EFFECT OF IMMERSION LENS PARAMETERS ON BEAM CUTOFF VOLTAGE AND SPOT SIZE

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MONO. PICTURE TUBE DESIGN ENGRG.
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SUMMARY

This report deals with the change in beam cutoff voltage and spot size with variations in the immersion lens parameters.

Beam cutoff voltage is mainly determined by the grid 1 aperture size, grid 1 - grid 2 spacing, grid 1 top thickness and grid 1 cathode spacing. Increasing grid 1 aperture diameter increases the beam cutoff voltage while increasing the grid 1 - grid 2 spacing, grid 1 top thickness and grid 1 cathode spacing reduces cutoff.

The results show that the beam spot size at the edge of the tube face increases with increased grid 1 cathode spacing and decreases with increased grid 1 aperture size, grid 1 top thickness and grid 1 - grid 2 spacing. The spot size at the center increases rapidly with increased grid 1 - grid 2 spacing and only slightly with increased grid 1 aperture size and grid 1 top thickness. Grid 1 cathode spacing appears to have very little effect on the center spot size.

I. INTRODUCTION

During past gun development programs it has often been necessary to build several groups of tubes in order to arrive at the desired beam cut-off voltage. Evaluation of the different groups of tubes has indicated that focus quality varies with cutoff voltage. These changes in focus quality depend on which parameters are varied to bring about the change in cutoff.

In order to learn more about the effect of mount parameter changes on cutoff and spot size a program was initiated to investigate separately each of the parameters believed to have an effect on beam cutoff. Because of the complexity of a direct mathematical approach most of the evaluation was done experimentally. An attempt will be made to explain the experimental data in terms of the general spot size equations.

In this report beam cutoff voltage will be defined as the negative voltage which applied to grid 1 will just extinguish the electron beam at the screen.

II. EFFECT OF MOUNT PARAMETERS ON BEAM CUTOFF

Very little mathematical analysis of the effect of the various mount parameters on beam cutoff has been attempted. Most of the work done has been experimental. Moss[1] assumed that for a triode the beam cutoff was a function of the grid 1 cathode spacing a, grid 1 thickness t, grid 1 - anode spacing b and grid 1 aperture diameter D.

$$CO = K\phi\,(D, t, a, b) \text{ when K is a constant}$$

Experimentally using triodes, Moss determined that cutoff was approximately proportional to D^3, and inversely proportional to t, a, and b.

$$CO = \frac{KD^3}{t, a, b} \quad (1)$$

Similar work done by Maloff-Epstein[2], using a triode of slightly different configuration, gave the same general results. When used for our present mount Moss's equation (substituting grid 1 - grid 2 spacing for the grid 1 - anode spacing) is only reasonably accurate for very small changes in mount parameters and useless for large changes in mount parameters.

The mount parameters which affect beam cutoff in our present day mounts for television picture tubes can conveniently be divided into two groups. The first group consists of the parameters that were studied by Moss.

1. Diameter of the grid 1 aperture.
2. Grid 1 top thickness.
3. Grid 1 cathode spacing.
4. Grid 1 - grid 2 spacing.

The second group consists of the parameters which have a small effect on cutoff and therefore are difficult to evaluate experimentally. These parameters control the penetration of the anode field into the cathode region and can be

(1) The Electron Gun of the Cathode Ray Tube, Part 2, Moss - Journal of British IRE
(2) Electron Optics in Television - Maloff-Epstein

considered part of the constant in Moss's equation.

These parameters are as follows:

1. Grid 2 - anode spacing.
2. Grid 2 dia. and height.
3. Grid 2 aperture diameter.
4. Anode cylinder diameter.

As indicated by Moss's results the grid 1 aperture diameter has the biggest effect on the cutoff voltage. The cutoff voltage is closely proportional to the aperture diameter cubed. Figure I shows the variation in beam cutoff with changes in grid 1 aperture size.

Fig. 2 and Fig. 3 show the variation in cutoff with changes in grid 1 top thickness and grid 1 - grid 2 spacing.

Figure 4 shows the variation in cutoff with changes in grid 1 - cathode spacing for both the .025" and the .031" grid 1 aperture. In the region of -50 to -60 volts cutoff there was a change in cutoff of 7V per .001" changes in spacing for the .025" grid aperture as compared with 5V per .001" change in spacing for the .031" grid aperture.

The voltages which are applied to the filament, grid 2 and anode also affect the cutoff voltage. Figure 5 shows the variation in cutoff with changes in grid 2 voltage.

Figure 6 shows the variation is cutoff with changes in anode voltage. If the parameters in group 2 could be changed such that the cathode could be completely isolated from the anode field there should be no change in cutoff with changes in anode voltage.

Figure 7 shows the change in beam cutoff with changes in filament voltage. As the filament voltage is increased the temperature of the cathode increases causing the cathode to expand, thereby decreasing the cathode - grid 1 spacing. The decrease in the cathode - grid 1 spacing in turn increases the cutoff voltage. The increase in cathode temperature also increases the velocity of the electrons leaving the cathode which also tends to increase cutoff slightly.

III. SPOT SIZE

Since the same mount elements which determine cutoff also form the immersion lens, one would expect a relationship between cutoff and crossover size and position. Using Snell's Law an expression for the final spot size at the screen in terms of crossover size and position can be found.

$$dc \operatorname{Sin} a_1 \sqrt{V_1} = ds \operatorname{Sin} a_2 \sqrt{V_2} \quad (2)$$

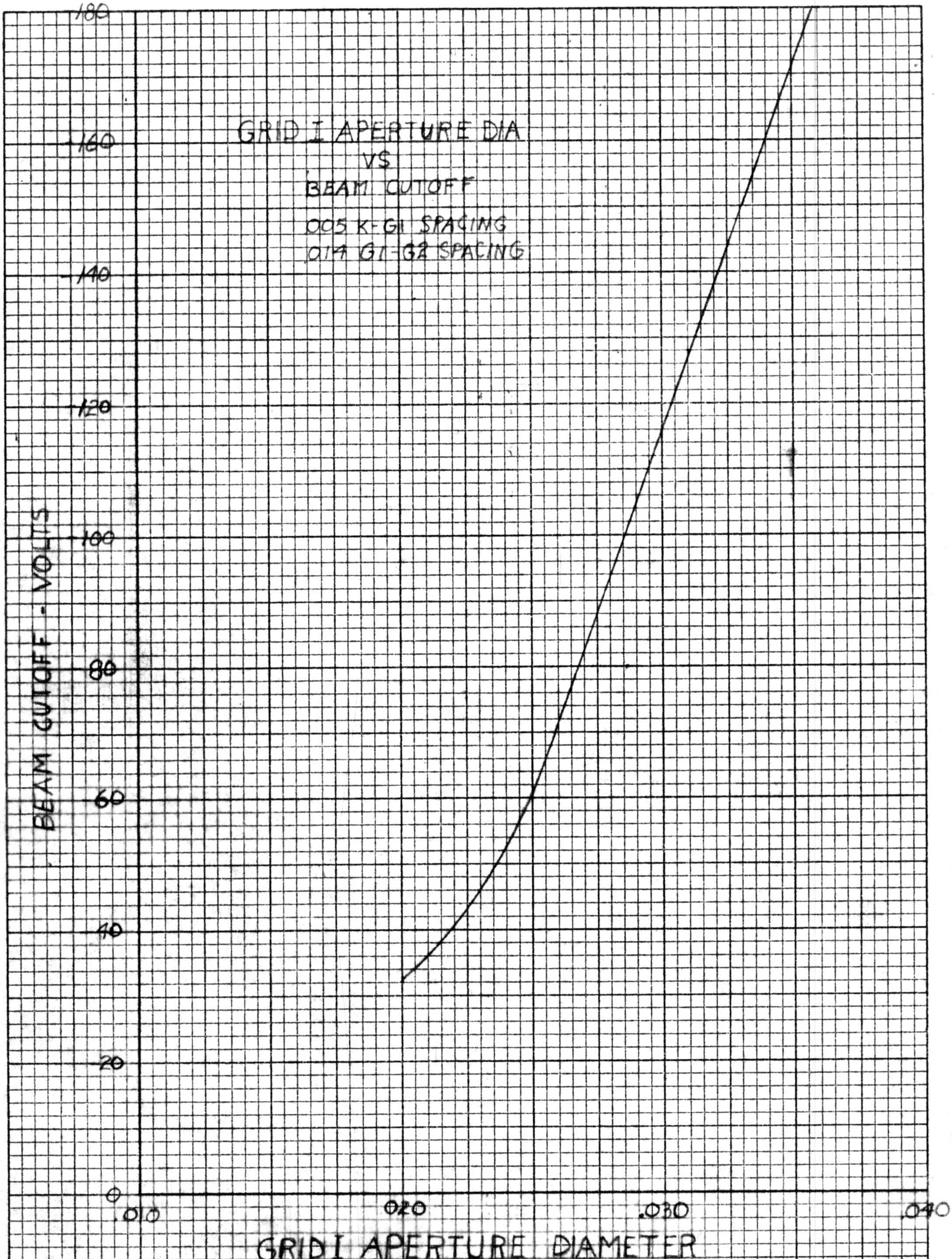


FIGURE I

5-12-59

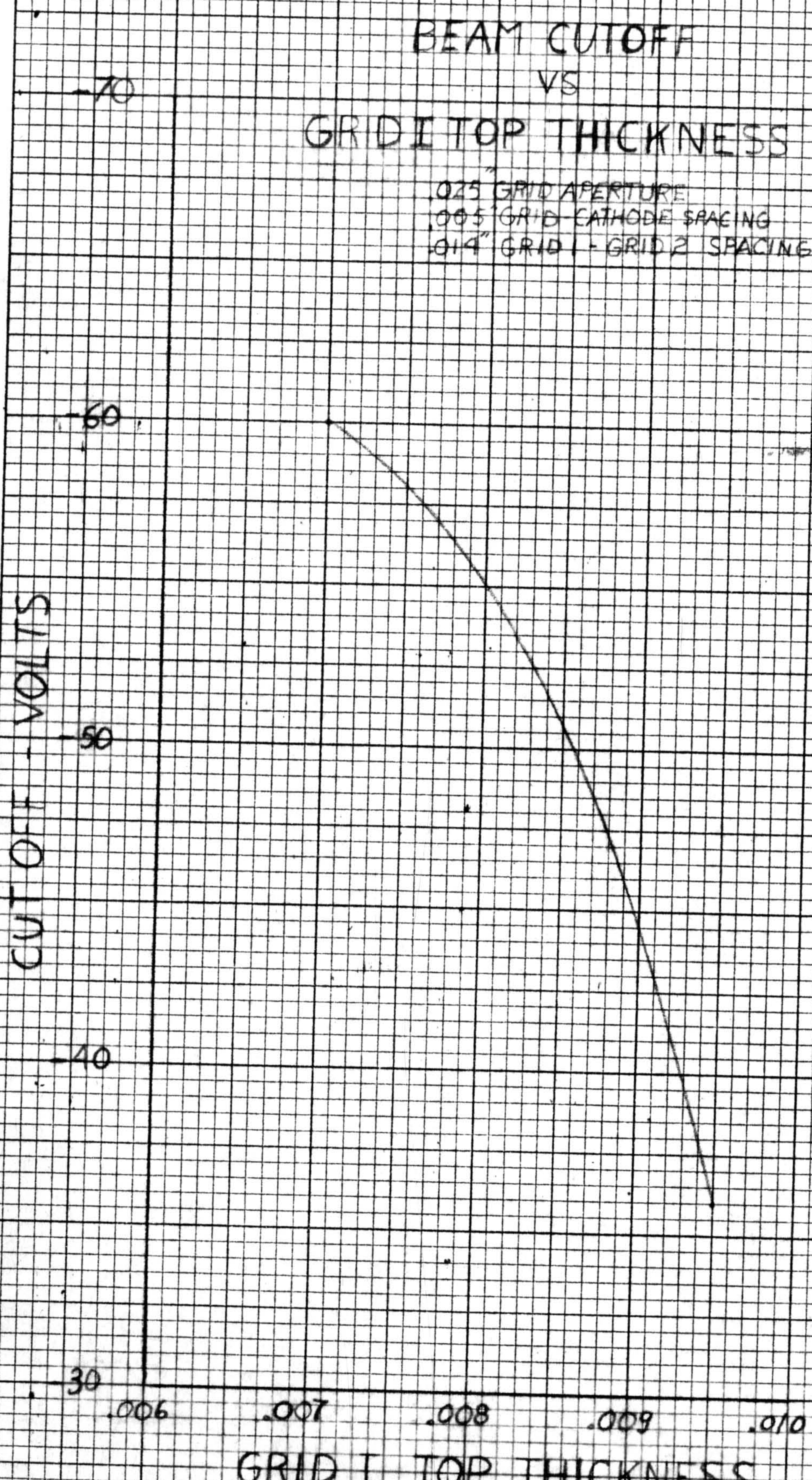


FIGURE 2

C.P. 5-5-58

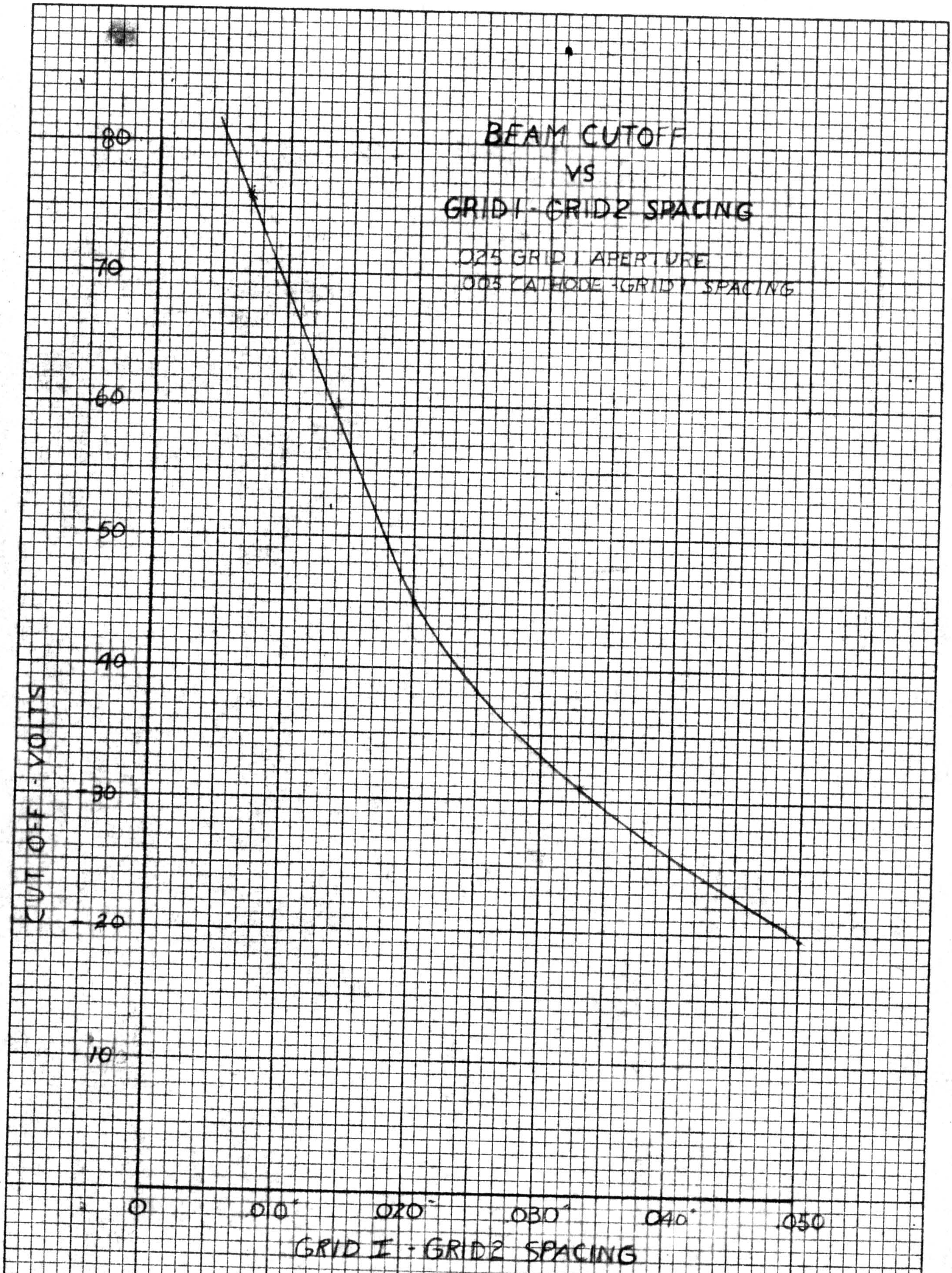


FIGURE 3

E.P. 5-12-58

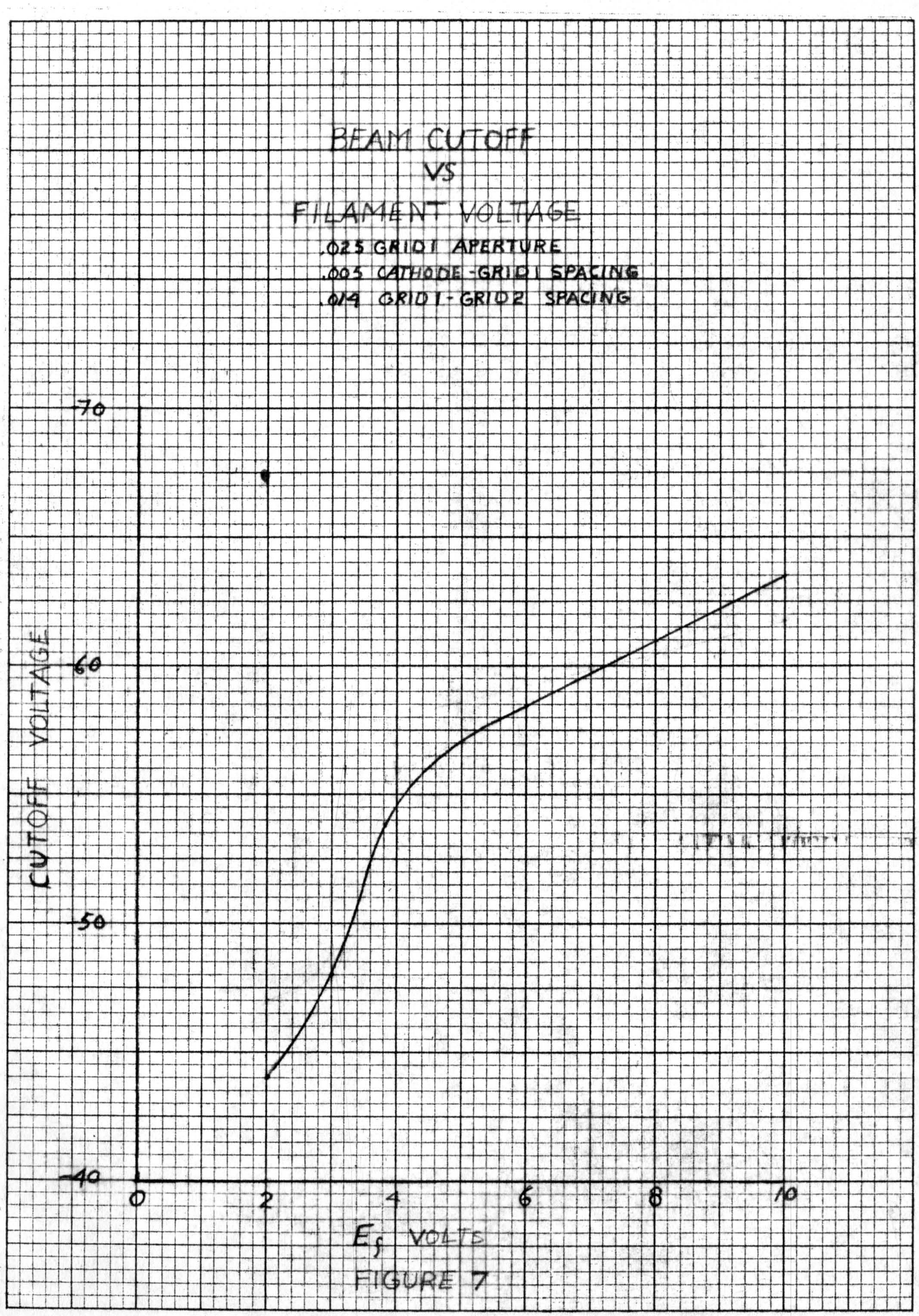

BEAM CUTOFF
VS
FILAMENT VOLTAGE
.025 GRID 1 APERTURE
.005 CATHODE - GRID 1 SPACING
.014 GRID 1 - GRID 2 SPACING
-70
-60
-50
-40
CUTOFF VOLTAGE
0
2
4
6
8
10
E_f VOLTS

FIGURE 7

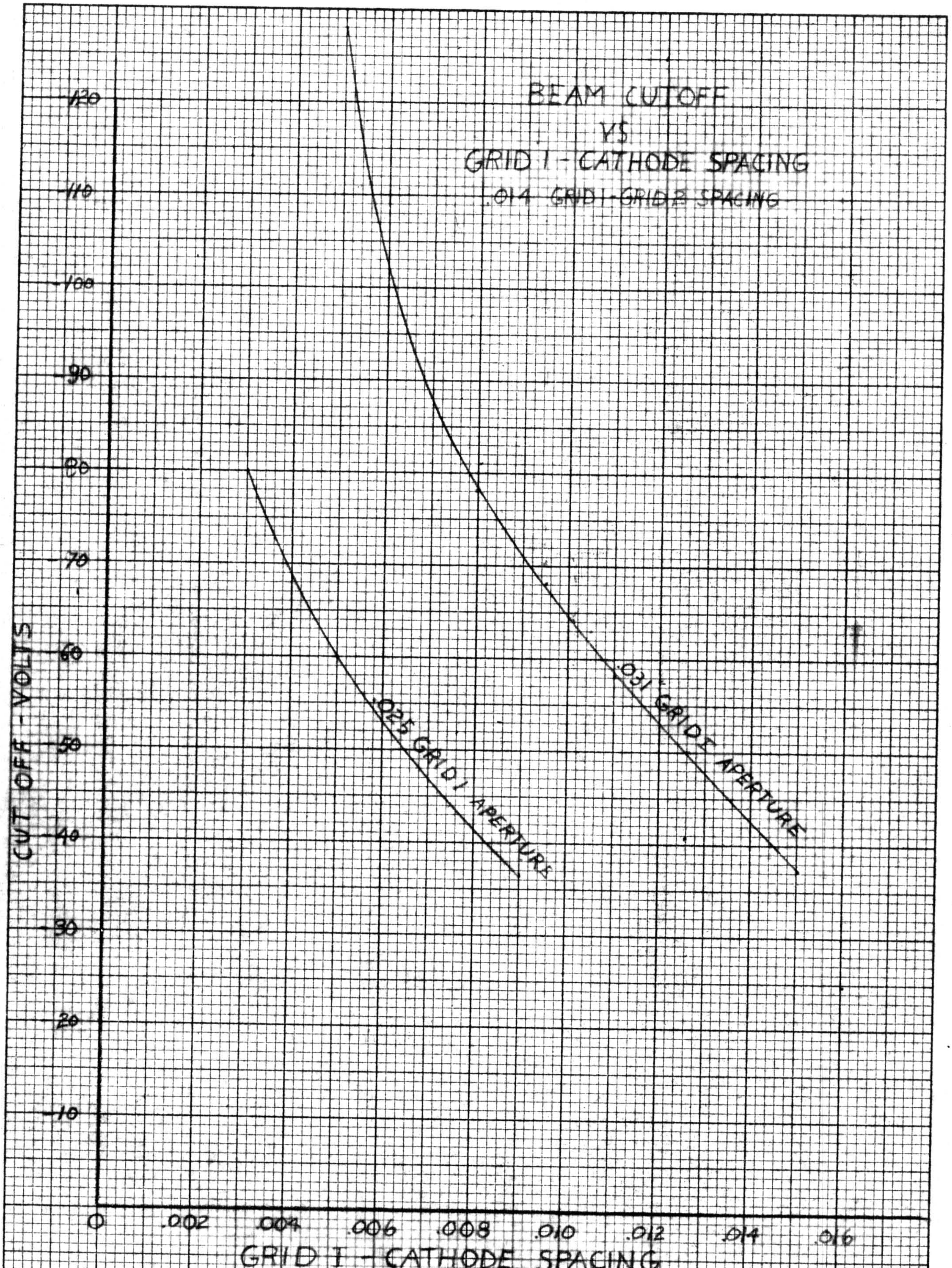


FIGURE 4

CP 5-12-58

RTD-363-K (3-47) rev.
(70X100-B)

ELECTRONICS DEPARTMENT
GENERAL ELECTRIC
SYRACUSE, N. Y.

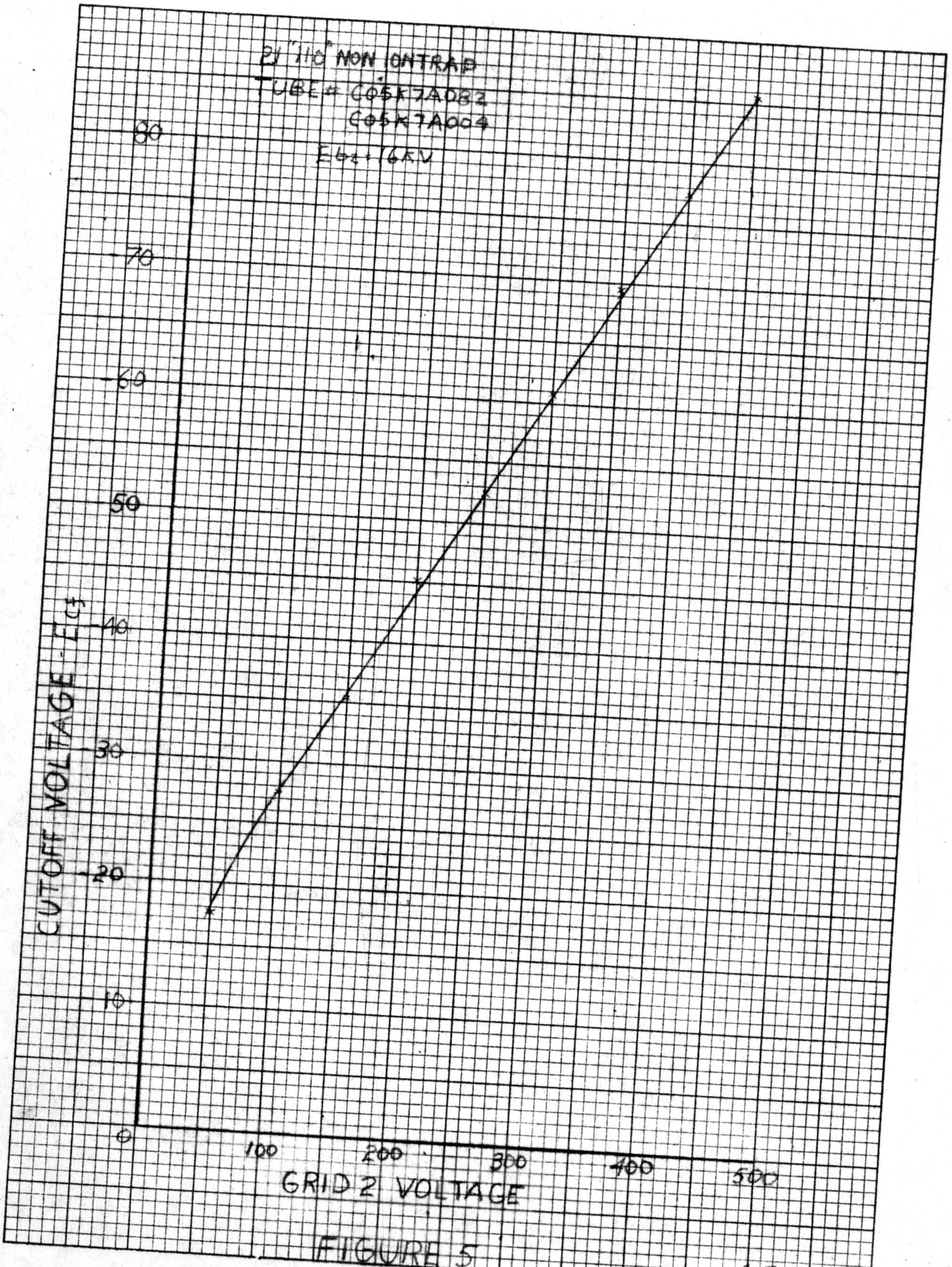


FIGURE 5

3-7-58

RTD-363-K (3-47) rev.
(70X100-B)

ELECTRONICS DEPARTMENT
GENERAL ELECTRIC
SYRACUSE, N. Y.

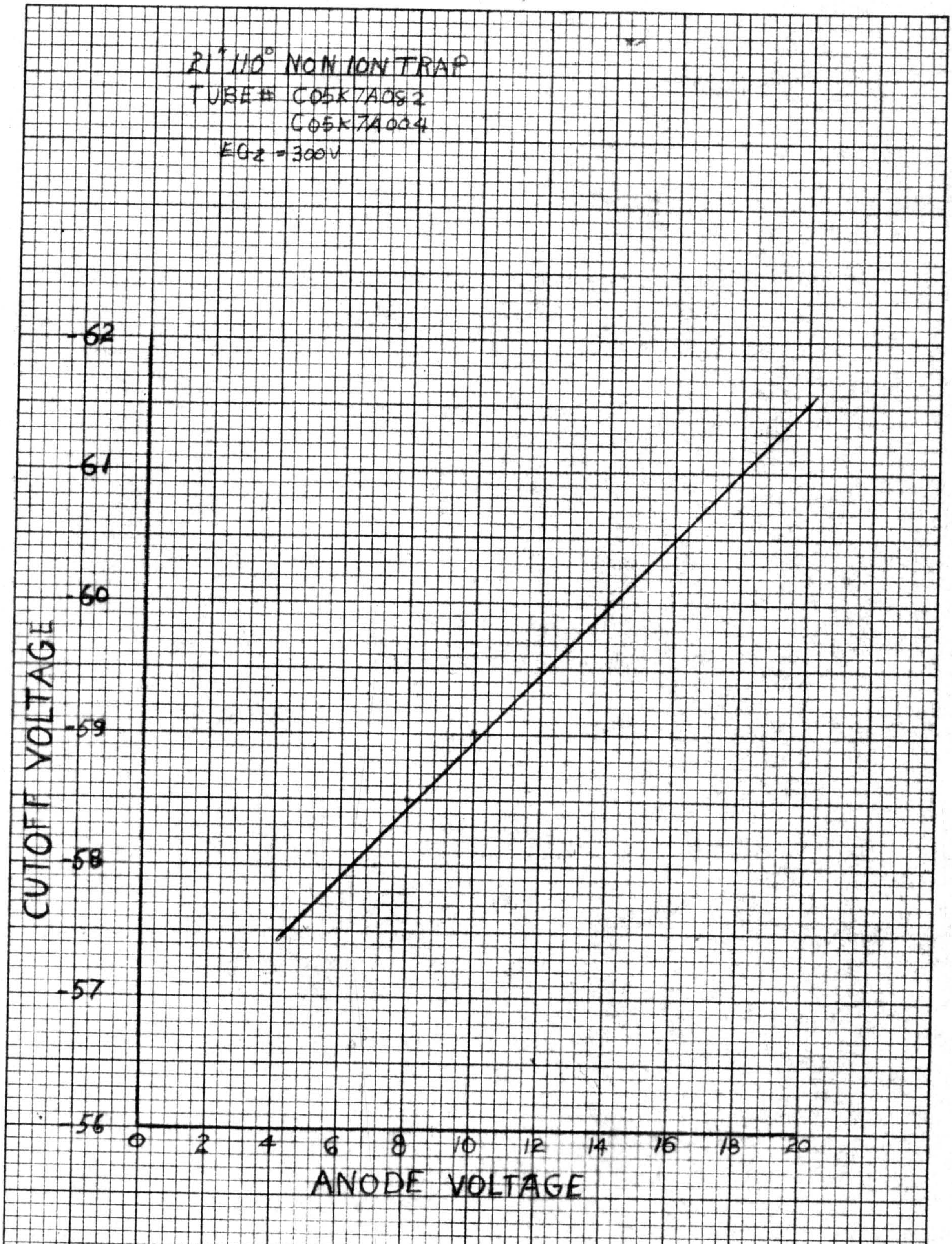


FIGURE 6

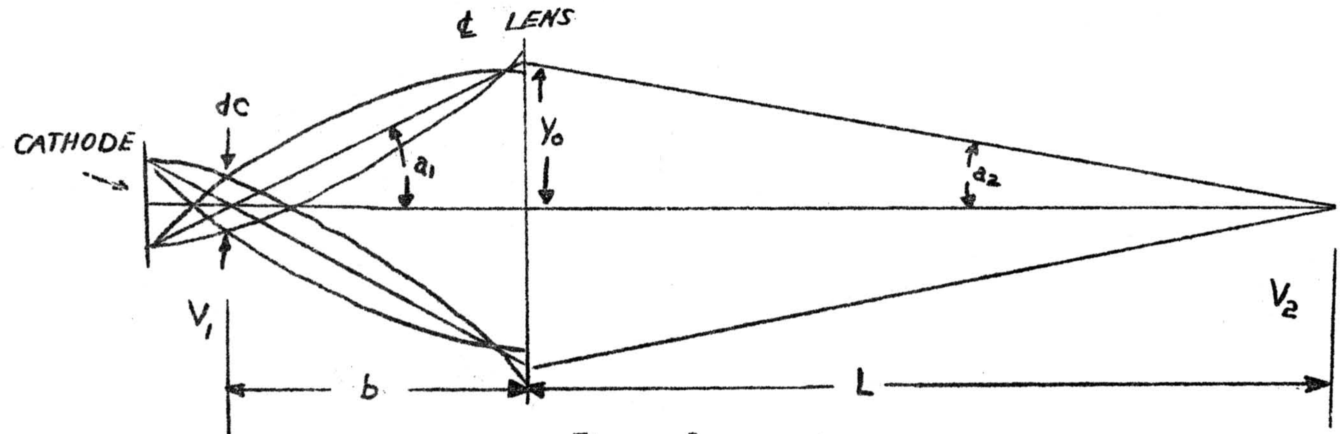


Figure 8

where

dC - object size (crossover)
b - distance from object to lens
Y_o - radius of lens occupied by the electron beam
L - distance from the lens to screen
a_1 - ray angle in object plane
a_2 - ray angle in image plane
ds - image size
V_1 - voltage at object
V_2 - voltage at image

Solving for ds

$$ds = dC \frac{\sin a_1 \sqrt{V_1}}{\sin a_2 \sqrt{V_2}} \qquad (3)$$

Since for small angles the sin a = tan a

$$\tan a_1 = \frac{Y_o}{b} \qquad \tan a_2 = \frac{Y_o}{L}$$

Substituting in eg 3

$$ds = dC \frac{\frac{Y_o}{b}}{\frac{Y_o}{L}} \frac{\sqrt{V_1}}{\sqrt{V_2}}$$

$$ds = dC \frac{L}{b} \frac{\sqrt{V_1}}{\sqrt{V_2}} \qquad (4)$$

As can be seen in equation (4) any change in the immersion lens which changes the position or size of the crossover will result in a change in the final spot size at the screen.

In evaluating tube focus quality the spot size at the edge of the screen as well as the spot size at the center of the screen must be considered. The spot size at the edge is directly related to the diameter of the beam in the focusing lens ($2Y_o$) and the distance from the focusing lens to the screen. Fig. 9 shows why the spot size at the edge increases when the beam diameter in the focusing lens increases. As Y_o is increased to Y_o', beam angle a_2 increases to a_2' and the resulting spot size increases from dL to dL'.

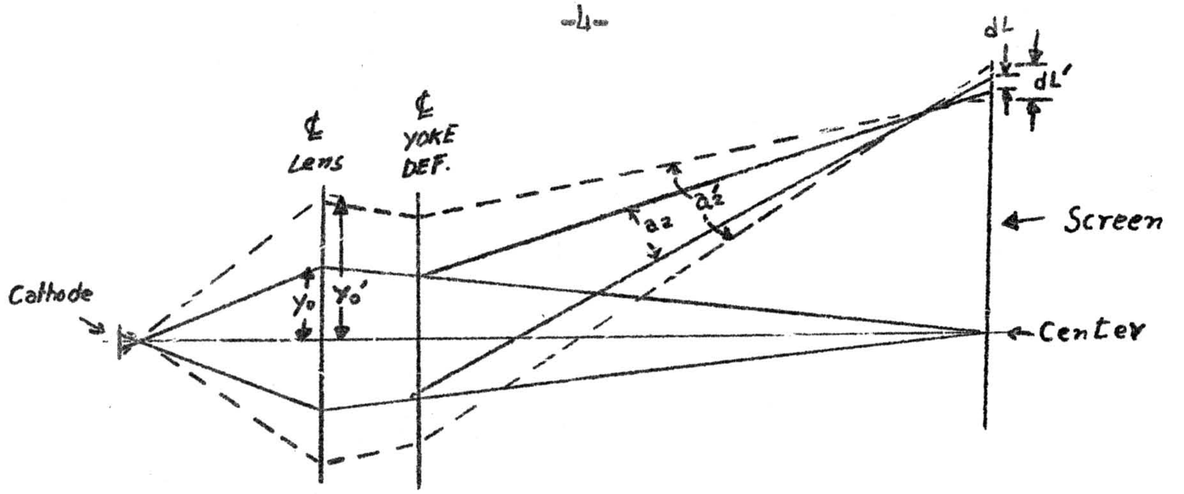


Figure 9

Although in this report the aberration of the beam due to the focusing lens is neglected it should be realized that the actual spot size at the screen is the sum of the spot size obtained from the geometrical relationship in eg. 2 and the spot size due to the aberration of the focusing lens. The spot size due to the aberration is proportional to the third power of the beam diameter in the lens.

IV. METHOD OF MEASURING SPOT SIZE

Before discussing the attached curves of spot size vs the immersion lens parameters a brief outline of the method used for measuring spot size may be beneficial. All but one or two lines of a normal raster are blanked out. The line is focused by a microscope through a narrow slit and onto a photo multiplier tube. The slit is placed parallel to the line and the line is slowly moved vertically across the slit so that the beam is divided into small horizontal elements. Each element is then sampled by the photo multiplier tube and a pulse which is proportional to the brightness of the element is applied to the vertical output of a scope. Because the beam is divided into a very large number of elements a uniform curve of light output or current density (Jk)vs the spot diameter (d) is obtained on the scope. See Figure 10a.

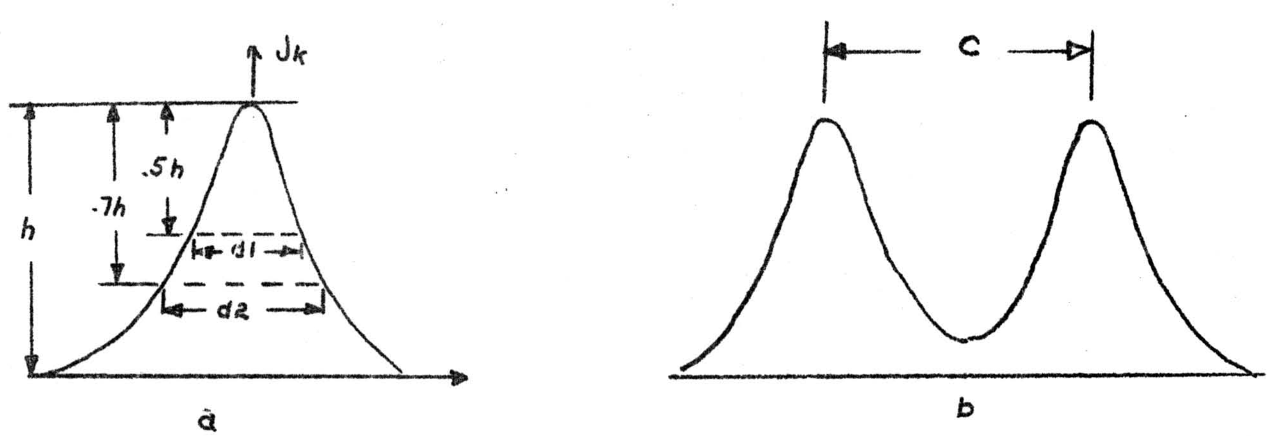


Figure 10

The width (d) of the curve is proportional to the beam spot diameter (ds)

$$ds = K_1 d$$

In order to determine the proportionality constant K_1 two lines, a known distance apart are swept across the slit giving two curves on the oscilloscope screen as shown in Fig. 10b. The distance C between the two curves is measured

$$K_1 = \frac{f}{c}$$ where f is the spacing between

the two lines on the screen.

In order to describe the spot size, two dimensions d1 and d2 are taken and these are called the .5 and the .7 value. For ease of measurements, photographs are taken of the curves and the measurements made on the photographs.

V. SPOT SIZE vs IMMERSION LENS PARAMETERS

Figure 11 shows the variation in spot size at the center and edge with changes in grid 1 - grid 2 spacing. As can be seen, the spot size at the center increases with grid 1 - grid 2 spacing while the spot size at the edge decreases indicating that the position of the crossover and the beam angle are changing with changes in grid 1 - grid 2 spacing. (See Figure 9) and equation (4)). As the grid 1 - grid 2 spacing increases the immersion lens is weakened thus decreasing the distance between the crossover and focus lens and reducing the beam angle a_2.

Figure 12 shows the variation in spot size with changes in grid 1 top thickness. The spot size at the center of the screen increases slightly with increased grid 1 top thickness while the spot size at the edge of the screen decreases slightly. The change in spot size indicates that the distance from the crossover to the focus lens is decreasing slightly and the beam angle a_2 is decreasing with increasing grid 1 top thickness.

The spot size in the center increases slightly with increasing grid 1 aperture diameter, while the spot size at the edge decreases. See Figure 13. The decreasing spot size at the edge of the screen indicates that the beam angle is decreasing with increasing aperture diameter. The increased spot size in the center may be due to a small increase in crossover size or a decrease in the distance from the crossover to the focusing lens.

Figure 14 shows the variation in spot size with variations in cathode - grid 1 spacing. The center spot size changes very little with changes in cathode - grid 1 spacing. However, the spot size at the edge increases sharply with an increase in grid 1 - cathode spacing indicating an increase in the beam angle. The constant center spot size indicates very little movement of the crossover and very little change in its size.

By the use of the curves shown on Figures 11, 12, 13 and 14 it should be possible to predict the effect of a design change in the immersion lens on the spot size. For example, an analysis of the recent change from the flat grid 1 with .007" top thickness to the coined grid 1 cup of .005" thickness around the aperture is shown in Table 1.

TABLE I

	Flat Grid 1	Coined Grid 1	Approx. Spot Size Changes (.5 Value) Center	Edge
Grid 1 - top thickness	.007	.005	-.002	+.002
Grid 1 - cathode spacing	.0045	.0055	0	+.003
Grid 1 - Grid 2 spacing	.014	.019	+.0015	0
Aperture Size	.025	.025	-	-
		Total	-.0005	+.005

The curves indicate that there would be little change in the center spot size and an incrase of .005" in the spot size at the edge. Although spot size measurement are not available on tubes using the coined grid 1 cup depth of focus ratings confirm that the edge spot size of these tubes is larger than that of tubes with the flat grid 1 cup.

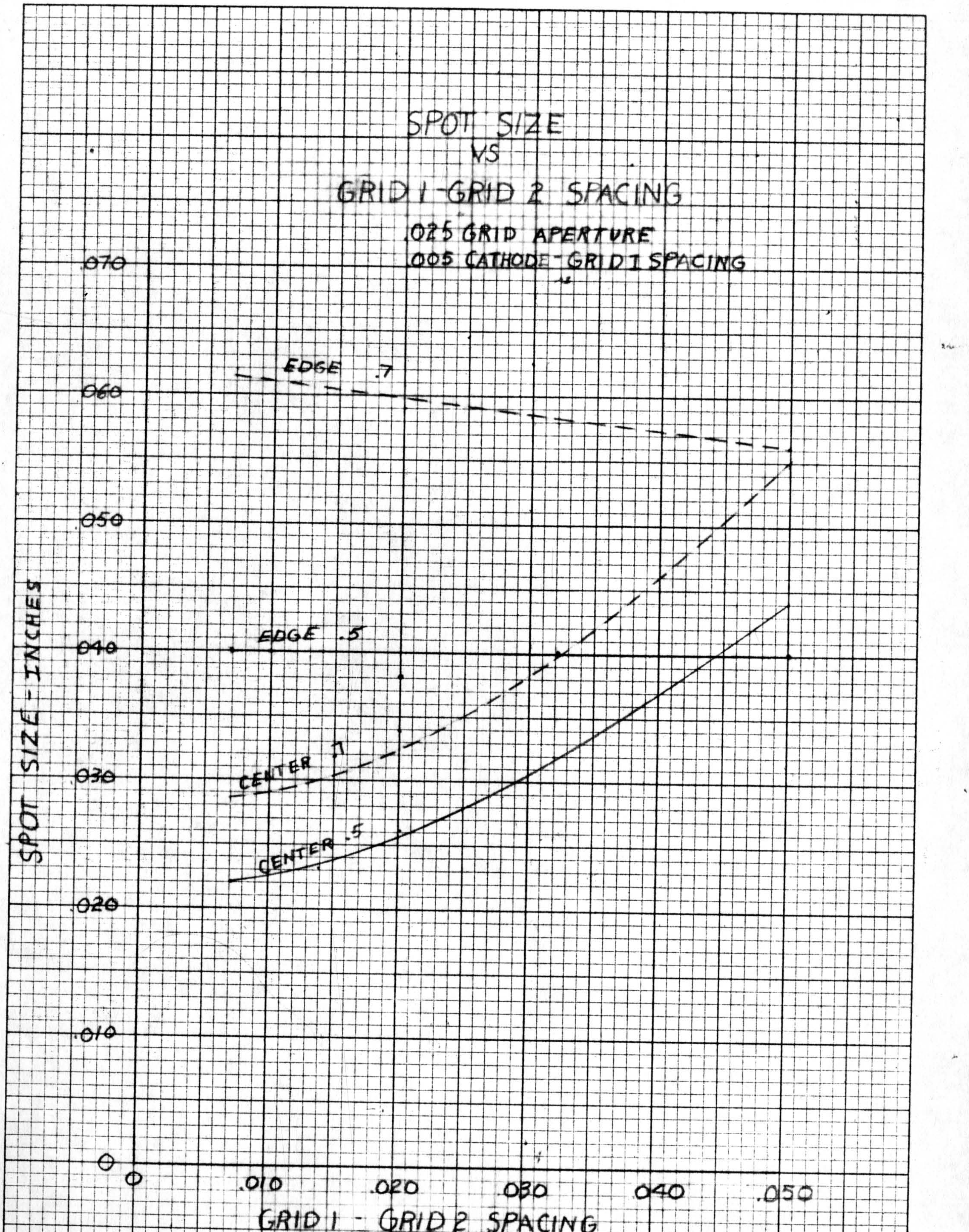
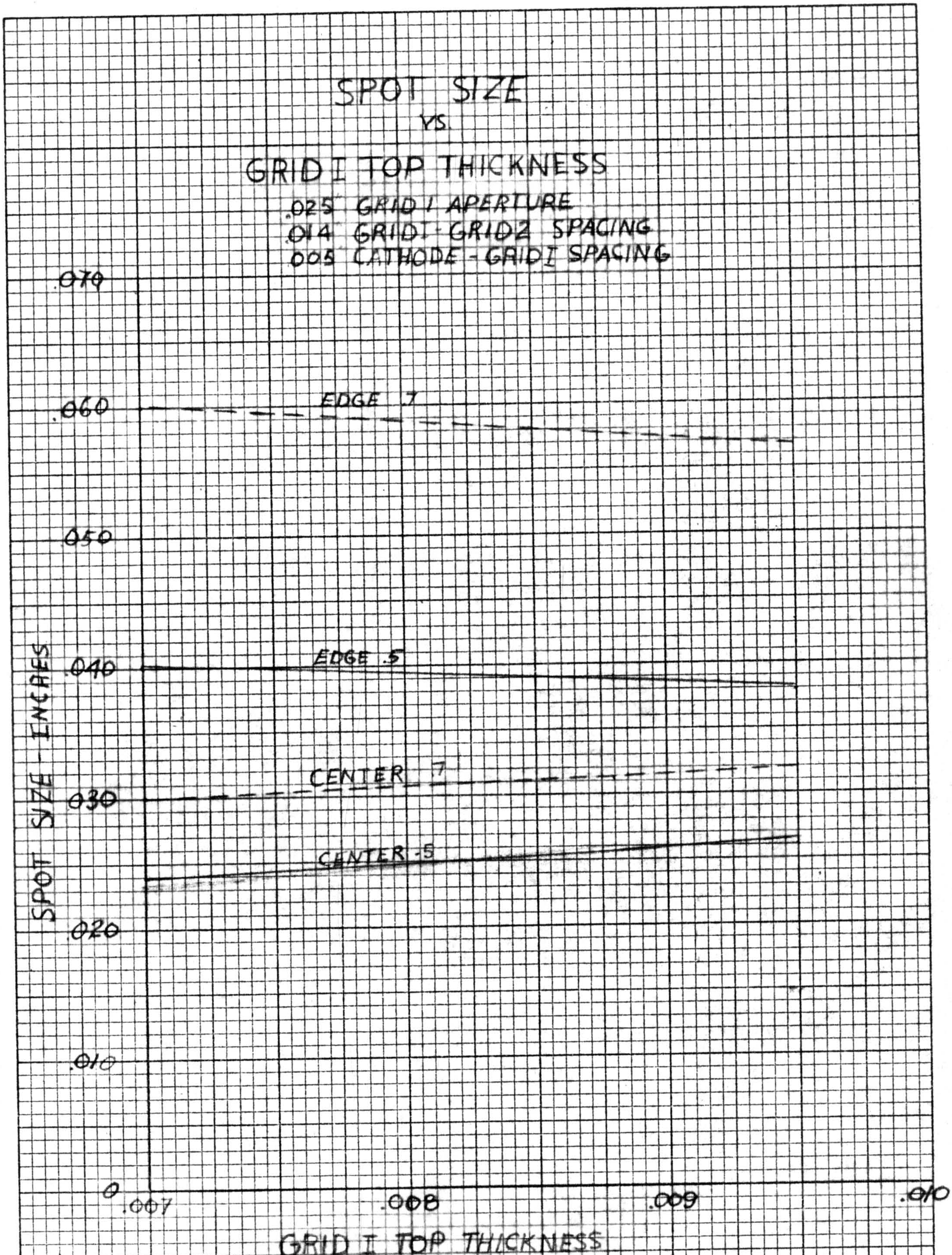

SPOT SIZE
VS
GRID 1-GRID 2 SPACING
.025 GRID APERTURE
.005 CATHODE-GRID I SPACING
EDGE .7
EDGE .5
CENTER .7
CENTER .5
SPOT SIZE - INCHES
.070
.060
.050
.040
.030
.020
.010
0
0
.010
.020
.030
.040
.050
GRID 1 - GRID 2 SPACING

FIGURE 11



SPOT SIZE
VS.
GRID I TOP THICKNESS
.025 GRID I APERTURE
.014 GRID I - GRID 2 SPACING
.005 CATHODE - GRID I SPACING
.070
.060
EDGE .7
.050
.040
EDGE .5
CENTER .7
.030
CENTER .5
.020
.010
0
.007
.008
.009
.010
SPOT SIZE - INCHES
GRID I TOP THICKNESS

FIGURE 12

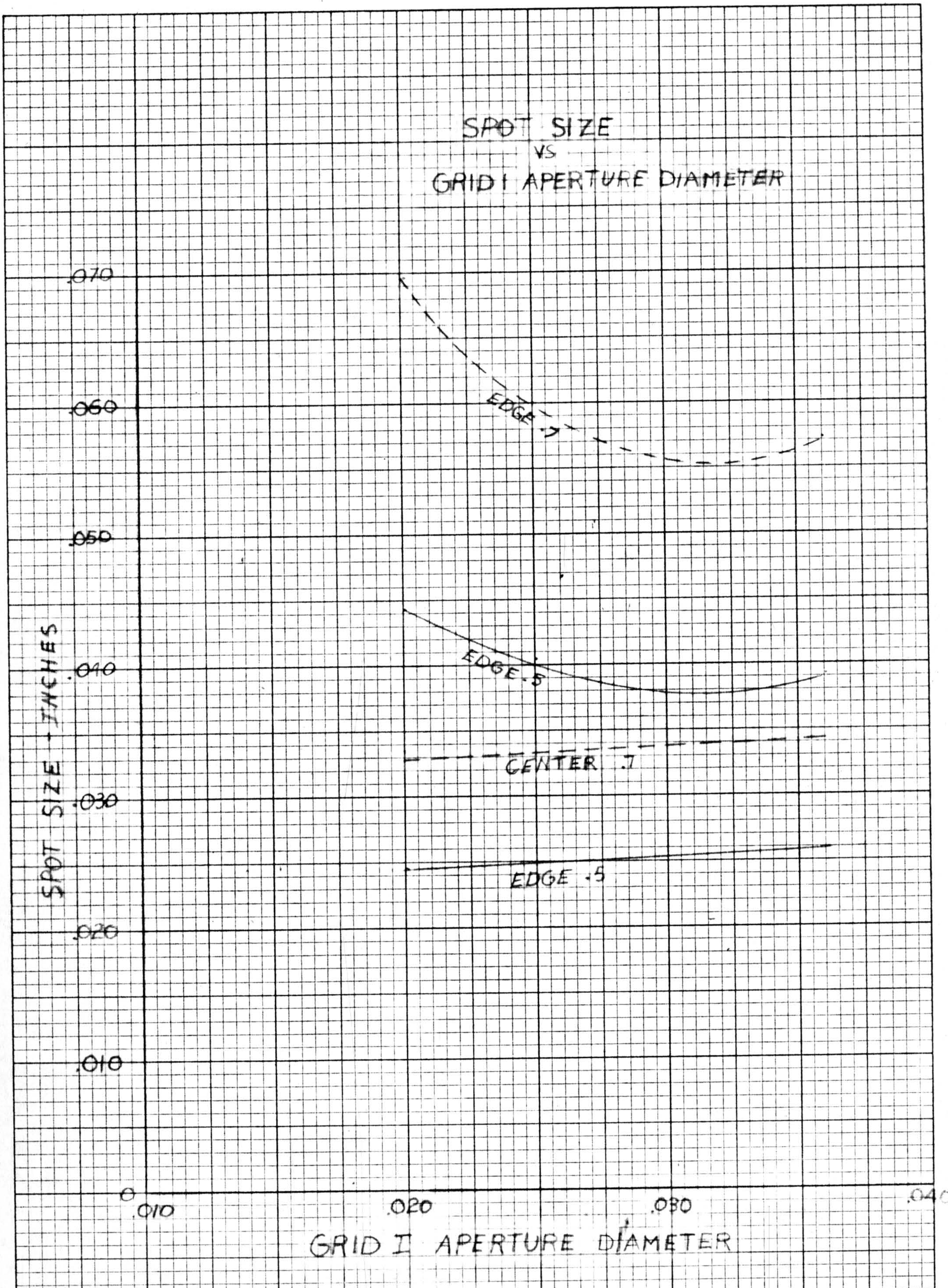

SPOT SIZE
VS
GRID I APERTURE DIAMETER
.070
.060
.050
.040
.030
.020
.010
0
.010
.020
.030
.040
SPOT SIZE - INCHES
GRID I APERTURE DIAMETER
EDGE .7
EDGE .5
CENTER .7
EDGE .5

FIG 18

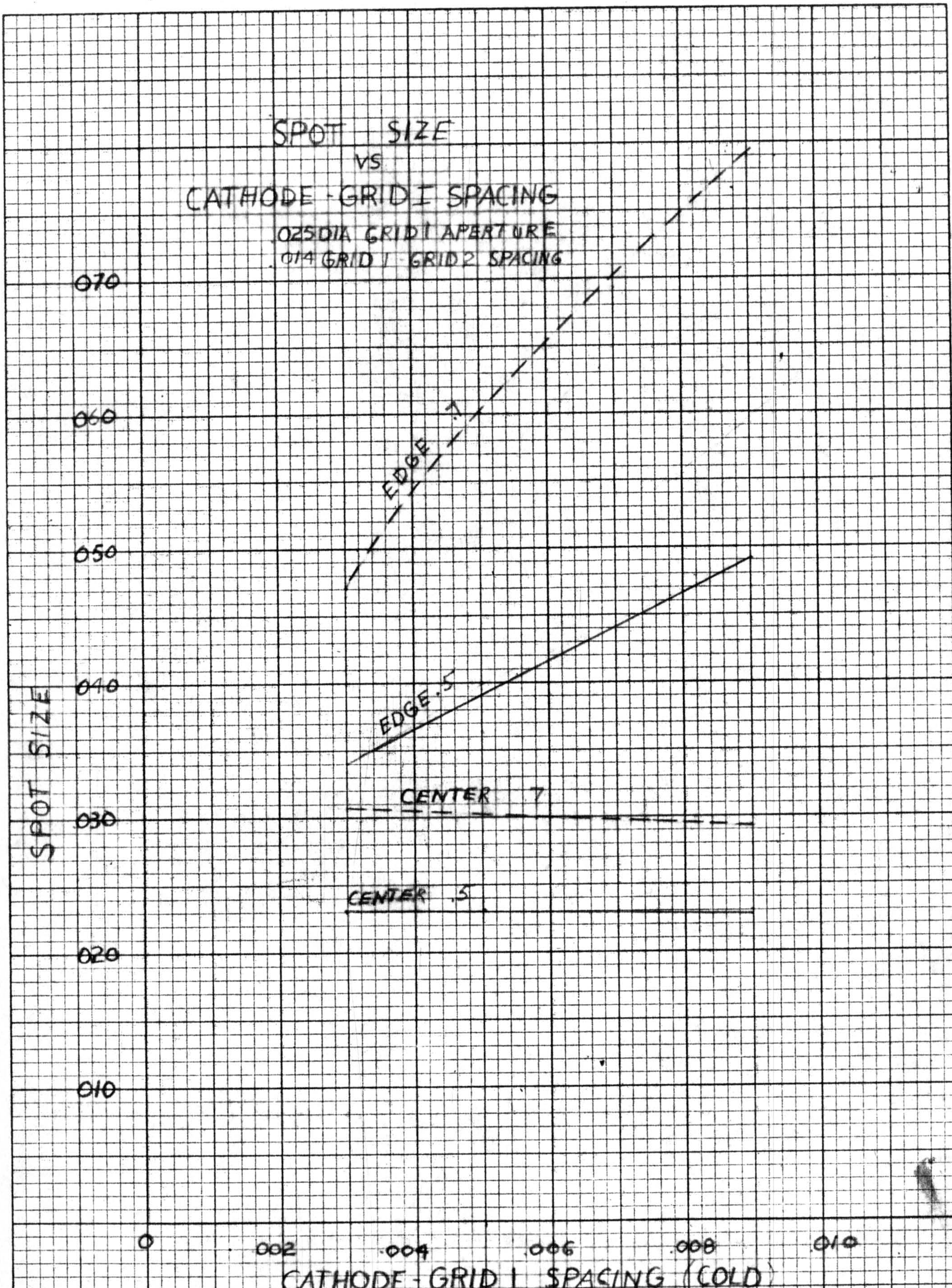

SPOT SIZE
VS
CATHODE - GRID I SPACING
.025 DIA GRID I APERTURE
.014 GRID I - GRID 2 SPACING
SPOT SIZE
.070
.060
.050
.040
.030
.020
.010
EDGE .7
EDGE .5
CENTER .7
CENTER .5
0
.002
.004
.006
.008
.010
CATHODE - GRID I SPACING (COLD)

FIGURE 14