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(54) **A development system using magnetic, insulating toner particles.**

(57) An apparatus which develops the latent image recorded on a flexible member (10) with an insulating developer material comprising at least carrier granules and insulating magnetic, toner particles. The developer material is transported closely adjacent to a flexible member having the latent image recorded thereon by means of a developer roller (40). In the development zone (74), the latent image attracts a portion of the toner particles thereto forming a powder image on the flexible member. The flexible member is maintained at a preselected tension and held partially wrapped around the developer roller (40) by means of idler rollers (42) so that the developer material being transported into contact therewith deflects the flexible member thereabout forming an extended development zone.

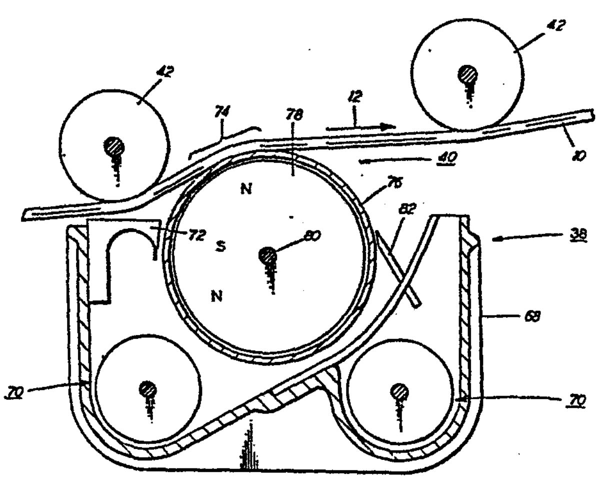


FIG. 3

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# A DEVELOPMENT SYSTEM USING MAGNETIC, INSULATING TONER PARTICLES

This invention relates to a development system for developing a latent image recorded on a flexible member. The system is of the kind comprising a developer material and a development apparatus for applying the developer material to the latent image, the developer material comprising carrier grannules and toner particles, and the apparatus including

means, positioned closely adjacent the flexible member to define a development zone therebetween, for transporting the developer material into contact with the flexible member in the development zone so that the latent image attracts a portion of the toner particles thereto forming a powder image on the flexible member; and

means for maintaining the flexible member at a preselected tension of sufficient magnitude so that the developer material being transported into contact therewith deflects the flexible member about said transporting means to form an extended development zone. In general, electrophotographic printing requires a photoconductive member which is charged to a substantially uniform potential to sensitize the surface thereof. A charged portion of the photoconductive surface is exposed to a light image of an original document being reproduced. This records an electrostatic latent image on the photoconductive surface which corresponds to the informational areas contained within the original document. After the electrostatic latent image is recorded on the photoconductive surface, it is developed by bringing a developer material into contact therewith. This forms a powder image on the photoconductive surface which is subsequently transferred to a copy sheet. Finally, the copy sheet is heated to permanently affix the powder image thereto in image configuration.

Frequently, the developer material is made from a mixture of carrier granules and toner particles. The toner particles adhere triboelectrically to the carrier granules. This two-component mixture is brought into contact with the latent image. Toner particles are attracted from the carrier granules to the latent image forming a powder image thereof. Most electrophotographic printing machines employ a magnetic brush development system for developing the latent image. The magnetic brush development system may use one or more developer rollers for transporting the developer material closely adjacent to the photoconductive surface. Magnetic brush development systems employ either a conductive developer material or an insulating developer material. The conductive magnetic brush development system and the insulating magnetic brush development system suffer from limitations in their abilities to meet the full range of copy quality requirements. Specifically, insulating magnetic brush development systems have difficulty in developing large solid areas. In order to optimize solid area development with an insulating developer material, the spacing between the developer roller and photoconductive surface must be made quite small. Although the solid area development is improved in this manner, other problems arise. For example, there is an increase in the severity of the cleaning field-related edge deletions typical of insulating magnetic brush development. Furthermore, there is also an increase in the sensitivity of the magnetic brush development system to the electrical bias. In addition, there may also be a decrease in the quality of fine line development. Hereinbefore, several developer rollers were required to overcome these problems. However, the utilization of additional developer rollers increases the cost of the development system. Conductive magnetic brush development systems inherently fail to reproduce low density lines when the electrical bias on the developer roll is increased in order to suppress the development of background areas. Conductive developer materials are not sensitive to fringe fields. In order to achieve low density fine line development with conductive developer materials, the cleaning fields must be relatively low. This produces relatively high background. Thus, in both of the foregoing systems there continues to exist the problem of achieving uniform development for both fine and low density lines and large solid areas in electrostatic latent images. With the increased use of flexible photoconductive belts and magnetic brush developer rollers, it has become more feasible to control the spacing therebetween. When the photoconductive belt is maintained at the proper tensioning, it has now become practical to permit the developer material to space the photoconductive belt from the developer roller. In this way, insulating developer materials may be used and still provide relatively satisfactory solid area development. However, this still does not solve the other problems associated with a system of this type.

Various approaches have been devised to improve development.

In U.S. patent No. 4013041 there is disclosed an electrophotographic printing machine having a magnetic brush developer roller contacting one side of a flexible photoconductive belt. In Figure 3, this patent shows guide rollers maintaining a portion of the belt in a slackened condition so that the belt is capable of moving freely toward and away from the developer roller in response to the varying contours thereof.

In Research Disclosure Journal, July 1979, Page 352, No. 18318 there is described an electrophotographic printing machine having a gimballed back-up roller engaging the backside of a photoconductive belt. The guide rollers opposed from the developer roller compensate for relative changes in the thickness of the developer material on the developer roller, as well as maintaining constant pressure in the nip between the developer and photoconductive belt.

In our European Patent application No. 81300054.4 (Publication No. 0032424) there is described an electrophotographic printing machine in which developer material on a developer roller deflects a tensioned photoconductive belt so as to space the developer roller from the belt, and wrap the belt about a portion of the developer roller. Similar printing machines are described in our copending European Patent Application No. , which claims priority from US patent application Serial No. 499578, filed 31 May 1983, as well as in our European Patent Application No. 81302440.3 (Publication No. 0041399).

The present invention is intended to overcome the disadvantages of the prior art, and provides a development system of the kind specified which is characterised in that the toner particles are insulating, magnetic particles.

Pursuant to another aspect of the present invention, there is provided an electrophotographic printing machine of the type having an electrostatic latent image recorded on a flexible photoconductive member and including the above defined development system.

Other aspects of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

Figure 1 is a schematic elevational view depicting an electrophotographic printing machine incorporating the features of the present invention therein;

Figure 2 is a fragmentary, perspective view showing the belt tensioning arrangement for the Figure 1 printing machine; and

Figure 3 is an elevational view illustrating the development system used in the Figure 1 printing machine.

For a general understanding of the illustrative electrophotographic printing machine incorporating the features of the present invention therein, reference is made to the drawings. In the drawings, like reference numerals have been used throughout to designate identical elements. Figure 1 schematically depicts the various components of an electrophotographic printing machine employing the development system of the present invention therein. Although this development system is particularly well adapted for use in the illustrative electrophotographic printing machine, it will become evident from the following discussion that it is equally well suited for use in a wide variety of electrostatographic printing machines and is not necessarily limited in its application to the particular embodiment shown herein.

Inasmuch as the art of electrophotographic printing is well known, the various processing stations employed in the Figure 1 printing machine will be shown hereinafter schematically, and their operation described briefly with reference thereto.

As shown in Figure 1, the electrophotographic printing machine employs a belt 10 having a photoconductive surface deposited on a conductive substrate. Preferably, the photoconductive surface is made from a selenium alloy. The conductive substrate is made preferably from aluminum which is electrically grounded. Belt 10 moves in the direction of arrow 12 to advance successive portions of the photoconductive surface sequentially through the various processing stations disposed about the path of movement thereof. The path of movement of belt 10 is defined by stripping roller 14, tensioning system 16, and drive roller 18. As shown in

Figure 1, tensioning system 16 includes a roller 20 over which belt 10 moves. Roller 20 is mounted rotatably in yoke 22. Spring 24, which is initially compressed, resiliently urges yoke 22 in a direction such that roller 20 presses against belt 10. The level of tension is relatively low permitting belt 10 to be easily deflected. The detailed structure of the tensioning system will be described hereinafter with reference to Figure 2. With continued reference to Figure 1, drive roller 18 is mounted rotatably and in engagement with belt 10. Motor 26 rotates roller 18 to advance belt 10 in the direction of arrow 12. Roller 18 is coupled to motor 26 by suitable means such as a belt drive. Stripping roller 14 is freely rotatable so as to permit belt 10 to move in the direction of arrow 12 with a minimum of friction.

Initially, a portion of belt 10 passes through charging station A. At charging station A, a corona generating device, indicated generally by the reference numeral 28, charges the photoconductive surface of belt 10 to a relatively high, substantially uniform potential.

Next, the charged portion of the photoconductive surface is advanced through exposure station B. At exposure station B, an original document 30 is positioned facedown upon transparent platen 32. Lamps 34 flash light rays onto original document 30. The light rays reflected from original document 30 are transmitted through lens 36 forming a light image thereof. Lens 36 focuses the light image onto the charged portion of the photoconductive surface to selectively dissipate the charge thereon. This records an electrostatic latent image on the photoconductive surface which corresponds to the informational areas contained within original document 30. Although an optical system has been described hereinbefore for forming a light image of the information contained on an original document, one skilled in the art will appreciate that a modulated beam of energy, e.g. a laser beam, may be employed to irradiate the charged portion of the photoconductive surface to form an electrostatic latent image thereon. Modulation of the laser beam is achieved by processing signals corresponding to information desired to be reproduced and, in turn, controlling the laser beam modulation in accordance therewith.

After the electrostatic latent image has been recorded on the photoconductive surface of belt 10, the latent image advances to development station C. At development station C, a magnetic brush development system, indicated generally by the reference numeral 38, advances an insulating developer material into contact with the electrostatic latent image. Preferably, magnetic brush development system 38 includes a developer roller 40. Developer roller 40 transports a brush of developer material comprising magnetic carrier granules and insulating, magnetic toner particles into contact with belt 10. As shown in Figure 1, developer roller 40 is positioned such that the brush of developer material deflects belt 10 between idler rollers 42 in an arc with belt 10 conforming, at least partially, to the configuration of the developer material and wrapping around developer roller 40 to form an extended development zone. The electrostatic latent image attracts the insulating, magnetic toner particles from the carrier granules forming a toner powder image on the photoconductive surface of belt 10. The detailed structure of the magnetic brush development system 38 will be described hereinafter with reference to Figure 3.

After development, belt 10 advances the toner powder image to transfer station D. At transfer station D, a sheet of support material 44 is moved into contact with the toner powder image. Sheet of support material 44 is advanced to transfer station D by a sheet feeding apparatus (not shown). By way of example, the sheet feeding apparatus may include a feed roll contacting the uppermost sheet of a stack of sheets. The feed roll rotates so as to advance the uppermost sheet from the stack into a chute. The chute directs the advancing sheet of support material into contact with the photoconductive surface of belt 10 in a timed sequence so that the toner powder image developed thereon contacts the advancing sheet of support material at transfer station D.

Transfer station D includes a corona generating device 46 which sprays ions onto the back side of sheet 44. This attracts the toner powder image from the photoconductive surface to sheet 44. After transfer, sheet 44 moves in the direction of arrow 48 onto a conveyor (not shown) which advances sheet 44 to fusing station E.

Fusing station E includes a fuser assembly, indicated generally by the reference numeral 50, which permanently affixes the toner powder image to sheet 44. Preferably, fuser assembly 50 includes a heated fuser roller 52 and a back-up roller 54. Sheet 44 passes between fuser roller 52 and back-up roller 54 with the toner powder image contacting fuser roller 52. In this manner, the toner powder image is permanently affixed to sheet 44. After fusing, a chute guides the advancing sheet 44 to a catch tray for subsequent removal from the printing machine by the operator.

Invariably, after the sheet of support material is separated from the photoconductive surface of belt 10, some residual particles remain adhering thereto. These residual particles are removed from the photoconductive surface at cleaning station F. Cleaning station F includes a rotatably mounted fibrous brush 56 in contact with the photoconductive surface. The particles are cleaned from the photoconductive surface by the rotation of brush 56. Subsequent to cleaning, a discharge lamp (not shown) floods the photoconductive surface with light to dissipate any residual electrostatic charge remaining thereon prior to the charging thereof for the next successive imaging cycle.

It is believed that the foregoing description is sufficient for purposes of the present application to illustrate the general operation of an electrophotographic printing machine incorporating the features of the present invention therein.

Referring now to the specific subject matter of the present invention, Figure 2 depicts tensioning system 16 in greater detail. As shown thereat, tensioning system 16 includes roller 20 having belt 10 passing thereover. Roller 20 is mounted in suitable bearings in a yoke, indicated generally by the reference numeral 22. Preferably, yoke 22 includes a U-shaped member 58 supporting roller 20 and a rod 60 secured to the mid-point of cross member 62 of U-shaped member 58. Coil spring 24 is wrapped around rod 60. Rod 60 is mounted slidably in the printing machine frame 66. Spring 24 is compressed between cross member 62 and frame 66. Compressed spring 24 resiliently urges yoke 22 and, in turn, roller 20 against belt 10. Spring 24 is designed to have the appropriate spring constant such that when placed under the desired compression, belt 10 is tensioned from about 0.1 to about 0.15 killograms per linear centimeter. Belt 10 is maintained under a sufficiently low tension to enable the developer material on developer roll 40 to deflect belt 10 through an extended development zone corresponding to an arc ranging from about $10^\circ$ to about $40^\circ$.

Turning now to Figure 3, the detailed structure of development system 38 will be described. Development system 38 includes a housing 68 defining a chamber for storing a supply of insulating developer material therein. The insulating developer material includes carrier granules and insulating, magnetic toner particles. The carrier granules have the magnetic toner particles adhering thereto triboelectrically. In this way, during the developing process, the insulating, magnetic toner particles are attracted from the carrier granules to the latent image forming a toner powder image thereon. A pair of augers 70 mix the developer material in the chamber of housing 68 and advance the developer material to developer roller 40. Developer roller 40 advances the insulating developer material into contact with the electrostatic latent image recorded on the photoconductive surface of belt 10. A trim bar 72 regulates the thickness of the developer pile height on developer roller 40. The tangential velocity of developer roller 40 is in the same direction and at about two to three times the magnitude of the velocity of belt 10. The compressed pile height of the developer material ranges from about 0.05 centimeters to about 0.10 centimeters. Trim bar 72 extends in a longitudinal direction substantially across the width of developer roller 40 so as to provide a uniform gap controlling the quantity of insulating developer material being moved into development zone 74. Developer roller 40 includes a non-magnetic tubular member 76 preferably made from aluminum having the exterior circumferential surface thereof roughened. Elongated magnet 78 is positioned concentrically within tubular member 76 and mounted on shaft 80. Magnet 78 has magnetic poles impressed about the circumferential surface thereof. Developer material being transported into development zone 74 becomes highly agitated due to the shearing action between the brush of developer material and the photoconductive surface facilitating development of the latent image. Blade 82 assists in scraping the used developer material from tubular member 76.

Preferably, tubular member 76 is electrically biased by a voltage source (not shown) to a suitable polarity and magnitude. The voltage level is intermediate that of the background voltage and the image voltage level recorded on the photoconductive surface of belt 10. By way of example, the voltage source electrically biases tubular member 76 to a voltage ranging from about 0 volts to about 100 volts relative to the background voltage on the photoconductive surface. As tubular member 76 rotates at a constant angular velocity, a brush of developer material is formed on the peripheral surface thereof. The brush of developer material advances into contact with belt 10 in development zone 74. As previous indicated, the brush of developer material in development zone 74 deflects belt 10 to wrap about developer roller 40 to form an extended development zone. Magnetic member 78 is mounted stationarily to attract the insulating developer material to tubular member 76 due to the magnetic properties of both the carrier granules and the toner particles adhering triboelectrically thereto. In development zone 74, the magnetic, insulating toner particles are attracted from the carrier granules to the latent image to form a toner powder image on the photoconductive surface of belt 10.

By way of example, the insulating developer material has a resistivity ranging from about $10^{12}$ to about $10^{17}$ ohm-cm. The developer material comprises carrier granules having insulating, magnetic toner particles adhering triboelectrically thereto. The toner particles may be made from a magnetic material such as a ferromagnetic metal embedded in an insulating material such as a polyamide resin. As used herein, the term "polyamide resin" refers to the polymerization product resulting from the interaction of a poly fatty acid or the ester of a poly fatty acid with amonia and an amine selected from the group consisting primarily of amines, secondary amines and alkylated amines. In general, any polyamide resin may be employed providing the melting point of the resin is within the range of about 70°C to about 165°C. Below 70°C, there is a danger of the resin being melted at the normal operating temperature of the printing machine, while temperatures above 165°C cause charring of the copy sheet and may have deleterious effects on the printing machine. Examples of suitable polyamides are the Versamid 930, 940 and 950 resins of General Mills, Inc., and the polyamide 1155, 1144 and 1074 resins of Lawter Chemical Company. Other materials such as polystyrenes, polyesters or ethylene/vinylacetate copolymers may be utilized as well. Any suitable ferromagnetic metal may be employed. For example, particles of iron, magnetic iron oxide, magnetite, nickel alloys, cobalt, cobalt alloys or chromium dioxide may also be used. The major dimensions of the toner particles may range from about 1 micron to about 300 microns with the preferred range being from about 5 microns to about 30 microns.

The use of insulating, magnetic toner particles increases the adhesion between the carrier granules and toner particles, reduces the required electrical bias on the developer roll, and permits increased spacing between the developer roll and photoconductive surface. This results in improved copy quality and less dirt in the printing machine.

In recapitulation, it is clear that the development apparatus of the present invention includes a developer roller transporting a developer material comprising carrier granules and insulating, magnetic toner particles into contact with the electrostatic latent image recorded on the photoconductive surface. The belt is maintained at a preselected tension of sufficient magnitude to enable the insulating developer material to deflect the belt in the development zone. In this way, an extended development zone is formed having high agitation therein and the improved development of solid areas by the insulating magnetic toner particles.

It is, therefore, evident that there has been provided in accordance with the present invention an apparatus for developing an electrostatic latent image that significantly improves line and solid area development.

Claims:

1. A development system for developing a latent image recorded on a flexible member (10), comprising a developer material and a development apparatus for applying the developer material to the latent image, the developer material comprising carrier granules and toner particles, and the apparatus including

means (40), positioned closely adjacent the flexible member to define a development zone (74) therebetween, for transporting the developer material into contact with the flexible member in the development zone so that the latent image attracts a portion of the toner particles thereto forming a powder image on the flexible member; and

means (16, 42) for maintaining the flexible member at a preselected tension of sufficient magnitude so that the developer material being transported into contact therewith deflects the flexible member about said transporting means (40) to form an extended development zone, characterised in that the toner particles are insulating, magnetic particles.

2. A system according to claim 1, wherein the flexible member (10) is a belt.

3. A system according to claim 2, wherein said transporting means (40) includes:

a tubular member (76) journaled for rotary movement; and

means (78) for attracting the developer material to said tubular member.

4. A system according to claim 3, wherein said attracting means includes (78) a magnet disposed interiorly of and spaced from said tubular member.

5. A system according to claim 4, wherein said tubular member (76) is made from a non-magnetic material.

6. An electrophotographic printing machine of the type having an electrostatic latent image recorded on a flexible photoconductive member, including the development system of any one of claims 1 to 5.

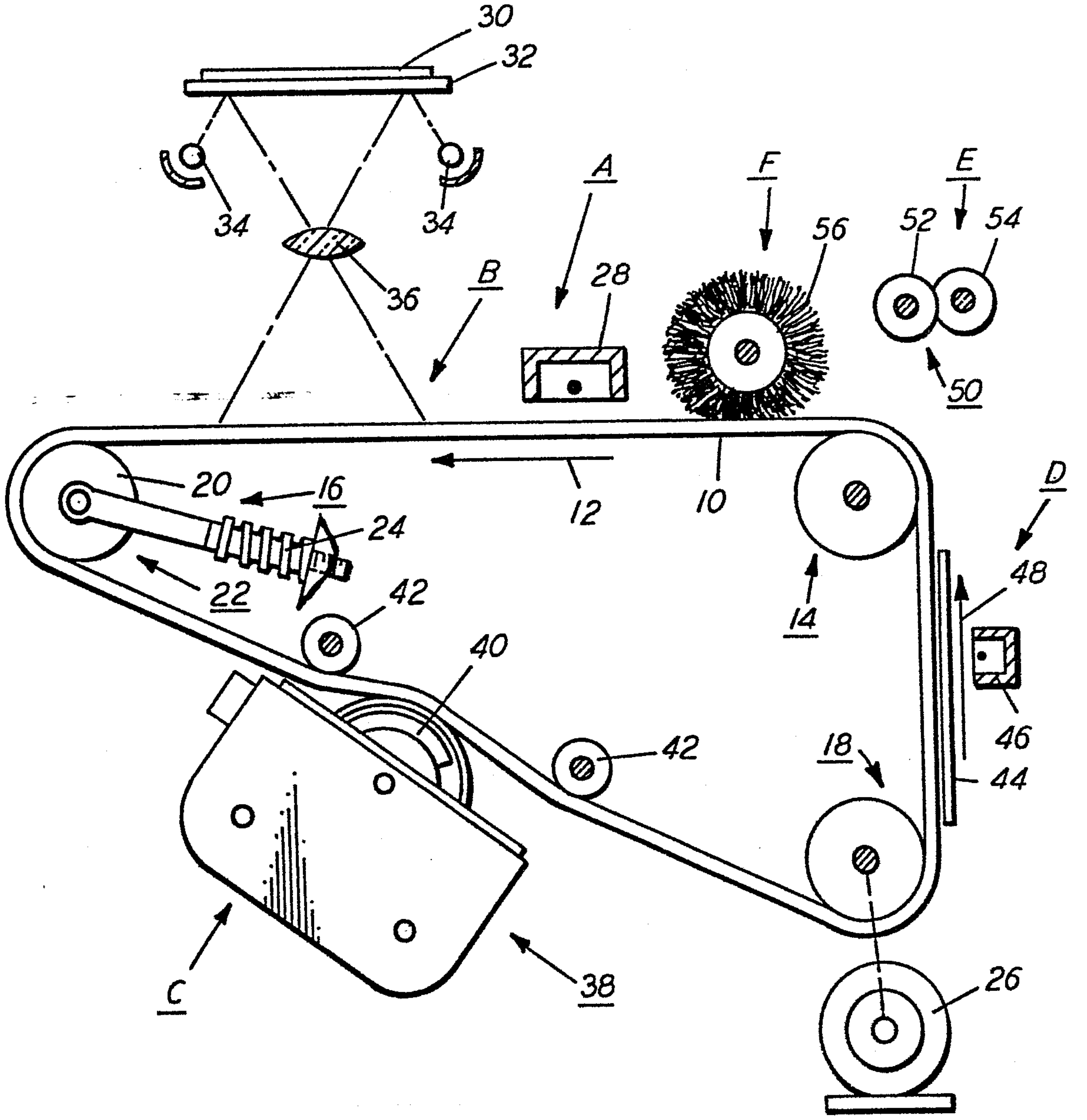
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FIG. 1

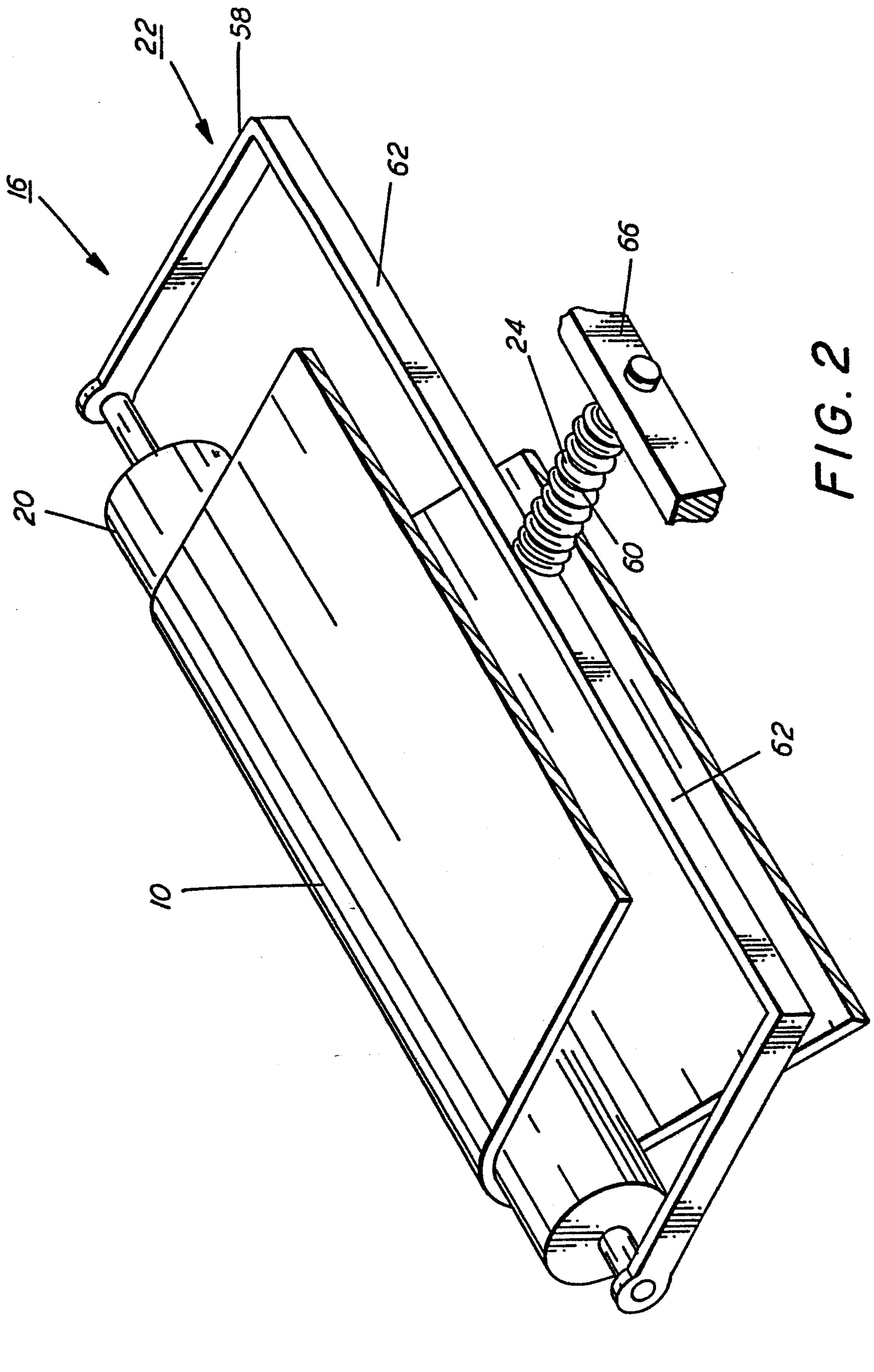


FIG. 2

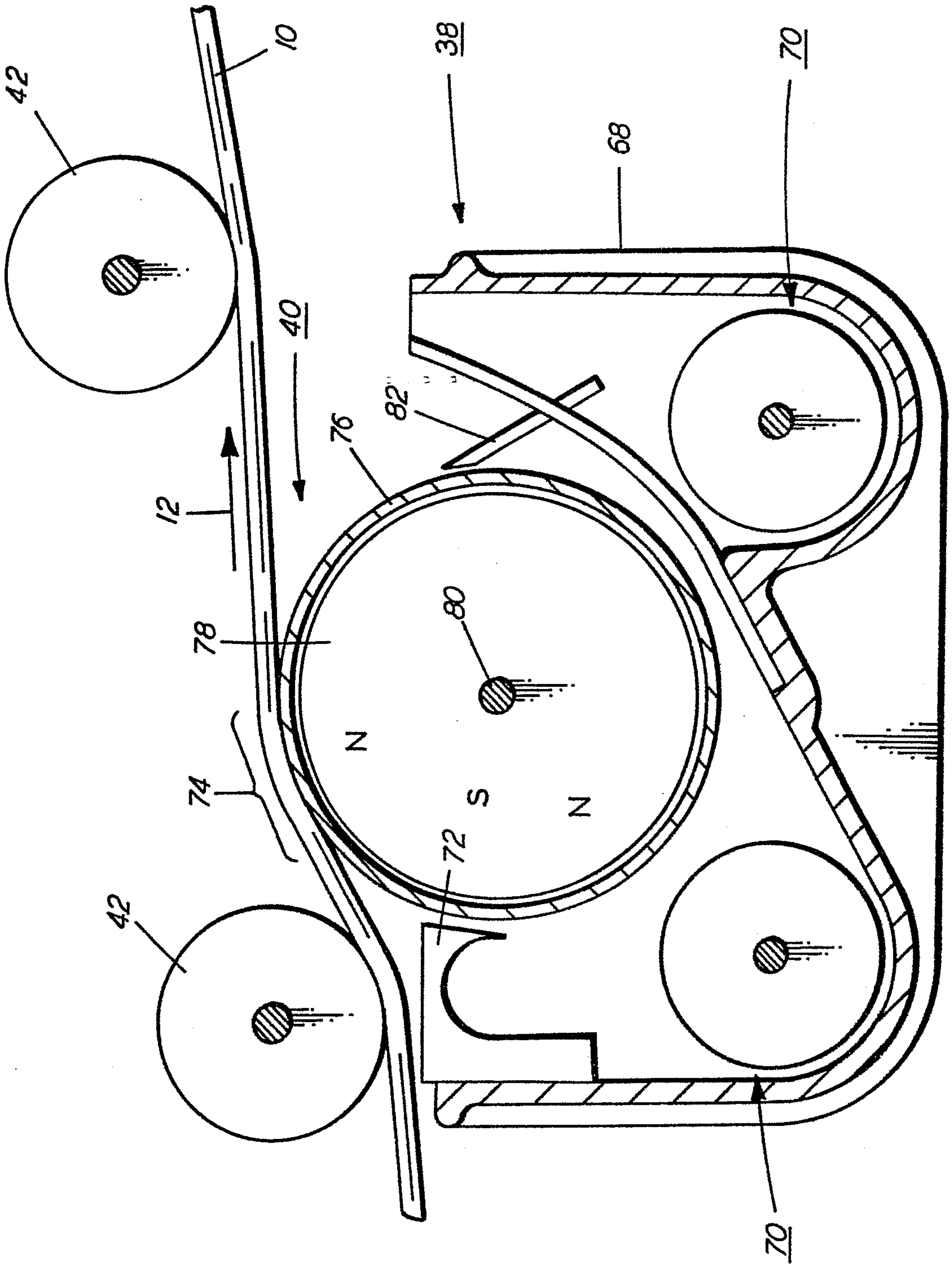


FIG. 3