United States Patent

Kangas et al.

[15] **3,643,629**

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[54] MAGNETIC POWDER APPLICATOR

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[52] **U.S. Cl.** **118/637**, 117/17.5, 335/303

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

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

[56] **References Cited**

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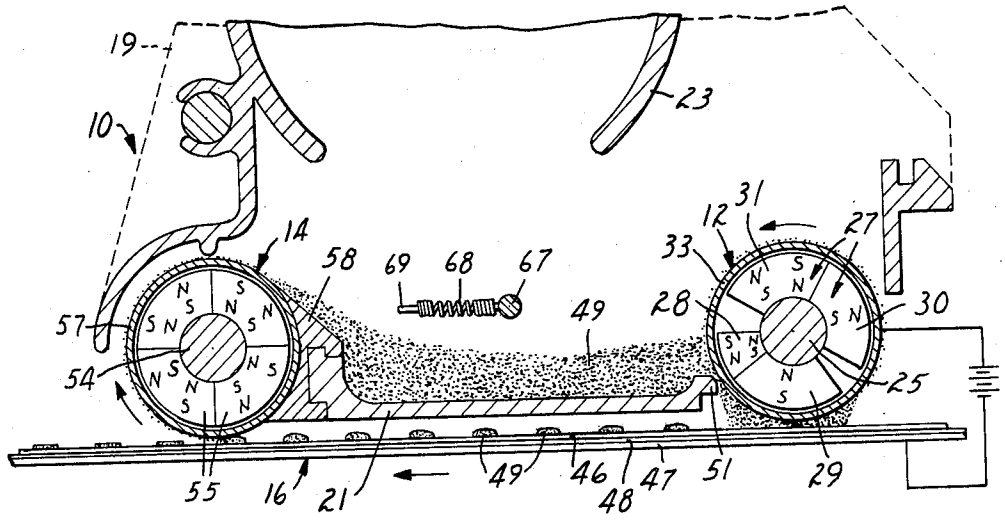
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Assistant Examiner—Leo Millstein
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[57] **ABSTRACT**

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 nonmagnetic 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 nonmagnetic sleeve to carry any free particulate material applied by the applicating roller away from the web surface and back to a tray.

6 Claims, 5 Drawing Figures



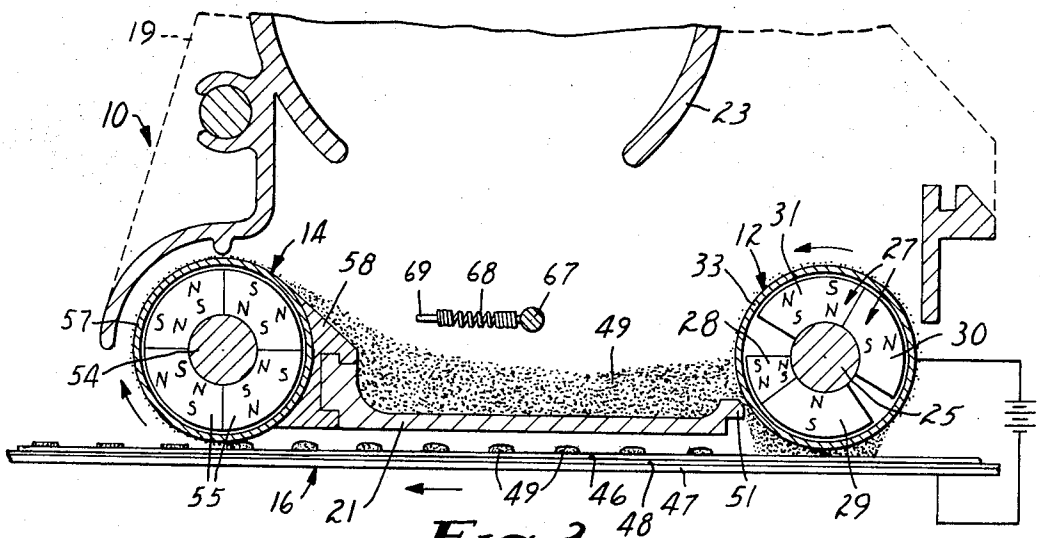


FIG. 3

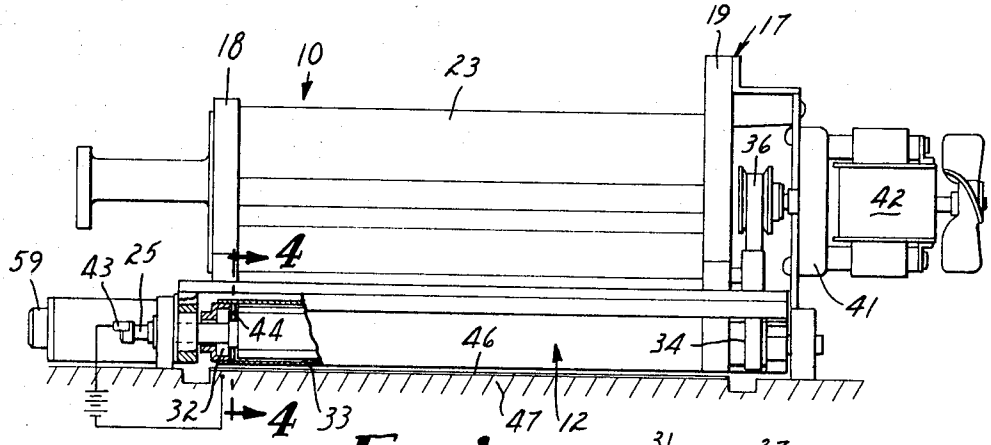


FIG. 1

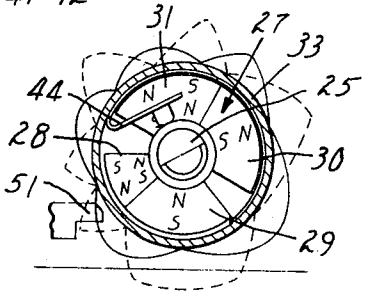


FIG. 4

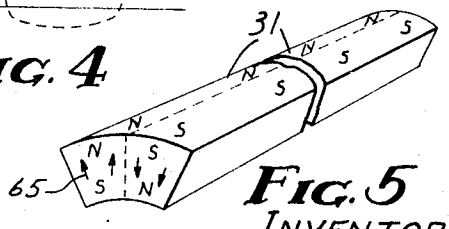


FIG. 5

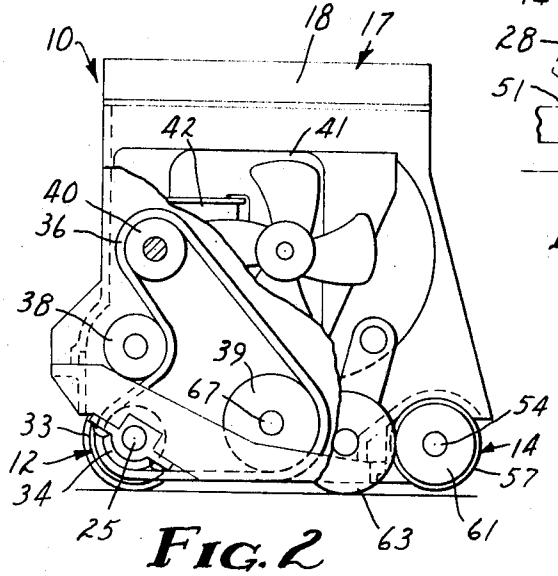


FIG. 2

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MAGNETIC POWDER APPLICATOR

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 nonmagnetic 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 nonmagnetic 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 8½ to 13 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 treelike 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 nonattractive (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 nonattracted 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 nonmagnetic 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 nonattracted 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 nonmagnetic 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 **86 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 nonmagnetic material such as glass with an electrically conductive, nonmagnetic 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 particulate 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 nonmagnetic 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 **59** (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 nonmagnetic 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 of thermosetting material, as for example, polyvinyl chloride. Preferably the ferrite particles are oriented such that each particle (as illustrated diagrammatically in FIG. 5 at **65**) 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 nonattractive 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 nonattracted 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 nonattracted 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** treelike piles of developer powder are formed at the imaged areas on the web. Any powder carried into contact with nonattractive 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 treelike 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 nonattractive areas of the web is attracted to the sleeve **57** of the scavenging roller **14** by the magnetic 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 photoconductive 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 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 to 0.150 inch. The scavenging roller magnets **55** are rotated by rotation of their shaft **54** at a speed between 100 and 500 r.p.m., preferably about 300 r.p.m.

We claim:

1. An applicating roller for placing a uniform layer of magnetically responsive dry particulate material in contact with a surface moved past the peripheral surface of said roller, said applicating roller comprising:

a stationary shaft of high magnetic permeability material,

magnetic means for producing a magnetic field about said peripheral surface of said roller having a feed zone with a generally radial field changing to a generally tangential field, an applicating zone following said feed zone with a generally radial field stronger than that of said feed zone and extending to both sides of the portion of said peripheral surface of said roller past which a said surface may be moved, and a return zone following said applicating zone and extending about said array to said feed zone, said return zone having a generally tangential field stronger than that of said feed zone immediately following said applicating zone, said magnetic means comprising a plurality of elongated generally sector-shaped in cross section strips of magnetic material formed of fine grain permanent magnetic material dispersed in a nonmagnetic 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 nonmagnetic hollow cylindrical sleeve fit over said arranged magnetic strips, extending axially of said shaft and supported for rotation about said magnetic strips to carry a quantity of said particulate material on the outer surface thereof.

2. An applicating roller as recited in claim **1** wherein said sleeve is electrically conductive.

3. An applicating roller as recited in claim **1** wherein each of said magnetic strips has an axial length of between 8 and 15 inches.

4 A magnetically responsive dry particulate material applicator comprising:

an applicating roller for placing a uniform layer of a said material in contact with a surface moved past the peripheral surface of said roller, comprising:

a stationary shaft of high magnetic permeability material,

magnetic means for producing a magnetic field about said peripheral surface of said roller having a feed zone with a generally radial field changing to a generally tangential field, an applicating zone following said feed zone with a generally radial field stronger than that of said feed zone and extending to both sides of the portion of said peripheral surface of said roller past which a said surface may be moved, and a return zone following said applicating zone and extending about said array to said feed zone, said return zone having a generally tangential field stronger than that of said feed zone immediately following said applicating zone, said magnetic means comprising a plurality of elongated generally sector-shaped in cross section strips of magnetic material formed of fine grain permanent magnetic material dispersed in a nonmagnetic 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 nonmagnetic hollow cylindrical sleeve fit over said arranged magnetic strips, extending axially of said shaft and supported for rotation about said magnetic strips to carry a quantity of said particulate material on the outer surface thereof,

means for supplying a said particulate material to said sleeve in said generally radial field of said feed zone, and

a doctor blade adjacent the periphery of said sleeve in said generally radial field of said feed zone for limiting the amount of said particulate material which may be carried from said supply means to said applicating zone.

5. An applicating roller as recited in claim **4** wherein said sleeve is electrically conductive.

6. An applicating roller as recited in claim **4** wherein each of said magnetic strips has an axial length of between 8 and 15 inches.

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