COLOR TELEVISION

By
H. W. SECOR

PART 1

TELEVISION images in natural colors appeal strongly to the imagination of the radio public. It is not easy for the layman to understand why it is so much more difficult to reproduce pictures in color than in black and white. That difficulty does exist, but several means of surmounting it have been proposed and at least partly developed.

To begin with, stations transmitting color television images require a much wider frequency band than black and white (B & W) images. The present B & W pictures occupy a band only 6 mc wide, while 14.5 mc is necessary for the simultaneous (color) system and 16 mc for the sequential (color) transmissions.

The cost of color television receivers would be about *twice* that of B & W sets, according to engineers' estimates.

One strong point in favor of color television is that the same apparent definition is attainable with a smaller number of lines. For example, with the present 525-line image used in the sequential system (color image) the same apparent definition is obtained as when using 900 lines in a black and white image (as explained in Dr. Peter Goldmark's [CBS] report presented to the Federal Communications Commission).

The two principal methods so far demonstrated for producing color television are RCA's simultaneous system and the CBS sequential method. In the *simultaneous* system all 3 basic colors (red, blue, and green) are transmitted at the same time; in the *sequential* plan the 3 colors are sent one after the other.

The Columbia Broadcasting System's sequential method has been tested experimentally for a period of about three years at a cost of $2,000,000.

This extensively demonstrated system transmits the 3 basic colors (red, blue, and green) one after the other. In picking up a *live* subject before the camera at the transmitter, the scene is brightly illuminated and an orthicon tube scans the scene through a revolving color filter. See Fig. 1-a. The images are progressively transmitted as black and white signals over a carrier of suitable width. Color is finally restored to the reconstructed image at the receiver, by spinning a second color filter in front of the picture tube. The rotating color filters at the transmitter and the receiver must revolve in perfect synchronism; not only must the speed of both discs be identical, but they must be *in phase*. When the red filter is before the image reflected into the orthicon tube at the transmitter, the red filter must be in front of the image at the receiver. Perfect registering of the two color filters is secured by transmitting a synchronizing pulse or signal at regular intervals. This has no effect on the picture.

One 16-mc carrier (see Fig. 2-a) is used to transmit the 3 colors in the sequential system. One color follows another in rapid sequence. In many of the CBS tests the sound was transmitted by injecting FM bursts or pulses on the picture signal carrier, without interfering with the image transmission. (Later tests as reported by Dr. Goldmark, have indicated that it is preferable to transmit the sound on a separate subcarrier. One of the advantages of the separate sound transmission is a greater signal-to-noise ratio under all conditions.)

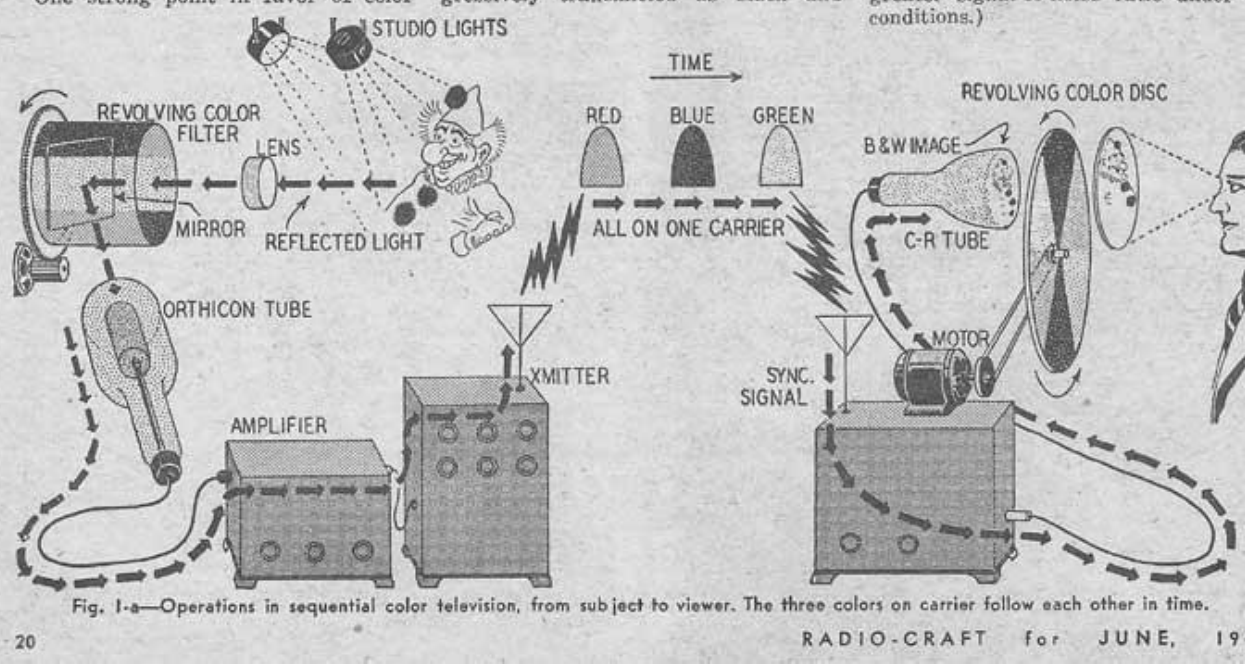

Fig. 1-a—Operations in sequential color television, from subject to viewer. The three colors on carrier follow each other in time.

The sequential system images are transmitted at present with 525 lines and 48 frames per second. The successive color tone images follow one another so rapidly that when they are superimposed on one another at the receiver, they produce a satisfactory color image, similar to that scanned by the camera at the transmitter.

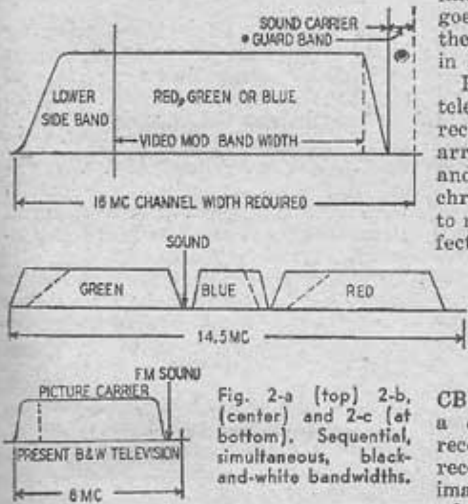

Fig. 2-a (top) 2-b, (center) and 2-c (at bottom). Sequential, simultaneous, black-and-white bandwidths.

The method of scanning the odd and even lines of the image progressively is shown in Fig. 3. At 48 color frames per second, each color scanning will occupy 1/144 second. Six color fields are shown in progressive scanning sequence. First the odd lines are scanned for red (by the red filter) in 1/144 second; next the even lines are scanned for blue. Third, the odd lines are scanned for green. In the fourth color field the even lines are scanned for red, in the fifth the odd lines are scanned for blue, and in the sixth field the even lines are scanned for green.

A complete color picture takes 1/24 second, as the diagram shows. This value was chosen as a happy medium—too low a number of pictures per second introduces an objectionable flicker; too many pictures per second unduly increases the carrier band width required.

Images with 525 lines have been found fairly satisfactory in the tests and demonstrations made by CBS; increase in detail has not been found to be in proportion to increase in the number of lines employed. Besides, as the lineage is increased, carrier band width goes up proportionately, thus reducing the number of stations that can operate in an assigned band.

Photos A and B show the CBS color television receiver; a diagram of the receiver appears in Fig. 4. This set is arranged for *diplex* (combination video and sound) reception. A color synchronizing separator amplifier is used to maintain the color disc motor in perfect step. The balance of the components corresponds to those found in the present black and white receivers.

One of the criticisms of the sequential receiver has been that it could not pick up B & W images by stations now on the air. The CBS report shows a *dual-band* CBS receiver that can receive both color images on the new u.h.f (480-920 mc) band and B & W pictures on the low-frequency (40-220 mc) band, by the addition of *four tubes*. A later circuit for a dual-band receiver submitted by Dr. Goldmark permits the reception of color and B & W images*without the addition of anytubes.* Suitable ganged switches are provided for changing the set for receiving either color or black and white pictures.

It is interesting to note that B & W images can be reproduced on the tube used for color images. *If the color disc is removed, a black and white image is observed on the screen of the cathode-ray tube.*

The size of the color image on the sequential receiver demonstrated by CBS was 7½ x 10 inches, the picture being magnified about 40 percent by a lens placed in front of the revolving color filter. The standard direct-viewing model color receiver (CBS sequential) employs 31 tubes, with a 10-inch picture tube. (The image size is 7½ x 10 inches.) Larger images, measuring 15½ by 21 inches, have been produced by a *projection-type* receiver (see Photo C and Fig. 5) utilizing a Schmidt optical system with a *truncated cone* revolving color filter. A recent model of such a receiver produced color images nearly the same size and used but 34 tubes.

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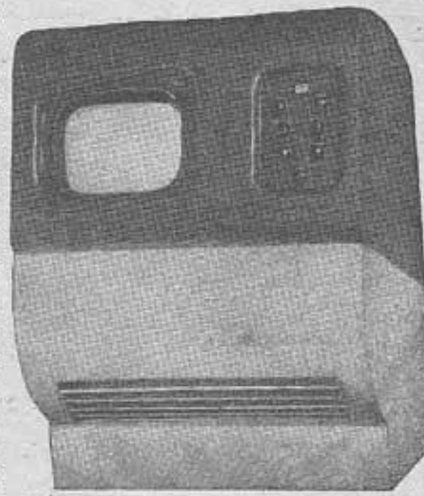

Photo A—Color television receiver by CBS.

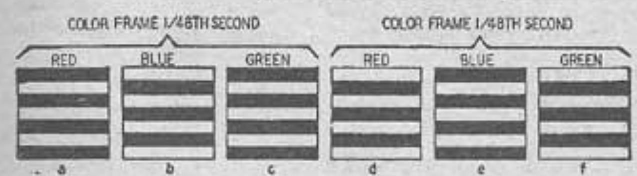

Fig. 3—The color interlacing method used in sequential scanning.

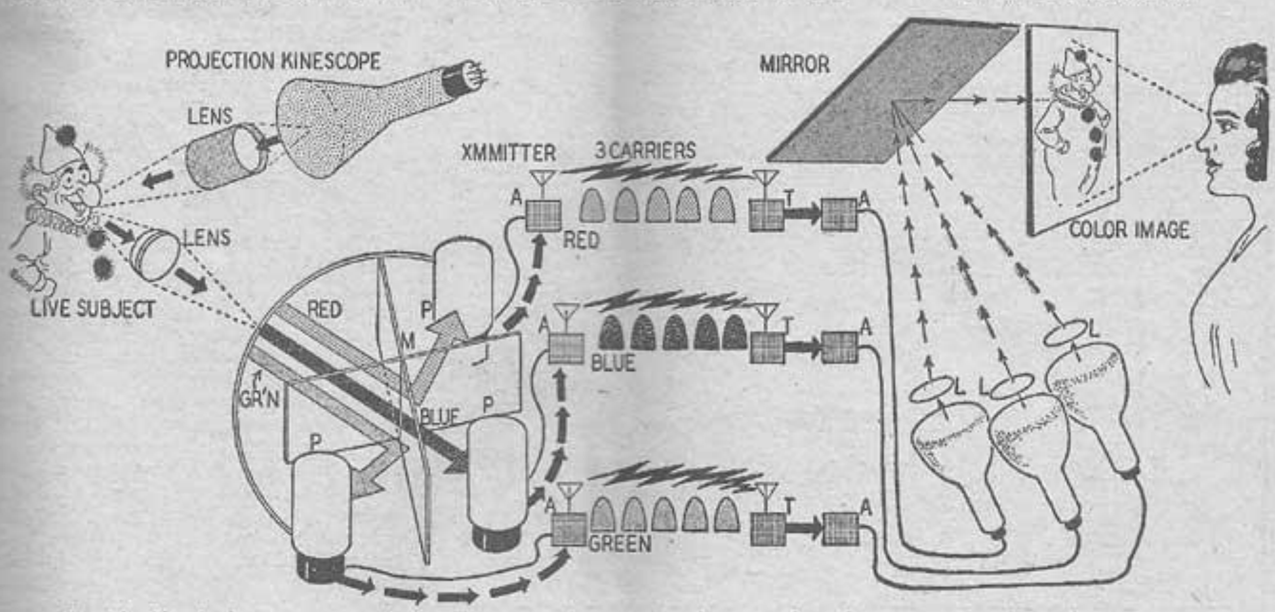

Fig. 1-b—The simultaneous system of color television. Light from the subject is split and transmitted on three adjacent carriers.

(Present-day B & W receivers of the direct-viewing type and using a 10-inch cathode-ray tube employ 30 tubes, thus the sequential color receiver compares favorably in the number of tubes.

A disadvantage of the sequential receiver is that it is not possible to pick up color images broadcast by the *simultaneous* system (without special design of the receiver).

The receiving aerials used to pick up the sequential color images were of simple design; in many tests a double-horn type proved efficient, dipole antennas being placed at the focus of the parabolic horns. The horns were made of latticed wire in some instances.

RCA simultaneous color system

In the simultaneous electronic system demonstrated by RCA the three basic colors (red, blue, and green) are transmitted all at the same time and continuously. No moving parts such as revolving color filters are used, the operation being fully electronic. Fig. 1-b and Fig. 2-b show how 3 separate carriers carry the three colors. The total band width of the 3 carriers is only 14.5 mc. (In a special test this was

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reduced to 12.5 mc.) Sound is transmitted on a relatively narrow band (a subcarrier of 524.1 mc), along with the video signals, as the figure makes clear.

At the transmitter, the film (or *live* subject) is scanned by a beam from a kinescope tube. After scanning the picture or subject, the beam is focused through a lens onto a system of semi-transparent mirrors and 3 photocells (Photo D). Each photocell picks up its respective color component and modulates the corresponding carrier.

For picking up *live* subjects a *flying spot* from a kinescope tube scans the scene, the reflected beam falls on a system of dichroic (color-selective) mirrors, which reflect the respective color components onto 3 photocells. These cells in turn modulate the 3 carriers used to transmit the signals. See diagram Fig. 1-b.

Each of the transmitted red, blue, and green images has the same number (525) of scanning lines and also the same horizontal scanning rate and picture repetition frequency of 30 per second, as in present B & W broadcasting.

At the receiver each carrier, modulated respectively by the red, blue, and green signals, is tuned in through separate band-pass circuits and amplifiers. One tuning control may be used to tune in the video signals. The 3-color signals are next fed into their respective cathode-ray tubes (each about 3 inches in diameter) on the ends of which appear the 3 images: one in red, one in blue, and the third in green. Each tube is made with a different phosphor on the screen which will respond to one color, one tube for the red, one for the blue, etc.

Magnifying lenses are placed in front

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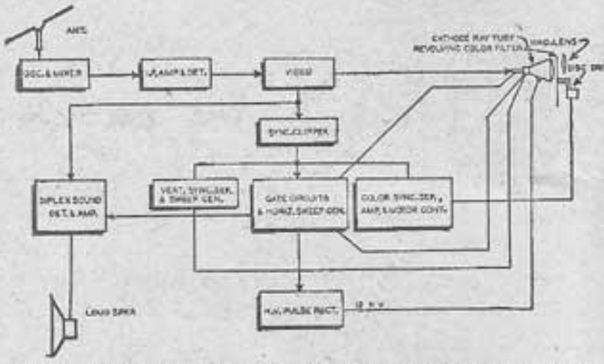

Fig. 4—A block diagram of the CBS color television receiver.

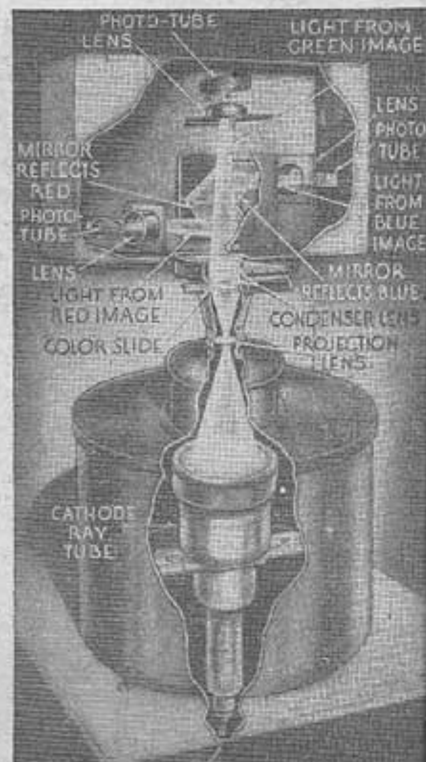

Photo D—Simultaneous system color analyzer.

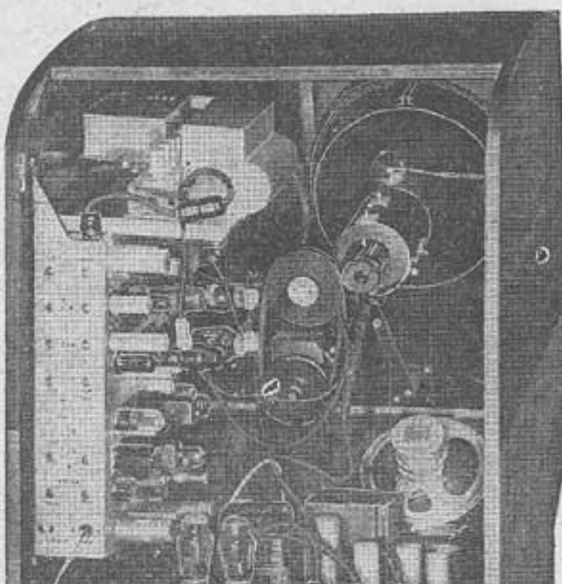

Photo B—CBS television receiver, rear view.

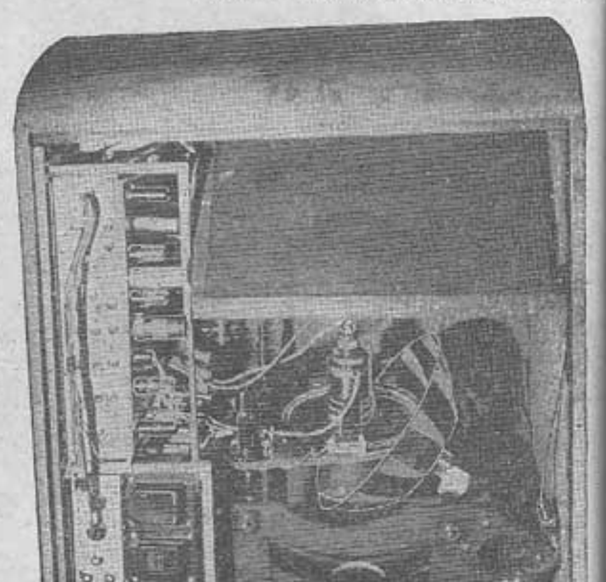

Photo C—The CBS projection color receiver.

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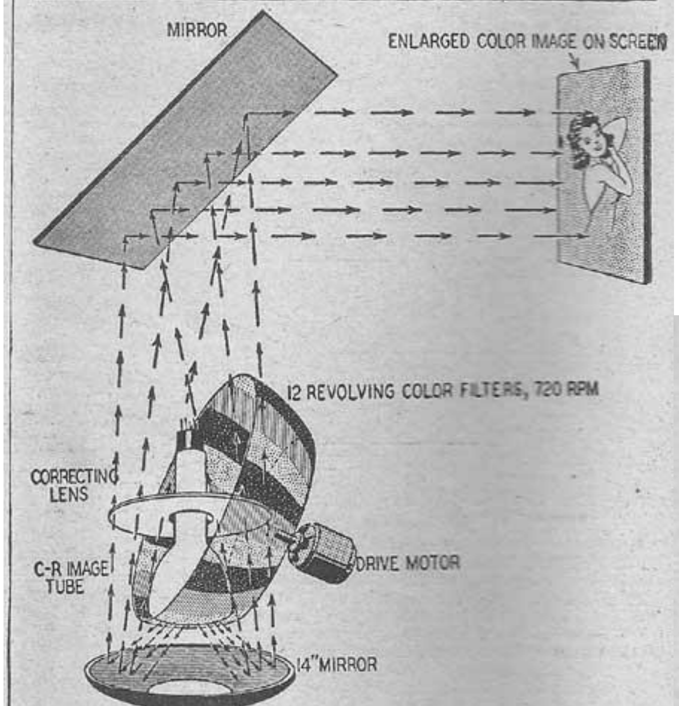

Fig. 5—Sequential color receiver, showing how color is restored.

of each tube, as Fig. 1-b and Photo E show. The 3 color beams are flashed onto a mirror, which reflects and blends them on a translucent screen. The observer sees a single composite color image or picture on the screen, the size of the image being 15 x 20 inches. The receiver is of the *projection* type and is not adapted to direct viewing, at least in its present design. About 45 tubes are used in the receiver; this includes sound.

In the tests conducted at Princeton, N. J., for the FCC, color images were transmitted by *radio* for a distance of about ½ mile, using a frequency of 520 mc.

For comparison it is interesting to note that the RCA console receiver for B & W reception, with a 10-inch tube for direct viewing, has 30 tubes. The B & W *projection* receiver for an image 15 x 20 inches has 45 tubes.

One of the advantages of the simultaneous color system is that a standard *black and white* receiver can be fitted with a nominally priced frequency converter so that B & W images may be picked up from a color broadcast. The converter permits the receiver to pick up the *green* carrier, and as this contains all the essential picture characteristics and the synchronizing signals, a satisfactory B & W picture can be reproduced on the receiver. This prevents obsolescence of B & W television receivers purchased in the past few years. The B & W receiver cannot pick up its images in color, of course. To do that a color receiver must be used. A sequential receiver must be of the *dual* type, fitted with changeover switches, to pick up

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black and white images as well as color pictures.

Simultaneous-type color receivers can pick up and reproduce images broadcast by B & W stations, with the aid of an adapter. The adapter is needed only because the color band is at a higher frequency than is covered by B & W receivers, and would be needed to receive B & W transmissions on those fre-

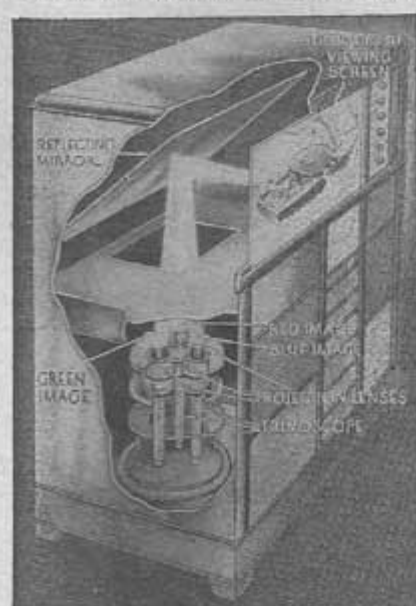


Photo E—A simultaneous television receiver.

quencies. At the present development stage, a mechanical or sequential color receiver cannot pick up a simultaneous image, either in color or as a black and white monochrome.

Among some of the advantages claimed for the *simultaneous* color system are: narrower band width than that required for sequential transmission; greater freedom from flicker; no color fringing and no color breakup; greater fidelity in picture detail and superior picture brightness for comparable size of images; superior flexibility for network broadcasts.

The second part of Mr. Secor's article—to appear in an early issue—will describe three other proposed methods of color television.

COLOR TELEVISION on a 7½-by-10-foot theater screen was shown publicly for the first time in Philadelphia, April 30, by Radio Corporation of America, in a demonstration of its all-electronic color television system at The Franklin Institute. Color motion picture films and slides were projected.

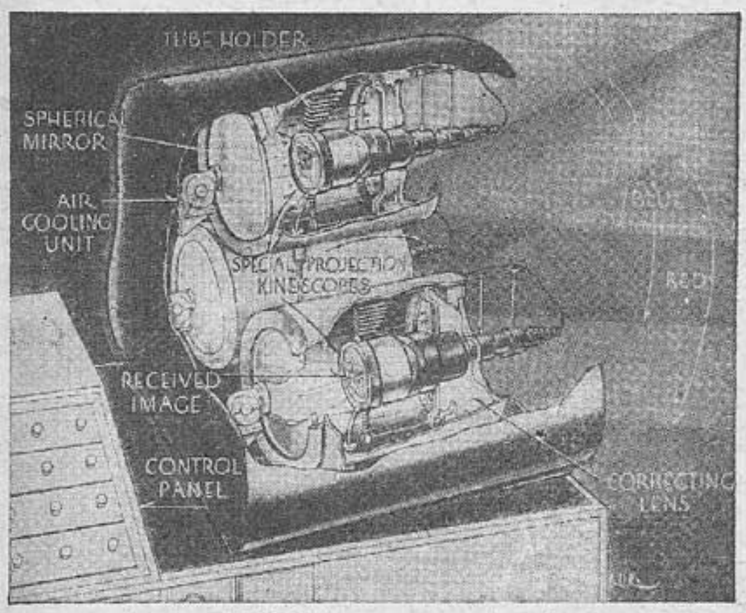
Dr. V. K. Zworykin, Vice-President and Technical Consultant of the RCA Laboratories Division, who demonstrated the new system to illustrate his address: "All-Electronic Color Television" before the Institute, disclosed that the pick-up unit used in the demonstration incorporates the electronic "flying spot" which has been under development for nearly ten years. In this system, he explained, the flying spot of light is created on the screen of the kinescope by the electron scanning beam.

The light from this spot is projected through color slides or films, scanning the entire surface of the scene or object, point by point. As the light beam, then tinted with color, emerges from the film or slide, it passes through a series of filters which separate respectively the red, green and blue portions of the color in the beam.

Each color then is reflected into photocells which change the light values into electrical signals for transmission to the receiver. The flying spot method, he added, assures perfect picture registration by permitting the transmission of the three color values of each picture element simultaneously.

At a press preview before the Institute meeting, correspondents asked a number of searching questions about the possible effects of large-screen television on the present moving-picture theaters.

In reply, David Sarnoff, president of RCA, stated that as opera and the concert hall had found that radio helped rather than harmed them, the moving picture industry might find television a great aid. The moving picture industry, he commented, had not been responsible for the introduction of the talkies, which came from the electronic industry. Possibly the moving picture industry people today are not fully alive to the possibilities of television, he suggested.



A cutaway drawing of RCA's large-screen color television projector.

MORE COLOR TELEVISION

A new television invention reported last month from the West Coast may make possible 3-color television with a single electronic image tube.

The system is the invention of George E. Sleeper, chief engineer of Color Television, Inc.

It employs a scanning device which converts filtered colors into a single picture at the transmitter, using a single electronic picture tube. The images are reproduced in a group in black and white on the receiving picture tube and then projected through filters and combined optically and projected to a screen as a color picture.

A feature of the system, it is pointed out, is that it is receivable on both sets equipped for color and those producing only monochrome images.

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By H. W. SECOR

PART II

ONE of the most interesting color television devices recently demonstrated to the FCC is the *Trichromoscope* picture tube. This tube, as Fig. 1 and Photo A show, has three electron guns built into it, one gun for each color to be reproduced. This tube may solve many problems for the simultaneous as well as the sequential devotees. For one thing it does away with the fussy adjusting and focusing of three separate cathode-ray tubes.

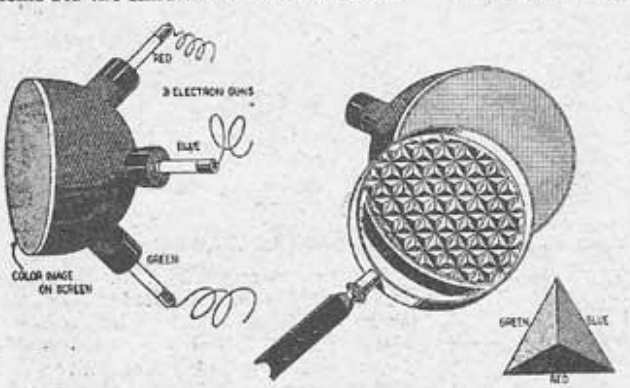

Fig. 1—The Trichromoscope. Magnified section is interior of screen.

Each color signal is injected into its respective gun in the new Du Mont tube. The three electron beams from the guns are focused on a special prismatic screen at the large end of the tube. The screen has myriads of small facets, shaped like pyramids, pressed on its inner surface. Each of the three sides of a pyramid is treated with a phosphor coating that glows with a different color (red, blue, or green) when the beam from its associated gun strikes it. When the various prismatic surfaces are illuminated by the modulated electron beams, a single image in natural color results. Pictures of great brilliance and contrast are produced by this tube, says Dr. Du Mont.

A unique method of producing color in movies from black and white images (on positive film) was recently demonstrated before the FCC in Washington by the inventor of the system, Richard Thomas. Its adaptation to television has not been demonstrated to date.

As Fig. 2-a shows, three black-and-white images are printed on a standard movie film, each image being graded for *color tone* by passing it through accurately balanced, red, blue, and green filters. The three images in each frame are picked up by a Thomas-color *optical color analyzer* unit as shown. For producing color movies, this lens and filter unit restores color to the three images and blends them into a *single* color image, which is projected onto the movie screen.

The optical color analyzer unit comprises a series of lenses, prisms, and color filters, which split the image into three new black-and-white images, corresponding in color value to red, blue, and green. A single lens in the optical color analyzer picks up the image or scene and splits it into three color tone images, which emerge from the unit through three separate lenses, as the diagram shows. See photo B.

At the projection end the action is reversed. The position of the color filter unit is such that the three color tone images picked up are resolved by colored filters into one image in full restored color. This image is projected onto a screen.

In its proposed adaptation to television, the optical color filter unit breaks up the image into three color images—red, blue, and green. These three color images are projected onto the mosaic screen (photoelectric) of an orthicon tube (See Fig. 2-b). Here the electron scanning beam within the tube scans the three images as *one* picture and sends the resulting signals (or modulated current) to the television transmitter.

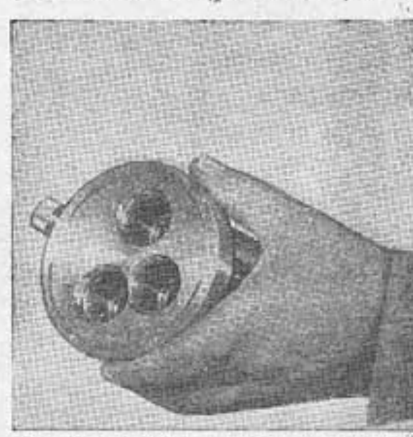
Photo B—The Thomas optical color analyzer.

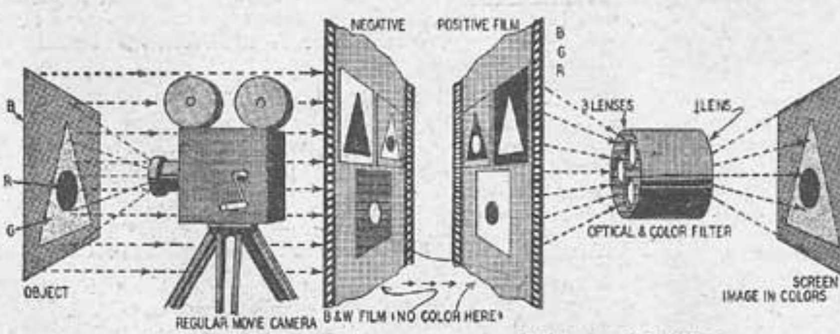

Fig. 2-a—The Thomascolor process, as applied to moving pictures.

The picture is transmitted the same as any ordinary black-and-white television image. At the receiver a kinescope tube reconstructs the image (really three *color tone* or monochrome images; they have no color yet). A second Thomascolor optical and color analyzer unit *(in reverse)* is placed in front of the kinescope screen. As the three images corresponding to red, blue, and green are passed through the analyzer, color filters restore color to each. A single color image emerges from the color unit and is projected onto the screen.

This system should be particularly well adapted to the simultaneous method of television. As the three separation images are spatially identical both in film and on the orthicon tube, they can be scanned as one, permitting transmission on *one* carrier. This means a great saving in the frequency band width required and merits the close study of television engineers.

It should be noted that one of the Thomascolor features is the fact that a movie (in black and white) can be taken of fires and other news events (which could not be approached by cumbersome television trucks). After rapid development of the film, it can be rushed to a television station and broadcast.

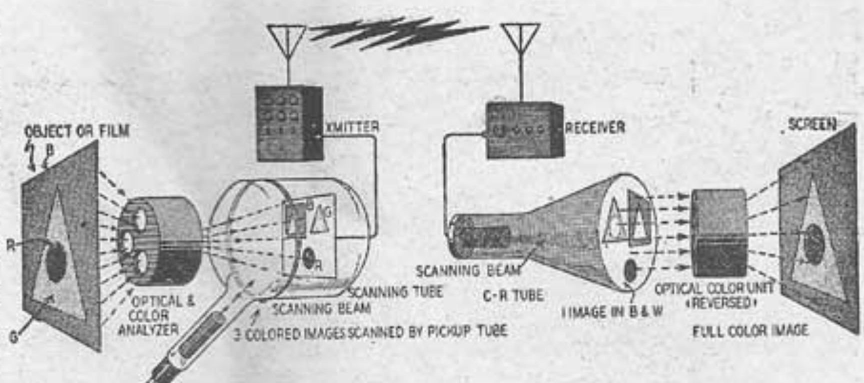

Fig. 2-b—How the Thomascolor process is applied to transmission of television signals.

Sleeper color system

Two patents have been issued to George E. Sleeper (Nos. 2,389,645 and 2,389,646) on a simplified system of *color television.* Fig. 3 shows the principle of the Sleeper system, which employs black and white transmission up until the time the image is finally thrown onto the receiver screen. This system has not been demonstrated, to our knowledge.

The object is picked up by the *quadchromatic* lens, which projects four images of different color onto the photoelectric screen in the camera tube. These images are scanned in a group as *one* picture, in the same manner as a black-and-white image. The picture (with its four *color tone* components) is transmitted as ONE *black-and-white* image, thus requiring but *one* carrier.

At the receiver a single cathode-ray tube reproduces in *black and white* (with graduated grays, whites, and blacks—tones corresponding to the four respective color values) four separate images, similar to those observed in the camera tube at the transmitter. These images at the receiver lack color so far, but they do possess the correct detail and intensities corresponding to the four colors. Color is now restored to each image (red, blue, yellow, and green) by collecting the images through a color filter and lens system. This unit is arranged in *reverse* order to the one at the transmitter, and projects the four blended color images onto the screen as a single image in full color.

The quadchromatic color filter unit contains lenses for picking up the images (or image, depending upon which function it is to perform—i.e., convert one image into four or the reverse), plus suitable prisms and color filters, as shown in Fig. 4. A simplified sketch of such an optical system, using four separate lenses and four color filters, Fig. 5, will aid in making the process clearer. As in the Thomas color system, no color is actually transmitted, only the shaded or toned images corresponding to each color.

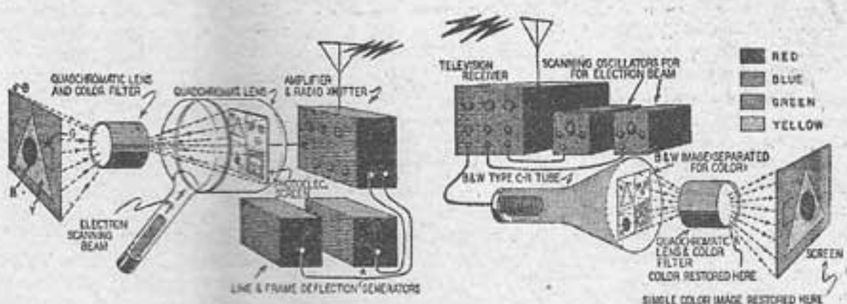

Fig. 3—The proposed Sleeper color television system separates and re-unites four colors.

How the systems compare

Considerable criticism has been leveled at the mechanical (revolving) color filter used in the sequential apparatus. Dr. Goldmark in his report to the FCC illustrates and describes a full electronic sequential system which employs no mechanical color filters.

The 525-line standard proposed in the CBS report to the FCC has been attacked by some experts, who advocate a greater lineage. Here is some interesting data on this controversial phase of color television.

The 525-line image approaches 16-mm movie performance, with regard to the resolution or detail of the image. A noticeable increase in definition is obtainable only at the expense of appreciably greater video band width. As Dr. Goldmark points out, the visual acuity or perception of detail is fairly well saturated at 525 lines. At least 50 percent more lines would have to be added to realize a noticeable improvement in definition. If 750 lines are used, as some advocate, the necessary band width is doubled and each station's channel will be 27 mc wide. The number of channels available in the high-frequency television band will be reduced to 16. If 750 lines and 60 color frames per second are used instead of 48, there will be required a video band width of 25 mc and a chan-

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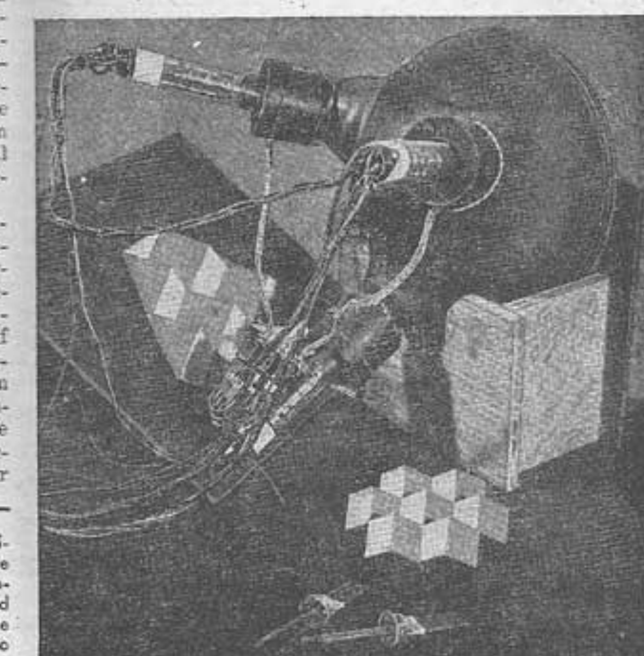

Photo A—Typical Trichromoscope in the experimental laboratory. Cardboard models of the inside screen surface are to be seen nearby.

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nel width of 32.5 mc, which is impractical under present frequency allocations and limitations of receiver design.

Network transmission of sequential color images were successfully carried out by CBS engineers. One test was made over the A. T. & T. Co. co-axial cable loop between New York City and Washington, D. C., and return (total length 453 miles). Tests were made at 40 and finally 48 color frames per second. The video frequency cutoff in this instance was 2.9 mc. A check by one of the visiting engineers who saw the demonstration revealed that there was a considerable loss in resolution due to the cutoff at 2.9 mc, which was to be expected.

A later test was conducted with the sequential system over the microwave radio link operated by the Bell Telephone Laboratories between New York City and Murray Hill, N. J.

The simultaneous color system developed and demonstrated by RCA has the advantage that all three basic colors are continuously transmitted. Some experts claim that this is very essential, when it comes to the pickup and transmission of fast-moving objects such as a football, tennis ball, etc., during the course of a game. Color breakup is liable to occur in such cases, with the result that an object moving across the screen rapidly may be seen in several different colors, owing to the fact that the necessary color is not transmitted at certain critical instants with the sequential system.

The first theater-size color television was recently demonstrated by RCA in Philadelphia, using the simultaneous system. The image was 7½ by 10 feet. The number of lines used was 525. Many who witnessed the demonstration said that the color television images compared favorably with regular technicolor movies. As 525 lines compares with 16-mm home movies, about 1,000 lines are ordinarily required to give the same resolution as 35-mm movies. As explained previously, the addition of color gives an apparent definition considerably above the 525 lines used.

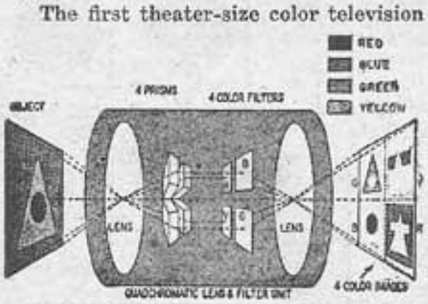

Fig. 4—The Sleeper color analyzer unit.

With the simultaneous system of color transmission black-and-white receivers can pick up monochrome images by the simple addition of a converter. (Present B & W receivers cannot pick up the high frequencies allotted to color television.) This is not possible with mechanical sequential systems. Another feature is that electronic color television receivers can pick up black-and-white programs. A broadcaster with the RCA electronic system can operate a B&W and also a color transmitter, using the signals from the color camera to operate both transmitters.

Other features of the electronic simultaneous system are: freedom from flicker; greater picture brightness; no color breakup; less band width than that required for the sequential system; greater flexibility for network operation; compatibility with present commercial television, to the extent of interchangeability and consequent avoidance of obsolescence of one by the other.

Radio-Craft, June and July 1947