July 17, 1928. 1,677,665

E. A. WEAVER

PHOTOGRAPHY

Filed Nov. 2, 1921

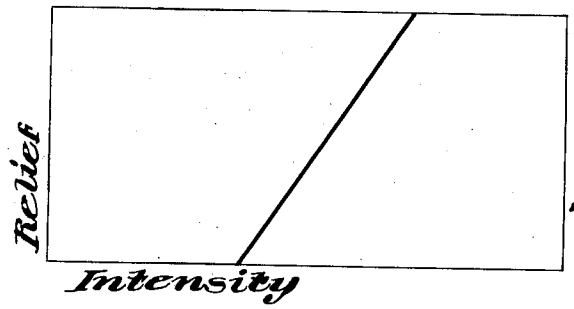


Fig. 2.

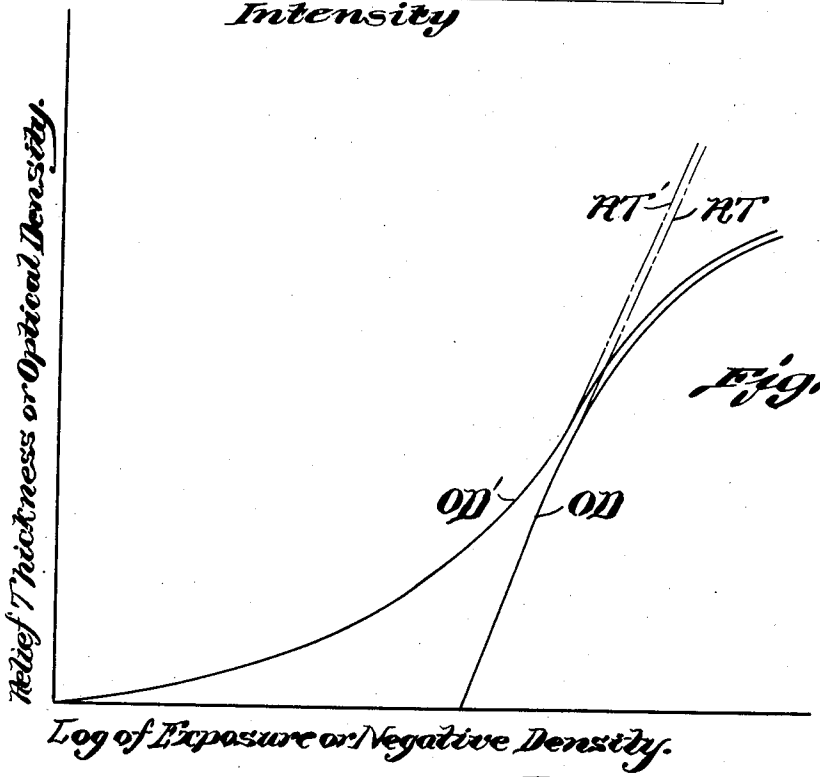


Fig. 1.

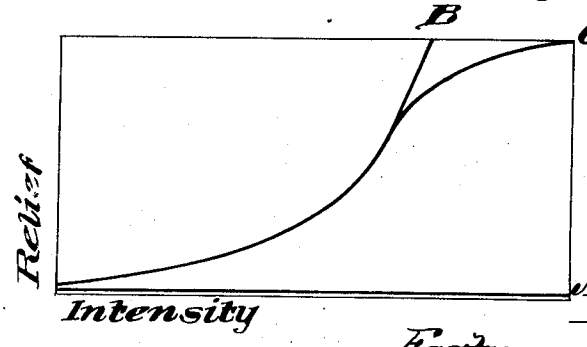


Fig. 3.

Inventor:
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by Roberts Roberts & Cushman
his attys.

Patented July 17, 1928. 1,677,665

UNITED STATES PATENT OFFICE.

EASTMAN A. WEAVER, OF BROOKLINE, MASSACHUSETTS, ASSIGNOR, BY MESNE ASSIGNMENTS, TO TECHNICOLOR MOTION PICTURE CORPORATION, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MAINE.

PHOTOGRAPHY.

Application filed November 2, 1921. Serial No. 512,390.

This invention relates particularly to the production of relief pictures in gelatine or other suitable medium but it may also be utilized in the production of other kinds of photographic pictures. It has been developed for use in producing motion pictures in colors but it is also applicable in producing black-and-white motion pictures or in producing still pictures whether black-and-white or colored. In the production of color pictures the invention may be utilized either in an additive process, e. g. in which the complemental images are separately projected along a branched path into registry on a screen, or in a subtractive process, e. g. in which the complemental images are superposed in registry and projected along a single optical path.

In many branches of the art of photography difficulty has been experienced in securing the proper contrast throughout the high-light, half-tone and shadow regions respectively. In some cases the contrast is unsatisfactory only in the high-light regions or only in the shadow regions, but in few cases can satisfactory gradations (i. e. variations in optical density relative to the variation of light intensity throughout corresponding portions of the object field) be secured throughout all three regions, especially in the various color processes employing stained reliefs.

This difficulty is particularly pronounced in relief processes where the most striking defect in the appearance of the pictures is the excessive difference or contrast between light and intermediate values as compared with the difference between intermediate and dark values. This is accompanied by an excessive degree of "lost detail" (which in ordinary silver pictures is produced in mild degree by insufficient exposure); and ordinarily the lightest areas of the pictures have no detail whatsoever, merely consisting of clear celluloid. When producing positive reliefs by printing from negatives, for example, if the printing is increased to record this high-light detail, the intermediate values become still more excessively dark; and if in turn this is relieved by decreasing contrast, the deep shadows of the pictures become gray or brown. In other words, if the printing and contrast are such as to produce satisfactory detail in the high-lights and good black shadows, half-tones such as faces are too dark.

In imbibition processes for example, where stained relief matrices are employed to transfer images in colors upon a blank film or films, a fundamental defect is improper contrast gradations throughout the light, intermediate and dark values of the pictures. Causes contributing to this are the following: First, practically all the dye from the thin portions of the relief migrates into the blank while increasing proportions of the dye are retained as the relief increases in thickness or depth. Secondly, the time required for migration of the dye from deep layers will be longer than that for thin layers, and as a commercial process requires the time of imbibition to be reduced to a minimum the deepest densities suffer somewhat from this cause. Thirdly, owing to the non-uniform spectral absorption of ordinary dyes successive additions of equal quantities of dye produce a continually decreasing series of effects on the color, since the portion of the spectrum most heavily absorbed by the dye will be largely filtered out by the earlier portions, so that the residual light is less subject to modification by the later strata. This corresponds to the well-known phenomenon experienced in using two identical color filters over a photographic lens, the second filter producing much less change in exposure than the first.

Another process in which certain of the aforesaid causes also operate against proper contrast gradations is that in which a plurality of stained complemental relief images are superposed and viewed with transmitted light.

A principal difficulty encountered in making photographic reproductions by means of gelatine reliefs is the tendency toward straightness of the characteristic curve, commonly called the H & D curve. In the typical curve for silver images the lower portion of the curve representing the under exposure is concave upwardly, the intermediate position representing the average exposure is straight, and the upper portion representing the over exposure is convex upwardly. In the relief curve the first and third portions tend to drop out, particularly when monochromatic light is employed in the exposure or in case the absorbing power of the emul-

sion is substantially uniform for all component colors of light employed in the exposure. The loss of the under exposure region in prior processes has rendered the use of relief images unsatisfactory.

Objects of the present invention are to correct defects in the contrast gradations of photographic images, particularly relief images for use in color photography, to control the contrast gradations at will to produce desired photographic and artistic effects, to increase the concavity of the characteristic curve in the lower portion ordinarily referred to as the under-exposure region, and to reduce the required image exposures in making relief pictures.

The present invention consists in exposing the film with light distributed to produce an image, as for example by contact printing, and also with light adapted to alter the contrast gradations of the picture or to reduce the required image exposure or both. For convenience I shall refer to the first as the image exposure and the second as the contrast exposure although the two exposures may be effected simultaneously as a single exposure and the contrast exposure may also be an image exposure as will hereinafter appear.

The contrast exposure may be made either before or after the image exposure as for example by running the film through a printer having a light of predetermined intensity and quality. When exposed to the contrast light (or otherwise treated to afford an equivalent effect) before being exposed to the image light, the film may be said to be a pre-exposed film. Instead of making the contrast exposure before or after the image exposure it may be made simultaneously with the image exposure, as for example in projection printing by simultaneously projecting the image light and the contrast light to the film along separate optical paths. Indeed, in printing, either by projection or by contact, both lights may pass through the printing image if the contrast light is absorbed less than the other light as would be the case, for example, if the printing image is a relief dyed to absorb differently colored lights in different dyes and if such differently colored lights are employed for the image and contrast exposures respectively. In this case the printing image may be impressed more or less upon the contrast light as well as upon the image light.

If the effect of the present invention is impressed upon the photographic film during the process of manufacture the film may be exposed in the same way as ordinary film, except that the exposure may be reduced as hereinafter described. The contrast exposure or pre-exposure herein referred to may be effected in ways other than by exposure to light as for example by exposure to the fumes of a chemical which produces a similar effect upon photographic emulsions as is well-known, or by heat, pressure, electricity, etc.

The intensity of the contrast light depends upon the effect to be produced but ordinarily it should be an amount approximately, but preferably somewhat under, the threshold exposure, the threshold exposure for the production of relief images being the exposure which results in an infinitesimally thin film of gelatine after development, hardening and etching. The image exposure should be somewhat less than ordinarily employed, for example that amount which alone records substantially no detail in the high-lights but which, in conjunction with the contrast exposure, records detail in the extreme high-lights.

The invention further consists in using a film which is light absorptive and making the contrast exposure with light which is absorbed by the film, thereby to cause the contrast light to affect the film most on the entrant side (that is, the side through which the image light enters) where the high-light portions of the resulting relief are formed. In this connection it is to be noted that the two exposures should be made from the same side of the film, that is, either both from the emulsion side or both from the celluloid side of the film. This can best be done by employing monochromatic light of which the film is absorptive, that is light having only one color or dominant hue to which the film is sensitive. An effect similar to that produced by monochromatic light can be obtained with polychromatic light if the film has approximately uniform absorptivity for all the colors employed. If white light is used in the contrast exposure the film should absorb substantially all the spectral range to which it is sensitive

The invention further consists in proportioning the image light and the contrast light to produce the predetermined contrast gradations desired; and, when using colored light of which the film is absorptive, of correlating the color of the light and the absorptivity of the film to control the contrast gradations.

The invention further consists in a relief image having more gradual thickness gradations (i. e. variations in relief thickness relative to variation in light intensity throughout corresponding portions of the object field) in the thinner portions than in the intermediate portions, and in a color relief image having more gradual optical-density gradations in the high-light portions than in the half-tone portions (relative to variations in light intensity throughout the corresponding portions of the object field). The effect of the invention is represented by a characteristic curve asymptotically ap-

proaching either the horizontal line of zero density, known as the exposure axis, or a line parallel thereto.

Referring to the accompanying drawing (Fig. 1) RT is a characteristic curve showing the thickness gradations of an ordinary relief image, OD is a characteristic curve showing the optical-density gradations of the same image when stained, and RT′ and OD′ are similar curves illustrating the effect of the present invention, it being understood that the curves of each pair of relief-thickness and optical density curves are coincident throughout their intermediate and lower portions.

The lower portion of curve OD′ which is upwardly concave and which approaches the line of zero density asymptotically, is known as the "underexposure region", and it is the absence of this region in ordinary reliefs, as illustrated by the straight lower portion of curve OD, which characterizes the difficulties against which this invention is directed.

Fig. 2 illustrates diagrammatically the linear increase in thickness of the relief of the developed film with respect to the intensity (or duration) of the exposure to which it is subjected.

Fig. 3 illustrates diagrammatically the thickness of the developed (or rather incipiently developed) portion of the film by uniform exposure to specifically absorbed light just short of or approximating the threshold exposure (line A) and the relief thickness of the film developed by the subsequent (or previous) exposure to the image light (curve B) and the optical reducing effect upon higher densities effected upon treating the film with dyes or other coloring agents, (curve C) as obtained in accordance with the procedure of the present invention.

It should be here noted that notwithstanding the straight-line curve OD may correspond to acurate physical reproduction of the object field (that is, it makes screen brightness proportional, neglecting color differences, to brightness in the object field) it is inferior for many purposes to the concave curve OD′. For example, in producing motion pictures, the negative almost never receives adequate exposure to make use of only the straight-line portion of the curve, and the contrast sensibility of the dark-adapted eye in a motion picture theater is such a rapidly varying function of the brightness that for accurate ocular or subjective reproduction of the original scene the straight-line curve is inadequate.

Another important disadvantage of the lack of the under-exposure region is the difficulty of printing correctly inasmuch as increase or decrease in printing exposure corresponds to translation to right or left respectively in the figure. With a straight-line curve such as OD, too much printing will carry the whites up to a considerable density whereas too little printing will carry the whites and possibly the light colors down to clear celluloid. With an asymptotic curve such as OD′, on the other hand, variation in printing exposure is much less significant.

The concrete mode of procedure which I recommend in practising the present invention is as follows:

First dye the positive film with a pigment more or less strongly absorptive of the contrast light. Inasmuch as the present invention is preferably employed in conjunction with that described and claimed in my co-pending application, Serial No. 512,391, filed on even date herewith, I preferably employ a dye which will serve both purposes. Examples of such dyes are naphtol-yellow and quinoline-yellow, or a mixture of these dyes, for example in equal amounts, as described in said application. The dye may be incorporated by bathing the film but is preferably incorporated in the emulsion before being coated on the celluloid. While the amount of dye may be much less than described in said application, the maximum amount which the emulsion will retain in non-crystalline form when employing said mixture, as described in said application, is satisfactory for most purposes.

Film thus dyed is then exposed both with image light and also with contrast light. In making color positives separate films may be printed respectively with complemental negatives representing different color aspects of the object field, one or both films also being exposed with contrast light of which the emulsion is absorptive, preferably to approximately the threshold exposure. When using yellow dyes such as above mentioned the contrast light is preferably violet, for example such as obtained with a Wratten D filter. The exposures are preferably effected by first running the positive film through a printer adapted to expose approximately to the threshold point with the contrast light, and then running both the positive and the negative films through the printer to print, with any suitable printing light, the images on the spaces previously exposed to the contrast light. When employing the invention disclosed in my aforesaid application the printing light employed in making the second exposure is polychromatic, as described in said application. If, for example, the finished product is to consist of a reddish-record direct-relief positive and a greenish-record direct-relief positive secured together back-to-back in registry, the two positives are exposed through the back (i. e. through the celluloid) both to the contrast light and to the image light, the films thus exposed being developed, hardened, etched and stained in any suit-

able way to produce colored reliefs. The positives may be secured together after completion but when securing them together back-to-back they are preferably joined together immediately after printing and before wetting in order to secure more accurate register of the complemental images.

If, for example, it is desired to give the finished picture a warm tint the contrast exposure of the reddish-colored positive may be carried somewhat beyond the threshold exposure.

The effect of the contrast exposure may be controlled by regulating the degree of the exposure, that represented by the lower concave portion of curve OD′ being the effect produced by approximately a threshold exposure. If the contrast exposure is decreased the upper end of the concave portion joins the straight portion at a lower point and intersects the base line at an angle instead of being accurately asymptotic to it. If the contrast exposure is increased the concave portion asymptotically approaches a horizontal line located above the base line a distance depending upon the amount of exposure in excess of the threshold exposure.

The effect on the contrast gradations may be further controlled by regulating the absorptivity of the emulsion, either in degree or with respect to the color of the contrast light, by regulating the sensitivity of the emulsion to various colors, and by regulating the color of the contrast light.

The image light should be reduced as the contrast light is increased, the total light preferably producing approximately the same tone in the extreme high lights as is ordinarily produced in printing without any contrast light, thereby to obtain greatest clearness in the extreme high lights.

The increase in speed produced by the contrast exposure is represented in the figure by the space between curves OD and OD′.

In the production of relief pictures the additional exposure herein described does not produce a veil over the picture unless employed in excess; indeed it has the opposite effect as if the negative had a fog or veil which is eliminated in reproducing according to the present invention.

An alternative method of making a relief image whose characteristic curve is upwardly concave at its lower end consists in exposing the emulsion with image light, to such extent that detail in the high lights is recorded in the resulting relief, staining the relief with a suitable dye, preferably substantially to saturation throughout, and subsequently washing the relief, e. g. with an aqueous solution. I have found that the dye washes out in different proportions in the thick, intermediate and thin portions of the relief and that a greater proportion washes out of the portions of intermediate thickness, that is a greater amount of dye washes out of the intermediate portions in proportion to the total amount contained in such portions than washes out of the thinner and thicker portions in proportion to the amounts contained therein respectively. The emulsion should be absorptive as above described but need not be so strongly absorptive. The dye washes out more or less rapidly depending upon the alkalinity or acidity of the wash solution, the rate being increased by increased alkalinity and decreased by increased acidity in case of acid dyes. The effect of the wash may therefore be controlled by varying the acidity or alkalinity of the solution; also by regulating the time of washing and the degree of agitation of the solution. This alternative method is more difficult to practice than the method involving a contrast exposure and does not give such good results, particularly as regards uniformity of color balance between the complemental images. However, for certain purposes a slight wash may be employed to advantage to supplement the contrast exposure method.

While the present invention is particularly applicable to relief processes it is obviously applicable wherever it is desirable to alter the characteristic curve, particularly by bending the lower portion of the curve.

I claim:

1. The method of producing a photographic printing matrix comprising printing a film with light distributed to produce a latent image therein, altering the contrast gradations of the image by exposing the film with correspondingly distributed light, and converting the altered latent image into a photographic printing matrix.

2. The method of producing a color picture which comprises printing an image on a sensitized film followed by uniformly exposing the film from the same side, developing and selectively coloring the film in accordance with the double exposure.

3. The method of producing photographic pictures comprising exposing a film with light distributed substantially uniformly and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

4. The method of producing relief pictures which comprises exposing a film with light distributed substantially uniformly and simultaneously also with light distributed to form an image therein, the two lights being proportioned separately to make substantially no image in the high-light portions but conjointly to record an image in such portions.

5. The method of producing relief images comprising printing a film with light distributed to produce a latent image therein,

altering the contrast gradations of the image by exposing the film with differently distributed light, and converting the altered image into a relief.

6. The method of producing relief images comprising exposing a film substantially uniformly and also non-uniformly to form an image therein, the two exposures being correlated to produce a predetermined detail in the high-lights, and subsequently converting the image into a relief.

7. The method of producing a photographic printing matrix comprising exposing a film substantially uniformly and also non-uniformly to form an image therein, the two exposures being correlated to produce a predetermined detail in the high-lights, and subsequently converting the image into a photographic printing matrix.

8. The method of producing photographic pictures comprising exposing a film which is absorptive of light of a certain color with light distributed to produce a picture and also with light of said color to alter the contrast gradations of the picture in a predetermined manner.

9. The method of producing relief pictures which comprises exposing a film, at some stage before development, in addition to the image exposure, an amount sufficient to carry the image exposure, in the high-light regions, beyond the threshold exposure and subsequently removing the residual undeveloped portions of the film for the production of relief pictures.

10. The method of producing photographic pictures comprising exposing a film with colored light and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

11. The method of producing photographic pictures comprising exposing a film with colored light of which the film is largely absorptive and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

12. The method of producing photographic pictures comprising exposing a film with substantially monochromatic light and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

13. The method of producing photographic pictures comprising exposing a film with colored light distributed substantially uniformly and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

14. The method of producing photographic pictures comprising exposing a film with colored light of which the film is largely absorptive distributed substantially uniformly and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

15. The method of producing photographic pictures comprising exposing a film with substantially monochromatic light distributed substantially uniformly and also with light distributed to produce an image therein, the two lights being proportioned to produce predetermined contrast gradations in the image.

16. The method of producing photographic relief images comprising exposing a film, which is rapidly absorptive of light of a certain color, with substantially monochromatic light of approximately said color, also exposing the film with light distributed to form an image therein, the two lights being relatively proportioned to produce a predetermined degree of contrast in the high-lights, and subsequently converting the image into a relief.

17. The method of producing photographic pictures which comprises exposing a film, at some stage before development, in addition to the image exposure with light of which the film is absorptive, and regulating the degree of absorption to control the contrast graduations.

18. The method of producing photographic pictures which comprises exposing a film, at some stage before development, in addition to the image exposure, with colored lights of which the film is absorptive, and correlating the color of the light and the absorptivity of the film to control the contrast gradations.

19. The method of altering the contrast graduations of a photographic picture which comprises exposing a film with light of which the film is strongly absorptive to produce a predetermined increase in the concavity of the lower portion of the characteristic curve of the picture.

20. The method of producing a photographic picture which comprises exposing a film to form a latent image representing a characteristic color aspect of the object field and altering the contrast gradations of the picture by exposing the film with secondary light.

21. The method of producing a photographic picture which comprises exposing a film to form a latent image representing a characteristic color aspect of the object field and altering the contrast gradations of the picture by exposing the film with light of which the film is strongly absorptive.

22. The method of producing a photographic picture which comprises exposing a film with image light and with contrast light whose spectral range is correlated with the

absorptivity of the film to produce predetermined contrast gradations.

23. In the production of photographic pictures by a process which tends to produce pictures having contrast gradations represented by a characteristic curve whose lower portion tends toward straightness, the method which comprises rendering said portion of the characteristic curve approximately asymptotic to the exposure axis by secondary exposure.

24. The method of producing photographic pictures which comprises making a film selectively absorptive in accordance with the light values of the scene to be depicted and staining the film, characterized in that the proportionate distribution of the stain throughout the high-light and half-tone portions of the pictures is altered by washing the pictures after staining.

25. A printing matrix image having more gradual optical-density gradations in the high-light portions than in the half-tone portions.

26. A printing matrix image having optical-density gradations represented by a characteristic curve in which the lower portion is located above a tangent to the central portion of the curve.

27. A printing matrix image having more gradual optical-density gradations in the high-light and low-light portions than in the half-tone portions.

28. A printing matrix image in which the gradations of optical-density are greater in the intermediate portions of the image than in the lighter portions, for the same range of light intensities in the scene.

29. A printing matrix image in which the gradations of optical-density are greater in the intermediate portions of the image than in the lighter portions, for the same range of light intensities in the scene, and which is substantially free from halation effects.

30. A photographic printing matrix having selective dye absorption characteristics represented by a characteristic curve in which the lower portion is concave.

31. A photographic printing matrix having selective dye absorption characteristics represented by a characteristic curve in which the lower portion approaches asymptotically to a line parallel to the exposure axis.

32. A photographic printing matrix having more gradual dye absorption gradations in the high-light portions than in the half-tone portions.

33. A photographic printing matrix comprising a stratum whose dye absorption capacity varies in accordance with light values of the scene depicted and a thin stratus of uniform absorptivity.

34. A photographic printing matrix in which the gradations of dye absorption are greater in the intermediate portions of the image than in the high-light portions, for the same range of light intensities.

35. Photographic film for use in the production of relief images comprising an emulsion which has been exposed from the back to alter the thickness gradations of the relief image.

36. Photographic film for use in the production of relief images comprising an emulsion which has been pre-exposed from the back an amount not substantially exceeding the threshold exposure.

37. Photographic film for use in the production of relief images comprising an emulsion which has been pre-exposed from the back an amount approximating the threshold exposure for the production of a relief.

38. Photographic film for use in the production of relief images comprising an emulsion which has been pre-exposed to a limited depth on its support side.

39. Photographic film for use in the production of relief images comprising an emulsion which has been pre-exposed to a limited depth on its support side an amount not substantially exceeding the threshold exposure.

40. Photographic film for use in the production of relief images comprising an emulsion which has been pre-exposed to a limited depth on its support side an amount approximating the threshold exposure for the production of a relief.

41. A photographic film having superposed complemental relief images whose thickness gradations are represented by a characteristic curve in which the lower portion is concave.

42. A photographic film having superposed complemental direct-relief images whose thickness gradations are represented by a characteristic curve in which the lower portion approaches asymptotically to a line parallel to the optical axis.

43. A photographic film comprising an integral film having on opposite sides thereof complemental relief images having more gradual thickness gradations in the thinner portions than in the thicker portions.

44. A relief positive having thickness gradations represented by a characteristic curve in which the lower portion is concave.

45. A relief positive having thickness gradations represented by a characteristic curve in which the lower portion approaches asymptotically to a line parallel to the exposure axis.

46. A relief positive having thickness gradations represented by a characteristic curve in which the lower portion approaches asymptotically to the line of zero density.

47. A relief image having more gradual thickness gradations in the thinner portions than in the intermediate portions.

48. A color relief image having more gradual optical-density gradations in the high-light portions than in the half-tone portions.

49. A color relief image having optical-density gradations represented by a characteristic curve in which the lower portion is located above a tangent to the central portion of the curve.

50. A color relief image having more gradual optical-density gradations in the high-light portions than in the half-tone portions.

51. A color relief image in which the gradations of optical-density are greater in the intermediate portions of the image than in the thinner portions, for the same range of light intensities in the scene.

52. A color relief image in which the gradations of optical-density are greater in the intermediate portions of the image than in the thinner portions, for the same range of light intensities in the scene, and which is substantially free from halation effects.

53. A relief picture comprising a stratum whose thickness varies in accordance with light values of the scene depicted and a thin stratum of uniform thickness.

54. A color picture comprising a support carrying an inner colored stratum of uniform thickness and an outer similarly colored stratum whose thickness varies in accordance with the light values of one characteristic hue of the scene depicted, the two strata together yielding a picture having the desired contrast gradations throughout the high-light and half-tone portions.

55. A color picture comprising a stratum in which the color distribution varies in accordance with the light values of one characteristic hue of the scene depicted and another stratum in which the color is relatively uniformly distributed.

56. A stained picture comprising a stratum in which the dye distribution varies in accordance with light distribution in the scene depicted and another stratum in which the dye is relatively uniformly distributed.

Signed by me at Boston, Massachusetts this 29th day of October 1921.

EASTMAN A. WEAVER.