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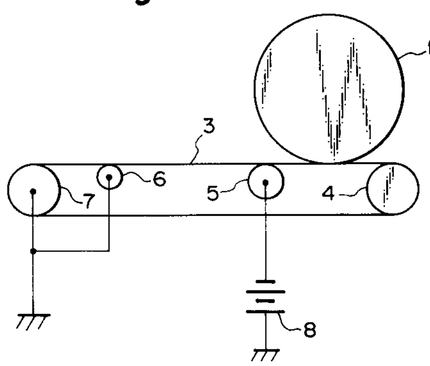
(54) **Image forming apparatus.**

(57) An image forming apparatus capable of surely transferring an image to produce an attractive image and, in addition, surely separating a transfer medium from a photoconductive element with no regard to the environment.

Fig. 1



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BACKGROUND OF THE INVENTION

The present invention relates to a copier, printer, facsimile apparatus or similar image forming apparatus of the type transferring a toner image from a photoconductive element to a transfer medium.

An image forming apparatus of the type described includes a transfer and separation device for transferring a toner image from a photoconductive element to a sheet or similar transfer medium and then separating the sheet from the element. This kind of device has customarily been implemented by a corona transfer and separation system, i.e., a first and a second corona discharger assigned to image transfer and sheet separation, respectively. The first corona discharger effects corona discharge at the rear of the sheet to transfer the toner image from the photoconductive element to the front of the sheet. The second corona discharger applies corona discharge to the rear of the sheet carrying the toner image to separate it from the photoconductive element.

A contact type transfer and separation system is another conventional system available for the image forming apparatus. In this type of system, while a transfer belt is in rotation, a bias potential is applied to the belt from a power source to transfer the toner image from the photoconductive element to a sheet or similar medium carried on the belt. The sheet with the toner image is separated from the photoconductive element by being electrostatically adhered to the belt. The transfer belt is sometimes replaced with a transfer roller. The contact type transfer and separation system has been proposed in various forms, as disclosed in Japanese Patent Laid-Open Publication No. 123385/1990, 123386/1990, and 187380/1990 by way of example.

Another conventional image forming apparatus includes a carrier for carrying a toner image transferred thereto at a transfer position and transporting it while being rotated. In this type of apparatus, a toner image formed on a photoconductive element is transferred to a belt at a first transfer position. As the belt is rotated to transport the toner image to a second transfer position, the toner image is transferred from the belt to a sheet. At a position upstream of the first transfer position, a transfer potential is applied to the belt to transfer the toner image from the photoconductive element to the belt.

The contact type image transfer and sheet separation system is advantageous over the corona type system in that it reduces ozone and requires only a low power source voltage. However, the problem with the transfer belt is that the adequate bias voltage to be applied from the power source to the belt changes due to various causes including irregularities in the resistance of the belt, varying ambient conditions, kind of sheets, and area of a toner image. This prevents the toner image from being surely transferred from the belt to the sheet. Specifically, the amount of charge deposited on the belt by the bias potential from the power source deviates from one required to effect desirable image transfer due to irregularities in the resistance of the belt ascribable to the production line, changes in the resistance ascribable to the varying ambient conditions, changes in the material and thickness of sheets, etc. More specifically, when the amount of charge required to effect desirable image transfer is deposited on a transfer belt, discharge does not occur in a pretransfer region upstream of the nip portion between the photoconductive element and the belt. In this condition, a toner charged to positive polarity, for example, is transferred to the sheet carried on the belt in a transfer region. In this case, a bias potential is applied from a power source to the belt. When the actual amount of charge on the belt is deviated from the expected one due to the above-stated reasons, discharge occurs in the pretransfer region. This causes a negative charge to deposit on the toner and thereby charges the front and the rear of the belt to positive polarity and negative polarity, respectively. As a result, despite that the bias potential from the power source is adequate, the toner is prevented from being transferred from the photoconductive element to the sheet, resulting in the local omission of an image on the sheet.

Further, the transfer belt not only transfer the toner image from the photoconductive element to a sheet or similar transfer medium, but also separates the sheet from the element by electrostatically retaining it thereon. However, the problem is that the separation of the sheet from the photoconductive element depends on the ambient conditions. Particularly, when the water content of the sheet increases in a hot and humid environment, it is likely that the sheet is adhered to the photoconductive element and not to the belt and cannot be separated from the element. Should the sheet be forcibly separated from the photoconductive element by a pawl or similar implementation, it would scratched or creased to degrade the image quality.

In the electrophotographic image forming apparatus, a transfer potential is applied to the belt at a position upstream of the first transfer position so as to transfer the toner image from the photoconductive element to the belt. This brings about a problem that the toner flies toward the belt at a position upstream of the first transfer position, thickening lines, blurring characters, reducing sharpness or otherwise degrading images.

SUMMARY OF THE INVNTION

It is, therefore, an object of the present invention to provide an image forming apparatus capable of surely transferring an image to produce an attractive image and, in addition, insuring desirable separation of a transfer medium from a photoconductive element with no regard to the environment.

In accordance with the present inventon, an image forming apparatus comprises a photoconductive element for forming a toner image thereon, a transfer medium movable in contact with the photoconductive element over a predetermined nip width to allow the toner image to be transferred from the photoconductive element to the transfer medium, a transfer bias applying device for applying a predetermined transfer bias to the transfer medium, and a potential gradient generating device for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from the photoconductive element to the transfer medium increases in a region upstream of a transfer region with respect to the photoconductive element and terminating at a point where the photoconductive element and transfer medium begin to contact each other.

Also, in accordance with the present invention, an image forming apparatus comprises a photoconductive element for forming a toner image thereon, a transfer belt movable in contact with the photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from the photoconductive element to the sheet, a transfer potential bias applying device for applying a predetermined transfer bias to the transfer belt, a potential gradient generating device for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from the photoconductive element to the sheet increases in a region upstream of a nip portion with respect to the photoconductive element and terminating at a point where the photoconductive element and transfer belt begin to contact each other, and a bias applying device for applying a bias to the potential gradient generating device after the sheet has moved a predetermined distance away from the nip portion.

Further, in accordance with the present invention, an image forming apparatus comprisesa photoconductive element for forming a toner image thereon, a transfer belt movable in contact with the photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from the photoconductive element to the sheet, a transfer bias applying device contacting the transfer belt at a position downstream of the photoconductive element for applying a predetermined bias to the transfer belt, and a potential gradient generating device having a dielectric layer on a surface thereof and contacting the transfer belt at a position upstream of the photoconductive element for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from the photoconductive element to the sheet increases in a region upstream of the nip portion with respect to the photoconductive element and terminating at a point where the photoconductive element and transfer belt contact each other.

Moreover, in accordance with the present invention, an image forming apparatus comprises a photoconductive element for forming a toner image thereon, a transfer belt movable in contact with the photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from the photoconductive element to the sheet, a transfer bias applying device contacting said transfer belt at a position downstream of the photoconductive element for applying a predetermined bias to the transfer belt, and a potential gradient generating device having an elastic dielectric layer on a surface thereof and contacting a rear of the transfer belt in a position upstream of the photoconductive element for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from the photoconductive element to the sheet increases in a region upstream of the nip portion with respect to said transfer belt and terminating at a point where the photoconductive element and transfer belt contact each other.

In addition, in accordance with the present invention, an image forming apparatus comprisesa photoconductive element for forming a toner image thereon, a transfer medium contacting the photoconductive element over a predetermined nip width in a transfer region and undergoing a step of transferring the toner image formed on the photoconductive element a plurality of times, a first electrode contacting the transfer medium at a position downstream of the transfer region, a second electrode contacting the transfer medium at a position upstream of the transfer region, and a potential gradient generating device for providing the transfer bias with a potential gradient by applying a transfer bias to the first electrode or both of the first and said second electrodes, and applying, when a toner is absent on the transfer medium, a bias of the same polarity as the toner to the second electrode or applying, when the toner is present on the transfer medium, a bias of opposite polarity to the toner to the second electrode, such that an amount of transfer of the toner image from the photoconductive element to the transfer medium increases in a region upstream of a transfer region with respect to the photoconductive element and terminating at a point where the photoconductive element and transfer medium contact each other.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description taken with the accompanying drawings in which:

FIGS. 1 and 2 are respectively a fragmentary front view and a section showing an image forming apparatus embodying the present invention;

FIG. 3 is a graph indicative of the results of experiments;

FIGS. 4-8 are front views each showing an alternative embodiment of the present invention;

FIG. 9 is a timing chart demonstrating a specific operation of the embodiment shown in FIGS. 1 and 2;

FIG. 10 is a timing chart representative of a specific operation of the embodiment shown in FIG. 5;

FIG. 11 is a timing chart representative of a specific operation of the embodiment shown in FIG. 6;

FIG. 12 is a timing chart demonstrating a specific operation of the embodiment shown in FIG. 7;

FIGS. 13 and 14 are block diagrams each schematically showing another alternative embodiment of the present invention;

FIGS. 15 and 16 are front views each showing another alternative embodiment of the present invention;

FIGS. 17 and 18 are views showing problems particular to a conventional image forming apparatus;

FIGS. 19, 20 and 21 are graphs indicative of, respectively, potential distributions particular to the embodiments shown in FIGS. 1 and 2, FIG. 6, and FIG. 7;

FIG. 22 is a side elevation showing another alternative embodiment of the present invention;

FIG. 23 shows a potential gradient of an intermediate transfer belt included in the embodiment of FIG 22;

FIG. 24 is a graph showing a relation between the potential between a bias roller and a contact point particular to the embodiment of FIG. 22;

FIG. 25 is a section associated with FIG. 22;

FIG. 26 is an enlarged view of a photoconductive drum, intermediate transfer belt and their associated members included in the embodiment of FIG. 25; and

FIGS. 27-32 are side elevations each showing a further alternative embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

To better understand the present invention, a brief reference will be made to a conventional image forming apparatus, particularly a contact type image transfer and sheet separation system available therewith, shown in FIGS. 17 and 18. The contact type image transfer and sheet separation system is advantageous over a corona type system in that it reduces ozone and requires only a low power source voltage, as discussed earlier. However, the problem with a transfer belt is that the adequate bias voltage to be applied from a power source to the belt changes due to various causes including irregularities in the resistance of the belt, varying ambient conditions, kind of sheets, and area of a toner image. This prevents a toner image from being desirably transferred from the belt to a sheet. Specifically, the amount of charge deposited on the belt by the bias potential from the power source deviates from one required to effect desirable image transfer due to irregularities in the resistance of the belt ascribable to the production line, changes in the resistance ascribable to the varying ambient conditions, changes in the material and thickness of sheets, etc. More specifically, as shown in FIG. 17, when the amount of charge required to effect desirable image transfer is deposited on a transfer belt, discharge does not occur in a pretransfer region upstream of the nip portion between a photoconductive element 37 and the belt. In this condition, a toner 39 charged to positive polarity, for example, is transferred to a sheet 38 carried on the belt in a transfer region. In this case, a bias potential is applied from a power source, not shown, to the belt 38. As shown in FIG. 18, when the actual amount of charge on the belt is deviated from the expected one due to the above-stated reasons, discharge occurs in the pretransfer region. This causes a negative charge to deposit on the toner 39 and thereby charges the front and the rear of the belt to positive polarity and negative polarity, respectively. As a result, despite that the bias potential from the power source is adequate, the toner 39 is prevented from being transferred from the photoconductive element 37 to the sheet 38, resulting in the local omission of an image on the sheet.

Referring to FIG. 2, part of an image forming apparatus embodying the present invention is shown and implemented as an electrophotographic copier. As shown, the apparatus includes an image carrier in the form of a photoconductive drum 1. The drum 1 is uniformly charged by a main charger while being rotated by a drive mechanism, not shown. A writing device writes image data on the charged surface of the drum 1 to form an electrostatic latent image. A developing unit develops the latent image to produce a corresponding toner image. A recording medium in the form of a sheet is fed from a sheet feed device to a register roller 2, brought to a stop for a moment, and then driven toward a transfer belt 3 in synchronism with the toner image formed on the drum 1. At least the front of the transfer belt 3 is made of a dielectric material.

The transfer belt 3 is passed over a drive roller 4 and driven rollers 5-7. The rollers 6 and 7 are connected to ground. The roller 5 plays the role of a bias roller or bias electrode while the roller 4 remains in an electrically floating state. As soon as the leading edge of the sheet approaches a portion where the drum 1 and transfer belt 3 are to contact, a solenoid 9 is energized to urge a lever 10 upward. The lever 10 in turn raises one side of the belt assembly, i.e., the belt 3 and rollers 47 until the belt 3 contacts the drum 1.

The drive roller 4 is driven by a motor to in turn rotate the transfer belt 3. The belt 3 contacts the drive roller 4 at a position upstream of the portion where it is capable of contacting the drum 1, and contacts the bias roller 5 at a position downstream of the contact portion. The belt 3 contacts the drum 1 over a predetermined nip width. As shown in FIGS. 1 and 9, when the belt 3 contacts the drum 1, a power source 8 applies to the bias roller 5 a predetermined bias voltage whose polarity is opposite to the polarity of the toner deposited on the drum 1, thereby depositing a corresponding charge on the belt 3. The belt 3 is made of a material having a specific volume resistivity (10^6 Ωcm to 10^{12} Ωcm). Hence, a current flows toward the rollers 6 and 7 due to the bias voltage from the bias roller 5, resulting in the fall of voltage.

While the sheet is transported between the belt 3 and the drum 1, the toner image is transferred from the drum 1 to the sheet due to the abovementioned bias voltage applied from the power source 8 to the belt 3. The sheet is polarized by the charge applied from the power source 8 to the belt 3. The polarizing voltage of the sheet and the true charge of the belt 3 generate an electrostatic force. As a result, the sheet is conveyed by the belt 3 while being electrostatically adhered to the belt 3.

While the sheet is conveyed by the belt 3, the charge thereof is reduced by being released to ground via the belt 3 and rollers 6 and 7. The rate at which the charge of the sheet decreases greatly depends on the resistance R and capacitance C of the sheet and is determined in terms of a time constant $\tau = R \bullet C$. The sheet is transported toward a fixing station by the belt 3. As the sheet approaches the inlet of the fixing station, the charge thereof is reduced to in turn reduce the electrostatic force acting between the sheet and the belt 3. Consequently, the sheet is separated from the belt 3 by the roller 7 connected to ground and having a small diameter and the elasticity of the sheet. Then, the toner image carried on the sheet is fixed at the fixing station. Preferably, the roller 7 has a diameter ranging from 14 mm to 16 mm.

As soon as the trailing edge of the sheet moves away from the nip portion between the drum 1 and the belt 3, the solenoid 9 is deenergized to retract the lever 10 and, therefore, the belt assembly including the belt 3 and rollers 4-7. As a result, the belt 3 is brought out of contact with the drum 1. This is to protect the drum 1 from deterioration while the transfer of a toner image is not performed.

While the belt 3 is in rotation, the toner scattered around from the drum 1 without being transferred to the sheet is directly deposited on the belt 3. This part of the toner has the charge thereof reduced by the rollers 6 and 7 connected to ground and then scraped off by a cleaning blade 11 into a collecting bottle 12.

In the illustrative embodiment, only the bias roller 5 deposits a charge on the belt 3. When the bias voltage from the power source is applied not only to the bias roller 5 but also to the drive roller 4, the potential distribution on the belt 3 has a linear gradient in a portion T between the rollers 4 and 5. Experiments showed that the belt 3 fails to electrostatically retain a sheet thereon as the water content of the sheet is as great as 8 % to 11 % due to a hot and humid environment. By contrast, when the bias voltage is applied only to the bias roller 5 as shown in FIG. 9, the embodiment insures the separation of the sheet from the drum 1 as shown in FIG. 3. This is presumably because when the charge is applied by the drive roller 4 contacting the belt 3 at a position upstream of the drum 1, the charge penetrates into the leading edge of the sheet as the water content of the sheet increases, preventing the sheet from electrostatically adhering to the belt 3.

When the drive roller 4 does not apply a charge to the belt 3 as in the embodiment, a charge does not penetrate into the leading edge of a sheet being transported by the belt 3. Hence, a repulsive force is not generated between the belt 3 and the sheet which would prevent the sheet from being fully separated from the drum 1.

FIG. 4 shows a second embodiment of the present invention. As shown, the drive roller 4 plays the role of a bias roller or bias electrode at the same time. The drive roller 4 is connected to ground via a varistor, Zener diode or similar constant voltage element 13. While the bias voltage to be applied to the bias roller is open to choice, it should preferably be close to the bias voltage to be applied to the downstream bias roller 5.

Specifically, in this embodiment, the bias voltage from the power source 8 is applied to the downstream bias roller 5. The upstream bias roller 4 is maintained at substantially the same potential as the downstream bias roller 5. This is successful in maintaining the potential at the position where the drum 1 and belt 3 contact stable and, therefore, insuring desirable toner image transfer with no regard to, for example, irregularities in the resistance of the belt 3. In addition, the charge injection into the sheet in a humid environment is reduced to promote sure separation of the sheet from the drum 1. Particularly, since this embodiment is even more stable than the first embodiment regarding the transfer of the toner image, the bias voltage to be applied from the power source 8 to the bias roller 5 can be low.

Referring to FIG. 5, a third embodiment of the present invention will be described which is similar to the first embodiment except for the following. The drive roller 4 plays the role of a bias roller or bias electrode. As shown in FIG. 10, a power source 14 starts applying a bias voltage to the drive roller 4 at the time when the sheet enters the nip portion between the drum 1 and the belt 3 and contacts the drum 1. Again, as shown in FIG. 19, the potential distribution of the belt 3 has a linear gradient in the portion T.

The third embodiment, like the first embodiment, enhances the separation of the sheet from the drum 1 and transfers the toner image to the sheet stably with no regard to irregularities in the resistance of the belt 3. Consequently, the belt 3 can be produced and selected at a high yield.

FIG. 6 shows a fourth embodiment of the present invention which is similar to the third embodiment except for a variable power source 15 substituted for the power source 14. As shown in FIG. 11, the variable power source 15 applies a bias voltage lower than the bias voltage to the bias roller 5 to the bias roller 4 and at the same time as the voltage to the bias roller 5. As soon as the leading edge of the sheet enters the nip portion between the drum 1 and the belt 3, the power source 15 applies the same bias voltage as applied to the bias roller 5 to the bias roller 4. The resulting potential distribution of the belt 3 is shown in FIG. 20.

As stated above, the fourth embodiment maintains the bias voltage to the bias roller 4 lower than the bias voltage to the bias roller 5 until the leading edge of the sheet enters the nip portion between the drum 1 and the belt 3. This also enhances the separation of the sheet from the drum 1.

FIG. 7 shows a fifth embodiment of the present invention which is similar to the first embodiment except that a power source 16 applies a bias voltage to the bias rollers 4 and 5 at a timing shown in FIG. 12. Specifically, the power source 16 starts applying a bias voltage to the bias rollers 4 and 5 at the time when the leading edge of the sheet has moved a predetermined distance shorter than 8 mm away from the nip between the drum 1 and the belt 3. As a result, the toner image is not transferred to the sheet over the predetermined distance as measured from the leading edge thereof. Specifically, the sheet is simply left blank over several millimeters as measured from the leading edge thereof. However, the sheet is surely separated from the belt 3 at the inlet of the fixing station, causing the toner image to be fixed there. In this case, the belt 3 has a potential gradient shown in FIG. 21.

FIG. 8 is representative of a sixth to an eighth embodiment corresponding to the third to fifth embodiments, respectively. As shown, in the sixth to eighth embodiments, the distance LA between the nip portion between the drum 1 and the belt 3 and the bias roller 4 is selected to be shorter than the distance LB between the nip portion and the bias roller 4. The power source 8, 15 or 16 starts applying the bias voltage to the bias roller 4 or 5 when the leading edge of the sheet has moved to a point A which is downstream of the roller 4 by the distance LB. Such alternative embodiments are also successful in surely separating the sheet from the drum 1.

A ninth embodiment of the present invention is similar to the third embodiment of FIG. 5 except that the time for applying the bias voltage to the bias roller 4 is adjustable at the outside of the apparatus. While the third embodiment starts applying the bias voltage to the bias roller 4 from the power source 14 after the sheet has contacted the drum 1, it is likely that the sheet transport control differs from one machine to another or changes within the same machine due to the wear of a sheet transport system. When the time for applying the bias voltage to the upstream bias roller 4 is too early, a charge is apt to deposit on the belt 3 before the sheet contacts the drum 1, making the separation of the sheet from the drum 1 unstable in a humid environment. Conversely, when the above-mentioned time is too late, the bias voltage from the power source 14 is applied to the bias roller 4 after the leading edge of the sheet has moved away from the nip portion between the drum 1 and the belt 3. Then, it is likely that the toner image cannot be surely transferred to the leading edge portion of the sheet when the belt 3 has a resistance component. In the light of this, the ninth embodiment allows the time for applying the bias to the bias roller 4 to be changed at the outside of the apparatus.

FIG. 13 shows circuitry for implementing the ninth embodiment. As shown, a main control section 17 has a CPU (Central Processing Unit 18, a ROM (Read Only Memory) 19, a RAM (Random Access Memory) 20, an input circuit 21, a load driver 22, and a system control interface (I/F) 23. A system controller 24, a high tension power source 25 and an operating section (SP mode) 26 are connected to the main control section 17. A serviceman, for example, manipulates the operating section 26 to condition the apparatus for a serviceman program (SP) mode and again manipulates it to enter an adjusting value associated with the application of the bias voltage to the bias roller 4.

The ROM 19 stores a program according to which the CPU 18 operates. As a signal indicative of the SP mode is entered on the operating section 26 and applied to the CPU 18 via the input circuit 21, the CPU 18 sets up the SP mode. When the adjusting value associated with the application of the bias voltage is entered on the operating section 26, it is written to the RAM 20 which is backed up by a battery. The CPU 18 adjusts the time for applying the bias voltage to the bias roller 4 from the power source 14 via the load driver 22 on the basis of the adjusting value stored in the RAM 20. If desired, in the fourth to eighth embodiments, the time for applying the the bias to the upstream bias roller 4 may also be adjusted at the outside of the apparatus to insure both of sure image transfer and sure sheet separation.

Referring to FIG. 14, circuitry representative of a tenth embodiment of the present invention is shown. As shown, a main control section 26 has a CPU 27, a ROM 28, a RAM 29, an input section 30, a load driver 31, and a system control I/F 32. A system controller 33, a high tension power source 34 and a humidity sensor 35 are connected to the main control section 26. Located in close proximity to the sheet feed device, the humidity sensor senses humidity around sheets stacked in the sheet feed device. During an ordinary mode operation (e.g. during copying), as the humidity sensor 35 sends a humidity signal to the CPU 27 via the input circuit 30, the CPU 27 determines whether or not the sensed humidity is higher than a predetermined humidity, e.g., 70 % in terms of relative humidity. If the actual humidity is higher than the predetermined one, the CPU 27 retards the time for applying the bias voltage to the bias roller 4 from the power source 14 via the load driver 31, i.e., causes the power source 14 to start applying the bias voltage to the roller 4 after the sheet has contacted the drum 1.

When the sensed humidity is lower than 70 %, the CPU 27 causes the power source 14 to start applying the bias voltage to the bias roller 4 at the same time as the power source 8 applies the bias voltage to the bias roller 5 via the load driver 31. In this configuration, even when the water content of the sheet is high due to high humidity, the charge injection from the upstream bias roller 4 into the sheet does not occur, so that the sheet is stably separated from the drum 1. After the leading edge of the sheet has been separated from the drum 1, the bias rollers 4 and 5 inject charges into the sheet. Hence, the toner image is stably transferred to the sheet at the rear of the leading end portion of the belt 3. So long as the humidity is lower than 70 %, the separation of the sheet from the drum 1 is satisfactory. Since the bias rollers 4 and 5 sequentially deposit a charge on the sheet, the toner image is stably transferred from the leading edge toward the trailing edge of the sheet at all times.

The above-stated advantages of the tenth embodiment are also achievable with an absolute humidity sensor in place of the relative humidity sensor. If desired, the humidity sensor may be used in combination with a temperature sensor to control the time for applying the bias voltage from the power source 14 to the bias roller 4. Further, the humidity sensor scheme of the tenth embodiment is also applicable to the fourth to eighth embodiments, if desired.

FIG. 15 shows an eleventh embodiment which is similar to the fifth embodiment except that the bias roller 4 is provided with a surface layer 4a made of a dielectric material. The surface layer 4a has a specific volume resistivity of, for example, 10^6 Ωcm to 10^{12} Ωcm and a thickness of 0.2 mm to 3 mm. The rollers 5 and 7 contacting the belt 3 at positions downstream of the drum 1 are made of metal. As the power source 16 applies a voltage to the bias rollers 4 and 5, the rollers 4 and 5 sequentially deposit a voltage on the belt 3 to maintain the potential at the portion where the belt 3 contacts the drum 1 stable, thereby insuring desirable transfer of the toner image. Since the bias roller 5 deposits a charge on the belt 3 more efficiently than the bias roller 4, the charge injection from the upstream bias roller 4 into the sheet sparingly occurs in a humid environment. This promotes sure separation of the sheet from the drum 1 in such a humid environment. Again, as shown in FIG. 19, the potential distribution of the belt 3 has a linear gradient in the portion T between the portions where the rollers 4 and 5 contact the belt 3.

FIG. 16 shows a twelfth embodiment of the present invention. As shown, this embodiment is similar to the eleventh embodiment except that a bias roller 36 is held in contact with the rear of the belt 3 at the position where the belt 3 contacts the drum 1, and in that the power source 16 applies a voltage to a bias roller 36 as well as to the roller 5.

The bias roller 36 has a surface layer made of an elastic dielectric material. For example, the surface layer of the roller 36 is made of a material having a specific volume resistivity of 10^6 Ωcm to 10^{12} Ωcm and a hardness less than 50° in terms of modulus hardness.and provided with a thickness of greater than 1 mm. As shown in FIG. 19, the potential of the belt 3 linearly changes in the portion T between the portions where the rollers 4 and 5 contact the belt 3.

As the power source 16 applies a voltage to the bias rollers 36 and 5, the rollers 36 and 5 each efficiently deposits a charge on the belt 3 even when the transfer voltage in the position where the belt 3 contacts the drum 1 is low. High transfer voltages are apt to cause an image to be locally omitted when transferred to a sheet. Since the surface layer of the bias roller 36 has a medium resistance, there can be eliminated the damage to the bias roller 36 and belt 3 due to the leakage of the charge and, therefore, the resulting defective image transfer. Moreover, since the charge deposition on the belt 3 by the bias rollers 36 and 5 does not occur at the upstream side with respect to the transfer station, no charges are injected into the sheet in a humid environment before the image transfer, insuring positive sheet separation.

In the embodiments shown and described, the transfer belt 3 may be replaced with a transfer roller, if desired. The transfer roller is as effective as the belt 3 regarding the stable sheet separation and, in addition, frees the sheets from the trace of a separator, creases and jams.

A thirteenth embodiment and successive embodiments to be described pertain to an image forming apparatus of the type including a carrier which transports a toner transferred thereto by the first transferring step to the second transferring step. The carrier may be implemented as a rotatable intermediate transfer body for carrying a toner image transferred from the image carrier and transporting it to a stage where the toner image should be transferred to a sheet or similar transfer medium. The carrier shares the same technical concept with the other carriers of the kind transporting an object while electrostatically retaining it thereon. The embodiments to be described will concentrate on an intermediate transfer belt by way of example.

FIG. 25 shows a thirteenth embodiment of the present invention implemented as an electrophotographic copier. FIG. 26 is an enlarged view of a photoconductive drum and an intermediate transfer belt included in the embodiment as well as members surrounding them. As shown, the color copier has a color scanner 101 including a lamp 104. As the lamp 104 illuminates a document 103 laid on a glass platen 102, the resulting reflection from the document 103 is focused onto a color image sensor 109 via mirrors 105-107 and a lens 108. The color image sensor 109 reads the color image data by separating them into blue, green and red and converts them to corresponding electric signals. In the illustrative embodiment, the color image sensor 109 is made up of blue (B), green (G) and red (R) color separating means and a CCD array or similar photoelectric transducer so as to read the three different colors at the same time. B, G and R image signals from the image sensor 109 are converted to black (BK), cyan (C), magenta (M) and yellow (Y) color image data by an image processor, not shown, on the basis of their intensity levels.

A color image recorder, or color printer as referred to hereinafter, 110 forms BK, C, M and Y toner images on the basis of the color data from the image processor thereof, thereby producing a color copy. As a control section sends a scanner start signal synchronous to the operation of the color printer 110 to the scanner 101, the lamp 104 and optics 105-107 included in the scanner 101 are moved to the left, as indicated by an arrow in FIG. 25. As the scanner 101 scans the document 103 once, image data of one color is produced. The scanner 101 repeats the scanning movement four consecutive times, producing BK, C, M and Y image data in succession. Every time the scanner 101 produces image data of one color, the color printer 102 forms a toner image of corresponding color. The toner images of four different colors are sequentially superposed to complete a full-color image.

The color printer 110 will be described specifically. An optical writing unit 111 converts the color image data from the image processor to an optical signal and then optically writes an image representative of the document image on a photoconductive drum 112 to thereby form an electrostatic latent image. The writing unit 111 includes a laser 113, a laser driver, not shown, for controlling the emission of the laser 113, a polygonal mirror 114, a motor 115 for driving the mirror 114, an f-theta lens 116, and a mirror 117. The drum 112 is rotatable counterclockwise, as indicated by an arrow in FIG. 25. Arranged around the drum 112 are a cleaning unit (including a precleaning discharger 118) 119, a discharge lamp 120, a main charger 121, a potential sensor 122, a BK developing unit 123, a C developing unit 124, an M developing unit 125, a Y developing unit 126, a density pattern sensor 127, and an intermediate transfer belt 128. As shown in FIG. 26, the developing units 123-126 have respectively developing sleeves 123a, 124a, 125a and 126a rotatable in contact with the drum 112, paddles 123b, 124b, 125b and 126b rotatable for scooping and agitating associated developers, and toner concentration sensors 123c, 124c, 125c and

126c responsive to the toner concentrations of associated developers. In a standby state, all of the four developing units 123-126 maintain the developers on their sleeves 123a-126a in an inoperative position. Let the developing units 123-126 be assumed to develop latent images in this order, i.e., in BK, C, M and then Y by way of example.

At the beginning of a copying procedure, the drum 112 is rotated and has the surface thereof uniformly charged by the main charger 121. At a predetermined time, the color scanner 101 starts reading the document 103 to produce BK image data. As the BK image data is applied to the writing unit 111 via the image processor, the unit 111 scans the charged surface of the drum 112 by a laser beam to electrostatically form a latent image thereon. Let the latent image derived from the BK image data be referred to as a BK latent image. Likewise, let latent images resulting from C, M and Y image data be referred to as a C latent image, an M latent image, and a Y latent image, respectively. To develop the BK latent image from the leading edge thereof, the sleeve 123a starts rotating before the leading edge of the image reaches a developing position where the BK developing unit 123 faces the drum 112. As a result, the developer on the sleeve 123a is brought to an operative position to cause a BK toner contained therein to develop the BK latent image. As soon as the trailing edge of the BK latent image moves away from the BK developing position, the developer on the sleeve 123a is restored to the inoperative position. This is completed at least before the leading edge of the next latent image, i.e., the C latent image arrives at the BK developing position. To restore the developer to the inoperative position, the sleeve 123a is reversed. At this instant, the other developing units 124-126 are not operated.

The BK toner image formed on the drum 112 is transferred to the surface of the intermediate transfer belt 128 being moved at the same speed as the drum 112. The transfer of the toner image from the drum 112 to the intermediate transfer belt 128 will be referred to as belt transfer for simplicity. The belt transfer is effected by applying a predetermined bias voltage to bias rollers of bias electrodes 129 and 130 while the drum 112 and belt 128 are held in contact. Alter the transfer of the BK toner image, the cleaning unit 119 including the precleaning discharger 118 removes the charge and toner remaining on the drum 112. Then, the main charger 121 again uniformly charges the drum 112. The BK, C, M and Y toner images sequentially formed on the drum 112 are transferred one after another to the same surface of the belt 128 and in register with one another, completing a four-color belt transfer image. The belt transfer image is collectively transferred from the belt 128 to a sheet. The construction and operation of an intermediate transfer belt unit including the belt 128 will be described in detail later.

The step of forming the BK image is followed by a step of forming a C image. The color scanner 101 starts reading the document 103 at a predetermined time to generate C image data. The C image data is fed to the writing unit 111 by way of the image processor. In response, the writing unit 111 forms a C latent image on the drum 112 by a laser beam. After the trailing edge of the BK latent image has passed the developing position of the C developing unit 124 and before the leading edge of the C latent image reaches it, the developing unit 124 has the sleeve 124a thereof rotated to bring the developer to the operative position. As a result, the C latent image is developed by a C toner contained in the developer. When the trailing edge of the C latent image has moved away from the C developing unit 124, the developer on the sleeve 124a is brought to the inoperative position. Again, this is completed before the leading edge of an M latent image reaches the C developing unit 124. The C toner image formed on the drum 112 is transferred to the surface of the belt 128 being driven at the same speed as the drum 112.

After the formation of the C image, the color scanner 101 starts reading the document 103 at a predetermined time to generate M image data. As the M image data is fed to the writing unit 111 via the image processor, the writing unit 111 forms an M latent image on the drum 112 by a laser beam. After the trailing edge of the C latent image has passed the developing position of the M developing unit 125 and before the leading edge of the M latent image reaches it, the developing unit 125 has the sleeve 125a thereof rotated to bring the developer to the operative position. As a result, the M latent image is developed by an M toner contained in the developer. When the trailing edge of the M latent image has moved away from the M developing unit 125, the developer on the sleeve 125a is brought to the inoperative position. Again, this is completed before the leading edge of a Y latent image reaches the M developing unit 125. The M toner image formed on the drum 112 is transferred to the surface of the belt 128 being driven at the same speed as the drum 112. After the transfer of the M toner image, the drum 112 is discharged and cleaned by the cleaning unit 11 including the precleaning discharger 118 and again uniformly charged by the main charger 121.

The step of forming the M image is followed by a step of forming a Y image. The color scanner 101 starts reading the document 103 at a predetermined time to generate Y image data. As the Y image data is fed to the writing unit 111 via the image processor, the writing unit 111 forms a Y latent image on the drum 112 by a laser beam. After the trailing edge of the M latent image has passed the developing position of the Y developing unit 126 and before the leading edge of the Y latent image reaches it, the developing unit 126 has the sleeve 126a thereof rotated to bring the developer to the operative position. As a result, the Y latent image is developed by a Y toner contained in the developer. When the trailing edge of the Y latent image has moved away from the Y developing unit 126, the developer on the sleeve 126a is brought to the inoperative position. This is completed after the trailing edge of the Y image has reached the Y developing unit 126. The Y toner image formed on the drum 112 is transferred to the surface of the belt 128 being driven at the same speed as the drum 112.

As shown in FIG. 26, the intermediate transfer belt 128 is passed over a drive roller 131, bias rollers 129 and 130, and driven rollers 132-134. The drive roller 131 is driven by a motor, not shown, to move the belt 128. A belt cleaning unit 135 has a brush roller 135a, a rubber blade 135b, and a mechanism 135c for moving the unit 135 into and out of contact with the belt 128. After the transfer of the first image or BK image to the belt 128, the brush roller 135a and rubber blade 135b are spaced apart from the bias roller 129 by the mechanism 135c while the transfer of C, M and Y images to the belt 128 is under way. A sheet transfer unit 136 has a bias roller 136a, a roller cleaning blade 136b, and a mechanism 136c for moving the unit 136 into and out of contact with the belt 128. The bias roller 136a is usually spaced apart from the belt 128. At the time when the four-color composite image is to be transferred from the belt 128 to a sheet, the mechanism 136c urges the bias roller 136a against the belt 128. In this condition, a predetermined bias voltage is applied from a bias power source to the bias roller 136a to transfer the four-color image from the belt 128 to a sheet being transported through between the roller 136a and the belt 128. Specifically, as shown in FIG. 25, a sheet is fed from one of a plurality of cassettes 137-140 to a register roller 145 by associated one of pick-up rollers 141-144, or it is fed from a manual sheet feed tray 146 by a pick-up roller 141 to the register roller 145. The register roller 145 drives the sheet such that the leading edge thereof meets the leading edge of the four-color image carried on the belt 128.

Now, after the first or BK toner image has been entirety transferred to the belt 128, the belt 128 may be moved in any one of the following three modes or any combination thereof (matching the copy size).

[I] Constant Speed Forward Mode

(1) Even after the belt transfer of the BK toner image, the belt 128 is moved at a constant speed in the forward direction.
(2) The second or C toner image is formed on the drum 112 such that just when the leading edge of the BK image carried on the belt 128 reaches the belt transfer position where the belt 128 and drum 112 contact, the leading edge of the C toner image arrives at such a position. As a result, the C image is transferred to the belt 128 in accurate register with the BK image.
(3) The above procedure is repeated to sequentially form and transfer the M and Y images to complete a four-color image on the belt 128.
(4) After the belt transfer of the fourth or Y toner image, the belt 128 is continuously moved forward to collectively transfer the four-color image to a sheet.

[II] Skip Forward Mode

(1)After the belt transfer of the BK toner image, the belt 128 is moved away from the drum 112, caused to skip at high speed in the forward direction over a predetermined distance, and then restored to the initial speed. Thereafter, the belt 128 is again brought into contact with the drum 112.
(2) The C toner image is formed on the drum 112 such that just when the leading edge of the BK image on the belt 128 again arrives at the belt transfer position, the leading edge of the C image reaches such a position. Consequently, the C image is transferred to the belt 128 in accurate register with the BK image.
(3) The above procedure is repeated to sequentially form and transfer the M and Y images to complete a four-color image on the belt 128.
(4) After the belt transfer of the fourth or Y toner image, the belt 128 is continuously moved forward to collectively transfer the four-color image to a sheet.

[III] Reciprocation (or Quick Return) Mode

(1) After the belt transfer of the BK toner image, the belt 128 is moved away from the drum 112 and then brought to a stop and, at the same time, returned at high speed in the reverse direction. The quick return of the belt 128 ends when the leading edge of the BK image on the belt 128 has moved a predetermined distance away from the belt transfer position.
(2) When the leading edge of the C toner image formed on the drum 12 reaches a position slightly short of the belt transfer position, the

belt 128 is again driven forward and brought into contact with the drum 112. The C image is also accurately superposed on the BK image on the belt 128.

(3) The above procedure is repeated to sequentially form and transfer the M and Y images to complete a four-color image on the belt 128.

(4) After the belt transfer of the fourth or Y toner image, the belt 128 is continuously moved forward at the same speed without being returned, thereby collectively transferring the four-color image to a sheet.

As shown in FIG. 25, the sheet carrying the four-color toner image is transported to a fixing unit 148 by a sheet transport unit 147. In the fixing unit 148, a heat roller 148a controlled to a predetermined temperature and a pressure roller 148b cooperate to fix the toner image on the sheet by heat and pressure. Finally, the sheet with the fixed toner image is driven out to a copy tray 149 as a full-color copy. As shown in FIG. 26, after the belt transfer, the drum 112 is uniformly discharged by the precleaning discharger 118 and then cleaned by the brush roller 119a and rubber blade 119b. On the other hand, the belt 128 completed the image transfer is cleaned by the cleaning unit 136 which is pressed against the belt 128 by the mechanism 136c.

In a repeat copy mode for repetitively copying the document 103, the operation of the color scanner 101 and the image formation on the drum 112 begin after the fourth or Y image for the first copy has been formed. Then, a step of forming the first or BK image for the second copy begins at a predetermined time. After the four-color image has been transferred to the first sheet, the belt 128 has the surface thereof cleaned by the cleaning unit 135. The BK toner image for the second copy is transferred to the cleaned surface of the belt 128. Such a procedure is repeated thereafter.

The cassettes 137-140 are each loaded with sheets of particular size. As the operator selects one of the cassettes 137-140 on an operation panel, not shown, sheets are sequentially fed from the cassette selected to the register roller 145 by associated one of the pick-up rollers 141-144. The manual feed tray 146 may be used to insert OHP sheets or relatively thick sheets by hand.

The above description has concentrated on a four- or full-color copy. In a three-color or two-color copy mode, the procedure stated above will be performed with each of the colors selected on the operation panel a desired number of times. In a single color or monocolor copy mode, only one of the developing units matching the desired color will be held operative until a predetermined number of copies have been produced. In this case, the belt 128 will be moved forward at constant speed in contact with the drum 112, and the belt cleaning unit 135 will also be held in contact with the belt 128.

In this embodiment, as shown in FIG. 22, the belt 128 is held in contact with the drum 112 to transfer the toner image from the drum 112 to the belt 128. At this instant, the bias roller 129 is located upstream of a point A where the belt 128 and drum 112 contact, while the bias roller 130 is located downstream of a point B where the belt 128 and drum 112 contact. A transfer potential is applied to the bias roller 130 located at the outlet side (downstream) of the contact point B, while a potential lower than that transfer potential is applied to the bias roller 130 located at the inlet side (upstream) of the contact point A. For example, 700 V and 0 V are applied to the bias rollers 130 and 129, respectively. As a result, as shown in FIG. 23, a potential gradient is also set up in the region where the drum 112 and belt 128 contact. This eliminates discharge in the pretransfer region which would disturb image transfer and, at the same time, insures the separation of a sheet with no regard to the environment. FIG. 24 is a graph showing a relation between the potential between the bias roller 129 and the contact point A and the sharpness of an image. As shown, if the potential between the bias roller 129 and the contact point A is maintained lower than 300 V, there can be reduced pretransfer, i.e., the flight of toner occurring before the belt 128 and drum 112 contact in the event of image transfer. The resulting image is free from thickened lines, blurred characters, degraded sharpness, etc.

As FIG. 24 indicates, a desirable degree of sharpness is attainable if the potential between the bias roller 129 and the contact point A is lower than 300 V. The bias rollers 129 and 130 may each be provided with a desired reference potential which sets up the potential lower than 300 V between, the bias roller 129 and the contact point A, if desired.

FIG. 27 shows a modification of the above embodiment in which the bias roller 129 and the other rollers 131-134 are connected to ground. In the modification, a transfer potential higher than the ground level is applied to the bias roller 130 from a variable transfer power source 150. This embodiment also reduces pretranfer and, in addition, simplifies the structure since the bias roller 129 is connected to ground.

FIG. 28 shows another alternative embodiment which is similar to the embodiment of FIG. 27 except that the bias roller 129 is electrically floating, and that a roller 151 is held in contact with the belt 128 at a position upstream of the bias roller 129. The roller 151 is connected to ground. Although the bias roller 129 increases the potential at the contact point A when electrically floating as illustrated than when connected to ground, it is possible to lower the transfer voltage to be applied to the bias roller 130.

FIG. 29 shows another alternative embodiment which is similar to the embodiment of FIG. 28 except that a transfer power source 152 applies to the bias roller 129 a voltage lower than the voltage of the variable power source 150 and of the same polarity as the toner (negative in this case). The voltage applied from the power source 152 to the bias roller 129 generates an electric field of polarity opposite to the polarity of the toner on the drum 112. As a result,the toner on the drum 112 is prevented from flying from the belt 128 side, so that an attractive image is insured.

FIG. 30 shows another alternative embodiment which is similar to the embodiment of FIG. 29 except that the transfer power source 152 is replaced with a variable transfer power source 153. The variable power source 153 applies a voltage of the same polarity as the toner to the bias roller 129, as in the embodiment of FIG. 29. Such a voltage generates an electric field opposite in polarity to the toner on the drum 112. As a result, the toner on the drum 112 is prevented from flying from the belt 128 side, so that an attractive image is insured. Generally, as the belt 128 is repetitively used, a film of toner 154 is formed on the surface of the belt 128 (so-called toner filming). The film 154 is undesirable since it lowers the effective potential of the voltage. In such a case, the output voltage of the variable power source 15 will be increased to prevent the toner from flying.

FIG. 31 shows still another alternative embodiment which is similar to the embodiment FIG. 30 except that a potential sensor 155 and a power source control circuit 156 are provided, and that the roller 151 is omitted. The variable power source 153 applies a voltage of the same polarity as the toner to the bias roller 129, as in the embodiment of FIG. 29. This voltage generates an electric field opposite in polarity to the toner on the drum 112. As a result, the toner is prevented from flying from the belt 128 side, so that an attractive image is insured. Generally, as the drum 112 is repetitively used, the potential remaining thereon sequentially increases. The increase in the residual potential lowers the effective potential of the above-mentioned reverse electric field. Then, the output voltage of the variable power source 153 will be controlled on the basis of the output of the potential sensor 155 by the power source control circuit 156, depositing an adequate potential on the belt 128.

FIG. 32 shows a further alternative embodiment which is similar to the embodiment of FIG. 32 except that the variable transfer power source 153 is replaced with a variable positive/negative power source 153A, and that a power source control circuit 157 is provided. In the illustrative embodiment, to produce a two-color, three-color or four-color copy, the power source control circuit 157 switches the positive/negative power source 153A in response to a copy mode signal sent from a controller which controls the entire embodiment. Specifically, When the toner image of first color is to be transferred from the drum 112 to the belt 128, the control circuit 157 selects a variable transfer power source 153b and applies a negative voltage, i.e., a potential of the same polarity as the toner to the bias roller 129. In the step of transferring the toner image of second color from the drum 112 to the belt 128 and successive steps, when the potential opposite in polarity to the toner is used, the toner deposited on the belt 128 by the first transfer step will fly since the polarity thereof is negative. To eliminate this occurrence, the control circuit 157 selects the other variable transfer power source 153a and applies a positive voltage to the bias roller 129, i.e., switches the potential of the belt 128 to 0 V or positive potential.

In summary, it will be seen that the present invention provides an Image forming apparatus having various unprecedented advantages, as enumerated below

(1) An image can be desirably transferred without any degradation, and a transfer medium can be surely separated.

(2) The separation of the transfer medium is not effected by the environment.

(3) Desirable image transfer is achievable with no regard to irregularities in the resistance of a transfer belt.

(4) Although sheet transport control changes from one machine to another or within the same machine due to aging, an image can be surely transferred.

(5) There can be eliminated the damage to electrodes and transfer belt due to charge leakage and, therefore, defective image transfer ascribable to such damage.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

Claims

1. An image forming apparatus comprising;

a photoconductive element for forming a toner image thereon;

a transfer medium movable in contact with said photoconductive element over a predetermined nip width to allow the toner image to be transferred from said photoconductive element to said transfer medium;

transfer bias applying means for applying a predetermined transfer bias to said transfer medium; and

potential gradient generating means for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from said photoconductive element to said transfer medium increases in a region upstream of a transfer region with respect to said photoconductive element and terminating at a point where said photoconductive element and said transfer medium begin to contact each other.

2. An apparatus as claimed in claim 1, wherein said transfer bias applying means comprises an electrode contacting said transfer medium at a position downstream of the nip portion with respect to an intended direction of movement of said transfer medium;

said potential gradient generating means comprising an electrode contacting said transfer medium at a position upstream of said nip portion with respect to the intended direction of movement of said transfer medium.

3. An apparatus as claimed in claim 2, wherein said potential gradient generating means is applied with a bias having a potential which prevents the toner image from being transferred from said photoconductive element to said transfer medium.

4. An apparatus as claimed in claim 2, wherein said potential gradient generating means is connected to ground.

5. An apparatus as claimed in claim 2, wherein said potential gradient generating means is connected to ground via a constant voltage element.

6. An apparatus as claimed in claim 2, wherein said potential gradient generating means is electrically floating.

7. An apparatus as claimed in claim 3, wherein said potential gradient generating means is applied with a potential of the game polarity as the toner image, said transfer bias applying means being applied with a potential opposite in polarity to a toner.

8. An apparatus as claimed in claim 3, wherein at least one of the bias potentials applied to said potential gradient generating means and said transfer bias applying means is variable.

9. An apparatus as claimed in claim 8, further comprising sensing means for sensing a condition of said photoconductive element, the bias voltage to be applied to said potential gradient generating means being varied in response to an output of said sensing means.

10. An apparatus as claimed in claim 1, wherein said transfer medium comprises a sheet carried on and transported by a transfer belt which contacts said photoconductive element over a predetermined nip width.

11. An apparatus as claimed in claim 10, wherein the bias potential is applied to said potential gradient generating means after the sheet has contacted said photoconductive element.

12. An apparatus as claimed in claim 11, wherein a time for applying the bias potential to said potential gradient generating means is variable.

13. An apparatus as claimed in claim 12, further comprising:

humidity sensing means for sensing humidity; and

control means responsive to an output of said humidity sensing means for adjusting the time for applying the bias potential to said potential gradient generating means when humidity is higher than a predetermined value or not adjusting said time when humidity is lower than said predetermined value.

14. An apparatus as claimed in claim 10, wherein said potential gradient generating means contacts said transfer belt at a position upstream of the nip portion and is applied with a bias lower than the transfer bias before the sheet contacts said photoconductive element and then applied with a bias substantially equal to said transfer bias after said sheet has contacted said photoconductive element.

15. An apparatus as claimed in claim 14, wherein a time for applying the bias potential to said potential gradient generating means is variable.

16. An apparatus as claimed in claim 15, further comprising:

humidity sensing means for sensing humidity; and

control means responsive to an output of said humidity sensing means for adjusting the time for applying the bias potential to said potential gradient generating means when humidity is higher than a predetermined value or not adjusting said time when humidity is lower than said predetermined value.

17. An apparatus as claimed in claim 10, wherein said potential gradient generating means contacts said transfer belt at a position upstream of the nip portion;

said transfer bias applying means and said photoconductive element being spaced apart by a distance shorter than a distance between said potential gradient generating beans and said photoconductive element;

said potential gradient generating means being applied with a bias after the sheet has been transported by said transfer belt over a distance exceeding the distance between said bias applying means and said photoconductive element.

18. An apparatus as claimed in claim 17, wherein a time for applying the bias potential to said potential gradient generating means is variable.

19. An apparatus as claimed in claim 18, further comprising;

humidity sensing means for sensing humidity; and

control means responsive to an output of said humidity sensing means for adjusting the time for applying the bias potential to said potential gradient generating means when humidity is higher than a predetermined value or not adjusting said time when humidity is lower than said predetermined value.

20. An image forming apparatus comprising:

a photoconductive element for forming a toner image thereon;

a transfer belt movable in contact with said photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from said photoconductive element to said sheet;

transfer potential bias applying means for applying a predetermined transfer bias to said transfer belt;

potential gradient generating means for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from said photoconductive element to said sheet increases in a region upstream of a nip portion with respect to said photoconductive element and terminating at a point where said photoconductive element and said transfer belt begin to contact each other; and

bias applying means for applying a bias to said potential gradient generating means after the sheet has moved a predetermined distance away from the nip portion.

21. An apparatus as claimed in claim 20, wherein a time for applying the bias potential to said potential gradient generating means is variable.

22. An apparatus as claimed in claim 21, further comprising:

humidity sensing means for sensing humidity; and

control means responsive to an output of said humidity sensing means for adjusting the time for applying the bias potential to said potential gradient generating means when humidity is higher than a predetermined value or not adjusting said time when humidity is lower than said predetermined value.

23. An image forming apparatus comprising:

a photoconductive element for forming a toner image thereon;

a transfer belt movable in contact with said photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from said photoconductive element to said sheet;

transfer bias applying means contacting said transfer belt at a position downstream of said photoconductive element for applying a predetermined bias to said transfer belt; and

potential gradient generating means having a dielectric layer on a surface thereof and contacting said transfer belt at a position upstream of said photoconductive element for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from said photoconductive element to the sheet increases in a region upstream of the nip portion with respect to said photoconductive element and terminating at a point where said photoconductive element and said transfer belt contact each other.

24. An image forming apparatus comprising:

a photoconductive element for forming a toner image thereon;

a transfer belt movable in contact with said photoconductive element over a predetermined nip width for transporting a sheet to allow the toner image to be transferred from said photoconductive element to said sheet;

transfer bias applying means contacting said transfer belt at a position downstream of said photoconductive element for applying a predetermined bias to said transfer belt; and

potential gradient generating means having an elastic dielectric layer on a surface thereof and contacting a rear Of said transfer belt in a position upstream of said photoconductive element for providing the transfer bias with a potential gradient such that an amount of transfer of the toner image from said photoconductive element to the sheet increases in a region upstream of the nip portion with respect to said photoconductive element and terminating at a point where said photoconductive clement and said transfer belt contact each other.

25. An image forming apparatus comprising;

a photoconductive element for forming a toner image thereon;

a transfer medium contacting said photoconductive element over a predetermined nip width in a transfer region and undergoing a step of transferring the toner image formed on said photoconductive element a plurality of times;

a first electrode contacting said transfer medium at a position downstream of the transfer region;

a second electrode contacting said transfer medium at a position upstream of the transfer region; and

potential gradient generating means for providing the transfer bias with a potential gradient by applying a transfer bias to said first electrode or both of said first electrode and said second electrode, and applying, when a toner is absent on said transfer medium, a bias of the same polarity as the toner to said second electrode or applying, when the toner is present on said transfer medium, a bias of opposite polarity to the toner to said second electrode, such that an amount of transfer of the toner image from said photoconductive element to said transfer medium increases in a region upstream of a transfer region with respect to said photoconductive element and terminating at a point where said photoconductive element and said transfer medium contact each other.

26. An apparatus as claimed in claim 25, wherein said transfer medium comprises an intermediate transfer belt for directly carrying the toner thereon and carrying a toner of particular color in each of a plurality of consecutive transfer steps.

Fig. 1

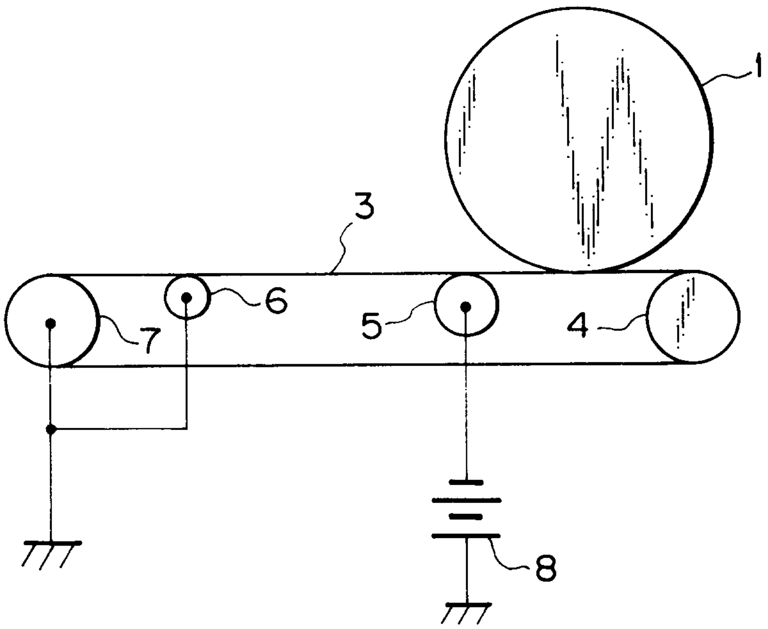


Fig. 2

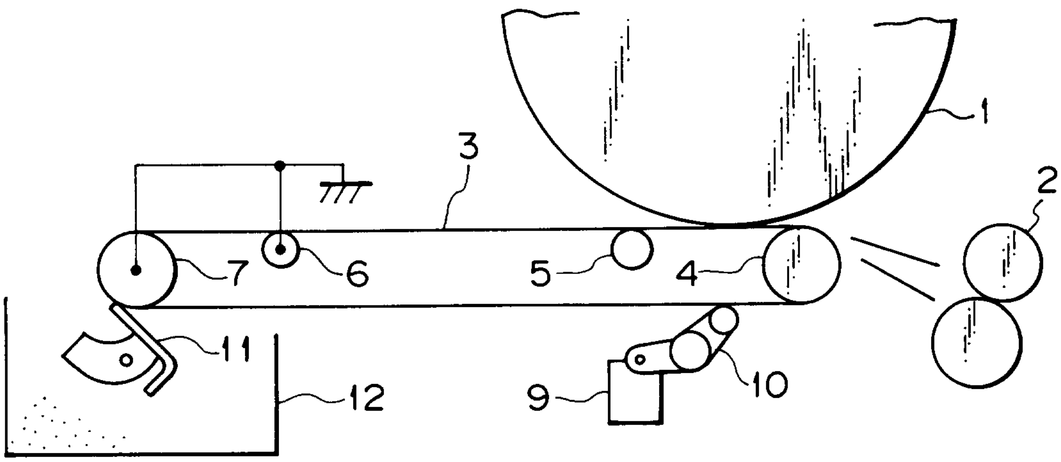
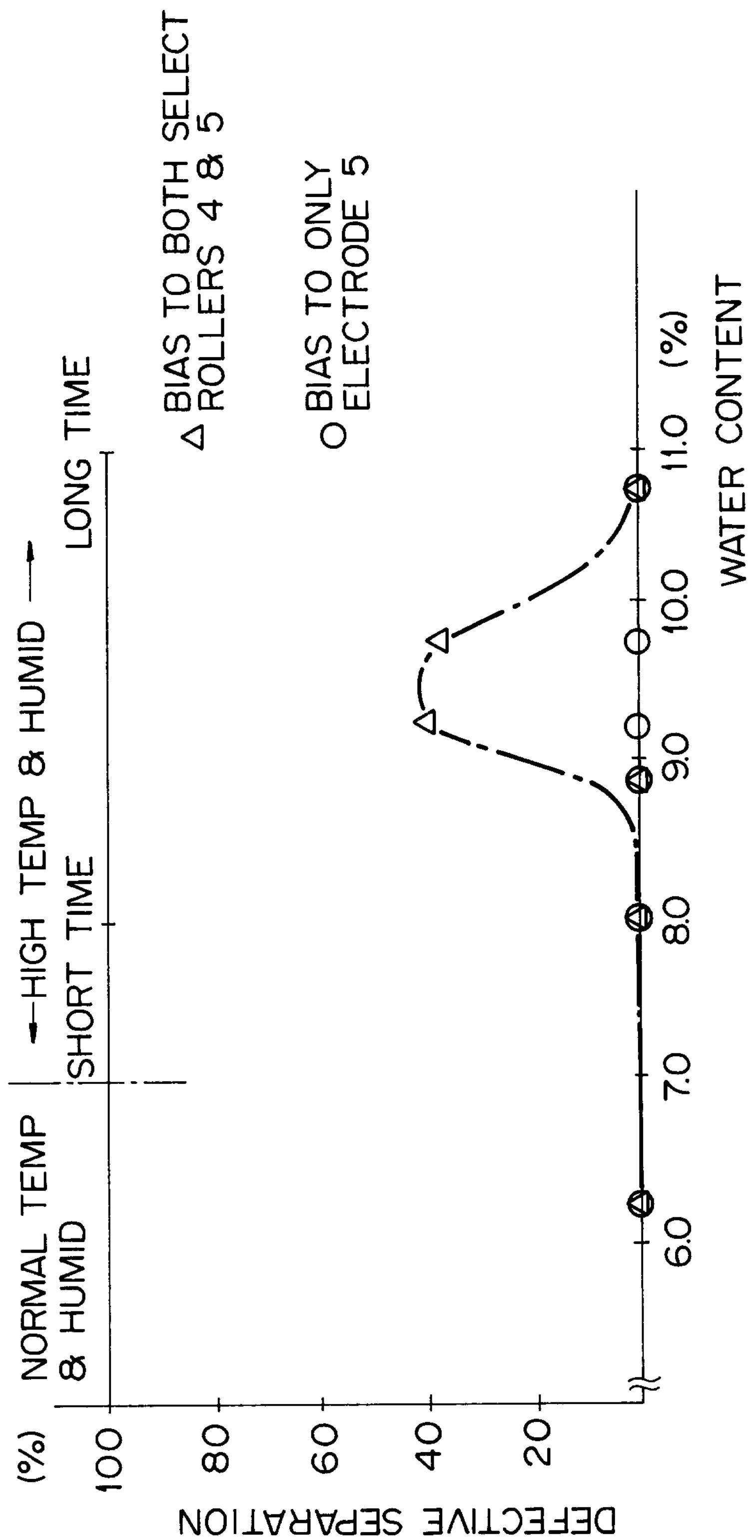


Fig. 3



NORMAL TEMP & HUMID
←HIGH TEMP & HUMID→
SHORT TIME
LONG TIME
Δ BIAS TO BOTH SELECT ROLLERS 4 & 5
O BIAS TO ONLY ELECTRODE 5
(%)
100
80
60
40
20
DEFECTIVE SEPARATION
6.0
7.0
8.0
9.0
10.0
11.0
(%)
WATER CONTENT

Fig. 4

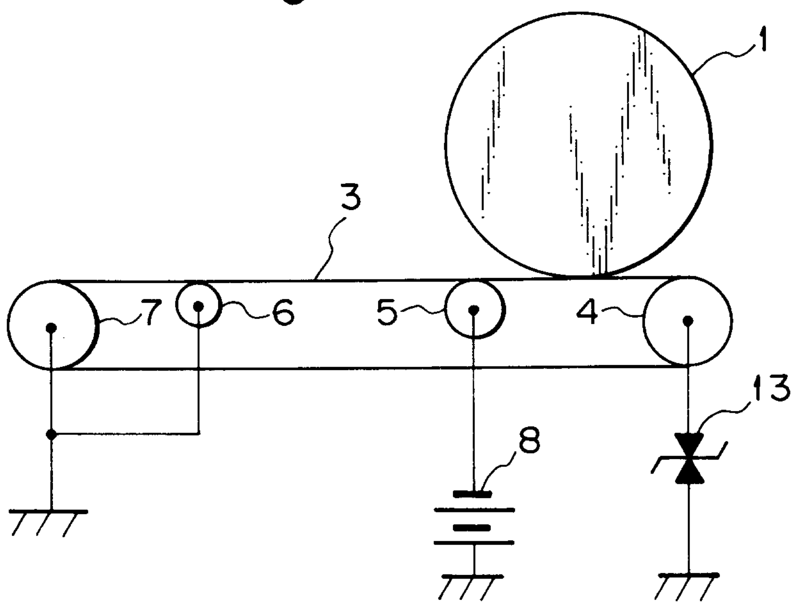


Fig. 5

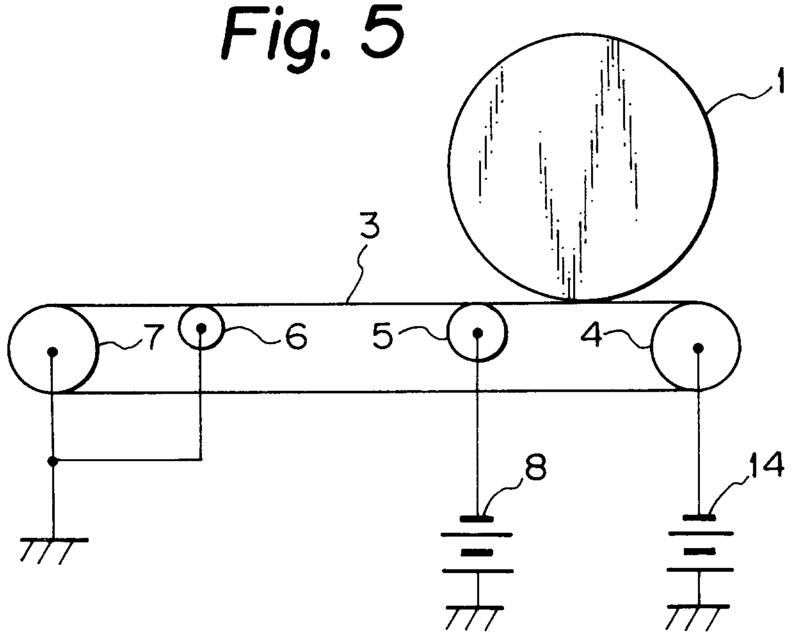


Fig. 6

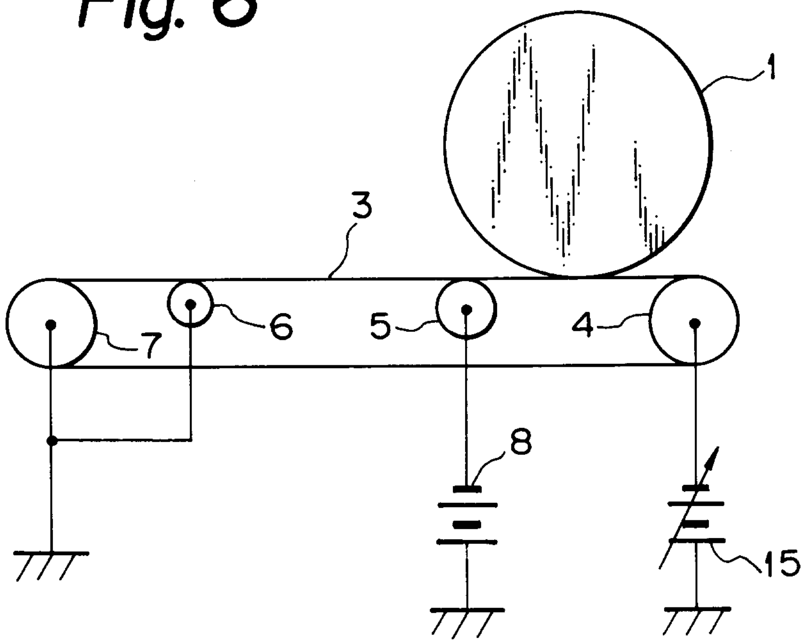


Fig. 7

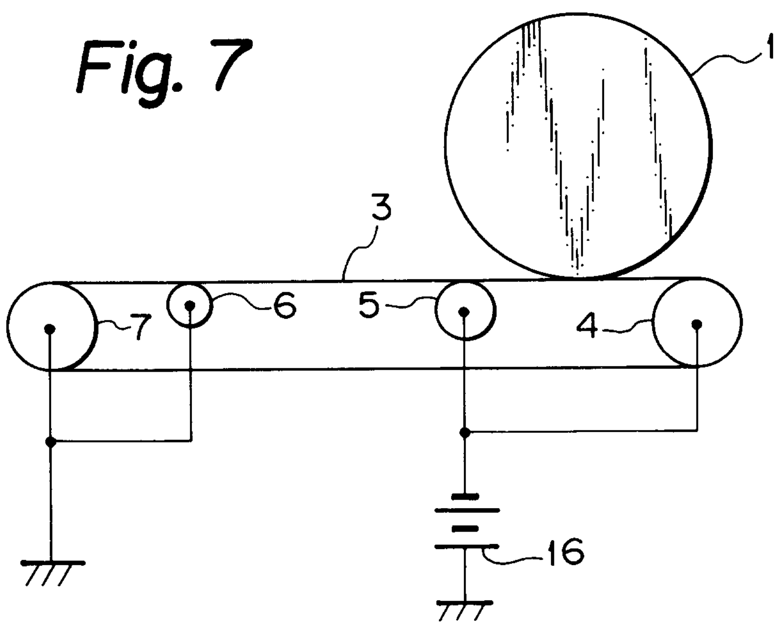


Fig. 8

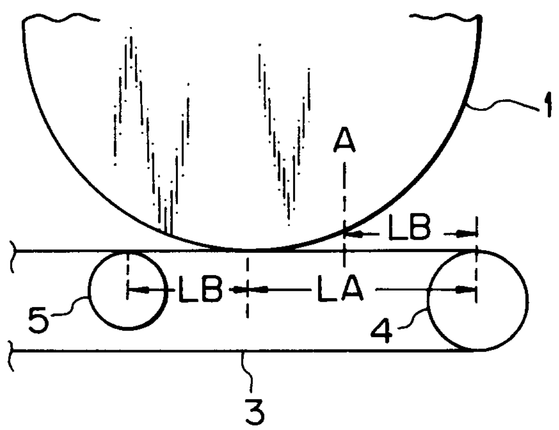

1
A
LB
LB
LA
5
4
3

Fig. 9

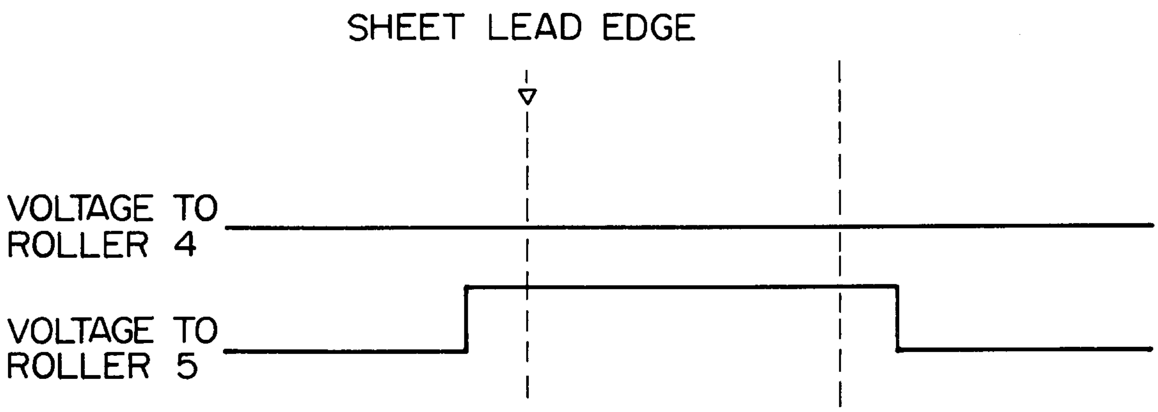

SHEET LEAD EDGE
VOLTAGE TO ROLLER 4
VOLTAGE TO ROLLER 5

Fig. 10

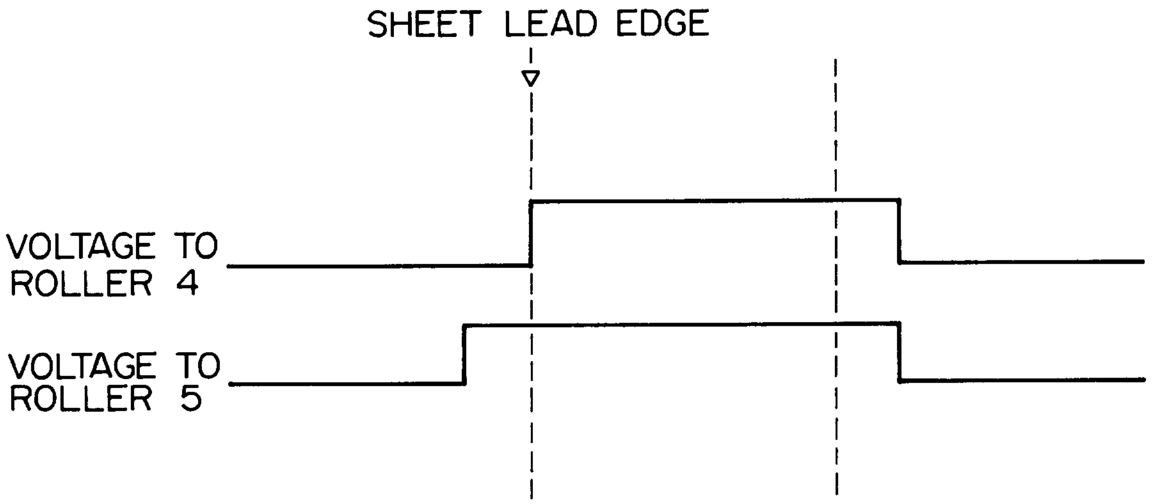

SHEET LEAD EDGE
VOLTAGE TO ROLLER 4
VOLTAGE TO ROLLER 5

Fig. 11

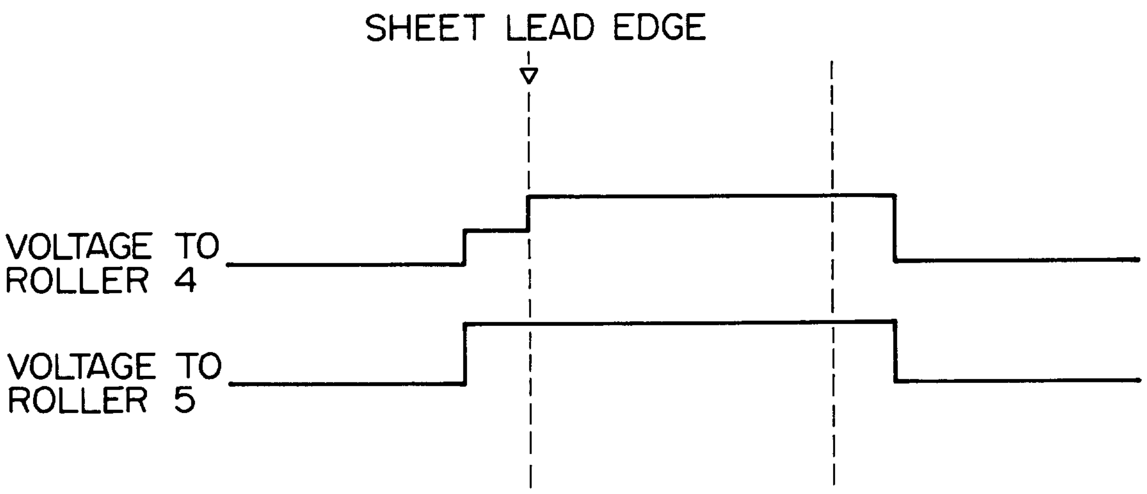

SHEET LEAD EDGE
VOLTAGE TO ROLLER 4
VOLTAGE TO ROLLER 5

Fig. 12

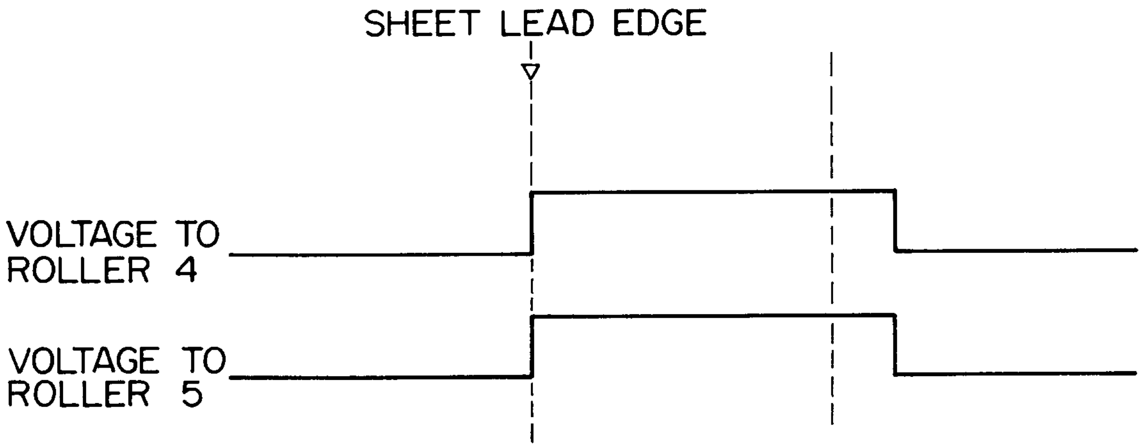

SHEET LEAD EDGE
VOLTAGE TO ROLLER 4
VOLTAGE TO ROLLER 5

Fig. 13

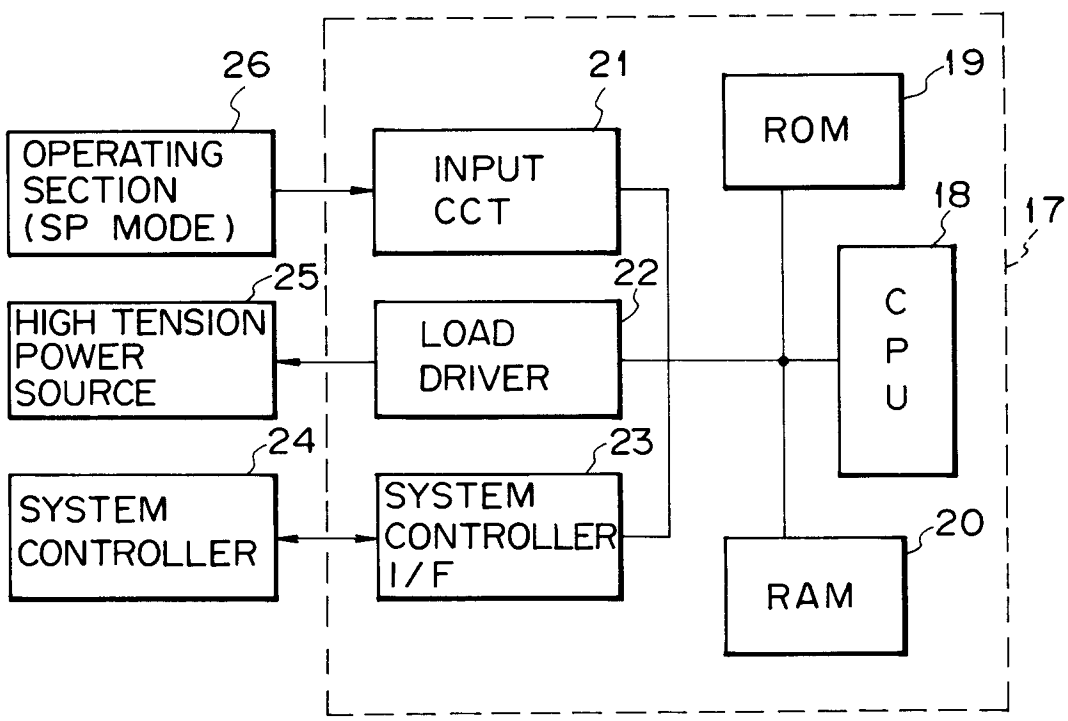

26
OPERATING SECTION (SP MODE)
25
HIGH TENSION POWER SOURCE
24
SYSTEM CONTROLLER
21
INPUT CCT
22
LOAD DRIVER
23
SYSTEM CONTROLLER I/F
19
ROM
18
CPU
20
RAM
17

Fig. 14

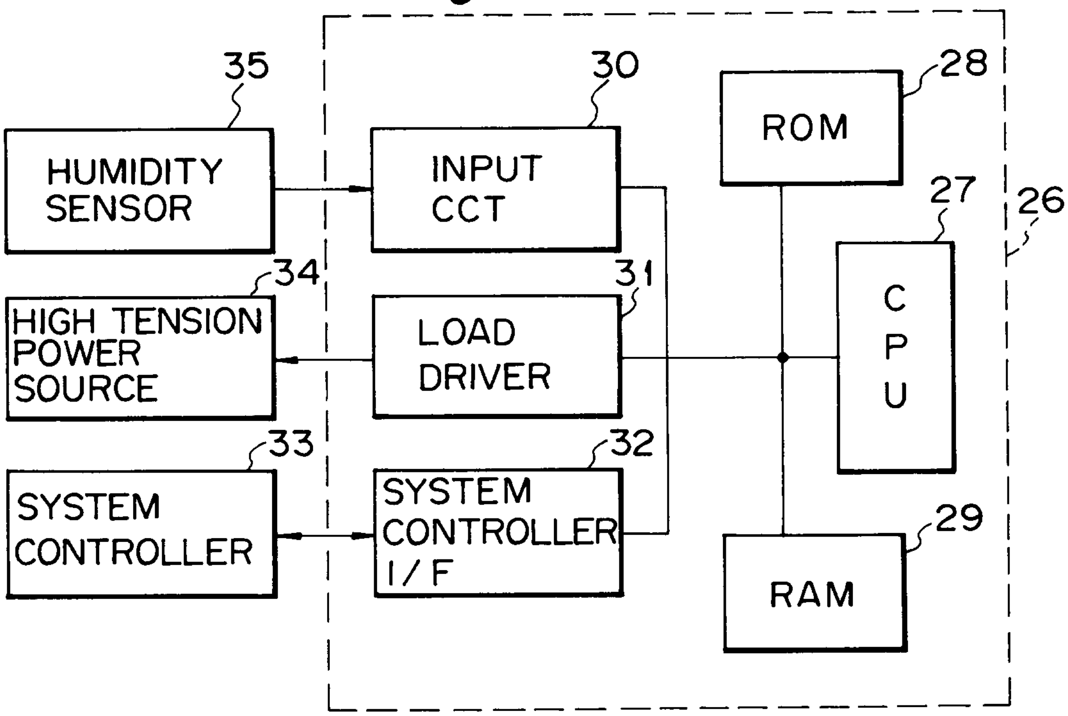

35
HUMIDITY SENSOR
34
HIGH TENSION POWER SOURCE
33
SYSTEM CONTROLLER
30
INPUT CCT
31
LOAD DRIVER
32
SYSTEM CONTROLLER I/F
28
ROM
27
CPU
26
29
RAM

Fig. 15

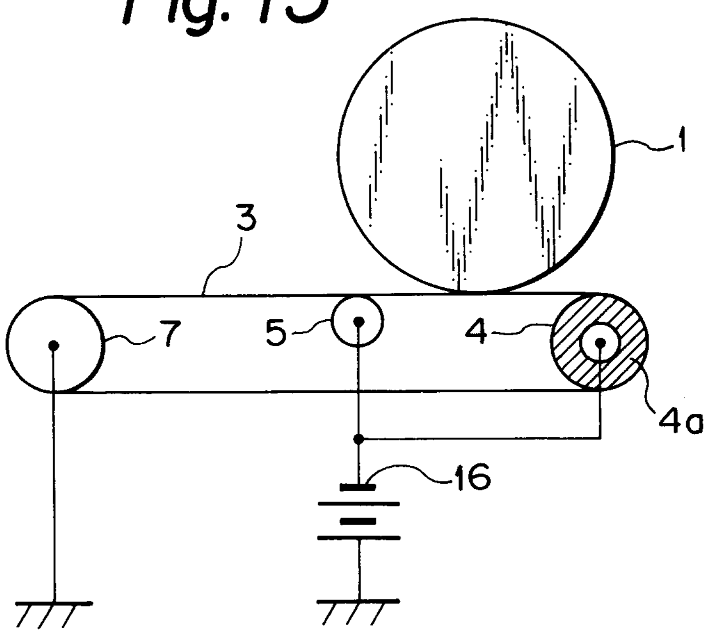

1
3
7
5
4
4a
16

Fig. 16

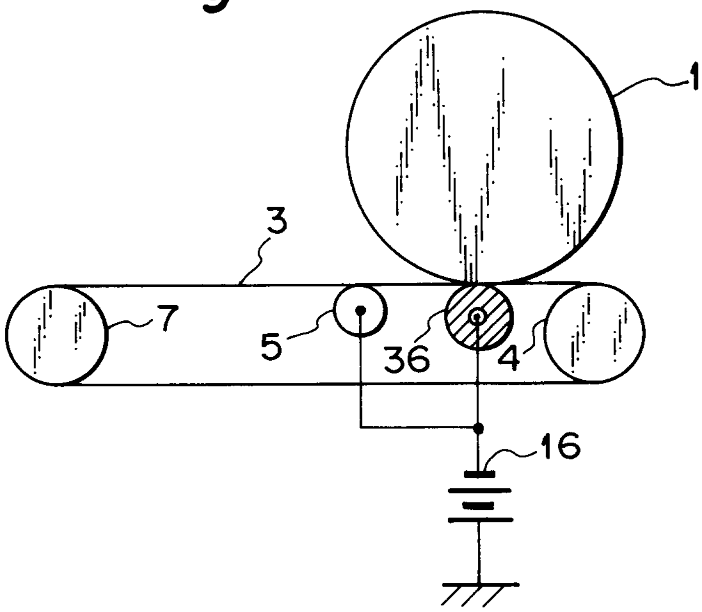


Fig. 17

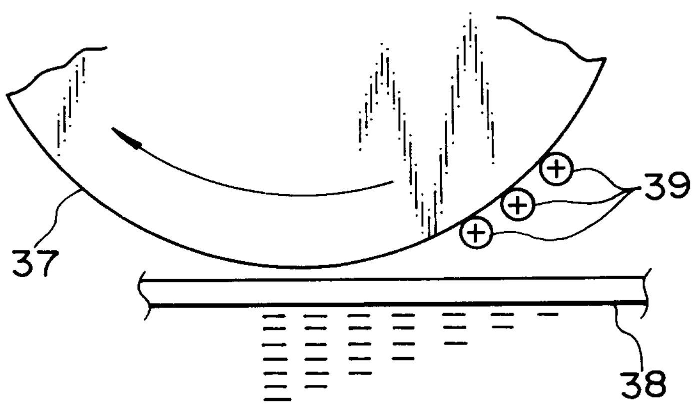


Fig. 18

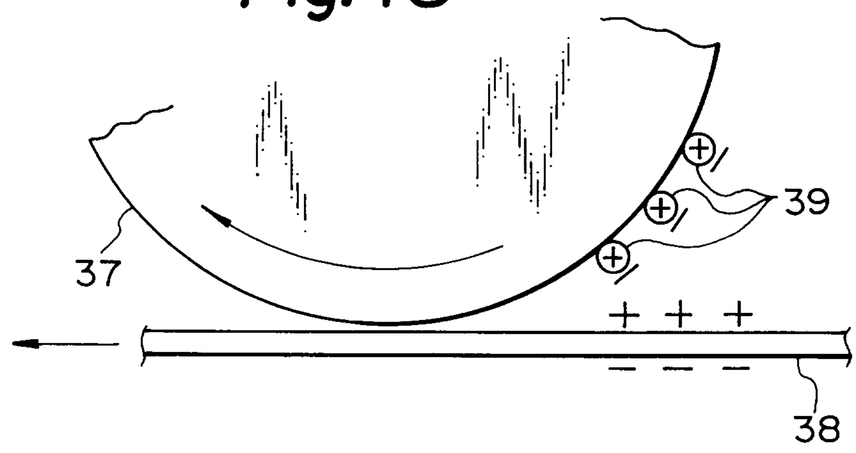


Fig. 19

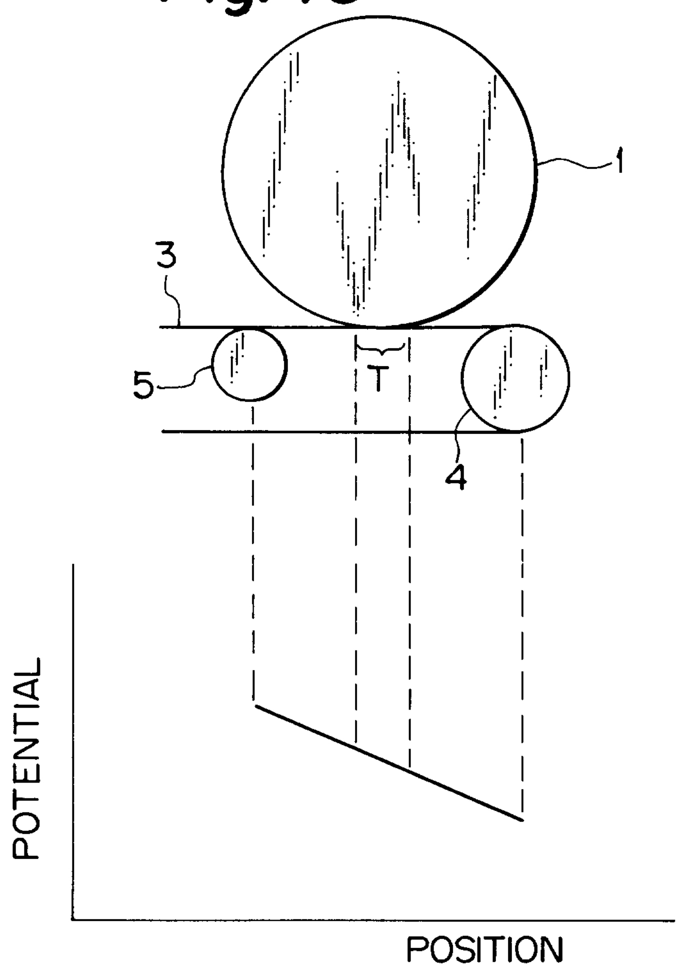


Fig. 20

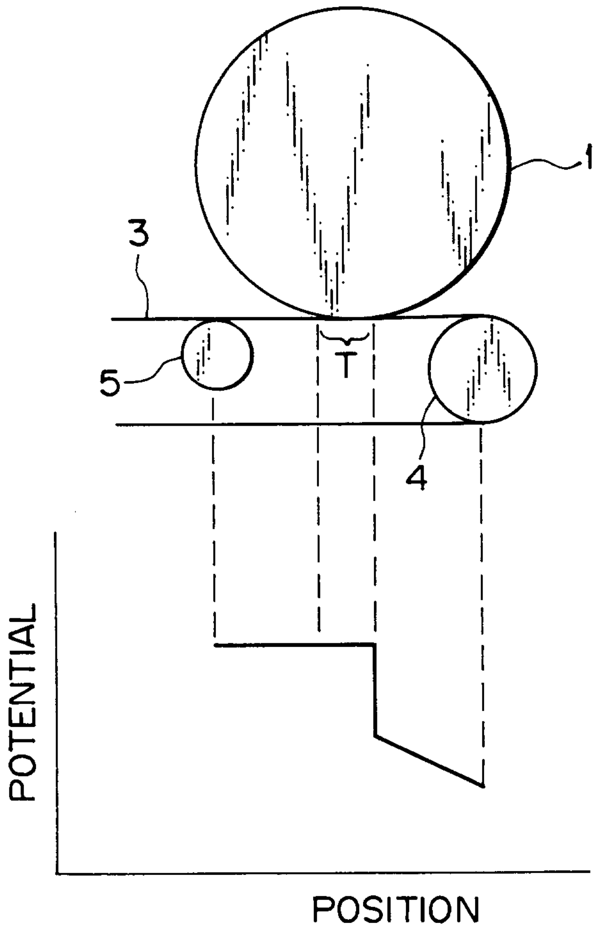


Fig. 21

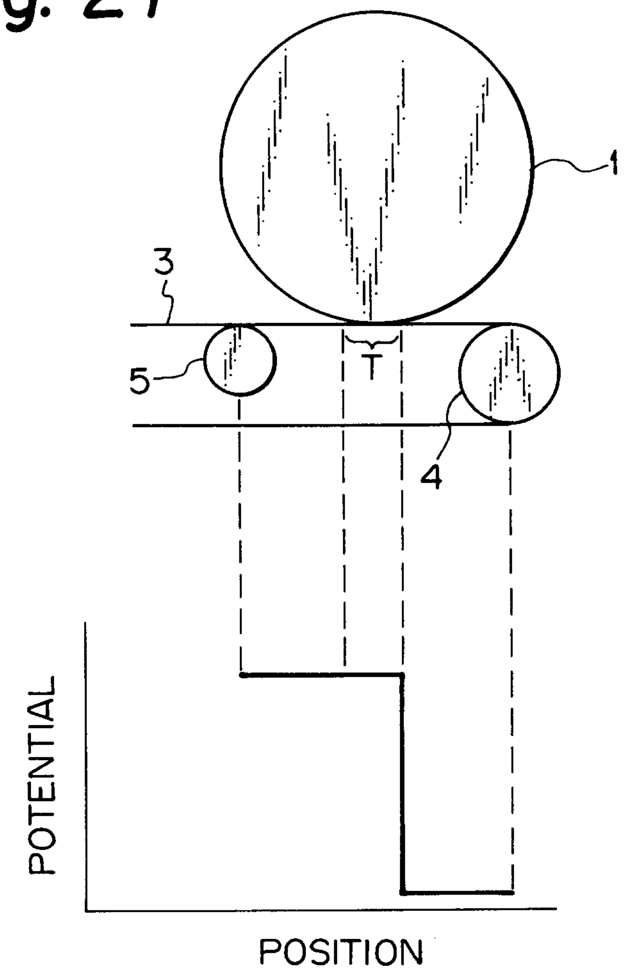


Fig. 22

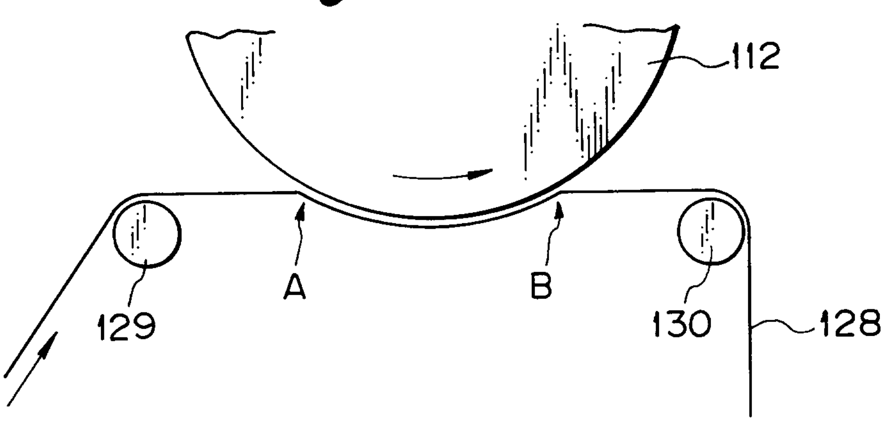


Fig. 23

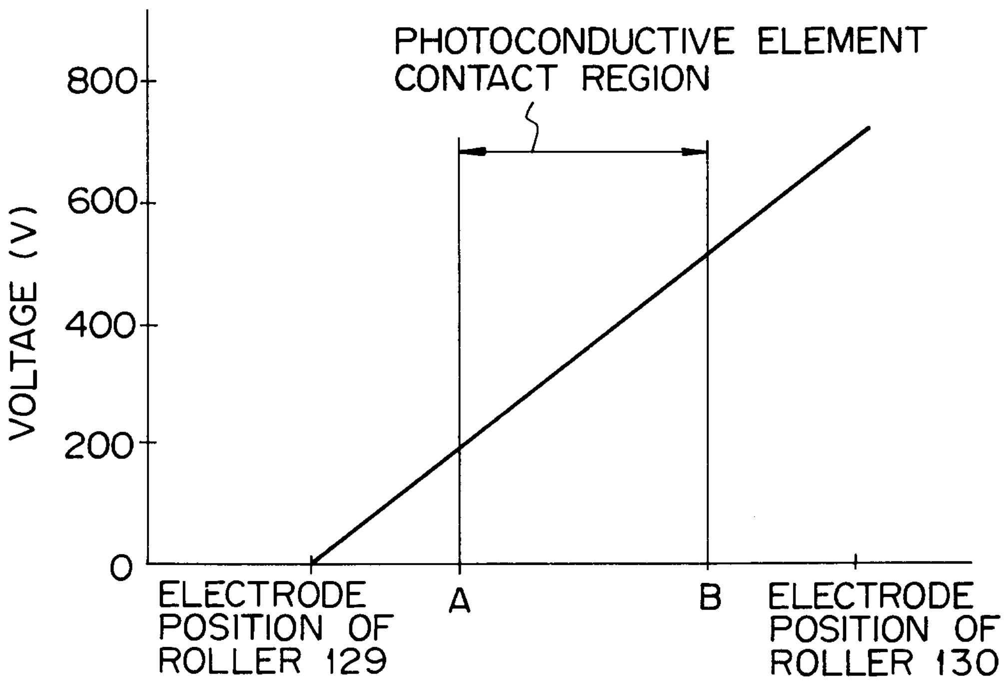

PHOTOCONDUCTIVE ELEMENT
CONTACT REGION
VOLTAGE (V)
800
600
400
200
0
A
B
ELECTRODE POSITION OF ROLLER 129
ELECTRODE POSITION OF ROLLER 130

Fig. 24

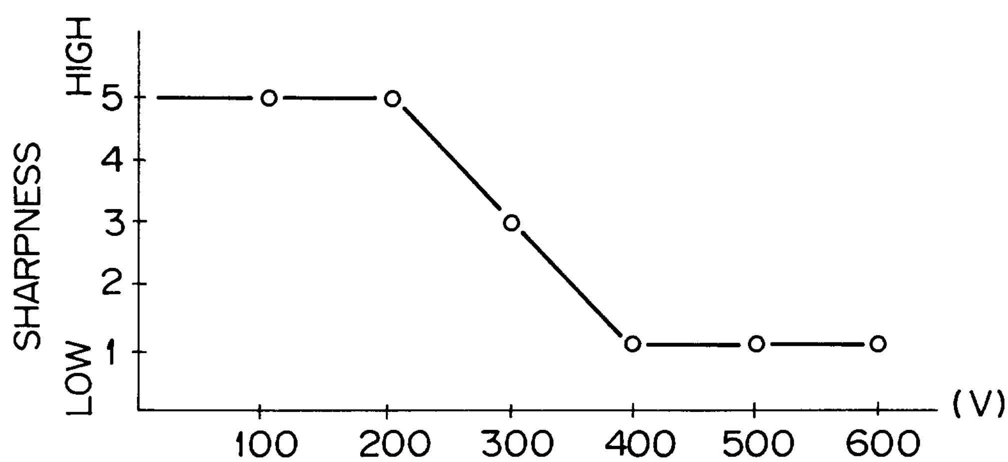

SHARPNESS
HIGH
LOW
5
4
3
2
1
100
200
300
400
500
600
(V)

Fig. 25

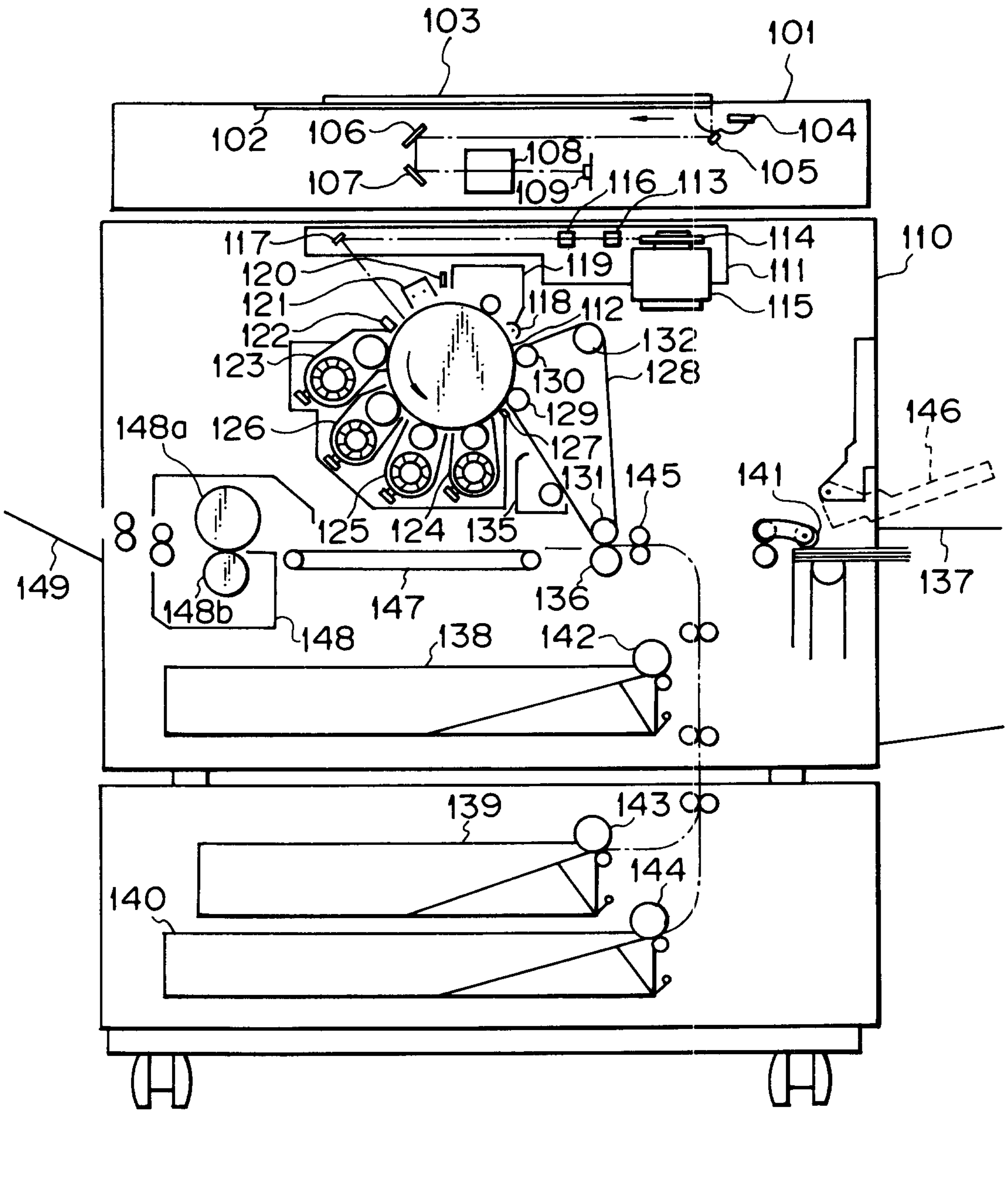

103
101
102
106
104
108
105
107
109
116
113
117
114
110
120
119
111
121
118
112
115
122
132
123
130
128
129
146
148a
126
127
131
145
141
125
124
135
149
137
136
147
148b
148
138
142
139
143
144
140

Fig. 26

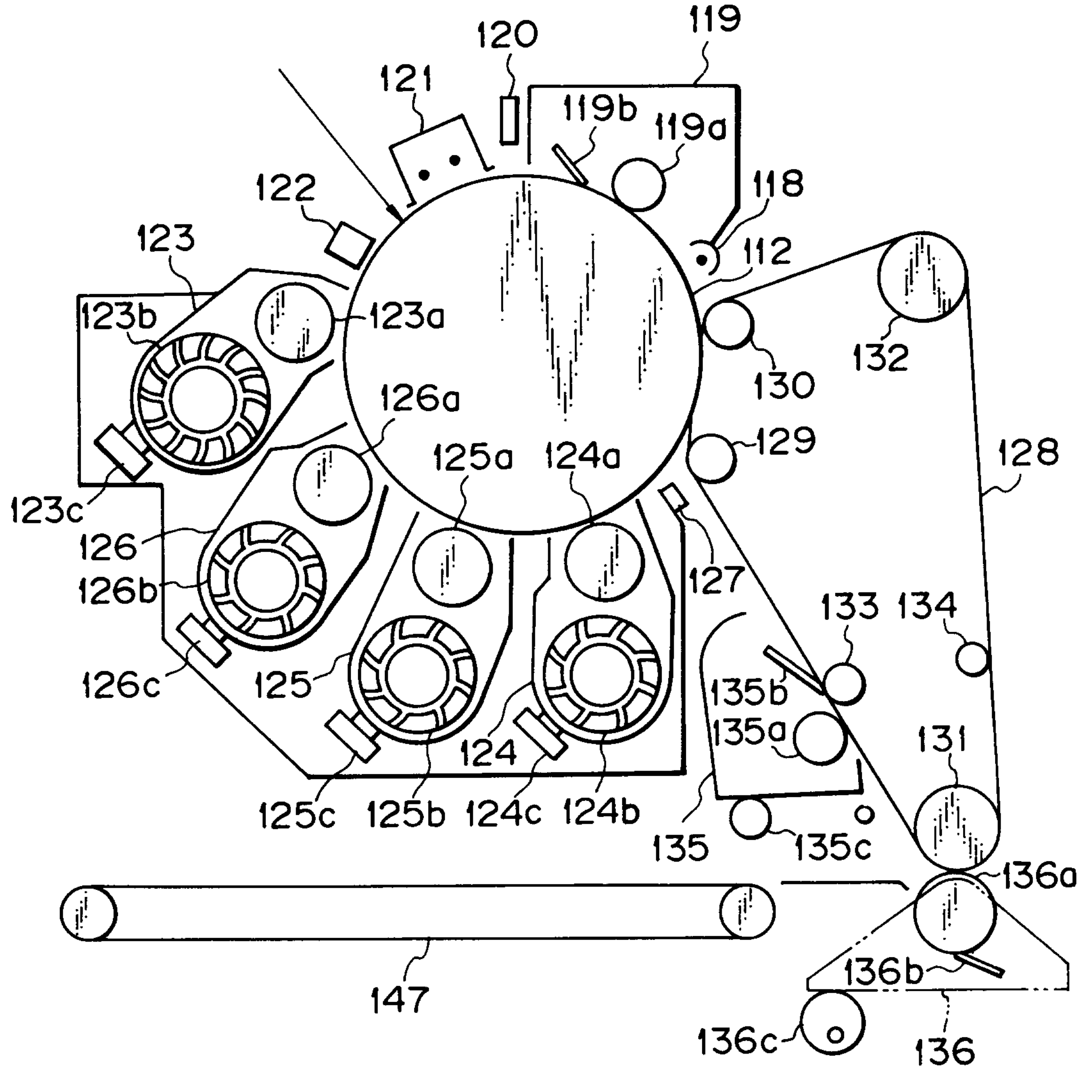

120
119
121
119b
119a
118
122
112
123
123b
123a
132
130
126a
129
128
125a
124a
123c
126
127
126b
133
134
126c
125
135b
135a
131
124
125c
125b
124c
124b
135
135c
136a
136b
147
136c
136

Fig. 27

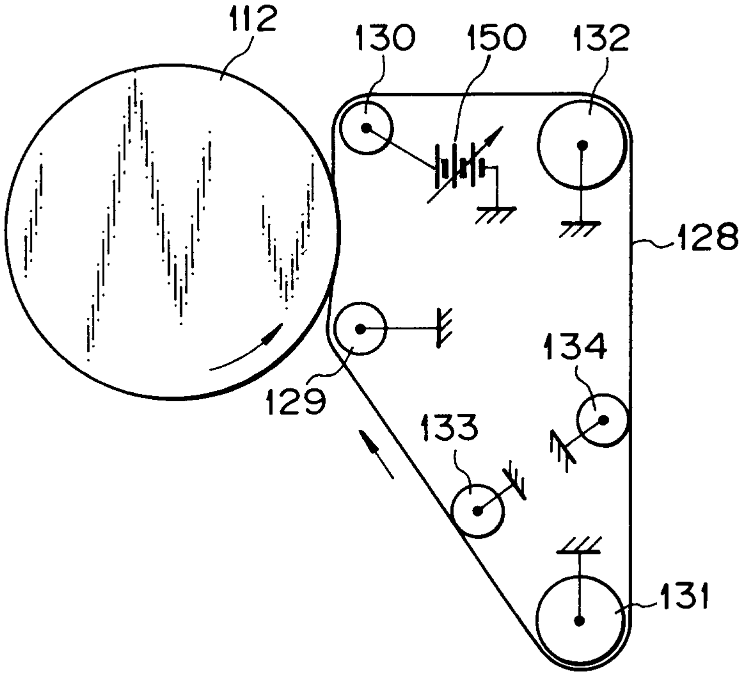

112
130
150
132
128
134
129
133
131

Fig. 28

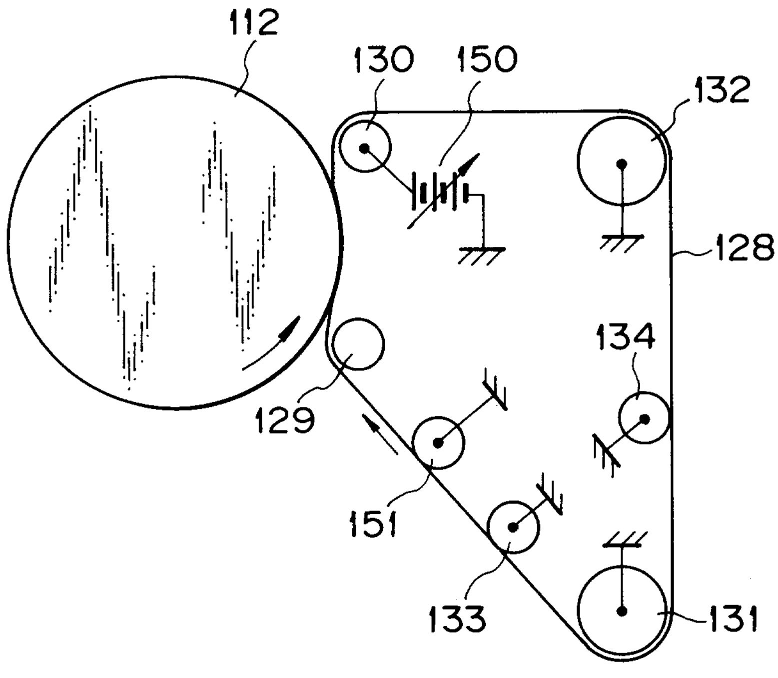

112
130
150
132
128
134
129
151
133
131

Fig. 29

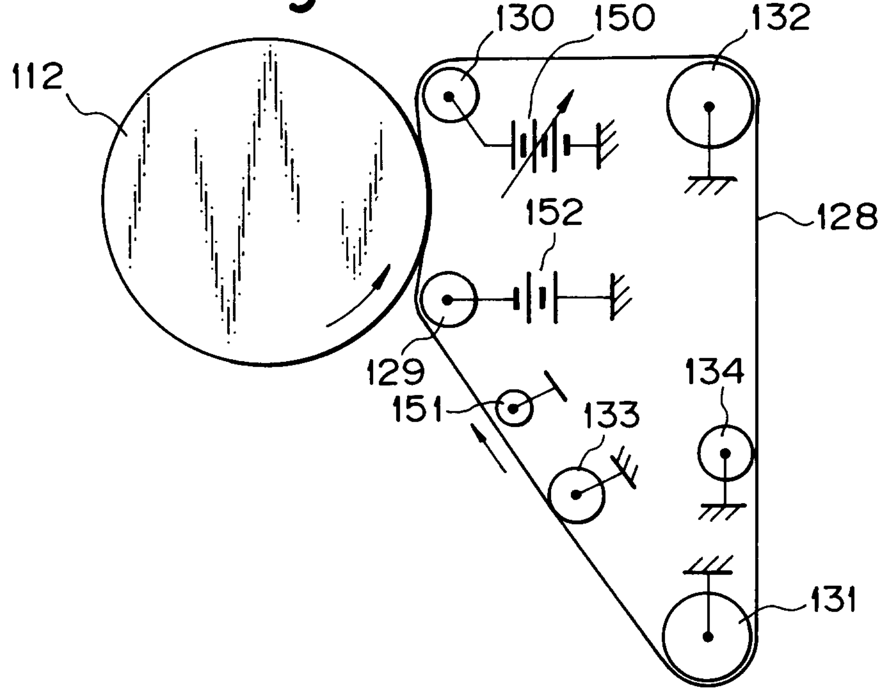

112
130
150
132
128
152
129
151
133
134
131

Fig. 30

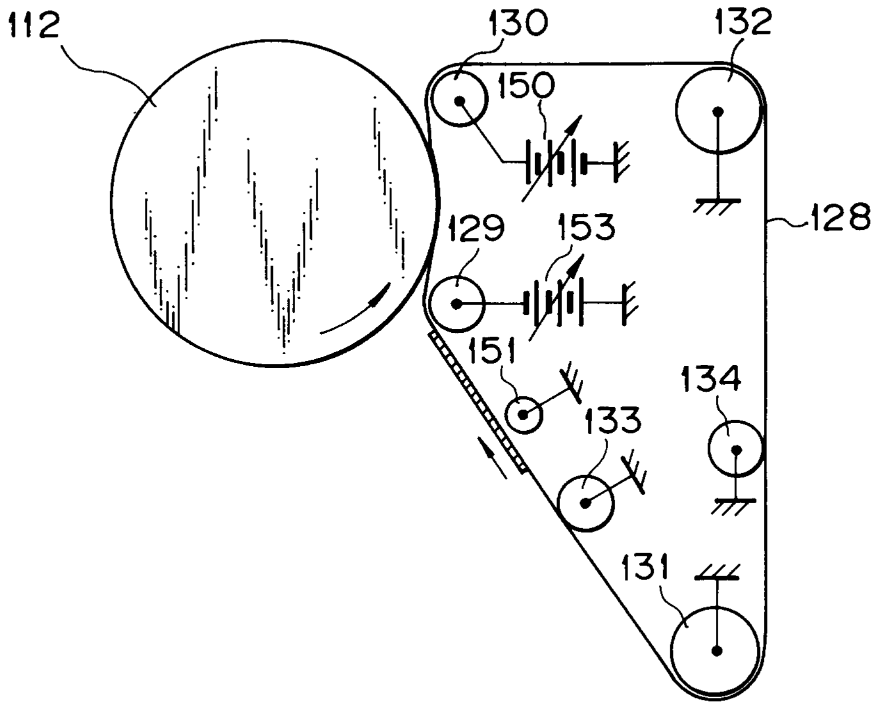

112
130
132
150
128
129
153
151
134
133
131

Fig. 31

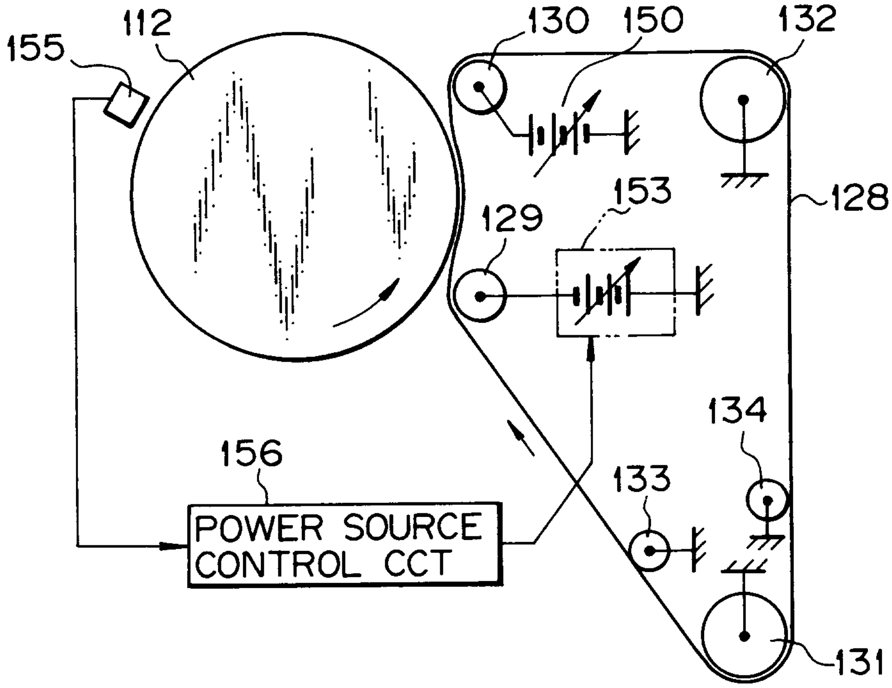
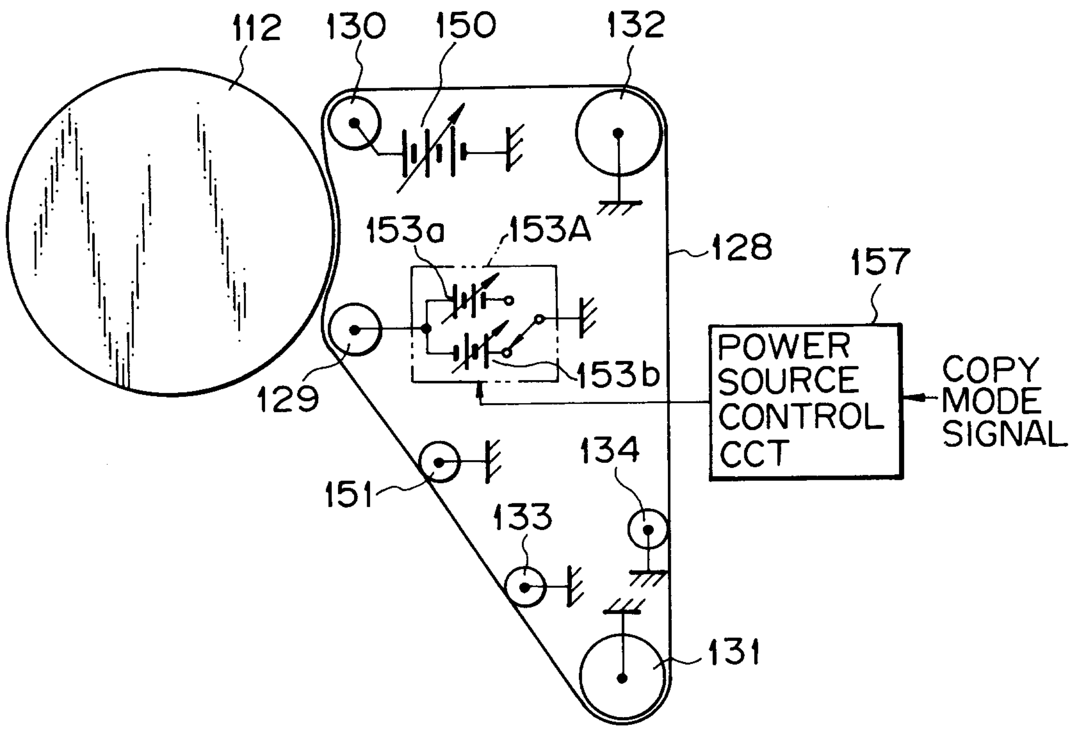

155
112
130
150
132
128
129
153
134
156
133
POWER SOURCE
CONTROL CCT
131

Fig. 32


112
130
150
132
153a
153A
128
157
POWER
SOURCE
CONTROL
CCT
COPY
MODE
SIGNAL
153b
129
134
151
133
131