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(54) **Method of improving maximum density and tonal range of electrographic images and an electrographic copying apparatus using the method.**

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(56) References cited:
DE - A - 2 704 361
GB - A - 940 577
GB - A - 1 072 557
GB - A - 1 412 350
US - A - 3 335 003
US - A - 3 341 326
US - A - 3 627 526
US - A - 3 639 245
US - A - 3 681 071
US - A - 4 076 857
US - A - 4 083 632
US - A - 4 124 287

H. E. Clark, Xenography and related processes, The Focal Press London and New York (1965), pages 112-117

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Description

This invention relates to the production of electrographic images and particularly to an electrophotographic method for forming improved copies of originals which contain a wide range of image densities.

Electrographic copying methods commonly produce images having high contrast. These methods are very useful for producing good line copy reproductions. However, such methods have not been particularly useful in reproducing originals that contain a wide range of image densities or relatively large areas of uniform density. Frequently, adjunct means such as halftone screens are used to improve the reproduction of such images which are so difficult to reproduce. Halftone tint screens have opaque dots of uniform density.

Typical techniques for producing half-tone copies of continuous tone images or of large image areas of uniform density involve transforming the image into a plurality of dots or lines which can then be developed. When an electrophotographic element is charged uniformly, and then exposed to light through a halftone screen, discrete charge-bearing zones (dots, lines or other shapes) are formed on the surface of the element, which zones are separated by areas that bear little or no electrical charge relative to that of the discrete charge-bearing zones. Such discrete charge-bearing zones are referred to herein as "charge islands". Latent electrostatic images comprising charge islands can be created by initially charging the electrographic surface in a screen pattern, by masking the original image with a halftone screen during exposure, or by uniformly exposing a charged photoconductive surface through a halftone screen before, during or after image exposure, but before development. A typical method is disclosed in U.S. Patent 2 598 732.

One problem shared by prior art methods for electrographic copying is that the entire range of densities of the original cannot be produced faithfully. The range of densities of the original which can be faithfully reproduced is referred to hereinafter as the tonal range.

We have discovered an electrographic copying method for producing copies having increased maximum density and tonal range, which method comprises:

a) forming on a insulating layer, a latent electrostatic image of an original;

b) before, during or after the step (a) forming a plurality of charge islands in the image area of said insulating layer in addition to any charge islands that result from said step (a), and then

c) developing the resulting latent electrostatic image with a dry two-component developer composition comprising toner particles and carrier particles, which developer has a resistance of less than 10^9 ohms as measured by the test procedure described herein or obtains such a resistance during the development step as a result of the establishment of an electrical field across the developer greater than the electrical breakdown value thereof.

Copies produced according to the present invention have greater than expected maximum densities and greatly improved tonal ranges as compared with images produced by prior art electrograhic methods in which halftone screens are used. Continuous tone originals, as well as originals having alphanumeric line copy and relatively large areas of uniform density, are reproduced with greater fidelity to the original than has been obtainable with such prior art electrographic methods.

In a preferred embodiment, the method of the present invention can be used to produce continuous tone images, which method comprises:

a) forming a latent electrostatic image on a photoconductive layer of the continuous tone subject;

b) before, during or after the step (a) forming a plurality of charge islands in the image area of said insulating layer in addition to any charge islands that result from the said step a), and then

c) developing the resulting charge island latent image with a dry two-component developer composition comprising toner particles and carrier particles, which developer has a resistance of less than 10^9 ohms as measured by the test procedure described herein or obtains such a resistance during the development step as a result of the establishment of an electrical field across the developer greater than the electrical breakdown value thereof.

In another preferred embodiment of the present method the charge islands are produced on a photoconductive layer by exposure through a halftone screen which is an integral part of the photoconductive element. This embodiment of the invention offers several advantages including 1) registration problems are minimised, 2) simple continous exposure techniques can be used since the screen moves with the photoconductive layer, 3) a fixed space is maintained between the screen pattern and the photoconductive layer and 4) high frequency screen patterns may be used without significant resolution loss.

This invention also provides electrographic copying apparatus comprising (a) means for forming on an insulating layer a latent electrostatic image of an original; (b) means for forming a plurality of charge islands in the image area of the said insulating layer in addition to any charge islands that result from use of the means (a); and (c) means for developing the latent image resulting from use of the means (a) and (b) with a dry two-component developer composition comprising toner particles and carrier particles, which developer has a resistance of less than 10^9 ohms as measured by the test procedure described herein or obtains such a resistance by electrical breakdown during development.

Description of the Drawings

Fig. 1 is a photomicrograph of an electrostatic image developed with a non-conductive liquid developer.

Fig. 2 is a photomicrograph of an electrostatic image produced according to the method of the present invention.

Fig. 3 is a drawing of a photoconductive element having a photoconductive layer and an integral halftone screen.

Figs. 4 and 5 are graphic representations of the results of the following Examples 1 and 2.

Fig. 6 is a drawing of an apparatus used in a preferred development method of the invention.

Fig. 7 is a schematic drawing of image forming stations in an electrographic apparatus or duplicator adapted to carry out the method of the present invention.

The unexpected nature of the present invention can be pointed out with reference to Figs. 1 and 2. These Figures show the results of developing charge islands with two kinds of developer; a non-conductive developer having been used in the case of Fig. 1 and a conductive developer, as required for the method of this invention, having been used for Fig. 2. In Fig. 1, the developed charge islands are discrete and faithfully retain the size and shape of the transparent areas of the halftone screen. In Fig. 2, however, the developed charge islands do not retain the dimensions of the transparent areas of the halftone screen. The developed charge islands of Fig. 2 appear to have expanded, making the open spaces between the islands smaller. This surprising expansion causes the maximum density of the image to be increased. The maximum density obtained using the method of the present invention is more than three times the predicted density. This effect, referred to herein as dot enlargement, is entirely unexpected. The improvement of the tonal range of images reproduced by the method of this invention is one result of dot enlargement.

The present invention is broadly applicable to any electrographic method for reproducing an image which method provides a modulated latent electrostatic image, e.g., a latent electrostatic image having a range of charge intensities.

In Fig. 3, the photoconductive element 11 contains a transparent support 12. The support provides mechanical strength to the element and makes it suitable for use in electrophotographic copying machines.

The support can be fabricated of almost any transparent material, and may be selected from such diverse materials as glass and plastics of various types. The support can be rigid as in the case of a plate or cylinder of glass or polymethylmethacrylate, or it can be flexible as with the case of a plastic such as polyethylene or polyethylene terephthalate. Although a transparent support is shown in Fig. 3, other types of supports can be used, especially in the circumstances where the photoconductive layer is to be exposed other than through the support.

Immediately adjacent to the support 12 is a halftone screen 13 made up of a number of finely divided, alternating, opaque and transparent areas. This screen is used to form charge islands on the photoconductive layer. The screen pattern of opaque and transparent areas can be a conventional dot pattern or line pattern of the type used for the fabrication of halftone plates for newspaper printing. The alternating opaque and transparent areas of the screen pattern may be of almost any shape, including round dots, elliptical dots and lines. The spacings of the pattern can also vary so that the pattern is regular, irregular, or random. The pattern can also be varied in size from dot-todot or line-to-line. Since the screen is utilized only for forming charge islands, it can be either electrically conducting or insulating. To minimize moiré patterns when copying images that already contain conventionally oriented 45° black and white halftone patterns, the halftone screen should be oriented such that after exposure through the screen, the resultant halftone pattern is at an angle of from 30° to 10° to any halftone pattern that may be present in the original which is to be copied.

When the halftone screen is used, it can be located in the film base as disclosed in U.S. Patents 3 310 401 and 3 335 003. It can be integral with the conductive layer as disclosed in Canadian Patent 577 137. It can be in the barrier layer as disclosed in U.S. Patent 3 341 326. It can be present as an overcoat layer over the photoconductive layer as disclosed in U.S. Patent 3 627 526 and it can be integral with the photoconductive layer as disclosed in U.S. Patent 3 681 071. Methods for producing electrophotographic images using halftone screens are well known. Such methods are disclosed in the aforementioned patents. The halftone screens can have almost any frequency. Particularly useful results are obtained with halftone screens having a frequency of 32 to 80 dots/cm and a percent tint i.e. percent opaque areas of 10 to 90%.

A halftone screen is not the only means for forming charge islands on the electrophotographic element. Other means can also be used for this purpose. For example charge islands can be formed by corona charge or discharge through a screen such as a grid-controlled screen or insulator screen, or by a pulsed corona charge through a longitudinal screen. They can also be formed using a patterned array of pulsed styli or wires, by discharging the photoconductive layer with a textured conducting roller, or by discharging in a voltage contrast pattern in a layer beneath the photoconductive layer.

Latent electrostatic images composed of charge islands according to the present invention can also be formed with a single exposure by using a scanning type exposure device such as a computer addressed light emitting diode array, cathode ray tube or laser. The continuous tone image can be momentarily or permanently stored in binary form in a computer memory. When it is desired to reproduce the continuous tone image, the proper output transducer circuits between the computer's memory and the exposure means are engaged. The computer's logic controls the transducer circuits in a way to cause the cathode ray tube, laser or light emitting diode array to modulate and/or pulse on and off according to the tonal range of the continuous tone image, while scanning and thus exposing a photoconductive layer. This exposure of the photoconductive layer results in a latent electrostatic image comprising charge islands of varying charge levels. Method and means for accomplishing a latent image comprising charge islands of varying charge intensity with scanning devices are disclosed in U.S. Patent 3 864 697 (laser); U.S. Patent 4 025 189 (light emitting diode array); and U.S. Patent 3 681 777 (cathode ray tube).

Immediately adjacent to the halftone screen 13 of Fig. 3 is a very thin transparent conductive layer 14 which can be composed of tin oxide, nickel, cermet, or copper iodide. Methods for forming such conductive layers are well known.

Optionally an electrical or chemical barrier layer can be used in combination with the conducting layer 14 and the halftone screen 13.

The photoconductive layer 16 can be any of the photoconductive insulating layers generally used in electrophotography, and can include layers of vitreous selenium, aggregate photoconductive layers of the type disclosed in U.S. Patent 3 615 414 or any one of many other organic photoconductive layers including multilayer photoconductive elements having separate charge generating and charge transport functions.

In one mode of operation, the photoconductive element is first charged in darkness so that the photoconductive layer is sensitized with a generally uniform electrostatic field.

During the image exposure step, photoconductive layer 16 of the element is exposed to an original containing a continuous tone image by projector means 17 thereby forming on said layer 16, a latent electrostatic image of the original. Formation of the plurality of charge islands within the latent electrostatic image is effected in this mode by a second uniform exposure of the photoconductive layer 16 through the rear of the element, and thus through the halftone screen 13. The rear exposure is carried out prior to, simultaneously with, or after exposure of the photoconductive layer to the image, the only requirement being that this rear exposure be carried out after the charging step and prior to the development step. This uniform exposure step is illustrated by arrows 18 in Fig. 3.

The uniform rear exposure of the charged photoconductive layer through screen 13 serves to discharge at least partially all areas of the photoconductive layer 16 directly opposite transparent areas of the screen. This exposure thus forms a plurality of charge islands on photoconductive layer 16. The amount of exposure used to form these charge islands will vary according to a variety of factors, including the nature of the photoconductive layer, type of developer, and mode of development.

The number and size of the charge islands is governed by the frequency and percent tint of the halftone screen used. Assuming image exposure after rear exposure through the screen, the charge islands opposite white areas of the original image being copied are substantially completely discharged by the exposure to the original. Charge islands opposite grays in the original are partially discharged. And charge islands opposite blacks in the original retain their original charge level.

If rear exposure is made after charging but prior to front exposure to an original, the charge islands are formed first and then modulated by the exposure to the original. If both front and rear exposures are made simultaneously, modulated charge islands are formed in a single step. If the image exposure is made prior to the rear exposure, the level of charge across the whole element is first modulated according to the light received from the image exposure to the subject. The resulting latent electrostatic image is then divided into charge islands by the subsequent rear exposure through the halftone screen. Regardless of which sequence is employed, the resulting charge pattern on the element is modulated by the uniform exposure through a halftone screen.

A photoconductive surface was used in the above described method. However, such charge islands could be formed by other means on a dielectric surface. Information about the original could be received from a computer or other data source and recorded by computer-addressed styli on a dielectric surface.

After formation of a latent electrostatic image which comprises a plurality of charge islands, the charge island image is contacted with a developer which is conductive either intrinsically or as a result of electrical breakdown. The resistance of an intrinsically conductive developer should be less than 10^9 ohms (Ω), preferably less than 10^6 ohms, when measured as described below.

Resistance is measured using a General Radio DC electrometer type 1230-A, 6–9 Volts, or comparable equipment, in accordance with the following procedure. For each measurement, a 15 gram quantity of developer material was used. A cylindrical bar magnet (560 Gauss North Pole) having a circular end of about 6.25 sq.cm. was used to attract the developer and hold it in the form of a brush. After formation of the brush, the bar magnet was positioned with the brush carrying end approximately parallel to and about 0.5 cm. from a burnished copper plate. The resistance of the particles in the magnetic brush was then measured between the magnet and the copper plate at 21°C and 40% relative humidity.

Typical conductive developers comprise a toner and a carrier and are non-liquid. The carrier may be conductive. Or a conductive additive may be present to improve the conductivity of the developer. Typical conductive developers include carriers such as iron, cobaltic oxide, stannic oxide, zinc and ferromagnesium, cupric carbonate, zinc carbonate, manganese carbonate, cupric oxide, lead acetate, zirconium, and nickel carbonate.

Many dry developers having a resistance higher than $10^9\Omega$ can be made conductive during the development step so that they can be used in the method of this invention. It is known that under controlled conditions, certain developer materials will undergo a phenomenon described as electrical breakdown. This phenomenon is described in U.S. Patent 4 076 857.

This electrical breakdown phenomenon exhibited by developers manifests itself when the resistance of the developer material is measured as a function of the electrical field across the developer. The resistance is conveniently measured by 1) placing a metal electrode in the plane of the photoconductive element above an operating magnetic brush, 2) applying a known potential to the electrode, and 3) measuring the current passing through the magnetic brush. Resistance is calculated by dividing the voltage by the current. At a certain level of the applied field, called the electrical breakdown value, for a small increase in field there is a large drop in the resistance of the developer material. The developer then acts as though it has a higher conductivity.

Development by using the electrical breakdown phenomenon can be carried out by a) contacting a latent electrostatic image with a developer composition and b) establishing across such developer an electrical field greater than the electrical breakdown value of the developer, thereby causing the developer to undergo electrical breakdown.

Development by the electrical breakdown mode can be influenced by a number of factors such as: the composition of the carrier particles; the concentration of toner particles in the developer; the strength of the electric field between the surface bearing the electrostatic charge pattern and the electrode; the thickness of the developer (i.e., the distance between the surface bearing the electrostatic charge pattern and the electrode); initial photoconductor charge or charge on the support; voltage on the electrode and the choice of photoconductor thickness to govern the surface potential per unit charge. Development is accomplished by selecting one or more of the aforementioned factors such that the electric field which forms across the developer during development is greater than the electrical breakdown value of the developer under the conditions of development.

Preferred developers are those which have relatively low electrical breakdown values. Less than 25 volts/mm is typical. Also, in order to prevent discharging of the latent electrostatic image, preferred developers are those which exhibit relatively high resistivity prior to electrical breakdown, i.e., when subjected to a low strength electrical field. A low field resistivity of at least 10^5 ohm-cm is preferred. By the term "low field resistivity" and "measured under low fields" as used herein, we mean resistance measurements made in accordance with the procedure previously described.

If desired, the latent image can be transferred to another support before it is developed. The transfer can be made before or after the latent image is made into a charge island image. In general, any of the methods for electrostatic image transfer described in the prior art can be used. If the latent electrostatic image is transferred before the charge islands are formed, the charge islands can be formed on an insulated receiving element before, during or after the transfer. Development is carried out on the transferred latent charge island image in the same manner as described for development on photoconductive layers.

Development with conductive developers or via the electrical breakdown mode can be carried out using any of the conventional electrographic developing means, including cascade and magnetic brush technique.

A particularly useful magnetic brush technique comprises 1) moving a member bearing an electrostatic image past a development zone and 2) transporting such developer a) through a first development zone in a direction generally countercurrent to the moving member and b) through a second development zone in the same direction as the moving member.

One structural embodiment for practice of this development procedure is disclosed in Fig. 6. The development apparatus 30 comprises two magnetic brushes 31, 32 mounted at a development station along the path of an electrographic member 33. The electrographic member can be a photoconductive insulating layer 34, an electrically conductive backing layer 35 and a film support 36. Each of the magnetic brushes 31, 32 comprises an array of strip magnets, denoted N and S, arranged as shown around the periphery of inner cores 38 and 39, which are stationary within developer reservoir 40. Each brush also includes an electrically conductive outer cylinder 41 and 42 respectively, which is non-magnetic and rotatable around the core to transport developer mixture, attracted by the magnets N and S, from the reservoir 40 into contact with the image member 33 and back into the reservoir to be replenished. To facilitate uniform distribution of developer longitudinally across the brush surface, augers 48, 49 can be provided in the reservoir as shown. Preferably, the augers have a pitch which varies longitudinally to equalize the quantity of developer supplied. It is to be noted that the cylinders 41 and 42 of brushes 31 and 32 are rotated in different directions, as indicated, by drive means 43, 44 respectively, and that each cylinder has a separate electrical voltage from respective potential sources Vb_1 and Vb_2.

In operation the image member 33 is moved as shown across the development apparatus as the magnetic brushes 31 and 32 are rotated in the directions described and shown.

Any electrographic apparatus which includes an image recording member having an image recording area and means for forming an electrostatic image on said area can be adapted to perform the method of the present invention. Such apparatus can be modified to include means for forming, in the image recording areas of the image recording member, a plurality of charge islands and development means which includes a supply of conductive developer for applying the developer to the resulting electrostatic image. Image-forming stations of a representative electrographic apparatus are presented schematically in Fig. 7. The electrographic apparatus, as presented, comprises a photoconductive image recording element 70 which includes the halftone screen described in Fig. 3. The apparatus also includes charging means 71, imaging exposure means 72, and means 73 for uniformly exposing the imaging area of the photoconductive layer through the halftone screen. The uniform exposure through the halftone screen can be made before, during or after formation of an electrostatic image or an original. Finally, the figure shows development means 74 which includes a conductive composition as required by the present invention.

The method of the present invention can be used to form both monochrome and polychrome copies. Suitable colorants can be incorporated into toners according to known methods.

The invention is illustrated by the following examples.

Example 1

A transparent aggregate photoconductive element of the type described in Example 1 of U.S. Patent 3 615 414 was charged and exposed to a step tablet having neutral density areas of 0.09, 0.41 and 1.05.

The element was given a second uniform exposure from the front side through a halftone screen having a frequency of 60 dots/cm, and a percent tint of 50 percent of its area. The resulting latent charge island image was then developed with a magnetic brush and a developer composition like that of Example 7 herein having a resistance of $1.5 \times 10^6 \Omega$ measured as described hereinbefore.

The reflection densities of the developed image of the step tablet were compared graphically with the densities one would ordinarily expect from the use of a 50 percent tint halftone screen. The expected densities were calculated assuming that the dots on each step of the step tablet were faithfully reproduced as in Fig. 1. The calculation was carried out in the following manner.

The density (D) of a particular image area is given by the formula

$$D = \log \frac{1}{R}$$

R represents reflectance. To a first approximation, reflectances are additive when viewed at a normal viewing distance. Hence, the total reflectance (R_t) of an area of several densities is given by

$$R_t = X_1R_1 + X_2R_2 + X_3R_3 - - + X_nR_n$$

in which X_n is the fraction of the total area covered by reflectance R_n.

It is assumed that the developed density on a given dot for a specific voltage is the same as the developed density would be for that same voltage in a large solid area. The solid area output density (copy) as a function of input density (original) can be experimentally determined. Hence, the expected output density for a halftone screen having a known percent dot area, can be calculated. For example:

Din (density input) of 1.0, for large solid areas results experimentally in Dout (density output) of 1.4 on a paper base of 0.1 density. Then for a halftone screen of 50 percent tint X = 0.5 and

$$D = \log \frac{1}{R} \text{ or}$$

$$R_1 = \frac{1}{\log^{-1} (D_1)}; \quad R_2 = \frac{1}{\log^{-1} (D_2)}$$

D_1 represents the density of the solid area. D_2 represents the density of the paper base.

$$R_1 = \frac{1}{\log^{-1} (1.4)} = 0.0398$$

$$R_2 = \frac{1}{\log^{-1} (0.1)} = 0.7943$$

Therefore the total expected density (D_t) is

$$D_t = \log \left[\frac{1}{X_1R_1 + X_2R_2} \right]$$

$$= \log \left[\frac{1}{0.5(0.0398) + 0.5(0.7943)} \right]$$

The calculation is then repeated for different Dout levels, as found by developing in the absence of a halftone screen.

The graphic comparison of the actual reflection densities and the expected densities is shown in Fig. 4. The graph of Fig. 4 shows that the expected output Dmax (0.38) is about ⅓ of the actual output Dmax (1.2). The tonal range of this example is also greater than that expected. More steps of the step tablet were faithfully reproduced than expected.

Example 2

To further illustrate the unexpected improvement in maximum density and tonal range obtained in Example 1, prints were made as in Example 1 with two different developers: a dry partially conductive developer, with a resistance of a $1.5 \times 10^6 \Omega$ (a developer like that of Example 7 herein) and a dry developer with a resistance of $4.4 \times 10^9 \Omega$.

In Fig. 5, the input density versus output density of each developed image is shown. Dmax for the image developed with the more conducting developer is much higher than Dmax for the image developed with the more resistant developer. Also, the total range of the former is much greater than that of the latter.

Example 3

Five halftone screens having a frequency of 33.5 dots/cm and tints of 67%, 52%, 42%, 40% and 30% respectively were prepared from 20 cm × 25 cm sheets of "Kodalith" Film available from Eastman Kodak Company ("Kodalith" is a trademark). Each of these screens were cemented to a transparent base photoconductor film to form five separate elements. The photoconductive layer was of the type disclosed in Example 1 of U.S. Patent 3 615 414.

Each element was imagewise exposed substantially as in Example 1 except that the uniform screen exposure was through the halftone screen from the rear of the film. A reflection original document was used as a test with areas having neutral densities of 0.09, 0.41, 0.75 and 1.05 respectively. The prints were developed as in Example 1 with a conductive developer having a resistance of $1.5 \times 10^6 \Omega$. Density measurements were made and plotted as in Example 2.

Observations

The prints showed smooth, uniform, neutral tones with very little mottle and edge defects. The graphs describing density input vs. density output showed high Dmax, lowered image contrast and extended tonal range as in Example 1.

Example 4–8

These examples were designed to illustrate the effect of developer resistance on the density of copies.

The developers used in Examples 4–8 contained toner particles comprising carbon black in a styrene-acrylate polymeric matrix and magnetic carrier particles coated with a vinylidene fluoride-fluoro-ethylene-copolymer. Various carrier particle cores were used (see list below) to produce developers exhibiting a range of resistances that were measured as previously described.

Example	Carrier Core
4	stainless steel
5, 6, 7	EH Oxidized Iron (sold by Hoeganaes Co.). Carrier cores for Examples 5, 6 and 7 were oxidized, as described in U.S. Patent 3 767 477, to three different levels of oxidation in order to vary the conductivity of the developer.
8	nickel plated EH Iron (Hoeganaes Co.).

In these examples an integral screen photoconductive element was prepared containing, in the following order:

a transparent film support of poly(ethylene terephthalate), a magenta halftone screen of 60 dots/cm, 50% tint, printed by offset lithography onto the film support, an evaporated nickel conducting layer, and an aggregate photoconductive layer of the type described in Example 1 of U.S. Patent 3 615 414.

Copies were made as in Example 3 with a reflection original document having neutral density area (referred to as input density or Din) as indicated in Table 1.

The results were consistent with those obtained in previous examples. Output densities (copy) vs. input densities (original) are reported in Table 1 for each developer at a different conductivity. Expected densities were calculated as in Example 1. These Examples show that developers having a resistance of about $10^9 \Omega$ or less produce higher Dmax than expected.

To illustrate the dot enlargement effect of the invention, photomicrographs were taken of output density (Dout) neutral areas corresponding to Din values: 1.58; 0.78; 0.40 and 0.21 of the print made in Example 8. The dot enlargement effect was observed as increased toner fill-in between the halftone dots at a given Din as developer resistance decreased. For comparison, a photomicrograph Figure 1 was taken of a halftone tone dot pattern on a photoconductive layer which had been developed with a non-conductive, liquid developer. The Figure 1 photomicrograph corresponds to an area having a Din value of 1.58 and shows no dot enlargement. Figure 2 is a representative photomicrograph of the dot enlargement effect achieved in Example 8.

Table I

Dout

Step of Neutral Density Wedge	Din	Ex. 4 $>10^{10} \Omega$	Ex. 5 $1.4 \times 10^9 \Omega$	Ex. 6 $1.4 \times 10^8 \Omega$	Ex. 7 $1.8 \times 10^7 \Omega$	Ex. 8 $1.2 \times 10^6 \Omega$	Expected
1	1.58	0.22	0.60	0.69	0.95	1.32	0.38
2	1.12	0.20	0.53	0.60	0.88	1.26	0.38
3	0.87	0.19	0.44	0.52	0.75	1.20	0.37
4	0.78	0.17	0.42	0.49	0.65	1.08	0.37
5	0.53	0.13	0.30	0.36	0.38	0.60	0.36
6	0.40	0.11	0.20	0.25	0.24	0.34	0.32

Table I (continuation)
Dout

Step of Neutral Density Wedge	Din	Ex. 4 >$10^{10}\Omega$	Ex. 5 $1.4 \times 10^9\Omega$	Ex. 6 $1.4 \times 10^8\Omega$	Ex. 7 $1.8 \times 10^7\Omega$	Ex. 8 $1.2 \times 10^6\Omega$	Expected
7	0.30	0.10	0.13	0.16	0.19	0.19	0.19
8	0.21	0.08	0.08	0.08	0.10	0.08	0.10
9	0.14	0.07	0.06	0.06	0.07	0.05	0.10
10	0.09	0.06	0.06	0.06	0.06	0.05	0.10

Example 9

This example illustrates the use of a developer that is made conductive by the breakdown development mode. The developer was similar to the developer described in Example 8 with the exception that the mean particles size of the toner was smaller (6.8 millimicrons). The toner concentration was 3.1%.

An integral screen photoconductive element was used similar to the element described in Examples 4–8 with the exception that the halftone screen had a frequency of 52 dots/cm. and a 40% tint.

The developer was run in a two-roller magnetic brush development station for 1 hour to allow the developer to come to equilibrium.

In operation, the photoconductive element was charged to −500 volts, exposed such that the film voltage corresponding to a 0.15 neutral density grey scale step was −150 volts, uniformly rear exposed through the screen and developed in a breakdown development mode in a two roller magnetic brush development device with 7.6 cm diameter rollers operating at brush speeds of 160 and 180 RPM. The film velocity was 25 cm/second and the magnetic brush spacing from the film surface was 1.9 milli-metres with a development brush bias of −140 volts. The breakdown value for this developer, as measured according to the procedure described hereinbefore was 13.6 volts per millimeter.

The resultant copies exhibited high Dmax, smoothness and extended tonal scale.

The present invention is also useful in forming reversal images. Image tone reversal can be obtained by developing the discharge areas of the images (instead of the charge islands) using a highly biased magnetic brush, and then developing with a toner having the same polarity as the brush bias.

Claims

1. An electrographic copying method which comprises:

a) forming on an insulating layer a latent electrostatic image of an original,

b) before, during or after the step (a) forming a plurality of charge islands in the image area of the said insulating layer in addition to any charge islands that result from the said step (a) and then

c) developing the resultant latent electrostatic image with a dry two-component developer composition comprising toner particles and carrier particles, which developer has a resistance of less than 10^9 ohms as measured by the test procedure described herein or obtains such a resistance during the development step as a result of the establishment of an electrical field across the developer greater than the electrical breakdown value thereof.

2. A method according to claim 1 wherein the developer obtains a resistance of less than 10^9 ohms during the development step as a result of the establishment of an electrical field across the developer greater than the electrical breakdown value thereof.

3. A method according to claim 2 wherein the developer composition has a breakdown value less than 25 volts per millimetre.

4. A method according to claim 1 wherein development is effected with a magnetic brush.

5. A method according to any of the preceding claims wherein the step (a) comprises imagewise exposure of a photoconductive layer.

6. A method according to claim 5 wherein the step (b) comprises exposing the photoconductive layer uniformly through a halftone screen.

7. A method according to claim 6 wherein the halftone screen has a frequency of 32 to 80 dots per centimetre and a tint of from 10 to 90%.

8. A method according to claims 6 or 7 wherein the halftone screen is part of a photoconductive element comprising the photoconductive layer.

9. A method according to claim 8 wherein the halftone screen is disposed between a transparent support for the element and the photoconductive layer, said layer being exposed imagewise from the front and through the halftone screen from the rear.

10. A method according to any of claims 1 to 7 wherein the insulating layer is part of an image receiving element.

11. A method according to any of claims 1 to 5 wherein the insulating layer is part of an image receiving element and the latent image formed in step (a) is transferred to the insulating layer before steps (b) and (c) are carried out.

12. A method according to any of claims 1 to 4 wherein the steps (a) and (b) are simultaneously effected by exposing a photoconductive layer to a computer addressed scanning exposure device.

13. Electrographic copying apparatus comprising a) means for forming on an insulating layer a latent electrostatic image of an original; b) means for forming a plurality of charge islands in the im-

age area of the said insulating layer in addition to any charge islands that result from use of the means (a); and c) means for developing the latent image resulting from use of the means (a) and (b) with a dry two-component developer composition comprising toner particles and carrier particles, which developer has a resistance of less than 10^9 ohms as measured by the test procedure described herein or obtains such a resistance by electrical breakdown during development.

14. Electrographic copying apparatus according to claim 13 wherein the insulating layer is a transparent photoconductive layer and the means (a) comprises means for uniformly charging a front surface of the said layer, and means for exposing that surface, when so charged, from the front imagewise to actinic radiation; and the means (b) comprises a halftone screen at the rear of the photoconductive layer and means for exposing that layer overall to actinic radiation through this halftone screen.

15. Electrographic copying apparatus according to claim 13 wherein the means (a) and (b) comprise a computer-addressed scanning exposure device.

Patentansprüche

1. Elektrographisches Kopierverfahren, bei dem man:

a) auf einer isolierenden Schicht ein latentes elektrostatisches Bild eines Originals erzeugt,

b) vor, während oder nach Schritt a) zusätzlich zu während des Schrittes a) entstandenen Ladungsinseln im Bildbereich der isolierenden Schicht eine Anzahl von Ladungsinseln erzeugt und dann

c) das erhaltene latente elektrostatische Bild mit einem trockenen Zwei-Komponenten-Entwickler mit Toner- und Trägerteilchen entwickelt, wobei der Entwickler einen Widerstand von weniger als 10^9 Ohm, gemessen mit dem in der Beschreibung beschriebenen Testverfahren aufweist oder einen solchen Widerstand während des Entwicklungsschrittes als Folge des Anlegens eines elektrischen Feldes an den Entwickler, das stärker als der elektrische Durchbruchswert desselben ist, erreicht.

2. Verfahren nach Anspruch 1, bei dem der Entwickler einen Widerstand von weniger als 10^9 Ohm während des Entwicklungsschrittes als Folge des Anlegens eines elektrischen Feldes an den Entwickler, das stärker als der elektrische Durchbruchswert desselben ist, erreicht.

3. Verfahren nach Anspruch 2, bei dem der Entwickler einen Durchbruchswert von weniger als 25 V/mm aufweist.

4. Verfahren nach Anspruch 1, bei dem die Entwicklung mit einer Magnetbürste durchgeführt wird.

5. Verfahren nach einem der vorhergehenden Ansprüche, bei dem Schritt (a) die bildmässige Belichtung einer photoleitfähigen Schicht umfasst.

6. Verfahren nach Anspruch 5, bei dem Schritt (b) die gleichförmige Belichtung der photoleitfähigen Schicht durch ein Raster hindurch umfasst.

7. Verfahren nach Anspruch 6, bei dem das Raster eine Frequenz von 32 bis 80 Punkten/cm und einen Tonwert zwischen 10 und 90% aufweist.

8. Verfahren nach Anspruch 6 oder 7, bei dem das Raster Teil eines photoleitfähigen Elements ist, welches die photoleitfähige Schicht aufweist.

9. Verfahren nach Anspruch 8, bei dem das Raster zwischen einem transparenten Träger für das Element und der photoleitfähigen Schicht angeordnet ist, wobei die Schicht bildmässig von der Vorderseite und durch das Raster hindurch von der Rückseite her belichtet wird.

10. Verfahren nach einem der Ansprüche 1 bis 7, bei dem die isolierende Schicht Teil eines Bildempfangselements ist.

11. Verfahren nach einem der Ansprüche 1 bis 5, bei dem die isolierende Schicht Teil eines Bildempfangselements ist und das in Schritt (a) erzeugte latente Bild auf die isolierende Schicht übertragen wird, bevor die Schritte (b) und (c) ausgeführt werden.

12. Verfahren nach einem der Ansprüche 1 bis 4, bei dem die Schritte (a) und (b) gleichzeitig ausgeführt werden, indem eine photoleitfähige Schicht einer computergesteuerten Vorrichtung zum fortschreitenden zeilenweisen Belichten ausgesetzt wird.

13. Elektrographisches Kopiergerät mit a) Mitteln zur Erzeugung eines latenten elektrostatischen Bildes eines Originals auf einer isolierenden Schicht; b) Mitteln zur Erzeugung einer Anzahl von Ladungsinseln im Bildbereich der isolierenden Schicht, zusätzlich zu den aufgrund der Verwendung der Mittel (a) entstandenen Ladungsinseln; und c) Mitteln zum Entwickeln des aufgrund der Verwendung der Mittel a) und b) entstandenen latenten Bildes mit einem trockenen Zwei-Komponenten-Entwickler mit Tonerteilchen und Trägerteilchen, wobei der Entwickler einen Widerstand von weniger als 10^9 Ohm, gemessen mit dem in der Beschreibung beschriebenen Testverfahren, aufweist oder einen solchen Widerstand durch elektrischen Durchbruch während der Entwicklung erreicht.

14. Elektrographisches Kopiergerät nach Anspruch 13, in dem die isolierende Schicht eine transparente photoleitfähige Schicht ist, die Mittel (a) zum gleichförmigen Aufladen einer vorderen Fläche dieser Schicht aufweisen sowie Mittel, die dazu dienen, die geladene Fläche von vorne bildmässig mit aktinischer Strahlung zu bestrahlen und die Mittel (b) ein Raster auf der Rückseite der photoleitfähigen Schicht aufweisen sowie Mittel, mit denen die gesamte Schicht durch das Raster hindurch mit aktinischer Strahlung bestrahlt wird.

15. Elektrographisches Kopiergerät nach Anspruch 13, dadurch gekennzeichnet, dass die Mittel (a) und (b) eine computergesteuerte Vorrichtung zum fortschreitenden zeilenweisen Belichten aufweisen.

Revendications

1. Procédé de reproduction électrographique qui comprend

a) la formation, sur une couche isolante, d'une image électrostatique latente d'un original,

b) avant, pendant ou après la phase (a), la formation d'une pluralité d'îlots de charge dans la plage d'image de ladite couche isolante, qui s'ajoutent aux îlots de charge dus à la mise en œuvre de la phase (a) et,

c) le développement de l'image électrostatique latente obtenue par une composition de révélateur sec, à deux composants comprenant des particules de véhicules et des particules de pigments, lequel révélateur présente une résistance inférieure à 10^9 ohms, mesurée par le procédé indiqué dans la description, ou qui acquiert cette résistance pendant le développement par suite de l'établissement à travers le révélateur d'un champ électrique supérieur au seuil de claquage électrique du révélateur.

2. Procédé conforme à la revendication 1, dans lequel le révélateur acquiert une résistance inférieure à 10^9 ohms pendant le développement par suite de l'établissement, à travers le révélateur, d'un champ électrique supérieur au seuil de claquage électrique du révélateur.

3. Procédé conforme à la revendication 2, dans lequel la composition révélatrice a un seuil de claquage inférieur à 25 V/mm.

4. Procédé conforme à la revendication 1, dans lequel le développement s'effectue à l'aide d'une brosse magnétique.

5. Procédé conforme à l'une quelconque des revendications précédentes, dans lequel, pendant la phase (a), on expose suivant une image une couche photoconductrice.

6. Procédé conforme à la revendication 5, dans lequel, pendant la phase (b), on expose uniformément la couche photoconductrice à travers un écran tramé.

7. Procédé conforme à la revendication 6, dans lequel l'écran tramé présente une linéature de 32 à 80 points par centimètre et un pourcentage de points tramés de 10 à 90%.

8. Procédé conforme aux revendications 6 ou 7, dans lequel l'écran tramé fait partie d'un produit photoconducteur qui comprend la couche photoconductrice.

9. Procédé conforme à la revendication 8, dans lequel l'écran tramé est placé entre un support transparent du produit et la couche photoconductrice, cette couche étant exposée suivant une image par sa face frontale et à travers l'écran tramé par sa face dorsale.

10. Procédé conforme à l'une quelconque des revendications 1 à 7, dans lequel sa couche isolante fait partie d'un produit récepteur d'image.

11. Procédé conforme à l'une quelconque des revendications 1 à 5, dans lequel la couche isolante fait partie d'un produit récepteur d'image et l'image latente formée pendant la phase (a) est transférée sur la couche isolante avant la mise en œuvre des phases (b) et (c).

12. Procédé conforme à l'une quelconque des revendications 1 à 4, dans lequel on effectue simultanément les phases (a) et (b) par exposition d'une couche photoconductrice à un dispositif d'exposition à balayage adressé par ordinateur.

13. Appareil de reproduction électrographique comprenant

a) un dispositif pour former, sur une couche isolante, une image électrostatique latente d'un original;

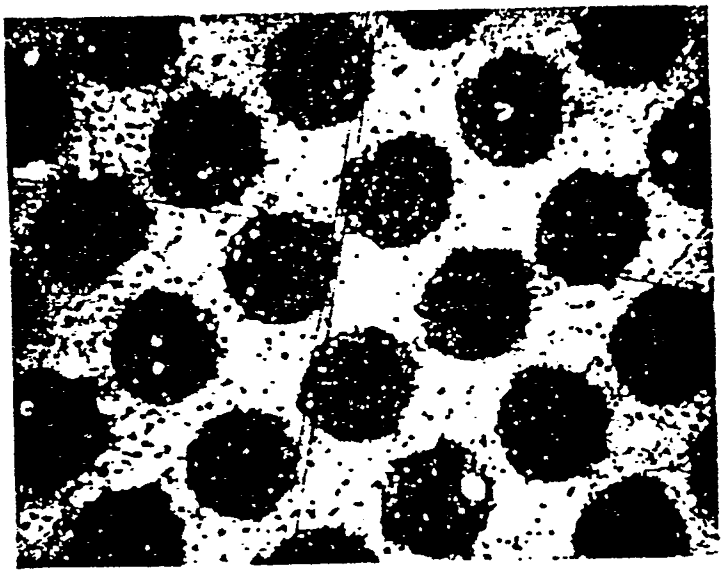
b) un dispositif pour former une pluralité d'îlots de charge dans la plage d'image de ladite couche isolante, qui s'ajoutent aux îlots de charge formés à l'aide du dispositif (a); et

c) un dispositif pour développer l'image latente, obtenue par utilisation des dispositifs (a) et (b), avec une composition révélatrice sèche à deux composants, comprenant des particules de véhicules et des particules de pigments, laquelle composition révélatrice présente une résistance inférieure à 10^9 ohms, mesurée par le procédé indiqué dans la description, ou qui acquiert cette résistance par claquage électrique pendant le développement.

14. Appareil de reproduction électrographique, conforme à la revendication 13, dans lequel la couche isolante est une couche photoconductrice transparente et le dispositif (a) comprend des moyens pour charger uniformément la face frontale de la couche et des moyens pour exposer suivant une image à un rayonnement activateur cette face ainsi chargée, par cette face frontale, et le dispositif (b) comprend un écran tramé placé du côté de la face dorsale de la couche photoconductrice et des moyens pour exposer toute cette couche à un rayonnement activateur à travers cet écran tramé.

15. Appareil de reproduction électrographique conforme à la revendication 13, dans lequel les dispositifs (a) et (b) comprennent un système d'exposition à balayage adressé par ordinateur.

FIG. 1



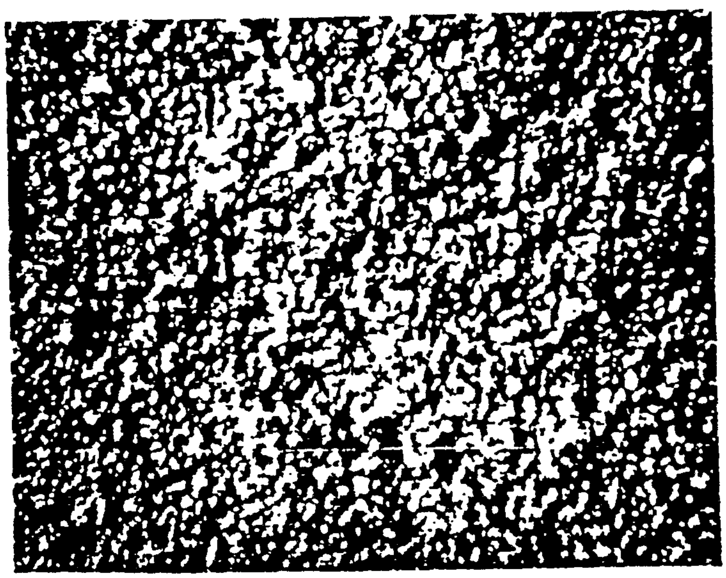
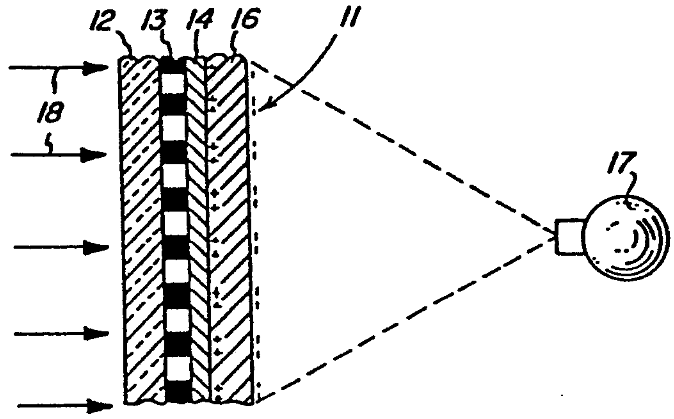


FIG. 2

FIG. 3


12
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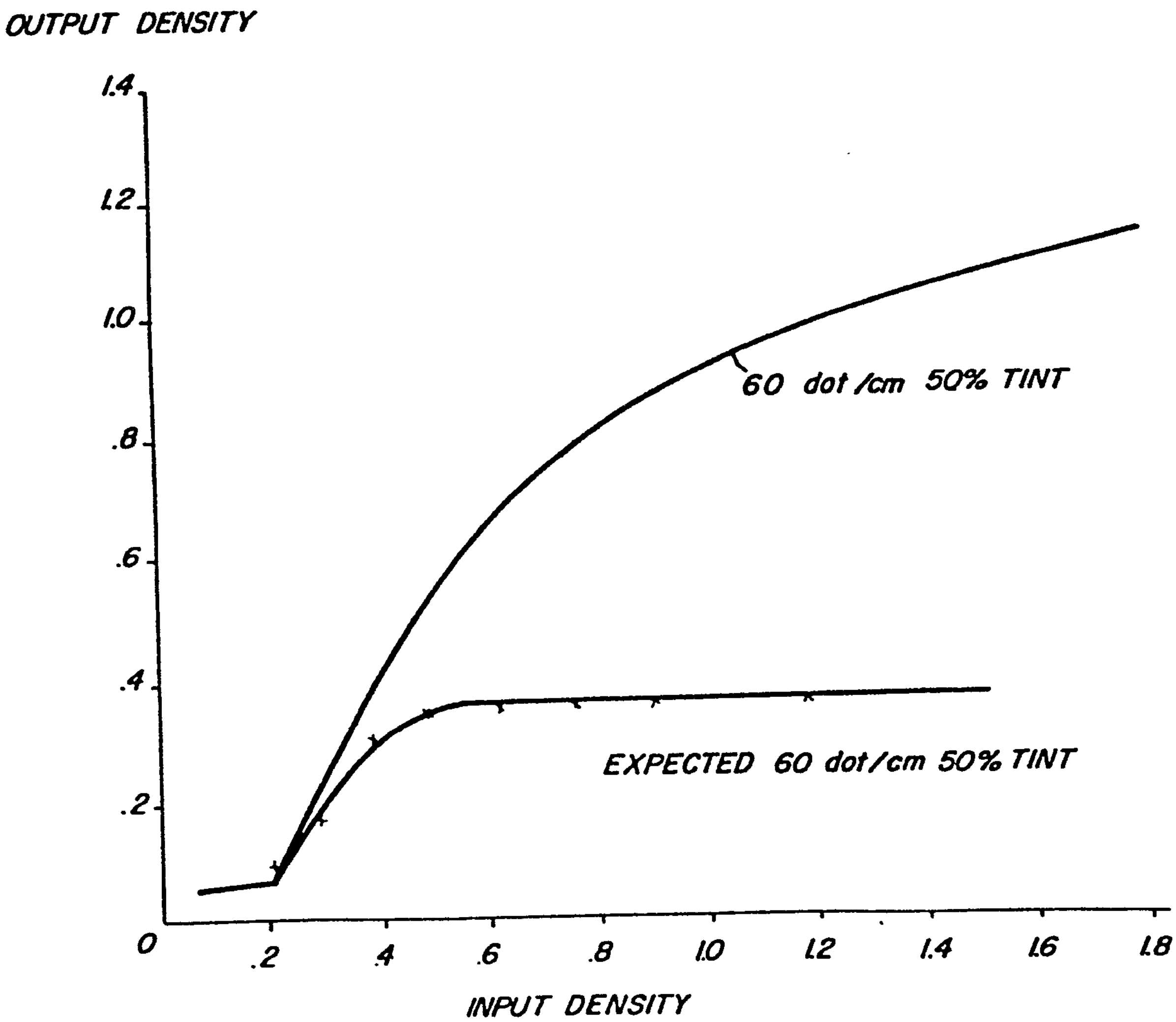
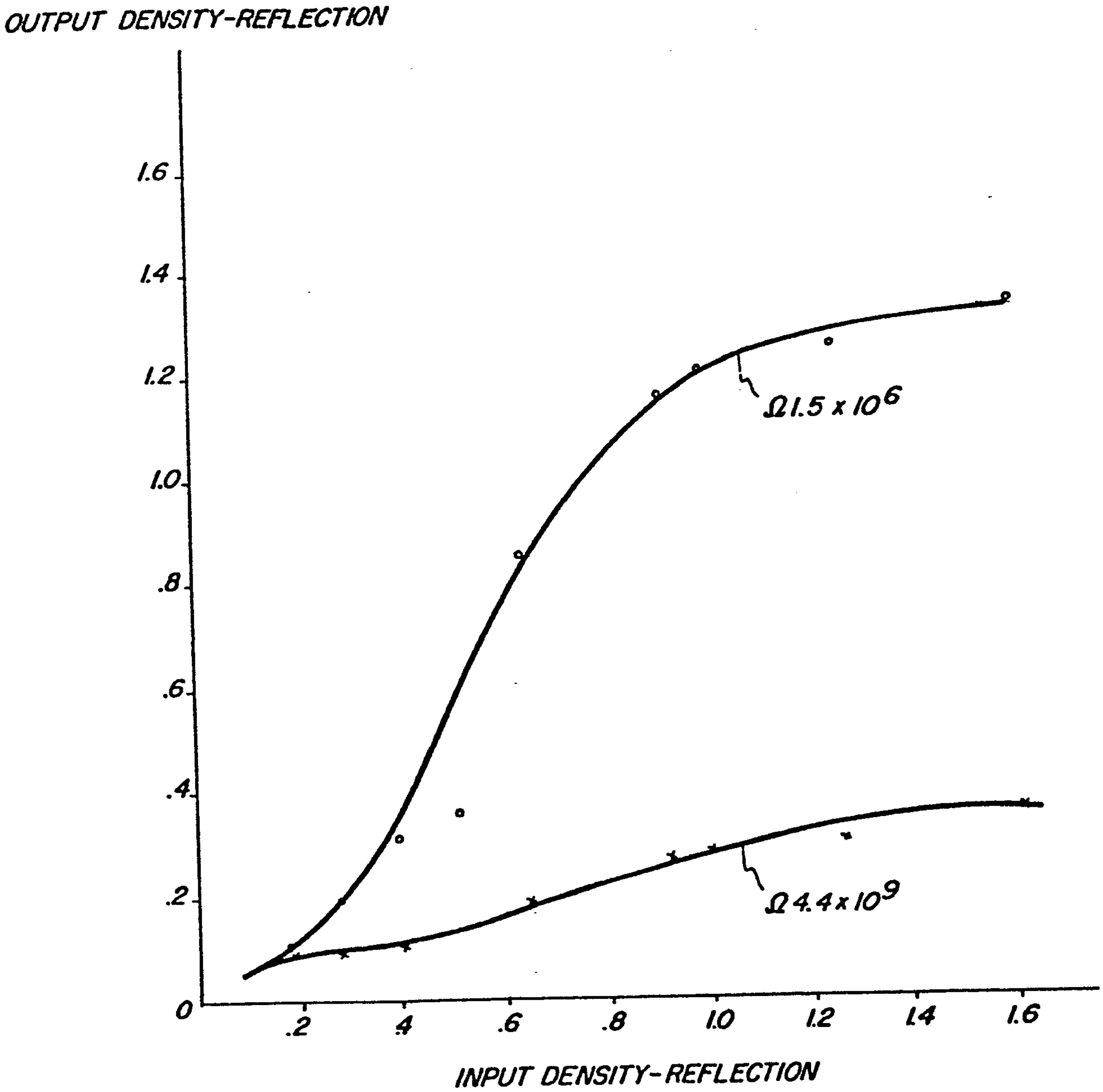

OUTPUT DENSITY
1.4
1.2
1.0
.8
.6
.4
.2
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
60 dot/cm 50% TINT
EXPECTED 60 dot/cm 50% TINT
INPUT DENSITY

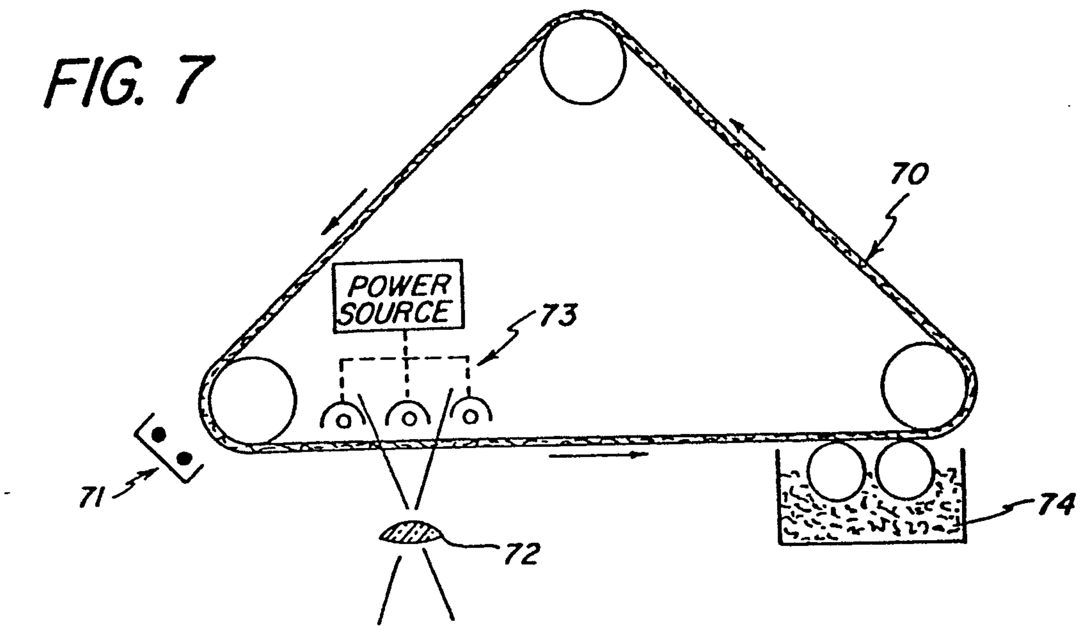
FIG. 4



EFFECT OF DEVELOPER CONDUCTIVITY ON SYSTEM H&D

FIG. 5

FIG. 7


POWER SOURCE
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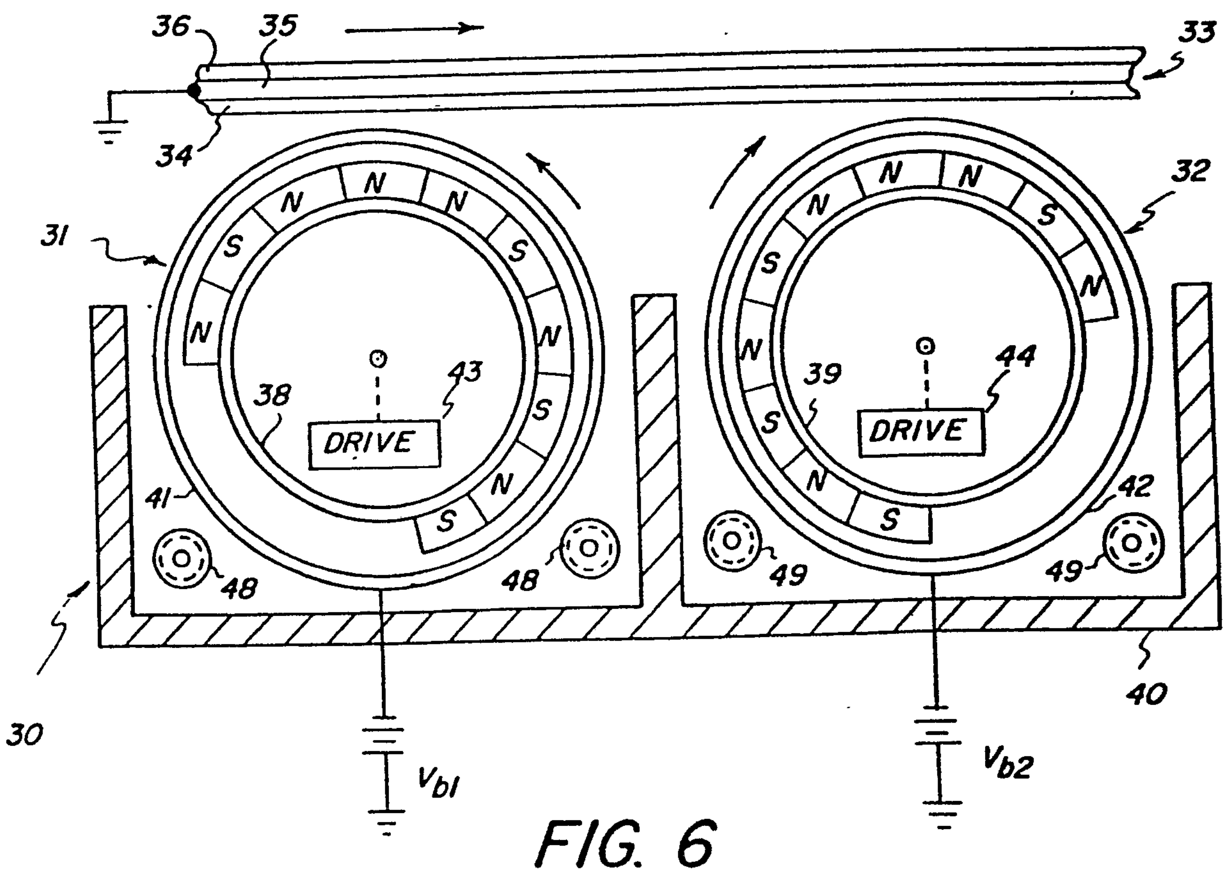
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DRIVE
DRIVE
N
S
V_{b1}
V_{b2}

FIG. 6