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Kangas et al.

[11] **3,739,749**

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[54] **MAGNETIC POWDER APPLICATOR**

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Related U.S. Application Data

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[52] **U.S. Cl.** **118/637,** 117/17.5

[51] **Int. Cl.** **G03g 13/00**

[58] **Field of Search** 118/637, 623; 117/17.5

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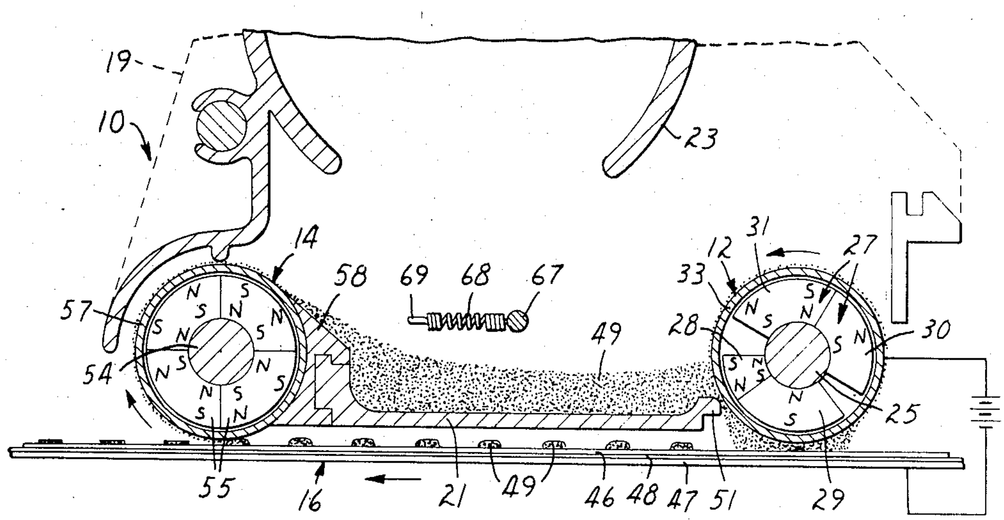
[57] **ABSTRACT**

An applicator for uniformly applying magnetically responsive dry particulate material to broad areas on a web moved past the applicator to deposit the material in pattern areas attracting the material thereto. The applicator comprises an applicating roller having a plurality of magnetic members arranged about a shaft within a rotatable non-magnetic sleeve to provide a magnetic field around the roller having a feed zone with a radial field changing to a tangential field, an applicating zone with a stronger radial field following the feed zone and a return zone extending from the applicating zone to the feed zone and having a stronger tangential field immediately following the applicating zone. A scavenging roller has a plurality of magnetic members arranged about a rotatable shaft within a non-magnetic sleeve to carry any free particulate material applied by the applicating roller away from the web surface and back to a tray.

8 Claims, 5 Drawing Figures



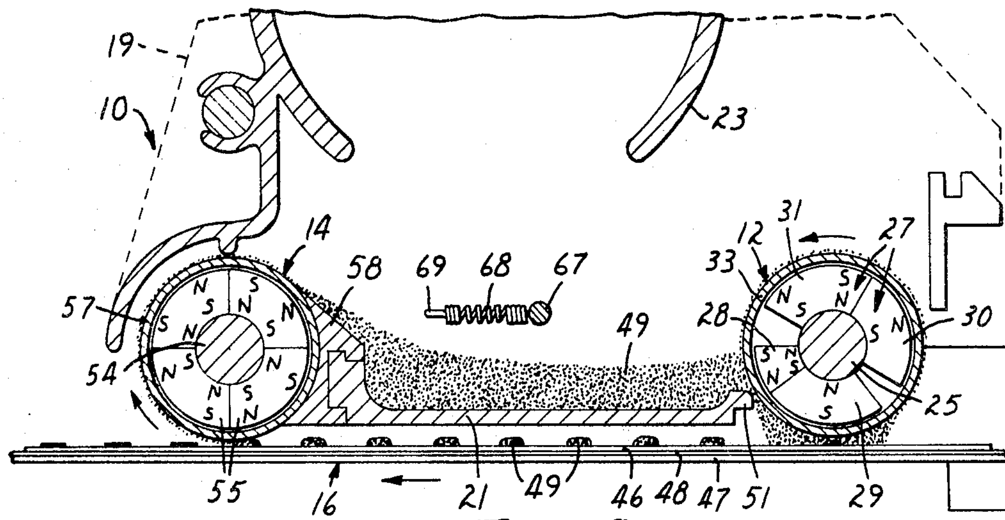


FIG. 3

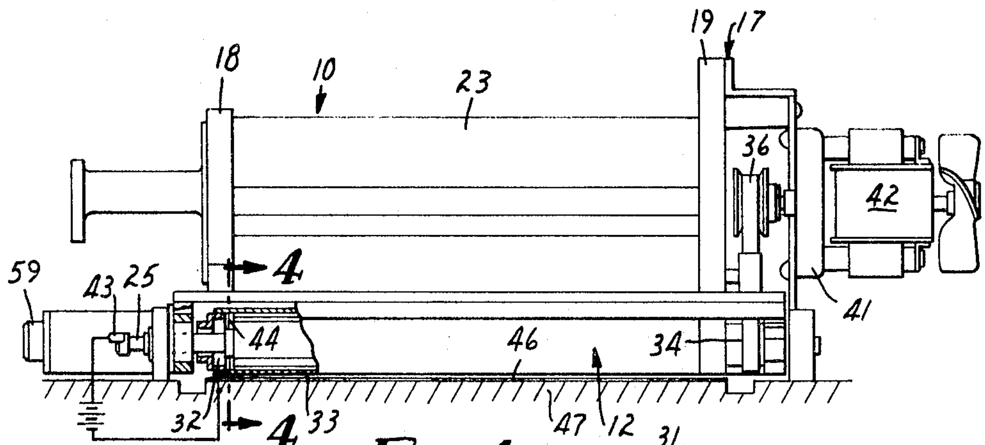


FIG. 1

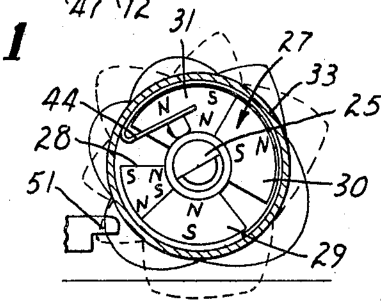


FIG. 4

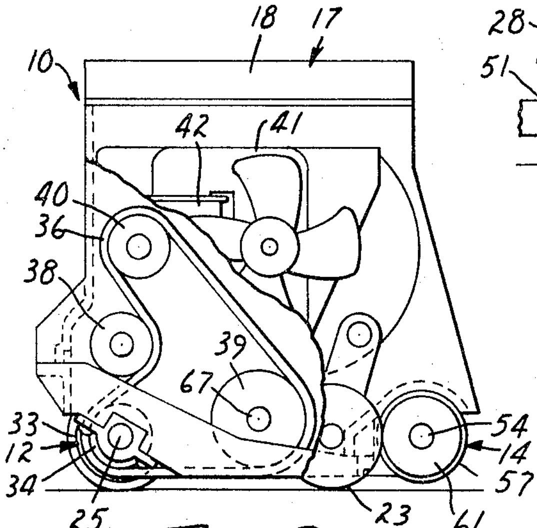


FIG. 2

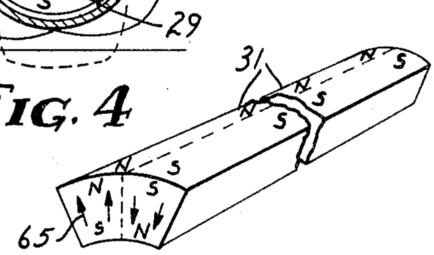


FIG. 5

MAGNETIC POWDER APPLICATOR

This application is a division of application Ser. No. 867,768, filed Oct. 20, 1969.

This invention relates to an applicator for applying a uniform layer of magnetically responsive dry particulate material to particle-attractive areas on a moving, differentially particle-attractive surface.

The present invention is particularly useful in applying pigmented particulate material to an article to develop an image thereon. One example of such use is in developing imagewise a differentially conductive pattern formed by projecting a light image on a photoconductive web. The photoconductive web being positioned between an insulative layer, backed by an electrode, and a second electrode contacting the particulate or powder which is in electrically conductive contact between the second electrode and the photoconductive web.

The prior art is replete with magnetically responsive powder applicators in which permanent magnets are arranged about a shaft within a non-magnetic outer sleeve, and the shaft and the sleeve are mounted for relative rotation. Recently, as illustrated by U.S. Pat. No. 3,455,276, it has been found advantageous in such devices to utilize magnetic members formed of fine grain permanent magnet material dispersed in a non-magnetic immobilizing matrix. With such magnetic members it is possible to present an even deposition of particulate material or developer powder to an image-bearing member with a width of eight and one-half inches to thirteen inches since the magnetic field along the magnetic members can be made constant for such length unlike other permanent magnets. While such an applicator does present a uniform layer of particulate material to a photoconductive web the desired uniform layer of particulate material on the particle attractive areas of the web has not been achieved. As the particulate material is transferred from the sleeve of the applicating roller to the photoconductive web where the attractive force on the web overcomes the magnetic attraction of the applicating roll, the powder extends between the web and the sleeve. As the web is advanced, the particulate material separates from the sleeve and forms tree-like piles on the web with the particles in the uppermost portion of the piles weakly attracted or free on the web. As the web continues to move along, these free particles may then become dislodged and come to rest on the non-attractive (e.g., background) areas of the web. Furthermore, upon transferring the particulate material from the photoconductive web to a sheet of copy paper to form an image thereon the non-attracted particles may be dispersed onto areas of the copy paper where they are not desired. In either case these dislodged particles will darken or change the image resolution on a sheet of copy paper which is highly undesirable.

According to the present invention, an improved applicating roller utilizing magnetic members formed of fine grain permanent magnet material dispersed in an immobilizing matrix is provided. The present invention also provides an apparatus for applying a uniform layer of magnetically responsive particulate material to particle-attractive areas on a moving differentially particle-attractive web such that the particles applied to the web are all attracted thereto. The present invention further provides an applicator for presenting a dimensionally uniform coating of magnetically responsive particulate material to a wide, differentially particle-attractive surface to deposit the particulate material in the particle-attractive areas.

The apparatus illustrated is adapted for applying a layer of magnetically responsive dry particulate material to particle attractive areas on a moving differentially particle attractive surface and comprises an applicating roller and a scavenging roller, each roller comprising a magnetically permeable shaft, a plurality of generally sector-shaped strips of magnetic material, said strips being magnetized to create axially extending areas of alternating polarity in adjacent circumferential position about said shaft, and a non-magnetic sleeve fitted over the magnetic strips, means for mounting the sleeve and the shaft of the applicating roller for relative rotation to carry particulate material on the sleeve to a said moving surface, and means for mounting the sleeve and the shaft of the scavenging roller to carry any non-attracted or free particulate material around the sleeve away from a said surface.

The novel features and advantages of the present invention will become apparent after reading the following description which refers to the accompanying drawing wherein:

FIG. 1 is a longitudinal elevational view of a particulate material applicator made in accordance with the present invention;

FIG. 2 is an end elevational view of the applicator of FIG. 1;

FIG. 3 is a diagrammatic vertical sectional view of the operation of the applicator of FIG. 1;

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 1; and

FIG. 5 is a perspective view illustrating one magnetic member.

A magnetically responsive dry particulate material applicator made in accordance with the present invention and generally designated **10**, is illustrated in FIG. 1 and comprises an applicating roller **12** and a scavenging roller **14** supported with their peripheral surfaces adjacent a moving surface **16** having areas differentially attractive to the particulate material. In the illustrated embodiment, the rollers **12** and **14** are supported by frame members **17** comprising a pair of end plates **18** and **19**, a developer powder tray **21** extending between the rollers **12** and **14**, and a developer powder hopper **23** extending between the end plates **18** and **19** above the powder tray **21**.

The applicating roller **12** comprises a shaft **25** formed of a material having a high magnetic permeability, such as soft iron, stationarily supported at opposite ends in the frame members **17**. Positioned above the shaft **25** are four generally sector-shaped strips of magnetic material **27**, which will be described in greater detail hereinafter. Rotatably mounted relative to the shaft **25** coaxially therewith, as by bearing mounted end caps **32** is a non-magnetic cylindrical sleeve **33** formed of a material (e.g., glass, aluminum, or polymeric material) which will not shield the magnetic field from the magnetic strips **27**. At one end the sleeve **33** is formed with a pulley **34** about which a drive belt **36** passes to rotate the sleeve **33** about the magnetic strips **27**. The drive belt **36** also passes around an idler roller **38**, a bail shaft pulley **39** and a drive pulley **40**. The drive pulley **40** is suitably driven from a drive motor **42** through gears in a gear box **41**.

As desired in some copying applications, the applicating roller 12 serves as an electrode; therefore, it is desired to connect the sleeve 33 to a source of electrical potential; and in the illustrated embodiment a connector 43 is attached to the shaft 25, to which a lead from a source of a potential may be coupled. The sleeve 33 is electrically connected to the shaft 25 by sliding leaf 44 (FIG. 5) of resilient conductive material. The sleeve 33 in this example is preferably formed of aluminum, but could be formed of another non-magnetic material such as glass with an electrically conductive, non-magnetic surface coating.

The applicating roller 12 is positioned adjacent the tray 21 in parallel aligned spaced relation to the moving differentially particle-attractive surface 16, defined by the surface of a web comprising, for example a differentially light struck photoconductive coating 46 carried on an insulative backing 48 supported in turn on an electrically conductive surface 47. In any instance, if the moving surface of the web 16 is to be coated, it carries an undeveloped differential image pattern to which is to be applied an even coating of particuate image-forming magnetically responsive material hereinafter referred to as developer powder 49, which may be supplied by the applicating roller 12 from a supply disposed in the tray 21.

Along the edge adjacent the applicating roller 12, the tray 21 is formed with an inclined surface defining a doctor blade 51 spaced from the sleeve 33 of the applicating roller 12 to define a doctor gap with the sleeve 33 across the width of the moving surface 16 through which the developer powder 49 must pass to be applied to the moving surface 16.

Like the applicator roller 12, the scavenging roller 14 comprises a shaft 54 formed of a material having a high magnetic permeability, such as soft iron, supported at opposite ends in the frame members 17. Positioned about the shaft 54 are similar generally sector-shaped strips of magnetic material 55, which will be described in greater detail hereinafter. A non-magnetic cylindrical sleeve 57 formed of a material which will not shield the magnetic field from the magnetic strips 55 is supported coaxially with the shaft 54. Like the applicating roller 12 the sleeve 57 and the shaft 54 of the scavenging roller 14 are relatively rotatable, however, unlike the applicating roller 12 the sleeve 57 of the scavenging roller 14 is fixed while the shaft 54 is rotatable. The sleeve 57 of the scavenging roller 14 has an insulating extension 58 secured along its length to mate with the edge of the tray 21 opposite the doctor blade 51. This forms a continuous surface along the base of the tray 21 around the scavenging roller sleeve 57 and into the tray 21. The scavenging roller shaft 54 is suitably bearinged in end caps 57 (only one of which is shown) of the sleeve 57. At one end the shaft 54 extends through an end cap 59 and supports a roller 61 which is suitably driven, such as by a roller 63 that contacts an extension of the moving surface 16 and the roller 61, to provide rotation of the shaft 54 and the magnetic strips 55 in a counterclockwise direction as viewed in FIG. 3.

The magnetic strips 27 and 55 are generally shaped as sectors of a hollow cylinder having radially inner faces concavely curved and convex radially outer surfaces joined by radially extending edge walls. In each roller 12 or 14 the magnetic strips 27 or 55 are arranged in a circular array about their associated shaft 25 or 54 with their edges generally radial and in side-

by-side relation. The strips 27 and 55 are formed by extrusion of a non-magnetic matrix which may be a resinous or plastic composition, and an elastomeric semisolid, or viscous liquid, capable of hardening, setting or being cured to a solid state in which is evenly dispersed anisotropic ferrite domain-sized particles, which particles are capable of achieving physical orientation when acted upon by internal shear stresses. Examples of the particles are certain fine-grained, permanent magnet materials, particularly the ferrites of barium, lead, and strontium which are easily magnetized to saturation. The matrix may be natural rubber with compound agents, plasticizers, vulcanizing agents, and the like to provide the hardness of the matrix desired, or may be a thermoplastic or thermosetting material, as for example, polyvinyl chloride. Preferably the ferrite particles are oriented such that each particle (as illustrated diagrammatically in FIG. 5 at 63) is positioned with its magnetic poles positioned radially relative to each other.

In the applicating roller 12, since the shaft 25 is fixed, the magnetic strips 27 are constantly positioned as schematically illustrated in FIG. 3. The strips 27 are arranged about the shaft 25 with the edges thereof generally radial and in side-by-side relation to substantially form a cylinder and they are magnetized to provide peripheral circumferential areas of constant polarity extending the lengths of the strips with adjacent areas oppositely polarized. Two such peripheral areas provided by a single magnetic strip 31 are illustrated in FIG. 5. The magnetic strips 27 produce the relative magnetic field component strengths illustrated in FIG. 4 where the radial field component is illustrated in dotted lines and the tangential field component is illustrated in full lines. The magnetic field just prior to and at the doctor blade 51 is generally exclusively radial thereby tending to align the developer powder particles in rows standing out perpendicularly from the surface of the sleeve 33. As the sleeve 33 rotates the doctor blade may then trim these rows of particles to pass particles through the doctor gap. A stronger tangential field is developed immediately past the doctor blade 51 to draw the powder passing the doctor gap against the sleeve 33 to improve the powder flow toward the moving surface 16. The radial field at the doctor blade together with the tangential field immediately thereafter define a powder feed zone.

Along the line nearest the moving surface 16 and to both sides thereof is an applicating zone. In the applicating zone the magnetic field is nearly exclusively radially oriented, thereby tending to align the developer powder particles in rows extending outward radially from the sleeve 33 to increase the density of powder contacting the moving surface 16. A uniform layer of developer powder is thereby presented to the photoconductive surface 46. The web 46 may then selectively attract developer powder from the applicator sleeve 33 according to the image pattern thereon while maintaining a space between the sleeve 33 and the web 46 to prevent powder from being pressed onto non-attractive areas of the web.

Moving about the sleeve 33 counterclockwise (as viewed in FIG. 3 or 4) away from the moving surface 16 is a powder return zone in which the magnetic field is rapidly changed to a dominant tangential field stronger than that in the feed zone to lay the rows of developer powder particles against the sleeve 33 to aid in moving any non-attracted particles away from the moving surface. Continuing in a counterclockwise direction about the applicating roller 12 the return zone extends to the feed zone and the magnetic field has a sufficient strength to carry the remaining non-attracted developer powder on the sleeve 33 back into the tray 21.

The unique magnetic field about the applicating roller 12 is accomplished by the size, polarization and positioning of the four magnetic strips 28, 29, 30 and 31. The weak radial field of the feed zone at the doctor blade 51 is generally provided by a four pole approximately 35° sector magnet 28. The weak tangential field of the feed zone is provided by the 35° four pole magnet 28 and a first two pole 90° sector magnet 29 abutting the 35° four pole magnet 28. Due to its mass the first two pole 90° sector magnet 29 also generally provides the strong radial field in the applicating zone and cooperates with a second two pole 90° magnet 30, that is adjacent and spaced from it, to provide the strong tangential field of the return zone. A four pole 90° sector magnet 31 abuts the second 90° two pole magnet 30 and is adjacent and spaced from the 35° four pole magnet 28 to complete the array of magnets. The magnet 31 provides a sharply varying magnetic field near the end of the return zone to promote increased tumbling action as the returned powder mixes in the tray with the supply powder.

As in the applicating roller 12, the magnetic strips 55 of the scavenging roller 14 are arranged about the shaft 54 with the edges thereof generally radial and side-by-side relation to form a cylinder and they are magnetized to provide peripheral circumferential areas of constant polarity extending the length of the strips 55 with adjacent areas oppositely polarized. However, unlike the applicating roller 12, the magnetic strips 55 are all similar, 90° sectors each of which is magnetized to provide a north pole and a south pole, generally of equal strength, on its peripheral surface. These strips 55 have sufficient magnetic strength to pull any free powder particles on the photoconductive web 46 against the sleeve 57.

A bail shaft 67 is rotatably supported above the developer powder tray 21 and extends parallel to the rollers 12 and 14. The bail shaft 67 is bearinged in the frame members 17 and extends through one end thereof to carry the bail pulley 39 so as to be suitably driven by the motor 42. Two helical springs 68 extend perpendicularly from the bail shaft 67, one generally at each end of the tray 21, and a wire bail 69 is supported at the free ends of the springs 68 to normally lie parallel to the bail shaft 67.

In use, a differentially exposed photoconductive web 46 is moved first past the applicating roller 12. As it does so, the developer powder 49 is moved from the tray 21 through the doctor gap and into contact with the web 46 on the applicating roller sleeve 33. Developer powder is transferred to the particle-attractive areas on the web 46 corresponding to the images carried thereon. As the developer powder on the sleeve 33 separates from the powder applied to the web 46 tree-like piles of developer powder are formed at the imaged areas on the web. Any powder carried into contact with non-attractive areas of the web continues to be carried on the sleeve 33 around the applicating roller 23 and back into the tray 21.

As the web 46 continues to be moved, it passes under the scavenging roller 14. As the tree-like piles of developer powder on the image areas of the web 46 pass under the scavenging roller 14 any weakly attracted powder at the tops of the trees or free powder on non-attractive areas of the web is attracted to the sleeve 57 of the scavenging roller 14 by the magnetica strips 55. While the shaft 54, and therefore, the magnetic strips 55 are rotated counterclockwise, as illustrated in FIG. 1, the powder attracted to the surface of the sleeve 57 progresses in a tumbling fashion around the sleeve in a clockwise direction (opposite the direction of rotation of the magnets) and thereby into the tray 21. Any powder returned to the tray by the scavenging roller 14 again becomes available as supply for the applicating roller 12, powder supplied adjacent the scavenging roller 14 being moved toward the applicating roller 12 by rotation of the bail shaft 67 and the bail 69.

In one specific operative embodiment the applicating roller sleeve 33 is aluminum with a wall thickness of 0.025 inch and an inside diameter to provide an air gap of about 0.012 inch between its inner surface and the periphery of the magnets 27. The sleeve 33 is spaced from the photo-conductive web 46 0.013 inch with a tolerance of plus or minus 0.002 inch. The gap at the doctor blade 51 is made 0.010 inch with a tolerance of plus or minus 0.002 inch and the center of the doctor blade is spaced about 60° (clockwise as viewed in FIGS. 3 and 4) from a vertical plane intersecting the axis of the applicating roller 12.

The strength of the radial field component in the applicating zone when measured on the outside of the aluminum sleeve 33 is about 400 gauss provided primarily by the first two pole 90° sector magnet 29. This radial field strength will produce an applicating zone on the planar photoconductive web 46 which extends across the web 46 and which is between 0.75 inch and 1.0 inch wide when the sleeve 33 is rotated at one-tenth the web speed in a direction opposite to the movement of the web 46.

The sleeve 57 of the scavenging roller 14 is preferably spaced from the web surface about 0.125 inch to 0.150 inch. The scavenging roller magnets 55 are rotated by rotation of their shaft 54 at a speed between 100 rpm and 500 rpm, preferably about 300 rpm.

We claim:

1. Apparatus for applying a uniform layer of magnetically responsive dry particulate material to particle-attractive areas on a moving differentially particle-attractive surface, comprising:

a pair of spaced rollers supported with their peripheral surfaces adjacent a said moving surface, each said roller comprising:

a shaft of high magnetic permeability material,

a plurality of elongated generally sector-shaped in cross-section strips of magnetic material formed of fine grain permanent magnetic material dispersed in a non-magnetic immobilizing matrix, said strips being arranged in a circular array about said shaft with the edges of said strips generally radial and in side-by-side relation to form at least a partial cylinder, each said strip being radially polarized with constant polarity along its length and adjacent strips being oppositely polarized along their adjacent edges, and

a non-magnetic hollow cylindrical sleeve mounted coaxially with said array of magnetic strips and said shaft, means for mounting said sleeve and said shaft of the first of said rollers for relative rotation to carry a quantity of said particulate material on the periphery of said first roller sleeve to a said moving surface, and

means for mounting said sleeve and said shaft of the second of said rollers for relative rotation to carry free particulate material on the periphery of said second roller sleeve away from a said surface.

2. Apparatus as recited in claim **1** wherein each of said strips of magnetic material has an axial length of between 8 and 15 inches.

3. Apparatus as recited in claim **1** wherein said sleeve of said first roller is electrically conductive.

4. Apparatus as recited in claim **7** wherein said shaft of said first roller is fixed and said sleeve is supported for rotation about said shaft and wherein said sleeve of said second roller is fixed and said shaft is supported for rotation within said sleeve.

5. Apparatus as recited in claim **4** including means for rotating said sleeve of said first roller and said shaft of said second roller in the same direction having tangential components at their peripheral portions nearest the differentially particle-attractive surface that are opposite to the direction of movement of the surface past the periphery of said sleeves of said rollers.

6. Apparatus as recited in claim **5** including a tray extending between said first and second rollers for storing a supply of said magnetically responsive dry particulate material in which said first roller sleeve may come in contact and for receiving said particulate material removed from said moving surface by said second roller and including means for transferring particulate material collected adjacent said second roller to a dispensing position adjacent said first roller.

7. Apparatus as recited in claim **6** wherein said shaft of said first roller is fixed and said sleeve is supported for rotation about said shaft and wherein said sleeve of said second roller is fixed and said shaft is supported for rotation within said sleeve.

8. Apparatus as recited in claim **7** wherein each of said strips of magnetic material have an axial length of between 8 and 15 inches.

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