

PATENT SPECIFICATION

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(54) CATHODE RAY TUBE HAVING IMPROVED SHADOW MASK

(71) We, RCA CORPORATION, a corporation organised under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, 10020, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present Application is divided on Application Serial No. 9360/76.

This invention relates to cathode-ray tubes having apertured shadow masks therein, and particularly to a shadow mask construction that reduces misregister between electron beams and phosphor elements of the tube screen caused by doming of the shadow mask during tube warmup.

In a shadow mask type cathode-ray tube for producing a color image, a plurality of convergent electron beams are projected through a multi-apertured color selection shadow mask to a mosaic screen. The beam paths through the mask are such that each beam impinges upon and excites substantially only one kind of color-emitting phosphor on the screen. Generally, the shadow mask is attached to a rigid frame, which in turn is suspended within the picture tube envelope.

When a color cathode-ray tube is operated, the electrons that strike the shadow mask cause it to heat up. Since the edges of the shadow mask are attached to a somewhat heavy frame which serves as a heat sink, a temperature differential develops between the center and peripheral portions of the mask. Because of the temperature differentials, the mask center, the mask edge and the frame expand at different rates. This difference in expansion rates causes a doming of certain portions of the mask toward the screen. In the center of the screen, doming causes little effect on the register between the electron beams and phosphor elements because the straight line projection of the beams to the elements remains unchanged with changes in mask to screen spacing. Since the edges of the mask are fixed to a peripheral frame, there is no doming at the mask edges. Therefore, maximum misregister caused by doming occurs approximately halfway between the mask center and mask edge. Misregister is defined as being the amount an electron beam is off-center from its respective phosphor element. Because of this doming, the electron beams passing through the mask misregister with the phosphor elements of the screen. The misregister effect of doming peaks after 3 to 5 minutes of tube operation but continues to have a diminishing effect on tube performance for an additional 10 to 15 minutes. Once the tube has reached steady state temperatures, general electron beam misregister caused by expansion of the mask is compensated by temperature sensitive frame supports which move the mask frame assembly toward the screen. Such temperature compensating support is disclosed in U. S. Patent 3,803,436 issued to Morrell on April 9, 1974.

Another problem somewhat related to doming is blister warpage. Blistering occurs during operation of the tube and is caused by a video pattern, such as a sustained white spot in the TV image, that develops localized heating of a part of the mask.

A cathode-ray tube of the apertured mask type according to the invention of parent patent Application Serial no. 9360/76 (Serial No. 1546889) includes a mask, apertures in the mask, and spacing between the mask and a cathode luminescent screen which continuously increases between the centre and edge of the mask to have a maximum 30, minimum value exceeding 15. The invention reduces doming and blistering and thereby also reduces electron beam misregister caused by these problems, the present invention does likewise.

According to the present invention there is provided a cathode-ray tube utilizing an apertured shadow mask for registering electron beams on phosphor elements of a cathodoluminescent screen; wherein the rate of change of spacing between said mask and said screen changes polarity at least once from the center to the edge of said mask, and wherein said spacing varies proportionally to the change in spacing between adjacent apertures of the mask.

Cathode-ray tubes of the prior art, the patent Application, and the invention can be seen in the drawings, in which:-

FIGURE 1 (sheet 1) is a plan view, partly in axial section of a prior art shadow mask cathode-ray tube.

FIGURES 2, 3 and 4 (sheet 1) are enlarged schematic views of portions of a line screen showing an electron beam impinging thereon;

FIGURE 5 (sheet 1) is a graph of electron beam misregister at a point halfway between the center and edge of a shadow mask versus time.

FIGURE 6 (sheet 1) is an enlarged view of a portion of the mask and screen in the area indicated by the numeral 6 in FIGURE 1.

FIGURE 7 (Sheet 3) is a schematic side view illustrating geometric relationships between an electron beam, a mask and a screen.

FIGURE 8 (sheet 2) is a rear view, partly cutaway, of a tube faceplate having a prior art shadow mask mounted therein.

FIGURES 8A, 8B and 8C (sheet 2) are enlarged views of indicated portions of the mask of FIGURE 8.

FIGURE 9 is a rear view, partly cutaway, of a tube faceplate having a shadow mask mounted therein that incorporates one embodiment of the parent invention.

FIGURES 9A, 9B and 9C are enlarged views of indicated portions of the mask of FIGURE 9.

FIGURE 10 (sheet 3) is a plan view, partly in axial section, of a shadow mask cathode-ray tube having a flat faceplate according to the parent invention.

FIGURE 11 (sheet 3) is a plan view, partly in axial section, of another shadow mask cathode-ray tube having a flat faceplate and embodying the present invention.

FIGURE 1 illustrates a prior art rectangular color picture tube, having an evacuated glass envelope 20 comprising a rectangular panel or cap 22 and a tubular neck 24 connected by a funnel 26. The panel 22 comprises a viewing faceplate 28 and a peripheral flange or sidewall 30 which is sealed to the funnel 26. A mosaic three-color phosphor screen 32 is located on the inner surface of the faceplate 28. The screen 32 is a line screen, i.e., comprised of an array of parallel phosphor lines or strips, with the phosphor lines extending substantially parallel to the vertical axis of the tube. The area between phosphor lines is filled with a light absorbing material. A multiapertured shadow mask 34 is removably mounted in predetermined spaced relationship to the screen 32. An inline electron gun 36, shown schematically by dotted lines in FIGURE 1, is mounted within the neck 24 to generate and direct three electron beams 38B, 38R and 38G along co-planar convergent paths through the mask 34 to the screen 32. When appropriate voltages are applied to a yoke 40, the three beams 38B, 38R and 38G are subjected to vertical and horizontal magnetic fields that cause the beams to scan horizontally and vertically in a rectangular raster over the screen 32.

For simplicity, the actual curvature of the paths of the deflected beams in the deflection zone is not shown in FIGURE 1. Instead the beams are schematically shown as having an instantaneous bend at the plane of deflection P-P.

Although the present invention is described herein with respect to an inline gun, line screen type cathode-ray tube, it should be appreciated that the broader concept of the invention is also applicable to the delta gun, dot screen cathode-ray tube as well as to other cathode-ray tube types.

For a full understanding of the present invention, it is desirable to know what electron beam misregister is. FIGURES 2, 3 and 4 show the electron beam 38G impinging on a portion of the screen 32. Each phosphor line (42R, 42G and 42B) is separated from its adjacent line by a gap that is filled in with a light absorbing substance 44. The width of the beam 38G is slightly wider than its associated phosphor line 42G. This arrangement is commonly referred to as a negative tolerance matrix and is a preferred screen construction for practicing the present invention. The present invention also is equally applicable to positive tolerance matrix tubes (phosphor lines which are separated by a light absorbing substance and which are wider than their associated beams) and to non-matrix tubes. In FIGURE 2, the electron beam 38G is exactly centered on its associated phosphor line 42G. This is the desired beam position for accurate color output. As the tube begins to warm up, doming of the shadow mask will occur moving the center of the mask toward the screen and the beam 38G will begin to misregister with its associated phosphor line 42G as in FIGURE 3. In this case, the green phosphor line does not receive full excitation and the green color

output falls off in intensity. FIGURE 4 shows a more extreme case where the electron beam 38G has become misregistered to the extent that it is impinging on an adjacent phosphor line 42B, thus causing a color purity problem.

As previously noted, the doming effect is caused by uneven heating of the shadow mask assembly. FIGURE 5 presents a graph of misregister as a function of time of an electron beam with a corresponding phosphor line located halfway between the center and edge of the screen. The solid curve 50 represents misregister for a prior art tube and the dashed curve 52 represents the misregister in a tube using one embodiment of the invention of the parent Application. The peaks of the curves 50 and 52 occur from 3 to 5 minutes after tube activation. The misregister then decreases as the mask continues to warm up.

It should be noted that doming is a movement of a portion of the mask toward the screen while the periphery of the mask is held stationary. The effect of this movement is illustrated in FIGURE 6. The shadow mask is indicated in two positions, its unheated, undomed position, designated 34 and its heated, domed position, designated 34'. The boundaries of a portion of a beam 38G that passes through an aperture of the unheated mask 34 are shown by dashed lines 39 and the boundaries of the beam portion that passes through the same aperture of the domed mask 34' are indicated by the dot and dash lines 39'. The distance "x" indicated in FIGURE 6, represents misregister occurring because of doming. The result of doming misregister is a shift of beam landing position on the screen toward the center of the screen 32.

As the mask warms up, the effect of doming decreases because the temperature gradients in the mask decrease. Furthermore, heating of the mask causes the mask to expand thereby moving the apertures in the mask laterally outwardly (i.e., parallel to the screen) from their original locations. Such outward movement produces a misregister away from the center of the screen. It is then this combination of doming reduction and heating of the mask that causes the mask apertures to return toward alignment with the associated phosphor lines. However, the expansion of the mask causes more severe misregister problems at the edge of the screen. In order to correct for the misregister problem at the edge of the screen, it is common to support the mask-frame assembly on heat sensitive supports that move the mask-frame assembly toward the screen to reduce or eliminate the misregister caused by mask expansion. Since the compensation provided is correct only when there is no heat gradient between the portions of the mask in the support frame some residual misregister at the halfway point as shown by the curves of FIGURE 5 will exist. It also should be noted that because the mask has a greater heat sink at its edge, i.e., mask frame, some temperature transient will always exist in the mask during the operation, and therefore some degree of doming will always be present.

FIGURE 7 illustrates the geometry of a shadow mask tube. Line P-P again represents the plane of deflection (at zero deflection) as in FIGURE 1. The distance from the plane P-P to the screen 32 is designated "L" and the spacing between the shadow mask 34 and the screen 32 (measured parallel to the axis A-A) is designated "q". The distance "S" represents the distance from the tube central axis A-A to the center 54 of an off-axis electron beam as it passes through the deflection plane P-P, and "a" represents the center-to-center spacing between apertures in the mask 34. The foregoing dimensions are approximately related as shown in the following equation:

$$q = L^2/s$$

In the parent invention, in order to reduce the effects of doming, the shadow mask 56 is given a contour or curvature to provide an edge-to-center variation in "q" of greater than 1.15. At the same time, the value of "a" is also varied proportionally to "q". This is a deviation from many prior art line screen cathode-ray tubes wherein "a" was made uniform over the entire mask and "q" was permitted to vary only with "L" and "S".

FIGURES 8, 8A, 8B and 8C present a prior art shadow mask having a radius of curvature of 1000mm. Values for "a" and slit width for this mask are given in millimeters. In the center 60, edge 62 and halfway 64 between the center and edge, the value of "a" is shown to be a constant 0.77 mm. The slit width is graded in decreasing size from the center 60 to the edge 62 of the mask 34.

In an embodiment of the parent invention given by way of introduction to the present invention, wherein the radius of curvature of a shadow mask 50 is 850 mm. shown in FIGURES 9, 9A, 9B and 9C, the aperture spacing in the mask 56 having greater curvature increases from 0.77 at the center 66 of the mask, to 0.885 at the halfway point 68, to 1.000 mm. at the edge 70 of the mask. If the same slit widths as used in the prior art mask 34 of FIGURE 8 were used in the mask 56 of FIGURE 9, the transmission of the mask would be reduced beyond a desired level. Therefore, to maintain the desired mask transmission, the slit width is increased relative to the slit width of the prior art mask. In fact, if the values for "a" were varied from 0.77 mm. at the mask center to 1.14 mm. at the edge of the mask, the

slit width could be held at a constant 0.15 mm. over the entire mask for a given grading factor. An increase in slit width is highly desirable since it eases manufacturing of the mask.

Table A presents the ratios of mask to screen spacings (q - measured parallel to central axis of tube) for two prior art tubes and for two tubes constructed in accordance with the parent invention. The first column shows the ratio of q spacing at an edge of a mask along its major axis to the q spacing at the center of the mask. The second column shows the same ratio taken along tube diagonal.

TABLE A

	Major axis q Center q	Diagonal q Center q
19" - 90°	1.13	1.12
25" - 11° Prior Art Tube	1.10	1.09
25" Tube 1 Incorporating Parent Invention	1.47	1.45
25" Tube 2 Incorporating Parent Invention	1.58	1.48

It can be seen that the edge-to-center q spacing ratios are substantially larger than the same ratios in the prior art tubes. For the two examples of tubes incorporating the parent invention, it can be seen that all edge-to-center q spacing ratios are greater than 1.15.

By increasing the curvature of the shadow mask from a radius of 1000 mm. to a radius of 850 mm. both doming and blister warpage as well as their associated resultant misregisters are reduced. It is known that added curvature can provide added strength. Therefore, mask warpage can be reduced. Furthermore, because of the geometric relationships when the tube is operated and the mask becomes heated, a point on a mask having greater curvature moves a smaller distance toward the screen than does a similarly located point on a mask having lesser curvature for a given mask expansion. For the foregoing mask curvatures, doming or movement of a portion of the mask toward the screen is reduced from about 48 microns in the 1000 mm. radius of curvature mask to approximately 30 microns in the 850 mm. mask. The increase in "a" permits increases in the misregister tolerances of the off-center phosphor lines. Again, as previously mentioned, the spacing between lines on the screen cannot be too large since it would produce an objectionable coarseness to the viewer. Therefore, the chosen spacing should be a compromise between the possible increase in tolerance and an acceptable coarseness of line trios. By maintaining a smaller value of "a" at the central portions of the screen and allowing the large "a" near the edge regions, the subjective appearance of the screen is that of a fine array.

Table B presents tolerance and doming misregister measurements for a prior art tube and for a tube with a shadow mask having greater curvature than the mask of the prior art tube (850 mm. vs. 1000 mm. radius) at points halfway between the centers and edges of the tubes. All units are in millimeters.

TABLE B

	Tolerance Available	Doming Misregister	Result
Prior Art Tube	.053	.079	.026
New Tube	.067	.066	.001

The increase in tolerance available in this tube according to the parent invention is caused by the larger "a" spacing and the reduction in doming misregister is due to the increased shadow mask curvature of the new tube. Therefore, by increasing mask curvature and "a" spacing, the resultant misregister at the point on the screen where the effects of doming are greatest can be significantly reduced (e.g., by 0.27 mm. in TABLE B).

Although the mask having increased curvature and varied "a" spacing has been shown with respect to a curved faceplate, the concept of the invention of parent Application 9360/76 (Serial No. 1546889) also permits use with a flat faceplate. Heretofore, although shadow masks for use with line screens have not had exactly the same curvature as their associated faceplates, often the mask and faceplates were substantially parallel. A flat faceplate is desirable since it permits greater viewing angle without distortion of a portion of the pic-

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ture. FIGURE 10 shows a cathode-ray tube 72 of the parent invention having curved shadow mask 74 but a flat faceplate 76. The "q" spacing in this tube increases substantially from the center to the edge of the mask and the "a" spacing of the mask apertures similarly increases to maintain acceptable nesting of the phosphor lines on the screen.

5 It should be appreciated that the concept of increasing mask curvature over that found in prior art tubes to strengthen the mask and reduce doming is not necessarily limited to masks of spherical or substantially spherical stage. As shown in the embodiment of the present invention in FIGURE 11, the curvature of a mask 78 in a flat-face cathode-ray tube 80 has a reverse curve to give greater strength to the mask. In this case, the "q" spacing increases then decreases from center to edge of the mask. The "a" value then is varied proportionally to the variation in "q" spacing, therefore, it too increases then decreases from center to edge of the mask. 10

15 The relationship $q = L\lambda/3s$ permits proper nesting of phosphor elements on the screen. Nesting is the relationship of phosphor element trios relative to each other wherein the spacing between dots or lines in a trio is the same as the spacing between adjacent dots or lines of different trios. 15

WHAT WE CLAIM IS:-

1. A cathode-ray tube utilizing an apertured shadow mask for registering electron beams on phosphor elements of a cathodoluminescent screen, wherein the rate of change of spacing between said mask and said screen changes polarity at least once from the center to the edge of said mask, and wherein said spacing varies proportionally to the change in spacing between adjacent apertures of the mask. 20

2. A cathode-ray tube substantially as hereinbefore described with reference to Fig. 11.

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