FOS STABILITY AFTER SHORT HV OFF

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Abstract

A full 30-minute delay is currently specified after every HV on, even when the HV has only been off for a few minutes, such as in an SAA passage. If this delay could be reduced to 10 minutes, we would potentially gain over 2 hours observation time per day. To study this matter we have searched the FOS engineering data base, but there was little usable data, and it was all at +20°C, with HV offs of 30 minutes or more. Tests were made at SAIC on spare digicons which show acceptable stability at +20°C after 2-3 minutes. These tests also show lack of acceptable stability until 5-30 minutes at 0°C, with a reasonable extrapolation to even longer times at -10°C, the operational temperature. A test at LMSC only confirmed the SAIC measurements at +20°C, at 10 minutes after HV on. It is strongly recommended that further tests be run at -10°C at SAIC.

I. Background

The FOS IDT received an Action Item at the 11/22/88 OV & SV preparedness meeting at GSFC to further study the FOS HV stabilization time, especially after a short off time such as during an SAA passage. Recognizing that the real issue is spectral stability, and that there may be considerations other than HV, we will henceforth refer only to overall stability. The motivation for this work is that if a full 30 min delay is required after SAA offs (5-24 min, averaging 10 min), then there is a severe impact on operations, and a loss of observing efficiency. A reduction of the delay to 10 min, for example, would result in 7x20=140 min extra observing time per day.

What constitutes stability? The answer depends upon the scientific objectives and instrument set-up of an observation. We have generally considered 10 microns as acceptable stability for most problems, although we can easily imagine cases where this degree of instability would seriously affect the scientific usefulness of an observation. As an example, we consider a shift which is linear in time throughout an exposure, and which totals 10μ. This is effectively convolution with a boxcar function, as shown in Figure 1. For a line (emission or absorption) with a gaussian profile, and full width at half maximum (FWHM) of 0.95 diodes (47.5μ), this shift will have neglible effect on both the width, which will be 48.0μ after this smoothing operation and height (or depth) which will change by only 1%. However, it will have a more noticeable effect on wavelength, where the line centroid will be shifted systematically by 5μ. For an unresolved absorption line, detected at 3σ, the error in the position (measured over 10 quarter steps) will be 11.9μ (following Young *et al.*

1979). This is a marginal detection, and so for any secure detection (5σ), the systematic error becomes a significant fraction of the total error. Thus for absorption line observations with moderate S/N data, the equivalent width of lines are not affected by shift of 10μ during an observation, but the absolute wavelengths can be.

For another class of projects, observations of bright emission-line nebulae, to determine spatially resolved emission line profiles and velocities, these wavelength errors can be unacceptable. Even through small apertures, emission line count rates can be very large, and in principle the line centroids can be determined to better than 1μ, based on photon counting statistics alone. (In actual practice, the wavelength scale itself may not be determinable to better than 5μ under the best circumstances.) Assuming that there are no other large sources of wavelength error (which will not be determined until after launch), 10μ shifts become unacceptable. For broad emission lines in quasars, on the other hand, while it may be possible to determine centroids precisely, the uncertainties in interpretation of the wavelength which result from the shape of the line profile can be considerably larger than those resulting from a 10μ shift. Thus the precise definition of an acceptable shift depends on the scientific objective of the observation.

In July of 1984, during FOS thermovac, a specific FOS detector stability test was taken at hot (T= -10°C) and cold (T= -26°C) operating temperatures. Although this test plan tracked the x-position image stability following a long high voltage off period, the results are likely a worse case limit to the high voltage on-off-on stabilization times under discussion in this report. H. Eck (1982) shows that stability time of the digicon image is at its highest value and independent of HV-off time if this time is greater than 5 minutes. Note that Eck's data was taken at room temperature: the GHRS operating temperature.

An analysis of the July 1984 FOS stability test is reported by Lindler and Bohlin (1984). Tables I and II summarize their work by listing the time duration it took the spectral image to move within 10 microns of the original position.

Note that the -26°C stability times are about twice as long as the -10° stability times, and that the stability times are dependent on diode position. The red tube at -26°C takes 29 minutes to stabilize whereas the blue tube takes up to 48 minutes.

An analysis of the direction of motion shows the transient image shift is initially toward the center of the tube and then the image moves outward to the stable position.

Table I
Blue Tube Stability Times (in minutes)

Diodes	1-100	201-300	401-500
-26°C	15	3	48
-10°C	7	11	24

Table II
Red Tube Stability Times (in minutes)

Diodes	101-200	301-400
-26°C	22	29
-10°C	15	14

II. Review of the UCSD data base

In order to determine if there was any useful archived data with HV on after a short interruption, we scanned 65,000 frames of FOS test data, dating back to 1983, with the Don Lindler/GHRS data base management program. This work was useful in itself, clarifying our ideas as to what is needed for an operational FOS DBMS. Some 25 records were identified as having the desired ON - OFF - ON characteristics. Of the 25 frames with possible data, 8 turned out to have useful data, split evenly between the A and B sides. This data all dates from 1983 and one test in June 1984, and is generally the result of anomalous testing. We have apparently become more cautious in using the FOS in recent years.

The relevant numbers are given in Table III:

Table III
X-Shifts from Archived Data

Date & Time	Max off time	Side	X shift,	microns
2/28/83 14:11	7 min	A	-8.3	Note: Accuracy is
3/21/83 22:23	42	A	-9.6	+ or - 3 microns.
3/21/83 23:36	44	A	0	
3/24/83 3:12	42	B	-5.0	
8/01/83 5:08	35	B	+4	
8/05/83 6:18	32	B	-6	
6/18/84 22:36	29	A	0	
6/23/84 3:38	27	B	+7.6	

While there was not nearly enough data, and a ground test was deemed necessary, the results were encouraging; we saw no large numbers like the 40 micron shift seen in the first 30 minutes after a long off. There was no information as to exactly when the HV off and on occurred relative to the two measurements that we used to calculate the shifts shown above. In addition, apparently (there were generally no SHPs available) all of these data were taken at ambient temperature, at 18 to 20°C. Other testing shows that there is a large temperature effect on re-stabilization times.

Our engineering data base does not contain the data that are needed to characterize the image drift in the FOS digicons immediately following short periods during which the HV is off. During the digicon alignment in the FOS, the detector HV was turned on and off repeatedly, sometimes with relatively short off periods (focus tweaks), but the data obtained after these periods does not appear to be particularly useful for image drift determination, and we were generally 'smart' enough to wait for some time after bringing the voltage back up before taking the data. It was suspected, however, that the required stabilization period is not strongly dependent on the length of time that the HV is off.

III. Stability Measurements on Spare Digicons at SAIC

In January 1989, during other scheduled testing at EVSD/SAIC, and with Project approval, we tested the FOS spare F1 Digicon, a red-sensitive detector which has been removed from the FOS. These tests consisted of increasing the detector deflection current until a photocathode mask edge lay near one end or the other of the diode array. The tube was allowed to reach electrical, magnetic, and thermal stability, then the position of the edge was measured. Next the HV was turned off for 5 minutes to simulate a SAA passage, and then turned back on over a 3 minute period. Measurements of the edge's position were then taken at intervals of approximately 1.5 minutes, until the edge position approached the pre-turnoff position. These tests were run at 20°C and at 0°C, with 22kV HV. A run at -10°C was missed due to equipment malfunction.

The results are shown in the attached Figures.

Figure 2 shows the recovery of the Left X-Edge at 20°C. The stable position at 12:05 is the right-most trace, with square boxes. The position after the HV was cut and then turned on again after 10 minutes is shown by the left-most trace, with + marks. The digicon recovers to within 10 microns (about 0.34 deflection steps) in 1 minute. There are 14.15 microns per deflection step for this testing. Recall that the detector resolution is 47.5 microns and a recovery to within 10 microns of the original position is thought to be sufficient for most scientific programs.

Figures 3 and 4 document the slow recovery of the same Left edge at 0°C. This process was followed for 20 minutes after an 8 minute off, and in that time recovered to within some 16 microns of the original position. By extrapolating the exponential decay, we predict a recovery to 10 microns in 30 minutes for the 0°C Left Edge. A similar set of measurements on the Right X-Edge at 0°C, not shown here, indicate that recovery to within 10 microns occurs after about 5 minutes.

Figure 5 summarizes the data in a plot of X-Edge position shift in microns versus time that the HV has been back on. For the 0°C data we see an initial position shift of the mask edge of as much as 113 microns on the left and 43 microns on the right. Recovery on the Right and Left sides at 0°C follows similar trends for the first 4 minutes, after which the Left curve flattens, while the Right one steepens. Both of these 0°C recoveries are notably slower than that at 20°C. Indeed the 0°C Left Edge recovery is 30 times slower than at 20°C.

The comparison of the results at 20°C and at 0°C is particularly worrisome, in that they indicate that results at the orbital operating temperature of -10°C may be even worse. However, the displacement is inwards, towards the axis of the tube, on both sides, so that the effects at more normal deflection values, from parts of the photocathode nearer the axis, may well produce smaller displacements and quicker recoveries. The width of the mask is 30 mm or 30,000 microns, and the diode array is 25.6 mm or 25,600 microns long. We have deflected the image of the edge some 2.2 mm or 2200 microns, and are measuring a maximum displacement of 114 microns. We are dealing here with electrons that have stayed close to the tube walls, where field inhomogeneities are the greatest.

To further characterize the transient fields inside the digicon tube after high voltage turn on, we intend to run the digicon electron ray tracing simulation program, "Trajec". This should allow us to analytically predict the transient image behavior throughout our image format at various temperatures.

IV. X and Y Drift Test Program for LMSC Testing

As mentioned, the stabilization time was investigated during FOS thermovac at MMDA in July 1984. This test was limited to investigation of drifts in the X (dispersion) direction. However, drift in the Y direction, and image rotation and magnification changes also will affect photometric accuracy.

The following program, generated by Dr. G. Hartig, monitors the X and Y drifts with about 6 min. temporal resolution:

H27 grating, B2 aperture, Red Side Cal Lamp (for both detectors)
XSTEPS=4, OVRSCAN=5, YSTEPS=5, YRANGE=4, WPL=516, LPF=21
LIV=500, DED=20, INTS=1, PTRNS=1
YBASE=nominal-(307, 179, 51), sequentially. Nominal=984 (red), -917 (blue).
Repeat above three exposures 5 times.
Turn cal lamp off during data dumps (at 4kbps, dumps represent more than half the elapsed time.)
Begin first exposure immediately after HV turn-on.
Perform test after HV off for: at least several hours (cold), 10 min.

The multiple exposures at different YBASEs are required to assure sufficient coverage and resolution in Y, along with the need for good sampling in the X direction and the limited size of FOS science data memory. The test time is about 1.5 hrs/side, and was expected to answer most of our questions. In any case, the questions remaining unanswered by this test would be whether the stabilization behavior is the same at 18kV and in ambient as it is at 22kV in the orbital environment (-10°C).

V. The YSAAOFF Test at LMSC

The YSAAOFF Test was run at LMSC on February 9, 1989 to test the stability of the Digicons after a short HV on-off-on, such as might be encountered in a SAA passage. The test was run as designed, except that there was a built-in 5 minute HV warm-up, of which we were unaware. Data acquisitions took 1 minute, data dumps took 1 minute, and there was an additional 40 sec to dump the SHP. The test was set up with Y-Base = 677 and Y-I = 25.6 microns for the first acquisition, Y-Base = 805 for the second, and Y-Base = 933 for the third. In fact, we encountered the center of the spectrum in the third data acquisition, after some 5 + (2×(1+1+.67)) = 10.34 minutes.

The first usable measurements thus occured only some 10 min after HV was turned back on. As shown in Figure 6, they showed a 2 microns x-shift for bright spectral lines near each end of the diode array, consistant with previous measurements at SAIC. This decreased fairly linearily to 0 microns shift by 40 min after HV on. Y-shift was also found to be some 2.6 microns after 10 min recovery. These measurements were accurate to plus or minus one micron. These LMSC results show only that useful stable data can be acquired 10 minutes after HV is turned back on, at room temperature.

VI. Conclusion

It will be necessary to wait the full 30 minutes anytime after HV is turned on in orbit, even for short HV offs. We must perform future testing to examine the period from 1 to 10 minutes after HV on, where the shifts are much larger in other ambient testing at SAIC. The shifts were much larger at 0°C, some 50 - 80 microns 2 minutes after HV on. We are satisfied that the flight tubes behave like our flight spares, and that further testing should be pursued at SAIC, where we have much more operational flexibility as well as thermal control. The YSAAOFF test should also be perfected, for use on orbit during our SAA testing.

References

Baity, W. November 1988. High Voltage Stabilization Time Studies.

Eck, H. August 24, 1982. Determination of HV-off time on Stability of Digicon Image, BASD Report HRS-DET-092.

Lindler, D. and Bohlin, R. December 1984. High Voltage Settle (FOS Calibration #8) CAL/FOS-010.

UCSD December 1988. FOS Stabilization Time Studies.

Young, P. J., Sargent, W. L., Boksenberg, A., Carswell, R. F, and Whelan, J. A. J., *Ap. J.*, **229**, 891, 1979.

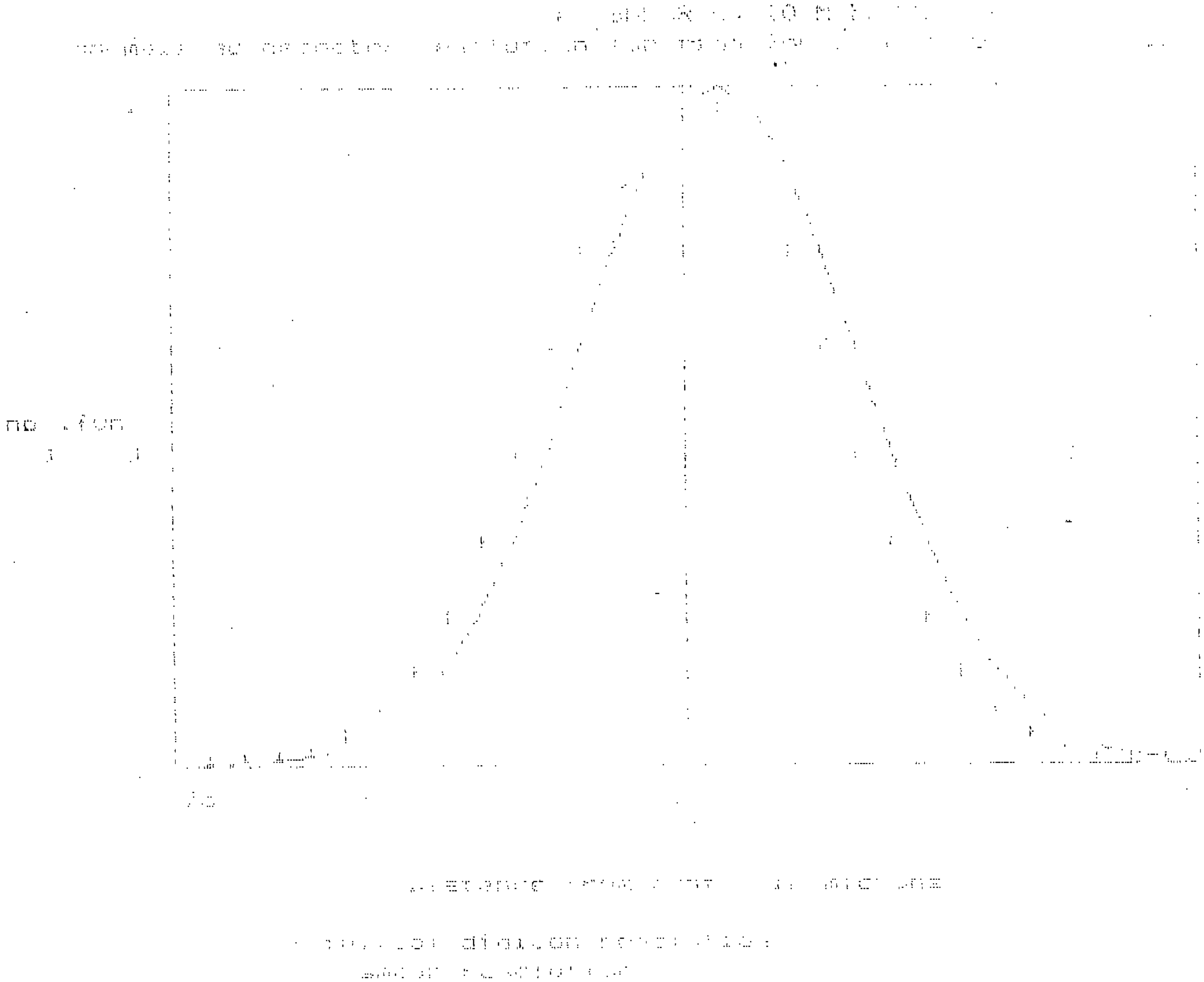


FIGURE 1

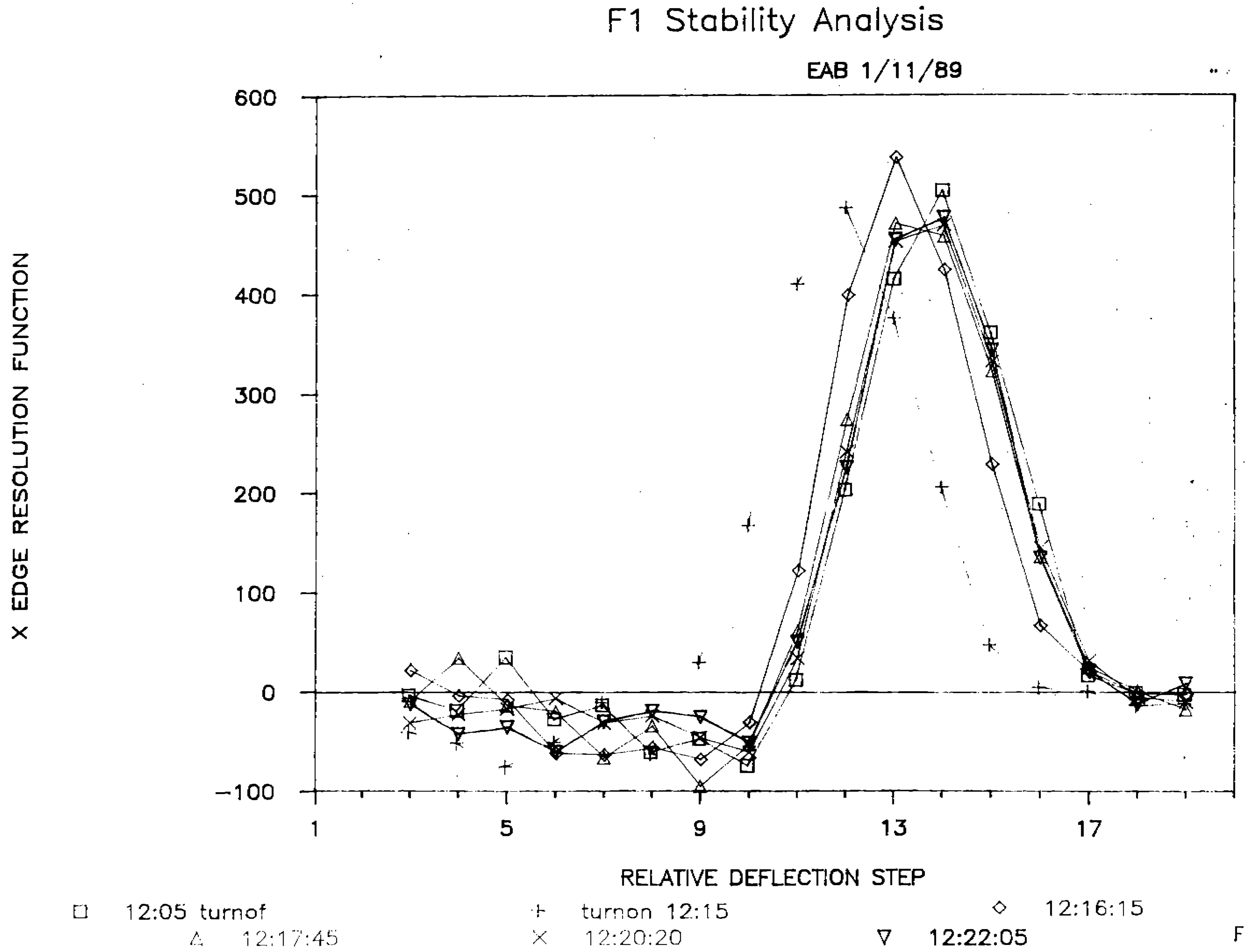

F1 Stability Analysis
EAB 1/11/89
X EDGE RESOLUTION FUNCTION
600
500
400
300
200
100
0
−100
1
5
9
13
17
RELATIVE DEFLECTION STEP
□ 12:05 turnof
+ turnon 12:15
◇ 12:16:15
△ 12:17:45
× 12:20:20
▽ 12:22:05

FIGURE 2

F1 Stability Analysis Oc ON/FF/ON CYCLE

1/13/89 HV OFF FOR 7 MIN. EAB1/25/89

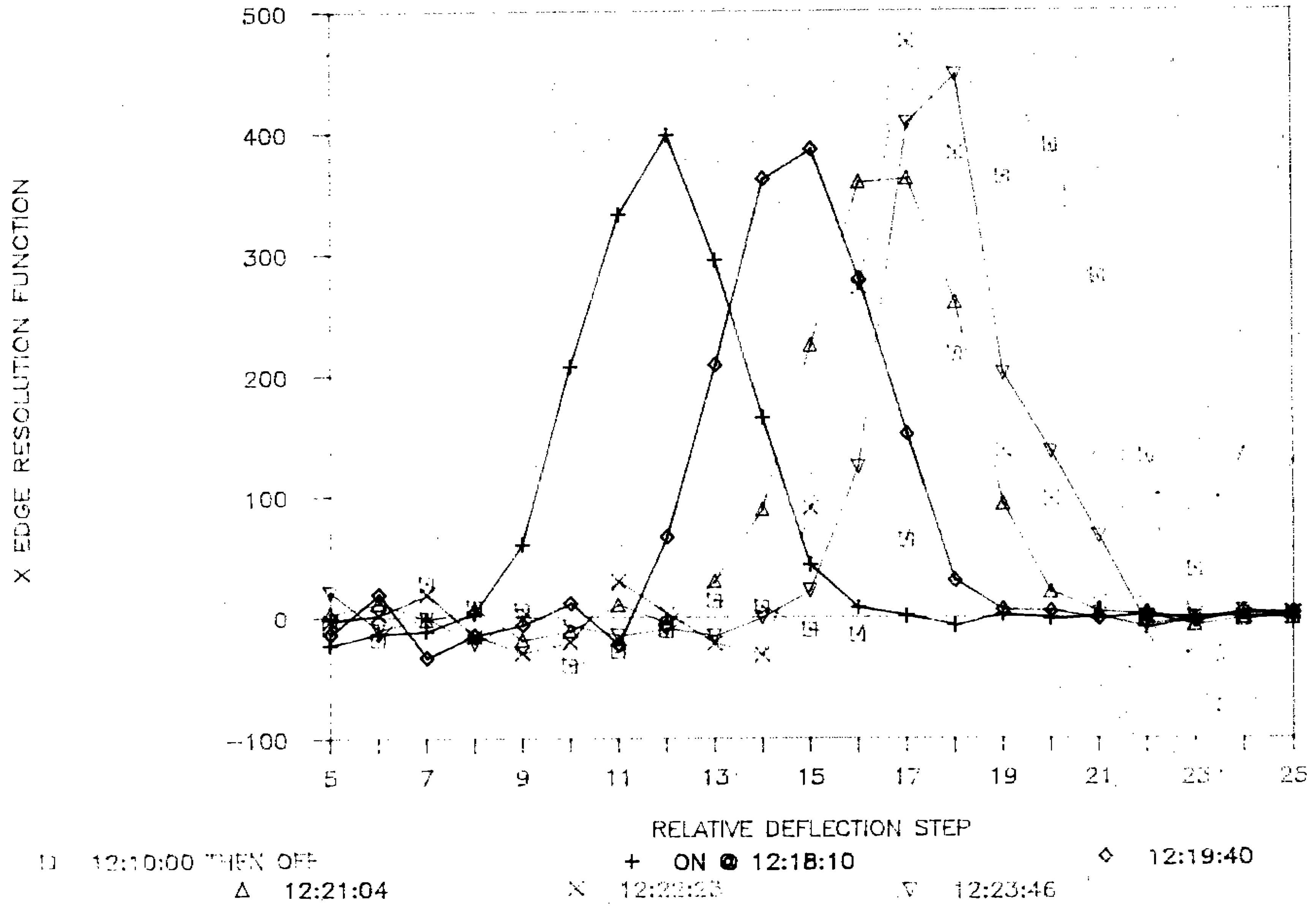
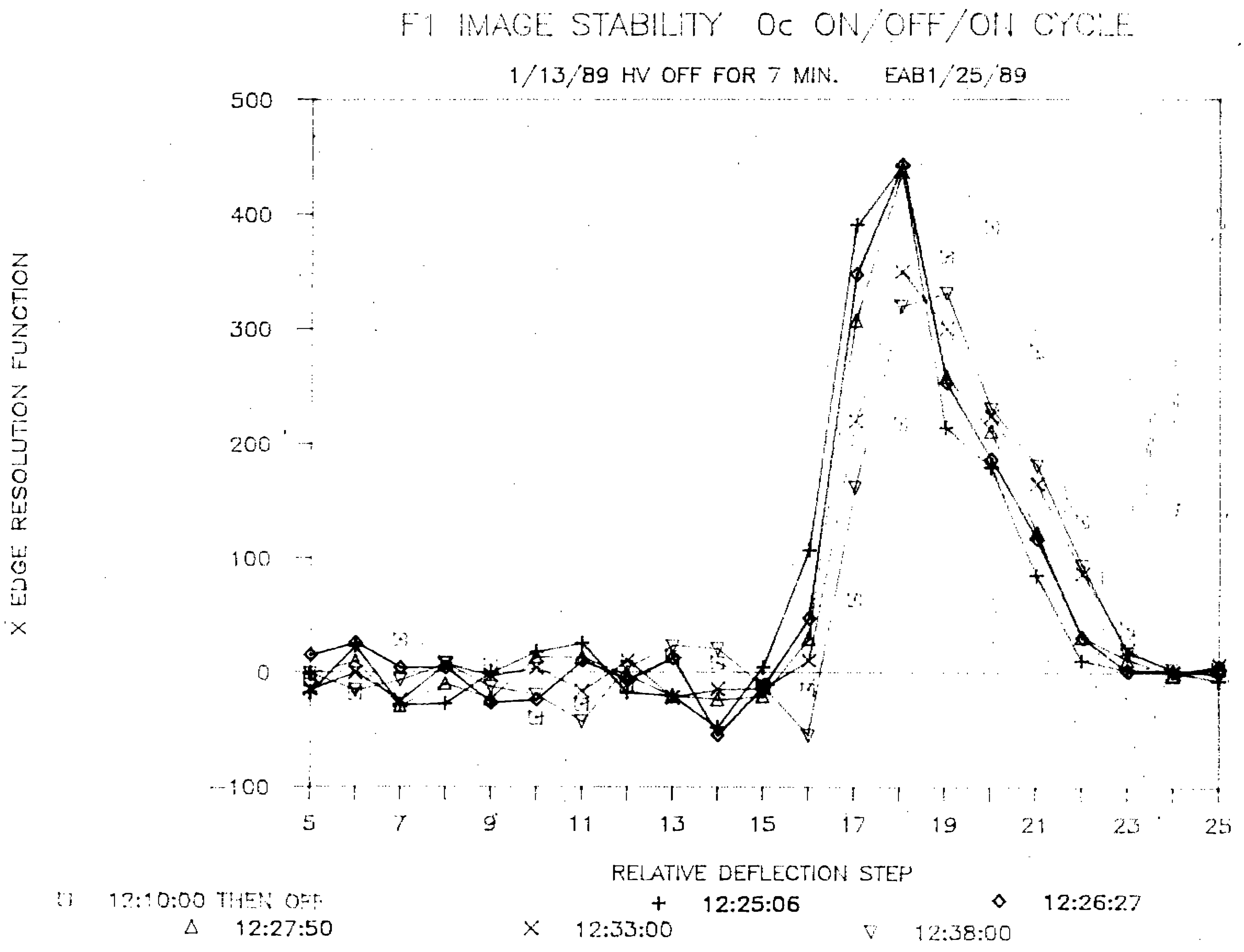


FIGURE 3



F1 IMAGE STABILITY Oc ON/OFF/ON CYCLE

1/13/89 HV OFF FOR 7 MIN. EAB1/25/89

FIGURE 4

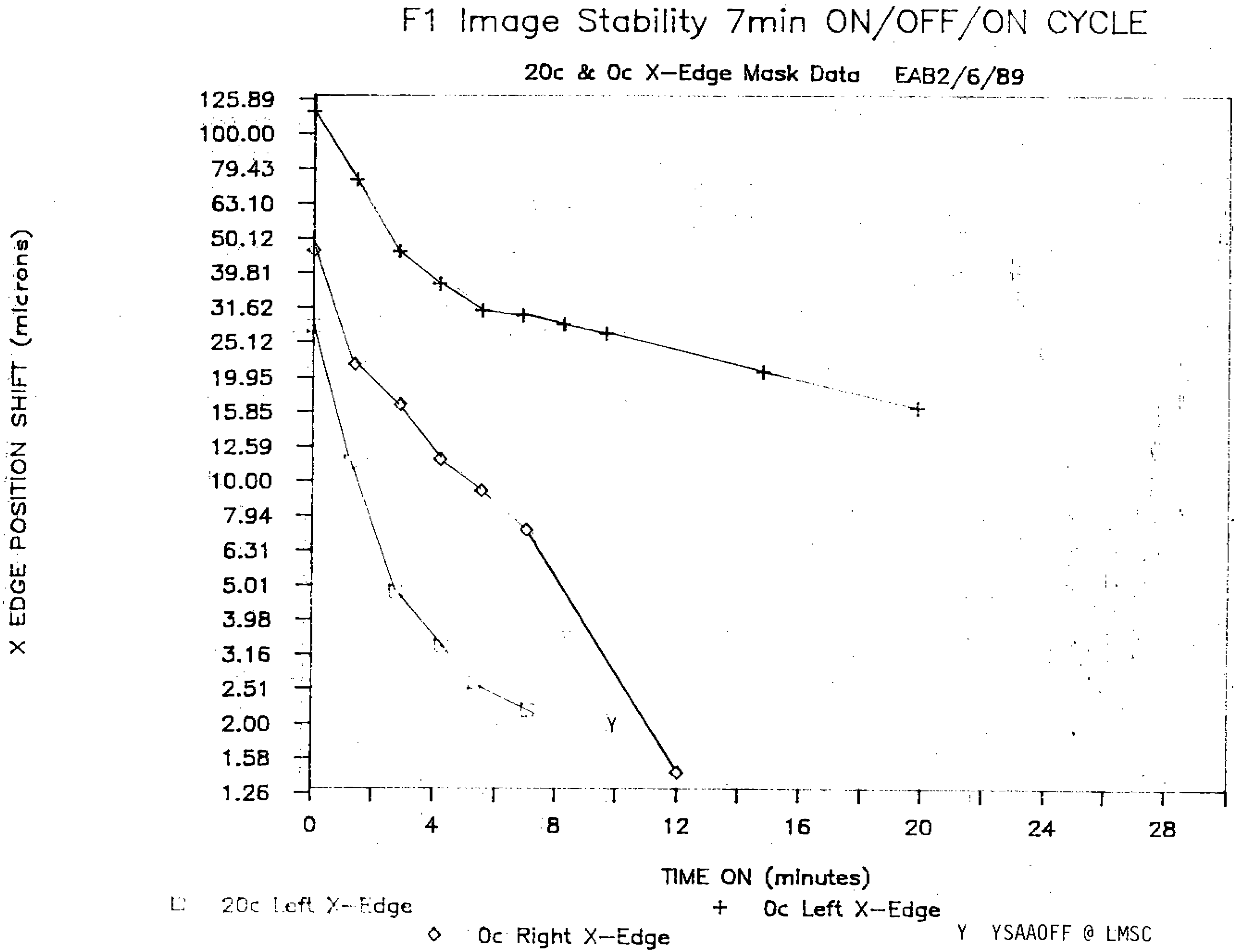

F1 Image Stability 7min ON/OFF/ON CYCLE
20c & 0c X–Edge Mask Data EAB2/6/89
X EDGE POSITION SHIFT (microns)
125.89
100.00
79.43
63.10
50.12
39.81
31.62
25.12
19.95
15.85
12.59
10.00
7.94
6.31
5.01
3.98
3.16
2.51
2.00
1.58
1.26
0
4
8
12
16
20
24
28
TIME ON (minutes)
Y
□ 20c Left X–Edge
+ 0c Left X–Edge
◇ 0c Right X–Edge
Y YSAAOFF @ LMSC

FIGURE 5

RED DETECTOR LOCKHEED STABILITY

50 MICRONS PER DIODE EAB 2/17/89

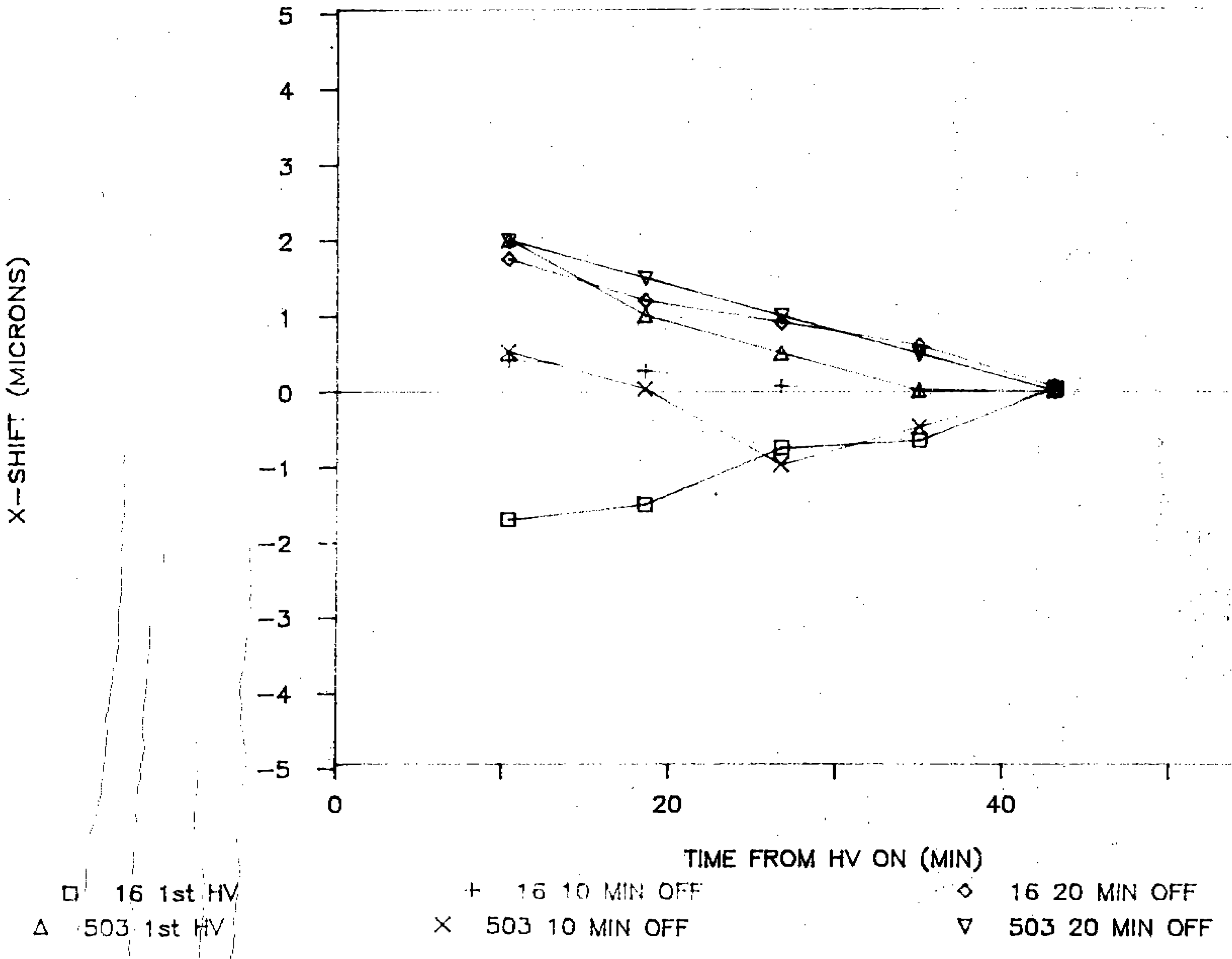


FIGURE 6