

Sept. 3, 1946.

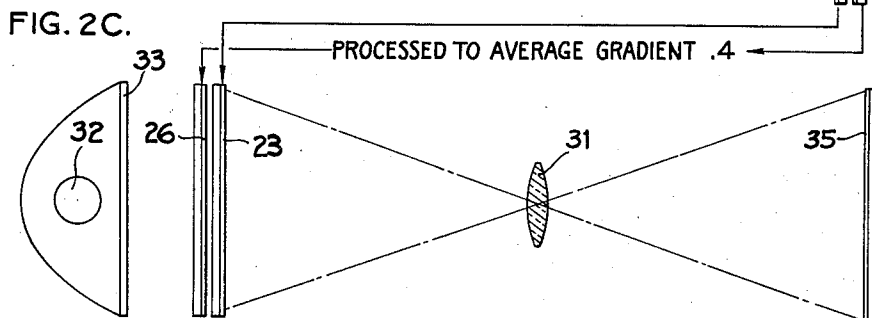
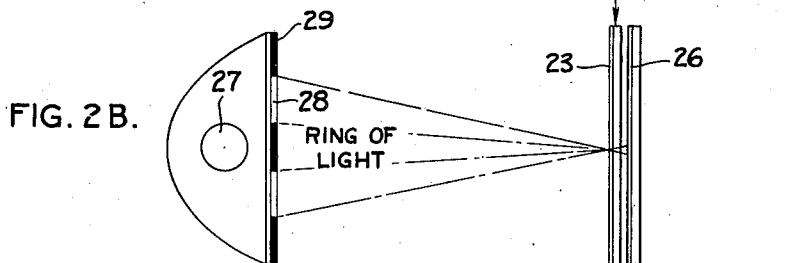
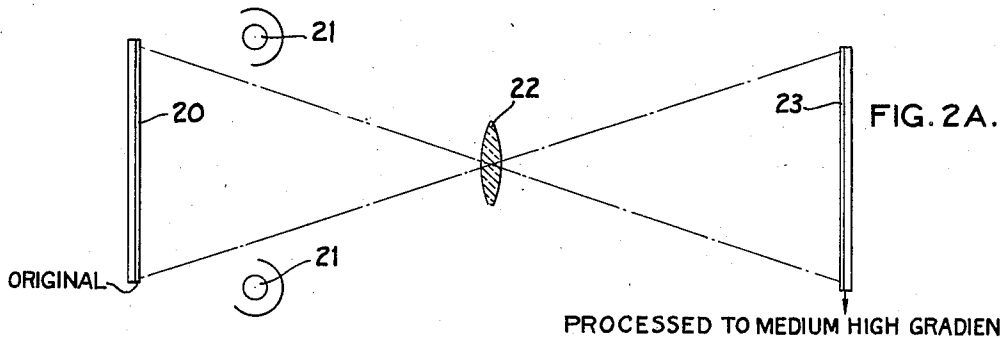
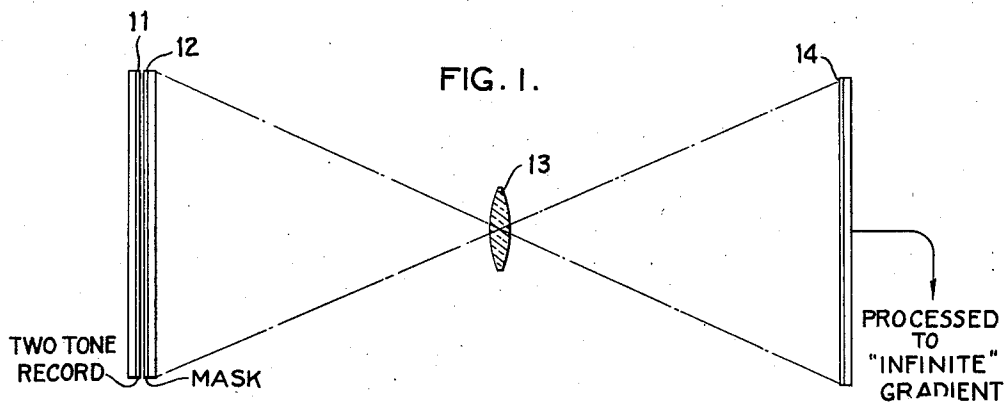
J. A. C. YULE

2,407,211

LINE AND HALFTONE REPRODUCTION

Filed May 26, 1944

3 Sheets-Sheet 1



JOHN A.C. YULE
INVENTOR

BY *Newton M. Perkins*
F. M. Emerson Holmes
ATTY & AGT

Sept. 3, 1946.

J. A. C. YULE

2,407,211

LINE AND HALFTONE REPRODUCTION

Filed May 26, 1944

3 Sheets-Sheet 2

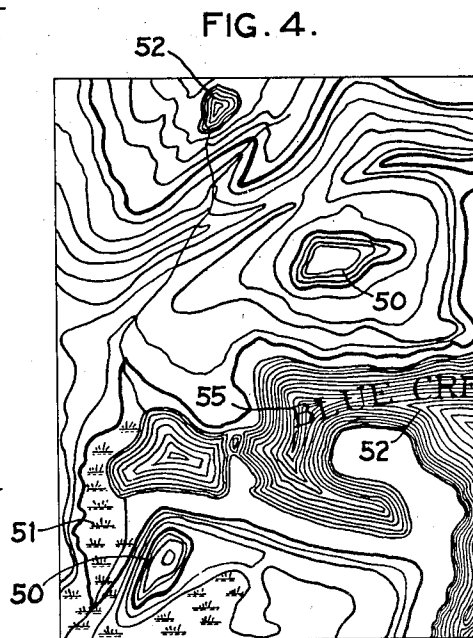
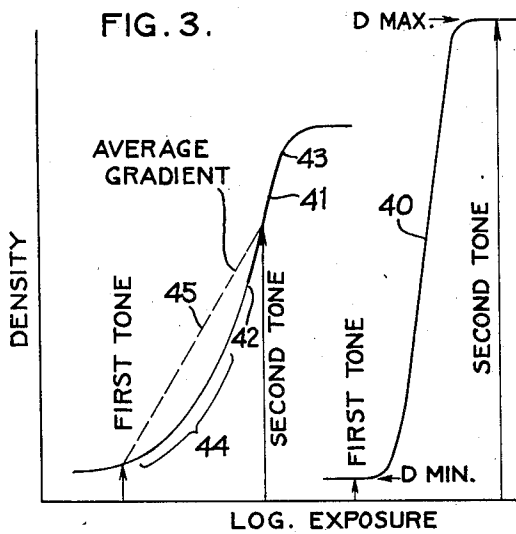
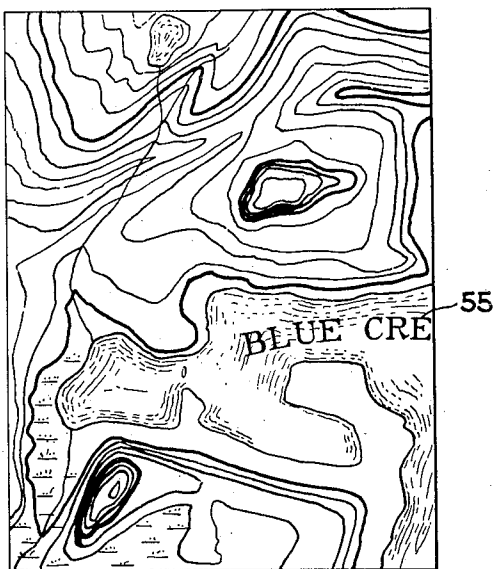
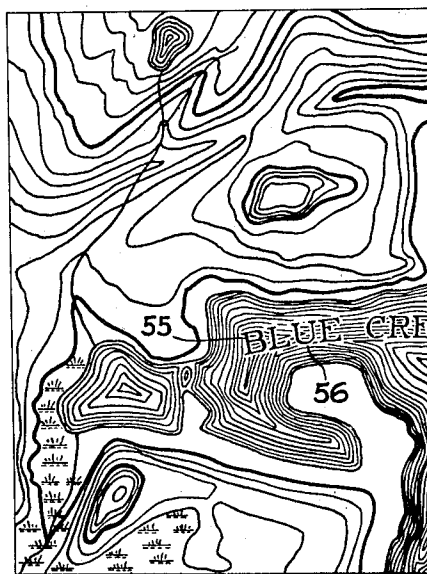


FIG. 5.



PRIOR ART

FIG. 6.



JOHN A.C. YULE
INVENTOR

BY *Newton M. Perrins*
F. M. Emerson Holmes
ATTY & AG'T

Sept. 3, 1946.

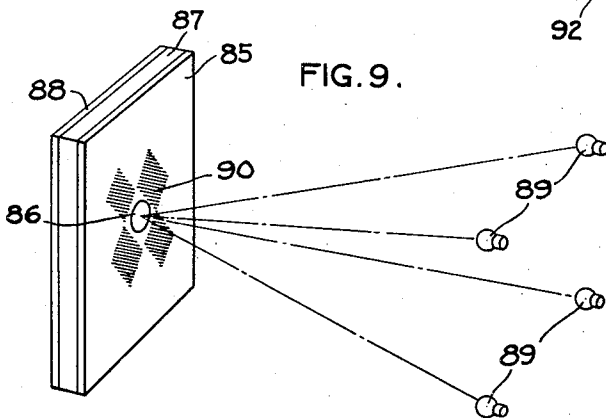
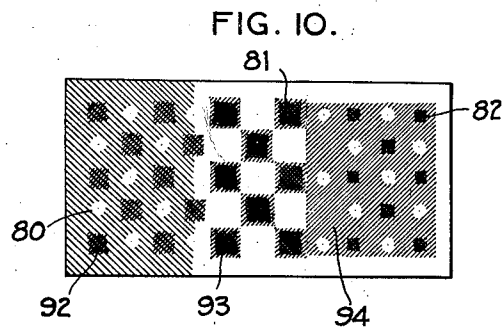
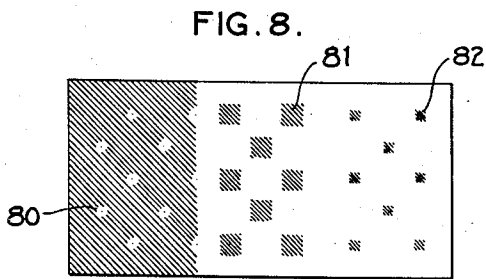
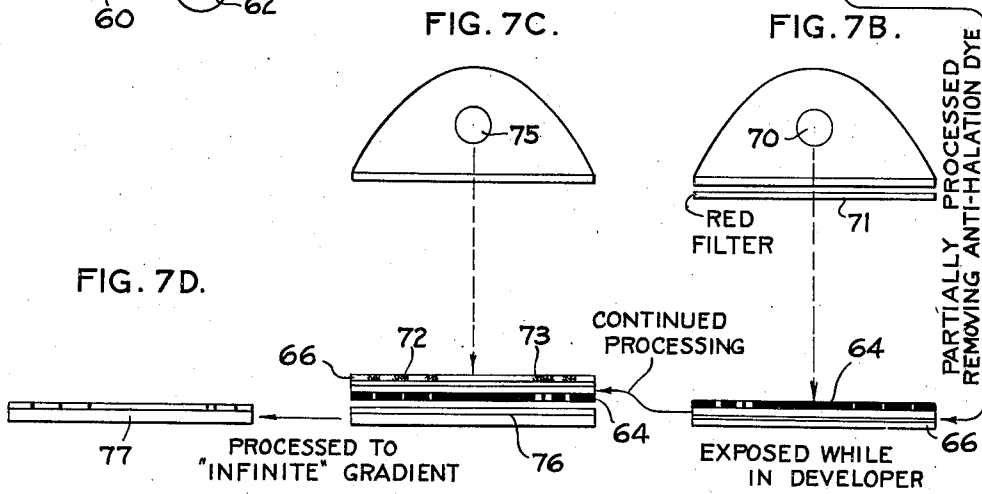
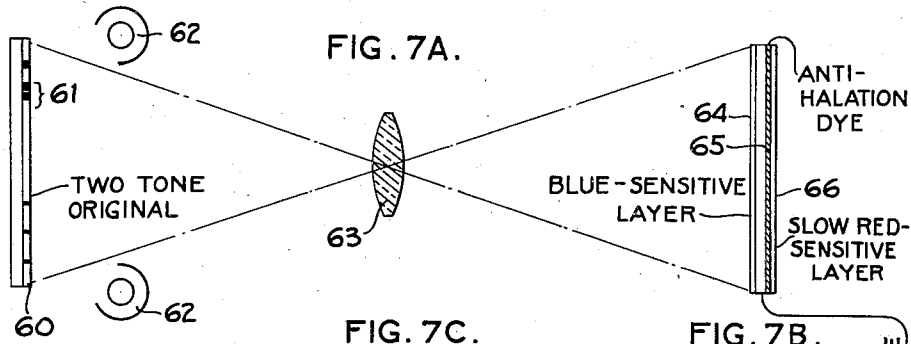
J. A. C. YULE

2,407,211

LINE AND HALFTONE REPRODUCTION

Filed May 26, 1944

3 Sheets-Sheet 3



JOHN A.C. YULE

INVENTOR

BY

Frederick M. Emerson Holmes
ATTY & AGT

UNITED STATES PATENT OFFICE

2,407,211

LINE AND HALFTONE REPRODUCTION

John A. C. Yule, Rochester, N. Y., assignor to
Eastman Kodak Company, Rochester, N. Y., a
corporation of New Jersey

Application May 26, 1944, Serial No. 537,443

18 Claims. (Cl. 95-5)

1

This invention relates to the reproduction of a two-tone record such as a line drawing or a halftone.

The object of the invention is to reproduce the record without loss of either fine light or fine dark details.

A description of the present invention involves certain possibly unfamiliar terms which are therefore now defined at least in a general way. Halftones or line drawings such as maps are described as two-tone records since they consist fundamentally of dark and light elements without any intermediate tones. Of course a map may be made with several colors so that contour lines appear brown, rivers appear blue, roads appear black etc. However, it is still fundamentally a two-tone record since it is treated as such in reproduction. For example, a blue filter over such a record renders the blue tones the same as the light tones leaving only the other dark tones; or without a filter, the colors can all be reproduced as the dark tone although perhaps not so conveniently. The reproduction of any two-tone original normally involves an "infinite gradient" process. Photomechanical processes generally come under this heading. An infinite gradient process is by definition one which will produce only two tones, a minimum density or light tone and a maximum density or dark tone. Any actual process may have a high but still finite gamma and this acts as an "infinite gradient" process because the difference in density of the two tones being reproduced is such that one of them gives the minimum density and the other gives the maximum density in the reproduction.

The present invention involves "unsharp" masking, and for completeness, reference is made to my copending application Serial No. 438,633 filed April 11, 1942. However the earlier application relates primarily to the reproduction of continuous tone originals and the effect of the unsharp masking in the present infinite gradient processes is different from that in continuous tone work. An unsharp mask is one which is made or used slightly out of focus. If the original from which it is made is perfectly sharp, the resulting circle of confusion in the unsharp mask is termed the "contribution to confusion." If the original has a circle of confusion, the contribution to confusion is just added thereto. In two-tone work however both the original and the final reproduction thereof usually have no apparent confusion or unsharpness. The unsharpness of the mask may be of the disk or ring type or in the case of halftone reproduction may

2

have what is termed a "square symmetry" corresponding to the rectilinear distribution of the halftone elements in the screen pattern.

Since it is not customary in two-tone reproduction to use any form of masking whatever, the normal masking terminology is perhaps unusual but still has a precise meaning. The masking factor is most easily defined in terms of the density range of the two records. For example if the mask has a density range only .4 of that of the record it is masking, the masking factor is .4. Density range itself is the difference in density between the light areas and dark areas of the two-tone record. Usually the mask is made from the record it is to mask and in this case the masking factor is numerically equal to the "average gradient" of the mask. "Average gradient" (see Journal of Optical Society of America, Oct. 1942, vol. 32, p. 558) refers to the contrast of a record relative to some previous, and unless otherwise specified, the immediately preceding record or scene from which it is made. Gamma is the particular average gradient which relates to the straight line portion of a characteristic curve. It can be shown that the average of the gradients at all log. exposure values between two given points on a characteristic curve is equal to the slope of the straight line joining those points which slope is the "average gradient" for the exposure range between those points.

In photomechanical or photographic reproduction of two-tone originals it is often difficult to reproduce both fine light and fine dark details simultaneously. Proper exposure for the light details (in dark areas) normally causes the dark details (in light areas) to disappear and vice versa. This is exemplified by the Patent Office requirement that drawings be made distinctly since the normal reproduction process will otherwise lose the fine details. The reproduction processes here concerned always involve at least one infinite gradient step. For example an original line drawing or map may be photographed by an infinite gradient process to produce a negative from which printing plates are made directly. Alternatively the negative may be made at high but not infinite gradient and the printing plates are then made from the negative by an infinite gradient process. It has been found that the infinite gradient step, wherever it occurs, is the one in which either the fine dark or the fine light details are usually lost, although they may have been already lost at a previous step.

According to the present invention this loss of detail is prevented by unsharply masking the

record being printed either at the infinite gradient step or at some prior step. The mask itself may be unsharp or may be used unsharply with an unsharpness sufficient to smooth out, degrade, or perhaps even obliterate entirely, the finer details thereof. The mask is negative to the record it is masking and should have an effective masking factor between .2 and .7 preferably between .3 and .5. The record being masked may be the line or halftone original itself in which case the resulting negative or any later record may be processed to an effectively infinite gradient. On the other hand the record being masked may be a negative of an original, the negative having a density range between 1.2 and 3.0 or even 4.0 and the positive mask for the negative having a density range between .25 and 2.1. A positive may be printed from the combination and processed to an effectively infinite gradient or to a lower gradient to be later reproduced at the high gradient.

In simple terms, the principle of the operation of the invention is as follows. The two-tone record consists primarily of two density values only but for various reasons (light scattering, diffraction etc.) fine dark details in a region of low density effectively do not have the maximum density and fine light details in a high density region effectively do not have the minimum density. In fact the finest dark details often have lower effective density than the finest light details. Any actual paleness of the dark details increases this effect. The mask according to the present invention reduces the over all contrast of the record but has little or no effect on the contrast of fine details. This raises the density of the light regions including the density of the dark details until the dark details have a density greater than the light details. Precise masking would raise the dark details to the maximum density exactly and also bring the light region or minimum density up to that of the light details. With such an arrangement it is easily possible to produce all details both light and dark by any infinite gradient process.

For clarity, the following example is included. A two-tone record is made up primarily of areas of density 0.2 and areas of density 2.0. However the effective density of fine dark details in light regions is only 0.8 (not 2.0) and that of fine light details in dark regions is 1.4 (not 0.2). No infinite gradient step can simultaneously record both sets of details since the dark ones have lower density than the light ones. Normal gradient processes can of course record all the details but cannot make the dark detail density greater than the light detail density and hence can never be suitable for infinite gradient reproduction. The mask according to the present invention has in this case a density of 1.3 in the highlights and 0.1 in the shadows (the mask is negative to the record). Total shadow density is now $2.0 + 0.1$ (2.1); the highlight density is $0.2 + 1.3$ (1.5); the fine light details, having practically the same amount of masking as the shadows because of the unsharpness, have a density $1.4 + 0.1$ (1.5) and the fine dark details receive the same masking as the rest of the highlight region and have a density $0.8 + 1.3$ (2.1). Thus fine details have the same densities as other regions of the same intended tone and can be reproduced easily.

In the reproduction of line drawings I have found that the contribution to confusion should preferably be between .003 and .03 inch so that

on the one hand it is effective and on the other hand the unsharpness is not apparent as objectionable outlining in the final print. The upper limit (.03 inch) and up to .06 inch in the fine type of work to which the invention is applied gives a detectable outlining of coarse details such as lettering so that fine lines appear in the reproduction terminated just before they cut the letters: This enhances the lettering. The lower values of unsharpness give precise reproduction of the original. On the other hand when the two-tone record being masked is a halftone the contribution to confusion in the mask or in the way it is used should be of the same order of size as the halftone element. Preferably the unsharpness should have a square symmetry and be equal to the size of the halftone element so that each light area in the halftone original contributes to the production of four dark areas in the mask which are located to mask the corresponding four dark areas in the original.

Another way of describing the operation of the invention is in terms of the difference in exposure which would be required without masking to reproduce fine light details in one case and fine dark details in another. For example, fine light details in an original might require four times as much exposure for proper reproduction as is required for good reproduction of the fine dark details. That is, the proper reproduction would require exposures differing by a factor of four. If the logarithm of this factor is D , the unsharp mask according to the present invention should have a density range approximately equal to D . With a factor of 4, D is equal to 0.6 and the mask should have a density range roughly between 0.5 and 0.7. The effect of the mask is to reduce the contrast of the record, but this is immaterial since it is being reproduced by an effectively infinite gradient process anyway; moreover the mask, due to its unsharpness, does not reduce the contrast of the fine details but only insures that they shall receive the correct relative exposure, therefore both the fine light details and the fine dark details are reproducible by the infinite gradient process. It will be realized that the present invention thus provides an automatic dodging in place of the inefficient manual dodging often adopted when such problems of differing exposures arise. Masking by too high a factor tends to give an unnatural lightness to dark areas containing light details.

Preferably the mask is held integrally in register with the record even when being processed, to avoid the need for careful registration later. Of course a certain amount of unsharpness renders the registration somewhat simpler but integral masking is preferable, especially when the above-mentioned square type of symmetry is employed in halftone production. With this square symmetry, registration of the mask and the record manually would be extremely difficult.

In any embodiments of the invention, it is possible to get at least part of the effect desired by making only the major portion of the printing step in question, through the mask, the remainder of the exposure being given without the mask. For most purposes however I prefer to make all of the exposure unsharply masked.

Fig. 1 represents one form of the fundamental step of the invention.

Figs. 2A, 2B and 2C constitute a flow chart illustrating several steps in one embodiment of the invention.

Fig. 3 is included to aid in the definition of certain technical terms used.

Fig. 4 is intended to represent an enlarged detail of an original map. It is drawn greatly enlarged since at normal size, the fine details would be objectionable to the Patent Office whose reproduction processes would not adequately reproduce them.

Fig. 5 is a similar enlarged detail of a reproduction of the map shown in Fig. 4 by prior processes.

Fig. 6 is similar to Fig. 4 illustrating reproduction according to the present invention.

Figs. 7A to 7D constitute a flow chart illustrating several steps of an embodiment of the invention involving integral masking.

Fig. 8 shows an enlarged detail of a halftone original to be reproduced.

Fig. 9 illustrates the step of making an unsharp mask with square symmetry from a halftone original.

Fig. 10 shows the combination of the original shown in Fig. 8 with an unsharp mask having square symmetry.

In Fig. 1 a two-tone record 11 which may be an original or a positive or negative photograph of an original and which may be a line drawing or a halftone record is unsharply masked by a mask 12 which is negative to the record. By means of a lens 13 the masked combination is printed onto a sensitive layer 14 which is then processed to an effectively infinite gradient. That is, it is processed so that the light areas in the original record appear at maximum density in the print and the dark areas appear at minimum density with no intermediate densities being formed in the layer 14. The mask 12 may be either unsharp itself or spaced from the record so as to act unsharply. Theoretically the mask could be adjacent to the sensitive layer rather than to the record but registration difficulties in this case would be greater. The effective unsharpness of the mask may be measured either at the record 11 or at the sensitive layer 14. The masking factor should be between .2 and .7 preferably between .3 and .5 expressed in another way between $D-0.1$ and $D+0.1$ where D is the logarithm of the factor by which the exposures would differ in properly reproducing the fine light details and the fine dark details of the record 11 without the mask 12. Alternately the layer 14 may be processed by reversal to be positive relative to the record 11. Also it may be processed to a lower but still high gradient and thus contain the fine light and fine dark details emphasized so as to be easily reproducible by a later infinite gradient step. The lens 13 is unnecessary of course when contact printing is employed.

The process may involve relatively low gradient steps prior to the infinite gradient step in which case the unsharp masking according to the present invention is not needed until the infinite gradient step is reached but may be used any time prior thereto. This is illustrated in Figs. 2A and 2C in which an original map or other line drawing 20 is illuminated by lamps 21 and printed through a lens 22 onto a medium high gradient negative record 23. The record 23 is then positioned as shown in Fig. 2B slightly out of printing relation with a sensitive layer 26 which is ultimately to become an unsharp mask for the negative 23. A ring source of light provided by a lamp 27 and a circular transparent area 28 in an opaque mask 29 exposes the sensi-

tive film 26 through the negative 23. The unsharpness or diffusion in the positive 26 is ring-shaped which has been found to be preferable for most purposes although the difference in the effects of various forms of unsharpness are relatively minor.

The positive 26 is then processed to an average gradient of .4 which means that it is processed to have a density range of .4 of that of the negative 23. When printing from the masked combination 23 and 26 as shown in Fig. 2C the slight magnification of the positive 26 relative to the negative 23 produced by the step shown in Fig. 2B is taken into account and compensated for by placing the positive behind the negative when printing therefrom. That is, the distance from the light source 28 to the negative 23 in Fig. 2B should be approximately the same as the distance from the negative 23 to the lens 31 in Fig. 2C. In the latter figure a lamp 32 with a light diffusing screen 33 illuminates the masked negative 23 and through the lens 31 exposes a sensitive layer 35 which is processed to an "infinite" gradient and which may be the printing plate itself. That is, the term processing is used to include both photographic processing and photomechanical processing.

As a particular example of the Figs. 2A to 2C the negative 23 may be on a high gamma emulsion sold under the trade name "Kodalith" but since it is to be processed only to medium high gradient, "Kodalith" developer is not used therewith. Instead it is developed by "Kodak Developer D-11" for three minutes. .05 gram of benzotriazole per liter of developer may be added to reduce fog if desired. "Kodalith Halftone film" is particularly useful and in this case the D-11 developer is perfectly satisfactory without the benzotriazole. Alternatively any of the following films or plates, developed in "Kodak Developer D-8" for $\frac{1}{2}$ to 2 minutes at 68° may be used: "Kodak Contrast Process Ortho film, Kodagraph Contrast Process Ortho thin base film, Kodagraph Contrast Process Ortho plate, Kodak Contrast Process Panchromatic film, Kodagraph Process Panchromatic thin base film or Kodagraph C. T. C. Panchromatic plates" (these are trade names). The mask 26 is made on "Kodak Commercial film" or on "Kodak 33 plates" developed to a gamma of about .7. This gives an average gradient of .4 as will be explained in connection with Fig. 3 due to the long toe on the characteristic curve. Four minutes development in "Kodak Developer DK-50" at 68° F. is satisfactory. The exposure should be such as to give a clear background but not so that more than the very lightest details if any are lost. The maximum density should be about .7 to 1.2.

Fig. 3 is included showing two typical H and D or characteristic curves of photographic emulsions. These are well known, but are included to aid in the definition of the terms used in this specification. Fundamentally there are only two tones, a light tone and a dark tone, in a two-tone original. When printing from this original there is a definite and fixed difference in exposure from the two tones. In curve 40, the darkest of the two tones of the original or so-called first tone does not give sufficient exposure to affect the film in any way. Therefore the first tone is reproduced at the minimum density. Similarly the second tone exposure is so great that it reproduces at D_{max} . Obviously the actual slope between D_{min} and D_{max} is of no importance and the reproduction is said to have effectively

"infinite" gradient. At this point no consideration is given to the possibility of fine details appearing as intermediate tones. Of course the total exposure must be controlled so that the first tone stays at D minimum and the second tone reaches D maximum but this leaves considerable latitude in the actual exposure. A lower gradient reproduction process such as is used in processing the negative 23 between Figs. 2A and 2B, is represented by the curve 41 in Fig. 3. If gamma is taken to be the slope of the straight line portion of the curve 41 between points 42 and 43, it will be noted that the gamma is only slightly less than that of the curve 40. However, due to the long toe portion 44 the effective average gradient represented by the broken line 45 is considerably less than the gamma. In this case the first tone reproduces on the toe of the curve somewhat above fog density and the second tone is reproduced part way up the characteristic curve. In general in two tone work it is satisfactory to discuss gamma, gradient, etc. in terms of density range. The difference in density between the first and second tones is said to be the density range and it is obvious that the density range in the reproduction of the two tones on curve 41 is only about half that on curve 40.

The map shown in Fig. 4 is greatly enlarged (actually 4 times as drawn) compared to the original map since otherwise the fine details would be objectionable to the Patent Office whose reproduction process being prior to the present invention necessarily involves the shortcomings which can be overcome by the present invention. However by drawing the section of the map greatly (4 times) enlarged, the fine details 50, which actually are the light areas between contour lines which happen to come close together, are still reproducible by normal processes. Similarly fine dark details 51 indicating marsh land and 52 indicating water would be lost if drawn at normal size but can be reproduced in the magnification shown. It will be seen in Fig. 5 that normal reproduction of the fine light details involves objectionable merging of the adjacent black areas. Similarly the fine dark lines are completely or partially lost in the normal reproduction. In actual maps the relative dimensions of coarse and fine details differ even more than indicated in these drawings. In these actual maps, the marsh and water lines were in pale blue and were therefore even less distinct than they appear in Fig. 4. The lines in question are only slightly narrower than (about 60% of) the contour lines, but this narrowness combined with paleness causes them almost to disappear from Fig. 5. The present invention provides reproduction of fine dark details whether their normal irreproducibility is due entirely to fineness or partly to paleness.

Fig. 6 is supposed to be drawn identical to Fig. 4 (except for a lettering feature discussed below) to show the reproduction of the map when made according to the present invention. It will be noted that neither the light nor the dark details are lost. Fig. 6 may be considered a black and white reproduction of a colored map represented by Fig. 4.

The lettering 55 in Figs. 4 to 6 is included to illustrate another feature of the invention which is appreciable when the mask unsharpness has a large value. It will be noted in Fig. 6 that the coarse details represented by the bold printing are outlined in white so that fine lines terminate before reaching the lettering leaving a space 55.

This enhances the printing rendering it more legible.

In Fig. 7A a two-tone original 60 is shown with six dark elements two of which 61 are close together to enclose a fine light detail. This original is illuminated by lamps 62 and is printed through a lens 63 onto a blue sensitive emulsion layer 64. This layer is mounted on a film with an antihalation inner layer 65 and a slow red sensitive layer 66 on the back thereof. The antihalation layer may actually be incorporated in the slow red sensitive layer, or may be separated therefrom, as shown for clarity. The antihalation dye and the slowness of the layer 66 prevents it being exposed while the blue sensitive layer is exposed. The film is then partially processed to develop the negative in the blue sensitive layer 64 as shown in Fig. 7B. The antihalation dye in the layer 65 is such that it is removed by this partial processing. Light from a lamp 70 through a red filter 71 exposes the red sensitive layer through the negative 64 without causing any additional exposure of the negative 64. The processing is then continued increasing the gradient of the negative 64 slightly and developing a positive unsharp mask in the layer 66 with an average gradient such that after the continued processing the masking factor is between .2 and .7. It will be noted that the unsharpness of the elements 72 in the masking layer is such that one element 73 thereof covers both images in the negative 64 corresponding to the original areas 61. Thus the mask does not reduce the contrast of the enclosed fine light detail. However there is an over all masking effect according to the factor just mentioned. Light from a lamp 75 exposes a photosensitive layer 76 through the masked combination. The mask is not only unsharp but it is used unsharply as shown. As before, some compensation may be made for the difference in magnification between the mask and the negative as in Figs. 2B and 2C but for clarity this factor is not considered in connection with Figs. 7B and 7C. Layer 76 is then processed to infinite gradient giving a final record 77 corresponding to the original 60 and not involving any loss of fine detail.

The layer 64 may be the emulsion of Kodalith Ortho film and with a partial development between Figs. 7A and 7B of three minutes in Kodak Developer D-11 (containing .05 gram per liter of antifoggant) reaches an average gradient of about 2 or 2.5. The continued processing after exposure of the red sensitive mask is such as to give an average gradient of about .4 to the mask. The antihalation dye to prevent halation of blue light and to absorb red light is preferably a gray mixture but practically any dye is partially effective. This dye will prevent exposure of the mask layer 66 when a slow red sensitive emulsion such as that on "Eastman Spectroscopic Safety Film Type 548 E" is used in this layer 66.

Particularly good dyes for this purpose are mixtures in roughly equal parts of a blue absorber, such as bis(1-p-sulfophenyl-3-methyl-5-pyrazolone-4) methine oxonol (U. S. 2,274,782 Gaspar) or (3-ethyl-2-benzoxazole) - (1 - ethyl - 2, 5-dimethyl-3 - pyrrole) - dimethine-cyanine chloride (U. S. 2,298,731 Brooker and Sprague), a green absorber such as bis(1-p-sulfophenyl-3-methyl-5-pyrazolone-4) trimethine oxonol (Gaspar supra) or acid fuchsin and a red absorber such as bis(1-p-sulfophenyl-3-methyl-5-pyrazolone-4) pentamethine oxonol (Gaspar supra) or the dye obtained by oxidizing 4,4'-tetramethyldiamino-

4''-methoxytriphenylmethane-3'' - sulfonic acid (U. S. 2,150,695 Muehler).

The integral masking film should preferably be between .003 and .03 inch thick. Such spacing combined with the normal scattering of light by the front layer permits an unsharp mask to be made easily using an extended light source for printing the mask. In order to handle two tone work adequately and sharply, the front layer should be one normally developable to an average useful gradient of about 2.5 (a range of 2 to 3 being permissible but less than 2 being too soft especially when 50 per cent masked). For stability and reproducibility, this front layer should reach about 80 per cent or more of its final gradient during the first half of said normal development. The rear layer is then exposed through the front and during the remaining half of said normal development should reach an average gradient such as to give a masking factor of .5 (a range of .2 to .7 being useful). This means that the rear layer exposed to an 80 per cent record of the final front layer image will make a 50 per cent mask for that final front image if developed to an average gradient of about 0.6. Note $.6 \times .8 \times 2.5$ approximately equals $.5 \times 2.5$. The useful range for the rear layer gradient is about .2 to .9 which is easily obtainable with common photographic emulsions.

In Fig. 8 a halftone original (that is, it is considered an original as far as the present invention is concerned) is made up of shadows with fine white details 80, intermediate tones with dark elements 81 and highlights with fine dark elements 82. Of course the size of the elements is greatly exaggerated and not intended to be in any exact proportion, but in practice there are some fine light dots and some fine dark dots which would be lost in a normal reproduction process. One method according to the present invention for the reproduction of such a halftone original would involve an unsharp mask in which the unsharpness is of the same order as the spacing of the elemental halftone dots. In fact such a method is preferable when the mask is separate from the original and the unsharpness may be either of the disk or ring type. However there is one specifically desirable form of unsharpness which is quite practical when an integral masking method is used such as that illustrated in Figs. 7A to 7D. When the original halftone is on one side of a film and the mask is made in an emulsion integrally attached to the original, registration is no longer a factor for consideration. As shown in Fig. 9 a halftone negative or positive 85 having an elemental light area 86 is on one side of a film 87, the other side of which is provided with a sensitive layer 88. Lamps 89 are located at the corners of the square and are positioned at such a distance from the halftone 85 that light from the four lamps through the light area 86 exposes four dark spots on the masking layer 88 which dark spots are located behind the dark areas 90 of the halftone original. Of course each dark area at 90 is then "masked" by a dark area in the mask 88 which is exposed through four different adjacent light areas of the original. Each light area contributes partially to the "positive" masking of the four adjacent dark areas and thus cooperates with the adjacent light areas in the production of each of these dark areas in the mask. In fact since dark areas are behind dark areas and light ones behind light ones, there is no "negative masking" of the elements themselves but there is an over all negative masking of the record.

This is perhaps best illustrated in Fig. 10 which represents the halftone negative of Fig. 8 with an integral mask made according to Fig. 9 so that dark areas 92 appear in the region of the shadow dots 80, dark areas 93 are superimposed on the dark dots 81 of the original and dark areas 94 are superimposed on the fine dark highlight dots 82 of the original. Since the elements 80 are small, the dark areas of the mask 92 are small. Since the light areas adjacent to the elements 81 are fairly large, the dark areas 93 superimposed on the elements 81 are fairly large and since the dots 82 are small with large light areas surrounding them, the masking elements 94 are quite large. With such an arrangement it has been found that an infinite gradient print may be made from the mask combination without loss of either the fine light details appearing in the shadows or the fine dark details appearing in the highlights.

Instead of using four lamps 89 as shown in Fig. 9, four successive exposures can be given, one corresponding to each of the lamps. One convenient way of doing this is to mount the film 87 on a horizontal turntable rotatable about the center of the film, with a lamp above the turntable and offset so that each light element of the halftone exposes an area behind an adjacent dark area. Four successive exposures are then given, rotating the turntable 90° between each of the exposures.

What I claim as my invention is:

1. A photographic process for the reproduction of a minutely detailed two-tone original including a series of printing steps, the last one of the series being the first infinite gradient step of the process, one of the steps of the series consisting of printing a record from a previous record which is unsharply masked at least during the major portion of the printing exposure, the mask being negative to the record it is masking and having an effective masking factor between .2 and .7 and an effective unsharpness sufficient to cause the finer details of the original to be substantially lost in the mask but not greater than .06 inch.

2. A photographic process according to claim 1 in which said infinite gradient step is the only infinite gradient one and is the unsharp masking step.

3. A photographic process according to claim 1 in which the printing at said one of the steps is entirely through the mask.

4. The photographic process for the reproduction of a minutely detailed two-tone original comprising printing an effectively infinite gradient record from an unsharply masked record, the mask being negative to the record it is masking and having an effective masking factor between .2 and .7 and an effective unsharpness sufficient to cause only the finer details of the record to be substantially lost in the mask.

5. The photographic process according to claim 4 in which the record being masked is an original positive and said printing gives an infinite gradient negative record.

6. The photographic process according to claim 4 in which the record to be masked is a negative of an original and has a density range between 1.5 and 4, in which said negative is masked by a positive mask having a density range between .3 and 1.8 and in which said printing gives an infinite gradient positive record of the original.

7. The photographic process according to claim 4 in which the masked record is line work and the mask has a contribution to confusion between .003 and .06 inch.

8. The photographic process according to claim

11

4 in which the masked record is a halftone record and the mask has a contribution to confusion of the same order of size as the halftone element.

9. The photographic process according to claim 4 in which the masked record is a dot type halftone and in which the unsharpness of the mask is of the square symmetrical type with an unsharpness equal to the halftone element to give a masking effect which is positive for the elemental areas but negative for the over all record.

10. The photographic process according to claim 4 in which said masking factor is between .3 and .5.

11. The photographic process according to claim 4 in which the mask has a density range between .3 and 1.8.

12. The photographic process according to claim 4 in which the mask has a density range between .6 and 1.2.

13. The photographic process according to claim 4 in which the masked record contains fine dark and fine light details whose respective reproduction unmasked by infinite gradient printing would require exposures differing by a factor whose logarithm is D and in which said mask has a density range approximately equal to D.

14. The photographic process according to claim 4 in which the mask is made from the record it is to mask and is held integrally in register therewith while being processed.

15. The photographic process for the reproduction of a fine line original comprising printing a negative of the original at an average gradient between 2 and 3 containing both the fine light and the fine dark details of the original, printing from the negative a positive mask therefor having an effective masking factor between .2 and .7,

12

unsharply masking the negative by said positive and printing an infinite gradient positive from the record so masked, the unsharpness of the masking being sufficient to cause only the finer details of the negative to be substantially lost in the mask.

16. The process according to claim 15 in which said negative is made on a film containing in addition to the negative emulsion, a sensitive emulsion spaced from the negative one and onto which the negative is printed and which is processed while integrally part of the film.

17. The photographic process for the reproduction of a dot type halftone record comprising placing a photosensitive layer slightly out of contact with the record, exposing the layer by four successive or simultaneous exposures laterally offset so as to record the image of each light area of the record, under each of the four adjacent dark areas of the record to give a square symmetrical form of unsharpness to the image in the sensitive layer, processing the sensitive layer to an unsharp mask for the record and printing an infinite gradient record from the masked record.

18. The photographic process for the reproduction of a two-tone record containing fine light and fine dark details which if printed by an infinite gradient process would require for their respective reproduction, exposures differing by a factor whose logarithm is D, which process comprises making a mask from and for the record, negative to the record and having a density range approximately equal to D, unsharply masking the record by said mask and printing an effectively infinite gradient record from the masked record.

JOHN A. C. YULE.