This document consists of 42 pages

AUTOMATED VEM SYSTEM
TEST AND EVALUATION

PFA-056

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The Perkin-Elmer Corporation
Optical Technology Division
Danbury, Connecticut

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INTRODUCTION

This PFA report describes the test and evaluation of the Automated VEM System manufactured by the Eikonix Corporation. The test and evaluation was performed by the Perkin-Elmer Corporation's Optical Technology Division by SAFSS request under the auspices of SP-7.

Perkin-Elmer is an extensive user of VEM (visual edge matching), a technique for evaluating photo-optical system performance, and has been using it specifically for evaluating and optimizing the Hexagon Satellite Reconnaissance System. Prior to the development of the Automated VEM System, Perkin-Elmer has used this technique with the manual VEM station. The automated system is a modification of the manual station.

The manual VEM process has major shortcomings: it is repetitive, tedious, and often boring. With an underlying design philosophy of increased speed and reliability, the automated VEM system is an attempt to overcome these shortcomings by modifying an existing VEM station so the operator can locate an edge, align and focus on it, and then direct a minicomputer to characterize and match an edge to a similar characterization of the VEM matrix. Besides the automatic edge match display, the matrix is driven by servos to that match on the matrix allowing the operator to evaluate the match and, if necessary, to record his own choice.

Another purpose of this report is to document the test results and suggest useful modifications -- not only to the present system, but also to future generations of an automated VEM system. This test and evaluation has led to evolutionary changes in both hardware and software. These changes are followed throughout the report as they occur up to the final system test -- a PFA thru-focus exercise.

SUMMARY AND CONCLUSIONS

The test and evaluation of the Automated VEM System conducted both at Perkin-Elmer and the MAA has shown that the Eikonix modification of a standard VEM station has resulted in a viable system analysis tool. The Automated System makes the characterization of edges as found in operational imagery faster and easier than the standard technique. One major drawback in using the automated system with Hexagon imagery, however, is that locating edges of the appropriate size takes longer. The scale of Hexagon imagery when coupled with the relatively large size of the active portion of the diode array makes it time consuming to complete a particular task; however, as operators gain more experience with the system, completion time will be decreased. Despite the fact that the Automated System took longer than the manual system for the 1213-1 Post Flight Analysis, it gave more reliable results.

Planned modifications will make the Automated System a faster and more powerful tool in operational imagery analysis. A focus optimization device will be added so that different operators can use the system and data can be pooled, thereby making the instrument operator independent. Since an objective measure is used for image characterization it will be possible to make inter-camera and perhaps inter-facility comparisons. Finally, a larger interactive computer is to be added to significantly decrease total time needed to complete a specific task from data collection to final analysis.

In conclusion, the Automated VEM System has proven to be an effective tool for the evaluation of photographic image quality. As such it should not be limited to use on the Hexagon program but introduced to photographic system programs with photographic scales equal to or greater than Hexagon.

GENERAL DESCRIPTION, AUTOMATED VEM

The automated VEM system is a manual VEM station that has been modified by adding a Reticon photodiode array, a reticle for sample edge location and a servo motor-driven matrix stage. Prior to operation, a parfocalization process ensures that the microscope and electronic detection system have identical optical path distances. This is necessitated by the use of two focusable occulars: the right-side occular containing the reticle that must be focused, and the left-side compensating occular. (The procedure for parfocalizing the system is documented in the Eikonix Operating Manual.) Once the optical paths are parfocal, the system may have to be calibrated. This entails characterizing each matrix edge element with Eigenvector coefficients, locating the coordinates of each element, and then storing this data in the system minicomputer. The data can be collected once the system is calibrated.

The data collection procedure is straightforward. The edge to be matched is aligned to the reticle and then focused. The edge profile is displayed on the CRT by depressing the Display (DIS) button on the control console causing the image to fall on the array. Focus can be checked electronically during this stage, if necessary. The next step is to scan the edge with the Reticon array by depressing the Scan (SCN) button. The minicomputer calculates the parameters of interest at this point. The next step is to depress the Match (MAT) button, which causes the minicomputer to match the edge to the nearest matrix element.

Finally, the operator has the option of either recording the edge match on tape or scanning the edge again; multiple scans of the same edge are averaged together. Throughout the sequence of operations, the operator is given directions via the control console scratch pad as to what the next operation is. When the Display button is depressed, the scratch pad displays the word Display; when the SCN button is depressed, the display reads Scanning. Upon completion of the scanning the display reads Match? i.e., depress the Match button. After Match is depressed, the display reads Matching and then RECORD; i.e., does the operator wish to record the match on magnetic tape?

HUMAN ENGINEERING ASPECTS

As previously mentioned, the manual VEM process is tedious, mainly because the manual VEM station (Figure 1) is poorly designed from a human engineering standpoint. Since off-the-shelf items were used with only minor modification, the operator must either stand at the station or sit in an uncomfortable position. Either alternative precludes use for extended periods of time. Power supply and control boxes are on either side and beneath the light table necessitating operation with both hands. The matrix control is located away from these boxes, but is only relatively comfortable to use.

Overall, the Eikonix redesign of the existing station (Figure 2) is excellent. The control boxes have been removed and the electronics consolidated in a box located behind the light table; all control functions have been centrally located on the control panel (Figure 3). However, as a result of using servo motors to drive the matrix to a specific row and column, the manual control knobs have been placed above the matrix stage. This location makes it necessary to keep the left arm elevated for extended periods of time during use in the manual mode. This is quite tiring.

If used exclusively in the automatic mode, though, the system is much more comfortable to sit at and operate than its predecessor. The table is a convenient height allowing the operator to place his legs beneath the table while sitting, and view the imagery through the microscope without undue stretching.

With the original reticle, a sample edge was difficult to align. The alignment marks were thick and the edges unsharp. In an attempt to correct the problem a new reticle was fabricated on a much higher resolution system. In so doing, however, the alignment marks and array outline were made too narrow making it difficult to see. In an attempt to strike a balance between the two extremes, a third reticle is presently being fabricated. Focus optimization of the sample microscope is quite critical especially at the sharp end of the matrix. Even after a parfocalization process has been accomplished, it is difficult to achieve best focus with any degree of certainty. This is inherent in the microscope and a scheme is being devised to aid the operator.

Presently, to aid focusing, the edge profile is displayed on a CRT located on the control panel. This profile, composed of the output of each diode, can be used to optimize focus.

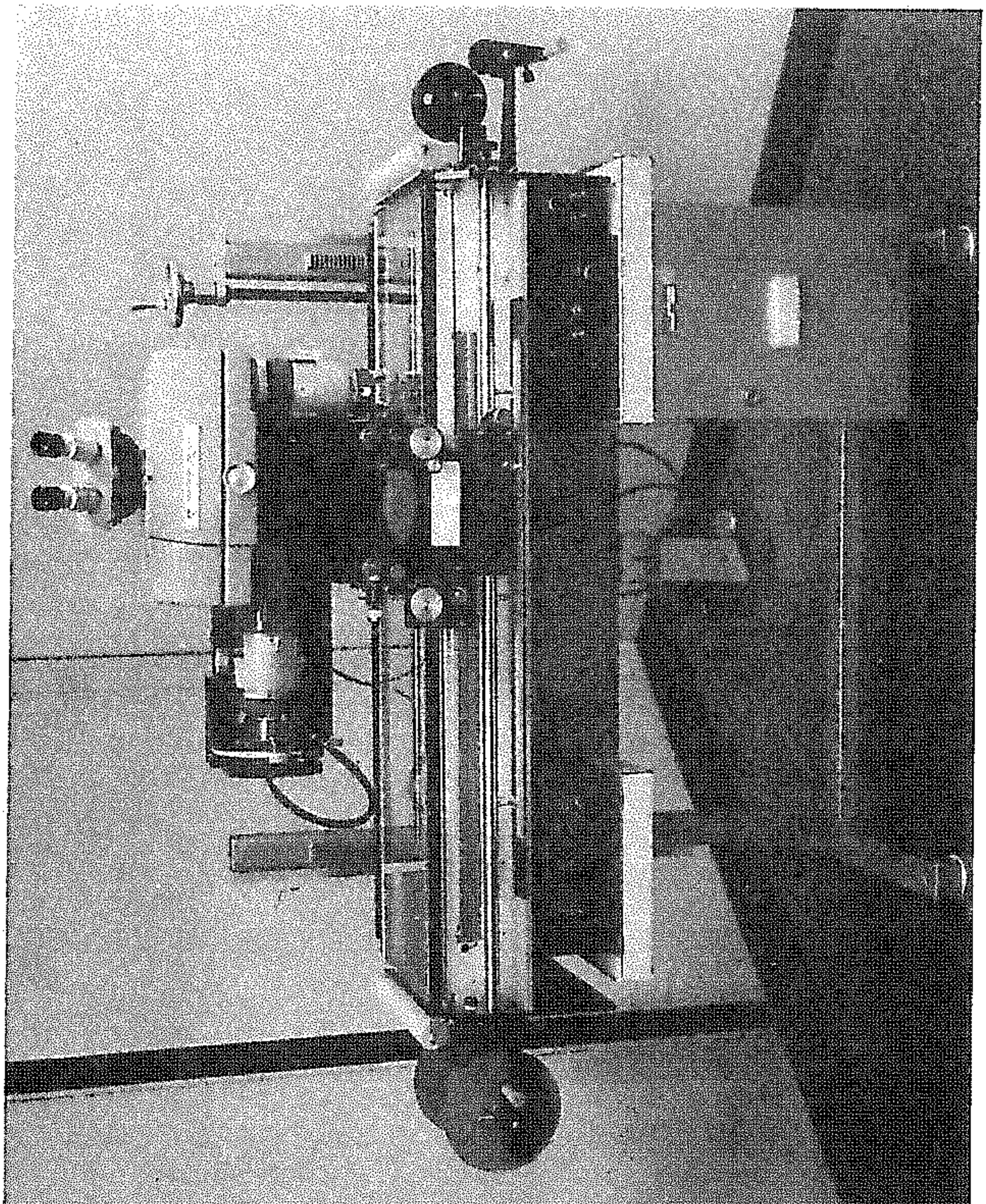

Figure 1. Manual VEM Station

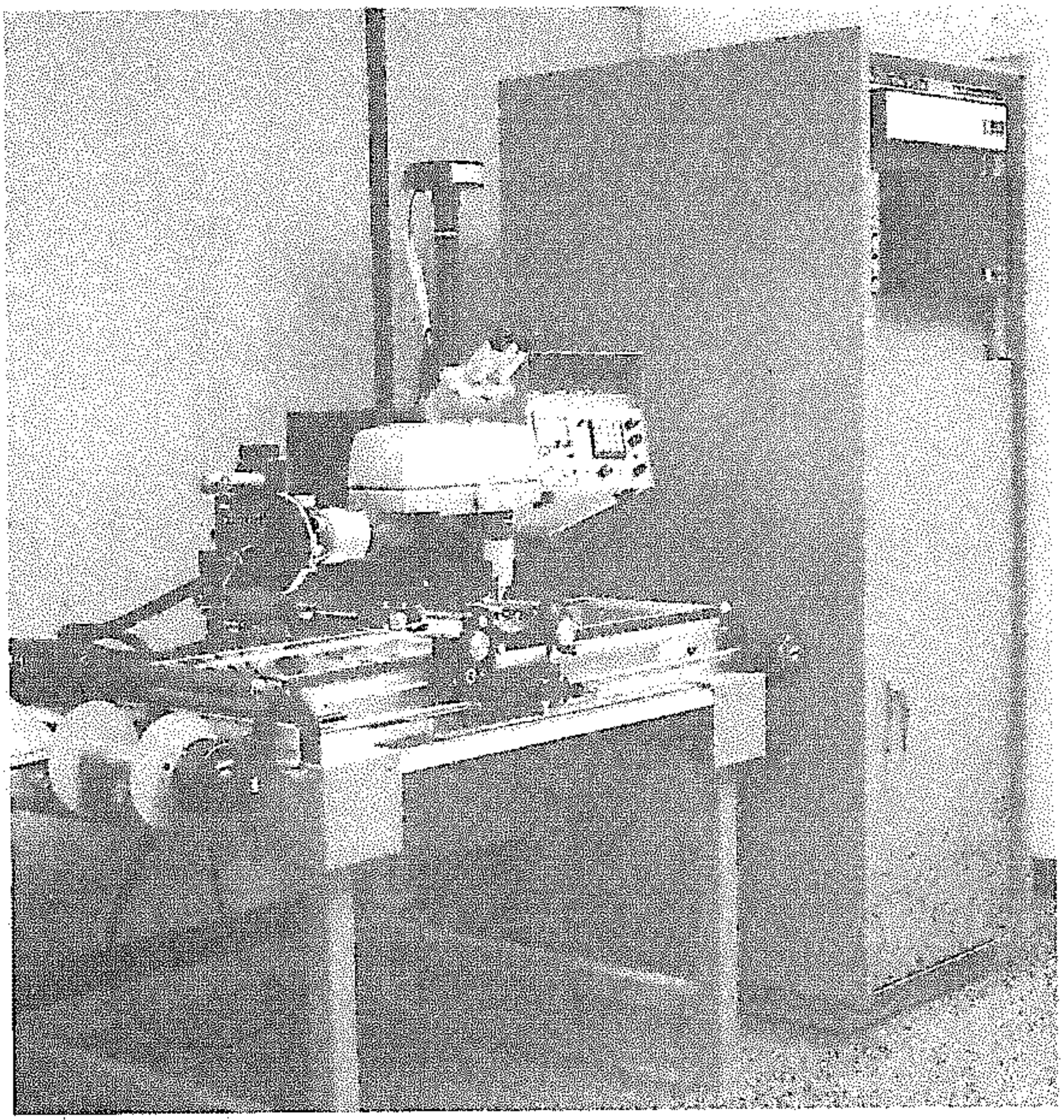

Figure 2. Automated VEM Station

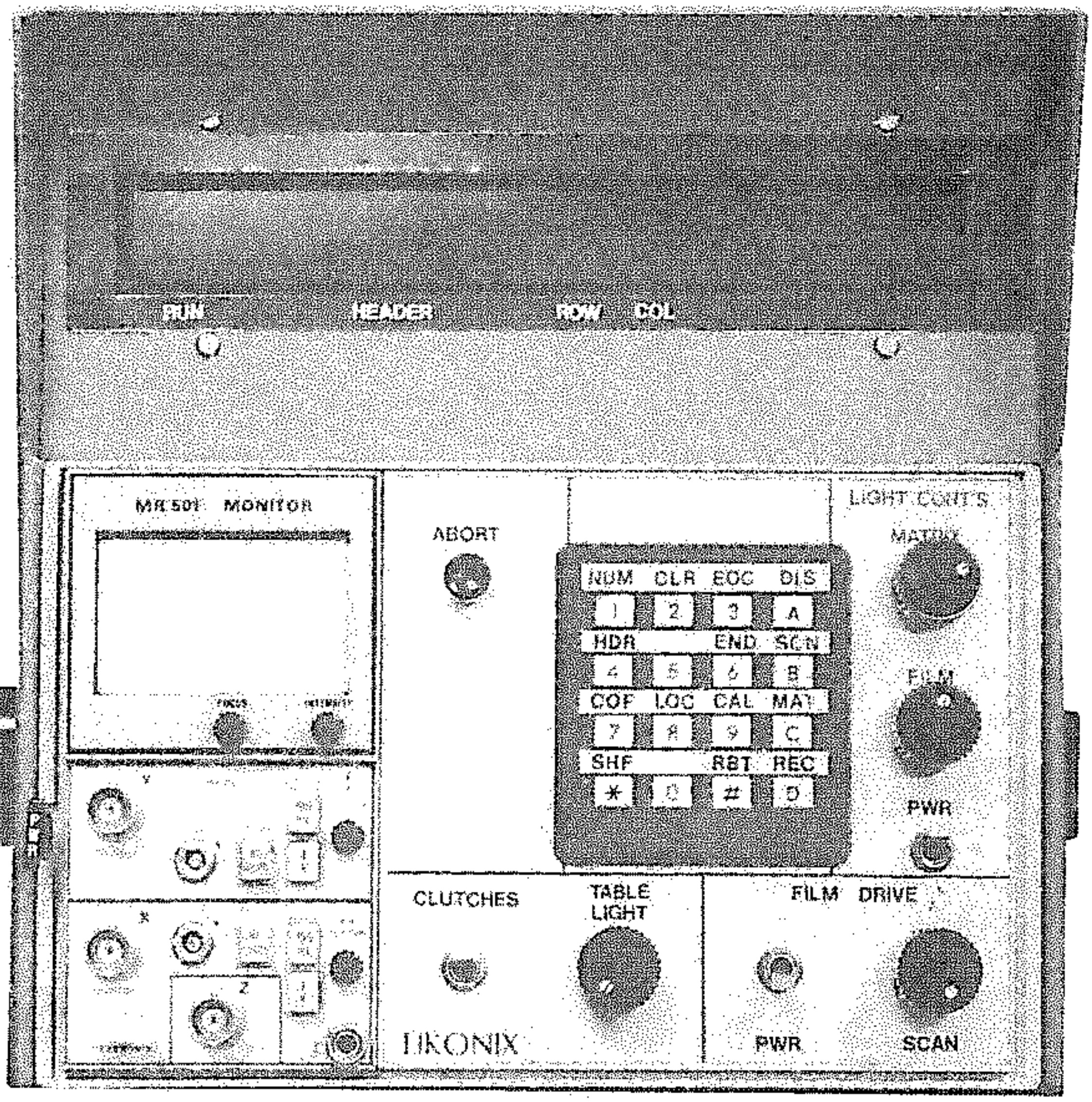

Figure 3. Automated VEM Station Control Panel

On very sharp edges the slope of the trace can be used to indicate "best focus"; better yet is the distance between diodes on the slope. Focus is optimized when the distance between diodes is a maximum. Use of the CRT, however, does not guarantee best focus. Vibration and even the touching of the fine focus knob causes the display to vibrate making it difficult to judge when best focus is attained.

PERFORMANCE EVALUATION

The Automated VEM System was conceived to model the human observer. The requirement was to have the automated system pick both contrast and sharpness within plus or minus one element of a trained observer. Initial evaluation (prior to acceptance) indicated that this is not reasonable because of the subjective nature of the manual match, and the difficulty in determining and modeling the psychophysical process involved. It was therefore decided to test the machine on its ability to determine changes in performance level. Absolute level in terms of edge number is a nebulous quantity, but it can be used in a relative sense to determine when optimum photo-optical performance has been achieved.

For Automated VEM System acceptance, a through-focus operation was evaluated and a plane of best focus determined. The PBF thus chosen was compared to existing manual readings and PBF determination for the same imagery. Although the absolute levels were different, the relative results were the same, proving the validity of the concept of an Automated VEM System.

Test Sequence

To vigorously test the Automated VEM System in the alloted time several tasks were defined. Accuracy and precision in terms of both contrast and sharpness choice were to be determined by matching a matrix to the Automated System's characterization of that matrix. While evaluating the system via the matrix, tests were devised to examine variability of edges within the matrix as well as operator error.

A second test phase consisted of evaluating thru-focus test imagery acquired from Hexagon chamber tests and laboratory bench imagery. Finally, operationally-acquired imagery was evaluated to choose a plane of best focus. At the end of this test sequence the Automated VEM System was shipped to the MAA for use on the 1213-1 Post Flight Analysis.

Test Results

The discussion of the test results of each test performed include: a detailed test description, a report of the test results, and the conclusion drawn. The sequence of test (as previously mentioned) is the matrix, chamber test imagery, laboratory bench imagery and finally operational imagery, which includes Missions 1212 and 1213.

Matrix Tests

Important in evaluating any device is the determination of its accuracy and precision. Since the matrix is used to calculate the Eigenvector coefficients used for comparative purposes, an identity exists for determining accuracy. Assuming that the matrix edge is invariant along its length, which will be shown is not the case, the automated edge match system should choose the input element with some degree of confidence. The matrix was scanned in its entirety five time in approximately the same region of each edge used for calibration purposes. An average edge value was calculated for each matrix element and compared to the matrix; Figure 4 graphically represents the automatic match as a function of matrix element for contrasts 1 and 4, 5 and 6, and 7 and 8. The automated system is not able to discriminate between contrasts 2 and 3 due to their similarity but was able to correctly choose contrast in the former instances virtually 100 percent of the time.

Obviously, the presented data is biased especially at the sharper end of the matrix. The solid line is at 45 degrees and represents perfect correlation. It is observed that the automated system is not able to properly match these edges. It consistently sees them as being less sharp than the stored characterization. There are two possible causes for this disparity. First, the focus, which is very critical at these sharpness levels, was not optimum. Secondly, the possibility that the software used on an IBM 370 to calibrate the automated system is different than that used in the system minicomputer to make the match. The latter was checked at Perkin-Elmer and found to be true. Eikonix was notified of these differences and the software was modified.

Due to time limitations, it was not possible to reconstruct the data shown in Figure 4 with the modified software. However, limited data was collected and satisfactorily showed that this bias no longer existed.

System precision was sampled throughout the useful range of the matrix. Because of time constraints only nine representative elements were checked, and these were independently scanned a total of 25 times each. Table 1 shows the results obtained in

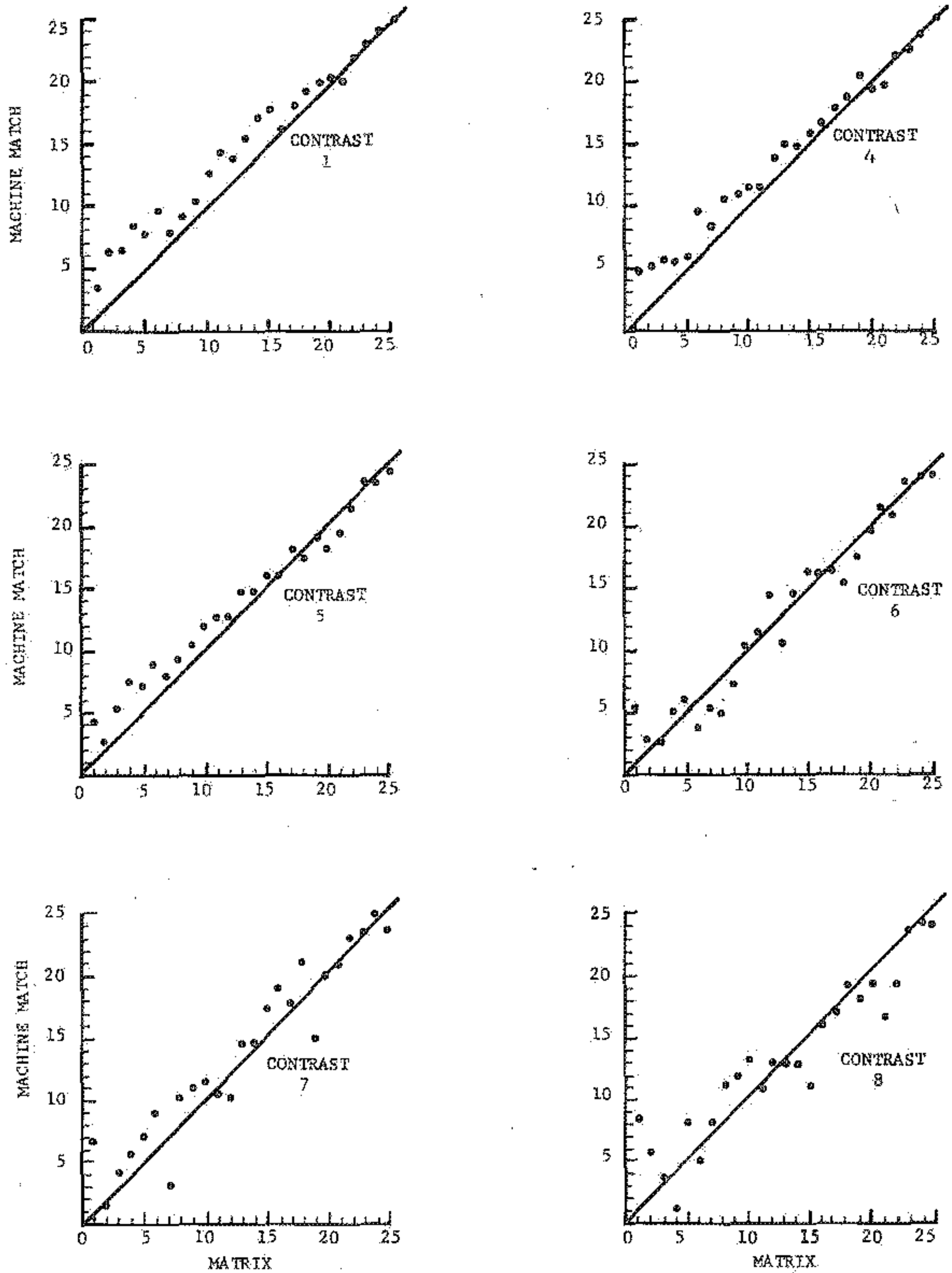

Figure 4. Inscal Matrix No. 2, Self Match (Contrast 1 and 4, 5 and 6, 7 and 8).

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TABLE 1

AUTOMATED VEM SYSTEM PRECISION

Matrix		Automatic Match+	
Contrast	Sharpness	Mean	1 Std. Dev.
1	5	8.64	1.04
	10	12.56	.87
	15	16.64	.70
4	6*	10.08	.76
	10	10.92	.41
	15	15.76	.52
6	5	6.28	.54
	10	10.08	.40
	15	16.20	.41

*Chosen because 4 - 5 had cosmetic defect

+Appropriate contrast always chosen

n = 25

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[redacted]

terms of mean edge number and standard deviation; Figure 5 presents this data graphically. For three sharpness levels, precision in terms of standard deviation is shown as a function of contrast and as a function of sharpness. The conclusion is that precision increases with decreasing contrast (8 being the lowest contrast on the matrix) and increases with decreasing sharpness (25 being the least sharp edge on the matrix).

An attempt was made to identify possible sources of error in the system. The matrix itself was identified as such a source. An edge of fair sharpness at three contrast levels was independently scanned in three locations across the length of the edge. Table 2 gives an indication of scan location and the results of this test. The data shows that for the lower contrast levels (4 and 6) edge sharpness varies along its length; this is not surprising since an observer can see similar though non-quantifiable differences throughout the matrix. Again the lack of time precluded a total evaluation of the matrix, but proves the existence of non-uniform edges. These non-uniformities make it imperative to scan only one portion of the matrix edge when performing a calibration, and equally important to manually match only a single portion of a matrix edge (for instance, the center of each element).

A single portion of these same matrix elements was independently scanned 25 times at three contrasts and the same portion scanned 25 times without changing focus (See Table 3). Note that the means are approximately the same but the variability changes; a general conclusion is that the Automated VEM System maintains focus quite well, the operator is a source of error and that the error appears to increase at the higher contrasts.

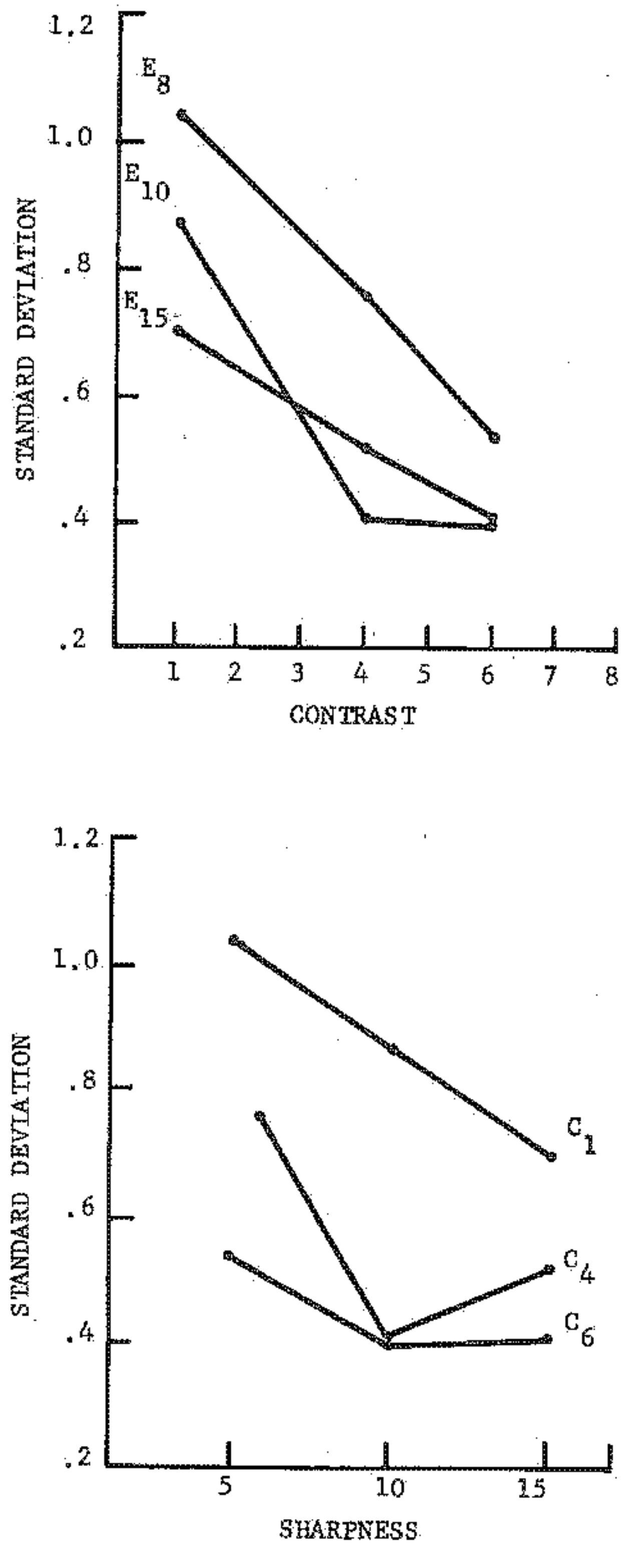
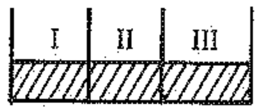


Figure 5. Precision as a Function of Contrast and Sharpness

TABLE 2

MATRIX EDGE VARIABILITY



Contrast	Edge	I	II	III
1	10	12.68(.69)	12.76(.66)	12.92(.76)
4	10	12.24(.44)	10.80(.89)	12.04(.54)
6	10	13.28(.46)	10.72(.46)	12.04(.45)

(   ) 1 Std. Dev.

n + 25

TABLE 3

FOCUS MAINTENANCE

Contrast	Edge	Independent Focus	Constant Focus
1	10	12.92(0.76)	12.40(0.50)
4	10	12.04(0.54)	11.95(0.22)
6	10	12.04(0.45)	11.76(0.44)

( ) 1 Std. Dev.

n = 25

LABORATORY IMAGERY

Upon completion of the matrix tests, laboratory-generated imagery of known quality was evaluated. This imagery is the laboratory bench and chamber test imagery acquired for the SV-12 Flight Readiness test sequence.

The Readiness test material, evaluated first, consisted of two thru-focus runs from the Forward Camera at two exposure levels. Duplicate positives of each of these runs were used and evaluated in terms of manual VEM and automated VEM for the two directions: in-track and cross-track. The purpose of this test was to check the accuracy of the automated VEM system in the determination of Plane of Best Focus (PBF).

To determine a baseline for comparison, the original negative 2:1 contrast tri-bars were evaluated and PBF chosen using quadratic regression analysis. The differently exposed tests are designated Runs 298 and 299. The results of the analyses are shown in Figures 6 through 13.

The thru-focus response for each of these runs are shown in terms of original negative, 2:1 contrast tri-bar resolution, manual Visual Edge Matching and Automated Visual Edge Matching in terms of both edge number and C_2 coefficient. The response shown for each of the diagnostics is similar; and using quadratic regression analysis leads to quite similar PBF determinations (these are summarized in Table 4.) As seen from these results, the automated VEM system is capable of determining the plane of best focus fairly accurately. The only condition under which there is a seemingly high deviation is Run 299 in the cross-track direction using edge number, but the cause is not known. The suspected reason is the degree of noise in the data and a spike at a negative platen position. Since a least-squares fit is used, the choice of PBF is understandably weighted toward this end.

The laboratory bench imagery consisted of a thru-focus array of edges of known contrasts, with the contrasts made to match contrast levels 4 and 7 on the Inscal No. 2 Matrix. Each of three replicate exposures at each platen position was edge matched three times for a total of nine automatic matches per contrast edge per platen position. This data is shown graphically in Figures 14 and 15. Also plotted on the same axes is the resultant data from microdensitometric scans of the same edges reported in edge width.

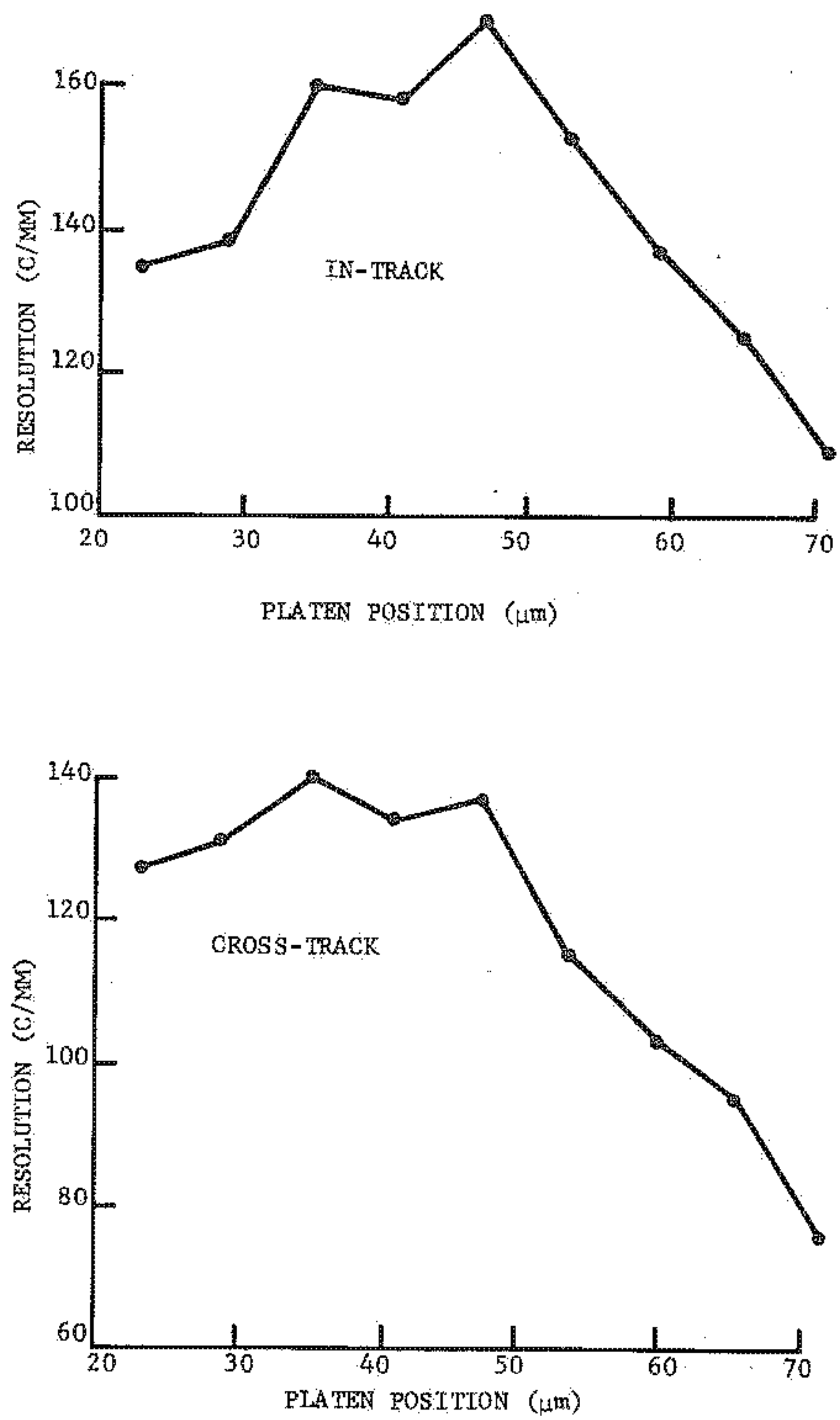


Figure 6. Run 298, Forward Camera, SV-12, Chamber 1A2, O.N. Resolution

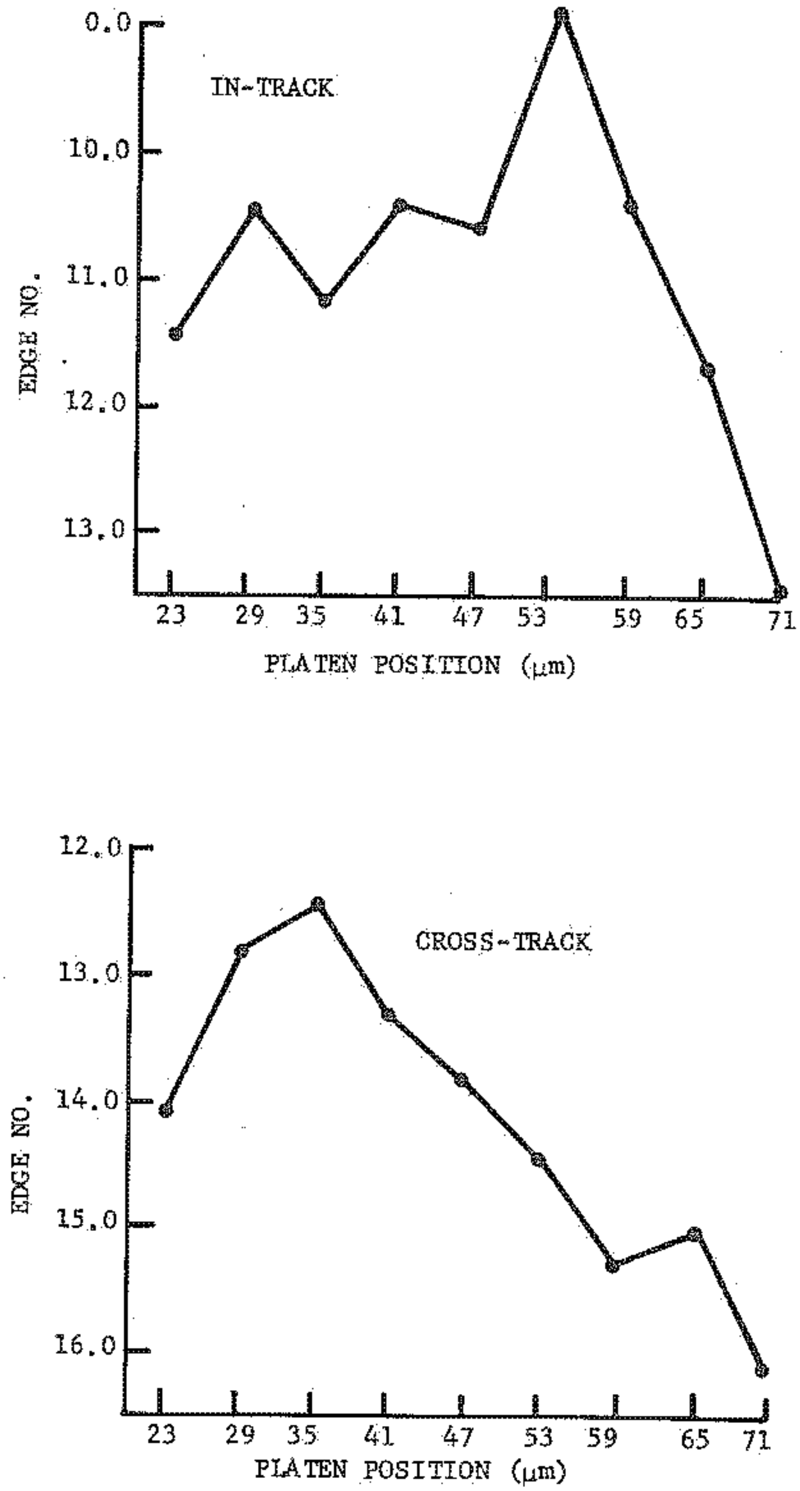
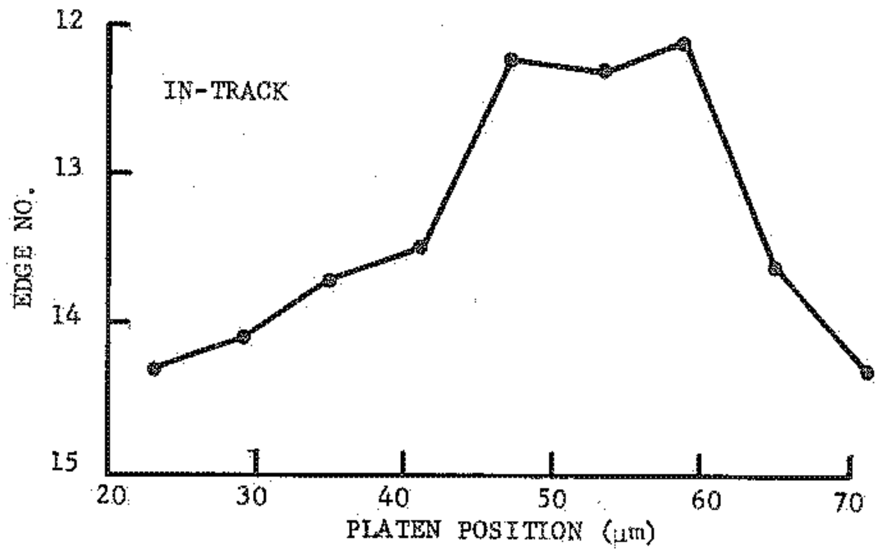


Figure 7. Run 298, Forward Camera, SV-12, Chamber IA2, Manual Edge Match



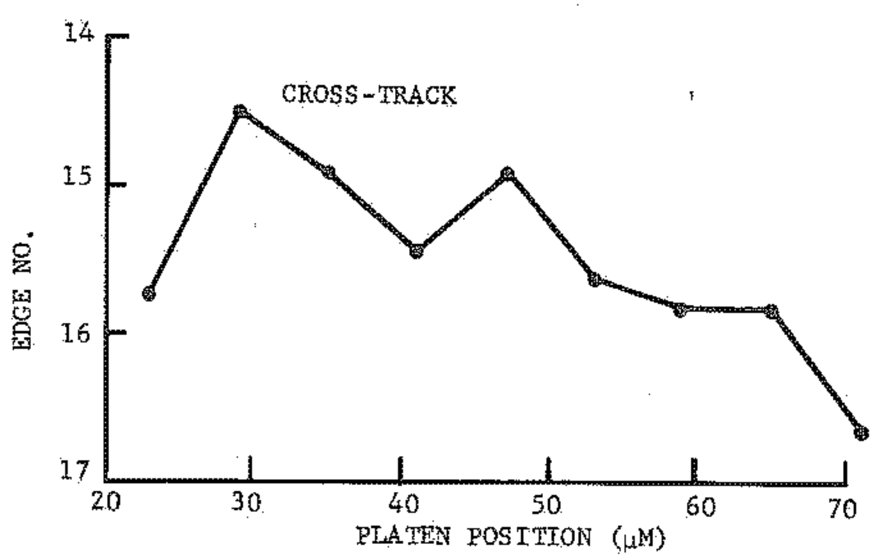


Figure 8. Run 298, Forward Camera, SV-12, Chamber IA2, Automated Edge Match

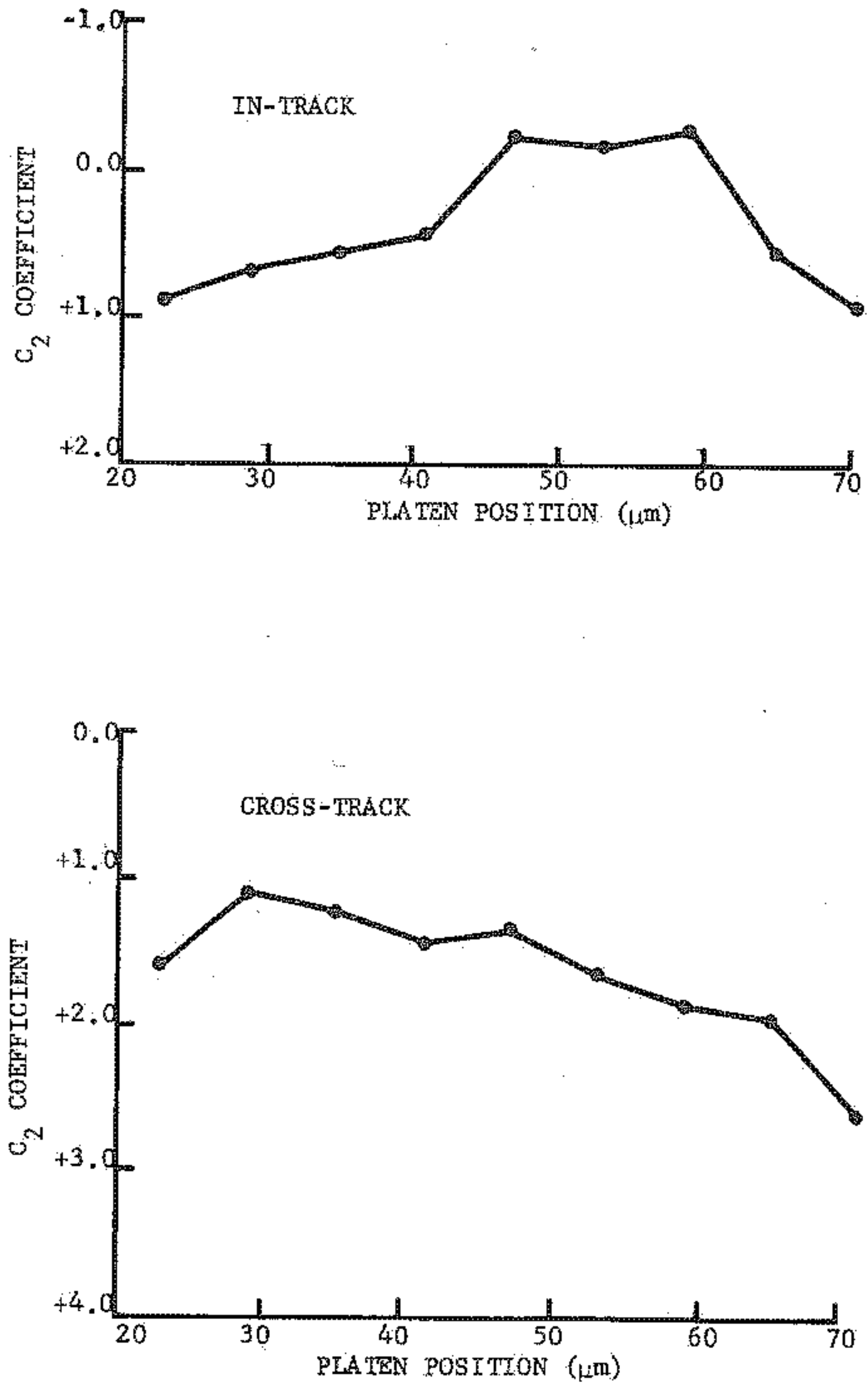


Figure 9. Run 298, Forward Camera, SV-12, Chamber 1A2, C_2 Coefficient

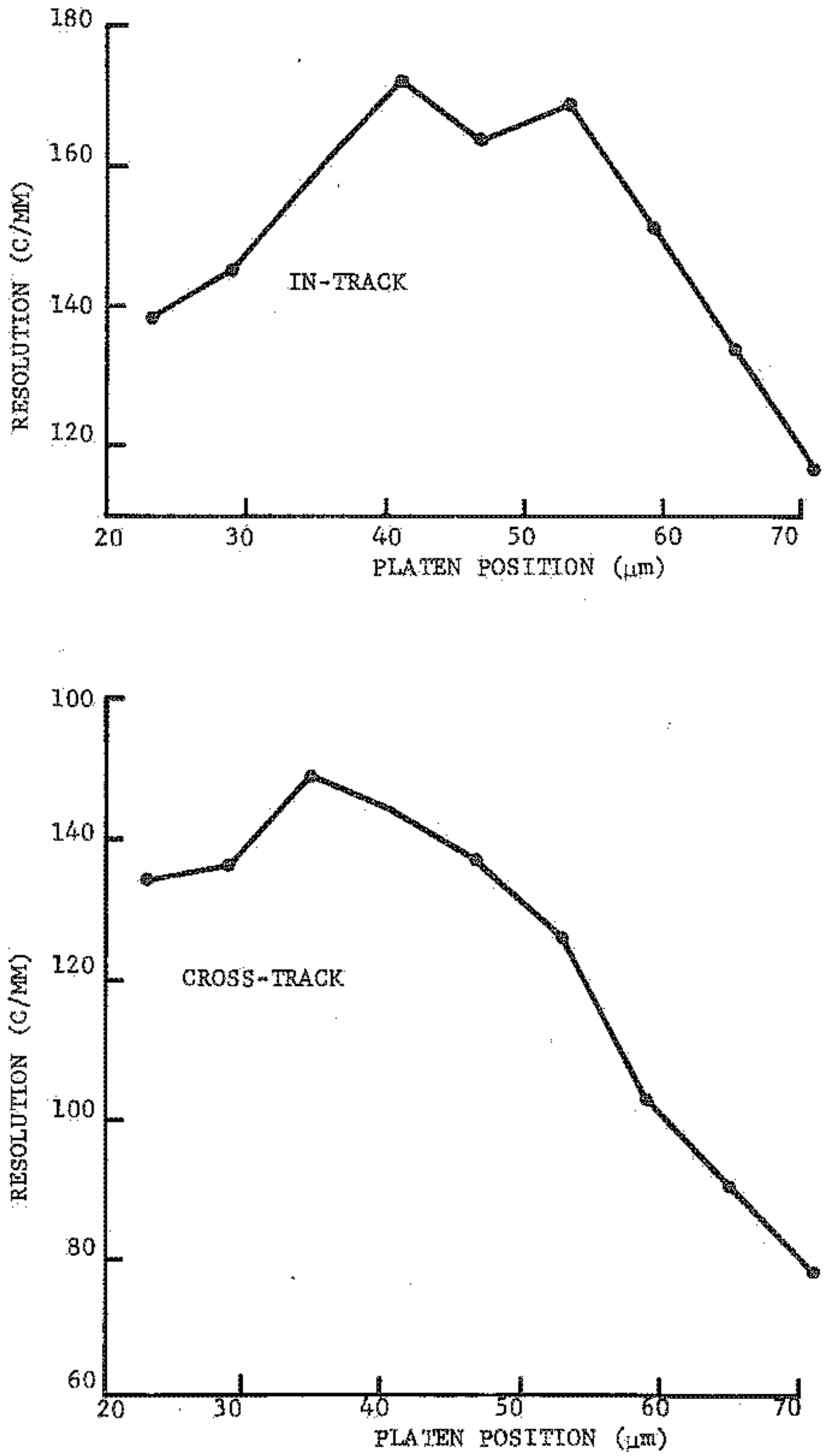


Figure 10. Run 299, Forward Camera, SV-12, Chamber 1A2, O.N. Resolution

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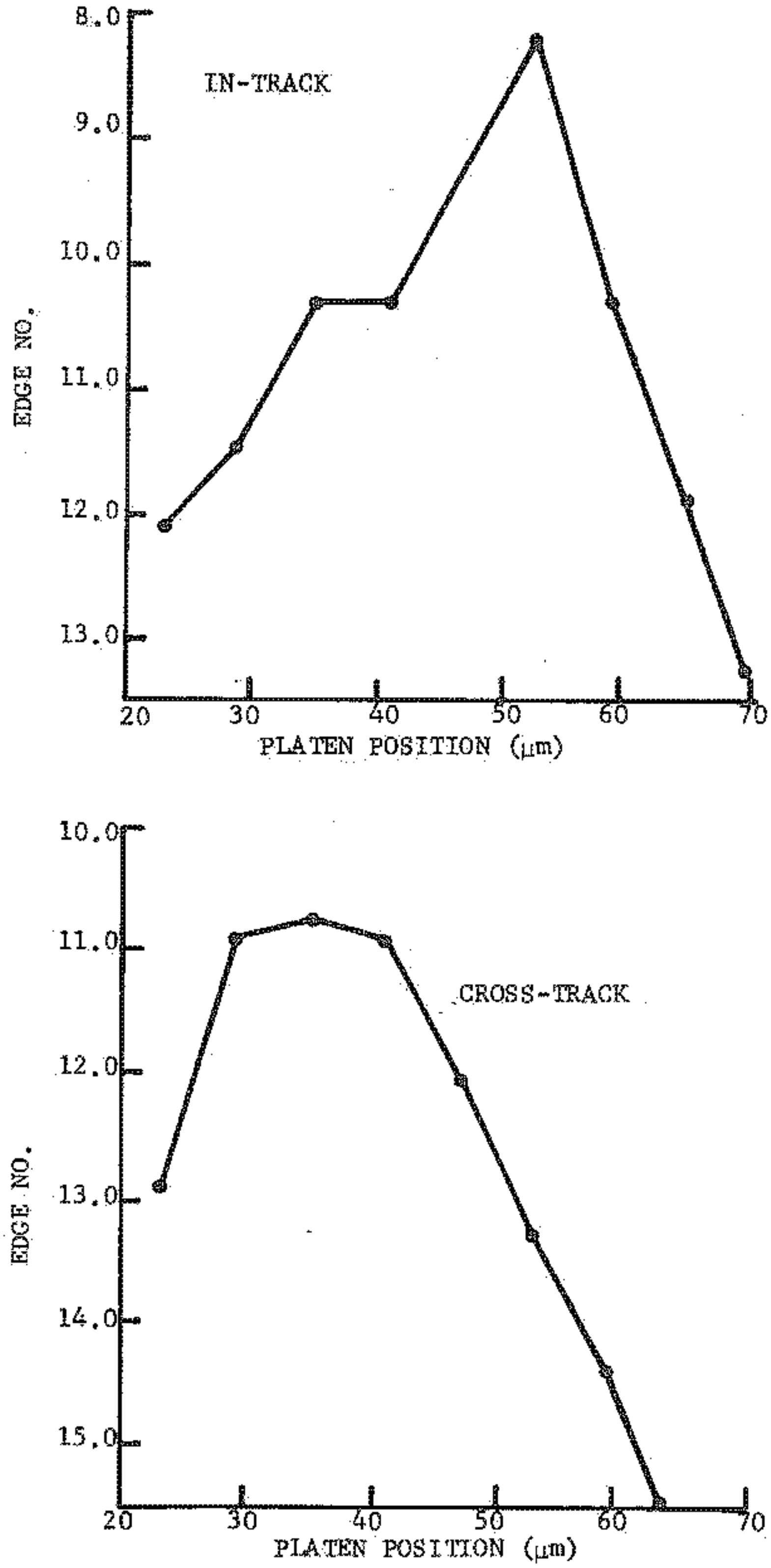

Figure 11. Run 299, Forward Camera, SV-12, Chamber 1A2, Manual Edge Match

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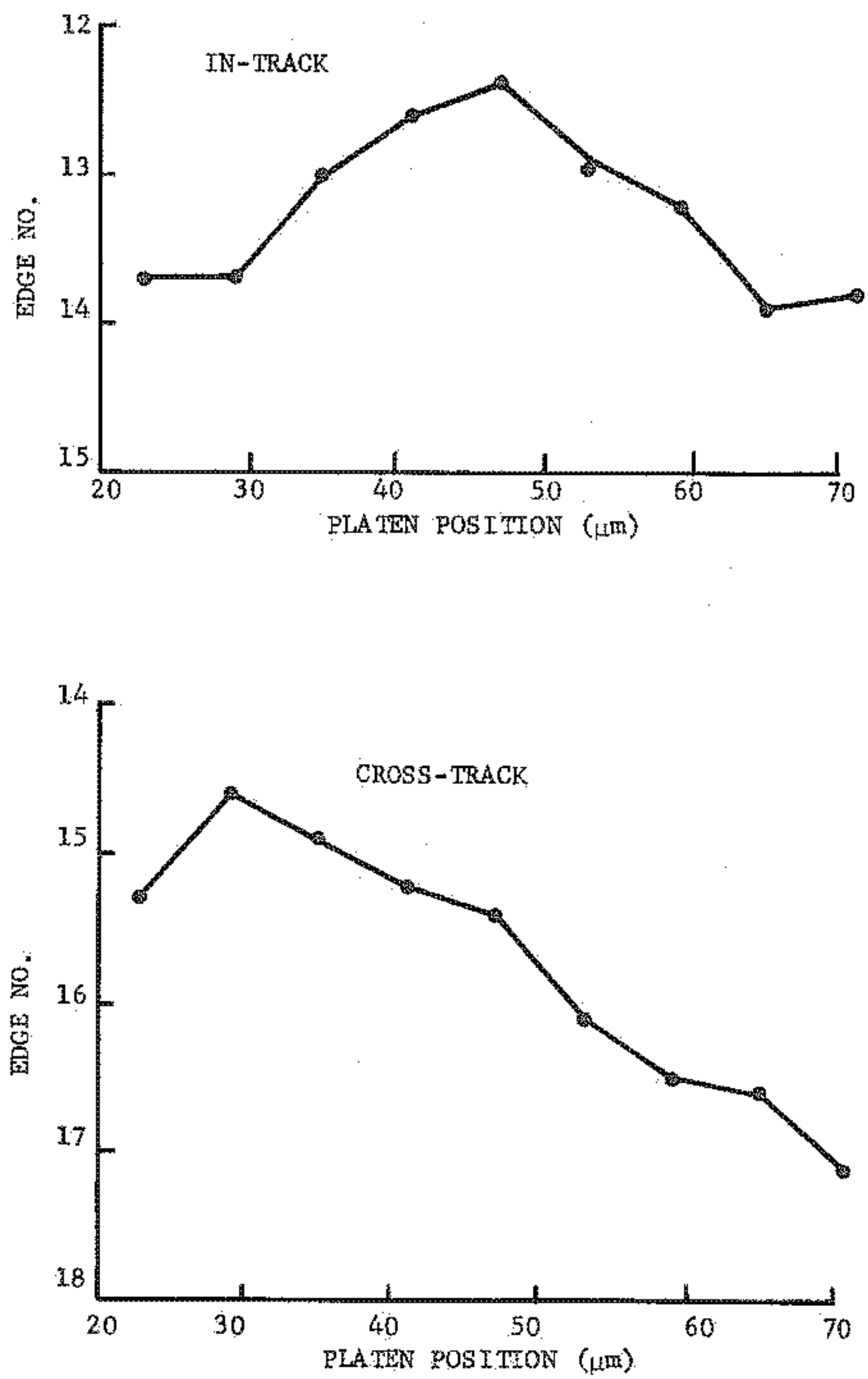

Figure 12. Run 299, Forward Camera, SV-12, Chamber IA2, Automated Edge Match

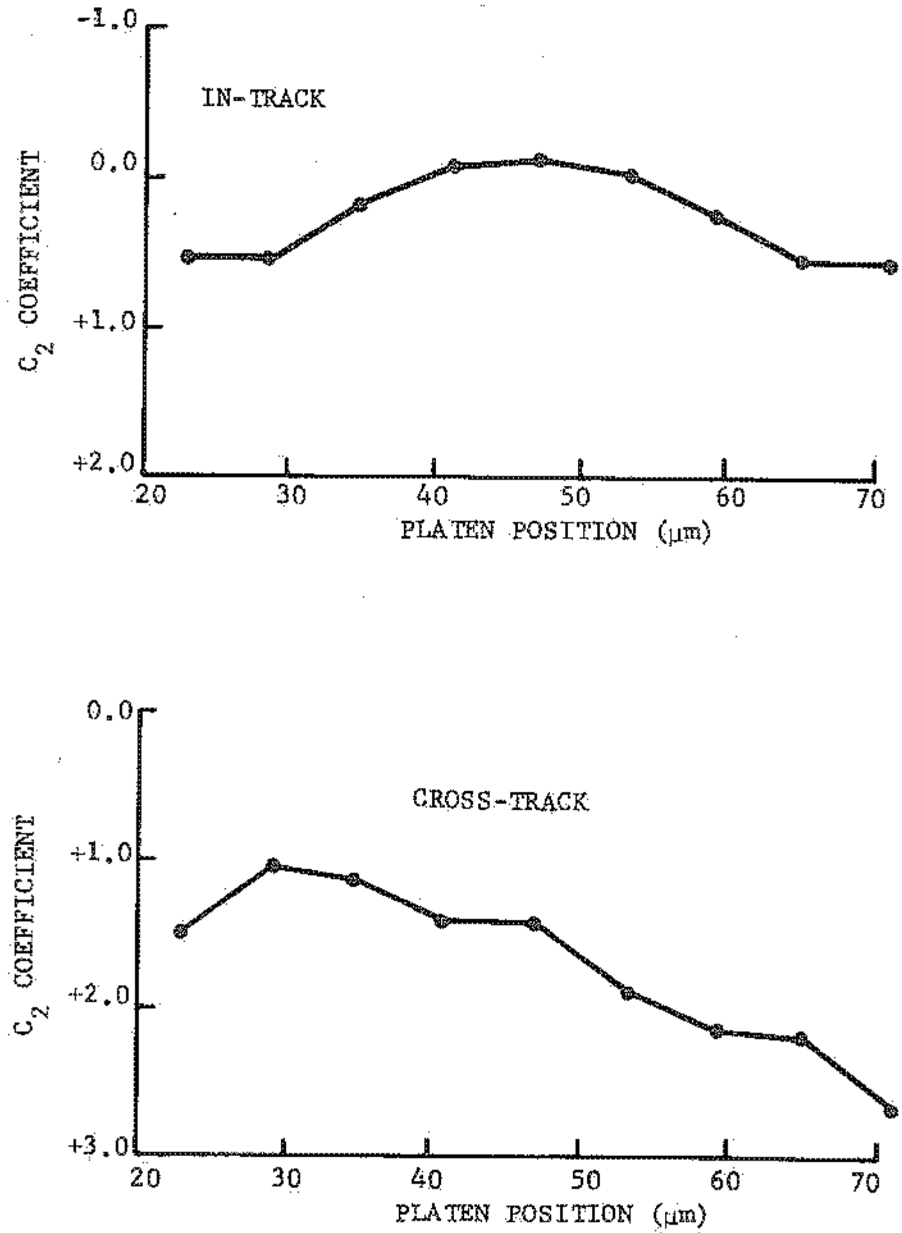

Figure 13. Run 299, Forward Camera, SV-12, Chamber IA2, C_2 Coefficient

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TABLE 4

COMPARISON OF PBF DETERMINATIONS

	Automated VEM			Manual VEM	O.N. Resolution
Run	Direction	Edge No.	C_2 Coeff.	Edge No.	C/mm
298	IT	50	49	44	43
	XT	37	35	33	36
299	IT	46	47	45	45
	XT	24	30	35	35

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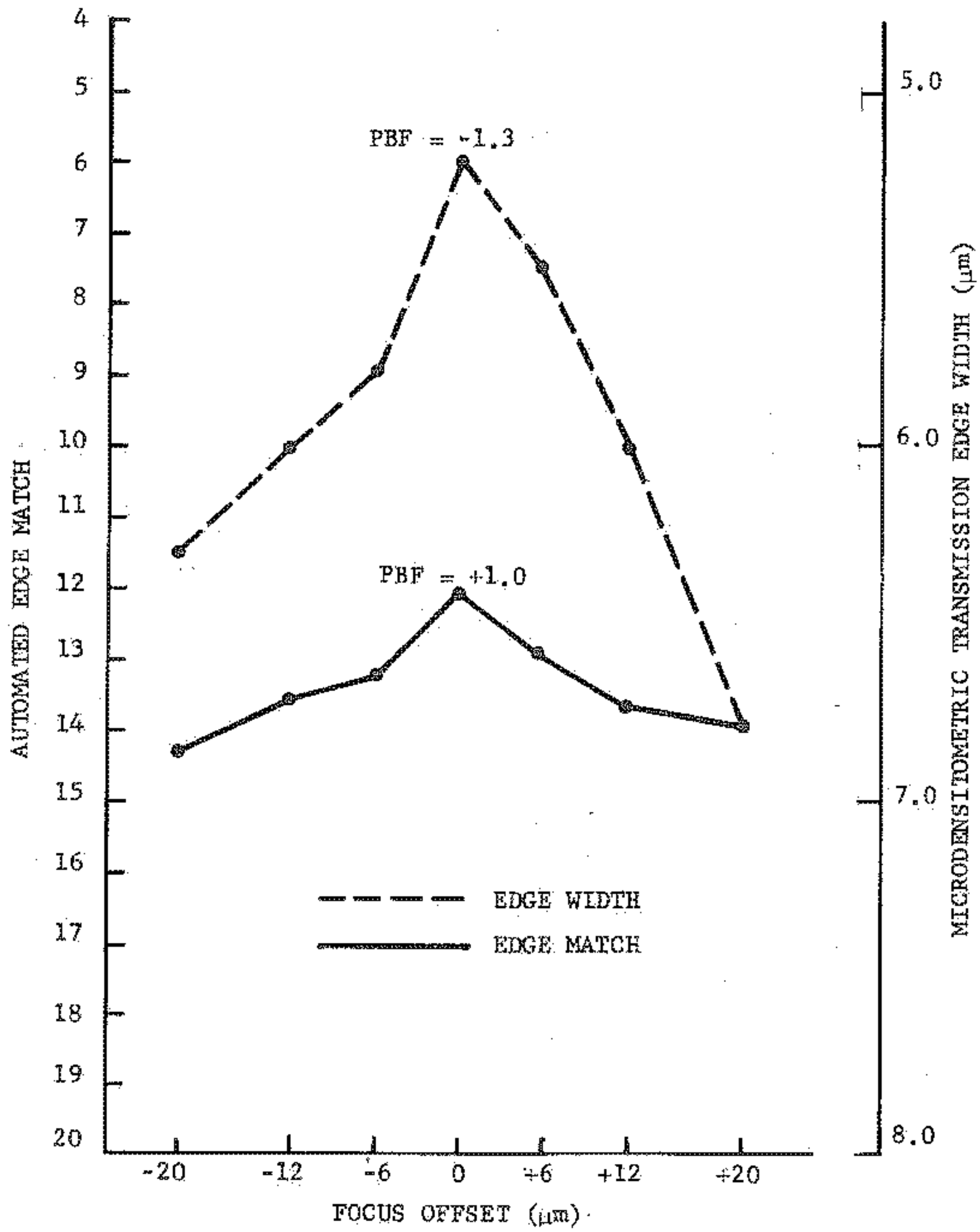

Figure 14. Lab Bench Through-Focus Assessment (Contrast 4) Using Automated VEM System

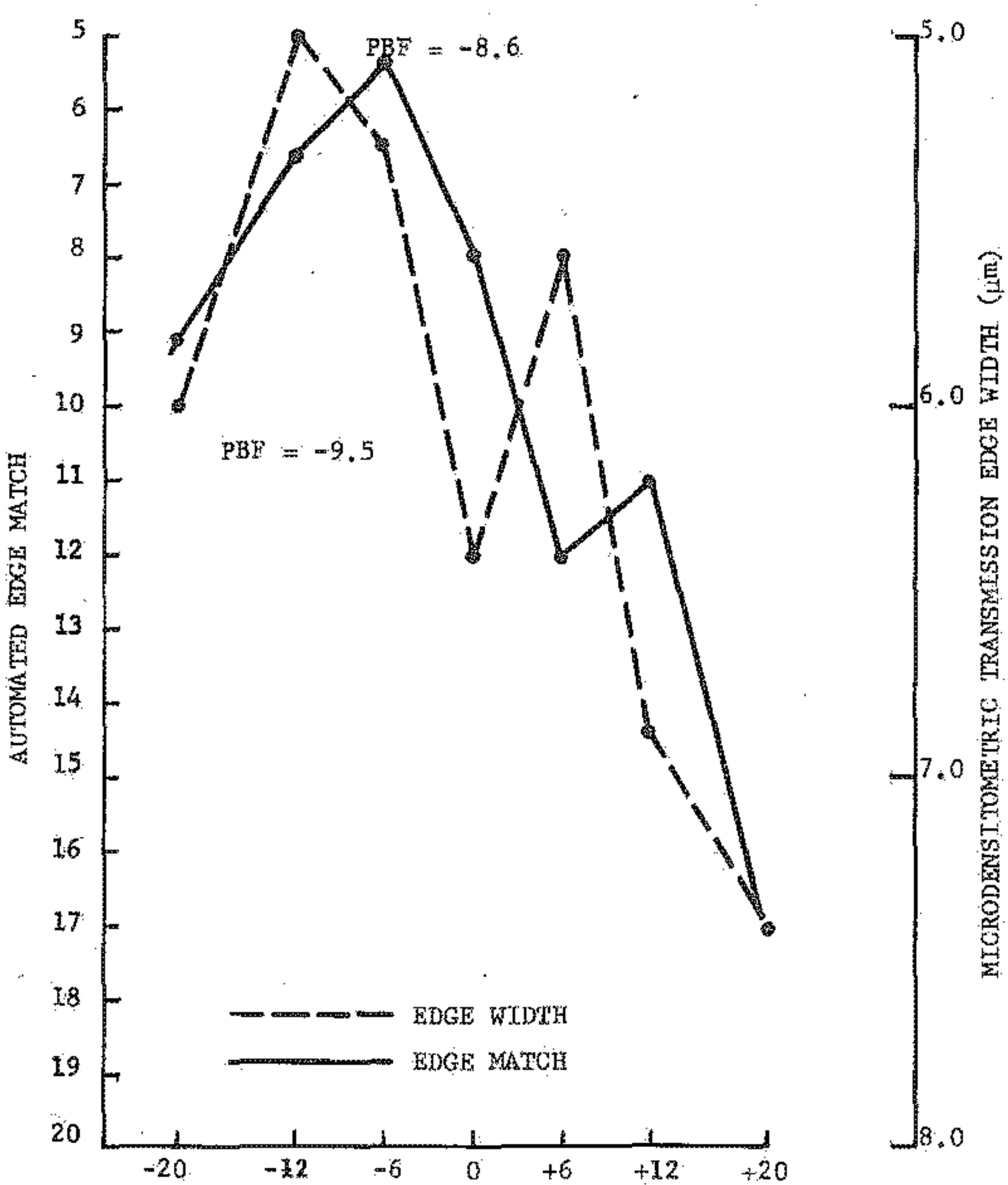

Figure 15. Lab Bench Through-Focus Assessment (Contrast 7) Using Automated VEM System

This comparison shows the automated edge match system is not as sensitive in terms of performance change measurement at the higher contrast edges. Edge width determinations, however, show approximately the same performance range at either contrast.

Plane of Best Focus determinations were also made at each contrast for each measure, i.e., edge number and edge width. The results of these comparisons are as follows:

	C_4	C_7
Automated Edge Match No.	+1.0	-8.6
Edge Width	-1.3	-9.5

Once again the automated VEM system has shown the capability to determine a plane of best focus, but still shows a lack of sensitivity at higher contrasts. It has been shown that the use of edge width increases the sensitivity of the technique and as such led to further investigation of it with the automated VEM system.

During the evaluation of the laboratory imagery, the inherent effects of contrast on sharpness were investigated. To solve this problem, the decision was made to characterize image quality via edge width. This approach had been taken with manual VEM readings and has proved to be an acceptable technique to negate contrast effects on sharpness within the matrix as well as increase the sensitivity of the automated VEM system.

Characterization was initially accomplished by investigating the relationships between the Eigenvector C_2 coefficient and edge number, and edge width as determined by microdensitometric scans of the matrix. These relationships were found to be linear with a high degree of correlation. Regression equations were then used to convert calculated C_2 coefficients to edge widths. This method, used with all subsequent testing at Perkin-Elmer, eventually, evolved into a system software change that allows measurement of edge width directly from the Reticon array response. This modification was implemented just prior to shipment to the MAA for Mission 1213 evaluation.

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MISSION 1212-1 THRU-FOCUS EVALUATION

The final analysis was the PBF determination for Mission 1212-1, Forward Camera. Prior to shipping the automated system to Bridgehead, however, a change was made in quality measure (from edge number or C_2 coefficient to edge width). As previously stated, edge width was determined via correlative procedures; C_2 coefficient was converted to edge number and then to edge width. This is the operational manner for determining PBF, i.e., the conversion of edge number to edge width.

The analysis procedure was identical to that followed at the MAA in terms of frames evaluated, positions sampled and number of readings taken per cell or format location. Data reduction was also similarly accomplished. The thru-focus response was characterized by average geometric-mean performance across the field. This data was plotted as a function of platen position offset and a quadratic regression performed to determine PBF. Figure 16 is a graphical representation of this analysis. Also shown is the result of the 1212-1 PFA analysis done at MAA. While the two analyses show different levels of performance, the PBF determinations are effectively the same. The MAA analysis led to a 4 micron advance of the platen. The automated VEM system analysis would have led to a decision that nominal focus (0μ) was optimum.

This difference in performance level is not considered a problem because the MAA analysis was a point-by-point conversion from edge number to edge width, while the automated VEM analysis was a series of conversions via smoothed linear fits. The important outcome was that the automated VEM would have led to a proper focus decision.

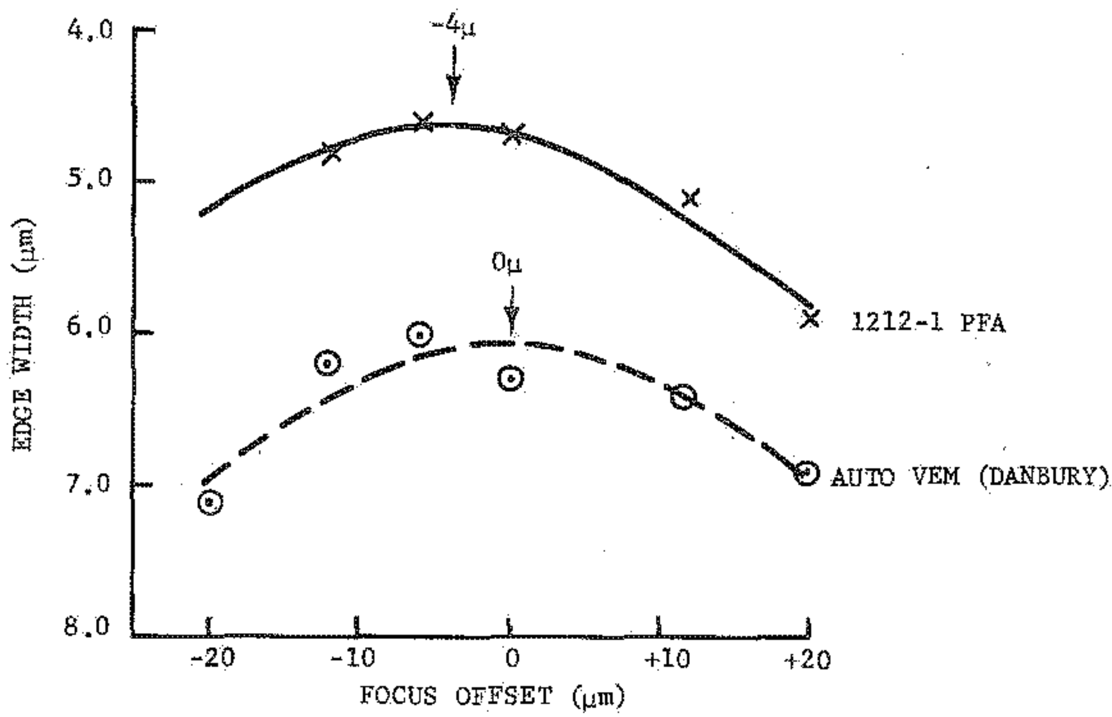

Figure 16, Mission 1212-1 Focus Analysis Comparison, Forward Camera

MISSION 1213-1 THRU-FOCUS EVALUATION

Since contrast varies from operation to operation depending on atmospheric conditions, a direct measurement of edge width was incorporated in the operating software. A variation of this technique has been in use with the manual VEM for the past several Hexagon missions obviating any contrast related problems.

It was decided to analyze only one camera's thru-focus response because only one operator was sufficiently trained in the operation of the automated VEM system. The Aft camera was arbitrarily chosen and two complete thru-focus runs were analyzed. In general, the data extracted was noisy. But a definite focus recommendation was achieved, which was consistent with subjective impressions, and a single set of manual readings on that camera.

The data collection procedure was the same as that used in the manual process i.e., characterize 2 frames of thru-focus imagery at each platen offset utilized (0, ± 6, ± 12, ± 20 μm). A frame is characterized by sampling seven discrete cells located at $\pm 2.5^{\circ}$, $\pm 2^{\circ}$, $\pm 1^{\circ}$ and 0° field positions. Each cell is 1/2 inch wide and within $\pm 15^{\circ}$ of scan nadir. The sampling technique is the measurement of seven in-track and seven cross-track edges per cell per frame. Table 5 is a summary of all the data collected for this analysis.

The system, at this point in time, differed from that delivered to Perkin-Elmer in that relative image quality was measured in terms of edge width as determined from the diode output to negate contrast effects on performance measurement.

To reduce noise and determine a plane of focus for best overall performance, the geometric mean data across the field is averaged. Figure 17 is a graphical representation of the full field thru-focus performance for both the in-track and cross-track data as well as the geometric mean. A quadratic regression of the latter shows the plane of best focus to lie at eleven microns farther away from the lens than the launch nominal; this is consistent in direction with all diagnostics used but different by several microns in magnitude. Table 6 shows the results of the other diagnostics used to analyze the Aft Camera imagery.

TABLE 5

1213-1 AFT CAMERA THRU-FOCUS ANALYSIS
AUTOMATED VEM (EDGE WIDTH)
SUMMARY SHEET

		Field Angle							
ΔF		-2.5	-2.0	-1.0	0.0	+1.0	+2.0	+2.5	Avg.
	IT	11.37	10.35	11.39	11.43	11.24	10.92	12.03	11.25
-20	XT	10.99	10.07	10.62	11.48	10.54	9.77	11.33	10.69
	GM	11.18	10.21	11.00	11.45	10.88	10.33	11.67	10.97
	IT	9.67	9.01	11.78	9.87	10.64	10.33	9.65	10.14
-12	XT	9.77	8.99	10.56	10.53	10.75	10.33	9.91	10.12
	GM	9.72	9.00	11.15	10.15	10.69	10.33	9.78	10.13
	IT	9.55	9.83	9.09	9.81	10.17	9.35	10.13	9.70
-6	XT	8.37	8.68	8.76	8.87	9.36	10.93	9.56	9.22
	GM	8.94	9.24	8.92	9.33	9.76	10.11	9.84	9.46
	IT	9.37	9.67	8.76	10.17	9.04	10.11	10.10	9.60
0	XT	9.06	9.43	8.20	9.48	8.96	8.78	11.03	9.35
	GM	9.21	9.55	8.48	9.82	9.00	9.94	10.55	9.37
	IT	8.94	8.99	9.66	8.97	10.11	9.42	9.05	9.31
+6	XT	8.10	9.11	8.63	10.16	9.57	7.88	9.71	9.02
	GM	8.51	9.05	9.13	9.55	9.84	8.62	9.37	9.16
	IT	9.48	10.08	8.77	8.09	8.73	9.01	9.70	9.12
+12	XT	8.96	9.90	8.87	8.59	8.96	8.56	8.32	8.88
	GM	9.22	9.99	8.82	8.34	8.84	8.78	8.98	9.00
	IT	8.52	9.78	9.71	9.31	9.70	9.11	9.40	9.36
+20	XT	9.43	9.16	9.30	8.84	9.56	8.87	8.78	9.13
	GM	8.96	9.46	9.50	9.07	9.63	8.99	9.08	9.24

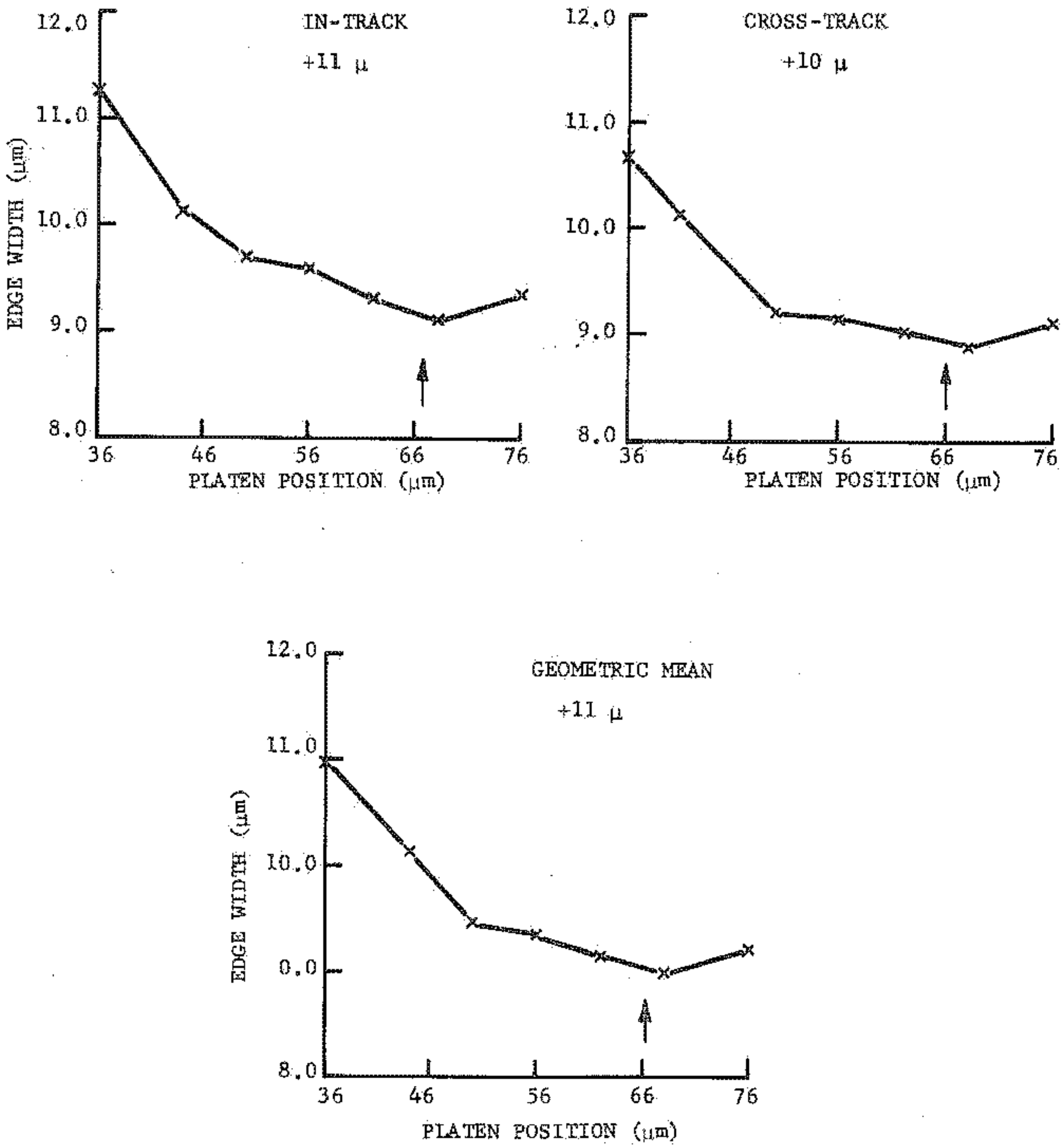

Figure 17. Mission 1213-1 Aft Camera Through-Focus Analysis, Automated VEM (Edge Width)

TABLE 6

SUMMARY OF DIAGNOSTICS

Subjective		+6 μ
Manual VEM*		
	Total Data Set	Inconclusive
	Final Data Set	+8 μ
Automated VEM		+11 μ
Optical Power Spectrum (OPS)		+2 μ

*For reasons explained elsewhere, first data set did not go through focus and inclusion in total set precluded the determination of a PBF.

As can be seen, the automated VEM system was in reasonably good agreement with most of the other available diagnostics. With the exception of the OPS results, the automated VEM determination falls within the 5μ range determined throughout the test phase.

Since the system, as modified with an objective measure, has continually agreed with other diagnostics, it should be pursued as a viable semi-objective technique and modified as necessary.

PROBLEM AREAS

As with any new piece of equipment, the Automated VEM System exhibited problems. The system has two primary building blocks: hardware and software. The hardware is briefly described elsewhere in this report as well as in the System Operators Manual along with the software. During the course of system test and evaluation at Perkin-Elmer and in the field, problems were encountered in both areas. This section addresses these problems in summary fashion since all problems have been previously addressed and apparently solved.

The majority of the problems encountered were hardware oriented. There were two instances of scanning microswitch failure where the prism velocity across the imaging light path had decreased, leading to varying array integration times. In both cases Eikonix representatives corrected the problem. In addition, prior to shipment to the MAA, a modification was made allowing for quick replacement of these microswitches.

A second problem exhibited itself in an extreme loss of sample illumination intensity. The cause of the problem was not immediately determined but it was later found that projection lamp orientation was the cause.

Repair or modification was necessary on several other occasions; one, a thermal problem, was solved by use of a fan and baffle to cool the electronics. An electronic failure occurred while the system was located at the MAA. An integrated circuit in the Electronic Interface Unit failed causing the unit to be inoperable. Because the troubleshooting and repair consumed so much time, no meaningful data could be collected for the 1213-2 PFA.

The automated VEM system was successfully used on the 1213-1 PFA, but not without problems. The first problem was operator induced. While in the process of striking the keyboard, the operator inadvertently hit the power switch on the control panel causing the machine to shut down. A magnetic tape was in use at the time and the previously recorded data was difficult to retrieve. A simple solution to this problem would be to put a cage over the power switch. Another problem similar in consequence was encountered during the 1213-1 exercise. For no apparent reason the system would not respond to any commands. To again achieve control the system had to be shut down and started up again. As mentioned previously, the existing data on the magnetic tape could only be retrieved with great difficulty. It is problems of this nature that cause great concern since it is not known what precipitated the failure.

There is one additional problem area and that is the offset between active diode array and the reticle footprint of that array. This mismatch makes it difficult to choose suitable edges especially at the scale achieved in the Hexagon System.

In summary, the Automated VEM System did exhibit problems; however, none of these was serious enough to preclude its future development. For most uses especially in the MAA, reliability is of the utmost importance and this system should be modified and new systems designed with this in mind.