

[54] **CONSTANT CURRENT BIASING TRANSFER SYSTEM**[76] Inventor: **Thomas Meagher**, 41 Anytrell Dr., Webster, N.Y. 14580[22] Filed: **June 11, 1973**[21] Appl. No.: **368,570****Related U.S. Application Data**

[62] Division of Ser. No. 309,562, Nov. 24, 1972, Pat. No. 3,781,105.

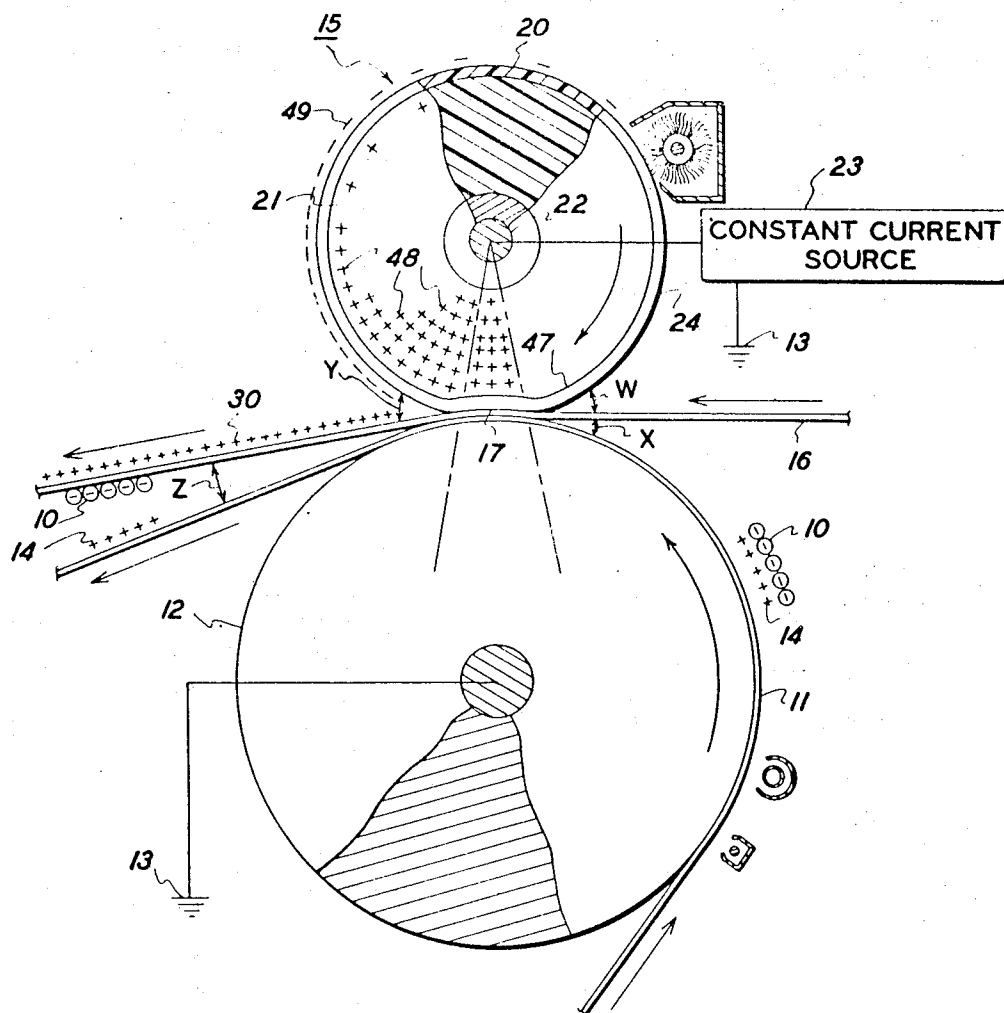
[52] U.S. Cl. **117/17.5, 96/1.4, 118/637, 118/638**[51] Int. Cl. **G03g 13/16, G03g 15/16**[58] Field of Search **117/17.5, 17, 93.4 R; 96/1.4; 118/637, 638; 250/49.5 ZC; 355/3, 16, 17**[56] **References Cited****UNITED STATES PATENTS**

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Primary Examiner—Michael Sofocleous[57] **ABSTRACT**

Electrostatic transfer of charged particles to a transfer member is accomplished using a roller electrode having electrically relaxable and self-leveling layers. The roller, along with the original support for the particles, defines a nip through which the transfer member is passed. Asymmetrical fields associated with the roller permit desirable post-nip air ionization while suppressing undesired pre-nip ionization. Constant current regulation of the roller current automatically corrects for electrical parameter variations affecting the desired field levels, such as variations in the thickness of the transfer member and variations in the resistance of the roller with relative humidity.

2 Claims, 6 Drawing Figures

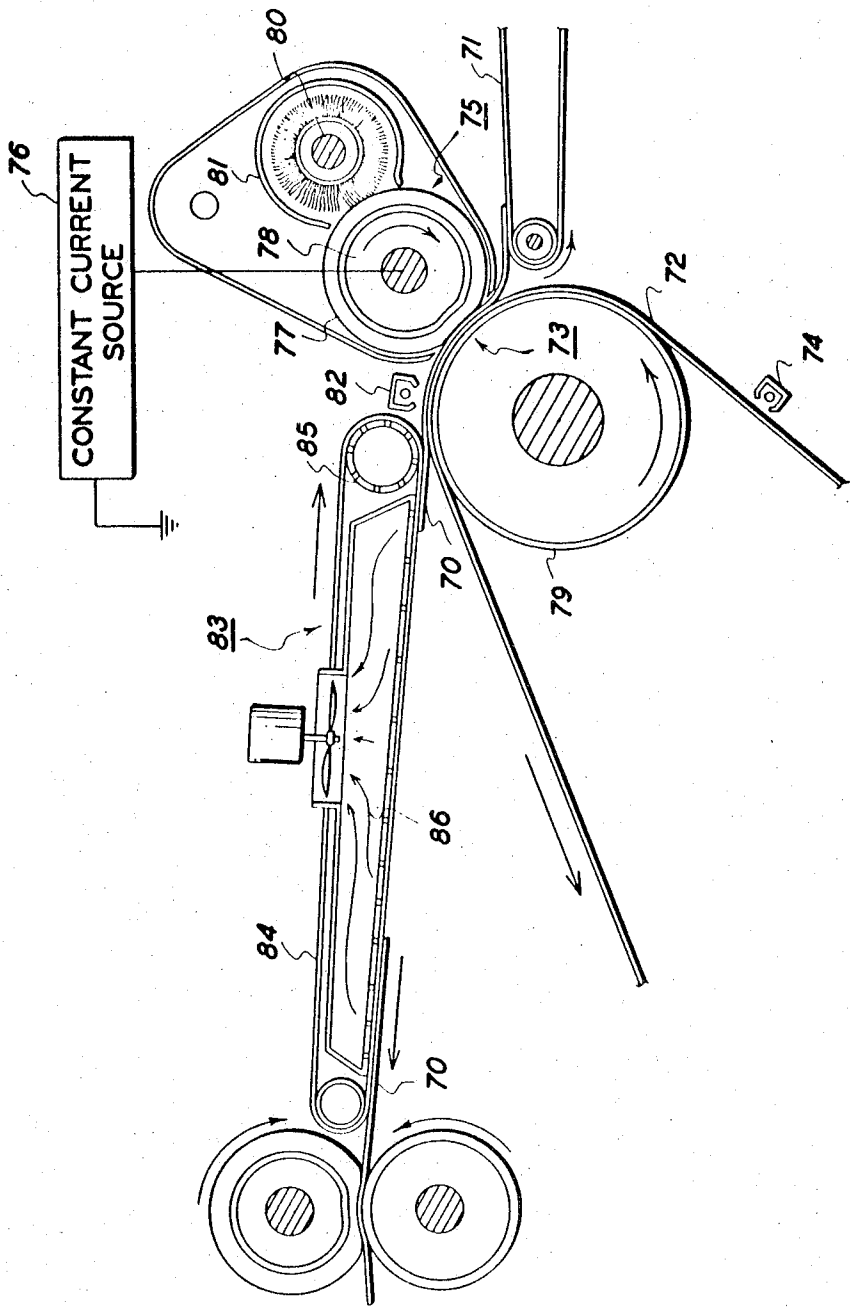


FIG. 1

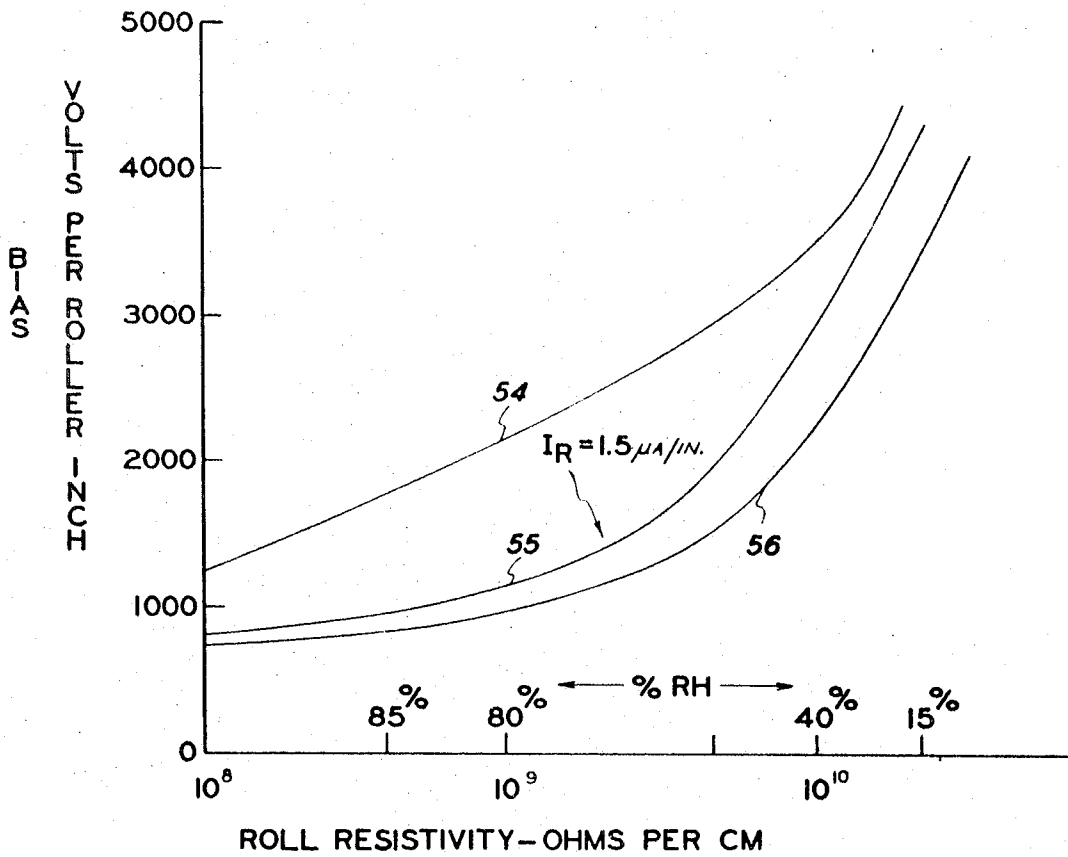


FIG. 4

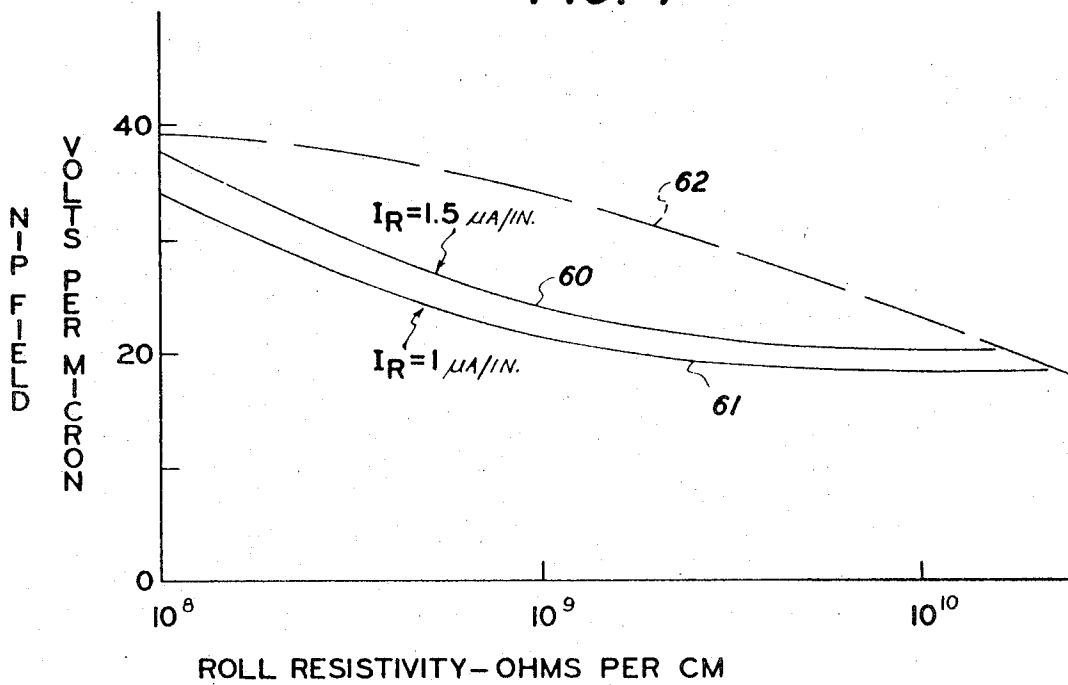


FIG. 5

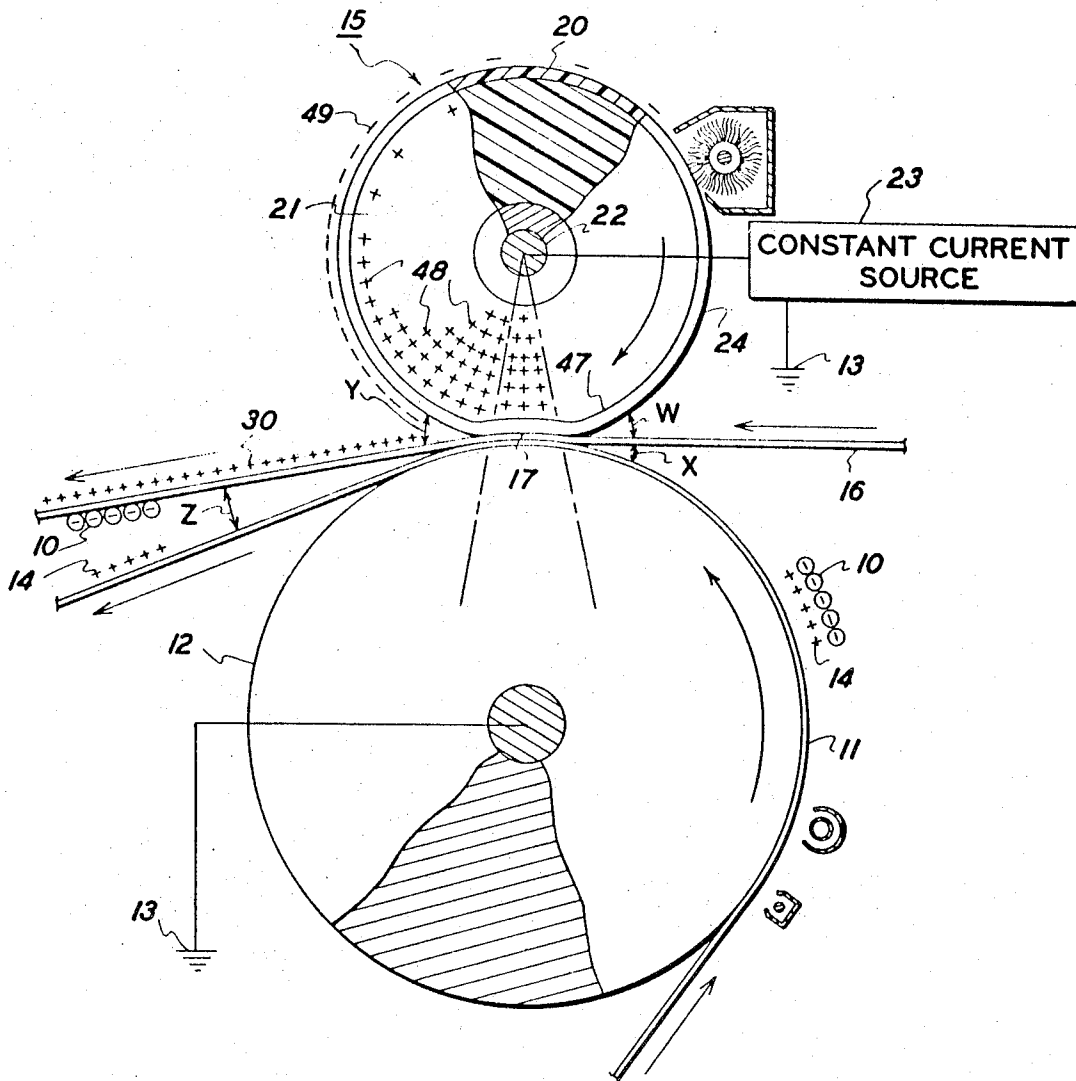


FIG. 6

CONSTANT CURRENT BIASING TRANSFER SYSTEM

This is a division, of application Ser. No. 309,562, filed Nov. 24, 1972 issued as U.S. Pat. No. 3,781,105, issued Dec. 25, 1973.

BACKGROUND OF THE INVENTION

This invention relates to the transfer of electrically charged particles between supports. Specifically, this invention relates to methods and apparatus for the improved electrostatic transfer of xerographic toner particles with electric fields established by roller or endless belt electrodes.

Roller electrode transfer systems employ D.C. electric fields to move charged particles such as xerographic toner from first to second supporting surfaces. (By D.C. it is meant that the direction of the field vectors are not reversed 180° on a unit time basis.) The purpose is to exert an electrical force on the charged particles that moves them from the first to the second support.

Among the difficulties is the fact that the direction and intensity of the electrical fields acting on a particle will vary at different locations relative to the roller electrode because the electric fields are geometrically dependent on the electrode configurations. Accordingly, the direction and intensity of the forces exerted on a particle by these fields will also vary with position and time because there is relative movement between the particles and the electrodes during transfer.

The electrodes establishing the transfer field generally include a roller electrode and a backing electrode. The backing electrode is one adjacent the support initially carrying the particles. The backing electrode is often in the configuration of either a flat plate or a cylinder, and is supported for movement relative to the roller electrode. The region of closest proximity between the two electrodes defines a nip region between which passes the second, or final, particle support or transfer member. Conventionally, the geometry of the various apparatus of roller transfer systems is symmetrical.

The initial particle support may be a conductive member and thereby comprise the backing electrode. Alternately, the initial support may be, for example, an insulator, a photosensitive semi-conductor, or have an insulative substrate, at least in a link or web positioned between the two electrodes, and may carry charges affecting the transfer field.

Historically, the transfer of toner images between supporting surfaces is accomplished with the electrostatic transfer of either a corotron or a roller electrode biased to constant potential (constant voltage) levels. Various trade-offs are made in choosing between the corotron or roller transfer systems. The corotron system is particularly noted for its relative simplicity, but the charges deposited by the corotron electrostatically tack the transfer support (e.g., paper) to the original toner support (e.g., a photoconductor) in addition to creating the desired electric field effecting transfer of the toner to the paper. This strong (tacking) attraction between the paper and the original toner support makes it mechanically difficult to separate or detach the two supports.

The detack problem is less severe when the transfer member is a web or other mechanically gripped member, and for that reason web transfer members have

been generally felt to be better suited for higher speed copying machines, and for biased roller transfer systems. No commercially successful copying machine is believed to have employed a roller transfer system with cut sheet transfer members.

As indicated, practical commercial corotron transfer systems have used constant voltage regulation for creating, directly or indirectly, the electric fields effecting transfer of the toner image. This is appropriate because a corotron is a voltage sensitive device that provides a current proportional to the potential difference between it and the surface from which it is spaced, by the generation of a corona with ion flow toward the surface. Current control is usually not a problem. To express it another way, corotron current control, when needed, may be accomplished by operating well above some minimum current level with a total current (largely to the shield) which is high and relatively constant. Furthermore, variable current sources are believed in the art to be preferred in applications where the objective is the charging of a non-uniformly charged surface to a more uniform potential. A photoconductor bearing an electrical image into a transfer area is such a non-uniformly charged surface.

Thus, in contrast, constant current, especially in connection with bias roller transfer systems, has heretofore been of little or no interest. The roller transfer systems rely upon some minimum voltage difference between the bias roller electrode and the photoconductor (or other initial toner support) to transfer the charged toner particles to the paper. However, some, but excessive, charging of the sheet of paper is highly desirable within the post-nip region to keep the transferred toner particles tacked to the paper after the paper has left the region of high field around the nip formed between the roller and paper. This corona charging can be provided in the present invention by the selective ionization of air at the nip exit region.

Significantly, it has been found by the present inventor that constant current control of the bias voltage supply in a transfer roller system as disclosed herein, rather than constant voltage control, provides a highly desirable and novel result. It can provide a controlled amount of desired post-nip corona with suppressed pre-nip corona over a wide range of physical variations in operating conditions, including substantial relative humidity changes.

In regard to the construction and materials of the bias roller described herein, incorporation by reference is made herein of a prior U.S. Pat. No. 3,702,482, by C. Dolcimascolo et al., issued Nov. 7, 1972. Further, some prior art in corotron charging voltage and current controls is shown, for example, in U.S. Pat. Nos. 2,576,047, 3,062,956 and 3,335,273, 4 and 5. Gundlach U.S. Pat. No. 2,912,586 discloses xerographic charging rollers and materials. Fitch U.S. Pat. No. 2,807,233 illustrates roller electrical toner transfer.

It is an object of this invention to employ constant current biasing in a toner transfer system.

Another object of the present invention is to enhance xerographic imaging systems by maintaining constant corona currents to members being charged in a biased member transfer system.

Yet another object of the invention is to reliably control the pre-nip and post-nip corona currents generated in a roller electrode system over a wide range of humidity and equipment variations.

These and other objects of the instant invention are accomplished by a novel system employing a special roller electrode biased with a constant current energy source. The present transfer system is capable of handling a wide range of transfer members wherein pre-nip and post-nip corona currents are effectively regulated, including cut sheets.

DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the instant invention will be apparent from the present description and from the drawings wherein:

FIG. 1 is a schematic elevational side view of an exemplary biased roller electrode transfer system in accordance with the present invention.

FIG. 2 is a schematic of one example of an electrical circuit capable of serving as the constant current energy source for the present transfer system.

FIG. 3 is a graph of electrical field as a function of time (where the center of the transfer roller nip is time) in three regions: at the nip entrance (pre-nip); in the nip; and after the nip (post-nip).

FIG. 4 is a graph comparing the applied bias to an exemplary transfer roll versus roll resistivity and relative humidity.

FIG. 5 is a graph comparing nip fields versus roll resistivities for an exemplary roll.

FIG. 6 is a schematic cross-sectional side view of another biased roller, transfer sheet, and photoconductor (or other insulating surface) illustrating the post-nip ionization of air around the roller during the transfer process and the relaxation and self-leveling abilities of the transfer roller.

DETAILED DESCRIPTION

Xerographic toner 10 typically comprises microscopic size particles (0.1 – 20 microns) that are opaque or include opaque materials. Electrically, the toner is highly insulating and carries a net electrical charge. The desired polarity of the toner charge depends on the polarity scheme of the imaging system. In the presently described embodiment the toner is assumed to have a net negative charge, which thereby suggests the other polarities illustrated, discussed and intimated. Quite clearly, alternative system based on positively charged toner particles are also benefited by the present invention, although a detailed description thereof is omitted here, as it would be redundant.

Referring particularly to FIG. 6, the photoconductor (photoreceptor) 11 is, for the purposes of the present discussion, a moving electrical insulator web. It is supported by a conductive core (roller) 12 which is electrically coupled here to a ground potential 13 as a convenient and safe potential level. The backing electrode may also be a continuous conductive backing layer of the photoreceptor belt, grounded by a contacting grounded wiper, in which case the backing roller 12 can be non-conductive. The transfer roller should not be allowed to contact any grounded surface during operation. The plus signs 14 on the photoconductor 11 represents positive charges associated with an electrical latent image on it. In one xerographic system the latent image is a pattern of charge 14 created by steps including uniformly charging the photoreceptor and then exposing it to a light image. Alternately, the latent electrical image may be created even on a non-photosensitive insulator by selectively depositing

charge on the insulator through a stencil shaped in the form of an image, or other imaging means. In most systems the latent electrical image is developed by steps including bringing toner particles 10 adjacent the latent images. The fields associated with charge 14 then electrostatically tack the charged toner particles to the insulator 11.

The transfer of the toner to a transfer member can be accomplished electrostatically by a roller electrode, as illustrated in Fitch U.S. Pat. No. 2,807,233, or by a corotron as described in Shaffert U.S. Pat. No. 2,576,047. In these references the bias supplied to the transfer device (roller or corotron) is indicated as a constant voltage energy source.

The present transfer system uses a novel transfer roller biasing scheme to greatly enhance the electrostatic transfer operation. Still referring to FIG. 6, a transfer roller 15 is appropriately journaled for rotation at an angular velocity such that the peripheral speed of the roller is substantially equal to the speed of the insulator 11. A cut sheet transfer member 16, e.g., $8\frac{1}{2} \times 11$ inch, 20 pound bond paper, is fed by appropriate means into the nip 17 formed between the roller 15 and insulator 11. The arrows shown indicate the relative direction of movement for the roller 15, insulator 11 and paper 16. The terms "pre-nip" and "post-nip" used herein refer to the direction of travel of the transfer sheet 16 through the nip, and in FIG. 6 correspond to the right and left hand regions respectively adjacent the nip 17.

The exemplary roller 15 here includes an electrically "self-leveling" outer layer 20, an electrically "relaxable" next (inner) layer 21 and a central conductive core or axle 22. The constant current electrical bias or energy source 23 is electrically connected to the conductive core 22.

The heart of the roller electrode 15 is the thick relaxable layer 21, which has a bulk resistivity falling in a well defined operating range selected in relation to roll diameter and surface velocity. For the specific system described herein, the bulk resistivity of the relaxable layer can vary over the range from about 10^7 to about 10^{11} ohms per centimeter. A variation in this resistivity of about two orders of magnitude, primarily as a result of static and dynamic changes in relative humidity or RH (extending generally from 5-to-10% RH to 85-to-100% RH), is observed for practical available commercial materials in this resistivity range. The preferred resistivity ranges may vary for transfer systems designed to operate at different throughput speeds of the transfer sheet 16. These numbers are for a roller 15 diameter of about 3 inches, a roller 12 diameter of about 5 inches, and a paper speed of from about 10 to about 20 inches per second. A properly selected resistivity range is critical for the relaxable layer 21 operation, even for present day copying speeds of 10 to 20 inches per second. (Doubling the speed is generally equivalent to halving the resistivity).

The relatively soft, thick, electrically relaxable body 21 may be mounted directly on the axle 22 of the bias roll. The relatively low durometer of this material allows good mechanical contact in the transfer zone at moderate pressures and eliminates "hollow character" transfer under normal operating conditions. Since the relaxation time of the core material is long compared to the ion transfer time of gaseous discharges, during air breakdown the roll acts like an insulator, protects

against arcing and helps control the amount of charge transferred at any point on the surface.

The relaxable layer 21 comprises a material that functionally takes a selected time period to transmit a charge from the conductive core 22 to the interface 47 between the relaxable layer 21 and the self-leveling layer 20 sufficient to restore said interface 47 to about the bias potential applied to the core 22. This selected time period is that corresponding to the roller surface speed and nip region width, i.e., roughly greater than the time any point on the transfer roller is in the nip region, and is chosen to be approximately one quarter of the roller revolution time. Functionally, this means that the magnitude of the external electric field increases significantly from the pre-nip entrance toward the post-nip exit, while the field within the relaxable layer diminishes. Thus, a relaxable layer is one that has an external voltage profile which is non-symmetrical about the transfer nip. As will be discussed shortly, the ideal conditions are to have a field strength below that for substantial air ionization in the air gap at the entrance to the nip, and a field strength above that required for air ionization in the air gap just beyond the exit of the nip. [Some pre-nip ionization may be allowable]. The present invention realizes these goals.

The (outer) self-leveling layer 20 is a leaky insulator. The layer 20 is selected for substantially higher resistive values, which in the present embodiments means in the order of about 10^{11} to 10^{14} ohms per centimeter. In addition, the self-leveling layer includes materials, (or is so related to the relaxable layer), such that charges applied to the outer surface 24 of the self-leveling layer 20 will be generally dissipated within one revolution of the roller 15. This dissipation of charge is desirable to prevent suppression of the transfer field in the nip.

It is desired that the self-leveling layer 20 thickness divided by its dielectric constant should be substantially greater than any other material in the nip in order for its capacitance to be much less than such other materials, as desired. The self-leveling layer 20 also acts as a thin insulating layer coated on the surface of the relaxable core material to help protect the roll during air breakdown, to act as a moisture barrier, to limit current flow through the roll, and to make the roll surface easy to clean. However, if the relaxable material is durable and cleanable the self-leveling layer 20 is not essential.

A constant current supply can compensate for non-leveling as long as the voltage buildup across this layer 20 does not cause the power supply to exceed its rated maximum output voltage, and as long as the charge on this layer is reasonably uniform. Some non-leveling is tolerable.

The paper or other transfer sheet 16 is here a cut sheet (versus a web) that is fed into and extracted from the transfer system by conventional or appropriate means. One example is illustrated in FIG. 1 and discussed in more detail later. The comparison of the sheet to the web is intended to differentiate sheet 16 from those transfer members that are guided through the transfer system by being mechanically coupled to the transfer roller, as illustrated in the above-cited Dolcimascolo et al patent, or wound between spools or the like as illustrated in the Fitch patent, supra.

The transfer sheet typically will be conventional 20 pound bond paper with or without a plastic coating. It

should be understood, however, that an advantage of the present system is that it can operate with paper weights ranging from nine pound "vellum" to 100 pound or greater card stock. Alternately, the transfer sheet here may include various transparent materials, such as polyester resin sheet sold commercially under the trade name MYLAR.

Electrically, paper is generally a fair insulator at low RH and a fair conductor at high RH. Consequently, the charge illustrated by the plus signs 30 on the non-image side of the transfer sheet 16 may actually leak onto the image side of the sheet if the sheet is reasonably conductive. The plastics are, of course, generally always highly insulating.

A key factor in the improved operation of the present transfer system is the constant current energy (bias) source 23. Its automatic current control controls pre-nip ionization to tolerable levels while allowing a desired amount of post-nip ionization even when RH variations, roller material aging, paper thickness changes, and other factors change the electrical parameters of the transfer system, and yet while maintaining high transfer fields. Before the bias circuit 23 is described here, however, it is helpful to first discuss the electric fields holding the toner to its support and the roles the relaxable and self-leveling layers of roller 15 play in the transfer process.

While the toner 10 is carried by the insulator 11 toward the nip region 17, the toner is tacked to the insulator by the fields associated with the latent image charge 14 and by other adhesive forces such as VanderWaal forces. In some imaging systems, there may also be charge in the non-image areas, i.e., areas adjacent charge 14, but this non-image charge is at a different potential or is otherwise separated from the image charge by some discontinuity that causes the toner particles 10 to preferentially adhere to the image areas. Furthermore, the charge 14 may be substantially altered before reaching the nip, as in systems where a photoconductor is involved, by exposing the photoconductor to light discharge. Even so, the original support is still able to retain the toner particles in place with such reduced field strengths. The reduced tacking fields are advantageous for the simple reason that transfer can occur with a lower nip field. Another reason is that if charge 14 is not reduced, excessive fields prior to entering the nip might cause air ionization, or cause "fuzzy" images (or loss in sharpness) due to premature transfer of the toner while the gap is too large. It is to be noted, however, that the present transfer system is effective whether or not the latent image, e.g., charge 14, is altered prior to transfer. One reason for this is that it is considered that the constant current bias 23 may offset the bad effects that excessive image charge 14 may otherwise have on the transfer operation.

With constant current bias, the pre-transfer illumination of the photoconductor is desirable because it insures that the transfer current density in image regions is nearly equal to the current density in background regions. Without it the current density in background regions would be much larger than in image regions, particularly with low resistivity bias rolls, thus reducing transfer efficiency.

The operation of roller 15 may be explained in connection with the generalized curves in FIG. 3. The time scale along the horizontal axis represents the move-

ment of the transfer sheet 16 through the nip region. The pre-nip period is to the left of the nip period 43, and the post-nip period is to its right. Since velocities are assumed constant here the horizontal axis also corresponds to path distances from the nip area 17.

The volts-per-micron scale along the vertical axis of FIG. 3 represents relative transfer field intensity along the path of the transfer sheet. The field observed is that between the outer surface 24 of the roller 15 and the free surface of the toner support 11. It is that field which effects the transfer of the toner 10 between supports 11 and 16.

Curve 40 in FIG. 3 is the Paschen curve which represents the field intensities at or above which ionization of air will normally occur (on both sides of the nip). Curve 41 is the field curve generated by the roller transfer system of FIGS. 1 and 6. Curve 42 is an exemplary curve for prior art rollers not having a relaxable layer 21, e.g., conductive rollers and conductive rollers overcoated with high resistance and/or high dielectric materials. This curve 42 is included to comparatively dramatize the desirable asymmetrical nature of the subject curve 41, which permits post-nip but prevents pre-nip ionization of air.

Discontinuities (not shown) may occur in curves 41 and 42 at the exit 44 to the nip due to the charge associated with the transfer of toner particles 10. When the toner 16 is not present, the portions 41A and B and 42A and B of curves 41 and 42, respectively, are continuous, as shown. (In contrast to curve 41B, the charge density of a non-coated conductive roller, or the field between an insulator and a conductive core, would begin to fall off immediately at the exit to the nip).

Curve 42 represents the prior approach to roller transfer in that it is symmetrical about the nip contact region (represented by the time period 43) in the absence of toner and air ionization effects. Curve 41 is asymmetrical because of the effects of the relaxable and self-leveling layers during and just after exit from the nip region 43. The object is to have portion 41B of the curve 41 continue upward in post-nip until the Paschen curve is reached, thereby initiating the desired post-nip corona ionization. Yet pre-nip portion 41A is selected to remain below the Paschen curve 40 to realize the preferred condition of no pre-nip ionization. In contrast, it is apparent from an inspection of symmetrical curve 42 that the prior art rollers must be biased either above or below the Paschen curve in both pre-nip and post-nip. If they are biased above, damaging pre-nip ionization accompanies the desired post-nip ionization. If they are biased below, the pre-nip ionization is suppressed, but so is the post-nip, and other means of keeping toner 10 tacked to sheet 16 must therefore be employed in lieu of post-nip ionization.

The transfer conditions depicted by FIG. 3 is schematically illustrated by the plus signs 48 in FIG. 6. The plus signs 48 represent charge at the roller internal interface 47. Prior to entering the nip, the relaxable layer 21 is not subjected to high internal fields; that is, its outer surface is at substantially the same potential as the core 22. Just prior to and in the nip area the roller surface becomes closely spaced from the grounded backing electrode (support) 12. This tends to draw charge toward the roller 15 surface, but charge movement is resisted by the roller resistivity. Thus, the charge density at interface 47 increases as the relaxable

layer proceeds through the nip in proportion to the resistivity of the relaxable layer. Initially after exiting the nip, the charge density will generally continue to increase due to the internal field in the relaxable layer 21, or the induced charge may have nearly reached equilibrium; in either case the rapid increase in the air gap soon after separation occurs causes the ionization level to be reached for the field strength corresponding to the residual charge density. (The Paschen curve level at which ionization occurs in a function of spacing as well as field strength, and in the present case it is mainly reached by the increase in the air gap rather than by an increase in the field).

Ions from this air breakdown are drawn to the opposing surfaces 24 and 30. Then, as the gap becomes substantially wider, the air gap field falls below the Paschen curve, and, as discussed above, charge relaxation occurs in the relaxable layer 21; so ionization stops.

The plus signs 30 and negative signs 49 represent positive and negative ions deposited on the transfer sheet 16 and the outer surface 24 of the roller 15, respectively, as a result of the post-nip ionization of the air in the gap. (Note that a plus sign 48 is positioned at interface 47 opposite each negative sign 49 to represent an induced counter-charge within the roller which was brought to interface 47 during relaxation of material 21 in the nip). The positive charge 30 holds (and continues to maintain) the transferred toner 10 to sheet 16. The negative charge 49, on the other hand, is dissipated by current flow through the self-leveling layer 20 during the subsequent one to five revolutions of the roller.

The field intensity required to break the bond of the toner 10 to the initial support 11, and to tack the toner to the sheet 16, is reached at some time after the entrance to the nip but before post-nip ionization occurs. (In FIG. 3, the transfer is depicted for convenience as having occurred at the exit of the nip). However, a continued "holding" or tacking field (from charge 30) must also be present during the subsequent stripping of the paper 16 from the support 11 for high efficiency and stable toner transfer.

With the above information, the significance of the constant current energy source is better understood. Stated simply the significance is that suggested earlier; namely, the constant current source provides automatic correction of post-nip fields to compensate for changes in the electrical parameter of the roller and its environment. The parameters that normally experience the greatest and most frequent fluxuations are roller resistivity, which is very sensitive to RH, and transfer sheet thickness. In terms of FIG. 3, constant current biasing is the method and means for keeping curve portion 41A below the Paschen curve 40 to prevent pre-nip ionization and for insuring that curve portion 41B intersects the Paschen curve in the post-nip region. This control of the extent of post-nip ionization controls the amount of deposited charge 30, and therefore the toner "holding" field on the paper 16 is more constant, and maintainable at a moderate level providing good toner holding, but also easier paper stripping. Thus, high transfer efficiency is achieved with a relatively lower applied current and charge density on the transfer member.

Curves 54, 55, and 56 in FIG. 4 depict the beneficial operation of constant current biasing. Curves 54 and 56 represent the field levels for pre-nip and post-nip

ionization, respectively, versus changes in the resistivity of roller 15 for the previously defined resistivity range. The roller resistivity variations are exemplary changes in the resistivity of the relaxable layer with changes in RH. Curve 55, which lies in the ideal region between curves 54 and 56, is obtained by keeping the roller current constant.

Curves 60 and 61 in FIG. 5 illustrate a family of curves for constant current that permit field intensities below the pre-nip ionization level. Curve 62 represents the pre-nip ionization level for the resistance range shown.

The current referred to as being held constant throughout this description is the current to the roller 15 core 23, I_R . This roller current I_R is, by reason of conservation of charge, basically equal to the post-nip ionization current I_N . (Substantially zero pre-nip current is, of course, one of the desired operating conditions here.) The constant current bias source 23 may be described as a device for automatically widely varying the potential level coupled to roller 15 to automatically compensate for I_R changes, due to the connected load (resistance) changes, which are due to changes in ambient RH and temperature and aging of materials plus other factors tending to effect the pre-nip, nip and post-nip field levels such as paper thickness, charge buildup on the self-leveling layer, etc. In the specific system described herein, the constant current source output I_R is equal to about 1.5 microamps per inch, where the inch refers to the length of the roller along its axis (perpendicular to the plane of FIG. 6). The wide internal roller resistivity swing previously discussed requires the bias potential on core 22 here to vary from about 800 to about 4,000 volts to maintain this constant current of 1.5 microamps per inch (Note FIG. 4). Thus, the bias source 23 output voltage must vary automatically over this voltage range.

It is important to point out at this time that effective constant current biasing is closely interrelated here to the earlier-discussed self-leveling ability of the outer layer 20. If the negative charge 49 on the roller surface 24 is not dissipated, it may suppress transfer performance during subsequent revolutions of the roller by exceeding the voltage compensation capability of the bias source 23. Alternatively providing external charge leveling means, such as a conductive roller in contact with the outer surface 24, or a biased neutralizing corotron, would not be satisfactory for the present constant roller current operation. The current drawn by any such external leveling devices, because of conservation of charge, would be substantially equal to the post-nip current I_N . This means that I_R would be zero, leaving nothing to regulate by the bias source 23 in response to changes in the roller electrical parameters. The currents in an external leveling device could be regulated by a constant current biasing circuit, but such a circuit would be insensitive to the roller electrical parameters. Consequently, it may be seen that the desired results of the present invention would be quite difficult to achieve with a constant current biasing of external, rather than internal, charge leveling means.

The air gaps W, X, Y and Z (FIG. 6) around roller 15, sheet 16 and support 11 are important. The paper transfer sheets with which this invention is particularly concerned will necessarily involve such various air gaps although possibly in some altered manner from that illustrated. As long as pre-nip ionization is suppressed,

gaps W and X cause no particular electrical problem to the transfer operation and the relation of gaps W and X to each other is not particularly critical. Pre-nip ionization in gap W results in charging of the sheet 16 which in turn may cause premature toner transfer resulting in poor image resolution. It also induces ionization in gap X. Ionization in gap X causes the charge associated with toner 10 to be altered. Pre-nip ionization effects will be less if X is smaller than W, i.e., if the paper is closest to the photoconductor. High fields in gap X can also cause the toner to jump prematurely across the air gap W.

Air gaps Y and Z are critical because the desired post-nip ionization must occur in gap Y. The ionization in gap Y enables the charge 30 of appropriate sign to tack the transferred toner to sheet 16. (However, as noted, it also tacks the sheet 16 to the photoconductor 11.) Ionization, if any, in gap Z usually follows that in gap Y and reduces the net charge in the paper and adds to the negative charge associated with the transferred toner 10, bonding it more strongly to the paper.

Ionization in gap Z before gap Y would lead to a negative charge on the paper and untacked toner. Ionization in gap Y in preference to gap Z, and efficient transfer prior to stripping, is insured by making gap Y open at a faster rate than, and prior to, gap Z. This is accomplished respectively in the present embodiment by selecting the radius of roller surface 24 to be less (e.g., by a factor of two to four times) than the radius of support 11, and by the partial wrap in post-nip of the sheet 16 and support 11 together on the backing roller 12. i.e., stripping occurs substantially after the transfer nip. The radius of support 11 is established for the apparatus of FIG. 6 by the radius of the backing roller 12.

It should also be noted that the shape of the Paschen curve for an air gap can be affected by the paper position. When the paper splits the inter-roller air gap into two gaps, as X and W, air ionization will require a higher field level than for a single gap, as Y (which is desired here.)

The exemplary electrical circuit shown in FIG. 2 is capable of providing the constant current biasing voltage source 23 for roller 15. Transistors Q301 and Q302 level out input power E_{in} to a transformer T1 primary. Initially assume the circuit is working in a steady state condition, supplying current I_R within the above-discussed specifications to the load (core 22). If the load resistance suddenly increases (e.g., when paper is fed between the bias roller and photoreceptor), the load current tends to decrease from its steady state value. A load current sensing return path is provided up through zener CR308, current setting pot R8 and resistance R312 and then to the transformer T1 secondary at tap P7. (The low side of the rectified output). Thus, as the load current decreases the voltage drops across R8 and R312 are reduced, and hence, the voltage across capacitor C305 to ground tends to go up. This decreases the connected base voltage input to transistor Q305, thereby decreasing its emitter current. The base of adjacent transistor Q304 is clamped to a fixed voltage (determined by voltage divider R308 and R317), so the voltage at its emitter is effectively constant. Current to transistors Q304 and Q305 is shared through a common emitter supply resistor R310. Thus, when the current through Q305 decreases, the current through Q304 proportionally increases, thereby increasing the voltage drop across its output resistor

R311. Resistor R311 connects to the base of a transistor Q303, and an amplified rectified a.c. output appears across its output resistor R306 which is connected to primary tap P5 as a control voltage E_c . The increase in E_c increases the total peak-to-peak voltage in the transformer T1 primary and, therefore, the output voltage developed across the load at the transformer secondary. The output voltage will thereby increase until the load current reaches its original value determined by setting of pot R8.

It will be appreciated that many other suitable applicable constant current supply designs are available in the electronics art, and that the above-described circuit is merely exemplary.

The mechanical features of the particular transfer system depicted in FIG. 1 are also described in copending applications. Briefly, transfer sheets 70 are fed through chute 71 in registration with a toner image on the photoconductive belt 72. Prior to reaching the nip region 73, the charge on the surface of the belt 72 may be altered by an appropriately biased corotron 74 and/or a pre-transfer lamp. The transfer roller 75 and constant current bias source 76 are of the same design as that described in connection with FIG. 6. As discussed in the previously cited Dolcimascolo application, a specific example of an appropriate self-leveling layer 77 is a polyurethane material commercially available from the DuPont Company under the tradename ADIPRINE (Type L315) while examples of the relaxable layer 78 include materials such as the polyester urethanes. An outer overcoating of low moisture permeability polymer material such as polyvinylidene chloride may be additionally applied. The speed of the sheet through the nip 73 is about 10-20 inches per second. The cleaning brush 80 with its associated vacuum housing 81 is positioned to clean stray toner and dirt from the outer surface of roller 75.

The corotron 82, in the post-nip area in FIG. 1, is commonly referred to as a detack corotron. It is designed to neutralize or lower the potential of the charge deposited onto the sheet 70 by transfer post-nip ionization. That is, corotron 82 is designed to neutralize most of the charge represented by the plus signs 30 in FIG. 6. Lowering the charge on the non-image areas of the transfer sheet makes the sheet easier to strip from the belt 72. In this regard, the output of the present constant current bias source 76 or 23 can be adjusted so that the tacking force of the charge on the non-image side of sheet 70 does not tack the sheet 70 to the belt

72 too strongly. In other words, the bias current previously described as I_N can be adjusted so that a detack corotron 82 is not necessary, although transfer efficiency may be lowered.

The extraction of sheet 70 from the transfer system and belt 72 is accomplished by a vacuum belt transport 83. Transport 83 includes the continuous belt 84 moving around roller 85 in the direction indicated. Acting through the bottom section of the belt 84 is a vacuum chamber 86 that pulls the sheet 70 to the bottom of the belt 84.

Obviously, the foregoing embodiments may be altered without departing from the spirit of the present invention. Clearly, a xerographic system using a photoconductor arranged on the surface of a cylinder is equally profited by the present system. Likewise, other variations in environments or in details of the above-described system are possible without departing from the instant invention.

What is claimed is:

1. A transfer method for transferring an image of electrically charged particles from an original support to a transfer member with an electrically relaxable transfer electrode comprising:

rotating said transfer electrode,

establishing a nip between said transfer electrode and said original support,

passing said transfer member through said nip from a pre-nip side of said nip through a post-nip side of said nip,

applying an electrical bias to said transfer electrode, forming with said electrical bias and said transfer electrode electrical fields which are asymmetrical between said pre-nip and post-nip sides of said nip and which have post-nip electrical fields substantially above air ionization levels and pre-nip electrical fields below substantial air ionization levels,

and automatically varying said electrical bias applied to said transfer electrode to maintain said pre-nip and post-nip electrical field levels under variable transfer conditions including variations in the resistivity of said transfer electrode by steps including maintaining said applied electrical bias at a substantially constant pre-set applied current level.

2. The method of claim 1 further including maintaining a larger air gap between said transfer member and said transfer electrode than between said transfer member and said original support at said post-nip side.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,860,436 Dated January 14, 1975

Inventor(s) Thomas Meagher

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Page 1, after the name and address of the inventor,
insert:

--[73] Assignee: Xerox Corporation, Stamford, Conn.--

Signed and sealed this 1st day of April 1975.

(SEAL)

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

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