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THERMAL TESTING OF THE RANGER BLOCK III SPACECRAFT IN THE JPL 25 FT. SPACE SIMULATOR

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In January, 1964, a test program was begun on the thermal design of the Ranger Block III spacecraft. The tests were performed in the newly operational JPL 25' Space Simulator over a period of 6 months. The objectives of these tests were two-fold:

A. To evaluate the 25' Space Simulator as a facility for proving the thermal design of spacecrafts, and

B. To verify the thermal design of the Ranger Block III spacecraft.

These two objectives are complimentary in the test series performed and are difficult to separate into distinct categories. An important part of the first objective was to learn what type of test preparation, instrumentation, and analysis was required for the meaningful evaluation of test data from the 25' Space Simulator tests. Although some experience had been gained in testing of components and incomplete spacecrafts in smaller solar simulation chambers during the early part of the Ranger program, we knew little about testing of a complete spacecraft in the 25' Space Simulator when this test program began.

Test analysis requires that the energy absorbed by various spacecraft components be known. This requires a knowledge of the area of solar absorption or sunlit area, the solar energy flux density on the area, and the effective absorptance of that area. Most of the problems encountered were associated with the determination of the last two quantities since the sunlit area may be obtained directly by inspection of spacecraft surfaces. This paper will present a discussion of our experiences during the Ranger Block III thermal test series on the Thermal Test Model (TCM). The TCM was thermally equivalent to the flight type Ranger spacecraft except for the lack of an antenna dish and solar panels. Flight type structural hardware was used with surface finishes equivalent to those of the flight spacecraft. Aluminum blocks simulated the spacecraft electronics thermal masses with resistance heaters simulating the electronic power dissipation. The discussion will be presented in a semi-chronological order and will be divided into the following areas:

1. Determination of solar simulation flux density on spacecraft surfaces.
2. Problems related to decollimation of the solar simulation source.
3. Determination of effective absorptance in the solar simulation spectrum.

Determination of Solar Simulation Flux Density

Due to the uncertainties in the flux densities on the spacecraft surfaces resulting from reflections and non-uniformity of the solar simulation source, a detailed mapping of flux densities on the spacecraft was performed before each solar simulation test. The mapping was done under ambient conditions and consisted of readings with a calibrated solar cell at several hundred points on the spacecraft surfaces for each flux density which was to be used during the vacuum cold-wall portion of the test. Solar cells were used for mapping because of their small size, fast response time, and principally for lack of a better device.

The first test was performed in January of 1963. The test object consisted of a thermal model of the RCA subsystem mounted on a plate which simulated the JPL bus as shown in Figure 1. Before the RCA subsystem was suspended in the chamber, flux density readings were made on the test fixture shown schematically in Figure 2. The discs of the test fixture had diameters equivalent to the fin diameters on the RCA subsystem and were spaced vertically at the proper positions. A solar cell calibrated against an air thermopile was used to measure the flux densities along the edges of each disc. After the RCA subsystem was suspended in the chamber, measurements of flux densities on the fin surfaces were made. When compared with the densities determined from the test fixture, it was found that a large amount of energy was being reflected from the skin of the subsystem to the top of each fin. The calibrated solar cell was used to monitor the flux density at the top of the RCA subsystem thermal model during the mapping and also during the vacuum cold-wall test with solar simulation.

The second test was performed in April of 1963. The test object was the complete TCM, consisting of the RCA subsystem mounted on the JPL bus as shown in Figure 3. For this test an Eppley thermopile was used to monitor the flux density during the mapping and the vacuum cold-wall test with solar simulation. This thermopile was mounted on a boom above the top of the spacecraft. Eight solar cells were mounted in various locations on the spacecraft for the purpose of checking the mapping data during the vacuum test and also to detect any variations or warping of the solar simulation energy field during the test. During the mapping, calibrated solar cells were used to determine the flux density at each cell location on the spacecraft. It was found that a vacuum calibration was needed in order to check the absolute flux density at each cell location during the vacuum cold-wall test. However, it was possible to check the relative flux densities among the various cells using the air calibration. No warping of the solar simulation energy field was detected. At the completion of the test we still wanted a method of checking the mapping data obtained under ambient conditions with the flux densities encountered during the vacuum tests.

The third test on the TCM was performed in June of 1963. Before the spacecraft was installed in the chamber, ten solar cells were calibrated under vacuum cold-wall conditions against an Eppley thermopile. The test configuration is shown in Figure 4. The cells were mounted on a plate which could be rotated so that each cell could be positioned over the detector of the thermopile. Alternate readings of cell output and thermopile output were recorded for each cell while the temperature of the cells was controlled by a heater mounted on the rotating plate. A difference of approximately 10% in the calibration number was found between the air calibration and the vacuum calibration. The cells were then mounted on the spacecraft as was done in the second test and a thermopile was mounted on top of the spacecraft for flux density monitoring. During the test it was possible to check and verify mapping data obtained under ambient conditions with the flux densities at the cell locations under vacuum conditions.

In mapping, the cell was held horizontally above sunlit areas and held parallel to surfaces which were shaded or vertical. For a horizontal cell (vertical light beam), the mapping data is thought to be accurate to within 7 watts per square foot at one solar constant due to a 3% thermopile tolerance and an instrumentation accuracy of ±1 millivolt. This error could be considerably worse for the shaded or vertical areas due to the questionable reflectance characteristics of the solar cells at high angles of incidence.

Before the third TCM test, it was found that the calibration of the only available thermopile was seriously in doubt. This resulted in a 4-day delay while the thermopile was flown to Eppley Laboratories for recalibration. This experience emphasized the need for a planned calibration program for thermopiles, with back-up thermopiles available before each test, or on-site calibration capability.

Decollimation of the Solar Simulator Source

Before the test of the RCA subsystem thermal model, an attempt was made to evaulate the degree of decollimation of the solar simulator source. A large aperture camera was used to photograph the sun image at the top of the chamber. Measurements of shadow lines on the test fixture mentioned previously were also made. These two investigations indicated an effective decollimation half-angle of 4.7°. When the RCA subsystem was suspended in the chamber and the solar simulation lights turned on, it was found that approximately 40% of the polished aluminum skin was partially illuminated by the "sun" as can be seen in Figure 1. This furnished another check on decollimation half-angle which agreed with the value determined previously.

The results of this test were somewhat disappointing. The RCA subsystem ran approximately 40°C hotter than predicted from the mapping data. It was found that approximately 15.5% of the input energy could not be accounted for even if the absorptance of the skin was taken into account.

Before the first test of the complete TCM, the effective diameter of the RCA fins was increased by the addition of polished aluminum rings to the outside edges of the fins. These rings eliminated the impingement of solar simulation energy on the polished aluminum skin as shown in Figure 5. At the conclusion of this test, RCA was able to account for the input energy to its subsystem to within 2%, a considerable improvement over the results of the first test.

Profiting from RCA's experience on their first test, JPL installed shading strips at the top of its electronic chassis to shade the white painted fronts of these chassis. The fronts of these chassis may be seen in the illuminated condition in Figure 5 and in the shaded condition in Figure 6.

At this time there seems to be some uncertainty as to whether the extension rings should have been added to the RCA subsystem. Ranger 6 flight data indicated that the RCA subsystem ran some 20°C hotter than predicted. To date, no satisfactory correlation has been possible between the data of the first RCA subsystem test without the rings, subsequent TCM tests with the rings, and flight data. Ranger 6 flight data also showed that the JPL electronic chassis ran only a few degrees hotter in flight than had been predicted. This correlation problem is indicative of the difficulties involved in performing meaningful solar simulation tests of this configuration and meaningfully interpreting data from these tests.

Determination of Effective Absorptance in Solar Simulation Spectrum

At the time these tests were performed, no monochrometer measurements of the 25' Solar Simulator spectrum had been made. This prevented calculation of the effective absorptance of the various spacecraft surfaces in the solar simulation spectrum. Therefore, these absorptances were measured experimentally with the device shown in Figure 7. Under vacuum cold-wall conditions, the six samples and black intensity standard were allowed to come to equilibrium temperature under solar simulation. The solar simulator was then turned off and internal heaters used to duplicate the temperatures obtained in the first part of the test. Calculations were then used to determine the effective absorptance of each sample. The values obtained from these measurements are given in Table 1.

Conclusions

The objective of verifying the Ranger Block III thermal design was largely satisfied in this series of tests. In addition, valuable experience was gained in pretest preparation, instrumentation, and test data analysis. Improvements remain to be made in areas such as mapping devices, better analysis techniques, and better measurements of solar simulation spectrum and absorptances in this spectrum. Hopefully, these improvements will be made within a reasonable period of time.

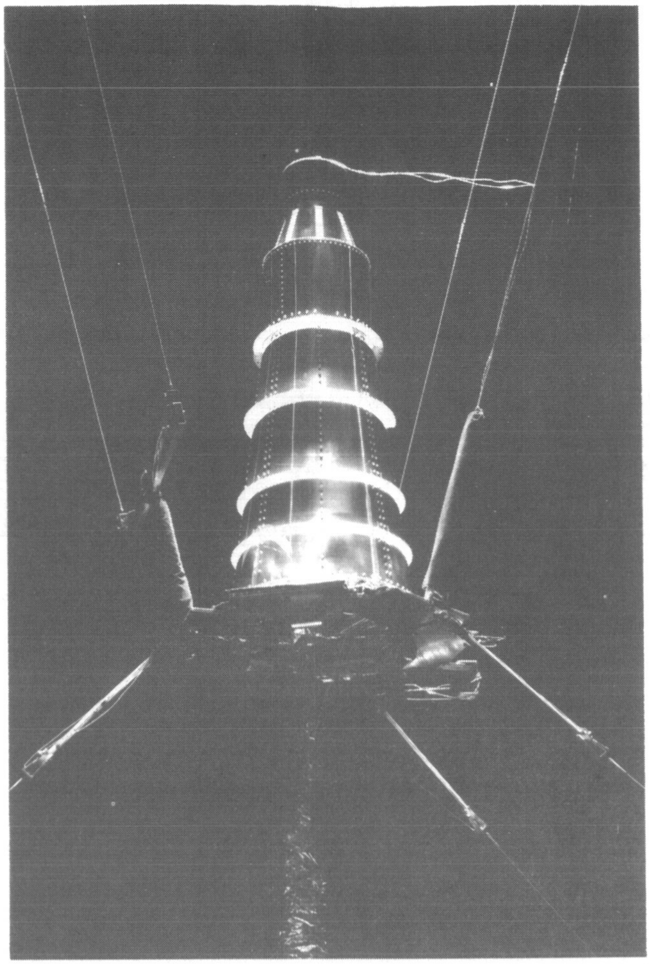

Figure 1. Thermal model of RCA subsystem suspended in JPL 25' Space Simulator for first test, January, 1963. Photograph taken with solar simulation lights on.

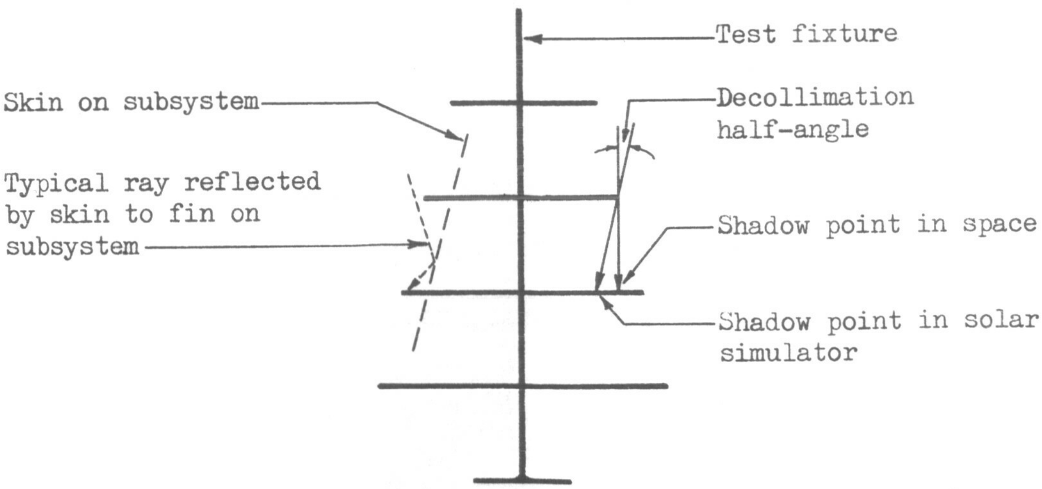

Figure 2. Test fixture used to evaluate solar simulation decollimation half-angle and amount of energy incident on RCA subsystem fins due to reflection from skin.

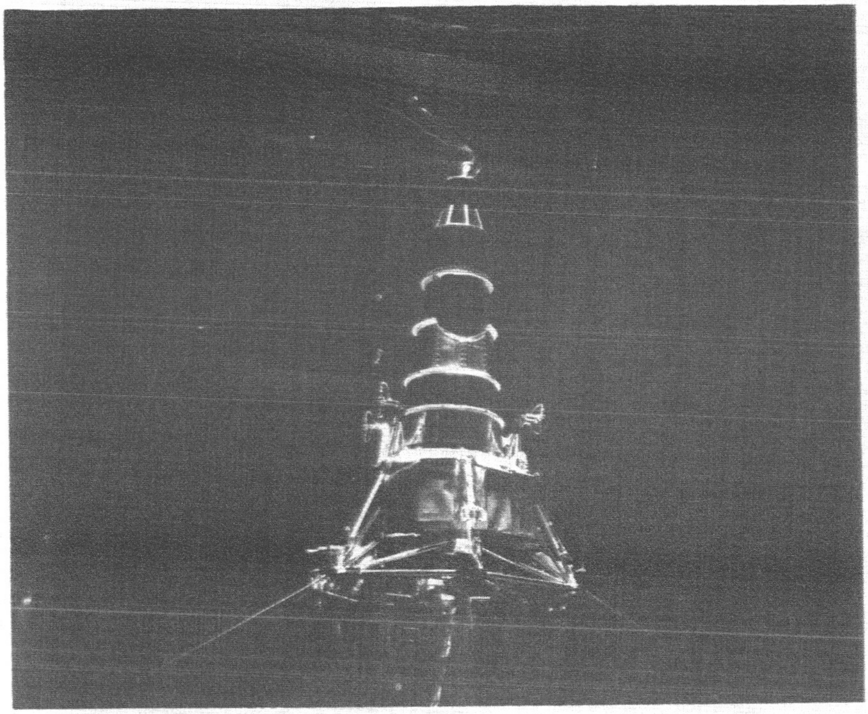

Figure 3. Ranger Block III TCM in JPL 25' Space Simulator.

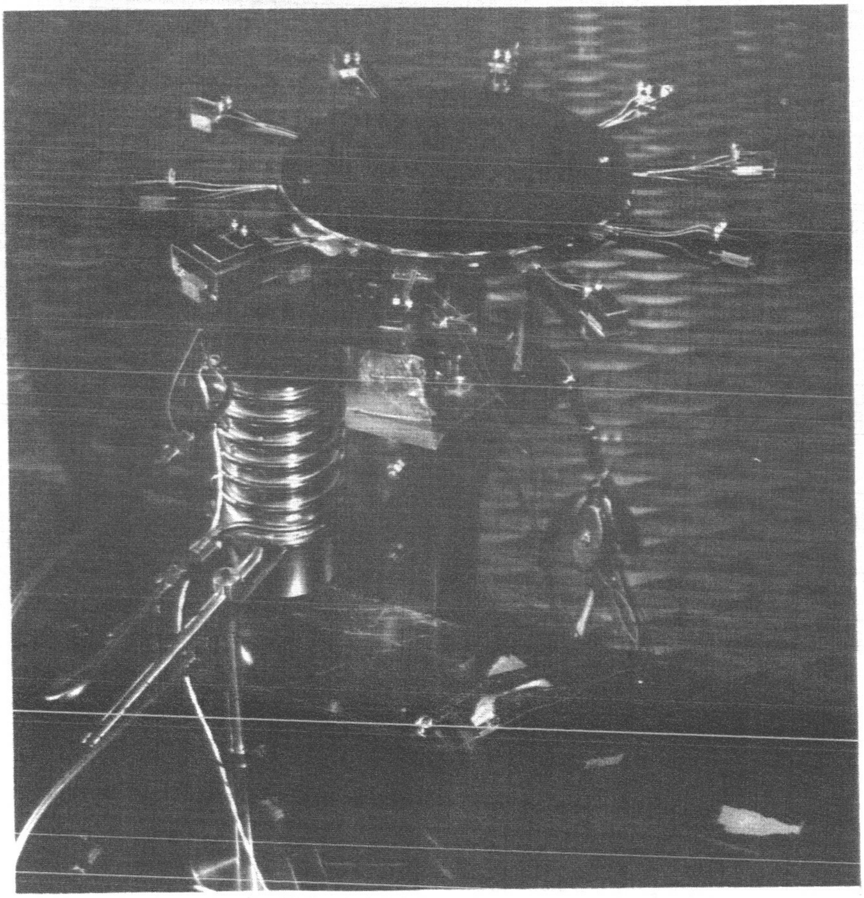

Figure 4. Apparatus used to calibrate solar cells against Eppley thermopile under vacuum conditions with solar simulation.

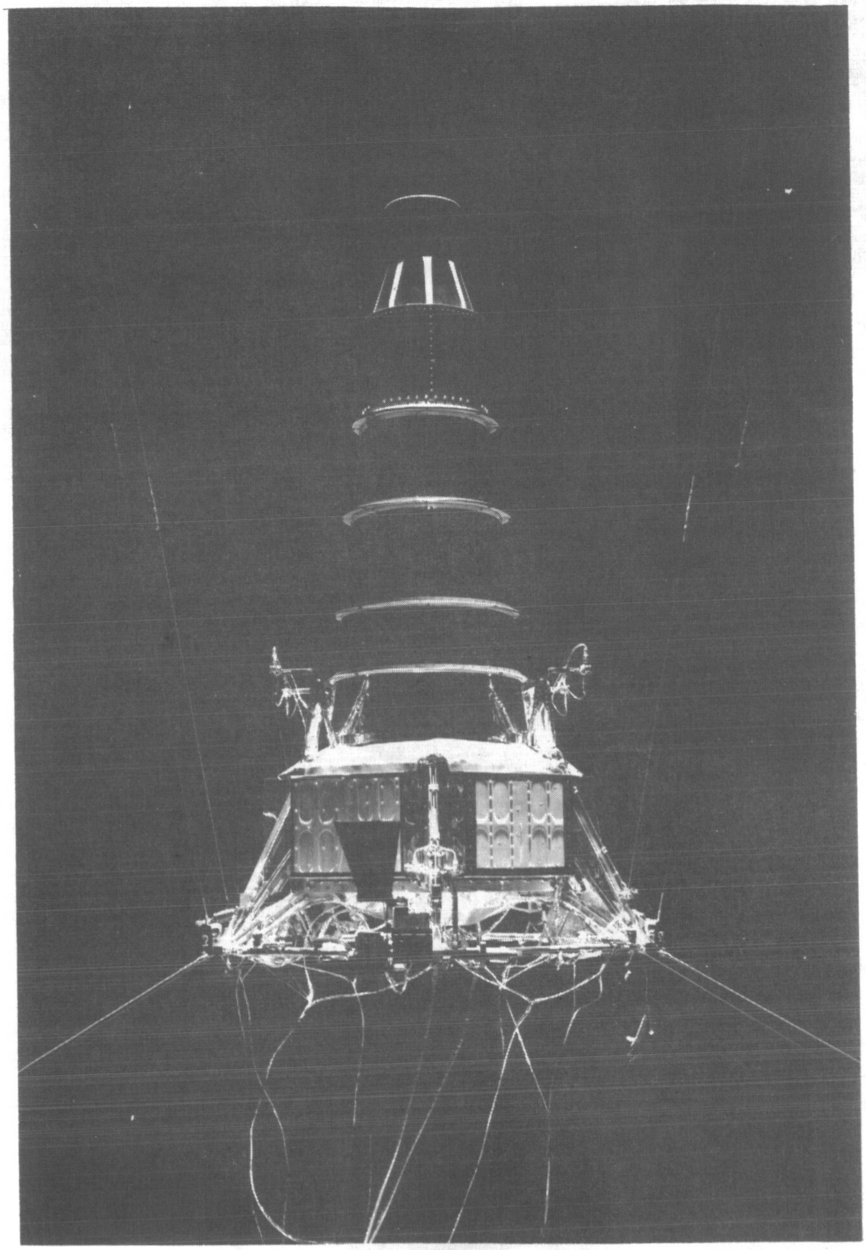

Figure 5. TCM after addition of fin extension rings on RCA subsystem but before addition of shading strips on top of JPL electronic chassis. Photograph taken with solar simulation lights turned on.

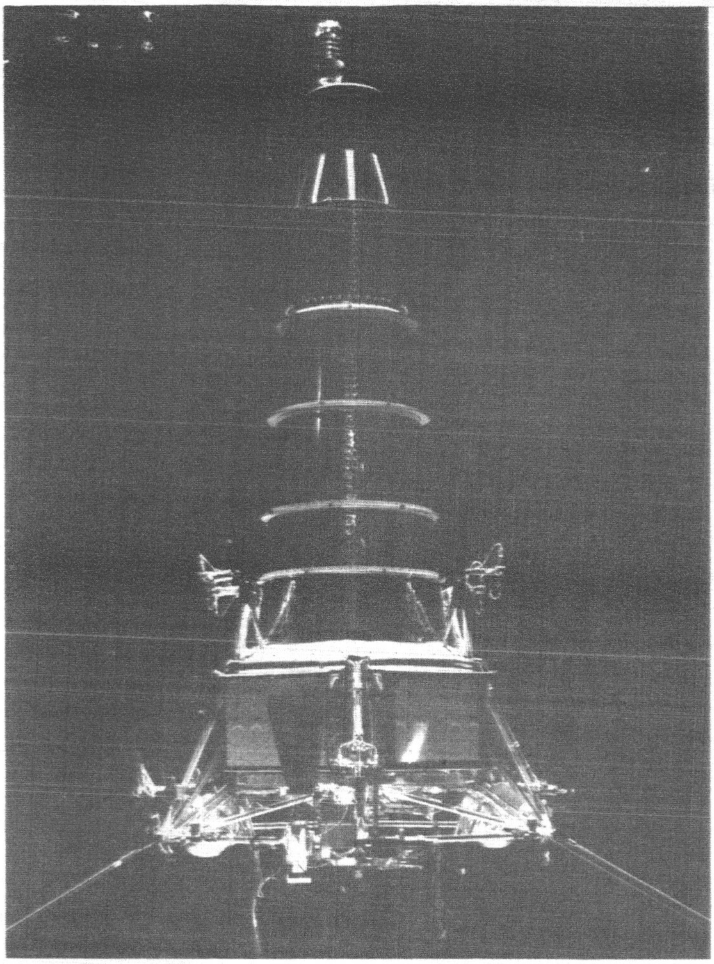

Figure 6. TCM after addition of fin extension rings on RCA subsystem and shading strips on top of JPL electronic chassis. Note thermopile mounted on top of spacecraft for intensity monitoring. Photograph taken with solar simulation lights on.

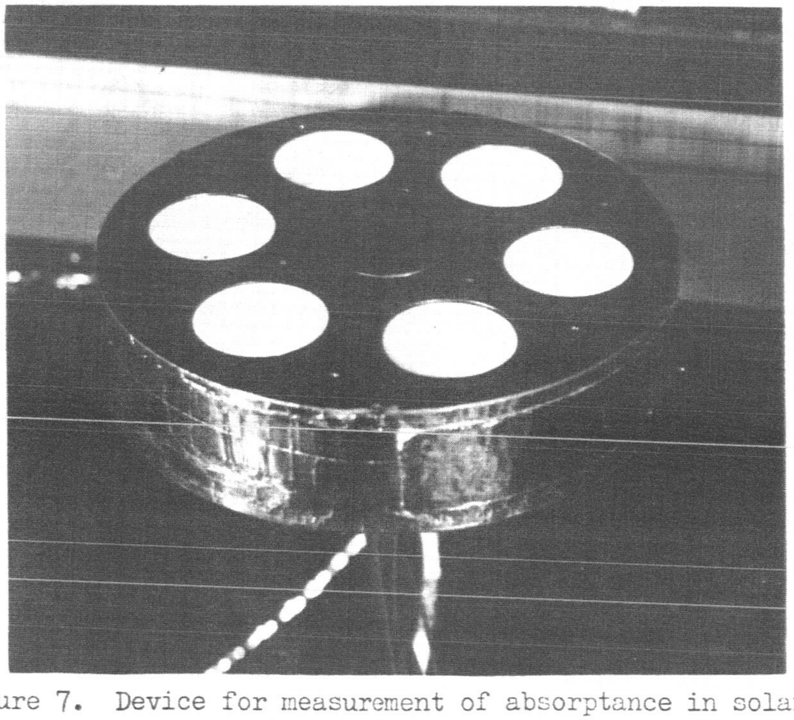

Figure 7. Device for measurement of absorptance in solar simulation spectrum. 1" diameter samples.

TABLE 1

Comparison of Measured Absorptance in 25' Space Simulator Hg-Xe Spectrum and Calculated Solar Absorptance for Several Surface Treatments

Surface	Hg-Xe	Solar	Error
Polished Aluminum	0.21	0.19	+11%
Polished Gold Plate	0.26	0.22	+20%
PV 100 White Paint	0.31	0.22	+41%
JW 40 White Paint	0.39	0.23	+70%
Cat-a-lac Black Paint	0.96	0.96	0%