June 2, 1925. 1,540,098

F. K. BEZZENBERGER

PROCESS OF PRODUCING COLOR SUBSTANCES

Original Filed June 30, 1921 3 Sheets-Sheet 1

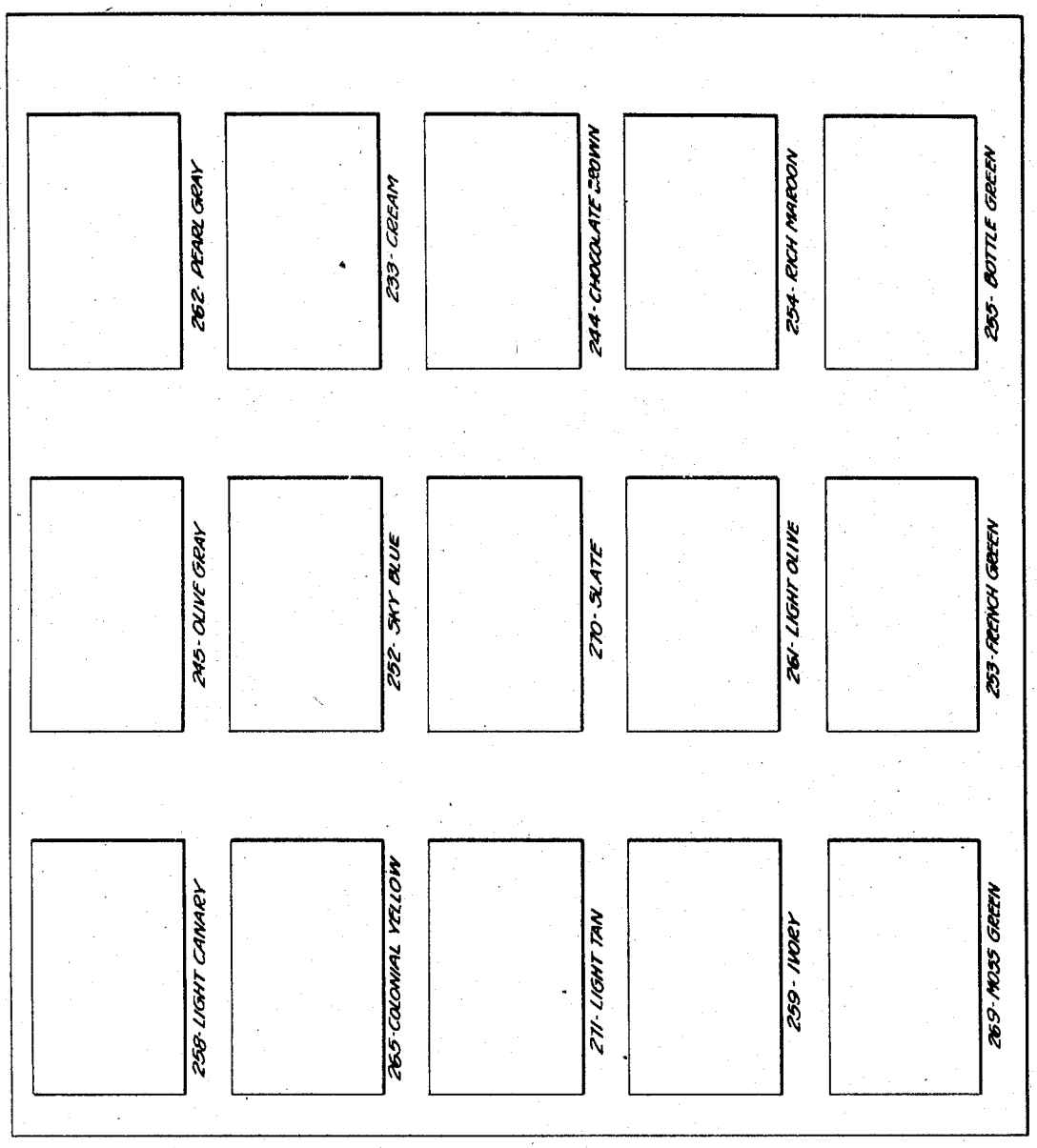


FIG. 1.

Inventor:
Fred K. Bezzenberger
by
Edward P. Alexander
Attorney

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Original Filed June 30, 1921 3 Sheets-Sheet 2

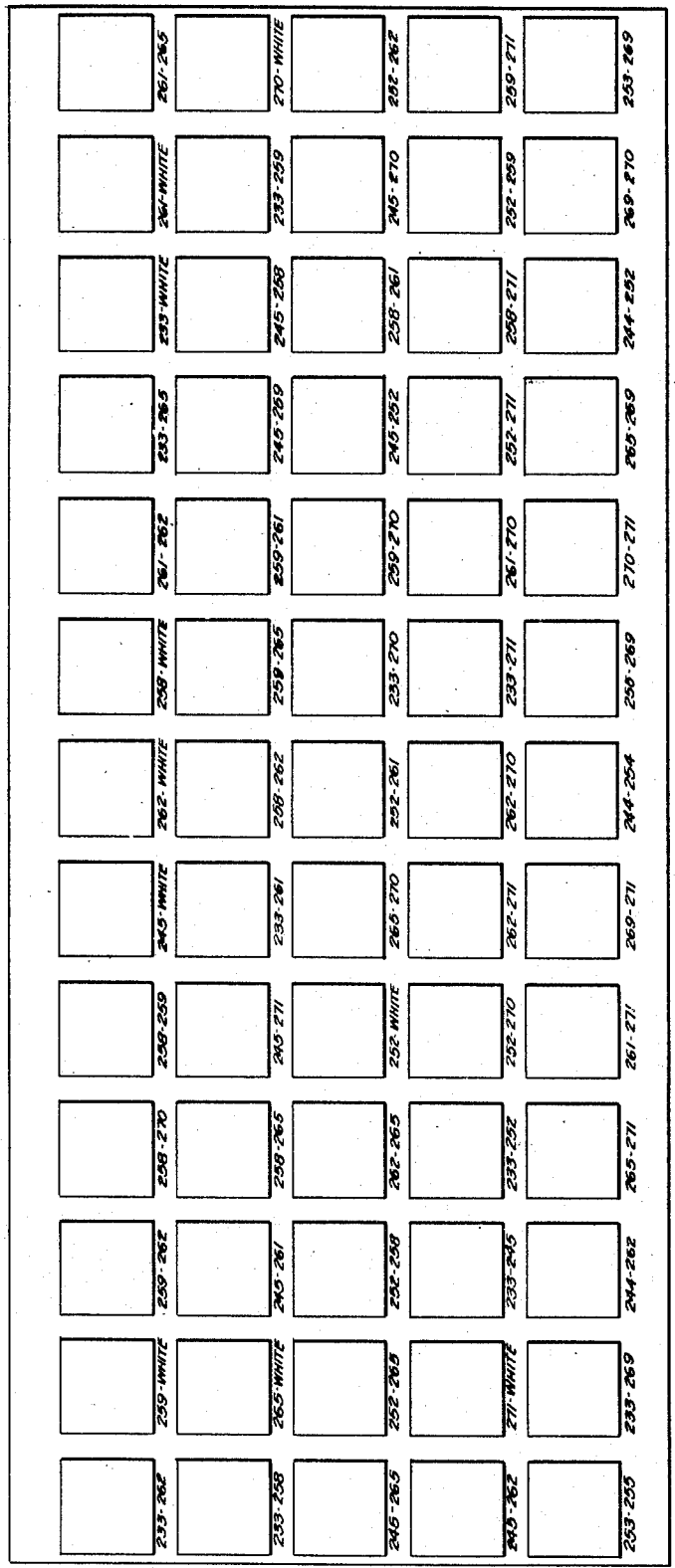


FIG. 2.

Inventor:
Fred K. Bezzenberger
by
Edward P. Alexander
Attorney.

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F. K. BEZZENBERGER

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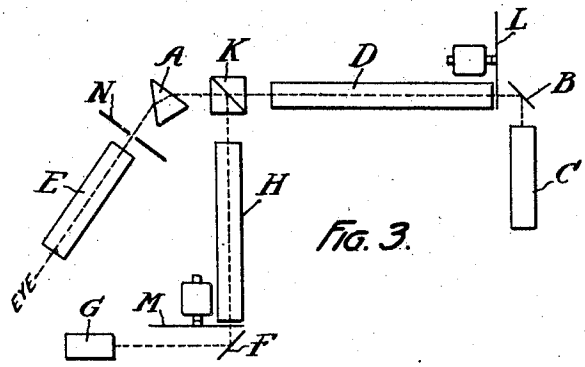


FIG. 3.

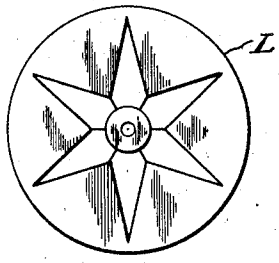
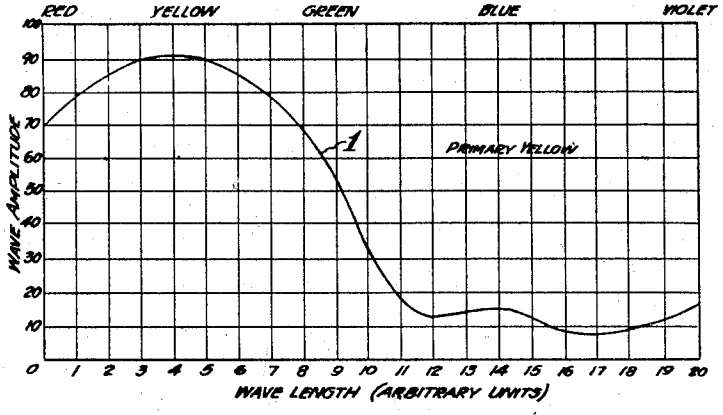
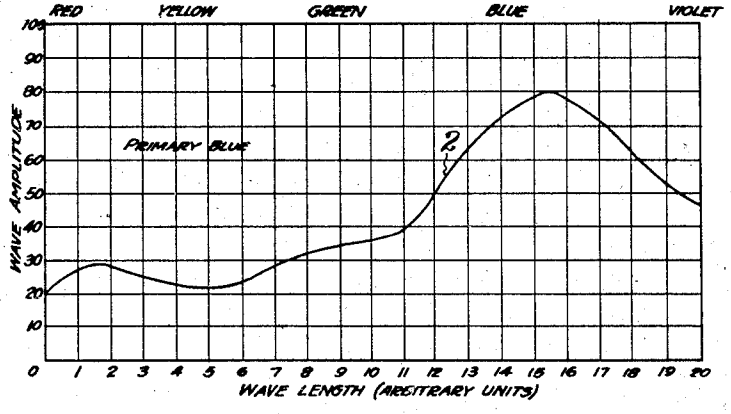


FIG. 4.





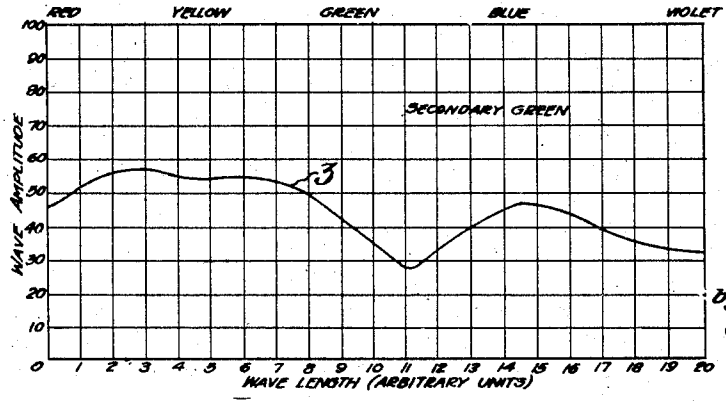


FIG. 5.

Inventor:
Fred K. Bezzenberger
by
Edward R. Alexander
Attorney.

Patented June 2, 1925. 1,540,098

UNITED STATES PATENT OFFICE.

FRED K. BEZZENBERGER, OF CLEVELAND, OHIO.

PROCESS OF PRODUCING COLOR SUBSTANCES.

Application filed June 30, 1921, Serial No. 481,489. Renewed October 4, 1924.

To all whom it may concern:

Be it known that I, FRED K. BEZZENBERGER, a citizen of the United States, residing at Cleveland, in the county of Cuyahoga and State of Ohio, have invented certain new and useful Improvements in and Relating to Processes of Producing Color Substances, of which the following is a specification, reference being had therein to the accompanying drawings.

The invention relates to an improved process of producing color substances of various kinds and particularly systems of related color substances of the kind devised by Norton A. Ross.

The chief object of the invention is the provision of an improved method of determining and producing a series of color substances of high brightness and chroma values, by admixture of which in predetermined relations can be produced a series of color substances of predetermined hue, brightness and chroma values.

Other objects of the invention, more or less incidental or ancillary to that above stated, will be apparent from the following description.

While the invention, in some at least of its aspects, is applicable to various kinds of color substances used in the arts, such as paints, dyes and inks, the invention has been developed in connection with the production of paints and, for purposes of explanation and illustration, will be set forth in that connection.

To insure clearness and definiteness in the description which follows, the color terminology employed will be in accordance with the following definitions:

1. By hue is meant the dominating wave length of the color.

2. By value, or strength, or intensity, or luminosity, or brightness, is meant the wave amplitude of the color.

3. By chroma or purity is meant freedom from admixture of wave lengths other than those constituting the dominating hue of the color.

The above mentioned system of Mr. Ross is based primarily upon the discovery, made in connection with the paint trade, that of the relatively large number of colors demanded by the consumer, a distinct minority meet the major part of the demand and that the colors constituting this minority are characterized by their relative brightness and purity, while on the other hand, the colors making up the larger or majority group are characterized by comparatively lower brightness and chroma qualities. This relation between the demands of color users and the nature of the colors is apparently based on the inherent color sense of the average user, the brighter and purer colors being demanded for the majority of uses in preference to those of lower brightness and chroma qualities.

In order to take advantage of the relation referred to, the Ross system provides a series of relatively pure bright paints adapted to meet the bulk of the trade demand and having such characteristics, physical and chemical, as to adapt them for intermixture in subgroups in definite proportions to produce a larger series of paints having lower brightness and purity or chroma values and responding to the major part of the remainder of the demand of the trade. With these two series of paints, it is necessary for the paint manufacturer to produce and for the distributor to carry in stock only those of the smaller series or group, the paints of the larger group being produced by the simple admixture of certain of the paints of the smaller group. In order that the paints of the larger or secondary group may be produced from the primary paints of the smaller group as easily as possible by the consumer, it is preferable that the relations of the colors of the two groups and of the physical and chemical characteristics of the paints of the smaller or primary group, shall be such that each of the secondary paints can be produced by the admixture of a plurality of the primary paints in equal amounts, and to make the process as simple as possible, it is preferable that each secondary paint be produced by the admixture of two of the primary paints in equal amounts.

My present invention provides an improved method of determining and producing a series of primary paints which shall be adapted by admixture in pairs and in equal amounts to produce a series of known secondary paints.

In the further explanation of the invention, reference will be had to the accompanying drawings in which

Figure 1 represents a chart having a series

of color panels corresponding to the primary paints of the Ross system.

Fig. 2 represents another chart having a larger series of color panels corresponding to the secondary paints of said system.

Fig. 3 is a diagrammatic plan view of a spectrophotometer suitable for carrying out my process.

Fig. 4 is an enlarged face view of one of the rotating disks shown in Fig. 3.

Fig. 5 shows a series of color curves such as are plotted with the aid of the spectrophotometer.

In carrying out my invention, I select from paints in use colors which sales statistics show are demanded by the trade. In practice it is found that the trade demand is almost completely met by eight colors supplemented by white. The selection of colors having thus been made, a curve is then platted for each of said colors with the aid of a suitably constructed and equipped spectrophotometer. In Fig. 3 of the drawings is indicated diagrammatically, ir plan, an instrument of the character in question, while in Fig. 5 is shown a series of curves such as are platted by the use of the instruments.

In Fig. 3, A is the prism of the instrument. B is a surface coated with a color substance or otherwise treated to give it the color which it is desired to examine. C is a strong source of light. D is a collimator tube with slit and lens equipment for transmitting a small beam of light reflected by the surface B from the source C to the prism A. E is a telescope adapted to collect and show on a graduated scale the colors derived from the beam of light reflected from the surface B. F is a surface coated with a white substance or otherwise given a white finish to serve as a standard of comparison. G is a strong source of light. H is a second tube similar to the tube D arranged to transmit a small beam of light emanating from the source G and reflected by the surface F. K is a double, full reflecting prism, disposed at the intersection of the axes of the tubes D and H but covering only the upper halves of said tubes. L and M are motor driven opaque discs formed with radially tapering slots and arranged to intercept the beams of light passing through the slits of the tubes D and H, respectively. The discs and their motors can be adjusted toward and from the tubes D and H by suitable means, such as micrometer screws, to vary in definite degrees the amounts of light transmitted through the tubes D and H. N is a plate with a vertical slit interposed between the prism A and the telescope E and, by moving this plate laterally, any desired lines or parts of the spectra can be selected for examination while the other parts are shut out and eye confusion is avoided. In the use of this apparatus, with the standard white surface at F, and the surface at B coated with some one of the colors to be examined, it will be seen that the spectrum of the light reflected from the surface B will appear on the lower half of the graduated scale or field of the telescope while the spectrum of the light reflected from the surface F will appear on the upper half of said scale. Thus the observer is able to directly compare similar parts of the two spectra and by the adjustment of one or the other of the discs L and M can render said parts of the spectra equal in brightness. Then, knowing from the positions and speeds of the discs L and M the relative amounts of light transmitted from the respective sources, the brightness of the color under examination is determined for the particular part of the spectrum under consideration. Thus, if the examination is being made of the red sections of the spectra, it is readily determined from the readings of the instrument that the red light reflected by the color under examination constitutes a definite proportion of the red light reflected by the white standard. By adjustment of the plate N, different parts of the spectrum of the color under examination can be evaluated and with the values thus determined a color curve such as those in Fig. 5 can be plotted. In these curves, the ordinates represent wave amplitude while the abscissæ represent wave lengths. Thus, in the case of the third curve of Fig. 5, the curve shows that a surface coated with the green color substance in question reflects about 50% of the red, about 55% of the yellow, about 45% of the green, about 45% of the blue and about 35% of the violet that is reflected of each of these colors by the standard white coated surface. In connection with the curves shown in Fig. 5, it is to be observed that the units employed are arbitrary, the curves being intended for illustrative purposes only.

Having, in the manner described, determined the brightness values for the one color under examination for successive lines all the way across the spectrum, thus securing data for the curve of the color, the other colors to be examined are substituted at B one after the other, examined and their curves platted. These curves, when suitably drawn from accurately determined values, give the true compositions of the light reflected by surfaces coated with the corresponding color substances as compared with the common standard, and consequently truly represent the relative color values as seen by the eye. In Fig. 5 of the drawing, the first curve representing a yellow color substance and the second curve representing a blue color substance, will

serve to typify color substances of the primary group of the system, while the third curve representing a green color substance may be taken to typify color substances of the secondary group. The color substance represented by the third curve is such as would be secured by mixing the yellow and blue color substances shown by the first and second curves, in equal amounts, neglecting effects due to the nature of the vehicles, particle size of the pigments, etc., these effects ordinarily being slight.

The curves of the character in question having been drawn for all of the colors which are to be represented in the complete system of paints to be reproduced, the next step in the procedure is the inspection of the curves. On comparison of the curves, it is found that they can be divided into two more or less well defined groups. In one group, each curve is characterized by relatively large wave amplitude values in one part or in relatively few parts of the spectrum, thus indicating colors of relatively great brightness and purity, while in the other group each curve is characterized by lesser wave amplitude values with said values about equal in a number of parts of the spectrum, thus indicating colors of lower brightness and chroma values than those of the first group. Furthermore, if as many as seventy-five or eighty colors representing the demands of the trade are under examination, it will be found that the first group of curves is relatively small in number in comparison with the second group. In a word, the small group of curves is found to correspond to the relatively small number of colors which are shown by experience to respond to the major part of the trade demand, while the larger group of curves corresponds to the larger group of colors which are shown by experience to respond to the remainder, or substantially all of the remainder, of the trade demand.

The curves having thus been divided into two groups corresponding to the primary and secondary color substances of the Ross system, the next step is to determine the nature of the colors which it will be necessary to combine in pairs and in equal quantities to produce the respective colors of the secondary group. A person familiar with the laws of color synthesis, on comparing the curves of the two groups, will, without any great difficulty, be able to determine what colors of the general character of those in the primary group are required to produce by combining, in pairs and in equal quantities, the respective colors of the secondary group. In this manner, it is possible to determine the number of different primary colors that will be required for the production of the secondary colors in the manner stated.

The next step in the procedure is the mathematical determination of the exact data for the curves of these undetermined primary colors. To do this a suitable number of points, say twenty points as indicated in Fig. 5, are taken on the base lines of the curves of the secondary colors and for each curve the ordinates corresponding to the twenty points are measured and recorded. We now denote the unknown ordinate values for each corresponding point on the undetermined primary color curves by the symbols x, y, z, etc., each of these corresponding to one of the undetermined curves. If we designate the known ordinate values of the secondary color curves by suitable symbols corresponding to one of the secondary color curves, then, bearing in mind that the primary colors are to be combined in equal quantities and having determined from a knowledge of the laws of color synthesis the primary colors which are combinable to produce the secondary colors, we can write for each of the twenty points of each of the unknown primary color curves an equation in this form:

$$\tfrac{1}{2}x+\tfrac{1}{2}y=a.$$

For each of the twenty points there will be as many equations as there are secondary colors and these equations for any one point will readily be grouped into simultaneous equations for solution as such. In this manner, the values of the wave amplitude ordinates for the respective primary color curves are determined for the first of the twenty points. Then corresponding computations are carried out for each of the remaining twenty points. The values derived from these computations will be plotted as new curves which will be mathematically descriptive of the primary colors capable of combination in pairs and in equal quantities to produce the secondary colors.

Having plotted these mathematically determined primary color curves, it will be found that in most cases, the mathematically determined curve corresponds more or less closely to one of the primary color curves plotted by the use of the spectrophotometer.

The next step in the procedure is the production of primary paints corresponding to the mathematically determined color curves. For this purpose, we require the curves of all common pigments which are mutually chemically inactive, or at least not susceptible to deleterious chemical reaction, and otherwise suited to the purpose. From these latter curves and the curves of the mathematically determined primary colors, it is possible by inspection and by simple proportionate addition of ordinates, to determine approximately the relative quantities of the various pigments which must be add-

ed together to produce the desired primary colors. It is to be understood that white is included in the primary color group.

Having determined the color pigments and the amounts thereof required for the desired primary paints, said pigments are compounded with suitable vehicles composed of oils, driers and the like, and any other suitable ingredients, of such a nature that the primary paints which must be mixed in pairs to produce the various secondary paints shall be capable of such admixture without deleterious chemical reaction or any other effect that would objectionably modify the working, drying or wearing qualities of the substances mixed. Where substantially the same vehicle can be used for all the primary paints, these conditions are obviously met in the simplest way, but, as will be obvious to those skilled in the production of paints, it is possible to secure substantially as good results by the use of different vehicles and driers which are capable of admixture without deleterious reactions.

An additional condition to be met is that when the primary paints are left standing in their containers, the paint shall not harden or separate so that it cannot be readily uniformly remixed. Otherwise, if two of the primary paints were mixed, the resulting mixture would not contain all of the predetermined constituents of the primary paints and, therefore, would not give the desired result. It is practically impossible to produce a paint of which the pigment will not settle to some extent on standing but, as is well known, it is possible to prevent caking, hardening or separating of the pigment so that by thoroughly stirring or boxing, all of the ingredients will be remixed in the desired proportions.

Having prepared the primary paints in accordance with the foregoing requirements, said paints are then examined with the spectrophotometer and their curves drawn and checked with the mathematically determined curves of the primary color substances.

Proceeding in the above manner, a series of primary color substances is produced which in turn are capable of producing, by admixture in equal quantities in pairs, the desired series of secondary color substances.

While, in carrying out my process, I prefer to plot the wave amplitude-wave length curves representing the color substances of low brightness and chroma values and the color substances of high brightness and chroma values and also the common pigments, because such graphic representations facilitate the procedure, it is to be understood that the process can if desired be carried out without plotting the curves. That is to say, the brightness values, measured or computed for the different lines of the spectrum of a color substance can be directly compared with the corresponding brightness values of another color substance without the use of the graphic representations of the values.

In the distribution of paints of the character above described, the dealer is provided with the color charts indicated in Figs. 1 and 2 of the drawings.

As will be understood, the paints represented by the small group of panels are the ones produced by the manufacturer and carried in stock by the dealer, while the paints represented by the larger group of color panels are produced by mixing the proper primary paints. To facilitate the production of the secondary paints by the user or the distributor, each of the primary paints is designated by some symbol other than the name of its color, preferably by numbers as indicated in Fig. 1 of the drawing. Then each of the secondary colors is designated by a legend made up of the numbers of the primary paints which when mixed in equal proportions produce said secondary paint.

Thus, if a purchaser selects paints from the secondary group, it is a very simple matter for the dealer to determine from the charts the necessary primary paints for the production of the secondary paints selected, and also a very simple matter for the purchaser on reference to the charts to mix the primary paints for the production of the secondary paints when the latter are required for use.

From the foregoing description, it will be seen that my invention provides a method which, by quantitive evaluation of color quantities, is adapted to determine the compositions of a series of desired color substances capable of mixture in a given way to produce another series of known color substances having the general character of the secondary colors of the Ross system. And this method, being based on the physical measurement of the fundamental color qualities, is accurate and dependable. Furthermore, an operator familiar with the method and the spectrophotometer employed can proceed rapidly and systematically through the several steps of the process with practically no recourse to time-consuming determinations of composition by trial.

It will be understood that my process is not limited in its application to the production of paints nor to the production of groups of color substances related in the specific manner above described, but that the scope of the invention is indicated by the appended claims.

What I claim as my invention is:

1. The process of making color substances for use in the arts which comprises making spectrophotometric measurements of the brightness values of each color to be produced at a series of points throughout its

spectrum, plotting a curve of the wave amplitude-wave length values thus determined for each of the colors, dividing said curves into two groups one of which comprises the colors having lower brightness and chroma values, than the colors of the other group, determining according to the laws of color synthesis the number and general character of primary colors of comparatively high brightness and chroma values that will be required to produce when mixed in certain sub-groups in uniform proportions the said colors having low brightness and chroma values, computing the brightness values for a series of points in the wave amplitude-wave length curves of said primary colors by simultaneous equations having unknown values representing brightness values of the primary color curves and known values representing the brightness values measured as aforesaid, plotting the wave amplitude-wave length curves of the primary colors with the values thus computed, plotting the wave amplitude-wave length curves of the common pigments capable of mixing without deleterious chemical reaction, determining the compositions of the primary color substances by comparison of the curves thereof and the curves of said pigments, preparing color substances having the compositions thus determined, and thereafter mixing together said primary color substances in the manner specified as the color substances of the lower brightness and chroma values are required for use.

2. The steps in a process of making color substances for use in the arts which consist in making spectrophotometric measurements of the brightness values of each color to be produced at a series of points throughout its spectrum, plotting a curve of the wave amplitude-wave length values thus determined for reach of the colors, dividing said curves into two groups one of which comprises the colors having the lower brightness and chroma values, than the colors of the other group determining according to the laws of color synthesis the number and general character of primary colors of comparatively high brightness and chroma values that will be required to produce when mixed in certain sub-groups in uniform proportions the said colors having low brightness and chroma values, computing the brightness values for a series of points in the wave amplitude-wave length curves of said primary colors by simultaneous equations having unknown values representing brightness values of the primary color curves and known values representing the brightness values measured as aforesaid, plotting the wave amplitude-wave length curves of the primary colors with the values thus computed, plotting the wave amplitude-wave length curves of the common pigments capable of mixing without deleterious chemical reaction, determining the compositions of the primary color substances by comparison of the curves thereof and the curves of said pigments, and preparing color substances having the compositions thus determined.

3. The process of making color substances of low brightness and chroma values for use in the arts which comprises making spectrophotometric measurements of each of such colors to be produced at a series of points throughout its spectrum, plotting a curve of the wave amplitude-wave length values thus determined for each of said colors, determining according to the laws of color synthesis the number and general character of colors of high brightness and chroma values that will be required to produce when mixed in certain sub-groups in uniform proportions the colors represented by said curves, computing the brightness values for a series of points in the wave amplitude-wave length curves of said high value colors by simultaneous equations having unknown values representing brightness values of the high value color curves and known values representing the brightness values measured as aforesaid, plotting the wave amplitude-wave length curves of the high value colors with the values thus computed, plotting the wave amplitude-wave length curves of the common pigments capable of mixing without deleterious chemical reaction, determining the compositions of the high value color substances by comparison of the curves thereof and the curves of said pigments, preparing color substances having the compositions thus determined, and thereafter mixing together said high value color substances in the manner specified as the color substances of low brightness and chroma values are required for use.

4. The process of making color substances for use in the arts which comprises making spectrophotometric measurements of the brightness values of each color to be produced at a series of points throughout its spectrum, dividing said colors into two groups one of which comprises the colors having lower brightness and chroma values than the colors of the other group, determining according to the laws of color synthesis the number and general character of primary colors of comparatively high brightness and chroma values that would be required to produce when mixed in certain sub-groups in uniform proportions said colors having low brightness and chroma values, computing the brightness values for a series of lines in the spectra of said primary colors by simultaneous equations having unknown values representing the brightness values of the primary colors and known values representing the brightness values measured as aforesaid, determining the com-

positions of the primary color substances by comparison of their brightness values computed as aforesaid with the corresponding brightness values of the common known pigments capable of mixing without deleterious chemical reaction, preparing color substances having the compositions thus determined, and thereafter mixing together said primary color substances in the manner specified as the color substances of the lower brightness and chroma values are required for use.

5. The steps in a process of making color substances for use in the arts which consist in making spectrophotometric measurements of the brightness values of each color to be produced at a series of points throughout its spectrum, dividing said colors into two groups one of which comprises the colors having lower brightness and chroma values than the colors of the other group, determining according to the laws of color synthesis the number and general character of primary colors of comparatively high brightness and chroma values that would be required to produce when mixed in certain subgroups in uniform proportions said colors having low brightness and chroma values, computing the brightness values for a series of lines in the spectra of said primary colors by simultaneous equations having unknown values representing the brightness values of the primary colors and known values representing the brightness values measured as aforesaid, determining the compositions of the primary color substances by comparison of their brightness values computed as aforesaid with the corresponding brightness values of the common known pigments capable of mixing without deleterious chemical reaction, and preparing color substances having the compositions thus determined.

6. The process of making color substances of low brightness and chroma values for use in the arts which comprises making spectrophotometric measurements of each of such colors to be produced at a series of points throughout its spectrum, determining according to the laws of color synthesis the number of colors of high brightness and chroma values that will be required to produce when mixed in certain subgroups in uniform proportions the colors represented by said brightness values, computing the brightness values for a series of lines in the spectra of said high value colors by simultaneous equations having unknown values representing the brightness values of said high value colors and known values representing the brightness values measured as aforesaid, determining the compositions of the said high value color substances by comparison of the brightness values computed as aforesaid with the corresponding brightness values of the common pigments capable of mixing without deleterious chemical reaction, preparing color substances having the compositions thus determined, and thereafter mixing together said high value color substances in the manner specified as the color substances of low brightness and chroma values are required for use.

7. The process of making color substances for use in the arts which comprises determining the brightness of each color to be produced at several points in its spectrum: dividing said colors into two groups one of which comprises the colors having lower brightness and chroma values than the colors of the other group; determining according to the laws of color synthesis the primary colors of comparatively high brightness and chroma values that would be required to produce when mixed in certain sub-groups in uniform proportions said colors having low brightness and chroma values; determining mathematically the brightness values at corresponding points in the spectrum requisite for said primary colors to produce the aforesaid colors of lower brightness and chroma values; determining the compositions of the primary color substances by comparison of their brightness values determined as aforesaid with the corresponding brightness values of the common known pigments capable of mixing without deleterious chemical reaction; preparing color substances having the compositions thus determined; and thereafter mixing together said primary color substances in the manner specified as the color substances of the lower brightness and chroma values are required for use.

8. The steps in a process of making color substances of low or moderate brightness and chroma values for use in the arts which consist in determining by spectro-photometric measurements the brightness values of each of said colors; determining according to the laws of color synthesis the primary colors of comparatively high brightness and chroma values that would be required to produce when mixed in certain sub-groups in uniform proportions said colors having low or moderate brightness and chroma values; computing mathematically the brightness values of said primary colors corresponding to the spectro-photometric determinations of the colors to be produced; determining the compositions of the primary color substances by comparison of their brightness values computed as aforesaid with the corresponding brightness values of the common known pigments capable of mixing without deleterious chemical reaction; and preparing color substances having the compositions thus determined.

In testimony whereof, I hereunto affix my signature.

FRED K. BEZZENBERGER.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,540,098, granted June 2, 1925, upon the application of Fred K. Bezzenberger, of Cleveland, Ohio, for an improvement in "Processes of Producing Color Substances," errors appear in the printed specification requiring correction as follows: Page 2, line 18, for the word "eight" read *eighty;* lines 21 and 27, for the word "platted" read *plotted;* page 4, line 103, for the word "quantities" read *qualities;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of July, A. D. 1925.

[SEAL.]

WM. A. KINNAN,
Acting Commissioner of Patents.