DESIGN AND DEVELOPMENT OF THE 21CYP22 21-INCH GLASS COLOR PICTURE TUBE*

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Summary—*This paper describes the features of the new 21-inch round glass color picture tube, RCA-21CYP22, and evaluates the improvements incorporated in this design as compared to earlier designs. The newly developed glass bulb having a frit closure is described, as well as the bulb-alignment system now used and the special glass properties. The improved design of the shadow mask, which provides increased light output and contrast, and the associated screen processing are discussed. Improvements in the electron gun and their effects on tube performance are also described, as well as the revised components and set-up procedure.*

THE RCA-21CYP22 is a 70° shadow-mask color-picture tube in an all-glass envelope. In general, it is similar to the 21AXP22-A except for several important design features which have been developed for this new type and the use of a glass rather than a metal envelope.

The over-all length of the 21CYP22 is 25 13/32 inches, which is the same as that of its metal predecessor. The outline drawing and major dimensions are shown in Figure 1. Comparison of the dimensions of the glass 21CYP22 and the metal 21AXP22-A shows that the major dimensions are the same, and with minor modifications in the mounting system the glass tube may be used as a replacement for the older metal tube; the weight of the glass tube is 33½ pounds. Two terminals are provided on the envelope for an external protective resistor to be used to protect the cathode in case of a momentary internal arc.

PERFORMANCE ADVANTAGES

The performance advantages that result from the new design features incorporated into the glass tube follow:

1. Ease of picture-tube mounting in receiver. Ease of mounting comes about from the use of a glass envelope which reduces insulation problems. Mounting of the 21CYP22 is essentially the same as with a black-and-white glass picture tube.

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2. Ease of set-up. The adjustments unique to color tubes, i.e., purity set-up and convergence, are simplified in the 21CYP22 because the number of corrections needed to obtain optimum performance are reduced.

3. Improved gun performance. Design changes in the internal convergence pole-piece assembly have reduced beam distortion and interaction between convergence pole-pieces and other neck components.

4. Increased light output. The increased light output of the 21CYP22 is due to the use of a graded-hole shadow-mask. The transmission of the mask in the edge regions is the same as that of the shadow-mask used in its predecessor tube; however, by the use of the graded-holes the transmission is gradually increased toward the center so that a 44-per-cent increase in transmission is achieved. The resultant light output is obtained at no sacrifice in register requirements since a lighthouse correction lens has been developed which compensates for the "degrouping" factor which, in previous types, was noncorrected and reduced light output. The "degrouping" factor is explained in more detail later.

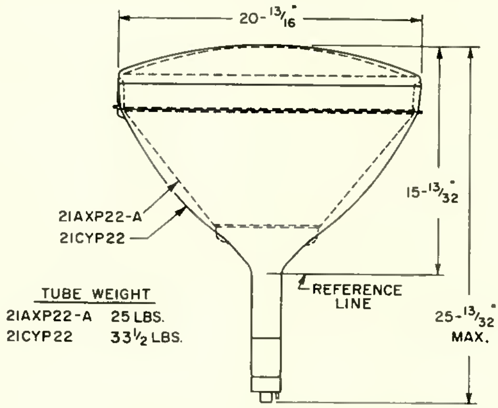

Fig. 1—Comparison of outline drawing and major dimensions for 21CYP22 and 21AXP22-A color picture tubes.

5. Improved contrast. This improvement has been achieved by several means. First, the greater electron-beam transmission of the mask allows the use of a filter glass in the faceplate of the 21CYP22 having a slightly lower light transmission. Secondly, the graded-hole shadow-mask also incorporates tapered apertures. Tapering minimizes the scattering of electrons from the sides of the apertures and thereby increases detail contrast and improves color saturation. Third, the use of a masking "electron shield" removes "stray" electrons at the edges and thereby minimizes a source of color dilution.

Envelope Features

The glass envelope used in the 21CYP22 differs from any other envelope used for color-picture tubes to date in that it makes use of a devitrifying frit seal and does not require a reinforcing metal band at the seal edges. As in former color-picture tubes the envelope is made in two parts, the funnel and the panel, and the two parts are sealed together during tube fabrication. The devitrifying frit used in this tube is a material unique to glass envelope manufacture and was developed by Corning Glass Works. The properties of the frit are shown in Table I. The important characteristic of this frit is that it is a soft solder glass until the time of sealing when the glass devitrifies or changes into a ceramic phase. The sealing process is not reversible, and once the seal is made subsequent thermal processing will not soften the seal. The frit, in a paste form held in suspension by an amyl acetate and nitrocellulose binder, is applied from an extrusion machine in a manner similar to toothpaste being squeezed from a tube. The ribbon of frit is applied to the seal edge of the funnel only. The sealing is accomplished by first allowing the frit to air dry, then positioning the panel in its appropriate position on the funnel, and sending the two parts through a sealing lehr. The thermal cycle involves raising the temperature of the parts to 440°C, holding this temperature for one hour, and then slowly cooling the parts. Upon completion of this process, the panel and funnel are sealed together and subsequently may be put through normal exhaust bakeout.

Table I—Properties of Devitrifying Frit used for Sealing the Funnel and Panel

	VITREOUS	DEVITRIFIED
SOFTENING POINT (°C)	368	510 ± 10
EXPANSION (0-300°C) (10^{-7}/°C)		96.5 ± 0.5
LOG OF VOLUME RESISTIVITY (OHM-CM.)		
AT 200°C		9.5
AT 300°C		7.8

Glass Properties

The properties of the glasses used in the panel and funnel are shown in Table II. In the selection of these glasses, several factors were taken into consideration. First, the use of a glass having a high strain point is necessary so that thermal effects and vacuum loading would cause minimum deformation. Deformations of the faceplate would cause a change of the faceplate contour and result in misregister caused by variations in spacing between mask and faceplate. The hardness of the faceplate glass used in the 21CYP22 has reduced this distortion and consequent misregister to a negligible value. This reduction of misregister in turn permits better color purity and white uniformity together with greater ease of tube set-up.

The use of two separate glasses, one for the panel and another for the funnel, is necessary so that the faceplate would have a non-browning characteristic and the funnel a high degree of X-ray absorption.

Table II—Properties of Glasses used in 21CYP22

	PANEL	FUNNEL	NECK
SOFTENING POINT (°C)	679-683	668-674	677-681
ANNEALING POINT (°C)	483-488	482-485	482-484
EXPANSION (10^{-7}/°C)	97.8-99.4	98.1-98.8	94.7-95.8
LOG OF VOLUME RESISTIVITY (OHM-CM.) @ 250°C	9.18-9.26	9.24-9.28	10.13-10.16

Faceplate Panel Features

In the design of the 21CYP22 envelope a primary aim was an envelope which would permit the design of a tube requiring the least amount of correction for optimum performance. This aim was accomplished by relating the lighthouse referencing to the envelope sealing alignment so that minimum purity correction would be required. Figure 2 illustrates the system used for referencing the panel on the screening lighthouse. It will be noted that the panel rests on the seal edge and is oriented by the V-pad and one of the plain molded-glass pads on the skirt of the panel. These two reference points are positioned during panel-funnel sealing to two ground pads near the seal edge of the funnel. These funnel pads have previously been ground concentric with the inside of the neck. Thus, when the gun is sealed into the neck its position will correspond to the positions of the light sources in the screening lighthouse. This coincidence of the position of the electron beams and the light sources means minimum purity correction will be necessary with this tube. The rotational orientation of the gun is established on the gun sealing machine with reference to the V-pad on the panel.

Another feature of this envelope is the accurate control of the inner contour of the faceplate with respect to the mask mounting studs. The glass envelope has made it possible to obtain a contour, referenced from the studs, accurate to within ±.023 inch at any point on the inner surface of the faceplate. This accurate contour together with a similarly accurate contour of the mask results in optimum phosphor-dot size and spacing which again shows up as good color purity and white uniformity.

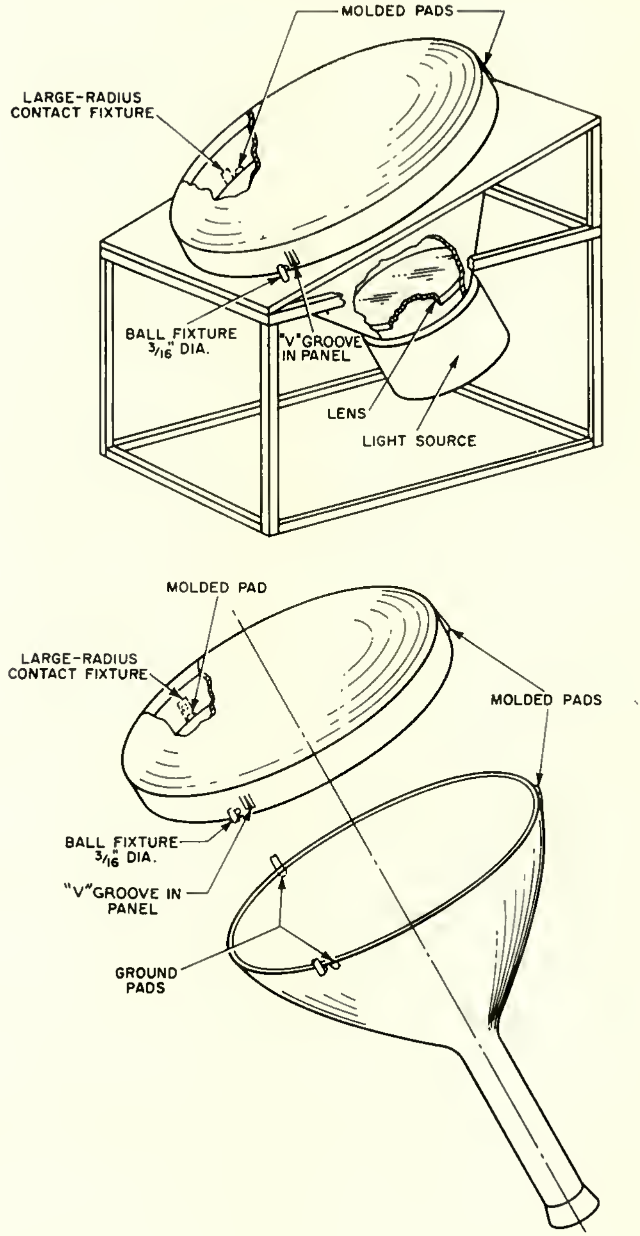

Fig. 2—System used for referencing (a) panel on screening lighthouse and (b) panel on funnel.

Shadow-Mask Considerations

The shadow-mask is one of the critical parts of the color tube. The methods of etching and forming this part to close tolerances are the basis for the high quality of the 21CYP22. Considerable effort has been expended in research on methods to improve the quality of the mask and reduce its cost.

A significant improvement has been obtained by changing the mask material from 0.0075-inch copper–nickel to 0.006-inch cold-rolled steel. In addition to savings in material cost, the steel mask provides several important advantages. The lower expansion of steel compared to copper reduces the changes during processing and gives a greater degree of stability during tube operation. Although the steel mask is thinner, it is still considerably stronger than the copper–nickel mask. This strength reduces the number of damaged masks due to mishandling during tube fabrication. In addition, the magnetic properties of the steel mask make the demagnetization process, used in tube set-up, more effective.

To eliminate the problem of rusting during tube fabrication and to increase thermal emissivity, the steel mask is steam blackened. This operation is a simplification of the iron plating and chemical blackening formerly used on the copper mask. Processing of the glass tube requires an additional high-temperature cycle because of the funnel-panel sealing. Problems due to flaking of a chemically blackened mask are eliminated by the use of steam blackening.

Graded-Hole Feature

In the 21CYP22 significant improvements in light output and contrast have been achieved. The gain in light output was made possible by the use of a graded-hole shadow-mask having apertures that increase gradually in diameter from the outer edge of the mask inward to the center. As a result of this gradation, the mask permits increased light output from the screen. Enlargement of the diameter of the apertures was made possible by the adoption of the "degrouping" correction lens in the lighthouse and an associated change in tube geometry. This lens optimizes phosphor-dot placement with respect to electron beam trio.

For a better understanding of why this lens is required, reference is made to Figure 3. For simplicity, the geometry is shown with only two beams in the plane of the axis. As the screen is scanned toward the edge, the convergence angle of the beams must be decreased, thus moving their deflection centers from A to A′ and from B to B′. The triad of fluorescent spots produced by the three beams passing through an aperture is, in effect, a demagnified image of the three beams as cut by the deflection plane. Thus, when dynamic convergence fields are applied, the object in the deflection plane AB is enlarged to A′B′ and its image, the fluorescent triad, is correspondingly increased in size. The phosphor screen is exposed from light sources at A and B, and the undeflected beams pass through these color centers. When deflection and dynamic convergence fields are applied, the fluorescent spots are "degrouped" with respect to the phosphor-dot triads.

In the 21CYP22 this effect is greatly reduced by the "degrouping" lens. This lens produces an optical analogy of the action of the electron

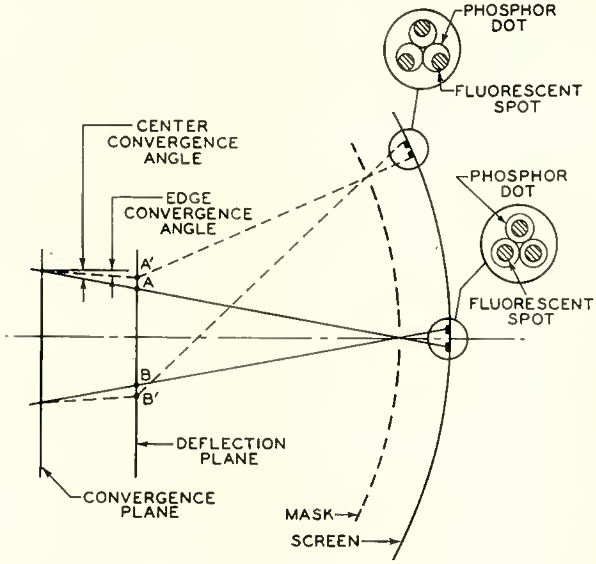

Fig. 3—Geometry of electron beam trio "degrouping."

beams. Thus, the light source does not appear to remain in one position but rather tends to simulate the motion of the beam (A to A′ and B to B′). This motion together with the associated change in mask-to-faceplate spacing produces tangent phosphor-dots and proper landing of the electron beam on the dot over the entire screen when dynamic convergence is applied. Removal of this degrouping error allows the diameter of the mask apertures to be increased in size, hence giving greater light output without any decrease in screen purity or uniformity tolerances.

The radial lens previously used in 21AXP22-A to compensate for the axial movement of the deflection plane as a function of the scanning angle is incorporated into the correction lens for the 21CYP22 lighthouse together with the degrouping feature. Thus, this single lens having two functions provides essentially a complete analogy between the movement of the light source in the screening lighthouse and the apparent motion of the electron beams during tube operation.

Considerable research effort was spent on determining the physical shape of the required degrouping lens, shown in Figure 4, and in obtaining a practical method for manufacturing them. The accuracy with which the lenses have been reproduced permits the use of an interchangeable system of lighthouses, allowing the three colors to be printed on different lighthouses. This interchangeable feature is important in mass production of the tube.

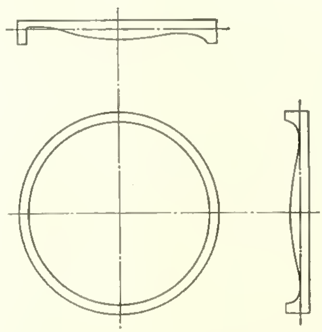

Fig. 4—Contour of "degrouping" lens.

Contrast Improvement

Another important performance feature of the 21CYP22 is the improvement in contrast. It might be noted that light output and contrast are related features in any picture tube and that a gain in one is as important as a gain in the other. The 21CYP22 incorporates four important design changes that improve contrast. The features are: (1) use of tapered apertures in the mask, (2) elimination of faceplate "haze," (3) introduction of a masking "electron shield," and (4) higher absorption in the faceplate glass.

In former color picture tubes the aperture in the shadow-mask was essentially straight-sided or cylindrically shaped. As the deflection angle increases, thereby causing the beam to approach the mask at some angle other than normal, the electron beam strikes one side of the aperture due to the finite thickness of the mask material. As a result of this striking of the side wall of the aperture, "stray" electrons are scattered and hit phosphor-dots other than those intended.

Because the efficiency of the blue or green phosphor is considerably higher than the red, the "strays" are more noticeable in the red field. The effect of these "strays" is to reduce the saturation of an individual color field and also reduce contrast when the three fields are used to produce white.

In the 21CYP22 this effect has been greatly reduced by the use of conically shaped or tapered apertures. Tapering permits the electron beams to be transmitted through the mask without striking the side wall of the apertures. Figure 5 shows this effect. The degree of taper in the shadow-mask is not the same over the entire mask. It is maximum at the edge and is gradually reduced toward the center. This gradation in taper simplifies mask manufacture while at the same time

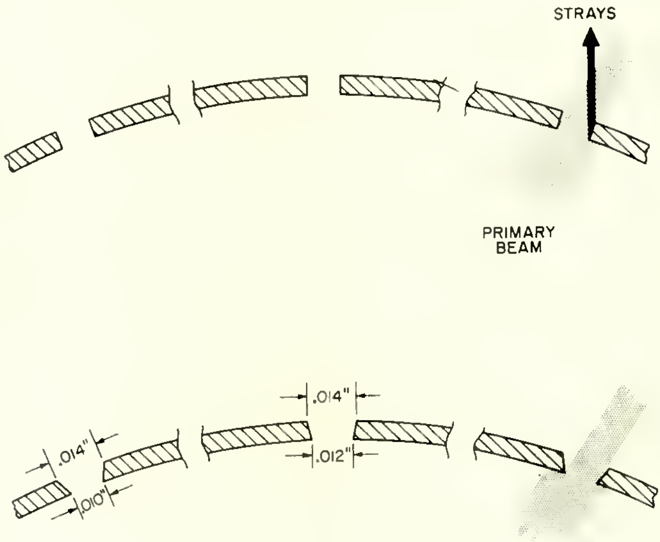

Fig. 5—Advantages of tapered apertures in reducing stray electrons.

provides maximum taper where it is needed, that is, near the edge of the mask where the electron beam approaches the mask at the greatest incident angle. Another advantage of the tapered apertures is the fact that more of the beam is allowed to pass through the aperture as compared to a straight-sided aperture wherein upwards of 20 per cent of the beam is blocked by the side wall. Thus, tapering achieves increased light output as well as improved contrast and color saturation.

Stray Electrons

Another cause of color dilution in former shadow-mask color picture tubes was stray electrons "sneaking" around the mask-frame assembly, bouncing off the panel side wall, and striking the phosphor screen. In the glass tube the manufacturing technique requires that the panel side wall be tapered approximately 4 degrees. This taper increases the distance between the frame and side wall. The greater spacing together with the overscan of the raster results in the concentration of a considerable number of stray electrons around the periphery of the screen. In the 21CYP22 an electron masking shield is welded to the under side of the frame closing the gap between the frame and the panel side wall. A small clearance is maintained between the glass wall and the outside edge of the shield to accommodate the differential

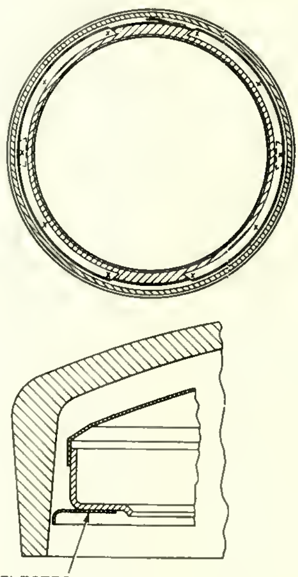

Fig. 6—Electron masking shield.

thermal expansion. The shield is made of thin steel in four sections for ease in manufacture and insertion. An opening in the shield at the top and bottom of the screen permits the required internal electrical connection between funnel and panel. The shield is illustrated in Figure 6.

FACEPLATE HAZE

In the 21AXP22-A a phenomenon which we call faceplate haze is evident. This phenomenon shows up as a tint of specific color when the screen is viewed at wide angles. It was determined that the cause of haze is related to the degrees of optical contact between the phosphor particles and the inner surface of the faceplate. With a high degree of optical contact, light from the phosphors would be internally reflected within the faceplate glass and appear as a haze. This problem also exists in black-and-white picture tubes. In a color tube, where three different color-emitting phosphors are used, the difference is contact of the three phosphors with the faceplate was such that the haze assumes the color of the phosphor having the best contact. Figure 7 illustrates the mechanism of the internal reflection. In this figure dot No. 1, a phosphor-dot of a particular color, is in poor optical contact with the glass panel. The light rays emitted beyond the critical angle are totally reflected from the glass surface and never enter the glass. Phosphor dot No. 2 is in good optical contact with the glass. As a result, the light rays emitted by this dot do not "see" the interface (vacuum to glass) and all the rays emitted beyond the critical angle are internally reflected within the glass. This internally reflected light is scattered within the glass and leaves the

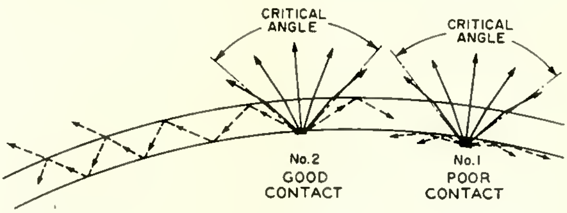

Fig. 7—Mechanism of internal reflections causing "faceplate haze."

glass near the edge of faceplate because of the increasing curvature. If the two dots emit different colors, the color of the dot having the better optical contact will be partially internally reflected and will give a specific color of haze.

In the initial stages of the development of the glass tube it was apparent that the thicker faceplate glass and variations in the curvature near the edge, commonly referred to as "suck up" in the glass panel, caused a haze pattern considerably more intense than that noted in the metal tube with its thinner parallel-surfaced faceplate.

One approach to reduce this effect was the etching of the inner surface of the faceplate to minimize over-all optical contact. This approach had a number of disadvantages both technically and economically. Another approach, which was the solution finally used in the 21CYP22, was to equalize the optical contact between the phosphors by adding a dispersing agent to the red phosphor slurry to increase its contact so that it would be equal to that of the green and blue phosphors.

An additional aid to contrast has been the increased light absorption of the tube faceplate. Although this change tends to decrease light output slightly, the gain in contrast makes up for the slight loss in light output and gives a substantial improvement under high ambient light.

Gun Improvements

Improvements have also been made in the design of the 21CYP22 gun. Although the gun is similar to that used in the earlier metal tube, revisions have been made to improve performance. The radial-converging pole-piece assembly shown in Figure 8 has been revised to provide improved dynamic convergence by means of easing the dynamic convergence adjustments. The shape of the pole-pieces has

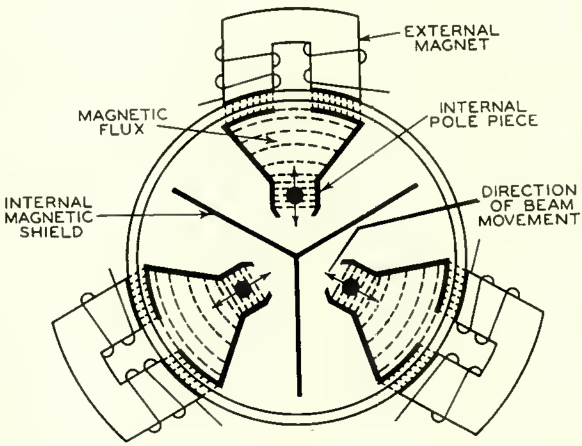

Fig. 8—Schematic of radial-converging pole pieces.

been redesigned and a magnetic "Y" shield has been introduced between them. The purpose of the pole-pieces is to couple the externally provided magnetic flux to the associated beam. In guns of earlier construction interaction occurs so that the field applied to the red gun also influences the green and blue beams. The direction and magnitude of this interaction is such that a field about 30 per cent stronger is required to obtain complete dynamic convergence than would be necessary if no interaction existed.

Another advantage of the "Y" shield is reduction of coupling between the deflecting yoke and the internal pole-pieces. Figure 9 shows how unshielded pole pieces distort the leakage field from the yoke so as to produce a so-called red–green crossover pattern. Formerly this effect had been minimized by shields on the back of the deflecting yoke. However, with the introduction of the "Y" shield this effect is reduced to a negligible value and yoke shielding is no longer required for this purpose.

To obtain maximum highlight brightness the limiting aperture formerly used in the grid No. 3 is removed. Reduction in the needed magnetic correction applied in the gun region has minimized beam distortion so that the limiting aperture could be removed with no loss in resolution. Since all the electrons leaving the cathode can now reach the mask or screen, highlight brightness is appreciably increased. This condition is particularly important when high grid-

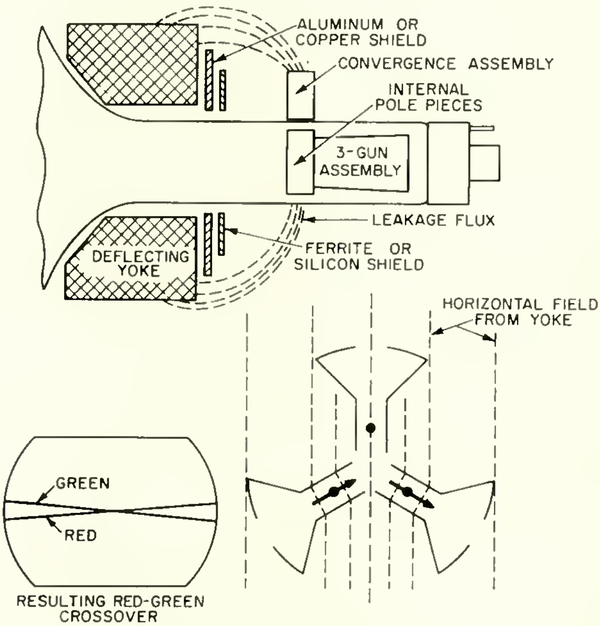

Fig. 9—Red-green crossover pattern caused by unshielded pole pieces.

No. 2 voltages are used because of the increased beam diameter in the grid-No. 3 region.

Tube Mounting

The mounting of the 21CYP22 is simplified, compared to the 21AXP22-A, because of the reduced insulation requirements of the glass envelope. As was noted earlier, the over-all dimensions are similar to those of the metal counterpart and hence the 21CYP22 may be used as a replacement for the metal tube. The mounting of this tube is similar to that of any glass black-and-white picture tube. To aid in the design of a mounting system specific g ratings have been established and are given in the technical data for this type. Thus, the mounting system may be designed and tested with accelerometers.

It is obvious that the magnetic properties of this tube type are different from the metal tube. To minimize the effects of the earth's field, it is recommended that a magnetic shield made of cold-rolled steel be used around the forward portion of the tube. It is possible to use cold-rolled steel rather than a high-permeability material because a degaussing operation is involved in the set-up of this tube.

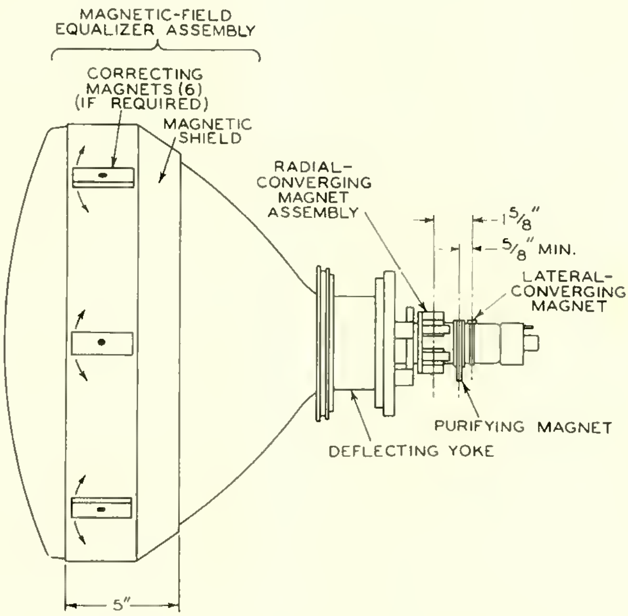

Fig. 10—Sketch showing relative placement of typical components on 21CYP22.

This degaussing operation, which is done when the tube is located in the customer's home, effectively counteracts the earth's magnetic field by setting up an opposing field in the shield as well as in the internal frame and mask of the tube. With this relatively simple shield the effect of the earth's field on the 21CYP22 is not essentially different than on the 21AXP22-A.

The components used on the 21CYP22 (Figure 10) are similar to those of the metal tube with the exception that the magnetic field equalizer assembly is considerably simplified. Because of the mechanical stability of the glass envelope, the random mechanical errors have been reduced to a point where the need for correction has been greatly minimized. In the 21CYP22, simple snap-on correcting magnets are used. In a majority of cases no magnets are required; however, under adverse field conditions it may be necessary to use several. The components associated with the gun, that is the purifying magnet, the lateral-converging magnet, and the radial-converging magnet assembly, are the same as formerly used. The deflecting yoke is similar except for its mounting and the fact that the "Y" shield used in the pole-piece assembly has reduced the need for shielding on the back of the yoke.

Conclusions

The 21CYP22 picture tube gives a brighter picture of better contrast than its metal predecessor, with excellent color purity and screen uniformity. The improvements made include: an improved gun and pole-piece assembly, use of a graded-hole shadow-mask, contrast improvement by means of an electron shield, tapered-hole shadow-mask, and increased filtering in the faceplate glass. These design improvements permit superior performance with major simplifications in the tube mounting, receiver circuitry, and set-up technique.