

SPECIFICATION

Method and apparatus for developer layer formation

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The present invention relates to the formation of developed images using a layer of one-component magnetic developer (hereinafter also called magnetic toner), and is concerned particularly with the technique of forming this layer, on a suitable toner carrying member, with limited thickness.

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The various known methods employed for image development in electrophotography and electrostatic recording can in general be classified into dry developing methods and wet developing methods. The former can further be classified into those utilizing a two-component developer and those utilizing a one-component developer. The two-component class includes, according to the type of carrier employed in combination with the toner particles, a magnetic brush method utilizing an iron powder carrier, a cascade developing method utilizing a bead carrier, a fur brush method utilizing a fur brush etc. Also the one-component class includes a powder cloud method in which the toner particles are used in the form of a sprayed cloud, a contact development of donor development method in which toner particles are brought in direct contact with a surface carrying an electrostatic image, a jump development method in which the toner particles are not brought into direct contact with said surface but are electrically charged and made to fly toward said surface by the electric field associated with the electrostatic image, a magnetic dry developing method in which magnetic electroconductive toner particles are brought into contact with the surface carrying the electrostatic image etc.

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In those two-component developing methods which employ a mixed developer consisting of carrier particles and toner particles, the latter are consumed more rapidly than the former, causing the mixing ratio of said particles to change as development proceeds. This gradual change results in fluctuation of image density, and the deterioration of the carrier particles, which remain unconsumed for a prolonged period, leads to a deterioration of image quality.

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On the other hand, among the one-component developing methods, the magnetic dry developing method utilizing magnetic toner and the contact developing method not utilizing magnetic toner both involve indiscriminate contact of toner particles with the entire surface to be developed, image area and non-image area inclusive. This tends to cause toner deposition even in the non-image area, thus resulting in so-called background fog. Such background fog also occurs using the two-component developing methods. Also, in the powder cloud method the toner particles tend to deposit from the powder cloud onto the non-image areas of the latent image carrier, again resulting in background fog.

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United States Patents 2 839 400 and 3 232 190 disclose a known single-component developing

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method wherein a toner carrying member such as a sheet member uniformly coated with toner particles is maintained at a close spacing from a surface carrying an electrostatic image, and the toner particles move under the force of electrostatic attraction from the carrying member toward said image carrying surface so as to develop said image. This method is advantageous in that the developed image so formed is almost free from the

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above-mentioned background fog since the toner is neither attracted to the non-image area nor brought into contact with the non-image area, and also in that the above-mentioned problems of change of mixing ratio and deterioration of carrier particles do not occur since the developer used does not include carrier particles.

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However, the above-mentioned method has suffered other drawbacks which result from the difficulties encountered in the formation on a toner carrier of a toner layer which is sufficiently thin and uniform to permit the production of developed images which are of sufficiently even density, and high resolution and which are free of undesired background fog. In the latter respect, it has been observed that in developing apparatuses using magnetic developer which is retained magnetically on a carrier surface and moved on that surface to a developing station via a gap defined between the carrier surface and a doctor blade, the toner may undergo a swelling effect immediately downstream of the blade so that the thickness of the toner layer moved from the gap to the developing station is greater than the gap width.

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It should be noted that as used herein, the term image area means that area on the surface carrying an electrostatic image on which the developer is to be deposited in a developing step, while the non-image area shall mean an area which should be free from toner deposition.

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According to one aspect of the present invention there is provided a method of forming a thin layer of one-component magnetic developer for use in the formation of a developed image comprising:

A) supplying the developer to a carrier for carrying the developer through a regulating zone to a developing station;

B) forming at said regulating zone a magnetic field in the region of a gap between the carrier and a magnetic member positioned in spaced relation to said carrier, said field having lines of force which converge towards said magnetic member and being such as to limit the thickness of the developer layer by causing the passage of said developer through said gap to be blocked except for a portion moved adjacent the carrier.

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According to another aspect of the invention there is provided apparatus for forming a thin layer of one-component magnetic developer for use in the formation of a developed image comprising:

A) a supply of one-component magnetic developer;

B) a carrier on which the developer is to be moved through a regulating zone to a developing station;

C) means for supplying developer to said carrier

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upstream of said regulating zone;

D) a magnetic member spaced from said carrier in said regulating zone to define therewith a gap through which the developer is to be moved; and

- 5 E) means for forming at said regulating zone a magnetic field which extends across said gap and of which the lines of force converge towards said magnetic member, said field and said developer being such that in use said field causes the thickness of said layer to be limited by causing the passage of
10 said developer through said gap to be blocked except for a portion moved adjacent the carrier.

With this method and apparatus an enhanced developer layer thinning effect can be obtained so as
15 to cause the layer thickness to be no greater than the gap width.

The magnetic member can be a doctor blade comprising magnetic material or a magnet.

- In either case, the magnetic field may be
20 stationary, the movement of the developer through the regulating zone and toward the developing zone being caused by movement of the carrier.

Alternatively, in the case of a doctor blade of magnetic material the magnetic field may move. The
25 required movement of developer can be achieved with the magnetic field moving in the same direction as, or in the opposite direction to the carrier.

- In either case, the magnetic field forming means may be disposed so that at the regulating zone the
30 carrier lies between the magnetic member and said magnetic field forming means. Where the magnetic field is stationary, the magnetic field forming means preferably includes a magnetic pole which faces the magnetic member across the carrier. The magnetic
35 field forming means also preferably has a plurality of magnetic poles for magnetically attracting the developer so as to hold the developer on the carrier during its movement thereon.

In the described embodiments the carrier
40 comprises a rotatable sleeve, also referred to herein as a cylinder, of non-magnetic material, such as aluminium, the magnetic field forming means comprising a magnet disposed within such sleeve.

This magnet may be fixed to produce the
45 aforementioned stationary magnetic field at the regulating zone, in which case it may further have a developing pole arranged to act on the developer layer on the carrier at the developing station.

Alternatively, to produce the moving magnetic field,
50 the magnet may be rotatable in the same direction as or in the opposite direction to the sleeve. In this case, the magnet preferably has a plurality of circumferentially spaced magnetic poles.

- In the disclosed embodiments, at the developing
55 station the carrier faces a member to which developer is to be transferred for developed image formation, this member and the carrier moving in the same direction at the developing station. The arrangement can be such that the carrier surface
60 supporting the developer layer moves at a greater or at a lower speed than the surface of the member to which developer is to be transferred. Preferably, however, the developer layer moves at substantially the same speed as the surface of the member to
65 which the developer is to be transferred.

The one-component magnetic developer is preferably an insulating developer.

- The arrangement is preferably such that, in use the thickness of the developer layer carried on the
70 carrier to the developing station is less than the clearance at the developing station between the carrier and said member to which the developer is to be transferred.

In the disclosed embodiments the width of the gap
75 is not greater than 500 microns.

The supply of one-component magnetic developer is preferably contained in a container from which said developer is supplied to a surface of said carrier, said container having an opening adjacent said
80 surface. The magnetic member may be arranged at a downstream edge of said opening with respect to the direction of movement of the developer toward said developing station. The magnetic member may be formed integrally with the container.

- 85 Alternatively, the container may be so arranged that the regulating zone is at a position between said opening and the developing station.

Some preferred embodiment of the invention will now be described by way of example with reference
90 to the accompanying drawings, in which:-

Figure 1 is a schematic explanatory view of an electrophotographic copying apparatus which can utilize a developing apparatus embodying the present invention;

- 95 *Figure 2* is a cross-sectional view of a developing apparatus embodying the present invention;

Figure 3 is an explanatory view illustrating the principle of developer layer thickness limiting according to the present invention;

- 100 *Figures 4 and 5* are cross-sectional views illustrating other forms of developing apparatus which embody the present invention; and

Figures 6 and 7 are explanatory views illustrating the transfer of developer from a developer carrier
105 toward an electrostatic latent image carrier.

- In *Figure 1* there is shown a photosensitive drum 1 constituting a member for carrying an electrostatic latent image, which member may also be formed as a sheet or a belt. This drum has a photoconductive
110 layer and may also, but need not, have a surface insulating layer. There is also provided a known sensitizing charger 2, and an image projecting device 3 for projecting onto the drum 1 an image of an original, a light image or a light beam modulated
115 by an image signal. By this arrangement an electrostatic image can be formed on the drum 1, for example by the so-called Carlson process, processes disclosed in the United States Patents 3 666 363 and 4 071 361 or other suitable processes. There is also
120 shown a developing apparatus which forms a visible toner image corresponding to said electrostatic image on the drum 1. This toner image is transferred at a transfer station 5, and by means of a transfer charger 7 onto a transfer sheet supplied from a
125 paper feed station 6. After this transfer of toner image, the transfer sheet is subjected to charging for separation from the drum by a charger 8, then to heat fixing by a fixing lamp 9 while moving on a conveyor belt, and is finally ejected by paper eject
130 rollers 10 onto a tray 11 provided outside the casing

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of the apparatus. On the other hand the electrostatic charge remaining on the photosensitive drum 1 is removed by overall illumination using a lamp 12 and remaining developer is removed in a cleaning station; the drum 1 is thereby prepared for another copy forming cycle. Also in the above-explained apparatus it is possible to employ a so-called electrostatic image transfer process wherein the electrostatic image formed on the photosensitive drum 1 is transferred onto another image carrying member and then is rendered visible by the developing apparatus 4.

In the developing apparatus of Figure 2 a photosensitive drum 1 constitutes an electrostatic image carrying means which may also be realized in the form of a sheet or a belt. A developer carrier 14 is positioned so as to face the drum 1 at a developing station D and comprises, in the present embodiment, a cylinder of non-magnetic material, such as aluminium. A magnet 15 is positioned rotatably within the cylinder 14 and is provided at least with magnetic poles capable of magnetically attracting the developer onto said cylinder. The magnet 15 is further provided preferably with developing magnetic poles which function at the developing station and with developer carrying poles between the above-mentioned magnetic poles. A magnetic member in the form of a doctor blade 16 of magnetic material is positioned at a regulating zone to face the cylinder 14 across a gap, and limits, in the manner to be described below, the thickness of a thin layer 17 of magnetic toner 18 formed on the cylinder 14. This developer carrying cylinder 14, on which the toner 18 is deposited, is rotated in the direction arrowed while supporting thereon the thin layer of toner, magnetically attracted thereto, which layer thereby develops the latent image on the drum 1 by toner transfer at the developing station without contacting the non-image area. The thickness of the toner layer 17 is limited by the combined effect at the regulating zone of the magnet roll 15 and the doctor blade 16, preferably to a value within a range of 30 to 100 μ . The magnetic field created by the magnet 15 at the regulating zone is concentrated toward the blade 16, i.e. its magnetic lines of force converge toward the blade, as shown in Figure 3, to form a curtain of toner particles linked in a brush-like state between the cylinder 14 and the blade 16, which curtain blocks the passage of toner 18 through the gap between the cylinder 14 and the blade 16 except for a small amount dragged by the cylinder 14 along its surface, thus forming an extremely thin toner layer 17 to be used for development as explained above. The concentration of magnetic field and consequently the effect of developer layer thickness limiting, can be enhanced by the use of a magnet as the doctor blade 16, though this may not be practicable in an arrangement in which the magnet 15 is rotated, since the rotating poles of the magnet 15, could cause the blade magnet to vibrate, and the rotating torque for the rotating magnet would need to be increased. However a doctor blade 16 made of a magnetic material can be employed in such an arrangement using a rotating magnet 15. In this case

the blade 16 is alternately approached by different magnet poles to create in the region of the gap between the blade and the cylinder, a vigorously changing magnetic field which is effective to break up coagulated toner particles.

Other forms of developing apparatus embodying the present invention are shown in Figures 4 and 5, in which the components having common counterparts in Figure 2 are represented by common reference numerals. In Figure 4 the electrostatic image carrying surface 1 is displaced in the direction arrowed, and the non-magnetic cylinder 14 constituting the toner carrier is driven so that at the developing station its surface moves in the same peripheral direction as the image carrying surface. The multi-pole permanent magnet 15 is rotated in the same or opposite direction whereby the one-component insulating ferromagnetic toner 18 supplied from a toner container 19 is coated on the surface of cylinder 14 and is given an electrostatic charge of a polarity opposite to that of the image area of the electrostatic image by the friction between the cylinder surface and the toner particles. Also, by means of an iron doctor blade 16a positioned close to the surface of the cylinder 14 (with a gap of 50 to 500 μ), the toner layer is limited uniformly and to a small thickness (in the range of 30 to 500 μ). The arrangement is preferably such as to produce a toner layer thickness of from 30 to 100 μ . The speeds of rotation of the non-magnetic cylinder 14 and the multi-pole permanent magnet 15 are adjusted in such a manner that the surfacial speed (and preferably the internal speed) of the toner layer becomes substantially equal or close to the speed of said electrostatic image carrying surface 1 in order to prevent any density variation in the developed image resulting from an inertial effect to be described later herein with reference to Figures 6 and 7. In the above-mentioned arrangement the surface of toner layer is separated at the developing station by a small gap (20 to 400 μ) from the image carrying surface 1 whereby a satisfactory image can be obtained by the flight of toner particles across such gap.

In a variation of the Figure 4 embodiment the image carrying surface 1 is moved in the direction arrowed while the multi-pole permanent magnet 15 is maintained stationary. In this case the non-magnetic cylinder 14 constituting the developer carrier is rotated so that at the developing station its surface moves in the same direction as the surface 1 whereby the single-component insulating ferromagnetic toner 18 supplied from the toner container 19 is coated on the surface of said cylinder and is given an electrostatic charge of a polarity opposite to that of the image area of the electrostatic image by the friction between the cylinder surface and the toner particles. Again an iron doctor blade 16a is positioned at the regulating zone close to the surface of cylinder 14 (with a gap to 50 to 500 μ) so as to face one of the magnetic poles of the permanent magnet 15 thereby limiting the toner layer uniformly and to a small thickness (30 to 300 μ , preferably 30 to 100 μ). The speed of rotation of the cylinder 14 is adjusted such that the surfacial speed,

and preferably the internal speed, of the toner layer becomes substantially equal or close to the speed of the image carrying surface. The doctor blade 16a may also be constituted by a permanent magnet, instead of iron, to provide a counter pole to that pole of the magnet 15 facing the blade.

In an embodiment shown in Figure 5 there are provided two iron doctor blades 16b, 16c on respective sides of the toner container 19 with respect to the direction of rotation of the cylinder 14. This arrangement is particularly applicable in the case where the non-magnetic cylinder 14 and the magnet 15 are both rotated so as to move in the same direction at the developing station as the image carrying surface 1. In this case, if the rotating speed of the magnet 15 is sufficiently high, there may result a condition wherein the surface portion of the toner layer moves in the opposite direction to the internal layer portion. The additional doctor blade 16c is effective to limit this surfacial flow, the remaining flow of toner in the toner layer being limited by the blade 16b as explained earlier to produce the thin toner layer required for development.

In the foregoing embodiments the doctor blade may be composed integrally with the toner container, and also may be constructed and arranged to incline relative to the surface of cylinder 14. Also the developer carrier need not necessarily be of cylindrical form but can also be of a belt form or any other suitable form. It may, for example, be formed as an endless belt having an endless toner supporting surface extending between a plurality of rollers. In such case there may be provided along the path of said endless belt, as in Figures 4 and 5 a toner supply station (container) 19, a blade 16a comprising a magnet or magnetic material and spaced from said belt by a small distance said belt being maintained, at the developing station D, separate from the latent image carrying surface by such a small distance as not to cause contact of toner with the non-image area but to allow transfer of toner to the image area, thereby performing development of the electrostatic image by means of a toner layer formed on said belt by the above-mentioned various means. There would also be provided means forming a magnetic field at least at the blade and preferably also at the developing station.

Thus, the described methods and apparatus employ a one-component ferromagnetic powdered material as the developer, a non-magnetic cylinder, provided therein with a multi-pole permanent magnet, as a toner carrier for providing controlled toner support, and also a doctor blade comprising a thin plate of a magnetic material or a permanent magnet provided in the vicinity of the surface of said cylinder for achieving a thin and uniform toner layer. The use of a doctor blade made of a magnetic material functioning to form a counter magnetic pole opposed to a magnetic pole of the permanent magnet provided inside the toner carrier causes the toner particles to form a curtain between said doctor blade and the said toner carrier, and is effective for forming a thin and uniform toner layer. Also the

magnetic supporting of the toner layer on the surface of the carrier allows toner transfer to the latent image with a higher degree of uniformity, stability and ease of control than in the case of toner supporting by Van de Waals force or by electrostatic attractive force.

Now there will be given an explanation of the composition and material of the components which may be used in the foregoing embodiments.

The magnetic toner is for example composed of a mixture of 50 parts of polystyrene, 40 parts of magnetite, 3 parts of a charge controlling agent and 6 parts of carbon and formed into particles of an average particle size of 5 to 10 μ by a known process, but other one component magnetic toners can be used. The toner carrier comprises an aluminium cylinder. The magnet is provided with a surface flux density within a range of 600 to 1300 gauss, for example 800 gauss, when a magnetic pole is positioned where the toner supporting member is closest to the image carrying member holding an electrostatic image of a potential contrast of ca. 600V.

Image development is achieved by the formation of a toner layer of such thickness that at the developing station the toner remains separated from the non-image area of the image carrying surface and can transfer to such surface in the image area thereof. During such toner transfer, the toner layer facing the image area increases in thickness under the effect of the attractive force due to the electric field of the image, and the toner particles form into erect and extending brush-like chains (a phenomenon hereinafter called "toner extension") under the influence of magnetic field in a position corresponding to a magnetic pole. These combined effects cause the extended toner to come into contact with the image area of the image carrying surface when it approaches the surface of the toner layer at the developing station and some of the toner remains on the image carrying surface when it moves away from the toner layer, thereby completing the image development. This method, which is distinct from so-called contact development and from jump development, is considered to achieve image development by toner contact with the image area through said toner extension while toner is maintained contact-free in the non-image area.

When the distance between the surface of toner layer and the image carrying surface is larger, the image development is considered to be achieved, in addition to the above-explained development method involving toner contact through the toner extension, by a phenomenon in which the toner chains extending towards but not reaching the image carrying surface are also maintained erect in the electric field and the end portion of said chains are torn and fly toward the image carrying surface.

Thus image development by the above-mentioned toner extension phenomenon and also by the simultaneous toner flight phenomenon can be achieved according to the distance between the image carrying surface and the toner carrier. The utilization of said toner extension phenomenon

wherein the toner layer is rendered erect and extends so as to contact the image carrying surface directly in the image area thereof reduces the amount of toner flying across the developing gap,

- 5 and it is possible to obtain an excellent image quality completely free from background fog when the dimensions of the gap are selected suitably so as to minimize the effect of air flow in the gap, weight of toner, and vibrations of the image carrying surface and of the toner carrier. In order to ensure
- 10 satisfactory toner extension, it has been found that the distance between the image carrying surface and the surface of the toner layer in its non-extended state in the non-image area should not exceed three
- 15 times the toner layer thickness. Also in order to achieve a development principally by said toner extension but also by simultaneous toner flight phenomenon, said distance should not exceed ten times the toner layer thickness.
- 20 Based on experimental and theoretical analysis, the distance b between the toner carrier and the electrostatic image carrying surface is preferably within a range from 50 to 500 μ , wherein the upper limit is determined by the requirement for the
- 25 reproduction with a satisfactory resolution of a character printed with the smallest commercial type-face (100 μ), while the lower limit is determined in relation to the thickness of toner layer. Also experimentally the thickness t of toner layer to be
- 30 supported on the toner supporting member is preferably within a range of 30 to 300 μ . At the image developing station the toner layer is extended under the influence of a magnetic field to a height which is considered to be in the order of three times said
- 35 thickness as explained in the foregoing. In order to allow the surface of toner layer to reach the image carrying surface, therefore, the distance s between the surface of toner layer and the image carrying surface should not exceed 300 μ . In general
- 40 satisfactory results are obtained when $s \geq t/5$. A predetermined distance b between the image carrying surface and the toner carrier can be maintained by a positioning member such as a spacer, a roller and a spring which is in abutment
- 45 with the image carrying surface or a counter electrode provided therebehind and is engaging with the toner supporting surface.

In a process disclosed in the United States Patent 3 232 190 a web supporting a toner layer thereon is

50 transported, in the developing station in a direction opposite to the moving direction of the photosensitive drum. However, with such counter movement, there may result an anisotropy in the distribution of toner deposited on the image area of

55 the image carrying surface if the relative speed of toner layer with respect to the electrostatic image is large. This phenomenon will now be explained with reference to Figures 6 and 7.

Referring to Figure 6 an electrostatic image

60 carrying member 1 carries an electrostatic image consisting of an image area d (composed of uniformly distributed positive charge) and a non-image area l , said image area d generating lines of electric force E as shown in the drawing. A toner

65 carrier 62 supports a thin toner layer 63 provided

with negative charge which is opposite to the polarity of charge in said image area d . Said image carrying member 1 is maintained in facing relationship to said toner carrier 62 with such a small

70 gap therebetween as not to cause toner transfer to the non-image area l but to allow toner transfer to the image area d by the electrostatic attractive force.

- It is now assumed that the toner carrier 62 moves in the direction of arrow A relative to the image
- 75 carrying member 1. In such case each toner particle 63 is considered to have an inertia in the direction arrowed and of a magnitude corresponding to the relative speed of the toner carrier 62. Thus the toner particle transferring from the toner carrier to the
- 80 image area d by the electrostatic attraction of the image area d moves in a direction of the force resultant from said inertial force and the electrostatic attractive force along said line of electric force E . In Figure 7 the arrows B show the movement paths of
- 85 toner particles. As can be seen in Figure 7, the density of arrows B is higher at the leading end of Arrow A than at the trailing end thereof. In other words, even if the image area d has a uniform charge distribution, the density of toner deposition is
- 90 greater at the leading end of the image area than the trailing end, thus resulting in a density difference between such opposite portions and also resulting in blurred image reproduction at the trailing end. This density difference naturally increases as said relative
- 95 speed increases or the toner particles become heavier (for example particles of magnetic toner containing magnetite or γ -hematite). Also it is to be noted that the above-mentioned phenomenon appears even when the image carrying member and
- 100 the toner supporting member are moved in the same direction, but with a significant speed difference.

Thus, in the image development performed using the above described forms of developing apparatus, wherein an electrostatic image formed on a moving

105 image carrying member is maintained in facing relationship to a developer carrier which can be made to support a layer of developer of a thickness so regulated that the distance between the developer and the image carrying member is such as

110 to avoid transfer of developer to the non-image area of said image carrying member, it is possible to obtain a satisfactory image quality without background fog.

The above-mentioned density difference between

115 leading and trailing portions of the developed image can also be avoided if the developer layer supported on the developer carrier is displaced in the developing station in the same direction as and at substantially the same speed as the electrostatic

120 image.

Thus, in a copying or recording apparatus, a developing apparatus as described above permits the production of high quality copies, free from background fog, on a suitable medium, such as plain

125 paper.

CLAIMS

1. A method of forming a thin layer of one
- 130 component magnetic developer for use in the



wherein the toner layer is rendered erect and extends so as to contact the image carrying surface directly in the image area thereof reduces the amount of toner flying across the developing gap, and it is possible to obtain an excellent image quality completely free from background fog when the dimensions of the gap are selected suitably so as to minimize the effect of air flow in the gap, weight of toner, and vibrations of the image carrying surface and of the toner carrier. In order to ensure satisfactory toner extension, it has been found that the distance between the image carrying surface and the surface of the toner layer in its non-extended state in the non-image area should not exceed three times the toner layer thickness. Also in order to achieve a development principally by said toner extension but also by simultaneous toner flight phenomenon, said distance should not exceed ten times the toner layer thickness.

Based on experimental and theoretical analysis, the distance b between the toner carrier and the electrostatic image carrying surface is preferably within a range from 50 to 500 μ , wherein the upper limit is determined by the requirement for the reproduction with a satisfactory resolution of a character printed with the smallest commercial type-face (100 μ), while the lower limit is determined in relation to the thickness of toner layer. Also experimentally the thickness t of toner layer to be supported on the toner supporting member is preferably within a range of 30 to 300 μ . At the image developing station the toner layer is extended under the influence of a magnetic field to a height which is considered to be in the order of three times said thickness as explained in the foregoing. In order to allow the surface of toner layer to reach the image carrying surface, therefore, the distance s between the surface of toner layer and the image carrying surface should not exceed 300 μ . In general satisfactory results are obtained when $s \geq t/5$. A predetermined distance b between the image carrying surface and the toner carrier can be maintained by a positioning member such as a spacer, a roller and a spring which is in abutment with the image carrying surface or a counter electrode provided therebehind and is engaging with the toner supporting surface.

In a process disclosed in the United States Patent 3 232 190 a web supporting a toner layer thereon is transported, in the developing station in a direction opposite to the moving direction of the photosensitive drum. However, with such counter movement, there may result an anisotropy in the distribution of toner deposited on the image area of the image carrying surface if the relative speed of toner layer with respect to the electrostatic image is large. This phenomenon will now be explained with reference to Figures 6 and 7.

Referring to Figure 6 an electrostatic image carrying member 1 carries an electrostatic image consisting of an image area d (composed of uniformly distributed positive charge) and a non-image area l , said image area d generating lines of electric force E as shown in the drawing. A toner carrier 62 supports a thin toner layer 63 provided

with negative charge which is opposite to the polarity of charge in said image area d . Said image carrying member 1 is maintained in facing relationship to said toner carrier 62 with such a small gap therebetween as not to cause toner transfer to the non-image area l but to allow toner transfer to the image area d by the electrostatic attractive force.

It is now assumed that the toner carrier 62 moves in the direction of arrow A relative to the image carrying member 1. In such case each toner particle 63 is considered to have an inertia in the direction arrowed and of a magnitude corresponding to the relative speed of the toner carrier 62. Thus the toner particle transferring from the toner carrier to the image area d by the electrostatic attraction of the image area d moves in a direction of the force resultant from said inertial force and the electrostatic attractive force along said line of electric force E . In Figure 7 the arrows B show the movement paths of toner particles. As can be seen in Figure 7, the density of arrows B is higher at the leading end of Arrow A than at the trailing end thereof. In other words, even if the image area d has a uniform charge distribution, the density of toner deposition is greater at the leading end of the image area than the trailing end, thus resulting in a density difference between such opposite portions and also resulting in blurred image reproduction at the trailing end. This density difference naturally increases as said relative speed increases or the toner particles become heavier (for example particles of magnetic toner containing magnetite or γ -hematite). Also it is to be noted that the above-mentioned phenomenon appears even when the image carrying member and the toner supporting member are moved in the same direction, but with a significant speed difference.

Thus, in the image development performed using the above described forms of developing apparatus, wherein an electrostatic image formed on a moving image carrying member is maintained in facing relationship to a developer carrier which can be made to support a layer of developer of a thickness so regulated that the distance between the developer and the image carrying member is such as to avoid transfer of developer to the non-image area of said image carrying member, it is possible to obtain a satisfactory image quality without background fog.

The above-mentioned density difference between leading and trailing portions of the developed image can also be avoided if the developer layer supported on the developer carrier is displaced in the developing station in the same direction as and at substantially the same speed as the electrostatic image.

Thus, in a copying or recording apparatus, a developing apparatus as described above permits the production of high quality copies, free from background fog, on a suitable medium, such as plain paper.

CLAIMS

1. A method of forming a thin layer of one component magnetic developer for use in the



formation of a developed image comprising:

A) supplying the developer to a carrier for carrying the developer through a regulating zone to a developing station;

5 B) forming at said regulating zone a magnetic field in the region of a gap between the carrier and a magnetic member positioned in spaced relation to said carrier, said field having lines of force which converge towards said magnetic member and being
10 such as to limit the thickness of the developer layer by causing the passage of said developer through said gap to be blocked except for a portion moved adjacent the carrier.

2. A method according to claim 1 wherein the
15 magnetic field is stationary and wherein the carrier moves so as to cause movement of the developer through the regulating zone and toward the developing station.

3. A method according to claim 2 wherein said
20 magnetic field is formed by a magnetic field forming means separate from the carrier and disposed so that at the regulating zone the carrier lies between said magnetic member and said magnetic field forming means.

25 4. A method according to claim 3 wherein said magnetic field forming means includes a magnetic pole which faces the magnetic member across the carrier.

5. A method according to claim 1 wherein the
30 carrier moves so as to cause movement of the developer in a given direction through the regulating zone and toward the developing station.

6. A method according to claim 5 wherein the
35 magnetic field is caused to move in the same direction as the carrier.

7. A method according to claim 5 wherein the magnetic field is caused to move in the opposite direction to the carrier.

8. A method according to any of claims 5 to 7
40 wherein the magnetic field is formed by a magnetic field forming means disposed so that at the regulating zone the carrier lies between said magnetic member and said magnetic field forming means.

45 9. A method according to claim 3 or claim 8 wherein said magnetic field forming means magnetically attracts the developer so as to hold the developer on the carrier during its movement thereon.

50 10. A method according to claim 9 wherein said magnetic field forming means includes a plurality of magnetic poles for magnetically attracting the developer.

11. A method according to claim 3 or any claim
55 dependent thereon wherein said carrier comprises a rotating sleeve of non-magnetic material and wherein said magnetic field forming means comprises a magnet fixedly disposed within said sleeve, the magnet having a developing pole which
60 acts on the developer layer on the carrier at the developing station.

12. A method according to claim 8 when
65 dependent on claim 6 or claim 7 wherein the carrier comprises a rotating sleeve of non-magnetic material and said magnetic field forming means

comprises a rotating magnet disposed within the sleeve and having a plurality of circumferentially spaced magnetic poles.

13. A method according to claim 11 or claim 12
70 wherein the non-magnetic sleeve is made of aluminium.

14. A method according to any preceding claim wherein at the developing station the carrier faces a member to which developer is transferred for
75 developed image formation.

15. A method according to claim 14 when
80 dependent on any of claims 2 to 13 wherein at the developing station said member to which the developer is transferred moves and the carrier moves in the same direction.

16. A method according to claim 15 wherein at
85 the developing station the carrier surface supporting the developer layer moves at a greater speed than the surface of the member to which the developer is transferred.

17. A method according to claim 15 wherein at
90 the developing station the carrier surface supporting the developer layer moves at a lower speed than the surface of the member to which developer is transferred.

18. A method according to claim 15 wherein at
the developing station the developer layer moves at substantially the same speed as the surface of the member to which the developer is transferred.

95 19. A method according to any preceding claim wherein the one-component magnetic developer is an insulating developer.

20. A method according to any preceding claim wherein the magnetic member is a doctor blade
100 comprising magnetic material.

21. A method according to claim 2 or any claim dependent thereon wherein the magnetic member is a doctor blade comprising a magnet.

22. A method according to claim 14 or any claim
105 dependent thereon wherein the thickness of the developer layer carried on the carrier to the developing station is less than the clearance at the developing station between the carrier and said member to which the developer is transferred.

110 23. A method according to any preceding claim wherein the thickness of the developer layer is no greater than the width of said gap.

24. A method according to any preceding claim wherein the width of said gap is not greater than 500
115 microns.

25. A method according to any preceding claim wherein a further magnetic member is disposed upstream, relative to the direction of movement of the developer on the carrier, of the regulating zone
120 and at a close spacing from said carrier.

26. A method according to claim 25 when
dependent on claim 6 wherein the speed of movement of the magnetic field is such as to cause a surface portion of the developer to move in the
125 opposite direction to an internal portion of the layer and said further magnetic member is used for limiting such opposite surfacial flow.

27. A method according to claim 1 wherein:
130 the developer carrier comprises a rotating sleeve of a non-magnetic material;



the one-component magnetic developer is an insulating developer;

the magnetic field is formed by a magnetic field forming means including a magnetic roller which is fixedly disposed within said sleeve and which has a developing magnetic pole at the developing station and a plurality of magnetic poles for attracting and holding the developer on the sleeve;

the magnetic member is a doctor blade comprising magnetic material;

the magnetic roller has a pole at a position facing the doctor blade through the sleeve; and a stationary said magnetic field is formed between the doctor blade and the said pole facing it.

28. A method according to claim 27 wherein the sleeve moves so that at the developing station it moves in the same direction as a member to which the developer is transferred and the speed of the developer carried on the sleeve is substantially equal to the speed of said member;

said magnetic doctor blade has an edge onto which the said magnetic field is concentrated, said edge being spaced from the sleeve by 500 microns or less; and

the developer layer formed on the sleeve is limited to a thickness smaller than the clearance between the sleeve and the said member to which the developer is transferred.

29. A method according to any preceding claim wherein the developer is supplied to a surface of said carrier from a container having an opening adjacent said surface.

30. A method according to claim 29 wherein the magnetic member is arranged at a downstream edge of said opening with respect to the direction of movement of the developer toward said developing station.

31. A method according to claim 30 wherein said magnetic member is formed integrally with said container.

32. A method according to claim 30 wherein the regulating zone is at a position between said opening and the developing station.

33. A method according to claim 1 wherein the carrier is a tubular sleeve of non-magnetic material the surface of which is supplied with the developer; the magnetic field is formed using a rotatable magnet roller which is disposed within said tubular sleeve and which comprises a plurality of magnetic poles;

the magnet roller is driven in a given rotational direction so as to form an alternating magnetic field at the surface of the tubular sleeve thereby carrying the one-component developer around said surface of the tubular sleeve, and wherein the magnetic member disturbs the alternating field on the sleeve surface by causing said convergence of the lines of force of the field.

34. A method according to any of claims 1 to 10 wherein the carrier is in the form of an endless belt extending around a plurality of rollers.

35. A method according to claim 34 wherein the belt has an endless developer carrying surface.

36. A method according to claim 6 wherein the moving magnetic field is produced by a magnetic

field forming means which at the developing station moves at a speed which is greater than the speed of the carrier.

37. A method according to claim 14 or any claim dependent thereon wherein at the developing station the developer is transferred to the said member for developed image formation by a process which involves the flight of developer particles across a gap from the developer layer toward said member.

38. A method according to claim 14 or any claim dependent thereon wherein said member to which the developer is transferred bears a latent image having image and non-image areas, as herein defined, and wherein at the developing station developer is transferred to said member for developed imaged formation by a process involving thickening of portions of the toner layer facing the said image areas.

39. A method according to claim 38 wherein said thickening of the developer layer is such that only the image areas are contacted by the developer in the thickened portions of the layer.

40. A method according to any of claims 37 to 39 wherein said process further includes the formation at the developing zone of a magnetic field which causes the developer particles to form into erect and extending brush-like chains.

41. A method according to any previous claim wherein the thickness of the developer layer is not greater than 500 microns.

42. A method according to claim 41 wherein the thickness of the layer is not greater than 300 microns.

43. A method according to claim 42 wherein the thickness of the layer is no greater than 100 microns.

44. A method according to any preceding claim wherein the thickness of the layer is no less than 30 microns.

45. A method according to claim 14 or any claim dependent thereon wherein at the developing station the distance between the surface of the carrier carrying the layer and the surface of the said member to which developer is transferred is no greater than 500 microns.

46. A method according to claim 14 or any claim dependent thereon wherein at the developing station the distance between the surface of the carrier carrying the layer and the surface of said member to which developer is transferred is not less than 50 microns.

47. A method according to claim 14 or any claim dependent thereon wherein if t is the thickness of the toner layer, the distance s between the surface of the developer layer and the surface of said member to which developer is transferred satisfies the relationship: $s \geq t/5$

48. A method according to claim 47 wherein said distance s is no greater than 300 microns.

49. A method according to any preceding claim wherein said one-component magnetic developer is composed of a mixture of 50 parts of polystyrene, 40 parts of magnetite, 3 parts of a charge controlling agent and 6 parts of carbon.

50. A method according to claim 49 wherein said



one-component magnetic developer comprises particles of an average size of 5 to 10 microns.

51. A method according to claim 14 or any claim dependent thereon when including the features of claim 8, wherein said magnetic field forming means produces a surface flux density of 600 to 1300 gauss when a magnetic pole is positioned at the developing station where said carrier is closest to said member to which developer is transferred.

52. A method according to claim 51 wherein said surface flux density is 800 gauss.

53. A method according to claim 51 or claim 52 wherein the potential contrast of an electrostatic latent image carried by said member to which developer is transferred is approximately 600 volts.

54. Apparatus for forming a thin layer of one-component magnetic developer for use in the formation of a developed image comprising:

A) a supply of one-component magnetic developer;

B) a carrier on which the developer is to be moved through a regulating zone to a developing station;

C) means for supplying developer to said carrier upstream of said regulating zone;

D) a magnetic member spaced from said carrier in said regulating zone to define therewith a gap through which the developer is to be moved; and

E) means for forming at said regulating zone a magnetic field which extends across said gap and of which the lines of force converge towards said magnetic member, said field and said developer being such that in use said field causes the thickness of said layer to be limited by causing the passage of said developer through said gap to be blocked except for a portion moved adjacent the carrier.

55. Apparatus according to claim 54 wherein the magnetic field forming means is arranged to produce a stationary said magnetic field at the regulating zone and wherein the carrier is arranged to move so as to cause movement of the developer through the regulating zone and toward the developing station.

56. Apparatus according to claim 55 wherein said magnetic field forming means is separate from the carrier and is disposed so that at the regulating zone the carrier lies between said magnetic member and said magnetic field forming means.

57. Apparatus according to claim 56 wherein said magnetic field forming means includes a magnetic pole which faces the magnetic member across the carrier.

58. Apparatus according to claim 54 wherein the carrier is arranged to move so as to cause movement of the developer in a given direction through the regulating zone and toward the developing station.

59. Apparatus according to claim 58 wherein the magnetic field forming means is arranged to produce a said magnetic field which moves in the same direction as the carrier.

60. Apparatus according to claim 58 wherein the magnetic field forming means is arranged to produce a said magnetic field which moves in the opposite direction to the carrier.

61. Apparatus according to any of claims 58 to 60

wherein the magnetic field forming means is disposed so that at the regulating zone the carrier lies between said magnetic member and said magnetic field forming means.

62. Apparatus according to claim 56 or claim wherein said magnetic field forming means is adapted to magnetically attract the developer so as to hold the developer on the carrier during its movement thereon.

63. Apparatus according to claim 62 wherein said magnetic field forming means includes a plurality of magnetic poles for magnetically attracting the developer.

64. Apparatus according to claim 56 or any claim dependent thereon wherein said carrier comprises a rotatable sleeve of non-magnetic material and wherein said magnetic field forming means comprises a magnet fixedly disposed within said sleeve, the magnet having a developing pole which is arranged to act on the developer layer on the carrier at the developer station.

65. Apparatus according to claim 61 when dependent on claim 59 or claim 60 wherein the carrier comprises a rotatable sleeve of non-magnetic material and said magnetic field forming means comprises a magnet rotatably disposed within the sleeve and having a plurality of circumferentially spaced magnetic poles.

66. Apparatus according to claim 64 or claim 65 wherein the non-magnetic sleeve is made of aluminium.

67. Apparatus according to any of claims 54 to 66 wherein at the developing station the carrier faces a member to which developer is to be transferred for developed image formation.

68. Apparatus according to claim 67 when dependent on any of claims 54 to 66 wherein said member to which the developer is to be transferred at the developing station is arranged to move, and the carrier is arranged to move in the same direction.

69. Apparatus according to claim 68 wherein the arrangement is such that at the developing station the carrier surface supporting the developer layer moves at a greater speed than the surface of the member to which the developer is to be transferred.

70. Apparatus according to claim 68 wherein the arrangement is such that at the developing station the carrier surface supporting the developer layer moves at a lower speed than the surface of the member to which developer is to be transferred.

71. Apparatus according to claim 68 wherein the arrangement is such that at the developing station the developer layer moves at substantially the same speed as the surface of the member to which the developer is to be transferred.

72. Apparatus according to any of claims 54 to 71 wherein the one-component magnetic developer is an insulating developer.

73. Apparatus according to any of claims 54 to 72 wherein the magnetic member is a doctor blade comprising magnetic material.

74. Apparatus according to claim 55 or any claim dependent thereon wherein the magnetic member is a doctor blade comprising a magnet.

75. Apparatus according to claim 67 or any claim



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dependent thereon wherein the arrangement is such that in use the thickness of the developer layer carried on the carrier to the developing station is less than the clearance at the developing station between the carrier and said member to which the developer is to be transferred.

76. Apparatus according to any of claims 54 to 75 wherein the arrangement is such that in use the thickness of the developer layer is no greater than the width of said gap.

77. Apparatus according to any of claims 54 to 76 wherein the width of said gap is not greater than 500 microns.

78. Apparatus according to any of claims 54 to 77 wherein a further magnetic member is disposed upstream relative to the direction of movement of the developer on the carrier, of the regulating zone and at a close spacing from said carrier.

79. Apparatus according to claim 78 when dependent on claim 59 wherein the magnetic field forming means is arranged to cause the magnetic field to move at a speed which is such as to cause a surface portion of the developer layer to move in the opposite direction to an internal portion of the layer and wherein in use said further magnetic member is effective to limit such opposite surfacial flow.

80. Apparatus according to claim 54 wherein: the developer carrier comprises a rotatable sleeve of a non-magnetic material;

the one-component magnetic developer is an insulating developer; the magnetic field forming means includes a magnetic roller which is fixedly disposed within said sleeve and has a developing magnetic pole at the developing station and a plurality of magnetic poles for attracting and holding the developer on the sleeve;

the magnetic member is a doctor blade comprising magnetic material;

the magnetic roller has a pole at a position facing the doctor blade through the sleeve, a stationary said magnetic field being formed between the doctor blade and the said pole facing it.

81. Apparatus according to claim 80 including means for moving said sleeve so that at the developing station it moves in the same direction as a member to which the developer is to be transferred and the speed of the developer carried on the sleeve is substantially the same as the speed of said member;

said magnetic doctor blade having an edge onto which the said magnetic field is concentrated, said edge being spaced from the sleeve by 500 microns or less; and

the stationary magnetic field formed between the edge and the said facing pole being such as to limit the thickness of the one-component magnetic developer layer on the sleeve to a thickness smaller than the clearance between the sleeve and the said member to which the developer is to be transferred.

82. Apparatus according to any of claims 54 - 81 wherein the supply of one-component magnetic developer is contained in a container from which said developer is supplied to a surface of said carrier, said container having an opening adjacent said

surface.

83. Apparatus according to claim 82 wherein the magnetic member is arranged at a downstream edge of said opening with respect to the direction of movement of the developer toward said developing station.

84. Apparatus according to claim 83 wherein said magnetic member is formed integrally with said container.

85. Apparatus according to claim 83 wherein the regulating zone is at a position between said opening and the developing station.

86. Apparatus according to claim 54 wherein: the carrier is a tubular sleeve of non-magnetic material the surface of which is supplied with the developer;

the magnetic field forming means comprises a rotatable magnet roller which is disposed within said tubular sleeve and which comprises a plurality of magnetic poles;

drive means is provided for driving the magnet roller in a given rotational direction so as to form an alternating magnetic field at the surface of the tubular sleeve thereby carrying the one-component developer around said surface of the tubular sleeve; and

the magnetic member disturbs the alternating field on the sleeve surface by causing said convergence of the lines of force of the field.

87. Apparatus according to any of claims 54 to 63 wherein the carrier is in the form of an endless belt extending around a plurality of rollers.

88. Apparatus according to claim 59 wherein the magnetic field forming means is arranged to move, at the developing station, at a speed which is greater than the speed of the carrier.

89. Apparatus according to claim 67 or any claim dependent thereon wherein the arrangement is such that at the developing station the developer is, in use, transferred to the said member for developed image formation by a process which involves the flight of developer particles across a gap from the developer layer toward said member.

90. Apparatus according to claim 67 or any claim dependent thereon wherein the arrangement is such that, in use, said member to which the developer is transferred bears a latent image having image and non-image areas, as herein defined, and at the developing station developer is transferred to said member for developed imaged formation by a process involving thickening of portions of the toner layer facing the said image areas.

91. Apparatus according to claim 90 wherein said thickening of the developer layer is such that only the image areas are contacted by the developer in the thickened portions of the layer.

92. Apparatus according to any of claims 89 to 91 wherein the arrangement is such that, in use, said process further includes the formation at the developing zone of a magnetic field which causes the developer particles to form into erect and extending brush-like chains.

93. Apparatus according to any of claims 54 to 92 wherein the arrangement is such that, in use, the thickness of the developer layer is no greater than



500 microns.

94. Apparatus according to claim 93 wherein the thickness of the layer is not greater than 300 microns.

5 95. Apparatus according to claim 94 wherein the thickness of the layer is no greater than 100 microns.

96. Apparatus according to any preceding claim wherein the arrangement is such that, in use, the thickness of the layer is no less than 30 microns.

10 97. Apparatus according to claim 67 or any claim dependent thereon wherein at the developing station the distance between the surface of the carrier for carrying the layer and the surface of the said member to which developer is to be transferred
15 is no greater than 500 microns.

98. Apparatus according to claim 67 or any claim dependent thereon wherein at the developing station the distance between the surface of the carrier for carrying the layer and the surface of said
20 member to which developer is transferred is not less than 50 microns.

99. Apparatus according to claim 67 or any claim dependent thereon wherein the arrangement is such that if t is the thickness of the toner layer, the
25 distance s between the surface of the developer layer and the surface of said member to which developer is to be transferred satisfies the relationship $s \geq t/5$

100. Apparatus according to claim 99 wherein
30 said distance s is no greater than 300 microns.

101. Apparatus according to any of claims 54 to 100 wherein said one-component magnetic developer is composed of a mixture of 50 parts of polystyrene, 40 parts of magnetite, 3 parts of a
35 charge controlling agent and 6 parts of carbon.

102. Apparatus according to claim 101 wherein said one component magnetic developer comprises particles of an average size of 5 to 10 microns.

103. Apparatus according to claim 67 or any
40 claim dependent thereon wherein said magnetic field forming means is arranged to produce a surface flux density of 600 to 1300 gauss when a magnetic pole thereof is positioned at the developing station where said carrier is closest to said member to which
45 developer is transferred.

104. Apparatus according to claim 103 wherein said surface flux density is 800 gauss.

105. Apparatus according to claim 103 or claim 104 wherein the potential contrast of an electrostatic
50 latent image carried by said member to which developer is transferred is approximately 600 volts.

106. An image-forming apparatus comprising:
a movable image recording member;
means for forming on said recording member an
55 electrostatic latent image;
means for moving said recording member through a developing station; and

a developing apparatus for developing the electrostatic latent image at said developing station,
60 said developing apparatus being constituted by an apparatus according to any of claims 54 to 105.

107. An image-forming apparatus according to claim 106 wherein the recording member is a photosensitive drum and wherein the image forming
65 means is adapted to perform at least the steps of

electrostatically charging the recording member and exposing the recording member to light such as to create said electrostatic latent image thereon.

108. A method of forming a thin layer of
70 one-component magnetic developer substantially as hereinbefore described with reference to Figures 2 and 3 of the accompanying drawings.

109. A method of forming a thin layer of one-component magnetic developer substantially as
75 hereinbefore described with reference to Figure 4 of the accompanying drawings.

110. A method of forming a thin layer of one-component magnetic developer substantially as
80 hereinbefore described with reference to Figure 5 of the accompanying drawings.

111. Apparatus for forming a thin layer of one-component magnetic developer substantially as
hereinbefore described with reference to Figures 2 and 3 of the accompanying drawings.

85 112. Apparatus for forming a thin layer of one-component magnetic developer substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

113. Apparatus for forming a thin layer of
90 one-component magnetic developer substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

114. An image forming apparatus which includes a developer layer forming apparatus according to
95 any of claims 54 to 107 and 111 - 113, and further substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.