# COLOR MATCHING IN THE COSMETIC INDUSTRY*

## By E. I. STEARNS

*Research Department, Calco Chemical Division, American Cyanamid Company, Bound Brook, N. J.*

THREE physical factors enter into every appearance of color. These factors are: the light which illuminates the sample; the object itself which is seen; and the eye which transmits to the brain the sensation of color. The psychologist may disagree with this and say that the mind may have a concept of color even in the absence of light. The physicist may disagree with this and say that an object has color even though there is no observer present to discern it; but without getting into these philosophical discussions, let us examine these three factors more closely and see how they are related to the sensation of color.

The importance of the illumination is easily demonstrated. If a red lipstick is held in white light, the eye receives a sensation of red. On the other hand, if the red lipstick is viewed in green light, the red lipstick will appear black. Illumination is, therefore, an important factor in the discernment of color. Even so-called white light is not always white, and daylight itself cannot be taken as a standard white

light, because it is so variable. Light from the north sky is very blue in color compared with light from the southern sky. Direct sunlight is quite yellowish in color, but as sunlight passes through the atmosphere, some of the light is scattered sideways. When a sample is viewed with north sky light, the illumination is not direct sunlight, but is the sideways scattered radiation. This sideways scattered radiation is quite bluish in color, and in fact it is this which gives the blue appearance to the sky. It is thus possible for two samples to look alike on the south side of the building where they are illuminated by direct sunlight, but to appear quite different when they are viewed by north sky light on the north side of the building. The color of daylight is not only variable depending upon whether the north or south sky is used to illuminate the sample, but also it varies from day to day because of cloudiness and other factors in the atmosphere, and it varies over one day from morning to night. If one wishes to make any scientific calculations on color, as viewed in daylight, it is necessary to define what is meant by daylight. This

has been done. The International Committee on Illumination in 1931 adopted a standard kind of white light which they call "Illuminant C." This illuminant is similar to a mixture of north sky light and sunlight, and is a definite, fixed kind of light.

Cosmetics are observed not only outdoors, but also, and perhaps even more importantly, under different kinds of artificial illumination. Modern lighting engineers have gone ahead with the development of tungsten filament lamps, fluorescent lamps having different phosphors in the coating, and gas or vapor lamps, such as the neon lighting signs. Added to this complexity are the various color effects introduced by means of colored filters placed over lights, particularly in places of amusement. Of all these artificial sources of light, only one has been defined; that is a tungsten light. Illuminant A was chosen by the International Committee on Illumination and this is a standard tungsten light substantially. The man responsible for formulating the color of a cosmetic therefore, has to consider the attractiveness of his product under all these different kinds of illumination.

The complete specification of an illumination consists of a distribution curve showing the relative energy of the light as a function of its wave length. When white light is passed through a glass prism, the white light is broken up into the different spectral colors, which are the familiar rainbow colors, and the

intensity of each kind of light is the spectral distribution curve. Since these spectral distribution curves are difficult to speak about, there has been a simplification introduced with the concept of color *temperature*. If an iron poker is placed in a furnace, as it warms up it will first become a dull red color, and as it gets hotter and hotter, the color will progressively change from a red to a yellow to a white, and finally to a bluish white color. This change in color of a so-called black body as it reaches different temperatures somewhat parallels the variation in apparent color of daylight under different conditions, and closely parallels the tungsten filament light at different voltages; and therefore the concept of color temperature has been used to specify the color of an illuminant. For instance, it may be said that the north sky at a particular time has blue color which is similar to the color which a black body would have if it were heated to a temperature of 10,000° Kelvin. It is approximately true to say that the color temperature of the north sky is 10,000° Kelvin on this particular day. This does not mean that the temperature in the sky is actually 10,000° Kelvin, but it really means that the color coming from the sky is similar to the color which would come from a black body at a temperature of 10,000° Kelvin. Fluorescent light differs still more in its spectral distribution from the spectral distribution of black body light at any temperature. The concept of color tem-

perature can be applied to these only with a considerable degree of approximation. Nevertheless, it is so convenient to refer to a simple and single number that color temperature is commonly used even for fluorescent light. The spectral distribution curve and the color temperature are the scientific terms used to describe the illumination which is one of the factors involved in the perception of color.

The second factor in the perception of color is the object. The fundamental specification of the color of an opaque object is the curve in which reflectance is plotted vs. wave length. In the case of clear liquids, the curve of transmission vs. wave length is the fundamental specification of color. If we consider that white light containing all the different colors of the rainbow is falling on a sample, a colored sample will selectively reflect these different kinds of light. A red sample will reflect more of the red light which is incident upon it than the blue light which is incident upon it. The white light has been altered in its spectral distribution by encountering the sample. One of the easiest ways to determine the reflectance characteristics of a sample is to measure it with an automatically recording spectrophotometer. This is an instrument which consists of a monochromator and a photometer. The function of the monochromator is to furnish light of only one wave length at a time, varied through all the rainbow colors as the plot is made automatically. The function

of the photometer is to compare the amount of this particular color light which is reflected from the sample to the amount which is reflected from the white standard. The white standard is usually taken to be magnesium oxide. This instrument automatically plots the reflectance curve or the transmission curve for a particular sample. This curve can be the specification of the color.

Because the curve of reflectance vs. wave length for a particular sample is difficult to talk about, it is common practice to reduce the data to a simpler set of numerical figures. It has been found that in general, at least three dimensions are necessary to specify a color. In this discussion we can do scarcely more than mention some of the more common ways of specifying the color. One of the methods is to use tri-stimulus values. As is well known by color matchers, using red, yellow and blue dyes or pigments in the proper proportion, it is possible to produce all dull colors. It is thus possible to express dull colors in terms of amounts of the three pigment primaries needed to duplicate them. In the tri-stimulus values, this fundamental method is used. A color is expressed in terms of three imaginary, additive primaries which have been internationally standardized by physicists and psychologists. Another way of specifying a color which also involves three terms, is to use the terms "apparent luminous reflectance," "dominant wave length," and "excitation purity." This is an additive method of speci-

fying a color which can be demonstrated physically with real colors. If white light is mixed in with spectral light, and the intensity of the mixed light adjusted, any particular color may be duplicated and thereby specified.

A third method of specifying color is in the Munsell notation. The Munsell notation involves specifying again three factors: value, hue and chroma. Value is related to the total amount of light reflected. Hue is related to the name of the color, that is whether it is red, green or blue. Chroma is related to intensity of a color, that is, it is the attribute by which a cherry red differs from a brick red.

In all of these cases where color is specified in terms of three numbers, the color of the illuminant and the properties of the eye must be taken into consideration. Therefore, if two samples have the same specifications in terms of any of these three simpler numbers, it means only that they will appear alike to a standard observer under standard illumination conditions. The fundamental specification of the color attribute of a sample itself is the spectrophotometric curve.

The eyes of individuals which are the third factor in appearance of color, vary quite widely in color perception. One reason for this is the phenomenon of color blindness. Colors which are confused by one person may be easily identified and distinguished by another person. Another factor which leads to differences is the age of the observer.

As the observer grows older, a yellow pigment develops in the eye and this has the effect of giving a sample the appearance of being viewed under tungsten light. Thus an old person and a young person may look at two samples under north sky light and the younger observer may find that the two samples look alike; but the older observer because of the yellow pigment in his eye is effectively viewing them under tungsten light where there may be mismatch and he may call the two samples different. An imaginary person with average eyesight, the so-called standard observer, has also been internationally adopted.

The process of observing color is thus a complex one involving all the variations of the illuminant, the sample, and the human eye. The only way that one can be sure that two samples will look alike to all observers at all times is to have their spectrophotometric curves identical, and even this must be qualified by the statement that they possess equal fluorescent properties and geometries.

There are two methods of mixing colors to get a desired new color. One is the additive method of color mixture, and the other is the subtractive method of color mixture. In the additive method of color mixture, one starts out with no light at all, and adds to the amount of light which the observer can see. This method is the basis of the tristimulus specification, but is of lesser interest to the cosmetic colorist because the cosmetic colorist

usually has the reversed problem of beginning with a source of light such as daylight, and having the problem of adding a dyestuff or several dyestuffs to an object to remove part of the white light. This is the principle of subtractive colorimetry, namely, to start out with white light and selectively remove parts of it by means of dyes or pigments.

Color matching is still an art rather than a science. By far the great majority of all color matches produced in industry are produced visually rather than by means of instruments. In practicing this art, the cosmetic color matcher will find the publications of Mr. W. H. Peacock particularly helpful. (Reference is made specifically to Calco Technical Bulletin No. 573 entitled "The Practical Art of Color Matching" by William H. Peacock; and Calco Technical Bulletin No. 715, "The Application Properties of Certified Coal Tar Colors" by William H. Peacock.) A useful concept in visual color matching is the color triangle which has red, yellow and blue at the points of the triangle. These are the primary colors. Equidistant between these three points, in the middle of the triangle, is the spot which is labeled "black." This is formed by mixing all three primaries together. Equidistant between any two primary points are three more points on the side of the triangle; the one midway between red and yellow is "orange"; the one mid-way between yellow and blue is "green"; and the one mid-way between blue

and red is "purple." This indicates that mixing a red and a yellow dye or pigment together will produce an orange color. This concept will be found very helpful in color matching. For instance, if someone has a standard red shade, and a sample which looks different from the standard, the question to ask is—in what manner does the sample differ from the standard? Suppose, for instance, that the standard is a red. With this color triangle in mind, the color matcher should ask himself if the sample differs from the standard red by being more of an orange; or if it differs by being more of a purple. Whichever way it differs, the sample can be brought to a match by adding the opposite color. Thus if the sample is tending toward an orange, then a purple pigment or toning color must be added to correct the shade. It is clear from this triangle that dark colors, such as greys and browns, can differ from the standard in at least three different directions, tending toward the three different primaries. Once this direction of divergence is established, the opposite color must be added to bring it back to shade.

A small percentage of color matching is done spectrophotometrically. Such color matching can be directed toward either one of two objectives. One objective might be to duplicate exactly the spectrophotometric curve of a standard. This is highly desirable, because in this case, the sample and standard will look alike to any observer under any condition of illumination. It is also possible,

though more complicated, to direct the color matching toward producing a visual color match to the standard observer under a standard illumination, although the spectrophotometric curves do not have to be alike. As an illustration with transmission data, the transmission curve of a blue glass filter is given by the spectrophotometric curve relating transmission to wave length. Similarly, the spectrophotometric curve gives the same kind of data for a yellow filter. If these two filters are in series, that is if the light passes first through one and then through the other, then the resultant curve may be obtained by multiplying the transmission of one filter by the transmission of the other. For instance, let the light pass first through the blue and then through the yellow filter. Suppose that at 500 millimicrons, 70% of the incident light is transmitted by the blue filter. Now let us further suppose that the transmission of the yellow filter at this wave length is 40%. Forty per cent is then the fraction of the blue transmitted fraction, which is transmitted by the yellow filter. The product of these two numbers, or 28%, is the portion of the initial light which passes through both filters. By multiplying the transmission curves of the filters together, wave length by wave length, the resulting transmission of the combination is found. It does not matter whether the light passes first through the yellow filter and then through the blue, or in the reverse order. In preparing a colored solution which must be green, it is possible to add first a yellow dye to the solution, and second a blue dye to the solution. It does not matter whether the light passes first through the yellow and then through the blue, or whether it passes through both of them simultaneously. Thus the color of the solution can be predicted from the color of the individual dyes used to make up the solution.

A similar situation holds for reflectance work, only it is more complicated. In reflectance work, there are two processes that affect the light; one is absorption and the other is scattering. In order to get a high reflection, it is necessary to have a material of low absorption and high scattering power, such as one of the white pigments. On the other hand, in order to get a dark sample, it is necessary to have a low scattering power, and a high absorption. Some prediction of colors of reflectance samples have been made, calculated on the basis of the reflectance of the individual pigments involved, but this kind of work is still in the experimental stage.

There are a number of factors involved in the judging of color effects, which the cosmetic color matcher must keep in mind. These factors are too numerous to elucidate here, and anyone interested is referred to the Calco Technical Bulletin No. 573 by W. H. Peacock, which lists and discusses twenty-two of these factors. One of the most important of these factors discussed by Peacock is partial solubility.

Most colorists in the cosmetic trade have trouble obtaining the same color in successive batches of a product. Two lots made with identical ingredients and used in identical proportions may yet vary in final color. This variation is especially probable when mixed colorants are employed that are largely insoluble in the vehicles used—for one reason, because of differences in the degree of dispersion of the colorant in each batch. For example, suppose a red and an orange pigment were used in a lipstick base, if in one run 95% of the red pigment and 90% of the orange pigment were dispersed, and in the succeeding run 88% of the red pigment and 95% of the orange pigment were dispersed the two batches would not appear alike in color even though the same weighed amounts of pigment were used. Similar effects are possible in cake powder mixtures. The wettability, texture and oil absorption of the colorant and other ingredients are additional influencing factors. With soluble dyes the final color effect is influenced by the solubility, concentration, and capillarity features of the colorant.

Color matching is very definitely an art, and the man who does color matching of cosmetics must be a highly skilled artisan.