

EMISSIVITY COATINGS FOR LOW-TEMPERATURE SPACE RADIATORS

Quarterly Progress Report No. 5
For Quarter Ending 30 September 1966
CONTRACT NAS-3-7630

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO

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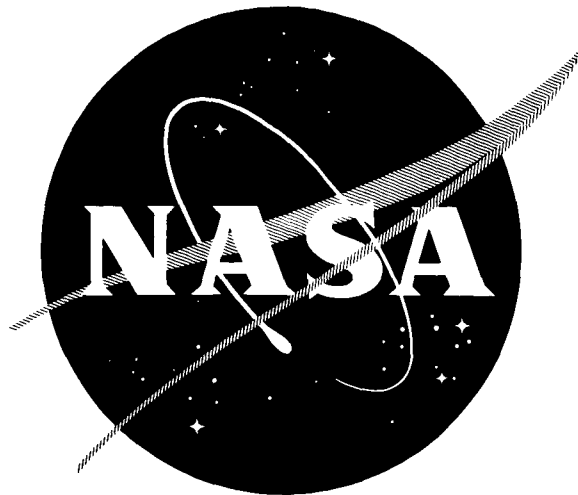
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Aerospace Sciences Laboratory
Lockheed Palo Alto Research Laboratory
LOCKHEED MISSILES & SPACE COMPANY
Sunnyvale, California



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FOREWORD

The results of the research activities carried out during the fifth quarterly period (1 July through 30 September 1966) of Contract NAS 3-7630, entitled Emissivity Coatings for Low-Temperature Space Radiators, are reported in this document. The work is being done by Lockheed Missiles & Space Company for the Lewis Research Center of the National Aeronautics and Space Administration.

Previous quarterly reports are listed below, with a brief description of their contents.

1. F. J. Smith et al., Emissivity Coatings for Low-Temperature Space Radiators, QPR-1, NASA-CR-54807, Lockheed Missiles & Space Company, Sunnyvale, Calif., Sep 1965.
Contents: Literature survey; coating selection; description of experimental apparatus.
2. F. J. Smith et al., Emissivity Coatings for Low-Temperature Space Radiators, QPR-2, NASA-CR-54807, Lockheed Missiles & Space Company, Sunnyvale, Calif., Dec 1965.
Contents: Apparatus description; uv source description; initial properties of coatings.
3. F. J. Smith et al., Emissivity Coatings for Low-Temperature Space Radiators, QPR-3, NASA-CR-54807, Lockheed Missiles & Space Company, Sunnyvale, Calif., Mar 1966.
Contents: Experimental procedure; spectral band absorption measurements; initial properties of coatings.
4. F. J. Smith et al., Emissivity Coatings for Low-Temperature Space Radiators, QPR-4, NASA-CR-72089, Lockheed Missiles & Space Company, Sunnyvale, Calif., Jun 1966.
Contents: Initial properties of coatings; thermal cycling results; experimental procedure; exposure test results on TiO₂/silicone (Thermatrol).

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Section 1
INTRODUCTION AND SUMMARY

The major objective of this program is the evaluation of candidate coatings for low-temperature spacecraft radiators. The use of certain classes of power sources on spacecraft having long operational lifetimes presents several complex problems with regard to the choice of radiator coatings. The surfaces must show a high total hemispherical emittance at operating temperature with a low absorptance to energy in the solar spectrum. The latter is of importance because of the low operating temperature level of some radiators, 530°K (495°F) or less. The stability of the radiative properties of the coating in the space environment is a critical factor as changes in either absorptance or emittance during the mission would result in severe problems with the operating power system. Changes in the radiative properties, particularly in solar absorptance, may occur because of exposure to temperature, vacuum, temperature cycling, and the complex radiation fields attributed to the space environment.

This initial program has as its objective the evaluation of the properties and stability of candidate coatings under conditions of exposure to ultraviolet radiation, vacuum of less than 10^{-7} Torr, elevated temperatures, and temperature cycling. During the first phase of the program, candidate materials will be exposed simultaneously to ultraviolet radiation at a 1-sun level, maximum operating temperature, and vacuum for 500-hr periods. The effects of temperature cycling will also be investigated.

The second phase of the program will be the exposure of two materials, selected on the basis of the results of the initial phase, for 5,000 hr.

The major tasks completed during this report period included the following:

- 500-hr uv exposure test of the S-13 coatings
- 500-hr uv exposure test of the S-13G coatings

- 500-hr uv exposure test of a Z-93 coating
- 500-hr and 100-hr uv exposure test of a $\text{ZrSiO}_4/\text{K}_2\text{SiO}_4$ coating

Detailed discussion of the activities for the quarterly period are presented in the following sections.

Section 2

EXPERIMENTAL RESULTS

To evaluate the stability of the solar absorptance and total hemispherical emittance of candidate space power radiation coatings in the space environment, samples are exposed for a period of 500-hr duration to ultraviolet radiation at a 1-sun level, defined by the 0.2 to 0.4 μ spectral band, from a xenon source; vacuum of 10^{-7} Torr or less; and maximum intended operating temperature level. The sample is temperature cycled from its operating temperature to room temperature approximately 110 times during the 500-hr exposure test. The results of these screening tests will form the basis for the selection of two coatings to be subjected to long-term exposure testing.

2.1 APPARATUS

The uv exposure apparatus used for these tests is described in detail in the first and second quarterly progress reports of this contract (Refs. 1 and 2).

2.2 SAMPLE PREPARATION AND DESCRIPTION

Preparation and description of all samples discussed in this report are described in detail in the second and fourth quarterly progress reports of this contract (Refs. 2 and 3).

2.3 TEST PROCEDURE

The test procedure and data analysis are described in detail in the third quarterly progress report of this contract (Ref. 4).

2.4 TEST RESULTS

2.4.1 ZnO/Silicone (S-13)

Two samples of the ZnO/Silicone coating (S-13) were exposed for a period of 500 hr to uv irradiation at a 1-sun level from a xenon lamp. The samples were maintained at a temperature of 395°K (252°F) and temperature cycled to room temperature every 4.7 hr. The pressure was maintained at less than 1×10^{-7} Torr.

The results of the calorimetric in situ measurements made during the exposure tests on the duplicate Samples No. 27 and 28 are tabulated in Tables 2-1 and 2-2. The solar absorptance of the two samples as a function of exposure time is shown graphically by Fig. 2-1. The solar absorptance of S-13 increases from 0.20 to 0.28 under uv irradiation at a 1-sun level. This increase occurred during the first 250 hours of exposure time with the absorptance remaining essentially constant after that time. The loss of vacuum for Sample No. 28 at 325 hr is marked by a partial recovery as is shown by the data presented in Fig. 2-1. After re-exposure under high vacuum, the absorptance of the sample increased to near its previous level and remained constant for the duration of the test. Sample No. 28 was exposed for a total of 636 hr. The change in solar absorptance, α_s , measured during these tests agrees well with that determined by S. Greenberg et al. at LMSC using the in situ bidirectional reflectance exposure apparatus (Ref. 5). They report a limiting value of $\Delta\alpha_s$ of 0.09 for the S-13 coating when exposed at approximately 300°K (81°F). Data from the OSO-II flight experiment (Ref. 6) show a change in solar absorptance of 0.06 for 500-hr exposure; however, no temperature data are given. After exposure, the sample coatings had turned to a light tan color. The color was not quite uniform, varying from light tan to almost white for a small portion on one side of the sample.

Pre- and post-test room temperature reflectance data for the two samples are shown in Figs. 2-2 and 2-3. The spectral band absorptances are determined from these reflectance curves and presented in the data tables for the two samples. Comparison

Table 2-1

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR S-13 COATING, ZnO/SILICONE, SAMPLE NO. 27

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	1	294 70	0.86	0.21	-	-	-	-	-
0	1	339 153	.87	.21	-	-	-	-	-
0	2	395 252	.86	.21	-	-	-	-	-
4	3	395 252	.85	.21	0.65	0.08	0.06	0.24	0.21
53	15	395 252	.86	.23	.65	.10	.06	.27	.23
61	27	395 252	.86	.24	.65	.15	.06	.28	.24
113	42	395 252	.85	.27	.70	.15	.08	.30	.26
158	52	395 252	.86	.26	.70	.19	.08	.28	.26
230	82	395 252	.86	.27	.75	.21	.09	.28	.27
280	94	395 252	.86	.27	.75	.25	.08	.29	.28
330	105	395 252	.87	.26	.70	.26	.10	.28	.28
402	125	395 252	.87	.27	.65	.26	.08	.28	.28
450	136	395 252	.87	.27	.65	.27	.08	.30	.28
500	147	395 252	.86	.27	.70	.27	.10	.28	.28
Before Exposure ^(c)				.18	.65	.08	.10	.14	.18
After Exposure ^(c)				.26	.76	.31	.15	.17	.28

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

Table 2-2

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR S-13 COATING, ZnO/SILICONE, SAMPLE NO. 28

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	290 63	0.85	0.21	-	-	-	-	-
0	0	342 156	.88	.20	-	-	-	-	-
0	1	395 252	.85	.21	0.70	0.10	0.10	0.19	0.20
4	2	395 252	.86	.22	.70	.10	.10	.23	.21
50	12	395 252	.87	.23	.65	.12	.10	.26	.23
146	33	395 252	.86	.26	.65	.18	.10	.28	.26
196	45	395 252	.87	.27	.65	.23	.08	.32	.28
246	57	395 252	.87	.30	.70	.28	.08	.32	.30
296	69	395 252	.82	.29	.70	.26	.09	.31	.30
328 ^(c)	75	395 252	.86	.25	.70	.21	.10	.26	.26
346	81	395 252	.86	.27	.70	.22	.10	.29	.27
396	93	395 252	.87	.28	.70	.22	.10	.31	.28
468	111	395 252	.86	.27	.70	.24	.11	.30	.28
516	123	395 252	.87	.27	.70	.23	.14	.30	.28
564	135	395 252	.87	.27	.70	.24	.14	.30	.28
636	153	395 252	.87	.27	.70	.24	.14	.30	.28
Before Exposure ^(d)				.19	.65	.08	.10	.14	.19
After Exposure ^(d)				.28	.78	.32	.17	.21	.31

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) Electronic pump off, pressure increase to $> 100 \mu$.

(d) From Cary room temperature reflectance measurements.

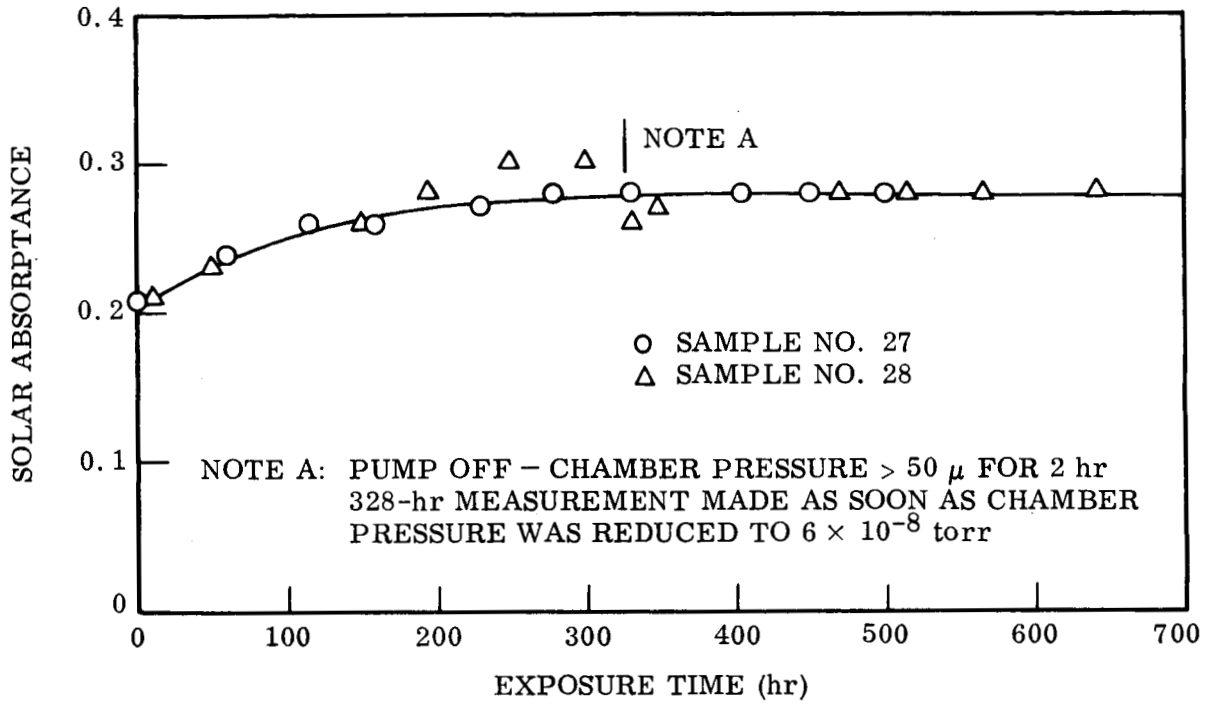


Fig. 2-1 Solar Absorbance of ZnO/Silicone (S-13) Coating Samples as a Function of Exposure Time at a 1-Sun Level and 395°K (252°F) Test Temperature

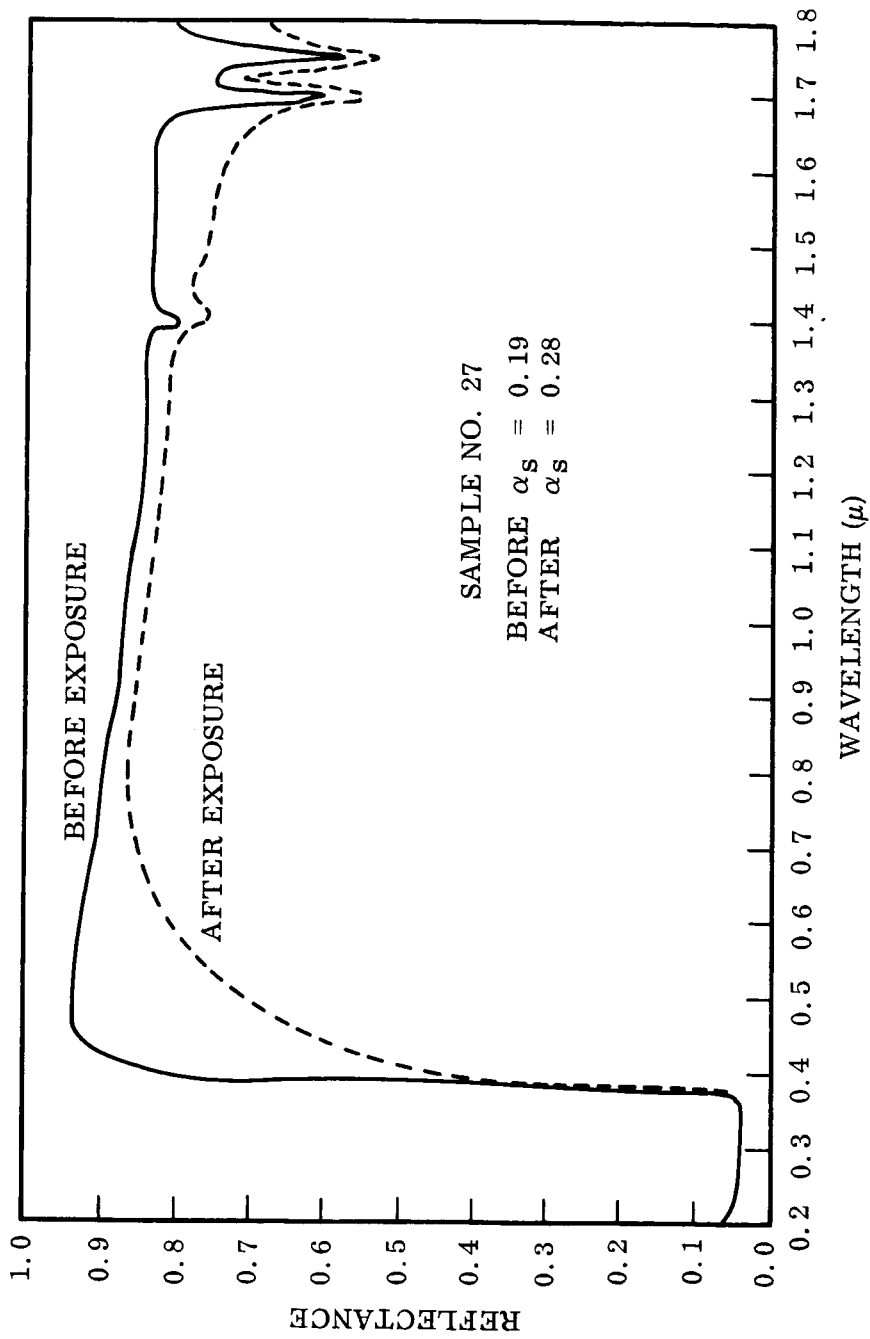


Fig. 2-2 Room Temperature Spectral Reflectance of S-13 Coating, Sample No. 27

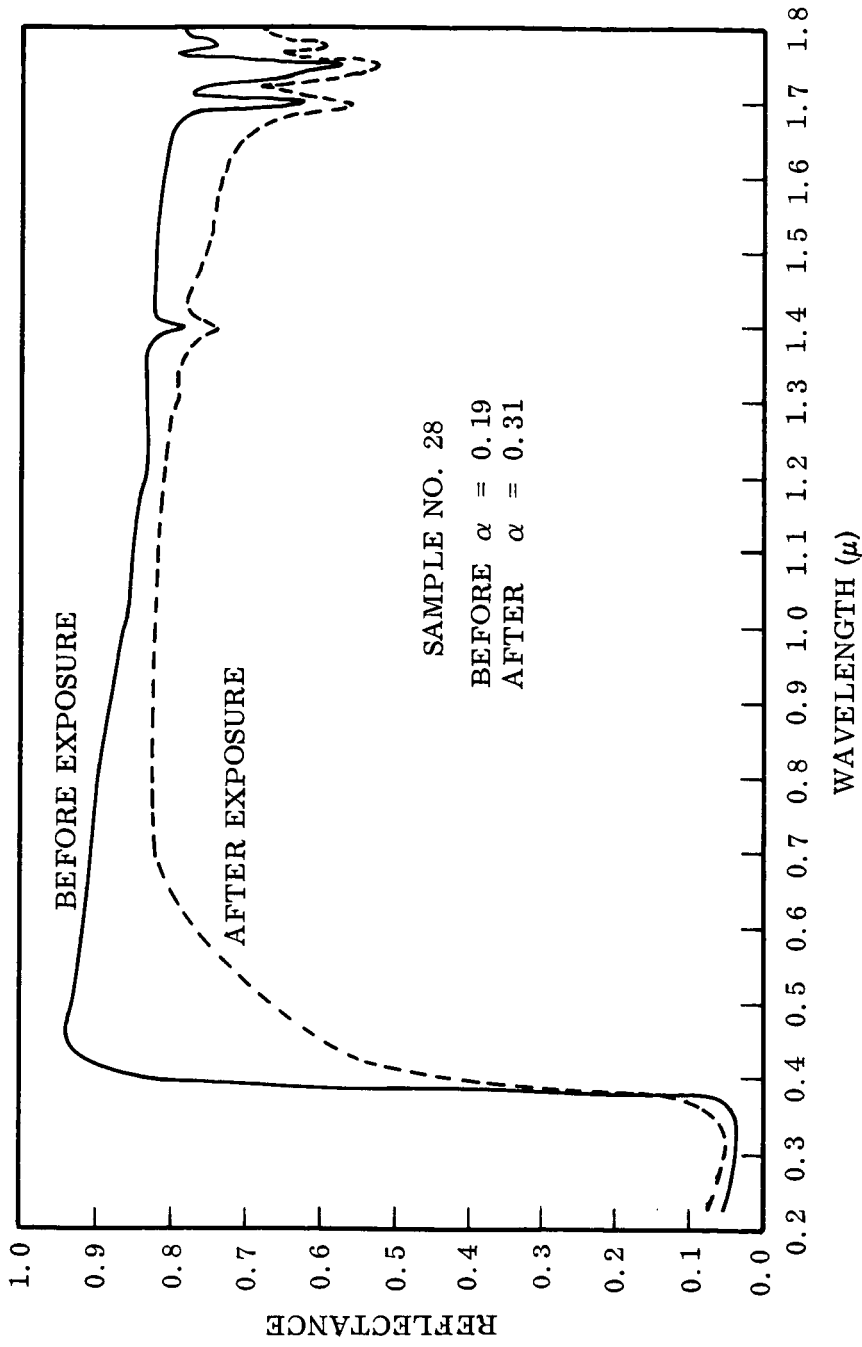


Fig. 2-3 Room Temperature Spectral Reflectance of S-13 Coating, Sample No. 28

of the $> 0.85\text{-}\mu$ spectral band absorptances from the in situ and reflectance data show the near infrared recovery of this system when exposed to air.

The total hemispherical emittance measured calorimetrically during the exposure test was 0.86 ± 0.02 for both samples, and was essentially constant for the test duration. The data are shown graphically in Fig. 2-4.

2.4.2 ZnO/Silicone (S-13G)

Two samples of ZnO/Silicone (S-13G), Samples No. 43 and 44 were exposed for a period of 500-hr to uv irradiation at a 1-sun level from a xenon lamp. The samples were maintained at a temperature of 395°K (252°F) and temperature cycled to room temperature every 4.7 hr. Pressure was maintained at less than 1×10^{-7} Torr.

The results of the calorimetric in situ measurements made during the exposure test of the duplicate Samples No. 43 and 44 are tabulated in Tables 2-3 and 2-4. The solar absorptance of the two samples as a function of exposure time is shown graphically by Fig. 2-5. The solar absorptance of S-13G increased from 0.20 to 0.28 under uv irradiation at a 1-sun level. The change in solar absorptance for Sample No. 44 was not as great as that observed for Sample No. 43; the corresponding change was from 0.20 to 0.26. Visual inspection of the sample shows an area on the side of the sample (approximately 20 percent of the exposed area) to be considerably lighter in color than the remainder of the surface. A slight shift in the beam position occurred which resulted in this portion of the sample being exposed to a somewhat lower uv intensity. Therefore, it is felt that the change in α_s of 0.08 is the relevant figure. Coating color was a light tan for both samples at the completion of the exposure tests.

The broadband spectral data show the improvement in the near infrared region reported by IITRI (Ref. 7). However, the change in absorptance from 0.2μ to 0.8μ is as great or greater than that for S-13, as is seen in the tabulated data.

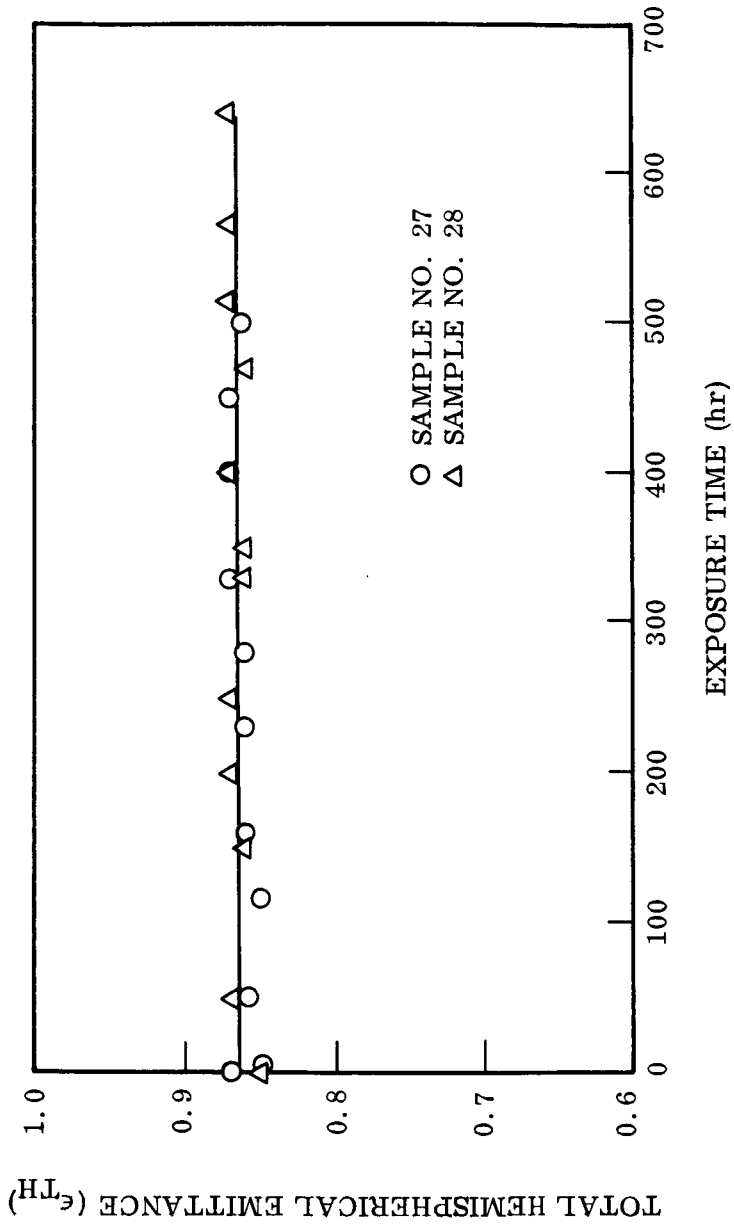


Fig. 2-4 Total Hemispherical Emittance of S-13 Coating as a Function of Exposure Time at 1-Sun Level and 395° K (252°F)

Table 2-3

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR S-13G COATING, SAMPLE NO. 43

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	294 70	0.86	0.23	—	—	—	—	—
0	0	339 153	.89	.21	—	—	—	—	—
0	1	395 252	.90	.21	—	—	—	—	—
0	1	395 252	.90	.20	0.85	0.12	0.05	0.15	0.20
4	1	395 252	.93	.21	.90	.12	.05	.16	.21
51	13	395 252	.92	.23	.90	.17	.08	.17	.24
149	46	395 252	.92	.24	.90	.21	.09	.17	.25
195	58	395 252	.92	.26	.92	.27	.10	.17	.27
248	70	395 252	.90	.26	.90	.28	.10	.17	.27
296	81	395 252	.92	.26	.90	.32	.09	.17	.28
344	92	395 252	.92	.26	.85	.35	.11	.17	.28
392	104	395 252	.90	.26	.85	.35	.11	.17	.28
500	125	395 252	.91	.26	.85	.35	.10	.18	.28
Before Exposure ^(c)				.19	.70	.10	.10	.13	.19
After Exposure ^(c)				.28	.82	.37	.20	.15	.31

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

Table 2-4

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR S-13G COATING, SAMPLE NO. 44

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	294 70	0.90	0.24	—	—	—	—	—
0	0	339 153	.93	.22	—	—	—	—	—
0	1	395 252	.91	.19	0.80	0.10	0.08	0.14	0.19
5	1	395 252	.91	.20	.80	.10	.08	.14	.20
75	17	395 252	.91	.20	.80	.16	.09	.15	.21
123	29	395 252	.91	.21	.80	.16	.08	.16	.22
172	41	395 252	.91	.21	.80	.21	.08	.16	.22
227	53	395 252	.92	.22	.75	.27	.08	.16	.23
274	65	395 252	.92	.22	.75	.27	.08	.16	.23
327	77	395 252	.91	.22	.75	.27	.10	.16	.24
423	100	395 252	.91	.22	.75	.27	.10	.17	.24
471	112	395 252	.90	.22	.75	.27	.10	.17	.24
520	125	395 252	.91	.22	.75	.28	.10	.18	.25
Before Exposure ^(c)				.18	.65	.10	.10	.13	.20
After Exposure ^(c)				.23	.75	.29	.12	.15	.27

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

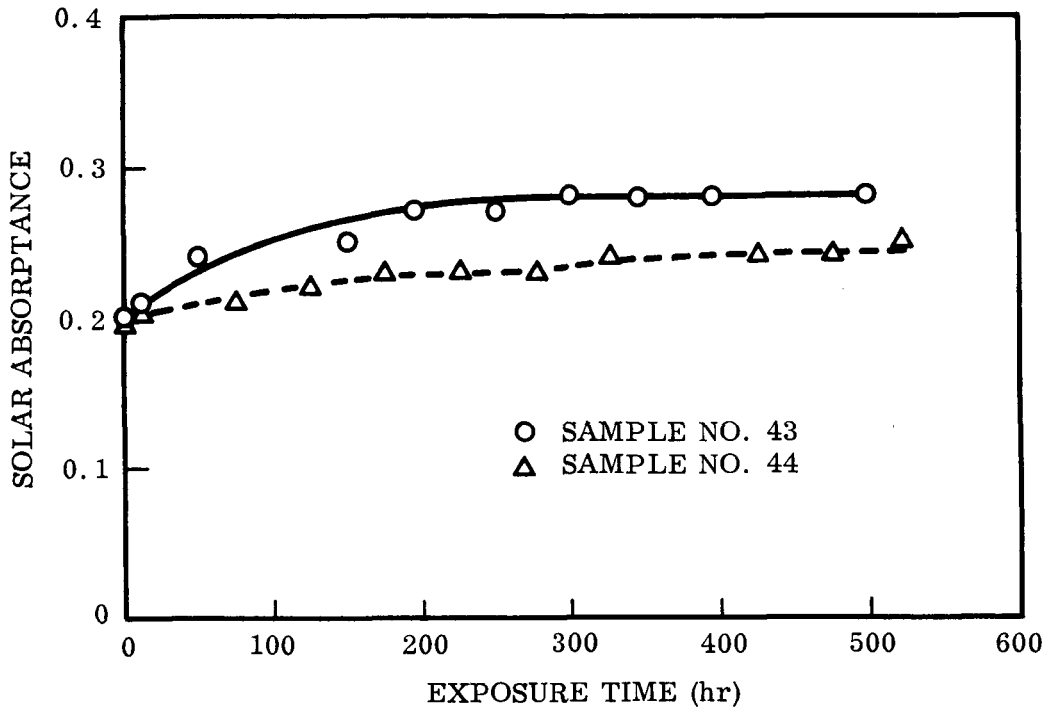


Fig. 2-5 Solar Absorbance of ZnO/Silicone (S-13G) Coatings as a Function of Exposure Time at a 1-Sun Level and 395°K (252°F)

Pre- and post-test room temperature spectral reflectance data are plotted in Figs. 2-6 and 2-7 for Samples No. 43 and 44. Again, Sample No. 43 shows a larger degradation over the 0.4- to 0.85- μ spectral region. Converting these data to broadband absorptance for a comparison with the in situ broadband data gives the following:

	<u>S-13G</u>		<u>S-13</u>	
	<u>Sample No. 43</u>	<u>Sample No. 44</u>	<u>Sample No. 27</u>	<u>Sample No. 28</u>
In situ $\alpha_{0.85 \rightarrow 2.0}$	0.18	0.18	0.28	0.30
Reflectance $\alpha_{0.85/1.8}$.15	.15	.17	.21

These data indicate that the damages, and subsequent recovery upon exposure to air, in the near infrared region did not occur for the S-13G coating.

The total hemispherical emittance measured calorimetrically during the exposure test was 0.91 ± 0.02 at 395°K (252°F) for both samples and was essentially constant for the test duration as is shown graphically by Fig. 2-8. Initial measurements of ϵ_{TH} as a function of temperature showed essentially no change for Sample No. 44 over the temperature range of 295°K (72°F) to 395°K (252°F) (0.90 to 0.91). For Sample No. 43, the measured values of ϵ_{TH} versus temperature were 0.86 at 295°K (72°F), 0.89 at 333°K (140°F), and 0.92 at 395°K (252°F). No obvious reason is apparent for the small temperature dependence of this sample. No temperature dependence was evident for either of the S-13 coatings or the other S-13G coating.

2.4.3 ZnO/K₂SiO₄ (Z-93)

One sample of ZnO/K₂SiO₄ (Z-93), Sample No. 35, was exposed for a period of 500 hr to uv irradiation at a 1-sun level from a xenon lamp. The sample was maintained at a temperature of 535°K (504°F) and temperature cycled to room temperature at 4.7-hr intervals. The pressure was maintained at less than 1×10^{-7} Torr for the test duration.

The results of the calorimetric in situ measurements made during the exposure test on Sample No. 35 are tabulated in Table 2-5. The solar absorptance of the sample as

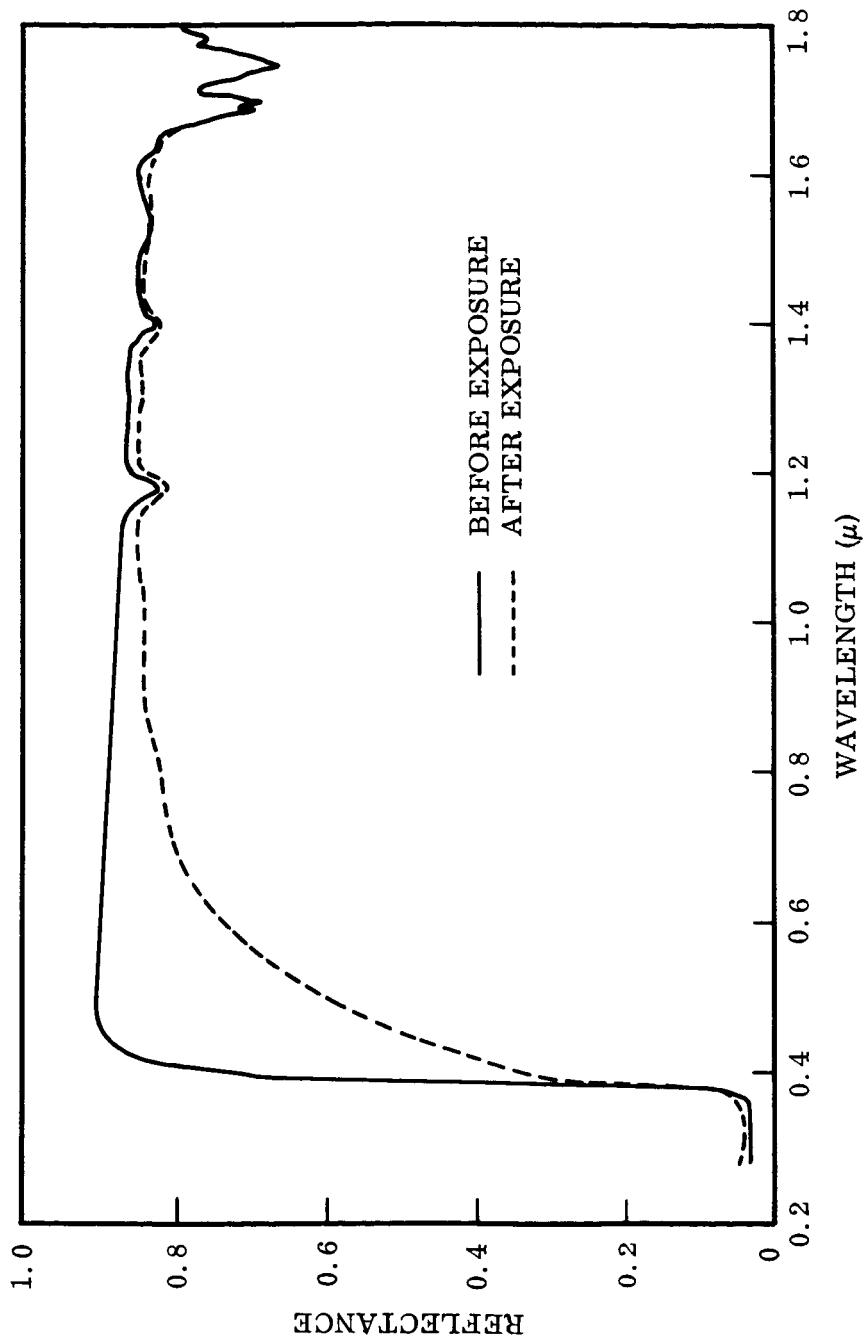


Fig. 2-6 Room Temperature Spectral Reflectance of S-13G Coating, Sample No. 43

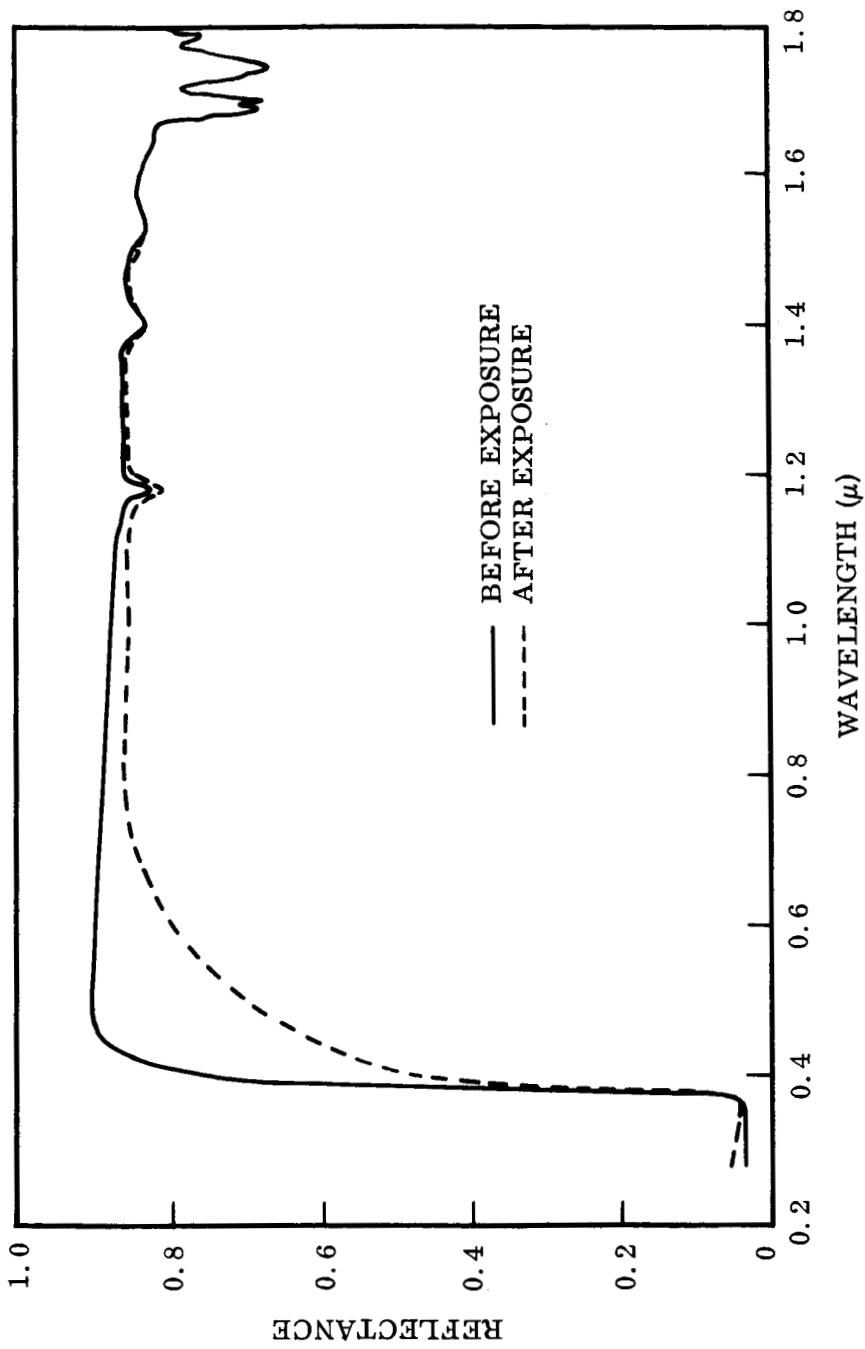


Fig. 2-7 Room Temperature Spectral Reflectance of S-13G, Sample No. 44

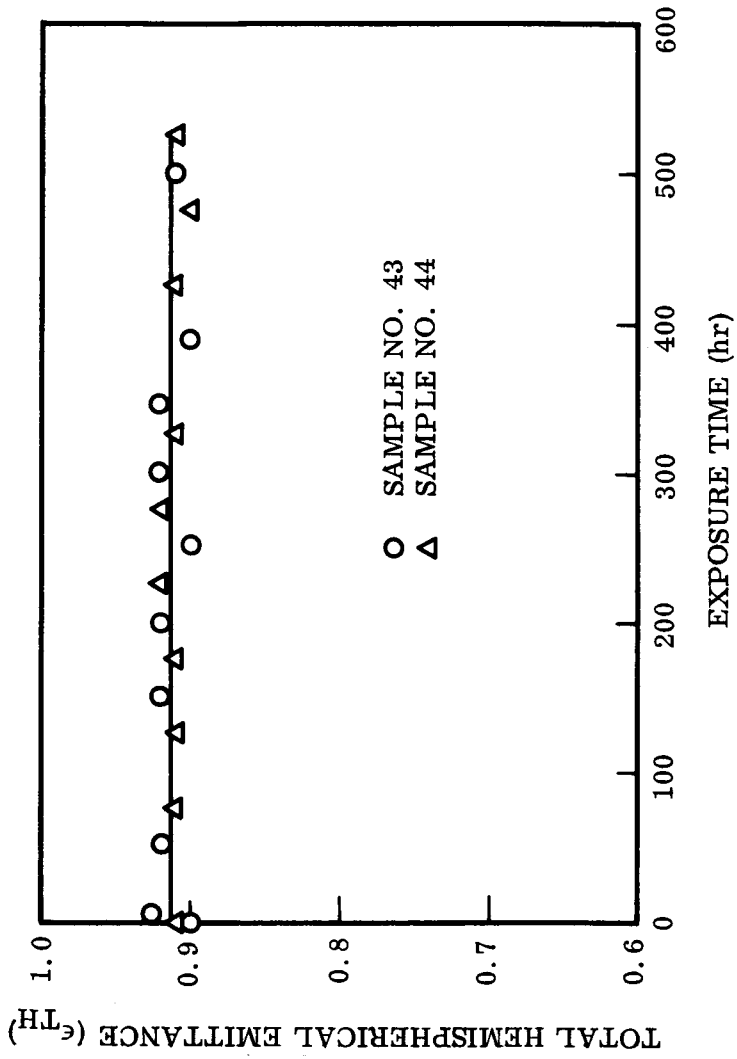


Fig. 2-8 Total Hemispherical Emittance of S-13G as a Function of Exposure Time at 1-Sun Level and 395°K (252°F)

Table 2-5

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR Z93 COATING, SAMPLE NO. 35

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	294 70	0.93	0.12	—	—	—	—	—
0	0	339 153	.94	.12	—	—	—	—	—
0	0	395 252	.91	.11	—	—	—	—	—
0	1	534 502	.81	.11	—	—	—	—	—
0	1	534 502	.81	.11	0.60	0.03	0.05	0.08	0.12
12	5	534 502	.80	.16	.55	.20	.08	.09	.16
60	16	534 502	.80	.20	.55	.27	.10	.12	.20
140	33	534 502	.80	.21	.55	.28	.13	.16	.22
181	43	534 502	.82	.22	.55	.27	.15	.17	.23
256	61	534 502	.82	.23	.55	.25	.20	.16	.24
304	72	534 502	.82	.23	.55	.25	.20	.18	.24
356	83	534 502	.81	.23	.50	.25	.20	.18	.24
404	94	534 502	.81	.24	.50	.25	.23	.19	.25
426	99	534 502	.82	.24	.55	.26	.22	.19	.25
502	120	534 502	.81	.24	.55	.26	.23	.19	.25
Before Exposure ^(c)				.13	.64	.05	.05	.07	.14
After Exposure ^(c)				.25	.70	.28	.19	.16	.26

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

a function of exposure time is shown graphically by Fig. 2-9. The solar absorptance of (Z-93) increased from 0.12 to 0.24 under uv irradiation at a 1-sun level. Practically all of this increase occurred in the first 300 hr. The post-test sample visual appearance showed a slight greying of surface with a small speckled area slightly darker in color.

Data from the OSO-II flight experiment shows no change in the solar absorptance of this coating for a period of 1,000 hr (Ref. 8). The temperatures of the samples are not mentioned. However, data presented by Arvensen et al. (Ref. 6) shows an increase in absorptance of the order of 0.17 for temperatures above 473°K (392°F) and exposure to a 15-sun level for 200 ESH.

Pre- and post-test room temperature reflectance data for the sample are shown in Fig. 2-10. Conversion of these data to broadband absorptances and comparison with the in situ broadband data shows only a minor recovery of this system in the near infrared.

The total hemispherical emittance measured calorimetrically during the exposure test is shown by Fig. 2-11. It is seen from the figure and from Table 2-5 that the total hemispherical emittance of the sample decreased from 0.91 at a temperature of 395°K (252°F) to 0.81 at a temperature of 534°K (502°F) and remained relatively constant at this value for the duration of the test.

2.4.4 $\text{ZrSiO}_4/\text{K}_2\text{SiO}_4$

Two samples of $\text{ZrSiO}_4/\text{K}_2\text{SiO}_4$, Samples No. 9 and 14, were exposed to uv irradiation at a 1-sun level from a xenon lamp. Sample No. 14 was exposed for a period of 100 hr. The test was terminated at this time due to chamber pressure failure. The LN_2 solenoid valve failed in the open position. This allowed a continuous flow of LN_2 which resulted in the freezing of an "O" ring seal at the entrance to the chamber with a subsequent loss of vacuum. The other sample, No. 9, was exposed for a period of 500 hr.

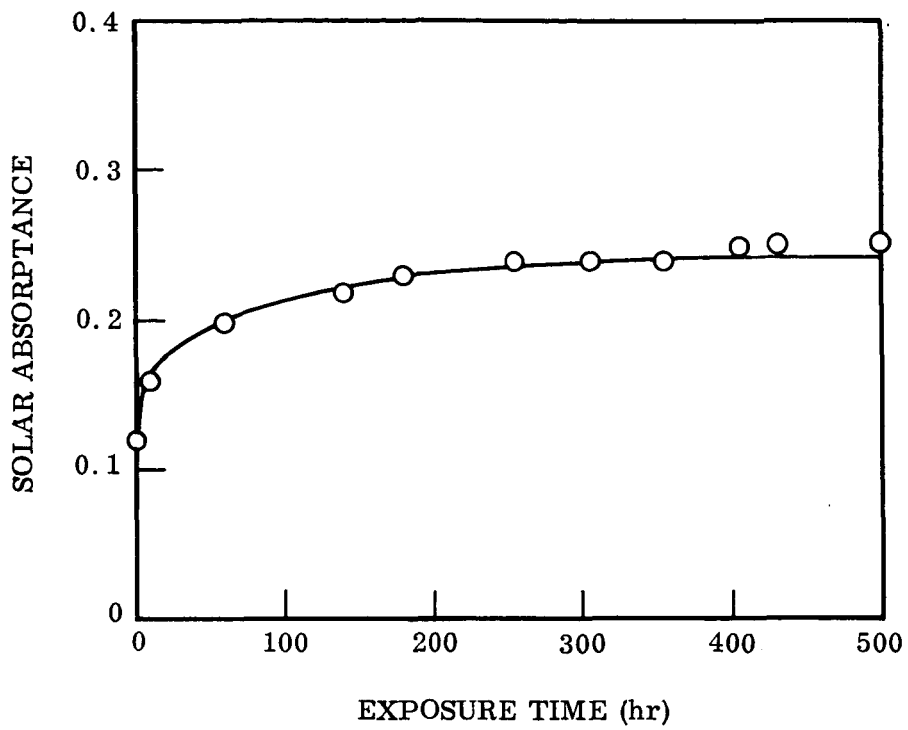


Fig. 2-9 Solar Absorptance of ZnO/K₂SiO₄ (Z-93) as a Function of Time of Exposure to a 1-Sun Level uv Intensity and 534°K (502°F)

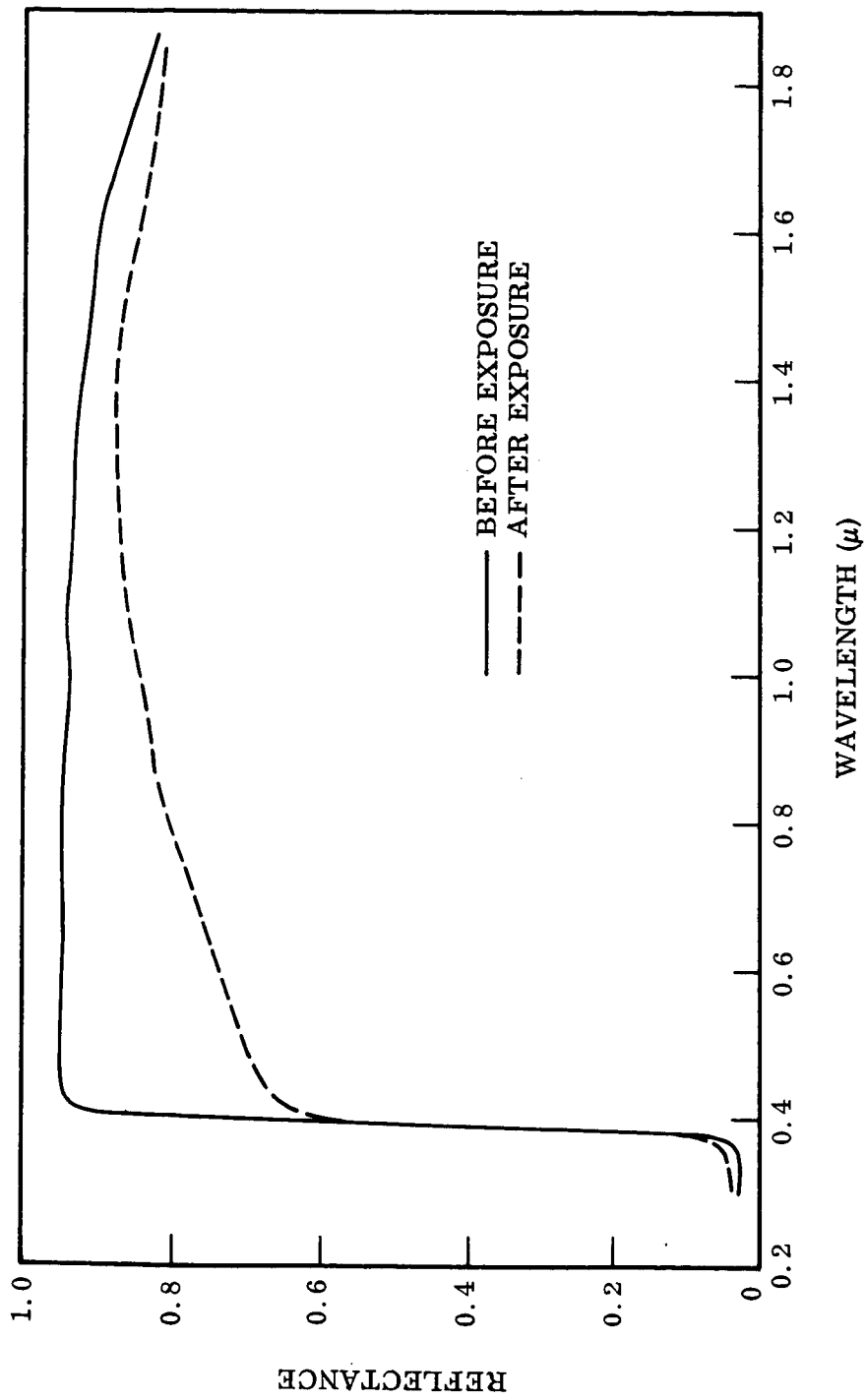


Fig. 2-10 Room Temperature Spectral Reflectance of Z-93 Sample No. 35

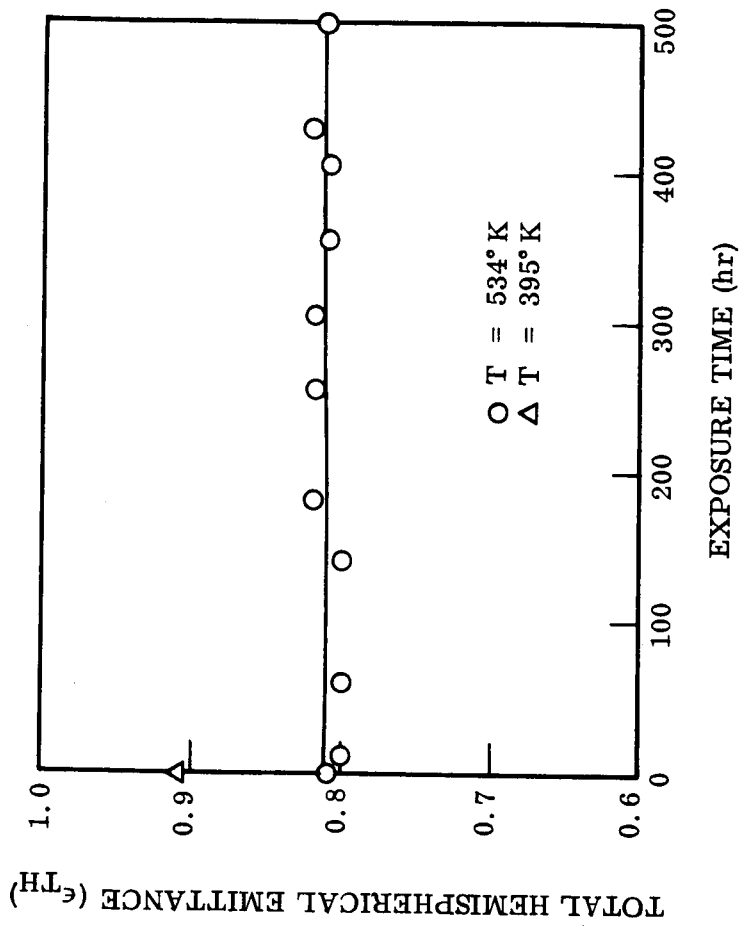


Fig. 2-11 Total Hemispherical Emittance of Z-93 Coating as a Function of Exposure Time at 1-Sun Level and 534°K (502°F)

The samples were maintained at a temperature of 535°K (504°F) and temperature cycled to room temperature every 4.7 hr. The pressure was maintained below 1×10^{-7} Torr.

The results of the calorimetric in situ measurements made during the exposure test on the samples are tabulated in Tables 2-6 and 2-7. The solar absorptance of the samples as a function of exposure time is shown graphically by Fig. 2-12. The solar absorptance of the $ZrSiO_4/K_2SiO_4$ coating increased from 0.11 to 0.42. Almost all this increase occurred in the first 150 hr of exposure time. This agrees very well with data presented by Streed (Ref. 9) which showed an increase from 0.13 to a final value of 0.42 for 700-sun hr at 10-sun intensity and at a temperature of 527°K (489°F). Since this coating shows a very high degree of degradation upon exposure to uv at a temperature of 527°K (489°F), and since the data for both agree fairly well (with the difference being explainable by the appearance of the sample surfaces after exposure), it was felt necessary to run a third sample.

Sample No. 14 turned a dark grey with a visible narrow ring around the edge of the sample. Inside of the ring the surface was slightly darker in color. This appears to be due to variations in surface texture and thickness.

Sample No. 9 was lighter in color than Sample No. 14, with a slightly tan hue. A large portion of surface had a mottled appearance.

Pre- and post-test room temperature reflectance data for the sample are shown in Figs. 2-13 and 2-14.

The total hemispherical emittance measured calorimetrically during the exposure test is shown by Fig. 2-15. This sample also shows a drop in emittance from 0.87 at 395°K (252°F) to 0.71 at 535°K (504°F). The emittance remained relatively constant at this value for the remainder of the test.

Table 2-6

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
DATA FOR $ZrSiO_4/K_2SiO_4$ COATING, SAMPLE NO. 9

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	$\alpha_H^{(a)}$					$\alpha_s^{(b)}$
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	294 70	0.87	0.13	—	—	—	—	—
0	0	339 153	.86	.16	—	—	—	—	—
0	0	395 252	.82	.17	—	—	—	—	—
0	0	534 502	.80	—	—	—	—	—	—
0	1	534 502	.70	.13	0.30	0.12	0.10	0.11	0.13
3	2	534 502	.70	.17	.35	.19	.19	.13	.18
50	14	534 502	.69	.26	.40	.29	.30	.24	.27
100	25	534 502	.71	.33	.50	.39	.36	.30	.36
Before Exposure ^(c)				.12	.25	.11	.09	.10	.12
After Exposure ^(c)				.38	.65	.51	.37	.25	.36

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

Table 2-7

CALORIMETRIC TOTAL HEMISPHERICAL EMITTANCE AND IN SITU ABSORPTANCE
 DATA FOR $ZrSiO_4/K_2SiO_4$ COATING, SAMPLE NO. 14

Hour	Cycle	Temp. (°K) (°F)	ϵ_{TH}	α_H (a)					α_S (b)
				Total	0.2-0.41	0.41-0.6	0.6-0.85	0.85-	Total
0	0	294 70	0.87	0.16	—	—	—	—	—
0	0	339 153	.87	.15	—	—	—	—	—
0	0	395 252	.87	.14	—	—	—	—	—
0	1	534 502	.71	.12	0.30	0.12	0.10	0.08	0.12
12	5	534 502	.71	.23	.50	.30	.23	.15	.25
24	10	534 502	.71	.31	.50	.31	.35	.23	.31
75	22	534 502	.71	.38	.50	.39	.43	.29	.37
127	33	534 502	.71	.39	.50	.45	.48	.33	.40
171	44	534 502	.70	.39	.50	.46	.46	.34	.41
196	49	534 502	.71	.38	.50	.39	.45	.34	.40
267	65	534 502	.72	.38	.50	.38	.50	.34	.40
315	77	534 502	.72	.40	.55	.39	.50	.37	.41
380	92	534 502	.72	.40	.55	.37	.49	.39	.41
432	104	534 502	.70	.42	.55	.40	.47	.40	.43
500	120	534 502	.71	.41	.55	.45	.48	.43	.42
Before Exposure ^(c)				.11	.23	.10	.09	.10	.12
After Exposure ^(c)				.48	.61	.60	.55	.40	.51

(a) Absorptance for xenon source.

(b) Absorptance for solar source.

(c) From Cary room temperature reflectance measurements.

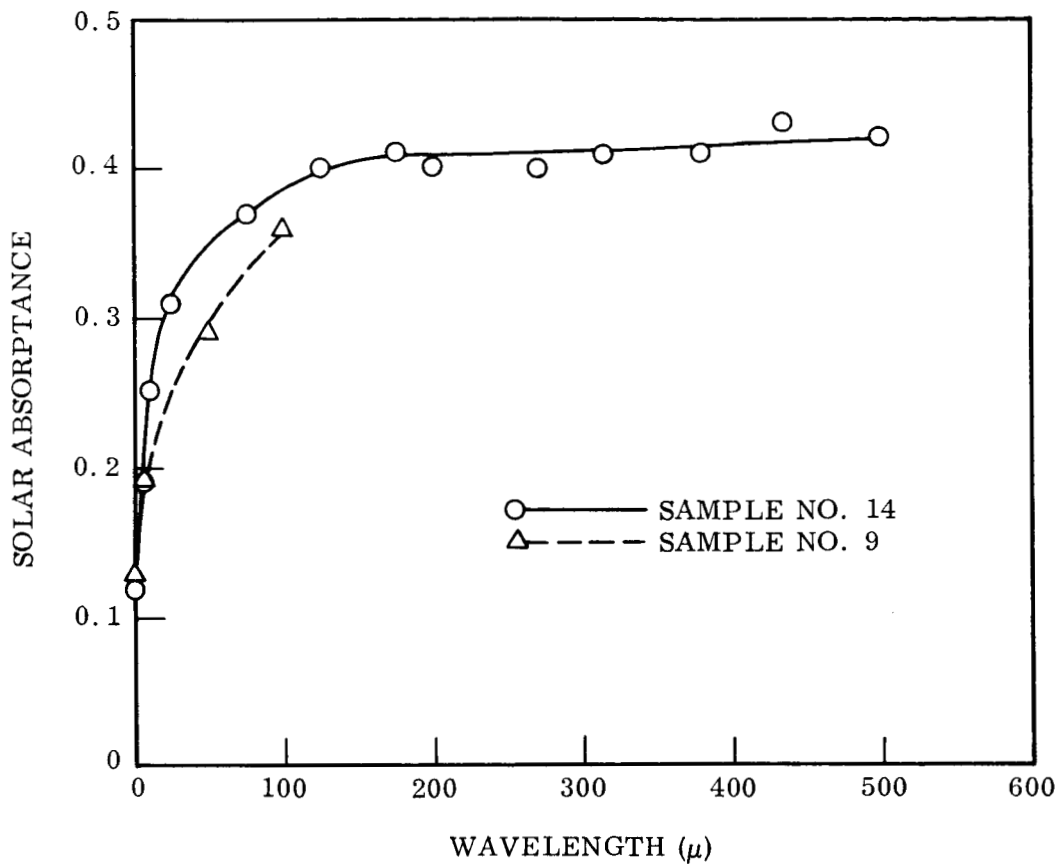


Fig. 2-12 Solar Absorbance of $ZrSiO_4/K_2SiO_4$ Coatings as a Function of Exposure Time at 1-Sun Level and 534°K (502° F)

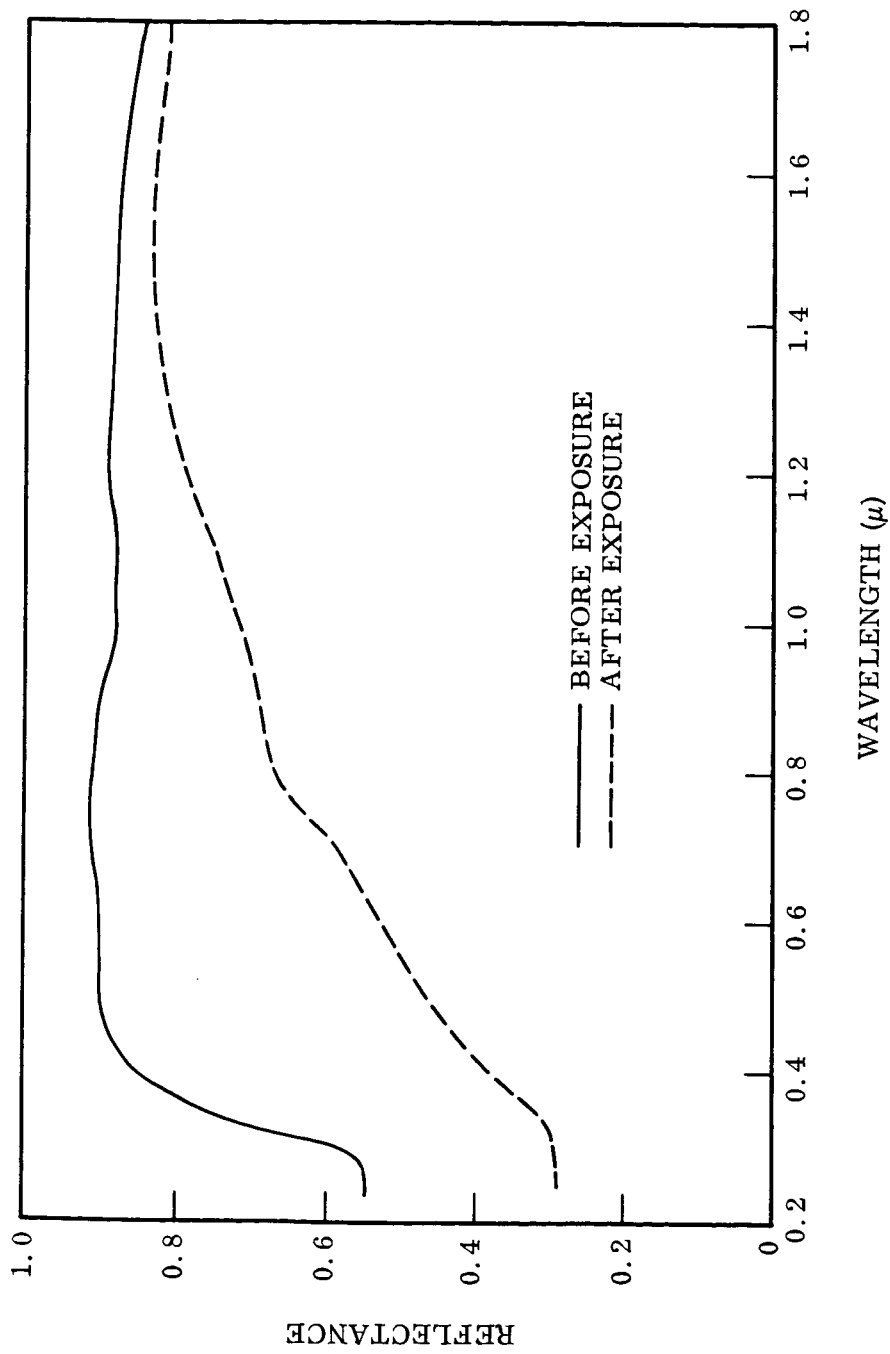


Fig. 2-13 Room Temperature Spectral Reflectance of $ZrSiO_4/K_2SiO_4$ Sample No. 9

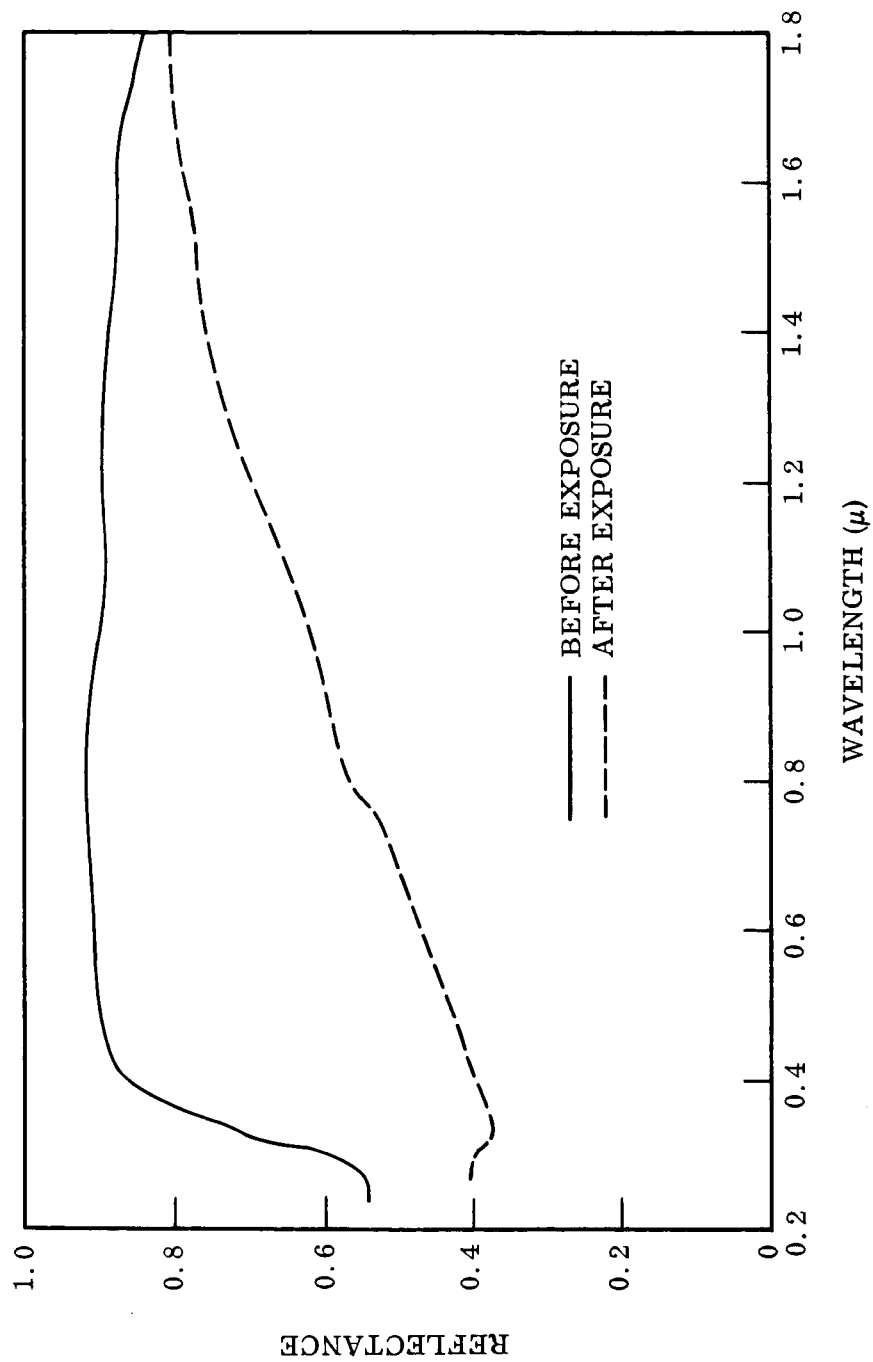


Fig. 2-14 Room Temperature Spectral Reflectance of $ZrSiO_4/K_2SiO_4$ Coating Sample No. 14

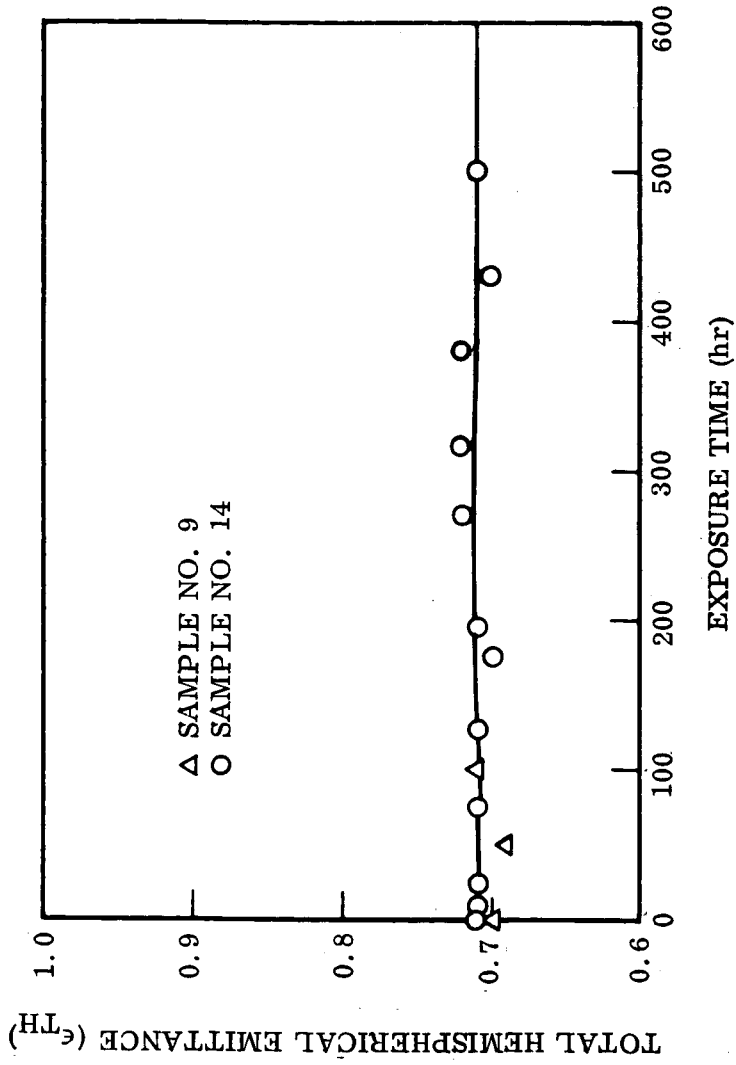


Fig. 2-15 Total Hemispherical Emittance of $ZrSiO_4/K_2SiO_4$ Coatings as a Function of Exposure Time at 1-Sun Level and $534^\circ K$ ($502^\circ F$)

Section 3
DISCUSSION

The 500-hr endurance testing at 395°K (252°F) has been completed on the Thermatrol, S-13, and S-13G coatings. The following data summarize the results for these three coatings at 395°K (252°F) after 500 hr:

	<u>α_s</u>		<u>ϵ_{TH}</u>	
	<u>Before</u>	<u>After</u>	<u>Before</u>	<u>After</u>
Thermatrol	0.16	0.32	0.87	0.87
S-13	.20	.28	.86	.86
S-13G	.21	.28	.92	.92

The degradation of the Thermatrol and S-13 coatings presented here is in close agreement to that determined by MacMillan et al. (Ref. 5) using a bidirectional reflectance in situ apparatus. No data on degradation of S-13G were available for comparison.

The 500-hr endurance testings at 534°K (502°F) have been completed on the Z-93 coating and the Lockheed $ZrSiO_4/K_2SiO_4$ coatings. The following data summarize the results for these two coatings at 534°K (502°F) after 500 hr of exposure:

	<u>α_s</u>		<u>ϵ_{TH}</u>	
	<u>Before</u>	<u>After</u>	<u>294°K (70°F)</u>	<u>534°K (502°F)</u>
Z-93	0.11	0.24	0.93	0.82
$ZrSiO_4/K_2SiO_4$.12	.42	.87	.72

The degradation of Z-93 as measured here is similar to that presented by Streed (Ref. 9). A comparison of a few points is given below:

	<u>0</u>	<u>50 hr</u>	<u>100 hr</u>	<u>500 hr</u>	<u>Temperature</u>
Streed	0.17	0.20	0.21	0.23	531°K (497°F)
LMSC	.12	.20	.22	.24	534°K (502°F)

The data presented by Streed were for exposure at the accelerated rate of approximately 10 suns. The data presented for the degradation of $ZrSiO_4/K_2SiO_4$ are in good agreement with those presented by Streed (Ref. 9). Streed shows a final value of 0.42 after 700 ESH at an approximately 10-sun level at a temperature of 533°K (500°F).

Section 4
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