May 16, 1950 J. A. BALL 2,508,213

PHOTOGRAPHIC PROCESS FOR REPRODUCING MULTICOLOR IMAGES

Filed Feb. 21, 1950 3 Sheets-Sheet 1

FIG. 1.

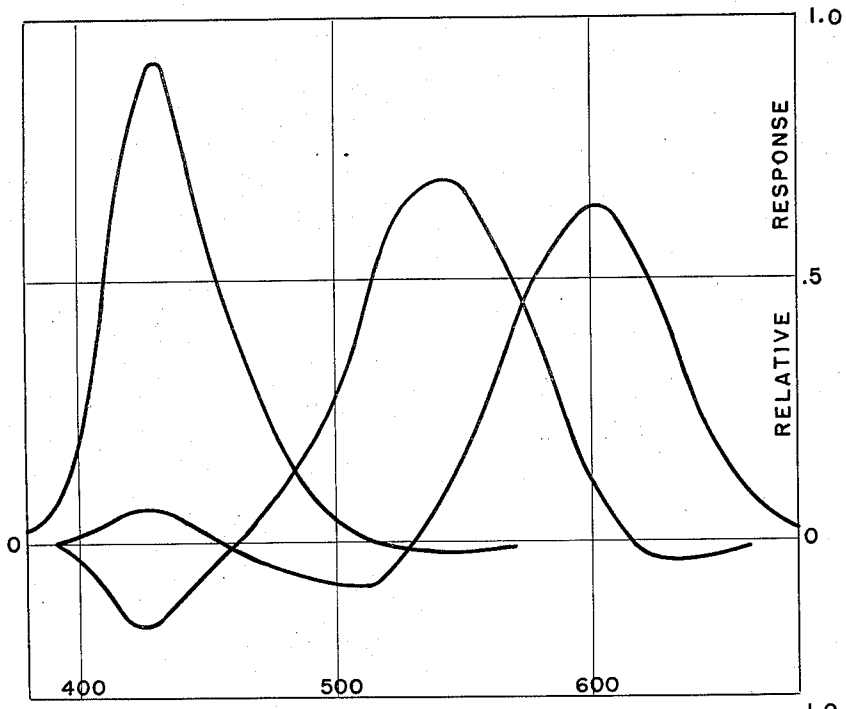
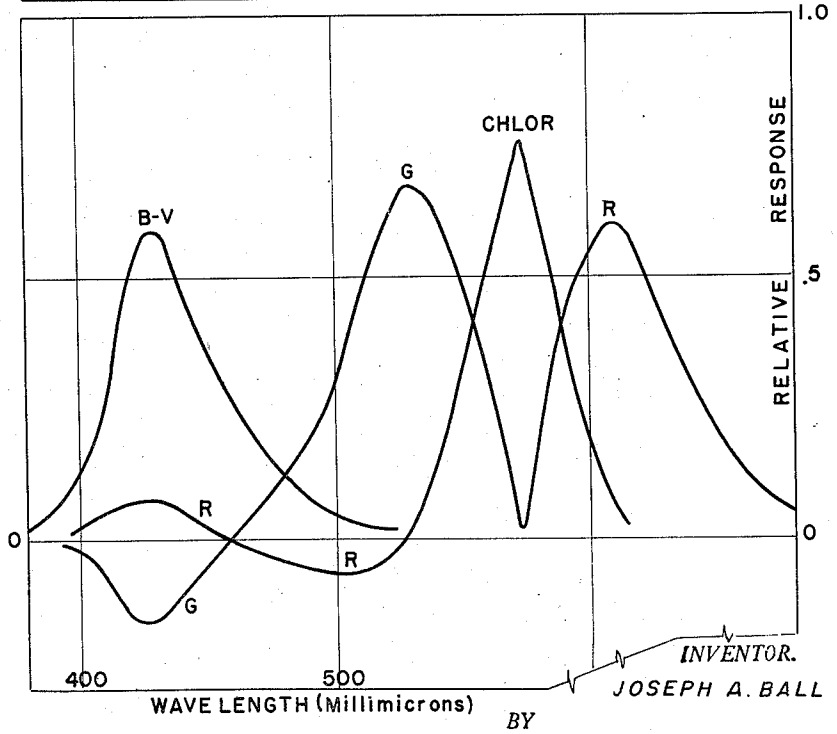


FIG. 2.



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PHOTOGRAPHIC PROCESS FOR REPRODUCING MULTICOLOR IMAGES

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FIG. 3.

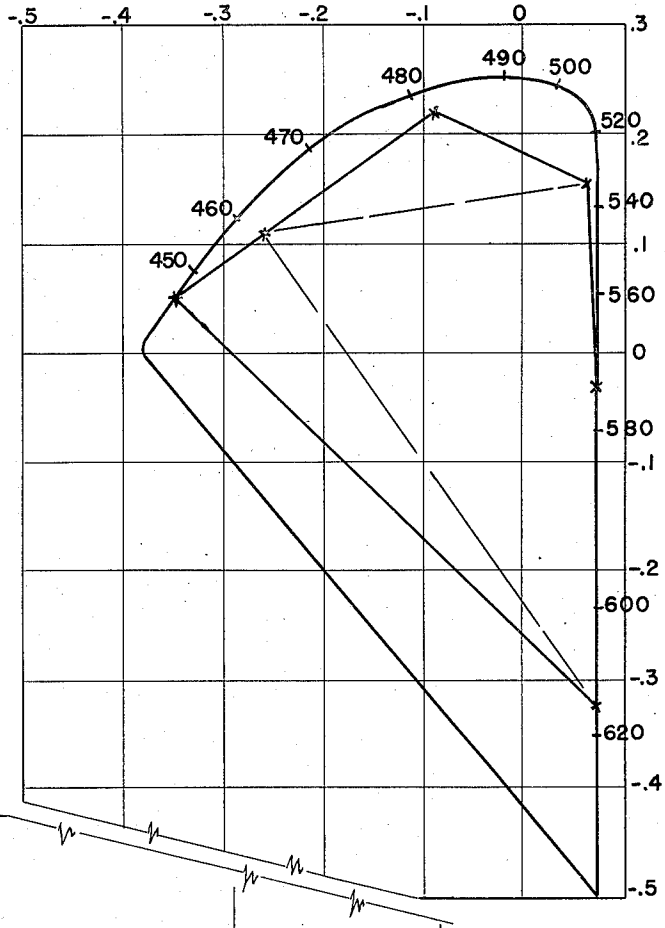
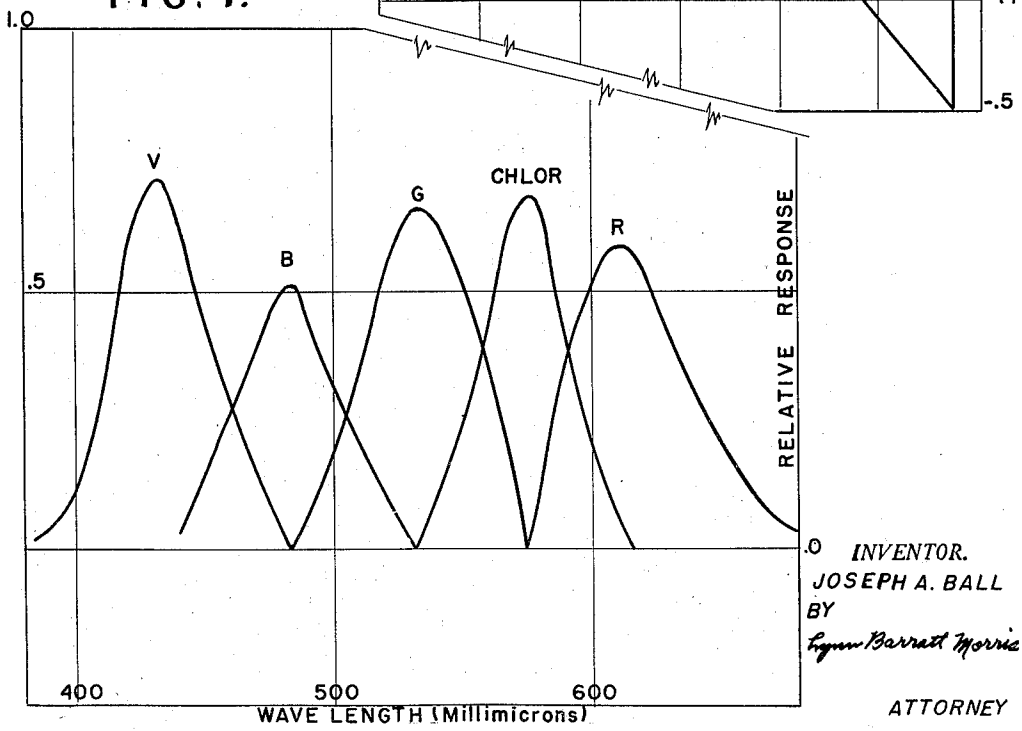


FIG. 4.



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FIG.5.

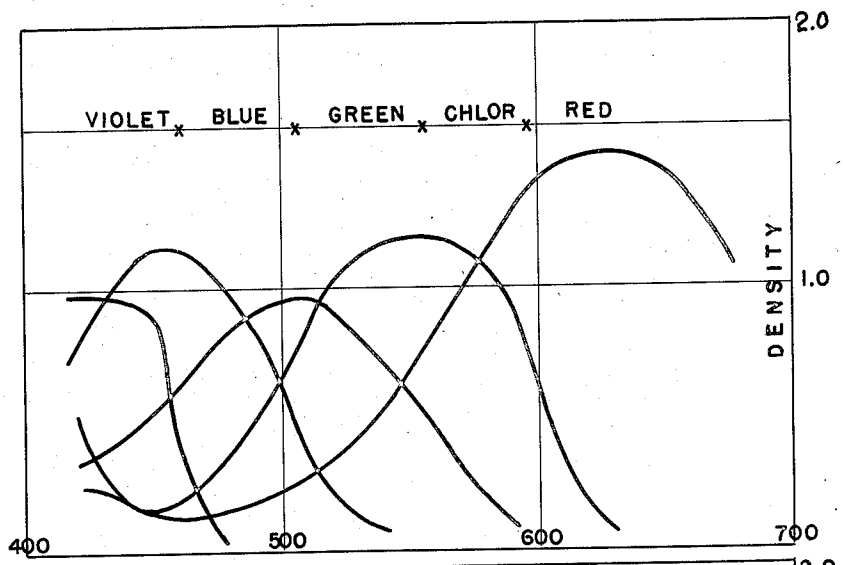
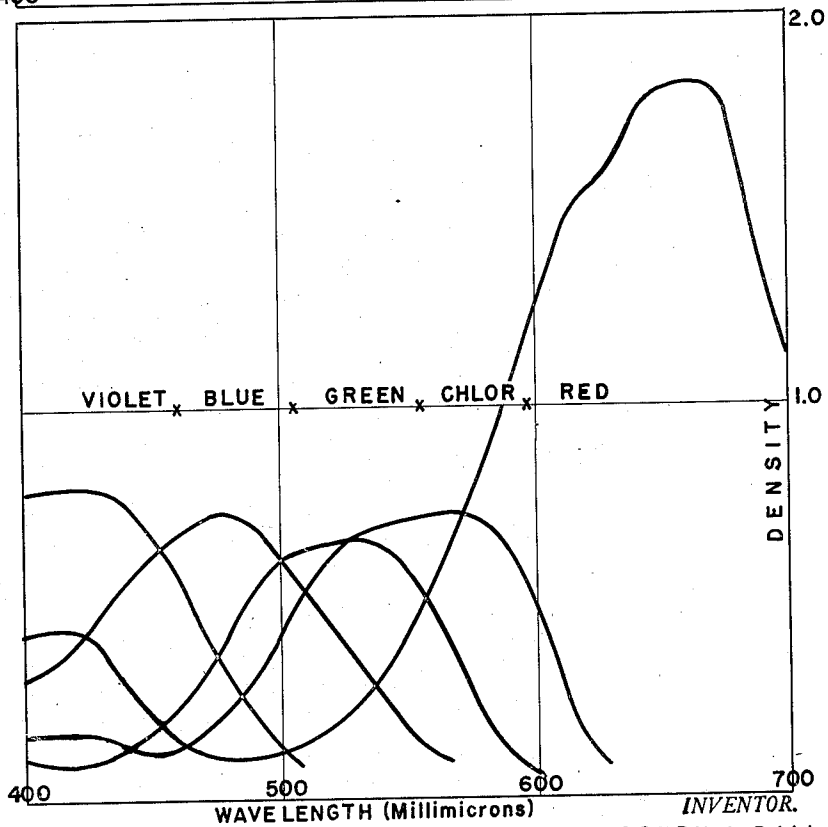


FIG.6.



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UNITED STATES PATENT OFFICE

2,508,213

PHOTOGRAPHIC PROCESS FOR REPRODUCING MULTICOLOR IMAGES

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Application February 21, 1950, Serial No. 145,382

8 Claims. (Cl. 95—2)

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This invention relates to processes for reproducing multicolor images utilizing five subtractive color components. In one of its useful aspects the invention relates to photographic processes for reproducing multicolor images which utilize five subtractive color components. Another useful aspect is concerned with processes for reproducing multicolor images utilizing five different colored substances.

This application is a continuation-in-part of copending application Ser. No. 771,790, filed September 2, 1947.

An object of this invention is to provide new and improved methods of multicolor reproduction. Another object is to provide such processes which are superior to the prior art processes. Still further objects are to provide such processes wherein negative components are rendered ineffective to disturb the final subtractive picture. Still further objects are to provide such processes wherein five color components are used. Yet another object is to provide color reproduction processes whose color gamuts will fill the spectrum locus on a uniform chromaticity diagram in such fashion as to enable the process to reproduce all colors with fidelity. Still other objects will be apparent from the following more detailed description of the invention and the accompanying drawings which constitute a part of the present specification.

My application U. S. Serial No. 771,790 describes the manner in which four spectral bands, or four sharp-cutting spectral absorbers, can be controlled in conformity with the fundamental trichromatic color mixture data, thereby producing a 4-primary process of color reproduction. In this application the method is extended to the control of five spectral bands or absorbers resulting in a 5-primary process. In the application, Serial No. 771,790, the existence of five unique spectral bands is pointed out. Three of these bands, namely, violet, green and red are located well into the corners of the spectrum locus and the other two, blue and yellow (chlor), represent the mid-sections of the two arms of the spectrum locus. That application also points out that in practical processes there are as many as five conditions to be met, namely, the three conditions imposed by the three dimensional aspect of color space and additional ones by the requirements that the entire spectrum range be covered and that negative components of response be minimized. That application further points out that 3-primary processes all demand a considerable degree of compromise so that improvement can

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be effected by passing to 4- or even 5-primary processes; but that application covers only the 4-primary process.

In designing a 3-primary process the spectrum can be split in any desired manner, and three equal area responses deduced for the control of the three arbitrary bands, because there is only one way in which white light can be recreated, namely, by the addition of equal amounts of all three bands. However, in the case of 4- and 5-primary processes this is no longer true. In such processes there are a number of ways of balancing the primaries to recreate white light. The valuable ways for application to subtractive reproduction are those for which, in the additive version, equal parts of all of the 4 or 5 primaries are required to recreate white light, because only then can the subtractive version be viewed in ordinary white light. This in turn means that the response functions should all be of equal area. Therefore, in the substitution method described in the app. Ser. No. 771,790, wherein the yellow or chlor band is substituted for parts of the red and green bands, thereby producing a 4-primary process, it is of some importance that equal parts of the red and green bands should be simultaneously involved because only then can the equality of the response functions be maintained. This in turn means that there should be a complementarity between the blue-violet band and the chlor band. Now, complementarity usually implies a subjective judgment which varies with a specification of white. In a photographic reproduction process, the camera may view the original scene illuminated by one type of "white" light whilst the final result is viewed in an entirely different type of "white" light. In view of this lack of determination or specification of white it appears desirable to use the equal energy spectrum as a basis of computation; and it should be noted that complementarity in the equal energy spectrum does have an objective significance. Correspondingly, neutrality of a gray area (which likewise usually implies a subjective judgment) also has an objective meaning if it is defined as a uniform absorption of flux throughout the spectrum.

To proceed to the elaboration of the subject of this application, let us assume that the equal energy spectrum is divided into four bands, the cuts being at 505, 554 and 594. This is not a favorable arrangement for a 4-primary process, but, as will appear later, it is favorable for a 5-primary process. According to the revised I. C. I. distributions of Judd (J. O. S. A., November 1949)

the chlor band, 554—594, is complementary to the blue-violet band, 380—505, and matches in hue the sum of the red and green bands, but represents only 37% of the total intensity. If then we compute the three equal area responses for a 3-color process based upon the blue-violet, green and red bands (with the chlor band left out) we get the data plotted in Figure 1. The overlap of the red and green areas is 36% of the total area. If then instead of this 36% of combined red and green light we use a corresponding intensity of the chlor band, it appears that the triangular overlap area can serve as the response function for practically the entire chlor band. This leads to the four response functions shown in Fig. 2 which must be applied for the complete control of the 4 bands. The gamut which is provided by such a process is shown by the dashed line in Figure 3. (This figure is a Rectangular Uniform Chromaticity Scale of Breckenridge and Schaub (ref. J. O. S. A., vol. 29, 1939) modified to be consistent with Judd's data). As mentioned before, this is not a particularly favorable setup for a 4-color process because of the limitation of gamut in the blue-violet region and also because of the substantial negative components existing in both the red and green response functions at wavelengths shorter than 530.

It has been discovered that a decided improvement can readily be effected if we split the blue-violet primary into its component parts, blue and violet; and this will result in equal area responses if the split takes places at or near the "center of gravity" of the blue-violet band, namely, 460. The essential data for these two bands using Judd's distribution functions are:

		X	Y	Z	x	y	dominant hue
V	380–460	16, 608	1, 959	86, 145	.159	.0187	435
B	460–505	1, 857	7, 950	19, 950	.0625	.2675	482

By colorimetric computations it is then possible to derive equal area response functions for these two separate bands; and in the process the secondary positive and negative parts of the red and green response functions in the blue and violet regions disappear. The combined results are shown in Figure 4. Simultaneously, the gamut of possible reproduction colors has been enlarged to the pentagonal figure shown in a solid line in Figure 3.

The above described responses have peaks and half-widths as follows (all figures being given in millimicrons):

	Peak	Half-width
Violet	430	45
Blue	482	45
Green	535	52
Chlor	574	35
Red	610	52

There is naturally some tolerance in the choice of bands and hence in the location of the response peaks but because of the narrow range within which so many components must be confined, the extent of the tolerance is not great and does not exceed plus or minus 10 millimicrons except in the case of the red record for which it is possible to locate the peak of response at considerably longer wavelengths, e. g., 610–650 millimicrons. In the case of the peak of the violet response the range is 425–445. For all the responses the maximum allowable half-width is 60 millimicrons.

The essential features of the response functions such as specified here are all readily attainable in a photographic process by a proper choice of sensitizers and filters. More specifically, suitable separation negatives for a 5-primary process can be made by the combinations of Wratten filters and commercially available plates as listed below:

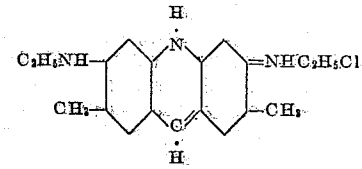
Record	Wratten Filter	Plate
Red	24A plus 11	Kodak Separation Negative Type 1.
Chlor	21	Super Ortho Press.
Green	67 plus 9	Do.
Blue	3	Kodak #33.
Violet	34 plus 2	Super Ortho Press.

When it comes to a choice of pigments or colorants to provide a subtractive print in the 5-primary process utilizing the novel response functions described above, additional considerations must be given. Most practical colorants have broader absorption bands than those specified in the ideal case described above, that is to say, they absorb somewhat in bands other than those they are intended to control. However, this is a common failing of subtractive colorants and pigments even as used in a three-primary process. The undesired absorptions can be countered by masking techniques. The principles underlying the art of masking are well-known and have been set forth in a number of articles and books. See, for example, the article entitled "Masking: a technique for improving the quality of color reproductions," by T. H. Miller in the Journal of the Society of Motion Picture Engineers for February 1949, or a series of articles by Preucil in the National Lithographer during 1947 and 1948. In selecting colorants and applying masking procedures it makes some difference as to whether the subtractive method is of the continuous-tone type as in gravure printing, or of the half-tone dot type as in letterpress, or in lithographic printing.

Suitable colorants for a half-tone dot process are shown in Figure 5 and for a continuous-tone process in Figure 6. In Figure 5 the precise colorants are:

Violet absorber—Hansa Yellow 13G.

Blue absorber—P. T. M. A.[1] precipitate of a basic Acridine Yellow of the following composition:



Green absorber—60% of the P. T. M. A. precipitate of 3-3-tetraethyldiaminoacridine. HCl.
40% of the P. T. M. A. precipitate of Rhodamine 6G (C. I. 752).

Chlor absorber—Phosphotungstic acid precipitate of Rhodamine 3B (C. I. 751).

Red absorber—95% Peacock Blue (Ref. The Chemistry and Physics of Organic Pigments by Pratt, pp. 183–185).
5% Iron Blue (Ref. National Paint Dictionary, 3rd ed., 1948, p. 317, published by Stewart Research Laboratory).

[1] P. T. M. A. stands for phosphotungstic, phosphomolybdic or mixed acids. See Pratt, Chem. and Phys. of Org. Pigments (Wiley 1947), pages 153 et seq.

In Fig. 5, the five spectral ranges are indicated and it will be noted that the four ideal spectral cuts are approximated by the four long wave cuts of the first four mentioned colorants. The significance of this is that the violet absorber alone is a lemon-yellow. Addition of the blue

absorber (which alone is a golden-yellow) produces a deep yellow. Addition of the green absorber (which alone is pink) produces an orange-red. Addition of the chlor absorber (which alone is purple) produces a deep-red. And then addition of the red absorber (which alone is cyan) produces a black. In the half-tone processes these intermediate colors made by superposition of the different primaries are of importance because they are all clearly visible when a half-tone image is observed under a magnifying glass.

At the same time it will be found that the red absorber is also contributing to the absorption of the chlor band and that the chlor absorber (and also to a lesser extent the red absorber) are contributing to the total absorption in the green band. In the blue band unwanted absorptions are contributed chiefly by the green absorber but also by the chlor and red absorbers. In the violet band unwanted absorptions are contributed by the blue absorber and also to a less extent by the green, chlor and red absorbers.

In the actual reduction to practice the following additional separation negatives were made and used to mask the primary records as follows:

	Filters	Plate
to mask the violet record	3+38	Kodak Sep. Neg. Type 1.
to mask the blue record	12+38	Kodak Sep. Neg. Type 1.
to mask the green record	21+38	Kodak Sep. Neg. Type 1.

In addition the chlor record was masked from the red record. All masking was of approximately 50% strength, that is to say, positive masks were made having 50% of the density range of the negatives to which they were to be applied and then mask and negative were bound together in accurate register. These sandwiches were then used as the continuous-tone negatives from which screened half-tone positives were produced. These screened positives were then used to produce deep-etch lithographic printing plates in the usual manner. The same masked negatives could, of course, be used to make a set of letterpress plates by well-known photo engraving methods.

The actual colorants shown in Fig. 6 are:

Violet absorber	diaryl guanidine salt of Polar Yellow (C. I. 642)
Blue absorber	50% of the P. T. M. A. precipitate of the Acridine Yellow previously described. 50% P. T. M. A. precipitate of 3-3-tetraethyldiaminoacridine·HCl.
Green absorber	P. T. M. A. precipitate of Rhodamine 6G (C. I. 752).
Chlor absorber	P. T. M. A. precipitate of Rhodamine 3B (C. I. 751).
Red absorber	50% diaryl guanidine salt of Monosol Fast Blue 2GS (I. C. I., London, England) (a sulphonated copper phthalocyanine). 50% diaryl guanidine salt of Brill, Milling Green B (C. I. 667).

They can be incorporated in a zein vehicle of approximately the following composition:

	Pounds
1-methoxy-2-propanol	42.6
Water	28.4
Zein	10.0
Colorant and extender	10–20

The above-described masked negatives can be used to produce a set of gravure cylinders by well-known procedures and these cylinders used to print continuous-tone images in the five colorants successively from the inks just described.

In application Ser. No. 771,790, I have defined the concepts of absorption center and adsorption band-width which are applicable to the blue, green and chlor absorbers. Below are listed the

locations of the absorption centers of the ideal absorbers for a 5-primary process and also the practical ones listed above and illustrated in Figs. 5 and 6, and also the range within which other practical absorbers might center. All figures are in millimicrons:

	Ideal	Fig. 5	Fig. 6	Range
blue	482.5	465	480	460–485
green	529.5	510	524	505–530
chlor	574.0	553	556	550–575

The practical absorbers all have absorption band-widths (within which absorption, expressed as density, is at least half the maximum) of about 100 millimicrons. The concepts of absorption centers and band-width are not applicable to the violet and red absorbers because they operate at the ends of the visible spectrum. They must obviously, however, have predominant absorption in the range 435 and shorter and 600 and longer, respectively.

It will be apparent from the above that one aspect of the invention consists of a process of reproducing multicolor object fields by exposing light-sensitive emulsion layers of photosensitive elements to said fields through five appropriate filters which produce responses peaking in the ranges described above and appropriately narrow. The elements are then developed, fixed, washed, and dried and five color separation negatives are produced. These image records are then copied and converted into five respective colored component image records which are in partial overlapping light-absorbing superposition having absorption characteristics predominating in the five zones described above, namely (1) a lemon-yellow which absorbs light generally at 435 millimicrons and shorter, (2) an orange-pink or "apricot" whose light absorption centers in the range 460 to 485, (3) a pink whose light absorption centers in the range 505 to 530 millimicrons, (4) a purple whose light absorption centers in the range 550 to 575 millimicrons, and (5) a cyan which absorbs generally at 600 millimicrons and longer wavelengths. Images (2), (3) and (4) should preferably have absorption bands whose widths are not greater than 100 millimicrons. The subtractive color component images, which may be in the form of various dyes, pigments, inks of organic or inorganic type, color developed dye images wherein the dyes are quinoneimine or azomethine dyes which are obtained by the color-coupling development of latent silver images with n-diethylamino-aniline in the presence of a color former, e. g., a phenol, naphthol, pyrazolone, acylacetamide, etc., derivative, color-toned images, etc., are superposed in register. When they are superposed in register on a transparent or opaque surface either multicolor transparencies or reflection prints are formed.

The 5-color reproduction processes of this invention have wide utility in the art of color reproduction. It is of general application in the photographic and graphic arts including continuous-tone and half-tone dot structure processes including photogravure processes of printing multicolor pictures.

In the foregoing specification and in the accompanying claims it will be understood that the converting of images into colored images may be accomplished either photographically (by any of the methods now in common use) or mechanically (by any of the printing methods now in

common use, e. g., relief, planographic or intaglio). Moreover, when it is stated that images are superposed in register, it is meant that if the selected process involves mechanical printing, the images to be observed by the eye are in register in the same sense that conventional relief, planographic or intaglio images are now superposed in register in conventional printing operations. When accomplished mechanically, these images may be formed by the printers' plates or by the ink as it exists on the plates just prior to the imprintation thereof upon the paper, or after imprintation.

An advantage of the invention is that it provides a process which more faithfully reproduces a multicolor scene. A further advantage is that it is automatic and eliminates the necessity for printing a black key-image and/or localized color correction.

A still further advantage resides in the fact that a wide range of color gamut can be reproduced with the five components thus eliminating the need for a large number of different colored inks commonly used in the graphic arts.

As many widely different embodiments of this invention can be made without departing from the spirit and scope thereof, it is to be understood that the invention is not to be limited except as defined by the claims.

What is claimed is:

1. In a five-component subtractive color reproduction process, the steps which comprise exposing five light-sensitive photographic layers to produce five color separation negatives through light filters which will produce response peaks in the ranges 425 to 445, 610 to 650, 472 to 492, 525 to 545, and 564 to 584 millimicrons, respectively, developing the latent images so produced, converting the resulting negative images to five colored positive images which have predominant absorption in the ranges 435 millimicrons and shorter, 600 millimicrons and longer, and absorptions centering in the ranges 460 to 485, 505 to 530, and 550 to 575 millimicrons, respectively, and superposing said positive colored images in register.

2. In a five-component subtractive color reproduction process, the steps which comprise exposing five light-sensitive photographic layers to produce five color separation negatives through light filters which will produce response peaks in the respective ranges 425 to 445, 610 to 650, 472 to 492, 525 to 545, and 564 to 584 millimicrons and which have transmission band-widths not greater than 60 millimicrons, developing the latent images so produced, converting the resulting negative images to five colored positive images which have predominant absorption in the ranges 435 millimicrons and shorter, 600 millimicrons and longer, 460 to 485, and 505 to 530, and 550 to 575 millimicrons, respectively, and superposing said positive colored images in register.

3. In a five component subtractive color reproduction process, the steps which comprise exposing five light-sensitive photographic layers to produce five color separation negatives through light filters which will produce response peaks in the ranges 425 to 445, 610 to 650, 472 and 492, and 525, to 452, and 564 to 584 millimicrons, respectively, developing the latent images so produced, printing five color separation positive image records therefrom, converting said images into colored images, which have predominant absorption in the ranges 435 millimicrons and shorter, 600 millimicrons and longer, and absorptions centering in the ranges 460 to 485, and 505 to 530, and 550 to 575 millimicrons, respectively, and superposing said colored images in register.

4. In a five-component subtractive color reproduction process, the steps which comprise exposing five light-sensitive photographic layers to produce five color separation negatives through light filters which will produce response peaks in the ranges 425 to 445, 610 to 650, 472 to 492, 525 to 545, and 564 to 584 millimicrons, respectively, developing the latent images so produced, making five respective printing plates with positive images from the developed images and making separate successive imprintations therefrom in register on sheet material from inks containing colorants, which have predominant absorption in the ranges 435 millimicrons and shorter, 600 millimicrons and longer, and absorptions centering in the ranges 460 to 485, 505 to 530, and 550 to 575 millimicrons, respectively.

5. In a five-component subtractive color reproduction process, the steps which comprise exposing five light-sensitive photographic layers to produce five color separation negatives through light filters which will produce response peaks in the respective ranges 425 to 445, 610 to 650, 472 to 492, 525 to 545, and 564 to 584 millimicrons, respectively, and having a transmission band-width not greater than 60 millimicrons at one-half the maximum transmission, developing the latent images so produced, making five respective printing plates with positive images from the developed images and making separate successive imprintations from the developed images in register on sheet material from inks containing colorants which have predominant absorption in the ranges 435 millimicrons and shorter, 600 millimicrons and longer, and absorptions centering in the ranges 460 to 485, 505 to 530, and 550 to 575 millimicrons, respectively.

6. In a process of reproducing multicolor pictures in which five separate light-sensitive layers are exposed to different spectral ranges of light and are converted into positives in five subtractive colors which collectively absorb throughout the visible spectrum, two of which layers are exposed through light filters which will produce response peaks in the ranges 425 to 445 and 472 to 492 millimicrons, respectively, the steps which comprise forming superposed partial image records in colorants of such five subtractive colors, one of which colored image records absorbs at 435 millimicrons and shorter and the other of which has an absorption centering in the range of 460 to 485 and correspond respectively with said response peaks.

7. In a process of reproducing multicolor pictures in which five separate, light-sensitive layers are exposed to different spectral ranges of light and the resultant images are converted into positive images in five subtractive colors which collectively absorb throughout the visible spectrum, exposing two of the said light-sensitive photographic layers through light filters which produce responses peaking at 425 to 445 and 472 to 492 millimicrons, respectively, having half-widths of not more than 60 millimicrons, developing the resultant two latent negative image records and converting the negative image records, respectively, to two colored positive images, one of which absorbs at 435 millimicrons and shorter wavelengths, and the other of which has an absorption centering in the range of 460 to 485 millimicrons and having a band-width not over about 100 millimicrons and corresponding, respectively with said response peaks.

8. In a five-component subtractive color reproduction process in which five separate, light-sensitive layers are exposed to different spectral ranges of light and the resultant images are converted into positive images in colorants which collectively absorb throughout the visible spectrum, the step which comprises exposing one light-sensitive photographic layer to produce a response of half-width not greater than 60 millimicrons and having a maximum in the range 564 to 584 millimicrons, developing the latent image formed and utilizing the image so produced to create a positive image in a purple colorant having an absorption centering in the range 550 to 575 and a band-width not greater than 100 millimicrons, and exposing another of said light-sensitive photographic layers to produce a response of half-width not greater than 60 millimicrons and having a maximum in the range 525 to 545 millimicrons, developing the latent image formed and utilizing the record so produced to create a positive in a colorant having an absorption centering in the range 505 to 530 millimicrons and a band-width not greater than about 100 millimicrons.

JOSEPH A. BALL.

No references cited.

Certificate of Correction

Patent No. 2,508,213 May 16, 1950

JOSEPH A. BALL

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 33, for "a" before "specification" read *the*; column 7, line 68, for "525 to 452" read *525 to 545*;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of November, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.