

Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) Publication number:

**0 429 684 A1**

(12)

**EUROPEAN PATENT APPLICATION**  
published in accordance with Art.  
158(3) EPC

(21) Application number: 90909488.0

(51) Int. Cl.<sup>5</sup>: **G03G 15/09, H01F 7/02**

(22) Date of filing: 20.06.90

(86) International application number:  
**PCT/JP90/00808**

(87) International publication number:  
**WO 90/16017 (27.12.90 90/29)**

(30) Priority: 21.06.89 JP 158919/89  
04.07.89 JP 172333/89  
04.07.89 JP 172334/89  
04.07.89 JP 172335/89  
04.07.89 JP 172336/89  
04.07.89 JP 172337/89  
04.07.89 JP 172338/89  
04.07.89 JP 172339/89  
12.07.89 JP 179507/89  
12.07.89 JP 179521/89  
12.07.89 JP 179522/89

(43) Date of publication of application:  
05.06.91 Bulletin 91/23

(84) Designated Contracting States:  
**DE FR GB Bulletin**

(71) Applicant: **SEIKO EPSON CORPORATION**  
4-1, Nishi-Shinjuku 2-chome  
Shinjuku-ku Tokyo-to 160(JP)

(72) Inventor: **KOGA, Yoshiro**  
Seiko Epson Corporation 3-5, Owa 3-chome  
Suwa-shi Nagano 392(JP)  
Inventor: **ISHIWATARI, Tahei**  
Seiko Epson Corporation 3-5, Owa 3-chome  
Suwa-shi Nagano 392(JP)  
Inventor: **HAMA, Takashi**  
Seiko Epson Corporation 3-5, Owa 3-chome  
Suwa-shi Nagano 392(JP)

(74) Representative: **Caro, William Egerton et al**  
**J. MILLER & CO.** Lincoln House 296-302 High  
Holborn  
London WC1V 7JH(GB)

(54) **DEVELOPING APPARATUS.**

(57) An apparatus for developing an electrostatic latent image formed on a latent image support in an electrophotographic image recording apparatus. The apparatus includes a cylindrical magnetic roller (9) having a plurality of magnetic poles and made of rare earth metal magnets. A developer (8) is directly supplied onto the magnetic roller (9), held on the surface of the magnetic roller by the magnetic field generated by the magnetic roller, and transferred by the rotation of the magnetic roller. Thus, the construction of the apparatus can be simplified and image quality can be improved.

**EP 0 429 684 A1**

## DEVELOPING DEVICE

### FIELD OF THE INVENTION

This invention relates to image recording devices which use an electrophotographic process, and more particularly it relates to developing devices for developing electrostatic latent images formed on a latent image carrier.

### BACKGROUND OF THE INVENTION

In commonly known magnetic brush developing devices (one-component magnetic brushes and two-component magnetic brushes) of the prior art, a cylindrical magnetic roller magnetized with a plurality of magnetic poles is positioned inside a rotating, non-magnetic, conductive, cylindrical developer transport member (also called a developer sleeve) typically made from stainless steel, aluminum or brass. In most developing devices which use this kind of sleeve, the developer is held on the developer transport member according to the magnetic field generated by the magnetic roller, and either the magnetic roller or the developer transport member rotates and transports the developer on the developer transport member.

However, in the above prior art, it is necessary to polish the magnetic roller to obtain an outside diameter of the required precision and to accurately position the magnetic roller and developer transport member with a small gap between them, thus increasing the labor and raising the cost, and since the outside diameter of the developer transport member must also be machined, the cost of the developing device is further increased. Further, there are many parts used to support the magnetic roller and developer transport device as well as the component parts that accompany these, and therefore it is difficult to make the developing device compact and lightweight. Also, when the number of magnetic poles is increased on the magnetic roller in order to reduce uneven developing characteristic the image obtained when the magnetic roller is rotated and caused by the pitch of magnetic poles on the magnetic roller, it is difficult to obtain sufficient leakage flux on the developer transport member, thus hindering the transport of developer.

### SUMMARY OF THE INVENTION

This invention is intended to solve these kind of problems, and its purpose is to offer a low-cost developing device that is easy to manufacture from production to assembly by employing a developing device structure which carries the developer directly on the surface of the magnetic roller. Another

purpose is to offer a compact, lightweight developing device. Another purpose is to offer a developing device capable of obtaining a high developer density by transporting a sufficient amount of developer through effective utilization of the magnetic field generated by the magnetic roller. Another purpose is to offer a developing device that will yield high print quality with reduced uneven developing caused by the magnetic roller.

That is, the developing device of this invention is a developing device for developing electrostatic latent image patterns formed on a latent image carrier in image recording devices employing an electrophotographic process, wherein the developing device comprises a cylindrical magnetic roller on which a plurality of magnetic poles are formed, the developer is supplied directly to the magnetic roller, the developer is held on the surface of the magnetic roller by the magnetic field generated by the magnetic roller, and the developer being held is transported by rotating the magnetic roller.

By means of the above invention, a developing device can be configured with a simple structure by eliminating the prior art developer transport member (sleeve) positioned around the outside of the magnetic roller. Further, since the developer is transported directly by the magnetic roller, the magnetic field generated by the magnetic roller (magnet) can be utilized most efficiently. Also, the magnetic roller can be configured to be compact and lightweight by forming it from a rare earth magnet with a high magnetic characteristic, and the magnetic roller can be configured to have excellent dimensional accuracy without the need for final machining by forming the magnet by injection molding, compression molding or extraction molding. The mechanical strength and magnetic characteristic, in particular, can be improved by including a yoke, which is made from a soft magnetic material and constitutes the magnetic circuit, in the magnetic roller. Other features of the invention will be made clear in the following explanations.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1, FIG. 4 and FIG. 5 are generalized diagrams of the developing device of this invention; FIG. 2 is a generalized cross section of the magnetic roller used in the developing device; FIG. 3 is a generalized cross section showing the developer being held on the surface of the magnetic roller; and FIG. 6A and FIG. 6B are each graphs depicting the impressed condition of the alternating voltage.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a generalized cross section of an image formation device including the developing device in a specific application of the invention. The latent image carrier 1 is formed from a photosensitive layer 3 made up of an organic or inorganic photoconductive material on top of a conductive support member 2. After the photosensitive layer 3 is charged using the charger 4 which can be a corona charger or other type of charger, the light emitted from the light source 5 passes through the imaging optical system 6 and is selectively irradiated on the photosensitive layer 3 according to the image, whereby potential contrasts are obtained on the photosensitive layer 3 and the desired electrostatic latent image pattern is formed. The developing device 7 charges the developer 8 which is the image formation material, transports it via the cylindrical magnetic roller 9, and develops the developer 8 according to the potential of the electrostatic latent image on the latent image carrier 1 and the bias voltage from the means for impressing the developing bias voltage in the developing gap where the latent image carrier 1 and the magnetic roller 9 come near each other. In this way, the electrostatic latent image on the latent image carrier 1 is manifested as an image by the developer 8.

The developer 8 which has manifest the electrostatic latent image is transferred to the recording paper 15 by the transfer unit 14 using corona discharging, an electric field, pressure or adhesion, and the developer 8 is fixed to the recording paper 15 by a pressurizing or heating means, whereby the desired image is formed from developer 8 on the recording paper.

In the developer device in FIG. 1, while holding the supplied developer 8 by magnetic force, the magnetic roller 9 transports the developer 8 regulated to an appropriate amount by the transport regulating member 11. The magnetic roller 9 can comprise a magnetic circuit made up of a cylindrical magnet 12 with a plurality of magnetic poles around its circumference and a cylindrical yoke 13 made from a soft magnetic material. The magnetic roller 9 is rotated with the developer 8 held directly on its surface by the leakage flux on the outside circumference of the magnet 12, thus facilitating direct transport of the developer 8. By this means, the magnetic flux is used to full advantage. Therefore, a magnetic restraint greater than in the prior art can be obtained with even a thin magnet. In FIG. 1, the arrows indicate the direction of rotation of the respective members, but this invention is not limited to this configuration.

As described above, by making the structure of

the magnetic roller a thin cylindrically shaped member which is essentially open on the inside, the installation and removal of the magnetic roller becomes extremely easy and the moment of inertia of the magnet is small when the magnetic roller is rotated, thus speeding up the start of rotation, nearly eliminating uneven rotation during both low-speed and high-speed rotation and only requiring a small torque for rotation. That is, since the inside of the magnetic roller 9 is open and its moment of inertial is small, the magnetic roller 9 can be quickly rotated, it demonstrates almost no uneven rotation during either low-speed or high-speed rotation, it requires little torque for rotation, and developer can be supplied in consistently appropriate amounts, thus making it possible to reduce uneven developing density and obtain high printing quality.

FIG. 2 is a generalized cross section of the magnetic roller being used in a developing device in another specific example of the invention. Developer is held and transported according to the magnetic distribution on the outside surface of the cylindrical magnet 12 which is made from a rare earth magnet and has a plurality of magnetic poles formed radially on its circumference, and the magnetic roller 9 has fitted on the inside of the magnet 12 by adhesion or other means the yoke 13 which makes up the magnetic circuit and is made from a soft magnetic material having iron, etc., as its main component. By forming the magnet 22 from a rare earth magnet in the invention, the weight of the magnet can be reduced to half of that of the prior art, and it also becomes possible to have more than 10 magnetic poles on the magnet 12 and decrease the weight of the yoke 13.

The magnet 12 and yoke 13 can be formed as a unit in the formation of the magnetic roller 9 by first positioning the yoke 13 made from a soft magnetic material in the mold when forming the magnet and injecting a magnetic material containing a magnetic powder or resin around the outside of the yoke. By means of this method, they can be easily formed as a unit by injection molding of plastic, and sufficient mechanical strength can be obtained even when the thickness of the magnet is only 0.5 to 2.0 mm. Further, the deviation in the outside diameter of the magnetic roller 9 can be reduced to less than 25  $\mu\text{m}$ , whereby fluctuations in the amount of developer transported and in the developing gap can be reduced.

All of the commonly known single-component magnetic brush developers and two-component magnetic brush developers can be used as the developer in the invention. Also, such commonly known magnetic materials as ferrite magnet, Alnico magnet, manganese-aluminum magnet or rare earth magnet can be used as the magnetic material for the magnetic roller employed in this invention.

By using a rare earth magnet made up of a 3d transition metal such as iron, nickel or cobalt added to one of the 14 rare earth elements ranging from cerium, atomic number 58, to lutetium, atomic number 71, i.e., neodymium, praseodymium and samarium, as the magnet 22, a strong magnetic field can be achieved with even a thin magnet, and therefore a compact, lightweight magnetic roller can be configured. Further, in addition to the sintering production method described above, a magnet formed by compression molding, injection molding or extraction molding can be used, in which case, greater freedom can be taken in the shape and magnetic field distribution of the magnetic roller in addition to making it lightweight and compact. In the case of a molded magnet, the yoke, etc., can be formed as a unit when configuring the magnetic circuit, and dimensional accuracy can be improved such as reducing the deviation in the outside diameter to less than 25  $\mu\text{m}$  without final machining. Also, since complex measures such as adhesion, etc., are not employed, fluctuations in the magnetic resistance of the magnetic circuit can be made smaller and the magnetic flux density at the magnet surface can be made uniform, whereby fluctuations in the amount of developer transported and in the amount of developing due to deviations in the magnetic flux can be reduced. Since the magnet can be made thin, a magnetizing yoke can be easily positioned inside or outside to form 10 or more magnetic poles even in a magnet with an outside diameter of only 20 mm. Therefore, by forming a plurality of magnetic poles at a pitch nearly equivalent to the thickness of the magnet, fluctuations in the amount of developer transported and in the amount of developing can be reduced.

Details on the materials that can be used in the formation of the above-mentioned rare earth magnet are disclosed in Japanese Laid-Open Patent Publications Nos. 60-194503 and 63-289807. Specific embodiments are described below.

#### Embodiment A1

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 4-mm-thick ferrite magnet with an outside diameter of 20 mm and a 2-mm-thick yoke with an outside diameter of 12 mm which made up the magnetic circuit inside the magnet, and the magnet was divided up into 16 magnetic poles which yielded a flux density of more than 1000 gauss on the magnet surface, whereby sufficient developer supply and transport amount were obtained. Also, the magnetic roller could be made lighter by the amount of weight of the metal sleeve used as the developer transport member in the prior art. Using this developing device to form images, we were

able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected when the magnetic roller was rotated at a linear speed four times greater than that of the latent image carrier.

#### Embodiment A2

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 1.5-mm-thick samarium-cobalt compression-molded magnet with an outside diameter of 20 mm and a 1-mm-thick yoke with an outside diameter of 17 mm which made up the magnetic circuit inside the magnet, and the magnet was divided up into 40 magnetic poles which yielded a flux density of more than 1000 gauss on the magnet surface, whereby sufficient developer supply and transport amount were obtained. Also, the magnetic roller could be made less than half as light as prior art units employing a ferrite magnet and metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected when the magnetic roller was rotated at a linear speed two times greater than that of the latent image carrier.

#### Embodiment A3

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick samarium-cobalt injection-molded magnet with an outside diameter of 12 mm and a 1-mm-thick yoke with an outside diameter of 10 mm which made up the magnetic circuit inside the magnet, and the magnet was divided up into 40 magnetic poles which yielded a flux density of more than 1000 gauss on the magnet surface, whereby sufficient developer supply and transport amount were obtained. Also, the magnetic roller could be made less than one-fourth as light as prior art units employing a ferrite magnet and metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected when the magnetic roller was rotated at a linear speed two times greater than that of the latent image carrier.

#### Embodiment A4

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick praseodymium extraction-molded mag-

net with an outside diameter of 20 mm and a 1-mm-thick yoke with an outside diameter of 18 mm which made up the magnetic circuit inside the magnet, and the magnet was divided up into 60 magnetic poles which yielded a flux density of more than 1000 gauss on the magnet surface, whereby a sufficient developer thin layer and transport amount were obtained. Also, the magnetic roller could be made less than half as light as prior art units employing a ferrite magnet and metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected when the magnetic roller was rotated faster than the linear speed of the latent image carrier.

#### Embodiment A5

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick resin-bonded ferrite magnet with an outside diameter of 20 mm and a 1-mm-thick yoke with an outside diameter of 18 mm which made up the magnetic circuit inside the magnet, and the magnet was divided up into 60 magnetic poles which yielded a flux density of more than 200 gauss on the magnet surface, whereby a sufficient developer thin layer and transport amount were obtained. Also, the magnetic roller could be made less than half as light as prior art units employing a ferrite magnet and metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected when the magnetic roller was rotated faster than the linear speed of the latent image carrier.

#### Comparison Example A1

In a single-component magnetic developing device of the prior art, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller positioned inside the developing device was configured from a sintered ferrite magnet machined to an outside diameter of 18 mm and a thickness of 2 mm. Even when the magnetic roller was divided up into eight or less magnetic poles, a flux density of only 500 gauss could be obtained on the surface of the developer transport member, thus preventing sufficient supply and transport of the developer. Also, when this developing device was used to form images, only low-contrast images with insufficient developer density could be obtained.

#### Comparison Example A2

In a single-component magnetic developing device of the prior art, a developer transport member with an outside diameter of 20 mm was used, and the magnetic roller positioned inside the developing device was configured from a sintered ferrite magnet machined to an outside diameter of 18 mm and a thickness of 5 mm. When the magnetic roller was divided up into eight or less magnetic poles, a flux density of greater than 500 gauss could be obtained on the surface of the developer transport member, thus providing sufficient supply and transport of developer. However, the weight of the magnetic roller was greater than 0.4 kg at a length of 220 mm, so the unit could not be made lightweight.

In addition to the embodiments described above, this invention can be applied to a wide range of electrophotographic and other types of developing devices, and it is particularly suited to printers, copiers, facsimile machines and displays.

As described above, by means of this invention, a low-cost developing device can be produced with fewer processes through to assembly by holding and transporting the developer directly on the cylindrical magnetic roller with a plurality of magnetic poles. Further, since the structure is simplified, a compact, lightweight developing device can be offered. Also, since the developer is transported by the leakage flux, a developing device can be offered which effectively utilizes the magnetic field generated by the magnetic roller to yield sufficient transport of developer and a high developing density. Moreover, even if the magnet is divided up into numerous magnetic poles, a sufficient magnetic characteristic can be obtained for holding and transporting the developer, whereby a developing device is realized which reduces uneven developing density caused by the magnetic roller and offers high printing quality.

By employing a rare earth magnet as the magnet for the magnetic roller, a developing device can be realized which yields a sufficient magnetic field for holding and transporting the developer even if the magnet is made thin, whereby the magnetic powder content of the developer can be reduced. Further, a superior fixing characteristic can be obtained at a lower fixing temperature, and images with a superior glossiness can be formed.

By employing a molded magnet as the magnet for the magnetic roller, the machining and assembly processes are eliminated, dimensional accuracy is improved and an efficient magnetic circuit can be configured with a smaller magnetic resistance.

By employing a magnetic roller structure containing a yoke of soft magnetic material inside the magnet, an efficient magnetic circuit can be config-

ured, and a magnetic flux sufficient for holding and transporting the developer can be obtained on the surface of the magnetic roller.

By employing a compression-molded magnet, an injection-molded magnet or an extraction-molded magnet as the magnet of the magnetic roller, machining and assembly processes are reduced and a magnetic roller is obtained with good dimensional accuracy and excellent moldability even when made thin, and sufficient magnetic flux for holding and transporting the developer can be obtained on the surface of the magnetic roller.

By dividing the magnet of the magnetic roller up into 10 or more magnetic poles, a developing device can be offered which reduces uneven developing density caused by the magnetic roller and yields high print quality.

By means of the above invention, a developing device can be offered which is compact and lightweight and forms high quality images.

#### Formation of Crests and Troughs

Next is an explanation of an embodiment in which crests and troughs are formed into the surface of the magnetic roller.

As shown in FIG. 3, crests and troughs are formed into the outside surface of the magnet 12 of the magnetic roller 9 in this embodiment. In this case, as shown in the figure, it is desirable to form the midpoints between the N poles and between the S poles as an indentation (trough) and the midpoints (border area) between the N and S poles as a protrusion (crest). By means of this crest-and-trough shape, the outside diameter of the magnetic brush formed by the developer 8 can be made uniform regardless of the position of the poles. The height of the crest in the crest-and-trough shape should be about one-half the thickness of the layer formed by the developer, whereby a good, uniform effect can be obtained.

The above crest-and-trough shape should have the following relationship to the magnetic poles as viewed from the axial direction and the circumferential direction of the magnetic roller.

When a plurality of magnetic poles are formed only in the circumferential direction of the magnetic roller, the same number of crests and troughs should be formed in the circumferential direction as the number of magnetic poles. When a plurality of magnetic poles are formed only in the axial direction of the magnetic roller, about the same number of crests and troughs should be formed in the axial direction as the number magnetic poles. When a plurality of magnetic poles are formed in both the circumferential direction and the axial direction of the magnetic roller, about the same number of crests and troughs should be formed as the num-

ber of magnetic poles according to the position of the magnetic poles. Further, the shape of the crests and troughs depends on the number of magnetic waves, but by making them arc shaped or sine wave shaped, the outside diameter of the magnetic brush can be made uniform.

By forming crests and troughs on the surface layer of the magnetic roller in this manner, the rotational radius of the end of the developer becomes fixed regardless of the position of the magnetic poles, and in the case of contact developing, the developing nip width can be maintained constant and a consistent image density can be obtained with a fixed developing time and demagnetizing force. In the case of non-contact developing, consistent image density can be obtained by maintaining a fixed developing electric field. Also, the prescribed crests and troughs can be easily formed on the surface of the magnetic roller by using the compression molding, injection molding or extraction molding described above.

An embodiment is explained below in which crests and troughs are formed on the surface of the magnetic roller.

#### Embodiment B1

In a developing device such as that shown in FIG. 1, a magnetic roller was configured from a resin-bonded ferrite magnet which had an outside diameter of 20 mm, was 1 mm thick at the crests and 0.85 mm thick at the troughs, and had 60 troughs and crests each, and a 1-mm-thick yoke which had an outside diameter of 18 mm and made up the magnetic circuit inside the magnet, whereby a magnetic roller was realized in which a flux density greater than 200 gauss was obtained on the surface of the magnet when the magnet was divided up into 60 magnetic poles and a thin layer of developer with a uniform outside diameter was formed on the surface of the magnet. Also, this magnetic roller could be made less than half as heavy as prior art magnetic rollers which used a ferrite magnet and a metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected.

#### Embodiment B2

In a developing device such as that shown in FIG. 1, a magnetic roller was configured from a samarium-cobalt compression-molded magnet which had an outside diameter of 20 mm, was 1.5 mm thick at the crests and 1.35 mm thick at the troughs, and had 40 troughs and crests each, and a 1-mm-thick yoke which had an outside diameter

of 17 mm and made up the magnetic circuit inside the magnet, whereby a magnetic roller was realized in which a flux density greater than 1000 gauss was obtained on the surface of the magnet when the magnet was divided up into 40 poles and a thin layer of developer with a uniform outside diameter was formed on the surface of the magnet. Also, this magnetic roller could be made less than half as heavy as prior art magnetic rollers which used a ferrite magnet and a metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected.

#### Embodiment B3

In a developing device such as that shown in FIG. 1, a magnetic roller was configured from a samarium-cobalt injection-molded magnet which had an outside diameter of 12 mm, was 1 mm thick at the crests and 0.9 mm thick at the troughs, and had 40 troughs and crests each, and a 1-mm-thick yoke which had an outside diameter of 10 mm and made up the magnetic circuit inside the magnet, whereby a magnetic roller was realized in which a flux density greater than 1000 gauss was obtained on the surface of the magnet when the magnet was divided up into 40 poles and a thin layer of developer with a uniform outside diameter was formed on the surface of the magnet. Also, this magnetic roller could be made less than one-fourth as heavy as prior art magnetic rollers which used a ferrite magnet and a metal sleeve. Using this developing device to form images, we were able to consistently form high-density, high-contrast images in which almost no unevenness in developing density could be visually detected.

#### Comparison Example B1

In a single-component magnetic developing device of the prior art, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller positioned inside the developing device was configured from a sintered ferrite magnet machined to an outside diameter of 18 mm and a thickness of 2 mm. Even when the magnetic roller was divided up into eight or less magnetic poles, a flux density of only 500 gauss could be obtained on the surface of the developer transport member, thus preventing sufficient supply and transport of the developer. Also, when this developing device was used to form images, only low-contrast images with insufficient developer density could be obtained.

#### Comparison Example B2

In a single-component magnetic developing device of the prior art, a developer transport member with an outside diameter of 20 mm was used, and the magnetic roller positioned inside the developing device was configured from a sintered ferrite magnet machined to an outside diameter of 18 mm and a thickness of 5 mm. When the magnetic roller was divided up into eight or less magnetic poles, a flux density greater than 500 gauss could be obtained on the surface of the developer transport member, thus providing a sufficient supply and transport of developer. However, the weight of the magnetic roller was greater than 0.4 kg at a length of 220 mm, so the unit could not be made lightweight, and uneven density accompanying fluctuations in the magnetic field were marked.

#### Control of Surface Roughness

Next is an explanation of how the surface roughness of the magnetic roller is controlled.

In the above direct-transport type developing device; i.e., developing device in which the developer (toner) is transported directly on the surface of the magnetic roller, filming (adhering or bonding) of the toner on the surface of the magnetic roller occurs rather easily. When this filming occurs, it becomes difficult to consistently form a toner layer that is uniformly charged, and this makes it difficult to form consistently high quality images over long periods.

In this invention, the surface roughness of the magnetic roller is controlled so that it is less than 40% of the volumetric mean particle diameter of the toner, which is a component of the developer, based on the average roughness measured at 10 points as per the JIS standard (JIS-B0601), whereby the above problem can be effectively solved.

It is not necessarily clear why the problem of filming is solved by strictly controlling the surface roughness as described above, but it is thought that when the toner passes between the magnetic roller and the developer transport regulating member, the pressure and friction applied at the contact between the toner and the magnetic roller are reduced, whereby filming of the toner on the magnetic roller or deterioration of the toner is reduced.

When the surface roughness is not less than 40% as defined above, then the filming prevention effect is poor. Control of the above surface roughness can also be applied similarly to rollers on which crests and troughs have been formed.

Below is a detailed explanation of the above based on a specific embodiment.

#### Embodiment C1

In this embodiment, a one-component developer made up of a magnetic toner having a volumetric mean particle diameter of 10  $\mu\text{m}$  and comprising carbon black,  $\text{Fe}_3\text{O}_4$  and a polyester resin as its principal components was used.

In an image formation device employing a developing device with the above configuration, we used magnetic rollers 9 with various surface roughnesses (1 to 10  $\mu\text{m}$ ) based on the JIS 10-point average roughness standard (JIS-B0601) and continuously formed images with each equivalent to 50 000 regular A4-size sheets. Images obtained with magnetic rollers 9 having a surface roughness greater than 4  $\mu\text{m}$  based on the JIS 10-point average roughness standard showed streaking and the appearance of background, thus clearly indicating filming of the toner on the magnetic roller 9, but good images with no streaking or appearance of background were obtained using a magnetic roller 9 with a surface roughness of less than 4  $\mu\text{m}$  based on the JIS 10-point average roughness standard, and filming of the toner on the magnetic roller 9 was not observed.

Since the volumetric mean particle diameter of the toner used in this embodiment was 10  $\mu\text{m}$ , good images were obtained when the JIS 10-point average roughness of the magnetic roller 9 was less than 4  $\mu\text{m}$ ; i.e., when the surface roughness of the magnetic roller 9 according to the JIS 10-point average roughness standard was less than 40% of the volumetric mean particle diameter of the toner.

#### Embodiment C2

In this embodiment, a two-component developer was used which combined a toner having a volumetric mean particle diameter of 12  $\mu\text{m}$  and comprising carbon black and a polyester resin as its principal components and soft magnetic particles with a particle diameter of 100  $\mu\text{m}$  as the carrier.

In an image formation device employing a developing device with the above configuration, we used magnetic rollers 9 with various surface roughnesses based on the JIS 10-point average roughness standard (JIS-B0601) and continuously formed images with each equivalent to 50 000 regular A4-size sheets. Images obtained with magnetic rollers 9 having a surface roughness greater than 4.8  $\mu\text{m}$  based on the JIS 10-point average roughness standard showed streaking and the appearance of background, thus clearly indicating filming of the toner on the magnetic roller 9, but good images with no streaking or appearance of background were obtained using a magnetic roller 9 with a surface roughness of less than 4.8  $\mu\text{m}$  based on the JIS 10-point average roughness standard, and filming of the toner on the magnetic roller

9 was not observed.

Since the volumetric mean particle diameter of the toner used in this embodiment was 12  $\mu\text{m}$ , good images were obtained when the JIS 10-point average roughness of the magnetic roller 9 was less than 4.8  $\mu\text{m}$ ; i.e., when the surface roughness of the magnetic roller 9 according to the JIS 10-point average roughness standard was less than 40% of the volumetric mean particle diameter of the toner.

#### Embodiment C3

In this embodiment, a one-component developer made up of a magnetic toner having a volumetric mean particle diameter of 9  $\mu\text{m}$  and comprising particles of carbon black, wax and  $\text{Fe}_3\text{O}_4$  as their principal components and covered with styrene acrylic resin was used.

In an image formation device employing a developing device with the above configuration, we used magnetic rollers 9 with various surface roughnesses based on the JIS 10-point average roughness standard (JIS-B0601) and continuously formed images with each equivalent to 50 000 regular A4-size sheets. Images obtained with magnetic rollers 9 having a surface roughness greater than 3.6  $\mu\text{m}$  based on the JIS 10-point average roughness standard showed streaking and the appearance of background, thus clearly indicating filming of the toner on the magnetic roller 9, but good images with no streaking or appearance of background were obtained using a magnetic roller 9 with a surface roughness of less than 3.6  $\mu\text{m}$  based on the JIS 10-point average roughness standard, and filming of the toner on the magnetic roller 9 was not observed.

Since the volumetric mean particle diameter of the toner used in this embodiment was 9  $\mu\text{m}$ , good images were obtained when the JIS 10-point average roughness of the magnetic roller 9 was less than 3.6  $\mu\text{m}$ ; i.e., when the surface roughness of the magnetic roller 9 according to the JIS 10-point average roughness standard was less than 40% of the volumetric mean particle diameter of the toner.

#### Formation of Corrosion Prevention Layer

As described above, ferrite, Alnico, manganese-aluminum, rare earth magnets and other known magnetic materials can be used as the magnetic material for the magnetic roller, but it is particularly desirable to use a rare earth magnetic made up of at least one rare earth element such as neodymium, praseodymium and samarium from among the 14 rare earth elements with atomic numbers ranging from 58 to 71 (symbols Ce to Lu) to which has been added at least one 3d transition

metal such as iron, nickel and cobalt. However, when a magnetic roller containing a rare earth magnetic, particularly one containing iron, is used, corrosion by oxidation (so-called "rusting") occurs on the surface of the magnetic roller due to the effect of oxygen or moisture in the air, and therefore consistently high quality images cannot be made over long periods.

In the developing device of this invention, the surface of the magnetic roller is provided with a covering layer (at least the developer transport surface of the magnetic roller is covered so the magnet is not exposed), whereby corrosion of the magnetic roller surface due to oxidation caused by oxygen or moisture in the air does not occur, and therefore consistently high quality images can be formed over long periods.

Any material capable of covering the magnetic roller 9 surface so the magnet 12 is not exposed can be used as the covering layer (not shown in figure) in the invention. For example, such non-ferrous metals as aluminum, nickel, gold and platinum, inorganic oxides such as  $\text{Fe}_3\text{O}_4$  and  $\text{SiO}_2$ , and such resins as polycarbonates and polystyrenes can be used. The covering layer should be at least  $1\text{ }\mu\text{m}$  thick to prevent the occurrence of pinholes in the formation of the covering layer and deterioration of the covering layer over long periods of use.

#### Embodiment D1

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with an epoxy resin as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the ambient conditions  $30^\circ\text{C}$  and 60% relative humidity, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D1

Using an image formation device based on a developing device with the same configuration as in embodiment D1 except that the surface of the magnetic roller 9 was not covered with an epoxy resin leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as

in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D2

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with nickel (nickel plating) as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D2

Using an image formation device based on a developing device with the same configuration as in embodiment D2 except that the surface of the magnetic roller 9 was not covered with nickel leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D3

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with  $\text{SiO}_2$  as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D3

Using an image formation device based on a

developing device with the same configuration as in embodiment D3 except that the surface of the magnetic roller 9 was not covered with  $\text{SiO}_2$  leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D4

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with  $\text{TiO}_2$  as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D4

Using an image formation device based on a developing device with the same configuration as in embodiment D4 except that the surface of the magnetic roller 9 was not covered with  $\text{TiO}_2$  leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D5

In this embodiment, a cast praseodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with  $\text{SiC}$  as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the mag-

netic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D5

Using an image formation device based on a developing device with the same configuration as in embodiment D5 except that the surface of the magnetic roller 9 was not covered with  $\text{SiC}$  leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D6

In this embodiment, a cast praseodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with  $\text{Al}_2\text{O}_3$  as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D6

Using an image formation device based on a developing device with the same configuration as in embodiment D6 except that the surface of the magnetic roller 9 was not covered with  $\text{Al}_2\text{O}_3$  leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D7

In this embodiment, a cast praseodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with  $\text{ZnO}$  as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets

were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D7

Using an image formation device based on a developing device with the same configuration as in embodiment D7 except that the surface of the magnetic roller 9 was not covered with ZnO leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D8

In this embodiment, an extraction-molded praseodymium-iron magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with aluminum as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D8

Using an image formation device based on a developing device with the same configuration as in embodiment D8 except that the surface of the magnetic roller 9 was not covered with aluminum leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D9

In this embodiment, an extraction-molded samarium-cobalt magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with nickel as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D9

Using an image formation device based on a developing device with the same configuration as in embodiment D9 except that the surface of the magnetic roller 9 was not covered with nickel leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment D10

In this embodiment, a compression-molded samarium-cobalt magnet was used as the magnetic roller 9, and the surface of the magnetic roller 9 was covered with TiO<sub>2</sub> as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1, but no deterioration of the image was observed, and images were obtained with the same high quality and high resolution as the first sheet. Further, no corrosion due to oxidation was observed on the surface of the magnetic roller 9, and a consistently uniform developer layer was formed on the magnetic roller 9.

#### Comparison Example D10

Using an image formation device based on a developing device with the same configuration as in embodiment D10 except that the surface of the magnetic roller 9 was not covered with TiO<sub>2</sub> leaving the magnet 12 exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment D1. The images showed deterioration such as

streaking and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Formation of Resin Layer

In direct transport type developing devices such as this invention, the charge held by the various developers varies greatly due to various charging mechanisms such frictional electrification between the surface of the magnetic roller and the developer, between developer and developer, and between the developer and components of the developing device such as the developer transport regulating member. Differences in these kind of charging mechanisms cause developers with a broad charge distribution to be transported on the magnetic roller, thus resulting in extremely poor image quality.

In the developing device of this invention, the above problem can be solved by providing a covering layer made from at least one type of resin on the surface of the magnetic roller. That is, the resin layer covered on the magnetic roller acts as a carrier, which is a component of a two-component developer, for the developer transported on the magnetic roller, thus controlling charging of the developer due to frictional electrification, whereby the distribution of the charge of the developer becomes uniform and in turn makes it possible to consistently form high quality images.

In this embodiment, we showed an example in which the covering layer (resin layer) was covered completely or uniformly on the surface of the magnetic roller 9, but this invention is not limited to this, in that the covering layer need not be formed on the surface of the magnetic roller 9 in a uniform thickness, it may be incomplete and leave the magnet (surface of magnetic roller) exposed, and it may be formed in a plurality of non-continuous independent resin islands.

Any known developer can be used as a one-component magnetic brush developer or a two-component magnetic brush developer in this invention, and by appropriately selecting the resin that makes up the covering layer, the charged polarity of the developer 8 can be controlled to the desired polarity, either positive or negative. When controlling the charge of the developer 8 by the covering layer, selection of the resin that makes up the covering layer is extremely important, but when the charge control agent is mixed with the developer 8 in a process which uses a one-component developer as the developer 8, it is desirable to use a resin of the same charge ranking as the resin that makes up the developer 8 in order to maximize the charging effect of the charge control agent. When the charge control agent is mixed with the devel-

oper 8 but sufficient charge cannot be obtained or excessive charge is obtained with the charge control agent, it is desirable to use a resin with a charge ranking which either enhances or inhibits the charging effect of the charge control agent on the resin that makes up the developer 8. When the charge control agent is not mixed in the developer 8, in which case this invention is particularly effective, it is desirable to use a resin with a charge ranking that will yield the desired charge for the resin making up the developer 8. Even in processes which use a two-component developer as the developer 8, resins can be selected for the covering layer in the exact same way, but from the standpoint of uniform charge distribution, it is particularly desirable to use a resin of the same charge ranking as the carrier or the resin covering the carrier surfaces.

#### Embodiment E1

In this embodiment, a sintered ferrite magnet was used as the magnetic roller 9, and island-like (multiple independent) coverings made from a polyester resin were formed as the covering layer (resin layer).

Using an image formation device based on a developing device with the above configuration, images equivalent to 5 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet.

#### Comparison Example E1

Using an image formation device based on a developing device with the same configuration as embodiment E1 except that the surface of the magnetic roller 9 did not have a covering layer, images were formed continuously under the same conditions, but low quality images were obtained having low image density and uneven density.

#### Embodiment E2

In this embodiment, an extraction-molded samarium-cobalt magnet was used as the magnetic roller 9, and island-like (multiple independent) coverings made from a polycarbonate resin were formed as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 5 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet.

#### Comparison Example E2

Using an image formation device based on a developing device with the same configuration as embodiment E2 except that the surface of the magnetic roller 9 did not have a covering layer, images were formed continuously under the same conditions, but low quality images were obtained having low image density and uneven density.

#### Embodiment E3

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and a uniform (magnet not exposed) covering made from a polyamide resin was formed as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 5 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet.

#### Comparison Example E3

Using an image formation device based on a developing device with the same configuration as embodiment E3 except that the surface of the magnetic roller 9 did not have a covering layer, images were formed continuously under the same conditions, but low quality images were obtained having low image density and uneven density.

#### Embodiment E4

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and a uniform (magnet not exposed) covering made from a silicon resin (organic silane resin) was formed as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet. Further, filming by the developer on the surface of the magnetic roller 9 was not observed.

#### Comparison Example E4

Using an image formation device based on a developing device with the same configuration as comparison example E3, images were formed continuously in the same manner as in embodiment E4, but the images obtained had low image density, and when images equivalent to 30 000 regular A4-size sheets were formed continuously, the im-

ages were of low quality having streaks, etc. Also, filming by the developer was observed on the surface of the magnetic roller 9.

#### Embodiment E5

In this embodiment, a cast praseodymium-iron magnet was used as the magnetic roller 9, and a uniform (magnet not exposed) covering made from a polyurethane resin was formed as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 5 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet.

#### Comparison Example E5

Using an image formation device based on a developing device with the same configuration as embodiment E5 except that the surface of the magnetic roller 9 did not have a covering layer, images were formed continuously under the same conditions, but low quality images were obtained having low image density and uneven density.

#### Embodiment E6

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and a uniform (magnet not exposed) covering made from a polyurethane resin diffused with tetrafluoroethylene resin particles was formed as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously, and the images obtained were of high quality having the same high resolution and high density as the first sheet. Further, filming by the developer was not observed on the surface of the magnetic roller 9.

#### Comparison Example E6

Using an image formation device based on a developing device with the same configuration as comparison example E5, images were formed continuously in the same manner as in embodiment E6, but the images obtained had low image density, and when images equivalent to 30 000 regular A4-size sheets were formed continuously, the images were of low quality having streaks, etc. Also, filming by the developer was observed on the surface of the magnetic roller 9.

### Formation of Conductive Material Layer

In the developing device of this invention, ferrite, Alnico, manganese-aluminum, rare earth magnet and other known magnet materials can be used as the magnet material for the magnetic roller. However, when using ferrite magnet and other high resistant materials as the magnetic roller, so-called "developing electrodes" must be provided separately to impress the developing bias voltage on the developer transported on the magnetic roller during developing or to enhance the electric field formed by the potential making up the electrostatic latent image on the latent image carrier, or the yoke or shaft inside the magnetic roller or other conductive material must be used as the developing electrode. In the case of the former, the structure becomes complicated, and in the case of the latter, resolution is reduced because the developer electrode is positioned away from the latent image carrier and the power consumption is increased by the increased output of the power source to compensate for the reduced effective developing bias. When rare earth magnet and other conductive materials are used as the magnetic roller, the magnetic part can be used as the developing electrode, but since corrosion due to oxidation occurs on the surface of the magnetic roller, consistently high quality images cannot be formed over long periods. Therefore, when a magnetic roller made from a rare earth magnet is actually used, it is necessary to provide a surface corrosion prevention layer on the surface to prevent corrosion due to oxidation on the surface of the magnetic roller, and when the magnetic roller is covered with a resin or other high resistance material as the surface corrosion prevention layer, either a complicated structure results due to the need to provide a separate developing electrode as in the case when ferrite or other high resistance material is used as the magnetic roller, or reduced resolution and increased power consumption result due to the need to position the developing electrode away from the latent image carrier or the developer.

In this invention, the above problems can be prevented by providing a covering layer made from at least one type of conductive material on the surface of the magnetic roller. That is, since the conductive material layer functions as the developing electrode, consistently high quality images can be formed over long periods.

The developing device 7 charges the developer 8 which is a component of the developer and transports the developer 8 on the rotating cylindrical roller 9. The developer held by magnetic force on the magnetic roller 9 is regulated to an appropriate amount by the developer transport regulating member 10 after which it is carried to the

developing gap where the latent image carrier 1 and magnetic roller 9 come near each other. In this case, the surface of the magnetic roller 9 is covered with a covering layer (not shown) made from at least one type of conductive material, and particularly in cases in which ferrite magnet or other high resistance material or rare earth magnet with a surface corrosion prevention layer is used as the magnetic roller, the covering layer functions as the developing electrode, whereby the bias voltage is impressed on the developer 8 by the means 10 for impressing the developing bias voltage and the electrostatic latent image on the latent image carrier is manifested by the developer 8 adhering to the electrostatic latent image on the latent image carrier according to the potential of the electrostatic latent image on the latent image carrier 1.

The desired image can be obtained by transferring the developer 8 (develops the electrostatic latent image) on the latent image carrier 1 to the recording paper 15 by the transfer device 14 and fixing it to the recording paper 15 by a pressurizing and heating means.

In FIG. 1, one end (end not electrically connected to the support member which makes up the latent image carrier 1) of the bias application means 10 is shown electrically connected to the covering layer, but this invention is not limited to this, and as can be seen, the one end of the bias application means can be electrically connected to at least one of the magnet 12 which makes up the magnetic roller 9, the yoke 13 or other conductive support member electrically connected to the magnet 12, and the covering layer. By electrically connecting the one end of the bias application means to at least the magnet 12 which makes up the magnetic roller 9, the yoke 13 or other conductive support member electrically connected to the magnet 12, or the covering layer, the covering layer in this invention demonstrates such developing electrode effects as enhancement of the electric field generated by the potential which makes up the latent image on the latent image carrier, but in order to obtain a sufficient developing electrode effect and from the standpoint of the output efficiency of the developing bias application means 10, it is desirable to connect the application means 10 to the covering layer so that the covering layer functions as the developing electrode, particularly in cases in which the magnetic roller 9 is a magnet made from ferrite or other high resistance material or is a rare earth magnet with an extremely thick, high-resistance surface corrosion prevention layer. In the case in which a conductive material such as rare earth magnet, which has been equipped with the covering layer of this invention to achieve an adequate effect as a surface corrosion prevention layer or a covering layer on an extremely thin

surface corrosion prevention layer, is used as the magnetic roller 9, an adequate developer electrode effect can be achieved by connecting to at least one of the magnet 12 which makes up the magnetic roller 9, the yoke 13 or other conductive support member electrically connected to the magnet 12, and the covering layer.

#### Embodiment F1

In this embodiment, a sintered ferrite magnet was used as the magnetic roller 9, and nickel was used as the covering layer (covered with nickel plating).

Using an image formation device based on a developing device with the above configuration, images equivalent to 1 000 regular A4-size sheets were formed continuously, and the images obtained had the same high quality and high resolution as the first sheet.

#### Embodiment F2

In this embodiment, the same configuration as that in embodiment F1 was used except that an epoxy resin diffused with aluminum particles was used as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 1 000 regular A4-size sheets were formed continuously, and the images obtained had the same high quality and high resolution as the first sheet.

#### Comparison Example F1

Using an image formation device based on a developing device of the same configuration as that in embodiments F1 and F2 except that the surface of the magnetic roller 9 did not have a covering layer leaving the magnet exposed, images were formed continuously under the same conditions, but the images obtained were blurred from the very first sheet and could not be deciphered visually.

#### Embodiment F3

In this embodiment, an injection-molded samarium-cobalt magnet was used as the magnetic roller 9, and the configuration was the same as that in embodiment F1 except that aluminum was used as the covering layer (covered with aluminum plating).

Using an image formation device based on a developing device with the above configuration, images equivalent to 1 000 regular A4-size sheets were formed continuously, and the images obtained had the same high quality and high resolution

as the first sheet.

#### Comparison Example F2

Using an image formation device based on a developing device of the same configuration as that in embodiment F3 except that the surface of the magnetic roller 9 did not have a covering layer leaving the magnet exposed, images were formed continuously under the same conditions, but the images obtained were blurred from the very first sheet and could not be deciphered visually.

#### Embodiment F4

This embodiment had the same configuration as that in embodiment F3 except that an extraction-molded samarium-cobalt magnet was used as the magnetic roller 9.

Using an image formation device based on a developing device with the above configuration, images equivalent to 1 000 regular A4-size sheets were formed continuously, and the images obtained had the same high quality and high resolution as the first sheet.

#### Embodiment F5

This embodiment had the same configuration as that in embodiment F4 except that a polyester resin diffused with carbon black was used as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 1 000 regular A4-size sheets were formed continuously, and the images obtained had the same high quality and high resolution as the first sheet.

#### Comparison Example F3

Using an image formation device based on a developing device of the same configuration as that in embodiments F4 and F5 except that the surface of the magnetic roller 9 did not have a covering layer leaving the magnet exposed, images were formed continuously under the same conditions, but the images obtained were blurred from the very first sheet and could not be deciphered visually.

#### Embodiment F6

In this embodiment, a sintered neodymium-iron magnet was used as the magnetic roller 9, and the configuration was the same as that in embodiment F1 except that aluminum was used as the covering layer (covered with aluminum plating).

Using an image formation device based on a

developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the conditions 20° C and relative humidity 60%, and the images obtained showed no deterioration and had the same high quality and high resolution as the first sheet. Also, no corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment F7

This embodiment had the same configuration as that in embodiment F6 except that a polycarbonate resin diffused with carbon black was used as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment F6, and the images obtained showed no deterioration and had the same high quality and high resolution as the first sheet. Also, no corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Comparison Example F4

Using an image formation device based on a developing device of the same configuration as that in embodiments F6 and F7 except that the surface of the magnetic roller 9 did not have a covering layer leaving the magnet exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment F6, but the images obtained showed such deterioration as streaking and other types of blurring and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

#### Embodiment F8

In this embodiment, the same configuration as that in embodiment F1 was used except that a cast praseodymium-iron magnet was used as the magnetic roller 9 and nickel was used as the covering layer (covered with nickel plating).

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment F6, and the images obtained had the same high quality and high resolution as the first sheet. Also, no corrosion due to oxidation on the surface of the magnetic roller 9 was observed.

#### Embodiment F9

In this embodiment, the same configuration as that in embodiment F8 was used except that a fluororesin diffused with aluminum particles was used as the covering layer.

Using an image formation device based on a developing device with the above configuration, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment F6, and the images obtained showed no deterioration and had the same high quality and high resolution as the first sheet. Also, no corrosion due to oxidation on the surface of the magnetic roller 9 was observed.

#### Comparison Example F5

Using an image formation device based on a developing device of the same configuration as that in embodiments F8 and F9 except that the surface of the magnetic roller 9 did not have a covering layer leaving the magnet exposed, images equivalent to 50 000 regular A4-size sheets were formed continuously under the same conditions as in embodiment F6, but the images obtained showed such deterioration as streaking and other types of blurring and appearance of background, and corrosion due to oxidation was observed on the surface of the magnetic roller 9.

As described above, by providing a covering layer made from at least one type of conductive material on the surface of the magnetic roller (developer transport surface) in a developing device having a cylindrical magnetic roller on which a plurality of magnetic poles have been formed, wherein the developer is held on the magnetic roller by the magnetic field generated by the magnetic roller and the developer is transported by rotating the magnetic roller, the conductive material acts as a developing electrode, whereby consistently high quality images can be formed over long periods.

#### Improvement of the Developer Transport Regulating Member

In the above developing devices of the this invention, it is not necessarily easy to adjust the amount of developer transported by only the pitch of the magnetic poles on the magnetic roller or form consistently uniform thin toner layers by such configurations as the developer transport regulating member 10 shown in FIG. 1.

The above problems are resolved in this embodiment by making surface contact between the surface of the magnetic roller and the developer transport regulating member and by employing a developer transport regulating member wherein the

end of the developer transport regulating member does not come in contact with the magnetic roller.

By means of the above embodiment, when the developer passes between the magnetic roller and the developer transport regulating member, the pressure applied to the developer on the magnetic roller increases, thus forming the developer transported by the magnetic roller into a thin layer. Further, by making surface contact between the magnetic roller and the developer transport regulating member, which is an elastic member, a uniform pressure is applied to the contact surface, whereby a consistently uniform developer layer can be formed which in turn makes it possible to form consistently high quality images.

FIG. 4 is a generalized cross section of an image formation device including the developing device of an embodiment of this invention.

The latent image carrier which rotates in the direction indicated by A in the figure comprises the conductive support member 2 on which has been applied a photosensitive layer 3 having photoconductivity, and after the photosensitive layer 3 has been charged to the prescribed potential by the charger 4, the light emitted from the light source 5 is irradiated on the photosensitive layer 3 by the imaging optical system 6 according to the image, whereby potential contrasts are obtained and the electrostatic latent image is formed on the latent image carrier 1.

The developing device 7 charges the developer 8 which is a component of the developer and transports the developer 8 on the cylindrical magnetic roller 9 which rotates in the direction indicated by B in the figure. The developer 8 held by magnetic force on the magnetic roller 9 is regulated to an appropriate amount by the developer transport regulating member 11, after which it is transported to the developing gap where the latent image carrier 1 and the magnetic roller 9 come near each other and the electrostatic latent image on the latent image carrier 1 is manifested by the developer 8 adhering to the electrostatic latent image on the latent image carrier 1 according to the potential of the electrostatic latent image on the latent image carrier 1 and the bias voltage from the power source 10 which is the developing bias voltage application means.

Here, the developer transport regulating member 11 is formed from phosphor bronze, stainless steel or other metal with elasticity or from an elastomer such as polyurethane rubber, and its surface is pressed against the magnetic roller 9 so it makes surface contact without the free end of the developer transport regulating member; i.e., edge positioned downstream as seen from the flow of the developer 8, coming in contact with the magnetic roller 9. By means of this configuration, when

the magnetic roller 9 is rotated in the direction indicated by A in the figure, the developer 8 follows the rotation of the magnetic roller 9 and is transported along the magnetic roller 9 to where it is subjected to the pressure of the developer transport regulating member. The developer transport regulating member 11 makes surface contact with the magnetic roller 9 so that the free end of the developer transport regulating member 11 does not come in contact with the magnetic roller 9. Therefore, the pressure the developer transport regulating member exerts on the magnetic roller 9 is uniform, and even under extremely high pressure; i.e., under a wide range of pressures, and when a developer is used that is susceptible to plastic deformation or is strongly self-cohesive, a uniform thin layer can be consistently formed.

The desired image can be obtained by transferring the developer 8 (which has developed the electrostatic latent image) on the latent image carrier 1 to the recording paper 15 by the transfer device 14 and fixing it to the recording paper 15 by a pressurizing or heating means.

In this embodiment, the latent image carrier 1 and magnetic roller 9 rotate in the directions indicated by A and B as shown in FIG. 4, but this invention is not limited to this configuration. Also, all known developers can be used in this invention as either a one-component magnetic brush developer or a two-component magnetic brush developer.

#### Control of Direction of Rotation

In the developing device of this invention, the image quality is further improved by setting the direction of rotation of the magnetic roller opposite the direction of rotation of the latent image carrier and setting the circumferential speed of the magnetic roller faster than the circumferential speed of the latent image carrier.

That is, by controlling both the direction of rotation and the speed of rotation, the developing preventing force by the magnetic roller is sufficiently large to reduce the adherence of developer to the background. Further, by making the direction of rotation of the magnetic roller opposite the direction of rotation of the latent image carrier and the circumferential speed of the magnetic roller faster than the circumferential speed of the latent image carrier, excess supply of developer by the magnetic brush at the leading end of the printing area can be prevented, whereby unnecessary accumulation of developer at the leading end edge is prevented and image quality can be improved.

As shown in FIG. 1, the direction of rotation (counterclockwise) of the magnetic roller 9 is opposite the direction of rotation (clockwise) of the

latent image carrier 1, and at the developing gap both are moving in the forward direction, excess supply and accumulation of the developer 8 at the leading end of the printing area are prevented and tailing is reduced, whereby resolution is improved. The arrows indicate the direction of rotation of the respective members.

#### Embodiment G1

In a developing device such as shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick ferrite magnet with an outside diameter of 20 mm and divided up into 60 magnetic poles and a 1-mm-thick yoke with an outside diameter of 18 mm which made up the magnetic circuit inside the magnet, and images were formed by rotating the magnetic roller counterclockwise at 200 rpm and rotating the latent image carrier with an outside diameter of 30 mm at 30 rpm in the opposite direction (clockwise) of the magnetic roller, whereby high contrast images with high density and no uneven density could be formed consistently with no tailing of the leading end of the printing area. Further, the weight could be reduced by more than half compared to prior art devices employing a ferrite magnet and metal sleeve.

#### Embodiment G2

In a developing device such as shown in FIG. 1, the magnetic roller was configured from a 1.5-mm-thick compression-molded samarium-cobalt magnet with an outside diameter of 20 mm and divided up into 40 magnetic poles and a 1-mm-thick yoke with an outside diameter of 17 mm which made up the magnetic circuit inside the magnet, and images were formed by rotating the magnetic roller counterclockwise at 200 rpm and rotating the latent image carrier with an outside diameter of 30 mm at 30 rpm in the opposite direction (clockwise) of the magnetic roller, whereby high contrast images with high density could be formed consistently with no tailing of the leading end of the printing area. Further, the weight could be reduced by more than half compared to prior art devices employing a ferrite magnet and metal sleeve.

#### Embodiment G3

In a developing device such as shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick injection-molded samarium-cobalt magnet with an outside diameter of 12 mm and divided up into 40 magnetic poles and a 1-mm-thick yoke with an outside diameter of 10 mm which made up the magnetic circuit inside the magnet, and images

were formed by rotating the magnetic roller counterclockwise at 200 rpm and rotating the latent image carrier with an outside diameter of 20 mm at 30 rpm in the opposite direction (clockwise) of the magnetic roller, whereby high contrast images with high density could be formed consistently with no tailing of the leading end of the printing area. Further, the weight could be reduced to less than one-fourth the weight of prior art devices employing a ferrite magnet and metal sleeve.

#### Comparison Example G1

In a developing device such as shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick ferrite magnet with an outside diameter of 20 mm and divided up into 60 magnetic poles and a 1-mm-thick yoke with an outside diameter of 18 mm which made up the magnetic circuit inside the magnet, and images were formed by rotating the magnetic roller counterclockwise at 200 rpm and rotating the latent image carrier with an outside diameter of 30 mm at 30 rpm in the same direction (counterclockwise) as the magnetic roller, whereby only low contrast images could be formed with developer remaining in the leading end of the printing area and tailing of the leading end of the printing area.

#### Comparison Example G2

In a prior art one-component magnetic developing device, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller inside the sleeve was configured from a 5-mm-thick sintered ferrite magnet with an outside diameter of 18 mm and divided up into 8 magnetic poles. Images were formed by rotating the latent image carrier with an outside diameter of 30 mm clockwise at 30 rpm, rotating the developer transport member in the same direction (clockwise) as the latent image carrier at 200 rpm and rotating the magnetic roller in the same direction (clockwise) as the latent image carrier at 1 000 rpm, but only low-contrast, low-resolution images could be formed with tailing of the leading end of the printing area. Also, the magnetic roller could not be made lighter.

#### Comparison Example G3

In a prior art one-component magnetic developing device, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller inside the sleeve was configured from a 5-mm-thick sintered ferrite magnet with an outside diameter of 18 mm and divided up into 8 magnetic poles. Images

were formed by rotating the latent image carrier with an outside diameter of 30 mm clockwise at 30 rpm, rotating the developer transport member in the opposite direction (counterclockwise) as the latent image carrier at 200 rpm and rotating the magnetic roller in the same direction (clockwise) as the latent image carrier at 1 000 rpm, but only low-contrast, low-resolution images could be formed with tailing of the leading end of the printing area. Also, the magnetic roller could not be made lighter.

#### Control of the Developing Gap

In the developing device of this invention, image quality is further improved by making the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier the same and the setting the interval at the developing gap (location where the magnetic roller and the latent image carrier come nearest each other) so that the height of the developer held on the magnetic roller is larger than the minimum value.

That is, by controlling the direction of rotation and the interval of the developing gap, the developing stopping force by the magnetic roller can be made sufficiently large to reduce adherence of developer to the background. Further, by using a configuration in which the developer has indirect contact or no contact with the latent image carrier, the adherence of unnecessary developer is reduced and image quality is improved.

Embodiments of this are explained in detail below.

#### Embodiment H1

In a developing device such as that shown in FIG. 1, the magnetic roller was configured from a 1-mm-thick ferrite magnet with an outside diameter of 20 mm and divided up into 60 magnetic poles and a 1-mm-thick yoke with an outside diameter of 18 mm which made up the magnetic circuit in the magnet. The magnetic roller was rotated clockwise at 200 rpm, the latent image carrier with an outside diameter of 30 mm was rotated at 30 rpm in the same direction as the magnetic roller (clockwise), and the developing gap was set so that the developer did not come in contact with the latent image carrier. The images formed using this configuration showed consistently high density and high contrast without tailing in the leading end of the printing area. Also, the weight could be reduced to less than half that of prior art devices which used a ferrite magnet and metal sleeve.

#### Embodiment H2

In a developing device such as that shown in

FIG. 1, the magnetic roller was configured from a 1.5-mm-thick compression-molded samarium-cobalt magnet with an outside diameter of 20 mm and divided up into 40 magnetic poles and a 1-mm-thick yoke with an outside diameter of 17 mm which made up the magnetic circuit in the magnet. The magnetic roller was rotated clockwise at 50 rpm and the latent image carrier with an outside diameter of 30 mm was rotated at 30 rpm in the same direction as the magnetic roller (clockwise). The images formed using this configuration showed consistently high density and high contrast without tailing in the leading end of the printing area. Also, the weight could be reduced to less than half that of prior art devices which used a ferrite magnet and metal sleeve.

#### Embodiment H3

In a developing device such as that shown in FIG. 1, the magnetic roller was configured as a single unit from a 1-mm-thick injection-molded samarium-cobalt magnet with an outside diameter of 12 mm and divided up into 40 magnetic poles and a 1-mm-thick yoke with an outside diameter of 10 mm which made up the magnetic circuit in the magnet. The magnetic roller was rotated clockwise at 50 rpm and the latent image carrier with an outside diameter of 20 mm was rotated at 20 rpm in the same direction as the magnetic roller (clockwise). The images formed using this configuration showed consistently high density and high contrast without tailing in the leading end of the printing area. Also, the weight of the magnetic roller could be reduced to less than one-fourth that of prior art devices which used a ferrite magnet and metal sleeve.

#### Comparison Example H1

In a prior art one-component magnetic developing device, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller inside the transport member was configured from a 5-mm-thick sintered ferrite magnet with an outside diameter of 18 mm and divided up into 8 magnetic poles. Images were formed by rotating the latent image carrier with an outside diameter of 30 mm clockwise at 30 rpm, rotating the developer transport member at 200 rpm in the same direction (clockwise) as the latent image carrier and rotating the magnetic roller at 1 000 rpm in the same direction (clockwise) as the latent image carrier, but only low-contrast, low-density images with tailing in the leading end of the printing area could be formed. Also, the magnetic roller could not be made lighter.

## Comparison Example H2

In a prior art one-component magnetic developing device, a developer transport member (non-magnetic metal sleeve) with an outside diameter of 20 mm was used, and the magnetic roller inside the transport member was configured from a 5-mm-thick sintered ferrite magnet with an outside diameter of 18 mm and divided up into 8 magnetic poles. Images were formed by rotating the latent image carrier with an outside diameter of 30 mm clockwise at 30 rpm, rotating the developer transport member at 200 rpm in the opposite direction (counterclockwise) as the latent image carrier and rotating the magnetic roller at 1 000 rpm in the same direction (clockwise) as the latent image carrier, but only low-contrast, low-density images with tailing in the leading end of the printing area could be formed. Also, the magnetic roller could not be made lighter. Control of Bias Voltage

In developing devices of the prior art, unevenness of the developer (unevenness in the magnetic brush) resulted due to fluctuations in the magnetic field of the developer transport member, and when the magnet was rotated, the developing nip length would fluctuate with the rotation of the magnet, thus resulting in uneven developing density caused by the magnetic pole pitch of the magnet.

In the developing device of this invention, the above problem is solved by providing a magnetic field detection means for detecting the magnetic field of the magnetic roller and a developing bias voltage fluctuation means for fluctuating the developing bias voltage in sync with the alternating magnetic fields detected by the magnetic field detection means.

By means of the above configuration, fluctuations in the developing density can be reduced by fluctuating the developing bias in sync with the alternating magnetic field of the developing nip so that the developing force acting on the developer of the developing nip can be made constant.

Further, when a magnetic roller is used which transports developer directly on the surface of the magnet, the magnetic field generated by the magnet can be utilized with the greatest efficiency since the developer is transported directly on the magnet and a developing bias voltage in sync with the alternating magnetic fields can be impressed between the magnet and latent image carrier.

FIG. 5 is a generalized cross section of an image formation device including a developing device of an embodiment of this invention. The latent image carrier 1 comprises a conductive support member 2 on which has been applied an organic or inorganic photosensitive layer 3 having photoconductivity. After the photosensitive layer 3 has been charged with a corona charger or other type

of charger 4, the light emitted from the light source passes through the imaging optical system 6 and is selectively irradiated on the photosensitive layer 3 according to the image, whereby potential contrasts are obtained and the electrostatic latent image is formed. The developing device 7 charges the developer 8 which is the image-forming material and transports it on the cylindrical magnet roller 9, develops the developer 8 at the developing gap where the latent image carrier 1 and the magnetic roller 9 come near each other according to the potential of the electrostatic latent image on the latent image carrier 1 and the bias voltage of the developing bias voltage application means 10 and manifests the electrostatic latent image on the latent image carrier 1 via the developer 8. The developer 8 which manifests the electrostatic latent image is transferred to the recording paper 15 by the transfer device 14 using corona discharge, an electric field, pressure or adhesive force, and the developer 8 is fixed to the recording paper 15 by a pressurizing or heating means, whereby the desired image formed from the developer 8 is obtained on the recording paper 15. In the developing device in FIG. 1, the magnetic roller 9 uses magnetic force to hold the developer supplied to it and transports the developer 8 after it has been regulated to an appropriate amount by the developer transport regulating member 11. The magnetic roller 9 forms a magnetic circuit by means of the cylindrical magnet 12 having a plurality of poles on its outside circumference and the soft, magnetic cylindrical yoke (not shown) positioned inside the magnet 12, and it transports the magnetic developer 8 by forming a magnetic field on the cylindrical, non-magnetic developer transport member 13 positioned inside the magnet 12 with a space between them. As shown in FIG. 5, in this embodiment, a magnetic field detection means 16 is positioned adjacent to the magnetic roller 9 to detect the magnetic field generated by the magnet 12 at the developing gap, and the alternating voltage superimposing means 17 superimposes an alternating voltage on the developing bias application means according to the fluctuations in the developing preventing force caused by the magnetic field at the developing gap, whereby the difference between the developing force (Coulomb force) due to the electric field and the developing preventing force due to the magnetic field is maintained constant and fluctuations in the force acting on the developer 8 are reduced, and therefore uneven developing density accompanying rotation of the magnet 12 is reduced and images can be formed with high printing quality. The magnetic field detection means 16 may be mounted anywhere near the magnetic roller 9, any alternating voltage can be superimposed that maintains the developing force

constant by converting to a magnetic field at the developing gap, and the waveform of the alternating voltage can be a sine wave, a rectangular wave or a saw-tooth wave.

FIG. 6A and FIG. 6B depict the impressed condition of the alternating voltage in an embodiment of this invention. The alternating voltage is impressed in periods one-half the period of the reversal of magnetization, and by superimposing the alternating voltage so that the developing electric field is small when the center of the magnetic poles where the height of the magnetic brush is high passes through the developing gap and the developing electric field is large when the interval between magnetic poles where the height of the magnetic brush is low passes through the developing gap, the difference between the developing force due to the developing electric field and the developing preventing force due to the magnetic force is maintained constant, whereby uneven developing density due to fluctuations in the magnetic field can be reduced.

A Hall-effect element, a magnetoresistance element, a coil, etc., can be used as the magnetic field detection means, or an optical encoder, mechanical switch or other device which detects the rotational position of the magnet can be used to indirectly detect the magnetic field (rotational position of magnet) and facilitate superimposition of the alternating voltage in the same manner.

#### Embodiment I1

In a developing device such as that shown in FIG. 5, the developer was transported on a magnetic roller employing a magnet with eight magnetic poles and having a magnetic flux of 800 gauss on the developer transport member, an organic photoconductor was employed as the latent image carrier, and the magnetic field detection means was located near the developing gap. When images were formed with reverse developing by superimposing an alternating voltage to impose a  $\pm 200$ -V AC component on the -550-V DC component so that the absolute value of the developing bias voltage was small when the center of the magnetic pole passed the center of the developing gap at a frequency twice the frequency of the change in the magnetic field, high quality images were obtained with no uneven developing density in solid images and little change in the width of fine lines.

#### Embodiment I2

When images were formed using the same configuration as that in embodiment I1 except that a rare earth magnet with a flux density of 400

gauss on the magnet and divided up into 32 magnetic poles was used in the magnetic roller, such as that shown in FIG. 5, to transport the developer directly and the magnetic field was detected indirectly with an optical encoder positioned at the end of the magnetic roller, high quality images were obtained with no uneven developing density in solid images and little change in the width of fine lines.

#### Comparison Example I1

When images were formed using the same configuration as that in embodiment I1 except that an alternating voltage was not impressed, only low quality images with poor gradation could be obtained in which uneven developing density corresponding to the changes in the magnetic field was observed in solid images and the change in the width of fine lines was marked.

#### Comparison Example 12

When images were formed using the same configuration as that in embodiment I1 except that the developing bias voltage was superimposed with a  $\pm 1000$ -V alternating voltage on the -550-V DC component so that the frequency of the alternating voltage was approximately 10 times (several thousand hertz) the frequency of the change in the magnetic field, uneven developing density in solid images like that in comparison example I1 occurred and only images with poor gradation could be obtained.

#### APPLICABILITY TO INDUSTRY

The developing device of the present invention can be widely used in image recording means employing an electrophotographic process, and more, particularly it is widely applicable to developing devices for printers, copiers and facsimile machines.

#### Claims

1. A developing device for developing electrostatic latent image patterns formed on a latent image carrier in image recording devices employing an electrophotographic process, wherein the developing device comprises a cylindrical magnetic roller made from a rare earth magnet on which a plurality of magnetic poles are formed, the developer is supplied directly to the magnetic roller, the developer is held on the surface of the magnetic roller by the magnetic field generated by the magnetic

- roller, and the developer being held is transported by rotating the magnetic roller.
2. The developing device of claim 1 wherein a yoke made from a soft magnetic material is laminated on the inside of the cylindrical magnetic roller. 5
  3. The developing device of claim 1 wherein the magnetic roller is made from rare earth magnet formed by compression molding, injection molding or extraction molding. 10
  4. The developing device of claim 1 wherein the magnetic roller is divided up into 10 or more magnetic poles. 15
  5. The developing device of claim 1 wherein crests and troughs are formed on the surface of the magnetic roller. 20
  6. The developing device of claim 5 wherein the crests and troughs on the surface of the magnetic roller are formed so they correspond to the pitch of the magnetic poles and the troughs are positioned on the center of the magnetic poles and the crests are positioned on the boundaries between the magnetic poles. 25
  7. The developing device of claim 1 wherein the surface roughness of the magnetic roller is less than 40% of the volumetric mean particle diameter of the toner, which is a component of the developer, based on the JIS 10-point average roughness standard (JIS-B0601). 30
  8. The developing device of claim 1 wherein a covering layer is formed on the surface of the magnetic roller. 40
  9. The developing device of claim 8 wherein the covering layer is made from a conductive material. 45
  10. The developing device of claim 8 wherein the covering layer is made from a resin. 50
  11. The developing device of claim 8 wherein the covering layer is made from an inorganic compound. 55
  12. The developing device of claim 1 wherein the developing device is equipped with a developer transport regulating member disposed such that it presses at least partially against the surface of the magnetic roller.
  13. The developing device of claim 1 wherein the surface of the magnetic roller and the developer transport regulating member have surface contact and the end of the developer transport regulating member is not in contact with the magnetic roller.
  14. The developing device of claim 1 wherein the structure of the magnetic roller comprises a thin, cylindrical shape with an essentially open space inside.
  15. The developing device of claim 1 wherein the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier are the same.
  16. The developing device of claim 1 wherein the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier are opposite and the circumferential speed of the magnetic roller is faster than the circumferential speed of the latent image carrier.
  17. The developing device of claim 1 wherein the developing device is equipped with a magnetic field detection means for detecting the magnetic field of the magnetic roller and a developing bias voltage fluctuation means for fluctuating the developing bias voltage in sync with the alternating of the magnetic field detected by the magnetic field detection means.
  18. A developing device for developing electrostatic latent image patterns formed on a latent image carrier in image recording devices employing an electrophotographic process, wherein the developing device comprises a cylindrical magnetic roller on which a plurality of magnetic poles are formed and on the surface of which crests and troughs are formed, the developer is supplied directly to the magnetic roller, the developer is held on the surface of the magnetic roller by the magnetic field generated by the magnetic roller, and the developer being held is transported by rotating the magnetic roller.
  19. The developing device of claim 18 wherein a yoke made from a soft magnetic material is laminated on the inside of the cylindrical magnetic roller.
  20. The developing device of claim 18 wherein the magnetic roller is divided up into 10 or more magnetic poles.

21. The developing device of claim 18 wherein crests and troughs are formed on the surface of the magnetic roller so they correspond to the pitch of the magnetic poles and the troughs are positioned on the center of the magnetic poles and the crests are positioned on the boundaries between the magnetic poles.
22. The developing device of claim 18 wherein the surface roughness of the magnetic roller is less than 40% of the volumetric mean particle diameter of the toner, which is a component of the developer, based on the JIS 10-point average roughness standard (JIS-B0601).
23. The developing device of claim 18 wherein a covering layer is formed on the surface of the magnetic roller.
24. The developing device of claim 18 wherein the covering layer is made from a conductive material.
25. The developing device of claim 18 wherein the covering layer is made from a resin.
26. The developing device of claim 18 wherein the covering layer is made from an inorganic compound.
27. The developing device of claim 18 wherein the developing device is equipped with a developer transport regulating member disposed such that it presses at least partially against the surface of the magnetic roller.
28. The developing device of claim 18 wherein the surface of the magnetic roller and the developer transport regulating member have surface contact and the end of the developer transport regulating member is not in contact with the magnetic roller.
29. The developing device of claim 18 wherein the structure of the magnetic roller comprises a thin, cylindrical shape with an essentially open space inside.
30. The developing device of claim 18 wherein the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier are the same.
31. The developing device of claim 18 wherein the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier are opposite and the circumferential speed of the magnetic roller is faster than the circumferential speed of the latent image carrier.
32. The developing device of claim 18 wherein the developing device is equipped with a magnetic field detection means for detecting the magnetic field of the magnetic roller and a developing bias voltage fluctuation means for fluctuating the developing bias voltage in sync with the alternating of the magnetic field detected by the magnetic field detection means.
33. A developing device for developing electrostatic latent image patterns formed on a latent image carrier in image recording devices employing an electrophotographic process, wherein the developing device comprises a cylindrical magnetic roller on which a plurality of magnetic poles are formed, the developer is supplied directly to the magnetic roller, the developer is held on the surface of the magnetic roller by the magnetic field generated by the magnetic roller, and the developer being held is transported by rotating the magnetic roller.
34. The developing device of claim 33 wherein a yoke made from a soft magnetic material is laminated on the inside of the cylindrical magnetic roller.
35. The developing device of claim 33 wherein the magnetic roller is divided up into 10 or more magnetic poles.
36. The developing device of claim 33 wherein the surface roughness of the magnetic roller is less than 40% of the volumetric mean particle diameter of the toner, which is a component of the developer, based on the JIS 10-point average roughness standard (JIS-B0601).
37. The developing device of claim 33 wherein a covering layer is formed on the surface of the magnetic roller.
38. The developing device of claim 37 wherein the covering layer is made from at least one type of material selected from a group comprising conductive materials, resins and inorganic compounds.
39. The developing device of claim 33 wherein the developing device is equipped with a developer transport regulating member disposed such that it presses at least partially against the surface of the magnetic roller.

40. The developing device of claim 33 wherein the surface of the magnetic roller and the developer transport regulating member have surface contact and the end of the developer transport regulating member is not in contact with the magnetic roller. 5
41. The developing device of claim 33 wherein the direction of rotation of the magnetic roller and the direction of rotation of the latent image carrier are opposite and the circumferential speed of the magnetic roller is faster than the circumferential speed of the latent image carrier. 10
42. The developing device of claim 33 wherein the developing device is equipped with a magnetic field detection means for detecting the magnetic field of the magnetic roller and a developing bias voltage fluctuation means for fluctuating the developing bias voltage in sync with the alternating of the magnetic field detected by the magnetic field detection means. 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

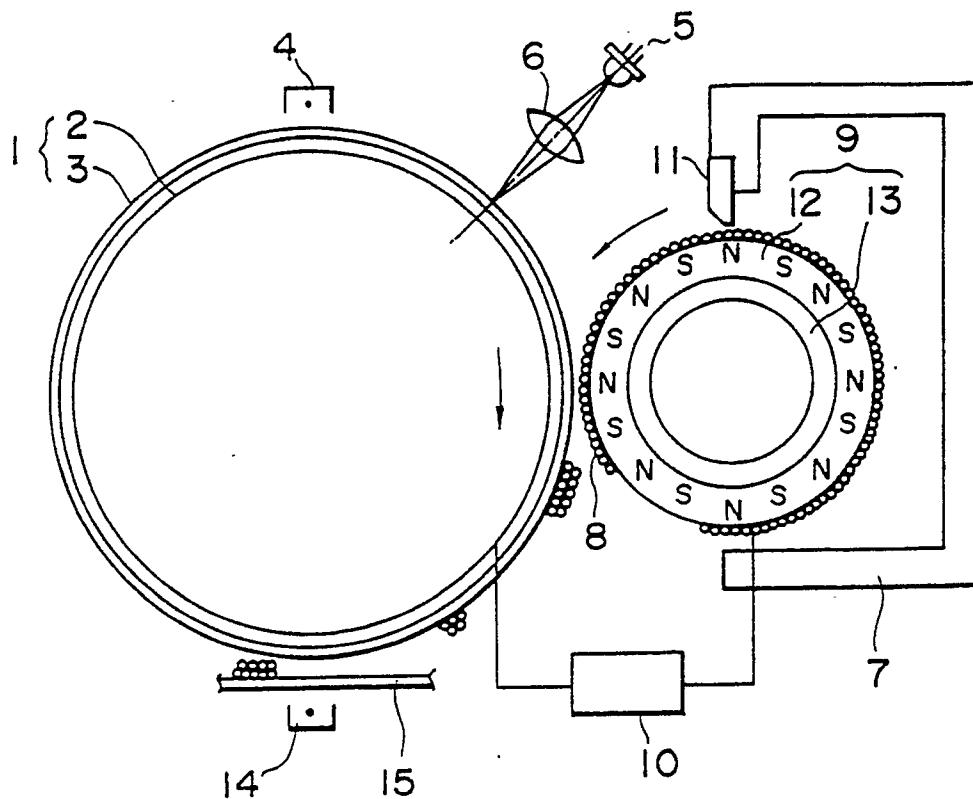


FIG. 1

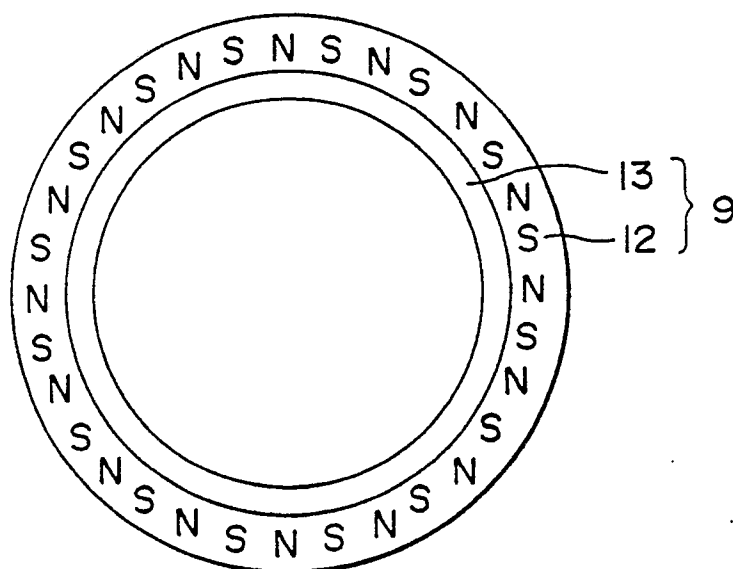


FIG. 2

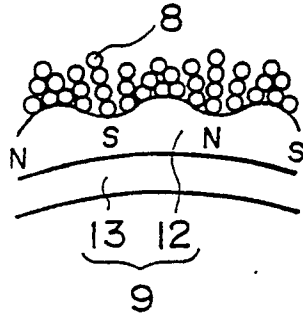


FIG. 3

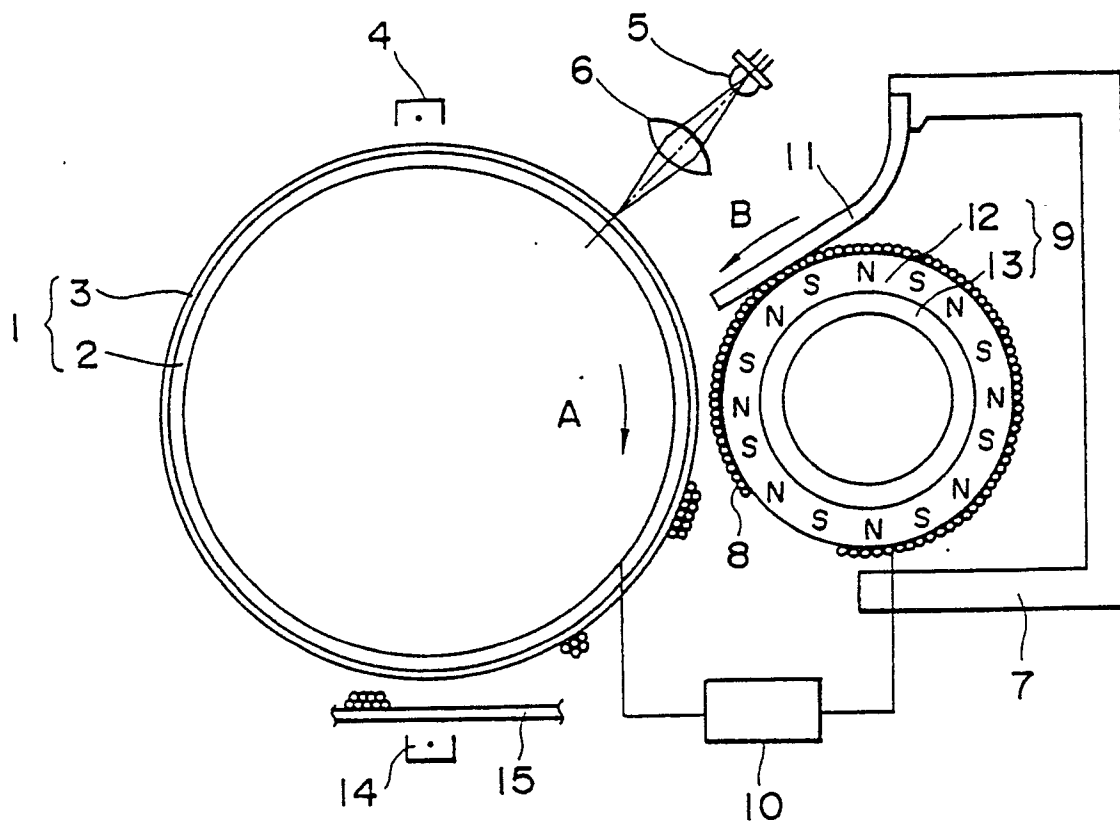


FIG. 4

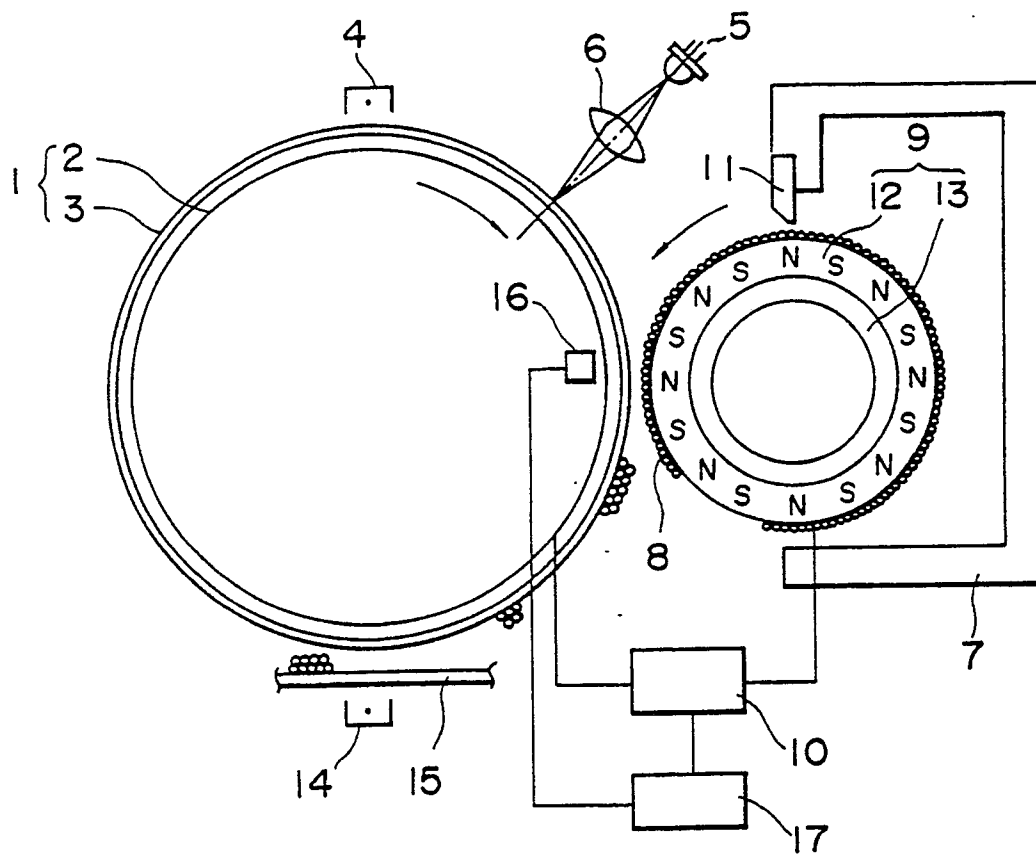
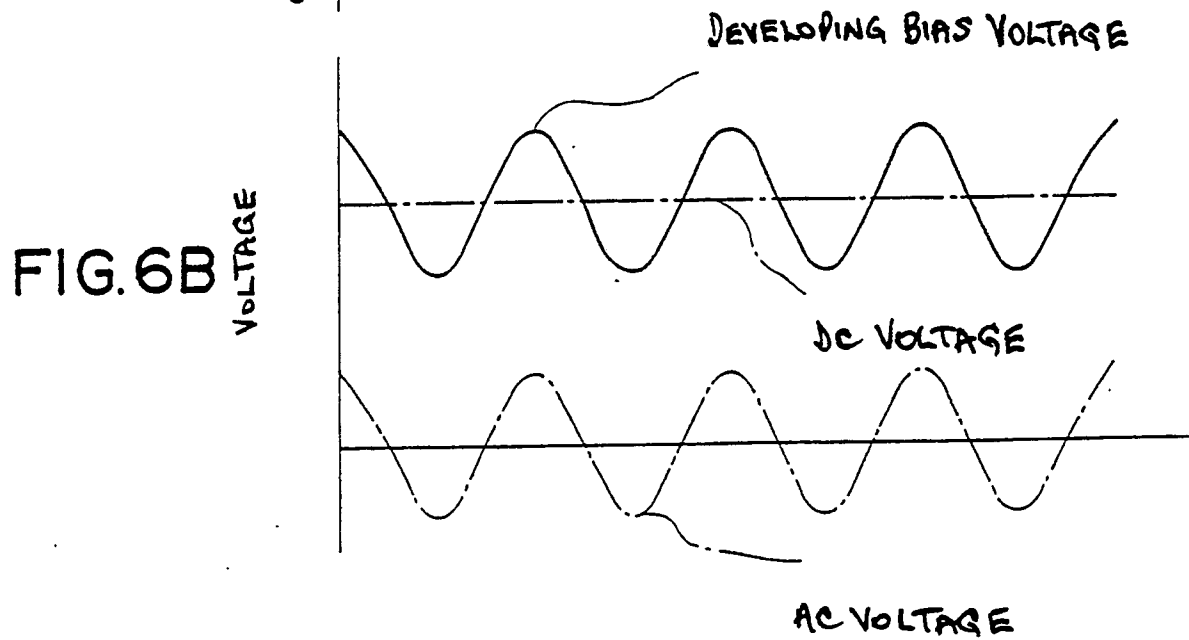
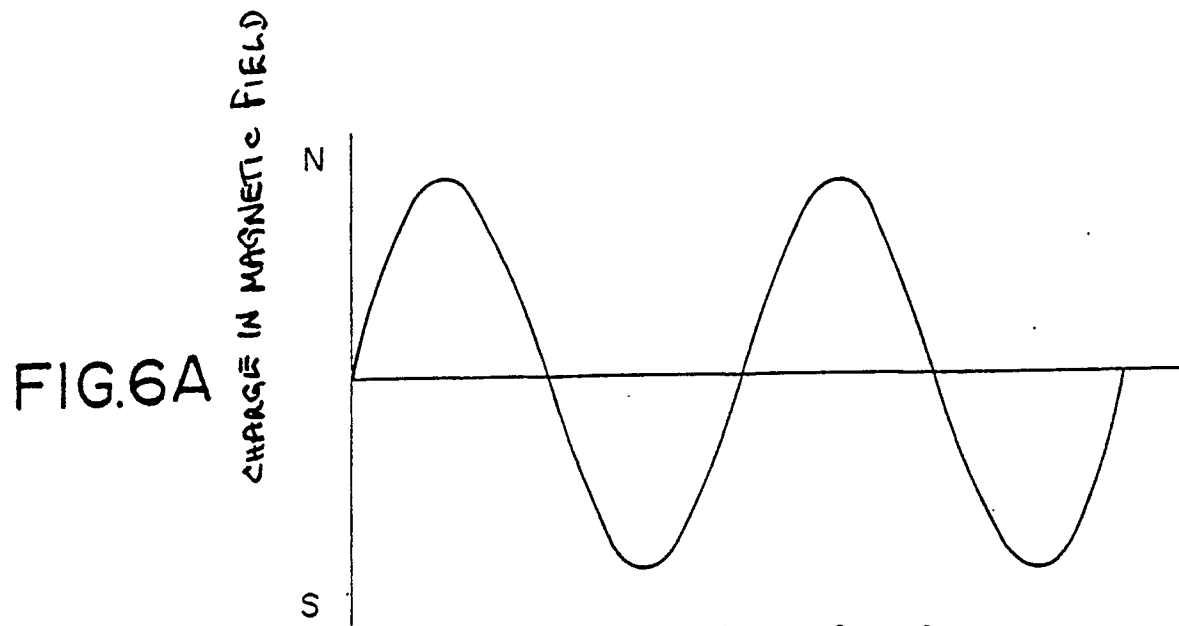


FIG.5



## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

|   |                                                                                                             |            |
|---|-------------------------------------------------------------------------------------------------------------|------------|
| Y | JP, A, 60-216512 (Suwa Seikosha K.K.),<br>30 October 1985 (30. 10. 85),<br>Line 20, column 6 (Family: none) | 14, 29     |
| Y | JP, A, 51-52831 (Hitachi Metals, Ltd.),<br>10 May 1976 (10. 05. 76),<br>Fig. 1 (Family: none)               | 15, 30     |
| Y | JP, A, 51-52831 (Hitachi Metals, Ltd.),<br>10 May 1976 (10. 05. 76),<br>Claim (Family: none)                | 17, 32, 42 |

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ....., because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claim numbers ....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3. ☐ Claim numbers ....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
  
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
  
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.