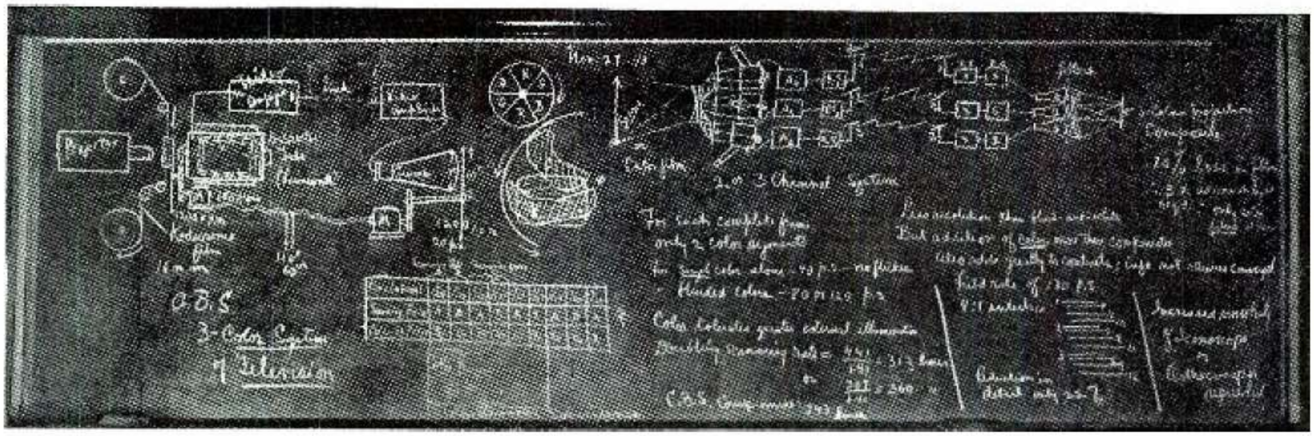

COLOR in Television

by Dr. Lee de Forest

How color television has been made possible; written by a famous inventor.

COLOR television, television in three colors, is a subject that is not only interesting but specially timely. Yesterday television itself was considered an impossibility and now we are clamoring for color, and I suppose before many years we will be clamoring for three-dimensional pictures.

Color television was recently demonstrated by *CBS* in New York but long prior to that it was shown in England by *Baird* who used the mechanical scanning and reproducing systems. But the only systems that have yet been demonstrated use the old device that produced the first motion pictures in color; that is the color disk which was first introduced by *Kinemacolor* away back in 1910. That color was a simple process. In front of the camera was located a two-sector color disk; one sector was a red filter, the other a green, or a combination of orange-red and green-blue was used. The photograph was taken first through one color screen and then through the other. In other words, one frame on the motion picture was taken through the red-orange filter and the next succeeding frame was photographed through the green-blue filter. When this colored film was projected they used a like color wheel in front of the projector so that one frame was projected on the screen through the red sector in the disk and the next was projected through the green sector. The images on the screen in red and green followed each other so rapidly that the impression of true color was registered in the brain of the observer. It wasn't true color reproduction but it was a fair approximation to natural colors. A combination of the right shades of red, green and blue will give very close to real colors such as you would get by using the seven colors of the spectrum. As proof of that, witness the beautiful technicolor pictures we see in theatres nowadays. Those pictures are made through three filters, the magenta red, a certain shade of green and one of blue. When these are properly mixed they give the perfect colors that you see. So Baird a few years ago, using mechanical scanning, employed a three-color disk.

During the recent *CBS* tests, Dr. Goldmark used the Cathode beam scanning at both transmitter and receiver plus many refinements which do him very great credit and which have resulted in very fine colored pictures on the receiving screen. But there are a great many imperfections in his method which make it impractical for commercialization.

As you know, the standard picture in black and white now is 441 lines, 30 frames or 60 fields, 60 scans per second. This is not well suited for three-color transmission, but very recently Dr. Alexanderson of the *General Electric Company* used the above arrangement for two-color transmission. He used the system that I first described as *Kinemacolor* and the reports are that this two-color system gave very good results. However, the history of motion pictures in color shows that there is a distinct advantage, a nearer approach to realism, by the use of three colors over that of two. So I have no doubt, although I have not seen either one of them, that if you put them side by side, the *CBS* three-color, tri-chromatic would be in greater demand than the system used by Alexanderson of *G. E.*

Now, in order to get the three-color picture, Dr. Goldmark had to sacrifice a number of lines in the picture. You cannot get three colors with 441 lines and still stay in the allowed frequency band of six megacycles—four and a half megs for the picture and the rest of the band being used for the sound and to give the necessary separation between the alloted frequency and the next band. Consequently Dr. Goldmark reduced the number of lines in his picture and doubled the scanning rate. Instead of 30 frames per second he used 60 frames or 120 fields per second. You will have to divide the 441 lines by the square root of 2 if you have doubled the number of frames per second. The square root of two is 1.41, and 441 divided by this figure is almost exactly 313 lines.

Now, if instead of 441 lines for black and white he had used the newer system standard of 507 lines, he would have had 360 lines in his color picture. So he compromised on 343 lines and 60 frames, or 120 fields per second. This means a vertical scan of 120 fields per second and a horizontal scan of 20,580 per second. (He has to do that, as I will show you, in order to get each color in front of the picture to be transmitted a sufficient number of times, and to reproduce them at the receiver an equal number of times so as to avoid a color flicker.)

If you had a succession of red, green and blue at the rate of 15 times per second, your eye would notice the color flicker and the effect would not be good. The schedule shown in the photograph will give you a better idea. The first scanning field is down on the odd number of lines—1, 3, 5, 7, 9, etc., while the next field you fill in these gaps on the even lines—2, 4, 6, 8, etc. The fields alternate, as you know, in scanning black and white. First the odd lines of one field and then the even lines of the other field as we go on down. Here each one of those fields is scanned in a 120th part of a second.

The color filters are introduced in front of the picture, between the picture and the pick-up tube, in this

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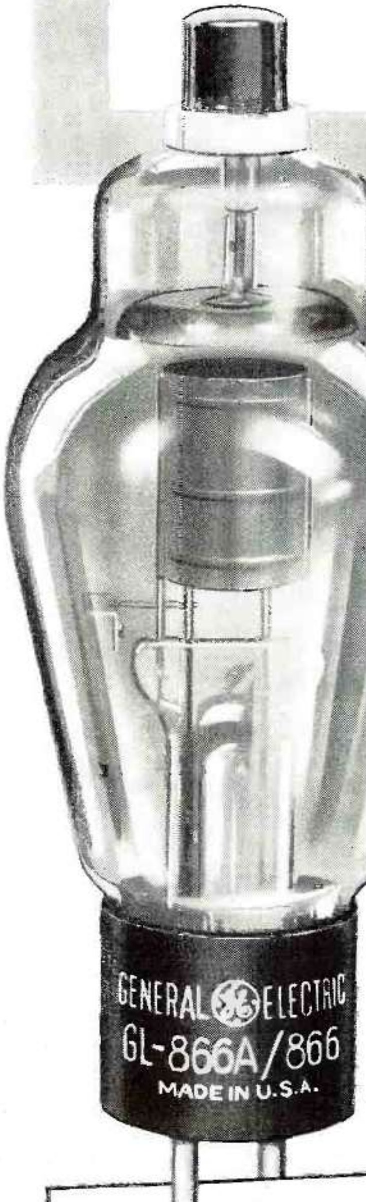
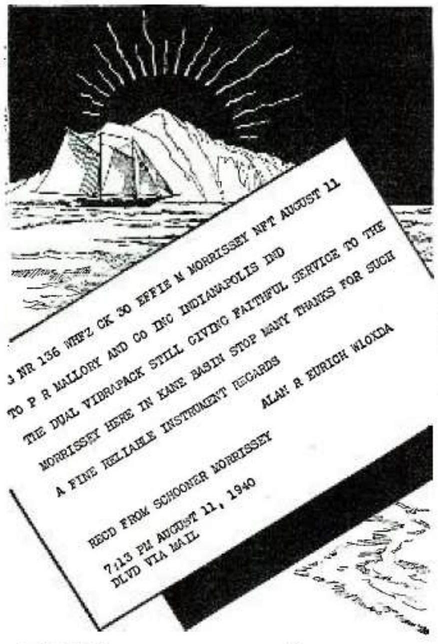
order: red, green blue, red green blue. But you see that the red is in front of the "A" field, green in front of the "B" field. The next time you scan the "A" field, or the odd number of lines, you have the blue filter in front of the camera, so the odd number of lines can pick up the blue which is in the picture. The next time on the "B" scan or the "B" field, we have the red screen in front of the picture so that the even number of lines can then pick up the red elements of the picture. You see the odd number of lines pick up the red here; here the even number of lines pick up the red, and the interval between the first red scan and the rest is three times 120 or 1/40th of a second. Every 1/40th of a second that you get a flash of red, the camera sees the picture through a red filter. Correspondingly, every 40th of a second you see the picture through the green, and so on for the blue.

Those flashes of color are introduced so rapidly that when they are reproduced in the same order, the eye is unable to distinguish the different flashes. They blend together on the retina of the eye and you get the effect of real color blending in the picture. Incidentally, Dr. Goldmark has so far used only colored film at his transmitter. He is not yet able to pick up outside scenes in natural color. This is so primarily for lack of light. A *kodachrome* 16 mm picture film passes down continuously, not step by step, between the continuous projector and a dissector tube, or pick-up. It uses a very bright light so as to get intense illumination of the colored picture. The colored light passes from the film through a lens into the *Farnsworth* dissector-tube, which Dr. Goldmark used instead of the iconoscope. But between the film and the pick-up tube is a color disk which is shown in the photograph in cross section. It is pivoted to a shaft carrying a gear which is driven by a smaller gear which, in turn, is driven by an 1,800 RPM motor, thirty revs per sec. This gear reduces the speed to 1,200 revs per sec., so that at any one instant there is a red picture, then a green, then a blue, thrown through the lens onto the photo-electric surface of the dissector-tube.

It is not necessary here to go into the details of the *Farnsworth* dissector-tube. I believe you are somewhat familiar with how it works and how it differs from the iconoscope of *RCA;* the dissector interprets the picture into electrons, one electron impulse after the other, one element of the picture after the other, as the cathode beam is swept up and down over the sensitive electro-emissive surface.

The output of the dissector tube passes into the grid of the video amplifier which is indicated in the box drawing. The last plate of the amplifier leads to the transmission line. This





picture was not transmitted through the air; for the purpose of demonstration this was not necessary. The output of the video amplifier is connected to a Kinescope which was, by the way, not quite an ordinary one. It was built by the *CBS* engineers particularly for this work and employs an unusually high voltage. The secondary anode has 7,000 volts applied to it, the primary anode, 5,000 volts, and there are a few other distinguishing features. He obtained a very bright spot on the fluorescent screen of the kinescope. This is 9 inches in diameter. In front of that is another rotating disk carrying the color sectors arranged in the same order as at the transmitter; red, green and blue, as is shown in the diagram. Only the sectors are not triangular-shaped but of a very irregular shape, as is shown herein.

If this wheel were removed and you looked directly at the screen you would see a black and white picture. And as far as the picture as thrown on the image dissector, it might just as well be a black and white picture because electrons do not distinguish between colors. (It's a matter of indifference to the electrons whether the picture is thrown on here in red, green or blue color.) The purpose of the color screen disk is that only the parts of the picture which transmit red light are thrown through the red filter upon the photo-electric surface at one instant. And when the disk has turned to the next sector, only the light which has passed through the green portion of the color disk enters the pick-up tube and so with the next sector, only the elements of the picture which are blue in the film are transmitted as light.

So we have transmitted over the line, in succession, a series of pictures which might just as well be black and white, and would be black and white, except for the inter-position between the viewer and the screen at this end of a color disk, the colors of which correspond to the colors here at the transmitter. I think you can understand that.

At the receiver we have a larger disk than at the transmitter, the latter being 10 inches in diameter and the receiver disk measuring 20 inches in diameter made necessary, as you can see, that a colored segment covers most of the entire picture at one instant. This color disk is also driven at 1200 r.p.s., geared down by a synchronous motor which carries 6 segments so that there are 120 color segments thrown in front of the tube every second.

The colored sectors are made of colored gelatin, stretched tightly in an aluminum frame which is mounted on a shaft. The sectors are cut in such a manner that when one sector is just entering the picture field its lower edge is parallel to the frame of the picture. The line scan, as you know, begins at the top of the picture and as the scan goes down further and further to the bottom this color sector just precedes the scan, so that the lines which have just been scanned, say over one half of the picture, are observed through the green sector and then when the next segment comes in, say blue, the blue portions of the picture will be seen, etc. The eye retains for a short interval the image of those blue lines, even though the sector itself has passed on beyond the portion which had been scanned. It is only necessary that these color sectors be always in front of the part of the picture which is being scanned, and the region of the picture immediately behind the scanning line. This disk is 20 inches in diameter, as I have said, because it has to cover this comparatively small kinescope of 9 inches diameter. The tube is not large and the picture on it is pretty small, so you can easily see the difficulties attendant on trying to use this system with a really large kinescope.

Take, for example, the 14-inch Dumont tube. This disk would then have to be at least 16 inches, nearly three feet in diameter. It would take a husky motor to turn that disk at 20 r.p.s. This is one of the fundamental drawbacks of this whole scene of color television.

At the transmitter this is not so serious as you are working from a small picture film, either 16 or 35 mm, and we don't care how much machinery or noise it makes at the transmitter so long as the noise is not picked up by the microphones. Or we can do as they do in motion picture studios; use a "blimp" and suppress the noise. But in a home it is a different proposition because at the present time it would require a large disc and a good-sized motor.

In these demonstrations the motor, the gear and the rush of the wind from this large disk revolving 20 times per second created quite a considerable noise. This was a distinct drawback, although the engineers present did not mind this because the wonder of getting a television picture in color. But that is one feature that must be reckoned with and must be overcome before color television can be a popular success.

Incidentally, it is essential that both transmitter and receiver color disks are synchronized. The two motors in the above photograph are connected to the same 60-cycle main and, of course, synchronization was very easy. But if, as in some cities, there are two different types of current used, it would be necessary to first transmit a synchronizing signal and bring in that synchronizing system at the receiver, amplify it and cause it to control the receiver motor. It is necessary that when a green sector is before the transmitter tube, the green sector be in front of the picture tube otherwise it would be impossible to get the correct color effects at all. The two disks must rotate in perfect synchronism and the colors in the two disks must correspond exactly.

Also, in getting the television color picture, you are sacrificing detail. You reduce the number of lines from 441 to 343. But you are more than making up for it in the contrast that you get by color which you cannot get in black and white. There is less resolution than in black and white but the addition of color more than compensates. Color also adds to contrast and gives information not otherwise conveyed except by color.

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Dr. Goldmark has gone further and made another line of experiments in which he has increased the field rate from 120 per second to 180 per second. This means, of course, everything must go faster; the disk at both ends must travel correspondingly faster, 180 sectors per second instead of 120. When he has that arrangement he uses a four-to-one interlace. By doing this he gets away even more from the flicker tendency than you do with the two-to-one standard interlace. And you find that the reduction in detail, when using 343 lines, is only 22% compared with the 441-line detail. So he gains very much in detail and still has his three colors, and still stays within the 4.5 megacycle frequency band.

But as against all those advantages are these disadvantages. The light used on the picture must be much greater. You can easily see that when the red sector is in front of the picture you are rejecting all your blues and all the greens. That represents so much light that doesn't get into the pick-up at all. So that if, in a certain picture, there was an equal amount of red, green and blue detail, you can see how, for any one picture you are only getting one-third of the total amount of light. And that means that you will get a correspondingly reduced amount of volume control of the cathode beam at the transmitter. Also you would get only one-third of the amount of contrast on the fluorescent screen at the receiver which would mean one-third of the translated visible light. In addition, that light has to pass through a colored filter which also absorbs it. The result is that we lose about 70% of the light that a black and white picture presents between the pick-up and the viewing screen. To make up for this great loss of light to a certain extent, high voltages are used on the kinescope so that a bright picture is seen on the screen.

Now in order to get live scene pick-ups instead of depending on films, the engineers must greatly increase the sensitivity of the pick-up device. And for that reason Dr. Goldmark proposes to abandon the *Farnsworth* Dissector Tube and go to the most refined form of the iconoscope, the Orthocron, the supersensitive iconoscope which has recently been developed by the *RCA* engineers. That would go a far way toward enabling color television to pick up live scenes.

There are any number of colored television schemes that have been proposed; a large number of patents have been taken out on various ingenious arrangements. Some of them are ridiculous and others offer considerable promise. One of these has shown this serious disadvantage—it is a three-channel system and the *FCC* so far has not licensed any transmission experimentation with this system. It would require practically three times six megacycles. In other words, where they allot seven channels in the city of Los Angeles, they would have to give three of these to one station for television in color. Of course, they are not ready to do that, although when they get to the G group of channels where the frequencies are of the order of 150 to 200 megacycles they might consent to consolidate three of those together for this purpose. Then we can look forward to a considerable improvement in color television.

Of course, if expense is taken into consideration, this last scheme is much more expensive than the *CBS* system. It will require three different iconoscopes, one for each of the colors, red, blue and green, a video amplifier for each iconoscope and each one is connected in turn to its own radio frequency transmitter. There must be three distinct channels through the ether, each using a different frequency. These three messages go through the ether and are picked up at the receiver by three independent antennae which can be fastened to the same mounting. There the three signals are led to its own radio frequency amplifiers—to the output of each is connected a kinescope. And by a very simple arrangement of prisms and lenses we can superimpose those three fragmentary pictures on a common translucent screen.

Thus we have the three color projected composite. There is nothing moving but the cathode beams which gets us away at once from the nuisance of the colored discs and the necessity of synchronizing those discs. Also larger tubes can be used. But you can see that the cost of the receiver is here multiplied almost three times.

These systems are not the last word by any means. I don't venture to say what will be the final solution, but you can be sure that we are going to have color television before a great many years. I believe that the solution is going to lie along the line of synchronizing the color screen of transmitter and receiver, but in some other way than the whirling disc which must be more than twice the diameter of the cathode ray tube. If we have a very small projection tube, say three inches in diameter, and a very brilliant picture, bright enough so you can project it through the lense onto a screen in the room, then it would be very simple to have a little color disc like that here described, driven by a little motor of fractional horsepower, all inside of a cabinet which is lined with sealotex or felt so there is practically no noise emerging from it. When we get this projection tube it will solve a great many difficulties that now look serious. That is the line that I would like to see television engineers concentrate on more than anything else—to get a good projection tube with reasonable voltage. We might use 5, 7 or even 10,000 volts, although the last is problematic. Seven thousand volts, yes. And I believe projection tubes can be built (we don't know how at the present time) that will give you a very bright picture on, say, 7,000 anode volts. The quicker this is discovered, the quicker we will have large screen television picture projection.

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What's New in Radio

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