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Report No. IITRI-C6258-5
(Final Report)

TESTING TO DETERMINE THE VACUUM-ULTRAVIOLET DEGRADATION RATE OF THERMAL CONTROL COATINGS

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
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FOREWORD

This is Report No. IITRI-C6258-5 (Final Report) of IITRI Project C6258, Contract No. NAS8-28765, entitled "Testing to Determine the Vacuum-Ultraviolet Degradation Rate of Thermal Control Coatings." This report covers the period from 5 May through 25 November 1972.

Major contributors to the program during this period include: Mr. J.E. Gilligan, Project Leader; Mr. F.O. Rogers, paint preparation; Mr. Robert F. Boutin, irradiation experiments and reflectance measurements; and Mr. Gene A. Zerlaut, general consultation and administrative management.

The work reported herein was performed under the technical direction of the Space Sciences Laboratory of the George C. Marshall Space Flight Center; Mr. H. Marshall King acted as the Project Manager.

This contract was funded under Code 933-50-07-000-50-2-004-000-2510.

Respectfully submitted,
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ABSTRACT

Samples of S-13G that had been exposed to the salt-air environment of Cape Kennedy, Florida were irradiated with simulated solar ultraviolet radiation after various cleaning treatments. In both of the tests conducted two of the salt-air exposed samples were not cleaned, two were lightly cleaned with water and detergent (i.e. rinsed), and two were vigorously scrubbed. Several other white thermal control coatings were also irradiated. The solar absorptance values of these coatings before and as a result of the ultraviolet irradiation are reported for exposure levels up to approximately 2000 ESH.

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1. INTRODUCTION

The principal purpose of this study was to determine the effects on the solar absorptance values of S-13G samples after subjecting them to the salt-air environment of Cape Kennedy, Florida, and to assess the benefit (in terms of reduced optical degradation) obtained by rinsing and/or by scrubbing these exposed samples. Several other coatings of interest to NASA-MSFC were also irradiated in the program. The specimens were irradiated in two (2) space simulation tests, IRIF Tests I-56 and I-57. In each irradiation test there were three (3) specimens that had been "salt-air" exposed at ground level near high tide (designated "corrosion"), and three (3) specimens that had been "salt-air" exposed at an approximate height of 150 ft on the Mobile Service Stand (designated "MSS")--both at the Saturn Launch Facility at Cape Kennedy, Florida. The other six (6) specimens in each test included Cat-A-Lac White (in I-56 only), Hughes Aircraft Corporation (HAC) porcelain enamel, and A-429M (in I-57 only) and other S-13G (control) specimens.

The salt-spray-exposed S-13G samples - six MSS and six Corrosion, - three of each exposure type were prepared for IRIF Test I-56, and three of each for I-57. One of each set of three specimens was set aside without any cleaning or other treatment, and was further designated "control." A second specimen was given a light rinse, simulating the cleaning action which would be expected if a vehicle on a launch pad were hosed down to remove loose dirt and contamination. These specimens were further designated "rinsed." The third specimen was vigorously scrubbed with detergent and water to simulate the effect of a vehicle scrub-down. The further designation "scrubbed" was given to these specimens.

2. TEST CONDITIONS AND MEASUREMENT SCHEDULES

After installation of the specimens in the IRIF, reflectance spectra of all samples were recorded in the wavelength range 325-2600 nm. In test I-56 reflectance measurements were also made prior to vacuum pumpdown. During both irradiation tests, the equivalent solar ultraviolet irradiation rate was maintained at 5 suns (solar equivalents). In I-56 the vacuum level remained below 2×10^{-7} Torr; in I-57, below 5×10^{-7} Torr. The sample temperature was held at ~45°F in I-56 and at ~153°F in I-57.

The initial (pre-irradiation) spectral measurements were followed by measurements after nominal exposures in I-56 of 400, 1100 and 3100 ESH, and in I-57 of 100, 500, 1000, 1500 and 2000 ESH. In I-56 post-exposure measurements with the IRIF at ambient pressure ("Air Bleach") were made on all samples; in I-57, only on selected samples.

3. TEST RESULTS

The solar absorptance values obtained in the irradiation tests have been tabulated in Table 1. It should be noted that these data from I-56 are not directly comparable with those from I-57 because in IRIF Test I-56 the sample temperature during irradiation was maintained at ~45°F and in I-57, ~153°F. Sample temperature is a major difference between the two tests.

The overall results of these tests show that the degradation of salt-spray exposed samples is decreased by vigorous scrubbing, but essentially unaffected by rinsing or no cleaning at all. The scrubbed samples in I-56 degraded even less than unexposed control S-13G samples, presumably because the scrubbing action removes excess curing agent from the surface. The effect of temperature, however, as I-57 results show, minimizes the curing agent effect - probably because excess curing agent is removed by high temperature also. No significant benefit will accrue as a result of cleaning S-13G surfaces (prior to flight), that have been exposed to a seashore environment, unless they are vigorously scrubbed.

The uncleaned ("control") and rinsed samples all reflect the accumulation of salt on their surfaces in terms of initial α_s, but their degradation rates compared to those of uncontaminated S-13G are approximately the same.

The rinsed samples, in fact, appear not only to possess higher initial α_s values, but also to degrade slightly more than the "control" samples.

Clearly, the effect of temperature is to increase the initial rate of solar absorptance increase; however, after the initial rapid rate, degradation apparently diminishes to a level approaching the room temperature rate.

The general trends of I-57, the second (high temperature), test parallel those of I-56, with the total degradation, of course, being considerably greater. An analysis of the spectral

Table 1A

SOLAR ABSORPTANCE VALUES, IRIF TEST I-56

Sample Description	Initial In Air	Initial 1×10^{-7}	Exposure, ESH 415	Exposure, ESH 1100	Exposure, ESH 3085	Air Bleach
MSS* S-13G; Control	0.250	0.270	0.273	0.286	0.307	0.306
MSS S-13G; Rinsed	0.247	0.252	0.257	0.273	0.304	0.301
MSS S-13G; Scrubbed	0.215	0.225	0.226	0.237	0.267	0.252
Corrosion** S-13G; Control	0.276	0.293	0.289	0.303	0.340	0.333
Corrosion S-13G; Rinsed	0.284	0.293	0.296	0.315	0.341	0.337
Corrosion S-13G; Scrubbed	0.215	0.229	0.229	0.238	0.246	0.237
S-13G Control (Batch C-389)	0.187	0.197	0.198	0.201	0.244	0.222
Porcelain Enamel (HAC)	0.257	0.263	0.279	0.293	0.306	0.296
Al Mirror (Control)	0.290	0.298	0.302	0.309	0.314	0.313
Cat-A-Lac White	0.291	0.294	0.442	0.513	0.614	0.572
Cat-A-Lac White	0.286	0.306	0.415	0.506	0.634	0.567
S-13G; Batch C-392	0.183	0.197	0.203	0.210	0.220	0.218

Table 1B

SOLAR ABSORPTANCE VALUES - IRIF TEST I-57†

Sample Description	Initial In Vacuo	Exposure, ESH 120	Exposure, ESH 480	Exposure, ESH 1032	Exposure, ESH 1540	Exposure, ESH 2010	Air Bleach
MSS S-13G, Control	0.245	0.272	0.302	0.317	0.319	0.332	0.312
MSS S-13G, Rinsed	0.331	0.352	0.386	0.396	0.397	0.410	0.376
MSS S-13G, Scrubbed	0.225	0.238	0.265	0.276	0.278	0.288	0.254
Corrosion S-13G, Control	0.284	0.314	0.340	0.355	0.362	0.377	
Corrosion S-13G, Rinsed	0.302	0.335	0.345	0.368	0.372	0.390	
Corrosion S-13G, Scrubbed	0.215	0.248	0.261	0.273	0.282	0.297	
S-13G Control (Batch C-389)	0.190	0.221	0.235	0.249	0.253	0.262	0.246
Porcelain Enamel (HAC)	0.291	0.323	0.335	0.342	0.346	0.354	
Al Mirror (Control)	0.335	0.338	0.343	0.344	0.347	0.358	
A-429M*** (Batch C-406), 250°F/15 hr	0.211	0.213	0.223	0.224	0.227	0.232	
A-429M (Batch C-406), 250°F/15 hr	0.212	0.210	0.222	0.225	0.232	0.234	0.225
A-429M (Batch C-406), 350°F/4 hr	0.260	0.262	0.271	0.273	0.283	0.299	0.255

*Exposed at approximately 150 feet up on the Mobile Service Stand at Cape Kennedy.
**Exposed on the beach at high tide level at Cape Kennedy.
***A-429M is a paint using S-13G pigment in an IITRI-modified Owens-Illinois 650 glass resin.
†Test I-57 samples temperature during exposure was 153°F; in I-56, they were at ambient.

reflectance data from I-57 shows that the degradation does not depend as much upon initial cleanliness as it did in I-56, where the results clearly indicated a beneficial effect of scrubbing. Degradation depends to some extent on the initial reflectance; the higher the initial reflectance, the greater the degradation. The α_s values of the "scrubbed" samples, even though lower than the "control" or the rinsed samples, are not as low as those of unexposed S-13G. A departure from a smooth curve between 1000 and 1500 ESH is apparent in Test I-57. This happened as a result of a seal failure, sometime prior to the 1500 ESH measurements, in the A-H6 cooling system. The cooling water became contaminated and undoubtedly prevented the full ultraviolet intensity of the source from reaching the samples.

The extraordinary stability of the A-429M paint system stands out very plainly among all the test data. Although this paint system has yet to be optimized with respect to PVC, thickness, curing conditions, primers, etc., it has consistently exhibited excellent stability. In tests at room temperature the degradation of A-429M has never exceeded 0.01 in 2000 ESH.

The Cat-A-Lac White coatings sustained extensive optical damage in I-56; α_s values more than doubled, nominally from 0.29 to 0.62, in 3085 ESH. Since this degradation occurred at room temperature, it was decided that this coating system should not be tested in the high temperature irradiation test.

The procelain enamel coatings prepared by Hughes Aircraft Co. (HAC) did not exhibit good performance. While this coating system does not have a strong dependence of ultraviolet degradation on temperature, it does sustain much more optical damage than would be expected of a porcelain system.

The spectral reflectance curves for all the MSS S-13G samples, for unexposed S-13G samples, for the HAC porcelain samples and for an A-429M sample are presented in Figures 1-11. As specified in the work order, two copies of the raw reflectance charts, on which the α_s calculations are based, have been supplied under separate cover.

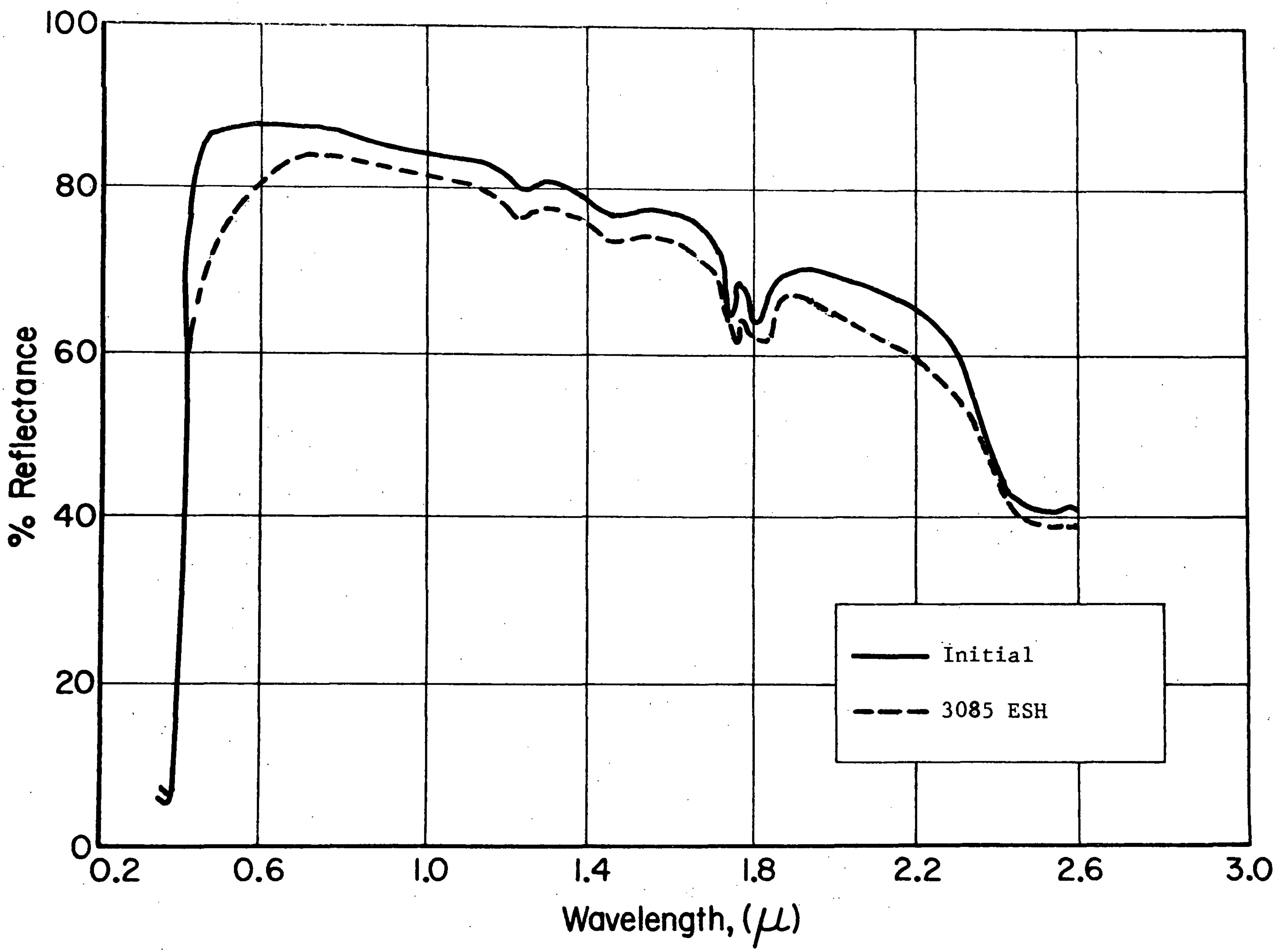

Figure 1 SPECTRAL REFLECTANCE OF MSS SALT-SPRAY EXPOSED S-13G - UNTREATED; I-56

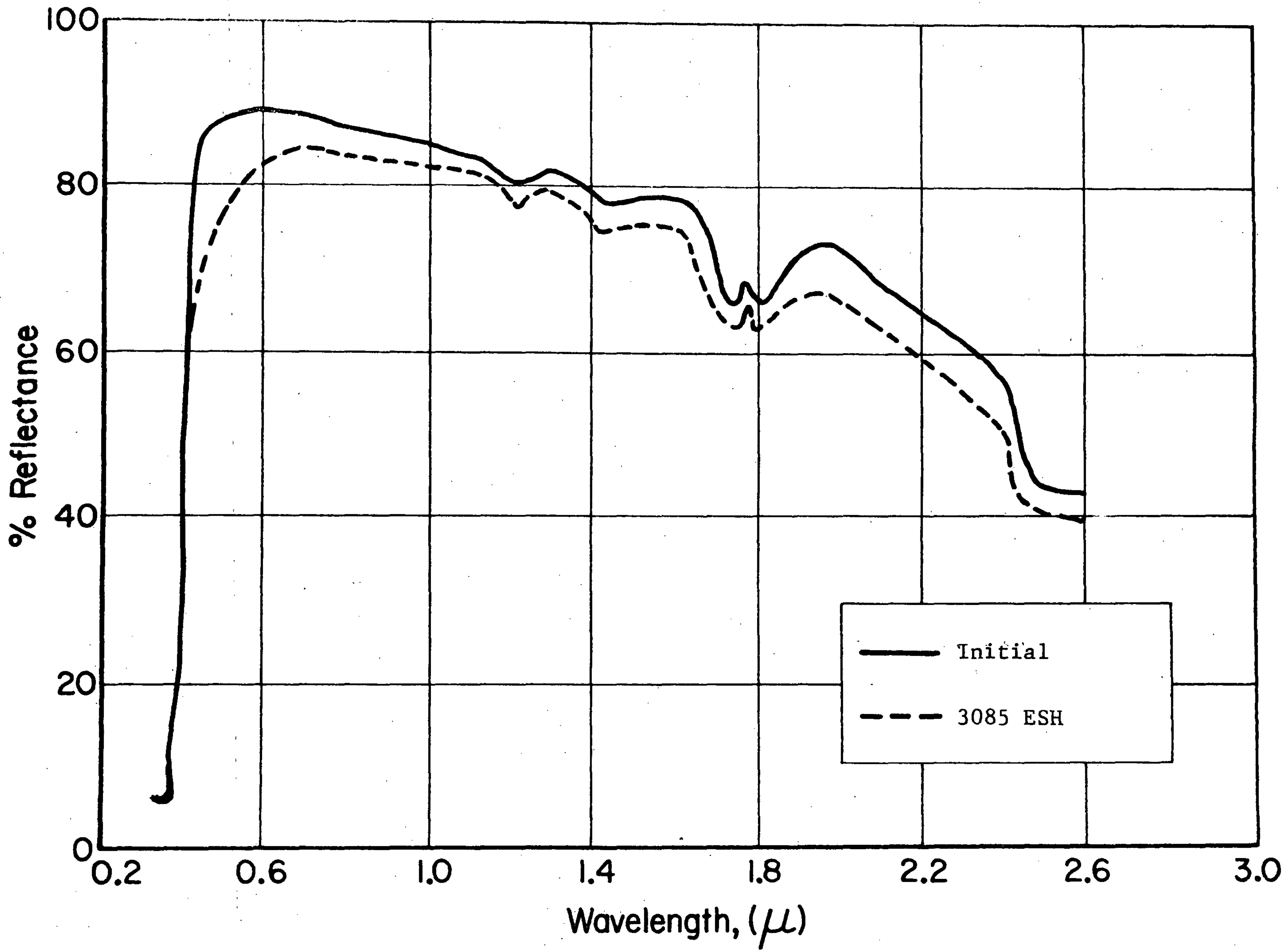

Figure 2 SPECTRAL REFLECTANCE OF MSS SALT-SPRAY EXPOSED S-13G - RINSED; I-56

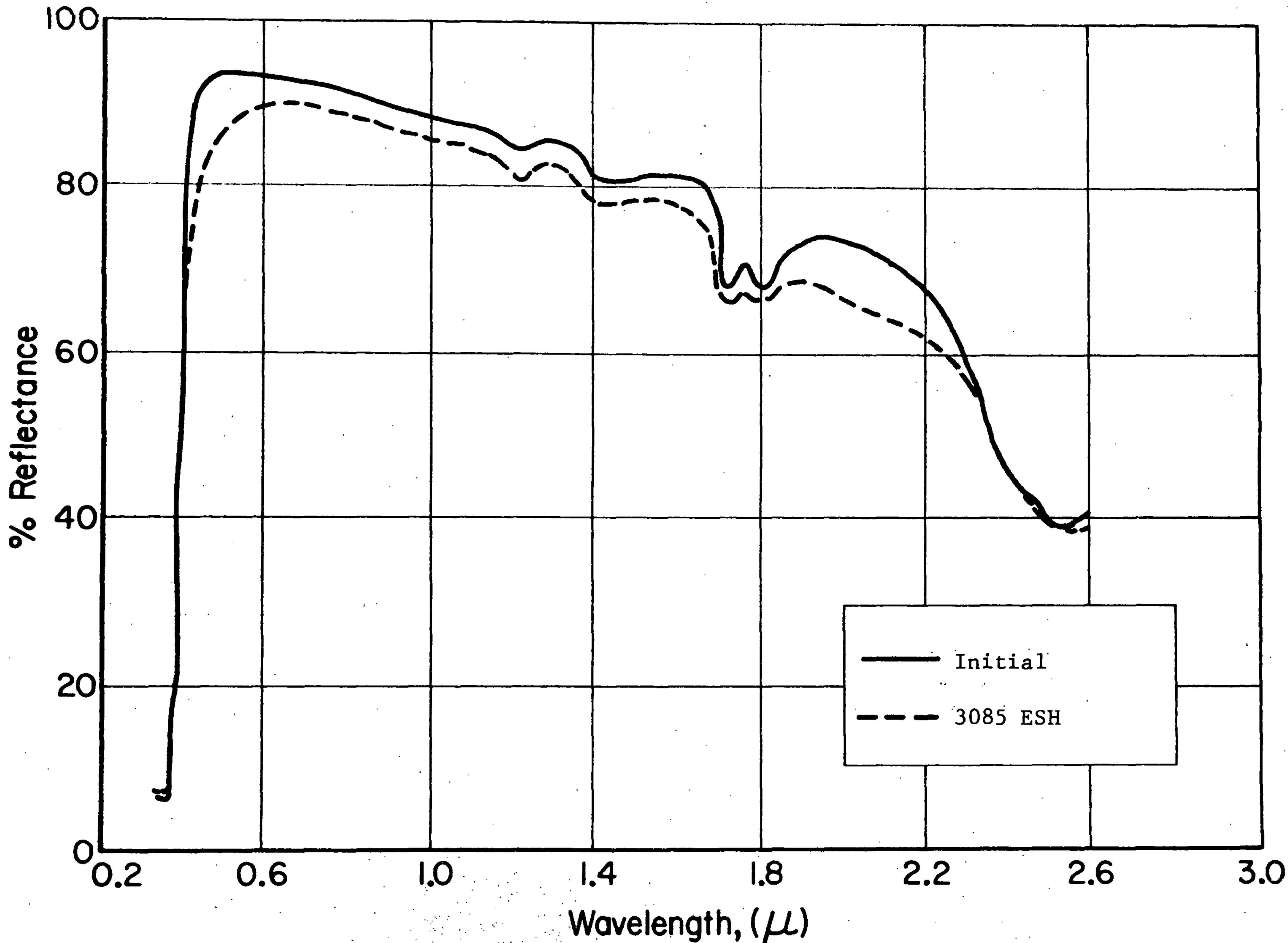

Figure 3 SPECTRAL REFLECTANCE OF MSS SALT-SPRAY EXPOSED S-3G - SCRUBBED; I-56

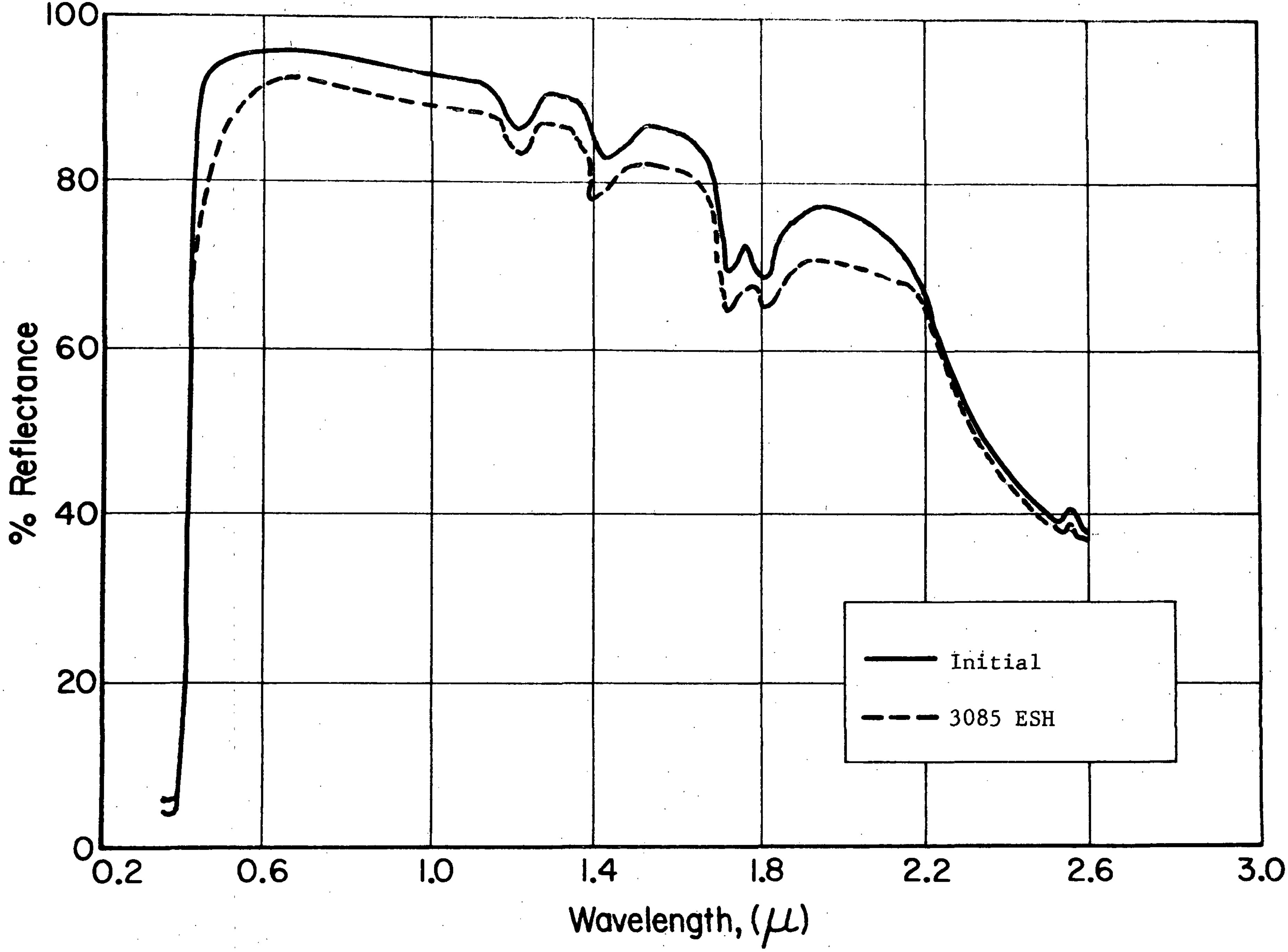

Figure 4 SPECTRAL REFLECTANCE OF UNEXPOSED S-13G, I-56

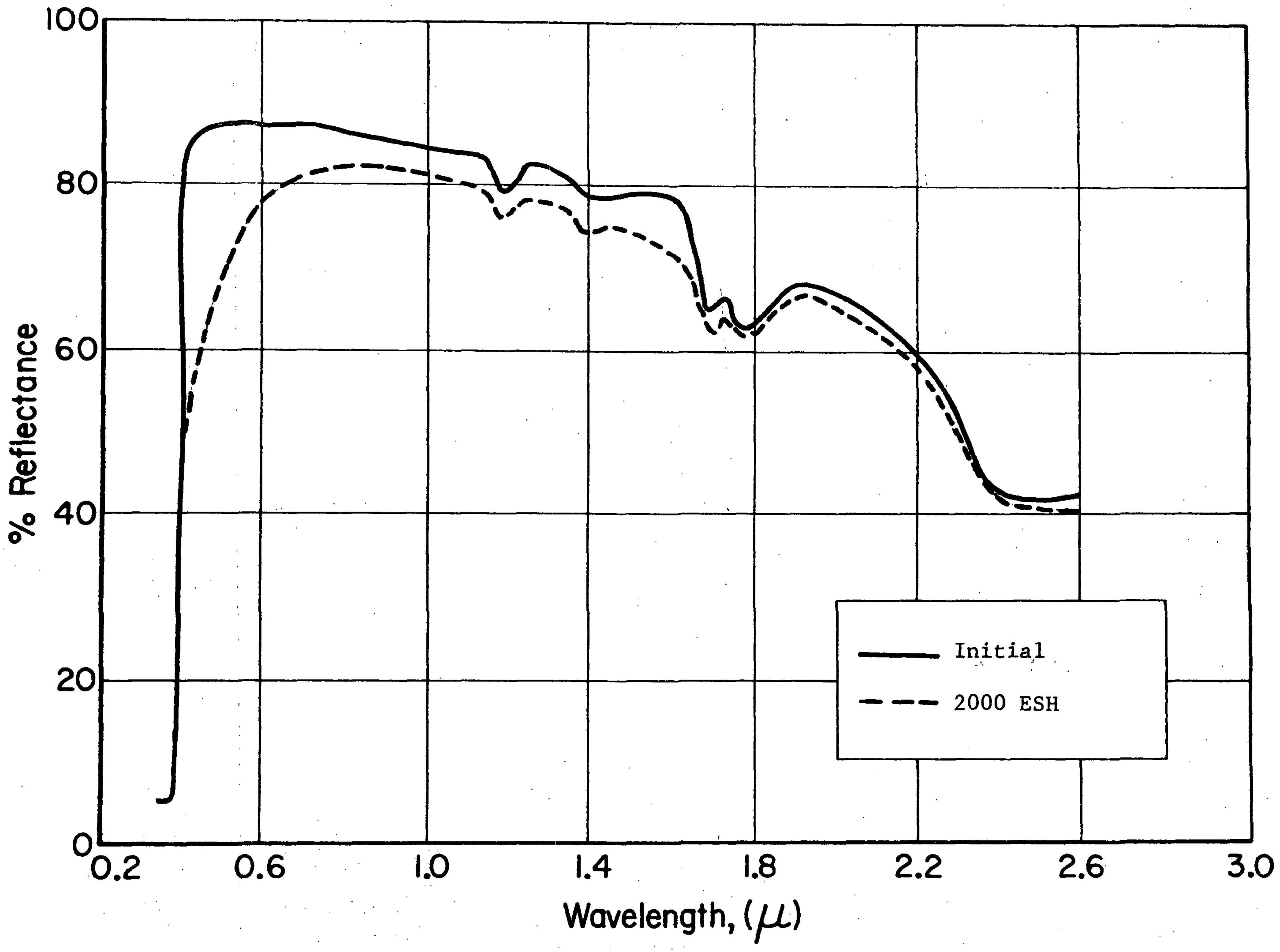

Figure 5 SPECTRAL REFLECTANCE OF UNEXPOSED S-13G - UNTREATED; I-57

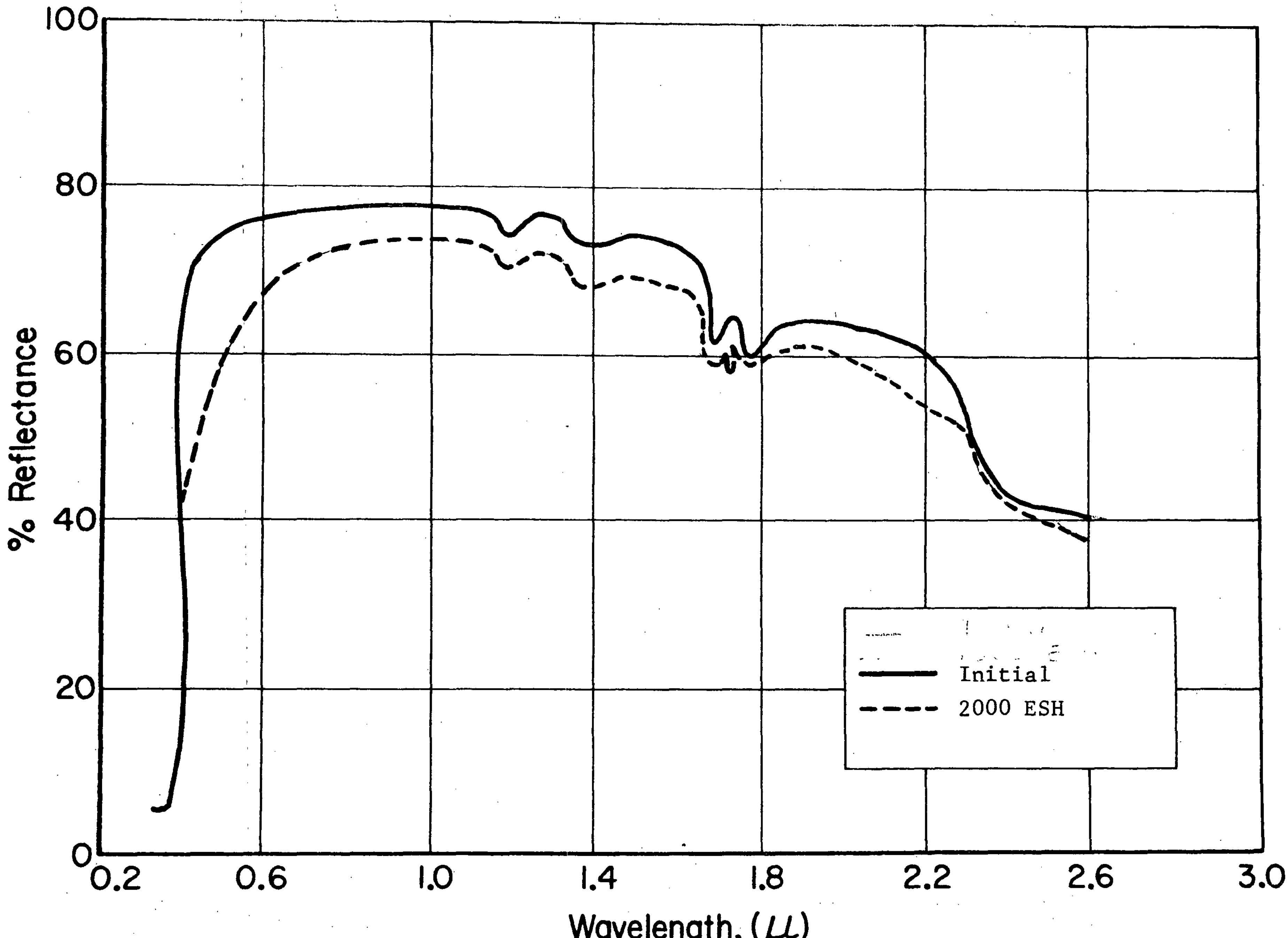

Figure 6 SPECTRAL REFLECTANCE OF UNEXPOSED S-13G - RINSED; I-57

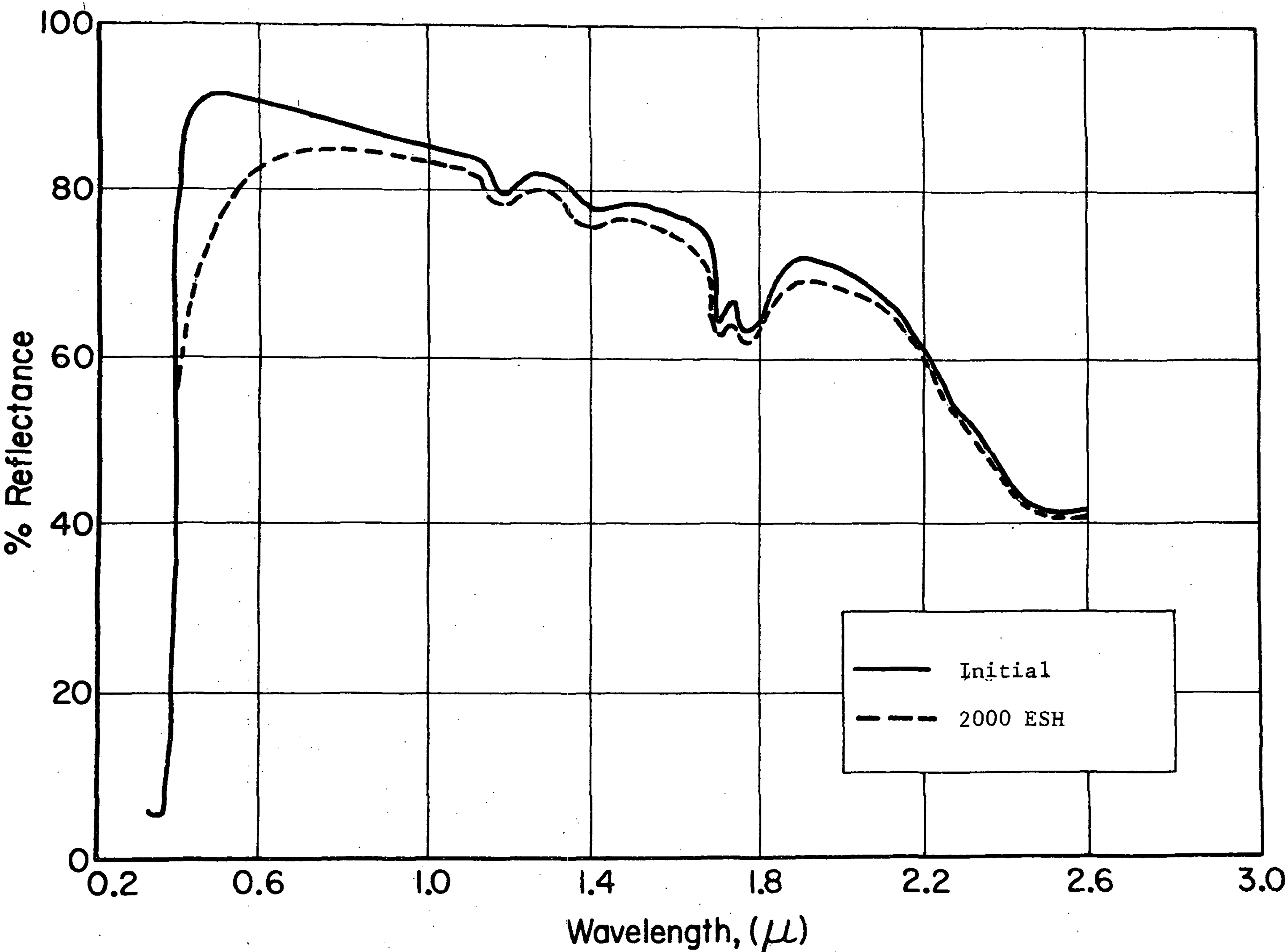

Figure 7 SPECTRAL REFLECTANCE OF UNEXPOSED S-13G - SCRUBBED; I-57

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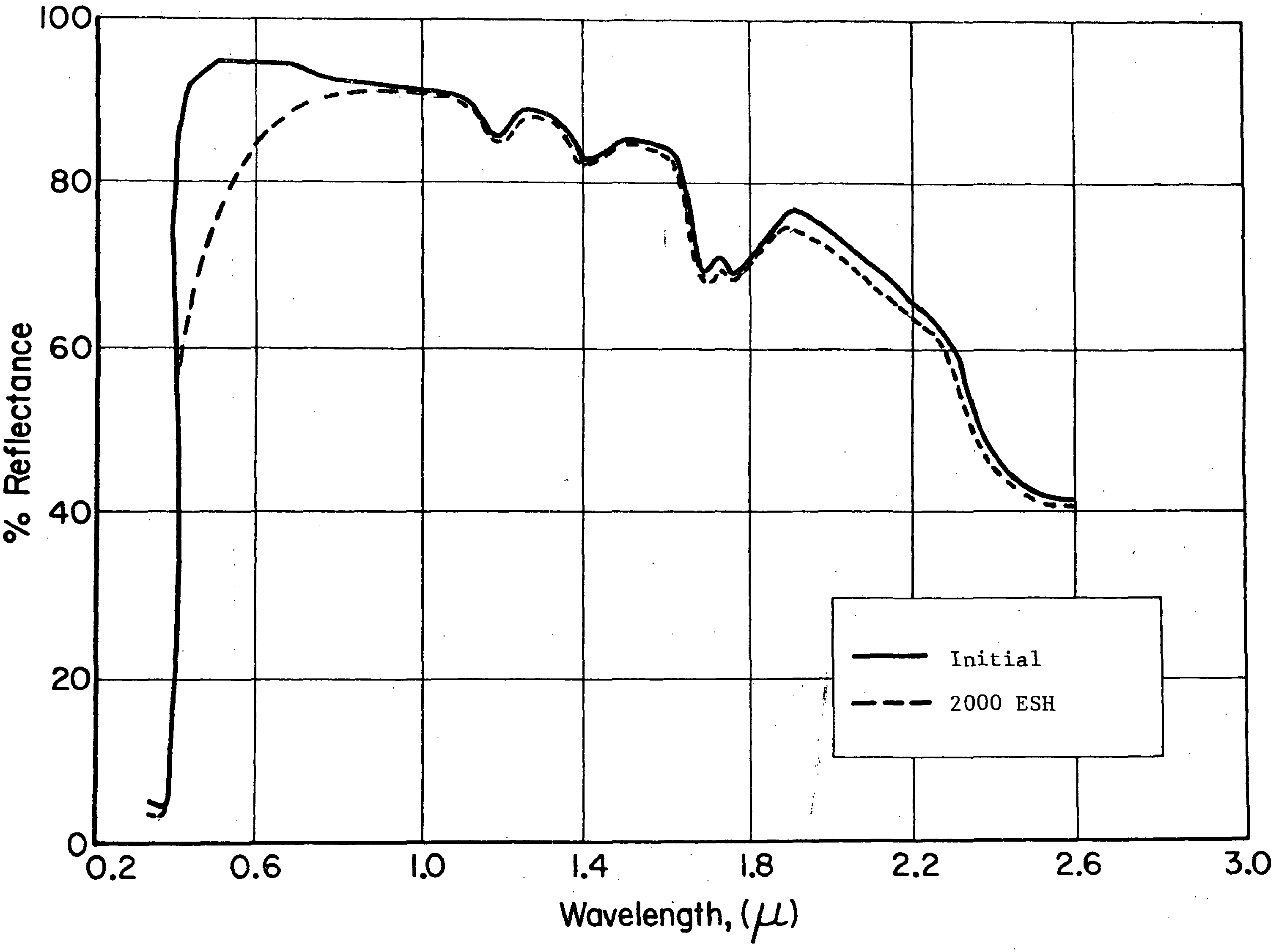

Figure 8 SPECTRAL REFLECTANCE OF UNEXPOSED S-13G; I-57

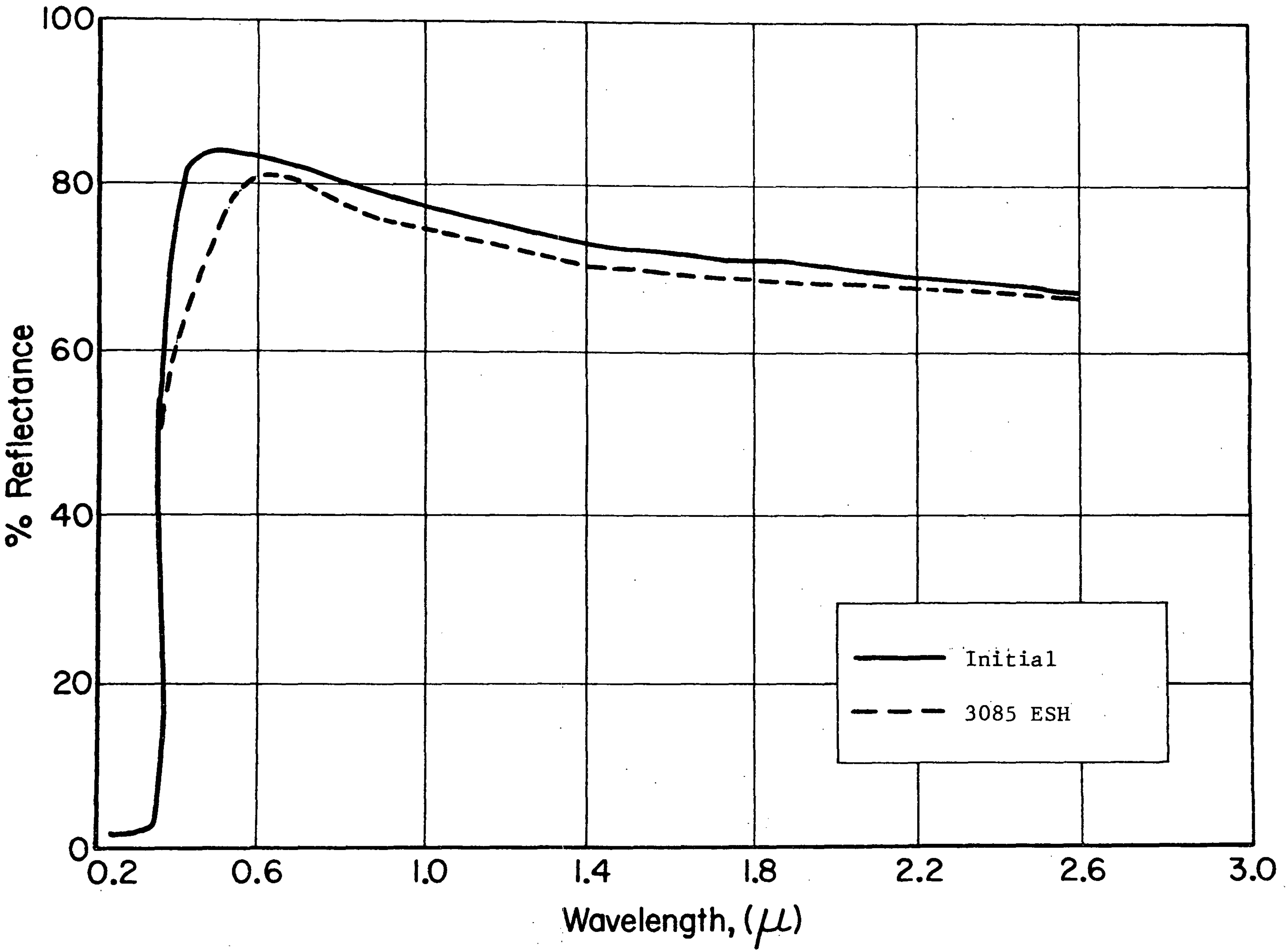

Figure 9 SPECTRAL REFLECTANCE OF HAC PORCELAIN ENAMEL; I-56

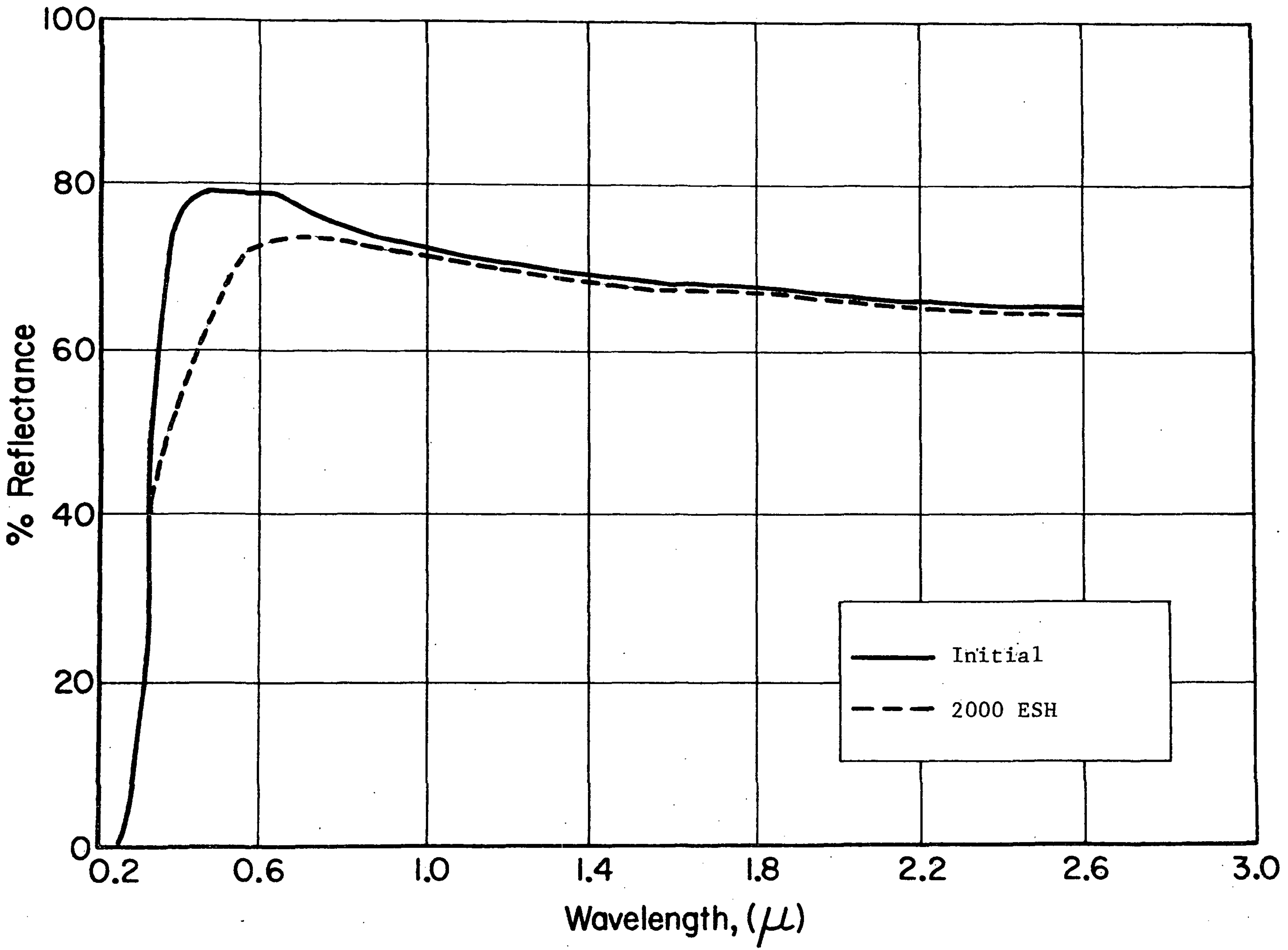

Figure 10 SPECTRAL REFLECTANCE OF HAC PORCELAIN ENAMEL; I-57

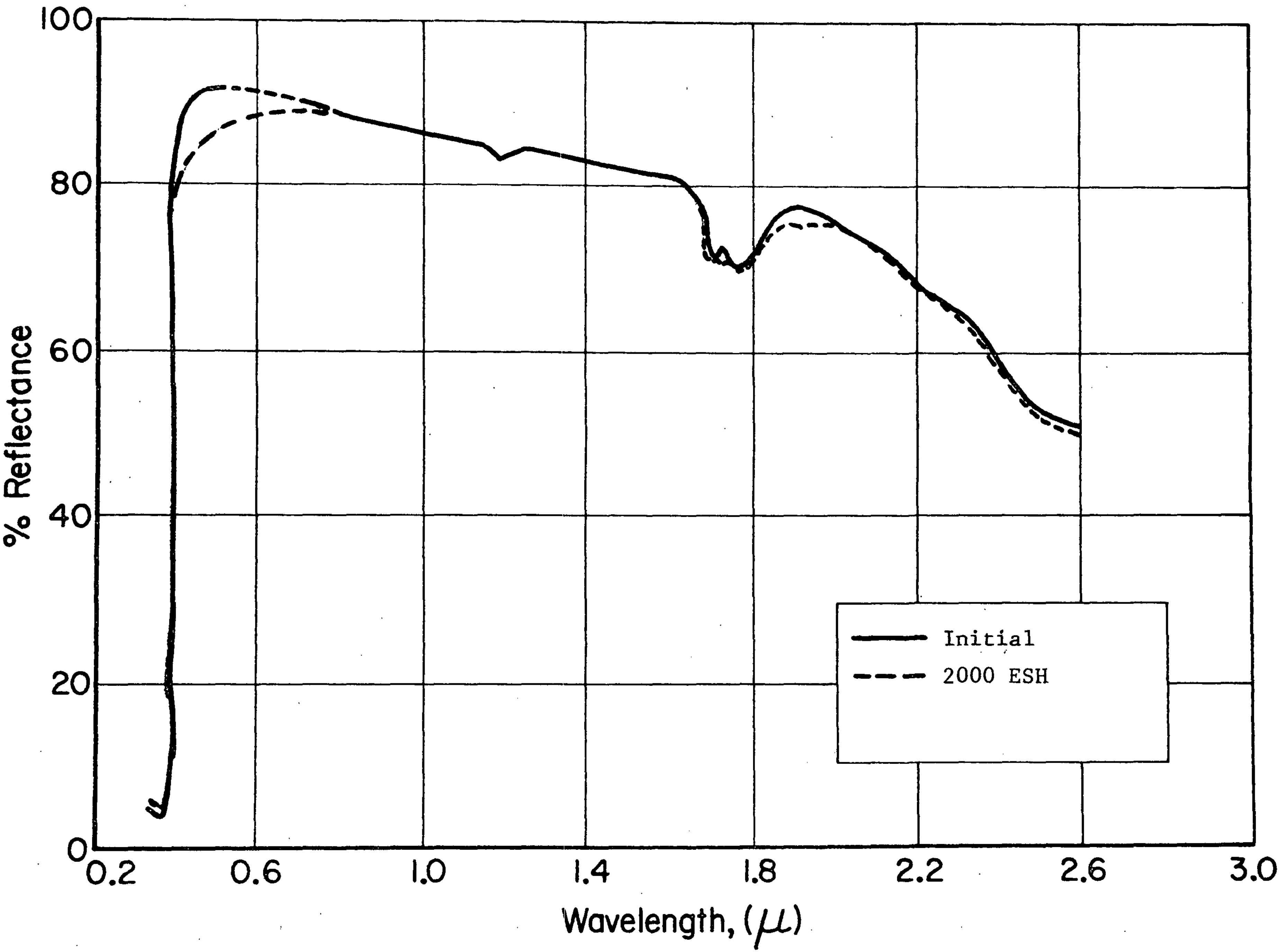

Figure 11 SPECTRAL REFLECTANCE OF A-429M, I-57

4. CONCLUSIONS

With respect to the principal objectives of this study we can state with reasonable certainty that exposure to the sea-shore environment definitely increases the solar absorptance of exposed S-13G thermal control coatings; that, unless such coatings are vigorously scrubbed prior to launch, any other cleaning procedure, e.g. "hosing down," will be ineffective in reducing the initial solar absorptance; and that the accumulation of salt, which is greater nearest the surf, has no significant effect on the initial degradation rate of these coatings. An alternative to the scrubbing procedure is a protective coating or cover while the vehicle is on the launch pad.

Operating S-13G paint coatings at 153°F results in greatly increased rates of initial optical degradation. Even at this high temperature, however, the S-13G does not degrade severely; the trends definitely indicate a leveling off of α_s vs ESH.

The initial solar absorptance value of A-429M notwithstanding, its optical performance in ultraviolet exposure tests shows it to be superior to any coating system thus far tested. Cat-A-Lac White, in contrast, represents a clearly inferior choice, and its instability is perhaps the reason for the slight decreases in the reflectance of the Aluminum mirror in I-56. The porcelain enamel coating systems also performed relatively poorly.