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INTRODUCTION

A second surface mirror type coating, vapor deposited silver on FEP Teflon, was used as a thermal control surface for one of the experiments aboard the Imp-I spacecraft launched from ETR on March 13, 1971. This coating was selected to obtain the low operating temperature required for this experiment, the Energetic Particle Experiment from the University of California at Berkeley - Dr. K. Anderson, Principal Investigator. The spacecraft thermal design was performed at the NASA Goddard Space Flight Center. Application of the metallized teflon film was performed by Mr. Albert Busch under the supervision of Mr. Robert Sheehy both from the Engineering Applications Branch. Initial flight temperature of this thermal control surface was -70.5°C, very close to the predicted value of -73°C and at a very satisfactory level.

SPECIFIC REQUIREMENTS:

The Imp-I spacecraft achieved a nominal orbit of approximately 200 miles perigee and 128,000 miles apogee with an inclination of 28.9° and a period of 4.6 days. The altitude at perigee gradually rises for the first two years to 8700 miles and then commences to decrease. The spacecraft is spin stabilized at 5 rpm with the spin axis kept approximately normal to the solar vector by a cold gas attitude control system.

The Energetic Particle Experiment is one of thirteen experiments aboard the spacecraft. Two of the four detectors comprising this experiment have to be operated at temperatures below 0°C and -35°C respectively with preferred temperatures <-50°C. This cool environment lowers the energy threshold of the detectors as well as improving their energy resolution.

DESCRIPTION OF THERMAL DESIGN:

Since temperatures within the spacecraft interior are not at this desired low level, the detectors had to be mounted exterior to the spacecraft with a good view of space, preferably in an area shaded from sunlight. When this latter preference proved unobtainable, the detectors were mounted on an aluminum plate located on the exterior of the spacecraft, parallel to the spin axis but rotating about the solar vector. The mounting plate was approximately 6.5 inches by 7.5 inches by 0.125 inches thick. To achieve the desired temperature level with the mounting plate in such a location, the thermal design had to minimize not only the effects of the relatively warm spacecraft environment but also the effects of the incident solar energy.

To minimize spacecraft influence on the temperature of the detector mounting plate, the plate was extremely well isolated both conductively and radiatively from the body of the spacecraft. To achieve conductive isolation, four special designed mounts were developed using Delrin to avoid any metal to metal contact. The approximately 1.5 inch long thermal mounts also kept the detector plate 0.25 inches from the spacecraft skin. Tests conducted on the effectiveness of the isolation mounts indicated a conductance through the mounts <0.01 Btu/HR°F. To achieve radiative isolation, a multilayer insulation blanket was used in the 0.25 inch space between the detector plate and the spacecraft skin. The insulation blanket consisted of 10 layers of 0.25 mil mylar aluminized on both sides with an inner and outer layer of 3 mil mylar aluminized on one side. A white nylon mesh material was used between each layer of mylar to prevent conduction through the insulation layers.

To minimize the effect of the incident solar energy, a second surface mirror type coating, vapor deposited sivler on 5 mil FEP Type A Teflon was used on the detector mounting plate. FEP Teflon is a relatively non-absorbing plastic film throughout the solar wavelength region and its absorptance depends strongly on the metal used as the backing. The size of the infrared absorption bands, which determine the magnitude of emittance, are strongly thickness dependent with the result that emittance can be controlled by varying the Teflon thickness. For silver backing, the absorptance to emittance ratio, α/ϵ, reaches a minimum value of approximately 0.1 when the Teflon is about 5 mils thick. The absolute values of absorptance and emittance are 0.08 and 0.82 respectively for this thickness coating.

QUALIFICATION TESTS:

This coating has been shown in laboratory tests to have high resistance to damage from ultraviolet irradiation and moderate stability to charged particle exposure which indicates that it is a good coating for near earth orbits and a fair coating for use in radiation belts or solar wind orbits.

Much laboratory investigation was performed to determine the optimum method of applying this coating for good adherence over the temperature range of -150°C to +50°C. The extreme cold temperature is significant because of the temperature decay experienced while the spacecraft is in the earth's shadow. The adhesive that has given the most satisfactory performance in laboratory tests over this temperature range is the pressure sensitive double sided adhesive tape (e.g. Mystik #7366). Inconel is vapor deposited over the silver backing to protect this film from possible degradation by the adhesive. The flight detector plate with the silver coated Teflon coating was tested under vacuum at temperatures of -150°C and +30°C without any detrimental effects.

FLIGHT DATA:

The predicted initial temperature for these detectors was -73°C and the initial flight temperature was -70.5°C corresponding to an absorptance of approximately 0.09. Flight temperatures are monitored both on the detector plate and inside the spacecraft near where the plate is mounted. Knowing these two temperatures, the physical parameters of the detector plate, and the heat transfer coefficient between the detector plate and the spacecraft, an energy balance can be established about the detector plate yielding the unknown parameter, the absorptance of the silver coated teflon.

$$\alpha_{sp} = \frac{K_{p\text{-}s}\ (T_p - T_s) + \sigma A_{T_p}\ \epsilon_p T_p{}^4}{SA_{P_p}}$$

where α_{sp} = absorptance of the silver coated Teflon on the detector plate

$K_{p\text{-}s}$ = heat transfer coefficient between detector plate and spacecraft

T_p = temperature of detector plate

T_s = temperature of spacecraft near where the plate is mounted

σ = Stefan–Boltzmann constant

A_{T_p} = total surface area of detector plate

ϵ_p = emittance of the silver coated Teflon on the detector plate

S = solar constant

A_{P_p} = projected area to sunlight of the detector plate

After 9 months in orbit, the temperature of the detector plate gradually rose from -70.5°C to -54°C corresponding to an increase in solar absorptance of the silver teflon of 0.077. It remained steady at this value for another 7 months at which time data keeping was ceased. In late October, 1972 the spacecraft passed through an apogee shadow of almost 6 hours duration. When data was observed after this event, it was seen that there was a sudden increase in detector plate temperature to -50°C with a continual rise thereafter. The flight data is shown in Figure 1.

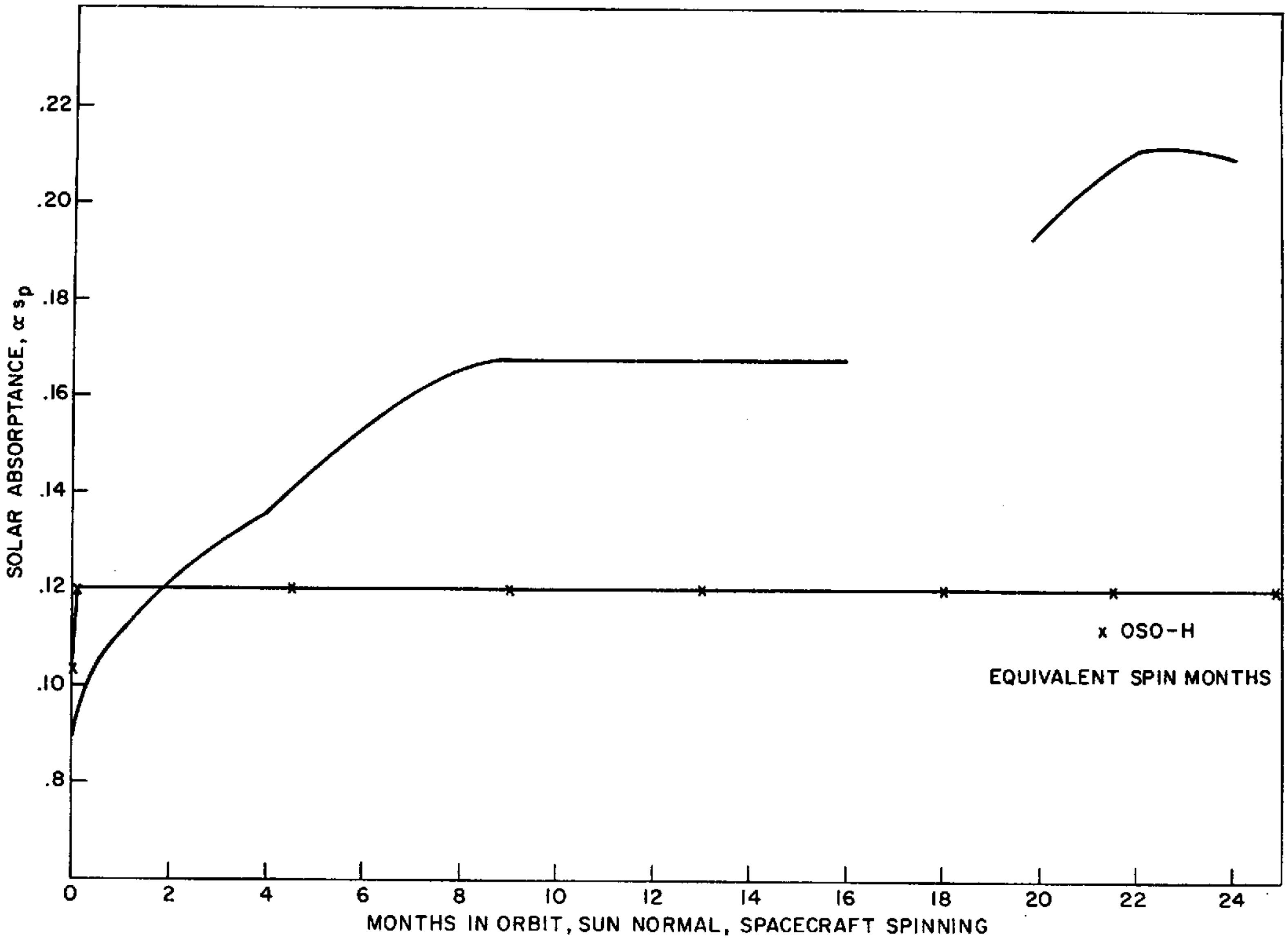
SOLAR ABSORPTANCE, α_{sp}
.22
.20
.18
.16
.14
.12
.10
.8
0
2
4
6
8
10
12
14
16
18
20
22
24
MONTHS IN ORBIT, SUN NORMAL, SPACECRAFT SPINNING
x OSO-H
EQUIVALENT SPIN MONTHS

Figure 1

The temperature of the detector plate after a 6 hour shadow was predicted to exceed the lowest temperature at which the coating on the plate was tested (-150° C). It is possible that the cold temperature experienced during this long shadow could have caused some separation of the teflon from the plate. This separation between the two surfaces would result in a warmer temperature on the detector plate.

The degradation experienced by the silver teflon is considered to be the result of solar wind and high energy proton irradiation rather than by solar ultraviolet irradiation. Estimated fluences to date according to enery are:

Solar Wind (0.1 MeV) 3×10^{15}

Electrons, all energies 10^{14}

Protons (0.1 MeV $\leq$ E $\leq$ 5 Mev) 3×10^{14}

Protons (4 MeV $\leq$ E $\leq$ 50 MeV) 3×10^{12}

Protons (50 MeV $<$ E) 3×10^{10}

Flight experience on OGO-6 and OSO-H (as shown in Figure 1) indicates no degradation of silver teflon due to ultraviolet irradiation only since both spacecraft are in near earth orbits and are not subject to charged particle irradiation. The initial offset on the OSO-H data is due to calibration error.

CONCLUSION

It was demonstrated that a spacecraft component exposed to solar illumination can be thermally designed to operate at a very cold temperature thereby affording good experimental data. In addition the information obtained on the behavior of vapor deposited silver on teflon in this type orbit was a significant contribution to the further use of this type of thermal control coating.