COLOR TV-
THAT ISN'T

OPTICAL ILLUSION CREATES COLOR IMPRESSION IN VIEWER'S MIND

By **LAURENCE R. GRIFFIN**

CAN AN ORDINARY black-and-white TV receiver reproduce a color image? "No," you say. Wrong! Believe it or not, the answer is a resounding yes—provided the telecast is in "electronic" color using the Color-Tel subjective color process*.

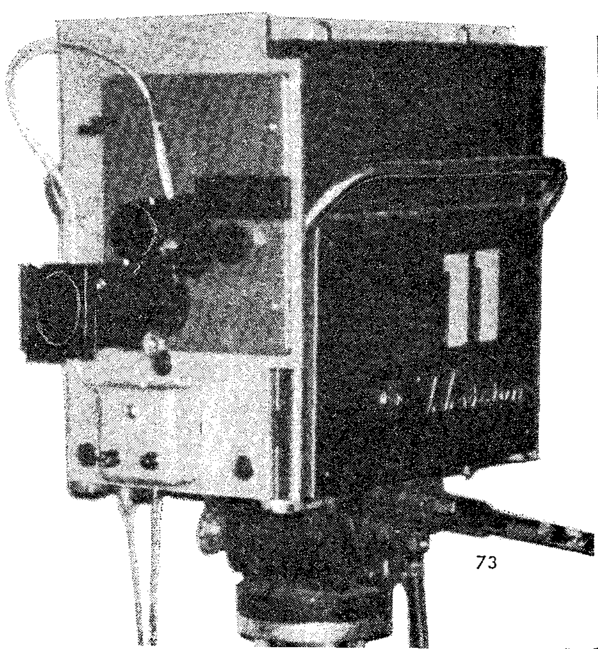
Developed by James F. Butterfield, Sherman Oaks, California, electronic color is a remarkable TV broadcasting technique using relatively unknown optical principles to transmit a monochrome picture that appears to be in color when viewed on an ordinary black-and-white TV receiver. Actually, no color appears on the TV screen—it exists only subjectively in the brain of the viewer. Although most viewers see colors, there are some viewers who do not—for reasons not completely understood. On the other hand, normally color-blind people frequently report being able to see the electronic subjective color display.

Light. Light waves are a form of radiant electromagnetic energy of which the visible spectrum is only a small part spanning the apparent color range from red to violet. Each color has a distinctive wave length, from violet at 16 millionths of an inch, to red at 32 millionths of an inch. Outside of this very narrow band of frequencies lie the optically invisible radiations that include ultraviolet, infrared, X rays, and even radio waves.

Vision begins when light strikes the retina, a light-sensitive nerve membrane covering the hemispherical back wall of the eyeball. Composed of three layers, the retina contains two types of special sensory bodies called rods and cones. These nerve cells respond to light stimulation by "telegraphing" a pulsing sequence of coded information along the optic nerves to the brain's sight center in the occipital lobe of the cerebral cortex. All color perception occurs in the cones and by evaluating the varying frequencies of the neuron impulses, the cortex is able to distinguish what hues are acting on the retina.

Slightly over 15 years ago, Butterfield reasoned that, if the frequencies of the nerve codes for specific colors could be mathematically analyzed, it would be possible to feed the cortex synthetic color data. This could be accomplished by stimulating the cones with flickering pulses of white light, keyed to match the known nerve frequency for a given hue. If the theory was correct, such flickering white light would then appear to the viewer to have color.

Television camera equipped with a Color Translator transmits pictures which appear to the viewer to be in color on a standard black-and-white receiver.



*U.S. Patent 3,311,699, and other patents and patent applications outstanding in the United States and foreign countries.

Subjective Color. Experiments in subjective color have taken place throughout the past one and one-half centuries. The first known experiment appears to have been conducted by the French monk, Benedict Provost, who discovered that when a black-and-white object was moved through a ray of sunlight in a darkened room, a spectrum of colors mysteriously appeared. In 1838, Gustav T. Fechner, a German physicist, using a disc composed of black-and-white areas discovered that, when the disc was rotated, portions of the disc "subjectively" appeared in colors. Fechner advanced a theory to explain the mechanism of the phenomenon. Helmholtz, among others, investigated this strange effect.

At the end of the nineteenth century, C. E. Benham devised a disc which presented these colors in a very striking manner. In appearance, the Benham disc is half black and half white. The white area is subdivided into three equal sections, each containing a black design composed of two closely-spaced parallel curving lines. A facsimile of the Benham disc is shown in Fig. 1. You can cut out this pattern and paste it on a piece of cardboard. Pin the center of the disc to a pencil eraser so that the disc may spin freely. As you spin the disc in a clock-

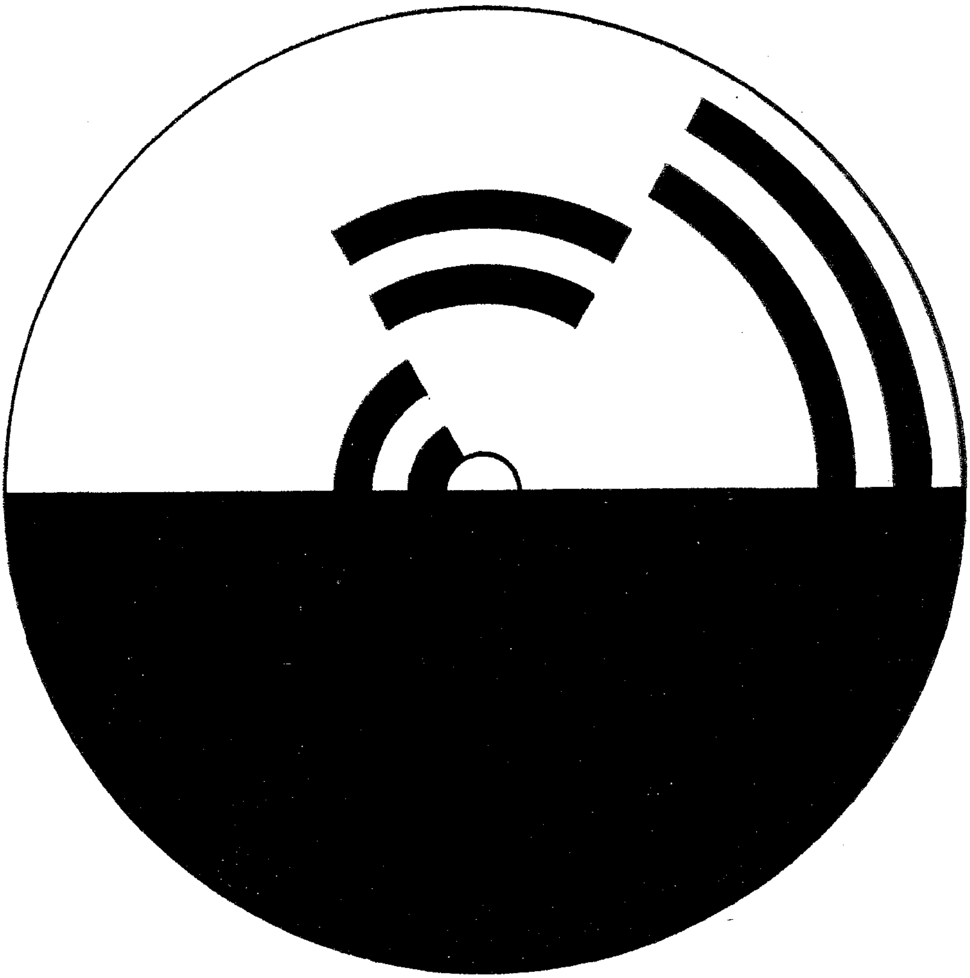


Fig. 1. Cut out or copy this duplicate of the Benham disc. Use rubber cement to adhere disc to a circular piece of cardboard. Punch a hole in the exact center of the disc and support it on a pushpin stuck in the eraser of a lead pencil. Rotate the disc at speeds between 3 and 10 rotations per second. The speed of rotation will affect hue and saturation of the colors. Changing direction of rotation reverses the colors.

wise direction as you face it, you will see subjective color just as Benham saw it 75 years ago.

As the disc rotates, the black lines—almost as if by magic—appear to take on shimmering colors. The lines nearest the hub are reddish, the middle lines appear greenish, and the outer lines are bluish. If this isn't sufficiently surprising, rotate the disc in the opposite direction and watch the display of colors reverse, blue nearest the hub and red on the outside.

In 1953, Butterfield consulted a Dr. Derek H. Fender and asked the famed eye expert to help analyze the Benham disc phenomenon so that it might be used to generate synthetic color codes.

TV Applications. When Butterfield and Fender had completed their tests, the next step was to apply their theory of subjective color to TV broadcasting. This resulted in the development of the Color Translator, a special TV-camera attachment that contains a modified form of the Benham disc. The disc is inserted in the light path between the scene being viewed and the TV camera lens. As shown in Fig. 2 what would have been the white section of the Benham disc is instead comprised of three tinted filter sections. Viewed from the front, the filters are, from right to left, cyan (blue-green), magenta (purple), and yellow, each a complementary color of red, green and blue respectively. When a colored object is seen through a tinted filter of a complementary color, the subject appears black against a pale background.

The Butterfield disc is rotated at 5 rev/m which means that one of the 12 filter elements is between the scene being viewed and the TV camera lens for 60 TV fields. When the cyan filter is in the light path, all red light is blocked out and only green and blue light appears. Therefore, all red areas are transmitted as black. The green, blue, and white areas pass through this filter and correspond to the white spaces of the original Benham disc. The magenta filter blocks out green light (which is transmitted as black), and passes the red and blue light which now acts as the white areas. The yellow filter blocks out the blue light.

Mixed colors are combinations of two or three primary hues and when they appear in the scene, they cause some

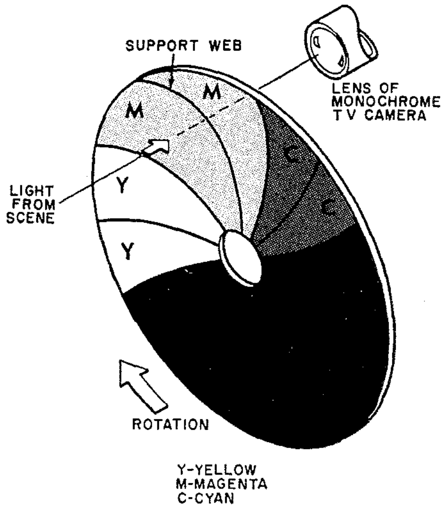


Fig. 2. Disc for use in TV has three sectors in colors that are complements of those seen on reception.

grey or black to be transmitted in the subjective color primaries. When the Color Translator is in operation, a flickering color picture of medium saturation and fidelity can be seen on a black-and-white TV receiver. The flickering is the result of two different effects. First, there is the opaque half of the disc that blocks out all light reaching the TV camera for 50% of the time. This causes a black flicker at 5 Hz (rotational speed of the disc). Secondly, the subjective red, green, and blue colors are each produced during a different sixth of a revolution of the disc. These color areas appear white during the remaining third of the disc revolution. This causes a white flicker in the color area. Mixed colors do not have the latter type of flicker since they are combinations of more than one primary color. Red seems to flicker more than green or blue, but this appears to be a physiological effect.

While Butterfield isn't the first to come up with a workable subjective-color process for black-and-white TV, his method is, by far, the most efficient and flexible system yet devised. The Nagler process, patented in 1958, requires specially prepared film to achieve the desired subjective-color effect. Butterfield's system, on the other hand, needs no preprocessed material, and can be used to shoot live color sequences, make color

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video-tape recordings, or even, if fitted to a motion-picture camera, turn out full-color movies, on black-and-white film.

What Next? While this optical system will broadcast pictures in natural color, it has a number of inherent flaws that have to date restricted the use of electronic color to certain types of "special effects" commercials.

The slow speed of the filter rotation—necessary for color definition—also makes the picture shimmer, flash and appear generally unsteady. The color quality isn't uniform and some viewers see hues almost as saturated as those of a conventional color TV receiver. Other viewers discern only one or two tints, and a minority of viewers apparently can detect no color whatsoever.

Yet despite its shortcoming, electronic color does seem to be a commercial success, and Color-Tel Corporation, Hollywood, California, is using the Butterfield process to make successful television commercials.

When electronic color was first publicly demonstrated in the Los Angeles area over KNXT, no prior announcement had been made at the request of a soft-drink manufacturer sponsoring the test. The beverage firm wanted its color commercials to be a complete surprise to viewers of black-and-white receivers. And, the telecasts were that, to say the very least. Within hours of the electronic-color broadcast, thousands of viewers began asking the same question, "What happened? Did I really see color on my black-and-white receiver? Or am I having hallucinations?"

Right now, Color-Tel engineers are checking into the possibility of using electronic color for such things as color radar displays, color computer readouts, and perhaps even color sonar pictures. It may be true that, in its present stage of development, Butterfield's process is nothing but a scientific curiosity—however, 25 years ago, so was television. —30—