NASA Contractor Report 4663

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Analysis of Silverized Teflon Thermal Control Material Flown on the Long Duration Exposure Facility

H. Gary Pippin

Contracts NAS1-18224 and NAS1-19247
Prepared for Langley Research Center

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FOREWORD

This report describes the results from the testing and analysis of silverized Teflon™ flown on the Long Duration Exposure Facility (LDEF). This work was carried out by Boeing Defense & Space Group under two contracts, NAS1-18224, Task 12 (October 1989 through May 1991), and NAS1-19247, Tasks 1 and 8 (initiated May 1991). Sponsorship for these two programs was provided by the National Aeronautics and Space Administration, Langley Research Center (LaRC), Hampton, Virginia.

Mr. Lou Teichman, NASA LaRC, was the NASA Task Technical Monitor. Mr. Teichman was replaced by Ms. Joan Funk, NASA LaRC, following his retirement. Mr. Bland Stein, NASA LaRC, was the Materials Special Investigation Group Chairman, and was replaced by Ms. Joan Funk and Dr. Ann Whitaker, NASA Marshall Space Flight Center (MSFC), following Mr. Stein's retirement. The Materials & Processes Technology organization of the Boeing Defense & Space Group was responsible for providing the support to both contracts. The following Boeing personnel provided critical support throughout the program.

Bill Fedor	Program Manager
Sylvester Hill	Task Manager
Dr. Gary Pippin	Technical Leader
Dr. Bruce Skoropinski	Testing and Analysis
Mark Dubois	Testing and Analysis
Gary Tuss	Testing and Analysis

Dr. Ken Rousslang of the University of Puget Sound also participated in the examination of many of these test specimens.

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GLOSSARY

AO	Atomic oxygen
ATR	Attenuated total reflectance
BRDF	Bidirectional reflectance distribution function
DMA	Dynamical mechanical analysis
DSC	Differential Scanning Calorimetry
ESA	European Space Agency
ESCA	Electron scattering for chemical analysis
FEP	Fluorinated ethylene-propylene
FTIR	Fourier transform infrared spectroscopy
GSFC	Goddard Space Flight Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LDEF	Long Duration Exposure Facility
LEO	Low Earth orbit
MSFC	Marshall Space Flight Center
PTFE	Poly-tetrafluoroethylene
SEM	Scanning electron microscopy
SIMS	Secondary ion mass spectroscopy
UHCRE	Ultra-heavy cosmic ray experiment

1.0 INTRODUCTION

Results of measurements on, and analysis of, the condition of the silver backed fluorinated ethylene propylene (FEP) thermal control material specimens from the Long Duration Exposure Facility (LDEF) are presented in this report. This material is currently in wide use as a passive thermal control system; given its low solar absorptance to thermal emittance (α/ε) ratio, its as-manufactured high specular reflectance, and relative ease of manufacture and processing, this use will likely continue. The objective of the study was to determine the effects of specific space environmental exposures on fundamental properties of the FEP material and engineering performance of Ag/FEP blanket's. In particular, leading edge (oriented facing ram) specimens were exposed to large amounts of both atomic oxygen and solar ultraviolet radiation; trailing edge specimens were exposed to only solar ultraviolet radiation. An assessment of each blankets condition, results of the individual measurements made on specimens from each blanket, and data from other organizations which have also examined this material, are included in this report. S.I. units are used in this report. When the original measurements were reported in English units, the values are included in parentheses.

2.0 LDEF MISSION PROFILE

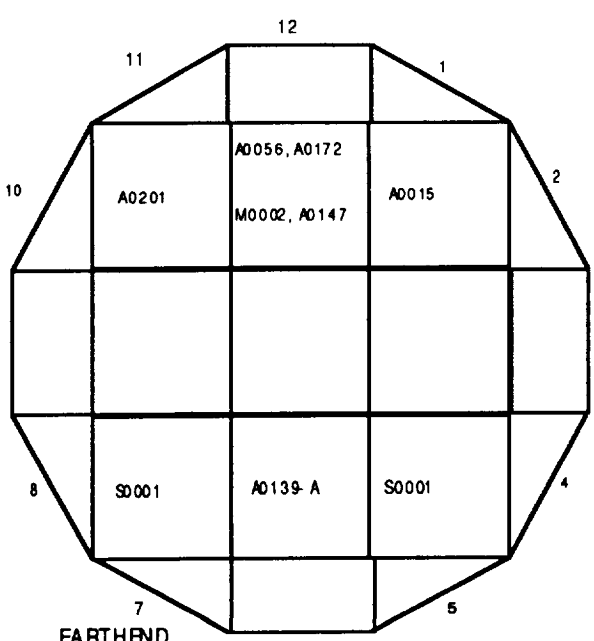
The LDEF was a large (about 9 m in length, 4.3 m in diameter), unmanned spacecraft built to accommodate technology, science, and applications experiments which require long-term exposure to the space environment. LDEF was designed to be transported into space in the payload bay of a Space Shuttle, free-fly in low Earth orbit (LEO) for an extended time period, and then be retrieved by a Shuttle during a later flight. The LDEF was passively stabilized, and each surface maintained a constant orientation with respect to the direction of motion.

The LDEF was deployed on April 7, 1984 by the Shuttle Challenger into a 482-km nearly circular orbit with a 28.4-deg inclination. The planned 10-month-to-1-year mission carried 57 experiments. A schematic diagram of the location(s) of each experiment on the LDEF is shown in figure 2.0-1. Due to schedule changes and the loss of the Space Shuttle Challenger, the duration of this flight was extended well beyond the original planned exposure period. The levels of exposure to atomic oxygen and solar radiation as functions of position on the LDEF are shown in figures 2.0-2 and 2.0-3, respectively.

The LDEF was retrieved by the Space Shuttle Columbia on January 12, 1990 after spending 69 months in orbit. A photo of the LDEF during retrieval operations is shown in figure 2.0-4. During these 69 months, LDEF completed 32,422 orbits of Earth and decreased in altitude to 340 km, where it was grappled, photographed extensively from the Shuttle crew cabin, and then placed in the Shuttle payload bay for return to Earth. The LDEF remained in the payload bay of the Space Shuttle Columbia for the landing at Edwards Air Force Base and during the ferry flight to Kennedy Space Center (KSC). The LDEF was removed from Columbia at KSC and brought to the Spacecraft Assembly and Encapsulation Building (SAEF-II) where the LDEF and its experiments were examined visually and photographed, radiation measurements were conducted, and the experiments removed from the structure tray by tray. Each tray was photographed individually subsequent to removal. System-level tests were carried out for particular experiments and support hardware. External surfaces were examined for evidence of impacts, contamination, and other exposure-induced changes.

BAY / ROW	A	B	C	
1	A0175	S0001	GRAPPLE	
2	A0178	S0001	A0015, A0187, M0006	
3	A0187	A0138	A0023, A0034, A0114, A0201	TRAILING EDGE
4	A0178	A0054	S0001	
5	S0001	A0178	A0178	P0005
6	S0001	S0001	A0178	P0003
7	A0175	A0178	S0001	
8	A0171	S0001, A0056, A0147	A0178	
9	S0069	S0010, A0134	A0023, A0034, A0114, A0201	LEADING EDGE
10	A0178	S1005	GRAPPLE	
11	A0187	S0001	A0178	
12	S0001	A0201	S0109	

BAY / ROW	D	E	F
1	A0178	S0001	S0001
2	A0189, A0172, S0001	A0178	P0004, P0006
3	M0003, M0002	A0187, S1002	S0001
4	M0003	S0001	A0178
5	A0178	S0050, A0044, A0135	S0001
6	A0201, S0001	A0023, S1006, S1003, M0002	A0038
7	A0178	S0001	S0001
8	M0003	A0187	M0004
9	M0003, M0002	S0014	A0076
10	A0054	A0178	S0001
11	A0178	S0001	S0001
12	A0023, A0019, A0180	A0038	S1001



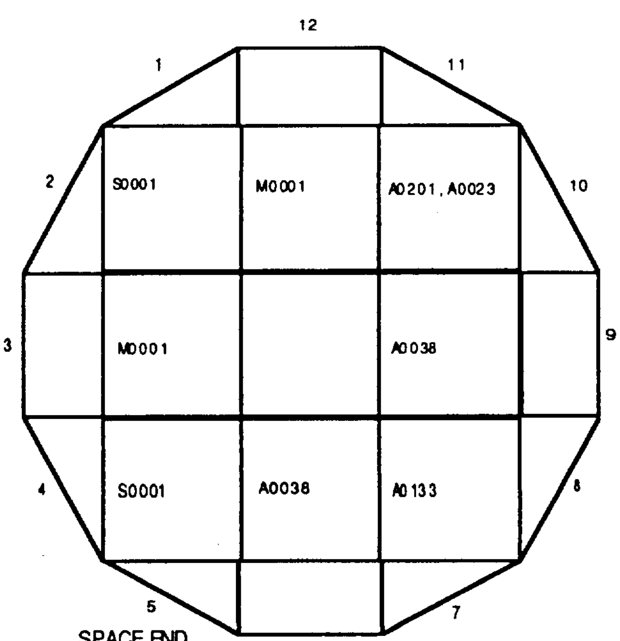


Figure 2.0-1 Schematic Diagram of the Location(s) of Each LDEF Experiment.

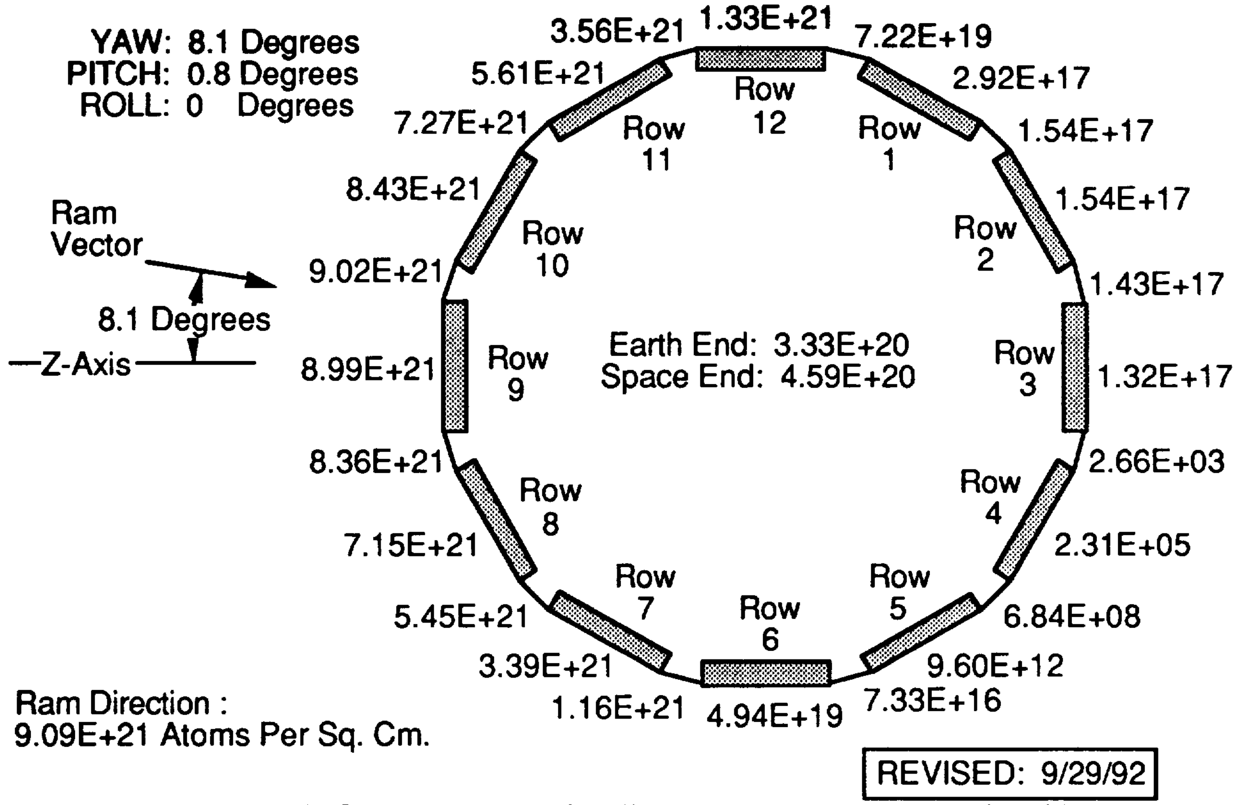


Figure 2.0-2. Atomic Oxygen Fluences for all LDEF Row, Longeron, and End-Bay Locations.

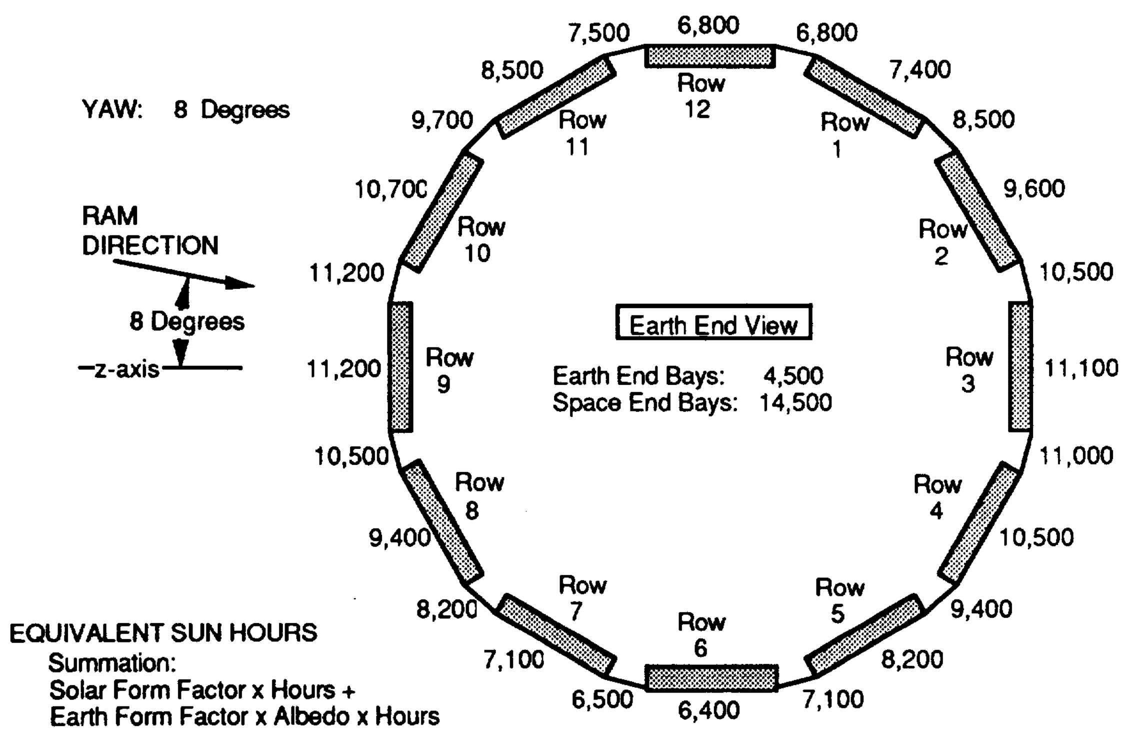


Figure 2.0-3. Solar Ultraviolet Fluence (Equivalent Sun Hours of Solar Radiation Normal to a Surface) as a Function of Location on the LDEF.

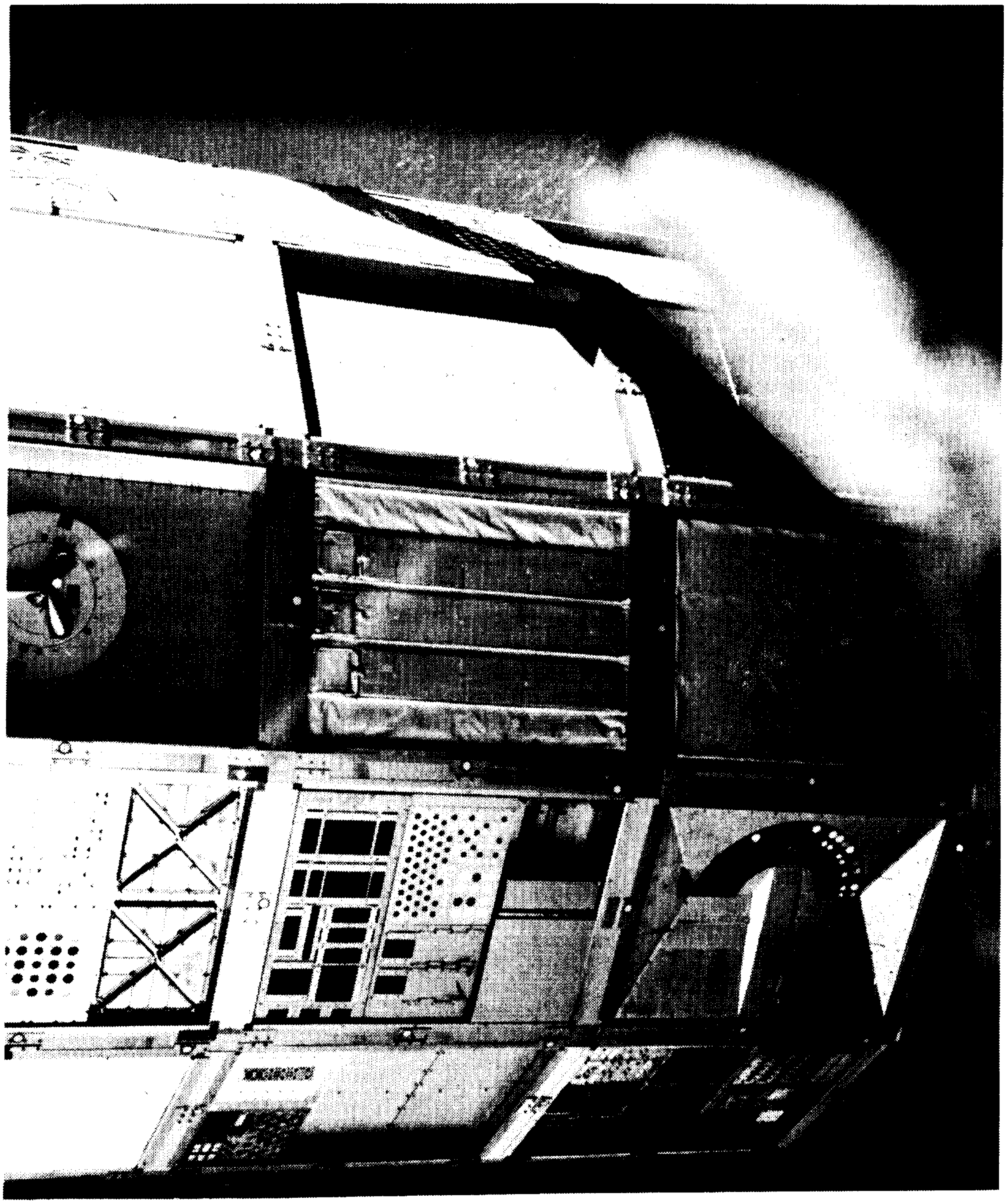


Figure 2.0-4. NASA on-orbit photo during retrieval showing rows 8-11, including several trays (A9, A10, B10) with substantial areas of Ag/FEP thermal control material.

3.0 MATERIALS DESCRIPTIONS

FEP is a visibly transparent polymer produced by DuPont with the general structure

$$-(F_2C{-}CF_2)_n{-}\underset{\displaystyle F}{\overset{\displaystyle CF_3}{\underset{|}{\overset{|}{C}}}}{-}\text{ , with } n \sim 7.$$

The strength of the C-F bond relative to typical C-H bond strengths gives FEP an advantage over organics in resisting attack by atomic oxygen.

The blanket material used for experiments A0178 and P0004 was manufactured by Sheldahl Corporation. The material consists of an approximately 5-mil-thick layer of FEP with approximately 800 angstroms of vapor deposited silver on one side and another 400 angstroms of vapor-deposited Inconel applied over the silver. Thirteen sheets of thermal control material (Sheldahl part number G401500) in 1.2 m by 3 m (4-ft by 10-ft) sections were delivered to the European Space Agency by Sheldahl Corporation. The lot numbers of these blankets are listed in appendix A. Blankets were cut from these sheets and a 2- to 3-mil thick coating of black Chemglaze Z306 polyurethane based paint was sprayed over the Inconel layer. A number of ~3 cm by 10 cm (1"x4") Velcro strips were attached to the back (Z306) side of the the blankets using a silicone-based adhesive, DC6-1104. The Velcro was used to fasten the blankets to corresponding Velcro strips attached to the framework mounted in the trays containing the experiments. Small keyhole-shaped notches were cut at a few locations along each side and at each corner of each blanket. This allowed an ~2.5 cm strip around the edge of each blanket to be folded such that the edge strip was oriented about 90° from the exposed areas of the blanket. This provided material along the edge of each blanket which had a distinctly different exposure than the majority of the blanket area. While this material is referred to as "tucked" or "unexposed," it should be recognized that for the portion of material bent around the radius, a continuous spectrum of exposures was produced over a short distance centered about 2.5 cm from the edge. This situation provided many advantages for characterizing the change in material properties with exposure.

3.1 SPECIMEN LOCATIONS ON THE SPACECRAFT

Sixteen trays of the A0178 experiment and the one tray of the P0004 experiment, covered with the Ag/FEP blankets, were distributed over nine rows of the LDEF spacecraft. Figures 3.1-1 and 3.1-2 show photos of blankets covering trays at locations E10 and D5. These locations are representative of the two basic types of exposure environments. Figure 3.1-3 shows a map of the blanket locations and the distribution of blanket pieces assigned to different organizations. Boeing was provided with ~10 cm x 45 cm strips from the NASA portions of each blanket of experiment A0178 and six ~5 cm x 45 cm pieces of blanket F2. Twelve copper grounding straps were also provided to Boeing. The locations of these straps are also shown in figure 3.1-3. Each strap had an approximately 10 cm radius hemisphere of Ag/FEP blanket attached. Three small Ag/FEP disks, cut out to gain access to screws during de-integration, and two silver Teflon covered aluminum bracket pieces were provided from experiment A0076, located on tray F9. A number of pieces were removed from the M0001 module at location H12. Selected pieces were taken from the ram-, trailing-, row six-, and space-facing sides of this module. A recessed, space-facing piece on the module was also removed for surface analysis. The specific location of the module caused the sides to be partially shielded by surrounding structure. The specimen from the S1002 experiment was flown inside a canister and was only exposed directly to the space environment for about 10 months, resulting in just under 1600 equivalent Sun hours of solar exposure. Ag/FEP specimens were also flown on M0003 and A0069. The material was used for thermal control on the A0076, A0069, and S1005 experiments. A photograph of tray A9, containing the A0069 experiment is shown in figure 3.1-4. A portion of the A10 blanket is also visible in this photograph. Goddard Space Flight Center (GSFC) also flew FEP, coated with a very thin layer of vapor-deposited aluminum, at locations F9 and F12.

3.2 SUMMARY OF EXPOSURES

There were two general types of exposure seen by external surface materials on LDEF: solar radiation or simultaneous atomic oxygen and solar radiation. The spacecraft also underwent 32,422 thermal cycles, and the impact rate from micrometeoroids and debris varied with location. The relatively low altitude and the non-polar orbit minimized the total dose of solar electrons and protons seen by these materials. The spacecraft flew during the complete range of conditions from solar minimum to solar maximum.

At least three secondary effects were created by the specific locations and method of fastening the blankets to experiment A0178. First, outgassing from both hydrocarbon-and silicone-based materials coated the surfaces of the blankets in an irregular manner, creating many different microenvironments, which changed independently as a function of time. Second, areas of the blankets bonded to the Velcro fasteners did not have the same freedom of motion as the remainder of the blanket. Thermal cycling put stress on the blanket at the interface between fastened and unfastened areas. Third, the area of the blanket forming the radius of curvature created by tucking the edge of the blankets into the trays was under tension and, depending on location, saw a wide range of exposures to atomic oxygen and/or solar ultraviolet radiation.

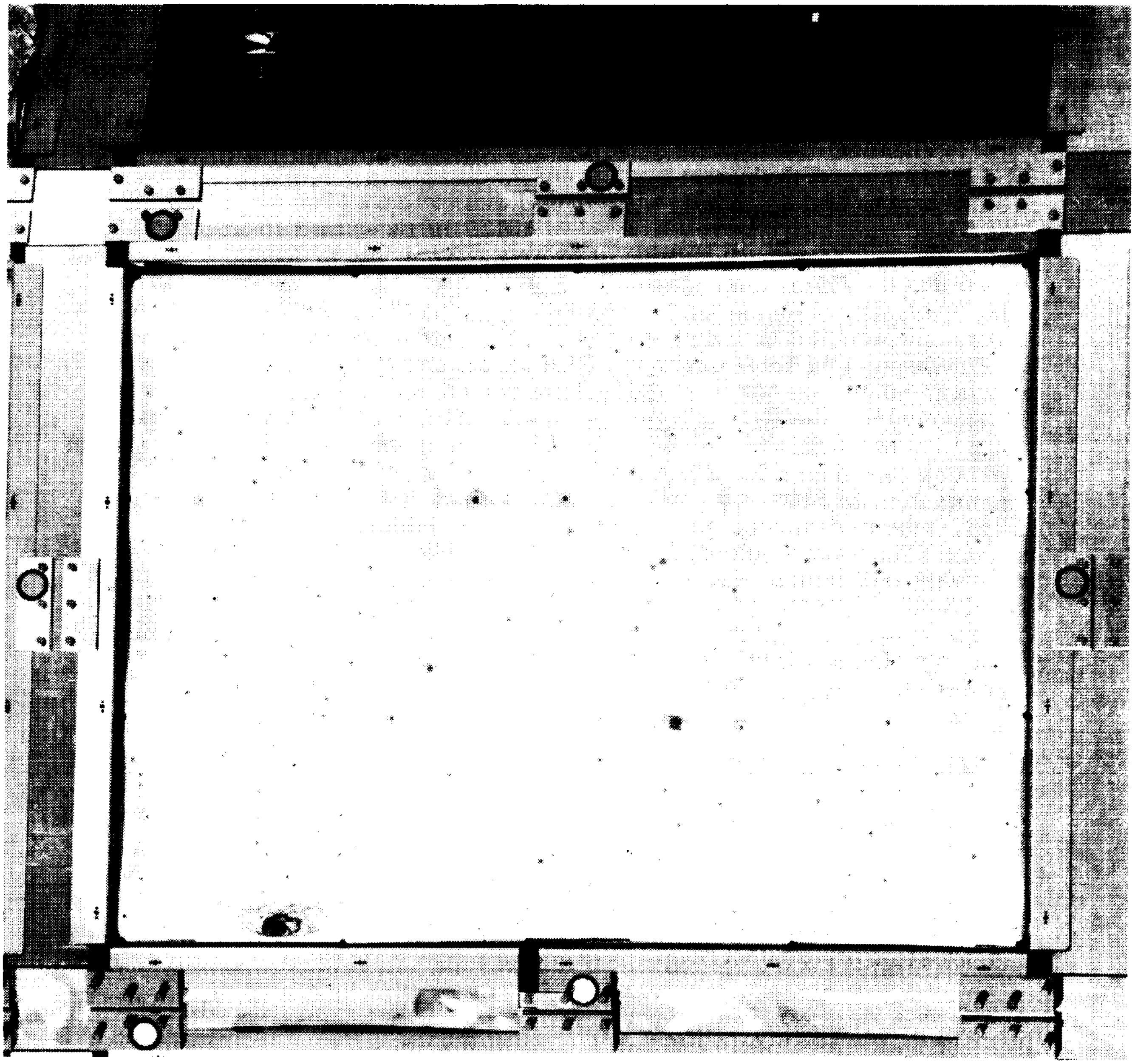


Figure 3.1-1 On-orbit photograph taken by NASA showing the thermal control blanket for tray E10.

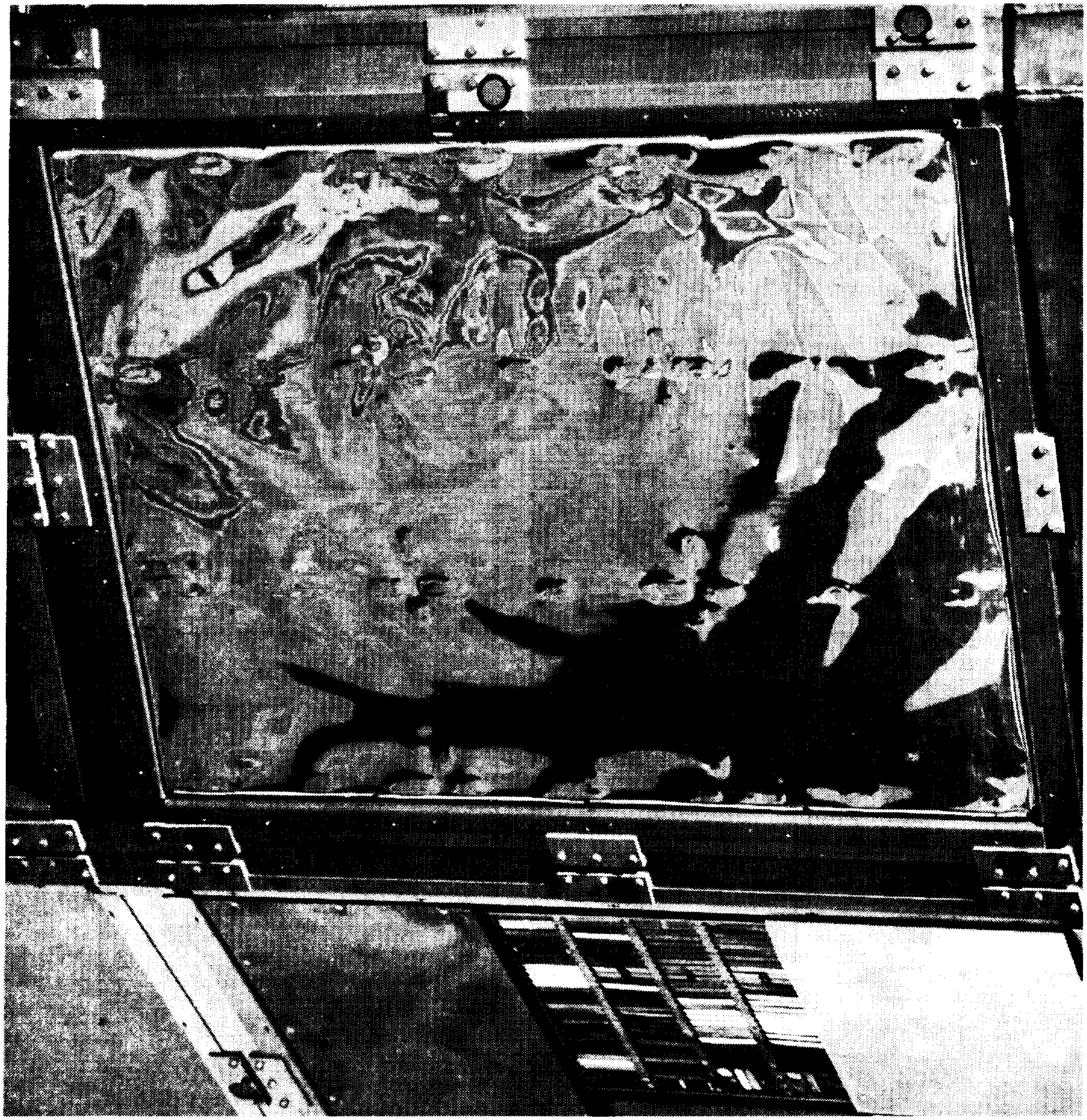


Figure 3.1-2. On-orbit photograph taken by NASA showing the thermal control blanket for tray D5.

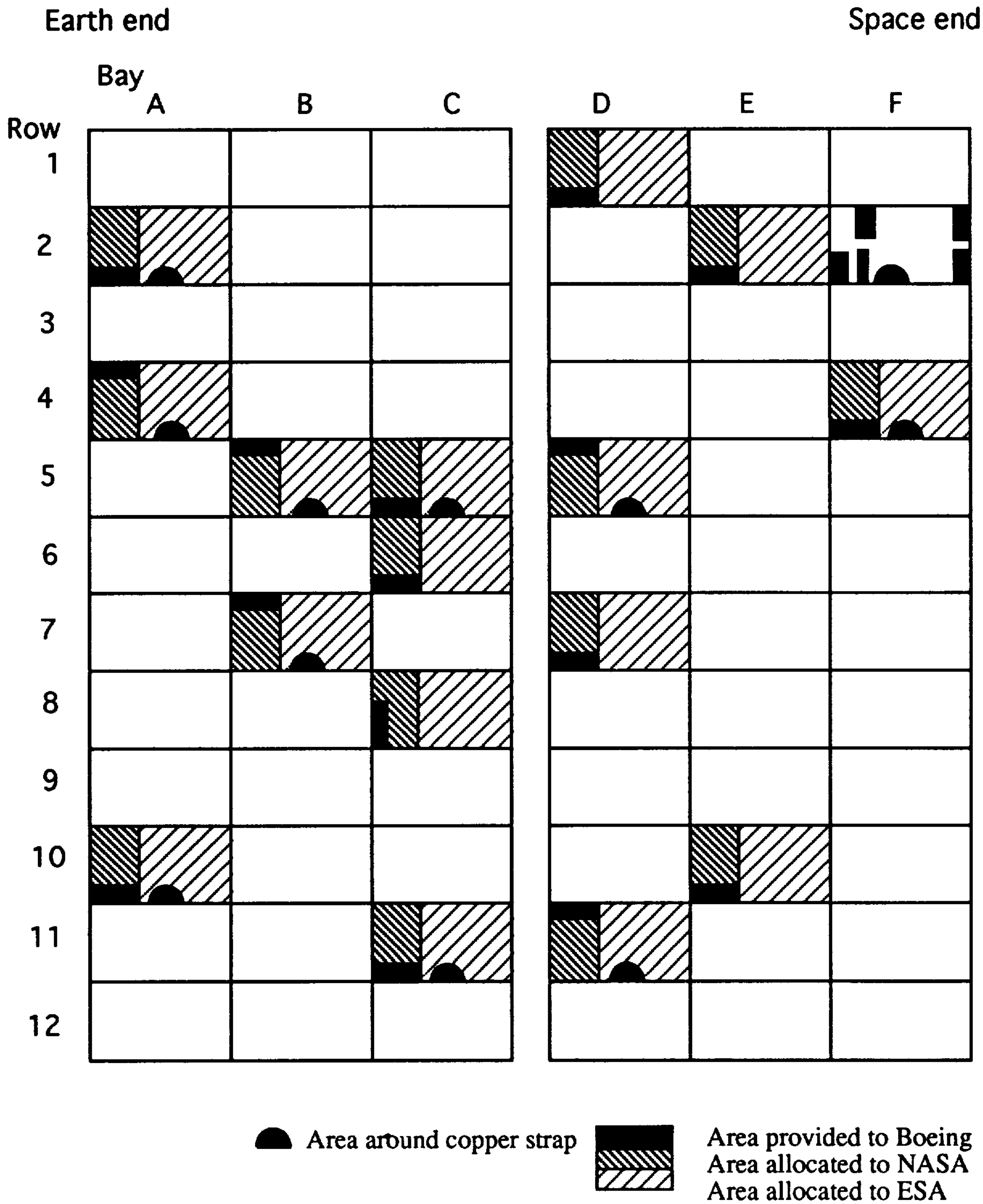


Figure 3.1-3. Locations of silverized Teflon material on LDEF and assignment to particular organizations.

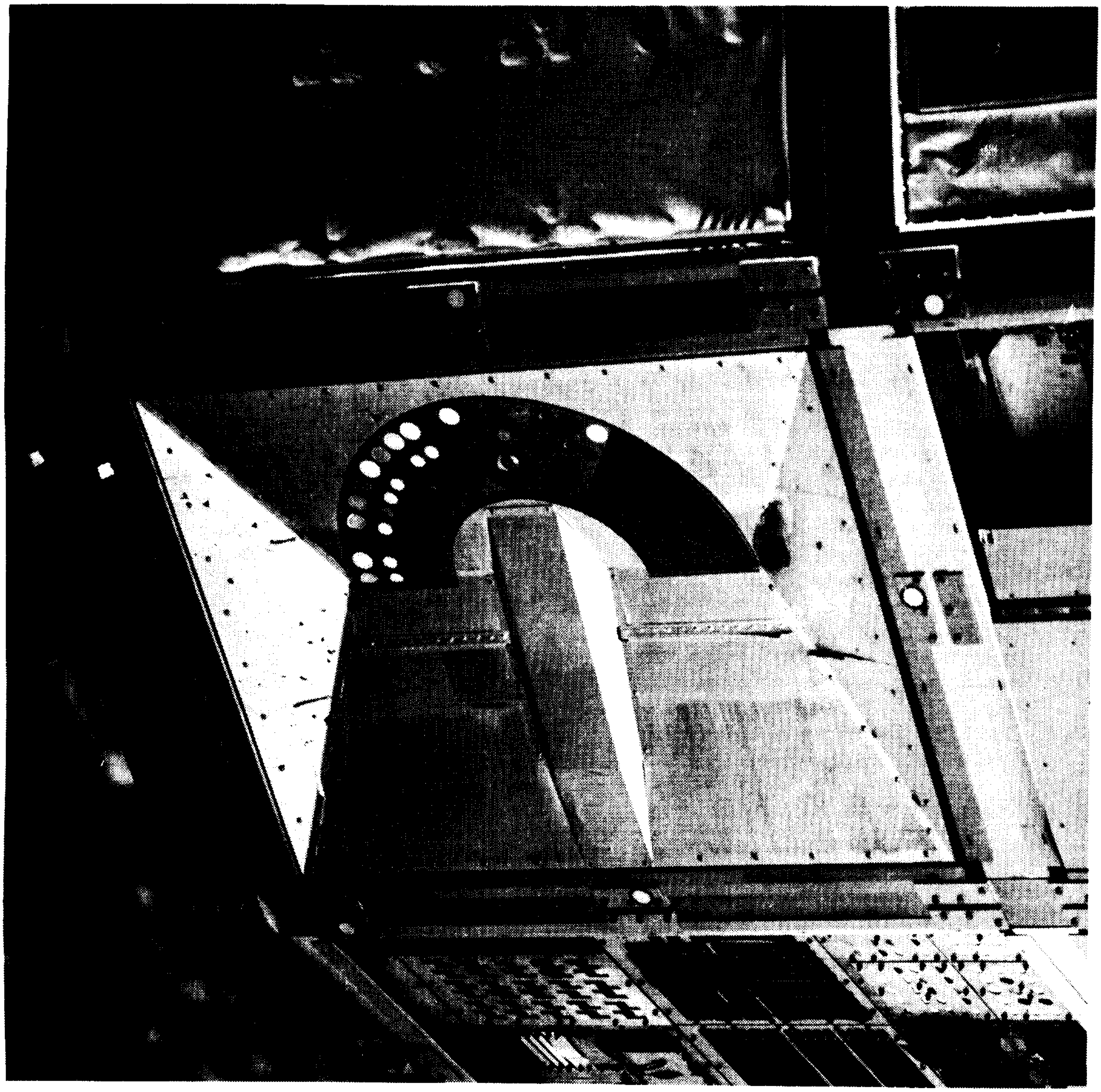


Figure 3.1-4. On-orbit photograph taken by NASA showing tray A9, containing the A0069 experiment with adhesive-backed silverized Teflon as the thermal control material.

3.2.1 Atomic Oxygen Exposures

The atomic oxygen exposures are significant for blankets on rows 7, 8, 10, and 11, the pieces from locations B8, A9, and F9, and specimens from A9 and D9. Moderate exposures, 2 to 3 times a typical shuttle dose, were received by certain space-end mounted specimens. The exposure level of blankets on row 6 is about $5 \times 10^{+19}$ atoms per cm^2. This is about the minimum fluence for which macroscopic material changes due to atomic oxygen can be visually observed. Pieces from blankets at locations D7 and D11 provided to Boeing for analysis are from the sides of these blankets nearest the ram-facing side of the spacecraft. This orientation allowed scattered oxygen atoms to reach the portions of these blankets not directly exposed to the ram atomic oxygen. Examination of tensile specimens from D7 and D11 showed that three of four specimens cut from the shielded edges of the blankets have been partially exposed to atomic oxygen. These particular specimens were not used in the recession determination.

3.2.2 Solar Ultraviolet Radiation

The equivalent Sun hours (ESH) of solar UV exposure for individual blankets from A0178 vary from about 6,400 to 12,200 ESH. Solar UV radiation of sufficiently short wavelengths has enough energy to break bonds in the FEP backbone and induce crosslinking in the polymer, making it brittle. Under simultaneous exposure, UV-induced bond breaking provides reaction sites for the atomic oxygen to attack the polymer backbone, producing volatile products which then leave, exposing new reaction sites. Similar processes occur with hydrocarbon and siloxane materials outgassed onto the FEP surface, although the oxidation of the siloxanes create less reactive silicon-dioxide films. Curved transition regions between the exposed and unexposed surfaces received a continuously varying range of solar exposures. The effects of solar ultraviolet radiation reaching the "unexposed" edges of the blankets can clearly be seen from Electron Spectroscopy for Chemical Analysis (ESCA) measurements of the regions of blankets D01 and C05. The specimen from row 3 received about 1,600 ESH, and specimens from the M0001 tape received about 14,500 ESH.

3.2.3 Thermal History

The materials on LDEF were exposed to 32,422 thermal cycles. Post-flight analysis of data provided by thermocouples in several locations on the LDEF showed actual temperatures were well within design extremes (ref. 1). The postflight solar absorptance values for each blanket were unchanged from their preflight values. Thermal emittance values were unchanged for trailing-edge blankets and changed only slightly for leading-edge blankets. The magnitudes of thermally induced stresses at the points of Velcro attachment are not known. The blankets maintained their integrity at every point of attachment. The precise temperature ranges experienced by each blanket are not known. However, since the end of flight optical properties are so similar to preflight values, temperatures were likely well within design values.

4.0 MATERIALS PROPERTY MEASUREMENTS

Survey measurements were made to characterize the end-of-life optical, mechanical, surface texture, bulk chemical properties, and thickness of the FEP film portion of the blankets and to compare these values with corresponding properties of ground control specimens. Exposure to solar radiation embrittled and weakened the FEP, but did not appreciably change the absorptance or emittance of the material. Exposure to simultaneous atomic oxygen and solar ultraviolet radiation caused recession of material, led to a slight decrease in tensile strength and percent elongation, roughened the surface, increased the diffuse component of the reflectance, and changed the emittance very slightly, but did not change the absorptance. Long-term outgassing contributions to mass loss are likely small but are, in fact, unknown. This effect should be accounted for to obtain true recession rates due to oxidation.

Survey measurements were made on samples taken from areas free from large visible impacts. This allowed assessment of the condition of the intact material. Property changes were determined as a function of exposure, but microenvironmental effects such as impact events, mechanical loads, shadowing by nearby structure, or contamination, have not been quantified.

4.1 MECHANICAL PROPERTIES

Determination of ultimate tensile strength and percent of elongation was carried out for exposed areas from each blanket, exposed areas partially overlying the velcro fasteners, and unexposed areas from selected blankets, and subsequently correlated to environmental exposure. Statistical analysis of the data shows three distinct populations within the tensile specimens: specimens from the unexposed portions of each blanket, specimens from the exposed portions of blankets from row 1 to row 6, and specimens from the exposed portions of blankets from row 7 to row 11. A high potential for indirect scattering of atomic oxygen and subsequent recession is possible for particular specimens oriented toward the leading edge but nominally shielded from exposure. Results of individual mechanical properties measurements are shown in figure 4.1-1. Figure 4.1-2 shows a summary of the average results from each location on LDEF. A 30 percent decrease in the percent of elongation at ultimate yield for specimens exposed only to UV (relative to unexposed specimens), was observed. Approximately a 4 percent decrease in the percent of elongation at ultimate yield for leading-edge specimens exposed to atomic oxygen and solar UV relative to unexposed specimens was also observed. Given the uncertainty of the measurements this is not significant.

The Ag/FEP adhesive-backed tape used to fasten MLI thermal blankets to the M0001 modules tore extensively and separated along at least two sides of every module. The likely cause is thermally induced stresses causing mechanical failure. A significant decrease in tensile properties due to damage from solar photons could also be a contributing factor. These particular surfaces received the maximum solar UV exposure of any location on the LDEF.

Figure 4.1-1. Thickness, Percent Elongation, and Load at Failure for Individual 3.50-cm^2 Specimens From Each Blanket.

Specimen	Separation (mm)		Percent Elongation	Load(lbs)	Thickness (mil) by		Tensile Strength (psi)
	Initial	Final			Cross-section	Weight	Calculated
Ground Control			250	2.2			
Ground Control			221	3.0			
D1 Exposed	13	47	262	1.4	5.2	5.08	1436
D1 Exposed	10	32	220	1.65			
D1 Unexposed	10	41	310	2.71	5.4	5.31	2677
D1 Unexposed	10	41	310	2.84			
A2 Exposed	10	34	240	1.92	5.3	5.19	1932
A2 Unexposed	10	40	300	2.39	5.1	5.09	2499
E2 Exposed	23	71	209	1.82	5.1	4.9	1903
E2 Exposed	23	73	217	1.80	5.15		1864
E2 Unexposed	23	99	330	2.96	5.2	5.09	3036
E2 Unexposed	23	98	326	2.93	5.2		3005
F2 Exposed	23	70	204	1.85	5.1	5.09	1935
F2 Exposed	23	82	257	1.92	5.0		2048
F2 Exposed	23	76	230	1.90			
F2 Exposed	23	84	265	2.00			
A4 Exposed	23	100	335	2.56	5.0		2731
A4 Exposed	23	85	270	2.08	5.3	4.88	2093
A4 Exposed			219	2.39	5.2		2451
A4 Exposed			197	2.18			
A4 Exposed			211	2.36			
A4 Exposed			285				
A4 Exposed			171	2.03			
A4 Unexposed			244	2.75		4.88	
A4 Unexposed	23	97	322	2.52			
A4 Unexposed*	23	64	178	1.78			
F4 Exposed	23	60	161	1.70		4.73	
F4 Exposed	23	63	174	1.72			
F4 Exposed			170	1.65			
F4 Exposed			133	1.72			
F4 Exposed			203	1.70	4.8		1889
F4 Unexposed			271	3.33	5.3	5.22	3351

*Specimen tore prior to test

Figure 4.1-1. (continued) Thickness, Percent Elongation, and Load at Failure for Individual 3.50-cm^2 Specimens from Each Blanket.

Specimen	Separation (mm) Initial	Separation (mm) Final	Percent Elongation	Load(lbs)	Thickness (mil) by Cross-section	Thickness (mil) by Weight	Tensile Strength (psi) Calculated
F4 Unexposed	23	95	313	2.65			
F4 Unexposed	23	100	335	2.90			
B5 Exposed	10	32	220	1.70		4.85	
B5 Exposed	10	31	210	1.81	5.2		1857
B5 Unexposed	10	44	340	2.84		5.04	
B5 Unexposed	10	44	340	3.10	5.4		3061
C5 Exposed	23	71	209	2.00	5.2	5.16	2051
C5 Exposed	23	66	187	1.91			
C5 Unexposed	23	90	291	2.56	5.1	5.09	2677
C5 Unexposed	22	93	323	2.73	5.1		2855
D5 Exposed	22	79	259	1.95	5.0	5.18	2080
D5 Exposed	23	76	230	1.93			
D5 Unexposed	22	97	341	2.60		5.20	
D5 Unexposed	24	99	312	2.98	5.3		2999
C6 Exposed	10	34	240	1.80		4.78	
C6 Exposed	10	35	250	1.72	5.3		1731
C6 Unexposed	10	41	310	2.57		4.83	
C6 Unexposed	10	41	310	2.41	5.0		2771
B7 Exposed	22	94	327	2.38	4.8	4.81	2645
B7 Exposed	22	88	300	2.31	4.7		2621
B7 Unexposed	23	84	265	3.00	5.1	5.10	3137
B7 Unexposed	23	97	322	2.69			
D7 Exposed	10	40	300	2.15	4.8	4.64	2389
D7 Exposed	10	43	330	2.35			
D7 Unexposed			260	1.86	5.0	5.0	1984
D7 Unexposed			300	2.30			
C8 Exposed			268	2.38			
C8 Exposed			257	2.31			
C8 Exposed			234	2.25			
C8 Exposed			259	2.10			
A10 Exposed			245	2.20	4.1		2862
A10 Exposed			316	1.93			
A10 Exposed*	10	38	280	1.77			

*Specimen tore prior to test

Figure 4.1-1. (continued) Thickness, Percent Elongation, and Load at Failure for Individual 3.50-cm^2 Specimens from Each Blanket.

Specimen	Separation (mm)		Percent Elongation	Load(lbs)	Thickness (mil) by		Tensile Strength (psi)
	Initial	Final			Cross-section	Weight	Calculated
A10 Exposed	10	44	340	2.01			
A10 Unexposed	10	47	370	2.78	4.7		3155
A10 Unexposed	10	43	330	2.92			
E10 Exposed	22	96	336	2.12	4.1		2757
E10 Exposed	23	94	309	2.02			
E10 Unexposed	23	95	313	2.58	5.0		2752
E10 Unexposed	24	100	317	3.00	4.8		3334
C11 Exposed	10	42	320	2.27		4.26	
C11 Exposed	10	41	310	2.20	4.6		2551
C11 Unexposed	10	40	300	2.15			
C11 Unexposed	10	43	330	2.63	5.0		2805
D11 Exposed	10	37	270	1.78	4.4	4.25	2157
D11 Unexposed	10	42	320	2.05	5.2	5.16	2103
Z-306 Backed FEP (Z-306 Layer Failure)							
D1 Unexposed			140	3.62			
A2 Exposed				3.7			
B5 Unexposed			150	4.37			
C6 Unexposed			140	4.80			
D7 Unexposed			140	3.52			
A10 Unexposed			140	3.59			
C11 Unexposed			140	4.04			
D11 Exposed				3.50			
D11 Unexposed				3.67			

Figure 4.1-1. (continued) Thickness, Percent Elongation, and Load at Failure for Individual 3.50-cm^2 Specimens from Each Blanket.

Specimens from locations near or partially over the velcro fasteners on each blanket.

Specimen	Separation (mm)		Percent Elongation	Load(lbs)	Thickness (mil)	Tensile Strength (psi)	
	Initial	Final			(by Weight)	Calculated	Measured Directly
A2 Exposed	10	28	185	1.82	5.17		-
A2-V1	10	29	186		4.81		-
A2-V2	10	25	153		5.15		-
A2-V3	10	37	270		5.19		1875
F4 Exposed	10	29	190	1.66	4.64	1908	1814
F4-V1	10	27	171	1.74	4.81	1928	1902
F4-V2	10	22	122	1.91	5.12(4.80)	2122	2087
F4-V3	10	29	191	1.77	4.80	1967	1860
B5-V1	10	25	150	1.80	5.18	1853	1858
B5-V2	10	27	151	1.75	5.23	1785	1784
B5-V3	10	27	167	1.92	5.09	2012	1724
C6-Exposed	10	27.5	175	1.88	5.02	1997	1941
C6-Unexposed	10	39	293	2.45	4.93	2651	2678
C6-V1	10	26	>155		4.97		-
C6-V2	10	30	196	1.85	4.93	2001	1837
C6-V3	10	20	>104		4.95		-
C6-V4	10	35	248	1.85	4.93	2001	2022
C6-V5	10	31	206	1.9	5.03	2015	1997
E10 Exposed	10	44	337	1.78	3.81	2492	2432
E10-V1	10	32.5	225	1.52	3.90	2079	2076
E10-V2	10	38	280	1.54	3.88	2117	2004
E10-V3	10	43	326	1.77	3.85	2452	2418
D11-V1	10	39	288	1.90	4.27	2373	2119
D11-V2	10	21	106	1.62	4.39	1968	1967
D11-V3	10	37	267	1.86	4.70(4.33)	2291	1848

Figure 4.1-2. Average Thickness, Percent Elongation, and Load at Failure for 3.50-cm^2 Specimens From Each Blanket Location.

Blanket Location	Thickness (mil) Unexp.	Thickness (mil) Exposed	Percent Elongation Unexp.	Percent Elongation Exposed	Load (lbs) Unexp.	Load (lbs) Exposed	Environment 10^{21} atoms/cm^2	ESH Solar
D1	5.31	5.08	310	241	2.77	1.52	insignificant	7400
A2	5.09	5.19	300	212	2.39	1.87	insignificant	9600
E2	5.09	4.91	328	213	2.94	1.81	insignificant	9600
F2	-	5.09	-	239	-	1.92	insignificant	9600
A4	4.88	4.88	283	267	2.63	2.25	insignificant	10500
F4	5.22	4.73	306	172	2.96	1.69	insignificant	10500
B5	5.04	4.85	340	215	2.97	1.75	insignificant	8200
C5	5.09	5.16	307	198	2.64	1.95	insignificant	8200
D5	5.20	5.18	327	244	2.79	1.94	insignificant	8200
C6	4.83	4.78	304	222	2.48	1.80	0.049	6400
B7	5.10	4.81	293	313	2.84	2.34	3.39	7100
D7	5.00	4.64	280	315	2.08	2.25	3.39	7100
C8	-	4.20	-	262	-	2.26	7.15	9400
A10	4.95	3.89	350	300	2.85	2.05	8.43	10700
E10	4.96	4.00	324	327	2.79	1.97	8.43	10700
C11	4.92	4.26	315	315	2.39	2.23	5.61	8500
D11	5.16	4.25	320	270	2.05	1.78	5.61	8500

4.1.1 Tensile Measurements

Most tensile measurements were made on a Monsanto Tensometer 500. The set of test specimens which were cut from material at the interface between areas supported by Velcro and unsupported areas were measured using a Monsanto T2000 Tensiometer. This device gives tensile readings directly. Tensile values determined using the Monsanto Tensometer 500 are from calculations from load and thickness measurements.

Specimens were cut using a 2 in-long die with a 3/16 in-wide test region. Specimens were pulled at 2 in/min until failure. Each measurement was videotaped and the applied force measured during each measurement. A few measurements were carried out with the blanket material intact. These measurements essentially determined the failure properties of the Z-306 paint layer rather than the FEP. Duplicate measurements were made on the FEP layer. A gentle separation of the FEP from the remaining layers of the blanket was achieved by starting a separation with a scalpel in the region of the tensile specimen to be held by the holder grips and then peeling the FEP from the remaining layers.

In cases where the first pair of tensile measurements from a given blanket varied considerably, a third measurement was carried out. The blanket region from C8 for which Boeing was responsible was cut at a 90° orientation relative to the other blankets. A tensile specimen oriented parallel to the specimens from other locations was cut from the blanket piece attached to the copper grounding strap on C8. No significant difference in tensile properties could be determined due to orientation.

Figure 4.1.1-1 is a plot of average post-flight mechanical properties values as functions of location on LDEF. Tensile strength data show virtually identical trends of 30 percent decrease in ultimate yield strength for specimens exposed to UV (rows 1-6), and 9 percent decrease for specimens exposed to AO and UV (rows 7-11), relative to unexposed specimens. Results of tensile measurements on specimens from the unexposed portion of each blanket show virtually no difference from results on ground-based control specimens. The decrease in tensile strength for all specimens exposed only to solar UV are the same within the uncertainty of the measurements.

An additional set of tensile specimens was run for material samples taken from areas partially over the Velcro fastening strips. Along the edge of the Velcro fastener was a potential stress point because the unbonded areas were free to flex with the thermal cycling, whereas the Velcro held portions of the blankets fairly rigid. This effect can be seen in the on-orbit photo of blanket E10. Tensile specimens for this set of measurements were pulled at 2.5 cm/min until they failed. The results suggest that material from the Velcro fastener and unsupported area interfaces may be slightly weaker relative to other exposed areas, but the uncertainty in the measurements does not allow a definite conclusion. These results are presented following the discussion of percent elongation.

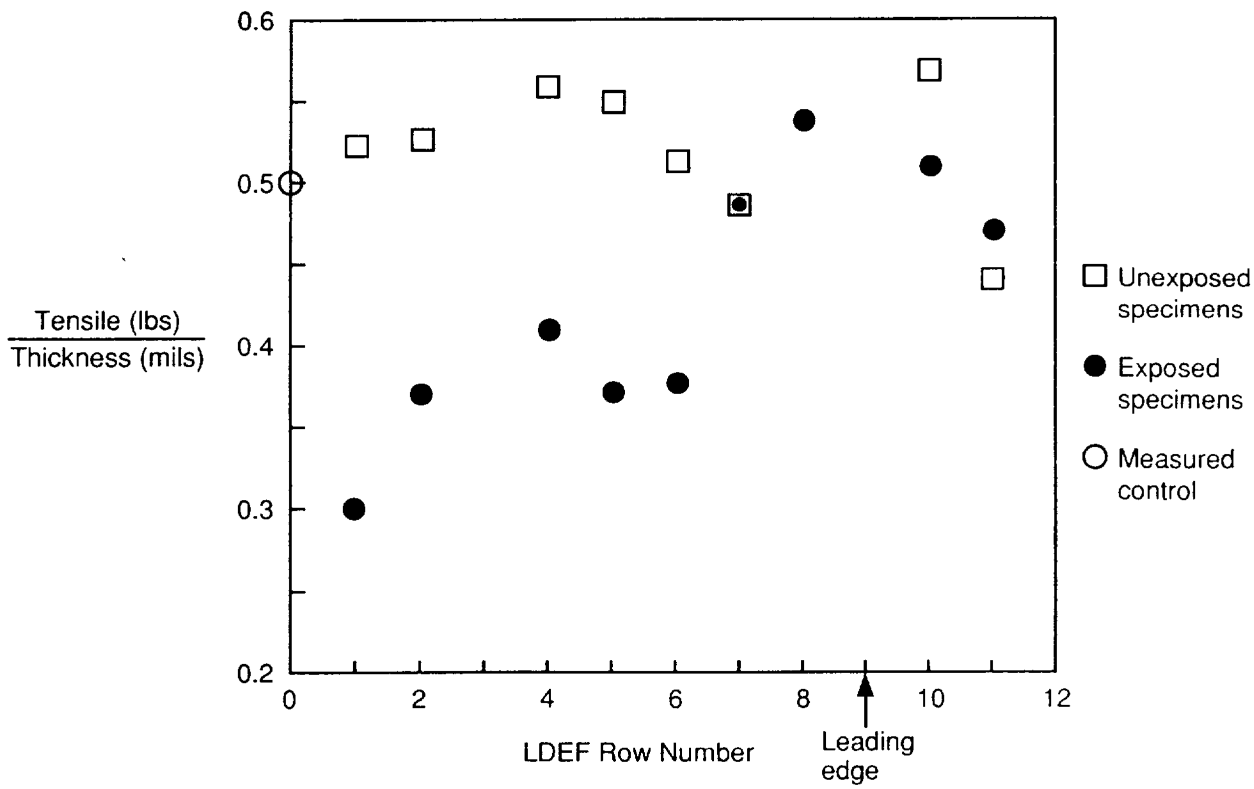


Figure 4.1.1-1 Average tensile values for exposed and unexposed specimens on each row of the LDEF

4.1.2 Percent Elongation

Individual percent elongation measurements of the exposed specimens show essentially two populations. The conclusion is that oxygen exposure is sufficient to remove most of the material altered by the UV photons, while exposure to only UV induces changes in the chemical structure and embrittlement due to crosslinking occurring in the bulk of the FEP. Results of a statistical analysis of the data, shown in figure 4.1.2-1, indicate the means of the two populations are different to a 90 percent level of confidence. While this is not a particularly high confidence level, a lower tensile strength seen in FEP exposed to AO and UV relative to unexposed specimens makes physical sense. Figure 4.1.2-2 shows the results of the percent elongation measurements plotted as a function of location on the LDEF. The average percent elongations for exposed leading edge specimens and for all unexposed specimens are not significantly different. The changes in both percent elongation and tensile strength between exposed and unexposed trailing-edge specimens are significant to greater than a 95 percent confidence level. The inference is that the degradation and cross-linking caused by the UV goes some distance into the bulk of the material while the atomic oxygen induced recession is essentially a surface effect. Correlations of the variation of elongation and tensile properties with exposure show that most of the variation in property values can be attributed to the specific AO and UV exposures. Small residual effects of long term outgassing and contamination deposition add uncertainty to these measurements. In particular, the question of whether the outgassing rate increases substantially if UV bond cleavage creates enough volatile species by chain scission, has not been answered.

Exposure	Percent Elongation	Uncertainty (+/-)	Number of Data Points
Unexposed	312	26	30
Exposed			
Rows 1-6	218	34	32
Rows 7-11	298	35	17
Exposed-Velcro			
Rows 1-6	184	42	12
Rows 7-11	249	70	6

Figure 4.1.2-1 Average values of mechanical properties of the FEP layer from the Ag/FEP blanket material for different sets of exposure conditions.

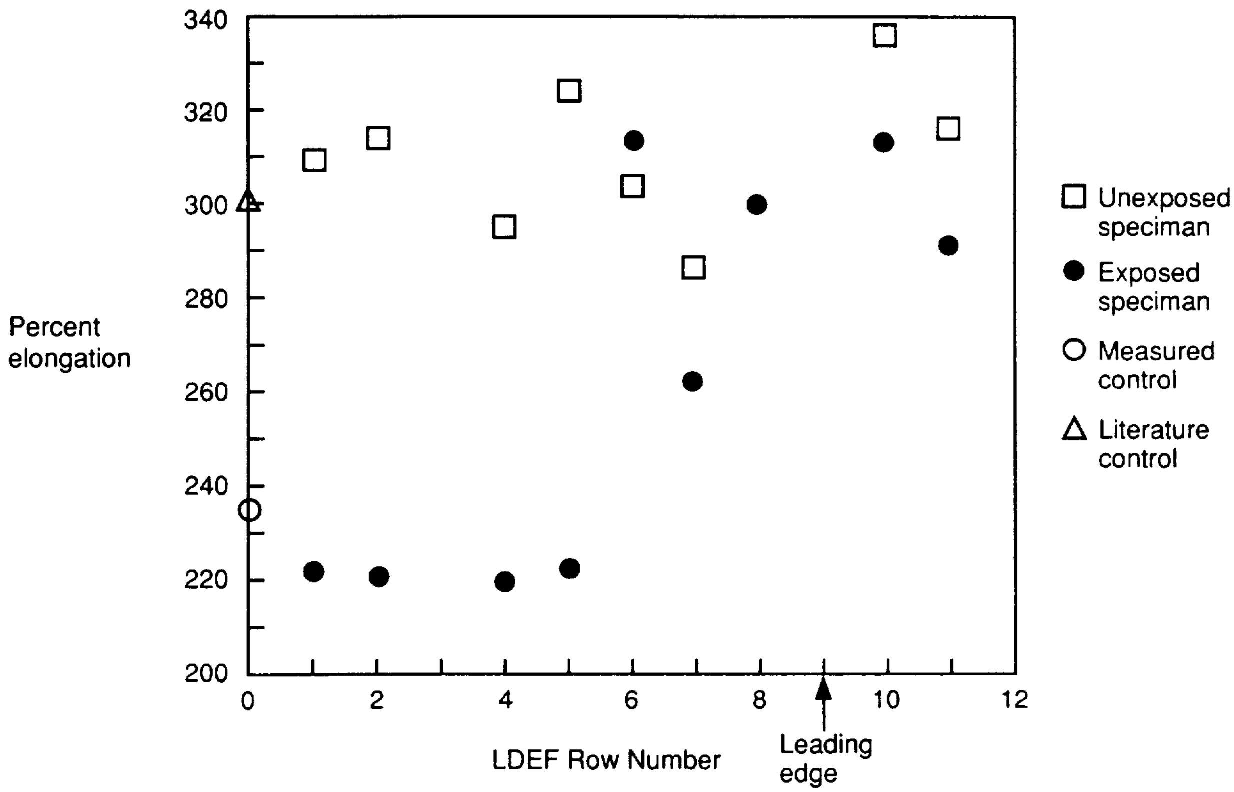


Figure 4.1.2-2 Percent elongation for exposed and unexposed specimens on each row of the LDEF.

4.1.3 Dynamic Mechanical Analyses

Dynamic mechanical analysis (DMA) showed the glass transition temperatures of the exposed and unexposed flight specimens to be essentially unchanged relative to ground control specimens. Results of individual measurements are shown in figure 4.1.3-1. Appendix B shows the curves from which the temperatures of the phase transitions of the FEP were determined. The phase transition labeled "G' beta" in figure 4.1.3-1 is related t(structural changes in the FEP. The exposed trailing-edge specimens show slight increases relative to the control values. Leading-edge specimens and certain "unexposed" trailing-edge specimens were virtually unchanged. The row 5 "unexposed" specimens also show slight increases as the "exposed" trailing-edge specimens. The reason for these anomalies is not known. However, it is possible that the "unexposed" row 5 specimens did receive substantial solar exposure. The edge of the blankets which was folded into the tray sides was rather narrow. This may also be the case for the row 7 specimen, where both the "exposed" and "unexposed" material show slight changes. DMA and differential scanning calorimetry (DSC) measurements of the melt and recrystallization temperatures, and their associated phase change enthalpies, do not show any trend with exposure. Therefore, the above interpretation of the DMA results should be considered only a suggestion. A much larger sample population is needed before a firm conclusion may be reached.

Specimen	DMA[1] G' beta transition	DMA[2] G' alpha transition	DSC[3] T_m (°C)	DSC delta H J/g	DSC[4] T_{rc} (°C)	DSC delta H J/g
Control	-110	60	265	17.9	245	-21.1
	-109	56	265	19.5	245	-18.9
			265	14.1	246	-15.5
			265	17.1	247	-17.5
F2 wide	-104	68	both F2 specimens exposed			
F2 narrow	-103	61	both F2 specimens exposed			
E2, unexposed	-105	55				
E2, exposed	-106	60				
A4, unexposed	-110	68	266	17.8	245	-22.3
A4, exposed	-103	46	266	18.6	245	-19.8
F4, unexposed	-111	60	268	20.0	247	-16.9
F4, exposed	-102	58	266	16.7	246	-14.1
C5, unexposed	-106	72				
C5, exposed	-106	56				
D5, unexposed	-101	62				
D5, exposed	-106	62				
B7, unexposed	-103	56	266	21.6	245	-20.9
B7, exposed	-107	61	265	16.2	245	-22.3
E10, unexposed	-110	63	265	17.0	246	-17.2
E10, exposed	-111	57	265	22.2	245	-17.4

1. Beta transition - second-order phase transition related to structure.
2. Alpha transition - first-order mechanical transition related to glass transition temperat (T_g).
3. T_m - melt temperature
4. T_{rc} - recrystallization temperature

Figure 4.1.3-1 DMA and DSC results of LDEF Teflon films

5.0 SURFACE ANALYSIS

Extensive measurements were made to characterize any changes in the bulk structure or surface composition of FEP due to space exposure. Electron Spectroscopy for Chemical Analysis (ESCA) measurements were used to provide surface elemental compositions and information about oxidation states of the surface species. Surface texturing by atomic oxygen was demonstrated by the use of Scanning Electron Microscopy (SEM).

The end of mission chemical properties of the FEP blanket layer were determined using Fourier Transform Infrared Reflecance (FTIR), visible, ultraviolet and infrared reflectance, ESCA, Secondary Ion Mass Spectroscopy (SIMS), attenuated total reflectance (ATR), and Raman measurements. Visible and infrared diffuse reflectance measurements were made to evaluate the material performance as a thermal control system. In each case a selection of blanket materials was examined to attempt to detect differences which relate to the variations in the actual environmental exposures. For each property of interest, a complete survey of all blankets was carried out only if measurements on a representative subset of the blankets showed variation from location to location.

5.1 ESCA

5.1.1 Elemental Analysis

Figure 5.1.1-1 contains data for percent carbon, fluorine, oxygen, and silicon detected on the surface of the blankets. The survey and carbon 1s spectra, and related data, are included in appendix C. These data show primarily the effects of contamination. Oxygen content on all unexposed surfaces and trailing edge exposed surfaces shows large variations. The oxygen content is correlated with observed silicone content. For leading edge exposed surfaces, the elemental compositions by mole percent are relatively constant. These surfaces do not have the silicon containing contaminant films due to the continual erosion by atomic oxygen. These observations are consistent with the SIMS data discussed below. The small percent oxygen observed on leading edge exposed specimens is due to partially oxidized species remaining on the surface. Figure 5.1.1-1 also includes results from ESCA data obtained by Dr. Carol Hemminger of The Aerospace Corporation. A summary of this data is discussed in the proceedings of the First LDEF Post-Retrieval Symposium (Ref. 2). The results of detailed individual measurements, upon which the reported averages are based, were provided by Dr. Hemminger. Figure 5.1.1-2 shows the relative amounts of CF, CF_2, and CF_3 functional groups on the surface of different FEP specimens. This figure includes results from two specimens taken from the trailing edge of the LDEF and reflown on the Space Shuttle, Flight STS-046, Energetic Oxygen Interaction with Materials-III (EOIM-3) experiment. The subsequent Space Shuttle flight left these specimens with increased silicon-based contamination relative to their post-LDEF flight condition. The atomic oxygen exposure on the STS-046 flight removed some of the hydrocarbon-based contamination from these specimens. The EOIM-3 results show a considerable reduction in the relative amount of CF_3 functional group relative to the CF_2 and CF groups due to atomic oygen exposure relative to their end of LDEF mission values.

Plots of changes in the relative amounts of these functional groups with environmental exposures are shown in figures 5.1.1-3 and 5.1.1-4. Figure 5.1.1-3 shows an apparent increase in both the fraction of CF and CF_3 peaks relative to CF_2 groups in the FEP with exposure to solar UV on LDEF. The data is extremely scattered however, and some values are influenced by the subsequent atomic oxygen exposure on EOIM-3. Figure 5.1.1-4 shows the effect of atomic oxygen exposure on FEP. The solar UV-damaged FEP has been oxidized and removed by atomic oxygen exposure. The scattered values along the yaxis shows that UV has become the dominant environmental consideration for exposures of $<10^{21}$ atoms/cm^2.

The increase in the CF and CF_3 groups relative to the CF_2 group occurs as the UV ruptures bonds in the polymer backbone, causing cross-linking and effectively increasing branching in these polymers. By contrast, the atomic-oxygen-induced recession of the material on exposed leading-edge surfaces removes the UV-altered material; the results show the expected ratios for undamaged FEP.

5.1.2 Bonding States

ESCA measurements have been used to indicate the oxidation state of the elements on the surface and infer the relative amount of crosslinking which has occurred. Carbon 1s spectra from ESCA measurements on leading edge specimens show the expected peaks characteristic of FEP. The carbon 1s ESCA peaks for CF, CF_2, and CF_3 groups are at approximately 289.8, 292.0, and 294.1 eV, respectively. Similar spectra taken on trailing edge specimens show a broader energy spread with peaks, and peak intensities characteristic of major structural rearrangements. Spectra from blanket C6 show the competition between rearrangement of bonds due to UV induced bond rupture and recession due to reaction with atomic oxygen. The peaks associated with rearrangement are present in this spectrum, but they are compressed relative to trailing edge specimens. Measurements on specimens from the curved transition regions of blankets D01 and C05 show a wide variation in relative intensities of the different carbon 1s peaks of each specimen. The specific locations were chosen to represent a range of UV exposures.

Location	C	F	O	Si
Ground Reference	34	66		
	31.4	67.8	0.81	
D1	39.4	57.3	2.90	
D1 Unexposed	44.9	12.1	31.0	9.50
A2	42.1	52.3	5.6	
A2	38.5	33.3	19.4	7.2
A2 Unexposed	42.1	21.6	25.3	8.9
E2	38.6	45.0	13.6	2.7
E2	25.8	8.6	43.3	22.3
F2	41.6	43.8	13.3	
F2	38.4	44.7	12.3	2.9
E3 (1400 ESH)	38.3	52.6	5.5	3.6
E3-3 minute sputter	46.3	52.8	0.2	0.7
A4	46.5	21.1	23.3	6.4
F4	42.1	51.8	6.0	
F4 Unexposed	23.8	5.00	47.2	24.0
B5	43.2	52.1	4.8	
B5 Unexposed	46.1	11.2	31.0	8.7
C5	42.5	52.2	5.3	
D5	40.5	54.7	4.8	
D5 Unexposed	31.1	26.1	30.1	12.6
C6	38.0	59.8	2.2	
C6 Unexposed	51.0	13.8	27.6	4.4
B7	33.6	65.0	1.4	
B7 Unexposed	30.3	41.0	28.7	
B7 Unexposed	20.1	1.4	50.3	25.6
D7	34.1	64.6	1.2	
D7 Unexposed	19.0	9.5	45.0	26.5
C8	34.8	63.5	1.7	
A10	34.7	63.9	1.4	
A10 Unexposed	33.0	65.1	2.0	
E10	33.9	64.6	1.5	
E10 Unexposed	14.9	1.5	51.8	31.8
C11	34.1	64.6	1.3	
C11 Unexposed	24.2	42.5	21.0	12.3
D11	35.5	63.5	0.96	
D11 Unexposed	22.5	15.4	42.6	19.4
Specimens Reflown on EOIM-3 STS-046 Space Shuttle Experiment				
B5	32.5	62.9	6.4	1.5
B5 Unexposed on LDEF	27.1	48.2	16.0	8.3
F2	32.5	61.7	3.9	2.0

Figure 5.1.1-1 Average percent elemental composition of FEP surfaces-exposed and unexposed, including contaminated and uncontaminated specimens

Location	C	F	O	Si
Averages From The Aerospace Corporation measurements				
Ground Reference	27	73	0.1	
D1	31	66	2	0.2
F2	24	4	51	19
F2 (values vary greatly)	37.5	31.5	24	6
A2	35	57	6	0.7
B3	31.5	51.5	9.8	5.9
A4	34	62	3	0.1
F4	44	19	28	6
F4	36.5	60	4.5	0.3
B5	36	59	4	
C5	34	61	4	
D5	37	58	5	
C6	30	68	1.5	
B7	27	72	0.6	
D7	27	73	0.6	
C8	28	71	0.6	
D9	26	73	0.8	0.1
F9	26.5	73	0.7	0.15
A10	27	73	0.6	0.1
C11	27	72	0.4	
D11	26	73	0.3	

Figure 5.1.1-1 (Continued) Average percent elemental composition of FEP surfaces-exposed and unexposed, including contaminated and uncontaminated specimens

Location	Exposure	CF (289-289.5 eV)	CF_2 (292 eV)	CF_3 (294 eV)
Measurements at Boeing				
Reference	Ground Exposure	4.05	89.67	6.28
D1	exposed	7.64	43.34	19.29
D1	exposed	8.93	43.95	18.09
E2	exposed	15.17	22.12	16.24
B5	exposed	13.42	29.81	20.14
C5	exposed	19.52	30.39	18.79
C5	exposed	7.92	28.16	20.36
C6	exposed	5.67	59.22	18.59
D7	exposed	2.90	78.42	11.79
C8	exposed	2.98	84.63	8.34
F9	exposed	2.77	79.74	8.18
F9	exposed	2.49	79.79	7.88
A10	exposed	7.06	73.71	10.66
C11	exposed	3.38	86.13	10.49
D11	exposed	2.23	79.68	7.53
E3	exposed (canister, ~1400 hrs)	35	157	56
F2	exposed	126	144	72
F2	exposed	126	119	48
C5	exposed	10.94	27.34	17.78
LDEF/EOIM-3 Specimens				
B5	exposed	252	253	45
B5	exposed	256	288	54
B5	unexposed	220	251	64
B5	unexposed	223	238	36
F2	exposed	260	292	51
F2	exposed	254	254	50

Figure 5.1.1-2 Summary of results of carbon 1s ESCA measurements showing the relative amounts of CF, CF_2, and CF_3 functional groups from each FEP specimen.

Location	Exposure	CF (289-289.5 eV)	CF_2 (292 eV)	CF_3 (294 eV)
Specimens around curved portion of selected blankets				
D1	Distance from center of curve (mm)			
	7 unexposed	4.02	13.29	7.35
	5 unexposed	1.45	12.78	4.87
	3 unexposed	3.52	10.78	4.57
	1 unexposed	2.25	8.82	4.78
	0 (center)	1.39	11.38	5.54
	1 exposed	2.10	9.75	3.77
	3 exposed	4.50	9.08	6.92
	5 exposed	3.92	13.32	12.67
	7 exposed	7.29	21.85	16.62
	11 exposed	8.96	40.49	13.77
	15 exposed	5.68	50.68	13.92
C5				
	13 unexposed	12.62	27.71	10.33
	3 unexposed	6.75	14.67	10.77
	1 unexposed	8.77	13.96	10.19
	0 (center)	10.36	13.46	10.80
	1 exposed	7.96	12.29	10.52
	3 exposed	9.58	13.00	11.57
	15 exposed	9.38	25.02	18.35
Data obtained by The Aerospace Corporation				
Reference		9	78	10
Reference		9	74	9
Reference		6	83	8
Reference		6	88	5
Reference		4	90	5
D1	exposed	13	49	19
F2	exposed *	-	2	-
F2	exposed*	6	8	13
F2	exposed*	16	7	8
F2	exposed*	16	16	14
F2	exposed	17	26	20
A2	exposed	14	32	20
A2	exposed	15	29	21
B3	exposed	5	46	13
B3	exposed*	-	31	8
F4	exposed	6	31	23
F4	exposed	10	31	20
F4	exposed*	19	7	9
F4	exposed*	18	7	7
F4	exposed*	17	6	7
F4	exposed	12	27	17
F4	exposed	10	30	21

* indicates sample with 5% or greater Si contamination

Figure 5.1.1-2 (Continued) Summary of results of carbon 1s ESCA measurements showing the relative amounts of CF, CF_2, and CF_3 functional groups from each FEP specimen.

Location	Exposure	CF (289-289.5 eV)	CF_2 (292 eV)	CF_3 (294 eV)
Data obtained by The Aerospace Corporation				
A4	exposed	16	33	24
A4	exposed	16	32	24
B5	exposed	7	27	22
B5	exposed	16	33	23
B5	exposed	16	27	22
C5	exposed	17	31	23
D5	exposed	6	29	20
C6	exposed	12	53	19
C6	exposed	12	55	20
B7	exposed	7	79	11
D7	exposed	6	80	11
C8	exposed	7	79	9
D9	exposed	3	89	7
F9	grazing incidence AO	6	81	11
F9	exposed	4	89	6
A10	exposed	4	81	9
C11	exposed	4	86	8
D11	exposed	4	86	8

Figure 5.1.1-2 (Continued) Summary of results of carbon 1s ESCA measurements showing the relative amounts of CF, CF_2, and CF_3 functional groups from each FEP specimen.

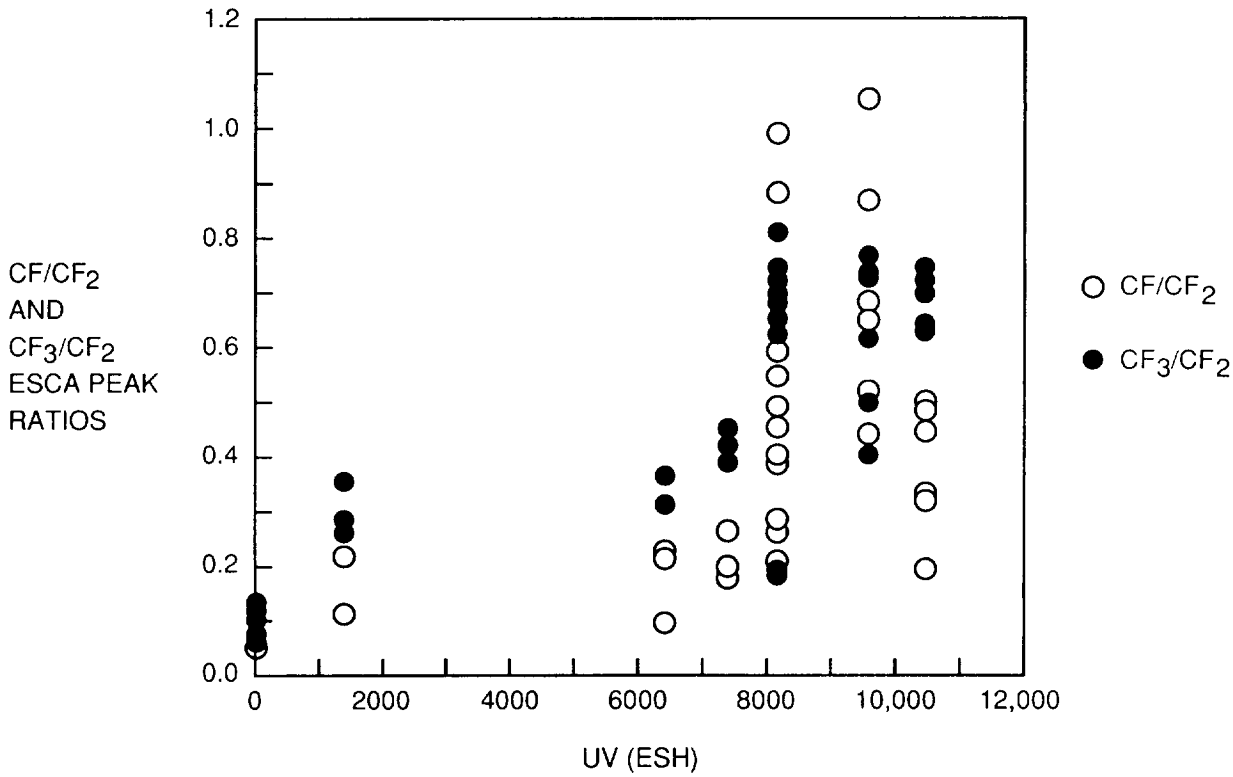


Figure 5.1.1-3 Ratio of CF and CF_3 to CF_2 peaks as a function of hours of solar exposure

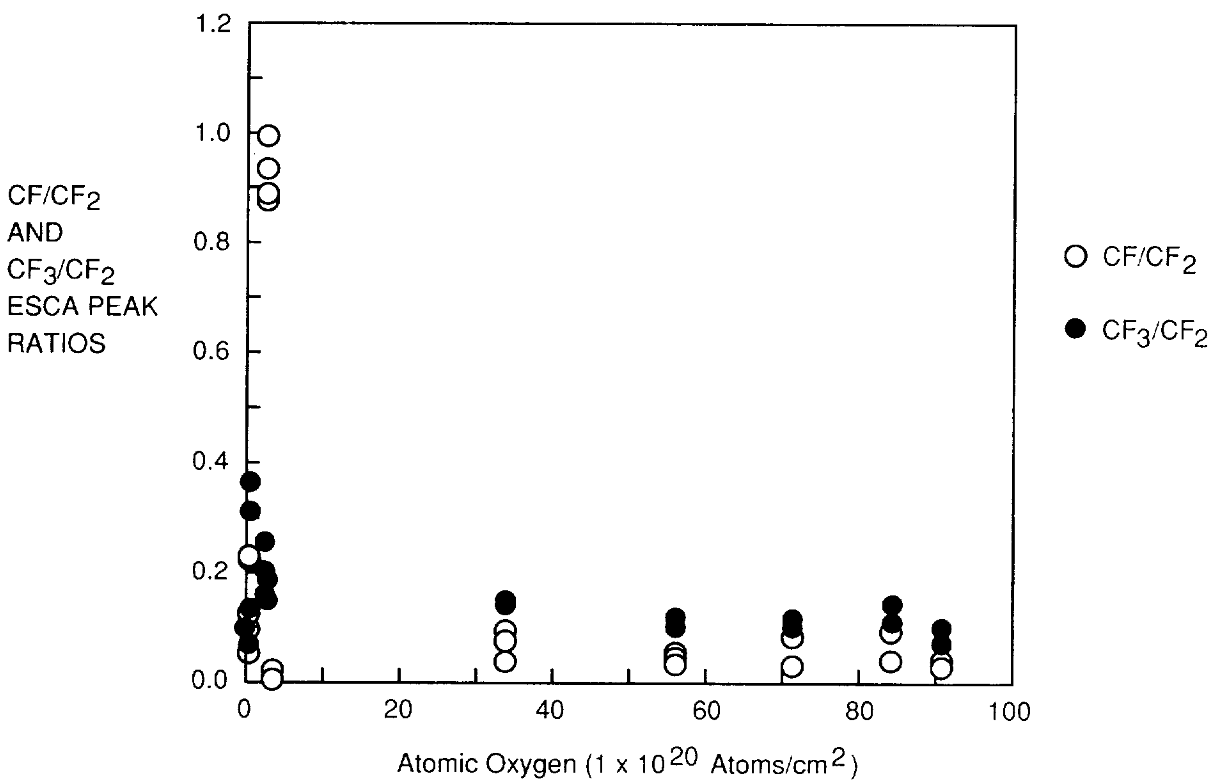


Figure 5.1.1-4 Ratio of CF and CF_3 to CF_2 peaks as a function of atomic oxygen exposure

5.2 SECONDARY ION MASS SPECTROSCOPY(SIMS)

Secondary ion mass spectroscopy (SIMS) of leading edge-exposed specimens shows the major FEP peaks. This data is shown in appendix D. SIMS on leading-edge unexposed specimens show more complex spectra which are attributed to detection of surface hydrocarbon and silicone films. The SIMS from both exposed and unexposed specimens from trailing edge blankets reflect the presence of fluorocarbon and contaminants. The exposed specimens show considerably different intensity ratios in the major peaks relative to exposed specimens from the leading-edge surfaces and ground control specimens. This indicates some rearrangements of bonds within the FEP due to solar radiation. The peaks clearly associated with FEP are present. For exposed specimens from the trailing edge, additional peaks appear at almost every mass between 25 and 250 amus. Certain of these peaks are attributed to deposited hydrocarbons and siloxane materials which have outgassed onto the blankets.

5.3 DIFFERENTIAL SCANNING CALORIMETRY

Differential scanning calorimetry (DSC) measurements were carried out on eight FEP specimens from LDEF and three standard FEP specimens with distinctly different molecular weight distributions. No difference was detected between the LDEF specimens as a result of the differing exposures. Eight Ag/FEP blanket specimens were analyzed to determine if the molecular weight of the FEP film had changed as a result of exposure to the space environment. The specimens were exposed and unexposed materials from trays C6, C11, D11, and B5. DSC has been used as a method for molecular weight determination for PTFE (polytetrafluoroethylene) (ref. 3). It was found that the greater the molecular weight, the smaller and broader the crystallization peak. The quantitative relationship between the number average molecular weight of PTFE and the heat of crystallization is

$$M_n = 1.3 \times 10^7 \, dH_c^{-5.16},$$

where M_n is the number average molecular weight and dH_c is the heat of crystallization in J/g. Based on this work, DSC was explored as a possible avenue for also determining molecular weight changes in the FEP film. The DSC results for the eight FEP specimens are shown in figure 5.3-1.

Specimen	dH_m(melting) J/g	dH_c (crystallization) J/g
C6 exposed	15.2	-5.84
C6 unexposed	14.5	-6.62
C11 exposed	15.3	-7.14
C11 unexposed	15.2	-6.71
D11 exposed	12.9	-6.7
D11 unexposed	12.8	-6.7
B5 exposed	13.9	-6.7
B5 unexposed	14.6	-8.6

Figure 5.3-1 Results of DSC measurements on selected FEP specimens

The DSC results did not reveal any significant differences in the heats of crystallization. To determine if any relationship exists between the number average molecular weight and heat of crystallization for FEP, three standards of different molecular weights (Teflon FEP 100, 140, and 160) were obtained from the DuPont Co. FEP 100 has the smallest number average molecular weight and FEP 160 has the highest. The DSC results for these standards are shown in figure 5.3-2. The results did not give any clear indication that this property could be used to estimate molecular weight changes and this investigation was not continued.

Specimen	dH_m J/g	dH_c J/g
FEP 100		
Run 1	15.8	16.9
Run 2	16.0	16.3
FEP 140		
Run 1	18.0	13.2
Run 2	15.7	14.3
FEP 160		
Run 1	16.7	17.6
Run 2	17.6	14.9
Run 3		16.8

Figure 5.3-2 Results for DSC measurements of DuPont FEP Teflon

5.4 SCANNING ELECTRON MICROSCOPY

SEM images show featureless surfaces with occasional particles of contamination on trailing-edge specimens. Specimens exposed to atomic oxygen showed the characteristic roughening of the surfaces seen on hardware previously returned from the Solar Max mission and materials experiments on Space Shuttle flights. The textured surface features point generally in the direction of the impinging atomic oxygen. This effect can be seen clearly in the transition region of blankets where a short distance provides about a 90° range of angles. These SEM images and a survey of additional SEM images from representative surfaces are included in appendix E. The orientation and degree of texturing changes dramatically with rapid change of angle. Measurements have been carried out on sections of selected specimens from rows 7, 9, and 11 to determine the thickness change as a function of angle. Erosion patterns in areas protected on-orbit by particulate contaminates show increased oxidation where enhanced scattering has occurred from the sides of the protected area. The surface texture is also smoother because the texturing associated with a well defined impingement angle is suppressed. Atomic oxygen reaches the surface from direct impingement and from secondary scattering off the side of the shielded area of the material.

6.0 SPECTROSCOPIC ANALYSES

FTIR and Raman spectroscopic measurements were obtained for a representative set of specimens. These spectral data are also shown in appendix D. Fourier-transform infrared results showed virtually identical spectra for all blankets examined. Solar absorptance values calculated from UV/visible and infrared reflectance measurements were virtually unchanged from pre-flight values and essentially constant from locations all around the spacecraft. Slight changes from pre- to post-flight thermal emittance values were only observed for exposed, leading-edge specimens. The diffuse component of reflectance, in both the visible and infrared regions of the spectrum, was increased for specimens exposed to atomic oxygen relative to trailing-edge surfaces. This result was demonstrated by measurements of normal reflectance and from bidirectional reflectance distribution function (BRDF) measurements. The BDRF results also show an anisotropy in the diffuse reflectance due to the highly oriented pattern of the surface texture of atomic-oxygen-exposed samples.

Attenuated total reflectance measurements show the expected FEP peaks and additional peaks associated with the surface contaminants. Raman spectroscopy measurements on exposed surfaces of blanket specimens from many LDEF locations, made at the Perkin-Elmer Corporation, each show transitions at identical wavelengths, indicating that the bulk chemical structure of the FEP is largely unchanged by the exposure. The background continuum increases with atomic oxygen exposure. This increase is attributed to a fluorescence phenomenon, but the cause has not been determined.

6.1 OPTICAL PROPERTIES

Measurements of solar absorptance, thermal emittance, and diffuse reflectance were carried out using both normal reflectance and BRDF techniques.

6.1.1 Absorptance and Emittance

Slight changes in the emittance were observed as a function of angle from ram. One specimen was cut from the exposed area of each blanket and three measurements of absorptance and emittance were made on each of these specimens.

Soon after the LDEF was returned to Earth and de-integrated in the SAEF-II building at KSC, selected specimens of Ag/FEP were cut for optical measurements at several laboratories. This resulted from the need to know the magnitude of lab-to-lab variations of optical measurements. Initial visual inspections of the LDEF at NASA-Kennedy Space Center indicated that some spacecraft thermal control materials and coatings were significantly affected by their 69-month low Earth orbit exposure. Because of the importance to space missions such as Hubble Space Telescope and Space Station, the LDEF MSIG formed an AdHoc Thermal Control Properties Group to quickly obtain representative data on the silverized Teflon material. Solar absorptance and thermal emmittance data were obtained for a selected set of material specimens in several international laboratories. Figure 6.1.1-1 describes the materials chosen for this set of measurements. Figure 6.1.1-2 provides the data obtained by various laboratories on the same specimens. The data for each set of specimens is listed in chronilogical order of testing and retesting. Retests of selected materials at both Boeing and MSFC show no significant differences in comparison with original measurements. The JSC measurements were made on a portable instrument and are not directly comparable with results from other labs. There are some differences in the diffuse standard results between the various labs, the reason for this variation is not known.

A later, more extensive comparison between ESA and Boeing results on the silverized Teflon showed optical measurement differences within instrument uncertainties (ref. 4). Figures 6.1.1.-3 through -5 show the results of these series of solar absorptance and thermal emittance measurements made at Boeing during 1990 and 1991. These optical property measurements show that the absorptance of Ag/FEP was essentially unchanged by the flight. Small changes observed in emittance are correlated with exposure to atomic oxygen. Figure 6.1.1-6 shows results of measurements on Ag/FEP made at the European Space Technology Engineering Center (ESTEC). These measurements and the Boeing measurements are in essential agreement.

Exposed Specimens

Specimen Designations: C-8/1 to C-8/5

Specimens cut from blanket in NASA-KSC SAEF 2 clean room and mounted on aluminum alloy discs with contact cement.

Specimens exposed on LDEF tray F2

Materials

~0.005 in- thick FEP Teflon

~1600Å silver, vapor deposited on the Teflon

~200Å to 400Å Inconel, vapor deposited on silver

~0.002 in-thick Z-306

Specimen Designations: F2/1 to F2/5

Specimens cut from blanket in NASA-KSC SAEF II clean room and mounted on aluminum alloy discs with contact cement.

Ag/FEP Control Specimens

Specimen Designations: SEEDS 1 to SEEDS 5

Control strip cut from Ag/FEP blanket in 1984 and stored at Park Seed Co., South Carolina, in plastic (polyethylene) bag until 1990. Specimens cut from blanket in NASA-KSC SAEF 2 clean room and mounted on aluminum alloy discs with contact cement.

Specular Standard Specimens(Ag/FEP)

Specimen Designations: Ag/FEP 1 through Ag/FEP 5

History of Sample: Prepared by Sheldahl Co. on July 15, 1975; Run #2723; Serial #102723

Maintained in dessicated storage at NASA-LaRC until distribution to test labs following LDEF retrieval.

Diffuse Standard Specimens(S13/GLO)

Specimen Designations: S13/GLO 1 through S13/GLO 5

Materials: S13/GLO thermal control paint on aluminum alloy disc

History of Sample: Prepared by IITRI on March 22, 1983, batch I-012 for NASA-LaRC coatings experiment on LDEF. Maintained in storage at LARC since preparation until distribution to test labs following LDEF retrieval.

Figure 6.1.1-1 Selected control materials and silverized Teflon from LDEF chosen for interlaboratory evaluations.

Specimen Set #1

Laboratory	F2-1, Specular	C8-3 Diffuse	α/ε SEEDS Expt., Control	Ag/FEP, Specular Std.	S13/GLO, DiffuseStd.
NASA MSFC	0.075/0.811	0.069/0.783	0.072/0.810 0.076/0.806	---	0.199/0.901
LaRC	0.063/0.801	0.055/0.773	0.055/0.804 0.068/0.801	0.048/0.800	0.157/0.894
GSFC	0.077/0.802	0.074/0.779	0.072/0.802	0.073/0.799	0.198/0.901
Boeing-(MSIG)	0.07/0.81	0.07/0.78	0.06/0.81	0.10/0.81	0.13/0.81
NASA-MSFC (retest)	0.087/0.804	0.079/0.775	0.081/0.805	0.077/0.804	0.214/0.893
JSC	0.11/0.81	0.17/0.78	0.11/0.81	0.11/0.80	0.19/0.89
LeRC	0.081/0.807	0.064/0.780	0.068/0.805	0.072/0.806	0.157/0.894

Specimen Set # 2

Laboratory	F2-2, Specular	C8-2 Diffuse	α/ε SEEDS Expt., Control	Ag/FEP, Specular Std.	S13/GLO, Diffuse Std.
Boeing (MSIG)	0.068/0.796	0.067/0.774	0.063/0.801	0.061/0.796	0.120/0.890
NASA MSFC	0.075/0.806	0.067/0.786	0.072/0.808	0.070/0.801	0.196/0.901
GSFC	0.075/0.798	0.073/0.780	0.071/0.802	0.076/0.800	0.184/0.901
LaRC	0.058/0.800	0.052/0.785	0.053/0.805	0.049/0.800	0.146/0.898 0.147/0.895
Boeing-(MSIG) (retest)	0.06/0.80	0.06/0.78	0.07/0.80	0.07/0.80	0.12/0.89
USAF WRDC	0.059/0.805	0.046/0.785	0.054/0.810	0.056/0.851	0.156/0.901
NASA JSC	-/0.79	-/0.78	-/0.81	-/0.80	-/0.89

Figure 6.1.1-2 Interlaboratory evaluation of Ag/FEP thermal control blankets, α and ε measurements.

Specimen	Individual Emittance Measurements		
F2	0.804	0.801	0.805
B5	0.805	0.802	0.806
E2	0.800	0.798	0.802
C8	0.777	0.775	0.779
A10	0.776	0.773	0.778
B7	0.789	0.787	0.791
A4	0.803	0.802	0.805
E10	0.779	0.777	0.780
D1	0.804	0.803	0.806
C6	0.799	0.798	0.801
D1 UN	0.806	0.803	0.804
C6 UN	0.801	0.797	0.799
D11	0.786	0.783	0.785
C11	0.787	0.785	0.785
F4	0.792	0.790	0.790
C5	0.807	0.805	0.808
D7	0.793	0.792	0.795
A10 UN	0.803	0.802	0.805
D5	0.803	0.802	0.806
A2	0.804	0.803	0.807
Ground Control	0.810	0.801	0.80

Specimen	Individual Absorptance Measurements		
F2	0.063	0.062	0.062
B5	0.061	0.062	0.062
E2	0.067	0.067	0.068
C8	0.062	0.063	0.061
A10	0.070	0.067	0.072
B7	0.059	0.059	0.060
A4	0.088	0.087	0.087
E10	0.072	0.073	0.070
D1	0.061	0.062	0.063
C6	0.060	0.061	0.061
D1 UN	0.062	0.064	0.063
C6 UN	0.063	0.063	0.067
D11	0.063	0.066	0.063
C11	0.062	0.067	0.068
F4	0.063	0.064	0.064
C5	0.064	0.065	0.065
D7	0.060	0.060	0.061
A10 UN	0.061	0.062	0.061
D5	0.062	0.063	0.062
A2	0.073	0.074	0.072
Ground Control	0.072	0.063	0.07

Figure 6.1.1-3 Thermal emittance and solar absorptance data from measurements at Boeing on 10/3/90.

Specimen Location	Solar Absorptance	Emittance
D7, area 1	0.07	0.80
D7,area 2	0.06	0.80
D7, UN, area 1	0.06	0.80
F2, sample 2	0.07	0.81
F4, sample 4	0.07	0.81
A2, teflon side	0.07	0.81
A2,Black paint side	0.95	0.90
C5, teflon side	0.07	0.81
C5,Black paint side	0.95	0.91
C8,teflon side	0.08	0.78
C8,Black paint side	0.95	0.90
C11, teflon side	0.07	0.79
C11,Black paint side	0.95	0.90

Figure 6.1.1-4 Optical characterization data measured at Boeing during the summer of 1990.

Specimen Location	Solar Absorptance	Emittance
A2	0.06	
A2	0.15	
A10	0.05	
A10	0.06	0.05
A2	0.05	
A2 UN	0.05	
A10 UN	0.07	
B5 UN	0.04	
C6 UN	0.06	
D1	0.04	
D1, SPECIMEN A	0.09	
D1, SPECIMEN B	0.05	0.80
D7	0.04	
D7 UN, SPECIMEN A	0.04	0.80
D7 UN, SPECIMEN B	0.04	
D11 UN	0.07	
A2	0.09	
A10	0.06	
C5	0.05	
C6	0.05	
C11	0.05	
D1	0.04	0.80
D7	0.04	0.79
D11	0.04	
F4	0.04	0.80
Ground Control	0.06	0.79
C6 UN	0.04	0.80
C6	0.04	0.80
C11 UN	0.05	0.80
C11	0.07	0.79
C11 (impact)	0.06	
D11	0.04	0.78
B5 UN	0.04	0.80
B7	0.04	0.81
B7 UN	0.04	0.79
C8 (contaminated)	0.24	0.84
C11	0.05	
D11 UN	0.05	0.78
F2 UN	0.06	0.81
D7	0.03	
F2	0.05	0.80

Figure 6.1.1-5 Optical properties measurements made at Boeing during the spring of 1991.

Individual Normal Emittance Measurements on Silver Backed FEP

Location (row number)								
1	0.802	0.796	0.789					
2	0.790	0.796	0.795	0.800	0.801			
4	0.795	0.796	0.798	0.799	0.802	0.803		
5	0.794	0.796	0.798	0.799	0.800	0.801	0.802	
6	0.792	0.796	0.799					
7	0.789	0.790	0.791	0.794	0.782	0.783		
8	0.771	0.774	0.775					
10	0.786	0.770	0.761	0.774	0.775	0.776		
11	0.776	0.777	0.781	0.784	0.788			
Ground control	0.789	0.792	0.793	0.794	0.796	0.797	0.798	0.799

Individual Solar Absorptance Measurements on Silver Backed FEP

Location (row number)			
1	0.073		
2	0.082	0.087	
4	0.079	0.082	
5	0.068	0.075	0.079
6	0.071		
7	0.068	0.073	
8	0.084		
10	0.087	0.102(sample delaminated)	
11	0.079	0.082	
ground control	0.077		

Figure 6.1.1-6 Data from "Preliminary Investigations Into UHCRE Thermal Control Materials" Levadou, Froggatt, Rott, and Schneider, LDEF First Post Retrieval Symposium, Orlando, Fl, June 1991 (ref. 5).

6.1.2 Diffuse Reflectance

Diffuse reflectance in the UV to visible to near infrared range of wavelengths is extremely low for trailing-edge specimens and increases as a function of atomic oxygen exposure, until, for specimens closest to the leading edge, the diffuse component is the major portion of the total reflectance in the visible region of the spectrum. The percent diffuse reflectance for 400, 700, and 1100 nm, chosen to be in the region of the spectrum exhibiting the largest change in the diffuse reflectance, is reported in figure 6.1.2-1. These wavelengths are representative of the amount of change in the visible region of the spectrum for specimens exposed to atomic oxygen. Diffuse reflectance measured in the IR region of the spectrum between 4000 and 5000 wave numbers show only a slight increase for specimens exposed to atomic oxygen relative to specimens exposed only to solar radiation. Trailing-edge specimens show relatively flat profiles at about 5 percent transmission. Slightly increased transmission of leading-edge specimens may be due to small decreases in the thickness; however, these curves are also essentially flat. Blanket A4 specimens are different from other trailing edge specimens, exhibiting large increases in diffuse reflectance between 4000 and 2500 wave numbers. The scuff plate at location A3 extends past the end of the spacecraft and is partially exposed to ram oxygen. Oxygen scattered from the scuff plate surface is the likely cause of the anomaly. The periodic opening and closing of the hardware of experiment A0187 on tray A3 could have caused significant perturbation in the oxygen atom scattering patterns.

Location	400 nm	700 nm	1100 nm
Ground Control	15.5	7	6
D1	13	3	2
A2	16	6	3.5
E2	19	7.5	3.5
A4	75	96	89
F4	18	6.5	3
C5	13.5	3.5	2.5
C6	15.5	5.5	4
B7	18	11	6
D7	29.5	11.5	5
C8	86	67.5	37.5
A10	84	91	64
C11	82	57.5	29.5
D11	59.5	32	15.5

Figure 6.1.2-1 The percent diffuse reflectance of Ag/FEP at selected wavelengths for specimens from different LDEF locations

6.2 BRDF

Bidirectional reflectance distribution function (BRDF) measurements, shown in figures 6.1.2-2, -3, and -4, also show increased diffuse reflectance for specimens exposed to AO. BRDF measurements on samples from C11 and A10 are asymmetric. This is caused by the orientation of the samples with respect to the incident laser beam and the directionality of the roughened surfaces of these specimens. The measurements on specimen C08 were taken with a TMA Technology uscan, fixed--wavelength (670-nm) source portable BRDF device. The specular reflectance measurements are made with a detector 25° off surface normal to the specimen. The measurements on C8 were taken starting at an unexposed location and then moving through locations which received a range of atomic oxygen exposures up to the full amount received by row 8. The BRDF detectors are at two fixed locations with respect to the surface being analysed. The remaining BRDF data for the specimen from C8 are shown in figure 6.1.2-5. The two sets of angles (0°,0° and 50°,180°) indicate the detector positions for each measurement, normal to the surface and 50° from normal, respectively.

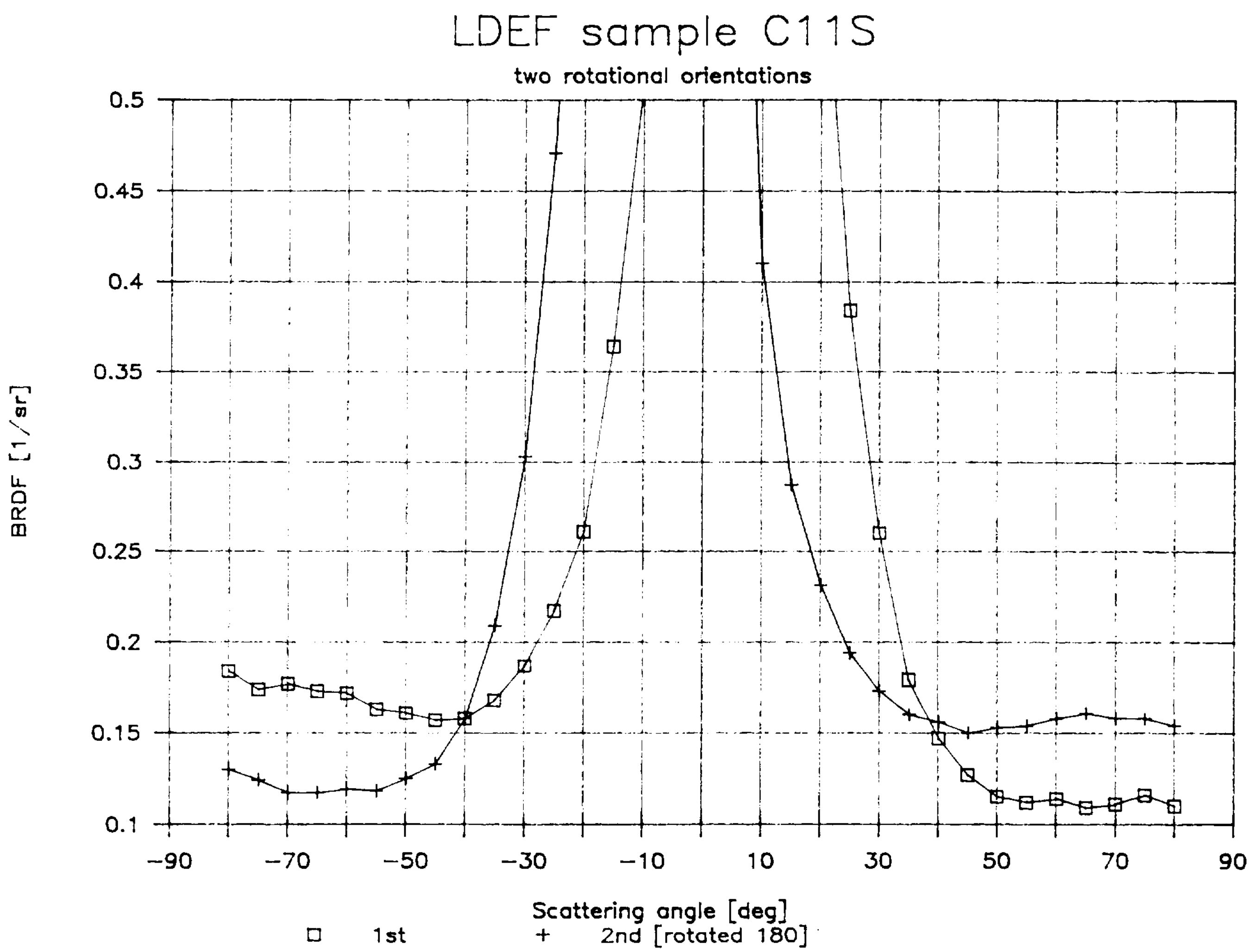


Figure 6.1.2-2 BRDF measurements on exposed specimens from blanket C11 with the sample at two different orientations with respect to the incident light beam.

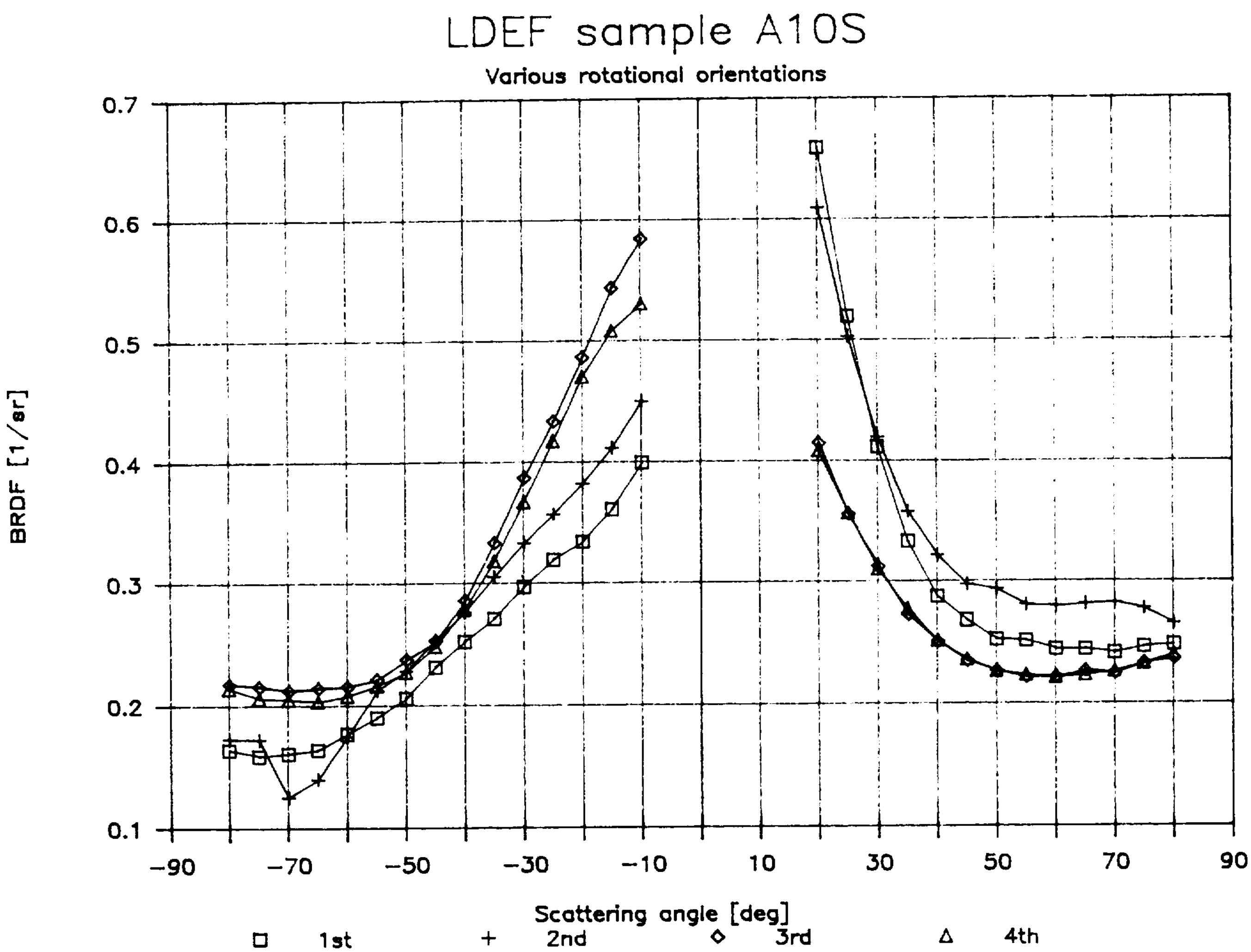


Figure 6.1.2-3 **BRDF measurements on exposed specimens from blanket A110 with the sample at four different orientations with respect to the incident light beam.**

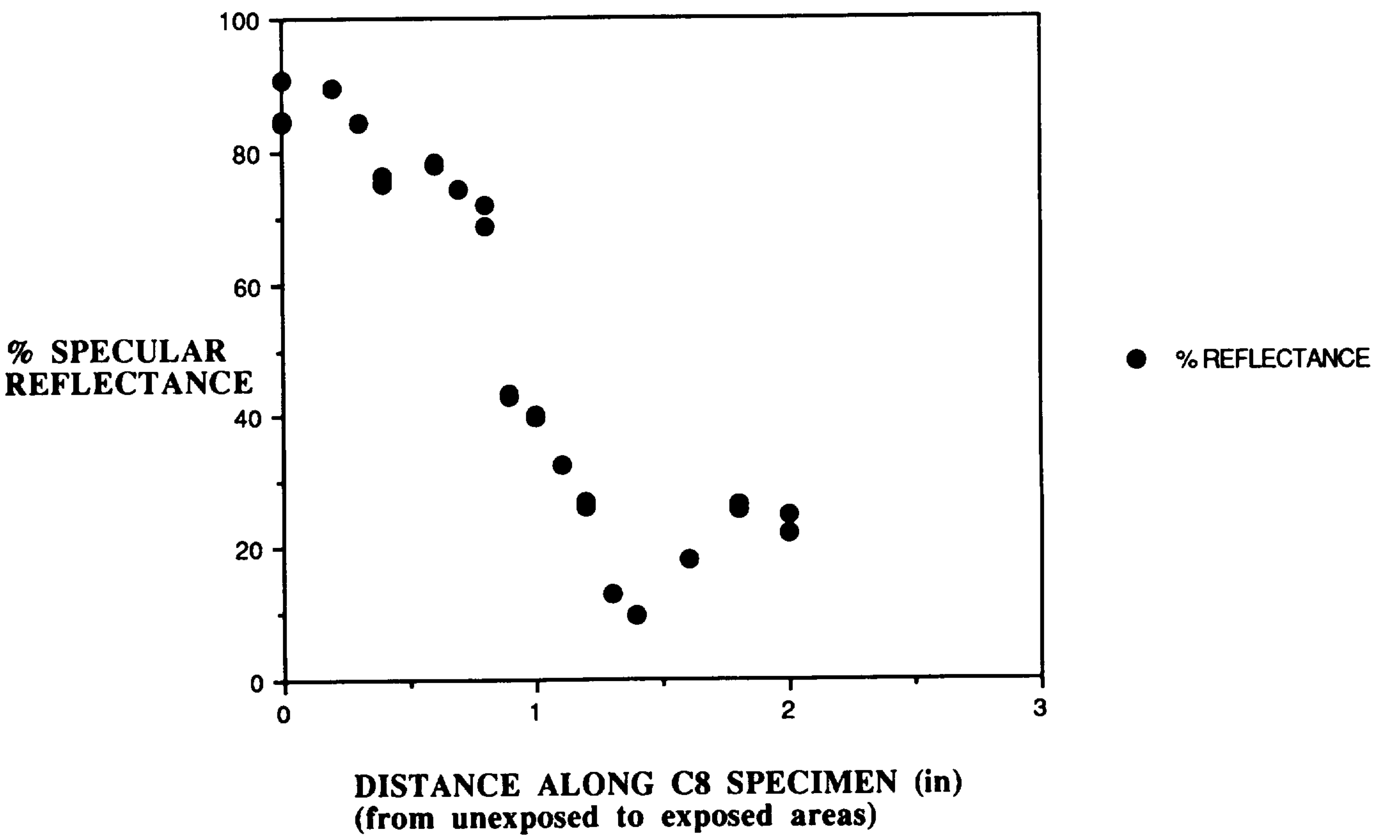


Figure 6.1.2-4 % specular reflectance as a function of location on C8 silverized Teflon specimen.

Distance (in.)	BRDF (0°,0°)	BRDF (50,°180°)
2.0	0.453	0.062
2.0	0.453	0.062
2.0	0.417	0.059
1.8	0.431	0.058
1.8	0.436	0.058
1.6	0.536	0.062
1.6	0.533	0.062
1.4		0.069
1.4		0.069
1.3	0.542	0.064
1.3	0.542	0.064
1.2	0.406	0.052
1.2	0.460	0.052
1.1	0.392	0.049
1.1	0.392	0.049
1.0	0.278	0.035
1.0	0.278	0.035
0.9	0.088	0.012
0.9	0.089	0.012
0.8	0.051	0.009
0.8	0.048	0.009
0.7	0.025	0.005
0.7	0.027	0.005
0.6	0.021	0.005
0.6	0.021	0.005
0.4	0.022	0.007
0.4	0.022	0.007
0.3	0.028	0.006
0.3	0.028	0.006
0.2	0.023	0.004
0.2	0.023	0.004
0.0	0.028	0.005
0.0	0.028	0.005
0.0	0.018	0.004

Figure 6.1.2-5 BRDF measurements at selected locations along a silverized Teflon specimen from blanket C8.

7.0 RECESSION RATES

Material recession was determined by taking photomicrographs of cross-sections of the FEP, by obtaining areal weights for exposed and unexposed pieces from the same blanket, and by examining surface areas around particulate contaminants which had blocked small areas of FEP from direct attack by atomic oxygen. The average recession rates determined by several independent researchers are consistently higher for the LDEF specimens in comparison with values determined from short-term Space Shuttle flights (ref. 15). Recession rates for silverized Teflon are based on mass measurements. Using values from rows 7, 8, 10, and 11, the average recession rate was determined to be $0.34 +- 0.13 \times 10^{-24}$ cm^3/atom. These measurements give recession rate values for each row which are identical to within the uncertainty of the measurements. Results of measurements based on the mass loss of tensile specimens punched from the same tool are reported in figures 7.01-1 through -3. Measurements were taken to determine elongation of the FEP layer of the Ag/FEP blanket and the load at failure using fixed area tensile specimens. Subsequent to failure each individual specimen was weighed. Two separate balances were used for two sets of specimens. The average area determined for specimens in one set was 3.47 cm^2 and 3.52 cm^2 for the other set. Areas were determined by punching templates from paper and cardboard, weighing, and comparing with weights of known(larger) areas of the same materials. An average value of 3.50 cm^2 was used for subsequent calculations. These measurements show recession rates greater than those determined by cross section (discussed in section 7.1). These mass loss measurements show clearly that populations of unexposed specimens from the trailing-edge and leading-edge are different.

There are potential "edge effects" which influence the degradation rate of the FEP. The stress on the material at the edge is different from that in the center of the blankets. Material stretched around a radius is under tension. At the very least, this alters the structure of the near surface material. A second effect, especially in curved transition regions between exposed and unexposed areas, is scattering of oxygen from the tray edge back onto the blanket. In each case the curved transition region provides a continuous range of exposure angles over about 90°. Both these effects should increase the erosion rate. Evidence for this includes SEM images of nominally unexposed areas of leading edge blankets which show surface roughening and slightly lower masses for tensile specimens from unexposed leading-edge blanket locations relative to trailing-edge unexposed blanket locations.

Blanket Location	Mass (g) (number of specimens) Unexposed Specimens	Exposed Specimens
D1	0.10052 (2)	0.09775 (3)
A2	0.09636 (2)	0.09815 (3)
E2	0.09627 (3)	0.09288 (3)
F2	-	0.09640 (6)
A4	0.09230 (3)	0.09241 (6)
F4	0.09886 (3)	0.08949 (4)
B5	0.09541 (2)	0.09173 (2)
C5	0.09636 (2)	0.09754 (3)
D5	0.09834 (3)	0.09806 (3)
C6	0.09142 (3)	0.09042 (3)
B7	0.09645 (3)	0.09096 (3)
D7	(0.09463*)	0.08773 (3)
C8	(0.09463*)	0.07951 (3)
A10	0.09370 (3)	0.07361 (5)
E10	0.09378 (3)	0.07568 (2)
C11	0.09308 (2)	0.08069 (3)
D11	0.09764 (1)	0.08043 (3)

*Used average of leading edge unexposed specimens for these values; no completely unexposed specimen was punched for these blanket locations.

Figure 7.0-1. Average mass for 3.47 cm^2 specimens from each blanket location.

Blanket	Masses of Individual Specimens(g)					
D1	0.09612	0.09886	0.09827			
A2	0.09871	0.09763	0.09812			
E2	0.08751	0.09531	0.09582			
F2	0.09723	0.09703	0.09672	0.09671	0.09391	0.09681
A4	0.08928	0.09540	0.09549	0.09381	0.08696	0.09351
F4	0.08753	0.09023	0.08989	0.09029		
B5	0.09322	0.09023				
C5	0.09301	0.09958	0.10004			
D5	0.09862	0.09775	0.09781			
C6	0.08884	0.08960	0.09281			
B7	0.09113	0.09001	0.09173			
D7	0.08700	0.08656	0.08962			
C8	0.07939	0.08030	0.07884			
A10	0.07300	0.07231	0.07456	0.07378	0.07440	
E10	0.07653	0.07482				
C11	0.07809	0.08097	0.08302			
D11	0.08091	0.07910	0.08128			

1993 Measurements

A2	0.09927		
A2-V	0.09244	0.09908	0.09974
F4	0.08925		
F4-V	0.09242	0.09235	
B5-V	0.09963	0.10049	0.09777
C6 Exposed	0.09651		
C6 Unexposed	0.09469		
C6-V	0.09559	0.09480	0.09518
E10	0.07336		
E10-V	0.07493	0.07459	0.07399
D11-V	0.08208	0.08427	

Figure 7.0-2. Masses of individual 3.47-cm^2 FEP specimens from exposed area of each blanket.

Blanket	Masses of Individual Specimens(g)		
D1	0.09970	0.10134	
A2	0.09811	0.09460	
E2	0.09992	0.09771	0.09118
A4	0.09277	0.09182	
F4	0.09697	0.09935	0.10026
B5	0.10001	0.09080	
C5	0.09807	0.09464	
D5	0.09649	0.09910	0.09944
C6	0.09257	0.09045	0.09123
B7	0.09668	0.09401	0.09865
D7	0.08981	0.08893	
A10	0.09481	0.09493	0.09136
E10	0.09808	0.09210	0.09117
C11	0.09336	0.09279	
D11	0.08788	0.09764	

Figure 7.0-3. Masses of individual 3.47-cm^2 FEP specimens from unexposed area of each blanket.

7.1 AVERAGES

Photomicrographs of cross-sections of selected blanket samples were used to determine thickness of the FEP layer. Thickness differences between exposed and unexposed portions of a given blanket have been used to determine recession rates of FEP under the different exposures. No thickness loss of FEP under exposure to only solar radiation was detected. Recession is observed for atomic oxygen exposed surfaces. The thickness of each blanket was not determined prior to flight. ESTEC did conduct post-flight thickness measurements along the entire length of one flight blanket (E02) and a ground control blanket (ref. 2). These measurements provide a good example of the magnitude of the thickness variations in the as manufactured material. The specification for this material allows a variation at least as great as the magnitude of the changes being determined. To overcome this lack of information, and to minimize the effects of the observed thickness variation, the thickness of exposed area of a given blanket was compared to the thickness of nearby unexposed material from the same blanket. Recognizing the possibility of indirect scattering of atomic oxygen onto supposedly unexposed areas, thickness measurements of exposed and unexposed areas of blankets from the trailing edge and unexposed areas from the leading edge were determined. This value is 5.2 mil with a standard deviation of 0.13 mil. Areal weights were also measured for selected specimens from both leading and trailing edges. Results of these measurements are shown in figures 7.1-1 and -2. These measurements confirmed that atomic oxygen exposed FEP was in general thinner than unexposed FEP, but the results showed considerable variation. Distances measured from the top of contaminant protected areas to the exposed, textured surface provided confirmation of the recession determined from the photomicrographs.

Data from photomicrograph cross-sections (200X).

Location	FEP Thickness (mil)	Overall blanket thickness
D7 UN	5.0-5.1	7.0-7.7
D7 (1)	4.7-4.9	6.0-7.4
D7 (2)	4.8-4.9	6.5-7.3
F2 (sample 2)	5.1-5.2	8.2-9.0
F2 (sample 4)	5.3-5.4	7.1-8.0

Data from photomicrograph cross-sections (500X).

Location	FEP Thickness (mil)
A2	5.3
A2 UN	5.1
A10	4.1
A10 UN	4.7
B5	5.2
B5 UN	5.4
C6	5.3
C6 UN	5.0
C11	4.6
C11 UN	5.0
D1	5.2
D1 UN	5.4
D7	4.8
D7 UN	5.0
D11	4.4
D11 UN	5.2

Figure 7.1-1. Recession measurements taken during summer 1990

Location	FEP layer	Paint layer
B7 (1)	4.8	1.9-2.2
B7 (2)	4.7	1.8-2.2
B7 UN	5.1	2.2-2.5
C5	5.2	2.7-2.9
C5 UN(1)	5.1	2.4-2.9
C5 UN (2)	5.1	2.7-3.1
D5	5.0	2.2-2.5
D5 UN	5.3	1.7-2.0
A4	5.0	1.2-1.6
A4 UN (1)	5.3	1.4-1.8
A4 UN (2)	5.2	1.2-1.4
F4	4.8	2.2-2.7
F4 UN	5.3	3.3-3.6
E10	4.1	2.2-2.6
E10 UN (1)	5.0	2.6-2.8
E10 UN (2)	4.8	2.7-2.9
E2 (1)	5.1	2.5-2.8
E2 (2)	5.1-5.2	2.7-2.9
E2 UN (1)	5.2	1.8-2.2
E2 UN (2)	5.2	1.9-2.1
F2 (wide)	5.1	3.1-3.5
F2 (narrow)	5.0	2.9-3.5

Figure 7.1-2. Thickness of FEP blanket specimens (mils) as determined by photomicrograph cross-sections, data from 3/27/91

7.2 MEASUREMENTS ON CONTINUOUS ANGLE CHANGES

A continuous range of angles with respect to the ram direction is available for the curved areas of blankets at the bend between the exposed surface and the tucked edges. For particular blankets along certain sides, the ram direction is traversed by the curved region. Selected FEP specimens were taken from the side of blanket B7 toward row 6, from near the B7 copper grounding strap attachment location, and from blanket D11. These specimens were cross sectioned through the curved region and the thickness of each was measured as a function of distance from the edge of each blanket. SEM images were obtained at known distances from the edge of the blanket 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. The advantage of using these specimens is that the thickness measurements are made at locations within 2 to 3 cm of one another. This minimizes the uncertainty in thickness arising from variations in the as-manufactured thickness of the blanket. The nominal angle from ram of the exposed portion of each blanket, and the fact that the unexposed portions are at approximately right angles to the exposed portion, were also used to help define the angles. This method resulted in angles from ram being defined within a few degrees. From recession measurements on exposed areas of blankets from rows 7, 8, 10, and 11, and the calculated atomic oxygen fluences as a function of angle from ram, it can be shown that atomic oxygen attack 90° from ram causes a thickness loss of less than 1 micron. For each specimen the location toward the unexposed edge where the thickness loss is measured to be less than one micron is assumed to be 90° from ram. The location of the blanket surface normal to ram is defined to within about 1 mm along the blanket specimen using only the SEM images. An additional consideration in the definition of angle is that the radius of curvature was not necessarily constant throughout the transition region from unexposed to exposed blanket surfaces; therefore, the angle change per unit linear distance may not be constant. Even with these difficulties, a reasonable estimate of the angle is possible (ref. 6). Thickness data versus angle from ram from measurements on blankets B07 and D11 are shown in figure 7.2-1.

Photomicrograph cross-sections for blankets D7 and D11, starting from the edge of each blanket, through the folded region, and into the exposed area, show thickness as a continuous function of exposure angle. The angle from ram is provided for specific locations along blankets B7 and D11. Angles are estimated by using SEM photographs to determine the orientation of the roughened textured surface. The textured peaks point on average in the ram direction. This technique allows definition of the angles to within about 5° of ram and allowed establishment of the location on the blanket facing ram to within about 1 mm. A second method was used to determine angles at non-ram locations. The assumption was made that angle change is linear with distance along the blanket. From 17.9-23.6 mm, the angle varies from 90° to 0°; from 23.6-36.9 mm, the angle varies from 0° to 52°. The distances from the edge of the blanket represent the location where the unexposed edge is 90° from ram, the location facing the direction of motion, and the exposed face of blanket D11, respectively. For blanket B7, from 11.3 mm to 20.5 mm, the angle changes from 90° from ram to 0° from ram. The angles determined at selected distances along blankets B07 and D11 are shown in figure 7.2-2. The correlation of recession with angle from ram provides the data to determine average recession rates because of the detailed knowledge of the atomic oxygen fluence as a function of angle from ram.

Another set of measurements was obtained from an Ag/FEP tape applied to an aluminum angle bracket holding the top of an electronics box on experiment A0076, location F9. These angle versus location data are presented in figure 7.2-3. The data correlates with the measurement results in figure 7.2-2. This specimen provides a well defined set of angles with respect to ram because the rigid aluminum structure was bolted in place. For the angle

Distance along specimen (mm)	Specimen (Thickness in mils) D11 flat	D11 curved	B7 flat	B7 curved	B7-strap area flat	B7-strap area curved	Angle Bracket
0.513	5.35	5.21	5.40	5.41	5.51	5.47	4.20
1.025	5.257	5.3078	5.207	5.298	5.388	5.409	4.14
1.538	5.177	5.1463	5.318	5.358	5.348	5.409	3.89
2.050	5.166	5.1564	5.257	5.489	5.388	5.348	3.82
2.563	5.197	5.1968	5.257	5.378	5.288	5.318	3.89
3.076	5.166	5.1665	5.318	5.328	5.308	5.469	3.83
3.588	5.177	5.1867	5.338	5.338	5.338	5.348	3.83
4.101	5.177	5.1362	5.247	5.308	5.338	5.368	3.85
4.614	5.066	5.0757	5.298	5.378	5.328	5.429	3.81
5.126	5.237	5.0454	5.409	5.338	5.388	5.439	3.85
5.639	5.156	5.0555	5.510	5.358	5.378	5.378	3.89
6.151	5.217	5.0050	5.288	5.267	5.298	5.419	3.96
6.664	5.207	5.0354	5.177	5.368	5.288	5.348	4.07
7.177	5.086	5.0454	5.207	5.298	5.277	5.358	4.02
7.689	5.126	5.0656	5.146	5.409	5.308	5.368	3.98
8.202	5.126	5.0858	5.227	5.338	5.277	5.308	4.14
8.714	5.156	5.1867	5.055	5.348	5.308	5.358	4.26
9.227	5.166	5.0858	5.277	5.399	5.378	5.217	4.42
9.740	5.156	5.1160	5.187	5.318	5.358	5.237	4.67
10.252	5.237	5.0858	5.086	5.247	5.257	5.328	4.80
10.765	5.156	5.1867	5.166	5.388	5.187	5.338	4.94
11.277	5.177	5.1766	5.156	5.368	5.308	5.267	4.76
11.790	5.217	5.156	5.136	5.358	5.257	5.257	4.93
12.303	5.277	5.247	5.207	5.298	5.177	5.217	4.91
12.815	5.257	5.106	5.187	5.217	5.055	5.156	4.87
13.328	5.227	5.136	5.156	5.328	5.146	5.136	5.00
13.841	5.207	5.217	5.015	5.328	5.126	5.106	4.89
14.353	5.207	5.1665	5.136	5.277	5.106	5.045	4.77
14.866	5.136	5.2160	5.116	5.217	5.177	4.975	4.73
15.378	5.318	5.2472	5.066	5.217	4.934	4.934	4.75
15.891	5.308	5.1463	4.985	5.035	4.894	4.803	4.56
16.404	5.348	5.1362	5.005	4.934	4.793	4.763	4.34
16.916	5.126	5.1665	5.015	4.985	4.793	4.712	4.20
17.429	5.146	5.0757	4.884	4.844	4.763	4.642	3.83
17.941	5.177	5.2170	4.945	4.712	4.612	4.622	3.66
18.454	5.126	5.1564	4.823	4.601	4.531	4.561	3.73
18.967	4.995	5.0555	4.652	4.511	4.531	4.501	3.63
19.479	5.035	4.9546	4.672	4.531	4.379	4.359	3.69
19.992	4.914	4.9243	4.511	4.531	4.339	4.369	3.69
20.505	4.561	4.7023	4.591	4.501	4.390	4.349	3.56
21.017	4.390	4.3088	4.733	4.450	4.359	4.359	3.51
21.530	4.390	4.3189	4.571	4.440	4.379	4.420	3.34
22.042	4.147	4.0565	4.511	4.390	4.460	4.410	3.27
22.555	3.966	4.0262	4.561	4.420	4.712	4.440	3.19

Figure 7.2-1. Thickness of FEP D11 and B7 blanket specimens(mils) and F9 angle bracket as determined by photomicrograph cross-sections.

Distance Specimen

along specimen (mm)	D11 flat	D11 curved	(Thickness in mils) B7 flat	B7 curved	B7-strap area flat	B7-strap area curved	Angle Bracket
23.068	4.026	4.1070	4.531	4.541	4.470	4.379	3.24
23.580	4.127	4.0464	4.531	4.531	4.390	4.410	3.13
24.093	4.127	3.9758	4.531	4.551	4.400	4.400	3.12
24.605	4.036	4.0061	4.531	4.561	4.440	4.309	3.31
25.118	4.026	3.9657	4.501	4.672	4.702	4.360	3.55
25.631	4.036	4.0767	4.632	4.642	4.662	4.460	3.63
26.143	4.077	4.1473	4.591	4.601	4.551	4.460	3.83
26.656	4.188	4.0565	4.662	4.612	4.662	4.410	3.81
27.169	4.127	4.0565	4.692	4.692	4.581	4.490	
27.681	4.057	3.9758	4.612	4.379	4.763	4.601	
28.194	4.087	4.1171	4.612	4.783		4.551	
28.706	4.107	4.1070	4.521	4.783			
29.219	4.188	4.0666	4.712	4.813			
29.732	4.309	3.9960	4.743	4.783			
30.244	4.147	4.2785	4.753	4.834			
30.757	4.258	4.2684	4.733	4.753			
31.269	4.218	4.3088	4.743	4.682			
31.782	4.329	4.4702	4.834	4.672			
32.295	4.430	4.3996	4.854	4.733			
32.807	4.440	4.3694	4.783	4.783			
33.320	4.531	4.3693	4.793	4.622			
33.832	4.420	4.3996	4.793	4.682			
34.345	4.480	4.4198		4.601			
34.858	4.581	4.4097		4.581			
35.370	4.591	4.5510		4.501			
35.883	4.692	4.5207		4.511			
36.396	4.541	4.5409		4.601			
36.908	4.723	4.5509		4.460			
37.421		4.6014		4.541			
37.933		4.6821		4.420			
38.446		4.5510		4.682			
38.959				4.632			
39.471				4.450			
39.984				4.420			
40.496				4.521			
41.009				4.460			
41.522				4.541			

Figure 7.2-1 (continued) Thickness of FEP D11 and B7 blanket specimens(mils) and F9 angle bracket as determined by photomicrograph cross-sections.

bracket specimen from row 9, the angles were measured directly from the photomicrographs using a protractor. The recession data show smooth changes in mass loss versus angle for the entire range of angles between 8° and 90° from ram. The concave and convex curved portions of the bracket represent two slightly different environments due to secondary scattering from the center portion of the angle bracket at 90° from ram onto the lower portion at 8° from ram. Figure 7.2-4 shows a piece of the angle bracket and a cross-sectional view of the bracket mounted for acquiring photomicrographs. The effect of the slight variation in environment is clearly shown in a plot of thickness against angle-from-ram in figure 7.2-5. The thickness loss is greater for the concave (with more secondary scattering) than the convex area of the bracket for angles between about 8° to 50° from ram.

Distance from blanket edge, mm, for D11	Angle from ram
18	50
20	26
21	18
23	5
25	17
27	23
29	27
31	36
33	50
38	65

Distance from blanket edge, mm, for B7	Angle from ram
11.3	90
16.5	54
17.5	30
19.5	5
20.5	0

Figure 7.2-2. Angles from ram versus distance along blankets D11 and B7.

Distance, mm	Angle from ram	Distance, mm	Angle from ram
0-3.6	8	9.87	76.5
4.1	9	10.00	79
4.6	13	10.12	81.5
5.1	19	10.25	84
5.6	24	10.38	85.5
6.15	30	10.51	87
6.7	35	10.64	88.5
7.2	40	10.76-13.84	90
7.69	44	14.35	83
7.82	46	14.87	79
7.95	47.5	15.38	74
8.07	49	15.89	69
8.20	51	16.40	64
8.33	53	16.92	58
8.46	54.5	17.43	52
8.59	56	17.94	46
8.71	58	18.45	40
8.84	60	18.97	33
8.97	62.5	19.48	28
9.10	65	19.99	24
9.23	67	20.51	20.5
9.36	69	21.02	18
9.48	70.5	21.53	13
9.61	72	22.04	10
9.74	74	23.56-26.66	8

Figure 7.2-3. Angle with respect to ram for specific locations on tray F9 angle bracket.

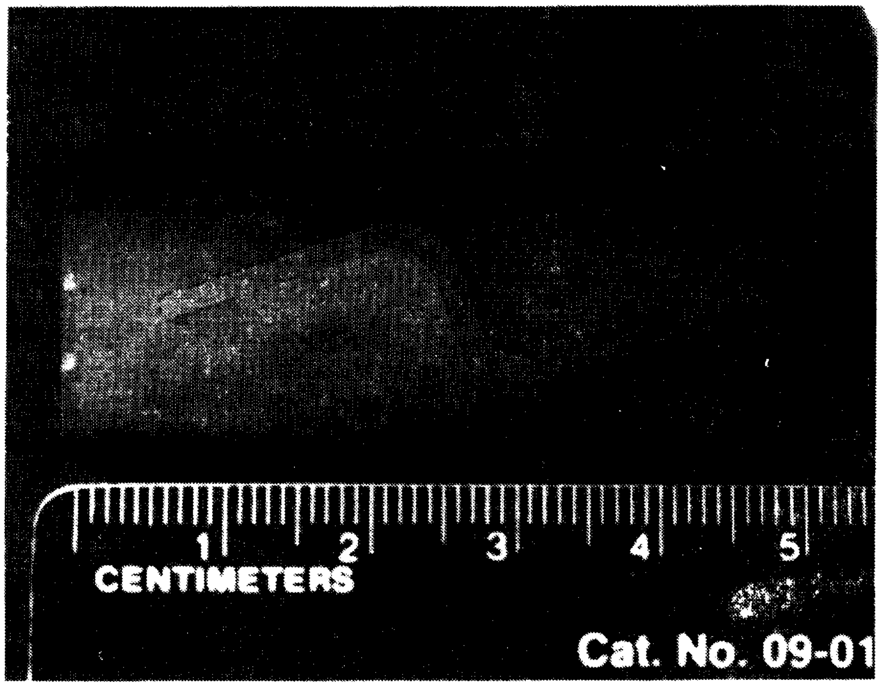


Figure 7.2-4. F09 angle bracket section mounted for photomicrographs.

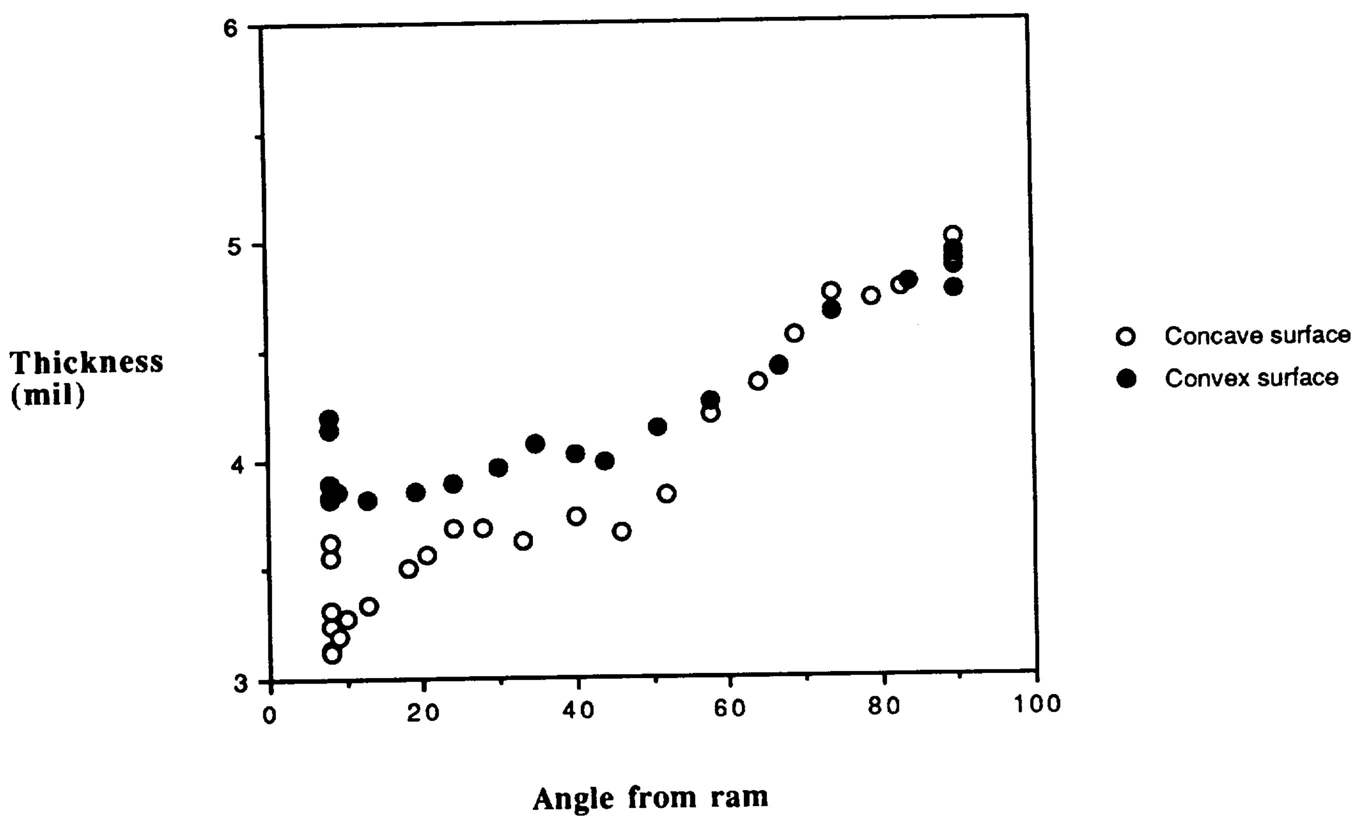


Figure 7.2-5. Thickness loss for FEP from angle bracket at location F9 plotted against angle from ram.

8.0 IMPACTS, DELAMINATIONS, CONTAMINATION

Impact events darkened only about 1.5 percent of the surface area on blankets near the leading edge and even less for trailing-edge blankets. However, the delaminated areas associated with impact events were much greater in comparison with the darkened areas. The delaminated areas can be clearly seen in figure 8.0-1, which is a close-up photo of a portion of the blanket from tray C8. A number of impact locations had alternating light and dark concentric rings around the impact crater. It has not been established whether these rings are due to shock waves at the time of impact alternately compressing and stretching the silver or subsequent diffusion of atomic oxygen oxidizing the silver. Many of the holes punched through the FEP blankets are essentially round. This suggests that the heat associated with these impacts was sufficient to melt a small area of FEP and the liquid surface drew itself into a circle to reach a minimum free energy state before resolidifying. The fraction of blanket area delaminated by impacts has not been quantified, but it is several times the area of the darkened regions. Oversizing the blanket area required for a thermal control application by ~5 percent would compensate for thermal performance changes due to impacts for missions up to at least 10 years duration. More precise determinations would require careful impact rate and thermal modeling.

Figure 8.0-1. NASA photograph of area of blanket C08 showing delamination areas associated with impact events.

9.0 SUMMARY

9.1 PERFORMANCE LIFETIMES

At the average recession rate for FEP measured for the specimens from LDEF, a 5-mil-thick film of this material would be completely removed by 3.6 x 10^{22} atoms/cm^2 of atomic oxygen. The emissivity decreases with thickness of FEP; the rate of change increasing considerably for blankets with FEP layers less than 2 mils thick. Those blankets exposed to UV, but not atomic oxygen, did not recess, and appear to have reached steady state values of percent elongation and tensile strength. Deposited molecular contamination films alter the recession rate by "consuming" oxygen or UV. There is more material with which to react, and formation of oxide films may block attack on the substrate. These effects probably slow the observed recession rate relative to clean material. Absorptance measurements on visibly darkened areas at the edge of certain blankets gave a values as high as 0.25. Similar results were obtained on material taken from the Solar Max satellite (ref. 7). Three specimens from LDEF trailing-edge locations (solar UV exposure only) were reflown on the EOIM-3 experiment on the STS-046 shuttle flight in early August 1992. These specimens received about 2.3 x 10^{20} atoms/cm^2 of atomic oxygen. Profilometry measurements on the EOIM-3 specimens were inconclusive, showing between 0- and 0.2- mm recession. Surface analysis of the EOIM-3 flight specimens previously flown on the LDEF show distinct differences in the proportion of CF, CF_2, and CF_3 groups in comparison with the LDEF specimens used as controls. This data is shown in figure 9.1-1, and the ESCA spectra are included as part of appendix C. The specimens from the blanket at location F2 have substantial contamination. Comparison of ESCA data from the LDEF F2 specimen used as a control and the LDEF/EOIM-3 specimen shows that oxygen exposure during the shuttle flight preferentially removed the contamination film. The LDEF Ag/FEP specimens from LDEF locations B05, B05 (unexposed), and F02 reflown on STS-046 were labeled D, E, and F, respectively.

The FEP blanket material was effective in protecting the silver second-surface mirror for the entire LDEF mission. In general, end-of-life optical properties were unchanged from preflight values and the blankets maintained their mechanical integrity. Expected surface texturing was observed for areas exposed to atomic oxygen. The average recession rate was greater than values reported for experiments flown on short-duration Space Shuttle flights.

	Specimens	Peak Intensities		Exposures	
		CF	CF_3	UV (hrs)	AO
					(Atoms/cm^2)
Ground Control		0.045	0.07	0	0
	B5	0.45	0.67	8200	$9.6\ 10^{12}$
LDEF	C5	0.46	0.65	8200	$1.5\ 10^{17}$
Specimens	F2-1	0.87	0.40	9600	$1.5\ 10^{17}$
	F2-2	1.06	0.50	9600	$1.5\ 10^{17}$
	E2-1	0.47	0.90	9600	$1.5\ 10^{17}$
	E2-2	0.69	0.73	9600	$1.5\ 10^{17}$
LDEF	B5-1	1.0	0.18	8200	$2.3\ 10^{20}$
Specimens	B5-2	0.89	0.19	8200	$2.3\ 10^{20}$
Reflown	B5-1 (shielded)	0.94	0.15	-	$2.3\ 10^{20}$
on EOIM-3	B5-2 (shielded)	0.88	0.25	-	$2.3\ 10^{20}$
	F2-1	0.89	0.17	9600	$2.3\ 10^{20}$
	F2-2	1.0	0.20	9600	$2.3\ 10^{20}$

Figure 9.1-1. Ag/FEP ESCA measurements for LDEF/EOIM-3 specimens compared with LDEF specimens. (CF and CF_3 peak intensities are relative to CF_2 peak intensities.)

Thermal performance data for Ag/FEP are available from a number of spacecraft in addition to LDEF. Blanket material has been returned from the Solar Max satellite and certain Space Shuttle flights. Test specimens have been flown on other low-Earth-orbit satellites, on SCATHA, IMP-I, OSO-H, and IMP-H (refs. 8-11). The cumulative results from these flights show that environments with substantial amounts of particulate radiation increase the absorptance of Ag/FEP, while environments with primarily solar UV do not. Data from IMP-I, Solar Max, ML-101 (refs. 12-13), and LDEF (ref. 14) provide indications of contamination-induced changes in the optical properties of this material (ML-101 used aluminum backed FEP). IMP-I and ML-101 data show a rapid increase in absorptance over the first month in orbit, followed by much slower increases over subsequent long time periods. The postflight measurements on visibly contaminated material from Solar Max and the LDEF show large increases in absorptance over both preflight values and postflight values of nonvisibly contaminated areas. Ag/FEP is also being widely used as the primary passive thermal control material on the Hubble Space Telescope and Magellen.

9.2 PREDICTIONS, LIMITATIONS

Predictions of material lifetime limitations due to recession of ram-facing surfaces on Space Station Freedom based on LDEF specimens only allow estimates of a lower bound of FEP thickness necessary for long-term use. If the recession rate of FEP under combined exposure is controlled by the UV exposure rate, then <5-mil thickness loss could be expected over a 30 year period for a ram facing surfaces. This is based on the observed recession over the 5-year 10-month exposure and the fact that the solar UV exposure rate should be essentially constant over the 30-year period. If the recession rate is controlled by the atomic oxygen exposure rate, then ~16-mil thickness loss could be expected over 30 years. This prediction is based on Space Station Freedom receiving an estimated ram fluence of $1.5x10^{23}$ oxygen atoms/cm^2. To maintain acceptable absorptance and emittance values over this time period would require at least 7, and possibly up to 23, mils of FEP. These estimates assume constant rates of degradation. The rate may accelerate, and is at least higher than our reported average, given an induction period prior to the onset of mass loss. The results demonstrate that UV alone does not cause recession of FEP. It has not yet been conclusively determined experimentally that oxygen alone is sufficient or if UV is necessary for erosion to occur. However, it is probable that UV is required, at least initially, to produce sites in the polymer susceptible to oxidation.

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11. J.J. Triolo, J.B.Heaney, and G. Hass, "Coatings in Space Environment," SPIE Vol. 121, Optics in Adverse Environments, 1977.

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13. D.E. Prince, ML-101 Thermal Control Coating Spaceflight Experiment, Technical Report AFML-TR-75-17, August 1975.

14. LDEF-69 Months in Space, First Post-Retrieval Symposium, NASA Conference Publication 3134, Part 2, June 2-8, 1991, pp 797-934 and pp. 945-974

10.0 REFERENCES

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APPENDIX A

Manufacturing Lot Numbers and Values of Optical Properties of Ag/FEP Blanket Materials for A0187 and P0004 Experiments, as Received by the European Space Agency.

In November 1982, Sheldahl Corporation provided 13 sheets of 5.0-mil Teflon backed by silver and inconel layers (Sheldahl part number G401500). The lot number of these sheets are 116349, 116350, 116476, 116477, 116479, 116480, 116482, 116484, 116485, 116486, 116487, and 116488. The results of the optical properties measurements shown in table A-1 are taken from a European Space Agency (ESA) memo of February 8, 1983. The measurements were made as part of the ESA receiving inspection of the blankets. Most absorptance measurements were made with a portable device; only blankets 1 and 2 were measured using a large fixed instrument.

Blanket Number	Run number	ε_n	α_p	α_s
1 and 2	116476	0.774		0.066
3 and 4	116485	0.771	0.068	
5 and 6	116349	0.772	0.063	
7 and 8	116488	0.771	0.063	
9 and 10	116486	0.771	0.068	
11 and 12	116479	0.777	0.066	
13 and 14	116487	0.773	0.065	
15 and 16	116484	0.773	0.069	
17 and 18	116482	0.778	0.066	
19 and 20	116480	0.777	0.065	
21 and 22	116478	0.773	0.064	
23 and 24	116477	0.772	0.071	

Measurement accuracy

Normal emittance (ε_n)

Max. absolute error $d\varepsilon_n = \pm 0.02$

Reproducibility $d\varepsilon_n = \pm 0.005$

Solar absorptance

Max. absolute error $d\alpha_s = \pm 0.02$

Reproducibility $d\alpha_s = \pm 0.005$

Protable solar absorptance

Max. absolute error $d\alpha_p = \pm 0.03$

Reproducibility $d\alpha_p = \pm 0.005$

Table A-1. Normal Thermal Emittance and Solar Absorptance of Ag/FEP Blanket Material Prior to the LDEF Flight.

APPENDIX B.

Dynamical Mechanical Analysis Results

List of Figures and Tables for Appendix B

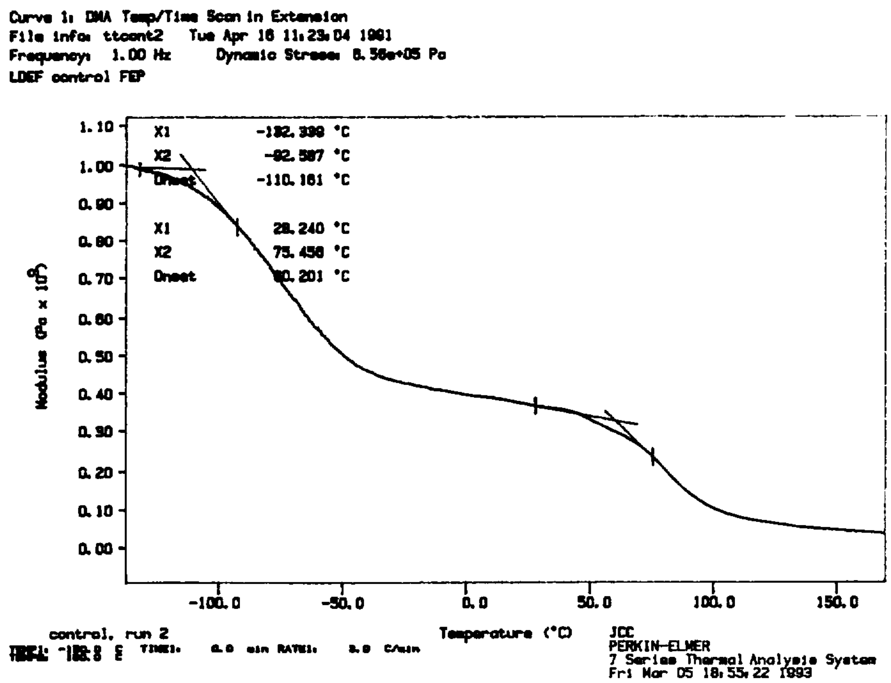


Figure B-1. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Control Specimen, Showing Modulus Versus Temperature.

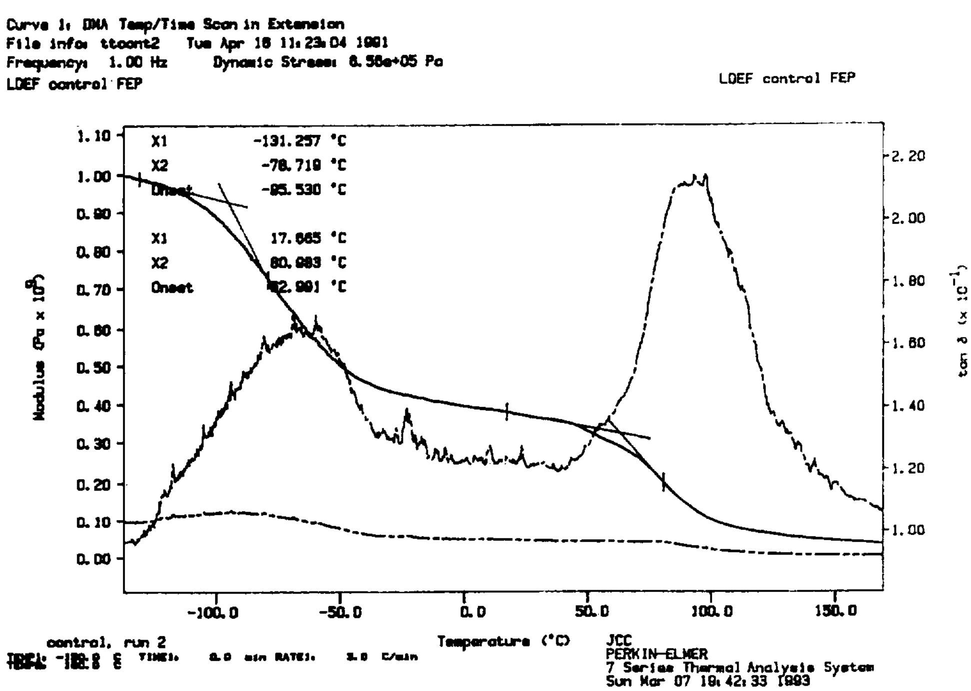


Figure B-2. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Control Specimen, Showing Modulus and Tan d Versus Temperature.

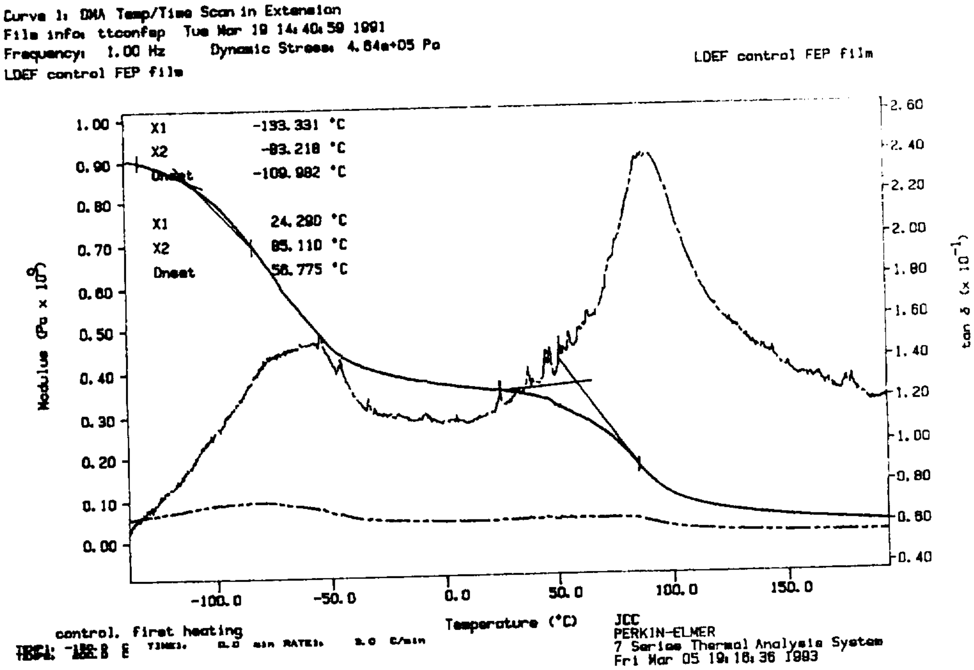


Figure B-3. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Control Specimen, Showing Modulus and Tan d Versus Temperature.

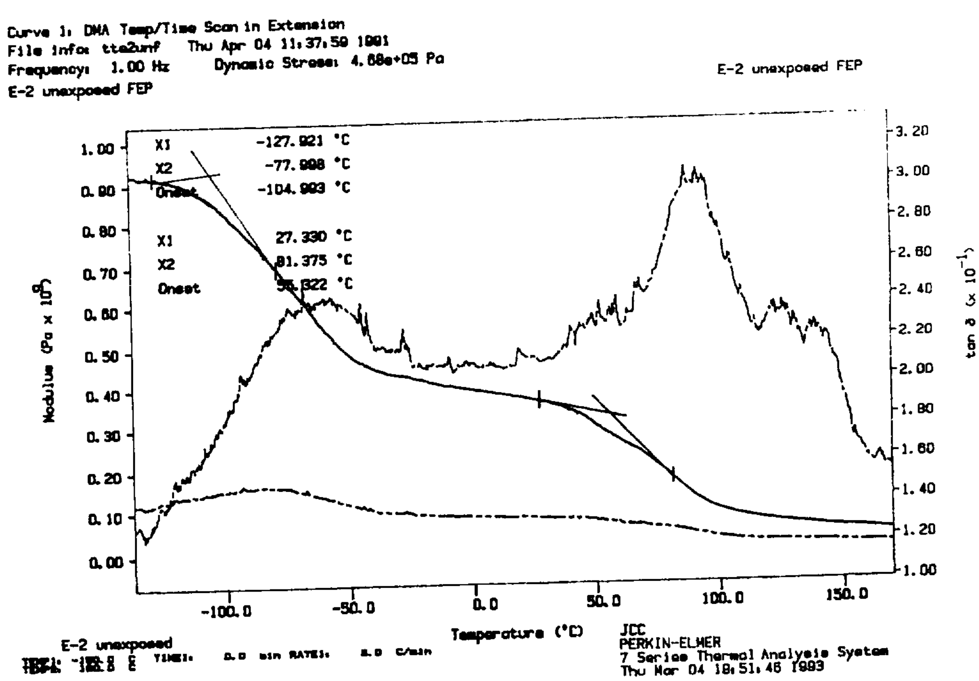


Figure B-4. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed For LDEF FEP Control Specimen From Blanket E-2, Showing Modulus and Tan d Versus Temperature.

112383/1-002 ai

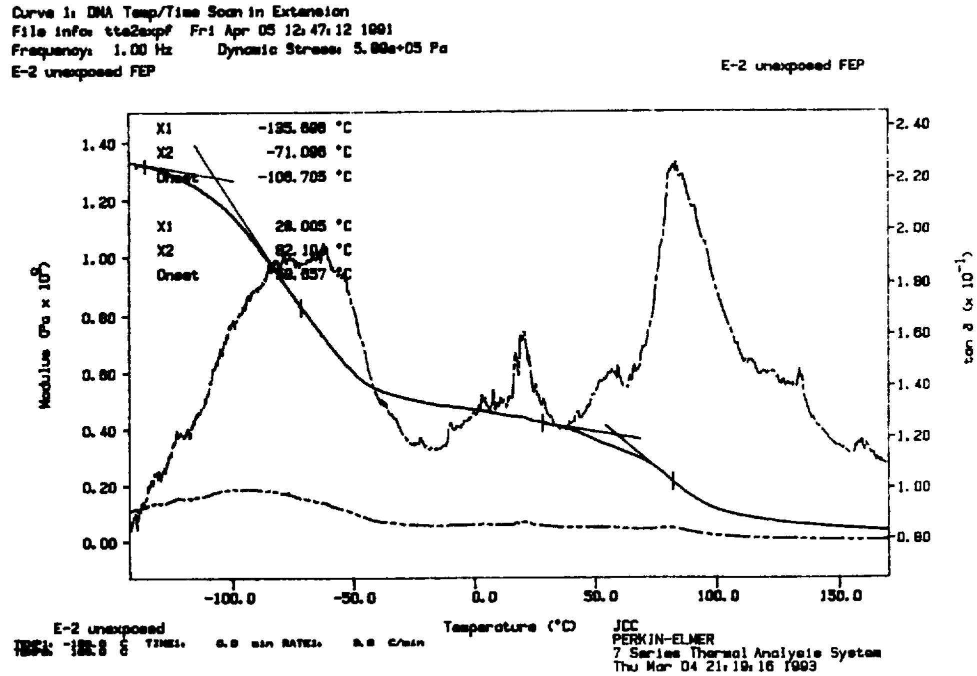


Figure B-5. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket E-2, Showing Modulus and Tan d Versus Temperature.

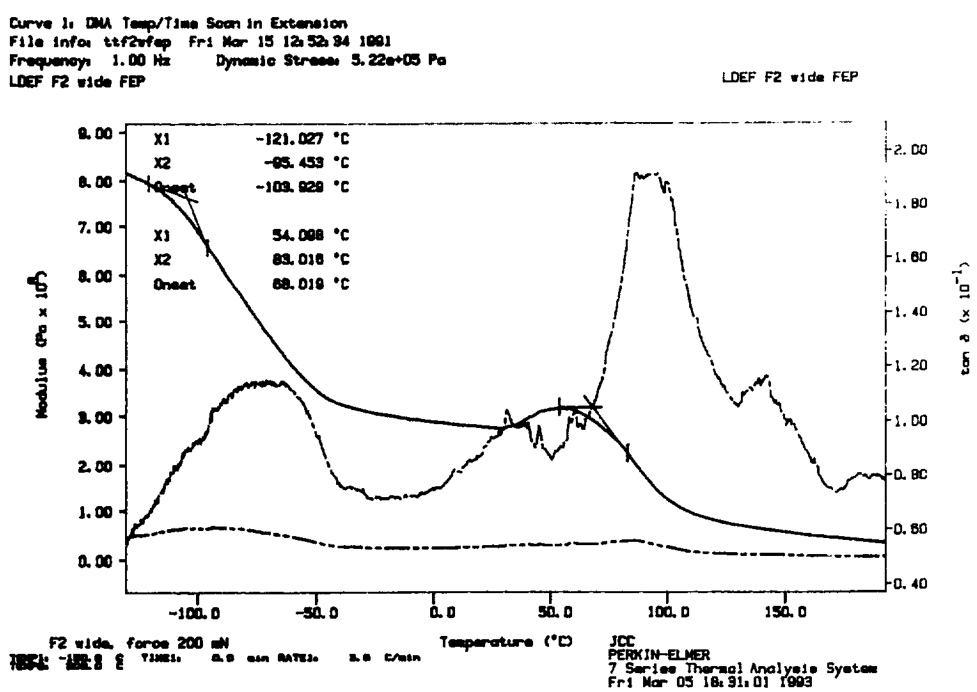


Figure B-6. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Control Specimen From Blanket F-2, Showing Modulus and Tan d Versus Temperature.

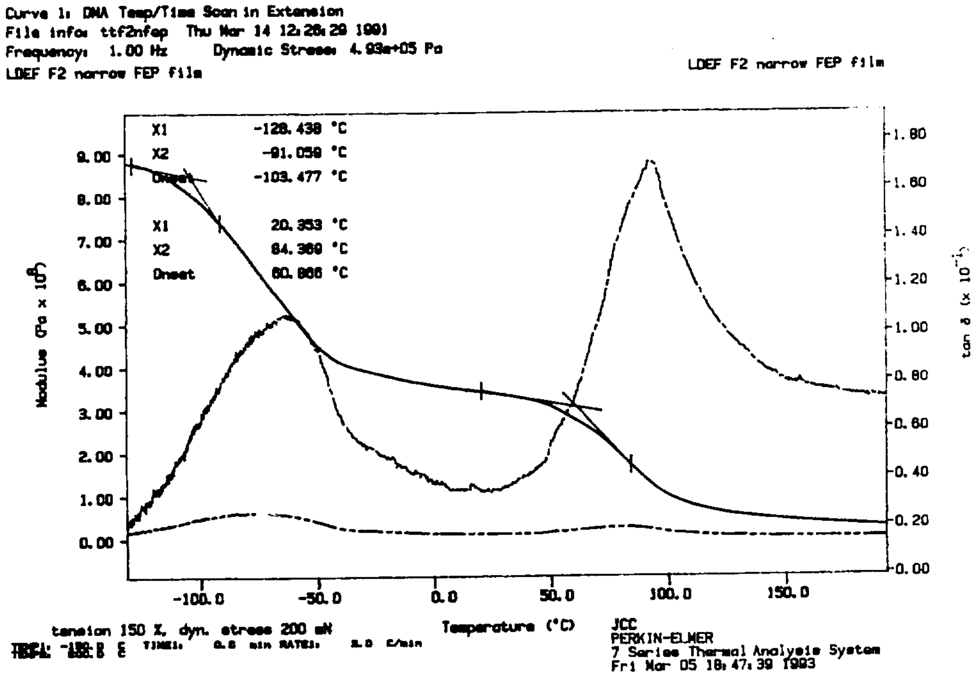


Figure B-7. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Second Exposed LDEF FEP Specimen From Blanket F-2, Showing Modulus and Tan d Versus Temperature.

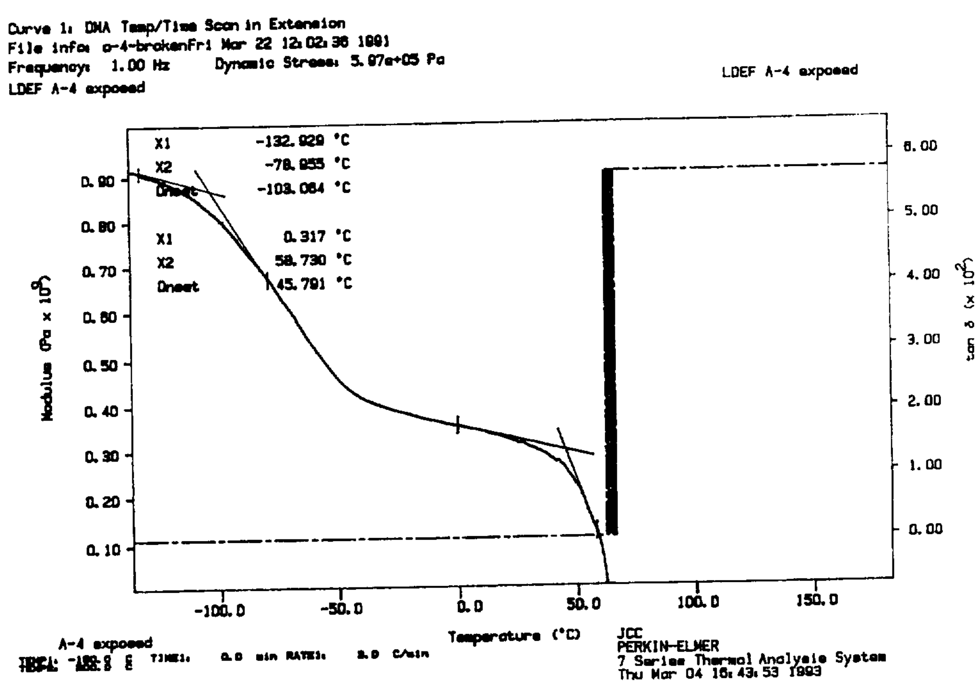


Figure B-8. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Control Specimen From Blanket A-4, Showing Modulus versus Temperature.

112383/1-004 ai

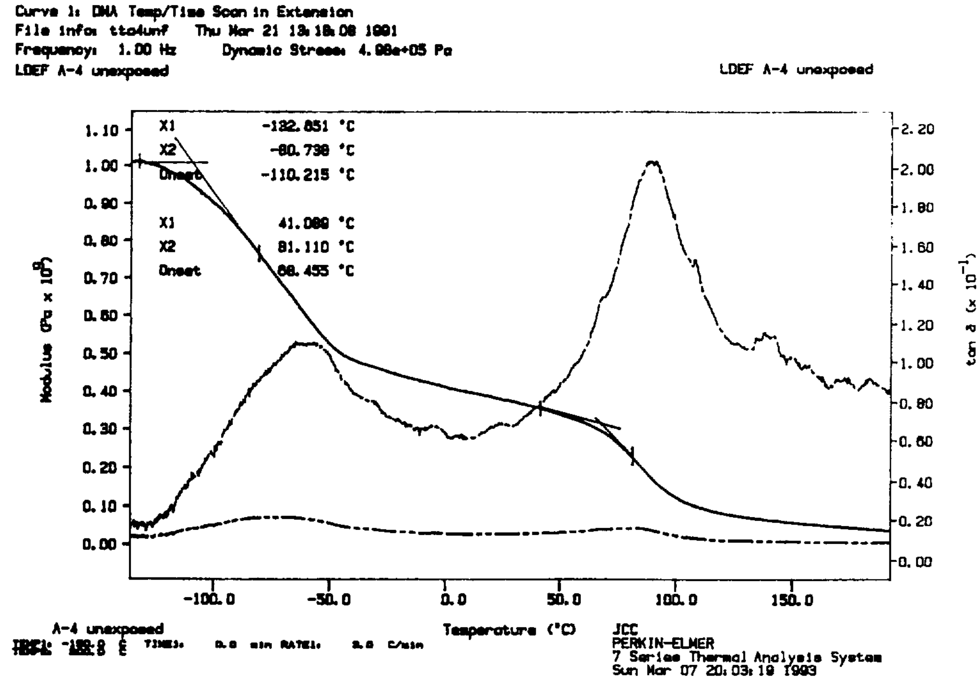


Figure B-9. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Second Unexposed LDEF FEP Specimen From Blanket A-4, Showing Modulus and Tan d Versus Temperature.

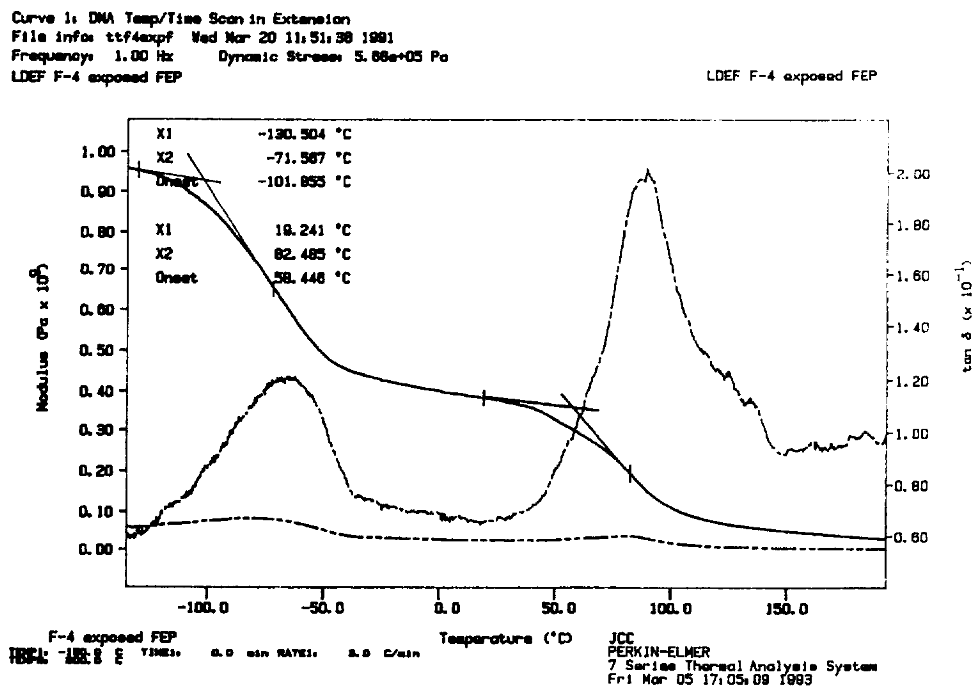


Figure B-10. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket F-4, Showing Modulus versus Temperature.

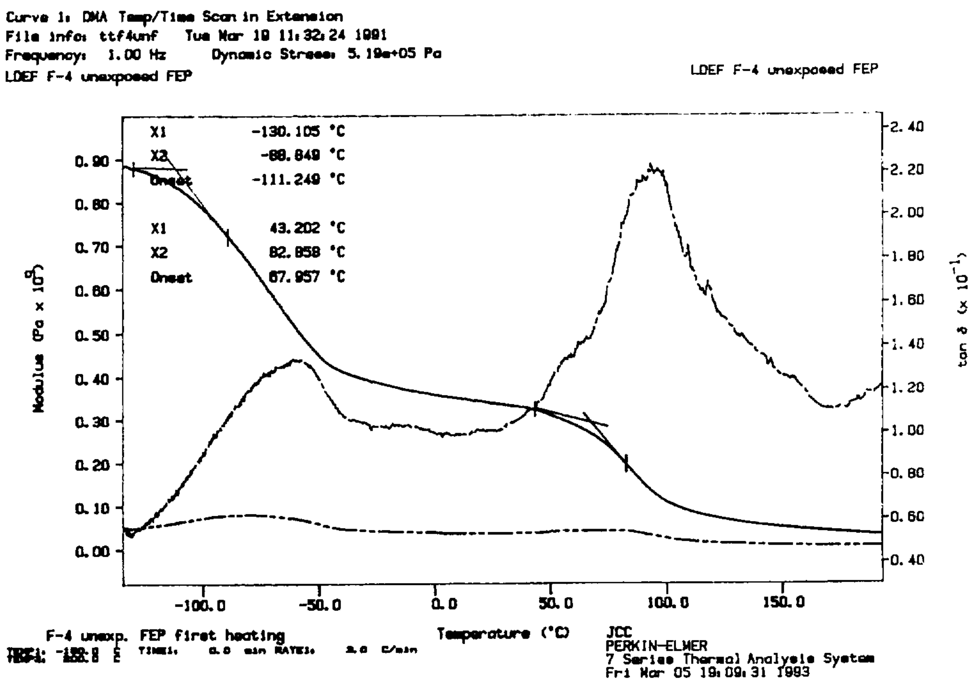


Figure B-11. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Specimen From Blanket A-4, Showing Modulus and Tan d Versus Temperature.

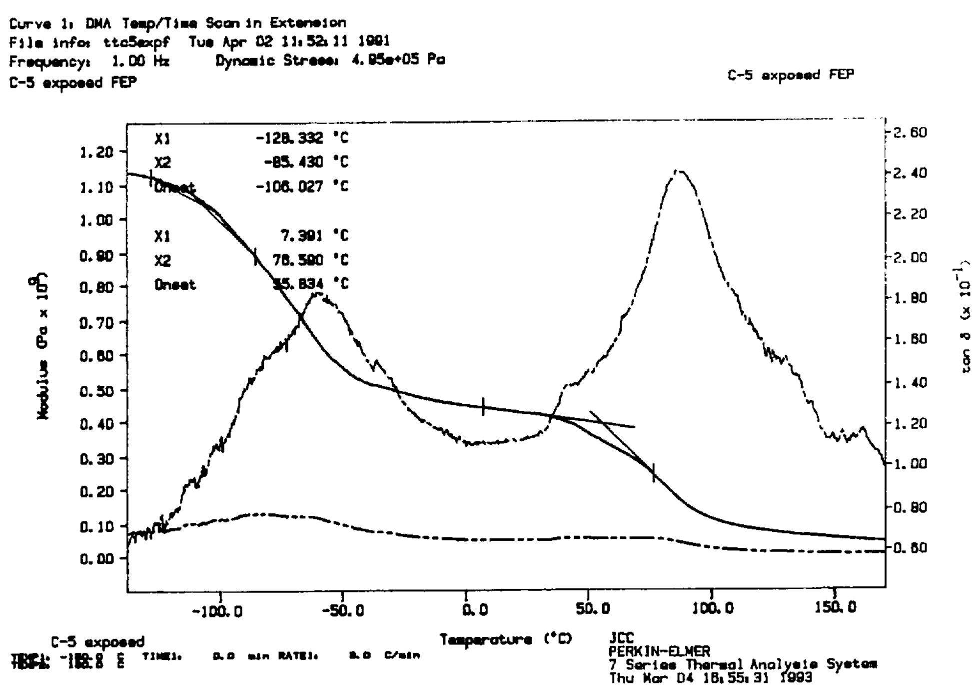


Figure B-12. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket C-5, Showing Modulus Versus Temperature.

112383/1-006 ai

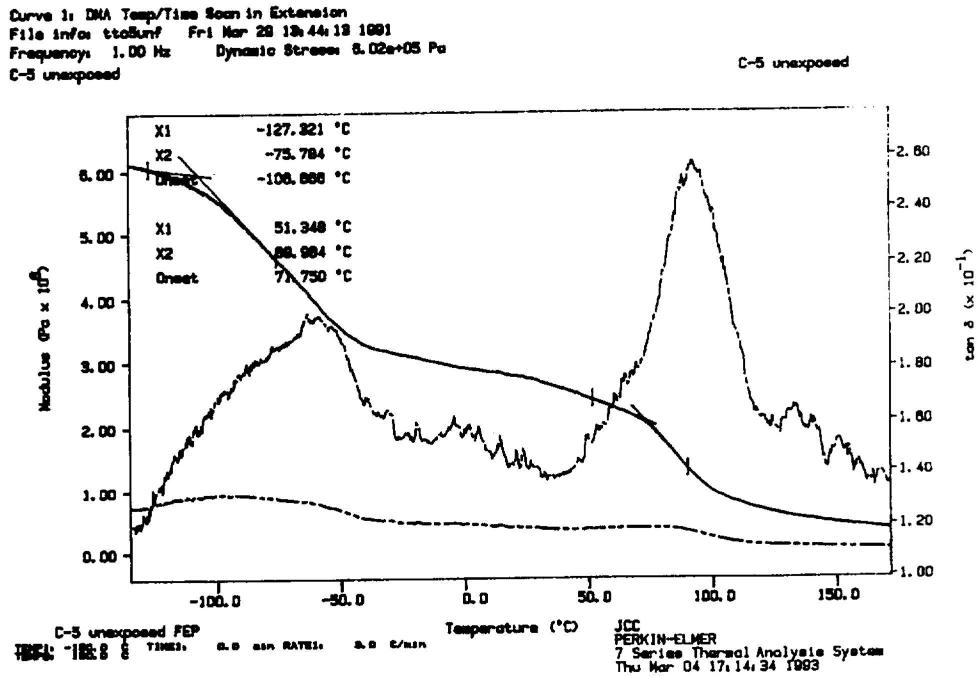


Figure B-13. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Specimen From Blanket C-5, Showing Modulus and Tan d Versus Temperature.

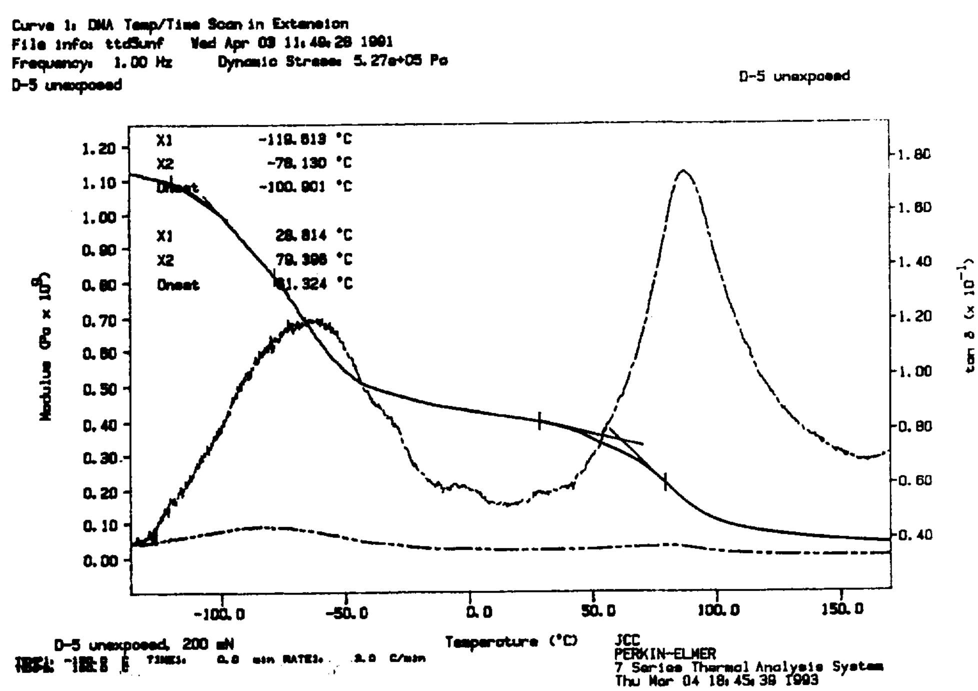


Figure B-14. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Specimen From Blanket D-5, Showing Modulus Versus Temperature.

112383/1-007 ai

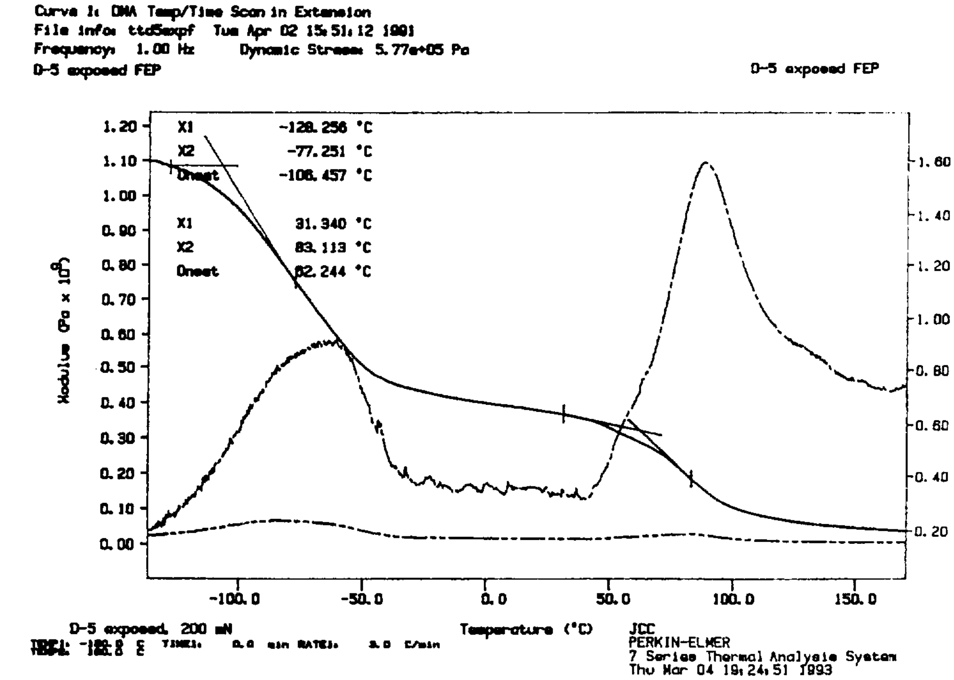


Figure B-15. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket D-5, Showing Modulus and Tan d Versus Temperature.

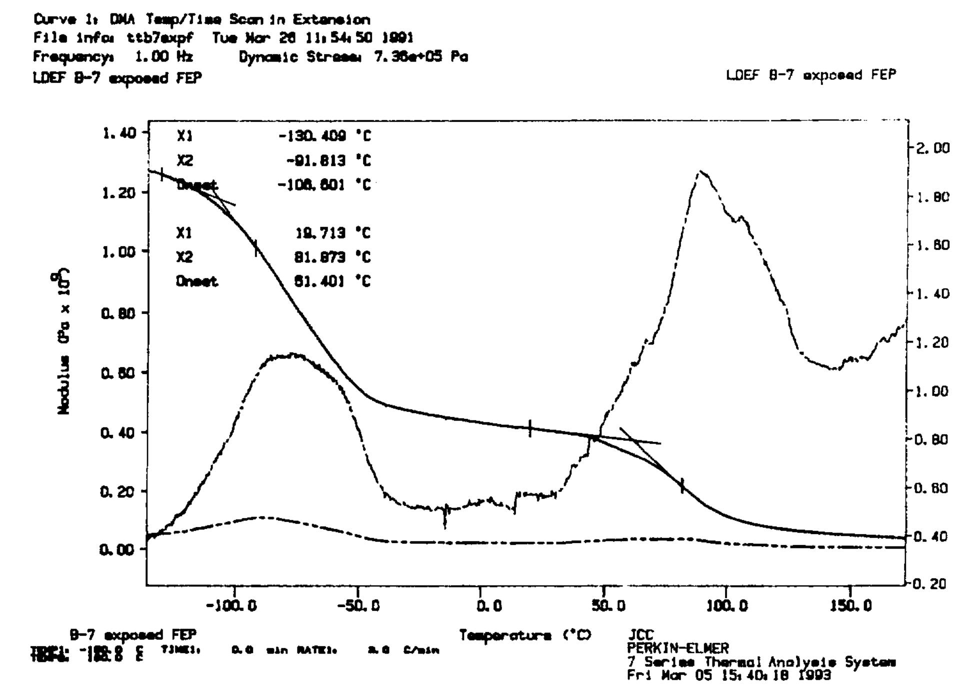


Figure B-16. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket B-7, Showing Modulus and Tan d Versus Temperature.

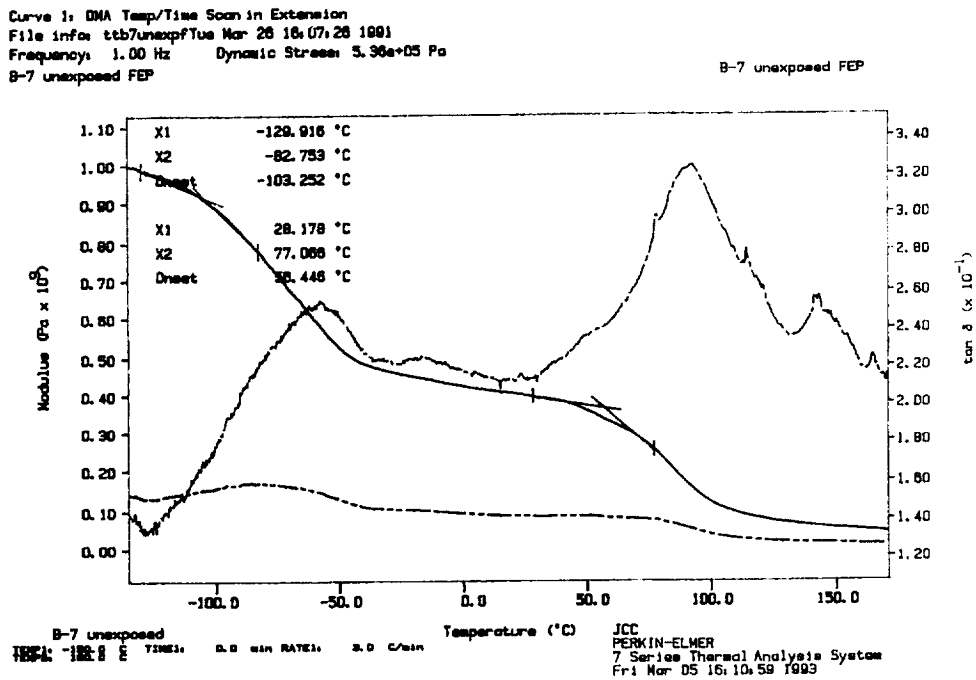


Figure B-17. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Specimen From Blanket B-7, Showing Modulus and Tan d Versus Temperature.

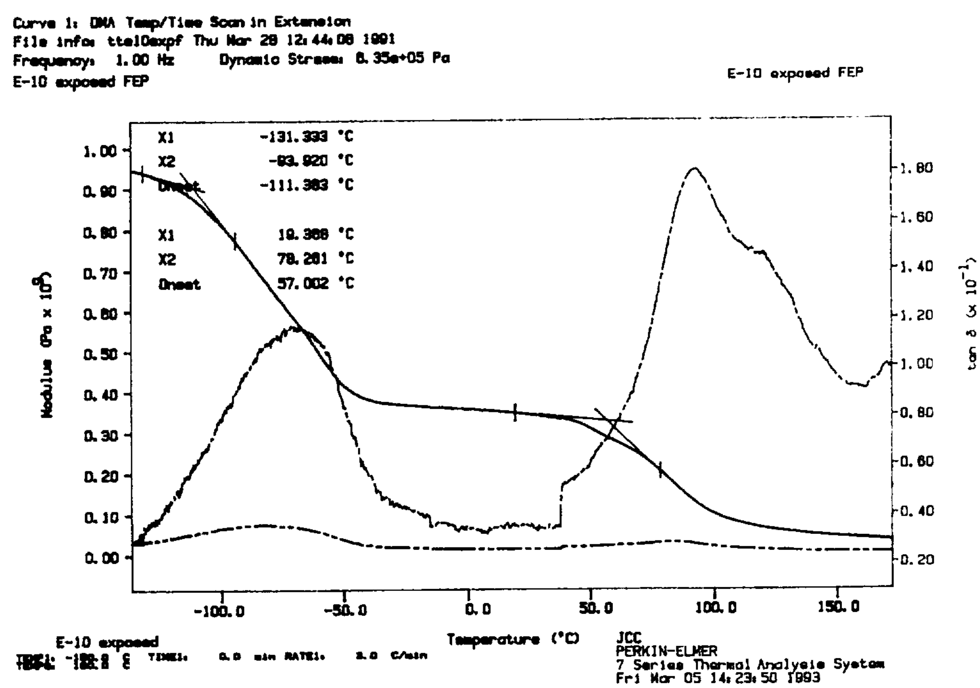


Figure B-18. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Exposed LDEF FEP Specimen From Blanket E-10, Showing Modulus and Tan d Versus Temperature.

112383/1-009 ai

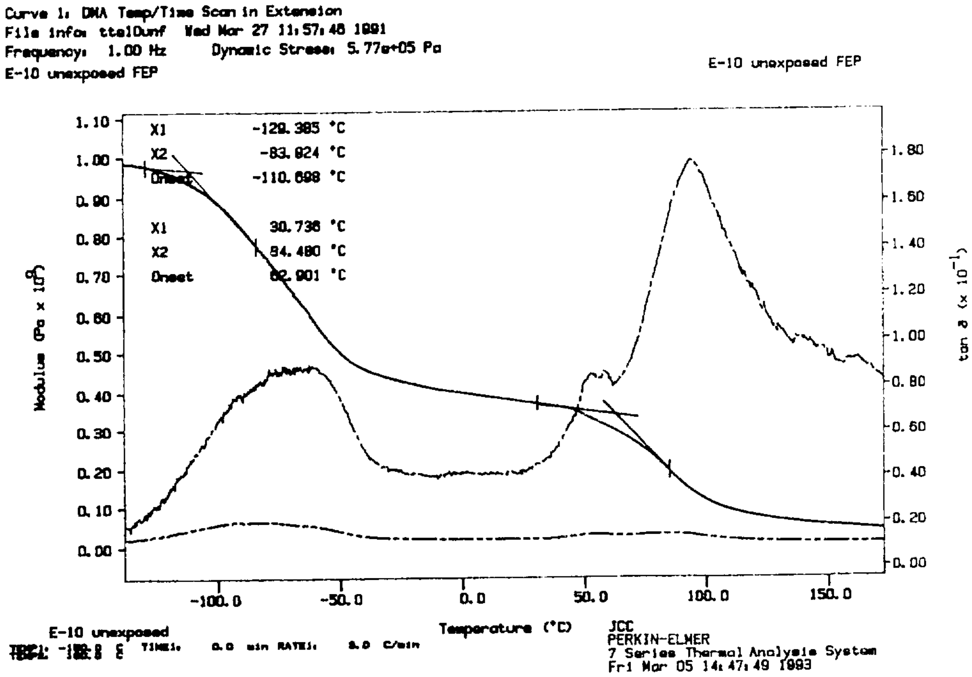


Figure B-19. Dynamic Mechanical Analysis Temperature/Time Scan In Extension For Unexposed LDEF FEP Specimen From Blanket E-10, Showing Modulus and Tan d Versus Temperature.

112383/1-010 ai

APPENDIX C

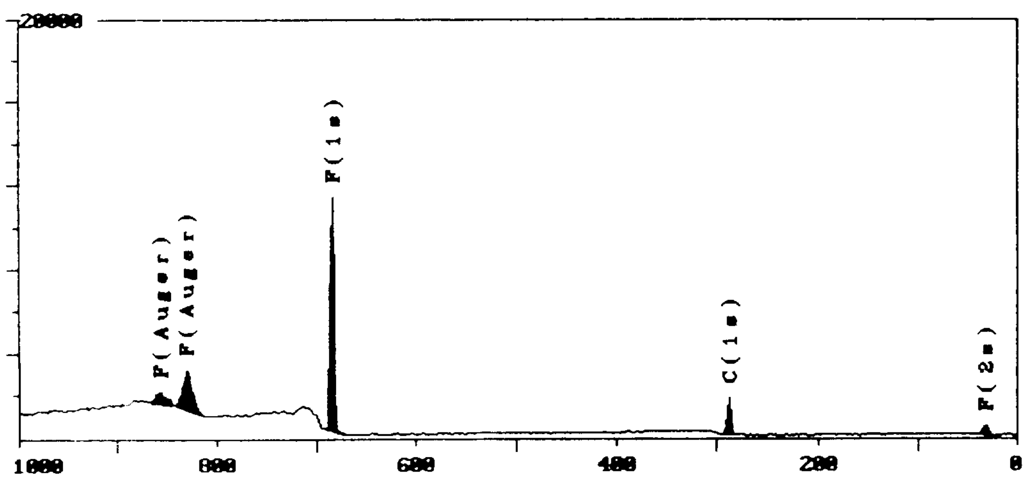
Surface Characterization Data Using ESCA

This appendix contains the spectra from ESCA measurements on the FEP surface of material from selected locations. The spectral peak assignments were made using the expected energies for 1s carbons in the CF_3, CF_2, and CF functional groups The fit allows the mole fraction of CF, CF_2, and CF_3 functional groups to be determined. The peaks at slightly lower energy in these spectra have not been well characterized. They are likely combinations of hydrocarbon contaminants and C-C crosslinks with no fluorines directly attached. This measurement technique samples approximately a 20Å layer on the surface. Spectra were taken for specimens from the large portions of the blanket directly exposed to the ambient space environment. These specimens are labeled as "exp" or "exposed." Spectra of specimens from the edges of the blankets which directly face the sides of the trays are labeled as "unexposed" or "tucked"; there is no essential difference in specimens labeled by either of these terms .

List of Figures and Tables for Appendix C

Thu Mar 21 05:54:01 M-Probe ESCA Console User ID: DATA
GRND_REF.MRS Wed Feb 13 17:43:55 1991 Operator: GARY TUSS
GROUND BASED REFERENCE

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: GRND_REF.MRS
Region: 1
Description: GROUND BASED REFERENCE

Operator: GARY TUSS
Date: Wed Feb 13 17:43:55 1991

Element	Binding Energy	atom %
F (1s)	689.99	67.05 %
C (1s)	292.13	32.95 %
	Total Percent	100.00 %

Figure C-1 Survey spectrum of ground control specimen.

Surface Composition Table Summary

File name: GRNDREF1.MRS
Region: 1
Description: GROUND BASED REFERENCE

Operator: GARY TUSS
Date: Fri Feb 15 14:04:41 1991

Element	Binding Energy	atom %
F (1s)	691.48	65.01 %
C (1s)	293.41	34.99 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: GRNDREF3.MRS
Region: 1
Description: GROUND BASED REF

Operator: GARY TUSS
Date: Fri Feb 15 13:23:30 1991

Element	Binding Energy	atom %
F (1s)	691.47	65.24 %
C (1s)	293.42	34.76 %
	Total Percent	100.00 %

Table C-1 Table of surface elemental composition of ground control specimen.

unexp. front

Tue Nov 13 11:42:16 M-Probe ESCA Console User ID: LDEF

Filename	Spot	Res	Flood eV	Description
AGTEF_6.MRS	200x751µ		5.0	SILVER TEFLON SURFACE REFERENCE

Baseline: 291.40 to 279.60 eV

• 1:	283.44 eV	1.28 eV	936.00 cts	4.05%
• 2:	284.96 eV	1.17 eV	20734.03 cts	89.67%
• 3:	286.85 eV	1.81 eV	1452.57 cts	6.28%

15 iterations, chi square = 1.0432

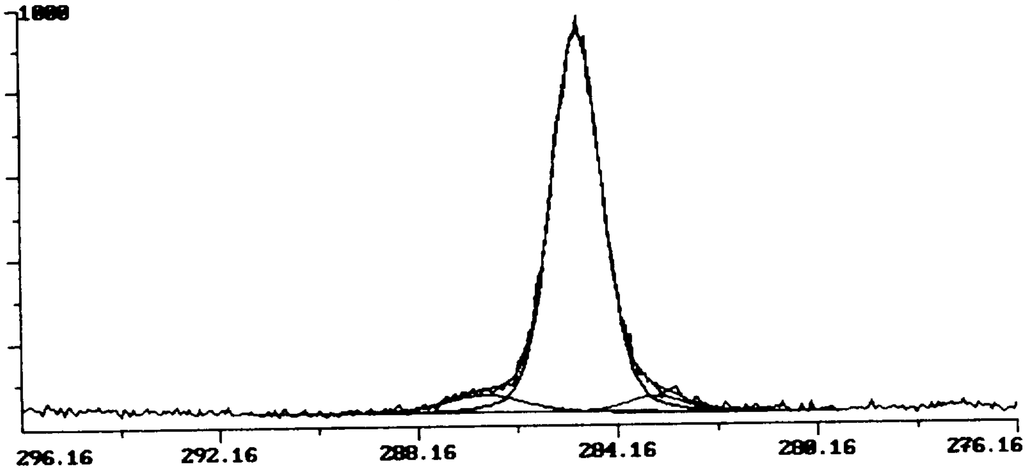
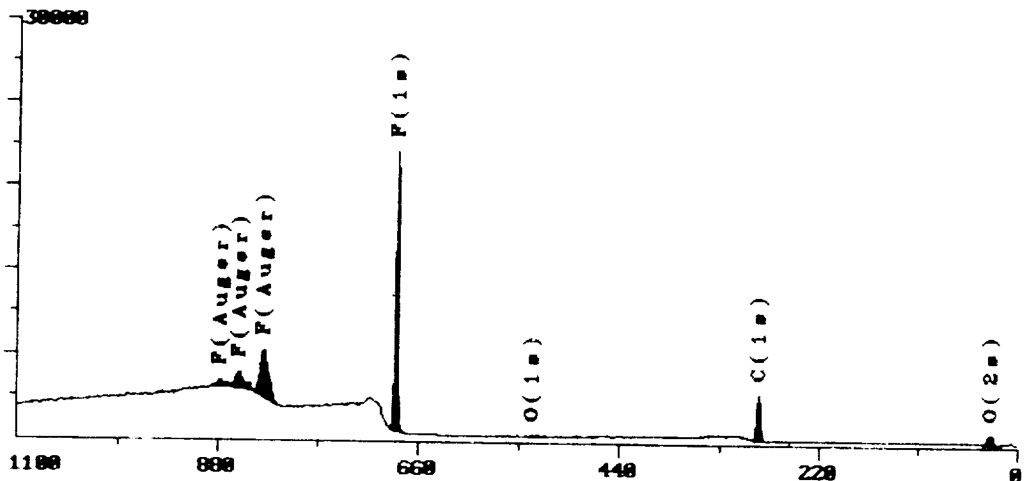


Figure C-2 Carbon 1s spectrum of ground control specimen.

Grey. front

Tue Nov 13 10:35:31 M-Probe ESCA Console User ID: LDEF
AGTEF_5.MRS Tue Nov 13 09:01:28 1990 Operator: GARY TUSS
SILVER TEFLON REFERENCE
Spot: 400x1000μ Resolution: 4 Energy:
Scans: 4 of 4 Neutralizer: 5.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: AGTEF_5.MRS
Description: SILVER TEFLON REFERENCE
Operator: GARY TUSS

Element	Binding Energy	atom %
F (1s)	683.31	67.80 %
O (1s)	533.18	0.81 %
C (1s)	285.46	31.39 %
	Total Percent	100.00 %

Figure C-3 Survey spectrum of ground control specimen.

unexp. front

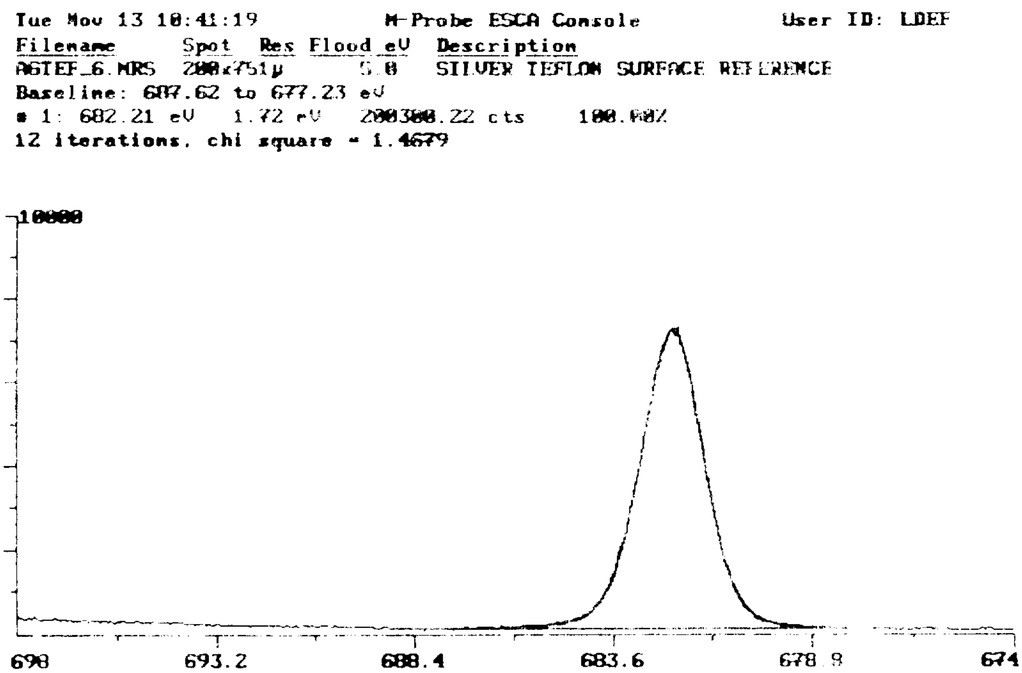
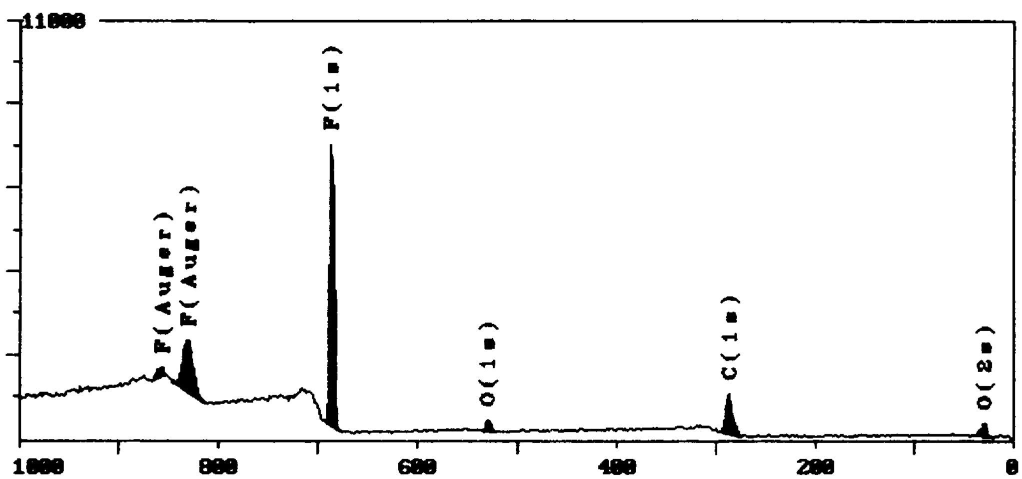


Figure C-4 Fluorine spectrum for ground control specimen.

Wed Mar 28 12:54:05 M-Probe ESCA Console User ID: DATA
D1EXP.MRS Fri Jan 25 14:33:14 1991 Operator: GARY TUSS
D01 EXPOSED

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: D1EXP.MRS
Region: 1
Description: D01 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:33:14 1991

Element	Binding Energy	atom %
F (1s)	690.13	57.08 %
O (1s)	533.54	3.12 %
C (1s)	291.20	39.80 %
	Total Percent	100.00 %

Figure C-5 Survey spectrum for exposed region of blanket D1.

Surface Composition Table Summary

File name: D1EXP2.MRS
Region: 1
Description: D01 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:30:16 1991

Element	Binding Energy	atom %
F (1s)	689.96	56.02 %
O (1s)	533.69	3.61 %
N (1s)	402.03	1.39 %
C (1s)	292.30	38.98 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D1EXP3.MRS
Region: 1
Description: D1 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:50:59 1991

Element	Binding Energy	atom %
F (1s)	691.34	57.99 %
O (1s)	535.49	2.45 %
C (1s)	293.40	39.56 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D1EXP4.MRS
Region: 1
Description: D1 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:09:48 1991

Element	Binding Energy	atom %
F (1s)	691.33	58.24 %
O (1s)	535.55	2.61 %
C (1s)	293.47	39.15 %
	Total Percent	100.00 %

Table C-2 Table of surface elemental composition of exposed regions of blanket D1.

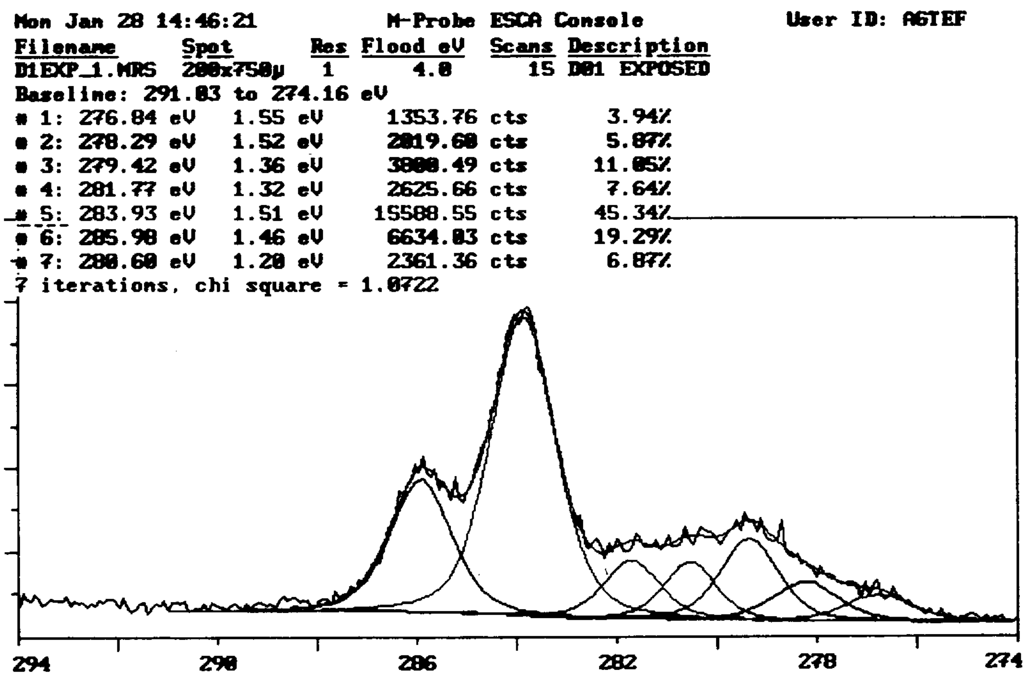


Figure C-6 Carbon 1s spectrum of exposed region of blanket D1.

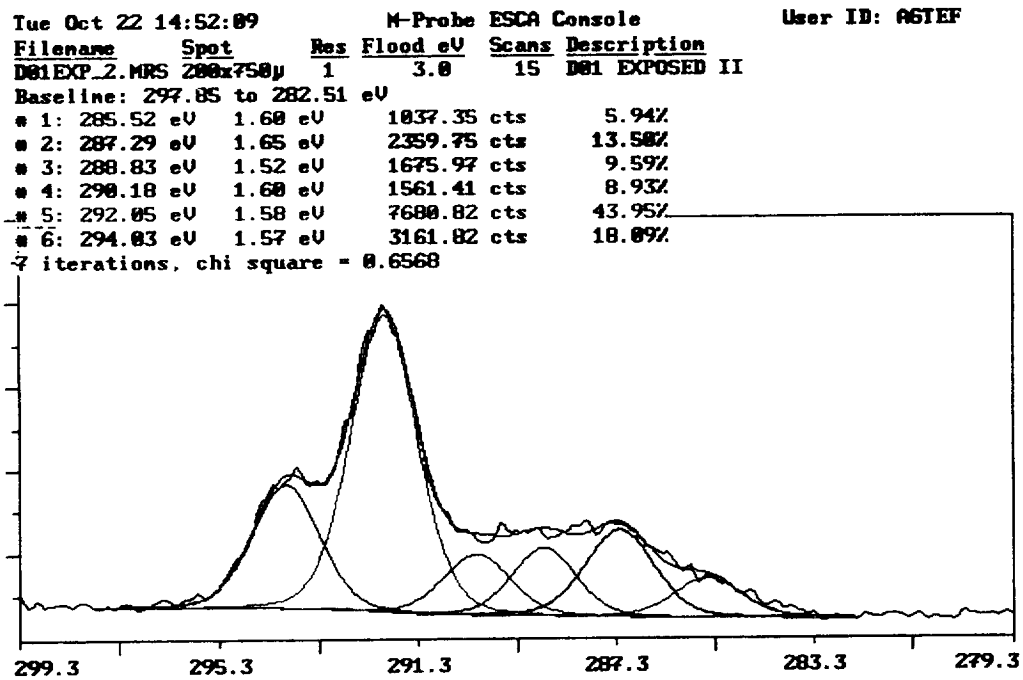
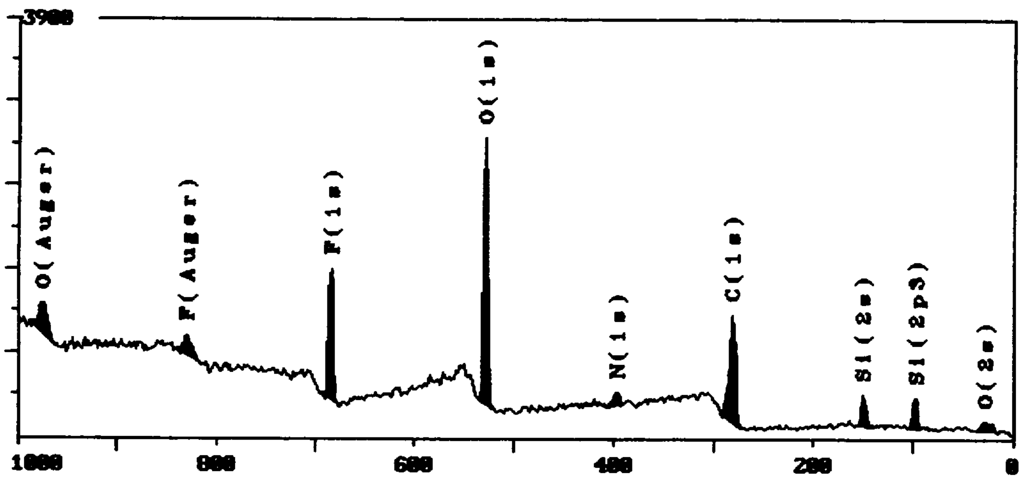


Figure C-7 Carbon 1s spectrum of exposed region of blanket D1(sample 2).

Thu Mar 21 06:46:45 M-Probe ESCA Console User ID: DATA
D1TUCKD.MRS Fri Jan 25 14:36:40 1991 Operator: GARY TUSS
D01 TUCKED EDGE

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: D1TUCKD.MRS
Region: 1
Description: D01 TUCKED EDGE

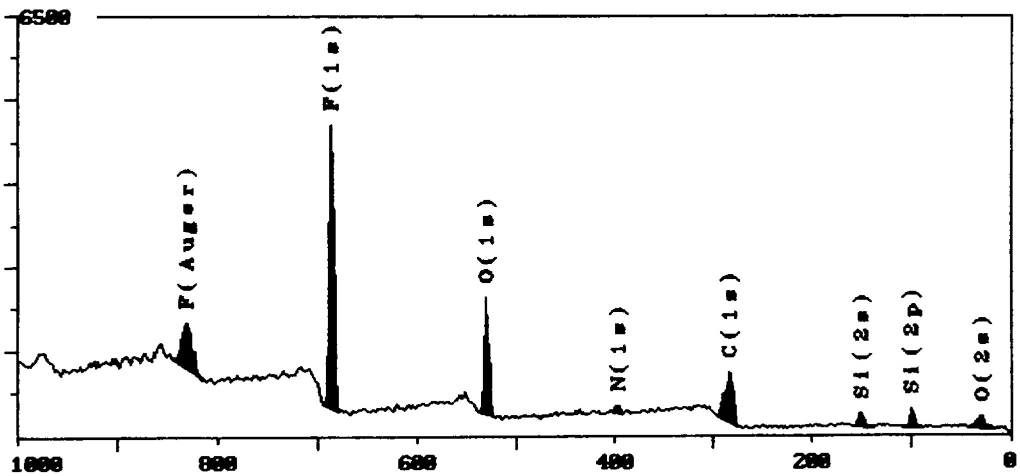
Operator: GARY TUSS
Date: Fri Jan 25 14:36:40 1991

Element	Binding Energy	atom %
F (1s)	689.35	12.10 %
O (1s)	532.66	31.00 %
N (1s)	400.33	2.49 %
C (1s)	285.02	44.91 %
Si (2s)	152.46	9.50 %
	Total Percent	100.00 %

Figure C-8 Survey 1s spectrum of unexposed region of blanket D1.

Wed Mar 20 11:51:02   M-Probe ESCA Console   User ID: DATA
A2EXP.MRS   Fri Jan 25 13:59:07 1991   Operator: GARY TUSS
A02 EXPOSED

Spot:	200x750µ	Resolution:	4	Energy:
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:
Region:	1/ 1	Aperture:	None	



Surface Composition Table Summary

File name: A2EXP.MRS
Region: 1
Description: A02 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 13:59:07 1991

Element	Binding Energy	atom %
F (1s)	690.49	33.27 %
O (1s)	533.80	19.40 %
N (1s)	400.36	1.64 %
C (1s)	286.53	38.53 %
Si (2s)	153.48	7.16 %
	Total Percent	100.00 %

Figure C-9 Survey spectrum of exposed region of blanket A2.

Surface Composition Table Summary

File name: A2EXP2.MRS
Region: 1
Description: A02 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:06:19 1991

Element	Binding Energy	atom %
F (1s)	690.20	51.09 %
O (1s)	533.95	7.23 %
C (1s)	292.43	41.68 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: A2EXP3.MRS
Region: 1
Description: A2 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:27:04 1991

Element	Binding Energy	atom %
F (1s)	691.09	52.99 %
O (1s)	535.11	4.98 %
C (1s)	292.97	42.03 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: A2EXP4.MRS
Region: 1
Description: A2 EXP

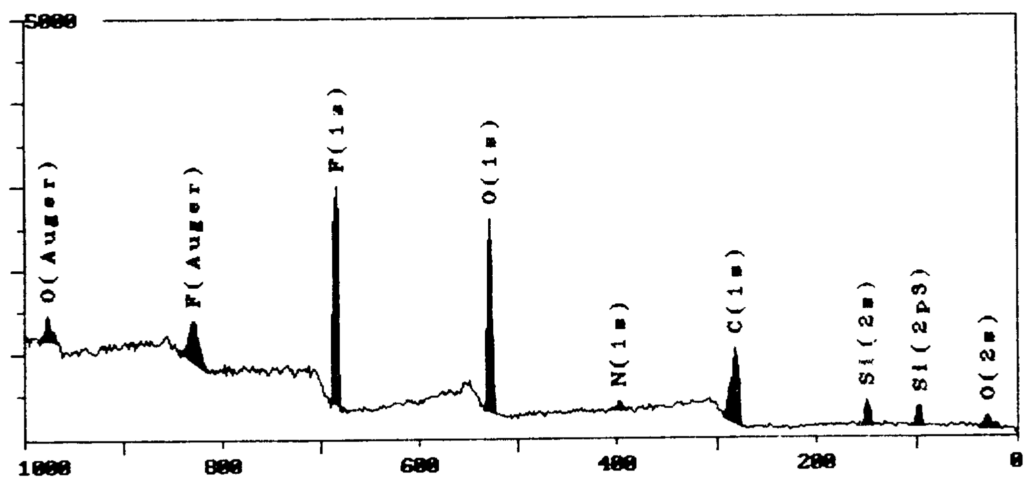
Operator: GARY TUSS
Date: Fri Feb 15 12:44:41 1991

Element	Binding Energy	atom %
F (1s)	691.39	52.74 %
O (1s)	535.25	4.69 %
C (1s)	293.68	42.58 %
	Total Percent	100.00 %

Table C-3 Table of surface elemental composition of exposed region of blanket A2.

Thu Mar 21 06:23:50 M-Probe ESCA Console User ID: DATA
A2TUCKD.MRS Fri Jan 25 14:02:31 1991 Operator: GARY TUSS
A02 TUCKED EDGE

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: A2TUCKD.MRS
Region: 1
Description: A02 TUCKED EDGE

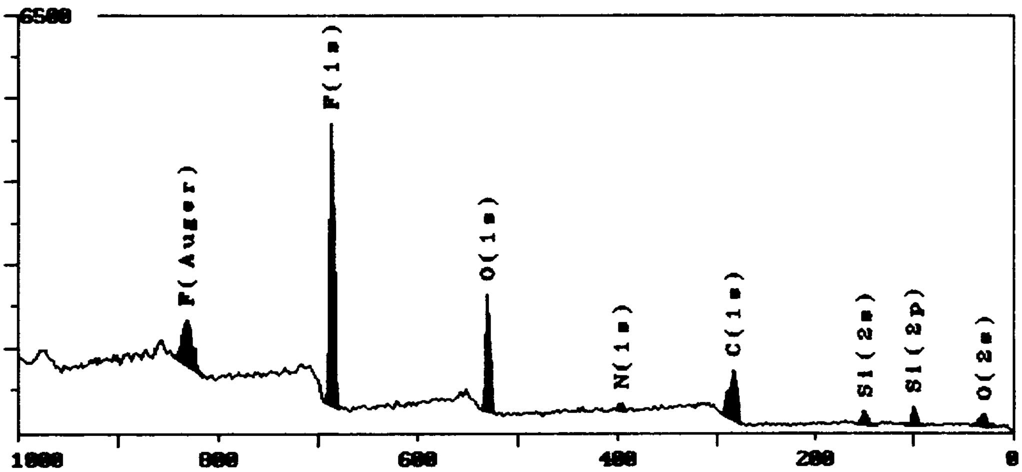
Operator: GARY TUSS
Date: Fri Jan 25 14:02:31 1991

Element	Binding Energy	atom %
F (1s)	689.31	21.60 %
O (1s)	532.67	25.35 %
N (1s)	400.98	2.04 %
C (1s)	285.25	42.10 %
Si (2s)	152.41	8.91 %
	Total Percent	100.00 %

Figure C-10 Survey spectrum of unexposed region of blanket A2.

Wed Mar 20 11:57:20 M-Probe ESCA Console User ID: DATA
A2EXPCN.MRS Fri Jan 25 13:59:07 1991 Operator: GARY TUSS
A02 EXPOSED CONTAMINATED

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: A2EXPCN.MRS
Region: 1
Description: A02 EXPOSED CONTAMINATED

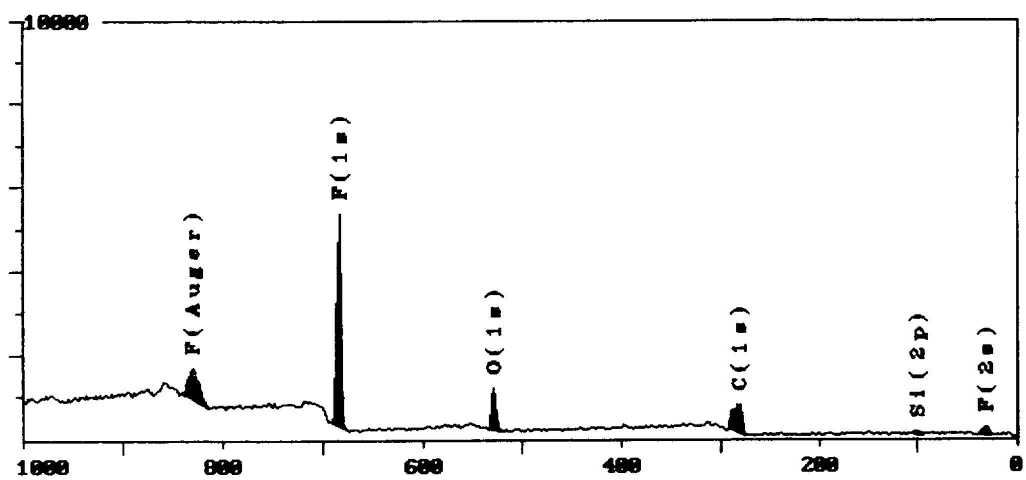
Operator: GARY TUSS
Date: Fri Jan 25 13:59:07 1991

Element	Binding Energy	atom %
F (1s)	690.49	33.27 %
O (1s)	533.80	19.40 %
N (1s)	400.36	1.64 %
C (1s)	286.53	38.53 %
Si (2s)	153.48	7.16 %
	Total Percent	100.00 %

Figure C-11 Survey spectrum of exposed, contaminated region of blanket A2.

Thu Mar 21 05:47:57 M-Probe ESCA Console User ID: DATA
E2EXP.MRS Tue Feb 26 12:15:32 1991 Operator: DOUG ELVBAKKEN
E-2 EXP

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: E2EXP.MRS
Region: 1
Description: E-2 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:15:32 1991

Element	Binding Energy	atom %
F (1s)	689.86	45.03 %
O (1s)	533.49	13.64 %
C (1s)	286.87	38.65 %
Si (2p)	103.63	2.68 %
	Total Percent	100.00 %

Figure C-12 Survey spectrum of exposed region of blanket E2.

Surface Composition Table Summary

File name: F2EXP2.MRS
Region: 1
Description: F02 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:40:30 1991

Element	Binding Energy	atom %
F (1s)	689.76	43.80 %
O (1s)	533.27	13.31 %
N (1s)	400.72	1.32 %
C (1s)	292.18	41.56 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: F2EXP3.MRS
Region: 1
Description: F2 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:20:05 1991

Element	Binding Energy	atom %
F (1s)	691.48	47.50 %
O (1s)	535.13	11.72 %
C (1s)	293.63	37.76 %
Si (2s)	155.37	3.02 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: F2EXP5.MRS
Region: 1
Description: F-2 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:44:48 1991

Element	Binding Energy	atom %
F (1s)	690.08	47.16 %
O (1s)	533.57	14.55 %
N (1s)	402.26	2.35 %
K (2s)	380.50	1.42 %
C (1s)	292.44	30.80 %
Si (2s)	153.98	3.72 %
	Total Percent	100.00 %

Table C-4 Table of surface elemental composition of exposed region of blanket F2.

Surface Composition Table Summary

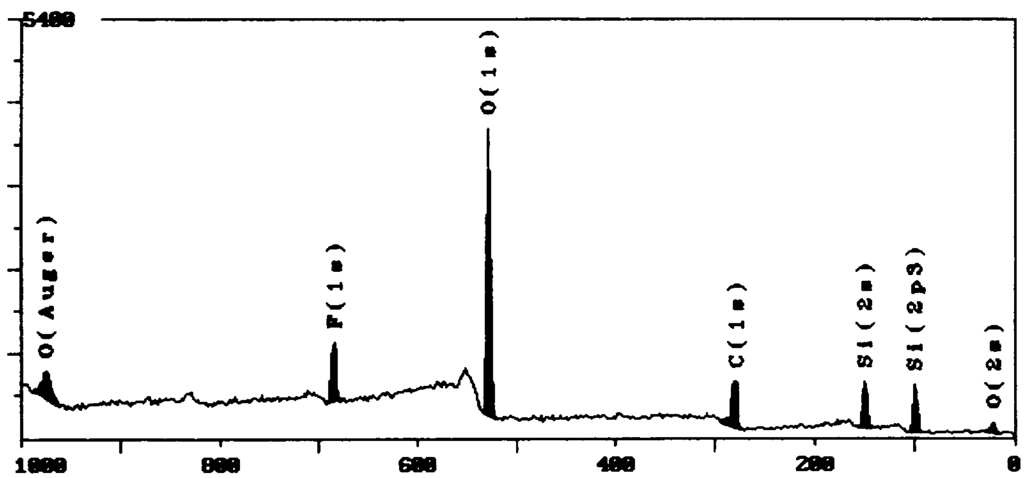
File name: F2EXP6.MRS
Region: 1
Description: F-2 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:50:19 1991

Element	Binding Energy	atom %
F (1s)	689.94	43.57 %
O (1s)	533.48	12.84 %
C (1s)	292.33	40.32 %
Si (2s)	153.81	3.27 %
	Total Percent	100.00 %

Table C-4 Table of surface elemental composition of exposed region of blanket F2 (continued).

Thu Mar 21 07:00:29   M-Probe ESCA Console   User ID: DATA
E2TUCKD.MRS   Tue Feb 26 12:19:24 1991   Operator: DOUG ELVBAKKEN
E-2 UNEXP
Spot: 200x750µ   Resolution: 4   Energy:
Scans: 3 of 3   Neutralizer: 5.0eV   Counts:
Region: 1/ 1   Aperture: None



Surface Composition Table Summary

File name: E2TUCKD.MRS
Region: 1
Description: E-2 UNEXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:19:24 1991

Element	Binding Energy	atom %
F (1s)	690.19	8.64 %
O (1s)	533.24	43.29 %
C (1s)	284.90	25.78 %
Si (2s)	153.84	22.29 %

	Total Percent	100.00 %

Figure C-13 Survey spectrum of unexposed region of blanket E2.

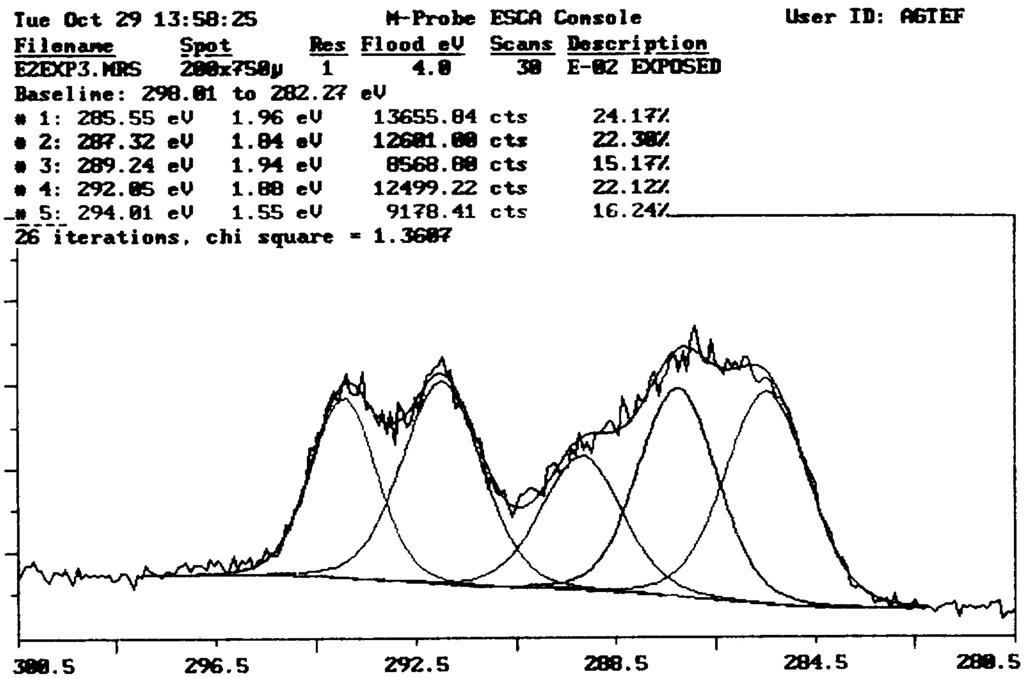
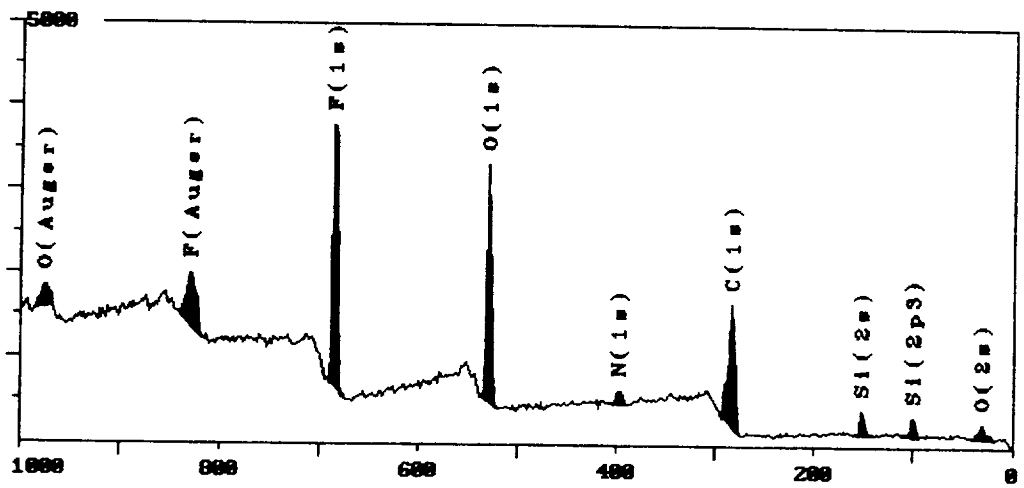


Figure C-14 Carbon 1s spectrum for exposed region of blanket E2.

Wed Mar 20 12:03:37 M-Probe ESCA Console User ID: DATA
A4EXP3.MRS Tue Feb 26 13:49:07 1991 Operator: DOUG ELVBAKKEN
A-4 EXP

Spot:	200x750µ	Resolution:	4	Energy:
Scans:	5 of 5	Neutralizer:	5.0eV	Counts:
Region:	1/ 1	Aperture:	None	



Surface Composition Table Summary

File name: A4EXP3.MRS
Region: 1
Description: A-4 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 13:49:07 1991

Element	Binding Energy	atom %
F (1s)	690.84	21.13 %
O (1s)	534.67	23.52 %
N (1s)	401.82	2.70 %
C (1s)	287.88	46.26 %
Si (2s)	155.01	6.38 %
	Total Percent	100.00 %

Figure C-15 Survey spectrum of exposed region of blanket A4.

Surface Composition Table Summary

File name: A4EXP4.MRS
Region: 1
Description: A-4 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 13:54:40 1991

Element	Binding Energy	atom %
F (1s)	690.70	21.30 %
O (1s)	534.60	23.59 %
N (1s)	402.54	2.20 %
C (1s)	287.54	46.53 %
Si (2s)	154.70	6.39 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: A4EXPCON.MRS
Region: 1
Description: A-4 EXP CONTAM

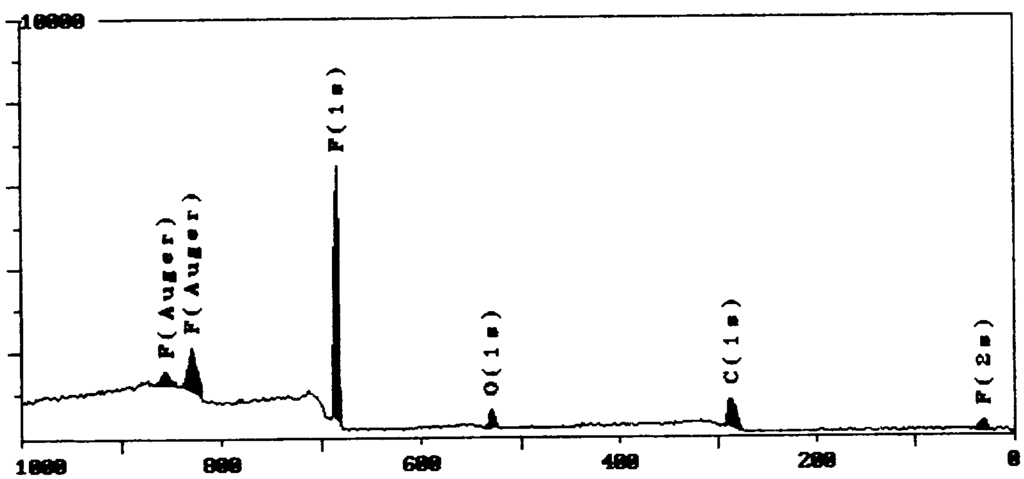
Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:40:56 1991

Element	Binding Energy	atom %
F (1s)	690.70	20.94 %
O (1s)	534.57	22.87 %
N (1s)	402.39	3.14 %
C (1s)	287.65	46.68 %
Si (2s)	155.07	6.37 %
	Total Percent	100.00 %

Table C-5 Table of surface elemental composition of exposed region of blanket A4.

Thu Mar 21 06:06:41 M-Probe ESCA Console User ID: DATA
F4EXP.MRS Tue Feb 26 12:34:03 1991 Operator: DOUG ELVBAKKEN
F-4 EXP

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: F4EXP.MRS
Region: 1
Description: F-4 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:34:03 1991

Element	Binding Energy	atom %
F (1s)	690.37	52.73 %
O (1s)	536.06	6.16 %
C (1s)	293.58	41.11 %
	Total Percent	100.00 %

Figure C-16 Survey spectrum of exposed region of blanket F4.

Surface Composition Table Summary

File name: F4EXP2.MRS
Region: 1
Description: F-4 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:55:56 1991

Element	Binding Energy	atom %
F (1s)	690.15	51.43 %
O (1s)	534.37	5.71 %
C (1s)	292.34	42.86 %
	Total Percent	100.00 %

Surface Composition Table Summary

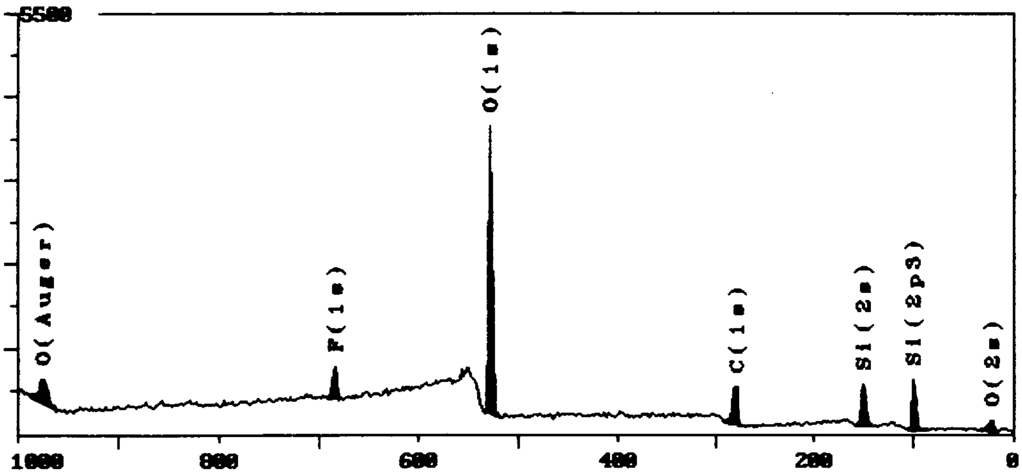
File name: F4EXP3.MRS
Region: 1
Description: F-4 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 15:01:28 1991

Element	Binding Energy	atom %
F (1s)	690.11	51.34 %
O (1s)	534.48	6.25 %
C (1s)	292.31	42.41 %
	Total Percent	100.00 %

Table C-6 Table of surface elemental composition of exposed region of blanket F4.

Thu Mar 21 07:03:33	M-Probe ESCA Console	User ID: DATA
F4TUCKD.MRS Tue Feb 26 12:37:27 1991		Operator: DOUG ELVBAKKEN
F-4 UNEXP		
Spot: 200x750μ	Resolution: 4	Energy:
Scans: 3 of 3	Neutralizer: 5.0eV	Counts:
Region: 1/ 1	Aperture: None	



Surface Composition Table Summary

File name: F4TUCKD.MRS
Region: 1
Description: F-4 UNEXP

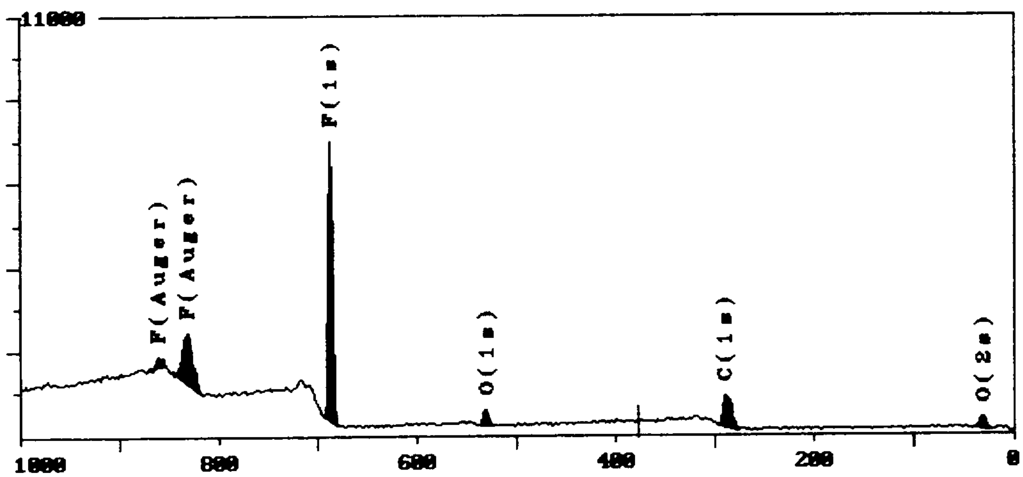
Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:37:27 1991

Element	Binding Energy	atom %
F (1s)	689.79	5.00 %
O (1s)	533.16	47.17 %
C (1s)	284.96	23.79 %
Si (2s)	153.76	24.05 %
	Total Percent	100.00 %

Figure C-17 Survey spectrum of unexposed region of blanket F4.

Wed Mar 20 12:09:47 M-Probe ESCA Console User ID: DATA
B5EXP.MRS Fri Jan 25 14:12:44 1991 Operator: GARY TUSS
B05 EXPOSED

Spot:	200x750µ	Resolution:	4	Energy:	378.76 eV
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	327
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: B5EXP.MRS
Region: 1
Description: B05 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:12:44 1991

Element	Binding Energy	atom %
F (1s)	690.99	51.55 %
O (1s)	535.01	5.54 %
C (1s)	292.58	42.91 %
	Total Percent	100.00 %

Figure C-18 Survey spectrum of exposed region of blanket B5.

Surface Composition Table Summary

File name: B5EXP3.MRS
Region: 1
Description: B05 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:13:13 1991

Element	Binding Energy	atom %
F (1s)	689.93	51.94 %
O (1s)	534.55	5.84 %
C (1s)	292.17	42.22 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: B5EXP4.MRS
Region: 1
Description: B5 EXPOSED

Operator: GARY TUSS
Date: Fri Feb 15 13:33:50 1991

Element	Binding Energy	atom %
F (1s)	691.15	52.32 %
O (1s)	535.14	4.16 %
C (1s)	293.30	43.52 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: B5EXP5.MRS
Region: 1
Description: B5 EXP

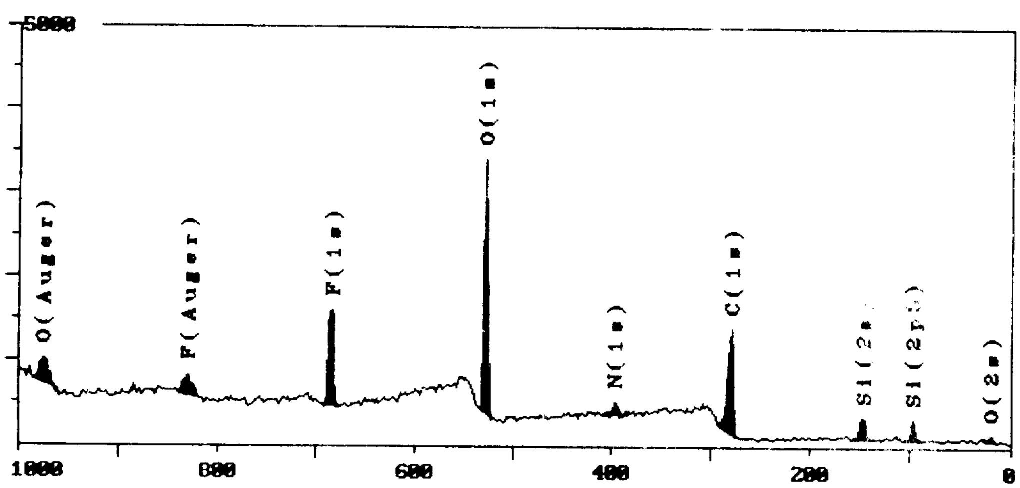
Operator: GARY TUSS
Date: Fri Feb 15 12:52:43 1991

Element	Binding Energy	atom %
F (1s)	691.27	52.47 %
O (1s)	535.47	3.54 %
C (1s)	293.45	43.99 %
	Total Percent	100.00 %

Table C-7 Table of surface elemental composition of exposed region of blanket B5.

Thu Mar 21 06:26:16 M-Probe ESCA Console User ID: DATA
B5TUCKD.MRS Mon Jan 28 08:29:46 1991 Operator: GARY TUSS
B05 TUCKED EDGE

Spot:	200x750µ	Resolution:	4	Energy:
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:
Region:	1/ 1	Aperture:	None	



Surface Composition Table Summary

File name: B5TUCKD.MRS
Region: 1
Description: B05 TUCKED EDGE

Operator: GARY TUSS
Date: Mon Jan 28 08:29:46 1991

Element	Binding Energy	atom %
F (1s)	689.47	11.19 %
O (1s)	532.12	31.04 %
N (1s)	399.42	3.01 %
C (1s)	283.51	46.10 %
Si (2s)	151.07	8.66 %
	Total Percent	100.00 %

Figure C-19 Survey spectrum of unexposed region of blanket B5.

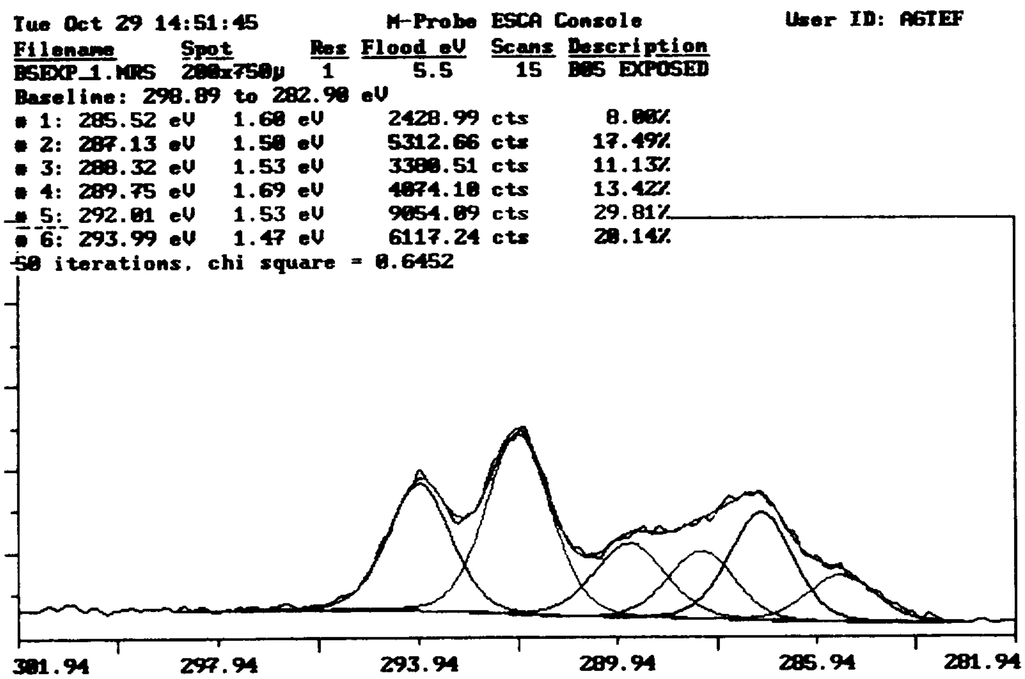
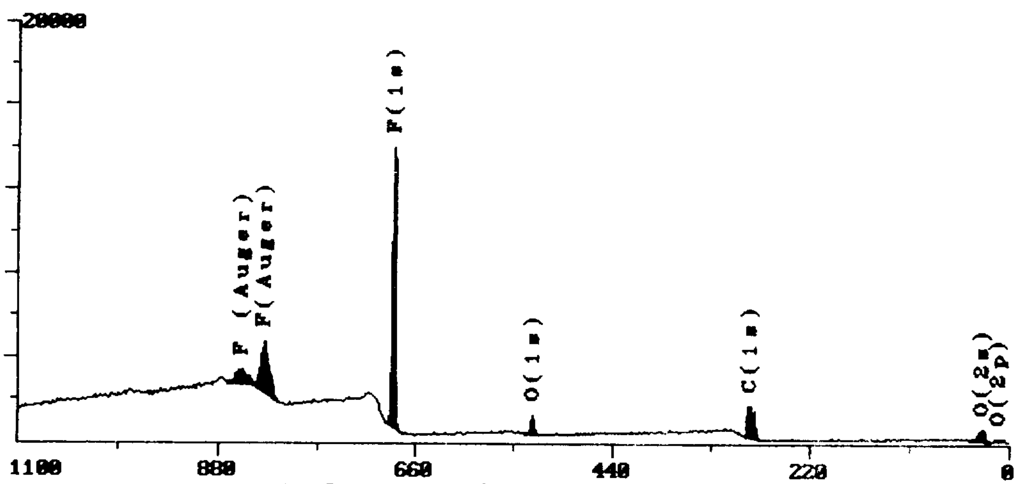


Figure C-20 Carbon 1s spectrum for exposed region of blanket B5.

C5 front

Thu Nov 08 10:32:01　　M-Probe ESCA Console　　User ID: LDEF
AGTEF_3.MRS　　Wed Oct 24 15:04:30 1990　　Operator: GARY TUSS
SILVER TEFLON SURFACE SHINY
Spot: 400x1000μ　　Resolution: 4　　Energy:
Scans: 4 of 4　　Neutralizer: 5.0eV　　Counts:
Region: 1/ 1　　Aperture: None



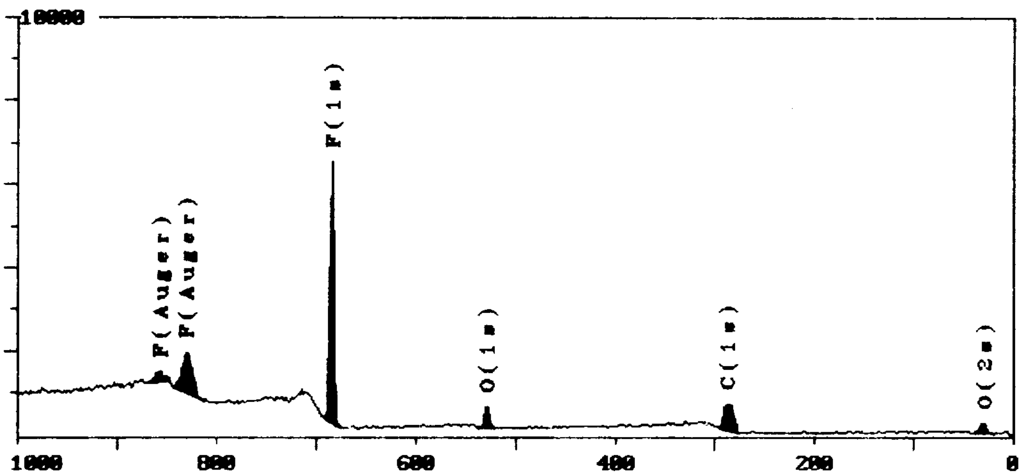
Surface Composition Table Summary

File name: AGTEF_3.MRS
Description: SILVER TEFLON SURFACE SHINY
Operator: GARY TUSS

Element	Binding Energy	atom %
F (1s)	683.24	53.47 %
O (1s)	527.61	4.86 %
C (1s)	285.82	41.67 %
	Total Percent	100.00 %

Figure C-21　　Survey spectrum of exposed region of blanket C5.

Wed Mar 20 12:21:31 M-Probe ESCA Console User ID: DATA
C5EXP2.MRS Wed Feb 13 17:16:38 1991 Operator: GARY TUSS
C05 EXPOSED SAMPLE II
Spot: 200x750µ Resolution: 4 Energy:
Scans: 3 of 3 Neutralizer: 5.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: C5EXP2.MRS
Region: 1
Description: C05 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:16:38 1991

Element	Binding Energy	atom %
F (1s)	689.90	48.95 %
O (1s)	533.79	6.91 %
C (1s)	293.58	44.14 %
	Total Percent	100.00 %

Figure C-22 Survey spectrum of exposed region of blanket C5 (sample 2).

Surface Composition Table Summary

File name: C5EXP3.MRS
Region: 1
Description: C5 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:37:15 1991

Element	Binding Energy	atom %
F (1s)	691.16	53.27 %
O (1s)	535.07	4.92 %
C (1s)	293.19	41.81 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C5EXP4.MRS
Region: 1
Description: C5 EXP

Operator: GARY TUSS
Date: Fri Feb 15 12:56:07 1991

Element	Binding Energy	atom %
F (1s)	691.26	53.07 %
O (1s)	535.18	4.65 %
C (1s)	293.39	42.28 %
	Total Percent	100.00 %

Table C-8 Table of surface elemental composition of exposed region of blanket C5.

C5 front

Thu Nov 08 10:33:05 M-Probe ESCA Console User ID: LDEF

Filename	Spot Res	Flood eV	Description
AGTEF_4.MRS	200x751μ	5.0	SILVER TEFLON SURFACE (SHINY)

Baseline: 290.40 to 274.35 eV

# 1:	278.57 eV	1.74 eV	3091.68 cts	10.03%
# 2:	280.24 eV	1.70 eV	6555.39 cts	21.27%
# 3:	282.28 eV	2.07 eV	6018.22 cts	19.52%
# 4:	284.96 eV	1.65 eV	9366.65 cts	30.39%
# 5:	286.96 eV	1.43 eV	5793.55 cts	18.79%

19 iterations, chi square = 1.2006

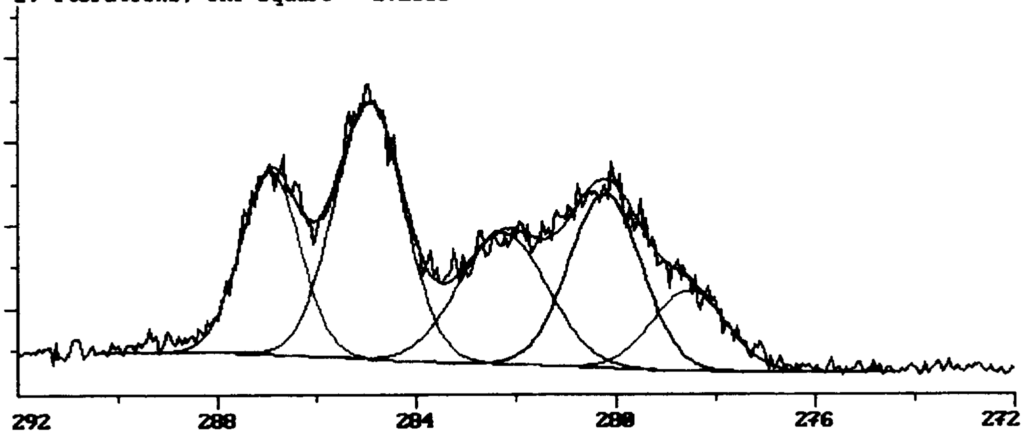


Figure C-23 Carbon 1s spectrum for exposed region of blanket C5.

Tue Oct 29 14:54:13 M-Probe ESCA Console User ID: AGTEF

Filename	Spot	Res	Flood eV	Scans	Description
C05EXP_2.MRS	200x750µ	1	3.0	15	C05 EXPOSED II

Baseline: 297.59 to 282.33 eV

# 1:	285.52 eV	1.68 eV	2631.95 cts	9.27%
# 2:	287.20 eV	1.61 eV	5853.18 cts	20.62%
# 3:	288.80 eV	1.61 eV	3913.77 cts	13.79%
# 4:	290.22 eV	1.61 eV	2247.22 cts	7.92%
# 5:	292.05 eV	1.58 eV	7993.33 cts	28.16%
# 6:	293.98 eV	1.64 eV	5750.58 cts	20.26%

4 interations, chi square = 0.7568

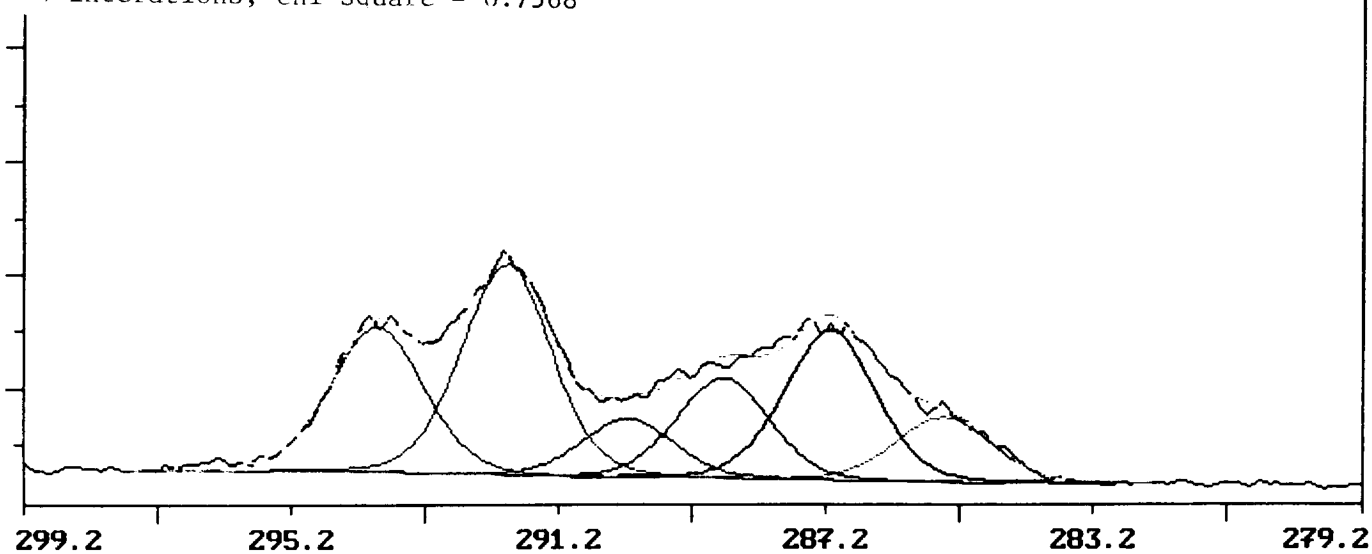


Figure C-24 Carbon 1s spectrum for exposed region of blanket C5(sample 2).

C5 front

Thu Nov 08 10:33:38 M-Probe ESCA Console User ID: LDEF

Filename	Spot	Res	Flood eV	Description
AGTEF_4.MRS	200x751µ		5.0	SILVER TEFLON SURFACE (SHINY)

Baseline: 688.92 to 677.78 eV

1: 682.19 eV 2.03 eV 141404.58 cts 100.00%

15 iterations, chi square = 1.7049

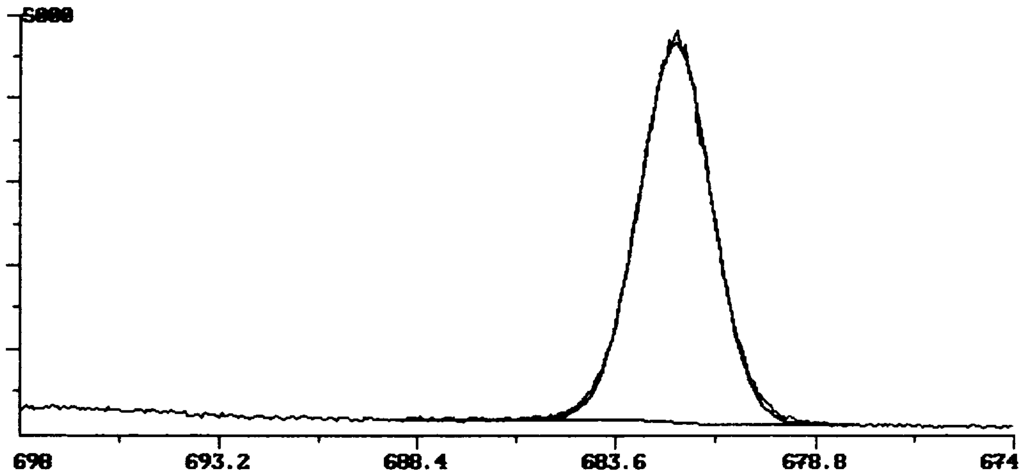
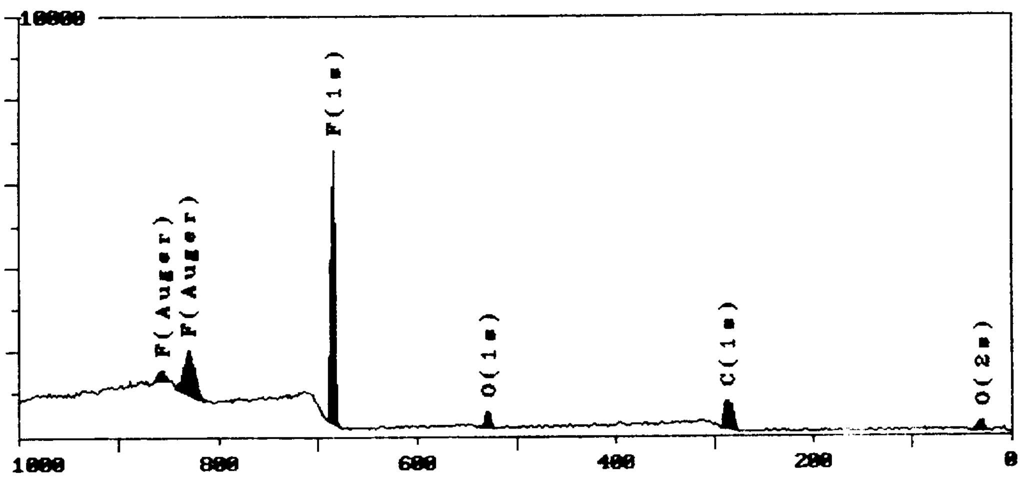


Figure C-25 Fluorine 1s spectrum for exposed region of C5.

Wed Mar 20 13:09:34 M-Probe ESCA Console User ID: DATA
D5EXP.MRS Tue Feb 26 12:08:02 1991 Operator: DOUG ELVBAKKEN
D-5 EXP

Spot:	200x750µ	Resolution:	4	Energy:
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:
Region:	1/ 1	Aperture:	None	



Surface Composition Table Summary

File name: D5EXP.MRS
Region: 1
Description: D-5 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:08:02 1991

Element	Binding Energy	atom %
F (1s)	689.91	51.41 %
O (1s)	534.01	6.09 %
C (1s)	292.12	42.50 %
	Total Percent	100.00 %

Figure C-26 Survey spectrum of exposed region of blanket D5.

Surface Composition Table Summary

File name: D5EXP2.MRS
Region: 1
Description: D-5 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:11:33 1991

Element	Binding Energy	atom %
F (1s)	689.92	52.68 %
O (1s)	533.85	5.91 %
C (1s)	292.26	41.41 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D5EXP3.MRS
Region: 1
Description: D-5 EXP

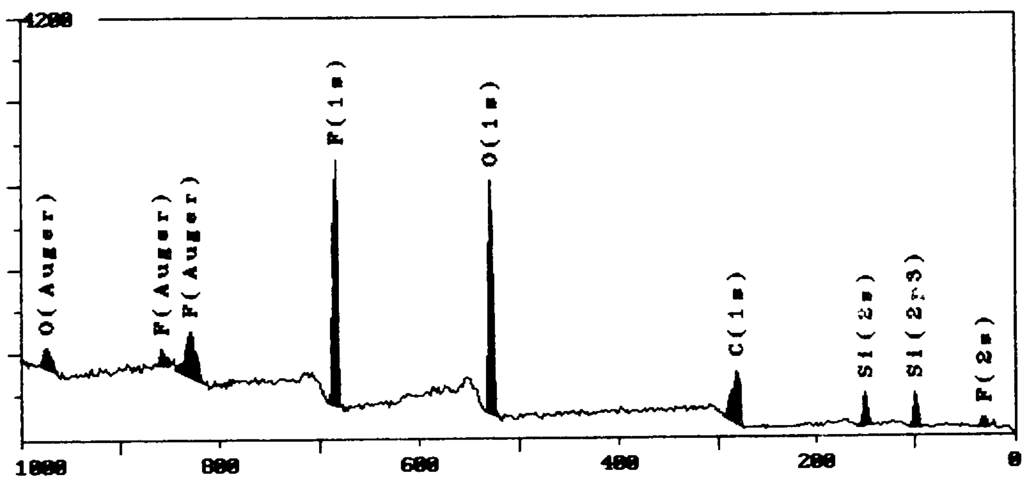
Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:17:04 1991

Element	Binding Energy	atom %
F (1s)	690.17	59.97 %
O (1s)	534.31	2.33 %
C (1s)	292.41	37.70 %
	Total Percent	100.00 %

Table C-9 Table of surface elemental composition of exposed region of blanket D5.

Thu Mar 21 06:49:57 M-Probe ESCA Console User ID: DATA
D5TUCKD.MRS Tue Feb 26 12:11:40 1991 Operator: DOUG ELVBAKKEN
D-5 UNEXP

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: D5TUCKD.MRS
Region: 1
Description: D-5 UNEXP

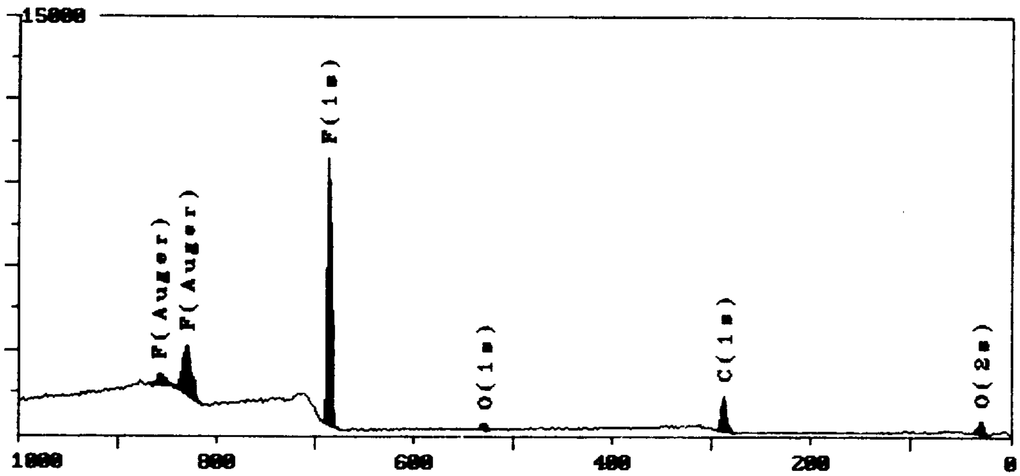
Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:11:40 1991

Element	Binding Energy	atom %
F (1s)	690.12	26.09 %
O (1s)	533.28	30.14 %
C (1s)	285.89	31.15 %
Si (2s)	153.96	12.62 %
	Total Percent	100.00 %

Figure C-27 Survey spectrum of unexposed region of blanket D5.

Wed Mar 20 12:25:36 M-Probe ESCA Console User ID: DATA
C6EXP.MRS Fri Jan 25 14:19:31 1991 Operator: GARY TUSS
C06 EXPOSED

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: C6EXP.MRS
Region: 1
Description: C06 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:19:31 1991

Element	Binding Energy	atom %
F (1s)	690.33	61.98 %
O (1s)	532.79	2.26 %
C (1s)	291.28	35.75 %
	Total Percent	100.00 %

Figure C-28 Survey spectrum of exposed region of blanket C6.

Surface Composition Table Summary

File name: C6EXP2.MRS
Region: 1
Description: C06 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:20:02 1991

Element	Binding Energy	atom %
F (1s)	689.99	59.00 %
O (1s)	534.02	2.85 %
C (1s)	292.24	38.14 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C6EXP3.MRS
Region: 1
Description: C6 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:40:39 1991

Element	Binding Energy	atom %
F (1s)	691.39	59.10 %
O (1s)	535.38	1.79 %
C (1s)	293.26	39.12 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C6EXP4.MRS
Region: 1
Description: C6 EXP

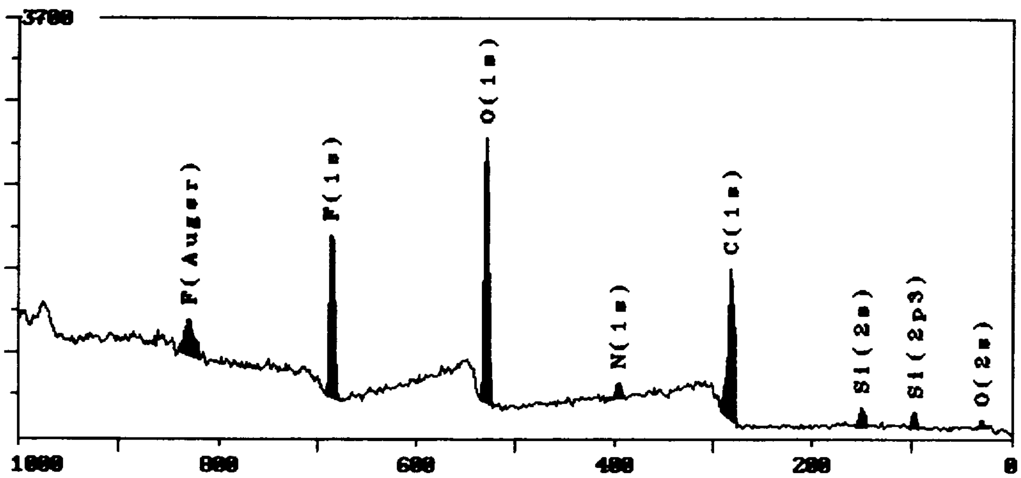
Operator: GARY TUSS
Date: Fri Feb 15 12:59:32 1991

Element	Binding Energy	atom %
F (1s)	691.40	58.96 %
O (1s)	535.89	1.94 %
C (1s)	293.08	39.10 %
	Total Percent	100.00 %

Table C-10 Table of surface elemental composition of exposed region of blanket C6.

Thu Mar 21 06:38:09 M-Probe ESCA Console User ID: DATA
C6TUCKD.MRS Fri Jan 25 14:22:56 1991 Operator: GARY TUSS
C06 TUCKED EDGE

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: C6TUCKD.MRS
Region: 1
Description: C06 TUCKED EDGE

Operator: GARY TUSS
Date: Fri Jan 25 14:22:56 1991

Element	Binding Energy	atom %
F (1s)	689.86	13.80 %
O (1s)	532.73	27.59 %
N (1s)	399.91	3.21 %
C (1s)	284.96	50.99 %
Si (2s)	152.45	4.40 %
	Total Percent	100.00 %

Figure C-29 Survey spectrum of unexposed region of blanket C6.

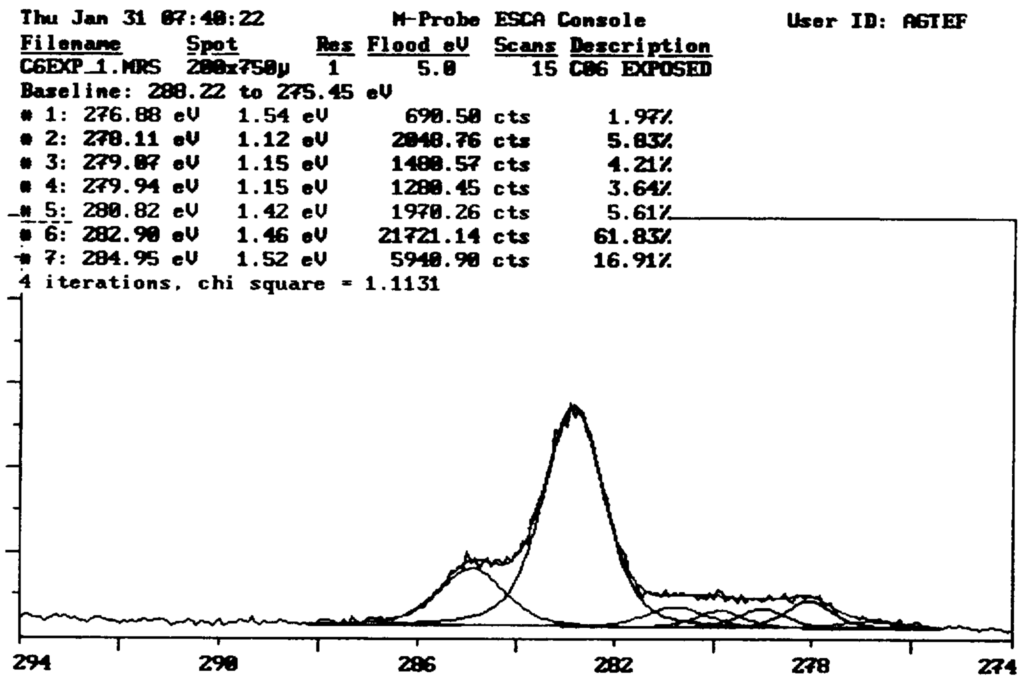
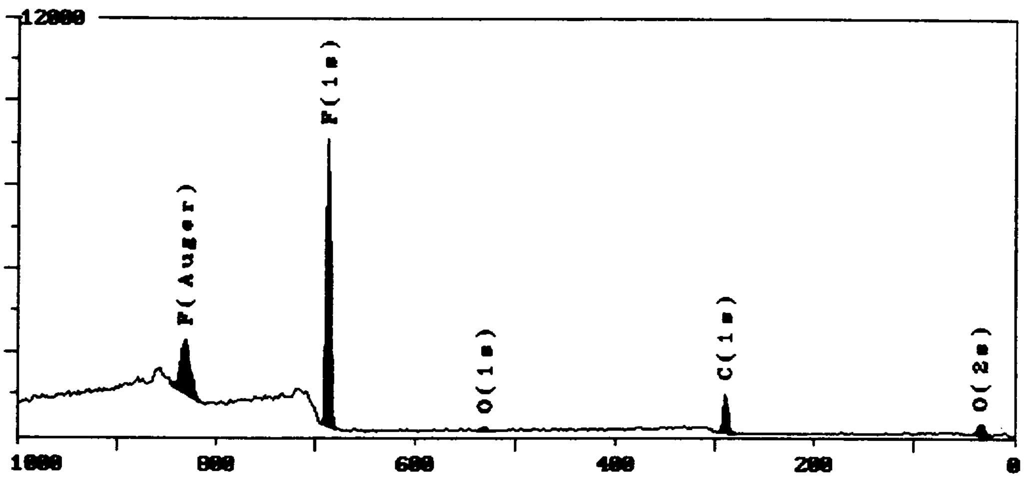


Figure C-30 Carbon 1s spectrum for exposed region of blanket C6.

Wed Mar 20 12:14:20 M-Probe ESCA Console User ID: DATA
B7EXP.MRS Tue Feb 26 11:57:48 1991 Operator: DOUG ELVBAKKEN
B-7 EXP

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: B7EXP.MRS
Region: 1
Description: B-7 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 11:57:48 1991

Element	Binding Energy	atom %
F (1s)	691.83	65.70 %
O (1s)	535.33	1.43 %
C (1s)	293.94	32.87 %
	Total Percent	100.00 %

Figure C-31 Survey spectrum for exposed region of blanket B7.

Surface Composition Table Summary

File name: B7EXP3.MRS
Region: 1
Description: B-7 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:00:12 1991

Element	Binding Energy	atom %
F (1s)	691.82	65.48 %
O (1s)	535.51	1.46 %
C (1s)	293.97	33.06 %
	Total Percent	100.00 %

Surface Composition Table Summary

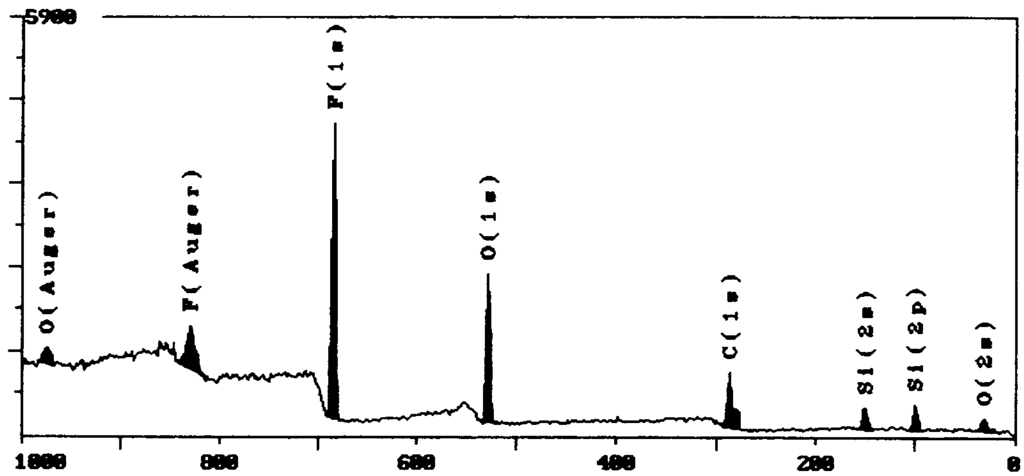
File name: B7EXP4.MRS
Region: 1
Description: B-7 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:06:02 1991

Element	Binding Energy	atom %
F (1s)	691.78	64.43 %
O (1s)	535.18	1.43 %
C (1s)	293.93	34.14 %
	Total Percent	100.00 %

Table C-11 Table of surface elemental composition of exposed region of blanket B7.

Thu Mar 21 06:29:10 M-Probe ESCA Console User ID: DATA
B7TUCKD.MRS Tue Feb 26 12:01:13 1991 Operator: DOUG ELVBAKKEN
B-7 UNEXP
Spot: 200x750μ Resolution: 4 Energy:
Scans: 3 of 3 Neutralizer: 5.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: B7TUCKD.MRS
Region: 1
Description: B-7 UNEXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:01:13 1991

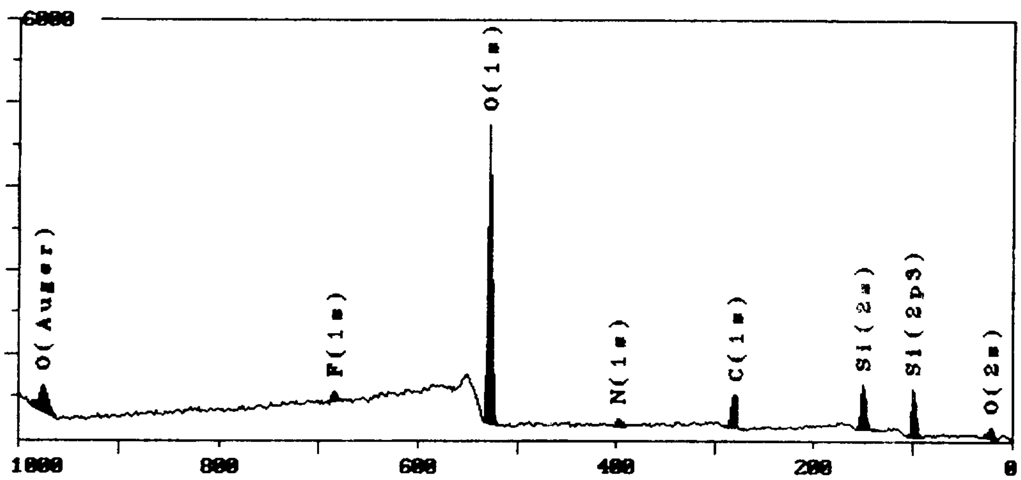
Element	Binding Energy	atom %
F (1s)	689.92	41.02 %
O (1s)	533.33	28.69 %
C (1s)	292.07	30.29 %

	Total Percent	100.00 %

Figure C-32 Survey spectrum of unexposed region of blanket B7.

Thu Mar 21 06:32:57 M-Probe ESCA Console User ID: DATA
B7YELLOW.MRS Tue Feb 26 12:04:37 1991 Operator: DOUG ELVBAKKEN
B-7 UNEXP YELLOW

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: B7YELLOW.MRS
Region: 1
Description: B-7 UNEXP YELLOW

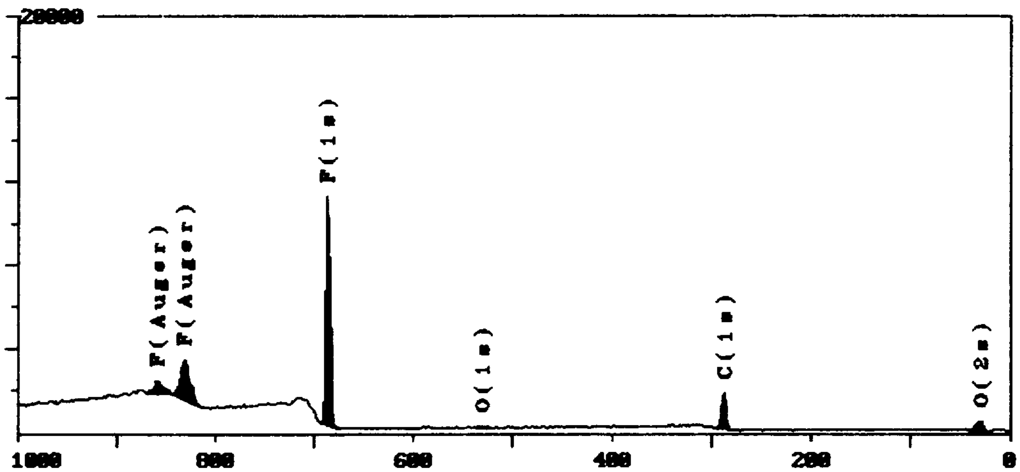
Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:04:37 1991

Element	Binding Energy	atom %
F (1s)	689.46	1.39 %
O (1s)	533.12	50.30 %
N (1s)	402.31	2.61 %
C (1s)	284.89	20.13 %
Si (2s)	153.76	25.57 %

	Total Percent	100.00 %

Figure C-33 Survey spectrum of unexposed, highly contaminated region of blanket B7.

Wed Mar 20 13:13:03 M-Probe ESCA Console User ID: DATA
D7EXP.MRS Fri Jan 25 14:40:05 1991 Operator: GARY TUSS
D07 EXPOSED
Spot: 200x750µ Resolution: 4 Energy:
Scans: 3 of 3 Neutralizer: 4.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: D7EXP.MRS
Region: 1
Description: D07 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:40:05 1991

Element	Binding Energy	atom %
F (1s)	690.36	63.61 %
O (1s)	533.59	1.02 %
C (1s)	291.30	35.37 %
	Total Percent	100.00 %

Figure C-34 Survey spectrum of exposed region of blanket D7.

Surface Composition Table Summary

File name: D7EXP2.MRS
Region: 1
Description: D07 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:33:41 1991

Element	Binding Energy	atom %
F (1s)	690.02	65.95 %
O (1s)	533.54	1.27 %
C (1s)	292.22	32.79 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D7EXP3.MRS
Region: 1
Description: D7 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:54:26 1991

Element	Binding Energy	atom %
F (1s)	691.46	64.82 %
O (1s)	535.01	1.22 %
C (1s)	293.47	33.96 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D7EXP4.MRS
Region: 1
Description: D7 EXP

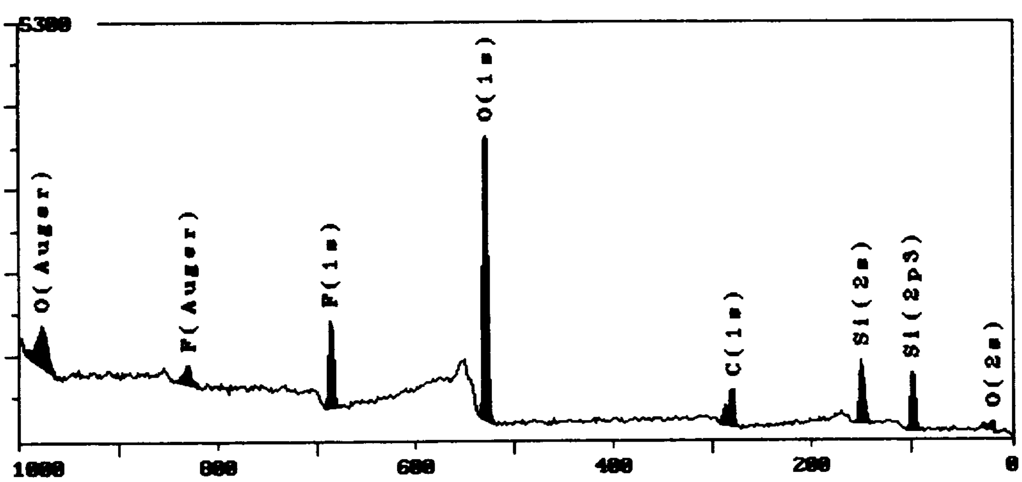
Operator: GARY TUSS
Date: Fri Feb 15 13:13:14 1991

Element	Binding Energy	atom %
F (1s)	691.45	64.04 %
O (1s)	535.68	1.47 %
C (1s)	293.54	34.48 %
	Total Percent	100.00 %

Table C-12 Table of surface elemental composition of exposed region of blanket D7.

Thu Mar 21 06:52:31 M-Probe ESCA Console User ID: DATA
D7TUCKD.MRS Fri Jan 25 14:43:28 1991 Operator: GARY TUSS
D07 TUCKED EDGE

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: D7TUCKD.MRS
Region: 1
Description: D07 TUCKED EDGE

Operator: GARY TUSS
Date: Fri Jan 25 14:43:28 1991

Element	Binding Energy	atom %
F (1s)	690.11	9.53 %
O (1s)	533.05	44.96 %
C (1s)	283.91	19.05 %
Si (2s)	152.68	26.46 %
	Total Percent	100.00 %

Figure C-35 Survey spectrum of unexposed region of blanket D7.

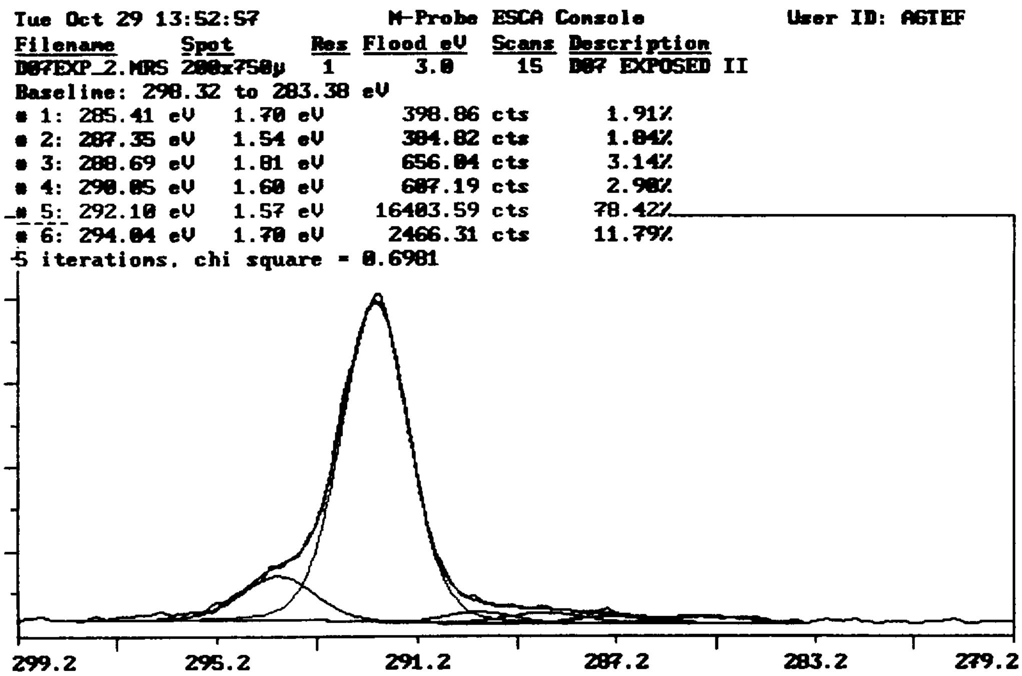
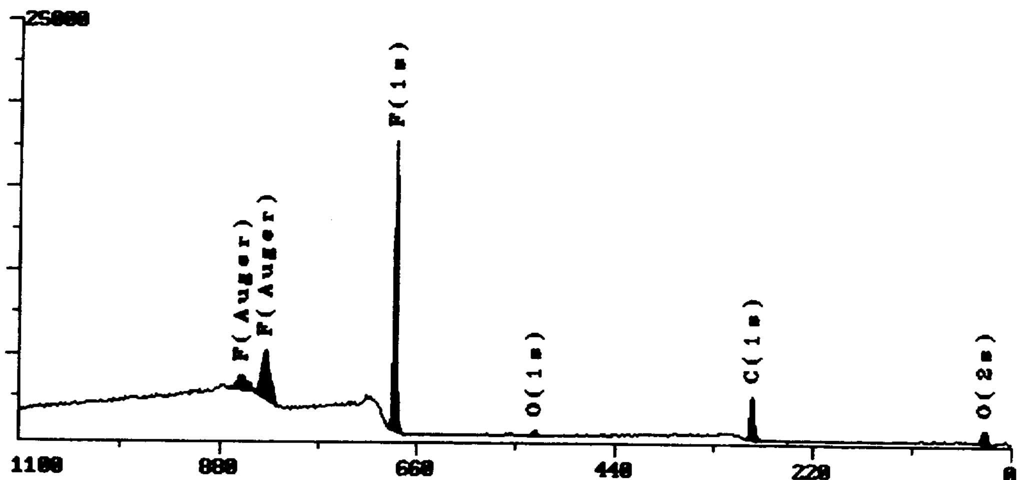


Figure C-36 Carbon 1s spectrum for exposed region of blanket D7.

C8 front

Thu Nov 08 10:24:43 M-Probe ESCA Console User ID: LDEF
AGTEF_1.MRS Tue Oct 23 14:30:40 1990 Operator: GARY TUSS
SILVER TEFLON DULL SURFACE I
Spot: 400x1000μ Resolution: 4 Energy:
Scans: 4 of 4 Neutralizer: 5.0eV Counts:
Region: 1/ 1 Aperture: None



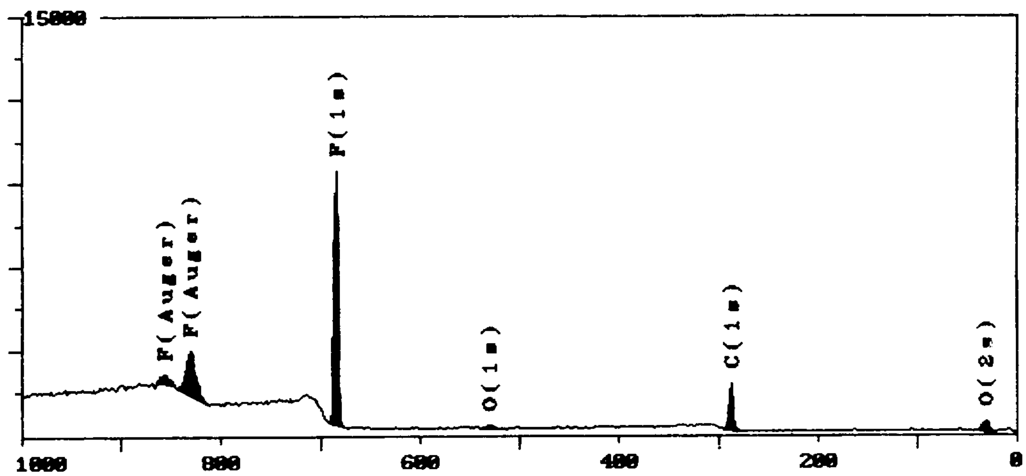
Surface Composition Table Summary

File name: AGTEF_1.MRS
Description: SILVER TEFLON DULL SURFACE I
Operator: GARY TUSS

Element	Binding Energy	atom %
F (1s)	683.52	64.38 %
O (1s)	526.54	1.47 %
C (1s)	285.67	34.15 %
	Total Percent	100.00 %

Figure C-37 Survey spectrum of exposed region of blanket C8.

Wed Mar 28 12:32:24 M-Probe ESCA Console User ID: DATA
C8EXP2.MRS Wed Feb 13 17:23:26 1991 Operator: GARY TUSS
C08 EXPOSED SAMPLE II
Spot: 200x750μ Resolution: 4 Energy:
Scans: 3 of 3 Neutralizer: 5.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: C8EXP2.MRS
Region: 1
Description: C08 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:23:26 1991

Element	Binding Energy	atom %
F (1s)	690.12	62.26 %
O (1s)	534.24	2.05 %
C (1s)	292.25	35.68 %
	Total Percent	100.00 %

Figure C-38 Survey spectrum of exposed region of blanket C8.

Surface Composition Table Summary

File name: C8EXP3.MRS
Region: 1
Description: C8 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:44:05 1991

Element	Binding Energy	atom %
F (1s)	691.58	63.22 %
O (1s)	534.65	1.29 %
C (1s)	293.70	35.49 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C8EXP4.MRS
Region: 1
Description: C8 EXP

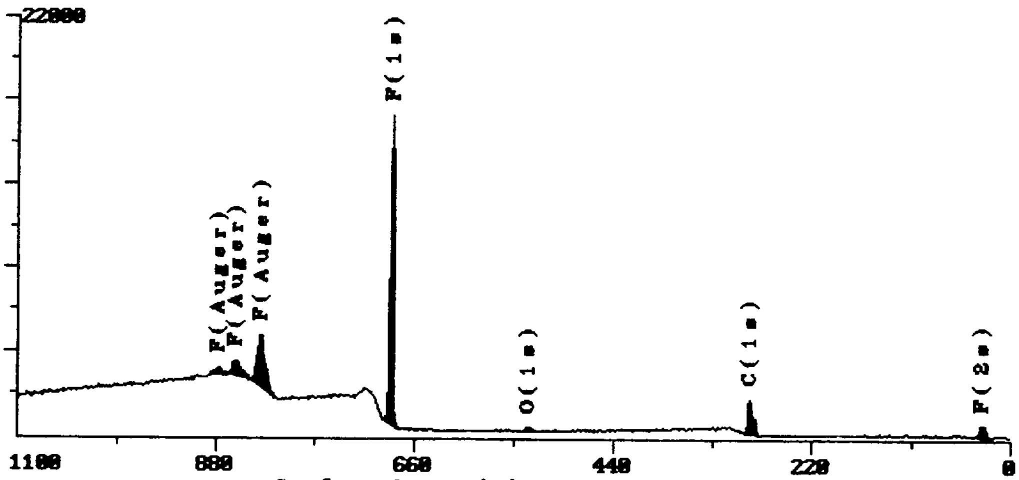
Operator: GARY TUSS
Date: Fri Feb 15 13:02:57 1991

Element	Binding Energy	atom %
F (1s)	691.60	64.23 %
O (1s)	534.81	1.96 %
C (1s)	293.74	33.81 %
	Total Percent	100.00 %

Table C-13 Table of surface elemental composition of exposed region of blanket C8.

C8 back

Tue Nov 13 12:24:21 M-Probe ESCA Console User ID: LDEF
AGTEF_7.MRS Tue Nov 13 10:04:26 1990 Operator: GARY TUSS
SILVER/TEFLON INTERFACE TEFLON SURFACE
Spot: 400x1000µ Resolution: 4 Energy:
Scans: 4 of 4 Neutralizer: 4.0eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: AGTEF_7.MRS
Description: SILVER/TEFLON INTERFACE TEFLON SURFACE
Operator: GARY TUSS

Element	Binding Energy	atom %
F (1s)	684.19	63.22 %
O (1s)	531.83	1.30 %
C (1s)	286.94	35.48 %
	Total Percent	100.00 %

Figure C-39 Survey spectrum of Ag/FEP interface of blanket C8.

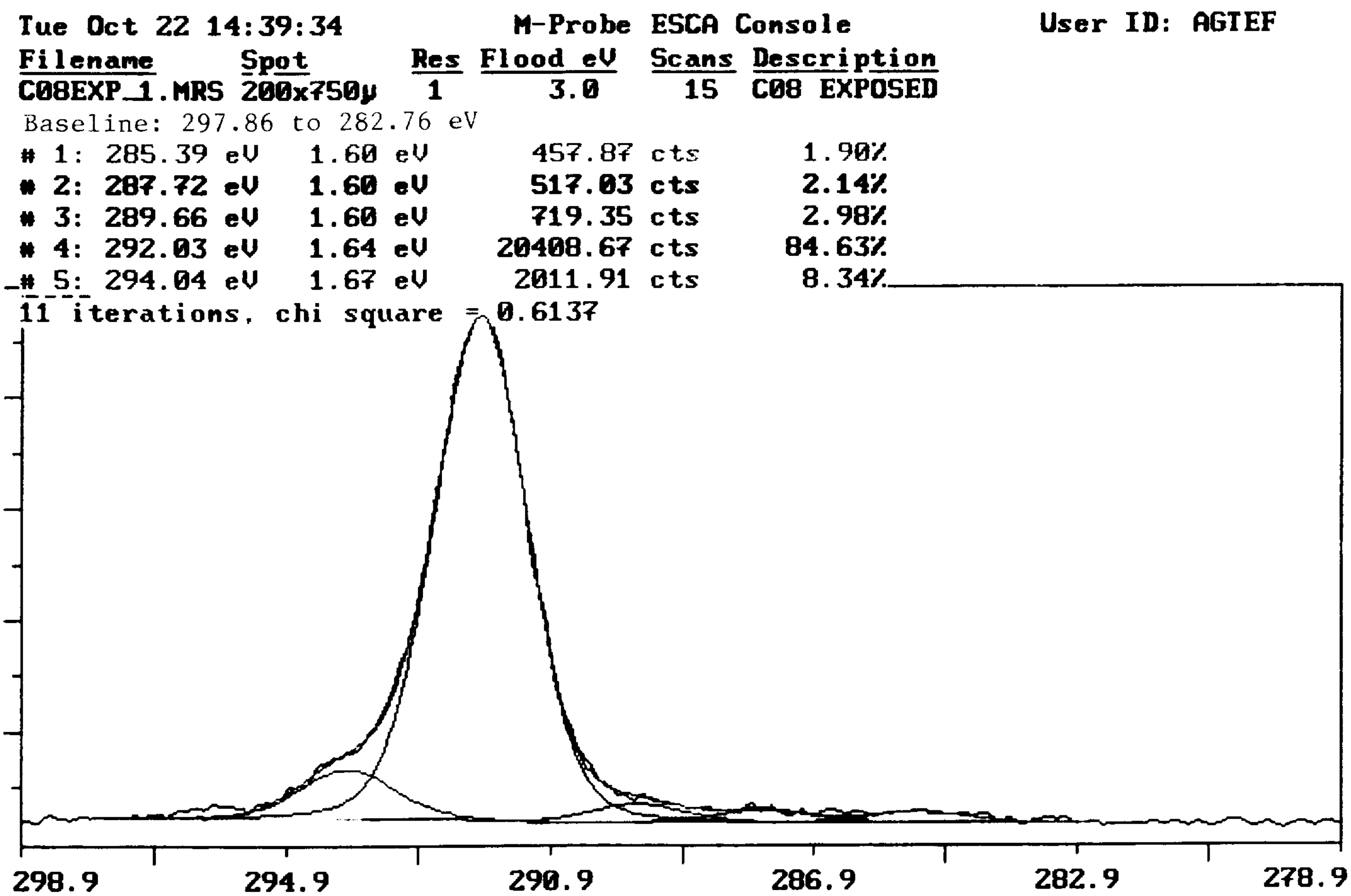


Figure C-40 Carbon 1s spectrum for exposed region of blanket C8.

C8 back

Tue Nov 13 12:05:55 M-Probe ESCA Console User ID: LDEF

Filename	Spot	Res	Flood eV	Description
AGTEF_8.MRS	200x751µ		4.0	SILVER/TEFLON INTERFACE TEFLON SURFACE

Baseline: 291.17 to 277.30 eV

# 1:	281.16 eV	1.53 eV	5810.98 cts	20.72%
# 2:	282.54 eV	1.45 eV	2225.67 cts	7.94%
# 3:	284.16 eV	1.68 eV	1660.03 cts	5.92%
# 4:	286.11 eV	1.31 eV	11995.28 cts	42.77%
# 5:	287.94 eV	1.40 eV	6356.53 cts	22.66%

11 iterations, chi square = 1.0703

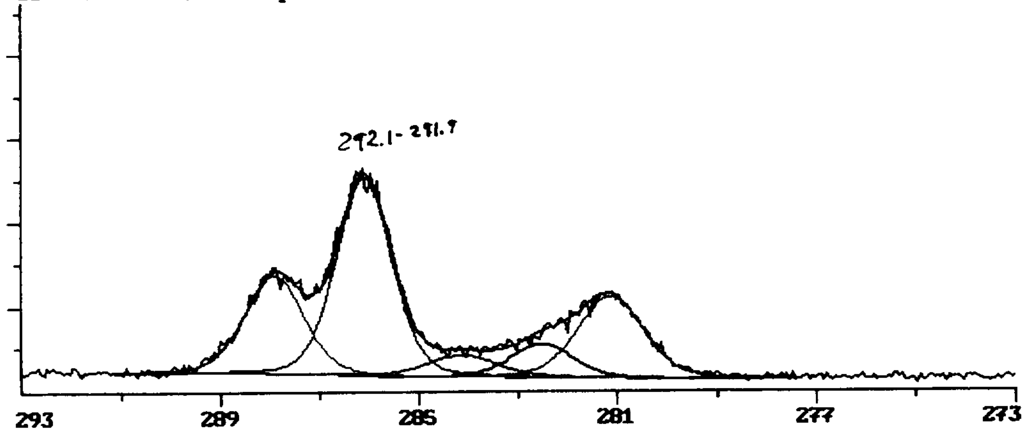


Figure C-41 Carbon 1s spectrum for Ag/FEP interface of blanket C8.

C8 front

Thu Nov 08 10:28:35   M-Probe ESCA Console   User ID: LDEF

Filename   Spot   Res Flood eV Description

AGTEF_2.MRS 200x751μ   5.0 SILVER TEFLON SURFACE (DULL)

Baseline: 687.41 to 676.48 eV

1: 682.32 eV   1.91 eV   146530.81 cts   100.00%

10 iterations, chi square = 1.2870

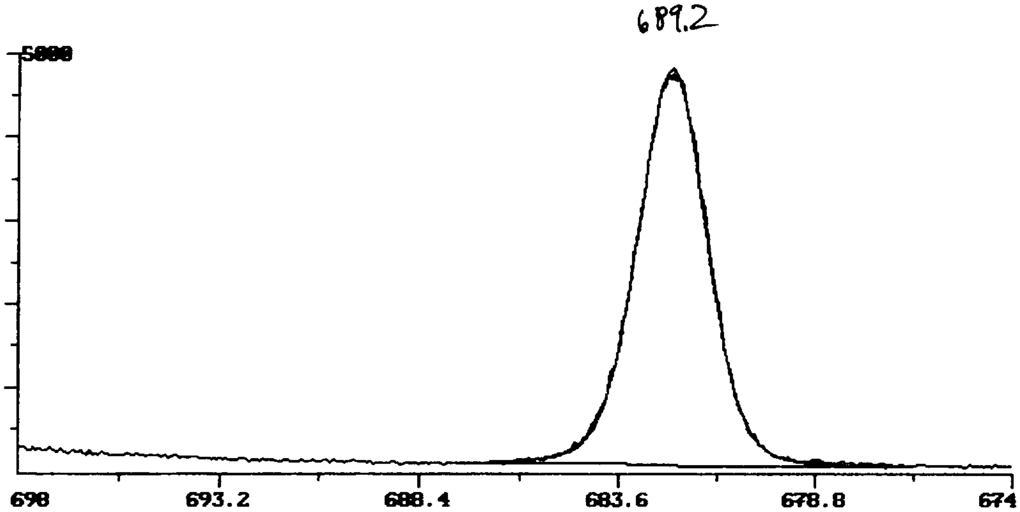


Figure C-42   Fluorine 1s spectrum for exposed region of blanket C8.

C8 back

Tue Nov 13 11:49:28 M-Probe ESCA Console User ID: LDEF

Filename	Spot	Res	Flood eV	Description
AGTEF_8.MRS	200x751µ		4.0	SILVER/TEFLON INTERFACE TEFLON SURFACE

Baseline: 688.30 to 678.26 eV

1: 683.28 eV 1.83 eV 189679.20 cts 100.00%

12 iterations, chi square = 1.4343

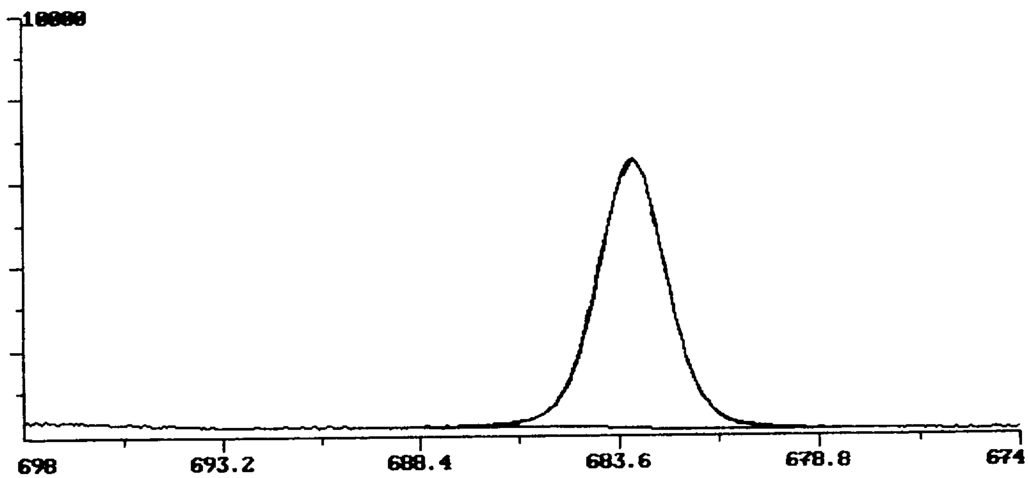


Figure C-43 Fluorine 1s spectrum for Ag/FEP interface of blanket C8.

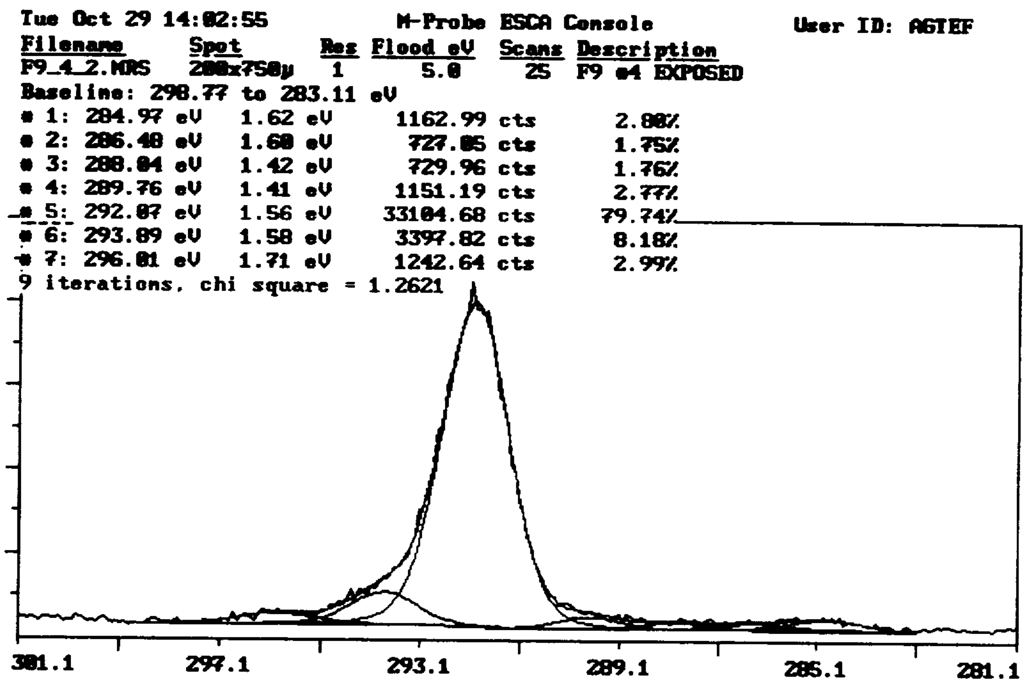


Figure C-44 Carbon 1s spectrum for exposed region of blanket F9(sample 1).

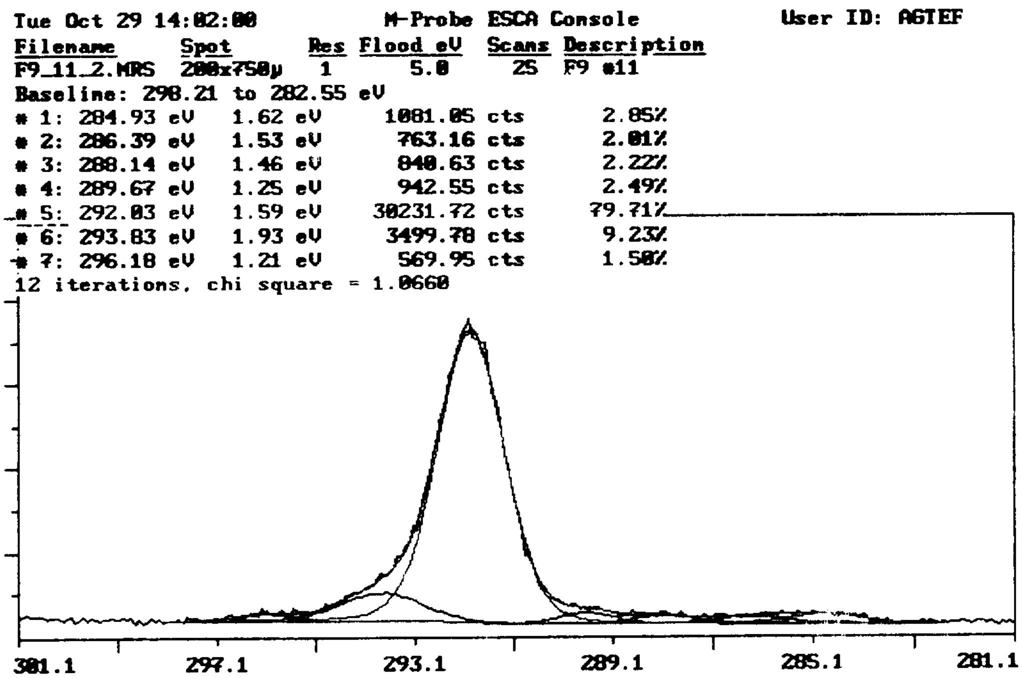


Figure C-45 Carbon 1s spectrum for exposed region of blanket F9(sample 2).

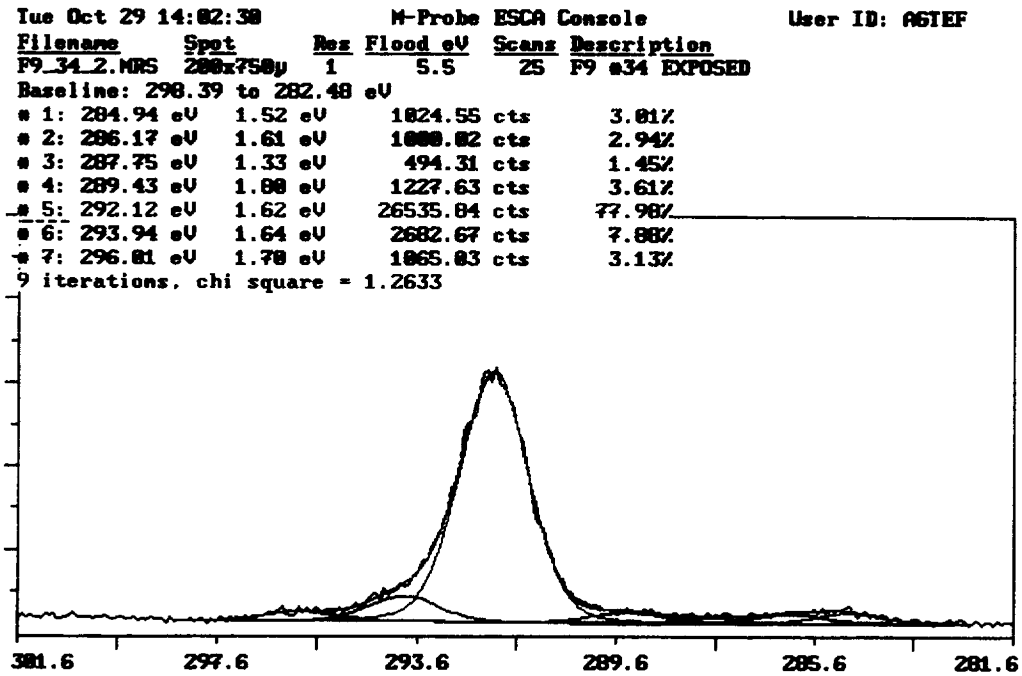
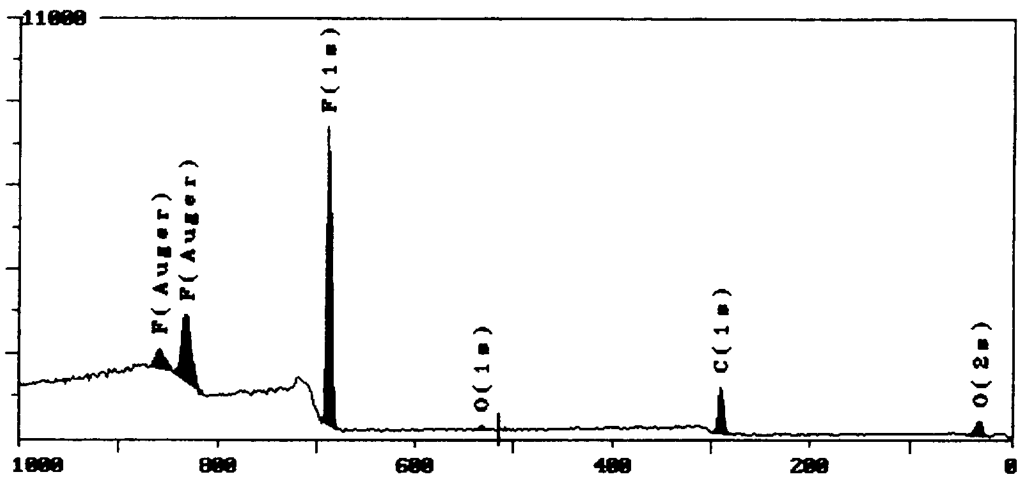


Figure C-46 Carbon 1s spectrum for exposed region of blanket F9(sample 3).

Wed Mar 20 11:45:14	M-Probe ESCA Console	User ID: DATA
A10EXP.MRS	Fri Jan 25 14:05:56 1991	Operator: GARY TUSS
A10 EXPOSED		
Spot: 200x750µ	Resolution: 4	Energy: 515.03 eV
Scans: 3 of 3	Neutralizer: 4.0eV	Counts: 209
Region: 1/ 1	Aperture: None	



Surface Composition Table Summary

File name: A10EXP.MRS
Region: 1
Description: A10 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:05:56 1991

Element	Binding Energy	atom %
F (1s)	692.18	64.97 %
O (1s)	535.86	1.08 %
C (1s)	293.30	33.95 %
	Total Percent	100.00 %

Figure C-47 Survey spectrum of exposed region of blanket A10.

Surface Composition Table Summary

File name: A10EXP2.MRS
Region: 1
Description: A10 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:09:52 1991

Element	Binding Energy	atom %
F (1s)	690.71	63.20 %
O (1s)	533.62	1.86 %
C (1s)	292.53	34.94 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: A10EXP3.MRS
Region: 1
Description: A10 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:30:26 1991

Element	Binding Energy	atom %
F (1s)	691.58	63.80 %
O (1s)	534.72	1.17 %
C (1s)	293.78	35.03 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: A10EXP4.MRS
Region: 1
Description: A10 EXP

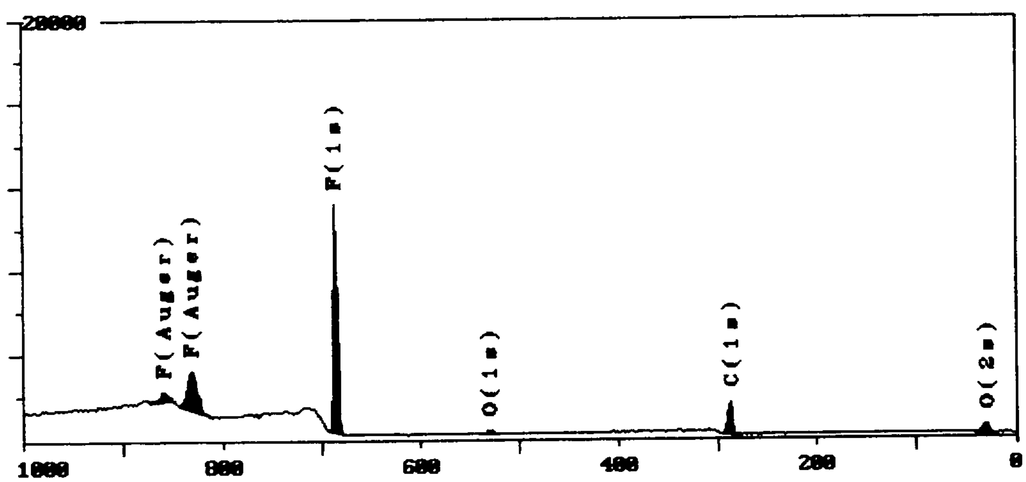
Operator: GARY TUSS
Date: Fri Feb 15 12:49:18 1991

Element	Binding Energy	atom %
F (1s)	691.68	63.74 %
O (1s)	533.96	1.50 %
C (1s)	293.93	34.76 %
	Total Percent	100.00 %

Table C-14 Table of surface elemental composition of exposed region of blanket A10.

Thu Mar 21 06:21:29 M-Probe ESCA Console User ID: DATA
A10TCKD.MRS Fri Jan 25 14:09:19 1991 Operator: GARY TUSS
A10 TUCKED EDGE

Spot:	200x750µ	Resolution:	4	Energy:
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:
Region:	1/ 1	Aperture:	None	



Surface Composition Table Summary

File name: A10TCKD.MRS
Region: 1
Description: A10 TUCKED EDGE

Operator: GARY TUSS
Date: Fri Jan 25 14:09:19 1991

Element	Binding Energy	atom %
F (1s)	690.56	65.08 %
O (1s)	533.63	1.95 %
C (1s)	291.44	32.96 %
	Total Percent	100.00 %

Figure C-48 Survey spectrum of unexposed region of blanket A10.

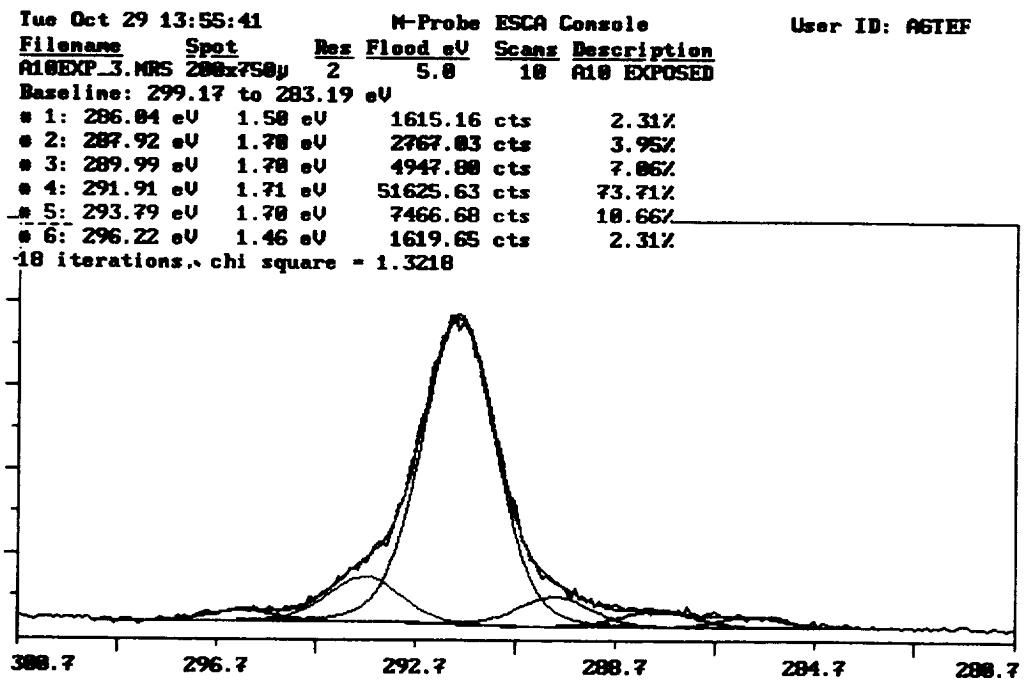
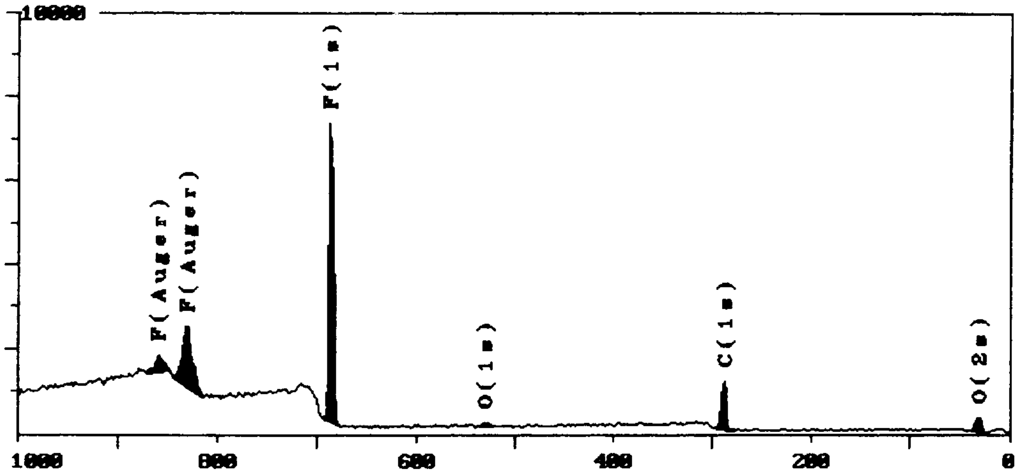


Figure C-49 Carbon 1s spectrum for exposed region of blanket A10.

Thu Mar 21 05:25:32   M-Probe ESCA Console   User ID: DATA
E10EXP.MRS   Tue Feb 26 12:23:12 1991   Operator: DOUG ELVBAKKEN
E-10 EXP

Spot:	200x750μ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	5.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: E10EXP.MRS
Region: 1
Description: E-10 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:23:12 1991

Element	Binding Energy	atom %
F (1s)	691.14	64.19 %
C (1s)	292.57	34.51 %
O (1s)	536.06	1.30 %

	Total Percent	100.00 %

Figure C-50 Survey spectrum of exposed region of blanket E10.

Surface Composition Table Summary

File name: E10EXP2.MRS
Region: 1
Description: E-10 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:33:39 1991

Element	Binding Energy	atom %
F (1s)	691.82	65.29 %
O (1s)	535.47	1.82 %
C (1s)	293.98	32.90 %
	Total Percent	100.00 %

Surface Composition Table Summary

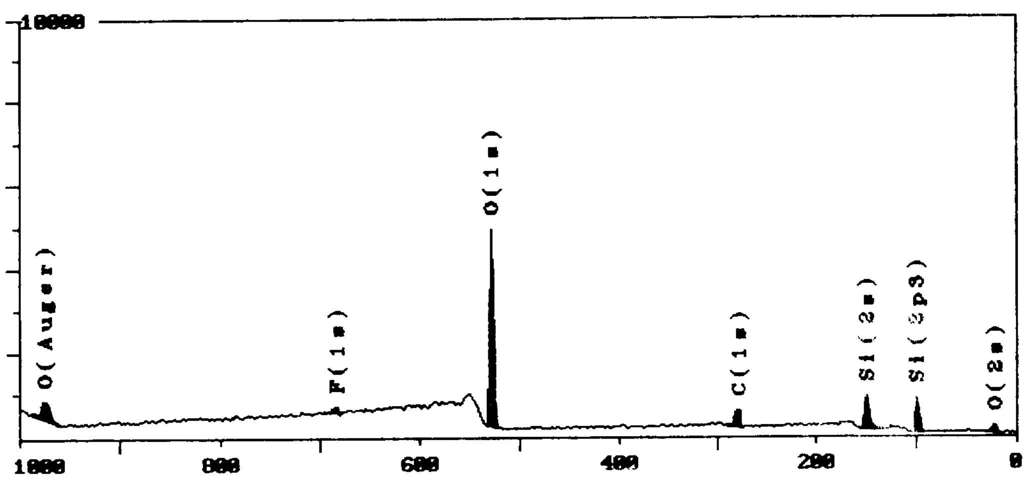
File name: E10EXP3.MRS
Region: 1
Description: E-10 EXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 14:39:15 1991

Element	Binding Energy	atom %
F (1s)	690.96	64.42 %
O (1s)	533.75	1.38 %
C (1s)	292.59	34.20 %
	Total Percent	100.00 %

Table C-15 Table of surface elemental composition of exposed region of blanket E10.

Thu Mar 21 06:56:03   M-Probe ESCA Console   User ID: DATA
E10TUCKD.MRS   Tue Feb 26 12:26:57 1991   Operator: DOUG ELVBAKKEN
E-10 UNEXP
Spot: 200x750µ   Resolution: 4   Energy:
Scans: 3 of 3   Neutralizer: 5.0eV   Counts:
Region: 1/ 1   Aperture: None



Surface Composition Table Summary

File name: E10TUCKD.MRS
Region: 1
Description: E-10 UNEXP

Operator: DOUG ELVBAKKEN
Date: Tue Feb 26 12:26:57 1991

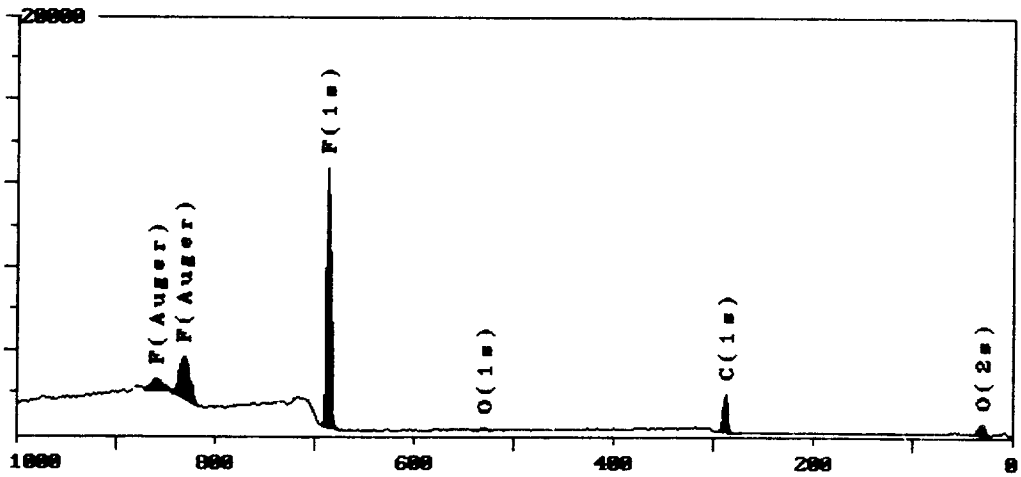
Element	Binding Energy	atom %
F (1s)	690.08	1.49 %
O (1s)	533.24	51.78 %
C (1s)	284.78	14.94 %
Si (2s)	153.96	31.79 %

	Total Percent	100.00 %

Figure C-51 Survey spectrum of unexposed region of blanket E10.

Wed Mar 20 12:10:10 M-Probe ESCA Console User ID: DATA
C11EXP.MRS Fri Jan 25 14:26:22 1991 Operator: GARY TUSS
C11 EXPOSED

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name: C11EXP.MRS
Region: 1
Description: C11 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:26:22 1991

Element	Binding Energy	atom %
F (1s)	690.48	65.76 %
O (1s)	532.82	1.43 %
C (1s)	291.39	32.81 %
	Total Percent	100.00 %

Figure C-52 Survey spectrum of exposed region of blanket C11.

Surface Composition Table Summary

File name: C11EXP2.MRS
Region: 1
Description: C11 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:26:51 1991

Element	Binding Energy	atom %
F (1s)	690.27	65.64 %
O (1s)	533.53	1.35 %
C (1s)	292.34	33.01 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C11EXP3.MRS
Region: 1
Description: C11 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:47:33 1991

Element	Binding Energy	atom %
F (1s)	691.54	63.61 %
O (1s)	534.72	1.26 %
C (1s)	293.62	35.13 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: C11EXP4.MRS
Region: 1
Description: C11 EXP

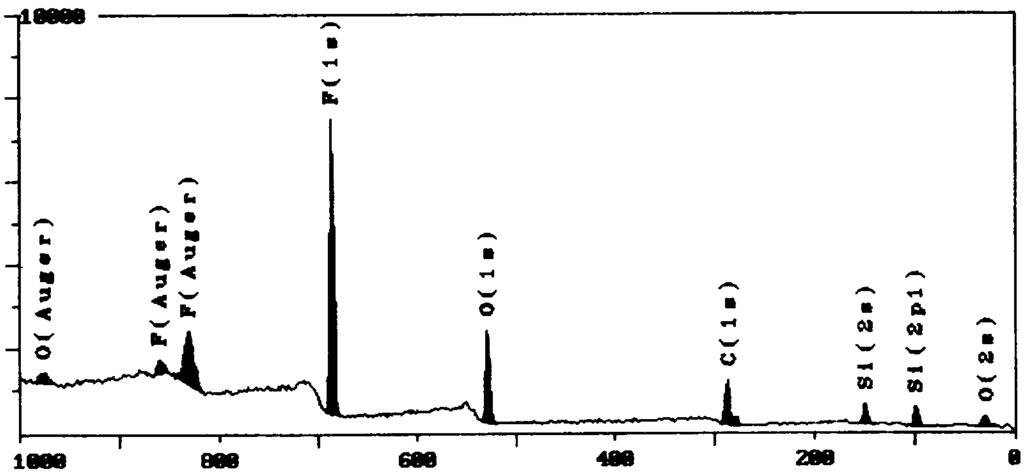
Operator: GARY TUSS
Date: Fri Feb 15 13:06:22 1991

Element	Binding Energy	atom %
F (1s)	691.55	63.37 %
O (1s)	534.42	1.01 %
C (1s)	293.65	35.62 %
	Total Percent	100.00 %

Table C-16 Table of surface elemental composition of exposed region of blanket C11.

Thu Mar 21 06:35:23 **M-Probe ESCA Console** **User ID: DATA**
C11TUCKD.MRS **Fri Jan 25 14:29:47 1991** **Operator: GARY TUSS**
C11 TUCKED EDGE

Spot:	**200x750µ**	**Resolution:**	**4**	**Energy:**	
Scans:	**3 of 3**	**Neutralizer:**	**4.0eV**	**Counts:**	
Region:	**1/ 1**	**Aperture:**	**None**		



Surface Composition Table Summary

File name: C11TUCKD.MRS
Region: 1
Description: C11 TUCKED EDGE

Operator: GARY TUSS
Date: Fri Jan 25 14:29:47 1991

Element	Binding Energy	atom %
F (1s)	690.53	42.52 %
O (1s)	533.42	20.99 %
C (1s)	291.39	24.21 %
Si (2s)	152.93	12.28 %

	Total Percent	100.00 %

Figure C-53 Survey spectrum of unexposed region of blanket C11.

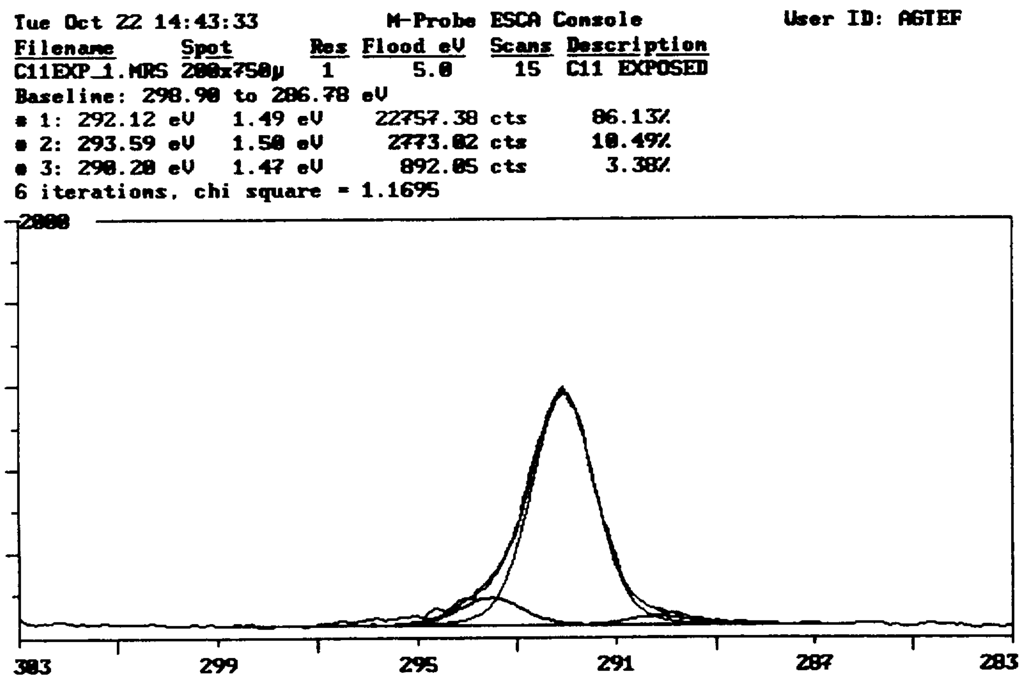
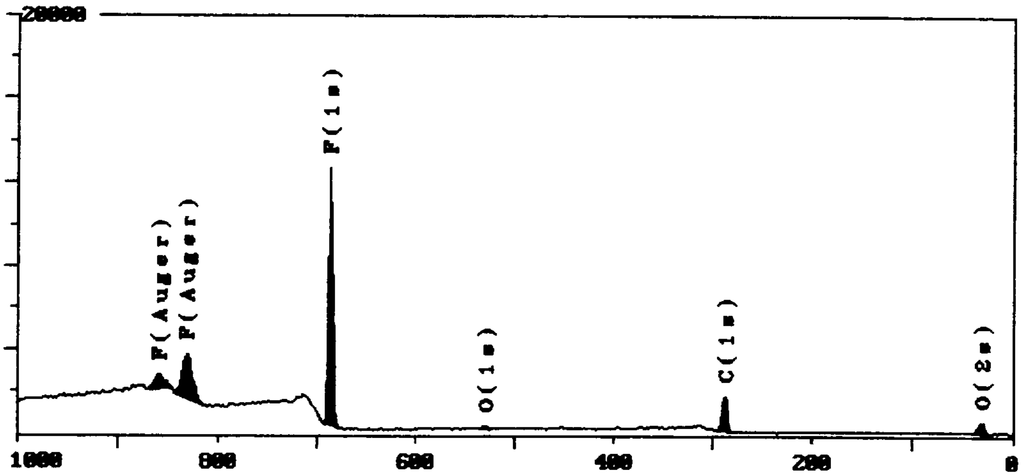


Figure C-54 Carbon 1s spectrum for exposed region of blanket C11.

Wed Mar 20 12:36:39 **M-Probe ESCA Console** **User ID: DATA**
D11EXP.MRS **Fri Jan 25 14:46:52 1991** **Operator: GARY TUSS**
D11 EXPOSED

Spot:	**200x750µ**	**Resolution:**	**4**	**Energy:**	
Scans:	**3 of 3**	**Neutralizer:**	**4.0eV**	**Counts:**	
Region:	**1/ 1**	**Aperture:**	**None**		



Surface Composition Table Summary

File name: D11EXP.MRS
Region: 1
Description: D11 EXPOSED

Operator: GARY TUSS
Date: Fri Jan 25 14:46:52 1991

Element	Binding Energy	atom %
F (1s)	690.64	64.62 %
O (1s)	532.89	0.78 %
C (1s)	291.64	34.60 %
	Total Percent	100.00 %

Figure C-55 Survey spectrum of exposed region of blanket D11.

Surface Composition Table Summary

File name: D11EXP2.MRS
Region: 1
Description: D11 EXPOSED SAMPLE II

Operator: GARY TUSS
Date: Wed Feb 13 17:37:05 1991

Element	Binding Energy	atom %
F (1s)	690.22	64.20 %
O (1s)	533.22	0.93 %
C (1s)	292.29	34.86 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D11EXP3.MRS
Region: 1
Description: D11 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:57:51 1991

Element	Binding Energy	atom %
F (1s)	691.55	62.75 %
O (1s)	535.07	1.15 %
C (1s)	293.66	36.10 %
	Total Percent	100.00 %

Surface Composition Table Summary

File name: D11EXP4.MRS
Region: 1
Description: D11 EXP

Operator: GARY TUSS
Date: Fri Feb 15 13:16:39 1991

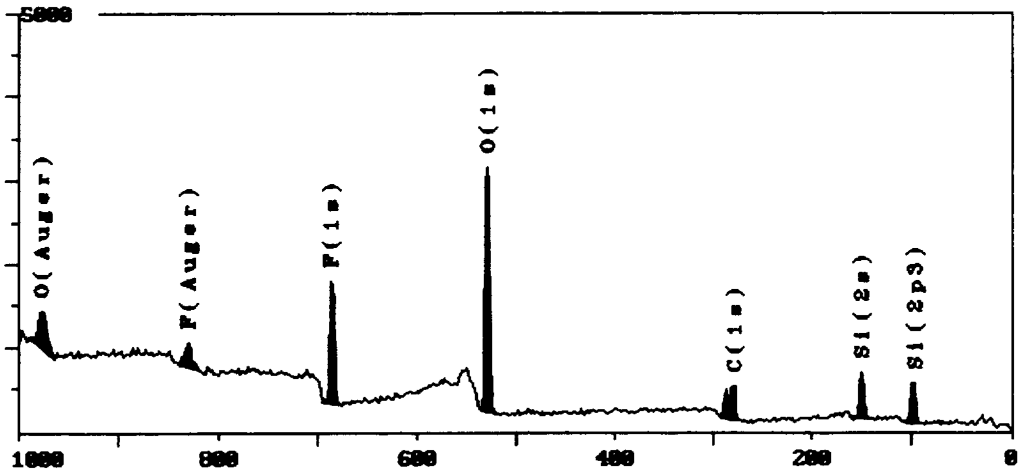
Element	Binding Energy	atom %
F (1s)	691.52	63.35 %
C (1s)	293.58	36.65 %
	Total Percent	100.00 %

Table C-17 Table of surface elemental composition of exposed region of blanket D11.

*t90R

Thu Mar 21 06:42:47　　M-Probe ESCA Console　　User ID: DATA
D11TUCKD.MRS　　Fri Jan 25 14:50:16 1991　　Operator: GARY TUSS
D11 TUCKED EDGE

Spot:	200x750µ	Resolution:	4	Energy:	
Scans:	3 of 3	Neutralizer:	4.0eV	Counts:	
Region:	1/ 1	Aperture:	None		



Surface Composition Table Summary

File name:　D11TUCKD.MRS
Region:　1
Description: D11 TUCKED EDGE

Operator:　GARY TUSS
Date:　Fri Jan 25 14:50:16 1991

Element	Binding Energy	atom %
F (1s)	690.04	15.44 %
O (1s)	532.92	42.64 %
C (1s)	284.00	22.47 %
Si (2s)	152.75	19.45 %
	Total Percent	100.00 %

Figure C-56　　Survey spectrum of unexposed region of blanket D11.

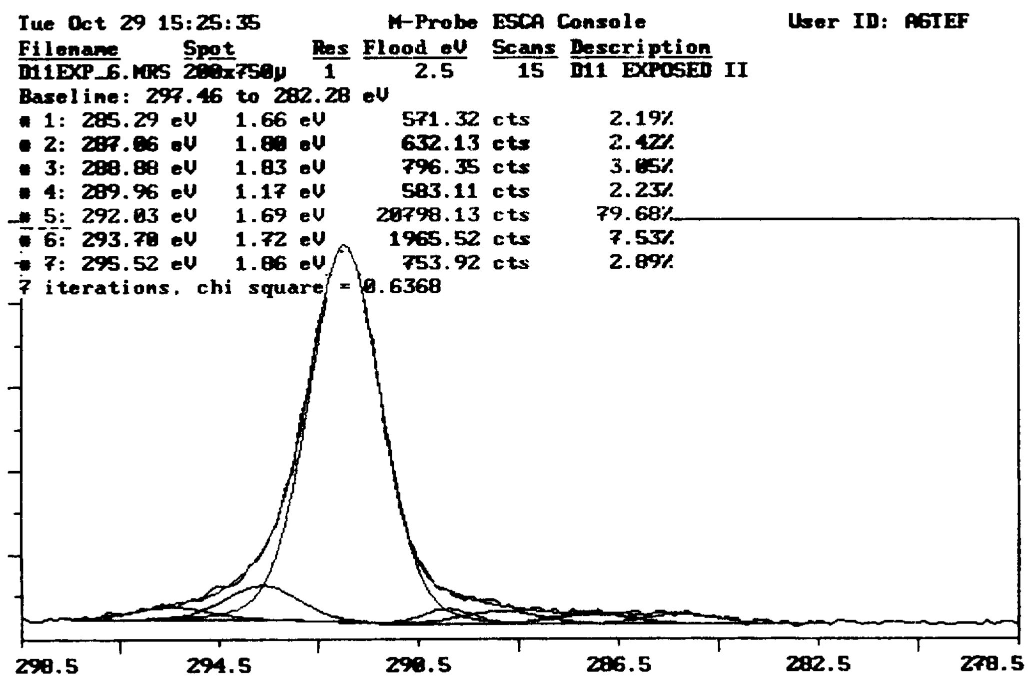
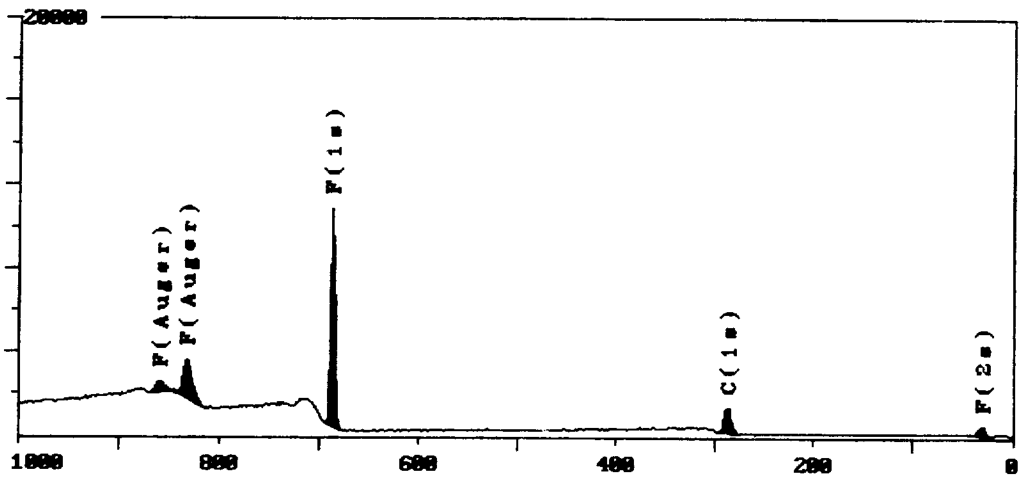


Figure C-57   Carbon 1s spectrum for exposed region of blanket D11.

Wed Mar 20 12:49:13 M-Probe ESCA Console User ID: DATA
D11EXP_3.MRS Tue Jan 29 10:21:27 1991 Operator: GARY TUSS
D11 EXPOSED AFTER 10 HOURS UNDER X-RAY BEAM
Spot: 200x750μ Resolution: 4 Energy:
Scans: 3 of 3 Neutralizer: 3.5eV Counts:
Region: 1/ 1 Aperture: None



Surface Composition Table Summary

File name: D11EXP_3.MRS
Region: 1
Description: D11 EXPOSED AFTER 10 HOURS UNDER X-RAY BEAM
Operator: GARY TUSS
Date: Tue Jan 29 10:21:27 1991

Element	Binding Energy	atom %
F (1s)	690.34	58.80 %
C (1s)	291.36	41.20 %
	Total Percent	100.00 %

Figure C-58 Survey spectrum of exposed region of blanket D11 after 10 hours under an X-ray beam.

Surface Composition Table Summary

File name: D11EXP_4.MRS
Region: 1
Description: D11 EXPOSED ADJACENT TO 10 HOUR X-RAY EXPOSURE
Operator: GARY TUSS
Date: Tue Jan 29 10:34:12 1991

Element	Binding Energy	atom %
F (1s)	690.49	62.63 %
O (1s)	533.29	1.00 %
C (1s)	291.96	36.37 %
	Total Percent	100.00 %

Table C-18 Table of surface elemental composition of exposed region of blanket D11, after 10 hours under an X-ray beam.

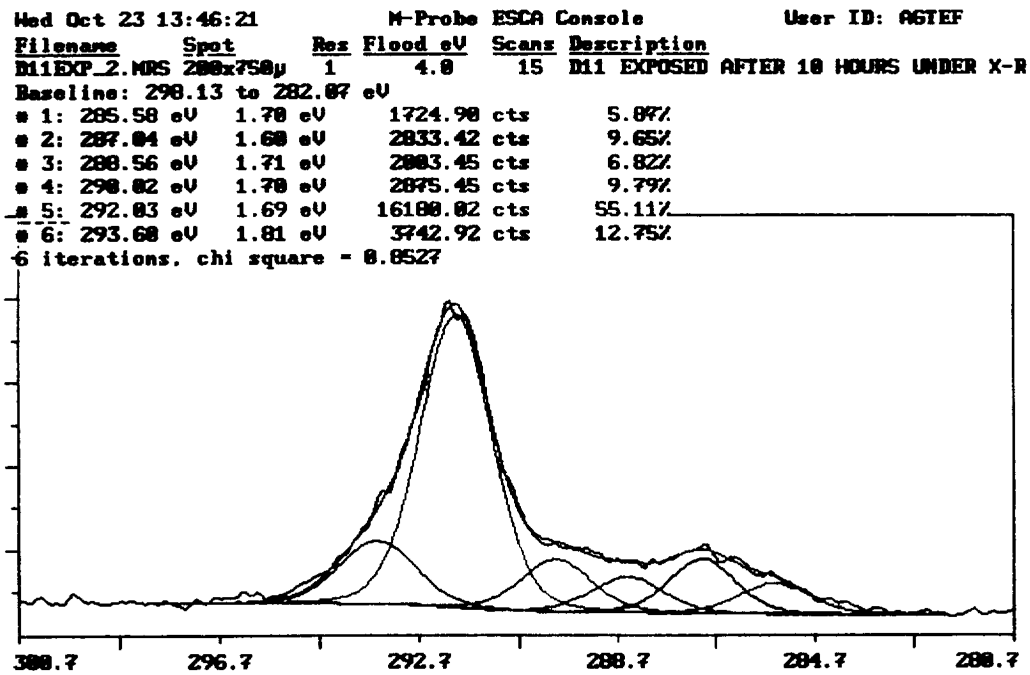


Figure C-59 Carbon 1s spectrum for exposed region of blanket D11 after 10 hours under an X-ray beam.

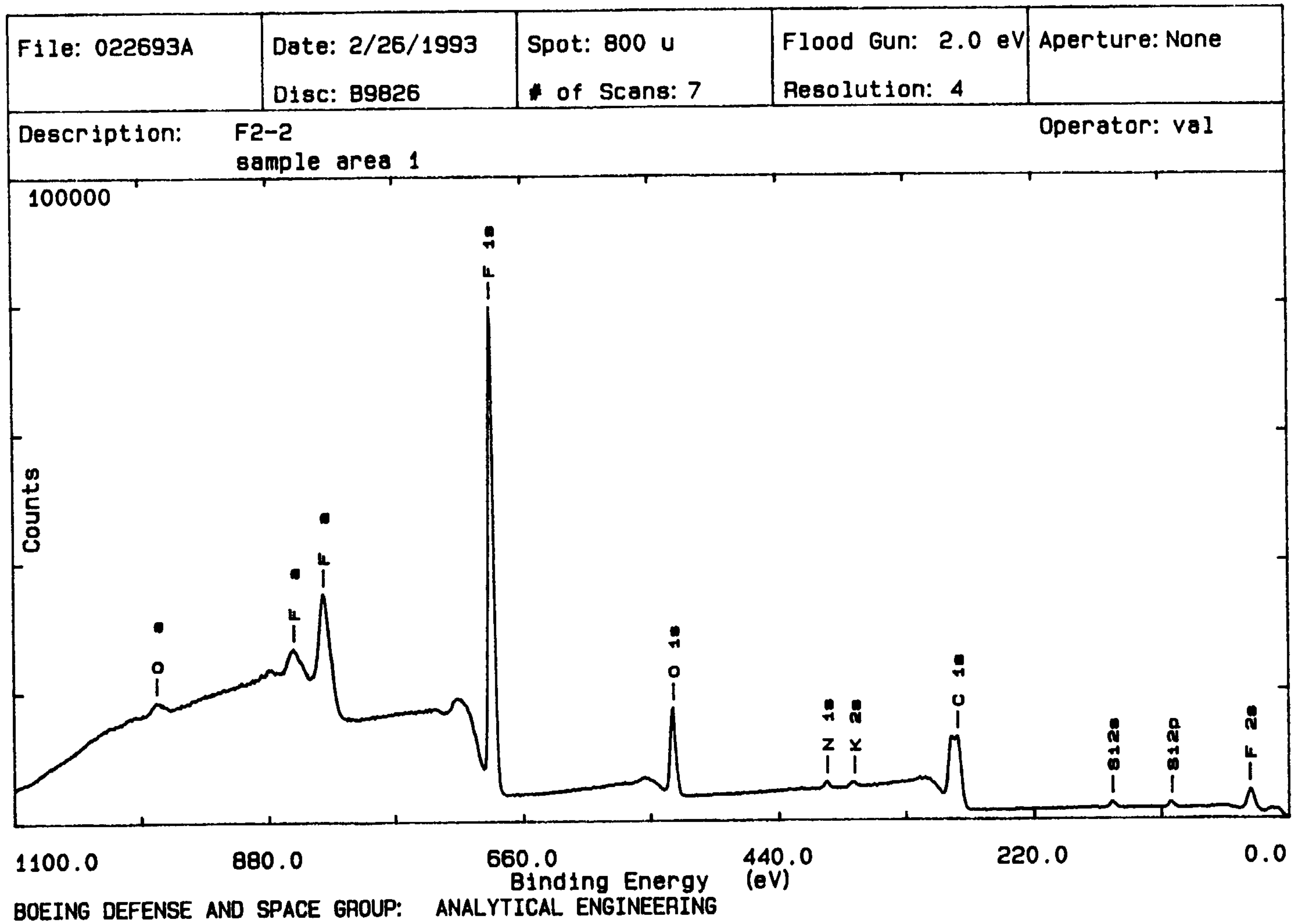


Figure C-60 Survey spectrum of exposed region 1 of blanket F2 from specimen used as EOIM-3 experiment control.

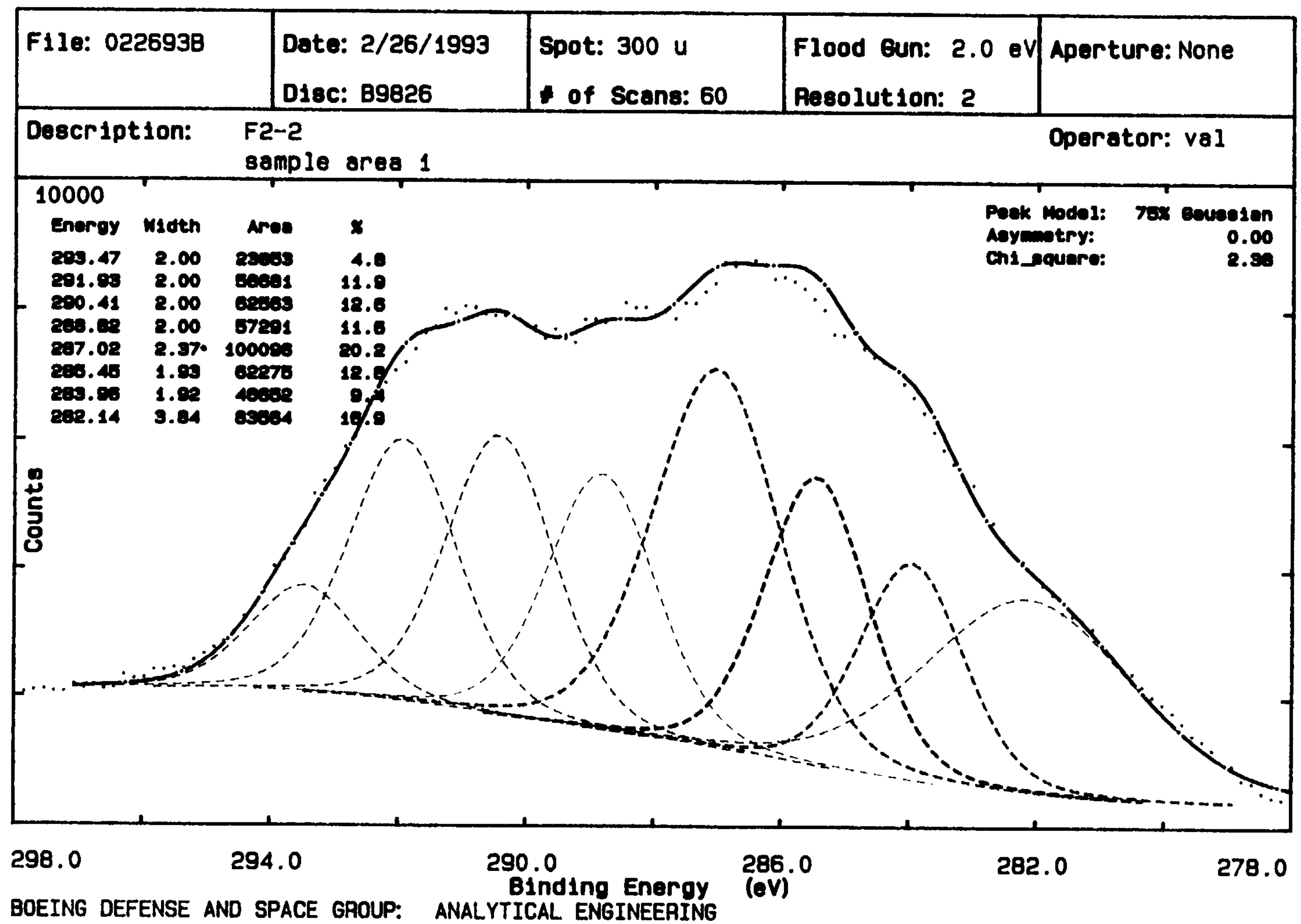


Figure C-61 Carbon 1s spectrum for exposed region 1 of blanket F2 from specimen used as EOIM-3 experiment control.

SURFACE COMPOSITION TABLE		
F2-2 sample area 1		
Element	B Energy	Atom %
F 2s	35.3	
Si2p	103.1	
Si2s	154.7	2.24
C 1s	288.0	41.60
K 2s	377.3	.89
N 1s	400.9	1.25
O 1s	533.2	11.08
F 1s	690.1	42.94
F a	835.3	
F a	861.1	
O a	979.4	
Total Percent		100.00

Table C-19 Table of surface elemental composition of exposed region 1 of blanket F2 from specimen used as EOIM-3 experiment control.

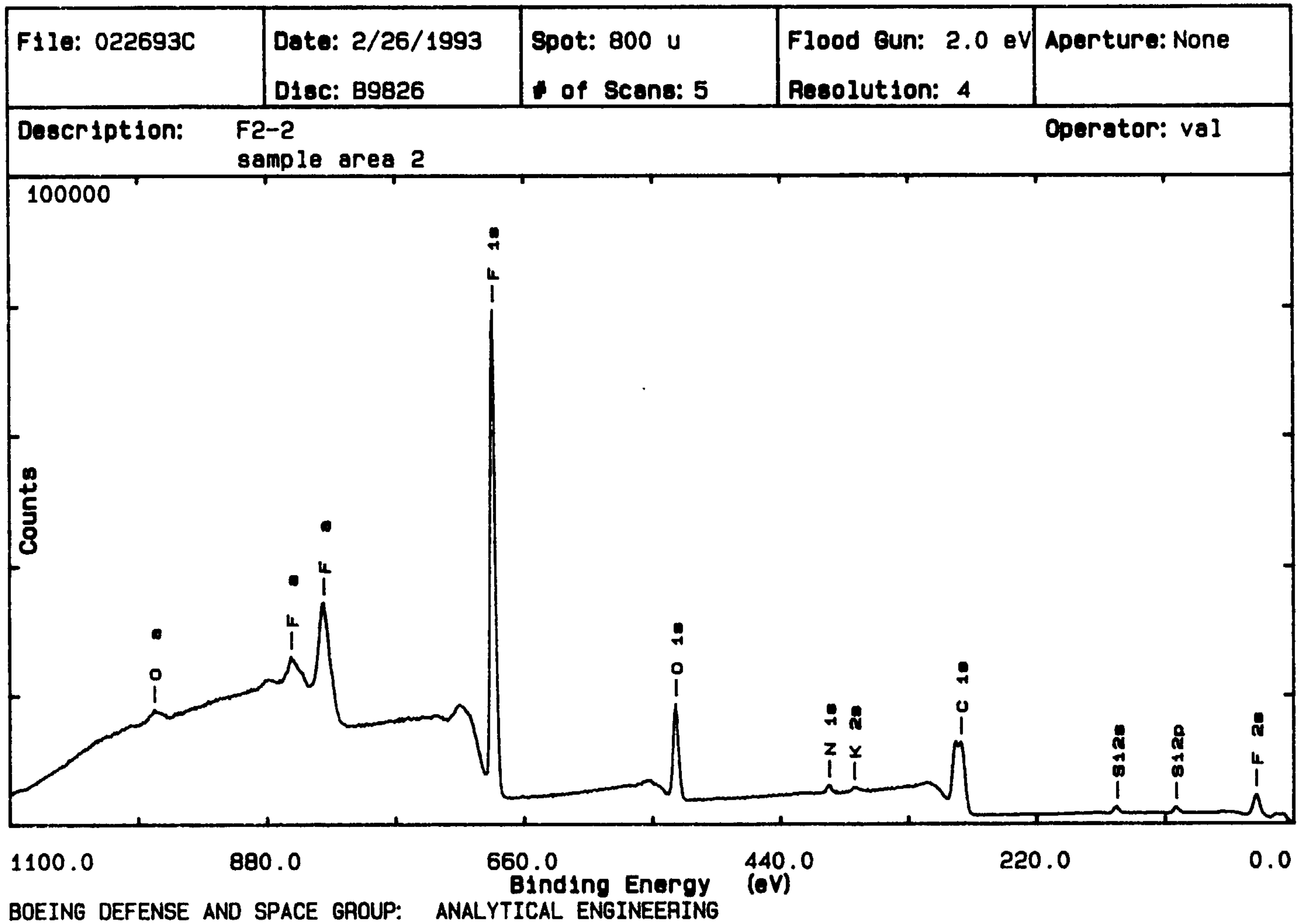


Figure C-62 Survey spectrum of exposed region 2 of blanket F2 from specimen used as EOIM-3 experiment control.

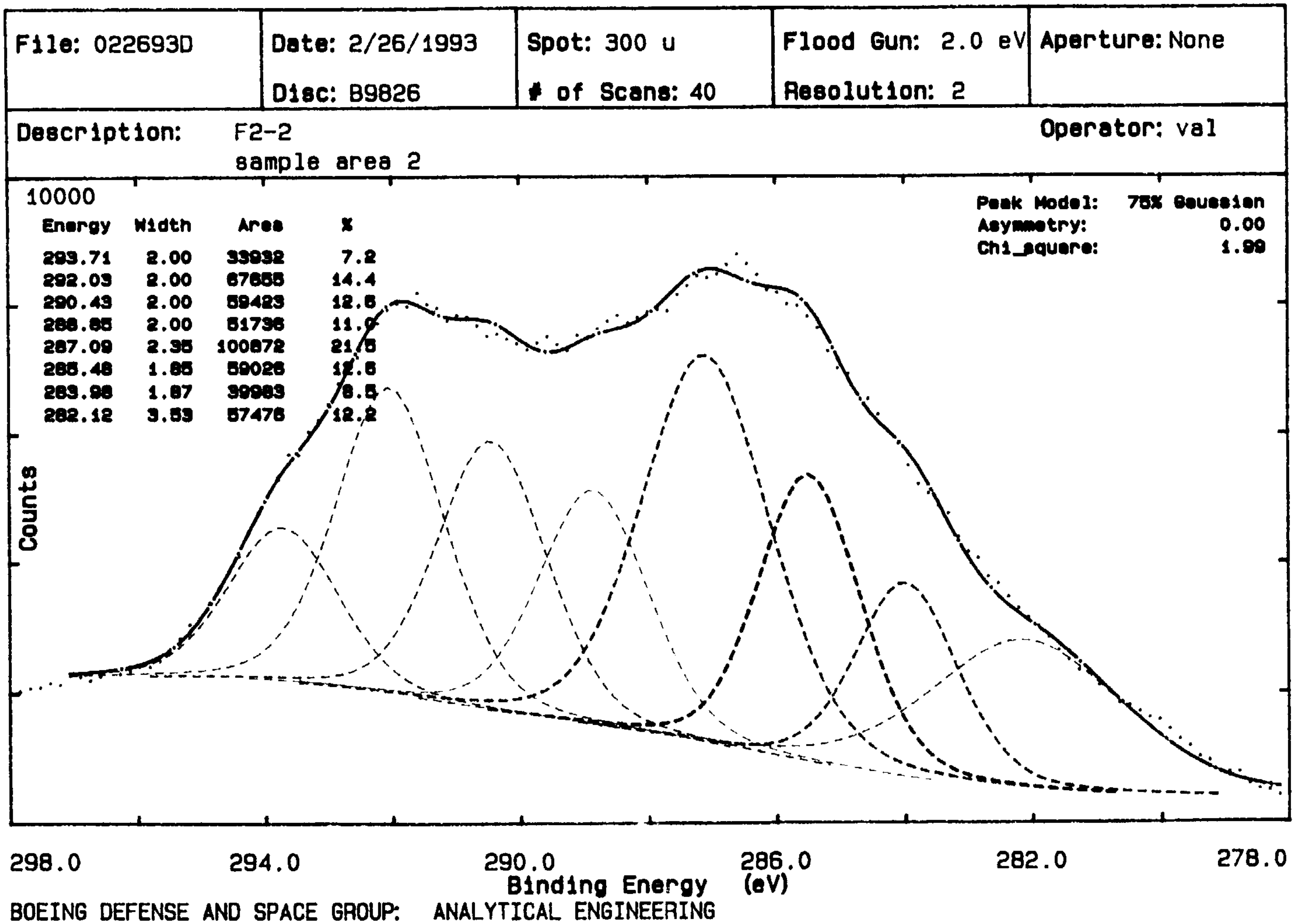


Figure C-63 Carbon 1s spectrum for exposed region 2 of blanket F2 from specimen used as EOIM-3 experiment control.

SURFACE COMPOSITION TABLE		
F2-2 sample area 2		
Element	B Energy	Atom %
F 2s	34.3	
Si2p	103.1	
Si2s	153.7	2.27
C 1s	288.0	41.40
K 2s	379.4	1.02
N 1s	400.9	1.62
O 1s	533.2	11.57
F 1s	689.2	42.13
F a	834.3	
F a	862.2	
O a	979.4	
	Total Percent	100.00

Table C-20 Table of surface elemental composition of exposed region 2 of blanket F2 from specimen used as EOIM-3 experiment control.

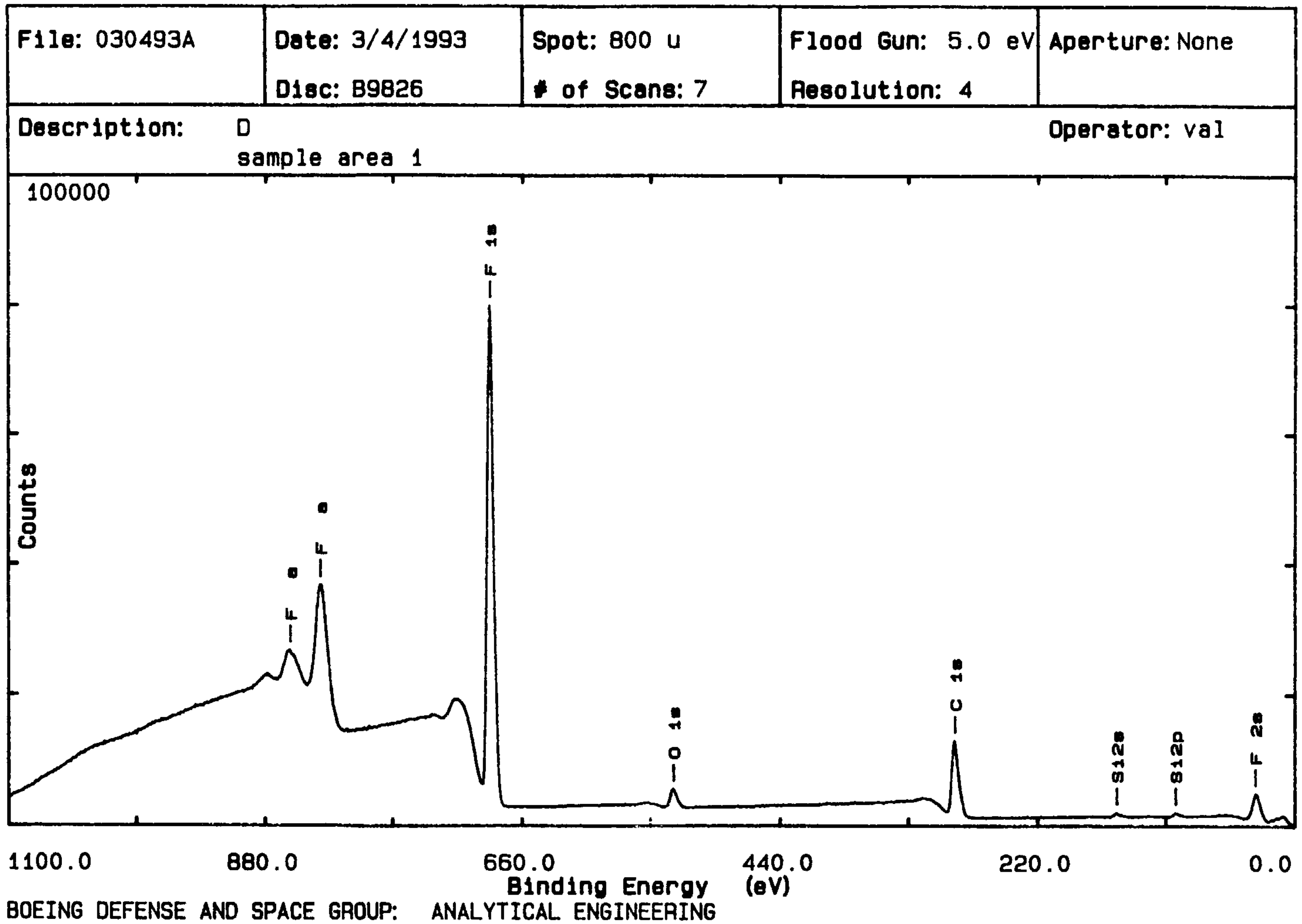


Figure C-64 Survey spectrum of exposed region 1 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D.

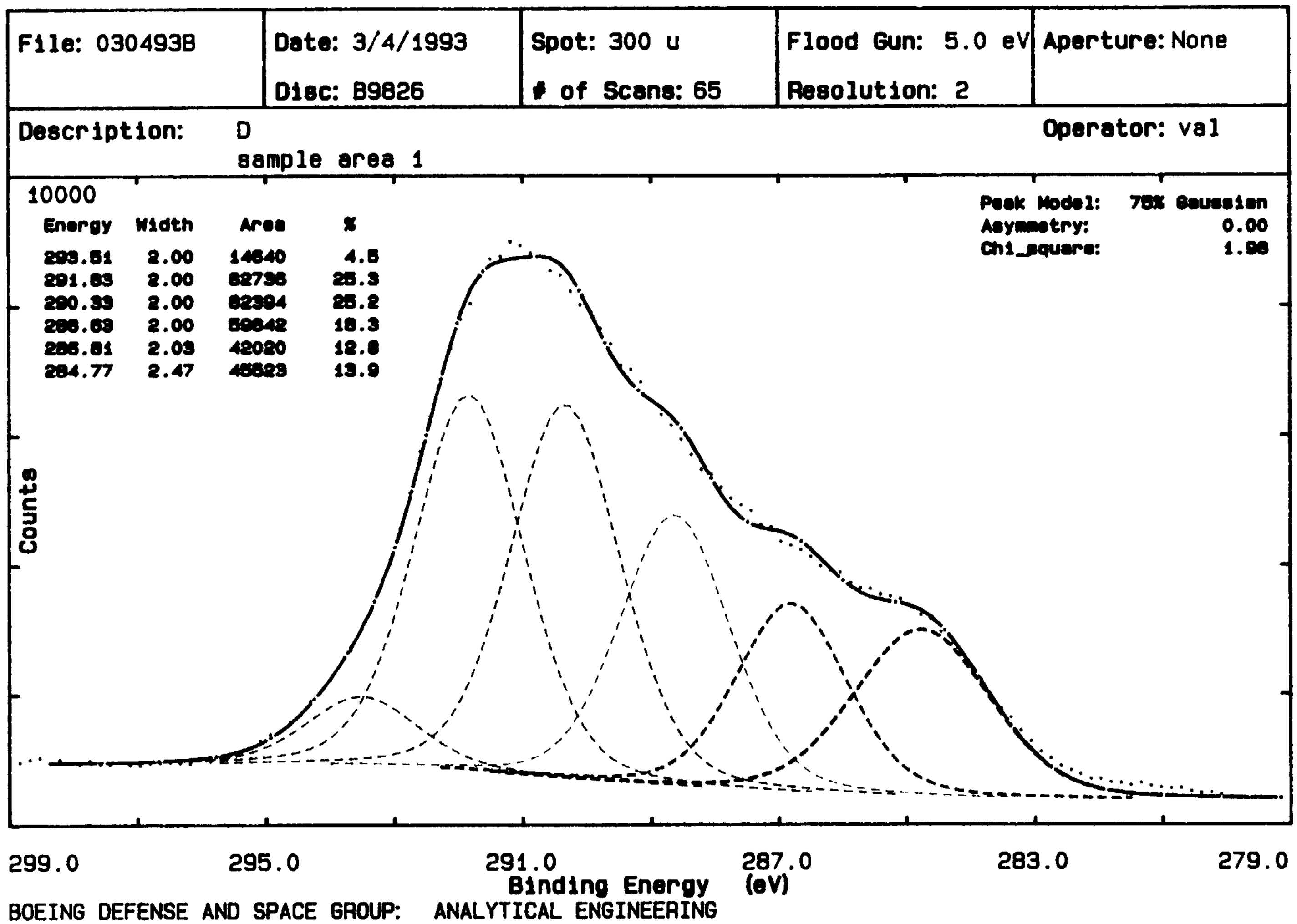


Figure C-65 Carbon 1s spectrum for exposed region 1 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D.

SURFACE COMPOSITION TABLE		
'D' sample area 1		
Element	B Energy	Atom %
Si2p	107.1	1.62
C 1s	295.3	32.55
O 1s	536.2	3.15
F 1s	693.1	62.68
F a	838.3	
F a	864.1	
	Total Percent	100.00

Table C-21 Table of surface elemental composition of exposed region 1 of blanket B05 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D.

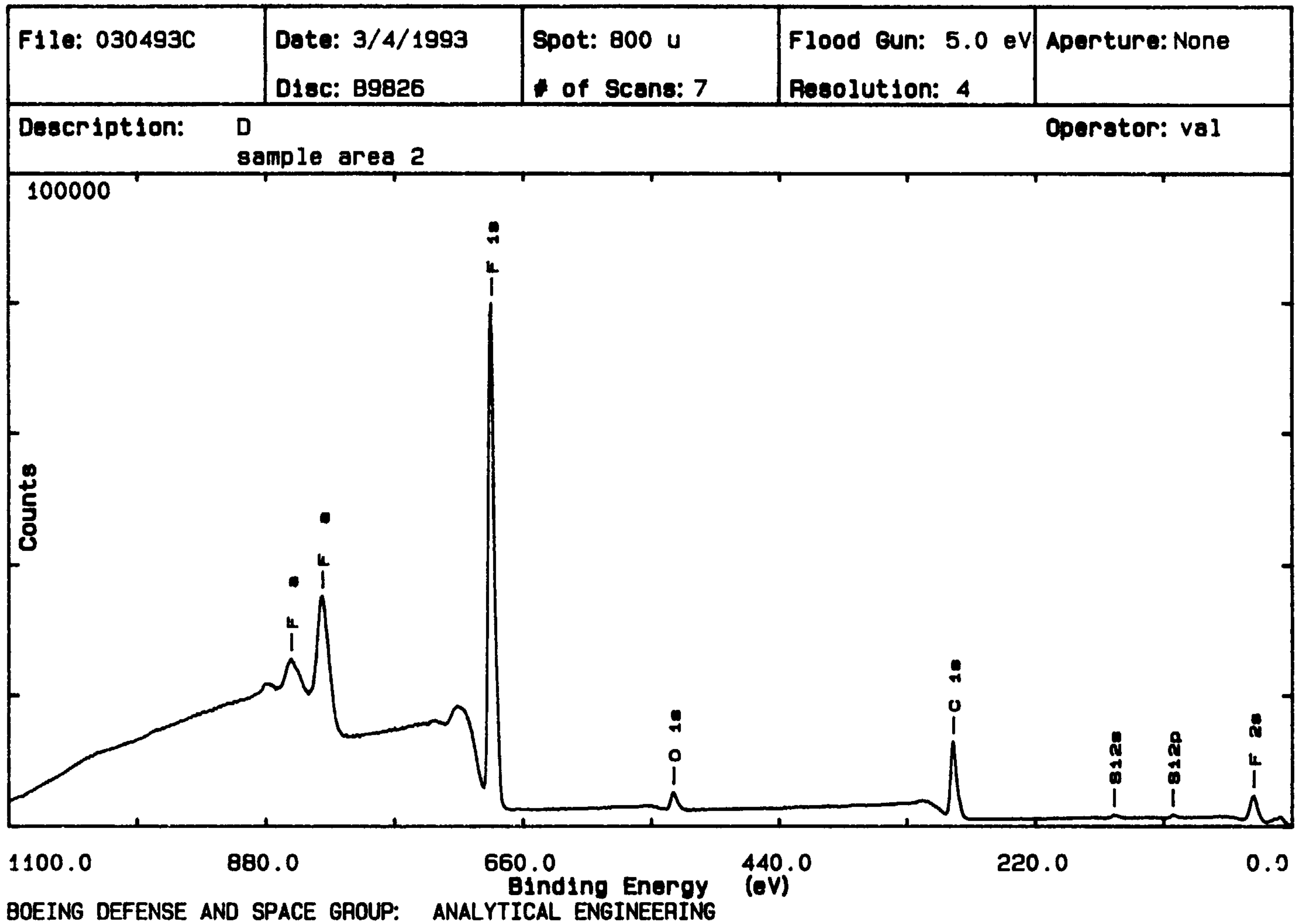


Figure C-66 Survey spectrum of exposed region 2 of blanket B05 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D .

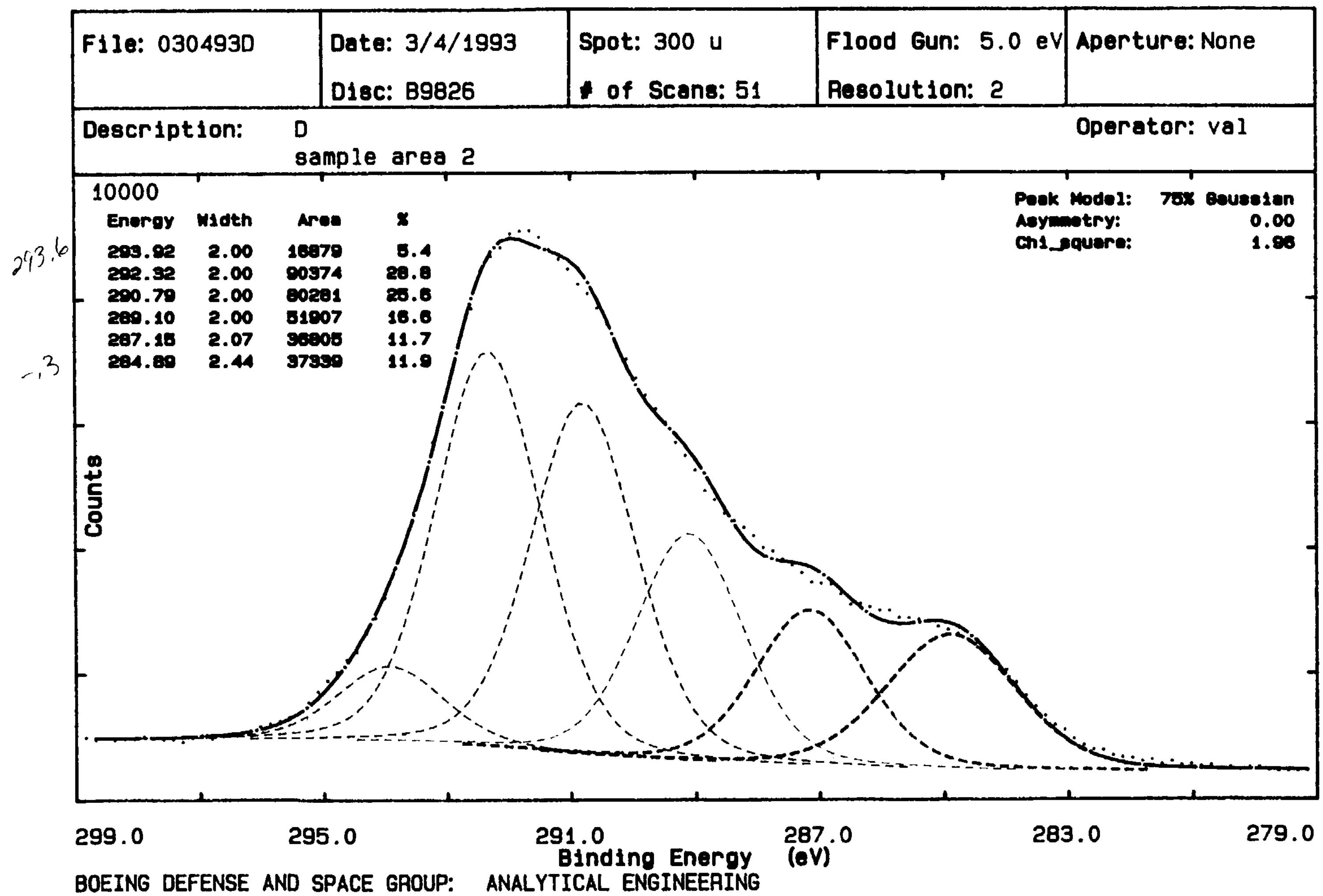


Figure C-67 Carbon 1s spectrum for exposed region 2 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D.

SURFACE COMPOSITION TABLE		
'D' sample area 2		
Element	B Energy	Atom %
Si2p	107.1	1.48
C 1s	295.3	32.48
O 1s	536.2	2.96
F 1s	692.2	63.09
F a	837.3	
F a	864.1	
Total Percent		100.00

Table C-22 Table of surface elemental composition of exposed region 2 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample D.

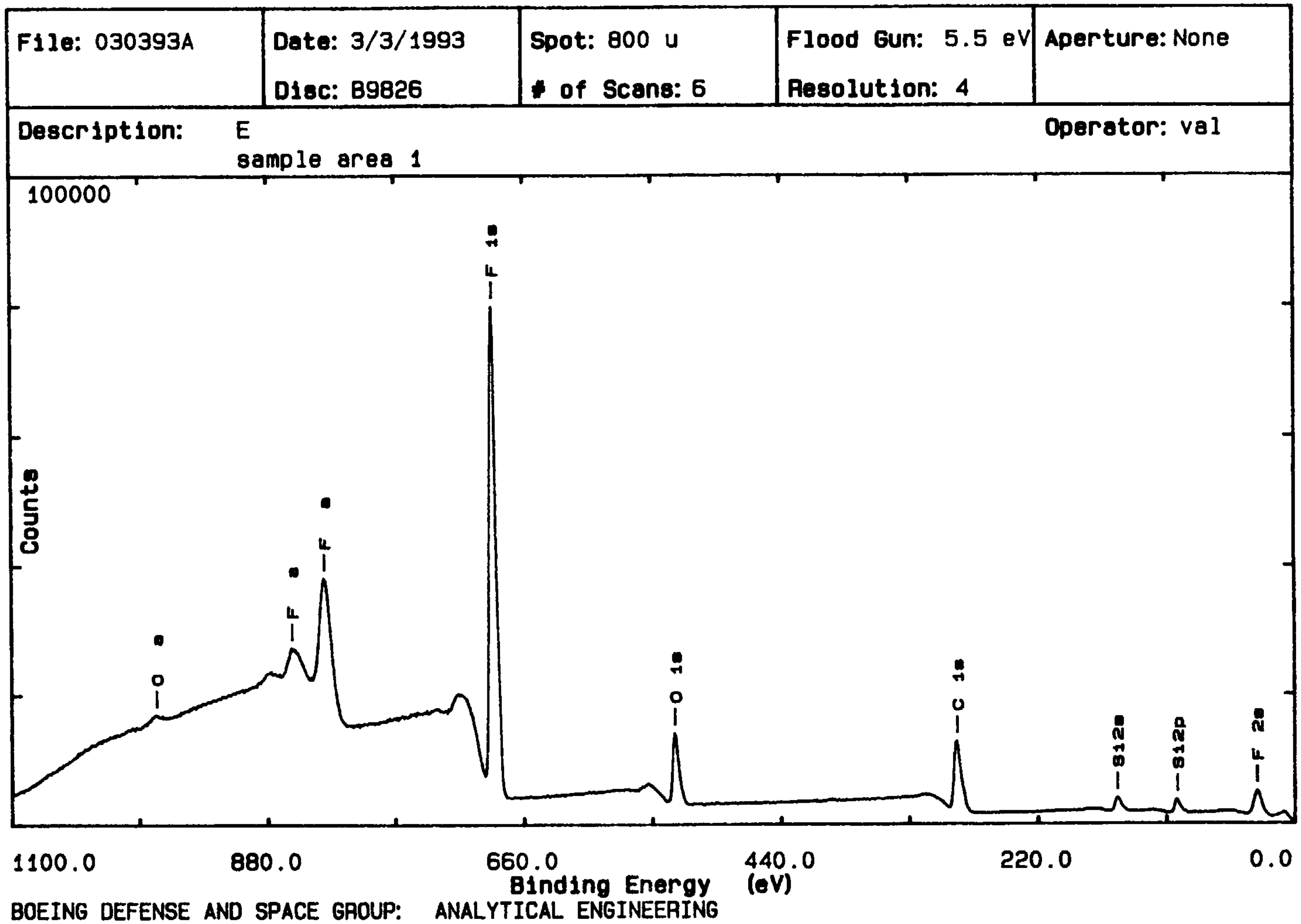


Figure C-68 Survey spectrum of unexposed region 1 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

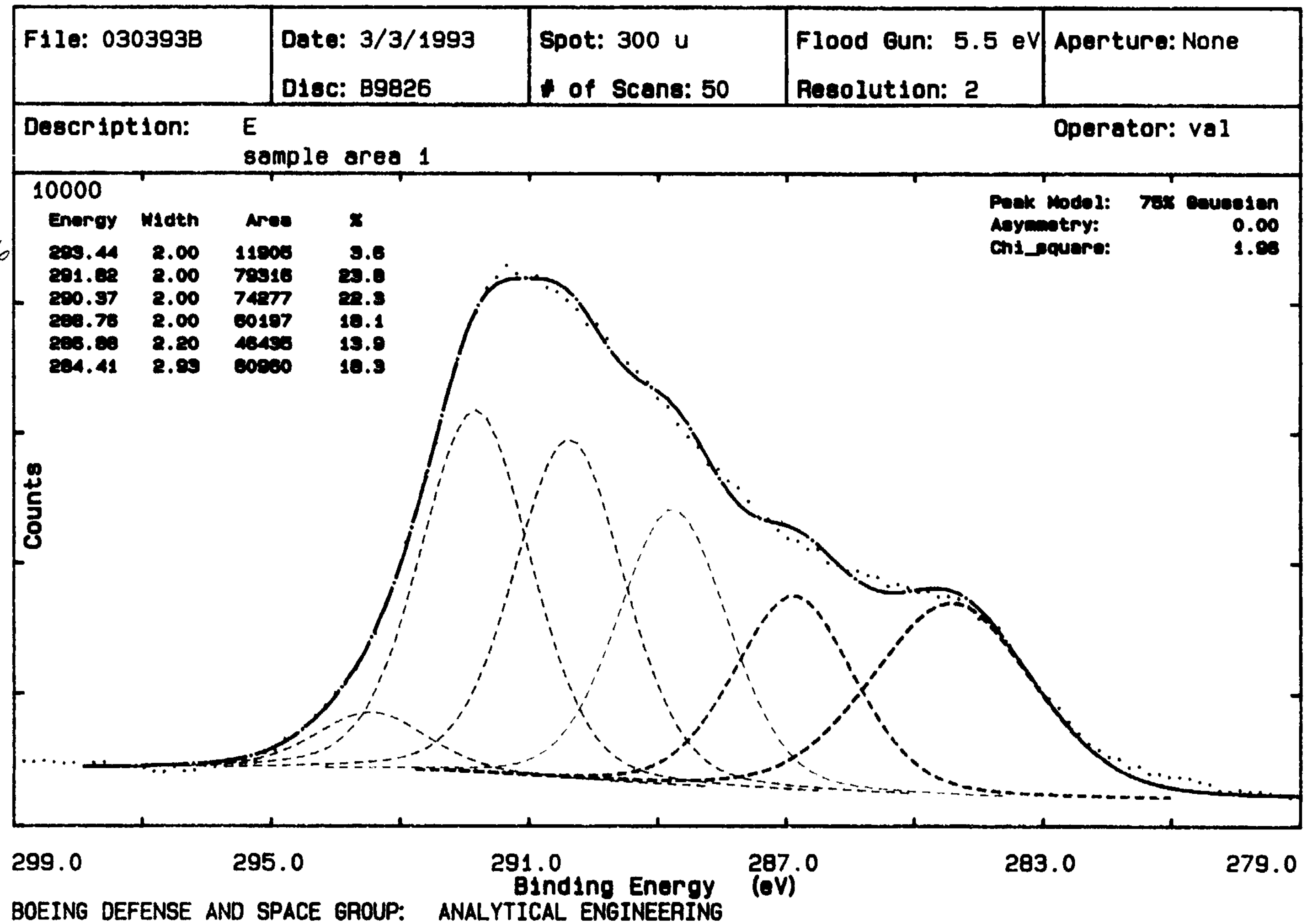


Figure C-69 Carbon 1s spectrum for unexposed region 1 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

SURFACE COMPOSITION TABLE		
'E' sample 1		
Element	B Energy	Atom %
Si2p	106.6	5.05
C 1s	294.8	29.69
O 1s	536.6	9.79
F 1s	692.6	55.48
F a	837.7	
F a	865.7	
O a	981.8	
	Total Percent	100.00

Table C-23 Table of surface elemental composition of unexposed region 1 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

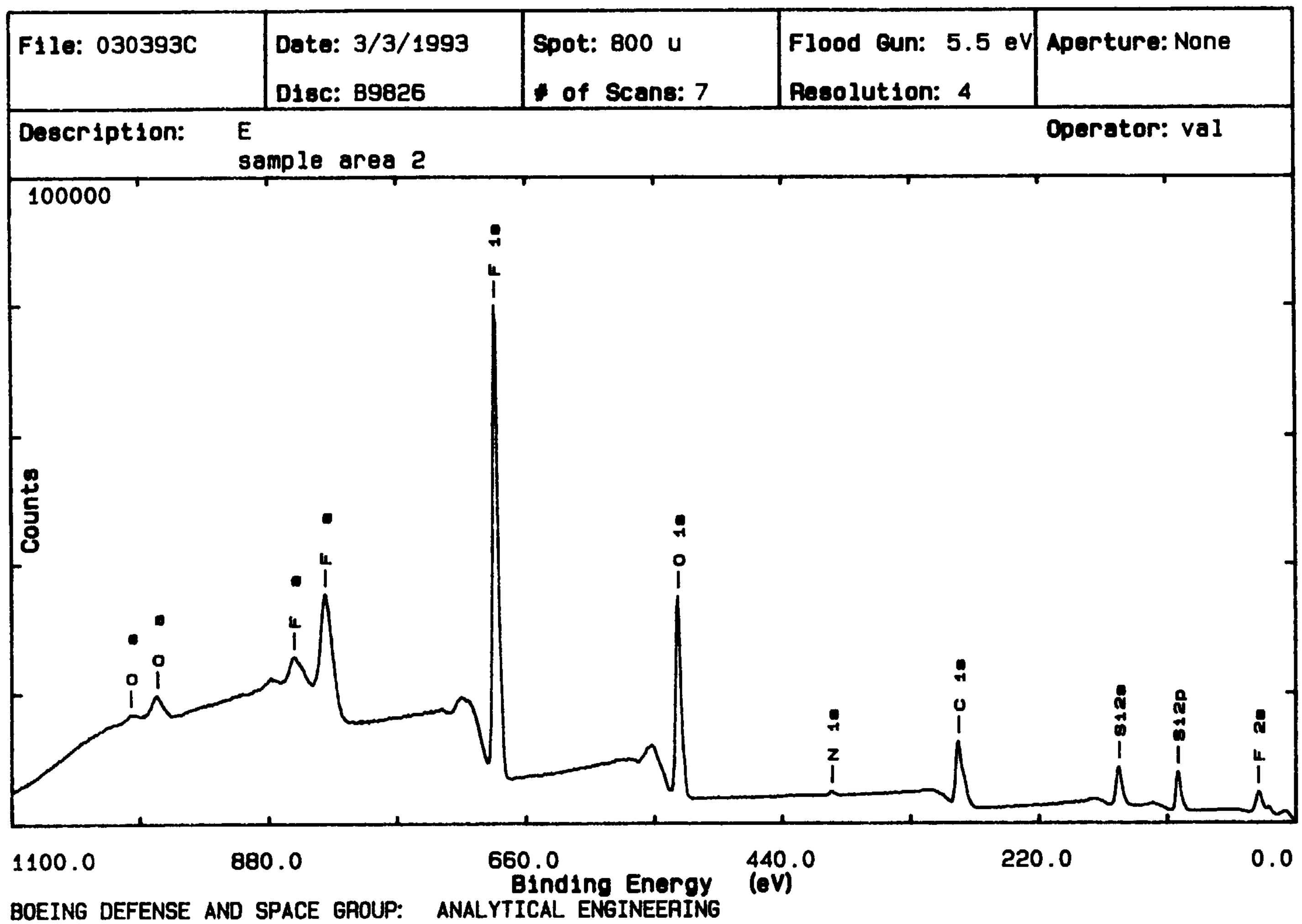


Figure C-70 Survey spectrum of unexposed region 2 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

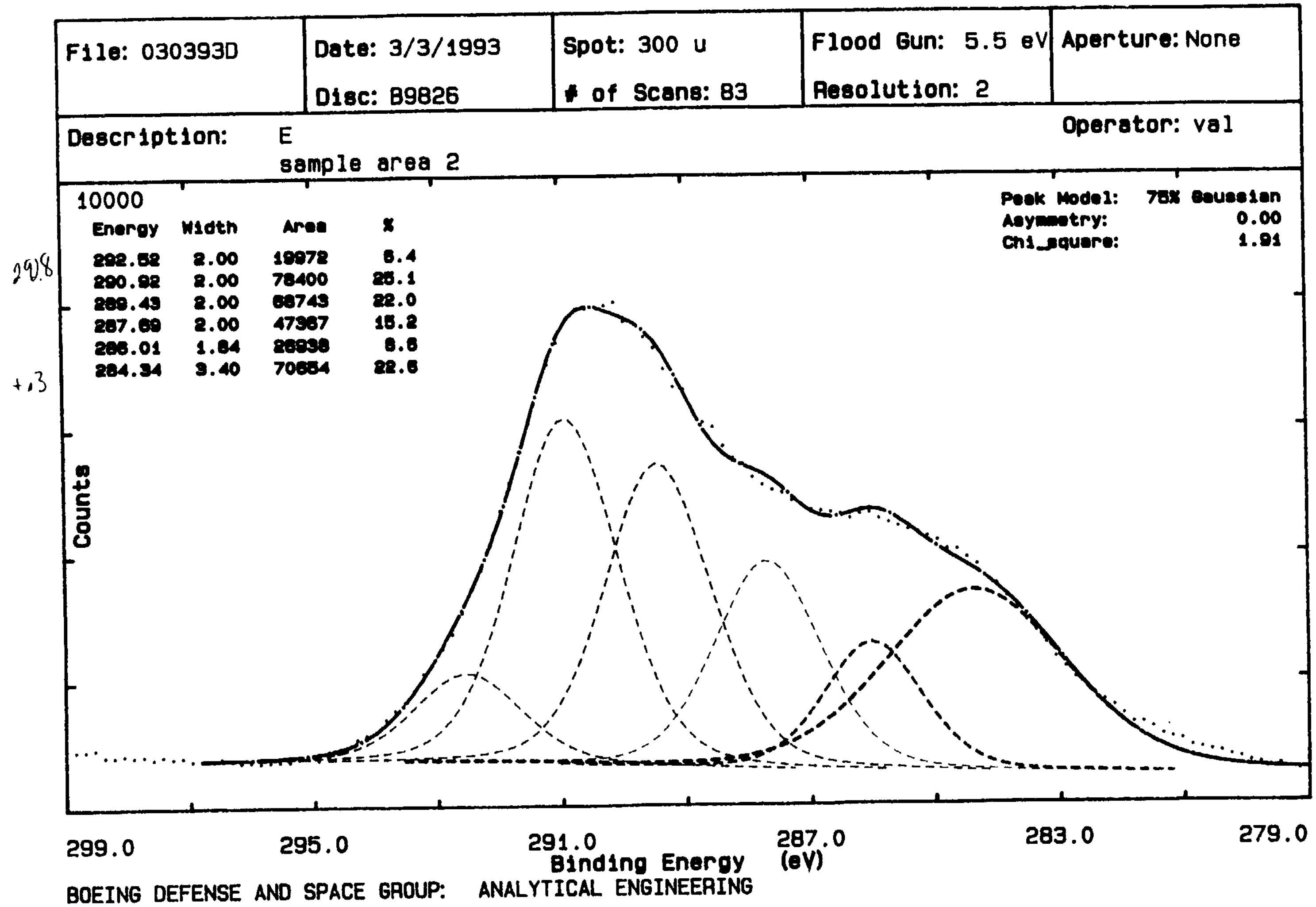


Figure C-71 Carbon 1s spectrum for unexposed region 2 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

SURFACE COMPOSITION TABLE		
'E' sample area 2		
Element	B Energy	Atom %
Si2p	106.5	11.59
C 1s	294.8	24.52
N 1s	403.4	.65
O 1s	535.6	22.31
F 1s	692.5	40.93
F a	837.7	
F a	864.6	
O a	981.9	
O a	1004.4	
Total Percent		100.00

Table C-24 Table of surface elemental composition of unexposed region 2 of blanket B5 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample E.

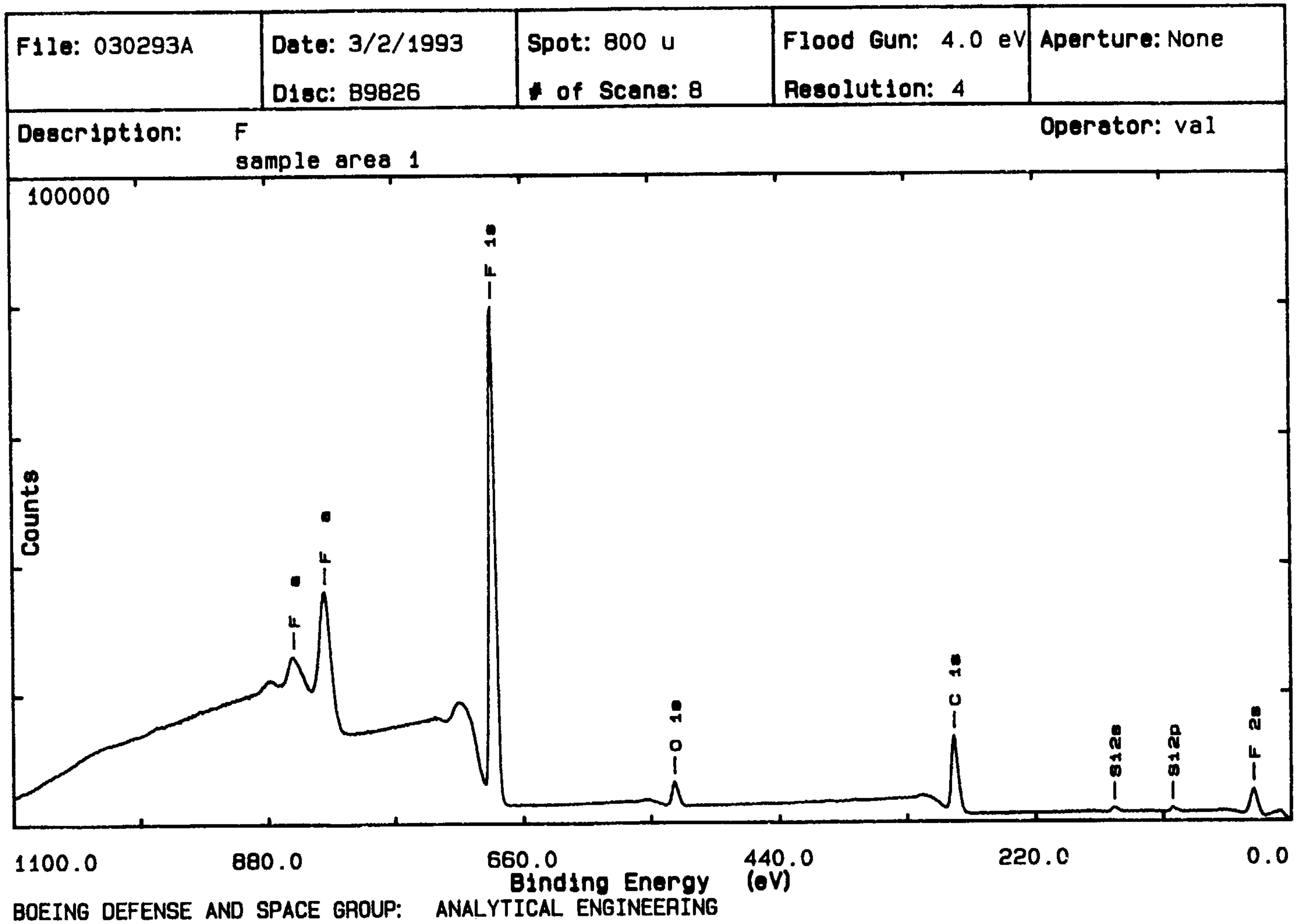


Figure C-72 Survey spectrum of exposed region 1 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

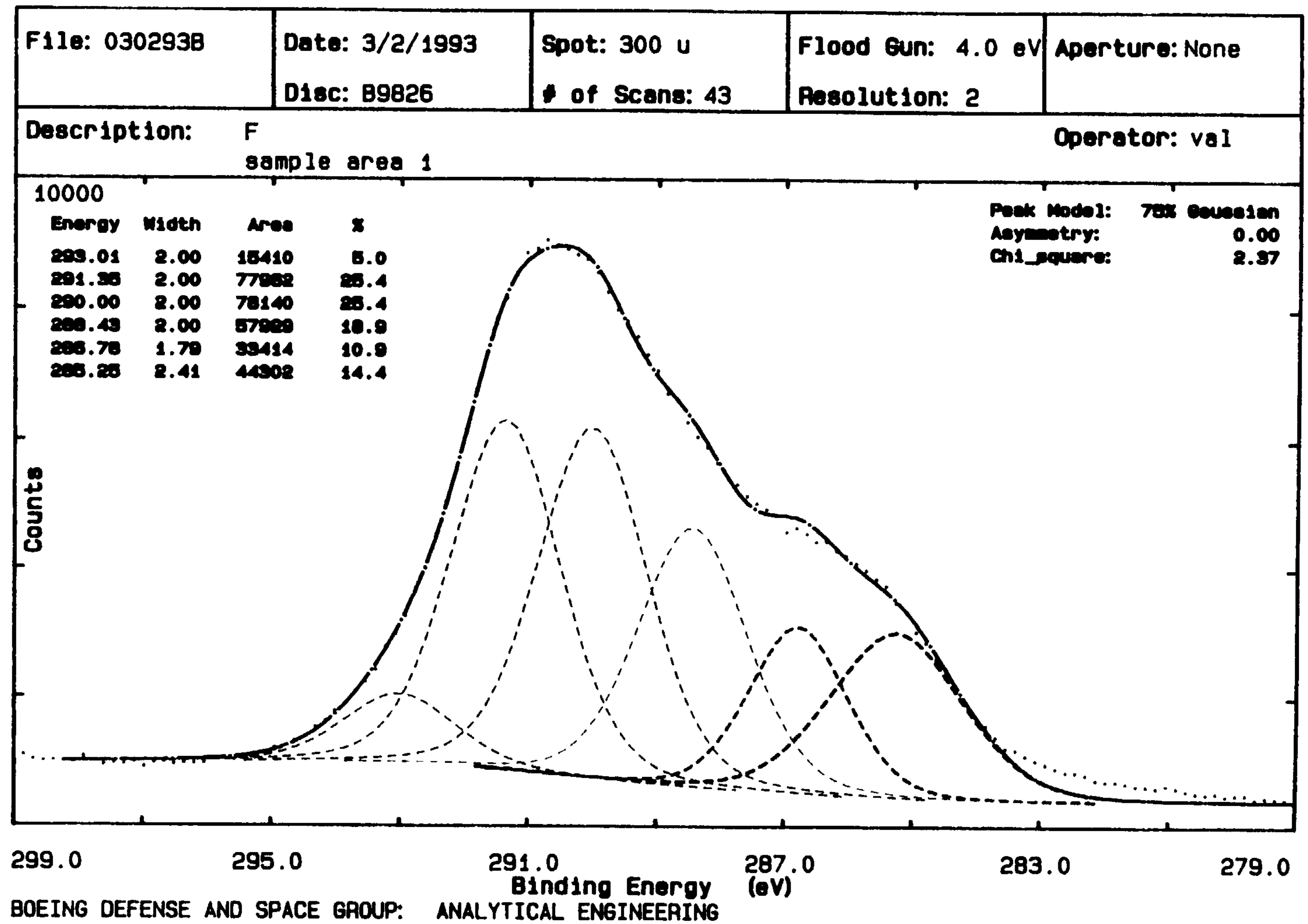


Figure C-73 Carbon 1s spectrum for exposed region 1 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

SURFACE COMPOSITION TABLE		
'F' sample area 1		
Element	B Energy	Atom %
SiZp	106.1	2.05
C 1s	294.3	32.52
O 1s	535.2	3.97
F 1s	691.2	61.45
F a	836.3	
F a	863.1	
	Total Percent	100.00

Table C-25 Table of surface elemental composition of exposed region 1 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

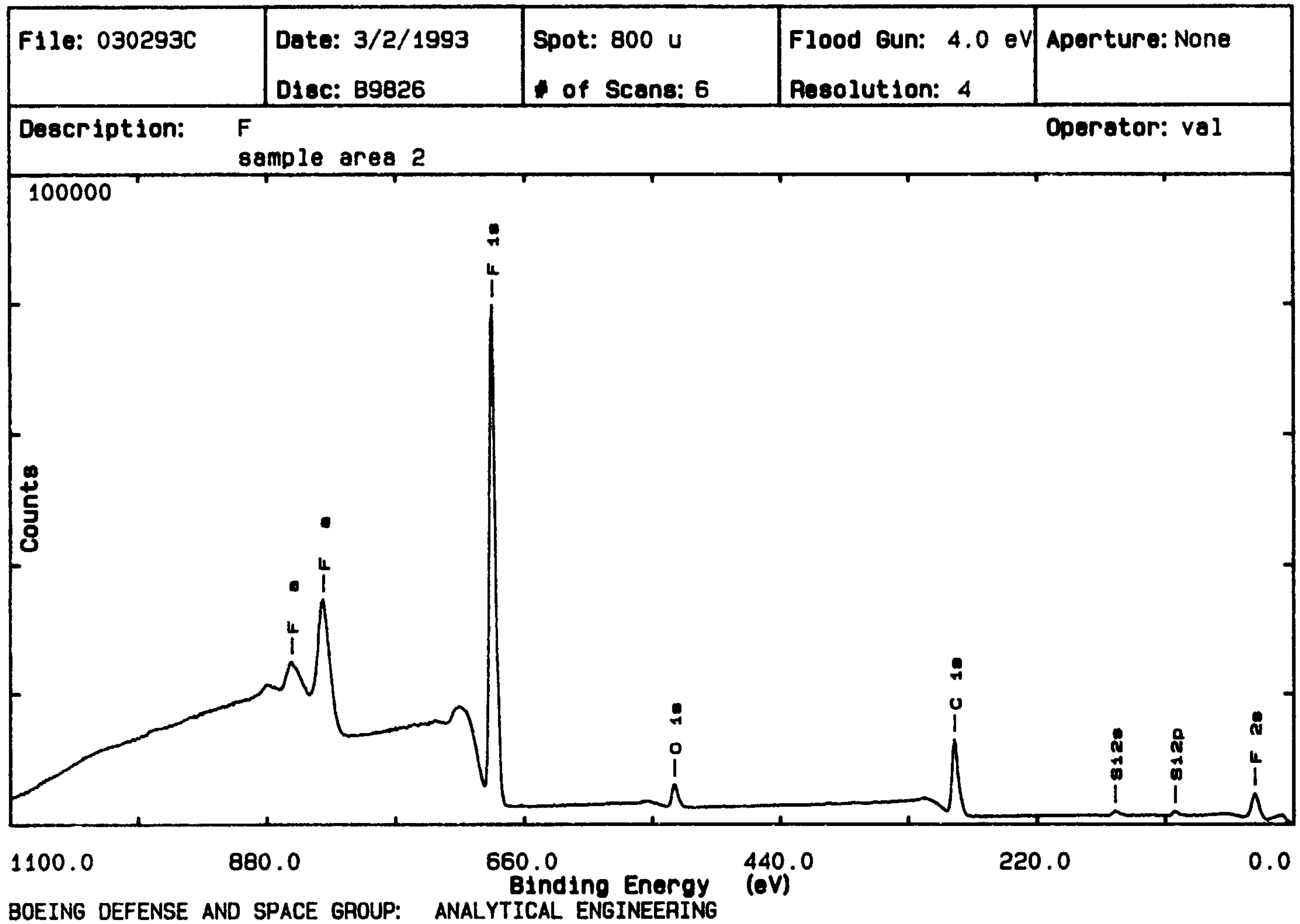


Figure C-74 Survey spectrum of exposed region 2 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

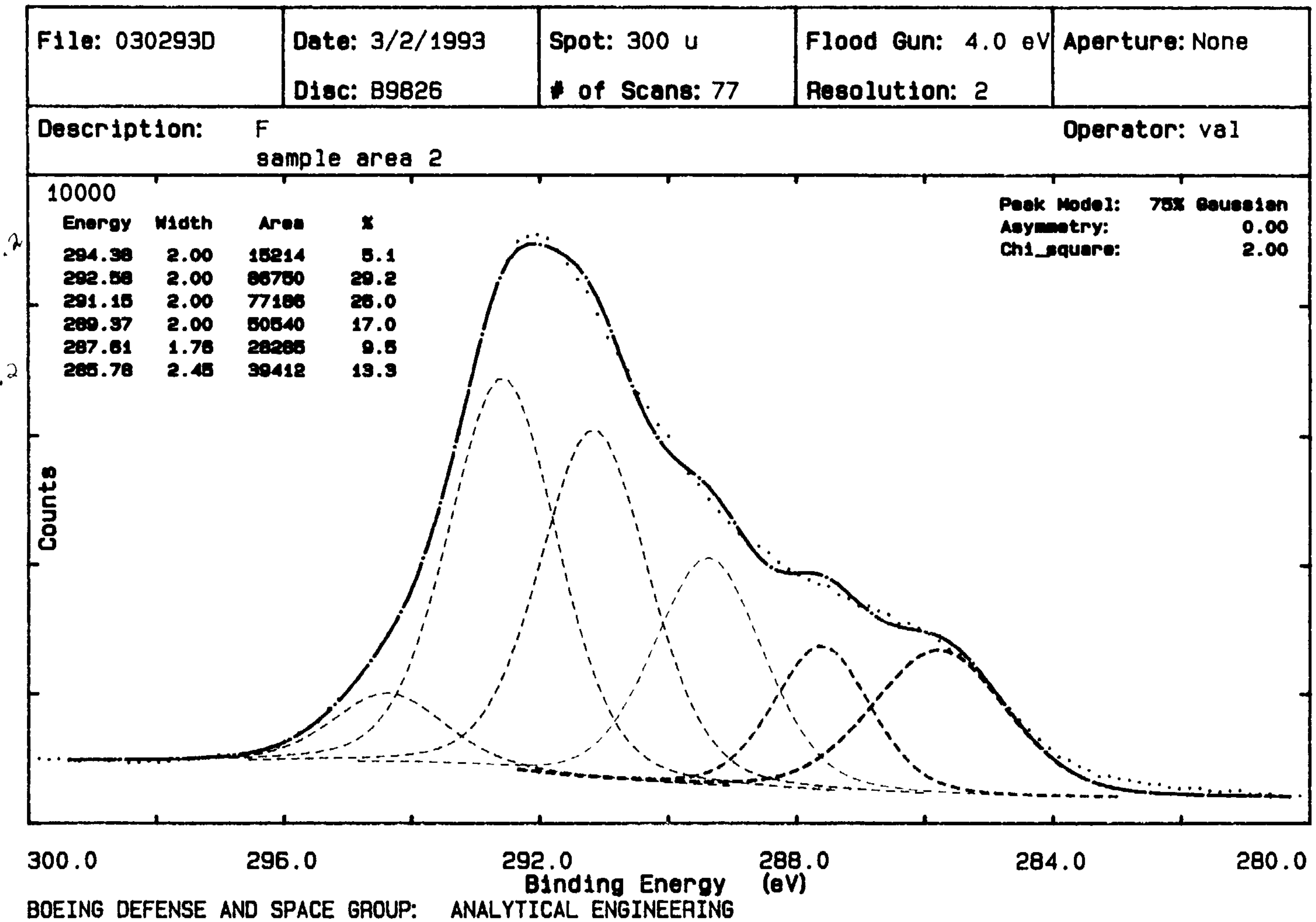


Figure C-75 Carbon 1s spectrum for exposed region 2 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

SURFACE COMPOSITION TABLE		
'F' sample area 2		
Element	B Energy	Atom %
Si2p	106.1	1.90
C 1s	295.3	32.40
O 1s	536.2	3.83
F 1s	692.2	61.88
F a	837.3	
F a	864.2	
	Total Percent	100.00

Table C-26 Table of surface elemental composition of exposed region 2 of blanket F2 from specimen reflown on STS-046 EOIM-3 experiment, labeled sample F.

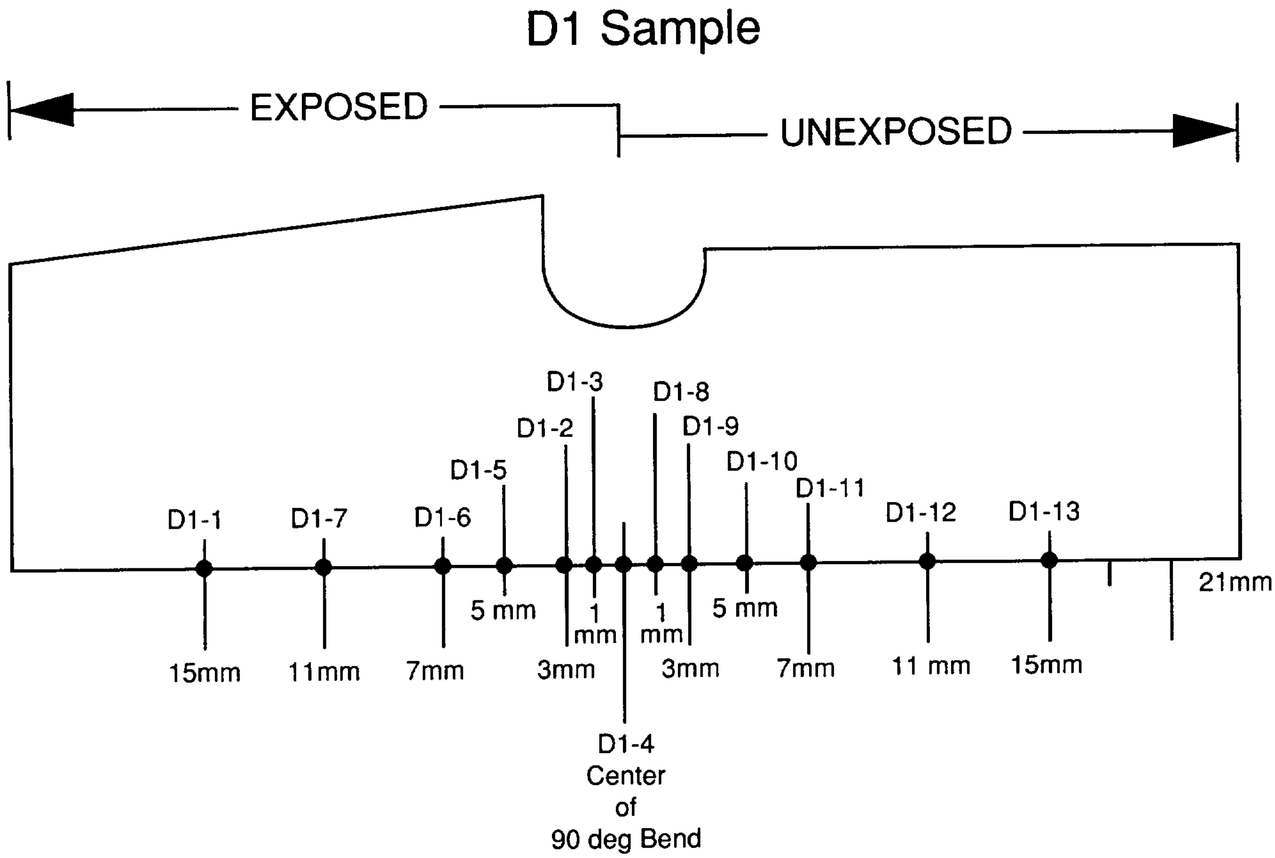


Figure C-76 Diagram of locations of ESCA measurements along the edge of blanket D1, extending from the unexposed edge of the blanket, through the curved region, extending into the exposed areas of the blanket.C-113

113612/1-001 ai

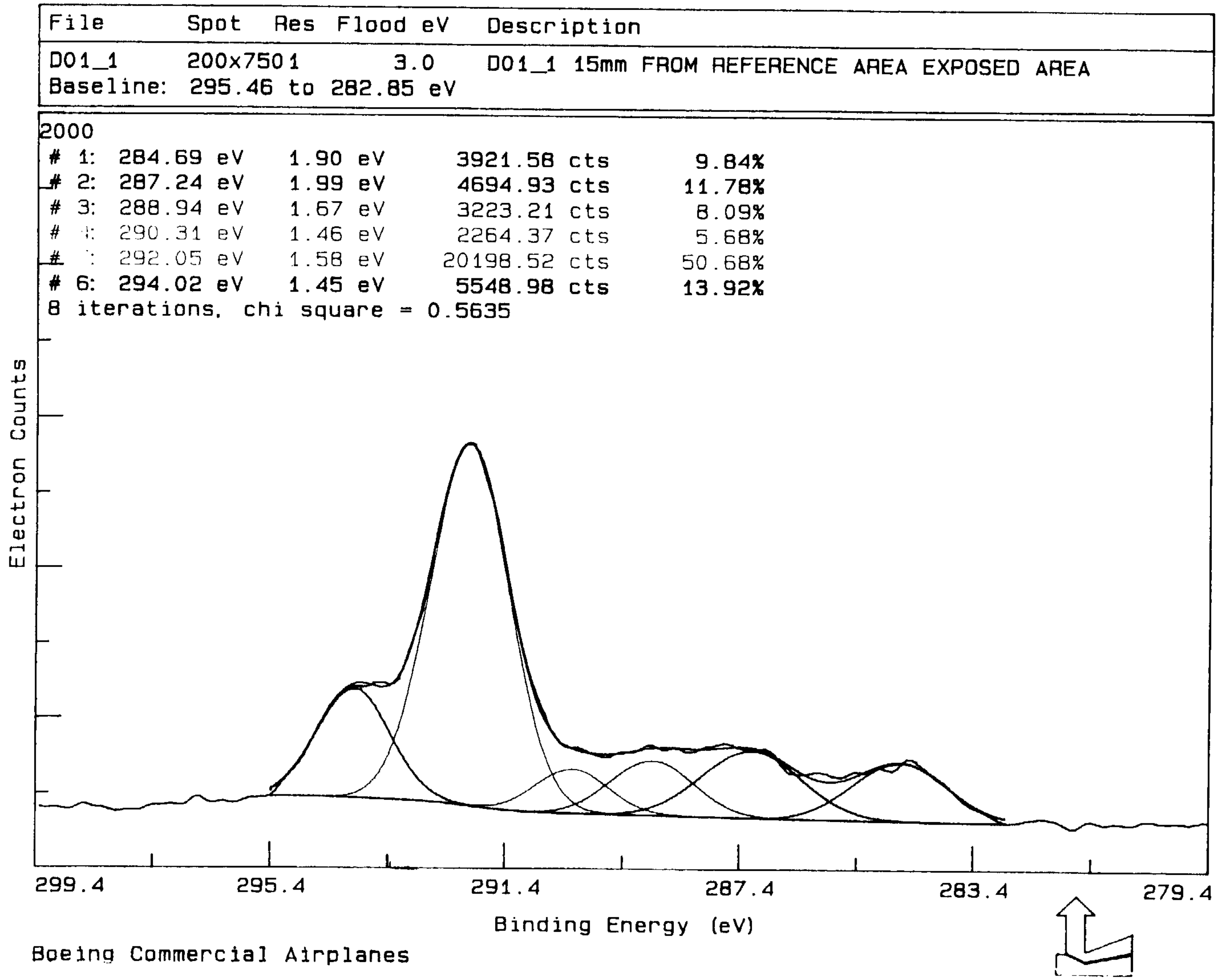


Figure C-77 Carbon 1s spectrum from blanket D1, 15 mm from center of blanket curve, toward exposed region of blanket.

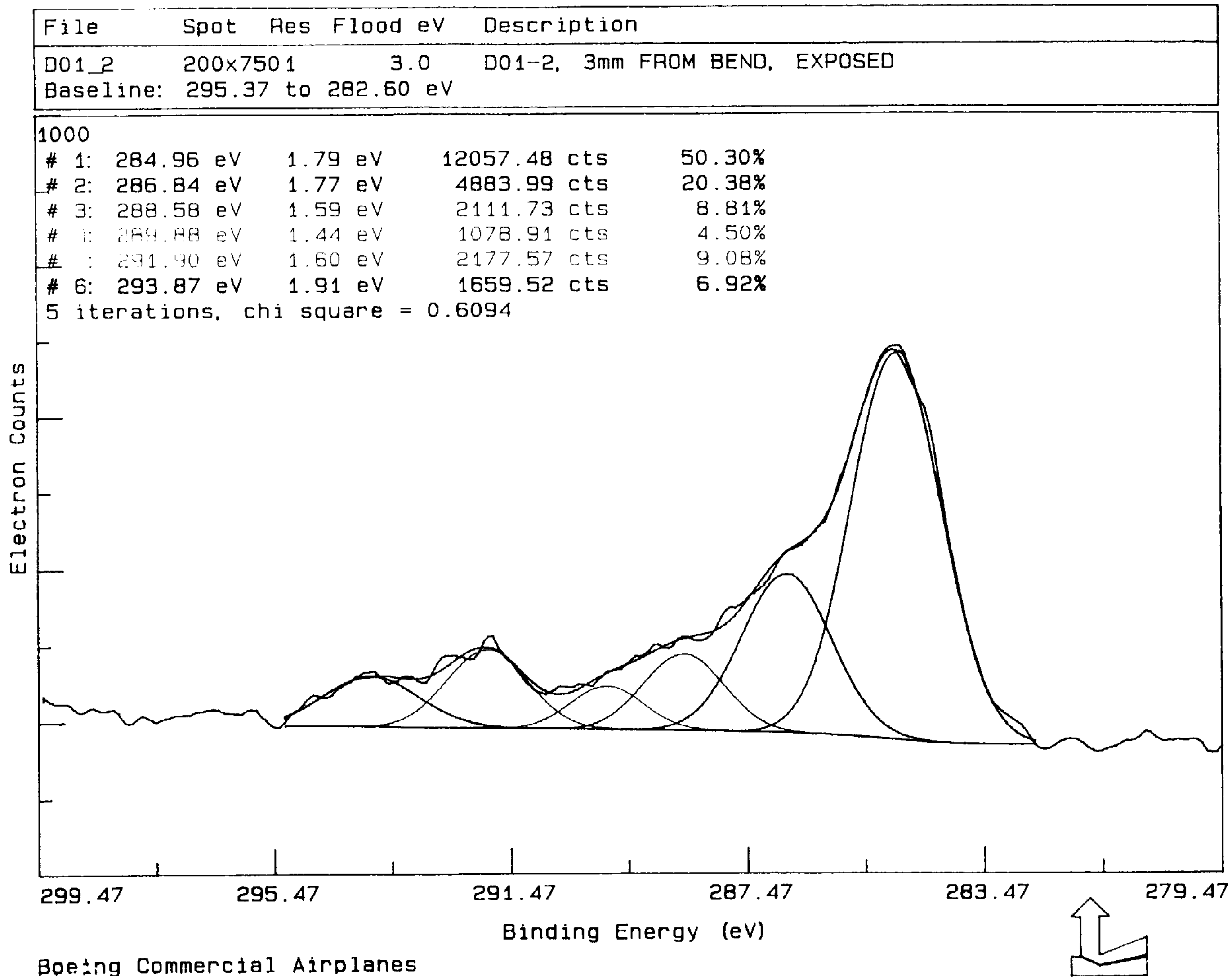


Figure C-78 Carbon 1s spectrum from blanket D1, 11 mm from center of blanket curve, toward exposed region of blanket.

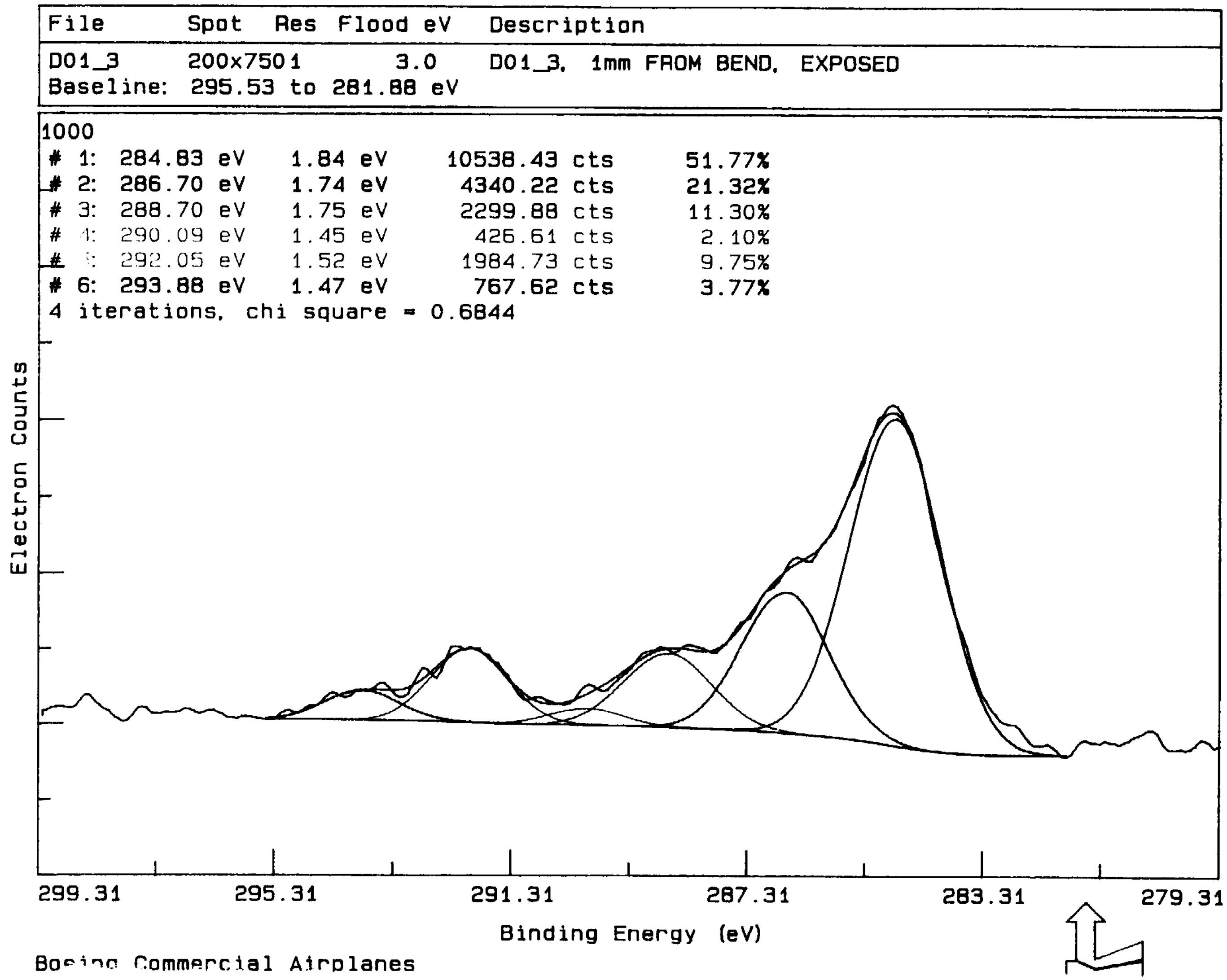


Figure C-79 Carbon 1s spectrum from blanket D1, 7 mm from center of blanket curve, toward exposed region of blanket.

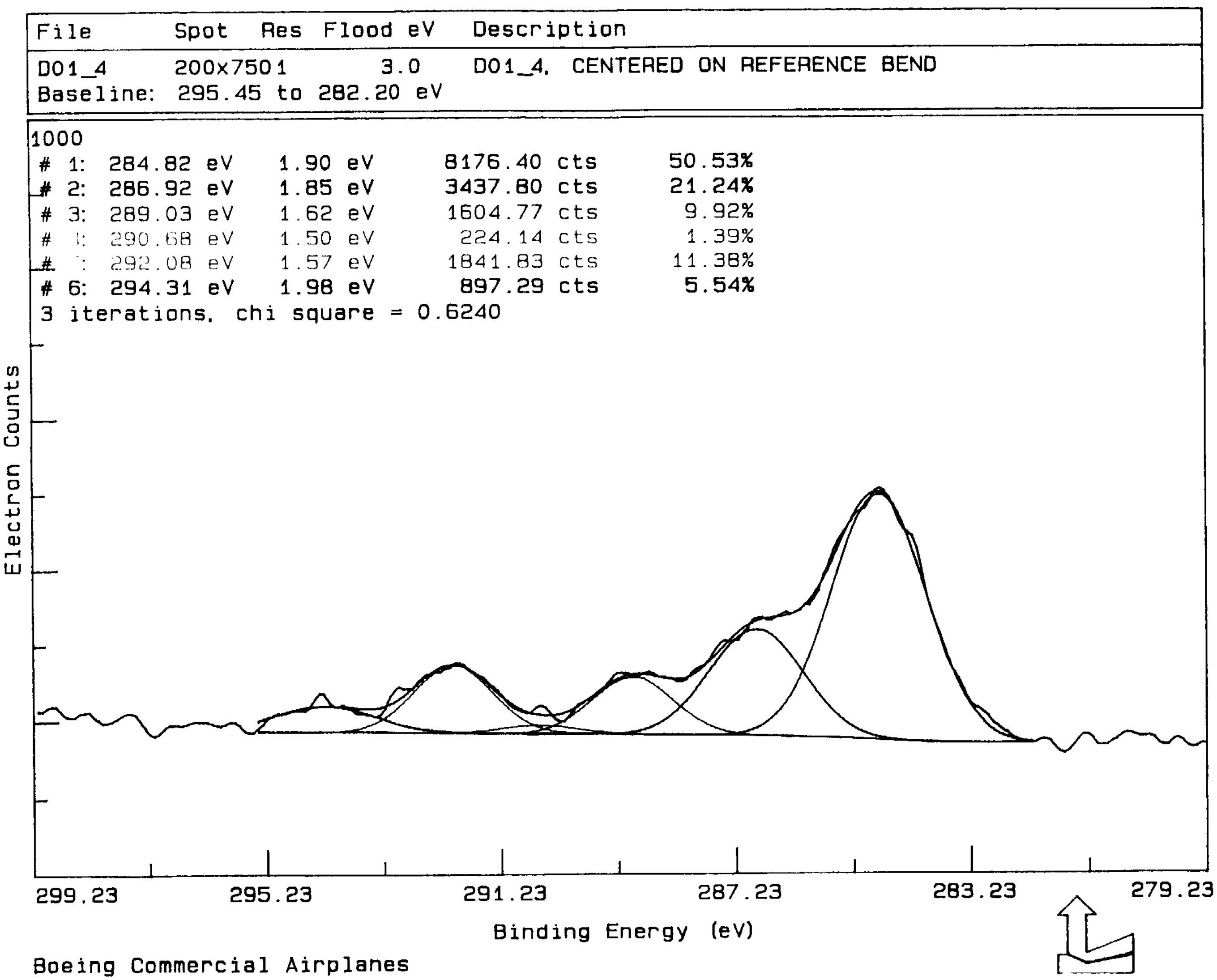


Figure C-80 Carbon 1s spectrum from blanket D1, 5 mm from center of blanket curve, toward exposed region of blanket.

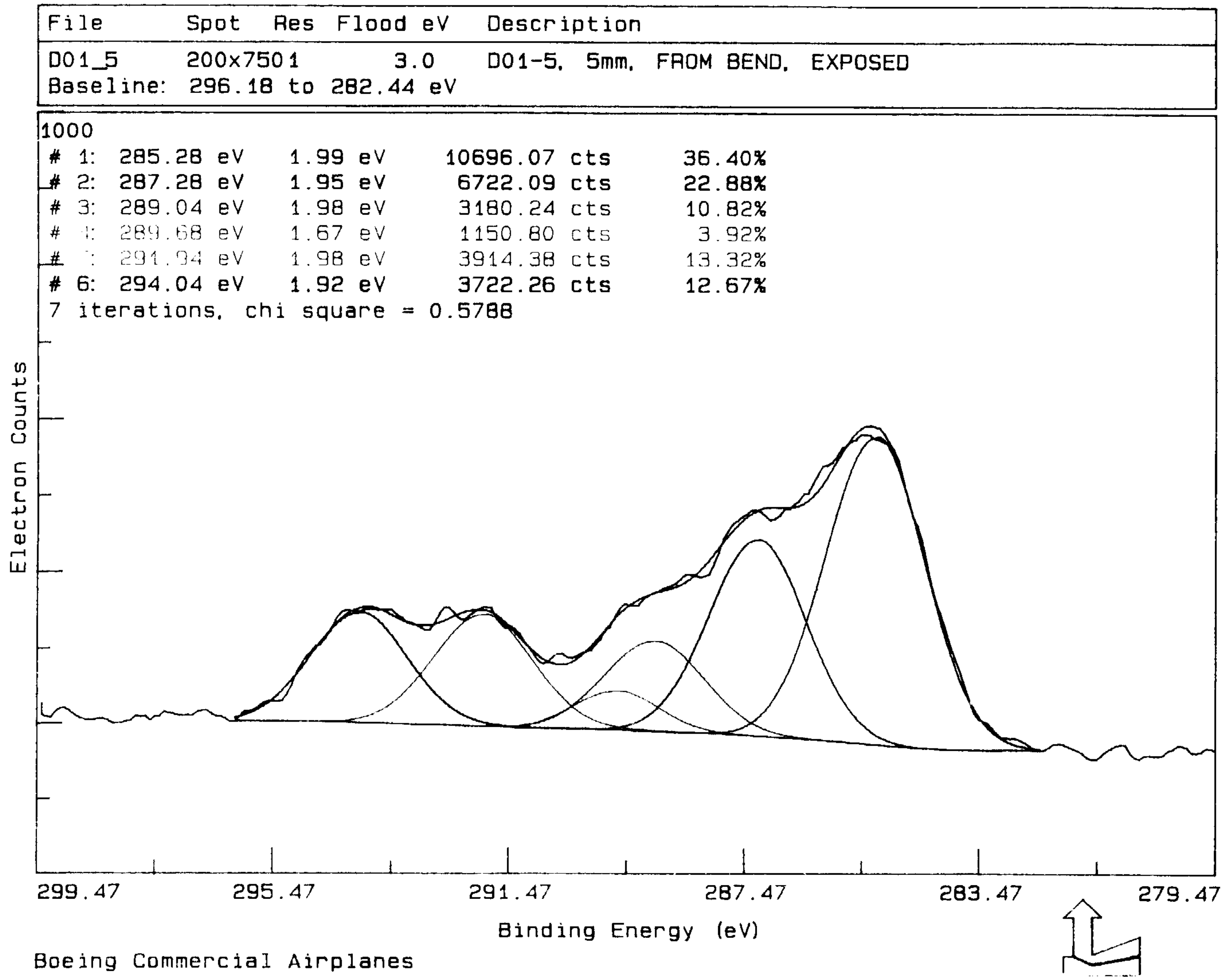


Figure C-81 Carbon 1s spectrum from blanket D1, 3 mm from center of blanket curve, toward exposed region of blanket.

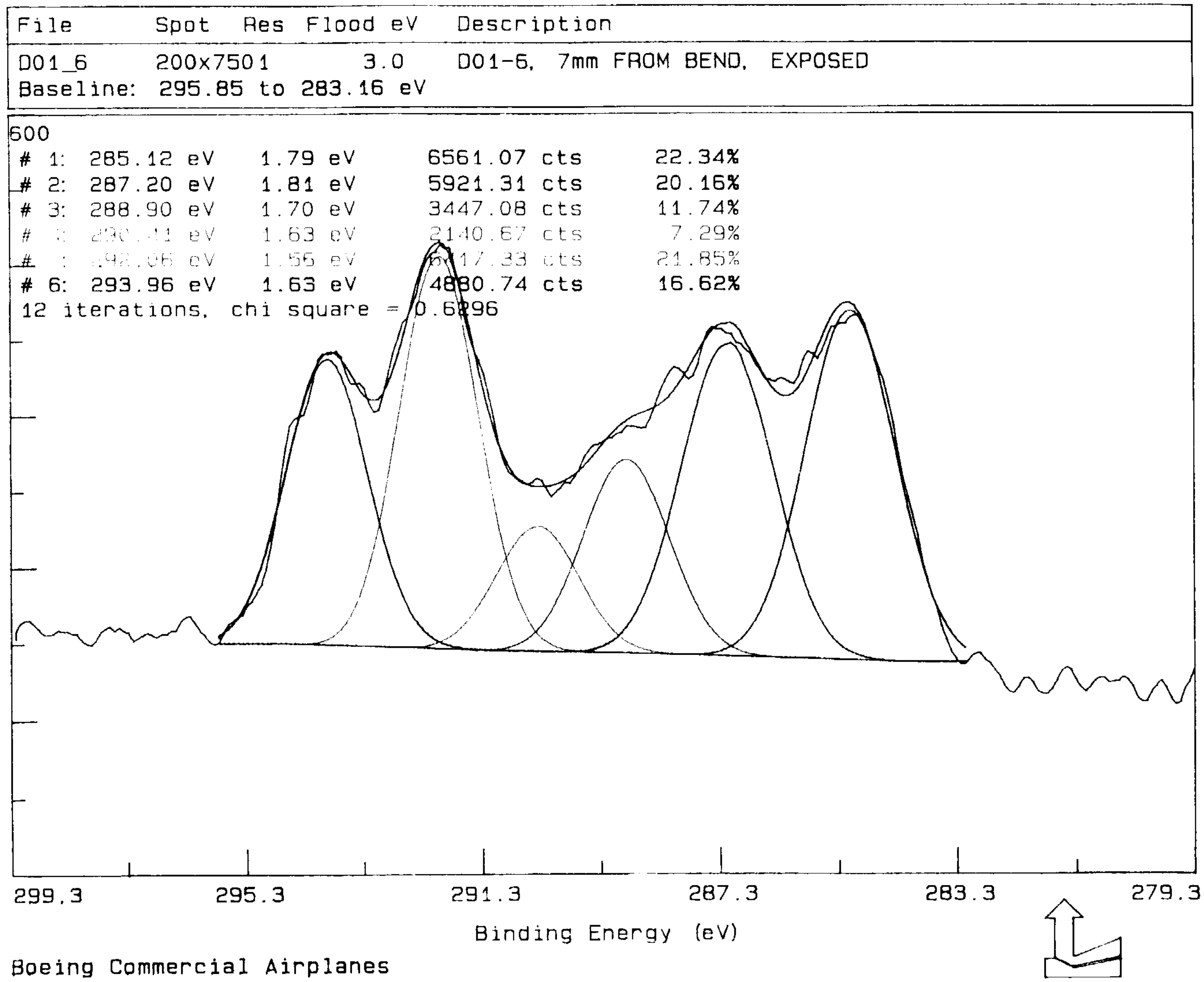


Figure C-82 Carbon 1s spectrum from blanket D1, 1 mm from center of blanket curve, toward exposed region of blanket.

File	Spot	Res	Flood eV	Description
D01_7	200x750	1	3.0	D01-7, 11mm FROM BEND, EXPOSED
Baseline: 295.54 to 282.52 eV				

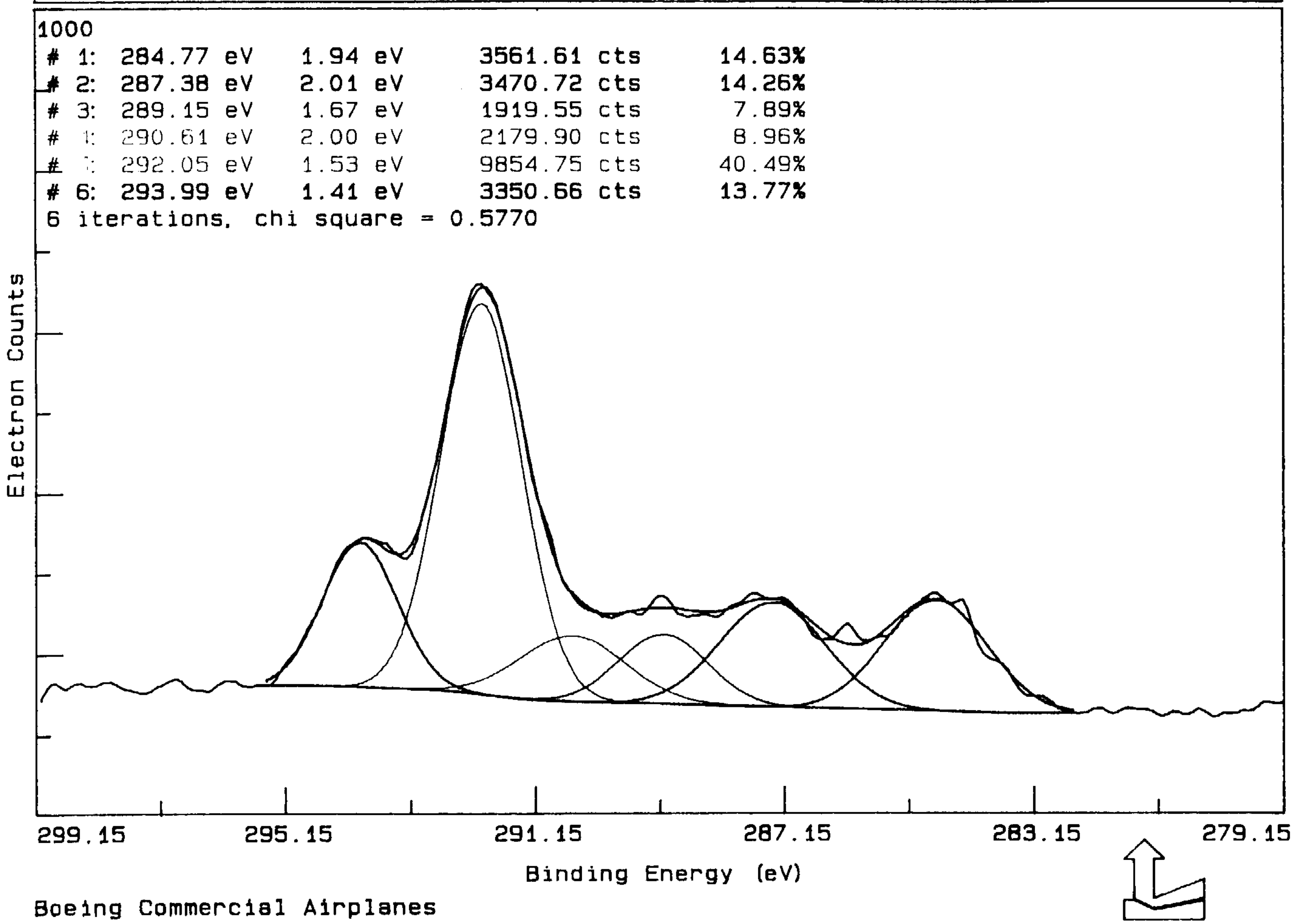


Figure C-83 Carbon 1s spectrum from blanket D1, at center of blanket curve.

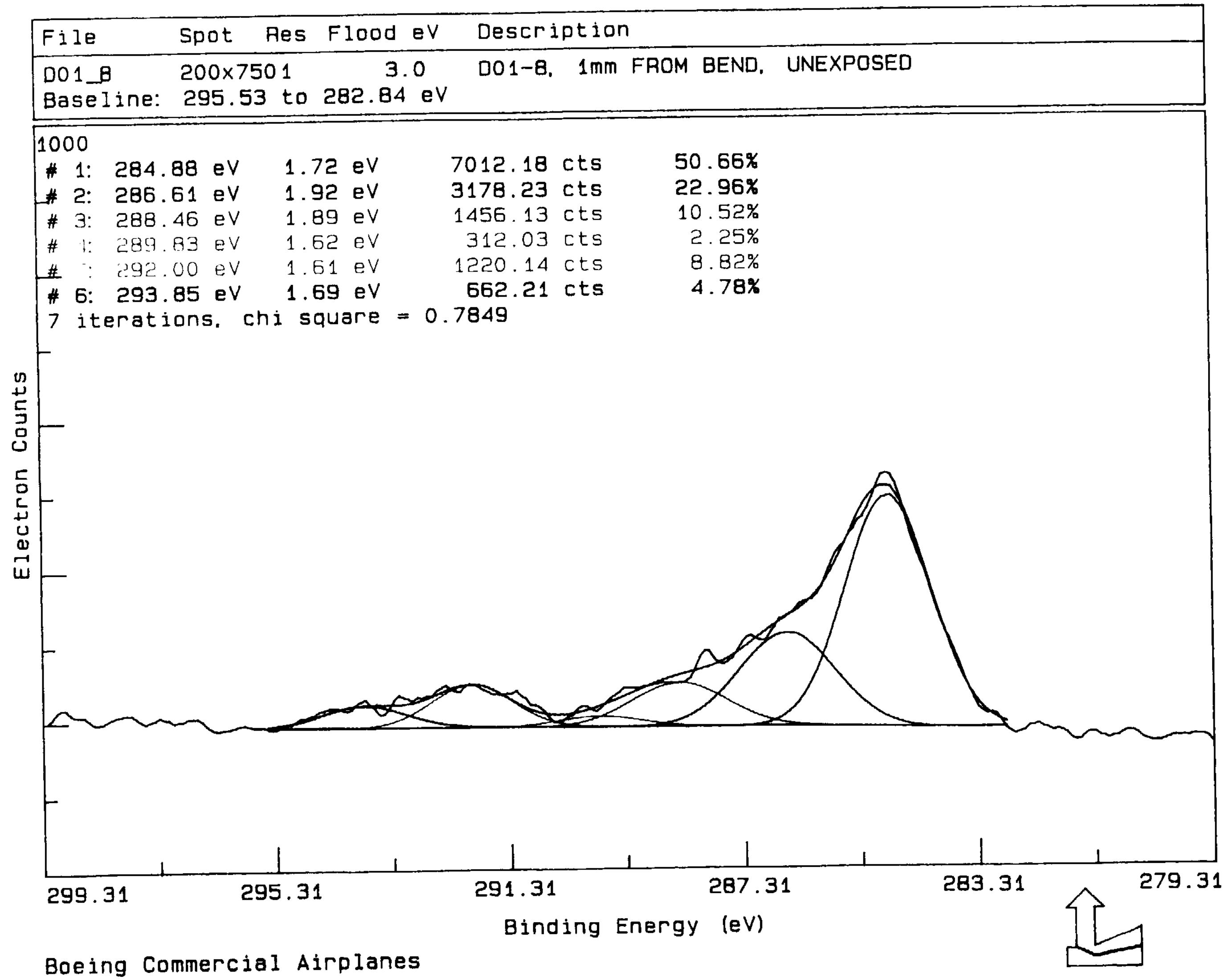


Figure C-84 Carbon 1s spectrum from blanket D1, 1 mm from center of blanket curve, toward unexposed region of blanket.

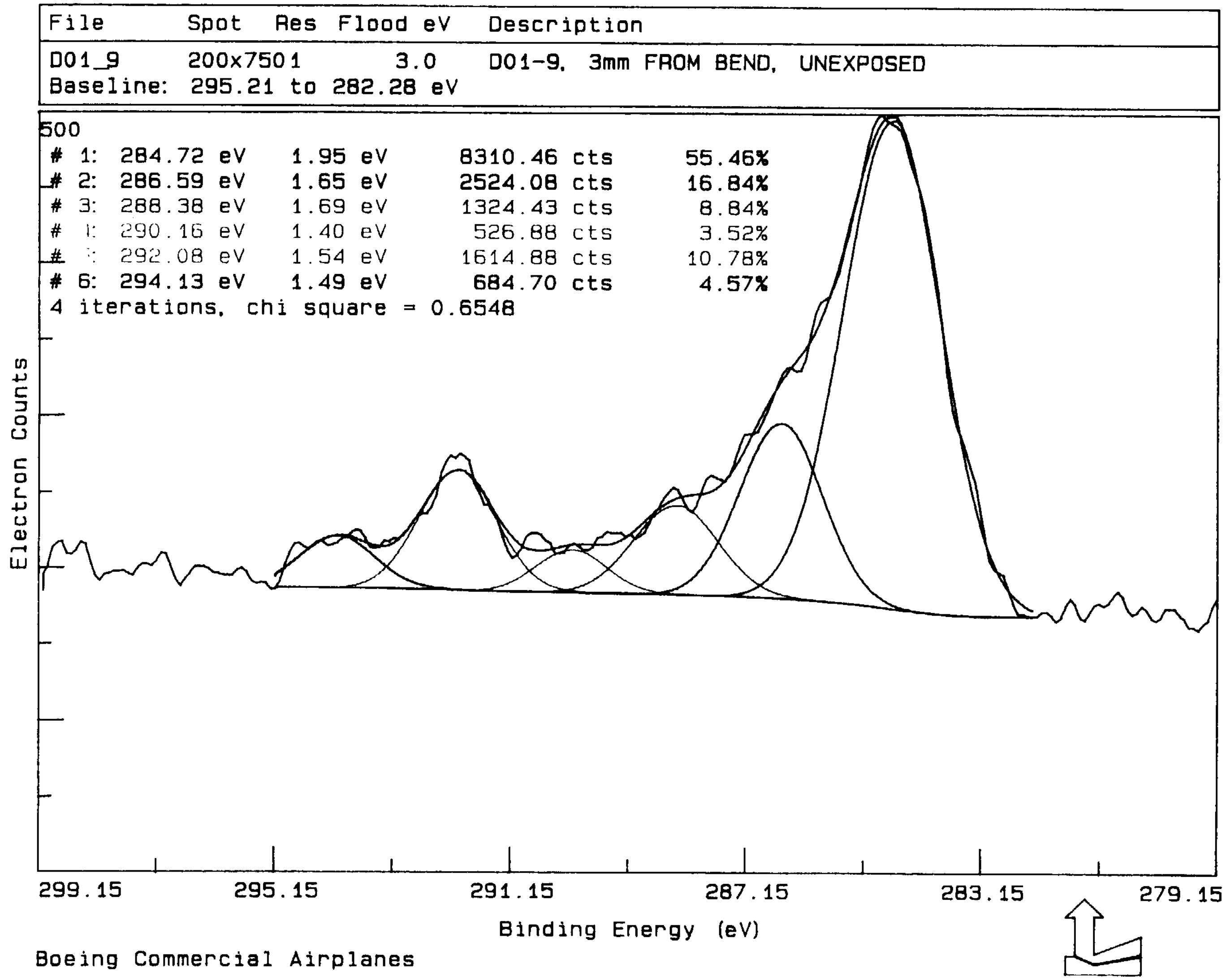


Figure C-85 Carbon 1s spectrum from blanket D1, 3 mm from center of blanket curve, toward unexposed region of blanket.

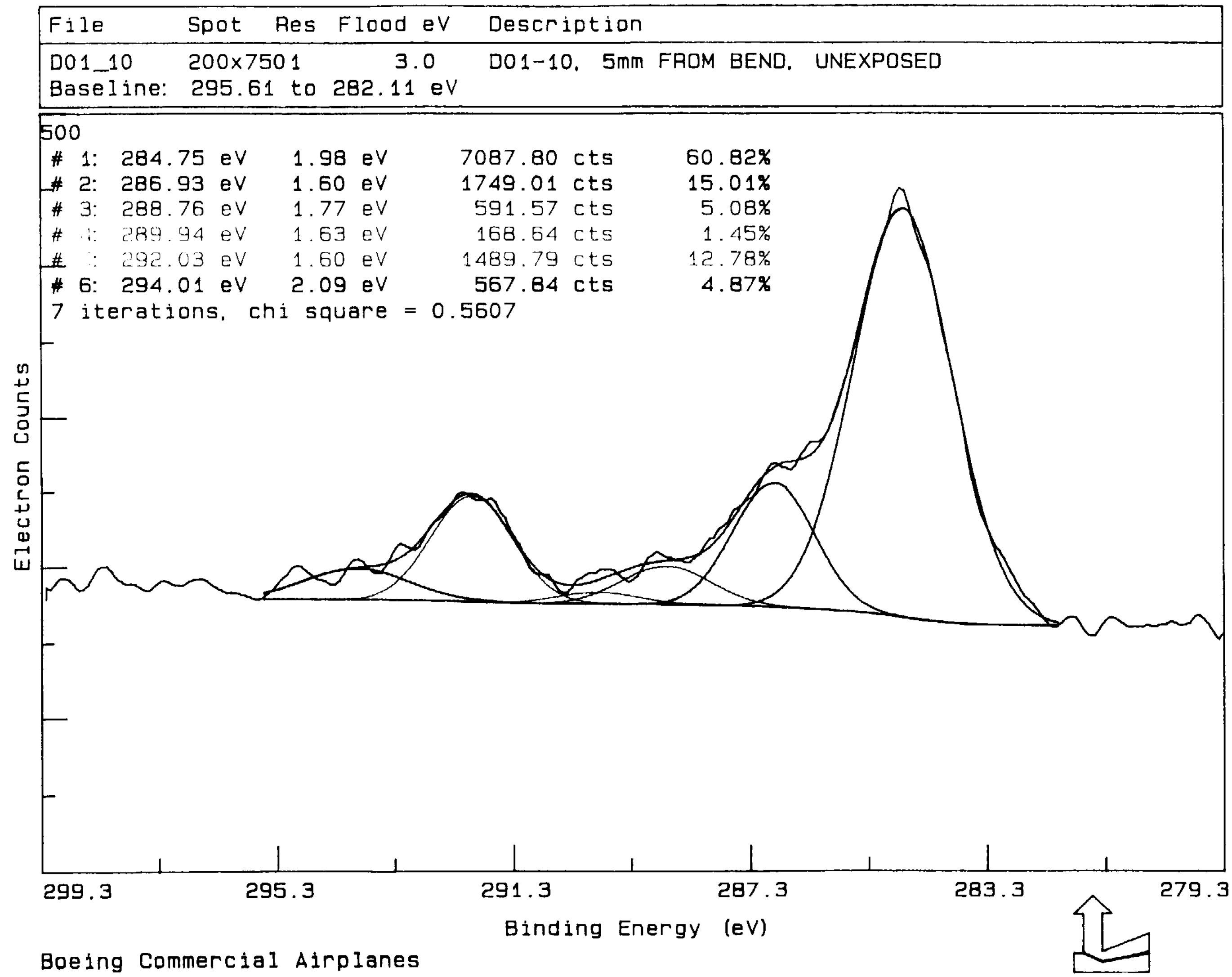


Figure C-86 Carbon 1s spectrum from blanket D1, 5 mm from center of blanket curve, toward unexposed region of blanket.

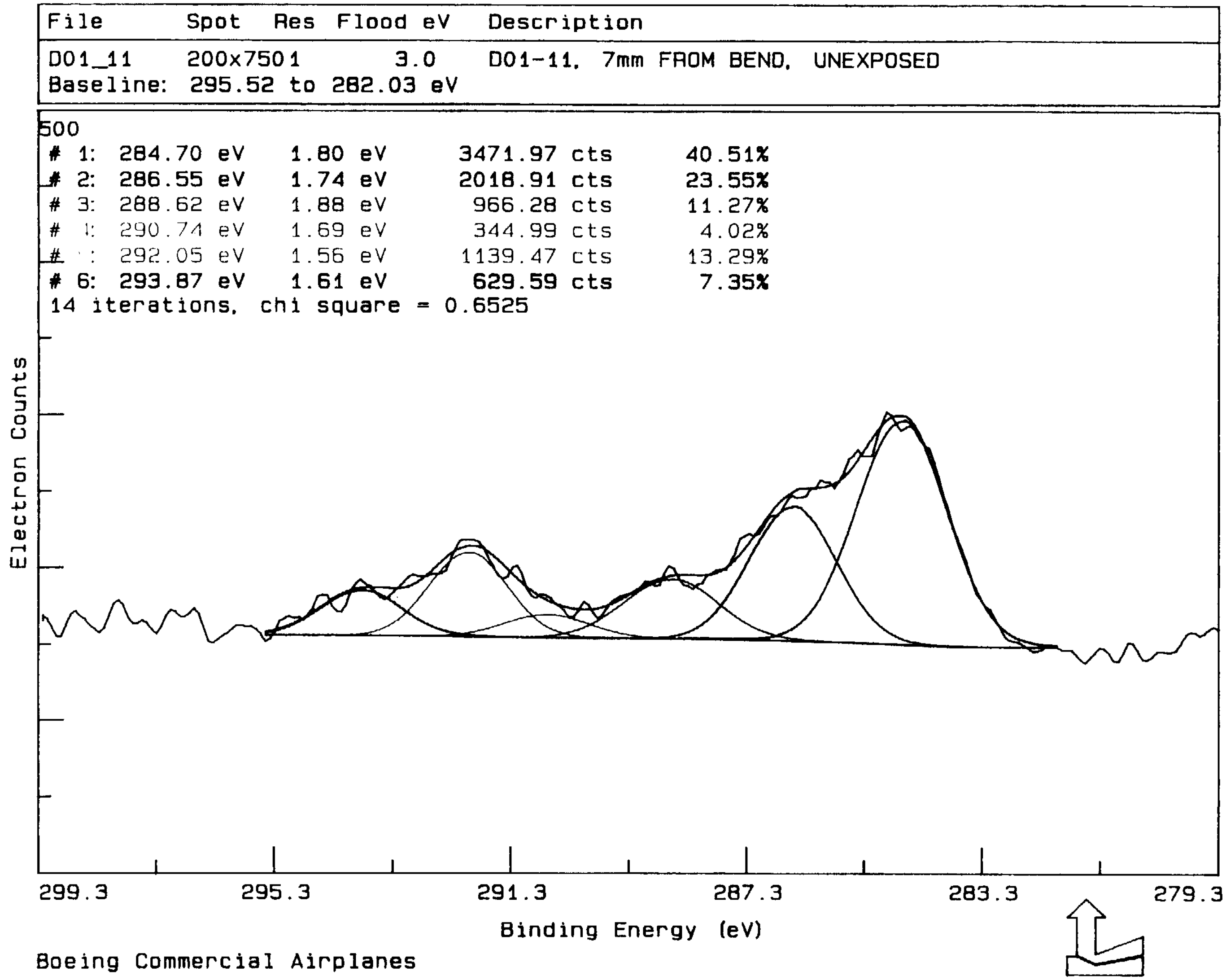


Figure C-87 Carbon 1s spectrum from blanket D1, 7 mm from center of blanket curve, toward unexposed region of blanket.

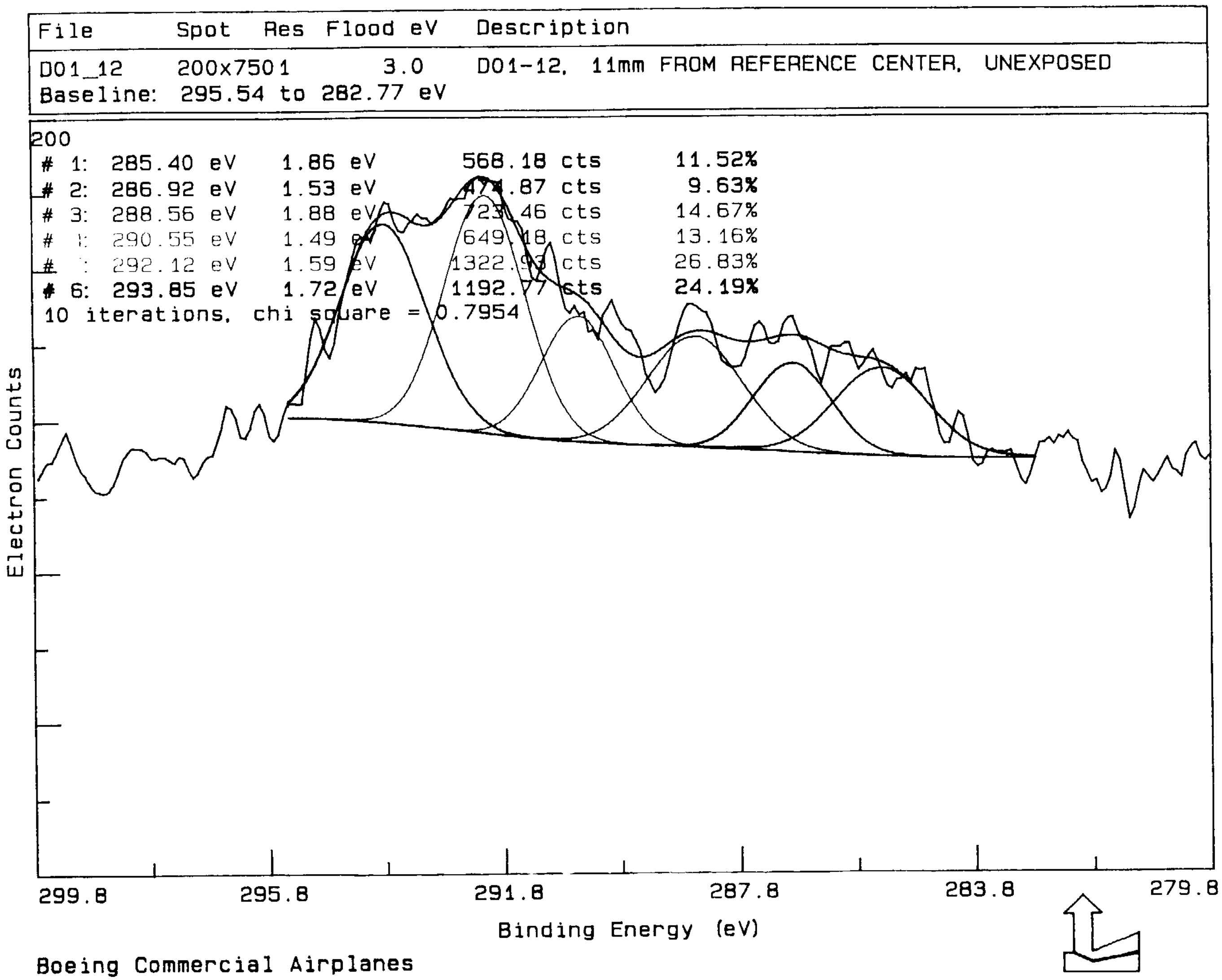


Figure C-88 Carbon 1s spectrum from blanket D1, 11 mm from center of blanket curve, toward unexposed region of blanket.

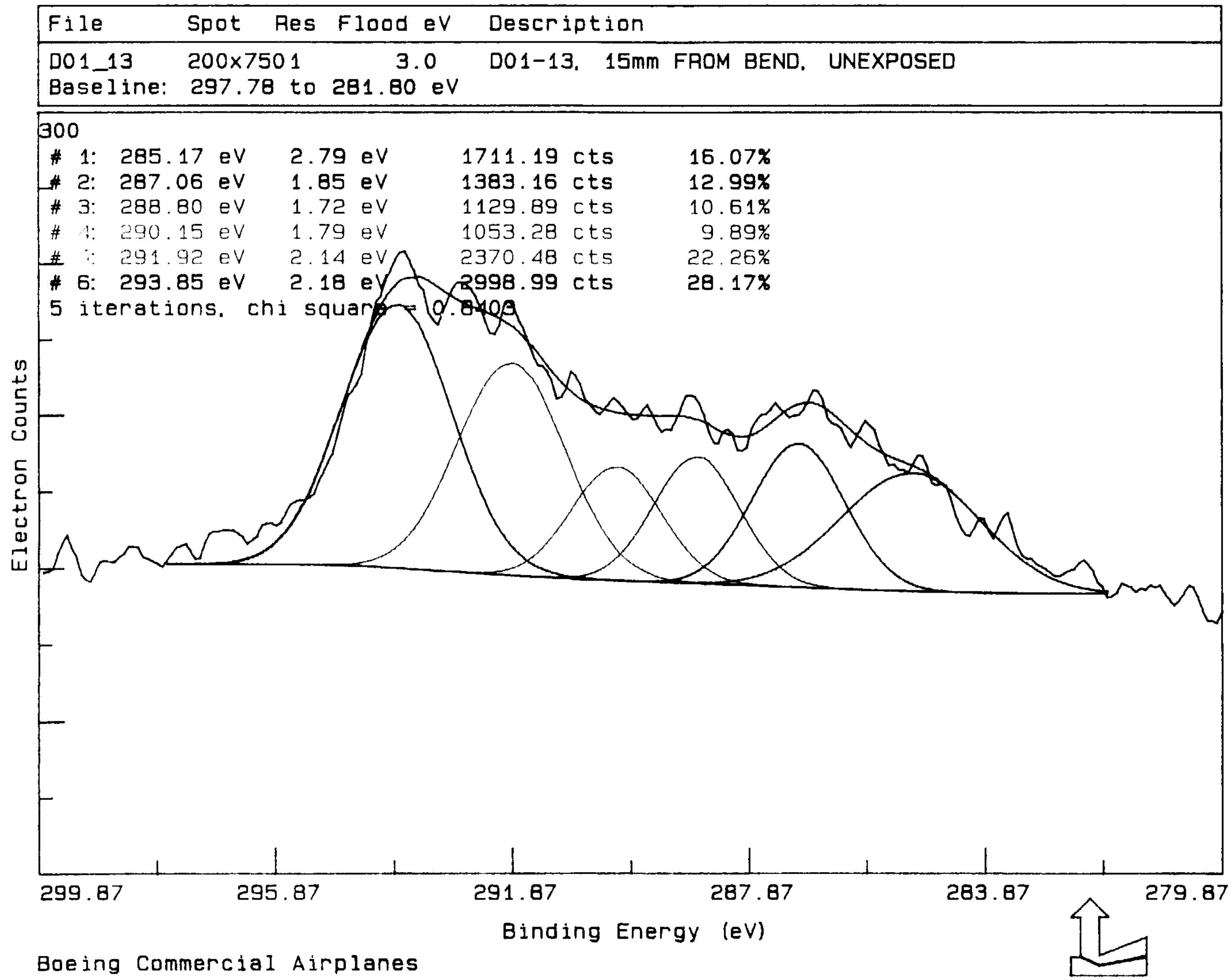


Figure C-89 Carbon 1s spectrum from blanket D1, 15 mm from center of blanket curve, toward unexposed exposed region of blanket.

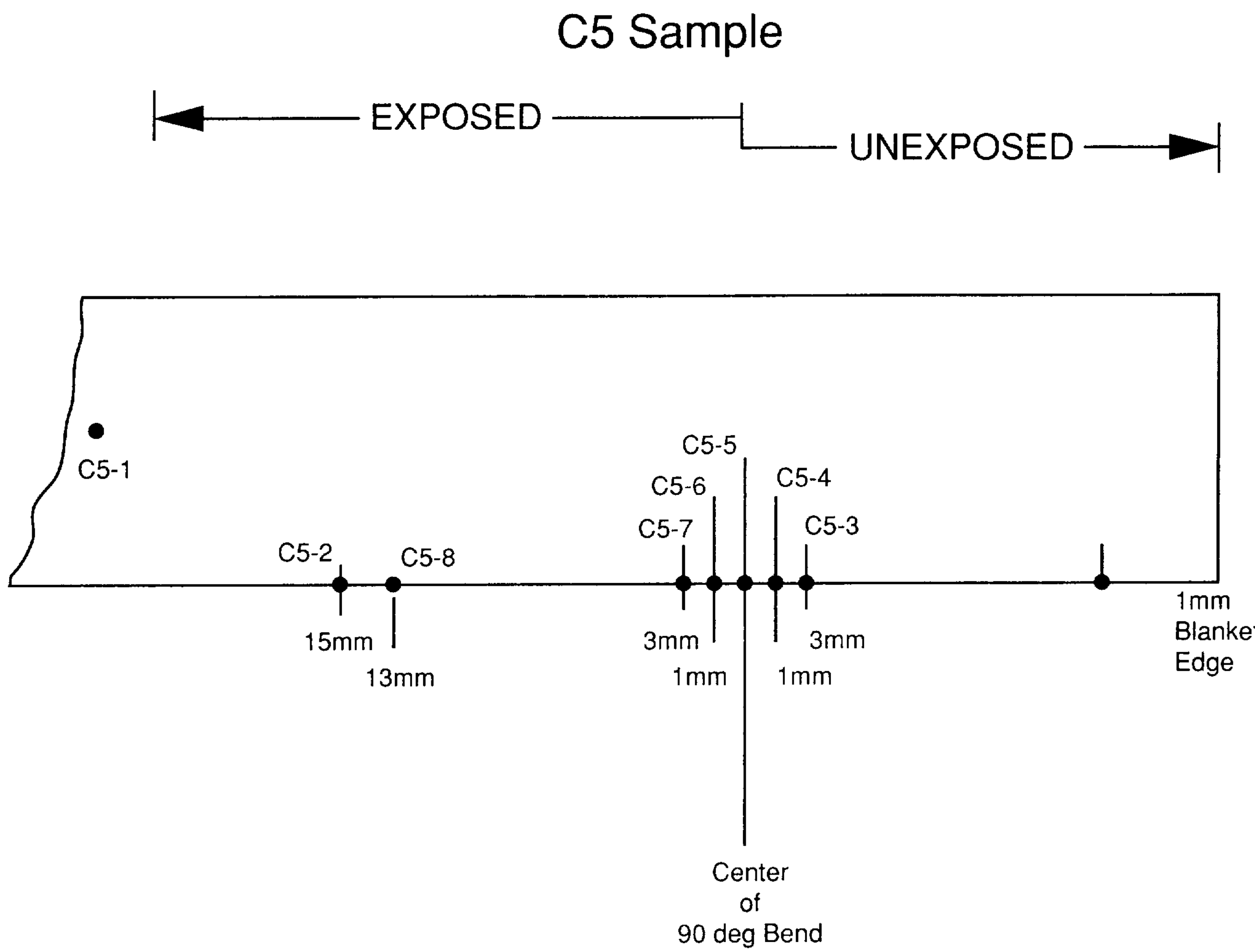


Figure C-90 Diagram of locations of ESCA measurements along the edge of blanket C5, extending from the unexposed edge of the blanket, through the curved region, extending into the exposed areas of the blanket.C-127

113612/1-002 ai

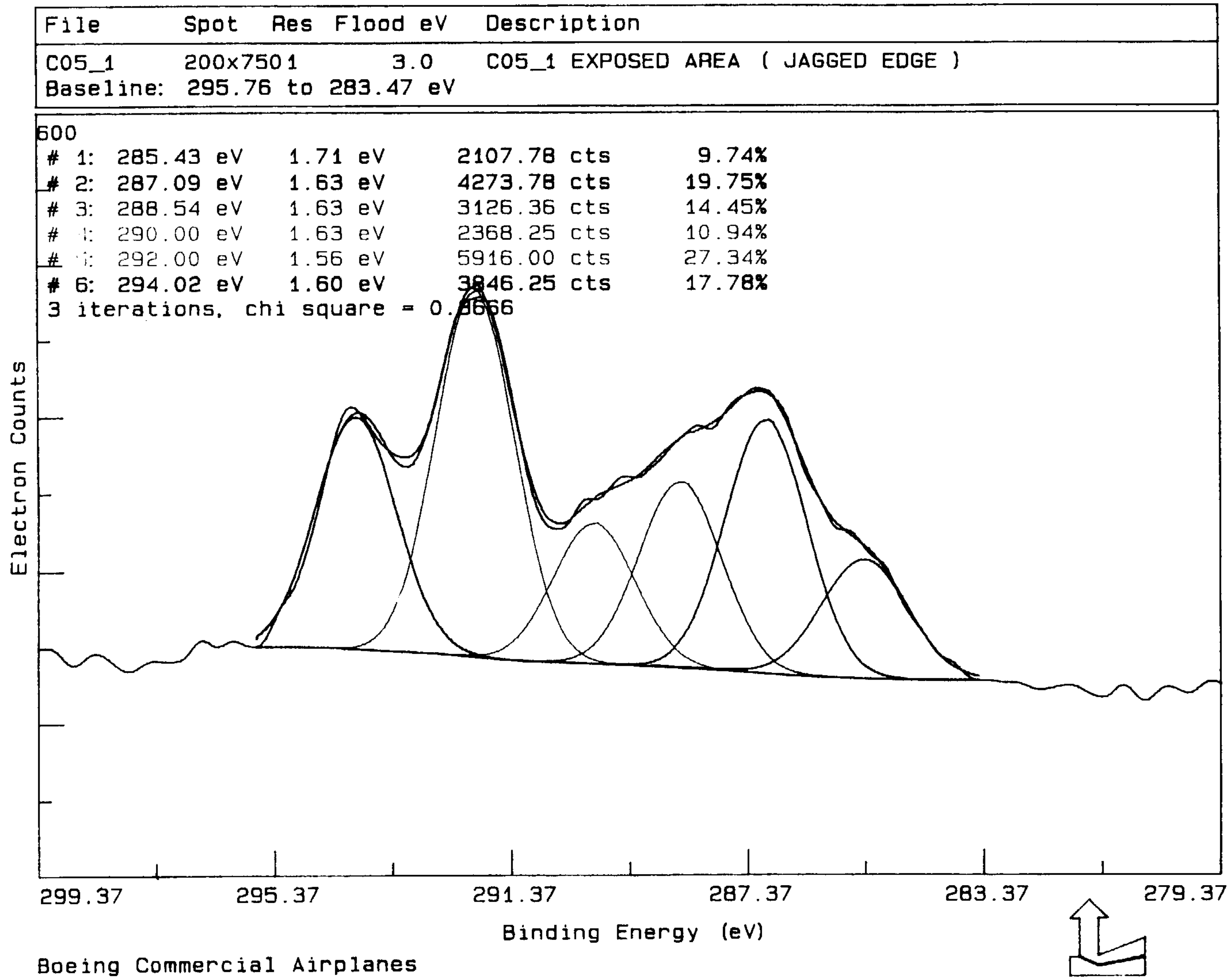


Figure C-91 Carbon 1s spectrum from blanket C5, exposed region of blanket toward jagged edge of blanket.

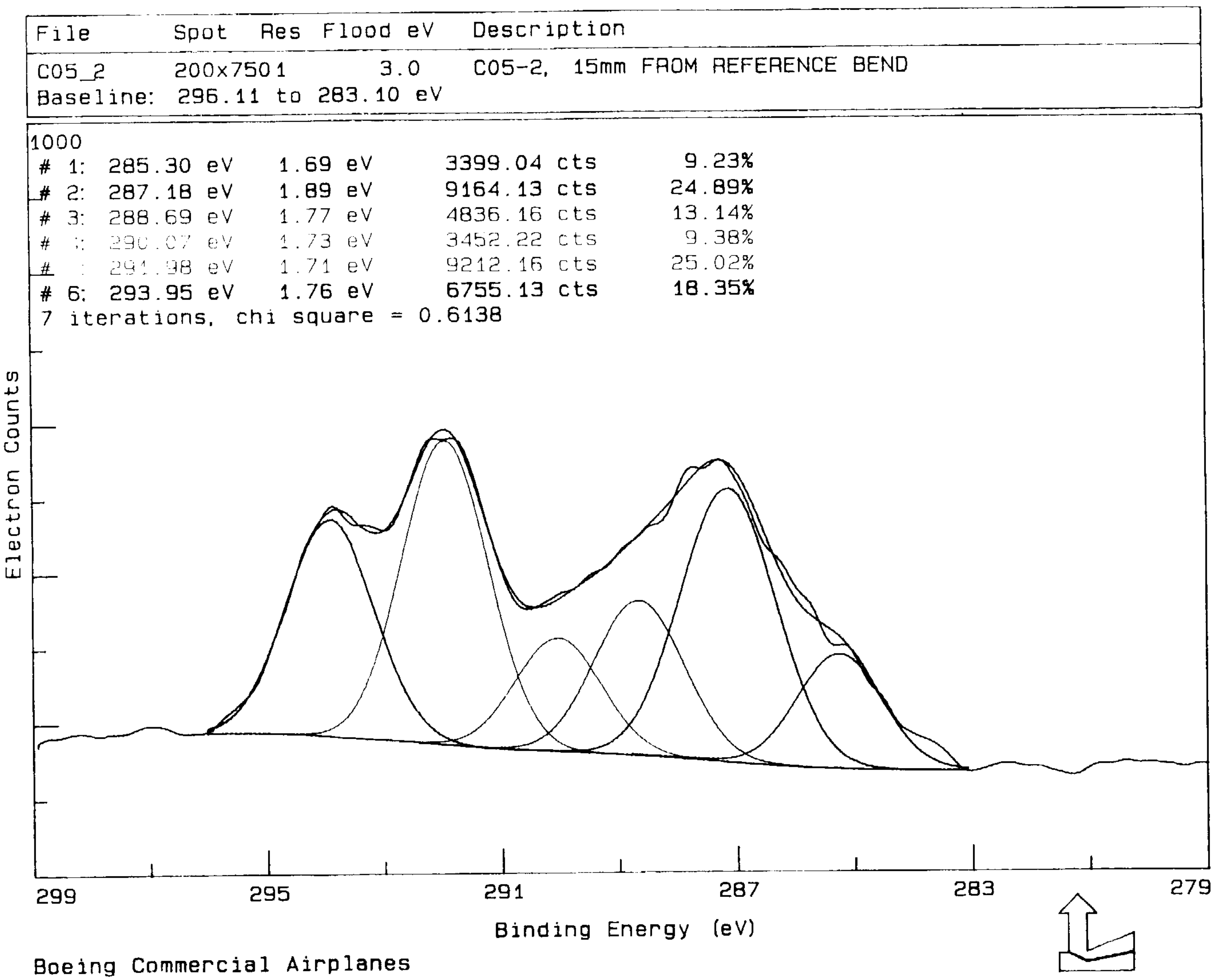


Figure C-92 Carbon 1s spectrum from blanket C5, 15 mm from center of blanket curve, toward exposed region of blanket.

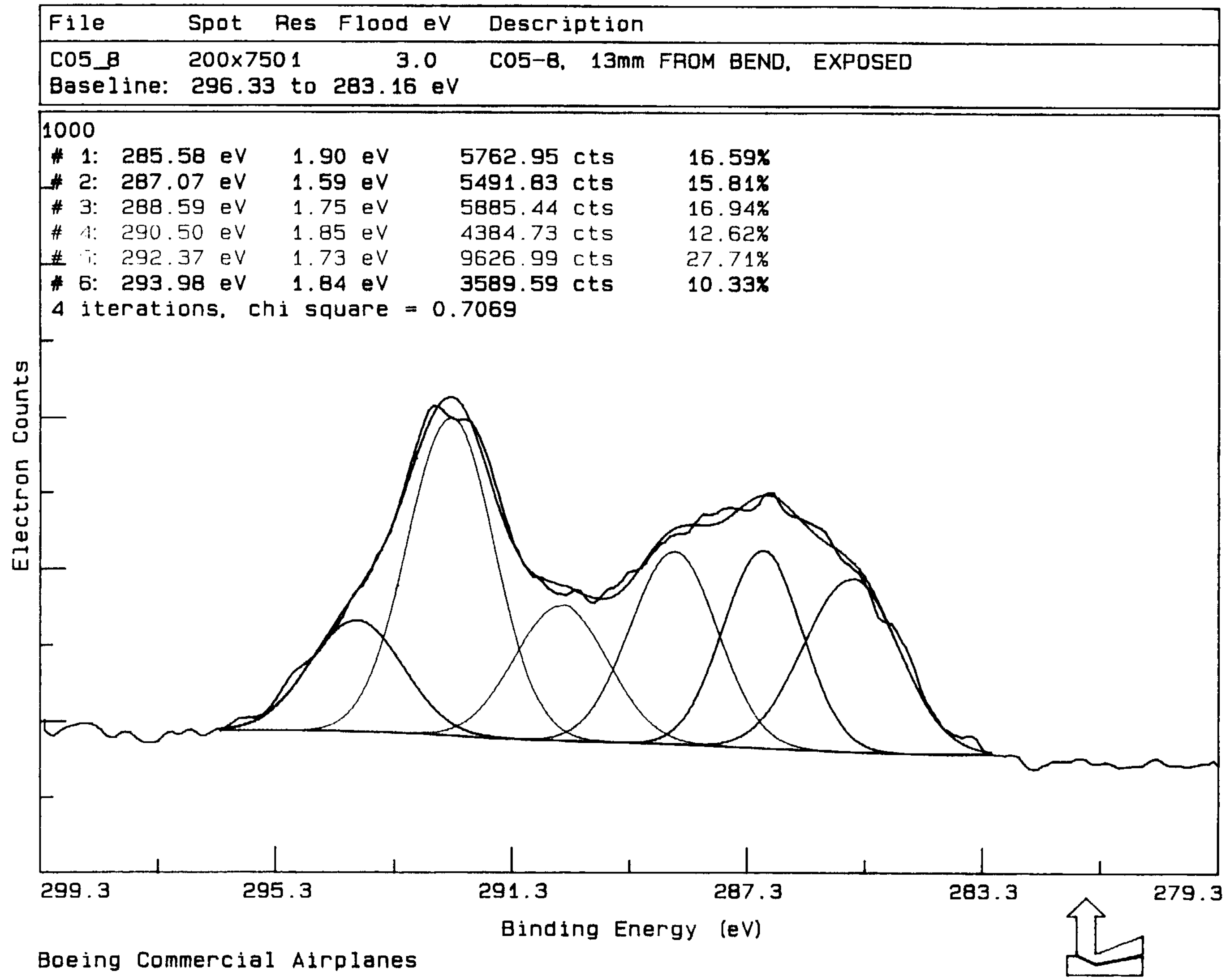


Figure C-93 Carbon 1s spectrum from blanket C5, 13 mm from center of blanket curve, toward exposed region of blanket.

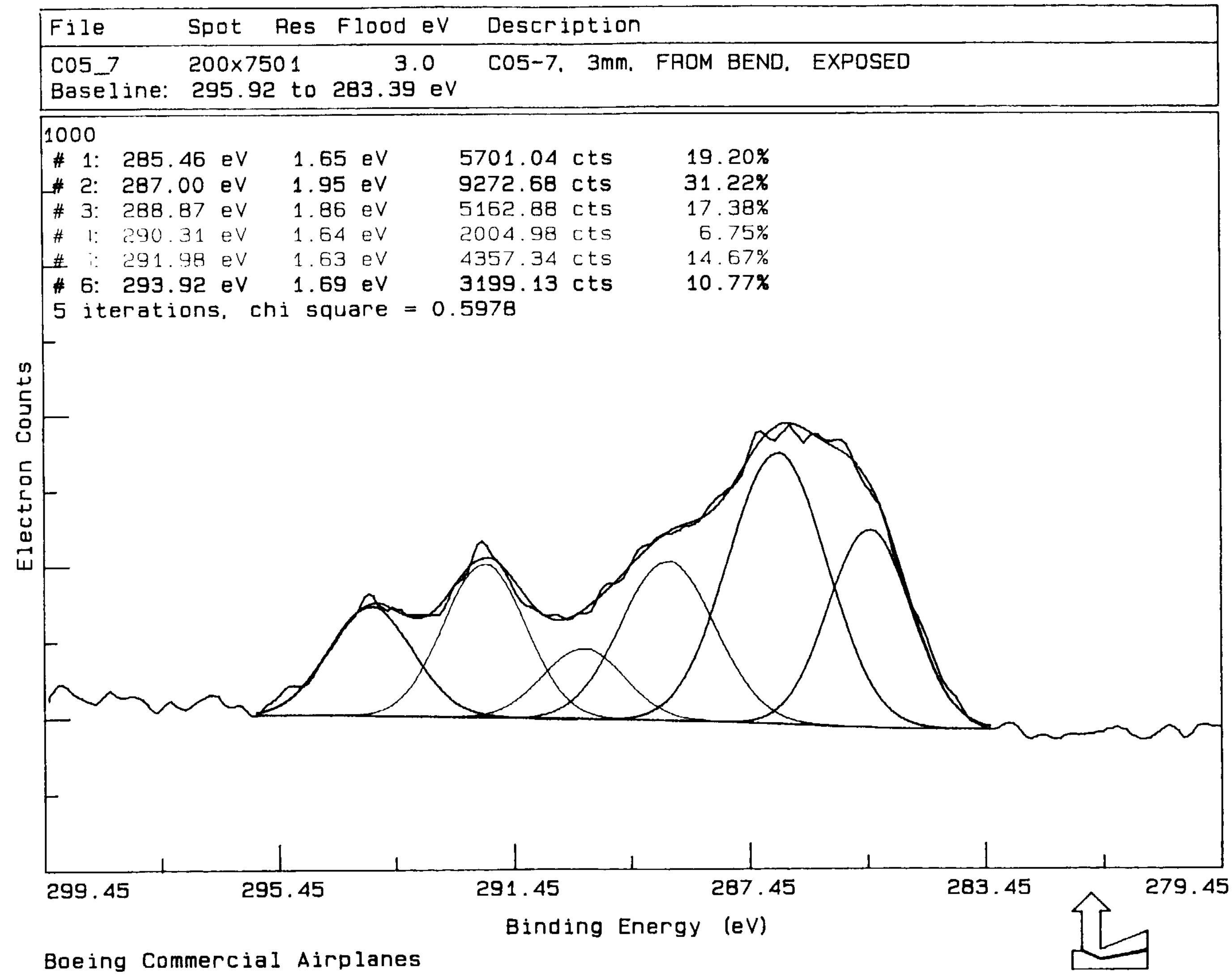


Figure C-94 Carbon 1s spectrum from blanket C5, 3 mm from center of blanket curve, toward exposed region of blanket.

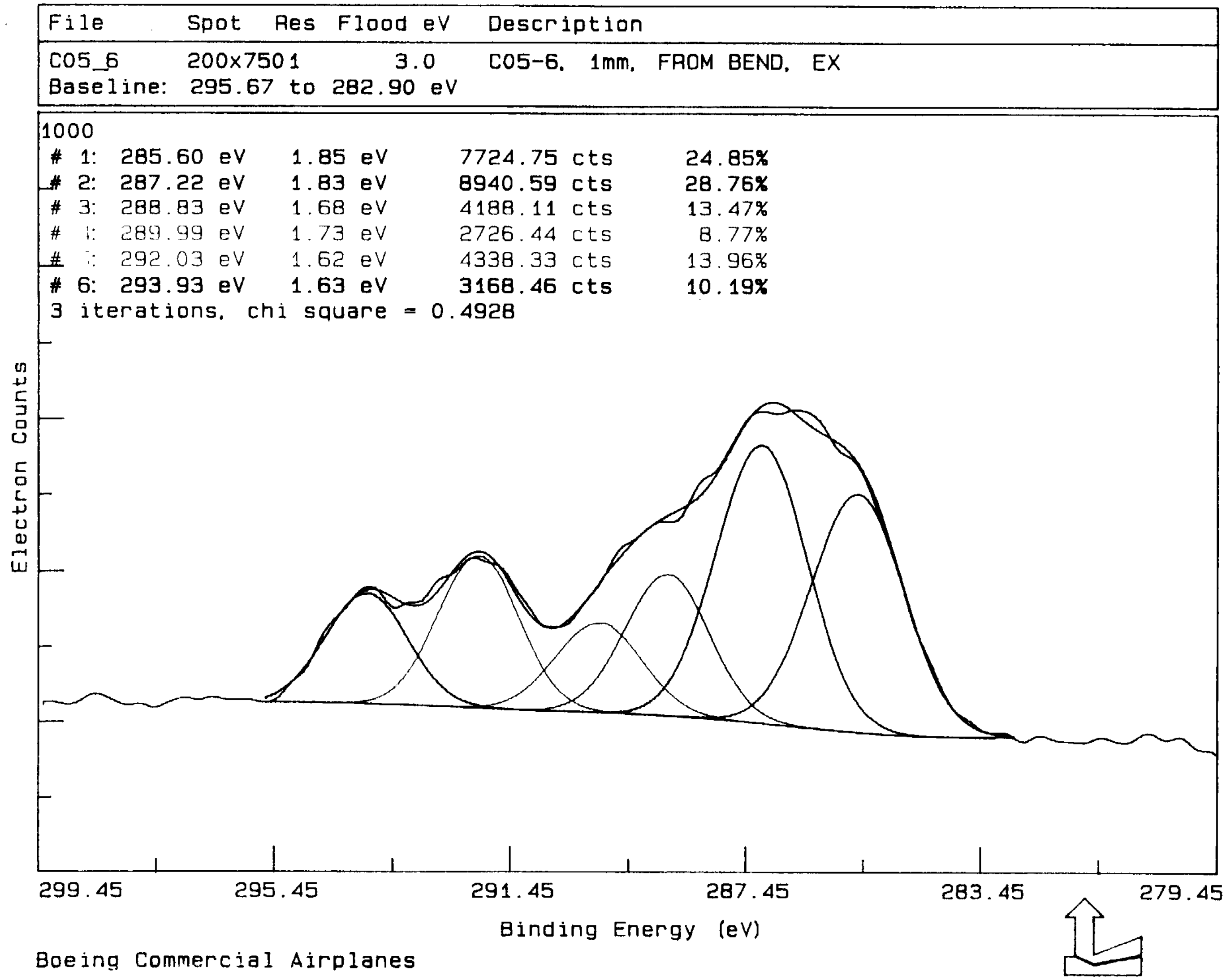


Figure C-95 Carbon 1s spectrum from blanket C5, 1 mm from center of blanket curve, toward exposed region of blanket.

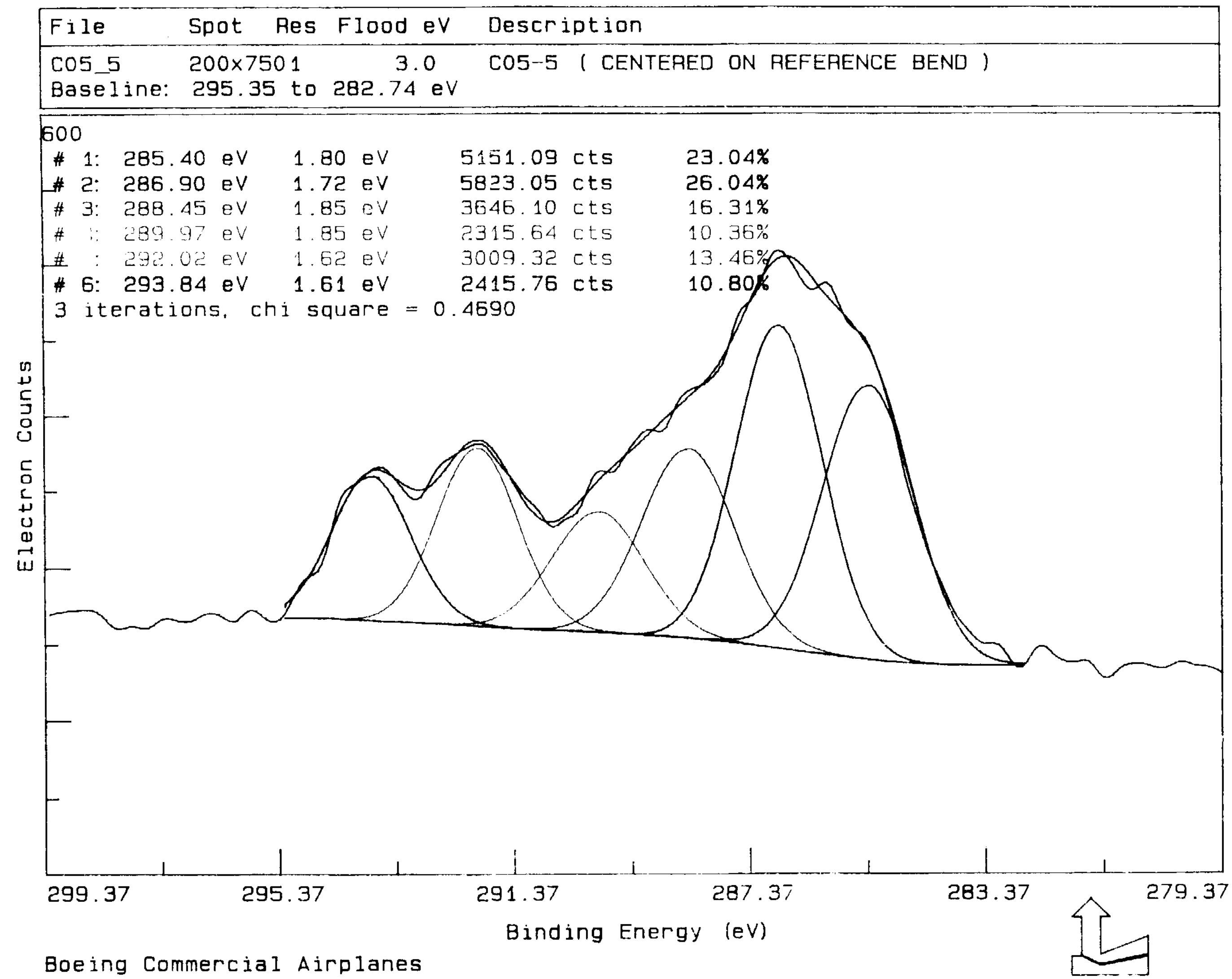


Figure C-96 Carbon 1s spectrum from blanket C5, specimen at center of blanket curve.

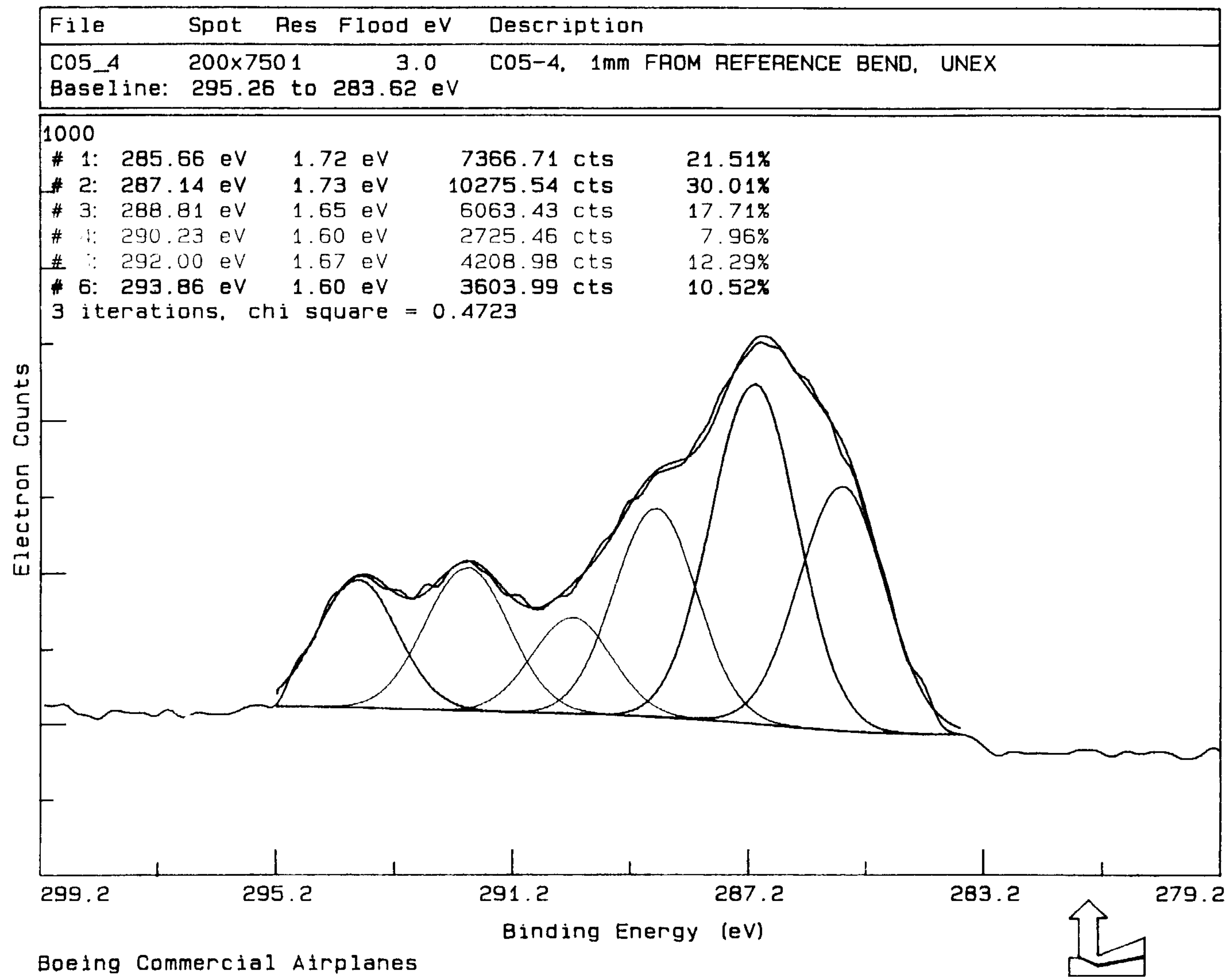


Figure C-97 Carbon 1s spectrum from blanket C5, 1 mm from center of blanket curve, toward unexposed region of blanket.

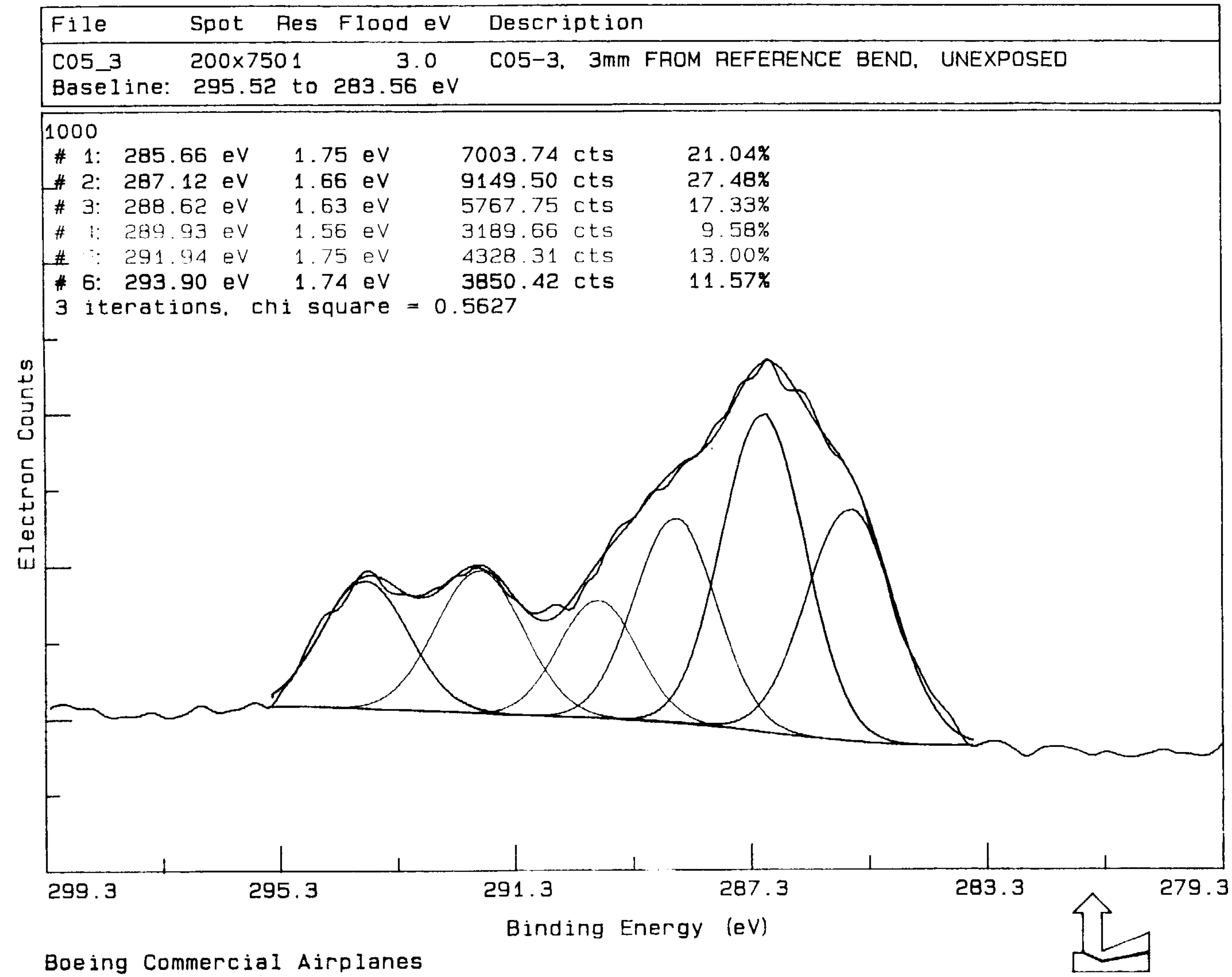


Figure C-98 Carbon 1s spectrum from blanket C5, 3 mm from center of blanket curve, toward unexposed region of blanket.

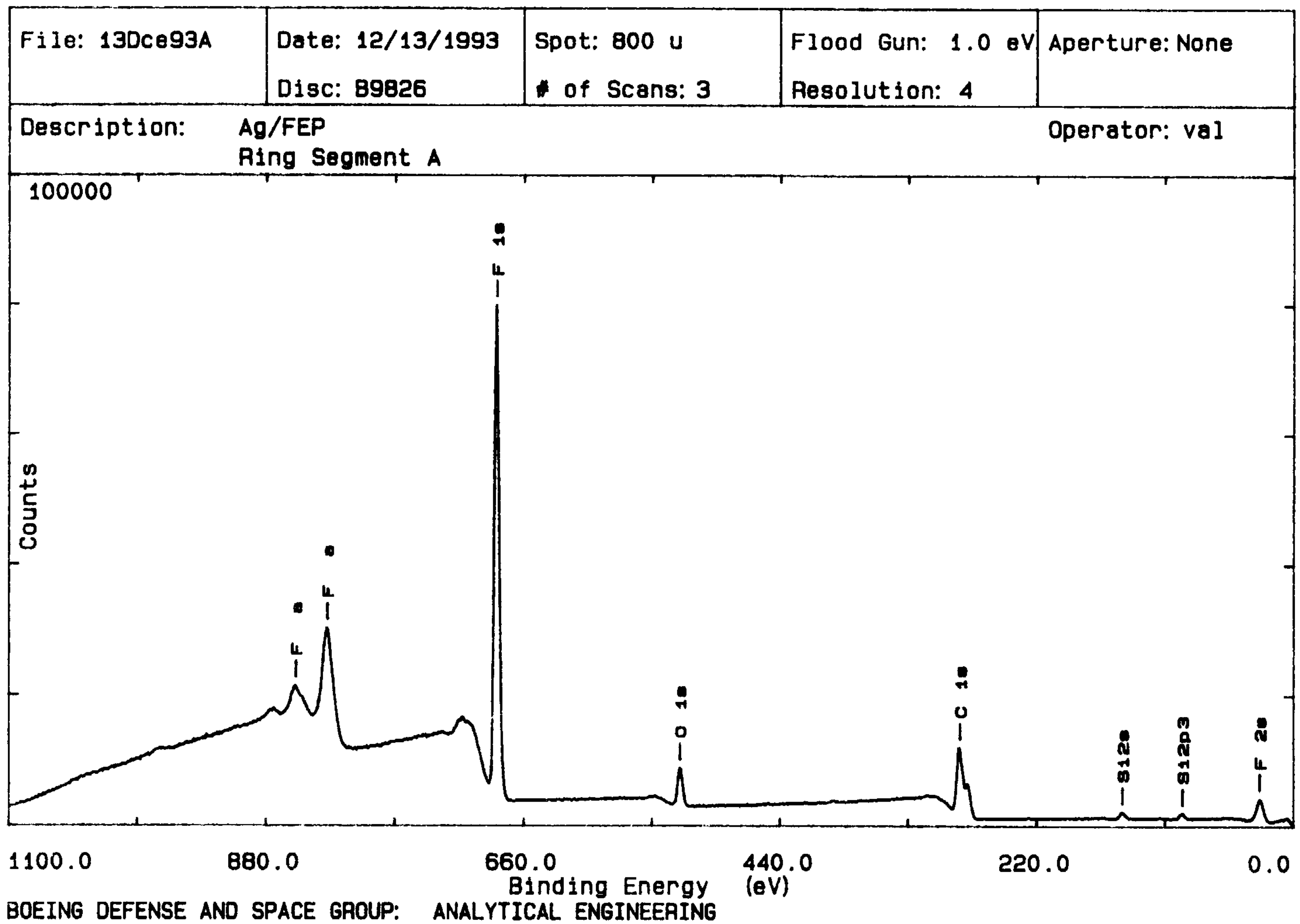


Figure C-99 Survey spectrum for specimen from S1002 experiment canister at location E03.

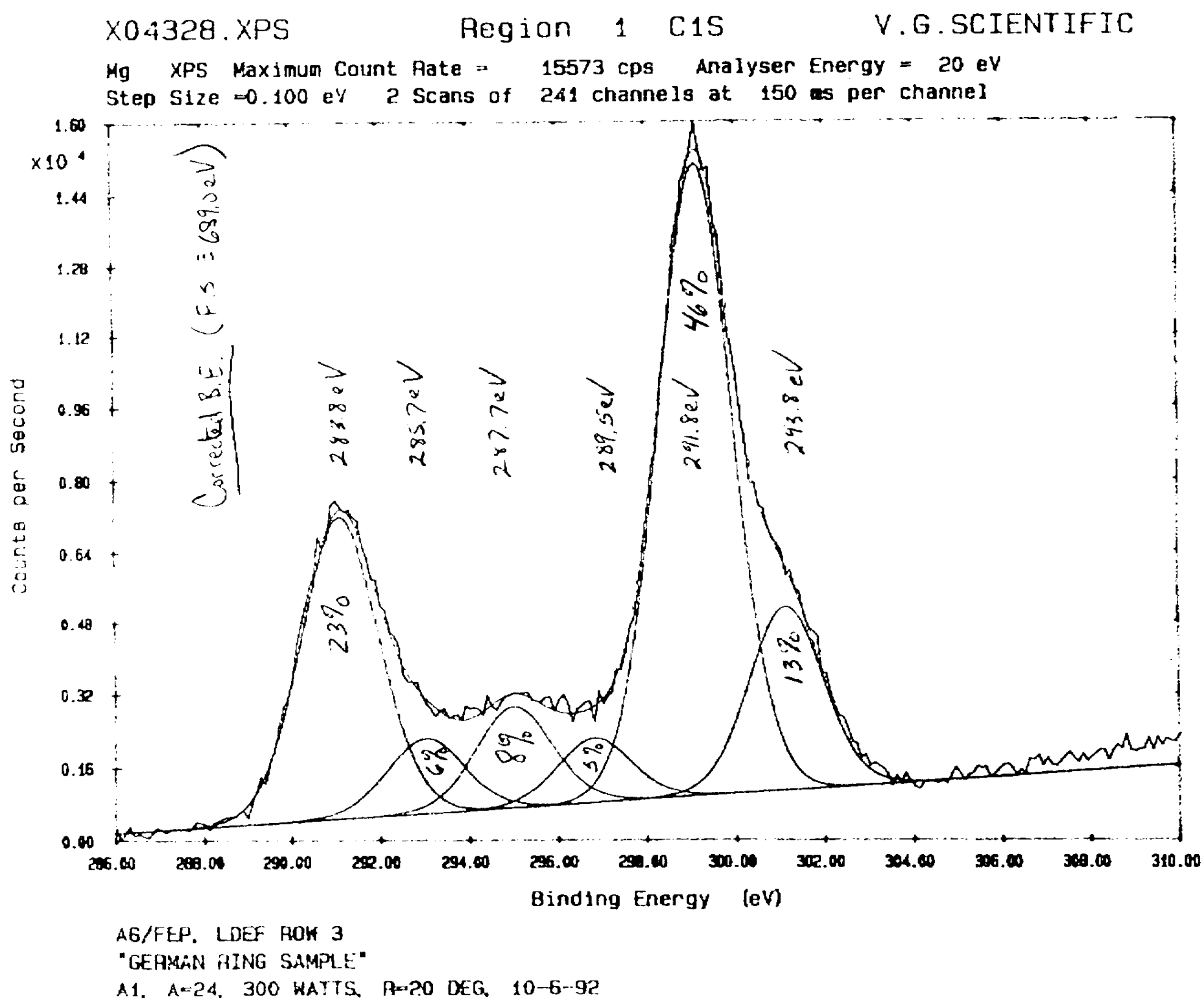


Figure C-100 Carbon 1s spectrum, provided by The Aerospace Corporation, for specimen from S1002 experiment canister at location E3.

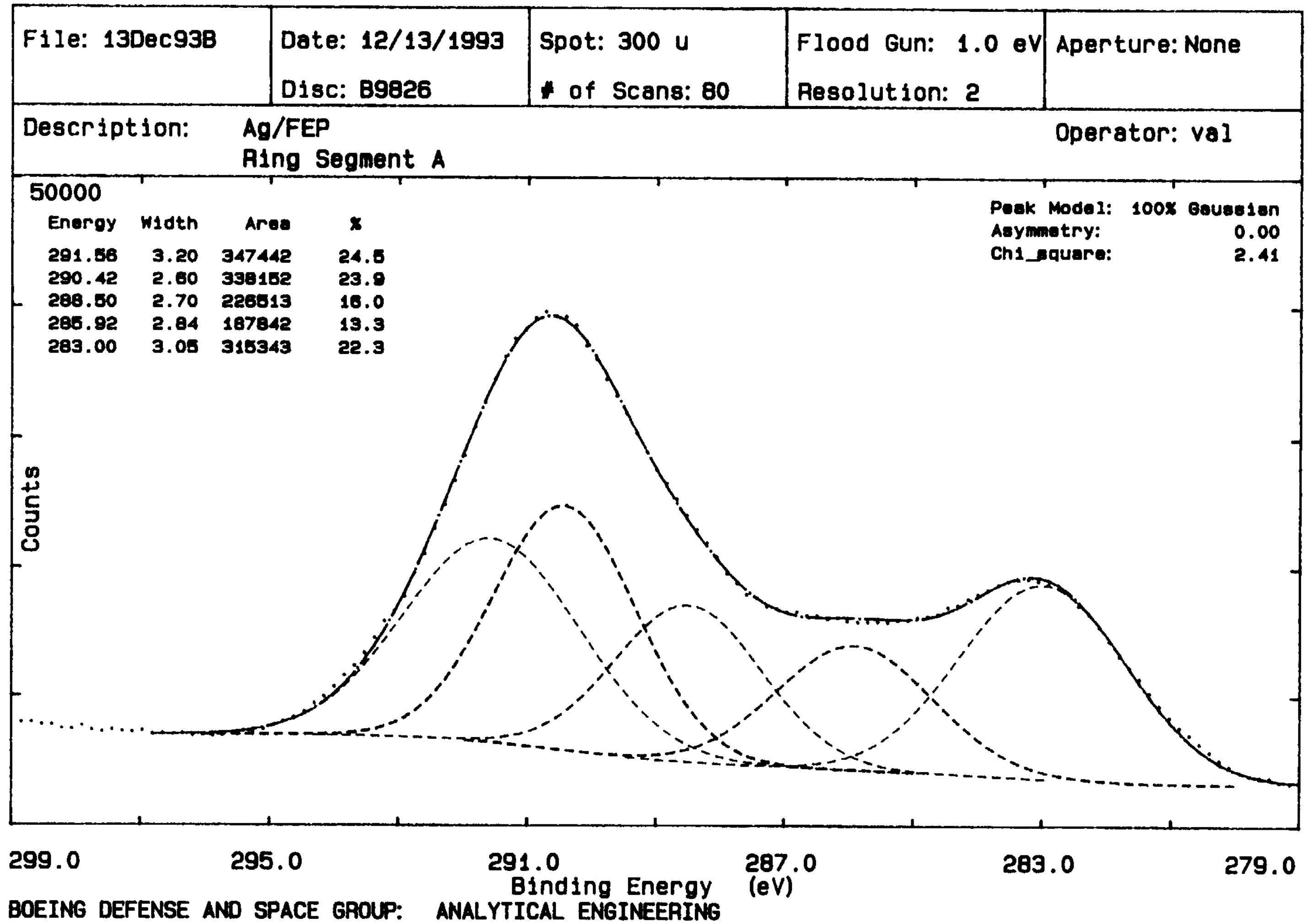


Figure C-101 Carbon 1s spectrum for specimen from S1002 experiment canister at location E3.

SURFACE COMPOSITION TABLE		
Ag/FEP Ring Segment A		
Element	B Energy	Atom %
Si2p3	96.7	3.55
C 1s	287.1	38.29
O 1s	527.8	5.53
F 1s	684.9	52.62
	Total Percent	100.00

Table C-27 Table of surface elemental composition for specimen from S1002 experiment canister at location E3.

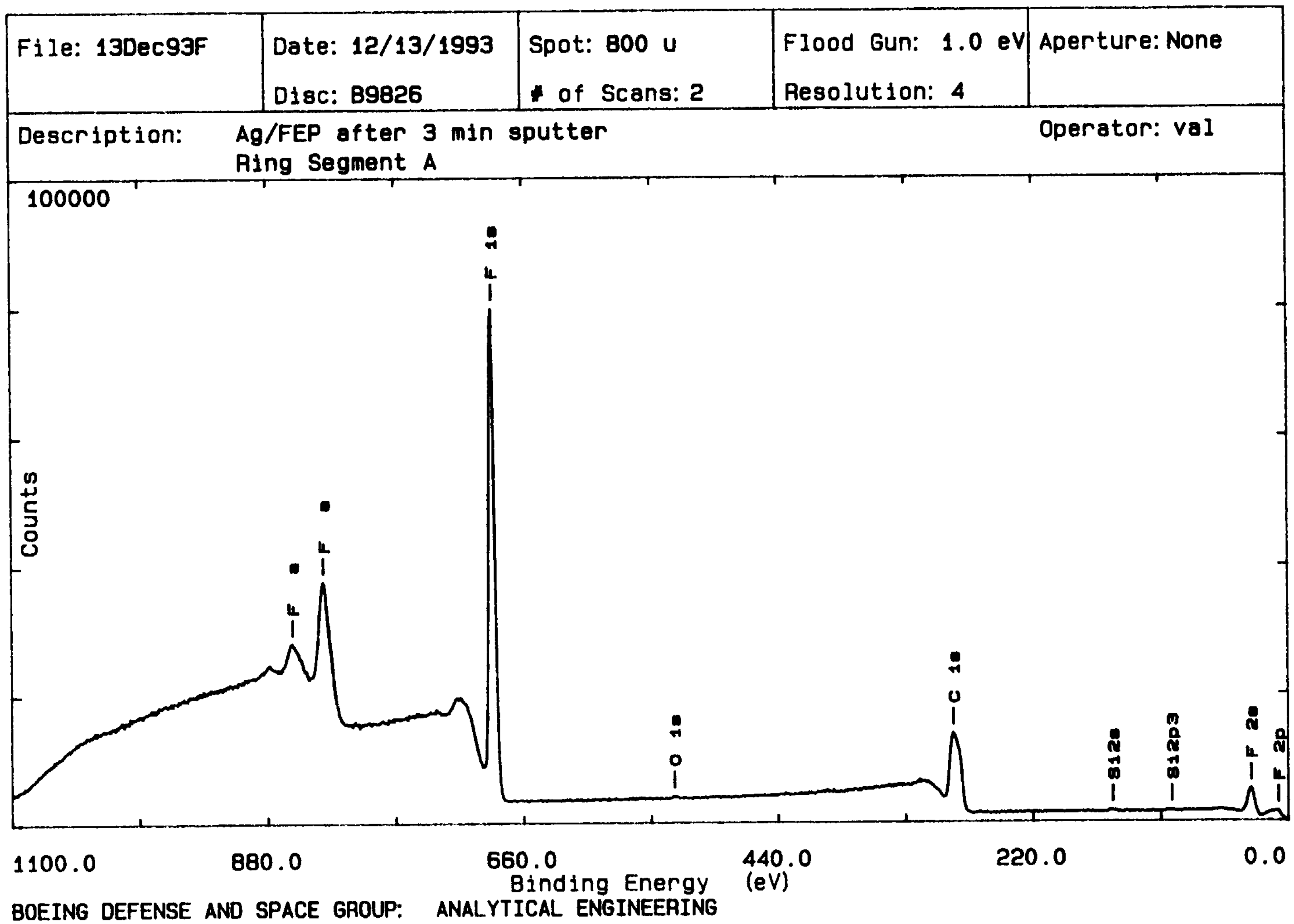


Figure C-102 Survey spectrum for specimen from S1002 experiment canister at location E3 after sputtering for 3 minutes.

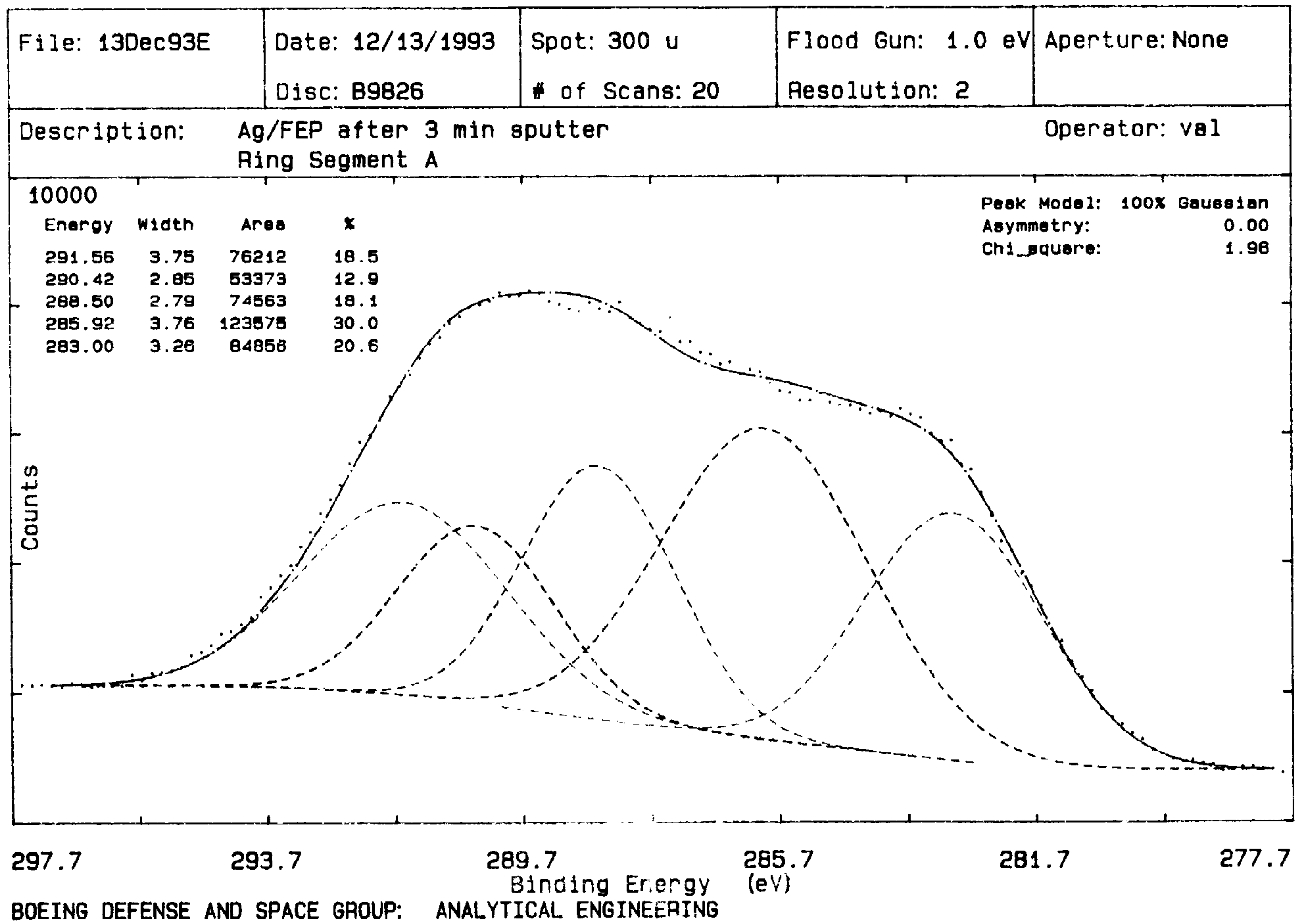


Figure C-103 Carbon 1s spectrum for specimen from S1002 experiment canister at location E3 after sputtering for 3 minutes.

SURFACE COMPOSITION TABLE		
Ag/FEP Ring Segment A 3 min sp		
Element	B Energy	Atom %
Si2p	102.1	.66
C 1s	290.2	46.34
O 1s	532.2	.25
F 1s	688.2	52.76
Total Percent		100.00

Table C-28 Table of surface elemental composition for specimen from S1002 experiment canister at location E3 after sputtering for 3 minutes.

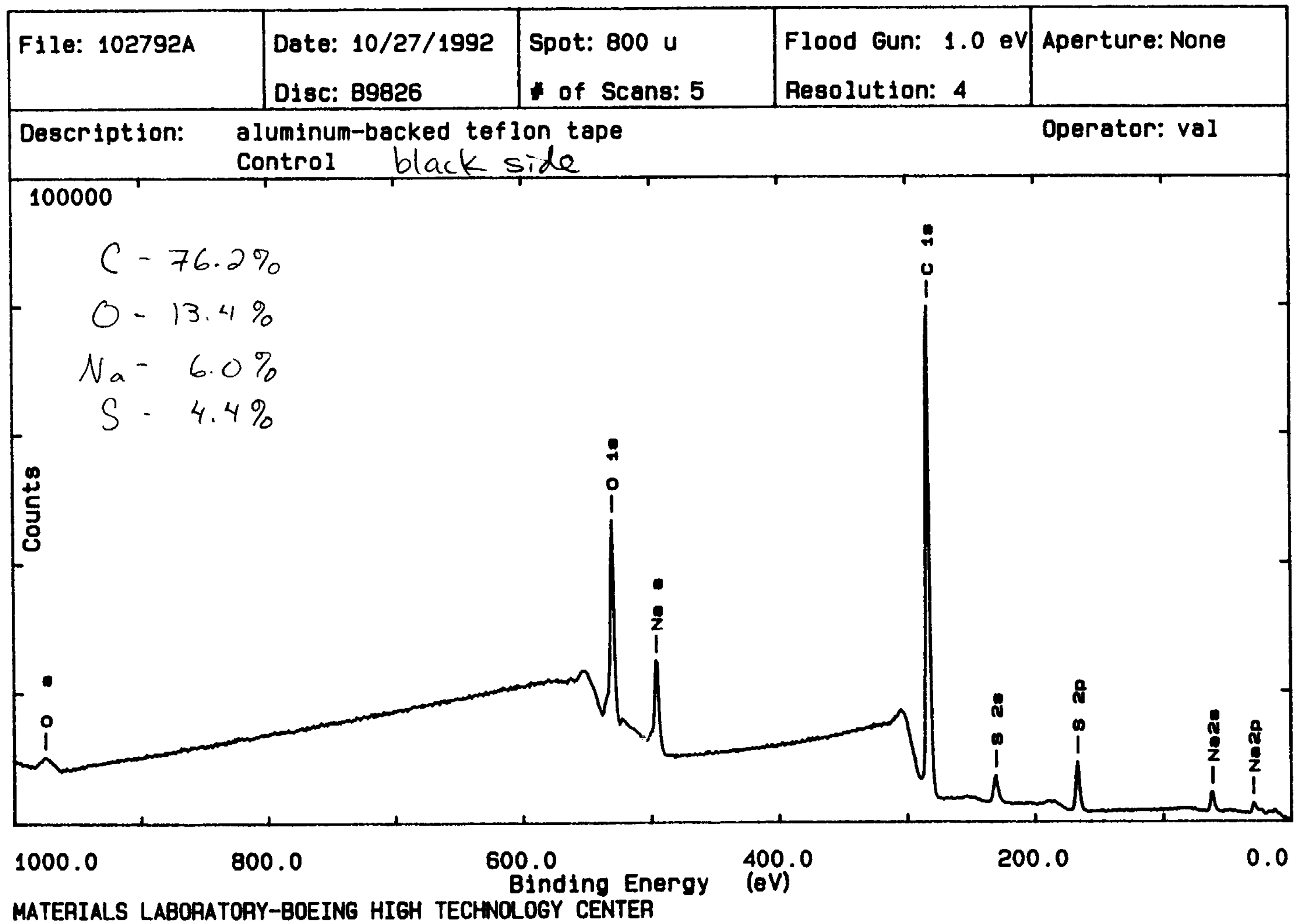


Figure C-104 Survey spectrum of aluminum backed FEP tape control specimen.

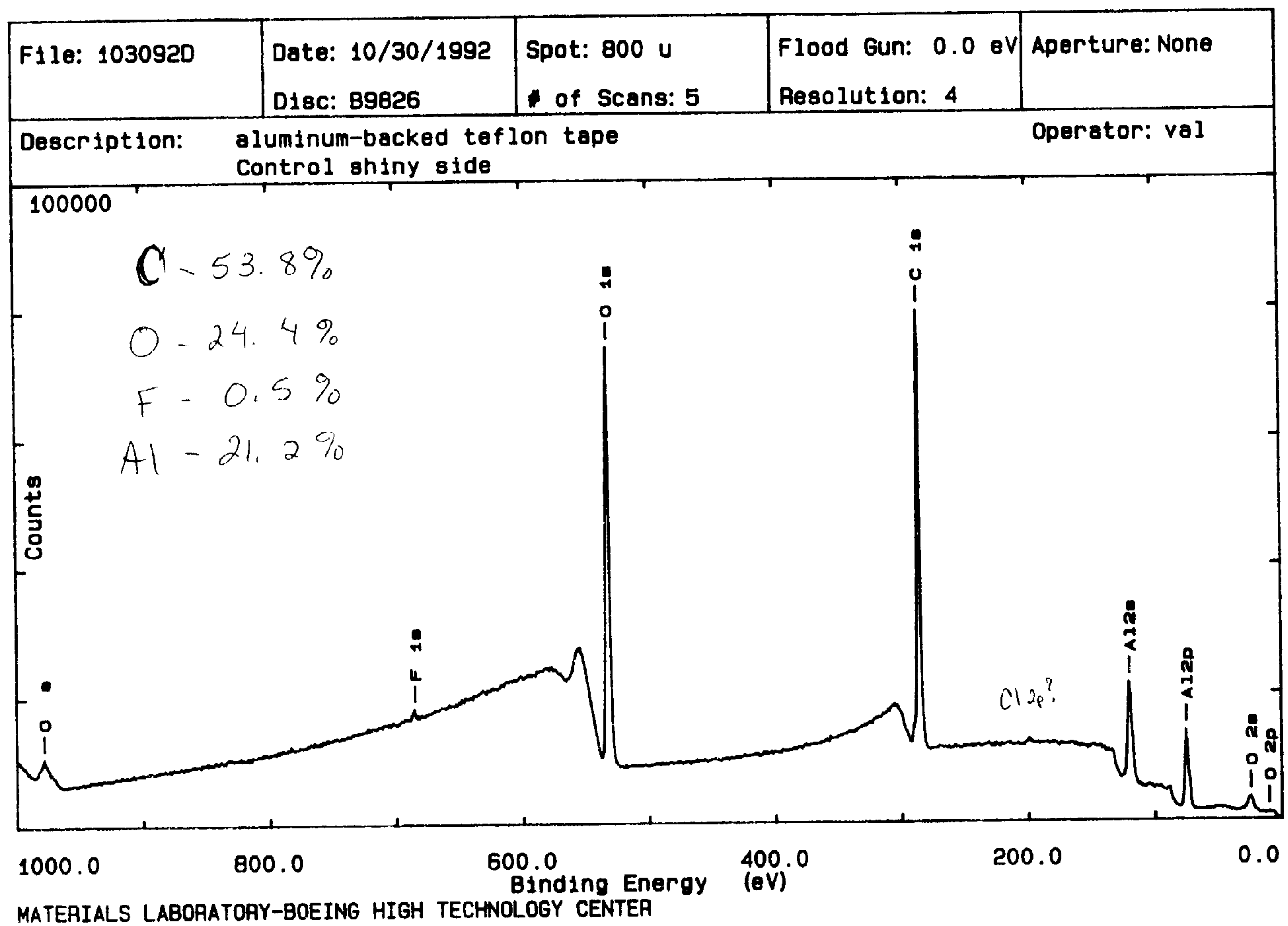


Figure C-105 Survey spectrum of aluminum backed FEP tape control specimen, aluminum side.

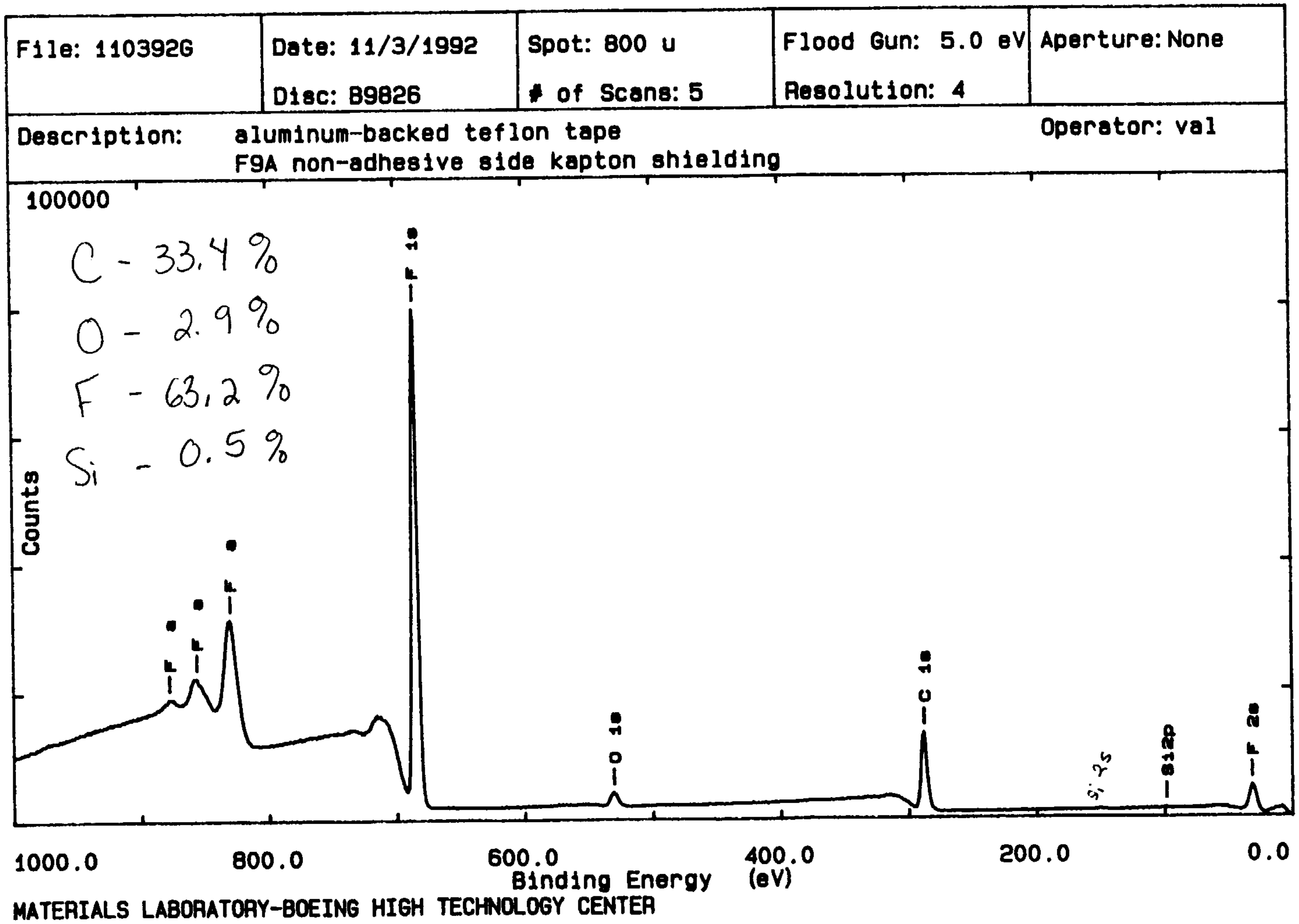


Figure C-106 Survey spectrum of FEP side of aluminum backed FEP tape from location F9, region of specimen A shielded by Kapton.

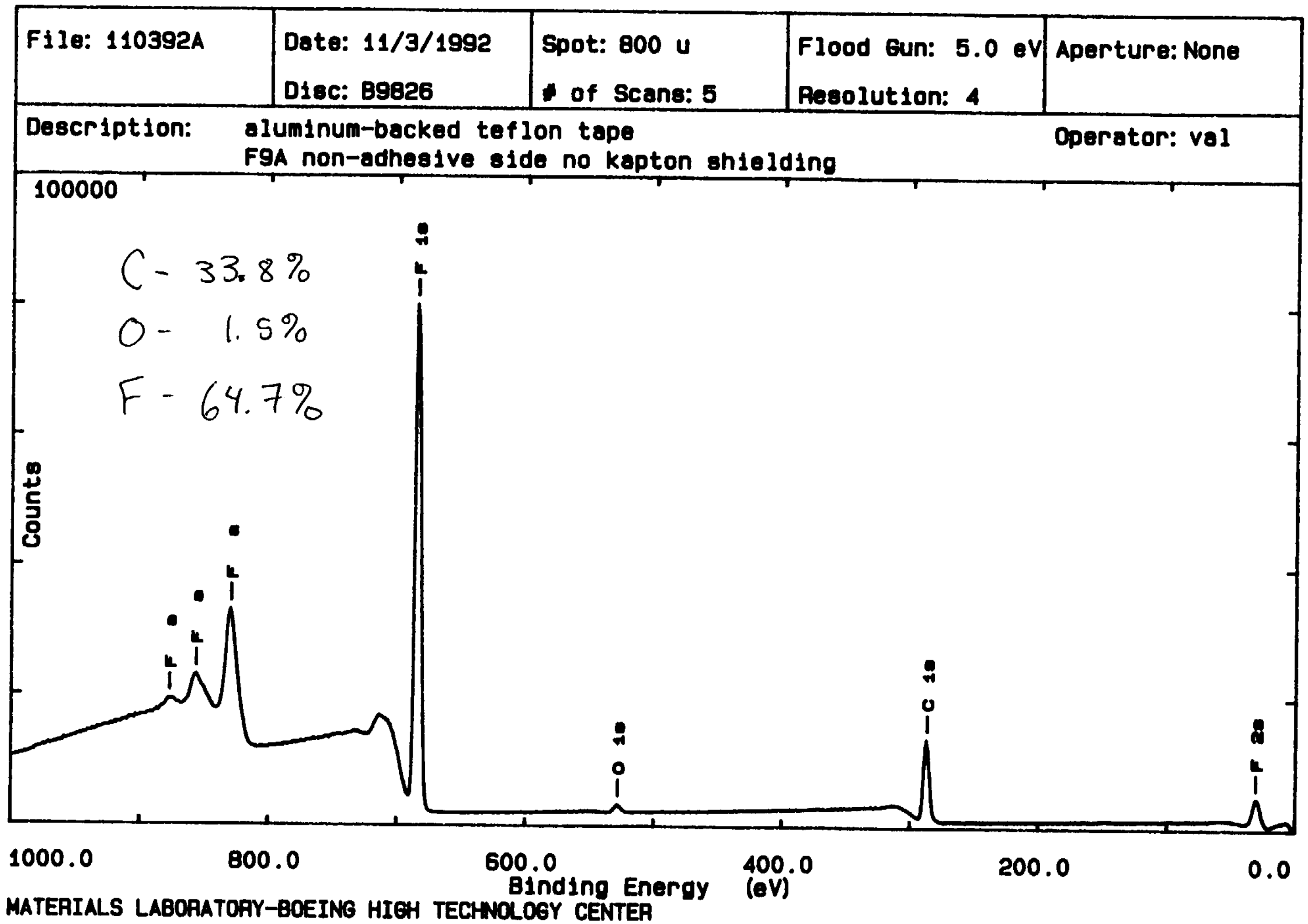


Figure C-107 Survey spectrum of FEP side of aluminum backed FEP tape from location F9, region of specimen A not shielded by Kapton.

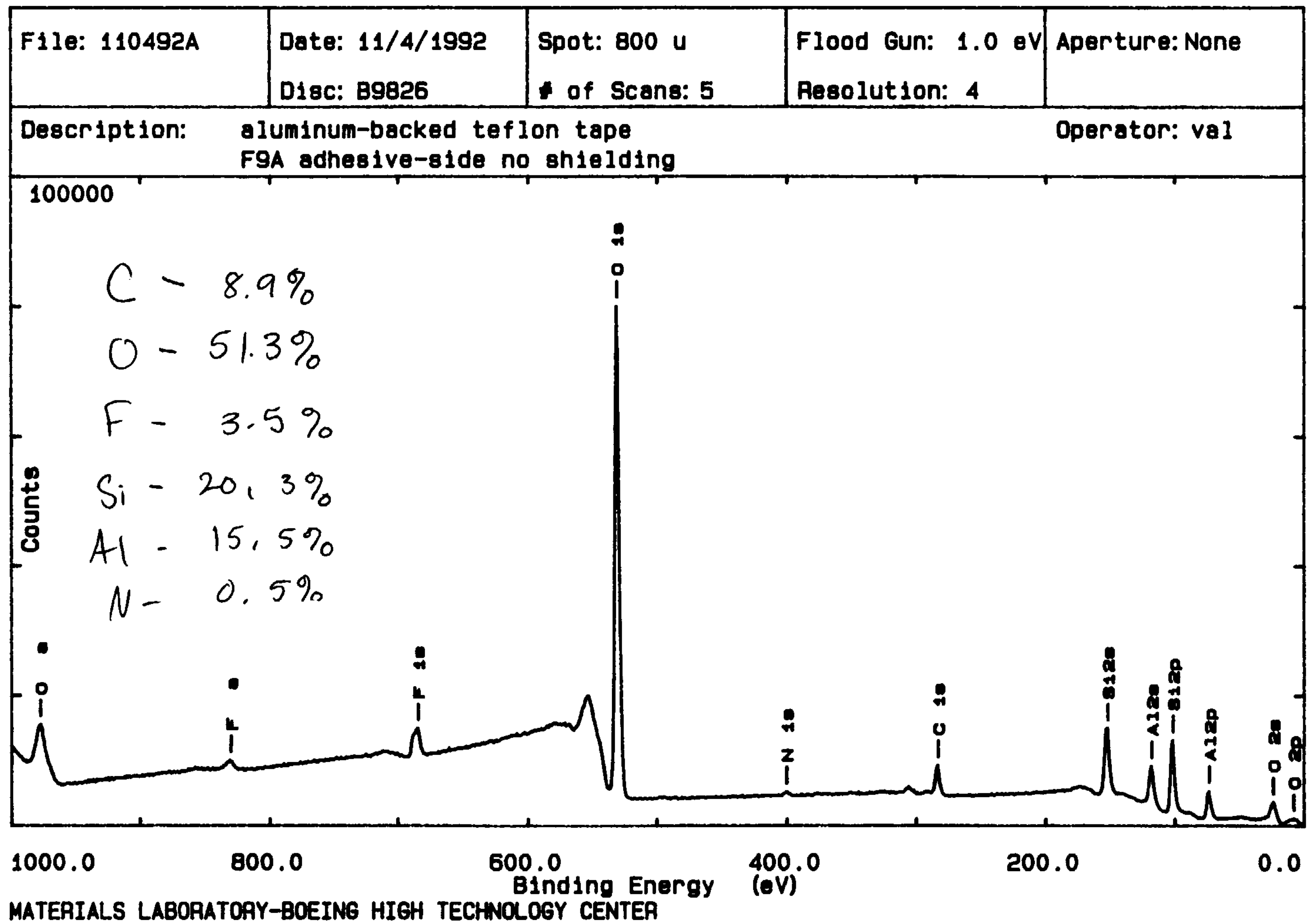


Figure C-108 Survey spectrum of aluminum side of aluminum backed FEP tape from location F9, region of specimen A not shielded by Kapton.

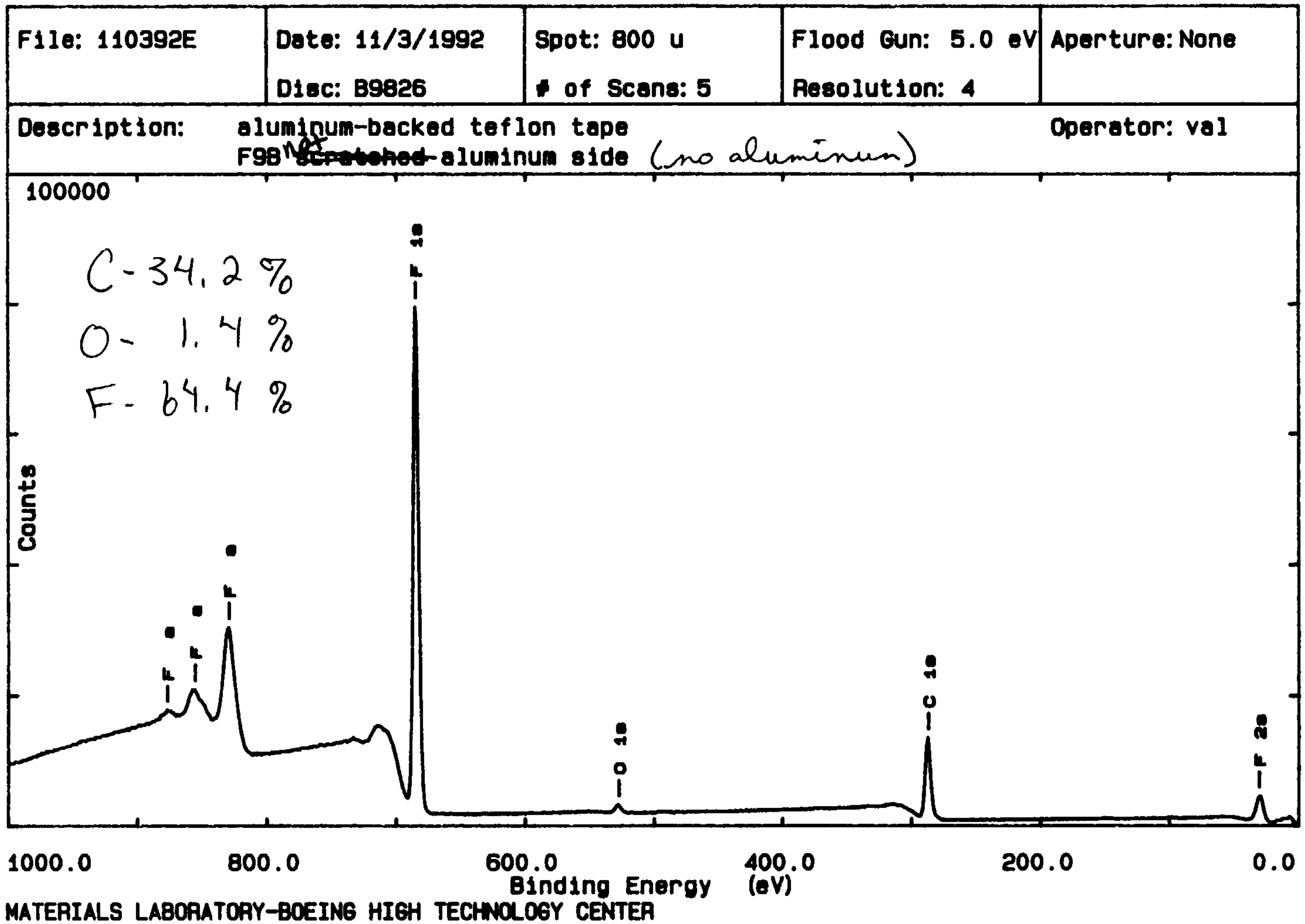


Figure C-109 Survey spectrum of FEP side of aluminum backed FEP tape from location F9, region of specimen B not shielded by Kapton.

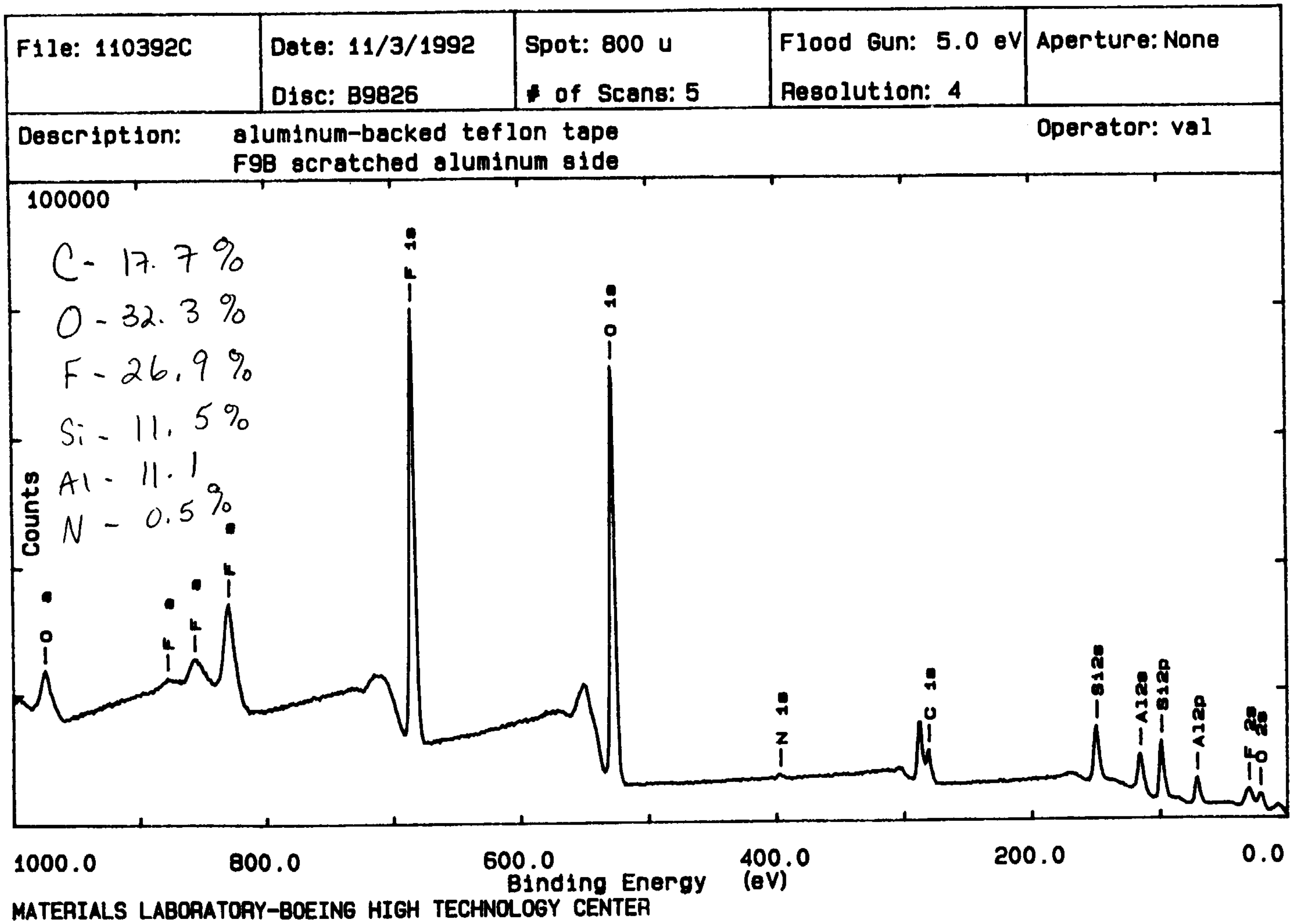


Figure C-110 Survey spectrum of aluminum side of aluminum backed FEP tape from location F9, region of specimen B not shielded by Kapton.

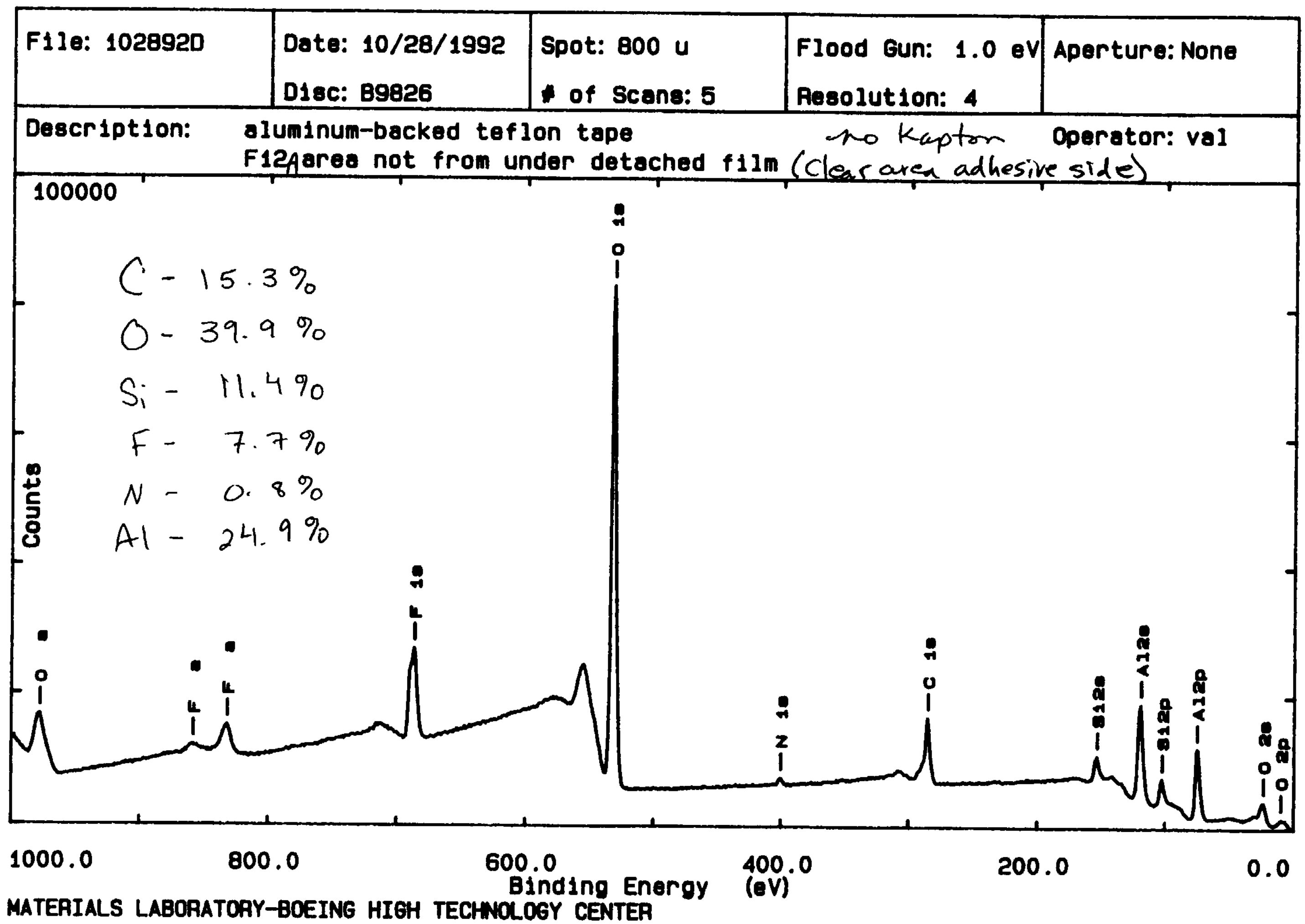


Figure C-111 Survey spectrum of FEP side of aluminum backed FEP tape from location F12, region of specimen A not shielded by Kapton.

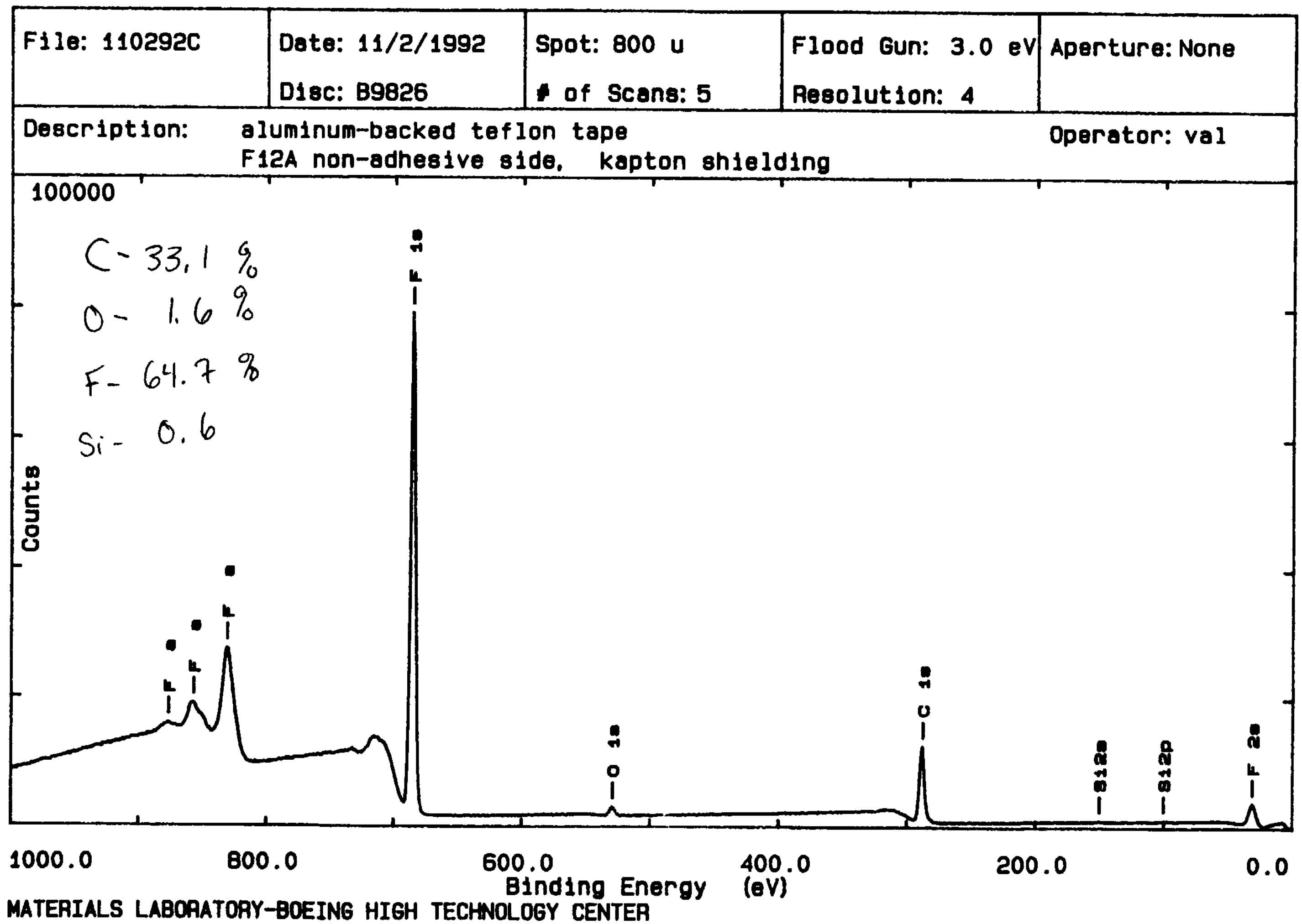


Figure C-112 Survey spectrum of FEP side of aluminum backed FEP tape from location F12, region of specimen A shielded by Kapton.

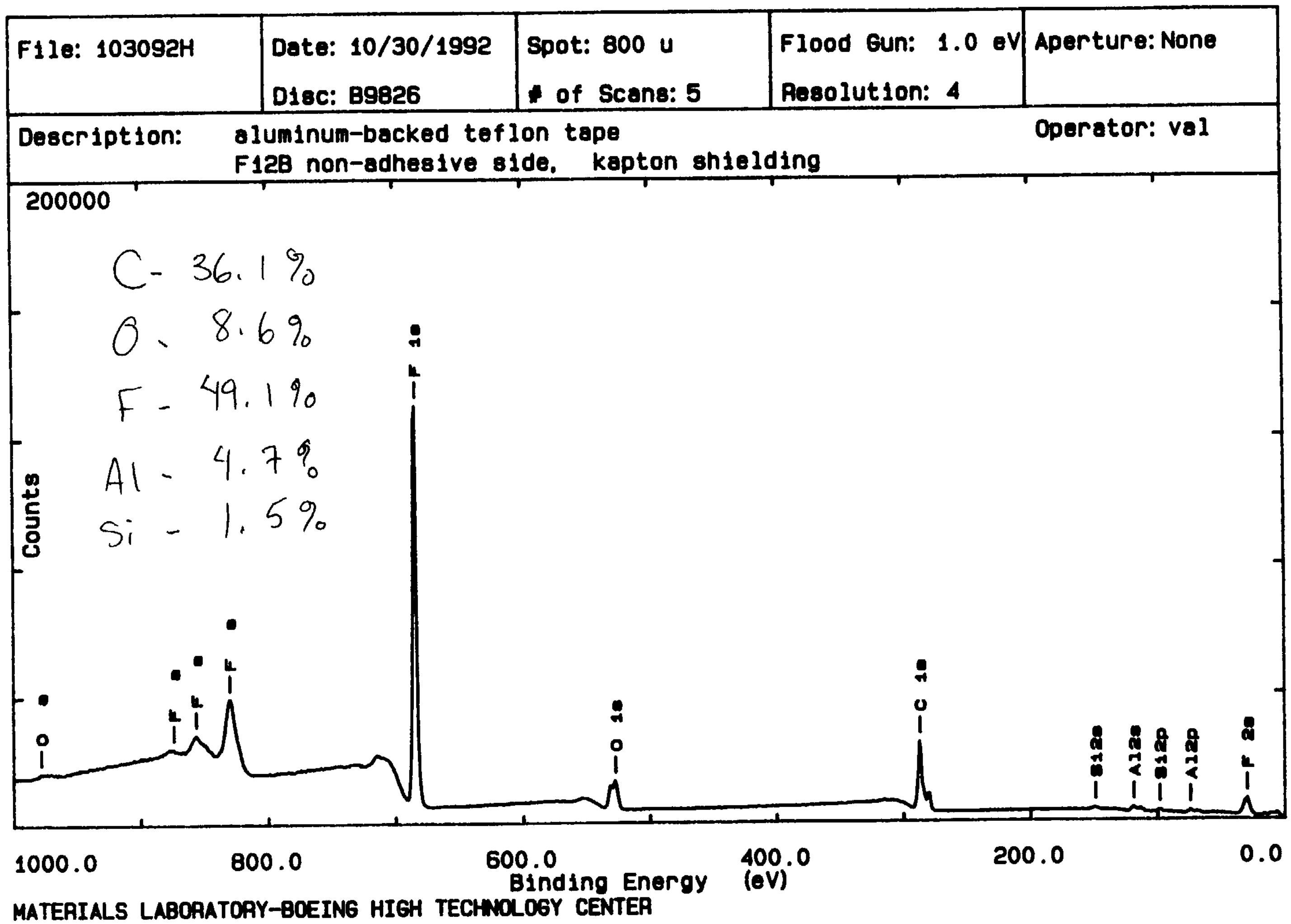


Figure C-113 Survey spectrum of aluminum side of aluminum backed FEP tape from location F12, region of specimen B shielded by Kapton.

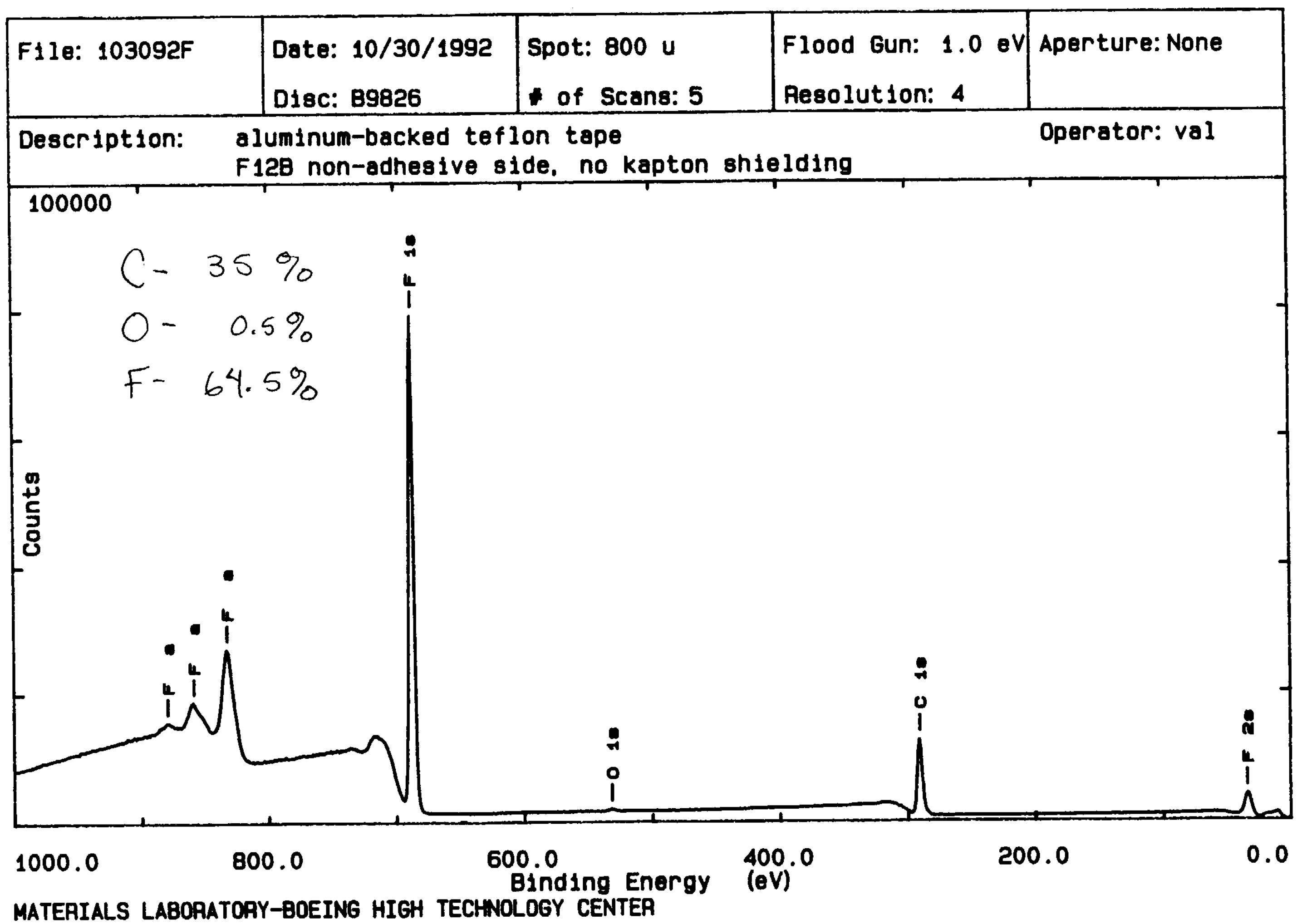


Figure C-114 Survey spectrum of aluminum side of aluminum backed FEP tape from location F12, region of specimen B not shielded by Kapton.

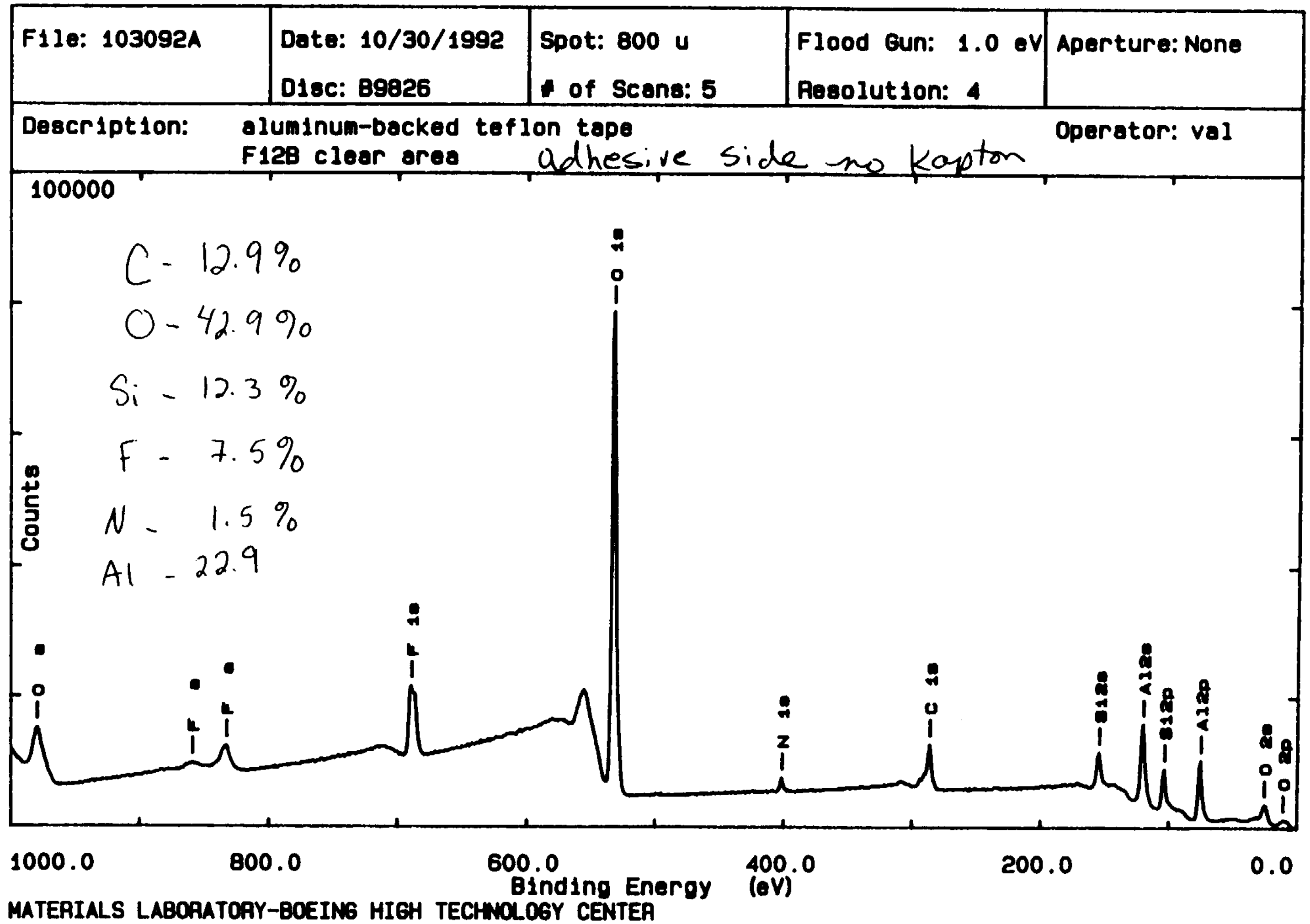


Figure C-115 Survey spectrum of FEP side of aluminum backed FEP tape from location F12, region of specimen B not shielded by Kapton.

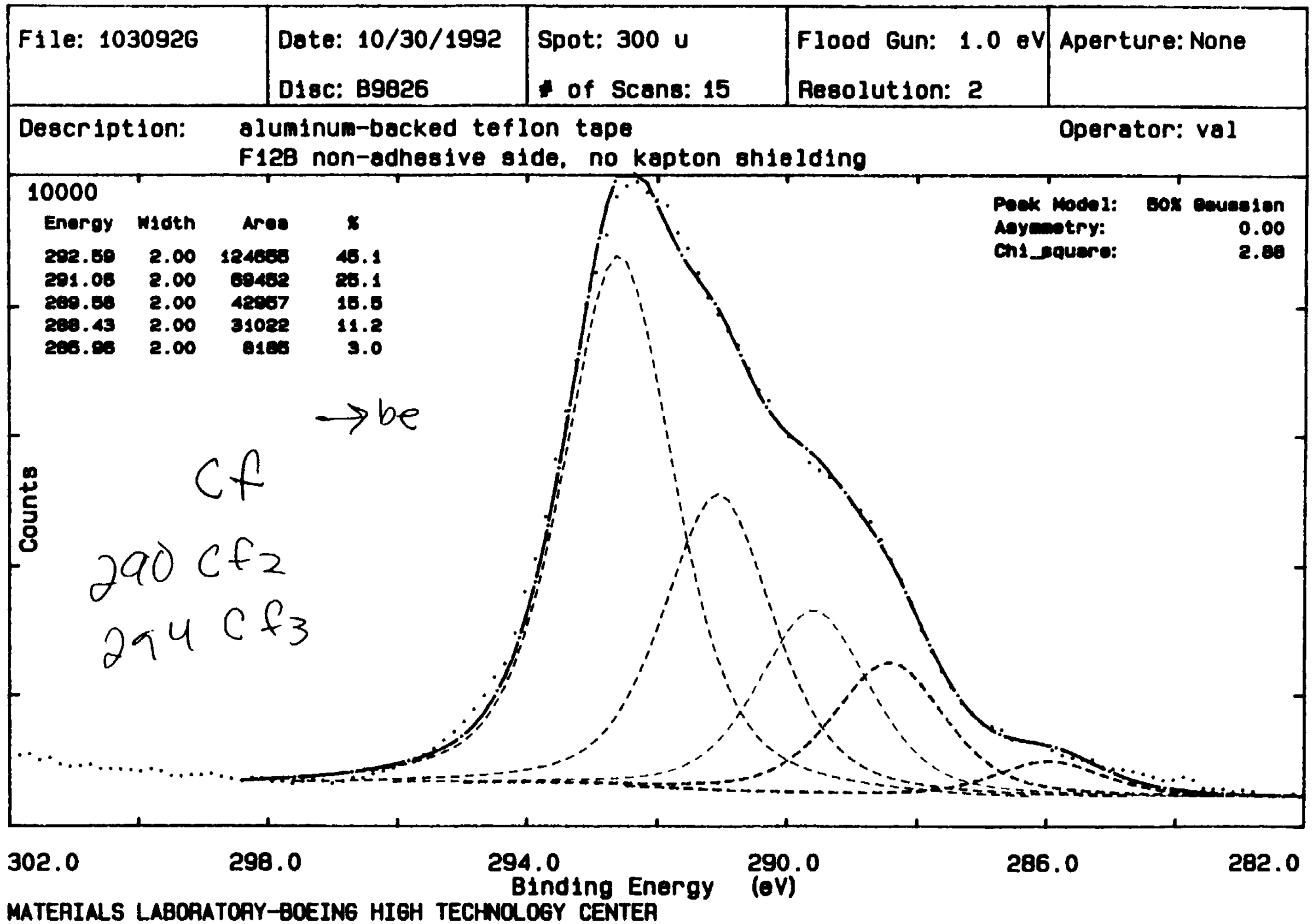


Figure C-116 Carbon 1s spectrum of FEP side of aluminum backed FEP tape from location F12, region of specimen B not shielded by Kapton.

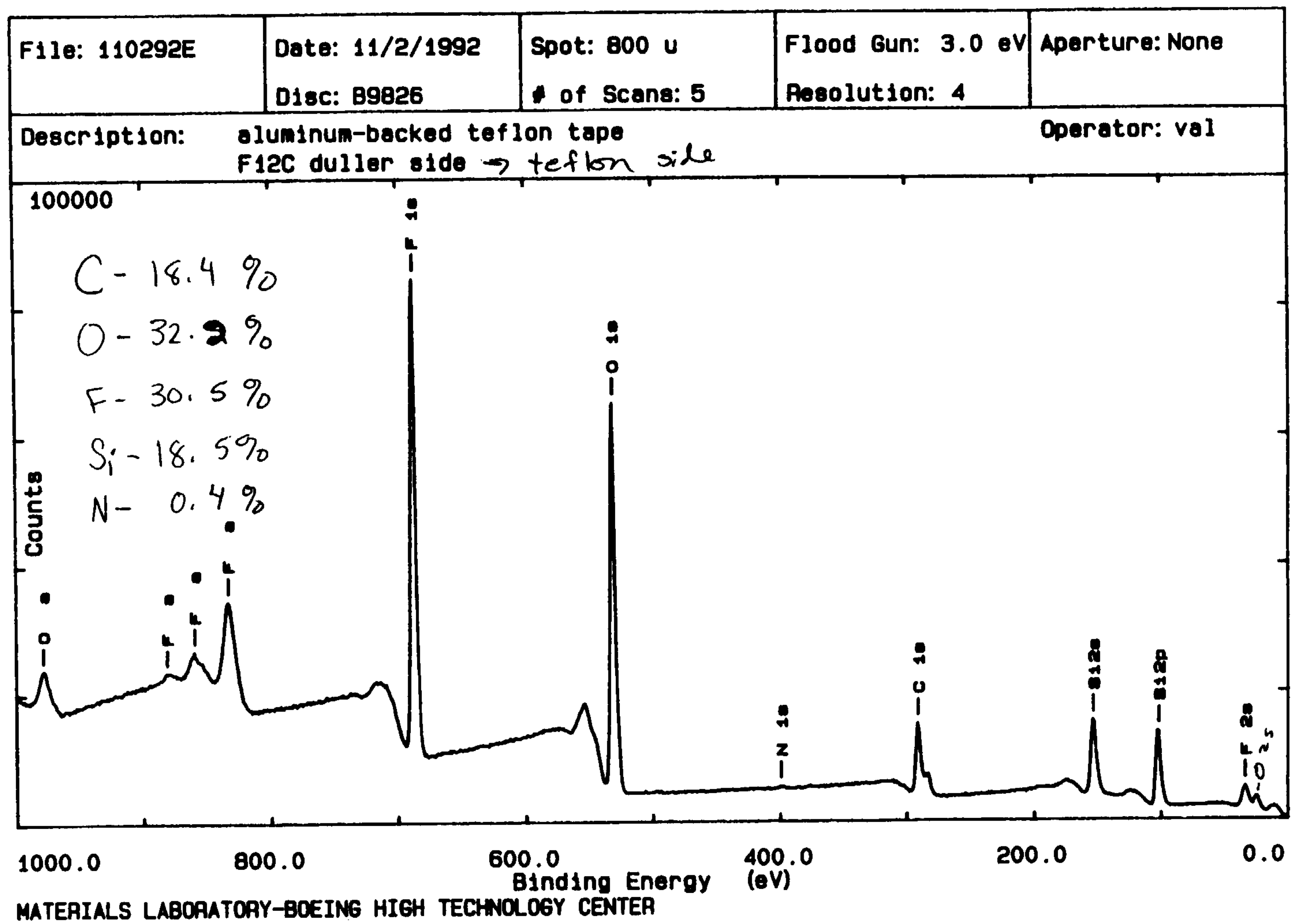


Figure C-117 Survey spectrum of aluminum side of aluminum backed FEP tape from location F12, region of specimen C not shielded by Kapton.

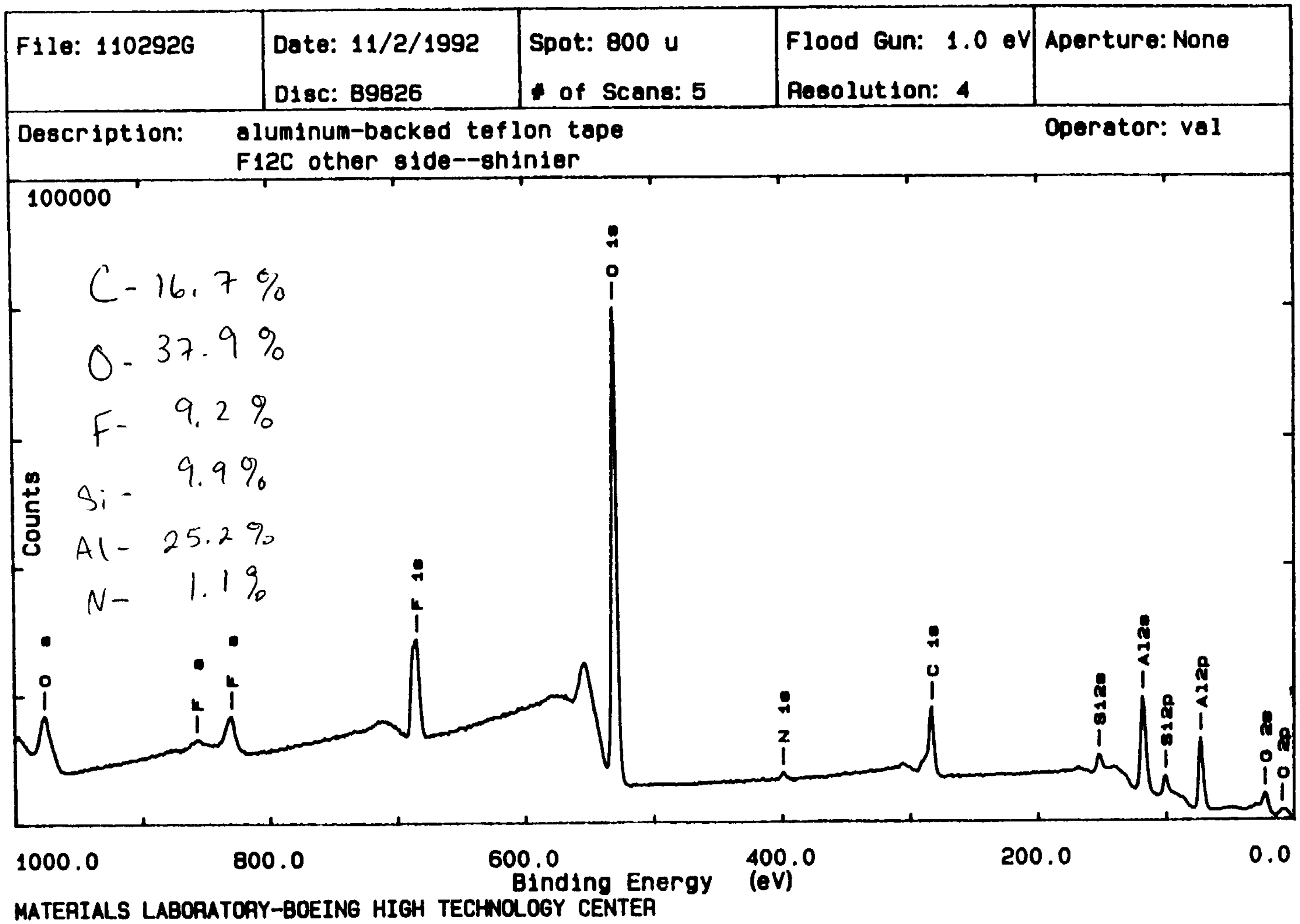


Figure C-118 Survey spectrum of FEP side of aluminum backed FEP tape from location F12, region of specimen C not shielded by Kapton.

APPENDIX D

Spectral Measurements of Ag/FEP Blankets From LDEF

This appendix contains the spectra from surface/chemical analysis of the FEP. Fourier transform infrared, Raman, UV-Vis-IR diffuse reflectance, attenuated total reflectance, IR diffuse reflectance, and secondary ion mass spectra survey results are included.

List of Figures for Appendix D

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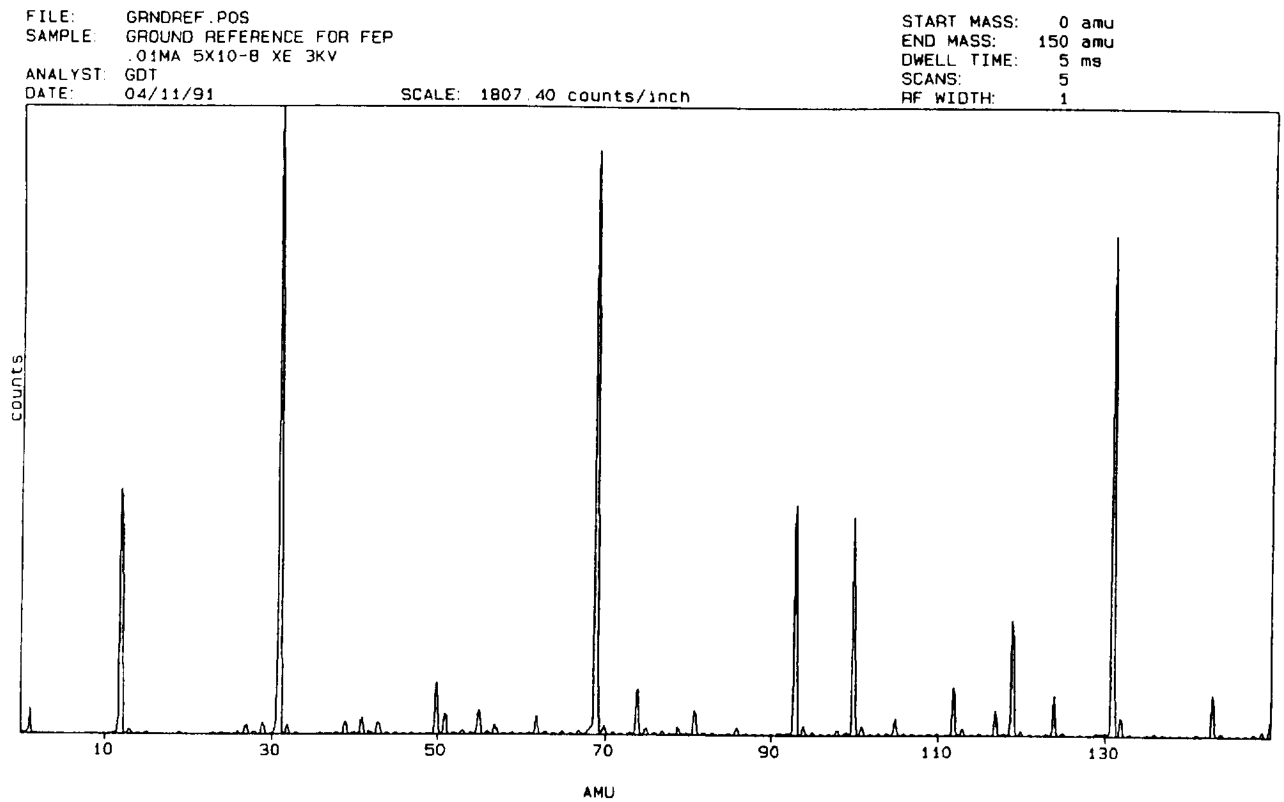


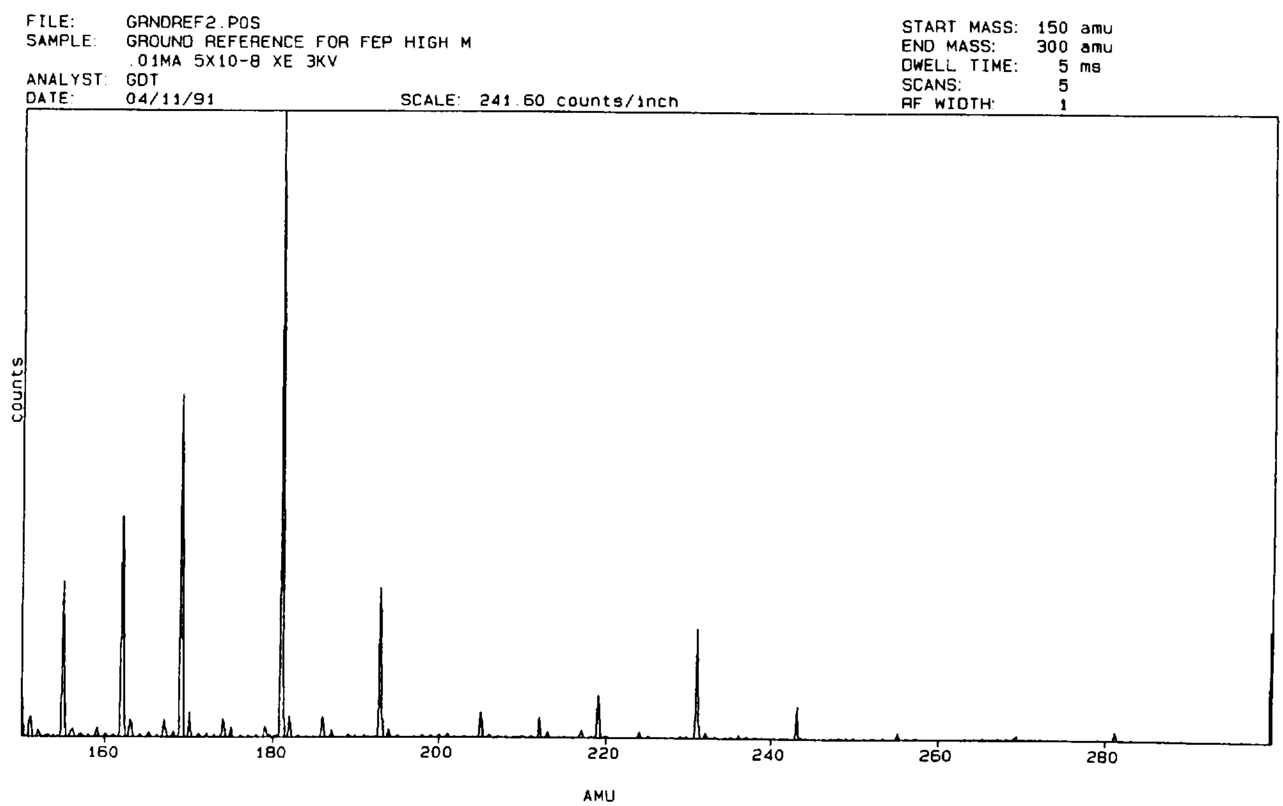
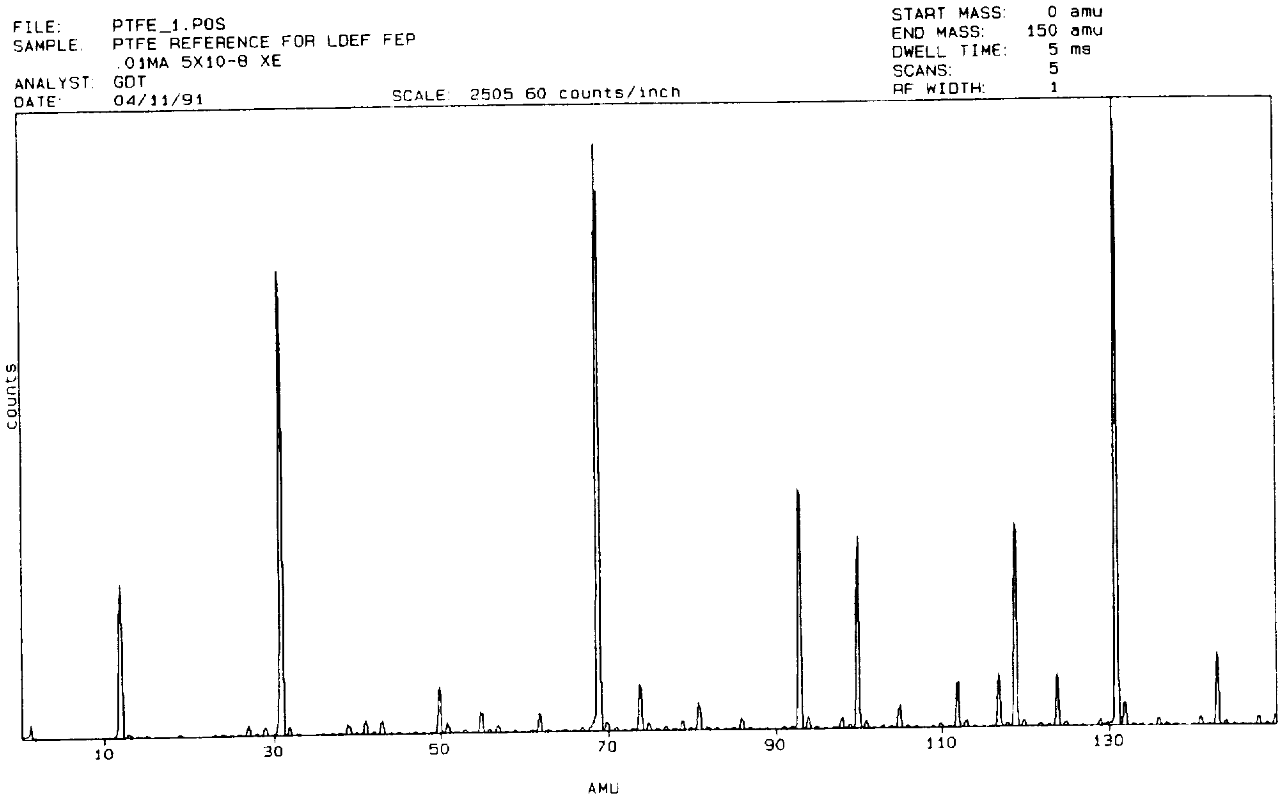


Figure D-1. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Ground Control Specimen.



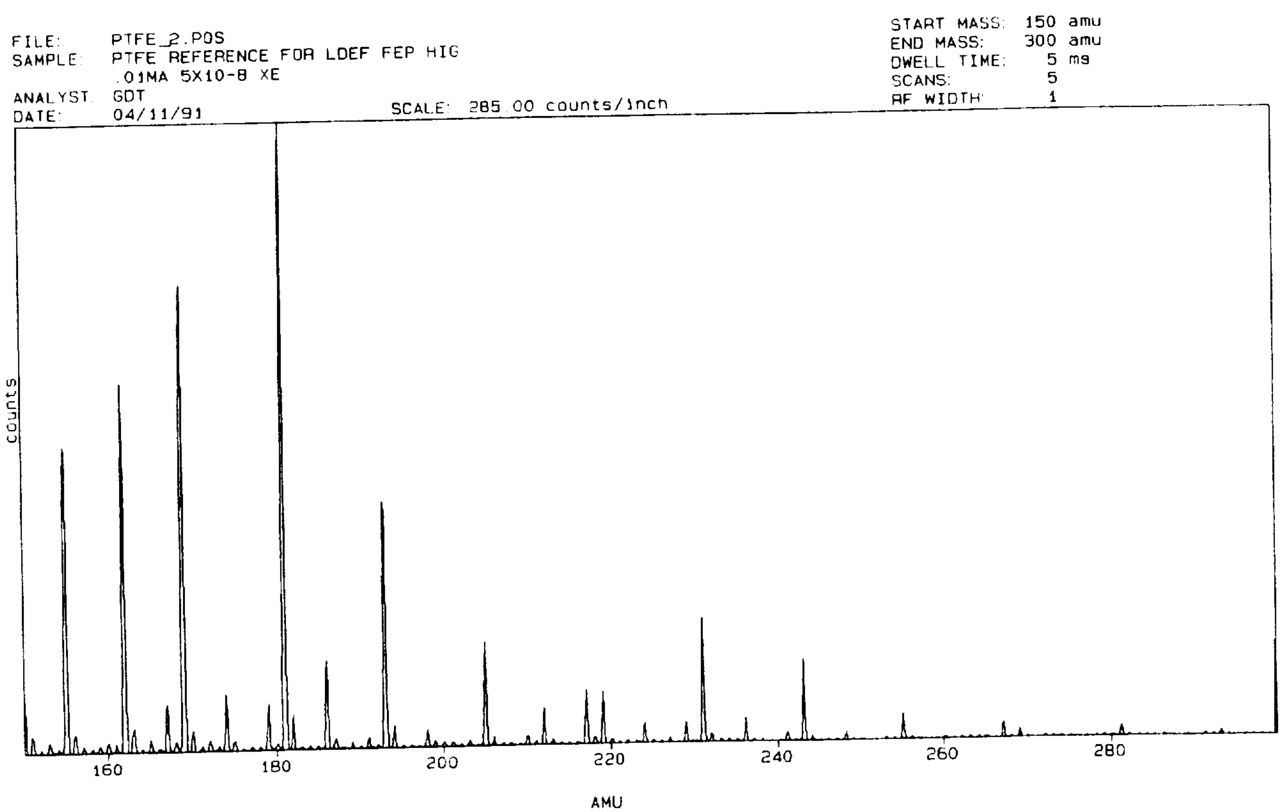


Figure D-2. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For PTFE Reference Comparison.

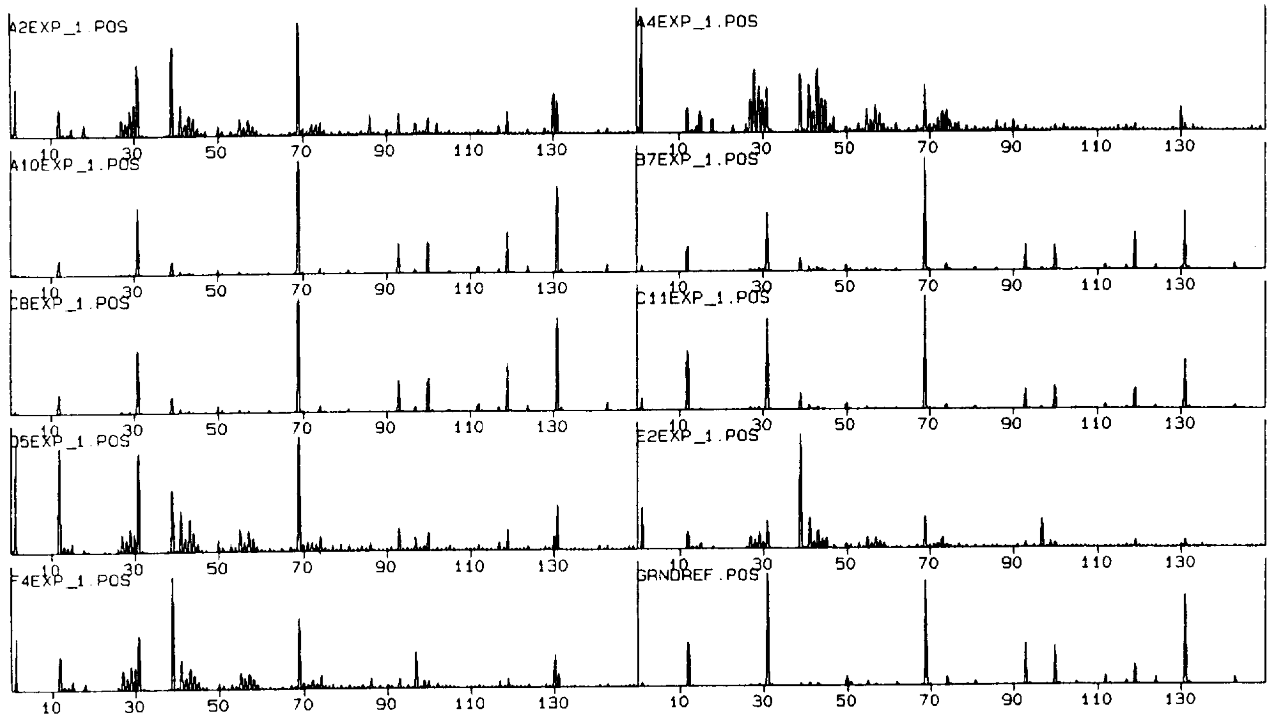
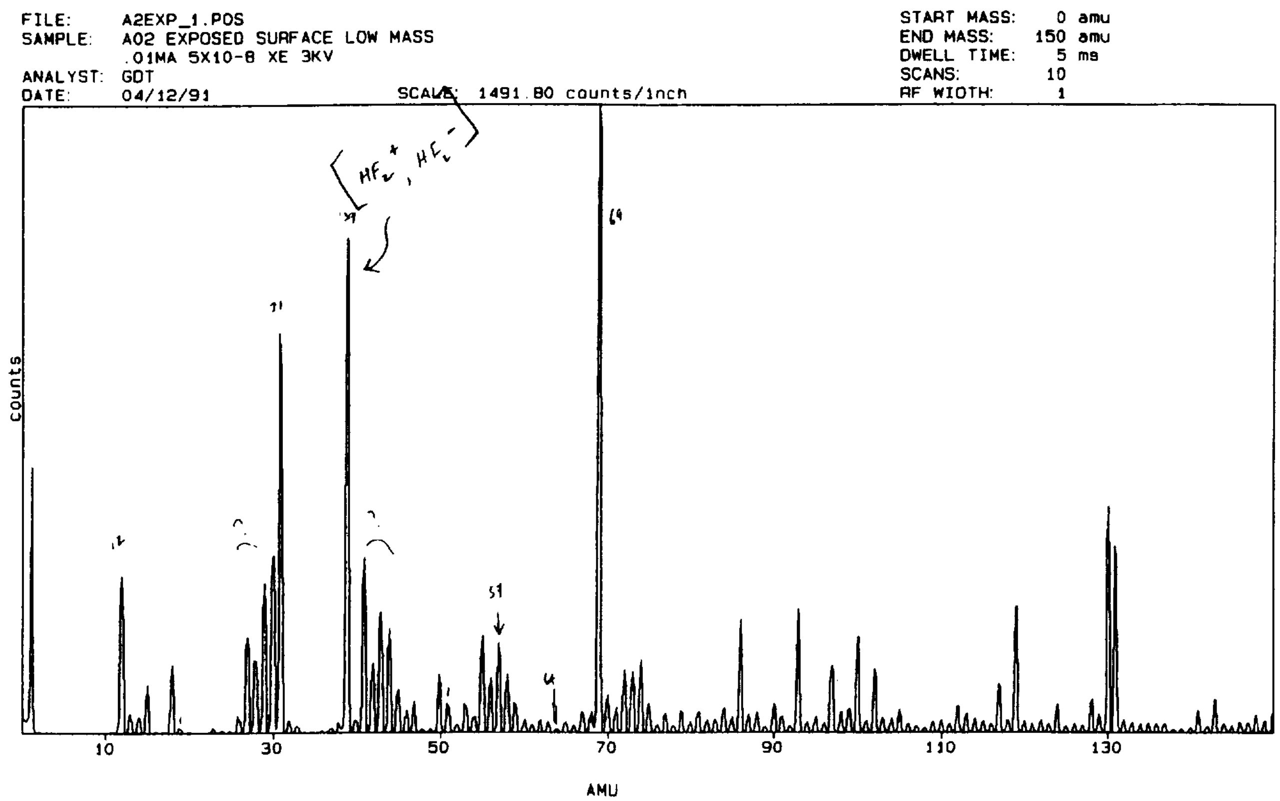


Figure D-3. Secondary Ion Mass Spectra For Selected LDEF Specimens.



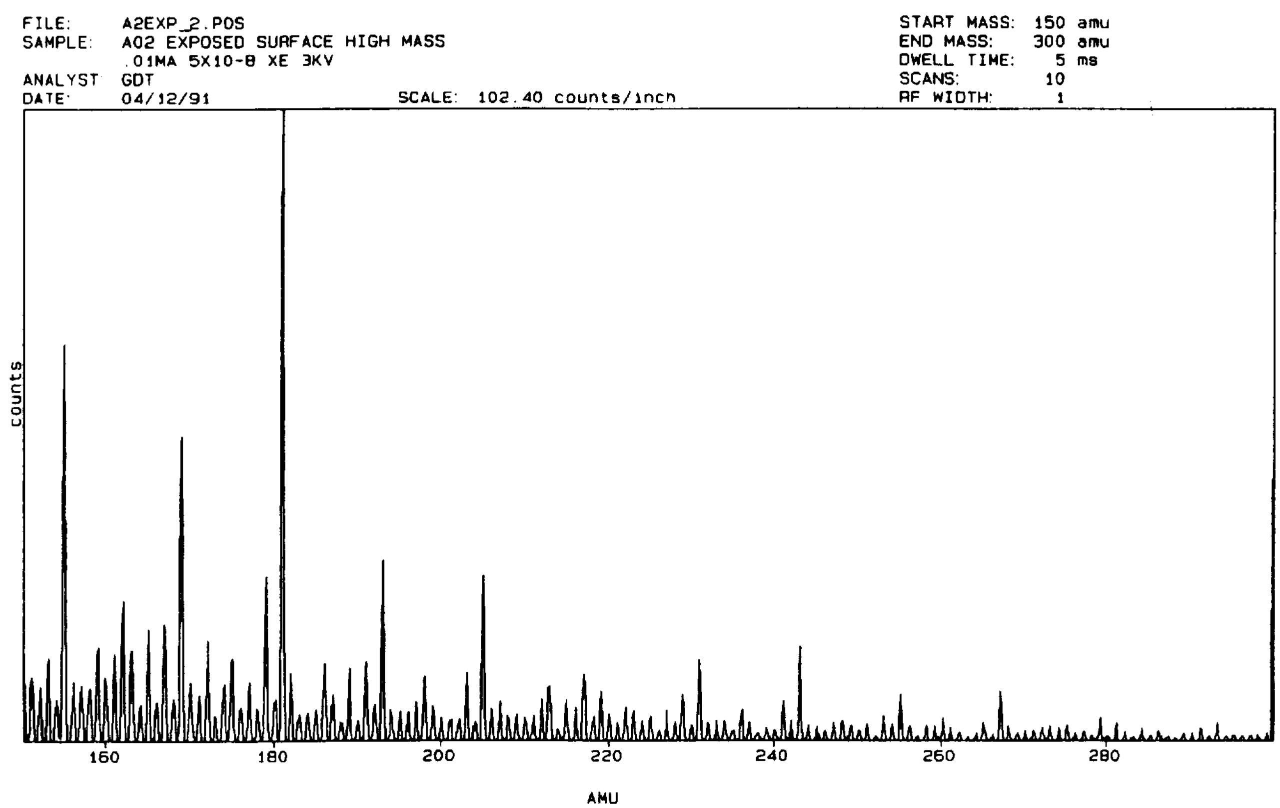
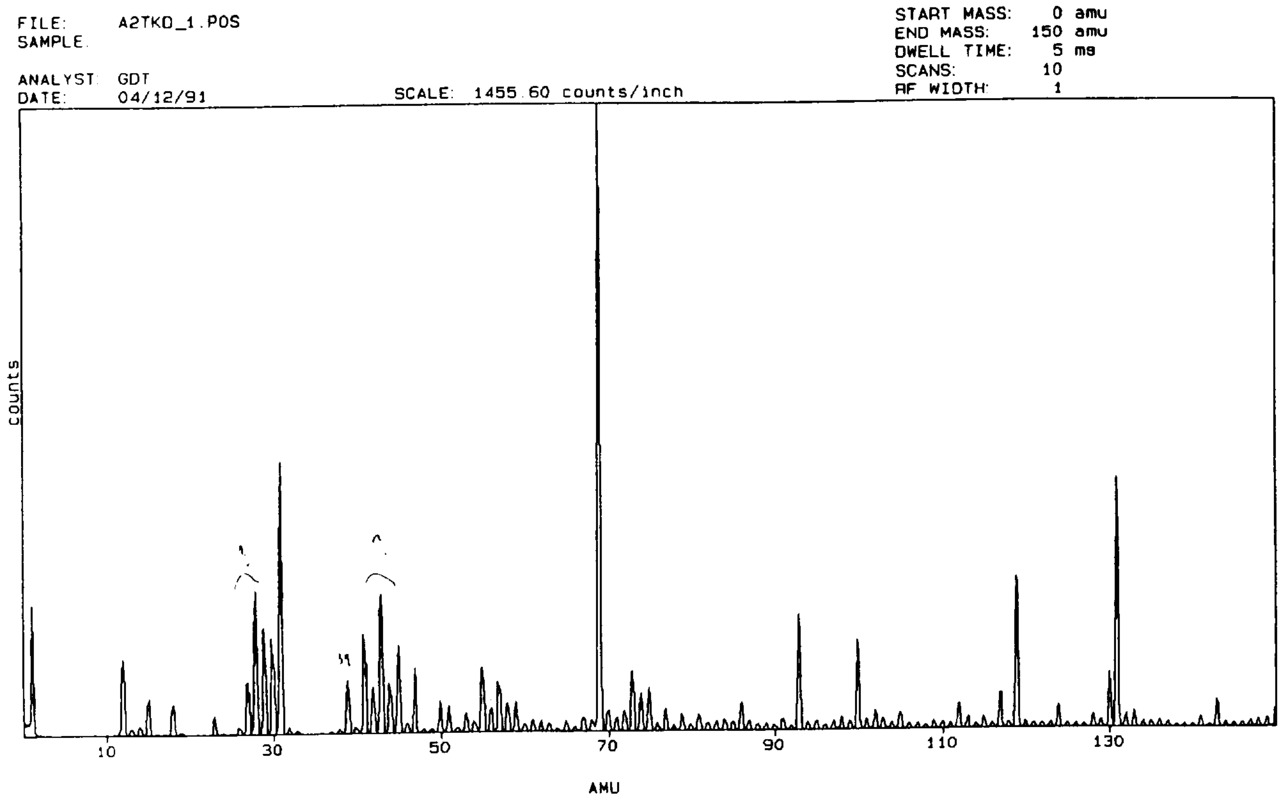


Figure D-4. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket A02.



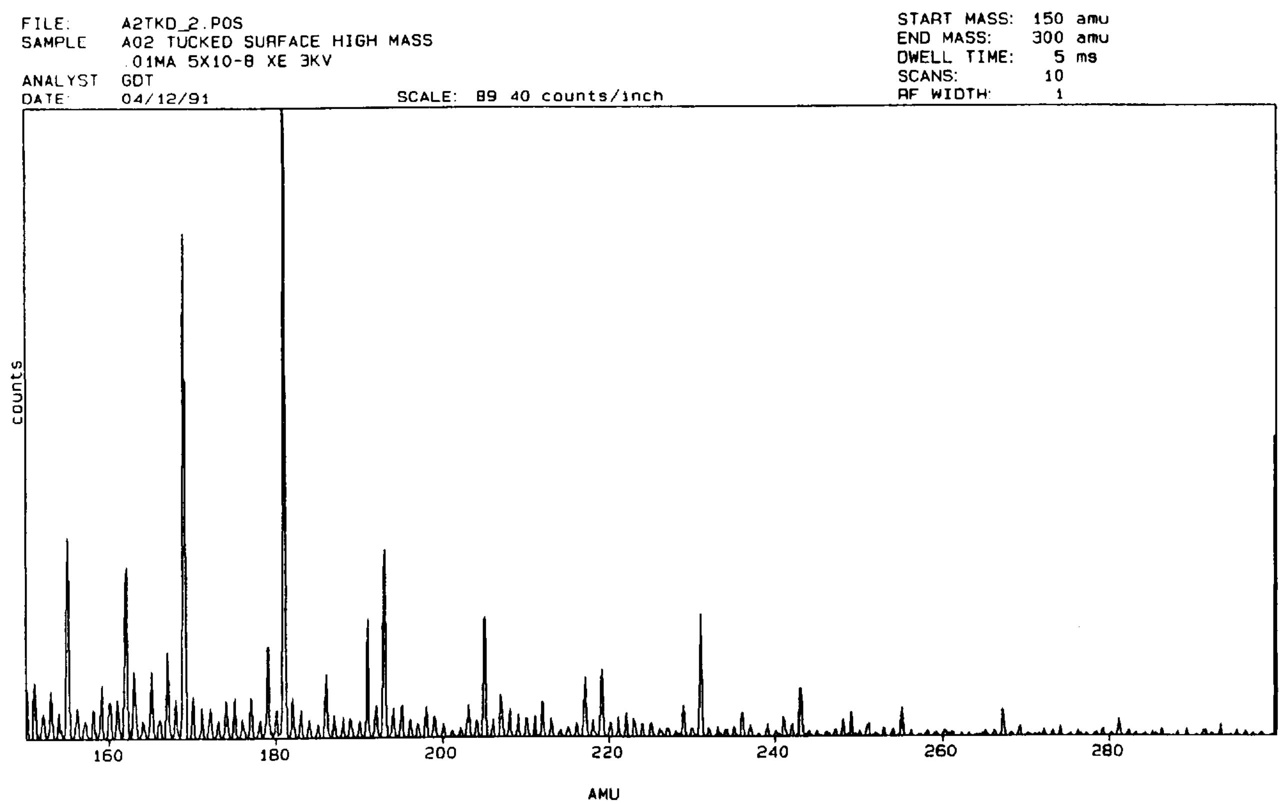
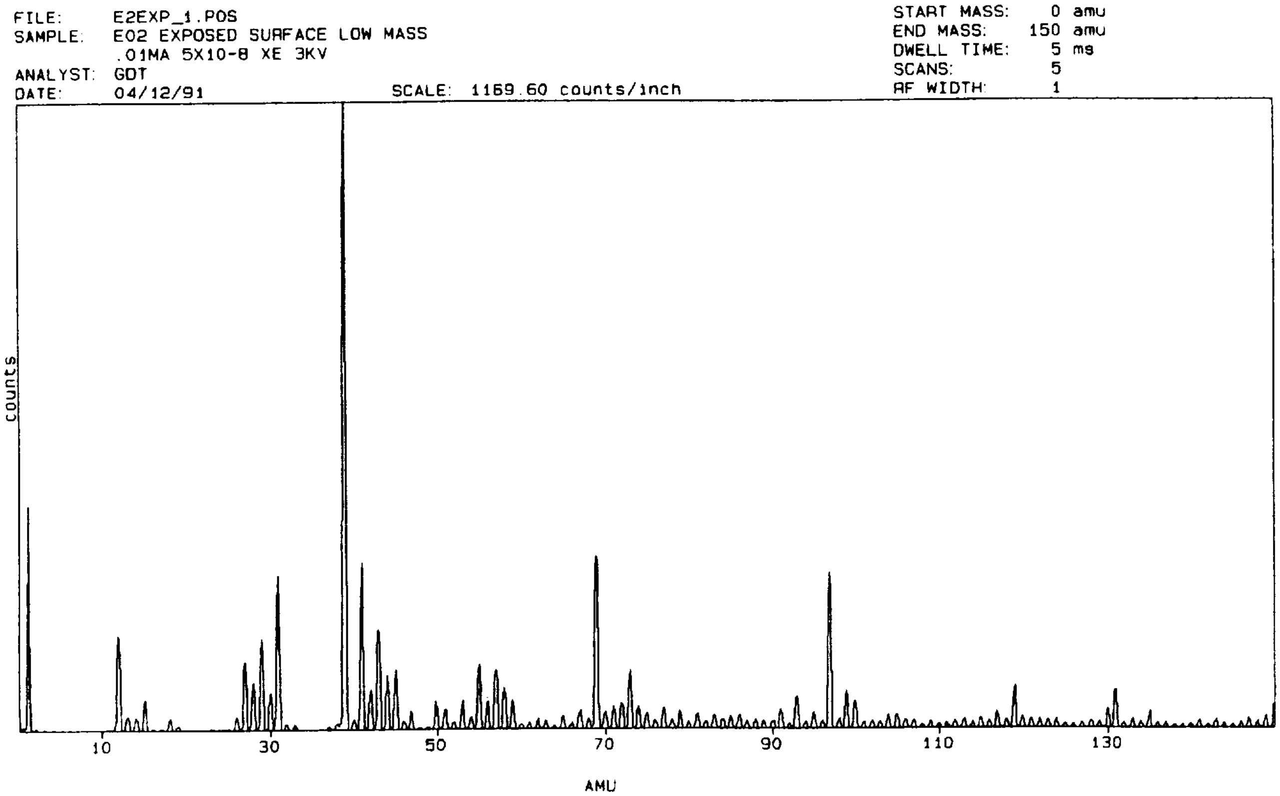


Figure D-5. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area On Blanket A02.



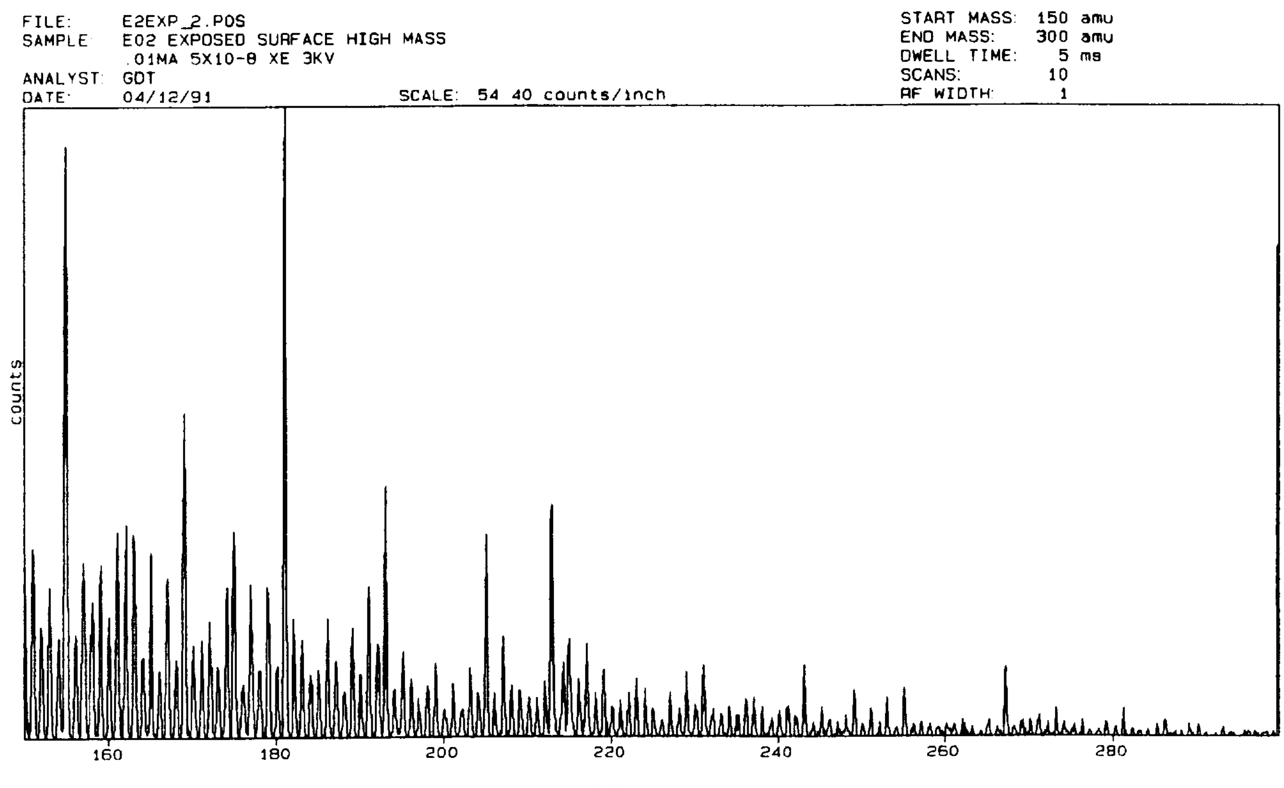
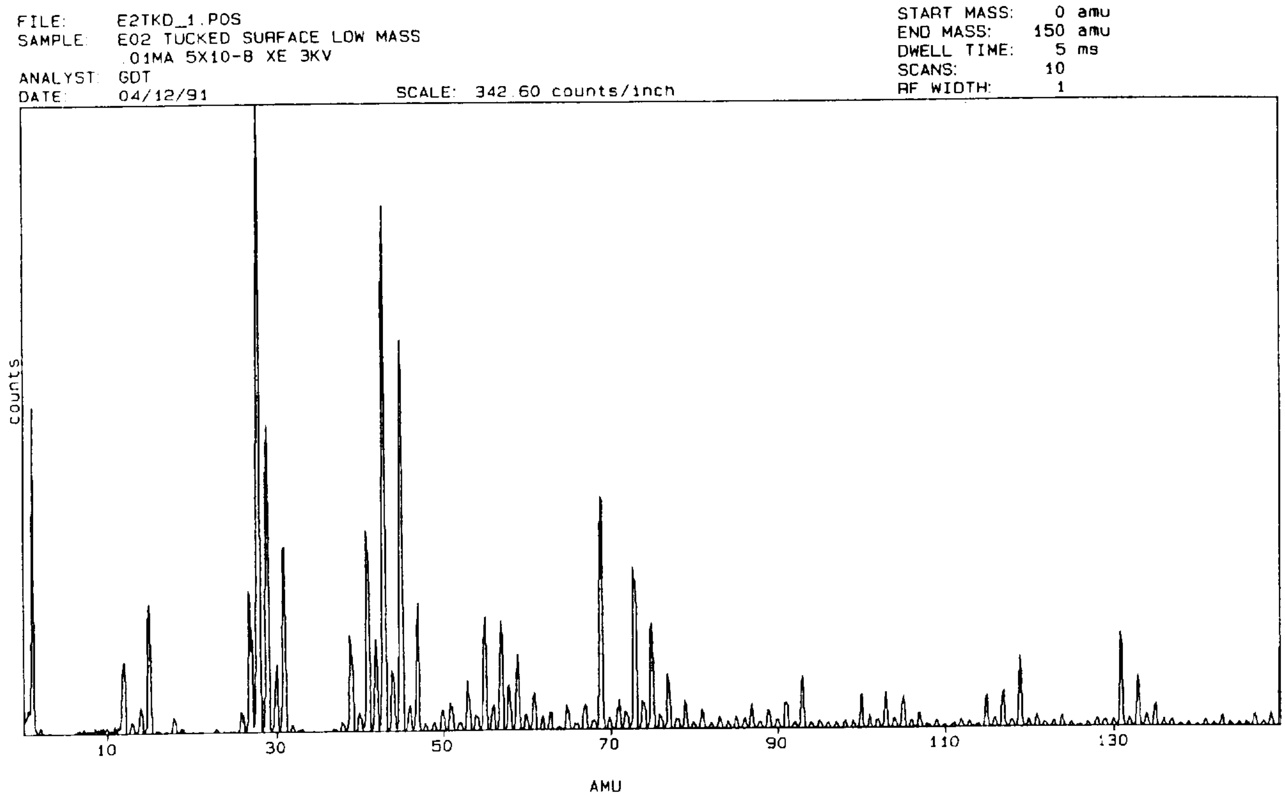


Figure D-6. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket E02.



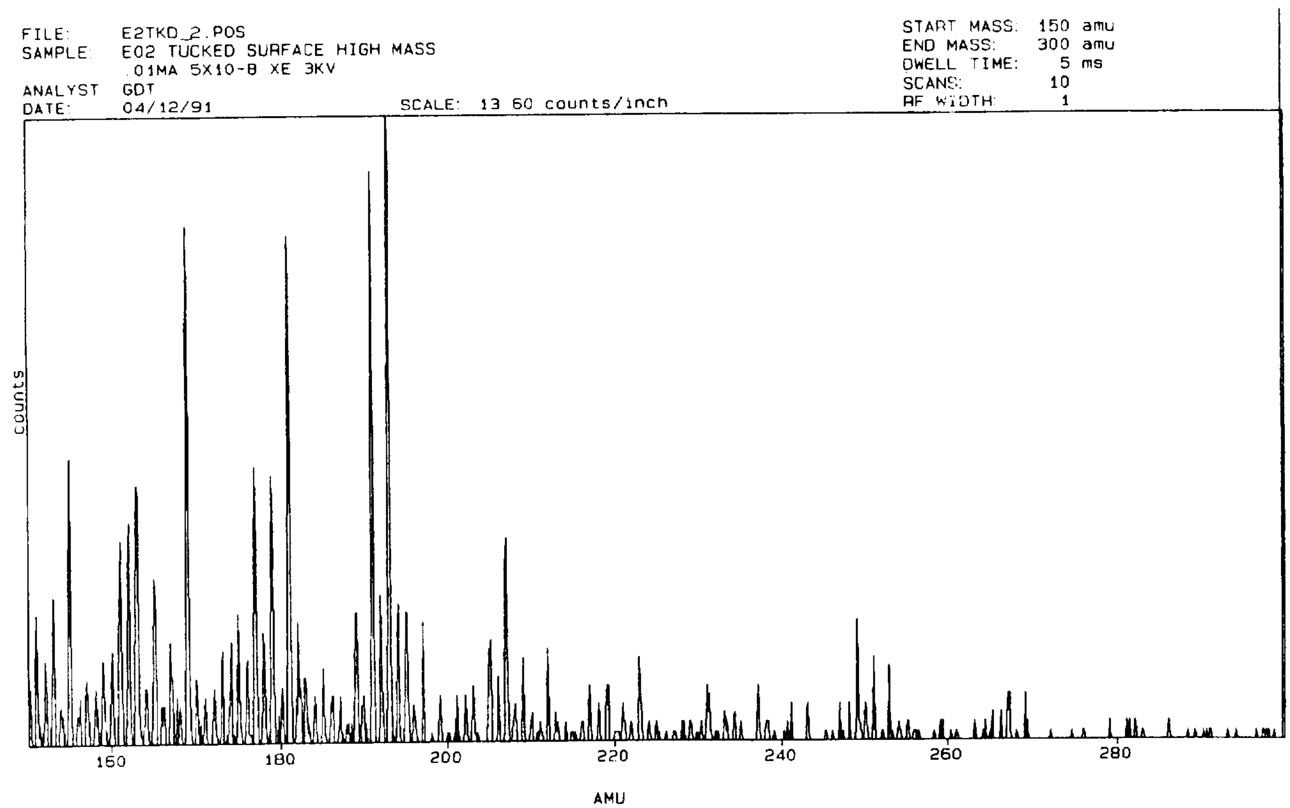
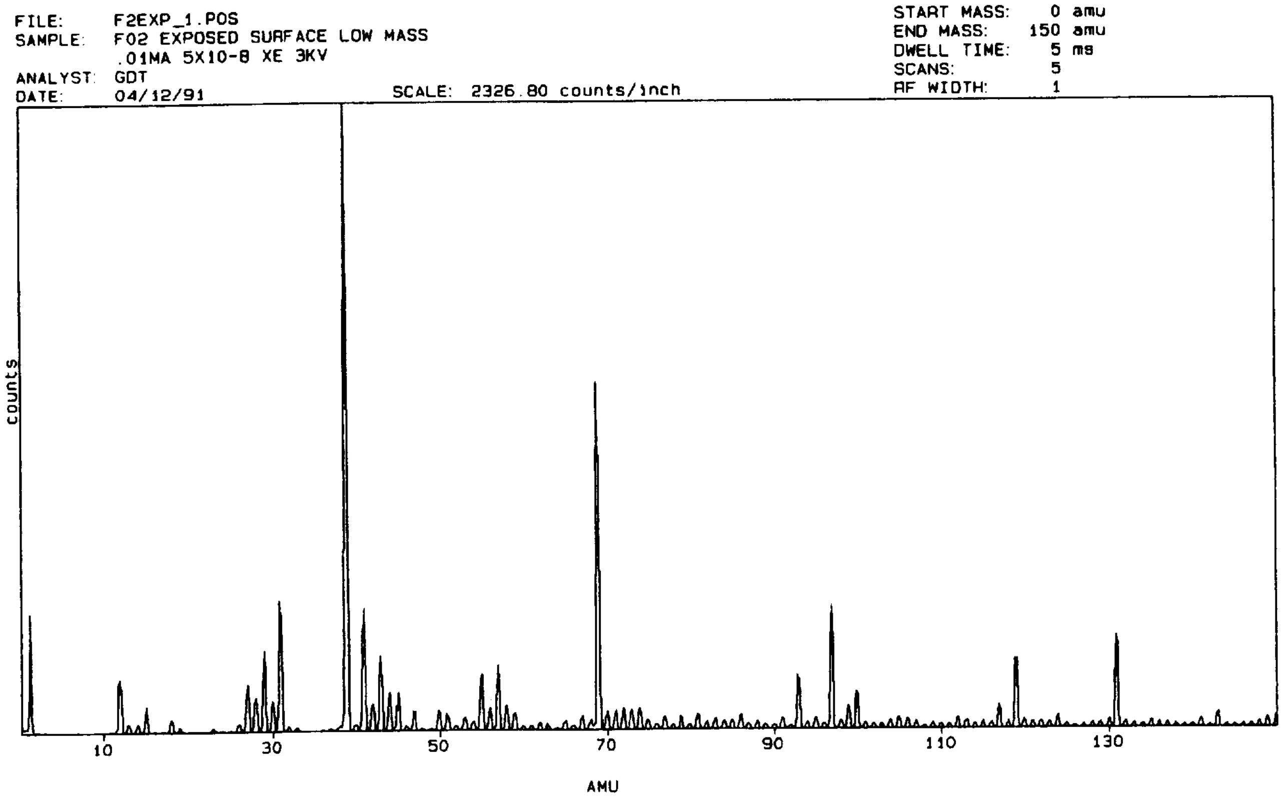


Figure D-7. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area On Blanket E02.



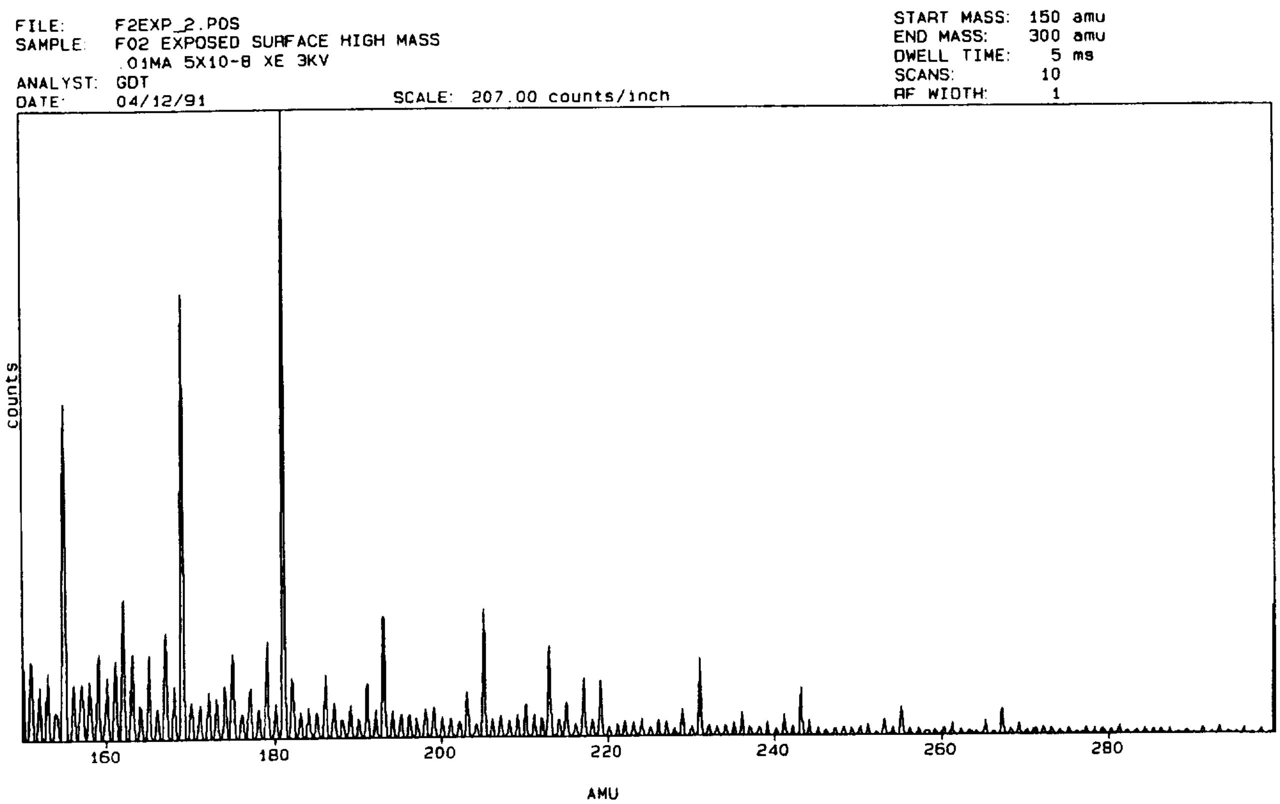
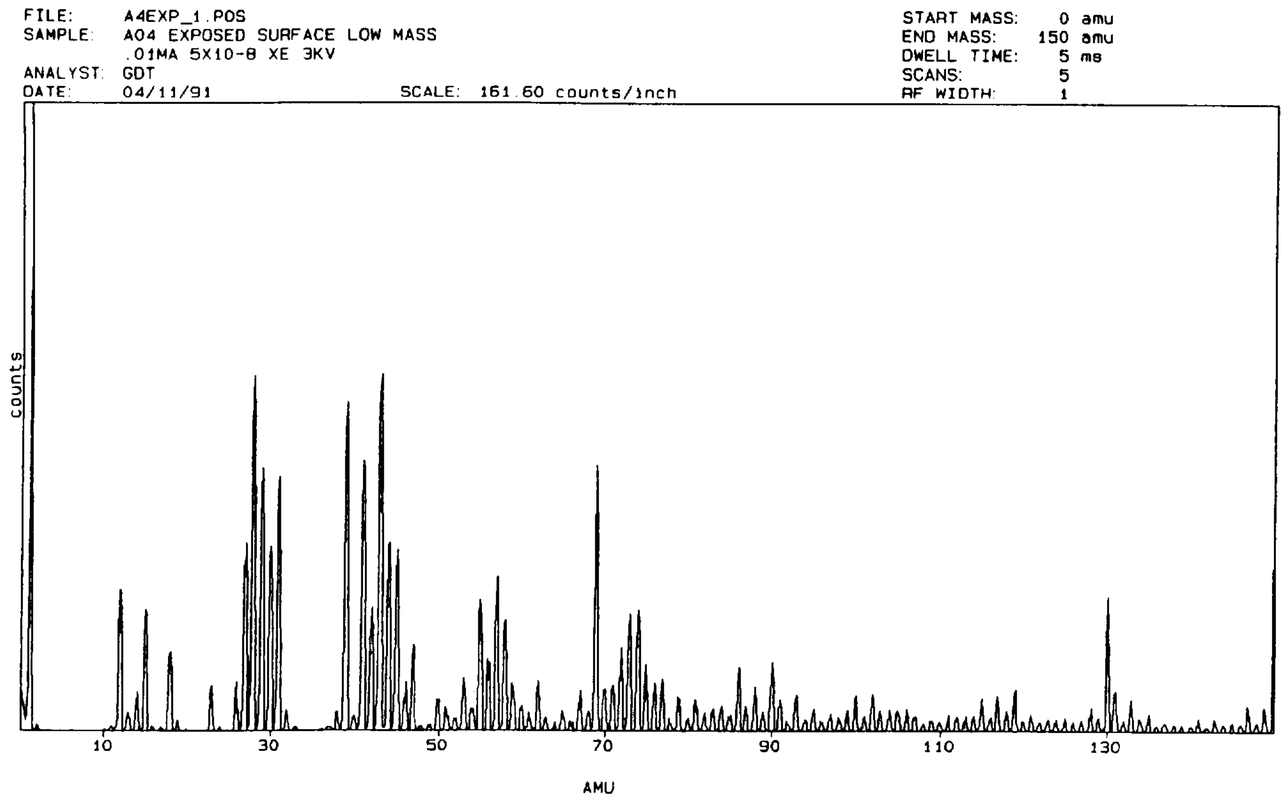


Figure D-8. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket F02.



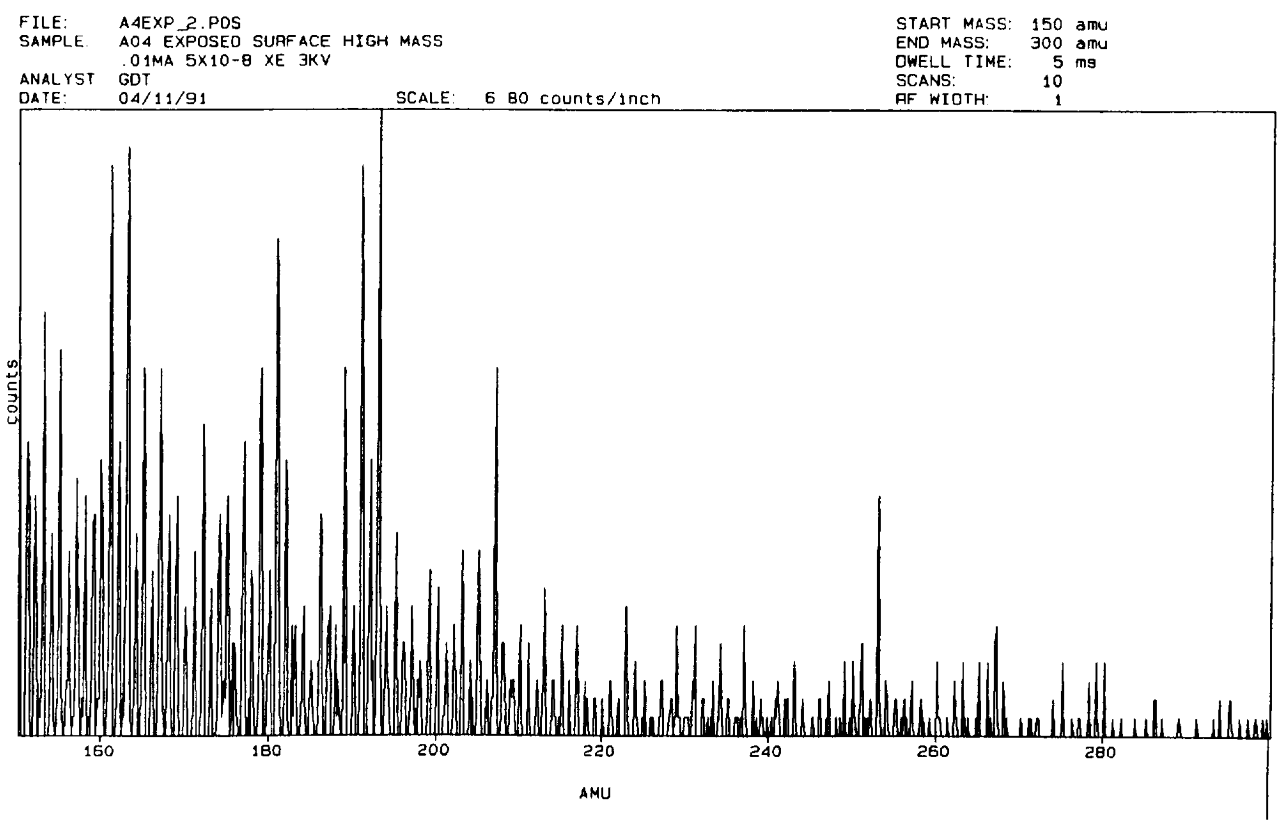
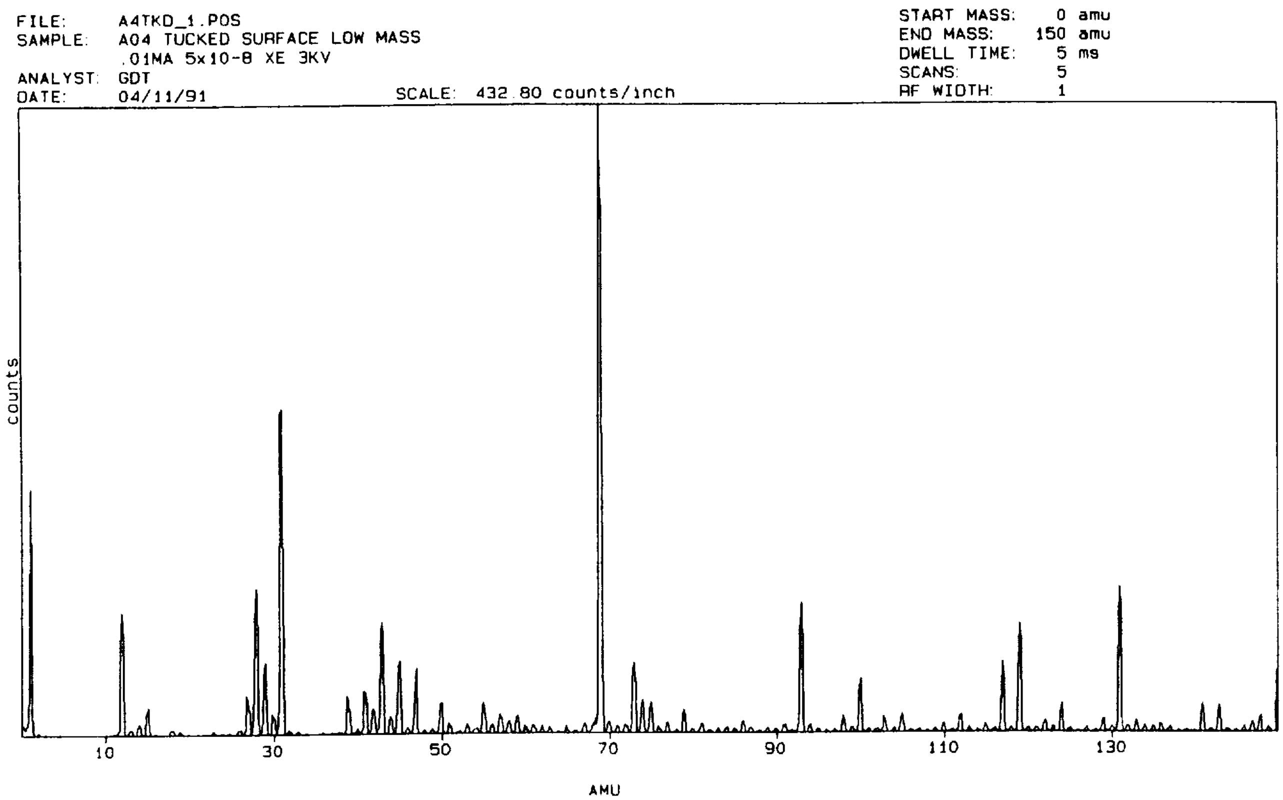


Figure D-9. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket A04.



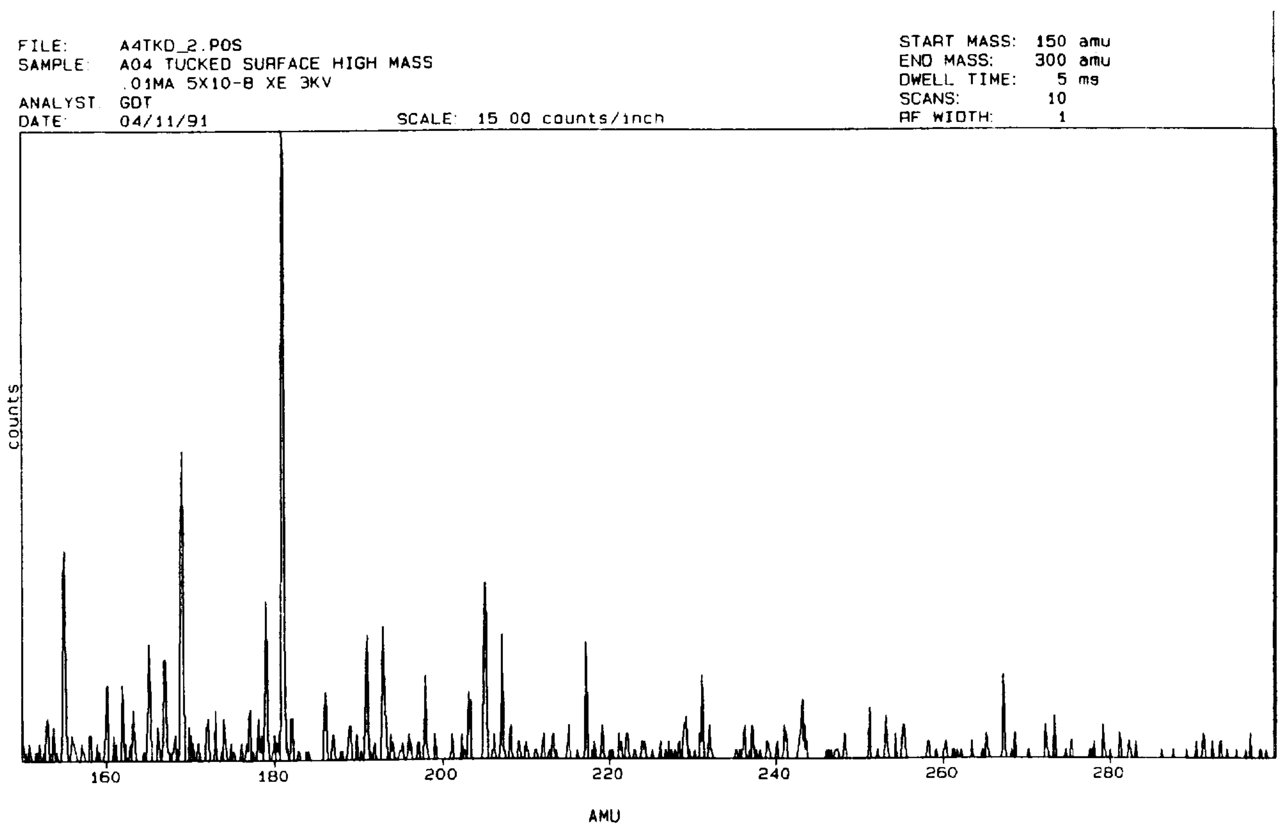
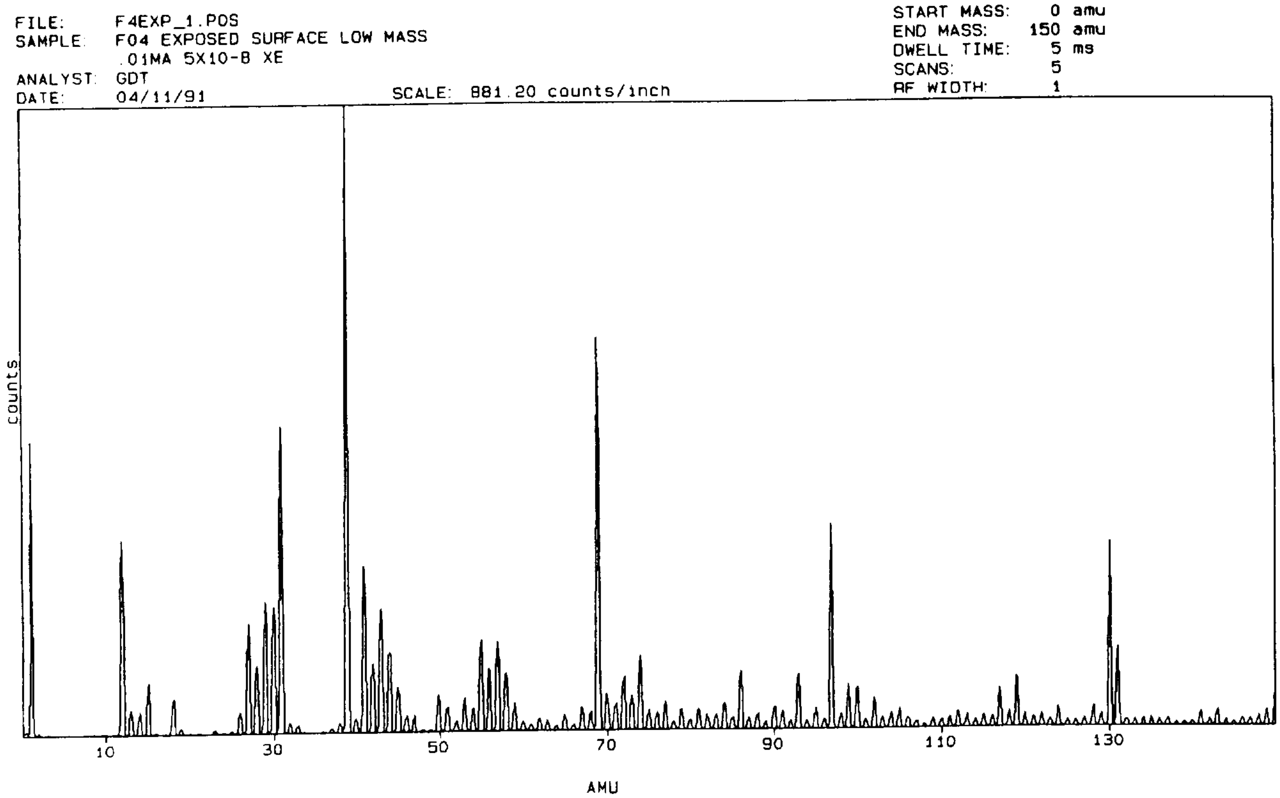


Figure D-10. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area On Blanket A04.



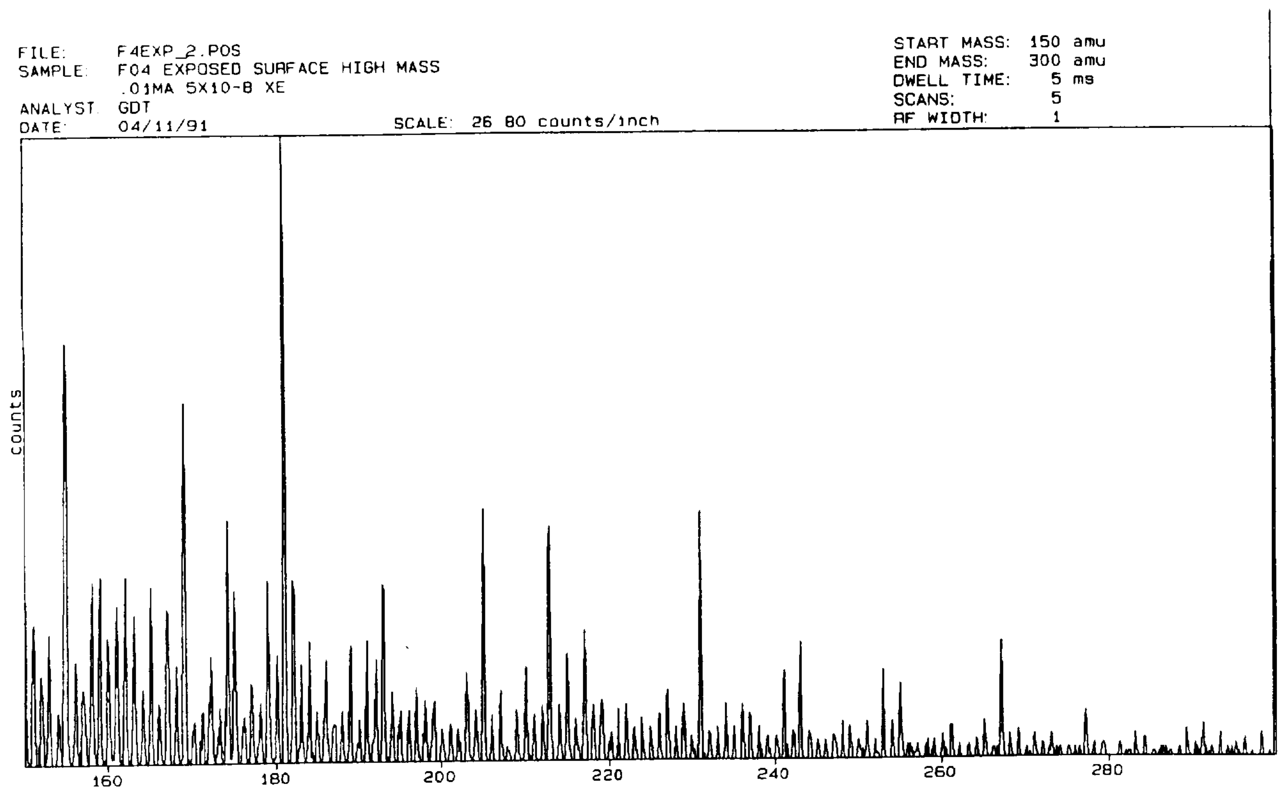
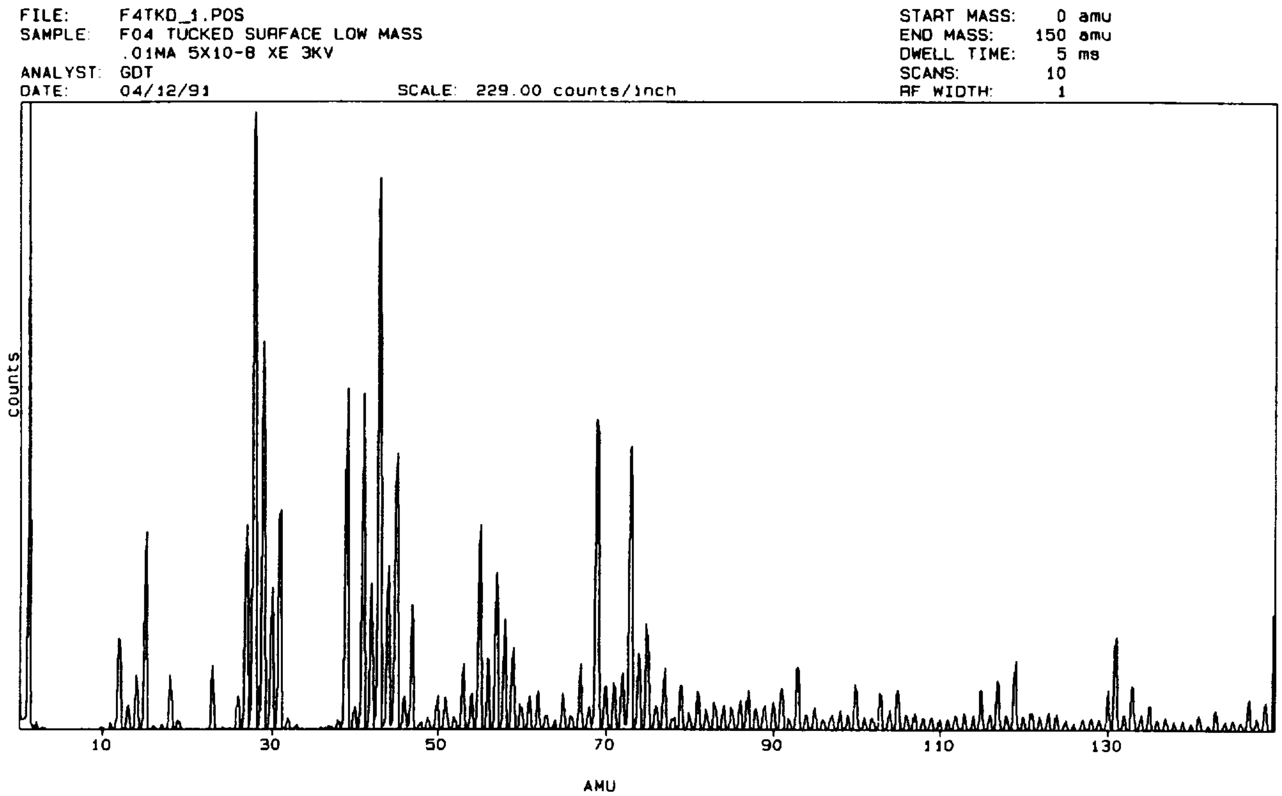


Figure D-11. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket F04.



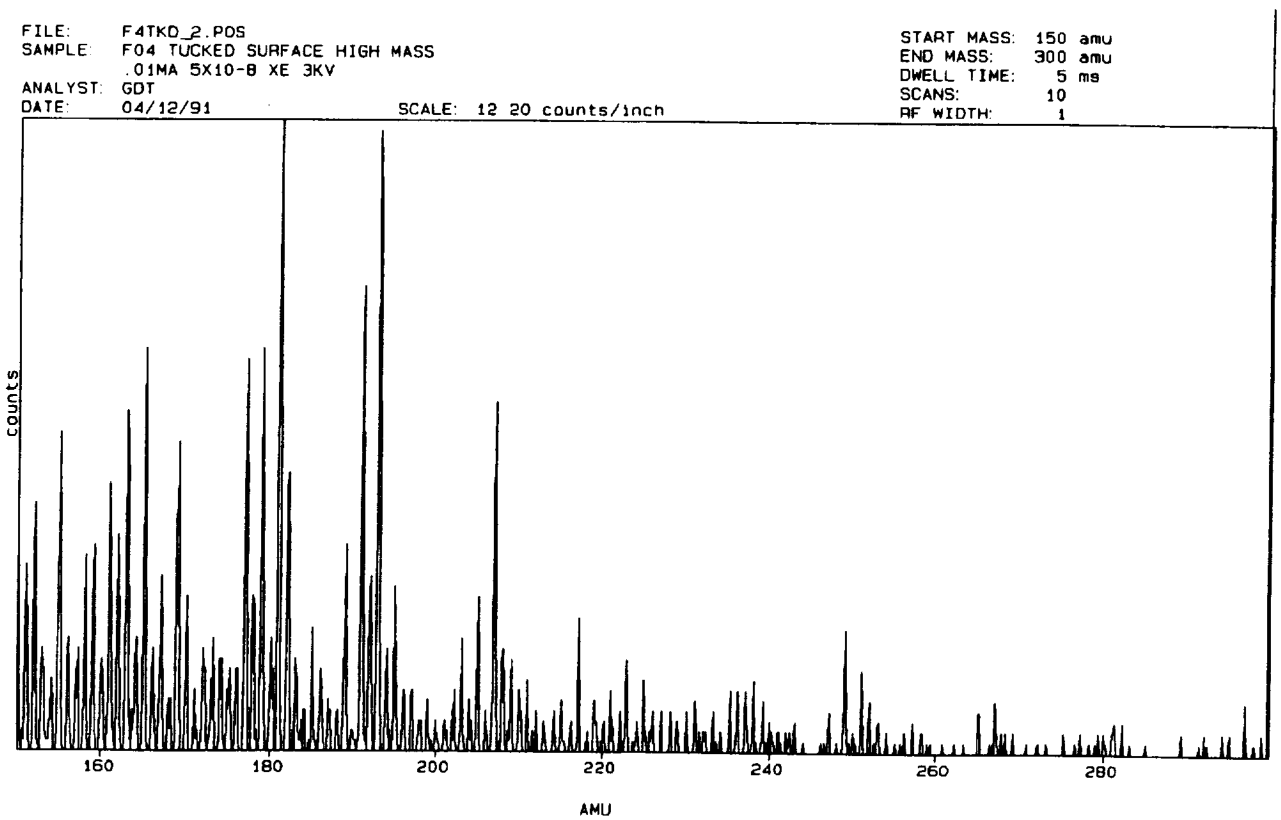
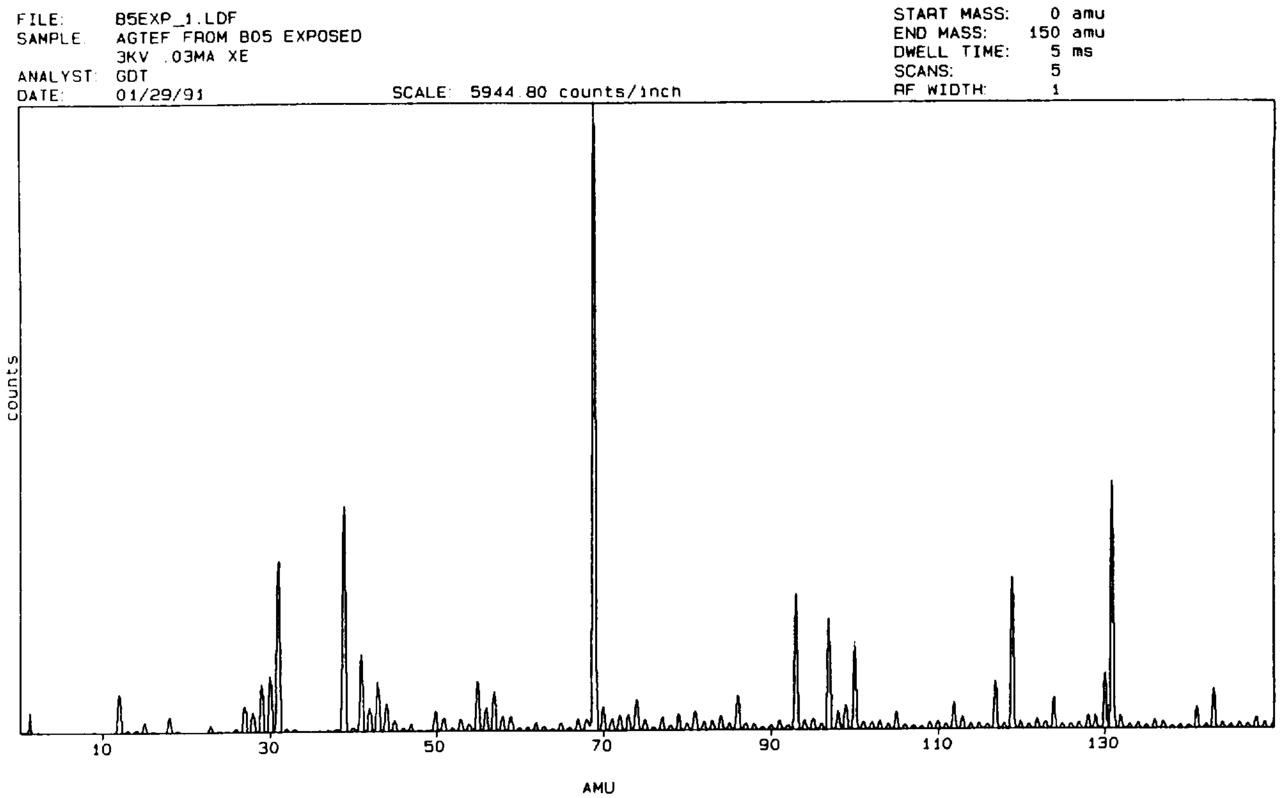


Figure D-12. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area On Blanket F04.



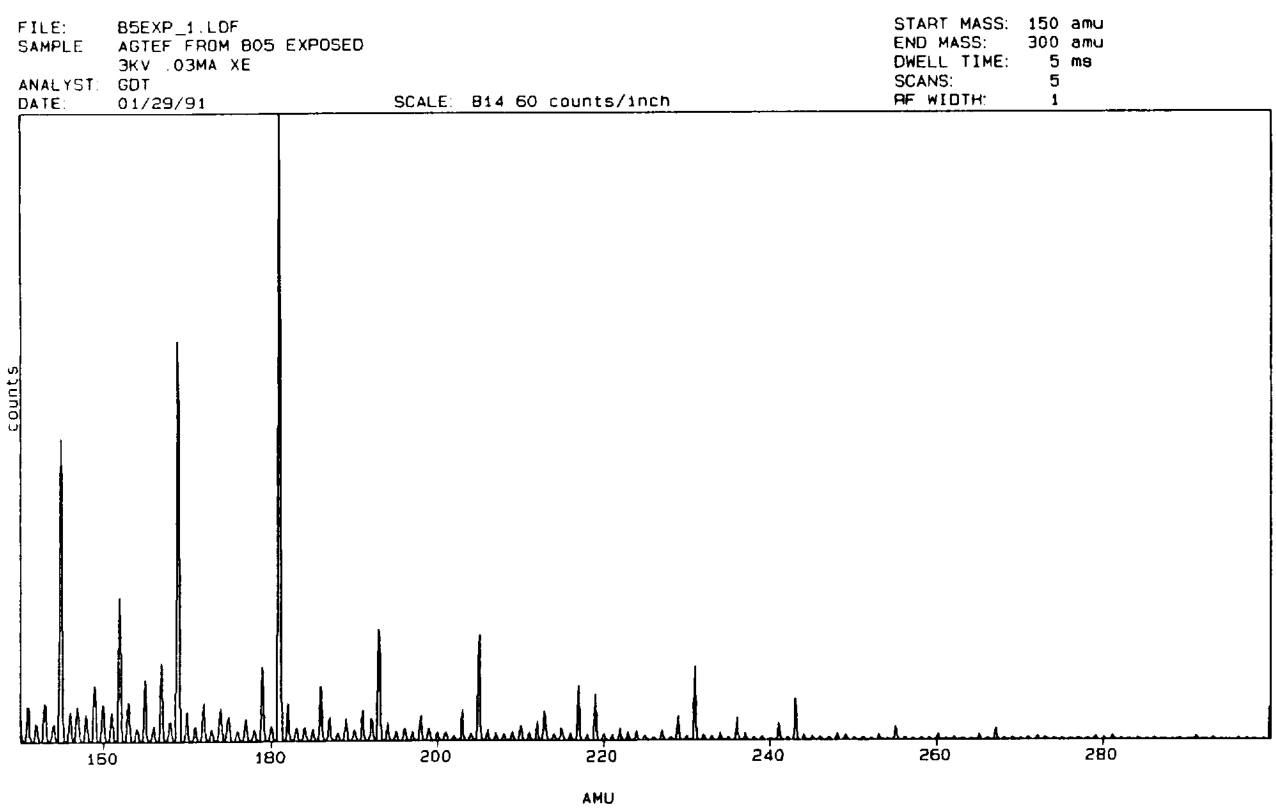


Figure D-13. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket B05.

C5 front 40s / spect.
120s between collection

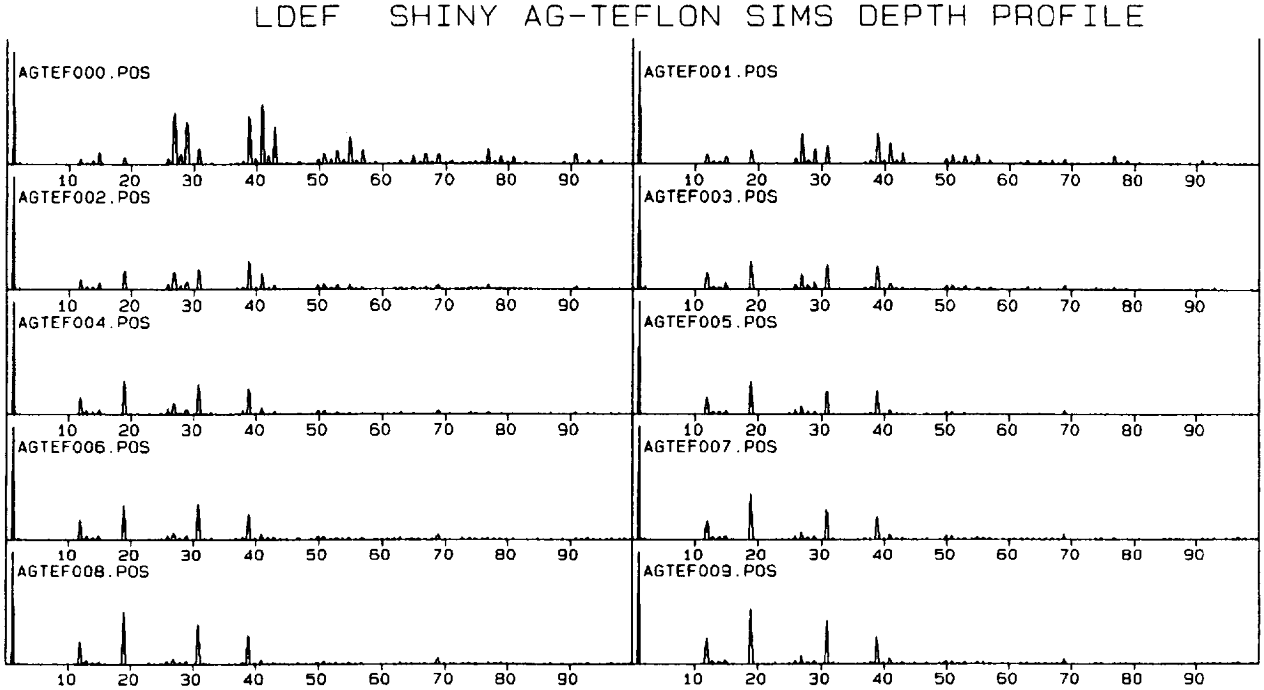
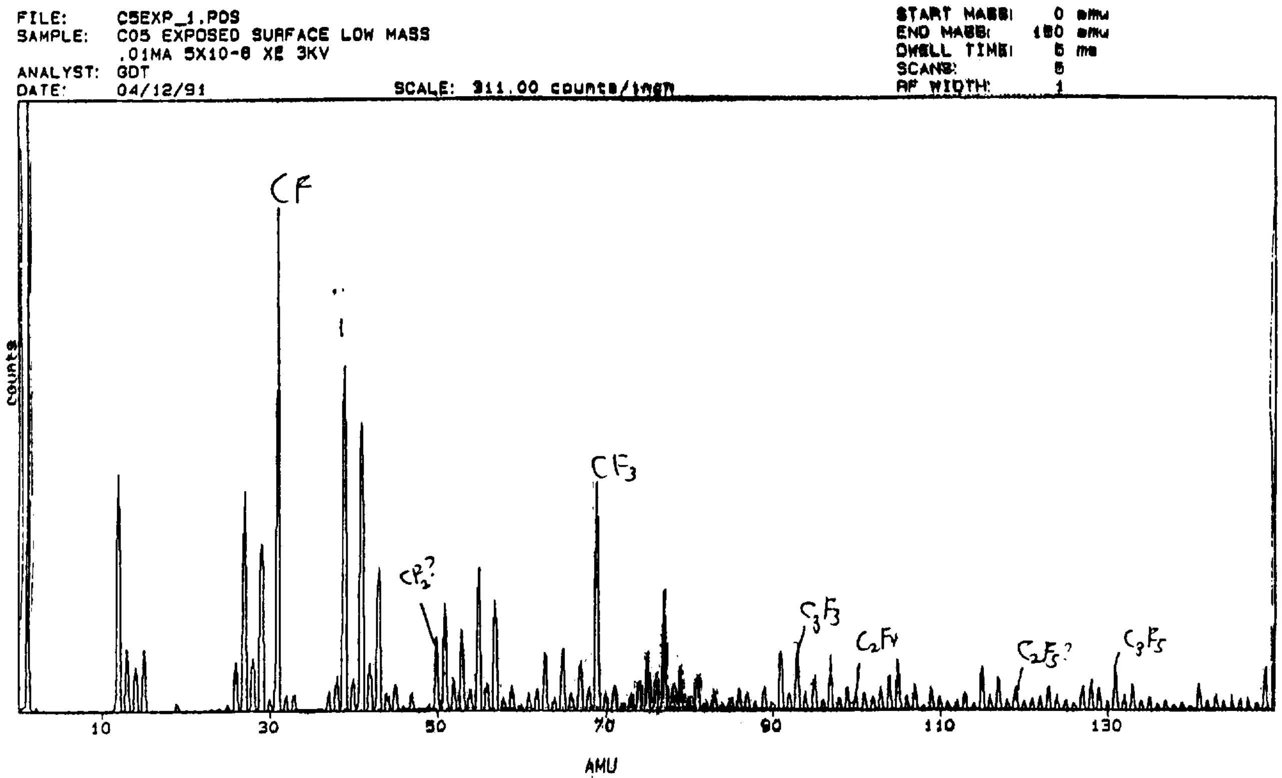


Figure D-14. Secondary Ion Mass Spectra, 0-100 amu Range, For Blanket C05 As A Function Of Time Under Exposure.



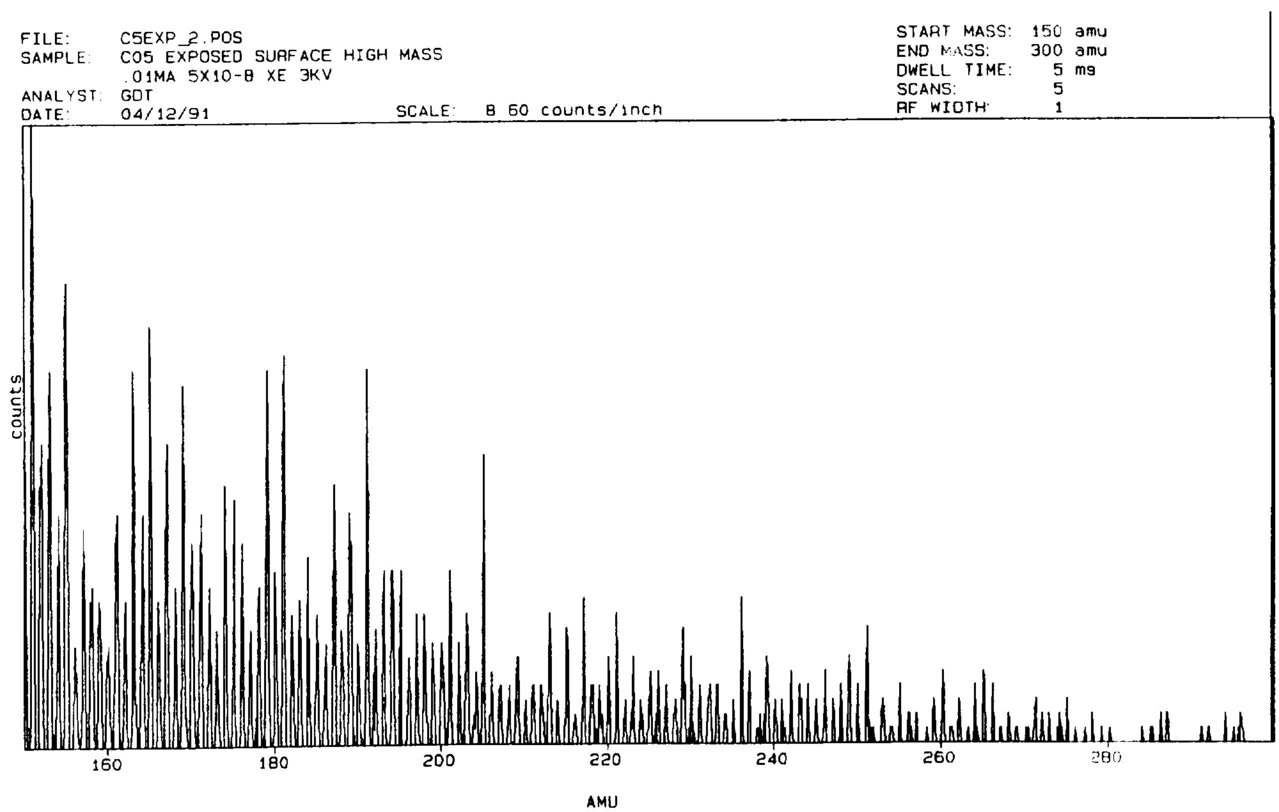
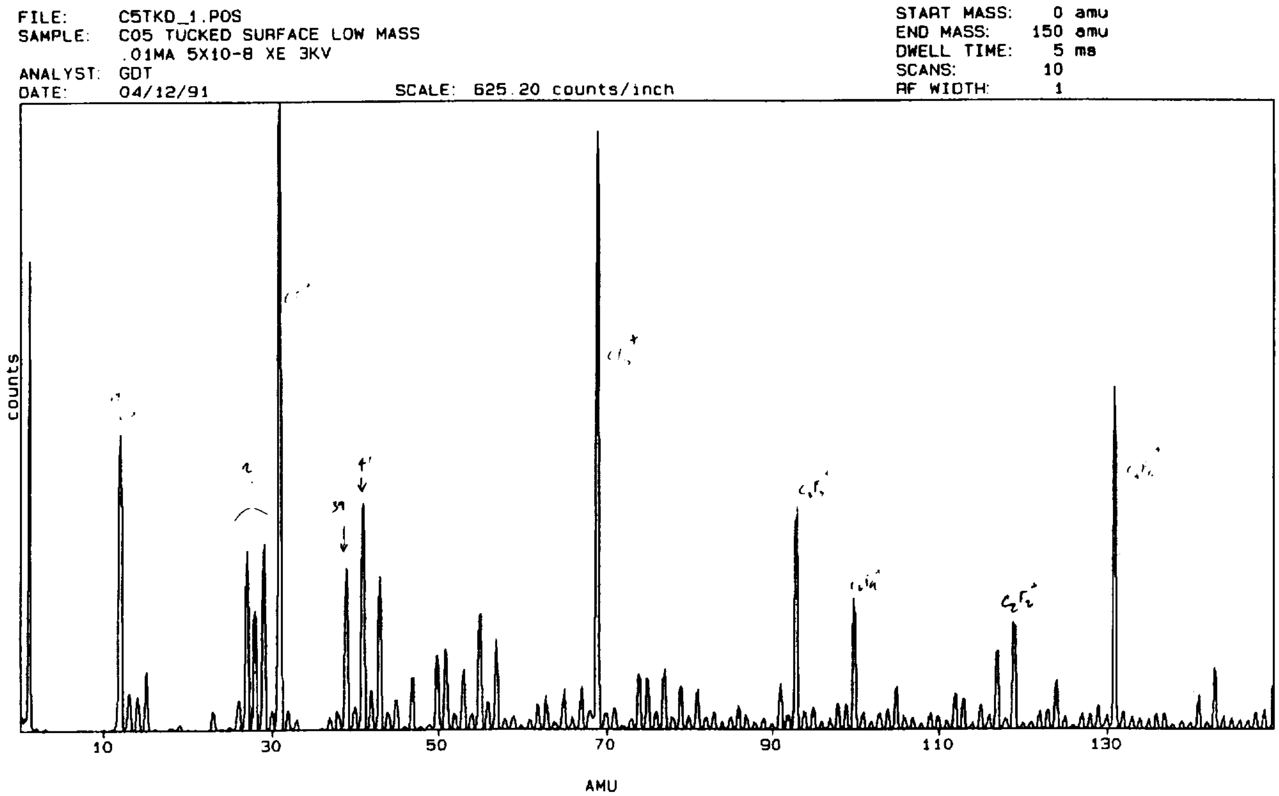


Figure D-15. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket C05.



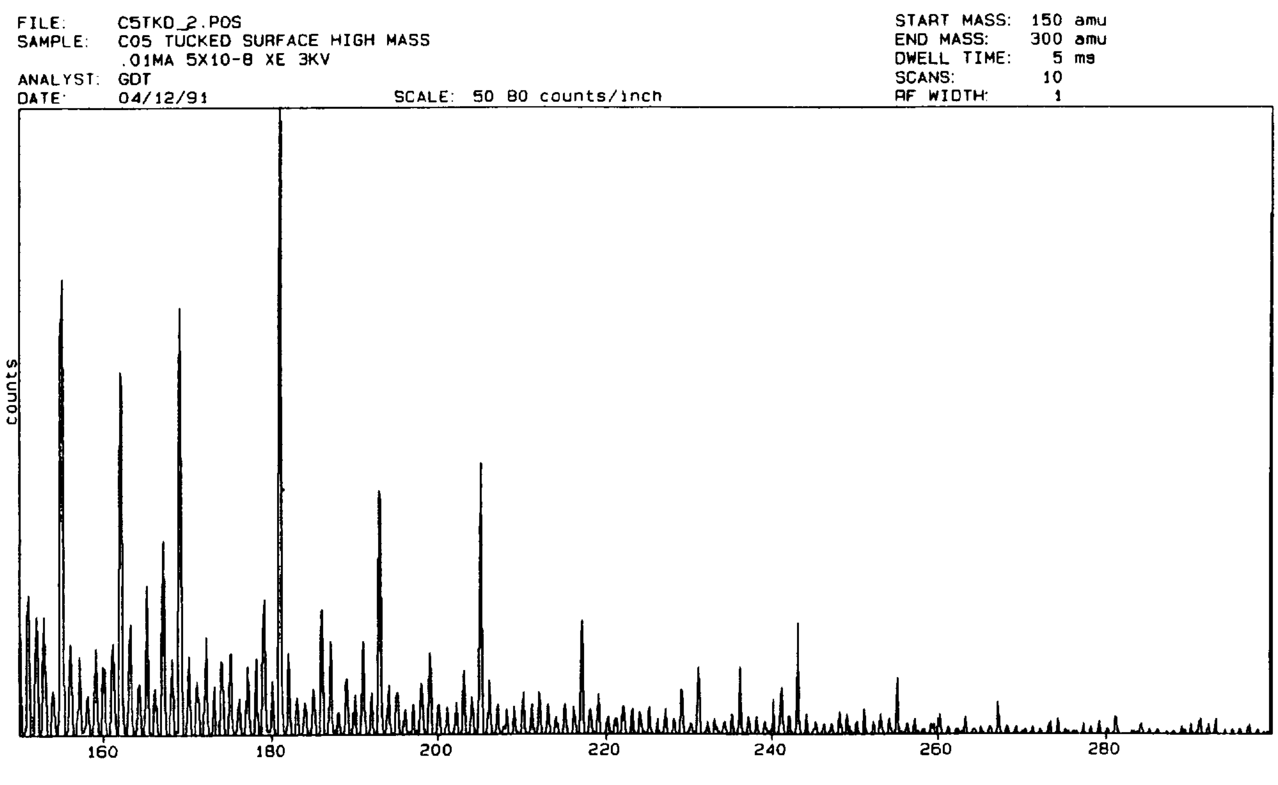
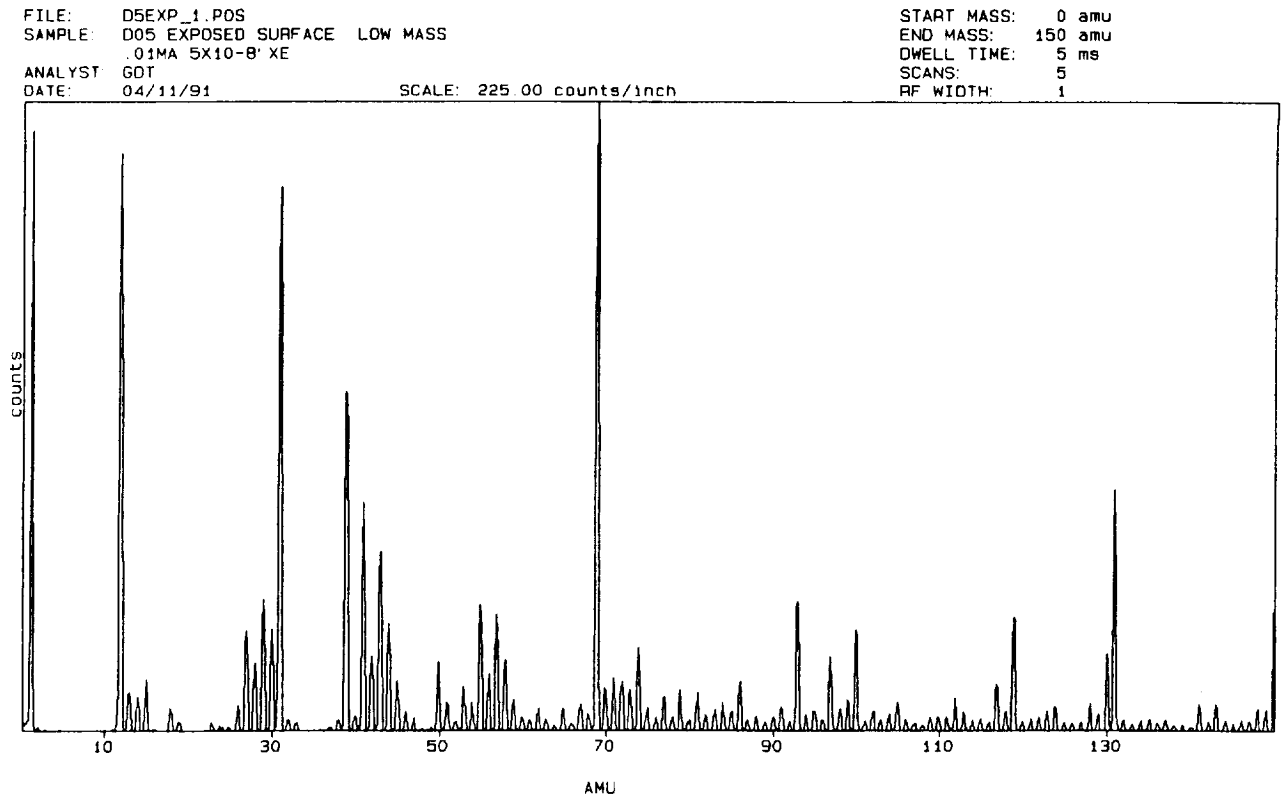


Figure D-16. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area On Blanket C05.



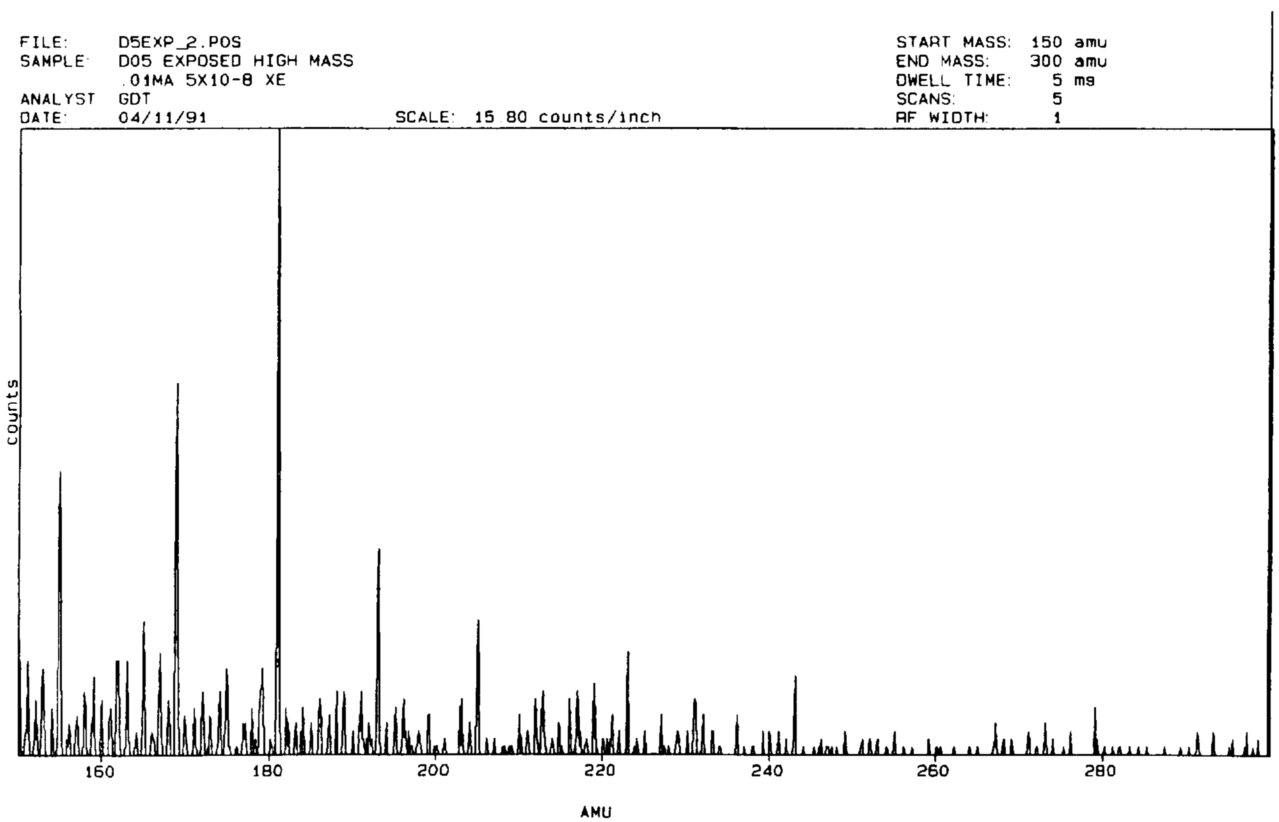
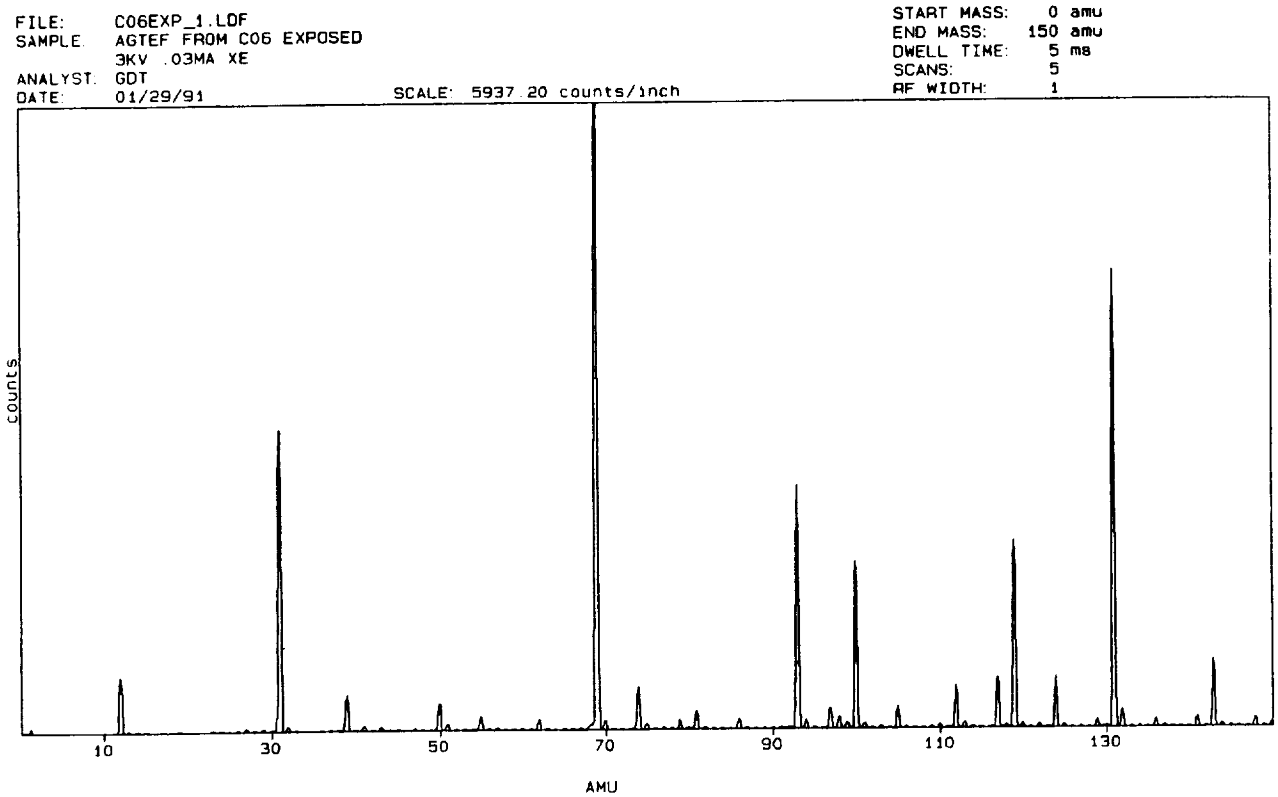


Figure D-17. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket D05.



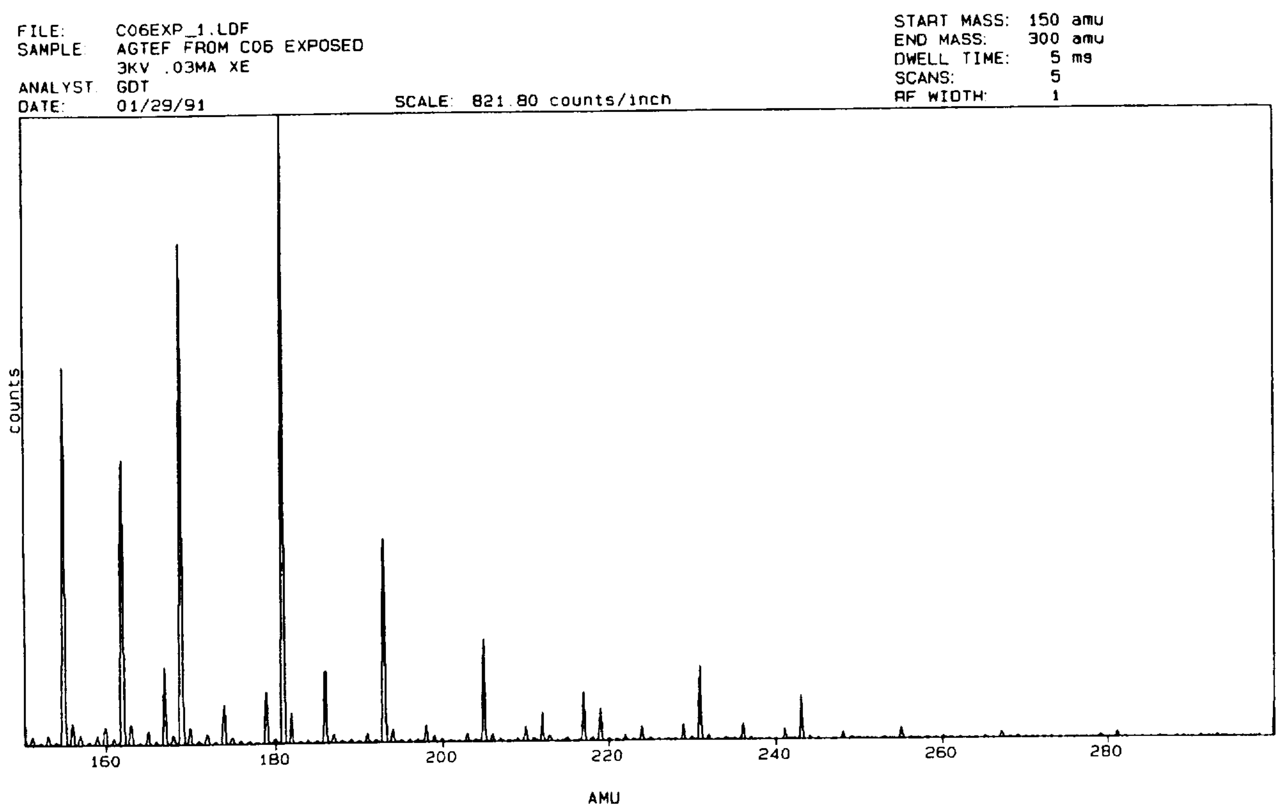
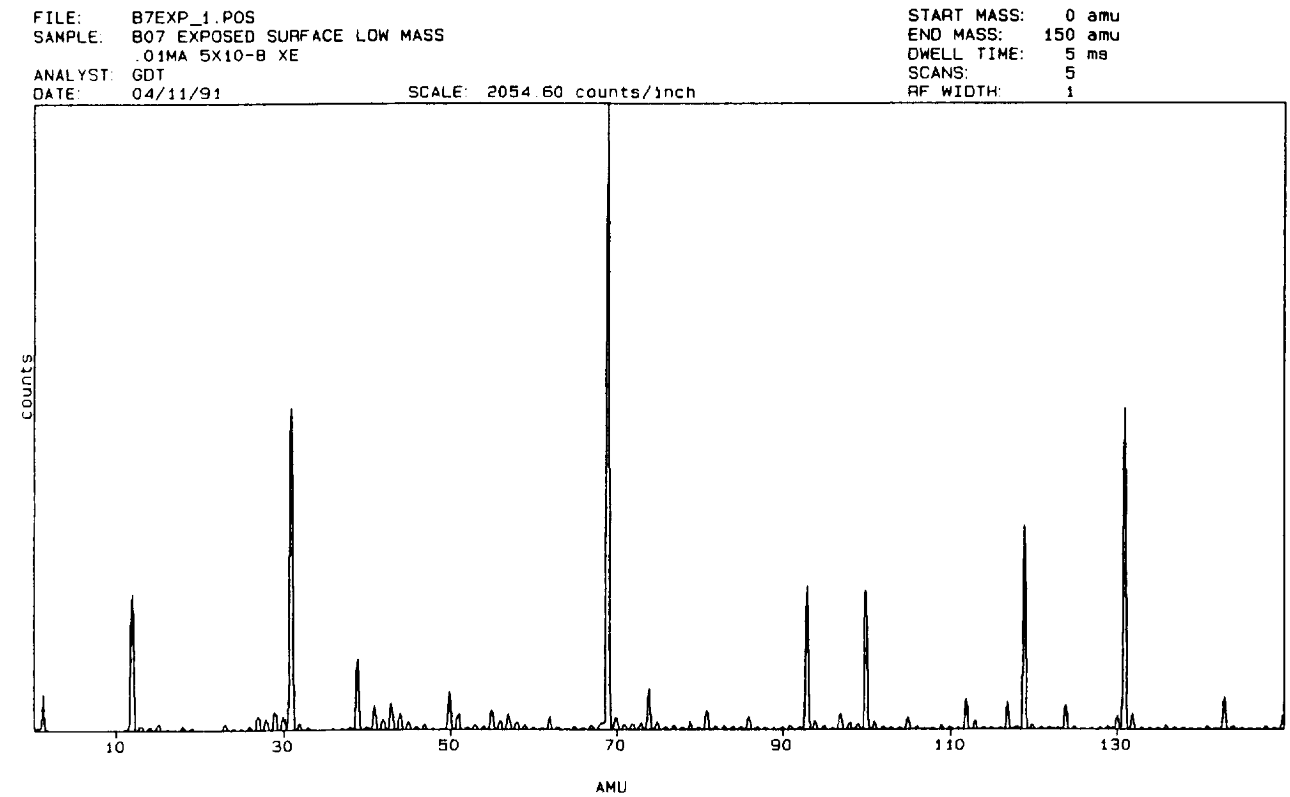


Figure D-18. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket C06.



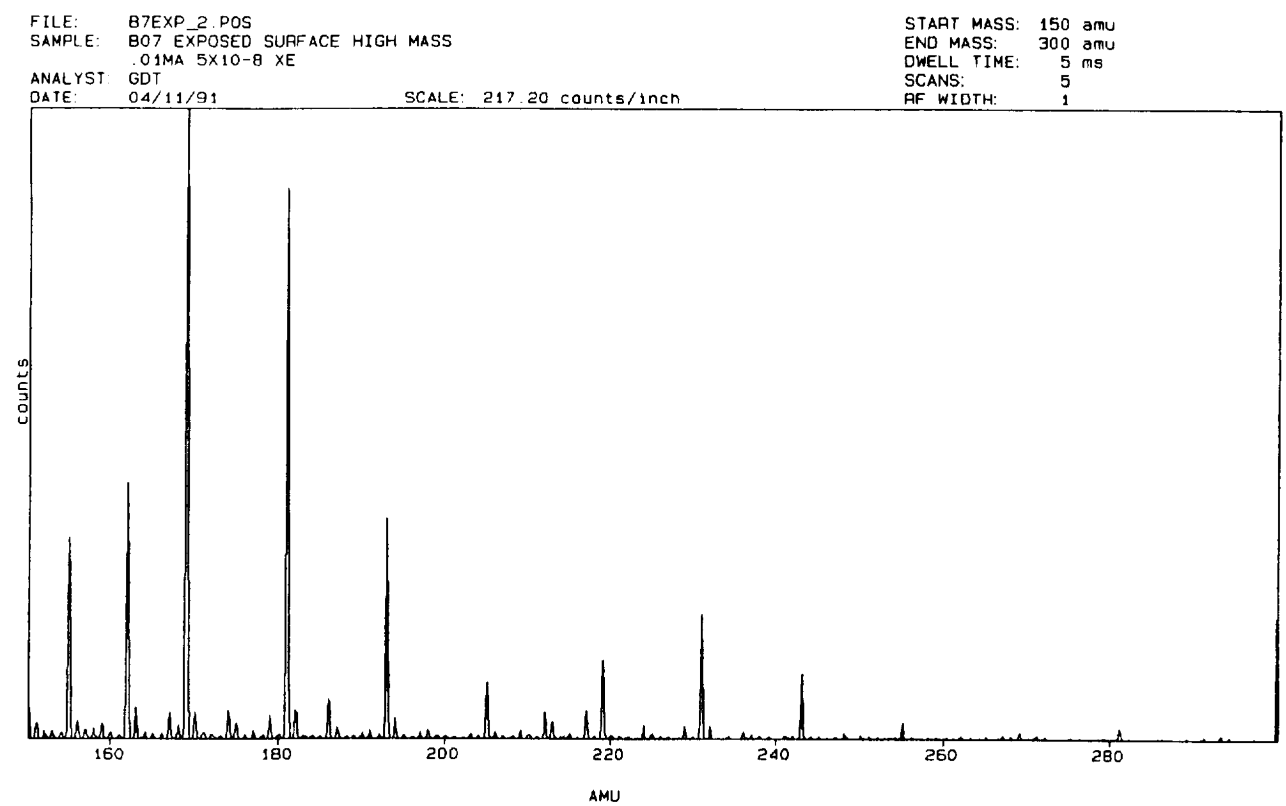
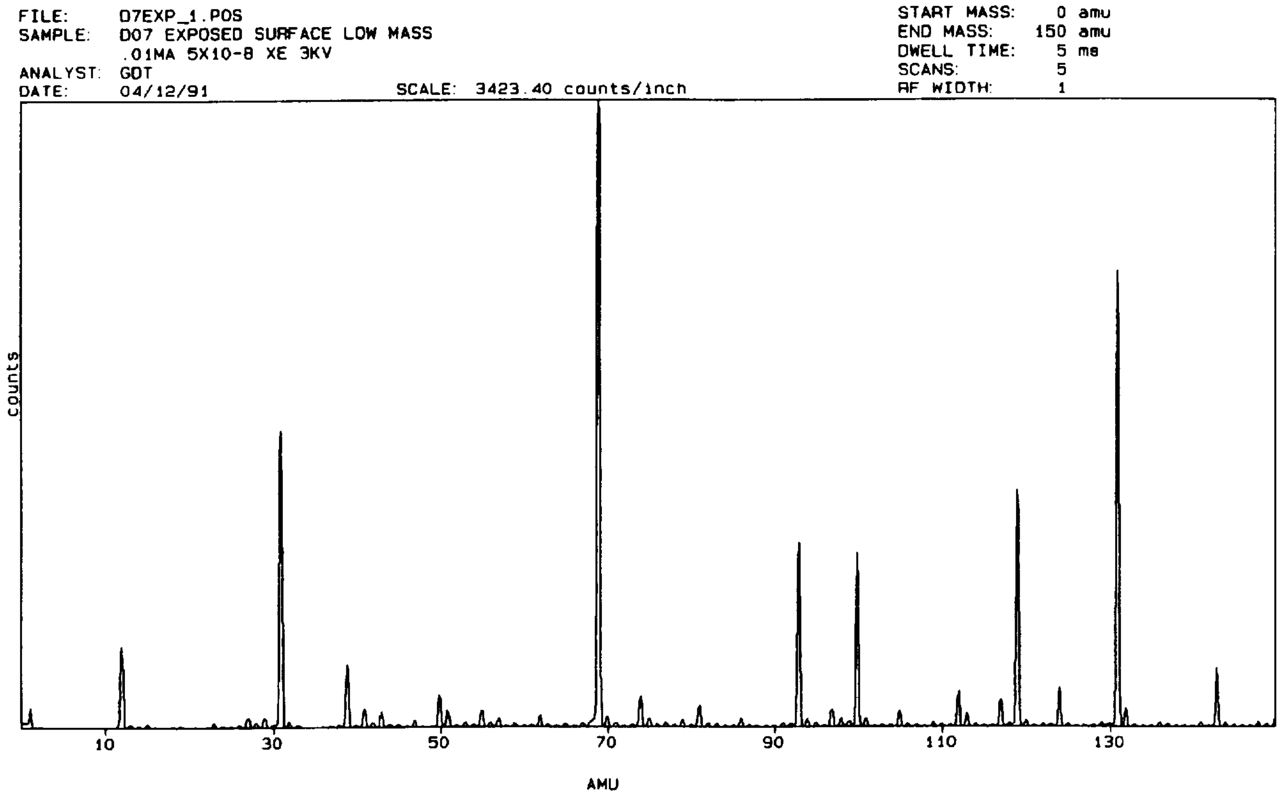


Figure D-19. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area On Blanket B07.



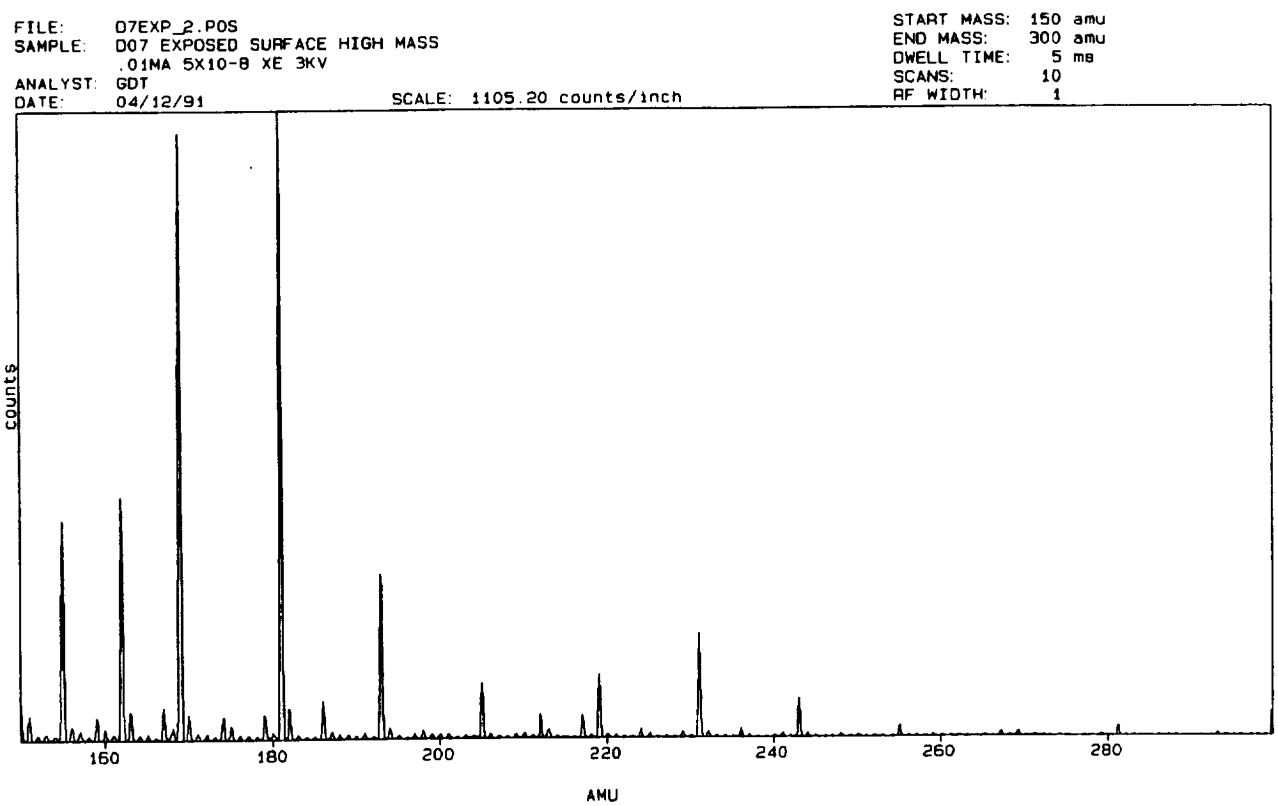


Figure D-20. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket D07.

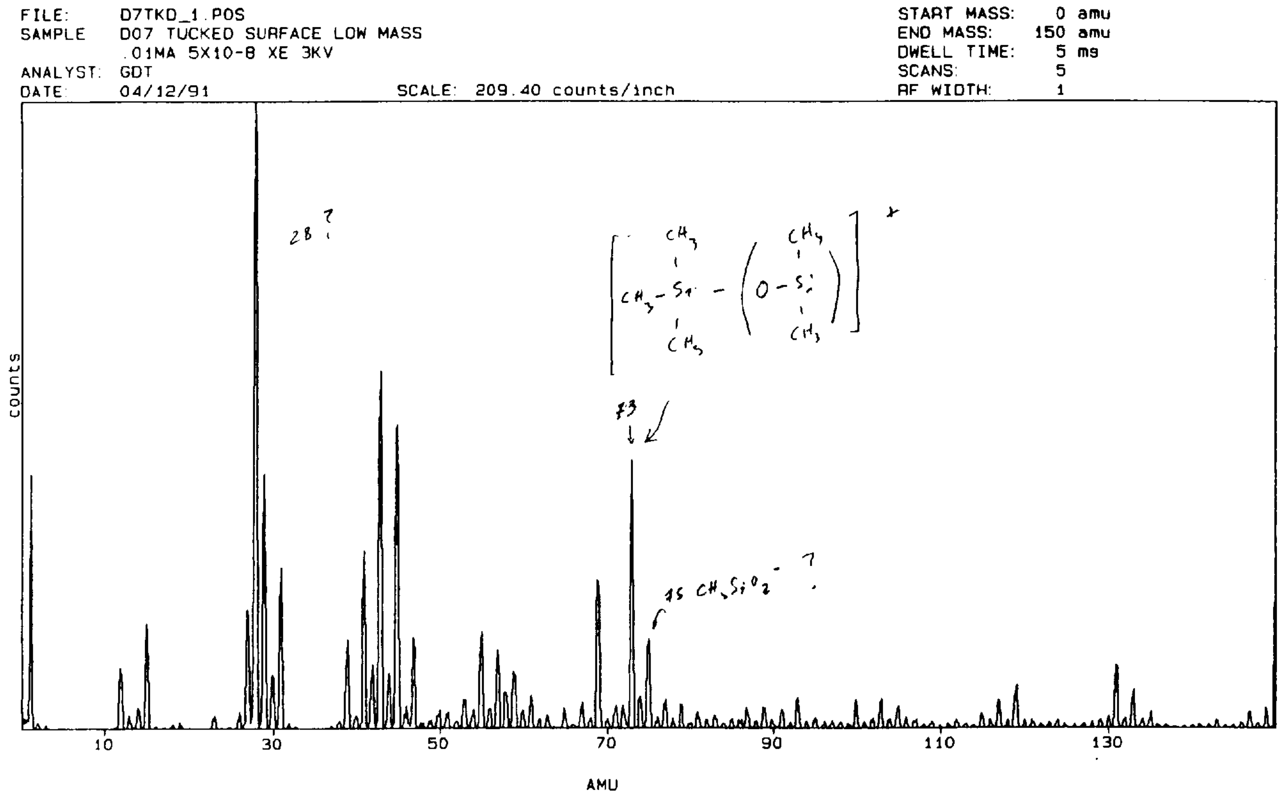


Figure D-21. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket D07.

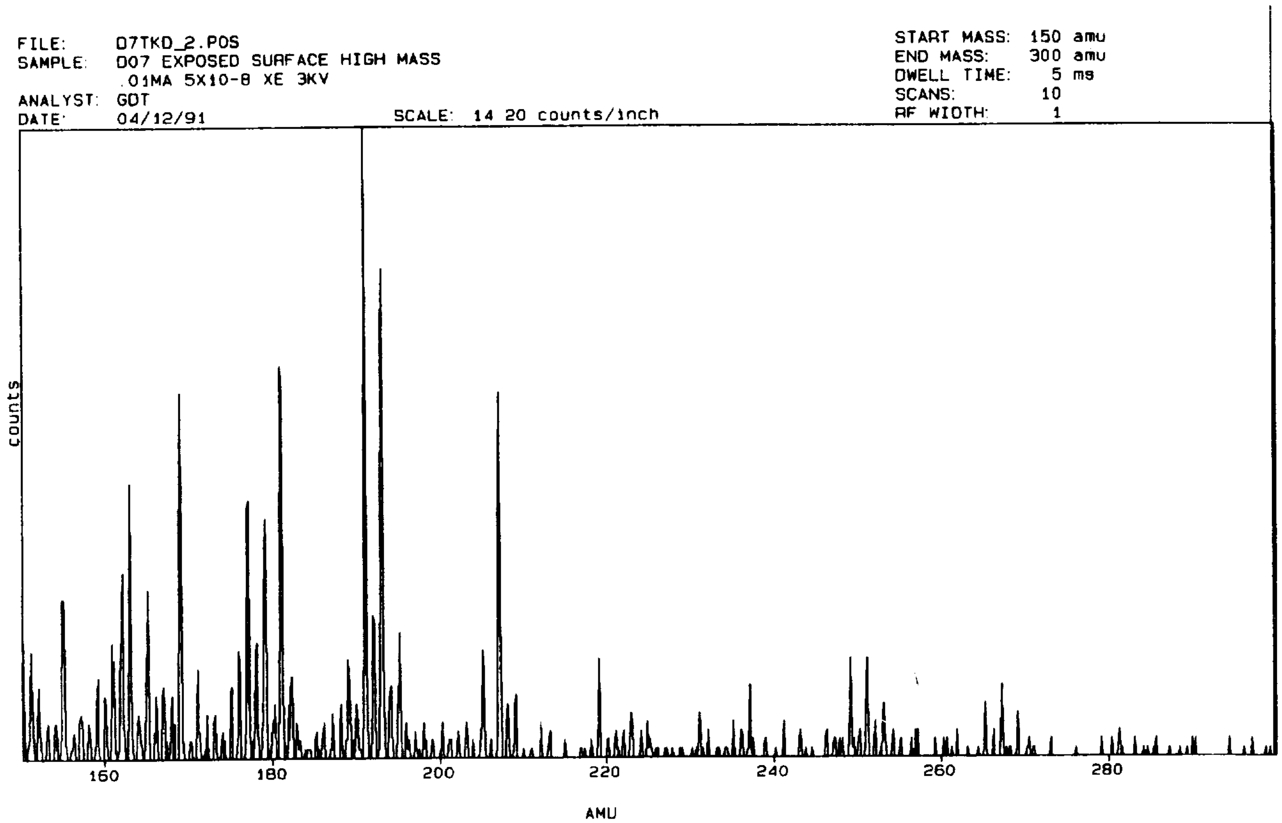
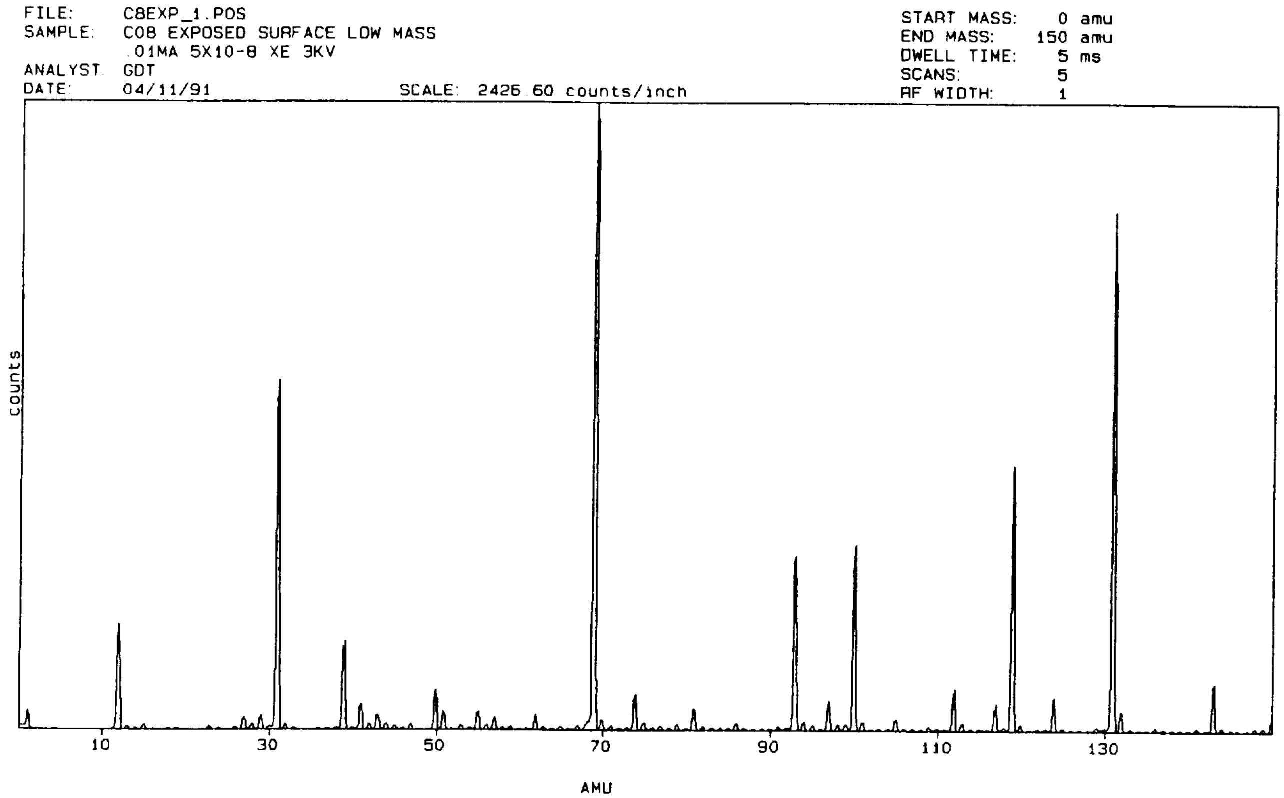


Figure D-22. Secondary Ion Mass Spectra, ~~0-150 amu And~~ 150-300 amu Ranges, For Exposed Area For Blanket D07, Expanded Scale.



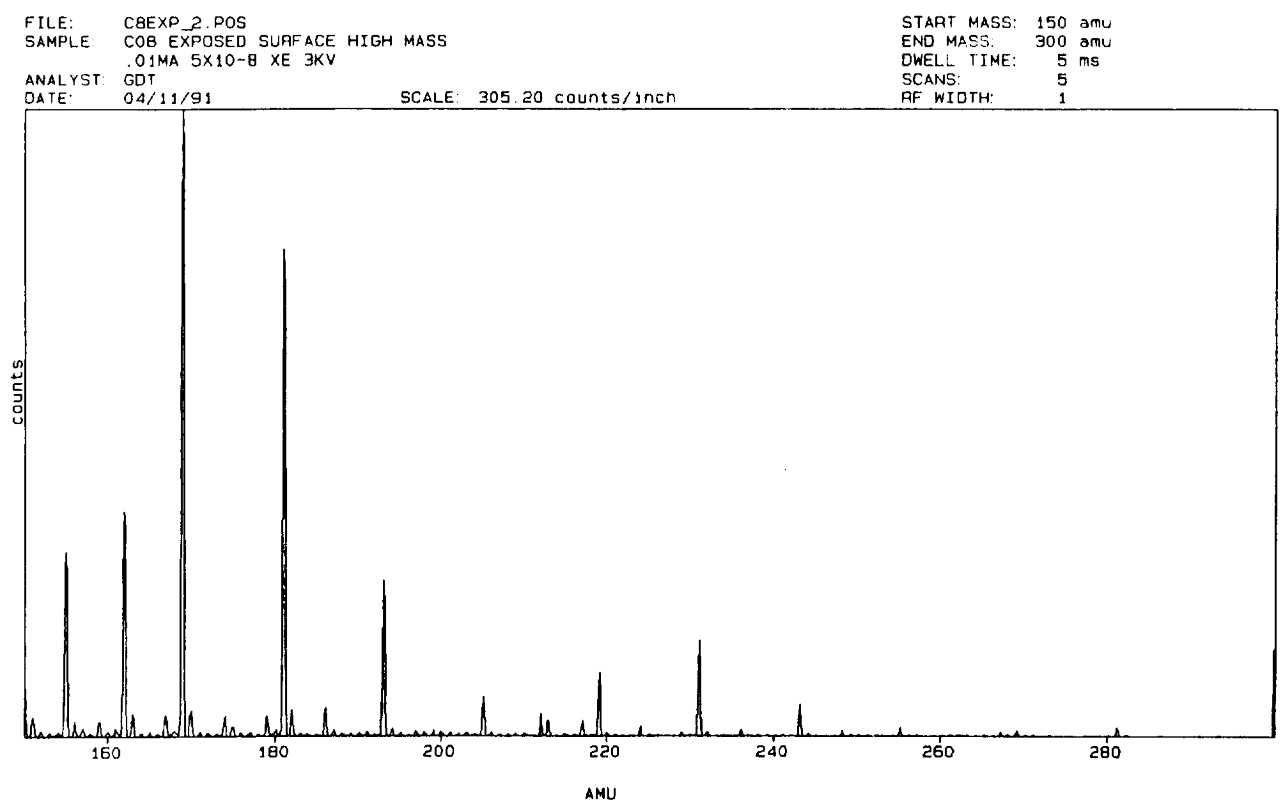
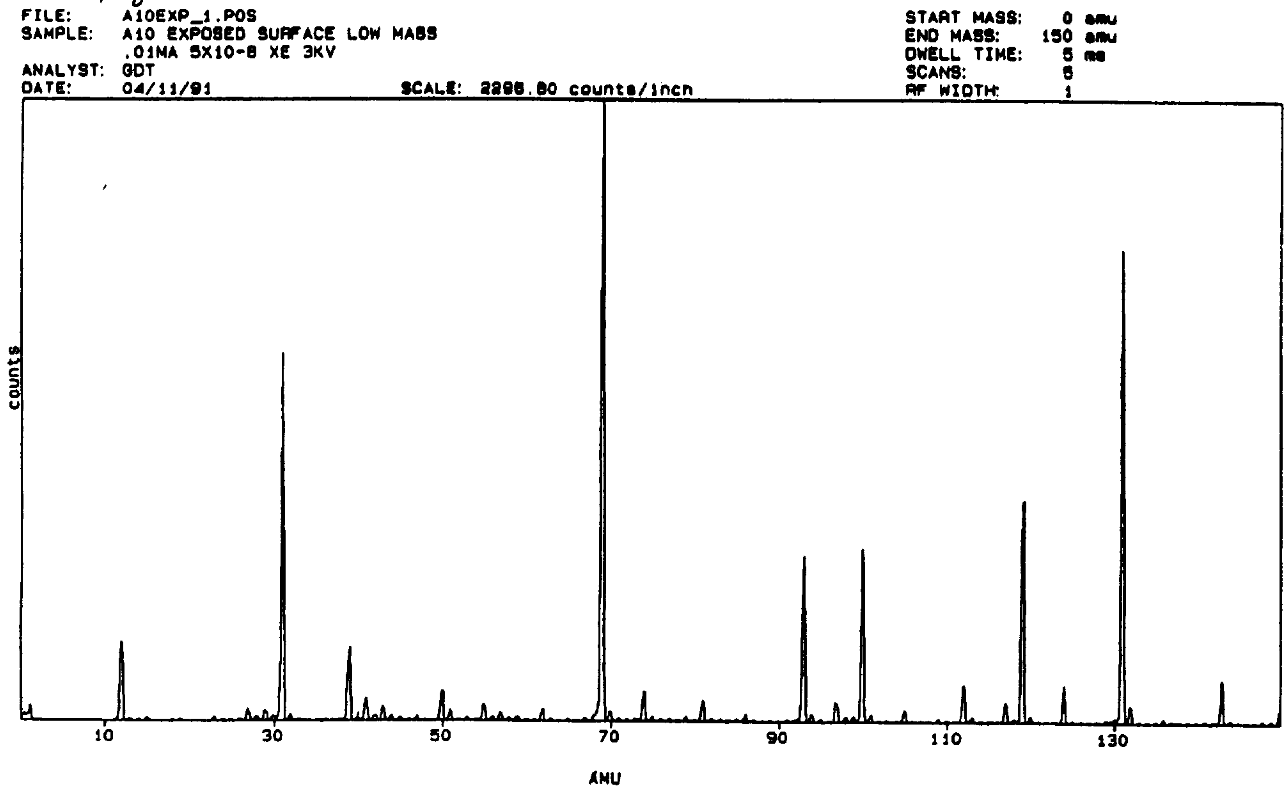


Figure D-23. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket C08.

Figure 4



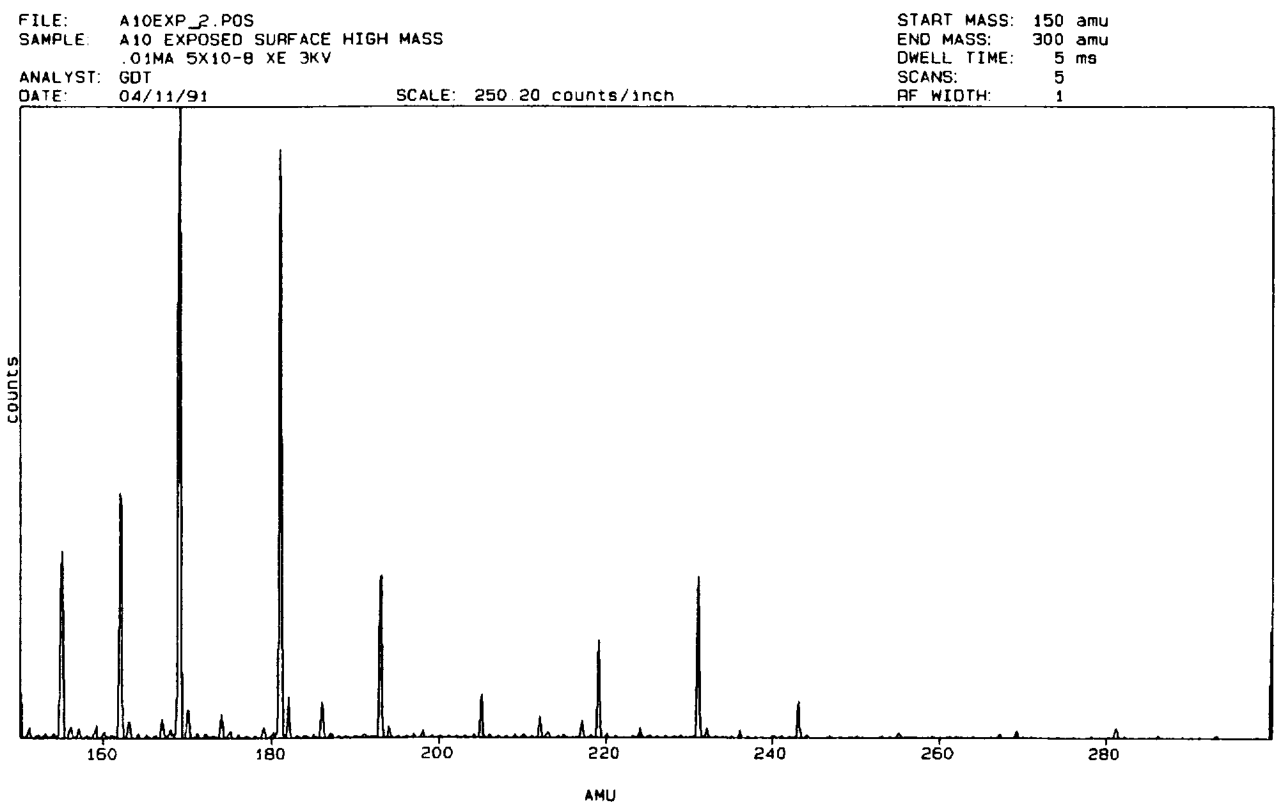
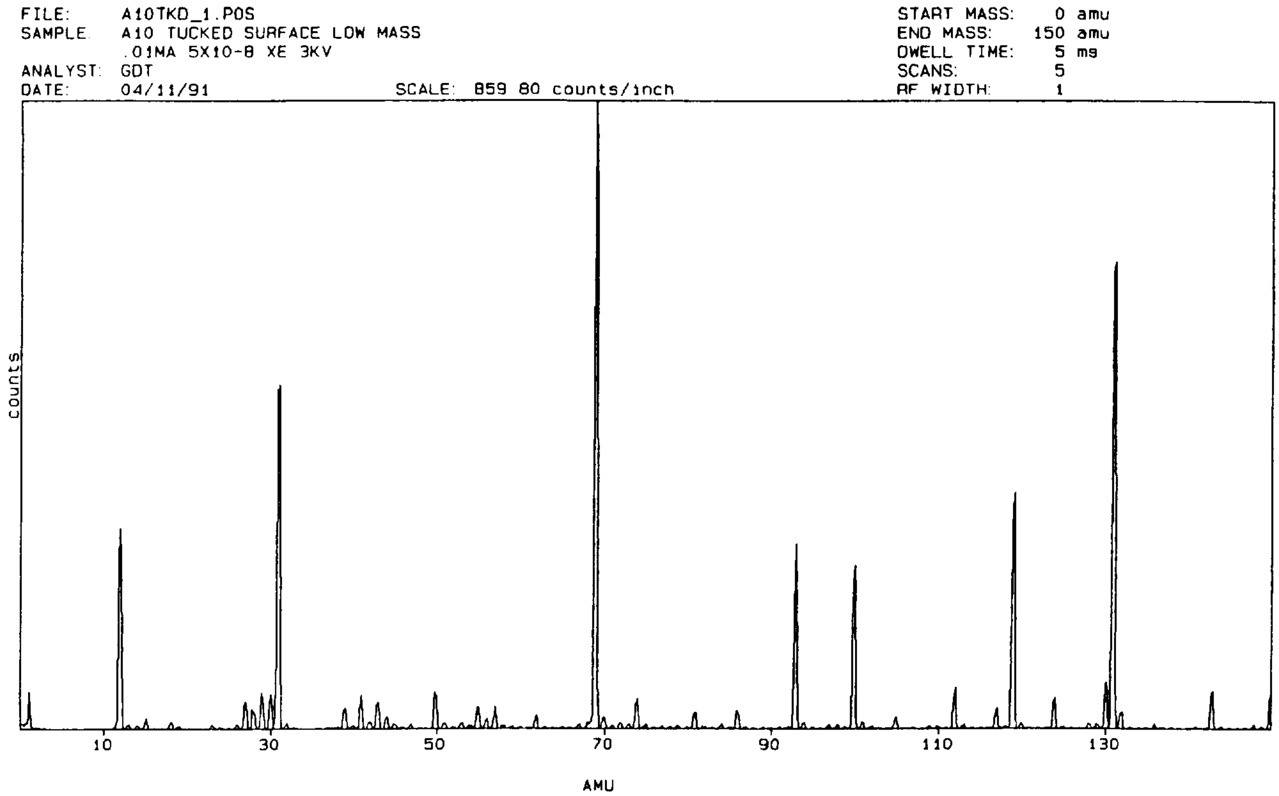


Figure D-24. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket A10.



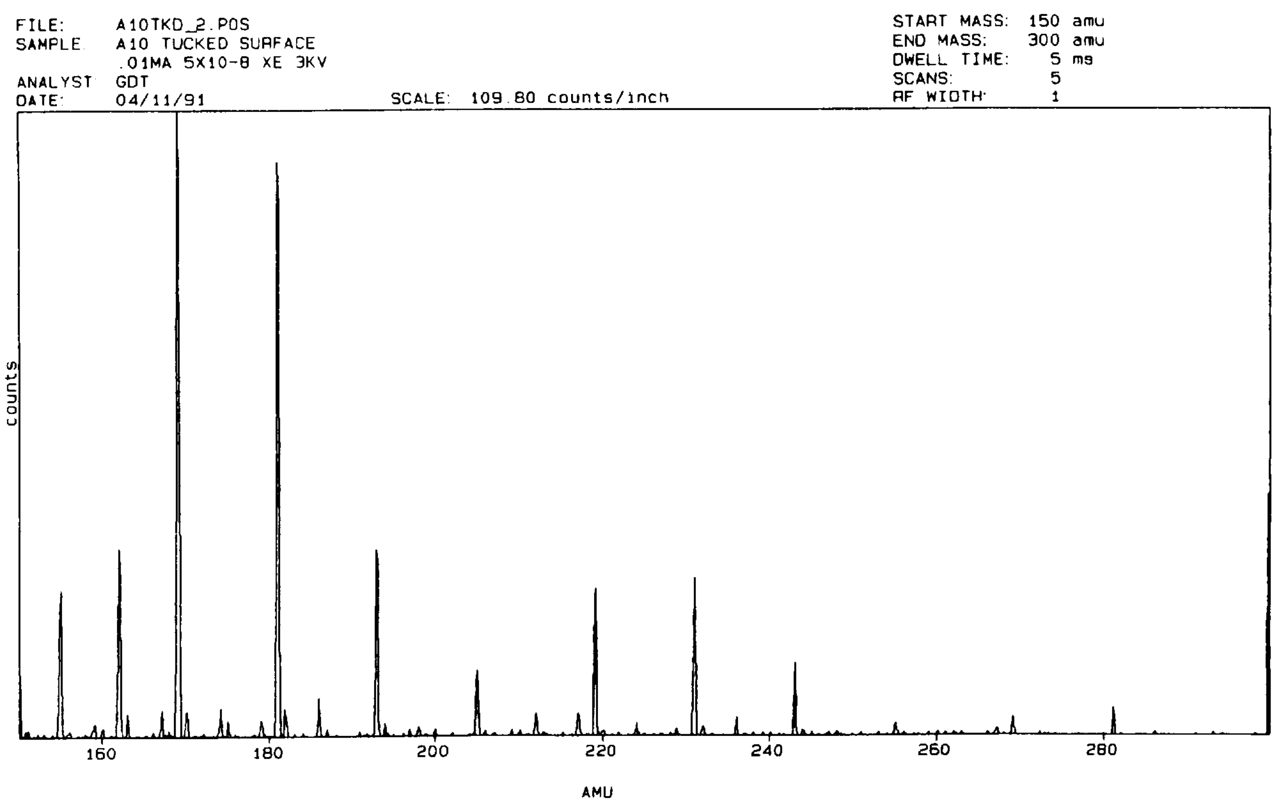


Figure D-25. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket A10.

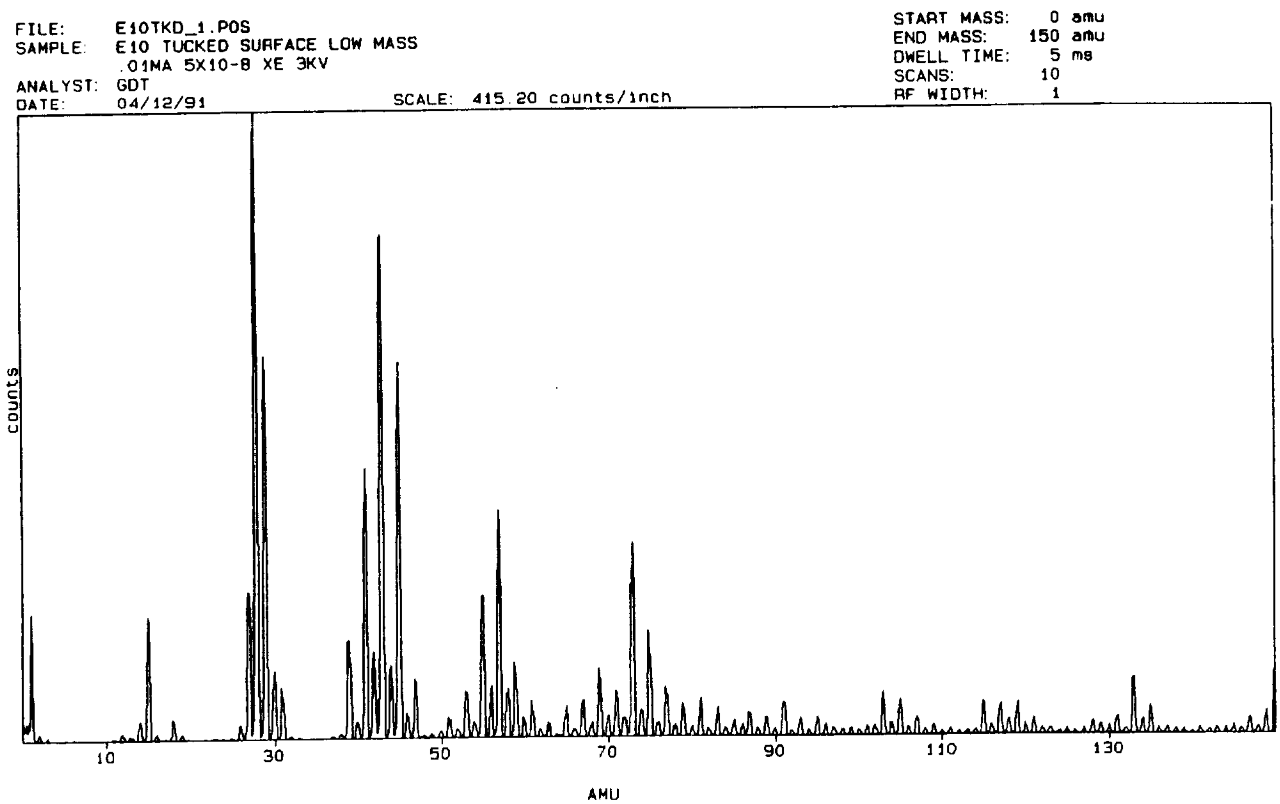
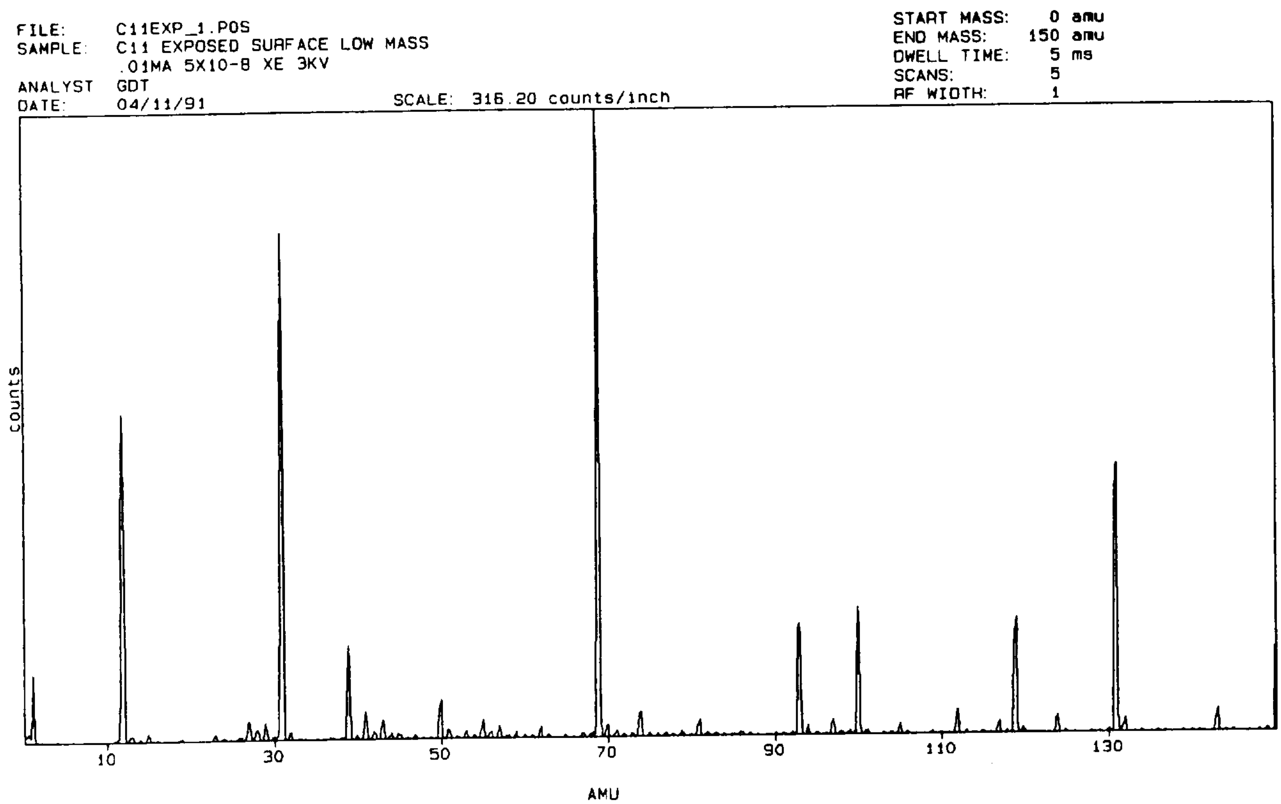


Figure D-26. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket E10.



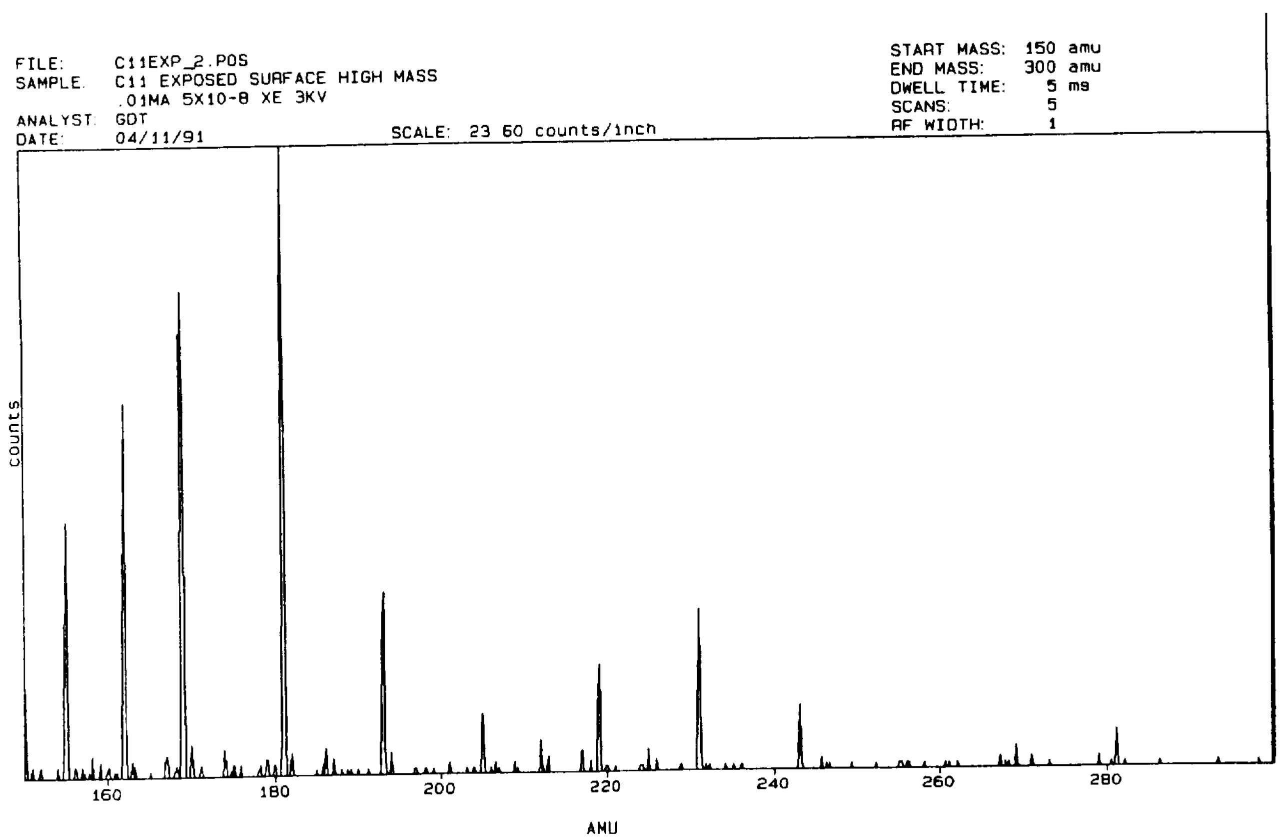
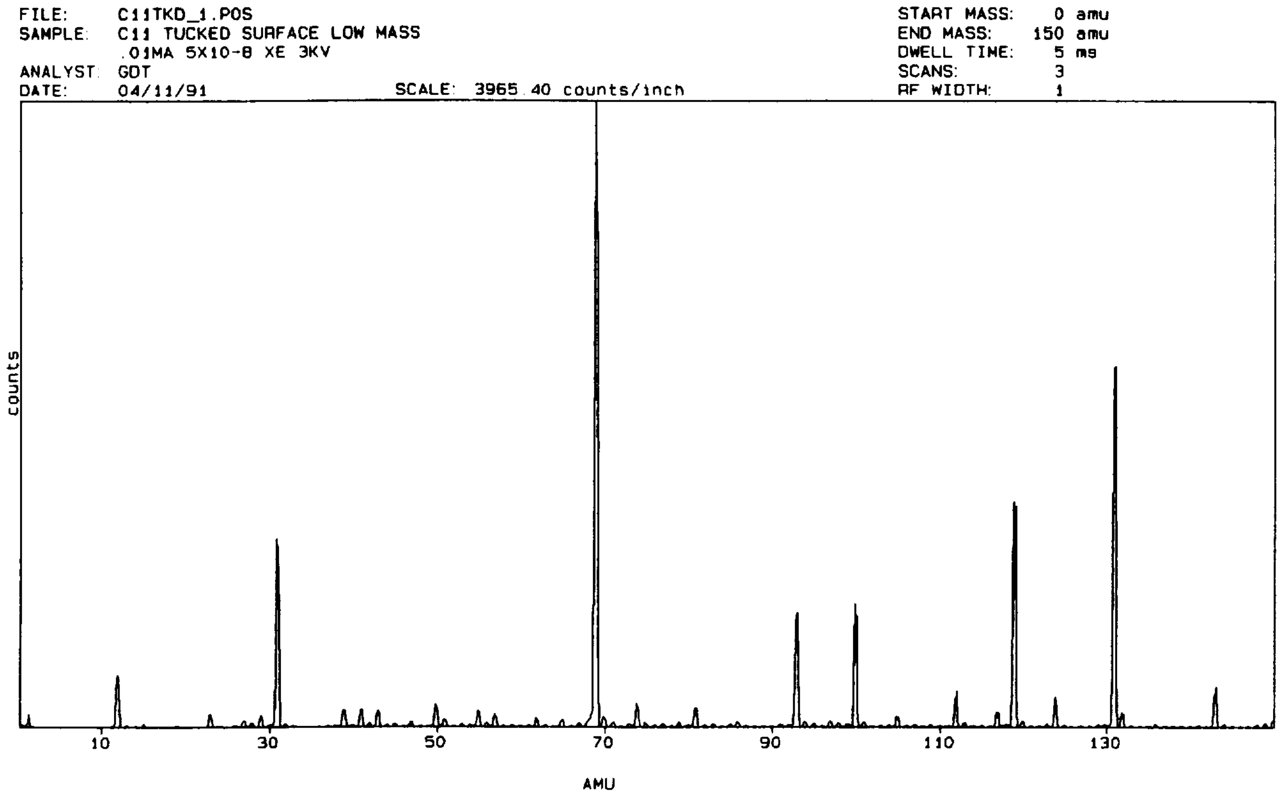


Figure D-27. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket C11.



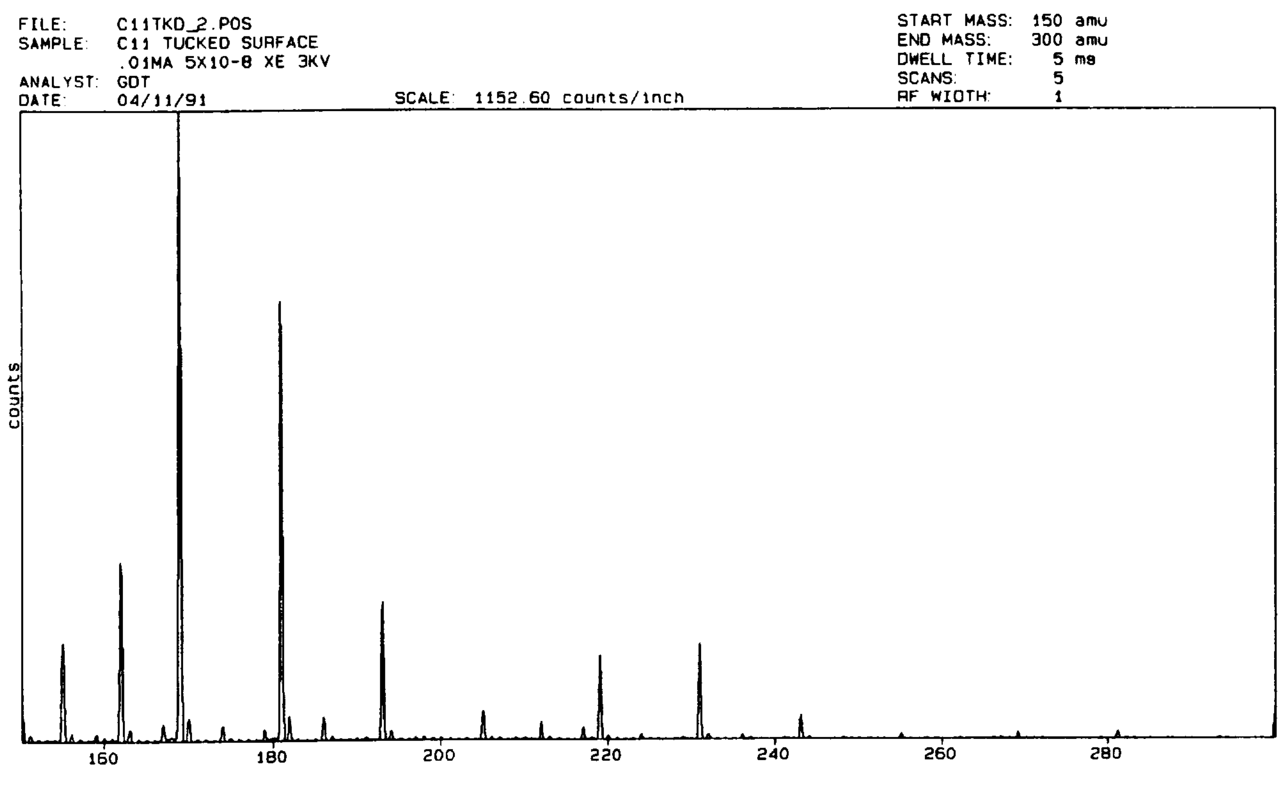
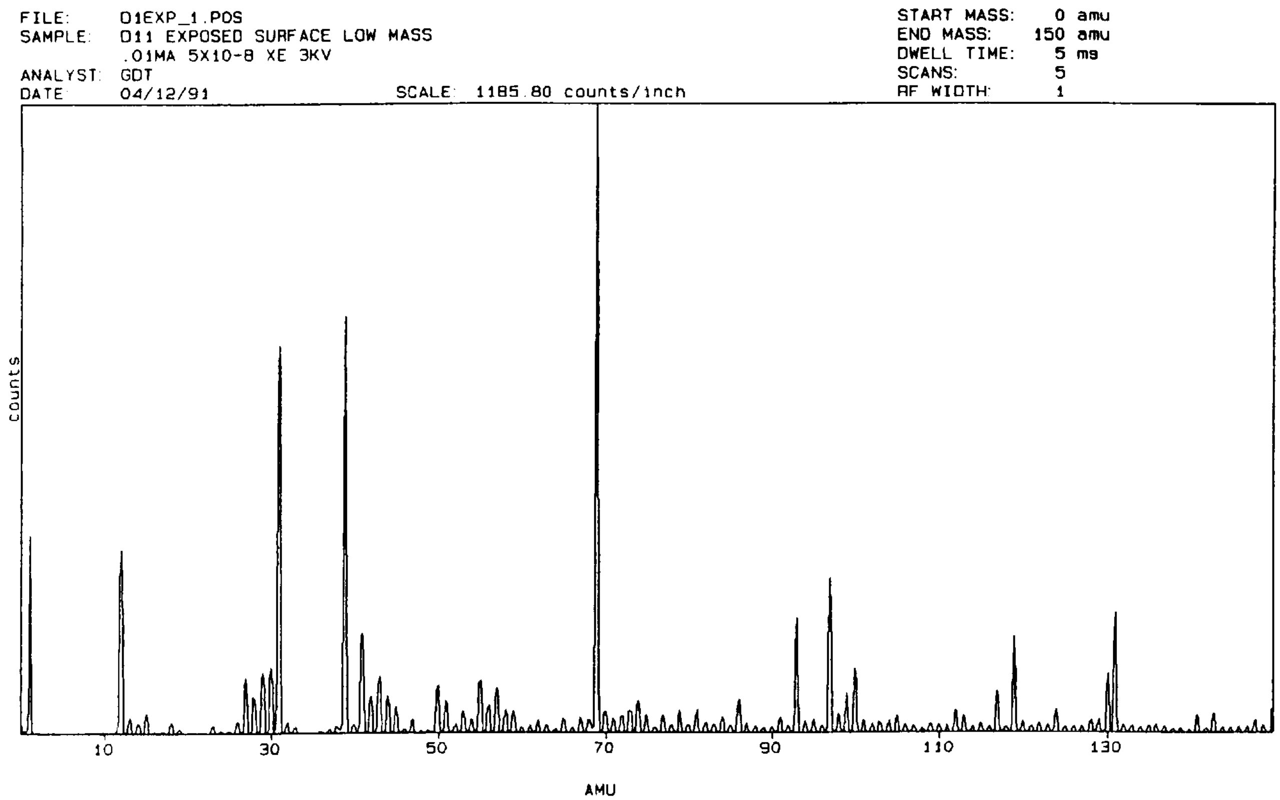


Figure D-28. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket C11.



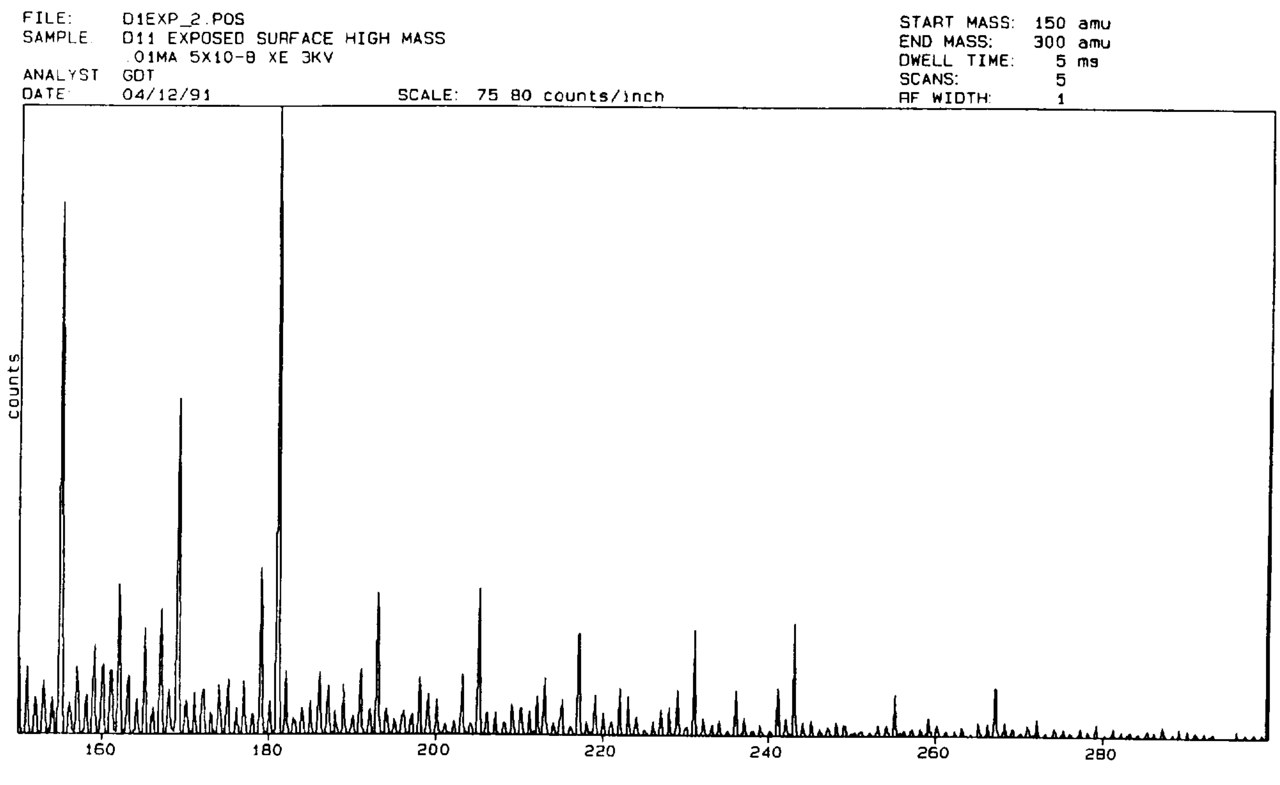
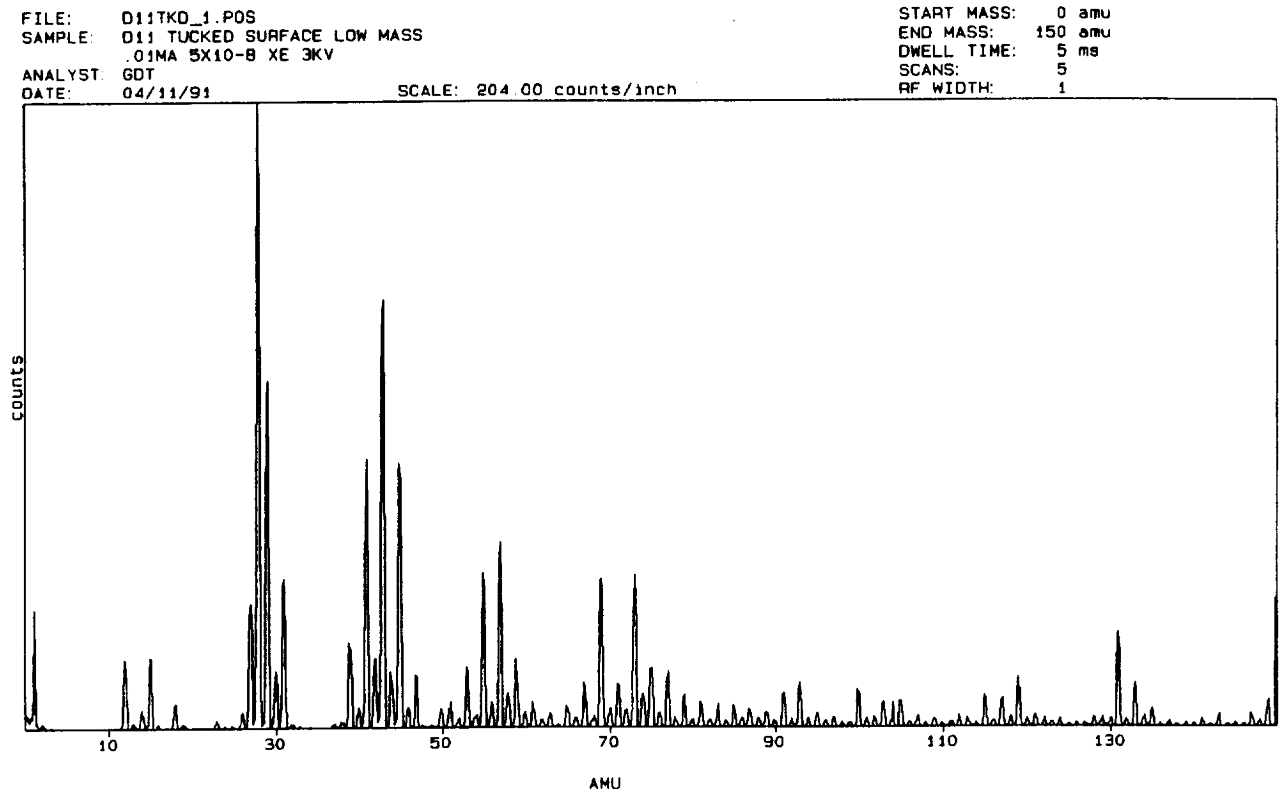


Figure D-29. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket D11.



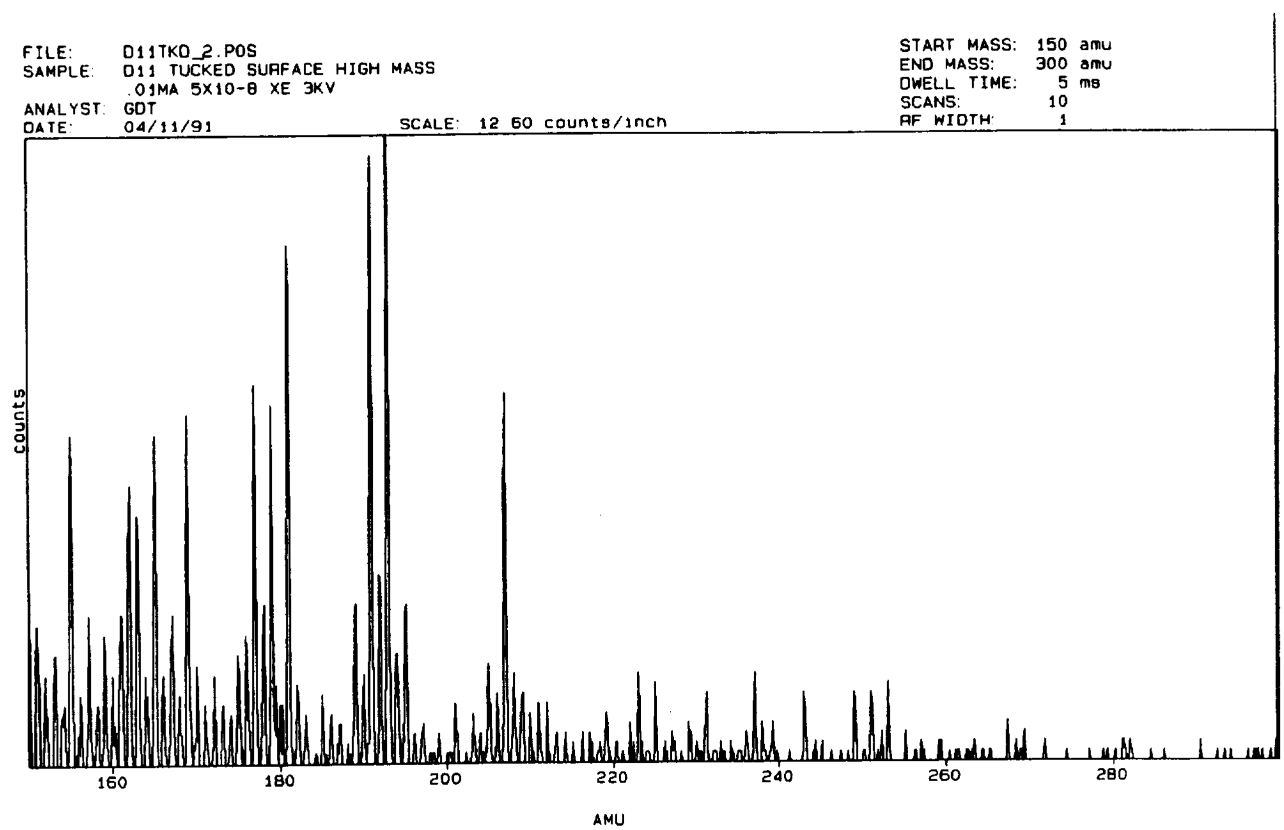
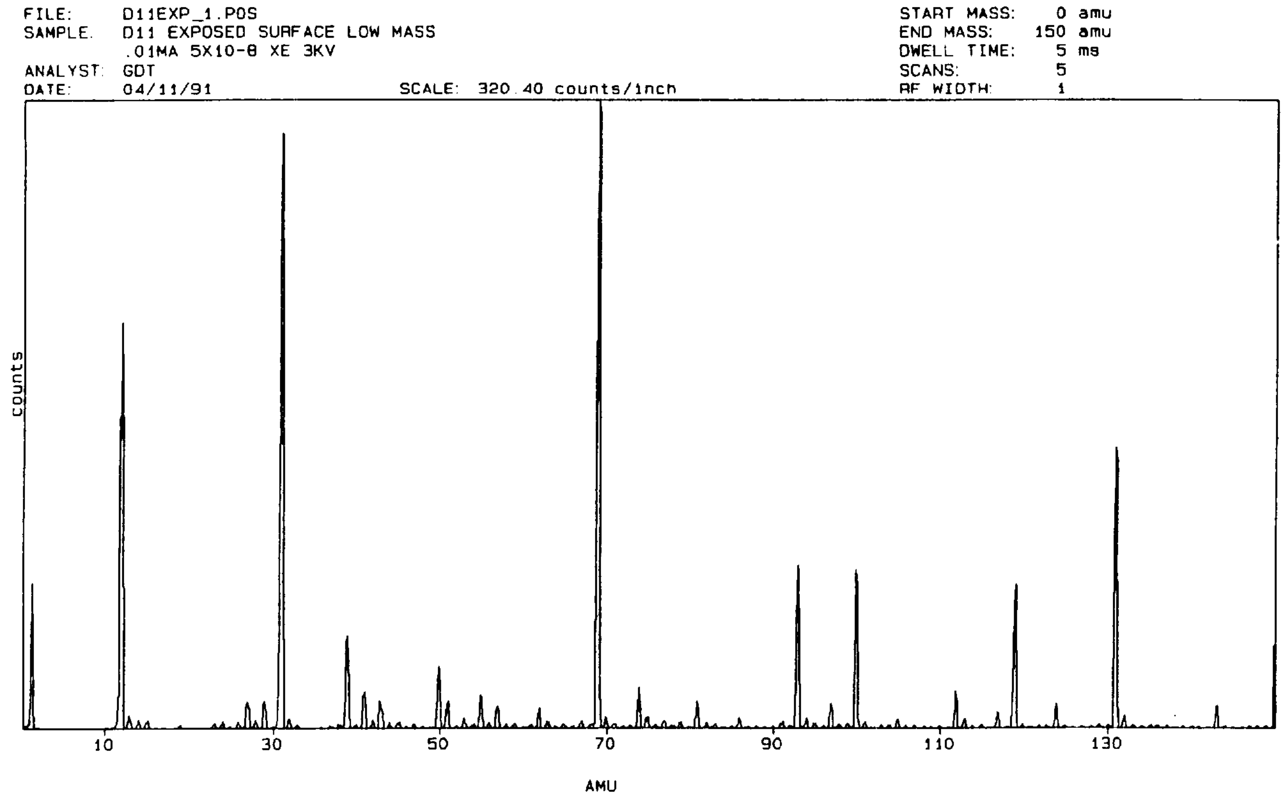


Figure D-30. *Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket D11.*



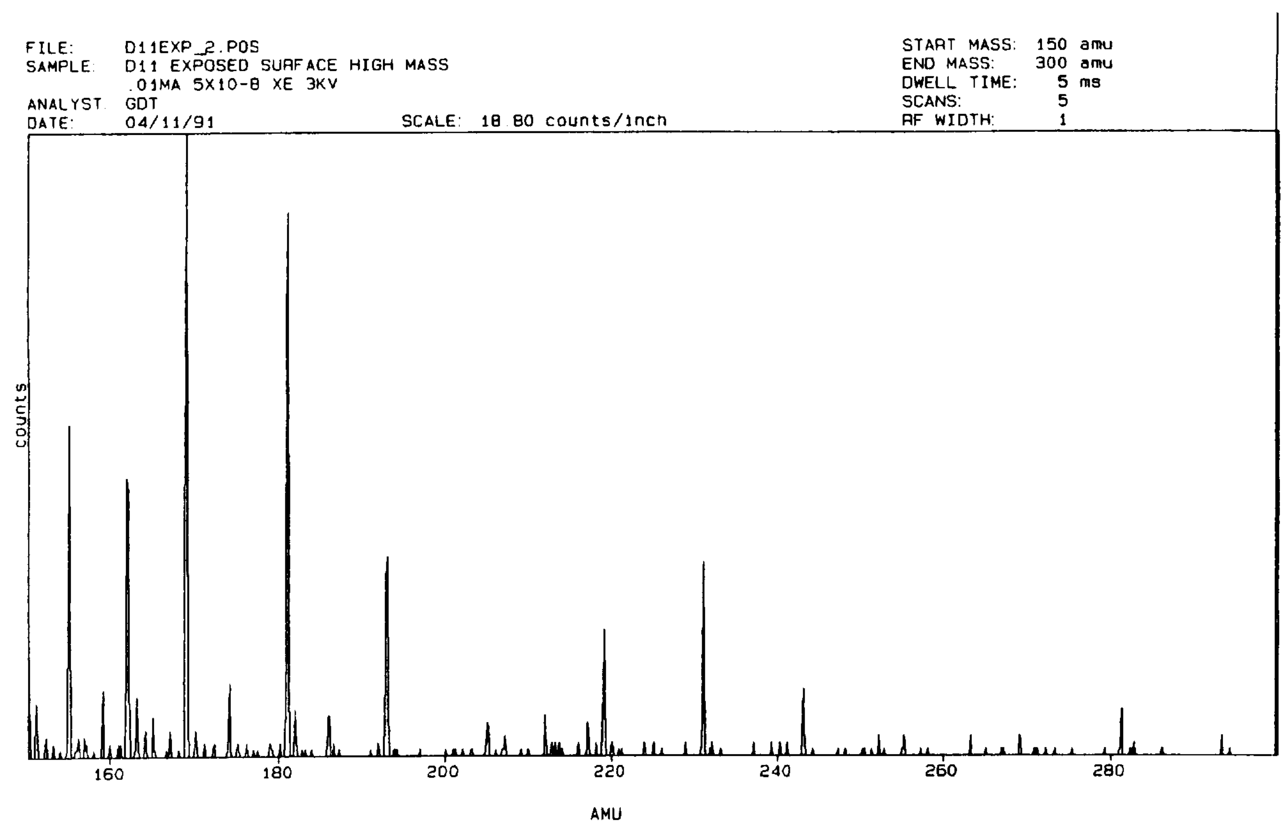
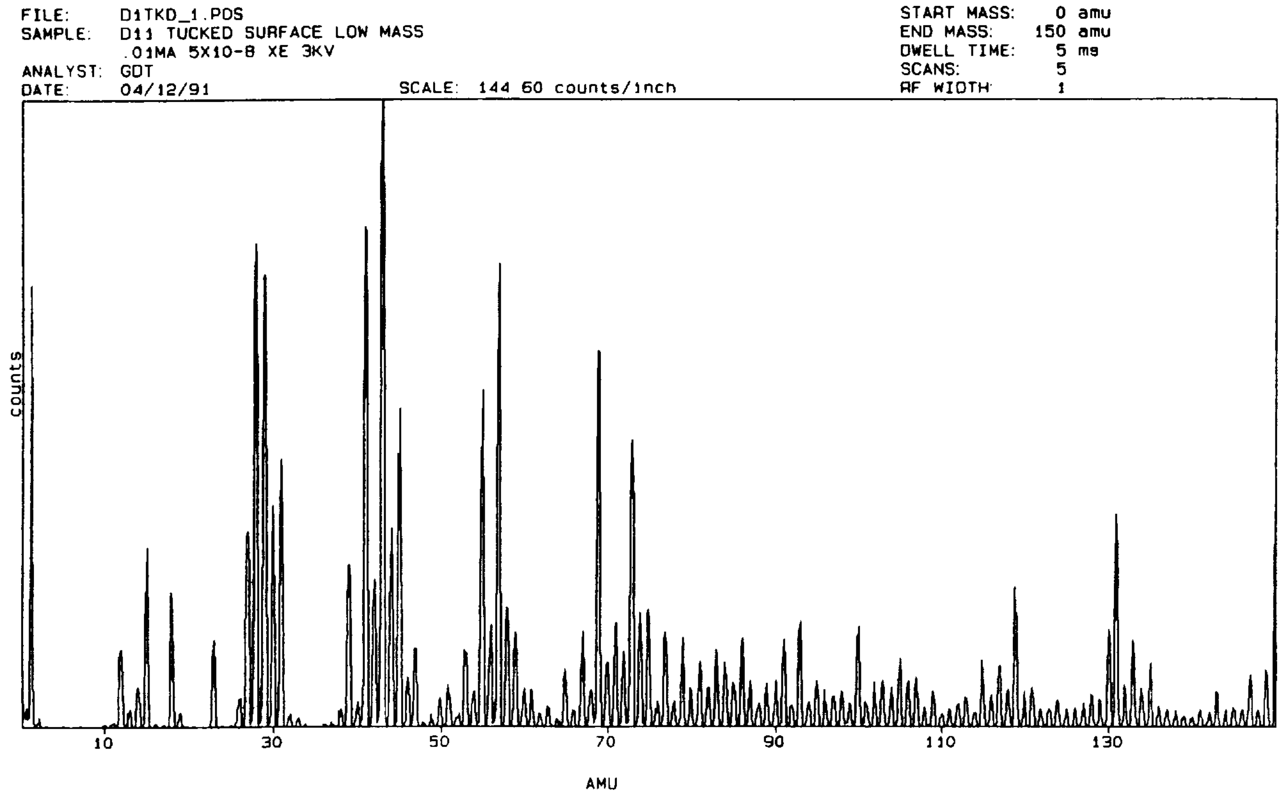


Figure D-31. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Exposed Area For Blanket D11, Expanded Scale.



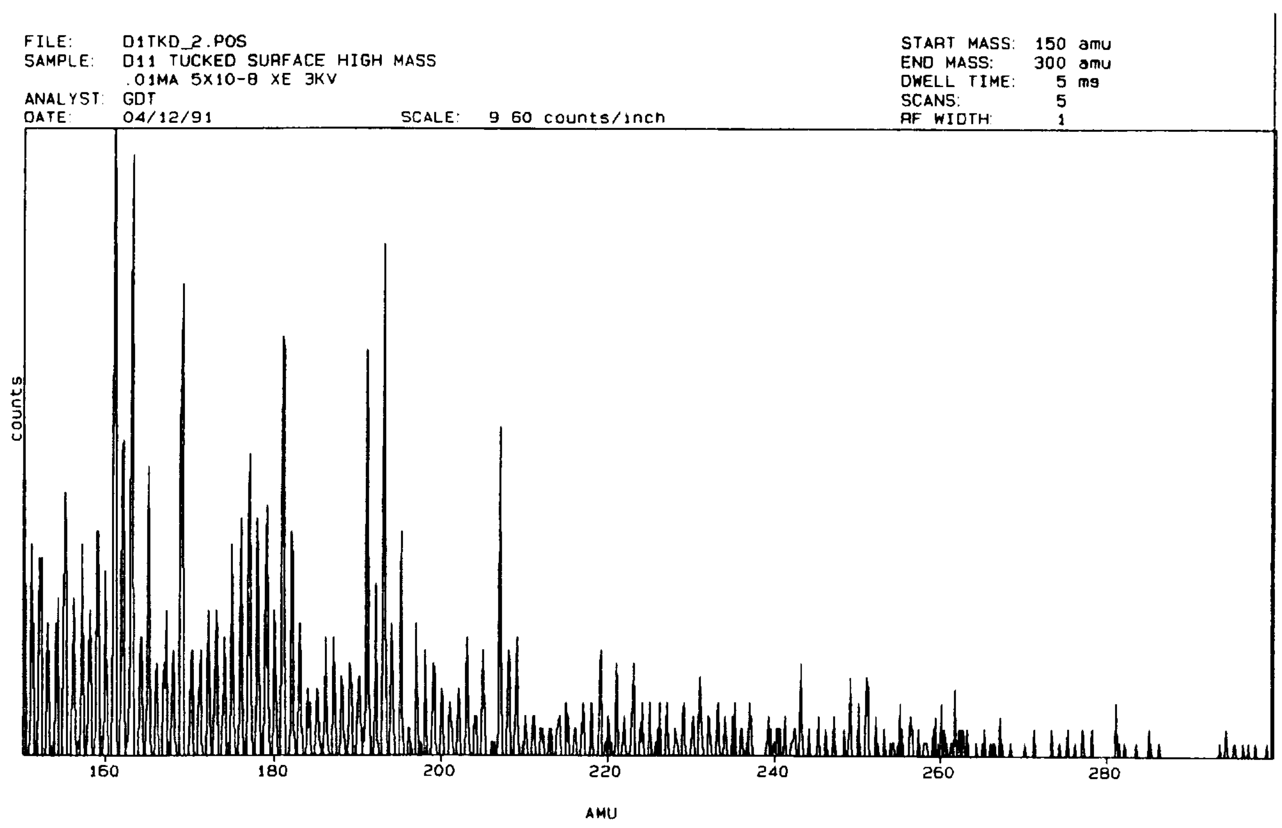


Figure D-32. Secondary Ion Mass Spectra, 0-150 amu And 150-300 amu Ranges, For Unexposed Area For Blanket D11, Expanded Scale.

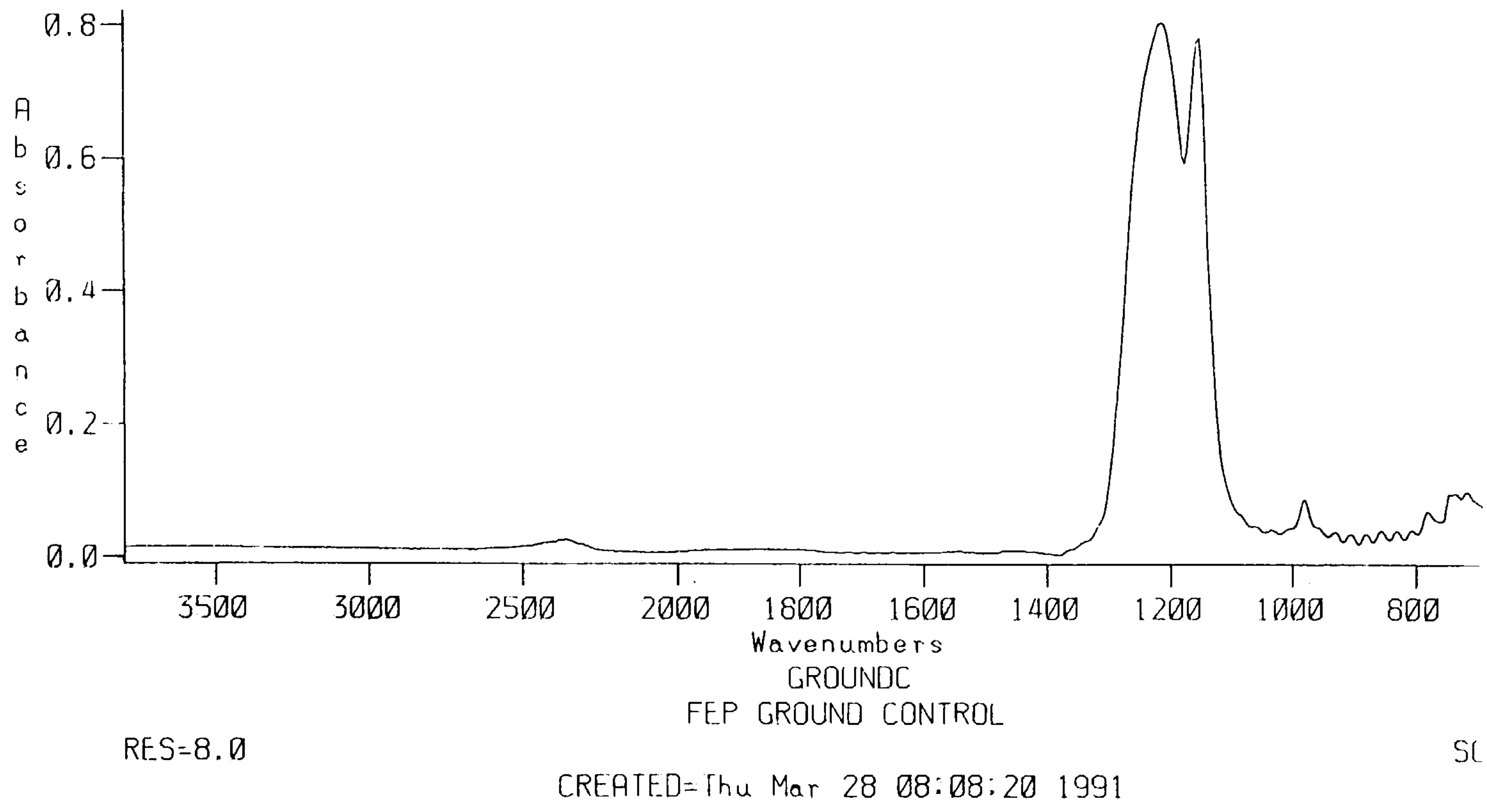


Figure D-33 Fourier Transform IR of ground control specimen.

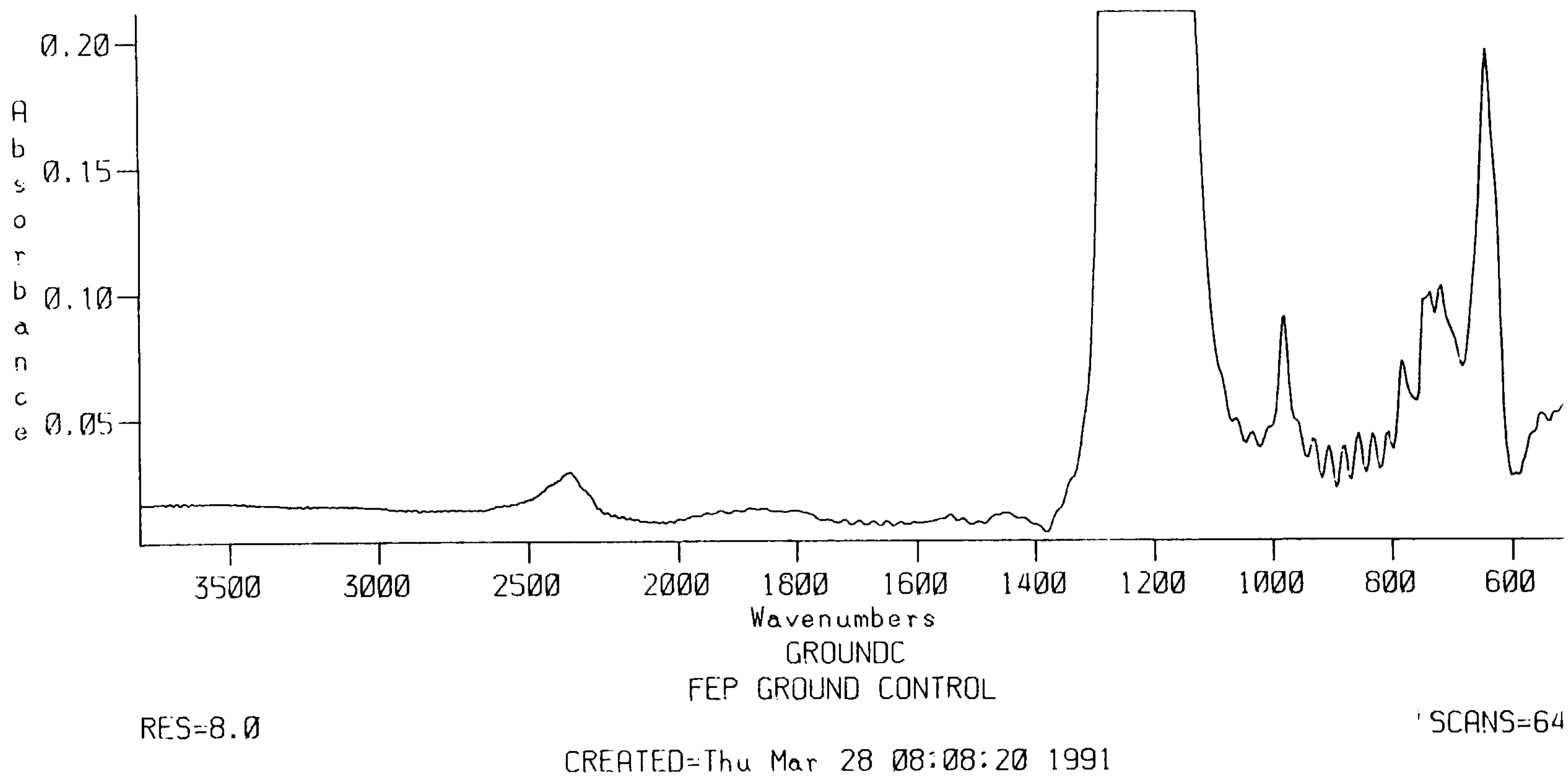


Figure D-34 Fourier Transform IR of ground control specimen, expanded scale.

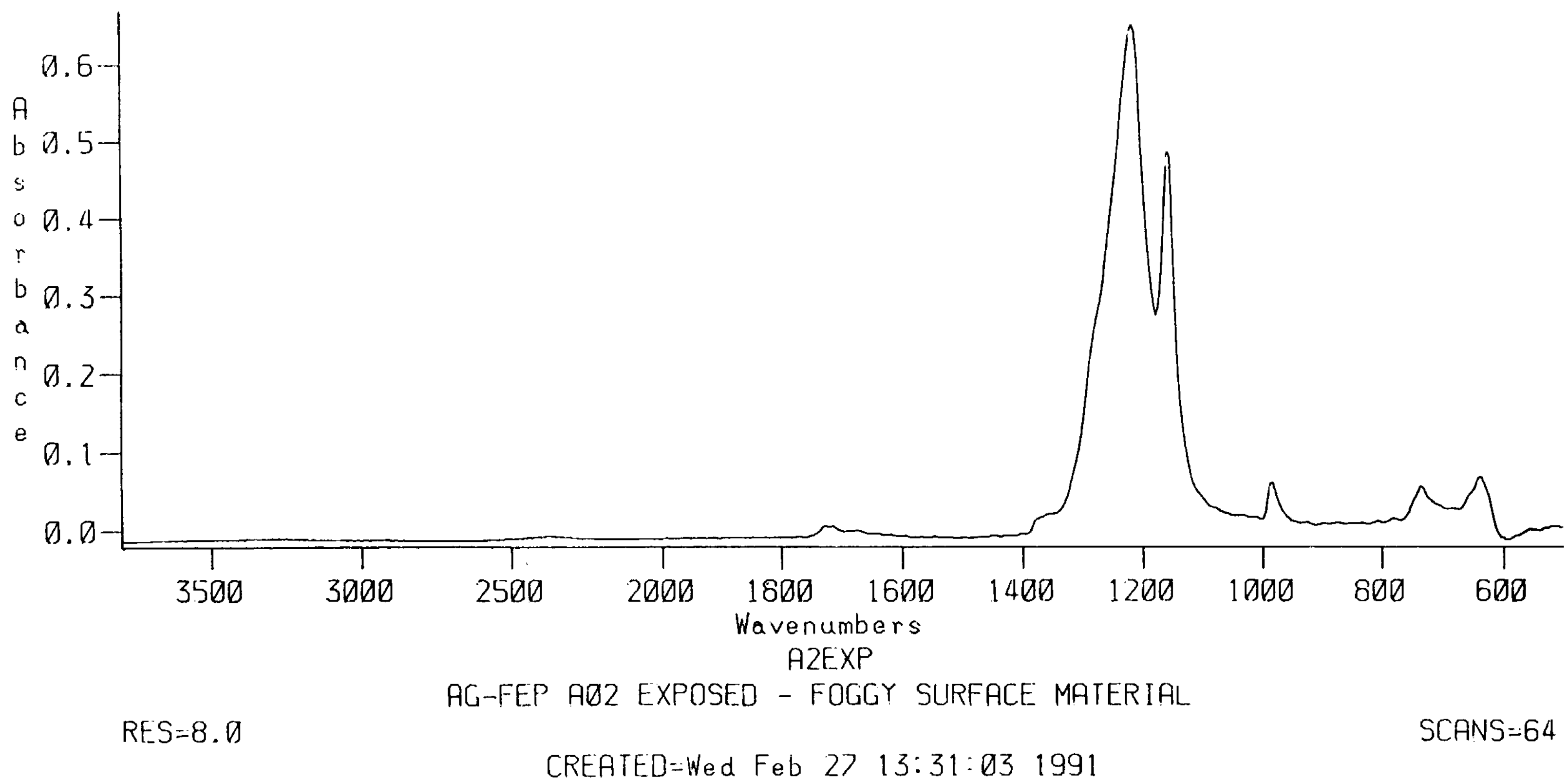


Figure D-35 Fourier Transform IR of blanket A2.

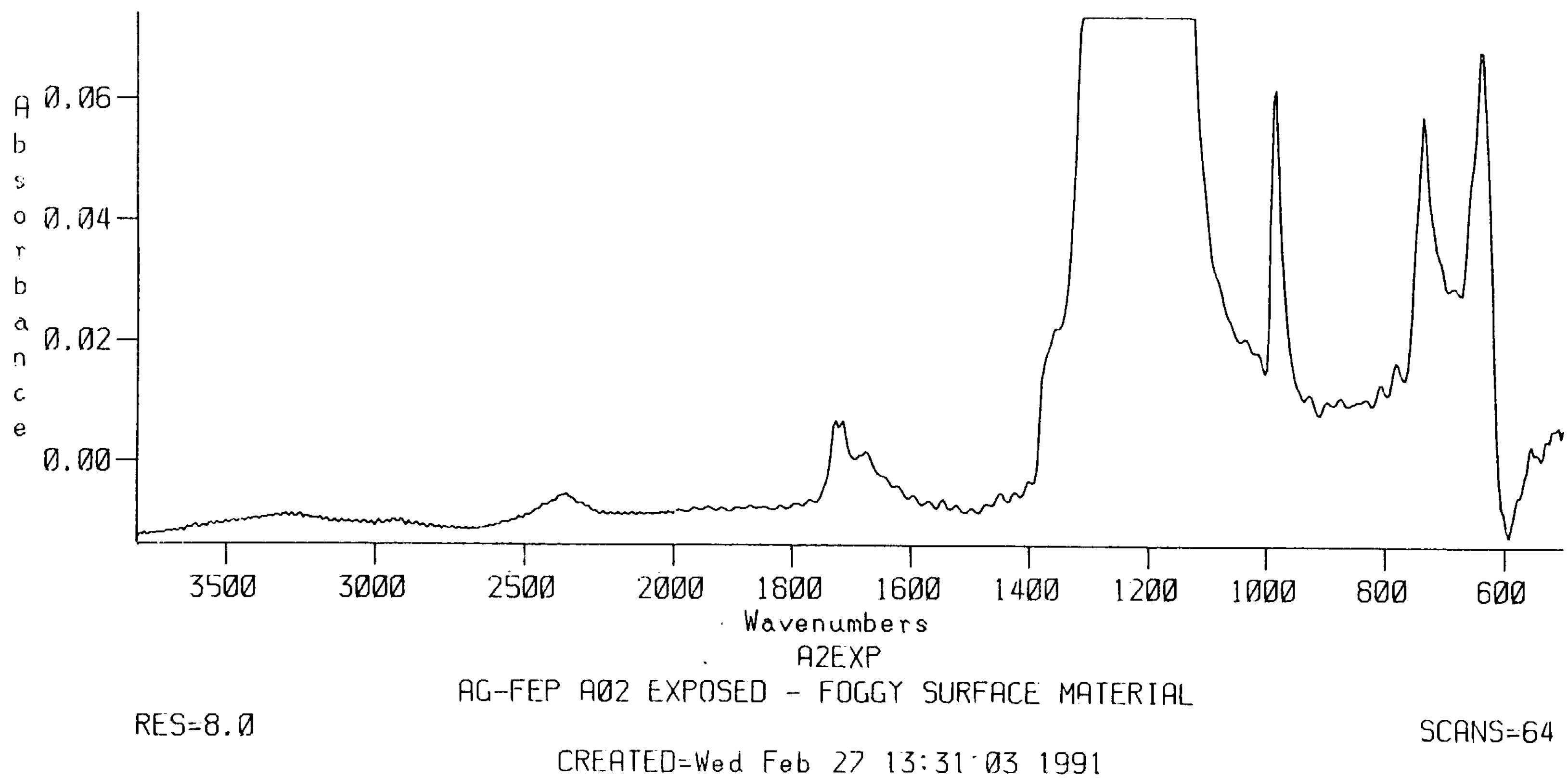


Figure D-36 Fourier Transform IR of blanket A2, expanded scale.

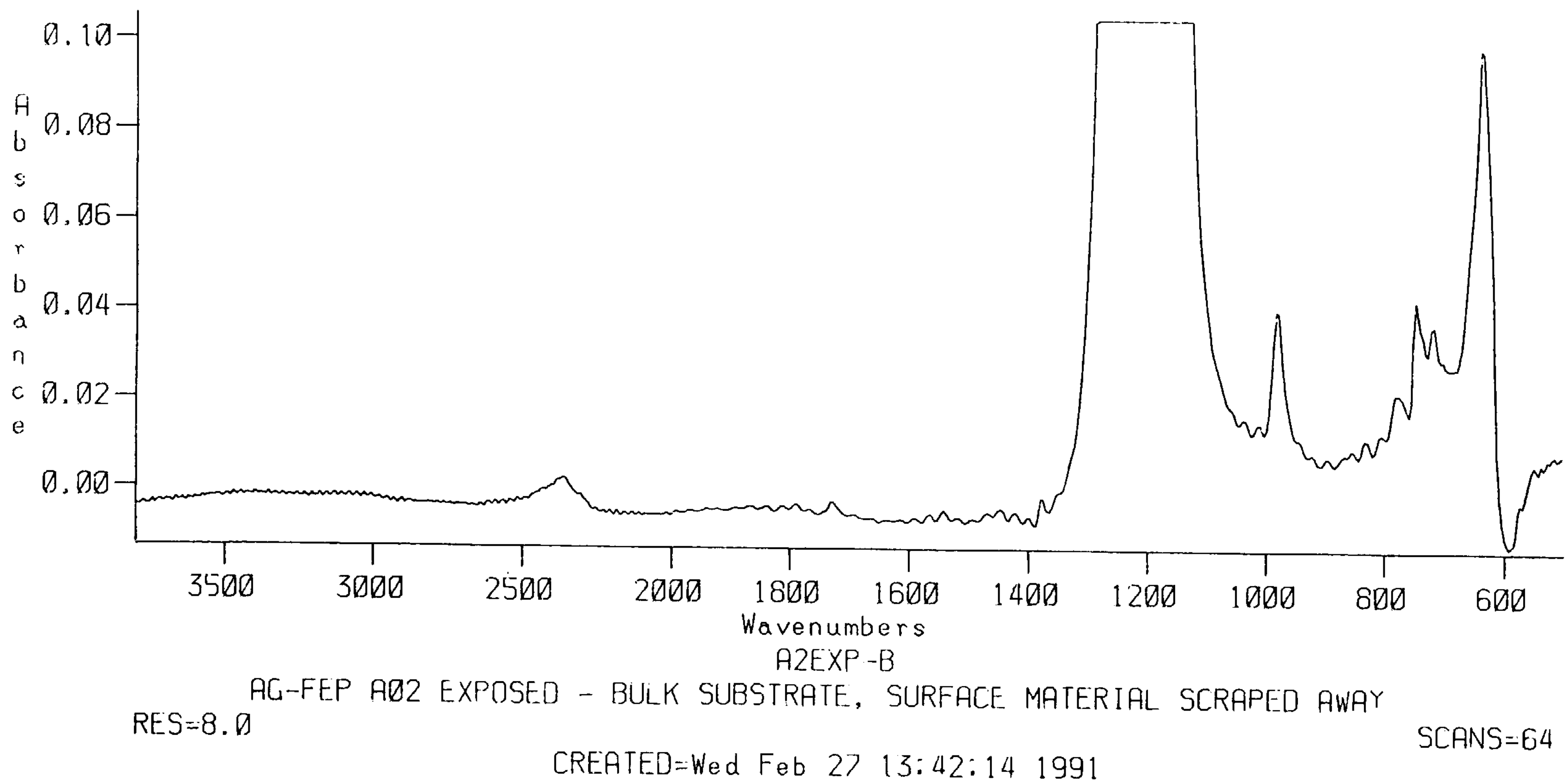


Figure D-37 Fourier Transform IR of blanket A2, bulk material, surface material removed.

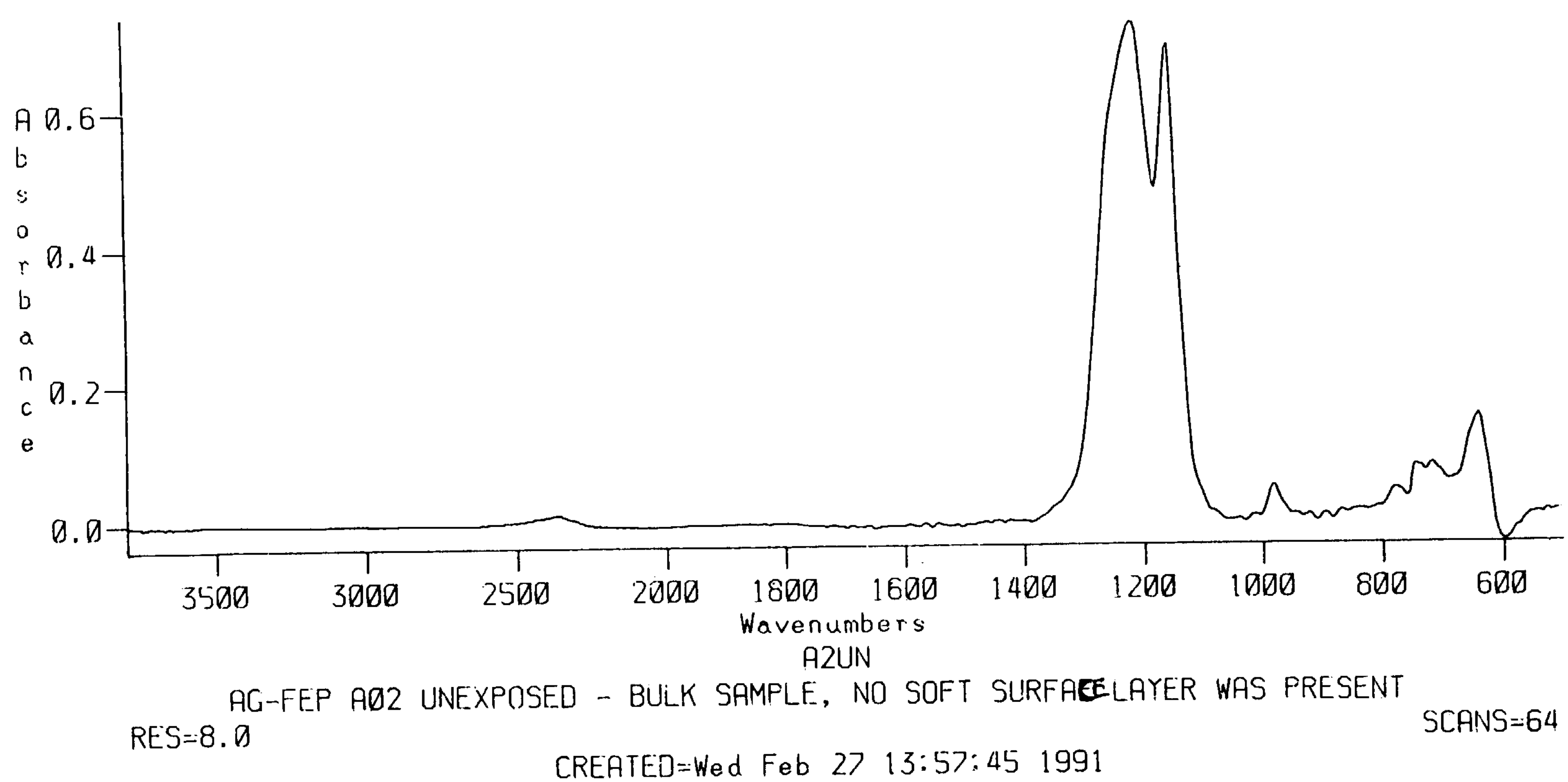


Figure D-38 Fourier Transform IR of blanket A2, unexposed area.

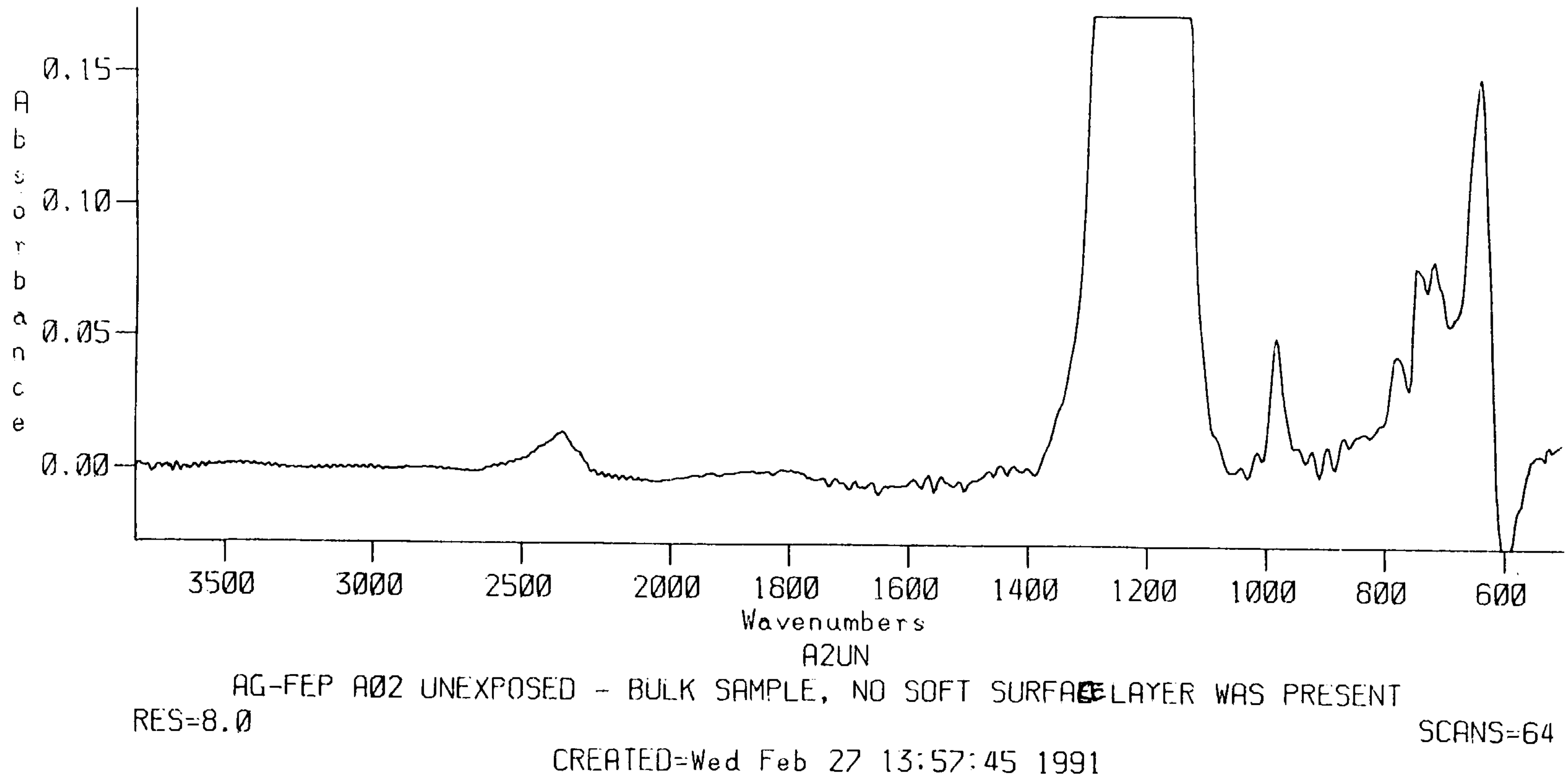


Figure D-39 Fourier Transform IR of blanket A2, unexposed area, expanded scale.

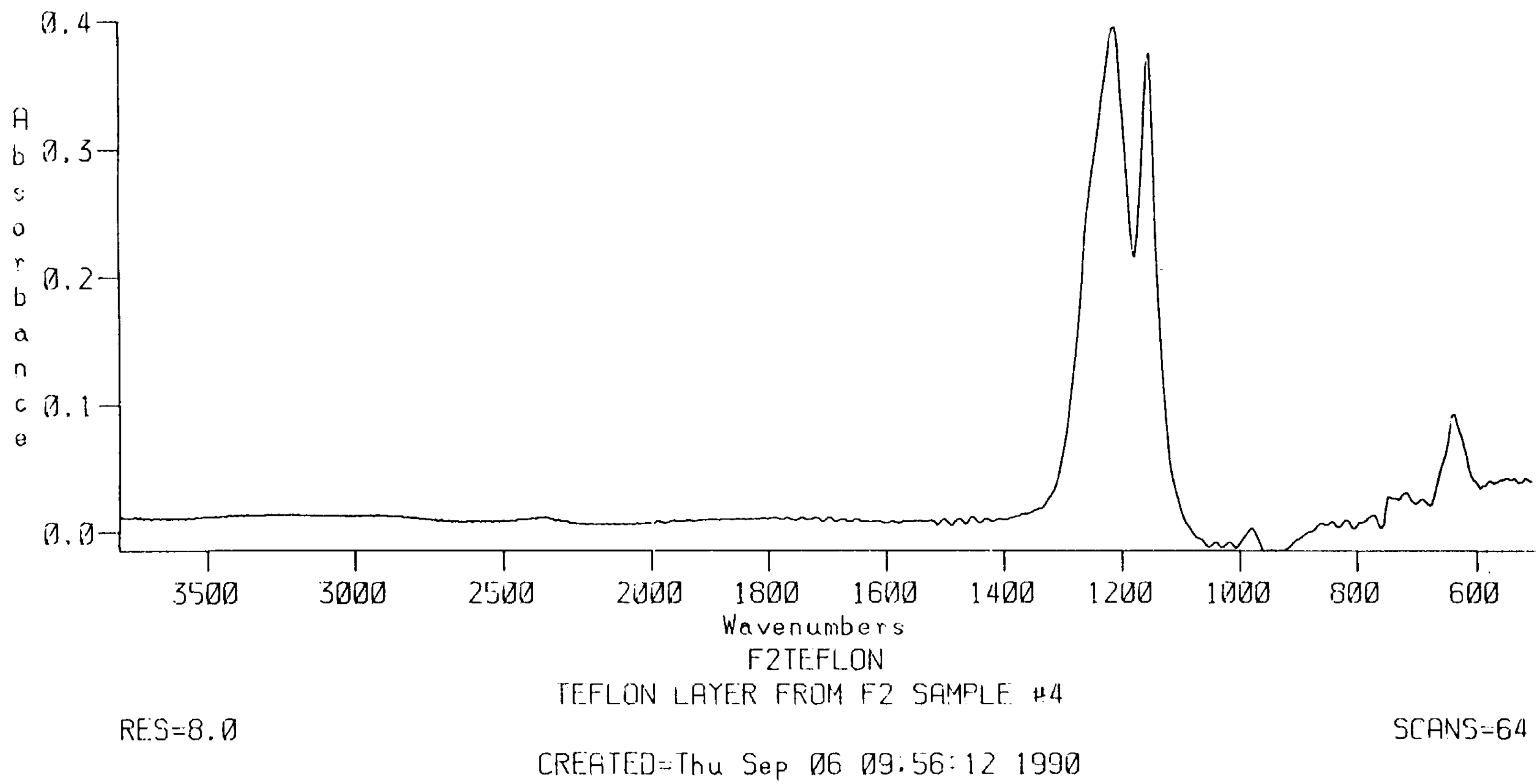


Figure D-40 Fourier Transform IR of blanket F2.

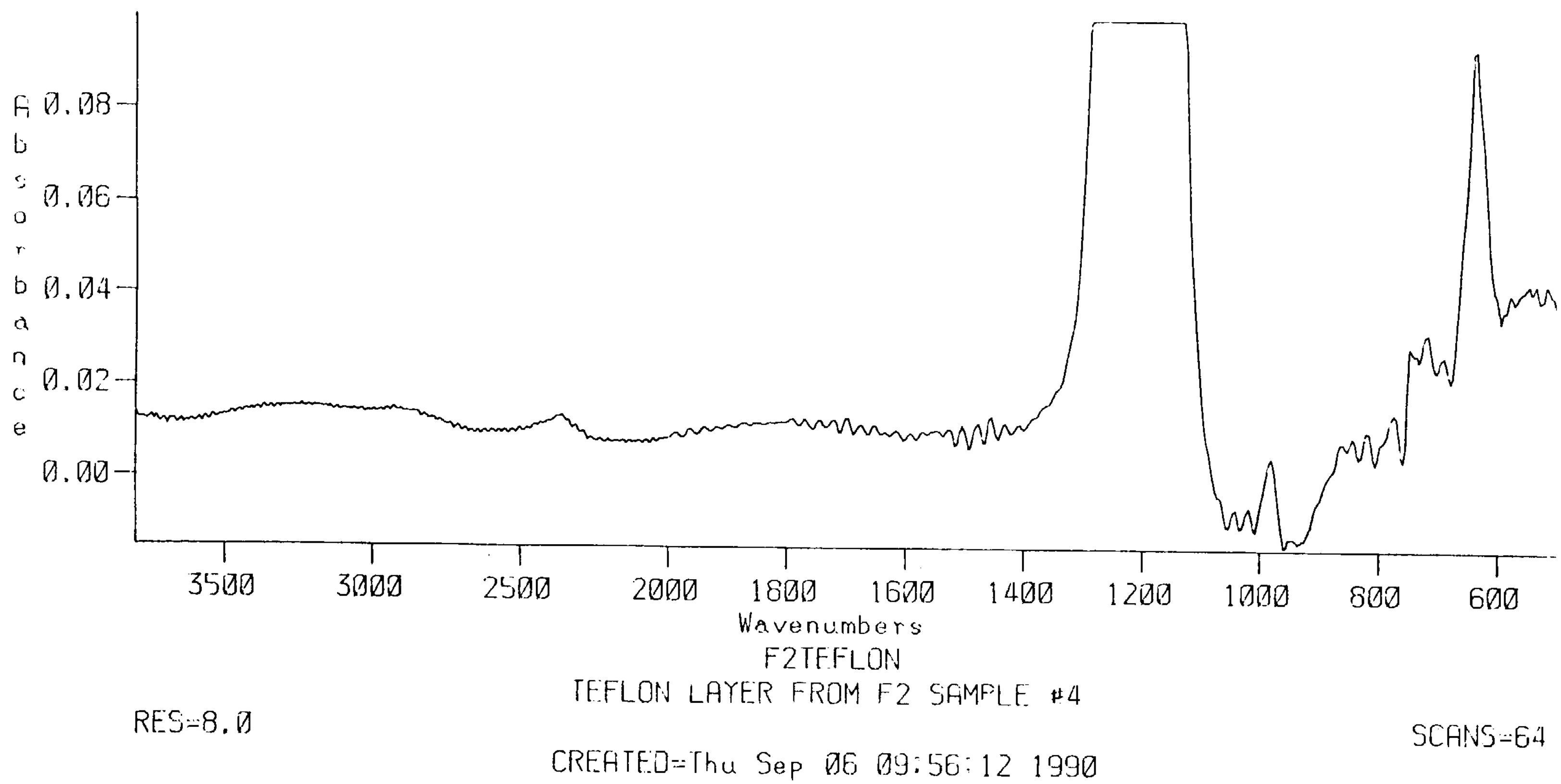


Figure D-41 Fourier Transform IR of blanket F2, expanded scale.

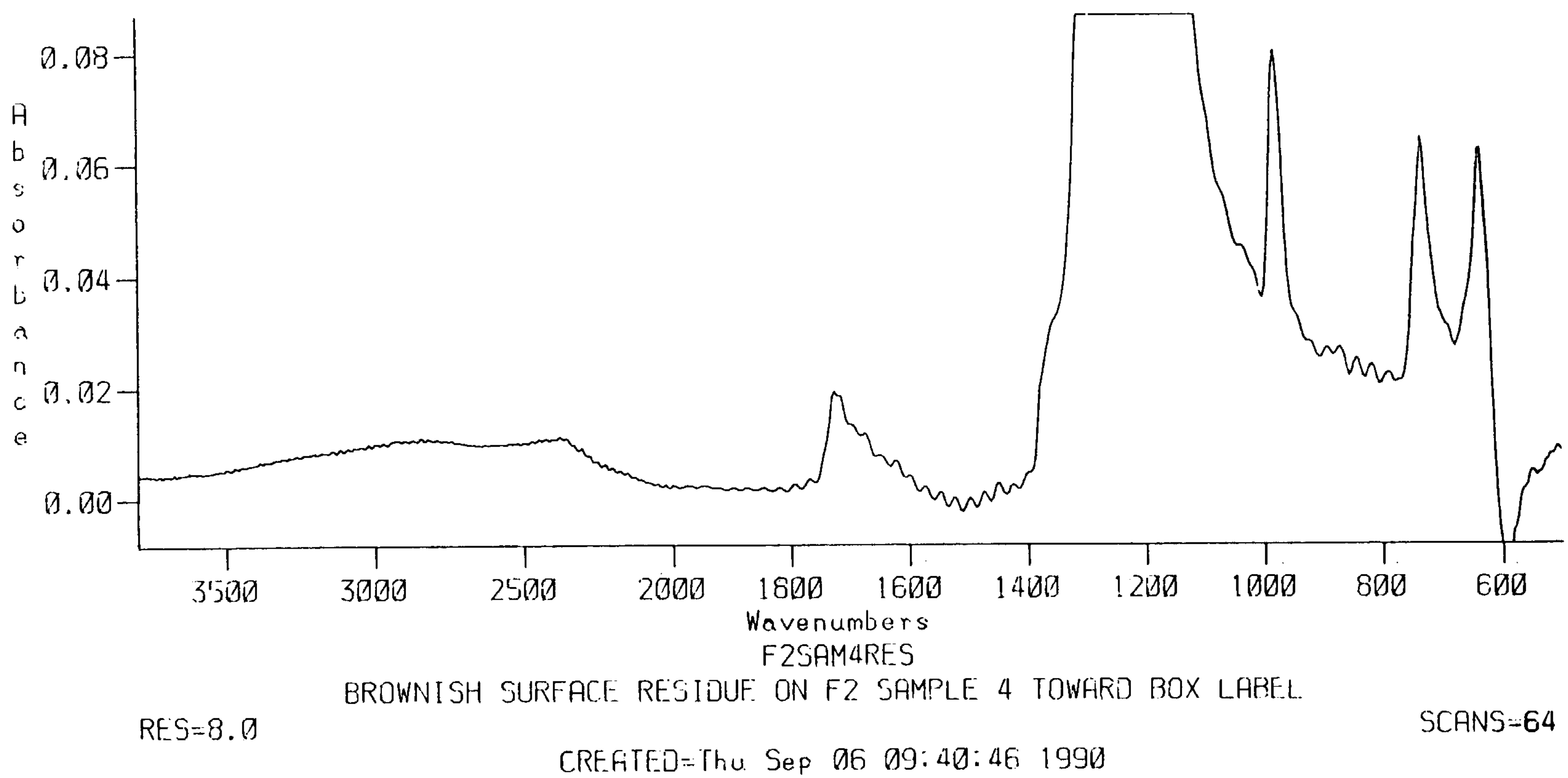


Figure D-42 Fourier Transform IR of blanket F2 sample 4, Brown contaminant deposit on surface.

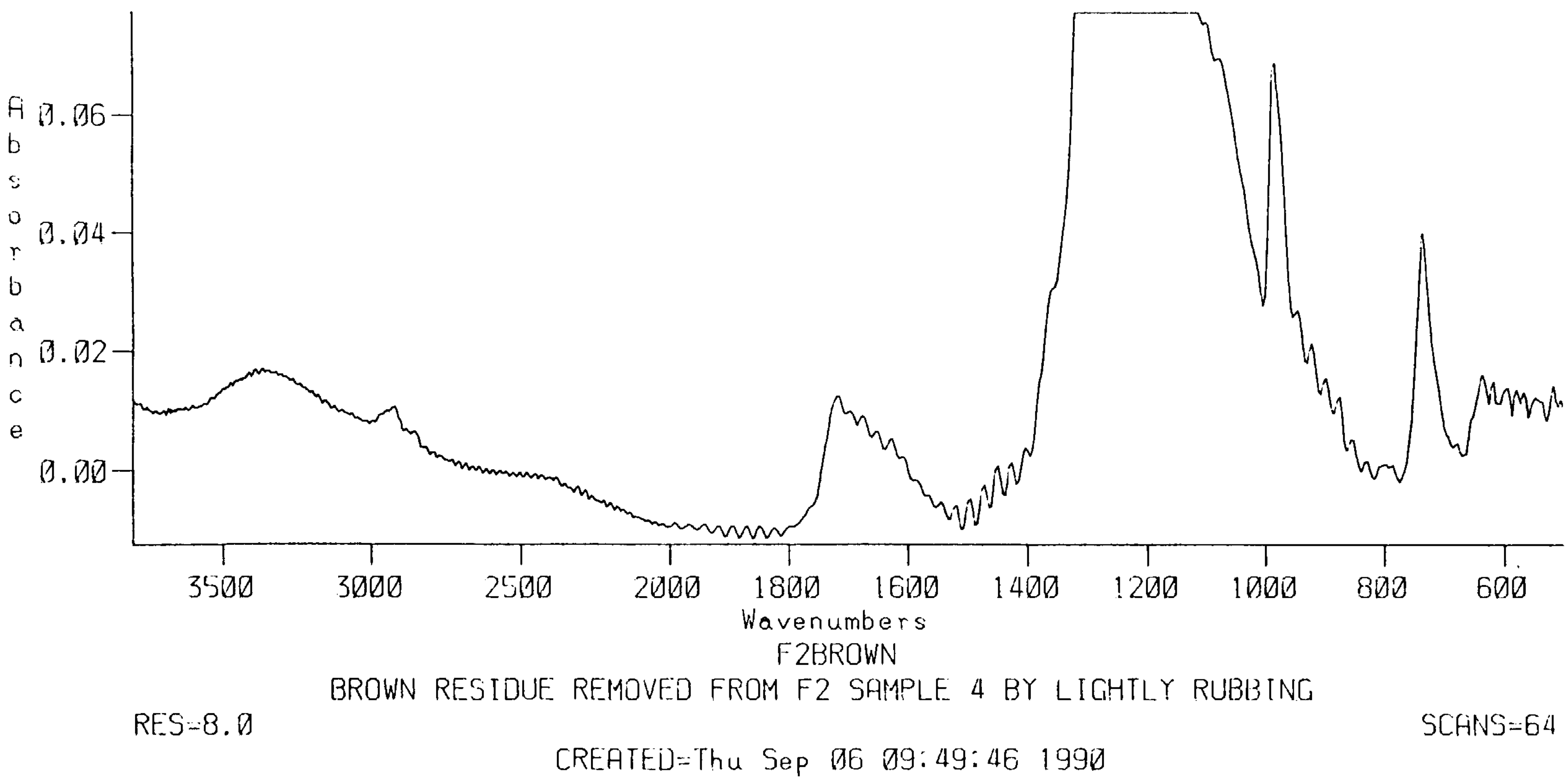


Figure D-43 Fourier Transform IR of blanket F2 sample 4, Brown contaminant removed by light rubbing.

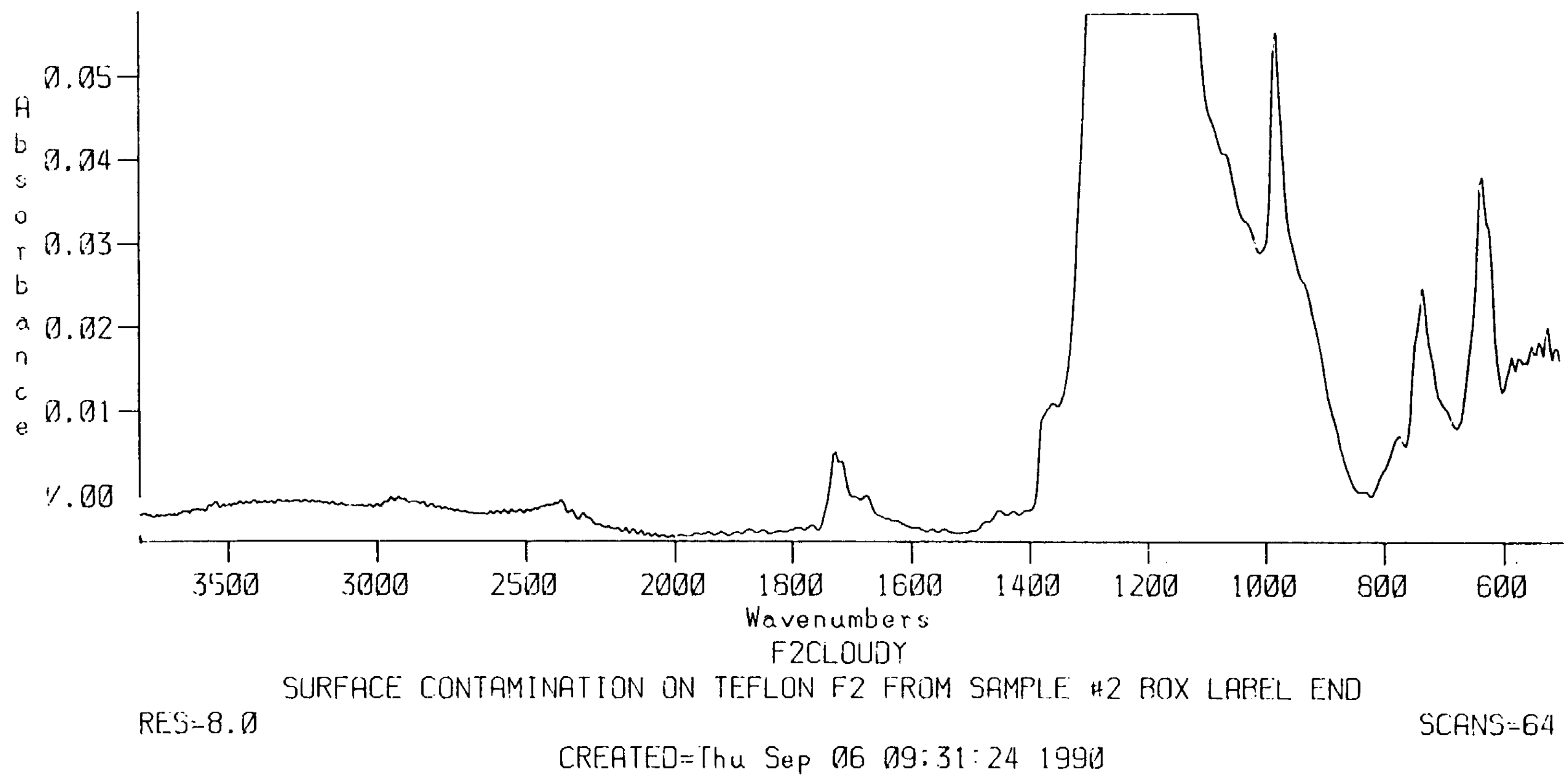


Figure D-44 Fourier Transform IR of blanket F2, Brown contaminant deposit on surface.

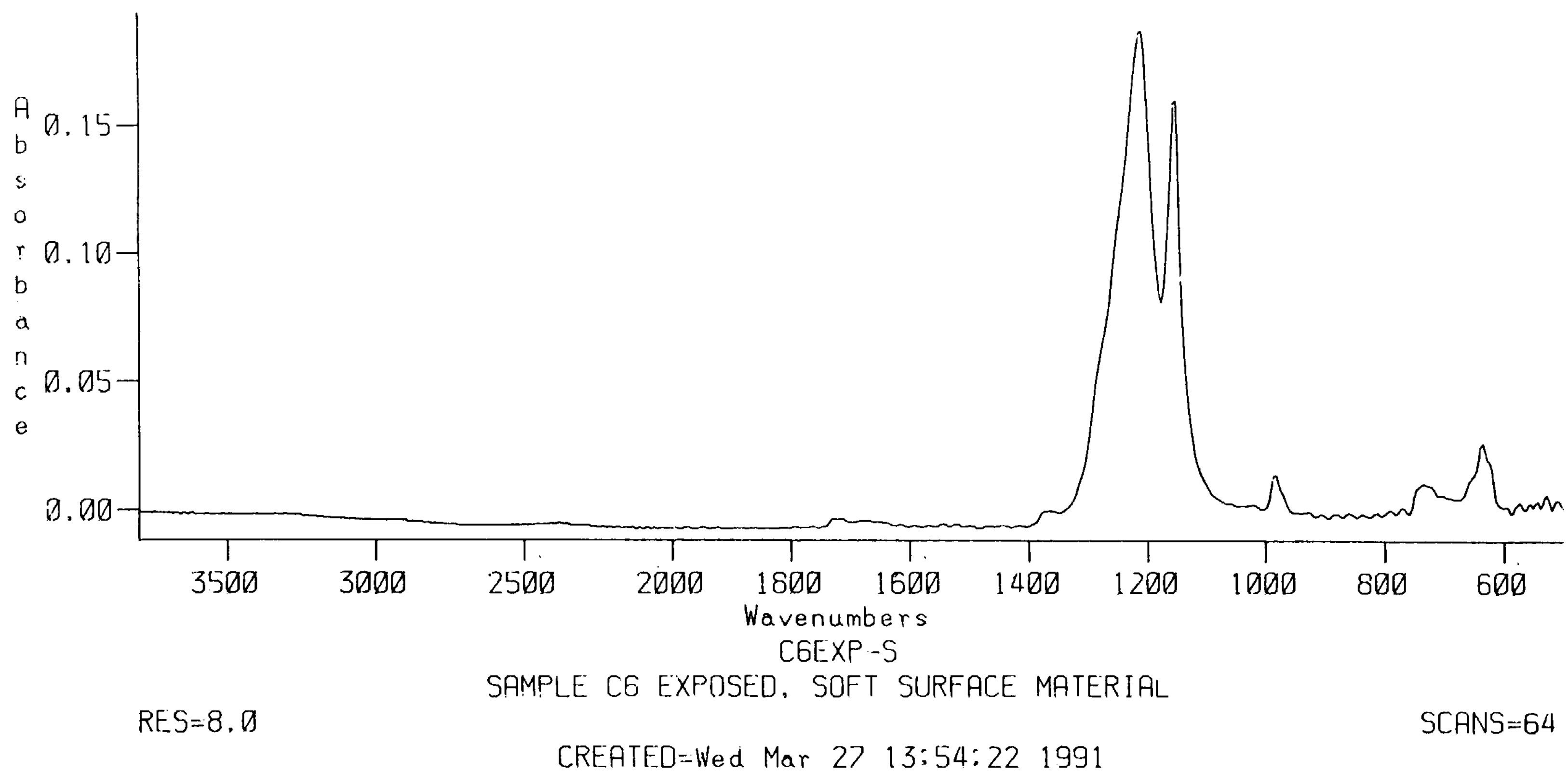


Figure D-45 Fourier Transform IR of blanket C6.

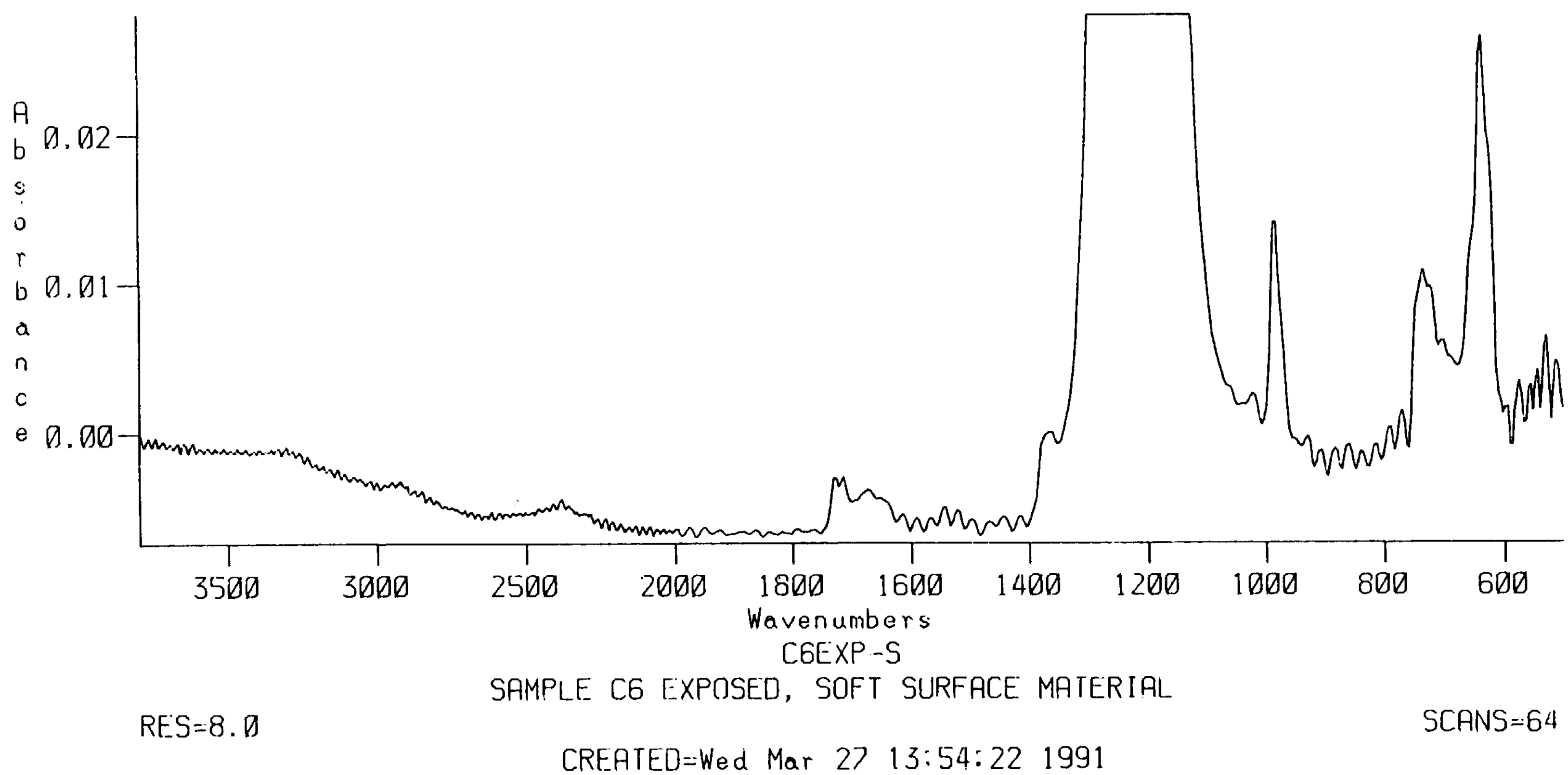


Figure D-46 Fourier Transform IR of blanket C6, expanded scale.

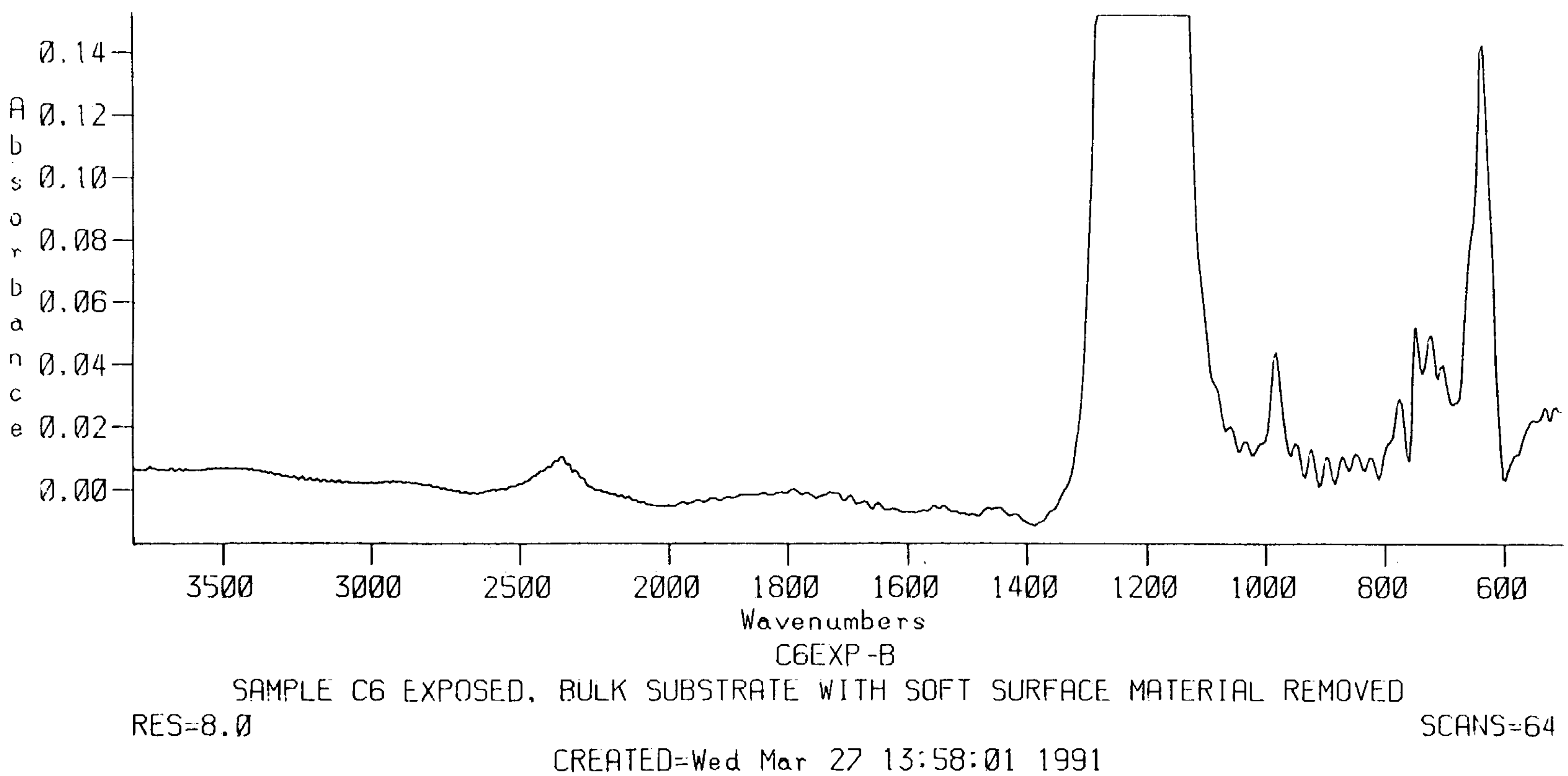


Figure D-47 Fourier Transform IR of blanket C6, bulk material, surface material removed.

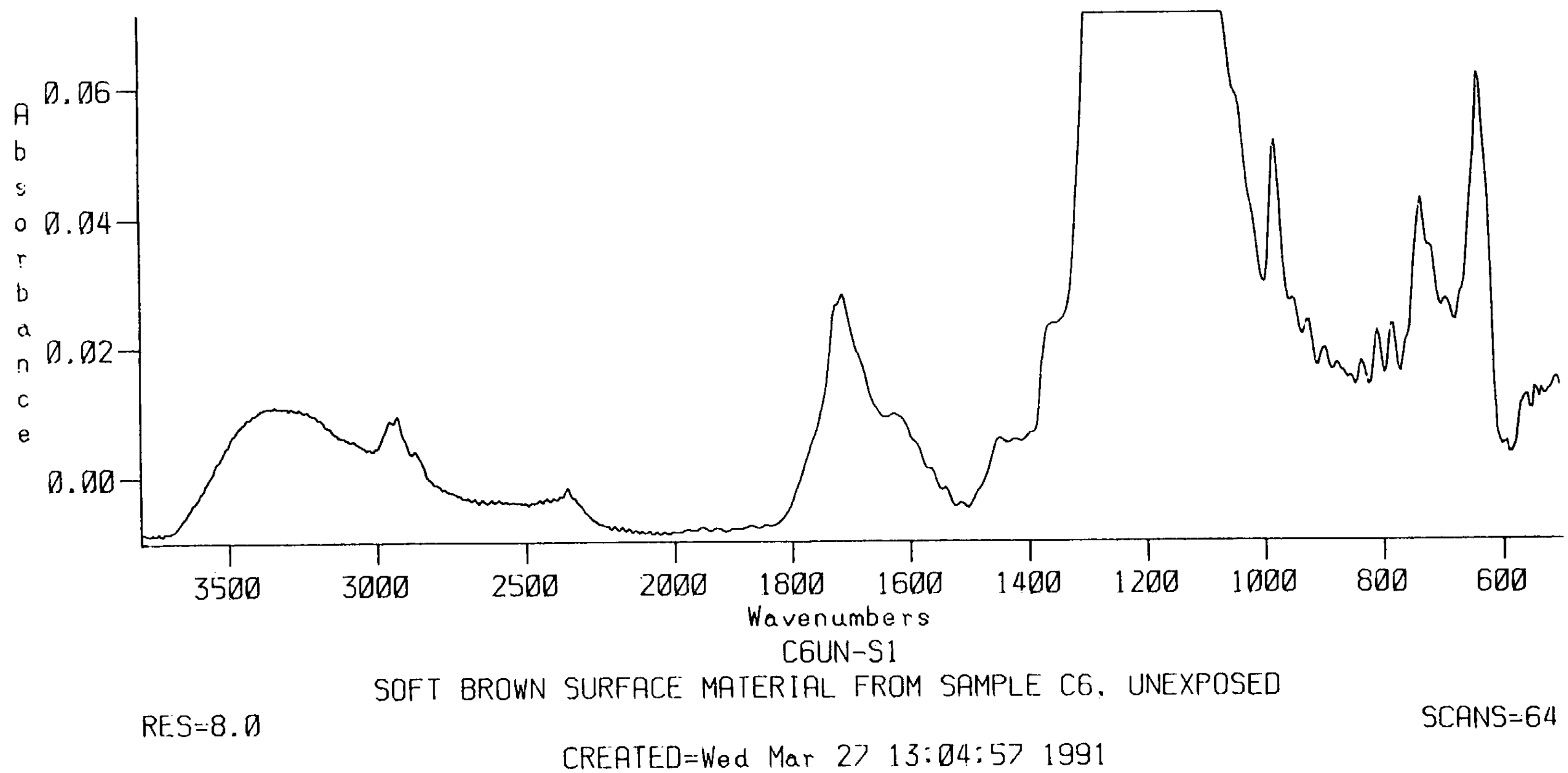


Figure D-48 Fourier Transform IR of blanket C6, unexposed area.

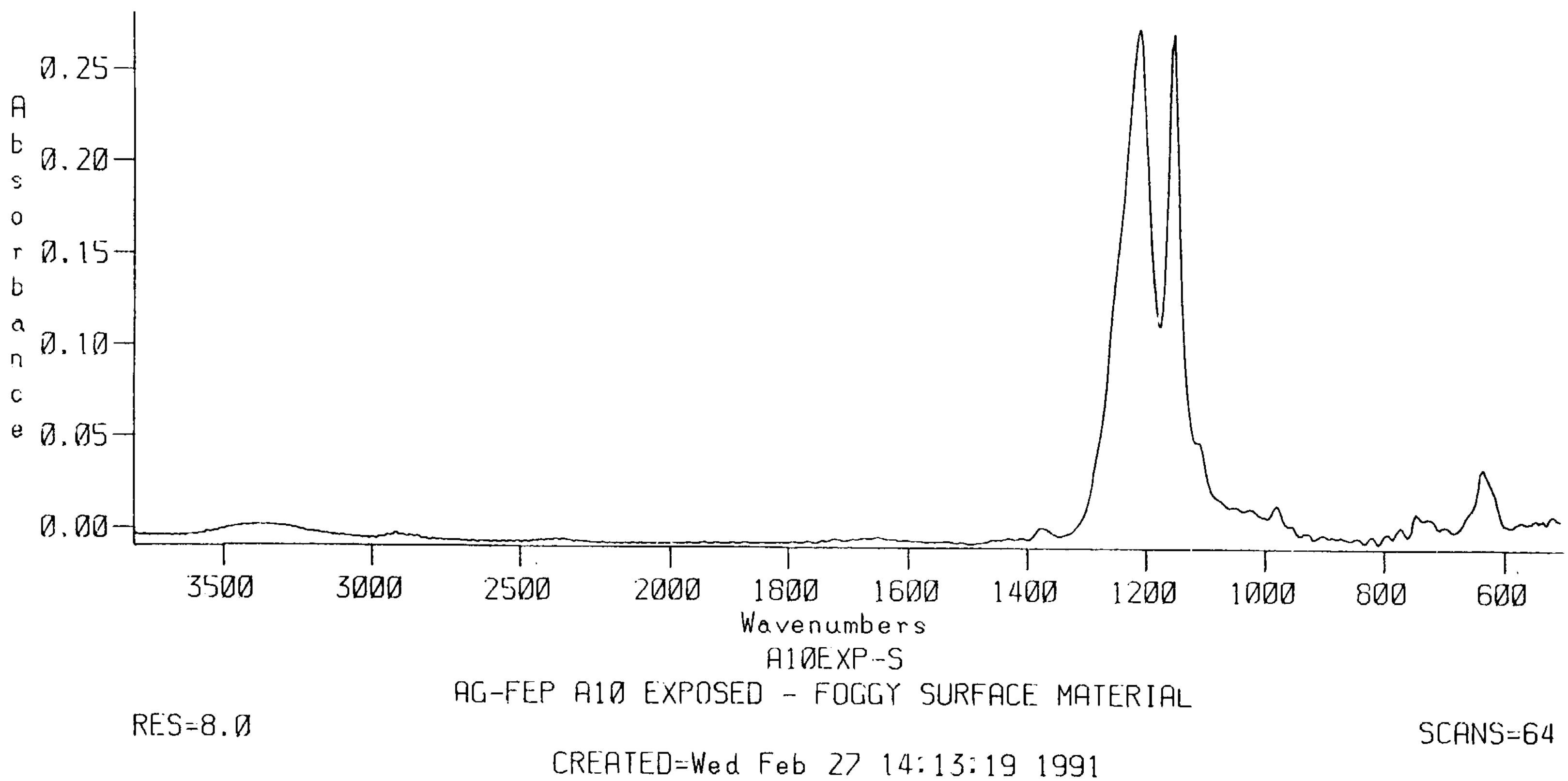


Figure D-49 Fourier Transform IR of blanket A10.

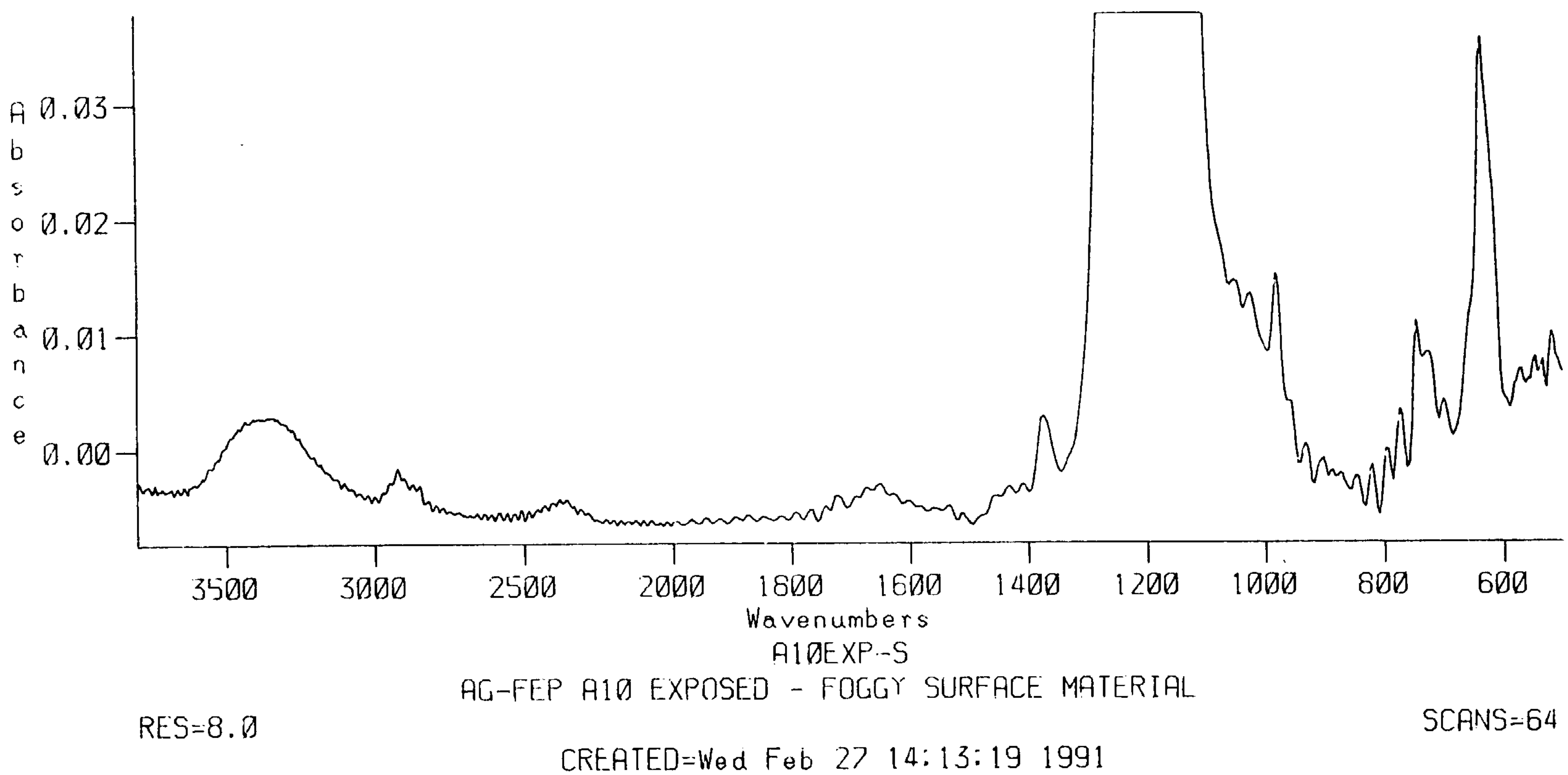


Figure D-50 Fourier Transform IR of blanket A10, expanded scale.

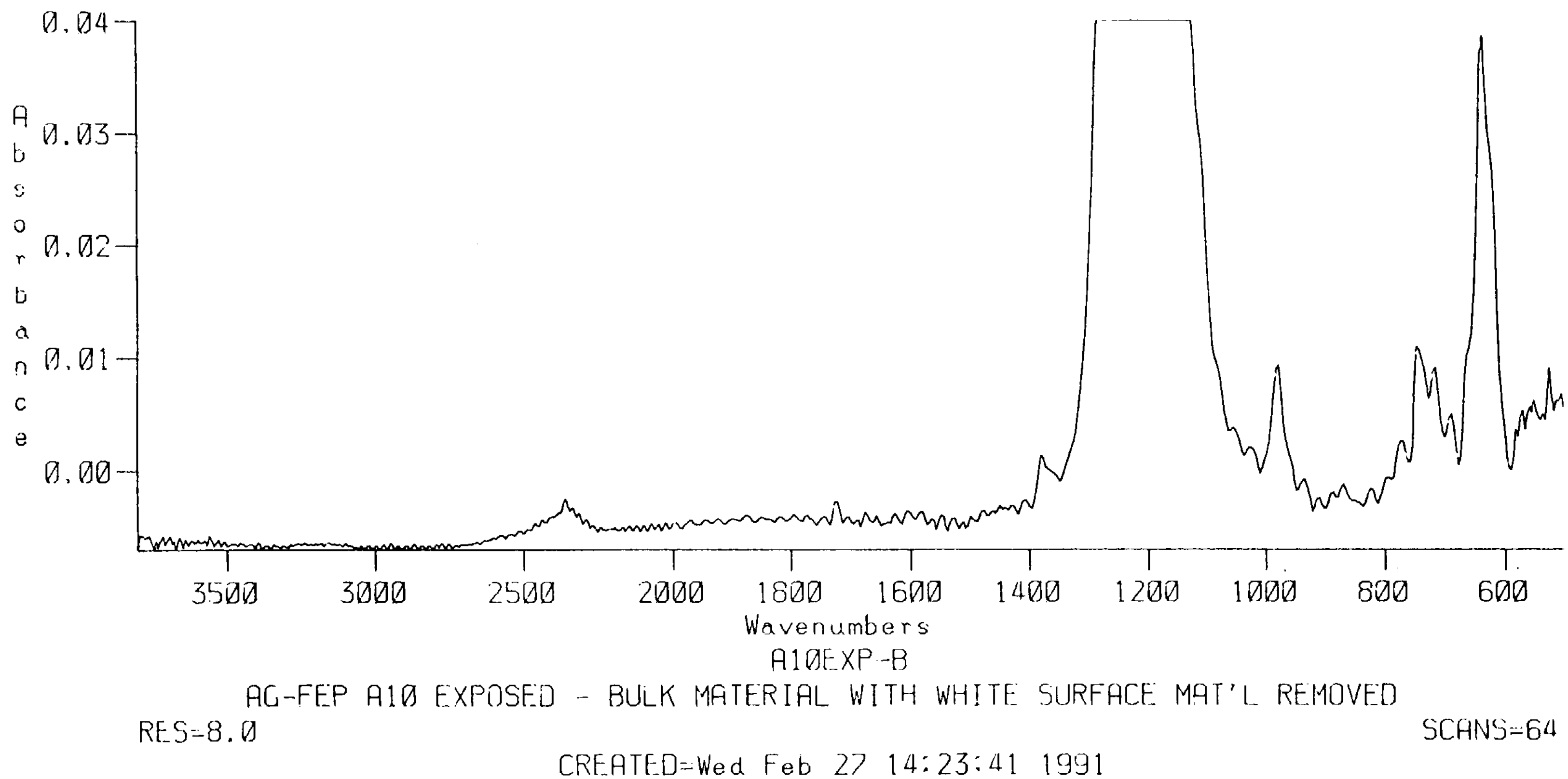


Figure D-51 Fourier Transform IR of blanket A10, bulk material, surface material removed.

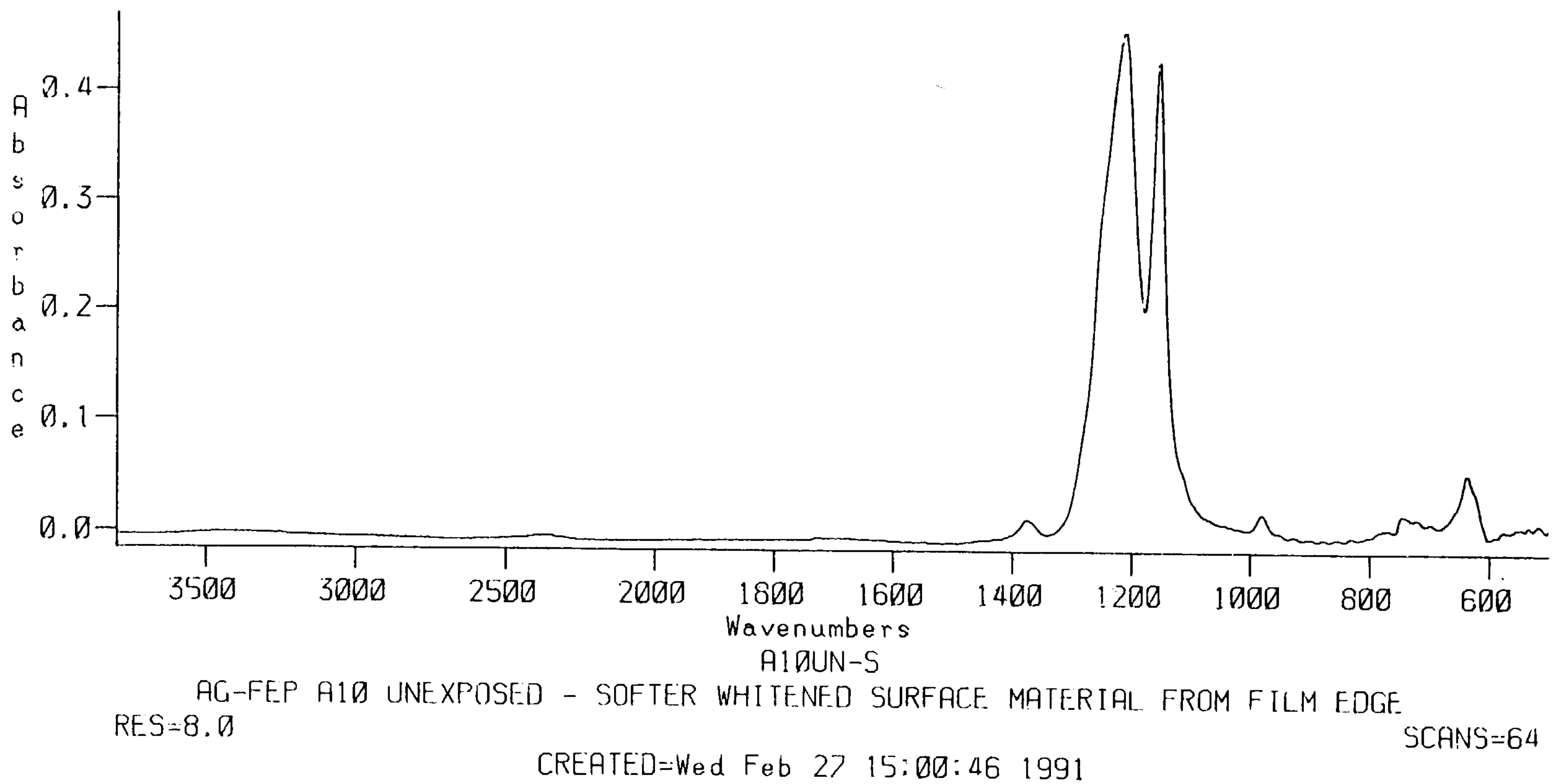


Figure D-52 Fourier Transform IR of blanket A10, unexposed area, soft, whitened material.

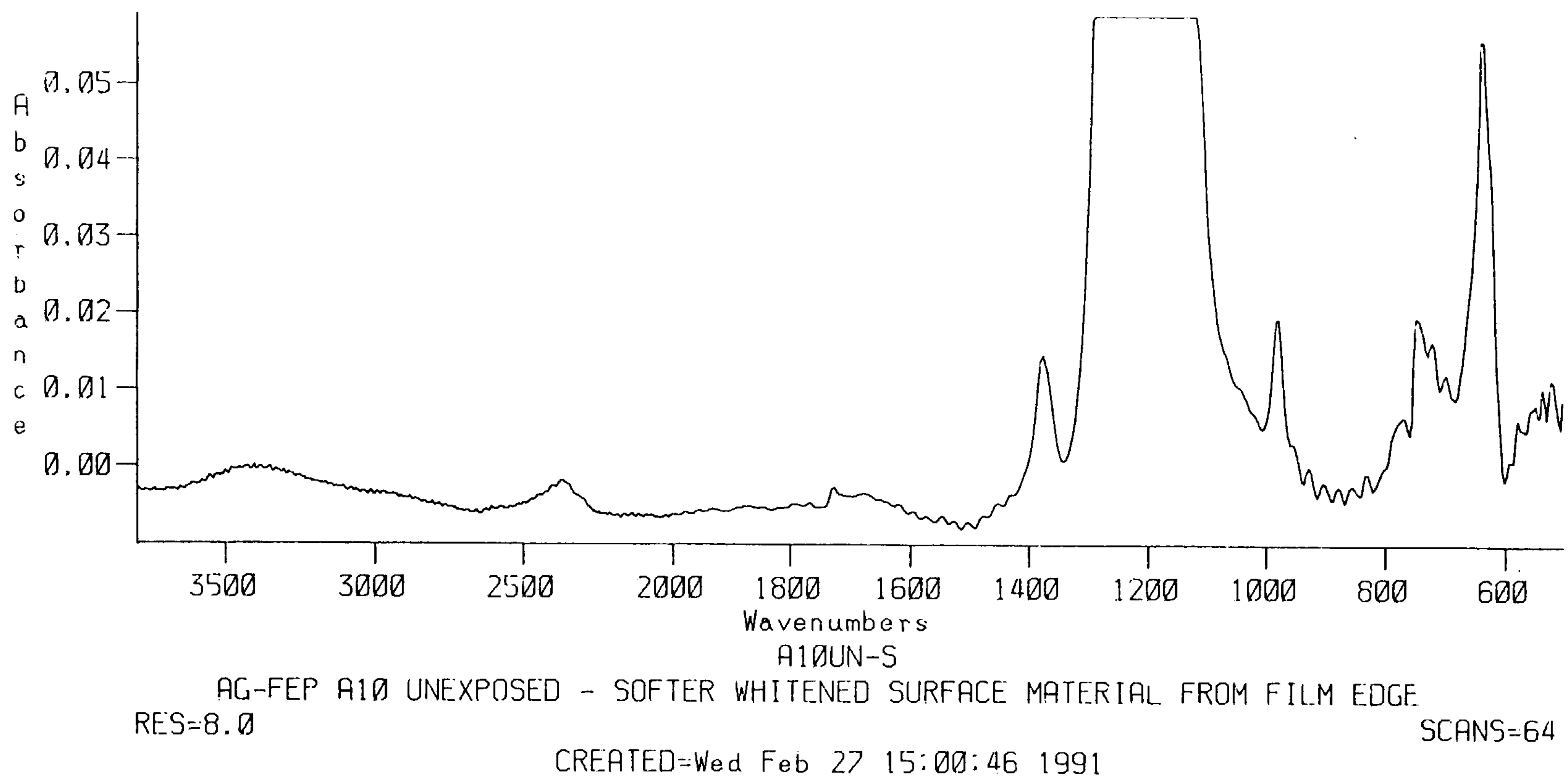


Figure D-53 Fourier Transform IR of blanket A10, unexposed area, expanded scale, soft, whitened material.

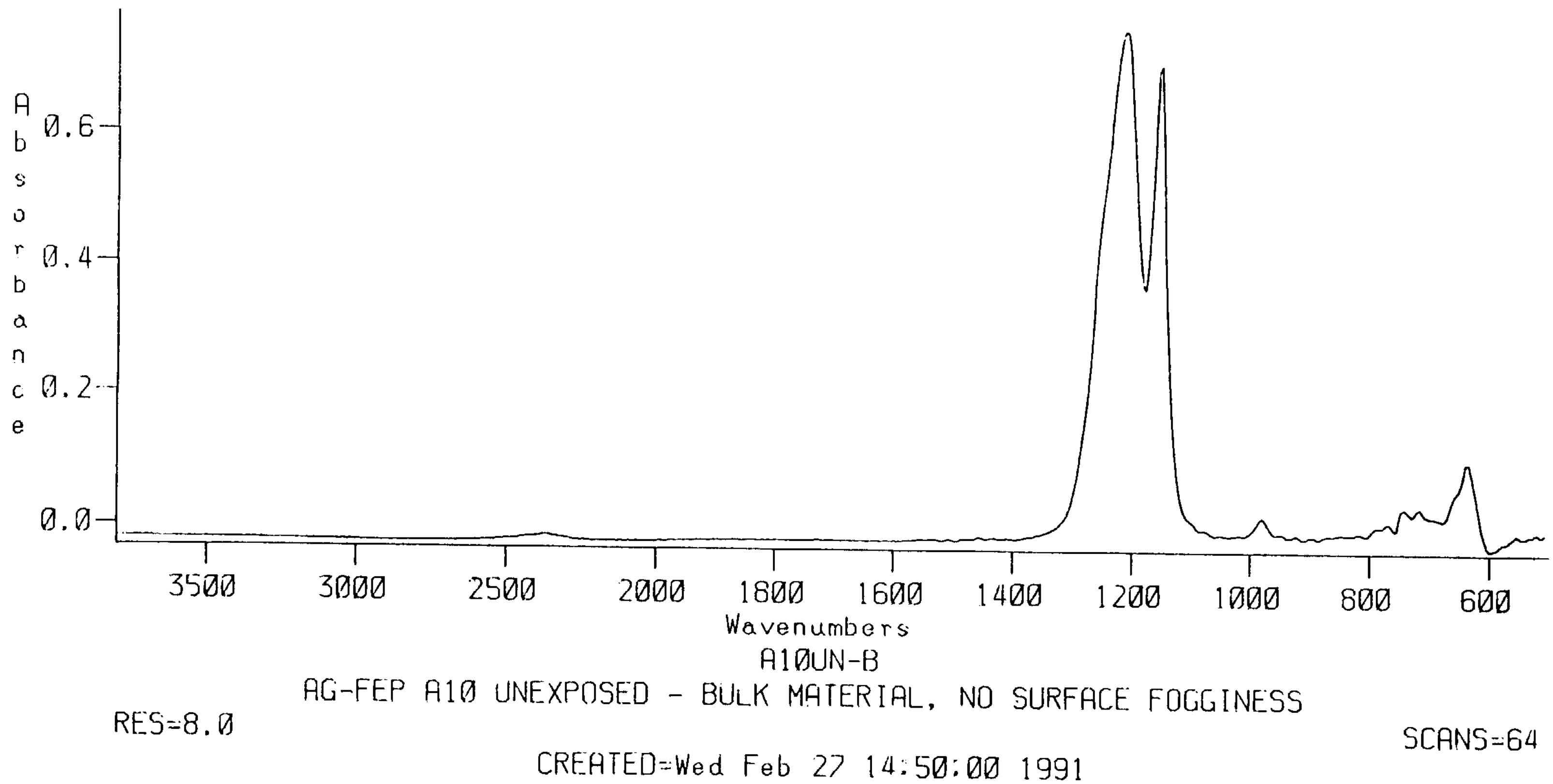


Figure D-54 Fourier Transform IR of blanket A10, unexposed area.

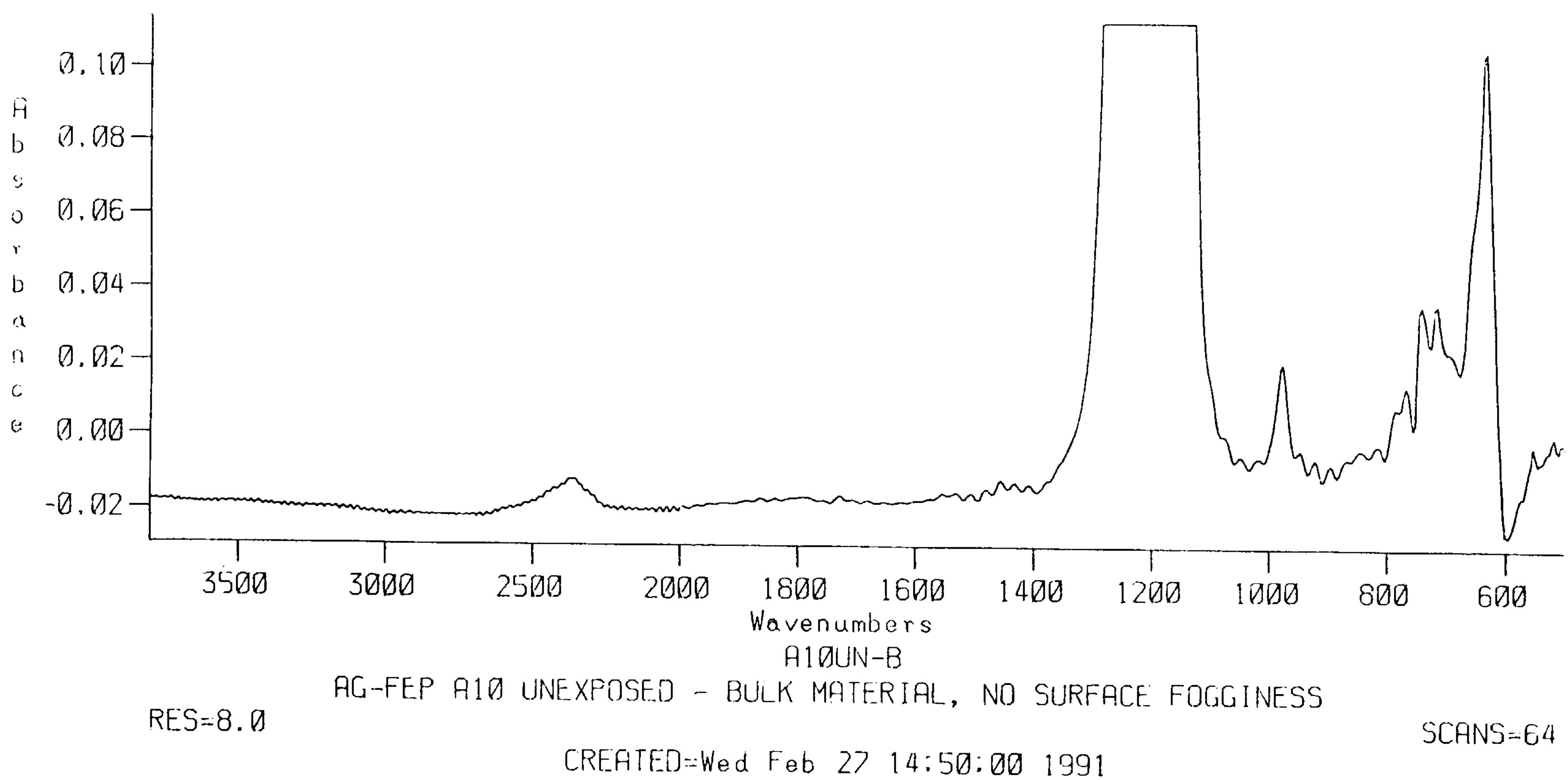


Figure D-55 Fourier Transform IR of blanket A10, unexposed area, expanded scale.

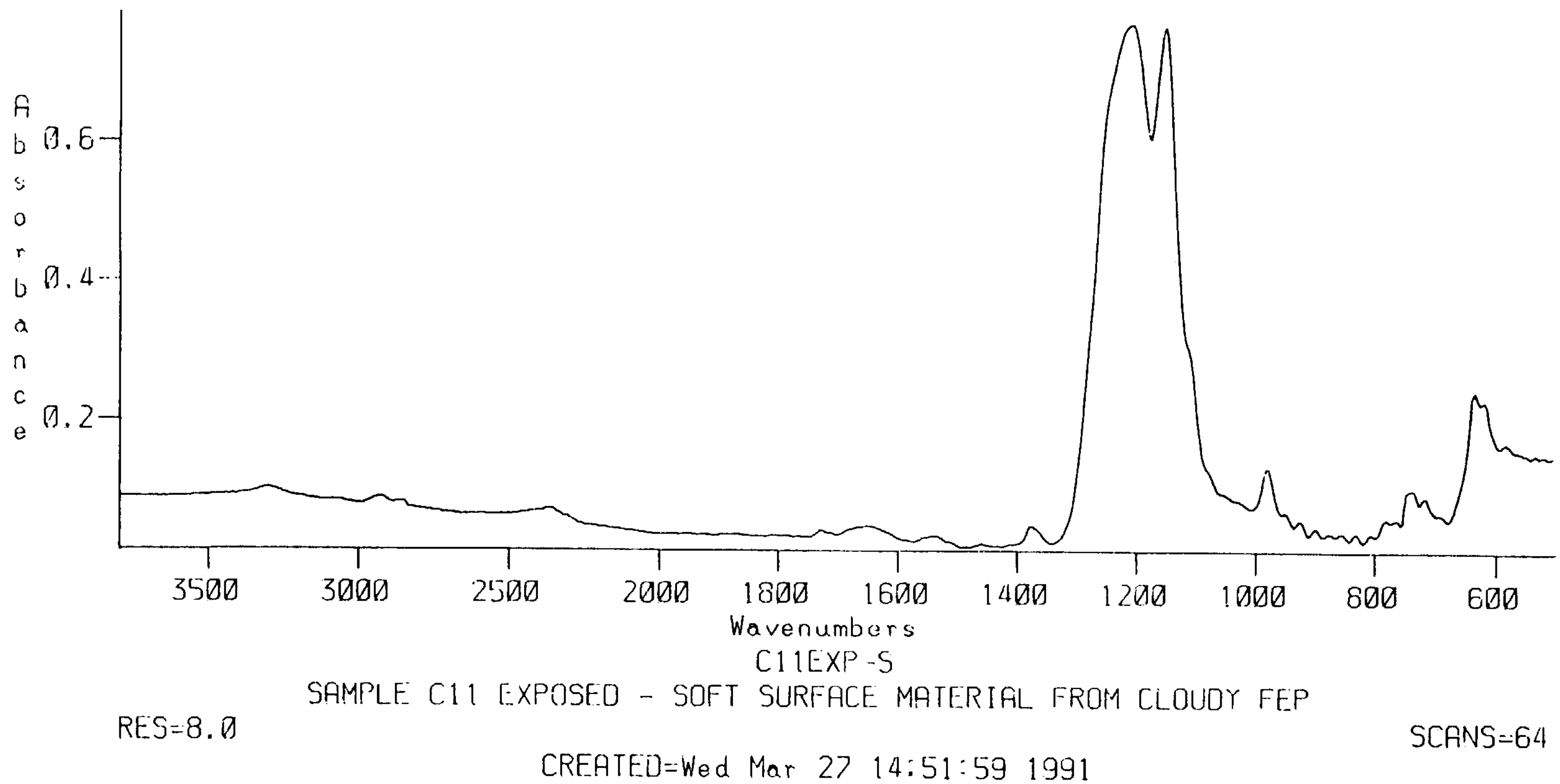


Figure D-56 Fourier Transform IR of blanket C11.

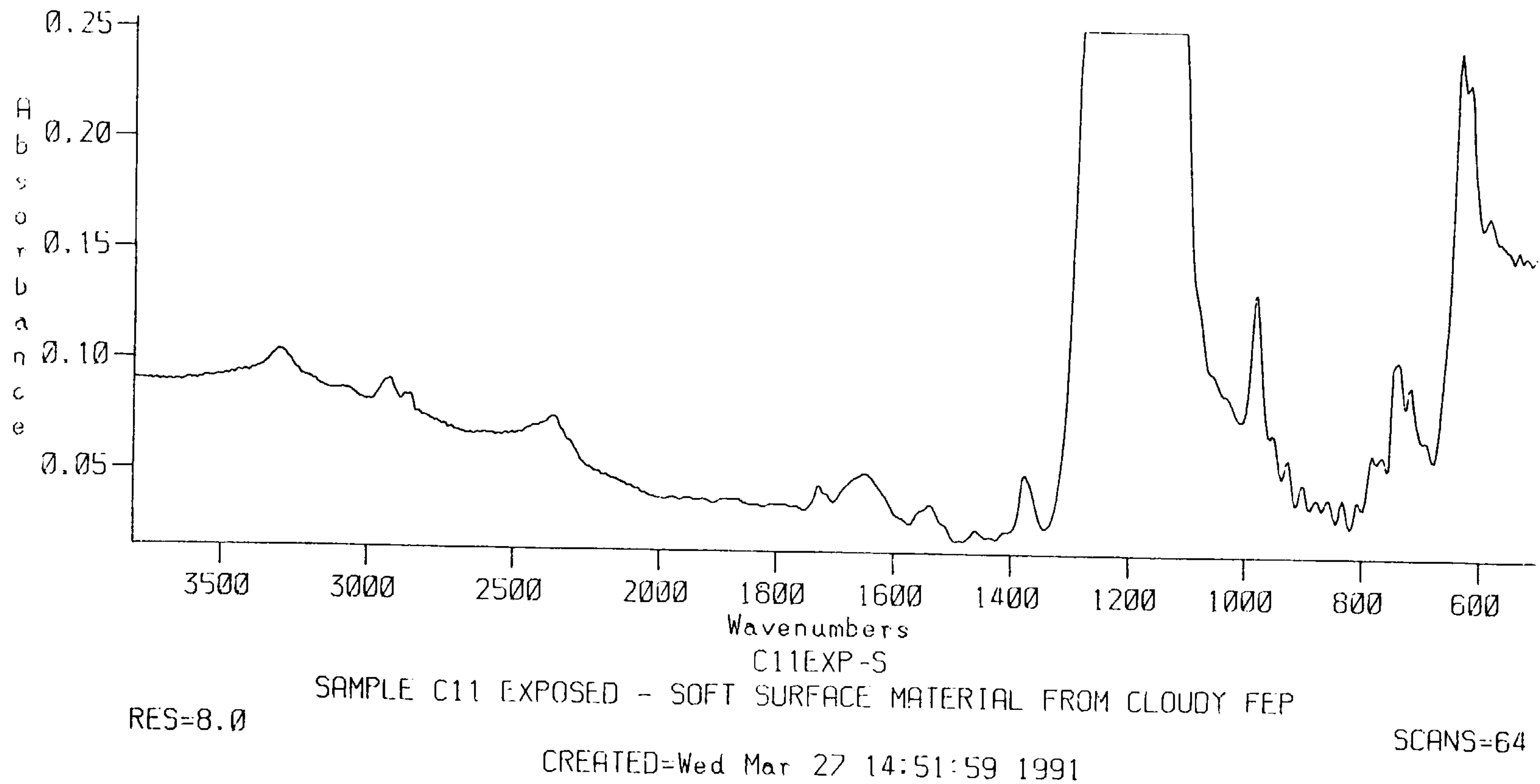


Figure D-57 Fourier Transform IR of blanket C11, expanded scale.

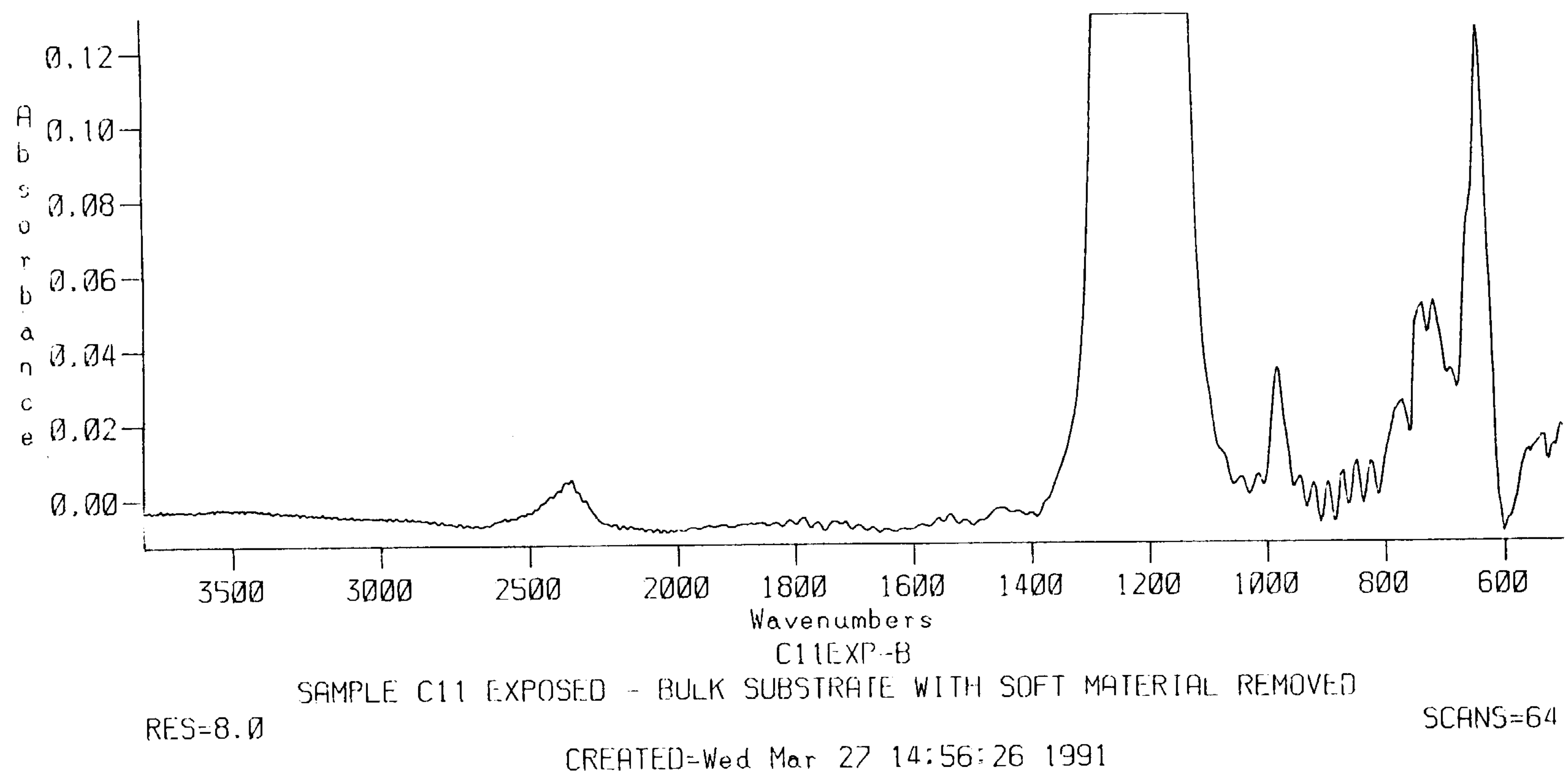


Figure D-58 Fourier Transform IR of blanket C11, bulk material, surface material removed.

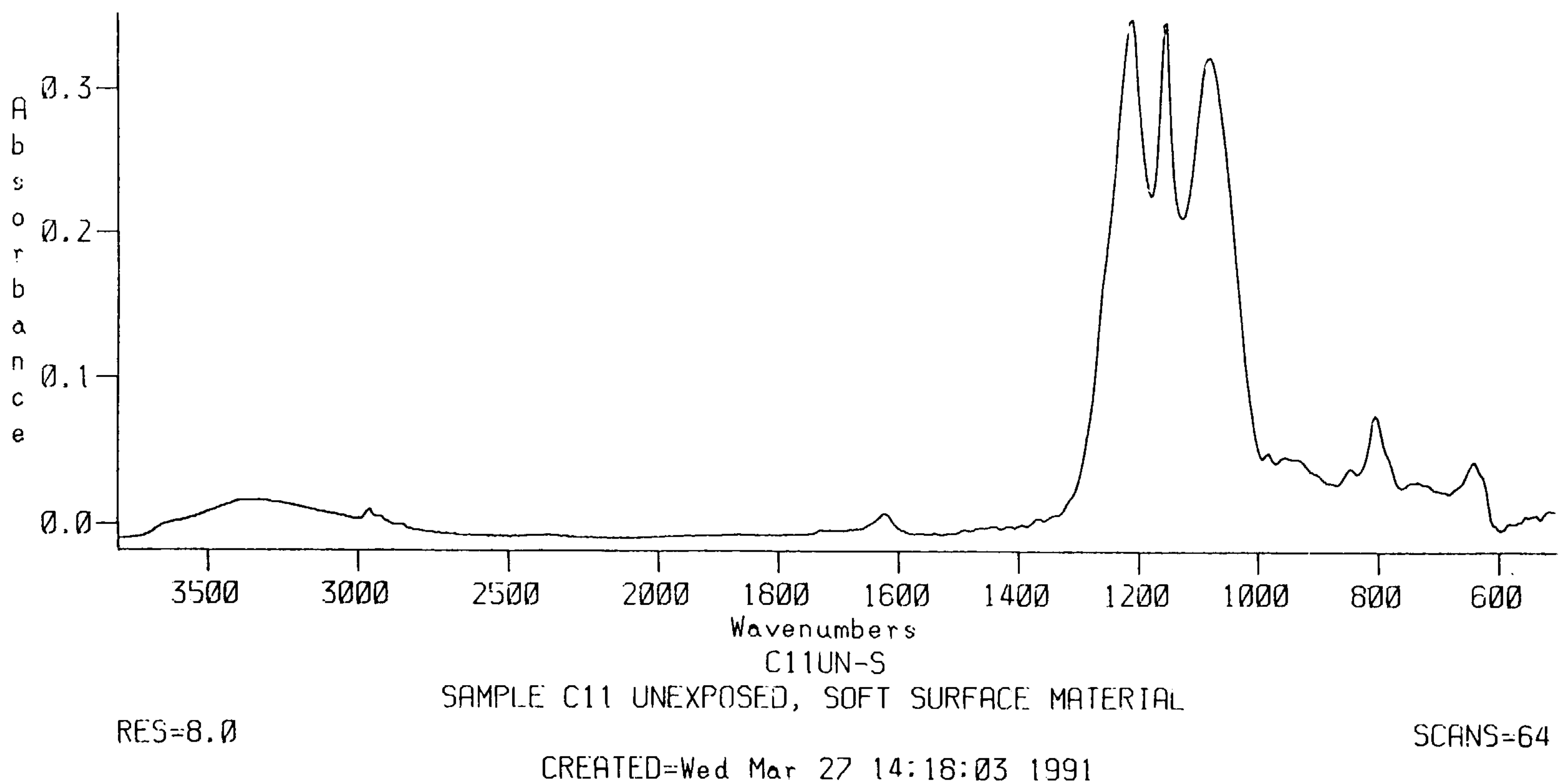


Figure D-59 Fourier Transform IR of blanket C11, unexposed area.

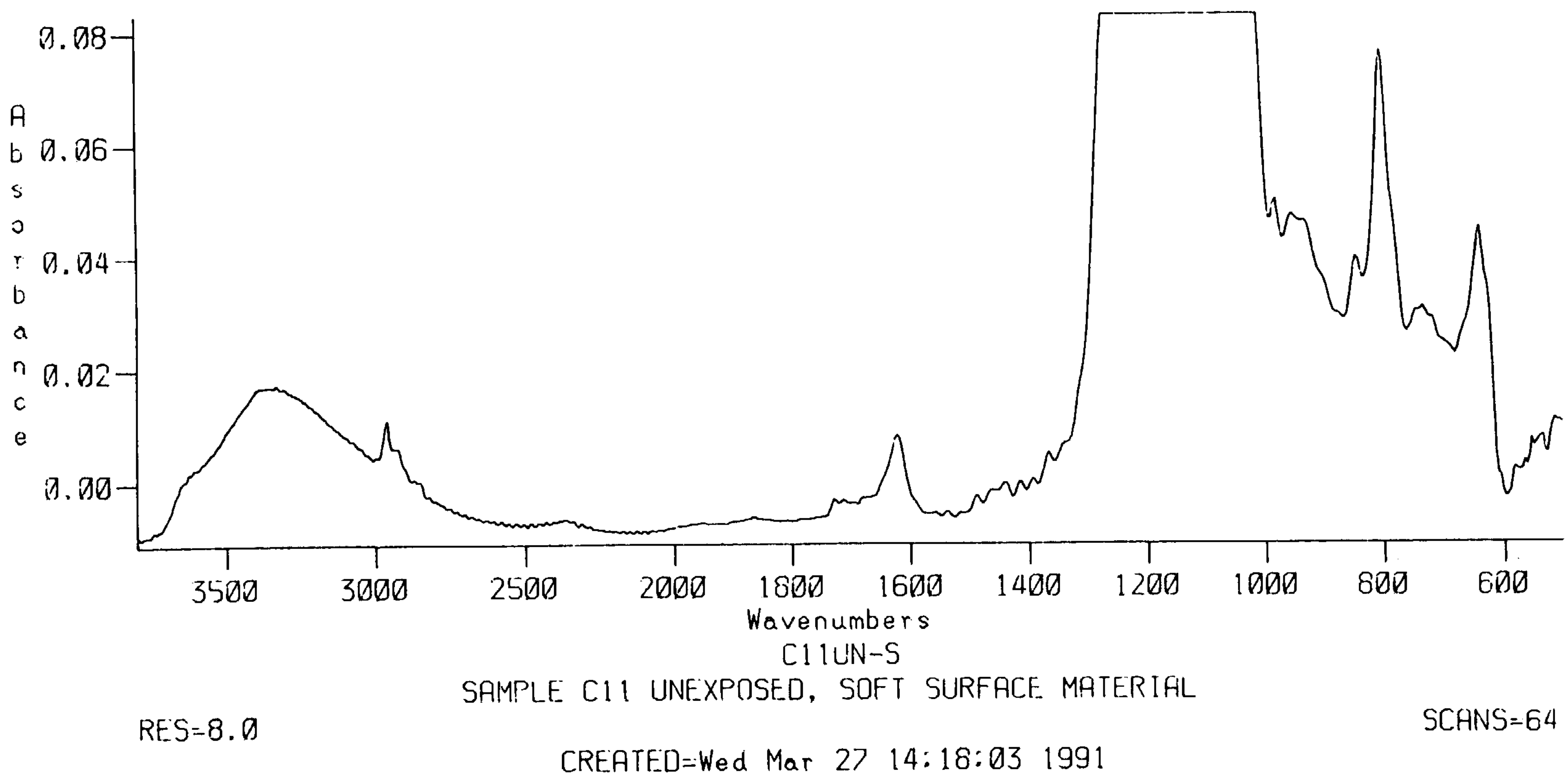


Figure D-60 Fourier Transform IR of blanket C11, unexposed area, expanded scale.

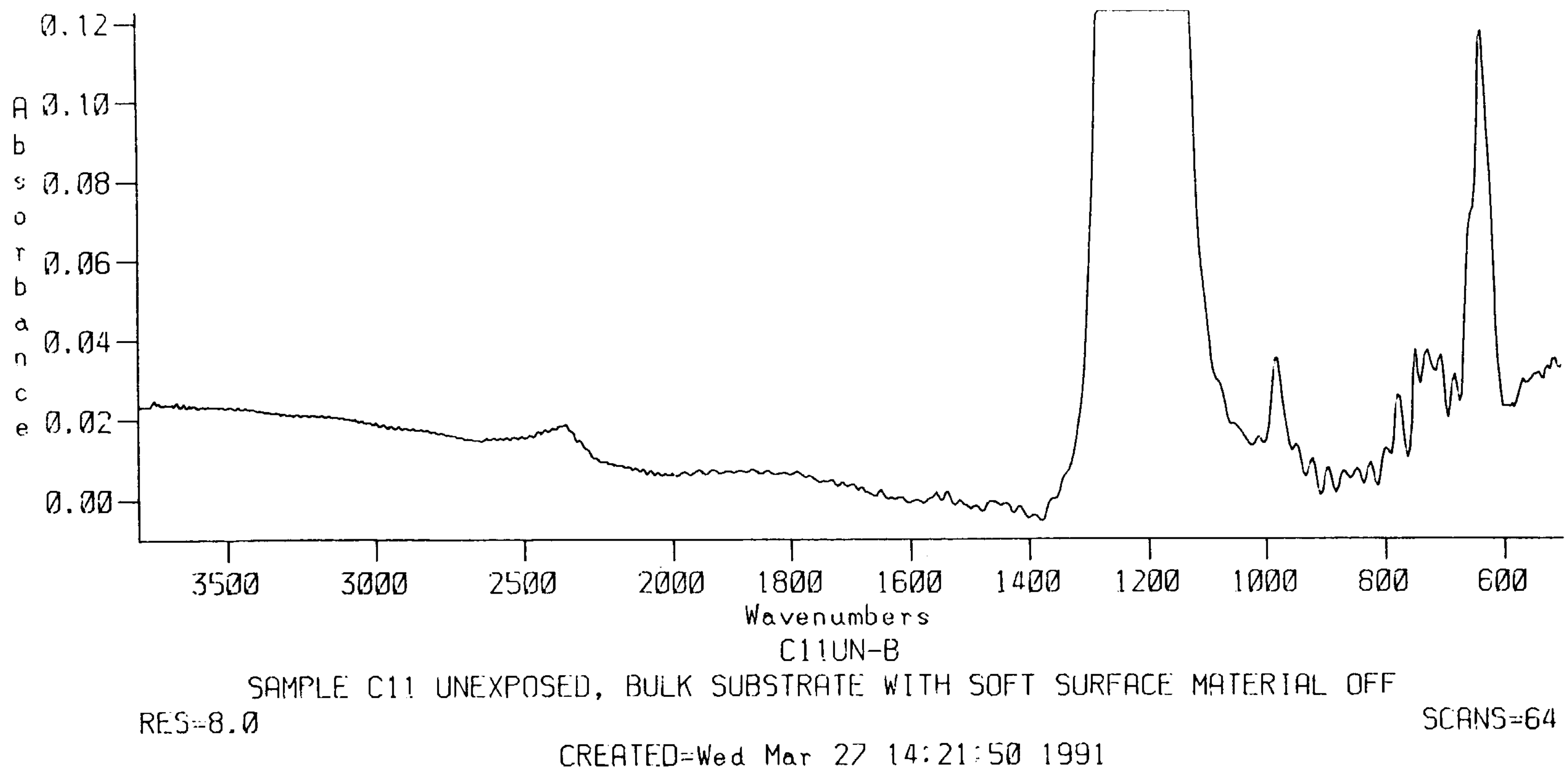


Figure D-61 Fourier Transform IR of blanket C11, unexposed area, bulk material, surface material removed.

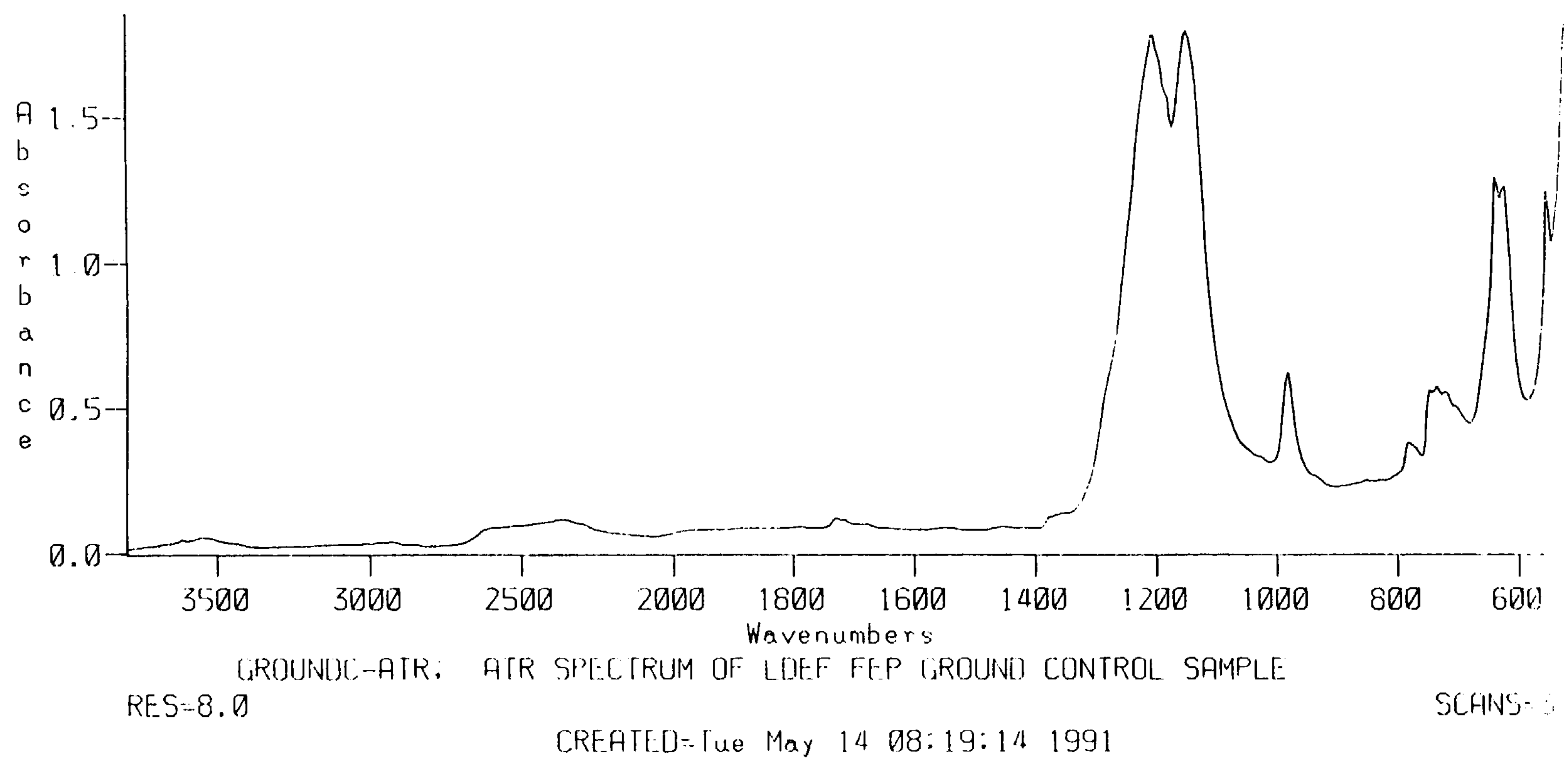


Figure D-62 Attenuated total reflectance spectrum of FEP ground control specimen.

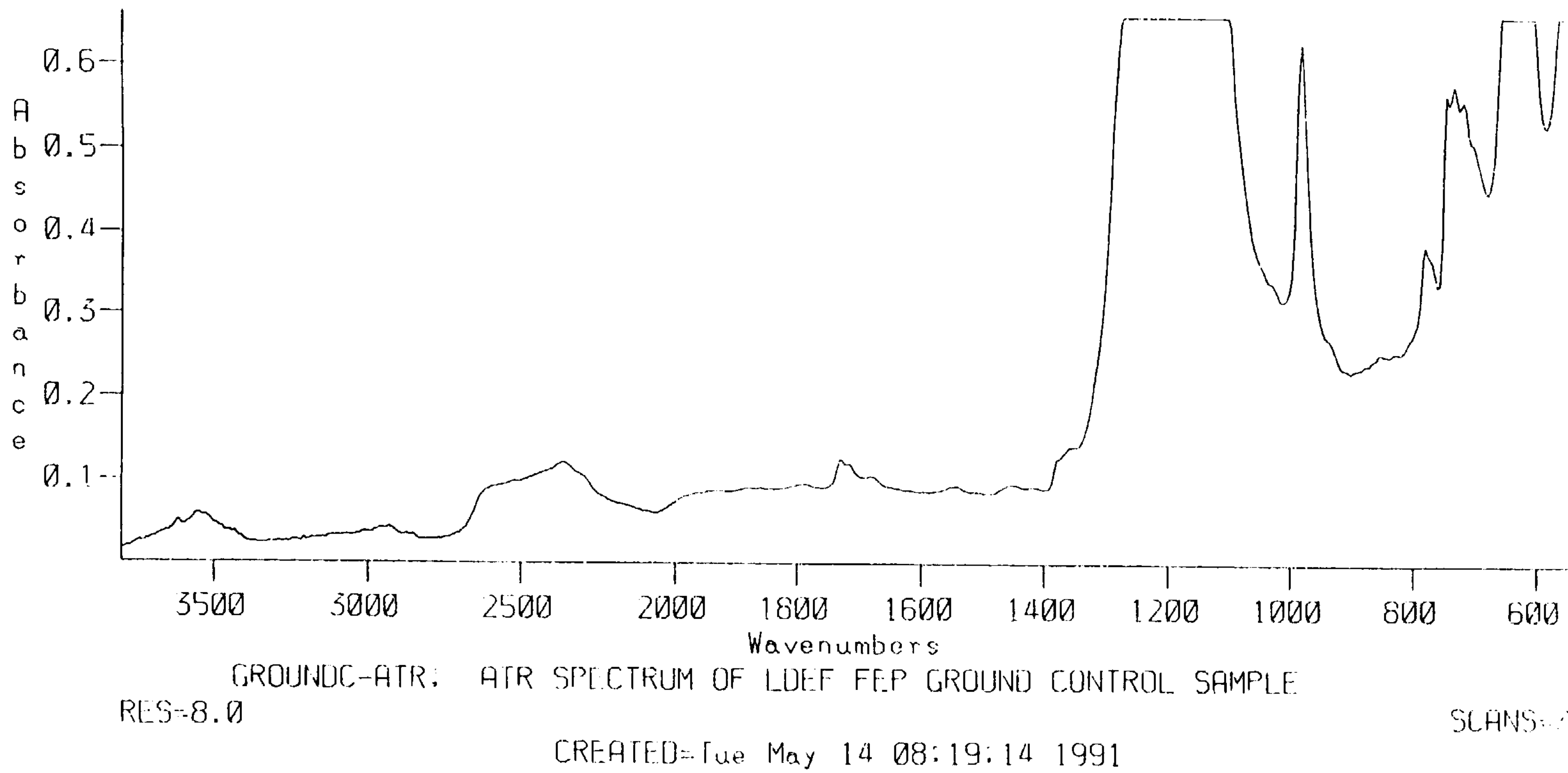


Figure D-63 Attenuated total reflectance spectrum of FEP ground control specimen, expanded scale.

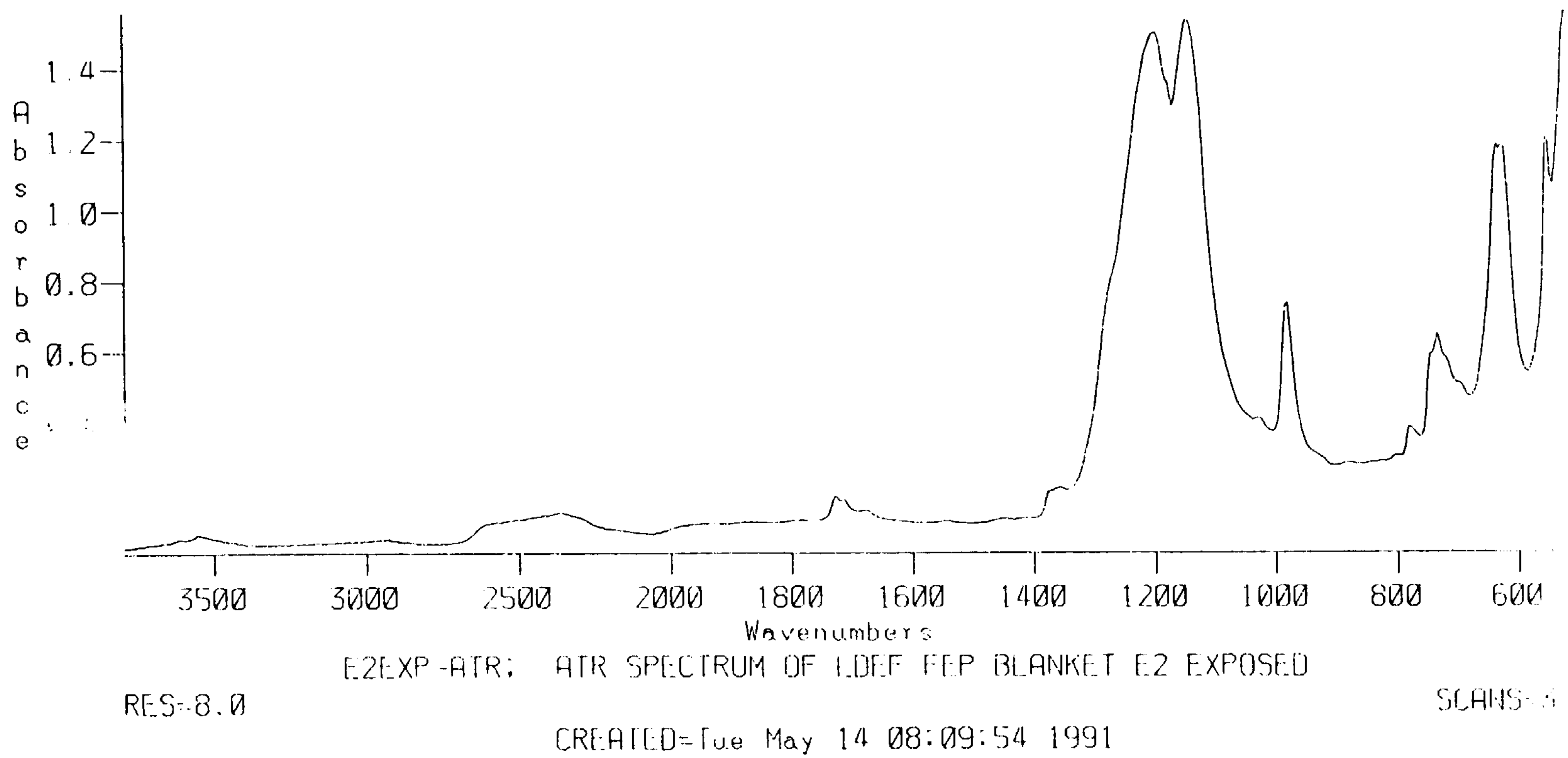


Figure D-64 Attenuated total reflectance spectrum of blanket E2.

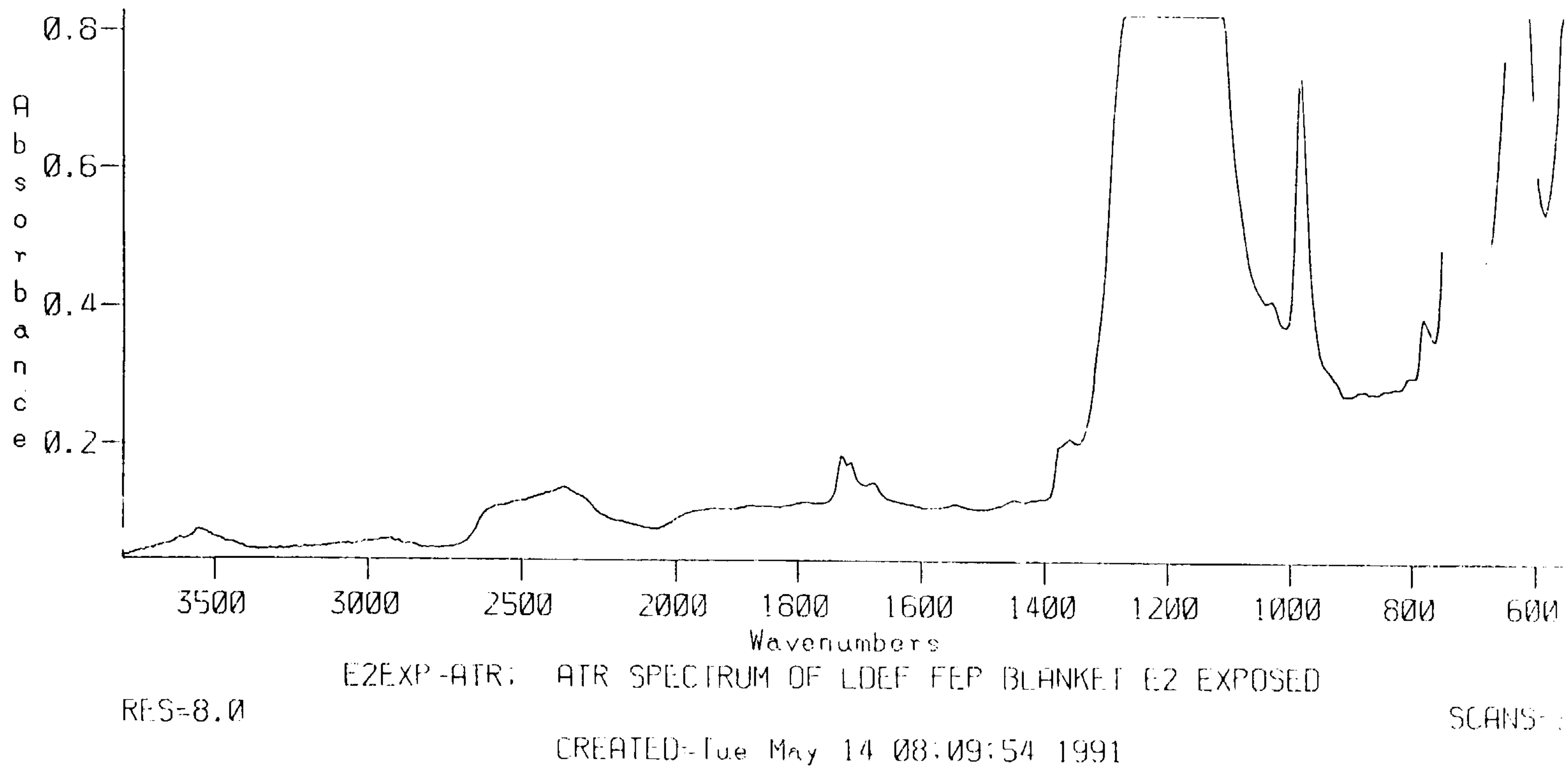


Figure D-65 Attenuated total reflectance spectrum of blanket E2, expanded scale.

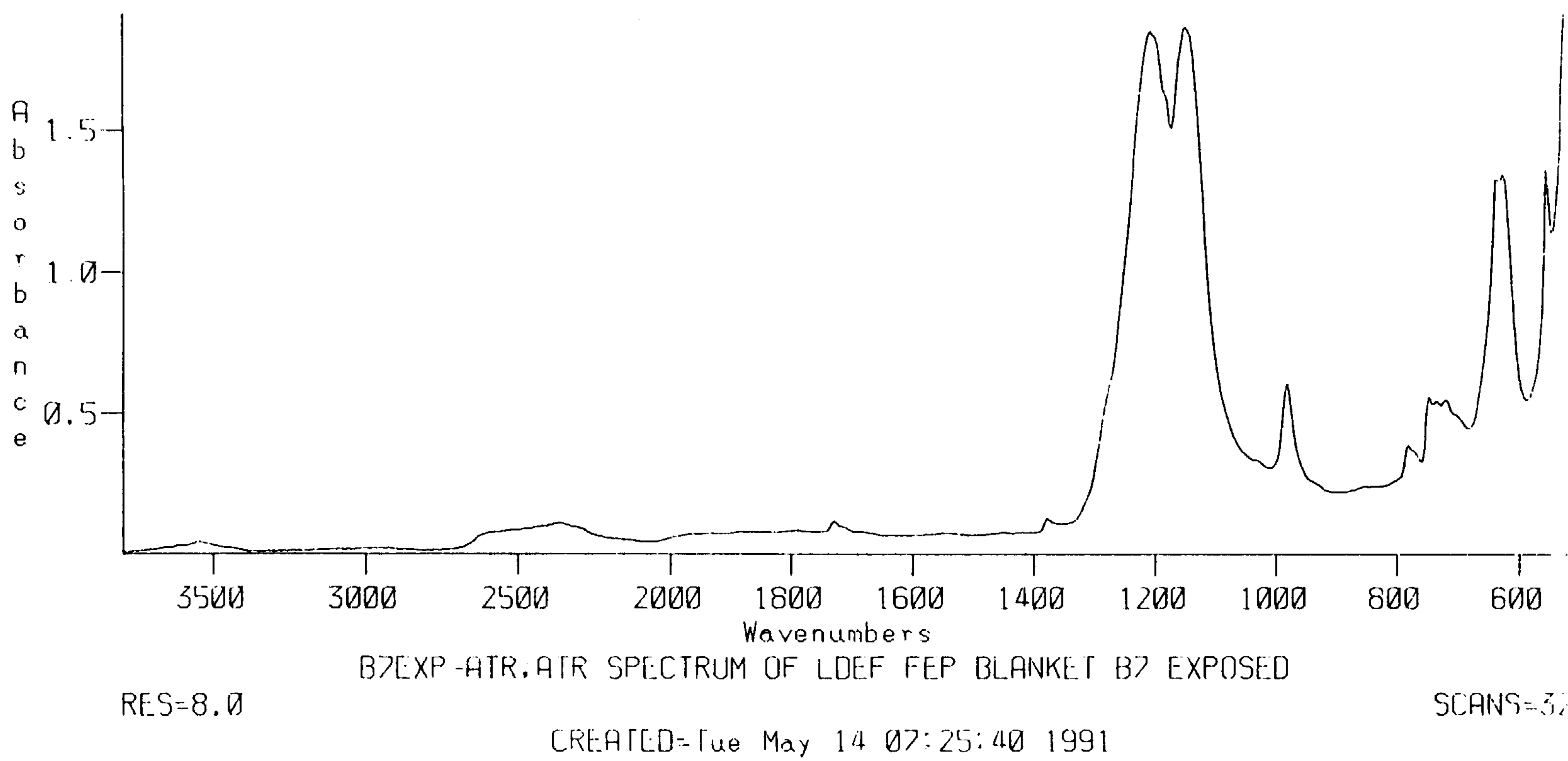


Figure D-66 Attenuated total reflectance spectrum of blanket B7.

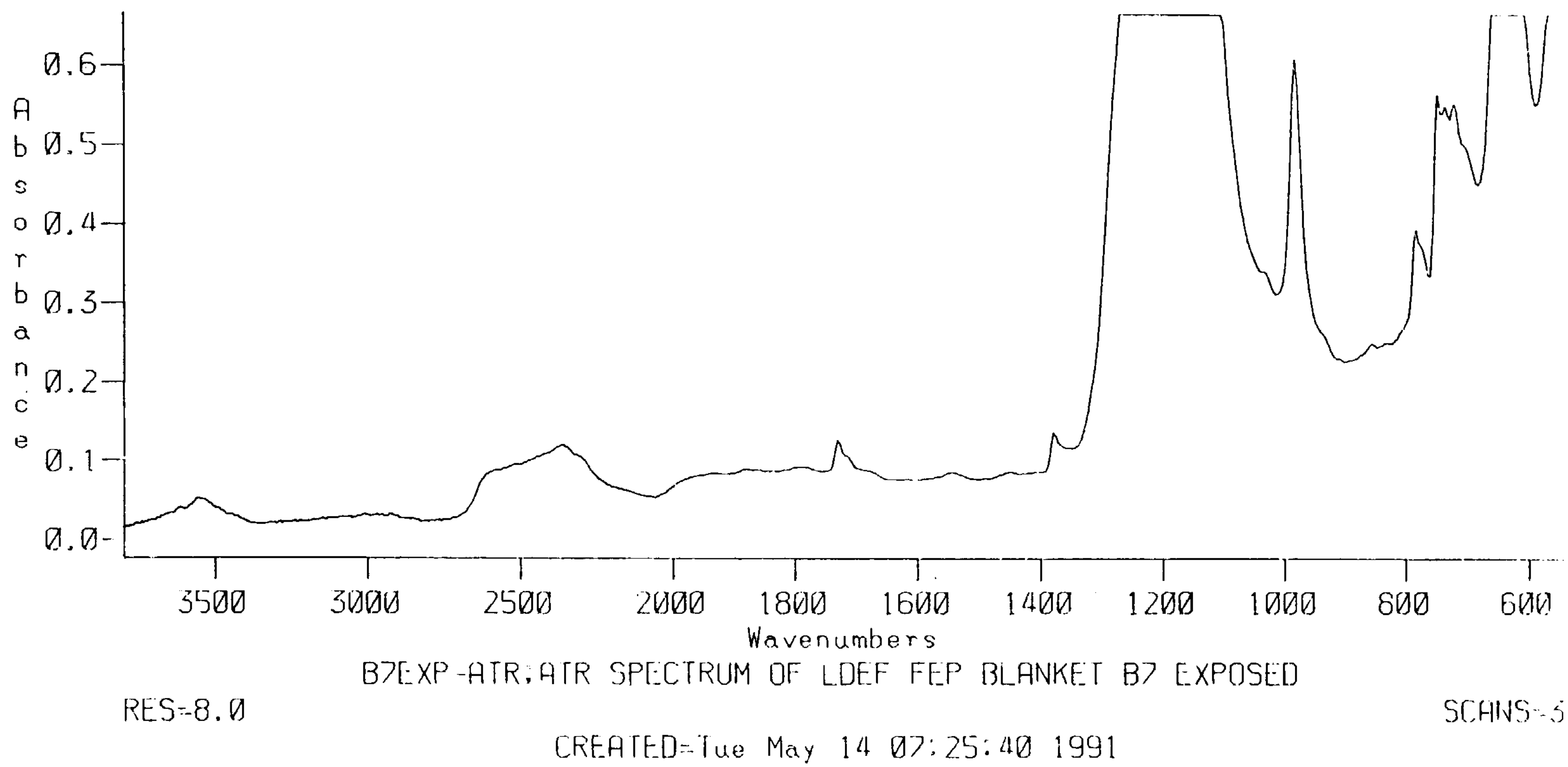


Figure D-67 Attenuated total reflectance spectrum of blanket B7, expanded scale.

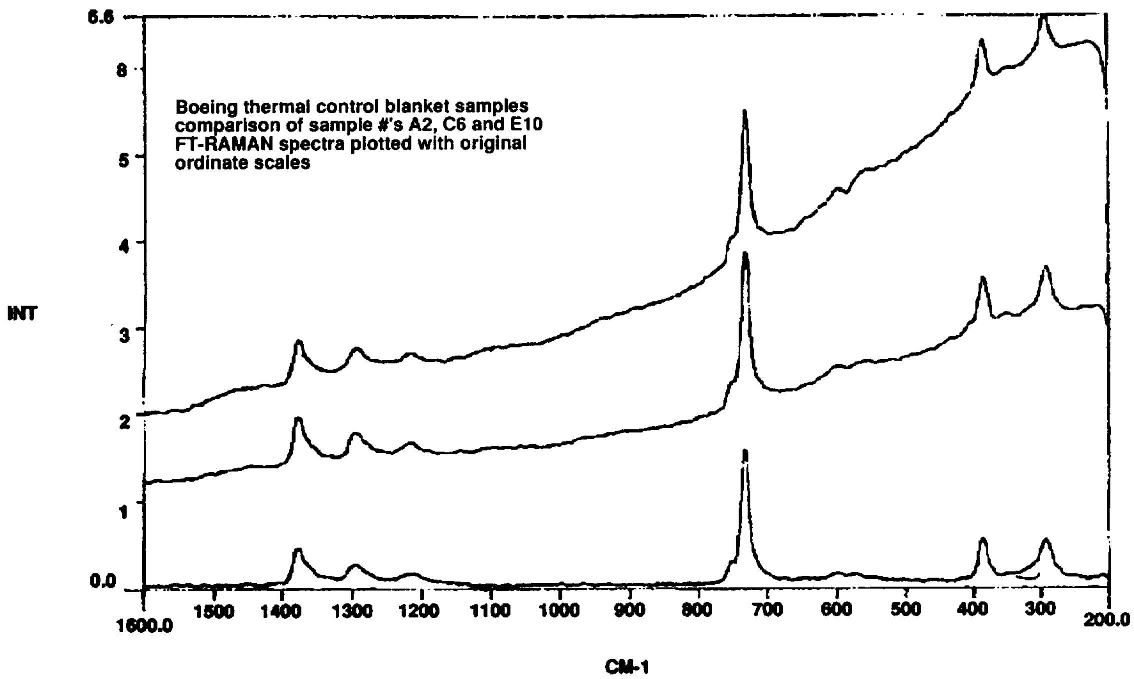


Figure D-68 RAMAN Spectra for blankets A2, C6, and E10.

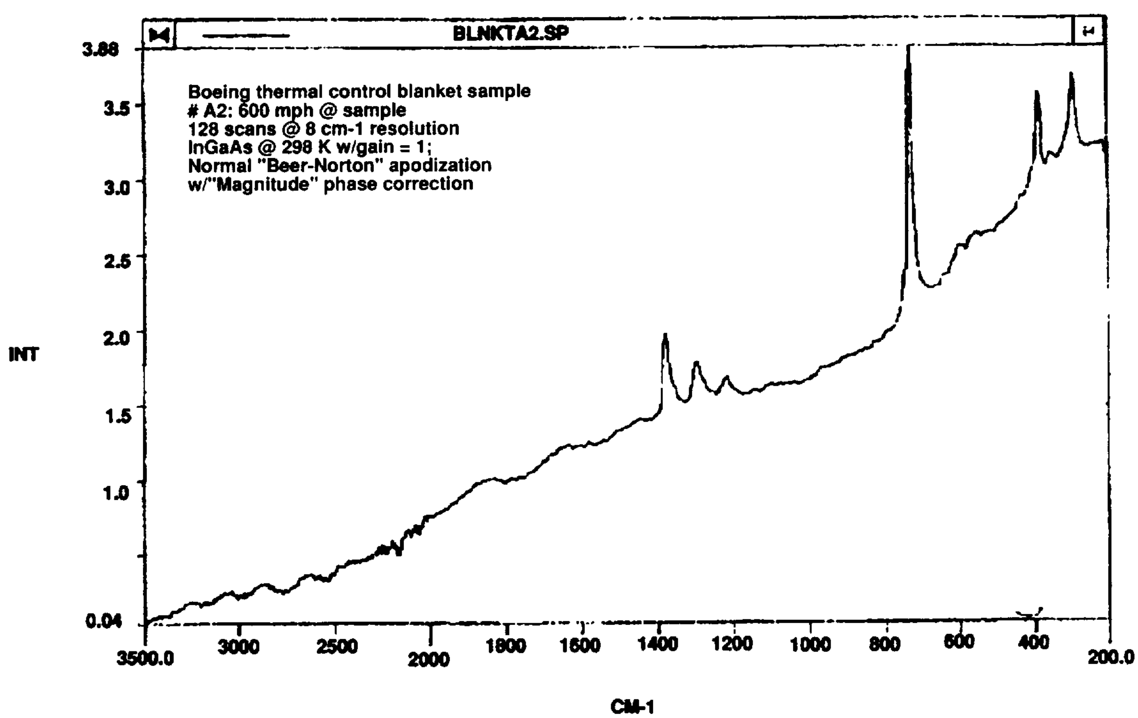


Figure D-69 RAMAN Spectra for blanket A2.

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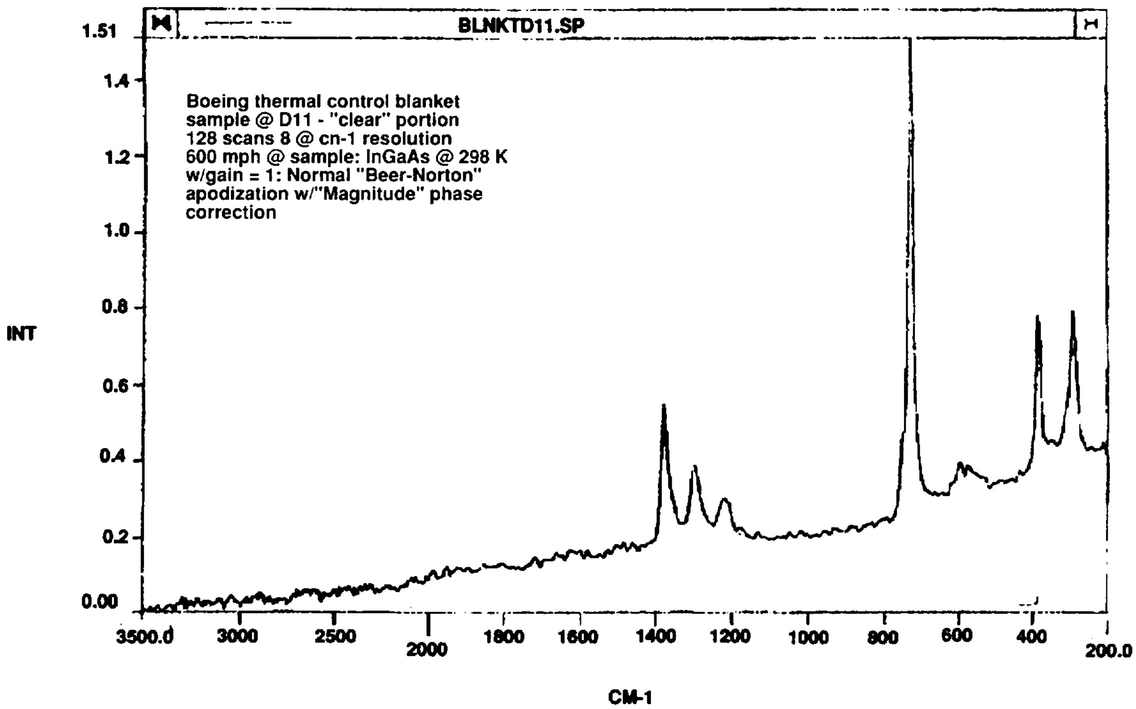

Figure D-70 RAMAN Spectrum for "clear" region of blanket D11.

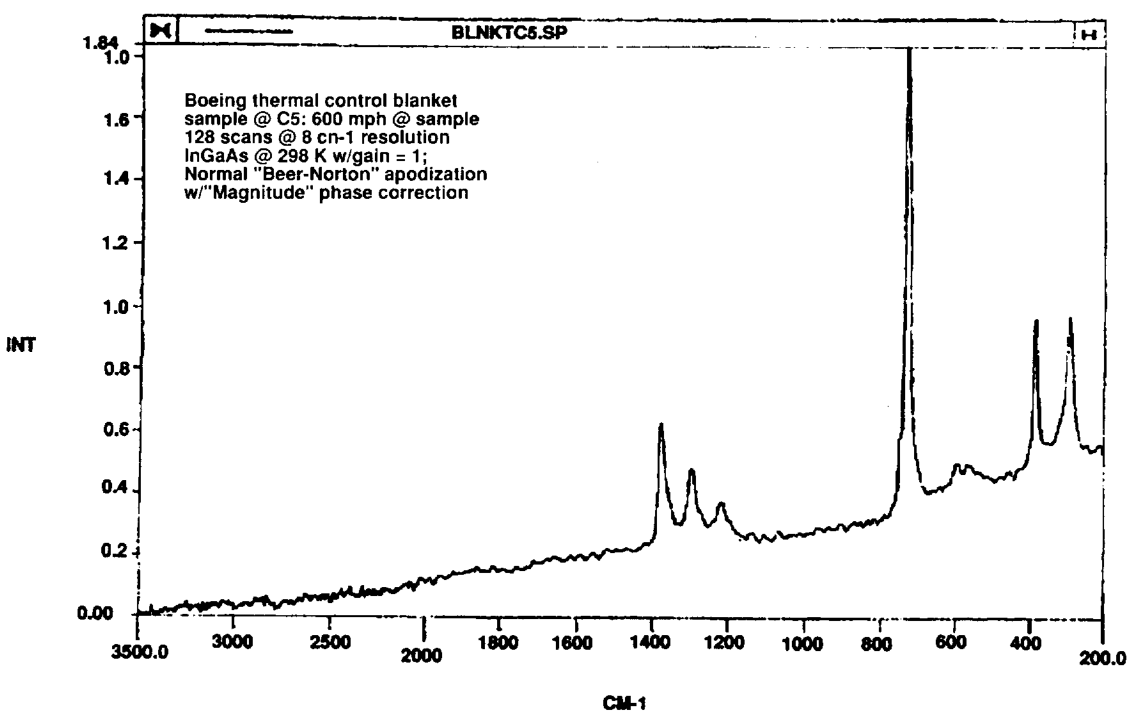

Figure D-71 RAMAN Spectrum for blanket C5.

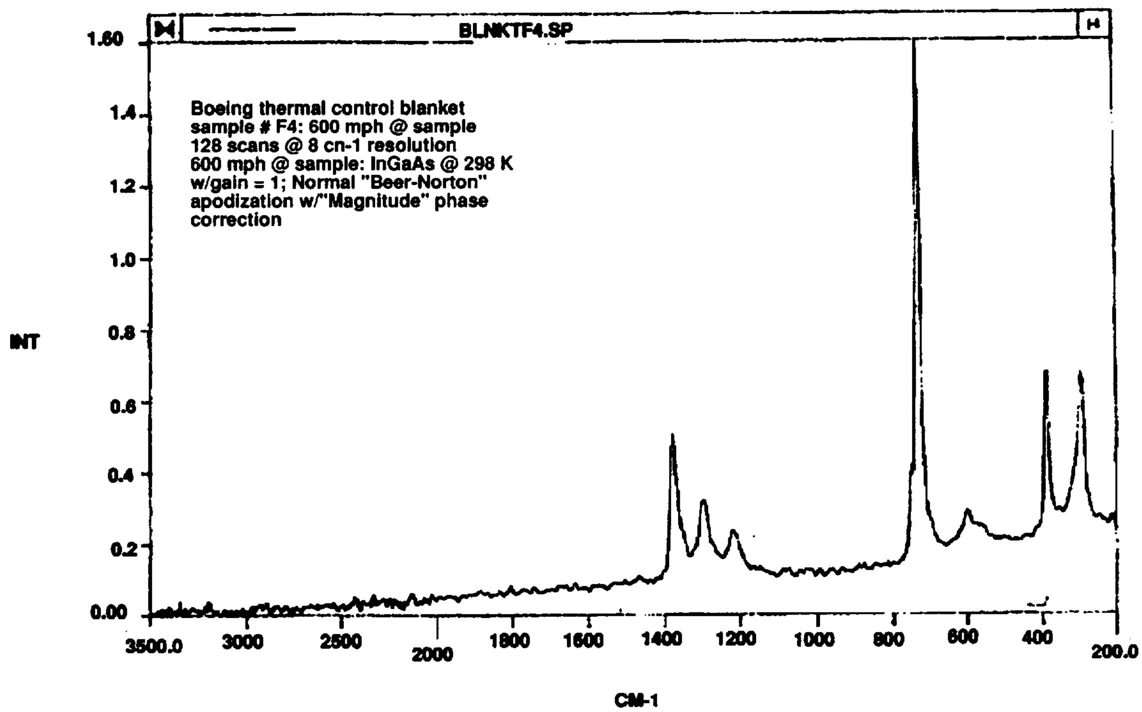

Figure D-72 RAMAN Spectrum for blanket F4.

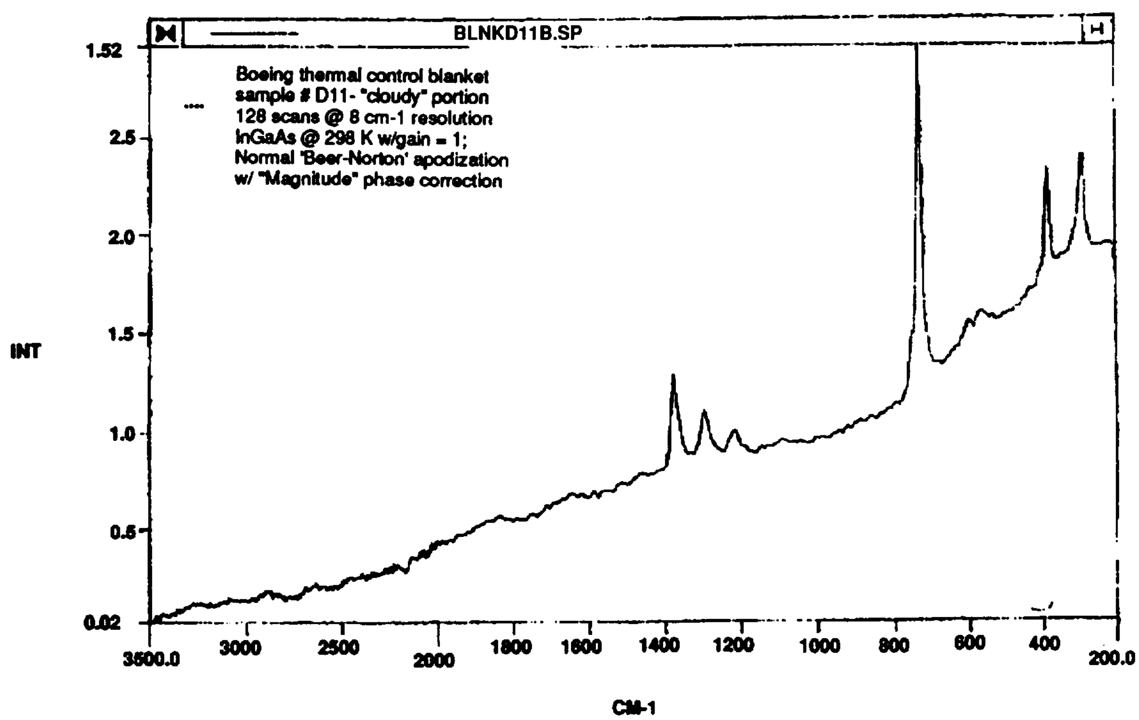

Figure D-73 RAMAN Spectrum for "cloudy" region of blanket D11.

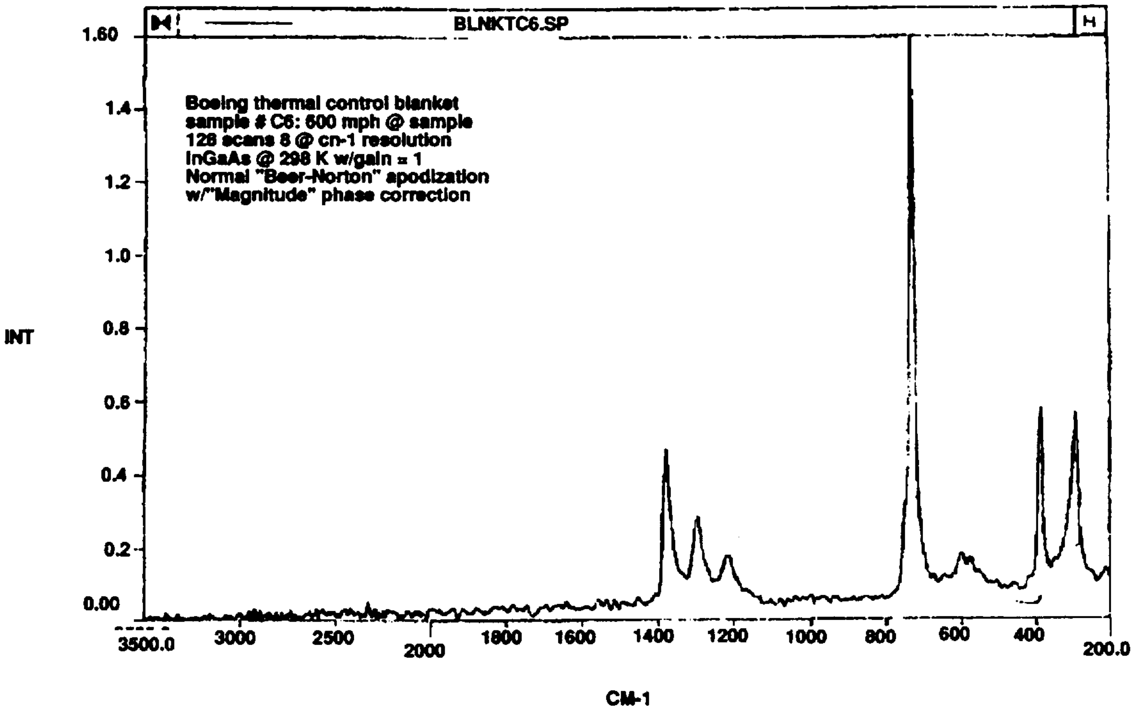

Figure D-74 Raman Spectrum for blanket C6.

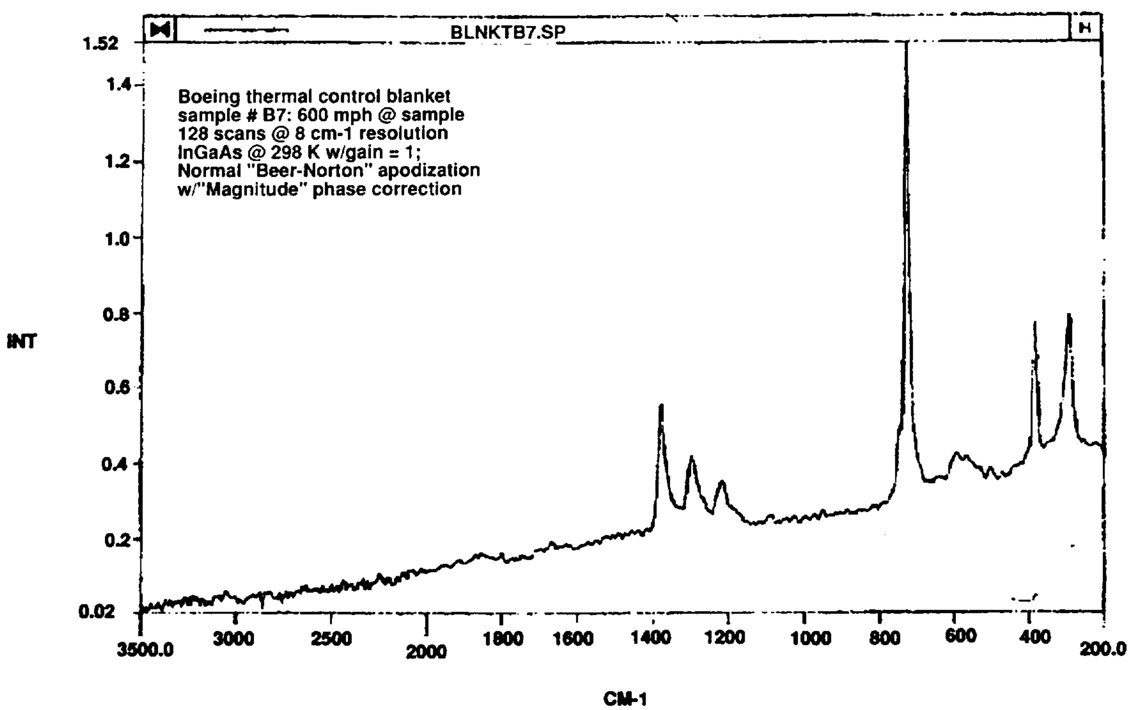

Figure D-75 Raman Spectrum for blanket B7.

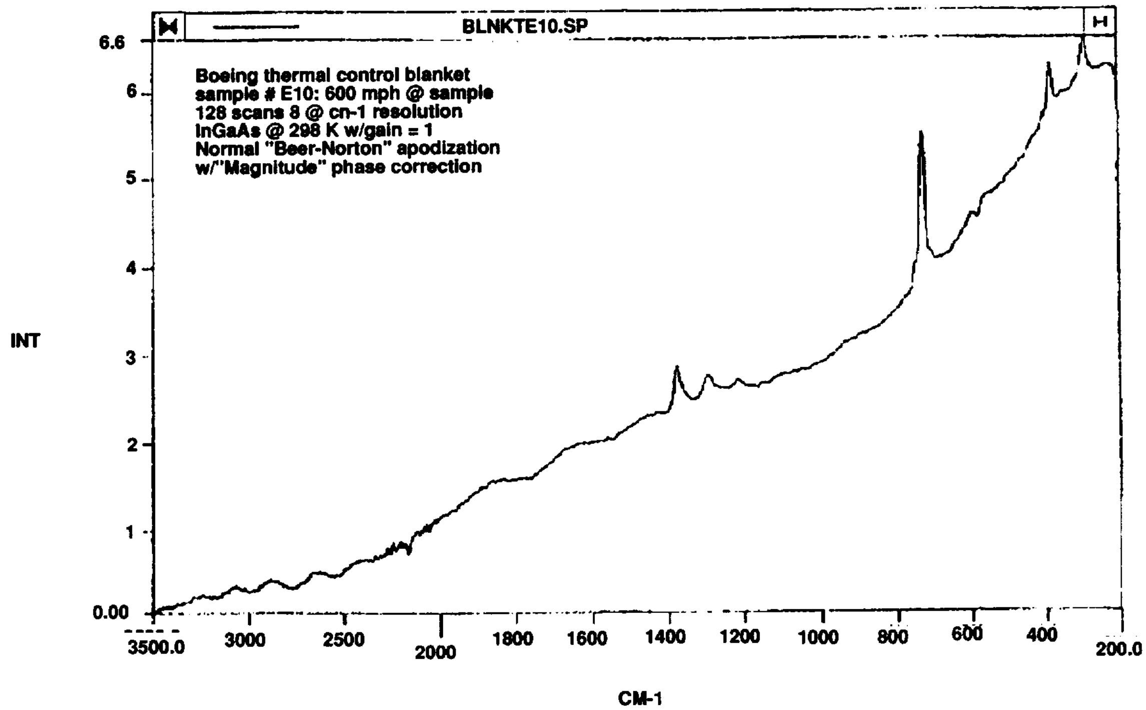

Figure D-76 Raman Spectrum for blanket E10.

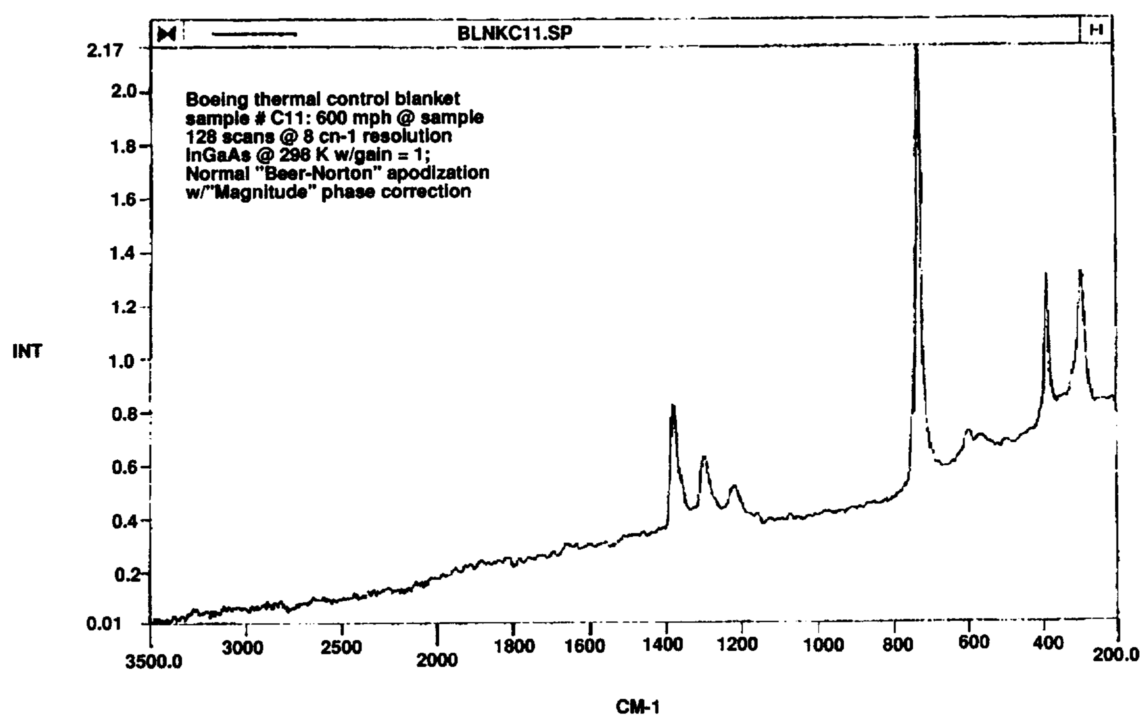

Figure D-77 Raman Spectrum for blanket C11.

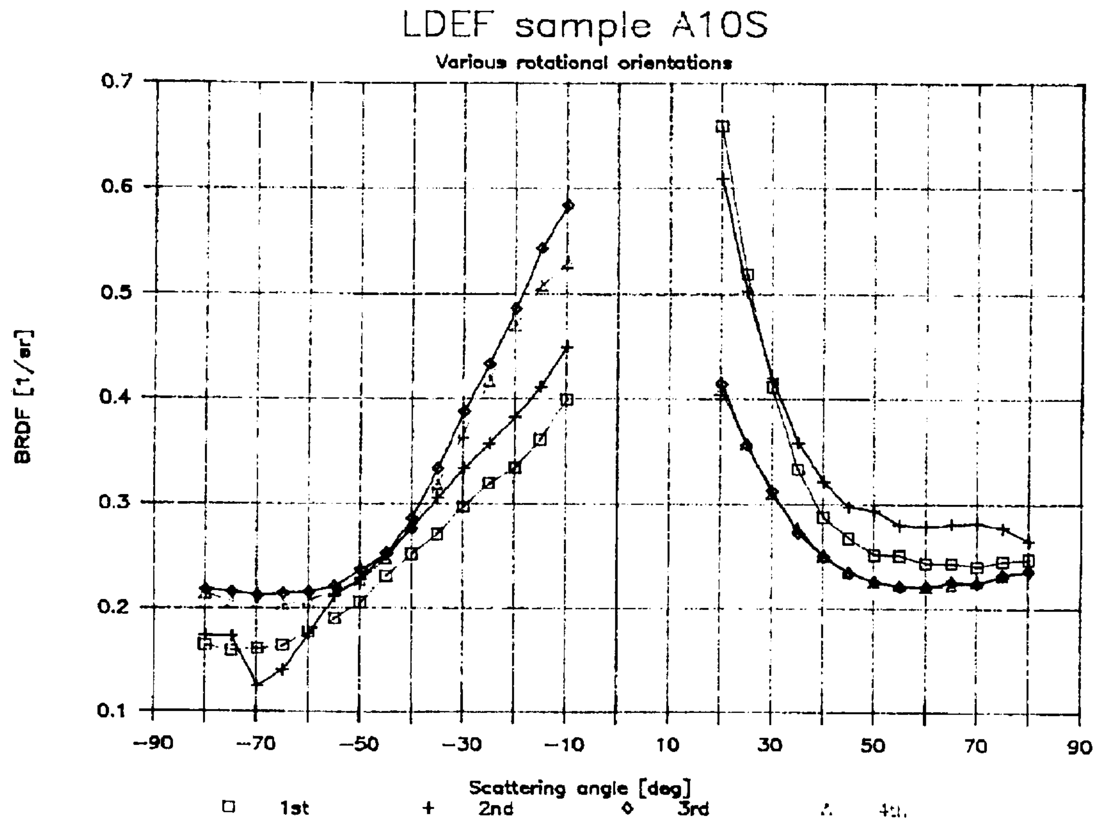

Figure D-78 BRDF Measurements for blanket A10.

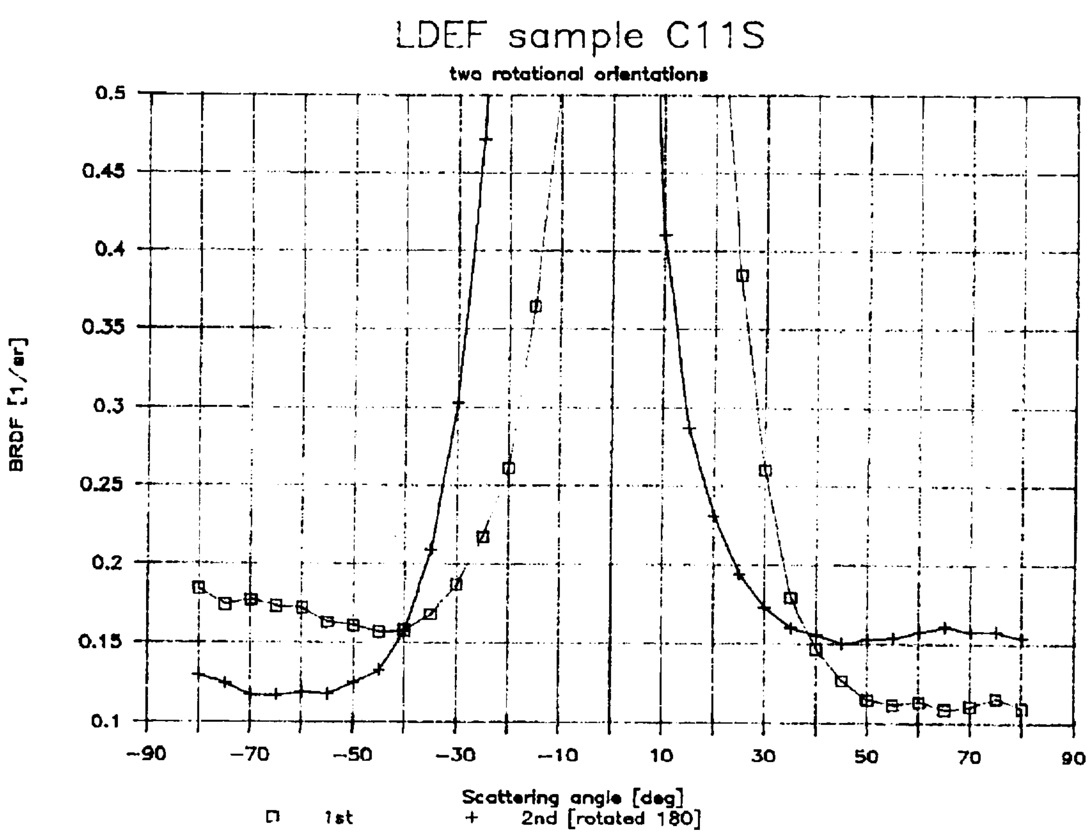

Figure D-79 BRDF Measurements for blanket C11.

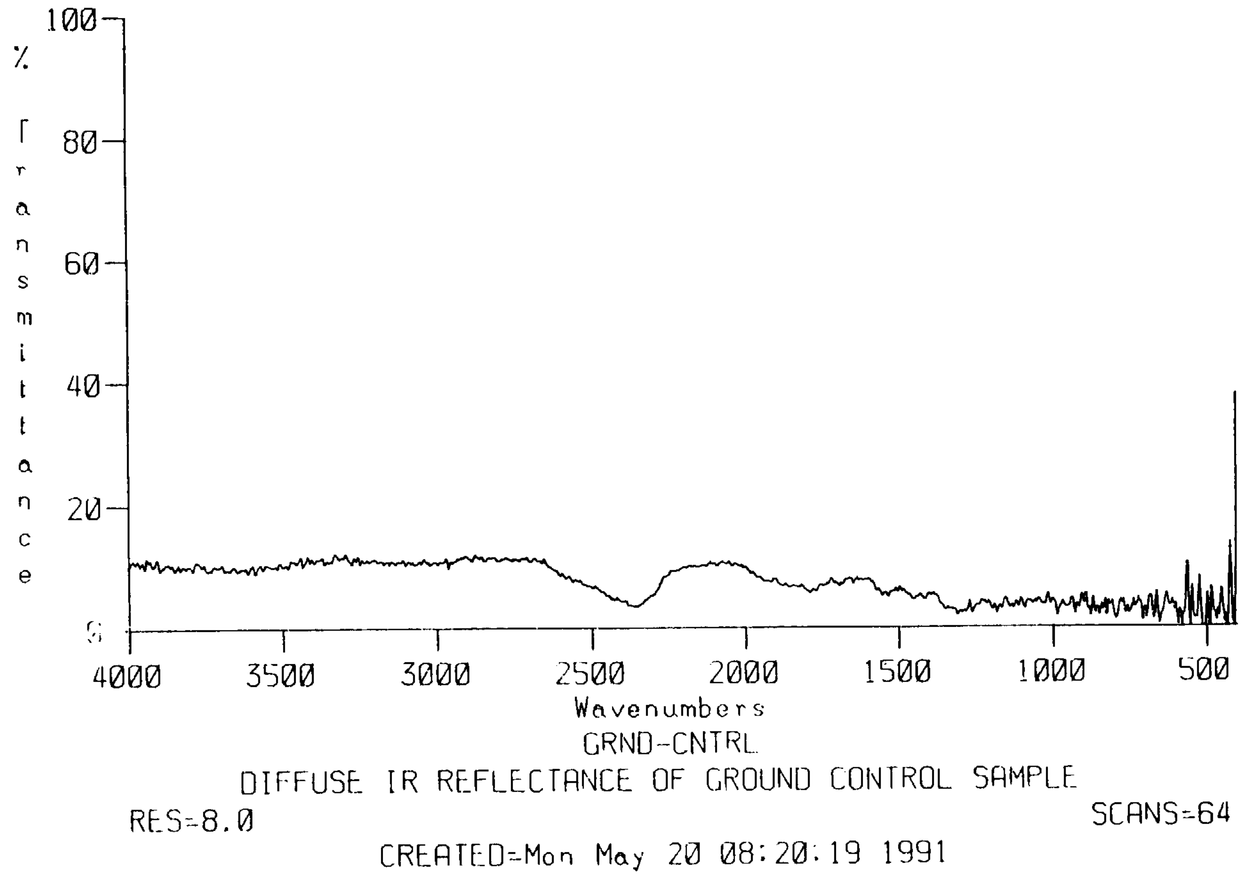

Figure D-80 Diffuse IR reflectance spectrum for ground control specimen.

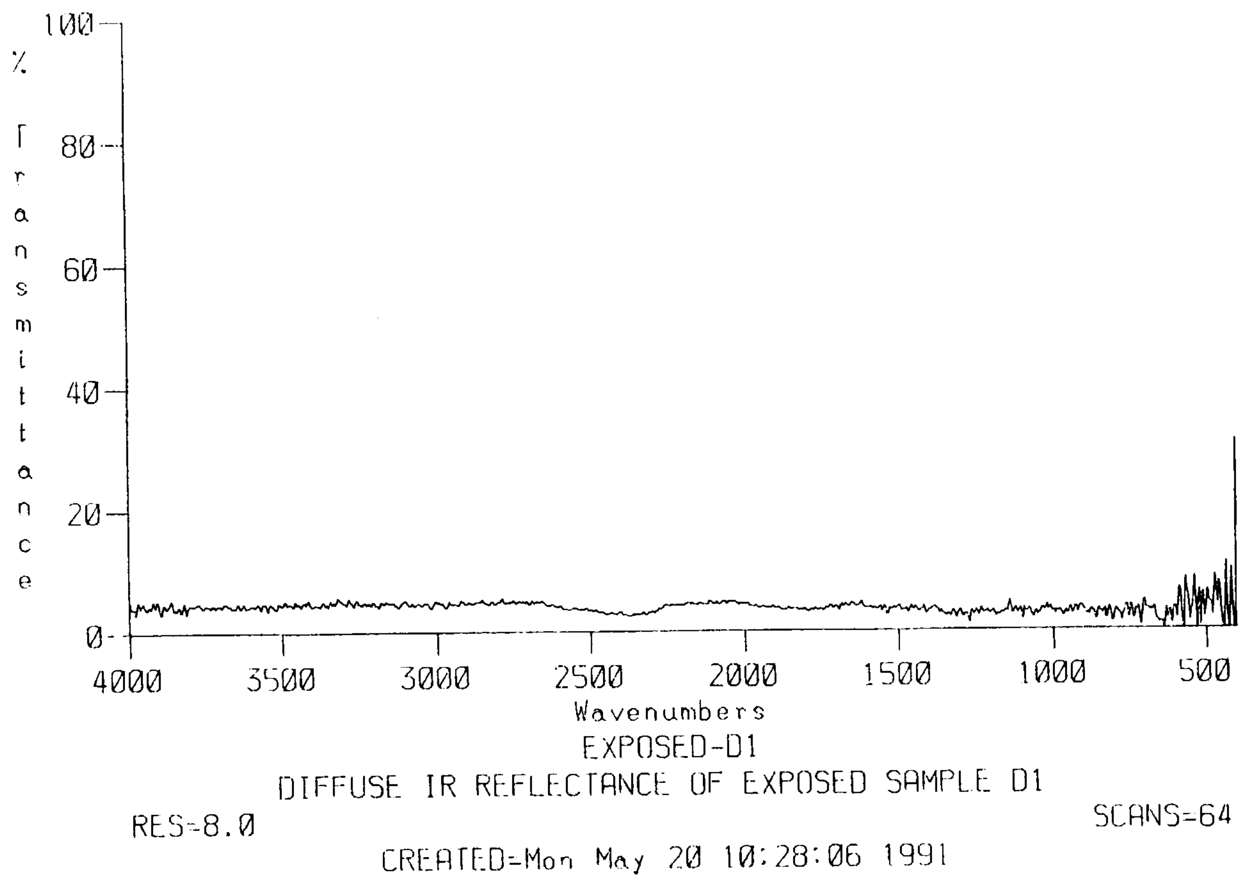

Figure D-81 Diffuse IR reflectance spectrum for blanket D1.

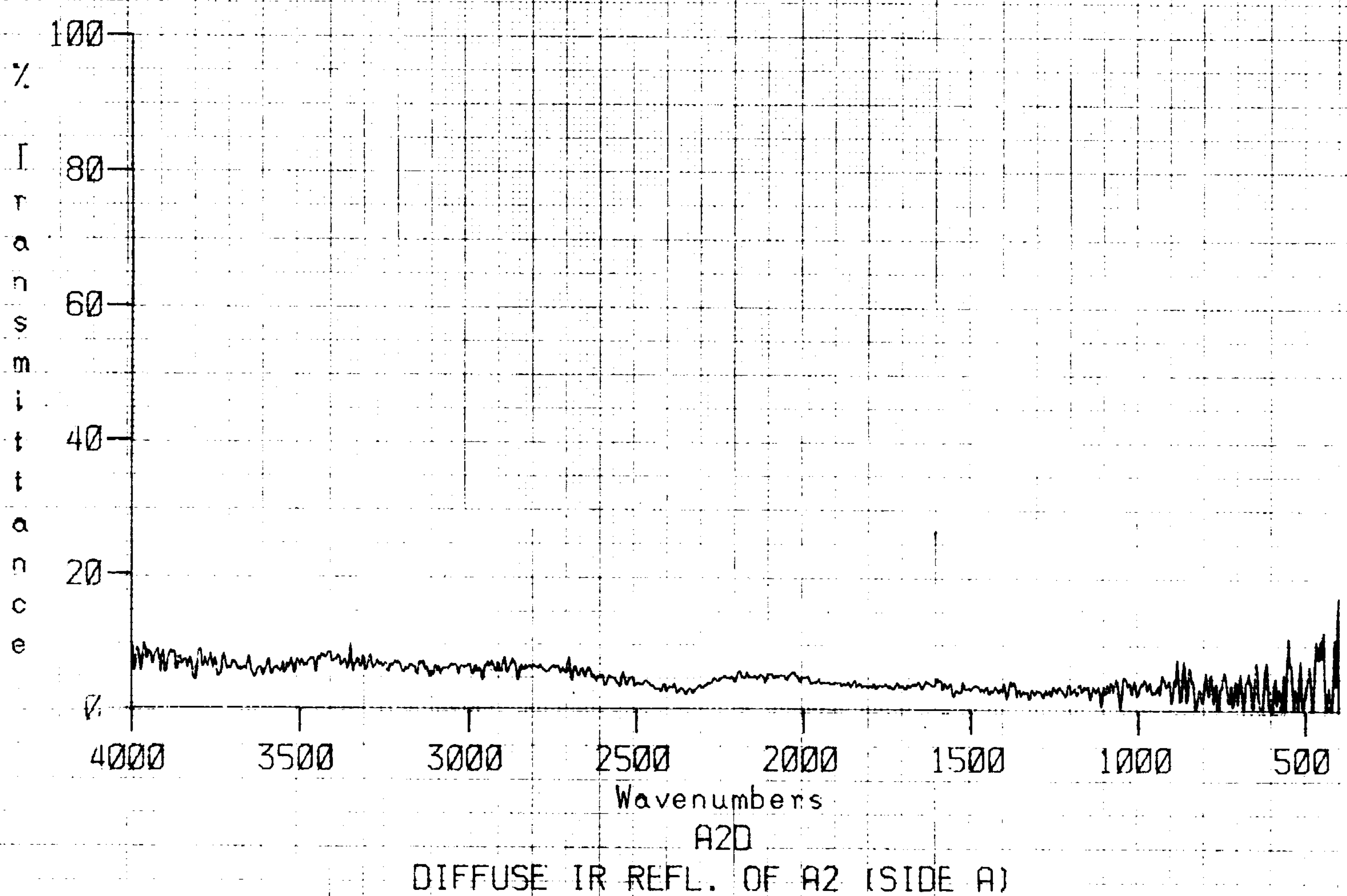

Figure D-82 Diffuse IR reflectance spectrum for blanket A2.

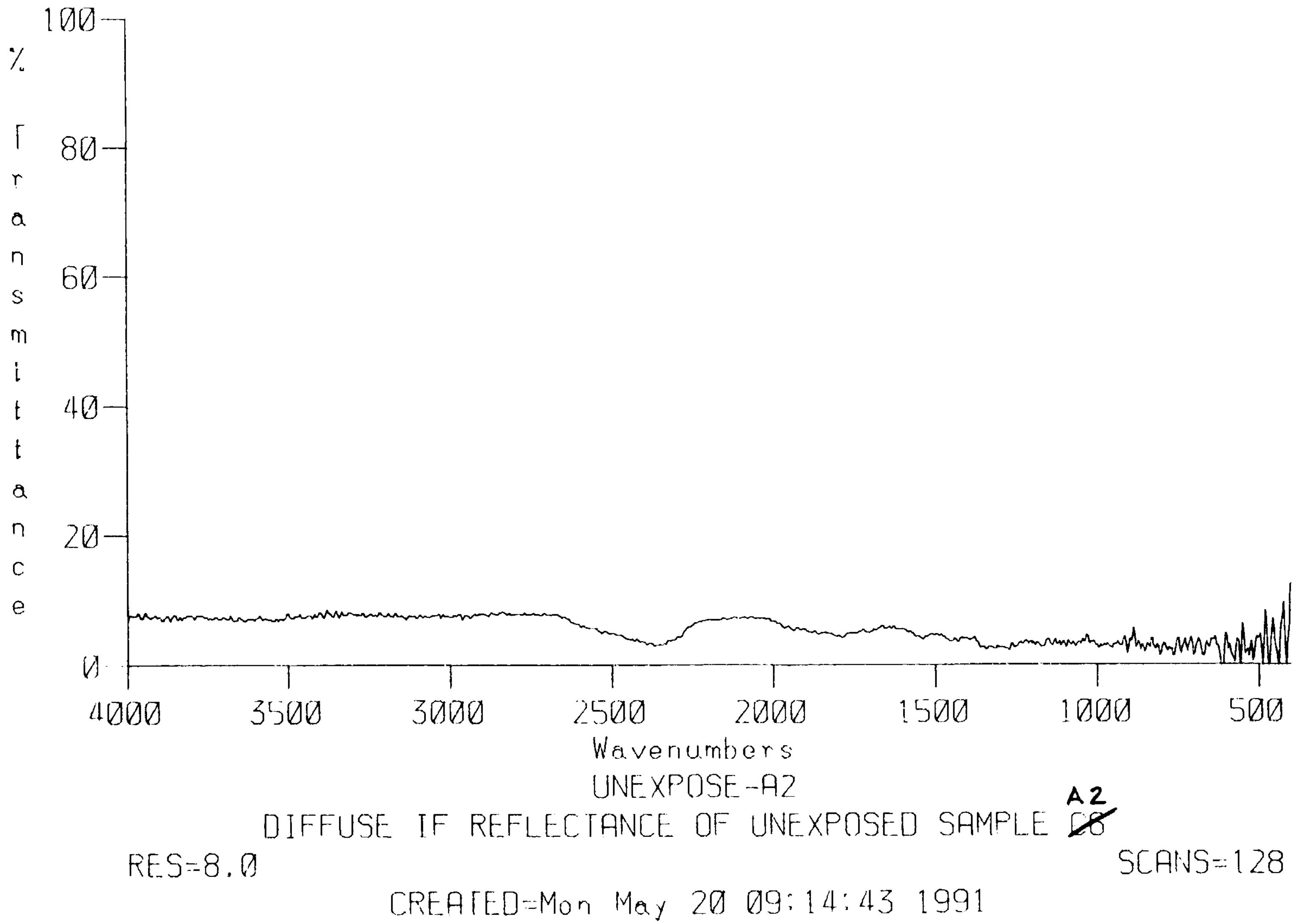

Figure D-83 Diffuse IR reflectance spectrum for blanket A2, unexposed area.

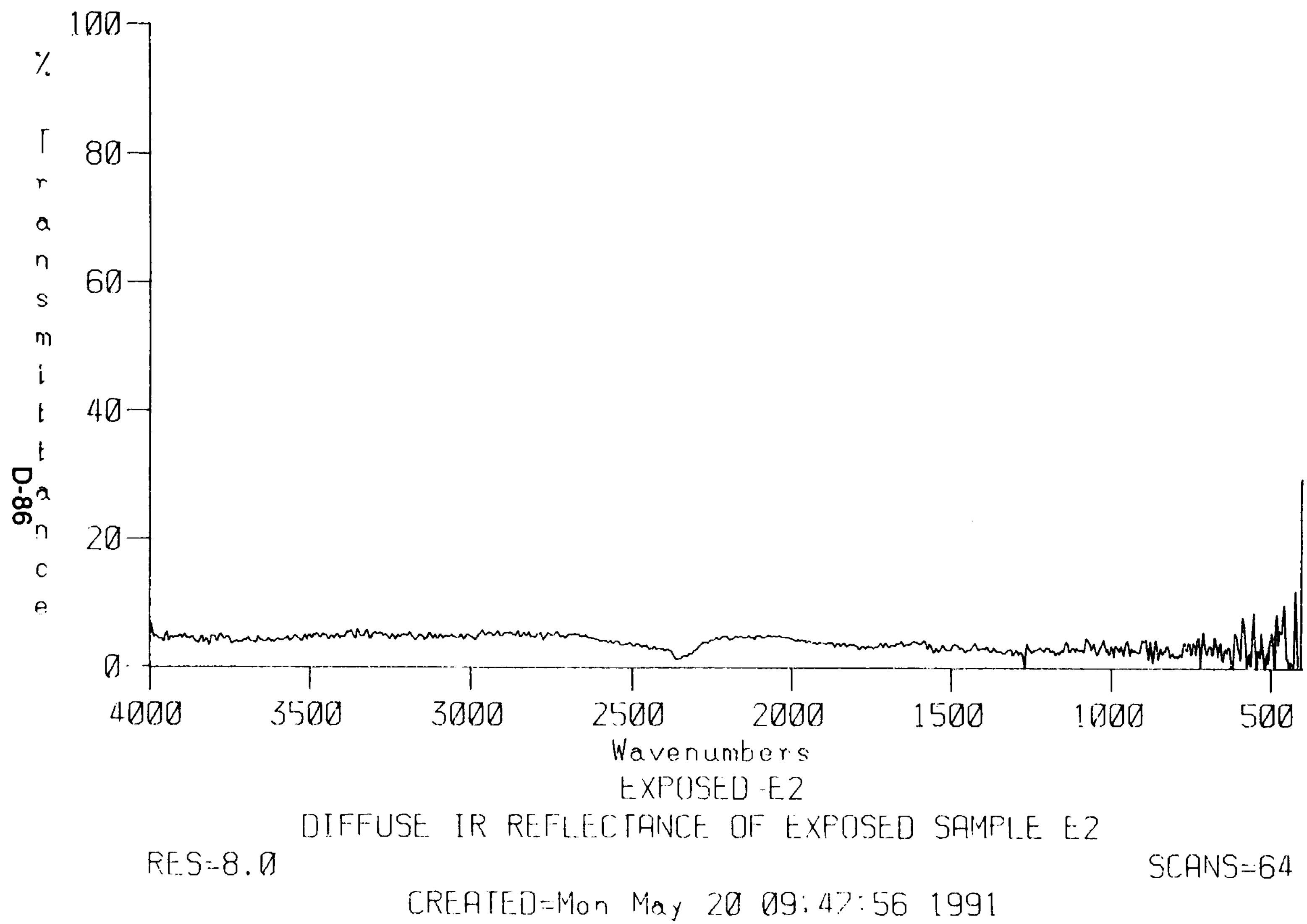

Figure D-84 Diffuse IR reflectance spectrum for blanket E2.

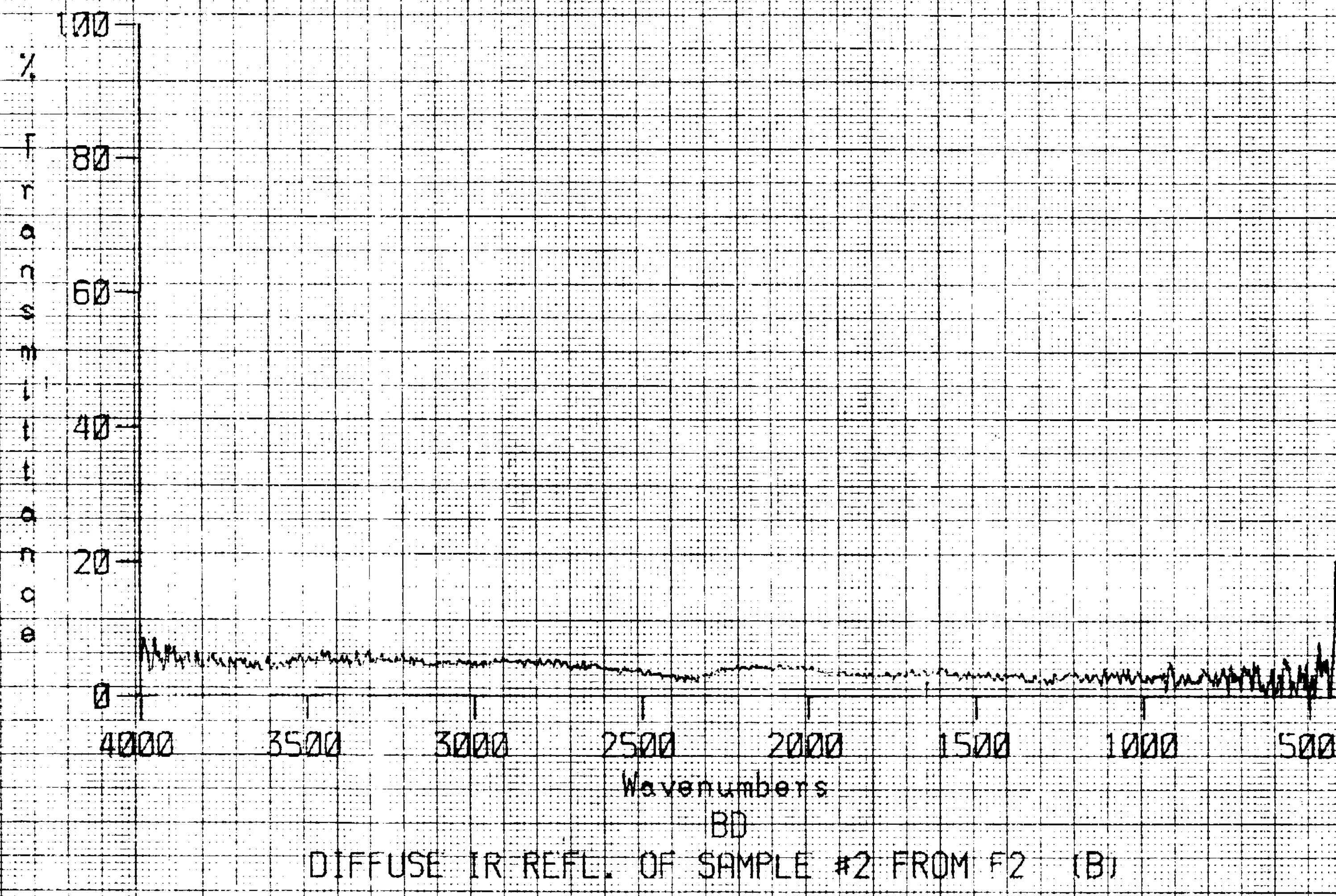

Figure D-85 Diffuse IR reflectance spectrum for blanket F2(#2).

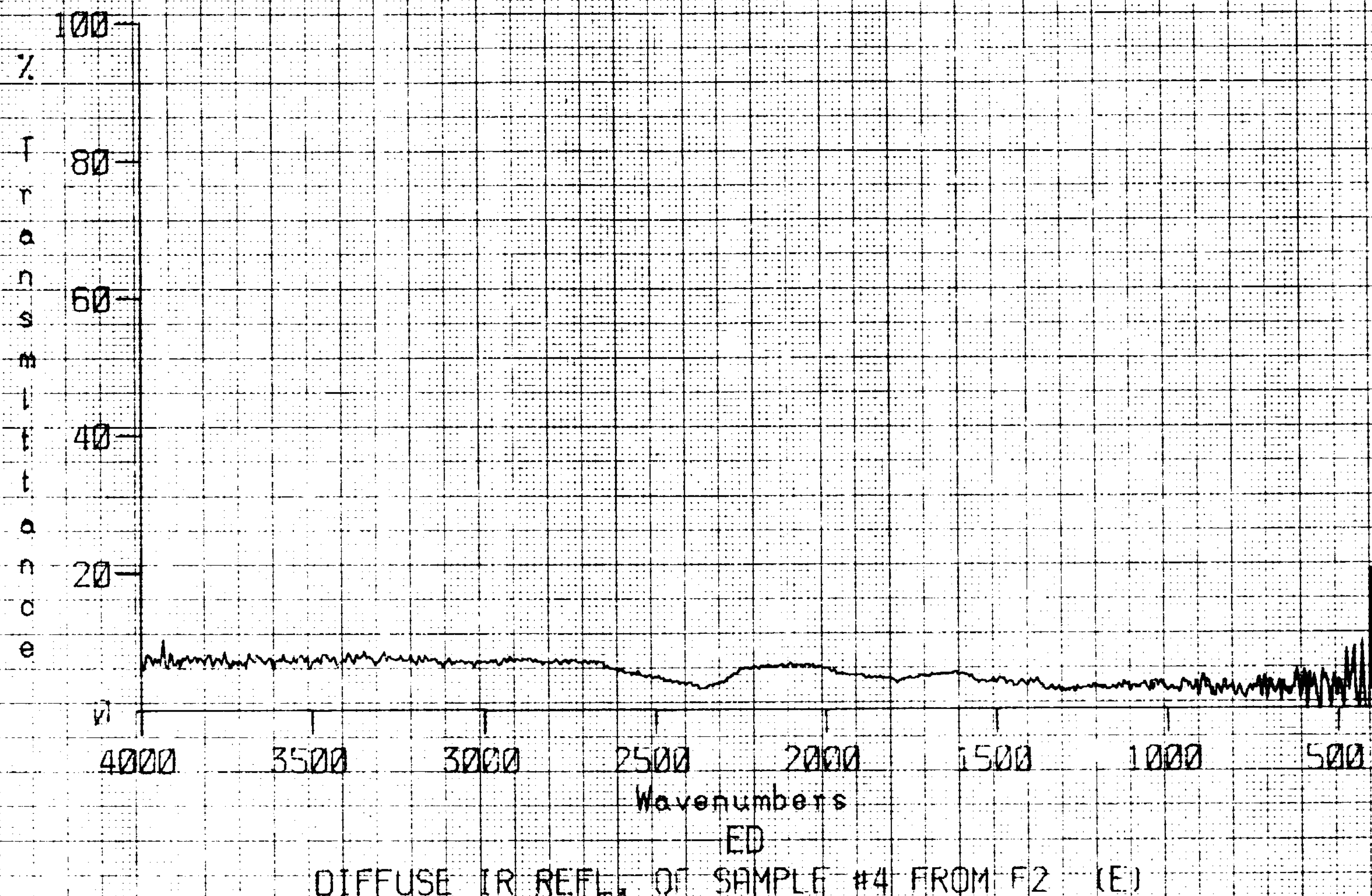

Figure D-87 Diffuse IR reflectance spectrum for blanket A4.

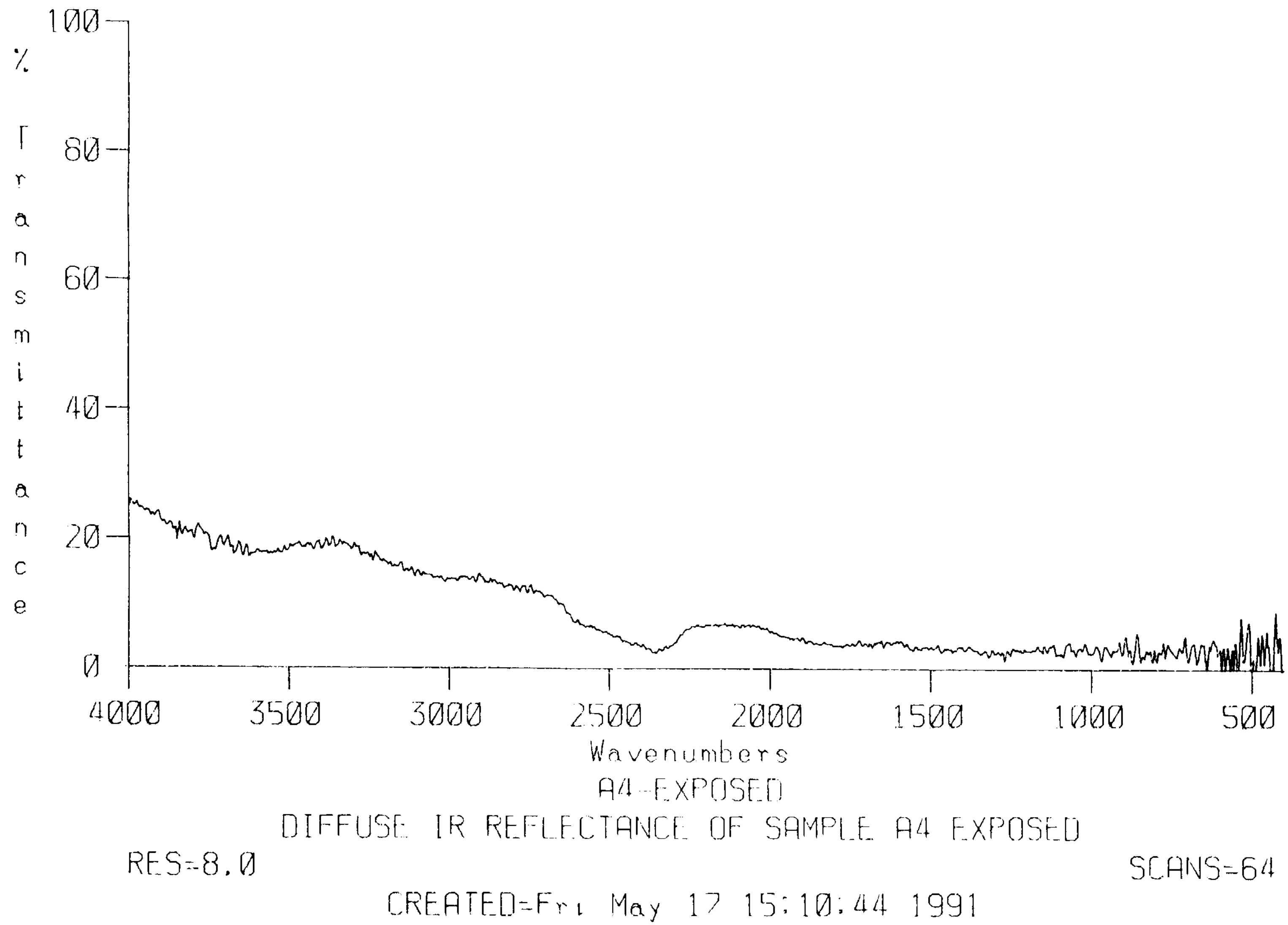

Figure D-86 Diffuse IR reflectance spectrum for blanket F2(#4).

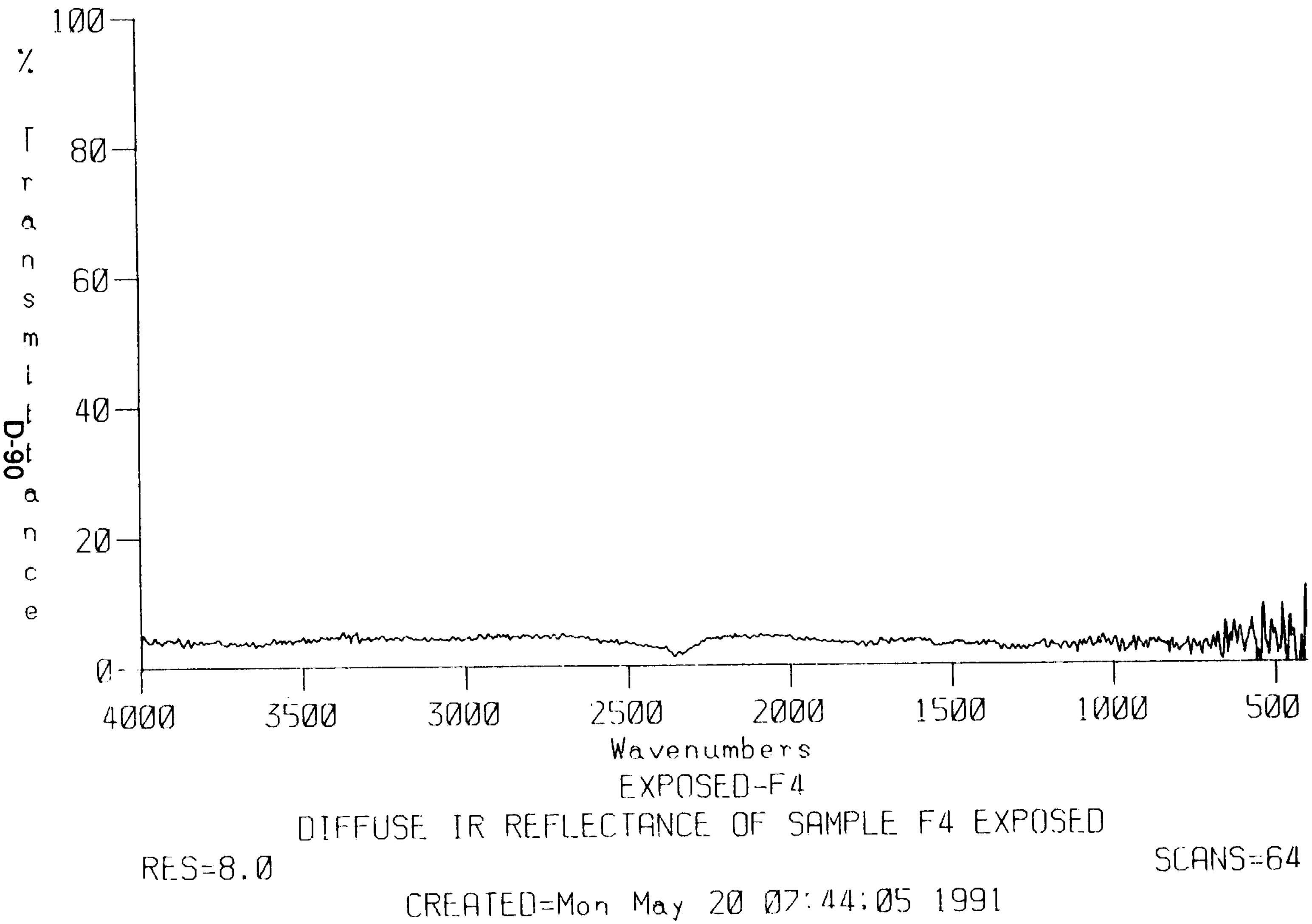

Figure D-88 Diffuse IR reflectance spectrum for blanket F4.

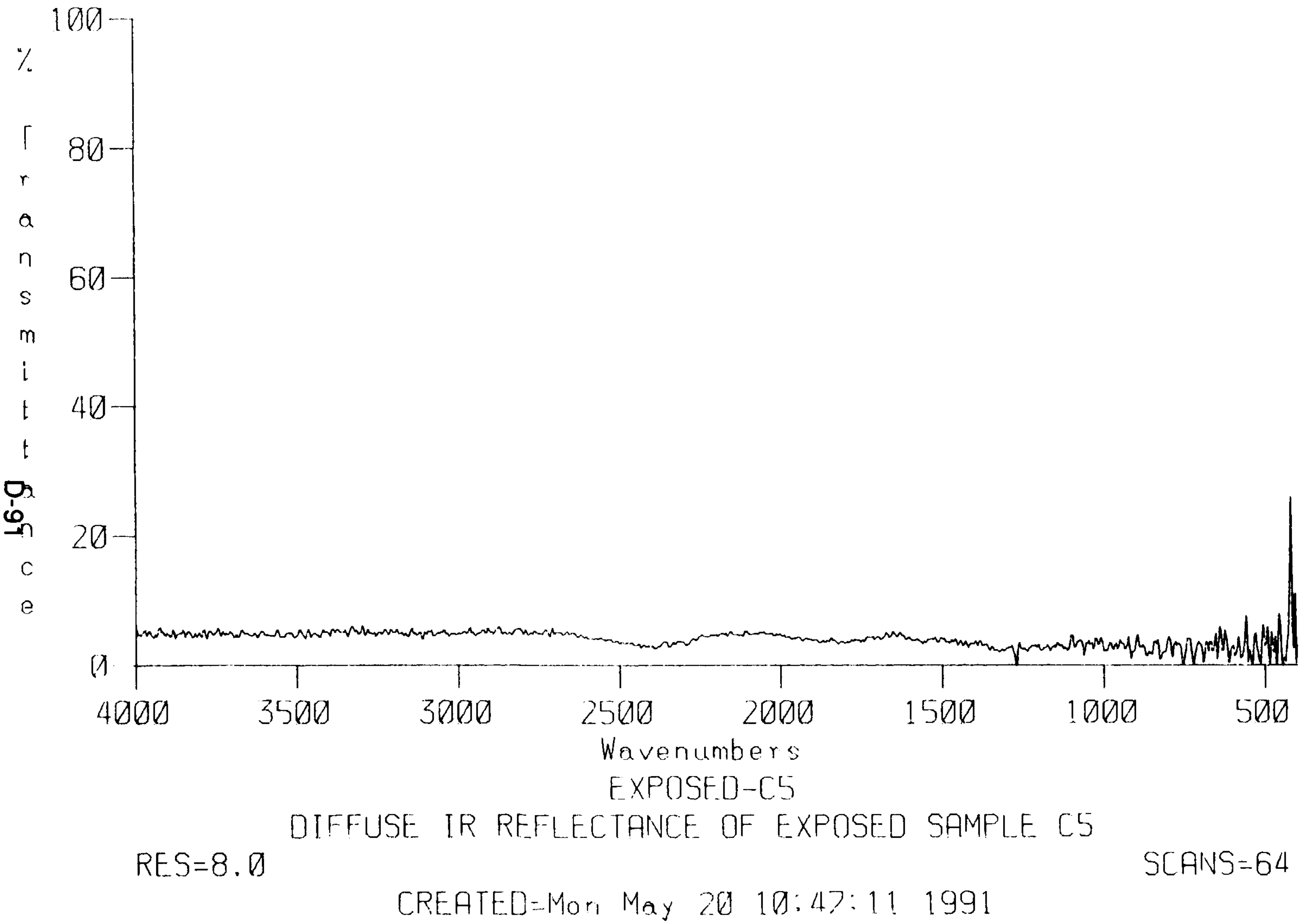

Figure D-89 Diffuse IR reflectance spectrum for blanket C5.

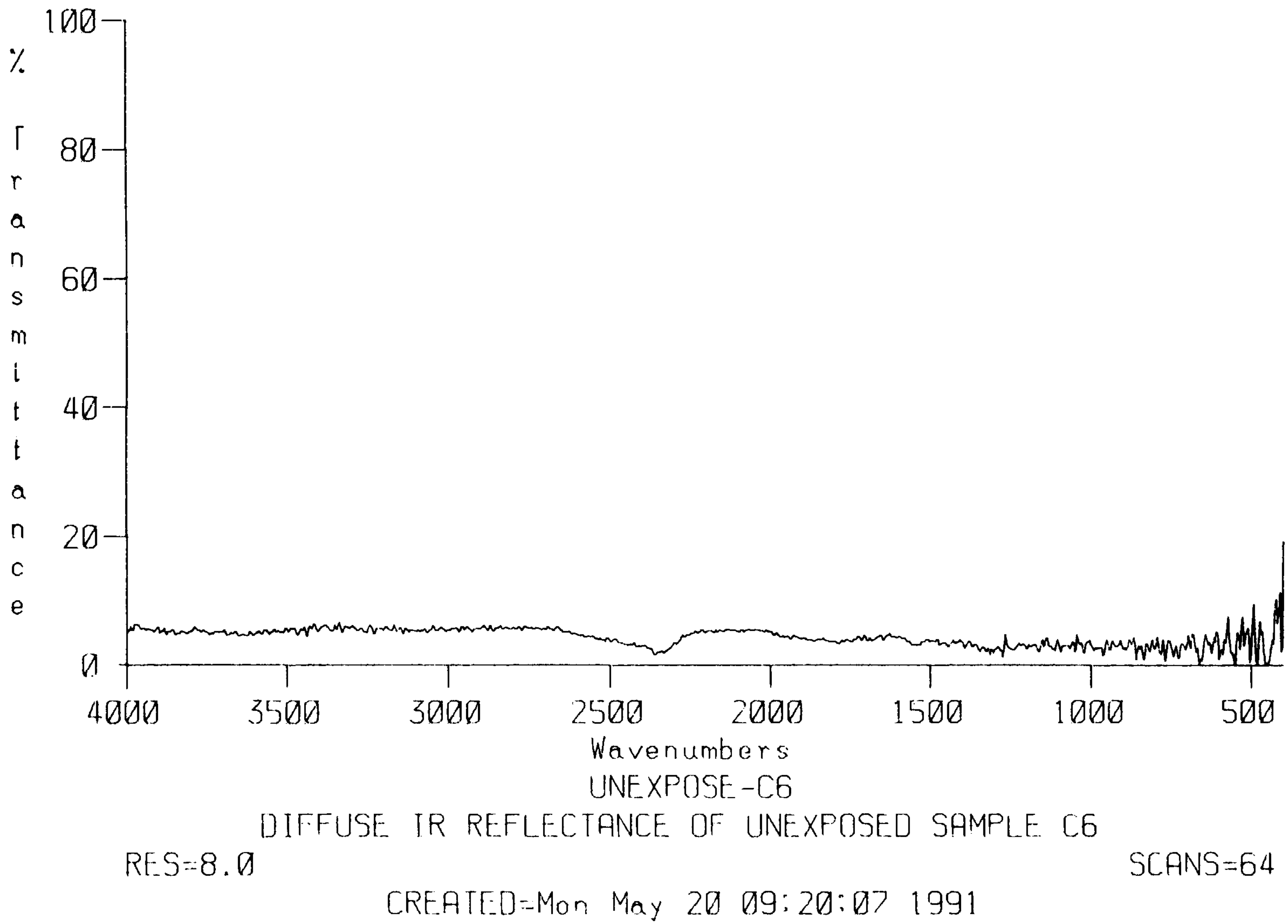

Figure D-90 Diffuse IR reflectance spectrum for unexposed area of blanket C6.

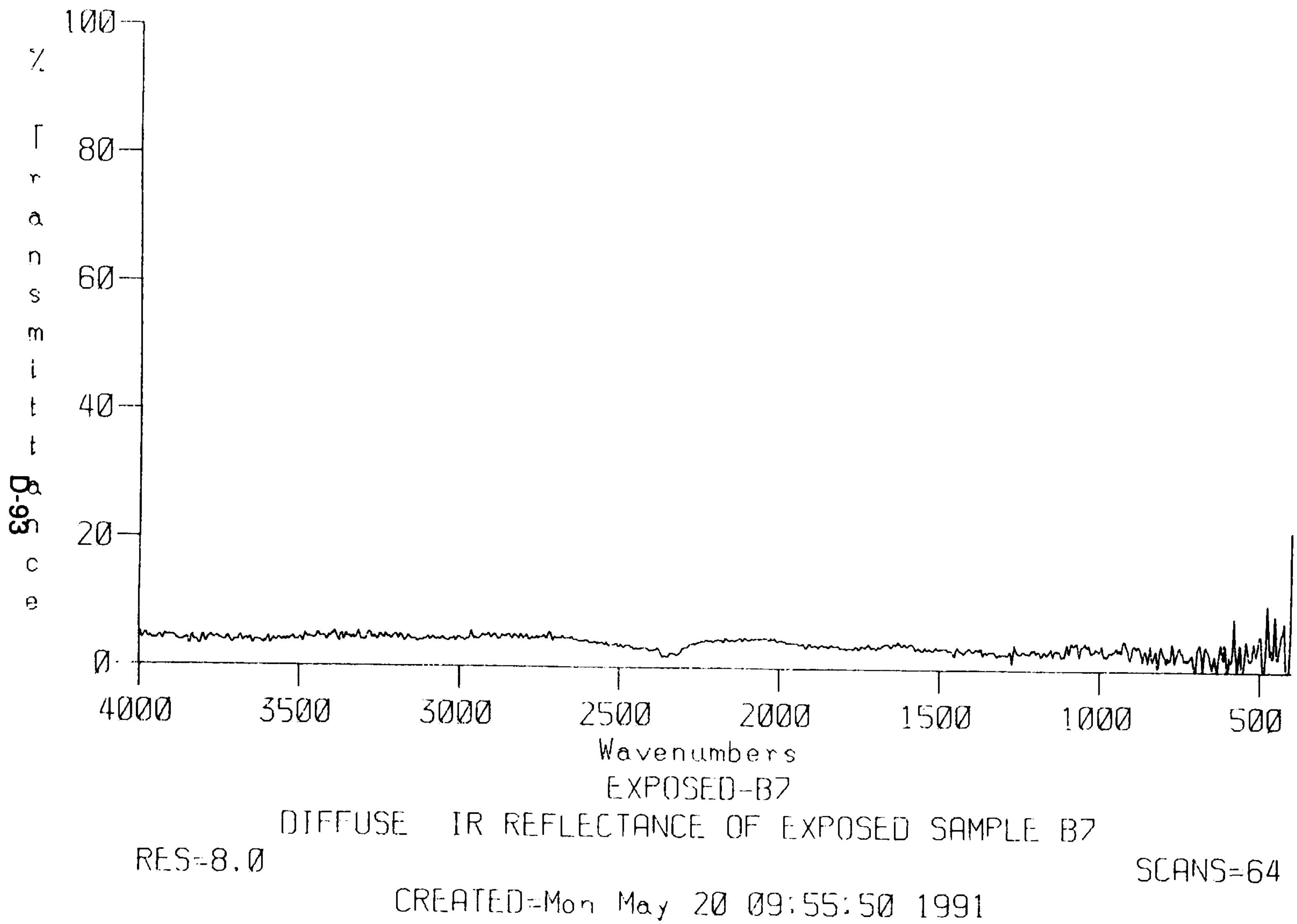

Figure D-91 Diffuse IR reflectance spectrum for blanket B7.

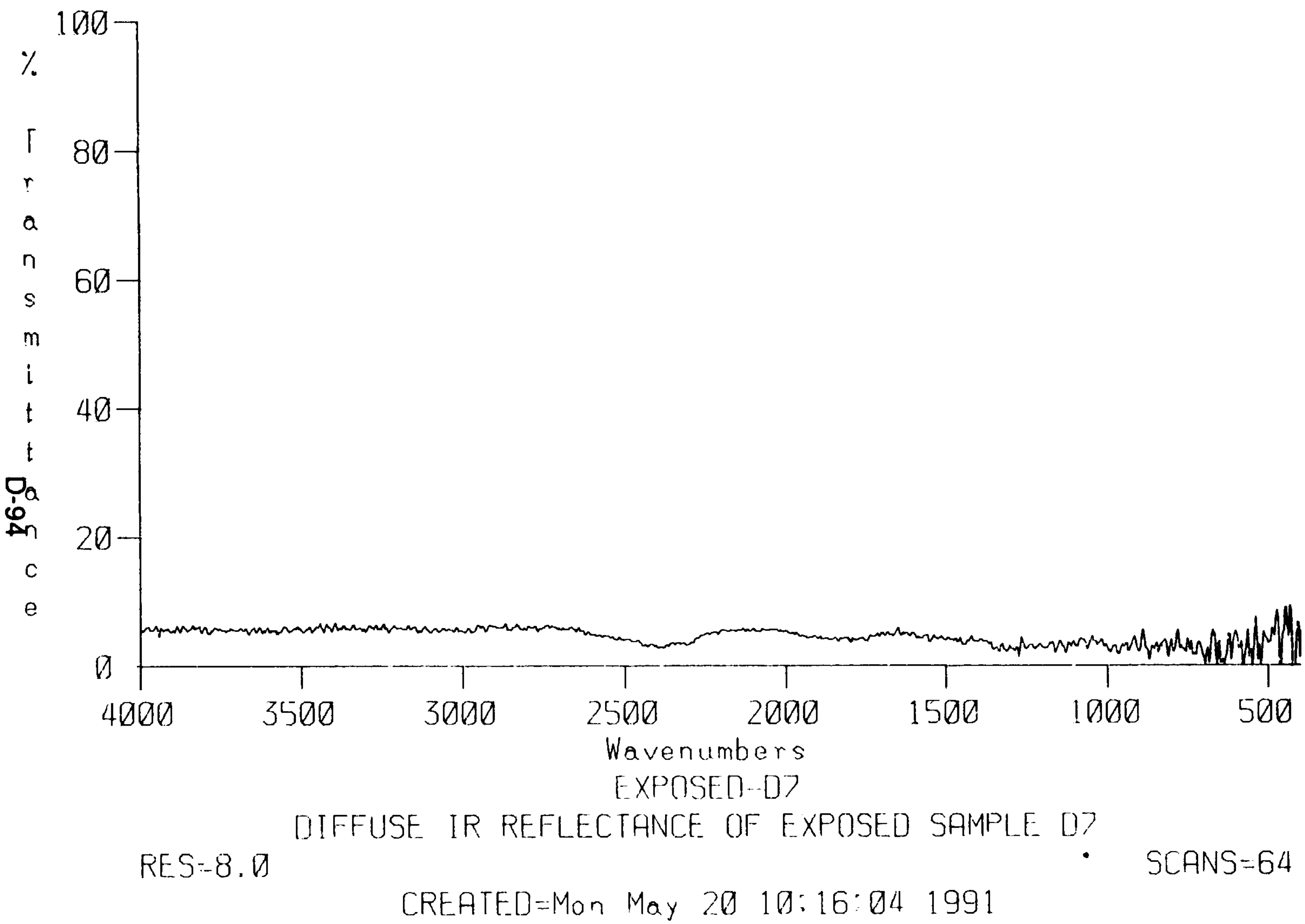

Figure D-92 Diffuse IR reflectance spectrum for blanket D7.

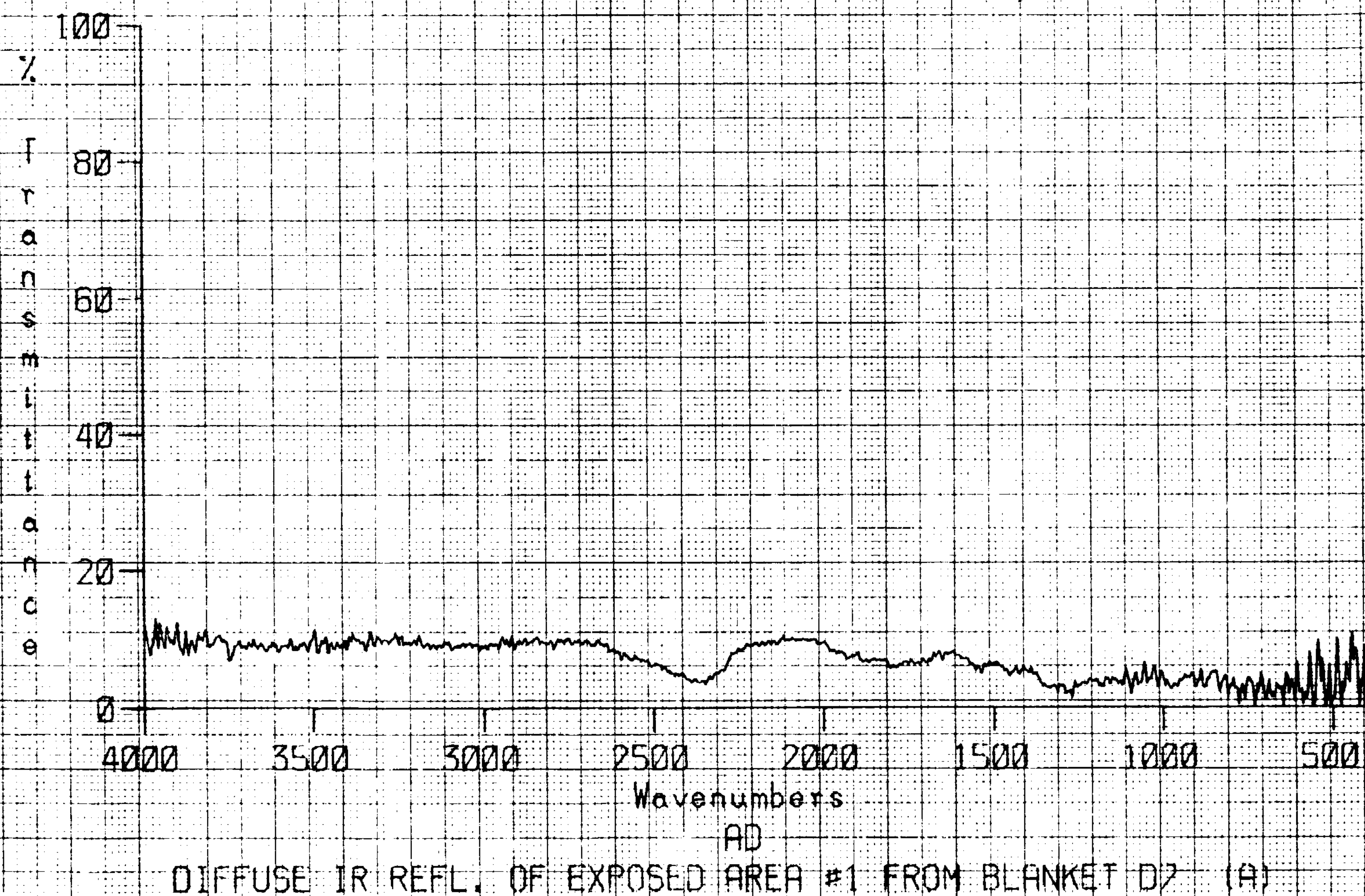

Figure D-93 Diffuse IR reflectance spectrum for blanket D7, Area 1.

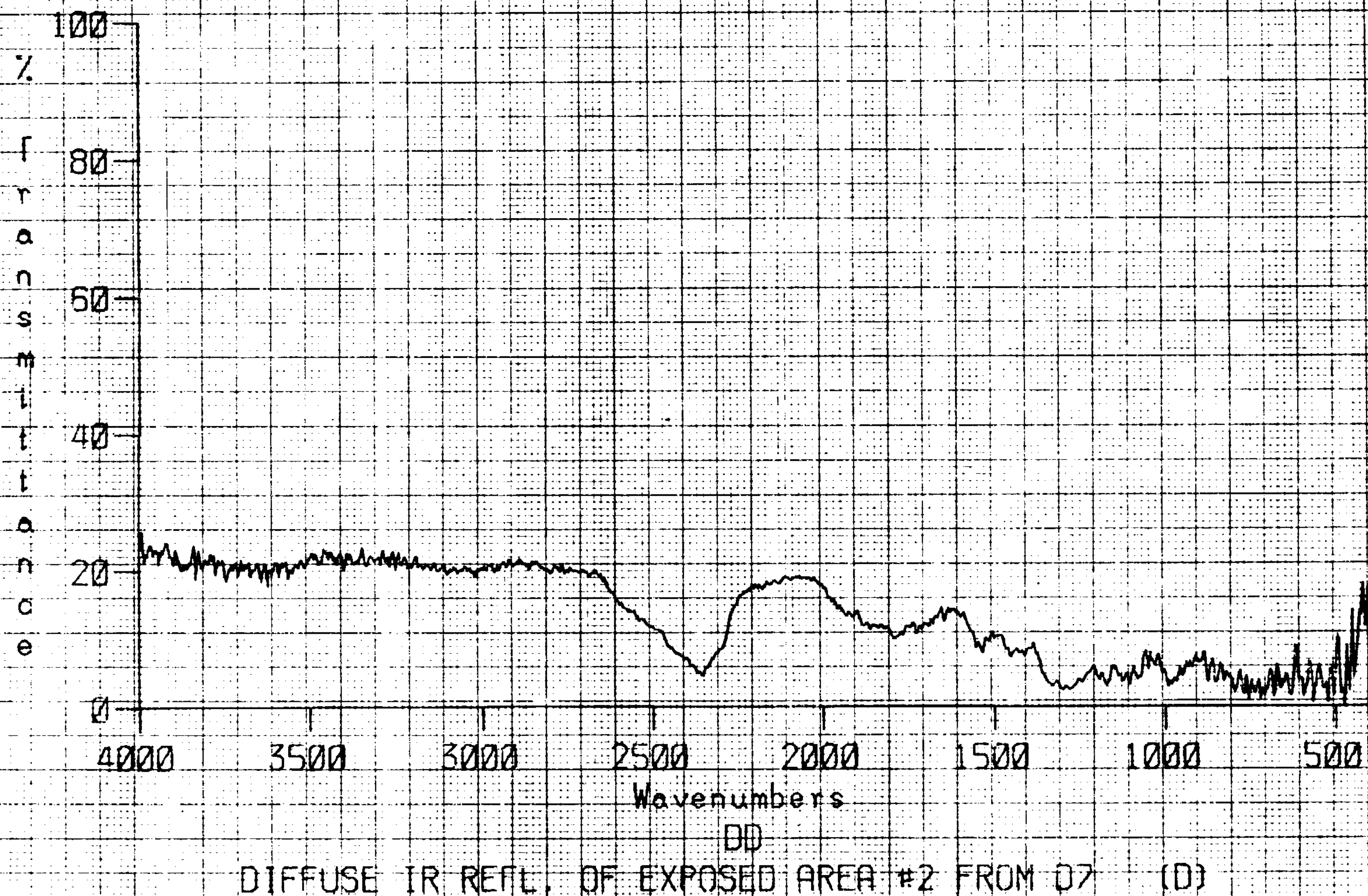

Figure D-94 Diffuse IR reflectance spectrum for blanket D7, Area 2.

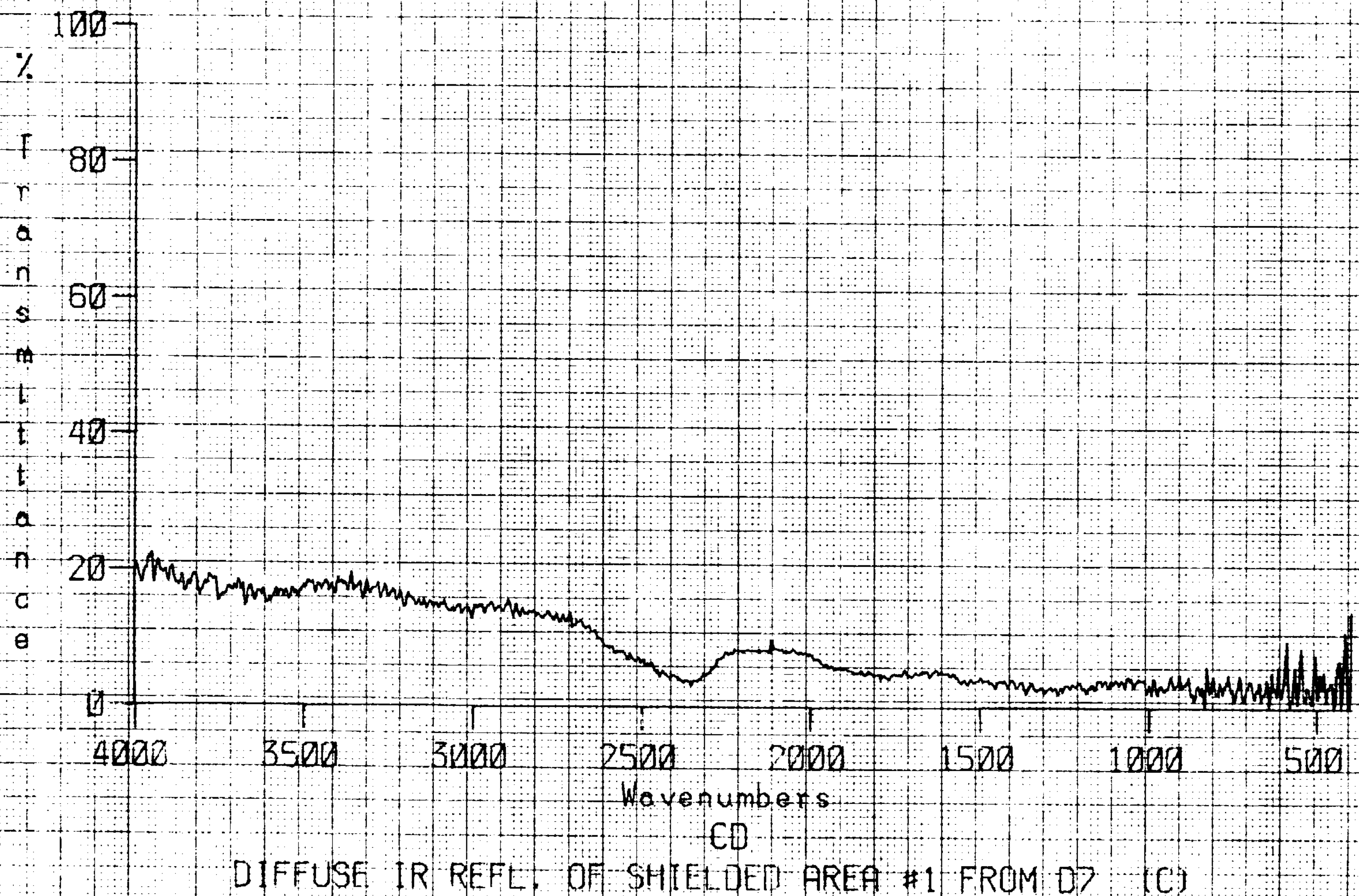

Figure D-95 Diffuse IR reflectance spectrum for shielded area from blanket D7.

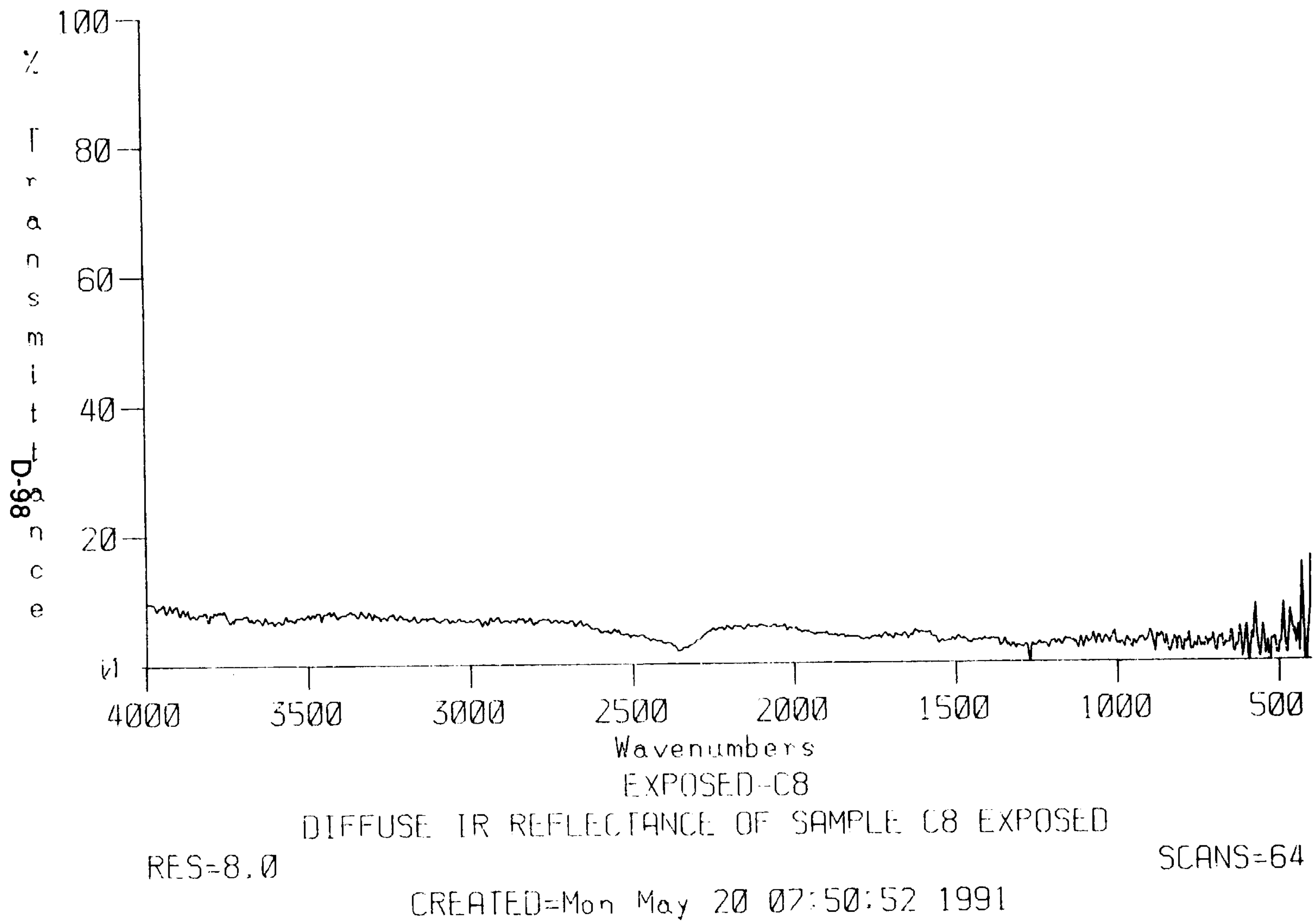

Figure D-96 Diffuse IR reflectance spectrum for blanket C8.

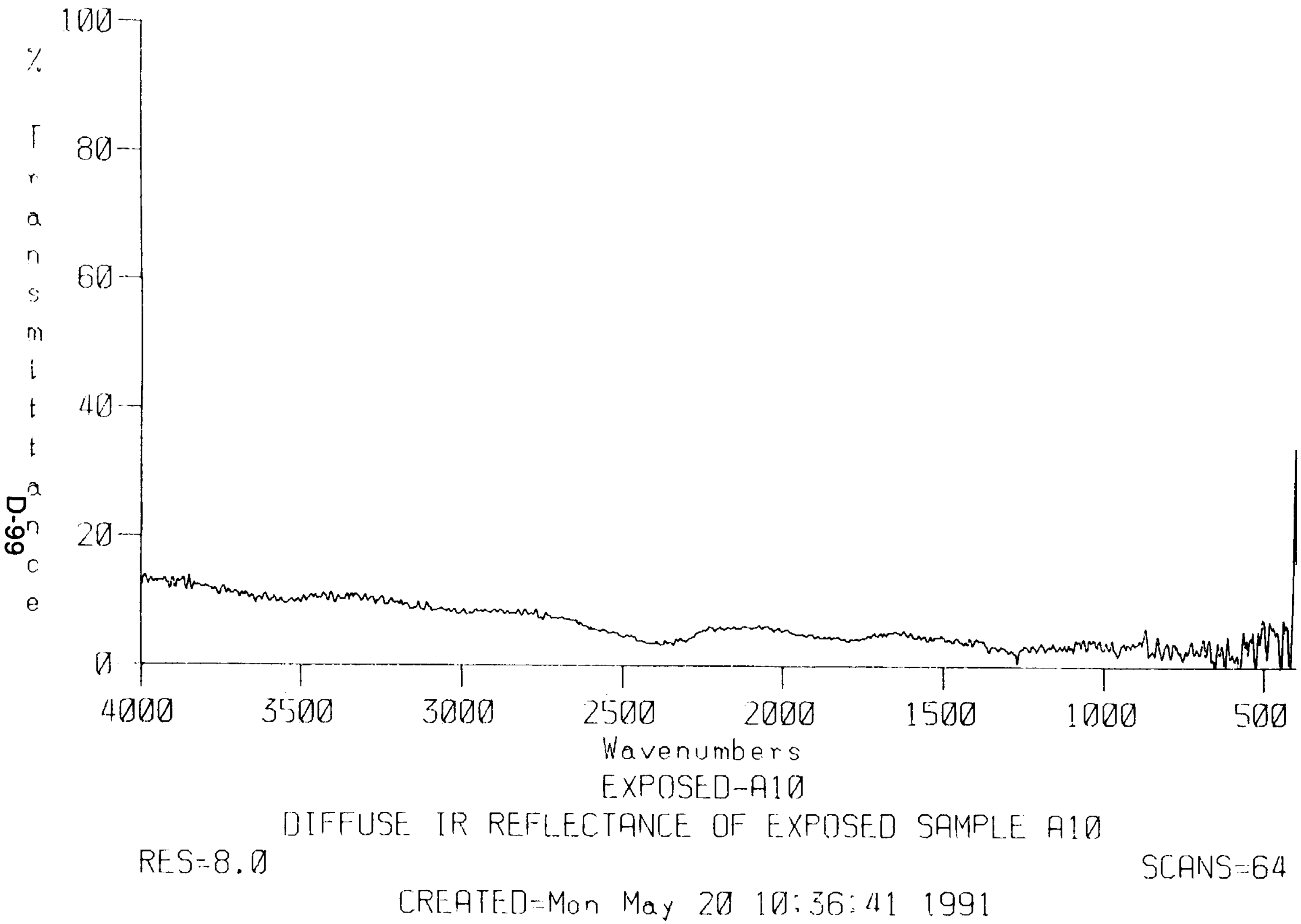

Figure D-97 Diffuse IR reflectance spectrum for blanket A10.

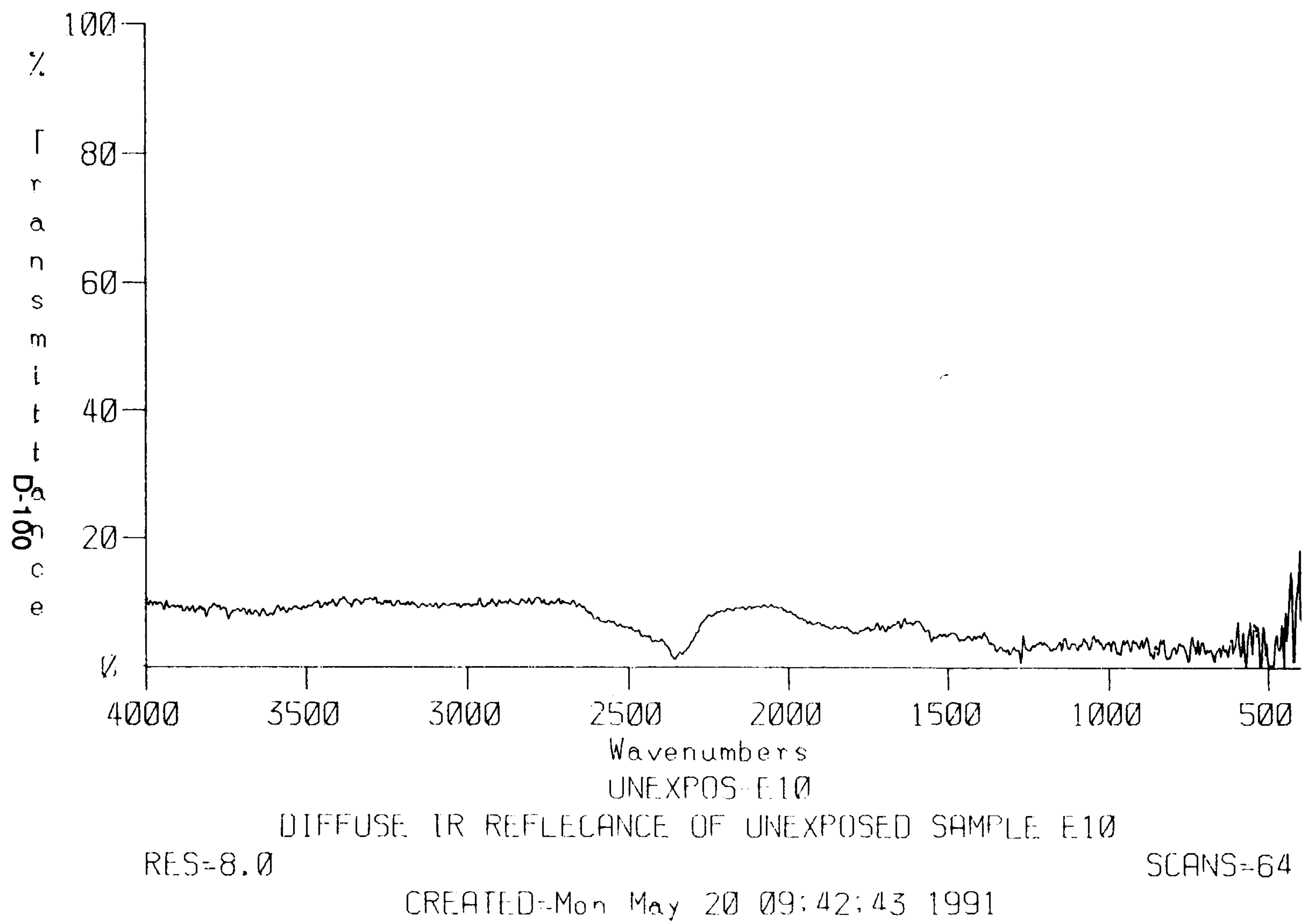

Figure D-98 Diffuse IR reflectance spectrum for unexposed area of blanket E10.

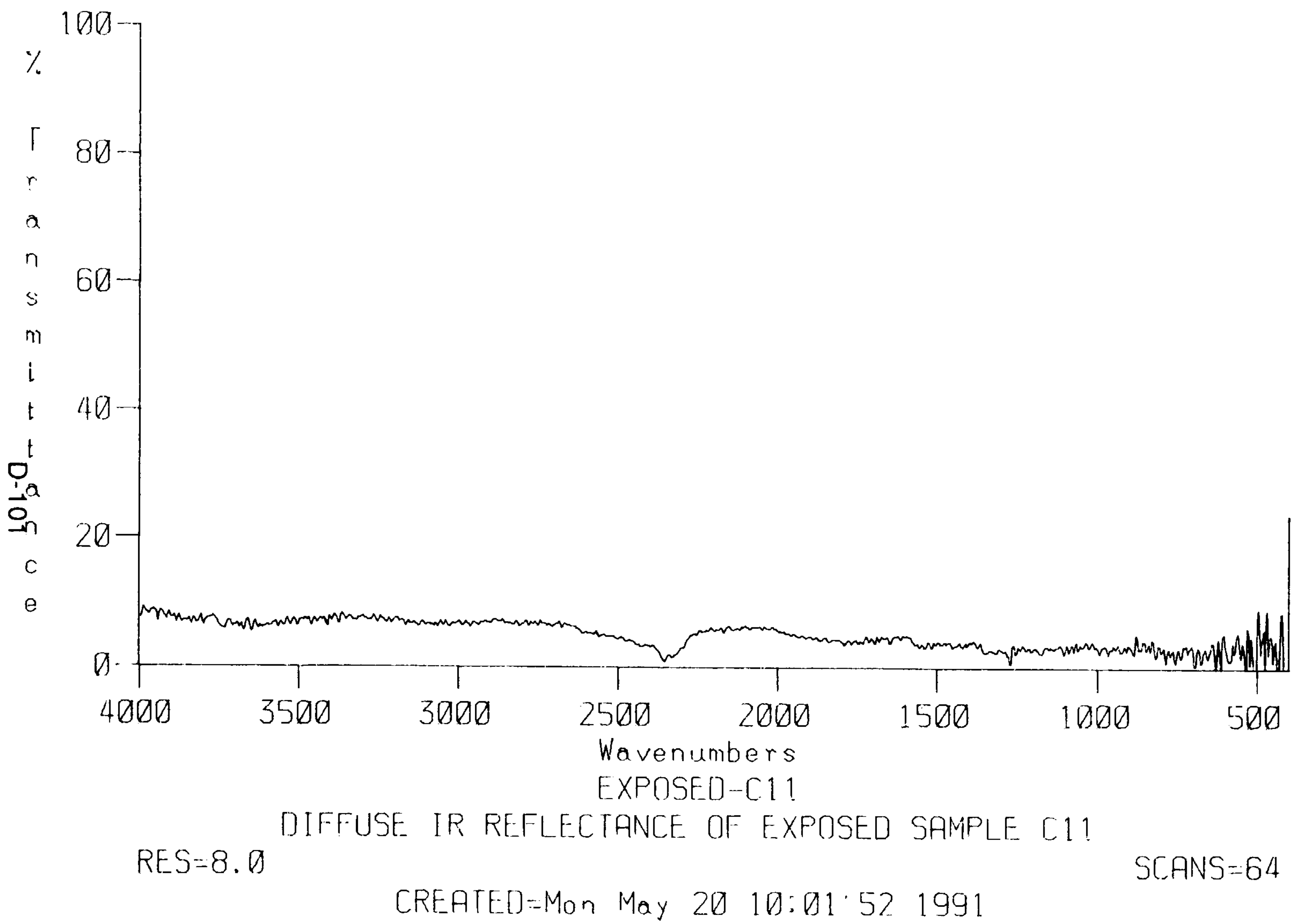

Figure D-99 Diffuse IR reflectance spectrum for blanket C11.

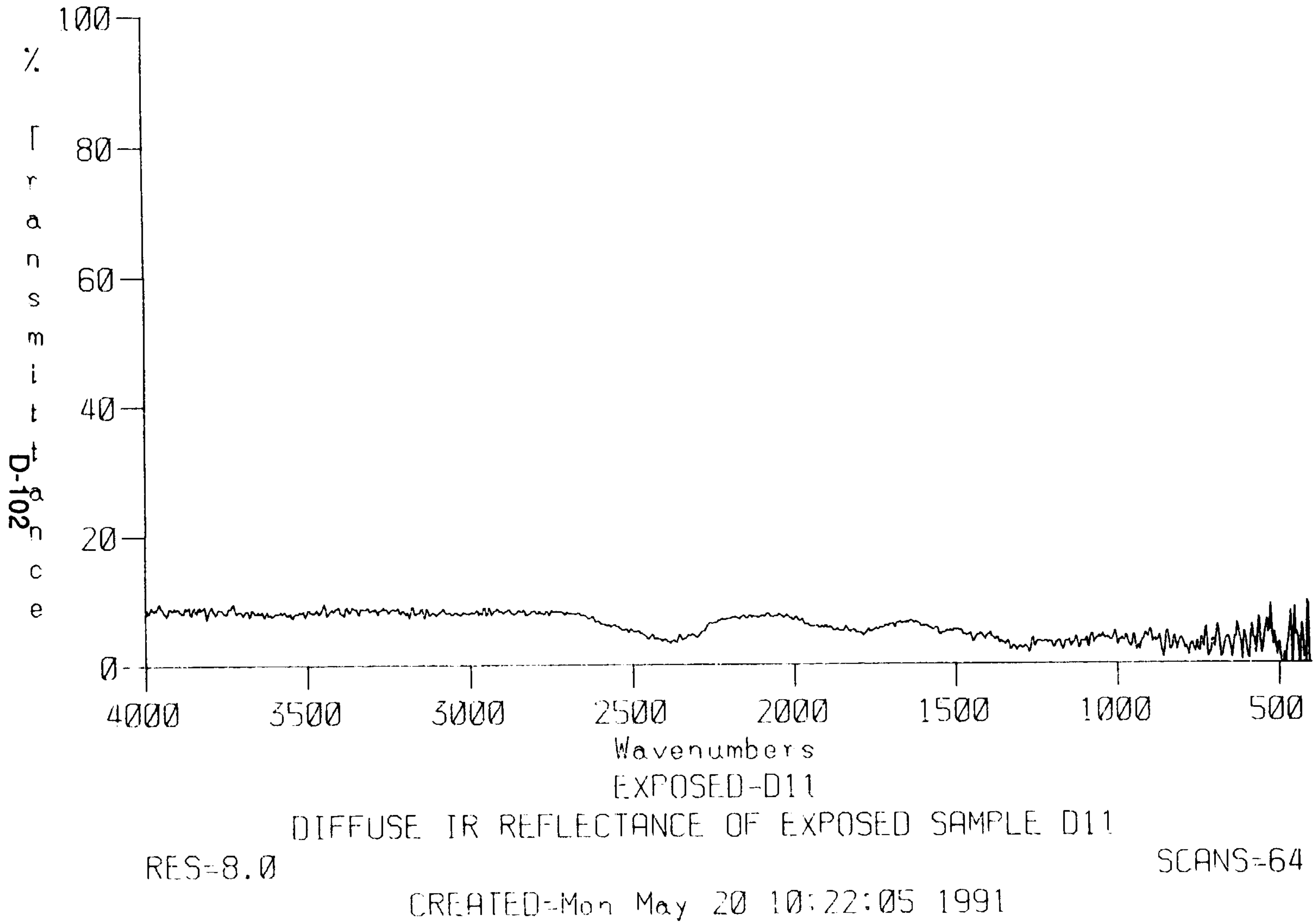

Figure D-100 Diffuse IR reflectance spectrum for blanket D11.

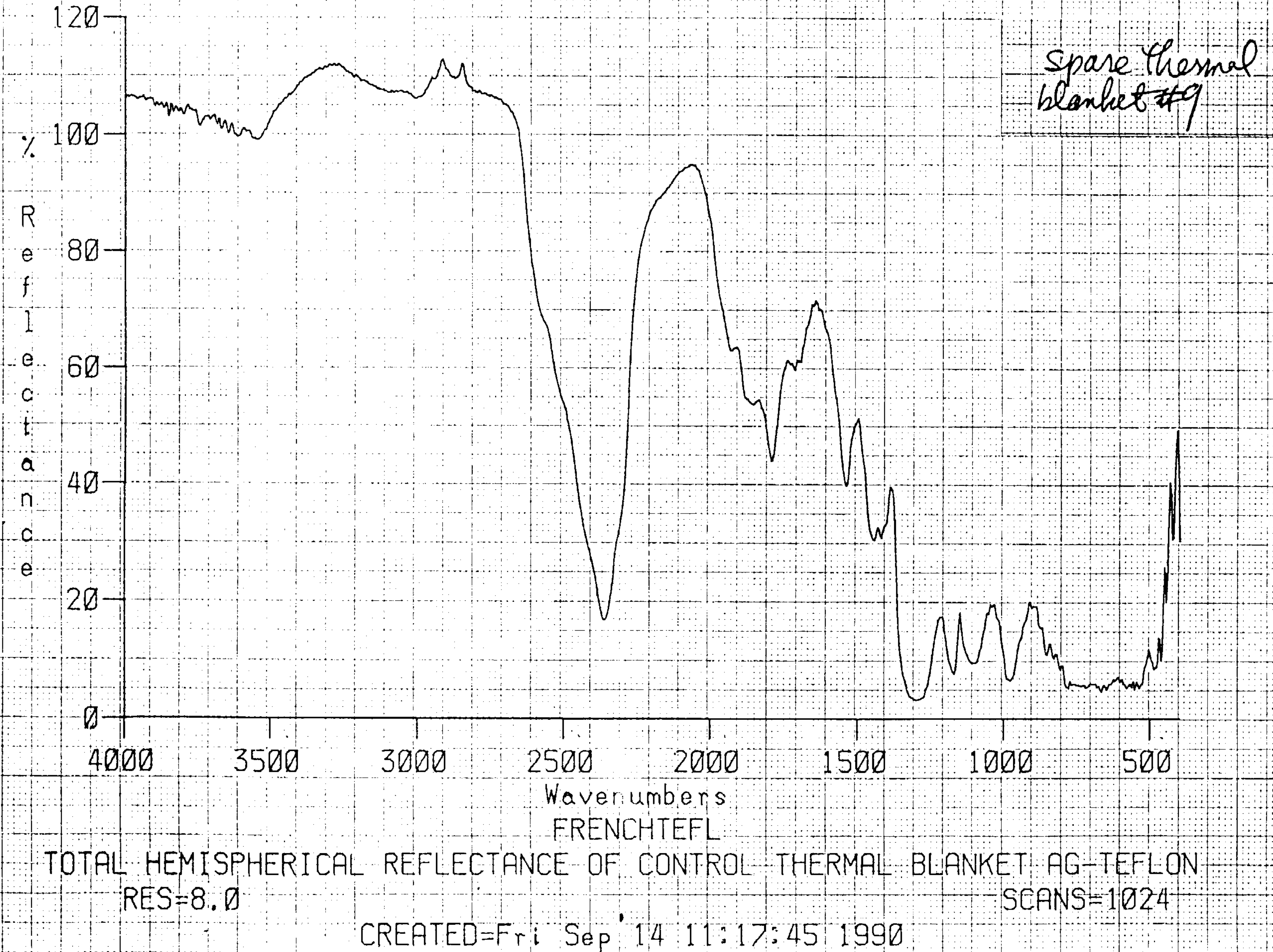

Figure D-101 Total Hemispherical Reflectance spectrum for ground control Ag/FEP blanket.

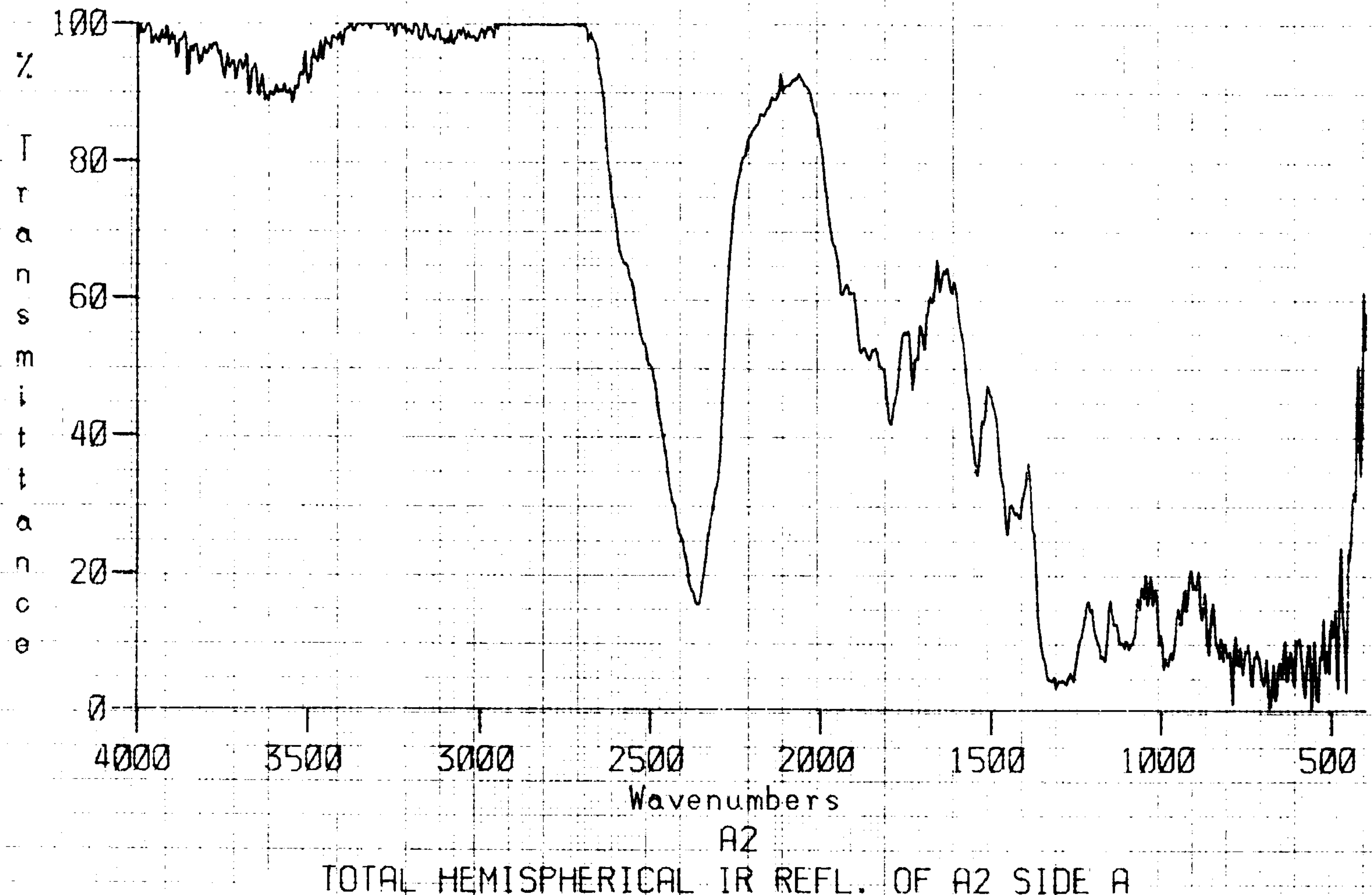

Figure D-102 . Total Hemispherical IR reflectance spectrum for blanket A2.

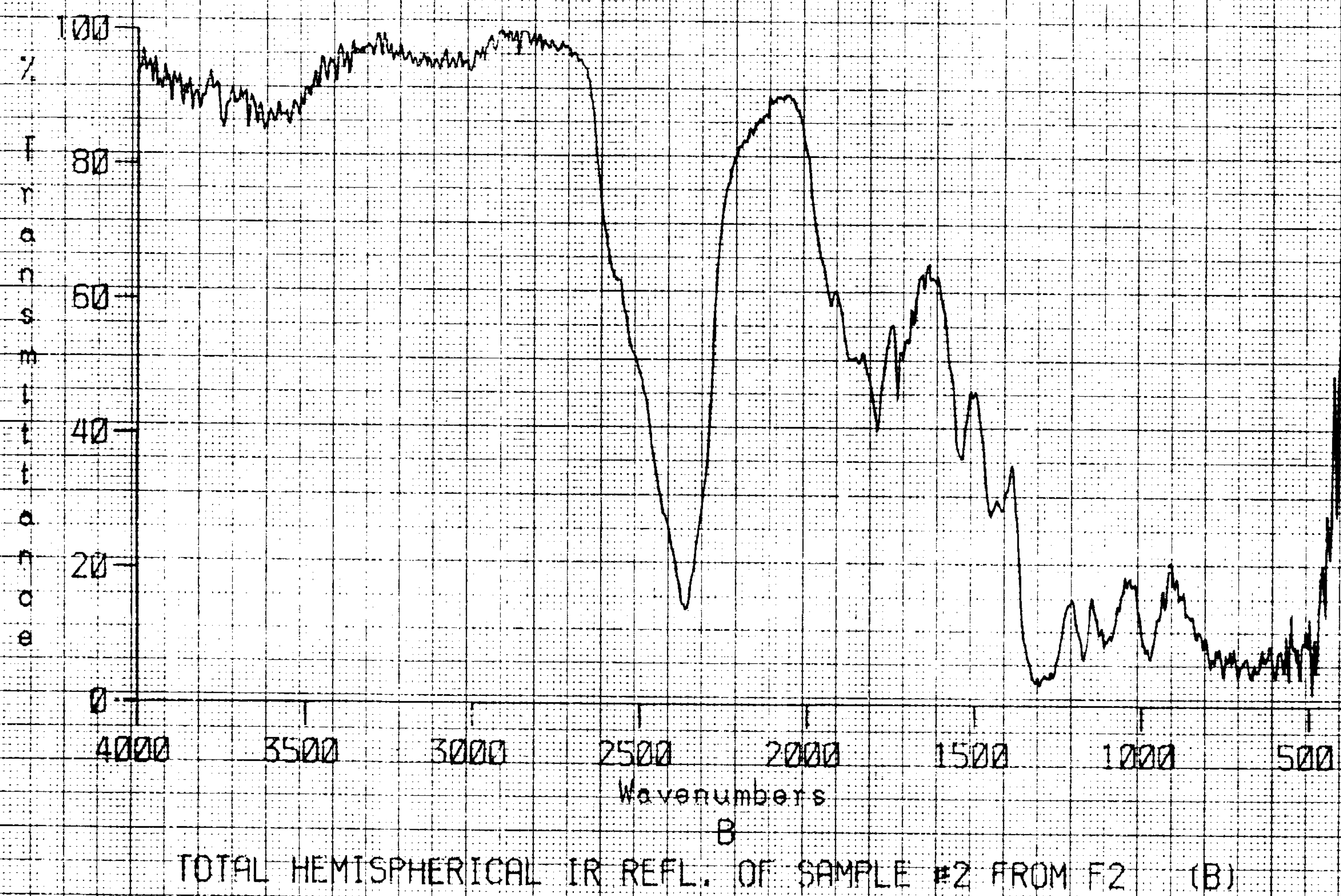

Figure D-103 Total Hemispherical IR reflectance spectrum for blanket F2(sample 2).

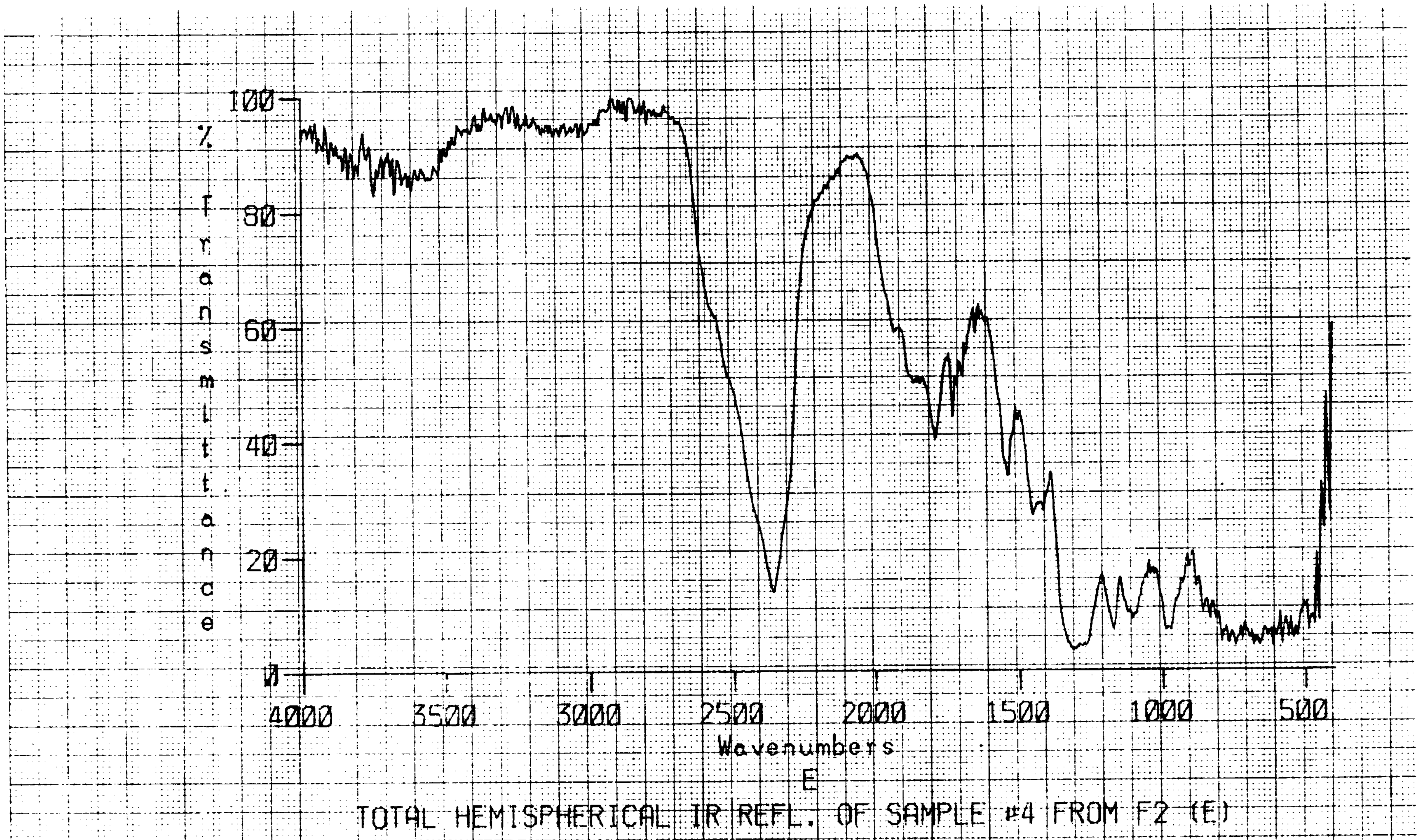

Figure D-104 Total Hemispherical IR reflectance spectrum for blanket F2(sample 4).

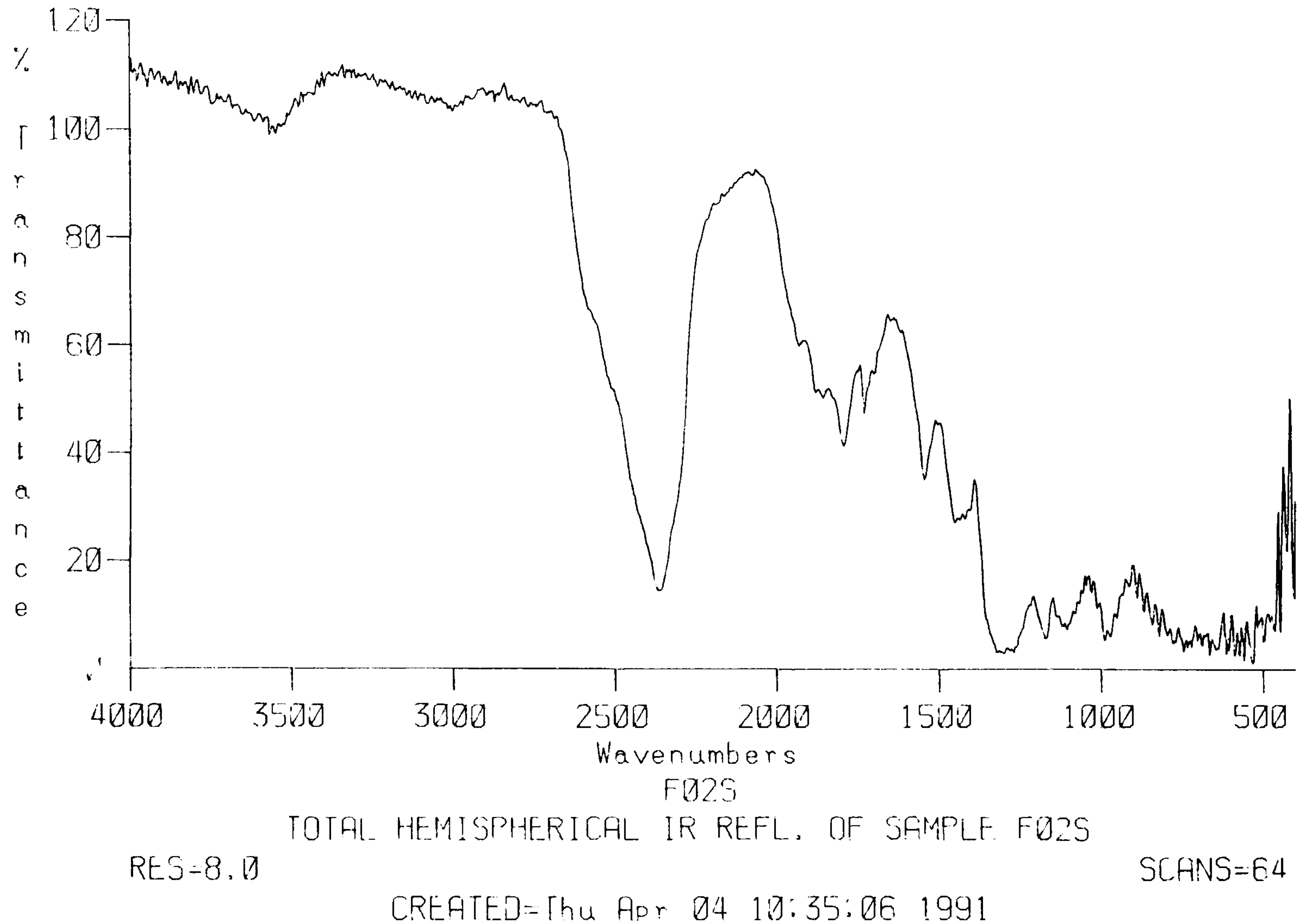

Figure D-105 Total hemispherical IR reflectance spectrum for unexposed area of blanket F2.

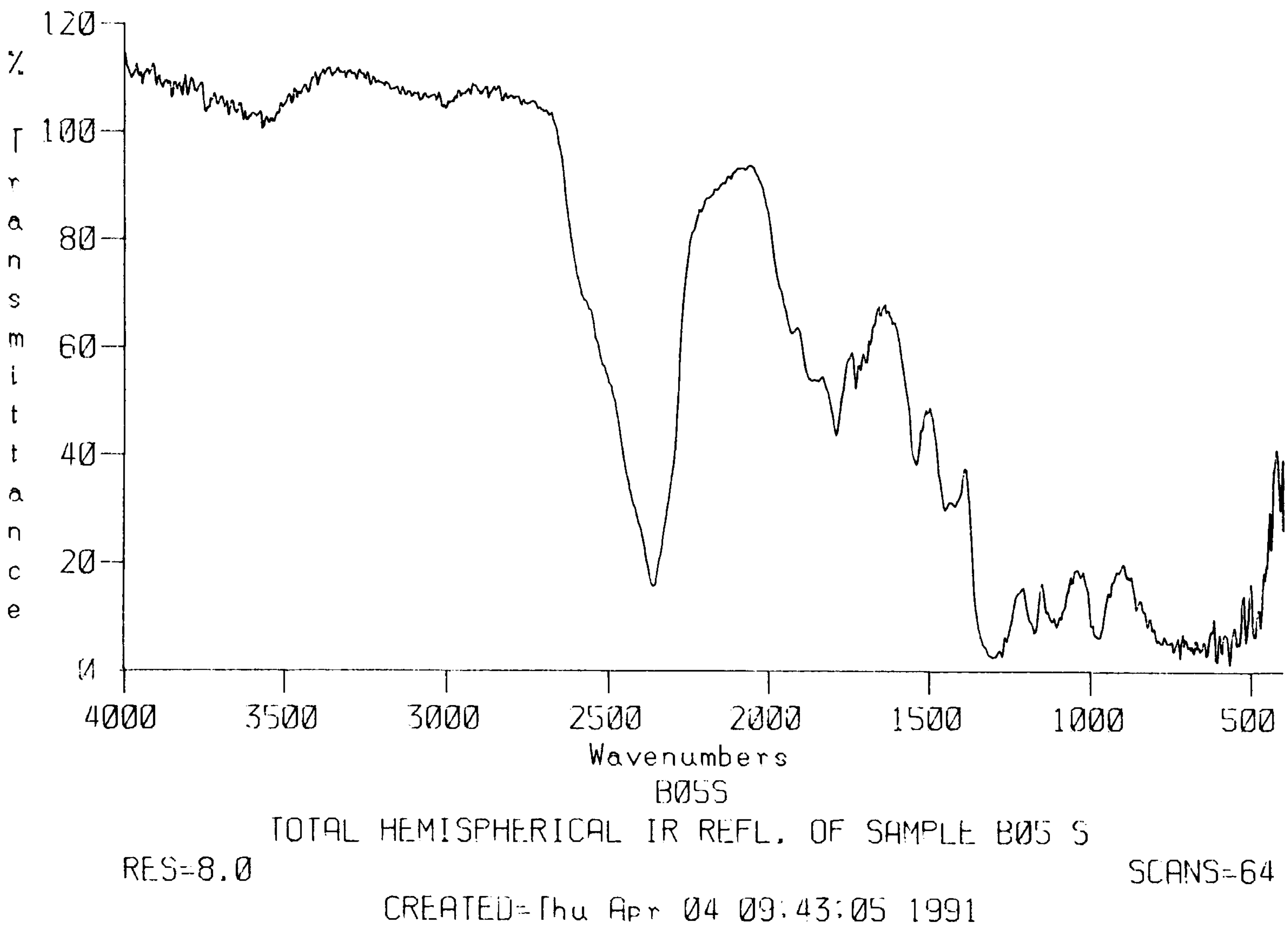

Figure D-106 Total Hemispherical IR reflectance spectrum for unexposed area of blanket B5.

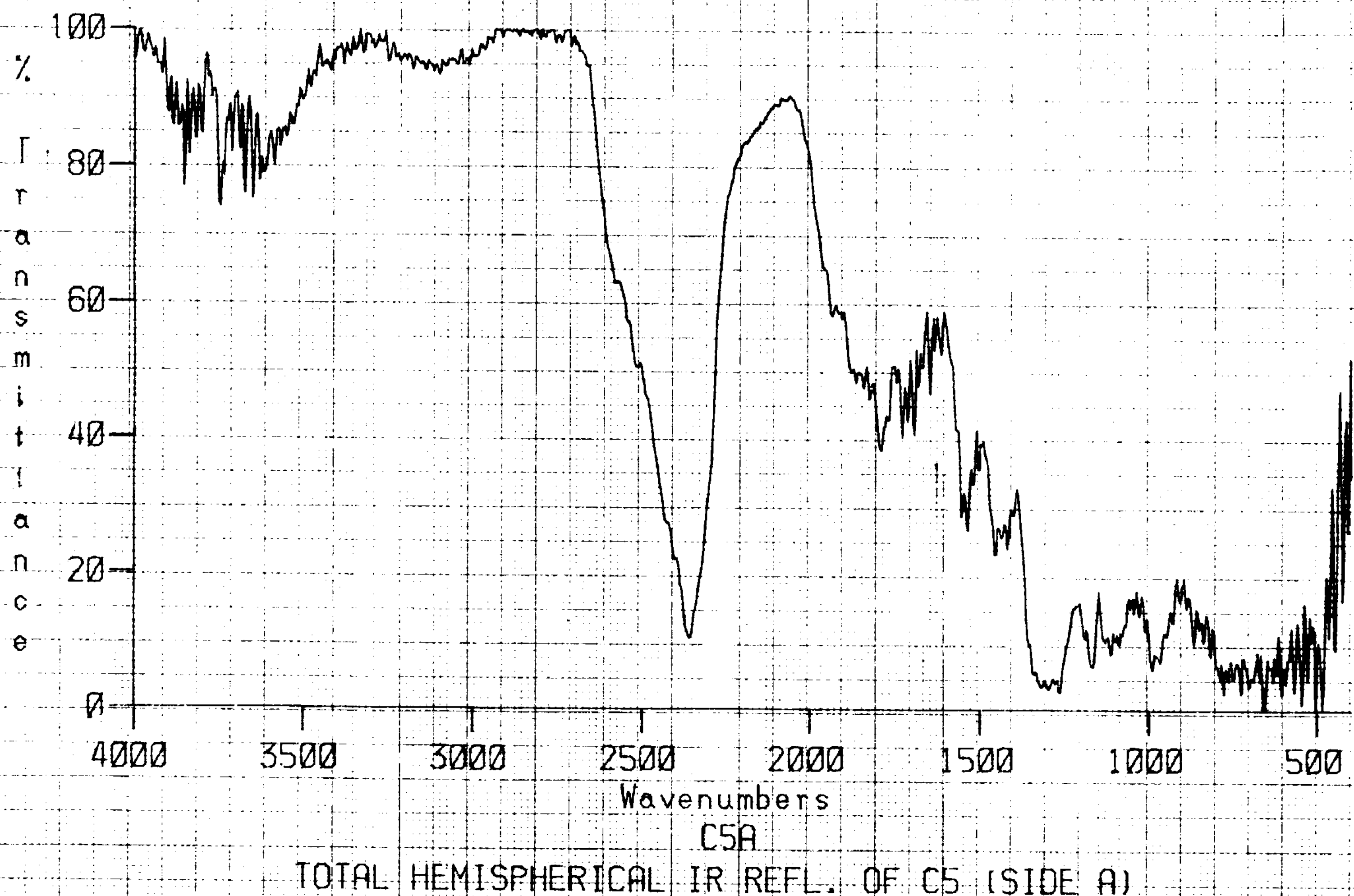

Figure D-107 Total Hemispherical IR reflectance spectrum for blanket C5.

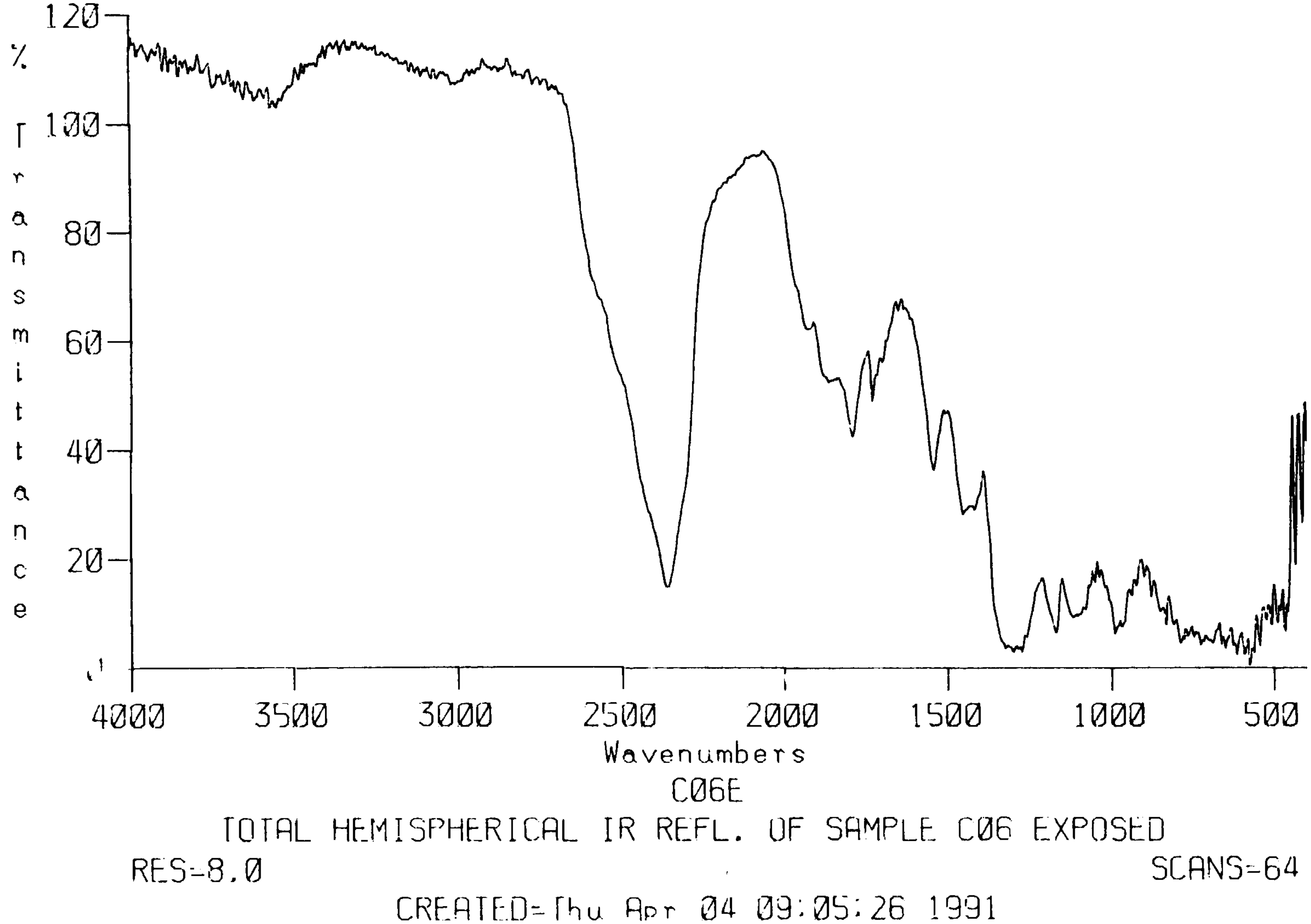

Figure D-108 Total Hemispherical IR reflectance spectrum for blanket C6.

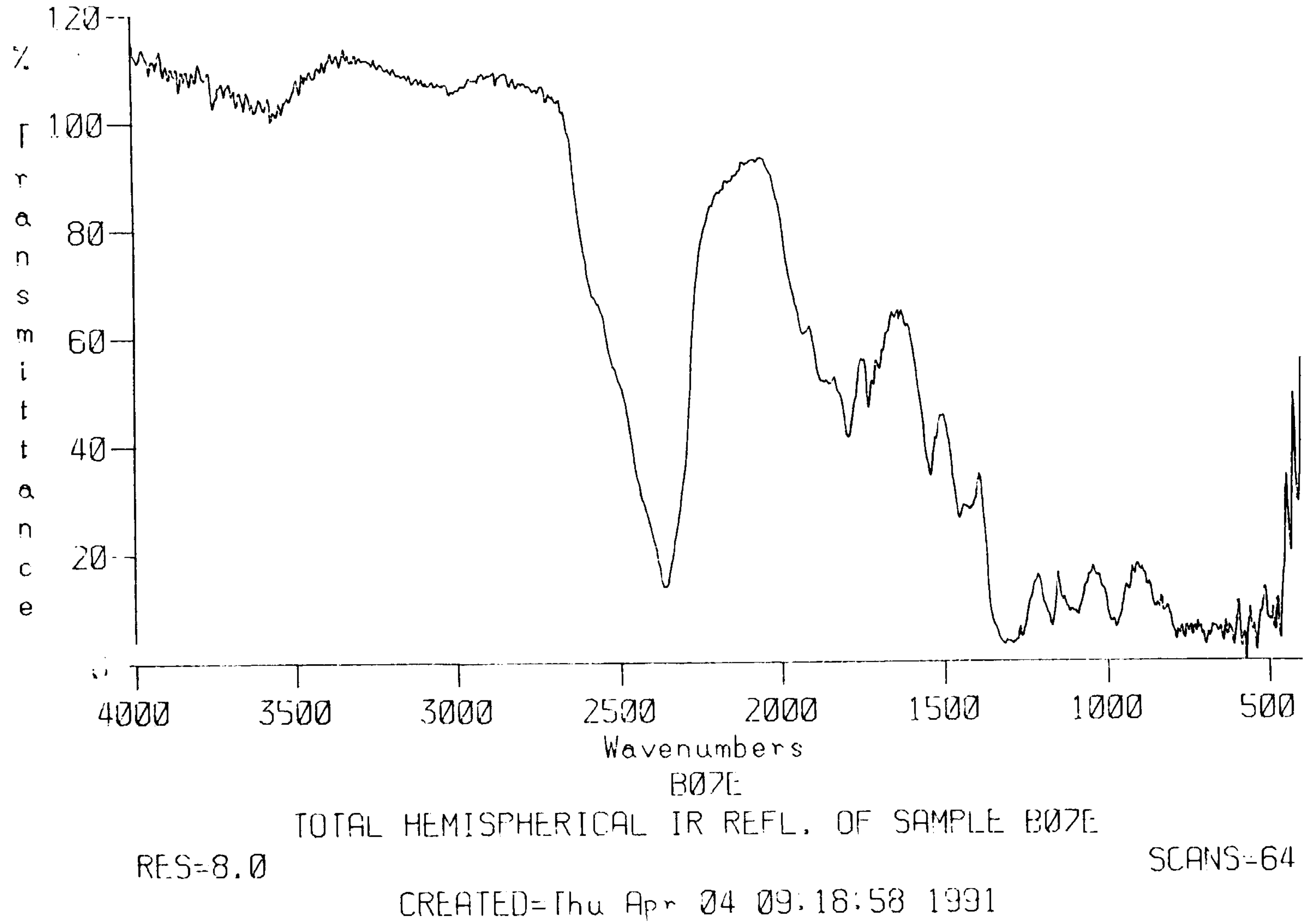

Figure D-109 Total Hemispherical IR reflectance spectrum for blanket B7.

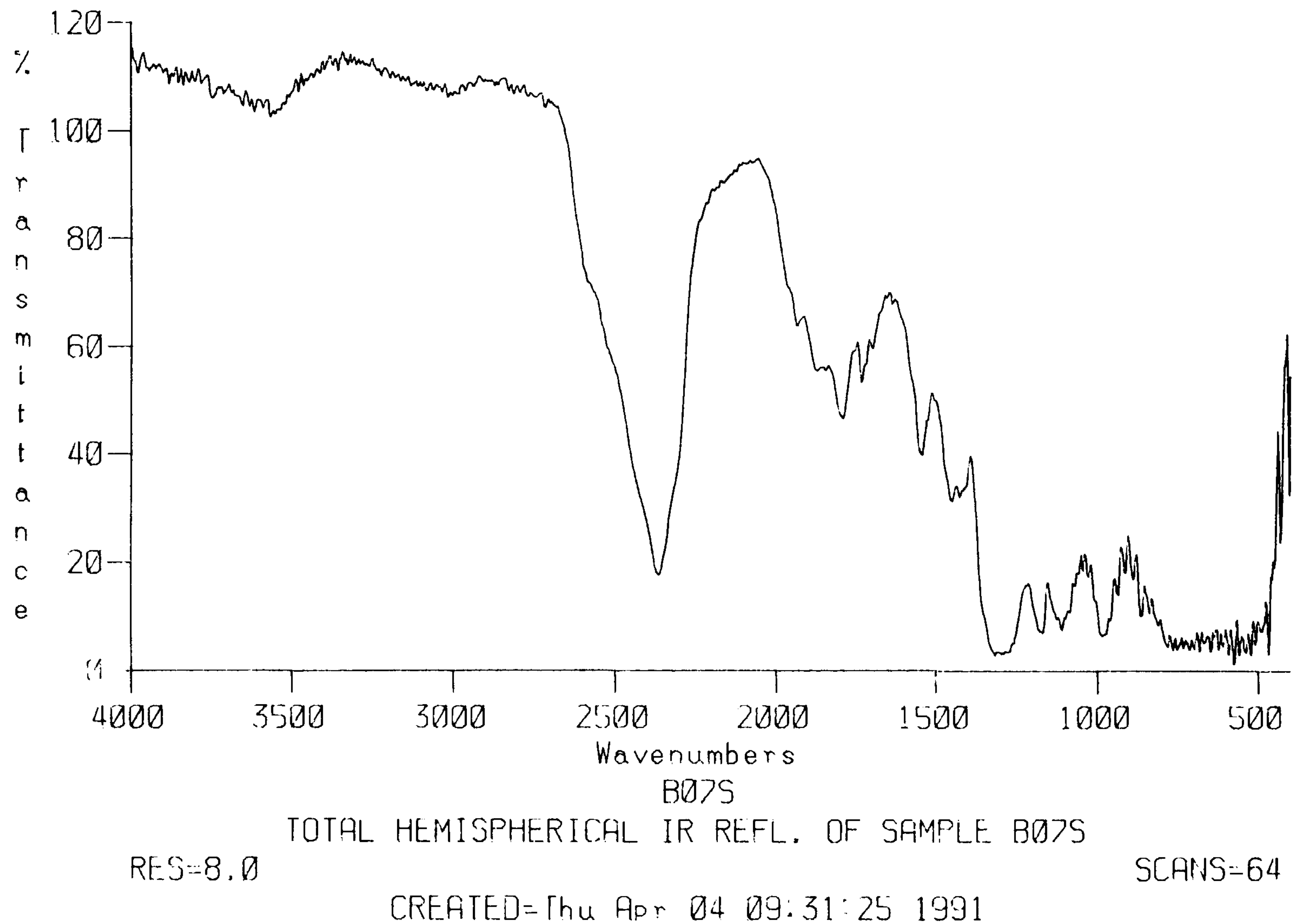

Figure D-110 Total Hemispherical IR reflectance spectrum for unexposed area of blanket B7.

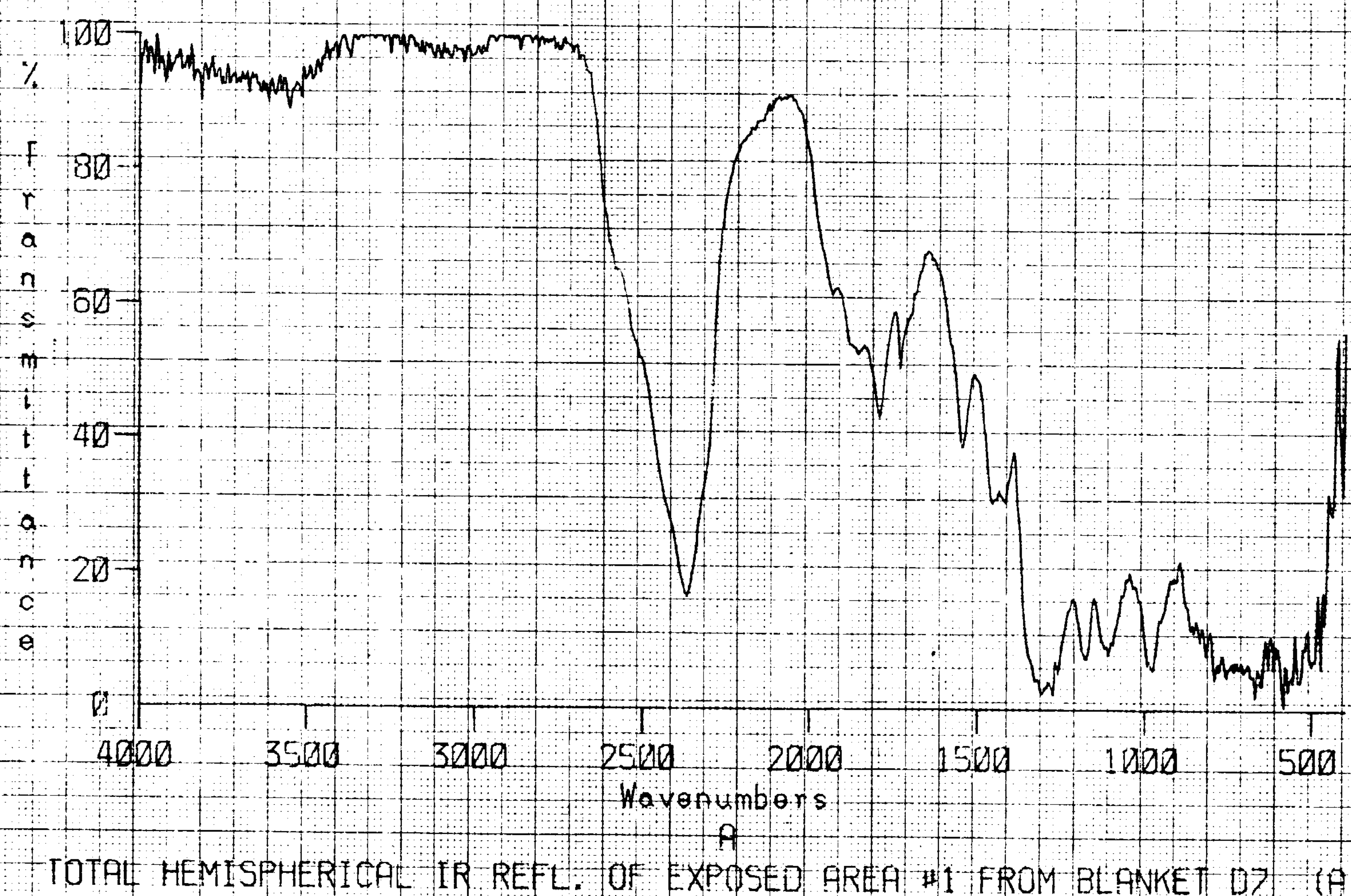

Figure D-111 Total Hemispherical IR reflectance spectrum for blanket D7(Area 1).

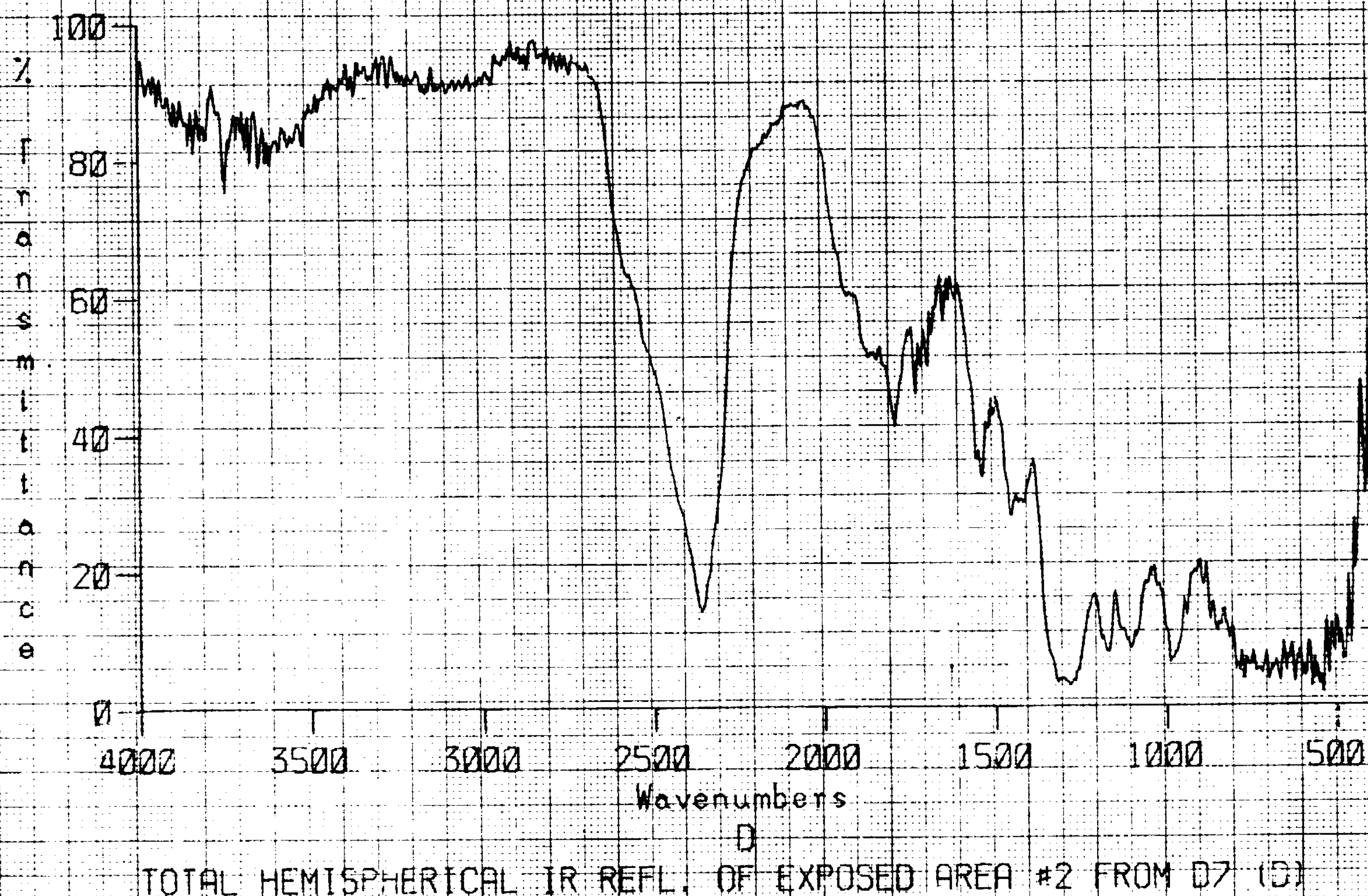

Figure D-112 Total Hemispherical IR reflectance spectrum for blanket D7(Area 2).

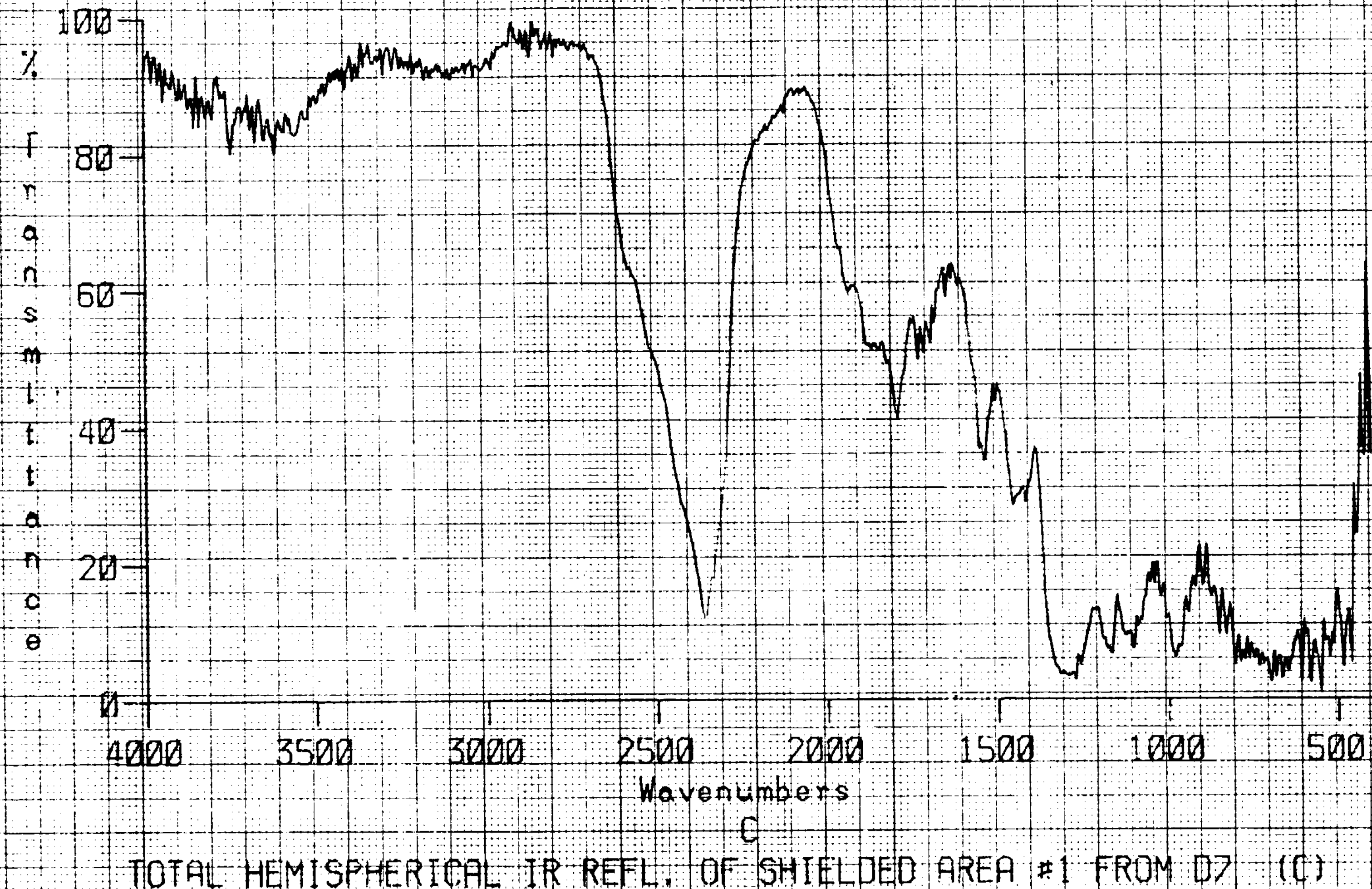

Figure D-113 Total Hemispherical IR reflectance spectrum for unexposed area of blanket D7(Area 1).

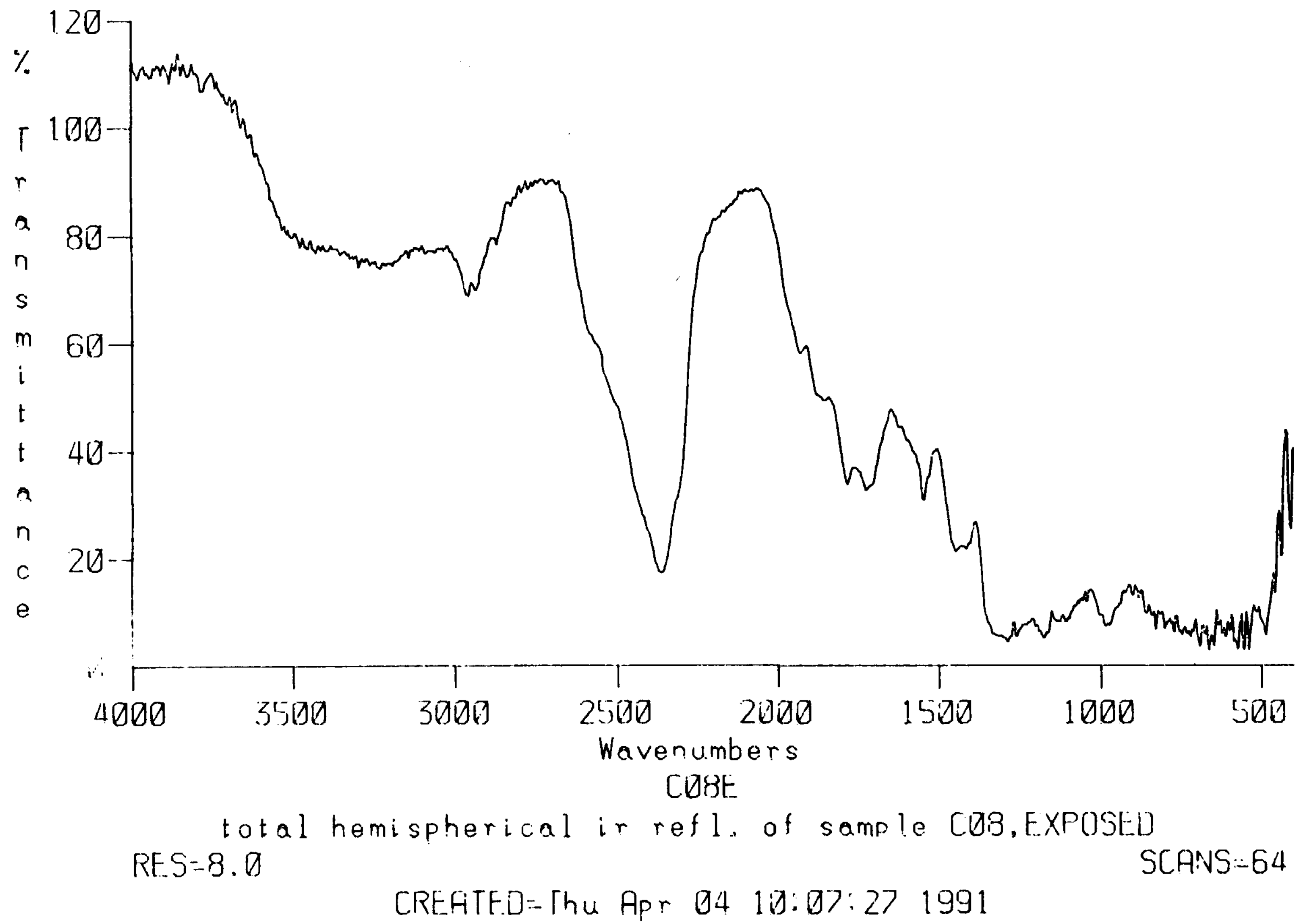

Figure D-114 Total Hemispherical IR reflectance spectrum for blanket C8.

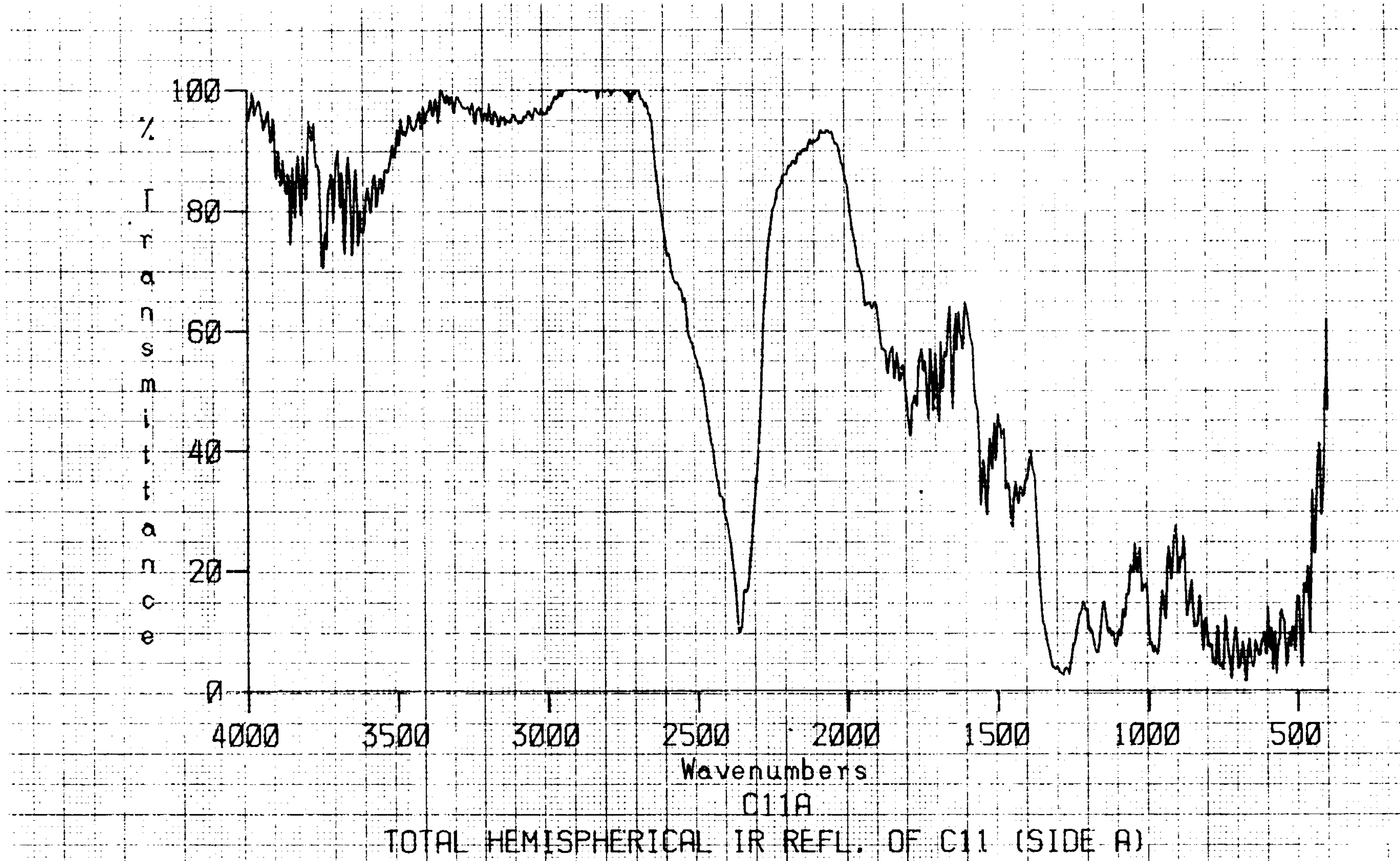

Figure D-115 Total Hemispherical IR reflectance spectrum for blanket C11

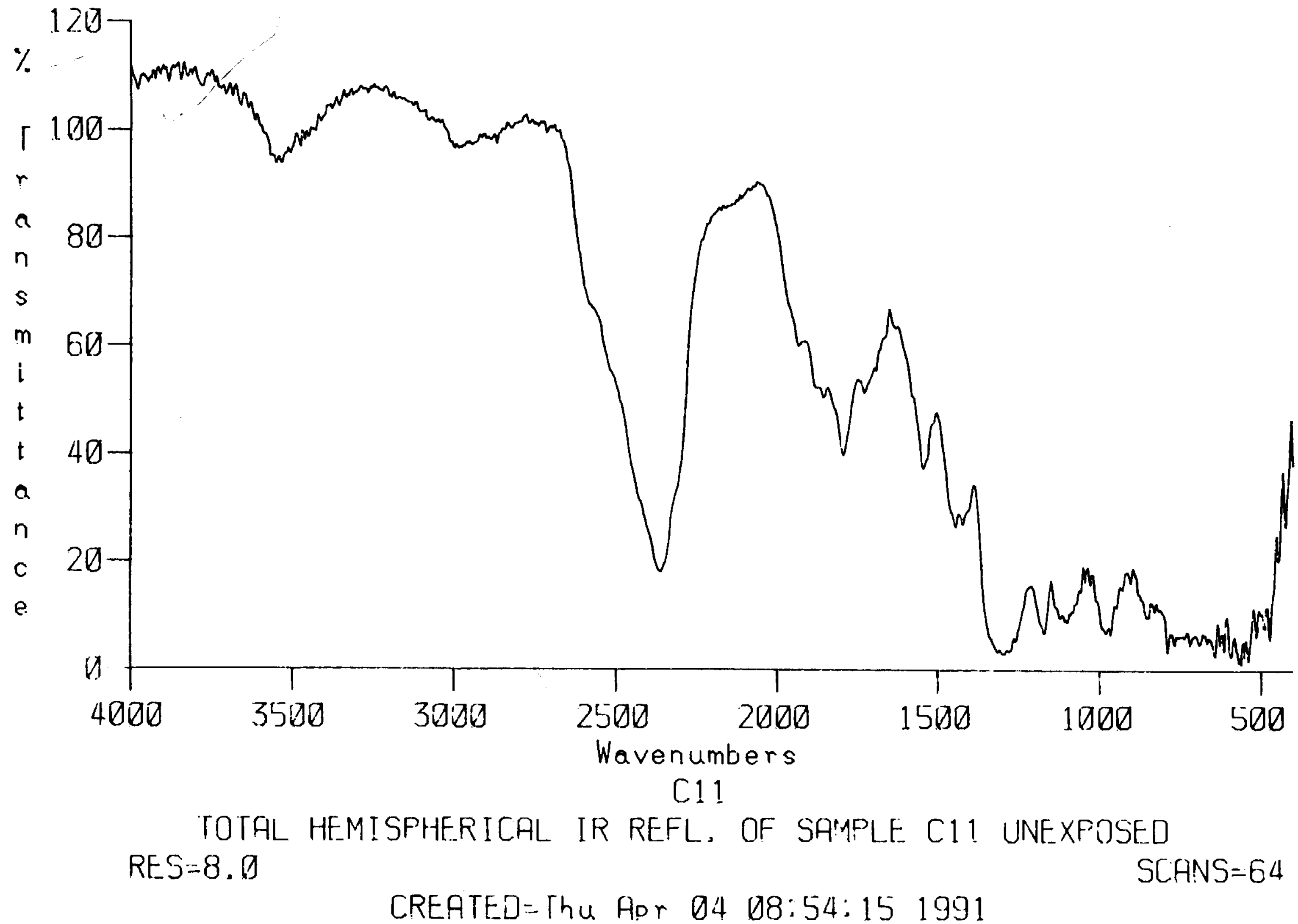

Figure D-116 Total Hemispherical IR reflectance spectrum for unexposed area of blanket C11.

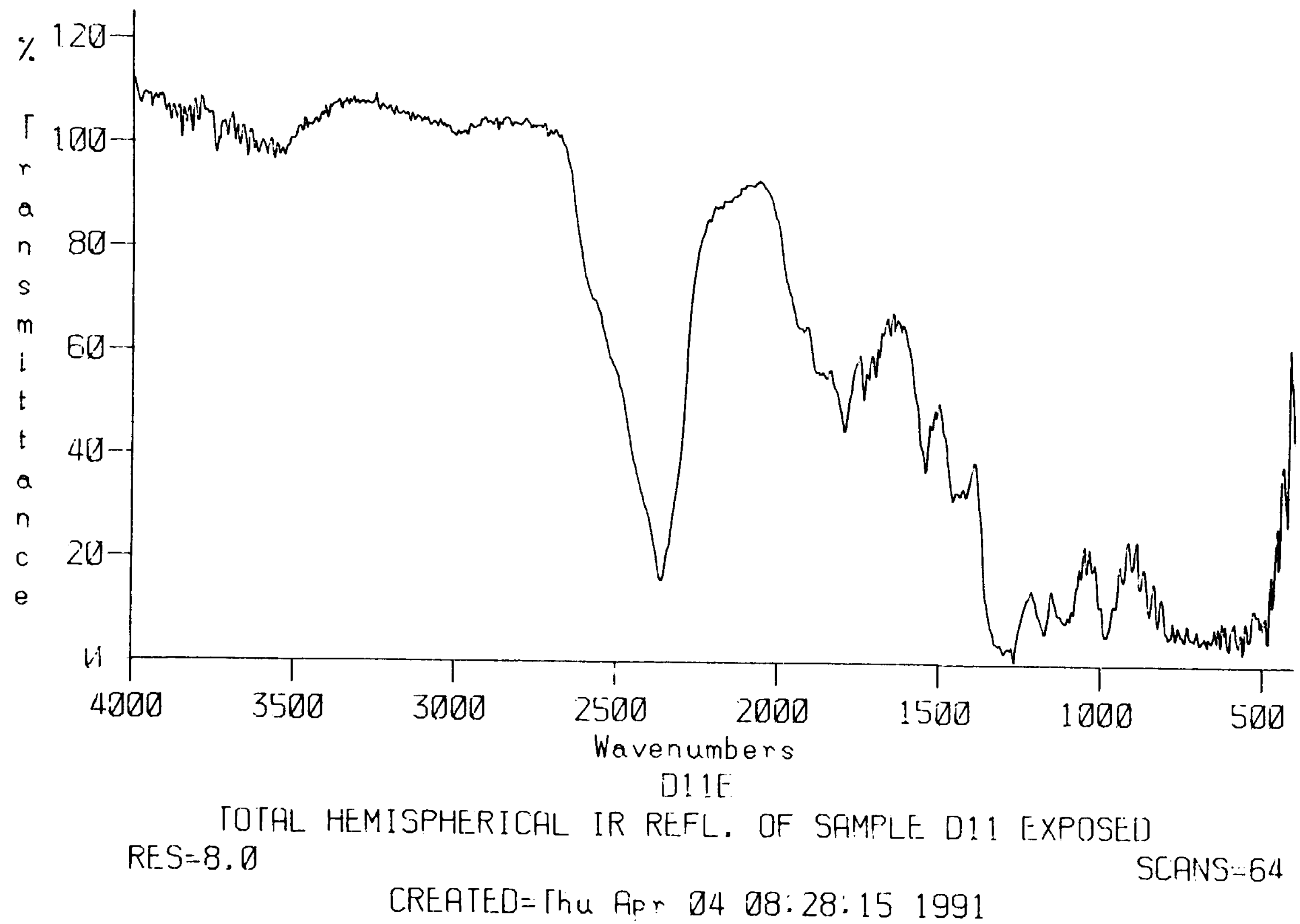

Figure D-117 Total Hemispherical IR reflectance spectrum for blanket D11.

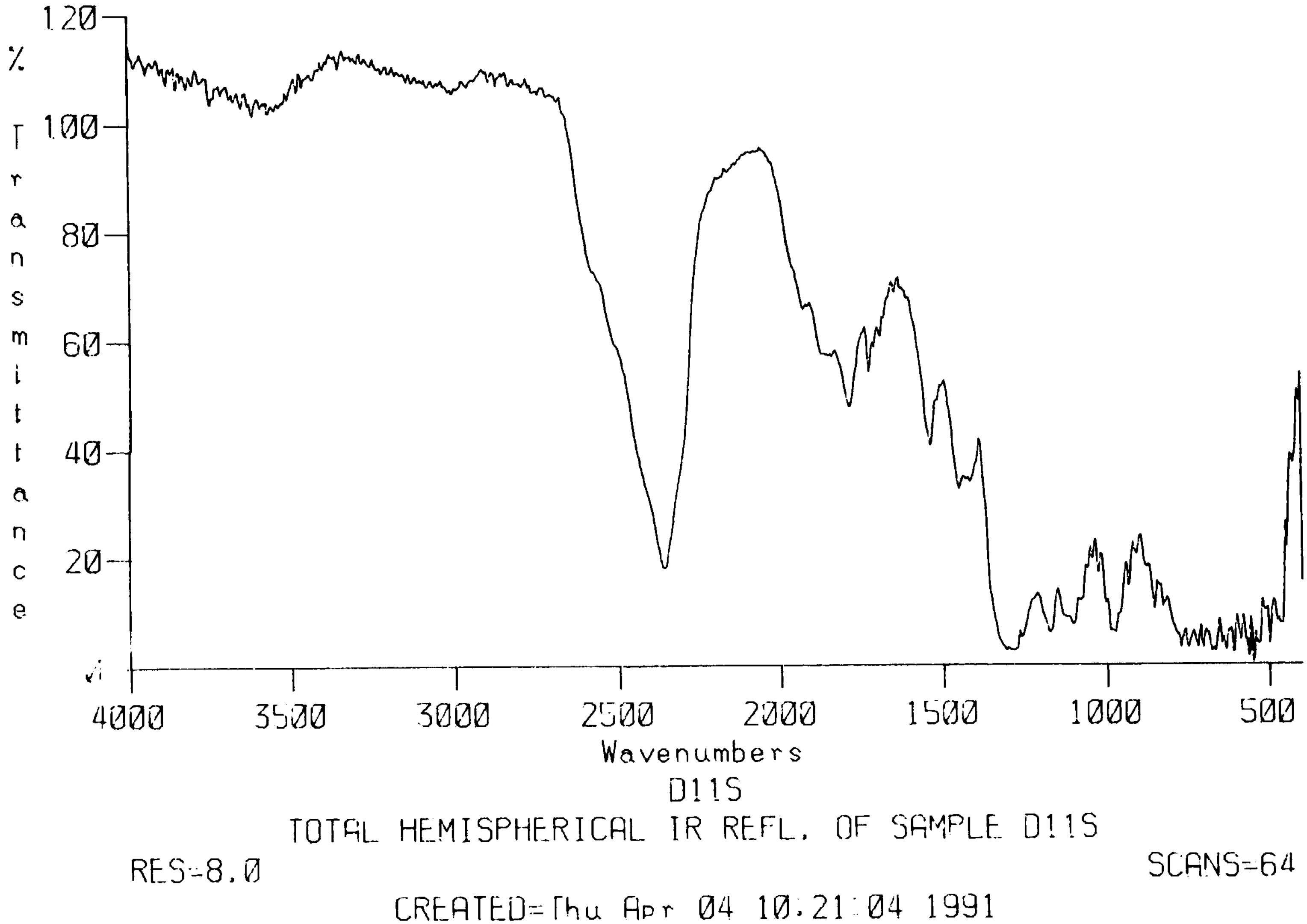

Figure D-118 Total Hemispherical IR reflectance spectrum for unexposed area of blanket D11.

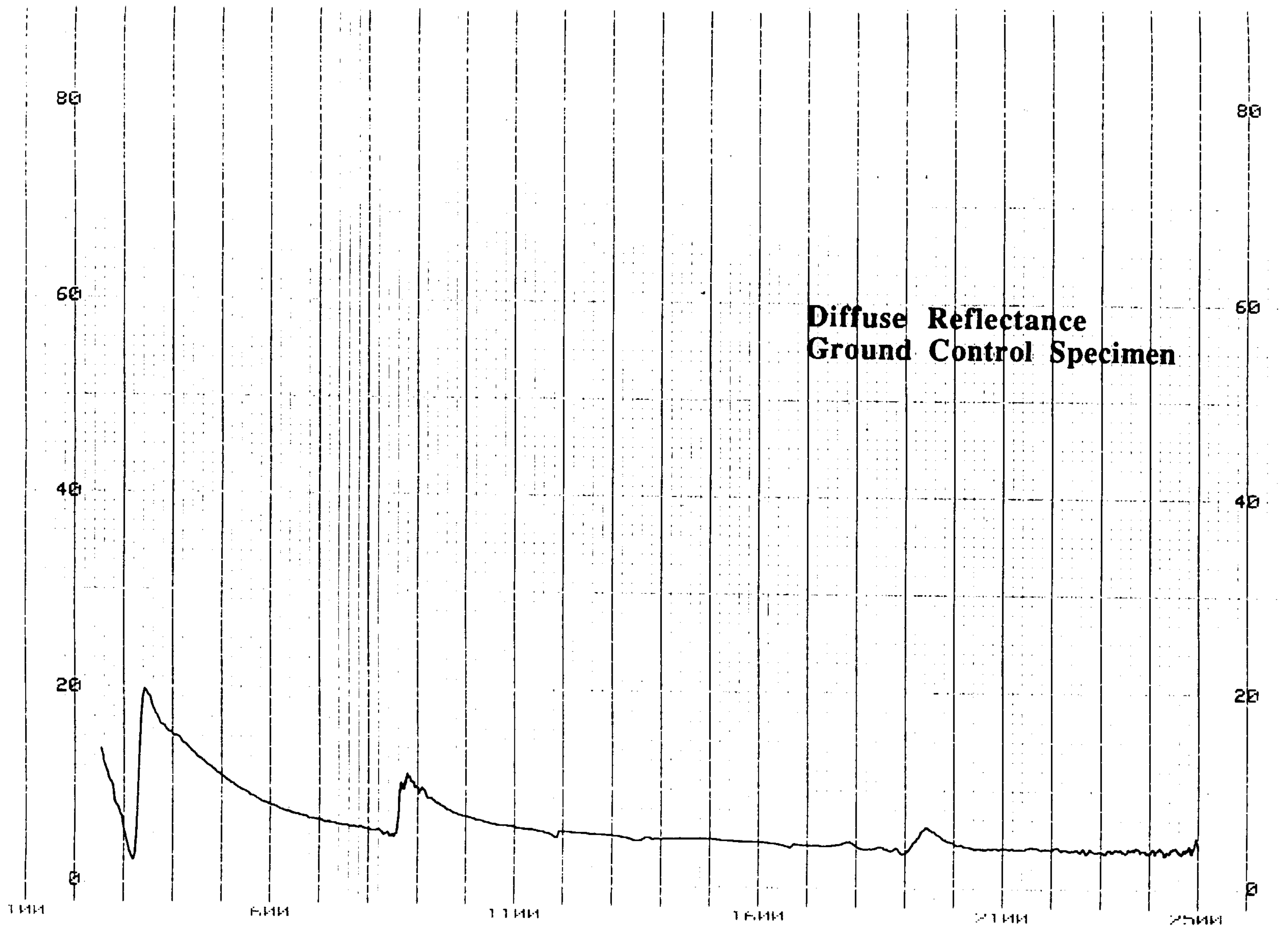

Figure D-119 UV-Vis-NR diffuse reflectance spectrum for ground control specimen.

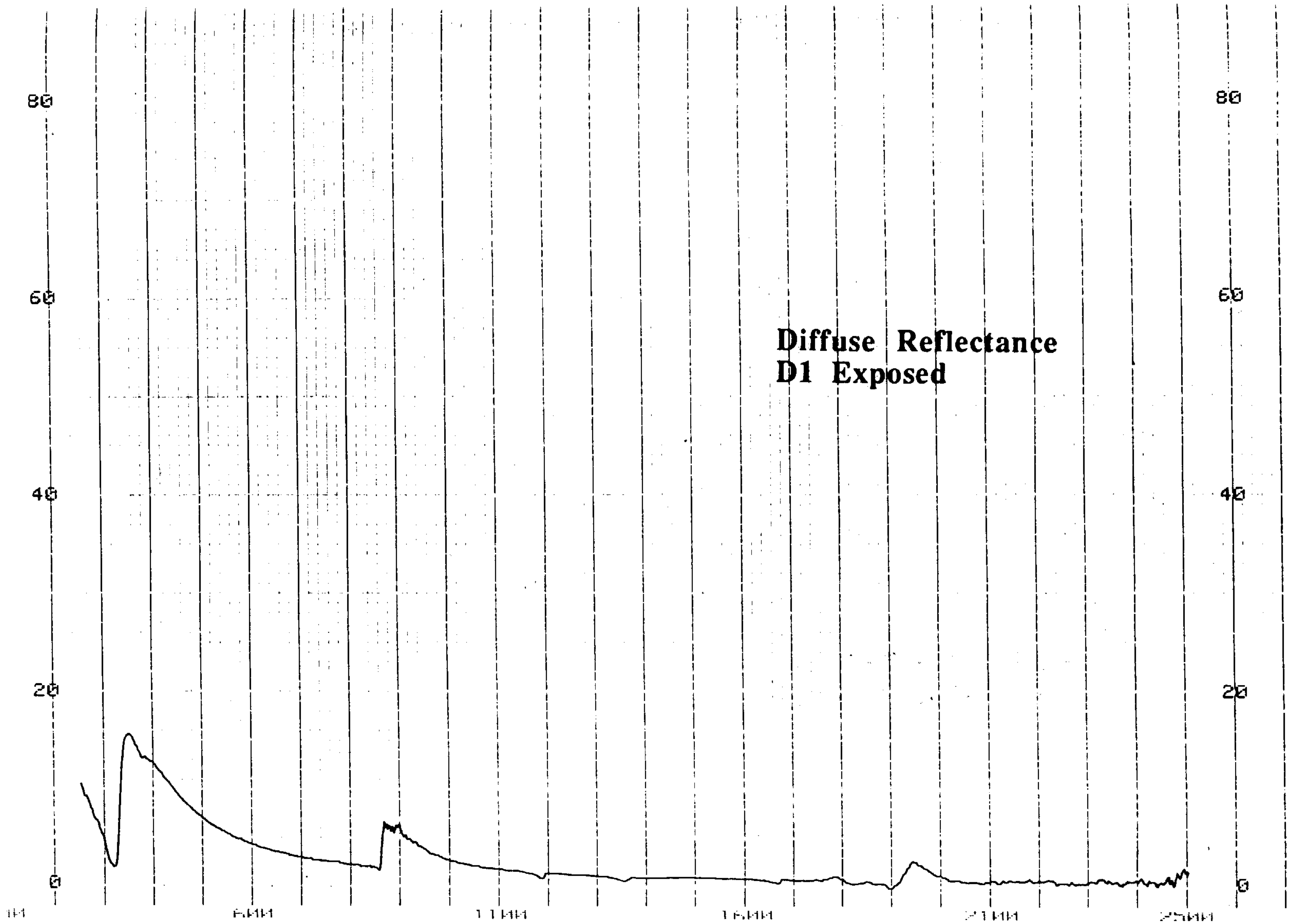

Figure D-120 UV-Vis-NIR diffuse reflectance spectrum for blanket D1.

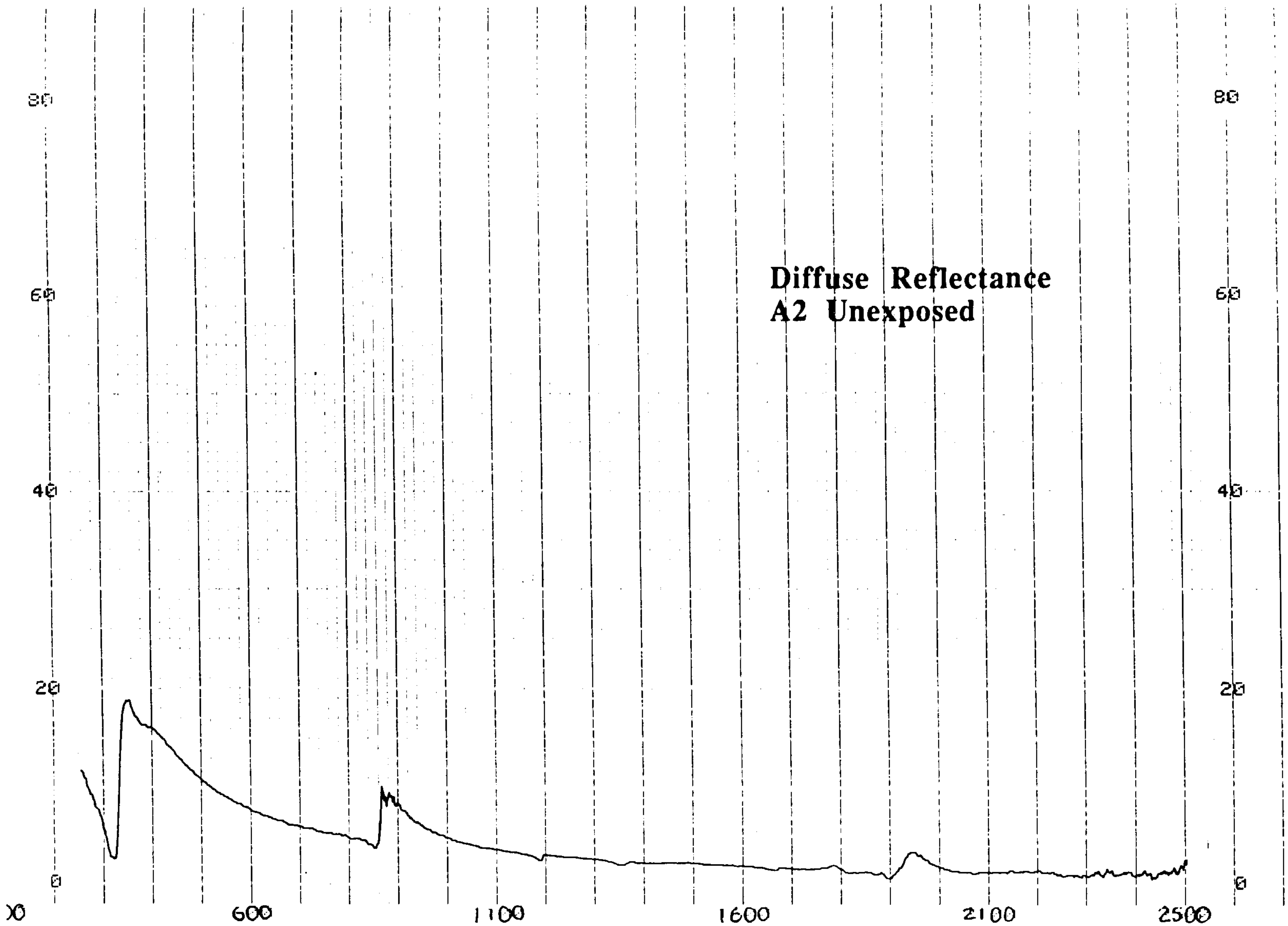

Figure D-121 UV-Vis-NIR diffuse reflectance spectrum for unexposed area on blanket A2.

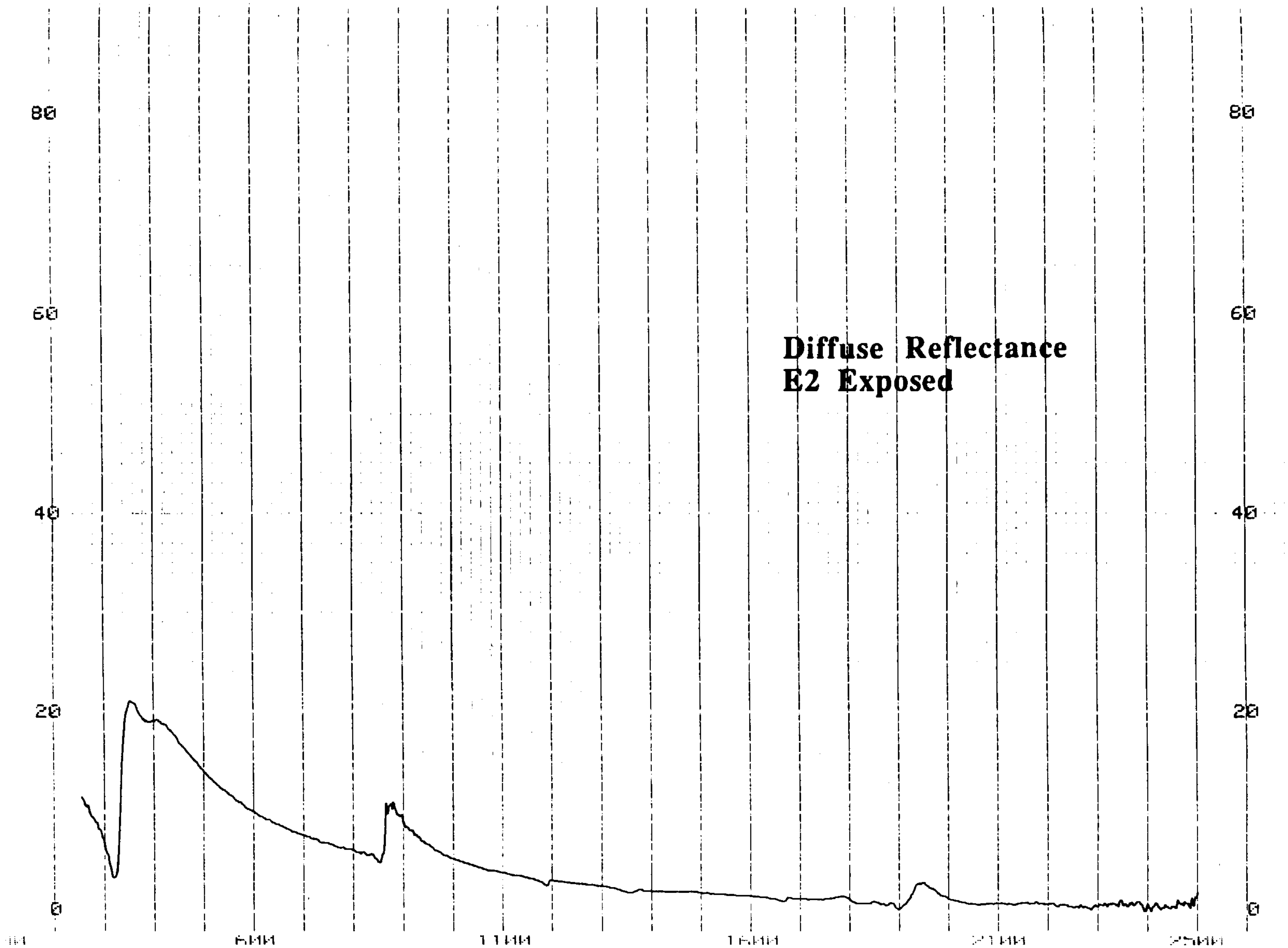

Figure D-122 UV-Vis-NIR diffuse reflectance spectrum for blanket E2.

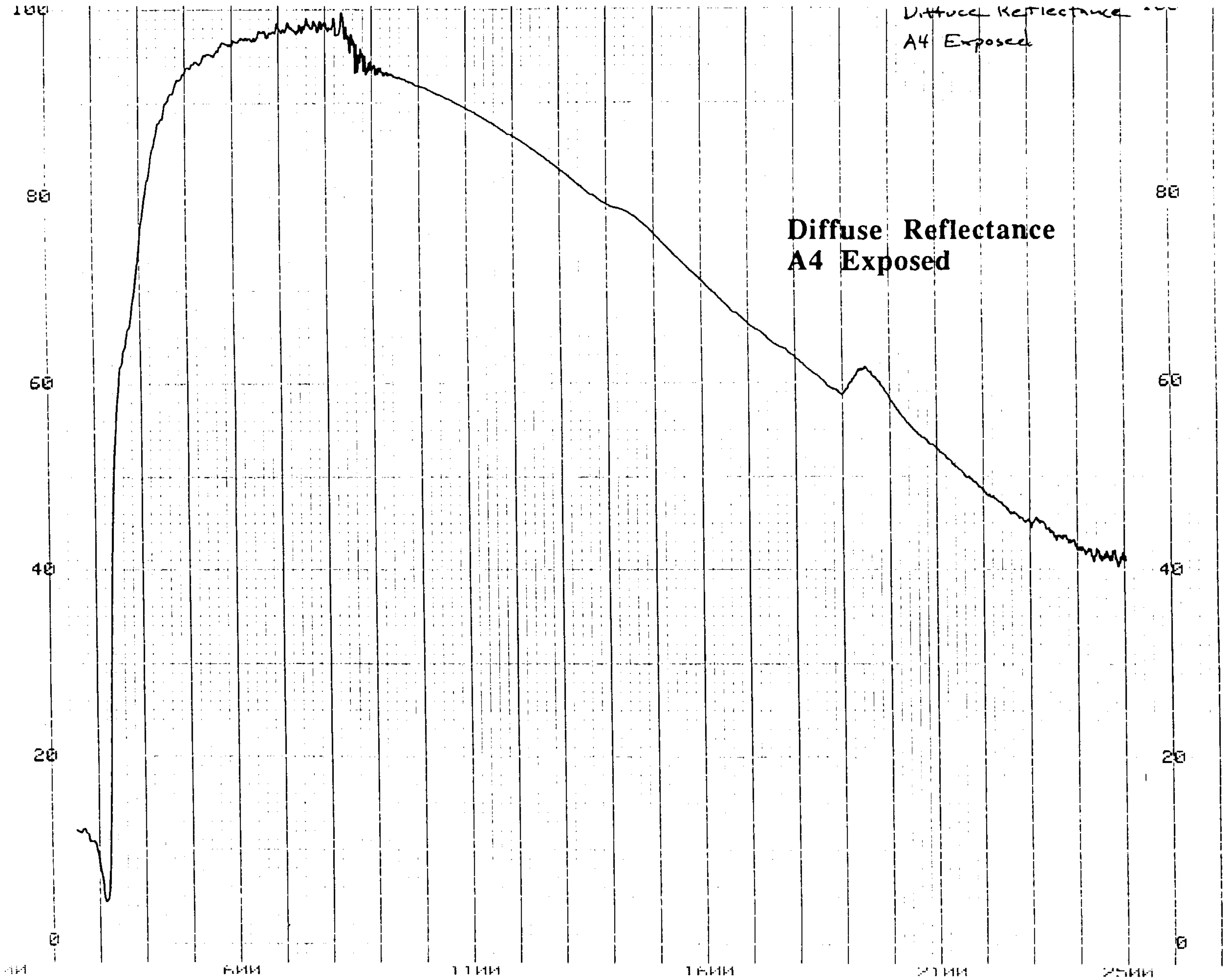

Figure D-123 UV-Vis-NIR diffuse reflectance spectrum for blanket A4.

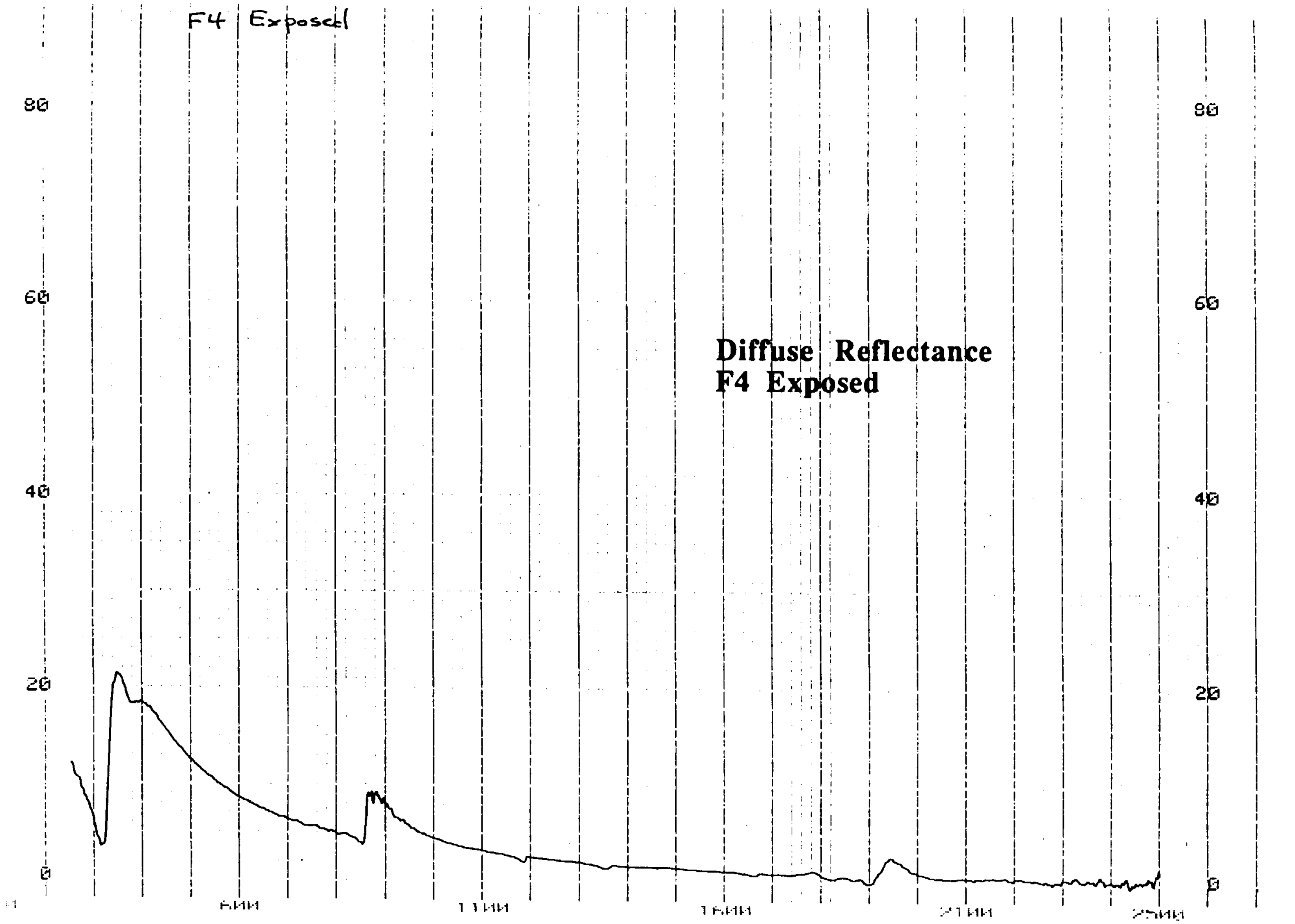

Figure D-124 UV-Vis-NIR diffuse reflectance spectrum for blanket F4.

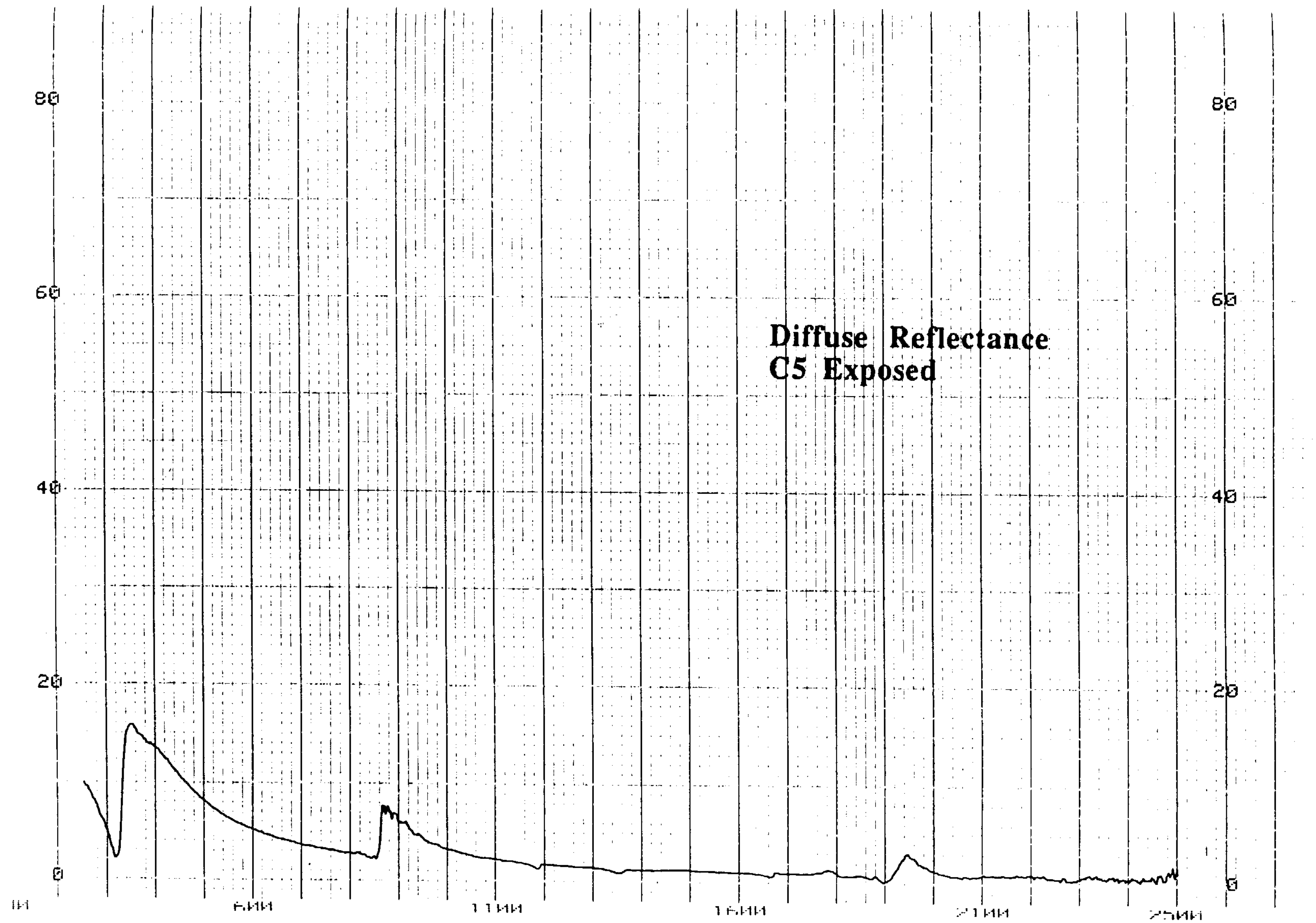

Figure D-125 UV-Vis-NIR diffuse reflectance spectrum for blanket C5.

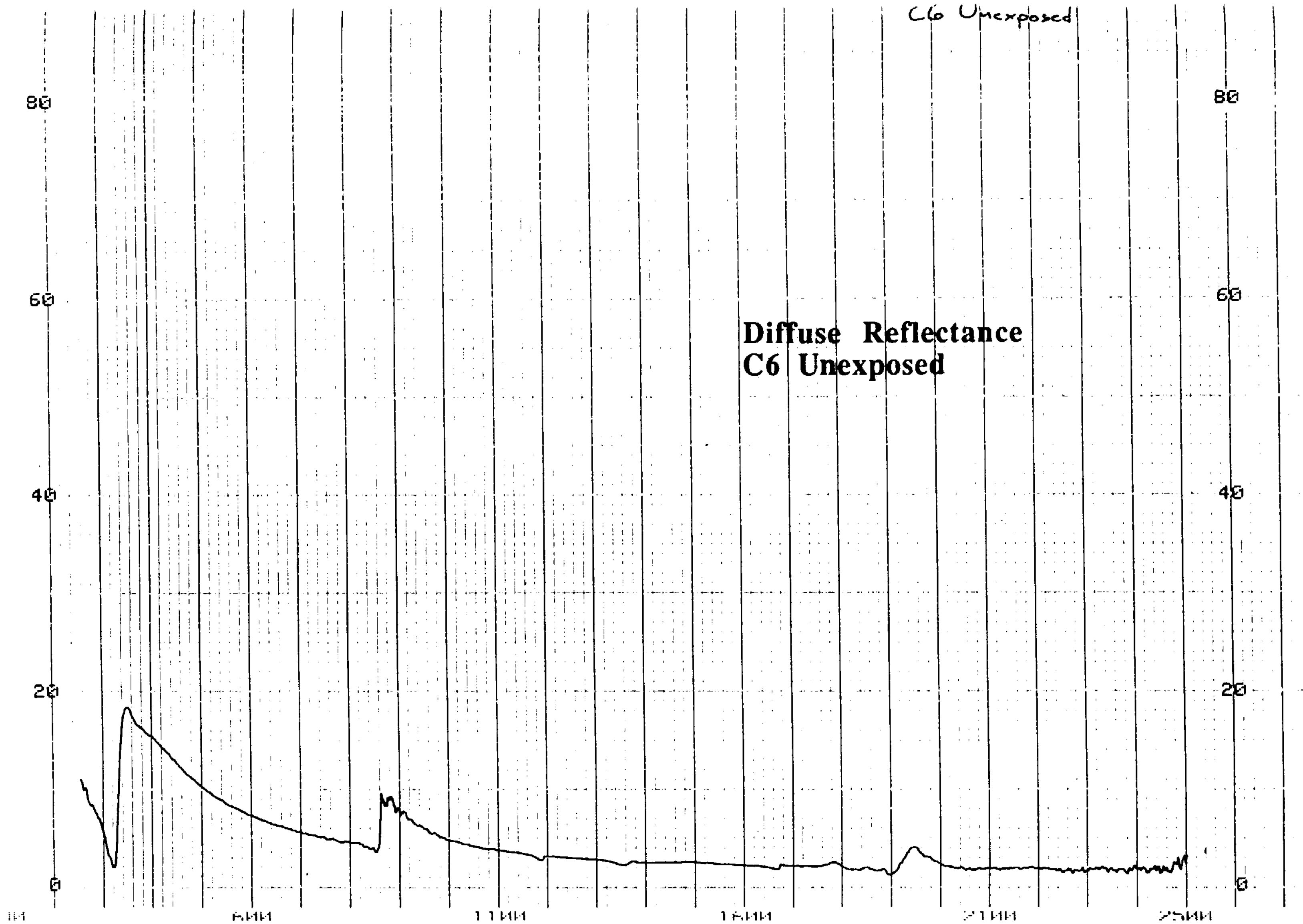

Figure D-126 UV-Vis-IR diffuse reflectance spectrum for unexposed area on blanket C6.

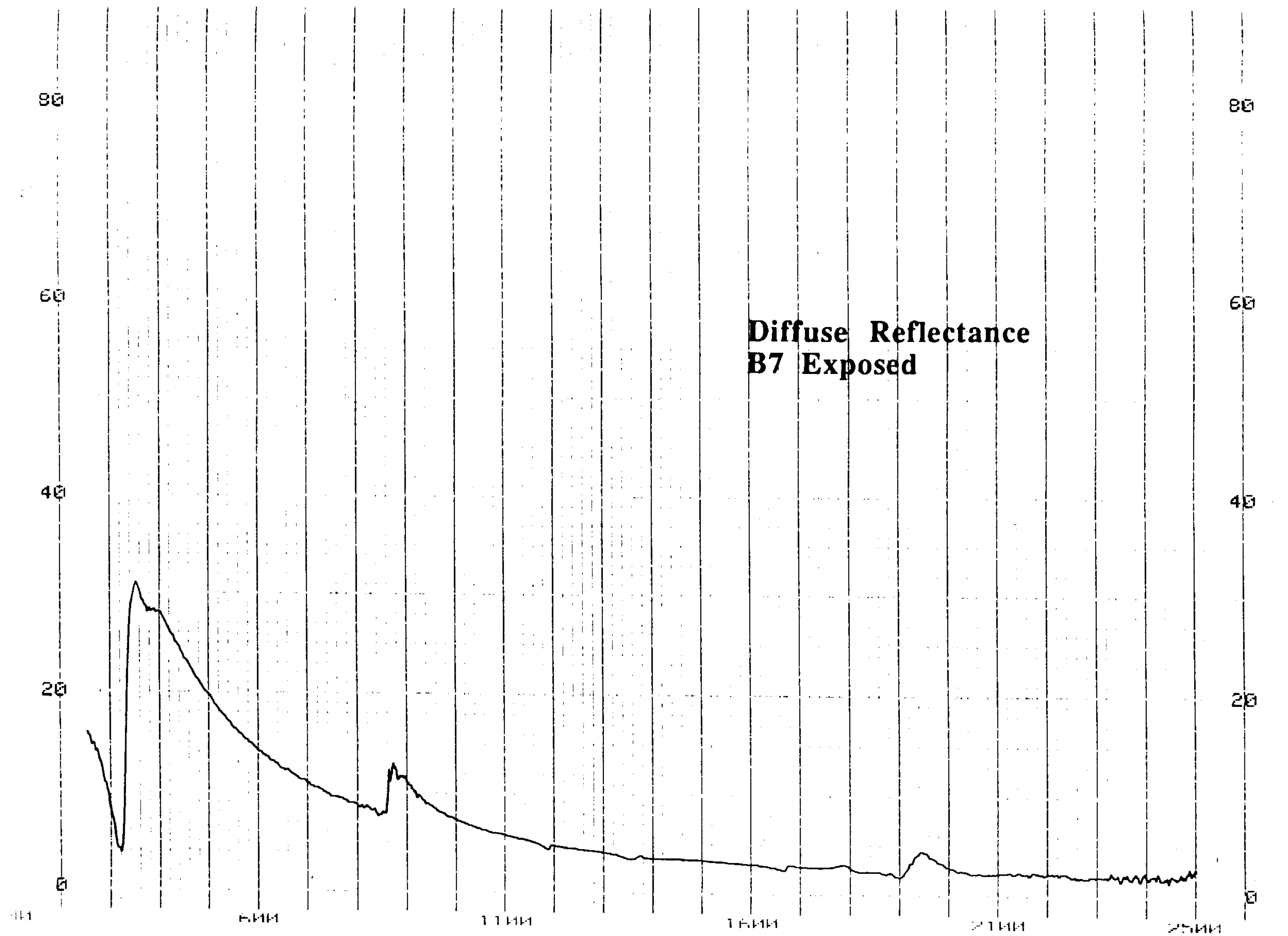

Figure D-127 UV-Vis-NIR diffuse reflectance spectrum for blanket B7.

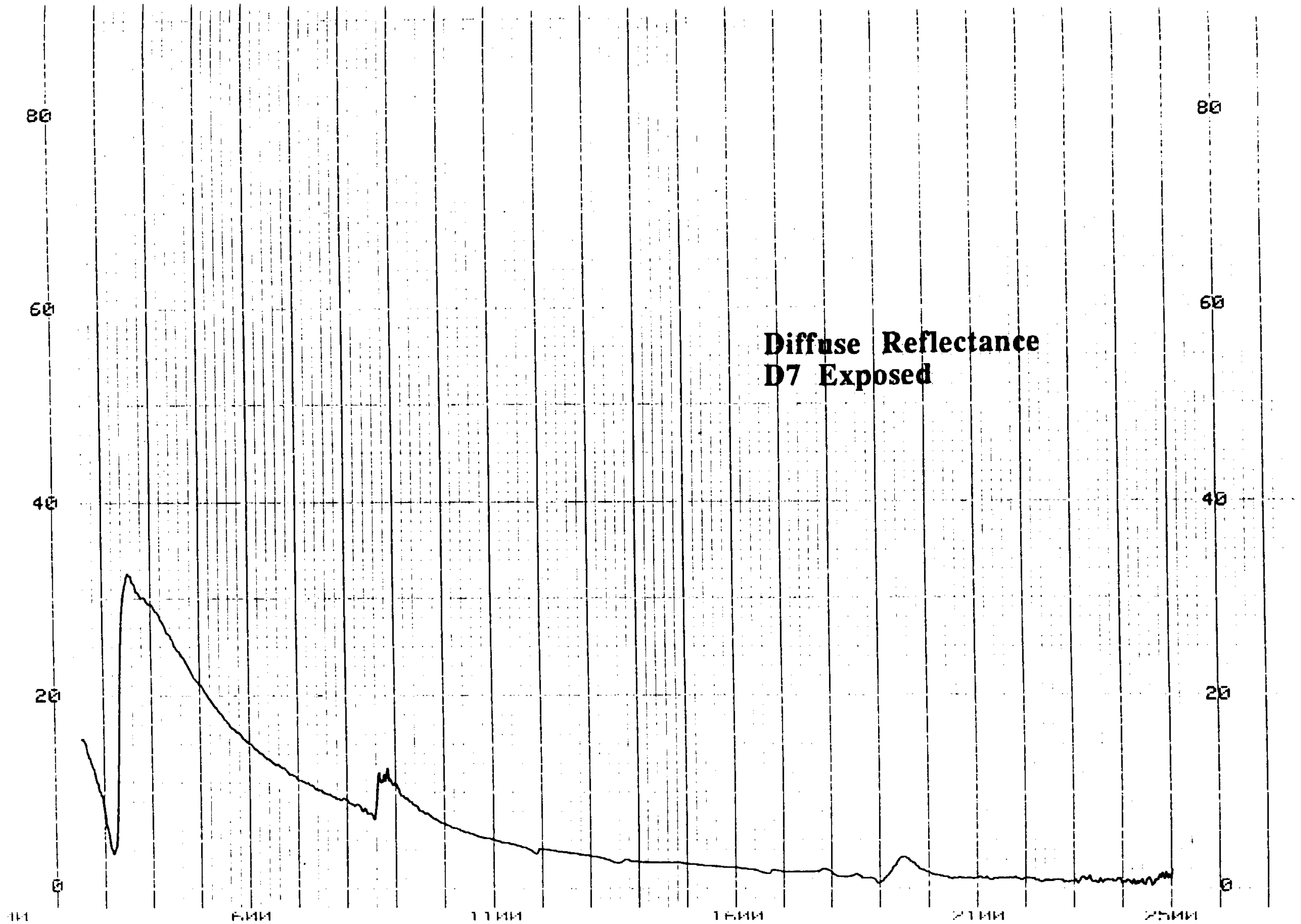

Figure D-128 UV-Vis-NIR diffuse reflectance spectrum for blanket D7.

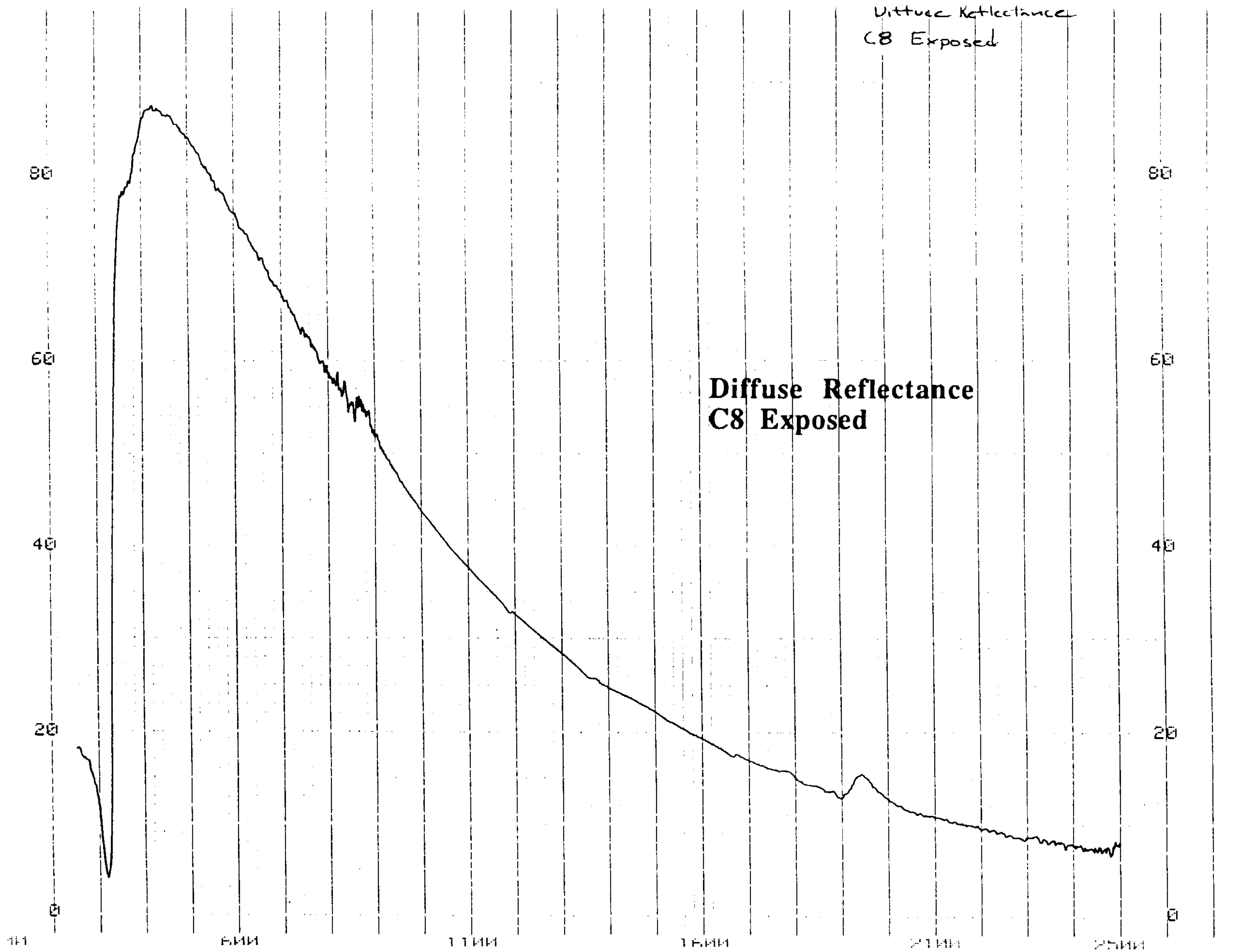

Figure D-129 UV-Vis-NIR diffuse reflectance spectrum for blanket C8.

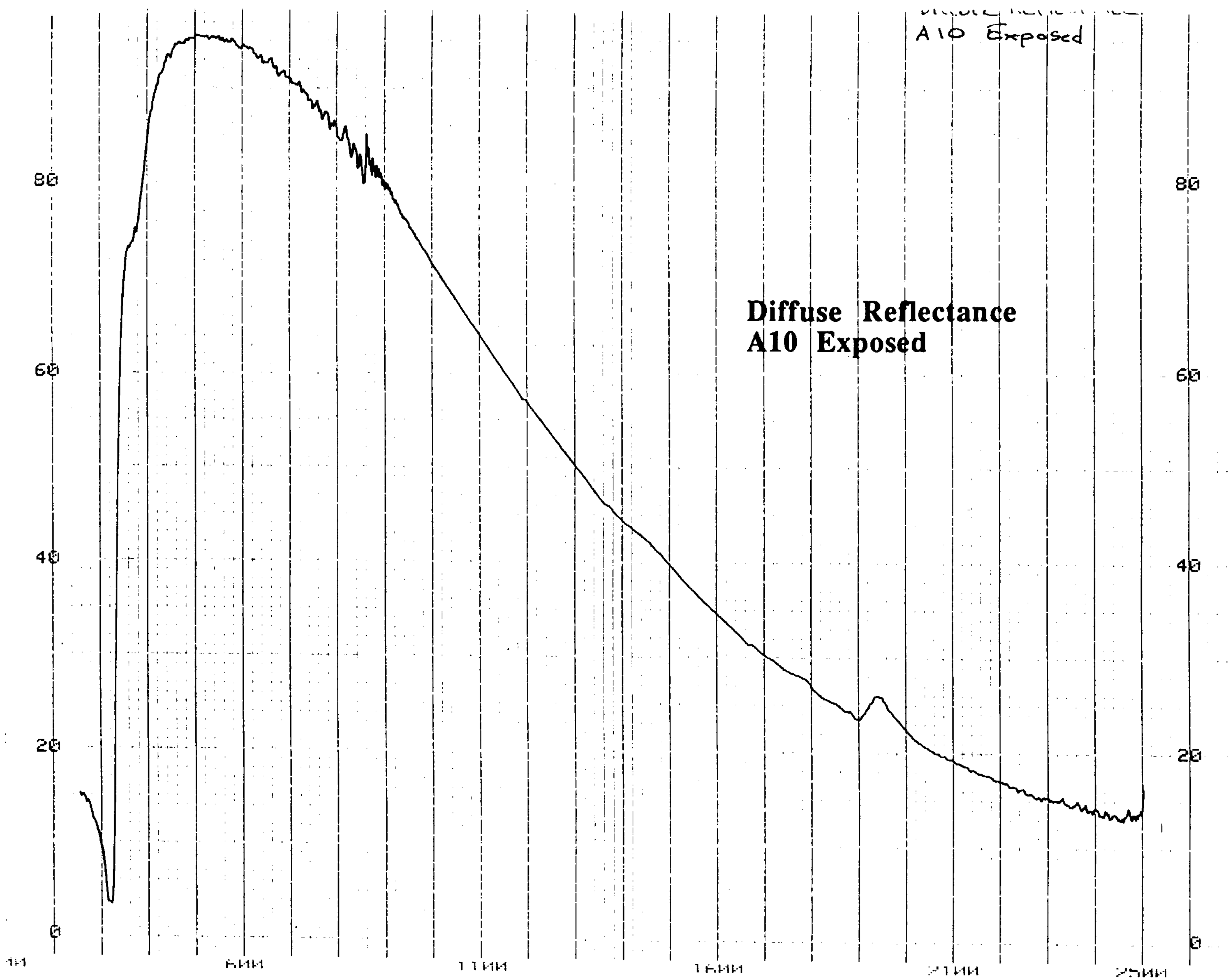

Figure D-130 UV-Vis-NIR diffuse reflectance spectrum for blanket A10.

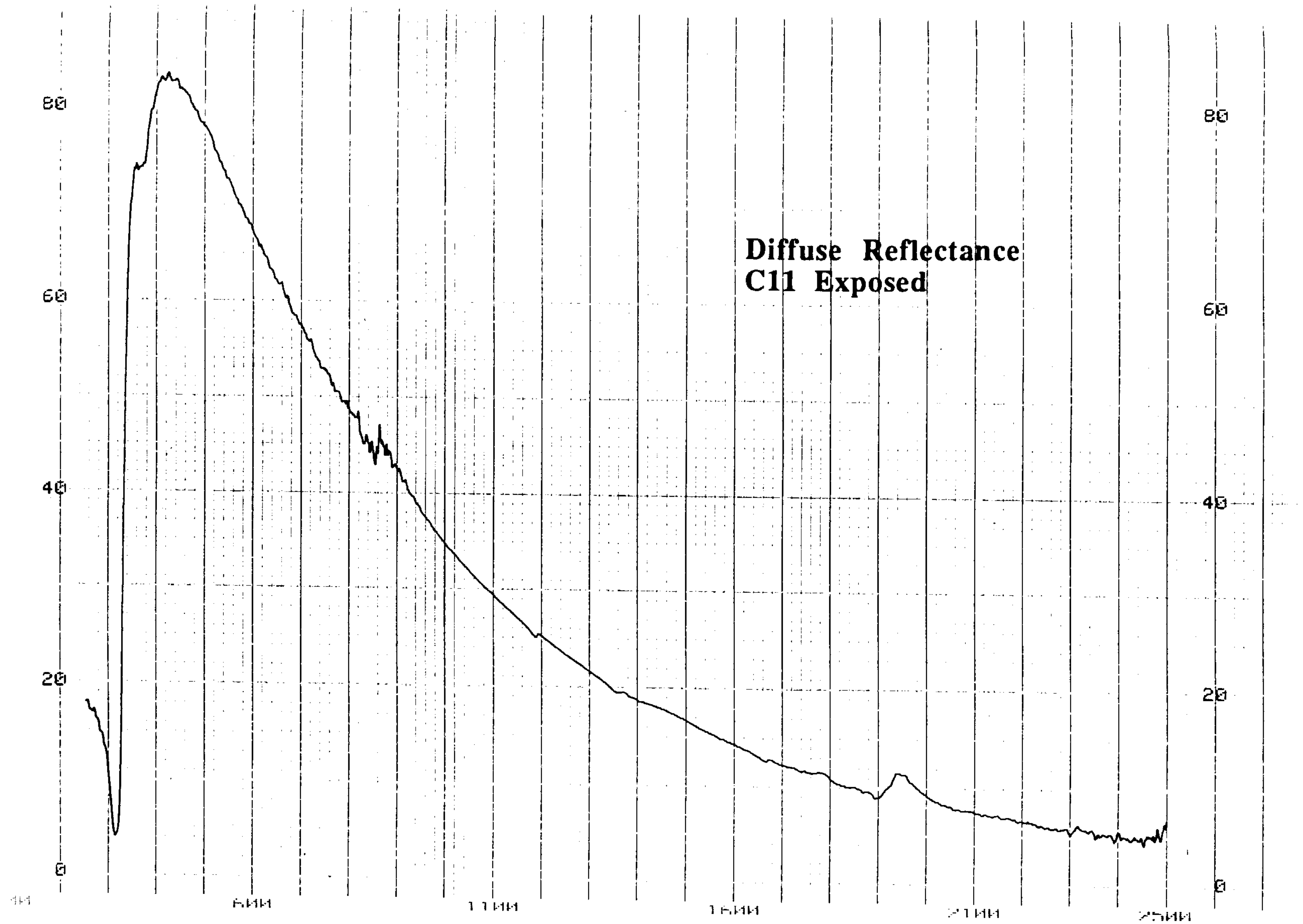

Figure D-131 UV-Vis-NIR diffuse reflectance spectrum for blanket C11.

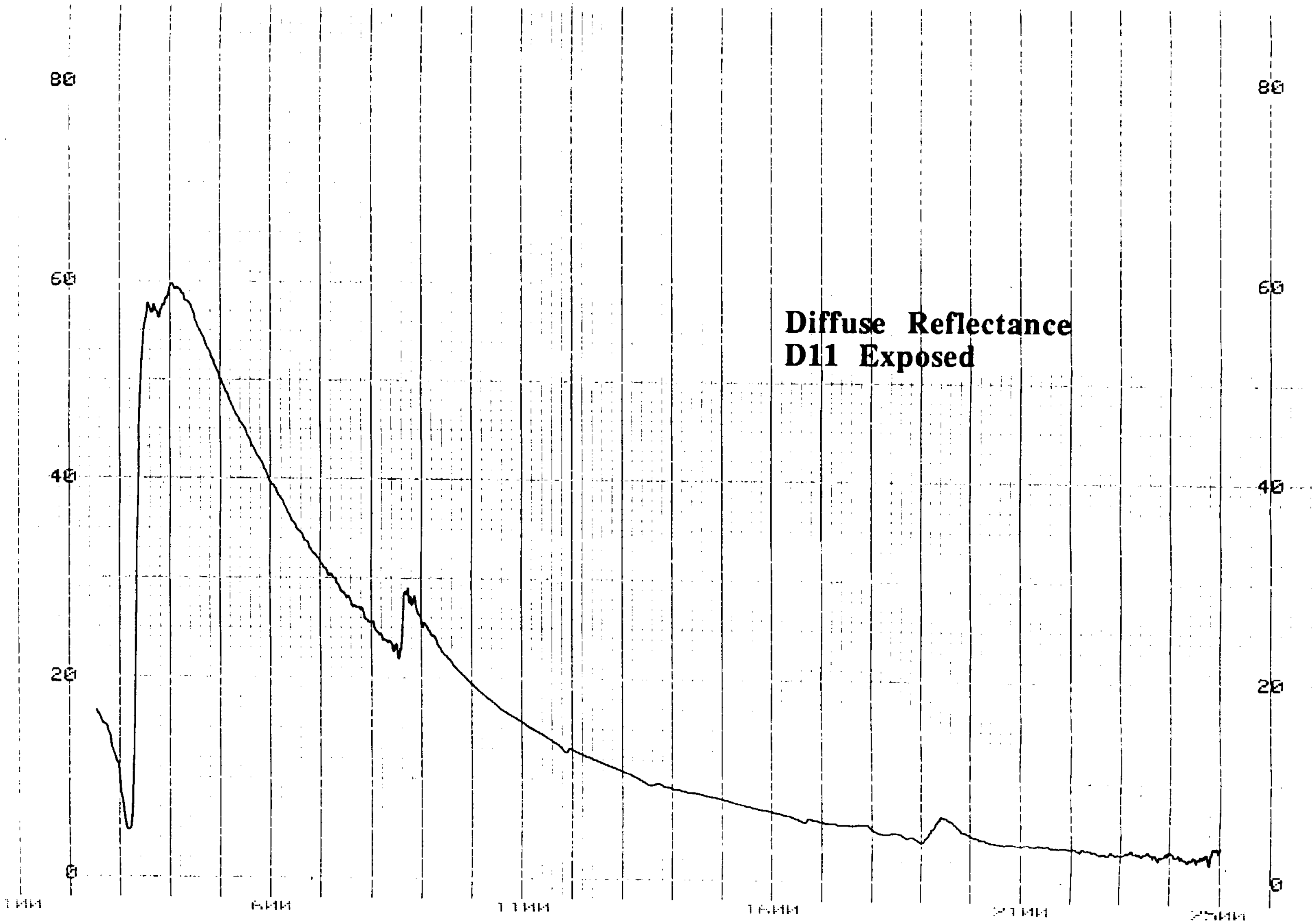

Figure D-132 UV-Vis-NIR diffuse reflectance spectrum for blanket D11.

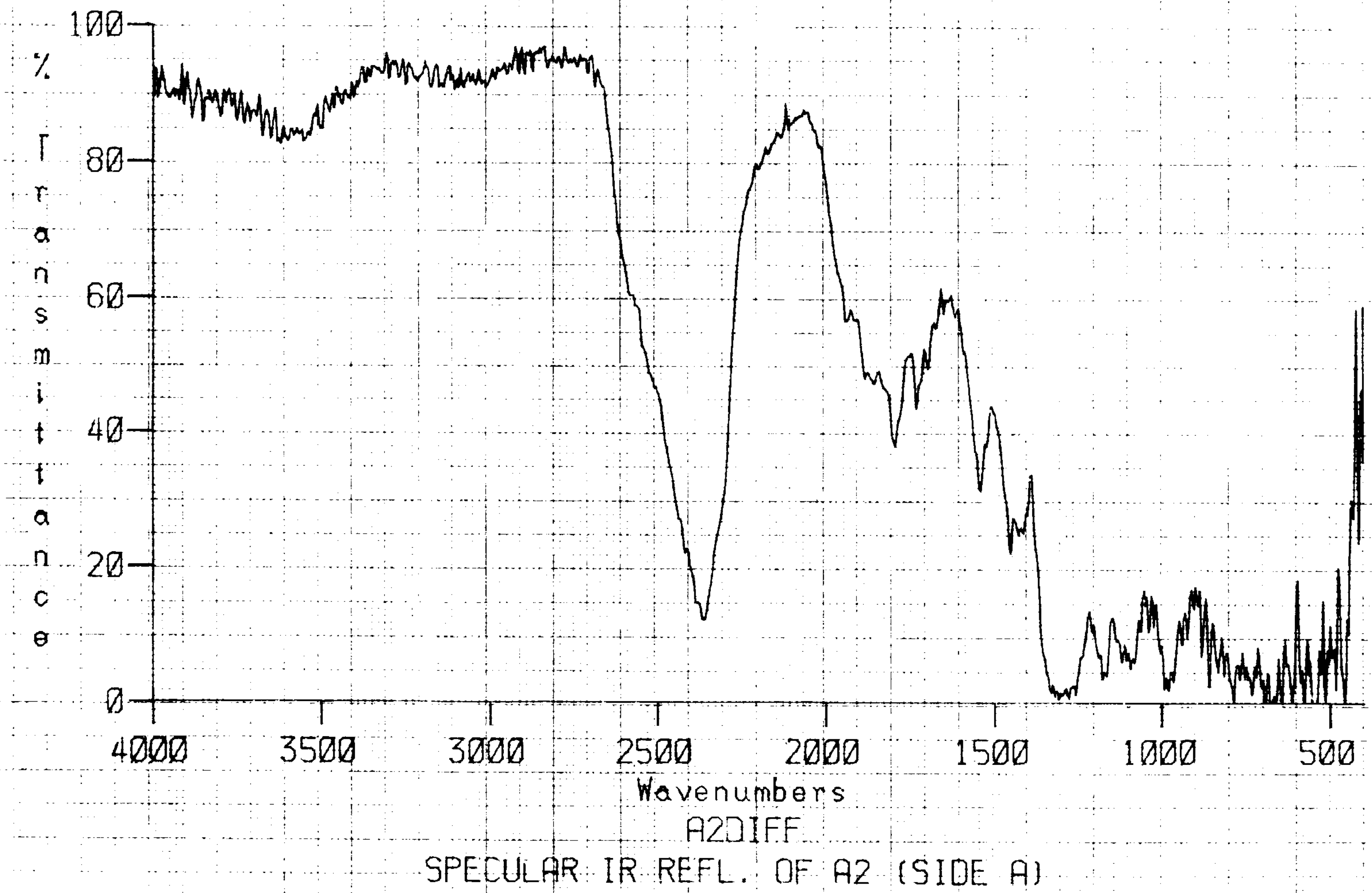

Figure D-133 IR specular reflectance spectrum for blanket A2.

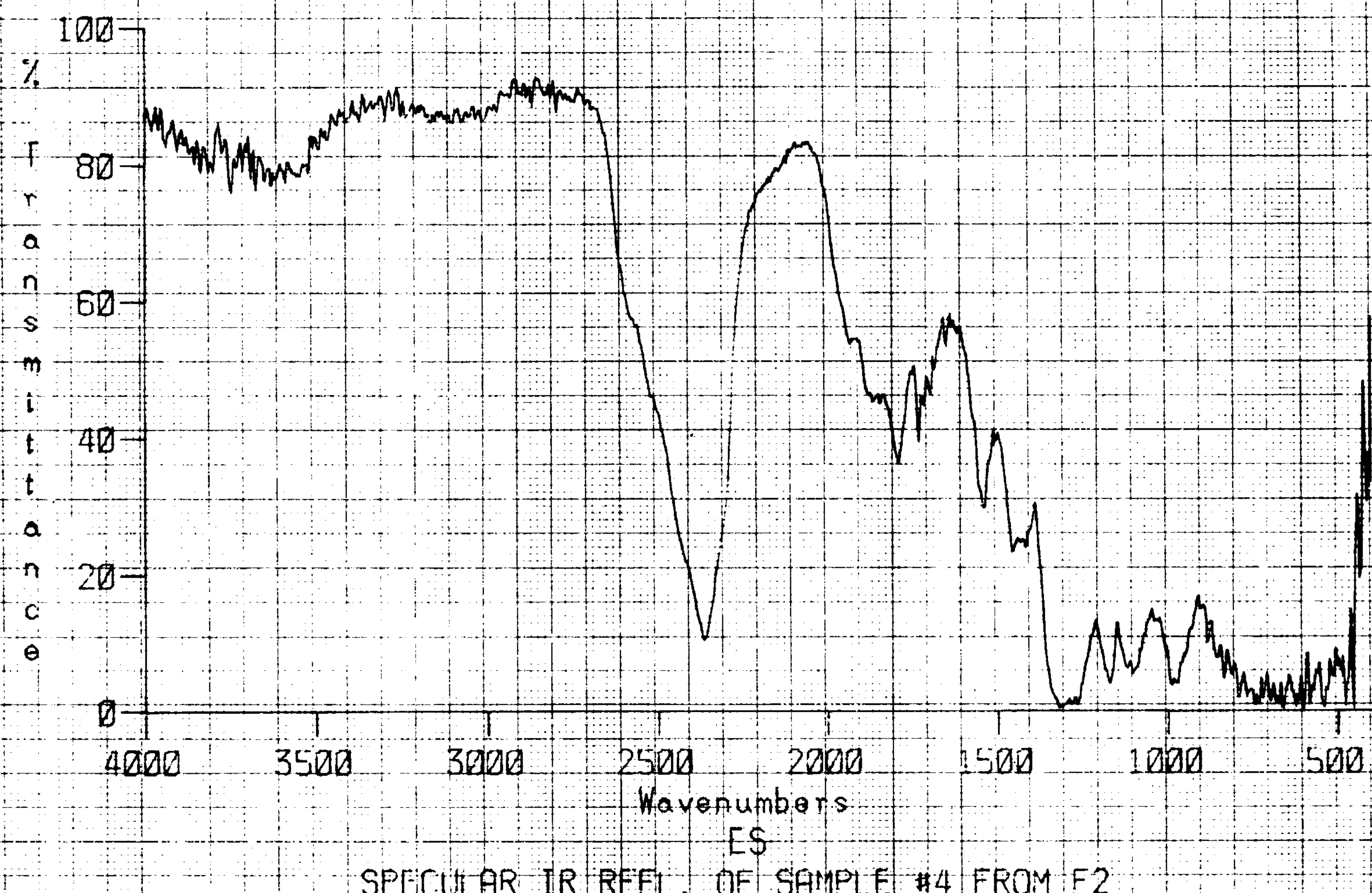

Figure D-134 IR specular reflectance spectrum for blanket F2(#4).

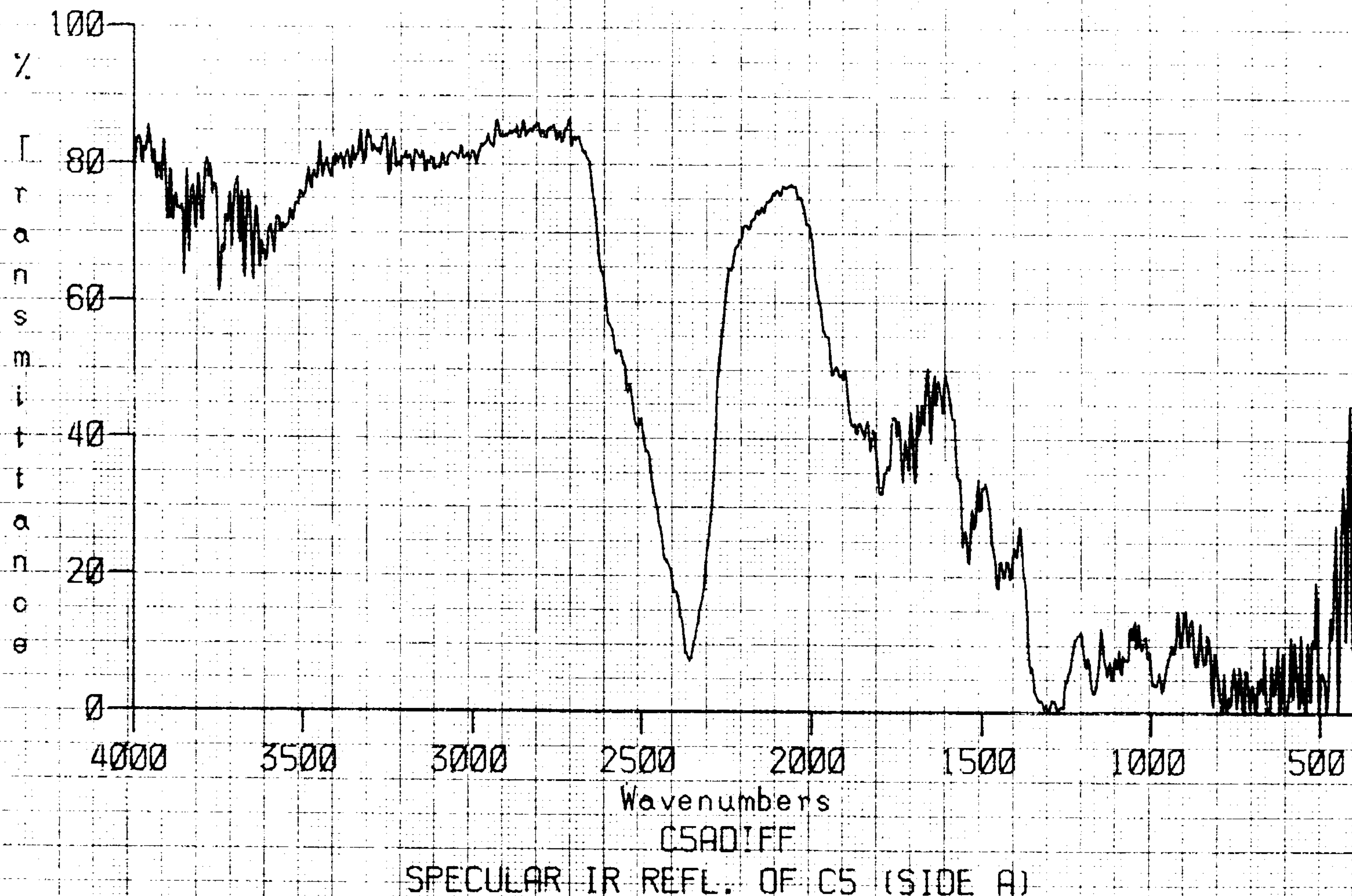

Figure D-135   IR specular reflectance spectrum for blanket C5.

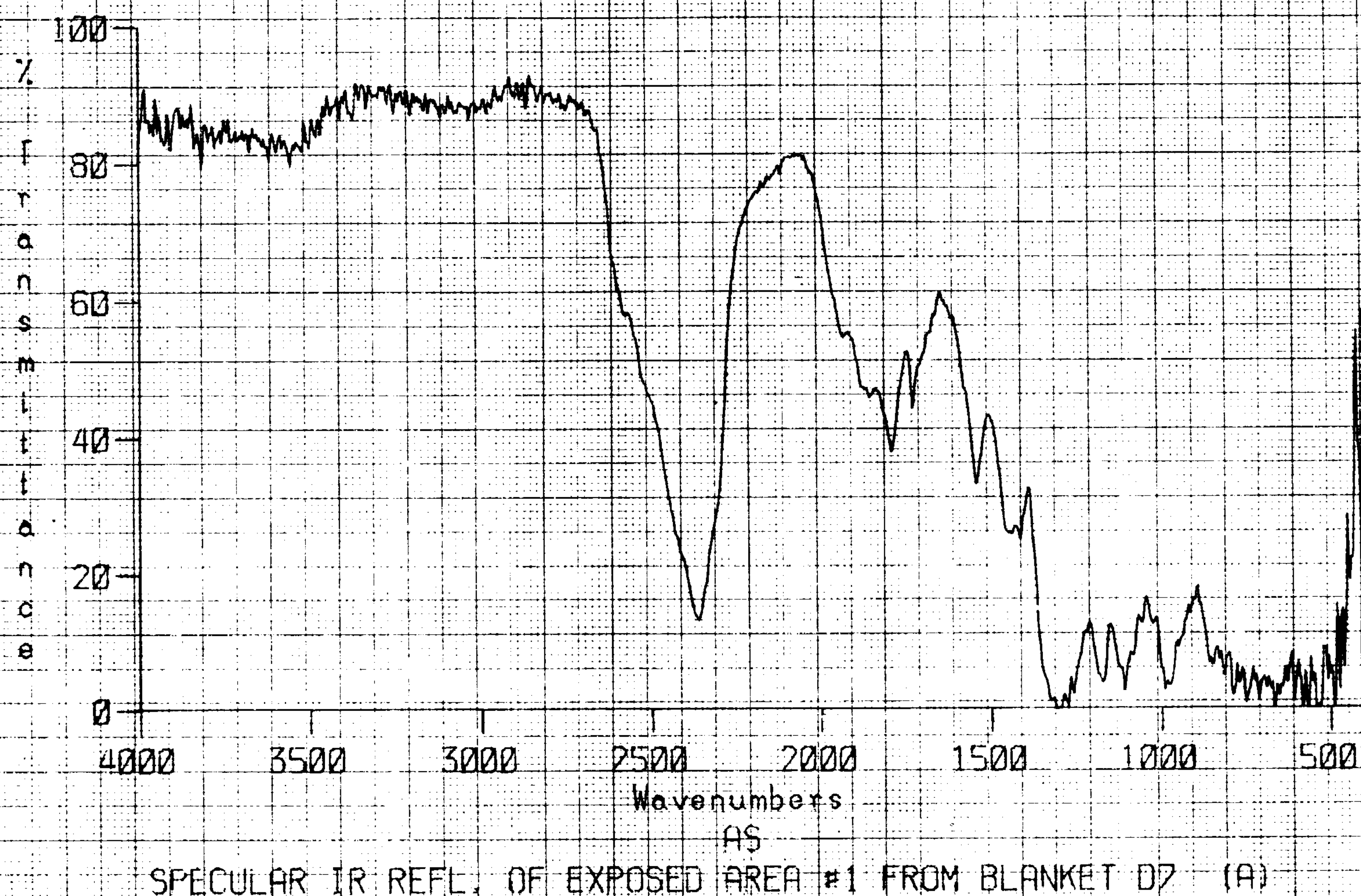

Figure D-136 IR specular reflectance spectrum for unexposed area 1 of blanket D7.

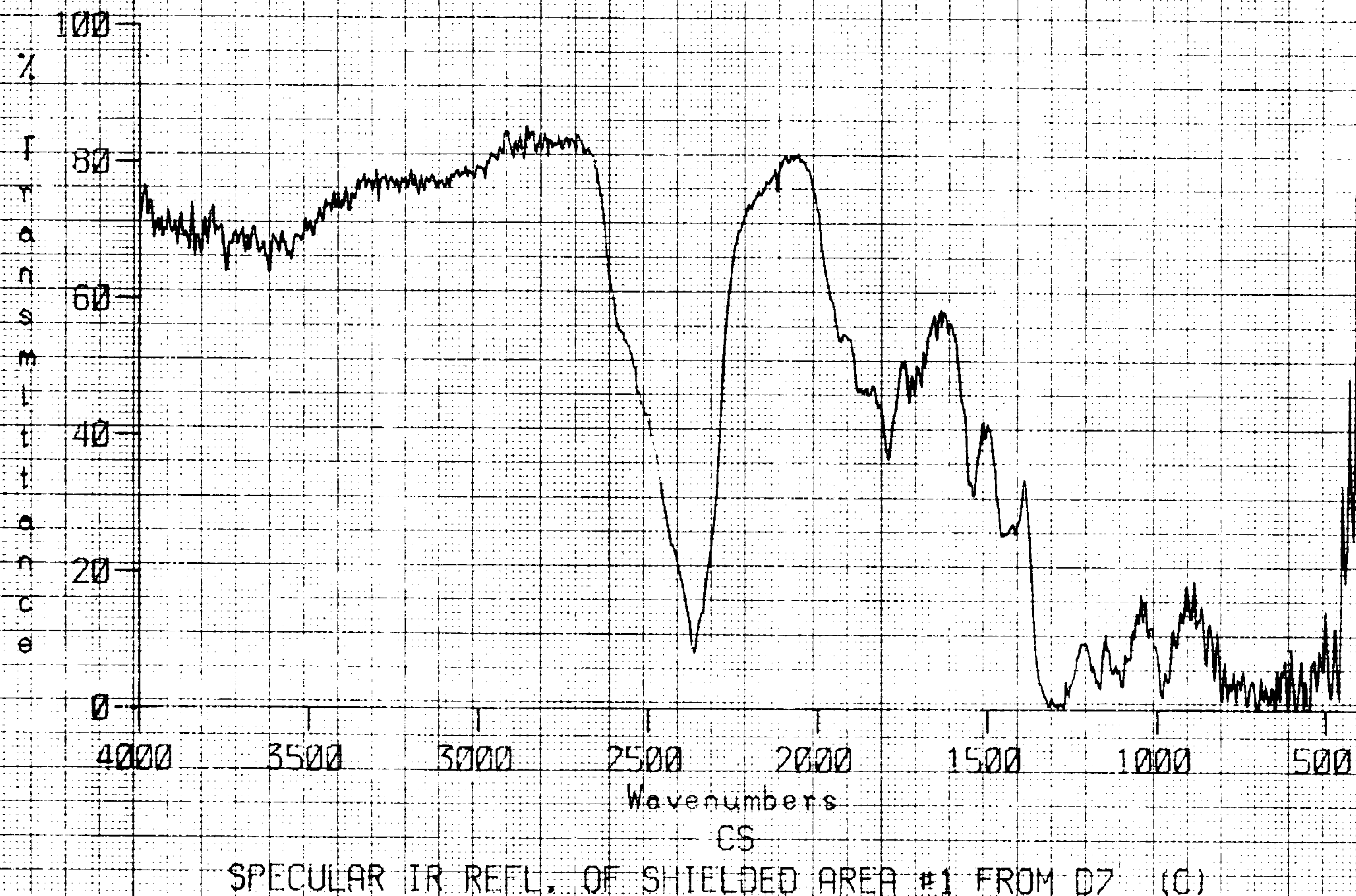

Figure D-137 IR specular reflectance spectrum for blanket D7, Area 2.

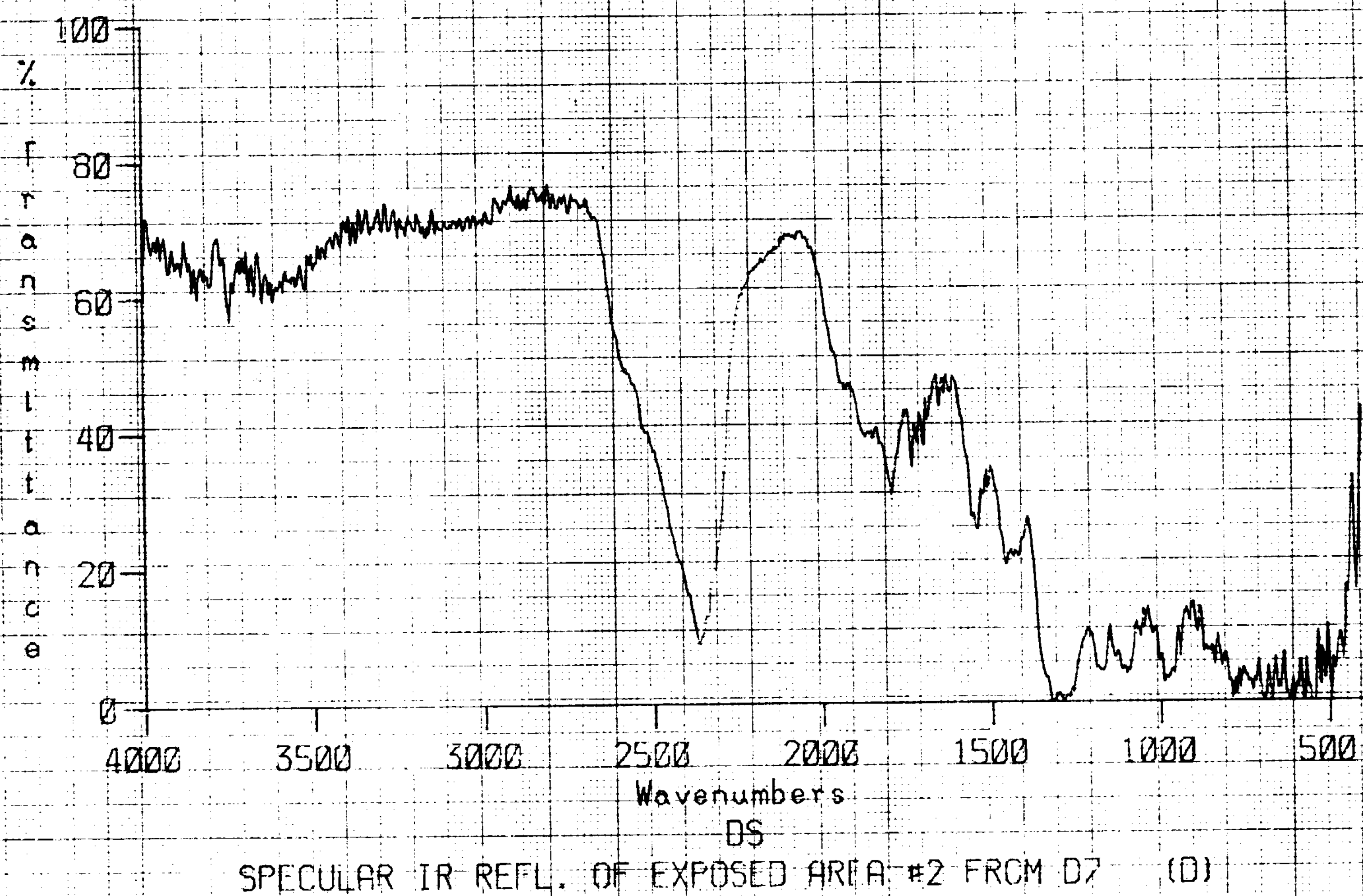

Figure D-138 IR specular reflectance spectrum for shielded area from blanket D7.

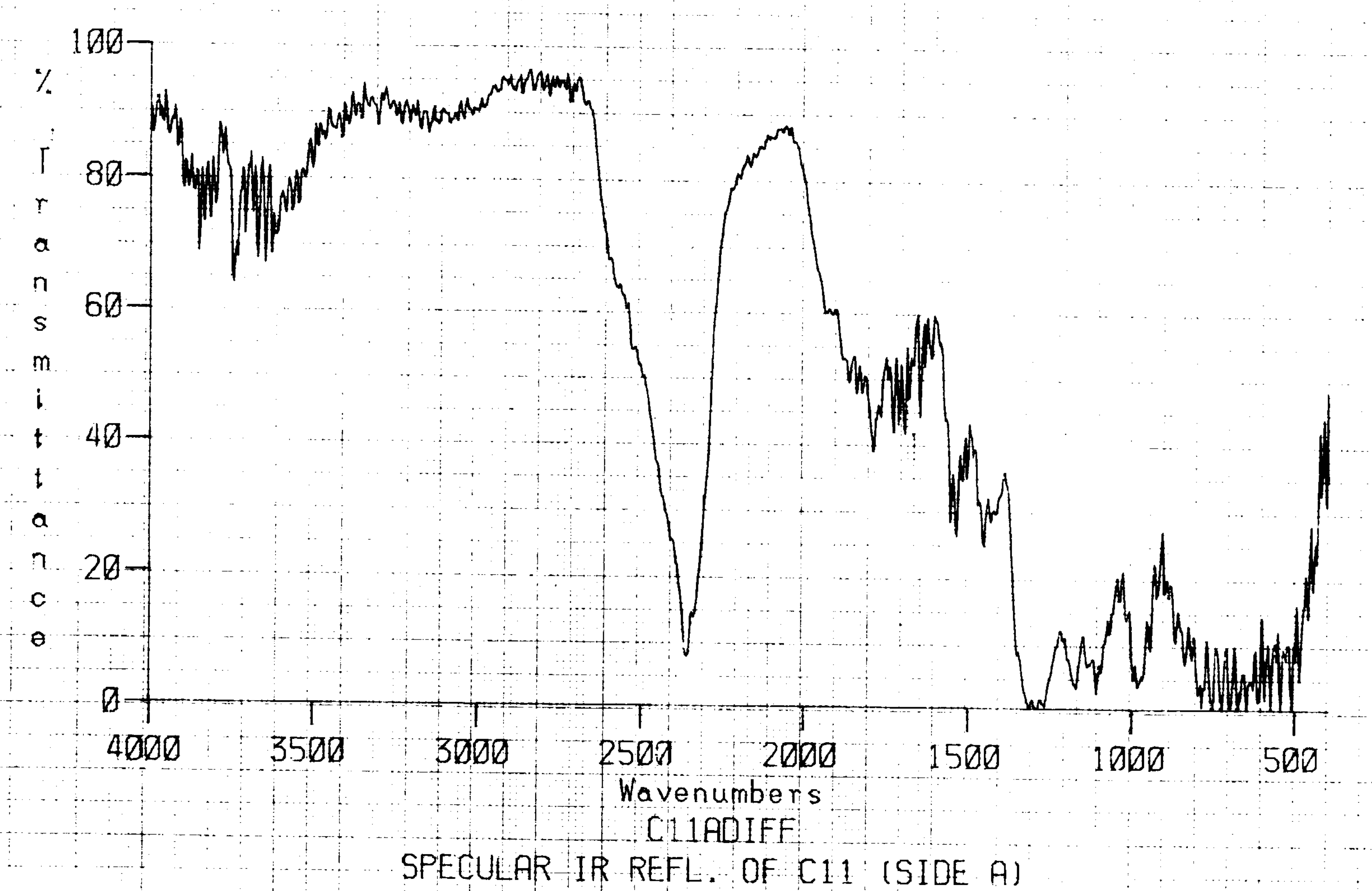

Figure D-139 IR specular reflectance spectrum for blanket C11.

APPENDIX E

Scanning Electron Microscopy Images

This appendix shows sequences of SEM photos showing effects of the various exposures on the FEP layers of the Ag/FEP thermal control blankets. Exposed and unexposed areas for leading and trailing edge surfaces, areas shielded by particulate contaminants, areas covered by molecular contaminants, and areas representative of the folds between exposed and unexposed surfaces are shown.

Figures E-1 to -14 are SEMs of the FEP surface of blanket D11 at specific distances from the edge of the blanket. The value of x listed on each image is the distance in mm from the edge. The range of distances from 33 to 80 mm covers exposure conditions for unexposed through near ram exposure in the region of the bend, to the exposed blanket face. Figures E-15 to -30 are a set of SEM's of the FEP surface of blanket B7 over a range of specific locations from unexposed edge to exposed blanket areas. The value x listed is the distance in mm from the edge. Figures E-31 to -35 are a series of SEM images of an impact crater on blanket D11. Figures E-36 and E-37 show the textured surface of C8, caused by atomic oxygen exposure. Figure E-38 contrasts the previous figures by showing the smooth texture of the exposed surface of C5. Figures E-39 to -42 show the variety of surface patterns observed on blanket F2; Figure E-40 shows the morphology of a surface with severe silicone contamination. Figures E-43-46 show a series of SEM's from locations on blanket D7. The exposed areas show texturing highly oriented from the extreme impingement angle.

List of Figures for Appendix E

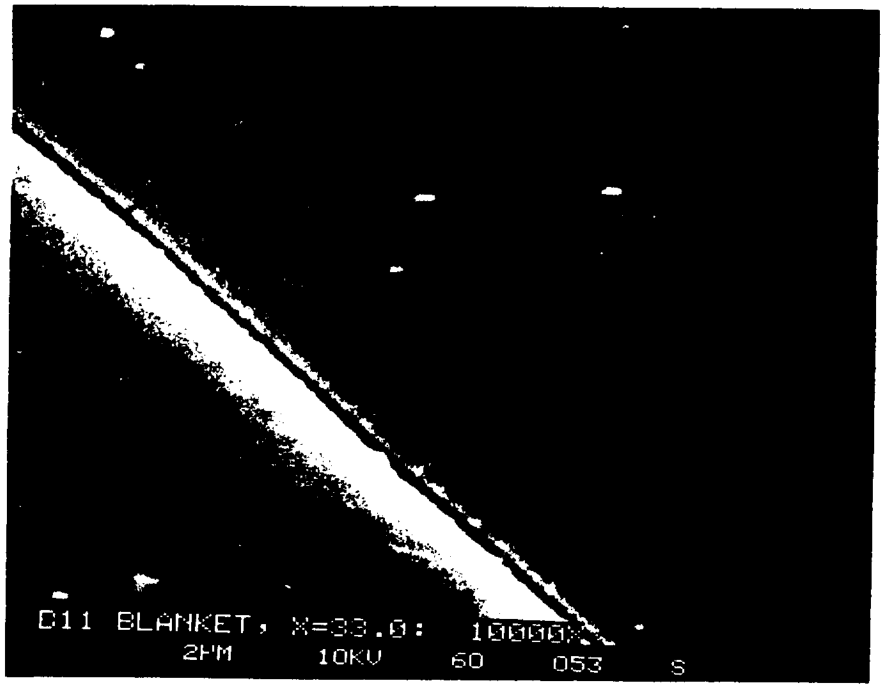

Figure E-1 10000X magnification SEM image of FEP surface 33.0 mm from the edge of blanket D11.

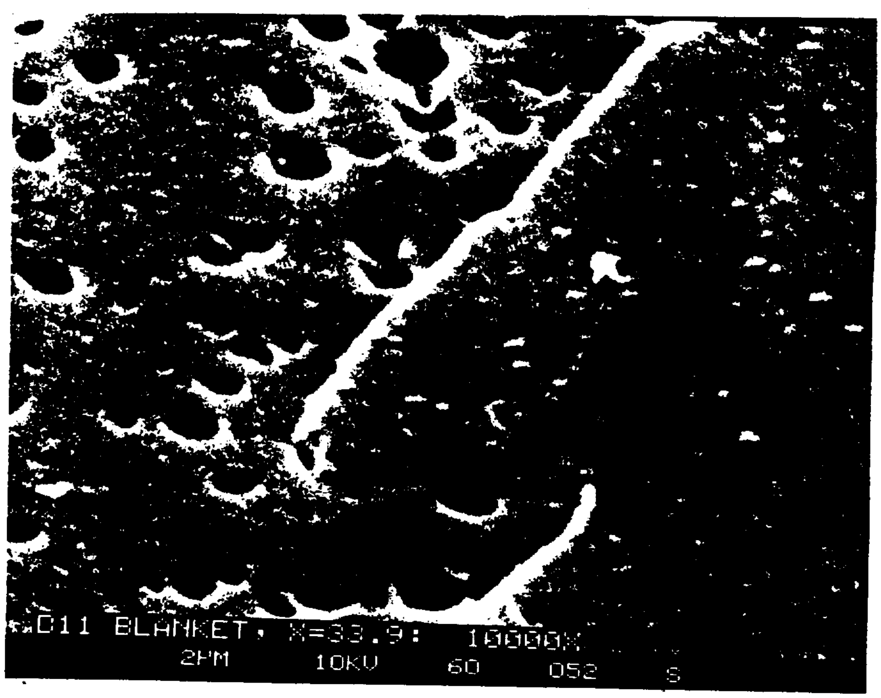

Figure E-2 10000X magnification SEM image of FEP surface 33.9 mm from the edge of blanket D11.

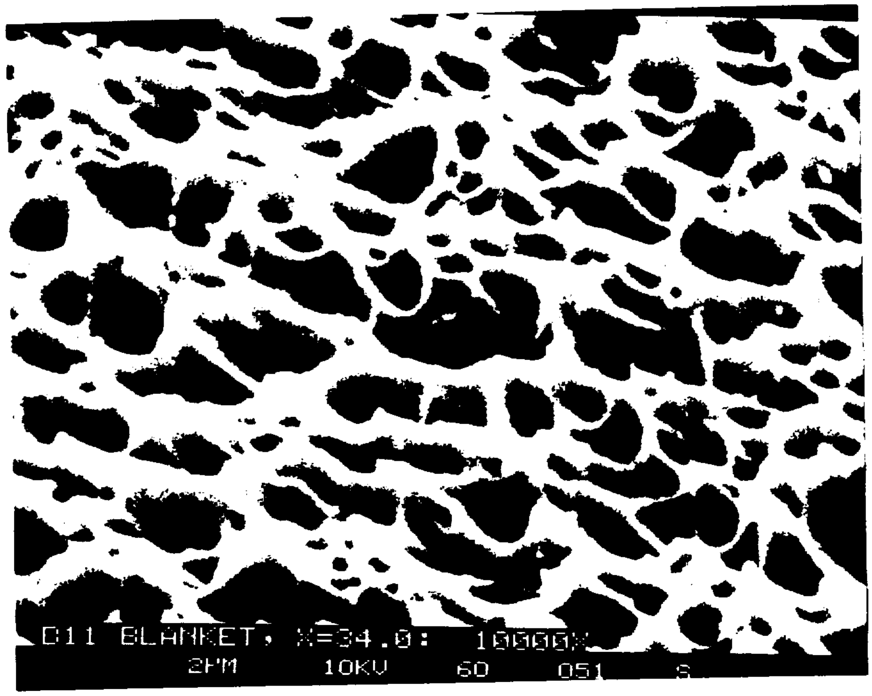

Figure E-3 10000X magnification SEM image of FEP surface 34.0 mm from the edge of blanket D11.

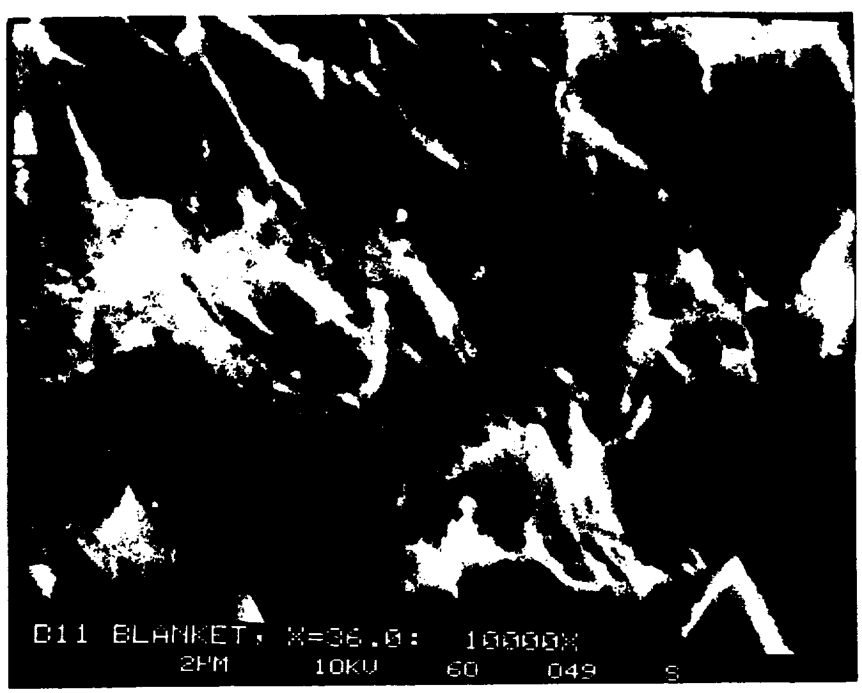

Figure E-4 10000X magnification SEM image of FEP surface 36.0 mm from the edge of blanket D11.

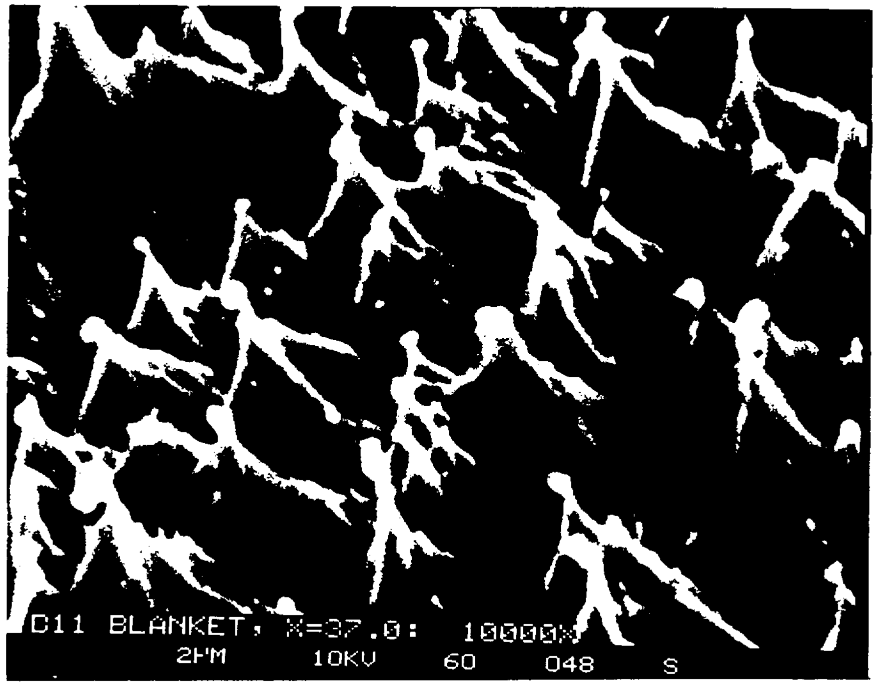

Figure E-5 10000X magnification SEM image of FEP surface 37.0 mm from the edge of blanket D11.

Figure E-6 10000X magnification SEM image of FEP surface 39.0 mm from the edge of blanket D11.

Figure E-7 10000X magnification SEM image of FEP surface 41.0 mm from the edge of blanket D11.

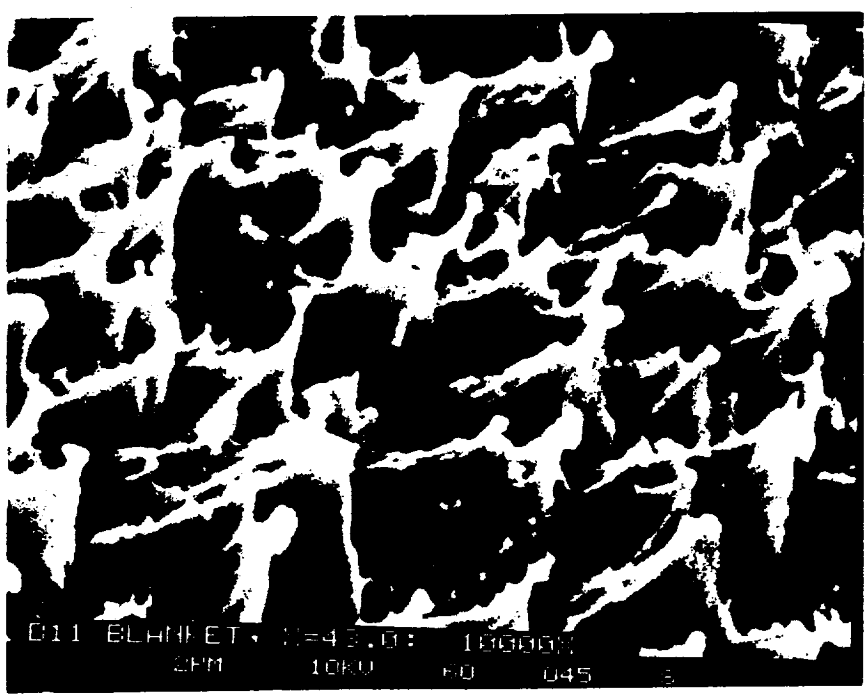

Figure E-8 10000X magnification SEM image of FEP surface 43.0 mm from the edge of blanket D11.

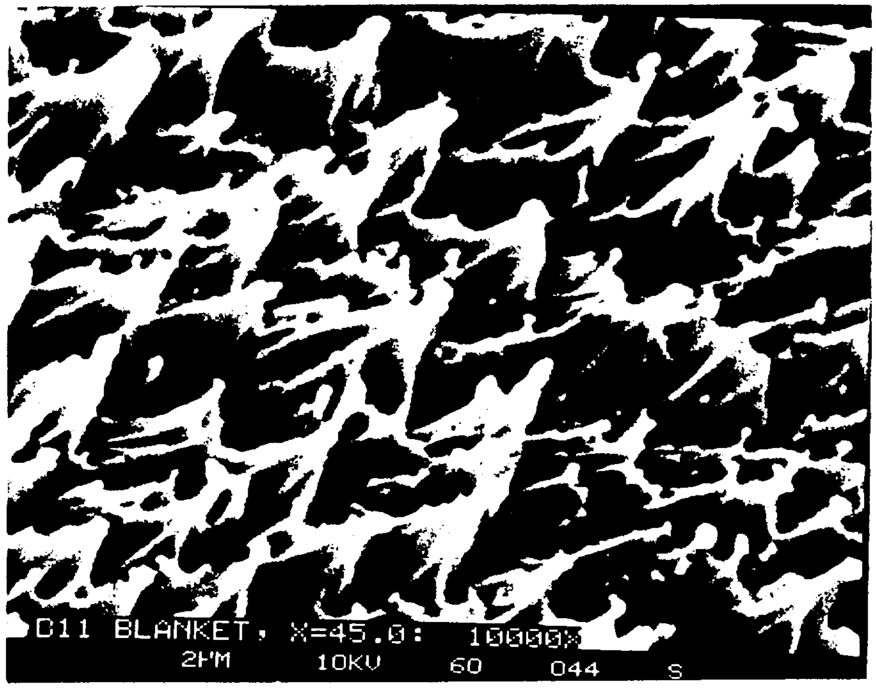

Figure E-9 10000X magnification SEM image of FEP surface 45.0 mm from the edge of blanket D11.

Figure E-10 10000X magnification SEM image of FEP surface 47.0 mm from the edge of blanket D11.

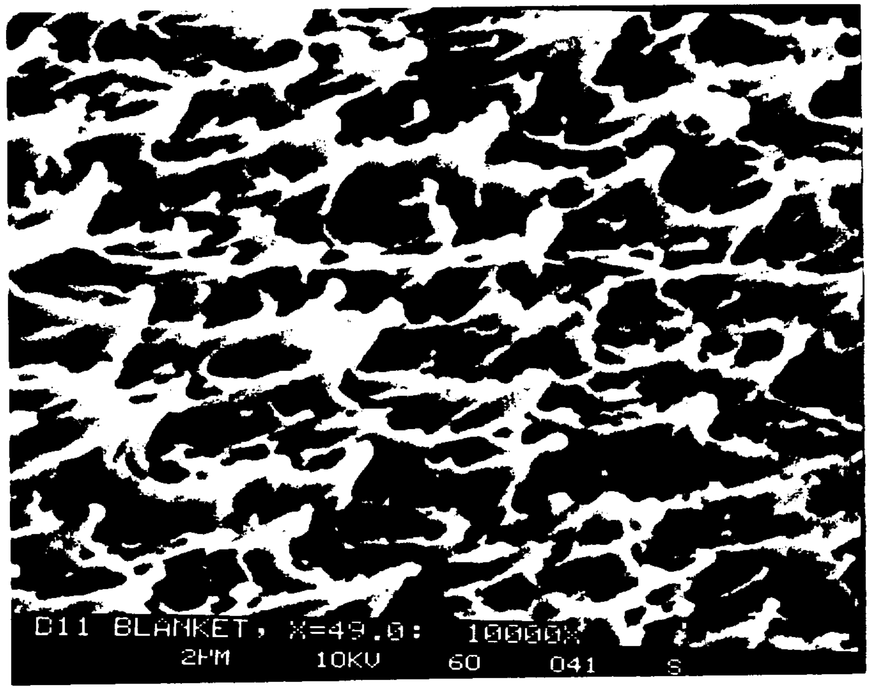

Figure E-11 10000X magnification SEM image of FEP surface 49.0 mm from the edge of blanket D11..

Figure E-12 10000X magnification SEM image of FEP surface 50.0 mm from the edge of blanket D11.

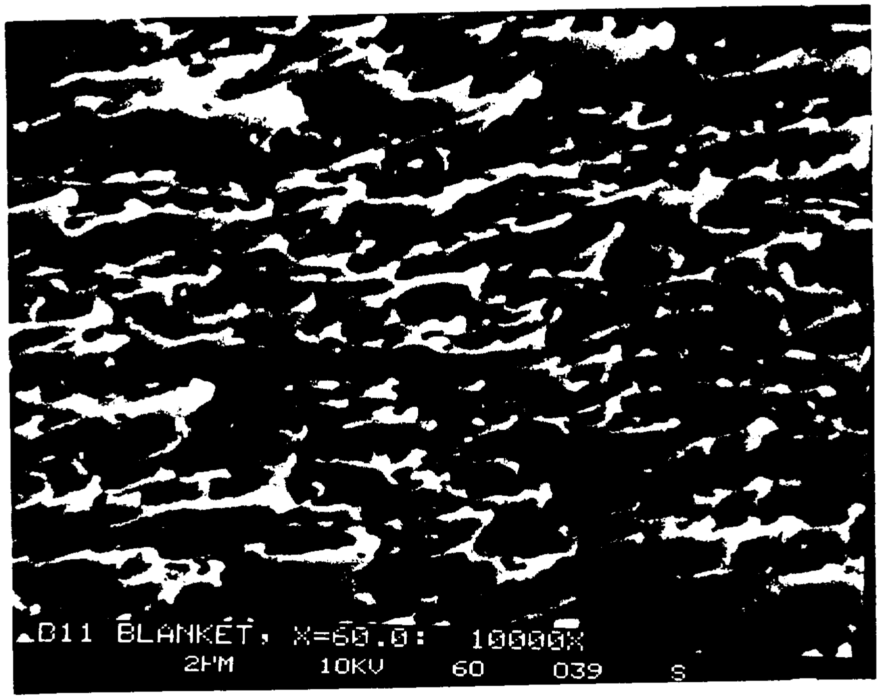

Figure E-13 10000X magnification SEM image of FEP surface 60.0 mm from the edge of blanket D11.

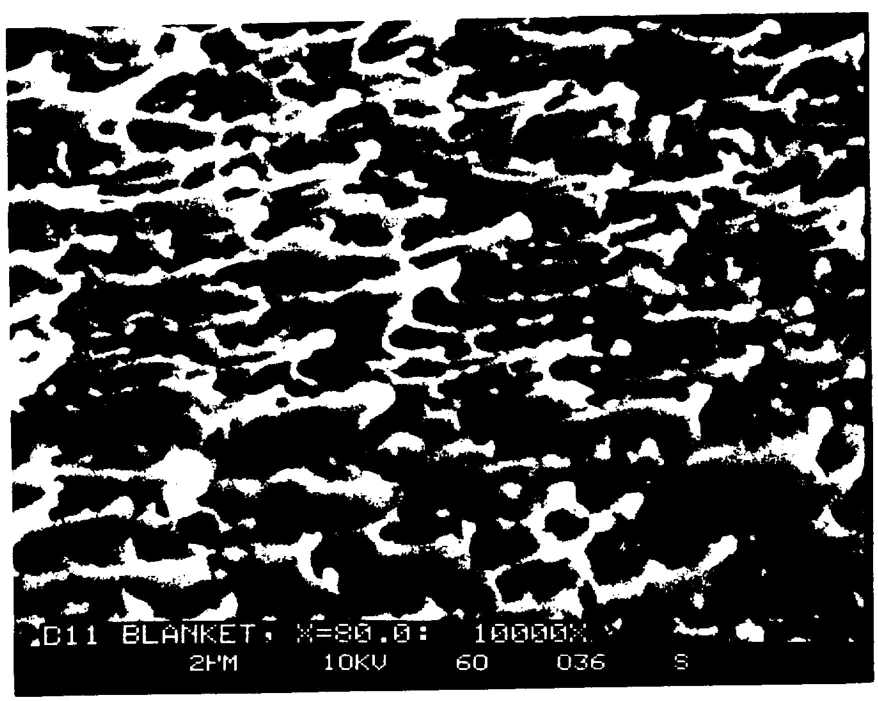

Figure E-14 10000X magnification SEM image of FEP surface 80.0 mm from the edge of blanket D11.

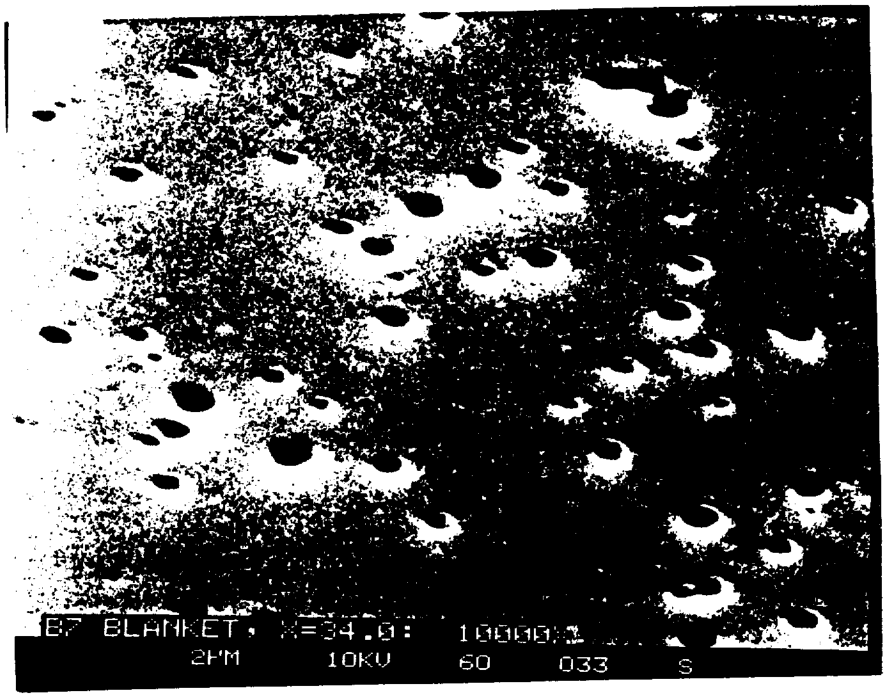

Figure E-15 10000X magnification SEM image of FEP surface 34.0 mm from the edge of blanket B7.

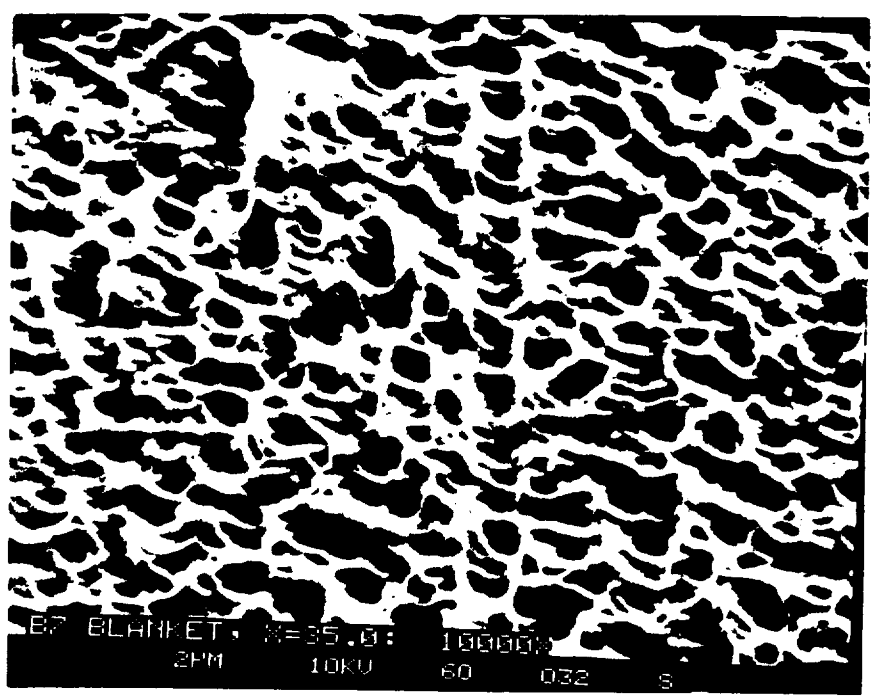

Figure E-16 10000X magnification SEM image of FEP surface 35.0 mm from the edge of blanket B7.

Figure E-17 10000X magnification SEM image of FEP surface 36.0 mm from the edge of blanket B7.

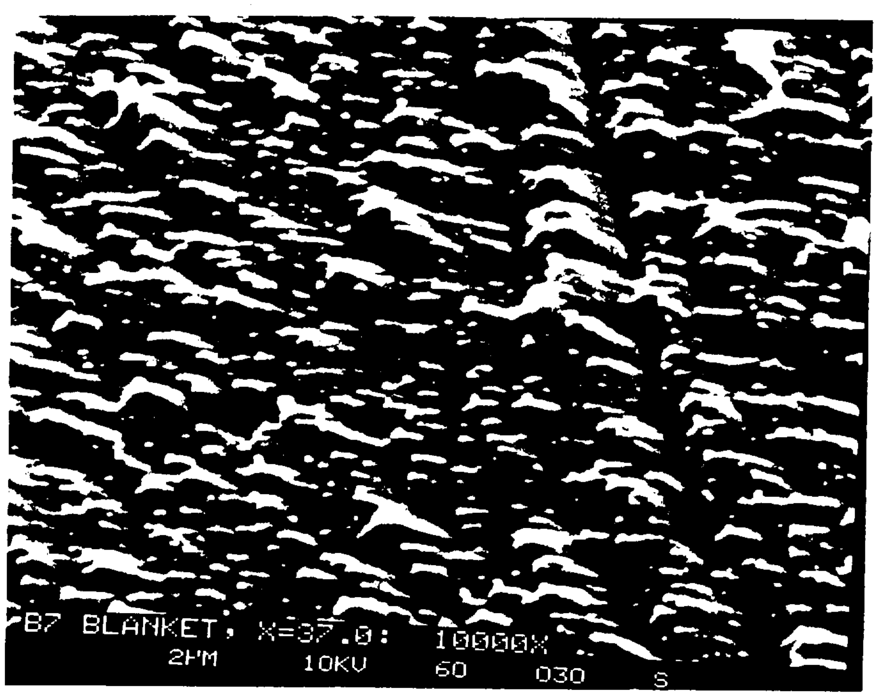

Figure E-18 10000X magnification SEM image of FEP surface 37.0 mm from the edge of blanket B7.

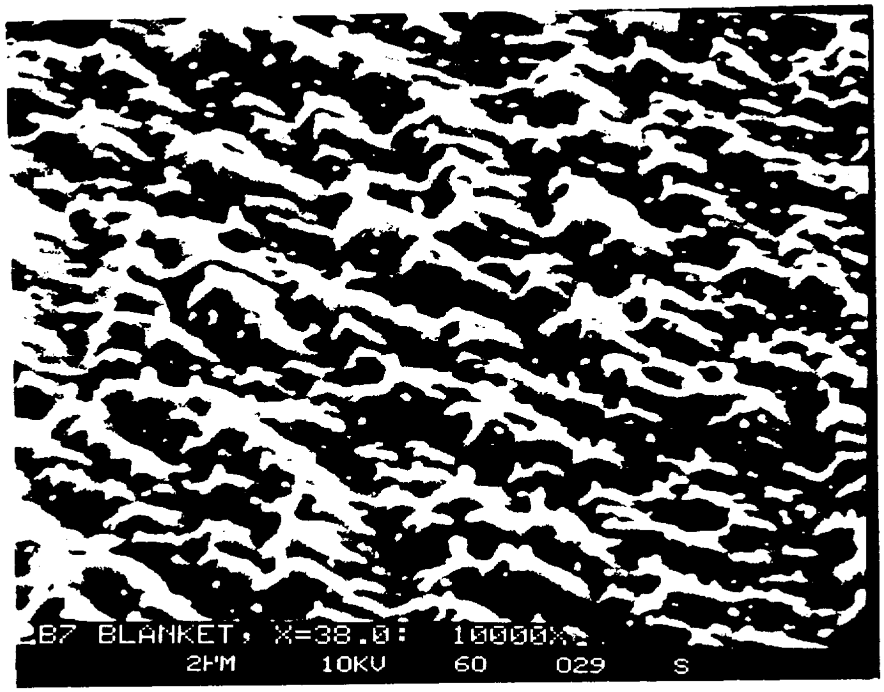

Figure E-19 10000X magnification SEM image of FEP surface 38.0 mm from the edge of blanket B7.

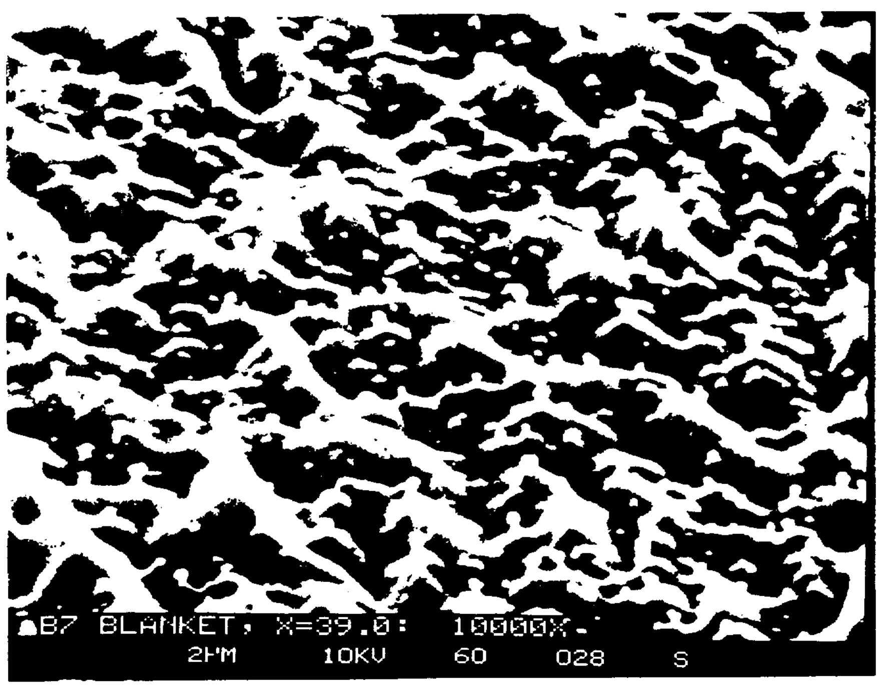

Figure E-20 10000X magnification SEM image of FEP surface 39.0 mm from the edge of blanket B7.

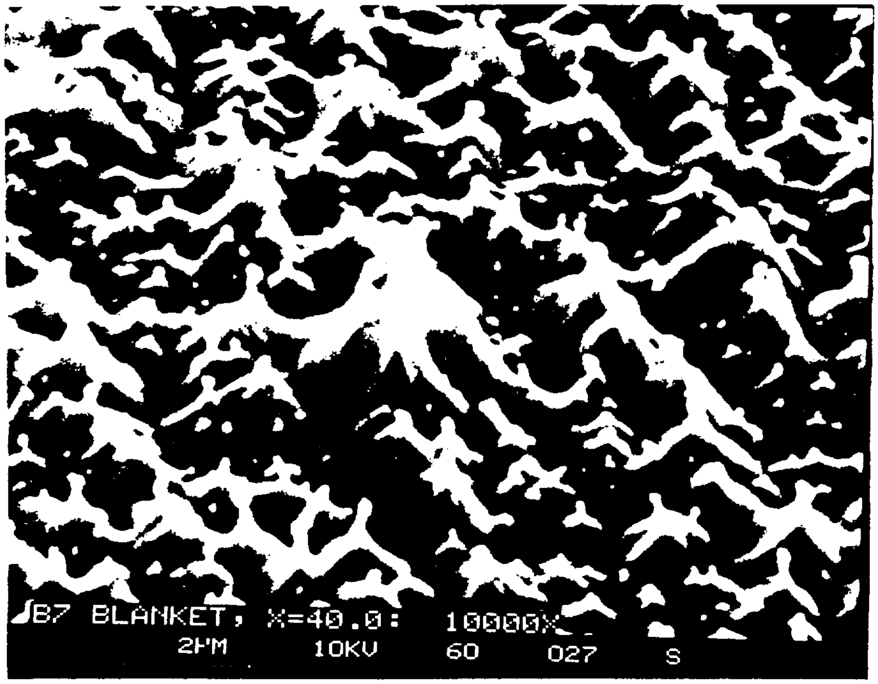

Figure E-21 10000X magnification SEM image of FEP surface 40.0 mm from the edge of blanket B7.

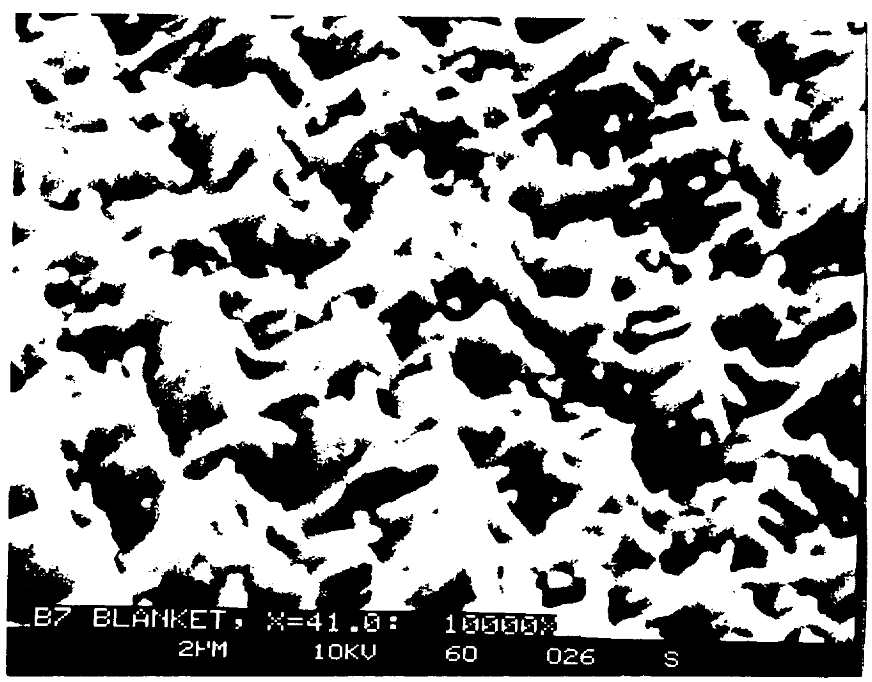

Figure E-22 10000X magnification SEM image of FEP surface 41.0 mm from the edge of blanket B7.

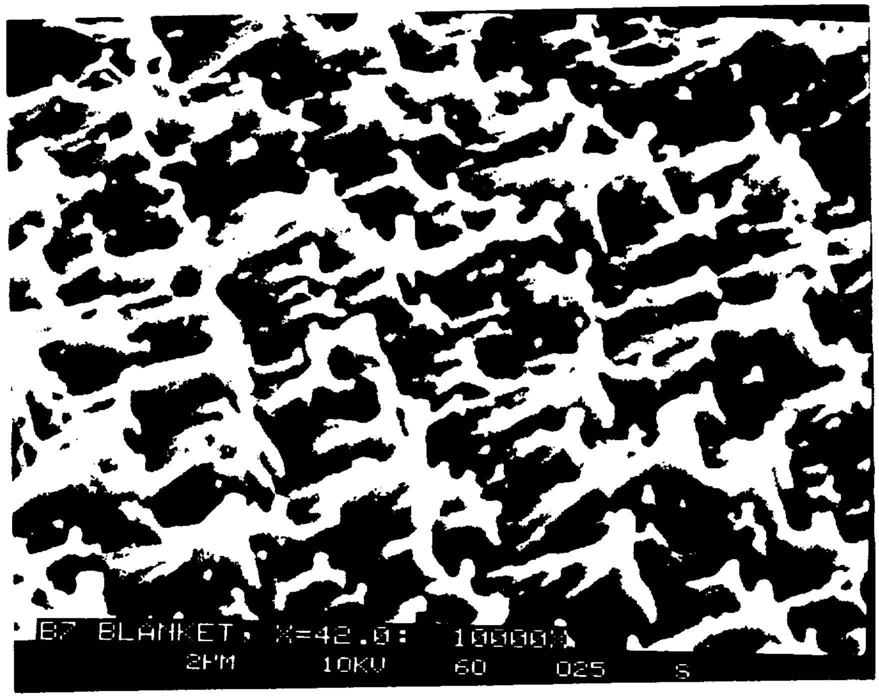

Figure E-23 10000X magnification SEM image of FEP surface 42.0 mm from the edge of blanket B7.

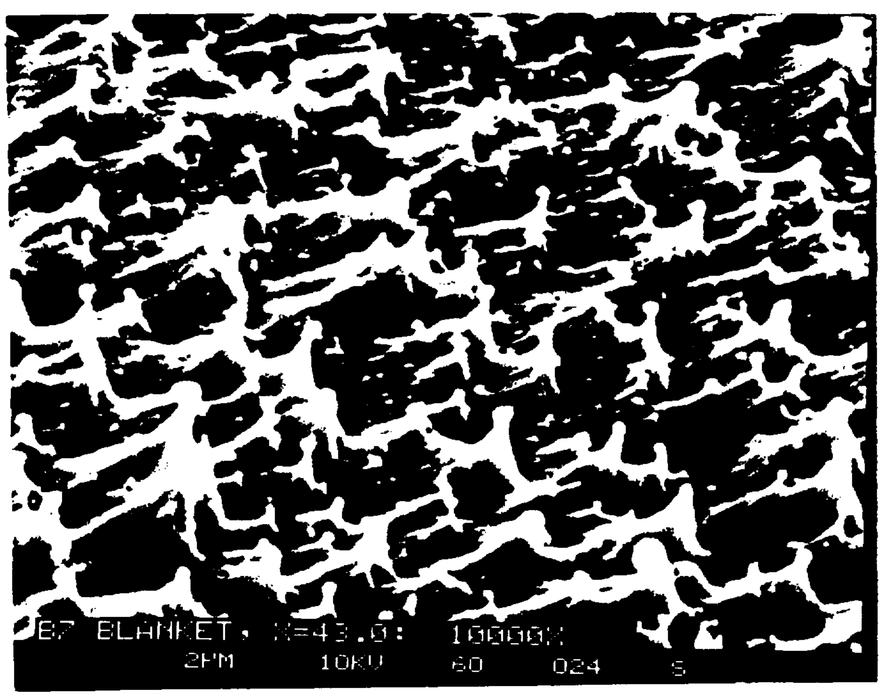

Figure E-24 10000X magnification SEM image of FEP surface 43.0 mm from the edge of blanket B7.

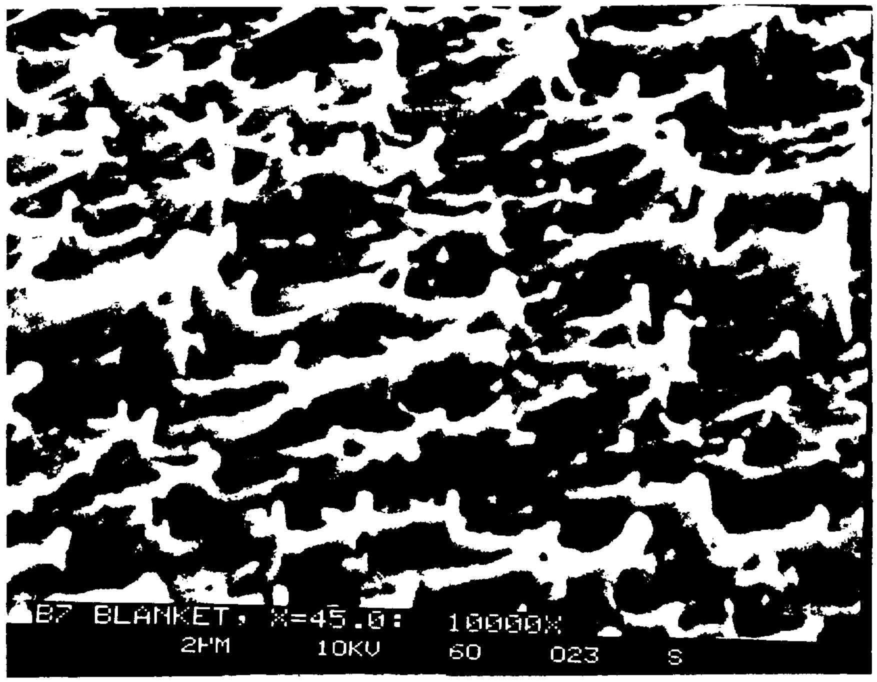

Figure E-25 10000X magnification SEM image of FEP surface 45.0 mm from the edge of blanket B7.

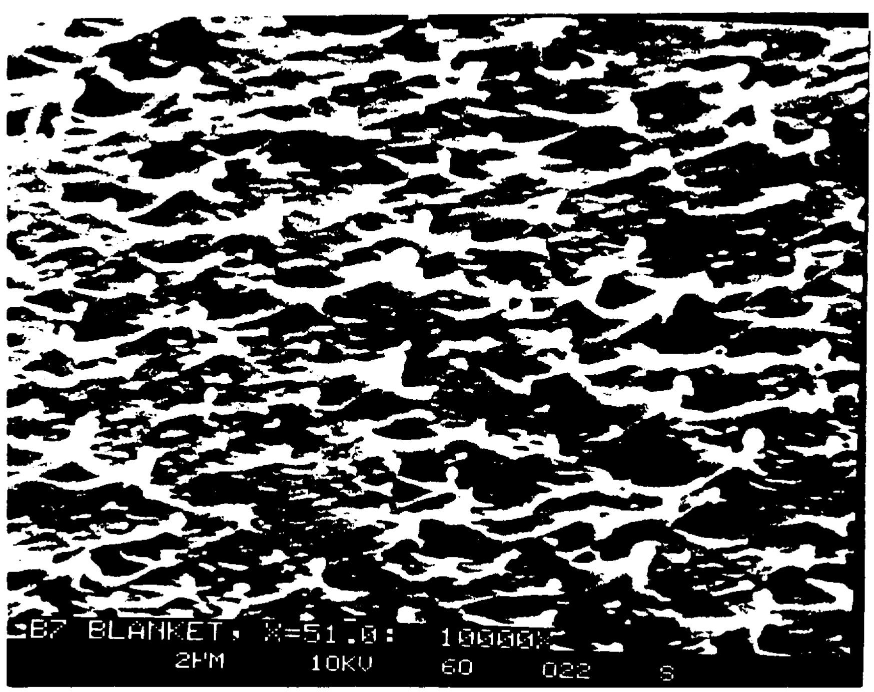

Figure E-26 10000X magnification SEM image of FEP surface 51.0 mm from the edge of blanket B7.

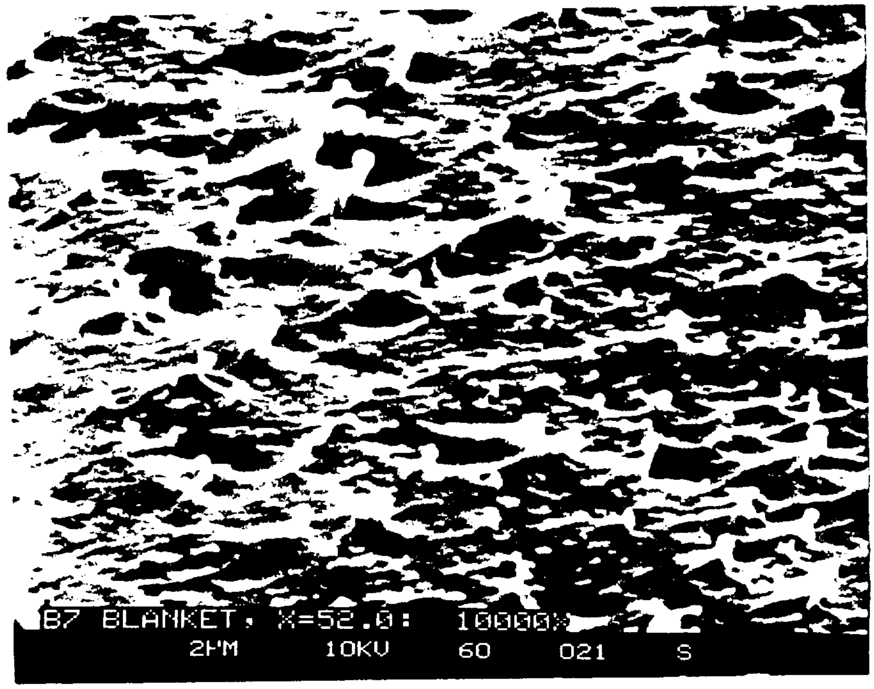

Figure E-27 10000X magnification SEM image of FEP surface 52.0 mm from the edge of blanket B7.

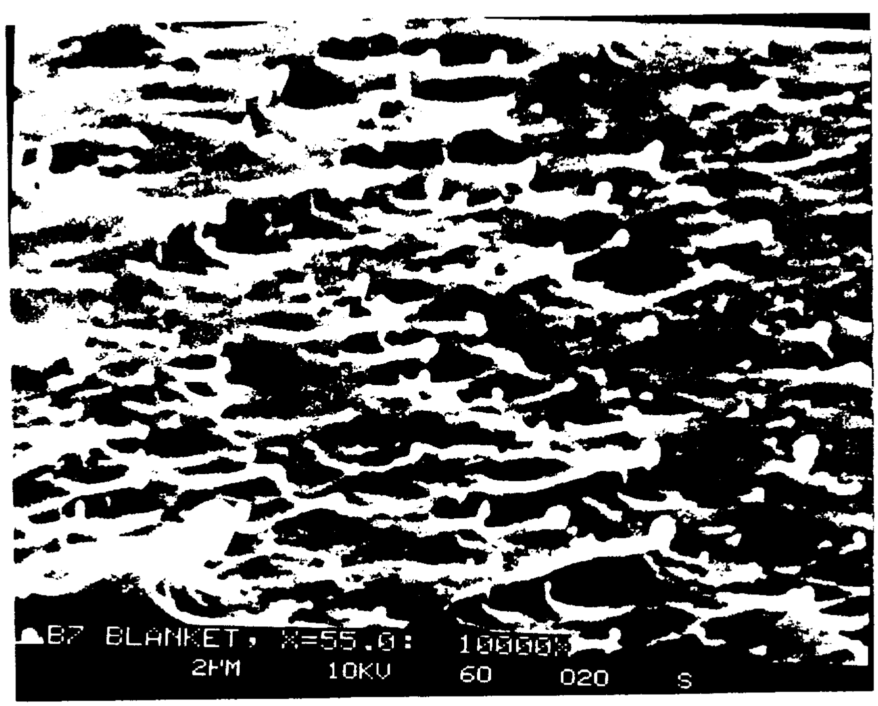

Figure E-28 10000X magnification SEM image of FEP surface 55.0 mm from the edge of blanket B7.

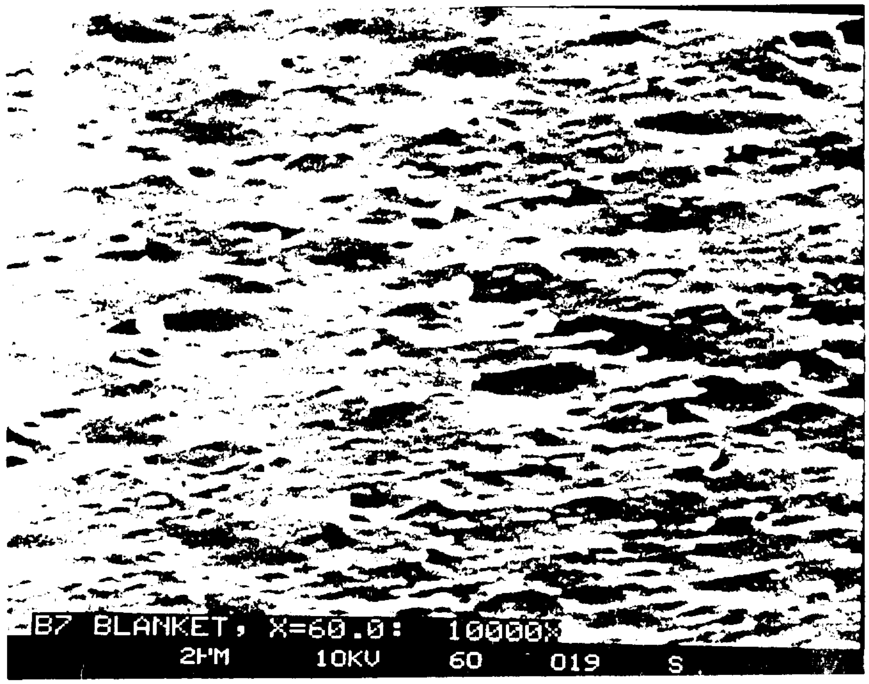

Figure E-29 10000X magnification SEM image of FEP surface 60.0 mm from the edge of blanket B7.

Figure E-30 10000X magnification SEM image of FEP surface 80.0 mm from the edge of blanket B7.

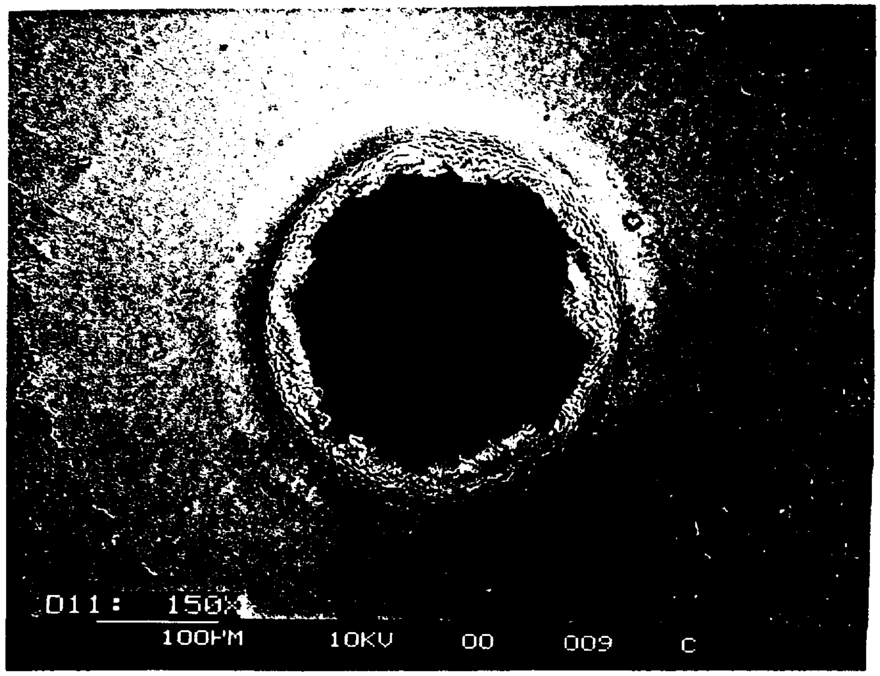

Figure E-31 150X SEM image of impact crater on FEP material from blanket D11.

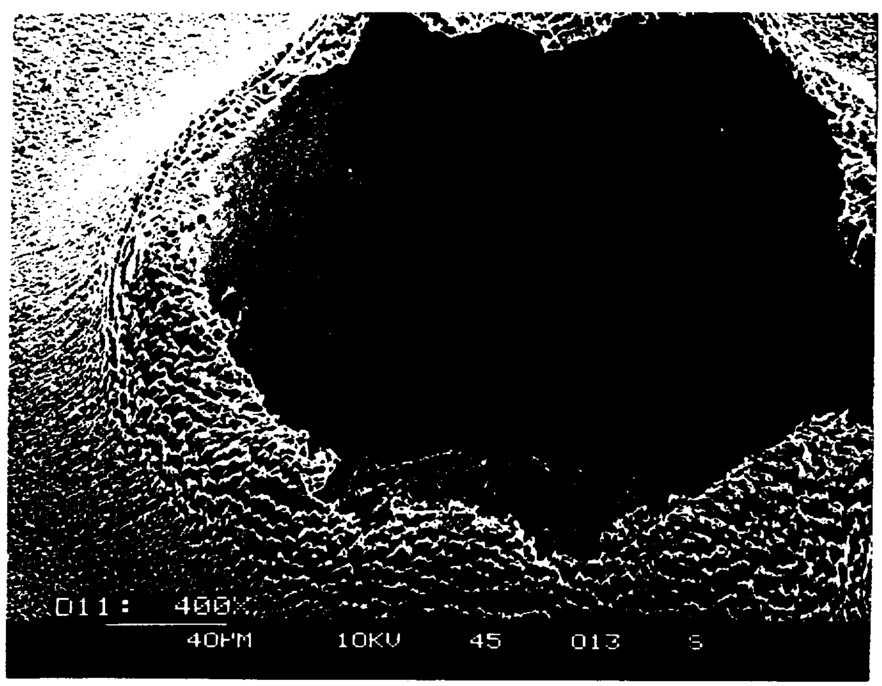

Figure E-32 400X SEM image of impact crater on FEP material from blanket D11.

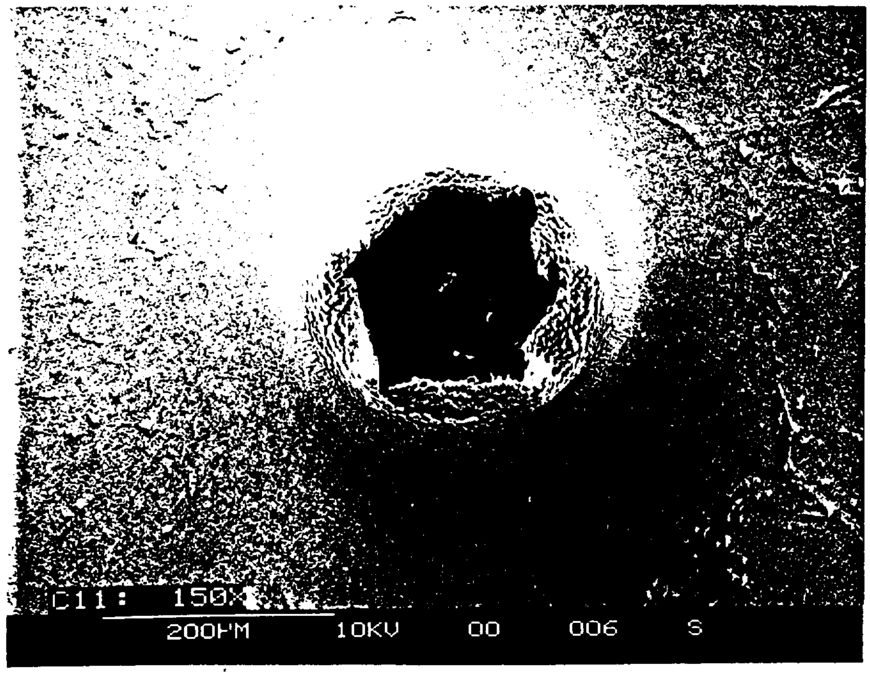

Figure E-33 150X SEM image of impact crater on FEP material from blanket C11.

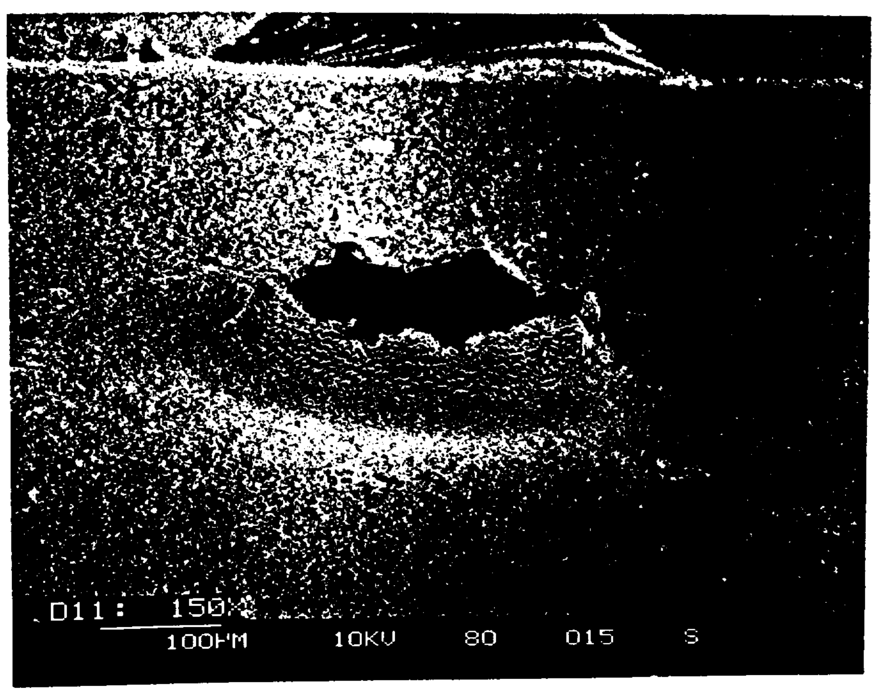

Figure E-34 150X SEM image of impact crater on FEP material from blanket D11, viewed from 10° above the blanket surface.

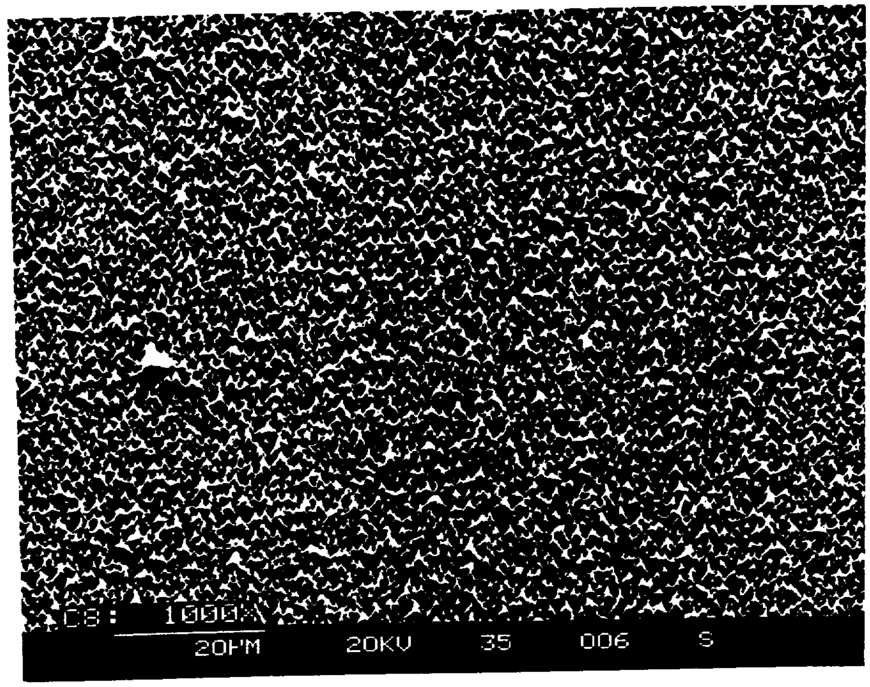

Figure E-35 1000X SEM image of exposed region of blanket C8.

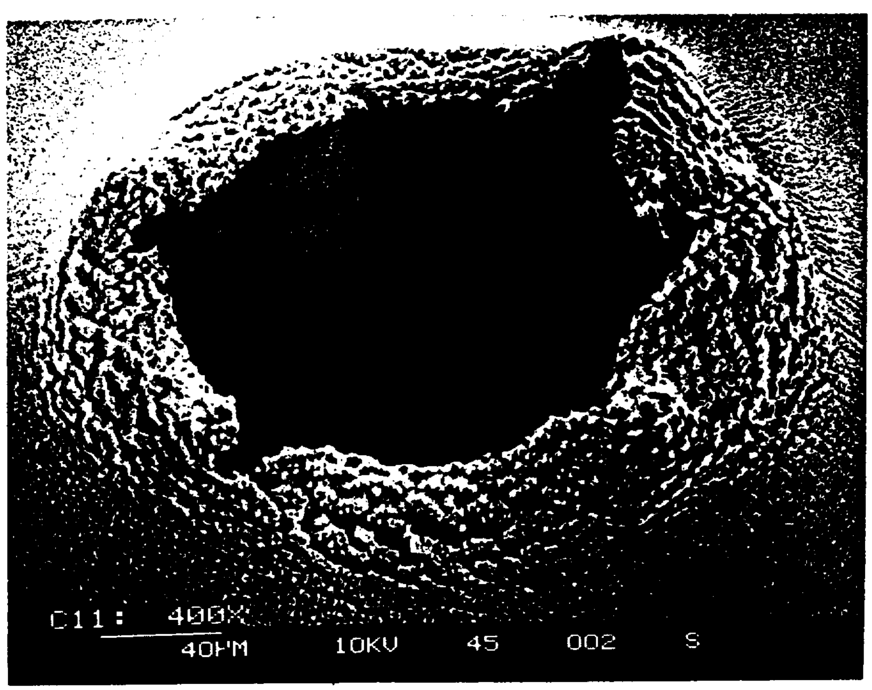

Figure E-36 400X SEM image of impact crater on FEP material from blanket C11.

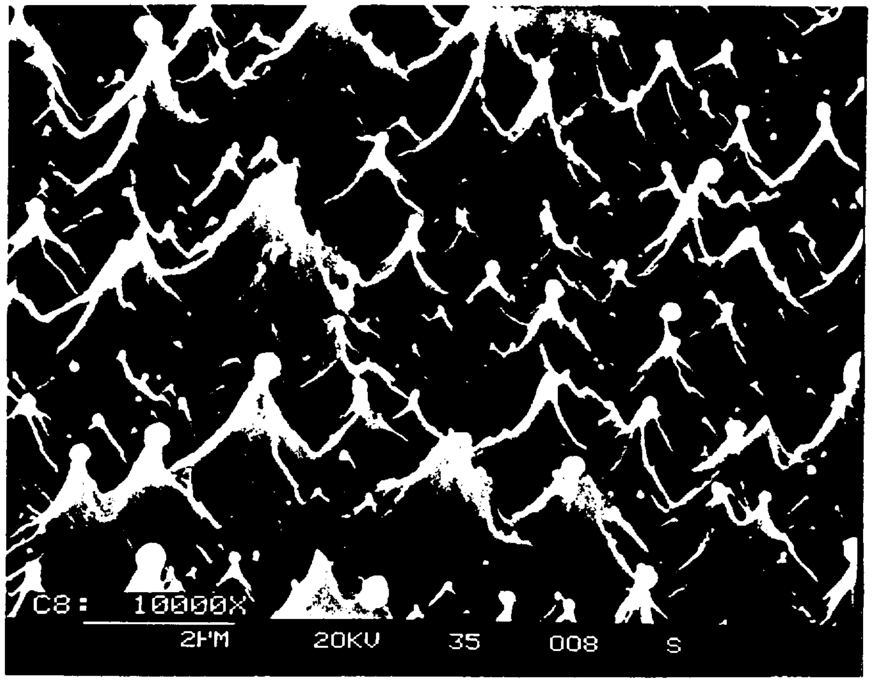

Figure E-37 SEM image of exposed surface of blanket C8 at 10000X.

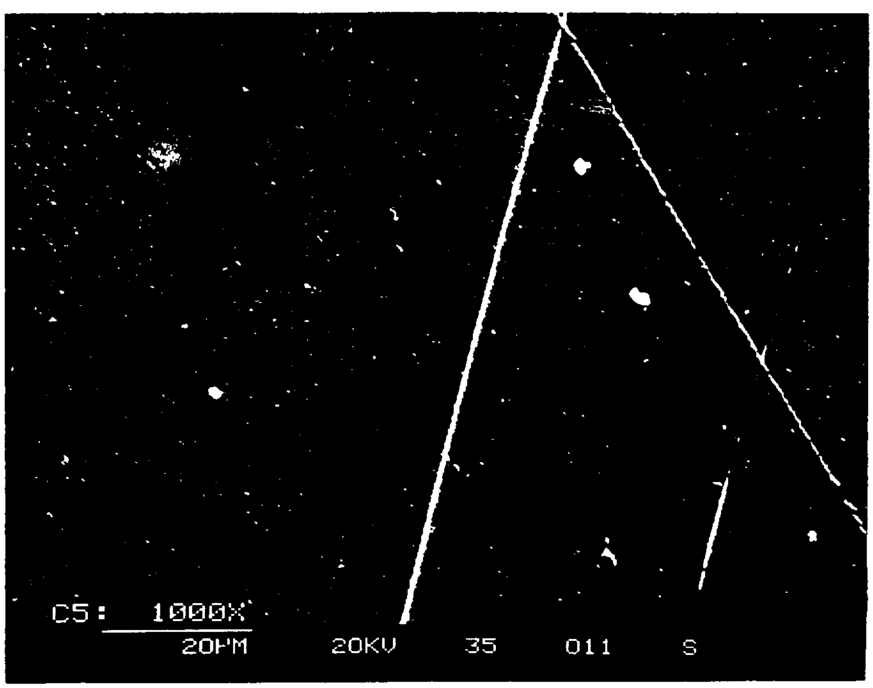

Figure E-38 SEM image of exposed surface of blanket C5 at 1000X showing the lack of surface texturing.

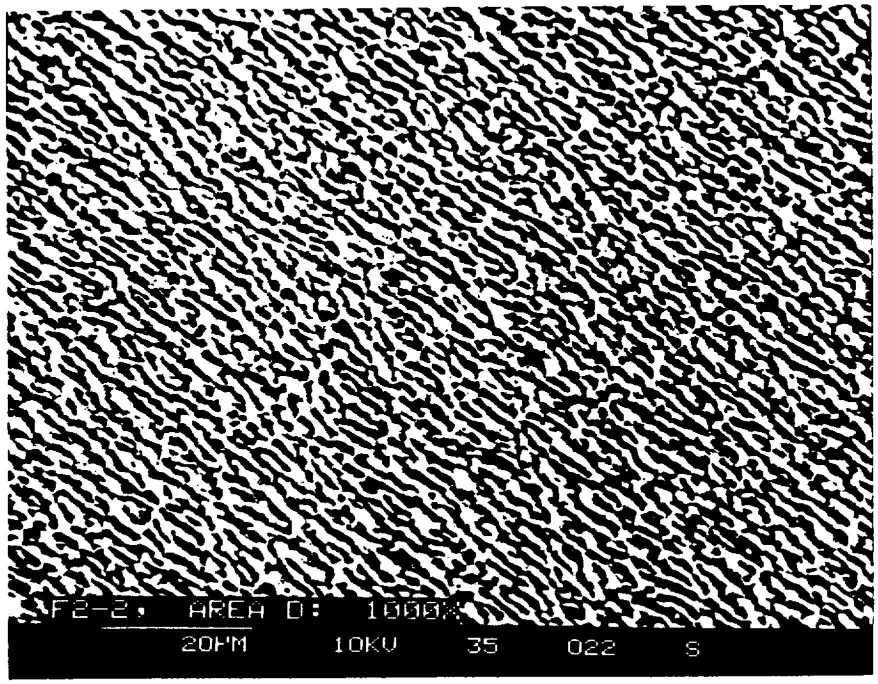

Figure E-39 Exposed area of blanket F2 showing slight texturing.

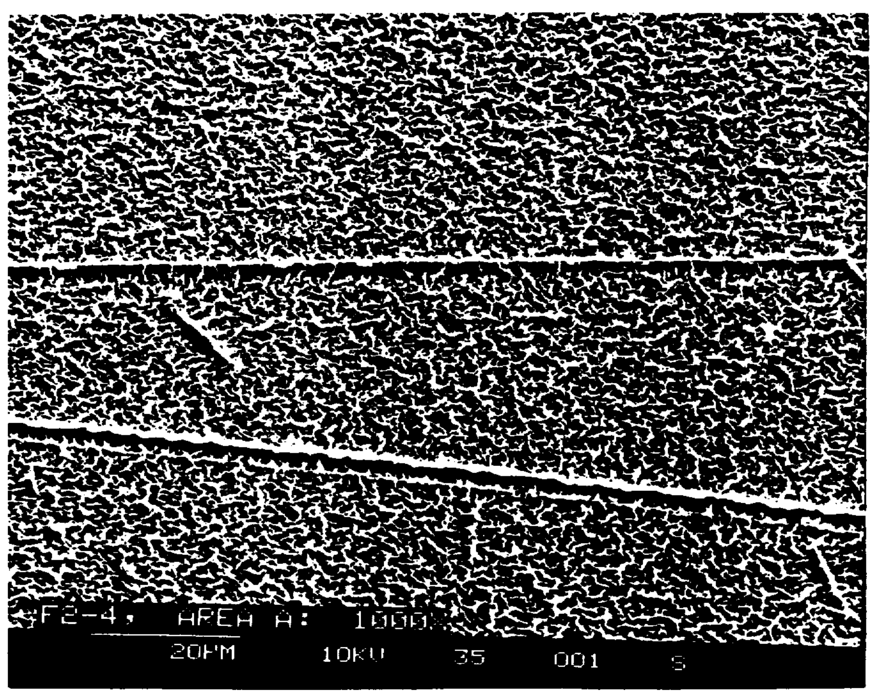

Figure E-40 Exposed area of blanket F2 with distinct morphology. This pattern is associated with areas of high surface silicone contamination.

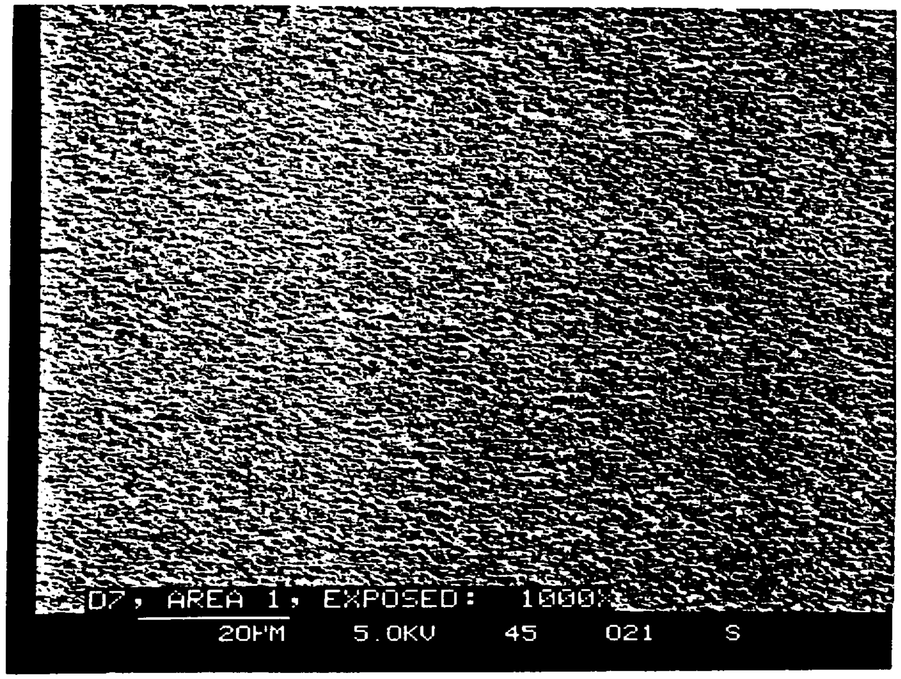

Figure E-41 1000X SEM image of exposed area of blanket D7, showing extreme impingement angle (68° from ram) of atomic oxygen.

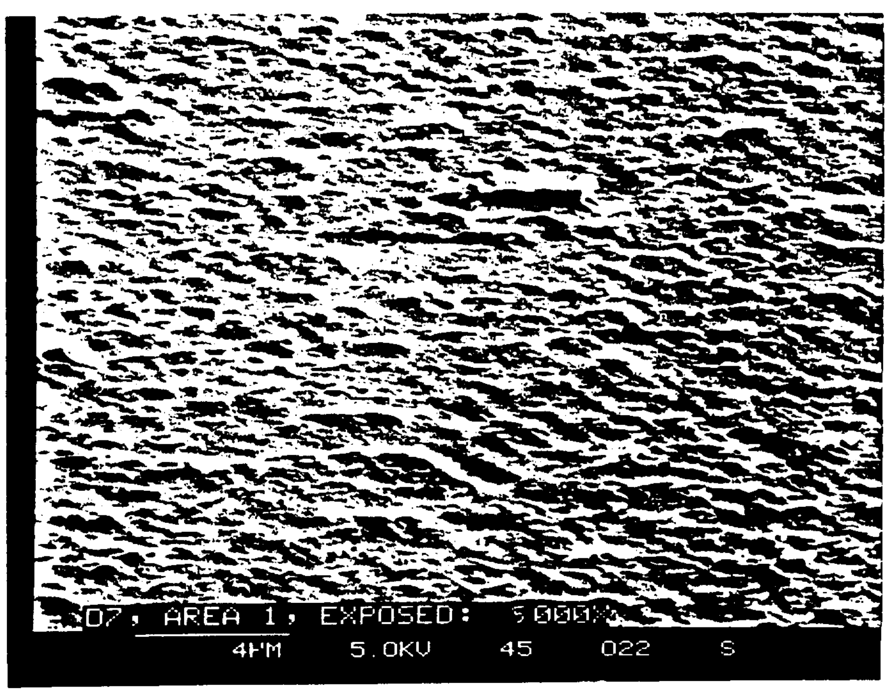

Figure E-42 5000X SEM image of exposed area of blanket D7.

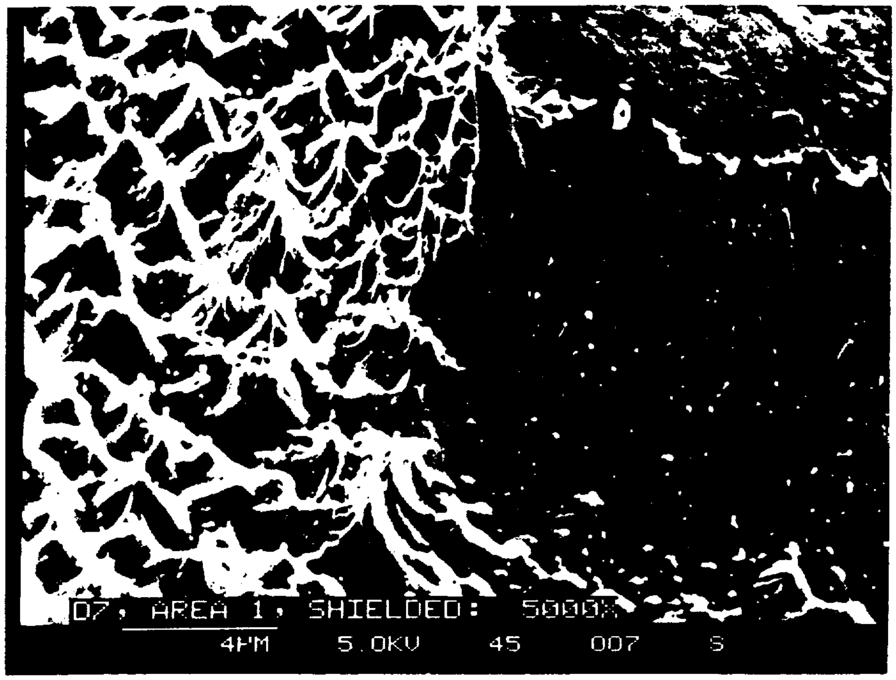

Figure E-43 5000X SEM image of a portion of the D7 blanket used to estimate recession of the FEP layer due to atomic oxygen exposure.

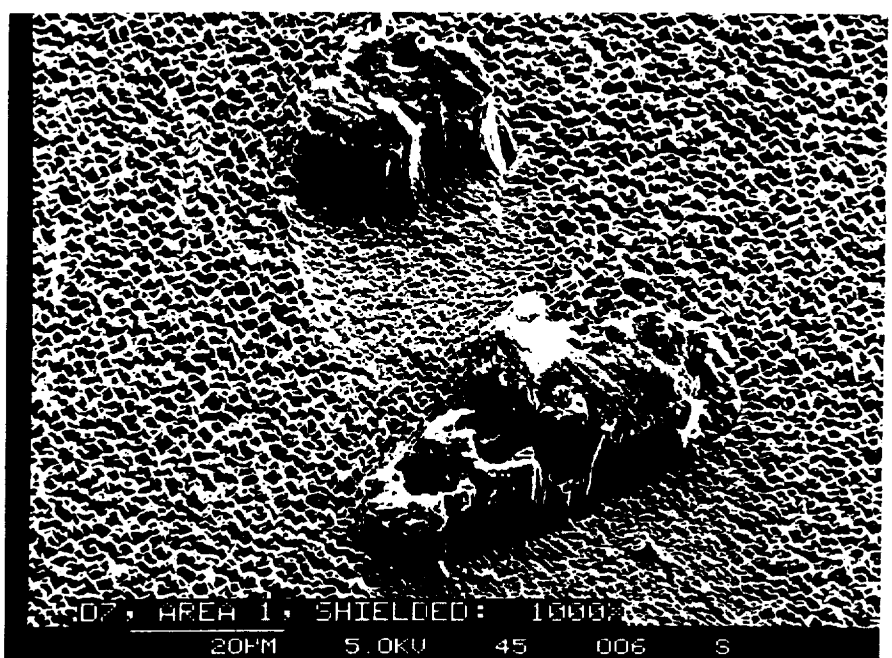

Figure E-44 Close up of area of blanket D7 showing areas protected from atomic oxygen by contaminants, and areas around the protected sites which were eroded.

Figure E-45 Area of blanket D7 fairly well shielded from atomic oxygen, with the central region of the image showing degradation from low levels of atomic oxygen attack.

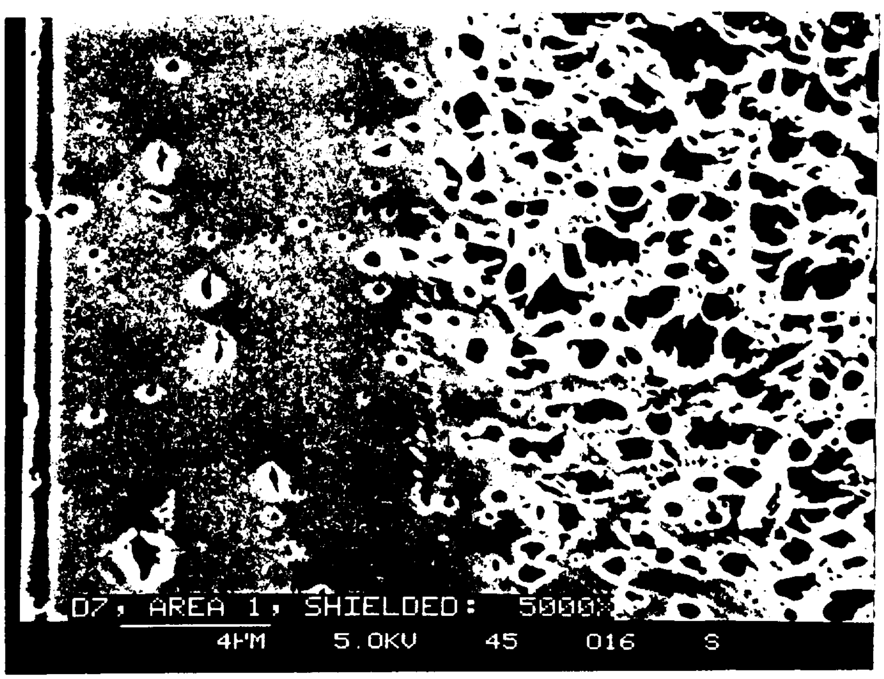

Figure E-46 A 5000X SEM image of the region from D7 shown in the previous figure, with the porous structure of the FEP clearly visible after a low level of atomic oxygen exposure.

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Silver backed teflon (Ag/FEP) material used for thermal control on the Long Duration Exposure Facility (LDEF) has been examined in detail. Optical, mechanical, and chemical properties were characterized for specimens exposed to a variety of space environmental conditions. Recession rates were determined for this material. Samples were obtained from virtually every LDEF location except the Earth-end. Atomic oxygen exposed regions changed from specular to diffusely reflective.

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