United States Patent [19]

Yamashita et al.

[11] **3,828,730**

[45] **Aug. 13, 1974**

[54] **ELECTROSTATIC RECORD DEVELOPING APPARATUS**

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[22] Filed: **May 16, 1972**

[21] Appl. No.: **253,900**

[30] **Foreign Application Priority Data**

May 21, 1971 Japan 46-40598
Aug. 11, 1971 Japan 46-71359

[52] **U.S. Cl.** **118/637**, 117/17.5
[51] **Int. Cl.** **G03g 13/00**
[58] **Field of Search** 118/623, 637; 117/17.5

[56] **References Cited**

UNITED STATES PATENTS

3,152,924	10/1964	Wanielista et al.	118/637
3,392,432	7/1968	Naumann	29/110
3,402,698	9/1968	Kojima et al.	118/637
3,455,276	7/1969	Anderson	118/637
3,457,900	7/1969	Drexler	118/637
3,654,902	4/1972	Hakanson	118/637

Primary Examiner—Robert R. Mackey
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[57] **ABSTRACT**

A cylindrical permanent magnet having an odd number of axially extending magnetic poles on the surface thereof is disposed coaxially within a hollow rotary cylinder of non-magnetic material. The cylindrical permanent magnet is fixed in such a position that one of the magnetic poles of one polarity adjacent to a pair of the magnetic poles of the other and same polarity is disposed opposite to the image carrying surface of an electrostatic recording sheet, and a powdery developer attracted to the surface of the hollow rotary cylinder under rotation passes beneath the image carrying surface of the recording sheet and then over the magnetic poles of the other and same polarity. The powdery developer attracted to the surface of the hollow rotary cylinder forms a magnetic brush on such surface for developing a latent electrostatic image recorded on the image carrying surface of the recording sheet.

4 Claims, 3 Drawing Figures

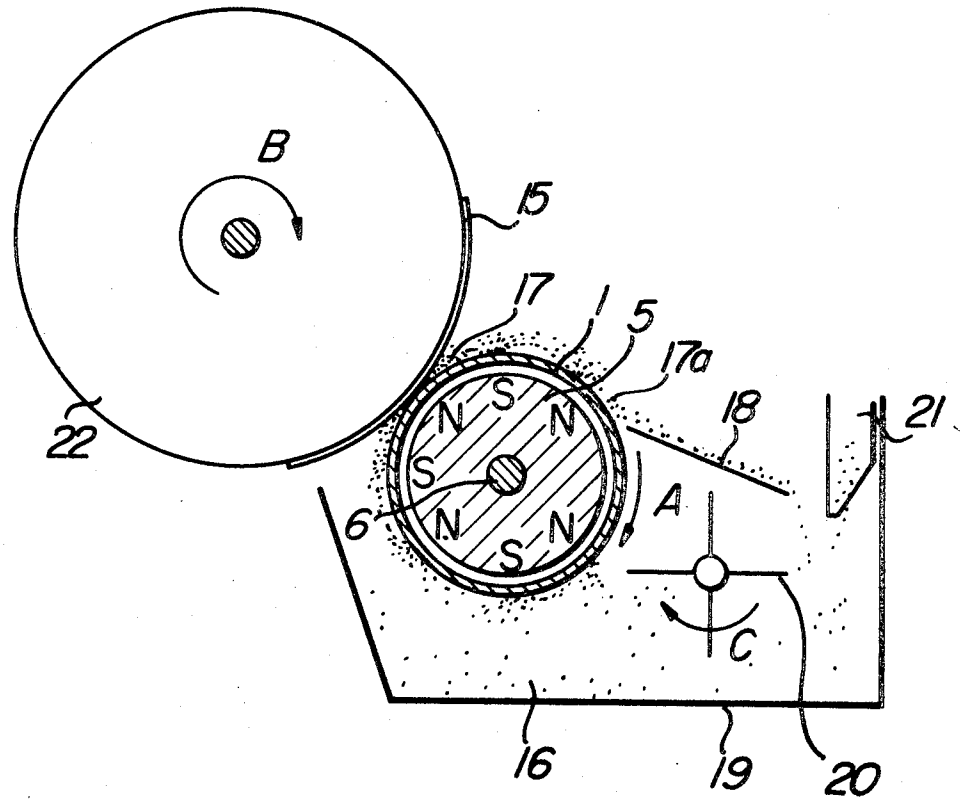


FIG. 1

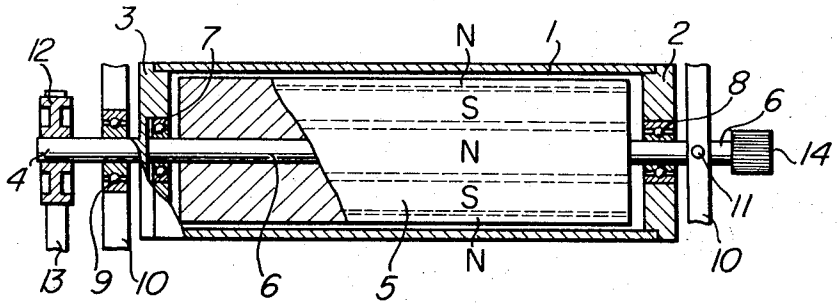


FIG. 2

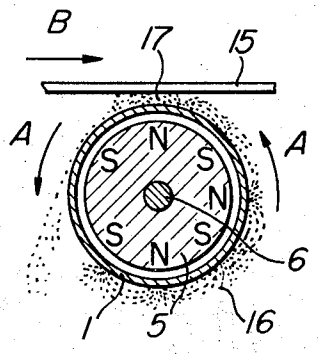
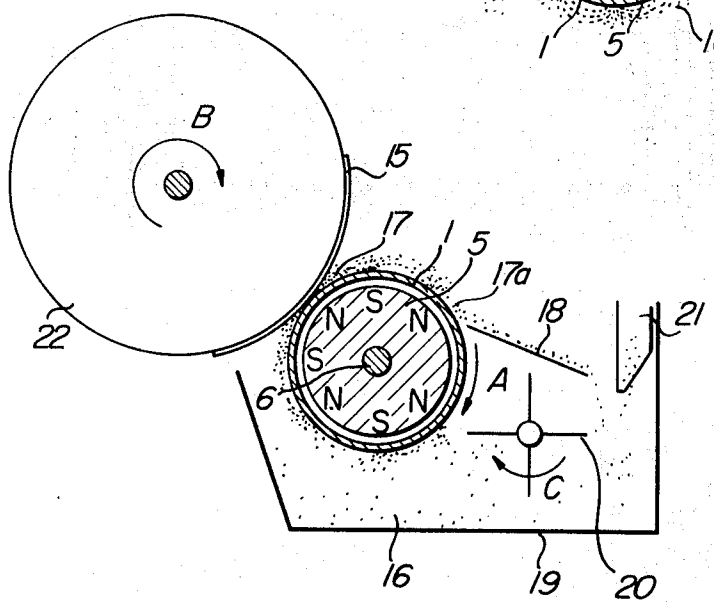


FIG. 3



ELECTROSTATIC RECORD DEVELOPING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electrostatic record developing apparatus which is adapted for developing by a magnetic brush method a latent electrostatic image formed on an electrostatic recording sheet by electrophotography such as xerography or facsimile.

2. Description of the Prior Art

In prior art apparatus of this kind, a method has been most commonly employed according to which a mass of a powdery developer, which is a mixture of fine particles of a developing pigment called a toner and fine particles of iron called a carrier, is contained in a container incorporated in the apparatus, and a magnet roller partly buried in the mass of the powdery developer is rotated for forming a so-called magnetic brush on the surface of the magnet roller and is brought into rolling contact with an electrostatic recording sheet disposed opposite thereto for developing a latent electrostatic image formed on the electrostatic recording sheet. In order to form the magnetic brush on the magnet roller, a plurality of elongated strip-like magnetic poles are provided on the cylindrical outer peripheral surface of the magnet roller in the axial direction thereof. However, this method has been defective in that the distribution of the powdery developer on the surface of the magnet roller is non-uniform, that is, the amount of the powdery developer attracted to the surface portion immediately above the magnetic pole differs from that attracted to the surface portion intermediate between the magnetic poles. After the developing operation, the powdery developer attaching to the surface of the magnet roller is scraped off by a doctor plate. However, the powdery developer attaching to the roller surface would not be easily scraped off by the doctor plate and the developer still remaining on the roller surface is repeatedly used for developing. Thus, this method has been further defective in that the amount of the toner in the developer is gradually decreased resulting in the reproduction of a blurred image on the electrostatic recording sheet or appearance of developing marks on the reproduced image.

Various apparatus have been proposed for the purpose of obviating these prior art defects. For example, U.S. Pat. Nos. 3,040,704, 3,152,924, 3,176,562 and 3,455,276 disclose improvements over the prior art apparatus of the kind above described. U.S. Pat. No. 3,040,704 discloses an apparatus which comprises a stationary permanent magnet of semicircular sectional shape having a pair of N and S poles or a stationary permanent magnet of circular sectional shape shielded at one of the semicircles and having pair of N and S poles, and a hollow cylinder of non-magnetic material rotatably disposed around the permanent magnet, said hollow cylinder having an inner diameter slightly larger than the outer diameter of said permanent magnet. The hollow cylinder is rotated with a portion thereof buried in a mass of a powdery developer. The powdery developer is attracted to the outer peripheral surface of the hollow cylinder by the lines of magnetic force emanating from the permanent magnet fixed in position within the hollow cylinder, and a magnetic brush is formed on the surface of the hollow cylinder and carried to a position opposite to an overlying electrostatic recording sheet thereby developing a latent electrostatic image recorded on the recording sheet. However, the ability of conveying the powdery developer upward through the medium of the surface of the hollow cylinder is very poor due to the fact that the magnetic poles of the permanent magnet are fairly spaced apart from each other. Further, the density of the magnetic flux acting upon the powdery developer through the surface of the hollow cylinder is quite low due to the fact that the number of the magnetic poles is small. Thus, this patent is defective in that the magnetic brush to be brought into contact with the image carrying surface of an electrostatic recording sheet has an insufficient amount of developer particles.

U.S. Pat. No. 3,152,924 discloses a structure which comprises a plurality of permanent magnet pieces embedded in the outer peripheral surface of a shaft of non-magnetic material, a hollow rotary cylinder of non-magnetic material disposed around the shaft, and means for causing differential rotation of the shaft and the hollow rotary cylinder relative to each other. However, due to the fact that the permanent magnet pieces to be embedded in the outer peripheral surface of the shaft of non-magnetic material are connected to each other in the axial direction by the non-magnetic material after magnetization, demagnetization occurs in these permanent magnet pieces during assembling and the degree of demagnetization is not uniform for all these pieces. This leads to variations in the magnetic force of the axially joined permanent magnet pieces, and therefore, a magnetic brush formed on the hollow rotary cylinder has a non-uniform distribution of developer particles. Thus, this patent is defective in that developing marks appear on the developed, image on the surface of an electrostatic recording sheet, resulting in impossibility of obtaining an image of good quality.

U.S. Pat. No. 3,455,276 discloses a structure which comprises even anisotropic rubber or synthetic resin bonded permanent magnets of sectoral cross-sectional shape securely fixed to the outer periphery of a shaft of ferromagnetic material, a sleeve of non-magnetic and electrically conductive material disposed around the shaft, and means for causing rotation of the shaft and sleeve at different speeds or causing rotation of the sleeve relative to the shaft. According to this patent, a mass of a powdery developer is contained in a tray and is supplied onto the surface of the rotary sleeve to be attracted to the sleeve surface for developing a latent electrostatic image recorded on an electrostatic recording sheet disposed opposite to the rotary sleeve. However, this structure is disadvantageous in that considerable amounts of labor and cost are required for the manufacture due to the fact that the permanent magnets must be worked to have a sectoral cross-sectional shape. Further, due to the fact that the powdery developer is not sufficiently agitated and is only unsatisfactorily removed from the surface of the sleeve, this patent is defective in that the powdery developer remaining on the surface of the rotary sleeve is repeatedly used for developing, resulting in reproduction of an image of bad quality on the image carrying surface of the recording sheet.

U.S. Pat. No. 3,176,652 discloses a structure which comprises a permanent magnet of salient cross section carried by a stationary shaft, a hollow rotary cylinder disposed around the shaft, and means such as a trough

for supplying a powdery developer onto the surface of the hollow rotary cylinder so that the powdery developer attracted to the surface of the cylinder, by the magnetic force of the permanent magnet develops a latent electrostatic image recorded on an electrostatic recording sheet disposed opposite to the hollow rotary cylinder. In this patent, the permanent magnet has even magnetic poles as in the patents above described and is commonly made by means of casting. Further, the magnetic poles must be fixed to protrude from the outer peripheral surface of the shaft. Therefore, the work involves very troublesome steps resulting in large amounts of labor and cost for the manufacture of the permanent magnet. Further, due to the fact that a large radial distance is required between the permanent magnet and the hollow rotary cylinder disposed around the permanent magnet, this patent is defective in that a small magnetic force is only available resulting in a poor ability of attracting and conveying the powdery developer.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an electrostatic record developing apparatus in which a powdery developer can be uniformly distributed on the surface of a magnet roller irrespective of the position directly above the magnetic pole or the position intermediate between the magnetic poles so as to ensure reproduction of an image of good quality on the image carrying surface of an electrostatic recording sheet.

Another object of the present invention is to provide an electrostatic record developing apparatus in which the used powdery developer can be reliably removed from the surface of the magnet roller so that the powdery developer having an undesirably low toner content may not be supplied to the image carrying surface of an electrostatic recording sheet again.

A further object of the present invention is to eliminate reproduction of a blurred image of non-uniform density on the image carrying surface of an electrostatic recording sheet so as to obtain a clear and distinct image.

Another object of the present invention is to ensure the formation of a magnetic brush having a uniform distribution and a sufficient amount of developer particles on the surface of the magnet roller opposite to the image carrying surface of an electrostatic recording sheet.

Still another object of the present invention is to provide an electrostatic record reproducing apparatus in which a permanent magnet constituting a part of the magnet roller is simple in construction and can be manufactured at low cost.

Yet another object of the present invention is to provide an electrostatic record developing apparatus having a powdery developer container in which means is provided for sufficiently and uniformly mixing the toner and the carrier with each other so that the powdery developer consisting of a uniform mixture of the toner and the carrier can be always supplied to the image carrying surface of an electrostatic recording sheet.

In one form of the electrostatic record developing apparatus according to the present invention, a cylindrical permanent magnet having odd axially extending magnetic poles on the surface thereof is disposed coaxially within a hollow rotary cylinder of non-magnetic material so that the hollow rotary cylinder is rotatable relative to the cylindrical permanent magnet. The cylindrical permanent magnet is fixed in such a position that one of the magnetic poles of one polarity adjacent to a pair of the magnetic poles of the other and same polarity is disposed opposite to the image carrying surface of an electrostatic recording sheet, and a powdery developer attracted to the surface of the hollow rotary cylinder under rotation passes beneath the image carrying surface of the recording sheet and then over the magnetic poles of the other and same polarity. The powdery developer attracted to the surface of the hollow cylinder forms a magnetic brush on such surface for developing a latent electrostatic image recorded on the image carrying surface of the recording sheet.

In the present invention, a cylindrical permanent magnet having an odd number of magnetic poles is adjustably secured in place so that one of the odd magnetic poles thereof can always take the optimum position opposite to the image carrying surface of an electrostatic recording sheet, and a fresh, stable and uniform magnetic brush can be continuously formed on the surface of a rotary cylinder without being in any way adversely affected by the difference in the magnetic force between the portion directly above the magnetic pole and the portion intermediate between the magnetic poles. This arrangement provides the advantage in that an image of good quality can be reproduced on the recording sheet.

The provision of the odd magnetic poles on the cylindrical permanent magnet provides another advantage in that any excess powdery developer remaining even after the developing operation is easily removed from the surface of the rotary cylinder by the repulsion acting between the magnetic poles of the same polarity so that a fresh powdery developer can be always supplied to the surface of the rotary cylinder.

In the present invention, the powdery developer attracted to the surface of the rotary cylinder from a container passes over a plurality of magnetic poles before reaching the image carrying surface of an electrostatic recording sheet and the toner and carrier particles in the powdery developer are subject to continuous motion. This provides a further advantage in that the toner and the carrier are thoroughly and uniformly mixed together thereby eliminating non-uniform deposition, developing marks and non-uniform image density and ensuring reproduction of a clear and distinct image.

Another advantage resides in the fact that the powdery developer being conveyed by the rotary cylinder is firmly attracted to the surface of the rotary cylinder by the action of the cylindrical permanent magnet until it reaches the image carrying surface of an electrostatic recording sheet so that undesirable non-uniformity of the image density can be completely eliminated.

In the present invention, the magnetic poles extend continuously in strip form in the axial direction of the cylindrical permanent magnet and are uniformly magnetized. This provides another advantage in that the powdery developer can be attracted free from any discontinuity and non-uniform deposition of the developer on the image carrying surface of an electrostatic recording sheet can be avoided.

Another advantage resides in the fact that the apparatus according to the present invention is simple in construction and can be manufactured at low cost.

In another form of the present invention, the magnetic brush is transferred from one magnet roller to another in a powdery developer container, and during this transfer movement, the toner and carrier are mixed together. This provides another advantage in that the powdery developer can be transferred to the surface of the upper rotary cylinder in a uniformly and thoroughly mixed state.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partly sectional front elevation showing schematically the structure of a magnet roller and associated parts in an embodiment of the present invention.

FIG. 2 is a schematic transverse section of the magnet roller shown in FIG. 1. FIG. 3 is a schematic vertical section of another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2, the structure of a magnet roller constituting an essential part of an electrostatic record developing apparatus according to the present invention will be described. In FIGS. 1 and 2, a hollow rotary cylinder 1 is made of a non-magnetic material such as brass, aluminum or stainless steel and is closed at opposite ends by a pair of side plates 2 and 3. A stub shaft 4 extends outwardly from the side plate 3. A cylindrical permanent magnet 5 is disposed coaxially within the hollow rotary cylinder 1 and has an outer diameter smaller than the inner diameter of the hollow rotary cylinder 1. A central shaft 6 extends through the cylindrical permanent magnet 5 and is securely fixed to the magnet 5. One end of the shaft 6 is journaled in a bearing 7 fitted in the side plate 3, while the other end portion of the shaft 6 is journaled in a bearing 8 fitted in the side plate 2 and extends outwardly through a portion of a frame 10 of the apparatus to be secured to that portion of the frame 10 by a set screw 11. The stub shaft 4 is journaled at a portion thereof in a bearing 9 fitted in another portion of the frame 10, and a pulley 12 is mounted on the outer or left-hand end of the stub shaft 4 to be driven from drive means (not shown) through a belt 13. An adjusting knob 14 is mounted on the right-hand end of the shaft 6. The cylindrical permanent magnet 5 is provided on the outer peripheral surface thereof with odd magnetic poles N and S. As seen in FIG. 1, the magnetic poles N and S are in the form of a strip having the same width and extend axially along the outer peripheral surface of the magnet 5. The present embodiment is shown as having seven magnetic poles consisting of three N poles and four S poles. An electrostatic recording sheet 15 is arranged to run in a direction as shown by the arrow B above the rotary cylinder 1 in close proximity thereto. A mass of a powdery developer 16 is a mixture of fine particles of a developing pigment called a toner and fine particles of iron called a carrier.

In operation, the rotary cylinder 1 is rotated in a direction as shown by the arrow A in FIG. 2 by the drive means (not shown) through the belt 13, pulley 12 and stub shaft 4. The cylindrical permanent magnet 5 is suitably turned by the adjusting knob 14 and is secured by the set screw 11 in such a position that one of the magnetic poles of one polarity among the odd magnetic poles formed on the outer peripheral surface thereof is brought opposite to the image carrying surface of the electrostatic recording sheet 15 and that the surface portion having the two magnetic poles of the other and same polarity is disposed on the trailing side of the electrostatic recording sheet 15 in regard to the advancing direction B of the recording sheet 15. When the cylindrical permanent magnet 5 is fixed in such a position and the rotary cylinder 1 is rotated in the direction of the arrow A in FIG. 2 with a portion of the lower half thereof buried in the mass of the powdery developer 16 which is the mixture of the toner and carrier particles, the powdery developer 16 is attracted to the surface of the rotary cylinder 1 by the magnetic force of the cylindrical permanent magnet 5 and is carried upward as the rotary cylinder 1 rotates. Motion of the particles of the powdery developer 16 thus attracted to the surface of the rotary cylinder 1 occurs on the rotary cylinder 1 depending on variations in the lines of magnetic force since the powdery developer 16 passes directly above more than one magnetic pole until it reaches the image carrying surface of the recording sheet 15. Even if the powdery developer 16 may be non-uniformly distributed at the time it is attracted to the rotary cylinder 1, such non-uniform distribution is eliminated by the above motion and the toner and the carrier are thoroughly mixed together. Thus, the powdery developer 16 forms a magnetic brush 17 consisting of a uniform and thorough mixture of the toner and the carrier when it is carried to the position directly beneath the image carrying surface of the recording sheet 15, and a clear and distinct image can be reproduced as the recording sheet 15 carrying a latent electrostatic image posses over the magnetic brush 17 in the direction of the arrow B in FIG. 2. Any excess of the powdery developer 16 remaining even after the developing operation is further carried in the direction of the arrow A by the rotary cylinder 1 to move into the zone including the magnetic poles S of the same polarity as seen in FIG. 2. In this zone, the powdery developer 16 is easily detached from the surface of the rotary cylinder 1 by the repulsion acting between these magnetic poles so that the remaining powdery developer can be completely removed.

While the embodiment shown in FIGS. 1 and 2 has referred to an arrangement in which the two magnetic poles S of the same polarity are disposed in substantially widely spaced apart relation, it will be understood that the same effect can be attained when these two magnetic poles S have a substantial width such that they are closely adjacent to each other.

In another embodiment of the present invention schematically shown in vertical section in FIG. 3, a doctor plate 18 is in contact at one end thereof with the surface of a hollow rotary cylinder 1 of the kind shown in FIGS. 1 and 2. A mass of a powdery developer 16 is contained in a container 19 and is continuously agitated by an agitator 20 rotating in a direction of the arrow C, and a fresh toner is supplied into the container 19 from a supply port 21. A cylindrical permanent magnet 5 is provided with odd magnetic poles S and N and is fixed in a position as shown in FIG. 3 so that one end of the doctor plate 18 engages the surface of the rotary cylinder 1 at a position intermediate between the two contiguous magnetic poles of the same polarity (N

poles in FIG. 3) and adjacent to one of these magnetic poles provided on the cylindrical permanent magnet 5. A rotary drum 22 is disposed in close proximity to the rotary cylinder 1 and rotates in a direction of the arrow B while holding an electrostatic recording sheet 15 on the surface thereof.

The developing operation on the electrostatic recording sheet 15 by the apparatus shown in FIG. 3 is similar to that described with reference to FIGS. 1 and 2. In operation, the rotary drum 22 holding thereon an electrostatic recording sheet 15 having a latent image thereon is rotated in the direction of the arrow B. At the nip between the rotary drum 22 and the rotary cylinder 1, the electrostatic recording sheet 15 is brought into contact with a magnetic brush 17 formed by the powdery developer 16 by the action of the lines of magnetic force so that the latent electrostatic image formed on the electrostatic recording sheet 15 can be developed by the powdery developer 16. Any excess of the powdery developer 16 remaining on the surface of the rotary cylinder 1 even after the developing operation is scraped off the surface by the doctor plate 18 engaging the surface of the rotary cylinder 1. Due to the fact that the end of the doctor plate 18 is disposed adjacent to the N pole of the two contiguous N poles as described above, that is, adjacent to the leading edge of a magnetic brush 17a formed by the excess powdery developer 16, this excess powdery developer 16 is smoothly transferred from the surface of the rotary cylinder 1 onto the doctor plate 18 to be completely removed from the surface of the rotary cylinder 1. It will thus be understood that the excess powdery developer 16 can be completely removed by the cooperation between the doctor plate 18 disposed at such an optimum position and the repulsive force acting between the magnetic poles of the same polarity. The excess powdery developer 16 thus removed falls down into the container 19 and is mixed with a fresh toner supplied from the toner supply port 21, the mixture being thoroughly agitated by the agitator 20 rotating within the container 19.

The gap between the rotary drum 22 and the rotary cylinder 1, the position of the specific magnetic pole of the cylindrical permanent magnet 5 opposite to the rotary drum 22, and the engaging position and angle of the doctor plate 18 may be suitably adjusted depending on the relative rotating speeds of the rotary drum 22 and rotary cylinder 1 and the property of the powdery developer 16.

Though the magnetic poles start with the S pole in the embodiment of FIG. 2 while the magnetic poles start with the N pole in the embodiment of FIG. 3, with which pole the poles start is immaterial and either will do.

We claim:

1. An electrostatic record developing apparatus comprising a hollow cylindrical rotary member of nonmagnetic material, means for causing rotation of said hollow cylindrical rotary member, a cylindrical permanent magnet disposed coaxially within said hollow cylindrical rotary member so as to be rotatable relative to said hollow cylindrical rotary member, said cylindrical permanent magnet being formed in a body having an odd number of magnetic poles and more than three magnetic poles extending in strip form in the axial direction thereof, said strip-like magnetic poles being arranged with alternating north poles and south poles except for one portion of the cylindrical body at which two adjacent magnetic poles of the same polarity are arranged for producing a repulsive force which effectuates the removal of developer from the surface of said cylindrical rotary member, means for feeding an electrostatic recording sheet relative to said hollow cylindrical rotary member, means for adjustably fixing said cylindrical permanent magnet in such a position that one of the magnetic poles is disposed opposite to the image carrying surface of the electrostatic recording sheet and the adjacent magnetic poles of the same polarity are disposed on the trailing side of the electrostatic recording sheet, and means for supplying a powdery developer to the surface of said hollow cylindrical rotary member so that the powdery developer is attracted to and forms a magnetic brush on the surface of said hollow rotary cylindrical member thereby developing a latent electrostatic image recorded on the image carrying surface of the electrostatic recording sheet.

2. An electrostatic record developing apparatus as claimed in claim 1, in which a doctor means is provided to engage at one end thereof with the surface of said hollow cylindrical rotary member at a position intermediate between said magnetic poles of the same polarity and adjacent to the trailing one of said magnetic poles of the same polarity.

3. An electrostatic record developing apparatus as claimed in claim 1, wherein said one magnetic pole disposed opposite to the image carrying surface of the electrostatic recording sheet is arranged adjacent to one of said magnetic poles of the same polarity.

4. An electrostatic record developing apparatus as claimed in claim 1, wherein said strip-like magnetic poles are formed in the surface of the cylindrical permanent magnet body.

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