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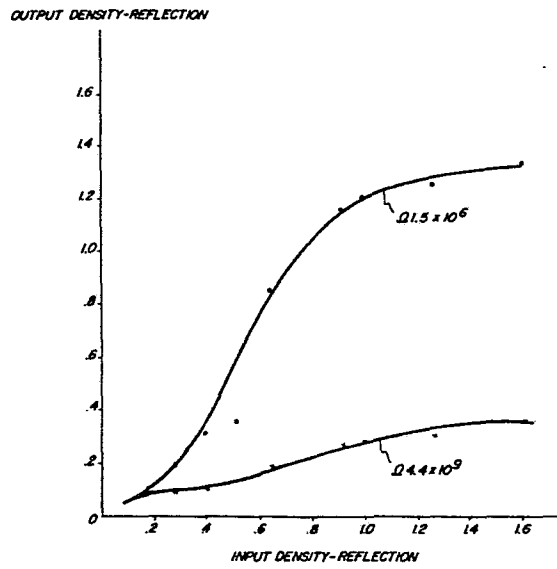
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54 **Method of improving maximum density and tonal range of electrographic images, a photoconductive element therefor and an electrographic copying apparatus using the method.**

57 The image quality obtainable by an electrographic copying process in which an electrostatic latent image formed by imagewise exposure of a uniformly charged photoconductive layer, or otherwise, is developed with a toner can be improved if the latent image comprises discrete charge bearing zones, preferably formed by a supplementary exposure through a half-tone screen, and if additionally the toner is electrically conductive either intrinsically or as a result of electrical breakdown. In this manner, the maximum density obtainable in a copy can be increased and the contrast decreased sufficiently to allow good reproduction of both continuous tone and high contrast images.

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EFFECT OF DEVELOPER CONDUCTIVITY ON SYSTEM H&D

FIG. 5

- 1 - TITLE MODIFIED
see front page

METHOD FOR IMPROVING MAXIMUM DENSITY AND TONAL RANGE
OF ELECTROGRAPHIC IMAGES

This invention relates to the production of electrographic images and particularly to an electro-
5 photographic 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
10 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
15 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
20 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
25 (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
30 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
35 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 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 areas of said insulating layer in addition to any charge islands that result from said step a), and then
- c) developing the resulting electrostatic latent image with a developer composition which is conductive or is made conductive during the development step.

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 electrographic 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 forming said image, creating a plurality of charge islands in the imaging area of said photoconductive insulating layer in addition to any charge islands that result from
5 step a), and then

c) developing the resulting charge island latent image with a developer composition which is conductive or which can be made conductive during the development step.

10 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
15 several advantages including 1) registration problems are minimised, 2) simple continuous 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
20 layer and 4) high frequency screen patterns may be used without significant resolution loss.

Description of the Drawings

Fig. 1 is a photomicrograph of an electrostatic image developed with a non-conductive liquid
25 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
30 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
35 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 5 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 10 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 15 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 20 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 25 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 30 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 35 machines.

- 5 -

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
5 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 circumstances where
10 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.
15 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
20 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
25 in size from dot-to-dot 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
30 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.

35 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
5 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
10 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%.

15 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
20 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
25 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
30 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
35 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 multi-layer 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.

- 9 -

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 can be 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
5 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.

10 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
15 as iron, cobaltic oxide, stannic oxide, zinc and ferromagnesium, cupric carbonate, zinc carbonate, manganese carbonate, cupric oxide, lead acetate, zirconium, and nickel carbonate. Single component conductive developers can be used.

20 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
25 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
30 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
35 the current passing through the magnetic brush. Resistance is calculated by dividing the voltage by the

- 11 -

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. Development by the electrical breakdown mode can be accomplished using liquid developers or dry developers.

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,

- 12 -

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 counter-current 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 developer composition as required by the present invention.

- 15 -

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, 0.75 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

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

5 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

$$10 \quad R_t = X_1 R_1 + X_2 R_2 + X_3 R_3 - - + X_n R_n$$

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
 15 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
 20 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

$$25 \quad D = \log \frac{1}{R} \quad \text{or}$$

$$30 \quad R_1 = \frac{1}{\log_{-1} (D_1)} \quad ; \quad R_2 = \frac{1}{\log_{-1} (D_2)}$$

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

$$5 \quad R_1 = \frac{1}{\log^{-1}(1.4)} = 0.0398$$

$$10 \quad R_2 = \frac{1}{\log^{-1}(0.1)} = 0.7943$$

Therefore the total expected density (D_t) is

$$D_t = \log \left[\frac{1}{\frac{X_1 R_1}{+} \frac{X_2 R_2}{+}} \right]$$

$$15 \quad = \log \left[\frac{1}{0.5(0.0398) + 0.5(0.7943)} \right]$$

The calculation is then repeated for different D_{out} 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 D_{max} (0.38) is about 1/3 of the actual output D_{max} (1.2). The tonal range of this example is also greater than that expected. More steps of the step stamlet 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.

10 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 x 25 cm sheets of "Kodalith" Film available from Eastman Kodak Company ("Kodalith" is a trademark). Each of these screens was 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.

20 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 25 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

30 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.

Examples 4-8

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

5 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
10 (see list below) to produce developers exhibiting a range of resistances that were measured as previously described.

<u>Example</u>	<u>Carrier Core</u>
4	stainless steel
15 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 20 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:
25 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
30 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 D_{in}) as indicated in Table 1.

35 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 1 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
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
5 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
10 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.

15 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
20 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 millimeters with a development brush bias of -140 volts.
25 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.

30 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
35 polarity as the brush bias.

CLAIMS

1. An electrographic copying method which comprises:
 - a) forming on an insulating layer a latent electrostatic
5 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
 - 10 c) developing the resultant latent electrostatic image with a developer composition which is conductive or is made conductive during the development step.
2. A method according to claim 1 wherein the developer composition used for step (c) is dry.
- 15 3. A method according to claim 2 wherein the developer composition has a resistance of less than 10^9 ohms as measured by the test procedure described herein.
4. A method according to claim 2 wherein the developer composition is conductive as a result of
20 electrical breakdown and has breakdown value of less than 25 volts per millimetre.
5. A method according to any of claims 2 to 4 wherein development is effected with a magnetic brush.
6. A method according to any of the preceding
25 claims wherein the step (a) comprises imagewise exposure of a photoconductive layer.
7. A method according to claim 6 wherein the step (b) comprises exposing the photoconductive layer uniformly through a halftone screen.
- 30 8. A method according to claim 7 wherein the halftone screen has a frequency of 32 to 80 dots per centimetre and a tint of from 10 to 90%.
9. A method according to claim 7 or 8 wherein the halftone screen is part of a photoconductive element
35 comprising the photoconductive layer.

10. A method according to claim 9 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
5 halftone screen from the rear.
11. A method according to any of claims 1 to 8 wherein the insulating layer is part of an image receiving element.
12. A method according to any of claims 1 to 6
10 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.
13. A method according to any of claims 1 to 5
15 wherein the steps (a) and (b) are simultaneously effected by exposing a photoconductive layer to a computer addressed scanning exposure device.
14. A photoconductive element comprising a transparent support bearing, on the same side thereof,
20 a transparent photoconductive layer and a halftone screen having a frequency of 32 to 80 dots per centimetre and a tint of from 10 to 90%.
15. Electrographic copying apparatus comprising
25 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
30 use of the means (a) and (b) with a dry developer composition which is conductive or which is made conductive by electrical breakdown during development.
16. Electrographic copying apparatus according to
35 claim 15 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
5 overall to actinic radiation through this halftone
screen.

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

1 / 4

FIG. 1

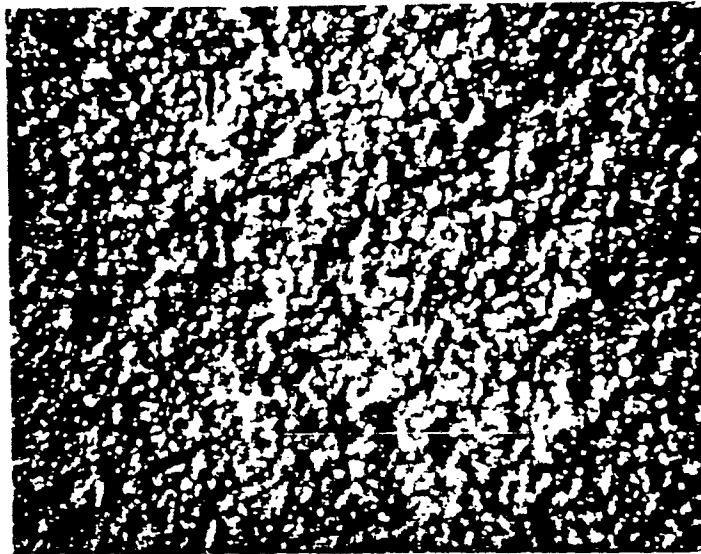
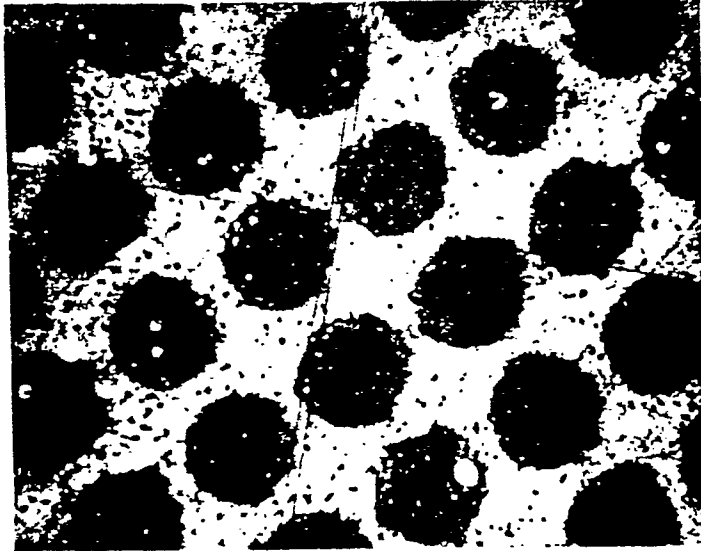
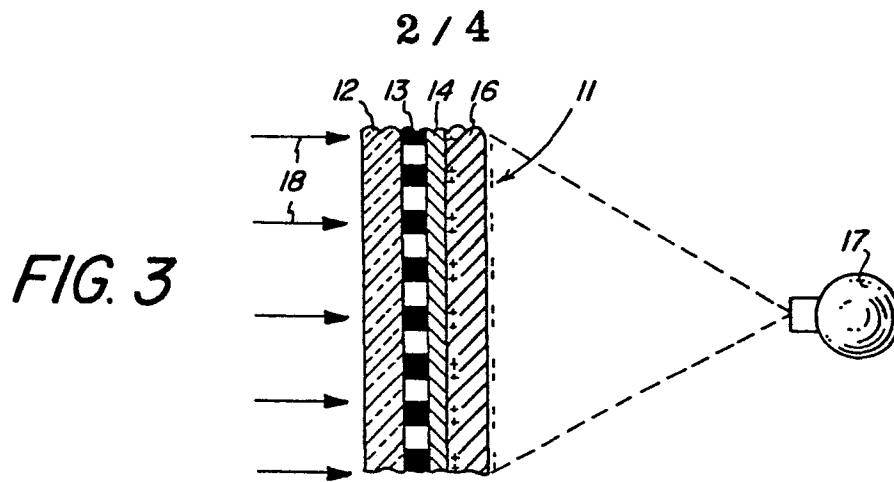


FIG. 2



OUTPUT DENSITY

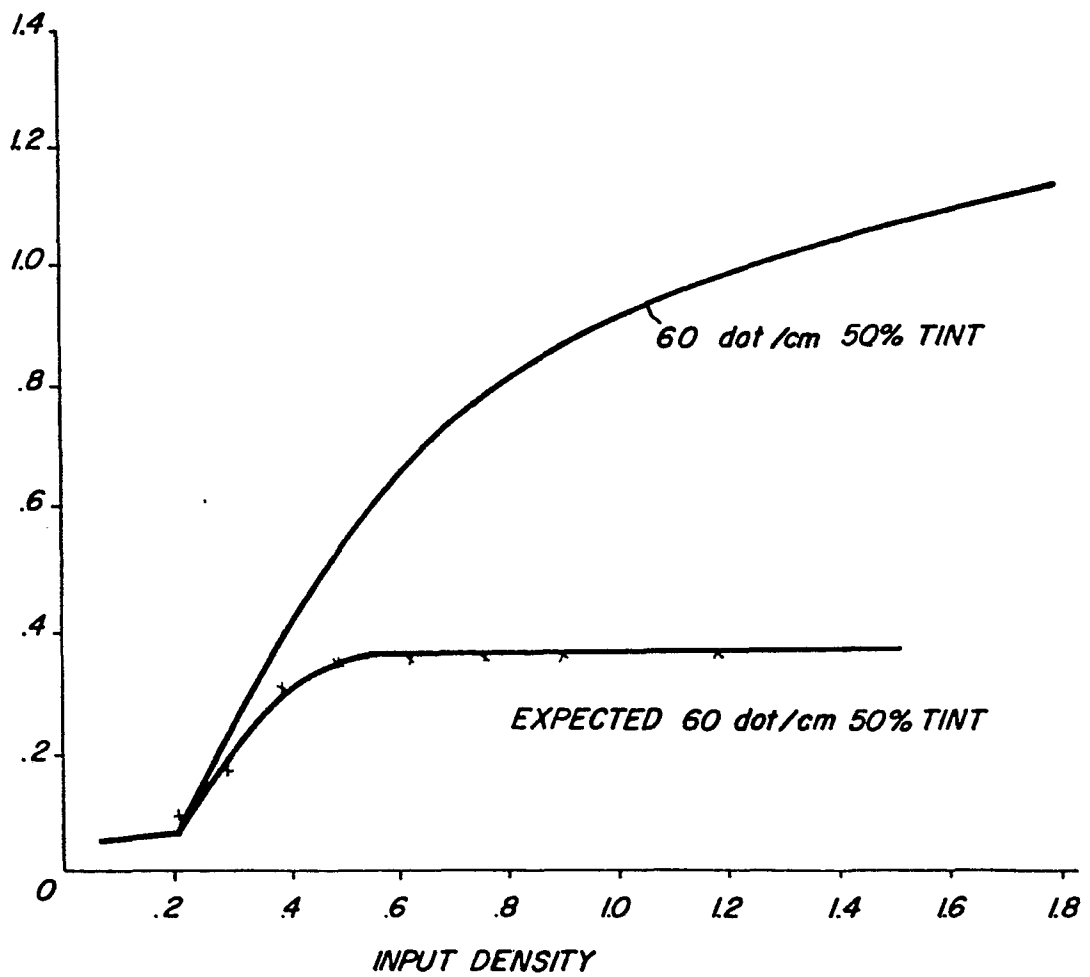
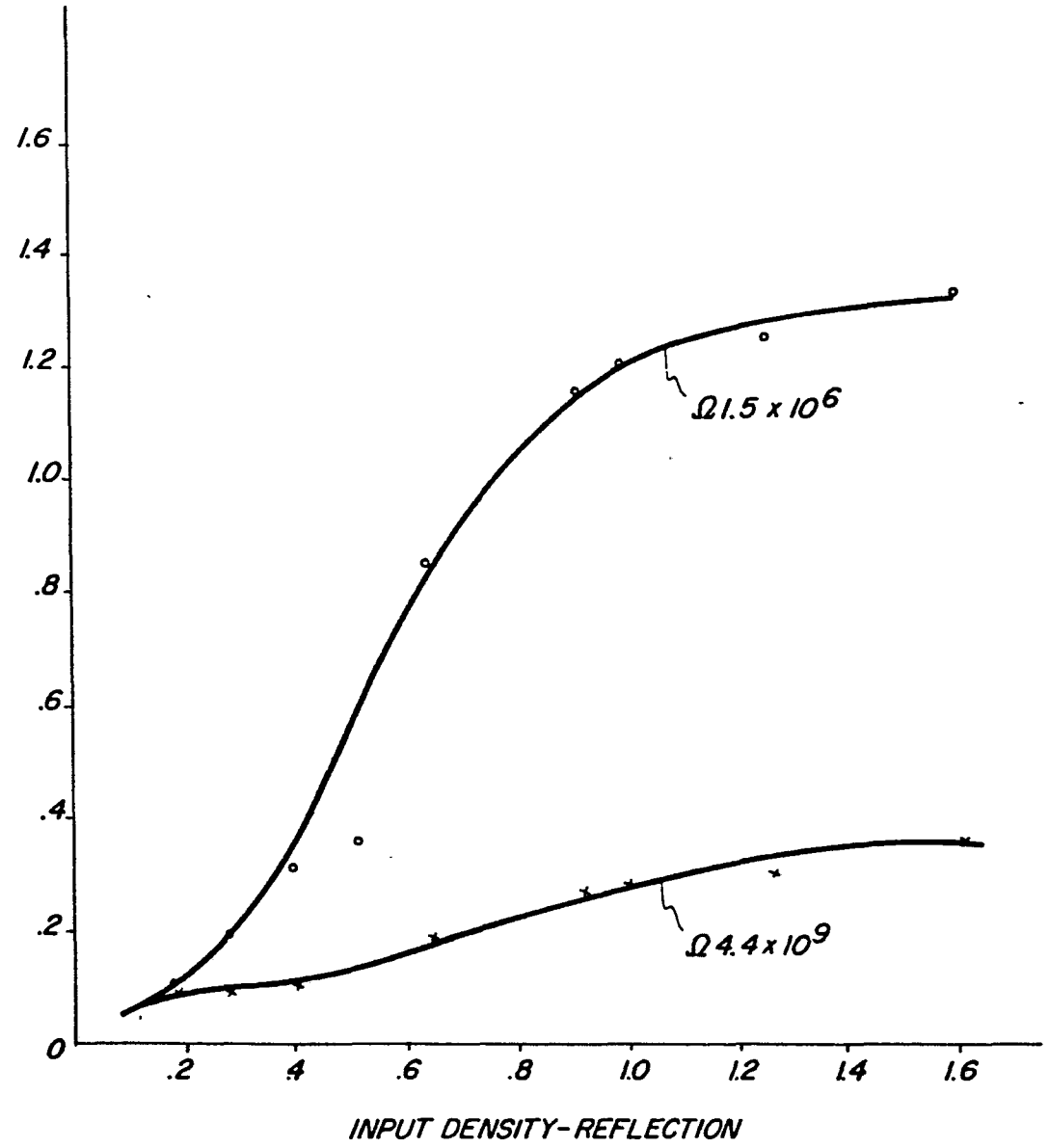


FIG. 4

OUTPUT DENSITY-REFLECTION



EFFECT OF DEVELOPER CONDUCTIVITY ON SYSTEM H&D

FIG. 5

4 / 4

FIG. 7

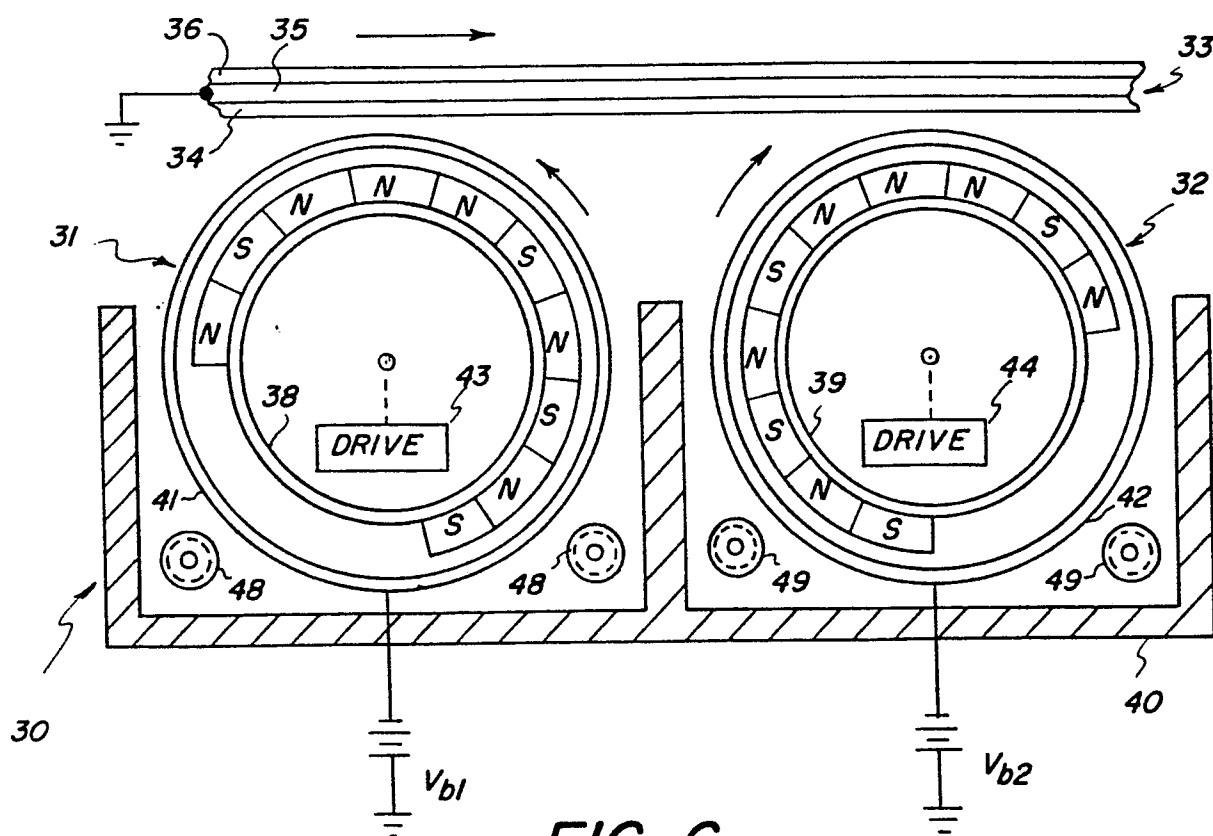
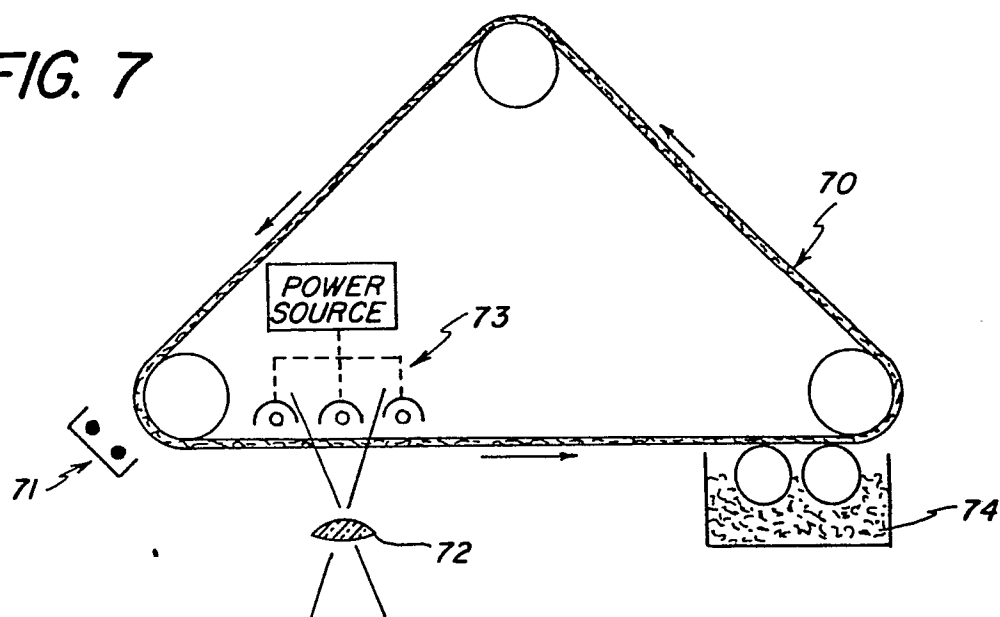


FIG. 6



DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ¹)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
	<u>US - A - 4 083 632</u> (L.D. MAILLOUX et al.) * Column 2, lines 1-42; claims 7,10; figure 3 * --	14	G 03 G 15/052 5/14
D	<u>US - A - 3 335 003</u> (C. SNELLING) * Column 6, lines 4-53; figures 2,3 * --	14	
D	<u>US - A - 3 341 326</u> (C. SNELLING) * Column 3, lines 32-72 * --	14	TECHNICAL FIELDS SEARCHED (Int.Cl. ³)
AD	<u>US - A - 3 627 526</u> (P.J. DONALD) * Abstract; figures * --	1,15	G 03 G 13/052 13/09 15/052 15/09 5/14 G 03 B 27/73
AD	<u>US - A - 3 681 071</u> (P.J. DONALD) * Claims 1-3 * --	1,15	
AD	<u>US - A - 4 076 857</u> (G. P. KASPER et al.) * Abstract; figure 2 * ----	1,15	CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
			&: member of the same patent family, corresponding document
X	The present search report has been drawn up for all claims		
Place of search	The Hague	Date of completion of the search	01-07-1980
Examiner	HILTNER		