

FOLLOW-UP ON THE EFFECTS OF THE SPACE ENVIRONMENT
ON UHCRE THERMAL BLANKETS

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SUMMARY

An overview of the effects of the space environment on the thermal blanket of the UHCRE experiment is presented with an emphasis on atomic oxygen (AO) erosion.

A more accurate value for FEP Teflon™ reaction efficiency is given and corresponds, at normal incidence, to $3.24 \cdot 10^{-25} \text{ cm}^3/\text{atom}$, therefore, the FEP Teflon™ erosion corresponding to the Long Duration Exposure Facility (LDEF) total mission is $29.5 \mu\text{m}$. A power 1.44 of the cosine of the incident angle of the oxygen atoms is found. It is shown that this value is not far from the power found using Fergusson's relationship between efficiency and energy of the O-atoms.

An hypothesis concerning the effect of oxygen ions (O^+) is also presented. The presence of oxygen ions may explain the different results obtained from different flights and from laboratory tests.

Finally an XPS analysis of Chemglaze Z306™ black paint demonstrates the presence of silicone in the paint which may explain part of the contamination found on LDEF.

FEP TEFLON™ EROSION

It has already been shown in previous papers (refs. 1,2) that the thickness of the FEP Teflon™ used for the UHCRE experiment (A0178) is not known with an accuracy better than $\pm 6 \mu\text{m}$ for a total thickness of $127 \mu\text{m}$ (5 mils). Such an inaccuracy may give an error of 50 percent on the reaction efficiency (R_E) estimation of FEP Teflon™. To improve this accuracy, the only way is to increase the number of samples used to evaluate R_E .

Therefore, three more samples were cut from each tray from rows 7, 8, 10 and 11 to reach a total of at least six measurements by tray. The total number of measurements is 77 samples for the spare blankets, giving a mean value of the thickness of $126.5 \mu\text{m}$ and a standard deviation of $3.35 \mu\text{m}$, and 45 eroded samples. Figure 1 shows the thickness decrease versus the AO fluence for each row.

Remark : The AO fluences at end of mission for all rows were changed, taking into account the revised data dated from September 29, 1992, which are mentioned in LDEF Newsletter vol. III No. 6 (November 15, 1992).

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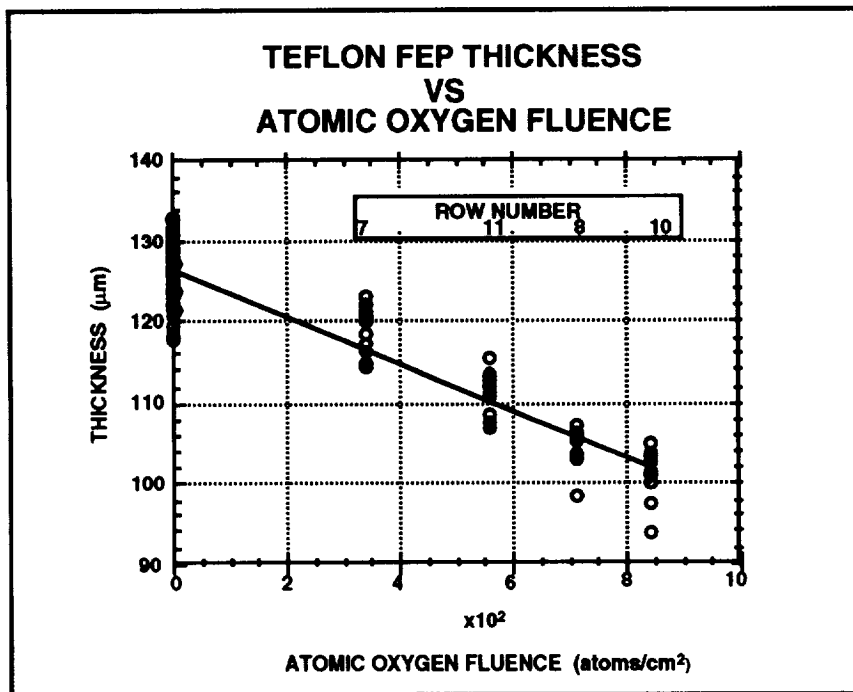


Figure 1

Each tray having received a different fluence, the thickness erosion of the film could be plotted versus the angle at which the oxygen atoms strike the thermal blanket and, to be more precise, versus the cosine of this angle (Figure 2). A power law regression curve could be calculated by the software used (Kaleidagraph from Synergy Software). An erosion of 29.5 μm is found for at normal incident angle and a power 1.44 of the cosine. This value is not far from the value of 1.5 found for the Kapton™ from previous flights and mentioned by Bruce Banks.

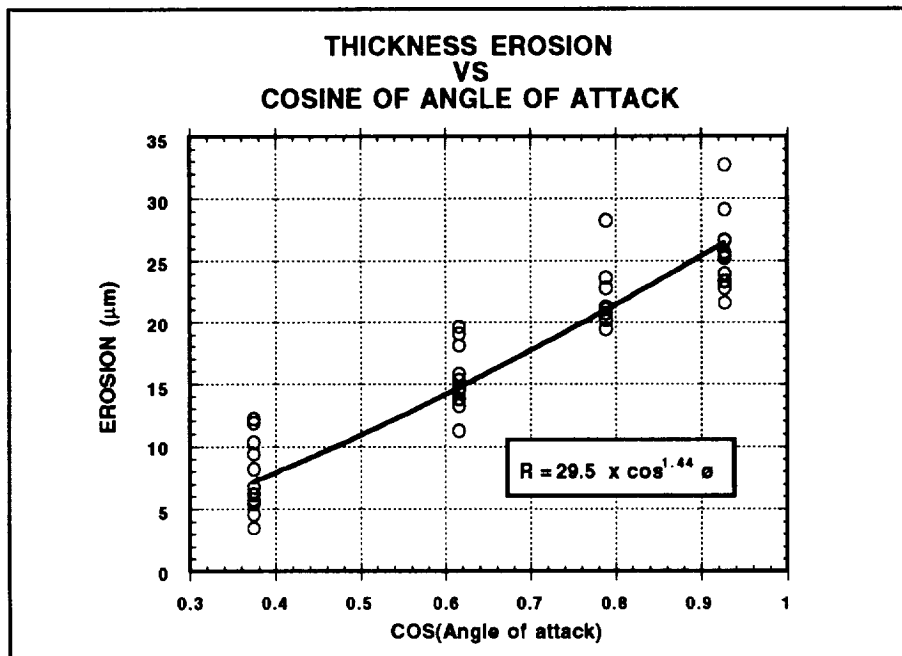


Figure 2

If the reaction efficiency is plotted instead of the recession (Figure 3), a value of 3.24×10^{-25} is found at normal incidence. For the other angles a law in $\cos^{0.44}$ applies. As the atomic oxygen fluence for each row is practically a cosine law of the incident angle of the atoms, it is quite normal to find a power 0.44.

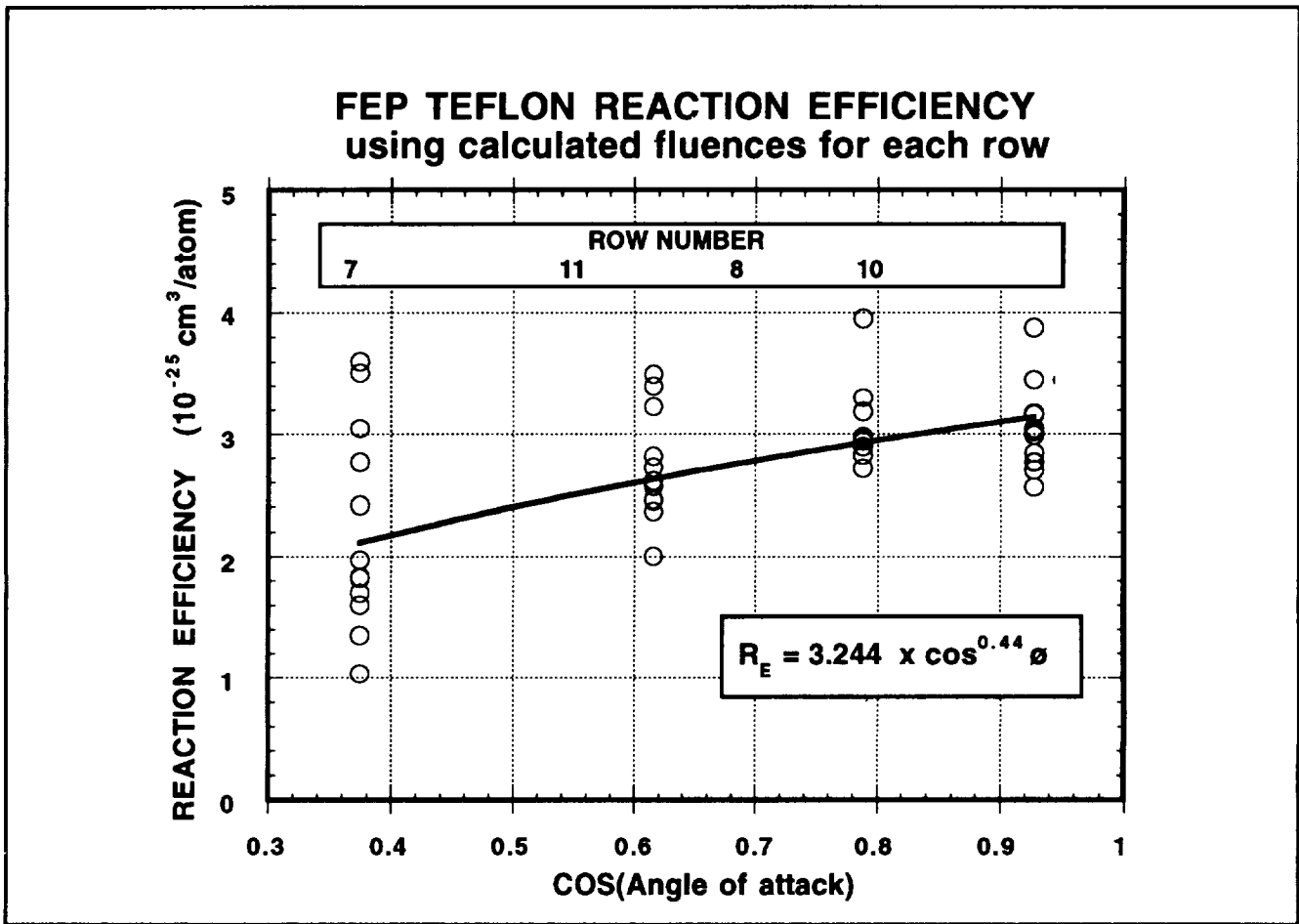


Figure 3

In addition, if the reaction efficiency is plotted versus the cosine of the angle of attack but, this time, when R_E is computed using only the fluence at normal incidence, i.e., 9.09×10^{21} atoms/cm², (Figure 4), the results obtained for the FEP Teflon™ film show an angular effect on the rate given by :

$$R_{\theta} = R_{\perp} \cos^{1.44} \theta$$

where R_{θ} is the erosion yield for the incidence angle θ , and R_{\perp} the erosion yield at normal incidence.

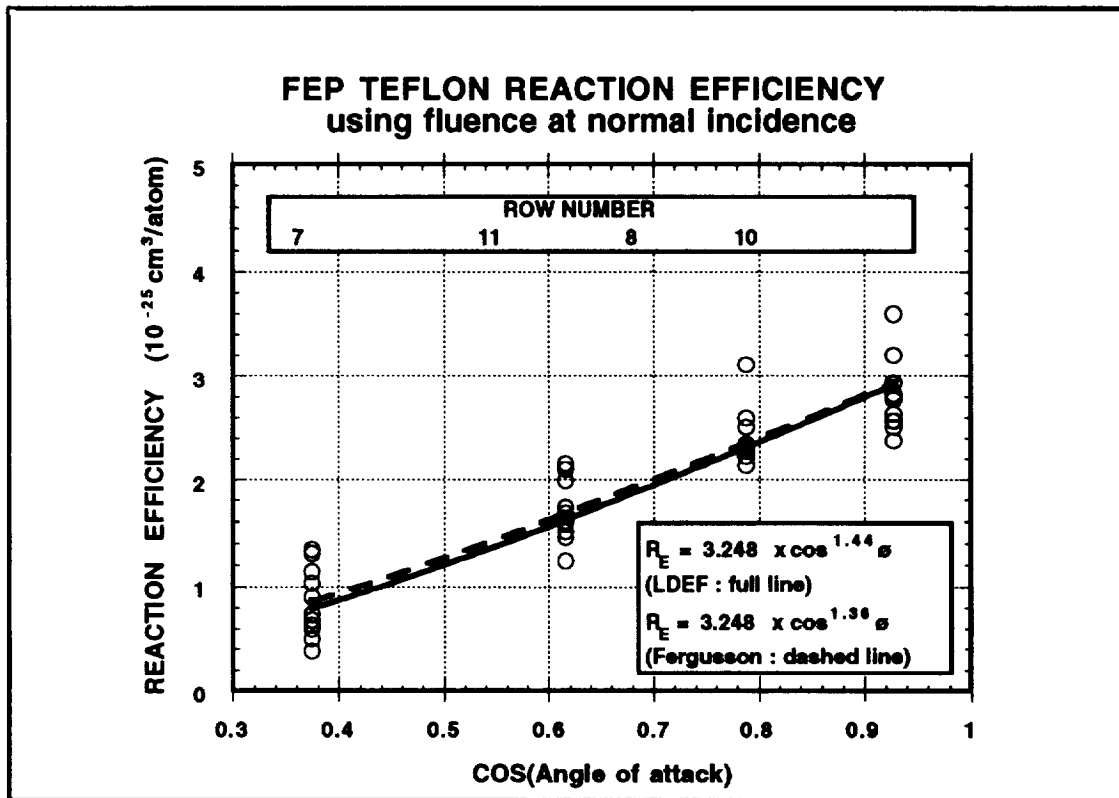


Figure 4

The effective energy of an oxygen atom is:

$$E_{\theta} = \frac{1}{2} m v_{\perp}^2 = \frac{1}{2} m (v_0 \cdot \cos \theta)^2 ,$$

for a normal incidence attack this energy would be:

$$E_{\perp} = \frac{1}{2} m v_0^2 .$$

Then :

$$E_{\theta} = E_{\perp} \cdot \cos^2 \theta .$$

For Kapton™, the reactivity as function of energy was given by Fergusson as:

$$R \approx E^{0.68} .$$

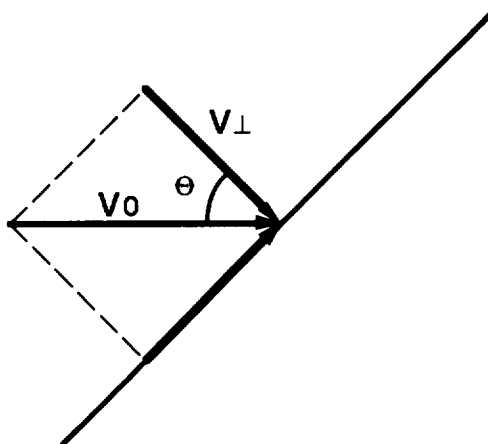
Therefore, assuming this empirical law is also valid for FEP Teflon, we would expect a reactivity:

$$R_{\theta} \approx E_{\theta}^{0.68} = (E_{\perp} \cdot \cos^2 \theta)^{0.68} ,$$

$$R_{\theta} \approx E_{\perp}^{0.68} \cdot \cos^{1.36} \theta ,$$

$$\boxed{R_{\theta} = R_{\perp} \cos^{1.36} \theta} .$$

The experimental value 1.44 found is not far from 1.36. For comparison the curve with cosine to the power 1.36 is plotted on the same Figure 4 assuming an identical reactivity at normal incidence.



COMPARISON BETWEEN FLIGHT DATA AND TEST DATA

Figure 5 shows the erosion yield of FEP Teflon™ as a function of AO fluence for several environments as well as during onground simulations and in-flight. Even flight data seems to give different results between shuttle flights STS-8, STS-41G, EOIM-3, and LDEF. The synergism between the reaction due to oxygen atoms and the ultraviolet (UV) irradiation, particularly the far UV below 2,000 Å, is often mentioned as an explanation. It is true that in all facilities used to simulate oxygen atoms there is a wide variation in the flux of the far UV that is present along with the oxygen atom beam. The wavelength range and the spectral energy of this UV is generally unknown.

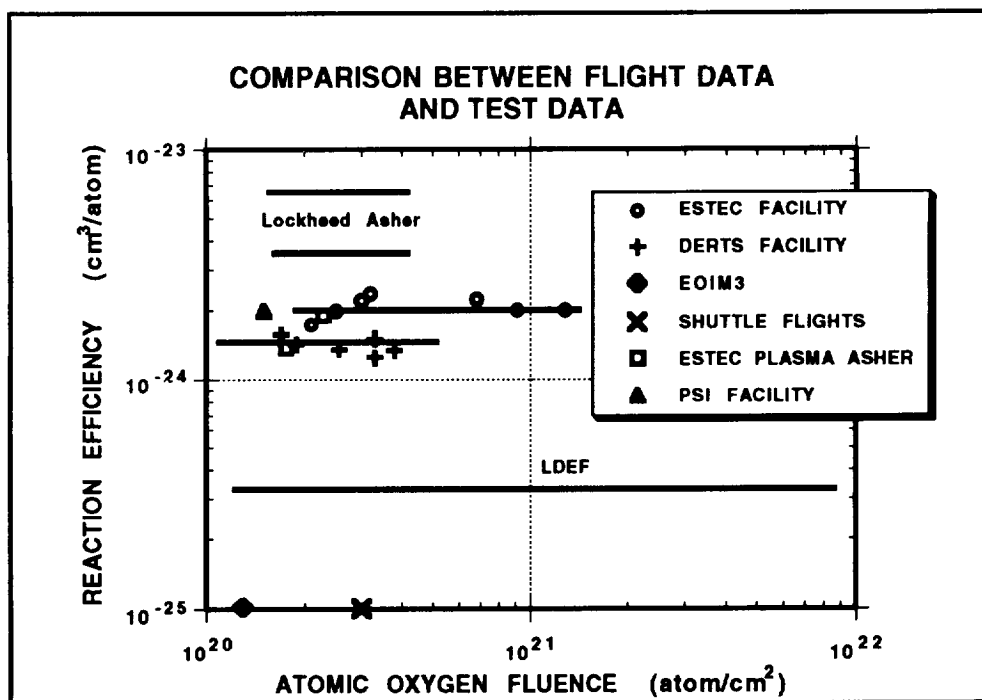


Figure 5

EFFECT OF OXYGEN IONS ON TEFLON FEP DEGRADATION

Another possible explanation, although somewhat speculative due to the lack of more exact data on ion concentration, is the presence of different ratios of oxygen ions and oxygen atoms as a function of altitude and the possibility that oxygen ions have a higher reactivity than neutral atoms. This hypothesis was mentioned a few years ago by D.G. Zimcik (ref. 3) to explain the differences between STS-41G and Solar Max Satellite.

The density of O^+ and O as function of altitude for minimum solar activity is given in Figure 6. This figure also shows that, for the given interval, the O^+/O_{tot} ratio between both species is increasing with altitude ($O_{tot} = O^+ + O$).

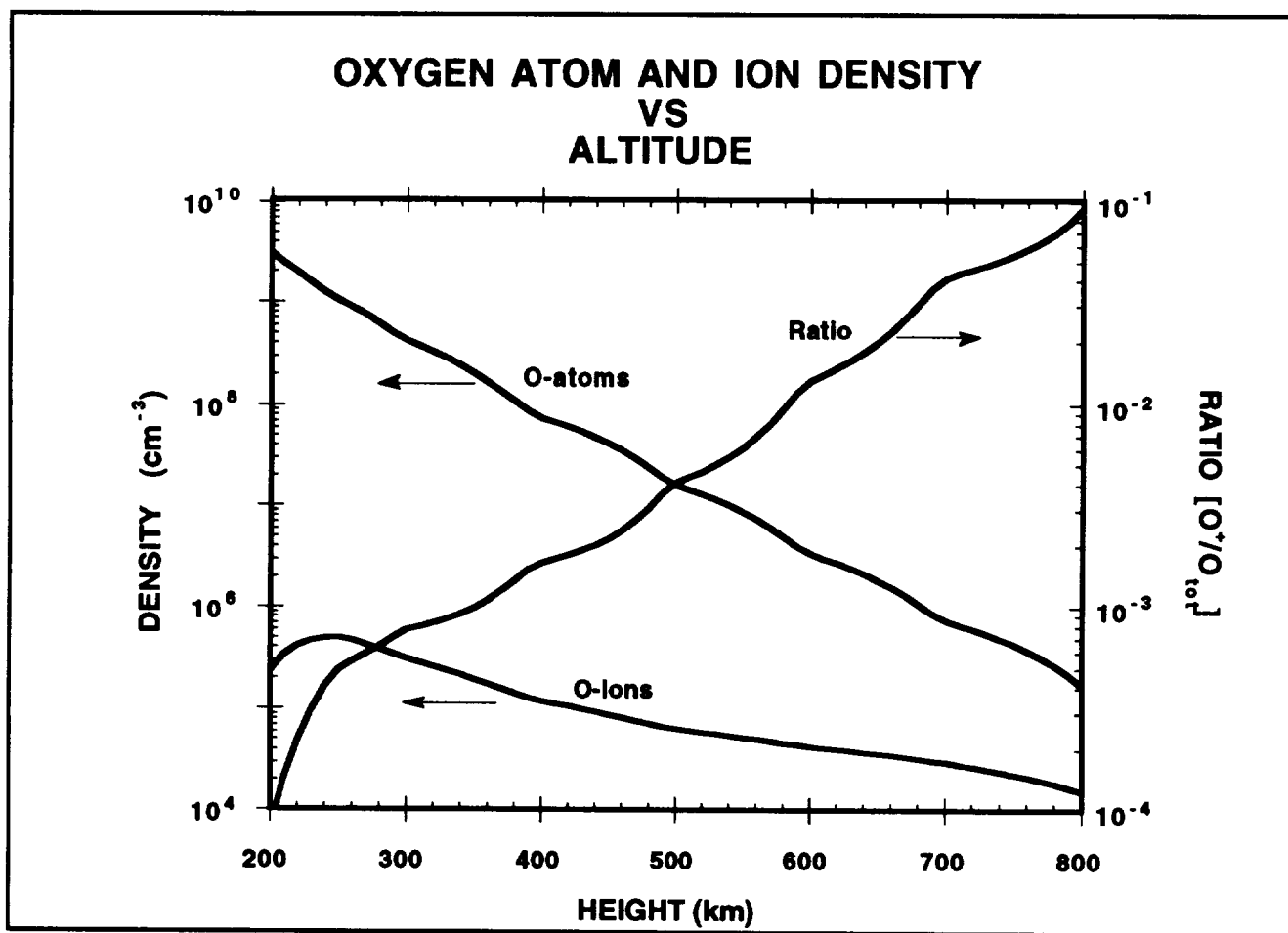


Figure 6

Although the nominal LDEF orbit for most of its lifetime was above 450 km, 50 percent of all fluence was accumulated in the last year, when the satellite orbit was decaying rapidly. Over this period, the height corresponding to the average flux was some 400 km, resulting in a O^+/O_{tot} ratio of 0.0016. The measured reaction efficiency was three times higher than what was found after STS-8, EOIM-3, and other exposures to the lower ratios (near 0.00025) encountered in the orbit of 225 km.

Onground simulations in Fast Atom Beam Facilities, such as the ones at PSI, CERT/DERTS and ESTEC, with an O^+/O_{tot} ratio of 0.01 or the Ion Beam Facility at Culham ($O^+/O_{tot} = 1$), show a further increase in yield.

From Figure 7, it appears that the relation between the yield and the O^+/O_{tot} ratio can be approached by a power function :

$$R = 6.2 \cdot 10^{-23} \times C^{0.78}$$

with R = reaction efficiency in $cm^3/O\text{-atom}$ and C = ratio O^+/O_{tot} .

The effects of ions could also explain why during Solar Max Mission (mean altitude 515 km, $O^+/O_{tot} = 0.0045$) the FEP Teflon™ deteriorated more dramatically than would be expected from shuttle flights or even LDEF results.

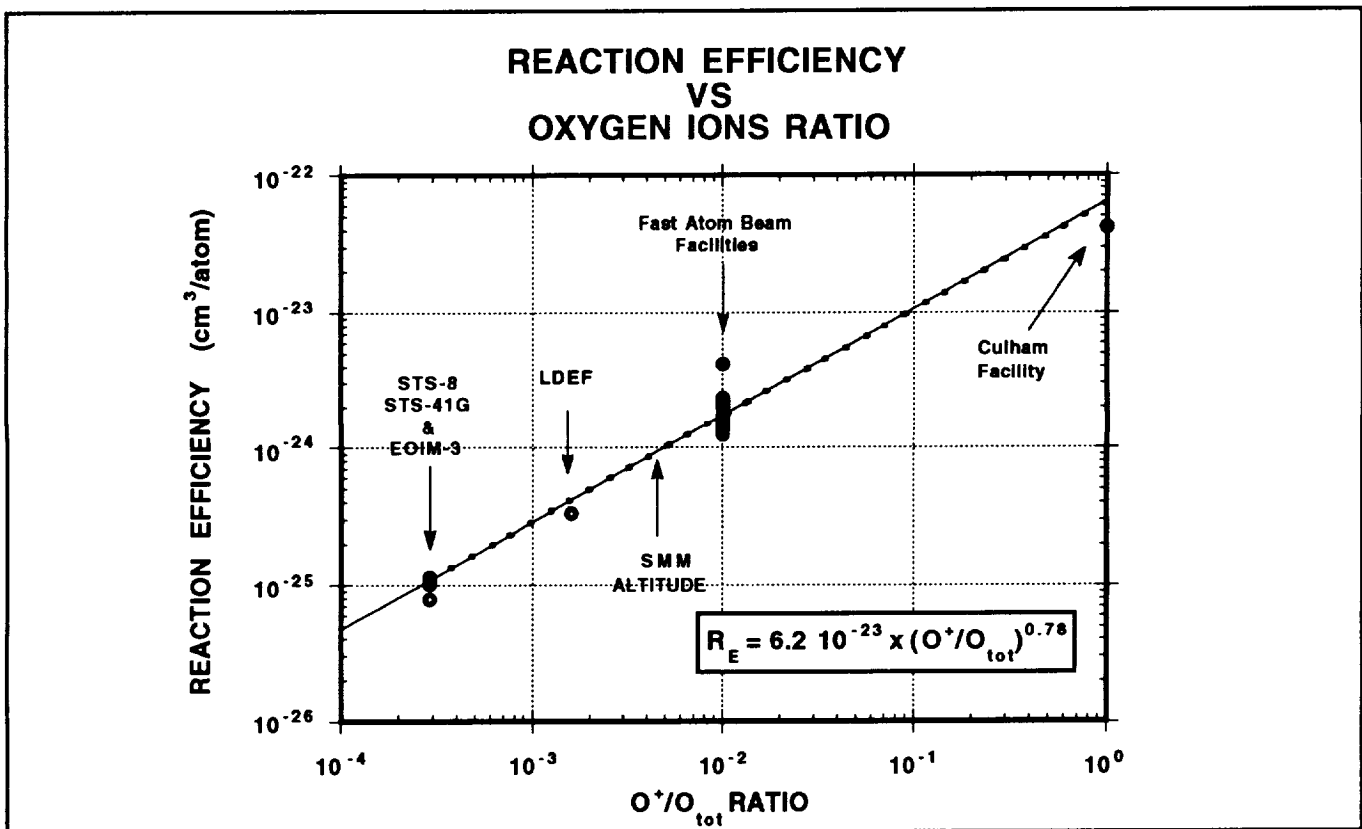


Figure 7

XPS ANALYSIS OF CHEMGLAZE Z306™

Purpose of this study

Since the beginning of the studies on LDEF contamination, the Chemglaze Z306™ was suspected to have been, among others, a source of silicone contaminant. In particular, the brown contamination which can be observed on leading trays, where oxygen atoms could penetrate inside LDEF, was strongly suspected to be due to this paint which covers the whole internal structure and some parts of the trays.

In the first instance, this assumption was based on information obtained from the British representative of the manufacturer, which confirmed the presence of a silicone fluid in the paint. Later on, the U.S. manufacturer denied that any silicone was present in the paint formulation, but the "Z306 formulation includes a fumed silica used as a flattening agent" (3.27 percent by weight). Therefore the presence of silica may explain the silicon peak found in all SEM/EDX analysis.

The study performed by Dr J. Golden (ref. 4), based on chemical extraction of silicone, has concluded that there is no silicone in the Z306. A similar measurement done for ESTEC by the TNO (ref. 5) (Delft, The Netherlands) has also given a negative answer.

In May 1992, the Max-Planck Institut Für Aeronomie sent to ESTEC an alert concerning the possible presence of siloxanes in Cab-O-Sil™ (American manufacturer) and Aerosil™ (German manufacturer). Consequently, to confirm or not the silicone content in Z306 formulation, XPS analysis were performed.

Experimental Technique

The analyses performed by CRPHT (ref. 6) (Orléans, France) were obtained using the ESCALAB Mark II from V.G. Instrument. The x-ray source line used is the Ka of magnesium at energy 1253,6 eV and width 0.75 eV. For nonconductive samples, the power is limited to 10 kV by 20 mA. During the measurements, the vacuum was 10^{-6} Pa and the samples were at room temperature. Acquisition time was 20 s, and the number of records for the different peaks were 50 scans for C1s, 30 scans for O1s, 200 scans for Si2p and 10 for another measurement of C1s at the end to verify that the sample did not charge during the acquisition.

Standard positions of the main peaks of chemical compounds are given by D. Briggs and M.P. Seah (ref 7).

Samples description

Table 1 lists the samples submitted to XPS analysis.

A1. The PS-7 silicate paint was submitted to analysis to determine the binding energy of the Si2p peak of silicate compared to silicone.

A2. This sample of Chemglaze Z306™ was cut from a spare flight blanket. It is therefore the formulation of the paint as manufactured circa 1981.

A3. The silicone adhesive C6-1104 was the one used to fix the Velcro™ on the thermal blanket and the frame of UHCRE as well as the Kapton™ sheets used to close the bottom of the trays.

A4. An unexposed sample of UHCRE thermal blanket cut from tray C11 on which a slight brown contamination can be seen.

The two following samples A5 and A6 are collected volatile condensable materials (CVCM), from Chemglaze Z306™ and Dow Corning C6 1104, obtained from recent lots of these materials. CVCM were obtained following ESA PSS-01-702 Specification (ref. 8) identical to ASTM E-695. If the black paint contains only fumed silica, then no silicon peak must be found in the CVCM.

Table 1

Sample	Description
A1	Silicate PS-7 Paint from Silvana
A2	Chemglaze Z306™ Paint from Lord (on UHCRE Spare blanket)
A3	C6 1104 Silicone Adhesive from Dow Corning
A4	Flight UHCRE blanket slightly contaminated (yellow stain)
A5	CVCM of Chemglaze Z306™ (recent lot)
A6	CVCM of C6 1104

Results

Table 2 gives the binding energies of the main peaks obtained for each sample. Tables 3 and 4 give these peaks for Chemglaze Z306™ (sample A2) and CVCM sample of Chemglaze Z306™ (sample A5).

Only results for Chemglaze are presented.

The analysis confirms the presence of silicone in the paint: for both samples, A2 and A5, the oxygen peak has its main component corresponding to the oxygen in silicone. The silicon peak is simple and corresponds to the bonding for silicones. Therefore, it is concluded in view of these results that there is silicone in the Chemglaze Z306™.

Table 2

Sample	A1	A2	A3	A4	A5	A6
C1s	284.6	284.6 286.1	284.6	284.6 286.6	284.6 285.9	284.6
O1s	530.5 532.3	532.2	532.1	532.8	532.0 533.3	532.5
Si2p	101.7	101.7	102.1	103.6	102.0	102.1
K2p3/2	292.3					
N1s		399.4				
F1s				687.4		

Table 3

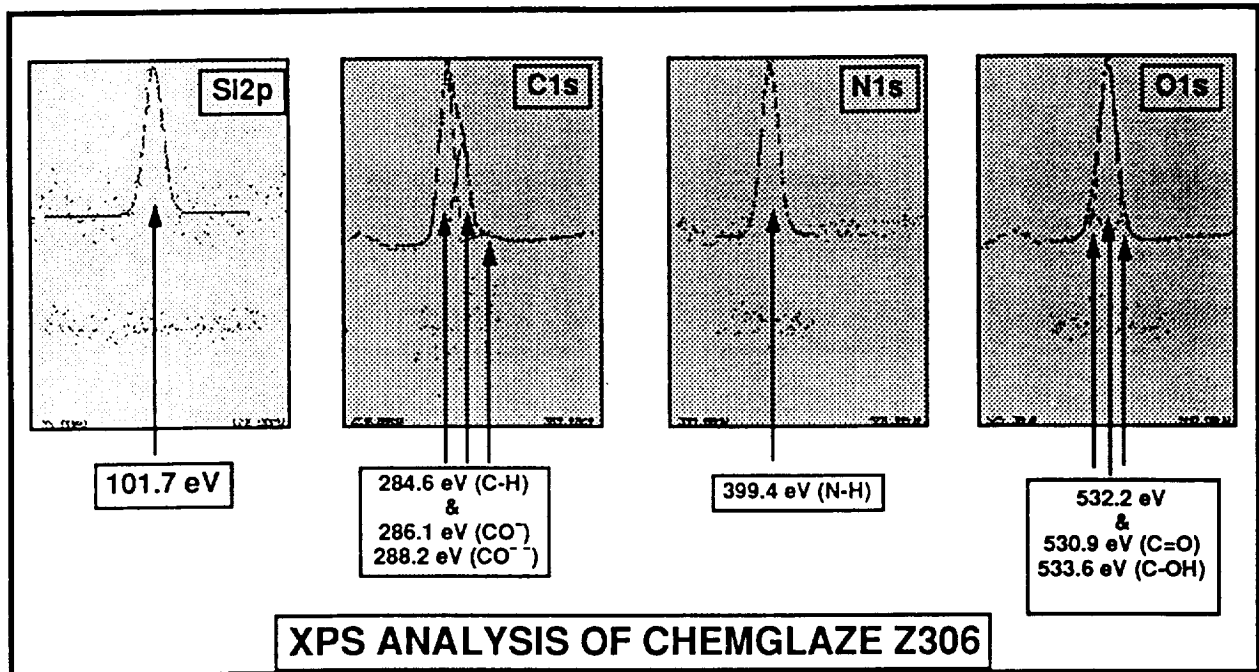
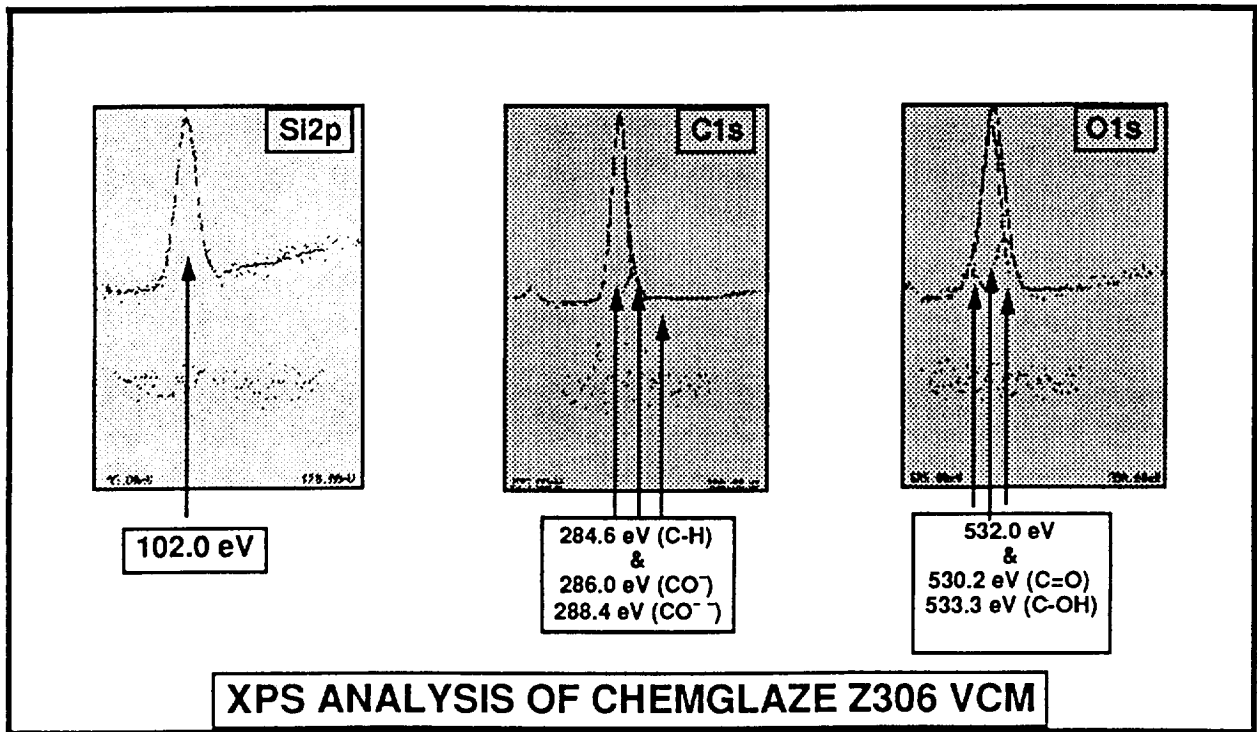


Table 4



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