Sept. 1, 1942. F. L. WURZBURG, JR 2,294,644

CONTRAST IMAGES FOR MAKING PRINTING PLATES

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Fig. 1.

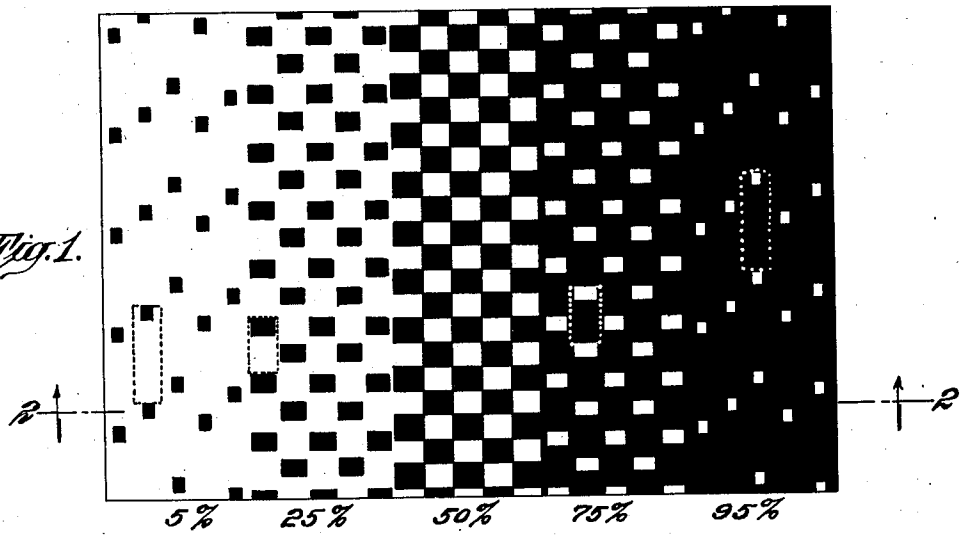


Fig. 2.



Fig. 3.



Fig. 4.

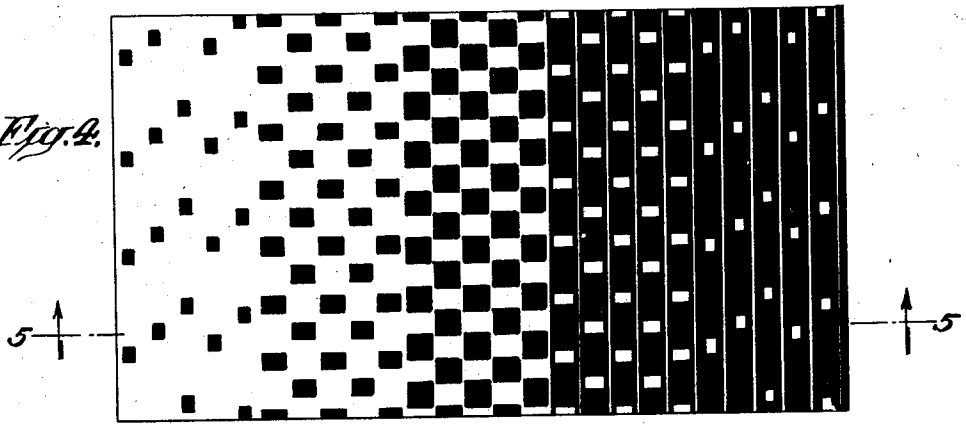
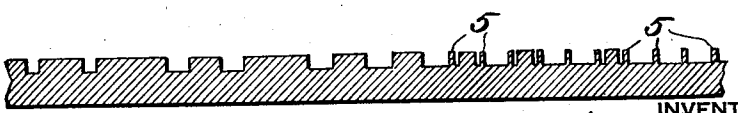


Fig. 5.



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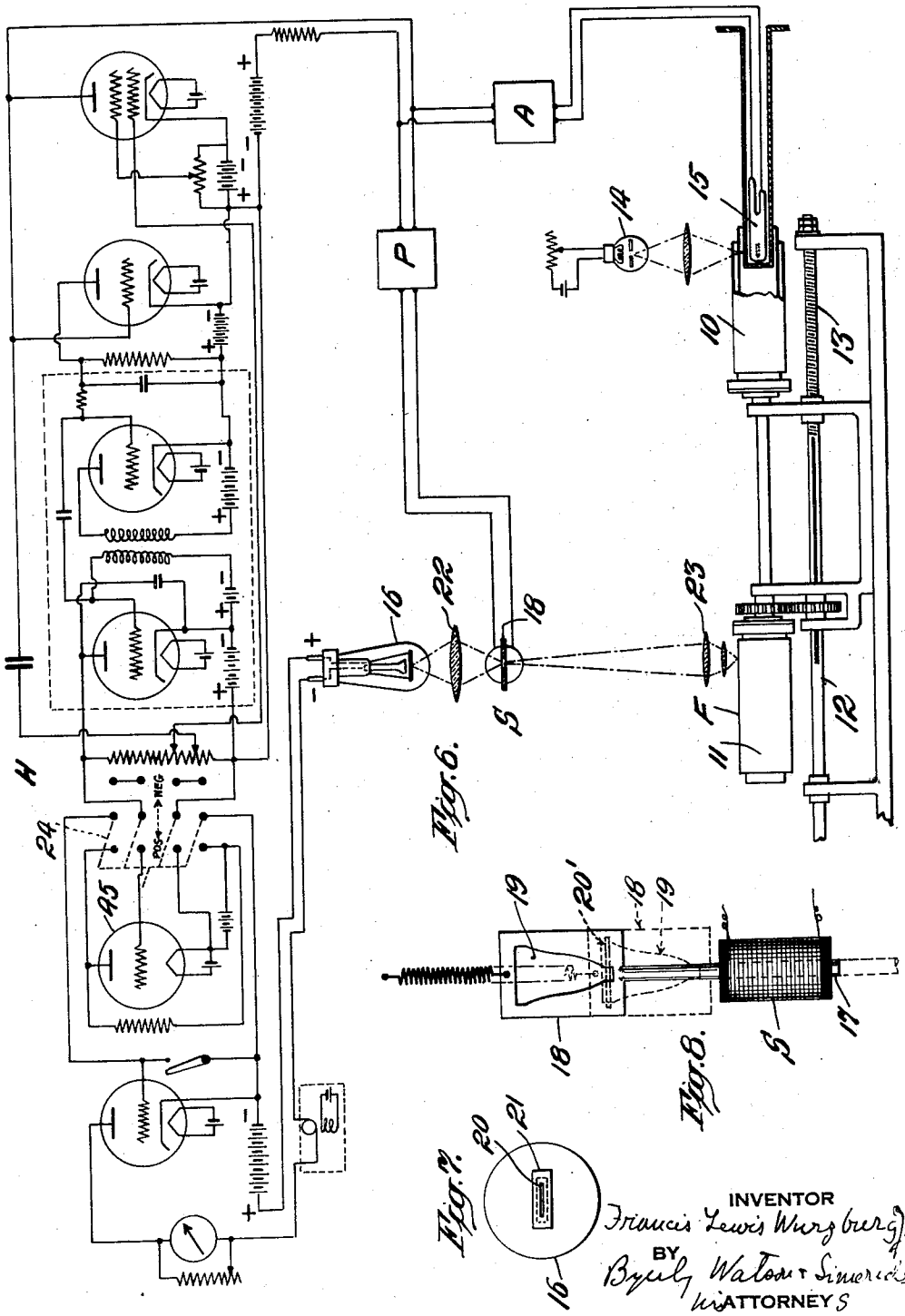


Fig. 6.

Fig. 8.

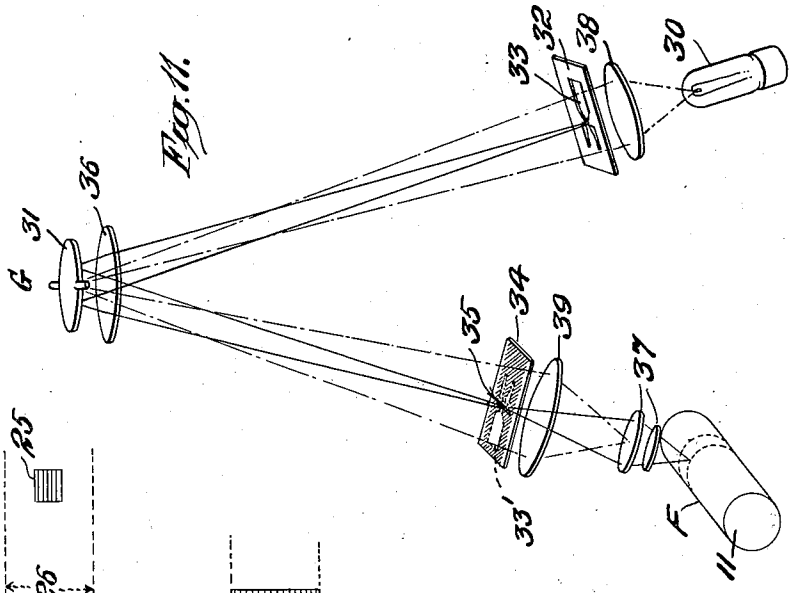
Fig. 7.

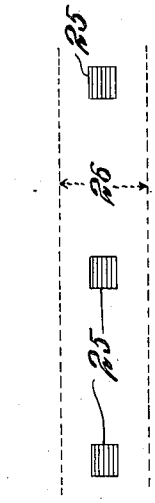
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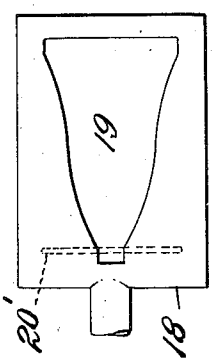
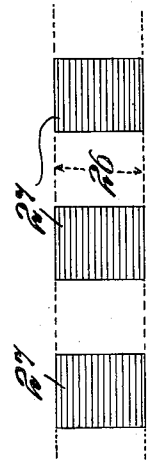


Fig. 9a.



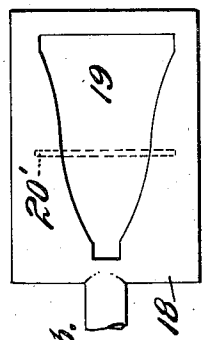
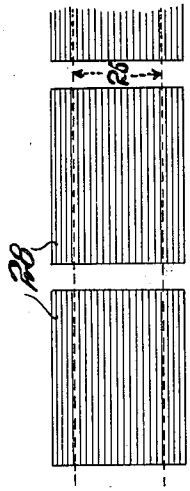


Fig. 9b.



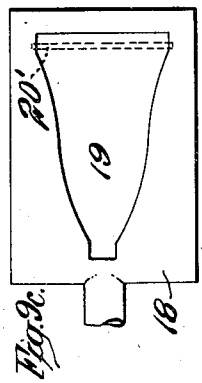
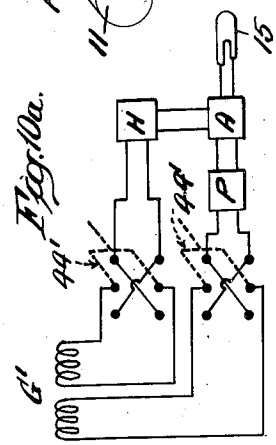
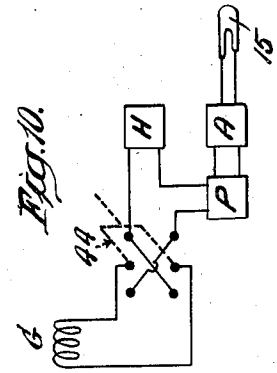


Fig. 9c.





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Fig. 13.

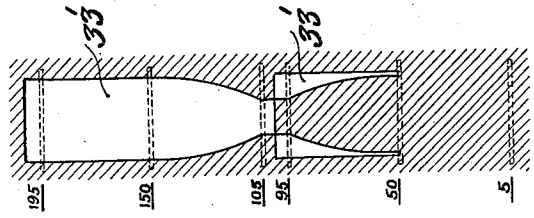


Fig. 12c.

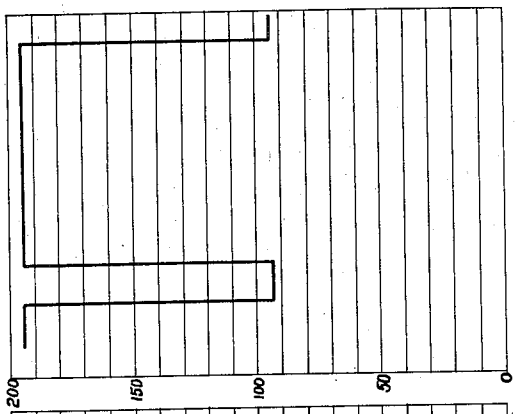


Fig. 12b.

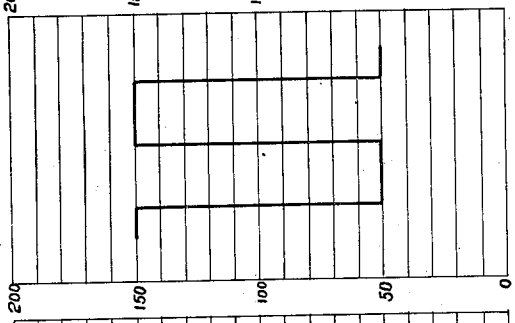


Fig. 12a.

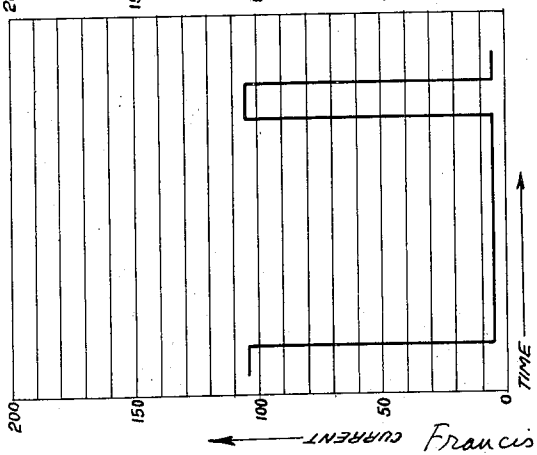


Fig. 14c.

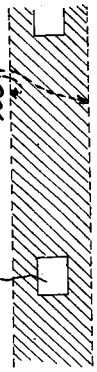


Fig. 14b.

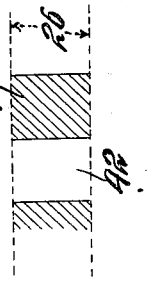
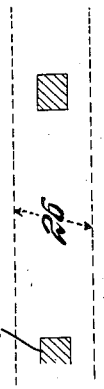


Fig. 14a.



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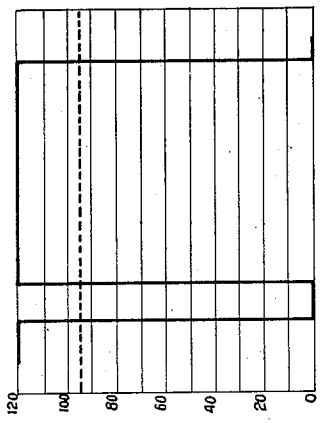


Fig. 15c.

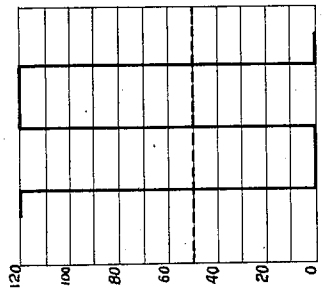


Fig. 15b.

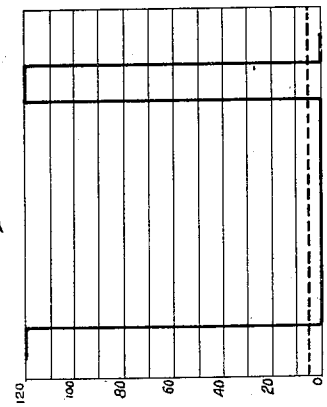


Fig. 15a.

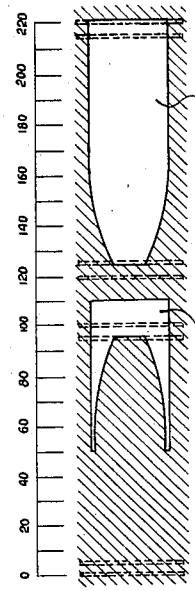


Fig. 17.

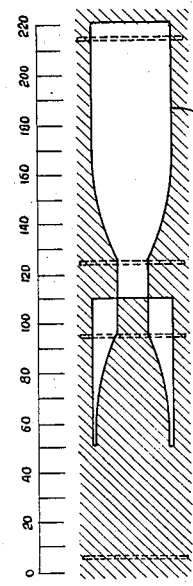


Fig. 16.

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Patented Sept. 1, 1942 2,294,644

UNITED STATES PATENT OFFICE

2,294,644

CONTRAST IMAGES FOR MAKING PRINTING PLATES

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Original application July 5, 1940, Serial No. 343,962. Divided and this application August 9, 1941, Serial No. 406,120

4 Claims. (Cl. 41—17)

This invention relates to contrast images for making printing plates.

The invention aims to provide for printed reproductions of continuous-tone original pictures in which the tones of the original are uniformly faithfully represented. The printed reproductions produced in accordance with my invention differ strikingly from those heretofore made in that they faithfully reproduce the very light tones and the very dark tones of any picture. It has heretofore been impossible to obtain uniform faithful reproductions of such tones.

In printed pictures, the light tones are represented by small black areas or dots on a white background and the dark areas are represented by small white areas, which I shall also term "dots," on a black background. It has long been recognized that in all usual methods of etching printing plates and printing from them, dots below a definite minimum size cannot be uniformly etched and printed. The limit varies with the method of etching and printing used and especially with the quality of the paper on which the print is made. In ordinary half-tone reproductions in which the dots are uniformly spaced, the size of the dots required for uniform printing makes impossible a faithful reproduction of either very light or very dark tones.

In printing plates made from contrast images produced by photo-electric scanning, such as those described in Hardy Patents Nos. 2,136,340, 2,190,185 and 2,190,186, better results are obtained by providing for a non-uniform spacing of the dots. This permits the obtaining of very light tones by increasing the space between the dots without decreasing the size of the dots below the limit required for etching and printing. There is, however, a limit to the lightness of the tones which can be obtained by the Hardy plates, since a satisfactory reproduction cannot be obtained if the dots are placed too far apart to be fused by the eye.

My invention is based in part on the observation that the difficulties which arise in etching and printing very small dots depends, not upon the area of the dot in question, but upon its shorter dimension. In the Hardy plates, the smallest dots have the form of long narrow rectangles. To etch and print properly, dots of this shape must have their shorter dimension above a predetermined limit and, in consequence, the area of such dots must be considerably larger than that of the round or square dots of a half-tone plate in order to etch and print with equivalent accuracy. This requires making the smallest dots of the Hardy plates of such large area that difficulty is experienced in placing the dots far enough apart to reproduce very light tones without placing them so far apart that they are not fused by the eye.

I have succeeded in overcoming the limitations of half-tone plates and those of the Hardy plates by providing variably spaced dots and providing for a variation in both dimensions of the dots, so that the dots are of approximately uniform shape and the smallest dots may have their two dimensions substantially equal and at the same time are spaced further apart than the larger dots. In this way, I have succeeded in representing very light tones by means of dots which may be uniformly etched and printed and which, while more widely spaced than the dots of the middle tones, are nevertheless not spaced too far apart to be fused by the eye.

What I have said as to the representation of very light tones is equally applicable to the representation of very dark (but not totally black) tones as the etching and printing of small light dots in the dark areas presents a problem similar to that of small black dots in the light areas.

My invention includes a scanning method of making contrast images for producing my new printing plate. This method is characterized by using part of a photo-cell current which varies with the tone of the original picture to control the length and the spacing of the dark areas of the reproduction, and at the same time using another part of the photocell current to control the width of the dark areas of the reproduction in such a way that the width of the dark areas which are short and widely spaced is made less than that of those dark areas which are long and closely spaced.

In describing my invention in detail, I shall refer to the accompanying drawings in which:

Fig. 1 is a greatly enlarged view of part of a contrast image or a diagrammatic face view of part of an inked typographic or lithographic printing plate, embodying my invention;

Fig. 2 is an enlarged fragmentary section of a typographic printing plate whose printing surface is diagrammatically represented in Fig. 1, sectioned on the line 2—3 of Fig. 1;

Fig. 3 is a view similar to Fig. 2 showing a lithographic printing plate;

Fig. 4 is a view similar to Fig. 1 showing a slightly modified contrast image embodying my invention, or a diagrammatic view of part of an inked intaglio printing plate;

Fig. 5 is an enlarged fragmentary section of an intaglio printing plate whose printing surface is diagrammatically shown in Fig. 4, sectioned on the line 5—5 of Fig. 4;

Fig. 6 is a diagrammatic view of an electro-mechanical scanning device for making contrast images;

Fig. 7 is an enlarged end view of the glow lamp shown in Fig. 6, showing the slit in the shield contained in the lamp;

Fig. 8 is an enlarged diagrammatic plan view of the solenoid and aperture plate shown in Fig. 6;

Figs. 9*a*, 9*b*, 9*c* are diagrams indicating the operation of the apparatus shown in Figs. 6, 7 and 8, each showing a position of the aperture plate with respect to the slit and the record made in that position of the aperture plate;

Fig. 10 is a diagram of the electric circuit of a modified scanning apparatus for making contrast images;

Fig. 10*a* shows a modification of the electric circuit diagram shown in Fig. 10;

Fig. 11 is a diagrammatic perspective view of the optical system used in a scanning apparatus containing the electric circuit shown in Fig. 10 or that shown in Fig. 10*a*;

Figs. 12*a* to 14*c* are diagrams illustrating the operation of the scanning apparatus of Figs. 10 and 11, Figs. 12*a*, 12*b* and 12*c* being graphs showing the variation in the galvanometer current, Fig. 13 a diagram indicating the relative position of the slit and aperture at different values of the galvanometer current, and Figs. 14*a*, 14*b*, 14*c* illustrating the record made when the galvanometer current has the values shown in Figs. 12*a*, 12*b*, 12*c* respectively;

Figs. 15*a*, 15*b* and 15*c* are graphs similar to Figs. 12*a*, 12*b* and 12*c* showing modified galvanometer currents; and

Figs. 16 and 17 are diagrams similar to Fig. 13 showing modified apertures.

The character of my new printing plate is clearly shown in Fig. 1 which may be taken as representing either the inked face of a printing plate, a contrast image for producing a printing plate, or a print obtained from the plate. Fig. 1 shows the manner in which a number of different tones of a continuous-tone original are represented. The tones represented by the different parts of the plate or print are indicated by the figures 5, 25, 50, 75 and 95 on Fig. 1 which may be taken as parts of a tone scale from 0 to 100 and as representing the percentage of black area required to represent each tone.

Any contrast image may be regarded as made up of a series of elements in each of which the percentage of black area to total area represents a tone of the original. The elements of my contrast image, several of which are delimited by dotted lines in Fig. 1, are of uniform width to facilitate making of the image by a photo-electric scanning operation. The elements vary in length. As in the contrast image of the Hardy patents above referred to, the elements are shortest at the middle tone and range upwardly in length from the middle tone towards the lightest tone and from the middle tone towards the darkest tone. The variation in the length of the elements is, however, not as great as in the contrast images of the Hardy patents. The dark areas of the elements in tones lighter than the middle tone differ from those of the Hardy contrast image in that they decrease in width as well as in length so that the smallest black areas (those in the 5% tone) are approximately square and have a width only about ⅓ of the width of the elements.

Fig. 2 shows the form of a typographic plate made from a contrast image such as that shown in Fig. 1, the plate having raised areas corresponding to the black areas of Fig. 1.

Fig. 3 shows a lithographic plate having ink-receiving areas corresponding to the black areas of Fig. 1.

Fig. 4 shows a slight modification of a contrast image of Fig. 1. This modification is desirable when the image is to be used for making an intaglio plate as it avoids large unbroken indented areas in the dark portions of the picture. The elements of the areas representing different tones in Fig. 4 are the same as those in Fig. 1, but the rows of elements, instead of being contiguous as in Fig. 1, are slightly separated so as to provide white lines in the dark areas. In an intaglio plate etched from the image shown in Fig. 4, the white lines in the dark areas produce narrow ridges 5 (Fig. 5) breaking up the large recesses in the plate, so that the doctor blade does not withdraw the ink contained in them. The ridges 5 may be made so narrow that they are eliminated by the spreading of the ink on the paper. Thus the intaglio plate of Fig. 5, engraved from the contrast image shown in Fig. 4, may be made to produce a print substantially like the contrast image shown in Fig. 1.

My method of producing a contrast image such as that shown in Fig. 1 may be carried out by means of various types of photo-electric scanning apparatus, such as the cylinder type shown in Hardy Patent No. 2,136,340 or the flat-bed type shown in my Patent No. 2,185,139. Various different electric circuits may be used, all of which, however, must include a circuit of the type shown in Hardy Patent No. 2,136,340 or some equivalent circuit. In order that the nature of my invention may be clearly understood, I will describe various different means for carrying out my method, beginning with one which is most easily explained, although not the most desirable form for actual use.

Fig. 6 shows a usual form of cylinder scanning apparatus like that shown in Hardy Patent No. 2,136,340, having a transparent picture drum 10 and a recording drum 11 which are given identical rotational and longitudinal movements through a driving mechanism 12 including a screw 13 whose pitch determines the distance between the spiral scanning bands. A constant intensity scanning lamp 14 directs light through successive elements of a continuous-tone transparent original on the drum 10 to a photo-electric cell 15. The current from the photo-cell 15 is first passed through an amplifier A which has the effect of a D. C. amplifier, although in practice it may best be composed of an A. C. amplifier and a rectifier. The amplified photo-cell current from the amplifier A is divided into two parts. One part of it is passed through a circuit H like the circuit shown in Fig. 6 of Hardy Patent No. 2,136,340, which, for brevity, I shall term "the Hardy circuit," so as to cause intermittent lighting of the glow lamp 16 whose light is directed to a film F on the recording drum 11 to produce exposed areas on this film whose length and spacing are determined by the tone of the original on the cylinder 10, as in the Hardy apparatus.

The other part of the amplified photo-cell current from the amplifier A is passed through a power circuit P and then to a device for regulating the width of the areas on the film F which are exposed to the glow lamp 16. In the form shown in Figs. 6, 7 and 8, this device consists of a solenoid S whose armature 17 carries a plate 18 containing an aperture 19 of non-uniform width. The solenoid, which is shown only diagrammatically, is of the high-response type commonly used in loud speakers. An image of the slit 20 in the shield 21 of the glow lamp 16 is focused by a lens 22 on the aperture plate 18 and this image is refocused by lenses 23 on the recording film F on the drum 11.

The operation of the apparatus illustrated in Figs. 6, 7 and 8 is indicated in the diagram Figs. 9a, 9b, 9c which show, for three different values of the photo-cell current, the position of the aperture 19 with respect to the image 20' of the slit 20, and the resulting exposed portions of the recording film F. The diagram illustrates the making of a negative contrast image and presupposes the placing of the reversing switch of the Hardy circuit H in the position marked "Neg." The operation is as follows:

(1) When a dark tone of the original is being scanned, the photo-cell current is low, and, under this condition, the part of the photo-cell current which is passed through the Hardy circuit (with its reversing switch in "Neg." position) results in lighting the glow lamp 16 for brief, widely-spaced intervals, as explained in the Hardy patent. The other part of the photo-cell current which is passed through the solenoid is too weak to move the armature of the solenoid against its usual return spring, so that the plate 18 remains in its normal position in which the narrow end of the aperture 19 coincides with the image 20' of the slit 20, as shown in full lines in Fig. 8 and Fig. 9a. As light can pass only through that part of the image of the slit which is within the aperture 19, a narrow beam of light strikes the film F during the brief intervals during which the glow lamp is lighted by the Hardy circuit. This produced on the film small, wide-spaced, exposed areas 25 which are much narrower than the spiral scanning track 26 on the film (whose width, as before stated, is determined by the pitch of the screw 13).

(2) When a middle tone of the original is being scanned so that the photo-cell curent is at half its maximum value, the portion of the photo-cell current which passes through the solenoid moves the plate 18 so as to place the middle of its aperture 19 under the image 20' of the slit 20, as shown in Fig. 9b. This permits a beam having the width of the scanning band 26 to reach the recording film when the glow lamp is lighted. As the Hardy circuit causes equal intervals of lighting and extinguishment when the photo-cell current is at half strength, the result is to produce exposed areas 27 of the form shown in Fig. 9b.

(3) When a light-tone part of the original is being scanned so that the photo-cell current is at or near its full strength, the Hardy circuit (with its reversing switch in "Neg." position) provides for keeping the glow lamp lighted for long periods separated by brief intervals of extinguishment. In this case, the portion of the photo-cell current passing through the solenoid positions the plate 18 with the wide end of its aperture 19 coincident with the image 20' of the slit, as shown in dotted lines in Fig. 6 and in Fig. 9c. The result is to produce long exposed areas 28 on the recording film which are wider than the scanning band 26, so that those in one scanning band overlap those of the next scanning band leaving only short and narrow unexposed spaces.

The three values of the photo-cell current whose effect has been illustrated and described are merely indicative of the operation of the apparatus throughout the tone range. It will be seen, therefore, that the result of this operation is to produce a negative contrast image of the sort shown in Fig. 1.

The apparatus which has been described may equally well be used to produce a positive contrast image by placing the reversing switch 24 of the Hardy circuit in "Pos." position and inverting the aperture plate 18 with respect to the armature of the solenoid S.

While the specific embodiment of my method which has been described well illustrates the principle of the method, it is by no means the most satisfactory way of carrying it out, for the expedient of obtaining narrow unexposed areas by an overlapping of the scanning lines is clumsy, and is inaccurate in case of a change in tone after a single band has been scanned.

An important feature of my invention consists in avoiding this difficulty by eliminating the use of a glow lamp or equivalent light valve with the Hardy circuit and using a mirror galvanometer to determine the length and spacing of the exposed areas as well as the width of these areas. The method involves dividing the photo-cell current into two parts and passing one of these parts through the Hardy circuit as before, but, instead of connecting the output of the Hardy circuit with a glow lamp or light valve, it is combined with the other part of the amplified photo-cell current and the two are passed together through the coil of the mirror galvanometer G. The recombining of the two parts of the photo-cell current may either be by direct electrical connection as shown in Fig. 10, or by passing the two currents through separate coils of a two-coil galvanometer G' as shown in Fig. 10a. The mirror galvanometers G and G' are of the high-response, low-inertia type used in sound recording. I prefer to use the magnetic galvanometer developed by G. L. Dimmick, described in his article in Journal Society Motion Picture Engineers, October 1930.

The nature of the combined current which is fed to the galvanometer coil of Fig. 10 is shown in the current diagram, Figs. 12a, 12b, 12c, which illustrates the variations in the galvanometer current at a low value, at the middle value, and at a high value, of the photo-cell current. These diagrams illustrate the effect of adding to the variable-frequency intermittent current of the Hardy circuit a direct current proportional to the photo-cell current. In the particular form shown, the current impulses of the Hardy circuit have a value of 100 units, while the maximum value of the current from the power tube P is also 100 units. As a result, the combined current may vary between 0 units and 200 units as indicated in Figs. 12a, 12b and 12c.

The optical system used with the galvanometer of this embodiment of my invention is shown in Fig. 11. Light from a fixed intensity lamp 30 is reflected by the mirror 31 of the galvanometer G to the recording film F on the cylinder 11, which is shown diagrammatically in Fig. 11 at much less than its actual size. A fixed plate 32 containing

an aperture 33 is placed between the lamp 30 and the mirror 31, and a fixed shield 34 containing a slit 35 is placed between the mirror and the recording film. An image of the aperture 33 is focused on the shield 34 by a lens 36, while an image of the slit 35 is focused on the recording film by a lens system 37. A conjugate lens system including the lenses 38 and 39 serves to focus the lamp 30 on the mirror 31 and to focus the mirror on the lens system 37.

The position on the shield 34 of the image 33' of the aperture 33 depends upon the position of the galvanometer mirror which in turn depends upon the amount of current passed through the galvanometer coil. Relative positions of the slit 35 and the image 33' of the aperture 33 for a number of different values of the galvanometer current are shown diagrammatically in Fig. 13. In order to relate this diagram to the current diagram of Figs. 12*a*, 12*b*, 12*c*, the slit 35 is shown at a number of different numbered positions corresponding to current values indicated in Figs. 12*a*, 12*b*, 12*c*, while the image 33' is drawn only once; but it should be understood that the different relative positions of the slit and aperture image which are shown in Fig. 13 are attained in the apparatus by movement of the image 33' while the slit 35 remains stationary (see Fig. 11).

The operation of this form of my invention can readily be understood from the current diagram Figs. 12*a*, 12*b*, 12*c*, the slit and aperture diagram Fig. 13 and the diagram of the scanning band of the recording film shown in Figs. 14*a*, 14*b*, 14*c*. As before, I will describe making a negative contrast image:

(1) When a certain dark-tone portion of the original is being scanned, the photo-cell current is so low that the galvanometer current varies between 5 and 105, remaining at the lower value for long intervals and the upper value for short intervals (Fig. 12*a*). The intervals are, of course, determined by the Hardy circuit. During the long intervals during which the value of the current is at 5, the image 33' of the aperture is entirely off the slit (see 5 in Fig. 13), so that no light reaches the recording film. During the short intervals when the current is 105, the aperture image 33' has a narrow portion coincident with the slit, as shown at 105 in Fig. 13, so that a narrow band of light from the recording lamp 30 reaches the recording film during these short intervals, making short, narrow exposed areas 40, as shown in Fig. 14*a*.

(2) When a middle-tone portion of the original is being scanned so that the photo-cell current is at its middle value, the galvanometer current varies from 50 to 150, as shown in Fig. 12*b*, remaining at the two limits for equal periods. From Fig. 13, it appears that, when the current is at 50, the aperture image 33' does not cross the slit (see 50 in Fig. 13), while, when the current is at 150, the aperture image 33' extends across the slit with its widest part coincident with the slit (see 150 in Fig. 13). The result, as shown in Fig. 14*b*, is to produce equal exposed and unexposed areas 41, 42 both of which may be of the full width of the scanning band 26.

(3) When a certain light-tone portion of the original is being scanned, the photo-cell current is so near its maximum that the galvanometer current varies between 95 and 195, as shown in Fig. 12*c*. It remains at the lower limit 95 for short intervals and at the upper limit 195 for long intervals. During the long intervals while the current is at 195, the aperture image 33' crosses the slit with its maximum width coincident with the slit (see 195 in Fig. 13), so that the entire width of the scanning track 26 is exposed during these long periods. During the short intervals when the current is at 95, the aperture 33' crosses the slit and has coincident with the slit a divided portion (see 95 in Fig. 13), so that two beams of light are directed upon the scanning band leaving a narrow unexposed portion 43 between them, as shown in Fig. 14*c*.

The three values of the photo-cell current whose effect has been illustrated and described are merely indicative of the operation of the apparatus throughout the tone range. It will be seen, therefore, that the result of this operation is to produce a negative contrast image of the sort shown in Fig. 1. It should be noted that, in achieving this result, the constants of the circuit of Fig. 10 were so chosen that the maximum value of the current from the power circuit P is equal to the value of the current impulses of the Hardy circuit, and the aperture 33 is symmetrical and consists of two halves which are related to each other as a positive to a negative, that is to say, if one half of the plate 32 were folded over on the line 100 (Fig. 13), the openings in the two halves would not overlap but would fit together to form a rectangular opening of uniform width.

The same results are obtained by passing the Hardy current and the current from the power circuit through two equal coils of a two coil galvanometer in such direction that the two coils tend to turn the mirror in the same direction. The use of a two-coil galvanometer has the advantage of permitting greater flexibility in the choice of the constants of the circuits. Thus, if the constants are chosen so as to make the maximum value current from the power circuit different from the value of the impulses of the Hardy circuit, the turning effects of the two may be made the same by the use of different numbers of turns in the two coils of the galvanometer. The operation of this arrangement can be understood by regarding the ordinates in Figs. 12*a*, 12*b* and 12*c* as measuring the combined turning effect of the two currents about the axis of the galvanometer rather than reading them as values of current.

While the operation of the apparatus in making a negative contrast image has been described, the apparatus is equally adapted to making a positive contrast image. In order to do this, it is necessary only to reverse the position of the aperture plate 32, or to reverse the direction of the current through the galvanometer by means of the reversing switch 44 shown in Fig. 10 or the two reversing switches 44' shown in Fig. 10*a*. In this way, a positive is produced while the reversing switch 24 of the Hardy circuit remains in "Neg." position. This is an advantage, since it permits simplifying the Hardy circuit by eliminating the tube 45 of that circuit since this tube is not used when the reversing switch 24 is in "Neg." position (see Fig. 6).

The apparatus which has been described may be used to produce an image for an intaglio plate like that shown in Fig. 4, by making a slight change in the width of the image of the aperture 33, so that the width of the exposed areas on the recording film is slightly less than the width of the scanning band.

The apparatus which has been described is rather delicate in operation owing to the fact that the positions of the image of the aperture

33a and the slit 35 for making small unexposed areas and for making small exposed areas are close together (see 95 and 105 in Fig. 13). This leads to some inaccuracy in case the galvanometer mirror oscillates slightly on a change in current before settling to its position. This difficulty may be avoided in accordance with my invention by making the maximum value of the direct current part of the galvanometer current considerably less than the value of the current impulses of the Hardy circuit, and separating the two halves of the aperture. This modification is indicated in the current diagrams, Figs. 15a, 15b, 15c, and the slit and aperture diagrams, Figs. 16 and 17.

Figs. 15a, 15b, 15c show the impulse part (full lines) and the direct current part (dotted lines) of the galvanometer current for the three different values of the photo-cell current previously discussed. The two currents shown may be passed through two equal coils of a two-coil galvanometer or may be passed together through a single galvanometer coil. The circuit constants are chosen so as to make the value of the current impulses of the Hardy circuit greater than the maximum value of the direct current. Thus, by way of example, the current impulses are shown as having a value of 120 while the maximum value of the direct current is 100, although the highest value shown is 95 (Fig. 15c).

Fig. 16 shows the image 33a of an aperture having positive and negative halves of the same shape as those of the aperture whose image is shown in Fig. 13. Thus the negative half of the aperture shown in the lower part of Fig. 13 is identical with the negative part of the aperture shown in Fig. 16 between 0 and 100 on the scale of that figure, and the positive half of the aperture shown in the upper half of Fig. 13 is identical with the positive part of the aperture shown in Fig. 16 between 120 and 220. Between the two separated halves of the aperture, a double slot of uniform width extends from 100 to 110 on the scale, while a single slot of uniform width extends from 110 to 120.

Fig. 16 indicates the relative positions of the aperture image 33a and the slit 35 for various different values of the combined galvanometer current shown on the scale in Fig. 16. The operation of this modification is the same as that already described in connection with Figs. 12 to 14, except that, for the three illustrative values of the photo-cell current referred to, the galvanometer current now oscillates between 5 and 125 for the low photo-cell current value (Fig. 15a), between 50 and 170 for the middle photocell value (Fig. 15b), and between 95 and 215 for the high photo-cell current (Fig. 15c). Consequently, the relative positions of the image 33a of the aperture and the slit 35 for making small unexposed areas and for making small exposed areas are separated by a considerable distance (note relative positions indicated by dotted slits at 95 and 125 on the scale in Fig. 16), so that a slight oscillation of the galvanometer mirror in its extreme positions does not change the character of the exposure which is being made.

A tone range from 5% to 95%, representing a variation in the photo-cell current and in the direct current from the power circuit from 5% to 95% of its maximum value, is quite sufficient for ordinary reproduction. In some cases, however, where it is intended to make reproductions within this range, it happens that the original contains tones lighter or darker than the tones previously measured as representing the extreme tones, and, in this case, the photo-cell current and the direct current part of the galvanometer current may fall below 5 units or rise above 95 units. When this occurs with an aperture such as that shown in Fig. 16, tones lighter than 5% produce dots of the same width as 5% tones, and tones darker than 95% produce dots of the same width as 95% tones. But the spacing of the dots in the tones under 5% and over 95% is increased by the operation of the Hardy circuit. This may have the objection of producing dots too far apart to be fused easily by the eye. In accordance with my invention, this danger may be eliminated by use of an aperture of the type shown in Fig. 17.

Fig. 17 shows the image 33b of an aperture whose outer parts are the same as those of the apertures of Figs. 13 and 16. The middle part of the aperture of Fig. 17 differs from those previously described. Between 95 and 110 on the scale shown in Fig. 17, the aperture has an opening the full width of the scanning line, while between 110 and 125 there is no opening. This aperture, when used with a galvanometer current shown in Figs. 15a, 15b, 15c produces precisely the same effect as the aperture shown in Fig. 16 so long as the direct current part of the galvanometer current does not fall below 5 or rise above 95. This is apparent from the relative positions of the image 33b of the aperture and the slit 35 indicated by the dotted slit positions at 5, 95, 125 and 215 on the scale in Fig. 17, which produce light beams of the same widths as the corresponding relative positions shown in Fig. 16. There is, however, a difference in the case of tones lighter than 5% or darker than 95%. If a tone is so dark that the direct current part of the galvanometer current falls to zero so that the combined current oscillates between 0 and 120, no light is admitted at either end of this oscillation (see dotted slit positions at 0 and 120 on the scale in Fig. 17) so that no portion of the recording film is exposed. Conversely, if a tone is so light that the direct current part of the galvanometer current rises to 100 so that the combined current oscillates between 100 and 220, a beam of light of the full width of the scanning line is admitted at both ends of the oscillation (see dotted slit positions at 100 and 220 on the scale in Fig. 17) so that the entire scanning band is exposed. Thus with this aperture, tones lighter than 5% and tones darker than 95% are represented by solid black or solid white without any dots. This avoids the defect of too widely spaced dots in these extreme tones.

An important feature of my invention consists in securing a strictly accurate, or as it is sometimes called linear, representation of the tones of an original, which cannot be obtained in an ordinary half-tone. In accordance with my invention, a linear representation of tones is secured by combining two compensating non-linear representations. The Hardy circuit, when used in my invention, is adjusted so as to produce a representation departing widely from the linear in the light and dark tones. The adjustment is made in the manner described in Hardy Patent No. 2,136,340 (p. 4, col. 2, l. 55 to p. 5, col. 1, l. 28) except that the photocell and discharging currents are adjusted so as to provide for about 15% of black area in the lightest tones of the original and about 85% of black area in the darkest tones of the original. The aperture is then formed in such a way that it cuts down the

amount of black area in the light tones to an amount proportional to the tones of the original, and, in the same way, increases the amount of black area in the darker tones to an amount proportional to the tone of the original. Apertures which have this effect for all tones from 5% to 95% when the Hardy circuit is adjusted as described are shown in Figs. 13, 16 and 17. The result is to produce a truly linear representation of the tones of the original.

This is a division of my application Serial No. 343,962, filed July 5, 1940.

The methods and apparatus described herein and the printing plates described herein are not claimed in this application as they constitute the subject-matter respectively of my said parent application Serial No. 343,962, filed July 5, 1940, and my application Serial No. 406,121, filed August 9, 1941, as a division of said parent application.

What I claim is:

1. A contrast image having variably-spaced, rectangular dots which vary both in length and in width.

2. A contrast image consisting of a plurality of elements of uniform width, each including a black area and a white area, the length of the elements ranging upwardly from a minimum length occurring in a middle tone and width of the white areas and of the black areas ranging downwardly from a maximum width occurring in a middle tone and as great as the width of the elements to minimum widths occurring in the lightest and darkest tones and less than the width of the elements.

3. A contrast image consisting of a plurality of elements of uniform width, each including an area and a contrasting dot, the length of the elements ranging upwardly from a minimum length occurring in a midde tone and the width of the dots ranging downwardly from a maximum width occurring in a middle tone and as great as the width of the elements to a minimum width occurring in an extreme tone and less than the width of the elements.

4. A contrast image constituting a linear representation of a continuous-tone original and consisting of a plurality of elements of uniform width in each of which the ratio of black area to total area is equal to the value of the tone at the corresponding part of the original, the length of the elements ranging upwardly from a minimum length occurring in a middle tone and the width of the white areas and of the black areas ranging downwardly from a maximum width occurring in a middle tone and as great as the width of the element to minimum widths occurring in the lightest and darkest tones and less than the width of the elements.

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