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# Color Television

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A NUMBER of organizations have demonstrated how it is possible to employ the old colormovie filter disc principle to the transmission of televised pictures. Experts state that even with a reduction in the number of lines per picture the addition of color has the effect of increasing the detail transmitted. The band width required is not reduced, however, with the present system of color television transmission.

The Columbia Broadcasting System recently demonstrated television in full color to a group of commissioners and members of the staff of the Federal Communications Commission.

The delegation was headed by Commissioners T. A. M. Craven, Frederick I. Thompson and Paul A. Walker, who viewed the demonstration in the CBS television laboratories and discussed the new development in some detail with Chief Television Engineer Peter C. Goldmark, inventor of the color television system. Chairman James L. Fly of the FCC saw a private laboratory demonstration of the color method several weeks ago.

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After showing motion pictures reproduced by television, both in color and in black and white, Dr. Goldmark presented a new and still experimental "magnified" screen development which, for comparative purposes, enlarged the color picture images by approximately 80 per cent without loss of detail.

Commissioner Craven's comment was: "Color television as demonstrated by the Columbia Broadcasting System is a valuable contribution to television development. Undoubtedly it will advance public acceptance of television. I hope color television will be made available at an early date as a service to the public."

Commissioner Thompson commented: "I think color television well confirms the commission's judgment in postponing the establishment of fixed standards six months ago."

Following the demonstration, the group discussed with Columbia officials the possibility of early color television for the public; the possibility of color pictures of two-foot size for home reception; the effect of color upon television programs and on public interest.

Members of the commission staff were particularly interested in the feasibility of converting ordinary black and white receivers into color receivers.

Dr. Goldmark pointed out that such conversion would be easy and inexpensive on sets built to anticipate such conversion, but would be more expensive, and therefore might not be practical on sets which have already been sold without provision for color.

Those who accompanied the commissioners were: Andrew W. Ring, chief engineer in charge of broadcasting; Nathan David, assistant to the chairman; William A. Bauer and Benjamin W. Cottone of the Legal Department; W. K. Boese, member of the engineering staff, and George C. Gillingham, director of information.

Although the simple rotating light filter disc is being employed there are many problems involved in the production of televised pictures in their natural color. I shall endeavor to make many of these problems evident to you by presenting the outstanding factors involved in the transmission of televised pictures in color.

There are two important characteristics of the human eye permitting the transmission of television and, of course, color television. These two characteristics are known as the persistence of vision and the fact that the human eye has the ability to discriminate between colors. Let's learn more about these two characteristics.

### The Eye and the Persistence of Vision

As an optical instrument, the human eye performs many functions. It is a well known fact that the human eye retains an impression of an object for a short time after the object has disappeared from view. This characteristic of the eye is known as the persistence of vision. Fig. 1 shows that *S* is the outer enclosure of the eye. *C* is the cornea, a strong transparent membrane, which forms a front covering for the eye. *I* is the iris, which is the colored part of the eye, with a central orifice (opening or ajustable shutter) called the "pupil" which admits light to the lens *L*. Through this lens images are thrown onto the retina, or screen, *R* situated at the back of the eye. The nerve centers which cover this screen

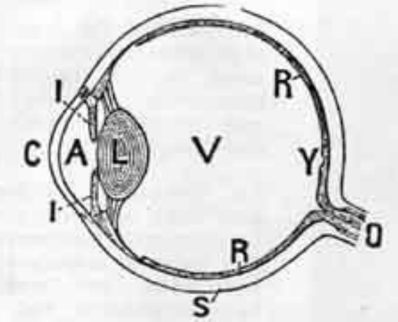



Figure 1

are stranded together like the wires in a cable and are joined to the optic nerve *O* which connects with the brain.

Persistence of vision is also the reason why the modern motion picture is possible. It is used in many daily applications, but it is absolutely essential in motion picture and in television, whether the pictures are in color or black and white. One of the simplest demonstrations of the persistency of vision is the condition which exists when you look at objects in between the blades of a motor driven fan, first when the fan is standing still and then after turning on the power to cause the blades of the fan to revolve. You now not only see the objects originally in the field of view, but also all other objects not hidden by the stationary frame of the motor. You are not seeing through the blades of the fan but retaining the views impressed upon the retina and by the aid of the persistence of vision!

Persistence of vision is a very favorable characteristic of the eye and is as stated above, absolutely essential in television. It is even more important in the case of color television.

### Color Discrimination

Again the eye, like all optical instruments, discriminates in the detection of various colors. After studying the color peculiarities of the eye, Young and Helmholtz developed the theory that there are three sets of nerve terminals distributed over the retina of the eye, and one set of nerves, if stimulated gives the sensation of blue, the second a sensation of green and the third the sensation of red light.

Furthermore, each set of nerves need not be excited by a monochromatic color identical to the impression it gives to the mind. The retina of the eye can be excited to some extent by lights of other monochromatic colors as shown in Fig. 2, each giving a red, green or blue sensation depending on which set of nerves it stimulates. For example, the red sensitive nerves can be stimulated by blue light and green light to give to this set of nerves a sensation of red. The strongest sensation of red is, however, experienced from a red light which has a color content similar to the red shown in Fig. 2. Such a color is referred to as a primary red. There are, as you have already guessed, three primary

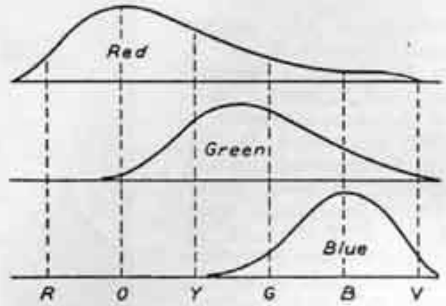



Figure 2

colors and it is still more interesting and valuable to know that all possible colors that you can see may be produced by combining a mixture of these three. This fact has already been demonstrated to all of us who have seen colored motion pictures. These pictures are produced with the aid of three primary colors.

The eye does not respond to any light unless it is strong enough to stimulate the nerves. This minimum quantity of light required for nerve excitation is called the threshold of quantity. Color is not recognized below the threshold of quantity. When all three sets of nerves are stimulated to the same degree, the impression received is white. It is also interesting to know and important to remember in the reproduction of color television that the eye is most sensitive to yellow-green light and that objects appear with clearer definition in lights of these colors. This means that it requires many times the light energy in the blue and red ranges to give the same effect to the eye as that required when using a light containing yellow-green frequencies. Incidentally this is one of the reasons the so called fog lights on cars are yellow.

### Production of Color

Every object that we see gives off light, that is, the objects are luminous, in other words they reflect light. The amount of light and the color sensation received will depend upon the relationship between the three primary colors as shown in Fig. 2. You will note that there are six letters across the bottom of Fig. 2. These represent the red, orange, yellow, green, blue and violet monochromatic colors. Of course, if any equal amount of all these colors are present then we will have white light.

### Selective Reflection and Absorption

When we look at an object that has various colors present and in particular when the object is illuminated by white light, then the bodies which reflect light generally do so selectively. That is, certain wavelengths of the incident light which are not absorbed and dissipated as heat are reflected. For example, the red tile roof reflects only the red components of sunlight and turns into heat all other rays of the sun. It is also interesting to know at this time that in moonlight, the red tile roof appears black because there is no red in the light falling on the roof which it can reflect selectively. Thus, in order to show the true color of an object in artificial light, it is of importance to have the presence of all light components in the source.

Transparent bodies like colored glass owe their colors to selective absorption. If a red glass, known to many as ruby glass, so essential in a photographer's room, is held between the eye and a daylight lamp, the glass will subtract or selectively absorb all other colors of the white light falling upon it and transmit only the deep red light. It is also well to remember that if we place a piece of blue glass over the red glass then the white light must now pass through one glass after the other. Now none of the components of the white light will be transmitted and as a result no light will be visible. The red glass absorbs the green, blue and violet from the white light; the blue glass absorbs the red, orange and yellow; that is, each of the two glasses absorbs those colors which the other transmits. From this we can draw the conclusion that the light used for illumination purposes in a color television studio must contain equal amounts of light at the frequencies represented by the green, blue, violet, red, orange and yellow. You will later find out that the light source must not have strong values of energy just above and below the visible range of frequencies.

### Color and the Persistency of Vision

If we change the blades of an electric motor driven fan to filter segments containing the primary colors, red, blue and green and do not allow openings in between the different segments of the disc we may then demonstrate as shown in Fig. 3, how it is possible to take advantage of not only the persistence of vision but also the color characteristics of the eye. With the disc containing the colored segments standing still you will be able to see only the greenish parts of the object when looking through the green segment. However, if the disc is rotated so that more than 15 colored segments of each of the primary colors pass alternately between the eye and the object, the eye will have an equal opportunity to view all colors passed by the 3 primary color filter an equal length of time. The rotation of the disc will not produce any objectionable flicker as the colored segments will be passing

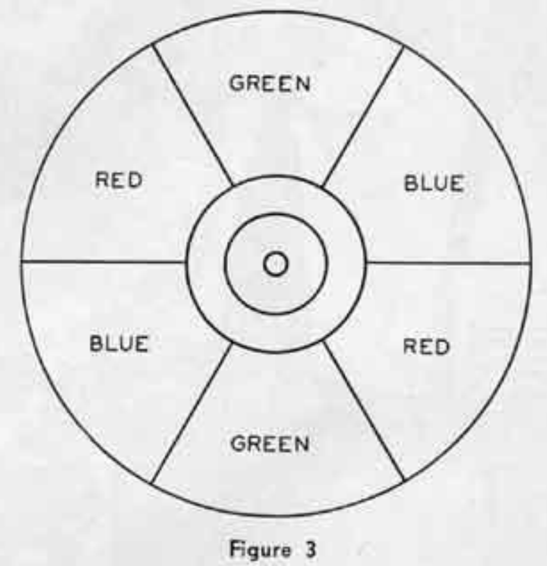


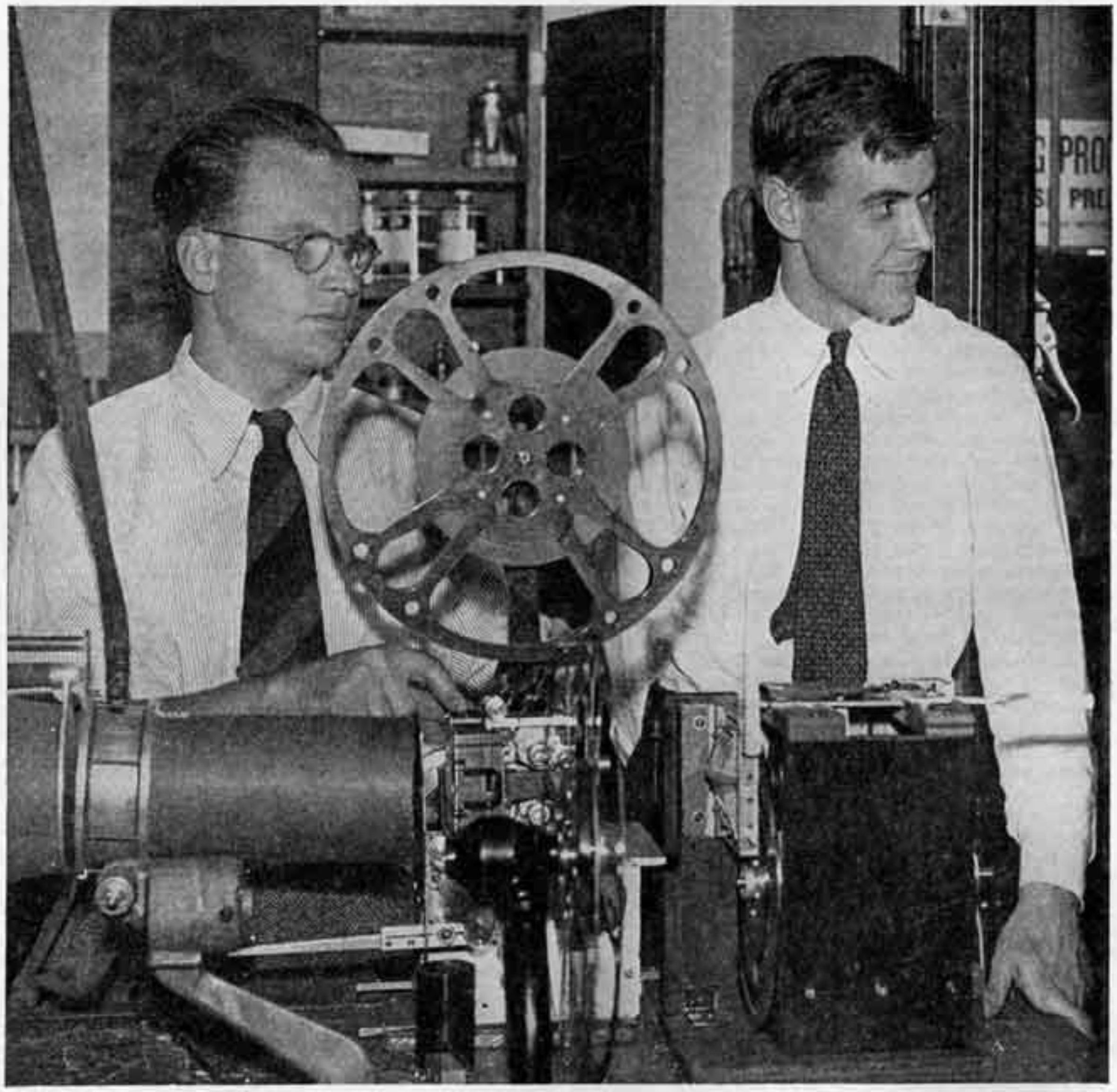

Figure 3

the eye at a rate high enough to permit the eye to retain each color for the duration of the other two primary colors. The relationship of the intensity of these 3 colors to each other will give us all of the colors of the visible spectrum, that is, the red, orange, yellow, green, blue and violet, depending, of course, upon the amount of light passing each one of the color filters.

We must not overlook the important fact that the efficiency of the filter segments must be taken into consideration. As stated above, the eye does not respond to any light unless it is strong enough to stimulate the nerves and if one filter is not very efficient that primary may be entirely missing, that is, below the threshold quantity. The color relationship in the object viewed will not be correct. There will be color distortion! That is, the light passed by the light filter must be well above the threshold quantity. This means that the revolving light filter must be efficient and the higher the efficiency, the easier it is to get good color television pictures.

#### Line or Element Scanning a Necessity

So far we have shown how the eye may view all of the colors in their proper relationship when each of the three primary light filter segments have the same degree of efficiency. The next step is the transmission of the picture viewed over a single radio channel. This can be done by what is known as scanning. The scanning system may



Dr. Peter C. Goldmark, Chief Television Engineer, and John N. Dyer, Assistant Chief Television Engineer,—making adjustments on the color television transmitting equipment and at the same time watching the results received on the television monitor in the television laboratories of the Columbia Broadcasting System at 485 Madison Avenue, New York City.

use the straight form of scanning as we read the page of a book or some form of interlacing. The same system of scanning must be employed at the receiving end in order that the proper sections of the picture be viewed. Regardless of the scanning system used, the mastery of the present color television picture transmission system will be understood and especially when using the revolving color filter disc. Of course, each system will have its individual problems.

Fig. 4 indicates the important sections and the working principle of the new color television system employed by Dr. P. C. Goldmark of the Columbia Broadcasting System and Dr. E. W. F. Alexanderson of Schenectady, New York. The arrangement shown in Fig. 4 is for use with Kodachrome color film. From the light source at the left, energy travels, literally speaking, to the right to the eye at the viewing position. The light source must contain equal amounts of the green, blue, violet, red, orange and yellow. In other words, it must be what is known as white light with very little energy at frequencies above and below the visible range.

Light energy then travels from the white light source, thence through the multi-section three primary revolving color filter to the film and then to the photo sensitive surface of the image pickup tube. By selective absorption of the color segments in the revolving color disc and the colored element of the picture in the film being scanned, only light of a given frequency will pass onto the photo sensitive surface of the image pickup. The relative intensity of the light energy passed by the film will determine the intensity of the signal fed to the grid of the first tube in the pre-amplifier stage of the video amplifier. If the relative sensitivity of the image pickup is the same for all light frequencies and the efficiency of each of the revolving color filter segments is the same, then the signal emitted by the transmitting antenna for all colored elements of the picture will be of the proper value for its reproduction on the screen of a black and white televisor. The image on the face of the picture reproducing tube will appear in proper halftone values. The aid of the second revolving color filter will, when properly synchronized, give us the colored televised picture.

Although both systems employ the revolving multi-color filter disc, each have some minor variations in order to compensate for some of the undesirable characteristics of the equipment used.

### Relative Sensitivity of the Eye and Image Tube

Since the selective absorption of the revolving color filter segments vary from the true value and the color sensitivity of the image pickup tube varies from the relative sensitivity of the human eye, the intensity of the various electrical values at the output of the transmitter will not be faithful. Some control of the color sensitivity must be incorporated in the television system. Some idea of the variation of the relative sensitivity of the eye and an image pickup tube may be obtained from Fig. 5. It can be seen that the image pickup tube drops in sensitivity where the sensitivity of the eye increases. This then means that some form of color sensitivity control must be introduced to compensate for the different characteristics.

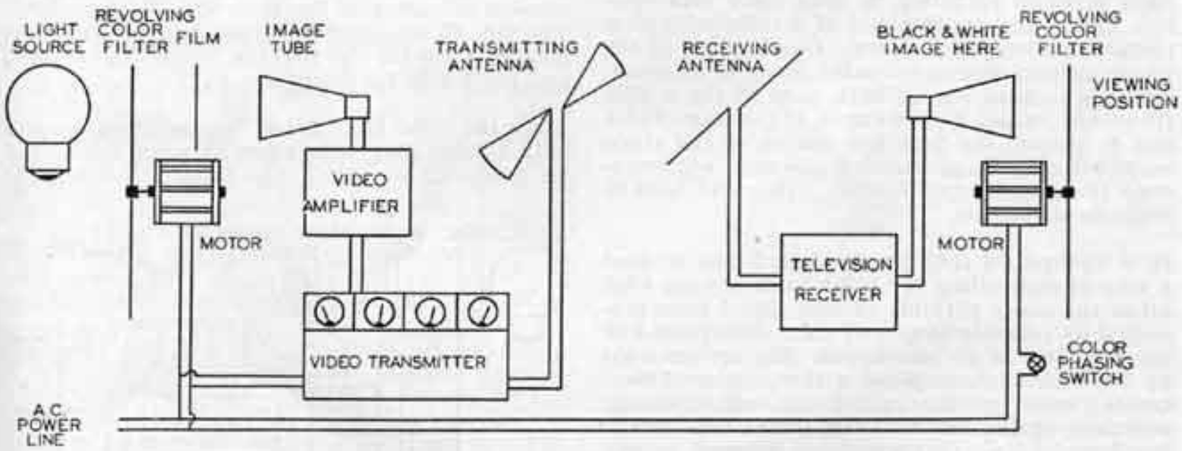



Figure 4

If we could construct red, green and blue color filters having the same relative sensitivity as that of the eye as shown in Fig. 2, then we would find that the compensation for the image pickup tube from the relative eye sensitivity would enable the passage of the correct signal intensities in the video amplifier circuit and consequently on the image reproducing screen, that is, providing the latter has all the properties of white light. This then means that a television receiver which is not equipped with color television apparatus may be used for the reproduction of standard televised programs. Furthermore, the use of a revolving color disc at the receiving end will permit true color reproduction of the scene being televised.

We must not overlook the relative sensitivity of the light used to flood the object or entertainers

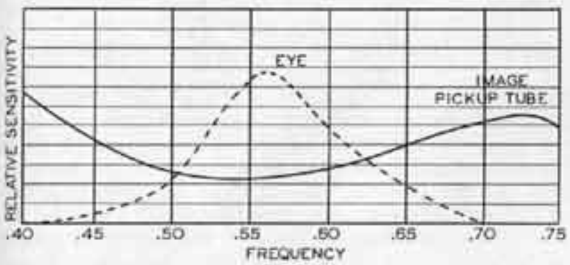



Figure 5

as a possible variation in true color reproduction at the transmitter end of a color television picture transmission system. Overloading of the image pickup tube may easily occur if its sensitivity is high at one or both ends of the visible frequency range. For example, if the ultra-violet end is strong, the first few stages of the video amplifier may be overloaded and may not introduce the proper amplification. This will lead to halftone distortion.

It is understood that Dr. Goldmark has devised a way of controlling the color balance even with all of the many variable factors that I have presented as possible causes of color distortion and the final loss of picture detail. The system used by Dr. Goldmark employs a three channel electronic color mixer which is electronically switched during the line and frame synchronizing impulses so that only one channel is employed at a given time. The three channels are referred to as the red, green and the blue channels. A better understanding of the method may be obtained by studying Fig. 6. The output of the pre-amplifier feeds into the input circuits of each of the three channels. Each channel has its gain or primary color level control. Furthermore, the electronic switch which is controlled by the sweep circuit synchronizing unit is so connected and designed to allow only one channel to operate at a given time and to operate when its respective segment of the rotating color filter is passing between the film and the image pickup tube.

Although no definite information is available on the method employed by Dr. Alexanderson, it is my opinion that he changed the illumination, that is, placed a special stationary light filter between the light source and the rotating color filter. This is very evident as the cover photo shows that a standard type black and white television receiver is used with no additional equipment other than the color revolving disc.

Incidentally, the cover photo is by courtesy of the General Electric Company. It shows a group of very distinguished men viewing the demonstration in Dr. Alexanderson's home. They are from left to right: Dr. Peter C. Goldmark, in charge of television engineering for the Columbia Broadcasting System; Philip D. Reed, Chairman of the Board of the General Electric Company; Dr. Alexanderson, and George Henry Payne, member of the Federal Communications Commission from Washington, D. C.

It is not very difficult to use a rotating color filter with 16-mm. Kodachrome movie film as that originally employed by Dr. Goldmark. It is another problem to get sufficient intensity of artificial light to make live studio pickups satisfactorily. This is a studio pickup limitation as the amount of heat generated while picking up "black-and-white television" studio pictures is tremendous. The large amount of light loss in the filters is due to the fact that the light transmission efficiency of the filter disc is about 30%. The No. 25 standard Wratten gelatin filter was used by CBS for the red, the No. 47 for the blue and the No. 58 for the green.

Since the color filter is but 30% efficient, we can only assume that three times as much light must be produced to obtain the same sensitivity or

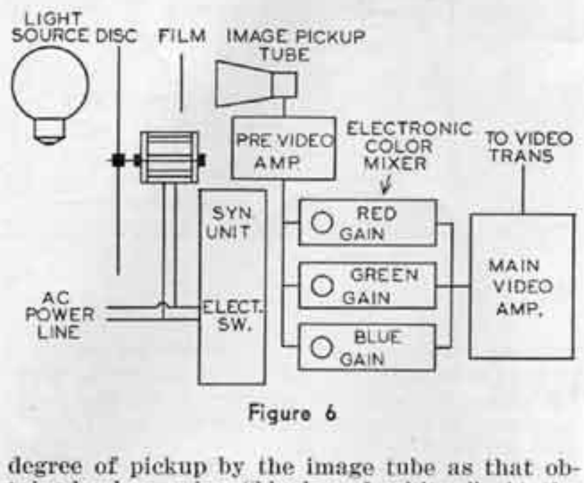



Figure 6

degree of pickup by the image tube as that obtained when using "black and whites." At the receiving end both engineers employed a rotating color filter of exactly the same characteristics as the one used at the transmitter. When using this system the motors rotating the discs must be of the synchronous type to enable filter segments of identical color to pass simultaneously.

When using the motor driven color filter in the home a color correcting switch is required to synchronize the colors or motors. This switch is cut off and on allowing one color segment to slip by when in synchronism, the picture will be properly colored and it will remain in step.

The use of synchronous motors on power lines that are not locked in frequency control would be of very little value. In order to permit the use of revolving discs for this purpose it is understood that a single beam power amplifier tube can be used to control the speed of a motor driven disc to give satisfactory color reproduction.

### Flicker

In order that flicker due to the revolving discs be kept at a minimum Dr. Goldmark constructed a disc having queer shaped color segments. The general shape of the filter is shown in Fig. 7. The aluminum disc used was about 8 inches in diameter and supported the gelatin filters. The special shaped filters are employed to permit the use of non-storage type camera image pickup tubes as the filter must cover at any instant of time that portion of the image tube which is being scanned. The disc rotates at 1200 R.P.M. An 1800 R.P.M. synchronous motor with a reduction gear unit was employed.

### CBS Scanning Method

The scanning method devised by Dr. Goldmark differs somewhat from that used in most black and white systems. The picture is completely scanned every 1/60th of a second instead of every 1/30th of a second. However, at the end of the first 1/60th of a second only 2 colors have been used. The third color requires an additional 1/120th of a second, bringing the total to 1/40th of a second for a single picture in full color. The following sequence may help to make this clear:

The odd number lines are scanned in red in 1/120th of a second. The even number lines are scanned in green in 1/120th of a second. At this point the whole picture has been scanned, but there is yet no blue in the picture. Time thus far: 1/60th of a second.

Now the red on the odd number lines has faded and these same lines are scanned in blue in 1/120th of a second. At this point the whole picture has been scanned one and one-half times, but in full color only once. Time thus far: 1/40th of a second.

Now the green on the even number lines has faded and these same lines are scanned in red in 1/120th of a second. At this point the picture has been scanned twice but in full color only once and a third. Time thus far: 1/30th of a second.

Now the blue on the odd number lines has faded and these same lines are scanned in green in 1/120th of a second. Time thus far: 5/120th of a second.

Now the red on the even number lines has faded and these same lines are scanned in blue in 1/120th of a second. At this point the whole picture has been scanned three times and in full color twice. Elapsed time thus far: 1/20th of a second.

And now the whole progressive cycle begins again with the even number lines being scanned in red.

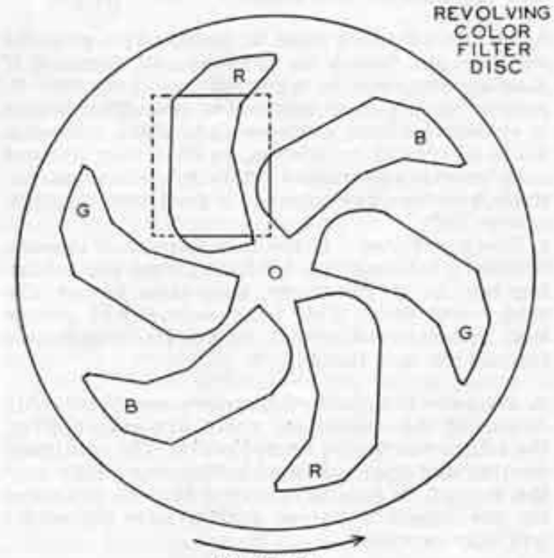



Figure 7

At the receiving end, Columbia employed a disc similar to the one used at the transmitter. The disc was about 20 inches in diameter and driven again by an 1800 R.P.M. with the reducing gear unit to revolve the disc at 1200 R.P.M. A projection type of C.R.O. tube was used to permit brighter than ordinary image production during the first color television demonstrations.

### Closing Comments on Color Television

The recent practical demonstrations of color television have proved again that that which appeared to be a difficult task was worked out using basic fundamentals and based upon those which proceeded. As we progress we use those basic fundamentals in working out our problems. The cleverness of both Dr. Goldmark and Dr. Alexanderson cannot readily be appreciated until

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