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Description

This application is divided out from parent application No. 84306683.8 (now EP-B-0143535).

The present invention relates to multiplex image reproducing methods wherein successive toner images are superposed on an image retainer.

Methods known in the art are disclosed in Japanese Patent Laid Open Nos. 144452/81, 116553/83 and 116554/83.

In each of these methods, the image retainer has a surface layer of a photoconductive photosensitive material such as Se, and image development is effected by a reversal method in which toner is applied to an electrostatic image having a lower potential than that of the background, the toner being frictionally charged with the same polarity as the image. According to this method, there arises a problem that the photoconductive photosensitive surface layer is generally and relatively liable to have its electrostatic image retaining performance changed by the charging step and to be subjected to "toner filming" or have its photosensitivity degraded. As compared with such a positive developing method as in the ordinary electrophotographic reproducing machine, i.e., the developing method in which the electrostatic image has a higher potential than the background so that a toner charged with an opposite polarity is applied to that electrostatic image, moreover, the development by the reversal developing method has a problem that control of the toner application is so difficult that a sufficient development density cannot be attained or that a reproducing apparatus is liable to have its inside blotted by scattered toner.

As the method in which an image retainer having a dielectric surface layer is used to retain an electrostatic image on the dielectric surface layer, on the other hand, there is known in the art a method using an electrostatic recording head, a method using a screen photosensitive member (as is disclosed in Japanese Patent Publication No. 34616/79) or a method using a screen control electrode. The electrostatic image retaining methods thus disclosed are superior in that the electrostatic image retainability and the toner image retainability required of the photosensitive member are separate from each other. In these methods, more specifically, it is deemed that the task of retaining the electrostatic image is borne by the electrostatic recording head, the screen photosensitive member or the screen control electrode, whereas the task of retaining the toner image is borne by the dielectric surface layer. Those methods are featured in that color data is retained consecutively and independently as the electrostatic image on the dielectric surface layer. However, the toner image formed on the dielectric surface layer cannot be other than a monochromatic one at all times.

This is because the developing method is conducted by contact development so that a previous toner image is disturbed or color mixing occurs upon development even if another electrostatic image could be recorded on the previously formed toner image.

As the method in which an image retainer having a magnetic surface layer is used to form a magnetic image on the magnetic layer, on the other hand, there are known in the art methods which are disclosed in Japanese Patent Laid-Open Nos. 90342/75, 100732/76 and 106253/81. These reproducing methods are excellent in that the retainability of an electrostatic image by the corona discharge or the like and the retainability of a toner image required of the photosensitive member can be separate from each other. In the reproducing methods using the magnetic image, more specifically, it is deemed that retention of the magnetic image makes use of the inside of the magnetic layer while not having its surface state changed, which is different from methods using a photosensitive member, and that the task of the toner image retainability is borne by the surface of the magnetic layer. Those methods are featured in that the color data can be newly retained as the magnetic image independently of the toner image formed on the magnetic surface layer. However, the toner image retained on the magnetic layer cannot be other than a monochromatic one at all times.

The method disclosed in Japanese Patent Laid-Open No. 144452/81 retains a color image on an image retainer: by forming an electrostatic image on the surface of an image retainer, which has been charged by a charger, by first exposure means and developing it by first developing means; by forming an electrostatic image on the same charged surface by second exposure means and developing it by second developing means; and by forming an electrostatic image on the same charged surface by third exposure means and developing it by third developing means. The method thus specified has problems that separate exposure means are required for the respective ones of the repeated formations of the electrostatic images thereby enlarging the size of the reproducing apparatus and raising the cost of the same, and that synchronization of the exposure of the respective exposure means with the image retainer has relationships with the respective positions of the exposure means so that the synchronous control is troublesome thereby to make it liable to color shift. Moreover, each of the development steps in that method is conducted by the forced method in which the electrostatic image having a lower potential at its exposed portion than that of the background has toner applied thereto charged with the same polarity. In that forced developing method, the toner for effecting the charge at the same polarity as that of the charge of the image retainer is so used in the developer that it may not be applied to the background. As a result, the reversal developing method has a problem that although the toner is repulsed by the background potential so that it is reluctant to create any fog, it is also reluctant to be attracted to the electrostatic images so that a sufficient developed density can hardly be obtained.

Since the reversed image is obtained, according to this reversal developing method, color reproduction of a positive image cannot be effected so that the coloring is limited to the technique using the dot exposure of a printer or the like. In case it is intended to obtain a positive image when an ordinary original is to be reproduced, it is reversed, and the counter-measure for this reversal is difficult. The potential at the photosensitive layer of the exposed portion has the same polarity as that of the developer and, although it is low, the reversal developing method has a problem that the developer is reluctant to be attracted to the electrostatic image so that it is liable to be scattered to blot the inside of the reproducing apparatus.

On the other hand, Japanese Patent Laid-Open No. 144452/81 describes a non-contact jumping developing condition in which the second and later developments by the reversal developing method are conducted such that the layers of the developers formed by the developing means are not in contact with the surface of the image retainer. This method has problems that the development is reluctant to have a sufficient density and is liable to be blotted with scattered toner unless a strong bias voltage is applied to the developing means to strongly attract the toner to the electrostatic images. Where such a strong bias voltage is applied to the developing means, it is liable to leak to the image retainer or the like, or toner of another color is liable to adhere to the toner image developed before or to the background.

The methods disclosed in Japanese Patent Laid-Open Nos. 116553/83 and 116554/83 are substantially the same as that in Japanese Patent Laid-Open No. 144452/81 in that the formation and development of the electrostatic images are conducted by different means for the respective repetitions. As a result, those methods also have problems in that the reproducing apparatus has its size enlarged thereby to raise the cost, and that synchronous control of the exposures of the respective exposing means is so difficult as to invite color shift. Here, the method disclosed in Japanese Patent Laid-Open No. 116554/83 is different from the method disclosed in Japanese Patent Laid-Open No. 144452 in that the respective developments by the reversal developing method are conducted under the contact developing condition, in which the developer layers formed by the developing means brush the surface of the image retainer, thereby to solve the problems of the reversal developing method that sufficient developing density can hardly be obtained and that the toner is liable to be scattered. The method disclosed in Japanese Patent Laid-Open No. 116553/83 is different from Japanese Patent Laid-Open No. 144452/81 in that, in the second and later retentions of the electrostatic images, the surface of the image retainer is recharged before exposure by the chargers, which are placed in front of the respective exposing means, so that toner of another color should not be attracted during a later development to the portions having the toner adhered thereto after the previous development. Since the second and later developments are conducted under the contact developing condition, however, those methods have a serious problem that the toner adhered after the previous development is liable to be shifted during the subsequent development or to be mixed into the developer of the subsequent developing means.

A prototype in which an electrostatic latent image is expressed in a multi-color image is concerned with color image reproduction using an electrophotographic system. This system of the prior art separates the colors of an original by an optical filter and repeats the charging, exposing, developing and transferring steps by using the separated colors. In order that respective images of colors such as yellow, magenta, cyan and black may be retained, more specifically, those steps are repeated four times by that system. There also exists the so-called "dichromatic developing method", in which electrostatic latent images of different polarities are formed on a common photosensitive member (or an image carrier) and are developed by toners of black and red colors. These multicolor image retaining methods are desirable, because they can add color data as compared with the data obtained from the dichromatic images, but have the following problems:

(1) Transfer to a transfer member is required at each development of each color thereby to enlarge the size of the machine and to elongate the time period necessary for image retention; and

(2) It is necessary to ensure the accuracy of positional shifts resulting from the repetitions.

In view of these problems, there has been conducted a trial in which a plurality of toner images are developed in a superposed manner on a common photosensitive member so that the transfer step may be finished in one step thereby to reduce the size of the machine.

As the developer to be used in this machine, there exists a two-component developer, which is composed of a toner and a carrier, and a one-component developer which is composed only of a toner. The one-component developer has some problems in the charge control of the toner but has advantages that no consideration is necessary into the concentration and agitation of the toner and the carrier, and that the size of the machine can be reduced.

The two-component developer requires control of the ratio of the toner to the carrier but has an advantage that it is easy to control the frictional charges of the toner particles. Since a magnetic material of black color need not be much contained in the toner particles, on the other hand, the two-component developer composed of a magnetic carrier and a non-magnetic toner can use a color toner having no color turbidity by the magnetic material so that a clear color image can be formed.

In the multiplex development, incidentally, it is sufficient to repeat several times the developments of the photosensitive member which has already been formed with the toner image. However, the multiplex development has problems that the toner image retained at a previous step on the photosensitive member is disturbed upon development of a subsequent step, and that the toner having already been applied to the photosensitive member is returned to a developing sleeve acting as a developer carrier until it steals into the developing means at a subsequent step, in which is retained a developer of a color different from that of the developer of the previous step, thereby to cause color mixing. In order to obviate those problems, there is disclosed in Japanese patent Laid-Open No. 144452/81, for example, means for superposing an a.c. component upon a developing bias while the photosensitive member is out of contact with the developer layer on the developing sleeve acting as the developer carrier for developing an electrostatic latent image, except the developing means for first forming the toner image on the photosensitive member. However, there arises a problem that the image can neither have a sufficient density nor be freed from the disturbance or color mixing.

From GB-A-2 111 868 it is known that for one-component developer certain conditions between the alternating field and the gap between image retainer and developer feeding carrier should be satisfied.

The present invention has been conceived so as to solve the above problems which arise with the image reproducing method of the prior art.

According to the present invention there is provided a method of reproducing multiplex images comprising the steps of forming an electrostatic image on an image retainer, developing the electrostatic image formed on the image retainer by using a developer (D) consisting of carrier and toner particles, and repeating said steps to superpose a plurality of toner images on the image retainer, characterized in that the or each subsequent developing step to be carried out on said image retainer already retaining a developed toner image or superposed images is carried out under the conditions:

$$0.2 \leqq | V_{AC} / (d \cdot \underline{f}) |$$
$$| \{(V_{AC} / d) - 1500\} / \underline{f} | \leqq 1.0$$

where V_{AC} is an amplitude (V) and $\underline{f}$ is a frequency (Hz) of an AC component of the developing bias, and d is the gap (mm) between the image retainer and a developer feeding carrier for feeding developer (D).

In another aspect the invention provides a method of reproducing multiplex images comprising the steps of forming an electrostatic image on an image retainer, developing the electrostatic image formed on the image retainer by using a one-component developer (D), and repeating said steps to superpose a plurality of toner images on the image retainer, characterized in that the or each subsequent developing step to be carried out on said image retainer already retaining a developed toner image or superposed images is carried out under the condition:

$$0.2 \leqq | V_{AC} / (d \cdot \underline{f}) | \leqq 1.6$$

where V_{AC} is an amplitude (V) and $\underline{f}$ is a frequency (Hz) of an AC component of the developing bias, and d is the gap (mm) between the image retainer and a developer feeding carrier for feeding developer (D).

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view showing the construction of one embodiment of reproducing apparatus suitable for practicing a method according to the present invention;

Fig. 2 is a schematic view showing the construction of a laser beam scanner for image exposure;

Fig. 3 is a partially sectional view showing one example of developing means;

Figs. 4 and 5 are schematic views showing examples of recording apparatus suitable for practicing a method according to the present invention;

Figs. 6 to 8 are flow charts showing steps in methods of the present invention;

Figs. 9 to 16 show a further embodiment of apparatus for carrying out a method according to the present invention, in which:

Fig. 9 is a sectional view showing developing means and a photosensitive drum;

Figs. 10 and 11 are diagrams showing changes in the image density when an A.C. current is changed;

Fig. 12 is a diagram showing the density characteristics when a field intensity and a frequency are changed;

Figs. 13 and 15 are schematic views showing the essential portions of a multiplex image reproducing apparatus equipped with a plurality of developing means;

Fig. 14 is a chart showing changes in the surface potential of the photosensitive drum which is used in the multiplex image reproducing apparatus of Figure 13;

Fig. 16 is a chart showing changes in the surface potential of the photosensitive drum which is used in the multiplex image reproducing apparatus of Figure 15;

Figs. 17 and 18 are diagrams showing changes in image density when an A.C. voltage applied to the developing means is changed; and

Fig. 19 is a diagram showing the density characteristics when a field intensity and a frequency are changed.

The present invention will be described in detail in the following in connection with the embodiments thereof with reference to the accompanying drawings.

Fig. 1 is a schematic view showing the construction of one example of recording apparatus for practising a method according to the present invention; Fig. 2 is a schematic view showing a laser beam scanner for image exposure; and Fig. 3 is a partially sectional view showing one example of developing means.

In the recording apparatus of Fig. 1: reference numeral 1 is a drum-shaped image retainer which is formed with a photoconductive photosensitive material such as Se and which is made rotatable in the direction of the arrow; numeral 2 is a charger for uniformly charging the surface of the image retainer 1; numeral 3 is an exposing lamp for uniformly exposing to a weak optical ray the surface of the image retainer; numeral 4 is an image exposing ray of color images of different colors; numerals 5 to 8 are developing means using as their developers toners of different colors such as yellow, magenta, cyan or black; numerals 9 and 10 are a pre-transfer charger and a pre-transfer exposing lamp which are provided, if necessary, respectively, so that a color image retained on the image retainer 1 with its plural superposed color toner images may be easily transferred to a recording member P; numeral 11 is transfer means; numeral 12 is fixing means for fixing the toner images transferred to the recording member P; numeral 13 is charge eliminating means which is composed of a charge eliminator and/or a charge eliminating corona discharger; and numeral 14 is cleaning means having a cleaning blade or a fur brush which is adapted to come into contact with the surface of the image retainer 1 after transfer of the color images for eliminating the residual toners left on the surface thereby to clean the surface of the image retainer 1.

Here, it is preferable to use as the charger 2 a corona discharger, as shown, which can apply such a stable charge as is hardly affected by a previous charge, especially in case the surface of the image retainer having already been charged is to be additionally charged. In case the drum-shaped image retainer 1 is used in that reproducing apparatus, moreover, the image exposing ray 4 may be such an optical ray as has been prepared by filtering a slit ray separately for colors, for example, the optical ray of an ordinary monochromatic electrophotographic reproducing machine. In order to reproduce a clear color image, however, an optical ray prepared by the laser beam scanner, as shown in Fig. 2, is preferable.

The laser beam scanner of Fig. 2 forms the image exposing ray 4 for scanning the surface of the image retainer 1 at a constant speed by turning on and off the laser beam, which has emanated from a laser 21 such as a He-Ne laser, by means of an acoustic-optical modulator 22 to deflect by means of a mirror scanner 23 composed of a rotating polygonal, e.g. octagonal, mirror thereby to guide it through a focusing f-θ lens 24. Incidentally, reference numerals 25 and 26 indicate mirrors, and numeral 27 indicates a lens for enlarging the diameter of a beam incident upon the focusing f-θ lens 24 so as to reduce the diameter of the beam on the image retainer 1. If such a laser beam scanner as is shown in Fig. 2 is used for forming the image exposing ray 4, the electrostatic images can be easily retained with a shift for different colors, as will be described hereinafter, so that a clear color image can be reproduced. Despite this fact, the image exposing ray 4 is not limited to the slit exposing ray or a dot exposing ray by the laser beam but may be one which is prepared by using an LED, a CRT, a liquid crystal or an optical fiber transmitter, for example. In the reproducing apparatus in which the image retainer has a planar shape such as a belt shape, moreover, the image exposing ray may be a flash light.

As the developing means 5 to 8, on the other hand, there can preferably be used those which have a construction as shown in Fig. 3.

In Fig. 3: reference numeral 31 indicates a developing sleeve which is made of a non-magnetic material such as aluminum or stainless steel; numeral 32 is a magnet which is equipped in the circumferential direction with a plurality of magnetic poles disposed inside the developing sleeve 31; numeral 33 is a layer thickness regulating blade for regulating the thickness of a developer layer formed on the developing sleeve 31; numeral 34 is a scraper blade for scraping the developer layer after development from the surface of the developing sleeve 31; numeral 35 is an agitating rotor for agitating the developer in a developer reservoir 36; numeral 37 is a toner hopper; numeral 38 is a toner supply roller which is formed in its surface with a recess for receiving the toner to supply the toner from the toner hopper 37 to the developer reservoir 36; and numeral 39 is a power supply for applying a bias voltage containing an oscillating voltage component to the developing sleeve 31 through a protecting resistor 40 to generate an electric field for controlling movement of the toner between the developing sleeve 31 and the image retainer 1. Fig. 3 shows that the developing sleeve 31 and the magnet 32 are rotatable in the directions of the arrows. It is, however, sufficient that the developing sleeve 31 and the magnet 32 be fixed, or that the developing sleeve 31 and the magnet 32 be rotatable in a common direction. In case the magnet 32 is fixed, it is customary to strengthen the magnetization or to dispose two magnetic poles of identical or different polarities adjacent to each other so that the density of the magnetic flux of the magnetic pole facing the image retainer 1 is stronger than that of the other magnetic pole.

In these developing means, the magnetic poles of the magnet 32 are usually magnetized to a density of magnetic flux of 500 to 5,000 gauss to attract the developer in the developer reservoir 36 to the surface of the developing sleeve 31 by that magnetic force so that the attracted developer is formed, while having its thickness regulated by the layer thickness regulating blade 33, into a developer layer. This developer layer is moved in the same direction as or in the opposite direction (although Fig. 3 shows the same direction) to the rotating direction of the image retainer 1, as indicated by the arrow, to develop the electrostatic image on the image retainer 1 in the developing region where the surface of the developing sleeve 31 faces the surface of the image retainer 1, whereas the residual toner is scraped away from the surface of the developing sleeve 31 by the scraper blade 34, until it is returned to the developer reservoir 36. Moreover, the development, e.g., at least the second or subsequent developments, which are repeated for superposing the color toner images, is conducted under the non-contact jumping developing condition so that the toner attracted by the image retainer 1 during the previous development is not shifted by the later development. Fig. 3 shows the state in which the development is executed under the non-contact jumping developing condition.

Moreover, it is preferable to use in the developing means 5 to 8 the so-called "two-component developer" which is composed of a non-magnetic toner and a magnetic carrier and which enables a toner image of clear color to be obtained without any necessity for containing a black or brown magnetic material in the toner and to easily effect control of charging the toner. Specifically, the magnetic carrier is preferably an insulating carrier which has a resistivity of 10^8 Ω cm or more or, preferably, 10^{13} Ω cm or more and which is prepared either by dispersing and containing fine particles of a ferromagnetic or paramagnetic material such as tri-ion tetroxide γ-ferric oxide, chromium dioxide, manganese oxide, ferrite or manganese-copper alloy in a resin such as a styrene resin, a vinyl resin, an ethyl resin, a denaturated rosin resin, an acrylic resin, a polyamide resin, an epoxy resin or polyester resin, or by covering the surfaces of the particles of those magnetic materials with the above-specified resins. If that resistivity is low, there arises a problem, in case the bias voltage is applied to the developing sleeve 31, that the charges are caused to migrate into the carrier particles so that they become liable to be trapped by the surface of the image retainer 1 and so that the bias voltage is not sufficiently applied. Especially, if the carrier particles are trapped by the image retainer 1, the color image has its tone adversely affected.

Incidentally, the resistivity is a value which is obtained by tapping the particles in a container having an effective sectional area of 0.50 cm^2, by subsequently loading the tapped particles with a load of 1 Kg/cm^2, and by reading out a current value when a voltage for generating an electric field of 1.000 V/cm is applied across the load and the bottom electrode.

If the carriers have an average particle diameter less than 5 μm, on the other hand, the magnetization obtainable becomes too weak. If the average particle diameter of the carriers exceeds 50 μm, there arise tendencies that the image is not improved, and that a breakdown and a discharge become liable to occur so that a high voltage cannot be applied. Therefore, the average particle diameter preferably has a value more than 5 μm and less than 50 μm, and a fluidizer such as hydrophobic silica is suitably added, if necessary.

The toner is preferably prepared by adding a variety of pigments and, if necessary, a charge controlling agent to a resin to have an average particle diameter of 1 to 20 µm and preferably to have an average charge of 3 to 300 µc/g or, especially, 10 to 100 µc/g. If the toner has an average particle diameter smaller than 1 µm, it becomes reluctant to leave the carrier. If the average particle diameter exceeds 20 µm, on the other hand, the image has its resolution degraded.

As the toner, there is used a magnetic or non-magnetic toner which is used as an ordinary toner and which is prepared by dispersing a coloring agent if necessary and a suitable amount of magnetic material in a known resin. As the resin, there can be enumerated a synthetic resin such as: phenol, polystyrene, alkyd, polyacryl or polyethylene; polycarbonate, polyester, polyamide, polyether, polyolefin, polystyrene, a styrene-acrylate copolymer, a styrene-methacrylate copolymer, an unsaturated styrene-ethylene monoolefin copolymer, styrene-vinylester copolymer, a styrene-vinylester copolymer, a styrene-vinylether copolymer, a styrene-acrylonitrile copolymer, a styrene-methacrylonitrile copolymer, a styrene-acrylamide copolymer, a styrene-halogated vinylidene copolymer or polyvinyl acetate; a binary, ternary or more copolymer of those; or a mixture of those copolymers.

As the coloring agent there are enumerated a variety of inorganic pigments, an organic pigment, a direct dye, an acid dye, a basic dye, a mordant, an acid mordant dye, a dispersed dye, an oil-soluble dye and so on. As a black pigment, more specifically, there can be enumerated carbon black, acetylene black, lamp black, graphite, mineral black, aniline black, cyanine black and so on. As a yellow pigment, there can be enumerated chrome yellow, zinc yellow, barium chromate, cadmium yellow, lead cyanamide, calcium plumbate, Naphthol Yellow S, Hansa Yellow 10G, Hansa Yellow 5G, Hansa Yellow 3G, Hansa Yellow G, Hansa Yellow GR, Hansa Yellow A, Hansa Yellow RN, Hansa Yellow R, Pigment Yellow L, Benzine Yellow, Benzine Yellow G, Benzine Yellow GR, Permanent Yellow NCG, Vulcan Fast Yellow 5G, Vulcan Fast Yellow R, Tartrazine Yellow Lake, Quinoline Yellow Lake, Anthragen Yellow 6GL, Permanent Yellow FGL, Permanent Yellow H10G, Permanent Yellow HR, Anthrapyrimidine Yellow, and so on. As a red pigment, there can be enumerated a red iron oxide, red lead, silver vermilon, Cadmium Red, Permanent Red 4R, Para Red, polytungustophosphoriclacid, Fire Red, vermilion, Parachlor Orthonitroaniline Red, Lithol Fast Scarlet G. Brilliant Fast Scarlet, Brilliant Carmine BS, Permanent Red F2R, Permanent Red F4R, Permanent Red FRL, Permanent Red FRLL, Permanent Red F4RH, Fast Scarlet VD, Vulcan Fast Rubin B, eosine lake, Rhodamine Lake, Rhodamine Lake Y, Alyzarin lake, Thioindigo Red B, Thioindigo maroon, Permanent Red FGR, PV Carmine HR, and so on. As a blue pigment, there can be enumerated ultramarine, prussian blue, cobalt blue, Alkali Blue Lake, Peacock Blue Lake, Victoria Blue Lake, Metalless Phthalocyanine Blue, copper phthalocyanine, Fast Sky Blue, Indanthrene Blue RS, Indanthrene Blue BS, Indigo, and so on. As a yellow dye, there can be enumerated C.I. (i.e., Color Index) Direct Yellow 98, C.I. Direct Yellow 89 and C.I. Direct Yellow 88 (all of which are of the direct type), C.I. Acid Yellow 1, C.I. Acid Yellow 3 and C.I. Acid Yellow 7 (all of which are of the acid type), C.I. Basic Yellow 1, C.I. Basic Yellow 2 and C.I. Basic Yellow 11 (all of which are of the basic type), C.I. Modern Yellow 26 (which is of the mordant or acid mordant type), C.I. Disperse Yellow 1, C.I. Disperse Yellow 3 and C.I. Disperse Yellow 4 (all of which are of the disperse type), C.I. Solvent Yellow 2, C.I. Solvent Yellow 6 and C.I. Solvent Yellow 14 (all of which are of the oil soluble type), and so on. As a red dye, there can be enumerated C.I. Direct Red 1, C.I. Direct Red 2 and C.I. Direct Red 4 (all of which are of the direct type), C.I. Acid Red 8, C.I. Acid Red 13 and C.I. Acid Red 14 (all of which are of the acid type), C.I. Basic Red 2, C.I. Basic Red 14 and C.I. Basic Red 27 (all of which are of the basic type), C.I. Modern Red 21 (which is of the mordant or acid mordant type), C.I. Disperse Red 1, C.I. Disperse Red 4 and C.I. Disperse Red 5 (all of which are of the disperse type), C.I. Solvent Red 1, C.I. Solvent Red 3 and C.I. Solvent Red 8 (all of which are of the oil-soluble type), and so on. As a blue dye, there can be enumerated C.I. Direct Blue 1, C.I. Direct Blue 6 and C.I. Direct blue 22 (all of which are of the direct type), C.I. Acid Blue 1, C.I. Acid Blue 7 and C.I. Acid Blue 22 (all of which are of the acid type), C.I. Basic Blue 7, C.I. Basic Blue 9 and C.I. Basic Blue 19 (all of which are of the basic type), C.I. Modern Blue 48 (which is of the mordant or acid mordant type), C.I. Disperse Blue 1, C.I. Disperse Blue 3 and C.I. Disperse Blue 5 (all of which are of the disperse type), C.I. Solvent Blue 2, C.I. Solvent Blue 11 and C.I. Solvent Blue 12 (all of which are of the oil-soluble type), and so on. However, the coloring agent should not be limited to those thus far enumerated. Moreover, the colors of the toners should not be limited to the above-specified four but can be freely selected in accordance with the object of use.

As the magnetizing material for magnetizing the toner, there can be used a material which is similar to that used in the carrier. The amount of addition of the magnetic material is preferred to be smaller than 60 wt. % of the toner and especially preferred to be up to 30 wt. % so that the clarity of the color of the toner is not impaired.

In order to improve the clarity of the color of the toner, moreover, it is possible to use a coloring magnetic material or a transparent magnetic material using a rare earth element. As a suitable coloring magnetic material, there can be enumerated: for a red color, an iron oxide (e.g. a red oxide), a material prepared by covering the surface of Ni with a copper oxide, or a material prepared by causing Ni to absorb Cadmium Red; for a blue color, cobalt or its compound; and for a yellow color, an iron oxide or a material prepared by causing Ni to absorb Cadmium Yellow.

Moreover, it is quite natural that there can be applied to the above-specified toner a variety of known additives, which are usually used in the toner, such as a charge control agent.

On the other hand, the toner to be used is preferred to have an average particle diameter of 1 to 20 μm and an average charge of 1 to 300 μc/g or, especially preferably, 3 to 30 μc/g. If the toner has an average particle diameter smaller than 1 μm, it becomes reluctant to leave the carrier. If the average particle diameter exceeds 20 μm, on the other hand, the resolution of the image is degraded.

If the developer is composed of a mixture of an insulating carrier and a toner as thus far described, it is possible to easily set the bias voltage, which is to be applied to the developing sleeve 31 of Fig. 3, without any fear of leakage such that the toner is sufficiently applied to the electrostatic image but without any fog. Incidentally, in order to make more effective the control of development and movement of the toner by the application of such bias voltage, the magnetic material to be used in the magnetic carrier may be contained in the toner within such a range as will not deteriorate the color clearness.

The description hereinbefore was directed to the construction of the developing means and the developer which are preferably used. However, there may be used such developing means and developer as are disclosed in Japanese Patent Laid-Open Nos. 30537/75, 18656 to 18659/80, 144452/81, 116553/83, and 116554/83. More preferably, there may be used such a non-contact jumping developing condition by a two-component developer.

In Fig. 4, reference numeral 41 indicates a drum-shaped image retainer which is constructed by laying a dielectric layer such as a resin on a metal base and which is made rotatable in the direction of the arrow, and numeral 43 indicates an electrostatic recording head which is equipped with needle discharge poles. The remaining portions are identical to those of the example of Fig. 1.

The pre-transfer charger 9 may be omitted in case the transfer can be sufficiently effected merely by the transfer means 11. The electrostatic recording head 43 is used to form an electrostatic image having a charged spot distribution on the dielectric layer of the image retainer 41 by means of the needle discharge poles which are arrayed in one or plural rows.

Of the toners: the black toner is similar to that of the two-component developer of the prior art; the cyan toner is prepared by adding copper phthalocyanine in place of carbon black having a black color; the Magenta is prepared by similarly adding polytungstophosphate; and the yellow toner is prepared by similarly adding a benzidine derivative. However, those toners should not be limited to those color toners made of such pigments, but it is naturally possible to use color toners made of dyes and to add an electrification controlling agent or the like, if necessary. On the other hand, the sequence of the colors to be developed by the developing means 5 to 8 using the developers of different color toners has to be carefully determined because it influences the tone of the color image.

Methods according to the present invention can be practised by the reproducing apparatus of Fig. 4 described above but can also be carried out by the reproducing apparatus shown in Fig. 5.

The reproducing apparatus of Fig. 5 is one in which a series of recording members are formed with dielectric layers on their surfaces to provide an image retainer 41'. The retentions and developments of electrostatic images are repeated while the image retainer 41' is being linearly conveyed. Along the conveyor passage of the image retainer 41', the pre-writing charger 2, the electrostatic recording head 43 and the developing means 5 to 8 are repeatedly arranged side by side, and the fixing means 12 for fixing the color image to the image retainer 41' is disposed at the last position. The reproducing apparatus under consideration does not require the pre-transfer charger, the transfer means, the charge eliminating means and the cleaning means but can reproduce a series of color images. In order that the image retainer 41' may not sag, however, it is necessary to increase the tension or to provide such a supporting roller midway as to prevent the toners applied to the image retainer 41' from being offset, although not shown.

In the reproducing apparatus shown in Fig. 4, too, the pre-transfer charger 9, the transfer means 11, the charge eliminating means 13 and the cleaning means 14 can be dispensed with if the image retainer 41 is prepared by rolling an image retainer similar to the image retainer 41', which is used in the reproducing apparatus of Fig. 5, on a drum.

Methods according to the present invention can be practised by the reproducing apparatus thus far described. Figs. 6 to 8 all show the steps of such methods until after a second development has been finished.

Fig. 6 shows a method comprising the steps of: subjecting the surface of the image retainer 41 to a first writing operation by means of the electrostatic recording head 43, either from the initial state (which is shown to be a charged state), in which the surface of the image retainer 41 has its charges eliminated by one or both of the charge eliminating means 13 and 13, cleaned by the cleaning means 14 and charged to be positive or negative by the pre-writing charger 2, if necessary, according to the reproducing apparatus of Fig. 4 or from the initial state, in which the image retainer 41' is conveyed from the left and charged to be negative or positive by the first pre-writing charger 2, if necessary, according to the reproducing apparatus of Fig. 5, thereby to retain an electrostatic image at a potential having a polarity different from that of the background potential; firstly developing that electrostatic image by the developing means 5; conducting a second writing operation by the electrostatic recording head 43 after the uniform charging operation by the charger 2, if necessary, either when the image retainer 41 comes into its second rotation, according to the reproducing apparatus of Fig. 4, or when the image retainer 41' advances to the position of the next charger, according to the reproducing apparatus of Fig. 5; secondly developing the electrostatic image thus retained by the developing means 6; subsequently repeating third and fourth writing and developing operations in a similar manner so that a color image having superposed color images is retained on the image retainer 41 or 41'; and either fixing the resultant color image to the recording member P by means of the fixing means 12, after the color image has been made ready to be transferred by the pre-transfer charger 9 so that it is transferred to the recording member P by the transfer means 11, according to the reproducing apparatus of Fig. 4, or directly fixing the same color image to the image retainer 41' by the fixing means 12 according to the reproducing apparatus of Fig. 5. According to the reproducing apparatus of Fig. 4, moreover, the surface of the image retainer 41 thus having the color image transferred thereto has its charges eliminated by the charge eliminating means 13, and cleared of the residual toners by the cleaning means 14, and further has its charges eliminated, if necessary, by the charge eliminating means 13, thus ending one cycle of the color image reproduction. According to the reproducing apparatus of Fig. 5, on the other hand, the portion of the image retainer 41', which has been formed with the color image, ends its steps of reproducing the color image when it completely passes the fixing means 12.

Moreover, the flow chart of Fig. 7 uses the reproducing apparatus of Fig. 4 and is similar to that of Fig. 6 except that the image retainer 41 having the toner images retained thereon has its charges eliminated by the charge eliminating means 13 before a subsequent image retaining stage is entered after each development.

The flow chart of Fig. 8 uses the reproducing apparatus of Fig. 4 and is different from that of Fig. 6 in that the pre-writing charger 2 is operated before each writing operation.

Incidentally, reference letters T and T' appearing in Figs. 6 to 8 indicate toners of different colors, which are applied to the image retainer 41 or 41'.

The developing means other than that conducting each development under the non-contact jumping developing conditions can be easily held in an inoperative state, even if the developer layer is not removed from the developing sleeve 31, by disconnection of the developing sleeve 31 from the power supply 39 into a floating state, by grounding the developing sleeve 31 to earth, or positively applying such a d.c. bias voltage to the developing sleeve 31 as has a polarity identical to that of the electrostatic image, i.e., opposite to that of the charges of the toners. Of these, the application of the bias voltage having the opposite polarity to that of the toners may be preferably used to hold the developing means in the inoperative state.

Next, the flow charts of Figs. 6 to 8, which are practised by the reproducing apparatus of Fig. 4, will be described in more detail as the following Examples 1 to 3, respectively.

Example 1

The reproducing apparatus shown in Fig. 4 was used. The image retainer 41 was prepared by laying an insulating layer having a thickness of 20 μm on an aluminum base and had a circumferential speed of 180 mm/sec. The image retainer 41 thus prepared had its surface charged to - 100 V by means of the pre-writing charger 2 using the scorotron corona discharger and then subjected to a writing operation at a distribution density of 10 spots/mm by means of the electrostatic recording head 43, the needle electrodes of which had their tips spaced by about 30 μm from the surface of the image retainer 41. As a result, there was retained on the image retainer 41 an electrostatic image which had a written portion potential of + 200 V with respect to the background portion potential of - 100 V. The resultant electrostatic image was firstly developed by the developing means 6 shown in Fig. 3. This developing means 6 used the developer, which was composed of: a carrier having 50 wt. % of magnetite dispersed and contained in a resin and having an average particle diameter of 20 μm, a magnetization of 30 emu/g and a resistivity of 10^{14} Ω or higher; and a nonmagnetic toner prepared by adding 10 wt. % of copper phthalocyanine and another electrification control agent as the cyan pigment to the styrene-acryl resin and which had an average particle diameter of 10 μm, in a ratio of 10 wt. % of toner to the carrier. Moreover, the non-contact jumping developing conditions were used under which the developing sleeve 31 had an external diameter of 30 mm and a number of revolutions of 100 r.p.m., the magnet 32 had a magnetic flux density of its N and S magnetic poles of 1,000 gauss and a number of revolutions of 1,000 r.p.m., the developer layer had a thickness of 0.7 mm at its developed portion, the gap between the developing sleeve 31 and the image retainer 1 was 0.8 mm, and a bias voltage having a d.c. voltage component of 0 V and an a.c. voltage component of 1.5 kHz and 1,000 V was applied to the developing sleeve.

The surface of the image retainer 41 having been firstly developed was subjected to a second writing operation with a spot position shift from the first writing operation but in the same spot density again by the same electrostatic recording head 43 but without operating the pre-transfer charger 9, the charge eliminating means 13 and 13, the cleaning means 14 and the pre-writing charger 2, and so that the written portion took a potential of + 300 V. Next, a second development was conducted by the developing means 6 under the same conditions as those of the developing means 5 except that the toner of the developer used was prepared by adding polytungstophosphate as the Magenta pigment in place of the cyan pigment, and that a bias voltage having a d.c. voltage component of 100 V and an a.c. voltage component of 1.5 kHz and 1,000 V was applied. Likewise, a third writing operation for elevating the potential of the written portion to + 400 V and a third development were conducted by the developing means 7 under the same conditions as those of the developing means 5 except that the toner of the developer used was prepared by adding a benzidine derivative as the yellow pigment, and that the developing bias was composed of a d.c. component of 200 V and an a.c. component of 1.5 kHz and 1,000 V. Moreover, a fourth writing operation for raising the potential of the written portion to + 500 V and a fourth development were conducted by the developing means 8 under the same conditions as those of the developing means 5 except that the toner of the developer used was prepared by adding carbon black as the black pigment, and that the developing bias had a d.c. component of 300 V and an a.c. component of 1.5 kHz and 600 V. The color image thus retained on the image retainer 41 was transferred to and fixed on the recording member P. Moreover, the surface of the image retainer 41 thus having the color image transferred thereto had its charges eliminated by the charge eliminating means 13 and cleared of the residual toners by the cleaning means 14.

The reproduced image thus obtained had little mixing of the color toners and was a remarkably clear color image.

Incidentally, in this Example, the spot position of the subsequent writing operation may be superposed over that of the previous writing operation, or, the discharge voltage of the electrostatic recording head 43, and the voltage value, frequency and selected time of the d.c. or a.c. component of the voltage to be applied to the developing sleeve may be so changed in the writing and/or developing operations as to adjust the developed densities of the respective colors. If the spot positions of the writing operations are superposed, color mixing occurs to make the colors liable to be vague. However, the tone can be enhanced by increasing the spot density. In this case, moreover, especially the sequence of colors to be developed plays an important role. By adjusting the developed densities of the respective colors in the manner thus far described, it is possible to obtain a color image which has a changed tone.

Example 2

Color image reproduction was conducted by use of the same reproducing apparatus as that of Example 1 and under the same conditions as those of Example 1 except that the charging operation of Example 1 by the pre-writing charger 2 prior to the first writing operation was not conducted to form an electrostatic image having a potential of + 150 V with respect to the background potential of 0 V by a first writing operation, that a superposed voltage having a d.c. voltage of + 50 V and an a.c. voltage of 3 kHz and 2,000 V was applied as the bias voltage upon the development to the developing sleeve 31, and that charge elimination was conducted before second and later writing operations by the charge eliminating means 13 to retain an electrostatic image having a potential of + 150 V with respect to the background potential of 0 V even in the second and later writing operations. The reproduced image thus obtained was a color image having an excellent clarity like that of Example 1.

Example 3

Color image reproduction was conducted by use of the same reproducing apparatus as that of Example 1 under the same conditions of those of Example 1 except that the charge of - 300 V was conducted by the pre-writing charger 2 so that an electrostatic image having a potential of + 50 V with respect to the background potential of - 300 V was retained by a first writing operation, that a superposed voltage composed of a d.c. voltage of -200 V and an a.c. voltage of 2 kHz and 1 kV was applied as a bias for the development to the developing sleeve 31, and that the pre-writing charger 2 was used before second and later writing operations. The reproduced image obtained was a color image having an excellent clarity like that of Example 1.

By using the image retaining means having its electrostatic retainability and toner image retainability separated, according to the foregoing Examples, there can be attained excellent effects that the color tone and so on of the color image can be easily changed, and that the color image having the excellent clarity and a high tone can be reproduced so that the reproduction can be stably effected.

Incidentally, methods according to the present invention can be applied to the case in which the image retainer has a belt or sheet shape, or to such an image retainer, e.g., electrofax paper, as is placed on a base as can fix without any transfer the color image retained thereon by the toners. In this case, it is necessary to consider the superposed order of the color toners, but there arises an advantage that the pre-transfer lamp, the transfer means and the cleaning means can be dispensed with. Despite this fact, the pre-transfer lamp and the charge eliminating means can be omitted in case the toners have predetermined polarities and quantities of charges so that they can be transferred. On the other hand, the transfer may be not only the corona type but also a bias roller type, an adhesion type and a pressure type through an intermediate transfer member. It is quite natural that the fixing operation should not be limited to a heat roller type.

Although the Examples thus far described used an electrostatic recording head as the writing means, other means can be similarly used if it can retain the electrostatic charge image on the dielectric layer. More specifically, there can be likewise applied either a method in which the passage rate of a corona ion flow is controlled by control electrodes so that an electrostatic image may be retained on the dielectric layer, or a method in which a screen photosensitive member is used so that the electrostatic charge pattern retained thereon may be used for controlling the passage rate of the corona ion flow to retain the electrostatic image on the dielectric layer.

Other Examples will be described in the following. In the method of consecutively superposing toner images by repeating the step of retaining a latent image on an image carrier and the step of developing the retained latent image, as has been described in the prior art, a development in a suitable density has to be conducted without disturbing the toner image which was retained on the image carrier at the previous step. Here, the term "superposition" means not only that the toner images are formed plural times in an identical position of the developing regions of the image carrier but also that the toner images are retained in plural times in another portion of the image region. The result of our investigations has revealed that an excellent image cannot be obtained even if the values such as the gap d (mm) (which may be simply called the "gap" in the following) between the image carrier and a developer carrier and the voltage V_{AC} and frequency f of the a.c. component of the developing bias are chosen so as to satisfy the above-specified conditions, and that those parameters have close relationships to each other. Therefore, experiments have been conducted by the developing means 16, as shown in Fig. 9, with the parameters such as the voltage and frequency of the a.c. component of the developing bias being changed, so that the results, as shown in Figs. 10 and 11, have been obtained. Incidentally, the toner image is previously formed on the photosensitive drum 1 acting as the image carrier drum. The developing means 16 carries a developer D in the direction of arrow B on the circumference of the sleeve 31 to supply the developer D to a developing region E as the sleeve 31 acting as the developer carrier and the magnetic roll 32 are rotated. Incidentally, the developer D is a two-component developer composed of a magnetic carrier and a non-magnetic toner. Said carrier is composed of ball-shaped particles which have an average particle diameter of 30 µm which is a weight-averaged value measured by means of the Omnicon Alpha (manufactured by Bausch & Lomb Inc.) or the Coulter Counter (manufactured by Coulter Inc.), a magnetization of 50 emu/g and a resistivity of 10^{14} Ω or more and which are coated with a resin. The resistivity is a value which is obtained by reading out a current value when a load of 1 kg/cm^2 is applied to the tapped particles so that the carrier particles have a thickness of 1 mm after the particles have been tapped in a container having an effective sectional area of 0.50 cm^2 and when a voltage for establishing an electric field of 1,000 V/cm is applied between the load and the bottom electrodes. Said toner is prepared by adding a small quantity of an electrification controlling agent to 90 wt. % of a thermoplastic resin and 10 wt. % of a pigment (e.g., Carbon Black) and by blending and pulverizing the mixture so that the particles may have an average particle diameter of 10 µm. The developer D is carried in the direction of arrow B by rotating the magnetic roll 32 in the direction of arrow A and the sleeve 31 in the direction of the arrow B. The developer D has its thickness regulated in its carrying course by means of the head regulating blade 33. A developer reservoir 47 is equipped therein with an agitating screw 35 so that the developer D may be sufficiently agitated. When the developer D in the developer reservoir 47 is consumed, a fresh supply is made from the toner hopper 37 by rotating the toner supply roller 38.

Between the sleeve 31 and the photosensitive drum 1, there is connected a d.c. power supply 45 for applying the developing bias. In order that the developer D may be vibrated in the developing region E to be sufficiently supplied to the photosensitive drum 1, an a.c. power supply 46 is connected in series with the d.c. power supply 45. Reference numeral 40 is the protecting resistor.

Fig. 10 shows the relationship between the amplitude of the a.c. component, when the gap d between the photosensitive drum 1 and the sleeve 31 is set at 1.0 mm; the thickness of the developer at 0.5 mm; when the charged potential of the photosensitive drum is set at 600 V; and the developing bias has its d.c. component at 500 V and its a.c. component at a frequency of 1 kHz, and the image density of a toner image which is formed by the reverse phenomenon on the exposed portion (at a potential of 0 V) of the photosensitive drum 1. The amplitude E_{AC} of the intensity of the a.c. electric field takes a value which is found by dividing the a.c. voltage of the developing bias by the gap d. Curves A, B and C appearing in Fig. 10 are the results obtained in case the toners used are controlled to have average charges of 30 μc/g, 20 μc/g and 15 μc/g, respectively. It is observed from the three curves A, B and C that the effect of the a.c. component appears for the amplitude of the a.c. component of the electric field of 200 V/mm or larger, and that the toner image retained in advance on the photosensitive drum is partially broken for the amplitudes of 2,500 V/mm or larger.

Fig. 11 shows the changes in the image density when the frequency of the a.c. component of the developing bias is set at 2.5 kHz and when the a.c. field intensity E_{AC} is changed under the same conditions as those of the experiments of Fig. 10.

According to these experiments, the image density is high when the amplitude E_{AC} of the a.c. field intensity exceeds 500 V/mm, and the toner image retained in advance on the photosensitive drum 1 is partially broken when that amplitude exceeds 4 KV/mm, although not shown.

Incidentally, as seen from the results of Figs. 10 and 11, the image density highly changes across a certain amplitude, which has a value obtainable hardly in dependence upon the average charges of the toners, as seen from the curves A, B and C. The reason therefor can be thought, as follows. In the two-component developer, specifically, it is predicted that the toners are charged by friction with the carrier or by mutual friction with one another, and that the charges of the toners distribute over a wide range, and it is thought that toners having a large quantity of charges are preferably developed. Even if the average charges are controlled by the electrification controlling agent, the ratio occupied by those toners having the large quantity of charges does not change so much. As a result, it is thought that the changes in the developing characteristics are found more or less but not highly observed.

Now, experiments similar to those of Figs. 10 and 11 were conducted under changing conditions to assess the relationship between the amplitude E_{AC} and frequency $\underline{f}$ of the a.c. field so that the results shown in Fig. 12 could be obtained.

In Fig. 12: indicated at Ⓐ is a region where a developing unevenness is liable to occur; indicated at Ⓑ is a region where the effect of the a.c. component does not appear; indicated at Ⓒ is a region where the toners are liable to return, i.e., where the color mixing is liable to occur; and indicated at Ⓓ and Ⓔ are regions where the effect of the a.c. component appears so that no color mixing occurs.

These results indicate that a proper region for the amplitude and frequency of the a.c. electric field exists so that a next (or subsequent) toner image may be developed in a proper density without breaking the toner image which was retained at the previous step on the photosensitive drum 1. This is thought to be explained by the following reasons.

In the region where the image density has a tendency to increase for the amplitude E_{AC} of the a.c. field intensity, e.g., for the density curve of Fig. 10, i.e., where the amplitude of E_{AC} of the a.c. field intensity ranges from 0.2 to 1.2 KV/mm, the a.c. component of the developing bias acts to make it liable to jump a threshold value at which the toners fly from the sleeve. As a result, even the toner having a small quantity of charges is trapped by the photosensitive drum 1 so that it can be used for the development. As a result, the image density is increased to the higher level as the amplitude of the a.c. field intensity becomes larger.

For the region where the image density is saturated for the amplitude E_{AC}, i.e., where the amplitude E_{AC} exceeds 1.2 KV/mm in the curve A of Fig. 10, this phenomenon can be explained as follows. In this region, more specifically, the toners are the more intensely vibrated as the amplitude of the a.c. field intensity becomes larger, and the cluster formed as a result of the aggregation of the toners becomes liable to be broken so that only the toners having high charges are selectively applied to the photosensitive drum 1 whereas the toner particles having low charges become reluctant to be developed. Moreover, the toners having low charges are liable to be returned to the sleeve 31 by the a.c. bias because they have a weak image forming force even if they are once trapped by the photosensitive drum 1. The charges on the surface of the photosensitive drum 1 leak because of the amplitude of the field intensity of the a.c. component, and the phenomenon that the toners become reluctant to be developed becomes liable to occur. As a matter of fact, it is thought that those causes overlap to make the image density constant for the increase in the a.c. component.

If the a.c. field intensity is raised to have an amplitude exceeding 2.5 KV/mm under the condition of obtaining the curve A of Fig. 10, for example, it is found that the toner image retained in advance on the photosensitive drum 1 is broken, and that the degree of this breakage is the higher for the higher a.c. component. This is thought to be caused by the fact that such a force is applied on the toners trapped by the photosensitive drum 1 as to return to the sleeve 31 by the a.c. component.

In case the development is conducted by consecutively superposing toner images on the photosensitive drum 1, it is a fatal problem that the toner image or images having already been retained are broken at a subsequent developing step.

As is seen by comparing the results of Figs. 10 and 11, on the other hand, the experiments conducted by changing the frequency of the a.c. component have revealed that the image density becomes lower at the higher frequency. This is caused by the fact that the toner particles have their vibrating range narrowed, because they cannot follow the changes in the electric field, so that they become reluctant to be trapped by the photosensitive drum 1.

On the basis of the experimental results thus far described, it has been concluded that a later development can be conducted in a proper density without disturbing the toner image already retained on the photosensitive drum 1, if each development is conducted under the conditions satisfying the following relationship when the amplitude of the a.c. component of the developing bias is designated as V_{AC} (V); the frequency of the same as $\underline{f}$ (Hz); and the gap between the photosensitive sleeve 1 and the sleeve as d (mm).

$$0.2 \leqq | V_{AC}/(d \cdot \underline{f}) | \text{; and}$$
$$| \{(V_{AC}/d) - 1500\} / \underline{f} | \leqq 1.0.$$

In order to ensure a sufficient image density and not to disturb the toner image retained by the previous step, it is preferable that the relationships of the above-specified conditions be satisfied:

$$0.5 \leqq | V_{AC}/(d \cdot \underline{f}) | \text{; and}$$
$$| \{(V_{AC}/d) - 1500\} / \underline{f} | \leqq 1.0.$$

If especially the following relationships of the above are satisfied, it is possible to obtain a multi-color image having a better clarity but no color vagueness and to prevent the toner of another color from being mixed into the developing apparatus even with a number of operations:

$$0.5 \leqq | V_{AC}/(d \cdot \underline{f}) | \text{; and}$$
$$| \{(V_{AC}/d) - 1500\}/\underline{f} | \leqq 0.8.$$

Moreover, it is further preferable to set the frequency of the a.c. component at 200 Hz or higher so as to prevent the developing unevenness due to the a.c. component and to set the frequency of the a.c. component at 500 Hz or higher so as to eliminate the influences from the beats, which are caused by the a.c. component and by the rotations of the magnetic roll in case the rotating magnetic roll is used as the means for supplying the developer to the photosensitive drum 1.

According to the methods thus far described, in order to consecutively develop the subsequent toner images in predetermined densities on the photosensitive drum without breaking the toner images retained on the photosensitive drum 1, it is further preferable to use either solely or in suitable combination the following methods in accordance with the repetitions of the developments:

(1) toners having consecutively higher charges are used;

(2) the amplitude of the field intensities of the a.c., component of the developing bias are made consecutively smaller; and

(3) the frequencies of the a.c. component of the developing bias are made consecutively higher.

In other words, the toner particles having the higher charges are the more susceptible to the influences of the electric field. As a result, the toner particles having high charges may return to the sleeve at the step of the subsequent development if they are trapped by the photosensitive drum 1 at an early development. Therefore, the method (1) is intended to prevent the toners having low charges from returning to the sleeve at a later development by using those toner particles at the early development. The method (2) is intended to prevent the toner particles, which have already been trapped by the photosensitive drum 1, from returning by making the field intensities consecutively smaller in accordance with the repetitions of the development (i.e., at the later steps of developments). As the specific method of consecutively weakening the electric field intensity, there is either a method of consecutively dropping the voltage of the a.c. component or a method of making larger the gap d between the photosensitive drum 1 and the sleeve 31 at the later steps of developments. On the other hand, the method (3) is intended to prevent the toner particles, which have already been trapped by the photosensitive drum 1 from returning by raising the frequency of the a.c. component consecutively to a higher level as the developments are repeated. Some effect can be obtained if those methods (1), (2) and (3) are solely used, but a better effect can be attained, if they are used in combination, for example by consecutively increasing the toner charges in accordance with the repetitions of the developments with the a.c. bias being consecutively dropped. In case those three methods are adopted, moreover, proper image density and color balance can be held by adjusting the d.c. biases, respectively.

Other specific Examples practised by the use of the constructions thus far described will be explained in the following with reference to Figs. 13 and 15.

Example 4

Fig. 13 is a schematic view showing an essential portion of a color image reproducing apparatus. The photosensitive drum 1 having been uniformly charged by means of the scorotron charger was exposed to the ray, which had been guided from the He-Ne laser light source (although not shown) by a rotary polygonal mirror 51 and a focusing lens 52, to retain an electrostatic latent image. This electrostatic latent image was developed by the first developing means 5 so that a first toner image was retained on the photosensitive drum 1. This first toner image was charged again by the scorotron charger 2 and exposed without being transferred to the recording paper so that a second toner image was then retained by the second developing means 6. This is repeated until a fourth toner image is retained. In other words, the steps of the charging operation (the second and later ones of which are not always required) → the exposure → the development were repeated four times in the form containing no transfer step. After the toner images had been wholly retained on the photosensitive drum 1, the pre-transfer exposing lamp 10 irradiated the region, in which the toner image had been retained on the photosensitive drum 1, to transfer the toner image to the recording paper (the path of which is indicated by a broken line), which was fed from the paper feeder (although not shown) by the transfer means 11. The recording paper was heated and fixed by the fixing means 12, which was composed of at least one heated roller, until it was discharged to the outside of the machine.

On the other hand, the photosensitive drum 1 having ended its transferring operation had its charges eliminated by the charge eliminating means 13, which had not been used during the toner image retention, and was then cleared of surplus toner, which had been left on the surface thereof, by the cleaning means 14 which had been left inoperative during the toner image retention.

The color image reproducing apparatus thus far described was caused to repeat the above operations each time its operation button was depressed. In the present Example, the photosensitive material used was selenium, and the photosensitive drum 1 had a diameter of 120 mm, a circumferential speed of 120 mm/sec and a charged potential of 600 V. To the developing means 5 and 6 used, there was applied at each developing time a developing bias which was composed of a d.c. component of 500 V and an a.c. component having an amplitude of 1 KV and a frequency of 1 kHz. The gap d between the photosensitive drum 1 and the sleeve of each of the developing means was set at 0.8 mm. Moreover, the developer used was a two-component developer which was composed of a magnetic carrier and a non-magnetic toner. As this carrier, there was used a ball-shaped carrier which had an average particle size of 30 μm, a magnetization of 50 emu/g and a resistivity of 10^{14} Ω or more and which was coated with a resin. The toner was prepared by adding a small quantity of an electrification controlling agent to 90 wt. % of a thermoplastic resin and 10 wt. % of a pigment. In the developing means 5, 6, 7 and 8, respectively, there were used the yellow, Magenta, cyan and black pigments, all of which had an average quantity of charges of 20 μc/g and an average particle diameter of 10 μm. The developer used was a mixture which was composed of 80 wt. % and 20 wt. % of the above-specified carrier and toner, respectively. Moreover, at each developing time the sleeve 31 and the magnetic roll 32 were rotated in each of the developing means in directions opposite to each other and had their heads regulated by the magnetic blade so that the developer layer had a thickness of 0.4 mm.

As has been described above, the toner images were consecutively superposed to form a multi-color image. As a result, a visible image having a sufficient density was obtained with neither breaking the toner images, which had already been retained on the photosensitive drum 1 at the subsequent development, nor any toner of another color being mixed into each of the developing means.

The resultant superposed toner images were transferred to and fixed to the recording paper so that a clearly reproduced image could also be attained. Even after the toner images had been reproduced on a number of sheets of the transfer paper, moreover, none of the other colors were mixed into each of the developing means. A small quantity of magnetic material was contained in the toner of each developing means so that the fog of the image could be further prevented by the magnetic force.

Example 5

This Example was practised by the color image reproducing apparatus shown in Fig. 13. The difference from Example 4 was that both the gap d between the photosensitive drum 1 and the sleeve and the d.c. component of the developing bias to be applied at the developing time were different among the developing means. The gaps and the d.c. components were set at 0.5 mm and 450 V, at 0.7 mm and 500 V, at 0.8 mm and 500 V, and at 1.0 mm and 550 V in the developing means 5, 6, 7 and 8, respectively. The average quantities of the charges of the toners and the amplitude and frequency of the a.c. biases were common among the developing means like the Example 4 and were set at 20 μc/g, 1 KV and 1 kHz, respectively.

In the present Example, the return of toners from the photosensitive drum 1 was prevented by constructing the photosensitive drum 1 and the sleeves of the respective developing means such that the gaps d in between were widened the more in the developing sequence, and the balance of the densities of the respective color toner images was held by raising the d.c. biases in the developing order.

According to this Example, a clearer image was obtained, and another color was not mixed into each of the developing means even after the reproductions of the multiple sheets.

Example 6

This Example was practised by the color image reproducing apparatus shown in Fig. 13, too. The difference from Example 4 was that the a.c. component and d.c. component of the developing bias to be applied at the developing time were different among the developing means. The amplitudes of the a.c. components and the d.c. components were set at 1.5 KV and 450 V, at 1.2 KV and 500 V, at 1.0 KV and 520 V, and at 0.8 KV and 550 V in the developing means 5, 6, 7 and 8, respectively. The average quantities of the toners, the frequencies of the a.c. biases, and the gaps between the photosensitive drum 1 and the sleeve were common among the developing means like the Example 4 and were set at 20 μc/g, 1 kHz and 0.8 mm, respectively.

In the present Example, return of the toners to the photosensitive drum 1 was prevented by setting the a.c. components at lower levels in the developing order, and the balance of the densities of the respective color toner images was held by consecutively raising the d.c. biases.

According to the present Example, a clear multi-colored image could be obtained without any mixing of another color into each developing means even after the reproducing operations of the multiple sheets.

Example 7

This Example was also practised by the color image reproducing apparatus shown in Fig. 13.

The developing conditions were such that the amplitudes of the a.c. components of the developing bias applied at the developing time were all 1 KV for the respective developing means, and such that the frequencies and the d.c. components of the same were set at 800 Hz and 450 V, at 1 kHz and 500 V, at 1.5 kHz and 550 V, and at 2 kHz and 600 V in the developing means 5, 6, 7 and 8, respectively.

In each developing means, moreover, at the developing time only the sleeve was rotated to supply the developer whereas the internal magnets were fixed. The head height regulation was conducted by the magnetic blade to provide a gap of 0.5 mm so that the developer had a thickness of 0.2 mm.

The average quantities of the charges of the toners and the gaps between the photosensitive drum 1 and the sleeve were common among the respective developing means and were set at 20 μc/g and 0.8 mm, and the remaining developing conditions and developers were the same as those of the Example 4.

In the present Example, the return of toners to the photosensitive drum 1 was prevented by increasing the frequencies of the a.c. components in the developing sequence, and the balance of the densities of the respective color toner images was held by consecutively raising the d.c. biases.

A clear multi-colored image could also be obtained by the present Example, and another color was not mixed into each developing means even after the reproductions of multiple sheets.

Fig. 14 is a flow chart showing the changes in the potential on the photosensitive drum 1 when the developments are conducted by the color image reproducing apparatus of Fig. 13. Reference letters PH and DA indicate the exposed portion and the unexposed portion, respectively.

The photosensitive drum 1 holds a predetermined potential when it is charged by the scorotron charger 2, and the portion having been optically irradiated has its potential dropped when the image exposure is conducted. Next, by applying a bias, which has its d.c. component substantially equal to the potential of that of the unexposed portion, to the developing means, the positively charged toner in the developing means is trapped by the exposed portion having a lower potential so that development is conducted to retain a first visible image. The potential at that particular portion rises a little (as indicated at DUP in the drawing) and as a result it traps the positive toners. Next, the potential on the photosensitive drum 1 is so uniformly charged again by the charger 2 that it is raised to a predetermined potential (as indicated at CUP in the same drawing). Next, if a second image exposure is conducted and if a development is similarly conducted, toner is applied to the exposed portion to retain a second visible image. By repeating these steps four times, four color visible images are retained in a superposed manner on the photosensitive drum 1.

In the methods thus far described, the second and later charging operations can be omitted. In case these charging operations are not omitted, on the other hand, a charge eliminating step may be inserted before each of the charging operations.

All of the three Examples described hereinbefore conduct the reversal developing method but can be practised by the normal developing method, i.e., the method in which the toners are applied to the unexposed portion to retain toner images. In case the superposed developments are conducted by the normal method, however, it is necessary to introduce the charging step at each time.

Example 8

Next, the description in the following is directed to the case in which the developments were conducted by means of the color image reproducing apparatus shown in Fig. 15.

The photosensitive drum 1 was made of a CdS photosensitive member which had its surface covered with an insulating layer and had a diameter of 120 mm, a circumferential speed of 120 mm/sec, an insulating layer thickness of 20 µm and a photosensitive layer thickness of 30 µm.

First of all, the photosensitive drum 1 had its surface charged to +1,000 V by means of the primary charger 2 while being exposed all over its surface by the action of a lamp L mounted in that charger 2. This exposure was conducted so as to facilitate injection of charges into the photosensitive layer of the photosensitive drum 1. Next, the surface of the photosensitive drum 1 was charged to - 100 V to reduce the positive charges on the surface of its insulating layer by means of the secondary charger 3' having an a.c. component. The photosensitive drum 1 thus charged to - 100 V was subjected to an image exposure with a ray which was reflected from the rotary polygonal mirror 51. The portion thus exposed took a positive potential and was developed by the first developing means 5 so that a first visible image was retained. Next, the photosensitive drum 1 was uniformly charged again to - 100 V by the secondary charger 3' and was then subjected to an image exposure so that a second visible image was retained by the second developing means 6. These operations were repeated four times to retain all the visible images on the photosensitive drum 1. After that, the pre-transfer exposing lamp 10 irradiated the region, in which the visible images of the photosensitive drum had been retained, and these visible images were transferred by the transfer means 11 to the recording paper (the path of which is shown by the broken line), which was fed from the paper feeder (not shown). The recording paper was heated and fixed by the fixing means 12, which was composed of at least one heated roller, until it was discharged to the outside of the machine.

On the other hand, the photosensitive drum 1 having its transferring operation completed had its charges eliminated by the charge eliminating means 13 which had not been used during the toner image retention. After that, the photosensitive drum 1 was cleared of the surplus toners, which were left on its surface, by the action of the cleaning means 14 which had been left inoperative during the toner image retention.

The color image reproducing apparatus thus far described repeated the foregoing operations each time its operating button was depressed. The developing conditions of each developing step were such that the developing bias to be applied at the developing time had its a.c. component set at 1.5 KV and having a frequency of 2 kHz and its d.c. component set at 0 V, and such the gap d between the photosensitive drum 1 and the sleeve of each developing means was 0.5 mm. In each developing means, at the developing time the sleeve and the magnetic roll were rotated in the same common direction to carry the developer, and this developer had its layer thickness regulated to 0.3 mm by the action of the magnetic blade.

Each of the developers had the same composition as that of the Example 4 except that its charge was controlled to - 20 µc/g.

With the construction thus far described, the multi-color images were retained to form a visible image having a sufficient density with neither breakage of the toner images, which had already been retained on the photosensitive drum 1, nor any mixing of the toner of another color into each developing means.

Example 9

This example was likewise practised by the color image reproducing apparatus shown in Fig. 15. The difference from Example 8 lay in that the average charge quantities of the developers used and the d.c. component of the developing bias applied at the developing time were different among the developing means and were set at - 10 μc/g and 0 V, at - 15 μc/g and 0 V, at - 20 μc/g and 20 V, and at - 40 μc/g and 50 V in the developing means 5, 6, 7 and 8 respectively. On the contrary, the amplitudes and frequencies of the a.c. bias and the gaps between the photosensitive drum 1 and the sleeve were common among the respective developing means like the Example 8 and were set at 1.5 KV, 2 kHz and 0.5 mm, respectively.

In the present Example, the return of toners to the photosensitive drum 1 was prevented by controlling the electrifications such that the average quantities of the charges of the developers had their absolute values increased in the developing sequence, and the balance of the densities among the respective color toner images was held by consecutively increasing the values of the d.c. biases.

According to the present Example, too, a clear multi-color image was obtained, and another color was not mixed into each developing means.

Example 10

This Example was likewise practised by the color image reproducing apparatus shown in Fig. 15. The difference from Example 8 was found in that the average charge quantities of the developers used and the amplitudes of the a.c. components of the developing biases applied at the developing time were different among the developing means and were set at - 10 μc/g and 1.6 KV, at - 15 μc/g and 1.4 KV, at - 20 μc/g and 1.2 KV, and at - 40 μc/g and 1.0 KV in the developing means 5, 6, 7 and 8, respectively. The frequencies of the a.c. biases, the potentials of the d.c. biases, and the gaps d between the photosensitive drum 1 and the sleeve were shared among the respective developing means and were set at 2 kHz, 0 V and 0.5 mm, respectively.

In the present Example, the return of toners to the photosensitive drum 1 was prevented, and at the same time the balance among the densities of the respective color toner images was held partly by controlling the electrifications such that the average quantities of the charges of the developers had their absolute values increased and partly by consecutively setting the a.c. biases.

According to the present Example, a clear multi-color image was obtained, and no color was mixed into each developing means even after reproductions of multiple sheets.

Fig. 16 shows the changes in the potentials on the photosensitive drum when the developments are conducted by the color image reproducing apparatus of Fig. 15.

After it has been charged positive by the primary charger 2, the photosensitive drum 1 is charged negative so that its surface potential is dropped substantially to 0 V. Next by conducting the image exposure, the portion optically irradiated has its potential raised to trap the toners, which have been charged negative in the developing means, so that the portion having trapped the toners has its potential dropped (as indicated at DDW in the drawing). Next, a uniform charging operation is so conducted by the secondary charger that the surface potential is dropped substantially to 0 V, and the image exposure and the development are repeated. After the visible images of all the colors have been formed on the photosensitive drum 1, the resultant toner images are transferred to the recording paper, and the photosensitive drum 1 has its charge eliminated and is then cleaned until the step advances to a subsequent image reproduction.

In the methods described hereinabove, the second and later secondary charging operations can be omitted. On the other hand, the primary and secondary charging operations may be conducted each time, and in this case the charge eliminating step may be introduced prior to each of the charging operations.

In the respective Examples thus far described, the corona transfer is used as the toner image transfer, but another type may be used. If the adhesion transfer disclosed in Japanese Patent Publication 41679/71, 22763/73 or the like, for example, is used, the transfer can be conducted without considering the polarities of the toners. Moreover, it is possible to adopt the method of effecting direct fixture of the toner image to the photosensitive member as in the electrofax method.

The two-component developer is preferably composed of a magnetic carrier as its carrier and a non-magnetic toner as its toner.

The compositions of the toners are as follows:

(1) Thermoplastic Resin: 80 to 90 wt. % of binder

Examples: polystyrene, styrene-acryl polymer, polyester, polyvinyl butyral, epoxy resin, polyamide resin, polyethrene, and ethylene-vinyl acetate copolymer, which are frequently used in a mixed form;

(2) Pigment: 0 to 15 wt. % of coloring agent
Examples:

Black:	Carbon Black;
Blue:	copper phthalocyanine, derivative dye of sulfonamide;
Yellow:	benzine derivative; and
Magenta:	polytungstophosphate, Rhodamine Lake, Carmine 6B;

(3) Electrification Controlling Agent: 0 to 5 wt. %
Examples:

Plus:	Nigrosine (i.e., electron donor); and
Minus:	organic complex (i.e., electron acceptor);

(4) Fluidizer:
Examples: coloidal silica or hydrophobic silica as representative, silicone varnish, metallic soap, non-ionic active agent;
(5) Cleaning Agent: intended to prevent filming of the toners on the photosensitive member
Examples:
fatty acid metal salt, oxidized silicate having a surface radical, surface active agent containing fluorine; and
(6) Filler: intended to improve the surface gloss of images and to reduce the cost for raw materials
Examples:
calcium carbonate, clay, talc, pigment.

In addition to the above-enumerated materials, a magnetic material may be contained so as to prevent a fog and a toner dispersion.

As the magnetic powders, there are proposed such powders of tri-iron tetraoxide, γ-ferric oxide, chromium dioxide, nickel ferrite or iron alloy as have a diameter of 0.1 to 1 μm. At present, however, the tri-iron tetraoxide is frequently used and is contained in 5 to 7 wt. % with respect to the toners. The resistances of the toners are variable in dependence upon the kinds and quantities of the magnetic powders. In order to provide a sufficient resistance, however, it is preferred to contain 55 wt. % or less of the magnetic material. Moreover, the quantity of the magnetic material is desired to be contained in 30 wt. % or less so that it may hold a clear color as the color toner.

In addition, as the resin suitable for the pressure fixing toner, an adhesive resin such as wax, poly-olefines, ethylene-vinyl acetate copolymer, poly-urethane or rubber is selected so that it may be plastically deformed and adhered to paper by a force of about 20 kg/cm. A capsule toner may also be used.

The toners can be made of the above-enumerated materials and prepared by the method known in the prior art.

In order to obtain a more preferable image the particle diameters of those toners are desired to be no more than 50 microns in their ordinary average values in relation to the resolution. Toner diameters of about 1 to 30 microns may preferably be used in relation to the resolution, the toner scattering and the carriage, although they are not restricted in principle.

In order to reproduce fine points and lines and to enhance gradation, moreover, the magnetic carrier particles may preferably be particles composed of magnetic particles and a resin, for example, a resin-dispersed system of magnetic powders and resin or resin-coated magnetic particles and may more preferably be rounded to have an average particle diameter of 50 μm or smaller, especially preferably, a particle diameter no more than 30 μm and no less than 5 μm.

Moreover, in order to prevent the problems that the carrier particles for providing an obstruction against the satisfactory image reproduction are made liable to receive the charges by the bias voltage so that they become liable to be trapped by the surface of the image carrier and that the bias voltage is not applied to a sufficient level, the carrier may have such an insulating property of a resistivity no less than 10^8 Ω, preferably, 10^{13} Ω, more preferably, 10^{14} Ω. Moreover, the carrier particles may have this resistivity and the above-mentioned diameter.

The carrier particles described above can be prepared either by coating the surface of the magnetic materials described as to the toners with the thermoplastic resin or by making the particles of a resin having fine magnetic particles dispersed and contained therein and by selecting the resultant particles by the well-known average diameter selecting means. Moreover, in order to improve the agitating characteristics of the toners and the carriers and the carrying characteristics of the developers and to improve the electrification controlling characteristics of the toners thereby to make the toner particles reluctant to aggregate or the toner particles and the carrier particles to aggregate, it is desirable to round the carriers. Of these rounded magnetic carrier particles, resin-coated ones are prepared by selecting magnetic particles as round as possible and by coating the particles selected with a resin, and carriers having fine magnetic powders dispersed therein are prepared either by rounding fine particles of a magnetic material, if possible, by hot wind or water after making the dispersed resin particles or by directly forming the rounded dispersed resin particles by the spray dry method.

In the Examples, the description has been made as to the case in which the two-component developer composed of the toner and the carrier was used as the developer having a plurality of components. However, the developer may additionally contain a third component.

In the Examples, the description is limited to the development of the color image. However, the methods can be applied to the case in which toners of the same color are developed in plural times. In this case, a toner having an excellent gradation can be retained on the photosensitive drum.

Still moreover, the methods can be applied not only to the reproducing apparatus by electrophotography but also to the non-impact printer making use of the electrostatic reproducing method or the magnetic reproducing method.

According to the Examples, an image at a subsequent step can be retained on an image carrier without disturbing an image retained at a previous step even if the step of retaining a latent image on the image carrier and the step of developing the latent image with a developer having a plurality of components are repeated a plurality of times.

In other words, a clear image can be retained on the image carrier if the amplitude V_{AC} and the frequency f of the a.c. component and the gap d between the developer carrier and the image carrier are so set as to satisfy the following relationships:

$$0.2 \leqq | V_{AC}/(d \cdot f) | \text{; and}$$
$$| \{(V_{AC}/d) - 1500\}/f | \leqq 1.0.$$

In the other Examples, the developer D used was a one-component magnetic developer which was prepared by blending and pulverizing 70 wt. % of a thermoplastic resin, 10 wt. % of a pigment (e.g., Carbon Black), 20 wt. % of a magnetic material and an electrification controlling agent to have an average particle diameter of 10 μm. The quantity of the charges is controlled by the electrification controlling agent.

In case the development is conducted with a one-component developer using only the magnetic or non-magnetic toner, there can be used developing means which is disclosed in U.S.P. Nos. 3,866,574 and 3,893,418. On the other hand, developing means having two or more magnetic rollers may be used. The electric bias containing oscillatory components and applied upon the development has to be set under such a condition that the toner image already retained on the image retainer may neither be disturbed nor have color mixing. Under the bias condition used in the non-contact jumping development, e.g., the condition as is disclosed in Japanese Patent Laid-Open Nos. 18656 to 18659/80 and 106253/81, the toner images having already been retained may be damaged by the vibrations of the toners, which are caused by the intense a.c. electric field. In case the developments are repeated to superpose the toner images, the intensity of the a.c. component of the bias has to be set within such a proper range without degrading the retained toner images that a subsequent toner image can be completely retained.

Fig. 17 shows the relationship between the amplitude of the a.c. component, when the gap d between the photosensitive drum 1 and the sleeve 31 is set at 0.7 mm; the thickness of the developer at 0.3 mm; the developing bias to be applied to the sleeve 31 has its d.c. component at 500 V and its a.c. component at a frequency of 1 kHz; and the charge potential of the photosensitive drum at 600 V, and the image density of a toner image which is formed by the reverse phenomenon on the exposed portion (at a potential of 0 V) of the photosensitive drum 1. The amplitude E_{AC} of the intensity of the a.c. electric field takes a value which is obtained by dividing the a.c. voltage of the developing bias by the gap d. Curves A, B and C appearing in Fig. 17 are the results obtained in case the magnetic toners used are controlled to have average charges of 5 μc/g, 3 μc/g and 2 μc/g, respectively. It is observed from the three curves A, B and C that the effect of the a.c. component appears for the amplitude of the a.c. component of the electric field of 200 V/mm or higher and 1.5 KV/mm or lower, and that the toner image retained in advance on the photosensitive drum is partially broken for the amplitude of 2,500 V/mm or larger.

Fig. 18 depicts the changes in the image density when the frequency of the a.c. component of the developing bias is set at 2.5 kHz and when the a.c. field intensity is changed under the same conditions as those of the experiments of Fig. 10.

According to these experiments, the image density is high when the amplitude E_{AC} of the a.c. field intensity is 500 V/mm or higher and 3.8 KV/mm or lower (although not shown in Fig. 17), and the toner image retained in advance on the photosensitive drum 1 is partially broken when that amplitude exceeds 3.2 KV/mm (although not shown in Fig. 17).

Incidentally, as seen from the results of Figs. 17 and 18, the image density highly changes across a certain amplitude, which has a value obtainable hardly in dependence upon the average charges of the toners, as seen from the curves A, B and C. The reason therefor can be thought, as follows. Specifically, it is predicted that the one-component developer has its charge quantities distributed widely across the positive and negative ranges because of the mutual friction of the toner particles. As a result, the average quantities of the charges take a small value, but in fact toners having a large quantity of charges, e.g., 20 μc/g or larger exist at a predetermined ratio and are thought to be mainly developed. Even if the average charge quantity is controlled by the electrification controlling agent, the ratio occupied by the toners having that large charge quantity is not varied so much, so that it is thought that the change in the developing characteristics is not substantially observed.

Now, experiments similar to those of Figs. 17 and 18 were conducted under changing conditions to assess the relationship between the amplitude E_{AC} and frequency f of the a.c. field intensity so that the results shown in Fig. 19 could be obtained.

In Fig. 19: indicated at Ⓐ is a region where developing unevenness is liable to occur; indicated at Ⓑ is a region where the effect of the a.c. component does not appear; indicated at Ⓒ is a region where the toners are liable to return; and indicated at Ⓓ and Ⓔ are regions where the effect of the a.c. component appears so that no toner return occurs.

These results indicate that a proper region for the amplitude and frequency of the intensity of the a.c. electric field exists so that a next (or subsequent) toner image may be developed in a proper density without breaking the toner image which was retained previously (at the previous step) on the photosensitive drum 1. This is thought to be explained by the following reasons.

In the region where the image density has a tendency to increase for the amplitude E_{AC} of the a.c. field intensity, e.g., for the density curve of Fig. 17, i.e, where the amplitude of E_{AC} of the a.c. field intensity ranges from 0.2 to 1.0 KV/mm, the a.c. component of the developing bias acts to make it liable to jump a threshold value at which the toners fly from the sleeve. As a result, even the toner having a small quantity of charges is trapped by the photosensitive drum 1 so that it can be used for the development. As a result, the image density is increased to the higher level as the amplitude of the a.c. field intensity becomes the larger.

On the other hand, the reason, for which the image density is dropped in accordance with the increase in the amplitude of the a.c. electric field (e.g., the region in which the amplitude E_{AC} of the a.c. field intensity is no less than 1 KV for the density curve A of Fig. 17), can be thought in several ways. The toners are the more intensely vibrated as the amplitude E_{AC} of the a.c. field intensity becomes the larger, and the cluster formed as a result of the aggregation of the toners becomes liable to be broken so that only the toner particles having high charges are selectively applied to the photosensitive drum 1 whereas the toner particles having low charges become reluctant to be developed. Moreover, the toners having low charges are liable to be returned to the sleeve 31 by the a.c. bias because they have a weak image forming force even if they had once been trapped by the photosensitive drum 1. Since the charges on the surface of the photosensitive drum 1 leak if the amplitude of the field intensity of the a.c. component is too large, the phenomenon that the toners become reluctant to be developed becomes liable to occur. As a matter of fact, it is thought that those causes overlap to make the image density constant for the increase in the a.c. component.

If the amplitude E_{AC} of the a.c. field intensity is enlarged, as has been described hereinbefore, on the other hand, the toner image retained in advance on the photosensitive drum 1 is broken, and the degree of this breakage is the higher for the higher a.c. component. This is thought to be caused by the fact that the toners trapped by the photosensitive drum 1 are acted on by a force for returning them to the sleeve 31 by the a.c. component. In case the development is conducted by consecutively superposing toner images on the photosensitive drum 1, it is a fatal problem that the toner image or images having already been retained are broken at a subsequent developing step.

As seen by comparing the results of Figs. 17 and 18, on the other hand, the experiments conducted by changing the frequency of the a.c. component have revealed that the image density becomes the lower for the higher frequency. This is caused by the fact that the toner particles have their vibrating range narrowed, because they cannot follow the changes in the electric field, so that they become reluctant to be trapped by the photosensitive drum 1.

On the basis of the experimental results thus far described, it has been concluded that a later development can be conducted in a proper density without disturbing the toner image already having been retained on the photosensitive drum 1, if each development is conducted under the conditions satisfying the following relationships when the amplitude of the a.c. component of the developing bias is designated as V_{AC} (V); the frequency of the same as f (Hz); and the gap between the photosensitive sleeve 1 and the sleeve as d (mm):

$$0.2 \leqq | V_{AC}/d \cdot f | \leqq 1.6.$$

In order to obtain a sufficient image density but not to disturb the toner images having been retained until the previous step, the following condition, i.e., the region of Figs. 17 and 18, in which the image density has a tendency to increase for the a.c. electric field, is desirably satisfied:

$$0.4 \leqq | V_{AC}/d \cdot f | \leqq 1.2.$$

Of this region, it is preferable to satisfy the following region corresponding to a slightly lower electric field in which the image density takes its maximum:

$$0.6 \leqq | V_{AC}/d \cdot \underline{f} | \leqq 1.0.$$

Moreover, it is further preferable to set the frequency f of the a.c. component at 200 Hz or higher so as to prevent the developing unevenness due to the a.c. component and to set the frequency of the a.c. component at 500 Hz or higher so as to eliminate the influences from the beats, which are caused by the a.c. component and by the rotations of the magnetic roll in case a rotating magnetic roll is used as the means for supplying the developer to the photosensitive drum 1.

On the other hand, not only the magnetic toner but also a non-magnetic toner can be used. As the developing method using the non-magnetic toner, there is known a method which is disclosed in Japanese Patent Laid-Open No. 30537/75 or 22926/77, for example. In order to easily transfer the visible image on the photosensitive drum 1 to the recording paper, the specific resistance of the toner is desired to be no less than 10^{13} Ω cm. The resistivity is a value which can be obtained by reading out a current value when a load of 1 Kg/cm^2 is applied to the particles tapped in a container having an effective area of 0.5 cm^2 and when a voltage for establishing an electric field of 1,000 V/cm is applied between the load and the bottom electrodes.

Moreover, the materials composing the developer except the magnetic material are similar to those of the foregoing Examples.

These materials may be simply blended and pulverized, but the following additional steps can be carried out:

1. An insulating material is added to the inside or surface of the toner.
2. The toner is prepared either by coating in advance the surfaces of magnetic powders with a surface active agent, an organic dye or a specified resin or by activating in advance the same surfaces to form cover films by polymerization and by mixing the magnetic powders with a resin or the like. This step is intended to facilitate uniform dispersion into the resin and to improve the image quality in a high humidity.
3. The developing quality is improved to prevent toner scatter, as the case may be, by selecting the magnetic characteristics of the magnetic powders such as the shape, the axial ratio or the retaining force of the same.
4. The fluidity is enhanced to improve the developing property by mixing magnetic toners which have different particle diameters, quantities of magnetic powders contained, magnetic characteristics and electric resistances.

On the other hand, most of the magnetic powders are black so that they can be used in place of the black pigment.

In addition, as the resin suitable for the pressure-sensitive toner, wax, polyolefines, ethylene-vinyl acetate copolymer, polyurethane, rubber and so on are selected such that they are elastically deformed and adhered to the paper by a force of about 20 Kg/cm^2. Capsulated toners may also be used.

The particle diameters of those toners may preferably be no more than 50 microns on an average value in relation to the resolution. The toner particle diameters are not limited in principle but may be about 1 to 30 microns in relation to the resolution and the scattering and carriage of the toners.

In the foregoing Examples, the description is restricted to the development of the color image. The methods can also be applied to the case in which toners of the same color are developed in plural times. In this case, a toner image having an excellent gradation can be retained on the photosensitive drum.

Moreover, the methods can be applied not only to the recording method for electrophotography but also the non-impact printer which makes use of the electrostatic reproducing method or the magnetic re-producing method.

Both the step of retaining the latent image on the same image carrier and the step of developing the latent image with the one-component developer are repeated plural times, according to the Examples, and an image at a subsequent step can be retained on the image carrier without disturbing the image which has been retained at a previous step.

In other words, a clear image can be retained on the image carrier if the amplitude V_{AC} and the frequency f of the a.c. component and the gap d between the developer carrier and the image carrier are so set as to satisfy the following relationships:

$$0.2 \leqq | V_{AC}/d \cdot \underline{f} | \leqq 1.6.$$

Claims

1. A method of reproducing multiplex images comprising the steps of forming an electrostatic image on an image retainer (1), developing the electrostatic image formed on the image retainer (1) by using a developer (D) consisting of carrier and toner particles, and repeating said steps to superpose a plurality of toner images on the image retainer (1), characterized in that the or each subsequent developing step to be carried out on said image

retainer already retaining a developed toner image or superposed images is carried out under the conditions:

$0.2 \leqq |V_{AC} / (d \cdot f)|$
$|\{(V_{AC} / d) - 1500\} / f| \leqq 1.0$

where V_{AC} is an amplitude (V) and f is a frequency (Hz) of an AC component of the developing bias, and d is the gap (mm) between the image retainer (1) and a developer feeding carrier (31) for feeding developer (D).

2. A method of reproducing multiplex images according to claim 1, wherein the gap (d) between the image retainer (1) and the developer feeding carrier (31) is kept larger than the thickness of the developer layer formed on the developer feeding carrier (31) in each developing step.

3. A method of reproducing multiplex images according to claim 1 or 2, wherein the multiplex images are formed by successively using developers (D) having a larger absolute value of mean charge quantity in each developing step.

4. A method of reproducing multiplex images according to claim 1, 2 or 3, wherein the multiplex images are formed by successively reducing the amplitude of an AC component of the electric field applied between the image retainer (1) and the developer feeding carrier (31) in each developing step.

5. A method of reproducing multiplex images according to claim 1, 2, 3 or 4, wherein the multiplex images are formed by successively increasing the frequency of an AC component of the electric field applied between the image retainer (1) and the developer feeding carrier (31) in each developing step.

6. A method of reproducing multiplex images comprising the steps of forming an electrostatic image on an image retainer (1), developing the electrostatic image formed on the image retainer (1) by using a one-component developer (D), and repeating said steps to superpose a plurality of toner images on the image retainer (1), characterized in that the or each subsequent developing step to be carried out on said image retainer already retaining a developed toner image or superposed images is carried out under the condition:

$0.2 \leqq |V_{AC} / (d \cdot f)| \leqq 1.6$

where V_{AC} is an amplitude (V) and f is a frequency (Hz) of an AC component of the developing bias, and d is the gap (mm) between the image retainer (1) and a developer feeding carrier (31) for feeding developer (D).

7. A method of reproducing multiplex images according to claim 6, wherein the gap between the image retainer (1) and the developer feeding carrier (31) is kept larger than the thickness of the developer layer formed on the developer feeding carrier (31) in each developing step.

8. A method of reproducing multiplex images according to claim 6 or 7, wherein the multiplex images are formed by successively using developers (D) having a larger absolute value of mean charge quantity in each developing step.

9. A method of reproducing multiplex images according to claim 6, 7 or 8, wherein the multiplex images are formed by successively reducing the amplitude of an AC component of the electric field applied between the image retainer (1) and the developer feeding carrier (31) in each developing step.

10. A method of reproducing multiplex images according to claim 6, 7, 8 or 9, wherein the multiplex images are formed by successively increasing the frequency of an AC component of the electric field applied between the image retainer (1) and the developer feeding carrier (31) in each developing step.

Patentansprüche

1. Vielfachbild-Reproduktionsverfahren mit den Schritten, ein elektrostatisches Bild auf einem Bildaufnehmer (1) zu bilden, das auf dem Bildaufnehmer (1) gebildete elektrostatische Bild unter Verwendung eines Entwicklers (D) zu entwickeln, der aus Träger- und Tonerteilchen besteht, und die Schritte zu wiederholen, um eine Mehrzahl von Tonerbildern auf dem Bildaufnehmer (1) zu überlagern,
dadurch gekennzeichnet,
daß der oder jeder nachfolgende Schritt, der auf dem Bildaufnehmer auszuführen ist, auf dem bereits ein entwickeltes Tonerbild oder überlagerte Bilder aufgenommen ist bzw. sind, unter den Bedingungen:

$0{,}2 \leqq | V_{AC} / (d \cdot f) |$
$| \{(V_{AC} / d) - 1500\} / f | \leqq 1{,}0$

ausgeführt wird, wobei V_{AC} eine Amplitude (V) und f eine Frequenz (Hz) eines AC-Bestandteils der Entwicklungsvorspannung und d der Spalt (mm) zwischen dem Bildaufnehmer (1) und einem Entwicklerzuführträger (31) zum Zuführen von Entwickler (D) ist.

2. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 1, wobei der Spalt (d) zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) größer als die Dicke der auf dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt gebildeten Entwicklerschicht gehalten wird.

3. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 1 oder 2,
wobei die Vielfachbilder durch aufeinanderfolgende Verwendung von Entwicklern (D) mit einem größeren absoluten Wert der mittleren Ladungsmenge in jedem Entwicklungsschritt gebildet werden.

4. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 1, 2 oder 3,
wobei die Vielfachbilder durch aufeinanderfolgendes Verringern der Amplitude eines AC-Bestandteils des elektrischen Feldes gebildet werden, das zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt angelegt wird.

5. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 1, 2, 3 oder 4,
wobei die Vielfachbilder durch aufeinanderfolgendes Vergrößern der Frequenz eines AC-Bestandteils des elektrischen Feldes gebildet werden, das zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt angelegt wird.

6. Vielfachbild-Reproduktionsverfahren mit den Schritten, ein elektrostatisches Bild auf einem Bildaufnehmer (1) zu bilden, das auf dem Bildaufnehmer (1) gebildete elektrostatische Bild unter Verwendung eines Einkomponenten-Entwicklers (D) zu entwickeln und die Schritte zu wiederholen, um eine Mehrzahl von Tonerbildern auf dem Bildaufnehmer (1) zu überlagern, dadurch gekennzeichnet,
daß der oder jeder nachfolgende Entwicklungsschritt, der auf dem Bildaufnehmer auszuführen ist, auf dem bereits ein entwickeltes Tonerbild oder überlagerte Bilder aufgenommen ist bzw. sind, unter der Bedingung:

$$0{,}2 \leq | V_{AC} / (d \cdot \underline{f}) | \leq 1{,}6$$

ausgeführt wird, wobei V_{AC} eine Amplitude (V) und $\underline{f}$ eine Frequenz (Hz) eines AC-Bestandteils der Entwicklungsvorspannung und d der Spalt (mm) zwischen dem Bildaufnehmer (1) und einem Entwicklerzuführträger (31) zum Zuführen von Entwickler (D) ist.

7. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 6,
wobei der Spalt zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) größer als die Dicke der auf dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt gebildeten Entwicklerschicht gehalten wird.

8. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 6 oder 7,
wobei die Vielfachbilder durch aufeinanderfolgende Verwendung von Entwicklern (D) mit einem größeren absoluten Wert der mittleren Ladungsmenge in jedem Entwicklungsschritt gebildet werden.

9. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 6, 7 oder 8,
wobei die Vielfachbilder durch aufeinanderfolgendes Verringern der Amplitude eines AC-Bestandteils des elektrischen Feldes gebildet werden, das zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt angelegt wird.

10. Vielfachbild-Reproduktionsverfahren gemäß Anspruch 6, 7, 8 oder 9,
wobei die Vielfachbilder durch aufeinanderfolgendes Vergrößern der Frequenz eines AC-Bestandteils des elektrischen Feldes gebildet werden, das zwischen dem Bildaufnehmer (1) und dem Entwicklerzuführträger (31) in jedem Entwicklungsschritt angelegt wird.

Revendications

1. Un procédé de reproduction d'images multiplex, comprenant les étapes consistant à former une image électrostatique sur un support d'image (1), à développer l'image électrostatique formée sur le support d'image (1) au moyen d'un rélévateur D composé d'un support et de particules de toner ou d'encre, et à répéter lesdites étapes afin de superposer une pluralité d'images réalisées par le toner sur le support d'images 1, caractérisé en ce que le ou (chacune) des étapes de développement ultérieures à réaliser sur ledit support d'images portant déjà une image en toner développé, ou des images superposées, est/sont réalisée(s) sous les conditions suivantes :

$$0{,}2 \leq |V_{ac} / (d.\underline{f}|$$

$|\{(V_{ac} / d) - 1500) / f$ 1.0

dans lesquelles V_{ac} est une amplitude (V) et f est une fréquence (Hz) d'un composant alternatif d'une tension de polarisation de développement, et d est l'intervalle (mm) entre le support d'image (1) et un support d'alimentation de révélateur (31) pour l'alimentation de révélateur (D).

2. Un procédé de reproduction d'images multiplex selon la revendication 1, dans lequel on maintient l'intervalle entre le support d'image (1) et le support d'alimentation de révélateur (31) à une valeur supérieure à l'épaisseur de la couche de révélateur formée sur le support d'alimentation de révélateur (31) à chaque étape de développement (3).

3. Un procédé de reproduction d'images multiplex selon la revendication 1 ou 2, dans lequel les images multiplex sont formées par l'utilisation successive du révélateur D présentant une valeur absolue plus importante de la quantité moyenne de charge pour chaque étape de développement

4. Un procédé de reproduction d'images multiplex selon la revendication 1, 2 ou 3, dans lequel les images multiplex sont formées par la réduction successive de l'amplitude d'un composant AC du champ électrique appliqué entre le support d'images 1 et le support d'alimentation de révélateur (31), à chaque étape de développement.

5. Une méthode de reproduction d'images multiplex selon la revendication 1, 2, 3 ou 4, dans laquelle les images multiplex sont formées grâce à l'augmentation successive de la fréquence d'un composant alternatif du champ électrique appliqué entre le support d'images (1) et le support d'alimentation de révélateur (31), à chaque étape de développement.

6. Une méthode de reproduction d'images multiplex comprenant les étapes consistant à former une image électrostatique sur un support d'images (1), à développer l'image électrostatique formée sur la seconde image (1) grâce à l'utilisation d'un révélateur à un seul composant (D) et à répéter les deux étapes afin de superposer une pluralité d'images réalisées en toner sur le support d'images (1), caractérisée en ce que le ou (chacune) des étapes de développement ultérieures à réaliser sur ledit support d'images portant déjà une image en toner développé, ou des images superposées, est/sont réalisée(s) sous la condition suivante:

$0,2 \leqq |V_{ac} / (d.f| \leqq 1,6$

dans lesquelles V_{ac} est une amplitude (V) et f est une fréquence (Hz) d'un composant alternatif d'une tension de polarisation de développement, et d est l'intervalle (mm) entre le support d'image (1) et un support d'alimentation de révélateur (31) pour l'alimentation de révélateur (D).

7. Un procédé de reproduction d'images multiplex selon la revendication 6, dans lequel on maintient l'intervalle entre le support d'image (1) et le support d'alimentation de révélateur (31) à une valeur supérieure à l'épaisseur de la couche de révélateur formée sur le support d'alimentation de révélateur (31) à chaque étape de développement (3).

8. Un procédé de reproduction d'images multiplex selon la revendication 6 ou 7, dans lequel les images multiplex sont formées par l'utilisation successive du révélateur D présentant une valeur absolue plus importante de la quantité moyenne de charge pour chaque étape de développement.

9. Un procédé de reproduction d'images multiplex selon la revendication 6, 7 ou 8, dans lequel les images multiplex sont formées par la réduction successive de l'amplitude d'un composant AC du champ électrique appliqué entre le support d'images 1 et le support d'alimentaiton de révélateur (31), à chaque étape de développement.

10. Une méthode de reproduction d'images multiplex selon la revendication 6, 7, 8 ou 9, dans laquelle les images multiplex sont formées grâce à l'augmentation successive de la fréquence d'un composant alternatif du champ électrique appliqué entre le support d'images (1) et le support d'alimentation de révélateur (31), à chaque étape de développement.

FIG.1

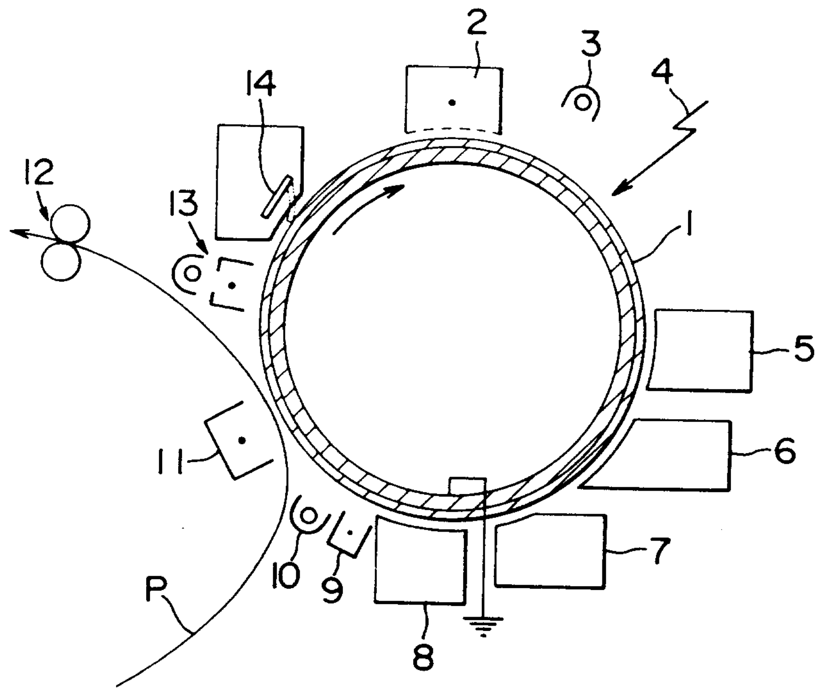


FIG.2

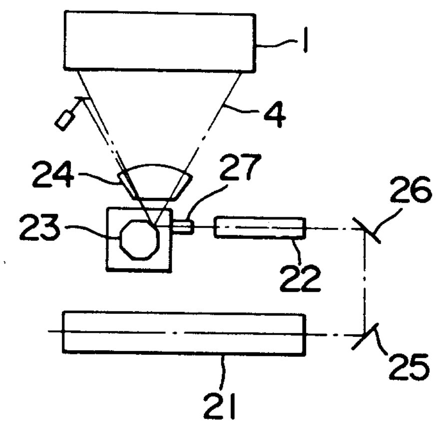


FIG.3

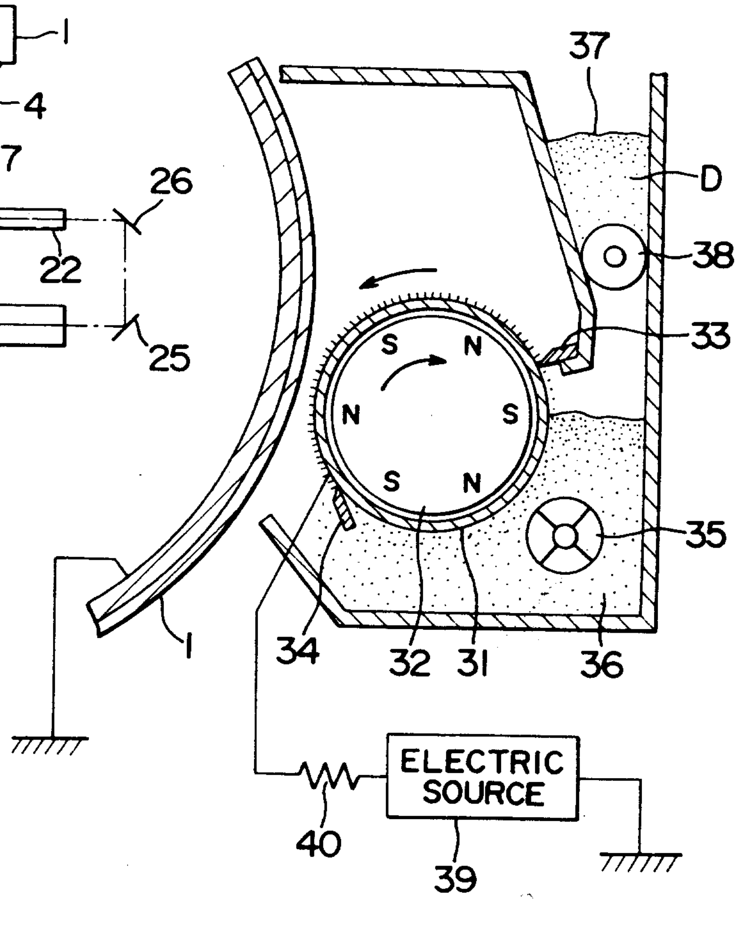


FIG.4

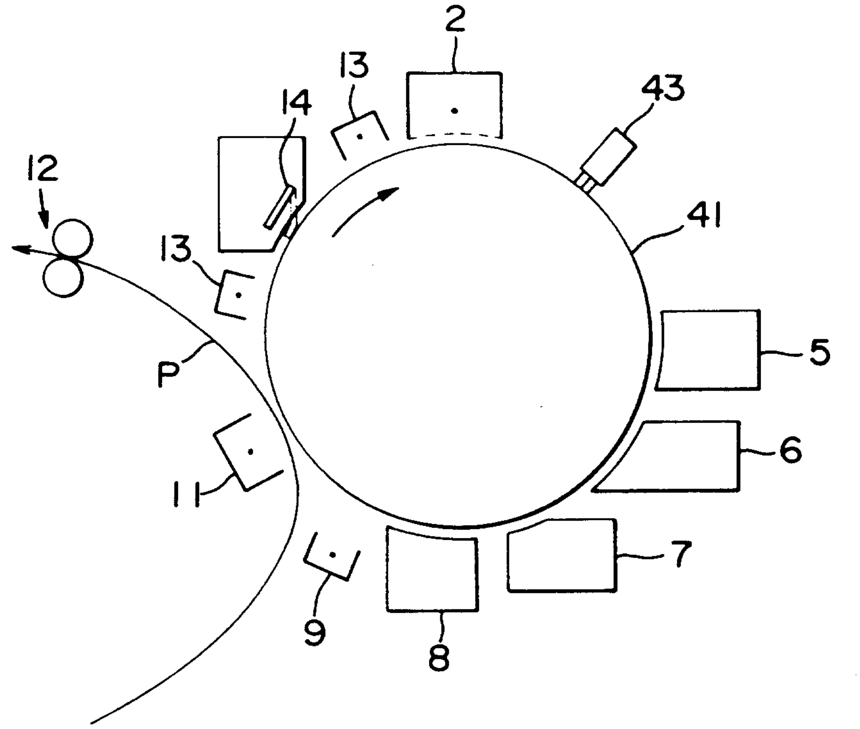


FIG.5

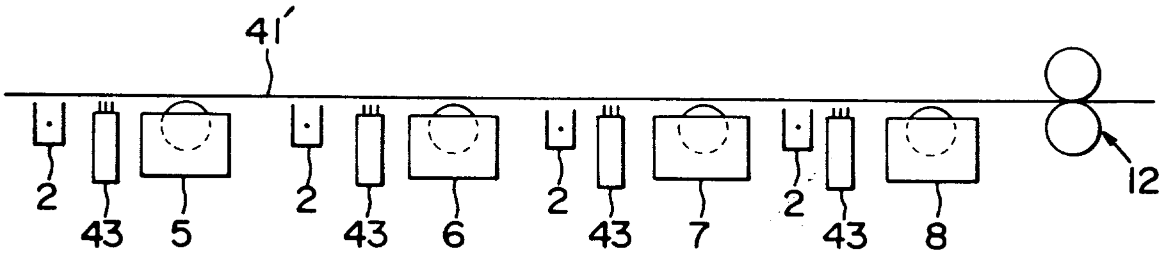


FIG. 6

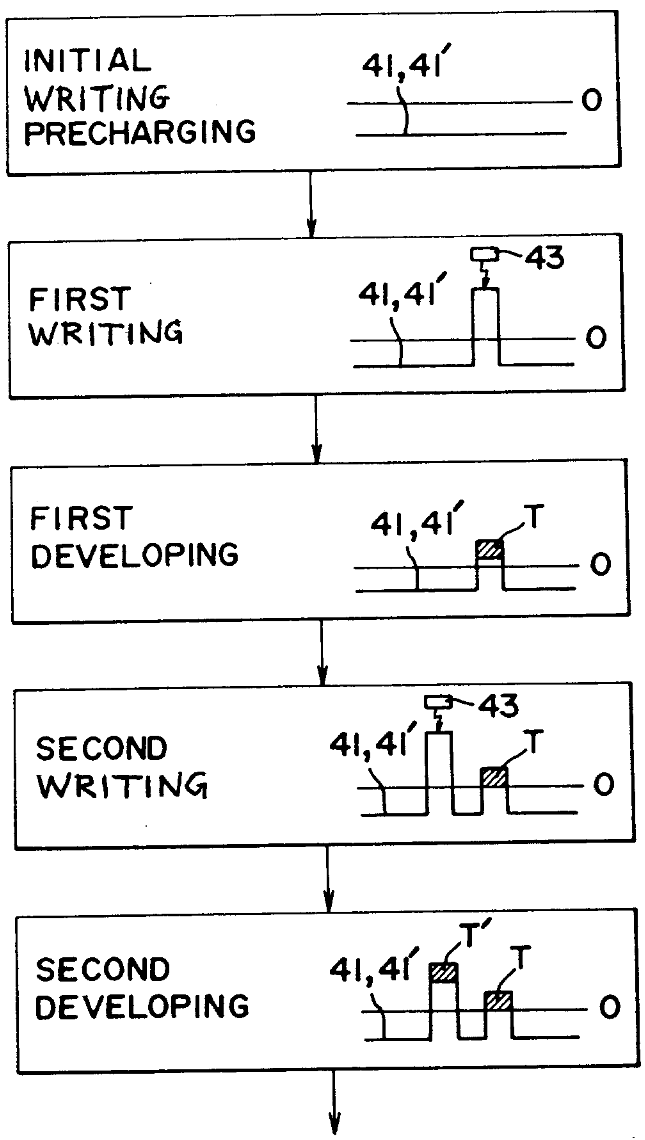

INITIAL
WRITING
PRECHARGING
41,41'
0
FIRST
WRITING
41,41'
43
0
FIRST
DEVELOPING
41,41'
T
0
SECOND
WRITING
41,41'
43
T
0
SECOND
DEVELOPING
41,41'
T'
T
0

FIG.7

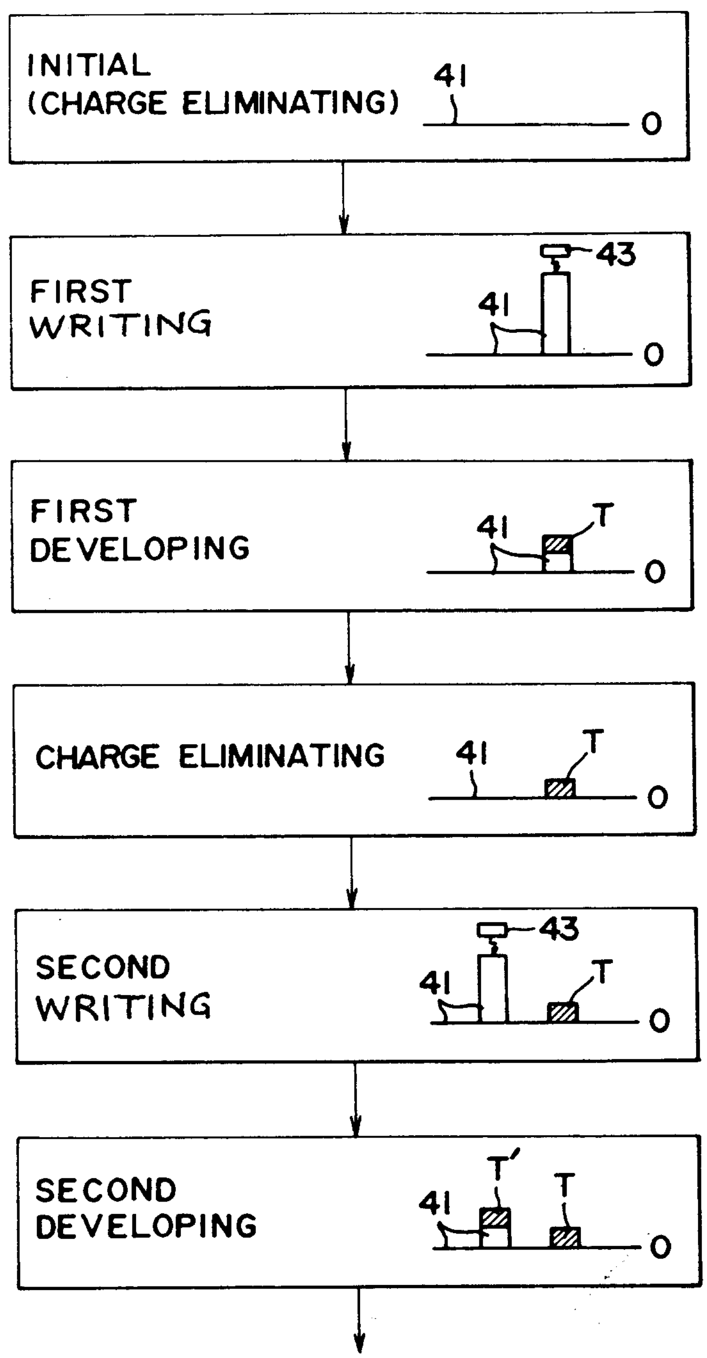

INITIAL
(CHARGE ELIMINATING)
41
0
FIRST
WRITING
43
41
0
FIRST
DEVELOPING
41
T
0
CHARGE ELIMINATING
41
T
0
SECOND
WRITING
43
41
T
0
SECOND
DEVELOPING
T'
T
41
0

FIG. 8

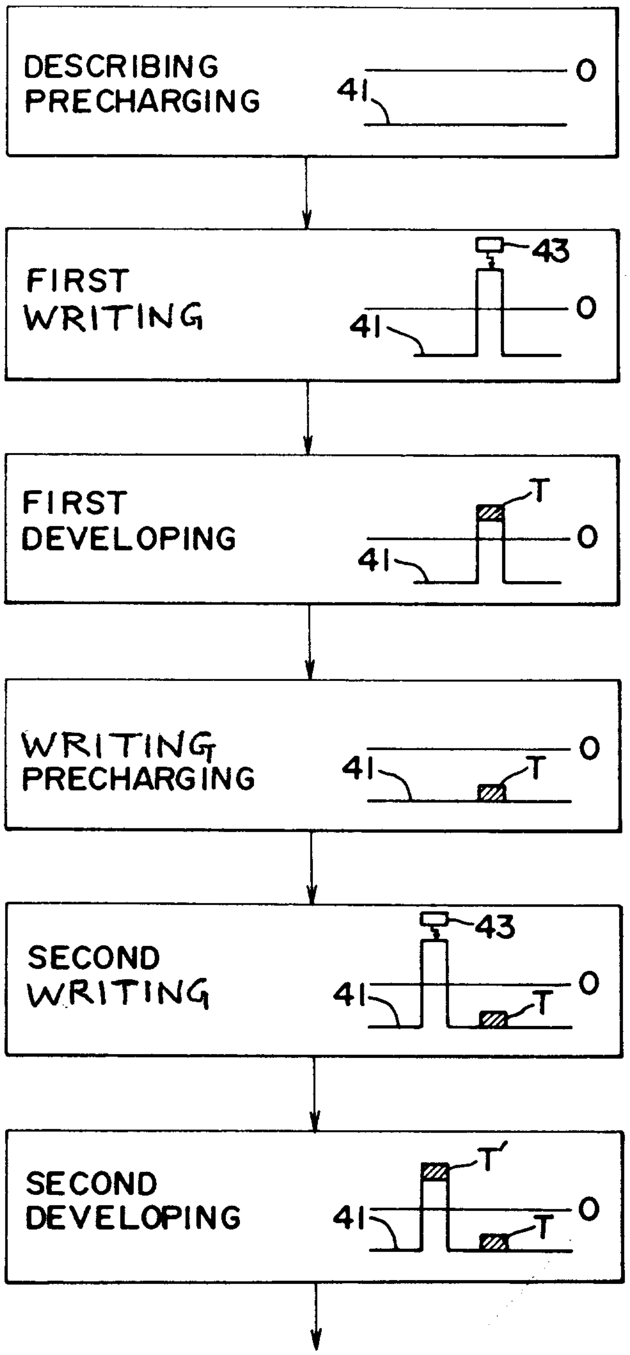

DESCRIBING
PRECHARGING
41
0
FIRST
WRITING
43
41
0
FIRST
DEVELOPING
T
41
0
WRITING
PRECHARGING
41
T
0
SECOND
WRITING
43
41
T
0
SECOND
DEVELOPING
T'
41
T
0

FIG. 9

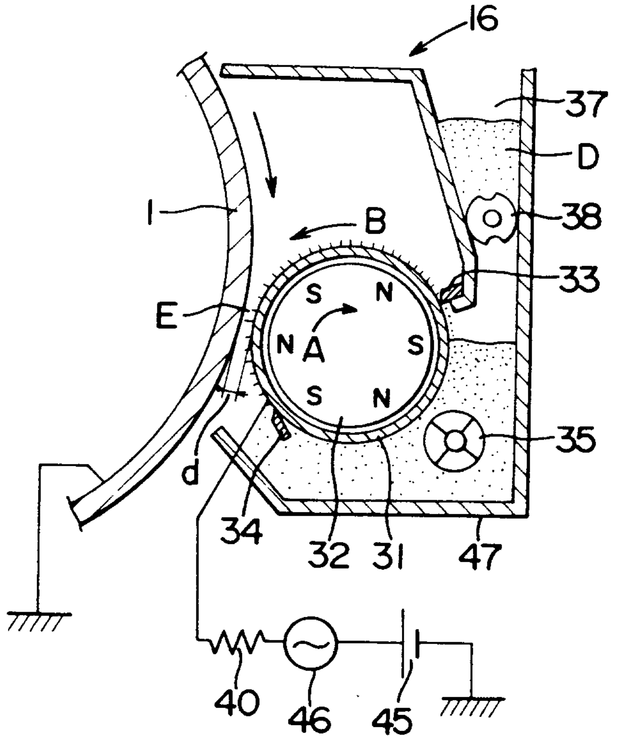


FIG. 12

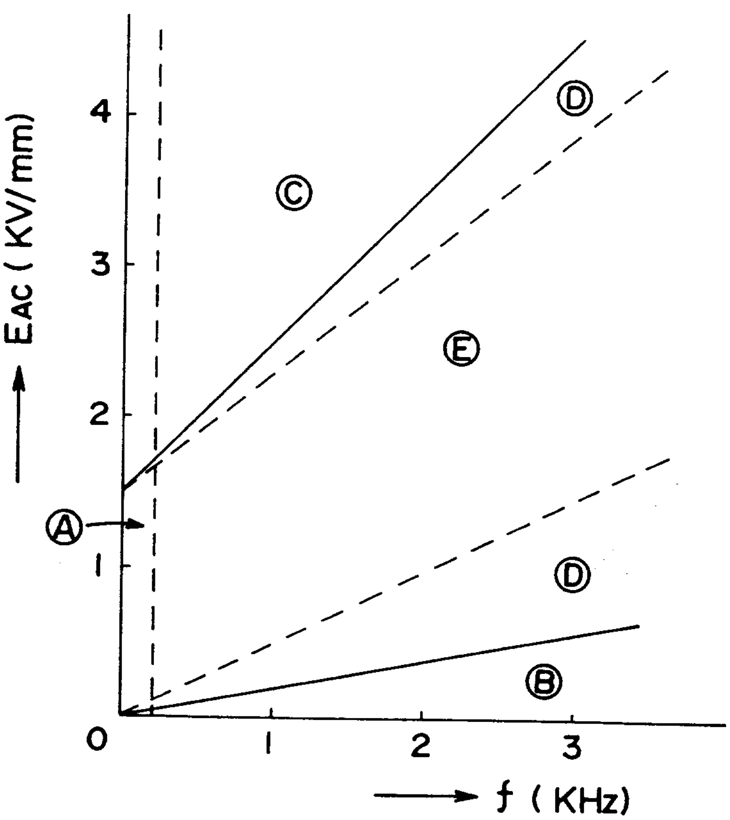


FIG. 10

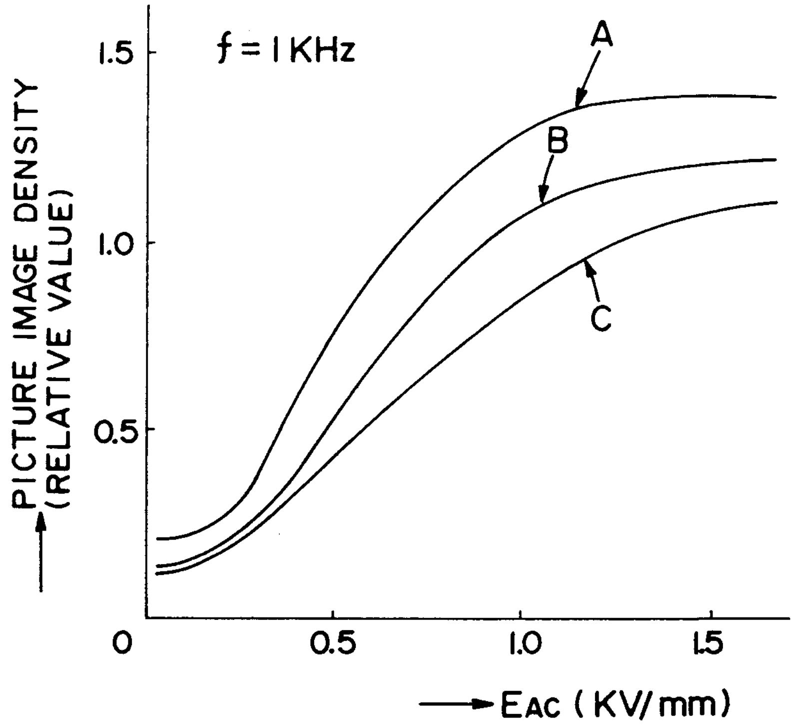
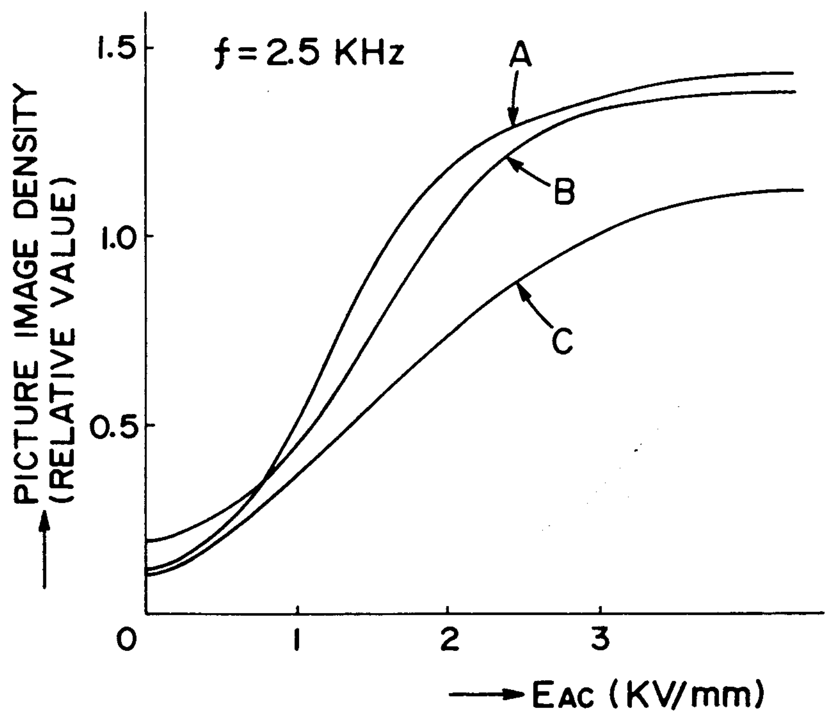
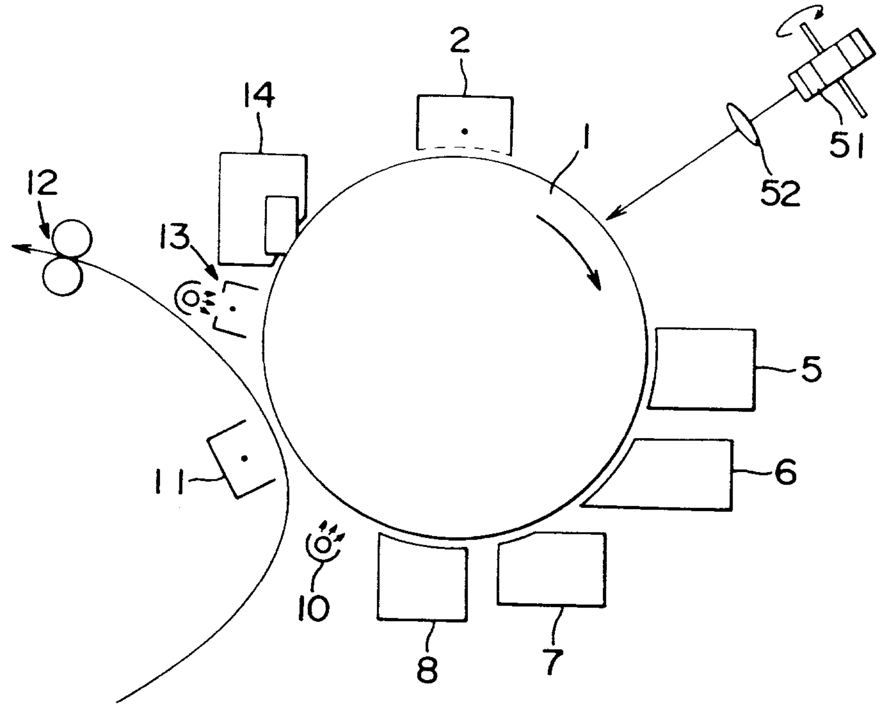

f = 1 KHz
A
B
C
1.5
1.0
0.5
0
0.5
1.0
1.5
PICTURE IMAGE DENSITY (RELATIVE VALUE)
EAC (KV/mm)

FIG. 11


f = 2.5 KHz
A
B
C
1.5
1.0
0.5
0
1
2
3
PICTURE IMAGE DENSITY (RELATIVE VALUE)
EAC (KV/mm)

F I G. 13



F I G. 15

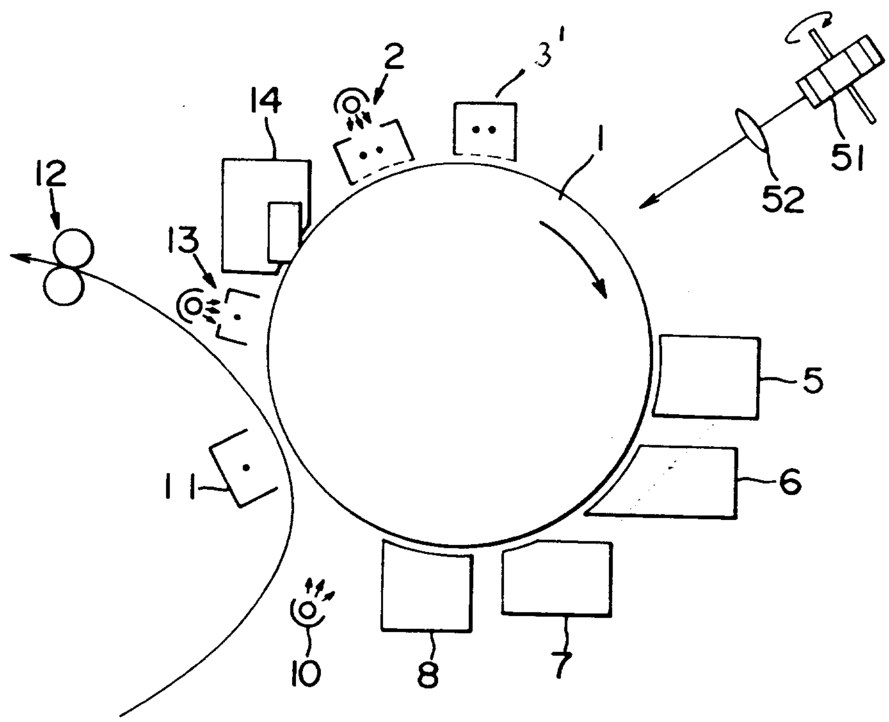
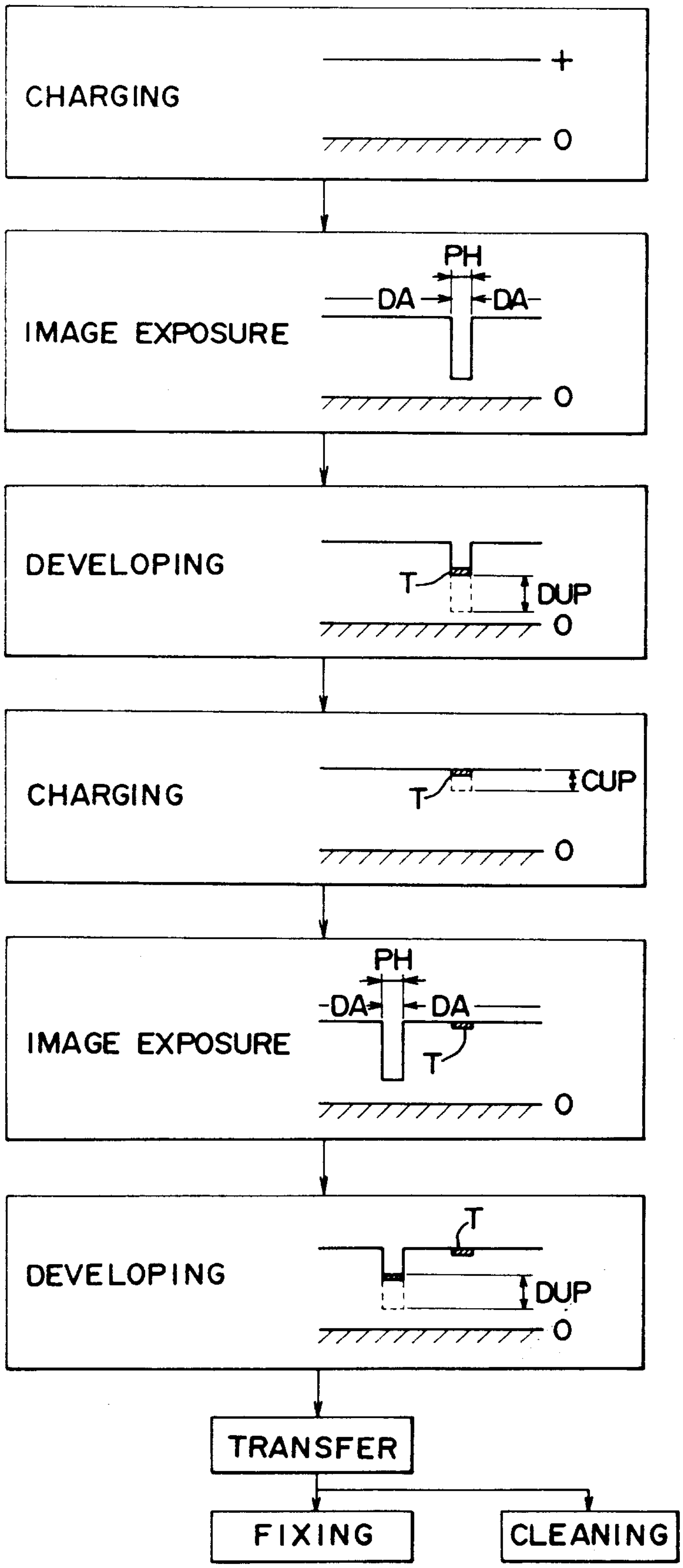


FIG. 14



CHARGING
+
0
IMAGE EXPOSURE
PH
DA
DA
0
DEVELOPING
T
DUP
0
CHARGING
T
CUP
0
IMAGE EXPOSURE
PH
DA
DA
T
0
DEVELOPING
T
DUP
0
TRANSFER
FIXING
CLEANING

FIG.16

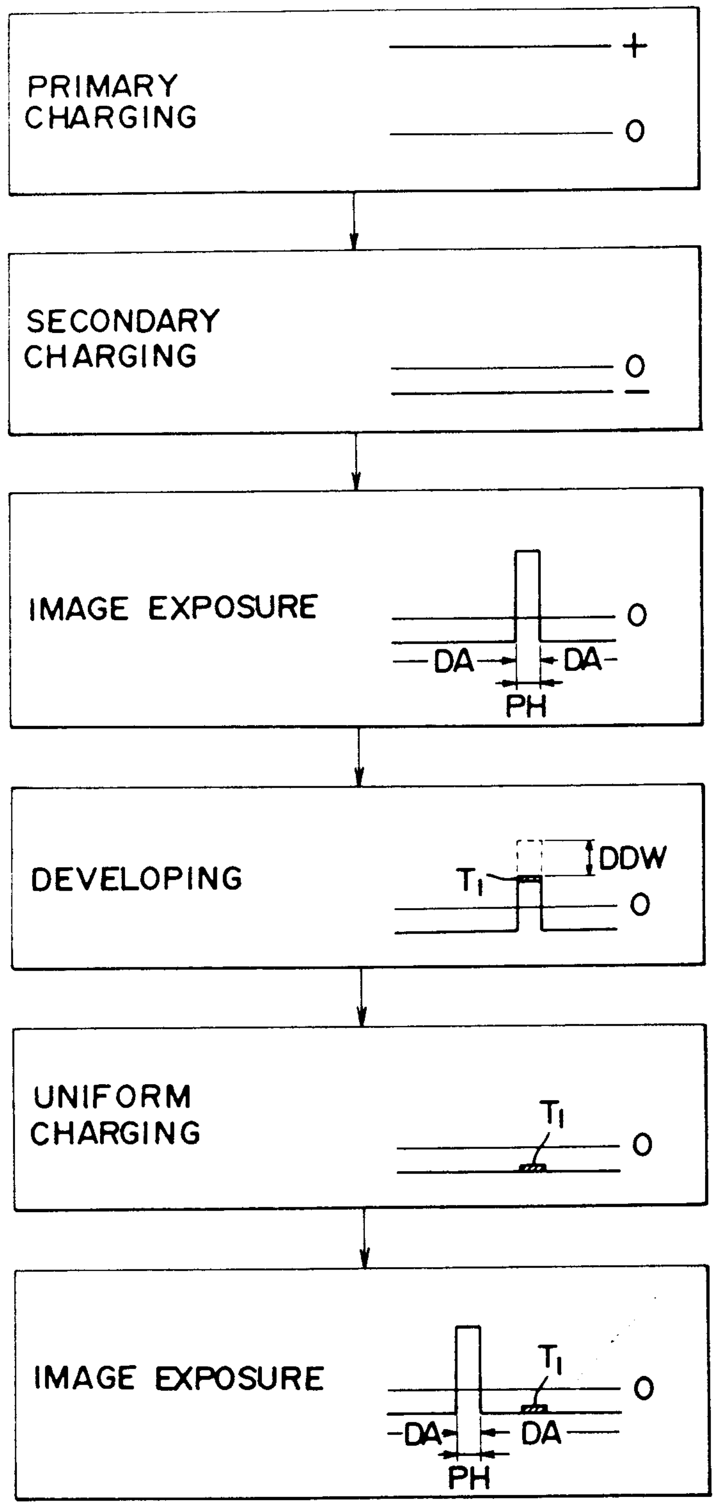

PRIMARY
CHARGING
+
0
SECONDARY
CHARGING
0
−
IMAGE EXPOSURE
0
DA
DA
PH
DEVELOPING
DDW
T1
0
UNIFORM
CHARGING
T1
0
IMAGE EXPOSURE
T1
0
DA
DA
PH

FIG.17

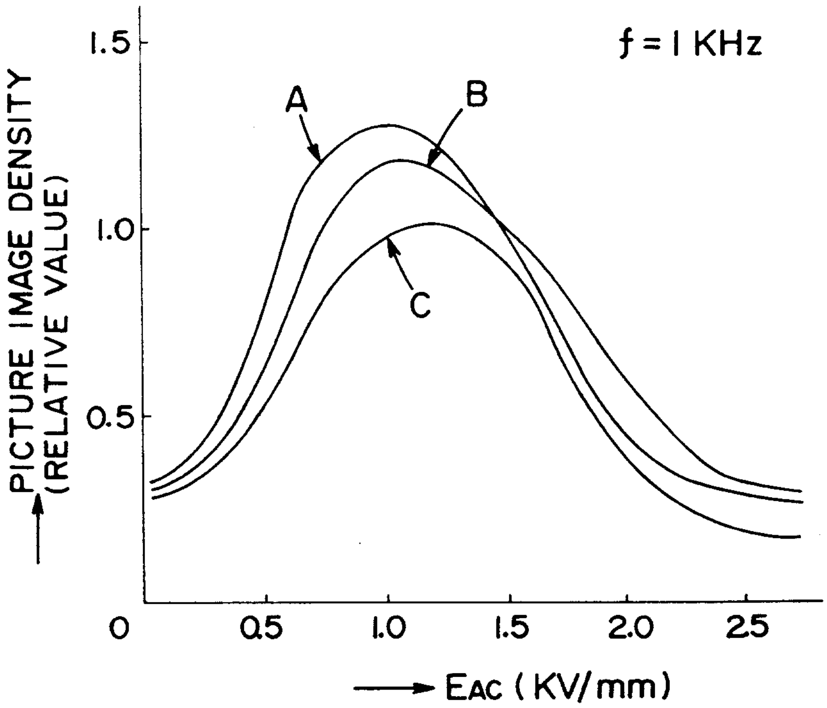

f = 1 KHz
A
B
C
PICTURE IMAGE DENSITY (RELATIVE VALUE)
1.5
1.0
0.5
0
0.5
1.0
1.5
2.0
2.5
EAC (KV/mm)

FIG.18

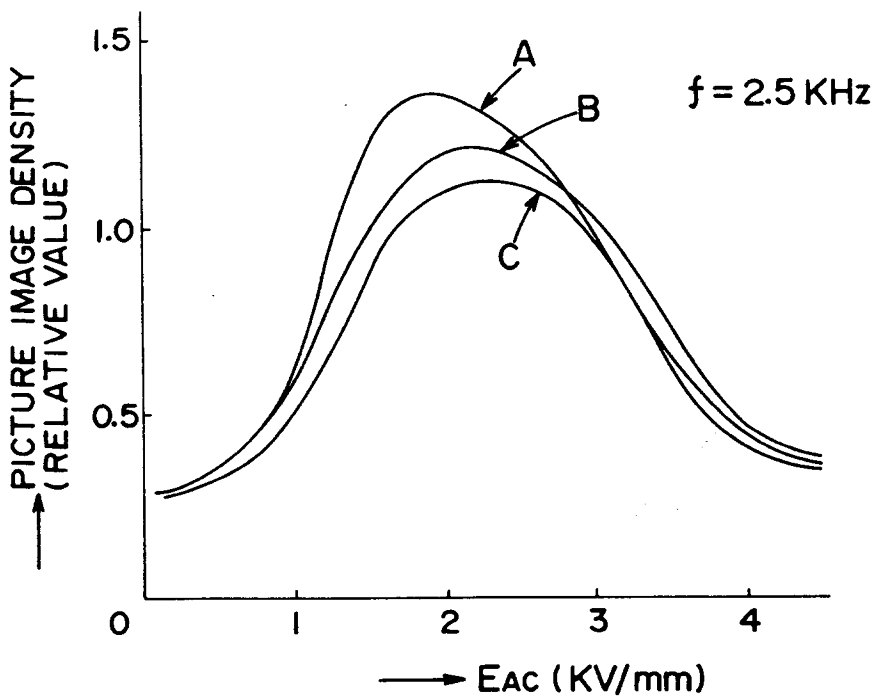

f = 2.5 KHz
A
B
C
PICTURE IMAGE DENSITY (RELATIVE VALUE)
1.5
1.0
0.5
0
1
2
3
4
EAC (KV/mm)

FIG. 19