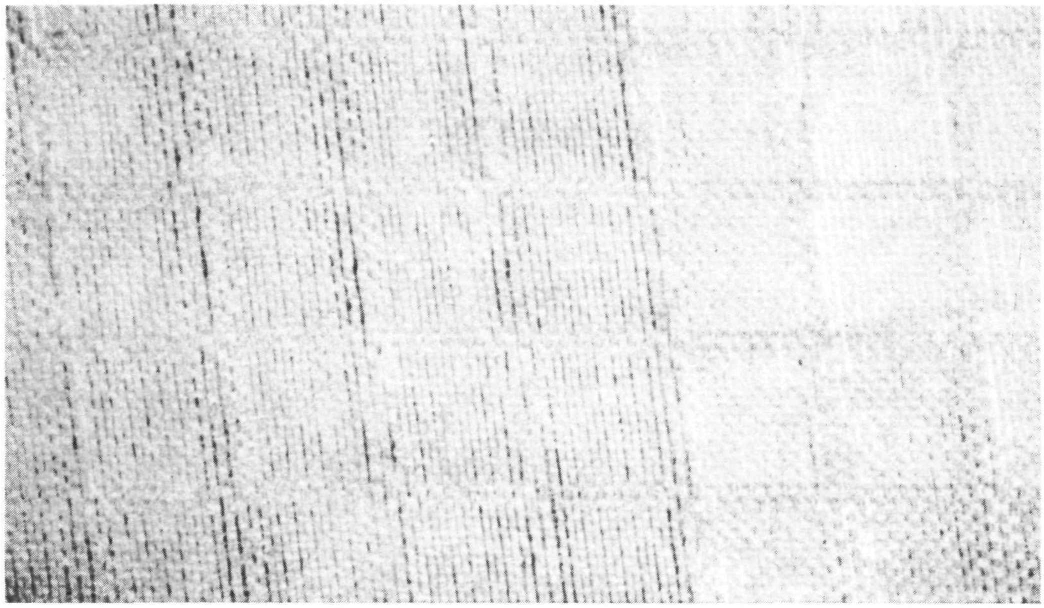
TABLE I.- SPECTRAL DISTRIBUTION OF SOLAR SIMULATORS

Wavelength band, μm	NRL solar energy		X75 simulator output energy		Deviation, percent
	W/m^2	Btu/ft^2-sec	W/m^2	Btu/ft^2-sec	
0.22 to 0.33	41.3	0.0036	32.5	0.0029	-21.3
.33 to .40	84.8	.0075	99.1	.0087	16.9
.40 to .50	201.1	.0177	199.9	.0176	-.6
.50 to .60	190.8	.0168	180.2	.0159	-5.6
.60 to .70	162.4	.0143	149.4	.0132	-8.0
.70 to .80	127.0	.0112	122.1	.0108	-3.9
.80 to .90	100.6	.0089	95.5	.0084	-5.1
.90 to 1.00	80.6	.0071	82.8	.0073	2.7
1.00 to 1.20	121.6	.0107	125.4	.0110	3.1
1.20 to 1.50	111.4	.0098	121.5	.0107	9.1
1.50 to 1.80	61.0	.0054	74.8	.0066	22.6
1.80 to 2.20	44.2	.0039	46.1	.0041	4.3
2.20 to 2.70	28.0	.0025	25.5	.0022	-8.9

TABLE II.- THE EFFECT OF SIMULATED SOLAR RADIATION ON THE RIPSTOP NYLON/ALUMINIZED MYLAR MATERIAL USED FOR CONSTRUCTION OF THE FIRST SKYLAB PARASOL

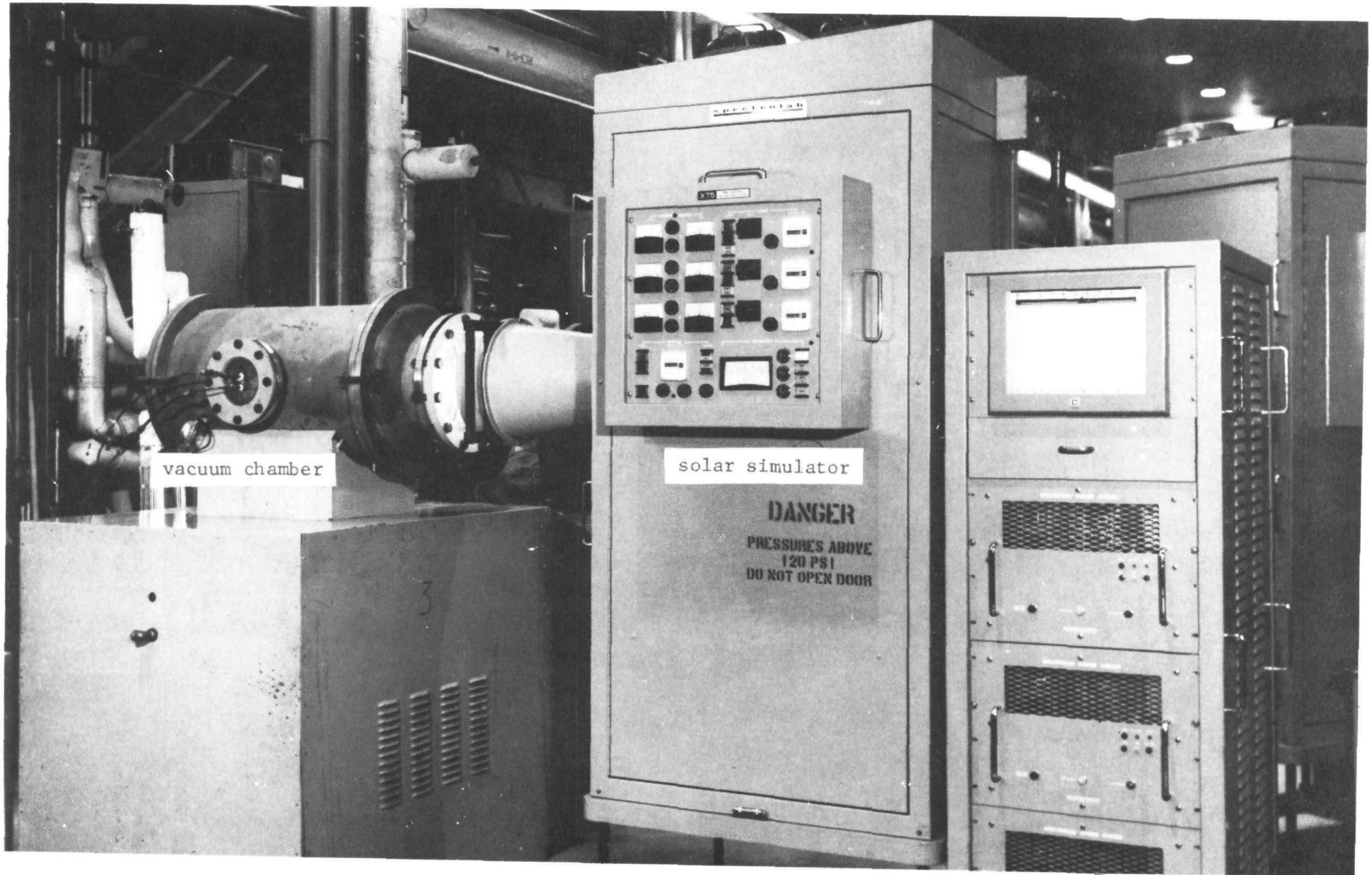
Equivalent solar hours of irradiation for solar constant –		Number of samples in the mechanical tests	Average elongation, percent	Standard deviation of elongation, percent	Average tensile strength		Standard deviation of tensile strength		Number of samples in the radiative tests	Solar absorptance, α_s	Total normal emittance, $\epsilon_{t,n}$	$\alpha_s/\epsilon_{t,n}$
3.5	1.0				N	lb	N	lb				
0	0	15	34.5	1.059	253.2	56.9	4.2	0.948	4	0.50	0.84	0.59
686		7	20.9	.926	155.8	35.0	3.6	.821	3	.48	.85	.56
	686	8	28.0	.723	198.5	44.6	3.0	.677	3	.47	.85	.56
[a] 686		2	15.1	1.603	134.4	30.2	7.6	1.720	2	.66	.86	.77
3316		7	19.4	1.048	150.9	33.9	6.3	1.415	3	.55	.85	.65

[a] Samples discolored from overheating due to loss of thermal contact to sample mounting plate.



L-74-1034

Figure 1.- Photomicrograph showing the weave of the ripstop nylon at $\times 5$ magnification.



L-73-4944.1

Figure 2.- Overall view of solar simulator and high vacuum chamber during irradiation of test samples (typical for both space environment simulation systems).

High reading 58.8 mV

Low reading 54.0 mV

Mean reading 56.4 mV

Uniformity ± 4.26%

				54.0	54.4	54.6	54.2				
			53.5	55.2	55.9	55.6	55.8	55.3			
		55.5	56.0	56.4	57.4	57.8	57.1	56.1	56.1		
	56.1	56.2	55.7	55.2	56.9	57.8	57.3	55.5	56.2	56.9	
	56.9	57.1	56.7	56.2	58.3	58.8	57.3	56.5	56.8	57.0	
	57.0	57.2	56.2	56.8	58.4	57.9	57.0	57.4	56.8	57.0	
	57.8	57.4	56.5	56.4	57.0	56.6	56.9	57.7	56.6	56.5	
		57.9	57.5	58.0	58.0	57.6	57.3	56.8	56.7		
			57.9	58.1	58.2	58.2	57.1	56.5			
				57.0	57.2	57.1	56.3				

Figure 3.- Uniformity of solar simulator beam.

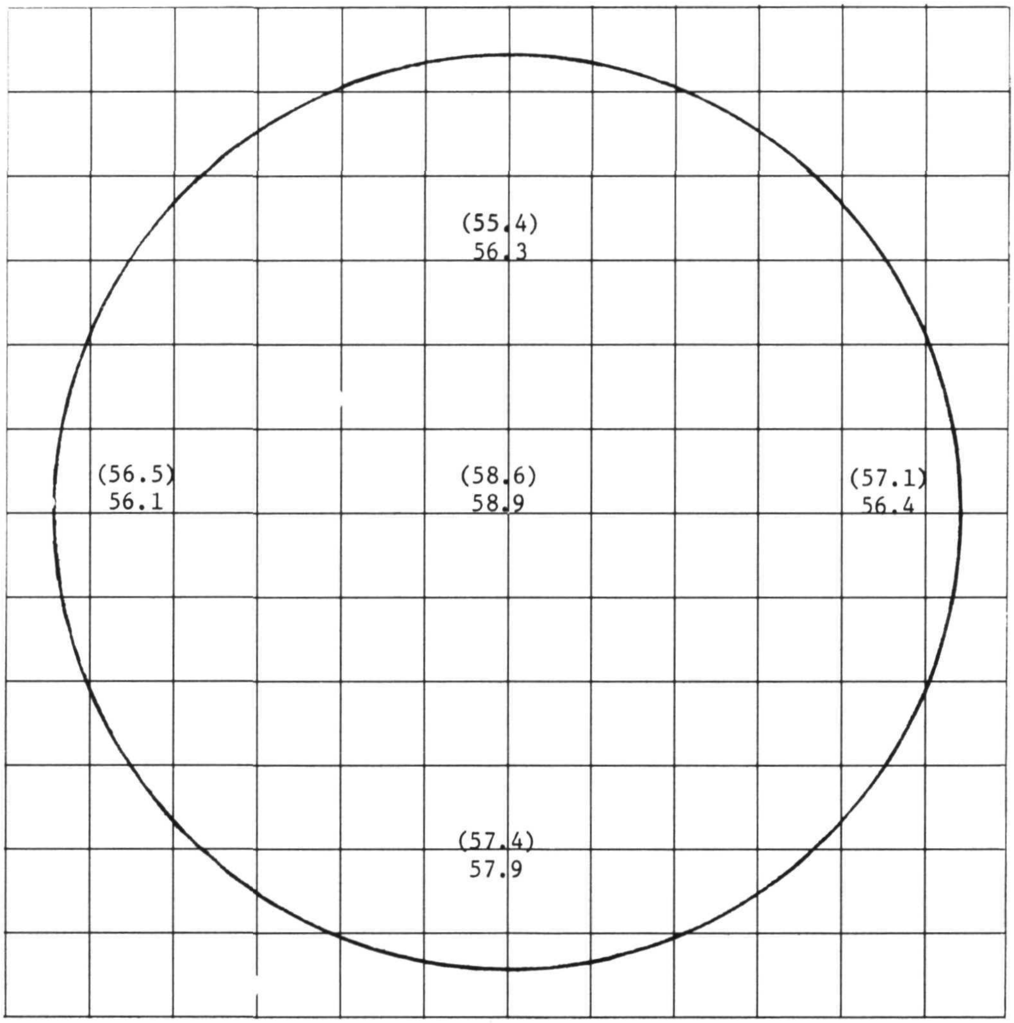
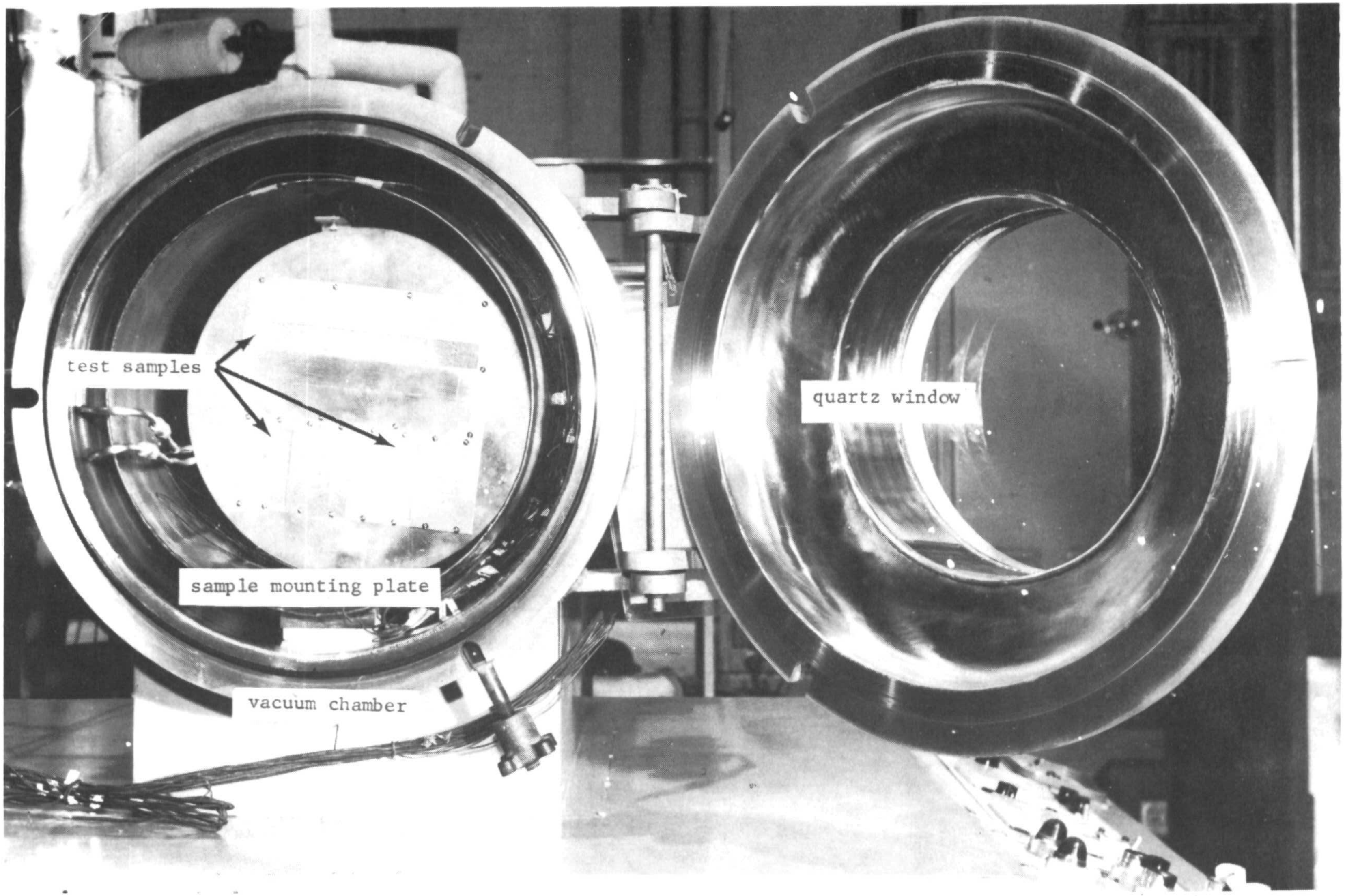
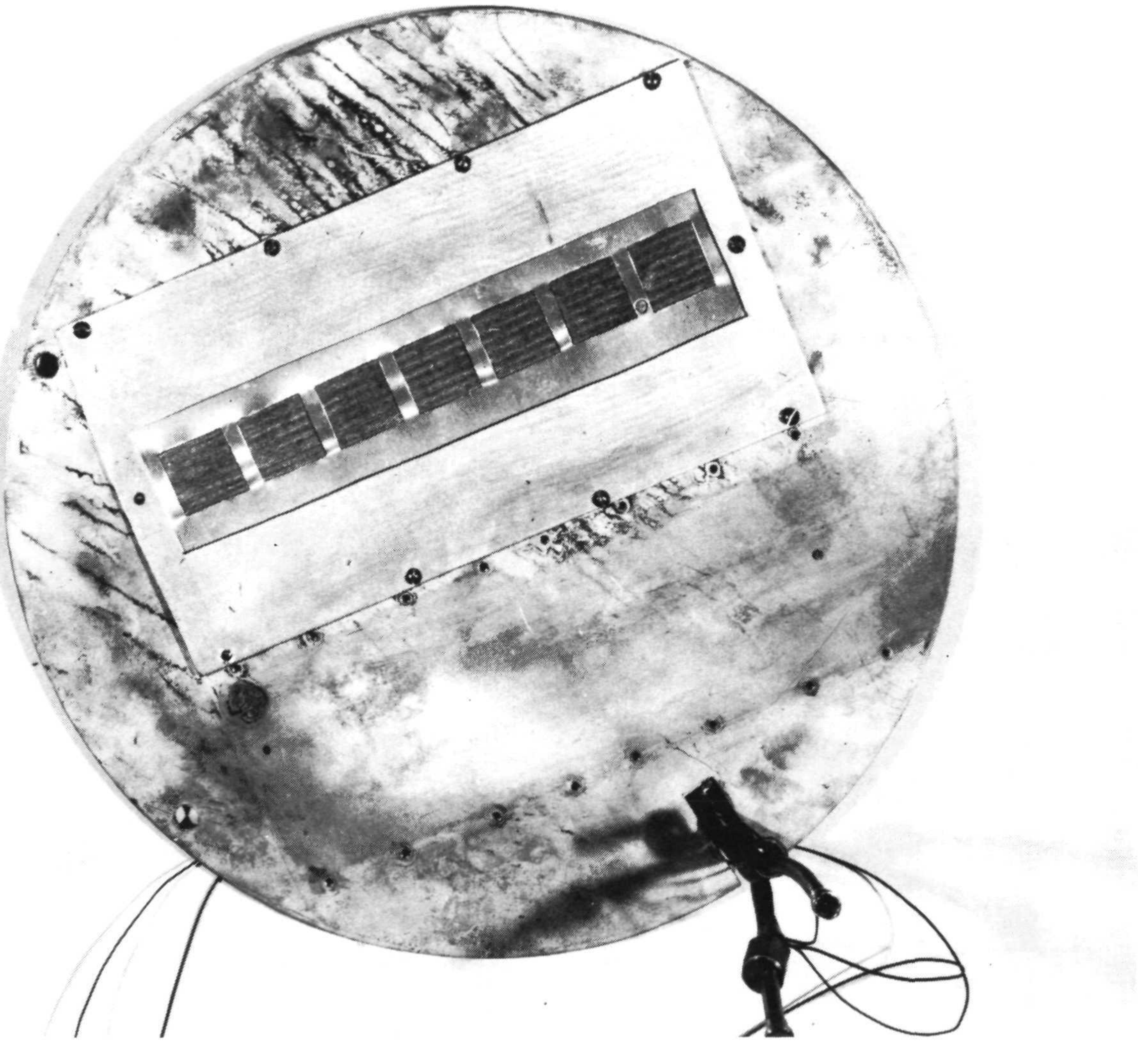


Figure 4.- Uniformity of solar simulators as determined prior to irradiation. (The numbers in parentheses are for one simulator and the other numbers are for the other simulator.



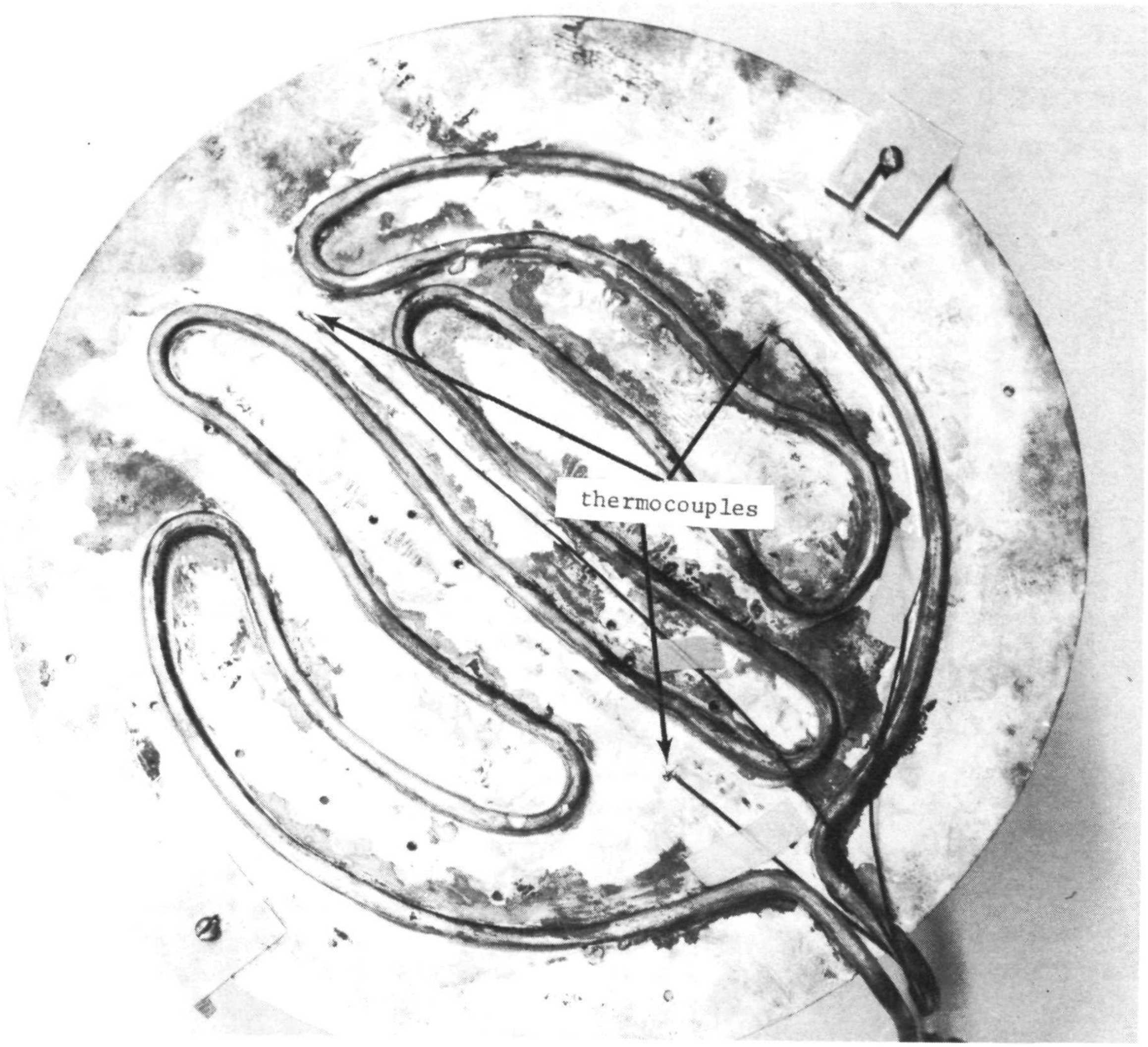
L-73-4943.1

Figure 5.- Vacuum chamber with samples in place prior to irradiation.



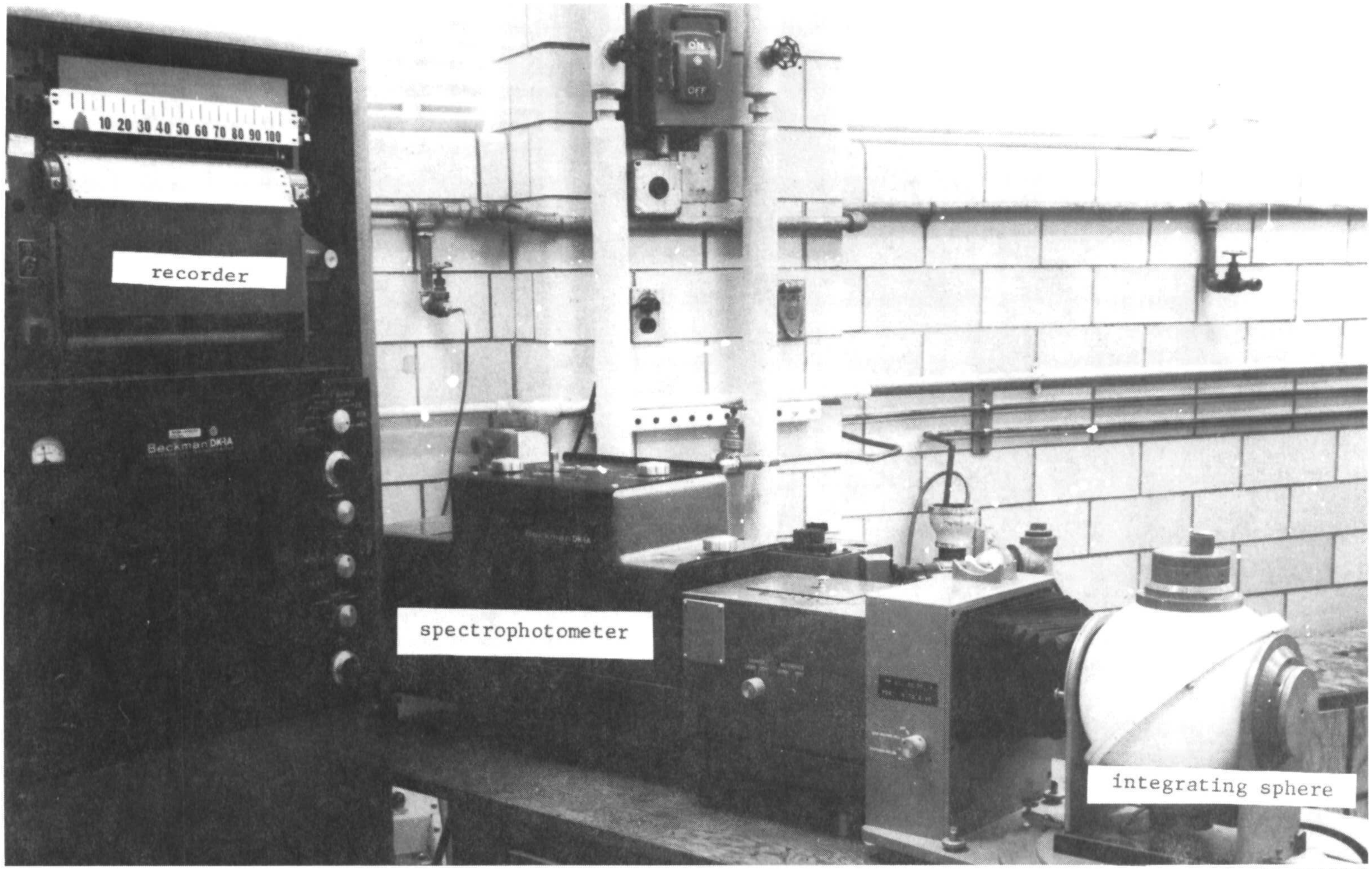
L-73-5469.1

Figure 6.- Sample mounting plate with aluminum frames used to hold the samples in place during irradiation.



L-73-5574.1

Figure 7.- Sample mounting plate showing water-cooling coils and thermocouples (typical for both plates).



L-73-5937.1

Figure 8.- Spectral reflectance measurement system.

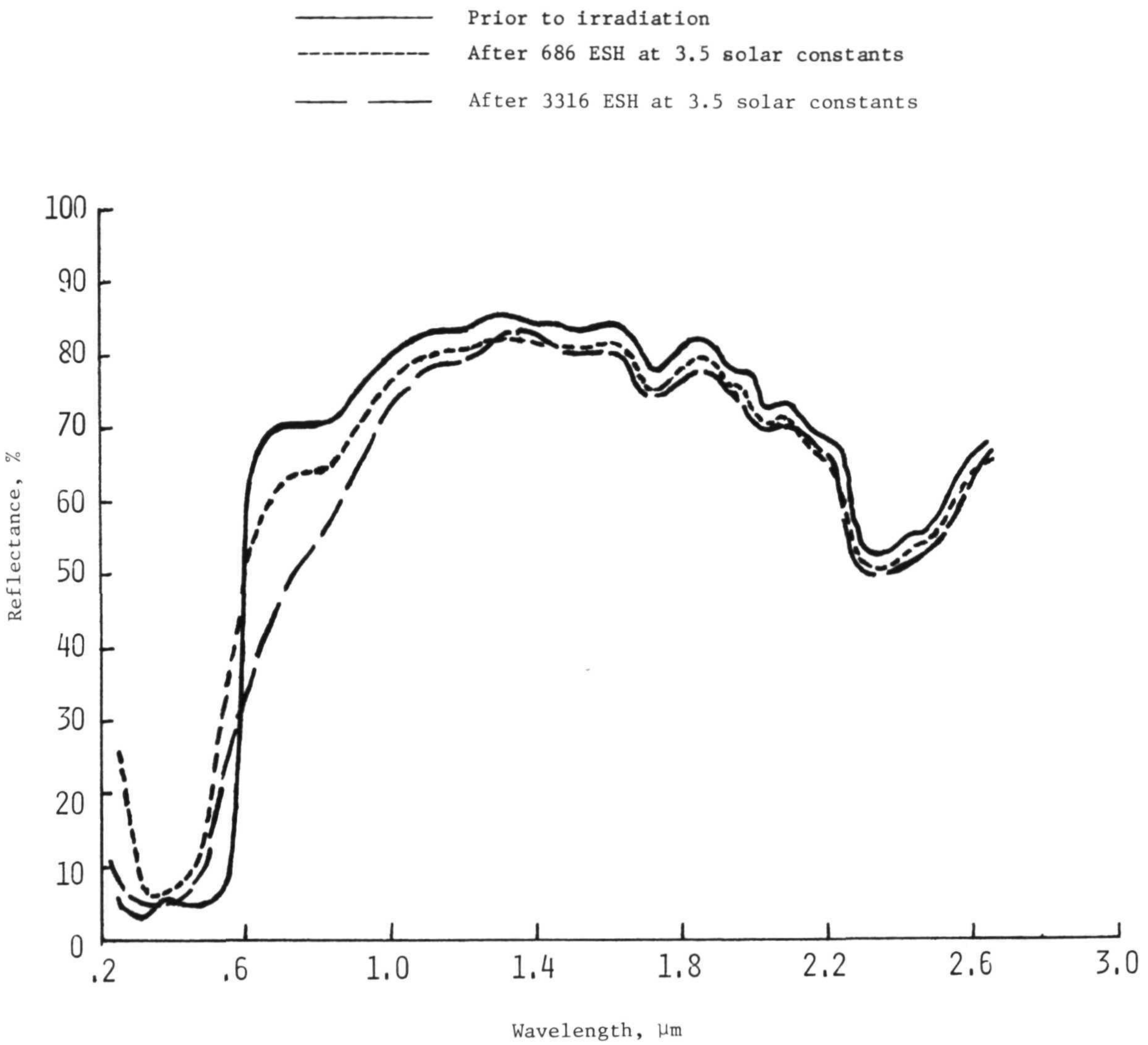


Figure 9.- Spectral reflectance of parasol material.

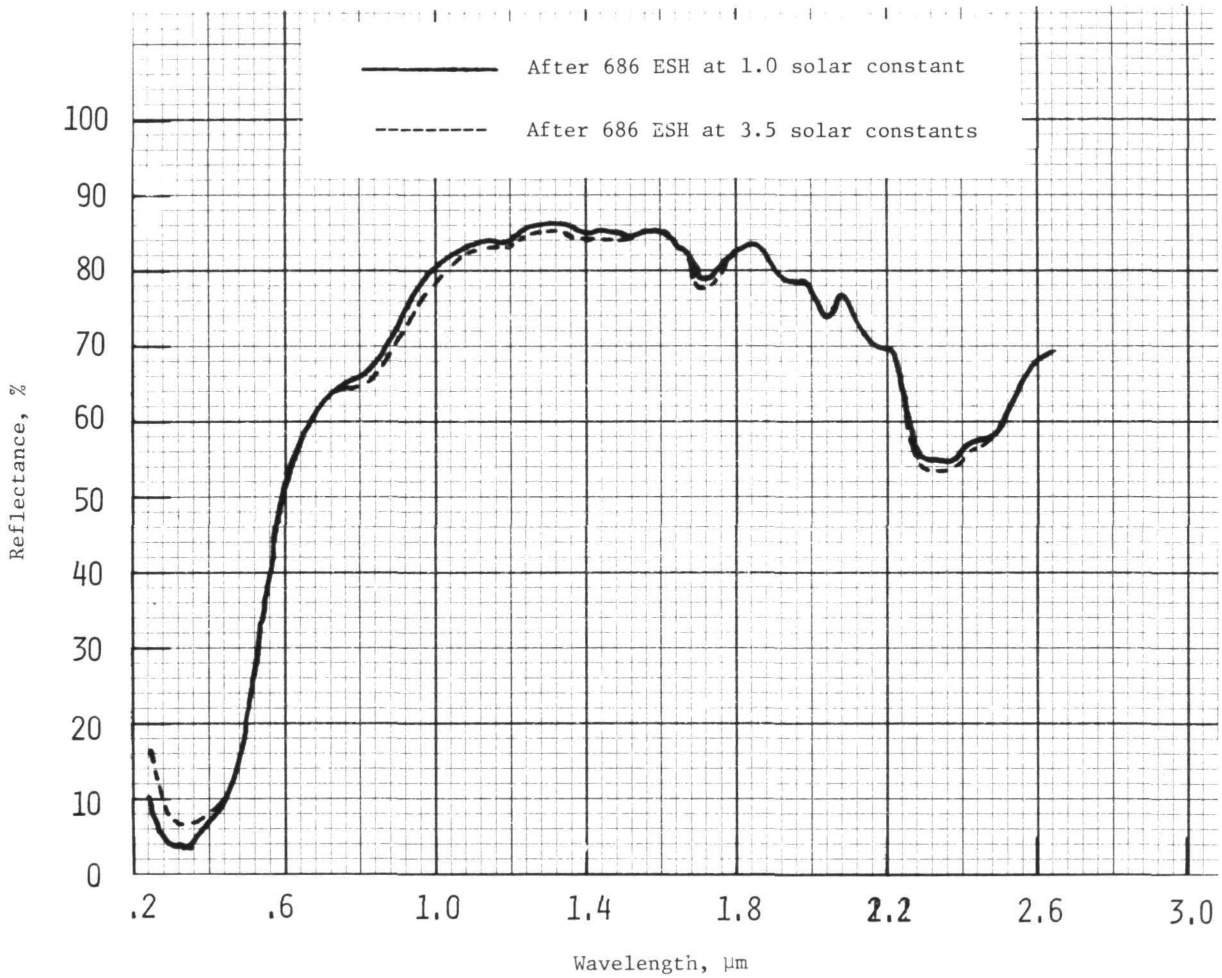
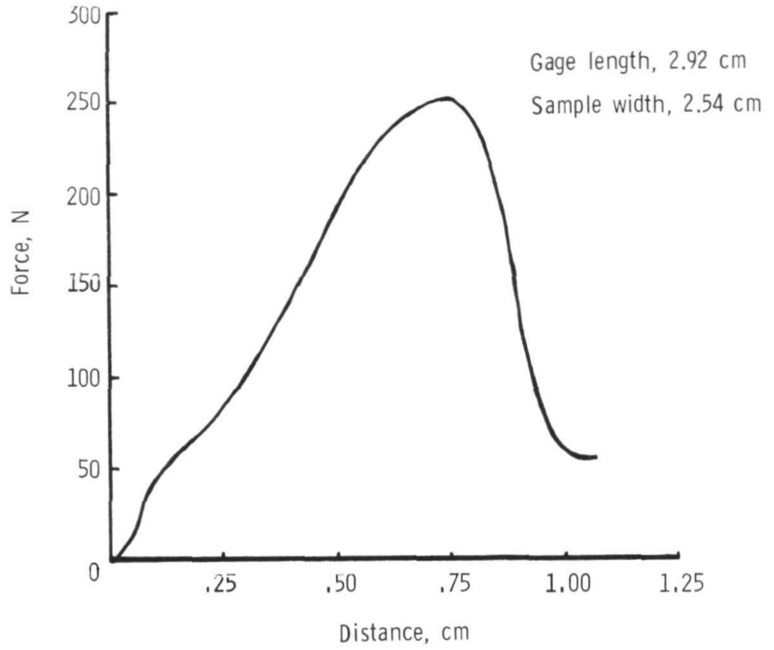
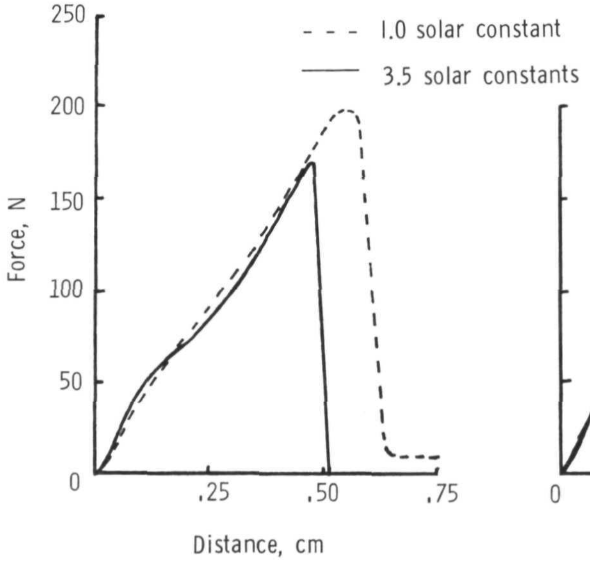


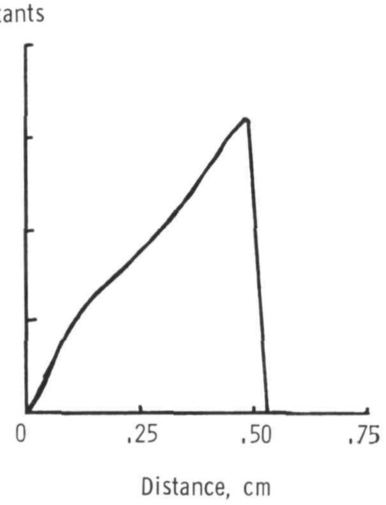
Figure 10.- Comparison of spectral reflectance of parasol material irradiated at 1.0 and 3.5 solar constants.



(a) Before irradiation.



(b) After 686 ESH of irradiation.



(c) After 3316 ESH of irradiation.

Figure 11.- Typical mechanical property curves for parasol material before and after simulated solar irradiation.

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546