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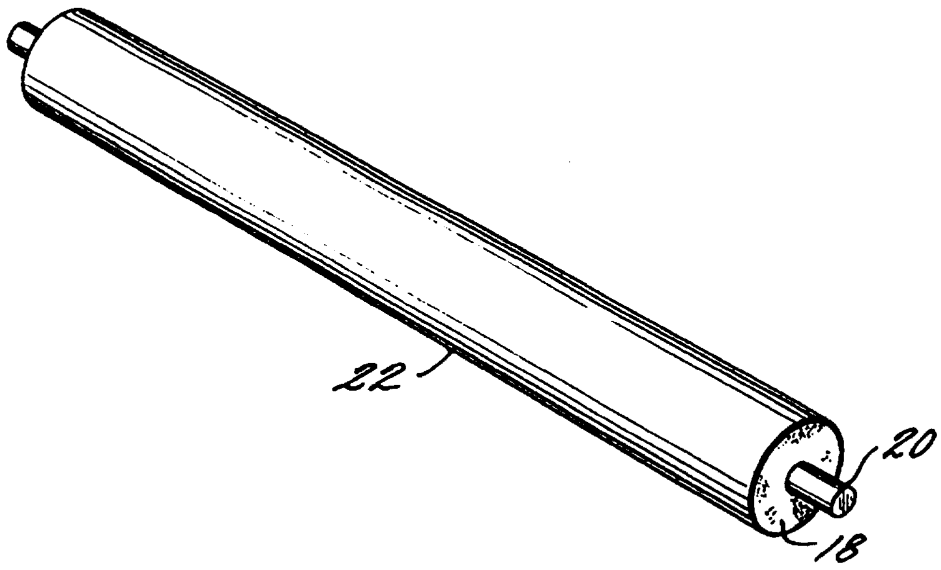

(57) Abstract

Extremely smooth surface on conductive foam cellular elastomeric rollers used in electrophotographic printing is provided, through the use of electrically conductive heat shrinkable tubing. The electrical conductivity of such rollers is insensitive to changes in temperature and humidity. The smooth surfaced rollers produced from the disclosed method increase the quality of the electrophotographic printing.

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CONDUCTIVE ROLLER WITH CONDUCTIVE HEAT SHRINK TUBING SURFACE

Background of the Invention:

1. Field of the Invention

This invention relates to electrically conductive elastomeric foam rollers. More particularly, this invention relates to a new method for making electrically conductive elastomeric foam rollers smoother, wherein the electrical properties of the rollers are less sensitive to temperature and humidity. Such conductive cellular elastomeric rollers are especially useful for electrophotographic printing, which requires very smooth surfaces to function properly. It is to be understood that this invention is generally well suited for any application utilizing electrically conductive elastomeric foam rollers that require smooth surfaces.

2. Brief Description of the Prior Art

In the conventional electrophotographic process, toner is metered from a toner cartridge onto a photoconductive (PC) drum on which a latent electrostatic image has been formed. The toner is then transferred to and fixed on paper or other substrate or print media. Each step of the electrophotographic process requires precise control of the amount of electrostatic charge present. The steps performed around the central PC drum are drum charging, exposing and developing, transfer of toner from the drum to the print medium (usually paper), and drum cleaning. Each of these steps, except exposing, can use electrically conductive elastomeric rollers, belts or other members. The electrical conductivity requirements depend on the function performed and the machine design. The conductivity range can require elastomeric materials with volume resistivities ranging from 1×10^3 to 1×10^{10} ohm-cm.

Several of these functions including charging, transferring, and cleaning can be improved through the use of conductive elastomeric foam members. Elastomeric foam provides higher compliance (lower durometer hardness, or lower compression force deflection) which provides a greater footprint against the PC drum with lower pressure and therefore lower abrasive wear compared to non-foamed (solid) elastomers. Additionally, high compliance, elastomeric foam rollers provide vibration isolation, which reduces operating noise in the electrophotographic printing device. Low modulus (high compliance) foam rolls also have utility as toner supply rolls, which are part of the PC drum developing system.

Charge rolls used in electrophotographic copiers and printers typically consist of multilayer constructions, where an electrically conductive elastomeric polymer layer is coaxially formed onto the circumference of a metal shaft, thereby forming a conductive roller. The function of this elastomeric layer is to transport the electrical charge from the printer or copier's power supply, through the roller shaft, to the outside of the charge roll. This electrically conductive resilient layer is conventionally formed of a mixture of synthetic rubber such as EPDM or silicone rubber, and electrically conductive powder, such as carbon black, metal powder, or the like. One suitable type of conductive elastomeric foam used in conventional electrophotographic process machines is disclosed in U.S. Application Serial No. 60/003,196 filed September 1, 1995 (which is assigned to the assignee hereof and incorporated herein by reference). While such foam is suitable and is exemplary for such rollers, it has the drawback of producing rollers with a surface that is not as smooth as is sometimes required to function optimally in the aforementioned electrophotographic process machines.

Depending on the type of rubber used, and on the amount of filler required to achieve the desired level of conductivity, the resilient layer of solid elestomeric charge rolls typically contains a softening agent, such as oil. The purpose of the softening agent is to impart an appropriate softness to the roller so that it may contact the PC drum with a uniform nip width along the length of the roll. The oil or other softening agent used has been found to “bleed” out of the rubber composition over time, thereby contaminating the surface of the PC drum. In order to prevent this from occurring, conventional charge rolls utilize a barrier layer disposed over the resilient layer. Typically, this barrier layer is formed of N-methoxy methylated nylon resin, usually with a conductive filler dispersed therein.

In another embodiment of the prior art, an intermediate layer is formed between the conductive resilient layer and the barrier layer. This layer is referred to by others as the “resistance adjusting” layer. It is typically a thin (50-200 μm) polymer layer of increased volume resistivity, which is applied to the outside of the resilient layer. The purpose of this layer is to adjust the roll resistance to the final desired value. When the resistance of the charge roll is too high, improper charging of the PC drum will occur, possibly resulting in high background or ghosting. When the resistance of the charge roll is too low, a defect such as a pinhole in the photoconductor drum surface will result in high current passing from the charge roll through that defect, robbing charge from the rest of the contacted area. The resulting lack of charge along the nip may result in a black line repeatedly printing on the page at the interval of once per photoconductor drum revolution.

One example of this type of roller is described in U.S. Patent No. 5,543,899 to Inami et al. This patent discloses a metal core with a conductive foamed layer coaxially disposed thereon. In one embodiment, an electroconductive layer comprising EPDM or polyurethane and an electrically conductive powder is coaxially disposed on the foamed conductive layer, and a resistance layer comprising epichlorohydrin rubber is coaxially disposed on the electroconductive layer. Another embodiment further comprises an N-methoxymethyl nylon protective layer coaxially disposed on the epichlorohydrin resistance layer.

However, when the resistance adjusting layer is formed of urethane or epichlorohydrin rubber, the rolls suffer from a marked change in volume resistivity with changes in ambient temperature and humidity. Therefore, although the resistance value of that layer can be chosen appropriately for roll operation at some nominal ambient condition (for example, 50% RH, 23 °C), any change in that ambient condition will result in a change in the resistance value of that layer, and hence of the roll. In order to accommodate changes in charge roll resistance, designers of photocopiers and laser printers have had to include more expensive power supplies that automatically adjust the applied voltage to the charge roll to maintain a proper charging level. In extreme cases, the change in charge roll resistance brought on by ambient humidity and temperature change can result in poor charging performance, and hence poor print quality despite the power supply's attempt to compensate.

There is, therefore, a perceived need to develop a method to economically produce a smooth conductive surface to achieve high quality printing that is not affected by changes in ambient temperature or humidity. This is particularly desirable because foam cellular elastomers have demonstrated distinct advantages when used for charge and developer rolls, such as providing a large footprint at low pressure against the PC drum or roll.

Summary of the Invention:

The above-discussed and other problems and deficiencies of the prior art are overcome or alleviated by the electrically conductive heat shrinkable tubing surface for conductive rollers of the present invention. In a particularly preferred embodiment of the invention, the electrical conductivity of the heat shrinkable tubing is insensitive to changes in temperature and humidity. In accordance with this invention, conductive heat shrink tubing is assembled over conductive foam cellular elastomer rolls. The resultant smooth surfaced rolls when used in electrophotographic printing provide the necessary smoothness for optimal functionality.

In a preferred embodiment, charge or developer rolls are produced in accordance with techniques known in the art. The outside diameter of the conductive cellular elastomer surface is then ground or otherwise finished by methods known in the art to provide a suitable surface to accept heat shrinkable tubing such as an electrically conductive polyolefin copolymer. The heat shrinkable tubing is slip fittingly placed over the aforementioned finished charge or developer roll. A suitable heat source is used to shrink the heat shrinkable tubing so that this tubing forms an integrally smooth surface on the outside diameter surface of the charge or developer roll, the surface being of high enough smoothness to produce high quality printing results. Optionally, an adhesive may be used to further adhere the heat shrinkable tubing to the foam of the roller.

The above-discussed and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description and drawings.

Brief Description of the Drawings:

Referring now to the drawings wherein like elements are numbered alike in the several FIGURES:

FIGURE 1 is a perspective view of a prior art charge or developer roller having a metal core and a conductive elastomeric foam suitable for use in conventional electrophotography;

FIGURE 2 is a perspective view of a smooth surfaced foam charge roller in accordance with the present invention;

FIGURE 3 is a side elevation view, partly in cross-section of a conductive heat shrinkable tube being fitted over a conductive foam roller in accordance with the present invention;

FIGURE 4 is a side elevation view of the roller of FIGURE 2;

FIGURE 5 is a cross-sectional elevation view along line 5-5 of FIGURE 4; and

FIGURE 6 is a cross-sectional elevation view of heat shrinkable tubing adhered to a foam roller with adhesive in accordance with the present invention.

Description of the Preferred Embodiment:

Referring first to FIGURE 1, a prior art conductive roller for use in electrophotographic equipment is shown generally at 16. An example of such an electrically conductive elastomeric foam roller for use in the aforementioned electrophotographic equipment is disclosed in aforementioned U.S. Application Serial No. 60/003,196. Conductive roller 16 includes a cylindrical layer of the conductive elastomeric (preferably polyurethane) foam 18 which is molded, extruded or otherwise positioned onto shaft 20. Although roller 16 performs adequately in electrophotographic equipment, there is a perceived need for a roller stable to changes in temperature and humidity, with a smoother surface on the outside of foam 18 to achieve higher quality electrophotographic printing.

The aforementioned problem of stability and smoothness is easily and economically resolved by referring now to FIGURES 2-6 wherein a conductive roller further comprises an electrically conductive heat shrink tubing surface in accordance with the present invention. Conductive heat shrink tubing 22 is sized to fit slip over surface 24 of elastomeric foam 18. Preferably, the outer surface 24 on the outside diameter of elastomeric foam 18 is suitably finished by grinding or other known finishing methods to provide a suitable surface to accept conductive heat shrinkable tubing 22, such that after the heat shrinkable tubing 22 has been shrunk, the resulting outside diameter surface is extremely smooth. Preferably, the finish is 5 μm Rz or better.

Electrically conductive adhesive 26 may optionally be used to further hold the heat shrinkable tubing in place. The adhesive 26 may be applied to the roller surface 24 in a separate step, before the heat shrinkable tubing 22 is slipped onto the roller. In another embodiment, the heat shrink tubing may be provided with a co-extruded inner layer of electrically conductive hot melt adhesive, which may be used to further adhere the tubing to the roller.

After the conductive heat shrinkable tubing 22 is in place over the prepared surface 24 of the elastomeric foam roll, a suitable heat source (not shown) is applied, such as by heat gun, or by placing the roller/shaft assembly and conductive heat shrinkable tubing 22 in a suitable oven (preferably for one minute at 300°F).

Following this shrinking operation, the inner diameter of the conductive heat shrinkable tubing 22 comes into intimate and cohesive contact with the outer surface 24 of the foam 18. This results in an extremely smooth and physically integrated roller assembly 32. The final step in the process is to trim away any excess heat shrinkable tubing 22 that overhangs the edges 28, 30 (see FIGURE 4) of the conductive elastomeric foam 18. The method may also be adapted to the construction of components for electrophotographic devices, such as pads, rollers, or belts.

The above-described method is advantageous in that is simple and economical. Only one layer is required, in contrast to the multiple layers of the prior art. Assembly is simplified by the ability to manufacture the foam layer first, then apply the heat shrinkable tubing second. (Prior art methods, for example U.S. Patent No. 5,543,899 to Inami et al., teach forming the foam inside the multiple outer layers.) The charge rolls or other components may further be constructed to exacting measurements by grinding or other means prior to application of the heat shrinkable tubing.

The electrically conductive heat shrinkable tubing 22 preferably has a volume resistivity in the range from 1×10^{2} to 1×10^{10} ohm-cm, and most preferably in the range from 1×10^{6} to 1×10^{7} ohm-cm. Suitable conductive heat shrinkable tubing 22 was obtained from Raychem of Menlo Park, California and is an electrically conductive polyolefin copolymer.

Without being bound by theory, polyolefin heat shrinkable tubing is hypothesized to be particularly suitable for bias charge rollers because it is impervious to moisture. Moisture resistance leads to stable volume resitivities over a range of temperatures and humidities. Accordingly, other materials may be suitable for use with the present invention, providing they are heat shrinkable, electrically conductive, and moisture-resistant.

The electrically conductive foam 18 preferably has a volume resistivity in the range from 1×10^{1} to 1×10^{7} ohm-cm. Suitable materials for foams include, but are not limited to, polyvinyl chloride polymers, polyurethanes, butadiene rubber polymers, ethylene propylene rubber, ethylene propylene diene monomer polymers, and acrylic polymers. The foam 18 of the present invention may be the conductive fiber filled foam of aforementioned USSN 60/003,196, or expanded rubber filled with conductive particulate fillers. Examples of conductive particulate fillers include graphite, nickel, aluminum, stainless steel and metal coated glass. Alternatively, foam 18 may also contain an ionic additive in addition to, or in place of, the electrically conductive fibers, allowing improved stability of volume resistivity with respect to voltage, temperature and humidity over ionic additives used alone. Such ionic additives include, but are not limited to quaternary ammonium salts present in the range of 0.5 to 10 parts of the total formulation. Alternatively, the foam of the present invention may also contain particulate fillers.

The invention is further illustrated by the following non-limiting example.

Example

Construction

A charge roll was constructed by known methods by first molding a urethane foam and sufficient electrically conductive filler such as carbon black, carbon fibers, and/or metal flakes so as to achieve a volume resistivity of 1×10^4 ohm-cm. The molded foam was assembled onto a highly conductive steel shaft using electrically conductive adhesive. The shaft may comprise a number of metals, wherein nickel-plated cold-drawn steel or stainless steel is preferred. The shaft has a diameter of 6 mm and a length of 250 mm (A4 size). The outer surface of the foam was then ground to approximately 12 mm. Electrically conductive adhesive was then applied to the surface of the foam, and the heat shrinkable conductive polyolefin sleeve was assembled over the foam surface. The assembled roll was then placed in an oven for 1 minute at 300 ^oF, until the sleeve shrunk snugly and conformed to the surface of the foam. After heat shrinking, the ends of the sleeve/foam were trimmed approximately 10 mm back from the ends of each shaft.

Testing

The above roll was placed in an Apple LASERWRITER 360 laser printer. Several test patterns were printed, including fine converging lines, half tones, and all-black and all-white pages. No defects were observed in any test patterns. The roller was left in the printer and approximately 20,000 pages (using a total of four toner cartridges) were printed with no deterioration in print quality. The printer was placed in a chamber maintained at 10 °C, 15% RH, and several hundred pages were printed with no deterioration in print quality. The printer was also placed in a chamber maintained at 30 °C, 85% RH and several hundred pages were printed with no deterioration in print quality.

The above roll was placed in contact with a PC drum from an Apple LASERWRITER 360, and aged for one month at 30 °C, 85% RH. No evidence of contamination of the drum surface was seen.

In order to determine the presence or absence of charge leakage across the surface of the charge roll, the above roll was placed in an Apple LASERWRITER 360 printer in which the PC drum was damaged with 1 mm, 2 mm, 3 mm, and 4 mm pinhole defects in the drum coating. Printed pages did not suffer from a black line being printed across the page coincident with those defects. The results of this test therefore indicate that charge leakage does not occur with the rollers of the present invention.

The volume resitivities of the roller in accordance with the above procedure were tested by placing the roll on a flat aluminum plate and applying a 1-Kg normal force. The positive lead of an HP High Resistance Meter 4239A was attached to the metal shaft of the charge roll, and the negative lead was attached to the aluminum plate. One hundred VDC was applied to the charge roll, measuring the resistance after 5 seconds. The test was conducted at 10 °C, 15% RH, 23 °C, 50% RH, and 30 °C, 85 % RH, and no change in resistivity was seen under these conditions. A value of 8×10^5 ohms nip resistance was measured in each case.

The volume resistivity of the charge roll constructed in accordance with the present invention was further compared to the volume resistivity of a foam charge roll obtained from an "HP5Si" laser printer cartridge. Based on analysis, the "HP5Si" foam roll is believed to comprise a steel shaft (8 mm diameter, 340 mm length, A3 size) and a conductive silicone foam coaxially disposed on the steel shaft. The foam roll is believed to further comprise a silicone-containing resistive layer approximately 330 μm thick coaxially disposed onto the foam, and an additional nylon-containing outer protective layer coaxially disposed onto the resistive layer. The test was conducted using the same procedures described above, with the exception that a lower test voltage was required because the "HP5Si" charge roll was more conductive, and the HP High Resistance meter has current limiting features that prevent testing the "HP5Si" charge roll at 100 VDC. The test was therefor conducted at 20 VDC, with the following results measured as nip resistance:

At 10 °C, 15% RH: 3.7 x 107 ohms (Log = 7.6)

At 23 °C, 50 % RH: 2.2 x 10^6 ohms (Log = 6.3)

At 30 °C, 85% RH: 2.1 x 10^5 ohms (Log = 5.3)

As is clear from the above results, variations in temperature and humidity lead to variations in volume resistivity (a log ohms difference of 2.3, i.e., a 2.3 orders of magnitude change) for the "HP5Si" roll, while the roll in accordance with the present invention has no variation in volume resistivity with variation in temperature and humidity.

This stability in the electrical resistance represent a significant advantage of the present invention over prior art rolls. As is further demonstrated by the above tests, the rolls print defect-free sheets for protracted periods, and are impervious to pinholes in the PC drum. The manufacture of the rolls is economical and simple.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

What is claimed is:

CLAIM 1. An electrically conductive charge roller for electrophotographic applications, comprising:

a shaft;

a layer of electrically conductive elastomeric foam, said layer of elastomeric foam covering at least a portion of said shaft; and

electrically conductive, heat shrinkable tubing disposed on said foam to define a smooth outer surface.

CLAIM 2. The roller of claim 1 wherein said electrically conductive elastomeric foam comprises:

an elastomeric foam; and

electrically conductive fibers dispersed within said foam, said fibers being in an amount effective to render said elastomeric foam electrically conductive.

CLAIM 3. The roller of claim 1 wherein said elastomeric foam is selected from a group comprising:

polyvinyl chloride polymers, polyurethanes, butadiene rubber polymers, ethylene propylene rubber, ethylene propylene diene monomer polymers, and acrylic polymers.

CLAIM 4. The roller of claim 1 wherein:

said elastomeric foam comprises polyurethane foam.

CLAIM 5. The roller of claim 4 wherein:

said foam is synthesized from a foamable polyurethane mixture comprising at least one polyhydroxyl compound, at least one organic polyisocyanate compound, a catalyst, and a foam stabilizing surfactant.

CLAIM 6. The roller of claim 2 wherein:

said effective amount of conductive fibers is in the range of about 5 to about 30 weight percent with respect to the total composition.

CLAIM 7. The roller of claim 1, wherein:

the electrical conductivity of said heat shrinkable tubing is insensitive to changes in humidity.

CLAIM 8. The roller of claim 1, further comprising:

a layer of adhesive coaxially disposed between said foam and said heat shrinkable tubing.

CLAIM 9. The roller of claim 1, wherein:

said heat shrinkable tubing further comprises a hot melt co-extruded adhesive disposed on an inner surface of the heat shrinkable tubing.

CLAIM 10. The roller of claim 1, wherein:

said heat shrinkable tubing comprises polyolefin copolymers.

CLAIM 11. An electrically conductive component for electrophotographic devices comprising:

electrically conductive elastomeric foam; and

electrically conductive heat shrinkable tubing positioned over said foam to define a smooth outer surface.

CLAIM 12. The component of claim 11 wherein:

said elastomeric foam is configured as a pad, roller or belt.

CLAIM 13. The component of claim 11, wherein

the electrical conductivity of said heat shrinkable tubing is insensitive to humidity.

CLAIM 14. The component of claim 11, wherein:

said heat shrinkable tubing comprises polyolefin copolymers.

CLAIM 15. The component of claim 11, further comprising:

a layer of adhesive disposed between said foam and said heat shrinkable tubing.

CLAIM 16. The component of claim 11, wherein:

said heat shrinkable tubing further comprises a hot melt co-extruded adhesive disposed on an inner surface of the heat shrinkable tubing.

CLAIM 17. A method of making a conductive roller for electrophotographic applications, comprising:

forming an elastomeric foam roller;

placing electrically conductive, heat shrinkable tubing over the foam roller; and

heating the heat shrinkable tubing to shrink the tubing and form a smooth outer surface on the roller.

CLAIM 18. The method of claim 17, wherein

the electrical conductivity of said heat shrinkable tubing is insensitive to humidity.

CLAIM 19. The method of claim 17, wherein:

said heat shrinkable tubing comprises polyolefin copolymers.

CLAIM 20. The method of claim 17, further comprising:

placing an adhesive on the foam of said elastomeric foam roller before placing said heat shrinkable tubing on said roller.

CLAIM 21. The method of claim 17, wherein:

said heat shrinkable tubing further comprises a hot melt co-extruded adhesive on at least one surface.

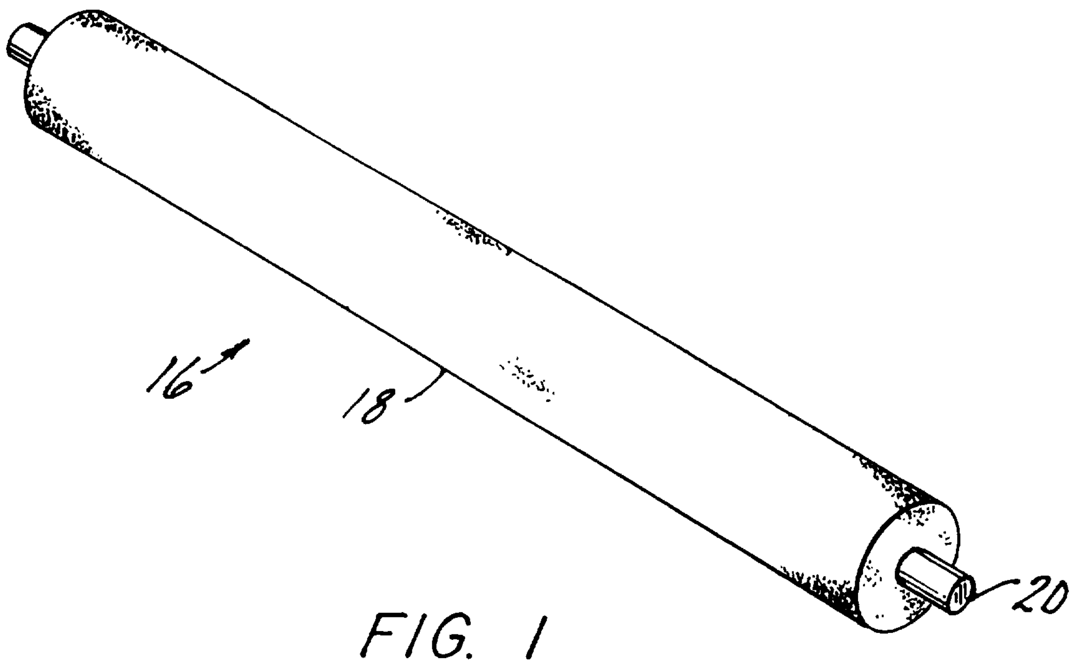

FIG. 1
(PRIOR ART)

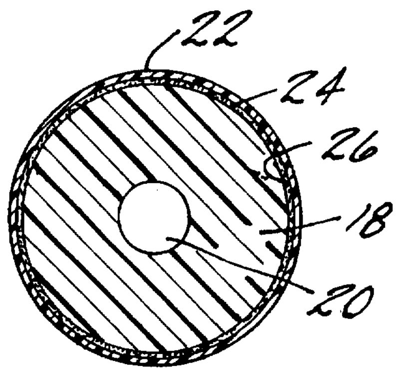

FIG. 6

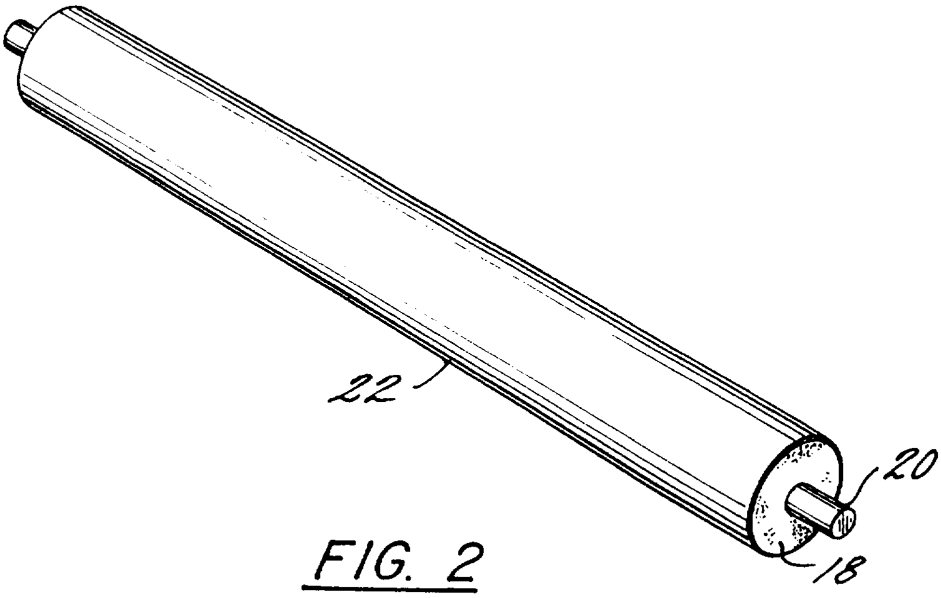

FIG. 2

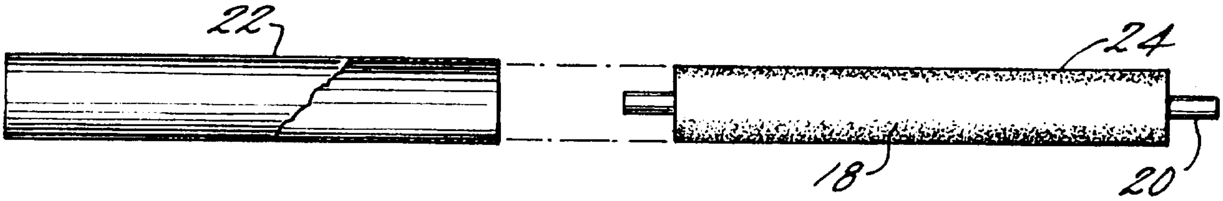

FIG. 3

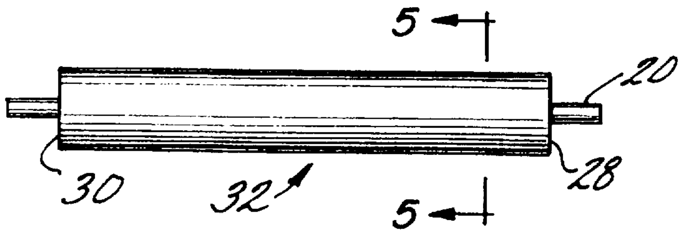

FIG. 4

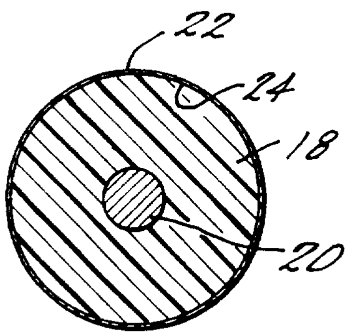

FIG. 5

INTERNATIONAL SEARCH REPORT

Inter   onal Application No
PC1/US 96/18958

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G03G15/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y		2,5-9, 13,15, 16,18, 20,21

Y	EP 0 565 237 A (BRIDGESTONE CORP) 13 October 1993 see column 3, line 11 - column 4, line 12 ---	2,5,6
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 March 1997	02.04.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Trepp, E

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

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