

May 17, 1966

J. T. BICKMORE  
METHOD OF CONTROLLING CONTRAST IN A XEROGRAPHIC  
REPRODUCTION PROCESS

3,251,685

Filed Oct. 19, 1959

3 Sheets-Sheet 1

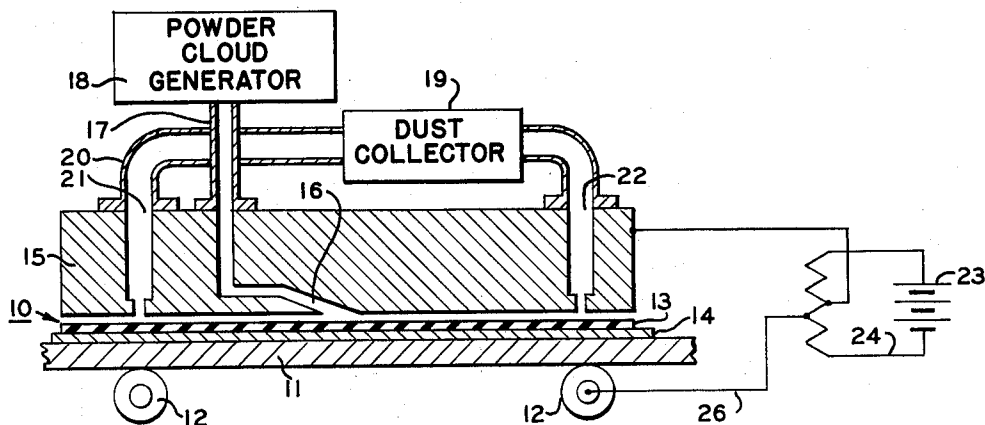


FIG. 1

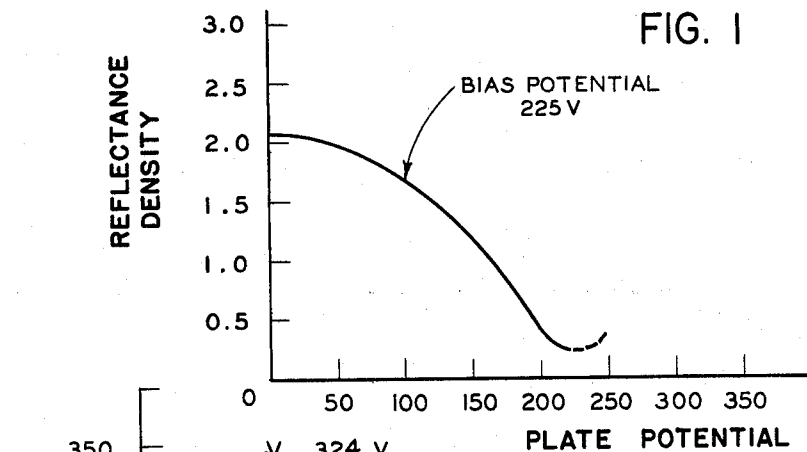


FIG. 2

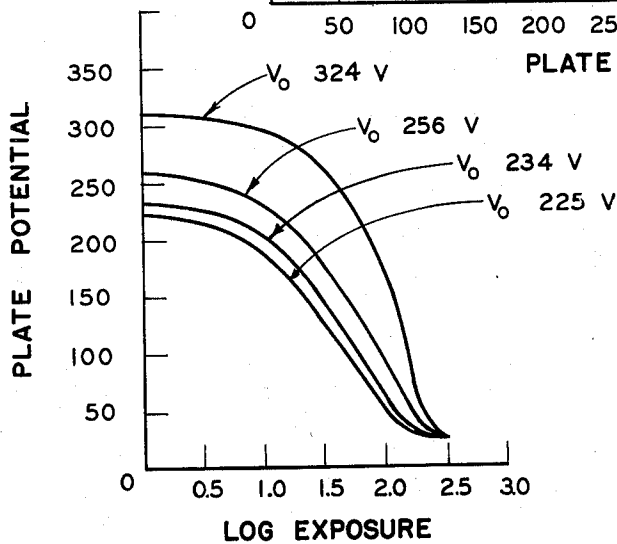


FIG. 3

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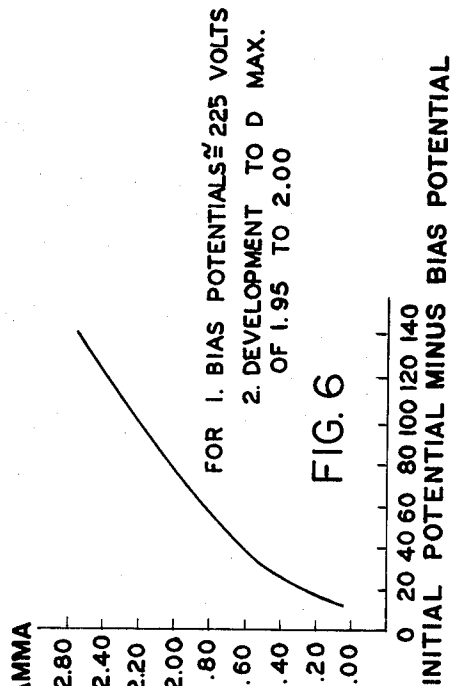
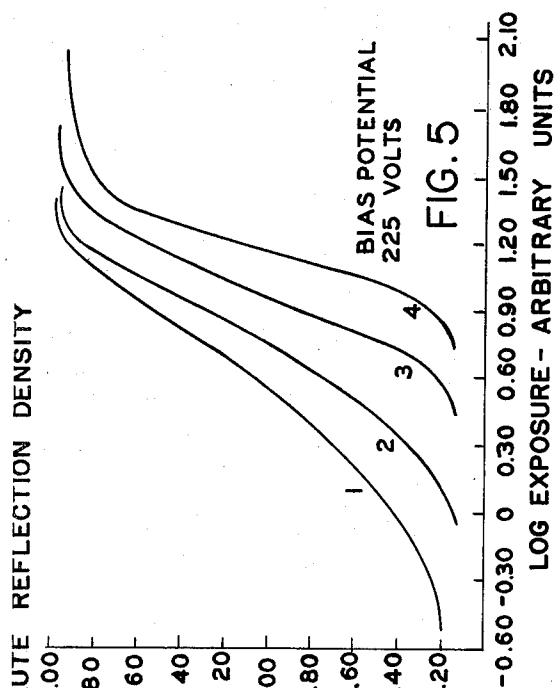
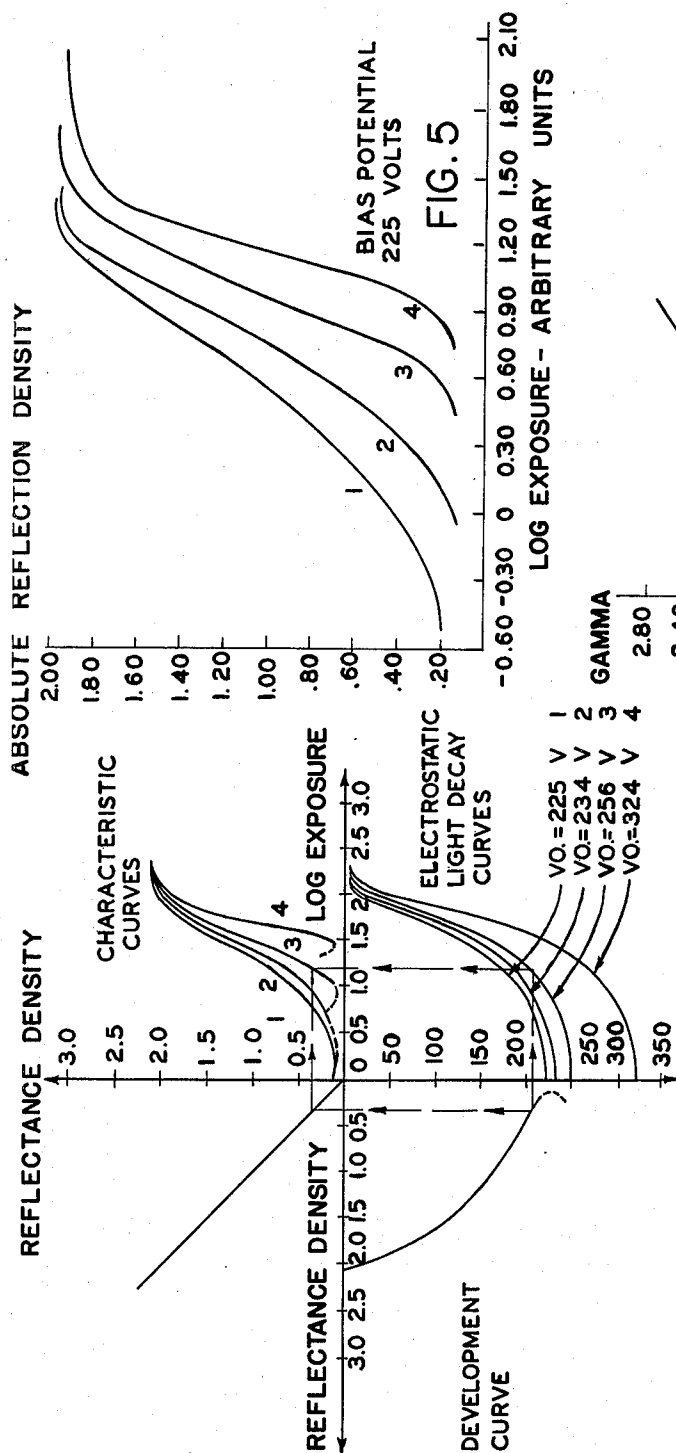
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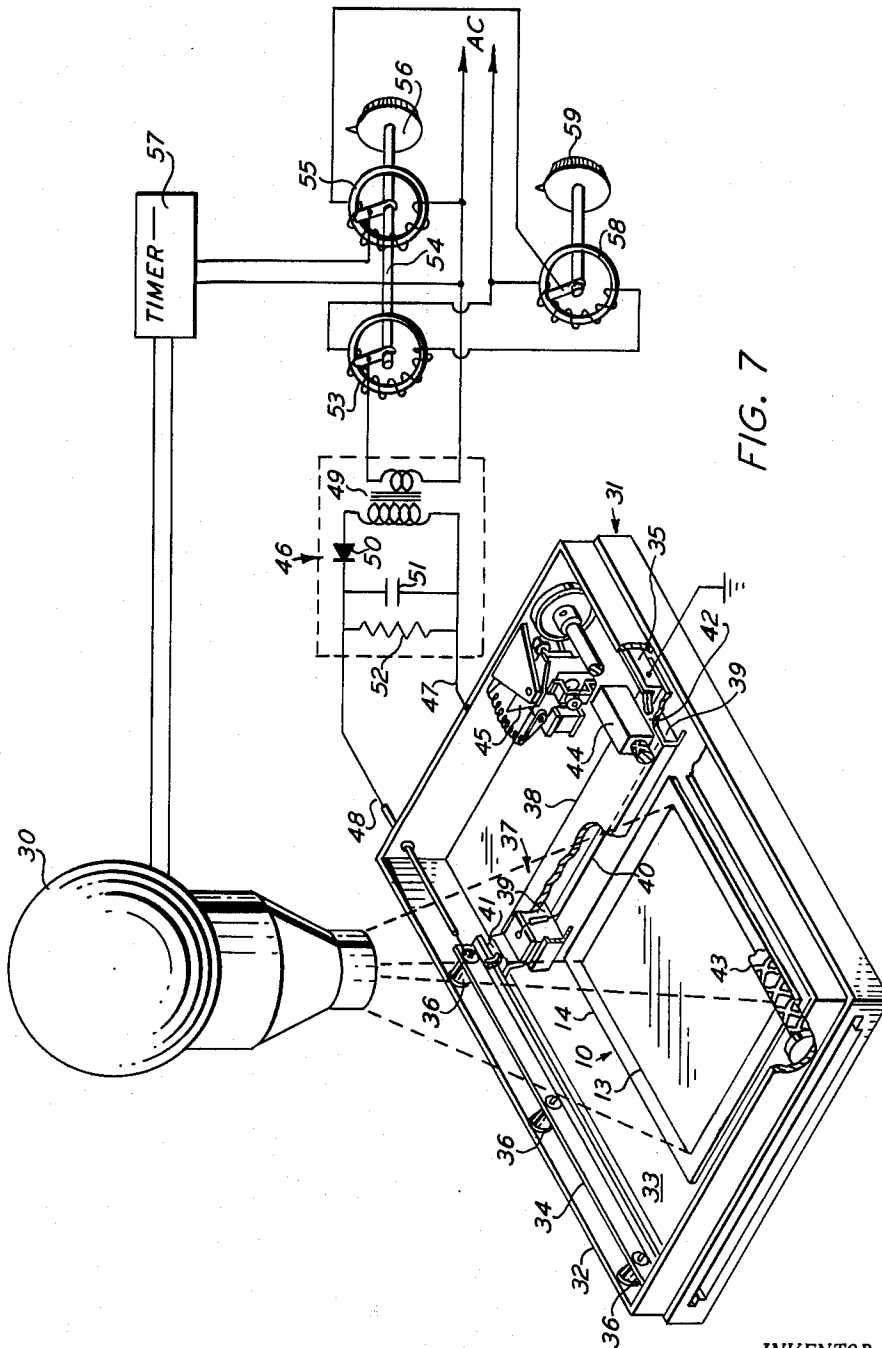
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3 Sheets-Sheet 3



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1

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## METHOD OF CONTROLLING CONTRAST IN A XEROGRAPHIC REPRODUCTION PROCESS

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Filed Oct. 19, 1959, Ser. No. 847,342  
3 Claims. (Cl. 96—1)

This invention deals with xerography.

In the basic method of xerography as disclosed in Carlson Patent 2,297,691 a xerographic plate, including a photoconductive insulating layer, is first uniformly charged in darkness to an electrostatic potential of the order of several hundred volts and then exposed to a pattern of light and shadow which has the effect of selectively dissipating electric charge from the illuminated areas of the photoconductive insulator thereby forming an electrostatic latent image. This latent image can be developed or made visible by bringing the surface of the photoconductive insulator into proximity with a mass or suspension of finely divided, electrostatically attractable material which is attracted to the surface of the photoconductive insulator in relation to the amount of charge residing thereon.

The electrostatically attractable material may be viewed on the photoconductive insulator or it may be transferred to another support such as a sheet of paper for more convenient viewing and to permit the reuse of the xerographic plate while retaining the image.

Various forms of image development are known and any of them may be used in connection with the present invention. One such method particularly suitable for use in developing continuous tone images is disclosed in Landrigan 2,725,304.

Where high quality continuous tone reproduction is desired in xerography, vitreous selenium in a thickness range from about 20 to 80 microns is commonly used as the photoconductive insulator, but other suitable photoconductive insulators are known including, but not limited to, sulfur, anthracene, and dispersions of photoconductive materials such as zinc oxide or other photoconductive pigment in a transparent insulating binder.

Selenium, and photoconductive insulating materials generally, have been found to lose their electrostatic charge or potential upon exposure to light in close accordance to the following relation:

$$\sqrt{V_0} - \sqrt{V} = KE$$

where  $V_0$  is the initial potential and  $V$  is the potential remaining after an exposure  $E$ , and  $K$  is a constant depending upon the particular photoconductive insulating material and the units of measurement. There is also a much smaller loss of potential which occurs even in darkness.

This type of charge exposure relationship, when coupled with the relationship between the charge on the photoconductive insulator and the developed image density as found in the Landrigan or other development methods, leads to an undesirably high contrast in the developed image where a positive-to-positive form of development is employed. Positive-to-positive development, also called charged area development, is that in which the portions of the xerographic plate exposed to the darkest parts of the light pattern and which accordingly retain the greatest charge also receive the greatest amount of attractable material during development. Copending application Serial No. 706,809, now abandoned, teaches methods and apparatus for overcoming such undesirably high image contrast.

It is often desirable in xerography to employ a form of development known as negative-to-positive development, reversal development, or uncharged area development. In

2

this form of development the portions of the xerographic plate corresponding to the brightest parts of the image pattern receive the greatest amount of development. Uncharged area development is particularly useful where it is desired to produce xerographic images from conventional silver halide film negatives or the like. It has been found that uncharged area xerographic development generally gives excessively low, rather than excessively high contrast. Accordingly, the contrast control techniques taught in application Serial No. 706,809 are not generally useful since they pertain to the reduction rather than enhancement of contrast.

It is accordingly an object to provide a novel method and apparatus to increase contrast in xerography.

It is a further object of the present invention to provide a novel method and apparatus for the control of xerographic image contrast in uncharged area development.

It is a further object to improve contrast control in xerography through a method in which exposure is controlled and in which initial plate potential is controlled relative to the level of development bias potential.

It is still a further object to provide apparatus for xerographic uncharged area reproduction in which initial potential and exposure are concurrently variable and are controlled to enhance and control contrast.

These and other objects will become apparent through the following description and drawings in which:

FIG. 1 is a cross section of a form of development apparatus suitable for carrying out the invention;

FIG. 2 is a set of curves showing the relation between plate potential and image density;

FIG. 3 is a set of curves showing the relation between plate potential and exposure;

FIG. 4 is a graphic method for predicting xerographic characteristic curves;

FIG. 5 is a series of characteristic curves obtained with the invention;

FIG. 6 is a curve showing a relation between gamma and initial potential; and,

FIG. 7 is a perspective view of a form of apparatus for carrying out this invention.

FIG. 1 is a partly schematic cross-sectional view of a form of development apparatus suitable for carrying out uncharged area development. It includes a xerographic plate 10 supported on a conductive carrier block 11 which in turn rests on drive rolls 12 by means of which plate 10 and block 11 may be moved right or left. Xerographic plate 10 comprises a photoconductive insulating layer 13 on a conductive support 14. An electrostatic charge pattern will normally have been formed on plate 10 before it is used in the apparatus of this figure. Development electrode 15, generally made of metal or other conductive material, is mounted so that the spacing between its substantially lower flat surface and that of the xerographic plate 10 is a small fraction of an inch. Development electrode 15 contains a slot 16 which directs a stream of fine electrostatic charged powder particles suspended in air against the surface of xerographic plate 10 as plate 10 is moved past slot 16. This particle suspension is supplied to discharge slot 16 through conduit 17 by powder cloud generator 18. Powder cloud generator 18 may be of any conventional type such as, for example, those described in U.S. Patents 2,812,883 and 2,859,128. In uncharged area development it is desirable to employ a powder particle suspension containing particles the majority of which are charged to the same polarity as that of plate 10. Since plate 10 is normally, although not exclusively, charged positive, powder cloud generator 18 should normally supply a cloud of predominantly positive particles. Suit-

able powder charging means are disclosed in co-pending applications Serial No. 706,807 and Serial No. 353,520 now U.S. Patent No. 2,943,950. A dust collector 19, which is a standard commercial device comprising a suction blower connected to a dust filter is connected through conduits 20 to two suction apertures 21 and 22 in development electrode 15. The right hand aperture 22 draws in most of the powder cloud issuing from slot 16 and in so doing causes the cloud to travel over the surface of xerographic plate 10. Suction aperture 21 collects any powder cloud leakage which might otherwise escape to the atmosphere. The apparatus also includes a battery 23 which is connected to a potentiometer 24 including both a fixed and a variable tap. Development electrode 15 is connected to one tap by wire 25 while xerographic plate 10 is connected to the other tap through wire 26 by way of drive roller 12 and support 11.

In order to effect uncharged area development the potential on electrode 15 with respect to plate 10 is adjusted through the use of potentiometer 24 to be substantially the same potential as the highest potential found on the surface of photoconductive insulating layer 13 at the time of development. When the potential of development electrode 15 is properly adjusted there is substantially no electric field between electrode 15 and those portions of the xerographic plate carrying the highest charge or potential and therefore a minimum of developer powder is attracted to the plate in these regions. However, a strong electric field exists between electrode 15 and plate 10 in uncharged areas of the latter and such uncharged areas accordingly attract large quantities of developer powder. It is accordingly possible to develop on plate 10 a deposit of powder the density of which varies approximately inversely as the charge or potential.

FIG. 2 is a curve showing a typical relation between the reflection density of powder deposits formed in the apparatus of FIG. 1 and the xerographic plate potential responsible for such deposits. The particular curve corresponds to a development electrode bias potential of 225 volts. The reflection density measurements were made after the powder was transferred from the xerographic plate to a sheet of white paper. It will be noted that the curve is somewhat non-linear displaying a maximum density (or blackness) at zero potential and a minimum density at a plate potential substantially the same as that of the development electrode. It can also be seen that the density starts to rise again as the plate potential is increased past the development electrode potential. Since this portion of the curve is preferably avoided in practical operation, it is indicated by broken rather than solid lines. The developed density rises at high plate potentials because at these potentials there is again an electric field between the plate and the development electrode, although opposite in polarity to that found at lower plate potentials. The occurrence of development under these conditions is explained by the presence of particles in the development cloud bearing charges opposite to the polarity desired for development. Curves corresponding to other values of bias potential will be generally similar except for being displaced to the left or right.

The curve in this figure represents a development carried out to a maximum density of about 2. In general, longer development times will somewhat increase the maximum available density, but will also cause excess deposition of powder in all areas of the plate including those where powder deposition is not desired. Excessively shortening development, on the other hand, will reduce maximum density as well as density at all points. A density of 2 was approximately the optimum maximum density for the particular apparatus and materials used in preparing this figure. While the particular curves of this figure correspond to a specific set of experimental data, the use of other development techniques or apparatus, transfer techniques or materials, plate materials, etc., will produce curves which vary from those shown, but

differences will, in general, be slight and such variations as might be found will not interfere with the workings of the invention.

FIG. 3 is a family of curves showing the relationship between xerographic plate potential and the amount of exposure in arbitrary units for various initial potentials. These curves generally correspond in form to the square root relationship previously described, except for an additional curvature caused by an observed departure from the square root relationship at very low potentials. Accordingly, no further discussion of this figure will be given.

FIG. 4 represents a form of graphical plot useful both for explaining and predicting results of the present invention. It comprises four quadrants of which the lower right contains a set of light decay curves relating xerographic plate potential to exposure in arbitrary log units. The particular curves chosen are the same as those which were presented in FIG. 3. The lower left quadrant contains development curves relating development density to xerographic plate potential. A single curve is shown which is taken from FIG. 2 and corresponds to a development electrode bias of 225 volts. The upper left hand quadrant contains a single diagonal line which is used only for relating points in the lower left quadrant to the upper right hand quadrant, which is the quadrant in which are plotted the xerographic characteristic curves relating developed image density to exposure.

To determine a point on a characteristic curve, a horizontal line is drawn from the light decay curve in the lower right quadrant to a point on the development curve in the lower left quadrant. A vertical line is then drawn upward from this point to a point on the diagonal in the upper left quadrant and a horizontal line is then drawn through this point on the diagonal. The intersection of this last horizontal line with a line drawn vertically upward from the original point on the light decay curve defines a point on the desired characteristic curve. Broken lines in the figure illustrate the method of determining a point on the characteristic curve. After many such points have been located in the upper right quadrant corresponding to many points on a light decay curve, a smooth curve may be drawn in the upper right quadrant representing a xerographic characteristic curve relating exposure to density.

Four such curves are shown corresponding to the four light decay curves chosen for illustrative purposes in the lower right quadrant. As can be seen, the four curves have markedly different slopes and therefore correspond to different degrees of contrast in xerographic image reproduction. The attainment of such contrast control is, of course, the primary object of the present invention. The curve marked as No. 1 corresponds to the situation where the initial plate potential is substantially the same as the development electrode bias potential used during development. This corresponds to the conventional technique which was in general use prior to this invention. The other curves correspond to conditions where the initial plate potential is substantially higher than the development bias potential and these curves give progressively higher contrast. The principal reason for this higher contrast is the utilization of only the right hand or steeper portion of the light decay curves as shown in the lower right quadrant. It can also be seen from the figure that where higher contrasts are obtained it is necessary to resort to a higher exposure. Although less apparent from the figure, it is also true that the plate potential corresponding to the middle portion of each of the characteristics curves is substantially the same. Each of the characteristic curves except the first has a broken portion corresponding to the increase in image density which occurs when plate potential is allowed to exceed development electrode potential. This generally represents an undesired condition and is avoided by employing sufficient exposure to insure that substan-

tially all portions of the xerographic plate are reduced in potential below the development bias potential.

FIG. 4 shows the various degrees of contrast obtainable by varying initial potential and exposure while maintaining the development electrode bias constant. The same results, however, can also be obtained by reducing the electrode bias rather than by increasing the initial potential, or even by doing both together. The principal factor in controlling contrast is the degree by which the initial potential of the xerographic plate exceeds the development electrode bias. For practical reasons, however, it is generally more convenient to vary the initial potential rather than the electrode bias. Where the bias potential is varied it is desirable to avoid excessively low potentials which generally cause low quality development. Where initial potential is varied it is likewise best to avoid excessively high potentials which may damage the plate or otherwise cause flaws in the developed image. The operating conditions which will be described hereafter are representative of a preferred range of values.

Table I below tabulates the characteristics of the four curves shown in the upper right quadrant of FIG. 4.

Table I

|                 | Curve 1 | Curve 2 | Curve 3 | Curve 4 |
|-----------------|---------|---------|---------|---------|
| $V_0$ -----     | 225v    | 234v    | 256v    | 324v    |
| $S_1$ -----     | .45     | .26     | .13     | .06     |
| $S_2$ -----     | .15     | .15     | .16     | .13     |
| $S_p$ -----     | 1.15    | .98     | .74     | .46     |
| $S_t$ -----     | 1.75    | 1.39    | 1.03    | .65     |
| $DS$ -----      | 1.97    | 1.98    | 1.98    | 1.98    |
| $D_{max}$ ----- | 2.08    | 2.08    | 2.08    | 2.08    |
| Gamma-----      | 1.46    | 1.71    | 2.27    | 3.65    |
| Contrast-----   | 1       | 2       | 3       | 4       |

The characteristics listed in Table I are defined as follows, in accordance with Air Force Specification MIL-P-4672A (Aug. 16, 1954):

- $V_0$ =initial potential.
- $S_1$ =toe scale=difference in the log exposure between points on the characteristic curve where reflectance densities are 0.04 above  $D_{min}$  and 0.20 above  $D_{min}$ .
- $S_2$ =shoulder scale=difference in the log exposure between points on the characteristic curve where reflectance densities are 0.04 below  $D_{max}$  and 0.20 below  $D_{max}$ .
- $S_p$ =partial scale=difference in log exposure between points on the characteristic curve where the reflectance densities are 0.20 above  $D_{min}$  and 0.20 below  $D_{max}$ .
- $S_t$ =total scale=difference in log exposure between points on the characteristic curve where the reflectance densities are 0.04 above  $D_{min}$  and 0.04 below  $D_{max}$ .
- $DS$ =density scale= $D_{max}-D_{min}$ .
- $D_{max}$ =maximum reflectance density.
- $D_{min}$ =minimum reflectance density.
- Gamma= $DS-0.40/SP$ .

FIG. 5 shows in some detail a series of four curves as found by experiment and which correspond generally to the four theoretical curves in the upper right quadrant of FIG. 4. Each curve is a relation between xerographic plate exposure in arbitrary units and the reflection density of an image developed on the plate. All are based on a bias potential of 225 volts. Table II below summarizes the essential data for each curve. It is apparent that a very wide range of contrast, or gamma is obtainable. This range generally spans the range of contrasts available in conventional photographic printing or enlarging papers. There is thus accorded to xerographic uncharged area development the same degree of flexibility in contrast control as has heretofore been possible with conventional photographic printing and enlarging techniques.

Table II

|                                       | #1   | #2   | #3   | #4   |
|---------------------------------------|------|------|------|------|
| 5 Initial Plate Potential--volts----- | 235  | 257  | 299  | 362  |
| Relative Exposure-----                | 3    | 8    | 19   | 35   |
| $S_1$ -----                           | 0.31 | 0.29 | 0.11 | 0.09 |
| $S_2$ -----                           | 0.13 | 0.11 | 0.17 | 0.28 |
| $S_p$ -----                           | 1.10 | 0.85 | 0.64 | 0.49 |
| $S_t$ -----                           | 1.64 | 1.15 | 0.93 | 0.86 |
| $DS$ -----                            | 1.78 | 1.82 | 1.82 | 1.79 |
| $D_{max}$ -----                       | 1.98 | 1.97 | 1.97 | 1.94 |
| 10 Gamma-----                         | 1.25 | 1.67 | 2.20 | 2.84 |

FIGURE 6 is an experimental curve showing the relationship between the gamma of a developed xerographic image and the amount by which the initial potential exceeds the development electrode bias potential. It can be seen that a tremendous variation in gamma is obtainable with a relatively small change in initial potential and/or bias. With the aid of a curve such as this used in connection with the present invention an operator making xerographic prints can exercise even greater and more predictable control of the print contrast than is possible even with established photographic techniques.

FIGURE 7 shows a form of apparatus suitable for carrying out the invention. It comprises generally a photographic enlarger 30 positioned over charging apparatus 31 together with associated electrical apparatus. Enlarger 30 may be of any conventional type adapted to project an image of a photographic negative or the like. Charging apparatus 31 comprises a supporting frame 32 adapted to position all elements and a base plate 33 generally made of conductive material upon which is placed xerographic plate 10 comprising photoconductive insulating layer 13 and a conductive support member 14. Alternatively, and depending upon the intended usage of plate 10, conductive support 14 may be omitted. A conductive rail 34 is positioned on one side of frame 10, and a second rail 35 is positioned on the other side. Rail 34 is secured to frame 32 but insulated therefrom by insulators 36 while rail 35 is directly attached to frame 32. A charging bar or corotron 37 is slideably mounted in frame 32 to pass over plate 10 at a slight distance therefrom. It comprises an open bottom channel 38 of conductive material carrying at each end insulating blocks 39 between which is strung a fine corona generating wire 40. Corotron 37 is supported in frame 32 by hangers 41 and 42 which slide on rails 34 and 35 respectively. Hanger 41 is connected to corona wire 40 while hanger 42 is connected to channel 38. Frame 32 also rotatably supports a reversible lead screw 43 which is adapted to move the corotron 37 back and forth over plate 10 by means of the lead screw block 44 which engages the groove in the lead screw and is attached to channel 38. Electric motor 45, also attached to frame 32, is used to rotate lead screw 43. High voltage power supply 46 is connected to base plate 33 and thus to conductive support 14 as well as rail 35 and channel 38 through wire 47, and is connected to rail 34 and thus to wire 40 through wire 48. The power supply, which is adapted to supply voltages on the order of 5,000 to 10,000 volts, may be of conventional design as illustrated and include a step-up transformer 49, rectifier 50, filter condenser 51 and bleeder resistor 52. Conventional control apparatus such as a microswitch, not shown, may be provided to stop motor 29 and corotron 37 after corotron 37 passes back and forth over plate 10 and returns to the starting position as shown. Alternatively, other mechanical arrangements may be used. When a corona generating potential is applied to wire 48 and the corotron passed over plate 10 an electrostatic charge is placed on plate 10, the magnitude of which may be controlled through varying the voltage or current supplied to wire 48. Further information on the construction and operation of corotron 37 may be found in U.S. Patent 2,836,725.

As can be seen from FIGURE 7, the input to power supply 46 is supplied from a toroidal autotransformer 53.

Thus, by adjusting autotransformer 53 the corona generating potential supplied to corona wire 40 may be varied. Autotransformer 53 is ganged on the same insulating shaft 54 with toroidal autotransformer 55. A knob 56 is provided on shaft 54 whereby both autotransformers may be simultaneously adjusted. Autotransformer 55 supplies an adjustable A.C. potential to enlarger 30 through timer 57. Autotransformer 53 is supplied directly with A.C. line voltage, but autotransformer 55 is fed from the output of another toroidal autotransformer 58 which is equipped with an operating knob 59. Accordingly, the corona potential applied to wire 48 and thus to corona wire 40 is determined solely by the setting of knob 56, whereas the voltage applied to the enlarger 30 depends on the settings of both knob 56 and knob 59. In operating this apparatus, knob 56 is turned to a setting corresponding to a desired level of contrast and knob 59 is turned to a setting corresponding to the average density of the negative to be projected from enlarger 30. Motor 45 is then energized to cause corotron 37 to pass over xerographic plate 10 to deposit thereon a potential determined by the setting of knob 56. Motor 45 is then turned off and timer 57 is then energized to project upon plate 10 for a fixed period of time a light image, the intensity of which is dependent on the setting of knobs 56 and 59. After exposure, plate 10 may then be removed from the apparatus of FIGURE 7 and developed in separate apparatus such as that of FIGURE 1.

Since contrast depends on the initial potential applied to plate 10, contrast is accordingly influenced by the setting of knob 56 which controls the charging potential. It has also been shown that as charging potential is raised to increase image contrast the required level of exposure is likewise raised. For this reason knob 56 increases the voltage input to enlarger 30 and therefore the light output of enlarger 30 at the same time that it increases the charging potential applied to wire 40. Since photographic negatives differ among themselves in average density, a further degree of control over exposure is desired which is provided by knob 59 which is adapted to raise or lower the voltage input provided to enlarger 30 over that otherwise determined by knob 56. Where a series of negatives are being reproduced, all of which have the same density, but varying contrast, xerographic prints of uniform quality may be had through adjustment of knob 56 alone. Where negatives of uniform contrast, but different density are encountered, prints of uniform quality may be had through adjustment of knob 59 alone. More typically, both knobs will be operated to compensate for both variations in negative contrast and negative density. Since the potential applied to plate 10 is not in general a linear function of the voltage applied to wire 40 and since the light output of enlarger 30 is not a linear function of the voltage applied to enlarger 30, it may be desirable to wind autotransformers 53 and 55 in a nonlinear fashion so as to provide the proper relationship between initial plate potential and exposure as called for in FIGURE 4.

The apparatus of FIG. 7 is shown for illustrative purposes only, and it is apparent that many modifications may be made to the apparatus without departing from the proper scope of the invention. Thus, different forms of charging apparatus may be used to replace corotron 37 or other elements of charging apparatus 31. Likewise, enlarger 30 may be replaced by contact exposure apparatus and other forms of control apparatus may be substituted for the illustrated autotransformers. The apparatus could also be adapted to operate with flexible xerographic plates including those in the form of a web. Although the illustrated apparatus is adapted to control contrast through variation of charging, it may also be adapted to control contrast through variations of development electrode bias potential by re-connecting the output of autotransformer 53 to a relatively low voltage power supply to supply bias potential to a separate development apparatus.

There are various devices now known and available on the market which are capable of determining the degree of contrast in a photographic negative or the like, and there are also available devices for determining the average transmission of a negative. Such devices may be incorporated to supplement the subjective judgment of the operator. Such devices can also be connected through known types of servo mechanism to directly operate the transformers in FIG. 7 thereby making the operation of the apparatus entirely automatic. The apparatus of FIG. 7 can also be equipped with an electrometer to measure the potential on xerographic plate 10 before or after exposure by enlarger 30, or both. Such an electrometer can be used to measure plate potential after exposure thereby providing a rapid check on the adequacy of the exposure, or it can be used to automatically control exposure. Modifications of this sort which will readily occur to those skilled in the art are intended to be encompassed by the appended claims.

What is claimed is:

1. The method of controlling contrast in a xerographic reproduction process wherein a xerographic plate is charged, exposed to a pattern of light and shadow to produce a latent charge pattern and developed in proportion to the amount by which the local potential  $V$  of the electrostatic charge pattern is less than a fixed bias potential on a development electrode, said method comprising applying a charging potential  $V_0$ , greater than said fixed bias potential, and exposing the plate to a pattern of light and shadow until substantially all areas thereof are reduced to a potential below said fixed bias potential whereby the said local potential  $V$  remaining at any given point on the plate, after said exposure is governed by the expression  $\sqrt{V_0} - \sqrt{V} = KE$  where  $E$  is the said exposure at the said given point and  $K$  is a constant which is a function of said plate, said  $V_0$  being chosen so that the said remaining local potential  $V$  will vary from point to point within a range of values corresponding to a desired contrast range in the developed plate, and positioning said development electrode adjacent to the developable surface of said plate for development.

2. The method of controlling contrast in an uncharged area development xerographic reproduction process wherein a xerographic plate is charged, exposed to a pattern of light and shadow to produce a latent charge pattern and developed in proportion to the difference between the local potential  $V$  of the electrostatic charge pattern and a bias potential on the development electrode, said method comprising charging the plate surface to a fixed potential  $V_0$ , reducing said bias potential below said fixed plate potential  $V_0$ , exposing the plate until substantially all charged surface areas thereof are reduced in potential at least to said bias potential, whereby the said local potential  $V$  remaining at any given point on the plate after said exposure is governed by the expression

$$\sqrt{V_0} - \sqrt{V} = KE$$

where  $E$  is the said exposure at the said given point and  $K$  is a constant which is a function of said plate, the difference between the said reduced bias potential and the said  $V_0$  being chosen so that the said remaining local potential  $V$  will vary from point to point within a range of values corresponding to a desired contrast range in the developed plate, and positioning the charged plate surface adjacent to said development electrode for development.

3. The method of controlling contrast in an uncharged area development xerographic reproduction process wherein a xerographic plate is charged, exposed to a pattern of light and shadow to produce a latent charge pattern and developed in proportion to the difference between the local potential  $V$  of the electrostatic charge pattern and a fixed bias potential applied to a development electrode maintained adjacent the surface to be developed, said method comprising charging the plate to a uniform po-

tential  $V_0$  greater than said bias potential, and exposing the plate until the potential on substantially all areas is reduced below said fixed bias potential, said uniform potential  $V_0$  being chosen so that the said local potential  $V$  remaining at any given point on the said plate after said exposure which is given by the expression

$$\sqrt{V_0} - \sqrt{V} = KE$$

where  $E$  is the said exposure at the given point and  $K$  is a constant which is a function of the said plate, will vary from point to point within a range of values corresponding to a desired gamma in the developed plate.

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