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Hamaker

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[54] **FORAMINOUS VACUUM BIAS ROLL TRANSFER SYSTEM**

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[51] **Int. Cl.** **G03g 15/16**

[58] **Field of Search** ..... 355/3 R; 96/1.4; 118/621

[56] **References Cited**

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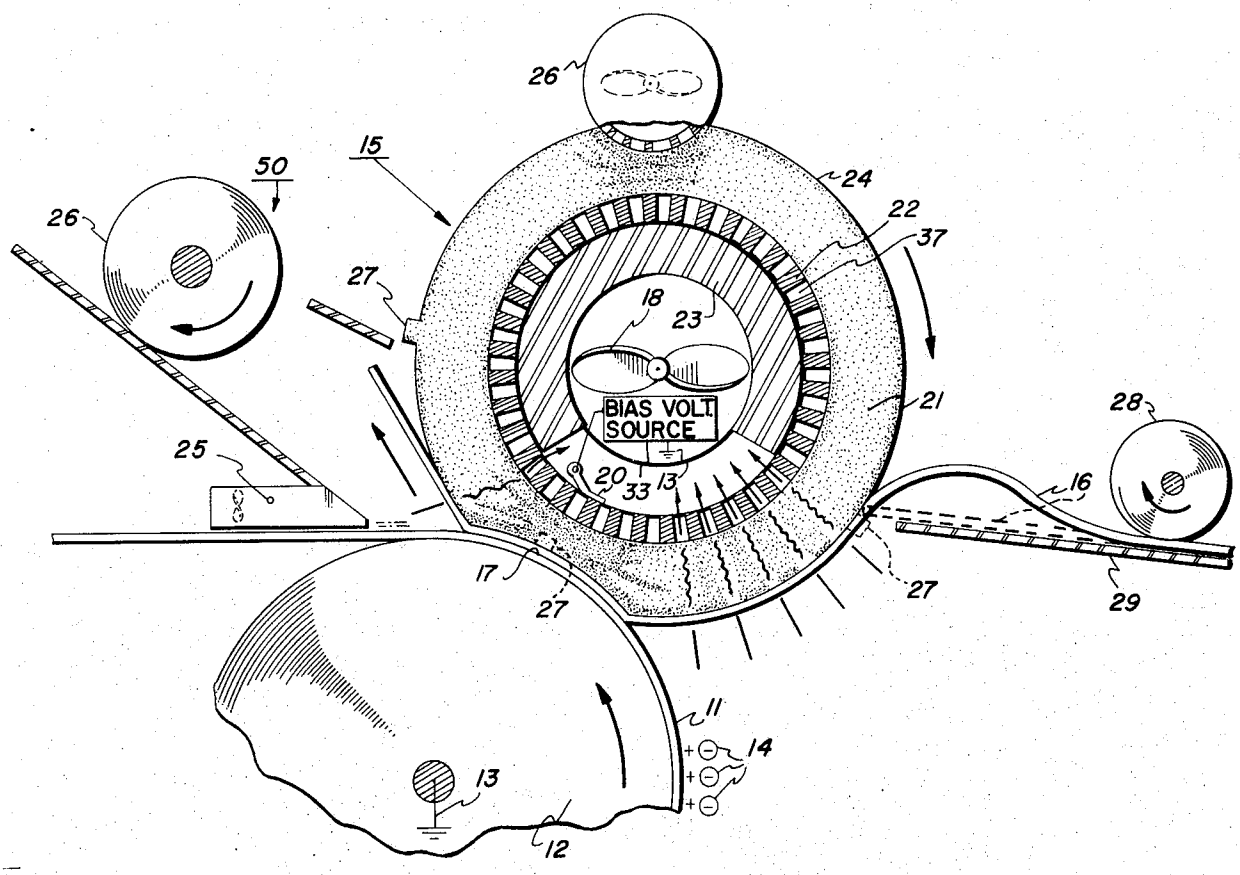
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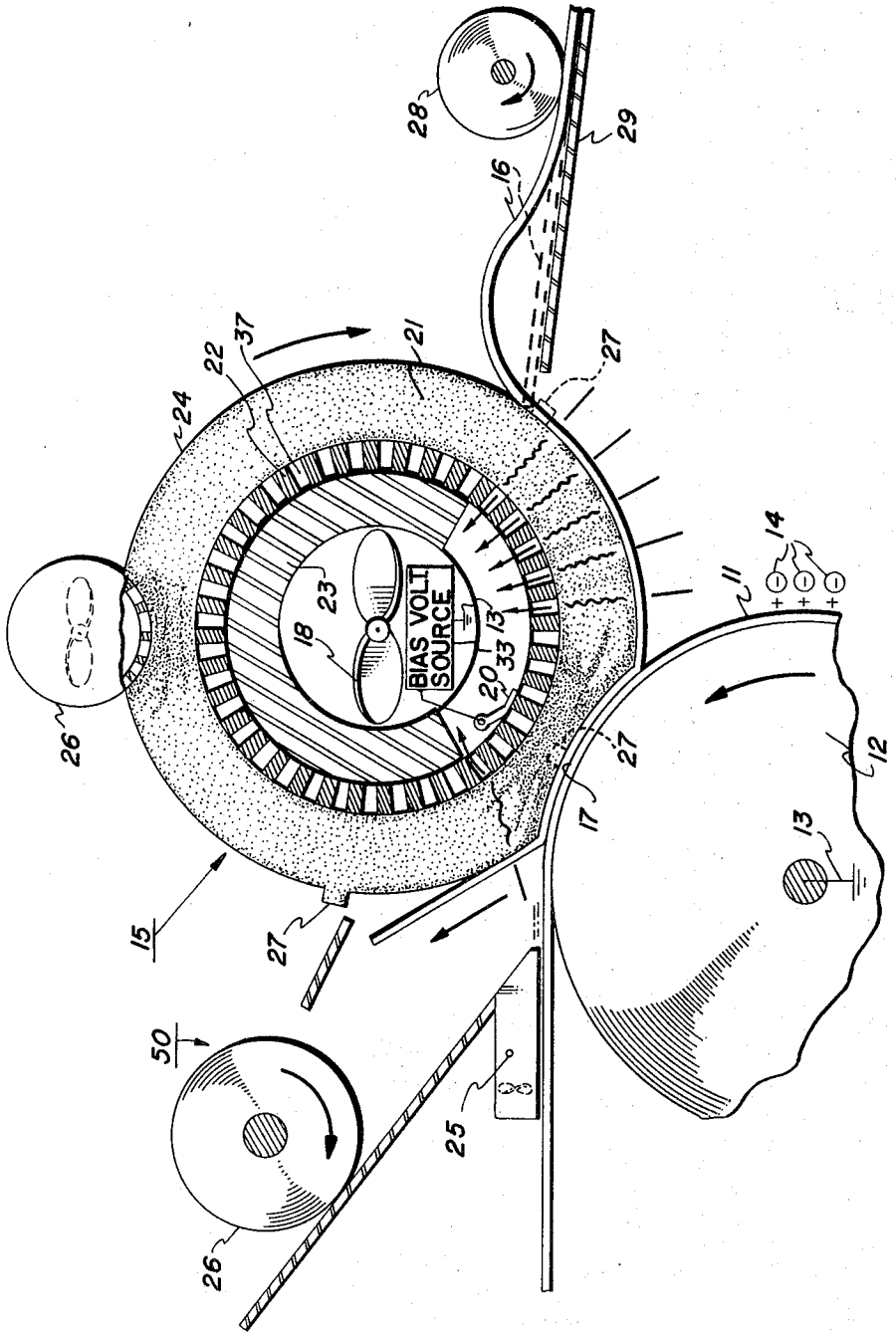
Primary Examiner—Robert P. Greiner

[57] **ABSTRACT**

In electrostatographic apparatus for applying a high bias voltage between a bias roller electrode and an original support surface to provide an electrical field for development material transfer to a cut sheet therebetween without arcing or undesired corona, a roller electrode having an electrically conductive core to which said high voltage is applied and a normally thick roller body of foraminous convolute open cell material compressed between the conductive core and the support surface and a vacuum applied through said foraminous material to hold said cut sheet against said roller electrode.

17 Claims, 1 Drawing Figure




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FORAMINOUS VACUUM BIAS ROLL TRANSFER SYSTEM

The present invention relates to the transfer of image developing charges or materials from one support surface to another in electrostatography, and more particularly to the use of endless foraminous members in connection with electrical fields for such transfers. It provides advantages of vacuum sheet retention to a generic transfer system disclosed and claimed in a co-pending U.S. Pat. application No. by Robert W. Gundlach entitled, "Foraminous Electrostagographic Transfer System" filed May 29, 1973 as Ser. No. 364,463 and having the same assignee.

The best known example of such transfer is the conventional transfer step in xerography wherein toner is transferred from the photoreceptor (the original support surface) to the copy paper (the final surface). However, such development material transfers are required in other electrostatographic processing steps.

In xerography, developer transfer is most commonly achieved by electrostatic force fields created by D.C. C. charges applied to the back of the copy paper (opposite from the side contacting the toner-bearing photoreceptor) sufficient to overcome the charges holding the toner to the photoreceptor and to attract most of the toner to transfer onto the paper. These xerographic transfer fields are generally provided in one of two ways, by ion emission from a transfer corotron onto the paper, as in U.S. Pat. No. 2,807,233, or by A D.C. biased transfer roller or belt rolling along the back of the paper. Examples of bias roller transfer systems are described in U.S. Pat. Nos. 2,807,233; 3,043,684; 3,267,840; 3,598,580; 3,625,146; 3,630,591; 3,691,993; 3,702,482; and 3,684,364. Also, French Pat. No. 2,065,390, German Application OLS 2,102,634 and British Pat. Nos. 1,210,666 and 1,302,922. U.S. Pat. No. 2,968,555 issued Jan. 17, 1961, to R. W. Gundlach in FIG. **3** and Column **10** briefly discloses a xerographic transfer system utilizing a soft resilient sponge rubber coated transfer roller, preferably electrically conductive. However, no substantial deformation of this roller is shown or suggested.

Foraminous members have, of course, been utilized in other different applications in electrostatography, such as paper handling, or photoelectrophoretic development rollers, e.g., Canadian Pat. No. 876,045. Also, a planar, evenly compressed conductive pressure pad for intermittent latent (charge) image transfer is disclosed in U.S. Pat. No. 3,635,556 issued Jan. 18, 1972, to R. L. Levy.

Various solid porous vacuum roll paper transport rolls are known in the art. U.S. Pat. No. 3,633,543 issued Jan. 11, 1972, to Carl R. Pitasi discloses a xerographic biased transfer roller having a resilient material surface layer capable of passing air therethrough for sheet retention. The specified material is either conductive rubber or a thin insulator, and the air passages are formed by pinholes through the material. This patent also discloses a recessed lip portion on the roll circumference for registration stopping of the copy sheet.

The transfer of the development materials involves the difficult and critical physical detachment and transfer over of such particulate materials by high intensity electrostatic force fields from one surface into attachment with another surface, maintaining the same pattern and intensity as the original latent electrostatic image being reproduced without scattering or smearing of the developer material. This difficult requirement can only be met by careful control of the electrostatic fields, which must be high enough for transfer yet not cause arcing or excessive corona generation at undesired locations, since such electrical disturbances can easily cause scattering or smearing of the development materials. Further, especially where the second surface is a cut sheet, it must be precisely registered with the image on the first surface prior to transfer.

The critical function of pre and post-nip corona in xerographic bias roll transfer is discussed, for example, in co-pending application Ser. No. 309,562 filed Nov. 22, 1972, by Thomas Meagher, entitled Constant Current Biasing Transfer System issued as U.S. Pat. No. 3,781,101 on Dec. 25, 1973, and in U.S. Pat. No. 3,702,482 by C. Dolcimascolo, et al., issued Nov. 7, 1972. Controlled generation of corona in post-nip for electrostatic tacking of toner to paper after transfer may be provided along with suppression of pre-nip corona.

Perhaps the most difficult technical problem in all of the roll or belt electrode systems for transferring of electrostatographic imaging development materials between supports is that discussed above of controlling or suppressing arcing and undesired corona generations. This is primarily due to the fact that in practical such systems the transfer of materials must be effected while the two surfaces between which the material is being transferred are both moving at the same speed. This as a practical matter requires the material transferring electrode to be an effectively endless surface of a cylindrical roller or small endless belt. This in turn means that the surface of the roller or belt electrode must continuously move in and out of contact with the original support surface. This creates varying width (exponential) air gaps at each side of the actual contact area (the nip region). The upstream or entrance air gap is conventionally referred to as the pre-nip region and the downstream air gap as the post-nip region. Due to the fact that the breakdown voltage across an air gap is very non-linear with changes in the gap dimensions (this characteristic is known as the Paschen curve) control of arcing or ionization in such air gaps when there is a high biasing voltage on the electrode is very difficult. The higher the applied bias voltage the more difficult such control becomes, yet in many applications high voltages are either required or highly desirable for efficient transferring of the material from the original surface or liquid suspension to the second surface. Further, since the field intensity for material transfer is a function of the spacing as well as the applied potential the biasing voltage charge is desirably applied as closely as possible to the original support, again further increasing the difficulty of preventing voltage breakdown by arcing or excessive corona generation in the nip itself as well as the pre and post-nip gaps. Further, both vector direction and intensity of the applied electrical fields varies at different locations and times relative to the roller electrode because the electrical fields are geometrically dependent upon the electrode configurations, and change as the electrode moves. The present invention provides a system in which such desired high biasing voltages and close spacings may be maintained with a simple and effective

arrangement also providing desired suppression of arcing and suppression or control of corona emissions in all of the nip, pre-nip and post-nip regions, for more efficient and reliable transfer of development materials.

Discussing in further detail the xerographic bias roller transfer process, the paper contact with the photoreceptor must precede the applied build up of high electrostatic fields by the transfer roller for two reasons. First, if excessive fields exist when the paper is still approaching the toner image on the photoreceptor, then toner particles can prematurely transfer, spreading as they jump the pre-nip gap, resulting in fuzzy images. Secondly, air ionization in the pre-nip gap can occur, reversing the polarity of toner particle charges and therefore preventing their subsequent transfer in the nip. The latter effect usually occurs intermittently, because it is self-quenching, and so manifests itself in what has been called "zebra stripe" transfer. In the nip an electrostatic field of about 10 volts per micron is sufficient to transfer loose charged toner particles from the photoreceptor to the paper surface. However, in order to establish a stable electrostatic bond between the toner and the paper after it is transferred, a net charge should be applied to the back of the paper opposite from the toner charge sufficient to tack the transferred toner to the paper so that it will not be dislodged in the subsequent paper handling, which includes the stripping of the paper from the photoreceptor. As disclosed in the Thomas Meagher U.S. Pat. No. 3,781,101, supra, and the Dolcimascolo et al. U.S. Pat. No. 3,702,482, this tacking charge may be created by deliberately inducing, but controlling, corona generation in the post-nip gap with a transfer roller of an electrically relaxable material. A constant current bias voltage supply can compensate for resistance charges in the relaxable material. Alternatively, if the roller and paper are conductive enough, this tacking charge may be applied to the paper in the nip by the contact between the roller and the paper. It will be noted that post-nip corona generation to generate toner tacking charges is not required for conventional xerographic corona transfer systems, where both transfer and tacking are effected by ionicly depositing charges on the back of the paper.

An embodiment of the present invention is shown and described hereinbelow as incorporated in otherwise conventional exemplary electrostatographic apparatus and processes. Accordingly, said processes and apparatus need not be described in detail herein, since the above-cited and other references teach details of various suitable exemplary structures, materials and functions to those skilled in the art. Further examples are disclosed in the books Electrophotography By R. M. Schaffert, and Xerography and Related Processes by John H. Dessauer and Harold E. Clark, both first published in 1965 by Focal Press Ltd., London, England. All of the references cited herein are hereby incorporated by reference in this specification.

Further objects, features and advantages of the present invention pertain to the particular apparatus, steps and details whereby the above-mentioned aspects of the invention are attained. Accordingly, the invention will be better understood by reference to the following description and to the drawing forming a part thereof, which is substantially to scale, except as noted, wherein:

The FIGURE is a plan view, partially in cross-section, of an exemplary xerographic bias roller transfer system in accordance with the present invention.

Referring to the Figure, it may be seen that there is illustrated a xerographic transfer station **50** incorporating a vacuum foraminous bias transfer roller **15** in accordance with the invention. Other details of the transfer system **50** such as the photoreceptor **11** and the related xerographic systems known in the art are taught in the above-incorporated references on bias roller transfer systems and need not be described in detail herein.

It may be seen from the partial cross-sectioning of this axial plan view that the roller **15** illustrated here is normally cylindrical and the vast majority of its cross-sectional area and outer volume comprises a roller body **21** of foraminous open cell material uniformly coaxially surrounding a smaller cylindrical hollow central core **22** of conductive material, such as a perforated metal roller. A vacuum is applied to the interior of the core **22** by conventional vacuum means, such as the blower **18** illustrated schematically. The foraminous material here is shown as normally cylindrical and bonded to the outside of the central core **22** surface, extending over the perforations **37.** However, it will be appreciated that the terms "roller electrode" or "roller" as used herein are not intended to be limited to integral cylindrical rollers. They are also intended to read broadly on equivalent structures such as moving endless belts of the same foraminous materials with either rolling or stationary (sliding contact) arcuate conductive vacuum backing members. Examples of such equivalent structures are disclosed in the above-cited references.

The foraminous material of the roller **15** is open cell material rather than closed cell, i.e., having open voids or pores which allow expulsion or transfer of the contents of individual cells when the cells are compressed, and movement of air through the material. This material is preferably highly foraminous, i.e., the principal volume of the material in its normal uncompressed state comprises a multiplicity of convolute and separated random voids or pores closely interspaced throughout the material, so that the solid material itself can be considered primarily as discontinuous cell walls separating these voids and occupying only a minor portion of the total volume of the foamed material. Examples of suitable materials are **45** pore (45 cells per inch) or **100** pore open celled polyurethane foam, which may be commercially obtained, for example, from the Scott Paper Company. The present invention is applicable to many different foraminous materials, many of which are commercially available, and given the criteria and teachings herein such materials may be readily selected by one of ordinary skill in the art of foraminous materials.

It may be seen that the foraminous body **21** of the roller **15** is highly compressed from its normal uncompressed radius into close to the radius of the conductive core **22.** The maximum compression of the roller body **21,** due to the curvature of the core **22** (which is not compressed), occurs at the normal nip area **17,** and the compression is substantially less in the pre-nip and post-nip areas. However, the low durometer resiliency of the foam roller body provides a large area of roller surface contact with the photoreceptor **11** surface extending well into the pre-nip and post-nip areas and

covering an area much larger than a normal solid roller nip contact area.

The minimum (compressed) distance between the core **22** and the outer surface **24** of the roller **15** is here preferably less than half the normal umcompressed thickness of the foraminous material, so that a substantial number of the normally open cells in the nip **17** are closed by compression. However, full compression (closing of substantially all cells in the center of the nip) is not desired where registration lips are provided as subsequently discussed. With 50 percent compression (not practicably achievable with a solid roller) the transfer field in the nip can be twice the field in the pre and post-nip air gaps. An uncompressed foraminous layer of approximately one centimeter in thickness can be utilized, or a deep "pillow" roller may be utilized.

In comparison, even very soft rubber rollers which are solid cannot achieve the desired forms and close nip spacings of the disclosed foraminous roller electrodes. Solid rollers can only be somewhat deformed, rather than compressed, causing severe internal stresses on the material in an attempt to bring the roller core close to the support surface. Further, with a foam roller a much lower effective durometer can be achieved than with a solid roller without having to go to a material which is so soft as to have poor strength and wear resistance properties. The much greater roller surface deformation which can be achieved with relatively light compression pressures in foam rollers provides a much greater surface contact area for improved transfer and paper hold-down, with much more even and reduced pressures for reduced wear and reduced distortion of components, in addition to the significant electrical advantages disclosed.

An air permiable coating may be provided on the circumferential exterior surface **24** of the roller electrode **15** which is sufficiently elastic and resiliently conformable to the compression of the foraminous material. An example is **10** mil perforated polyurethane. Such a surface coating of non-compressible material can be used to permit surface speed synchronization of the system, and to provide increased wear resistance and cleanability.

Considering further the exemplary xerographic transfer bias roller **15,** it has a foraminous roller body **21** with a conductive core **22** connected to a conventional transfer bias voltage source **33** by wiper contact **20.** The bias source **33** may be connected through common grounds **13** to a conductive backing roll **12** against which the roller **15** is highly compressed with moderate pressure. Through the nip **17** between the two rollers passes a flexible belt photoreceptor **11** and paper or other final support sheet **16.** Negatively charged toner particles **14** previously developed onto the photoconductor **11** surface are retained thereon by positive latent image charges until transfer is effected. Here, transfer by the bias source **23** occurs from the high fields in the nip area **17** created by the foraminous roller body **21** being highly compressed so that the conductive core **22** is closely spaced in the nip from the photoconductor.

The disclosed structure provides greatly improved control capabilities as compared to an ordinary transfer roller which maintains a generally cylindrical configuration and simple pre and post-nip air gap configurations. Not only is the shape and contact area of the nip different here, but also the foraminous material fills the space between the conductive core and the contacting support surface with a multiplicity of small discontinuities provided by the cells in the material, thereby providing a greatly improved air ionization control barrier. The foraminous material is significantly less compressed (less dense) in the pre-nip and post-nip areas than in the nip area. That is, it has a much greater thickness and porosity between the conductive core and the support surface in the normal pre-nip and post-nip areas. The foraminous material extends much further laterally into the pre-nip and post-nip areas, due to its greater deformation, i.e., it has a much larger surface contact area. This increasing thickness and porosity of the foraminous material can be utilized to provide a varying ionization control barrier in the pre-nip and post-nip areas. Further, as previously noted, even further ionization control variability between the nip area and the pre and post-nip areas can be provided by the degree of compression of the foraminous material in the nip. As the compression is increased, the individual cells may be collapsed, whereby the tops and bottoms of the cell walls contact one another. As more cells are collapsed, the electrical properties of the roller in the nip can change dramatically from those of the normal uncompressed porous material to those of a thinner solid roller in the same material. This greatly adds to the effect of the increase in field strength due to the closer conductor spacing geometry of the nip.

It will be noted that the deformed radius of curvature of the roller **15** surface **24** at the post-nip exit is much less than the normal roll radius. This sharp curvature, together with the paper beam strength, assists in assuring stripping of the paper from the transfer roll **15.**

The foraminous bias roller systems disclosed herein may be utilized in different material modes, with different operational properties and functions, although the above-described features and advantages are applicable to all of them. One mode is to provide a foraminous material **21** which is highly insulative, and therefore non-conductive to the bias voltage supply. Another mode is to provide a foraminous material which is resistive, but at least semi-conductive, such as an electrically relaxable material as disclosed in the above-cited references on bias transfer rollers. In this second mode at least part of the transfer bias charge will be conducted out toward the outer surface of the transfer roller.

Considering first the mode wherein the foraminous roller body is insulative and the pores are air filled, it may be seen that in this case the foraminous material does not affect the vector direction or intensity of the transfer fields. These fields will be controlled entirely by the geometry of the spacing between the conductive core and the opposing conductive support **12** surface. In this case the above-described function of the foraminous material in breaking up the air gap into many smaller individual air gaps separated by cell walls provides an important function. The foraminous material allows the application of biasing potentials of over 1,000 to 3,000 volts between the conductive core and the support surface with very close nip proximity therebetween to provide very high field intensities. The foraminous material can allow such high field intensities while either totally suppressing ionization in the entire air gap, or allowing some ionization in post-nip and suppressing it in the pre-nip and nip areas.

As will be recalled, the electrical field intensity at which any air breakdown occurs is a function of the air gap distance, and a smaller gap will support a much higher field intensity without breakdown. This is represented by the characteristic Paschen curve. The wide lateral extent of the roller contact area and its relatively even pressure insures that the air gap between the outer surface of the roller and the support surface is small and substantially constant to well outside of the normal nip areas, thereby suppressing arcing or undesired corona. No larger air gaps which would induce ionization are formed until the distance from the conductive core is so great that the field intensity or stress in the air gaps is below the ionization potential, i.e., the field intensity is greatly reduced by the time the larger pre or post-nip air gap is formed. With the foraminous roller, the normal position of the pre-nip and post-nip gaps can be greatly laterally displaced, yet simultaneously the distance between the conductors forming the transfer field can be made very small. These two inter-related desired criteria cannot be effectively met by a solid roller. They can be readily met by a foraminous roller body which is sufficiently thick and sufficiently compressible.

Considering now the materials mode in which the foraminous material of the bias roll is resistive rather than insulative, as noted above this mode can be used to provide unsymmetrical fields. That is, the internal resistivity relaxation properties of the material can provide suppression of ionization in the pre-nip air gap while simultaneously encouraging it in the post-nip air gap. Suitable material resistivities for such relaxable transfer operations are discussed in above-cited references such as the Dolcimascolo, et al., U.S. Pat. No. 3,702,482 and the Thomas Meagher U.S. Pat. No. 3,781,101 supra. The foraminous material of the invention can provide significant improvements in such systems because the bulk resistivity (resistance per unit volume) of the foraminous material can be changed substantially by its compression. That is, as the foraminous material is compressed in the nip the actual resistance between the conductive core and the roller surface decreases. Therefore, the roller resistance and relaxation time in the nip is greatly lower than in the uncompressed pre-nip area of the roller. This allows a faster relaxation of the material in the nip, which in turn provides higher fields between the roller surface and the support surface in the nip and in post-nip over a much greater area. Accordingly, the effective latitudes for transfer are much greater electrically as well as mechanically. This allows a relatively higher resistivity material to be used, which material can be less humidity sensitive as to its resistivity and, therefore, more reliable. Such higher resistivity material, where foraminous, can insure pre-nip corona suppression even with substantial variations in humidity and paper, yet also prevent inadequate relaxation (excessive roll internal fields) which could cause inadequate transfer fields or inadequate post-nip gap ionization fields. In fact, the foraminous relaxable material can effectively act as a complete insulator on the uncompressed entrance side of the nip.

Resistivity changes under compression for foraminous relaxable materials of several orders of magnitude have been experimentally observed, which clearly allows greatly improved design and operating control over charge relaxations. That is, once the tops and bottoms of the cell walls touch one another in compression the resistivity has been observed to sharply drop immediately. Conductivity changes of 100 to 1,000 times have been measured between the fully expanded foam and a practical degree of high compression achievable with low pressures.

A much larger and more uniform mechanical contact area of a foraminous roller surface with any paper between it and a photoreceptor provides greatly improved mechanical tacking of the paper to the photoreceptor. Thus, the chances of premature toner transfer across any significant air gap between the paper and the photoreceptor are greatly reduced, since the paper is already mechanically held against the photoreceptor before it can be subjected to fields sufficient for toner transfer, either from the transfer roll or from charges deposited on the paper from pre-nip corona. This is even more true of the fully insulative foraminous material mode previously described. Uniform and positive paper/photoreceptor contact, especially at the leading and trailing edges, is, of course, one of the principal advantages of a bias roll transfer system as opposed to a corotron transfer system and a foraminous roll is superior in this regard.

Due to the fact that the foraminous material **22** of the transfer roller **15** expands to its normal thickness everywhere except in the nip area **17** (and its entrance and exit), the outer surface **24** of the roller can be substantially spaced from the conductive core **22.** This allows a sheet of paper **16** or other second support to be held against the roll surface **24** before and after the sheet contacts the photoreceptor **11** without being charged by the bias voltage and in sufficiently low fields so that undesired arcing or corona in the feeding or stripping off of the sheet from the transfer roll **15** is not a problem.

The transfer roll **15** provides positive vacuum retention of the cut sheet **16** on its outer surface **24** from before the pre-nip area until substantially after the post-nip area. This is provided here by applying a uniform vacuum on the interior of the foraminous material in these areas so that the paper is uniformly positively mechanically tacked by air pressure to the surface **24.** Even though the foraminous material **22** is relatively thick the open cell structure provides a multiplicity of small air passages from the outer surface **24** to the interior surface, where the air then passes through the perforations **37** in the perforated conductive core tube **22.** Only the portion of the roller **15** encompassing the initial sheet registration, pre-nip and post-nip areas need to be subjected to the vacuum. Blocking of the vacuum to the rest of the roll may be accomplished as shown here by a stationary semi-cylindrical manifold tube **23** which slideably abuts most of the interior surface of the perforated tubular core **22** to block the air passageways **37** in all but the desired vacuum area (in which the manifold **23** is cut away). A Teflon or other lubricant surface may be provided therebetween. With this configuration the manifold **23** may also provide the support for rotation of the roll **15.** However, the roll **15** may also be rotatably mounted by the core **22** providing suitable electrical insulation is provided at the ends of the tube. The vacuum means **18** may be applied at one end of the interior of the manifold **23,** and the other end sealed.

The foraminous vacuum transfer roller **15** provides a significant advance over the perforated vacuum trans-

fer roller exemplified by the U.S. Pat. No. 3,633,543 disclosure noted in the introduction. That reference discloses a thin transfer roller surface material wherein the vacuum air passages are formed by pinholes directly through the material. While these pinholes provide the necessary air passageways for vacuum retention of sheets on the roll surface, they increase the danger of air breakdown in the nip, pre-nip and post-nip areas. This is because for effective transfer a relatively high bias voltage must be applied between the bias roll conductive element and the opposing surface, and air breakdown therebetween is a function of the air path length, as modified by an effective interposed dielectric. With a pinhole arrangement the air path length is axial and effectively limited to the thickness of the insulative material through which pinholes are formed. Such pinholes cannot be lengthened without using a thicker solid insulative material layer, but that would increase the nip spacing and therefore lower the effective transfer fields. The pinholes provide direct uninterrupted spark discharge paths in the nip, in effect rendering the insulative layer relatively ineffective for spark suppression, other by than maintaining an air gap distance equal to the thickness of the layer. While such a system is nevertheless operative in that it can provide effective controlled spacing and vacuum retention of the sheet thereon, the foraminous roller of the invention is a substantial improvement thereon allowing higher intensity transfer fields yet reduced sparking danger.

Specifically the foraminous roller **15** provides significant advantages over a perforated roller in that the air path length is not limited to the thickness of the insulative material. Rather the foraminous open cell material has highly convolute air passageways therethrough. These passageways have extensive lateral convolutions and discontinuities and do not provide direct axial spark discharge paths therethrough. Thus, the foraminous material provides a substantial ionization control barrier capable of controlling or suppressing much higher intensity electrostatic fields than an air gap of equivalent thickness. The spark discharge air paths through the material are very much longer than the radius or thickness of the foam layer even when the material is uncompressed. Thus, the foraminous material provides a cellular structure which is sufficiently convolute so as to effectively not provide air breakdown paths, yet provides sufficient air permiability for applying a vacuum to its outer surface **24.**

As the foraminous material of the roller is compressed in the nip **17** and its adjacent areas the air passageways through the pores thereof becomes even more convolute relative to the material thickness. As the foraminous materials compresses the pores providing the air passages become constricted and then begin to close completely. Under sufficient compression, which may be achieved with relatively low pressures, the air passages in the nip may be substantially all effectively closed. This provides an even more unique function and operating advantage since it means that the transfer bias roller can effectively operate in the nip region with a continuous uninterrupted insulative (or semi-conductive if desired) outer layer (without any spark path discontinuities). Such properties are highly desirable in the nip for withstanding the high fields therein, and the disclosed roller can provide this function simultaneously with the desired quite different porous vacuum sheet retention function in the pre and post-nip areas. It will be noted that vacuum retention of the sheet **16** is not needed in the nip region **17** in any case, since the sheet **16** is being held between the photoreceptor **11** and the transfer roll in this area.

The greatly improved spark discharge barrier as well as the much higher compressibility of the foraminous roll allows much closer nip transfer spacings, with resulting higher transfer field intensities, thus providing higher transfer efficiencies, yet without sacrificing vacuum sheet retention. Thus, it may be seen that the disclosed foraminous transfer roller provides very significantly improved results and benefits over the use of a pinhole rubber or other such transfer roller in the same application.

Additional means which may be provided in the transfer system **50** includes a blower or puffer **25** for blowing air into the post-nip area. This assists in the stripping of the sheet **16** from the roller **15.** As the leading edge of the sheet **16** comes out of the nip **17** it may tend to adhere to the photo-receptor **11** in spite of the vacuum being applied to it by the vacuum means **18** through the foraminous material **21** as the material expands in the post-nip area. This is because air cannot easily get under the paper **16** (between it and the photoreceptor) except by surface irregularities to provide the necessary air pressure differential lift. The puffer **25,** although not essential, assists in blowing air under the sheet **16** and giving it sufficient lift to make its initial separation from the photoreceptor **11.** Once that is effected the vacuum force from the transfer roller **15** is sufficient to overcome the gravitational and/or beam strength forces of the sheet and to hold the sheet on the roller **15** until the sheet passes through the post-nip region and reaches the area of the transfer roller **15** in which the vacuum force is cut off by the stationary manifold **23.** At that point the spacing of the surface **24** away from the charged core **22** and the weight and beam strength of the paper allows the paper to readily strip itself away from the surface **24** so that it can be carried away by conventional sheet feed-out means **26.**

It will also be noted that the convolute and small diameter air passageways through the foraminous layer provide a relatively high resistance to rapid air flow therethrough. This protects against excessive vacuum losses in areas of the roller surface **24** which are not covered by a sheet **16** at any given time, so that the vacuum in other areas is not effected.

It will be noted that with the disclosed arrangement that the transfer roller **15** is preferably positioned above the photoreceptor **11** at the nip, and that the segment of the transfer roller **15** to which the vacuum is applied (i.e., the pre-nip and post-nip areas) is in the lower-most sector of the transfer roller. With this arrangement the weight of the paper may be utilized in stripping it from the transfer roller **15.** However, this arrangement is merely exemplary and if a reversed arrangement is utilized a positive air pressure may be applied in the area of the manifold **23** (rather than merely blocking the vacuum in that area) for positive paper expulsion from the surface **24,** utilizing the same air passageways in the foraminous material.

Another feature which may be provided in the transfer system **50** is a system for cleaning the exterior surface **24** continuously as the roller **15** rotates. This is provided here by a stationary hollow vacuum tube **26**

deformably engaging the surface **24** as the surface passes under it. The tube **26** is stationed substantially away from the nip **17** so as not to interfer with the transfer operation. A vacuum is applied through apertures in the wall of the tube engaging surface **24** for removing toner or paper lint, etc., which may otherwise accumulate on surface **24.** It may utilize the same, or separate, vacuum means.

Accurate registration of the incoming sheet of paper **16** or other final support member in the transfer station **50** is extremely important. The sheet **16** must be accurately aligned with the position of the electrostatic latent image on the photoreceptor **11** in order for that image to transfer to the paper **16** in the proper position. This registration is normally accomplished by control of the position and timing of the lead edge of the paper **16** at it directly enters the transfer nip **17.** However, there is disclosed herein, and claimed in a contemporaneous application by the same inventor and assignee entitled, Foraminous Sheet Registration System, Ser. No. 367,280, filed June 5, 1973, a simple and inexpensive novel registration means made possible by a foraminous roller. This is illustrated here by the exemplary registration lip **27** on the outer surface **24** of the roller **15.** The initial registration operation is illustrated by the alternate (dashed line view) position of the paper **16** and the registration lip **27,** in contrast to the solid line position of these elements. Another alternate position dashed line view of the registration lip **27** shows its fully flattened configuration in the nip **17.**

As may be seen, the sheet **16** is fed in toward the roller **15** by a feed-in roller **28** and an underlying guide plate **29,** or other suitable feed means. However, rather than being fed directly into the nip **17** with registration fully controlled by the feed roller **28,** in this case the lead edge of the paper **16** is fed into abutment with the surface **24** of the roller **15** substantially spaced from the nip. This is shown by the dashed view (unbuckled) position of the paper **16.** The rotation of the roller **15** is coordinated therewith so that the registration lip **27** at that point provides a stop for the lead edge of the paper **16.** The input speed of the paper **16** provided by the feed roll **28** is such as to form a buckle of the sheet **16** between the feed roller **28** and the transfer roll **15** as shown. The registration lip **27,** however, prevents the lead edge of the paper from sliding on the surface **24** and therefore maintains the registration of the sheet **16** at all times until it is fed into the nip **17.** The vacuum applied to the sheet **16** holds it down against the surface **24** behind the registration lip **27** so that it cannot lift or be driven over this lip, i.e., the sheet lead edge may move slightly into abutment with the lip **27,** but cannot pass over it.

The general function of grippers or paper stop recesses in transfer rollers and their function is known in the art, as exemplified by the above-discussed U.S. Pat. No. 3,633,543, and accordingly need not be discussed in detail herein. The unique structure and function of this particular registration means relates to the foraminous layer **21** of the roller **15.** In prior art devices the sheet registration gripper or lip has generally necessitated a discontinuity in the roller surface. This discontinuity, continuing as the registration lip passes through the nip region, interferes with the transfer operation by creating uneven fields or air gaps or by masking from transfer a portion of the lead edge. In contrast, the registration system disclosed herein provides positive mechanical sheet registration lips which do not create any discontinuity or interruptions in the nip region and does not affect transfer in any way.

This is possible because the registration lip **27,** even though it may extend radially substantially above or below the normal surface **24** of the roller **15,** can be fully crushed or compressed in the nip to the same surface level as the adjacent areas of surface **24.** As long as the foraminous material **21** is not compressed or crushed in the nip to its full extend (its solid height) the lip will not even cause a "bump" . Thus, in addition to eliminating any air gap discontinuities, vibration or uneven pressure problems associated with the passage of the registration lip through the nip are also eliminated. The lip is easily compressed into the layer of underlying foraminous material **21.**

The registration lip **27** is preferably monolithically molded as an extending rib in the same formation process as the rest of the foam material **21** so as to be homogenious therewith. However, where, as here, the depth of foraminous material underlying the lip is substantially greater than the height of projection of the lip above the surface **24,** it can also be formed of solid rubber or other suitable materials which are integrally molded or bonded in or to the foraminous material. As long as the foraminous material is not fully compressed, the registration rib will simply emerse itself in the foraminous material in the nip as shown and not affect the nip **17** characteristics. The lip member (or lip forming recess) is pressed into smooth, even alignment with the rest of the surface **24** in passing through the nip, to provide smooth even contact with the opposing sheet feeding surface (the photoreceptor **11** in this case). The lip forming rib is shown here as rectangular in cross section. However, it could be provided in various other configurations, such as a saw-tooth, etc., since only a trailing face or notch is needed for registration of the sheet lead edge.

The drive means for sheet feeding in the disclosed embodiment is the moving photoreceptor **11,** which in turn may be driven by its support roll **12.** This frictionally drives the roll **15** and sheet **16** through the nip. However, the roll **15** itself may be rotatably driven if desired.

In conclusion, it may be seen that there has been described herein a foraminous roll transfer system providing greatly improved operating properties and paper handling and capable of overcoming many problems in electrostatographic systems. It will be obvious that the disclosed system is applicable to many other electrostatographic systems than those specifically discussed above. One example is in TESI systems wherein latent electrostatic image charge patterns are transferred from one support surface to another and the surfaces are subsequently separated. The rollers of the invention can overcome some of the similar ionization and sheet control problems in such TESI systems.

The exemplary embodiments described herein are presently considered to be preferred; however, it is contemplated that further variations and modifications within the purview of those skilled in the art can be made herein. The following claims are intended to cover all such variations and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In electrostatographic apparatus wherein a transfer bias voltage is applied between a roller electrode

and a first support surface to provide an electrical field for image transfer to a sheet providing a second support surface there-between while relative movement is provided between said roller electrode and said first support surface and said sheet, and said roller is variably deformed by said first support surface at a roller nip area with pre-nip and post-nip areas at each side of said nip area, the improvement in said roller electrode comprising:

an electrically conductive core to which said bias voltage is applied, spaced from said first support surface; and

a highly compressible and air permeable roller body of foraminous convolute open cell material extending between said conductive core and said first support surface and having a substantial normal uncompressed thickness,

said foraminous material occupying the space between said conductive core and said first support surface with a multiplicity of small convolute air passage discontinuities provided by said cells in said material and providing an ionization control barrier,

said foraminous material being compressed between said conductive core and said first support surface in said nip area to a thickness substantially less than said normal uncompressed thickness, to close air passages therein,

said foraminous material being less compressed in said pre-nip and post-nip areas than in said nip area and having a greater thickness and porosity between said conductive core and said first support surface therein over a substantial area of said surface for ionization control in said pre-nip and post-nip areas; and

vacuum means for applying a vacuum through said roller body for aminous material to provide vacuum retention of said sheet on said roller body.

2. The apparatus of claim **1** wherein said first support surface is a photoreceptor and said roller electrode is a xerographic bias transfer roller for electrostatic image transfer of xerographic developer material from said first support surface to said second support surface.

3. The apparatus of claim **1** wherein said foraminous roller body is non-conductive to said bias voltage and electrically insulates said conductive core from said first support surface and does not affect the electrical field therebetween.

4. The apparatus of claim **1** wherein said conductive core and said foraminous roller body are curvalinear and said core has a radius greatly smaller than the normal uncompressed radius of said foraminous roller body.

5. The apparatus of claim **1** wherein said open cells of said foraminous roller body are air filled.

6. The apparatus of claim **1** wherein said foraminous material in said nip is compressed to at least approximately one-half of said normal uncompressed thickness.

7. The apparatus of claim **1** wherein said foraminous material in said nip is compressed sufficiently to collapse a substantial portion of said open cells in said nip to correspondingly close said air passages in said nip.

8. The apparatus of claim **1** wherein said conductive core and said roller body are cylindrical and coaxially mounted with said conductive core uniformly wrapped with said foraminous material, and said conductive core is a hollow perforated tube with said vacuum means communicating with the interior thereof.

9. The apparatus of claim **1** wherein said foraminous material is electrically resistive and conducts said transfer bias, and wherein the resistivity of said material in said normal state is rendered substantially greater than its compressed resistivity in said nip by a substantial percentage of compressively collapsed cells in said nip, to provide increased nip transfer field strength.

10. The apparatus of claim **9** wherein foraminous material in said nip is compressed to at least approximately one-half of said normal uncompressed thickness.

11. The apparatus of claim **1** wherein said conductive core is hollow and air permeable and said vacuum means communicates with the interior thereof.

12. The apparatus of claim **1** further including air blowing means blowing into said post-nip area for assisting stripping of said sheet from said roller.

13. The apparatus of claim **1** wherein said first support surface is a photoreceptor and said roller electrode is a xerographic bias transfer roller for electrostatic image transfer of xerographic developer material from said first support surface to said second support surface.

said conductive core and said roller body are cylindrical and coaxially mounted with said conductive core uniformly wrapped with said foraminous material, and said conductive core is a hollow perforated tube with said vacuum means communicating with the interior thereof.

14. In electrostatographic apparatus wherein a transfer bias voltage is applied between a roller electrode and a first support surface to provide an electrical field for image transfer to a sheet providing a second support surface therebetween while relative movement is provided between said roller electrode and said first support surface and said sheet, and said roller is variably deformed by said first support surface at a roller nip area with pre-nip and post-nip areas at each side of said nip area, the improvement in said roller electrode comprising:

an electrically conductive core to which said bias voltage is applied, spaced from said first support surface; and

a highly compressible and air permeable roller body of foraminous convolute open cell material extending between said conductive core and said first support surface and having a substantial normal uncompressed thickness,

said foraminous material occupying the space between said conductive core and said first support surface with a multiplicity of small convolute air passage discontinuities provided by said cells in said material and providing an ionization control barrier,

said foraminous material being compressed between said conductive core and said first support surface in said nip area to a thickness substantially less than said normal uncompressed thickness,

said foraminous material being less compressed in said pre-nip and post-nip areas than in said nip area and having a greater thickness and porosity between said conductive core and said first support surface therein over a substantial area of said sur-

face for ionization control in said pre-nip and post-nip areas; and

vacuum means for applying a vacuum through said roller body foraminous material to provide vacuum retention of said sheet on said roller body,

further including vacuum cleaning apparatus spaced from said nip area deformably engaging the surface of said roller for vacuum cleaning it.

15. In electrostatographic apparatus wherein a transfer bias voltage is applied between a roller electrode and a first support surface to provide an electrical field for image transfer to a sheet providing a second support surface there-between while relative movement is provided between said roller electrode and said first support surface and said sheet, and said roller is variably deformed by said first support surface at a roller nip area with pre-nip and post-nip areas at each side of said nip area, the improvement in said roller electrode comprising:

an electrically conductive core to which said bias voltage is applied, spaced from said first support surface; and

a highly compressible and air permeable roller body of foraminous convolute open cell material extending between said conductive core and said first support surface and having a substantial normal uncompressed thickness,

said foraminous material occupying the space between said conductive core and said first support surface with a multiplicity of small convolute air passage discontinuities provided by said cells in said material and providing an ionization control barrier,

said foraminous material being compressed between said conductive core and said first support surface in said nip area to a thickness substantially less than said normal uncompressed thickness,

said foraminous material being less compressed in said pre-nip and post-nip areas than in said nip area and having a greater thickness and porosity between said conductive core and said first support surface therein over a substantial area of said surface for ionization control in said pre-nip and post-nip areas; and

vacuum means for applying a vacuum through said roller body foraminous material to provide vacuum retention of said sheet on said roller body,

further including sheet registration lip means providing a sheet edge detaining surface discontinuity in said foraminous material, which discontinuity is suppressed in said nip by said compression of said foraminous material to maintain a smooth and continuous nip engagement by said roller.

16. The apparatus of claim **15** wherein the dimensions of said sheet registration lip means are substantially less than the thickness of said foraminous material.

17. The apparatus of claim **16** wherein said roller is cylindrical and said sheet registration lip means comprises an integral projecting rib extending along the outer surface of said roller parallel to the axis of said roller.

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