RB-74

VIEWING STORAGE TUBES FOR LARGE DISPLAYS

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Fig. 1 – Direct-view storage tube with 10-inch diameter target.

This bulletin describes two experimental viewing storage tubes which provide large displays. The first type, contained in a 15-inch metal color-picture-tube bulb, provides a directly-viewed display 10 inches in diameter with 250 foot-lamberts highlight brightness. The second is a projection storage tube which uses reflective optics to provide a four-foot diameter radar display with 2 foot-lamberts highlight brightness.

The resolution for both displays is better than 500 lines. These tubes extend the advantages of smaller viewing storage tubes to applications requiring large displays.

Introduction

A halftone-viewing storage tube with 4-inch picture size, described in previous publications[1,2,3,4], has been found particularly useful for daylight operation in airplanes[5] as well as for storage of single television frames[3] and oscilloscope patterns[4]. Because larger pictures are desirable for certain radar displays, e.g., for traffic monitoring at airports, for shipboard applications, and for certain television and telemetering applications, a 10-inch direct-view storage tube and a projection-type storage tube have been developed.

Ten-Inch Target Direct-View Storage Tube

An experimental version of the direct-view storage tube with a flat storage target and a 10-inch diameter useful viewing screen is shown in Figs. 1 and 2.

The metal envelope, equipped with a faceplate and neck of soft glass, is similar to that used in early developmental models of the RCA 15GP22 color kinescope. Both the spread angle of the viewing beam and the total deflection angle of the writing beam are 42 degrees rather than 27 degrees as in the 4-inch flat-screen tube. The axes of the writing and viewing guns are parallel to and displaced ¼ inch from the tube axis. After the image-amplifier section is mounted on the chrome-iron cone, the envelope is closed by heliarc-welding the top cap in place. Supported within the conical section of the envelope is a conical electrode which forms a double-condenser lens.

The target structure consists of two grids and a luminescent screen supported by a cold-rolled steel ring. The collector grid (G_1) composed of 230-mesh woven stainless steel is welded directly to the support ring. The storage grid (G_2), which consists of 100-mesh electro-formed nickel formed on a stainless-steel ring, and the Pyrex-plate luminescent screen are assembled to the principal support by machine screws and ceramic spacers.

The storage grid was prepared by evaporating magnesium fluoride from three platinum 'boats' onto the heated nickel mesh in an evacuated 18-inch bell jar at approximately 10^{-4}mm Hg. These boats were arranged in a triangle with their centers about three inches from the center of the array, the top of which was about 14 inches below the mesh. The thickness of the evaporated layers was uniform to within 10 percent.

Such large direct-view tubes are capable of reproducing at least 4 halftones with a highlight brightness of 300 foot-lamberts at 10-kilovolt phosphor potential. The resolution is at least 400 lines per target diameter, although picture uniformity is poorer than in the smaller tubes. Because of the wide divergence angle of the viewing beam, strong electron lenses are required to

*The work described in this bulletin was done at the David Sarnoff Research Center, RCA Labs. and was supported by a Signal Corps contract, DA 36039 sc. 64572.

[1]M. Knoll, NBS circular 527, p. 329.

[2]M. Knoll and P. Rudnick, NBS circular 527, p. 339.

[3]M. Knoll, P. Rudnick, and H. O. Hook, *RCA Review* 14 (Dec. 1953) p. 492.

[4]M. Knoll, H. O. Hook and R. P. Stone, *Proc. I.R.E.* (Oct. 1954) p. 1496

[5]C. E. Reeder, 'Evaluation of the Direct-View Storage Tube'. Lecture given at the IRE Convention, Prof. Group for Electron Devices, Oct. 24, 1955 at Washington, D. C.

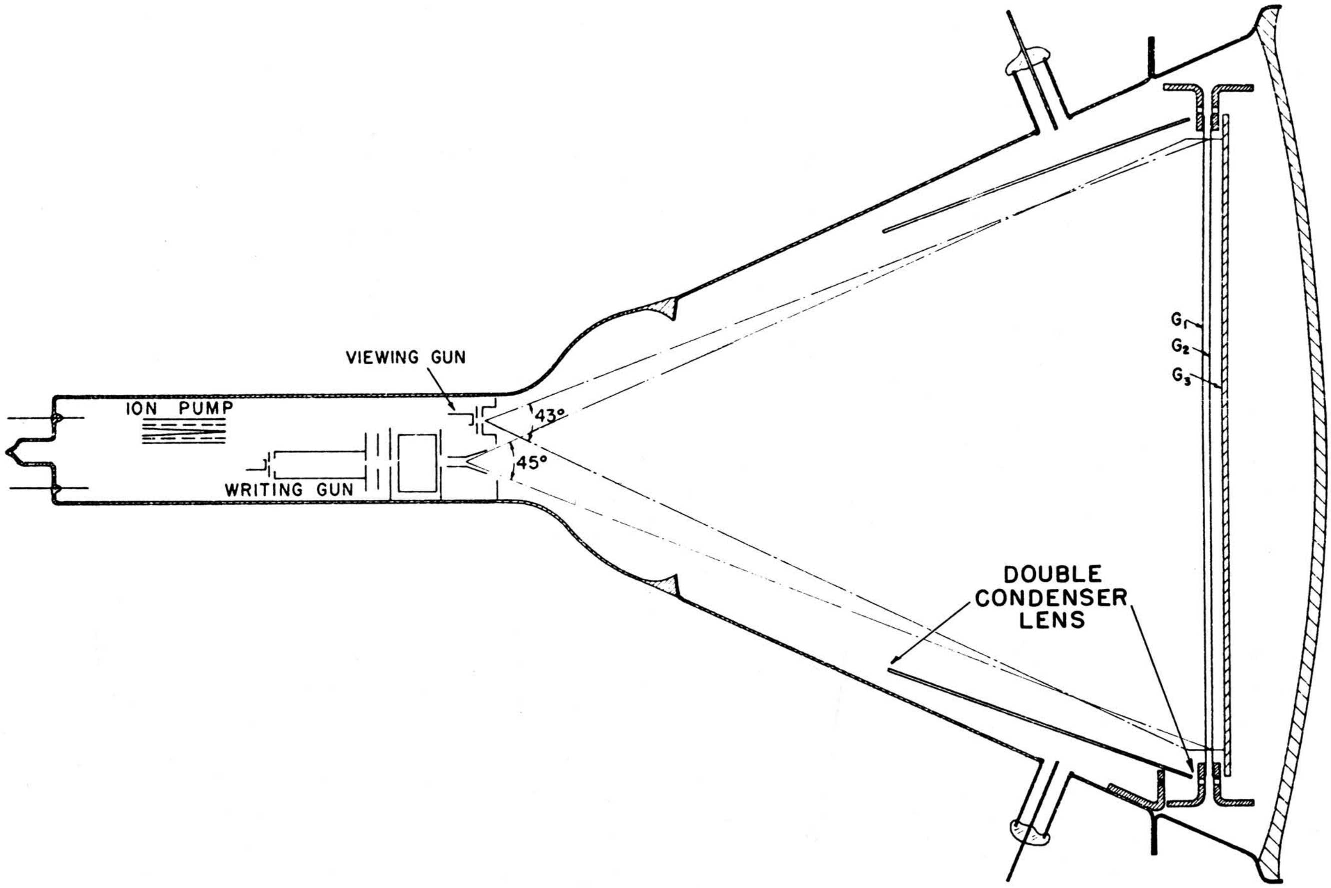


Fig. 2 – Large-screen storage tube.

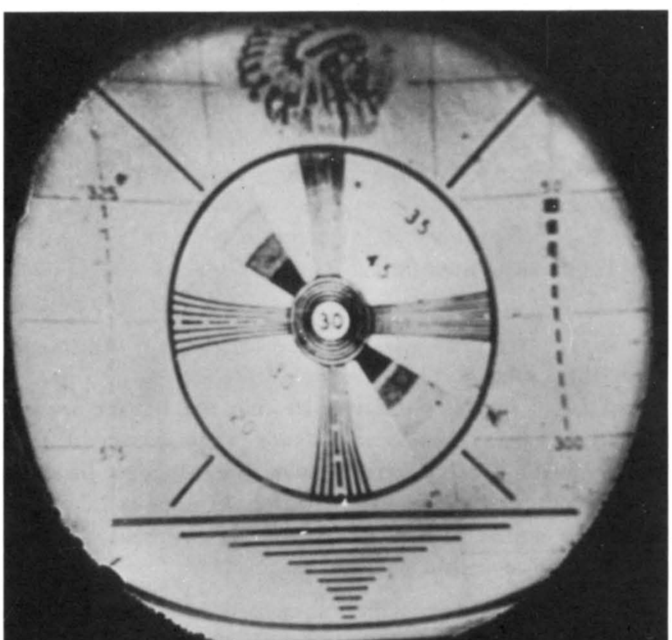


Fig. 3 – Photograph of 10-inch test pattern.

make the beam arrive normal to the storage grid; the aberrations of these lenses (Fig. 11a) account for much of the 10 to 15 percent variation in storage-grid cut-off voltage[6]. This variation can be reduced to 5 to 8 percent by operating with an 8-inch instead of a 10-inch display (Fig. 11b) which not only reduces lens strength but also the area of the lens used. (The 4-inch tubes showed a variation of 8 to 10 percent). Fig. 3 is a photograph of a test-pattern display 10 inches in diameter.

Although satisfactory results have been achieved with the flat target structure, experience with 4-inch tubes indicates that curved screens will give better uniformity and higher brightness as well as improved mechanical and thermal stability. These results should apply to larger tubes also. The reasons for this assumption are discussed more fully in the following section.

Storage Tube With Spherical Image Amplifier

Description

Fig. 4 is a schematic representation of the experimental projection storage tube. To match the reflective

[6] The difference between the cutoff voltages for the darkest and brightest areas of the viewed pattern without a written picture expressed as a percentage of their mean is used as a measure of non-uniformity.

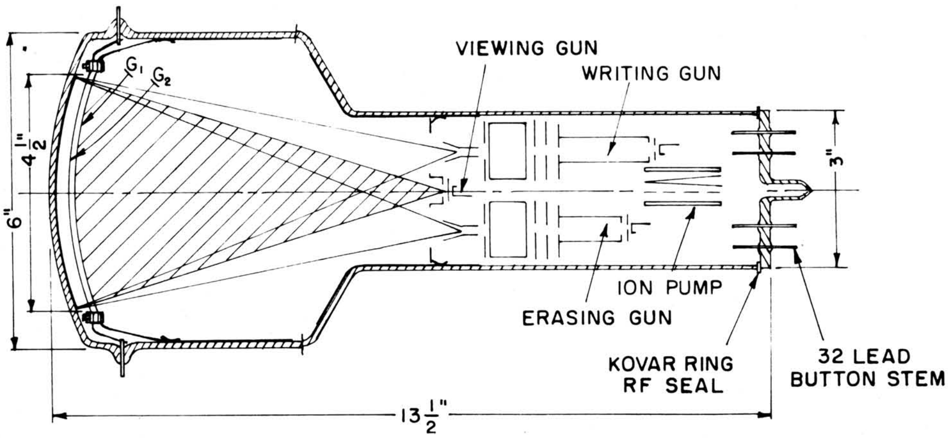


Fig. 4 – Design for spherical-screen projection storage tube.

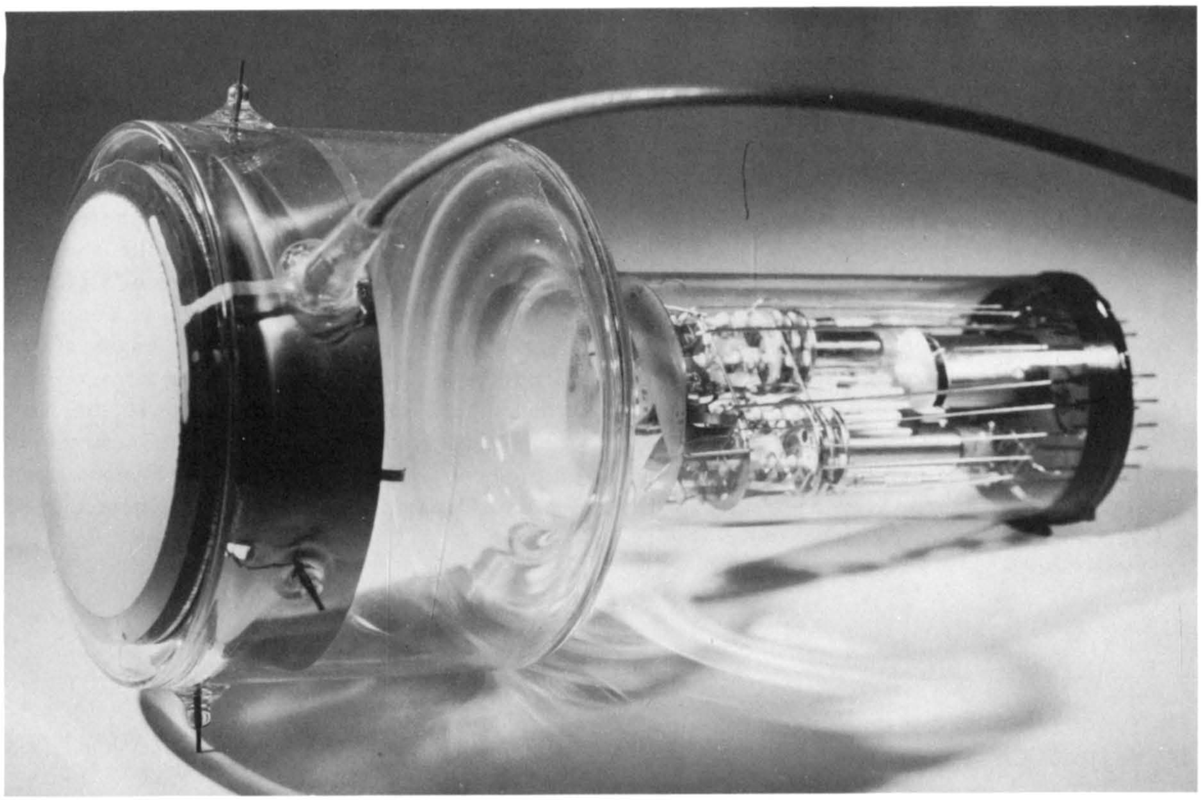


Fig. 5 – Projection storage tube.

optical system of the 5TP4 projection kinescopes, which was used for the experiment, a curved luminescent screen with a 7.1-inch radius of curvature was employed. In addition, a curved storage target and an approximately concentric collector grid were used; these permit normal incidence of the viewing beam without an electron condenser lens or with a very weak one. The crossover of the viewing gun was near the center of curvature of the collector and storage grids. Minor electron optical corrections may be achieved by making the curvature of the grids non-concentric to the curvature of the luminescent screen. In general, the functions of the collector grid, storage grid and the luminescent screen (final anode) as well as the functions of the writing, viewing and erasing guns are similar to those already described for the viewing storage tube with a flat-image amplifier[4]. Also, the electron paths in the electron lens raster system are similar to those in flat-image amplifier systems. However, the electron optical condenser system of the image amplifier is different.

Fig. 5 shows an experimental projection storage tube which may also be used for very bright direct-view applications. The ion pump and the writing and erasing guns, both of which are parallel to the tube axis, are in the tube neck. The viewing gun, which is quite short, is located on the tube axis between the writing and erasing guns.

Technological Problems

a. Curved Storage and Collector Grid

The storage-grid mesh is made of electroformed nickel, and the collector grid of woven stainless-steel wire screen (both about 250 mesh per inch). It was found that both kinds of mesh could be formed by cold drawing between soft aluminum sheets. The mesh was completely annealed before drawing; the work-hardening during the drawing process provided sufficient stability and negligible spring-back[7].

b. Luminescent Screens for High Field Gradients

Another problem is the design of an aluminized phosphor screen which can withstand gradients of about 30 kv/cm between it and the storage grid. Under such gradients, ordinary phosphor screens such as used in television tubes, where practically no gradient is present at the phosphor surface, disintegrate.

Satisfactory phosphor screens can be produced by settling a fine-grained phosphor and rinsing it with a silicate solution. After the phosphor is baked it is firmly bound to the curved glass support. Then a very thin collodion film is deposited which permits phosphor particles to protrude through and bond directly to the aluminum layer which is evaporated on the collodion.

Such a phosphor screen has an 'egg shell' appearance, and it can be rubbed lightly with a finger tip without damage. Spark-overs produce a shiny spot on the aluminum, but no damage to the phosphor screen.

Projection Arrangement

Fig. 6 shows the projection arrangement which was designed for an 88-inch throw when used with a 5TP4 projection kinescope. A magnification of 12 times gives a 4-foot diameter display from a 4-inch display on the face of the tube. Curtains placed about the display were used to darken the viewing area, as shown in Fig. 7. The ambient light level from an overhanging incandescent lamp was controlled by varying the lamp voltage.

Brightness, Halftones and Resolution of the Projected Picture

Tube-face brightness at 20 kilovolts (applied to the luminescent anode) measures approximately 5000 foot-lamberts. The optical efficiency of the reflective optics projection system is estimated to be about 15 percent, and the gain of the projection screen (a piece of drafting vellum) varies from about 0.25 to 2, compared to a perfect diffuser depending on the angle of observation. From these figures, and assuming a magnification of 12, one should expect a brightness at the center of the projection screen of 1 to 10 foot lamberts. Because of the properties of the light optical system, there is known to be a decrease in brightness from center to edge of the display.

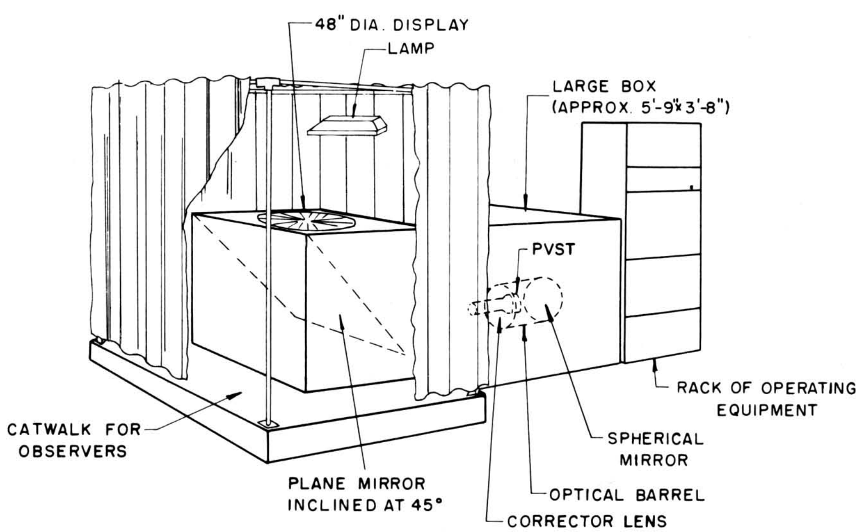


Fig. 6 – Storage tube projection display.

[7]Because of its simplicity and positive results, this technique can be employed for the design of large electron optical mesh lenses.

Actual measurements made with a Luckiesh-Taylor light meter held normal to the projection screen slightly away from center indicated a highlight brightness of 3 to 4 foot lamberts, which is within the limits of the estimate above. About two foot candles of ambient light on the projection screen were necessary to cause any visible deterioration of picture contrast; about 10 foot candles of ambient light caused enough deterioration to make the picture unusable.

The tolerance to ambient light is due partly to the screen (P1) phosphor which provides color contrast with the reddish incandescent ambient light. Better tolerance can be expected by using a green filter over the projection screen, and a higher directivity screen.

In the radar display, (Fig. 8), the erasing beam is not visible although in the display itself it is visible as a faint strobe line. The writing beam (invisible) follows 10 to 15 degrees behind it. Because most of the targets are buildings in the metropolitan Philadelphia-Camden area, the picture is rather cluttered. The course of the Delaware River appears as a dark streak, nearly devoid of targets, running along the dotted line from about 6 o'clock to the center, and then curving out toward 3o'clock. The erased sector is slightly to the right of the lower part of the Delaware River.

Fig. 9 (an enlarged picture of the area enclosed by the white lines on Fig. 8) shows details of the structure of the projected radar picture. The small grey spots distributed at random between the targets are noise pulses from the input stages of the radar receiver. The targets are not only distinguished by their shape but also by their brightness because of antenna beam-width integration at the storage grid.

Selective Erasure and Condenser Lens Design

For ideal picture uniformity, the viewing electrons must arrive normal to the surface of the storage grid.

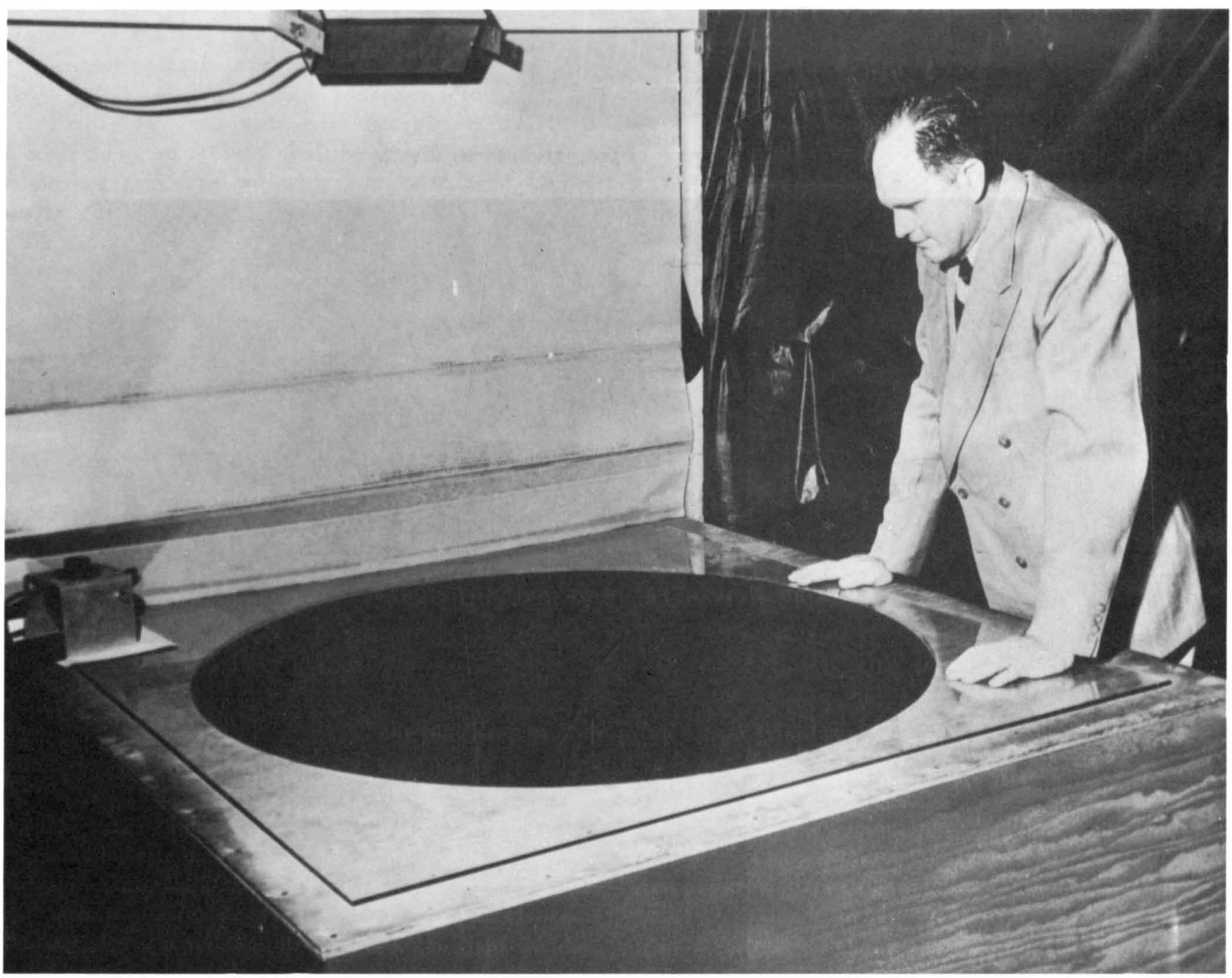


Fig. 7 – Viewer's position at projection radar display.

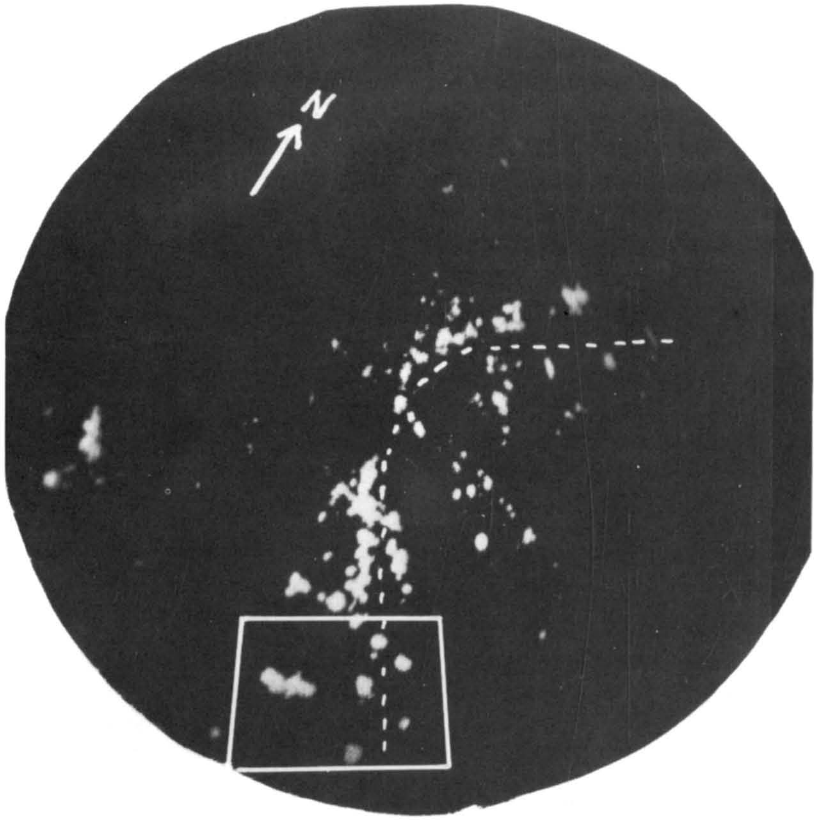


Fig. 8 – Photograph of projection radar display.

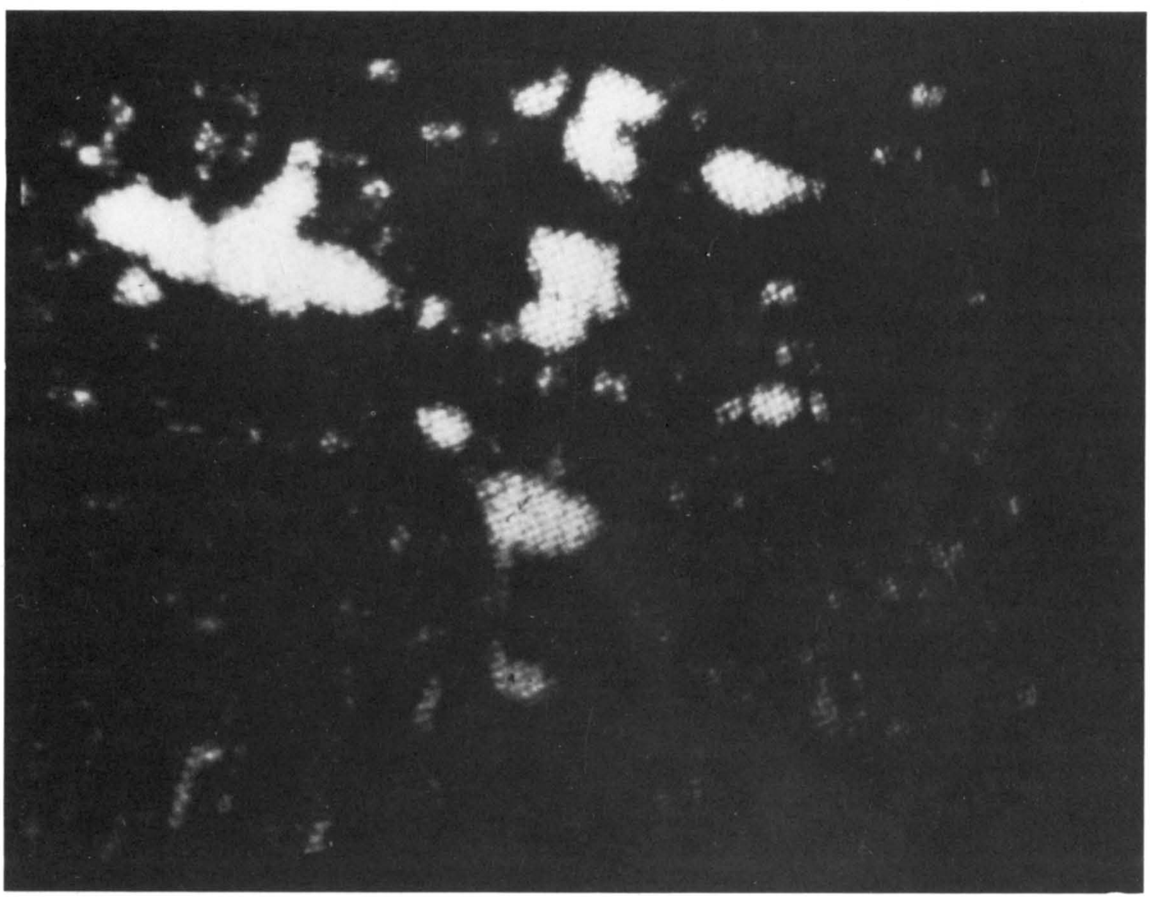


Fig. 9 – Photograph of portion of projected radar display showing stored noise.

With a *flat* storage grid and a point source of the flood beam a single strong condenser lens may be used. (Fig. 10a). One electrode of this lens is formed by the collector grid, the other by a conducting wall coating (at viewing-gun anode potential). To keep the viewing beam angle of divergence as small as possible, and thus decrease spherical aberration, this lens should be close to the collector grid. In such an arrangement, two sources of concentric non-uniformities are variations in the angle of incidence of viewing electrons approaching the storage grid, and spherical aberration of the condenser lens (as in Fig. 10a). These non-uniformities disappear as the viewing-beam diameter decreases (Fig. 10b). Still other non-uniformities, usually asymmetric, are caused by magnetic poles in the storage or collector grid frames (Fig. 10c). Although demagnetizing helps reduce the latter type, both types of non-uniformity can be reduced by increasing the ratio of the voltage gradients on the phosphor side to that on the gun side of the storage grid. This uniformity improvement occurs probably because viewing-beam electrons with non-normal incidence (which at lower gradient ratios would be reflected) are collected by the field of the elementary lenses. Thus, for a uniform picture background, a low collector-grid voltage (<100 volts) or a high phosphor-screen voltage is desirable for lens-raster-type image amplifiers. On the other hand, to prevent positive ions from landing on the storage grid, the collector grid must be at higher positive potential than any electrode between it and the viewing or erasing beam cathodes. Also, a higher collector-grid voltage (>100 volts) is desirable to obtain optimum gun voltage for a well-focused erasing beam. As a result, there must be a compromise between concentric background patterns, and a poor erasing-beam resolution for a viewing storage tube with a flat storage target and a single condenser lens. Such a system, however, may be tolerated if overall (flooding) erasure with the viewing beam is used.

One way to improve selective erasure in a viewing storage tube with flat-image amplifier is the introduction of a *double* condenser lens (Fig. 10b). There are three advantages:

(1) The erasing (and viewing) gun anode voltage may be as much as 70 percent of the collector voltage instead of less than 20 percent for the single condenser lens, which permits more viewing-beam and erase-beam current and better erase-beam spot with the electron guns used.

(2) Less spherical aberration.

(3) Less space-charge defocusing of the erasing beam in the condenser lens region.

However, although selective erasing is possible with the double condenser lens, the low voltage available for the erasing gun makes possible a well focused beam with sufficient current only for slow erasing speeds (e.g., radar). To a certain degree, therefore, the alternative exists between concentric background patterns and slow or poorly focused selective erasing for the double condenser lens as well as for the single condenser lens.

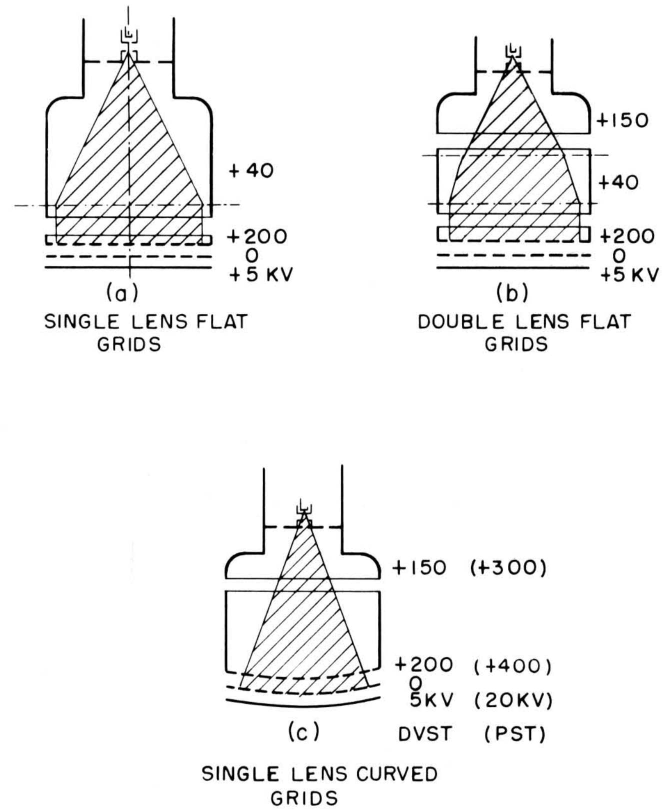
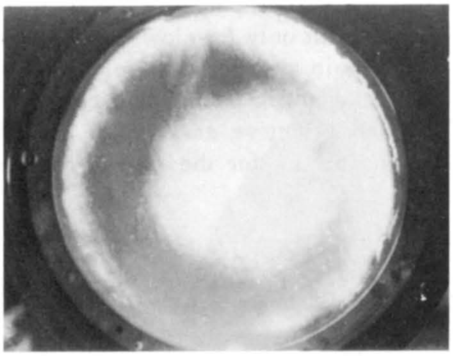


Fig. 10 – Condenser lens configurations for viewing storage tubes.

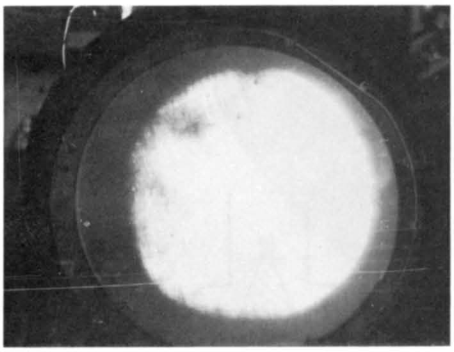
This compromise is much less severe for *spherical* image amplifier systems (Fig. 10c). In this case, normal incidence can be obtained by simply placing the viewing-beam crossover near the center of curvature of the storage grid. Thus, only a weak condenser lens is needed for small corrections of the angle of incidence and for repelling positive ions which would otherwise land at the storage target. Because such a weak condenser lens has a small spherical aberration, it permits a higher collector voltage (in the order of 500 volts if needed) and also higher voltages for the anodes in the viewing and erasing guns. These higher voltages are essential for a small erasing beam spot and high current of the viewing beam[8].

For proper tube operation, the viewing beam must arrive normal to the storage grid, whether flat or curved. In the first case, a condenser lens is required close to the grid. However, in the curved-grid tube, normal incidence is obtained with a diverging beam. Thus, the

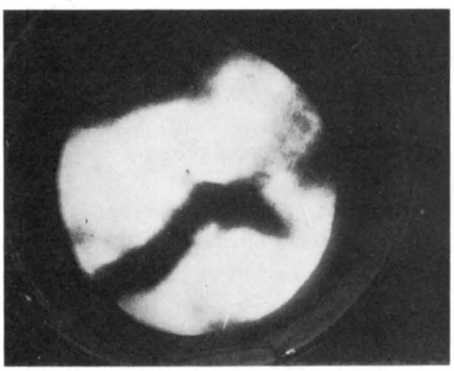
[8] With conventional gun structures.



(a) 10-inch diameter picture with brightness adjusted to emphasize spherical abberation.



(b) 8-inch diameter picture showing decrease in spherical abberation from (a).



(c) Magnetic disturbance (4-inch tube).

Fig. 11 – Non-uniformity due to lack of normal incidence of viewing beam at storage grid.

condenser lens can be placed nearer the viewing-beam cathode without increasing the viewing-beam angle. By using a smaller portion of this lens, spherical aberration is reduced further and a larger viewing screen may be used for the same envelope size.

Conclusions

Based on earlier work[1,2,3,4] two new experimental versions of viewing storage tubes have been developed for use where larger stored pictures are required.

The first version is a tube with a large, flat (10-inch diameter) viewing screen which is bright enough to be used in a well lighted place such as a laboratory or a ship's bridge. It has adequate writing speed for radar and similar displays, at lease one minute viewing duration, and approximately 500 lines resolution (television standards).

The second version is a projection storage tube with a $4\frac{1}{4}$ inch spherical luminescent screen. It provides more than 5000 foot lamberts brightness at 20 kv; when the image is projected to a 48-inch diameter display, the brightness is high enough for use with room illumination of 3 to 5 foot candles. Such tubes have high maximum writing speed, (up to 10^8 spots/sec), good line-by-line erasing, adequate storage for radar displays, and 500-line resolution.

The investigation of curved-image amplifier systems for this projection storage tube revealed several important advantages of curved screens which are applicable for direct view storage tubes. Curved screens make it easier to achieve normal arrival of viewing electrons at the storage grids, thus eliminating background non-uniformity caused by spherical aberration of the condenser lens. Also, higher voltages may be used on the collector grid and viewing and erasing guns, which provide better focus of a separate erasing beam and more current in both the viewing and erasing beams.

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