(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 819 991 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
19.04.2006 Bulletin 2006/16

(51) Int Cl.:
G03G 15/00 *(2006.01)*

(21) Application number: **97201898.0**

(22) Date of filing: **21.06.1997**

(54) **Process control of an electrophotographic device**

Prozesssteuerung in einem elektrografischen Gerät

Procédé de commande d'un dispositif électrophotographique

(84) Designated Contracting States:
BE DE FR GB NL

(30) Priority: **18.07.1996 EP 96202041**

(43) Date of publication of application:
21.01.1998 Bulletin 1998/04

(73) Proprietor: **Punch Graphix International N.V.**
2500 Lier (BE)

(72) Inventors:
- **Slabbaert, Jean-Pierre**
2640 Mortsel (BE)
- **Jansens, Robert**
2640 Mortsel (BE)
- **Broddin, Dirk**
2640 Mortsel (BE)
- **Heirbaut, Werner**
2640 Mortsel (BE)

(74) Representative: **Bird, Ariane et al**
Bird Goën & Co
Klein Dalenstraat 42A
3020 Winksele (BE)

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Printed by Jouve, 75001 PARIS (FR)

Description

Field of the invention

[0001] The present invention relates to devices and methods for an image forming apparatus, such as an electrophotographic digital copying machine or digital printer with a two-component development system.

Background of the invention

[0002] One of the main factors to quantify the quality of a printed image is the tone scale representation, expressed by the optical density range and the exactness and stability of the contone rendering. In a digital printing machine, such as an electrophotographic engine, each tone of a contone image is produced by a certain spatial combination of some or all of the available tones per pixel. This process is referred to as screening. The set of tones, available in the machine, is defined by the properties of the exposure device. For instance, in an electrophotographic printer that uses a binary exposure device, only two tones (black and white) are available to the screening algorithm to reproduce a contone image. In some machines however, multiple tone levels are available to the screening process by applying area or intensity modulation on the output spot of the exposure device (see below). As screening is well-defined and, by its nature, perfectly repeatable, the image quality of the engine is largely determined by the ability to reproduce the set of tones. In an electrophotographic engine the contone density of each microdot is determined by the mass of toner per unit area transferred to paper. This toner mass, referred to as M/A and expressed in mg/cm^2, is a function of an almost limitless amount of parameters. Most of these parameters can be regarded as fixed by design and thus invariable during the operation of the engine. Some however are extremely variable. The most important in a two-component developer system are :

- toner concentration (TC) = the ratio of the amount of toner and the amount of carrier available in the developing unit in a two-component system.
- toner charge per unit of mass (Q/M), expressed in $\mu C/g$.
- development potential (V_{DEV}), expressed in Volt = the potential difference V_E-V_B over the development gap between the developer supply roller (bias voltage V_B) and the photosensitive element (voltage after exposure V_E) upon which a latent image is present. The photosensitive element is mostly implemented as an Organic Photoconductor or OPC.
- transfer efficiency (TE), expressed in % : the ratio of the amount of toner transferred to the printing medium and the amount of toner developed on the photosensitive element. This dependency can be formally expressed as :

$$M/A = f\ (\ TC,\ Q/M,\ V_{DEV},\ TE\ )$$

and is generally referred to as the developability and transferability f() of the toner.

[0003] In an electrophotographic engine, the reproduction of multiple tones is highly sensitive to each of these variables. Toner concentration TC changes during engine operation due to depletion of toner caused by image development and toner addition under control of the engine. Toner charge Q/M is determined by :

- the triboelectric properties of toner and carrier,
- toner concentration TC,
- relative humidity RH of the air in the developing unit,
- agitation of developer in the developing unit.

[0004] When the developer is properly agitated, an unambiguous relationship can be found between Q/M, TC and RH. The development potential V_{DEV} is determined by :

- the initial charge level V_C of the OPC,
- the bias voltage V_B applied to the toner supply roller of the developing unit and
- the intensity E_{EXP} of the image dependent illumination of the photosensitive element.

[0005] Transfer efficiency TE on its turn is, amongst other factors, determined by :

- toner charge Q/M,
- amount of toner on the photosensitive element and

- the value of the electric field in the transfer zone.

[0006] Present electrophotographic machines maintain the optical density of their produced tones by keeping toner concentration TC at a constant level. For this purpose they use a toner concentration sensor in the developing unit, or a density sensor that measures the density D_{OPC} developed on the OPC, or both. Changes of the toner charge Q/M, due to relative humidity RH or variations of RH are compensated for by changing the development potential V_{DEV} and the value of the transfer electric field. Disadvantages of this technique are :

- extremely low toner charge Q/M at high relative humidity RH, leading to an increase in dust production, fogging and possibly inconsistent transfer quality over the whole tone scale.
- extremely high toner charge at low relative humidity, decreasing the developability of the toner. This requires large electric fields in the developing stage and consequently implies more powerful engine hardware.

[0007] Furthermore, it can be shown that for a two-component developing system, the development of the latent image is almost purely driven by toner charge Q/M. Therefore toner charge Q/M would be a valuable input to any process control system for steering the electrophotographic process. Generally, online toner charge measurement Q/M can not be implemented easily without the need for high precision measurement hardware, which leads to an increase in system variable cost. As stated before, producing several tones in an electrophotographic engine can be done by area modulation or by intensity modulation of the light beam of the exposure device (or by any combination of both). In this way, a set of microscopic tones at the pixel or microdot level are created. These form a microscopic gradation that has to be kept constant for the contone rendering, handled by the screening process, to be repeatable. US-A-4,026,643 discloses and apparatus and method wherein the toner charge Q/M is determined by combining a measurement of the difference between the photoreceptor potential in the presence and in the absence of charged toner particles with a measurement of a difference in optical reflectance in the presence and in the absence of charged toner particles. The measurement of the difference in the electrostatic potential of the photoreceptor provides a quantity proportional to the toner particle charged per unit area. The measurement of the difference in optical reflectance provides a quantity related to the toner mass per unit area, a quantity that is linear for low particle densities. Combining the two difference measurements provides a value proportional to the Q/M of the toner.

[0008] EP-A-510 325 describes an image forming apparatus, a measuring unit for measuring the optical density of an image and control unit for determining an operation condition of the image forming unit based on the measurement.

[0009] EP-A-276 107 describes an electrographic image forming apparatus in which image forming conditions, e.g. exposure conditions, are regulated according to the ambient conditions, such as humidity, detected by suitable sensors.

Objects of the invention

[0010] It is therefore a first object of the present invention to provide a process control method that maintains quality contone rendering and at the same time avoids negative effects such as excessive dust creation, fogging, deteriorated transfer on paper and necessity of strong electric fields.

[0011] It is a further object of the invention to provide a method of measuring toner charge Q/M, online in the engine, without the need for any extra external hardware in the form of sensors or other measuring devices.

[0012] Further objects and advantages of the invention will become apparent from the description hereinafter.

Summary of the invention

[0013] The above mentioned objects are realised by the specific features according to claim 1. Preferred features of the invention are set out in the dependent claims.

[0014] These objects can be accomplished according to the present invention by an electrophotographic image forming apparatus as shown in Fig. 3. This apparatus comprises a charging device 2, such as a scorotron, that charges a photosensitive element 1, such as an Organic Photo conductor (OPC). The charged photoconductor 1 is exposed by an exposure device 3, such as a LASER, an LED-array, a spatial light modulator (like a DMD : deflective mirror device) etc., to form a latent image. The latent image is developed by a two-component developing system to form a toner image. The toner image is transferred to an output medium 22 such as paper or transparency and fused by applying heat and/or mechanical pressure. The apparatus preferentially comprises a densitometer 6 that measures the optical density D of the image developed on the OPC, preferably to correct the developing process for possible deviations. The apparatus contains a contact-less electrostatic voltage sensor 4 that measures the surface potential of the OPC 1. The apparatus preferably also contains a toner concentration sensor 16, preferentially located in the developing system 5. The developability and transferability of the toner particles are maintained over the complete range of environmental conditions, developer lifetime, etc. by keeping the charge of the toner, Q/M, within a narrow range. This range is defined by the unambiguous relationship between Q/M, TC and RH and the range for TC that can be allowed without penalizing developer lifetime. By changing the toner concentration TC by means of toner addition or toner depletion during operation of the engine, toner charge Q/M can be maintained at its required level. Toner charge Q/M may be indirectly measured, based upon the unambiguous relationship that exists between M/A, Q/M and V_{DEV}, for that range of M/A where development is not limited by toner supply (low- and midtones).

Detailed description of the invention

[0015] The invention is described hereinafter by way of examples with reference to the accompanying figures wherein :

- Fig. 1 is a graph representing measured points of developability curves typical for a two-component developer for various toner concentration values TC and different relative humidity values RH ;
- Fig. 2 is a graph representing the toner charge per unit of mass Q/M of the toner in a two-component developer system as a function of the toner concentration TC, with relative humidity RH as parameter ;
- Fig. 3 represents an electrophotographic engine suitable for the current invention ;
- Fig. 4 represents a closed loop control system for regulating toner charge Q/M ;
- Fig. 5a represents the discharge potential V_E after exposure of the photosensitive element 1 by the exposure device 3, as a function of the amount of exposure energy E_{EXP}, along with a reference to the bias potential V_B = -200 V and the charge potential V_C = - 300 V ;
- Fig. 5b represents the development potential $V_{DEV} = V_E - V_B$ as a function of the exposure energy E_{EXP} for a charge potential V_C = - 300 V ;
- Fig. 5c represents the transmission density D_{TRANS} as a function of the exposure energy E_{EXP} for a charge potential V_C = - 300 V.
- Fig. 5d represents the discharge potential V_E after exposure of the photosensitive element 1 by the exposure device 3, as a function of the amount of exposure energy E_{EXP}, along with a reference to the bias potential V_B = - 400 V and the charge potential V_C = - 500 V ;
- Fig. 5e represents the development potential $V_{DEV} = V_E - V_B$ as a function of the exposure energy E_{EXP} for a charge potential V_C = - 500 V ;
- Fig. 5f represents the transmission density D_{TRANS} as a function of the exposure energy E_{EXP} for a charge potential V_C = - 500 V ;
- Fig. 6 shows the density D_{OPC} of 10 patches, as recorded with a densitometer, in a 10 step wedge with respect to relative exposure energy $E_{EXP}/(E_{EXP})_{MAX}$;

[0016] While the present invention will hereinafter be described in connection with preferred embodiments thereof, it will be understood that it is not intended to limit the invention to those embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents which are included within the scope of the invention as defined by the appending claims.

<u>Electrophotographic engine</u>

[0017] The most important components of an electrophotographic imaging apparatus suitable for the current invention are shown in Fig. 3. A photosensitive element 1, such as an OPC, is charged by a charging device 2 (such as a scorotron) and exposed by an exposure device 3 (laser scan system, LED-array, DMD, etc.). The exposure device 3 is capable of generating more than one exposure energy level E_{EXP} per pixel. For instance a binary device can image two levels (0 and some other level different from 0), a 16-level (4 bit/pixel information) exposure device can generate 16 distinguishable levels per pixel (including 0), etc. The exposure device 3 receives image data 33 from an image processing unit 14, generally called a RIP or Raster Image Processor, which translates image data, presented in a page description language, to a bitmap. The bitmap contains the required exposure tone level I for each pixel in the image. Inside the exposure device 3 there is preferably a translation table 15 (look-up-table or LUT) to translate the data in the bitmap to physical exposure energy levels E_{EXP}. The effect of charging to a charge voltage V_C and subsequently discharging by exposure E_{EXP} can be measured by a contact-less electrostatic voltage sensor 4. The resultant latent image is developed by a two-component developing system 5. Charged toner particles are transferred from the magnetic brush 8 to the OPC surface by the force of the electric field V_{DEV} present between the OPC surface at potential V_E and the surface of the magnetic roller at potential V_B. The density D_{OPC} 31 of the developed image can be measured with a densitometer 6 focused on the OPC surface. The engine comprises a toner container 12 from which toner can be added to the developing unit 5 through a control means 13. The developing unit 5 further preferably contains a toner concentration sensor 16 which is merely used as a watchdog for detecting extreme toner concentration values. The toner image is transferred to a medium 7 (paper, transparency, etc.). The engine also contains an environmental sensor 9 (referred to as RH/T sensor) that senses both relative humidity RH and temperature T. Toner particles that are not transferred to the medium 7 are scraped from the OPC by a cleaner system 11 and dumped into the toner waste box 10.

Definitions of terms (see Fig. 3)

[0018]

- The charge potential (V_C 23) of the OPC is defined as the surface voltage with respect to ground after charging the OPC by means of a charging device 2 such as a scorotron and in absence of any exposure to light. The charge potential may be measured by a contact-less electrostatic voltage sensor such as a TREK™ model 856.
- The potential after exposure or discharge potential (V_E 27) is defined as the surface voltage of the OPC with respect to ground after charging the OPC followed by exposure E_{EXP}. The potential after exposure may be measured by a contact-less electrostatic voltage sensor such as a TREK™ model 856
- The bias potential (V_B 29) is the voltage of the sleeve of the magnetic roller 8 of the developing unit 5, with respect to ground.
- The development potential (V_{DEV} 30) is the difference $V_{DEV} = V_E - V_B$ between the potential after exposure V_E 27 and the bias potential V_B 29. When this value is negative, it is regarded as 'not-developing' and considered as set to a value of 0.
- The cleaning potential (V_{CL}) is the difference $V_{CL} = V_B - V_C$ between the bias potential V_B and the charge potential V_C and is preferentially regarded as a fixed value.
- the saturation potential (V_{SAT}) is the residual potential on the OPC, after a charge cycle followed by exposure with a limitless intensity value E_{EXP}. For every charge potential V_C there is a constant value for V_{SAT}.
- toner supply (TS) : the amount of toner supplied to the developing gap 28 per second. TS is dependent on toner concentration TC, doctor blade distance, speed of the magnetic roller 8, etc.
- toner concentration (TC) : ratio of amount of toner to amount of carrier in the developing unit 5.
- PID controller : Proportional, Integral and Differential controller, referring to a general control method, incorporating one, two or three of these techniques, as described in 'Modern Control Engineering' by K. Ogata, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Measuring Q/M

[0019] As described above, the density D_{OPC} of the developed image on the OPC can be measured online by a densitometer 6. The development potential V_{DEV} may be measured by a contact-less electrostatic voltage sensor 4. The graph in Fig. 1 represents a set of values for deposited toner mass M/A in a small, rectangular image or patch, homogeneously exposed over its complete area i.e. full density patch. This deposited toner mass M/A is measured for different toner concentrations TC and different relative humidity RH, for a range of values of the development potential V_{DEV}, divided by the actual toner charge Q/M at which development took place. All data are experimental. From Fig. 1 it can be seen that for low deposited toner mass M/A values (below approximately 0.4 mg/cm^2), the toner mass M/A is, to a certain extent, independent of toner concentration TC or relative humidity RH. As a consequence, by developing a full density patch with a M/A within the range of e.g. 0.1 to 0.4 i.e. the linear part of the developability curve, and by measuring both the development potential V_{DEV} - indirectly by measuring V_E - and the toner mass M/A, the almost linear relationship between M/A and V_{DEV} / (Q/M), allows to easily extract charge information with a reasonable accuracy i.e. better than 10%. This is regarded as being sufficient.

Stabilizing developability

[0020] Fig. 2 shows the toner charge per unit of mass Q/M as a function of toner concentration TC for different values of the relative humidity RH.

- Curve 36 represents Q/M = f(TC) for RH = 70 % ;
- curve 37 represents Q/M = f(TC) for RH = 50 % ;
- curve 38 represents Q/M = f(TC) for RH = 30 %.

[0021] As stated earlier, both the developing process and the transfer process benefit from a stable charge level Q/M of the toner. It is the aim of the process control to maintain toner charge Q/M at one level for all environmental conditions. The applied method will be explained below.

[0022] From Fig. 2, it can be seen that maintaining toner charge Q/M at one level would require a very wide range of toner concentration TC values to operate in. For instance, keeping the charge at 10 μC/g on the vertical Q/M axis, requires an operative range of 3% to 6% in TC on the horizontal axis. Extreme toner concentration values lead to negative effects on the quality of the developer, for instance shorter lifetime, which have to be avoided. Therefore, the target value of the toner charge Q/M is preferably made dependent on the actual relative humidity of the environment. The relative humidity RH is preferably measured by the environmental RH/T sensor 9 :

$$(Q/M)_{target} = a + b \cdot RH$$

where a and b are constants to be chosen based on the actual characteristics of the developer. So, by measuring the toner charge Q/M in the way described earlier and calculating the target value $(Q/M)_{target}$ based on the environmental relative humidity RH, a closed loop control system can be devised as depicted in Fig. 4. The actual toner charge $(Q/M)_{actual}$ is calculated by the block 43. The target Q/M is calculated by the block 44. The target and actual toner charge are compared by the comparator 41. Through a control algorithm 42 such as a PID controller, the process control decides on which corrective action to take :

- add toner to increase toner concentration TC ; or,
- deplete toner to decrease the toner concentration TC. This can be achieved by developing a dummy image and dumping the toner into the toner waste box 10, or - which is the preferred method - not adding toner while images are being made.

In this way, toner concentration TC is always set at the most optimum value for all environmental conditions.

Stabilization of microscopic gradation

[0023] The figures 5a to 5f present the relationship between exposure energy E_{EXP} and the discharge potential V_E, development potential V_{DEV} and density D_{TRANS} on paper for two different values of the charge potential V_C=-300 V, -500 V.

[0024] The relationship is shown between exposure energy E_{EXP} and :

- Charge potential V_C, bias potential V_B, potential after exposure V_E in Fig. 5a for V_C = - 300 V and in Fig. 5d for V_C = - 500 V ;
- development potential $V_{DEV} = V_E - V_B$ for V_C = - 300 V in Fig. 5b and for V_C = - 500 V in Fig. 5e ;
- transmission density of an evenly exposed patch D_{TRANS} for V_C = - 300 V in Fig. 5c and for V_C = - 500 V in Fig. 5f.

[0025] From the graphs it becomes very clear that the relationship between exposure energy E_{EXP} and the resulting transmission density D_{TRANS} changes drastically :

- The minimum exposure energy E_{MIN}, shown in Fig. 5b and Fig. 5e, that will cause toner to be transferred to the OPC moves from a value of about 3 mJ/m^2 (Fig. 5b and Fig. 5c) to less than 2 mJ/m^2 (Fig. 5e and Fig. 5f)
- an exposure energy E_{EXP} of 10 mJ/m^2 on the OPC results in a density of 0.8 (Fig. 5c) while in the graph of Fig. 5f resulting from the same exposure level E_{EXP} = 10 mJ/m^2 but starting from another charge potential V_C = - 500 V the density is about 1.7.

[0026] This means that, as the charging potential V_C is being changed in order to maintain the required density D_{TRANS} as the toner charge Q/M and toner supply TS change, the exposure energy levels E_{EXPi} that correspond to each of the microscopic tones I_i have to be redefined, in order for the microscopic gradation to remain the same. Several methods can be used for redefining the exposure levels. A first way to do this is to develop a wedge of, for instance, 10 patches, each patch being homogeneously exposed by a different exposure energy E_{EXPi}, I = 1..10. E_{EXPi} may be expressed in % of the available range E_{MAX} for a certain exposure device. The number of patches does not have to correspond to the number of bits/pixel that the engine can produce. The number of patches may be freely chosen depending on the required accuracy of the microscopic gradation calibration. The higher the number the higher the accuracy of the procedure, as described. The wedge may be preferentially measured online by the densitometer 6. The results of such measurement are presented in a graph in Fig. 6. The wedge can be generated at start-up, at regular time intervals after start-up, or after a certain number of prints, or when operating points of the engine have changed significantly, or any combination of these criteria, whatever is appropriate according to the stability of the engine's components. At factory calibration of the engine, a table is preferentially stored in the memory of the controlling microprocessor. This table contains the required output values $(D_{OPCi})_{RQ}$ of the densitometer 6 for each of the microscopic density levels. For instance, in a 4 bit/pixel engine, 16 microscopic density levels $(D_{OPCi})_{RQ}$ can be produced (including density 0). By taking the inverse function of the graph presented in Fig. 6, it is possible to calculate for each entry D_{OPCi} in the table the corresponding exposure energy E_{EXPi}, as shown graphically for one value in Fig. 6. On the vertical D_{OPC} axis the required target density value D_{OPC} 17 is indicated. Via the sensitometric curve 19 in Fig. 6 $D_{OPC} = f(E_{EXP}/E_{MAX})$, one can find the corresponding required exposure energy level 18 to achieve the target density D_{OPC} 17. The exposure level is given as a percentage with respect to E_{MAX} : the maximum exposure energy level. These values may then be stored in the look-up table (LUT) 15, located in the control electronics of the exposure device.

[0027] A second way to re-calibrate the microscopic gradation, is to expose for i = 0 .. 15 to E_{EXPi} but not develop a similar wedge as the one described above. By means of the electrostatic voltage sensor 4 the development potentials V_{DEVi} for each of the patches i can be recorded. This allows to construct a graph similar to the one described in Fig. 6.

[0028] Preferably, again at factory calibration of the engine, the required development potentials V_{DEVi} are stored in a table resident in the memory of the controlling microprocessor. By taking the inverse of the recorded function, the required exposure energy level E_{EXPi} for each of the entries in the table can be found and stored in a LUT 15 inside the exposure device.

[0029] Having described in detail preferred embodiments of the current invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the following claims.

Claims

1. A method for controlling output density in an electrophotographic device with a two-component development system, said device having a photosensitive element and a toner supply means, said method comprising the following steps:

   - establishing a relation between optical density (D_{OPC}) of applied toner, development voltage (V_{DEV}) and toner charge (Q/M) of applied toner, the development voltage being the difference between the surface potential on the photosensitive element after an exposure but before toner development and a bias potential on the toner supply means;
   - generating on said photosensitive element an electrostatic patch corresponding to medium optical density;
   - measuring the development voltage (V_{DEV}) on said electrostatic patch;
   - developing said electrostatic patch by application of toner, giving a toner patch on said photosensitive element;
   - measuring the optical density (D_{OPC}) of said toner patch;
   - computing, using said relation, from said development voltage and said optical density, the toner charge (Q/M); and
   - modifying toner concentration (TC) in correspondence with said computed toner charge (Q/M).

2. Method according to claim 1, wherein modification of said toner concentration TC comprises the steps of increasing or decreasing toner supply TS.

3. Method according to any of the preceding claims, wherein measuring the development voltage V_{DEV} comprises the steps of :

   - measuring potential after exposure V_E of said electrostatic patch ;
   - finding bias potential V_B of said toner supply means ;
   - making the difference between v_E and V_B.

4. Method according to any of the preceding claims, wherein the step of modifying said toner concentration TC is based on a target toner charge $(Q/M)_{TARGET}$.

5. Method according to claim 4, wherein said target toner charge $(Q/M)_{TARGET}$ is computed comprising the following steps :

   - establishing a second relation between relative humidity RH and target toner charge ;
   - measuring a relative humidity RH ;
   - computing using said second relation, from said measured relative humidity, the target toner charge $(Q/M)_{TARGET}$.

6. Method according to claims 4 or 5, comprising the steps of :

- regularly computing the Q/M and $(Q/M)_{TARGET}$ values ;
- using these values in a PID system to compute the required TC change.

7. Method according to any of claims 1 to 6, comprising the step of exposing a plurality of patches on said photoconductive element to different exposure levels E_{EXPi}, constant within each patch.

8. Method according to claim 7, further comprising the steps of :

- developing said patches by application of toner ;
- measuring the optical density of each patch by a densitometer ;
- establishing a conversion table giving exposure level as a function of required optical density, based on said measured optical density.

9. Method according to claim 7, further comprising the steps of :

- measuring the voltage level of said exposed patches ;
- establishing a conversion table giving exposure level as a function of required optical density, based on said measured voltage level.

10. An electrophotographic image forming device with a two component development system comprising:

- a photosensitive member (1);
- a charging device (2) for charging the photosensitive member (1);
- an exposure device (3) for exposing the photosensitive member including exposing a patch thereon;
- a contact-less electrostatic voltage sensor (4) for measuring a discharge potential of the patch, the discharge potential being the surface voltage after exposure but before toner development;
- toner supply means (5) for applying toner to the photosensitive member (1) including applying toner to the patch to develop a toner patch;
- a densitometer (6) for measuring the optical density of the toner patch; and
- a closed-loop control system for computing the toner charge (Q/M) from a predetermined relationship and for modifying toner concentration (TC) in accordance with the computed toner charge (Q/M),

characterised in that said predetermined relationship is between the development voltage of the patch, the optical density of the toner patch and the toner charge (Q/M), the development voltage of the patch being the difference between the discharge potential of the patch and a bias potential on the toner supply means (5).

11. The electrophotographic image forming device according to claim 10, **characterised in that** the closed-loop control system includes a calculator (44) for calculating a target toner charge (Q/M_{TARGET}), and a comparator (41) for comparing the computed toner charge (Q/M) of the toner patch with the target toner charge (Q/M_{TARGET}).

12. The electrophotographic image forming device according to claim 11, further **characterised by** an environment relative humidity sensor (9) and wherein the calculator (44) is adapted to calculate the target toner charge (Q/M_{TARGET}) based on the environment relative humidity.

13. The electrophotographic image forming device according to claim 11 or 12, **characterised in that** the closed-loop control system includes a process controller (42) for controlling the toner concentration (TC) in accordance with the output of the comparator (41).

Revendications

1. Procédé pour commander la densité de sortie dans un dispositif électrophotographique comportant un système de développement à deux composants, ledit dispositif ayant un élément photosensible et un moyen d'alimentation d'encre en poudre, ledit procédé comprenant les étapes suivantes consistant à :

- établir une relation entre la densité optique (D_{OPC}) de l'encre en poudre appliquée, la tension de développement (V_{DEV}) et la charge d'encre en poudre (Q/M) de l'encre en poudre appliquée, la tension de développement étant la différence entre le potentiel de surface sur l'élément photosensible après une exposition mais avant le dé-

veloppement de l'encre en poudre et un potentiel de polarisation sur le moyen d'alimentation d'encre en poudre ;
- produire sur ledit élément photosensible d'une plage électrostatique correspondant à une densité optique moyenne ;
- mesurer la tension de développement (V_{DEV}) sur ladite plage électrostatique ;
- développer ladite plage électrostatique en appliquant de l'encre en poudre, donnant une plage d'encre en poudre sur ledit élément photosensible ;
- mesurer la densité optique (D_{OPC}) de ladite plage d'encre en poudre ;
- calculer, en utilisant ladite relation, à partir de ladite tension de développement et de ladite densité optique, de la charge d'encre en poudre (Q/M) ; et
- modifier la concentration d'encre en poudre (TC) en correspondance avec ladite charge d'encre en poudre calculée (Q/M).

2. Procédé selon la revendication 1, dans lequel une modification de ladite concentration d'encre en poudre TC comprend les étapes consistant à augmenter ou à diminuer l'alimentation d'encre en poudre TS.

3. Procédé selon l'une quelconque des revendications précédentes, dans lequel la mesure de la tension de développement V_{DEV} comprend les étapes consistant à :

- mesurer le potentiel après exposition V_E de ladite plage électrostatique ;
- trouver le potentiel de polarisation V_B dudit moyen d'alimentation d'encre en poudre ;
- établir la différence entre V_E et V_B.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape consistant à modifier ladite concentration d'encre en poudre TC est basée sur une charge d'encre en poudre cible $(Q/M)_{CIBLE}$.

5. Procédé selon la revendication 4, dans lequel ladite charge d'encre en poudre $(Q/M)_{CIBLE}$ est calculée en comprenant les étapes suivantes consistant à :

- établir une seconde relation entre l'humidité relative RH et la charge d'encre en poudre cible ;
- mesurer une humidité relative RH ;
- calculer en utilisant ladite seconde relation, à partir de ladite humidité relative mesurée, la charge d'encre en poudre cible $(Q/M)_{CIBLE}$.

6. Procédé selon les revendications 4 ou 5, comprenant les étapes consistant à :

- calculer régulièrement les valeurs Q/M et $(Q/M)_{CIBLE}$;
- utiliser ces valeurs dans un système PID (Proportionnelle-Intégrale-Dérivée) pour calculer le changement de TC exigé.

7. Procédé selon l'une quelconque des revendications 1 à 6, comprenant l'étape consistant à exposer une pluralité de plages sur ledit élément photoconducteur à des niveaux d'exposition différents E_{EXPi}, constant à l'intérieur de chaque plage.

8. Procédé selon la revendication 7, comprenant de plus les étapes consistant à :

- développer lesdites plages par l'application d'encre en poudre ;
- mesurer la densité optique de chaque plage par un densitomètre ;
- établir une table de conversion donnant le niveau d'exposition comme une fonction de la densité optique exigée, sur la base de ladite densité optique mesurée.

9. Procédé selon la revendication 7, comprenant de plus les étapes consistant à :

- mesurer le niveau de tension desdites plages exposées ;
- établir une table de conversion donnant le niveau d'exposition comme une fonction de la densité optique exigée, sur la base dudit niveau de tension mesuré.

10. Dispositif électrophotographique de formation d'image comportant un système de développement à deux composants, comprenant :

- un élément photosensible (1) ;
- un dispositif de charge (2) pour charger l'élément photosensible (1) ;
- un dispositif d'exposition (3) pour exposer l'élément photosensible comprenant l'exposition d'une plage dessus ;
- un capteur de tension électrostatique sans contact (4) pour mesurer un potentiel de décharge de la plage, le potentiel de décharge étant la tension de surface après l'exposition, mais avant le développement d'encre en poudre ;
- un moyen d'alimentation d'encre en poudre (5) pour appliquer l'encre en poudre à l'élément photosensible (1) comprenant l'application d'encre en poudre à la plage pour développer une plage d'encre en poudre ;
- un densitomètre (6) pour mesurer la densité optique de la plage d'encre en poudre ; et
- un système de commande en boucle fermée pour calculer la charge d'encre en poudre (Q/M) à partir d'une relation prédéterminée et pour modifier la concentration d'encre en poudre (TC) selon la charge d'encre en poudre calculée (Q/M),

caractérisé en ce que ladite relation prédéterminée est entre la tension de développement de la plage, la densité optique de la plage d'encre en poudre et la charge d'encre en poudre (Q/M), la tension de développement de la plage étant la différence entre le potentiel de décharge de la plage et un potentiel de polarisation sur le moyen d'alimentation d'encre en poudre (5).

11. Dispositif électrophotographique de formation d'image selon la revendication 10, **caractérisé en ce que** le système de commande en boucle fermée comprend un calculateur (44) pour calculer une charge d'encre en poudre cible (Q/M_{CIBLE}), et un comparateur (41) pour comparer la charge d'encre en poudre calculée (Q/M) de la plage d'encre en poudre à la charge d'encre en poudre cible (Q/M_{CIBLE}).

12. Dispositif électrophotographique de formation d'image selon la revendication 11, **caractérisé de plus par** un capteur d'humidité relative d'environnement (9) et dans lequel le calculateur (44) est conçu pour calculer la charge d'encre en poudre cible (Q/M_{CIBLE}) sur la base de l'humidité relative d'environnement.

13. Dispositif électrophotographique de formation d'image selon la revendication 11 ou 12, **caractérisé en ce que** le système de commande en boucle fermée comprend une unité de commande de processus (42) pour commander la concentration d'encre en poudre (TC) selon la sortie du comparateur (41).

Patentansprüche

1. Verfahren zum Steuern einer Ausgangsdichte in einer elektrofotographischen Vorrichtung mittels eines Zweikomponenten-Entwicklersystems, wobei die Vorrichtung ein fotoempfindliches Element und eine Tonerversorgungseinrichtung aufweist, mit den folgenden Schritten:

- Herstellen einer Beziehung zwischen einer optischen Dichte (D_{OPC}) eines aufgebrachten Toners, einer Entwicklerspannung (V_{DEV}) und einer Tonerladung (Q/M) des aufgebrachten Toners, wobei die Entwicklerspannung den Unterschied zwischen dem Oberflächenpotenzial auf dem fotoempfindlichen Element nach einer Belichtung, aber vor einer Tonerentwicklung und einem Biaspotenzial des Tonerversorgungsmittels bezeichnet,
- Erzeugen eines elektrostatischen Patches auf dem fotoempfindlichen Element entsprechend der mittleren optischen Dichte,
- Messen der Entwicklerspannung (V_{DEV}) an dem elektrostatischen Patch,
- Entwickeln des elektrostatischen Patches durch Anwenden eines Toners, wodurch ein Tonerpatch auf dem fotoempfindlichen Element entsteht,
- Messen der optischen Dichte (D_{OPC}) des Tonerpatches,
- Berechnen der Tonerladung (Q/M) aus der Entwicklerspannung und der optischen Dichte unter Verwendung der Beziehung und
- Modifizieren einer Tonerkonzentration (TC) entsprechend der berechneten Tonerladung (Q/M).

2. Verfahren nach Anspruch 1, wobei eine Modifikation der Tonerkonzentration die Schritte eines Erhöhens oder eines Verringerns der Tonerversorgung TS beinhaltet.

3. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Messen der Entwicklungsspannung V_{DEV} die Schritte beinhaltet:

- Messen eines Potenzials nach einer Belichtung V_E des elektrostatischen Patches,
- Finden eines Biaspotenzials V_B der Tonerversorgungsmittel,
- Bilden des Unterschieds zwischen V_E und V_B.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt des Modifizierens der Tonerkonzentration TC auf einer Soll-Tonerladung $(Q/M)_{Target}$ basiert.

5. Verfahren nach Anspruch 4, wobei die Soll-Tonerladung $(Q/M)_{Target}$ berechnet wird, mit den folgenden Schritten:

- Herstellen einer zweiten Beziehung zwischen einer relativen Feuchtigkeit RH und einer Soll-Tonerladung,
- Messen einer relativen Feuchtigkeit RH,
- Berechnen der Soll-Tonerladung $(Q/M)_{Target}$ aus der gemessenen relativen Feuchtigkeit unter Verwendung der zweiten Beziehung.

6. Verfahren nach einem der Ansprüche 4 oder 5, mit den Schritten:

- regelmäßiges Berechnen der Q/M- und $(Q/M)_{Target}$-Werte,
- Verwenden dieser Werte in einem PID-System, um die benötigte TC-Änderung zu berechnen.

7. Verfahren nach einem der Ansprüche 1 bis 6, mit dem Schritt eines Belichtens einer Vielzahl von Patches auf dem fotoempfindlichen Element mit verschiedenen Belichtungsniveaus E_{EXPi}, welche innerhalb jedes Patches konstant sind.

8. Verfahren nach Anspruch 7, mit den weiteren Schritten:

- Entwickeln der Patches unter Anwendung eines Toners,
- Messen der optischen Dichte jedes Patches durch ein Dichtemessgerät,
- Herstellen einer Umwandlungstabelle, welche einen Belichtungspegel als eine Funktion der benötigten optischen Dichte angibt, basierend auf der gemessenen optischen Dichte.

9. Verfahren nach Anspruch 7, mit den weiteren Schritten:

- Messen des Spannungspegels der belichteten Patches,
- Festlegen einer Umwandlungstabelle, welche einen Belichtungspegel als eine Funktion einer benötigten optischen Dichte angibt, basierend auf dem gemessenen Spannungspegel.

10. Elektrofotographische Bildformungsvorrichtung mit einem Zweikomponenten-Entwicklungssystem, mit:

- einer fotoempfindlichen Einrichtung (1),
- einer Ladevorrichtung (2) zum Laden des fotoempfindlichen Teils (1),
- einer Belichtungsvorrichtung (3) zum Belichten des fotoempfindlichen Teils einschließlich einer Belichtung eines darauf befindlichen Patches,
- einem berührungslosen elektrostatischen Spannungssensor (4) zum Messen eines Entladepotenzials des Patches, wobei das Entladepotenzial die Oberflächenspannung nach der Belichtung, aber noch vor der Tonerentwicklung bezeichnet,
- Tonerversorgungsmittel (5) zum Aufbringen eines Toners auf die fotoempfindliche Einrichtung (1) einschließlich eines Aufbringens des Toners auf den Patch, um einen Tonerpatch zu entwickeln, und
- einem Dichtemessgerät (6) zum Messen der optischen Dichte des Tonerpatches, **gekennzeichnet, durch**
- ein Regelsystem zum Berechnen der Tonerladung (Q/M) aus einer vorbestimmten Beziehung zwischen der Entwicklerspannung des Fleckens, der optischen Dichte des Tonerfleckens und der Tonerladung (Q/M), wobei die Entwicklerspannung des Fleckens den Unterschied zwischen dem Entladungspotenzial des Fleckens und einem Biaspotenzial der Tonerversorgungseinrichtung (5) bezeichnet, und zum Modifizieren einer Tonerkonzentration (TC) entsprechend der berechneten Tonerladung (Q/M).

11. Elektrofotographische Bildformungsvorrichtung nach Anspruch 10, **dadurch gekennzeichnet, dass** das Regelsystem einen Rechner (44) zum Berechnen einer Soll-Tonerladung (Q/M_{Target}) und einen Komparator (41) zum Vergleichen der berechneten Tonerladung (Q/M) des Tonerfleckens mit der Soll-Tonerladung (Q/M_{Target}) beinhaltet.

12. Elektrofotographische Bildformungsvorrichtung nach Anspruch 11, weiter **gekennzeichnet durch** einen Sensor für eine relative Feuchtigkeit (9) der Umgebung und wobei der Rechner (44) zum Berechnen der Soll-Tonerladung (Q/M_{Target}) basierend auf der relativen Feuchtigkeit der Umgebung eingerichtet ist.

13. Elektrofotographische Bildformungsvorrichtung nach Anspruch 11 oder 12, **dadurch gekennzeichnet, dass** das Regelsystem eine Prozesssteuerung (42) zum Steuern der Tonerkonzentration (TC) entsprechend des Ausgangs des Komparators (41) beinhaltet.

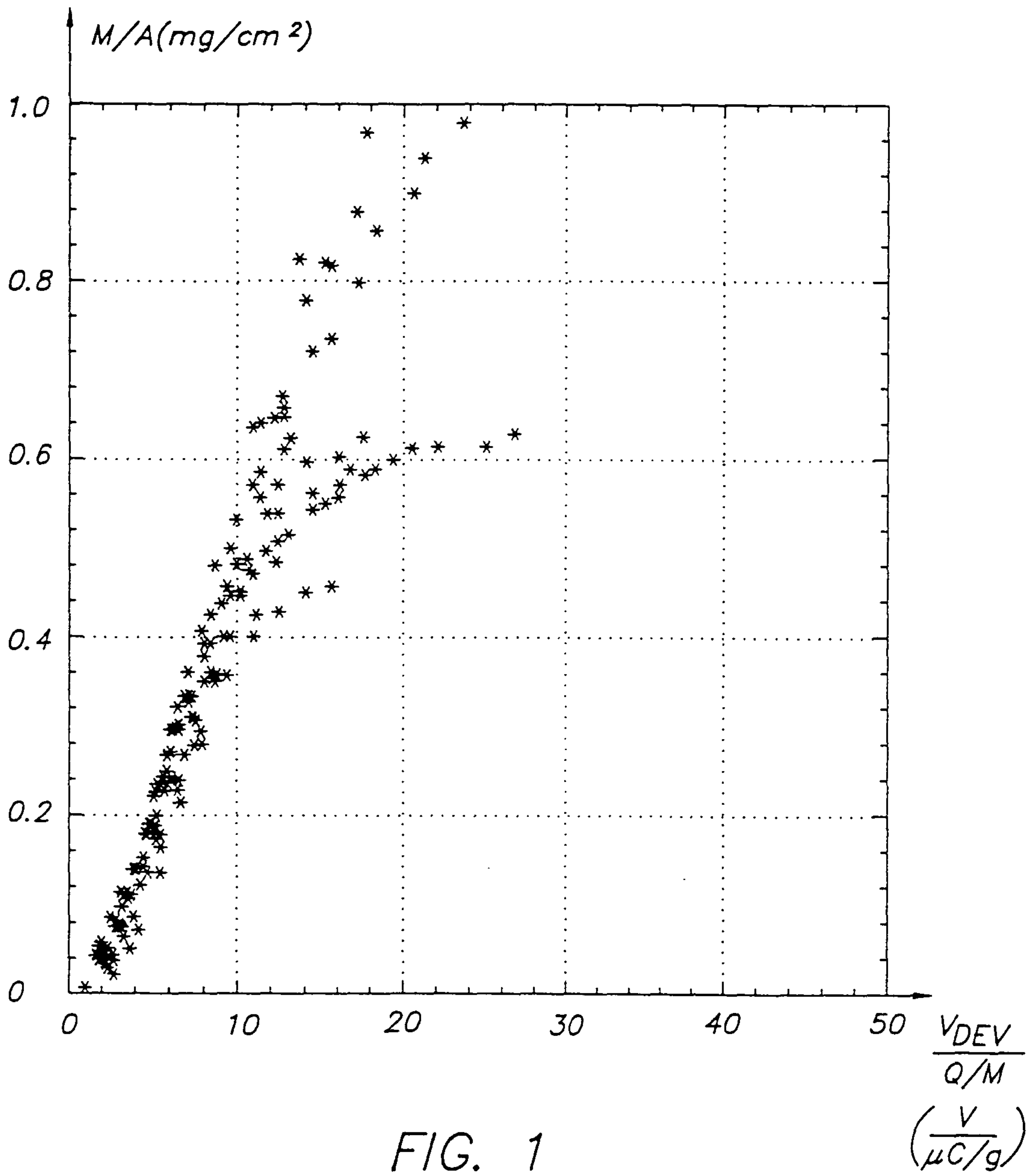


FIG. 1

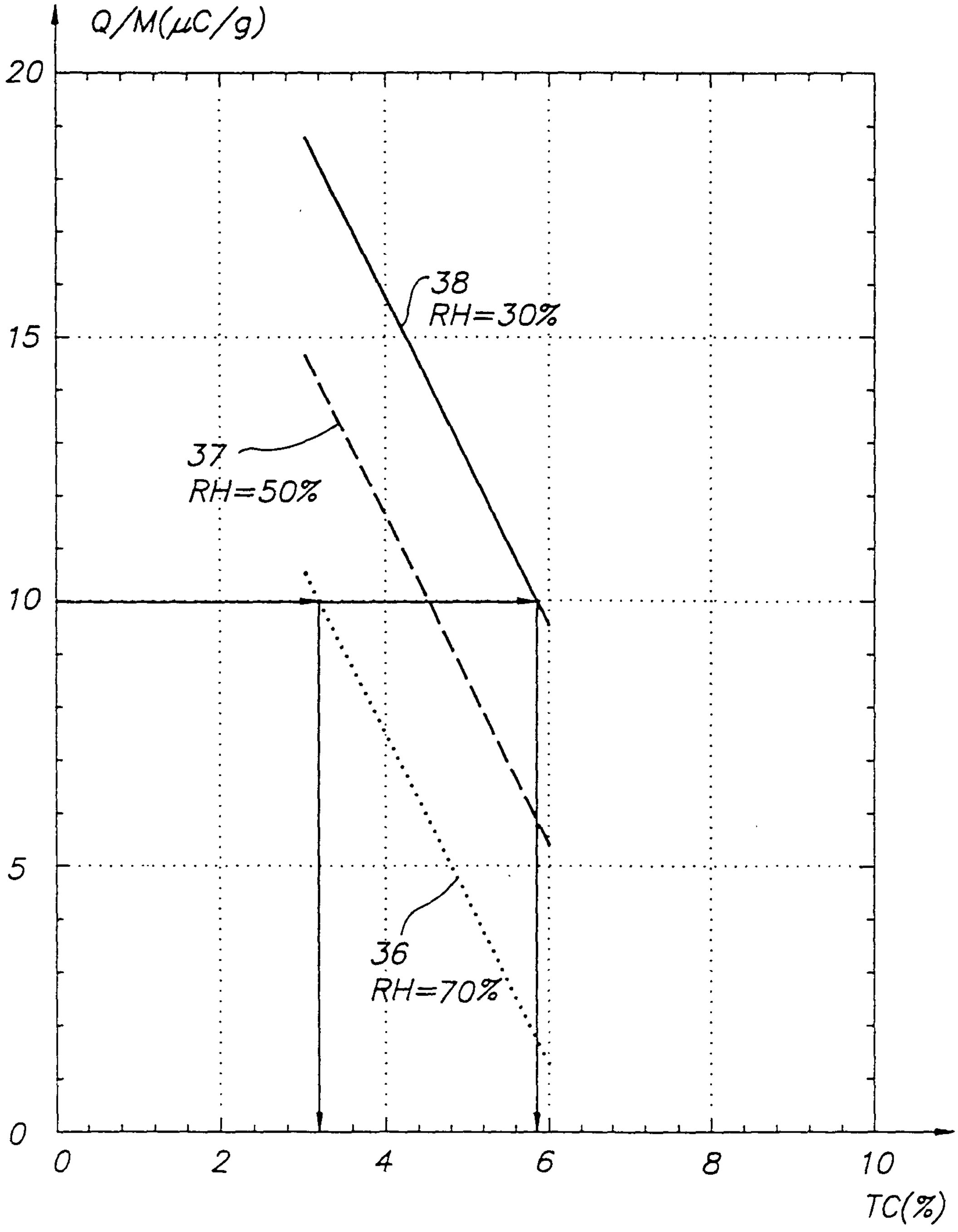
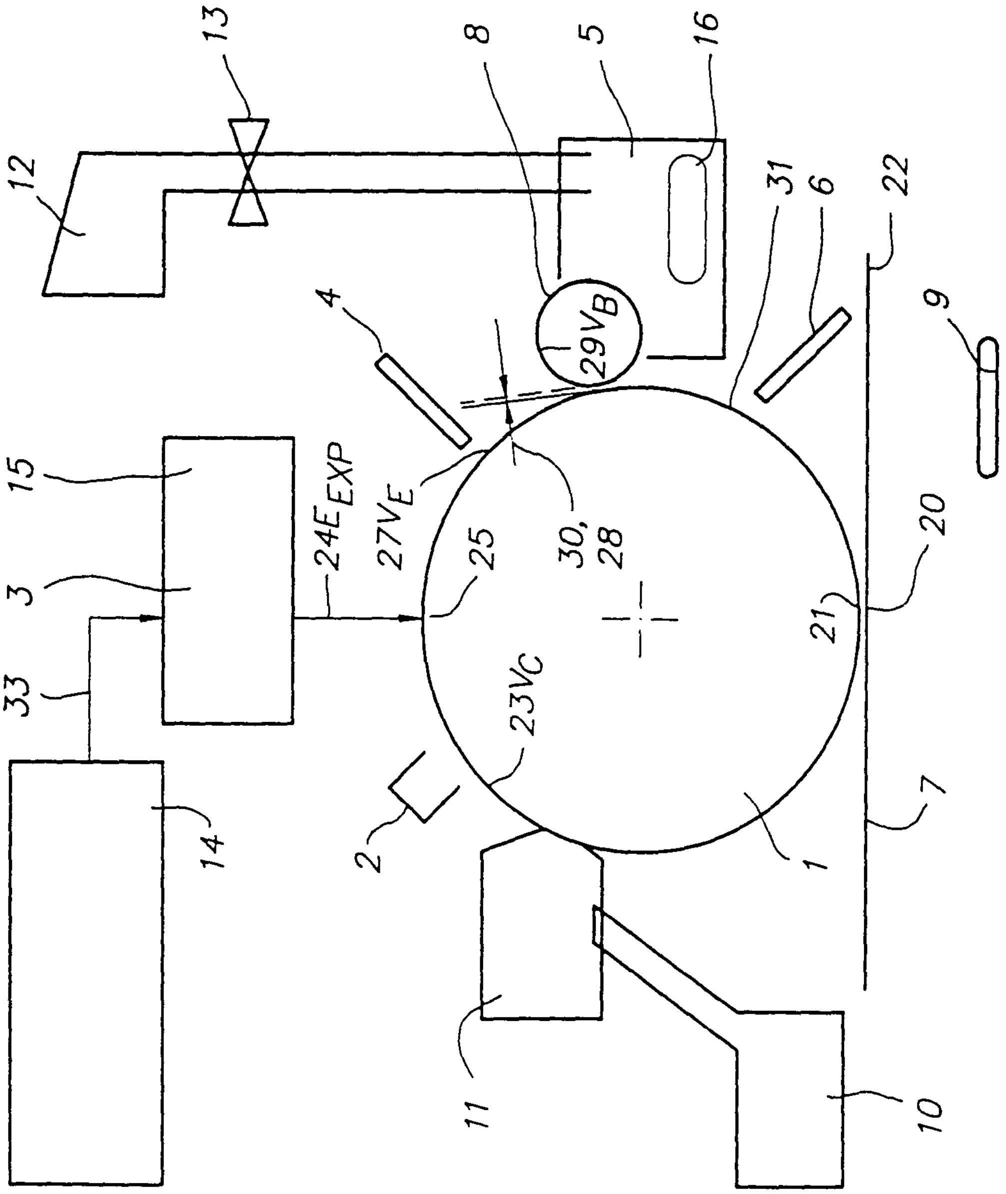


FIG. 2



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
20
21
22
23V_C
24E_{EXP}
25
27V_E
29V_B
30,
28
31
33

FIG. 3

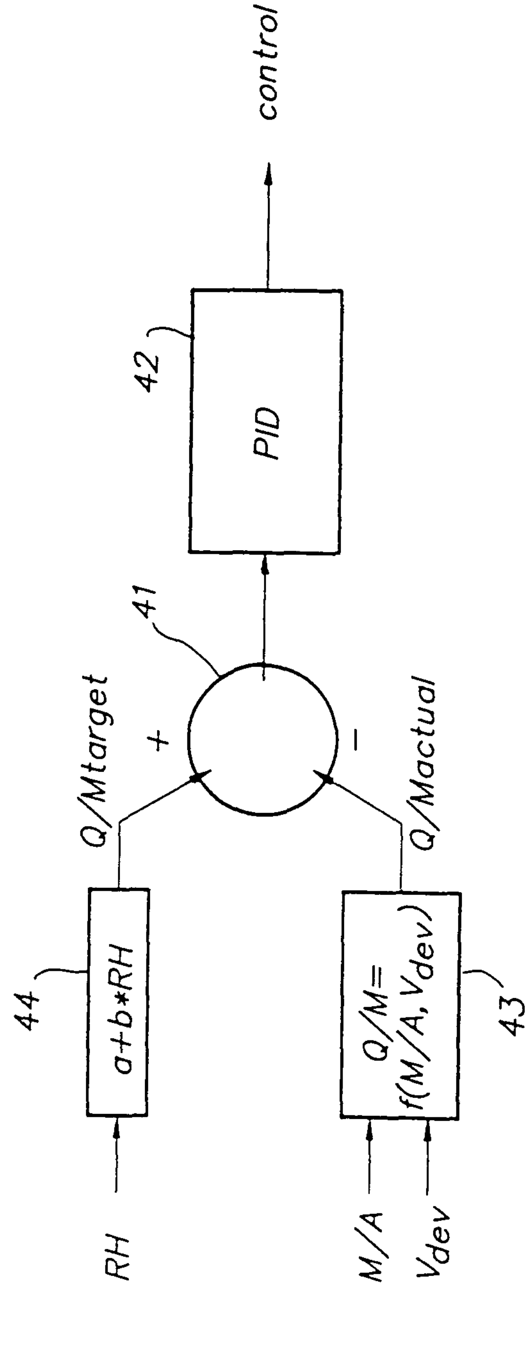

control
PID
42
41
+
−
Q/Mtarget
Q/Mactual
44
a+b*RH
Q/M=
f(M/A, Vdev)
43
RH
M/A
Vdev

FIG. 4

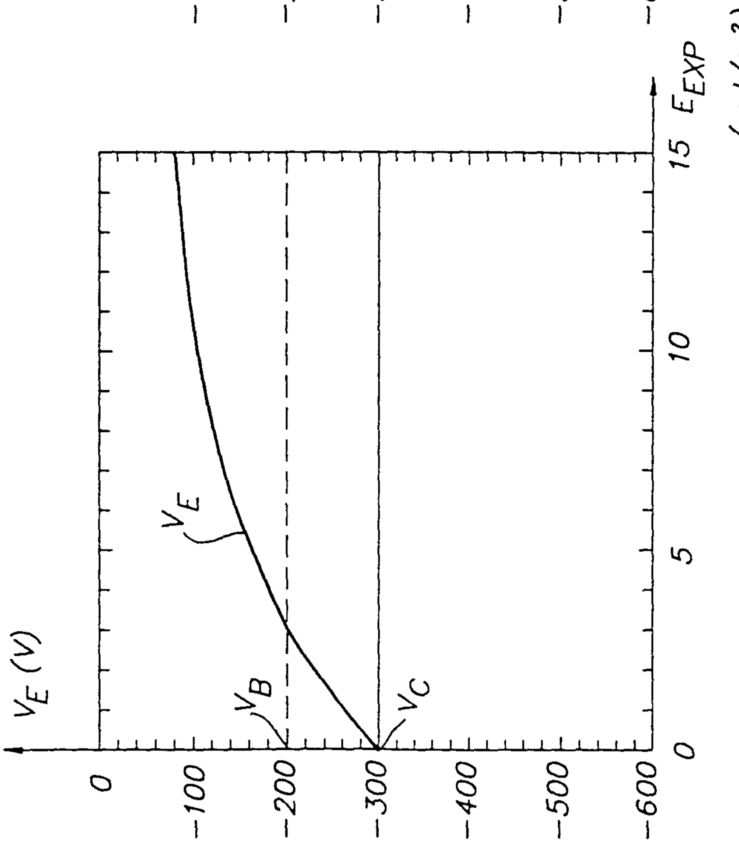

V_E (V)
0
−100
−200
−300
−400
−500
−600
0
5
10
15
E_{EXP}
(mJ/m²)
V_B
V_C
V_E

FIG. 5a

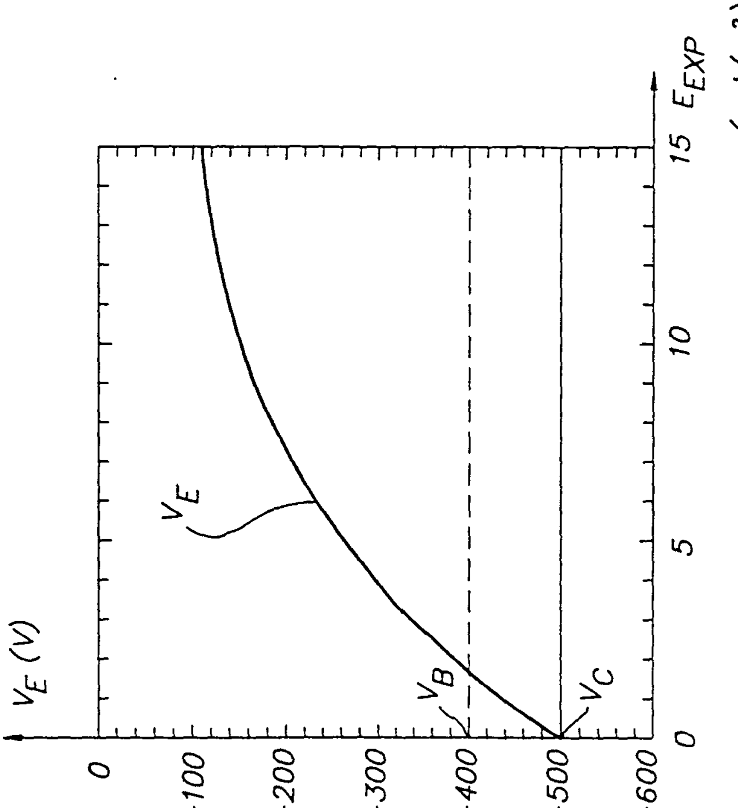

V_E (V)
0
−100
−200
−300
−400
−500
−600
0
5
10
15
E_{EXP}
(mJ/m²)
V_B
V_C
V_E

FIG. 5d

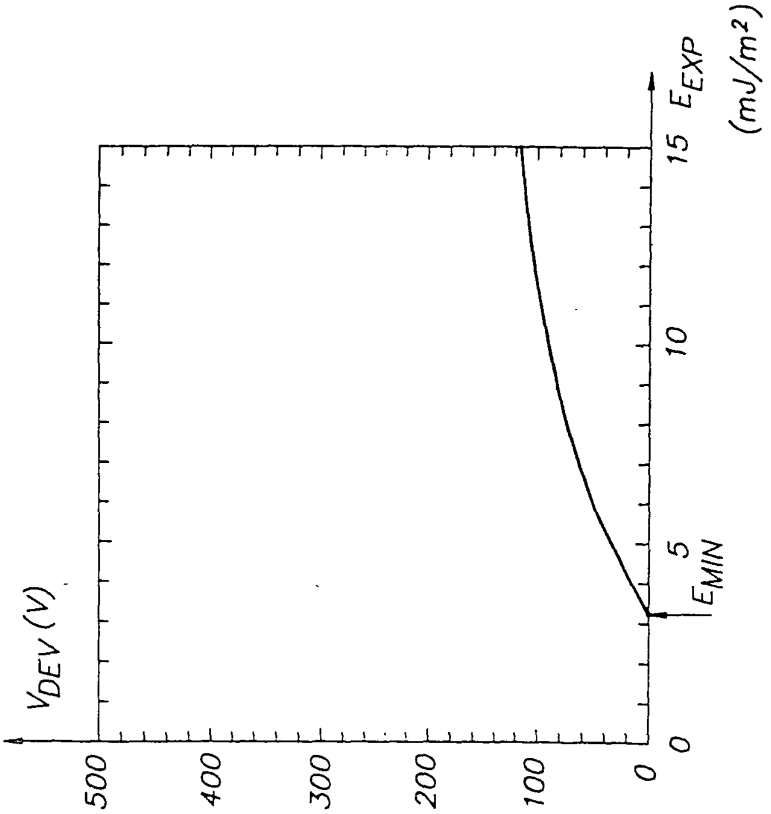

V_{DEV} (V)
500
400
300
200
100
0
0
5
10
15
E_{EXP}
(mJ/m²)
E_{MIN}

FIG. 5b

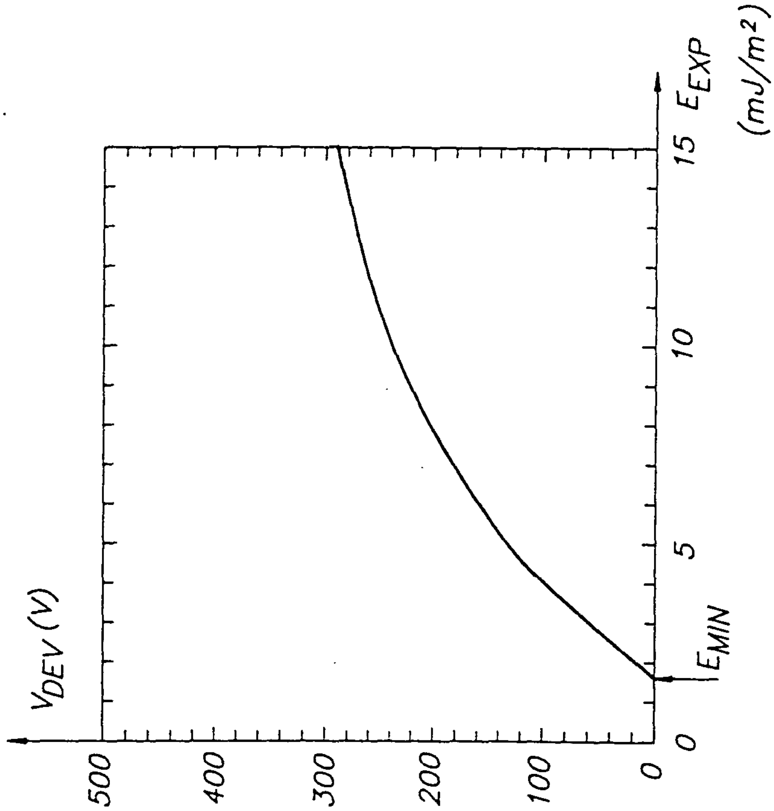

V_{DEV} (V)
500
400
300
200
100
0
0
5
10
15
E_{EXP}
(mJ/m²)
E_{MIN}

FIG. 5e

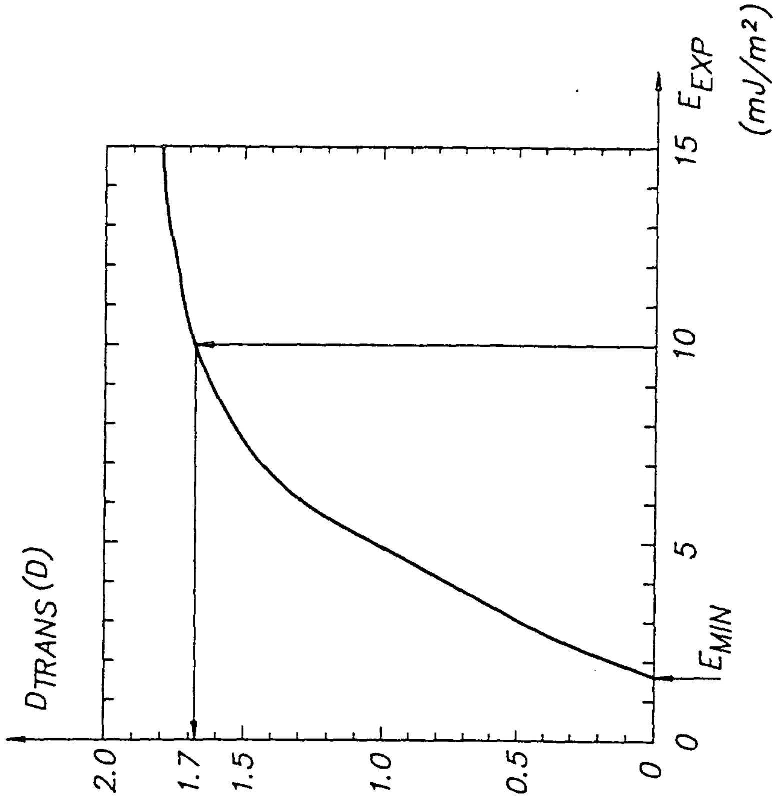

DTRANS (D)
2.0
1.7
1.5
1.0
0.5
0
0
5
10
15
EMIN
EEXP
(mJ/m²)

FIG. 5f

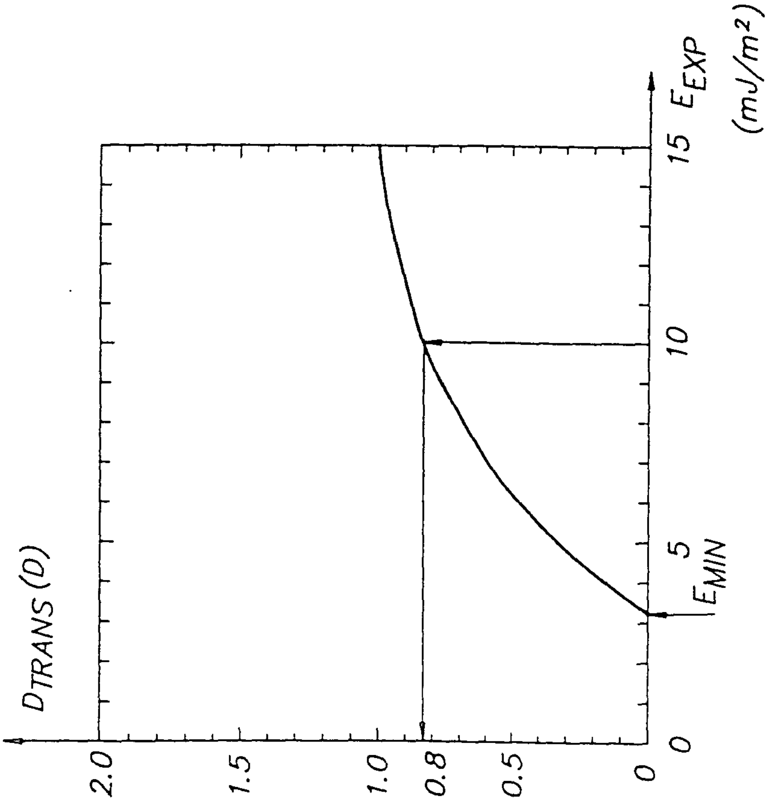

DTRANS (D)
2.0
1.5
1.0
0.8
0.5
0
0
5
10
15
EMIN
EEXP
(mJ/m²)

FIG. 5c

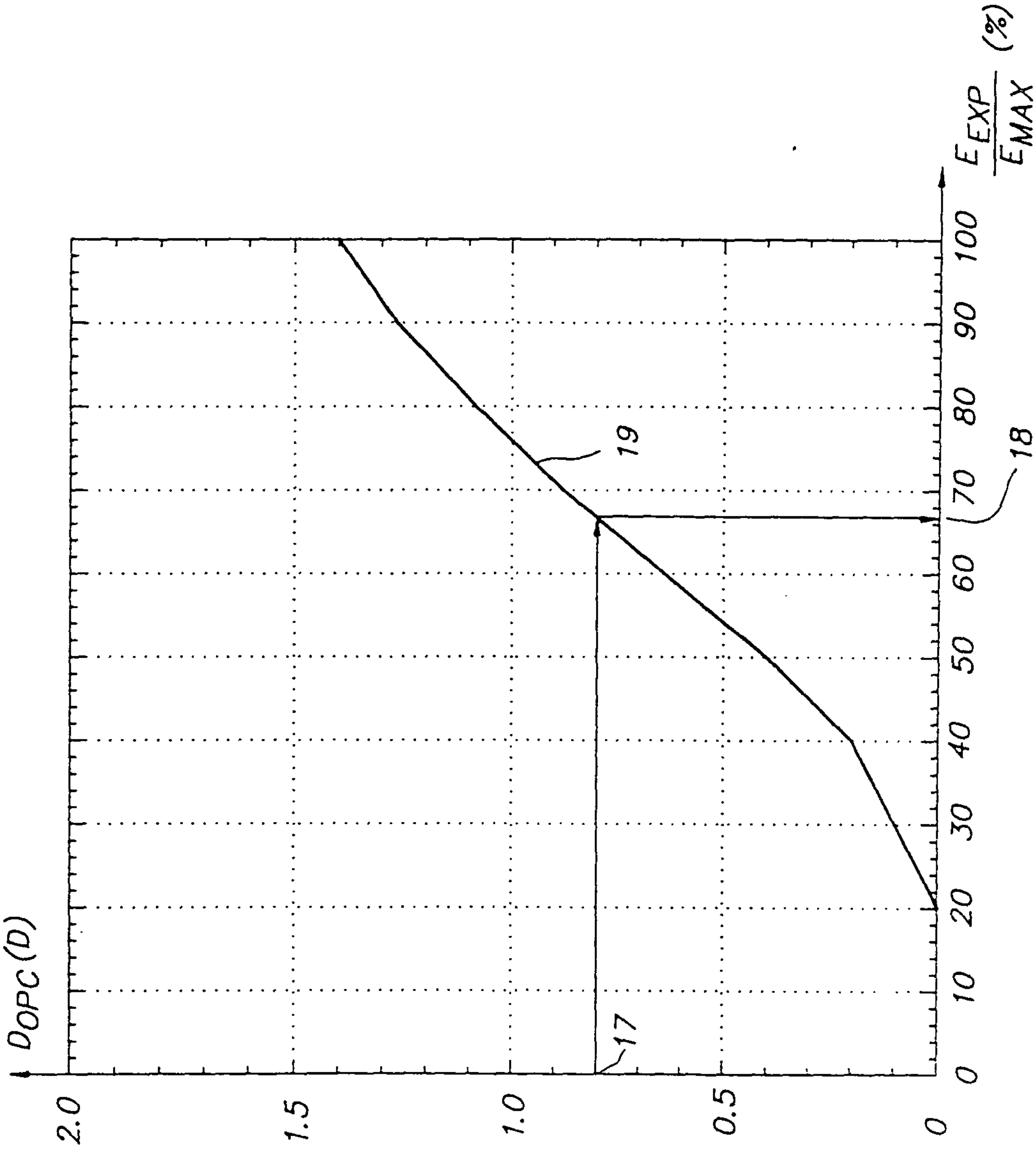

$D_{OPC}(D)$
2.0
1.5
1.0
0.5
0
0
10
20
30
40
50
60
70
80
90
100
$\frac{E_{EXP}}{E_{MAX}}$ (%)
17
18
19

FIG. 6