Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 266 823 A2

EUROPEAN PATENT APPLICATION

(21) Application number: 87201989.8

(22) Date of filing: 17.08.81

(51) Int. Cl.⁴: G03G 15/16 , G03G 15/20

(30) Priority: 21.08.80 US 180218
06.10.80 US 194649
05.01.81 US 222829
05.01.81 US 222830

(43) Date of publication of application:
11.05.88 Bulletin 88/19

(60) Publication number of the earlier application in accordance with Art.76 EPC: 0 140 399

(84) Designated Contracting States:
AT CH DE FR GB LI NL SE

(71) Applicant: Dennison Manufacturing Company
300 Howard Street
Framingham, MA 01701(US)

(72) Inventor: Fotland, Richard A.
200 Chamberlain Street
Holliston Massachusetts 01746(US)
Inventor: Beaudet, Leo A.
85 Congress Street
Milford Massachusetts 01757(US)
Inventor: Briere, Richard L.
5 West Main Street
Hopkinton§Massachusetts 01748(US)
Inventor: Carrish, Jeffrey J.
22 Ferguson Road
Milford Massachusetts 01757(US)
Inventor: Lennon, Donald J.
91 Newtown Road R.F.D. 1
Acton Massachusetts 01720(US)
Inventor: Vandervalk, Casey S.
25 Lovell Street
Mendon Massachusetts 01756(US)

(74) Representative: Robinson, Anthony John Metcalf et al
Kilburn & Strode 30 John Street
London, WC1N 2DD(GB)

(54) Electrostatic printing and copying.

(57) Printing or photocopying apparatus for forming a toner image on a receptor sheet (35) comprises a imaging roller (25); means (19, 31) for forming a toner image on the imaging roller; and a transfer roller (37) in rolling contact under pressure with the imaging roller, the transfer and imaging rollers being maintained in non-parallel orientation with the receptor sheet fed therebetween to receive the toner image.

EP 0 266 823 A2

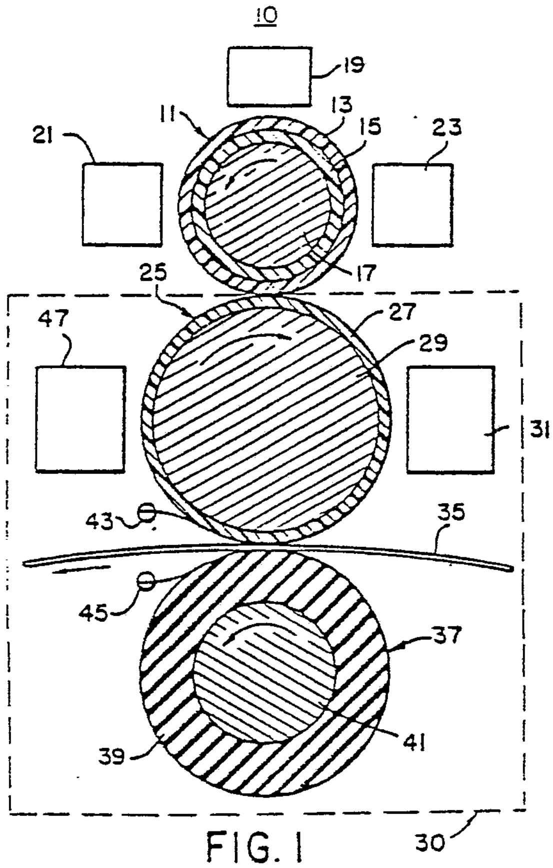


FIG. 1

ELECTROSTATIC PRINTING AND COPYING

This invention relates to electrostatic printing and photocopying, particularly at high speeds.

Electrostatic printers and photocopiers share a number of common features as a rule, although they carry out different processes. Electrostatic printers and photocopiers which are capable of producing an image on plain paper may generally be contrasted in terms of the method and apparatus used to create a latent electrostatic image on an intermediate member.

Copiers generally do so by uniformly charging a photoconductor electrostatically in the dark, and optically exposing the charged photoconductor to an image corresponding to the image to be reproduced. Electrostatic printers use non-optical means to create a latent electrostatic image on a dielectric surface, in response to a signal indicative of an image to be created. In theory, after creation of the electrostatic latent image, the same apparatus could be used to carry out the common steps of toning the image, transferring it to plain paper, and preparing the member bearing the electrostatic latent image for a subsequent cycle, usually by erasure of a residual latent electrostatic image. It would, in fact, be desirable to standardise the apparatus to perform these functions.

Various toner image transfer methods are known in the art. The transfer may be accomplished electrostatically, by means of a charge of opposite polarity to the charge on the toner particles, the former charge being used to draw the toner particles off the dielectric member and onto the image receptor. Patents illustrative of this transfer method include US-A-2,944,147; US-A-3,023,731; and US-A-3,715,762. Alternatively, the image receptor medium may be passed between the toner-bearing dielectric member and a transfer member, and the toner image transferred by means of pressure at the point of contact. Patents illustrative of this method include US-A-3,701,966; US-A-3,907,560; and US-A-3,937,571. Usually, the toner image is fused to the image receptor subsequently to transfer of the image, at a further process station. Postfusing may be accomplished by pressure, as in US-A-3,874,894, or by exposure of the toner particles to heat, as in US-A-3,023,731 and US reissue patent 28,693.

It is possible, however, to accomplish transfer and fusing of the image simultaneously, as shown for example in the patents cited above as illustrative of pressure transfer. This may be accomplished by a heated roller, as in US reissue patent 28,693, or simply by means of high pressure between the image-bearing dielectric member and a transfer member, between which the image receptor passes.

A problem which is typically encountered in transferring a toner image solely by means of pressure is the existence of a residual toner image on the dielectric member after image transfer, due to inefficiences in toner transfer. The residual toner particles require scraper blades or other removal means, and accumulate over time at various process stations associated with the dielectric member, including the apparatus for forming the latent electrostatic image. These toner accumulations decrease the reliability of the appratus, necessitating service at intervals. Furthermore, inefficiences in toner transfer may lead to mottling of the images formed on the image receptor sheets. These problems have not been overcome in the prior art through the use of extremely high pressures at the transfer nip.

A phenomenon which is commonly observed when subjecting rollers to high pressures is that of "bowing" of the rollers. This phenomenon occurs when the rollers are subjected to a high compressive force at the ends, thereby imparting a camber to each roller. The effect is to have high pressure at the ends of the rollers but lower pressure at the center. It is known in the prior art to alleviate this problem when encountered in pressure fusing apparatus by skewing the pressure rollers, i.e. by adjusting the mounting of the rollers to create an oblique orientation of the roller axes. Representative United States patents include US-A-3,990,391; US-A-4,188,104; US-A-4,192,229; and US-A-4,200,389. This technique has the disadvantage of causing "walking" of a receptor sheet fed between the rolls. In addition, this apparatus commonly encounters the problem of wrinkling of the receptor sheets.

Hardcoat anodization of aluminum alloys is an electrolytic process which is used to produce thick oxide coatings with substantial hardness. Such coatings are to be distinguished from natural films of oxide which are normally present on aluminum surfaces and from thin, electrolytically formed barrier coatings.

The anodization of aluminum to form thick dielectric coatings takes place in an electrolytic bath containing an oxide such a sulfuric or oxalic acid, in which aluminum oxide is slightly soluble. The production techniques, properties, applications of these aluminum oxide coatings are described in detail in <u>The Surface Treatment and Finishing of Aluminum and Its Alloys</u> by S. Wernick and R. Pinner, fourth edition, 1972, published by Robert Draper Ltd., Paddington, England (chapter IX page 563). Such coatings are extremely hard and mechanically superior to uncoated aluminum. However, the coatings contain pores in the form of fine tubes with a porosity on the order of 6.4516 x 10^{14} to 6.4516 x 10^{16} pores per square meter (10^{10} to 10^{12} pores per square inch). Typical porosities range from 10 to 30 percent by volume. These pores extend through the coating to a very thin barrier layer of aluminium oxide, typically 3 x 10^{-8} to 8 x 10^{-8}m (300 to 800 Angstroms).

US-A-3,664,300 discloses a process for surface treatment of xerographic imaging cylinders wherein the surface is coated with zinc stearate to provide enhanced surface lubrication and improved electrostatic toner transfer. This treatment technique does not, however, result in a permanent dielectric surface of requisite hardness and smoothness for pressure transfer and fusing of a toner image. For improved mechanical properties as well as to prevent staining, it is customary practice to seal the pores. One standard sealing technique involves partially hydrating the oxide through immersion in boiling water, usually containing certain nickel salts, which form an expanded boehmite structure at the mouth of the pores. Oxide sealing in this manner will not support an electrostatic charge due to the ionic conductivity of moisture trapped in the pores.

The invention provides compatibility of design for electrostatic printing and photocopying apparatus. It also provides high speed printing and photocopying with excellent image quality.

The invention further provides a plain paper photocopying system which is simple, compact and low in cost. The photocopying system requires fewer processing steps than those of conventional copying systems, with an extremely short and simple paper path.

The invention provides electrostatic imaging apparatus for pressure transfer of a toner image from a dielectric surface to plain paper and the like. Such apparatus effects simultaneous fusing of the toner image, and is characterized by a high efficiency of toner transfer.

A preferred embodiment of the invention incorporates an impregnated aluminum layer for the dielectric member. This dielectric surface possesses smoothness and hardness properties which facilitate toner transfer, while possessing sufficient resistivity to obtain a latent electrostatic image until toning. The dielectric surface created by this preferred method maintains the above properties at elevated humidities.

According to a first aspect of the invention, apparatus for forming a toner image on a receptor sheet is characterised by the features of claim 1.

According to a second aspect of the invention, a method of forming a toner image on a receptor sheet is characterised by the features of claim 10.

The invention thus encompasses both electrophotography and electrostatic printing, as well as preferred components to be employed in these processes.

Another version of the invention is seen in the shared processing stages in the electrostatic copier and printer apparatus of the invention. After an electrostatic latent image has been formed on a dielectric cylinder, the image is toned and pressure transferred to plain paper or any suitable image receptor. Preferably, this transfer is achieved by inserting the image receptor between the dielectric cylinder and a transfer roller under high pressure. Advantageously, this pressure transfer is effected with simultaneous fusing of the toner-image. Provision may be made for cleaning the surface of the dielectric cylinder and transfer roll, and for discharging any residual electrostatic image on the dielectric surface.

In the nip between the rollers, the ratio of the dielectric surface speed to the image receptor speed is advantageously in the range of about 1.01 to 1.1, most advantageously between 1.02 and 1.04. Best results are achieved where the dielectric surface has a smoothness in excess of 0.508 mrms (20 microinch rms). and a high modulus of elasticity. The transfer roller is preferably coated with a stress-absorbing plastics material. The roller materials are advantageously chosen so that the image receptor will have a tendency to adhere to the surface of the transfer roller in preference to that of the dielectric roller. The apparatus provides effective toner transfer and fusing without wrinkling of the receptor medium. The surface may be impregnated with a material which consists essentially of a group II metal with a fatty acid containing between 8 and 32 carbon atoms, saturated or unsaturated.

The invention may be carried into practice in various ways and several specific embodiments will now be described, by way of example, with reference to the drawings, in which.

FIGURE 1 is a sectional schematic view of electrophotographic apparatus in accordance with a preferred embodiment of the invention;

FIGURE 2 is a partial sectional schematic view of the nip area of the upper rollers of Figure 1;

FIGURE 3 is a sectional schematic view of electrophotographic apparatus in accordance with an alternative embodiment of the invention;

FIGURE 4 is a sectional schematic view of electrostatic printing apparatus in accordance with a preferred embodiment of the invention;

FIGURE 5 is a partial sectional schematic view of an illustrative charge neutralizing device for the dielectric roller of Figure 4;

FIGURE 6 is an elevation view of a preferred mounting arrangement for electrostatic printing apparatus of the type illustrated in Figure 4;

FIGURE 7 is a schematic view of the rollers of Figure 7 as seen from above;

FIGURE 8 is a geometric representation of the contact area of the rollers of Figure 6;

FIGURE 9 is a plot of residual toner as a function of end to end skew for the apparatus of Example IV-3.

DETAILED DESCRIPTION

I. Introduction

Two main embodiments of the invention are described, namely the double transfer electrophotographic apparatus which is the subject of Section II, and the electrostatic transfer printer which is the subject of Section III. These two embodiments differ in the means by which a latent electrostatic image is created on a dielectric imaging roller; thereafter, identical apparatus may be employed.

The skewed roller apparatus of Section IV is profitably employed to provide enhanced toner transfer and fusing in either of the main embodiments.

II. Double Transfer Electrophotographic System

Figures 1 to 3 show double transfer electrophotographic apparatus 10 comprised of three cylinders, and various process stations.

The upper cylinder is a photoconductive member 11, which includes a photoconductor coating 13 supported on a conducting substrate 17, with an intervening semiconductor substrate 15. Advantageous materials for the photoconductor surface layer 13 include cadmium sulphide powder dispersed in a resin binder (photoconductive grade Cds is employed, typically doped with activating substances such as copper and chlorine), cadmium sulphoselenide powder dispersed in a resin binder (defined by the formula CdS_xSe_y, where $x+y=1$), or organic photoconductors such as the equimolar complex of polyvinyl carbazole and trinitrofluorenone.

The photoconductor is electrostatically charged at charging station 19 and then exposed as exposing station 21 to form on the surface of the photoconductor an electrostatic latent image of an original. The photoconductor may be charged employing a conventional corona wire assembly, or alternatively it may be charged using the ion generating scheme described in the parent application. The optical image which provides the latent image on the photoconductor may be generated by any of several well known optical scanning schemes. This latent image is transferred to a dielectric cylinder 25 formed by a dielectric layer 27 coated on a metal substrate 29. The latent electrostatic image on the dielectric cylinder 25 is toned and transferred by pressure to a receptor medium 35 which is fed between the dielectric cylinder 25 and a transfer roller 37. There are means 43, 45. 47 to remove residual toner from cylinder 25 and roller 37 and to erase any electrostatic image remaining on cylinder 25 after transfer. Apparatus for effecting toning and subsequent steps shown generally at 30 in Figure 1, is discussed detail in subsection IIIB below.

The method by which a latent electrostatic image is transferred from the photoconductive cylinder 11 to the dielectric cylinder 25 employs a charge transfer by air gap breakdown. The process of uniformly charging and exposing the surface of the photoconductive coating 13 results in a charge density distribution corresponding to the exposed image, and a variable potential pattern of the surface of the photoconductor coating 13 with respect to the grounded conductive substrate 17. With reference to Figure 2, the charged area of the photoconductor 11 is rotated to a position of close proximity (less than 0.05 mm) to the dielectric surface. An external potential 33 is applied between electrodes in the conductive substrate of the photoconductive cylinder 11 and the metal substrate 29 of the dielectric cylinder 25, with a typical initial charge of about 1.000 volts on photoconductive layer 13, to which an additional 400 volts are added by the externally applied potential 33. The aggregate charge of 1,400 volts is decreased by about 800 volts during the exposing process.

It is possible to maintain the photoreceptor 11 in direct contact with the dielectric roller 25, an arrangement which provides the advantage of simplicity in mounting and driving the cylinders. An effective TESI process may be achieved under these conditions, but this will result in toner transfer to the upper cylinder and therefore will require additional cleaning apparatus.

The charge transfer process requires that a sufficient electrical stress be present in the air gap to cause ionization of the air. The required potential depends on the thickness and dielectric constants of the insulating materials, as well as the width of the air gap (see Dessauer and Clark, Xerography and Related Processes, the Focal Press, London and New York, 1965, at 427). Electrical stress will vary according to the local charge density, but if sufficient to cause an air gap breakdown it will result in a transfer of charge from photoconductor surface 13 to dielectric surface 27, in a pattern duplicating the latent image. This means that a certain threshold potential must be generated across the air gap. Roughly half the charge will be transferred, leaving a potential of around 600 volts on the dielectric surface 27.

The necessary threshold potential may exist as a result of the uniform charging and exposure of the photoconductor surface or an externally applied potential may be employed in addition. Image quality is generally enhanced through the use of an external potential.

It is important to maintain the integrity of the latent electrostatic image, in the face of disruptive charge transfer, which occurs under certain conditions when charge transfer is effected on the approach of the two insulating surfaces. It has been observed that the addition of a semiconducting layer 15 between the photoconductive surface layer 13 and the conductive substrate 17 considerably reduces this effect as compared with using the usual two-layer photoconductor. Although the phenomenon by which the semiconducting layer eliminates the disruptive breakdown is not completely understood, it is believed that the time constant introduced by this semiconducting layer has the effect of smoothing or reducing the precipitous behavior otherwise associated with disruptive breakdown. The employment of this preferred construction of the photoconductor member 11 avoids a mottling and blurring of detail in the transferred image. A typical range of air gap distances for charge transfer using this configuration would be on the order of 0.0125 to 0.0375 mm.

The use of this method of charge transfer alleviates some of the problems resulting from undesirable discharge characteristics of the photoconductive member. The employment of an external potential in achieving a threshold potential leaves a higher voltage on the dielectric cylinder than would be the case of a single transfer system relying on the contrast potential of the photoconductor surface. This, in turn, results in a greater contrast between the light and dark portions of the toned, visible image.

In order to provide uniformity from copy to copy, particularly with certain photoconductors which exhibit fatigue, it is advantageous to discharge the residual latent image remaining on the photoconductor after the latent image has been transferred to the dielectric surface 27. This erasure may be conveniently carried out by an erase lamp 23 which provides sufficient illumination to discharge the photoconductor below a required level. The erase light 23 may be either fluorescent or incandescent.

Example II-1

In a specific operative example of an electrophotographic system of the construction described, the cylindrical conducting core 29 of the dielectric cylinder 25 was machined from 7075-T6 aluminum to a diameter of 76 mm. The length of this cylindrical core, excluding machined journals, was 230 mm. The journals were masked, and the aluminum anodized by use of the Sanford process (see S. Wernick and R. Pinner, The Surface Treatment and Finishing of Aluminum and its Alloys, Robert Draper Ltd., 4th Edition 1971/72, Vol. 2, Page 567). The finished aluminum oxide layer was 60 μm (micrometres) in thickness. The cylinder 25 was then placed in a vacuum oven at 101.5917 kPa (30 inches mercury). After half an hour, the oven temperature was set at 150°C. The cylinder was maintained at this temperature and pressure for four hours. The heat cylinder was brush-coated with melted zinc stearate and returned to the vacuum oven for a few minutes at 150°C, 101.59kPa (30 inches mercury). The cylinder was removed from the oven and allowed to cool. The impregnated surface 27 of the dielectric cylinder 25 was then finished to 0.125 to 0.25μm rms using 600 grit silicon carbide paper.

The pressure roller 37 consisted of a solid machined 50 mm diameter core 41 over which was press fitted a 50 mm inner diameter, 62.5 outer diameter polysulphone sleeve 39.

The conducting substrate 17 of the photoconductor member 11, comprising an aluminum sleeve, was fabricated of 6061 aluminum tubing with a 3 mm wall and a 50 mm outer diameter. The outer surface was machined and the aluminum anodized (again, using the Sanford process) to a thickness of 50 m. In order to provide the proper level of oxide layer conductivity, nickel sulphide was precipitated in the oxide pores by dipping the anodized sleeve in a solution of nickel acetate (50 g/l, pH of 6) for 3 minutes. To form the semiconducting layer 15, the sleeve was then immediately immersed into concentrated sodium sulphide for 2 minutes and then rinsed in distilled water. This procedure was repeated three times. The impregnated anodic layer was then sealed in water (92° Celcius, pH of 5.6) for ten minutes. The semiconducting substrate 15 was spray coated with a binder layer. the photoconductor coating 13 consisting of photoconductor grade cadmium sulphoselenide powder milled with a heatset DeSoto Chemical Co. acrylic resin. diluted with methyl ethyl ketone to a viscosity suitable for spraying. The dry coating thickness was 40 µm, and the cadmium pigment concentration in the resin binder was 18% by volume. The resin was crosslinked by firing at 180°C for three hours.

The dielectric cylinder 25 was gear driven from an AC motor to provide a surface speed of twenty cms per second. The pressure roller 37 was mounted on pivoted and spring-loaded side frames, causing it to press against the dielectric cylinder 25 with a pressure of 55 kg per linear cm of contact. The side frames were machined to provide a 1.10 end-to-end between rollers 25 and 37.

Strips of tape 0.025 mm thick and 3 mm wide were placed around the circumference of the photoconductor sleeve 11 at each end in order to space the photoconductor at a small interval from the oxide surface of the dielectric cylinder 25. The photoconductor sleeve was freely mounted in bearings and friction driven by the tape which rested on the oxide surface.

The photoconductor charging corona station 19, single component latent image toning apparatus 31, and optical exposing station 21 were essentially identical to those employed in the Develop KG Dr. Eisbein & Co. (Stuttgart) No. 444 copier.

The toner removal means 43 and 45 comprised flexible stainless steel scraper blades and were employed to maintain cleanliness of both the oxide cylinder 25 and the polysulphone pressure roll 37. The residual latent image was erased using a semiconducting rubber roller in contact with the dielectric surface 27 (see Fig. 5).

With reference to the photoconductor-dielectric cylinder embodiment of Figure 2, a DC power supply 33 was employed to bias the photoconductor sleeve 11 to a potential of minus 400 volts relative to the dielectric cylinder core 29, which was maintained at ground potential. The photoconductor surface 13 was charged to a potential of minus 1,000 volts relative to its substrate 17. An optical exposure of 25 lux-seconds was employed in discharging the photoconductor in highlight areas. In undischarged areas, a latent image of minus 400 volts was transferred to the oxide dielectric 27. This image was toned, and then transferred to a plain paper receptor medium 35 which was injected into the pressure nip at the appropriate time from a sheet feeder.

Copies were obtained at a rate of 30 per minute, having clean background, dense black images, and a resolution in excess of twelve line pairs per millimetre. No image fusing, other than that occurring during pressure transfer, was required.

Example II-2

In another embodiment of the double transfer copier, the photoconductor sleeve 11 was replaced with a flexible belt photoconductor 11', as shown in Figure 3. The photoconductor 11' was comprised of a photoconductor layer 13' which was formed from a one to one molar solution of polyvinyl carbazole and trinitrofluorenone dissolved in tetrahydrafuran, and coated onto a conducting paper base 15' (West Virginia Pulp and Paper 45 No. LTB base paper) to a dry thickness of 30µm. The photoconductor rollers 17'a and 17'b were friction driven from the dielectric cylinder 25. The lower roller 17'b was biased to minus 400 volts. The photoconductor was charged to 1,000 volts with the double corona assembly 19' shown in Figure 3. The electrostatic latent image was generated by a flash exposure 21' so that the entire image frame was generated without the use of scanning optics.

The rest of the system was identical to the previous example with the exception of the dielectric cylinder 25. which was fabricated from non-magnetic stainless steel coated with a 15 µm layer of high density aluminum oxide. The coating was applied using a Union Carbide Corp. (Linde Division) plasma spray technique. After spraying, the oxide surface was ground and polished to a 0.25 m rms finish. Again. high quality copies were obtained, even at operating speeds as high as 75 cms per second.

III. Electrostatic Transfer Printing

The electrostatic transfer printing apparatus to be described includes apparatus for forming a latent electrostatic image on a dielectric surface (e.g. an imaging roller) and means for accomplishing subsequent process steps.

A. Latent Electrostatic Image Formation

Apparatus from generating charged particles and for extracting them to be applied to a further surface is disclosed in detail in section V below. Any of the embodiments of such apparatus which are suitable for forming a latent electrostatic image on a dielectric surface may be employed in the electrostatic printing apparatus discussed in this section; for example, see the embodiments of Figures 11, 12, and 13 and particularly the preferred matrix printing apparatus of Figure 13, which may be employed for multiplex printing. Alternatively, the printing apparatus may incorporate any embodiment of the electrostatic imaging device disclosed in the parent application.

All of the above charging devices are characterized by the production of a "glow discharge," a silent discharge formed in air between two conductors separated by a solid dielectric. Such discharges have the advantage of being self-quenching, whereby the charging of the solid dielectric to a threshold value will result in an electrical discharge between the solid dielectric and the control electrode. By application of a time-varying potential, glow discharges are generated to provide a pool of ions of both polarities.

It is useful to characterize all of the charging device embodiments in terms of a "control electrode" and a "driver electrode." The control electrode is maintained at a given DC potential in relation to ground, while the driver electrode is energized around this value using a time-varying potential such as a high voltage AC or DC pulse source.

B. Subsequent Processing

Identical apparatus may be employed for both electrophotography and printing to carry out process steps subsequent to the creation on the dielectric cylinder of a latent electrostatic image (compare Figures 1 and 4). The apparatus of Figure 4 will be considered for illustrative purposes.

In Figure 4, the dielectric layer 75 of the dielectric cylinder 73 should have sufficiently high resistance to support a latent electrostatic image during the period between formation of the latent image and toning, or, in the case of electrophotographic apparatus, between image transfer and toning. Consequently, the resistivity of the layer 75 must be in excess of 10^{12} ohm centimeters. The preferred thickness of the insulating layer 75 is between 0.025 and 0.075 mm. In addition, the surface of the layer 75 should be highly resistant to abrasion and relatively smooth, with a finish that is preferably better than 0.25μ m rms, in order to provide for complete transfer of toner to the receptor sheet 81. The smoothness of dielectric surface 75 contributes to the efficiency of toner transfer to the receptor sheet 81 by enhancing the release properties of this surface. The dielectric layer 75 additionally has a high modulus of elasticity, typically on the order of 6.89476×10^7 kPa (10^7 PSI), so that it is not distorted significantly by high pressures in the transfer nip.

A number of organic and inorganic dielectric materials are suitable for the layer 75. Glass enamel, for example, may be deposited and fused to the surface of a steel or aluminum cylinder. Flame or plasma sprayed high density aluminum oxide may also be employed in place of glass enamel. Plastics materials, such as polyamides, polyimides and other tough thermoplastic or thermosetting resins, are also suitable. A preferred dielectric coating is anodized aluminum oxide impregnated with a metal salt of a fatty acid, as described in the parent application.

The latent electrostatic image on dielectric surface 75 is transformed to a visible image at toning station 79. While any conventional electrostatic toner may be used, the preferred toner is of the single component conducting magnetic type described by J.C. Wilson, U.S. Patent No. 2,846,333, issued August 5, 1958. This toner has the advantage of simplicity and cleanliness.

The toned image is transferred and fused onto a receptive sheet 81 by high pressure applied between rollers 73 and 83. It has been observed that providing a non-parallel orientation, or skew, between the rollers of Figure 4 has a number of advantages in the transfer/fusing process. An image receptor 81 such as plain paper has a tendency to adhere to the compliant surface of the pressure roller 83 in preference to the smooth, hard surface of the dielectric roller 73. Where rollers 73 and 83 are skewed, this tendency has been observed to result in a "slip" between the image receptor 81 and the dielectric surface 75. The most notable advantage is a surprising improvement in the efficiency of toner transfer from dielectric surface 75 to image receptor 81. This efficiency may be expressed in percentage terms as the ratio of the weight of toner transferred to that present on the dielectric roller before transfer. Apparatus of this nature is disclosed in section IV.

The bottom roller 83 consists of a metallic core 87 which may have an outer covering of engineering plastics 85. The surface material 85 of roller 83 typically has a modulus of elasticity on the order of 1378952 to 3102642 kPa (200.000-450,000 PSI). The image receptor 81 will tend to adhere to the surface 85 in preference to the dielectric layer 75 because of the relatively high smoothness and modulus of elasticity of the latter surface. In the embodiment of section IV, one function of this surface 85 is to bond image receptor 81 when the latter is subjected to a slip between the roller surfaces. Another function of the plastics coating 85 is to absorb any high stresses introduced into the nip in the case of a paper jam or wrinkle. By absorbing stress in the pastics layer 85, the dielectric coated roller 73 will not be damaged during accidental paper wrinkles or jams. Coating 85 is typically a nylon or polyester sleeve having a wall thickness in the range of 3 to 12.5 mm.

The pressure required for good fusing to plain paper is governed by such factors as, for example, roller diameter, the toner employed, and the presence of any coating on the surface of the paper. It has been discovered, in addition, that the skewing of rollers 73 and 83 will decrease the transfer pressure requirements. See section IV, below. Typical pressures run from 18 to 125 kg per linear cm of contact.

Scraper blades 89 and 91 may be provided in order to remove any residual paper dust, toner accidentally impacted on the roll, and airborne dust and dirt from the dielectric pressure cylinder and the back-up pressure roller. Since substantially all of the toned image is transferred to the receptor sheet 81, the scraper blades are not essential, but they are desirable in promoting reliable operation over an extended period. The quantity of residual toner is markedly reduced in the embodiments of section IV, infra.

The small residual electrostatic latent image remaining on the dielectric surface 75 after transfer of the toned image may be neutralized at the latent image discharge station 93. The action of toning and transferring a toned latent image to a plain paper sheet reduced the magnitude of the electrostatic image, typically from several hundred volts to several tens of volts. In some cases where the toning threshold is too low, the presence of a residual latent image will result in ghost images on the copy sheet, which are eliminated by the discharge station 93.

At very high surface velocities of dielectric coating 75, the remaining charge can again result in ghost images. In this case, multiple discharge stations will further reduce the residual charge to a level below the toning threshold. Erasure of any latent electrostatic image can be accomplished by using a high frequency AC potential between electrodes separated by a dielectric, as described in section V below.

The latent residual electrostatic image may also be erased by contact discharging. The surface of the dielectric must be maintained in intimate contact with a grounded conductor or grounded semiconductor in order effectively to remove any residual charge from the surface of the dielectric layer 75, for example, by a heavily loaded metal scraper blade. The charge may also be removed by a semiconducting roller which is pressed into intimate contact with the dielectric surface. Figure 5 shows a partial sectional view of a semiconductor roller 98 in rolling contact with dielectric surface 75. Roller 98 advantageously has an elastomer outer surface.

EXAMPLE III-1

In a specific operative example of an electrographic printer in accordance with the invention, the cylindrical conducting core 5 of the dielectric cylinder 1 was machined from 7075-T6 aluminium to a 76.2 mm (3 inch) diameter. The length of the cylindrical core, excluding machined journals, was 228.6 mm (9 inches). The journals were masked and the aluminum anodized by use of the the Sanford Process (see S. Wernick and R. Pinner. The Surface Treatment and Finishing of Aluminum and Its Alloys. Robert Draper Ltd. fourth edition, 1971/72 volume 2. page 567). The finished aluminum oxide layer was 60 microns in thickness. The conducting core was then heated in a vacuum oven, 101.5917kPa (30 inches mercury); to a temperature of 150°C which temperature was achieved in 40 minutes. The cylinder was maintained at this temperature and pressure for four hours prior to impregnation.

A beaker of zinc stearate was preheated to melt the compound. The heated cylinder was removed from the oven and coated with the melted zinc stearate using a paint brush. The cylinder was then placed in the vacuum oven for a few minutes at 150°C. 101.5917 kPa (30 inches mercury), thereby forming dielectric surface layer. The cylinder was removed from the oven and allowed to cool. After cooling, the member was polished with successively finer SiC abrasive papers and oil. Finally, the member was lapped to a 0.1143 µm (4.5 microinch) finish.

The pressure roller 11 consisted of a solid machined two inch diameter aluminum core 12 over which was press fit a 50.8 mm (two inch) inner diameter, 63.5 mm (2.5 inch) outer diameter polysulfone sleeve 13. The dielectric roller was gear driven from an AC motor to provide a surface speed of 304.8 mm/s (12 inches per second). The transfer roller 11 was rotatably mounted in spring-loaded side frames, causing it to press against the dielectric cylinder with a pressure of 5337.4 kg/m (300 pounds per linear inch) of contact. The side frames were machined to provide a skew of 1.1° between rollers 1 and 11.

A charging device of the type described in U.S. Patent No. 4.160,257 was manufactured as follows. A 25.4µm (1 mil) stainless steel foil was laminated on both sides of a 25.4µm (1 mil) sheet of Muscovite mica.

The stainless foil was coated with resist and photoetched with a pattern similar to that shown in Figure 12, with holes or apertures in the fingers approximately 0.1524 mm (.006 inch) in diameter. The complete print head consisted of an array of 16 drive lines and 96 control electrodes which formed a total of 1536 crossover locations capable of placing 1536 latent image dots across 195.072 mm (7.68 inch) length of the dielectric cylinder. Corresponding to each crossover location was a 0.1524 mm (.006 inch) diameter etched hole in the screen electrode. Bias potentials of the various electrodes were as follows (with the cylinder's conducting core maintained at ground potential):

screen potential -600 volts
-control electrode potential -400 volts (during the application of a -400 volts print pulse, this voltage becomes -700 volts)
driver electrode bias
with respect to Screen Potential +300 volts

The DC extraction voltage was supplied by a pulse generator, with a print pulse duration of 10 microseconds. Charging occured only when there was simultaneously a pulse of negative 400 volts to the fingers 44, and an alternating potential of 2 kilovolts peak to peak at a frequency of 1 Mhz supplied between the fingers 44 and selector bars 43. The print head was maintained at a spacing of 203.2 mm (8 mils) from dielectric cylinder.

Under these conditions it was found that a 300 volt latent electrostatic image was produced on the dielectric cylinder in the form of discrete dots. The image was toned using single component toning apparatus essentially identical to that employed in the Develop KG Dr. Eisbein and Company (Stuttgart) No. 444 copier. The toner employed was Hunt 1186 of the Phillip A. Hunt Chemical Corporation.

The printing apparatus 70 included user-actuatable sheet-feeding apparatus (not shown) for feeding individual sheets 81 of paper between cylinders 73 and 83. The paper feed, toning apparatus, and cylinder rotation were driven from a unitary drive assembly (not shown). Paper feed was synchronized with the rotation of dielectric cylinder 73 to ensure proper placement of the toned image.

Digital control electronics and a digital matrix character generator, designed according to principles well known to those skilled in the art, were employed in order to form dot matrix characters. Each character had a matrix size of 32 by 24 points. A shaft encoder mounted on the shaft of the dielectric cylinder was employed to generate appropriate timing pulses for the digital electronics.

Flexible steel scraper blades 89 and 91 were employed to maintain cleanliness of dielectric cylinder 73 and transfer cylinder 83. With reference to the electrostatic image erasing embodiment shown at 98 in Figure 5 the residual latent image was erased using a semiconducting rubber roller in contact with the dielectric surface 75.

IV. Toner Transfer Apparatus With Skewed Rollers

Figure 6 shows in a plan view illustrative transfer printing apparatus 70 of the type shown schematically in Figure 4, including details of a preferred mounting arrangement. Side frames 59 and 69 house bearing retainers 57 and 67, which are fitted to rollers 73 and 83 in order to allow the rotation of the rollers while constraining their horizontal and vertical movement. Substantially identical side frames and bearing retainers are located at the other end of rollers 73 and 83. Bearing retainers 57 and 67, which advantageously are of the type known as "self-aligning", fit within lips 51 and 61 on the respective side frames, and against shoulders (not shown) on the respective rollers. The side frames are mounted on one side to superstructure 55, and are mounted on the other end in spring-loaded journals 58 in order to provide a prescribed upward pressure against roller 73. Roller 73 is driven at a desired rotational velocity by means not shown, while roller 83 is frictionally driven due to the contact of the rollers at the nip.

The mounting illustrated in Figure 6 is machined in order to provide a specified "skew", or deviation of the axis of rollers 73 and 83 from a parallel orientation. Rollers 73 and 83 may be adjustable around a pivot point at one end, by varying the angular relationship (in the vertical plane) of the rollers at the other end. Alternatively, the rollers may pivot around a central point of contact, by adjusting the offset of one of the rolls about the axis of the other, this adjustment being equal at both ends. This latter, "end-to-end" skew will be assumed hereinafter for illustrative purposes.

The mounting arrangement shown in Figure 6 may be easily adapted to electrophotographic apparatus of the type shown in Figure 1. In a further embodiment, the dielectric imaging roller (upper roller) may comprise a photoconductive surface layer over a conducting substrate. With reference to the sectional view of Figure 4, the imaging apparatus 71 may be replaced with any suitable apparatus known in the art for depositing a uniform charge on surface 75, and for exposing the surface to a pattern of light and shadow whereby the charge is selectively dissipated to form a latent electrostatic image. As in the dielectric embodiment, photoconductive surface 75 is advantageously smooth and abrasion resistant, with a high modulus of elasticity. See Example IV-4.

As shown in Figure 6, axle 50A is disposed in end-to-end skew, which may be measured as an offset L in the plane of side frame 59. A more significant measure of skew, however, is the angle between the projected axes of rollers 73 and 83 as measured in the horizontal plane, or plane of paper feed. An illustrative value of skew to effect the objects of the invention is 0.10 inch, measured at the center of roller bearings 57 and 67, which are separated by a distance of 263.525 mm (10.375 inch) for 228.6 mm (9 inch) long rollers. This respresents an angle of roughly 1.1°.

Figure 7 schematically illustrates skewed rollers 73 (with axis B-B) and 83 (with axis C-C) as seen from above. Roller 83 is skewed at the bearing mounts by horizontal offset L from the vertically projected axis B'-B' of roller 73. This corresponds to an angle θ between axes B-B and C-C. Axis B-B is perpendicular to the direction A of paper feed.

Figure 8 is a geometric representation of the surface of contact of the rollers at the nip, showing the direction of paper feed before and after engagement by the rollers. As a sheet of paper 81 travelling in direction A enters the nip, it is subjected to divergent forces in direction D (perpendicular to the projected axis B″-B″ of roller) and E (perpendicualar to the projected axis C'-C' of roller). Because of the relatively high smoothness and modulus of elasticity of the surface 75 of roller 73, the paper will tend to adhere to the lower roll, and therefore to travel in direction E. This results in a surface speed differential or "slip" between the surface of paper and roller.

Due to the compression of the lower roller 83 at the nip, paper 81 will contact both roller surfaces over a finite distance M in direction D. The width of the contact area, M, can be calculated using a formular found in Formulas For Stress and Strain (4th edition) by Ronald J. Roark, published by McGraw-Hill Book Company. The formula for the case of two cylinders in contact under pressure with parallel axes can be found on page 320 of the Roark Text, table XIV, section 5.

The transaxial width in metres of the contact of the two cylinders is given by

$$W' = 0.041\sqrt{\frac{P' D_1' D_2'}{D_1' + D_2'}\left[\frac{1-V_1^2}{E_1'} + \frac{1-V_2^2}{E_2'}\right]}$$

where P represents the cylinder loading in Nm^{-1};

D', D^2 represents the diameters of the cylinders in m;

V_1 and V_2 represent Poissons ratio in compression for the materials of the cylinders; and

E_1', E'_2 represents the modulus of elasticity in compression for the materials of the cylinders in Pa. (with W expressed in inches thus is:-

$$W = 1.6\sqrt{\frac{P\ D_1\ D_2}{D_1 + D_2}\left[\frac{1-V_1^2}{E_1} + \frac{1-V_2^2}{E_2}\right]}$$

where P is in pounds per linear inch:
D_1, D_2 are in inches;
V_1 and V_2 as above;
E_1 and E_2 in pounds per square inch).

With reference to the resultant triangle in Figure 8, the surface of receptor 81 will undergo a proportional side travel N with respect to the surface of roller 73, the factor of proportionally being the surface speed differential.

The skewing of rollers 73 and 83 in the above described manner results in a surprising improvement in the efficiency of toner transfer from dielectric surface 73 to image receptor 81. This efficiency may be expressed in percentage terms as the ratio of the weight of toner transferred to that present on the dielectric roller before transfer. This bears a complementary relationship to the weight of residual toner on the dielectric roller after transfer. The increase in transfer efficiency, which is the most notable advantage of the invention, minimizes the service problems attributable to the accumulation of residual toner at the process stations associated with the image roller 73, including scraper blades 89 and 91, erase head 98 and image generator 71. This effect depends on the choice of surface material 75 and toner.

It is another surprising advantage of this technique that this enhanced toner transfer is achieved without wrinkling of the receptor medium 81. These advantages accrued even in the case of nonfibrous substrates 81, such as Mylar film.

Example IV-1

Apparatus of the type illustrated in Figures 4 and 6 incorporated a 228.6 mm (9 inch long), 101.6 mm (4 inch) outer diameter roller 73 having a dielectric surface 75 of anodically formed porous aluminum oxide, which had been dehydrated and impregnated with zinc stearate and then surface polished. The dielectric surface of roller 73 was polished to obtain a finish of better than 0.254µm rms (10 microinch rms).

The pressure cylinder 83 included a 228.6 mm (9 inch) long steel mandrel with an outer diameter of 79.375 mm (3.125 inches) over which was pressed a 9.525 mm (0.375 inch) thick sleeve of polyvinylchloride. The rollers were pressed together at 6250.3 Kg/m (350 pounds of pressure per linear inch) of nip.

A latent electrostatic image was formed on the dielectric surface of roller 73 by means of an ion generator of the type disclosed in the parent application. The the various voltages to the ion generator 71 were maintained at constant values. The tests were conducted under the same ambient conditions throughout.

The toner employed was Hunt 1186 of the Phillip A. Hunt Chemical Corporation. The single component latent image toning apparatus was essentially identical to that employed in the Develop KG Dr. Eisbein & Co., (Stuttgart) No. 444 copier.

The toner was transferred onto Finch white bond paper, #60 vellum of Finch, Pruyn and Co. This paper was fed into the nip between the dielectric and pressure rollers at a constant speed throughout the tests.

Using the above specifications, the apparatus was operated at 0° skew, .55° skew, and 1.1° skew, where the skew was measured as a 2.54 mm (0.10 inch) offset at the bearing retainers of the 228.6 mm (9 inch) long pressure roll. The results shown in Table IV-A were obtained by collecting the residual toner and comparing its weight to the known weight of toner before transfer. No after transfer printing was present on the upper cylinder during the tests with 0.55° and 1.1° skew. However, transfer was so poor during the test without skew that printing was plainly visible on the upper cylinder after transfer.

TABLE IV-A

END-TO-END SKEW	PERCENTAGE OF TONER NOT TRANSFERRED
none	12.60
.55°	.10
1.1°	.10

Example IV-2

The apparatus of Example IV-1 was employed with Desoto toner 2949-5 of Desoto Inc. The toner was transferred onto coated OCR Imagetroll paper, manufactured by S.D. Warren. The rollers were pressed together without skew at 7500.36 Kg/m (420 pounds per linear inch), resulting in a transfer efficiency of 92.6 percent, measured by comparing the weight of toner before image transfer to the weight of residual toner. The rollers were then pressed together at 1.1° skew, with a pressure of 3571.6 Kg/m (200 pounds per linear inch), and all other parameters unchanged, resulting in a transfer efficiency of 99.95 percent.

Example IV-3

The apparatus of Example IV-1 was employed with the following modifications. The pressure cylinder 83 comprised a 228.6 mm (9 inch) long steel mandrel with a 1.945 inch outer diameter, over which was pressed a 228.6 mm (9 inch) long Celcon sleeve with a 88.9 (3.50 inch) outer diameter. (Celcon is a trademark of Celanese Chemical Co. for thermoplastic linear acetal resins). The two rollers were pressed together at 3571.6 Kg/m (200 pounds of nip pressure per linear inch) of nip.

The toner employed was Coates RP0357 of the Coates Bros. and Co., Ltd. The toner was transferred onto Finch white bond paper, #60 vellum.

Using the above specifications, the apparatus was operated with end-to-end skew, varied over a range of angles from 0.0° to 1.1°. The apparatus was operated using a constant weight of toner prior to transfer, and the residual toner present on dielectric roller 73 was collected and weighed. The results are shown in Table IV-B, and are graphed in Figure 9. In the case of the test using no skew, the residual toner was visible as printing remaining on the upper roller.

These tests showed a dramatic improvement in the efficiency of toner transfer when the skew was increased from 0.0° to .42°; this resulted in a decrease in the weight of residual toner by a factor of 53. Increases in skew from .42° to .85° and from .55° to 1.1° further reduced the weight of residual toner by factors of somewhat better than 2.

TABLE IV-B

TONER TRANSFER EFFICIENCY, EXAMPLE IV-3

END-TO-END SKEW	RESIDUAL TONER (GRAMS)
0°	6.034
.42°	0.114
.55°	0.066
.85°	0.050
.97°	0.036
1.1°	0.031

Example IV-4

The apparatus of Example IV-4 was employed with the modification that the imaging roller 73 comprised a photoconductive roller. An aluminum sleeve was fabricated of 6061 aluminium tubing with 3.175 mm (1/8") wall and 101.6 mm (4") outer diameter. The sleeve was spray coated with a binder layer photoconductor consisting of photoconductor grade Sylvania PC-100 cadmium sulfide pigement of Sylvania Comp. Electronics Corp., dispersed in a melamine-acrylic resin, diluted with methyl ethyl ketone to a viscosity suitable for spraying. The resin was crosslinked by firing at 600° for three hours.

A photoconductor charging corona and optical exposing system were essentially identical to those employed in the Develop KG Dr. Eisbein & Co. (Stuttgart) No. 444 Copier. The toner transfer efficiency underwent improvements comparable to those of Example IV-1 for increasing skew angles of 0.0°, 0.55°, and 1.1°.

Claims

1. Apparatus for forming a toner image on a receptor sheet (35), comprising: an imaging roller (25); means (19, 31) for forming a toner image on the imaging roller; and a transfer roller (37) in rolling contact under pressure with the imaging roller, characterised in that the transfer roller and imaging roller are maintained in a non-parallel axial orientation with the receptor sheet feed therebetween to receive the toner image.

2. Apparatus as claimed in Claim 1 in which the receptor sheet (35) adheres to the surface of the transfer roller (37) in preference to the surface of the imaging roller (25).

3. Apparatus as claimed in Claim 1 or Claim 2 in which the imaging roller (25) includes a dielectric surface layer (27) over a conductive sublayer.

4. Apparatus as claimed in any one of the preceding claims in which the transfer roller (37) includes a surface layer (39) consisting of an engineering thermoplastics or an engineering thermoset material.

5. Apparatus as claimed in Claim 3 or in Claim 4 when dependent upon Claim 3 in which the said dielectric surface layer (27) is comprised of porous anodized aluminium impregnated with a metallic salt of a fatty acid.

6. Apparatus as claimed in any one of the preceding claims when dependent upon Claim 3 in which the dielectric surface layer 927) has a smoothness in excess of 5.1 10^{-7}m rms (20 microinch rms).

7. Apparatus as claimed in any one of the preceding claims in which the imaging roller (25) includes a hard photoconductive surface layer.

8. Apparatus as claimed in any one of the preceding claims in which one of the rollers is frictionally driven by the rotation of the other roller.

9. Apparatus as claimed in any one of the preceding claims arranged for simultaneous fusion of the toner image to the receptor sheet during transfer thereto.

10. A method of forming a toner image on a receptor sheet (35), comprising forming a toner image on the surface of an imaging roller (25), rotating the toner image into an area of contact between the image roller and a transfer roller (37), and feeding the receptor sheet onto the area of contact of the said rollers; characterised in that the transfer roller (37) is maintained at a non-parallel axial orientation to the imaging roller (25).

11. A method as claimed in Claim 10 in which the toner image is transferred and simultaneously fused to the receptor sheet.

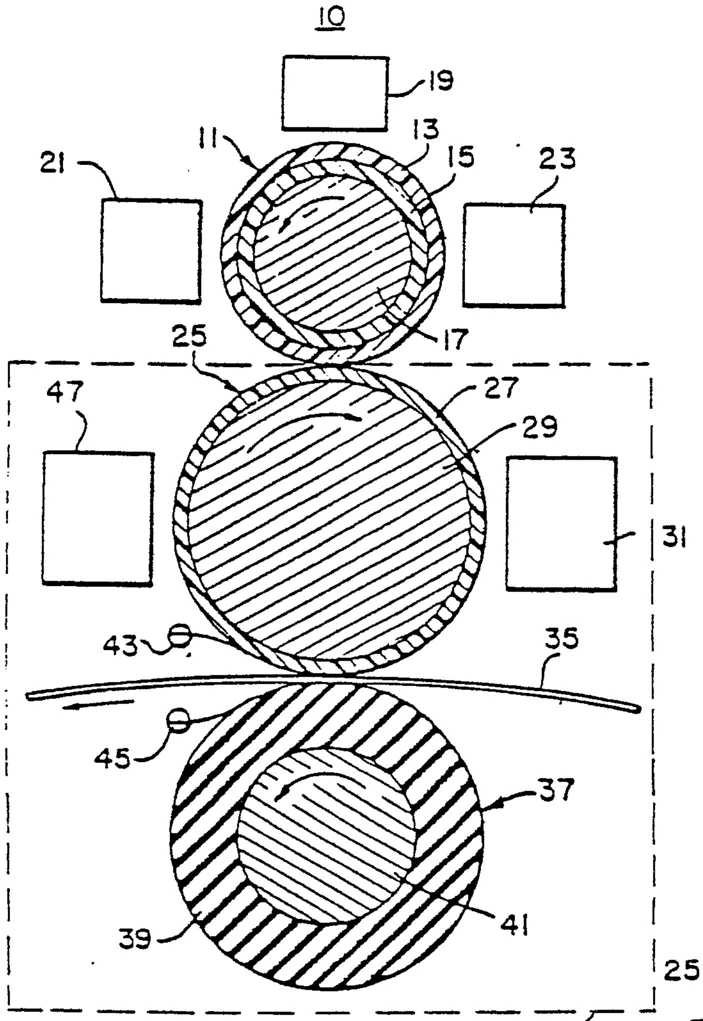


FIG. 1

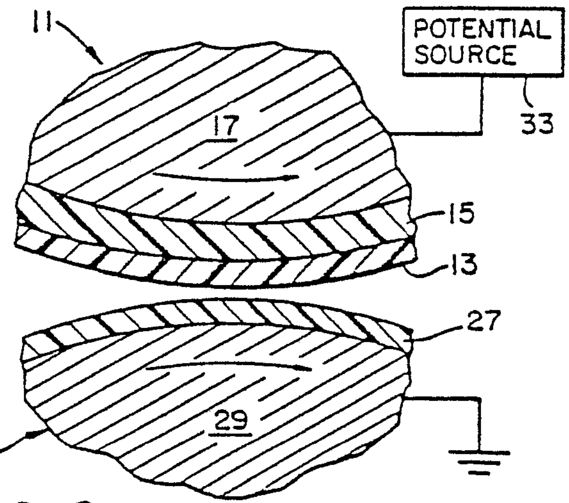


FIG. 2

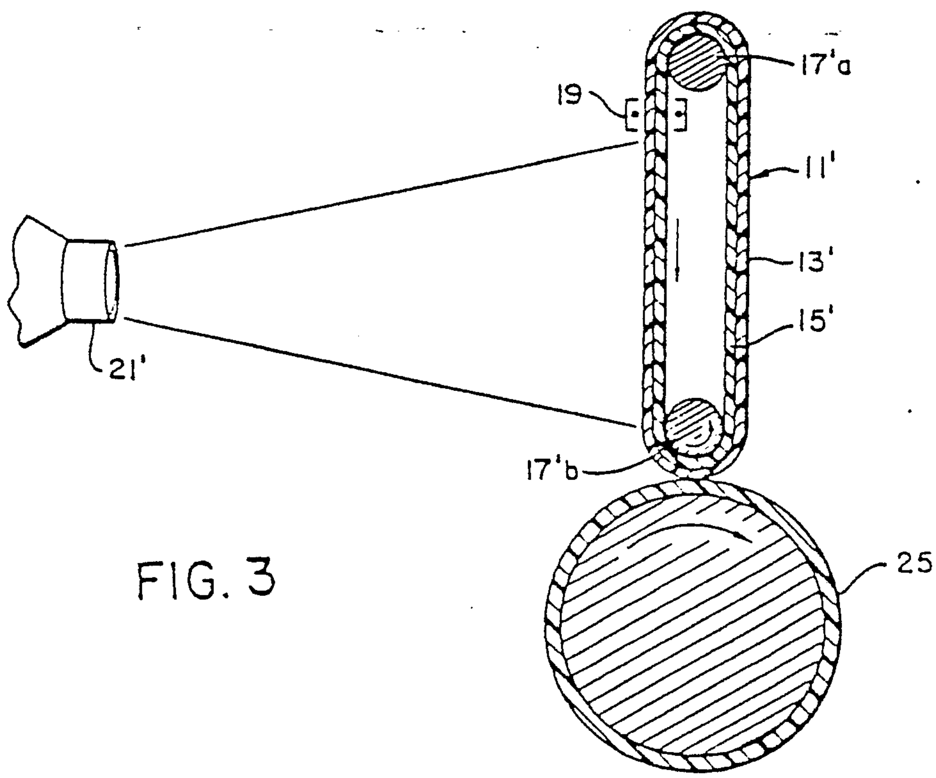


FIG. 3

FIG. 4

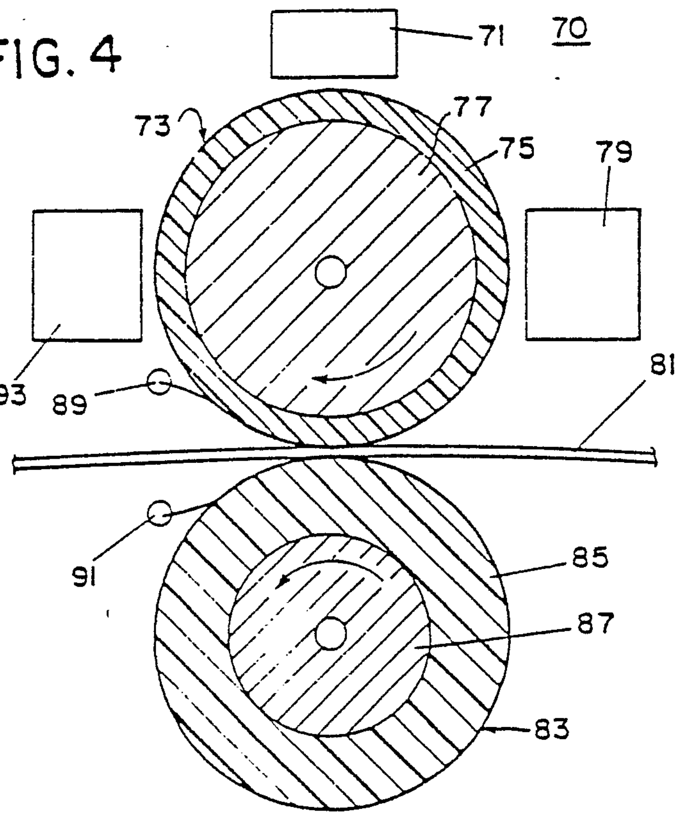


FIG. 5

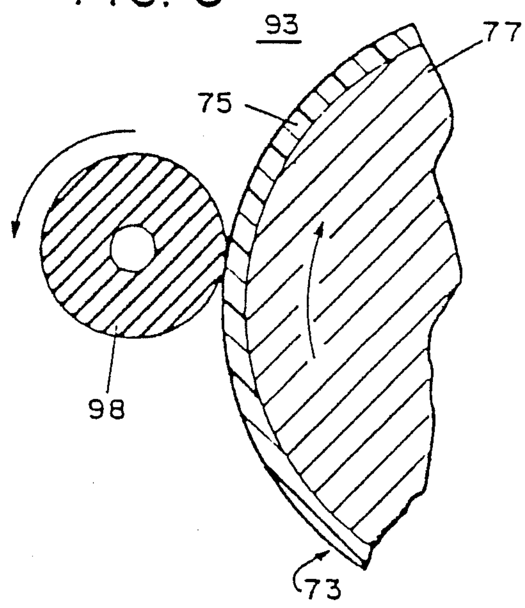
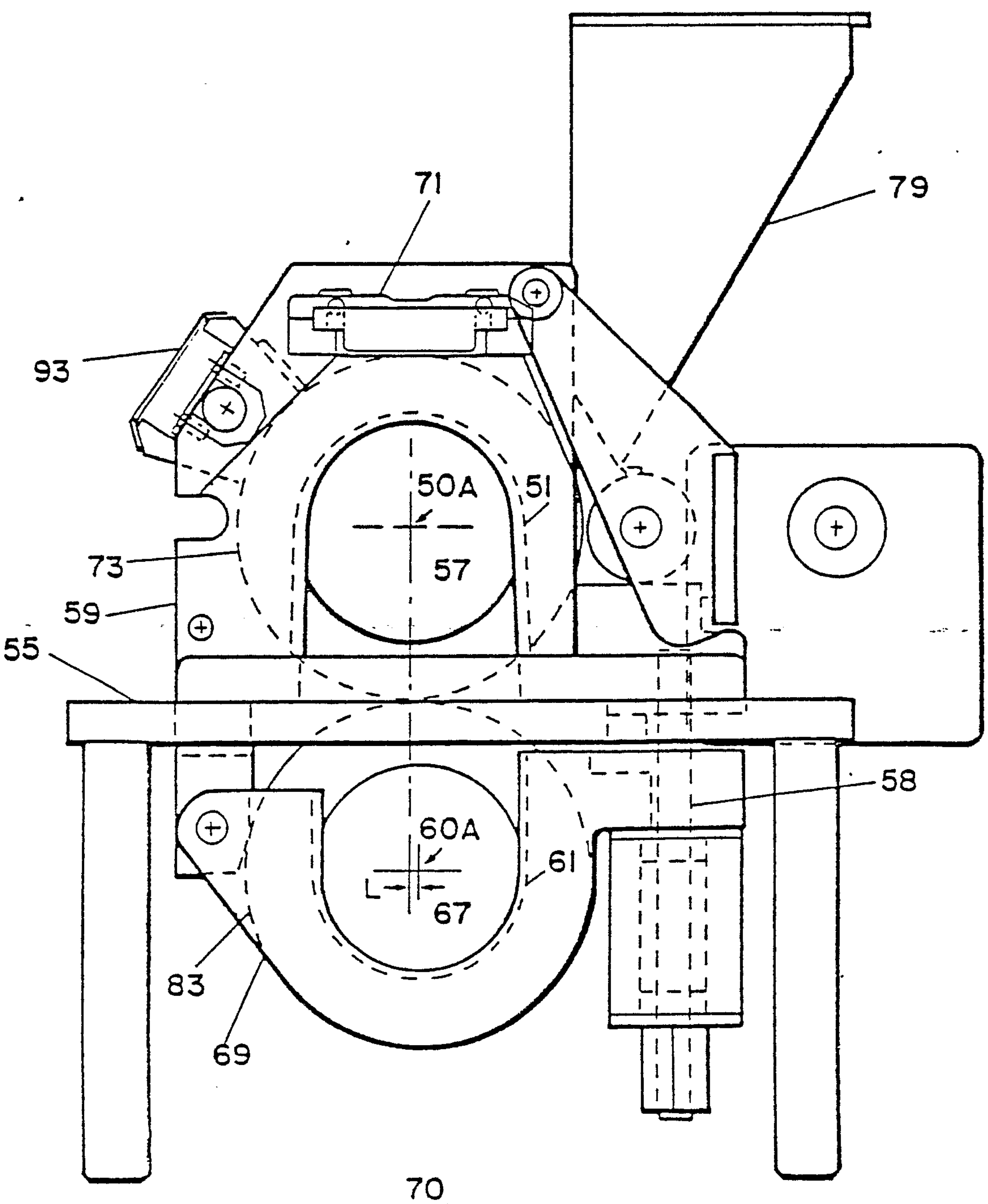


FIG. 6



70

FIG. 7

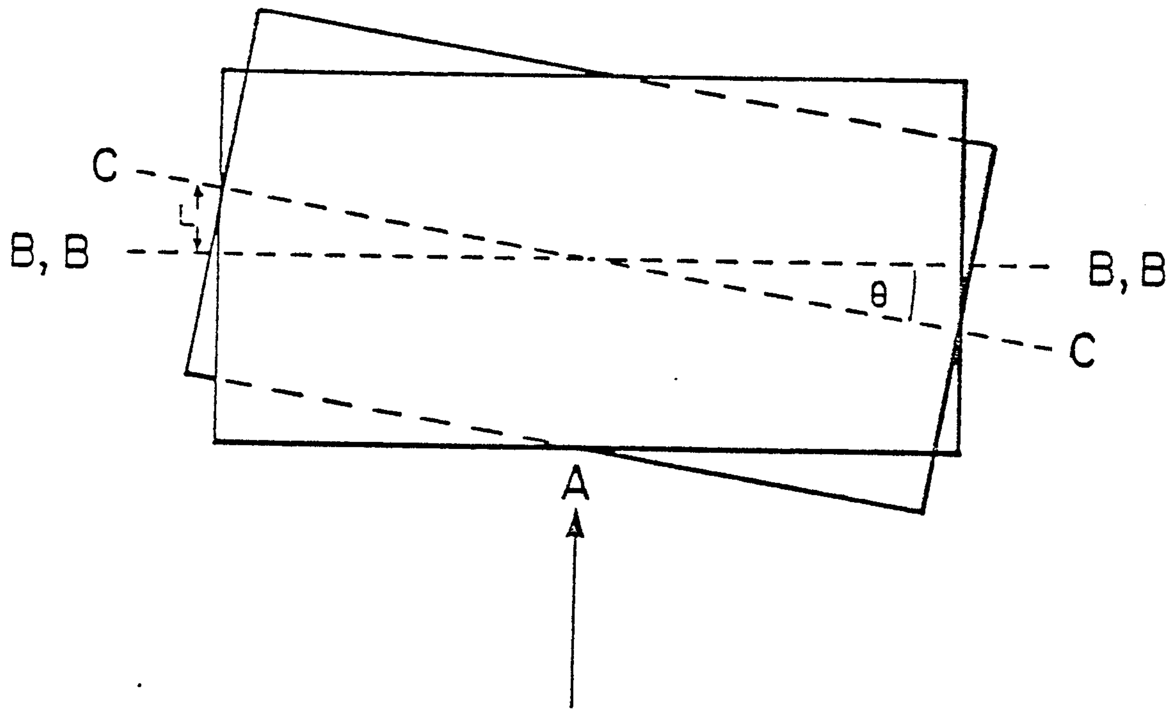


FIG. 8

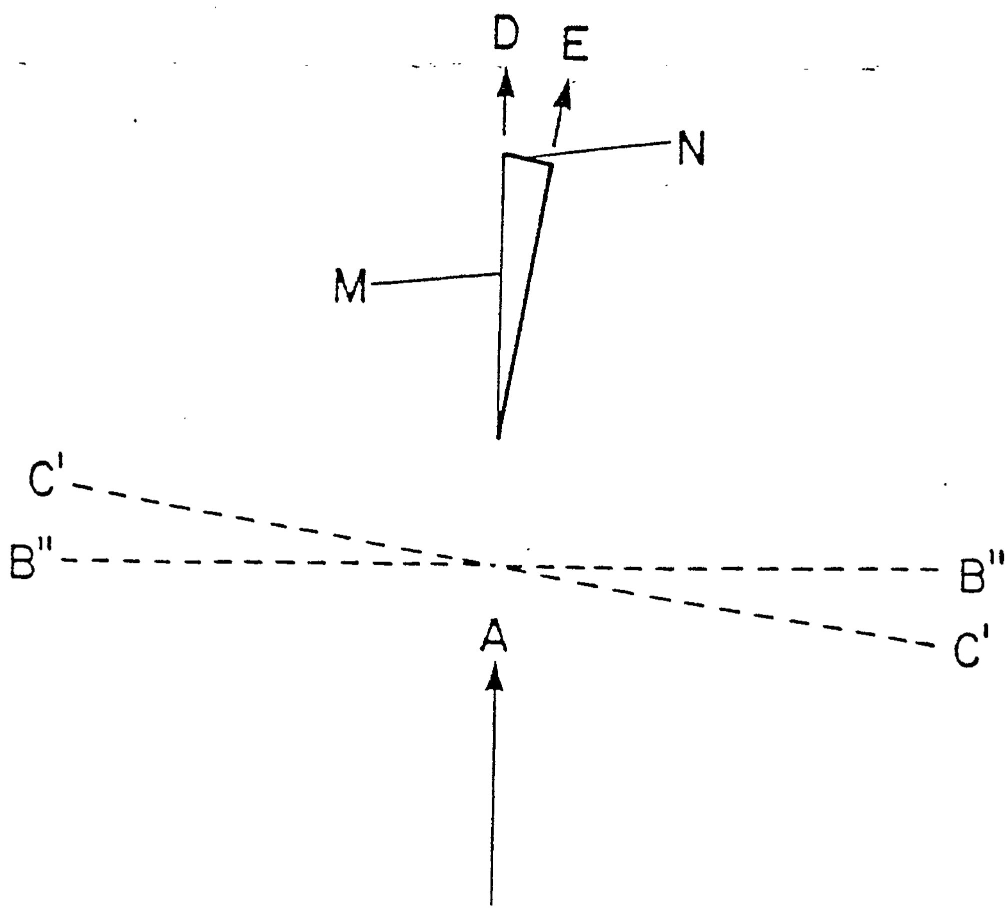
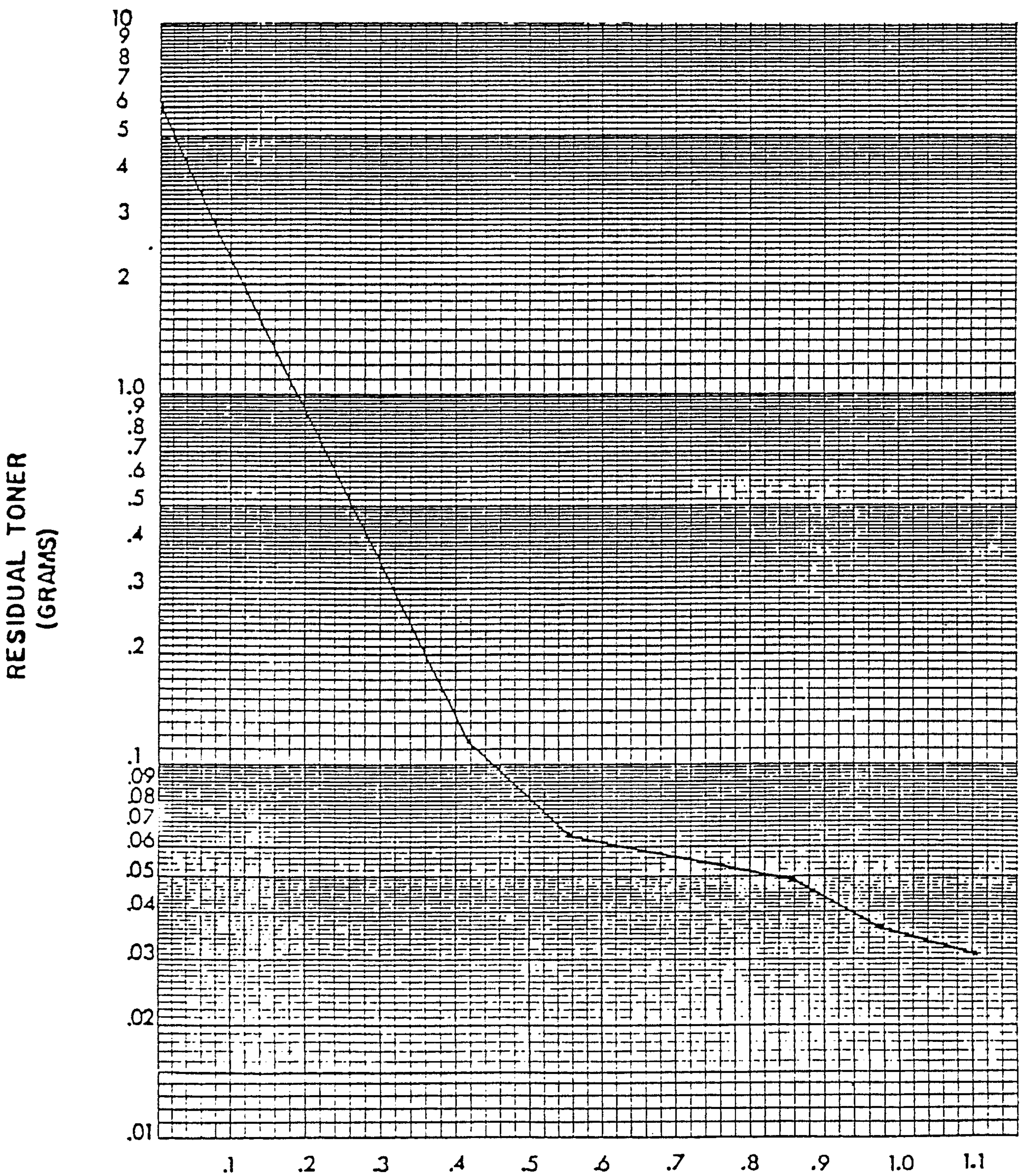


FIG. 9


RESIDUAL TONER
(GRAMS)
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1