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FLUORESCENCE OF THERMAL CONTROL COATINGS ON S0069 AND A0114

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INTRODUCTION

Many of the thermal control surfaces exposed to the space environment during the 5.8 year LDEF mission experienced changes in fluorescence. All of the thermal control coatings flown on LDEF experiments S0069 and A0114 were characterized for fluorescence under ambient conditions. Some of the black coatings, having protective overcoats, appear bright yellow under ultraviolet exposure. Urethane based coatings exhibited emission spectra shifts toward longer wavelengths in the visible range. Zinc oxide pigment based coatings experienced a quenching of fluorescence, while zinc orthotitanate pigment based and other ceramic type coatings had no measurable fluorescence.

CATEGORIES OR TYPES OF FLUORESCENCE EFFECTS OBSERVED

The specific fluorescence effects observed on the experiments can be divided into three categories as outlined in figure 1. Urethane binder type coatings including the black Z302 and the white A276 experienced similar shifts of fluorescence from the near ultraviolet toward the visible range. Zinc oxide pigmented coatings, using either the silicone or silicate binders, demonstrated the same quenching of original (pre-flight) fluorescence. Silver Teflon did not originally fluoresce, but now shows a weak, but measurable, fluorescence in the visible.

- URETHANE BINDER TYPE COATINGS
  - ►BLACK COATINGS
  - ►WHITE COATINGS
- ZINC OXIDE PIGMENTED COATINGS
  - ►SILICONE & SILICATE TYPE BINDERS
  - ►WHITE COATINGS
- SILVER TEFLON COATINGS
  - ►ACRYLIC ADHESIVE EFFECT

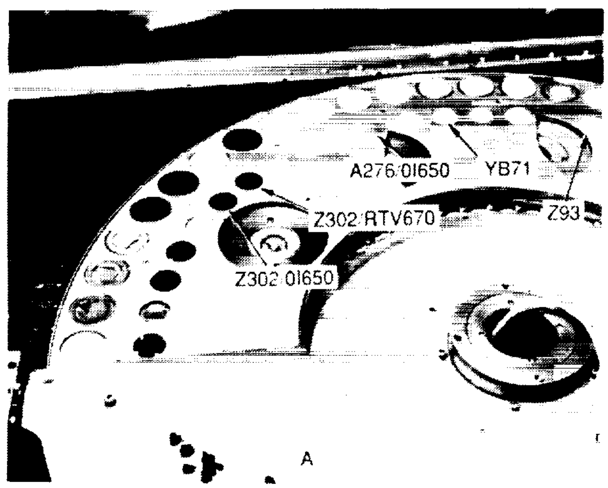
Figure 1. Three Categories of Fluorescence Effects Observed.

Note: Teflon is a trademark of Dupont.

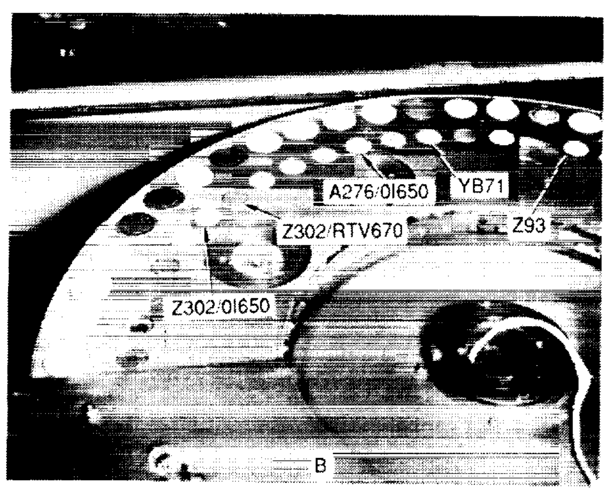
PHOTOGRAPH OF THE VISUAL FLUORESCENCE OF S0069 SAMPLES

A pronounced visual demonstration of the post-flight fluorescence glow of the urethane type paints with protective atomic oxygen overcoats is provided in figure 2. Photographs were made using either white or ultraviolet lighting. Black Z302/OI650, under ultraviolet lighting, shows a bright visible yellow fluorescence. Even the white A276/OI650 shows a bright yellow fluorescence under ultraviolet lighting. The other samples lack sufficiently pronounced visible fluorescence for normal photographic observation.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



White Light



Ultraviolet Light

Figure 2. Fluorescence of Thermal Control Coatings Comparison of Samples Under White and Ultraviolet Light.

MEASUREMENT SETUP

Spectral measurements of the fluorescence of the samples from both the S0069 and A0114 were made using the instrumentation setup shown in figure 3. Monochromatic irradiation of the samples was provided using a mercury/xenon high pressure discharge source and attached prism monochromator. An excitation wavelength centered at 280 nm was used for all measurements described in this paper. All measurements utilized a test control sample of MgO to setup and verify consistent system response. In addition, sample controls were run for comparison.

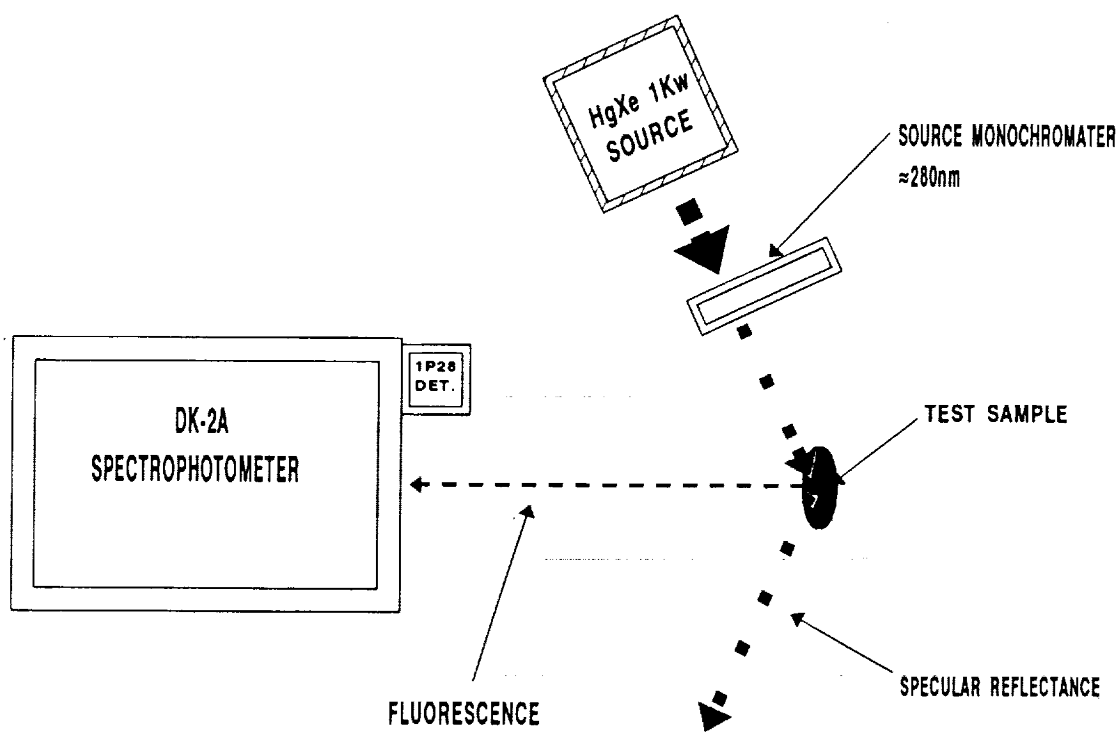


Figure 3. Schematic of Fluorescence Measurement.

FLUORESCENCE SPECTRA OF Z302

A typical example of the measured spectral fluorescence of the black Z302 samples is provided in figure 4. At about 280nm the scattered signal of the incident excitation light is recorded. An increase in the 280nm data indicates an increase in scatter or a decrease in absorptance, whereas a decrease could be attributed to an increase in the absorptance of the coating in the wavelength region. Since the unprotected Z302 is eroded by atomic oxygen, this increase over the ground control is most likely caused by a surface roughening. Note, this sample was exposed for only the 1.6 years and was still black. The Z302 sample exposed for the full 5.8 years was eroded down to the base primer, as can be seen in figure 2 (fourth sample from left, on outer row). The ground control sample shows a weak but measurable signal in the 400 to 500 nm wavelength range. In comparison the flight sample shows a shift of fluorescence into the visible region.

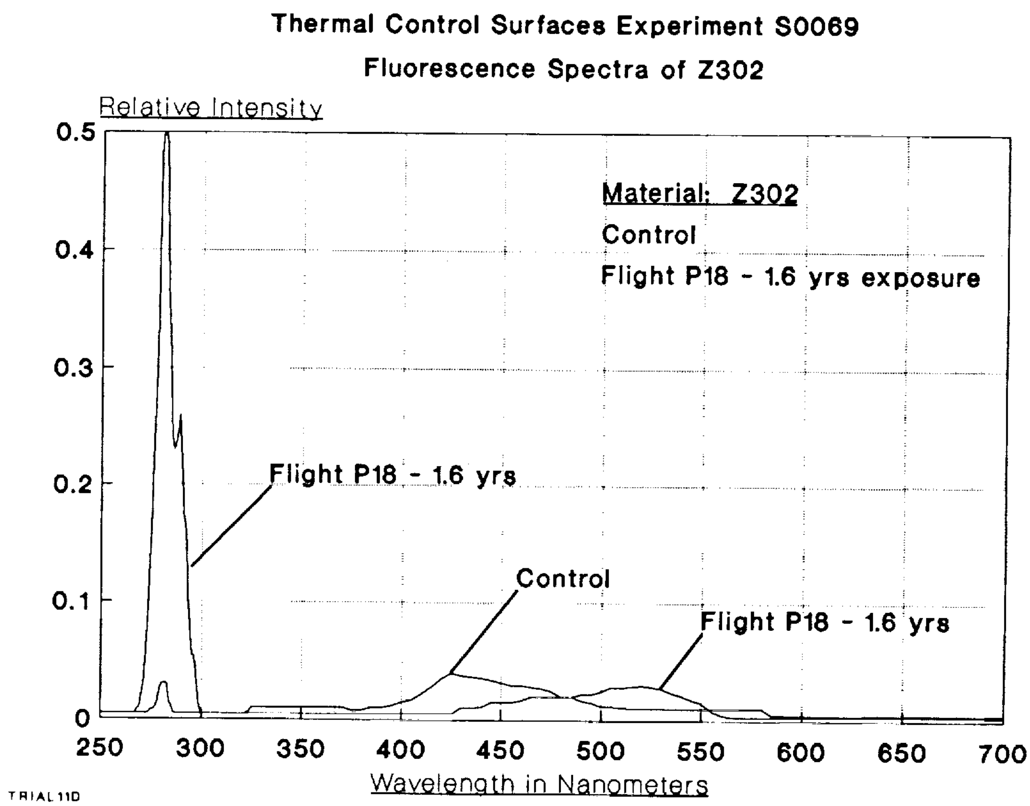


Figure 4. Fluorescence Spectra of Z302.

FLUORESCENCE SPECTRA OF Z302 WITH OI650 OVERCOAT

The brightest visual fluorescence was observed for the OI650 overcoated urethane based paint samples, as was shown in Figure 2. An example of the measured emission spectra is provided by the scan in Figure 5. It is interesting to note that the fluorescence of the Z302 and the OI650 are relatively distinct for the stored control sample; whereas, after flight exposure this distinction is not obvious. As compared to the Z302 sample, the Z302/OI650 emission shifts toward the visible region, but is considerably stronger. Although the data is not corrected for variations in instrumentation spectral response, the relative response between different scans at the same wavelength are comparable. A reference control was utilized to calibrate and maintain consistent total system response.

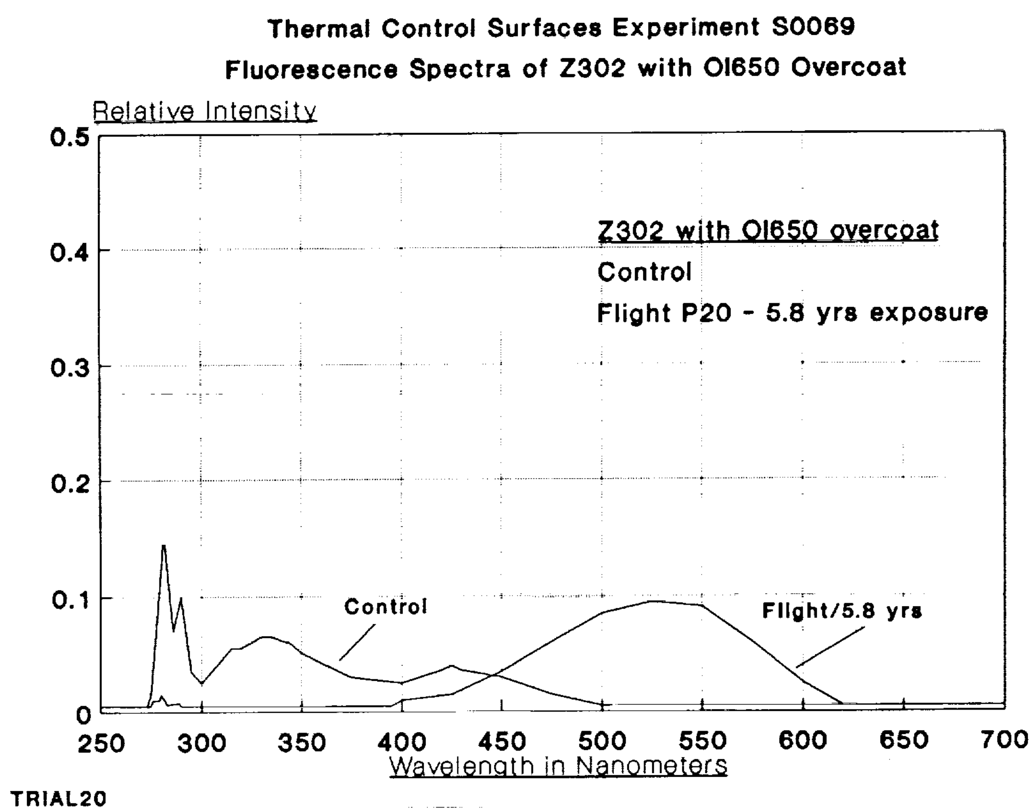
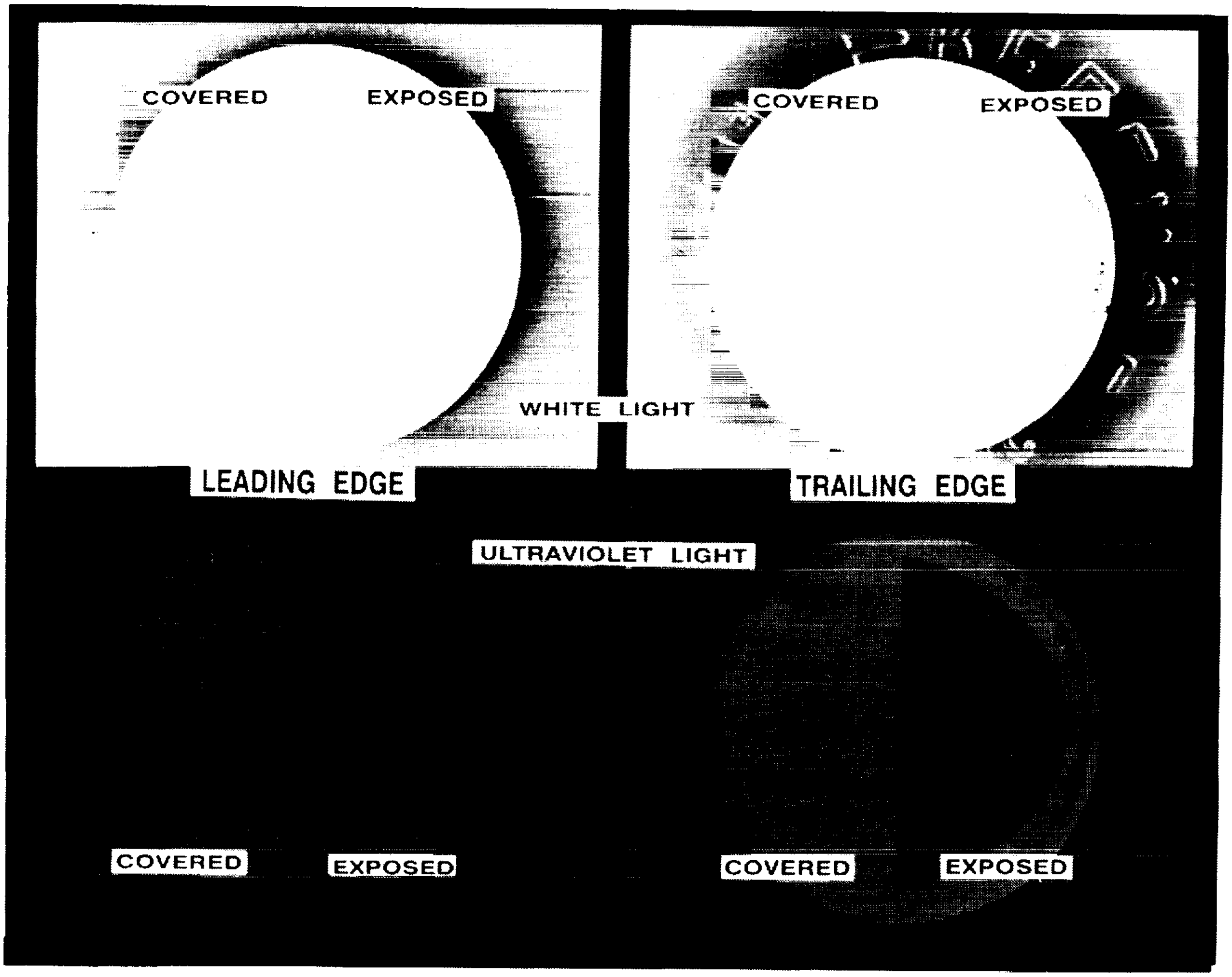


Figure 5. Fluorescence Spectra of Z302 with OI650 Overcoat.

Z93 WHITE PAINT VISIBLE FLUORESCENCE EFFECT

Photographs of Z93 samples from experiment A0114, under both visible and ultraviolet light (Figure 6), clearly show the quenching or reduction of the observed fluorescence emissions. These samples had covers that exposed only half of the surface. In white light, the exposed area is difficult to discern, whereas under the ultraviolet light it becomes very clear which area was exposed. Also note that the ram or leading edge sample and trailing edge sample experienced the same quenching of fluorescence. Comparison of the exposed to covered sample areas provides a good visible demonstration of the reflectance stability of this material to the low earth orbit space environment for extended periods.



White Light and Fluorescence of Z93
Samples from Experiment A0114

Figure 6. White Light and Ultraviolet Light Photographs of Z93.

FLUORESCENCE SPECTRA OF Z93 WHITE PAINT

Significant quenching of the fluorescence of the Z93 white paint occurred within the first 1.6 years of on-orbit exposure. Additional quenching occurred with continued exposure as shown in the fluorescence spectra in Figure 7. S13G/LO also showed a similar quenching of fluorescence. Both of these coatings are based on a ZnO pigment, but have different binders. Z93 has a silicate binder, whereas S13G/LO utilizes a silicone binder. Previous work reported by Zerlaut and Harada at IITRI (ref. 1) observed a decrease of fluorescence in the zinc oxide material after ultraviolet irradiation in vacuum. The original fluorescence was attributed to "interstitial zinc atoms or other crystal imperfections," with the decrease attributed to a "stabilization or approach of stoichiometry" after ultraviolet irradiation exposure.

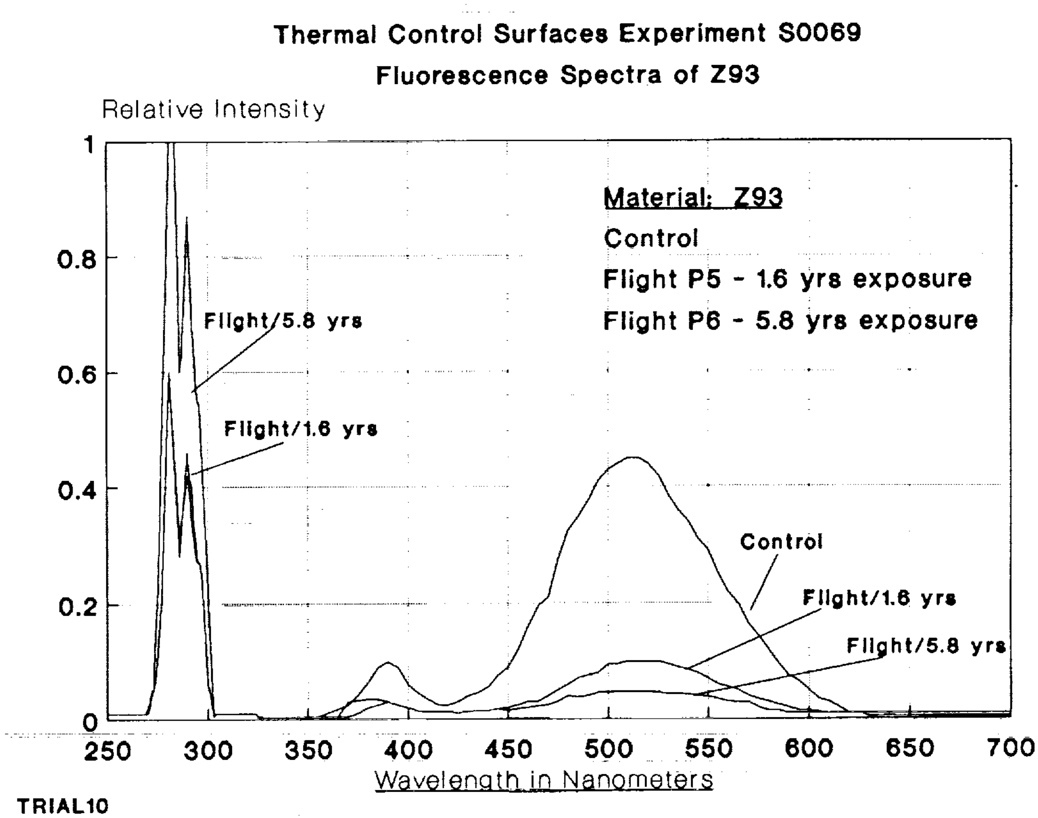


Figure 7. Fluorescence Spectra of Z93.

SILVER TEFLON SURFACE ON S0069 DURING ON-ORBIT RECOVERY

The first images returned of the front surface of experiment S0069 were similar to the on-orbit photograph shown in Figure 8. Originally the silver Teflon had the normal, specular mirror-like surface, but, as seen in the photograph, it has turned a diffuse whitish color with brown streaks. As reported previously, these brown streaks are caused by cracks in the silver/inconel layer which permits the adhesive (or components) to migrate between the Teflon/silver interface. After exposure to the space environment, mainly solar ultraviolet irradiation, the adhesive degrades to the observed brownish color. Note that the silver Teflon covered by the side panels still has the original mirror-like specular appearance.

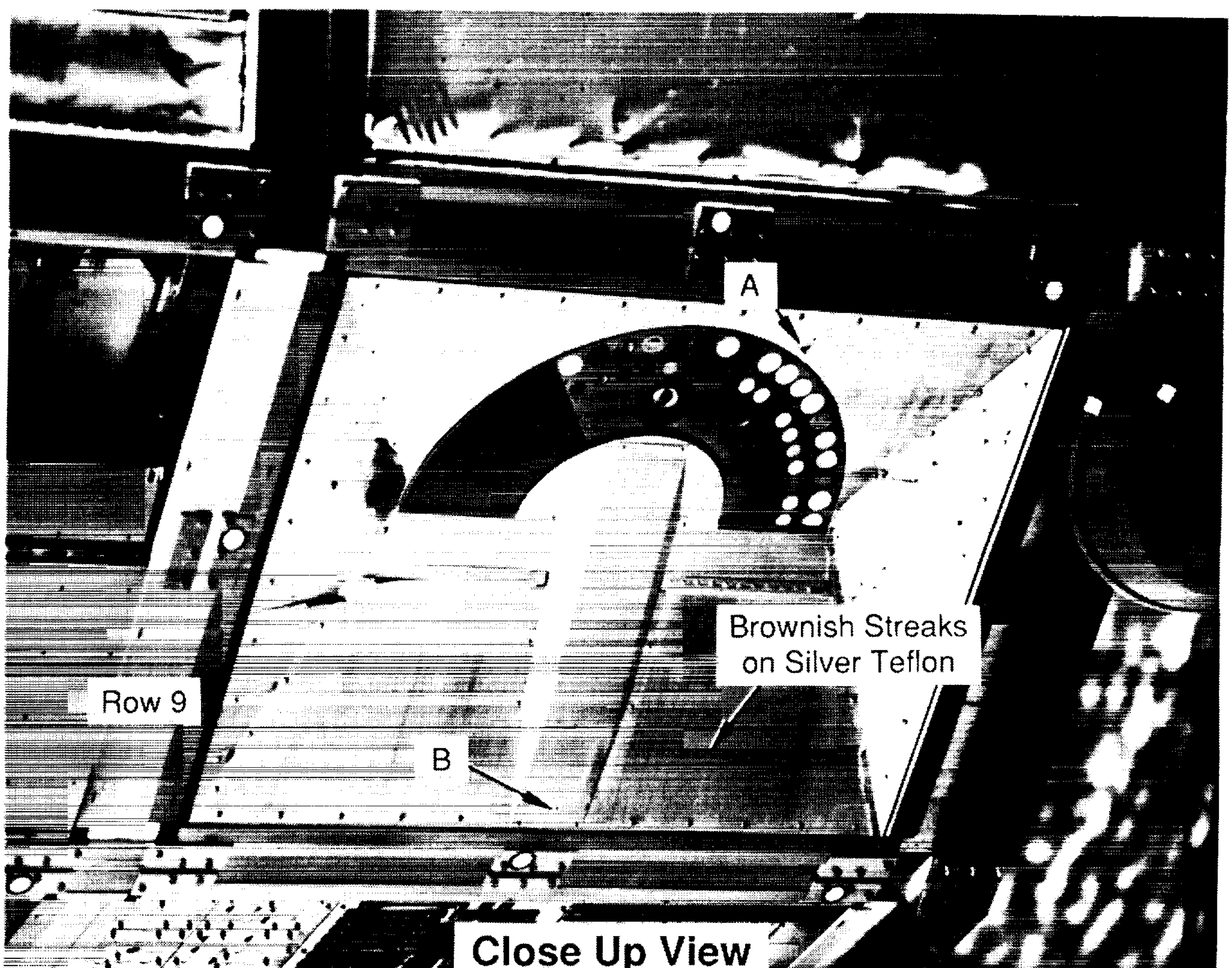


Figure 8. Close Up View of S0069 During Recovery.

FLUORESCENCE OF SILVER TEFLON SURFACE ON S0069

Several samples were cut from the front cover of S0069 in Figure 8 to determine if fluorescence could be detected. As can be seen in Figure 9, a weak but measurable fluorescence was obtained. This fluorescence is considerably less than the scattered light level, so that it cannot be detected during normal visual inspection with an ultraviolet light.

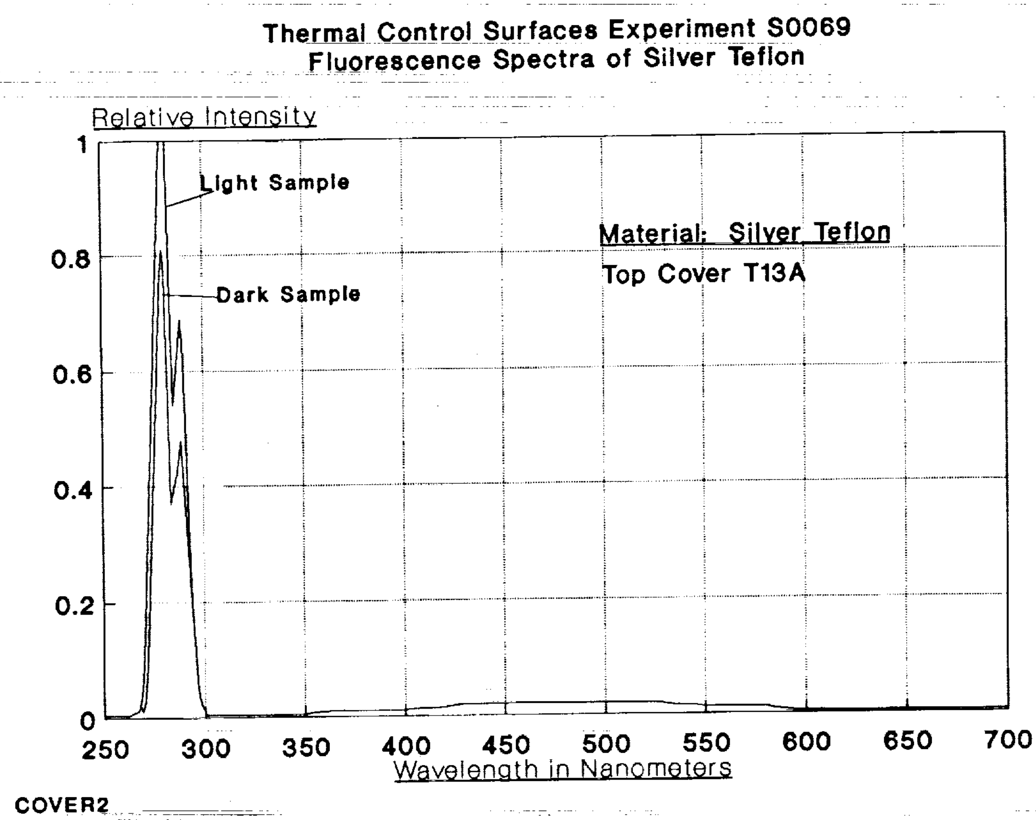


Figure 9. Fluorescence Spectra of Silver Teflon on S0069 After Recovery.

FLUORESCENCE OF SILVER TEFLON ADHESIVE 3M(966)

Samples of the acrylic adhesive used to bond silver Teflon to the S0069 front cover were exposed to simulated solar ultraviolet radiation for various times. These samples, including a control, were measured to see if they fluoresced and to determine the change, if any, from irradiation exposure. As can be seen from the data in Figure 10, not only did the original adhesive fluoresce, but after irradiation the emission shifts to the visual region, similar to what was observed on the flight material. As can be seen by comparing the emission spectra of Figures 9 and 10, the fluorescence of the ground sample is considerably stronger than the flight silver Teflon material. This can be attributed to several factors: the adhesive on the ground samples is totally exposed, while the flight samples have only very little surface area of the adhesive exposed along the silver/inconel cracks. In addition, the ground samples have only been exposed in air (no long term vacuum exposure) and were not covered with Teflon which could attenuate the signal. Further testing is under way to more accurately simulate the flight conditions.

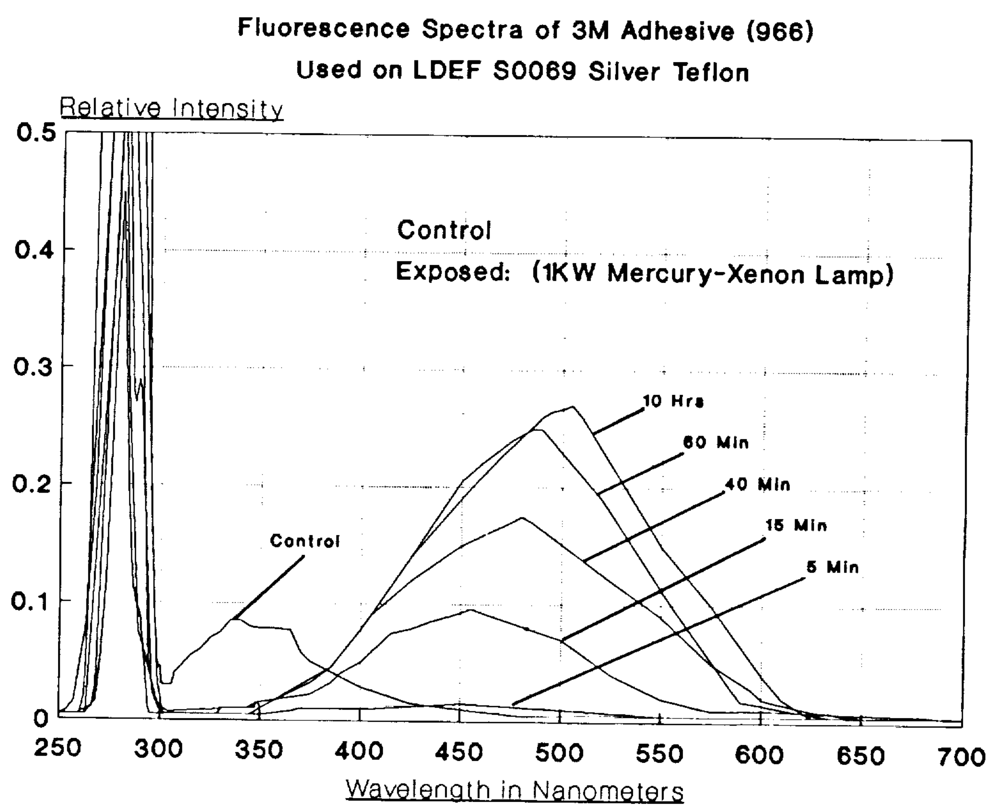


Figure 10. Fluorescence Spectra of 3M Adhesive (966) Used to Attach Silver Teflon to S0069 Front Cover.

SUMMARY OF FINDINGS

Fluorescence was detected on all thermal control surfaces flown and exposed to the space environment on S0069 and A0114 except the white Tedlar* and black ceramic paint D111 samples. In some cases the fluorescence was extremely weak as for the YB71 ceramic white paint using a zinc orthotitanate pigment. In other cases, the fluorescence was very striking, changing to the bright yellow emission under ultraviolet lighting. This change is similar to that shown by the black urethane, silicone overcoated Z302 samples.

The overall change in fluorescence emission characteristics can be classified into three types. Urethane based paints showed a shift in fluorescence from the near ultraviolet region toward the visible, while the zinc oxide pigment based paints exhibit a quenching of their fluorescence emission. In contrast, the silver Teflon material which does not itself show any measurable fluorescence, does exhibit a measurable fluorescence after recovery from the LDEF mission. This appears to be caused by the acrylic adhesive in the silver/inconel cracks.

Studies to fully document the fluorescence observed on experiments S0069 and A0114 are continuing, and will be reported in future papers.

* Tedlar is a trademark of Dupont.

REFERENCE

1. Zerlaut, Gene A. and Harada, Y: *Stable White Coatings,* Subcontract under NAS7-100, contract 950111, Interim Report No. IITRI-C207-27, January 9, 1964.