COLOR processes are broadly divided into two classes: the subtractive and the additive. In subtractive processes the image is actually composed of colored substances, usually dyes. The Technicolor, for example, is a two-color subtractive process. All subtractive processes worked out thus far require considerable knowledge and skill in processing and are, therefore, unsuitable for amateur photography.

In additive processes two, or more usually, three images are taken through color filters and are viewed or projected through similar filters, the color separation images recombining in the eye or on the screen to produce the color picture. In additive methods the images in the emulsion layer contain no coloring matter of any kind, and the processing of the film presents no greater difficulties than in black and white photography.

The additive method may in turn be divided into two classes. In one class three separate photographs are made through a red filter, a green filter, and a blue filter, each filter in turn completely covering the taking lens during exposure. In the other class the three filters are distributed as extremely small units immediately under the panchromatic emulsion layer. The microscopic filters may be in the form of lines, a regular mosaic pattern, or they may be irregularly disposed. The Joly screen plate is an example of the first, the Paget screen plate of the second, and the Autochrome of the third.

Very beautiful results can be obtained by these processes.

The Eastman Kodak Company has experimented on color photography for the last twenty-five years, and has examined process after process.

About three years ago Keller-Dorian of Paris demonstrated some color pictures on 35 mm. film which they had produced by the Berthon additive process. These appeared so promising that the Eastman Kodak Company arranged to purchase the Keller-Dorian patents and the Research Laboratory started to work out the process for the Ciné Kodak.

* Research Laboratory, Eastman Kodak Co., Rochester, N. Y.
In this method all of the advantages of a fine three-color line screen film apparently could be secured without actually ruling the microscopic filter units on the film support. This is accomplished simply by placing close to the front component of the taking lens, color filters in the form of three vertical bands and embossing on the entire surface of the film support microscopic cylindrical lenses arranged longitudinally as shown in Fig. 1. The number of these lenses actually used is 22 to the linear millimeter.

Fig. 2 is a schematic diagram showing the arrangement in a Ciné Kodak of the color filters, the taking lens and the embossed Kodacolor film. When a picture is taken without the color filters in position, the light coming from every point in the subject completely fills the front aperture of the lens with light of the color reflected by each point. This light is, of course, brought to a focus in the plane of the film and forms an image having the color of each point in the subject. Since any portion of the lens will form of itself a complete image, the image is not changed except in intensity when the three banded filter is placed close to the front of the lens, provided the integrated transmission of the three filters is white.

With no filters in position, the eye, when placed at any point in the plane of the image, sees the lens as a uniformly illuminated circular area of a color corresponding to the color of the object being imaged at that point. When the filters are in place the relative brightness of the three filters when viewed from any point in the film plane will depend upon the brightness and color of the particular point of the subject being imaged there. If the point, for instance, happens to be red, only the red filter will appear bright because only the red filter can transmit red light. If the point should be a green one, only the green filter would be bright, and so on.

Fig. 1. Cross section of embossed film. Section perpendicular to axes of embossed cylindrical lenses.
In the light of the foregoing explanation of the action of an objective lens, the function of the small lenses embossed on the film support can be readily understood. The focal length and magnification of the embossed lenses are such that they each sharply image the three filters, as seen through the taking lens, onto the emulsion layer. The images of the three filters as formed by each embossed lens are of such a size as to just occupy the area behind that small lens without intruding on the space belonging to its neighbor. If the camera lens is pointed at a large white sheet and the embossed film, without its emulsion layer, is examined through a microscope, one clearly sees the tiny filter images formed by the embossed lenses as a beautifully arranged line screen composed of red, green, and blue lines. If the camera is directed towards a landscape and various portions of the image are viewed through the microscope, the brightness of the small filter images will depend upon the color and brightness of the particular portion of the scene being examined. A deep blue sky, for instance, will be found to be made up of bright blue filter images, less bright green images, and very dark red images. A red flower will be seen as red filter images only, and so on.

Fig. 2. Diagram of the arrangement in a Cine Kodak of the color filters, the taking lens, and the embossed Kodacolor film.
The Kodacolor film, after being put through the reversal process to produce a positive picture, is a black and white reproduction of the subject split up into an immense number of tiny images of the three-color filters (as shown in Fig. 3). The color filters and the embossed lenses on the film have in effect analyzed the colors of the objects photographed.

Now, it is a well known optical principle that any optical system is reversible, so if the developed film were replaced in the Kodacolor camera in exactly the position it occupied during exposure, and illuminated from behind, all of the tiny red filter images would be projected through the red filter in the camera lens, all of the green images through the green filter, and all of the blue images through the blue filter. The camera lens would then focus the various rays onto a screen and give a picture in the natural colors of the original subject.

The camera is not ordinarily used as a projector, nor is the camera type of lens used for projection. This complicates matters slightly, mainly because projector lenses are of longer focal length than those used in cameras. The Kodascope projector, for example, has a two-inch lens, while the Ciné Kodak has a one-inch. If the regular Kodascope, equipped with filters, were used to project the
Kodacolor film, the filter images projected by the film lenses would fail to register on their respective filters and a faulty screen picture would result. To overcome this optical fault, a compensating lens of a suitable focal length is placed in front of and close to the embossed film so as to direct the various rays in the right direction.

In any process of color photography, it is necessary to obtain equal exposures through the red, green, and blue filters. Since different coatings of emulsion may differ slightly in color sensitivity, some adjustment is necessary. In Kodacolor this is made by means of a small metal cap called a ratio diaphragm (Fig. 4) which is placed over the filter bands and regulates their height in accordance with the spectral sensitivity of the emulsion. The correct diaphragm is attached to the leader on each roll of film so that it can be fitted onto the filter by the user.

It is peculiar to the process that the exposure cannot be regulated by the usual iris diaphragm in the camera lens because the embossed film must have an unobstructed view of the three filter bands on the lens; so the lens is used fully open and a suitable neutral density filter of glass is placed in front of the lens when the subject is being photographed in unusually bright light.

The curved gate of the Model B Ciné Kodak serves a useful purpose in Kodacolor. Flatness of the film from side to side in both camera and projector, is essential to even color across the screen. The curvature of the gate about a horizontal axis has no detrimental effect, but, on the contrary, prevents curl in the opposite direction and helps to make a picture of uniform color.

The development and reversal of Kodacolor film is carried out on continuous machines by a process similar to the one used for
black and white Ciné Kodak film. A controlled second exposure regulates the density of the final picture, and compensates for slight variations in camera exposure.

For projection of Kodacolor film, either the Model A or the Model B Kodascope may be used, when fitted with the proper attachments. These consist of a tri-color filter and a compensating lens. Although the taking and projection lenses are of the same F value, the taking lens is of 25 mm. focus, and the projection lens, of 50 mm. focus. Without a compensator, this difference would cause the color to vary from side to side on the screen. In order that

![Image of a Kodascope](image)

**Fig. 5.** The lens with compensator as used in the Model A Kodascope.

all of the embossed lens elements may project their filter images through the proper filter bands, the projection filter must appear of the same size and at the same distance from the film as the camera filter. The compensator, which is a plano-concave element fitting against the front of the gate, accomplishes this by forming a reduced virtual image of the projection filters at the proper distance from the film.

Aside from preserving the color balance on the screen, the only apparent effect of the compensator is to give a very slightly smaller picture than would be obtained at the same distance without it. It needs to be cleaned occasionally, since dust particles on its surface appear as colored spots on the screen.
For the Model A Kodascope, the objective, filters, and compensator have been made as a unit, which is inserted in the Kodascope in place of the ordinary lens. This is shown in Fig. 5. For insertion and removal, the compensator telescopes against the projection lens. When in use, it is pushed back against the gate by means of a lever.

![Image of compensator](image-url)

**Fig. 6.** Filter mounted on the Model B Kodascope.

The filter for the Model B Kodascope is mounted in a cap (Fig. 6) that slips on over the end of the lens barrel. When not in use, it fits into a box with a screw top mounted on the base of the projector. The compensator is carried in a telescoping mount that screws into the rear end of the lens barrel. A spiral spring presses the compensator against the gate. In cleaning the compensator,
the projection lens is swung upward to expose the rear surface. The compensator may be left in place during the projection of black and white film.

To secure correct and uniform color in all parts of the projected picture, the screen must be nearly white and uniform with no film in the gate. This necessitates correct adjustment of the illuminating system. An improved lamp house has therefore been supplied for the Model A Kodascope, that holds the lamp in a prefocussed base. The condenser is stronger than formerly used and is rigidly mounted in the correct position. A lateral adjustment of the lamp by means of a screw is necessary only when a new lamp is inserted. The proper position is determined by running the Kodascope without film, and watching the color and uniformity of the screen as the screw is turned. Perfect uniformity is not necessary, since the embossing on the film helps to even up the illumination by diffusing the light beam from the condenser.

The Model B Kodascope has not only the pre-focussed lamp with lateral screw adjustment, but also a special relay condenser that turns the image of the lamp filaments through 90°, after the manner of Porro prisms. Since the filament images now run across the filter bands, the screen is more easily made uniform in color.

The projection filters have been chosen to give as good a reproduction of daylight as possible.

On account of the light necessarily absorbed by the filters, a smaller picture must be projected than with black and white film. The Model A Kodascope screen, $22\frac{1}{2}'' \times 30''$ can be used but a special $16\frac{1}{2}'' \times 22''$ screen is preferable and is sufficiently large for home use.

Since, in Kodacolor, the three color records are taken simultaneously, no color fringes are formed on the images of moving objects. Fringes, if present, indicate that objects were out of focus in the camera, or that the projector is not focussed on the screen.

As a three color process, Kodacolor is capable of giving a good reproduction of all the colors found in nature. Landscapes, marine views, flowers, and persons in out of door settings are well rendered. Kodacolor therefore excels in those subjects which amateurs wish to photograph.