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H. E. CLARK
 HALF-TONE XEROGRAPHY WITH THERMOPLASTIC
 DEFORMATION OF THE IMAGE
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3,196,012

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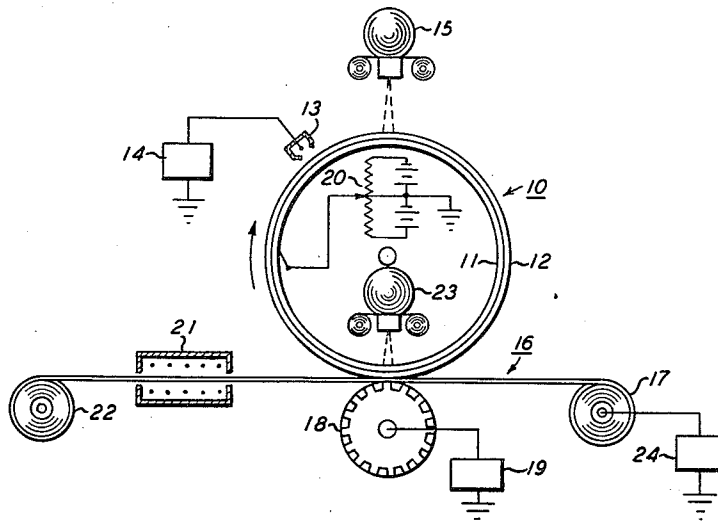


FIG. 1

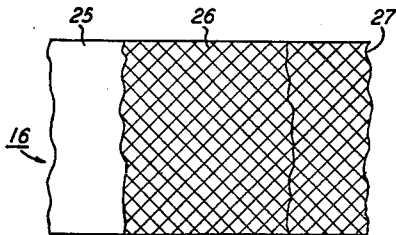


FIG. 2A

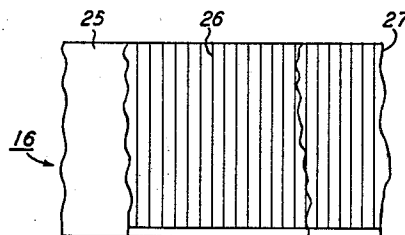


FIG. 2B

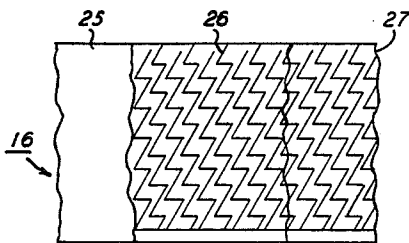


FIG. 2c

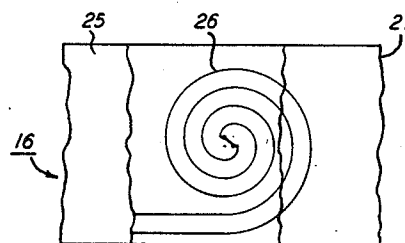


FIG. 2d

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3,196,012

HALF-TONE XEROGRAPHY WITH THERMO-PLASTIC DEFORMATION OF THE IMAGE

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This invention relates to xerography and more particularly to novel electrostatic methods of forming visible patterns in response to optical images.

In the usual forms of xerography an electrostatic latent image is formed by the combined action of an electric field and a pattern of light and shadow on a photoconductive insulating layer. The latent image is immediately, subsequently, or in some cases simultaneously, converted into a visible image by the selective attraction, repulsion, or redistribution in image configuration of finely divided solid or liquid particles.

A variety of xerographic methods are known which generally conform to the above description and which enjoy widespread commercial use as well as being fully described in various patents and other publications. Methods are also known in which an image is electrostatically reproduced as surface deformations in a continuous layer of material, but such methods have required high vacuum systems to form the image, and have lacked the ability to reproduce continuous tone images for large solid areas.

A modified electrostatic deformation image reproduction method has been proposed in which an electrostatic image pattern is transferred in air from a conventional xerographic plate or the like to a layer of deformable insulating material in which surface deformations are then formed in response to the transferred charge pattern. The transfer of charge patterns across narrow gaps has been termed TESI (Transfer of Electrostatic Images) and the general principles underlying such procedures are set forth in U.S. Patent 2,937,943 to which reference should be had for the detailed operating conditions appropriate to electrostatic image transfer. The foregoing method is capable of providing photoexact reproductions and does not require a vacuum system, but it still lacks the ability to reproduce solid areas or continuous tone images. This lack is due, not to the charge transfer mechanism, but rather to the way in which a surface deforms in response to electrostatic charges thereon. Various proposals have been made to overcome these shortcomings but these have generally required the use of excessively complicated structural elements or the like. It is an object of the present invention to provide an improved and simplified method of providing reproductions of continuous tones and solid areas in a xerographic deformation imaging system. It is a further object to form a continuous tone charge pattern on one surface into a halftone charge pattern on an adjacent surface. These and other objects and features of the invention will become more apparent in connection with the following specification and claims taken in conjunction with the drawings in which:

FIG. 1 is a schematic reproduction of an apparatus adapted to carry out several embodiments of the invention; and,

FIG. 2 represents several forms of image recording member according to the invention.

It is believed worthwhile to discuss halftone printing which shares certain features of the present invention. Conventional printing processes, such as letterpress or lithography, can print only black or white and are inherently incapable of printing intermediate shades of gray. In addition, other printing processes, such as intaglio, can print only small black areas and cannot print large solid black areas. These problems have been over-

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come in printing through the use of halftone methods in which the image is broken down into a series of closely spaced dots the size of which depends upon the degree of blackness which it is desired to simulate. These dots are generally very small and closely spaced since the dots spacing sets a lower limit on the reproduction of image detail. The dots are generally, but not necessarily uniformly spaced and may be round, diamond-shaped or of still other shapes. In closely related forms of printing a continuous tone image may be reproduced by a pattern of lines, which may be straight or curved, the thickness of which varies along their length in accordance with the blackness of the image being printed. For the purposes of the present invention all of these methods will be referred to as halftone methods regardless of whether it is contemplated to reproduce a continuous tone image as a pattern of dots, lines, or elements of other shapes.

Xerographic methods in which a charge pattern is made visible through the mechanical deformation of a surface resemble printing processes in that lines or dots can be well reproduced but not intermediate shades of gray nor large solid areas. It has been proposed to adapt the teaching of the printing art by reproducing grays or large solid areas as a recurrent pattern of surface deformations. It has been proposed that this be accomplished by varying the mechanical properties of the deformable layer in a point-to-point fashion but this has led to complicated structures and unsatisfactory results. It has also been proposed to introduce a halftone screen or the like during the exposure step. However, in accordance with the present invention structures and methods are provided whereby these halftone effects can be introduced into the transferred charge pattern during charge transfer itself.

FIG. 1 illustrates a form of apparatus which can be used to carry out the invention in several ways. It includes a xerographic plate 10 in the form of a drum which is rotatable about its axis by drive means, not shown. The drum includes a mechanical support layer 11 which is preferably electrically conducting and may comprise various metals such as aluminum or the like. It may comprise a piece of glass or other transparent material upon which is coated an electrically conductive layer, preferably a transparent conductive layer such as tin oxide or copper iodide. Coated upon support member 11 is a photoconductive insulating layer 12 which may comprise any of the photoconductive insulating materials known in the art of xerography. These materials are generally characterized as being sufficiently insulating in the dark to retain an electrostatic charge for a useful length of time while being sufficiently conductive when exposed to light or other activating radiation to dissipate such charge. Photoconductive insulators may comprise vitreous materials, of which selenium is an example enjoying commercial popularity, or they may comprise dispersions of photoconductive pigments, of which zinc oxide is at present employed commercially, dispersed in an electrically insulating film-forming binder. A corona charging device 13 and its associated high voltage power supply 14 are provided and cooperate to deposit an electrostatic charge of several hundred volts on the surface of plate 10 in accordance with conventional xerographic practice.

A projector 15 is positioned to project an image onto plate 10 after it has been charged by corona device 13 and thereby form an electrostatic charge pattern on plate 10. Projector 15 preferably projects a moving image which moves in synchronism with the motion of plate 10. Plate 10 next passes into contact with a web of deformable transfer material 16 which is fed from a supply roll 17 and which is maintained in close proximity with plate 10 by an electrically conductive transfer roller 18 which is connected to a D.C. power supply 19. Trans-

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fer material 16 may comprise any electrically insulating material which is capable of being readily softened through the application of heat, solvent vapors, or other means. Polystyrene is a particularly suitable material but most natural or synthetic resins, waxes, or the like are reasonably satisfactory. Transfer material 16 may also include a support layer, not illustrated in this figure, to provide mechanical support for the deformable layer. This latter material should desirably be flexible, although it may be rigid in some cases, should be an electrical insulator and should retain its mechanical properties under conditions which caused the deformable material to soften. Various materials are suitable of which polyethylene terephthalate is outstanding for its excellent electrical properties, high strength and great resistance to heat and nearly all common solvents. Application of a potential to transfer roller 18 from power supply 19 creates a strong electric field between roller 18 and plate 10. Plate 10 in this embodiment is preferably grounded and this may be accomplished through power supply 20 which is connected to plate 10 and which may be shorted to ground. It will be appreciated, however, that the desired potential difference between plate 10 and roller 18 may be accomplished by applying potentials through either or both of power supplies 19 and 20.

The potential difference established between roller 18 and plate 10 would in accordance with the art superpose a uniform electric field on that due to the charge pattern on plate 10 and thereby cause the charge pattern previously formed on plate 10 to be transferred to transfer material 16 to form a substantial facsimile thereon of the original charge pattern. In accordance with the present invention, however, transfer roller 18 does not have a smooth cylindrical surface but instead has a pattern of pits or depressions formed thereon so that the surface of roller 18 contacts transfer material 16 in a pattern which may comprise a series of dots, parallel, lines, intersected lines, or the like. Application of an electrical field sufficient to effect image transfer results in a transfer that varies in accordance with the lands and depressions of the surface. Accordingly, the charge pattern transferred to transfer material 16 has a halftone pattern superimposed on the continuous tone pattern originally formed on plate 10. Deformable material 16 then passes through an oven 21 where it is softened and where the electrostatic charge pattern thereon causes the softened material to deform in image configuration. The size of an individual area of deformation will, of course, vary with the amount of charge transferred to that area, thereby giving a continuous tone effect. A vapor chamber filled with solvent vapors for transfer material 16 could equally well be employed. After passing through the oven the material cools and rehardens and may be projected by schlieren optics or the like or wound up on take-up roll 22 for further use.

In a further embodiment of the invention, corona charging unit 13 and projector 15 are not used and supporting layer 11 is limited to the transparent variety with a conductive layer as described above. A projector 23 mounted within plate 10 is used to project an image onto photoconductive insulating layer 12 through support layer 11 at the region where photoconductive insulating layer 12 is in proximity with transfer roller 18. An electric field is established between plate 10 and roller 18 by either or both of power supplies 19 or 20 and causes the charge pattern to be transferred from plate 10 to transfer material 16 in image configuration simultaneously with the illumination of plate 10 in image configuration. Again the fields acting through transfer material 16 are sufficiently intense to cause charge transfer only in the areas where transfer material 16 is actually contacted by transfer roller 18 and again a halftone pattern is superimposed upon the transferred charge pattern.

While the invention has been disclosed in terms of a rotating cylindrical xerographic plate and a transfer roller

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tions can be carried out intermittently employing a flat xerographic plate and a flat conductive platen in place of transfer roller 18.

The principles of the present invention may also be carried into effect through the use of novel forms of transfer material 16. It is already known that transfer materials may consist, for example, of a structure comprising an optional layer of insulating support material, a thin layer, preferably transparent, of conducting material, and a surface layer of deformable material. With such a structure transfer roller 18 may be eliminated since the electric fields necessary for charge pattern transfer can be established through the application of controlled potentials to the conductive layer of transfer material 16. Accordingly, a further power supply 24 is shown in FIG. 1 which is adapted to be connected to such a conductive layer.

FIG. 2A illustrates one form of transfer material incorporating a conductive layer and modified in accordance with the present invention. It comprises an electrically insulating support layer which, again, may comprise polyethylene terephthalate or other mechanically tough insulating material which is resistant to either or both of heat or solvent. Coated over support layer 25 is a thin electrically conductive layer 26 over which is coated a layer 27 of deformable material. Layer 27 is preferably, though not necessarily, transparent. If it is, transparent charge pattern formation and transfer may be effected by projecting a light pattern through transfer material 16 rather than through plate 10 and image projection may be effected by transmitted rather than reflected light. In terms of FIG. 1 this can be carried out by positioning an enlarger at the location occupied by transfer roller 18. As illustrated in FIG. 2A, conductive layer 26 does not form a continuous layer as known to the art but instead comprises a pattern of intersecting lines. When this material is employed in the apparatus of FIG. 1 or other apparatus, the electric field created through deformable layer 27 and to plate 10 is not a uniform field but instead varies over the surface of layer 27 in accordance with the pattern of layer 26. Accordingly, charge transfer from plate 10 to layer 27, which is a field controlled phenomena, takes place in a halftone rather than in a continuous tone pattern.

The pattern of crossed lines illustrated in FIG. 2A is not the only pattern suitable for conductive layer 26. It may comprise, for example, a pattern of parallel straight lines as in FIG. 2B or a pattern of zig-zag lines as in FIG. 2C, provided these lines are electrically connected to each other so as to remain always at the same potential, or even a spiral as shown in FIG. 2D. In each case, however, these patterns are adapted to provide a spatially varying electric field between transfer material 16 and plate 10 in that the field varies as one moves over the surface of transfer material 16 and this variation contains a component corresponding to the conductive layer 26 although it may generally also contain a pattern determined by the image exposure.

Transfer roller 18 can conveniently be prepared by an etching technique. Thus, an initially smooth roller may be coated with a layer of photoresist such as bichromated gelatin or Kodak Photoresist, available from the Eastman Kodak Company, Rochester, N.Y. The layer of photoresist is then exposed to a pattern of light and shadow corresponding to the desired halftone pattern and the unexposed photoresist is then washed off. Roller 18 is then immersed in an acid bath which etches away the surface in areas not protected by the photoresist. As a final step the remaining photoresist is removed, leaving the desired relief pattern on roller 18. If desired the depressed areas may be filled in with plastic or other insulating material to form a smooth surface. Various other techniques may be used to form a pattern on roller 18 and these techniques or the etching technique already described may be used to form

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18, it will be understood that precisely the same operable surface patterns on flat plates or other functional equivalents for transfer roller 18.

Where the transfer material includes a conductive layer, this may be formed in various ways from various materials. Conductive layer 26 may, for example, comprise a metal layer applied as a foil, as a vacuum evaporated layer, as a chemically deposited layer, or the like. When sufficiently thin, such as a metal layer may be transparent. Where support layer 25 comprises glass or similar refractory material, a transparent conductive layer of tin oxide may be coated thereon by known methods. Where support layer 25 comprises a plastic or similar material incapable of withstanding the heat required to apply a tin oxide coating, a transparent electrically conductive coating of copper iodide may be applied instead.

The desired pattern may be formed in any of these coatings by various methods. One such method is to apply the coating through a stencil held in contact with support layer 25. Another method is to selectively remove portions of layer 26 after the application thereof by using the same etching technique described in connection with the formation of transfer roller 18. As is known, it is also possible to selectively remove portions of a thin film such as a conductive layer 26 by controlled electron bombardment in a high vacuum chamber. After conductive layer 26 has been formed in the desired pattern on support layer 25, a layer of deformable material 27 may be applied by any conventional coating technique.

In a further embodiment of the invention conductive layer 26 may comprise two superposed layers, one of them being an extremely thin continuous layer of relatively great electrical resistivity and the other being a more conductive patterned layer of the type already described. In accordance with this embodiment the electric field effecting charge transfer does not vary as abruptly from point to point along the surface of transfer material 16 as when conductive layer 26 merely comprises areas of high electrical conductivity intermixed with areas of essentially zero conductivity. Other methods of achieving a halftone pattern of conductivity variation in conductive layer 26 would be equally effective in achieving a more gradual spatial variation in the electric field available for charge transfer. It has been found that such gradual variation in field tends to produce a higher resolution in the ultimate deformation image pattern than is obtained with the more abrupt field variations associated with a conductive layer 26 which is either present or totally absent at any given point.

In some instances it has been found advantageous to coat plate 10 or transfer web 16 with an electrically insulating liquid such as silicone oil. For example, silicone oil type DC-200 available from Dow Corning. Such an oil film fills the gap between plate 10 and web 16 providing a more uniform contact and improving the mobility of electrical charges between the two. Thus, with such as oil interlayer it has been found that the electrical potential required for a TESI transfer is substantially reduced.

While the invention has been described in terms of specific structures, methods and application, these have been for illustrative purposes and it is not intended to limit the invention except by the scope of the appended claims. In particular, the above described methods are useful for securing a halftone effect in transfer of electric charge patterns, regardless of whether such charge patterns are transferred to a deformable surface or to other types of surface for other purposes.

What is claimed is:

1. The method of reproducing a continuous tone pattern of light and shadow comprising the steps of:

(a) applying an electrostatic transfer field effective in a defined geometric halftone field pattern to transfer a continuous tone pattern of electric charge conform-

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ing to said pattern of light and shadow from the surface of a uniform photoconductive insulating layer to the surface of a contiguously supported layer of deformable insulating material whereby the transferred charge densities on said deformable material are correlated pattern-wise to said applied half-tone transfer field,

(b) separating the photoconductive insulating layer from the layer of deformable material, and

(c) deforming the deformable material in response to the charge pattern transferred thereto.

2. The method of claim 1 in which the applied transfer field has a geometric variation over an average distance less than the minimum size of pattern detail to be reproduced.

3. The method of reproducing continuous tone pattern of light and shadow comprising the steps of:

(a) placing a layer of deformable insulating material in contiguous relation with a uniform photoconductive insulating layer bearing a continuous tone charge pattern,

(b) applying an electrostatic transfer field effective in a defined geometric halftone field pattern between the deformable layer and the photoconductive insulating layer whereby charge is transferred only in discrete areas correlated to the pattern of said applied field,

(c) separating the photoconductive insulating layer from the layer of deformable material, and,

(d) deforming the deformable material in response to the charge pattern transferred thereto.

4. The method of reproducing a continuous tone pattern of the light and shadow comprising the steps of:

(a) placing a layer of deformable insulating material in contiguous relation with a uniform layer of photoconductive insulating material,

(b) applying an electrostatic transfer field effective in a defined geometric halftone field pattern between the deformable layer and photoconductive insulating layer,

(c) illuminating the photoconductive insulating layer with a continuous tone pattern of light and shadow whereby charge is transferred discretely in a pattern correlated to the pattern of said applied field,

(d) separating the deformable layer from the photoconductive insulating layer, and

(e) deforming the deformable material response to the charge pattern transferred thereto.

5. The method of reproducing a continuous tone pattern of light and shadow comprising the steps of:

(a) forming an electrostatic charge pattern corresponding to said continuous tone pattern on the photoconductive insulating layer of a xerographic plate comprising a uniform photoconductive insulating layer overlying a conductive support layer,

(b) placing a first surface of a layer of deformable insulating material in contiguous relation with said photoconductive insulating layer,

(c) placing a conductive member having a geometric halftone pattern of surface depressions thereon adjacent the second surface of the deformable insulating material,

(d) establishing a potential difference between said conductive support layer and said conductive member whereby charge is transferred from said photoconductive insulating layer to said deformable material in a pattern controlled by both said electrostatic charge pattern and the pattern of depressions on said conductive member,

(e) separating the deformable material from the xerographic plate, and

(f) deforming the deformable material in response to the charge pattern transferred thereto.

6. The method of reproducing a continuous tone pattern of light and shadow comprising the steps of:

(a) placing a first surface of a layer of deformable

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insulating material in contiguous relation with the photoconductive insulating layer of a xerographic plate comprising a uniform photoconductive insulating layer overlying a conductive support layer,

- (b) placing a conductive member having a geometric halftone pattern of surface depressions thereon adjacent the second surface of the deformable insulating material, 5
- (c) establishing a potential difference between said conductive support layer and said conductive member, 10
- (d) concomitantly with said last-recited step applying a continuous tone pattern of light and shadow to said photoconductive insulating layer, and
- (e) separating said deformable material from said photoconductive insulating layer whereby charge is transferred from said photoconductive insulating layer to said deformable material in a pattern controlled by both the original pattern of light and shadow and the pattern of depressions on said conductive element, and, 20
- (f) deforming the deformable material in response to the charge pattern transferred thereto.

7. The method of reproducing a continuous tone pattern of light and shadow comprising the sequential steps of: 25

- (a) forming a latent electrostatic image on a uniform first insulating surface,
- (b) positioning said first insulating image carrying said latent electrostatic image in contiguous relation with a deformable second insulating surface overlying a halftone pattern of continuous electrically conductive material, and 30
- (c) applying a potential across said first insulating surface and said second insulating surface sufficient to effect image transfer so that said latent electrostatic image is transferred to said second insulating surface modified by said halftone pattern. 35

8. The method of reproducing a pattern of light and shadow comprising the steps of: 40

- (a) forming an electrostatic image of said pattern on a uniform first insulating surface,
- (b) positioning a second insulating surface of deformable plastic contiguous to said first insulating surface,
- (c) arranging electrodes behind each of said first and second insulating surfaces in a geometric halftone configuration to obtain a dielectric between said electrodes and across said first and second insulating surfaces that varies in said halftone pattern, 45
- (d) applying a potential to said electrodes sufficient to effect transfer of the latent electrostatic image to said second insulating surface in halftones correlated to said electrode configuration, and
- (e) softening said second insulating surface so that the deformable plastic deforms in accordance with the halftone electrostatic charge image. 50

9. The method of reproducing a pattern of light and shadow comprising the steps of:

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- (a) electrostatically charging a uniform surfaced xerographic plate,
 - (b) exposing said plate to a light image of the original to obtain a latent electrostatic image on the plate,
 - (c) positioning said plate against a deformable plastic layer backed by an electrically conductive material formed geometrically in a halftone pattern,
 - (d) applying a potential between said conductive material and the back of the xerographic plate sufficient to effect image transfer, and
 - (e) heat softening said deformable plastic layer so that it deforms in accordance with the original as modified by said halftone pattern.
10. The method of reproducing a pattern of light and shadow comprising the steps of:
- (a) positioning a xerographic plate having a uniform photoconductive surface on a conductive backing against a transfer member comprising a deformable dielectric surface layer and a conductive layer one of said layers having non-uniformities that vary in a halftone pattern,
 - (b) applying electrical potential between said conductive layer and said conductive backing,
 - (c) exposing said xerographic plate to a projected light and shadow pattern of the original while said potential is applied until charge transfer occurs in the light areas as modified by the non-uniformities in said transfer member, and
 - (d) softening said deformable dielectric surface layer to form a halftone reproduction of the original.

11. The method of forming a halftone deformation image in accordance with claim 10 in which said transfer member is transparent and said projected light and shadow pattern is projected through said transfer member. 35

12. The method of forming a halftone deformation image in accordance with claim 10 in which said conductive backing is transparent and said projected light and shadow pattern is projected through said conductive backing. 40

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NORMAN G. TORCHIN, *Primary Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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July 20, 1965

Harold E. Clark

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 72, column 6, lines 17, 32, 49, and 74, column 7, line 58, and column 8, line 16, before "steps", each occurrence, insert -- sequential --. Column 6, line 3, "contigously" should read -- contiguously --. Column 7, line 29, "image" should read -- surface --; line 57, after "reproducing" insert -- continuous tone --. Column 8, line 23, before "electrical" insert -- an --.

Signed and sealed this 10th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents