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RECESSION OF FEP SPECIMENS FROM TRAYS D11 and B7

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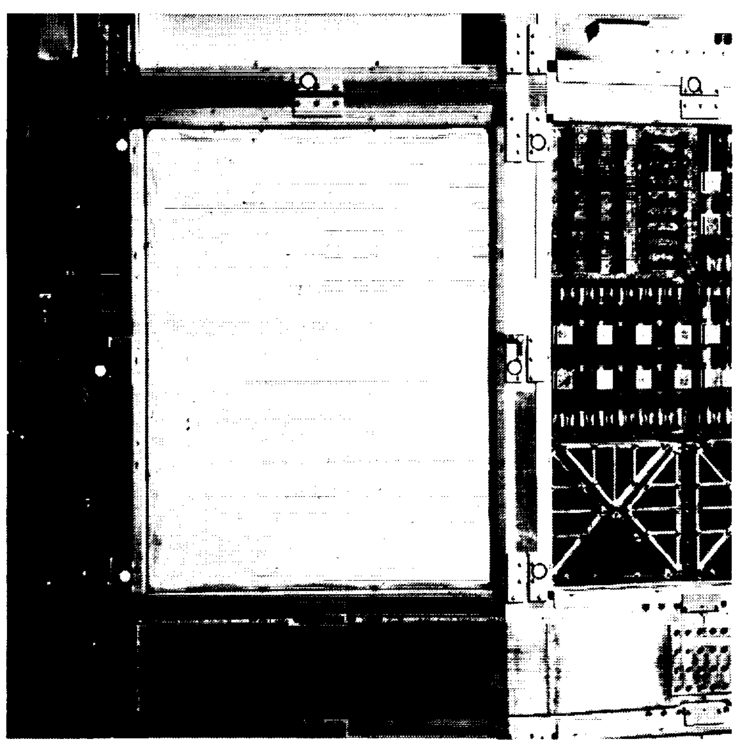
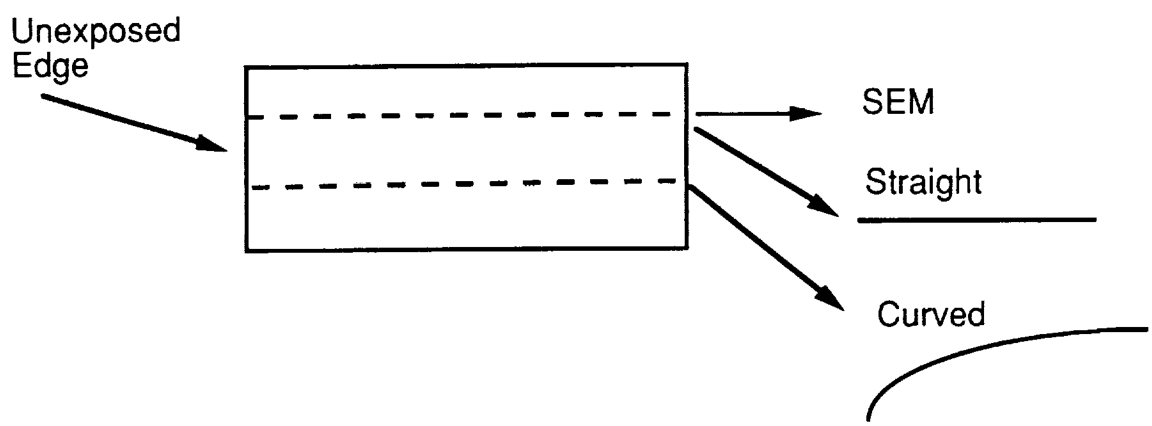
In this presentation we reported work done at Boeing Defense and Space Group on analysis of silvered teflon specimens taken from selected locations of the Long Duration Exposure Facility under support from a contract provided by NASA LaRC.

This photograph was taken on orbit during the retrieval of LDEF and shows blanket D11. The samples discussed in this presentation were taken from the unexposed side of D11 and extended through the folded area of this blanket into the exposed area. Two similar areas were cut from blanket B7, one from the edge of the blanket near row six and one from the edge of the blanket near row eight and within a few centimeters of the copper grounding strap for B7.



The specimens were each divided into three sections by cutting with a scapel. Two of the sections were mounted in a potting compound, which was cut and polished such that the cross-sectional thickness of each was exposed. One piece was mounted straight and the other was mounted in an attempt to configure the specimen such that it was bent with a radius of curvature similar to the on-orbit configuration. The third portion of each specimen was used for SEM images to help define the angle of exposure with respect to the ram at each location on the specimen.

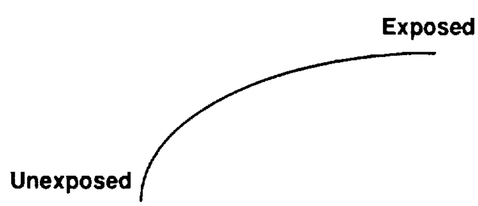
FEP SPECIMENS FROM BLANKETS D11 and B7



Photomicrographs were taken in cross section from the edge of the blanket through the curved transition region into the exposed area of the blanket. The thickness of the Fluorinated Ethylene Propylene (FEP) layer was determined at known distances from the edge of the blanket. SEM images were obtained at known distances to help define the angle with respect to ram and therefore establish the atomic oxygen fluence on each location and correlate this exposure with thickness. Thickness measurements made within a two to three centimeter distance minimized the uncertainty arising from variations in the as-manufactured thickness of each blanket. The nominal angle from ram of the exposed portion of each blanket, and the fact that the unexposed edge portions are approximately at right angles to the exposed portion were also used to help define the angles.

Thickness measurements were taken at specified locations. An average thickness for the unexposed portion of the blanket was determined. Changes in thickness were then determined by difference.

Orientation of Individual Specimens



- **Obtained photomicrographs from edge of blanket, through transition region, into exposed area**
    - **Obtained thickness vs. distance from edge of blanket**
    - **Obtained Sem Images at known distances from edge of blankets to verify angle from RAM at specific locations**

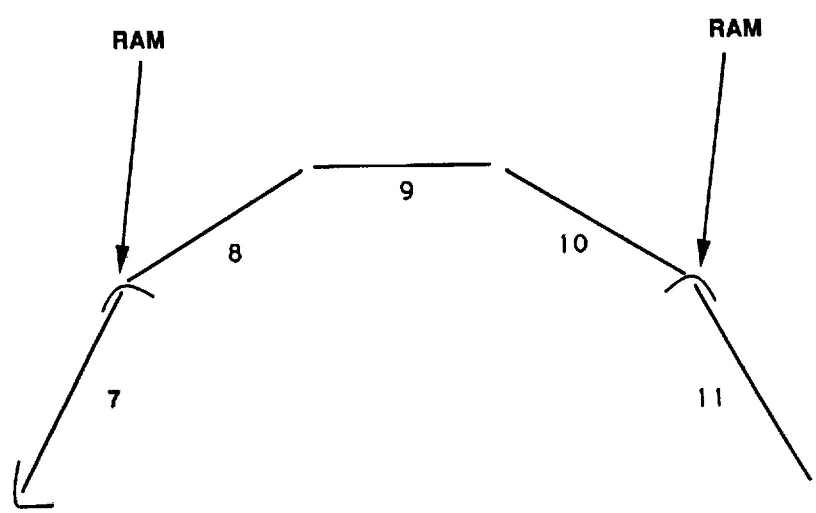
RESULTS

THICKNESS vs LOCATION

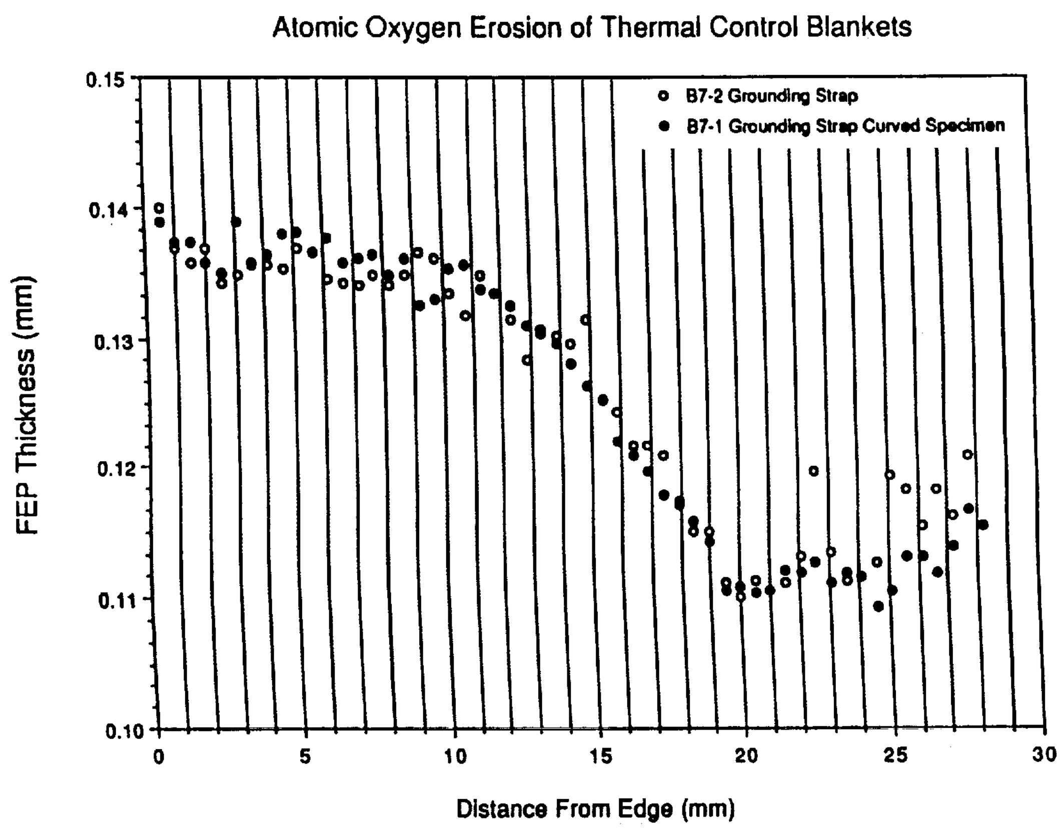
CHANGES IN THICKNESS vs LOCATION

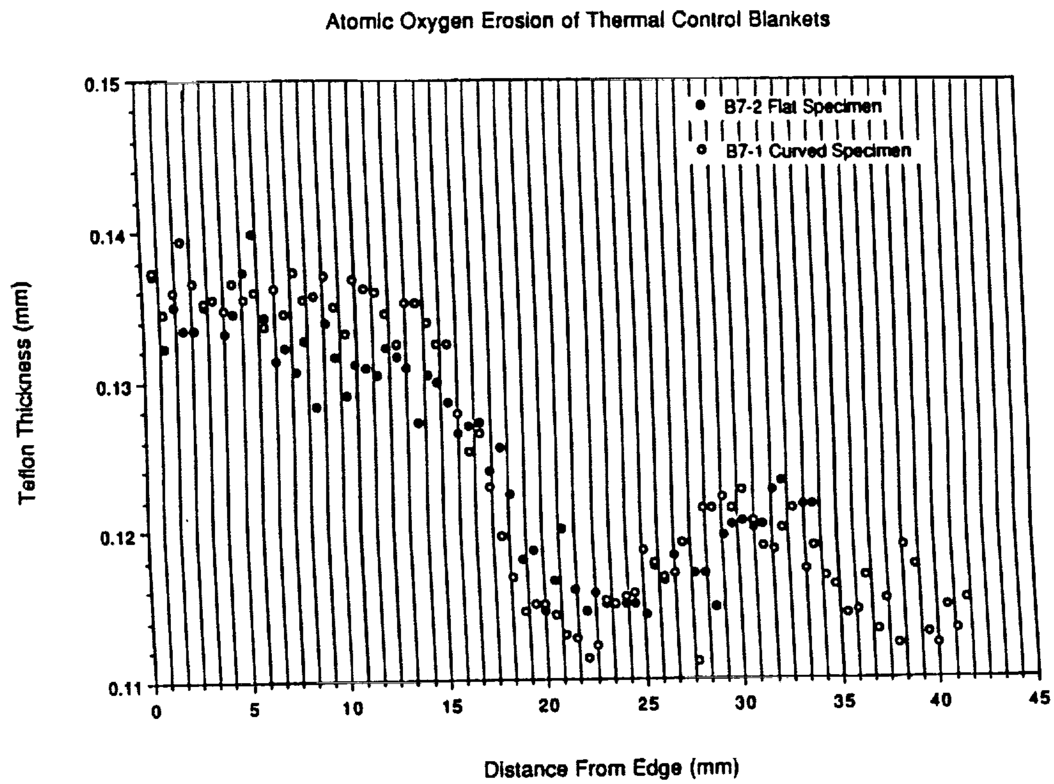
The details of the locations of the three specimens are shown in this diagram. The specimen from D11 was the most "open" to the ram direction; that is, its orientation was such that the least complication from secondary scattering was likely for this specimen. For the specimen from B7 near the copper grounding strap (on the row eight side) there is some possibility that some oxygen atoms may be blocked by the edge of the tray and longer on toward row eight. The slightly raised side of the tray and longeron immediately behind the B7 specimen near row six is a source of secondary scattering and enhanced dosage of atomic oxygen for the surface of the specimen which approaches ninety degrees from ram. SEM photos of locations show surface roughening consistent with atoms scattered from this surface.

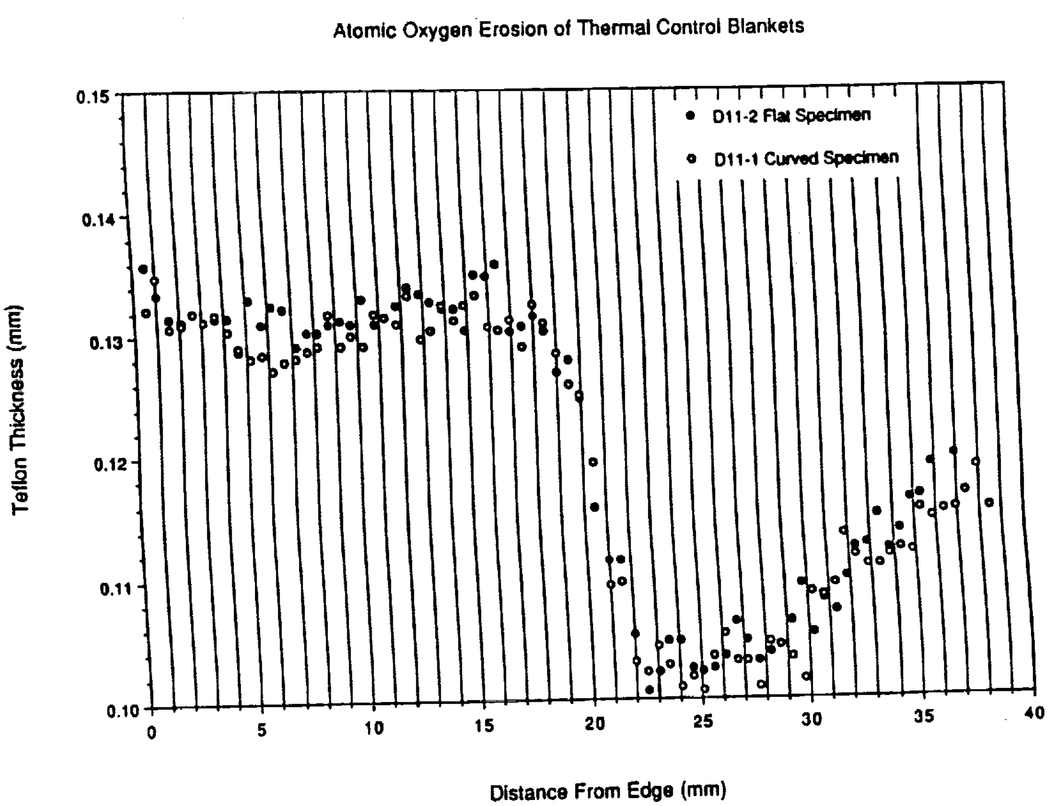
ORIENTATION OF FEP SPECIMENS



The next three charts show the results of the thickness measurements. There was essentially no difference in the measured thickness of the curved specimens under tension and the straight specimens at each location. Based on thickness variations measured by ESSA/ESTEC over the entire length of a blanket, one can expect a thickness variation of 1-2 micros over the length of material examined in each of these specimens. This thickness variation is also borne out by the slight thickness differences of the unexposed portions of the various specimens.

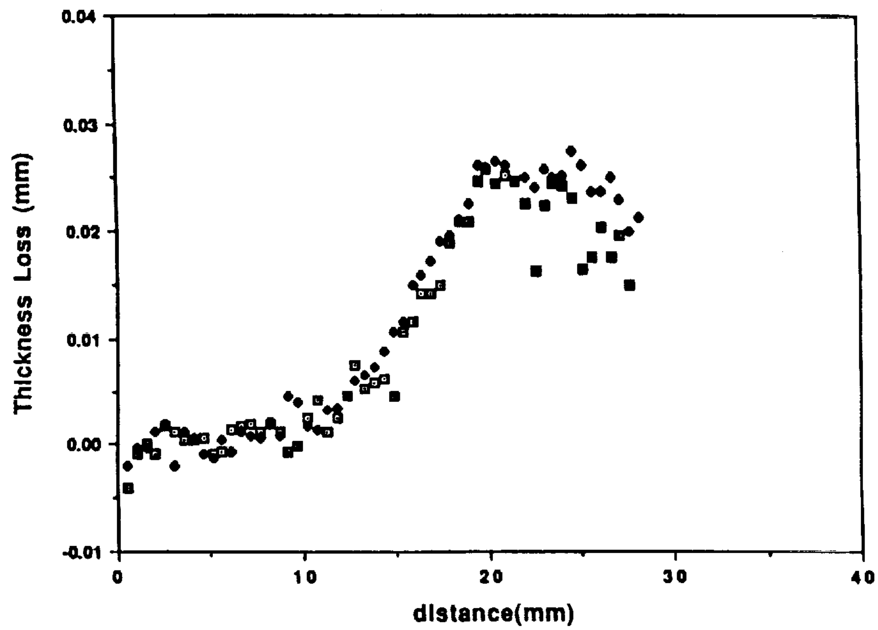



Atomic Oxygen Erosion of Thermal Control Blankets
0.15
0.14
0.13
0.12
0.11
Teflon Thickness (mm)
0
5
10
15
20
25
30
35
40
45
Distance From Edge (mm)
B7-2 Flat Specimen
B7-1 Curved Specimen

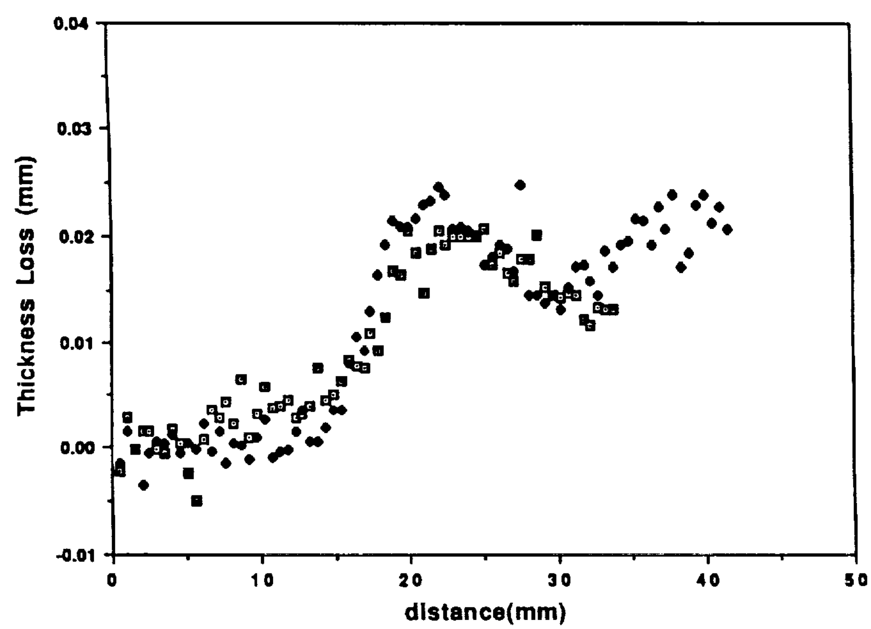

Atomic Oxygen Erosion of Thermal Control Blankets
0.15
0.14
0.13
0.12
0.11
0.10
Teflon Thickness (mm)
0
5
10
15
20
25
30
35
40
Distance From Edge (mm)
D11-2 Flat Specimen
D11-1 Curved Specimen

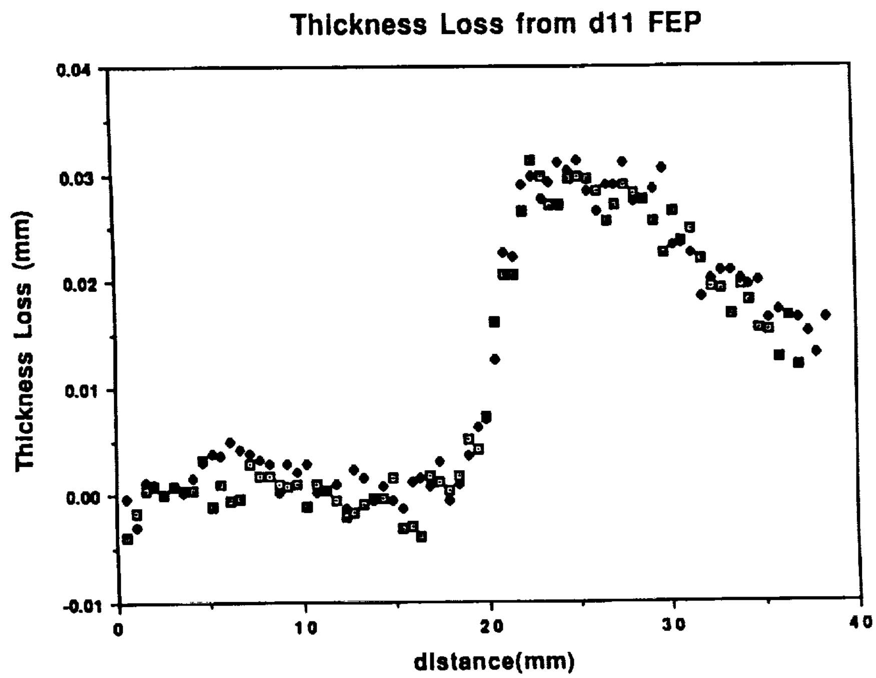
The next three charts show the thickness loss for each specimen as a function of distance from the edge of the blanket. The values essentially correct for initial thickness differences in the various specimens. The shape of the thickness loss curve from the B7 blanket specimen from the row six side is due to curvature in this blanket, clearly visible in the on-orbit photos. Data are shown for two specimens from each blanket.

Thickness Loss B7 near Grounding Strap



Thickness Loss from B7 FEP




Thickness Loss from d11 FEP
0.04
0.03
0.02
0.01
0.00
-0.01
Thickness Loss (mm)
0
10
20
30
40
distance(mm)

FITS TO DATA

ANGLE DETERMINATION

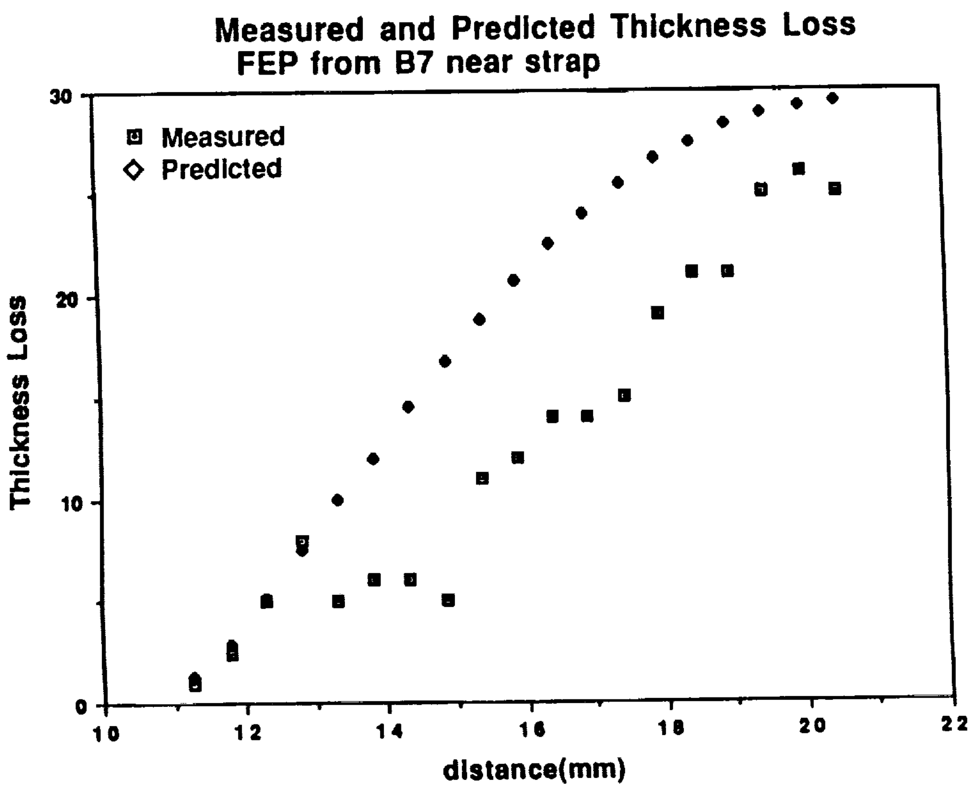
SEM-SEMI QUANTITATIVE

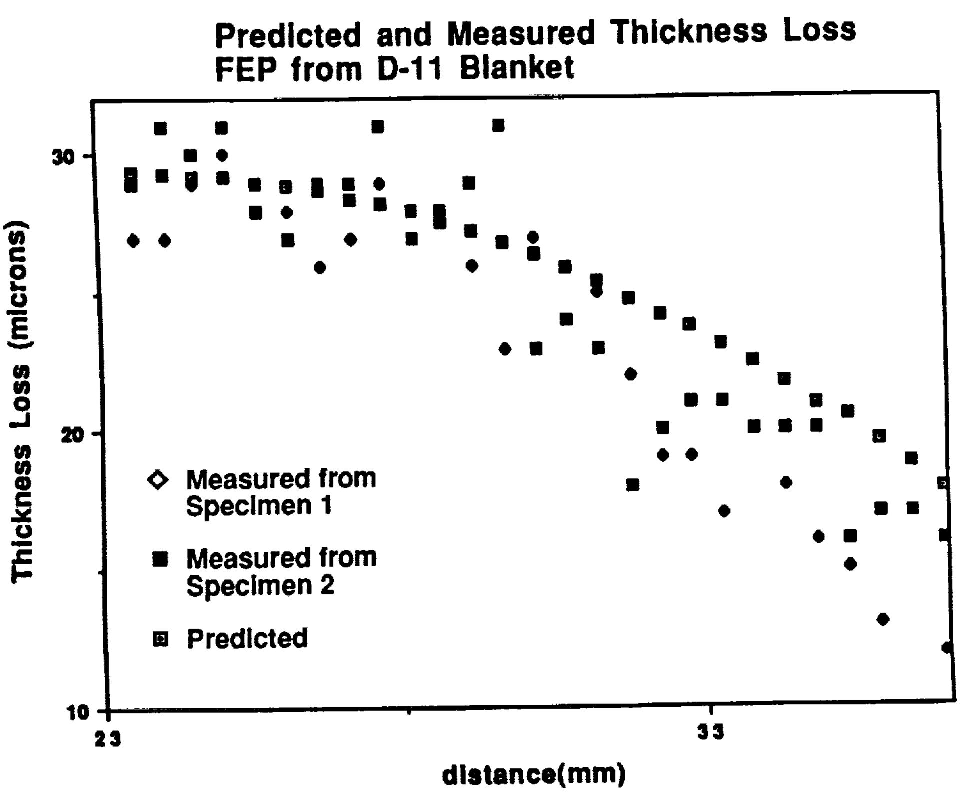
RADIUS OF CURVATURE CHANGES

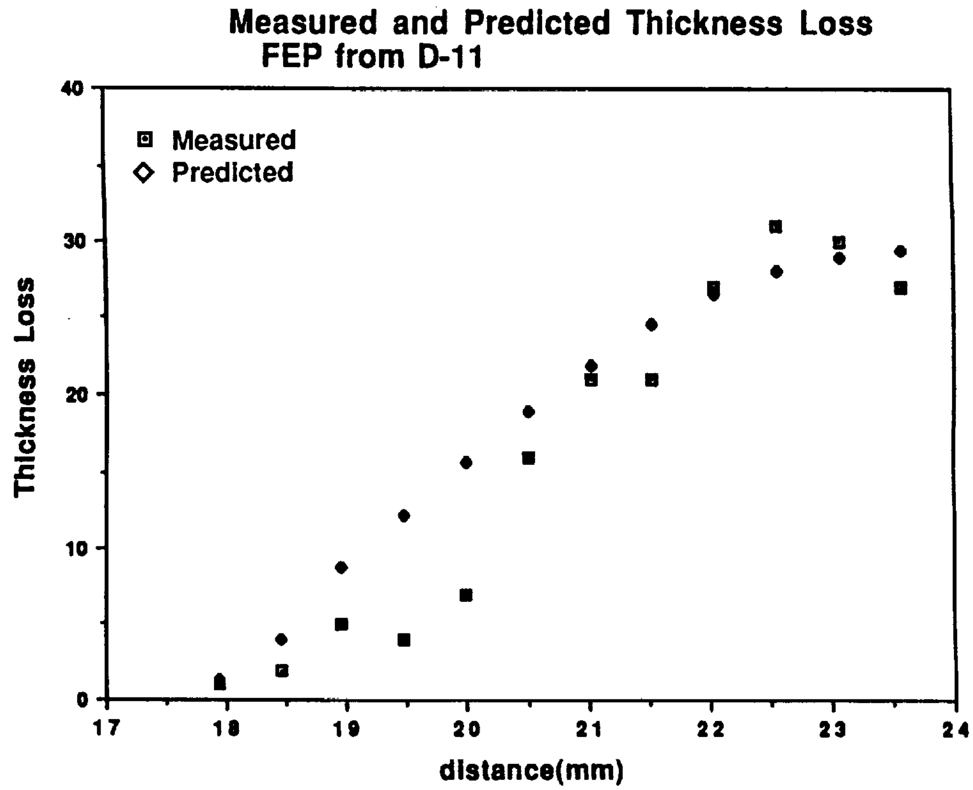
To complete this determination of the recession vs angle, it was necessary to define the angle with respect to ram. The use of SEM images to determine the orientation of the textured peaks with respect to the ram direction was only semi-quantitative and established the angle from ram only within a few degrees in each case. However, these measurements did allow definition of the ram direction exposure location to within a millimeter along the length of the specimen for two of the three specimens. Due to the apparent indirect scattering from adjacent aluminum surfaces, the angles for the B7 specimen were not clear from the SEM images. A second consideration in trying to determine the angle from ram is that the radius of curvature was not necessarily constant throughout the transition region from unexposed to exposed blanket surfaces, and therefore the angle change per fixed distance is not constant. With these caveats as reminders, we estimated the angles by assuming a constant radius of curvature as a first approximation and compared the results to recession rates determined from measurements of the exposed areas of the blankets from rows 7, 8, 10, and 11. The results of this exercise are shown in the next few charts.

From the calculated atomic oxygen fluences, it can be shown that 90 degrees from the ram produces a thickness loss of less than 1 micron. For each specimen the distance along the blanket where the thickness loss reaches less than one micron is assumed to be 90 degrees. The location of the ram direction is well enough defined from the SEM images. A calculation of thickness loss is made from the end-of-mission atomic oxygen fluences as a function of angle. The angle change is assumed to be linear with distance between the 90 from ram and ram locations. The results of this fit are shown for the B7 specimens taken from near the grounding strap. The predicted recession of 29.4 microns is about 15% higher than the value taken from these measurements.

The next two charts show a comparison of thickness loss calculated from recession rates with the measured recession rates for two regions of the specimens from blanket D11. For this blanket the fit is good, indicating that our assumption of constant rate of angle change with linear distance was valid for this specimen. For distances greater than 30 mm from the edge of the blanket the calculated values appear to be slightly high, indicating our assumption of 52 degrees at the end of the specimen farthest from the unexposed edge is slightly off.


Measured and Predicted Thickness Loss
FEP from B7 near strap
Measured
Predicted
Thickness Loss
distance(mm)
0
10
20
30
10
12
14
16
18
20
22


Predicted and Measured Thickness Loss
FEP from D-11 Blanket
Measured from Specimen 1
Measured from Specimen 2
Predicted
Thickness Loss (microns)
distance(mm)
10
20
30
23
33


Measured and Predicted Thickness Loss
FEP from D-11
Measured
Predicted
Thickness Loss
distance(mm)
0
10
20
30
40
17
18
19
20
21
22
23
24

Fits of mass loss vs apparent angle show the data from D11 is consistent with our fluence determinations and our recession measurements from the exposed areas of the blanket surfaces. The fact that the B7 results do not lie along this line indicates that the actual angles for these specimens are not so well defined. However, these results can be improved from repeat measurements using specimens from both edges of blankets from rows 11, 10, 8, and 7, and possibly from material from the edge of row six nearest row seven. Adhesive backed FEP tape on brackets from the McDonnell-Douglas experiment on row nine offer well defined angles since the tape is mounted to aluminum. Tape from areas on the space end of LDEF and on portions of the A0069 experiment on row nine also provide FEP exposures through well defined ranges of angles with respect to ram.