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LDEF THERMAL CONTROL COATINGS POST-FLIGHT ANALYSIS

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EXTENDED ABSTRACT

The NASA Long Duration Exposure Facility (LDEF) provided a unique flight opportunity for conducting experiments in space and return of these experiments to Earth for laboratory evaluation (1). This paper reports the results of one of these experiments, S0010, Exposure of Spacecraft Coatings, in which selected spacecraft thermal control coatings were exposed to the low-Earth orbital (LEO) environment on LDEF.

Figure 1 is a preflight photograph of the LDEF tray which housed this and another experiment. This experiment was located in Tray B on Row 9, which was the leading edge of LDEF. A compilation of the Row 9 exposure conditions for the 5-year 9-month orbital lifetime of LDEF is summarized in Table I. The canister shown open on the left side figure 1 was opened for 10 months, early in the LDEF mission. This allowed flight data to be obtained for 10-month and 5-year 9-month exposures on the selected coating specimens. The objective of this experiment is to evaluate the response of thermal control coatings to LEO exposure, which includes atomic oxygen, ultraviolet and particulate radiation, meteoroid and debris, vacuum, and temperature cycling.

Table II lists the coatings in this experiment, and Table III presents the solar absorptance and total normal emittance of a selected group of these coatings for preflight, 10-month exposure, and the full 5-year 9-month exposure. The mass loss data for the 10-month exposure of these coatings is presented in Table IV. Typical thicknesses of the optical solar reflectors (OSR), metallized FEP Teflon, and the paint coatings ranged from 1.3 x 10^{-2} cm to 2 x 10^{-2} cm. The anodized and sputtered coatings were much thinner, ranging from 3 x 10^{-4} cm to 3 x 10^{-3} cm for the anodized to 1 x 10^{-5} cm to 2.5 x 10^{-5} cm for the sputtered multi-layered coatings.

X-ray Photoelectron Spectroscopy (XPS) and Energy Dispersive X-ray (EDS) studies of these coatings indicate that a silicone molecular contamination film was deposited on the specimens during LDEF flight. Such contamination films were also identified in other experiments on LDEF (2-5). Since these silicones are typically converted to a silicate when exposed to atomic oxygen (6), they are not easily removed from the surface of coatings. This contamination may influence the mass loss and optical property data generated by this experiment.

These results show that the chromic acid anodized aluminum and the YB-71 (zinc orthotitinate/ potassium silicate) white paint have extremely stable optical properties when exposed in the LEO environment. Similar results were found in references 7 and 8. The silvered FEP Teflon retained its initial solar absorptance after 5.8 years of exposure, although the surface roughness increased and the FEP Teflon thickness decreased by 0.0011 inches. In the case of the S-13GLO (treated zinc oxide/silicone), exposure to air (oxygen) after UV exposure is known to "bleach" the reflectance degradation caused by the UV exposure. It is therefore surprising that the S-13GLO exhibited a 25-percent increase in solar absorptance in this study and in reference 9, although subjected to atomic oxygen in space and oxygen from air upon return to Earth.

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TABLE 1. EXPOSURE CONDITIONS FOR TRAY B ON ROW 9

- Atomic oxygen
  8.99×10^{21} atoms/cm^2
- UV radiation
  100-400 nm; 11,000 hrs
- Particulate radiation
  e^- and p^+: 2.5×10^5 rad surface fluence
  Cosmic: <10 rads
- Micrometeoroid and debris
  734 impact craters <0.5 mm
  74 impact craters >0.5 mm
- Vacuum
  1.33×10^{-4} - 1.33 x 10-5 N/m^2 (10^{-6} - 10^{-7} torr)
- Thermal cycles
  ~34,000 cycles: -29 to 71°C, ±11°
  (-20 to 160°F, ±20°)
- Altitude
  4.72×10^5 - 3.33×10^5 m (255-180 nautical miles)
- Orbital inclination
  28.5°

TABLE II. THERMAL CONTROL COATINGS IN EXPERIMENT S0010.

TYPE	COMPOSITION	SUBSTRATE
Second-surface mirrors	Quartz/Ag Quartz/Al FEP Teflon/Ag FEP Teflon/Al	Al Al Al Al
Black paints	Chemglaze, Z-306	Al
White paints	Zinc oxide-silicone, S-13GLO Zinc orthotitinate-silicate, YB-71 Chemglaze, A-276	Al Al Al
Anodized	Chromic acid, high emissivity Chromic acid, medium emissivity Chromic acid, low emissivity	Al Al Al
Sputtered	Al Al/Ni SiO_2/Ni SiO_2/Al/Ni SiO_2/Cr	Graphite-epoxy Graphite-epoxy Graphite-epoxy Graphite-epoxy Graphite-epoxy

TABLE III. OPTICAL PROPERTY CHANGES OF COATINGS EXPOSED IN EXPERIMENT S0010 ON LDEF.

Coating	Preflight		10 Months Exposure		5.8 Years Exposure	
	α_S	ε_{TN}	α_S	ε_{TN}	α_S	ε_{TN}
Thin Anodized AL	.295	0.16	.299	0.17	---	---
	.288	0.18	---	---	.296	0.19
Mid-Range Anodized AL	.292	0.43	.287	0.43	---	---
	.306	0.45	---	---	.311	0.46
Thick Anodized AL	.330	0.71	.337	0.71	---	---
	.341	0.75	---	---	.354	0.74
A276 White Paint	.229	0.89	.237	0.90	---	---
	.243	0.91	---	---	.259	0.88
S-13GLO White Paint	.158	0.90	.182	0.89	---	---
	.163	0.90	---	---	.206	0.89
YB-71 White Paint	.121	0.91	.123	0.91	---	---
	.128	0.90	---	---	.125	0.90
Z-306 Black Paint	.926	0.91	.911	0.91	---	---
	.922	0.92	---	---	.902	0.91
Silvered FEP Teflon	.069	0.80	.068	0.80	---	---
	.070	0.80	---	---	.073	0.78

TABLE IV. MASS LOSS OF COATINGS IN LDEF EXPERIMENT S0010

Test Material Description	Mass Loss/cm^2 AO Fluence$^{(a)}$
1. Quartz/Aluminum 0SR	0 x 10^{-20}
2. Quartz/Silver OSR	.01
3. 1034C/N:/SiO_2	.05
4. 1034C/N:/AL/SiO_2	.06
5. YB-71 on Aluminum	.15
6. S-13GLO on Aluminum	.19
7. A276 on Aluminum	.23
8. Z306 on Aluminum	.26

(a) Fluence = 2.6 x 10^{20} atoms/cm^2

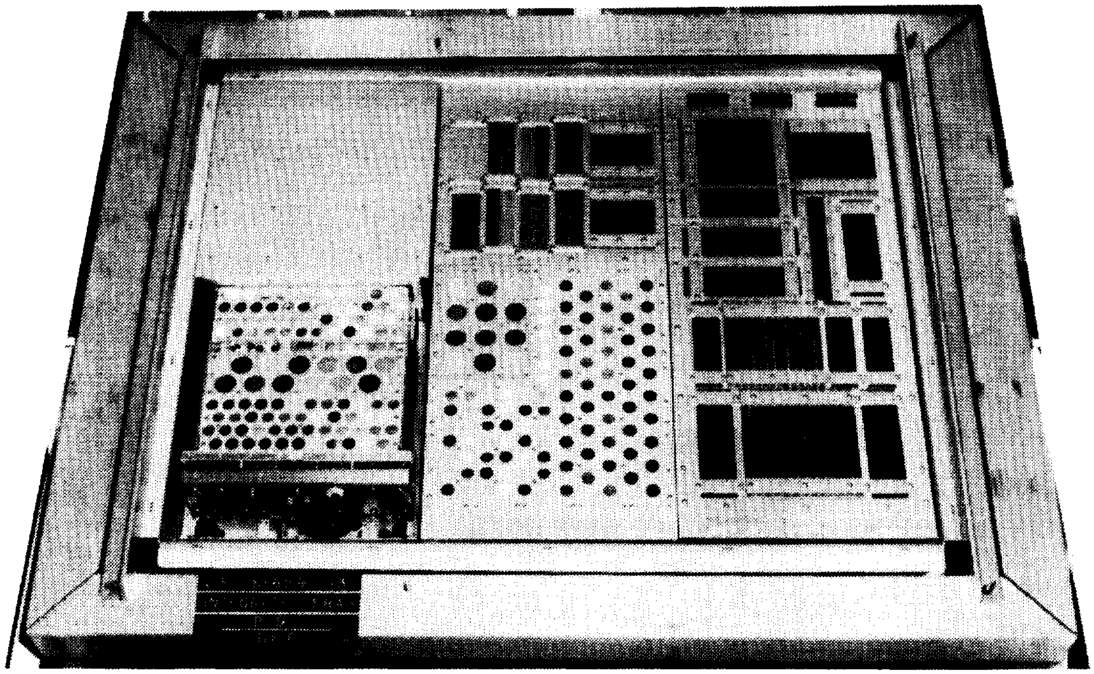

Figure 1. Langley materials exposure experiments in LDEF Tray B on Row 9.