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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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EVALUATION OF MATERIALS FOR HIGH PERFORMANCE SOLAR ARRAYS (STATUS REPORT NO. 1)

INTRODUCTION

A program has been underway to evaluate materials for advanced solar arrays which are required to provide power to weight ratios up to 100 W/kg. Such arrays employed on the Solar Electric Propulsion (SEP) spacecraft will be exposed to severe environmental conditions imposed by extended duration planetary and geosynchronous missions. Missions such as Mercury orbit, Enche Flyby, and Halley's Comet Rendezvous will subject the array materials to extremes in temperature, solar radiation to 11 equivalent suns, and particle flux densities to 10^{16} particles/cm^2.

The long duration functional lifetime requirements on these lightweight, high performance arrays demand careful selection of array materials. The space environment, in general, can be considered a hostile environment to many materials and even classes of materials. Space environment material problems are well documented. A thermal/vacuum environment can affect materials by accelerating the outgassing of volatile species. The condensation of these outgas products on array cover slips will lead to reduced solar cell electrical output, a situation especially critical at high astronomical units (AU). Outgassing can reduce mechanical strength in materials and thus affect the integrity of array substrate, hinge and deployment mechanisms, and create electrical problems through insulation breakdown. A further effect of outgassing is the degradation of thermal control and reflector surfaces. Some extended performance SEP arrays that have been studied but never flown utilize deployable concentrators whose reflectance is especially important at large AU's. Protons, electrons, and ultraviolet (UV) irradiation encountered contribute to surface damage in these array materials. Thin film materials can become embrittled and thermal control surfaces discolored by this irradiation. Severe mission environments together with the lack of knowledge of space environmental materials degradation rates require the generation of irradiation and outgassing engineering data for use in the initial design phase of flight solar arrays.

TEST PROGRAM

The objectives of this program are to subject candidate array materials to selected mission environments of vacuum, UV, and particle irradiation and to determine their mechanical and/or optical properties where appropriate. Approximately 50 materials were identified as candidate materials from the following functional categories: (1) solar cell covers, (2) adhesives, (3) substrate paddings, (4) harness materials, (5) substrate strength materials, (6) mast materials, and (7) thermal control treatments. To date 25 materials have undergone environmental testing and evaluation. The materials being tested are listed in Table 1 together with their identification code, supplier, generic nomenclature, and functional category.

Figure 1 shows the test flow plan established for the evaluation of these materials. Major test facilities utilized to implement this test plan include two weight loss systems, one 1 kW UV source, one 2.5 kW UV source, one 5 kW UV source, one 20 kW solar simulator, and one 2 MeV Van de Graaff. These facilities have accompanying vacuum systems and instrumentation. The UV/vacuum test series consists of exposures of 500 Equivalent Sun Hours (ESH) at 1 sun, 1500 ESH at 3 suns, 1500 ESH at 6 suns, and 1500 ESH at 10 suns at 10^{-4} pascal. Particle irradiation/vacuum test series consisted of electron flux densities of 10^{12} particles/cm^2 to 10^{16} particles/cm^2 at 10^{-4} pascal. Material evaluations include optical and mechanical property determinations and damage mechanism studies of irradiated materials. The portion of the test flow plan covered for these materials includes outgassing exposures, UV/vacuum exposures through 1500 ESH at 3 suns, and proton exposures in vacuum to 10^{-16} particles/cm^2. Property determinations considered in this report are absorptivity, emissivity, spectral reflectance, breaking strength, elongation, and flexure for appropriate materials.

Material tests included in this report are given in Table II. All materials are first subjected to outgassing screening test. Those materials which fail this test are no longer considered as candidate materials and are not subjected to irradiation testing. However, because of a scheduling problem during this program, irradiation data were generated on one material which later failed outgassing tests.

MATERIALS PREPARATION

For outgassing and weight loss determination, solid material specimens are sized to have an initial weight of 50 to 60 mg and not be over 0.16 cm thick. These specimens are limited to a maximum dimension of 2.5 by 2.5 cm to fit the balance weighing pan. Certain materials such as liquid and tape with adhesive require special preparation techniques.

For irradiation testing, size of test specimen varies depending on the type of optical or mechanical property measurements to be made. For irradiation testing, test specimens of sheet materials were prepared in widths of 2.5 cm and roll direction lengths of 17.8 cm. UV radiation of these specimens covered 10.1 and 12.7 cm of length with the mechanical properties determined over this length. Particle irradiation of specimens occurred over a diameter of 3.8 cm and mechanical properties for these were determined using a gauge length of 12.7 cm. Those materials specifically evaluated for optical property changes were configured in squares of 2.5 cm to a side.

Rod type materials such as battens and longerons were tested in the "as received" configuration. The temperature of the specimen is controlled by mounting it on a thermally controlled plate. All materials were maintained in a clean, low humidity environment.

TEST PROCEDURES

Weight Loss and Residual Gas Analysis (RGA) Outgassing Test Procedures

One of the weight loss/RGA test systems is shown in Figure 2. The weight loss and RGA outgassing test is performed in a thermal/vacuum environment. The specimen is evacuated to 10^{-3} to 10^{-6} pascal using an oil diffusion pumped system backed by a mechanical roughing pump and trapped by an optically blind LN_2 baffle. Temperature control of a specimen is programmed at a heating rate of 2°C per minute from ambient to 100°C. Weight loss is measured continuously using a Cahn RG electrobalance set up to measure with a sensitivity of 25 μg. RGA scans are made periodically during the test using a UT1100C RGA which is capable of scanning from 0 to 400 atomic mass units (AMU). The test duration is from 8 to 24 h depending on outgassing characteristics of the material being tested. This test apparatus also has the capability of exposing the specimen to UV of one solar constant while weight loss and RGA data are being recorded.

If required, a temperature controlled optical collector can also be placed in the system during test to provide optical degradation data. To be acceptable from an outgassing standpoint, a material must have a maximum rate of weight loss no greater than 0.2 percent/cm^2/h and its RGA data must show no mass peaks above 50 AMU which are no less than the major peak by a factor of 100.

The test apparatus is initially evacuated to less than 5×10^{-3} pascal and background RGA scans made on the system at ambient temperature and at 100°C to determine if the system is sufficiently clean to test materials or if the system will require a thermal/vacuum bakeout before it is acceptable for testing. If background data show the apparatus to be clean, it is brought to ambient conditions and a specimen is placed on the balance and the system evacuated to 5×10^{-3} pascal with weight loss being recorded simultaneously. RGA scans are made as soon as the system reaches 5×10^{-3} pascal and periodically during the temperature rise to 100°C and while holding at that temperature. The frequency of the scans is determined by weight loss data and system pressure rise.

Proton Irradiation Test Procedures

Proton irradiations were performed using a 2.5 MeV Van de Graaff ion accelerator (Fig. 3) as a proton source. For all irradiations, the accelerator was operated at a potential of 2.0 MeV. The proton exposures were varied by changing proton beam current and time of exposure. The range of proton exposures was from 10^{12} protons/cm^2 to 10^{16} protons/cm^2. The lower limit is determined by the minimum controllable beam produced by the accelerator, and the upper limit is determined by the maximum proton current the 1 mil aluminum foil (used as an ion filter) could transmit without melting. The aluminum foil degraded the proton beam energy by 220 keV; thus, the actual proton exposure energy was 1.78 MeV.

The specimens were irradiated in a high vacuum chamber (76.2 cm in diameter by 121.9 cm in length) that is evacuated via an oil diffusion pump 15.2 cm in diameter pumping through two in-line LN_2 cold traps. Pressures of the order of 1×10^{-5} pascal were achieved in the chamber prior to operation of the accelerator. Hydrogen gas leaking from the ion source of the accelerator raises the pressure during irradiation to between 5×10^{-4} to 1×10^{-3} pascal.

UV Irradiation Test Procedures

Test specimens are irradiated with a xenon lamp source under ambient conditions in a vacuum environment of 10^{-3} to 10^{-6} pascal. Specimens were screened initially for UV stability by exposing them for 500 ESH at one solar constant. A typical UV/vacuum system with associated equipment is shown in Figure 4.

Xenon lamp sources being used are 1 to 20 kW and produce radiation intensities of 1 to 10 solar constants. The intensity of the sources is measured with a Hy-Cal calibrated pyroheliometer and the source spectrum is checked for changes periodically over a range of 2000 to 10 000 Å using a McPherson Model 218 monochromator.

The vacuum environment is maintained using an ion pumped stainless steel vacuum system or an oil diffusion pump backed by a mechanical roughing pump and trapped by an optically blind LN_2 baffle. The vacuum system can also be equipped with optical collectors to provide optical degradation data and an RGA to monitor outgassed constituents.

Material Property Measurements

Optical properties reported for these materials include absorptivity (α), emissivity (ϵ), and spectral reflectance. Absorptivity measurements were made with a Gier-Dunkle Model MS 251 mobile solar reflectometer. This measurement is independent of temperature and accurate to ±2 percent. Emissivity (ϵ) was determined using a Gier-Dunkle Model DB 100 infrared reflectometer. This measurement also is independent of temperature with accuracy to ±3 percent. A Beckman DK 2A specrophotometer with a scan from 2.5 to 0.25 μ was used for spectral reflectance measurement.

Mechanical properties measurements were made using an Instron testing machine. This standard test system can apply tensile or compressive loads from 2 gm to 10 000 kg. Accuracy of the detection system is better than ±5 percent. Flexure was determined by applying load across a 5 cm span of the test sample mounted on a knife edge attachment to the Instron testing machine.

RESULTS AND DISCUSSION

This is the first status report on materials being evaluated under the described test plan. No priority was placed on materials chosen for test. However, practical considerations of reducing system contamination and subsequent down time resulted in the testing of those classes of materials which are known to provide minimum outgassing in vacuum. Considerable data have been generated during the course of these tests.

Nominal mechanical and optical property data are given in Tables 3 and 4, respectively. Outgas screening data for these materials are provided in Table 5. In analyzing the irradiation data, the standard deviation (σ) was computed from control specimens data and 2σ values were used as a test for significance. Values greater than 2σ were considered to be caused by the exposure environment. Tables 6 and 7 give a summary of these analyses for mechanical properties of materials exposed to proton/vacuum and UV/vacuum environments, respectively. Table 8 summarizes the changes in optical properties of UV/ vacuum exposed materials.

One composite material, T-8, failed the outgas screening tests because of material separation (Fig. 5) during the 100°C/vacuum exposure. Two more materials, P-3 and M-4, require a thermal vacuum (T/V) bake to be acceptable.

Examples of substrate strength materials after exposure are shown in Figures 6, 7, 8, and 9. Although mechanical property changes were insignificant, except for S-3 in Table 7, discoloration of these materials occurred at the higher irradiation exposure levels.

Figures 10, 11, and 12 show M-3, M-5, and M-1/M-2 after proton exposures. Significant changes in flexure tests were noted for M-1/M-2 at the 10^{16} protons/cm^2 exposure.

Irradiated adhesive systems are shown in Figures 13, 14, and 15. Some shrinkage was noted in the exposed areas of the proton irradiated samples.

Irradiated padding materials are shown in Figures 16, 17, and 18. Excessive warpage occurred to P-3 when exposed to vacuum/proton and vacuum/ UV environments as shown in Figures 15 and 17, respectively.

Thermal control materials T-2a and T-2b performed well in all environments, with the exception that T-2b showed a 3 percent reduction in spectral reflectance at the 10^{16} protons/cm^2 exposure.

Material T-6 (Fig. 19) failed in the proton irradiation environment as demonstrated by the complete destruction of the substrate.

CONCLUSIONS

All materials will outgas when exposed to an appropriate environment. The environment of space constitutes a hostile environment for most organic materials and it is essential that all such materials proposed for space flight applications be evaluated as to their outgassing characteristics in a thermal vacuum environment and that UV resistance be determined relative to mechanical and optical property degradation. Both UV irradiation and outgassing test data show the need for this type of material evaluation.

Prolonged exposure to proton radiation significantly affects the bulk properties as well as the surface properties of many of the candidate materials proposed for these high performance solar arrays. Thin film materials are especially sensitive to proton radiation induced property changes.

The test data clearly indicate a requirement for evaluation of all nonmetallic materials selected for long duration mission spacecraft. Deleterious effects of synergistic interactions of different particulate and solar radiation must also be determined for otherwise acceptable materials.

The next phase in the test program will be a series of material exposure tests at higher levels of particulate and solar radiations and an assessment will be made of the damage mechanisms pertinent of these materials.

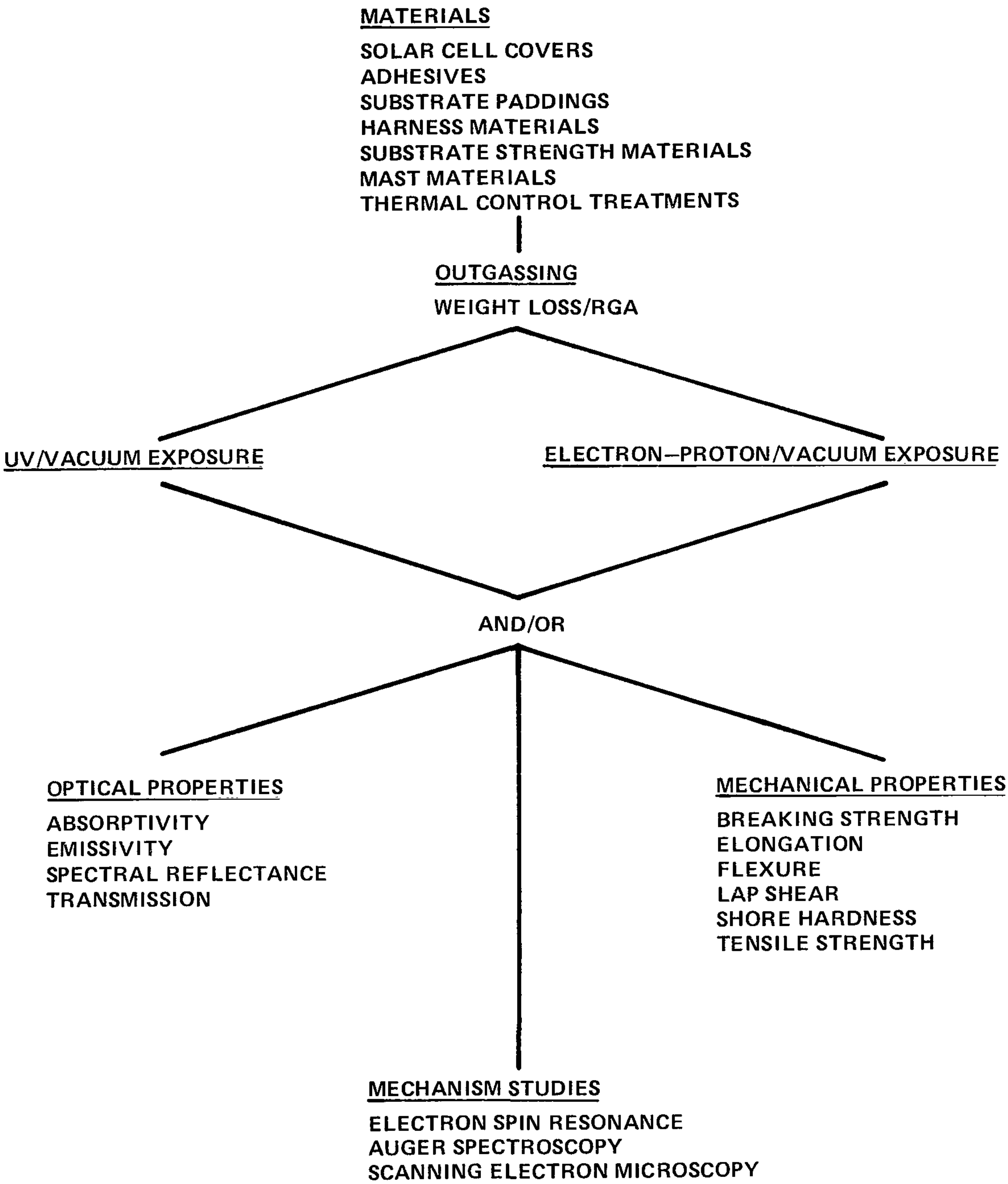

Figure 1. Test flow plan.

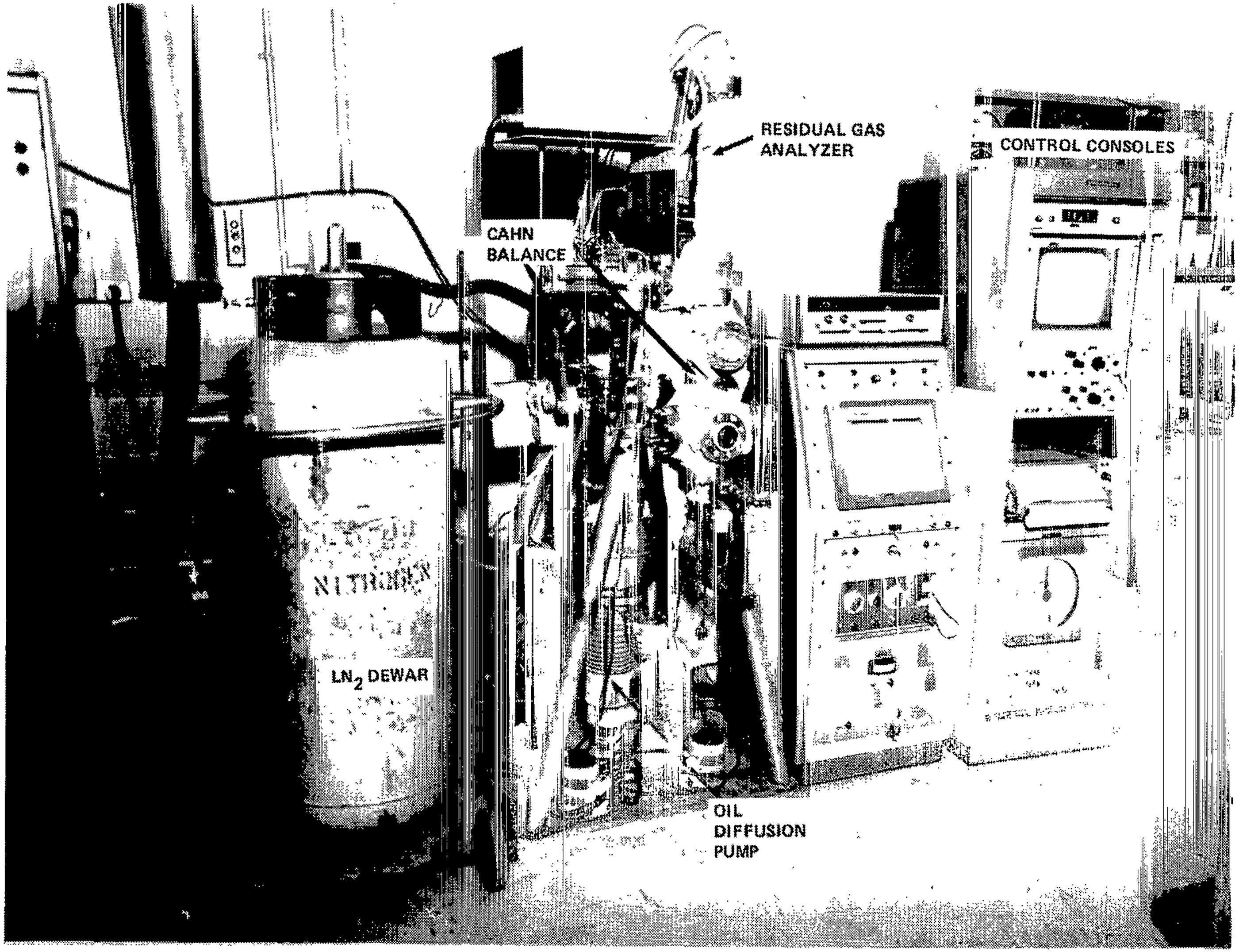

Figure 2. Weight loss/RGA test system.

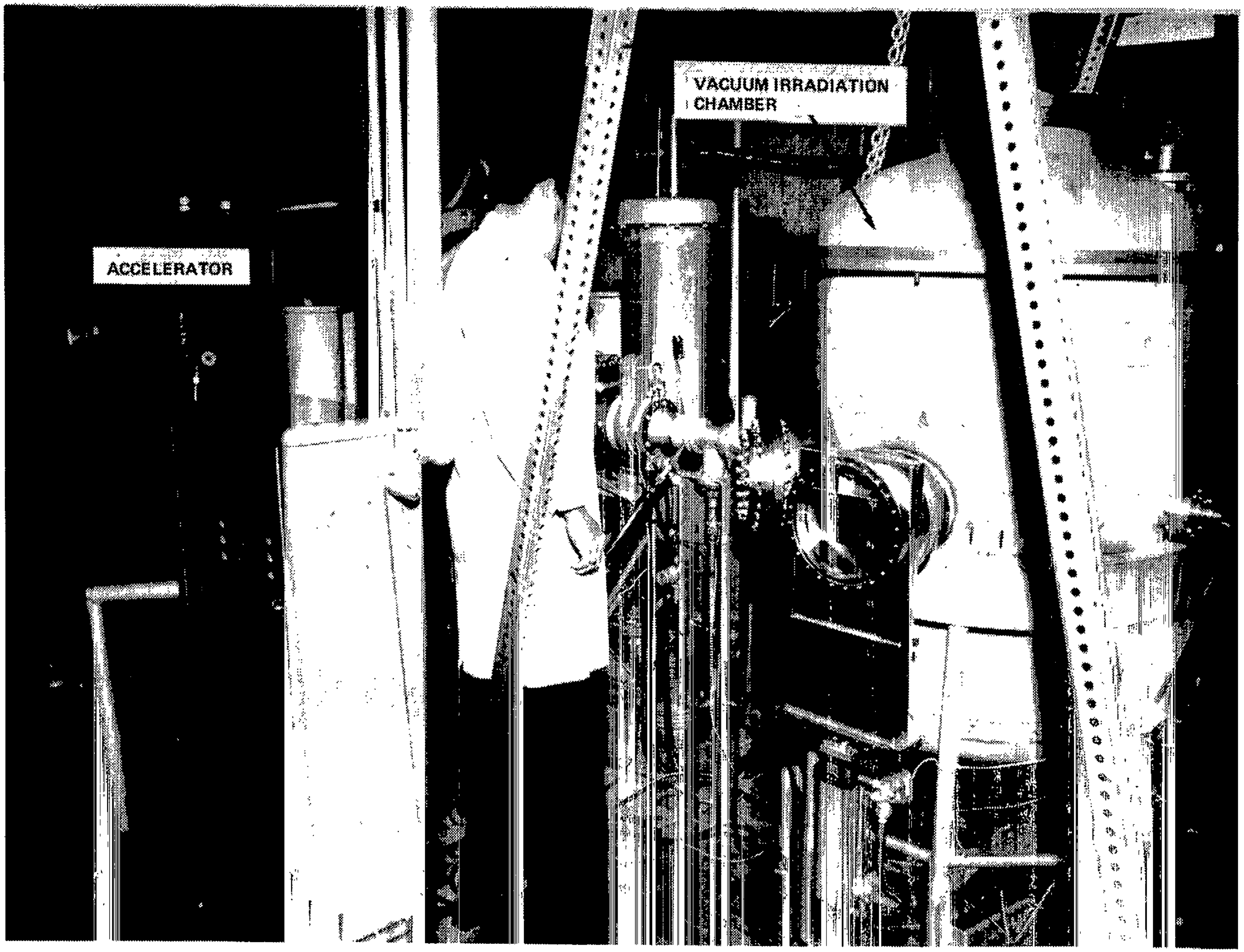

Figure 3. Van de Graaff ion accelerator and instrumentation.

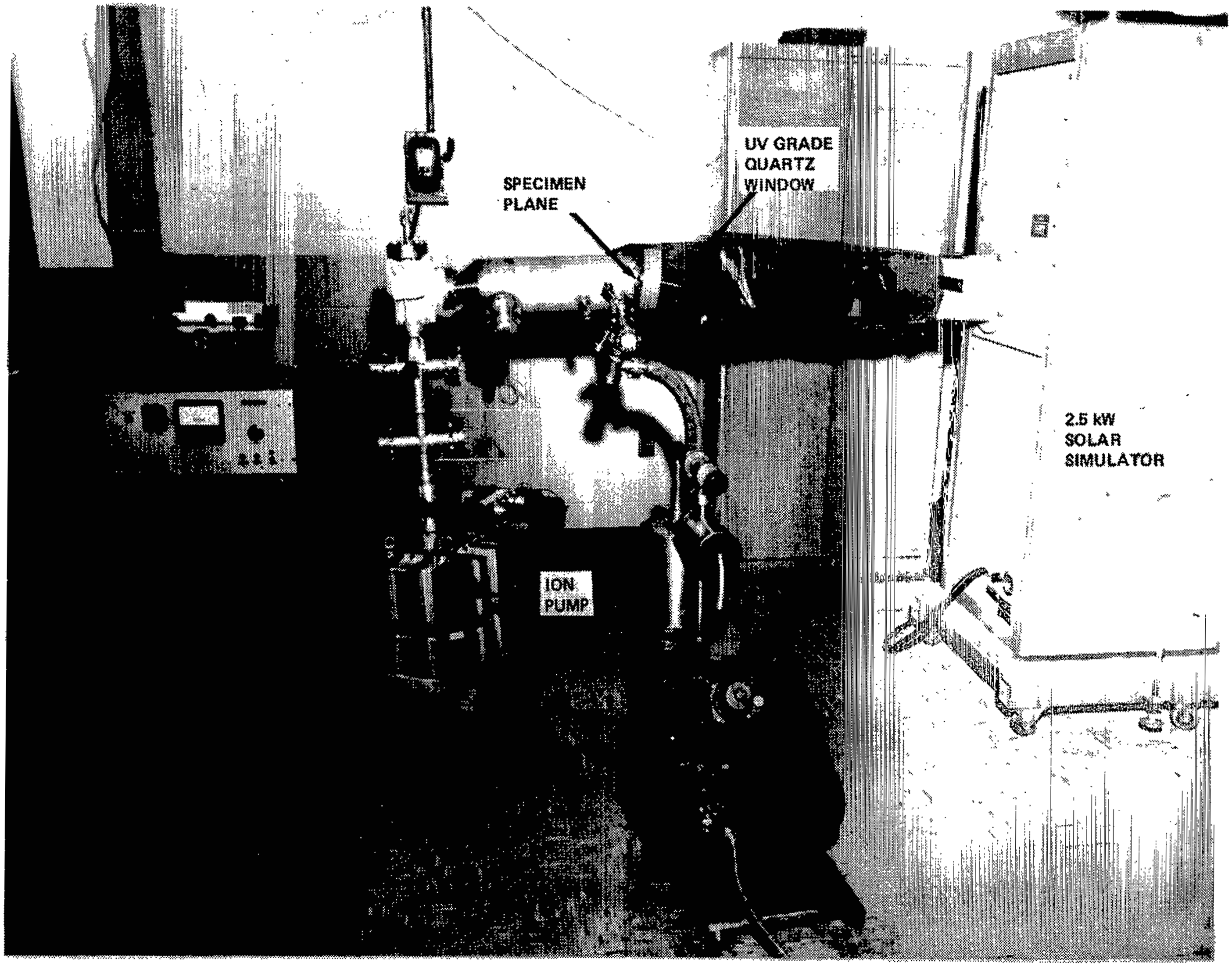

Figure 4. UV irradiation test system.

4 MIL ACRYLIC COATING/SILVER/POLYESTER
OUTGASSING, 100°C, 5 x 10^{-5} PASCAL

CONTROL

TEST

Figure 5. 4 mil acrylic coating/silver/polyester outgassing (100°C, 5×10^{-5} pascal).

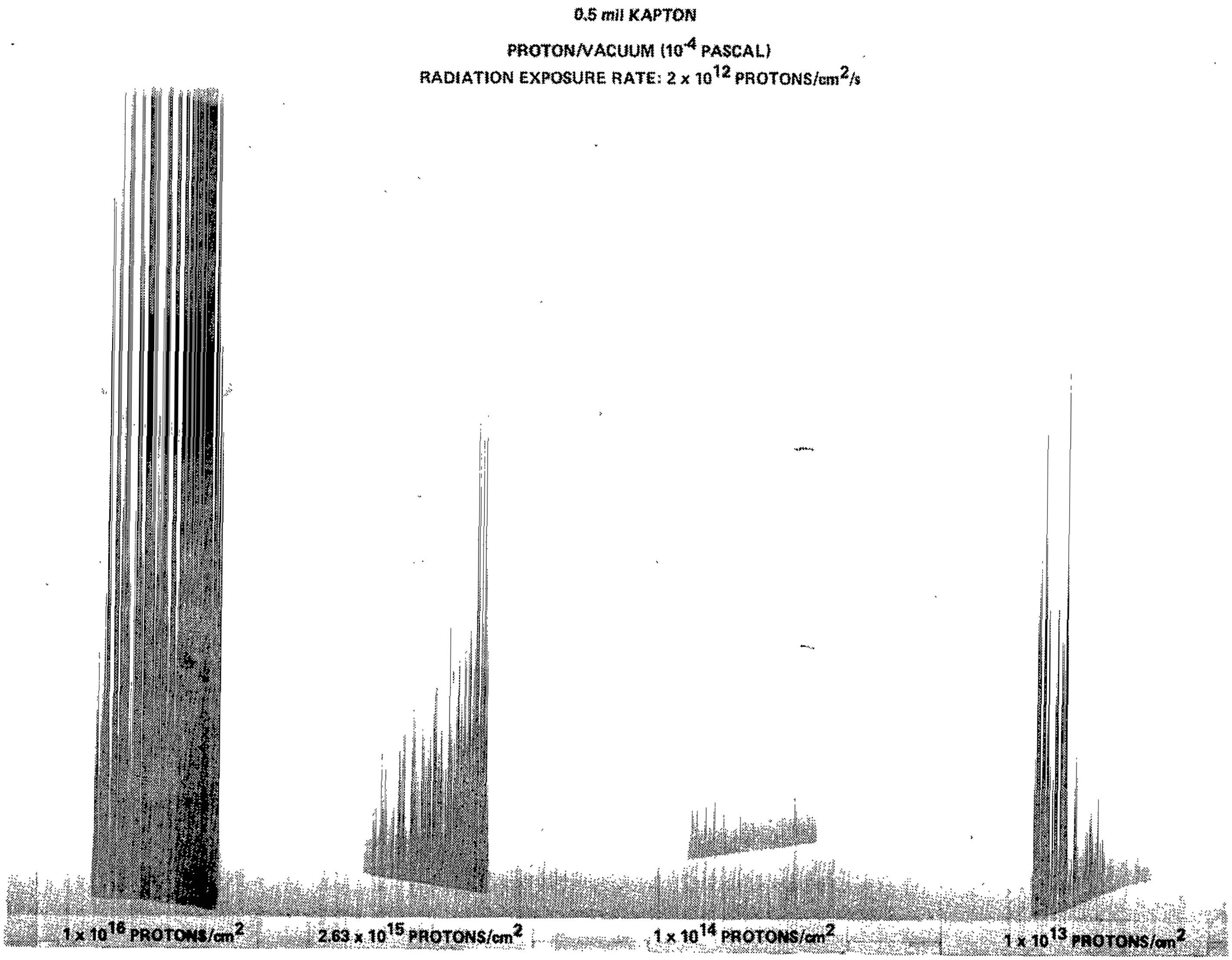

Figure 6. 0.5 mil Kapton proton/vacuum exposure test (10^{13}, 10^{14}, 10^{15}, and 10^{16} protons/cm^2).

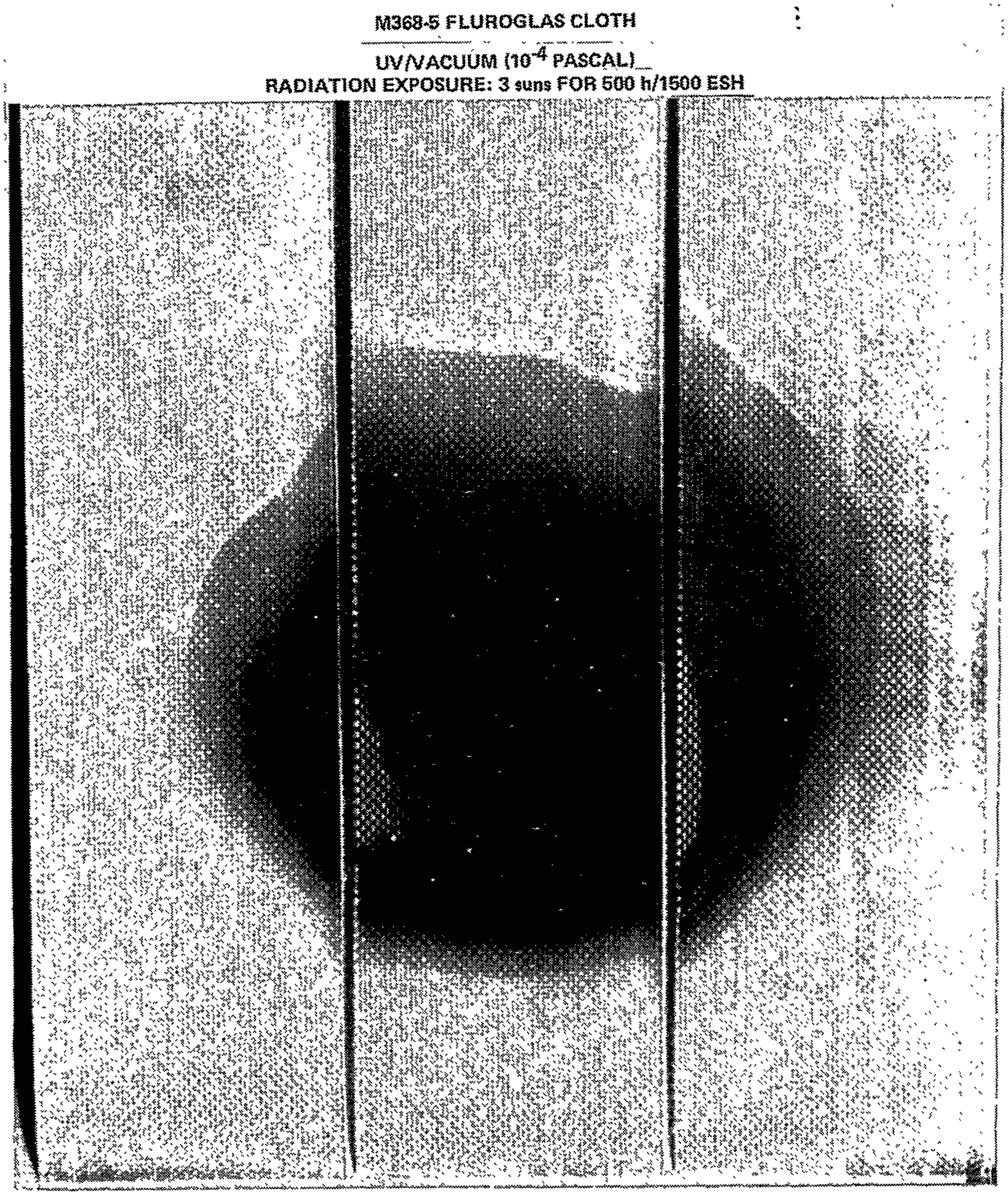

Figure 7. M368-5 Fluroglas cloth UV/vacuum exposure test (1500 ESH at 3 suns).

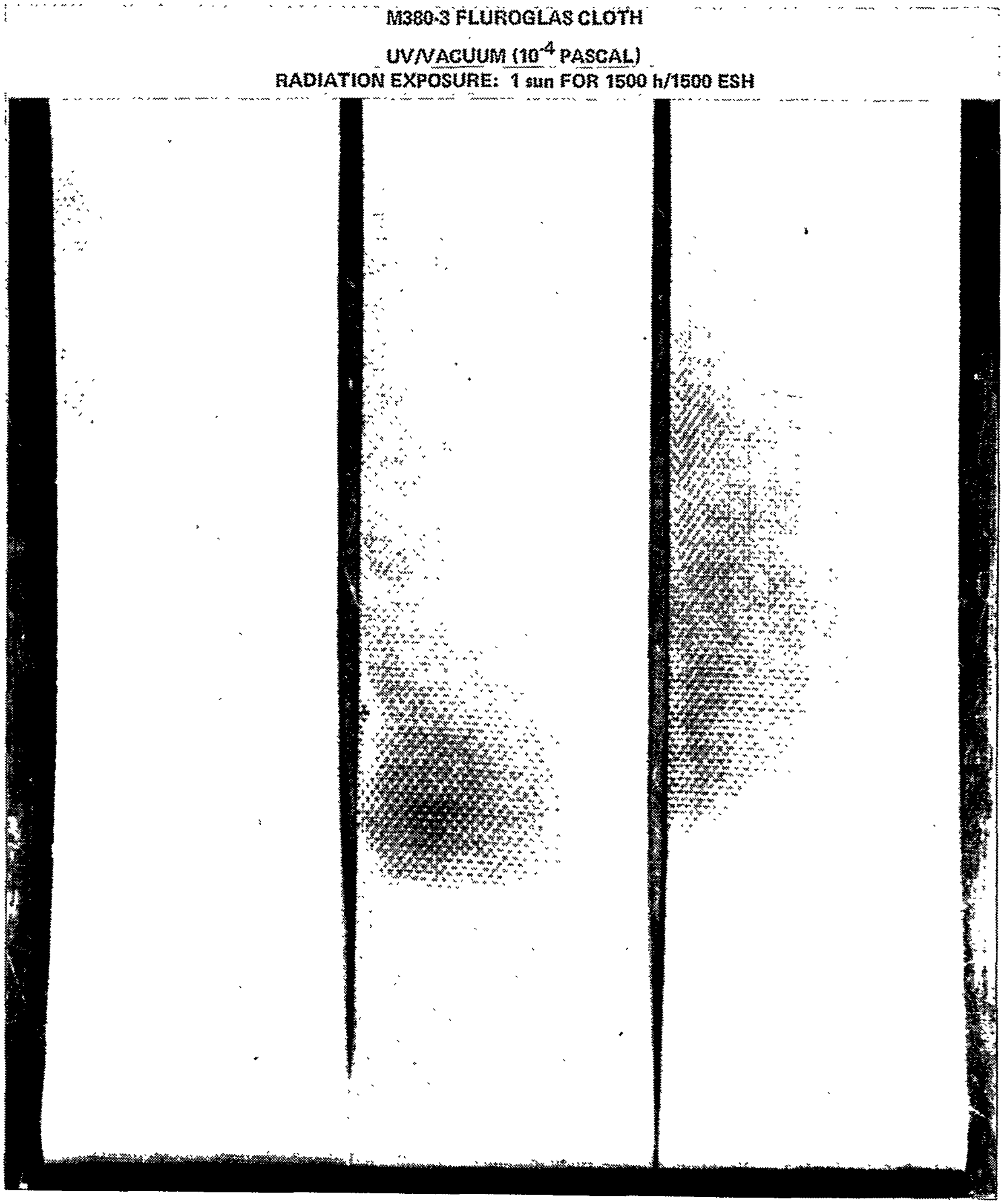

Figure 8. M380-3 Fluroglas cloth UV/vacuum exposure test (1500 ESH at 1 sun).

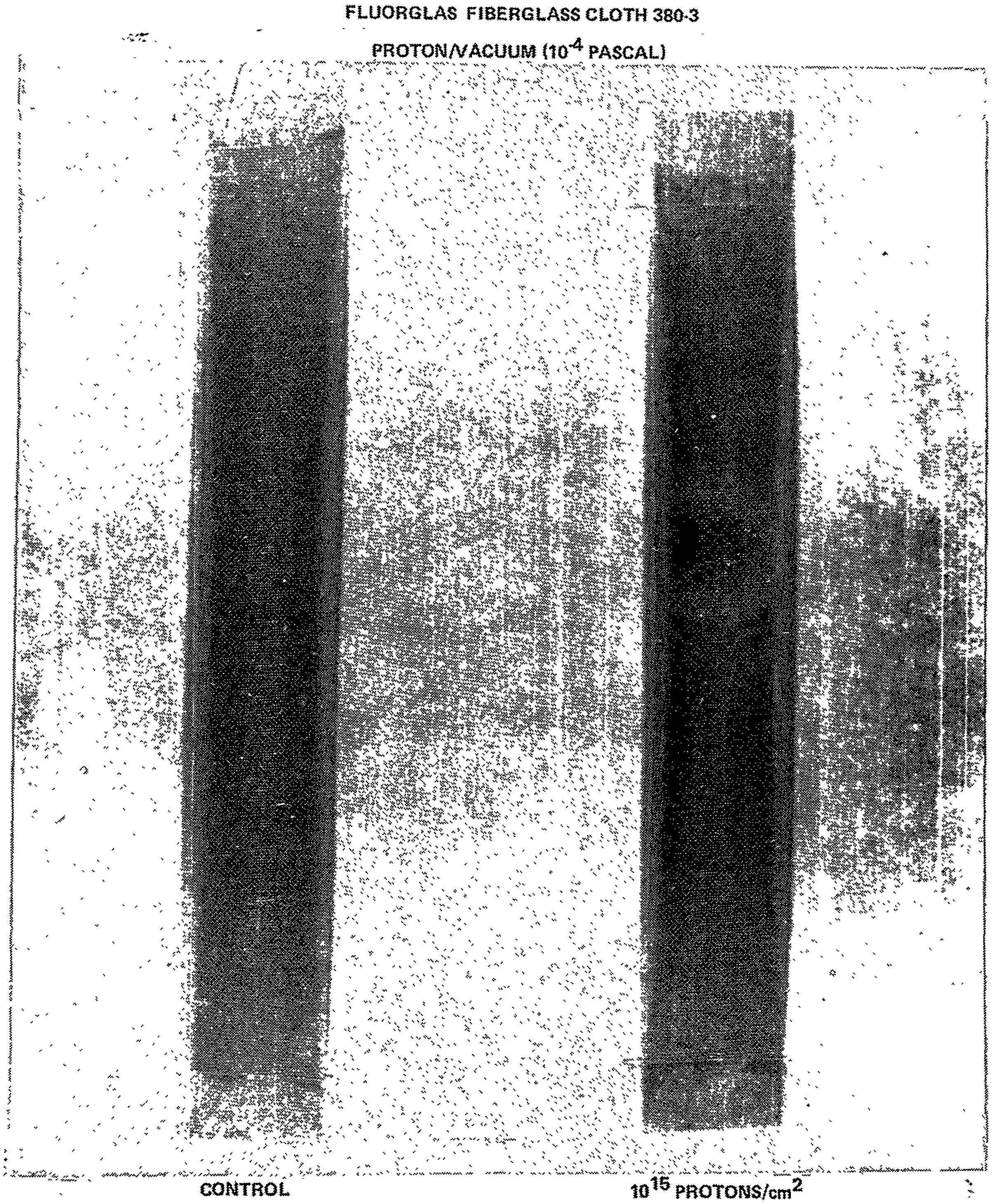

Figure 9. M380-3 Fluroglas cloth proton/vacuum exposure test (10^{15} protons/cm^2).

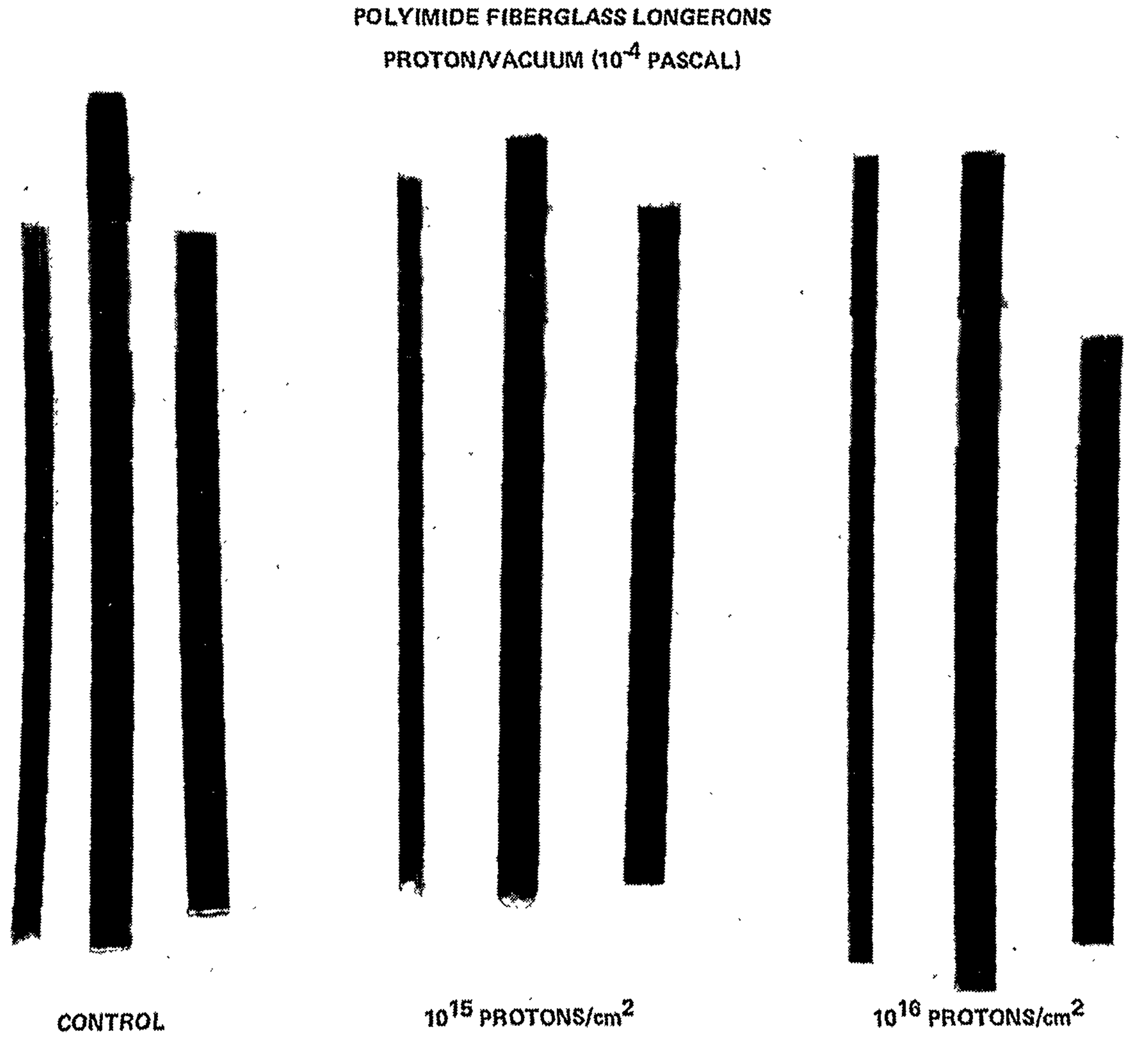

Figure 10. Polyimide fiberglass longerons proton/vacuum exposure test (10^{15} and 10^{16} protons/cm^2).

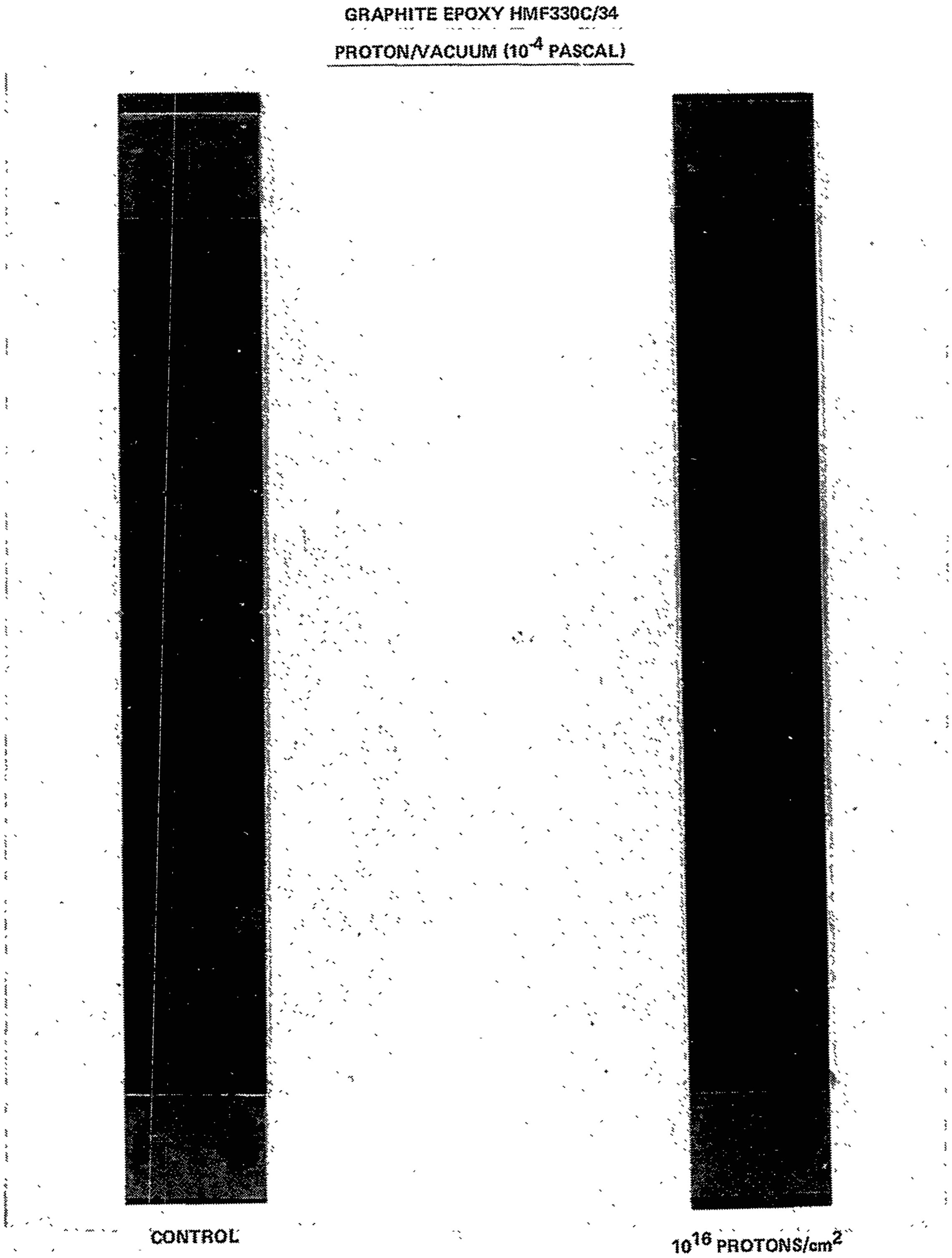

Figure 11. Graphite epoxy HMF 330C/34 proton/vacuum exposure test (10^{16} protons/cm^2).

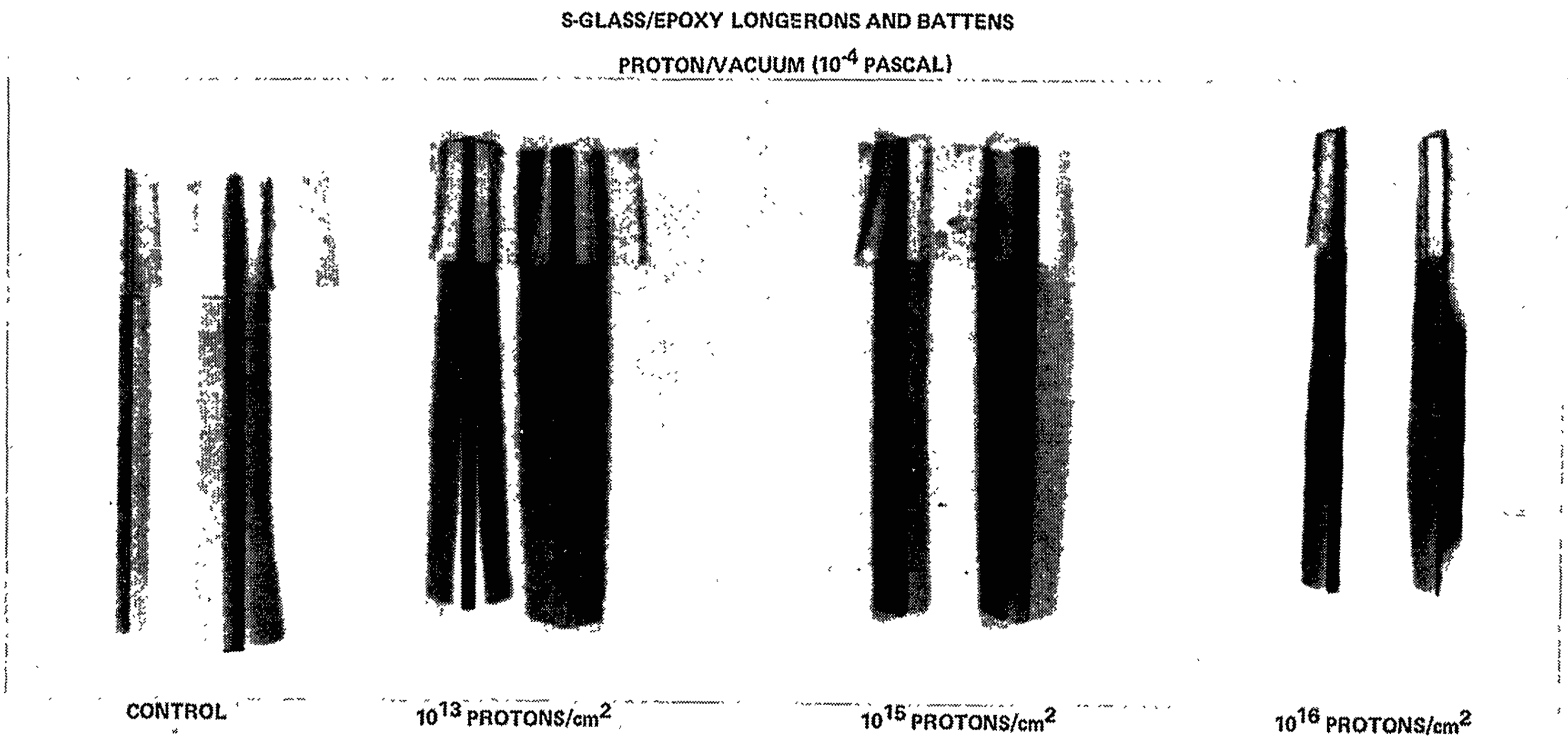

Figure 12. S-Glass/epoxy longerons and battens proton/vacuum exposure test (10^{13}, 10^{15}, and 10^{16} protons/cm^2).

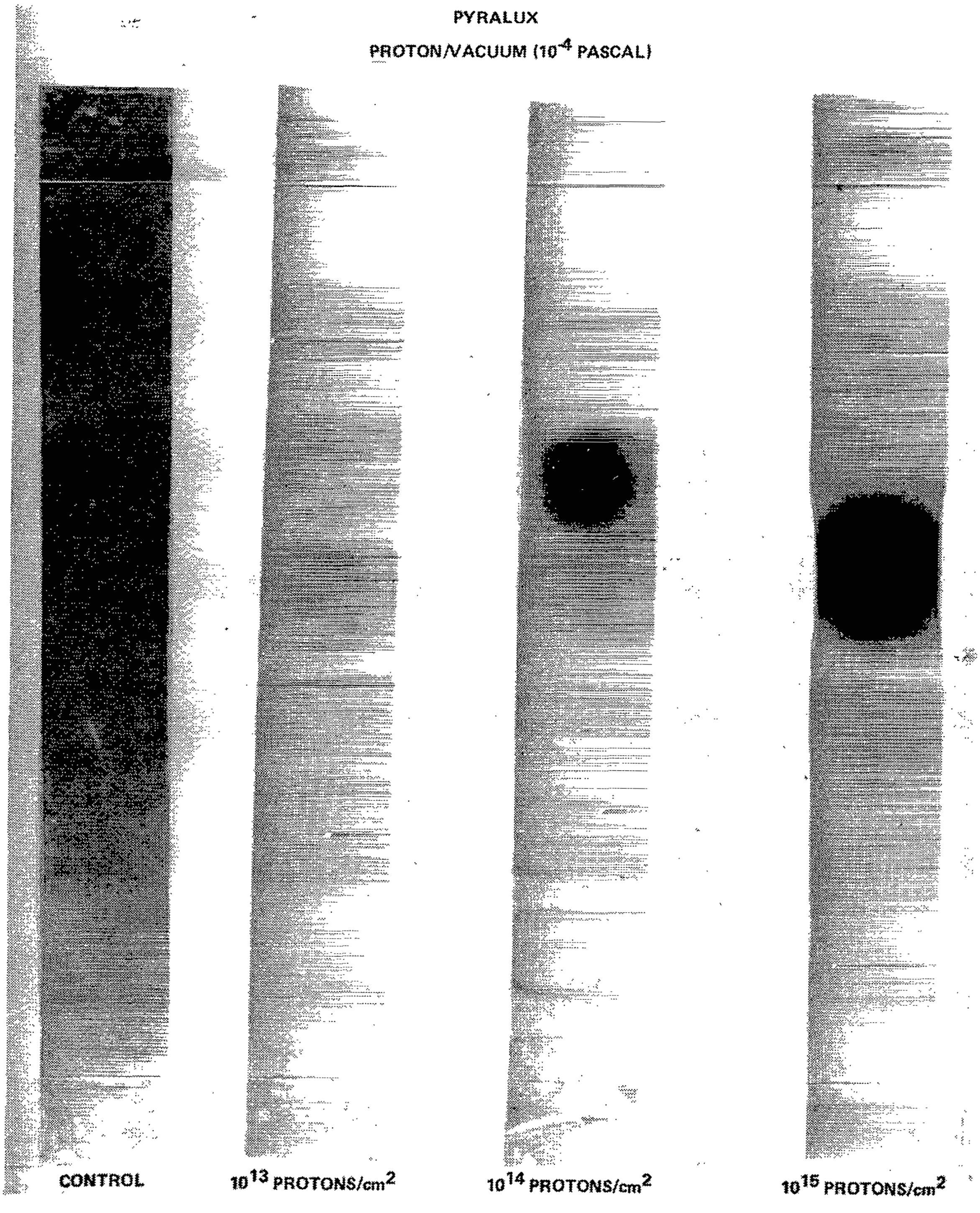

Figure 13. Pyralux proton/vacuum exposure test (10^{13}, 10^{14}, and 10^{15} protons/cm^2).

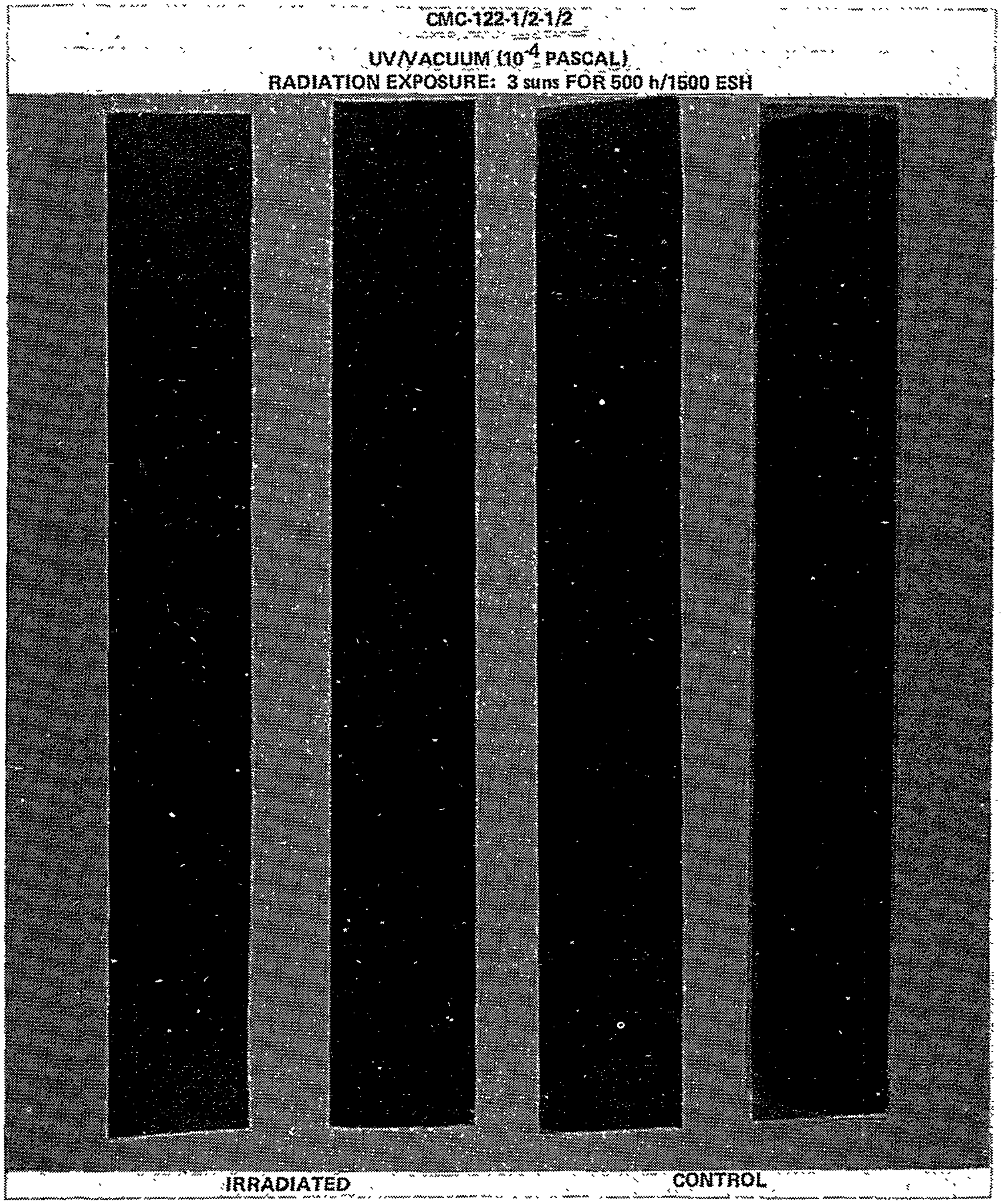

Figure 14. CMC-122-1/2-1/2 UV/vacuum exposure test (500 ESH at 3 suns).

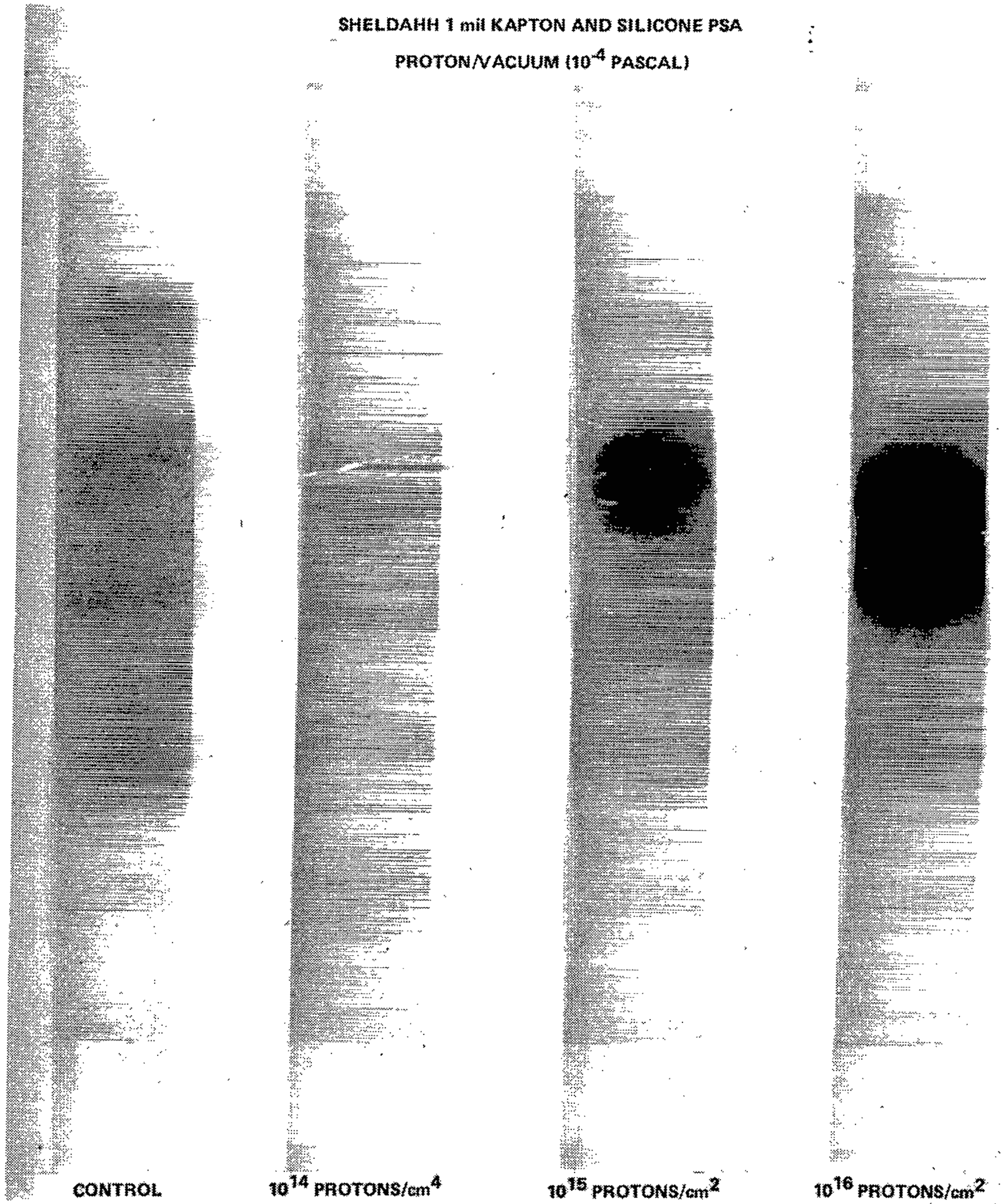

Figure 15. Sheldahl 1 mil Kapton and silicone PSA proton/vacuum exposure test (10^{14}, 10^{15}, and 10^{16} protons/cm^2).

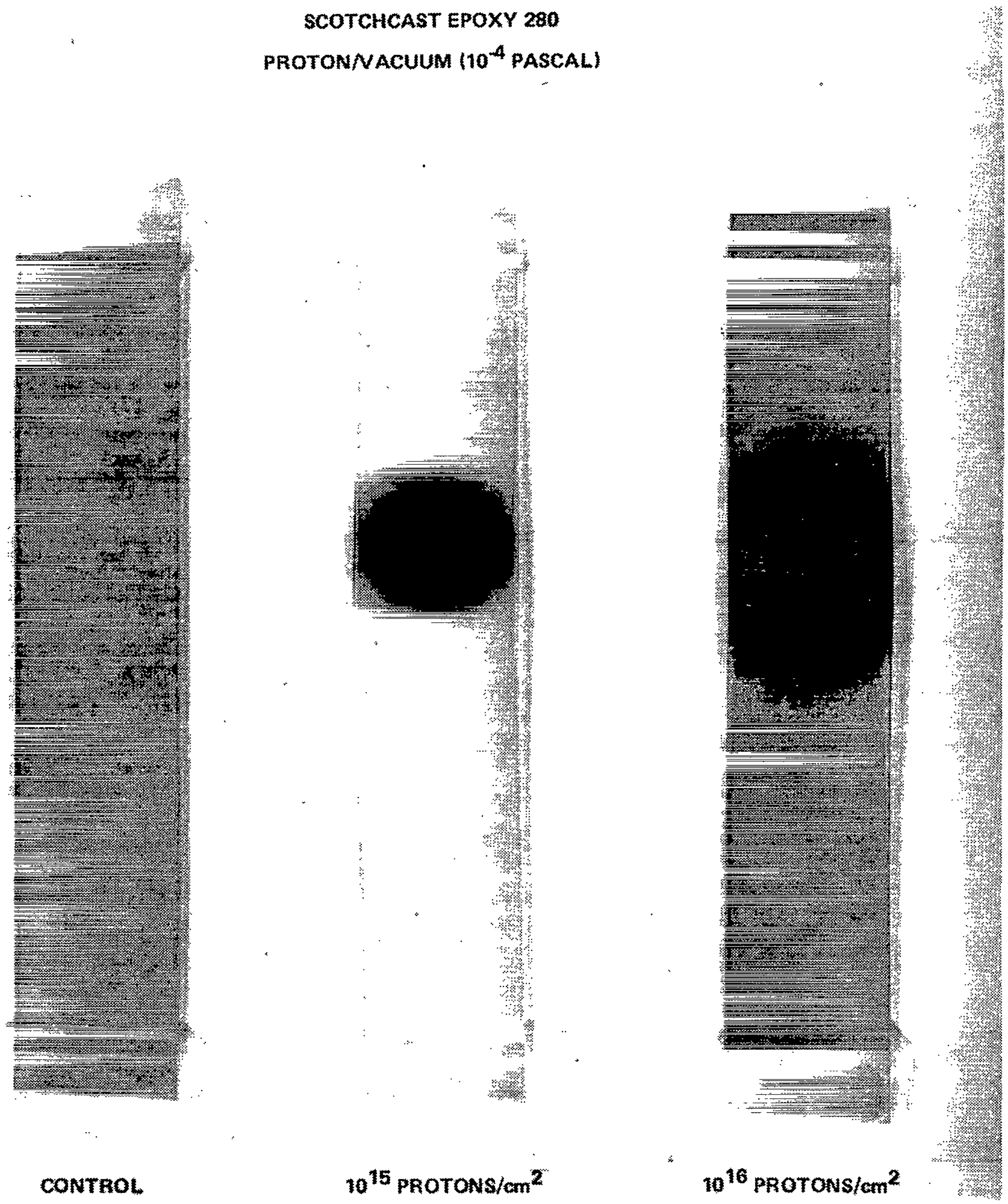

Figure 16. Scotchcast epoxy 280 proton/vacuum exposure test (10^{15} and 10^{16} protons/cm^2).

Figure 17. Fairprene proton/vacuum exposure test (10^{13}, 10^{14}, and 10^{15} protons/cm^2).

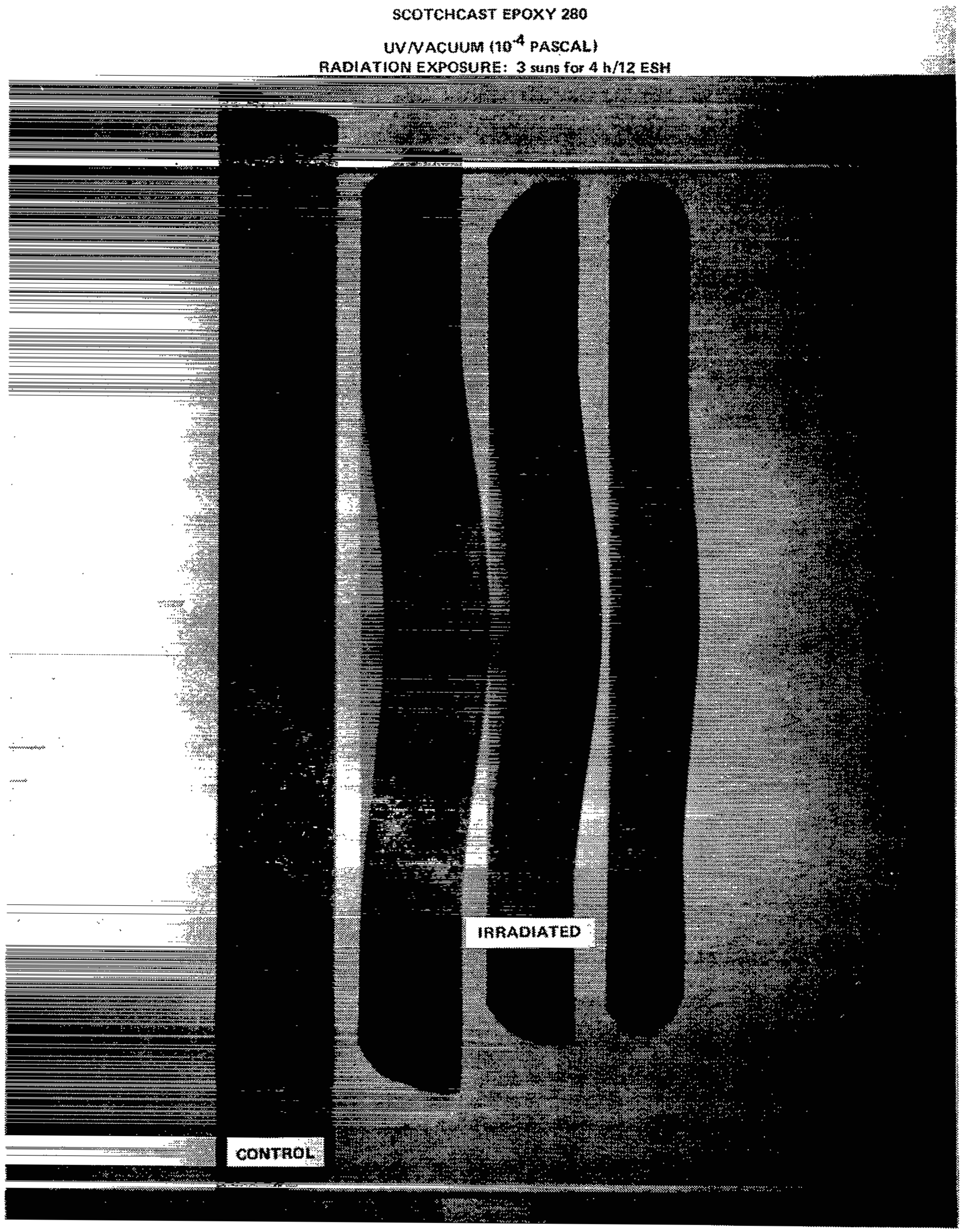

Figure 18. Scotchcast epoxy 280 UV/vacuum exposure test (12 ESH at 3 suns).

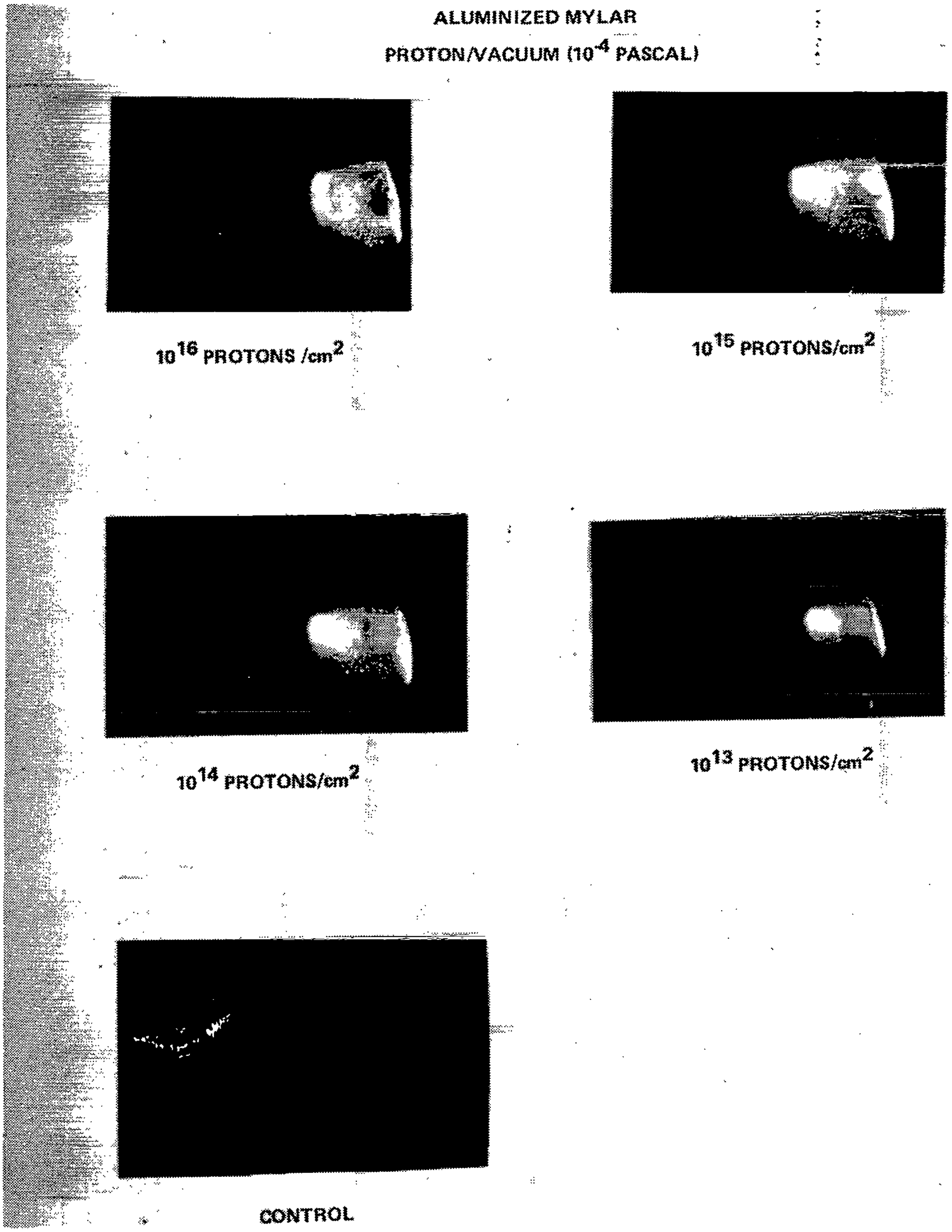

Figure 19. Aluminized mylar proton/vacuum exposure test (10^{13}, 10^{14}, 10^{15}, and 10^{16} protons/cm^2).

TABLE 1. MATERIALS IDENTIFICATION

Name	Code	Supplier	Generic Nomenclature	Functional Category
Kapton H (0.5 mil)	S-1	DuPont	Polyimide	Substrate Strength
Epoxy Fiberglass Longerons	M-1	Astromast	Epoxy/Fiber-glass	Mast
Epoxy Fiberglass Battens	M-2	Astromast	Polyimide/ Fiberglass	Mast
Polyimide Fiber-glass Longerons	M-3	Astromast	Polyimide/ Fiberglass	Mast
AR Coated No. 7940 Fused Silica	C-1	SCLI	Magnesium Fluoride/ Fused Silica	Cell Cover
Kapton F (0.5 mil)	A-1	DuPont	Polyimide/FEP Teflon	Adhesive Substrate Lamination
Pyralux (0.5 mil Kapton + 0.5 mil Acrylic Adhesive)	A-2	DuPont	Polyimide/ Acrylic	Adhesive, Substrate Lamination
Kevlar 49	M-4	DuPont	Aramid Fiber	Panel Skin Containment Box Cover and Bottom
CMC-122-1/2-1/2 (0.5 mil Kapton + 0.5 mil Polyester Adhesive)	A-3	Circuit Materials	Polyimide/ Polyester Adhesive	Adhesive, Substrate Lamination
Aluminized Kapton Tape	T-1	Sheldahl	Aluminum/ Polyimide	Thermal Control
Aluminized Kapton (0.5 mil Kapton)	T-2a	Hastings	Aluminum/ Polyimide	Thermal Control
Aluminized Kapton (1 mil)	T-2b	Hastings	Aluminum/ Polyimide	Thermal Control
M380-3 Fluroglas Fabric	S-2	Dodge Industries	PTFE Teflon/ Fiberglass	(Panel Hinge) Hinge Loop, Substrate Edge Reinforcement

TABLE 1. (Concluded)

Name	Code	Supplier	Generic Nomenclature	Functional Category
M368-5 Fluroglas Fabric	S-3	Dode Industries	PTFE Teflon/ Fiberglass	Hinge Loop, Substrate Edge Reinforcement
PTFE Coated Teflon E-12 Fiberglass Thread	P-1	Owen-Corning	Fiberglass/ PTFE Teflon	On Array Padding
Fairprene SS-5550	P-2	DuPont	Silicone Rubber	Substrate Padding
White Paint S13GLO	T-3	IITRI	Silicone Paint/ Low Outgassing	Thermal Control
Aluminized Teflon + Acrylic PSA	T-4	Sheldahl	Aluminum/ Teflon/Acrylic	Thermal Control
Graphite Epoxy HMF 330C/34	M-5	Fiberite Corporation	High Modules Graphite/ 934 Epoxy	Panel Skin Containment Box Cover and Bottom
Scotchcast Epoxy 280	P-3	3M	Epoxy	On Array Padding
Kapton + Silicone PSA	A-4	Sheldahl	Polyimide/ Silicone	Adhesive System
Silvered (3 mil) Mylar	T-5	Sheldahl	Silver/Poly-ester	Thermal Control
Aluminum + (1 mil) Mylar	T-6	Sheldahl	Aluminum/ Polyester	Thermal Control
Aluminum + (2 mil) Mylar + (2 mil) Teflon Coating	T-7	Sheldahl	Aluminum/ Polyester Teflon	Thermal Control
Silvered (1 mil) Polyester with 4 mil Acrylic Coating	T-8	Sheldahl	Silver/ Polyester/ Acrylic	Thermal Control

TABLE 2. MATERIALS TESTS

Test \ Material	S-1	M-1	M-2	M-3	C-1	A-1	A-2	M-4	A-3	T-1	T-2a	T-2b	S-2	S-3	P-1	P-2	T-3	T-4	M-5	P-3	A-4	T-5	T-6	T-7	T-8
Outgassing	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
UV Radiation																									
500 ESH at 1 sun	X	X	X		X	X	X	X[a]					X	X[d]			X[e]								
1500 ESH at 3 suns	X	X	X		X		X		X		X	X	X	X	X[b]	X[b]		X	X	X[c]				X	
Proton Radiation:																									
10^{13} protons/cm^2	X	X	X				X									X							X		
10^{14} protons/cm^2	X						X			X						X					X		X		
10^{15} protons/cm^2	X	X	X	X			X			X						X				X	X		X		
10^{16} protons/cm^2	X	X	X	X						X									X	X	X				

a. 20 ESH at 1 sun (failure)

b. 500 ESH at 3 suns

c. 12 ESH at 3 suns (failure)

d. 1 sun, 120 ESH

e. Data generated for 100 to 300 ESH at 1 sun

TABLE 3. NOMINAL MECHANICAL PROPERTY VALUES

Mechanical Property / Material	Breaking Strength (lb/in.)	Elongation (Percent)	Maximum Fiber Stress (ksi)
S-1	11.8	30.5	—
S-2	81.3	2.6	—
S-3	143.0	3.5	—
M-1	—	—	235.3
M-2	—	—	121.7
M-3	—	—	175.0
M-4	1198.0	32.0	—
M-5	—	—	132.0
A-1	20.5	9.3	—
A-2	12.2	30.4	—
A-3	7.6	6.4	—
A-4	29.0	52.5	—
T-1	152.7	58.7	—
T-4	10.7	—	—
P-1	11.6	5.1	—
P-2	13.2	422.0	—
P-3	308.0	321.0	—

TABLE 4. NOMINAL OPTICAL PROPERTY VALUES

Optical Property / Material	Absorptivity	Emissivity	Spectral Reflectance
T-2a	0.11	0.04	—
T-2b	—	—	0.89
T-4	0.14	0.80	—
T-3	0.17	0.90	0.83
T-5	0.12	0.04	—
T-6	0.19	0.60	—
T-7	0.14	0.66	—
T-8	0.17	0.71	—

TABLE 5. MATERIALS OUTGAS SCREENING RESULTS

Material	Maximum Rate Weight Loss (percent/cm/h) Total Weight Loss (Percent)	RGA
S-1	0.03/0.58	A[a]
M-1	NWL	A
M-2	NWL	A
M-3	0.32/0.19	A
C-1	—	—
A-1	NWL	A
A-2	0.007/0.22	A
M-4[b]	0.76/1.8	A (T/V Bake)
A-3	0.10/0.98	A
T-1	0.05/0.76	A
T-2a	0.04/1.71	A
T-2b	—	—
S-2	NWL	A
S-3	NWL	A
P-1	NWL	A
P-2	—/0.34	A
T-3	0.11/0.29	A
T-4	NWL	A
M-5	0.15/0.37	A
A-4	0.2/2.42	A
T-6	0.01/0.54	A
T-7	NWL	A
T-8[c]	0.03/0.12 (F)	A
P-3[d]	0.15/0.54	A (T/V Bake)

a. A = Acceptable
b. Acceptable with a T/V bake at 100°C at 10^{-4} pascal for 4 h.
c. Failure due to materials separation.
d. Acceptable with a T/V bake at 100°C at 10^{-4} pascal for 12 h.

TABLE 6. PERCENTAGE CHANGE IN MECHANICAL PROPERTIES OF PROTON IRRADIATED MATERIALS (DATA GENERATED USING 2σ STATISTICS)

Mechanical Property / Material	Breaking Strength				Elongation				Maximum Fiber Stress			
	10^{13}	14^{14}	10^{15}	10^{16}	10^{13}	10^{14}	10^{15}	10^{16}	10^{13}	10^{14}	10^{15}	10^{16}
S-1	—	—	—	—	—	—	—	—	NA			
M-1	NA →				NA →				NC	—	+2	+2
M-2	NA →				NA →				NC	—	NC	+11
M-3	NA →				NA →				—	—	NC	NC
A-2	NC	NC	NC	—	-5	+15	+11	—	NA →			
P-2	-42	-54	-69	—	-36	-50	-65	—	NA →			
M-5	—	—	—	—	—	—	—	—	—	—	—	NC
P-3	—	—	NC	-1	—	—	-30	-77	NA →			
A-4	—	NC	-19	*	—	NC	-54	*	NA →			
T-6	*	→		—	*	→		—	NA →			

NA = Data not applicable to sample.

NC = No significant change, within 2σ statistics.

— = Data not available for this report.

* = Vacuum produced severe warpage and degradation.

TABLE 7. PERCENTAGE CHANGE IN MECHANICAL PROPERTIES OF UV IRRADIATED MATERIALS (DATA GENERATED USING 2σ STATISTICS)

Material \ Mechanical Property	Breaking Strength		Elongation		Maximum Fiber Stress	
	500 ESH at 1 sun	1500 ESH at 3 suns	500 ESH at 1 sun	1500 ESH at 3 suns	500 ESH at 1 sun	1500 ESH at 3 suns
S-1	—	-15	—	-32	NA	
S-2	-1	NC	NC	NC	NA	
S-3	NC	-10	+21	+4	NA	
M-1	—	—	NA		NC	+2
M-2	—	—	NA		NC	+16
M-4	NC	—	-86	—	NA	
A-1	NC	—	NC	—	NA	
A-2	NC	-8	NC	-21	NA	
A-3	—	+1	—	+33	NA	
P-2	—	-54	—	-85	NA	
P-3*	—	+54	—	-93	NA	

NA = Data not applicable to sample.

NC = No significant change, data within 2σ limits.

— = Data not available.

* = Data obtained after only 4 h/12 ESH exposure due to excessive outgassing.

TABLE 8. PERCENTAGE CHANGE IN OPTICAL PROPERTIES OF UV IRRADIATED MATERIALS (DATA GENERATED USING 2σ STATISTICS)

Optical Property / Material	Absorptivity		Emissivity		Spectral Reflectance	
	500 ESH at 1 sun	1500 ESH at 3 suns	500 ESH at 1 sun	1500 ESH at 3 suns	500 ESH at 1 sun	1500 ESH at 3 suns
T-2a	NC	NC	NC	NC	—	—
T-4	—	NC	—	NC	—	—
T-3[a]	NC, NC	—	NC, NC	—	-3, -7 percent	—
T-8[b]	NA					

a. Data generated for 1000 ESH and 3000 ESH at 1 sun

b. Severe degradation during weight loss test.

NA = Data not applicable to sample.

NC = No significant change, data within 2σ limits.

— = Data not available.

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16. ABSTRACT

A program has been underway to evaluate materials for advanced solar arrays which are required to provide power to weight ratios up to 100 W/kg. Severe mission environments together with the lack of knowledge of space environmental materials degradation rates require the generation of irradiation and outgassing engineering data for use in the initial design phase of the flight solar arrays. Therefore, approximately 25 candidate array materials were subjected to selected mission environments of vacuum, UV, and particle irradiation, and their mechanical and/or optical properties were determined where appropriate.

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