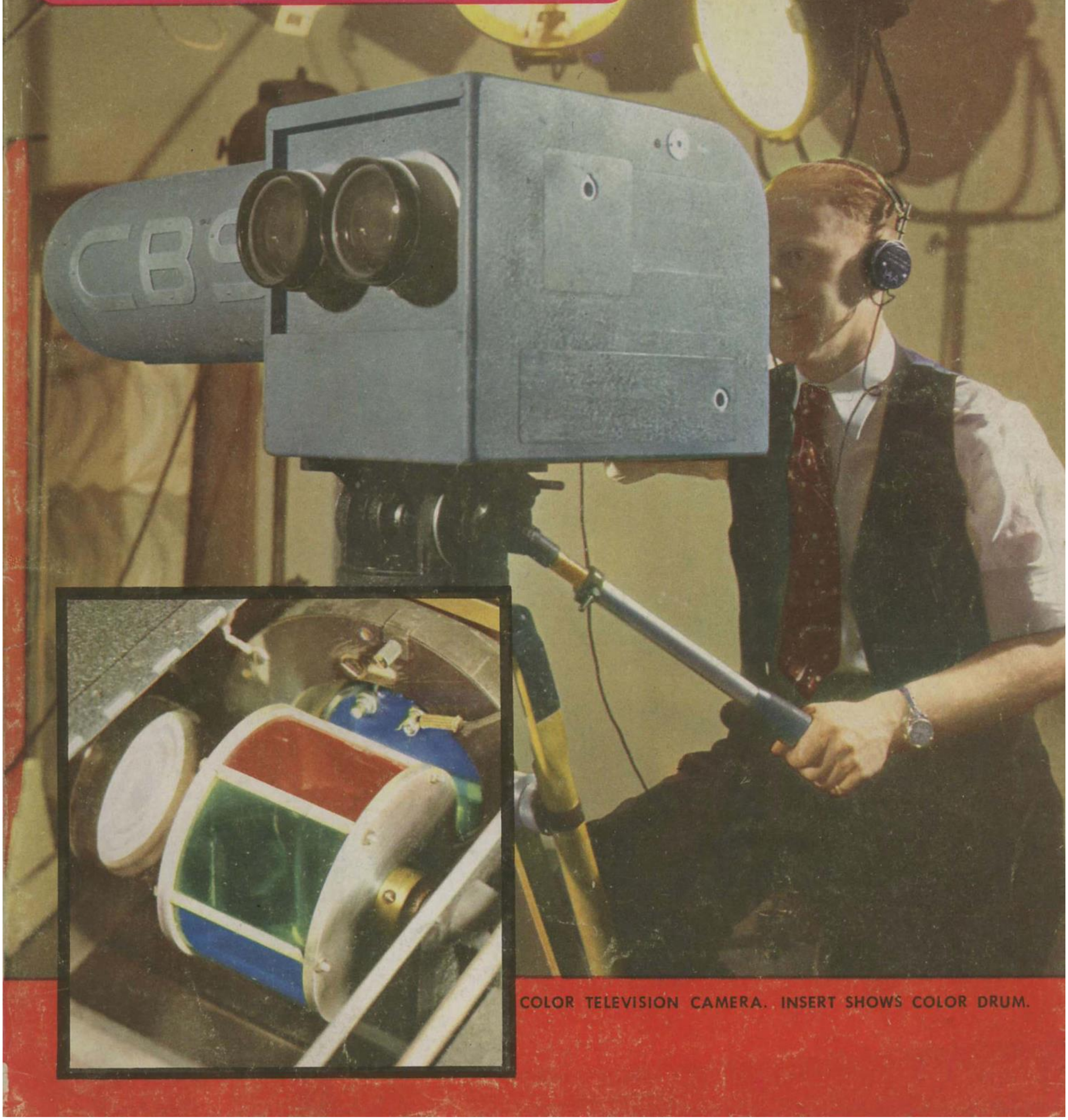
RADIO NEWS

RADIO-ELECTRONIC ENGINEERING EDITION

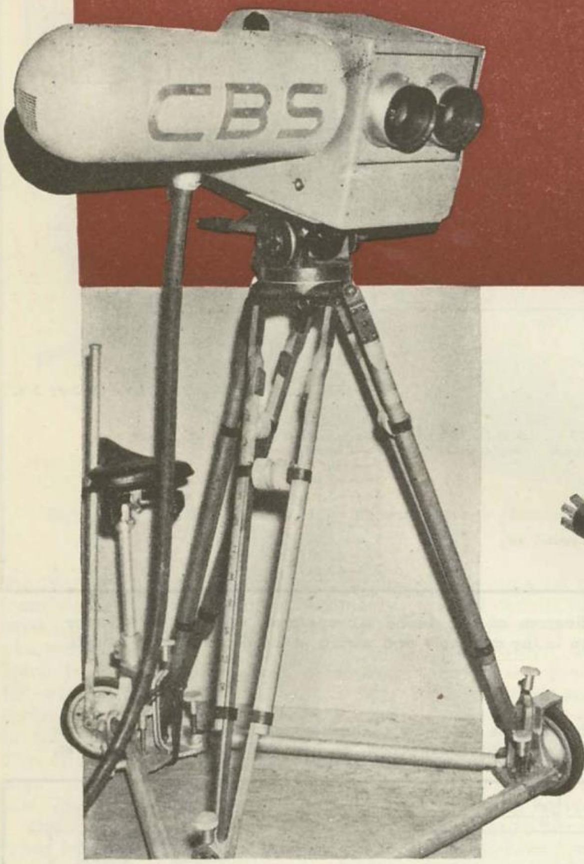
JULY 1945

35c

18



COLOR TELEVISION CAMERA. INSERT SHOWS COLOR DRUM.



COLOR TELEVISION

By ROBERT W. EHRLICH

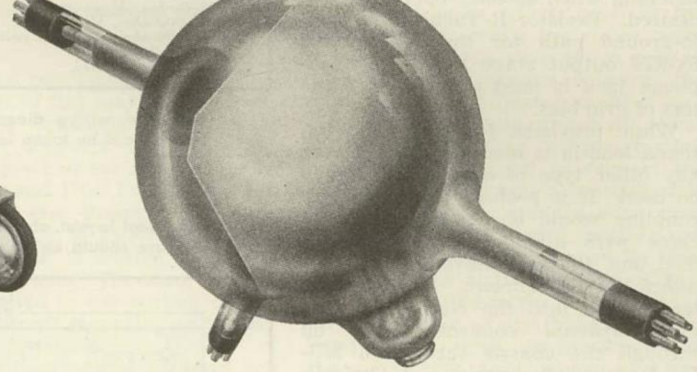


Fig. 1. Color camera developed by CBS with orthicon pick-up. One of the lenses is used for pick-up, the other for view finding.

Fig. 2. Artist's conception of proposed John L. Baird multi-beam three color television tube. Beams from the three electron guns are focused on the screen which is coated with colored phosphors, producing three colors in the final image.

AS WORLD events move closer to the point where the radio industry can once again operate on a peacetime basis, the thoughts of designers, experimenters, producers, and advertisers turn toward television and its future. One feature that is expected eventually to be a part of television is the use of color. The purpose of the following article is to discuss the principles by which color television can be obtained, the problems involved in doing so, and finally what may be expected of color television in the future.

Color television is by no means new. As far back as 1928 it was demonstrated by Mr. J. L. Baird in England. Ten years later, an 8 by 12 foot color picture was shown before an audience of 3000 people at the Dominion Theatre, in London. In these early demonstrations, mechanical scanning was used, with its attendant limitations. With the advent of modern cathode ray tubes and circuits, it has been possible for experimenters in both England and the United States to develop practical color television systems. Before going into the details of some of these modern systems, a discussion of the principles of color reproduction is presented to give the reader a better idea of the problems in transmitting and reproducing a color picture.

All light which the eye can see consists of electromagnetic radiations, just like radio waves, whose wavelengths fall in the region between .00004 centimeters and .00007 centimeters. A more convenient unit of length for such small wavelengths is the angstrom unit, which is 10^{-8} cm. In terms of angstrom units, visible light ranges from about 4000 Å to about 7000 Å.

The wavelength of light determines its color. Long wavelengths, around 7000 Å produce the sensation of red; while successively shorter wavelengths of light appear orange, yellow, green, blue, and finally violet. These are the colors of the spectrum, and their relation is illustrated in Fig. 14. When all of these wavelengths are present with equal intensity, the result is white light; when there is no light, the sensation of black is produced.

When white light falls on a surface, some wavelengths are absorbed and others are reflected with varying intensities. The predominant wavelengths in the reflected light determine the basic color that the surface seems to have, while the relative intensities of various other wavelengths determine the exact shade. Figures 9A through 9F show the reflection characteristics for some typical colors. The job of any color reproducing system is to produce at each point on a viewing surface the same wavelengths of light that were present at the corresponding point on the original image.

The operation of a color system is based on the fact that it is possible to break up the entire color spectrum into a number of narrow band components. In the pick-up device, the color image is viewed in terms of each separate component, and a series of individual images is produced. The several images are then reproduced by conventional black and white processes. Finally, each image is colored to correspond with the band of wavelengths it represents, and all the

Resumé of what has been done in color television, emphasizing the problems involved and what the future holds.

images are recombined once again to produce the color picture.

In order to reproduce perfectly any possible color, it would be necessary to break the color spectrum into a great number of narrow bands. In practice, however, it is found that a system which utilizes only three relatively wide color bands can reproduce colors accurately enough for the average observer. Even a two-color system will work, but a picture based on just two primary colors is not as satisfactory as a three-color picture, whereas a four-color system would not give sufficient picture improvement to warrant the extra effort involved. For these reasons, present day color systems, including color photography and color television, are usually based on three colors.

The mechanism which breaks up a color image into three primary colors is a series of color filters. A color filter is simply a piece of colored glass or gelatin which transmits a definite band of wavelengths. Transmission characteristics of three color filters used in a typical television system are shown in Fig. 10. When viewed against white light, the filters appear blue, green and red, respectively. For convenience, they will be designated by those names in the succeeding discussion.

The action of a three-color system is represented schematically in Fig. 7. There, an idealized picture is to be reproduced consisting of a red spot, a green ring, a blue background, and a white border. The red filter passes only red light, so its image is a spot surrounded by a rectangular border. Similarly, the green image is a ring surrounded by a rectangular border, and the blue image is a rectangle with a hole in it. The rectangular border appears in all three images because it is white and contains all colors. The three images are reproduced in black and white at the receiving end, where each is viewed through its corresponding filter. They add together on the viewing screen to produce a color image.

The most important single problem in televising a color picture arises from the fact that three images must be transmitted for each image in an equivalent black and white system. The three images might be transmitted simultaneously on three different car-

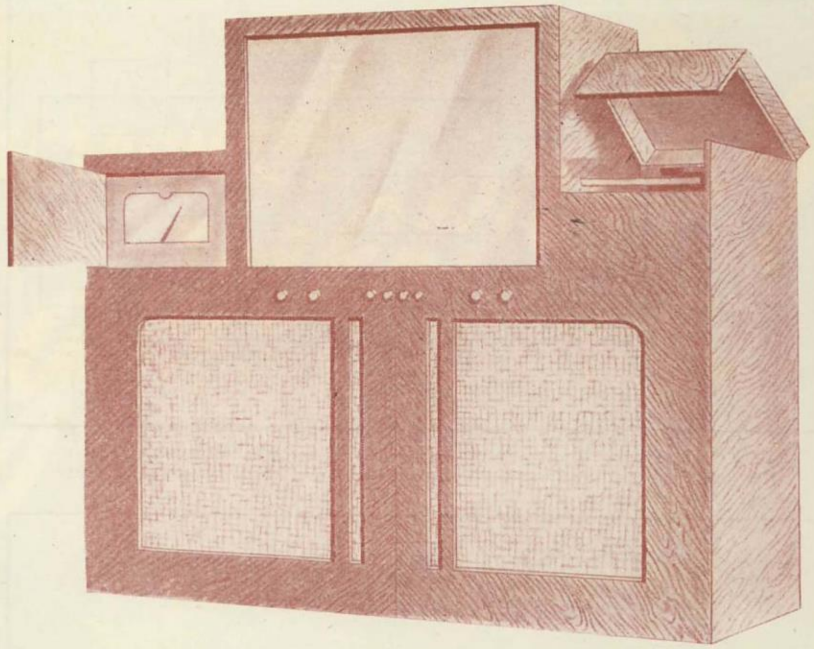


Fig. 3. Projection receiver, 24" x 30", demonstrated by Baird in 1940. Television controls, center; all-wave receiver, left; and phonograph pick-up shown on right.

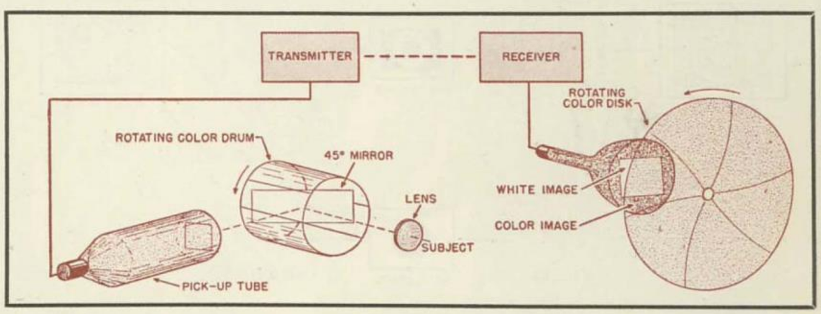
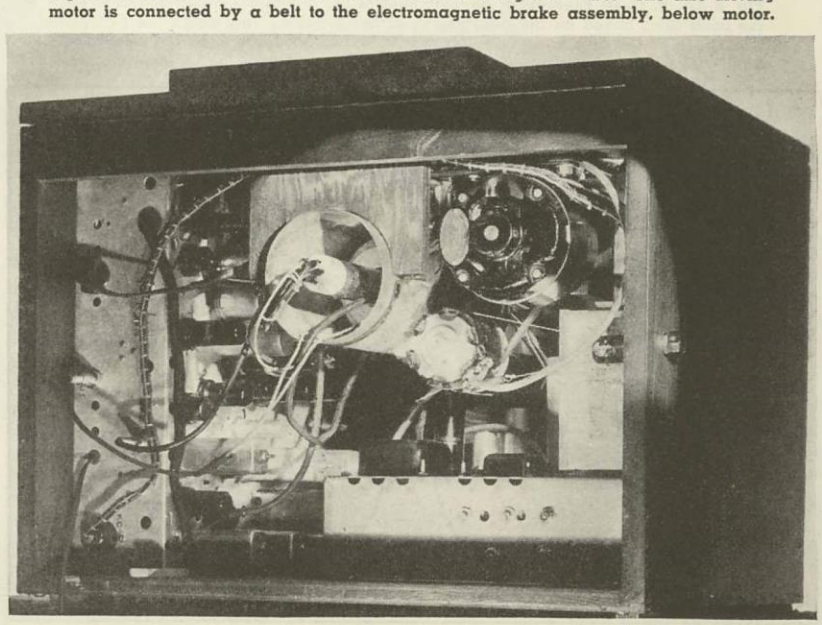


Fig. 4. Fundamental elements of the CBS color television system. The rotating color drum and synchronized color disc each contains two sets of three-color filters.

Fig. 5. Rear view of a CBS table model receiver using a 7" tube. The disc driving motor is connected by a belt to the electromagnetic brake assembly, below motor.



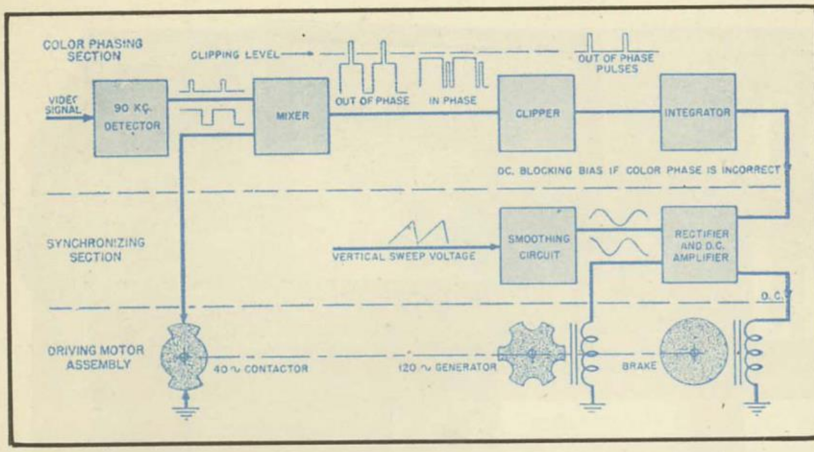


Fig. 6. Diagram of disc synchronizing circuit used by CBS. All functions shown are accomplished by three multi-element tubes and their associated circuits.

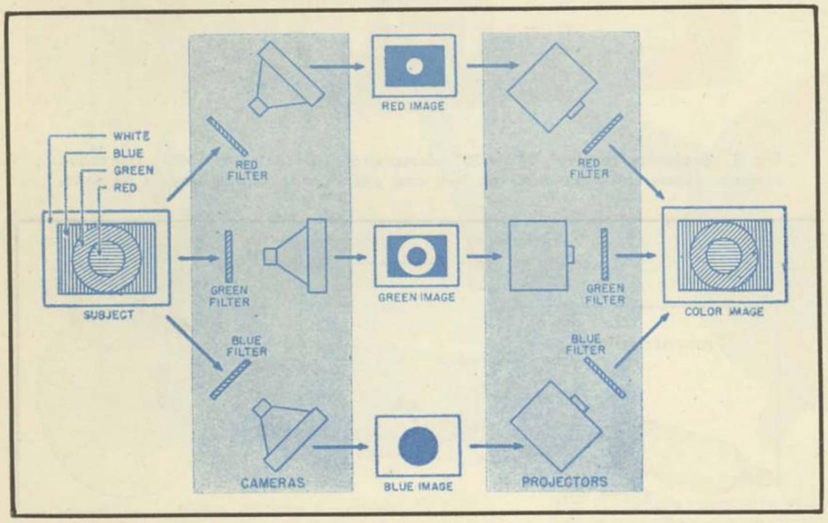
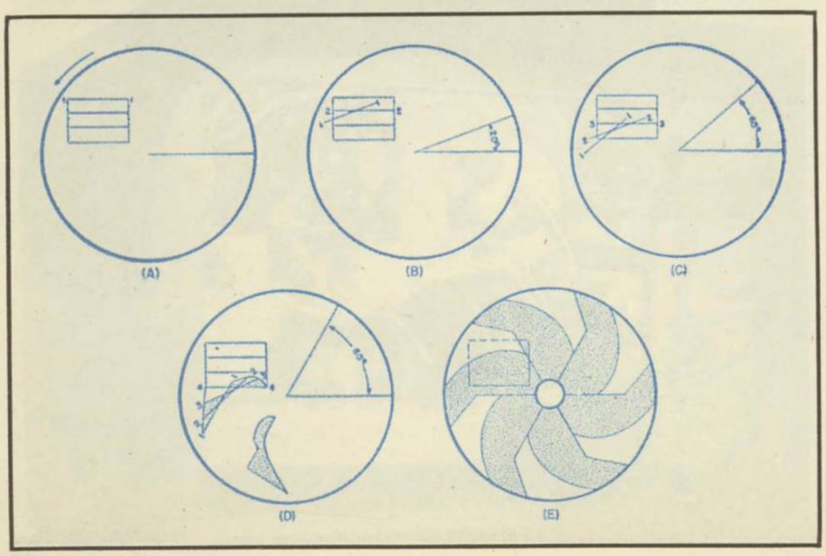


Fig. 7. Diagrammatic representation of the action of a three-color reproduction system.

Fig. 8. (A, B, C, D) Theoretical development of the shape of a filter segment for the color disc, based on the progression of the scanning spot down the picture. The speed of the disc is adjusted so that it rotates 60 degrees during one color field. (E) demonstrates pictorially the actual shape of the filter segments used.



riers, in which case the color station would occupy a band of radio frequencies just three times as wide as the conventional television channel; e.g., 18 megacycles. On the other hand, the three images might be transmitted in rapid succession on the same carrier, relying on persistence of vision to mix the colors at the receiver. With picture information coming through the video channel at three times the rate required for a black and white picture, the video channel band width must be three times as great. Assuming the same standards of scanning as are used now for black and white picture transmission, the video signal would contain frequencies up to three times 4.5 megacycles, or 13.5 megacycles, requiring a radio frequency channel about 15 to 17 megacycles wide. Whether the three images are transmitted successively or simultaneously, it is inevitable that the color picture signal will occupy a radio frequency channel width about 2½ or 3 times greater than that employed by an equivalent black and white picture signal.

Simultaneous transmission of the three images on three separate channels has some advantages in that it involves a minimum of technical transmission problems, since each image can be transmitted in exactly the same way as a black and white picture, and no additional flicker is introduced. However, the necessity of a threefold multiplication of r.f., i.f., and video circuits at the receiver constitutes a serious drawback. With the further development of wide-band amplifiers to handle a band width up to 10 or 15 megacycles, it will be possible to use the successive method of transmission to convey high definition color pictures over a single channel. Therefore, the greater amount of attention at the present time is being devoted to successive systems and methods.

The color system which has received the most attention in the United States is that developed by the *Columbia Broadcasting System,* under the supervision of Dr. P. C. Goldmark. Experimentation has proceeded to a point where complete receivers have been built, suitable for use in homes; and experimental broadcasts have been successfully carried out. It is accordingly of value to discuss some of the features of its operation.

Separation of the three colors in the camera is obtained by use of a rotating color drum, as diagrammed in Fig. 4. This drum contains red, blue, and green color filters, and its speed of rotation is so governed that each successive field is scanned in terms of a different color. At the receiver, the images are produced in rapid succession on a white-screen cathode ray tube; and a color wheel, rotating in synchronism with the camera's color drum, places the proper filter in front of each image. Persistence of vision combines the three images into a color picture.

(*Continued on page* 130)

Color Television

(*Continued from page 34*)

The introduction of the three color cycle into a television system requires that some new scanning periods be defined. A "color field" is defined as the interval during which a single primary color is being scanned, normally one cycle of the vertical sweep oscillator. A "frame" retains its conventional definition as the period required to scan every line on the screen, regardless of color. A "color frame" includes the scanning of all three primary colors, and is normally three color fields. A "color picture" embraces the entire cycle of operations and may include several color frames, depending on the interlace ratio.

In order to develop the most practical system and still conform to the limitations of a six megacycle channel, a number of possible combinations of line, color field, frame, color frame, and color picture frequencies was tried, as shown in Table 1. These combinations were judged in terms of definition, flicker characteristics, and color breakup fringes that would appear around rapidly moving objects. System number three was selected as the best combination.

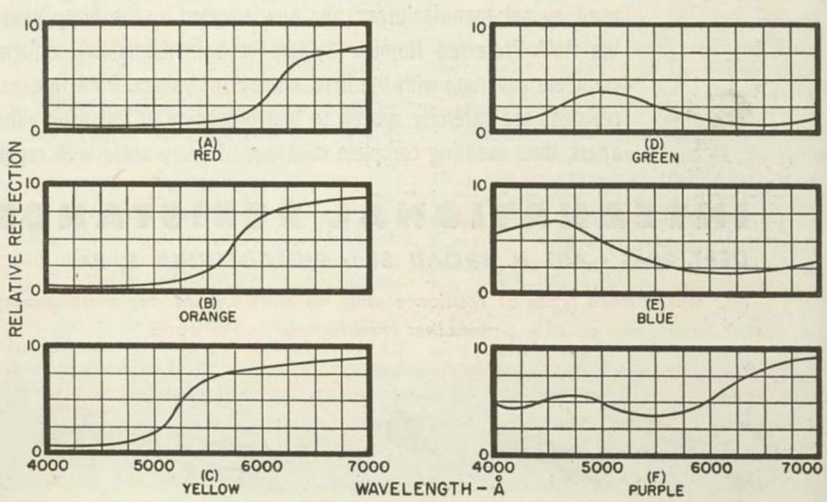
The difference between 525 lines in black and white pictures and 375 lines in system number three represents the sacrifice in definition that is made to add the color. A further sacrifice is made in flicker quality, since only 20 complete pictures are transmitted per second as against 30 in black and white system. Fortunately, the loss of definition is made up to some extent by the presence of color, which seems to add sharpness and brilliance to the picture. At best, however, color system number three represents a concession made to the limitations of available channels. In the future it is expected that wideband amplifiers will be developed further and that frequency allotments in the u.h.f. region will be made to enable a high definition color picture to be transmitted.

The color camera used by CBS is illustrated in Fig. 1. The bulge on the right of the camera houses a sensitive orthicon tube and preamplifiers, while the central part contains the view finder, optical system, synchronous motor, and rotating color drum. This drum has six segments and is driven at 1200 rpm.

The color camera is found to be several times less sensitive than a black and white camera using the same pick-up tube. A considerable loss of light takes place in the color filters, since each filter could theoretically transmit only one-third of the light from a white object, and, in practical cases, transmits even less. The results of this lost sensitivity are that high levels of studio illumination (around 200 foot-candles) must be used, making it difficult for actors to perform without discomfort; that outdoor subjects not in the sunlight are eliminated as program material; and that focusing problems are complicated by wide lens openings. Before the CBS color system can transmit the wide range of program material presently available to black and white television, a pick-up tube more sensitive than the orthicon will have to be developed.

Most of the CBS color studio equipment, such as synchronization signal generators and scanning generators, is similar to conventional television equipment, but at the control panel there is a unit called a color mixer which is special to color work. In this unit, the camera signal is fed into three identical amplifiers, designated as the red, green, and blue channels. A special keying circuit allows each amplifier to operate only during the time its corresponding color field is being transmitted. An independent gain control is thus available for each color. The outputs of the three amplifiers are mixed, and the result is a balanced video signal.

Fig. 9. Spectral reflection characteristics for some typical colored surfaces.



The operator at the color mixer panel has before him a complete color picture, and he adjusts the balance of the three colors so that the white portions of the picture are as nearly as possible true white. During periods of experimentation, it was found that after a few hours the operator's judgment of what constitutes true white becomes faulty. His situation is similar to that of a person who works for long periods under artificial light and then is surprised to find how blue the daylight is. To correct errors of color judgment, a small panel, illuminated by a standard white light, is mounted next to the operator's color screen so that he has a continuous reference. Of course, at the will of the director it is possible to unbalance colors to produce any special dramatic effect desired.

Another new item of equipment found in the color studio is a signal generator to produce synchronizing signals for the receiver's color disc. This generator produces a square wave whose fundamental frequency is four times the horizontal scanning frequency, or 90 kilocycles. The 90 kc. signal is keyed into the composite video signal during the latter part of the vertical blanking period just before each red color field. In the receiver, a 90 kc. tuned circuit detects these pulses and uses them to establish the phase of the color disc.

A CBS color receiver is illustrated in Fig. 11. With the exception of the color disc, driving motor, and disc synchronizing circuits, it is no different from a conventional black and white receiver. The receiver illustrated produces a six by eight inch picture, and its over-all size is comparable to that of a similar prewar black and white receiver.

In the design of the color disc, advantage was taken of the fact that the image is just a moving spot of light. The center of the disc is located just off one corner of the picture, and its radius need only be a few inches greater than the diameter of the image tube, as shown in Fig. 8A. The direction of rotation is such that it follows the progression of the spot from top to bottom of the picture, so each filter segment can be somewhat smaller than screen size. The development of the shape of a theoretical

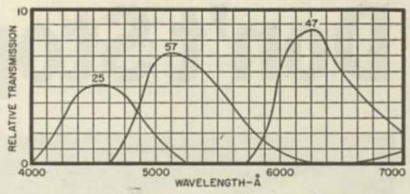


Fig. 10. Spectral transmission characteristics for a typical set of three-color separation filters. These are for Wratten filters, Nos. 47 (red); 57 (green), and 25 (blue) viewed against daylight screen.

filter segment for a 1200 rpm six-segment disc, as shown in Figs. 8A through 8D, is made by plotting the positions at which various lines of the picture image fall on the disc as it is rotated. The filter segments on the actual disc (Fig. 8E) are made much larger than theoretically required in order to allow for phase deviations in the disc and to take advantage of the persistence of the screen.

The driving motor for the color disc is a small 1/20 hp. induction motor whose free-running speed, with the disc connected, is somewhat over the desired 1200 rpm. Control of the disc speed and phase is accomplished by an electromagnetic brake, which is actuated by the receiver's disc synchronizing circuit.

A functional diagram of the disc synchronizing circuit is shown in Fig. 6. Operation of this circuit takes place in two steps, corresponding to the two sections of the diagram. The first section utilizes the color phasing pulses that are sent out as part of the video signal just before each red field, and its purpose is to hold out any further synchronization until the receiver disc drifts close to correct color phase with respect to the transmitter. When the second part of the circuit takes over, it compares the phase of the vertical sweep voltage with that of a 120 cycle voltage generated within the driving motor assembly. The phase relation between these two voltages determines the d.c. current through the electromagnetic brake, thereby locking the color disc into close synchronization with the sweep voltages and hence with the transmitter. The size of the disc segments is such that the disc can deviate up to 4 degrees in either direction without any effect, and the action just described has been found capable of holding the disc within this value over a range of motor voltages from 96 volts to 124 volts.

The lower scanning frequencies used with the CBS system require that some attention be given to problems of flicker and brilliance. The Ferry-Porter law states that the critical flicker frequency, below which flicker is apparent to the eye, increases in proportion to the logarithm of the apparent luminosity, regardless of wavelength. To avoid flicker, then, it is necessary to limit the screen brilliance to a point where no flicker will be observed.

The worst possible flicker conditions exist when a pure green color is being transmitted, because a single color appears on the screen only 40 times per second, and green has the greatest apparent luminosity of the three colors. Calculations based on the Ferry-Porter law show that the limiting brightness for a frequency of 40 cycles is 1.8 foot-candles. That figure represents the greatest brilliance which the green component can be allowed to contribute to the picture. Further calculations based on the relative apparent luminosities of the color show that a white area in which the green component has a brightness of 1.8 foot-candles will have a total brightness of 2.7 foot-candles.

On a conventional white screen, a picture whose highlight brightness was limited to 2.7 foot-candles would not be satisfactory because room illumination washes out the blacks and reduces the tonal range and contrast. In the color receiver, however, the attenuation of light by the color disc helps to make practical the lower value of highlight brightness. Light that comes from the screen is attenuated by a factor of about 7 as it passes through the color disc, but outside light that would tend to wash out the dark areas is attenuated two times, once as it passes through the color disc to the screen, and again as it is reflected and passes outward to the observer. The total attenuation of incident light is then about 49 times. The result is that the color receiver's screen appears black (see Fig. 11) and that a highlight brightness of 2.7 foot-candles gives plenty of apparent brilliance.

Another problem that arises as soon as field frequencies are raised above 60 cycles is one of hum. With the 60 cycle field frequency used in black and white transmission, hum in deflection circuits appears as a static distortion of the image, whereas in the CBS color system number three, any hum pickup results in an objectionable 20 cycle color flicker, pairing of some vertical lines in the image, and loss of interlacing. Accordingly, CBS has undertaken research to determine the best methods to shield against hum pickup from the disc driving motor, power supplies, and other 60 cycle components. Effective shields have been developed, but such shielding will

Table 1. Chart showing combinations of scanning frequencies that were tried by CBS to obtain a color system for transmission in conventional television channels.

	1	2	3	4	5
Color Field Freq.	60	120	120	180	120
Color Frame Freq.	20	40	40	60	40
Frame Freq.	30	120	60	45	30
Color Picture Freq.	10	40	20	15	10
Interlace Ratio	2–1	1–1	2–1	4–1	4–1
Lines	525	260	375	450	525
Horizontal Oscillator Freq.	15,750	31,200	22,500	20,250	15,750
Color Breakup	U	S	S	S	S
Interline Flicker	U	S	S	D	U
Picture Flicker	U	S	S	S	S

S—Satisfactory U—Unsatisfactory D—Doubtful naturally add another increment to the cost of any color receiver.

On the other side of the ocean, Mr. John L. Baird, England's foremost television pioneer, has been responsible for many unique contributions to the science of color television. Although he was the first to demonstrate the use of rotating color discs for color separation, most of his recent experiments have been made with a view toward producing a system in which no moving parts are needed at the receiver, the colors being combined by electronic or optical means. In addition, he has devoted some thought to the possibility of adding stereovision, or third dimension, to color images.

The characteristic of stereovision has been a supplementary feature in nearly all of Mr. Baird's more recent systems. In his "anaglyphic" method, used with a two color system, the images representing the two primary colors (orange-red and blue-green) are picked up from two different viewpoints, corresponding to the position of two eyes. At the receiver, both images are flashed in succession on a white screen, and the observer wears glasses that have one orange-red lens and one blue-green lens. One eye sees the orange-red image, and the other sees the blue-green image, and the two images fuse into a three-dimensional color picture. Another stereoscopic system, more adaptable to three-color work, does not require that the observer wear glasses, but it does require him to sit in a certain spot where two images taken from different angles can be focused by an optical system on his two eyes. In view of the inconvenience to the observer, stereovision is not expected to play an important part in the future of color television any more than it did in movies.

In his search for a means to avoid the use of moving parts at the receiver, Mr. Baird has produced several ingenious systems. In one of these (Fig. 12) the several images were produced side by side on a cathode ray tube, and an optical system accomplished the filtering and recombination; however, it was found that the required optical system was too elaborate. On August 16, 1944, Mr. Baird demonstrated a new system which has evoked considerable interest, both here and abroad, because it seems to afford a practical means of color synthesis without the use of moving parts at the receiver. The heart of the new system is a multi beam cathode-ray tube, shown in Fig. 2 and Fig. 13, for two and three color systems.

The viewing screen on the new tube consists of a thin sheet of transparent mica, the two sides of which are coated with colored fluorescent powders as indicated in the diagrams (Figs. 13A and B). The structure of the tube is such that the image might be viewed from both sides, provided a suitable filter were used on one side to compensate for light transmission through the mica. Alternatively, the screen

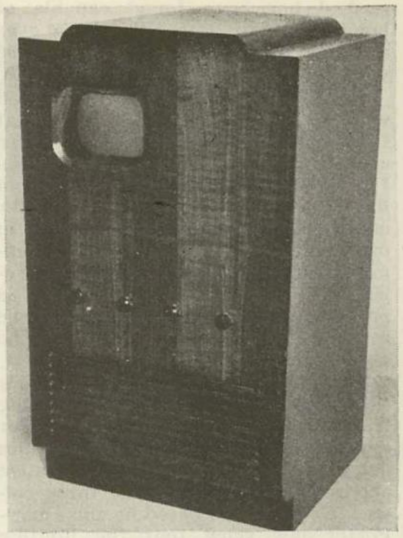


Fig. 11. CBS color receiver, using a 9" tube. Note that the viewing screen appears black due to the presence of the color filters in back of viewing screen.

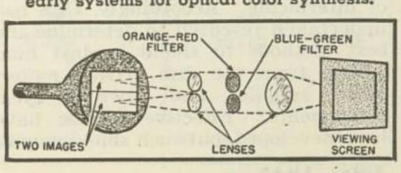
might be arranged for viewing from one side only, in which case a white fluorescent material would be used on the back side and the mica itself colored to filter the light coming through to the front.

The pick-up and transmission methods used in Mr. Baird's recent demonstration exhibit several differences from those used in the CBS system, but most of these differences are matters of experimental convenience rather than differences in principle. A rotating color disc is used for color separation at the transmitter, just as in the CBS system, for as yet Mr. Baird has demonstrated no method for electronic color separation at that point.

One obvious difference is the use of two primary colors rather than three. Most of Mr. Baird's experiments have been carried out with two color systems in order to simplify experimentation and to make use of the anaglyphic method of stereovision. It may be that two color systems will be adopted as standard in England in spite of the inherent color limitation, but it is clear that Mr. Baird has in mind the possible use of three colors since he has proposed a scheme whereby his multi-beam tube could be adopted for three beams (see Fig. 13B).

Another point of difference is the use of the flying spot method of scanning at the transmitter. A scanning raster generated on the face of a high intensity tube is focused by means of a lens on the subject. Photocells grouped nearby pick up the light variations as they are reflected from the subject. This form of scanning simplifies experimentation by eliminating the difficulties involved in the use of a sensitive pick-up tube, but it rigidly limits movements of the subject. In a practical color system, a movable camera would be employed.

Fig. 12. Diagram of one of Baird's early systems for optical color synthesis.



For his demonstrations, Mr. Baird has lately been using 600-line systems, with scanning frequencies based on 50 cycles. The actual frame and field frequencies varied, of course, with the particulars of the system being worked on at the time. The use of a 50 cycle basis for scanning frequencies is an outgrowth of the extensive use of 50 cycle power lines in England, while the use of 600 lines for color transmission reflects the fact that Mr. Baird's laboratory experiments are not limited to postwar bandwidths. A commercial application of the Baird system would be faced with the same channel limitation problems that have faced CBS engineers from the outset of their experiments.

It is clear that the Baird multi-beam tube could readily be adapted for use with American pick-up and transmission equipment. It, therefore, would be of interest to discuss the relative merits of the two methods of color synthesis, the rotating disc and the multi-beam tube, to determine which one will be eventually used in this country. The rotating color disc has some distinct drawbacks, principally noise, vibration, and loss of light through the color filters. These drawbacks can only be minimized by the use of good motor mountings, soundproof cabinets, and high intensity cathode ray tubes.

On the other hand, there are problems in the use of a multi-beam tube, chiefly those of register and keystoning. The three beams must be made to scan the screen in identical fashion, otherwise the color images will be displaced and fringes of color will appear around objects. Keystoning complicates these problems of register because two of the beams must be made to increase their sweep width near the bottom of the picture, while the third must sweep over its greatest angle near the top. This means that different deflection amplifiers are required for the beams, with the result that changes in circuit constants can affect the register. Certainly the necessity for making readjustments of size and position of three images as the set warms up would be undesirable from the standpoint of the operator.

In considering the possible application of any color system, it is necessary to investigate its suitability with projection, since it is expected that most of the larger postwar receivers will employ this mode of presentation. In a paper published by Dr. Goldmark and his associates in September, 1943, it was pointed out that although the color disc and motor could be smaller and quieter with a projection tube, the loss of light in the color filters would seriously limit the available illumination. With a given projection tube, the screen diameter would have to be reduced by a factor of about 2.7 to give the same screen brightness. A Baird multi-beam tube adapted for projection would not suffer from filter loss; with careful attention to the fluorescent powders used, it would deliver about the same amount of light as a black and white tube.

Adaptability to black and white reproduction is another important consideration, since receivers for color should also be capable of receiving black and white pictures. A color disc receiver is particularly suitable for this type of service, for it is essentially a black and white receiver in the first place. To change over, it would be necessary only to change the scanning oscillator frequencies and move the color disc out of the way. While movement of the color disc assembly would be difficult in a table model direct viewing receiver, it would be easier in a roomy console model or in a projection receiver where the disc was small. On the other hand, it would be difficult to provide dual service with the multi-beam tube. To make a black and white picture, all three beams would be operated simultaneously. Problems of register would still be present, and these problems would be further complicated by the fact that color fringes caused by off-register operation would be more objectionable in a black and white picture.

The majority of engineers here in the United States feel that the simplicity and reliability of the color disc method, as demonstrated in the CBS color system, dictate its probable use in future color systems. This reliability was exemplified in Dr. Goldmark's lecture before the A.I.E.E.-I.R.E., in the spring of 1944. He pointed out that during the course of experimentation nearly every resistor and capacitor in the equipment had gone out at least once, while the disc motor and brake continued to operate with no trouble. Problems of filter loss in the color disc will introduce considerable difficulty in developing a projection receiver; however, Mr. Baird himself demonstrated such a receiver on December 20, 1940. Baird's receiver produced a 24 by 30 inch picture using a two-color disc and a 30,000 volt tube. It is to be expected that recent developments in cathode ray tubes, power supplies, and optical systems will make it possible to make a practical projection receiver for home use.

At present Mr. Baird is working on a new electronic color system in which successive lines are scanned in different colors. By making the total number of lines an odd multiple of the number of colors, each line would eventually be scanned by every color. The development of such a system would minimize problems of color flicker and color breakup that are inherent in all present color systems.

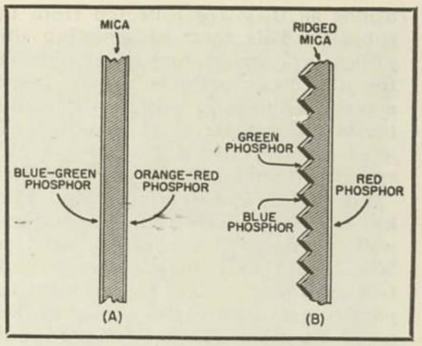


Fig. 13. Magnified cross-section of viewing screen for Baird's multi-beam tube. (A) For two primary colors and two electron beams. (B) For three primary colors and three beams.

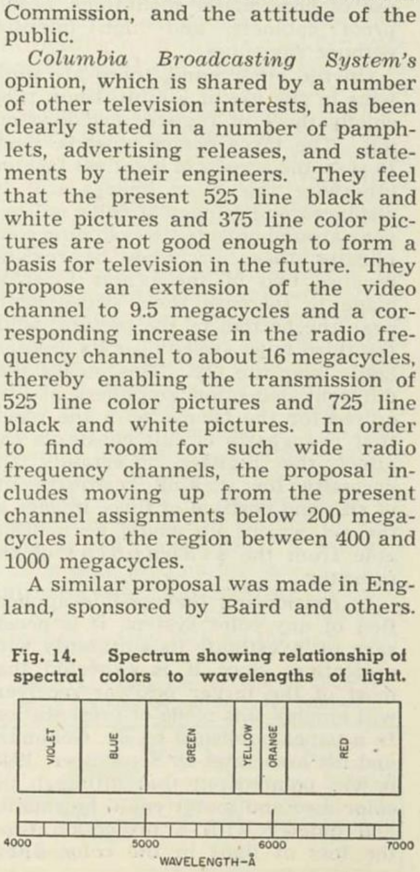
Naturally, a mechanical color disc could not be used because of the extremely rapid change from color to color; both the transmitter and the receiver would have to utilize some form of electronic color separation. If the new system could be developed to compare in simplicity with the color disc method, it would then offer serious competition to the latter. Until that time, American engineers are expected to concentrate on the development of mechanical color separation systems.

The future of color television will depend upon a number of economic as well as technical factors. Some of these economic factors are: The policies of *Columbia Broadcasting System* and other large radio organizations, those of the Federal Communications Commission, and the attitude of the public.

Columbia Broadcasting System's opinion, which is shared by a number of other television interests, has been clearly stated in a number of pamphlets, advertising releases, and statements by their engineers. They feel that the present 525 line black and white pictures and 375 line color pictures are not good enough to form a basis for television in the future. They propose an extension of the video channel to 9.5 megacycles and a corresponding increase in the radio frequency channel to about 16 megacycles, thereby enabling the transmission of 525 line color pictures and 725 line black and white pictures. In order to find room for such wide radio frequency channels, the proposal includes moving up from the present channel assignments below 200 megacycles into the region between 400 and 1000 megacycles.

A similar proposal was made in England, sponsored by Baird and others.

Fig. 14. Spectrum showing relationship of spectral colors to wavelengths of light.



Both here and abroad, these proposals have aroused active controversy. Manufacturers who sold sets before the war have, in many cases, contested them on the grounds that present pictures are good enough, and that set owners would be disgruntled by the sudden obsolescence of their equipment. While present standards might be "good enough" for black and white pictures, there is no question that they would not allow a satisfactory commercial application of color television.

In their recently announced frequency allocations, the Federal Communications Commission gave some encouragement to the new plan. While a series of 6 megacycle channels was assigned in the lower frequencies to enable the industry to continue substantially where it left off at the outset of the war, the region between 480 and 920 megacycles was set aside for television experimentation with no limitations as to band-width. Along with the new allocation came an encouragement to experiment with these new frequencies and the definite indication that a good part if not all of the television industry would eventually have to move to the upper frequencies in order to provide a good competitive basis for future expansion.

Accordingly, the television industry may be expected to undertake serious experimentation on high frequencies as soon as the cessation of war work makes it possible for them to do so. CBS claims that 80 to 90 percent of the experimentation necessary to render high definition color and black and white service on the high frequencies has been completed, and that they, in cooperation with *Federal Radio and Telephone Corporation* and *Zenith Radio Corporation*, could demonstrate the necessary equipment within a year or two after the war. While prewar developments would not indicate such progress, the CBS estimate takes into consideration the accelerated development of high frequency apparatus brought on by the war. Only the future can determine the accuracy of their estimate.

It is clear that, barring some radical changes in policy, the advent of color television will depend on the movement of a good part of the television industry into the upper frequency brackets. Such a transition will involve many enormous problems, such as duplicate transmission on two standards, obsolescence of old sets, and convincing the television listener that he should demand better standards and that his investment in new equipment will not be jeopardized in a few years by a new system. A detailed discussion of these problems is beyond the scope of this article, but the writer feels that it will take several years, even after technical details are perfected, for the various interests in the television industry to iron out their differences and accomplish a smooth and economically practical transfer to standards which will enable the transmission of high quality color pictures.

Based on data presently available, it is possible to form a fairly accurate picture of the television receiver that will be offered to the public once the foregoing problems have been solved. It will be a large console model employing the projection method to produce a picture approximately 18 by 24 inches. It will be capable of receiving 725 line black and white color pictures as well as 525 line color pictures. In addition, it will probably contain provision for receiving conventional radio programs, as well as a phonograph pick-up.

The r.f. frequencies for television will be between 400 and 1000 megacycles. Such frequencies will require highly directive antenna arrays, not only to make up for the loss in sensitivity occasioned by the small size of a single dipole at such frequencies, but also to help avoid troubles due to multipath transmission. So that it will be possible to receive stations from different directions, several arrays will be needed for each installation, or a single array may be used if it is rotatable. The great amount of research performed during this war on the subject of directional antennas and their mass production will make such arrays commercially practicable.

Converter and r.f. circuits will employ concentric line resonators and cavity resonators, and extensive use will be made of special u.h.f. tubes developed during the war, such as the *G.E.* Lighthouse tube. Wide-band i.f. amplification, color synchronization, and special power supplies will require that several more tubes be used compared to present television receiver practice.

Such receivers, with their associated antenna equipment, will certainly not be cheap. It will be necessary to impress upon the customer, as A. D. Sobel pointed out in his recent RADIO NEWS article, that he must not expect television sets to become more inexpensive, but rather that he can expect technical improvements to give him more for his money as time goes on. The owner of a receiver will regard it as an investment, just as he does his automobile. He will place it in a prominent position in his home; and he and his family will enjoy the superlative entertainment of world events and dramatic episodes, brought to their living room in full color.

BIBLIOGRAPHY

1. *Goldmark, P. C., Dyer, J. N., Piore, E. R., Hollywood, J. M. "Color Television" Parts 1 and 2, Proc. of the I.R.E., April, 1942 and September, 1943.*
2. *"Handbook of Colorimetry," Color Measurement Laboratory, M.I.T.*
3. *"Baird High Definition Colour Television," Wireless World, February, 1941.*
4. *"Stereoscopic Colour Television," Wireless World. February, 1942.*
5. *"Colour Television Development," Wireless World, February, 1943.*
6. *'Electronic Colour Television," Electronic Engineering, September, 1944.*
7. *Goldmark P. C., "Summary of A.I.E.E.-I.R.E. Lecture on Color Television" Communications, May, 1944.*
8. *Sobel, A. D. "The Design of Television Receivers, Radio News. March, 1945.*