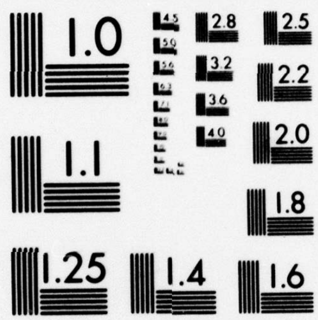
AD-A063 434 WESTINGHOUSE ELECTRIC CORP HORSEHEADS N Y INDUSTRY AN--ETC F/G 9/1
DEVELOPMENT OF 40 AND 80 MM CAMERA TUBES WITH DEEP ETCH METAL C--ETC(U)
JAN 78 V J SANTILLI DAAK02-75-C-0127

UNCLASSIFIED NL

1 OF 1
AD
A063434

END
DATE
FILMED
3-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

FINAL TECHNICAL REPORT
CONTRACT DAAK02-75-C-0127 (15)

(6) DEVELOPMENT OF 40 AND 80 MM CAMERA TUBES
WITH DEEP ETCH METAL CAP TARGETS
FOR SPACE SURVEILLANCE

WESTINGHOUSE ELECTRIC CORPORATION
INDUSTRIAL & GOVERNMENT TUBE DIVISION
WESTINGHOUSE CIRCLE
HORSEHEADS, NEW YORK

(9) Final rept. 1975-1977.

TO

(10) V. J. Santilli (11) Jan 78 (12) 90p.

U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

D

Prepared by

V. J. Santilli
V. J. Santilli
Project Engineer

Approved by

W. J. Whitson
W. J. Whitson, Manager
Image Development Engineering



410 106

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

## REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) Final Report
Development of 40 and 80 mm Camera Tubes with Deep Etch Metal Cap Targets for Space Surveillance

5. TYPE OF REPORT & PERIOD COVERED
Technical Report
1975-1977

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
V. J. Santilli

8. CONTRACT OR GRANT NUMBER(s)
DAAK02-75-C-0127 new

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Westinghouse Electric Corporation
Industrial & Government Tube Division
Westinghouse Circle
Horseheads, N.Y. 14845

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Night Vision Laboratory
USAECOM AMSEL-NV-SD
Fort Belvoir, Virginia 22060

12. REPORT DATE
Jan 1978

13. NUMBER OF PAGES
87 pages with 3 appendices

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

**DISTRIBUTION STATEMENT A**
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Camera tubes, fixed magnification and zoom tubes, electron optics, design and development of tubes, extra large silicon diode targets, tube characteristics, specification of WX 32719, point source resolution, and tube life.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Final technical report summarizes tube design and development program for large format camera tubes capable of high performance. The report describes the results of the two year program relative to number of tubes and tube performance. Large 32 mm silicon diode target performance as part of tube characteristics discussed. Development problems such as photocathode processing and their solution is recorded. The report ends with a profile of tubes through their specification and an overall look at tube life.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

79 01 12 049

FINAL TECHNICAL REPORT
CONTRACT NO. DAAK02-75-C-0127

## 1. INTRODUCTION

In 1975, Westinghouse was awarded an NVL contract to develop camera tubes of the EBSICON variety for space surveillance. The contract entitled, "The Design and Development of a 40 mm and 80 mm EBSICON", ran for two years after its inception. The contract required Westinghouse to design, develop and assemble tubes as well as test and evaluate tubes for delivery. This is the final report of the contract and a summary report of the program carried out to fulfill the contract.

Westinghouse developed two tube types during the two year period: the WX-32719 - 40 mm and the WX-32670 - 80 mm tubes. One of these, the WX-32719 it considers fully developed, and the WX-32670 only partially developed. The photocathode fabrication techniques in the WX-32670 being the main reason for this consideration. During the program approximately 100 tubes were fabricated and processed resulting in 43 tubes of both types delivered. These tubes are the first tubes ever made containing a large 32 mm diagonal silicon diode array target. This report will discuss briefly the effort going into major task areas defined in the program and the performance results of all the tube starts.

In addition to tube development and manufacture, Westinghouse probed the characteristics of the large EBSICON target insofar as targets influenced tube manufacture, performance, and tube life. Thus, target data will also be discussed in this report. A substantial achievement of the program is the

the derivation of an EBSICON product specification, including target description specification. Both tube and targets will be seen to be fully described and this report will include the specifications.

These specifications are considered an achievement because they reflect actual tested performance over a significant sample of tubes. Thus, a system designer using such a tube as the WX-32719 can determine with a high degree of confidence the advantages and limitations imposed by the EBSICON sensor.

Besides discussion of development efforts, tube results, and technical specification, a summary list of all tubes made and tested for the program will be given. The list is also a disposition record based on Westinghouse collation of NVL contract records.

Finally, a study of a tube tested for life will be presented and the status of the program will be given.

## 2. CONTRACT WORK - HISTORY

An original plan of work for this contract is shown in Figure 1. The plan was devised to meet stated contract goals. Goals were identified as providing tubes with high performance in the areas of point source response, blooming, saturation current, distortion, gain control, life and ruggedness. (Contract line item F.)

### 2.1 Tube Design - 40 mm EBSICON - WX-32719

The 40 mm camera tube design called for in the plan was modeled after the Westinghouse B-1 tube WX-32432, an original 32 mm EBSICON tube. To the B-1 tube was added the concept of gating and accommodation of a large silicon diode array target with associated mesh while still retaining a 1-1/2" readout section for compatibility with existing sockets. These conceptual additions were implemented in practice according to the results of electron optic calculations. The electron optic studies determined gate electrode position, size and image plane size, focal points and predicted tube performance such as distortion, magnification and resolution.

This was the first major task to be completed for this contract and resulted in the mechanical configuration shown in Figure 2. Figure 2 is a cross section of the WX-32719 - 40 mm EBSICON. It includes a triode image section with a "zero" focus gate electrode. The image

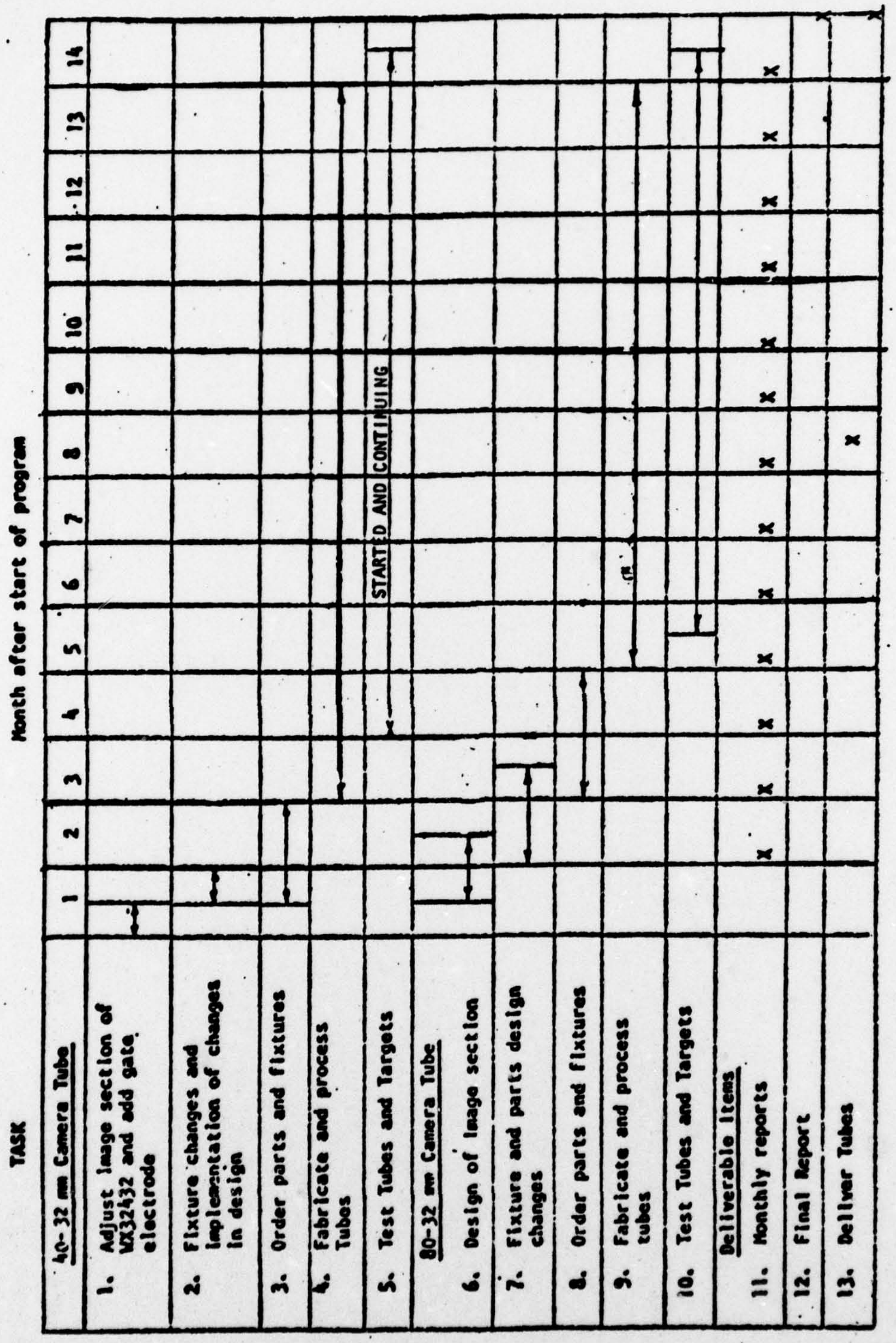



FIGURE 1: PROGRAM OF WORK MILESTONE CHART

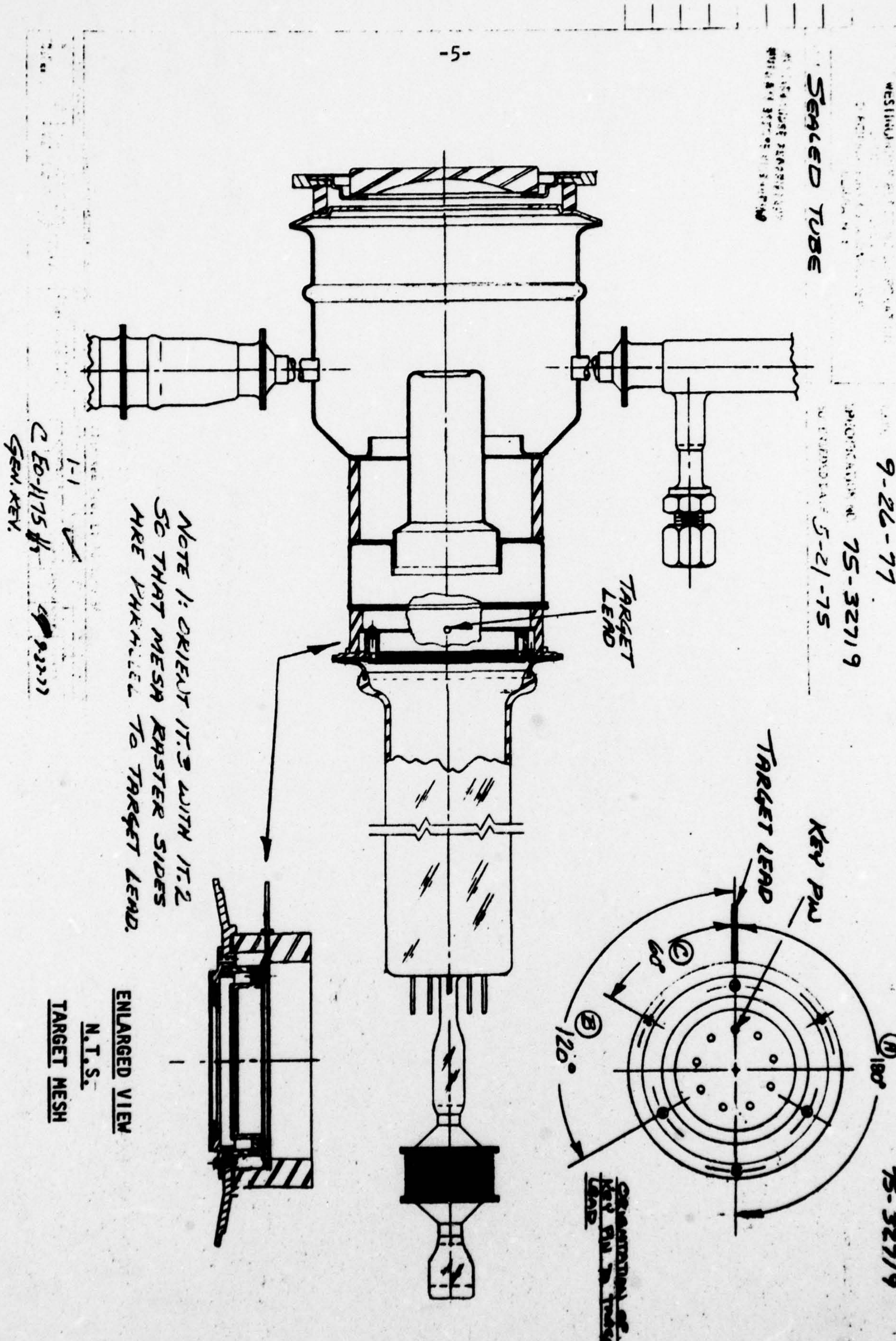



FIGURE 2: CROSS SECTION OF WX-32719

section is an electrostatically focussed section that uses a 40 mm input curved photocathode on a fiber optic substrate.

The target is positioned in the tube at the focal plane which gives a magnification of 0.8. Thus, the input 40 mm object is reduced to exactly 32 mm on the silicon diode target image plane.

The silicon diode array target has a physical diameter size of 41 mm and fits a low capacitance integrated target-mesh ceramic assembly. (See target-mesh inset - Figure 2.) The mesh support is rastered for ruggedness in a 1 x 1 format with a slightly larger than 32 mm diagonal. The static target shunt capacitance of 25 pf compares favorably with smaller target structure capacitances.

As constructed and built the target-mesh assembly when inserted in the tube and anchored to its support member, effectively seals the image section from the gun readout section. This particular concept is used to purposely isolate both sections of the tube for longer tube life.

The scanning section used in the WX-32719 employs a standard electron gun utilizing a long beam drift space capable of high resolution at high current density. Electron optic studies of the gun and coil environment were made during the first year of the program to find ways for future gun improvements and for a better understanding of the gun-coil operation.

2.2 Tube Design - 80 mm EBSICON - WX-32670

A cross section of the 80 mm EBSICON tube is shown in Figure 3. This companion tube of the contract is different from the WX-32719 except for the read section. The image section design was the second major task of the contract as shown under item 6 of Figure 1.

The 80 mm EBSICON contains an electrostatically focussed triode image section. As such, its electron optical system is capable of focussing photoelectrons originating from the full 80 mm input optic on to a 32 mm target. With proper adjustment of zoom electrode voltage focussing can be achieved with a magnification ranging from .8 to .39. Thus, the concept of electronic zoom is available in this design. The two magnification extremes are designated wide angle and narrow angle, respectively.

With an application of a negative voltage to the focus electrode (negative with respect to the photocathode) the photoelectrons can be gated off thereby preventing any electron charging of the target. Thus, the 80 mm image section is designed for zoom and gating.

Because the 80 mm image section is more complicated in concept than a diode, it is further discussed below as an example of the type of electron optics study performed and results so obtained in this program.

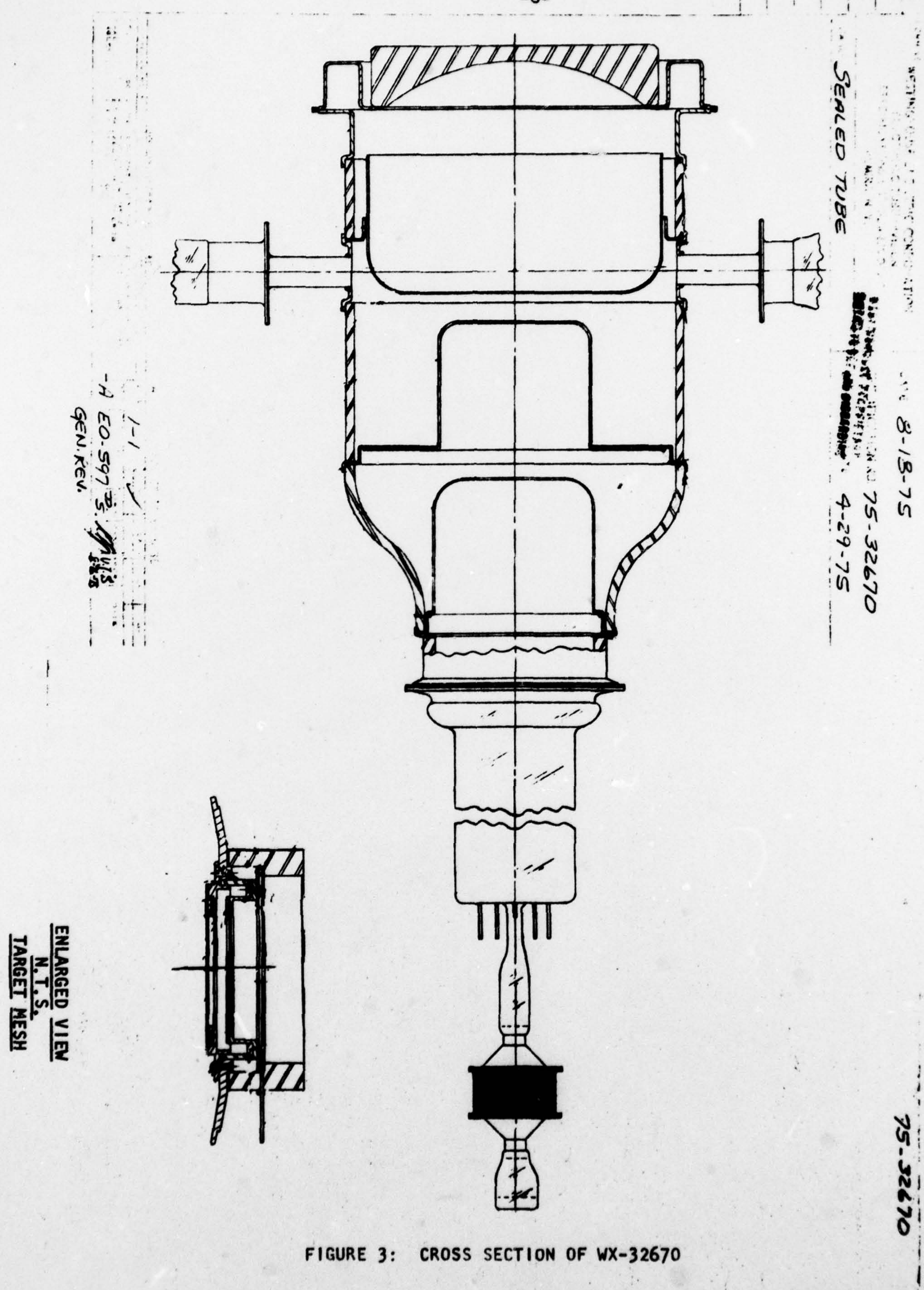



FIGURE 3: CROSS SECTION OF WX-32670

2.2.1 First Period - Electron Optics - 80 mm WX-32670

The electron optic design and study was carried out by James Vine of Westinghouse Research Laboratories at Pittsburgh. The design was based on previous Westinghouse experience with zoom-gated intensifier devices and involved a computer program package for electron optical ray tracing. The program delineates geometrical aspects of an electron beam as it leaves the photocathode and is accelerated toward the silicon diode array target. For an object point on the photocathode, the program traces multiple rays through the image section to define by their intersections at the silicon target end of the image section, the corresponding image points. By repetition of the procedure for several object points of the photocathode, the image surface as a collection of image points is obtained.

From several ray tracings the purely geometrical aspects of the image sections are determined. Thus, an electron-optical prediction of the image section can be made as to magnification distortion and astigmatism. Resolution is assessed from a knowledge of beam angles and image surfaces. A sample of the results is shown in Fig. 4. The figure is a cross-sectional plot of several electron paths for center and edge electrons emanating from the photocathode under conditions of wide angle operation. The object plane is the curved photocathode, the electrodes are the cylindrical elements in the figure and the image plane is the focus of focal points for the electron paths. Results of the study predicted the image section of the WX-32670 to have wide angle mode resolution of the order of 20 lp/mm. The resolution is uniform out to approximately 25 mm diameter on the target (approximately 80% of the raster

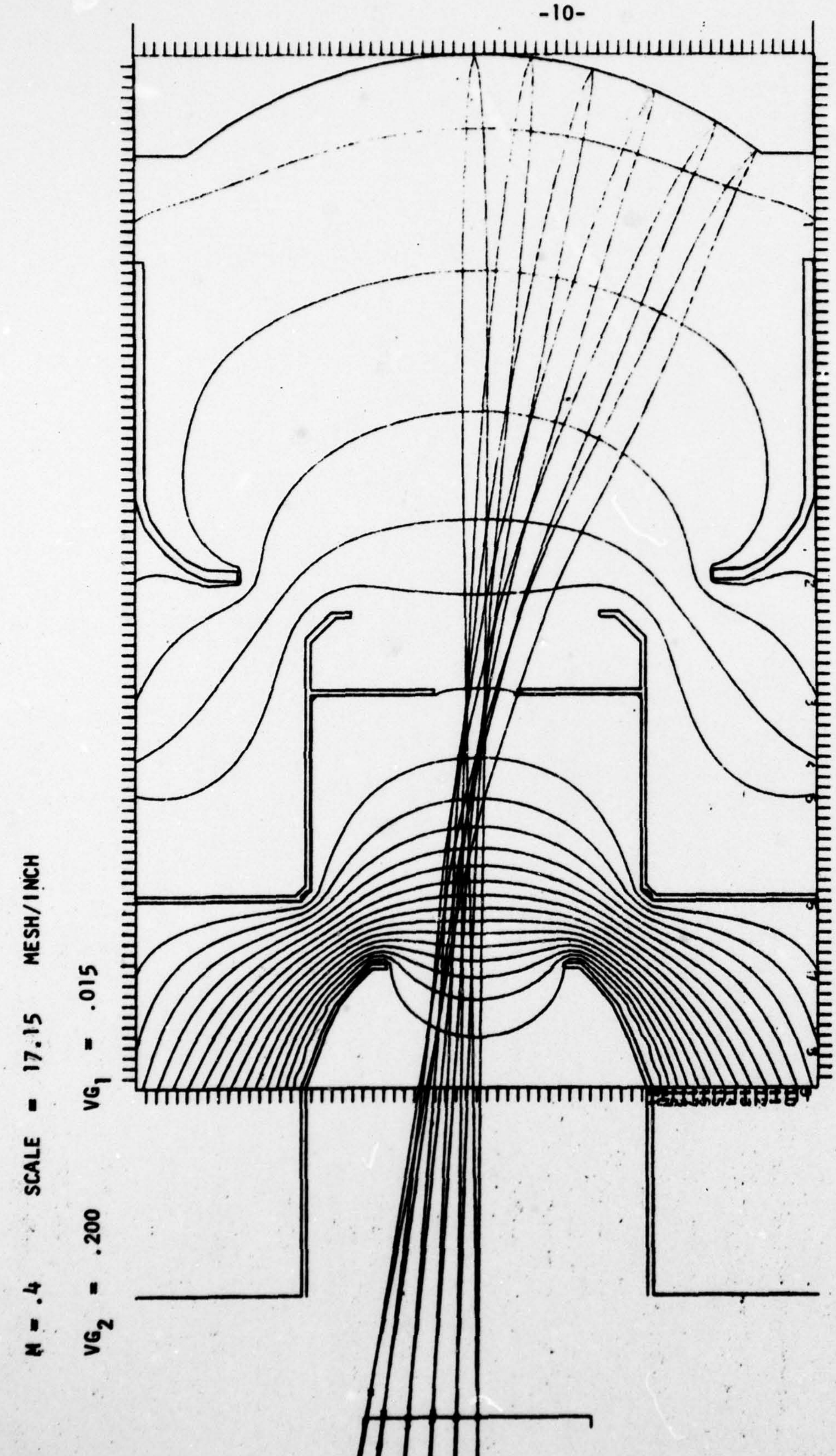



FIGURE 4: WX-32670 E-O RAY TRACE

diagonal). Beyond this diameter the resolution drops to about 15 lp/mm. These resolution figures are predicted figures of spatial resolution referred to the tube input. In the wide angle mode the magnification is nominally 4/10 and therefore at the target 50 lp/mm is expected. In TVL per raster height, the optic study predicted the tube to be capable of resolving about 1900 TVL/RT HT of a 4x3 aspect ratio at most in wide angle. In the Narrow angle mode, the image section is predicted to resolve 52 lp/mm referred to the target or 1996 TVL/RT HT.

As indicated in the program chart, the electron optics study for modification of the 40 mm tube and 80 mm design proceeded with the 40 mm first and 80 mm last. Both tasks were completed in the first few months of the contract. With the studies completed, engineering planning and production of tubes began. No changes were made in both tube types. As tubes were processed the essential performance measurements were carried out on each tube. During this time emphasis was placed on obtaining good tubes of the 40 mm type. For this reason quality targets were reserved for the 40 mm WX-32719.

2.2.2 Second Period - Electron Optics - 80 mm WX-32670

New funding was obtained for the second year and the program shown in Figure 5 was planned and carried out. The principle emphasis during this period was on the 80 mm tube; particularly to obtain solutions to problems of high voltage operation and photocathode fabrication.

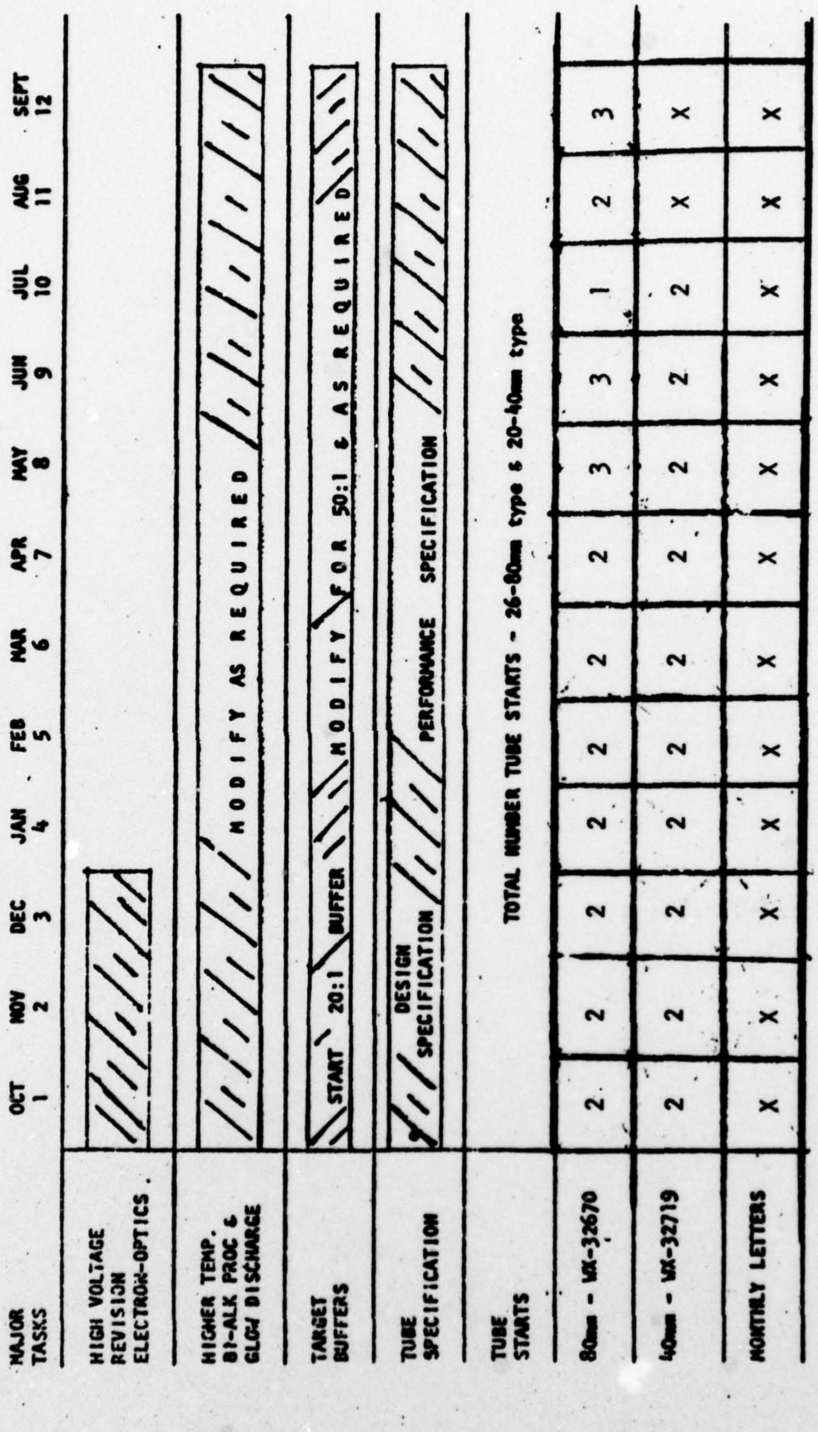



FIGURE 5: SECOND YEAR PLAN

Specifically, many 80 mm tube starts were not capable of operating at high voltage in the narrow angle mode. It was discovered that narrow angle operation was complicated by spurious emission affects. Spurious emission or extraneous emission is the phenomenon of undesired electron emission that usually manifests itself as arcing, high voltage breakdown, field emission and ultimately heavy charging of the silicon diode target.

The effect of the spurious emission problem on 80 mm tube operation is shown in the histogram of Figure 6. From a total of 15 tubes sampled, six operated at the designed high voltage point in both wide and narrow angles whereas nine failed to operate at high voltage in narrow angles. The spread in voltage operation is from 6 to 10 kV for the non-operating tubes. Because of heavy target charging the result of spurious emission from the nine tubes were clearly visible during tube operation, but the cause and source of the problems were difficult to assess. In other words, the problem or problems required identification before a solution could be rendered.

From the nine tubes a careful study was made to locate the causes. Tubes were stressed at double the design voltage and outward signs of spurious emission were catalogued. Electron currents between tube electrodes were measured and field emission plots made to determine possible field emission. In addition, a second electron optic study was performed for abnormal electron paths; electrons which may emanate from electrodes and edges of electrodes. From these engineering analyses, it was determined that design changes in the image section were called for. Thus, the second phase of this contract

WESTINGHOUSE ELECTRIC CORPORATION

1ST PERIOD

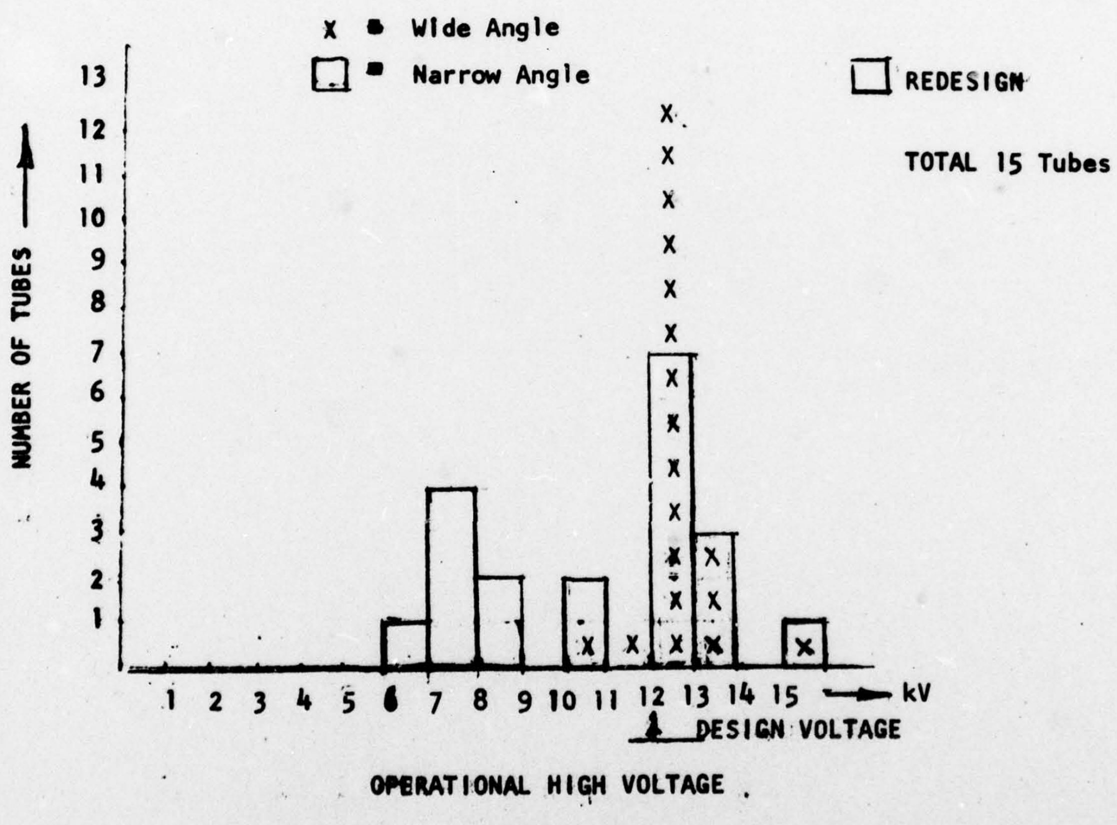



FIGURE 6: HI VOLTAGE PERFORMANCE OF THE WX-32670 80 mm EBSICON

work began as shown in the plan (Figure 5) with high voltage design revision being of paramount importance.

The image section of the 80 mm tube was redesigned by modifying electrodes, rolling edges of electrodes and selecting different materials for cleaner tube fabrication. The second run of tubes were clearly improved and evidence of this is shown on the same histogram above. Tubes, in general, operate at the design voltages of 12 kV and can be zoomed at this voltage without any spurious emission. There remained only photocathode processing techniques to further the development of the large EBSICON.

## 2.3 Photocathodes And Photoresponse

Throughout the program S-20 photocathodes were a direct concern in fabricating tubes with high performance. The photocathode processing for the 40 mm tube had however been determined by the time the program got underway. In the 40 mm tube, Westinghouse had a wealth of experience to guide it with the fabrication of hundreds of tubes of similar type. The photocathode for this type averaged 175 μA/lm for white light response and 15 mA/w for 5900°K. Good response photocathodes were common in this tube type and therefore will not be discussed.

As the second phase plan indicates however, the immediate concern was for the 80 mm photocathode. The photocathode in this tube being different in the sense that a larger format required more alkali source materials and a different recipe for its formation. The 80 mm photocathode substrate is 7.8 $in^2$ in an image section volume space of 85 $in^3$. This fact alone makes it unlike any photocathode manufactured by Westinghouse.

The program was begun using photocathode formation techniques which had proved successful in the 40 mm tube. Briefly, this schedule involved a rigid sequence of events to be followed. These were as follows: 1) deposit a layer of potassium, 2) co-evaporate potassium and antimony, 3) deposit a layer of sodium, 4) co-evaporate potassium and antimony, and 5) repeat with a layer of sodium. This sequence is called bi-alkali processing and is followed by a final step in the process to complete the tri-alkali, S-20 photocathode. The final step is to overlay the bi-alkali with layers of cesium and antimony.

For the 80 mm tube, the results of this type of schedule was as shown in Figure 7. Obviously, from these results, it could be seen that the tube's photocathode processing was not in control.

During the contract's second phase, various modifications to the photocathode techniques discussed above were attempted. Some of these involved high temperature processing of the bi-alkali photocathode. What was attempted was higher substrate temperature, i.e. temperature was raised from the normal temperature by 25 to 50°. The temperature differential was an attempt to drive more sodium into the bi-alkali formation because previous analysis of first phase photocathodes indicated a lack of Na. Since it is known that a chemical reaction is enhanced by temperature, it followed that a good solution might be a purposeful push of the Na. However, it was realized that a compromise situation would ensue. Any higher temperature imposed on the substrate would decrease the sticking coefficient of the sodium. Both of these factors are always determined empirically and thus the attempt was made on several 80 mm tubes to try the scheme of high temperature processing.

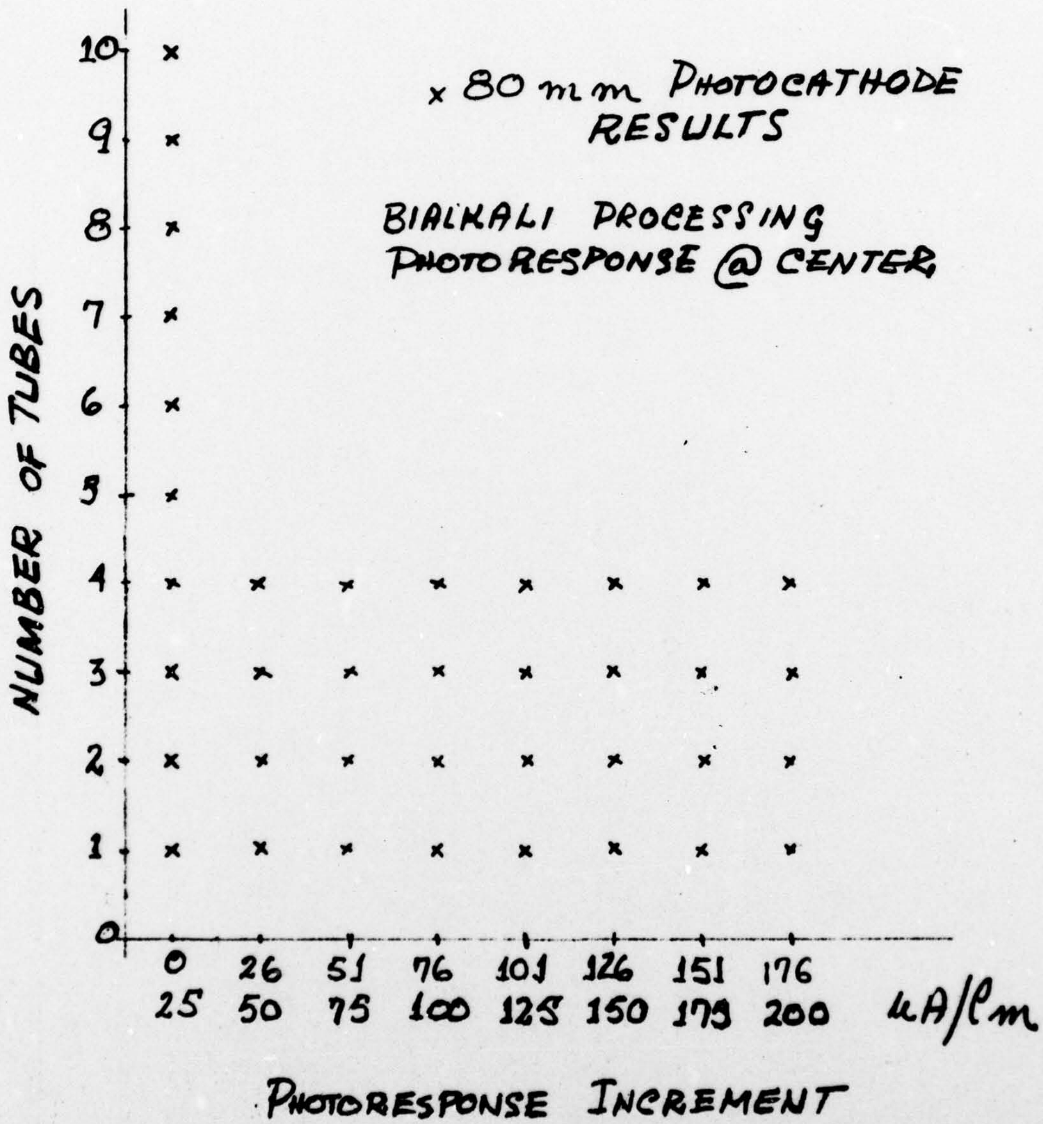



FIGURE 7: PHOTORESPONSE DISTRIBUTION FOR 80 MM TUBES

In additon to the actual recipe for photocathode formation, our plan as indicated in the second phase program, called for glow discharge cleaning of the substrate. This is not a departure from earlier 40 mm photocathode processing procedures but an emphasis of the cleaning step by a longer time of glow discharge at higher gas pressures.

The results of the second phase using this general scheme are shown in Figure 8. These newer results indicated that some semblence of photocathode processing control was achieved. A number of practical difficulties attended the implementation of the scheme or schedule discussed above. Some of the difficulties reflected the method of heating the substrate, some involved unforeseen leakage problems internal to the image section and others involved the distribution of alkali and antimony on the substrate leading to non-uniformities.

From the experience gathered on heating the substrate, the reverse scheme of cooling the substrate with additional higher temperature of the image section appears as an important alternative.

To solve these problems, Westinghouse has embarked on a new program for photocathodes in the 80 mm tube which it will pursue in the future. This involves trials of two basically different schemes: 1) rigid timed sequence of alkali generation and evaporation in proper sequence and throughout the photocathode formation, and 2) co-evaporation of cesium antimony only in the final cesiation step.

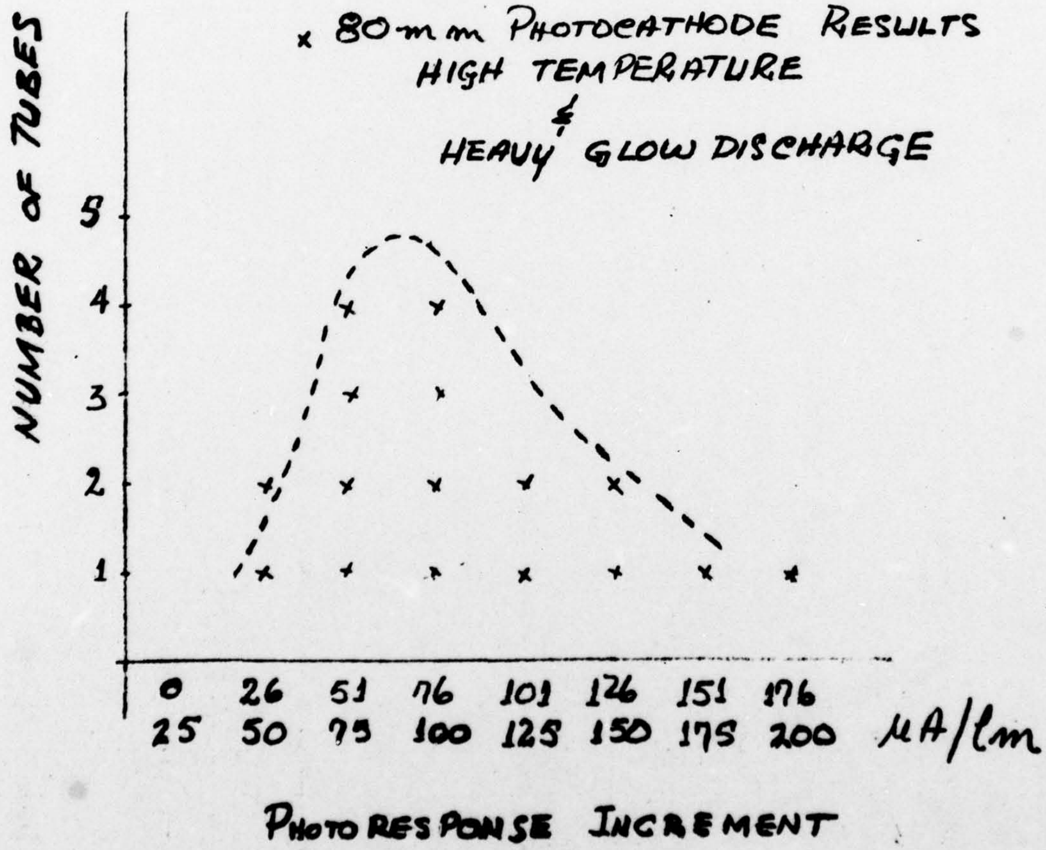



FIGURE 8: PHOTORESPONSE DISTRIBUTION FOR WX-32670
80 mm EBSICON

## 3. TUBE RESULTS

In this section the tube results of all the program plans discussed above will be related. Because the contract involved many tubes and targets as well as hundreds of measurements on both, these results will be recorded in statistical terms.

### 3.1 Point Source Imaging/Resolution

Tube capability of resolving juxtaposed point sources is one of the most important EBSICON parameters measured in this contract. It is common tube practice to specify resolution capability in terms of response to vertical bars of varying spatial density, for example, square wave response or sine wave response. For tubes developed in this program where surveillance of point sources in space is the primary application, a more direct specification of resolution has been adopted in terms of a signal sample area ($A_s$). The signal sample area is the volume of the point spread function divided by its height and thus has a dimension of area. It corresponds to that area in the television output display which arises from a "point" of excitation in the tube photocathode. Below saturation of the EBSICON tube target the signal sample area is related to the tube MTF as described later in the section on tube specifications. For this contract $A_s$ was measured in terms of raster areas and has been evaluated as a function of location on the target (i.e. center and corners), as a function of voltage and for the 80 mm tube as a function of zoom range. In addition, $A_s$ was measured under simulated slow scan conditions for selected tubes.

The predominant number of measurements were made of center $A_s$ and these results are shown in the histogram and frequency distribution sketch of Figure 9. For the tubes sampled the average value of $A_s = 6.0 \times 10^{-6}$ R.A. Low $A_s$ values, between $3 - 4 \times 10^{-6}$ R.A. accounted for approximately 20% of the tubes and high values of $10 - 11 \times 10^{-6}$ R.A., a smaller 8% of the tubes sampled. Lumped into the statistics are results for both tube types but the 80 mm tubes had evidence of lower $A_s$ values.

Attempts at correlation of $A_s$ and square wave response are shown in the sketch of Figure 10. The sketch is for a square wave spatial frequency of 400 TVL/RT.HT. and center $A_s$. Thus, it can be seen that only a trend can be stated, exact correlation was not possible. Again, as stated, low $A_s = 3 - 4 \times 10^{-6}$ R.A. indicates resolution in excess of 50% at 400 TVL/RT.HT. can be expected.

It has been noted in this report that the tubes developed for NVL are designed to have uniform resolution across the target from center to edge. Thus, the 40 mm WX-32719 has a flat image plane as does the 80 mm WX-32670. At 70% diagonal the image plane begins to show curvature and therefore the resolution on a flat target at this point cannot be the same as the center of the target. The measurement of $A_s$ followed this qualitative picture as can be seen in the point source corner results of Figure 11.

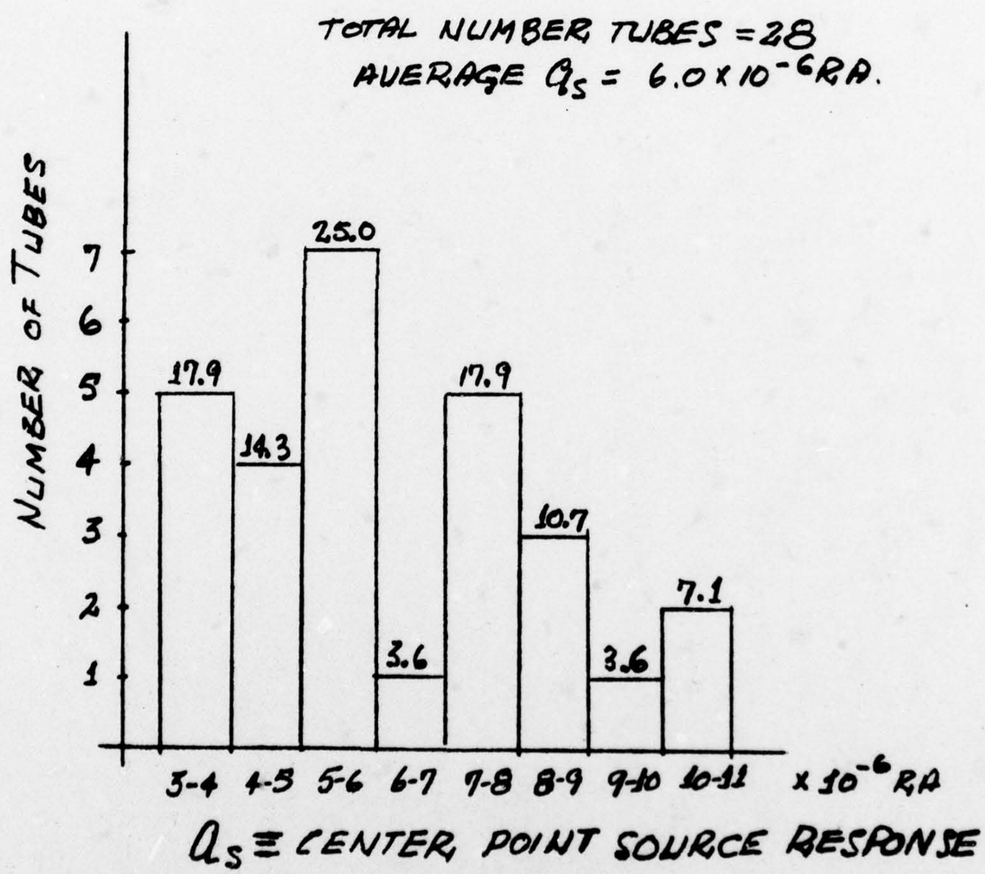



FIGURE 9: $A_s$ POINT SOURCE RESPONSE RESULTS ALL TUBE TYPES CENTER $A_s$ AT HIGH VOLTAGE

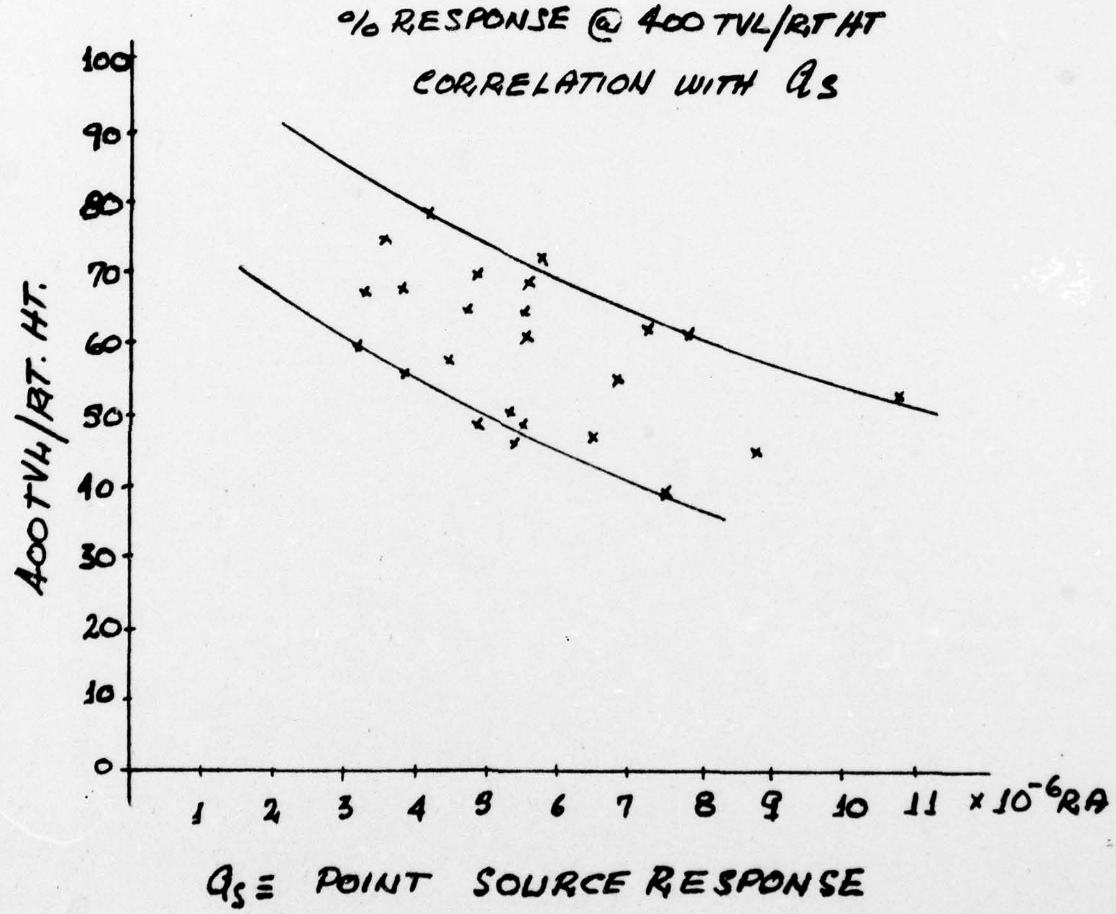



FIGURE 10: $A_s$ POINT SOURCE RESPONSE VERSUS SQUARE WAVE RESPONSE AT HIGH VOLTAGE

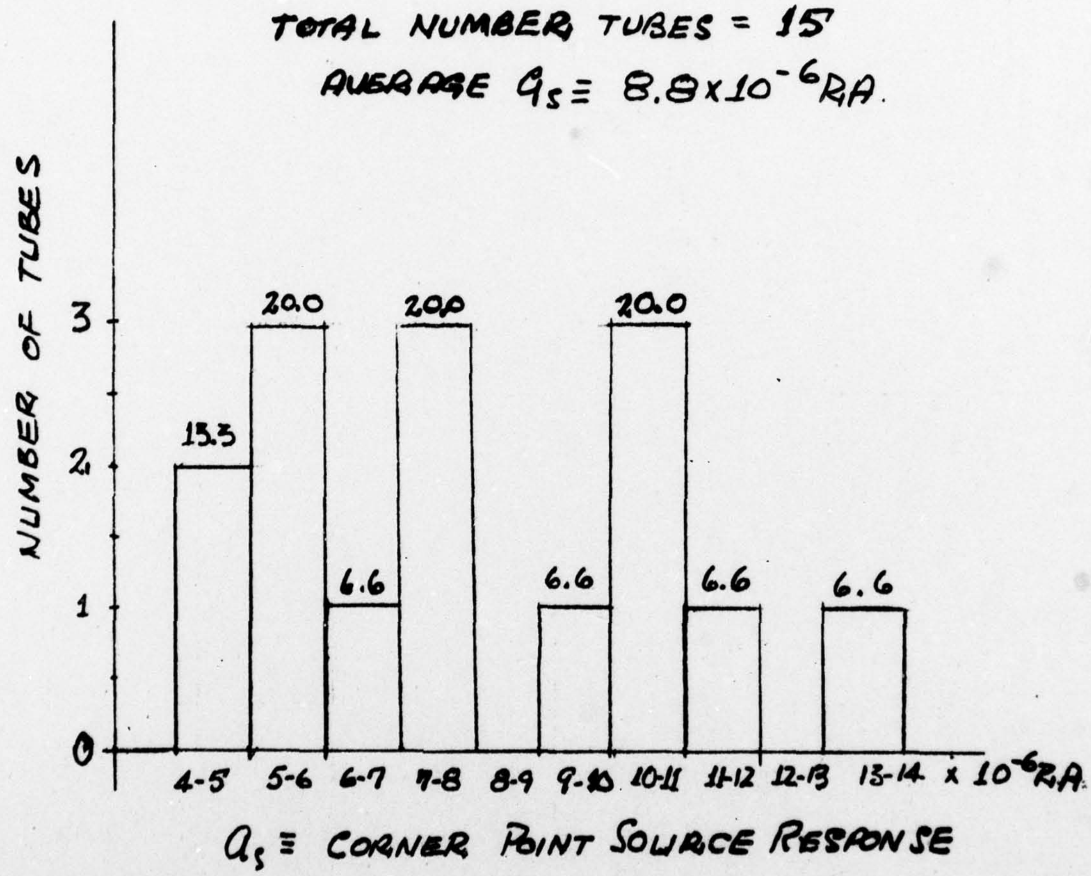



FIGURE 11: $A_s$ - POINT SOURCE RESPONSE AT 70% CORNERS

RESULTS FOR ALL TUBE TYPES AT HIGH VOLTAGE

For the corners of the tubes $A_s$ was measured by refocussing the gun section ($G_3$ voltage) and the average values of the four corners were recorded. Thus, the tubes sampled show these averages to have an average value of $A_s = 8.83 \times 10^{-6}$ R.A. The spread in $A_s$ was similar to the center $A_s$ values with approximately 7% of the tubes showing higher values in the range of $13\text{-}14 \times 10^{-6}$ R.A. Similar statistics have been obtained for center and edge $A_s$ at low voltages, i.e. 4 kV. These results are shown in Figures 12 and 13. All the average values are collated in Table 1 below to allow, at a glance, comparison of the sketched results.

TABLE I

AVERAGE $A_s$ SUMMARY

$A_s$ = Raster Area x $10^{-6}$

| | Center | Min. | Max. | Corner | Min. | Max. |
|---|---|---|---|---|---|---|
| High Voltage 12 kV | 6.0 | 3.2 | 10.7 | 8.8 | 4.0 | 14.0 |
| Low Voltage 4 kV | 6.6 | 3.9 | 10.3 | 8.2 | 4.0 | 12.7 |

**WESTINGHOUSE ELECTRIC CORPORATION**

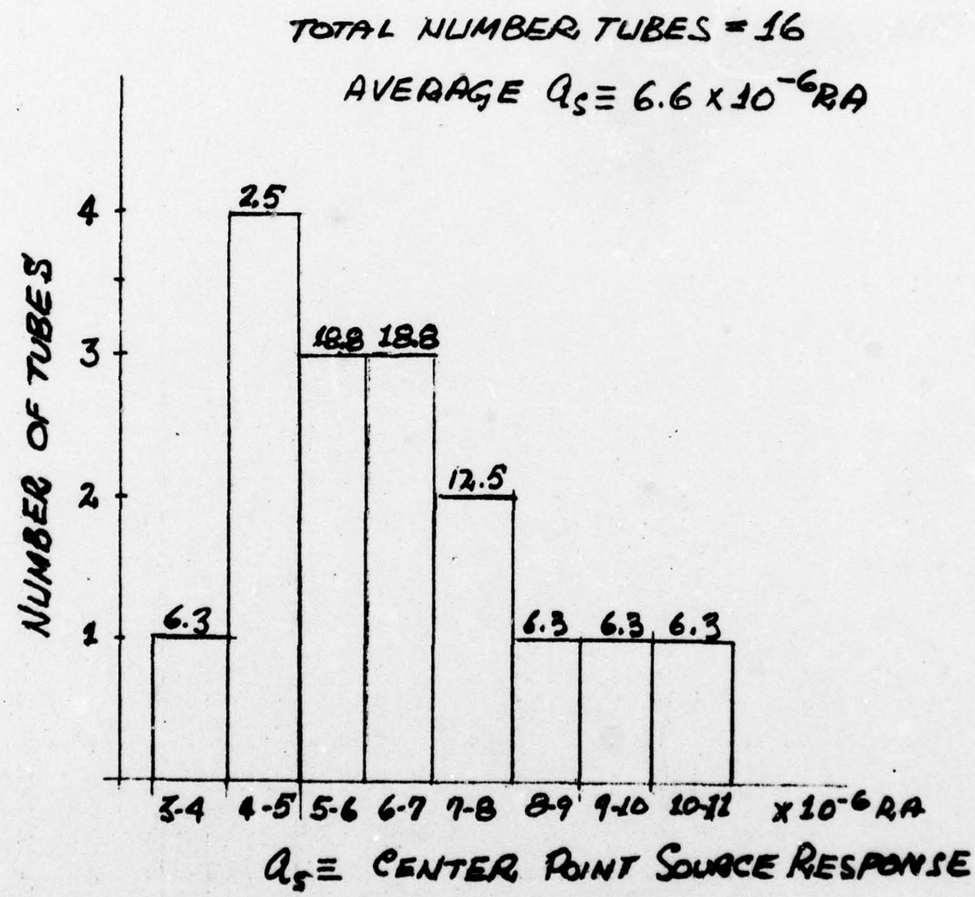



FIGURE 12: $A_s$ POINT SOURCE RESPONSE AT CENTER AND TUBE OPERATING AT LOW VOLTAGE

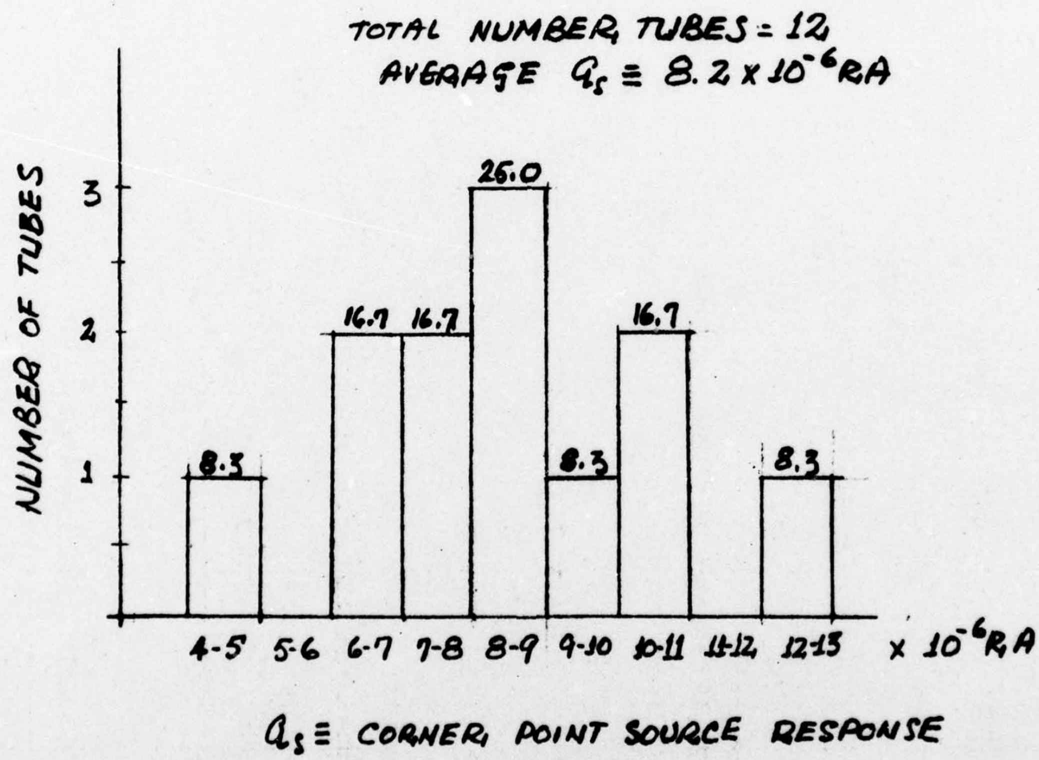



FIGURE 13: $A_s$ CORNER POINT SOURCE RESPONSE WITH TUBE OPERATING AT LOW VOLTAGE

Before concluding the discussion of $A_s$ results, it might be noted that measurements of this parameter were also made under simulated slow scan conditions. In this case the deflection of the beam, as it scans across the target in a given tube, was made to travel at a slower than standard scan velocity; by underscanning a selected portion of the target. Thus, a 32 mm target scanned in a 4 x 3 format has a horizontal dimension of 25.6 mm and vertical dimension of 19.2 mm. Under standard scan conditions of 53 μsec/line, the beam velocity in the horizontal dimensions is $4.8 \times 10^{5}$ mm/sec. Reducing this by a factor used in the simulation studies of 2 and 3, the velocity is $2.4 \times 10^{5}$ and $1.6 \times 10^{5}$ mm/sec., respectively.

Results of $A_s$ as function of the simulated slow scan for a 40 mm tube is shown in Figure 14. In this case the $A_s$ is also measured with various beam settings as indicated.

As expected, because of a longer beam dwell time, the charge in a point source is read out more accurately with a lower beam velocity, hence the $A_s$ values are lower. For example, in the tube tested $A_s = 7.8 \times 10^{-6}$ R.A. under standard scan conditions with a factor of 3 slow down of the beam velocity in the horizontal direction, the $A_s = 7.0 \times 10^{-6}$ R.A. Thus an improvement of 10% in the $A_s$ value is realized by increasing the beam dwell time. Since $A_s$ in these terms is a raster area and the 32 mm silicon target has an area of 492 $mm^2$ the 10% improvement means also that an extra 16,500 $A_s$ units can be resolved for the same raster by slow down of the horizontal beam velocity.

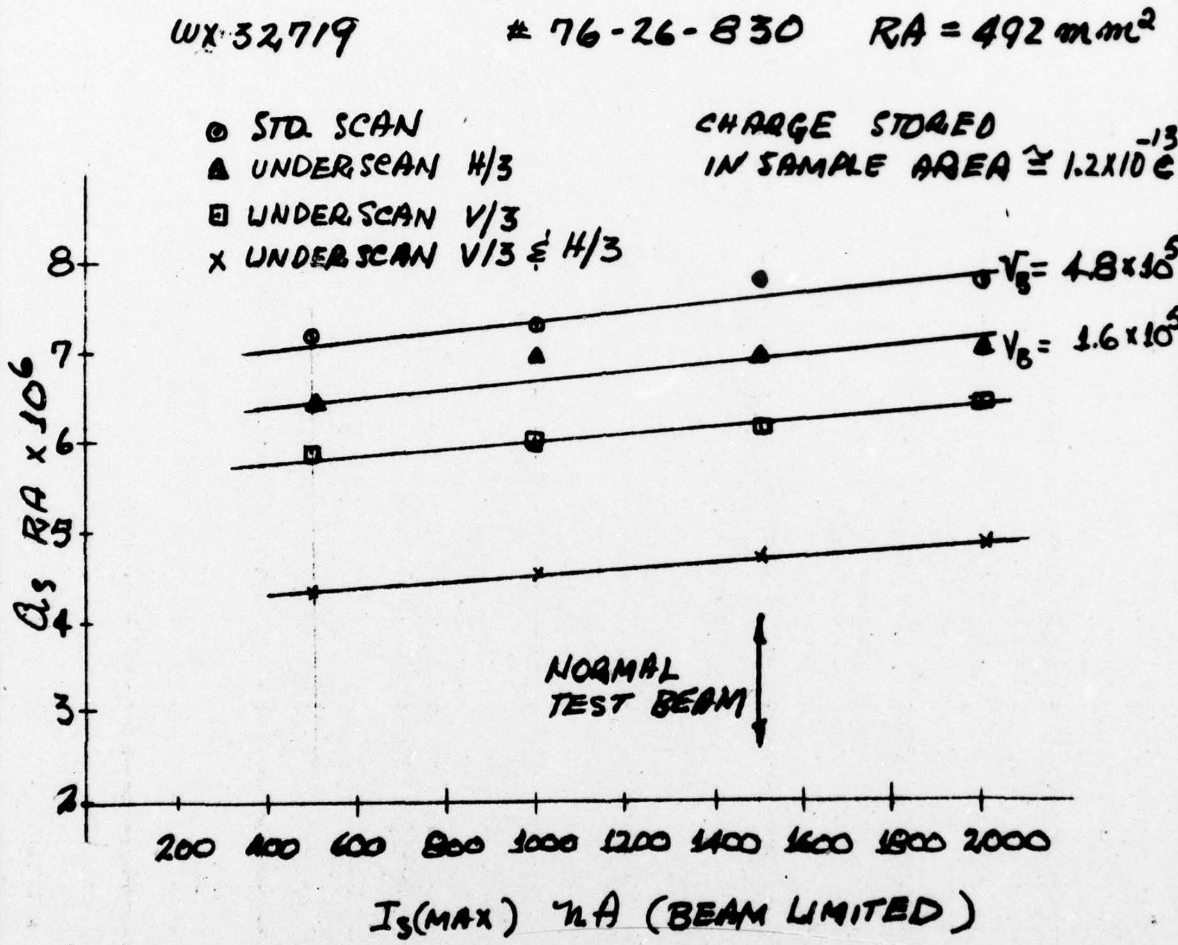



FIGURE 14: DEPENDENCE OF $A_s$ ON MAXIMUM SIGNAL CURRENT WITH SCAN MODE AS A PARAMETER

The example made is for a factor of 3 decrease in beam velocity of the horizontal travel of the beam. A similar underscanning in the vertical direction together with the horizontal underscan is shown in the graph as the bottom line. Here the change is even more dramatic with an $A_s$ change of from $7.8 \times 10^{-6}$ to $4.7 \times 10^{-6}$ or a decrease of approximately 66% for a factor of 9 times underscan. This 9 times underscan involves a reduction in horizontal scan speed of a factor of 3 and an increase in the scan line density of a factor of 3. Likewise, the total beam current used in the measurement has an effect on the $A_s$ value. This is similar to the situation with square wave response measurements in which improvements are obtained with "starved beam" conditions.

## 3.2 Signal Blooming

A second important contract objective was to develop tubes with good blooming characteristics and therefore blooming measurements were made on both tube types. Blooming is the spreading of charge in the silicon diode target resulting from lateral diffusion of holes created in the body of the target. This depends to a large degree on the target's solid state design and the amount of localized charge. Other factors contribute to tube blooming such as fiber optic cross talk and internal light reflections.

During the first phase of the contract tube blooming was measured as spot growth for an initial spot size of 1% of the raster diagonal or .32 mm for the large 32 mm diagonal target used in these tubes.

Results for a sample of both tube types, 40 mm and 80 mm tubes, is shown in Figure 15. Thus, the graph is a plot of the spot growth relative to the initial spot as the illumination in the spot varies from that producing saturation to 100,000 increase in illumination. Because the target is the same in both tubes, the grand average is shown on the same graph. From phenomenological considerations, it is possible to arrive at an effective hole diffusion-recombination length Lp for the targets used. This was done for both tube types and $L_p$ calculated to be $L_p$ = .084 for the 80 mm results and $L_p$ = .134 for the 40 mm results. Although both tubes have the identical targets, this difference in $L_p$ is believed to be due to a statistical variation in groups of targets; for example, variations are found in thickness depending upon target lot.

The effect of differences in targets can be seen in the histogram of Figure 16. This sketch shows that some tubes had exceedingly low values of blooming in the range of 4 to 5 times growth for $10^5$ overload. The maximum growth shows that no tubes measured above 11 to 12 growth for $10^5$ overload.

Following these results a new method of specifying blooming was adopted that utilized the concept of signal sample area $A_s$. In this method a small point source of illumination 60 μ in size is imaged on the tube's photocathode. The resulting temporal width of the point charge on the target is measured and this is converted to an $A_s$ value. The blooming is then given in terms of the value of $A_s$ for which a specified total change is accumulated in the target during a frame time. This new method is described in the Appendix specifications and involves the value of $A_s$ at a given total charge accumulation.

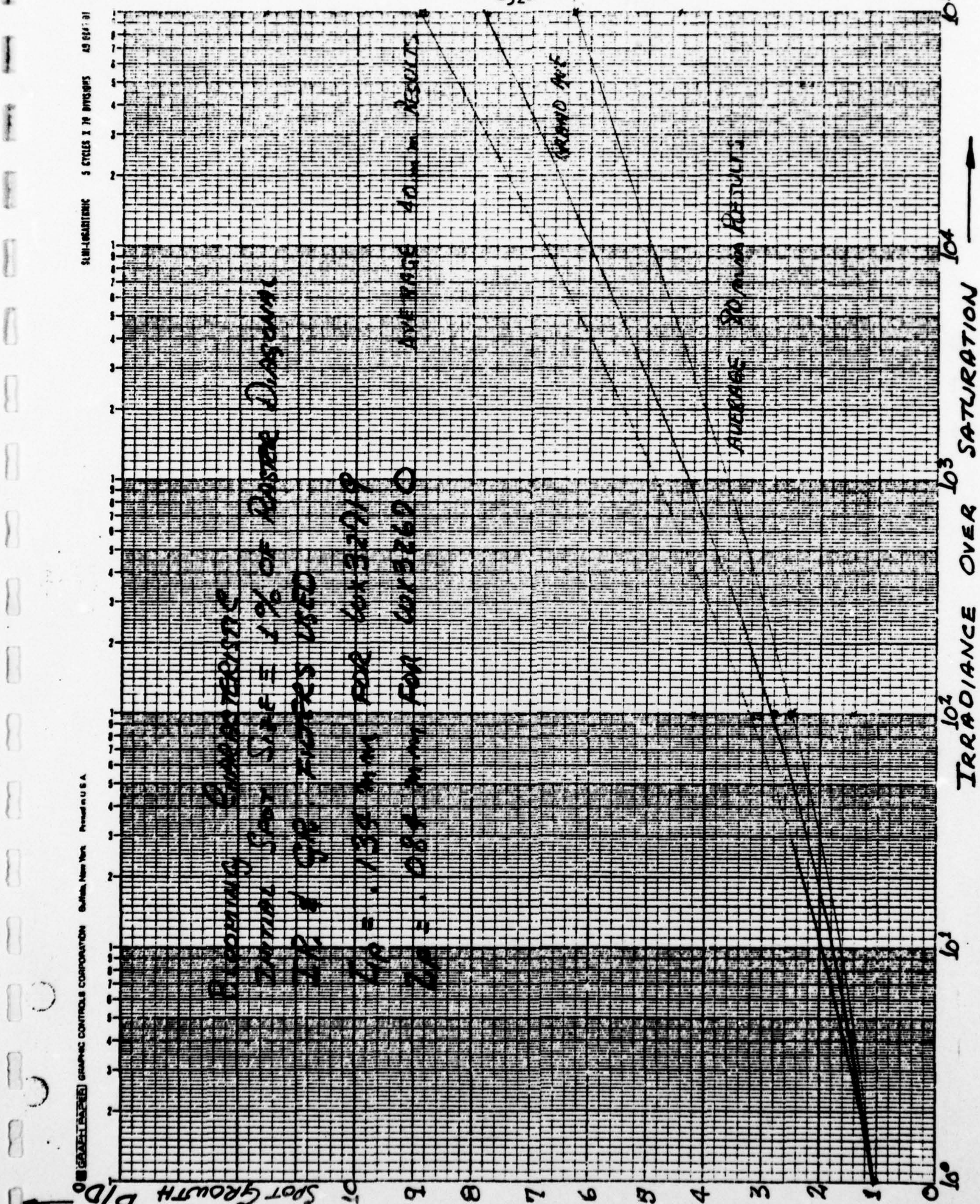

BLOOMING CHARACTERISTIC
INITIAL SPOT SIZE = 1% OF RASTER DIAGONAL
AVERAGE 40 mm RESULTS
GRAND AVE
AVERAGE 20 mm RESULTS
IRRADIANCE OVER SATURATION
SPOT GROWTH D/D0

FIGURE 15

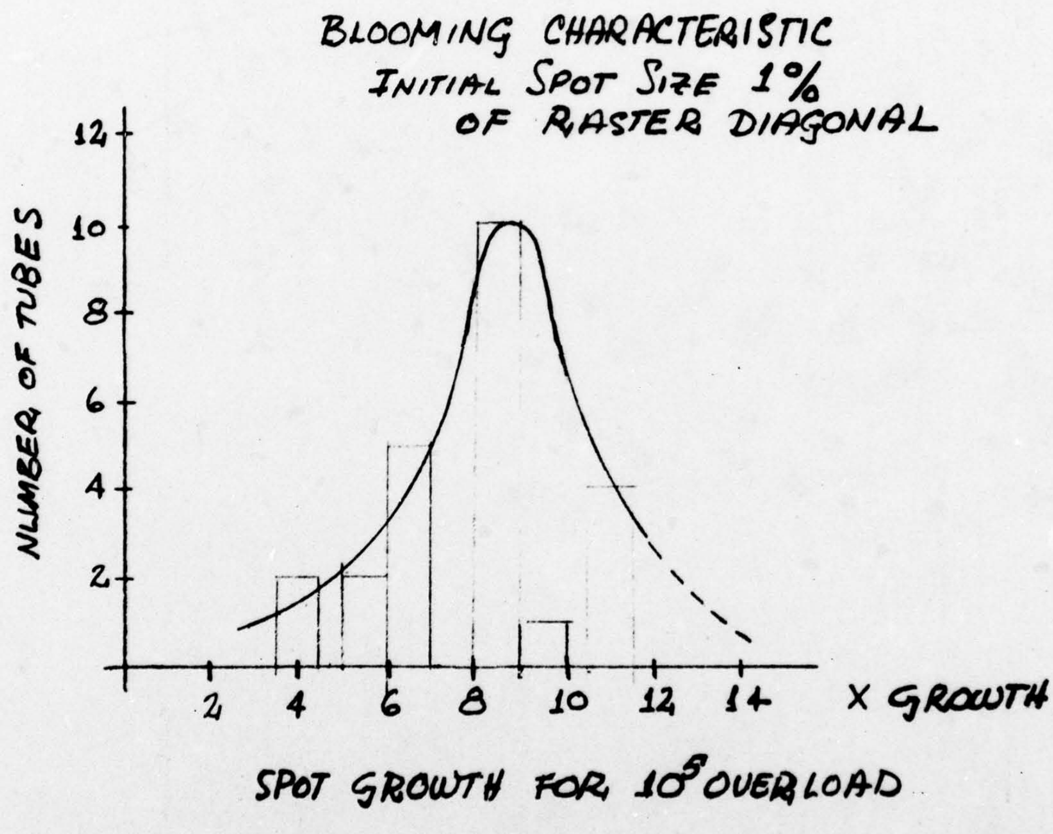



FIGURE 16: SPOT GROWTH FOR $10^5$ OVERLOAD ABOVE SATURATION

Results for several tubes measured or point source blooming are shown in Figure 17. The ordinate $A_s$ value is in terms of raster areas and the abscissa is the value of the charge stored in the target spot. Most tubes follow the same blooming characteristic insofar as the slope of the blooming curve is concerned. On a log - log plot, as shown, the slope in general is less than one for a range of charge values. The spot begins to grow in width at about $10^{-13}$ coulombs and continues to grow with ever increasing illumination. By way of an example, the curve for tube 822 shows an $A_s = 6.5 \times 10^{-4}$ R.A. at $10^{-10}$ coulombs compared to an initial value of $A_s = 8.0 \times 10^{-6}$ R.A. at $1.6 \times 10^{-13}$ coulombs. Thus, the area of the initial spot has increased 81 times in 625 times increase in illumination.

3.3 Saturation Signal

The silicon diode array target in common with any charge storage device can retain a finite amount of charge. This amount depends mostly upon the target design, i.e. its geometrical configuration, silicon wafer conductivity, reverse bias, etc. Because of this, not a great deal could be accomplished by Westinghouse to optimize performance regarding saturation signal. What could be done is determine the quantitative values that could be assigned. the various targets received and operate the diode target at a bias which would maximize the saturation signal current while at the same time offer optimum performance in other parameters.

To arrive at target saturation signal values tubes were run in the underscanned mode and illuminated to produce saturation. Evidence of saturation was obtained by visual checks of overload washing out of the video signal and by highlight signal compression of the local signal in a black to white area of the target.

Approximately twenty tubes were measured for saturation signal by underscanning. Some of the results are shown in the histogram of Figure 18. The minimum saturation signal measured was 600 nA and the maximum 2000 nA. The average value for this parameter indicates a saturation signal of 1166 nA was typical. Because these measured values are obtained for a target underscanned by 9 times, they show an average saturation signal of 10,494 nA. That is the target would be capable of storing 10,494 nA x $\frac{1}{30}$ sec. = $3.49 \times 10^{-7}$ coulombs of charge.

This high capability of charge helps in two important EBSICON characteristics, dynamic range and low light level imageing. Thus, a large dynamic range can be accommodated and, in fact, the 80 mm EBSICON eg can cover four to five orders of increased illumination before the read beam becomes exhausted of charge. At the other end of the illumination scale the large saturation capability makes it possible to integrate low photon flux for proper signal to noise processing in camera tube systems.

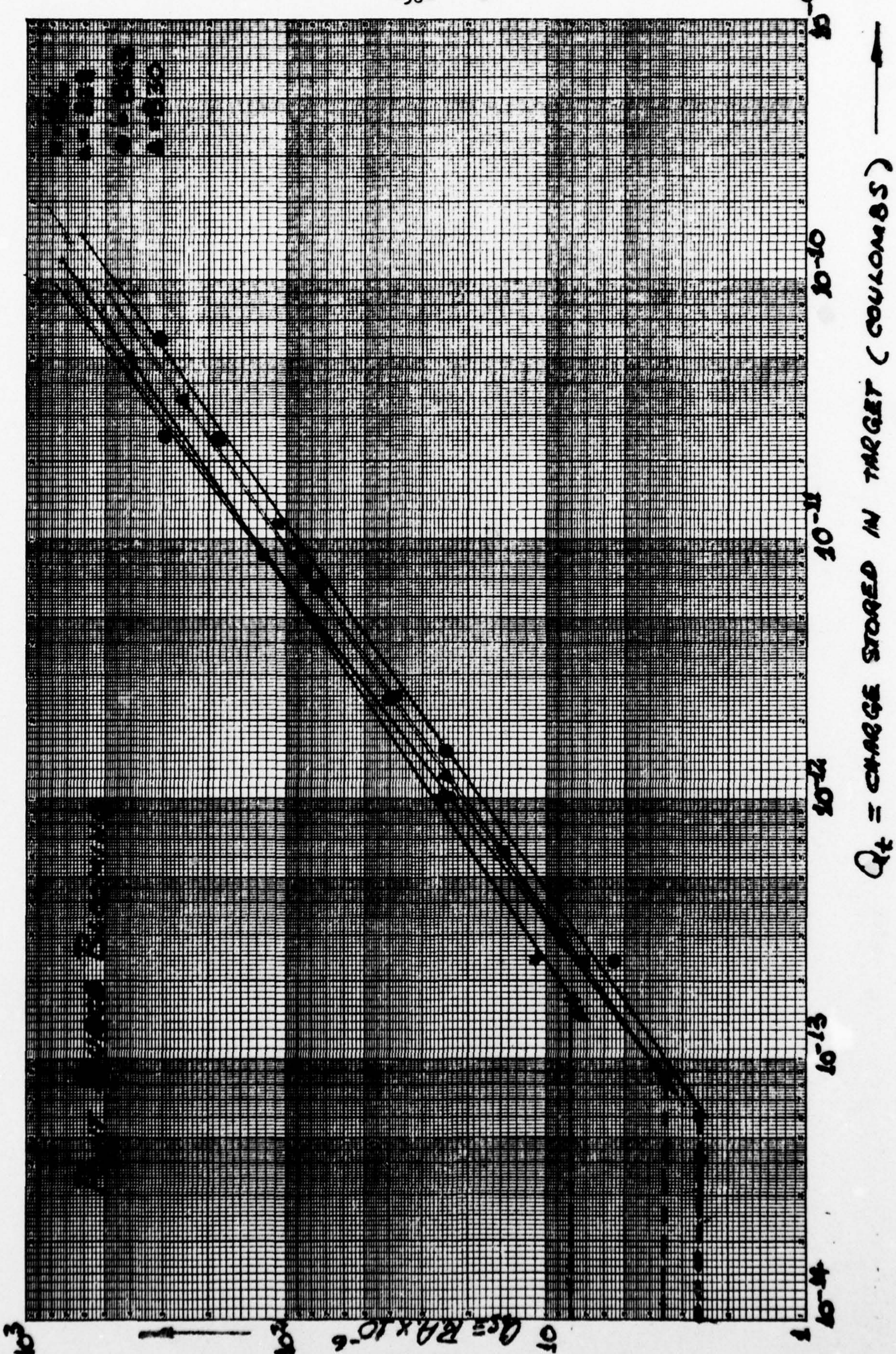

Qt = CHARGE STORED IN TARGET (COULOMBS)
Qs = RA x 10^-6
10^-14
10^-13
10^-12
10^-11
10^-10
10^-9
1
10
10^2
10^3

FIGURE 17

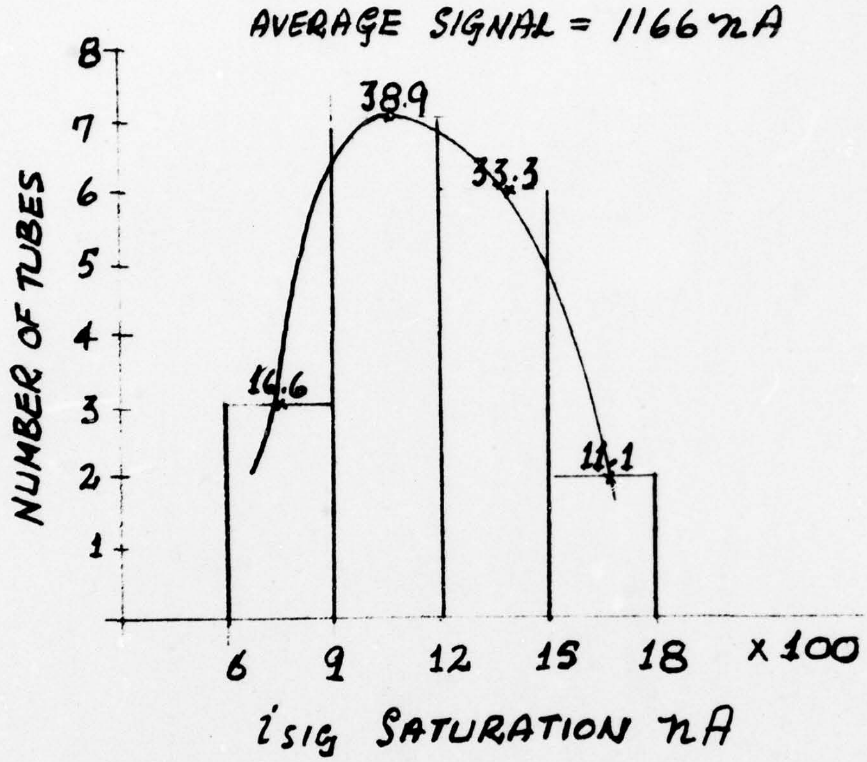



FIGURE 18: DISTRIBUTION OF SIGNAL CURRENTS AT SATURATION

3.4 Residual Signal/Lag

Another parameter that involved our attention throughout this development program was tube lag. Briefly, it should be stated that the standard method of developing a TV image is to scan every element of the EBSICON target with an electron beam. The image element on the target is a collection of holes which must be neutralized by electrons from the read beam. This act of neutralization produces the element signal. Scanning every element in a line and every line in the target raster constitutes the total signal. Not all the charge is neutralized in one complete scan of the raster and therefore the beam must be made to retrace its path for further attempts at neutralization of holes.

The percentage of a signal that remains 50 msec. after light is removed from the EBSICON is termed $3^D$ field lag. Third field lag measurements were generally those made for this contract to characterize the tubes. Some special determination of lag was made for simulated slow scan conditions and other than third field lag for lifetime studies of lag.

The EBSICON $3^D$ field lag measured for initial signal of 500 nA and 800 nA and rated high voltage is catalogued in Figure 19. Especially, it should be noted these are results for a large array 32 mm active diameter target. A similar target of smaller diameter would appropriately scale down the lag results. Thus, the average lag observed for an initial signal of 800 nA is about 17% for all tubes sampled. On the other hand, the average lag increases for lower signal of 500 nA to a value of about 25%.

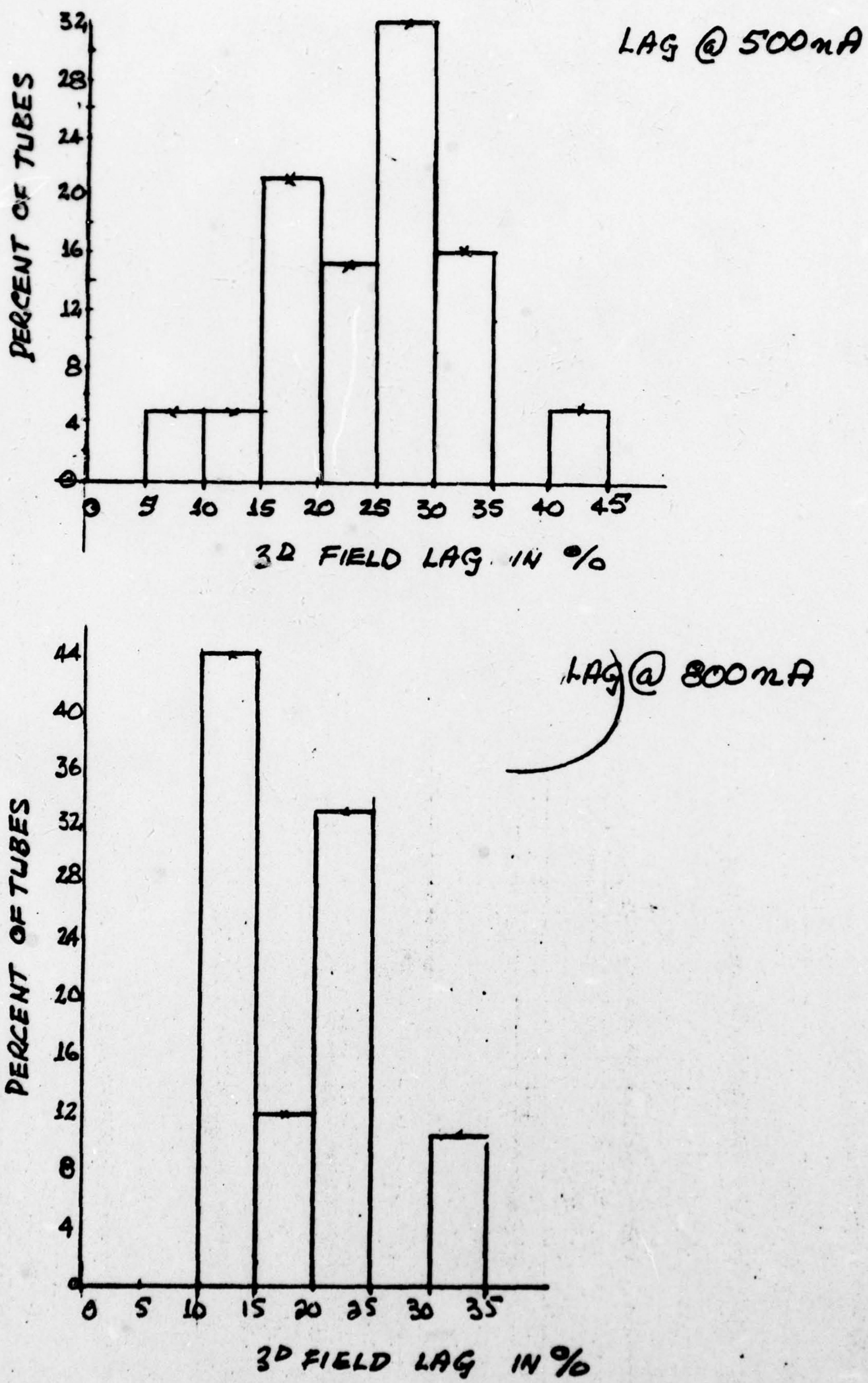



FIGURE 19: LAG DISTRIBUTION - WX-32719 AND WX-32670

It should be noted that all targets used in tubes made are shown in these distributions, including a limited number of G.E. targets. If the T.I. targets only were to be considered the lag distribution would exclude some of the higher lag values shown.

Some targets showed exceptional lag characteristics and these were selected for more in depth studies of this parameter. Results to be described were also compared to the target vendor data and in cases such as the one below, information and data was relayed back to N.V.L. and T.I. regarding the particular target used. In this way new information was made available in order to make possible beneficial changes in target fabrication.

TABLE I

| T.I. Demountable Data | (W) Demountable Data | (W) Tube |
|---|---|---|
| $I_D$ = 38 nA | 24 | 14 |
| 400 TVL/Resp. - 14% | 28 | 52 |
| $3^D$ Lag Field - 9% | 38 | 15 |
| Blemishes - Many<br>Blk. | 3 @ 3<br>1 @ 3 | Zone 1 - None<br>Zone 2 - 3<br>Zone 3 - 3 |

We discovered this particular target showed a constant lag characteristics at signal current used in operational test 800 nA and greater but was variable below 800 nA. The functional characteristic is shown in Figure 20.

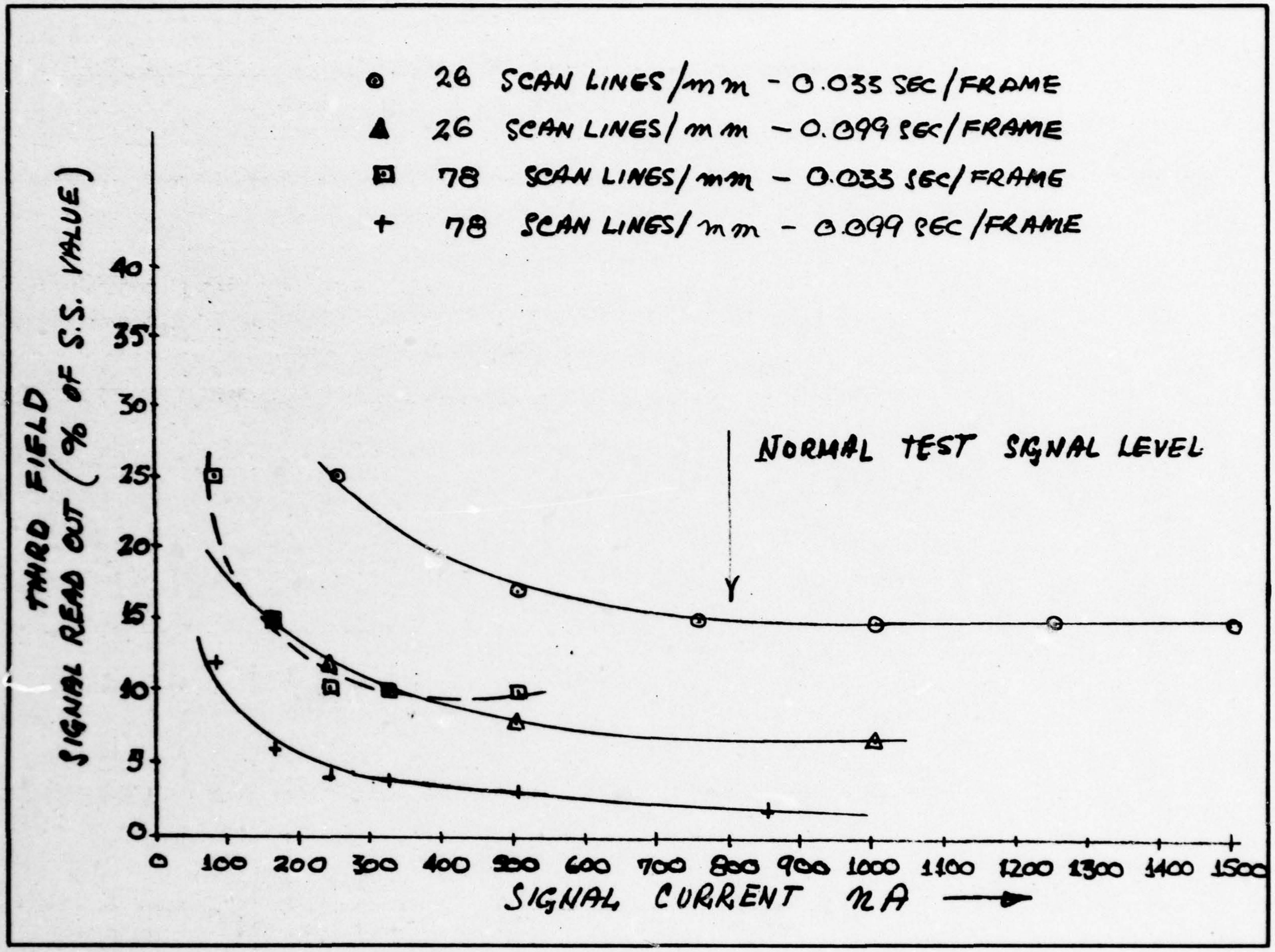



FIGURE 20: LAG VS. SIGNAL CURRENT AT VARIOUS SCAN LINE DENSITY

With an increased dwell time of the beam the charge neutralization process described above becomes more efficient as the second curve for .099 sec./frame shows. The largest decrease in lag came from an increased dwell time and increase in line density. Thus, the curve for this set of conditions shows the third field lag to be about 2-1/2% at 800 nA.

It is interesting to speculate as to the physical, perhaps fundamental reason not evident in the data as to how this particular target showed low lag. It is in fact at the low end of the lag distribution for both 500 nA and 800 nA signals. This particular target had a diode coverage of 88%. That is the diodes of the target covered the scan raster to that extent and the remaining area consisting of silicon oxide is 12%. So it can be surmised that the target once primed with charge could accept a number of electrons proportional to its diode coverage, i.e. charge transfer is efficient. A microphotograph of the target magnified 710 times is shown in the photograph of Figure 21.

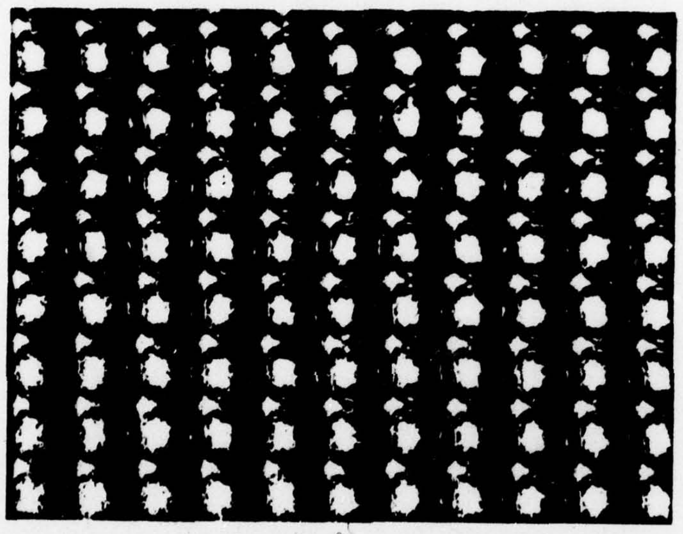


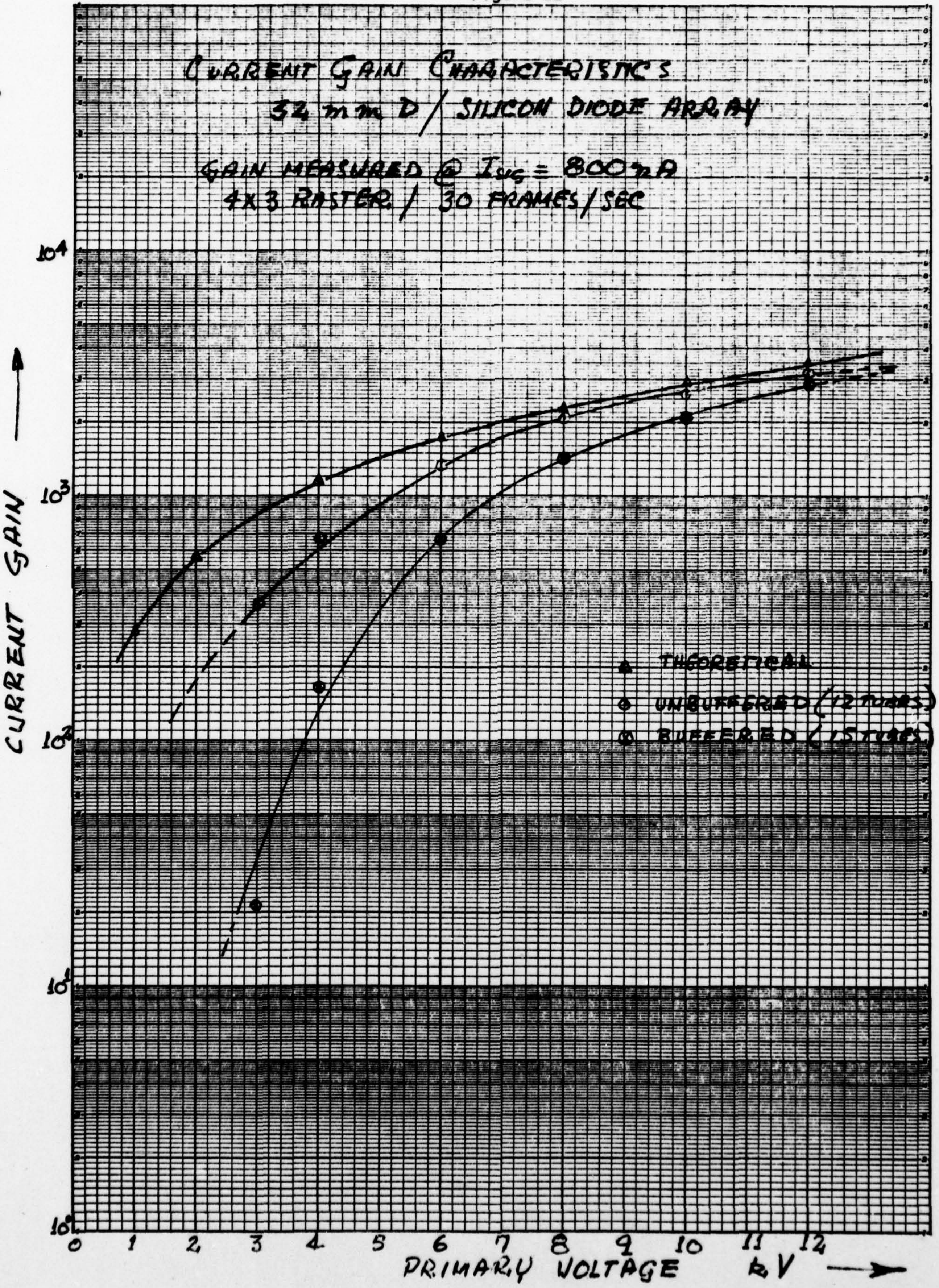
FIGURE 21: PHOTOGRAPH OF AN EBSICON TARGET
DIODE SIDE - MAGNIFIED 710X

## 3.5 Target Gain

One outstanding feature of an EBSICON is the target gain. By target gain is meant the amount of charge created in the body of the target for a given charge input to the target. In the EBSICON the charge created depends on the bombarding energy of the photoelectrons penetrating the target. Calculations based on an idealized model of electron energy loss in penetrating a silicon wafer predicts creation and storage of one hole for every 3.5 ev of incident electron energy. Thus, at the nominal tube operating potential of 12,000 volts, the charge stored in the silicon diode target is 12,000 ev/3.5 ev/hole - or 3428 holes. The result of this calculation for a range of tube operating voltages is shown in Figure 22. Since the theoretical values are based on an ideal model experimentally obtained values would be expected to be lower. In practice, the current gain is measured rather than charge gain and results of gain measurements are presented in this way. For conversion to charge gain the multiplying factor of .765 must be used.

Figure 22 shows the results obtained for a raw target and buffered targets. The raw target gain curve shows that values very close to theoretical gain can be obtained in a tube, especially at high voltages. This curve is an average curve obtained from a dozen tubes fabricated with targets as received.

Figure 22


CURRENT GAIN CHARACTERISTICS
32 mm D / SILICON DIODE ARRAY
GAIN MEASURED @ I_SIG = 800 nA
4X3 RASTER / 30 FRAMES/SEC
THEORETICAL
UNBUFFERED (12 TURNS)
BUFFERED (15 TURNS)
CURRENT GAIN
PRIMARY VOLTAGE kV
10^4
10^3
10^2
10^1
10^0
0
1
2
3
4
5
6
7
8
9
10
11
12

Gain values of 3000 at 12 kV are very close to the theoretical 3500. The buffered target tubes show gain characteristics with more curvature and reduced absolute gain. Thus, at 12 kV the buffered target is generally down 10% in gain and at 4 kV, down by a factor of 5' compared to unbuffered targets.

Buffering of targets consists of adding a metallic film to the silicon for the purpose of adjusting the gain range in an operating voltage range. Because of a greater gain range capability a buffered target tube, as utilized in a camera system, can accommodate larger variations in illumination. With the buffer films used by Westinghouse the curve shows the average range between 12 and 4 kV to be approximately 20 to 1.

As remarked, high gain is a unique feature of the EBSICON. For reader clarity, only averages have been shown in the curves. It is rare however, to find targets made for this program to have low gain. The lowest gain measured at 12 kV for a particular unbuffered target was 920. In practice, the gain can be even higher than shown for the silicon diode target, providing the higher voltages required for higher gain can be imposed on the EBSICON. Generally EBSICON tubes are capable of being stressed higher than 12 kV. Gain measurements made for several tubes show an average gain of 4100 and 5050 at 14 kV and 15 kV, respectively.

## 3.6 Dark Current - Target Effort

The specific contract items of tube performance have been discussed above. A target performance characteristic that has been omitted is target dark current. This is discussed briefly below together with the general target effort.

The Westinghouse target effort consisted in the proper utilization of over 130 large silicon diode array targets. That is, a good target would be used in the 40 mm EBSICON rather than in the 80 mm if a choice was necessary. This was because the 40 mm was in greater need and the 80 mm tube performance was being explored. Making a target choice required the collection of significant data; pre-tube type fabrication. The following general procedures were used prior to tube assembly.

- Target visual inspection - High magnification optical checks of diodes and wafer - Determination of diode coverage.
- Demountable test of dark current, resolution lag and quality.
- Chemical clean, wash, rinse and dry.
- Buffer filming.
- Inspection for final assembly.

Results from these tests and inspections were analyzed, cross checks made with T.I. demountable information and choide made for a particular tube. Heading the list of target items tested in the Westinghouse and T.I. demountable is dark current. As used in an EBSICON the dark current has three contributions: the inherent leakage of the silicon diodes, current from stray light emission in the tube (eg from the heater) and "front end" target leakage derived from thermal emission of the photocathode/or field emission. The inherent leakage is by far the main contribution to dark current and as is well known is dependent upon the silicon diode configuration and starting material. It also is known that the dark current has a thermal dependency generally found to be a doubling in value for every 10 degree rise in temperature.

A target, as used in the EBSICON tubes, reflects all these contributions in the measured value of dark current. In both tube types of the contract we have minimized the amount of light from the heater by design. This is done by means of a light shield around the heater. The tube's construction and target buffer films also are designed to minimize the front end leakage contributions. Thus, the dark current results of a large number of tubes generally show the true value of dark current. These results are shown in the dark current histogram of Figure 23. Average values of dark current for the full raster area of 5 $cm^2$ is found to be 30 nA with extreme values of 10 nA and 95 nA. At least 70% of the targets received from T.I. measured dark current of $\leq$ 40 nA. The 40 nA value is that considered to be a Class A target specification for the target manufacturing program. On the basis of target area the dark current of 40 nA represents a density of 8 nA/$cm^2$ which is a respectable dark current value for the large silicon diode target.

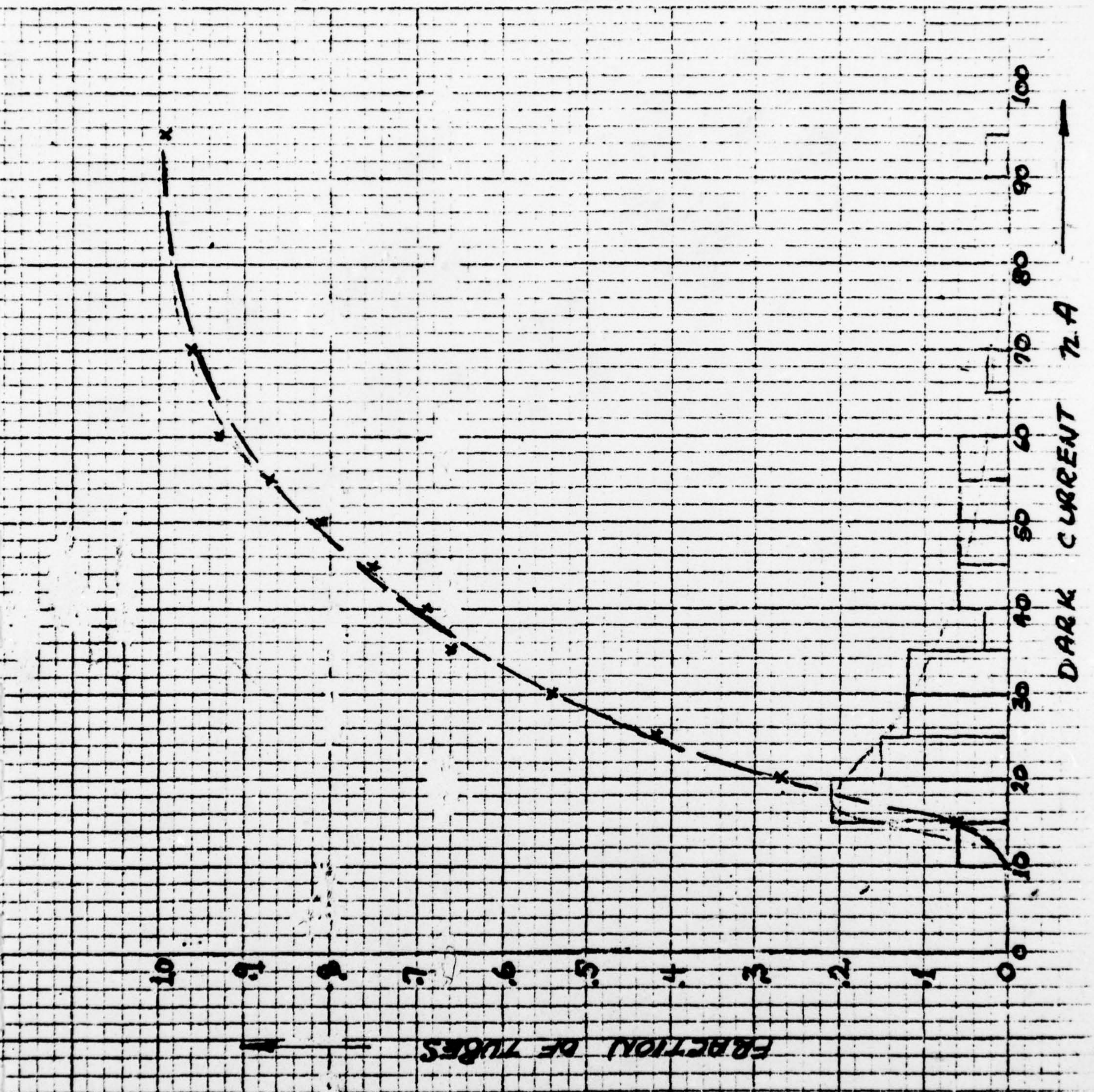



FIGURE 23: DARK CURRENT DISTRIBUTION

## 3.7. Gun-Coil Results

As discussed and shown above, the properties of the image sections used in the EBSICON were known, theoretically through electron optics study and practically from tube building and testing. The silicon diode target array was studied to determine some ot its properties. The electron gun and coil remained as the last major tube component to study and investigate. Time did not permit an exhaustive investigation, however a modest effort was undertaken to make electron-optical calculations and empirical measurements of the available gun design. Knowledge of the gun-coil properties, in particular resolution could be added to that of the image section and target to complete our picture of the EBSICON tubes.

To study the gun and coil three special tubes were made for test purposes. These tubes were made without an image section and without the silicon diode target. The tubes retained the 1-1/2" gun and mounting hardware exactly as the EBSICON. In place of the silicon target a high resolution non-array storage photo conductor was used. The target in size (32 mm diameter) and location relative to the electron gun was a duplicate of any completed EBSICON. The coil used for the study was also a copy of the coil generally used for the EBSICON except the deflection coils were adjustable in position relative to the gun and to some degree adjustable in diameter.

For the electron optic's properties the gun-coil combination was modeled in two sections: the primary electron producing section of the gun, cathode and accelerating electrodes and the secondary section including magnetic focus and deflection of the electron beam.

The computer program used was similar to that described above in section 2.2.1. The additional focus magnetic field strengths required for the model were taken as those actually used in the focus coil. The deflection coil was simulated as two single turns wrapped around the outside of the main focus coil. The electron-optic properties we determined using the gun-coil model are discussed below. Basically, these are crossover points for electrons emitted from the primary section, focus points of the electrons at the target and estimates of resolution at the target.

Electron-Optic Summary

Figure 24 shows a computer plot corresponding to an electron beam half angle $\alpha = 0.2°$. In this figure, the Z direction scale is compressed by a factor of 25. Focal points marked by a cross are for electrons initially traveling in the X-Z plane of the diagram and those marked by a circle are for electrons initially traveling perpendicular to that plane Y-Z plane. These are not true foci in the optical sense, but merely minimum blur positions. The diameter of the blur for the two different planes and at various positions on the target, is a measure of deflection defocussing. The calculated results are shown in Table 1.

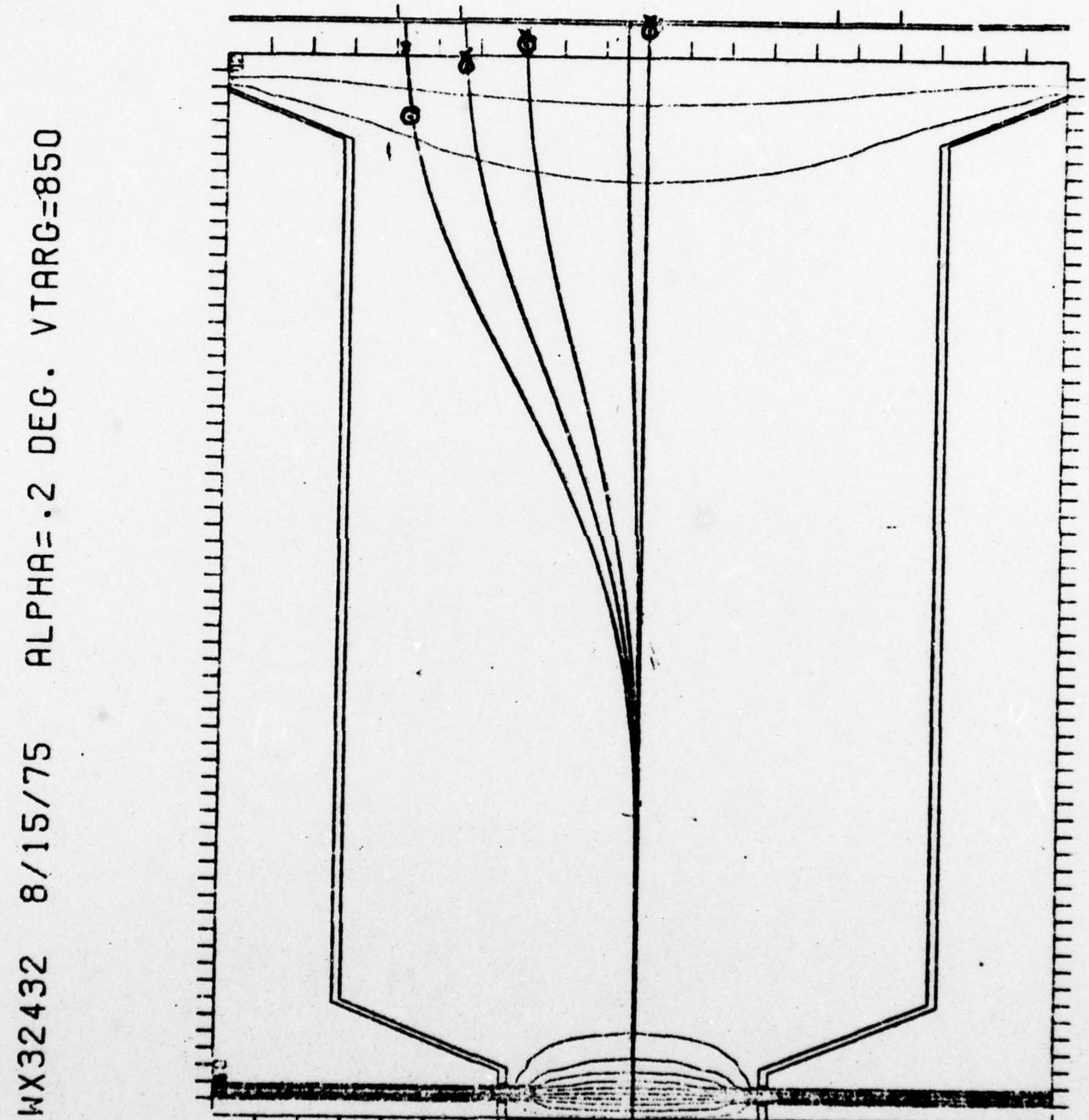



FIGURE 24: ELECTRON GUN E-O RAY TRACE

## TABLE I - DEFLECTION DEFOCUSSING

Contribution to Electron Spot Diameter For Each of Two Directions

| | Target Position mm Radius | Dia. @ Target mm | Dia. @ Focus mm |
|---|---|---|---|
| | Center | 0 | 0 |
| | 1.3 | .001, .001 | .001, .001 |
| | 7.9 | .046, .032 | * .030 |
| 75% of Target Diagonal → | 11.9 → | .106, .068 → | * .058 |
| | 15.7 | .198, .108 | .196, .090 |

The actual electron spot diameter at the target, due to direct imaging of the .001" limiting aperture in the gun, was calculated to be .02 mm. Use of the paraxial spot size was added to the above deflection defocussing by $d^2 = d_o^2 + d_2^2$ to obtain an estimate of the limiting resolution. The results compounded in this way are shown in Table II.

## TABLE II

## LIMITING RESOLUTION ESTIMATES

| | Target Position mm Radius | Limiting REZ $\alpha = 02°$ | Limiting REZ $\alpha = 2°$ |
|---|---|---|---|
| | Center | 49 lp/mm | 49 lp/mm |
| | 1.3 | 49 | 43 |
| | 7.9 | 23 | 3 |
| 75% of Target → | 11.9 → | 12 → | 1 |
| Disgonal | 15.7 | 7 | .7 |

Thus, the E-O calculations predicted for the electron gun being used a limiting center resolution of approximately 50 lp/mm and 12 lp/mm at the edge of the target (edge being defined at 75% of target diagonal 24 mm).

Experimental Tube Test Summary

The gun experimental tubes were tested for center and edge resolution. We performed the tests at various primary gun section voltages and focus voltages. In addition, to correlate with the E-O studies, we investigated resolution at differing axial positions of the deflection coil and two specific diameters of the deflection coil.

Some of the important results from the experimental tubes were shown in the curves of Figure 25. The edge resolution measurements are averaged over all four corners of the target raster, with the corners defined as 75% of the raster diagonal. We observed a limiting center resolution of 2000 TVL/RT HT with the experimental tube, comparing favorably with the E-O estimated value of 2214 TVL/RT HT. At 75% of the diameter the tube showed an average 1800 TVL/RT HT. Compared to a calculated 542 TVL/RT HT the tube resolution was up by a factor of 3. We believed the discrepancy to be the result of improper modeling of the deflection field in the vicinity of the raster edges. A second computer calculation made with modified deflection field showed improved calculated performance of 1000 TVL/RT HT. The center resolution remained approximately as given. Because these calculated E-O values were low by comparison with the real experimental tube the E-O studies were abandoned in favor of direct experimental results.

The resolution values observed and quoted above are the maximum resolutions shown in the figure. These are in fact what was compared with E-O calculations. Resolution properties at other spatial frequencies are also important. For example, there is general interest in the spatial frequencies of 400, 600 and 800 TVL/RT HT, because these points taken together with the limiting resolution are sufficient to define the total response. The experimental tube measured at these points average 90, 80 and 63% response. The edge response for the same three frequencies measured 83, 60 and 43%.

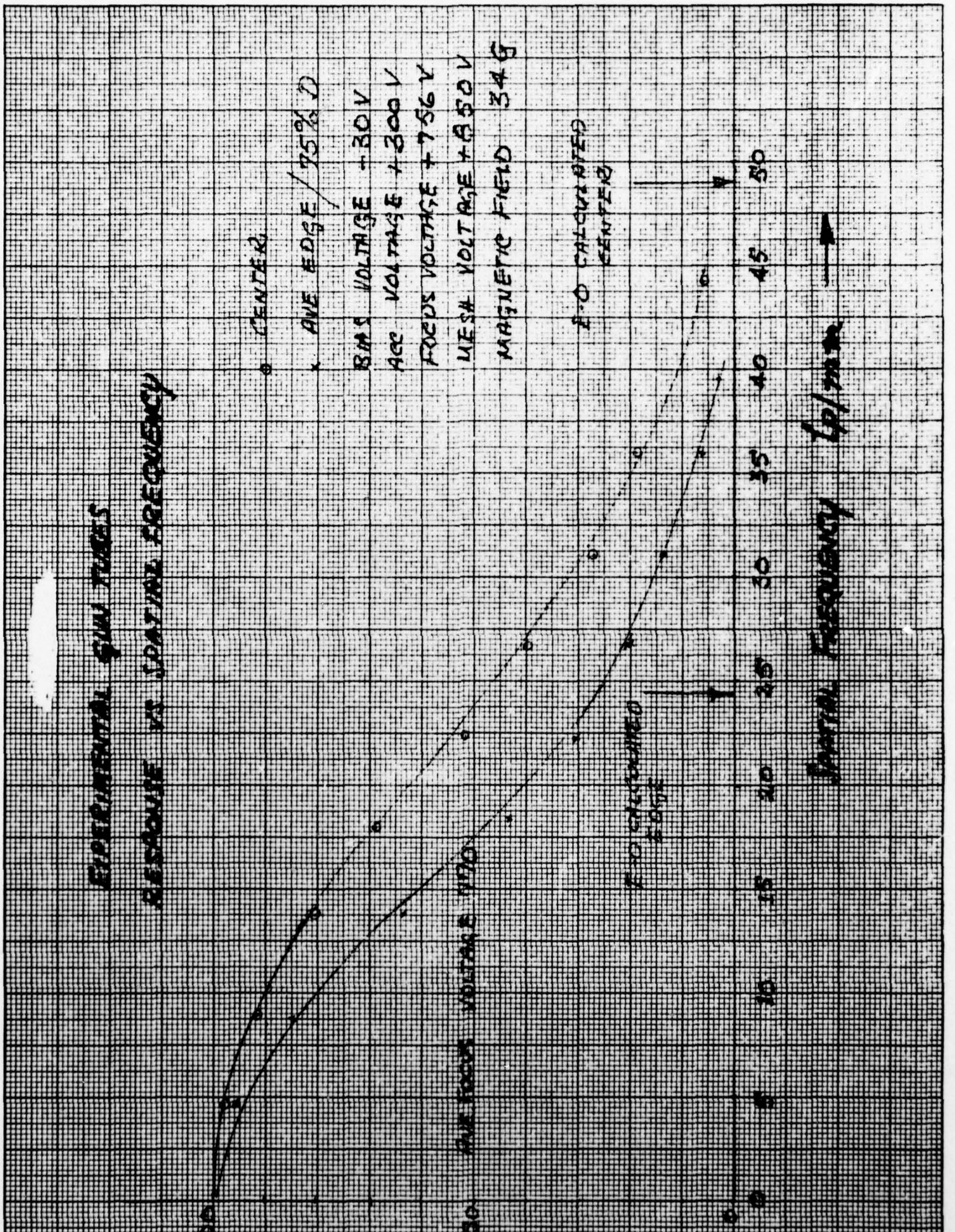

EXPERIMENTAL GUN TUBES
RESPONSE VS SPATIAL FREQUENCY
⊙ CENTER
× AVE EDGE/75% D
BIAS VOLTAGE -30 V
AGC VOLTAGE +300 V
FOCUS VOLTAGE +756 V
MESH VOLTAGE +850 V
MAGNETIC FIELD 34 G
E.O CALCULATED CENTER
E.O CALCULATED EDGE
AVE FOCUS VOLTAGE 770
RESPONSE %
SPATIAL FREQUENCY Lp/mm
100
50
0
5
10
15
20
25
30
35
40
45
50

FIGURE 25

Thus, we determined the gun resolution properties as a separate tube entity. If the silicon diode array target resolution were known we could, at this point, combine the image section, gun and target resolution performance of the EBSICON. To arrive at target resolution response an estimate was calculated based on diffusion of holes in the target. The result of the gun response, image section response and target estimates are plotted together in Figure 25. By combining all three curves as a product result for the three spatial frequencies selected, we arrived at the predicted overall resolution of the bottom curve.

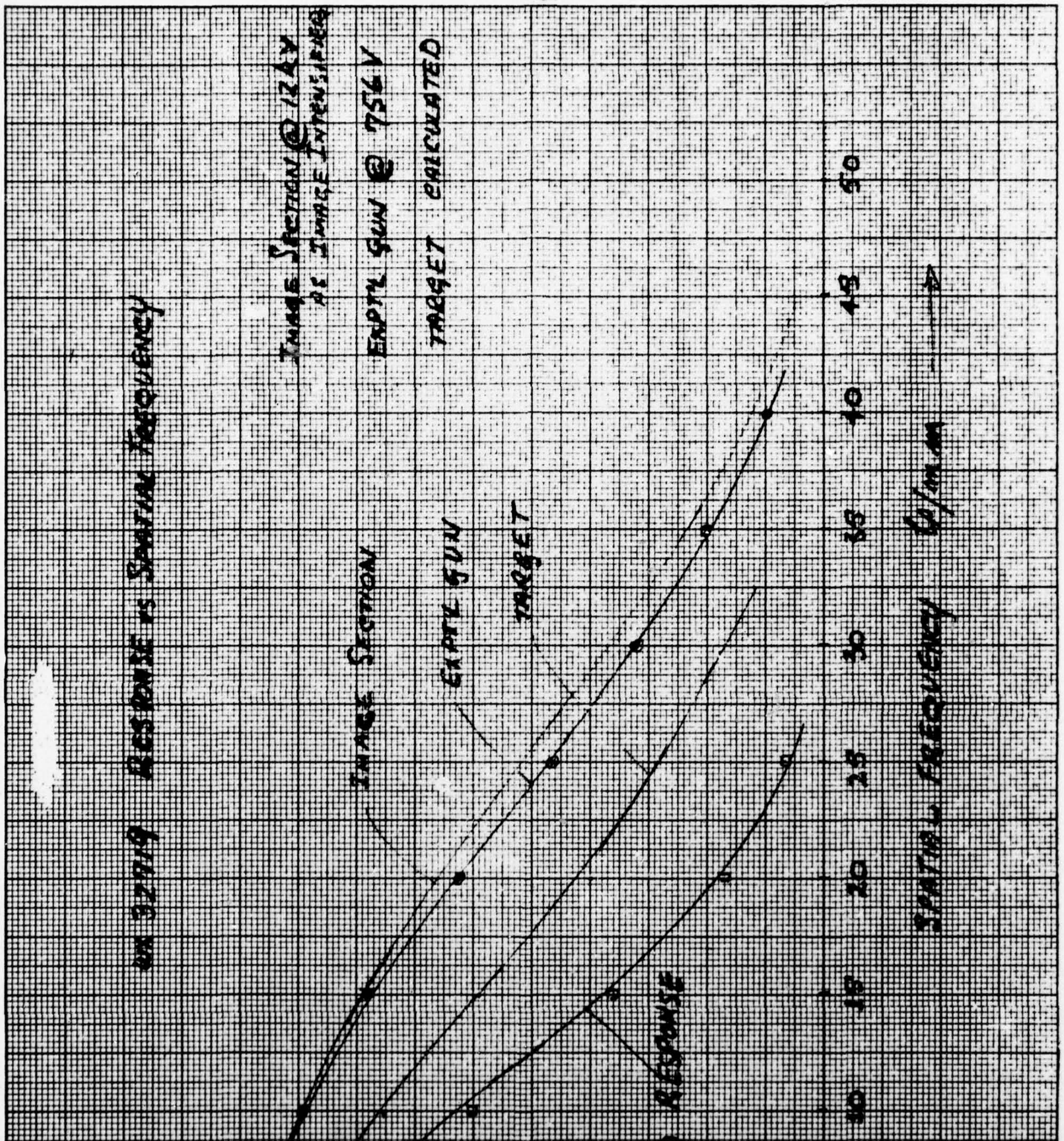

RESPONSE vs SPATIAL FREQUENCY
IMAGE SECTION @ 12KV
EXPTL GUN @ 756V
TARGET CALCULATED
IMAGE SECTION
EXPTL GUN
TARGET
COMBINED RESPONSE
SPATIAL FREQUENCY
% RESPONSE
100
50
0
5
10
15
20
25
30
35
40
45
50

FIGURE 26

## 3.8 Life Test

To gather life information on the EBSICON tube a 40 mm tube was operated continuously for 8000 hours. At appropriate intervals the tube was removed from life test camera and measured for some important parameters. In particular, the tube was measured for dark current, lag, max. signal, gain and electron gun characteristics. The results of the life test are summarized in Appendix 2. There is available 8,760 hours in one year's time and therefore this tube represents the changes in EBSICON performance one could expect in a tube operating for one year. During a year's time of the contract newer targets *with modified processing* techniques were received and therefore tube life test shown was terminated. In actuality, the tube could have run for even longer time.

Included in Appendix 2 is data taken from a field operating tube in the MIT-Lincoln Lab Camera #1. Although the tube is not one built on this contract it is a Westinghouse tube identical to the WX-32432 used to report the 8000 hour life test.

Briefly summarizing the Appendix, it should be noted that the EBSICON can operate continuously for 8000 hours. The dark current approximately doubles for the first 1000 hour operation. Maximum signal current remains relatively constant throughout life and the target gain actually increases.

# 4. PROGRAM AND CONTRACT OVERALL RESULTS

## 4.1 Summary

This report has discussed those high performance items required to be available in tubes supplied to NVL, namely; point response, lag, blooming, saturation current and operating life. We believe the contract was fulfilled in this respect. The 40 mm tubes delivered showed high performance in these areas and good evidence of this is the use of some of these tubes in the field camera systems being utilized by MIT-Lincoln Labs for the Air Force.

The status of the tubes developed is as described. The 40 mm WX-32719 is now fully developed. With good silicon diode targets this type of EBSICON tube can be made with high performance.

The report has emphasized the high performance and to what extent performance can be considered "high" performance. However, problems associated with the development of tubes occur and these also have been discussed. This is especially evident in the 80 mm WX-32670. This tube also has seen field use in a limited number and one is a candidate tube for a single sensor system being built for MIT-Lincoln Labs. This tube requires more development in the area of photocathode technology in order to obtain high performance. Further funding is being solicited to finish this development so that a large format tube will be available to system users.

To summarize the performance obtained from the contract tubes, we give in the Appendix 1, the WX-32719 specification. This specification defines the limits for all parameters and also the typical values one could expect from such a tube. All these boundary conditions have been obtained directly from the results presented in this report.

The question of life has been answered with the attached Appendix 2. Life test on this particular tube was terminated at 8000 hours not because of any tube failure but rather to retest life properties with new targets.

Finally, in Appendix 3, a list of all tubes of both types is compiled. The brief statement of condition and disposition is self-explanatory.

Acknowledgment is due to the efforts of NVL and NVL contracting Officer, R. Franseen, Remote View Group Manager. His efforts in devising and reducing to practice the point source response and tube specification model as well as general monitoring of this contract were beneficial to NVL and Westinghouse.

# APPENDIX I

## EBSICON CAMERA TUBE SPECIFICATION FOR WX 32719

## TENTATIVE SPECIFICATION AND TEST PROCEDURE

A. PERFORMANCE

1.0 Scope: This specification applies to high resolution electron bombarded silicon target television camera tubes having useful 40 mm diameter S20 type photocathodes. The image format on the photocathode is a rectangle with 4 by 3 aspect ratio.

2.0 Applicable Documents:

| | |
|---|---|
| EIA Standard RS343 | Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera. |

3.0 Requirements: Tubes will satisfy the following requirements by utilizing one set of optimum electrode potentials. Variable potentials are limited to the following:

| | |
|---|---|
| Photocathode | Gain variation - from -12 kV to - 4 kV |
| Gate | Follows photocathode potential for focus and is driven negative WRT photocathode to affect gating. |
| G3 | Dynamic focusing allowed as a function of scanning beam position on raster max. voltage 850 V. |
| G1 | Negative beam-gate pulse only. |
| Cathode | Cathode may be pulsed if desired for beam blanking. |

3.1 Image Size and Alignment: The camera tube will reproduce the following size image located in the center of the fiber optic faceplate:

40 mm tubes - 24mm high x 32mm wide

3.2 Photocathode Sensitivity: The tube will have minimum sensitivity of 130 μA/l to 2854°K or 10 mA/W at 5900°K.

3.3 Gain Characteristics: The tube will provide, as a minimum, the following target current gain characteristic.

| | Photocathode | Current Gain |
|---|---|---|
| 40mm tubes | High Voltage (-12 kV) | 2000 |
| | Low Voltage (- 4 kV) | 100 |
| Gain range between | -12 kV and -4 kV | 10 |

The gain figure is instantaneous current gain measured at the center of the target raster. Corresponding charge gain is calculated by multiplying the current gain by the scan efficiency which is approximately 0.8.

3.4 Saturation Characteristics: With the tube operating at standard electrode potentials with a 525 line, 30 frame/sec. 2:1 interlace scan, the saturation current will be no less than 1500 nanoamperes. With the tube operating with X3 vertical and X3 horizontal underscan, the saturation current will be no less than 1000 nanoamperes.
Note: The underscan portion of this requirement is equivalent to a target saturation current of 6000 nanoamperes under standard readout conditions or charge density storage of $4 \times 10^{-8}$ coulombs/cm$^2$.

3.5 Shading: With uniform faceplate irradiation, the video signal current elsewhere in the raster will be no less than 70% of the current in the center of the raster. This performance parameter (shading) pertains only to high voltage image section operation.

3.6 Dark Current

3.6.1 Average Dark Current: The equivalent dc dark current of the tube will not exceed 50 nA at 25°C tube surface temperature. The tube surface temperature will be measured in the target area. The dark current will be normalized to 25°C based on doubling of dark current for every 10 C° rise in temperature.

3.6.2 Dark Current Uniformity: The dark current over the scanned raster area of target will be within the limits of ± 15% of the value at the raster center. Excluded from this specification are dark current variations of the type normally considered as blemishes.

3.7 Gating Capability: The tubes will have a gating electrode capable of providing a 10,000 to 1 attenuation of the photocurrent at low light levels and high photocathode voltage. At high light levels and nominal gate voltage of -1000 v with respect to the photocathode the attenuation will be 1000 to 1.

3.8 Lag: The signal current which is read during the third field following the removal of steady state illumination will be no greater than 25% of the steady state signal current for an initial steady state signal current of 800 nA.

3.9 Distortion: The maximum geometric distortion will not exceed 4%. Compliance with this requirement will be demonstrated at the low voltage limit determined for paragraph 3.3. At the nominal high voltage condition the maximum geometric distortion will not exceed 3%.

3.10 Image Quality: There will be no objectional fixed pattern noise or grain, evidence of arcing, flashing, image section emission, target oxide charging or any other intermittent or continuous image degrading phenomenon applicable to entire target.

3.11 Blemishes: The tube will have no more than 26 blemishes yielding a signal greater than ± 100 nA under normal scanning conditions with a photocathode illumination sufficient to give a background signal of 300 nA at the center of the scanned raster. The size of these blemishes will be equal to or less than $1 \times 10^{-4}$ image area. The blemish specification will apply to low voltage measurements only (where worse case operation exists).

3.12 Resolution

3.12.1 Signal Sample Area: For point source imaging the signal sample area $A_s$ will be equal to or less than $10 \times 10^{-6}$ Image Area at the center. The average of the signal sample areas at the four corners located at 70 % of the raster diagonal will be equal to or less than $14 \times 10^{-6}$ Image Areas. The value of the signal sample area $A_s$ measured in the center of the raster with X3 vertical underscan and X3 horizontal underscan will be equal to or less than $6 \cdot \times 10^{-6}$ Image Area. In the low voltage operation, the tube will have a signal sample area equal to or less than $15 \times 10^{-6}$ Image Area under normal scan conditions and $10 \times 10^{-6}$ Image Area with X3 vertical underscan and X3 horizontal underscan.

3.12.2 MTF: The square wave response of the tube for 800 nA signal will be as follows:

400 TVL/RH @ Center $\geqq$ 50 %

400 TVL/RH @ 70 % Diag. $\geqq$ 45 %

The edge resolution is specified as an average of four corners with refocussing allowed. Typically, the MTF at the center is 60 % at 400 TVL/RH scanning a 4 X 3 raster.

3.13 Blooming Requirement: The camera tube will exhibit a signal sample area less than $5 \times 10^{-3}$ Image Area for point charges stored in the target equal to $1 \times 10^{-10}$ coulombs per frame time.

3.14 Image Rotation: The maximum rotation of a horizontal line passing approximately through the center of the Image Area at the high voltage operating point (12 kV) shall not exceed 3% of the picture height (or 3.5°) when the high voltage is reduced to 4 kV. This is not a spec. item but is listed for completeness.

3.15 Sensitivity: The sensitivity of the tube when operated at a photocathode potential of -12 kV will be equal to 3000 μA/fC when operated under standard television scan conditions. This is not a spec. item but listed for completeness.

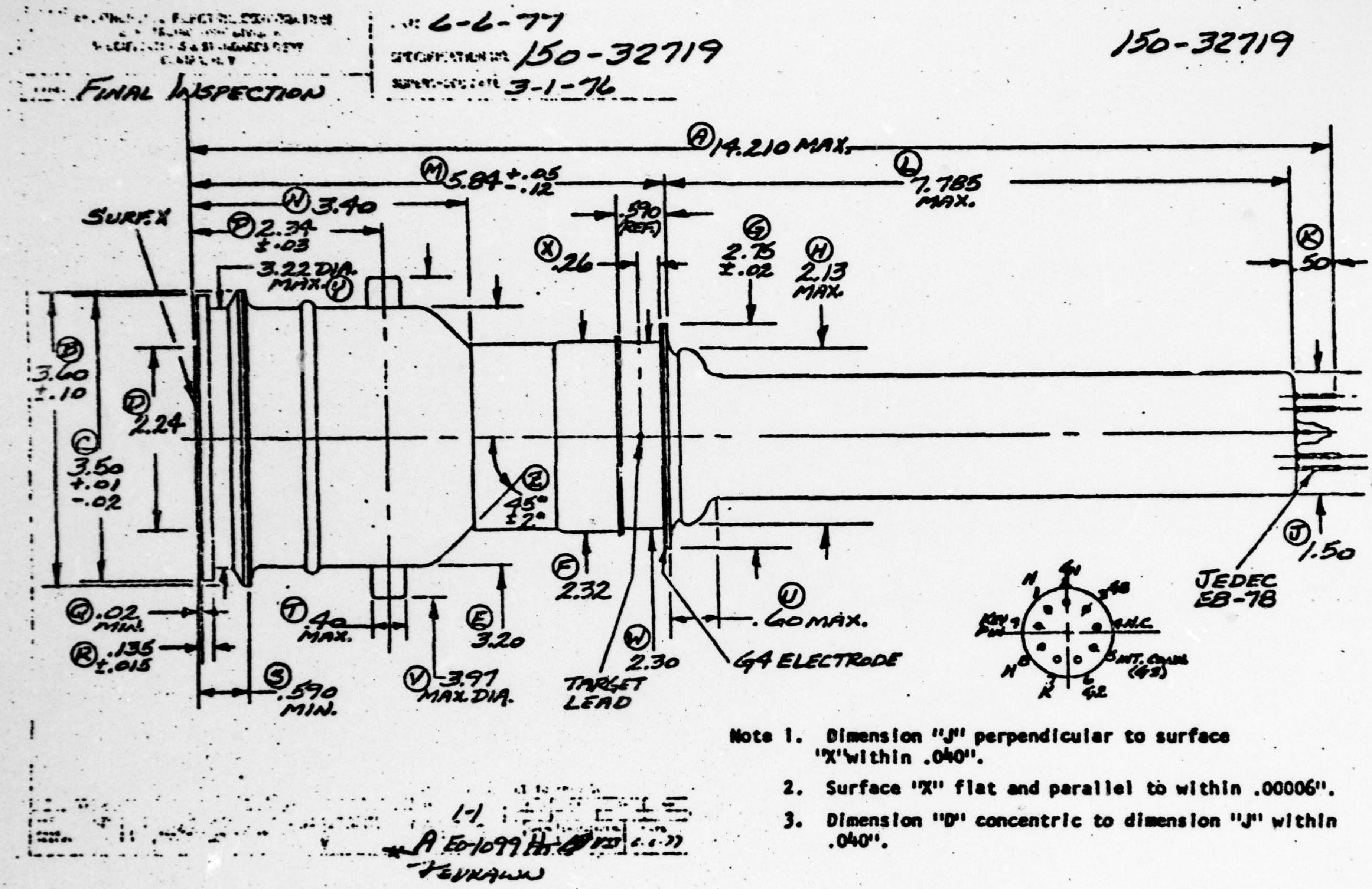
3.16 Scintillations: There will be no more than 2 scintillations per second measured on a 16 microsecond portion of a scan line through the center of the raster with the photocathode set at high voltage.
NOTE: This requirement establishes the maximum allowable high voltage for the camera tube. This is not a spec. item but listed for qualitative assessment of high voltage performance.

3.17 Vibration: The WX-32719 has been designed and built to withstand the following vibration exposure.

a) Figure 1 - Sine Vibration Operating and Non Operating.
b) Figure 2 - Random Vibration Operating.
c) Figure 3 - Random Vibration Non-Operating.

The operating microphonic signal for both sine and random vibration exposure will be equal to or less than 80 nA.

3.18 Mechanical: A WX-32719 will conform to the outline drawing as shown in 150-32719, page 66. All candidate tubes for coupling to intensifiers will be ground and polished. The flatness of the 40mm fiber optic active picture area will be within 7 fringes using sodium D line illumination. See notes to 150 drawing.




Note 1. Dimension "J" perpendicular to surface "X" within .040".

2. Surface "X" flat and parallel to within .00006".

3. Dimension "D" concentric to dimension "J" within .040".

B. TEST PROCEDURES

4.0 Quality Assurance Provisions: All tubes will be performance tested by the manufacturer to demonstrate compliance with each of the requirements of paragraph 3.0. The test procedures utilized by the manufacturer are designed to satisfy the following descriptions with tube potential fully described for each test:

4.1 Image Size and Alignment Test: Photocathode masks having exact image size openings concentrically located with respect to the tube axis will be utilized to demonstrate compliance with paragraph 3.1.

4.2 Photocathode Sensitivity Test: This test is performed by irradiating a specified portion of the center of the 40 mm photocathode by light from a calibrated 2854°K black body source. The irradiated area of the photocathode is a circle of 0.9 cm in diameter. All electrodes of the image section of the tube are connected together and held at a potential of + 300 volts with respect to the photocathode. A microammeter is inserted in the circuit loop to measure the photoelectron current. The photocathode sensitivity is obtained by dividing the microammeter current by the luminous flux falling on the photocathode.

An alternate method of determining the photocathode sensitivity of the tube may be used. In this method, the photocathode current is measured for wavelengths between 360 nm to 950 nm at given wavelengths of known power. The spectral response thus measured in ma/w is then multiplied by the normalized spectral energy distribution of a 5900°K blackbody source. The sum of the incremental ma/w, so derived, shall comply with the sensitivity requirement of paragraph 3.2.

4.3 Gain Characteristic Test: Photocathode current from the Image Area is determined as in paragraph 4.2. With the camera tube operating in the normal imaging mode, a broad area signal current at the center of the camera raster is measured with uniform illumination. The tube signal current divided by the photocathode current from the corresponding broad area equals the target current gain. Current gain is measured from 12 kV to 4 kV to yield the current gain characteristic of the tube. These high and low voltages will then be utilized in the signal sample area test 3.12.

4.4 Saturation Characteristic Test: With the tube in the normal operating mode and the tube gun voltages set for normal operation, except for G1 bias, the faceplate irradiance is increased and G1 bias decreased until the target charge cannot be neutralized by the beam. The target signal current as measured on a line select oscilloscope just before signal suppression and complete raster discharge, will comply with the requirement of 3.4.

The vertical and horizontal scan sizes are then decreased by 3 in the vertical direction and X3 in the horizontal direction. The irradiance is then further increased until evidence of saturation or unusable image quality occurs. The current measured at this point will comply with the saturation requirement of paragraph 3.4.

4.5 Shading Test: With uniform photocathode irradiance, a line selecting oscilloscope will be utilized to inspect each line of the video signal. The minimum response points observed on all video lines will comply with the shading requirement of paragraph 3.5.

4.6 Dark Current Test:

4.6.1 Average Dark Current Test: With no faceplate illumination, the target current will be measured with a current meter in the target bias lead, or measured by comparing the dark signal with a calibrated signal pulse. The temperature of the tube surface on the target support ceramic is also measured simultaneously. Adjustment of the dark current to 25°C will be made on the basis of a doubling of current for each 10°C change in tube surface temperature. Dark current will comply with the requirement of paragraph 3.6.

4.6.2 Dark Current Uniformity Test: For dark current uniformity, the same test will apply except the entire raster area will be sampled line by line with a line select oscilloscope for compliance with 3.6.2.

4.7 Gating Capability Test: The tube will be operated in the normal mode with uniform faceplate irradiance at high voltage to obtain an average background signal current of 500 nA. The tube is then gated by applying the nominal negative voltage to the gate electrode so as to reduce the 500 nA background to the dark current level. Increasing the irradiance by 100X will not cause an increase in signal level. If this condition is not satisfied, the gating voltage may be suitably adjusted.

4.8 Lag Test: The tube is set up so that a small rectangular square area in the center region of the raster is excited by illumination of the photocathode. The signal resulting from the illumination is displayed on a line select oscilloscope adjusted to present at least twenty fields of readout. The signals sampled in this case appear as pulses, each pulse being associated with a given field. The lag is obtained by pulsing the light on and off during vertical retrace periods. The on and off periods of duration are adjusted to insure the achievement of a steady state signal current $I_o$ and a zero steady state signal current (in excess of dark current). Calling the last full value of signal prior to removal of the light $I_o$, and the value of the signal pulse read in the third field following the removal of the light $I_3$, the lag is given in percent by $(100)\ I_3/I_o$.

4.9 Distortion Test: The tube is set up for standard operation at low image section voltages and low gain to image an IRE circle ball chart. A graticule electronic signal is simultaneously inserted in the main amplifier so as to display on a monitor the graticule and circle ball image. With proper alignment of tube center, all grid line intersections of the graticule shall fall within the corresponding circles of the ball chart. The limitation of paragraph 3.9 will apply to all circles out to B-15 of the chart.

4.10 Image Quality Test: This test is to be carried out with the camera tube operating at full operating voltage under standard scan conditions. The image area shall be as indicated in Section 3.1 for the 40 mm tube format. With uniform faceplate irradiance adjusted to give a signal current of 800 nA, examination of the monitor picture for the conditions specified in Section 3.10 shall be carried out. To show compliance with the specification 3.10, a photograph of the monitor picture will be made.

4.11 Blemishes Test: With the tube operating in the low voltage mode of 4 kV (i.e. at the low gain end of the gain range) the tube will be uniformly illuminated over the entire image area. In the 40 mm tube, this will be 32 mm X 24 mm. The blemish count is to be made in the entire raster area and not restricted to zones. Both black and white blemishes will be counted according to paragraph 3.11.

The intent of this test, being conducted under low gain conditions, is to impose tube operation under the worst case for blemishes.

4.12 Signal Sample Area Test: Theory - The signal sample area, $a_s$, is physically defined as the volume of the point spread function, h(x,y) divided by its height. An equivalent definition for $a_s$ is the reciprocal of the volume of the two dimensional modulation transfer function, H(N,M):

$$a_s = \frac{\iint_{-\infty}^{\infty} h(x,y)\, dxdv}{h(o,o)} = \frac{1}{\iint_{0}^{\infty} H(N,M)\, dNdM} \quad (RH)^2$$

where x and y are orthogonal raster dimensions normalized by the raster height, and N and M are the orthogonal spatial frequency components in the raster expressed in the units TV lines/Raster Height.

Raster scanning destroys the theoretical continuity of the point spread function, never the less, useful values of $a_s$ can be obtained for camera tubes operating $a_s$ linear (unsaturaged, gamma = 1) systems.

Measurement - $a_s$ is measured by imaging the near equivalent of a point of light on the camera tube. This is accomplished using a backlighted precision metal foil aperture in the pattern (object) plane. The area of this aperture, $a_o$, is normalized by the area of the raster pattern in the object plane and expressed in Raster Area, RA, units.

A scan line through the center of the spread function (image of $a_o$) is observed on the oscilloscope and G3 is focused (note value) for maximum response. Also adjust vertical scan position slightly to obtain the maximum peak response, r, for the spread function. The flux intensity of the image should be sufficient to yield a high signal to noise ratio measurement without approaching saturation, i.e., a peak signal of 300 to 500 nanoamperes.

The aperture is then removed to expose a large opening yielding uniform broad area response, R. A filter with transmission, T, must usually be inserted in the optical system to preclude target saturation.

The calculation for $a_s$ includes a correction factor for the finite size of the aperture:

$$a_s = a_o \left(\frac{R}{rT} - 1\right) \qquad \text{(RASTER AREA)}$$

The value of the signal sample area, $a_s$, is to be measured for standard scan rates; X3 vertical, X3 horizontal underscan; high and low photocathode voltage; and in the center and the 70% corners of the raster as specified in the requirement of paragraph 3.13. The values of $a_s$ shall be equal to or less than the values specified in paragraph 3.12.

4.13 Blooming Characteristic Test: The blooming characteristic is a plot of the signal area as a function of the point source stored in the target during one frame integration time. The point charge is determined by utilizing an aperture of known area in the object (pattern) plane and calculating photocathode current from the current obtained in the photocathode sensitivity test. The charge stored in the target is then this current times the gain obtained in the gain characteristics test. The aperture size must be restricted to an area 5 % of the signal sample area or less. The signal sample area should be measured in the center of the raster utilizing the method of the signal sample area test until the area is sufficiently large to measure directly from the oscilloscope. Measurement of the signal sample area directly from the pulse form observed on the line select oscilloscope shall be made by calculating the area of a circle of radius $r_s$ where $r_s$ is the half width of the point spread function at one-third the peak height of the function. The blooming characteristic should be determined for point charges in the target ranging from the unsaturated condition ($\approx 10^{-14}$) to $10^{-10}$ coulombs. This characteristic shall demonstrate compliance with the blooming requirement of paragraph 3.13.

4.14 Image Rotation: The tube is set up for standard operation as described in the distortion test (section 4.9).. With the photocathode voltage set at -12 kV, a graticule lines intersection is set at the center of the circle G-9 and a graticule lines intersection is set at the center of circle G-15. The photocathode voltage is then increased to -4 kV while maintaining the graticule lines intersection centered in the circle at G-9. The shift in the position of the graticule lines intersection at the G-15 position is taken as a measure of the image rotation occurring between photocathode operation at $V_{pc}$ = -12 kV and $V_{pc}$ = -4 kV.

4.15 Sensitivity: Tube sensitivity is measured by operating the tube with nominal voltages and $G_{-1}$ adjusted to permit maximum signal current. The light box used for illumination is set in a calibrated position. Lens aperture stop is then adjusted for varying light levels and the signal current is determined for each step of illumination. Tube sensitivity is calculated from signal current and 2854°K illumination.

4.16 Scintillations Test: Operating the tube as in the gating capability test, a 16 microsecond central portion of a scan line through the raster center will be photographed from the oscilloscope with 10 seconds exposure time. The oscilloscope vertical sensitivity will be adjusted so that the background noise band subtends ± division from the average value (corresponds to ± 3 sigma). Scintillations are counted in the photograph as pulses that peak at or above + two divisions above the average background (corresponds to + 6 sigma). Divide by 10 to obtain scintillations per second which shall satisfy the requirement of paragraph 3.14.

C. DEFINITIONS

1. Image Area - That area of the fiber optic window of the camera tube onto which a field of view of a scene (object) is imaged. For the 40 mm input tube, this area is 768 $mm^2$, which corresponds to a rectangular area of 40 mm diagonal, 4 X 3 aspect ratio.

2. Raster - That area of the charge storage target scanned by the readout electron beam under normal operating conditions. For the 40 mm tube, which uses a 32 mm target, the raster area is 492 $mm^2$.

3. Picture Area - That area of the input image on tube fiber optic which is finally presented for reviewing. This area may be smaller than the image area when the charge storage target is underscanned.

# APPENDIX 2

## LIFE TEST - EBSICON

During this contract, an EBSICON with a 25mm deep etched metal cap target was life tested for over 7,000 hours. The test was conducted by exposing the tube to uniform illumination such that a 1,000 nA signal could be obtained at 10,000 V in a slight overscan mode. The tube used for life test is a WX-32432 with a 32mm bi-alkali photocathode in a hermitic sealed image section.

The results of the test for dark current, maximum signal current and lag are shown in this report and comments made in an attempt to elucidate these results.

### I. Dark Current

The tube measured dark current of 17 nA at the beginning of life. The dark current rose gradually throughout life until approximately 5,000 hours after which the dark current had risen to 30 nA. Still a respectable dark current for 25mm diameter target (300mm$^2$ active scan area).

Between 5,0000 and 7,000 hours the dark current rose sharply almost doubling every 3,000 hours until now at 7,000 hours the measured dark current is 90 nA. See Figure 27.

Throughout life the target was observed not to charge until approximately 5,000 hours. Because of the charging phenomenon at that point in time, subsequent measurements were made after a discharge cycle had been performed. Testing for charging after 7,000 hours shows the affect is severe with a rise of about 50 nA in 30 minutes. For some feeling of this it was noted a charge pattern on the target was monitor visible after 5 sec. scan.

The target in the dark is after 7,000 hours showing evidence of "step and repeat" pattern as well as dark biemishes. See photos in Figure 28.

II. Signal Current

Maximum signal current measured 2150 nA at the beginning of life and rose gradually to 2400 nA, then tapered off in value until now it is at 2350 nA. Roughly one can assume the charge capacity of the target remains constant throughout life at about $7 \times 10^{-8}$ coulombs based on this maximum of 2350 nA.

III. Lag

The lag, in particular 3D field lag, was monitored throughout the 7,000 hours first at many target voltages, but after 500 hours was only determined at the nominal target operating voltage. As can be seen from Figure 29, the lag made a few excursions upwards within the 300 - 1,000 hour period, then stabilized. After the stabilization period a downward trend was noted and finally a 20% lag is measured after 7,000 hours.

IV. Gain

Target gain was not specifically monitored throughout life but a gain curve was obtained initially after a burn in time of 50 hours. To determine if the target gain mechanism did change after the many hours of operation, the gain was remeasured after the 7,000 hours. Both before and after life test curves are shown in Figure 30.

The gain at 12 kV rose a hefty 16% but an even more dramatic change was noted at 10 kV. At 10 kV the gain more than doubled. Interestingly enough is the fact that 10 kV is the bombarding voltage used throughout the life test as mentioned before.

V. Thermionic Emission

After the tube had been built the normal procedure for the WX-32432 was carried out; namely, the cathode is aged for at least 16 hours subsequent to a hot shot of 10-1/2 volts.

Curve tracer oscilliscope photos were then taken to show some of the emission characteristics of the tube. After approximately a 100 hours of operation the G1 voltage necessary for a beam current of 1500 nA was monitored. This value started out at -39.9 volts and gradually approached more positive bias until at 7,000 hours the value of G1 voltage is -30 volts for the same 1500 nA.

APPENDIX

V. Thermionic Emission (cont'd.)

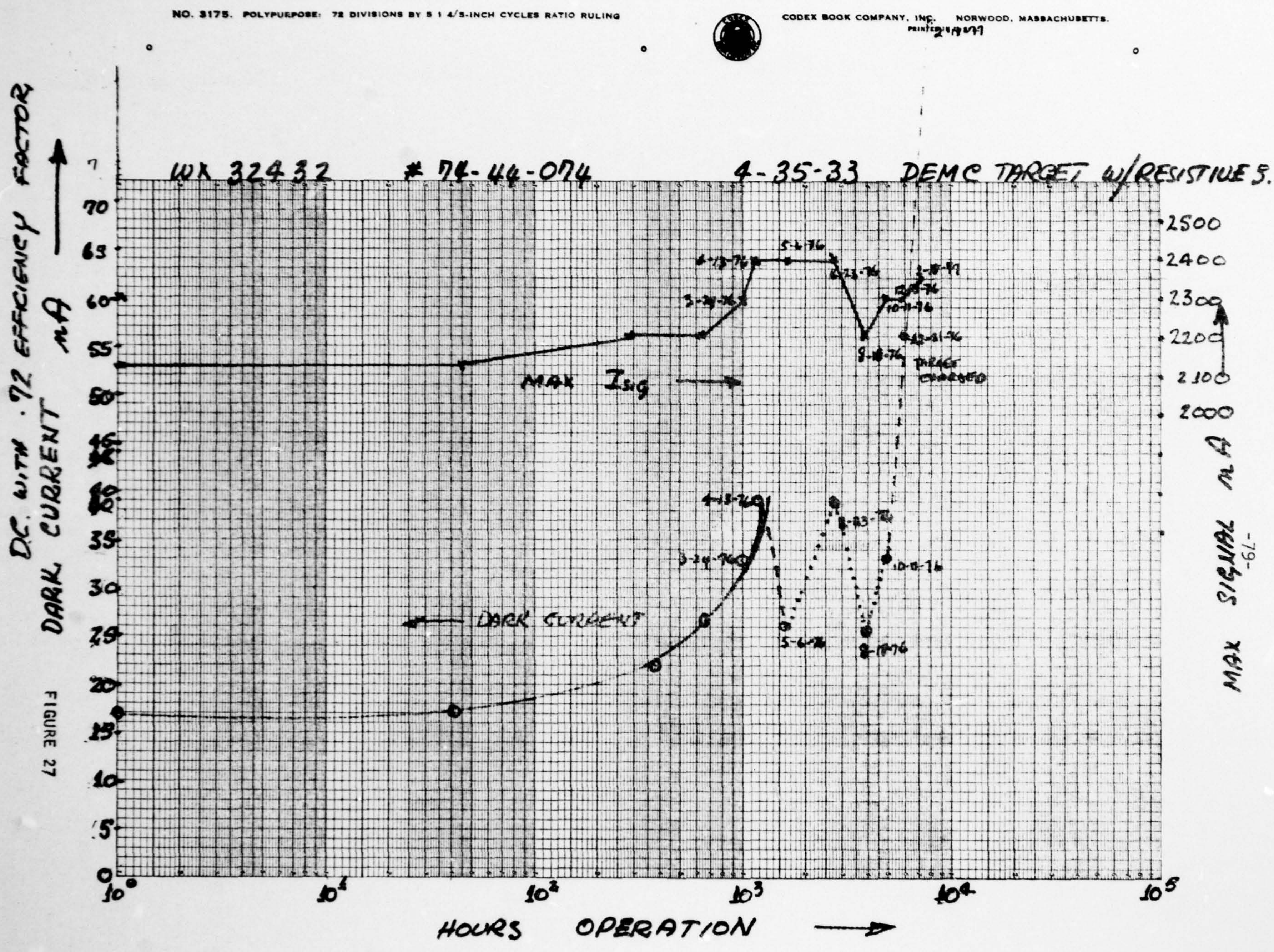
The maximum $Ig_2$ from the cathode was recorded as 5.2 mA at the beginning of life test and dropped to 3.8 mA at the end of 7,000 hours. All cutoff measurements, both visual and current, indicated the voltage for cutoff remained constant throughout life and therefore the cathode emission is in fact deteriorated; at this point about 27% based on $IG_2$ current values.

VI. Miscellaneous

The photocathode of the life test tube measured 30 μA/lm at the start of life and finished at 31 μA/lm. No excursions were noted in the photocathode sensitivity either in absolute value or uniformity.

As mentioned earlier, the photocathode is a bi-alkali of sodium and potassium in combination with antimony. No cesium is present in the tube and the image section of the WX-32432 is for all intents and purposes sealed from the gun section.

The fact that photocathode sensitivity did not change confirmed the gain change reported above because tube sensitivity increased substantially throughout life.



NO. 3175. POLYPURPOSE: 72 DIVISIONS BY 5 1 4/5-INCH CYCLES RATIO RULING
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.
WX 32432
# 74-44-074
4-35-33
DEMC TARGET W/RESISTIVE S.
D.C. WITH .72 EFFICIENCY FACTOR
DARK CURRENT mA
MAX $I_{sig}$
DARK CURRENT
TARGET CHARGED
MAX SIGNAL mA
HOURS OPERATION


FIGURE 27

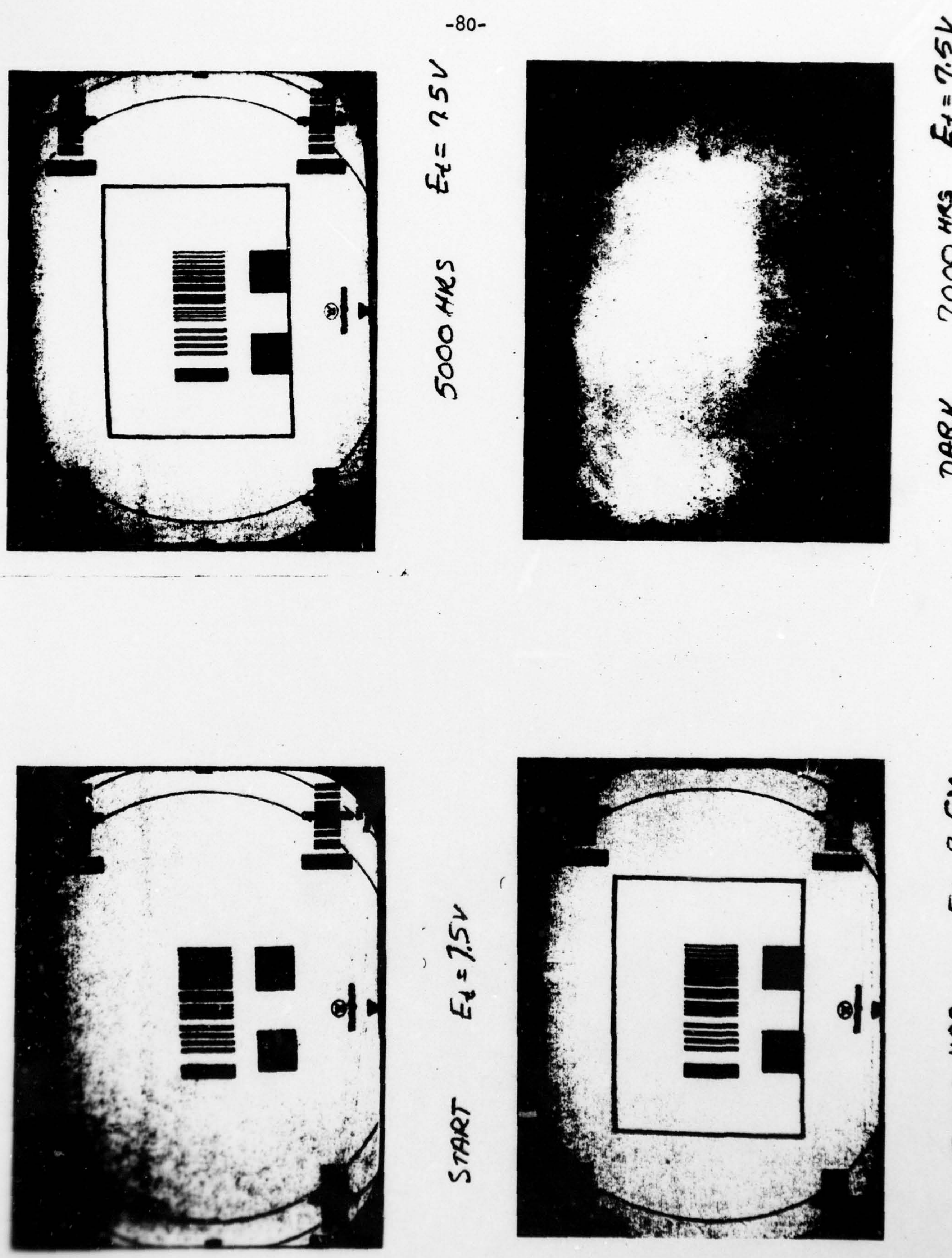

START $E_t = 7.5V$
5000 HRS $E_t = 7.5V$
7000 HRS $E_t = 7.5V$
DARK 7000 HRS $E_t = 7.5V$

FIGURE 28

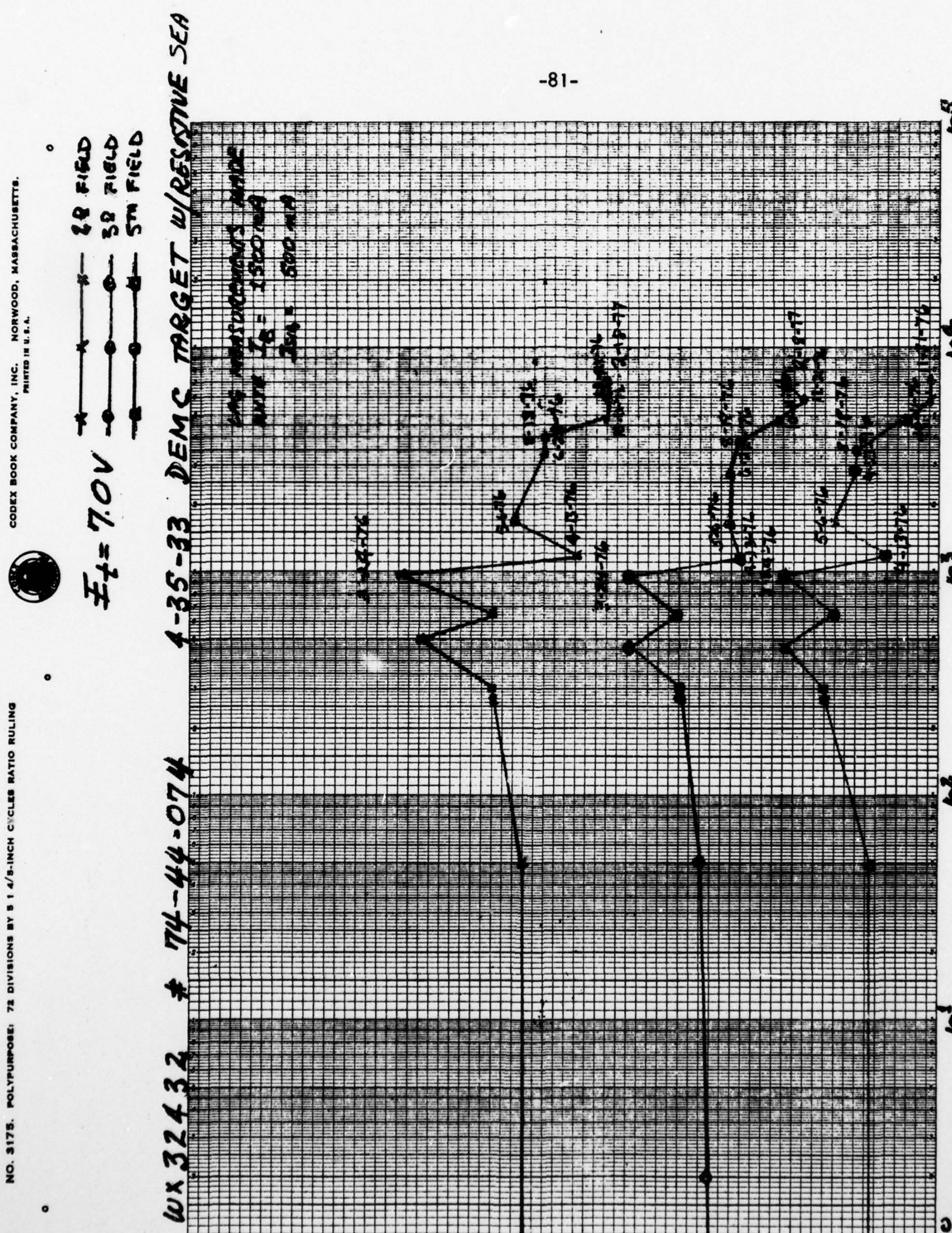

NO. 3175. POLYPURPOSE: 72 DIVISIONS BY 5 1/5-INCH CYCLES RATIO RULING
CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS.
PRINTED IN U.S.A.
2nd FIELD
3rd FIELD
5th FIELD
$E_f$ = 7.0V
WX32432 # 74-44-074 4-35-33 DEMC TARGET W/RESISTIVE SEA
HOURS OPERATION
LAG %

FIGURE 29

WX 32432 # 74-44-077 TGT 4-35-33

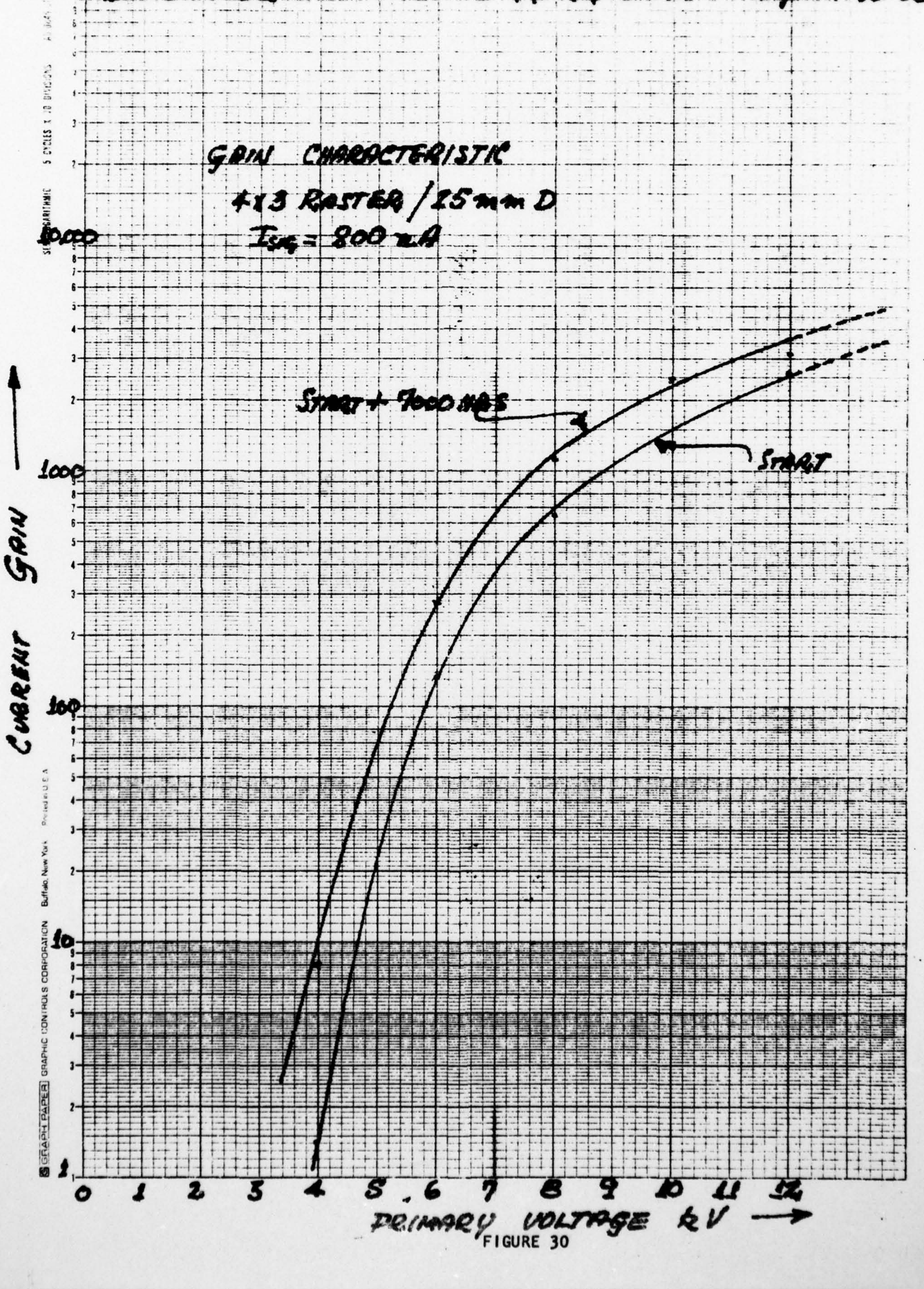



FIGURE 30

# APPENDIX 3

WESTINGHOUSE NVL CONTRACT DAAK-02-75-C-0127

DISPOSITION OF TUBES MANUFACTURED BY WESTINGHOUSE

LIST COMPILED FROM DD250 & WESTINGHOUSE RECORDS

1975 - 1977

WX-32719/WX-32432 40 mm EBSICON TUBES * = TUBES DELIVERED

| Date | | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|---|
| 6/19/75 | * | 75-05-317 | Poor/Dummy Target | Del. to NVL/at NVL |
| | * | 75-22-795 | Fair/No gate | Del. to URI/Eval. |
| | * | 75-22-799 | Fair/Nitride Process Target | Del. to MIT/Lincoln Labs |
| | * | 75-22-797 | Scrap | Lower Bulb Cracked |
| 8/18/75 | * | 75-22-801 | Poor/Oxide + sea | Del. to NVL/at NVL |
| | * | 75-26-135 | Fair/Oxide + sea | Del. to NVL/at NVL |
| 10/15/75 | * | 75-26-139 | Fair/Oxide + sea | Del. to NVL/NASA Goddard |
| | * | 75-26-142 | Fair/AIB + 100% sea | Del. to NVL/MIT Lincoln Labs |
| 12/8/75 | * | 75-39-161 | Good/No gate | Del. to NVL/Ret. Ⓦ For Camera Del. to Lincoln Labs |
| | * | 75-44-443 | Good | Del. to NVL/Camera #3 Later broken in #3 |
| 3/4/76 | * | 75-44-444 | Good | Del. to NVL/In Camera #3 at White Sands. Returned broken. |
| 3/25/76 | * | 75-44-383 | Fair | Del. to NVL/at NVL |
| | * | 76-08-247 | Good/Low MTF | Del. to NVL/Loaned ESA |
| 3/28/76 | * | 75-44-381 | Fair/Charges | Del. to MIT/Lincoln Labs for ITEK Camera |
| | * | 76-08-249 | Good | Del. to MIT/Lincoln Labs for Camera #2 |
| 8/3/76 | | 75-05-394 | Poor/Low/PR | Salvaged at Ⓦ |
| | | 75-05-389 | Poor/Gassy Tube/Exploded Getters | Salvaged at Ⓦ |

(continued)

WX-32719/WX-32432 (Cont'd.)

| Date | | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|---|
| 8/3/76 (cont'd.) | | 75-44-442 | Poor/Scrapped/Target Broke | Salvaged at Ⓦ |
| | | 75-39-162 | Poor/Excessive Target Dark Current/Would not image | Salvaged at Ⓦ |
| | | 76-04-862 | Scrap | Salvaged at Ⓦ |
| | | 76-08-250 | T-M short | Salvaged at Ⓦ for analysis |
| 10/22/76 | | 76-26-827 | Fair/Speckled Photocathode | At Ⓦ |
| | | 76-26-829 | Poor/Non-Uniform | At Ⓦ |
| | * | 76-26-822 | Fair | Del. to NVL/at NVL |
| | | 76-26-824 | Gassy/Tested Low $I_D$ | Salvaged Target at Ⓦ |

*End of Phase I - DAAK-02-75-C-0127 - 25 tubes made and 15 tubes delivered. Contract required 20 tube starts.

| Date | | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|---|
| 2/1/77 | * | 76-30-145 | Good | Del. to MIT/Lincoln Labs Camera #3 |
| 2/15/77 | * | 76-26-830 | Good | Del. to MIT/Lincoln Labs |
| | | 76-30-146 | Fair/Charges | Reserve/Expt. Vibration |
| 2/16/77 | * | 76-30-147 | Good | Del. to MIT/Lincoln Labs Moving Target Indicator |
| | | 76-30-149 | Poor | Salvaged/Target/Mesh at Ⓦ |
| | | 76-48-975 | Poor/Target Damaged | To be Salvaged |
| | | 76-48-979 | Poor/Target Damaged | To be Salvaged |
| | | 77-21-861 | Leaker | Salvaged/GE Target |
| | | 77-21-862 | Finished | GE Target at Ⓦ |
| 6/23/77 | * | 77-21-863 | Good | TI Target - delivered to MIT/Lincoln Labs/camera |
| | | 77-21-865 | Loose G2 | To be Salvaged |
| | | 77-26-197 | Speckled photocathode Good rez. | To be Salvaged |
| | | 77-26-201 | Good Resolution/Blemishes | To be delivered |
| | | 77-26-200 | GE Target | To be delivered |

- continued -

WX-32719/WX-32432 (Cont'd.)

| Date | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|
| 8/18/77 | 77-26-205 | Good/High Resolution | Deliver to MIT/Lincoln Labs |

End of Phase 2 - DAAK-02-75-C-0127 - 15 tubes made and 5 tubes delivered

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Total 40 mm Tube Starts - 40    Total Delivered - 20    Total Contract Starts Required - 40

Additional tubes made for life test, gun resolution studies and target processing affects.

WESTINGHOUSE NVL CONTRACT DAAK-02-75-C-0127
DISPOSITION OF TUBES MANUFACTURED BY WESTINGHOUSE
LIST COMPILED FROM DD250 & WESTINGHOUSE RECORDS
1975 - 1977

WX-32670 80 mm EBSICON TUBES * = TUBES DELIVERED

| Date | | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|---|
| 3/4/76 | * | 75-44-374 | Poor | Del. to NVL/at NVL |
| | * | 75-44-379 | Fair | Del. to NVL/at NVL |
| | * | 75-44-380 | Good/Blemishes | Del. to NVL/at NVL |
| | * | 75-44-382 | Poor | Del. to NVL/at NVL |
| 5/25/76 | * | 75-44-384 | Fair | Del. to NVL/at NVL |
| | * | 76-08-246 | Poor/Photocathode | Del. to NVL/at NVL |
| 7/30/76 | * | 76-26-832 | Good/12 kV/WA<br>7 kV/NA | Del. to MIT/Lincoln Labs |
| 8/3/76 | | 75-44-377 | Poor | Salvaged at Ⓦ |
| | | 76-04-863 | Poor/Gas | Analysis/Salvaged |
| | | 75-44-375 | Poor | Salvaged at Ⓦ |
| | | 76-26-780 | Poor/Conductive Target | EOS Show/Retain for Salvage |
| 10/22/76 | | 76-04-865 | Fair | Salvaged at Ⓦ |
| | | 76-08-252 | Target-Mesh Short | Salvaged at Ⓦ |
| | | 76-26-823 | Target Broke After Processing | Salvaged at Ⓦ |
| | | 76-26-826 | Conductive Target | Salvaged at Ⓦ |
| | | 76-26-831 | Heavy Non-Uniformity | Open for Analysis/Salvaged |
| | | 76-30-139 | Pt Photocathode | Salvaged at Ⓦ |
| | | 76-08-251 | Fair | Salvaged at Ⓦ |
| | * | 76-26-825 | Fair | Del. to MIT/Lincoln Labs |
| | | 76-26-833 | Fair 12 kV WA | Open for Analysis/Salvaged<br>Target broke during Salvage |
| | | 76-30-142 | Poor/High ID | Salvaged at Ⓦ |
| | | 76-30-143 | Poor | Salvaged at Ⓦ |
| 11/4/76 | * | 76-26-141 | Good | Del. to NVL/at NVL |

End of Phase 1 - DAAK-02-75-C-0127 - 23 tubes made and 9 tubes delivered

- continued -

| Date | | Tube No. | General Condition | Ⓦ Known Disposition |
|---|---|---|---|---|
| 2/15/77 | | 76-43-190 | Poor/Photocathode | Salvaged at Ⓦ |
| | | 76-43-191 | Poor/Excessive Dark Current | To Be Salvaged - Scrap Target |
| | | 76-43-192 | Poor/Excessive Dark Current | Salvaged at Ⓦ - Target Scrapped |
| | | 76-48-976 | Poor/Damaged Target | Salvaged at Ⓦ - Target Scrapped |
| | | 76-48-977 | Poor/Low PR | Salvaged |
| | | 76-48-980 | Poor/Low PR | Salvaged |
| | | 76-48-982 | Poor/Low PR | Salvaged |
| | | 76-13-162 | Poor/Low PR | Salvaged |
| | | 77-13-164 | Low/PR | Salvaged |
| | | 77-13-169 | Low/PR/10 | Salvaged |
| | * | 77-13-165 | Fair/Non-Uniform PR | Del. to NVL/MIT/Lincoln Labs |
| | | 77-13-167 | No PR | Salvaged |
| | | 77-13-166 | Low PR | Salvaged |
| | * | 77-13-171 | Poor/High $I_D$ | Del. to NVL/at NVL |
| | | 77-21-855 | Poor/Low PR | Salvaged |
| | * | 77-21-856 | Low PR | To Ⓦ Camera Sample |
| | | 77-21-859 | Low PR | Salvaged |
| | | 77-21-857 | Low PR | Salvaged |
| | | 77-21-860 | Low PR | Salvaged |
| | | 77-21-864 | Low PR<br>Useable for Test | Salvaged |
| | | 77-26-196 | Low PR - Heavy Leakage<br>Z-F - No N.A.<br>Good Rez<br>Life Test Target | Life Test<br>100 hrs. |
| | | 77-26-199 | Leaked at cool down at Test | Salvaged |
| | | 77-26-202 | Low PR/High $I_D$ | |
| | | 77-26-204 | Poor/Low PR | Salvage |
| | | 77-26-203 | Bi-Alkali/Poor | Salvage |
| | | 77-26-206 | Poor/Low PR | Salvage |
| | * | 77-26-335 | Good/Fair | MIT Cam #4 |
| | | 77-26-339 | Scrap/Bulb Cracked | |
| | | 77-26-336 | Experiment | |

End of Phase 2 - DAAK-02-75-C-0127 - 29 tubes made and 4 tubes delivered

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Total 80 mm Tube Starts - 52 Total Contract Starts Required - 50

********