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2,455,849

PHOTOGRAPHIC UNSHARP MASKING METHOD

Filed March 11, 1944

2 Sheets-Sheet 1

FIG. 1.

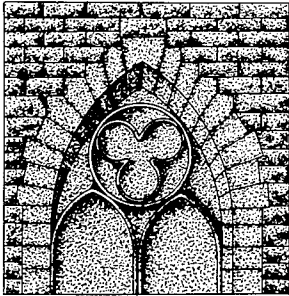
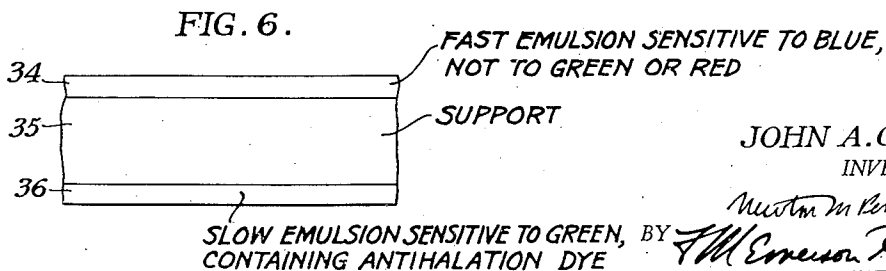
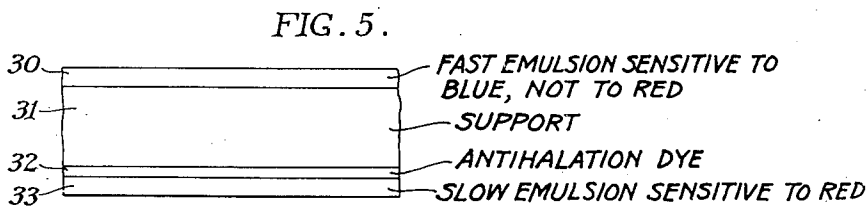
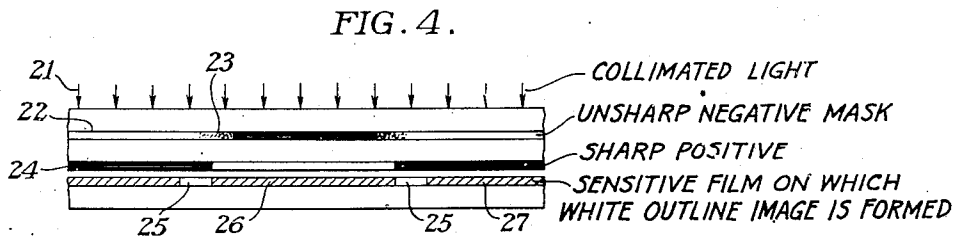
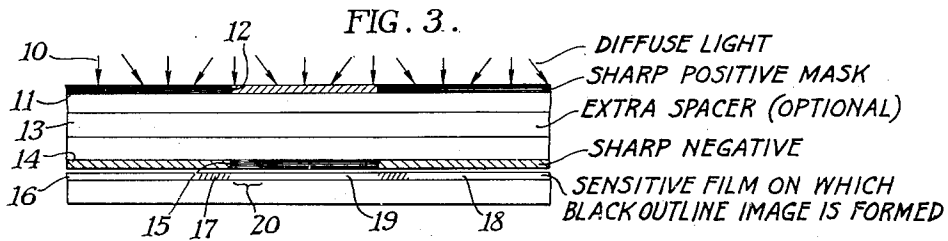
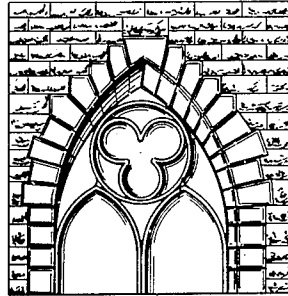


FIG. 2.



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2 Sheets-Sheet 2

FIG. 7A.

FIG. 7B.

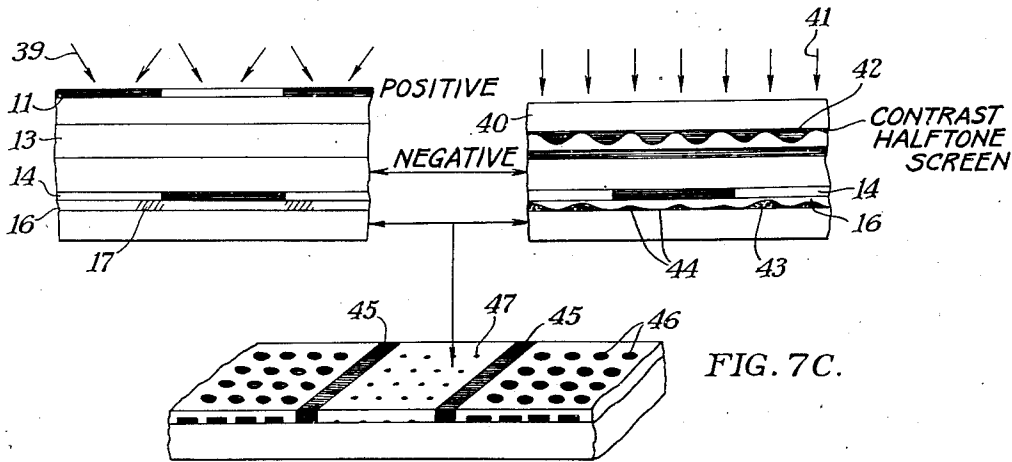
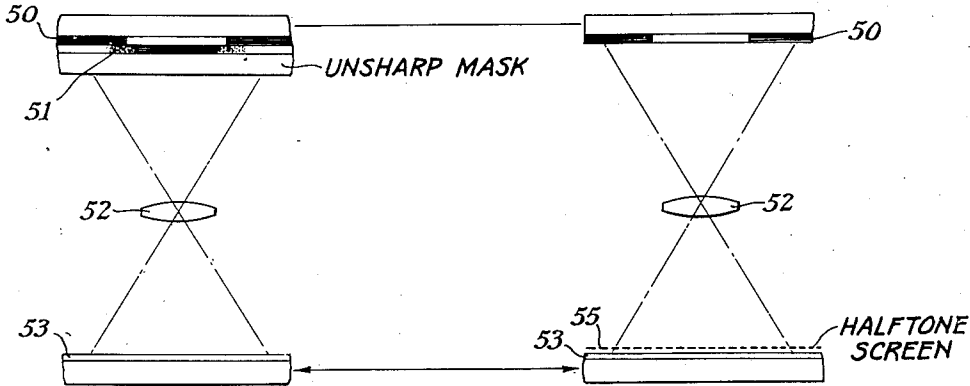


FIG. 8A.

FIG. 8B.



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PHOTOGRAPHIC UNSHARP MASKING
METHOD

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Application March 11, 1944, Serial No. 526,040

9 Claims. (Cl. 95—5)

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This invention relates to photo reproduction processes and is particularly useful in the making of negative or positive records for reproduction by photomechanical methods.

In common with my application Serial No. 438,633, filed April 11, 1942, now Patent No. 2,420,636, May 13, 1947, this invention has to do with the astounding effects produced by unsharp masking. The term "masking" is here used in the specific sense now commonly adopted in which two complete punctual records (both negative, both positive or a positive and a negative) of the same original are placed in exact register so that one modifies the other when printing therethrough. "Unsharp" masking has to do with arrangements in which one of the records is itself out of focus or is located out of focus, i. e. out of printing relation whereas the other record is sharp and in focus when printing from the combination. The mask or its manner of use may be referred to as diffuse or blurred or out of focus, but I prefer to use the term "unsharp" since it is more exact and more adequate especially when various forms of unsharpness are described, for example when the unsharpness produced by a disk source of light is compared with that produced by a ring source. My previous application had to do with printing a continuous tone record from a continuous tone original or a line record from a line original. The present case relates particularly to outline printing although it may be combined with continuous tone and one particular embodiment with half-tone printing.

It is the primary object of the present invention to produce an outline picture, positive or negative, from a continuous tone photograph. The resulting outline picture has a very striking effect which must be seen to be appreciated. It simulates an extremely fine etching or engraving. The outline occurs wherever there is a sharp change in density in the original, even though it is only a slight change. The line produced is somewhat wider or broader when the change in density is great but even a slight change, provided it is not a gradual one, produces the outline.

This outline effect produced by the present invention may be used entirely by itself. On the other hand in one embodiment, a small portion of the continuous tone background, specifically the extreme shadow portion is printed along with the outline with very pleasing results.

Another highly preferred embodiment of the invention combines the outline image with a half-tone image of the same original. Any of the three forms of the invention (pure outline, outline with

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a small portion of background or outline with part or all of the background reproduced in halftone) are particularly useful as illustrations for use in catalogues.

My previous application mentioned above has to do with the enhancement of fine details in any photo reproduction. From an academic point of view the present invention may be considered as a process in which the detail is greatly enhanced and all other effects are eliminated.

According to the present invention an outline image is made from a continuous tone record by employing a 100 per cent mask; (i. e. one whose contrast or density range is equal to that of the record) the mask is an unsharp one or is used unsharply. If a negative were masked by a sharp positive which has the same contrast as the negative, the two records being in contact and in register the combination would have a uniform all over gray appearance, except possibly for inequalities due to the non-linearity of the characteristic curves of the positive and negative emulsions. However due to unsharp masking according to the present invention it is only the over all contrast which is reduced to zero by the 100 per cent mask since sudden or sharp changes in density are not exactly masked out because of the unsharpness of the mask. Therefore these details of the picture remain in the combination and when printed onto a high contrast material the net result is a pure outline effect.

The same general enhancement giving an outline effect is produced with masks which differ slightly from 100 per cent but in any case the contrast of the mask must be within 30 per cent of that of the transparency which it is masking. Preferably the mask should have a contrast between 70 per cent and 100 per cent that of the sharp transparency (i. e. a masking factor between .7 and 1) but when weird or peculiar effects are desired the mask may have a contrast slightly greater i. e. up to 130 per cent of that of the transparency. Using a mask of slightly different contrast from the sharp record and giving proper exposure, allows a residual of the background to print with the outline enhancing the appearance. When the mask contrast is slightly less than that of the record and just sufficient exposure is given, the extreme shadows print through with the outline.

There is another trick which also emphasizes the extreme shadows and which may be used along with a reduced contrast mask or which may be used separately. It was pointed out above that the breadth of the outlines depends on the

degree of density change in the original. By making the original on the toe of the characteristic curve, i. e. by under exposure when making a positive original from which a negative is to be made, or by overexposing to be on the shoulder of the curve when making a negative record from an ordinary original, it is possible to give the shadows much higher contrast than the highlights. When such a record is unsharply masked according to the present invention the outline is broader in the shadows than in the highlight regions. This enhancement of the shadow outline may be combined with the embodiment in which shadow background is printed with the outline.

Probably from an academic point of view it should be pointed out that the present invention actually gives an exposure resulting in white outlines and black outlines immediately adjacent to one another. However in practice the absolute value of the final exposure is such that only one or the other is recorded. When making a positive print from an unsharply masked negative, the exposure is such as to print the black outlines but the rest of the background (except possibly extreme shadows) is left white so that the theoretically existing white outlines appear just as part of the white background. Thus in the embodiment where the extreme shadows are allowed to print through a white outline appears in these shadows which is also quite an attractive feature since it appears as a highlighted line. Of course, whatever contrast mask is used, sufficient exposure to print both the black outline and the background (also black if a high contrast sensitive material is used) but not sufficient to print the white outlines, results in a white outline picture. In general the selection of exposure is such as to give a black outline in printing a positive or to give a white one when the print is intended to be used as a negative since the ultimate positive print is more generally desirable in the form of a black outline.

Another relatively independent effect produced by the present invention which in many circumstances has been found to be extremely useful has to do with the sharpness of the record being masked. In an ordinary photograph for example the principal subject is usually photographed sharply with the background out of focus. The out of focus details of the background are blurred so that there are no sharp changes in density in the background portions of the photograph. The present invention produces an outline effect only where sharp details exist. Therefore the blurred background just doesn't print at all and the net result is an outline reproduction of the principal subject only. Obviously there are multitudinous ways in which this feature can be put to use when making illustrations. The operator in making an original photograph no longer has to worry about the background objects provided they are sufficiently out of focus so as not to be reproduced.

On the other hand the negative or other record to be reproduced or at least the desired details thereof must be sharp. The sharper the better is the preferable policy since this allows a greater range of unsharpness in the masking and better outlining effect in the result. If the original contained slightly unsharp details which are to be reproduced, the mask would have to be considerably more unsharp in order not to mask out these details. Too unsharp a mask on the other hand reduces the effectiveness.

Various forms of unsharp masking using a

sharp mask out of printing relation, e. g. out of contact, or an unsharp mask in or out of printing relation are described in my previous application which is mentioned above. Also there are various forms of unsharpness such as those produced when printing by an extended source of light in the form of a disk or in the form of a ring. The effect of a ring may be produced by a small source of light laterally displaced from the printing axis so as to send light obliquely through the record and by revolving this light about the printing axis or by rotating the sensitive material and the record which are in contact. The ring type illumination or its equivalent have in general proved preferable to the over all diffuse illumination embodiments. Of all possible forms the one most preferred in the present case employs a sharp positive mask for and out of contact with a sharp negative, the sensitive film being held in close contact with the negative. Printing is done by diffuse light so that the mask is effectively unsharp or diffuse when considered at the plane of the sensitive material and also at the plane of the negative itself. The second most preferable form employs an unsharp negative mask as nearly as possible in contact with a sharp positive, parallel light being used to prevent any unwanted effects due to lack of contact between the mask and the negative. In the first of these two forms of the invention the positive mask should have a contrast between 70 per cent and 100 per cent that of the negative when one desires the resulting positive print to be a pure outline one or an outline print with a slight amount of residual positive image in the shadows. In the second case the unsharp negative mask should for the same purpose have a contrast equal to or slightly less than (between 70 and 100 per cent of) that of the positive so that the resulting print is a pure negative outline (white lines on dark ground) or a negative outline with a residual background. Of course the exposure as in any photographic or photo reproduction process must be correct to bring out the details desired. The point is mentioned here merely because of the fact that in the first of the two forms both white and black outlines are theoretically printed but of course the exposure is just sufficient to record the black outlines. In the second case the exposure through the combination is sufficient to print the background black and hence all black outlines are not separately recorded.

While these two particular forms of unsharp masking have been found to be preferable, unusual effects which are sometimes wanted can be obtained by allowing the contrast of the mask to become slightly greater than that of the image being masked or by using transparencies which have a variable contrast factor between the highlights and shadows as discussed above in the example for broadening the outlines in the shadows.

Since the relative masking factor, i. e. masking factor, of the two records (the positive and the negative) determines the amount of residual background which is printed with the outline, it is sometimes desirable to be able to select the contrast desired after the records are made. To do this the records should be differently colored (one being black and white and the other a dye image for example) and when printing therefrom the color of the printing light is selected to give the masking factor desired.

In illustrating catalogues and in similar work, it is quite convenient to produce a negative or

positive by printing successively onto the same sensitive film by a transparency in one case masked according to the present invention and in the other screened to give a halftone image. Either printing may be first of course and any form of unsharp masking and any form of halftone screening may be used. Again it is often desirable to select the relative contrast desired after the images are made and for this purpose any pair of the three elements (the transparency, the mask and the half tone screen) may be differently colored, the printing light color being selected to give the relative contrast desired. The simplest form of this latter invention uses a colored negative, the mask and screen being neutral. The contrast during both the outline and the halftone printing is controlled by proper selection of printing lights.

The invention will be fully understood from the following description when read in connection with the accompanying drawings, in which:

Fig. 1 is intended to illustrate an ordinary continuous tone photograph but is of course drawn to permit mechanical reproduction.

Fig. 2 illustrates the outline effect produced by the present invention; this serves to illustrate the present invention but is very inadequate when considered as a demonstration of the beautiful effects actually obtained.

Fig. 3 is a schematic showing of a greatly enlarged detail in cross section of a negative being printed according to the invention.

Fig. 4 similarly illustrates printing from a positive.

Figs. 5 and 6 illustrate integral masking materials for use with the present invention.

Figs. 7A, 7B and 7C constitute a flow chart illustrating a combination of the present invention with halftone printing; Fig. 7C is in perspective.

Figs. 8A and 8B similarly illustrate schematically the combination of outline and halftone printing using projection printing.

Figs. 1 and 2 are included to illustrate the outline effect produced from a continuous tone negative or positive. That is, Fig. 1 is intended to represent a continuous tone print made from an unmasked negative. Fig. 2 is an outline print made from the same negative using a 100 per cent positive mask which is either unsharp or preferably is a sharp mask used unsharply i. e. out of printing relation with the negative and the sensitive material. If the positive mask has a contrast slightly less than 100 per cent, some shading remains in the shadows which is very pleasing in combination with the outline shown in Fig. 2. If the positive mask has a contrast slightly higher than that of the negative the residual negative printed with the positive outline gives a very weird effect useful under unusual circumstances.

In Fig. 3 a sharp negative 14 is masked by a sharp positive 11 held out of contact with the negative by the supports for both the positive and the negative and in the arrangement shown also by an additional spacer 13 which is optional. Since the mask is a sharp one the edge 12 of any detail therein is in exact register with the corresponding edge 15 in the negative. However diffuse light represented by small arrows 10 going in various directions is used so that the mask acts unsharply and an excess amount of light gets around in edge 15 to expose an area 17 in a sensitive film 16 which is in contact with the negative.

In the illustration the detail in the negative is shown as a dark one on a slightly less dense surrounding area. The corresponding part of the mask has a light element adjacent to darker areas. When the contrast of the two records is exactly the same (equal and opposite) the sum of the negative and positive densities at each point of the image is constant from point to point. Thus in general the areas 18 and 19 in the sensitive film 16 receive exactly the same exposure except near the edge of any detail. Due to the unsharpness of the masking however, the areas 17 receive slightly more exposure and the immediately adjacent areas 20 which correspond to the white outline effect discussed above receive less exposure. The total exposure for areas 18, 19 and 20 are all held below the threshold value and hence only the areas 17 prints giving the black outline effect desired. Continued exposure would first cause the areas 18 and 19 to become developable with a white line 20 and eventually would even expose the area 20 so as to be developable.

Consider now the case where the positive mask has slightly less contrast than the negative. In this case the area 18 will receive a greater exposure than the area 19 because the sum of the densities of the positive and negative in front of the area 18 will be less than the sum of the densities in front of the area 19. By proper selection of exposure, the outline 17 and the extreme shadows only are printed. In the middle tones and highlights the exposure is usually still kept below the threshold value so that the background remains clear in those areas. In practice this use of a slightly lower contrast mask and printing of the extreme shadows along with the outline actually results in more of the outlines being printed in the shadow areas than in the highlights. The diffuse light 10 is shown as being from a uniformly extended source but for many purposes a ring source is preferable or the equivalent of a ring produced by a light source obliquely illuminating the combination and moved in a circle to maintain a substantially constant angle of obliquity, producing a relative movement of a light source and the pile of layers shown in Fig. 3. The same result can be produced by holding the light source steady, laterally displaced from the printing axis to give the oblique illumination, and by rotating the pile of records in its own plane. At first glance it would appear that either the positive or the negative could be the one that is out of printing relation with the sensitive material to act as the mask. The black outlines would be formed around each detail as before, but there is one very important difference. In Fig. 3 the black outlines actually occupy part of the area corresponding to a less dense area on the negative and a more dense area on the positive. That is the black lines encroach upon the area 18. If the position of the positive and the negative were reversed, the black lines would encroach on the area under the less dense element of the positive. For large areas this difference would hardly be detectable, but for small clear areas in the positive such as a small highlight spot, the encroachment of the black outline might be just sufficient to fill up the spot entirely. This would give a black spot instead of a highlight dot in the resulting positive print which is not quite as attractive a result as that obtained by the arrangement shown in Fig. 3. With some originals of course, the difference would never be detected.

In Fig. 4 a sharp positive 24 is masked by an unsharp negative mask 22 which is placed as

nearly as possible in contact with the positive. The unsharpness is illustrated by the fact that the dark area 23 of the mask extends beyond the corresponding light area of the positive but is not so dense near the border of this area. Since it is not possible to have the mask exactly in contact with the positive, collimated light represented by parallel arrows 21 is used for the exposure. A sensitive film in contact with the positive is exposed sufficiently to give a white outline image represented by area 25 where the exposure is reduced both by the positive and by the unsharp negative mask. The other areas 26 and 27 are uniformly exposed if the mask and the positive have the same contrast, but if the negative mask has slightly less contrast than the positive, the area 26 receives more exposure than the area 27 and in the shadows, this additional exposure produces some background effect when printing from the resulting negative. The advantages of ring type diffusivity as described above are obtained when the unsharp mask 22 is made by ring illumination.

Fig. 5 illustrates, in greatly enlarged section, an integral masking film particularly useful for the practice of the present invention and corresponding to a similar film intended for use with the process described in my previous application mentioned above. The negative to be masked is recorded in a blue sensitive emulsion 30 which may also be sensitive to green but which is not sensitive to red. Preferably this is a high contrast emulsion but not so high as those used for halftone negatives. In special embodiments the emulsion may be selected to have certain predetermined relative contrast for the highlight, middle tone and shadow regions. This emulsion is carried by a support 31 provided with an antihalation layer 32 which is substantially impervious to all light including red. On the back of this film there is coated a slow red sensitive emulsion which is protected by the antihalation layer 32 from being exposed at the time the negative image is recorded in the layer 30. During development of the layer 30 which is not sensitive to red light, a beam of parallel red light exposes the layer 33 to the negative image which has developed up in the layer 30; the antihalation dye in the layer 32 having been removed or bleached by the developing solution. Since the layer 30 is not sensitive to red light this layer is given no additional exposure, but a sharp positive masking image is produced in the layer 33. The emulsions are selected so that when the development continues for a certain time after the mask producing exposure the contrast developed in the image 33 substantially equals (i. e. is within 30 per cent of) the contrast of the image in the layer 30. That is the emulsion 33 has a gamma just slightly greater than unity for the time of development provided. For example, if after the first exposure of the layer 30, it is developed for three minutes producing an image whose gamma relative to the original picture is not critical to the present invention and then through this image, the layer 33 is exposed and development continued for four minutes longer, the following conditions should hold to give exactly 100 per cent masking. The gamma of the image produced in the layer 33 by the four minutes continued development should be greater than unity by the proportion equal to the increase in contrast of the image in the layer 30 which increase occurs during the second development period of four minutes. Since a mask contrast slightly different from 100 per cent is satisfactory for

most purposes, the gamma and development relationships of the two layers are not too critical for commercial adoption. The characteristic of this film which distinguishes it from other integral masking arrangements is first the relative sensitivity of the two layers, second the fact that the rear emulsion is prevented from receiving the primary exposure by the antihalation layer and/or by being of such low sensitivity and thirdly (which distinguishes it from similar films for use in my previously mentioned application) by the gamma of the rear emulsion during the standard development time being substantially equal to unity multiplied by the ratio factor for the increase in contrast in the front emulsion during the same period which constitutes prolonging of the development of the front emulsion.

This integral masking film as thus exposed produces a combination of a sharp positive for masking a sharp negative as in Fig. 3. However, it may be used to produce a sharp positive with an unsharp negative mask for use as in Fig. 4, as follows. A sharp positive image is exposed and partly developed in the front emulsion 30 and then by diffuse (instead of parallel) red illumination an unsharp negative mask is produced in the rear emulsion 33. Because of the separation due to the support 31 the resulting combination must be printed by collimated light such as 21 in Fig. 4.

Fig. 6 differs from Fig. 5 mainly by the rear emulsion 36 being made up with the antihalation dye incorporated right in the emulsion layer. The effect is just the same as before. Merely in order to disclose a slightly different embodiment of the relative sensitivities of the two layers, Fig. 6 has the front emulsion 34 blue sensitive only and a rear emulsion which is sensitive to green. The rear emulsion may also be sensitive to red and either green or red or both may be used in exposing the rear emulsion. Both emulsions are carried on and separated by a support 35. Thus in general the front emulsion is sensitive only to a short wave length region of the spectrum including blue and the rear emulsion has a sensitivity which includes a region of longer wave lengths. As before the film shown in Fig. 6 may be used for producing either a sharp out of contact mask by exposure with parallel light or for producing an unsharp mask which must be used with collimated light but which is produced with diffuse light. The term "diffuse light" as pointed out above is intended to include both all over diffusion and that limited to the form produced by a ring source of light or its equivalent.

Figs. 7A and 7B illustrate two steps of a procedure either of which may be first. Fig. 7A corresponds to Fig. 3 in which a sensitive film 16 receives an outline image represented by areas 17. The illumination represented by arrows 39 is intended to represent illumination from a ring source of light or a small source of light moved in a circle about the optical printing axis. Of course complete over all diffusion such as from a disk source of light as represented by arrows 10 in Fig. 3 could alternately be used but merely to illustrate both variations, the ring illumination represented by arrows 39 is substituted for the disk illumination represented by arrows 10. The contrasts of the positive 11 and the negative 14 are substantially equal so that only this outline image 17 is recorded. In Fig. 7B the same negative 14 is printed onto the same sensitive film 16, but the mask 11 is removed and the exposure is through a contact halftone screen 40, parallel light represented by arrows 41 being used to elim-

inate any effect due to the fact that there is not perfect contact between the negative image and the screen. Each element 42 of the halftone screen results in reduced exposure on the sensitive film. Behind a light area of the negative 14 relatively large areas 43 are exposed and behind a dark area relatively small areas 44 are exposed.

After receiving both the halftone exposure and the outline exposure, the film is processed to a high gamma as shown in Fig. 7C in which the outline exposure results in black lines 45. The halftone exposure results in a halftone pattern made up of dots 46 and 47 in which the latter are smaller due to the reduced exposure throughout the negative. This element shown in Fig. 7C is a combination halftone and outline positive which may be used for any photomechanical reproduction process either by making a printing plate directly therefrom or by making a corresponding negative from which the printing plates are made in turn.

A similar combination halftone and outline process is illustrated in Figs. 8A and 8B either exposure being first. In Fig. 8A the positive 50 is unsharply masked by a negative 51 and by projection printing through a lens 52 exposes a sensitive film 53. The unsharp mask 51 is then removed and a halftone screen 55 is placed a suitable distance in front of the sensitive film 53 and a supplementary exposure given. The sensitive film 53 is then processed to a combination halftone outline negative.

It is sometimes desirable to control the contrast at will after the records have been made. In the embodiment shown in Fig. 3 this is accomplished by having the negative 14 or the positive mask 11 colored or by making them both colored but differently. For example, if the mask 11 is a dye image of red hue, it will have a relatively high contrast if the printing light is filtered blue and a relatively low contrast if the printing light is filtered red. This embodiment is particularly useful when absolutely pure outline effects are desired which require that the contrasts of the negative and the positive be exactly the same.

Similarly in the combination outline halftone process illustrated in Figs. 7A, 7B and 7C the negative 14 may be colored or the negative 11 may be colored or the contact screen 40 may be colored and the various contrasts controlled by the color of the printing light. The effect of a colored halftone screen is described in my U. S. Patent 2,304,988. These various arrangements for contrast control are particularly useful with my present invention first because of the desirability of having exactly 100 per cent masking when pure outline effects are desired or having a predetermined difference from 100 per cent masking when slight background effects or extra outlining in the shadows are also desired and on the other hand to control the relative effects of the outline and the halftone exposure in the combination process.

It will be noted that even in the most general embodiment of the present invention the original record being copied is a continuous tone record having all stages of highlights, middle tones and shadows. The meaning of "continuous tone record" is well known and exact; it distinguishes of course from line work and from halftones. The various special features of the invention such as when extreme shadows are also printed in or the shadow outlines are broadened or the outline is combined with a halftone background also all depend directly and implicitly on the fact

that the sharp record being printed is a continuous tone one. Secondly the fact that the mask contrast is equal to or at least within 30 per cent of that of the sharp record has been found to be quite critical in the production of the results described. In the third place, the present invention should not be confused with the bas relief or cameo effects produced by placing a positive and a negative slightly out of register. Presumably the present invention can be combined with the out of register effect if an unbalanced outlining were desired but in all the pictures that I have so far printed according to my invention I have found that the unbalancing is undesirable or at least adds nothing of value to the appearance of the picture obtained directly according to my invention alone. In the fourth place it is of course critical to my invention that both the sharp record and the masking record be complete or punctual images not just a vignetting mask for example, and that the mask be negative with respect to the sharp record. That is the invention does not work with any masking system employing a positive mask for a positive record or a negative mask for a negative record.

Having thus fully described the invention I wish to point out that it is not limited to these specific embodiments but is of the scope of the appended claims.

What I claim is:

1. The method of producing from a continuous-tone picture having a maximum, a minimum and a plurality of intermediate tones, a two-tone reproduction with outline effects in which outline effects over at least a major portion of the picture-tone range all tones are reproduced as one tone, i. e. with effectively equal density and zero contrast, and only sudden changes in tone over the picture area are reproduced as lines of the other of the two tones and in which over the remaining portion, if any, of the picture-tone range all tones are reproduced as the other tone and sudden changes in tone are reproduced as lines of said one tone and which two-tone reproduction includes in addition to said outline effect a halftone reproduction of intermediate tones which method comprises masking a continuous tone transparency in an unsharp manner using a continuous tone mask which is negative with respect to the transparency and which has a contrast approximately equal to that of the transparency, placing and exposing a sensitive material in printing relation with the transparency, the superimposed images of the transparency and mask being respectively sharp and unsharp at the sensitive material during said exposing removing the mask, placing a halftone screen in screen relation with the transparency and the material, exposing the material to the screened transparency and processing the material to a combination halftone and line record.

2. The method of producing from a continuous-tone picture having a maximum, a minimum and a plurality of intermediate tones, a two-tone reproduction with outline effects in which outline effects over at least a major portion of the picture-tone range all tones are reproduced as one tone, i. e. with effectively equal density and zero contrast, and only sudden changes in tone over the picture area are reproduced as lines of the other of the two tones and in which over the remaining portion, if any, of the picture-tone range all tones are reproduced as the other tone and sudden changes in tone are reproduced as lines of said one tone and which two-tone re-

production includes in addition to said outline effect a halftone reproduction of intermediate tones which method comprises two printing steps in either succession one of which consists of placing in masking register a positive and a negative continuous tone record of the same original, and with substantially the same contrast, the positive being effectively unsharp with respect to the negative when printing therefrom and printing onto a sensitive material in printing relation with the negative the superimposed images of the negative and positive records being respectively sharp and unsharp at the sensitive material during said printing and the other of which steps consists of printing onto said sensitive material from the negative through a halftone screen without the positive.

3. The method according to claim 1 in which at least two of the transparency, the mask and the halftone screen are of different colors and the color of the printing light for at least one of the two printing steps is selected in accordance with the masking factor desired.

4. The method according to claim 2 in which at least two of the negative record, the positive record and the halftone screen are of different colors and the color of the printing light for at least one of the two printing steps is selected in accordance with the masking factor desired.

5. The method of producing from a continuous-tone picture having a maximum, a minimum and a plurality of intermediate tones, a two-tone reproduction with outline effects in which outline effects over at least a major portion of the picture-tone range all tones are reproduced as one tone, i. e. with effectively equal density and zero contrast, and only sudden changes in tone over the picture area are reproduced as lines of the other of the two tones and in which over the remaining portion, if any, of the picture-tone range all tones are reproduced as the other tone and sudden changes in tone are reproduced as lines of said one tone, which method comprises placing a sharp positive and a sharp negative continuous tone record of the same original and with substantially the same contrast, slightly out of printing relation in exact masking register and printing through one record onto a sensitive material substantially in contact with and behind the other record by a small light laterally displaced from the printing axis orthogonal to the center of the records and during the printing moving the light and records with a circular motion relative to one another to give the equivalent of a ring of light.

6. The method of producing from a continuous tone picture having a maximum, a minimum and a plurality of intermediate tones, a two-tone reproduction with outline effects in which outline effects over at least a major portion of the picture-tone range all tones are reproduced as one tone, i. e. with effectively equal density and zero contrast, and only sudden changes in tone over the picture area are reproduced as lines of the other of the two tones and in which over the remaining portion, if any, of the picture-tone range all tones are reproduced as the other tone and sudden changes in tone are reproduced as lines of said one tone, which method comprises placing a sharp positive and a sharp negative continuous tone photographic record of the same original slightly out of printing relation in masking register, the positive having a contrast between 70 per cent and 100 per cent of that of the negative, placing a sensitive ma-

terial in printing relation with the negative and exposing the material to said negative as masked, the superimposed images of the negative and positive on the sensitive material being respectively sharp and unsharp during said exposing, in which the exposing is by a small source of light laterally displaced relative to the optical printing axis and in which the light and records are moved with a circular motion relative to one another during exposure to give the equivalent of a ring of light.

7. The method according to claim 1 in which the first mentioned exposing of a sensitive material in printing relation with a masked transparency is by a small source of light laterally displaced relative to the optical printing axis and in which the light and records are moved with a circular motion relative to one another during exposure to give the equivalent of a ring of light.

8. The method of producing from a continuous tone picture having a maximum, a minimum and a plurality of intermediate tones, a two-tone reproduction with outline effects in which outline effects over at least a major portion of the picture-tone range all tones are reproduced as one tone, i. e. with effectively equal density and zero contrast, and only sudden changes in tone over the picture area are reproduced as lines of the other of the two tones and in which over the remaining portion, if any, of the picture-tone range all tones are reproduced as the other tone and sudden changes in tone are reproduced as lines of said one tone, which method comprises masking a continuous tone photographic transparency in an unsharp manner using a continuous tone mask which is negative with respect to the transparency and which has a contrast within 30 per cent of that of the transparency and printing from the transparency as masked, the superimposed printing images of the transparency and mask being respectively sharp and unsharp during said printing, in which the exposing is by a small source of light laterally displaced relative to the optical printing axis and in which the light and records are moved with a circular motion relative to one another during exposure to give the equivalent of a ring of light.

9. The method according to claim 8 in which the masking factor is less than 100%.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
242,412	Guillebaud	May 31, 1881
687,107	D'Asar	Nov. 19, 1901
812,748	Ippers	Feb. 13, 1906
887,845	Reckard	May 19, 1908
1,356,442	Garbutt	Oct. 19, 1920
1,447,759	Christensen	Mar. 6, 1923
1,677,965	Fruwirth	July 24, 1928
1,725,395	Fruwirth	Aug. 20, 1929
1,967,057	Irvine	July 17, 1934
1,978,559	Zimmerman	Oct. 30, 1934
2,110,496	Babcock	Mar. 8, 1938
2,183,598	Weaver	Dec. 19, 1939
2,193,931	Michaelis	Mar. 19, 1940
2,241,413	Michaelis	May 13, 1941
2,320,693	Yauck et al.	June 1, 1943
2,340,656	Gaspar	Feb. 1, 1944

(Other references on following page)

FOREIGN PATENTS

Number	Country	Date
80,038	Germany -----	Feb. 26, 1895
5,620	Great Britain -----	1903
365,498	Germany -----	Dec. 16, 1922
405,764	Germany -----	Nov. 7, 1924
532,233	Germany -----	Apr. 5, 1932

OTHER REFERENCES

Spiegler and Juris, "Photographische Korrespondenz," Band 67, 1931, pp. 4-9; Band 69, 1933, pp. 36 to 41.

Clerc, "Photography, Theory and Practice," 1934, p. 319; publ. by Sir Isaac Pitman & Sons, Ltd., N. Y.