AN ASPECT OF COLOR PHOTOGRAPHY AND INTERPRETATION*

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ABSTRACT

The three-color aspect of human vision and its application to modern color photographic processes are briefly reviewed. Some of the spectrophotometric characteristics of the dyes used in modern subtractive color photographic materials are outlined, and it is pointed out that there is no simple direct relationship between the spectrophotometric characteristics of an object photographed and the spectrophotometric characteristics of the dyes forming the image of that object. These characteristics limit the use of these materials for interpretation purposes in aerial photography.

IN JANUARY, 1942, the Eastman Kodak Company began the manufacture of a special color film, Kodacolor Aero Film for Reversal, for use in aerial photographic reconnaissance. The material was manufactured exclusively for the Allied Armed Forces during World War II and was later made available, with certain reservations, to civilian customers. It should be noted that the name of the material was changed in 1950 to Kodak Ektachrome Aero Film (High Contrast). Since its introduction, there has been a steady, although slow, increase in interest in the use of aerial color photography for interpretation, and a brief review of some of the characteristics of modern three-color photographic materials may indicate the potentialities and limitations of these materials for interpretation purposes.

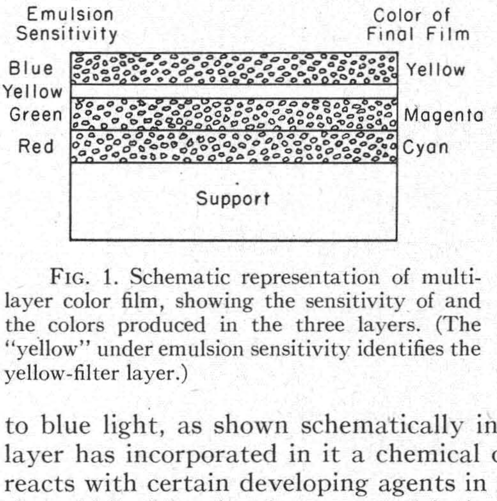

FIG. 1. Schematic representation of multilayer color film, showing the sensitivity of and the colors produced in the three layers. (The "yellow" under emulsion sensitivity identifies the yellow-filter layer.)

Kodak Ektachrome Aero Film (High Contrast) is an incorporated-coupler, multilayer, or monopack, type of color film which is reversal-processed by the customer to yield a positive color transparency. In a multilayer, or monopack, type of film, three emulsions are coated on a single film base, the emulsion next to the film base being sensitive to red light, the middle emulsion sensitive to green light, and the top emulsion sensitive to blue light, as shown schematically in Figure 1. The red-sensitive emulsion layer has incorporated in it a chemical compound, known as a coupler, which reacts with certain developing agents in the oxidized state to form a cyan dye; the middle layer has incorporated in it a coupler which yields a magneta dye with the same developing agent; and the top layer has incorporated in it a coupler which yields a yellow dye with the same developing agent (Figure 1).

During reversal-processing, the negative image only is first developed in a black-and-white developer, after which the film is flashed to white light, and the remaining silver halide (which is a positive image) is reduced to silver by a developing agent of the type just mentioned, the oxidized form of which combines with the couplers to form, *in situ*, the appropriate colors in the three layers.

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Both the positive and the negative silver images are then removed, leaving a positive image in color.

The colors produced, therefore, by the type of color film just described, are some combination of the three dyes formed in the film during processing. The spectrophotometric characteristics of these dyes have a bearing on the interpretation possibilities of the film and should be considered.

The spectrophotometric characteristics of all colors reproduced by this type of color process are the sum of the spectrophotometric characteristics of the quantities of the three dyes formed by the process for the particular color in question. There is no direct simple relationship between the spectrophotometric characteristics of the color formed by the process and the spectrophotometric characteristics of the color of the object photographed. Figure 2 shows the spectrophotometric curves of three subtractive color dyes representative of those used in Ektachrome Aero Film (High Contrast). The concentration of the dyes chosen for measurement was such as to produce a neutral density of 1. Each density represented by the neutral density line is the sum of the absorptions of each of the three individual dyes at the particular wavelength. In other words, a neutral density is formed by a mixture of the proper amounts of the three dyes, and the resulting spectrophotometric curve of this neutral is directly related to the spectrophotometric curves of the three individual dyes used.

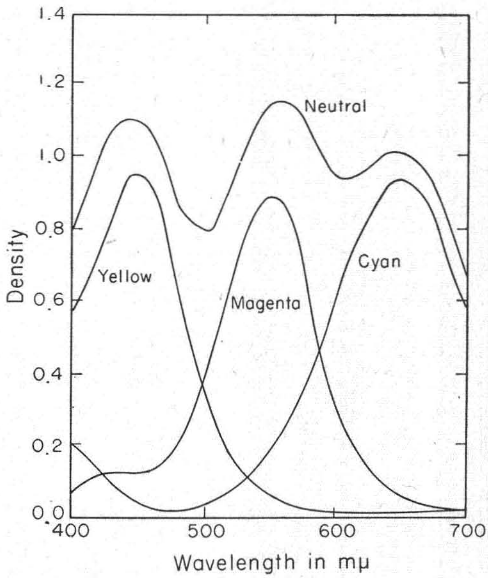

FIG. 2. Representative spectrophotometric curves of the colors produced in a multilayer color film.

An extreme example of the lack of correlation between the spectrophotometric characteristics of the object and of its photograph is illustrated by sodium light. The yellow light from sodium vapor consists primarily of two wavelengths of radiation at 588.99 millimicrons and 589.59 millimicrons, as shown in Figure 3. In a color photograph, the color of the light from sodium vapor is represented by the yellow dye of the process having a broad spectrophotometric curve, as shown in Figure 4, and obviously does not match the line spectra of the light from the sodium vapor. It is of interest to note however, that, despite this lack of correlation of the spectrophotometric curves, the color photographic reproduction of sodium-vapor light is visually satisfactory.

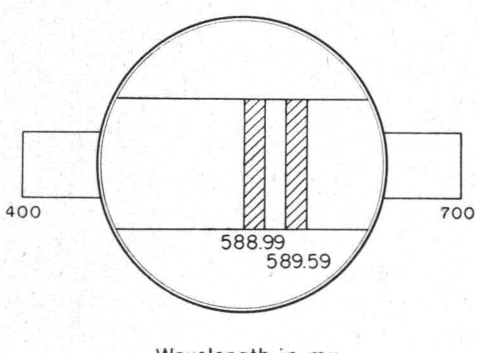

FIG. 3. Spectral characteristics of the most effective radiation, in the visible spectral region, from sodium-vapor light.

Objects with line spectra such as the sodium-vapor lamp are seldom subjects for color photography, but another example which illustrates a

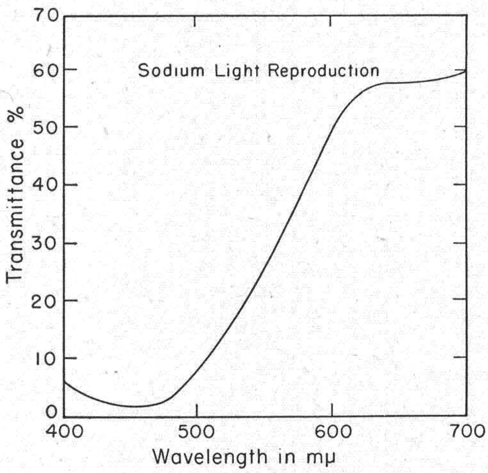

FIG. 4. Spectral-transmission curve of a multilayer color-film reproduction of the sodium-vapor light.

striking difference between the spectrophotometric characteristics of the object and those of its photograph is the ageratum flower. Figure 5 consists of the spectral-reflectance curve of an ageratum flower and the spectral-transmission curve of a color photograph of this flower, and shows the lack of correlation between them.* In this case, there is a difference between the visual sensation of color produced by the flower and that by the color photograph of the flower. The actual flower appears lavender in color, while the color photograph from which the curve in Figure 5 was made appears pink.

Fortunately, very few natural objects have line spectra or unusual spectral characteristics as do sodium light and the ageratum flower and, therefore, color photography is usually a fairly accurate representation of the appearance of the objects and almost invariably satisfactory to the eye.

It is important, however, for interpreters to understand the limitation of color photography in reproducing the spectrophotometric characteristics of objects and to realize that determining the spectral characteristics of a color photographic reproduction of an object does not constitute a necessarily unique identification. Perhaps the simplest procedure to follow in determining the usefulness of color photography in identifying or distinguishing objects is to photograph the objects with the color process that is to be used. In this way, all the factors which affect the photographic reproduction of colors—and there are a number of factors not discussed here—will be taken into consideration. If differences between objects are evident in the photograph, these differences can be enhanced by the use of filters and also by further photographic manipulation.

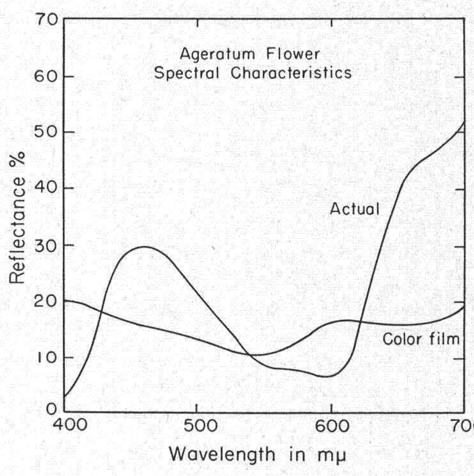

FIG. 5. Spectral-reflectance curve of an ageratum flower compared with the spectral-transmission curve of a multilayer color-film reproduction of the flower.

It should be mentioned for completeness that, although three-color photography, as exemplified by Kodak Ektachrome Aero Film (High Contrast), cannot be used effectively to determine the spectral characteristics of colors of objects, there are photographic techniques which can be used for this purpose and which can be applied in aerial photography.

* Data supplied by E. M. Bancker, Color Control Division, Eastman Kodak Company; unpublished work.