# RECENT IMPROVEMENTS IN THE APPLE BEAM-INDEXING COLOR TUBE

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## Summary

One year ago three papers were presented here describing the Apple system, a new system of color television display. During the vast year work has actively continued in the Philco laboratories to improve system performance, to reduce cost and to simplify both tube and circuits. Advances have been made in several areas. This paper treats the recent improvements in the Apple tube itself. Improvements in the circuits will be described in a following paper.

## Wide Red Line

A significant increase in the brightness of the Apple tube has been achieved by altering the relative widths of the red, green and blue phosphor stripes. This increase in brightness has been obtained while still maintaining the "white balanced" feature of the screen; that is, scanning the screen with an electron beam of constant intensity still produces the white we desire for monochrome pictures. This "white balanced" screen is an important feature of Apple because it is predominantly responsible for the simplicity and the excellence of Apple monochrome performance. With a "white balanced" screen only conventional monochrome circuitry is used in the generation of monochrome pictures.

In the Apple tube of a year ago, the red, green and blue lines were of equal width. Since the green and blue phosphors are more efficient than the red, It was necessary to dilute the green and blue phosphors with a suitable unactivated material before deposition to obtain the proper white point in the finished tube.

In today's improved Apple tube, the relative amount of red, green and blue light is controlled by using color stripes of unequal widths. This has resulted in a 60% increase in screen efficiency. Slide 1 compares the old and the new screen structure. The screen of a year ago is shown at the top of the slide. The red, green and blue stripes are of equal width, each 10 thousandths of an inch wide. The black guard lines between each color phosphor stripe are each also 10 thousandths wide. The black dots in the green and blue stripes represent the diluents.

In the new screen, shown in the lower portion of the slide, 60% more red phosphor is used simply by making the red line 16 thousandths of an inch wide instead of 10. 60% more green phosphor is used even though the green line is now only 8 thousandths wide. This has been made possible by eliminating the diluent. 60% more blue phosphor is similarly used but some dilution is still necessary because the blue is extremely efficient. The black guard lines have also been changed as indicated. Thus, the new screen is 60% brighter than the old screen while maintaining the same white point.

Theoretically one might carry this process of line width control of white point a step further. One might remove the diluent from the blue line and narrow it somewhat. However, the benefits that would accrue appear relatively slight.

This new screen is not only 60% brighter but has a further advantage that can be used in a variety of ways such as loosening tube manufacturing tolerances or improving picture quality.

This advantage stems from a characteristic of the human eye. To the normal observer contamination of red light by green or blue is substantially more objectionable than contamination of blue light by green or red. Contamination of green light is the least objectionable of all.

This characteristic of color is easily demonstrated. We have here three projectors, a red, a green and a blue. Their colors are chosen to duplicate the phosphors currently employed in color television. The relative intensities of the three are adjusted so that when combined as they now are they produce a white of about 8500° Kelvin. Unfortunately the directional characteristics of this screen make the exact color white you see a function of your location. In some areas this white may appear somewhat pink and in other areas somewhat blue. We've chosen the best compromise we could.

To compare the effect of green contamination in red and blue, we will move red to the right, blue to the left and green upwards. We will attenuate the green light to 15% of its previous value. Clearly the 15% green light produces a more objectionable effect in the red than in the blue.

Next, we can compare the contaminating effect of red and blue on each other. We make the red and blue overlap, creating magenta in the middle. Attenuating the blue light to 15% of its previous value, we get a bluish red. Attenuating the red light to 15% we get a whitish blue. Trying it again, I believe you will agree that the red with 15% blue is less satisfactory than the blue with 15% red.

We will now duplicate the experiment with red and green, using blue as the contaminant. Here we have 15% blue contaminating the red and green. The contam-inated red is much worse than the contaminated green. Comparing the effect of red and green on each other, we first attenuate the green light to 10%, making orange, and then attenuate the red light to 15%, producing a scarcely noticeable effect in the green.

We conclude from these experiments, that in color television, contamination of red is more objectionable than a comparable contamination of green and blue. The same conclusion is drawn from actual operating experience with color receivers.

This conclusion is not in conflict with the work of MacAdam, Wright and others concerning minimum perceptible color differences. Their data are derived from totally different experiments, involving side-by-side comparisons within a 2º field of vision. Our discussion here today is a comparison of subjective needs rather than of minimum perceptible color differences.

Now, how then does all this give the new wide red Apple screen an additional advantage? In the old Apple screen shown at the top of Slide 2 an equal amount of space was allocated to red, green and blue.
In any given triplet, it was possible to land electrons over a 30 thousandths interval and still excite only the red stripe. Likewise, a 30 thousandths interval was available for green and for blue.

In the new Apple screen, it is now possible to land electrons over a 32 thousandths interval and still excite only the red stripe, providing 7% more space. The available spaces for green and blue have been reduced to 28 thousandths but we have just shown these colors to be less critical.

This 7% advantage can be used in numerous ways. We could tolerate a 7% larger spot size - thus either loosening tube tolerances or permitting one to drive the tube to higher peak currents. Alternatively, we could loosen tolerances on line width control. Still another way might be to loosen tolerances affecting color uniformity. In summary, this wide-red-line feature tends to make the tube easier to produce and easier to use.

The colorimetry of the pictures created with the wide-red-line structure is similar to that with an equal line width tube. The next paper treats this subject.

We feel that there is nothing absolute about the exact widths of the stripes now employed but rather that the numbers we have chosen represent a good compromise among the many factors involved. These factors include colorimetry, brightness, tube tolerances and receiver economics. The matter is still under investigation in our laboratories.

## Phosphor Line Geometry

A second major improvement in the Apple tube has involved a change in the curvature of the phosphor lines over the tube face, that is, the "pin cushion" of the phosphor lines. This change, although reflecting no additional tube cost has permitted substantial simplification and improvement of the receiver deflection system.

This modification of the pin cushion has been effected while still preserving two basic Apple system requirements. They are:

1. The frequency of the index signal must be nearly constant, that is, the intervals of time required to cross a triplet must be approximately equal over the entire tube face.

2. The pilot beam, which is used to determine the location of the writing beam, must generate accurately-phased index information. Each pulse from the pilot beam must occur when the writing beam is at a particular point within a color triplet. Thus, the positional relationship of the two beams must be known at all times, that is, the two beams must track each other, and the index lines must be suitably located within the color triplet.

Previously, accurate index phasing was achieved by depositing the color lines in such a way that both beams always landed on the same color or index stripe simultaneously in all areas of the screen. Slide 3 shows several of the color lines, greatly exaggerated in pin cushion for the purposes of explanation. It also shows the relative position of the two beams as they strike various areas on the tube face. The writing beam is the upper circle; the pilot beam is the lower small dot. Because both beams crossed a given line simultaneously, the pulse from the lower pilot beam accurately indicated the position of the writing beam. It is seen that with this arrangement the color line geometry was essentially chosen to match the double-beam corner-twist pattern.

There were two disadvantages to this particular color line pattern. First, the pin cushion of the color lines did not exactly match the pin cushion of the yoke. Therefore, the deflection velocity had to be increased at the top and bottom of the tube to satisfy the constant index-frequency requirement, since the triplet was wider in these areas. The necessary increase in deflection velocity was achieved by modulating the sweep width with a 5% vertical parabola. Vertical modulation of the horizontal deflection system increased the circuitry cost, and introduced a possible source of color error through misadjustment

The second disadvantage was purely subjective in that the raster shape appeared to the viewer slightly pincushioned. This was somewhat objectionable in occasional picture content such as vertically moving titles.

The new Apple screen structure eliminates both these disadvantages. The color line geometry of the new Apple screen is chosen to match the natural yoke pin cushion. Thus, no vertical modulation of the horizontal deflection system is required and the sweeps are substantially simplified. Further more, the resulting raster appears to the viewer to be without any pin cushion; the pictures look rectangular.

To obtain accurate index phasing with the new Apple screen, a slight modification of the index structure is required. Slide 4 shows the relationship between the two beams and the color lines. Since the curvature of the color lines has been changed, the two beams no longer cross a given color line simultaneously in the corners of the tube. The pilot beam leads the writing beam in the upper left and lower right corners and lags in the other two corners.

To compensate, it has been necessary to vary the position of the index line within a triplet.

The index is positioned later in the color triplet in the under left-hand corner than it is upper right. The reverse displacement pattern occurs at the bottom of the tube (Slide 5).

Introduction of this additional component to the displacement of the index stripe does not interfere with the displacement, described a year ago, that is employed to compensate for the variation in transit time of the secondary electrons.

This modification of the screen geometry represents no additional cost in the manufacture of the Apple tube. The only change required in the manufacturing process is the use of a new set of photographic masters. The new masters are similar to the old. The additional displacement of the index lines to compensate for the beam corner twist pattern was simply added to the previously existing displacement that compensated for transit time. It represents no significant complication.

## Black Guard Line

A third recent improvement in the Apple tube has involved a change in the guard line material. The use of an opaque, dark colored, nonluminescent material as a guard line between the phosphor stripes to improve color saturation and contrast under normal ambient lighting was described in a paper presented here a year ago.

The material being used for this purpose a year ago had certain disadvantages that prevented full realization of the benefits possible, During the past year a significantly better material has been found in the form of a ceramic coloring agent consisting of a calcined mixture of metallic oxides. The material is inexpensive and readily available commercially. The new material is blacker, more opaque, and better adapted in particle size and wettability for photographic deposition. The use of the new material substantially reduces screen reflectivity.

This reduction in screen reflectivity improves picture contrast under normal viewing conditions by increasing the blackness of the black areas of the picture without reducing the light output of the screen itself.

## Life Testing

Extensive life testing of Apple tubes has continued during the past 12 months. It had previously been thoroughly demonstrated by life tests extending up to 10,000 hours on a substantial number of tubes that no difficulties developed on life as far as the secondary emission index phenomenon was concerned. Continuing life tests have only served to completely confirm this fact.

Additional-life-test-end-point criteria based on spot size and cathode emission have been established during the past year. Since the effective spot size is a function not only of the total cathode emission but of the distribution of emission over the area of the cathode being used, the normal end point based on cathode emission has been supplemented by a measurement of spot size, an item of obvious importance in the Apple system. Life tests of almost 100 Apple tubes during the past year have shown performance fully equivalent to monochrome tubes based on 2,000 hour tests.

## Manufacturing Techniques

In addition to the improvements and refinements which have just been described, pilot production activity during the past year has made it possible to reduce to a sound production basis the various manu-facturing techniques required for the Apple tube. Screen disposition methods have been improved in reliability and simplified in their execution. Various of the screening operations have been converted from hand to automatic methods. Processing time has been reduced. Testing methods and performance criteria have been refined to a very considerable extent, permitting excellent correlation between test results, and picture performance of the tubes in actual receivers.

## Conclusion

In conclusion, the authors continue to believe that the Apple tube permits lower cost manufacture than other types of color tubes. Its performance is felt to be superior. The work of the last year with the attendant increase in brightness, simplification of tube use, increased contrast ratio and further experience in tube life and the reliability of the tube manufacturing process has strengthened this conviction.

## Acknowledgements

The advice and guidance of Messrs. Clapp, Ringley, Parsons, Pratt and Sadowsky throughout the past year has been essential and greatly appreciated. Louis Angelucci, Monte Burgett, Charles Gray, John Krynock, Richard Stouffer, Charles Teacher and Paul Williams have all made substantial contributions to our progress.

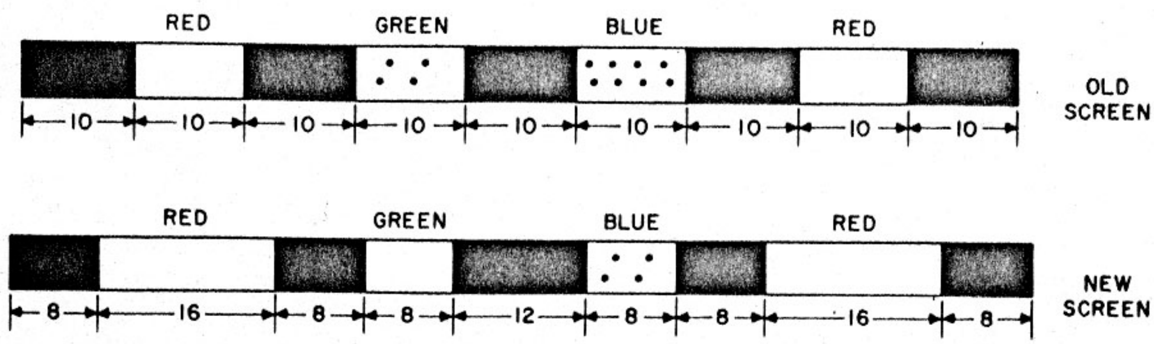


FIGURE 1 Comparison Between Old and New Stripe Proportions Within Triplet

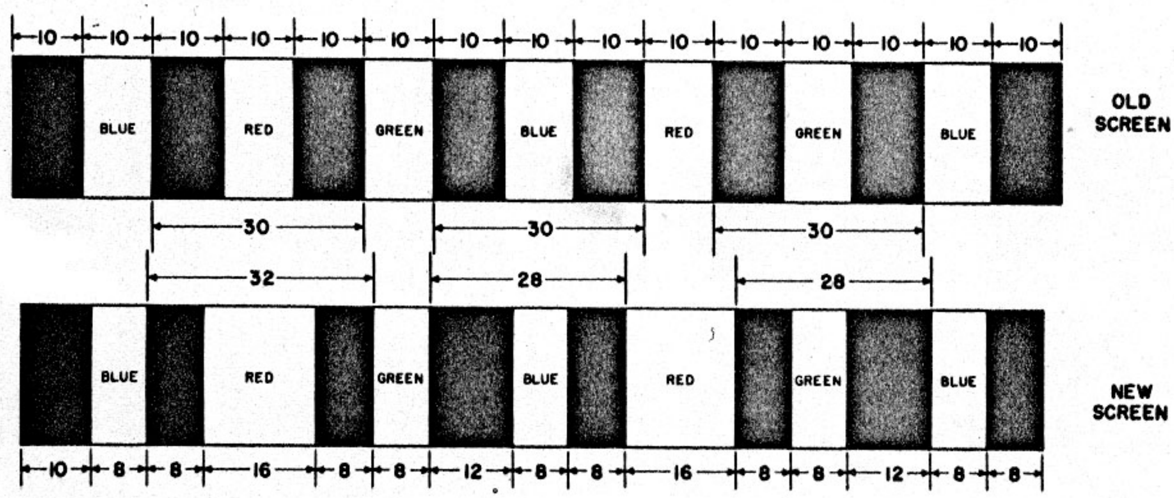


FIGURE 2 Comparison Between Old and New Triplet Grouping

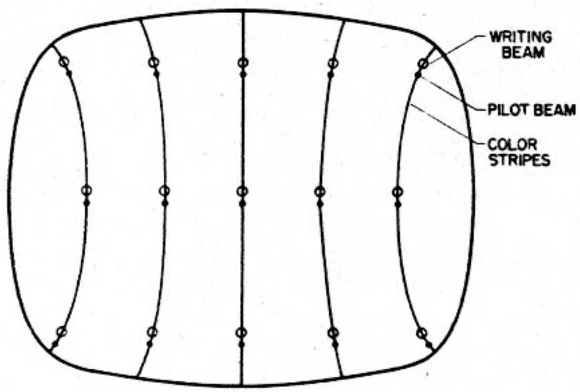


FIGURE 3 Old Screen Geometry Showing Relation Between Writing and Pilot Beams

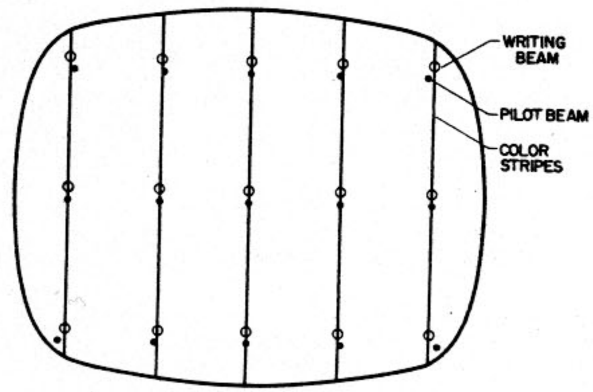


FIGURE 4 New Screen Geometry Showing Relation Between Writing and Pilot Beams

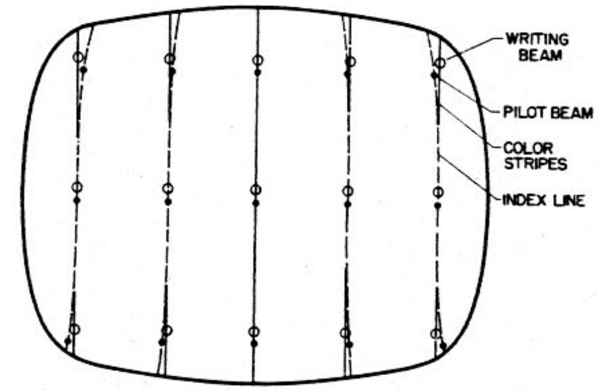


FIGURE 5 The New Index Structure and its Relation to the Color Stripes