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SKYLAB PARASOL MATERIAL EVALUATION

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HOUSTON, TEXAS 77058

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16. Abstract

Results of experimental work to evaluate the degradation rate of a parasol that was used as a means of alleviating thermal problems encountered soon after the launch of Skylab 1 space vehicle are presented. Material selection criteria are discussed, the material chosen is described, and results of tests performed after environmental exposure at five facilities are given. The facilities used for exposure to ultraviolet radiation/thermal-vacuum environments and the equipment used for testing physical properties before and after exposure are described. Comparisons of ground test and flight test data are included.

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SKYLAB PARASOL MATERIAL EVALUATION

Stephen Jacobs and
Thomas J. Ballentine
Lyndon B. Johnson Space Center
Houston, Texas 77058

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SKYLAB PARASOL MATERIAL EVALUATION

By Stephen Jacobs and Thomas J. Ballentine
Lyndon B. Johnson Space Center

SUMMARY

The critical properties of the material used in the fabrication of the Skylab parasol that was deployed during the Skylab 2 mission were evaluated before and after exposure to simulated and actual flight environments. The material selected for the parasol consisted of an orange nylon ripstop fabric laminated to the Mylar side of an aluminized Mylar film. Ultraviolet radiation degradation of the laminate was evaluated to determine the flight life of the parasol material.

Environmental tests were performed at several facilities having flux levels ranging from 1.2 to 5.4 times solar flux, durations as long as 1260 equivalent solar hours, and temperatures ranging from 311 to 394 K. Following ultraviolet/thermal-vacuum exposure, a series of measurements was made on the parasol material that included solar absorptance, total emittance, breaking strength, elongation, and tear strength. These measurements were compared to similar measurements that were taken on control samples of the unexposed material. Scanning electron microscope photomicrographs were also taken of the parasol material before and after ultraviolet/thermal-vacuum exposure. The greatest degradations that were observed in the test program were a 68-percent loss in breaking strength, a 92-percent loss in elongation, and a 90-percent reduction in tear strength. No change was detected in total emittance after sample exposure, but the solar absorptance increased moderately with ultraviolet exposure, as expected.

Two 30.48- by 30.48-centimeter specimens of the parasol material were deployed during the Skylab 3 second extravehicular activity, and one sample was returned by the Skylab 3 crew after approximately 475 hours solar exposure in the flight environment. As before, solar absorptance, total emittance, and mechanical properties such as breaking strength and elongation were measured on the returned sample. A 31-percent loss in breaking strength and a 40-percent loss in elongation compared favorably to the average ground test data for a comparable period. The final 30.48- by 30.48-centimeter specimen was returned by the Skylab 4 crew after approximately 1580 hours of solar exposure in the flight environment. As expected, the solar absorptance increased to 0.58 (from 0.49 for the Skylab 3 sample and from 0.36 before exposure), and breaking strength and elongation further decreased (54 percent loss and 63 percent loss, respectively).

INTRODUCTION

A structural failure of the micrometeoroid shield on the Skylab orbital workshop occurred 63 seconds after launch of the Skylab 1 (SL-1) space vehicle. The initial failure caused premature deployment and, ultimately, separation of solar array system wing 2 from the orbital workshop. In addition, debris from the micrometeoroid shield prevented the normal deployment of solar array system wing 1. Loss of the micrometeoroid shield caused immediate and severe thermal problems inside the orbital workshop. Several proposals were considered to alleviate the thermal problems. A parasol was initially accepted to be the most feasible concept from mechanical, logistic, and installation standpoints. The SL-2 crew deployed the parasol thermal shield through the solar scientific airlock soon after initially manning the orbital workshop.

To determine the expected use life of the SL-2 nylon ripstop parasol material, and to establish confidence in satisfactory performance of the material throughout the SL-2 mission, a series of ultraviolet radiation degradation tests was initiated. The effects of ultraviolet exposure on the critical properties of the material were evaluated, and the optical and mechanical properties of the degraded material were compared to the properties of the unexposed material. The mechanical properties initially tested consisted of breaking strength and elongation and of tear strength. Because of the nature and importance of the initial investigation, a wide variety of additional material properties such as stiffness, shrinkage, shock loading, and total mass loss were also evaluated to ensure compliance with the flight requirements. The results of these tests, although in some cases extraneous to the overall qualification of the material, are reported for completeness.

MATERIAL DESCRIPTION

Several materials were considered for the SL-2 parasol; packaging characteristics, physical properties, and availability of the material were of prime concern. The material finally chosen was a laminate consisting of orange nylon ripstop cloth weighing 37.1 g/m^2. The cloth was laminated with a thick thermosetting polyester to an aluminized Mylar film (0.0125 millimeter), and the aluminized surface was on the outside. The material, identified as batch 558, GT-76, had a total thickness of 0.08 millimeter and an average weight of 54.3 g/m^2.

ULTRAVIOLET DEGRADATION GROUND TESTS

Ultraviolet/thermal-vacuum exposure of the SL-2 parasol material was initially performed at the NASA Lyndon B. Johnson Space Center (JSC) and the NASA George C. Marshall Space Flight Center (MSFC). Shortly thereafter, exposures were performed at TRW Systems, General Electric (GE), and NASA

Langley Research Center (LaRC) facilities. At each of the five testing facilities, an attempt was made to simulate the vacuum, thermal, and ultraviolet space radiation environments likely to be encountered by the SL-2 parasol deployed in Earth orbit.

Test Conditions

Breaking strength and elongation measurements were made at the five facilities. The objective was to determine whether the material met basic strength requirements and also to determine the amount of degradation that would result from ultraviolet and thermal-vacuum exposure. Test conditions for the five facilities are summarized in table I and in the discussions in the following sections.

Lyndon B. Johnson Space Center.- Most ultraviolet exposures at JSC were performed in the chamber D facility (1.2 solar flux, xenon lamp) of the Space Environment Simulation Laboratory, where a 91.24- by 91.24-centimeter parasol sample was suspended (nylon side toward the lamp) and was instrumented with eight thermocouples evenly spaced along one diagonal of the material. One end of the parasol was mechanically flexed twice a day through a 12.7-centimeter range to roughly simulate motions that would be induced by the reaction control system engine plume impingement. Radiometers covered with the nylon material were also mounted at 45° angles to the nylon sample to detect changes in reflectance of the sample surface. Figure 1 is an overhead photograph of the test setup in chamber D. Temperature of the parasol sample was maintained at 306 to 316 K by means of quartz heaters mounted below the aluminized side of the sample in addition to the xenon lamp. Sample conditions were recorded on video tape at selected intervals during the test by means of a black and white television camera mounted in the chamber. At the conclusion of the chamber D test, the sample was removed and the optical properties were measured on a Gier-Dunkle MS-251 reflectometer (solar absorptance) and a DB-100 emissometer (total emittance). The 91.24- by 91.24-centimeter sample then was cut into specimens for testing of various physical properties. In addition to the chamber D tests, a 60.96- by 60.96-centimeter parasol sample was exposed to carbon arc radiation at 2.5 solar flux for 50 hours in chamber E of the Space Environment Simulation Laboratory. Optical and mechanical properties also were measured after this exposure.

George C. Marshall Space Flight Center.- In the MSFC tests (2.0 solar flux, xenon lamp), a 30.48- by 30.48-centimeter parasol sample was exposed. This sample was mounted on a water-cooled substrate plate. A high-conductivity, low-outgassing, hydrocarbon vacuum grease (FS-1281) was used to maintain good thermal contact between the sample and the substrate plate. Temperatures were maintained between 344 and 366 K. At the conclusion of the exposure, optical properties were measured using an MS-251 reflectometer (solar absorptance); then, mechanical properties were tested.

TRW Systems.- For the TRW tests (1.35 solar flux, xenon lamp; 4.0 solar flux, xenon lamp; 5.4 solar flux, xenon lamp), performed under NASA Contract NAS 9-13523, the samples were exposed in two separate facilities, the combined environment facility and individual ion-pumped chambers located around a compact xenon arc lamp. In the first test, a holder for eight samples, each approximately 2.79 by 15.24 centimeters, was fabricated and installed in a high-vacuum test chamber, where the samples were exposed to 4.0 times solar ultraviolet irradiance for 315 hours (1260 equivalent solar hours) at a temperature of 349 K that was maintained during the test with a temperature-controlled circulation bath. The samples were attached to a 0.64-centimeter-thick copper mounting plate with a thin layer of Krytox 240-AC grease. The samples were enclosed in a "picture frame" cover that prevented curling at the edges. A sketch of the sample-mounting arrangement is shown in figure 2. Another series of tests was started concurrently with the first test, and the samples were placed in six individually pumped vacuum tubes. The sample configuration was 2.79 by 15.24 centimeters, and the central 2.54- by 2.79-centimeter portion was used as the test section. The samples were cooled in the same manner as in the previous test, but the temperature was "controlled" using laboratory tap-water, the temperature of which varied from 293 to 333 K. One sample was exposed at 1.35 times solar ultraviolet irradiance until an exposure of 400 equivalent solar hours was reached. Four samples were exposed at 5.4 times solar ultraviolet irradiance; three were measured after 650 equivalent solar hours, and exposure of the fourth was extended to 1260 equivalent solar hours. One vacuum tube failed. At the conclusion of the combined environment facility and small chamber exposures, the samples were removed and the optical properties were measured. Solar absorptance measurements were performed using an Edwards-type integrating sphere reflectometer on a Beckman DK-2A spectrophotometer. Reflectance measurements were taken at 15° from the normal plane in the wavelength region 0.28 to 2.5 micrometers; the spectral data were integrated over the solar spectral distribution to obtain the solar absorptance. Emittance measurements were made using a Gier-Dunkle emissometer, model DB-100. Breaking strength and elongation measurements were also performed on the samples after removal from the test chambers.

General Electric.- The GE testing (5.0 solar flux, mercury/xenon lamp), performed under NASA Contract NAS 9-13593, was designed to irradiate the GT-76 material for long-term ultraviolet exposure at a high flux. The source used was a 5-kilowatt mercury/xenon lamp; solar intensity at the sample locations was calibrated at 5.0 solar ultraviolet irradiance using an Epply thermopile. Virgin material was supplied to GE, and eight 2.54- by 20.32-centimeter GT-76 sample strips were cut and placed at the 5.0-solar-flux sample plane backed by a water-cooled (350 K) metallic plate simulating the configuration used by TRW. The test was then continued until an exposure of 3460 equivalent solar hours was achieved on the GT-76 material. However, because of nonintimate contact between the cooled metal plate and the sample material, several burnthroughs occurred. Enough material was still available to enable measurement of breaking strength and elongation after removal of the material from the test chamber. Optical property measurements were not performed for these tests.

Langley Research Center.- In the LaRC tests (1.0 and 3.5 solar flux, xenon lamp), 24 samples were mounted vertically in 2 vacuum chambers, each mounted on a water-cooled copper plate (8 at 1.0 solar flux, 16 at 3.5 solar flux). A high-thermal-conductivity, low-outgassing thermal grease was used between the test sample and the water-cooled plate to ensure good thermal contact. An aluminum frame was used to hold the samples in place during irradiation and to enable exposure of only 6.45 square centimeters of each sample to the simulated solar radiation. The samples in each chamber were maintained at 350 to 360 K by regulation of the cooling-water flow to each sample-mounting plate. Three thermocouples were attached to each sample plate, and the output of these thermocouples was monitored continuously by means of a temperature-compensating potentiometer having a strip-chart recorder. At 686 equivalent solar hours of exposure, nine of the test specimens were removed from the 3.5-solar-flux accelerated test for comparison with the specimens exposed for the same period at only one solar constant. These data were used to check the validity of the accelerated testing. The remaining seven specimens were tested for the full duration exposure of 3316 equivalent solar hours.

Test Results

The overall visual appearance of all samples from the five testing organizations was virtually the same; that is, the color had changed from bright orange to dull gold. No apparent physical degradation was noticed during a visual examination of the specimens. Becaure of anomalies during the TRW tests (outgassing of the Krytox 240-AC vacuum grease), bubbling of several specimens and subsequent overheating, including burnthrough, occurred in four of the eight samples exposed in the combined environment facility. Also, because of the GE-sample burnthroughs discussed earlier, data are reported for only three GE samples. Data for control samples are also presented for comparison with post-test measurements and with measurements performed on a flight sample. In all cases, the degraded mechanical properties are compared to properties of the unexposed samples. Undoubtedly, in some cases, the degradation was due to both radiation and thermal exposure.

Optical properties.- The only in situ data available on optical properties (as opposed to post-test data) were from the radiometers mounted in chamber D for the JSC tests. These data show a slight decrease in solar absorptance at levels as high as 180 equivalent solar hours (0.40 to 0.35). Recovery in absorptance to approximately 0.38 is shown at the test conclusion. The measured optical properties at the conclusion of these exposures are shown in table II. Figure 3 shows the change in solar absorptance with equivalent solar hours. General Electric did not perform optical property measurements.

Mechanical properties.- Test data on mechanical properties include breaking strength, elongation, tear strength, and shrinkage.

Breaking strength and elongation: The breaking strength and elongation testing at JSC was accomplished on a Scott CRE Tensile Tester in accordance with Federal Test Method Standard 191, Method 5102. Testing at TRW, GE, and MSFC was accomplished on comparable equipment and followed comparable test methods. In testing at LaRC, a somewhat different procedure was followed in that the mechanical properties were measured on a commercially available power-driven Instron testing machine having a constant rate of jaw separation. Figures 4 to 7 were prepared from the test data.

Tear strength: The tear strength of the nylon ripstop aluminized Mylar laminate was determined at JSC on the Elmendorf tear tester in accordance with Federal Test Method Standard 191, Method 5132. The results are shown in table III.

Shrinkage: The shrinkage of the nylon ripstop aluminized Mylar laminate was determined at JSC after the material had been exposed to an ultraviolet/vacuum environment for 500 equivalent solar hours. The objective of the measurement was to determine whether the overall shrinkage of the parasol would cause any structural problems while in use. The dimensions of 40 squares of the ripstop material were measured before and after exposure in the longitudinal and transverse directions. The results show a 0.97-percent shrinkage in the longitudinal direction and a 1.6-percent shrinkage in the transverse direction.

Scanning electron microscopy.- A scanning electron microscope (Cambridge Stereoscan S-4) was used at JSC to examine surface morphology of the nylon ripstop material as received, after 500 equivalent solar hours ultraviolet exposure, and after 1260 equivalent solar hours ultraviolet exposure. Typical photographs of these samples are shown in figures 8 to 10. The appearance of dark spots on the 500-hour specimen is accompanied by a slight surface roughening and by the formation of a thin crust. Evidence of some embrittlement can be seen on the cut end of the 500-hour specimen. The 1260-hour specimen shows a marked increase in surface roughness, and the surface crust is well defined. Increased embrittlement is indicated by marked surface cracking near the cut region. No evidence of flaking or lack of crust adherence was observed at these exposure levels.

Additional JSC test results.- The following additional tests were performed on the parasol material and were independent of the ultraviolet radiation exposure tests.

Corner strength: Three corners simulating the parasol corners were tested to determine structural integrity. At each corner of the parasol was a polybenzimidazole (PBI) loop, which attached to the Skylab structure. Each end of the PBI cord was sewn to 1.27-centimeter Nomex webbing, and the webbing was sewn to each side of the corner. The corner was reinforced with an additional layer of the parasol material, as shown in figure 11. The corner was tested on the Scott Tensile Tester by placing a pin through the PBI cord loop and attaching the pin to a fixture on the load cell. Two 30.48- by 30.48-centimeter aluminum plates were used as bottom jaws to retain the ripstop cloth. The jaws and the crosshead were separated at a rate of 2.54 cm/min. The results show two types of failure mechanisms: failure of the PBI cord leading to a corner strength of 61.7 kilograms, and failure of the seam leading to a breaking strength ranging from 50 to 77.1 kilograms.

Stiffness: The relative stiffness of the laminate as a function of temperature was determined. The relative stiffnesses of several seam configurations were measured on 2.54- by 22.8-centimeter strips of material in a temperature-controlled ambient-pressure cabinet, and a balance was used to measure the extension force as shown in figure 12. Springback distance, expressed as a percentage of sample free length, and force necessary to extend the sample to 90 percent of its free length were measured. These results are presented in table IV.

Shock loading: A shock-loading test was devised to investigate the effects of deployment and of other rapidly applied loads on the parasol material. A 61.0- by 2.54-centimeter sample was shock-loaded by a falling weight dropped from varying heights. The induced tensile force was measured by using a load cell (attached to the top of the sample) in conjunction with a high-speed oscillograph. The falling body weighed 1360 grams. The impact height was varied from 2.54 to 55.9 centimeters. The measured forces for specific drop heights varied from 12.9 to 21.5 kilograms.

Total mass loss and volatile condensable material: An Ainsworth vacuum balance system was used for the evaluation of the outgassing characteristics of the parasol material. This system provides a continuous in situ measurement of mass loss. Figure 13 shows data on the total mass loss and the volatile condensable matter for the unexposed parasol material.

FLIGHT-SAMPLE MEASUREMENTS

Two 30.48- by 30.48-centimeter specimens of the parasol material were deployed by the SL-3 crew during the second extravehicular activity. One sample was returned by the SL-3 crew after approximately 475 hours solar exposure in the space environment. The second specimen was returned by the SL-4 crew after approximately 1580 hours solar exposure. Optical properties, breaking strength, and elongation were measured.

Optical Properties

The instrumentation used for the flight-sample optical property measurements was the same as that used for the ground test specimens, namely the MS-251 reflectometer for solar absorptance and the DB-100 emissometer for total emittance. For the SL-3 sample, solar absorptance increased from the preflight value of 0.36 to 0.49; for the SL-4 sample, to 0.58. Total emittance was virtually unchanged from preflight values for the two exposed samples. These data are shown in table V.

Mechanical Properties

As shown in table V, measurements of the flight samples indicated a sharp decrease in breaking strength and elongation. These changes in mechanical properties were due to the combination of ultraviolet radiation and elevated parasol temperature. Additional mechanical property measurements were not possible because of the limited amount of exposed material.

COMPARISON OF GROUND TEST AND FLIGHT DATA

When possible, ground test data were compared with flight test data to prove the validity of the ground simulations and to determine the expected flight life of the deployed parasol.

Optical Properties

The increase in solar absorptance of the parasol material due to ultraviolet radiation, as shown from ground test data and flight-sample measurements, was within the expected range and was found to be acceptable by the thermal analysis of the parasol and of the orbital workshop. No direct correlation was observed between increased ultraviolet solar intensity and increased solar absorptance. However, for the same solar intensity, an increase in equivalent solar hours led to an increased solar absorptance. No measurable change existed in total emittance from preexposure values for ground-test or for flight-sample measurements.

Mechanical Properties

Ground test results indicated that a decrease in breaking strength and elongation does occur as a result of radiation/thermal-vacuum exposure. After ultraviolet radiation exposure (ground simulation), testing at room temperature (295 K) revealed a degradation of 18 percent; whereas tests at 394 K indicated a degradation exceeding 50 percent. Measurements of the flight samples also indicated a sharp decrease in breaking strength and elongation (greater than 50 percent) after recovery of the SL-4 sample. As previously mentioned, this condition was due to the combination of ultraviolet radiation and elevated parasol temperature (calculated to be 327 to 409 K). This information compares well with ground test data.

Tear strength.- A significant decrease in tear strength occurred after exposure to combined ultraviolet radiation/thermal-vacuum conditions. The material deterioration contributed to the decrease in tear strength, but most of the decrease was due to the thermal exposure, which improved the bonding between the layers of the laminate. Before exposure, the nylon ripstop and Mylar were not rigidly bonded together; therefore, as the samples began to tear, the yarns in the fabric could move fairly freely. This freedom of movement allowed the yarns to absorb most of the energy of the swinging pendulum while tearing. The movement of the yarns in the exposed sample was inhibited because the fabric adhered too rigidly to the Mylar. Consequently, a much lower tear strength resulted. The decrease of tear strength did not affect the structural integrity because of the minimum loading imposed in the flight environment.

Shrinkage.- Shrinkage values indicate that the material contracted when exposed to the ultraviolet radiation. However, the maximum value of 1.6 percent was insignificant for this application.

DISCUSSION OF ADDITIONAL TEST RESULTS

Some results of additional tests in the areas of corner strength, stiffness, shock loading, and volatile condensable material are discussed below.

Corner Strength

Three samples simulating parasol corners (as previously described) were tested, but in only one case did the PBI loop break. With the other two samples, the seams broke initially, and the PBI loops eventually pulled out. However, the breaking strength values exceeded the design requirements.

Stiffness

The laminate generally was not unacceptably stiff over the temperature range from 200 to 394 K. However, the addition of reinforcing webbing at the edge seam caused a marked increase in stiffness, especially at cold temperatures. Nomex webbing was found to be exceptionally stiff when cold.

Shock Loading

The laminate is not sensitive to the strain rates encountered during deployment. A 61.0- by 2.54-centimeter section of the material withstood a 55.9-centimeter drop of the 1360-gram weight (which produced a tensile force of 21.5 kilograms and an onset rate of 547 kg/sec) without breaking.

Total Mass Loss and Volatile Condensable Material

Total mass loss and volatile condensable material were measured for the parasol material. Total mass loss (0.3 percent) was within the requirements specified in NASA SP-R-0022 (less than 1 percent), and volatile condensable material was slightly greater than the requirement of 0.1 percent. Although the volatile condensable material in the parasol was slightly above specified values, the figure was not considered to be sufficiently high to interfere with the performance of the Skylab parasol.

CONCLUDING REMARKS

The results of the evaluation program indicate that exposure of the Skylab parasol material to an ultraviolet radiation/thermal-vacuum environment causes degradation of the components of the parasol. The effects are pronounced in the mechanical properties and, less important, in the optical properties. Good correlation was achieved between measurements performed on flight samples and those from ground-based test data. Even these degraded properties, however, were acceptable for the parasol because of the minimum loading the material received in service. No visual evidence indicated that exposure to ultraviolet radiation caused the material to be undesirable in other ways such as particle generation. Other properties of the parasol material were also acceptable for the Skylab Program. The successful parasol deployment during the Skylab 2 mission and the subsequent satisfactory performance verified that the material selected for the parasol was appropriate and useful.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, April 23, 1975
986-15-31-03-72

TABLE I.- SUMMARY OF TEST CONDITIONS FOR ULTRAVIOLET RADIATION DEGRADATION EXPOSURES

Exposure location	Sample size, cm	Solar ultraviolet irradiance	Duration, equivalent solar hr	Exposure temperature, K
JSC:				
Chamber E	60.96 by 60.96	2.5	50	394
Chamber D	91.24 by 91.24	1.2	500	311 ± 5
MSFC	30.48 by 30.48	2.0	60, 80, 200, 300, 650	394
	30.48 by 30.48	3.5	50, 280	344 to 366
TRW	[a]2.54 by 15.24	5.4	650, 1260	327
		4.0	1260	350
GE	[a]2.54 by 20.32	5.0	3460	350 ± 5
LaRC	[a]2.54 by 20.32	3.5	686, 3316	355 ± 5

[a]2.54- by 2.54-centimeter test section.

TABLE II.- SUMMARY OF OPTICAL PROPERTY DATA FROM ULTRAVIOLET DEGRADATION EXPOSURES

Exposure location	Solar ultraviolet irradiance	Duration, equivalent solar hr	Exposure temperature, K	Optical properties				Instrument used for absorptance measurement
				Before exposure		After exposure		
				Absorptance	Emittance (a)	Absorptance	Emittance (a)	
JSC:								
Chamber E	2.5	50	394	0.36	0.85	0.44	0.85	MS-251
Chamber D	1.2	500	311 ± 5	.36	—	.44	—	MS-251
MSFC	2.0	60	394	.39	—	.46	—	MS-251
	2.0	80	394	.39	—	.46	—	MS-251
	2.0	200	394	.39	—	.46	—	MS-251
	2.0	300	394	.39	—	.46	—	MS-251
	2.0	650	394	.39	—	.69	—	MS-251
	3.5	50	344 to 366	.49	—	.62	—	Beckman DK-2A
	3.5	280	344 to 366	.49	—	.66	—	Beckman DK-2A
TRW	4.0	1260	350 ± 5	.49	—	.52	—	Beckman DK-2A
	4.0	1260	350 ± 5	.49	.84	.56	—	Beckman DK-2A
	4.0	1260	350 ± 5	.49	.84	.51	—	Beckman DK-2A
	4.0	1260	350 ± 5	.49	.84	.53	—	Beckman DK-2A
	5.4	650	327	.49	.84	.58	.85	Beckman DK-2A
	5.4	650	327	.49	.84	.58	.86	Beckman DK-2A
	5.4	650	327	.49	.84	.58	.84	Beckman DK-2A
	5.4	1260	327	.49	.84	.57	.86	Beckman DK-2A
LaRC	3.5	686	355 ± 5	.49	.84	[b].66	.85	Comparable to Beckman DK-2A
	3.5	3316	355 ± 5	.49	.84	.55	.85	

[a]All measurements were performed with the Gier-Dunkle DB-100 portable emissometer.

[b]Sample overheating.

TABLE III.- SUMMARY OF TEAR STRENGTH DATA FROM JSC

Solar ultraviolet irradiance	Duration, equivalent solar hr	Exposure temperature, K	Test temperature, K	Tear strength, g
Before exposure	—	—	294 ± 5	4700
2.5	50	394	294 ± 5	590
1.2	500	311 ± 5	294 ± 5	1420

TABLE IV.- STIFFNESS AS A FUNCTION OF TEMPERATURE

Sample description	Test Temperature, K					
	200 ± 10		295 ± 4		395 ± 10	
	Springback distance, percent (a)	Force to 90-percent extension, g	Springback distance, percent	Force to 90-percent extension, g	Springback distance, percent	Force to 90-percent extension, g
GT-76 unseamed	86.5	0.06	81.5	1.85	--	--
GT-76 triple-lapped seam	46.7	28	54.5	25.6	41.0	25.5
GT-76 nylon tape edge seam	31.0	112	78.0	36.6	64.5	86
GT-76 Nomex tape edge seam	29.0	[b]156	82.0	[b]156	--	--
GT-76 double-lapped seam	--	--	--	--	54.5	12

[a]Percent springback = measured springback divided by free length of the sample.

[b]Exceeded pull force of test equipment.

TABLE V.- FLIGHT-SAMPLE MEASUREMENT RESULTS

Condition	Optical properties		Breaking strength, kg/2.54 cm of width	Elongation, percent	Duration, equivalent solar hr
	Absorptance (a)	Emittance (b)			
Before exposure	0.36	0.85	9.3	35.0	0
After SL-3	.49	.86	6.4	20.9	475
After SL-4	.58	.86	4.3	13.3	1580

[a]Measurements performed with MS-251 reflectometer.

[b]Measurements performed with DB-100 emissometer.

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Figure 1.- Chamber D test setup.

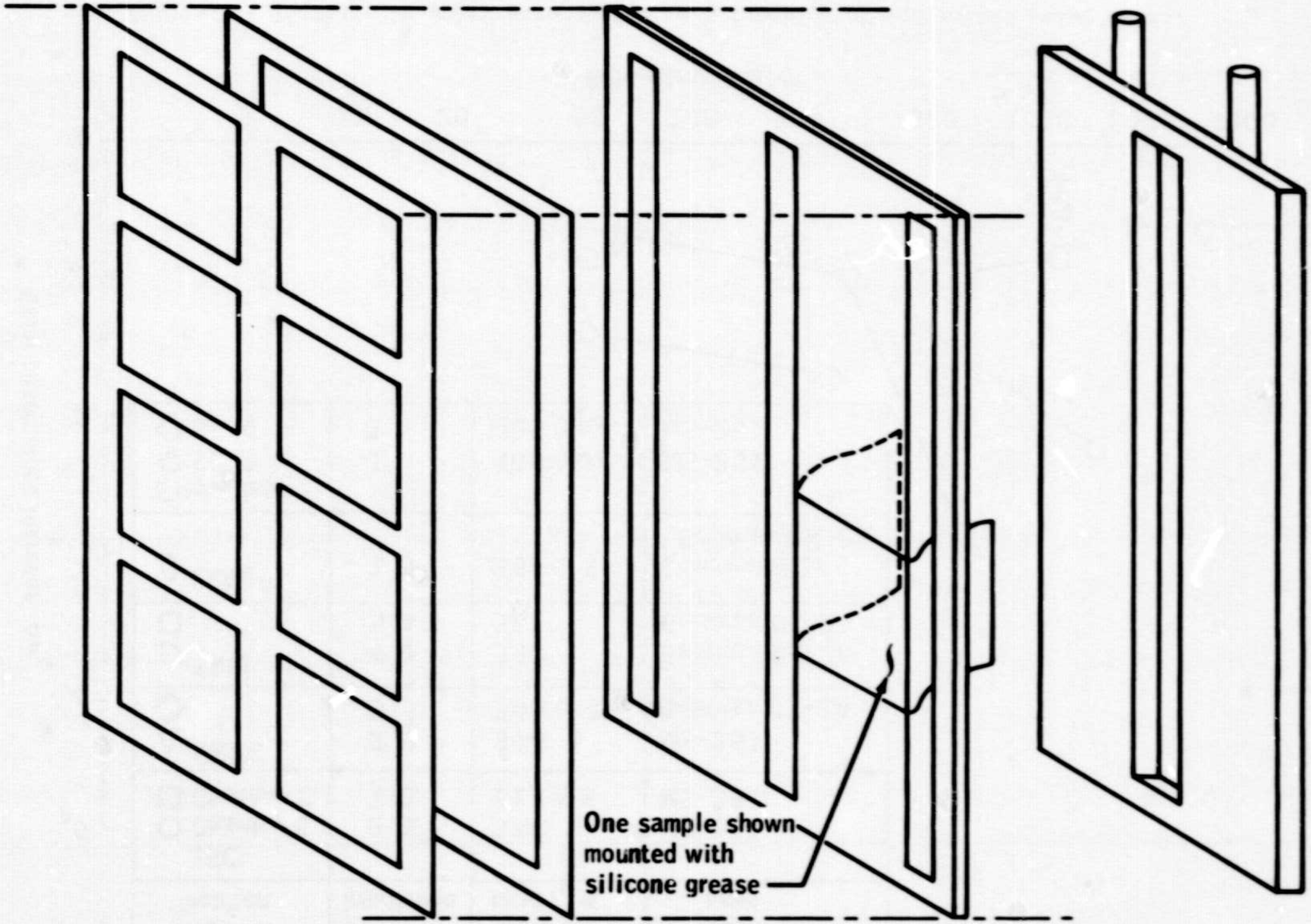
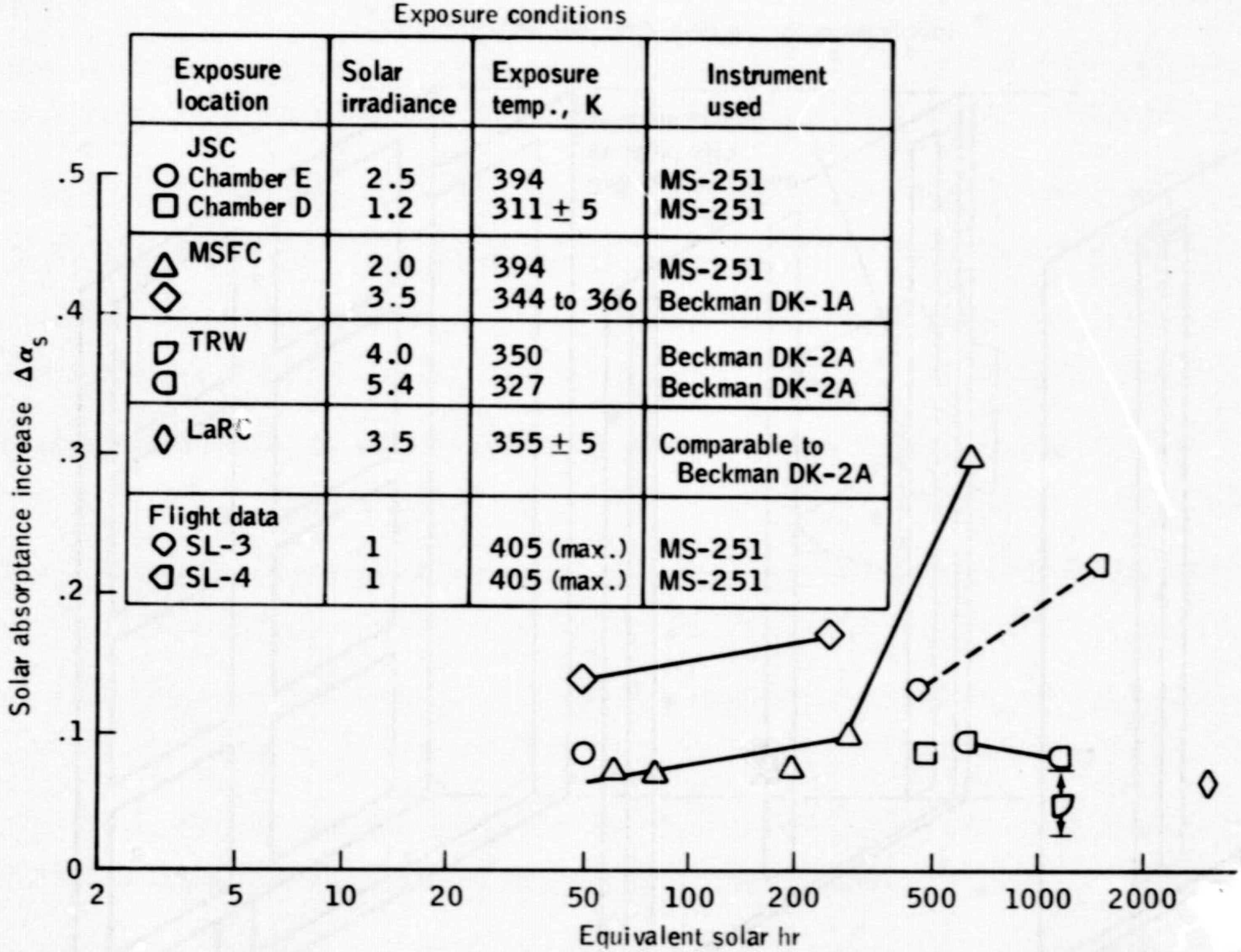


Figure 2.- The TRW sample-mounting arrangement.



Exposure location	Solar irradiance	Exposure temp., K	Instrument used
JSC			
○ Chamber E	2.5	394	MS-251
□ Chamber D	1.2	311 ± 5	MS-251
△ MSFC	2.0	394	MS-251
◇	3.5	344 to 366	Beckman DK-1A
TRW (flagged square, slanted side right)	4.0	350	Beckman DK-2A
(flagged square, rounded left)	5.4	327	Beckman DK-2A
◊ LaRC	3.5	355 ± 5	Comparable to Beckman DK-2A
Flight data			
(pointed circle) SL-3	1	405 (max.)	MS-251
(pointed square) SL-4	1	405 (max.)	MS-251

Figure 3.- Increase in solar absorptance as a function of equivalent solar hours.

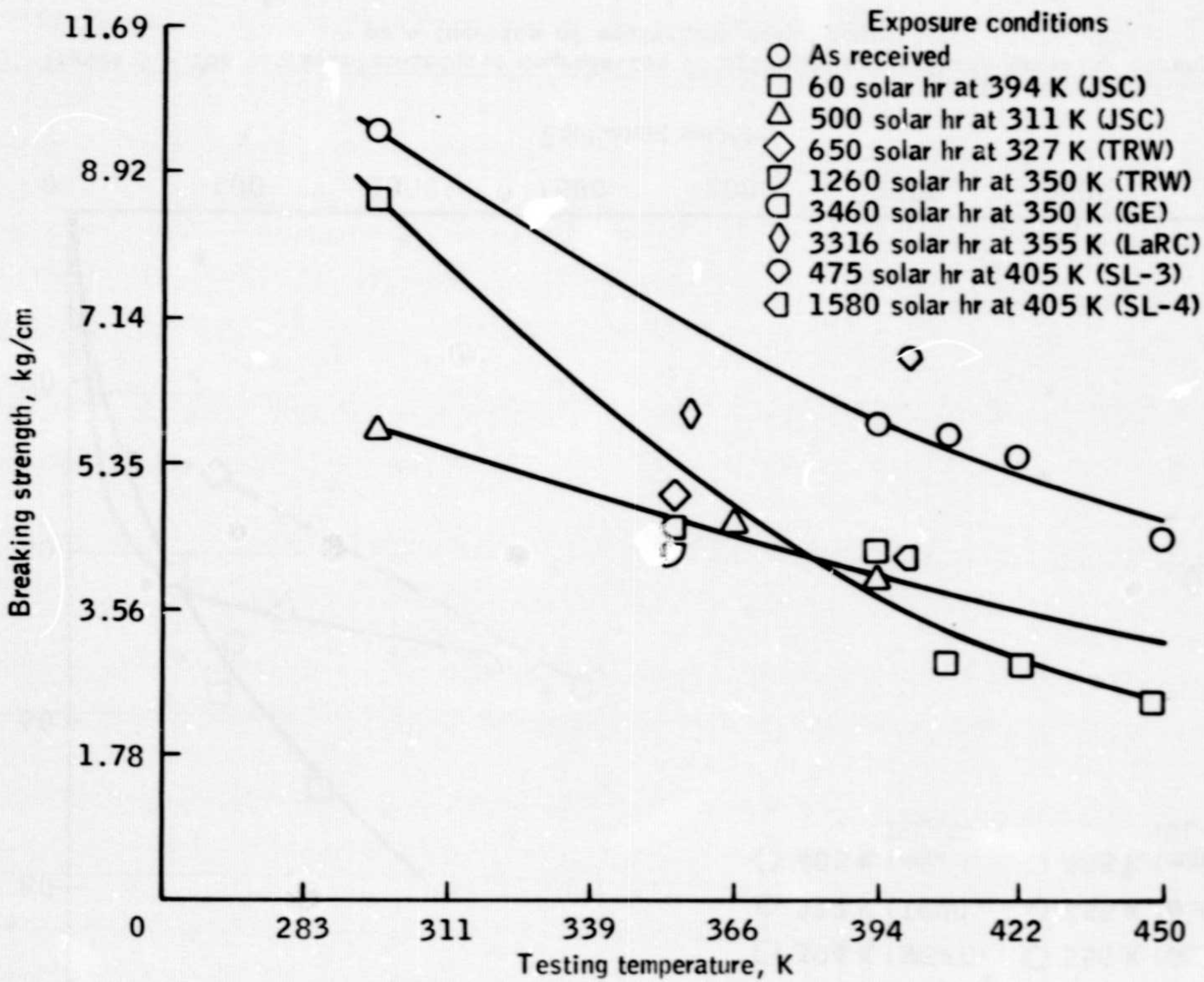


Figure 4.- The ultraviolet-induced degradation of GT-76 breaking strength as a function of temperature.

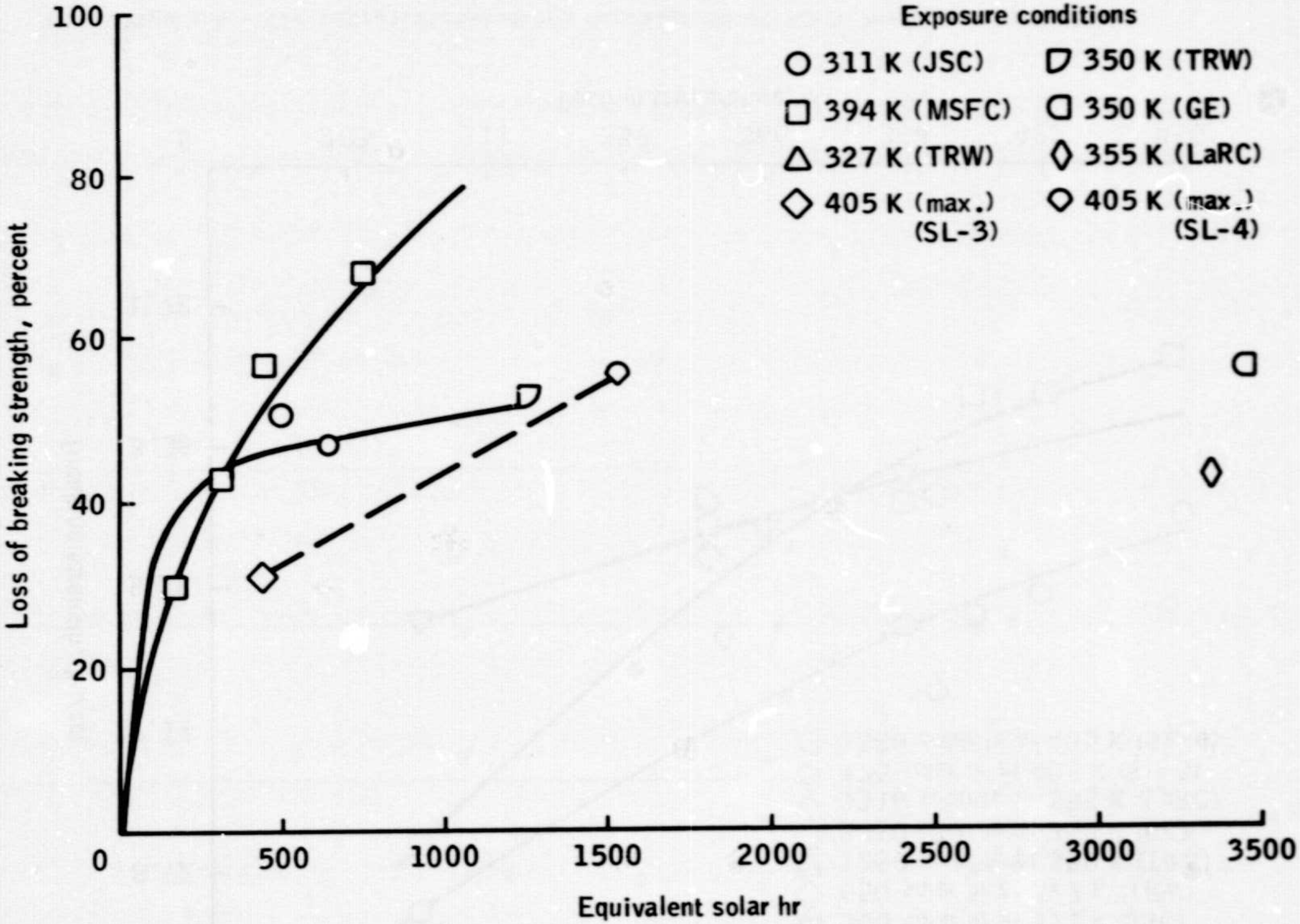


Figure 5.- The ultraviolet-induced degradation of nylon/Mylar laminate breaking strength as a function of equivalent solar hours.

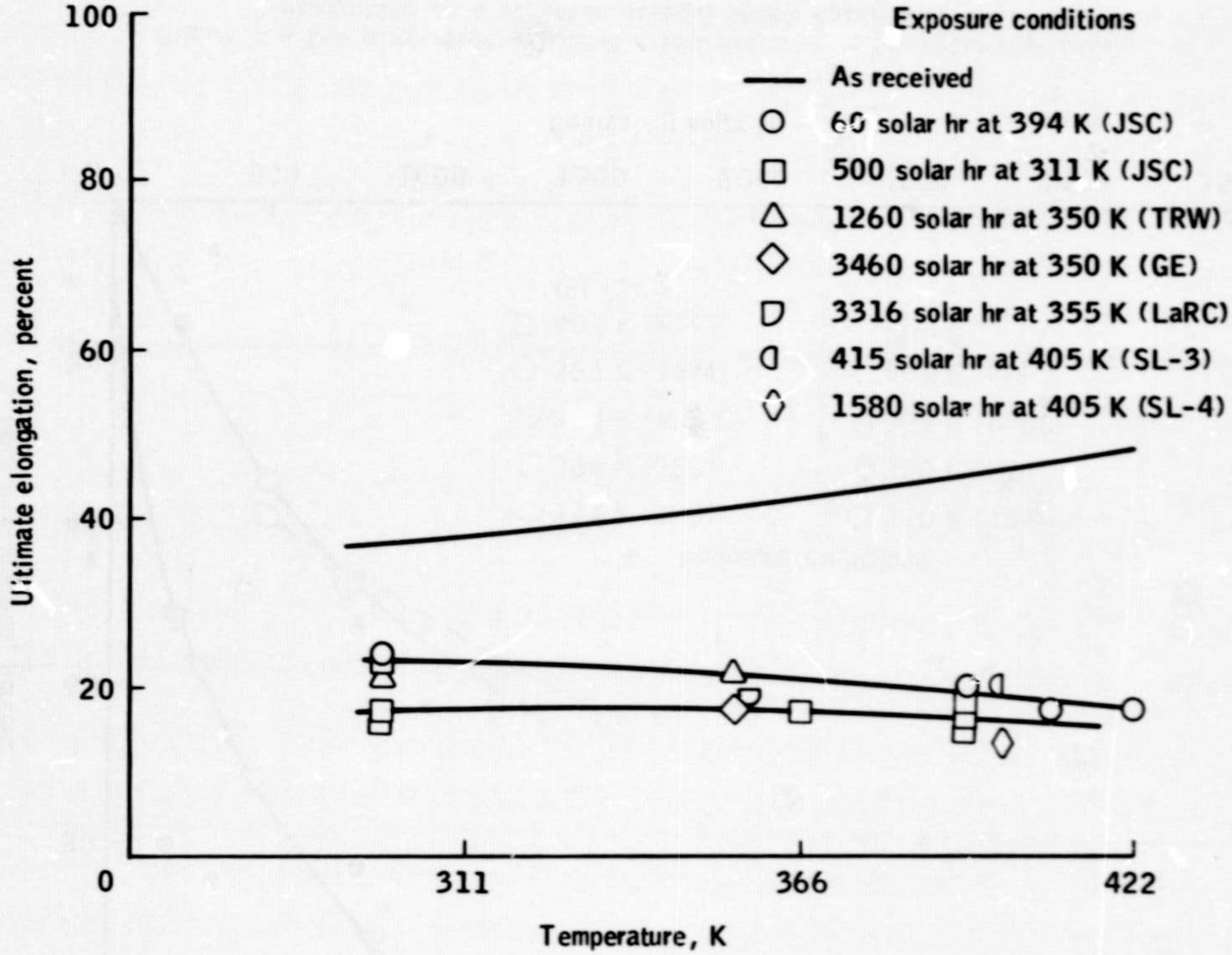


Figure 6.- The ultraviolet-induced degradation of GT-76 elongation as a function of temperature.

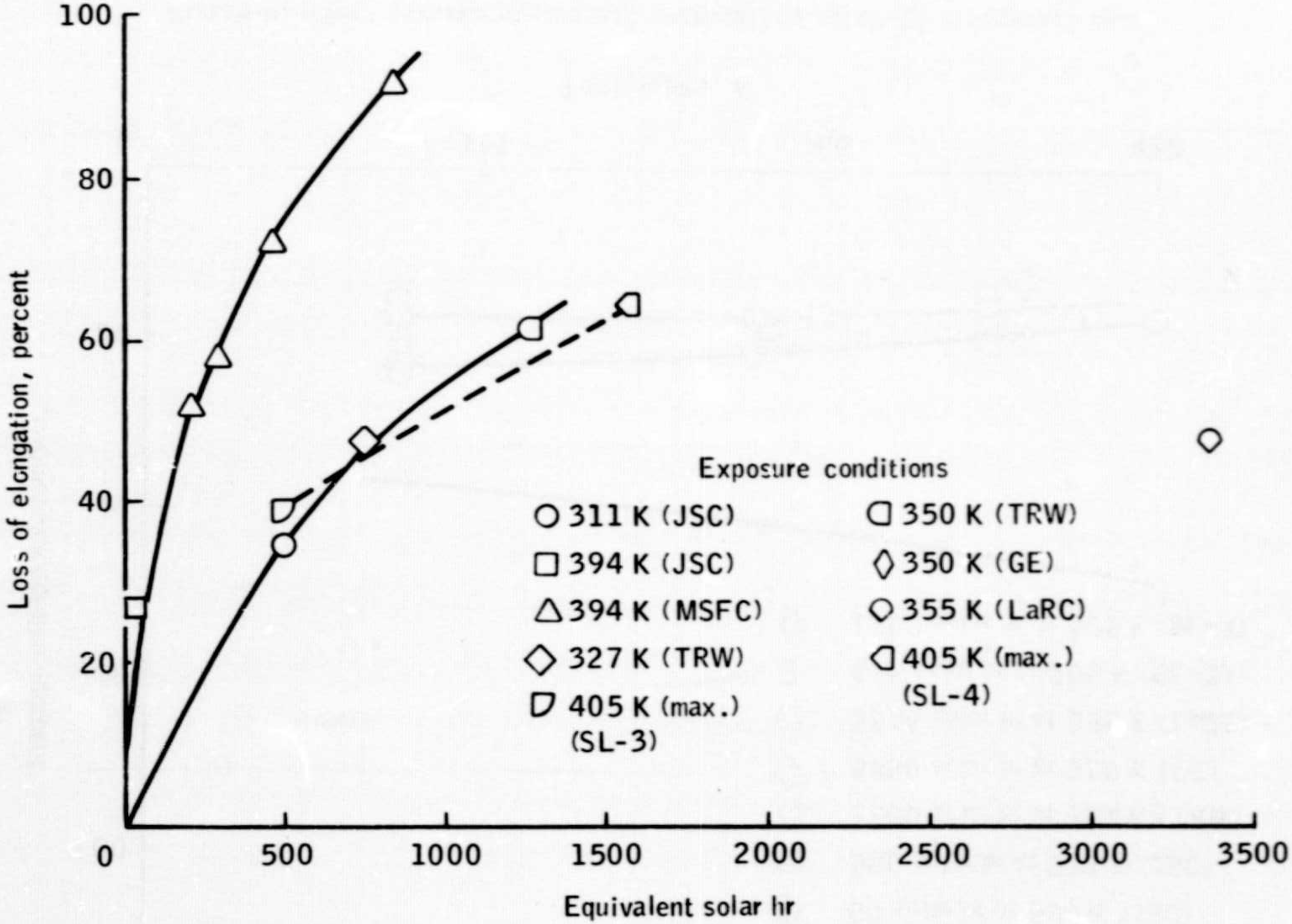
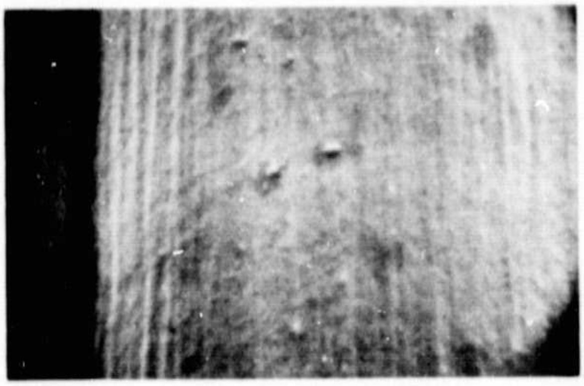
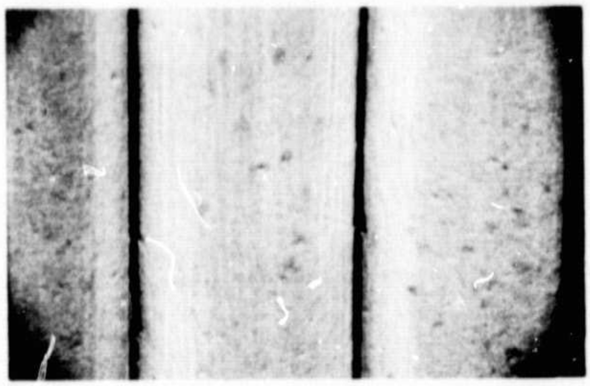


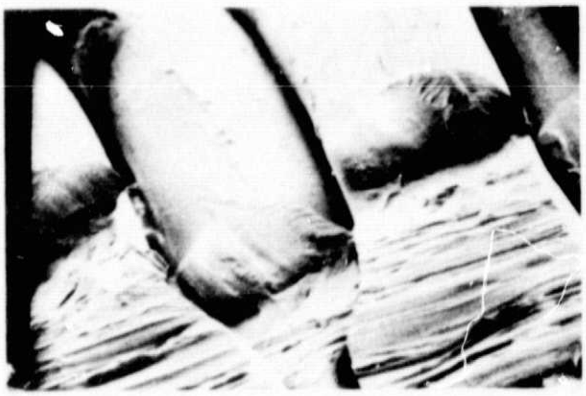
Figure 7.- The ultraviolet-induced degradation of nylon/Mylar laminate elongation as a function of equivalent solar hours.



(a) At 5000× magnification.

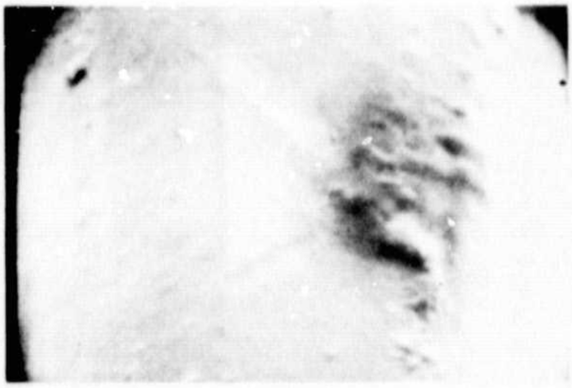


(b) At 2000× magnification.

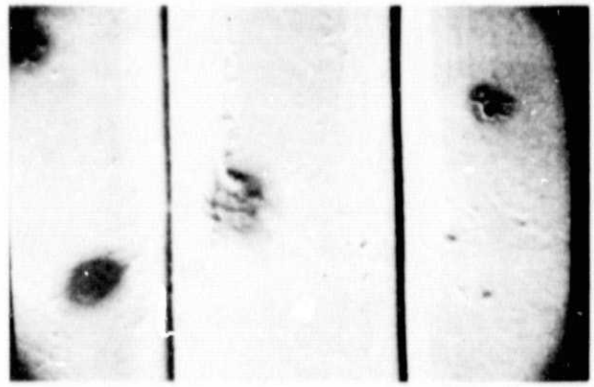


(c) At 2000× magnification, cut.

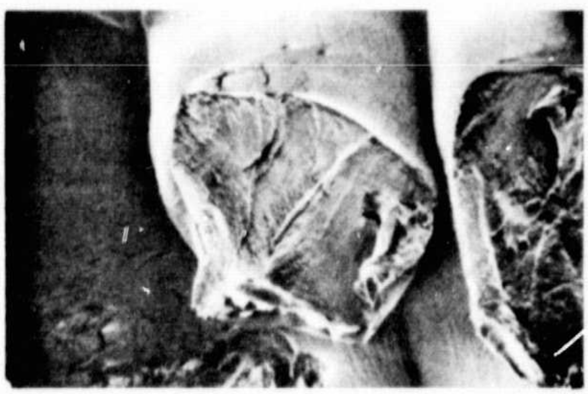
Figure 8.- Scanning electron microscope photomicrographs of unirradiated nylon ripstop material.



(a) At 5000× magnification.

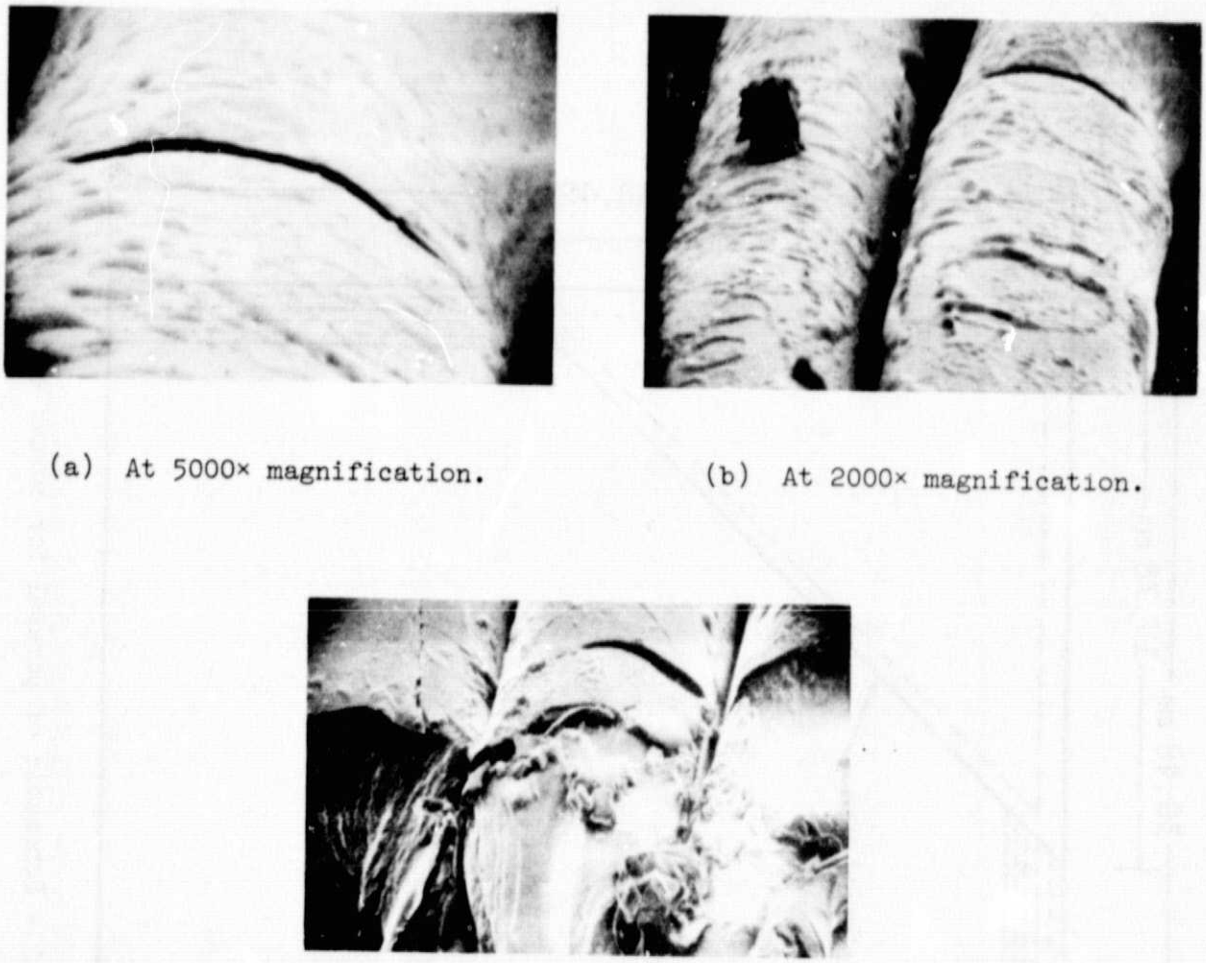


(b) At 2000× magnification.



(c) At 2000× magnification, cut.

Figure 9.- Scanning electron microscope photomicrographs of nylon ripstop material after 500 equivalent solar hours exposure.



(a) At 5000× magnification.

(b) At 2000× magnification.

(c) At 2000× magnification, cut.

Figure 10.- Scanning electron microscope photomicrographs of nylon ripstop material after 1260 equivalent solar hours exposure.

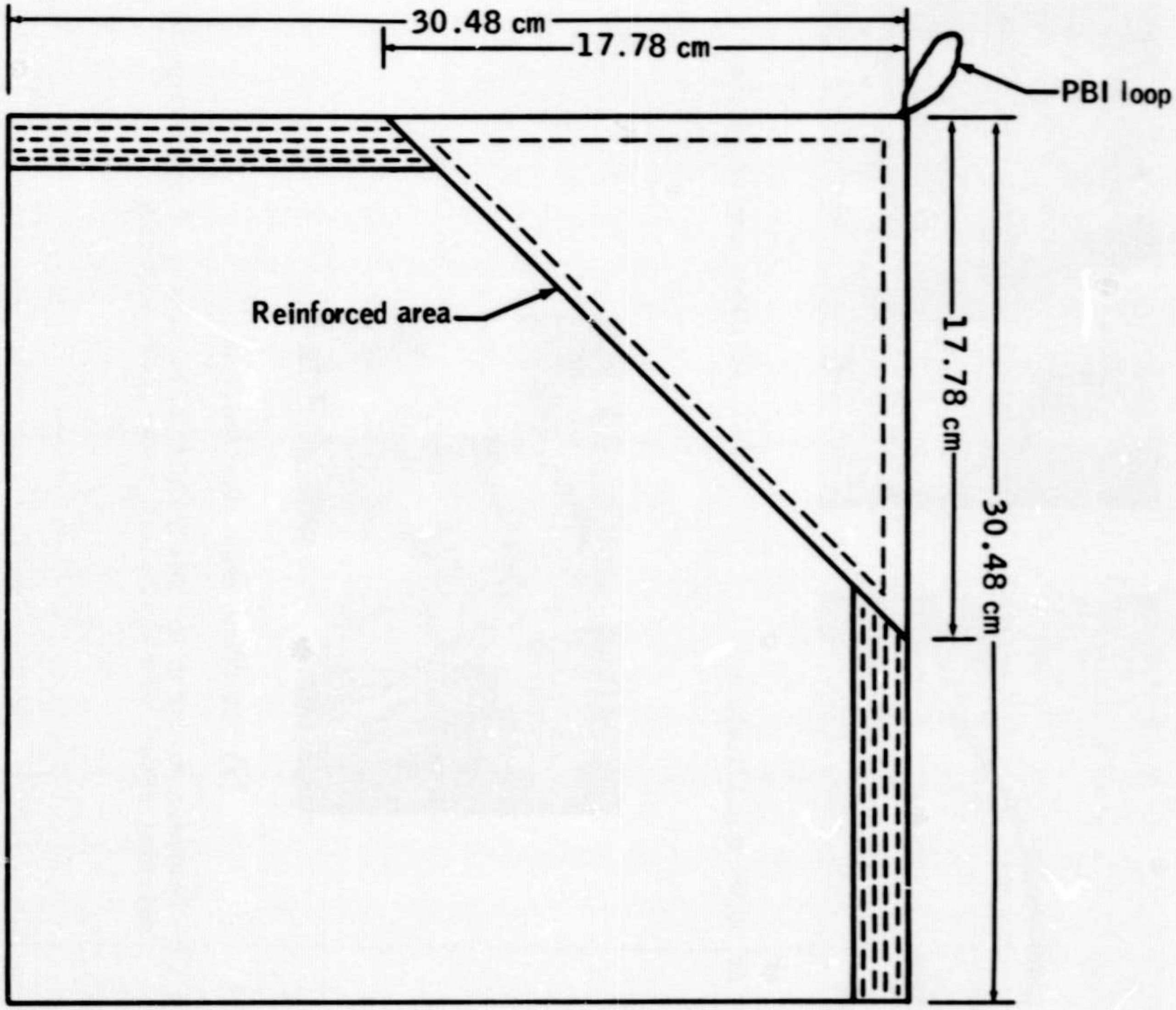


Figure 11.- Schematic of parasol for corner strength test.

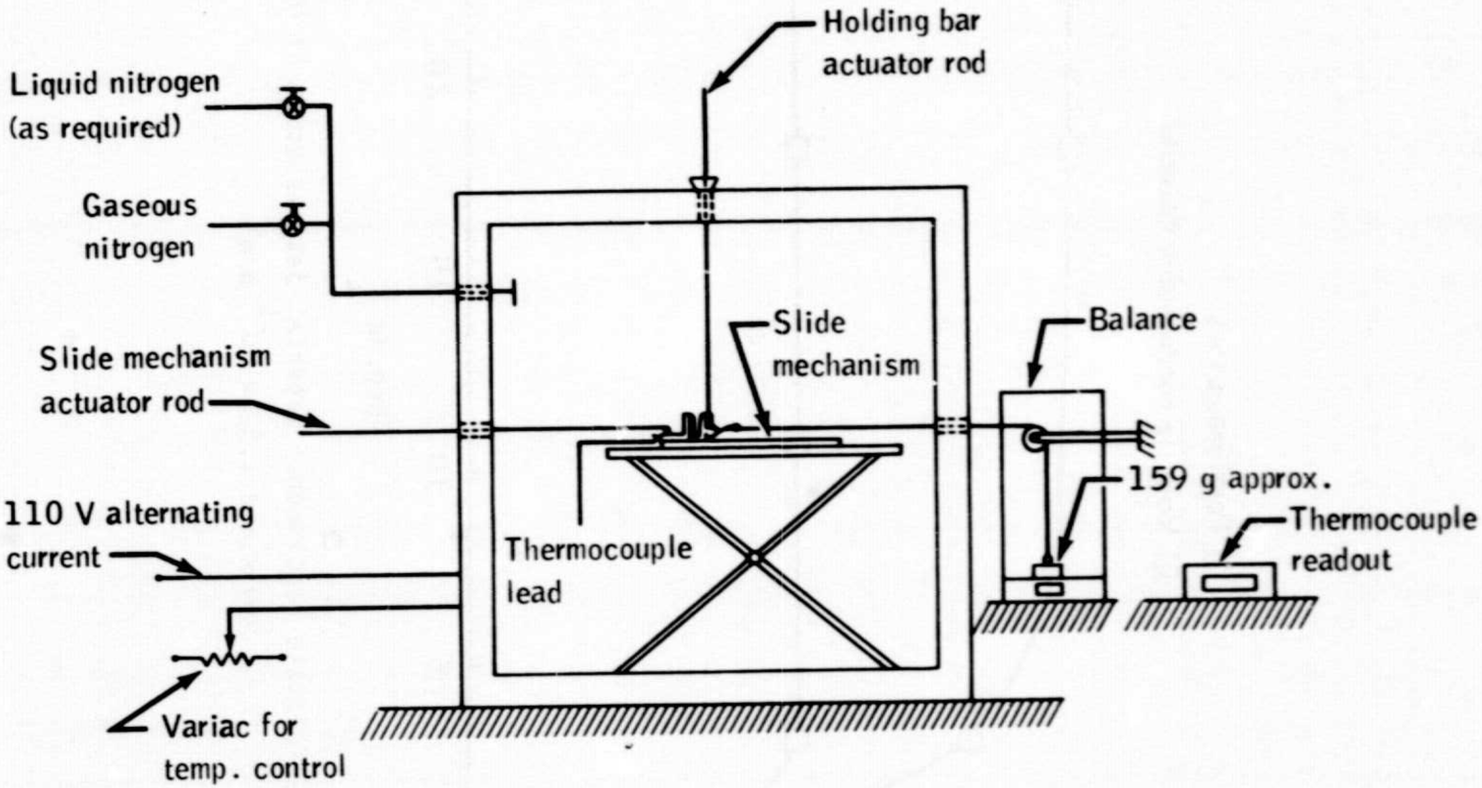


Figure 12.- Stiffness measurement apparatus.

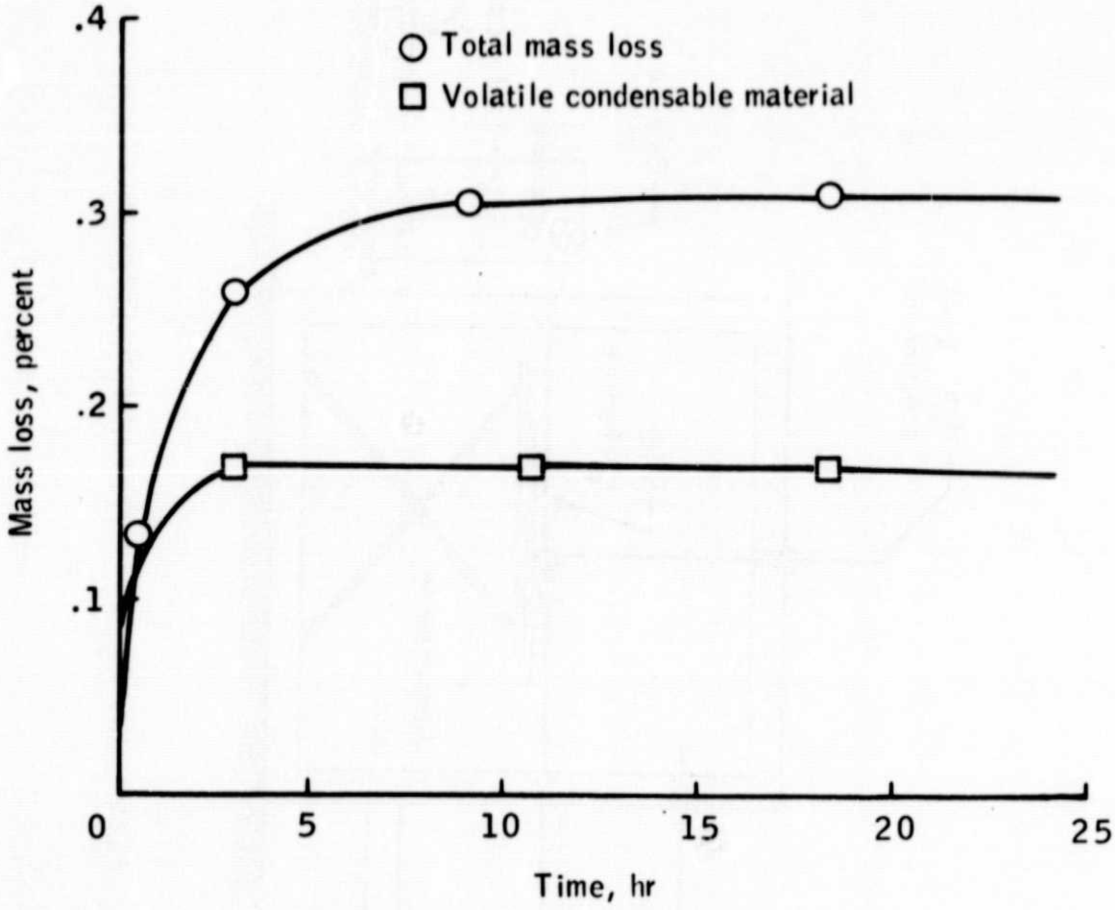


Figure 13.- Volatile condensable material determination of GT-76 at 399 K and 1.33×10^{-4} N/m^2.

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