Basic Considerations in Tri-Color Picture Tubes

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I. Color

Radiant energy in the band of frequencies between 400 million and 800 million megacycles per second is capable of stimulating the sensation of color. Color has three attributes -- brightness, hue and saturation. These psychological concepts are non-quantitative. The correlating quantitative concepts to brightness, hue and saturation are luminance, dominant wavelength and purity.

We are all familiar with brightness or luminance from our black-and-white experience but are less familiar with the other two attributes of color. The hue or dominant wavelength tells us whether a color is red, yellow, green, etc. The saturation or purity of a color indicates the amount of "white" light mixed with a pure spectrum color. A spectrum color is 100 per cent saturated whereas white light has zero saturation. The saturation attribute of color is generally described by such terms as pale, pastel, deep, etc.

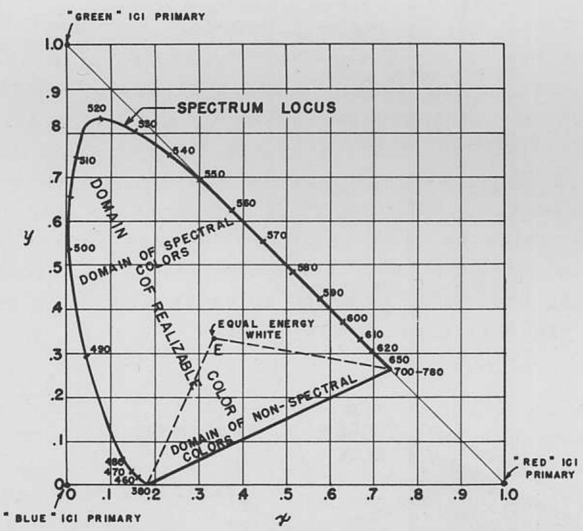

Fig. I - ICI chromaticity diagram showing ICI primaries.

It was found a long time ago that red, green and blue lights when added in all possible combinations and amounts can stimulate the sensations of practically all colors met in nature. In other words, practically all colors can be produced by all possible combinations and amounts of suitably chosen red, blue and green lights. These lights are called the primaries.

It is this fact that is the basis for colorimetry and for television color reproducers.

The International Commission on Illumination adopted in 1931 three standard primaries with which all possible colors can be produced. This necessitated choosing primaries which are not real colors, that is, these primaries correspond to supersaturated red, green and blue lights. Fig. 1 shows the ICI chromaticity diagram. Each point in this diagram specifies the chromaticity (hue and saturation) of a color independent of its luminance or brightness. All colors within or on the boundary of the triangle formed by connecting the ICI primaries can be produced by combinations of these primaries. The horseshoe curve within this triangle comprises the domain of all real colors. Any real primaries must therefore be represented by points located either on or inside this horseshoe curve.

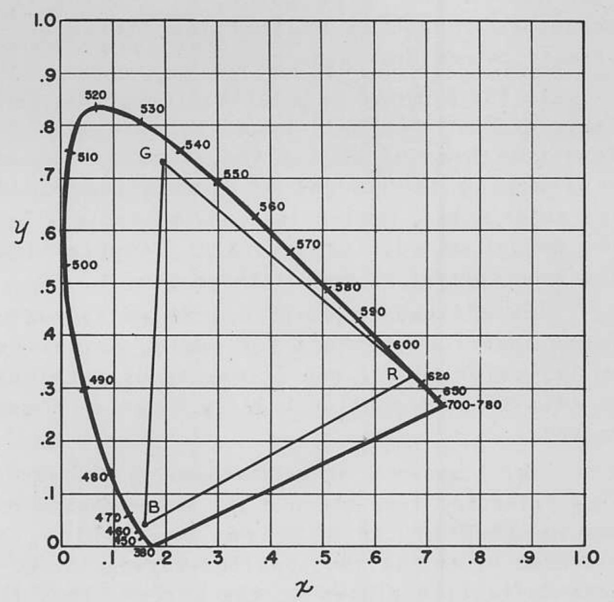

Fig. 2 - ICI chromaticity diagram showing primaries of phosphors used in tri-color kinescopes.

The points R, G and B in Fig. 2 represent the colors of the lights emitted by the red, green and blue emitting phosphors used in the tricolor tubes. All colors within the RGB triangle can be produced by suitably mixing the R, G and B primary lights, but no color outside the triangle can be produced.

The color triangle RGB encompasses practically all the colors ordinarily encountered, and as a result the gamut of colors that it is possible to produce with these primaries compares very favorably with that possible with the best processes of color reproduction and is much superior to most commercial processes.

II. Color Television Reproducers

It follows from the science of color that the basic requirements of any color television reproducer are:

(1) A set of suitable primary lights
(2) A method for adding these primaries and
(3) A method for controlling the amount of each primary to be added.

The basic differences in color television reproducers occur because of differences in one or more of the above requirements. Thus we may have two-color, three-color, or n-color reproducers depending whether two, three or n primary colors are used.

In the case of tri-color kinescopes, the basic differences will occur because of different methods of adding the primaries or of controlling the amount of each primary. In tri-color tubes, the simplest way of controlling the amount of each primary is by controlling the beam current of one or three guns.

The RCA Laboratories has investigated a large number of methods for adding primaries in tri-color tubes, and it may be of interest at this time to mention briefly a few of these methods.

Fig. 3 shows a method for adding primaries in a tri-color tube wherein the color phosphors are excited by an electron beam which is directed by the voltage applied between alternate deflection plates at the screen. Thus if the plates covered with red-emitting phosphor are made sufficiently positive with respect to the blue plates, the electron beam will strike the red-emitting phosphor; if the plates covered with blue-emitting phosphors are made positive relative to the red plates, the beam will strike the blue-emitting phosphor; if the potential difference between the deflection plates is zero the beam is undeflected and will strike the green-emitting phosphor on the glass plate. This is an example of a tube wherein the primaries are added by optical superposition, that is, the light emitted by the three phosphors is added by scattering at the green phosphor. It should be noted that in case of optical superposition each point on the picture appears to emit all three primaries regardless of viewing distance.

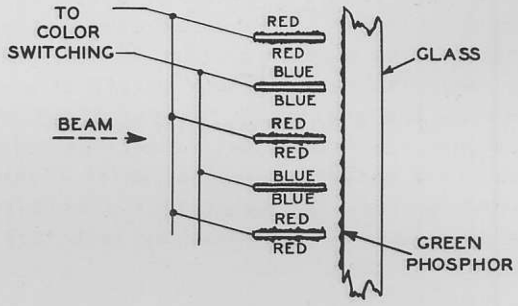

Fig. 3 - Venetian blind type screen.

Fig. 4 shows a method for adding primaries in a tri-color tube wherein the red, green and blue emitting phosphors are laid down as line triplets. Individual phosphor lines are excited by a fine electron beam which is accurately deflected. This shows an example of adding primaries by juxtaposition. A requirement of this method is that the elements, i.e., lines, dots, etc., be too small to be readily resolved at ordinary viewing distances.

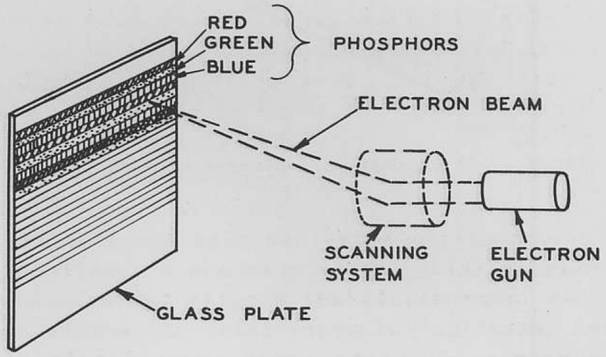

Fig. 4 - Line type screen.

Fig. 5 shows a multi-layer phosphor screen wherein the primary color excited depends upon electron beam penetration. This is an example of optical and spacial superposition of the primaries.

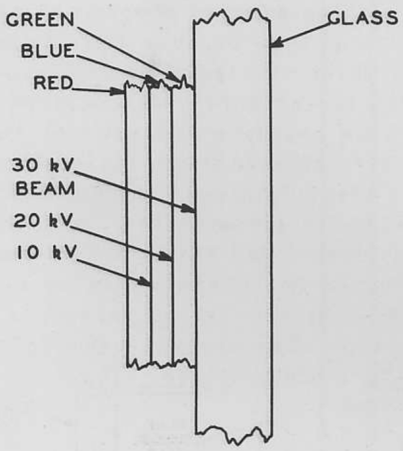

Fig. 5 – Multi-layer type screen.

Fig. 6 shows another example of adding primaries by spacial juxtaposition. It is to be noted that in this case a mask is used for shadowing.

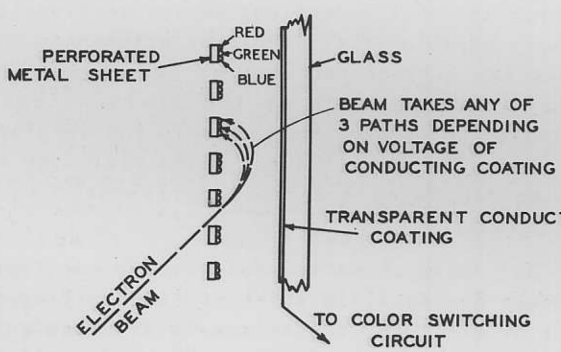

Fig. 6 – 45-degree reflection type screen.

Fig. 7 shows a cubical-pyramid color screen. This is an example of adding primaries by both spacial juxtaposition and optical superposition. It is to be noted that in this case one phosphor face shadows the other two.

From our investigations on these and many other methods of adding primaries it was concluded that the better method of adding primaries in tri-color tubes is by juxtaposition. It was also concluded that, in general, the best methods of obtaining color purity which is independent of electron beam focus and deflection is by means of shadowing by a mask. Manufacturing and mechanical considerations indicated the aperture mask to be the simplest to make with known techniques.

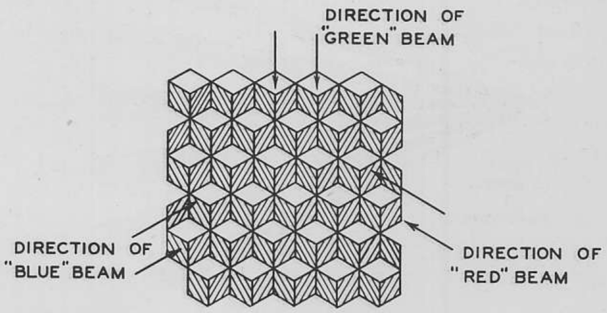

Fig. 7 – Cubical pyramid type screen.

The above were the main considerations that led to the concentration of a large effort on the aperture mask type tri-color tube which is the main subject of discussion at this meeting.

III. How an Aperture-Mask Tri-Color Tube Operates

Perhaps the simplest way of understanding how the tube operates is with the aid of the concept of color centers. A color center is simply a point, or more accurately, a small region in space from which one can see only one set of color dots, i.e., all the dots of one color over the entire screen, the other two sets of color dots being masked. Thus in Fig. 8 the point 0 is a color center. If the color center 0 is located in the deflection plane, then the electrons as they are deflected at 0 can strike only one set of color dots all over the screen. Similarly there are two other color centers from which the other two sets of color dots may be seen. This is shown in Fig. 9.

For correct operation it is therefore necessary that (1) the yoke be located so that the plane of deflection coincides with the plane of the color centers and (2) that the three electron beams pass through the three color centers.

It is further necessary that the three electron beams pass through the color centers in the plane of deflection with the correct angles so that they are converged on the aperture mask.

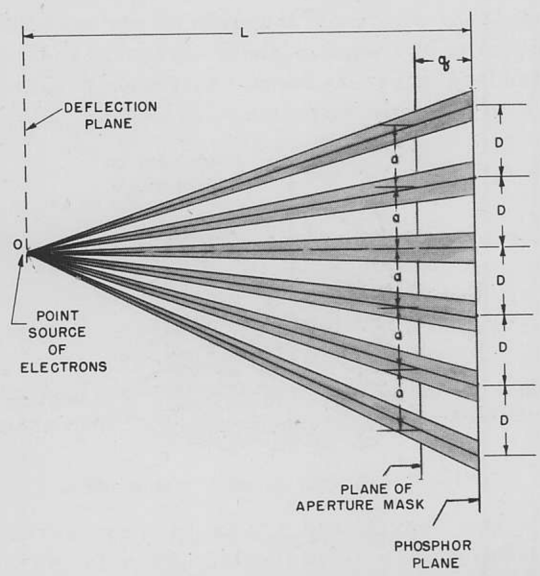

Fig. 8 - A plane through an axis normal to the plane of the phosphor array and passing through a color center O in the RCA tri-color kinescope.

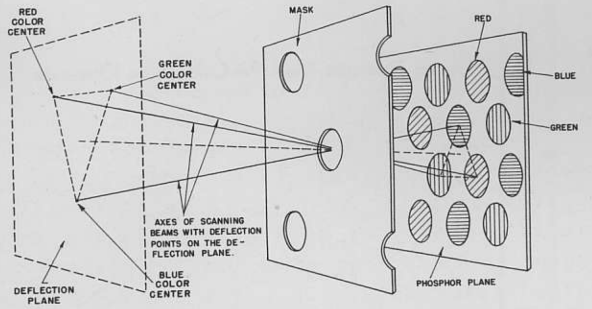

Fig. 9 - Diagram showing the location of the three color centers in the RCA tri-color kinescope.

So far the operation has been described in terms of a three-gun tube with three beams; the mode of operation is basically the same with a single-gun tube having but one electron beam. In the case of a single beam, it is merely necessary to move the beam over so that it would successively pass through the three color centers with the correct convergence angle.

Up to about a year ago our effort on the aperture mask type tri-color tube was about equally divided between single and triple gun tubes. It was then decided that from a manufacturing point of view it would be preferable to concentrate primarily on one type of tube. The decision was made in favor of the triple gun primarily because of the following generally features: the triple gun tube is more suitable for simultaneous presentation, it is capable of producing pictures of higher brightness, and is more suitable for operation with unbalanced phosphors -- by unbalanced phosphors is meant the situation when unequal beam currents are required to produce white.

IV. Present Development and Research Work

Our development work on the aperture mask tri-color tube is directed toward improved performance and cost reduction. We are working (1) on tubes capable of still higher brightness and resolution, (2) on rectangular tubes, and (3) on larger tubes such as the 21-inch tube, several of which have been made in the development shop. The 16-inch tubes which will soon be sampled are being made in the tri-color tube pilot plant.

Our research on tri-color tubes continues to cover a wide field which includes different types of tri-color tubes as well as basic work on phosphors, color screens, electron optics, and guns.