KILOLINE RECORDING

STORAGE TUBE

By

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PRESENTATION AT P.G.E.D.
OCTOBER 31, 1958

FOR PRESENTATION AT P.G.E.D. 10/31/58

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Summary

A completely redesigned Recording Storage Tube has been developed in both single and dual-gun versions. Both types exhibit resolution in the order of 1000 TV lines at 50% modulation. Additional improvements in tube performance found in the new design include a vastly improved background uniformity, reduced output capacitance, a tetrode type electron gun, and the ability to use either electrostatic or magnetic focusing. This paper will concern itself specifically with the single-gun version, the QK685, since the many modifications described were incorporated first in this design.

Background

The prototype Recording Storage Tubes, the QK357 and the QK464, have been in production at Raytheon since 1951. The current version, the QK464A, is presently specified in several military equipments and has an excellent reputation for high resolution, long useful life, and reliable performance. This tube is specified as having 600 TV lines minimum resolution per tube diameter measured at a relative amplitude of 50%. (This resolution is measured as per the proposed IRE Standards 57 IRE 7. PS3 Section 11.3.2.1.) The tube has a continuous dynamic range with a maximum degree of background non-uniformity specified as 20% of peak amplitude signals. Thousands of read-outs can be obtained after a single frame of writing without loss of the stored information. Other operating characteristics, such as writing speed, erasing speed, and the theory of operation, have been described in previous articles, 1, 2, 3.

The purpose of the recent development work was to maintain the many valuable features of the QK464A while improving resolution and background uniformity.

QK685 Design Parameters

As has been described previously in the literature, the Recording Storage Tube works on the basic principle of secondary-emission writing on a dielectric surface and reading out while using the stored charge pattern to modulate an electron beam. This principle permits the continuous dynamic range and results in the ability to read-out a stored pattern many thousands of times without substantial deterioration of the written signal inasmuch as the electron beam does not strike the negatively biased surface of the dielectric when the tube is in the "Read" mode of operation.

Figure 1 is a schematic representation of the QK685 design illustrating the basic components. Fundamentally we consider the tube to be made up of four sections; the tetrode gun, the focus structure, the collimating lens, and the storage assembly. In the redesign of each of these sections, the foremost considerations were high resolution, good background uniformity, and a ruggedized construction to permit the tube to operate under extreme environmental conditions.

Electron Gun Design

A basic limiting factor in the resolution of the Recording Tube was known to be the spot size of the electron beam. A program was, therefore, initiated to re-evaluate the effect of changing the various parameters in the electron gun in an effort to improve upon spot size.

To permit rapid evaluation of the effect of changing the various parameters, a slotted-target tube was constructed and each of the various gun designs were tested in such a tube. Figure 2, schematically representing the slotted-target tube, shows that it was designed to simulate as closely as possible the prototype Recording Storage Tube. The slotted target, itself, was a solid metal plate with pair of parallel slots spaced fifteen mils apart and with a slot size of one mil. These pairs of slots were located at varying distances from the center of the storage ring to permit evaluation of deflection and collimating-lens defocusing.

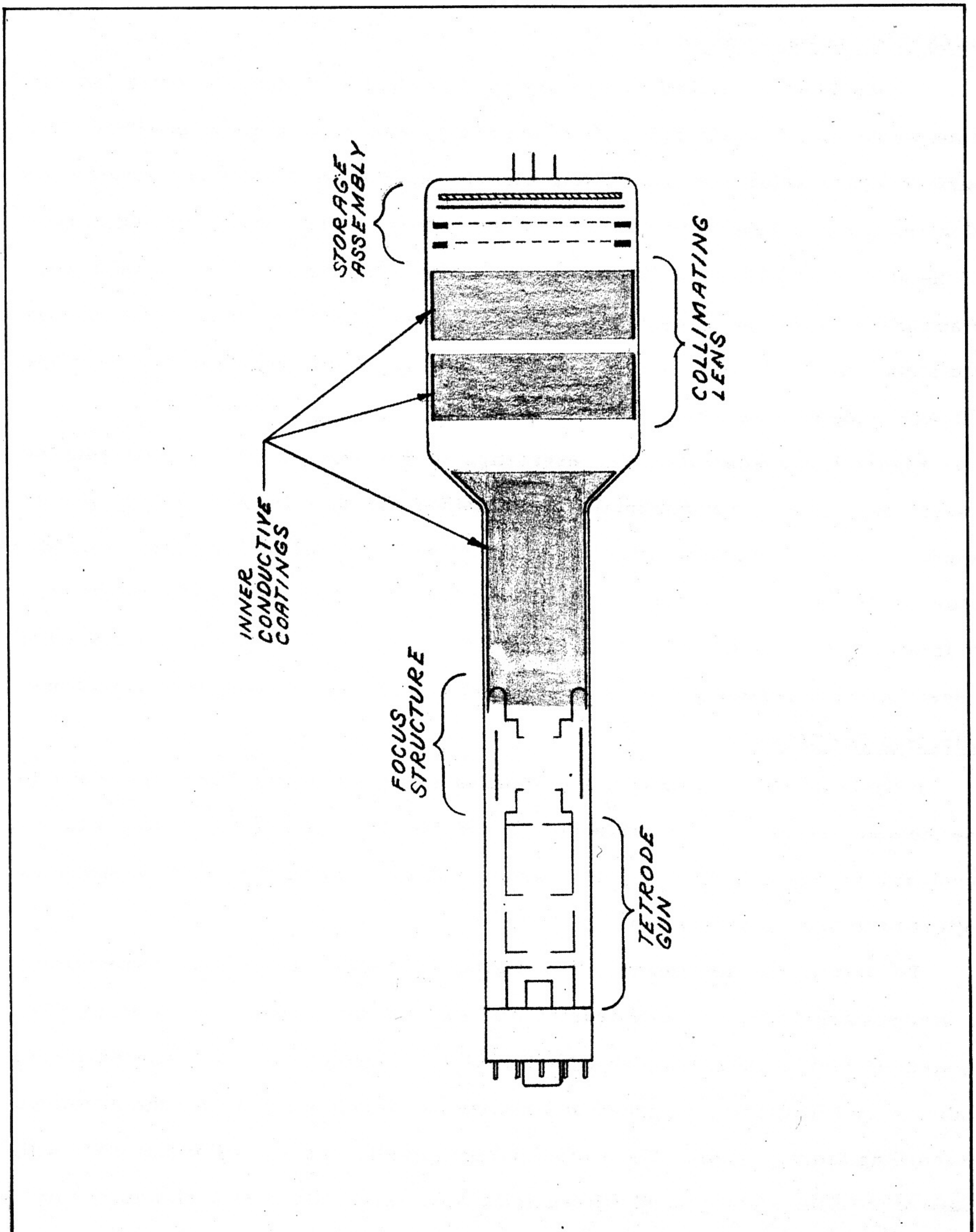

Figure 1-QK685 Schematic

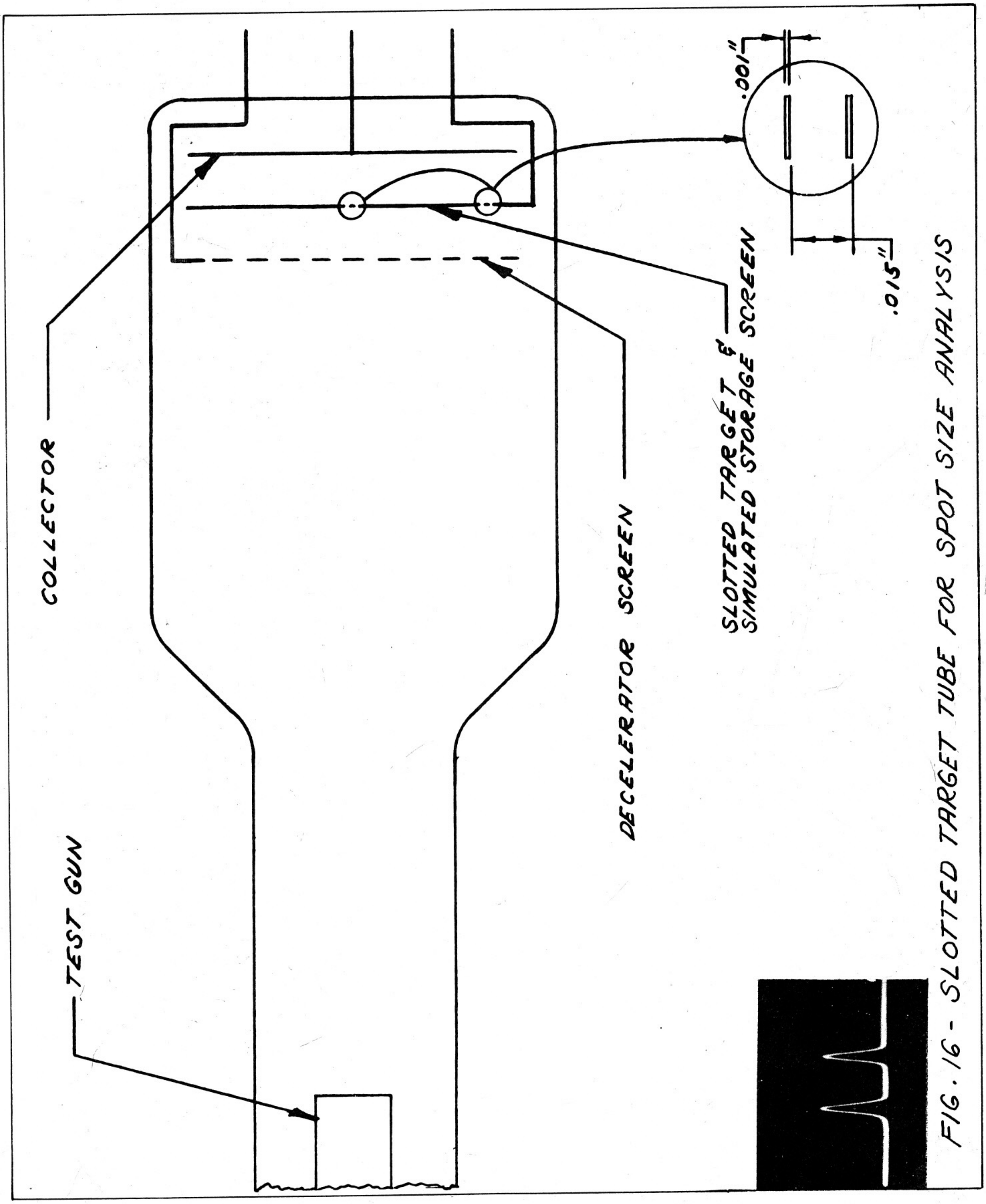

FIG. 16 - SLOTTED TARGET TUBE FOR SPOT SIZE ANALYSIS

Figure 2-Slotted Target Tube For Spot Size Analysis

The insert in Figure 2 is a typical output pattern seen on the oscilloscope when the slotted-target tube is scanned in synchronism with an oscilloscope with the current passing through the slotted targets collected and displayed as the vertical deflection on the oscilloscope trace. Since the spacing between slots is known to be fifteen mils, the cross-section of the beam can be accurately measured on the photograph of the oscilloscope trace. (Of course, the effect of the finite one mil aperture size must be taken into consideration when computing the beam diameter.)

Figures 3, and 4, are plots of the spot size of the electron beam in the region of the storage screen as functions of the cathode-grid spacing, and control grid to accelerator grid spacing. Similar curves derived from varying combinations of two and three parameters simultaneously to determine inter-relationships resulted in the development of a gun with extremely fine spot size and with a minimum of change in spot size with different values of beam current. Figure 5 is a plot of spot size versus beam current comparing the triode gun used in the QK464A design with a gun developed and used in the QK685. The final gun design is not an optimum with regard to spot size but rather is a compromise between spot size and the practical limitations imposed when utilizing inter-electrode spacings which can be accurately controlled using production techniques for manufacturing cathode-ray tube electron guns.

Focusing System

It is well known that, because of the difference in proportion of the lens aperture used, magnetic focusing will provide smaller spot sizes than electro-static focusing in typical cathode-ray tube designs. On the other hand, several important advantages exist favoring the use of electrostatic focusing, especially where it is desirable to dynamically focus the spot in order to maintain optimum spot size across the full storage screen. To capitalize on the advantages of both focusing systems, the QK685 was designed to permit the use of both focusing systems simultaneously. That is, magnetic focusing can be used to supply the

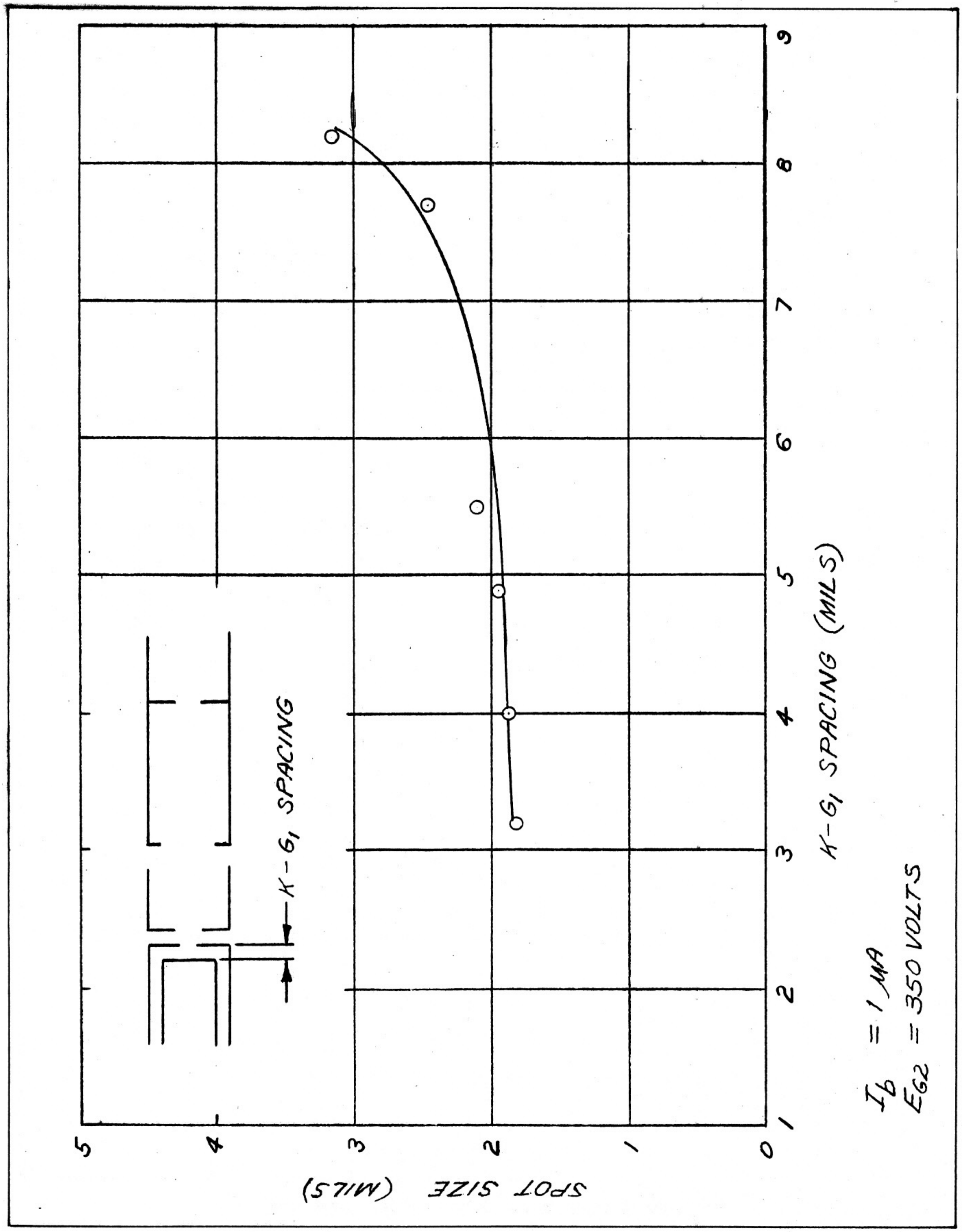

Figure 3-Spot Size VS K-G$_1$ Spacing

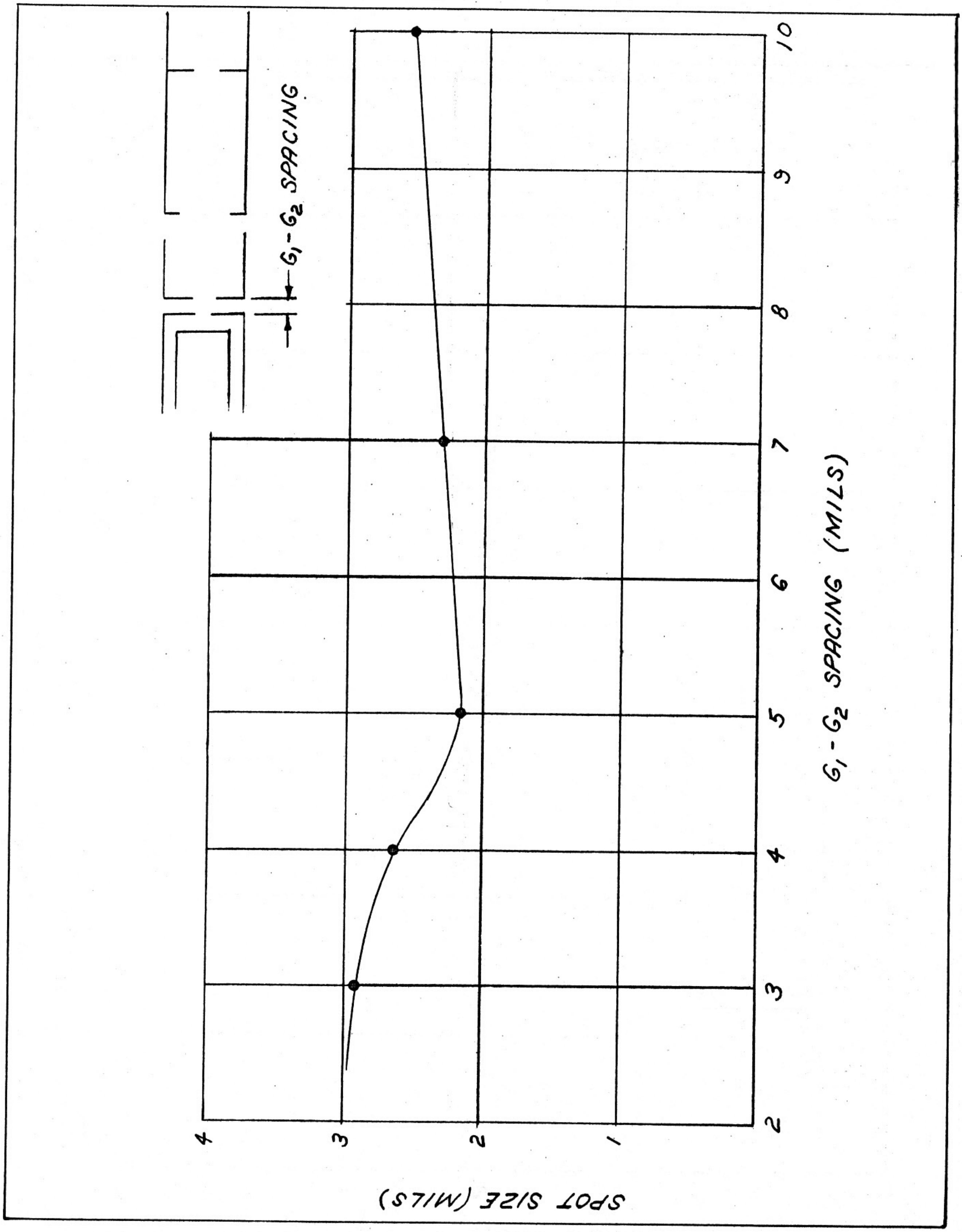

Figure 4-Spot Size VS G_1-G_2 Spacing

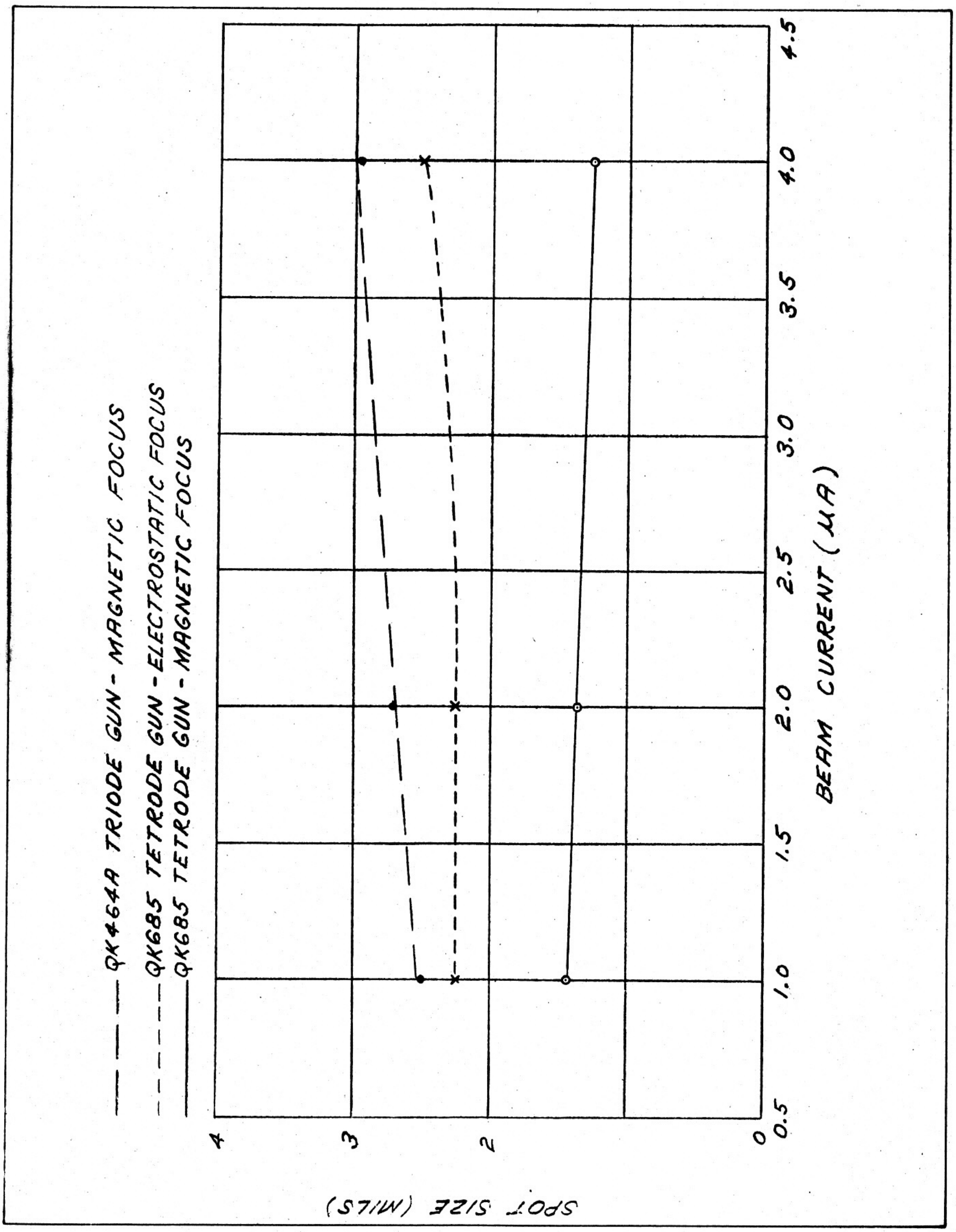

Figure 5-Spot Size VS Beam Current

greatest part of the focusing action, while electrostatic focusing can be used to trim or optimize focus and to dynamically focus the electron beam. It should be noted that, as with other low-voltage cathode-ray beams, the magnetic focus field must be quite homogeneous if astigmatism and deflection defocusing are to be minimized.

Collimating Lens

The collimating lens of the prototype tube, the QK464A, maintained background uniformity to within 20% but resulted in considerable beam defocusing toward the edge of the lens field and severely limited maximum usable deflection angle, and thus resolving power. An attempt to improve upon the lens uniformity and increase deflection angle at the same time was made in spite of the fact that the two requirements were quite conflicting.

To permit an accurate analysis of the optimum field shape for collimation at wider deflection angles, a special tube was developed with a large number of individually controllable lens electrodes. This lens-analyser tube, shown schematically in Figure 6, permits one to set up a large number of voltage-field configurations. The degree of collimation that each field configuration provides can be analysed by examining the shading characteristics. (That is, by varying the storage screen voltage one can see whether the whole area cuts off at nearly the same voltage or whether the cut-off voltage is different for the center of the screen and the region around the periphery.) The difference in screen cut-off voltage is, of course, a function of the angle at which the electron beam is approaching the screen at any point. Ideal collimation, which means perpendicular incidence of the electron beam at the storage screen over the complete storage screen area, would result in a single cut-off voltage for the whole screen. This approach to studying the collimating lens systems proved much simpler and more accurate than the more typical approach involving the use of an electrolytic trough.

A voltage configuration was found which provided excellent collimation over

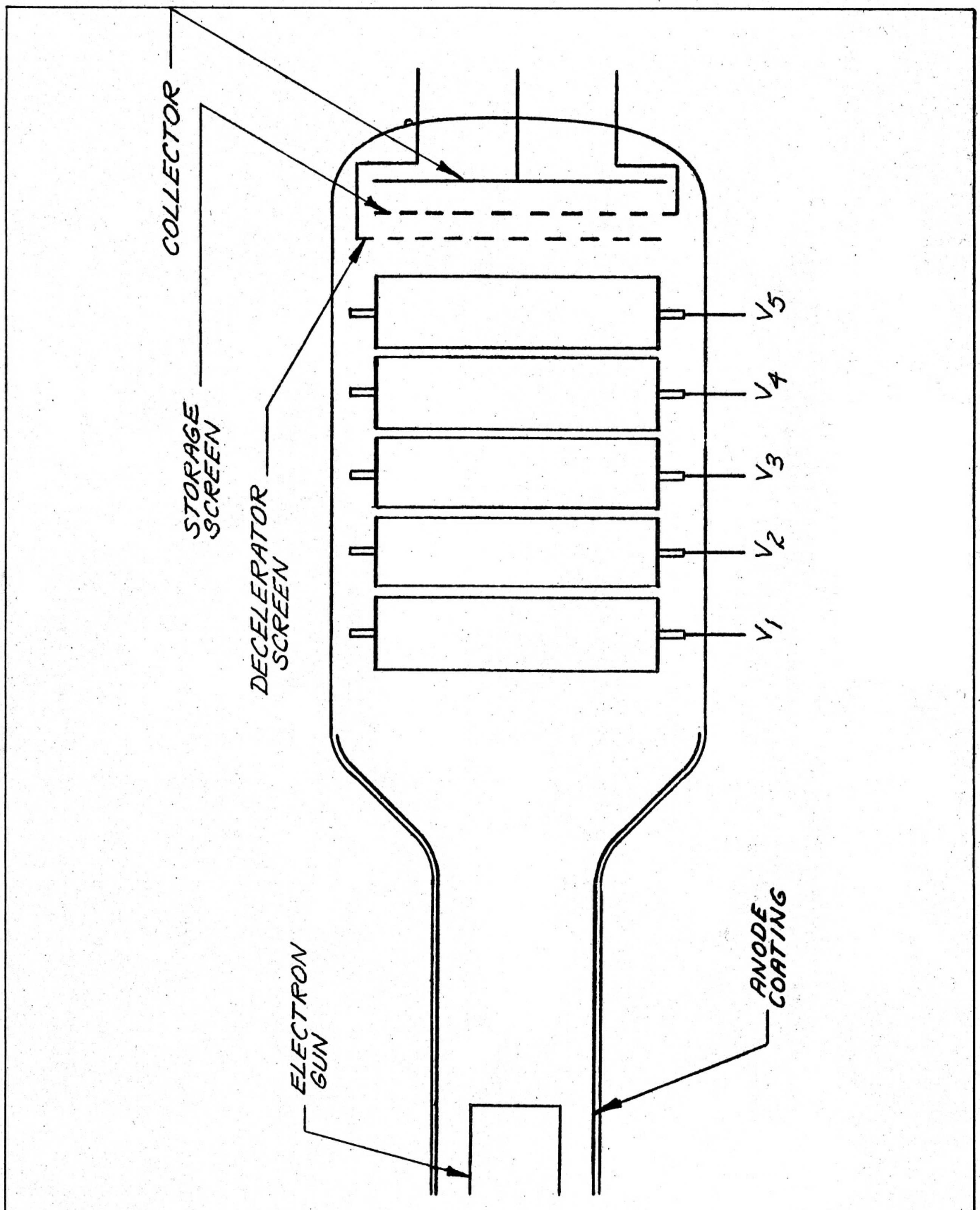

Figure 6- Collimating Lens Analyser Tube

a deflection angle in excess of 25°. Fortunately the resultant lens system was sufficiently simple to incorporate directly into the finished tube. The equipotentials of this lens configurations, as plotted in an electrolytic trough, are shown in Figure 7. As can be seen, the lens is made up of the field patterns produced by the anode, two cylinders painted on the wall of the bulb, and the flat decelerator screen. Typical voltages for good collimation with this lens would be 4000 volts on the anode, 500 volts on the first lens electrode, 300 volts on the second lens electrode, and 500 volts on the decelerator screen.

Since the necessity for collimating at all could be avoided if a spherically curved screen system were used with the center of curvature at the center of deflection of the electron gun system, a thorough analysis was made of this approach. An additional advantage which would be attained from such an approach would be the elimination of the need for dynamic focusing. An analysis of this approach to the problem indicated, however, that either the first screen would have to be at the same potential as the accelerating anode with the deceleration done between the first screen and the storage screen or field shaping would be necessary so that the equipotentials from the center of deflection to the first screen would be concentric spherical curves. The latter approach seemed quite impractical, whereas the former required an extreme deceleration rate between the two screens. An analysis of the equation for shading noise is

$$\frac{V_e}{V_2} = 1 - \frac{V_1}{V_2} \sin^2 \theta_1$$

Where V_e = Effective Shading Voltage

V_1 = Voltage of First Screen

V_2 = Voltage of Second Screen

θ_1 = Angle that the beam makes with the normal to the first screen.

Thus, the angle of incidence of the electron beam at the first screen becomes

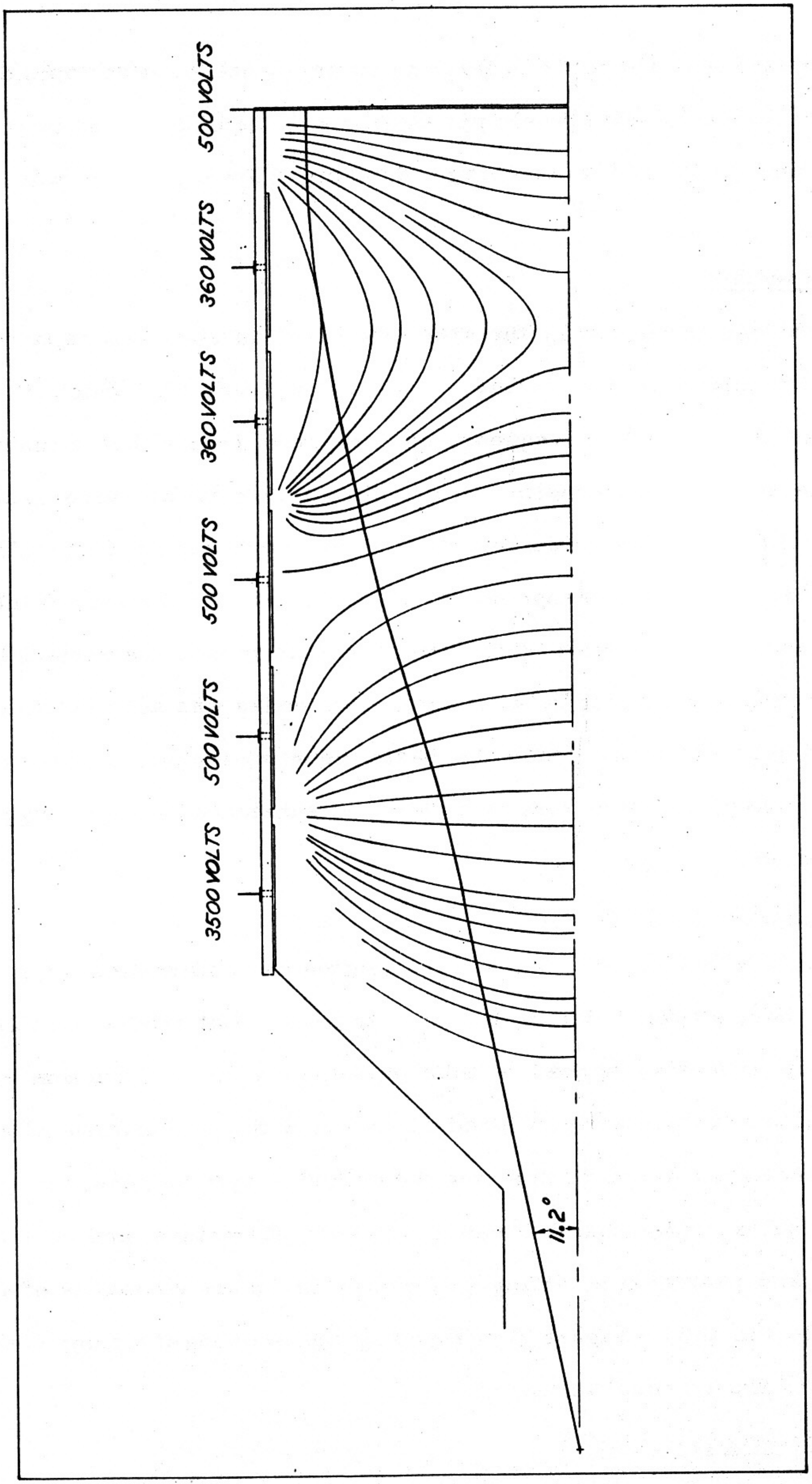

Figure 7-Equipotentials In Collimating Lens Analyser

vastly more critical where V_2 is large in value---that is, with rapid deceleration between the screens. This would put an extreme requirement on the coaxiality of the deflection coils and the storage system. This approach was, therefore, abandoned.

Storage Assembly

The storage assembly in the prototype tube had an output capacitance in the order of 20 micro micro farads. Since the load into which the tube can operate and the amount of frequency compensation required is a function of this output capacitance, the reduction to 10 micro micro farads accomplished in the QK685 results in a direct two to one gain in output signal derivable from the storage tube. The basic change in design was to reduce the size of the collector electrode and use a ceramic disc from which to mount the various electrodes. Precise control and spacing between these electrodes was accomplished by use of ground ceramic washers. Since the basic mounting technique relies on ceramic to metal brazing, the structure is considered substantially more rugged than the earlier designs.

Processing Requirements

To maintain the higher values of resolution and collimation, it is necessary not only to have a proper design but also to insure that production tolerances do not result in excessive spread of tube parameters in a production run. Basic steps taken to insure a uniform product included the development of a precision alinement technique for manufacturing the cathode-ray tube guns, the use of glass necks and bulbs with close-tolerance internal diameters and a minimum of ellipticity, and precision mounting techniques to insure coaxiality of all the elements within the tube. Figure 8 is a photograph showing the components making up the QK685 and a typical tube.

Tube Characteristics

As was mentioned earlier, the QK685 design which resulted from the several

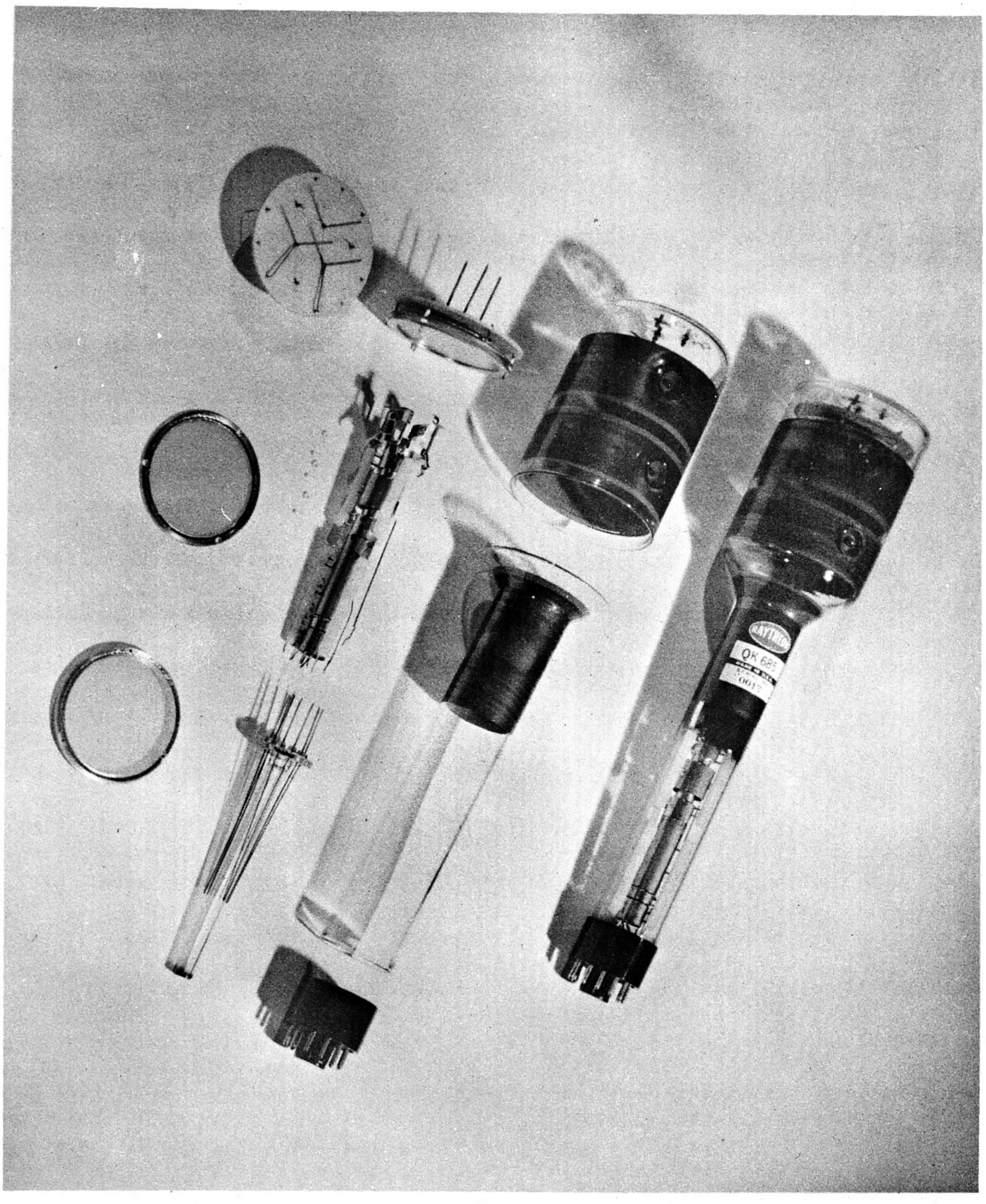

Figure 8- Components Of QK685 And A Typical Tube

changes described met all the requirements originally set as target specifications. Perhaps the most dramatic improvement over other storage tube types is the resolution which can now be obtained. Figure 9 is a complete resolution chart comparing typical tubes of the QK685 design and the QK464A design. The increase in resolution is of course, attributed not only to the improved spot size of the electron beam but, in equal measure, to the wider deflection angle made possible by the improved collimating lens. Moreover, despite the increase in deflection angle to nearly 25° shading effects have been improved from a specified value of 20% in the QK464A design to better than 10% of peak amplitude signals. Decrease in output capacitance from 20 micro micro farads to about 10 micro micro farads allows the use of a higher value of load resistance for equivalent high frequency response. Other features considered of value in the new design include incorporation of a screen grid in the resultant improvement in electron gun transfer characteristics and wider control of drive and cut-off parameter. The ability to focus the tube using either a solenoid or the electrostatic focus elements, or for optimum performance, a combination of the two adds still further to the versatility and usability of the tube. Figure 10 below shows a picture stored on a small area of the storage surface. The second and third panels are contracted and expanded views of the picture which is stored in the center of the storage screen. Since, as can be seen, only about one third of the storage screen diameter was used for this charge pattern, and since the resolution of this sector is seen to be quite high, the more than 1000 lines resolution capability of the tube is accurately demonstrated. Figure 11 is a stored TV picture showing the capability of the tube to record the complete range of gray shades.

A dual-gun Recording Storage Tube, the QK703, has been developed using the same lens system as the QK685 and same electron guns for both the reading and writing structures. As would be expected, this tube also demonstrates the high

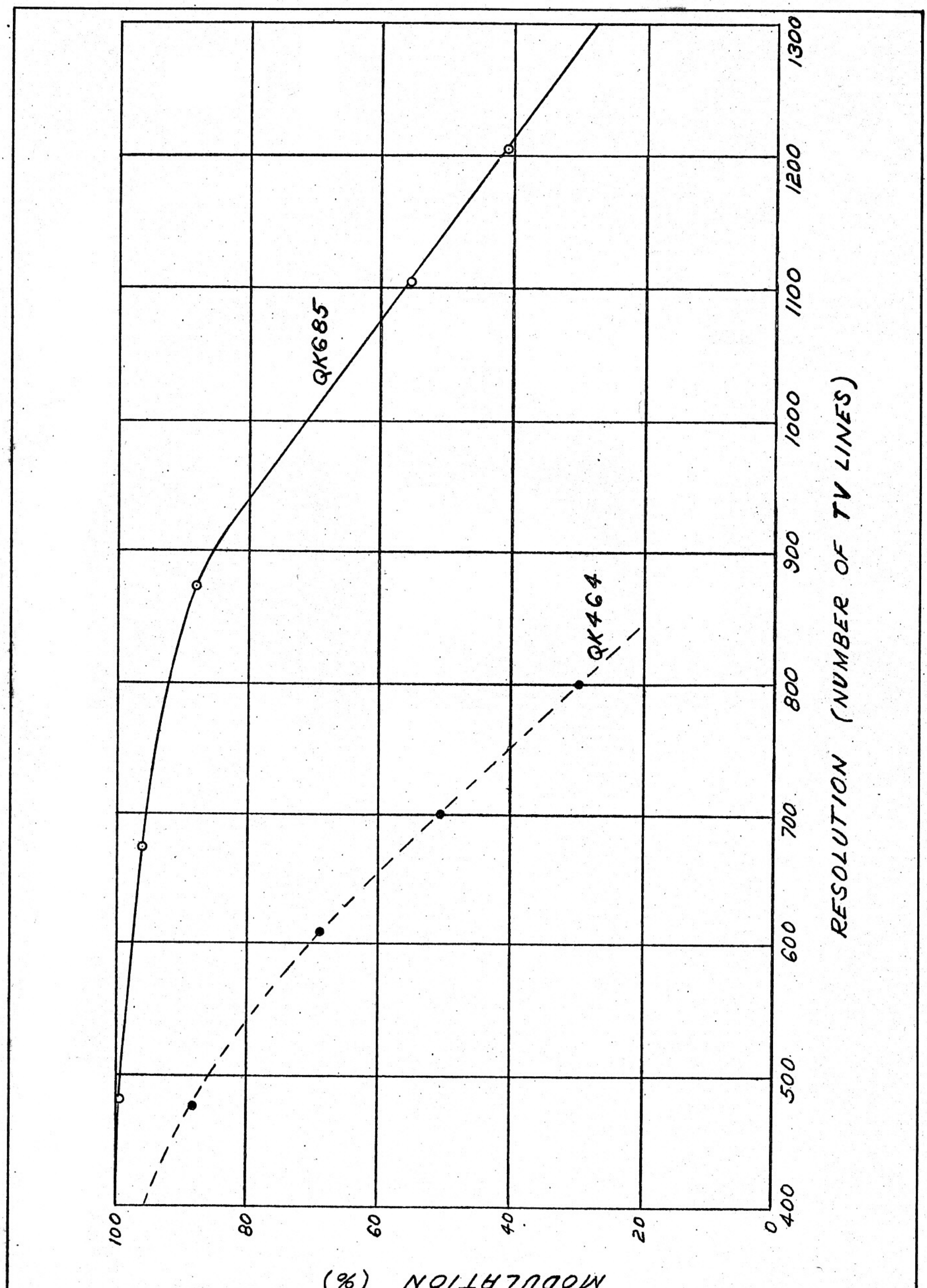

Figure 9-Typical Resolution Curves

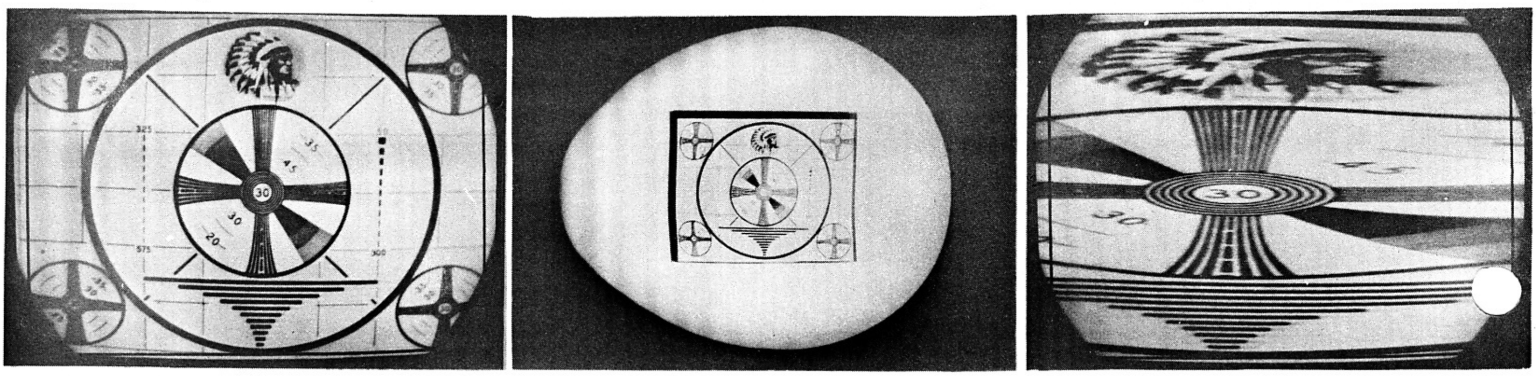

Figure 10-Picture Stored On Small Area Of Storage Surface

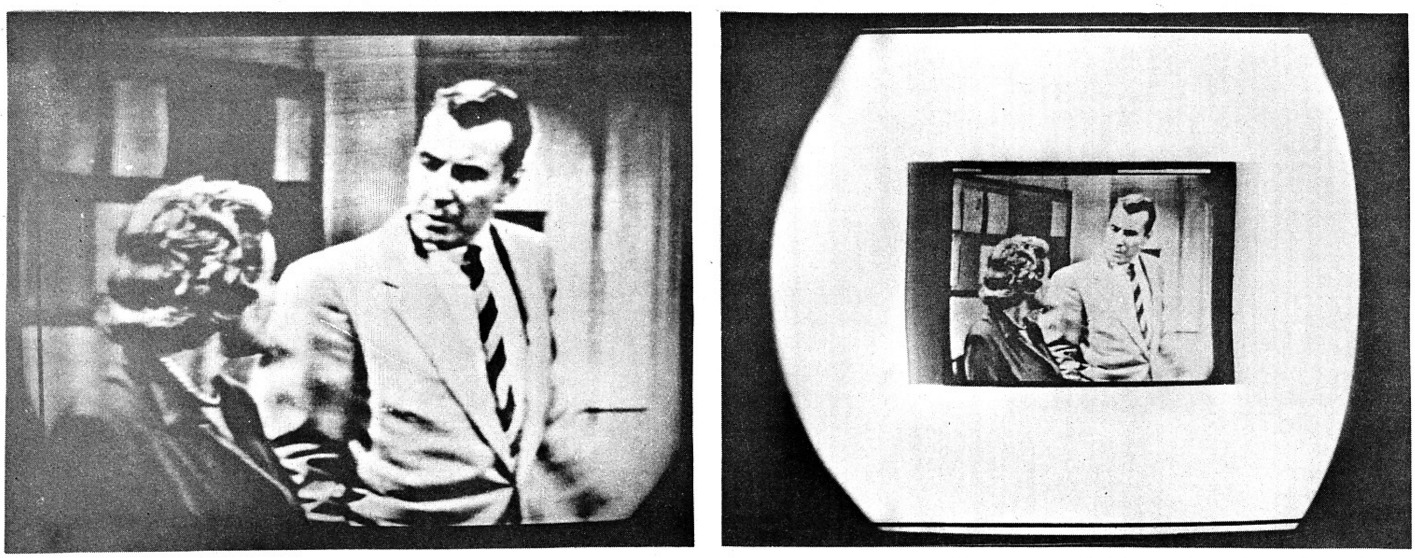

Figure 11-Stored TV Picture Showing Tube's Capability To Record Complete Range Of Gray Shades

resolution and excellent shading characteristics of the QK685. The additional feature of the dual-type tube, the ability to simultaneously read and write, makes this type especially applicable to scan-conversion applications such as slow-down video and conversion from PPI to TV scan pattern for "Bright Display".

Acknowledgement is due to Dr. R. C. Hergenrother for his continuing leadership in storage tube development and to J. A. Buckbee, J. S. Maienza, D. D. Duggan, T. Dunne, and A. Cloutier, engineers working on this project, for their many contributions.

The QK685 development program was supported by I.B.M. under their Air Force Contract No. AF33(600)36599.