TINTED FILMS FOR SOUND POSITIVES

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POSITIVE motion picture film on tinted support has been available for many years. It has been used extensively; in fact during some periods within the past few years eighty to ninety per cent of the total production has been printed on tinted positive film. There is little doubt that the employment of material which imparts a pleasing and variable color to the screen adds to the beauty of the production, breaks the monotony of looking for long periods at a plain black and white picture, and softens harsh outlines which otherwise may produce unpleasant impressions. But of much greater importance than these rather incidental æsthetic contributions of color is its great potential power to enhance, by either objective or subjective association, the emotional significance of the scene with which it is associated. It must be admitted that the language of color—the more or less precise evaluation of the emotional value of the various hues, tints, and shades—is at present in a very rudimentary stage of evolution. Correlations are in many cases subconsciously *felt* without being consciously *defined*. It is entirely possible, and in fact probable, that careful study and experimentation may lead to the development of this language or symbolism into a powerful emotional tool in the hands of the master motion picture dramatist.

Recent scientific advances have made possible the reproduction of sound along with the motion picture, the sound record, consisting of a series of photographic images varying in either density or width, being carried on the edge of the positive film band. Although this has added enormous possibilities to the dramatic power of the motion picture, it has made it impossible to continue the use of the tinted positive films which have been employed during past years. The recorded sound is reproduced by the action of light which passes through the record on the positive film and excites a photo-electric cell. The majority of dyes used in making these tinted bases absorb strongly those wave-lengths of radiation to which the photo-electric cell is most sensitive. Hence the response of the cell is so reduced

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in magnitude that high amplification of the photo-electric currents is required to obtain sufficient volume of sound. This high amplification may increase unduly the inherent cell noises and microphonic disturbances in the amplifier so that the reproduced sound is of intolerably poor quality. As a result, the use of tinted film has been entirely discontinued in the production of positives carrying a photographic sound record. There is little doubt that this absence of color from the screen constitutes a serious impairment of the beauty and dramatic power of the screen production. It is desirable, therefore, that a means be found for producing a tinted positive film which, when used in making sound positives, will not interfere with the satisfactory reproduction of the sound record carried thereon.

All-over Tints vs. Clear Sound Track

This problem can be solved provided coloring materials can be found which, while absorbing a relatively small amount of that radiation to which the photo-electric cell is most sensitive, will produce, by selectively absorbing the radiation to which the eye is sensitive, colors or tints of the desired hue and brilliance. These dyes, or carefully determined combinations of dyes, can be applied to the film base in the usual manner and thus enable the manufacturer to offer a product at no greater cost than the regular clear base positive film.

Another solution of the problem lies in applying the tinting dyes to the film band in such a manner as to leave untinted a narrow strip of proper dimensions and position on the film band. The sound record can then be printed on this uncolored area and the sound will be satisfactorily reproduced without interference of the tinting material. Unfortunately this method involves a greater cost of manufacture, since the tinting dyes must be applied to the individual 35 mm. strip after the base has been emulsion coated and cut into narrow widths. It is obvious that technically this represents the most satisfactory solution. This was recognized by us some considerable time ago and applications were made for patents to cover the idea. Methods and machines for accomplishing this have been devised which give very satisfactory results and it is probable that this material will be available in the near future.

The first solution suggested, namely, the use of dyes or other coloring materials applied over the entire area of the film and so adjusted spectrophotometrically as to transmit freely the radiation to which the photo-electric cell is sensitive, seemed worth further study, and after a rather lengthy series of experiments a number of satisfactory tints have been obtained. These represent the entire gamut of hue and, in our opinion, are of the most satisfactory depth or color saturation for use in applying color to the motion picture screen.

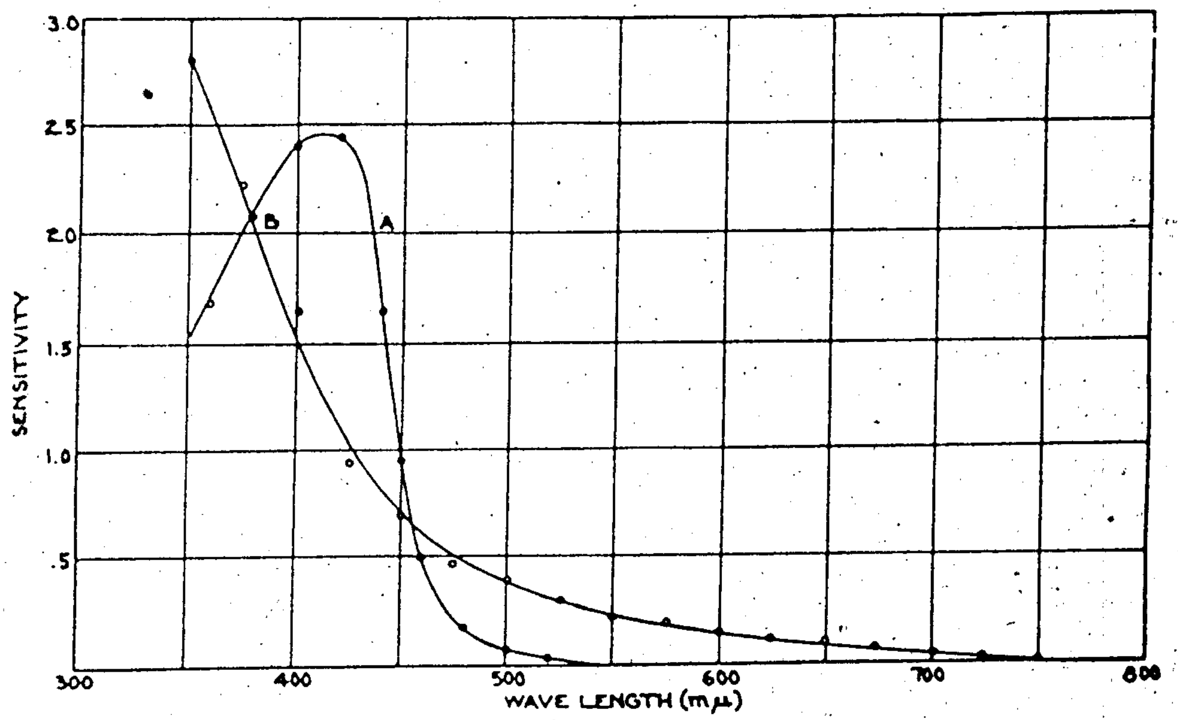

FIGURE 1. Spectral sensitivity curves for (*A*) potassium gas-filled photo-electric cell, (*B*) caesium photo-electric cell.

Color Sensitivity of Different Photo-electric Cells

In approaching the problem of selecting dyes for this purpose it is necessary, first of all, to determine just what wave-lengths of radiation most strongly excite the photo-electric cell with which the tinted material is to be used. It is necessary, therefore, to determine the spectral sensitivity of such cells. Photo-electric cells may be made by using any one of several different materials, such as potassium caesium, sodium, and other alkali metals. These may be of either the evacuated or the gas-filled type. The spectral sensitivity depends upon many factors and as a result cells differing enormously in spectral sensitivity are available. To the best of our knowledge, however, there are only two types of cells used extensively in commercial installations for the photographic reproduction of sound. One of these, manufactured by the Western Electric

Company and used in the equipment installed by the Electrical Research Products Incorporated, is of the potassium gas-filled type. The other, used in the equipment installed by the Radio Corporation of America, is of the caesium type.

In Fig. 1 are shown the spectral sensitivity curves of these two cells, curve A being that for a potassium and curve B that for a caesium cell. The ordinates of these curves are proportional to the photo-electric currents generated when excited by equal amounts of energy of the wave-length as indicated by the abscissa values. The proportionality constant used in blotting these curves is not the same for the two cells; hence these curves cannot be interpreted as indicative of the relative total sensitivities of the two cells. They do show, however, the way in which sensitivity varies with wave-length, and this is the information in which we are particularly interested at present. The monochromatic radiation used in the determination of these sensitivity functions was of high spectral purity, being obtained by using two monochromatic illuminators operated in tandem so as to effectively eliminate all scattered radiation. The photo-electric current generated was measured with a high-sensitivity galvanometer. The amount of energy incident upon the photo-electric cell was measured by means of the thermopile

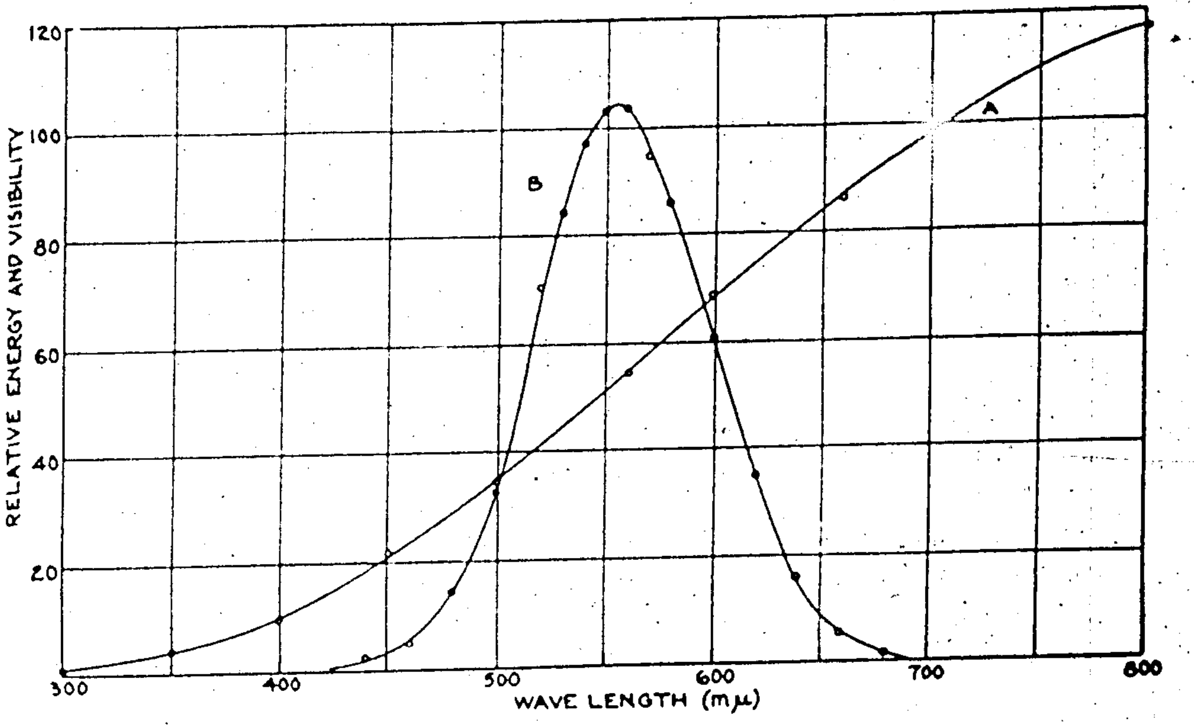

FIGURE 2. Visibility and tungsten energy (3000°K): (A) relative energy of radiation from tungsten at 3000°K; (B) visibility of radiation (relative brightness for equal energies).

and high-sensitivity galvanometer. Since the thermo-electric current is directly proportional to the energy incident upon the thermopile (regardless of wave-length) it follows that the sensitivity of the photo-electric cell, defined in terms of the photo-electric current per unit of energy, is directly proportional to the ratio of the photo-electric current to the thermo-electric current, P_c/T_c. Every precaution was taken to eliminate all possible errors and it is felt that the curves shown in Fig. 1 represent with high precision the sensitivity of the cells in question. The author is indebted to Dr. Otto Sandvik of these laboratories for these data.

The curves in Fig. 1 show the relative magnitude of the photo-electric currents resulting from the action of equal amounts of energy of different wave-lengths. In practice, the photo-electric cell is excited by an incandescent tungsten lamp which does not emit equal amounts of energy at all wave-length. To obtain the effective spectral response curve it is necessary to know the spectral distribution of energy in the radiation emitted by the incandescent tungsten lamp. This depends upon the temperature at which the filament is operated. In commercial sound reproducing installations this is approximately 3000°K. In Fig. 2, curve A shows the relative intensity of the radiation emitted at different wave-lengths for this source. It will be noted that relatively little energy is emitted in the short wave-length region to which the photo-electric cells are most sensitive, while relatively large amounts of radiation are emitted at longer wave-lengths.

In Fig. 3 are shown the effective spectral response curves for each of the two cells when used with a tungsten lamp operating at 3000°K. The ordinates of these curves are determined by multiplying, at each wave-length, the ordinate of the sensitivity curve (see Fig. 1) by that of the tungsten energy curve, Fig. 2.

It will be noted that the response curve of the potassium cell (A, Fig. 3) has a relatively high sharp maximum at wave-length 425 mμ. It decreases rapidly for both longer and shorter wave-lengths, reaching a value of 10 per cent of the maximum at 490 mμ, on the one hand and 340 mμ (estimated) on the other. The effective response curve for the caesium cell is shown in Fig. 3, curve B, and is of a broad flat type having a maximum at 420 mμ. For longer wave-lengths the response decreases gradually reaching a value which is 10 per cent of the maximum at approximately 750 mμ.

The response at 700 mμ, the long wave-length limit of the visible spectrum, is 35 per cent of that at the maximum. It will be noted that the maximum of response is at practically the same wave-length for these two cells, although the caesium cell has a much broader spectral sensitivity than the potassium cell. It is evident from a consideration of these response curves that any coloring material which absorbs strongly in the region between 400 and 500 mμ will have a relatively high density if measured in terms of this photo-electric cell and a tungsten lamp. These wave-lengths impinging on the retina give rise to the colors described qualitatively as violets and blues, and if these wave-lengths are absorbed from white light the remainder produces a yellow color. Yellow dyes in general therefore have high photo-electric densities. This is true qualitatively for both cells although it applies with much greater force in case of the potassium cell which has a relatively narrow sensitivity band in the short-wave region. As a result of the difference in shape of the response curves, certain colors, such as yellows, give relatively lower photo-electric densities when measured with the caesium cell than when this quantity is determined by means of the potassium cell.

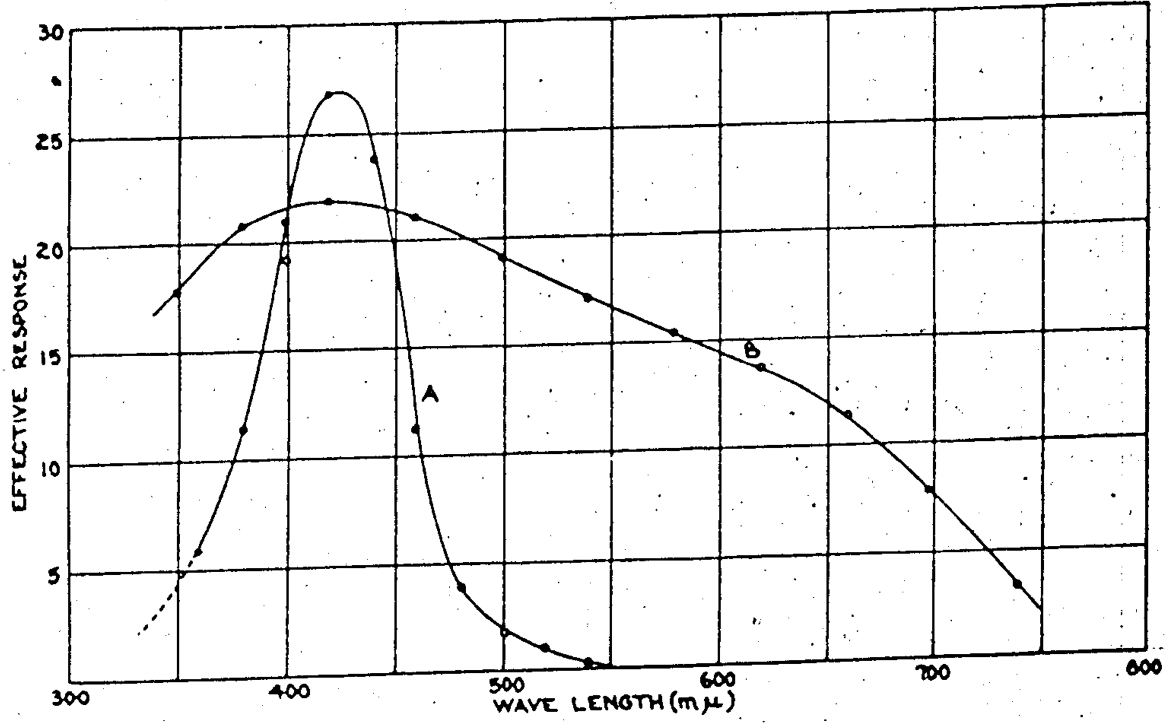

FIGURE 3. Effective spectral response curves when using a tungsten lamp operating at 3000°K: (A) potassium cell; (B) caesium cell.

Color Sensitivity of the Eye

The eye is a receptor of the synthetic type and does not analyze a heterogeneous radiation into its component parts. The sensation arising from the impingement of heterogeneous radiation on the retina has a single hue characteristic, and identical sensations of hue may be excited by heterogeneous radiations differing very widely in actual spectral compositions as determined spectrophotometrically. It is evident, therefore, that there is a possibility of obtaining a desired color by several different types of spectral absorption curves. Since the radiation required to actuate the photo-electric cell is localized in a very definite wave-length region, it follows that the course to be pursued in the solution of the problem in hand is to select absorbing materials which most efficiently transmit these wave-lengths and at the same time most completely absorb those wave-lengths which, when subtracted from white light, operate most efficiently toward the production of a color having the desired hue and saturation characteristics.

In order to proceed most directly and logically in this direction, knowledge of the visibility of radiation is of considerable importance. This knowledge is of assistance in deciding just what particular type of selective absorption will most efficiently produce a desired color and, at the same time, most efficiently transmit those wave-lengths which are required to excite a photo-electric cell. Curve B in Fig. 2 shows this visibility function, the ordinates being proportional to the magnitude of the visual sensation produced by the action on the retina of equal intensity of radiation of the various wave-lengths, as indicated by the abscissa values.

By judicious choice of dyes and dye mixtures which give spectral absorptions correctly adjusted with respect to the photo-electric response and to the retinal sensitivity, it has been found possible to produce a series of colors having hues distributed throughout the entire hue scale and at the same time having relatively low densities as measured with either the potassium or the caesium photo-electric cell-tungsten lamp (3000°K) combination.

As a preliminary to this work a careful spectro-photometric analysis showing the selective absorption characteristics of several hundred available dyes was made. It was soon found that it would be quite impossible to produce colors of the red-orange-yellow group without absorbing some of the radiation to which these photo-electric cells are most sensitive. The question then arose as to the absorption permissible in practice. There are really two phases to this particular problem, one involving a determination or decision as to the magnitude of photo-electric absorption for which satisfactory compensation can be made by increasing amplification without encountering serious electrical difficulties or sacrifice of quality in the reproduced sound. The other involves a consideration of the volume change which takes place in passing from one color to another when these are assembled consecutively in a reel of sound positive.

Permissible Range of Photo-electric Density of Tints

A large number of experiments were made in this laboratory to gather information upon which a rational decision relative to these points could be made. After having reached conclusions as to satisfactory values for maximum and minimum photo-electric density values, the matter was discussed with several authorities in the field of photographic sound reproduction, communicating engineering, and acoustics. The opinions from these individuals corresponded surprisingly well with those based upon our experimental results. There seems to be no difficulty encountered in increasing amplification to compensate a photo-electric density of 0.3. This photo-electric density can be looked upon as equivalent to a certain loss of volume which in turn can be expressed in terms of transmission units (decibels). In order to convert a density value, density being defined as the logarithm of the reciprocal of transmission, to equivalent decibels it is only necessary to multiply by 20. Thus if an optical density of 0.3 (measured, of course, in terms of the photo-electric cell and tungsten lamp combination being used) be inserted between the exciting lamp and the photo-electric cell it will be necessary to increase the amplification by 6 decibels in order to obtain the same volume output. On commercial equipment the volume control is adjustable by steps, in some cases each step corresponding to 2 decibels, and in others to 3 decibels. Thus, the use of a tinted film base having a density of 0.3 will necessitate advancing the volume control by either 2 or 3 steps. This represents a relatively small percentage of the total amplification, and there seems to be little doubt that the required increase in amplification can be obtained satisfactorily.

Permissible Volume Changes

The permissible change in volume occurring in passing from one tint to another is, in the last analysis, dependent upon the sensitivity of the ear to changes in volume. Under ideal conditions of observation, the change in loudness corresponding to a volume change produced by one decibel variation in amplification is just perceptible. It should be remembered that this change is perceptible only under ideal conditions. The situation is similar to that which exists relative to photometric sensitivity, that is, the sensitivity of the eye to differences in brightness. For instance, in a photometric field where the two halves are immediately juxtaposed in such a manner that when the two parts of a field are identical in brightness the division line is invisible, a difference in brightness of 2 per cent (actually 1.7 per cent) is just perceptible provided that the field subtends a visual angle of 3°, that the brightness level is optical, and that all disturbing factors are removed. Such ideal conditions seldom exist in practical work, however, and it is customary to regard a brightness difference of 5 per cent as the least difference which is of importance. Similarly, in the case of oral sensitivity, when the comparison is made between pure tones of the same frequency immediately juxtaposed in time and of a loudness to which the ear is most sensitive, one decibel is just perceptible. In practice, however, it is probable that 2, or even 3 decibels constitutes a more rational specification of the amplification change which will produce a just noticeable difference in volume. On assuming, therefore, that a section of uncolored base is followed by a colored base having a photo-electric density of 0.3, the change in volume of 6 decibels will represent two, or perhaps three, just noticeable differences. Although this variation in most cases may not be unduly objectionable, it is felt that it is somewhat too great to meet the most rigid requirements. It is therefore proposed to establish also a lower density limit of 0.10 and to adjust the selective absorption of all the members of the series so that none shall have a density less than this value. Furthermore, it is proposed that when a hueless screen is desired a positive film tinted with a neutral (non-selective) dye be used. The photo-electric and, incidentally, the visual density of this is adjusted to a value of 0.10 corresponding to 2.0 decibels. If this material is used in conjunction with one having a density of 0.3 the volume change occurring at the transition from one to the other will be that corresponding to a change in amplification of 4.0 decibels. This total change is a little greater than the volume change which under practical conditions is just noticeable, and is certainly less than two such steps. It is felt that volume changes of this magnitude are entirely negligible in practical work, especially since a change from one tint to another usually occurs with a scene change at which point a slight volume change may logically be expected.

It is of interest to apply this reasoning also to the case of maximum permissible density discussed in the previous paragraph. It will be recalled that a value of 0.3 for photo-electric density was fixed as being a reasonable upper limit. The amplification change required to give the same volume with such a film, as compared with clear base positive, is 6 decibels, which corresponds to two or perhaps three just noticeable volume differences. It is evident that this represents a relatively small increase in amplification and that no serious difficulty should be encountered in raising amplification sufficiently to compensate for the use of a colored base having a photo-electric density of 0.3.

The conditions which have been established, relative to permissible photo-electric density of tinted base for use in making sound positives, may be summarized as follows:

Maximum photo-electric density 0.3, amplification increment 6 decibels.

Minimum photo-electric density 0.10, amplification increment 2 decibels.

Maximum variation in density 0.20, maximum volume variation 4 decibels.

It should be understood that the values of density specified above are relative to clear film base taken as equivalent to a transmission of 100 per cent, density 0. It seemed desirable to express all results in this manner since the factors of interest are those relating to the changes of photo-electric transmission, volume, etc., as compared to the conditions existing when the sound record is carried on a clear film base.

Visual Characteristics of the Seventeen Tints

In Table 1 are given data relative to the visual characteristics of these tinted materials. Considerable thought has been given to the names by which these tints are to be designated. It seems desirable, from a consideration of the probable associational and emotional value of color when applied to the motion picture screen, to designate these tints by names suggestive of their potential psychological effects and appropriate uses. This particular phase of the subject will be discussed in greater detail in a later section of the paper. In the column designated as "λ" under the title "Hue" are given the values of the dominant hue expressed in wavelength. These determinations refer specifically to the color of a white screen when illuminated by light from an arc of the reflector type with the tinted base placed between the light source and the screen. It therefore is a specific designation of the screen color obtained when these materials are used with a light source of this character. It is realized that in practice a certain variation in these hue values will result from the use of light sources differing from the one with which these hue measurements were made. For instance, with a high intensity arc of either the condenser or the reflector type, the color of the emitted light is probably slightly bluer than that emitted by a reflector arc using ordinary hard-cored carbons. Under these conditions the hue values will be shifted slightly. The difference, however, is so little as to be considered negligible

TABLE I

Visual characteristics of the series of tints

No.	*Color Name*	*Hue*		*T*	*Description*
		λ	*No.*	%	
0	Clear base	—	—	100	**Hueless, clear**
1	Rose Dorée	633	1.0	57	**Deep warm pink**
2	Peachblow	619	4.0	61	**Flesh pink**
3	Afterglow	603	7.5	66	**Orange**
4	Firelight	596	12.0	66	**Yellow-orange**
5	Candleflame	585	17.5	75	**Orange-yellow**
6	Sunshine	579	23.0	83	**Yellow**
7	Verdante	520	36.0	57	**Green**
8	Aquagreen	505	40.0	40	**Blue-green**
9	Turquoise	490	43.0	46	**Blue**
10	Azure	484	47.0	28	**Sky-blue**
11	Nocturne	476	51.0	28	**Violet-blue**
12	Purplehaze	455	56.5	38	**Blue-violet**
13	Fleur de lis	—575	60.0	25	**Blue-purple**
14	Amaranth	—557	64.0	31	**Red-purple**
15	Caprice	—537	67.5	53	**Cool pink**
16	Inferno	—508	71.5	36	**Red-magenta**
17	Argent	—	—	71	**Hueless**

from the practical standpoint. If these materials are used in a projector employing a high efficiency tungsten lamp there will probably be a rather great departure from the hue values indicated in Table 1. This light is much yellower than that emitted by the arc

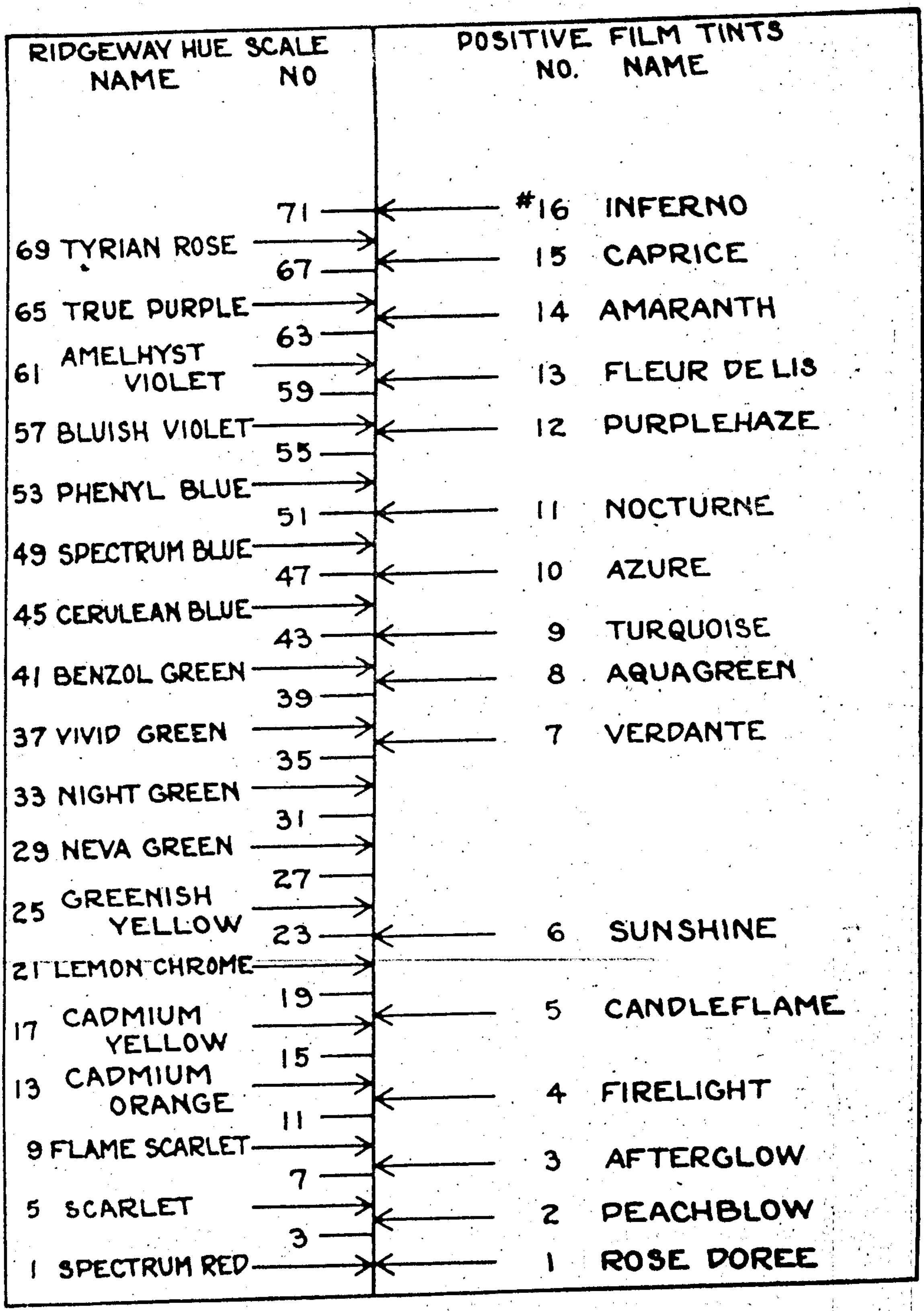

FIGURE 4. Positions of the tints on the Ridgway Hue Scale.

and hence the use of a screen illuminated by a tungsten lamp in conjunction with these tinted bases will give appreciably different hues from those indicated in Table I. In the column designated as "No." under "Hue" are the Ridgway hue numbers. The system of color nomenclature developed by Ridgway[1] is one of the best available. The entire hue gamut, including the spectral hues and the non-spectral purples, is divided into 72 hue steps. These hue steps are equally placed on the sensation scale.

Tints Evenly Spaced Along Normal Hue Scale

In setting up a scale of hue it is not satisfactory to adopt intervals which are identical in wave-length difference because the sensitivity of the eye to hue differences varies enormously throughout the spectrum. In order to establish a normal hue scale in which the steps are equal in terms of sensation, it is necessary, therefore, to use wave-length intervals differing widely in magnitude. It will be noted that, with the exception of a region in the orange, yellow, and yellow-green, the hues of these tinted materials are fairly evenly spaced on the normal hue scale. It seems highly desirable to adopt such spacing, since it makes available the entire gamut of hue and a change from one tint to another produces a hue displacement of known and fairly equivalent subjective magnitude. The positions of the dominant hues of these colors are shown graphically on the chart in Fig. 4. At the left are given the Ridgway hue numbers and the names applied by Ridgway to these hues when occurring in colors of high saturation. At the right in the first column are the numbers for the tinted positive films, and the names applied to these. It should be remembered that these colors are in general of relatively low saturation and it is considered that these more delicate tints are of greater utility for use in applying color to the motion picture screen than those of higher saturation. It is a rather peculiar coincidence that the colors corresponding to the hue numbers 25 to 35, which are absent from this positive film series, are those which, according to all of the available psychological data (see Lukiesh, *loc. cit.*), are the colors *classified* as least agreeable or least preferred. These color preference data are derived from a large group of observers and hence are very significant. It has been impossible thus ar to obtain these hues with sufficiently low photo-electric density.

Possibly further search may reveal dyes which will permit the manufacture of these hues if such seems to be necessary or desirable.

In Table 1, in the column designated as "T," are the values of total transmission for these colored materials as measured visually using the reflector arc as a light source. These values are therefore

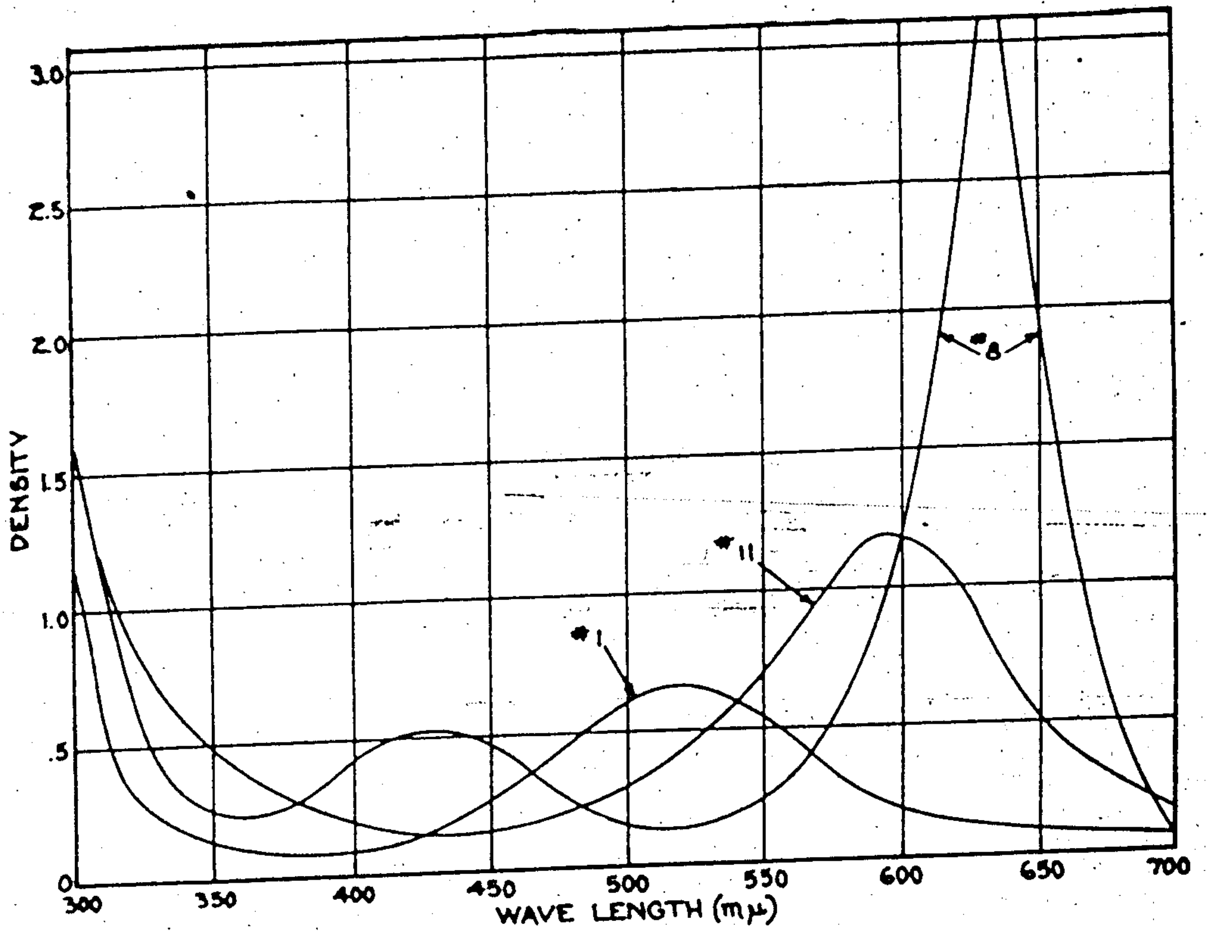

FIGURE 5. Spectrophotometric curves for Rose Dorée, Aquagreen, and Nocturne.

a direct measure of the screen brightness obtained when using these tinted materials as compared with the screen brightness existing when using clear base positive. It will be noted that the visual transmissions of the red, orange, yellow, and yellow-green colors are relatively high, while those of the green, blue, violet series are relatively low. This condition exists since it is desired to obtain fairly definite color saturation effects. It follows as a natural consequence of the visual sensitivity and transmission characteristics of dyes that the colors in the former group have relatively high visual transmissions for a specified color saturation, while the transmission values in the second group are in general low when a corresponding color saturation is obtained. In the last column are given short verbal descriptions of the color characteristics.

To show spectro-photometric curves for all of the seventeen members of this series seems unnecessary, but it may be of interest to consider two or three typical cases. In Fig. 5 are given such curves for tint No. 1 (Rose Dorée), a warm deep pink; tint No. 8 (Aquagreen), a clear blue-green; and tint No. 11 (Nocturne), a deep violet-blue. Inspection of the curves shows that each of these colors has a decided density minimum throughout all or some part of that wave-length region in which the photo-electric response is maximum. The minimum density does not fall at the same wave-length in each case but shifts with the demands of the selective absorption necessary for obtaining the desired visual hue.

TABLE II

Photoelectric density characteristics of the series of tints

	Film Tint	*Potassium Cell*		*Caesium Cell*	
		D	*T.U.*	*D.*	*T.U.*
0	Clear base	0.0	0.0	0.0	0.0
1	Rose Dorée	0.19	3.8	0.15	3.0
2	Peachblow	0.17	3.4	0.11	2.2
3	Afterglow	0.27	5.4	0.15	3.0
4	Firelight	0.27	5.4	0.11	2.2
5	Candleflame	0.24	4.8	0.09	1.8
6	Sunshine	0.27	5.4	0.06	1.2
7	Verdante	0.28	5.6	0.18	3.6
8	Aquagreen	0.26	5.2	0.27	5.4
9	Turquoise	0.10	2.0	0.24	4.8
10	Azure	0.09	1.8	0.27	5.4
11	Nocturne	0.09	1.8	0.28	5.6
12	Purplehaze	0.10	2.0	0.22	4.4
13	Fleur de lis	0.14	2.8	0.30	6.0
14	Amaranth	0.11	2.2	0.24	4.8
15	Caprice	0.09	1.8	0.14	2.8
16	Inferno	0.18	3.6	0.22	4.4
17	Argent	0.09	1.8	0.10	2.0
	Mean	0.176	3.5	0.184	3.7
	Maximum	0.28	5.6	0.30	6.0
	Minimum	0.09	1.8	0.06	1.2
	Maximum Δ	0.19	3.8	0.24	4.8

In Table II are given data relating to the photo-electric density characteristics of these materials for potassium and caesium cells of the types in extensive use in commercial installations. Density values are designated as "D," while in the columns designated as

"TU" are given the equivalent values in decibels, these representing the amplification increment required to compensate for the volume depression occasioned by the use of these materials.

It will be noted that the specifications relative to maximum density and maximum density difference previously set forth as desirable have been met in actual materials with a fair degree of precision. In case of the potassium cell the maximum density is 0.28 (No. 7, Verdante), slightly less than the value of 0.30 considered allowable, while the density difference between the upper and lower limits is 0.19 (equivalent to 3.8 decibels), also slightly less than that considered tolerable. With the caesium cell the maximum density is exactly 0.30 (No. 13, Fleur de lis), while the maximum difference is 0.24, not appreciably greater than the specified 0.20.

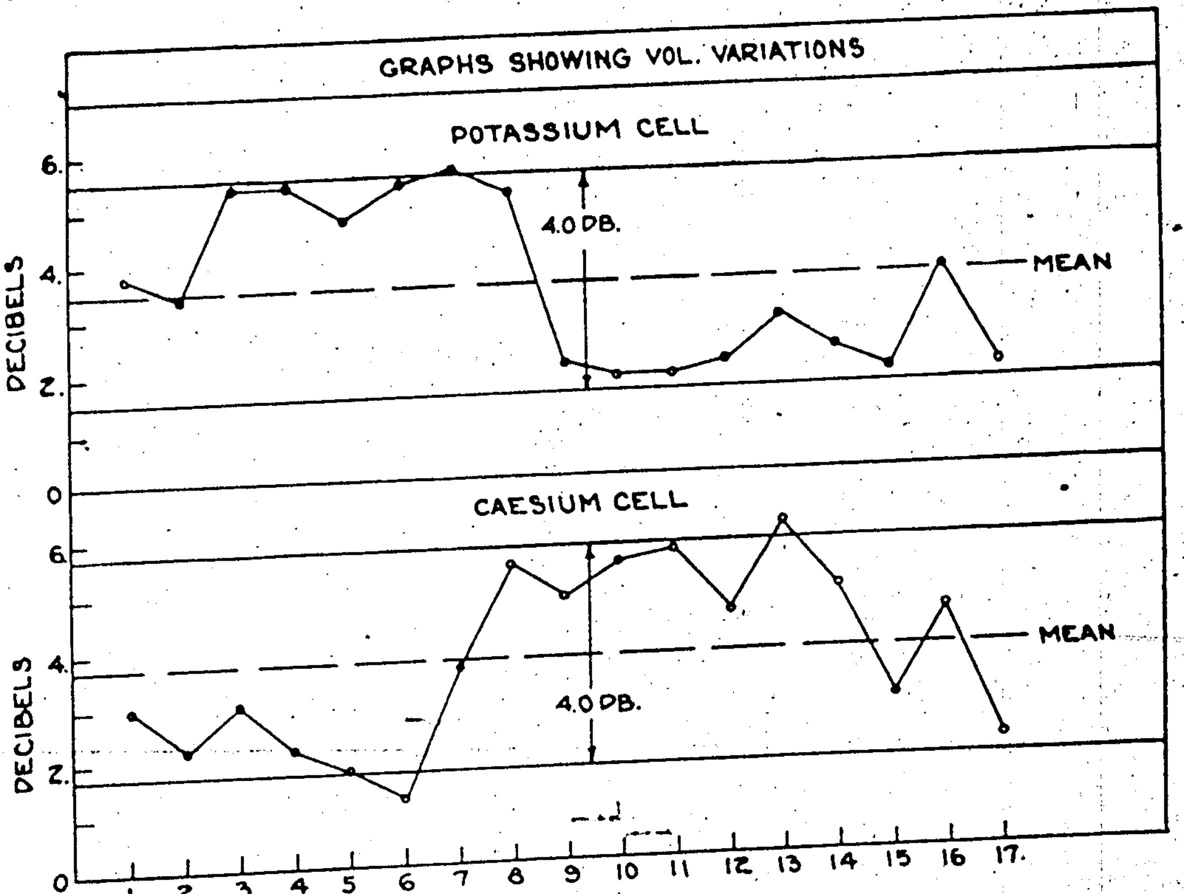

FIGURE 6. Volume variation resulting from the use of the series of seventeen tints.

The volume variation through the entire series of seventeen tints is shown in Fig. 6. The ordinates indicate the increase in amplification, expressed in decibels, required in each case to give the same volume output, with the tint as indicated by the numbers at the bottom of the figure, as compared with a sound record of identical characteristics on the regular clear positive film. Th horizontal lines are drawn at plus and minus 2 decibels from th mean of the entire group. These lines therefore define the allowable volume change as previously specified. In case of the potassium cell all of the tints fall between these limits; with the caesiu cell two of the tints fall slightly outside these limits.

Prints have been made on all of these colored bases and soun reproduction with each cell is considered satisfactory, both wit respect to the increase in amplification required and the maximu volume variation. It is hoped that the sound prints to be shown a little later will demonstrate this point to your satisfaction.

This concludes that part of the paper which may be designated as technical, dealing, as it does, with the objective or physical characteristics of tinted positive film base. The application of these colors to a motion picture production involves the consideration of a radically different group of relationships belonging to that phase of the motion picture industry which has been designated, for want of better term, as artistry.[2] While it may be presumptuous on the part of the author of this paper to invade a field so remote from that of his accustomed activities, he feels that there may be some members of the Society more concerned with the artistic and emotional reactions than with the cold facts of scientific technology, who may be interested (or perhaps amused) by some thoughts and suggestions as to the possible emotional and artistic value of color applied to the motion picture screen. Some of you may have been present on one or two previous occasions when the author has had the privilege of presenting to this Society papers, written in collaboration with Townsend[3] and Tuttle,[4] discussing the use of color in more or less abstract static and dynamic forms as a valuable element in a motion picture program. You are already aware, therefore, that he has long been interested in the possibilities of color as an aid to the creation of dramatic atmosphere. In fact he is firmly convinced that color *per se*, if properly employed, may exert a powerful influence on the emotional reactions. He therefore begs your indulgence while in the following pages a few ideas along these lines are presented for your consideration.

The Language of Color

The literature pertaining to the language, symbolism, and emotional effects of color, though scattered and fragmentary, extends over the entire period of recorded history. Mythology is replete with the symbolism of color. On the Greek stage the colors of the costumes were adjusted to the mood of the action. Color is intimately associated with the entire history of the Christian Church and a very definite color symbolism has developed. Color has been so inseparably linked with sensory experience throughout the evolution of mankind that it has acquired by objective and subjective association definite and important emotional value.

No attempt can be made within the confines of this paper to give anything approaching a complete bibliography of the subject. One or two references, however, may be valuable to those interested. Field in his *Chromatography*[5] discusses various colors from the standpoint of their emotional value and gives numerous references tending to show rather general agreement as to the character of such effects. A quotation given by Field[6] from Opie,[7] an English artist of the late 18th century, is of particular interest.

"Every passion and effection of the mind has its appropriate tint and coloring, which if properly adapted, lends its aid, with powerful effect, in the just discrimination and forcible expression of them; it heightens joy, warms love, inflames anger, deepens sadness, and adds coldness to the cheek of death itself."

The most recent, complete, and by far the best publication on this subject is that by Luckiesh.[8] This is a carefully considered conservative treatment in which are given numerous data collected from many fields along with the valuable contributions of the author to this subject. The book will repay careful study and is earnestly recommended to the attention of those interested. The following quotation[9] is of interest as it indicates the attitude of the author toward the subject and is an admirable statement of the point of view which should be taken by any investigator in a little known field.

"It would be unscientific to deny the existence of a language of color because we do not understand it thoroughly at present and quite unprogressive to reject the possibility of finally completing the dictionary of this language. Color experiences are indeed very intricate at present but it is likely that this is due to our scanty knowledge of the elements and processes involved in the emotional appeal of colors, and to our inability to interpret and to correlate properly the various factors. Much knowledge must be unearthed before a rudimentary dictionary of this language is available but first the scientific attitude should admit the possibility that the language of the group of experiences associated with color eventually will be understood."

In considering color from this point of view it must be remembered that we are now dealing with color as it appears, that is, the sensation evoked in consciousness, rather than with the objective character of color as determined by its physical characteristics. All of the various factors, therefore, which determine the character of the subjective reactions, such as simultaneous contrast, previous retinal excitation, and many others must be considered in attempting to define the emotional reaction that may be induced by subjecting the eye to stimulation by radiation of known physical composition. Moreover, a color may, just as a word or phrase, have more than one emotional value or significance; and, as in the case of the spoken language, the intended meaning must be determined by the contextual factors such as general character of the scene structure, subject matter of preceding sequences, type of dramatic action, etc. For instance, a green matching in hue and saturation characteristics the color of spring foliage, may connote by direct subjective association, springtime, trees, grass, gardens, etc. Used on radically different types of scenes, however, such as interiors, it may be found particularly valuable for suggesting by indirect or subjective association certain more abstract concepts, such as youth, freshness, hope, aspiration, and those moods closely linked in our consciousness with the springtime of life.

Objective and Subjective Color Associations

A rather careful analysis of the admittedly rudimentary color language indicates that the great majority of existing connotations may be classified in two rather distinct groups which may be designated as *(a)* direct objective association and *(b)* indirect subjective association. It is relatively easy to quote many examples of the class *a* correlations. For instance, sunlight is quite definitely suggested by yellow. Now, as a matter of fact, sunlight is not yellow, and it has been shown definitely that when the retina is excited by sunlight or by radiation of identical spectral composition in a visual field from which all possible contrasting areas have been removed, the sensation evoked is hueless, that is, corresponding to gray or white. A white object, however, illuminated by sunlight under a clear blue sky appears yellow. It seems quite evident, therefore, that through centuries of evolution a definite conscious or subconscious relationship between sunlight and yellow has been so established that under artifical conditions yellow almost invariably suggests sunlight. Thus a motion picture scene printed on yellow base, such as tint No. 6 (Sunshine), should definitely suggest sunlight illumination whether it be an exterior flooded with light from the sun or an interior into which light is streaming through open doors or windows.

In a similar manner there seems to be a very definite relationship between other colors and the well-known artificial sources of heat and light. Artificial illumination of interiors is definitely suggested by a color which is either more saturated or has a hue somewhat more orange than the yellow suggesting sunlight. Firelight may be suggested by a color even more reddish in character. Such examples of objective association can be multiplied almost indefinitely. Subjective associational relationships are somewhat more tenuous and difficult to establish with certainty. Some of these undoubtedly have been built up in consciousness by somewhat artificial association of certain colors with definite emotional states. Others of these correlations may probably be traced to extensions of more direct associational factors. For instance, there seems to be a character of warmth associated with all of the colors in the yellow, orange, red, magenta category, while the remainder give a definite impression of cold or coolness. This is very probably an extension of the more direct associational value arising from the color of sunlight and fire and the atmospheric conditions normally associated with coldness. The association of color with certain temperamental phases of life, such as youth, maturity, old age, etc., can probably be traced to an extension of a more direct association with the seasons of the year. Space does not permit us to carry this analysis into greater detail, but a serious study of this subject can hardly fail to convince the fair-minded student that there is really some definite and psychologically sound relationships between colors and emotional states. Although a great deal of the work on this subject has been of purely qualitative, and perhaps temperamental type, there are available some rather definite and significant data. For instance, Luckiesh[10] *(loc. cit.* p. 200) gives some very interesting

TABLE III

Wells' data on the affective values of various colors

Total Number of Replies from 63 Subjects Indicating Three General Types of Mood-Reactions Due to the Twelve Different Colors

	Exciting Influence	*Tranquilizing Influence*	*Subduing Influence*
Crimson	41	0	10
Scarlet	56	0	0
Deep orange	59	0	0
Orange-yellow	55	6	0
Yellow	53	6	0
Yellow-green	14	39	5
Green	28	32	0
Blue-green	32	23	6
Blue	11	21	30
Violet-blue	0	17	45
Violet	0	6	54
Purple	3	1	48

data compiled by Wells[11] relative to the general types or mood reactions produced by twelve different colors. These data are shown in Table III. They are derived from sixty-three subjects and the correlation is indeed striking. There seems to be no escape from the conclusion that those colors designated as yellow, orange-yellow, deep orange, scarlet, and crimson have a definitely exciting influence. In the mid-spectrum yellow-green, green, and blue-green, seem to be definitely tranquilizing or soothing. Blue, violet-blue, violet, and purple are depressive or subduing. The student who approaches this subject with an open mind and with the intension of seriously searching for correlation factors can scarcely fail to be convinced that here is something of a very tangible nature which can be ascribed to a definite psychological reaction to color.

The chart in Fig. 7 shows the affective values of the various colors as computed from Wells' data. No definite information is available relative to the dominant wave-length of the colors used by him so they are plotted arbitrarily at equal intervals along the base line. The ordinates are computed from the data in Table III, each number being reduced to a percentage of the total number of decisions. The curves have the following significance: (A) curve of exciting influence; (B) curve of tranquilizing influence; (C) curve of subduing influence.

These curves are surprisingly similar in general shape and position to the three fundamental retinal excitation curves for red, green, and blue-violet. Although the present data are too meager to established any correlation between emotional effect and the retinal processes, the similarity is certainly sufficient to encourage some further consideration.

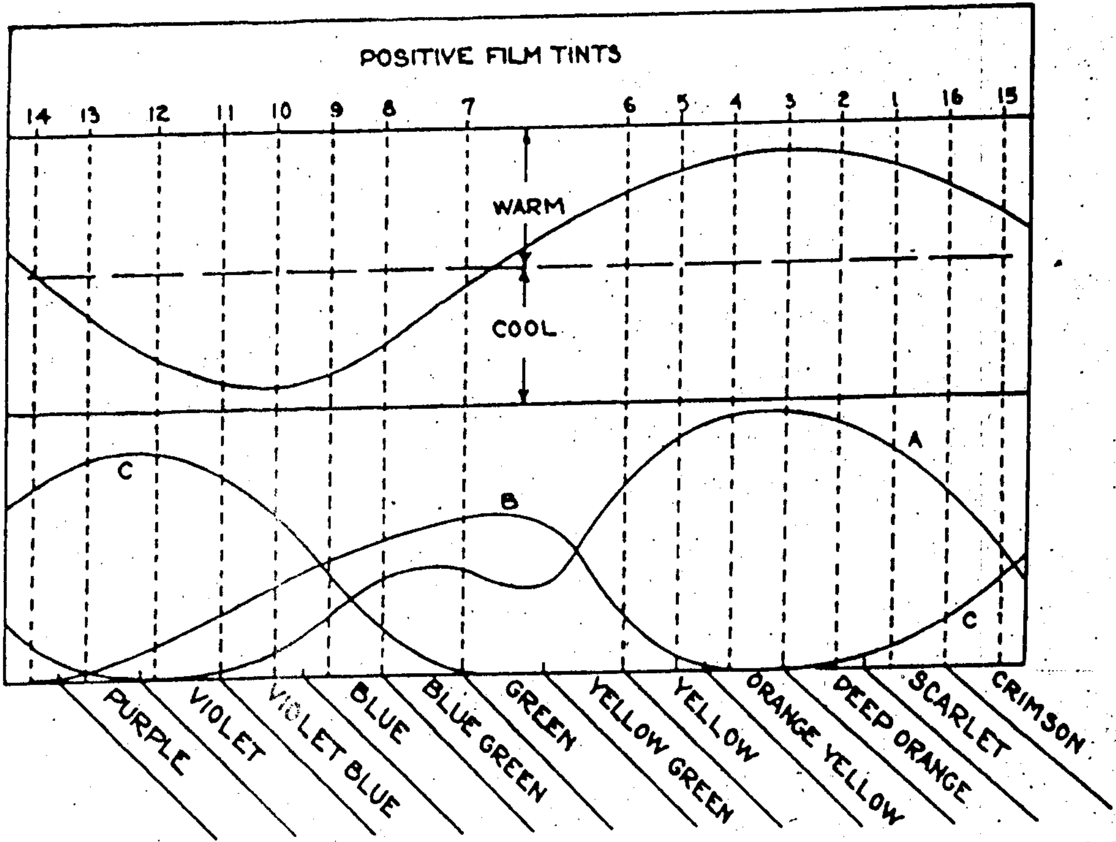

FIGURE 7. Affective values of the various colors computed from Table III: (A) curve of exciting influence; (B) curve of tranquilizing influence; (C) curve of subduing influence.

Along the top line of the chart are placed the numbers referring to the positive film tints, the position of each relative to the color scale at the bottom being determined as carefully as the qualitative data will allow. The dotted lines dropped from these points cut the three curves and the heights of these ordinates give some idea of the character and strength of the mood reaction which each color maye be expected to induce.

In the upper part of the chart is drawn a curve showing in a qualitative way the position on the warm-cool mood reaction scale. This, it must be confessed, is based on very insufficient evidence, being determined by the rather casual judgments by a few observers working under poorly controlled conditions.

Characterization of the Seventeen Tints

In the following paragraphs an attempt has been made to give a brief description of the visual and psychological characteristics of the film tints. It is evident that no very definite statements can be made or rigid specifications set up for the use of these colors. It is hoped that these rather disconnected and rambling remarks relative to the various colors may be of interest to those concerned with working out the application of color to the motion picture screen and serve as a foundation, however insecure, upon which something of real value may be built by others more qualified by training and temperament for such work. Although these characterizations of the symbolic and emotional values of these colors are necessarily tinged by the author's own reactions and by the results of his own introspective analysis, they are based, in so far as is possible, upon a careful summary and integration of data derived from the available literature. They should therefore represent approximately the reactions to be expected from the average observer.

Tint No. 17, Argent. This is a hueless color, a silvery gray showing no chromatic characteristics. It may be regarded as the zero or starting point on the scale of saturation or color strength. It is very necessary as a means of establishing a visual accommodation in terms of which a hue may be appreciated by contrast. It may be used to fatigue the eye to the point of monotony, after which the presentation of a hue will have enhanced effect.

Tint No. 6, Sunshine. A clear brilliant yellow approximately complementary to sky-blue, therefore quite closely matching the subjective color of sunlight when seen in contrast to blue sky. The visual transmission is high (83 per cent); therefore it is particularly adapted for use on a scene designed to give the impression of brilliant sunlit conditions and where an interior is obviously illuminated by sunlight entering through windows and open doors. This color is definitely warm but not to the same extent as Candleflame, Firelight, and Afterglow which make with this color a series increasing progressively in warmth. It is mildly stimulating, suggesting a mood of lively interest and attention, but not one of high excitement of nervous tension.

Tint No. 5, Candleflame. A pastel orange-yellow. It is slightly lower in transmission (75 per cent) than Sunshine, giving a screen more orange in hue and lower in brilliance which definitely suggests artificial illumination when used on interior scenes. Somewhat warmer than No. 6. Possibly useful on exteriors in suggesting morning or afternoon with less intense sunlight than prevails at midday. By objective association useful in inducing rather mild mood reactions such as feelings of coziness, comfort, intimacy, well being, peace and plenty without opulence, etc.

Tint No. 4, Firelight. A soft yellow-orange. This is warmer than Candleflame to which it is closely akin in mood reaction value. The lower transmission (66 per cent) gives a somewhat less brilliant screen and this with the more orange hue makes it particularly adapted for use on an interior scene where it is desired to suggest an artificial illumination softened and subdued perhaps by shaded lamps and candles. It is suggestive also of illumination eminating from an open fire; but it is not quite orange or red enough to satisfactorily render the fire itself if visible, for which Afterglow is perhaps better. It stimulates mood reactions of the same category as Candleflame but with greater intensity. Suggestive of warmth, comfort, intimate home relationships, mild affection, etc.

Tint No. 3, Afterglow. A soft rich orange color. It is probably the warmest color of the series. It is appropriate to exterior scenes at dawn and sunset. It lends to interiors an atmosphere of warmth and intimacy stronger than Firelight. It should excite mood reactions in general connected with luxury, wealth, security, and relatively strong affections. It is also related to the autumnal mood by obvious direct association with the autumn colors of nature. By indirect or subjective association it is symbolic of the same relative period in the life of an individual and its associated moods. It is indicative, therefore, of repose, ambitions attained, accomplishment, and similar psychological aspects of maturity.

Tint No. 2, Peachblow. A delicate flesh pink. This has a small but definite blue content, making it somewhat less warm than Afterglow. It is adapted to the rendition of close-ups where it is desired to do full justice to feminine beauty. The hue and saturation are such as to suggest the glow of life.

Tint No. 1, Rose Dorée. A deep warm pink suggesting sensuousness and passion. Amorous, romantic, and exotic. It is adapted to the rendition of scenes representing an intimate atmosphere, such as a luxuriously appointed boudoir. In keeping also with feelings of happiness, joy, and excitement.

Tint No. 7, Verdante. A pure green, rather pastel in character. It is the hue of spring foliage, suggesting directly trees, grass, and vernal landscapes. By subjective association typical of youth, freshness, unsophistication, innocence, etc. It is only slightly warm, but definitely not cold. It is very close to the neutral point in the warm-cool scale.

Tint No. 8, Aquagreen. A brilliant blue-green. The color of more northern waters and suitable to the rendition of the sea under clouds and in storm. It is suggestive of wetness. Its transmission (40 per cent) being lower than that of Verdante, it gives a less brilliant screen. This together with its greater blue tint probably makes it more suitable for the rendition of the darker green of mature foliage, dense forests of pine, jungles, etc. By extension from the objective correlation to summer it is suggestive of such mood reactions as pertain to maturity, wisdom, dignity, repose, and restfulness. It is cool but not cold; tranquil, but not subduing.

Tint No. 9, Turquoise. A clear brilliant blue. It is definitely cool, but less cold than Azure or Nocturne. The visual transmission (43 per cent) is high for a blue of this hue but low as compared to the warm colors. This gives a screen of depressed brightness which together with the hue tends to produce a mood of peace, reposefulness, and tranquility. It is the color of calm tropical seas under clear skies. It is suggestive of the Mediterranean and the South Sea Islands. If used on interiors it should impart a feeling of restfulness, dignity, and reserve without inducing appreciable depressive moods. With proper contextual influence it might be used for the suggestion of brilliant moonlight effects, although No. 10 may be somewhat better for this purpose.

Tint No. 10, Azure. A strong sky-blue. It is colder than Turquoise; tranquilizing to the point of becoming depressing. The visual transmission (28 per cent) is relatively low and hence gives a screen of low brightness. It is suggestive of the sedate and the reserved, even approaching the austere or forbidding; under certain conditions slightly gloomy.

Tint No. 11, Nocturne. Deep violet-blue. The visual transmission is low (28 per cent) giving a screen of low brightness. It definitely suggests night, shadows, gloom, coldness, etc. By subjective associational reactions appropriate to depressive conditions, despair, failure, unattained ambitions, intrigue, the underworld.

Tint No. 12, Purplehaze. A bluish-violet or lavender, rather pastel in character. It has a relatively high visual transmission (40 per cent) giving a screen of greater brilliance, higher key, than the adjacent tints, Nocturne and Fleur de lis, to both of which it is closely related in emotional value. The mood induced by this color is particularly dependent (more so than many of the other colors) upon contextual factors. For instance, to a twilight scene on the desert with distant mountains it imparts a feeling of distance, mystery, repose, and languorous warmth; used on a scene containing snow fields, glaciers, snow-capped mountains, etc., it has a pronounced cooling effect. The hue of this color is approximately the same as that of the shadows on sunlit snow under a clear blue sky.

Tint No. 13, Fleur de lis. A rich royal purple. This color has long been the badge of royalty, high office, power, and pomp. In ancient times the dye was very costly and was used to color the garments of the aristocracy. The transmission of this film tint is low (25 per cent), thus giving a depressed screen brightness suggestive of reserve, dignity, and austerity. It has a relatively cool color but not as cold as Nocturne.

Tint No. 14, Amaranth. This is also a purple but has a greater red content than Fleur de lis; therefore it is warmer and less austere. It is adapted to the rendition of scenes showing opulence and luxury together with refinement. With proper contextual relation it may be well adapted to scenes approaching sensuality and abandon, such as bacchanalian revels staged in settings of wealth, luxury, and elegance.

Tint No. 15, Caprice. Cool pink. Visual transmission (53 per cent) relatively high, thus giving a brilliant sparkling screen. It is a jolly, carefree, hilarious color suggestive of carnivals, Mardi gras, fête days, and merry making in general.

Tint No. 16, Inferno. Fiery red tinged with magenta. Since it is directly suggestive of fire, it is adapted to scenes of burning buildings, glowing furnaces, forest fires, etc. By subjective association indicative of riot, panic, anarchy, mobs, turmoil, strife, war, battle, and unrestrained passion.

Proper Use of Color on the Screen

It is not desired that the reader shall gain the impression from this rather enthusiastic discussion of the potential emotional value of color that the lavish and unrestrained use of color treatments is advocated. On the contrary it is desired to emphasize the necessity of using the color accompaniment to a motion picture production with care and discretion. The use of too strong or saturated colors is in general not good, since such colors are usually obtrusive and distracting and may defeat rather than promote the attainment of the desired effect. A more subtle method will yield better results. This involves the employment of pastel tints which may be increased in subjective strength for a brief period of time by the action of successional contrast or juxtaposition in time. Thus the eye accommodated to, or fatigued by a green, such as Verdante, will perceive, at the beginning of the following scene done on a pink tint, a color of enhanced subjective saturation. This immediately fixes the mood of the scene, after which the accommodational processes in the retina begin to operate and cause the effective saturation to decrease appreciably. Thus the color having fulfilled its mission, saying definitely that this scene has a specific emotional atmosphere, fades into the background and while continuing to make itself felt in the subconscious mind of the observer by lending a warmth and softness to the scene permits the action to carry forward the dramatic sequence without the unpleasant and distracting influence of pronounced color.

There are perhaps some who may question the advisability of attempting to use color on the screen as an aid to the creation of an emotional atmosphere on the ground that individuals react differently to the same color. Is it not true that the same musical composition may excite different feelings in individuals, and that the same word or phrase may convey to different minds somewhat divergent ideas? Perhaps it will be necessary to spend much time and effort on the development of a language of color, to compile dictionaries with definitions of the symbolical, associative, and emotional values, just as we write and agree upon definitions of words in order that specific ideas may be conveyed from one mind to another by spoken and written language. If there is in the human mind, or, more specifically, in the collective mind of the motion picture public, a color consciousness, even though it be at present latent or but slightly developed, is it not worth considerable effort in thought and experimentation to develop a technic such that color can be applied to the screen in such a way as to enhance the emotional and dramatic values of the motion picture of the future?

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