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(54) Cleaning a transfuse system

(57) A printing apparatus has a photoreceptor (22,24,26,28) for forming a toner image. An intermediate transfer member (12) defines a first transfer nip (42) with photoreceptor (22,24,26,28) and has an image area for receiving the toner image. A transfuse member (50) defines a second transfer nip (48) with the intermediate transfer member (12). A fuser roll (84) forms a third transfer nip with the transfuse member (50) for generally simultaneous transfer and fusion of the toner image to a substrate (70). A release agent applicator (189,290) applies a release agent to the transfuse member (50), and a cleaning station (54) engages the intermediate member (12) for cleaning release agent from the intermediate transfer member (12).

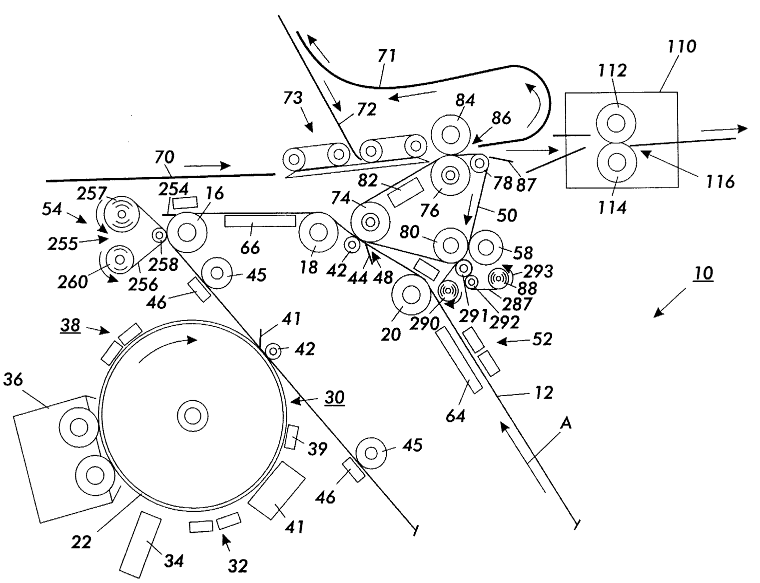

FIG. 3

EP 1 107 075 A2

Description

[0001] Electrostatographic printers are known in which a toner image is electrostatically formed on a photoreceptive image bearing member. The toner image is transferred to a receiving substrate, typically paper or other print receiving material. The toner image is subsequently fused to the substrate.

[0002] In known color electrostatographic printer with an intermediate transfer member, a plurality of image bearing members are used to develop multiple color toner images. Each color toner image is electrostatically transferred sequentially from the image bearing members and registered to an intermediate transfer member. The composite toner image is then electrostatically transferred from the intermediate transfer member to the final substrate. Such systems that use electrostatic transfer to transfer the composite toner image from the intermediate to the final substrate and then subsequently fix the image on the substrate in a fusing system have transfer limitations. For example, there are limitations due to stresses introduced with rougher paper stock, foils, paper moisture content variations, etc. Also, the need to electrostatically transfer a full layered color composite toner image to the substrate creates additional high stresses for electrostatic transfer.

[0003] Stressful system conditions can include for example systems that may wish to use papers allowed to condition at wide ranges of relative humidity, and systems that may wish to image onto a large range of paper roughness and widths. Such stresses can have significant effect on transfer due to the effect on the electrostatic fields used in electrostatic transfer, and they can also have significant effect on paper transport. In addition with direct to paper transfer, fibers, talc and other particulate or chemical contaminants can readily directly transfer from the paper to the imaging modules during direct contact in the electrostatic transfer zones. This can tend to contaminate the imaging drums, development systems, cleaner systems, etc., and can lead to early failure of the imaging systems. This is especially true for certain stressful paper types including for example certain types of recycled papers. Due to all these and other problems, systems that use direct transfer to the final media generally have narrow media latitude for obtaining and/or for maintaining high print quality.

[0004] Alternatively, a toner image is formed on a photoreceptor. The toner image is transferred to a transfuse member. The transfuse member is employed to generally simultaneously transfer and fuse the toner image to a substrate. The transfuse member preferably has good release properties for efficient transfer of the toner image to the substrate. However, materials having acceptable release properties can have unacceptably short component life therefore resulting in increased costs for replacement and increased printer down time. In addition, materials having acceptable release properties can fail to exhibit additional desirable transfer properties such as improved conformability for good transfer to rougher substrates.

[0005] Briefly stated, a printing apparatus has an image producing station, an intermediate transfer member for receiving a toner image from the image producing station, and a transfuse member having a support surface for receiving a toner image. An optional release agent management system having a release agent applicator applies a layer of release agent to the support surface. A toner image is subsequently transferred over the release agent and onto the support surface. The toner image is then transferred to a substrate and preferably simultaneously fused to the substrate to form a document. An intermediate transfer member cleaner in accordance with the invention, engages the surface of the intermediate transfer member to clean release agent from the intermediate transfer member transferred from the transfuse member to the intermediate transfer member.

[0006] In one preferred embodiment, an electrostatographic printing machine with a release agent management system engaging a transfuse member in accordance with the invention has multiple toner image producing stations, each forming a developed toner image of a component color. The developed toner images are electrostatically transferred at the first transfer nip to an intermediate transfer member to form a composite toner image thereon. The composite toner image is then transferred at a second transfer nip to a support surface formed by a transfuse member. The transfuse member preferably has improved conformability and other properties for improved transfusion, generally simultaneous transfer and fusion, of the composite toner image to a substrate. The composite toner image and the substrate are brought together in the third transfer nip to generally simultaneously transfer the composite toner image and fuse the composite toner image to the substrate to form the final document.

[0007] A release agent management system applies a release agent to the surface of the transfuse member prior to the second transfer nip. The release agent improves transfer of the composite toner image from the transfuse member to the substrate. The release agent could include silicone and other types of oil, wax, and even water. The release agent is metered at a preestablished rate onto the surface of the transfuse member. The release agent is at least partially transferred to the substrate, along with the toner image, in the third transfer nip.

[0008] Alternately a transfuse member made of silicone rubber has natural release properties due to the internal silicone oils present in the material. In this case only a small amount or no external release agent management system is required. Regardless whether the release agent is internal, external or both, the release agent can be transferred from the transfuse member to the transfer member.

[0009] Toner image producing stations, in particular those employing photoreceptors, are susceptible to contamination from oils. A cleaning station in accordance with the invention, engages the surface of the intermediate member to clean release agent transferred from the transfuse member to the intermediate member. The cleaning station is positioned downstream in the process direction from the second transfer nip and prior to the first transfer nips.

[0010] The cleaning station is preferably formed of a cleaning blade slidingly engaging the surface of the intermediate transfer member. The cleaning blade removes toner, debris and particular release oil from the intermediate member. In addition, a web cleaner preferably engages the surface of the intermediate member to further clean release oil from the surface of the intermediate member.

[0011] One preferred material for the transfuse member is silicone. Silicone typically has natural release properties from the silicone oils present in the material. However, once these silicone oils are depleted, the transfuse member exhibits reduced release properties and rapid decrease in transfuse member quality leading to failure. Therefore the release management system preferably replaces the natural silicone oils at a rate generally equal to the rate of loss the silicone oils during the printing process. Alternatively the rate of application of the silicone oils can be less than the rate of loss the silicone oils to still result in increased transfuse member operational life relative to a system having no application of the release agent.

[0012] An alternative preferred material for the top most surface of the transfuse member is Viton™ (Trademark of E.I. DuPont for a series of fluoroelastomers based on the copolymer of vinylidene fluoride and hexafluoropropylene). Viton™ exhibits improved transfuse member properties with a generally extended operational life. However, Viton™ can provide insufficient release of the toner image. The release agent management system preferably meters at a preestablished rate a release agent onto the topmost surface of the transfuse member. An initial quantity of release agent, preferably a silicone oil, is applied to the Viton™ coated transfuse member. The release agent is then applied at the rate the release agent is transferred to the substrate or otherwise lost in the printing process.

[0013] The intermediate transfer member buffers the image bearing member from the third transfer nip. In particular, the intermediate transfer member can buffer the image bearing member from release agents on the transfuse member. The release agent can be inherent in the topmost layer of the transfuse member, such as silicone oil in a silicone top most layer, and/or can be applied to the transfuse member by a release agent management system. The cleaning station cleans the release agent from the intermediate member regardless of source, including release agents naturally occurring in the transfuse member or applied by a release agent management system.

[0014] The release agent management system preferably has a release agent applicator formed of a web impregnated with a release agent. The web is brought into contact with the transfuse member to transfer the release agent to the surface of the transfuse member. An applicable system employed with a fuser roller is disclosed in US-A-5,749,038. Alternately, the release agent management system can have a roll configuration release agent applicator. Applicable systems employed with fuser rolls are disclosed in US-A-4,214,549, and US-A-4,254,732.

[0015] A particular embodiment in accordance with this invention will now be described with reference to the accompanying drawings; in which:-

Figure 1 is a schematic side view of a duplex cut sheet electrostatographic printer having an intermediate transfer member cleaning station in accordance with the invention;

Figure 2 is an enlarged schematic side view of the transfer nips of the printer of Figure 1;

Figure 3 is an enlarged schematic side view of the intermediate transfer member cleaning station and the release agent management system of the printer of Figure 2;

Figure 4 is an enlarged schematic side view of the intermediate transfer member cleaning station and an alternate embodiment release agent management system of the printer of Figure 2;

Figure 5 is an enlarged schematic side view of a further alternate transfer member cleaning station of the printer of Figure 2;

Figure 6 is a graphical representation of residual toner as a function of transfuse member temperature;

Figure 7 is a graphical representation of crease as a function of transfuse member temperature for given representation of residual substrate temperature; and,

Figure 8 is a graphical representation of oil on copy as a function of copy count.

[0016] With reference to Figures 1 and 2, a multi-color cut sheet duplex electrostatographic printer 10 has an intermediate transfer belt 12. The intermediate transfer belt 12 is driven over guide rollers 14, 16, 18, and 20. The intermediate transfer belt 12 moves in a process direction shown by the arrow A. For purposes of discussion, the intermediate transfer member 12 defines a single section of the intermediate transfer member 12 as a toner area. A toner area is that part of the intermediate transfer member which receives the various processes by the stations positioned around the intermediate transfer member 12. The intermediate transfer member 12 may have multiple toner areas; however, each toner area is processed in the same way.

[0017] The toner area is moved past a set of four toner image producing stations 22, 24, 26, and 28. Each toner image producing station 22, 24, 26, 28 operates to place a color toner image on the toner image of the intermediate transfer member 12. Each toner image producing station 22, 24, 26, 28 operates in the same manner to form developed toner image for transfer to the intermediate transfer member 12.

[0018] The image producing stations 22, 24, 26, 28 are described in terms of a photoreceptive system, but it is readily recognized by those of skill in the art that ionographic systems and other marking systems can readily be employed to form developed toner images. Each toner image producing station 22, 24, 26, 28 has an image bearing member 30. The image bearing member 30 is a drum or belt supporting a photoreceptor.

[0019] The image bearing member 30 is uniformly charged at a charging station 32. The charging station is of well-known construction, having charge generation devices such as corotrons or scorotrons for distribution of an even charge on the surface of the image bearing member 30. An exposure station 34 exposes the charged image bearing member 30 in an image-wise fashion to form an electrostatic latent image at the image area. For purposes of discussion, the image bearing member defines an image area. The image area is that part of the image bearing member which receives the various processes by the stations positioned around the image bearing member 30. The image bearing member 30 may have multiple image areas; however, each image area is processed in the same way.

[0020] The exposure station 34 preferably has a laser emitting a modulated laser beam. The exposure station 34 raster scans the modulated laser beam onto the charged image area. The exposure station 34 can alternately employ LED arrays or other arrangements known in the art to generate a light image representation that is projected onto the image area of the image bearing member 30. The exposure station 34 exposes a light image representation of one color component of a composite color image onto the image area to form a first electrostatic latent image. Each of the toner image producing stations 22, 24, 26, 28 will form an electrostatic latent image corresponding to a particular color component of a composite color image.

[0021] The image area is advanced to a development station 36. The developer station 36 has a developer corresponding to the color component of the composite color image. Typically, therefore, individual toner image producing stations 22, 24, 26, and 28 will individually develop the cyan, magenta, yellow, and black that make up a typical composite color image. Additional toner image producing stations can be provided for additional or alternate colors including highlight colors or other custom colors. Therefore, each of the toner image producing stations 22, 24, 26, 28 develops a component toner image for transfer to the toner area of the intermediate transfer member 12. The developer station 36 preferably develops the latent image with a charged dry toner powder to form the developed component toner image. The developer can employ a magnetic toner brush or other well known development arrangements.

[0022] The image area having the component toner image then advances to the pretransfer station 38. The pretransfer station 38 preferably has a pretransfer charging device to charge the component toner image and to achieve some leveling of the surface voltage above the image bearing member 30 to improve transfer of the component image from the image bearing member 30 to the intermediate transfer member 12. Alternatively the pretransfer station 38 can use a pretransfer light to level the surface voltage above the image bearing member 30. Furthermore, this can be used in cooperation with a pretransfer charging device. The image area then advances to a first transfer nip defined between the image bearing member 30 and the intermediate transfer member 12. The image bearing member 30 and intermediate transfer member 12 are synchronized such that each has substantially the same linear velocity at the first transfer nip 40. The component toner image is electrostatically transferred from the image bearing member 30 to the intermediate transfer member 12 by use of a field generation station 42. The field generation station 42 is preferably a bias roller that is electrically biased to create sufficient electrostatic fields of a polarity opposite that of the component toner image to thereby transfer the component toner image to the intermediate transfer member 12. Alternatively the field generation station 42 can be a corona device or other various types of field generation systems known in the art. A prenip transfer blade 44 mechanically biases the intermediate transfer member 12 against the image bearing member 30 for improved transfer of the component toner image. The toner area of the intermediate transfer member 12 having the component toner image from the toner image producing station 22 then advances in the process direction.

[0023] After transfer of the component toner image, the image bearing member 30 then continues to move the image area past a preclean station 39. The preclean station employs a preclean corotron to condition the toner charge and the charge of the image bearing member 30 to enable improved cleaning of the image area. The image area then further advances to a cleaning station 41. The cleaning station 41 removes the residual toner or debris from the image area. The cleaning station 41 preferably has blades to wipe the residual toner particles from the image area. Alternately the cleaning station 41 can employ an electrostatic brush cleaner or other well known cleaning systems. The operation of the cleaning station 41 completes the toner image production for each of the toner image producing stations 22, 24, 26, and 28.

[0024] The first component toner image is advanced at the image area from the first transfer nip 40 of the image producing station 22 to the first transfer nip 40 of the toner image producing station 24. Prior to entrance of the first transfer nip 40 of the toner image producing station 24 an image conditioning station 46 uniformly charges the component toner image to reduce stray, low or oppositely charged toner that would result in back transfer of some of the first component toner image to the subsequent toner image producing station 24. The image conditioning stations, in particular the image conditioning station prior to the first toner image producing station 22 also conditions the surface charge on the intermediate transfer member 12. At each first transfer nip 40, the subsequent component toner image is registered to the prior component toner images to form a composite toner image after transfer of the final toner image by the toner image producing station 28.

[0025] The geometry of the interface of the intermediate transfer member 12 with the image bearing member 30 has an important role in assuring good transfer of the component toner image. The intermediate transfer member 12 should contact the surface of the image bearing member 30 prior to the region of electrostatic field generation by the field generation station 42, preferably with some amount of pressure to insure intimate contact. Generally, some amount of pre-nip wrap of the intermediate transfer member 12 against the image bearing member 30 is preferred. Alternatively, the pre-nip pressure blade 44 or other mechanical biasing structure can be provided to create such intimate pre-nip contact. This contact is an important factor in reducing high electrostatic fields from forming at air gaps between the intermediate transfer member 12 and the component toner image in the pre-nip region. For example, with a corotron as the field generation station 42, the intermediate transfer member 12 should preferably contact the toner image in the pre-nip region sufficiently prior to the start of the corona beam profile. With a field generation station 42 of a bias charging roller, the intermediate transfer member 12 should preferably contact the toner image in the pre-nip region sufficiently prior to the contact nip of the bias transfer roller. "Sufficiently prior" for any field generation device can be taken to mean prior to the region of the pre-nip where the field in any air gap greater than about 50mm between the intermediate transfer member 12 and the component toner image has dropped below about 4 volts/micron due to falloff of the field with pre-nip distance from the first transfer nip 40. The falloff of the field is partly due to capacitance effects and this will depend on various factors. For example, with a bias roller this falloff with distance will be slowest with larger diameter bias rollers, and/or with higher resistivity bias rollers, and/or if the capacitance per area of the insulating layers in the first transfer nip 40 is lowest. Lateral conduction along the intermediate transfer member 12 can even further extend the transfer field region in the pre-nip, depending on the transfer belt resistivity and other physical factors. Generally the desired pre-nip contact is between about 2 to 10 mm for resistivities within the desired range and with bias roller diameters between about 12 mm and 50 mm.

[0026] The field generation station 42 will preferentially use very conformable bias rollers for the first transfer nips 40 such as foam or other roller materials having an effectively very low durometer ideally less than about 30 Shore A. In systems that use belts for the imaging modules, optionally the first transfer nip 40 can include acoustic loosening of the component toner image to assist transfer.

[0027] In the preferred arrangement, "slip transfer" is employed for registration of the color image. For slip transfer, the contact zone between the intermediate transfer member 12 and the image bearing member 30 will preferably be minimized subject to the pre-nip restrictions. The post transfer contact zone past the field generation station 42 is preferentially small for this arrangement. Generally, the intermediate transfer member 12 can optionally separate along the preferred bias roller of the field generation station 42 in the post nip region if an appropriate structure is provided to insure that the bias roller does not lift off the surface of the image bearing member due to the tension forces of the intermediate transfer member 12. For slip transfer systems, the pressure of the bias roller employed in the field generation station 42 should be minimized. Minimized contact zone and pressure minimizes the frictional force acting on the image bearing member 30 and this minimizes elastic stretch issues of the intermediate transfer member 12 between first transfer nips 40 that can degrade color registration. It will also minimize motion interactions between the drive of the intermediate transfer member 12 and the drive of the image bearing member 30.

[0028] For slip transfer systems, the resistivity of the intermediate transfer member 12 should also be chosen to be high, generally within or even toward the middle to upper limits of the most preferred range discussed later, so that the required pre-nip contact distances can be minimized. In addition, the coefficient of friction of the top surface material on the intermediate transfer member should preferentially be minimized to increase operating latitude for the slip transfer registration and motion quality approach.

[0029] In an alternate embodiment the image bearing members 30, such as photoconductor drums, do not have separate drives and instead are driven by the friction in the first transfer nips 40. In other words, the image bearing members 30 are driven by the intermediate transfer member 12. Therefore, the first transfer nip 40 imparts sufficient frictional force on the image bearing member to overcome any drag created by the development station 36, cleaner station 41, additional subsystems and by bearing loads. For a friction driven image bearing member 30, the optimum transfer design considerations are generally opposite to the slip transfer case. For example, the lead in of the intermediate transfer member 12 to the first transfer zone preferentially can be large to maximize the friction force due to the tension of the intermediate transfer member 12. In the post transfer zone, the intermediate transfer member 12 is wrapped along the image bearing member 30 to further increase the contact zone and to therefore increase the frictional drive. Increased post-nip wrap has a larger benefit than increased pre-nip wrap because there will be increased pressure there due to electrostatic tacking forces. As another example, the pressure applied by the field generation device 42 can further increase the frictional force. Finally for such systems, the coefficient of friction of the material of the top most layer on the intermediate transfer member 12 should preferentially be higher to increase operating latitude.

[0030] The toner area then is moved to the subsequent first transfer nip 40. Between toner image producing stations are the image conditioning stations 46. The charge transfer in the first transfer nip 40 is normally at least partly due to air breakdown, and this can result in non uniform charge patterns on the intermediate transfer member 12 between the toner image producing stations 22, 24, 26, 28. As discussed later, the intermediate transfer member 12 can optionally include insulating topmost layers, and in this case non uniform charge will result in non uniform applied fields in the subsequent first transfer nips 40. The effect accumulates as the intermediate transfer member 12 proceeds through the subsequent first transfer nips 40. The image conditioning stations 46 "level" the charge patterns on the belt between the toner image producing stations 22, 24, 26, 28 to improve the uniformity of the charge patterns on the intermediate transfer member 12 prior to subsequent first transfer nips 40. The image conditioning stations 46 are preferably scorotrons and alternatively can be various types of corona devices. As previously discussed, the charge conditioning stations 46 additionally are employed for conditioning the toner charge to prevent re-transfer of the toner to the subsequent toner image producing stations. The need for image conditioning stations 46 is reduced if the intermediate transfer member 12 consists only of semiconductive layers that are within the desired resistivity range discussed later. As further discussed later, even if the intermediate transfer member 12 includes insulating layers, the need for image conditioning stations 46 between the toner image producing stations 22, 24, 26, 28 is reduced if such insulating layers are sufficiently thin.

[0031] The guide roller 14 is preferably adjustable for tensioning the intermediate transfer member 12. Additionally, the guide roller 14 can, in combination with a sensor sensing the edge of the intermediate transfer member 12, provide active steering of the intermediate transfer member 12 to reduce transverse wander of the intermediate transfer member 12 that would degrade registration of the component toner images to form the composite toner image.

[0032] Each toner image producing station positions component toner image on the toner area of the intermediate transfer member 12 to form a completed composite toner image. The intermediate transfer member 12 transports the composite toner image from the last toner image producing station 28 to pre-transfer charge conditioning station 52. When the intermediate transfer member 12 includes at least one insulating layer, the pretransfer charge conditioning station 52 levels the charge at the toner area of the intermediate transfer member 12. In addition the pre-transfer charge conditioning station 52 is employed to condition the toner charge for transfer to a transfuse member 50. It preferably is a scorotron and alternatively can be various types of corona devices. A second transfer nip 48 is defined between the intermediate transfer member 12 and the transfuse member 50. A field generation station 42 and pre-transfer nip blade 44 engage the intermediate transfer member 12 adjacent the second transfer nip 48 and perform the same functions as the field generation stations and pre-transfer blades 44 adjacent the first transfer nips 40. The composite toner image is transferred electrostatically and with heat assist to the transfuse member 50.

[0033] The electrical characteristics of the intermediate transfer member 12 are also important. The intermediate transfer member 12 can optionally be constructed of a single layer or multiple layers. In any case, preferably the electrical properties of the intermediate transfer member 12 are selected to reduce high voltage drops across the intermediate transfer member. To reduce high voltage drops, the resistivity of the back layer of the intermediate transfer member 12 preferably has sufficiently low resistivity. The electrical characteristics and the transfer geometry must also be chosen to prevent high electrostatic transfer fields in pre-nip regions of the first and second transfer nips 40, 48. High pre-nip fields at air gaps of around typically >50 microns between the component toner images and the intermediate transfer member 12 can lead to image distortion due to toner transfer across an air gap and can also lead to image defects caused by pre-nip air breakdown. This can be avoided by bringing the intermediate transfer member 12 into early contact with the component toner image prior to the field generating station 42, as long as the resistivity of any of the layers of the intermediate transfer member 12 are sufficiently high. The intermediate transfer member 12 also should have sufficiently high resistivity for the topmost layer to prevent very high current flow from occurring in the first and second transfer nips 40, 48. Finally, the intermediate transfer member 12 and the system design needs to minimize the effect of high and/or non-uniform charge buildup that can occur on the intermediate transfer member 12 between the first transfer nips 40.

[0034] The preferable material for a single layer intermediate transfer member 12 is a semiconductive material having a "charge relaxation time" that is comparable to or less than the dwell time between toner image producing stations, and more preferred is a material having a "nip relaxation time" comparable or less than the transfer nip dwell time. As used here, "relaxation time" is the characteristic time for the voltage to drop across the thickness of the layer of the intermediate transfer member. The dwell time is the time that an elemental section of the transfer member 12 spends moving through a given region. For example, the dwell time between imaging stations 22 and 24 is the distance between imaging stations 22 and 24, divided by the process speed of the transfer member 12. The transfer nip dwell time is the width of the contact nip created during the influence of the field generation station 42, divided by the process speed of the transfer member 12.

[0035] The "charge relaxation time" is the relaxation time when the intermediate transfer member is substantially isolated from the influence of the capacitance of other members within the transfer nips 40. Generally the charge relaxation time applies for regions prior to or past the transfer nips 40. It is the classic "RC time constant", that is rke_o, the product of the material layer quantities dielectric constant k times resistivity r times the permitivity of vacuum e_o. In general the resistivity of a material can be sensitive to the applied field in the material. In this case, the resistivity should be determined at an applied field corresponding to about 25 to 100 volts across the layer thickness. The "nip relaxation time" is the relaxation time within regions such as the transfer nips 40. If 42 is a corona field generation device, the "nip relaxation time" is substantially the same as the charge relaxation time. However, if a bias transfer device is used, the nip relaxation time is generally longer than the charge relaxation time. This is because it is influenced not only by the capacitance of the intermediate transfer member 12 itself, but it is also influenced by the extra capacitance per unit area of any insulating layers that are present within the transfer nips 40. For example, the capacitance per unit area of the photoconductor coating on the image bearing member 30 and the capacitance per unit area of the toner image influence the nip relaxation time. For discussion, C_L represents the capacitance per unit area of the layer of the intermediate transfer member 12 and C_{tot} represents the total capacitance per unit area of all insulating layers in the first transfer nips 40, other than the intermediate transfer member 12. When the field generation station 42 is a bias roller, the nip relaxation time is the charge relaxation time multiplied by the quantity $[1+ (C_{tot}/ C_L)]$.

[0036] The range of resistivity conditions defined in the above discussion avoid high voltage drops across the intermediate transfer member 12 during the transfers of the component toner images at the first transfer nips 40. To avoid high pre-nip fields, the volume resistivity in the lateral or process direction of the intermediate transfer member must not be too low. The requirement is that the lateral relaxation time for charge flow between the field generation station 42 in the first transfer nip 40 should be larger than the lead in dwell time for the first transfer nip 40. The lead in dwell time is the quantity L/v. L is the distance from the pre-nip region of initial contact of the intermediate transfer member 12 with the component toner image, to the position of the start of the field generation station 42 within the first transfer nip 40. The quantity v is the process speed. The lateral relaxation time is proportional to the lateral resistance along the belt between the field generating station 42 and the pre-nip region of initial contact, and the total capacitance per area C_{tot} of the insulating layers in the first transfer nip 40 between the intermediate transfer member 12 and the substrate of the image bearing member 30 of the toner image producing station 22, 24, 26, 28. A useful expression for estimating the preferred resistivity range that avoids undesirable high pre-nip fields near the field generation stations 42 is: $[r_L VLC_{tot}] >1$. The quantity r_L is referred to as the "lateral resistivity" of the intermediate transfer member 12. It is the volume resistivity of the member divided by the thickness of the member. In cases where the electrical properties of the member 12 is not isotropic, the volume resistivity of interest for avoiding high pre-nip fields is that resistivity of the layer in the process direction. Also, in cases where the resistivity depends on the applied field, the lateral resistivity should be determined at a field of between about 500 to 1500 volts/cm.

[0037] Thus the preferred range of resistivity for the single layer intermediate transfer member 12 depends on many factors such as for example the system geometry, the transfer member thickness, the process speed, and the capacitance per unit area of the various materials in the first transfer nip 40. For a wide range of typical system geometry and process speeds the preferred resistivity for a single layer transfer belt is typically a volume resistivity less than about 10^{13} ohm-cm and a more preferred range is typically $<10^{11}$ ohm-cm volume resistivity. The lower limit of preferred resistivity is typically a lateral resistivity above about 10^8 ohms/square and more preferred is typically a lateral resistivity above about 10^{10} ohms/square. As an example, with a typical intermediate transfer member 12 thickness of around 0.01 cm, a lateral resistivity greater than 10^{10} ohms/square corresponds to a volume resistivity of greater than 10^8 ohm-cm.

[0038] Discussion below will specify the preferred range of electrical properties for the transfuse member 50 to allow good transfer in the second transfer nip 48. The transfuse member 50 will preferably have multiple layers and the electrical properties chosen for the topmost layer of the transfuse member 50 will influence the preferred resistivity for the single layer intermediate transfer member 12. The lower limits for the preferred resistivity of the single layer intermediate transfer member 12 referred to above apply if the top most surface layer of the transfuse member 50 has a sufficiently high resistivity, typically equal to or above about 10^9 ohm-cm. If the top most surface layer of the transfuse member 50 has a somewhat lower resistivity than about 10^9 ohm-cm, the lower limit for the preferred resistivity of the single layer intermediate transfer member 12 should be increased in order to avoid transfer problems in the second transfer nip 48. Such problems include undesirably high current flow between the intermediate transfer member 12 and the transfuse member 50, and transfer degradation due to reduction of the transfer field. In the case where the resistivity of the top most layer of the transfuse member 50 is less than about 10^9 ohm-cm, the preferred lower limit volume resistivity for the single layer intermediate transfer member 12 will typically be around greater than or equal to 10^9 ohm-cm.

[0039] In addition, the intermediate transfer member 12 should have sufficient lateral stiffness to avoid registration issues between toner image producing stations 22, 24, 26, 28 due to elastic stretch. Stiffness is the sum of the products of Young's modulus times the layer thickness for all of the layers of the intermediate transfer member. The preferred range for the stiffness depends on various systems parameters. The required value of the stiffness increases with increasing amount of frictional drag at and/or between the toner image producing stations 22, 24, 26, 28. The preferred stiffness also increases with increasing length of the intermediate transfer member 12 between toner image producing stations, and with increasing color registration requirements. The stiffness is preferably >800 PSI-inches and more preferably >2000 PSI-inches, (>90 Nm and more preferably >225 Nm).

[0040] One of the material candidates for the single layer intermediate transfer member 12 is a polyamide that achieves good electrical control via conductivity controlling additives.

[0041] The intermediate transfer member 12 may also optionally be multi-layered. The back layer, opposite the toner area, will preferably be semi-conductive in the discussed range. The preferred materials for the back layer of a multi-layered intermediate transfer member 12 are the same as that discussed for the single layer intermediate belt 12. Within limits, the top layers can optionally be "insulating" or semiconductive. There are certain advantages and disadvantages of either.

[0042] A layer on the intermediate transfer member 12 can be thought of as behaving "insulating" for the purposes of discussion here if the relaxation time for charge flow is much longer than the dwell time of interest. For example, a layer behaves "insulating" during the dwell time in the first transfer nip 40 if the nip relaxation time of that layer in the first transfer nip 40 is much longer than the time that a section of the layer spends in traveling through the first transfer nip 40. A layer behaves insulating between toner image producing stations 22, 24, 26, 28 if the charge relaxation time for that layer is much longer than the dwell time that a section of the layer takes to travel between the toner image producing stations. On the other hand, a layer behaves semiconducting in the sense meant here when the relaxation times are comparable or lower than the appropriate dwell times. For example, a layer behaves semi conductive during the dwell time of the first transfer nip 40 when the nip relaxation time is less than the dwell time in the first transfer nip 40. Furthermore, a layer on the intermediate transfer member 12 behaves semiconductive during the dwell time between toner image producing stations 22, 24, 26, 28 if the relaxation time of the layer is less than the dwell time between toner image producing stations. The expressions for determining the relaxation times of any top layer on the intermediate transfer member 12 are substantially the same as those described previously for the single layer intermediate transfer member. Thus whether or not a layer on the multi-layered intermediate transfer member 12 behaves "insulating" or "semiconducting" during a particular dwell time of interest depends not only on the electrical properties of the layer but also on the process speed, the system geometry, and the layer thickness.

[0043] A layer of the transfer belt will typically behave "insulating" in most transfer systems if the volume resistivity is generally greater than about 10^{13} ohm-cm. Insulating top layers on the intermediate transfer member 12 cause a voltage drop across the layer and thus reduce the voltage drop across the composite toner layer in the first transfer nip 40. Therefore, the presence of insulating layers requires higher applied voltages in the first and second transfer nips 40, 48 to create the same electrostatic fields operating on the charged composite toner image. The voltage requirement is mainly driven by the "dielectric thickness" of such insulating layers, which is the actual thickness of a layer divided by the dielectric constant of that layer. One potential disadvantage of an insulating layer is that undesirably very high voltages will be required on the intermediate transfer member 12 for good electrostatic transfer of the component toner image if the sum of the dielectric thickness of the insulating layers on the intermediate transfer member 12 is too high. This is especially true in color imaging systems with layers that behave "insulating" over the dwell time longer than one revolution of the intermediate transfer member 12. Charge will build up on such insulating top layers due to charge transfer in each of the field generation stations 42. This charge buildup requires higher voltage on the back of the intermediate transfer member 12 in the subsequent field generation stations 42 to achieve good transfer of the subsequent component toner images. This charge can not be fully neutralized between first transfer nips 40 with image conditioning station 46 corona devices without also causing undesirable neutralization or even reversal of the charge of the transferred composite toner image on the intermediate transfer member 12. Therefore, to avoid the need for unacceptably high voltages on the back of the intermediate transfer member 12, the total dielectric thickness of such insulating top layers on the intermediate transfer member 12 should preferably be kept small for good and stable transfer performance. An acceptable total dielectric thickness can be as high as about 50 mm and a preferred value is <10 mm.

[0044] The top most layer of the intermediate transfer member 12 preferably has good toner releasing properties such as low surface energy, and preferably has low affinity to oils such as silicone oils. Materials such as PFA, TEFLON™, and various fluoropolymers are examples of desirable overcoating materials having good toner release properties. One advantage of an insulating coating over the semiconductive backing layer of the intermediate transfer member 12 is that such materials with good toner releasing properties are more readily available if the constraint of needing them to also be semiconductive is removed. Another potential advantage of high resistivity coatings applies to embodiments that wish to use a transfuse member 50 having a low resistivity top most layer, such as <<10^9 ohm-cm. As discussed, the resistivity for the intermediate transfer member 12 of a single layer is preferably limited to typically around >10^9 ohm-cm to avoid transfer problems in the second transfer nip 48 if the resistivity of the top most layer of the transfuse member 50 is lower than about 10^9 ohm-cm. For a multiple layer intermediate transfer member 12, having a sufficiently high resistivity top most layer, preferably >10^9 ohm-cm, the resistivity of the back layer can be lower.

[0045] Semiconductive coatings on the intermediate transfer member 12 are advantaged in that they do not require charge leveling to level the charge on the intermediate transfer member 12 prior to and between toner image producing stations 22, 24, 26, 28. Semiconductive coatings on the intermediate transfer member are also advantaged in that much thicker top layers can be allowed compared to insulating coatings. The charge relaxation conditions and the corresponding ranges of resistivity conditions needed to enable such advantages are similar to that already discussed for the back layer. Generally, the semiconductive regime of interest is a resistivity such that the charge relaxation time is smaller than the dwell time spent between toner image producing stations 22, 24, 26, 28. A more preferred resistivity construction allows thick layers, and this construction is a resistivity range such that the nip relaxation time within the first transfer nip 40 is smaller than the dwell time that a section of the intermediate transfer member 12 takes to move through the first transfer nip 40. In such a preferred regime of resistivity the voltage drop across the layer is small at the end of the transfer nip dwell time, due to charge conduction through the layer.

[0046] The constraint on the lower limit of the resistivity related to the lateral resistivity apply to the semiconductive top most layer, to any semiconductive middle layers, and to the semiconductive back layer of a multiple layer intermediate transfer member 12. The preferred resistivity range for each such layer is substantially the same as discussed for the single layer intermediate transfer member 12. Also, the additional constraint on the resistivity related to transfer problems in the second transfer nip 48 apply to the top most layer of a multiple layer intermediate transfer member 12. Preferably, the top most semiconductive layer of the intermediate transfer member 12 should be typically >10^9 ohm-cm when the top most layer of the transfuse member 50 is typically somewhat less than 10^9 ohm-cm.

[0047] Transfer of the composite toner image in the second transfer nip 48 is accomplished by a combination of electrostatic and heat assisted transfer. The field generation station 42 and guide roller 74 are electrically biased to electrostatically transfer the charged composite toner image from the intermediate transfer member 12 to the transfuse member 50.

[0048] The transfer of the composite toner image at the second transfer nip 48 can be heat assisted if the temperature of the transfuse member 50 is maintained at a sufficiently high optimized level and the temperature of the intermediate transfer member 12 is maintained at a considerably lower optimized level prior to the second transfer nip 48. The mechanism for heat assisted transfer is thought to be softening of the composite toner image during the dwell time of contact of the toner in the second transfer nip 48. The toner softening occurs due to contact with the higher temperature transfuse member 50. This composite toner softening results in increased adhesion of the composite toner image toward the transfuse member 50 at the interface between the composite toner image and the transfuse member. This also results in increased cohesion of the layered toner pile of the composite toner image. The temperature on the intermediate transfer member 12 prior to the second transfer nip 48 needs to be sufficiently low to avoid too high a toner softening and too high a resultant adhesion of the toner to the intermediate transfer member 12. The temperature of the transfuse member 50 should be considerably higher than the toner softening point prior to the second transfer nip to ensure optimum heat assist in the second transfer nip 48. Further, the temperature of the intermediate transfer member 12 just prior to the second transfer nip 48 should be considerably lower than the temperature of the transfuse member 50 for optimum transfer in the second transfer nip 48.

[0049] The temperature of the intermediate transfer member 12 prior to the second transfer nip 48 is important for maintaining good transfer of the composite toner image. An optimum elevated temperature for the intermediate transfer member 12 can allow the desired softening of the composite toner image needed to permit heat assist to the electrostatic transfer of the second transfer nip 48 at lower temperatures on the transfuse member 50. However, there is a risk of the temperature of the intermediate transfer member 12 becoming too high so that too much softening of the composite toner image occurs on the intermediate transfer member prior to the second transfer nip 48. This situation can cause unacceptably high adhesion of the composite toner image to the intermediate transfer member 12 with resultant degraded second transfer. Preferably the temperature of the intermediate transfer member 12 is maintained below or in the range of the Tg (glass transition temperature) of the toner prior to the second transfer nip 48.

[0050] The transfuse member 50 is guided in a cyclical path by guide rollers 74, 76, 78, 80. Guide rollers 74, 76 alone or together are preferably heated to thereby heat the transfuse member 50. The intermediate transfer member 12 and transfuse member 50 are preferably synchronized to have the generally same velocity in the transfer nip 48. Additional heating of the transfuse member is provided by heating rollers 74 and 76, and further the transfuse member 50 can be heated by the addition of a heating station 82. The heating station 82 is preferably formed of radiant lamps positioned internally to the path defined by the transfuse member 50. Alternatively the heating station 82 can be a heated shoe contacting the back of the transfuse member 50 or other heat sources located internally or externally to the transfuse member 50. The transfuse member 50 and a pressure roller 84 define a third transfer nip 86 therebetween.

[0051] To assure acceptable release of the toner from the transfuse member 50, an optional release agent applicator 88 applies a uniform, controlled quantity of a releasing material or agent, such as a silicone oil, to the surface of the transfuse member 50. (See Fig. 3) The releasing agent is applied to the surface of the transfuse member prior to the second transfer nip. The toner image is transferred onto the surface of the transfer member having the release agent. The releasing agent serves to assist in the subsequent release of the composite toner image from the transfuse member 50 to the substrate in the third transfer nip 86. The release agent forms a weak boundary layer that aids in separation of the toner image from the transfuse member 50. Silicone oil typically has a low surface energy therefore spreading easily on the surface of materials having a relatively higher surface energy. Silicone oil is additionally tolerant of the heat in the third transfer nip. A transfuse member having an outer most or topmost layer of silicone will have natural release properties from the silicone oil present in the material. However, this silicone oil will be depleted overtime leading to a decrease in release properties and therefore decreased transfer efficiency of the toner image to the substrate. In addition the transfuse member will eventually fail. With reference to figure 8, disclosing a transfuse system having a transfuse member with a top most layer of silicone, and without a release agent management system, line 490 calculated from the data shown discloses the amount of silicone oil per copy decreases as the copy count increases. The decrease in oil on the copies is an indicator of the depletion of natural oil in the silicone of the transfuse member. This decrease results in degraded release of the toner image form the transfuse member and transfer to the substrate, and eventual failure of the transfuse member. The release agent applicator applies a preestablished amount of release agent, typically a silicone oil, to reduce or eliminate the loss of the natural silicone oils during the printing process. The application rate is preferably the rate of loss of the release agent to typically the substrate. This application rate results in neither an increase nor a decrease of silicone oils present on the transfuse member. Release agents can be absorbed by substrates, such as paper, at rates of about . 1-.2 mg/sheet of substrate. Therefore, at a steady operating state, the preferred application rate, represented by line 491 is generally the transfer rate of release agent to the substrate at a given process rate. A slower process rate typically results in increase absorption of release agent by the substrate. Initially the application rate may need to be increased to fully coat the transfuse member and other associated components. The application rate can also be higher if additional release agent is desired for additional purposes. However, a relatively high amount of release agent is generally not preferred due to the potential for the additional release agent to be transferred to the intermediate member and ultimately to a photoreceptor.

[0052] The release agent applicator 88 is preferably of a web configuration for application of relatively low levels of release agent (See Fig. 3). The release agent applicator 88 has a web 289 impregnated with release agent. The web 289 is fed off of a supply roll 290 and urged or biased against the surface of the transfuse member 50 by a nip roll 291. Release agent is transferred from the web 289 to the surface of the transfuse member by frictional contact of the relatively slower surface speed of the web 289 against the relatively higher surface speed of the transfuse member 50. After contact with transfuse member 50, the web is directed around a wrap roll 292 and spooled onto a take up roll 293. The nip roll 291 and take up roll are preferably rotatably driven to move the web 289 past the transfuse member 50. The supply roll 290 is preferably undriven. The web 289 can additionally serve to clean the residual toners, paper debris, and other contaminants on the surface of the transfuse member 50.

[0053] For application of relatively higher levels of release agent, a release agent applicator 188 of a roll configuration can be employed in place of the release agent applicator 88. (See Fig. 4) The release agent applicator 188 has a metering roll 190 partially immersed in a bath of release agent 193. The release agent 193 is contained in a sump 192 and is replenished as depleted. The metering roll 190 rollingly engages a donor roll 189 interposed between the metering roll 190 and the transfuse member 50. The metering roll 190 and donor roll 189 are preferably idler rolls whereby the rotation of the metering roll 190 and donor roll 189 are derived from the rolling contact of the donor roll 190 with the moving transfuse member 50.

[0054] Release agent 193 coats the surface of the rotating metering roll 193 and is transferred to the donor roll 189 at the nip defined therebetween. A wick 194 submersed in the sump 192 and slidingly engaging the surface of the metering roll 190 disturbs the air layer on the surface of the metering roll 190 to thereby assist in application of the release agent to the metering roll 190. The metering roll 190 is preferably formed of a steel surface roll.

[0055] A wiper blade 191 contacts the metering roll 190 to meter the quantity of release agent on the surface of the metering roll 190 to a preestablished thickness to result in the preferred rate of release agent applied to the transfuse member 50. The release agent transferred to the donor roll 189 is further transferred to the transfuse member 50 at the nip defined therebetween. The donor roll 189 preferably has a conformable surface, such as silicone, for improved transfer of the release agent 193 to the transfuse member 50. Other arrangements of oil application include oil rolls or webs. This includes both fibrous or microporous sleeved rolls and webs.

[0056] Transfuse members 50 having a top most layer of Viton™ will typically require a higher rate of application of release agent to provide sufficient release of the toner image from the transfuse member. There is essentially no natural excretion of natural oils from Viton™. Therefore additional release agent is preferably applied to ensure complete coating of the top most surface of the transfuse member 50. The application rate is preferably from .2-10 mg/sheet of substrate, but can be higher.

[0057] The transfuse member 50 is preferably constructed of multiple layers. The transfuse member 50 must have appropriate electrical properties for being able to generate high electrostatic fields in the second transfer nip 50. To avoid the need for unacceptably high voltages, the transfuse member 50 preferably has electrical properties that enable sufficiently low voltage drop across the transfuse member 50 in the second transfer nip 48. In addition the transfuse member 50 will preferably ensure acceptably low current flow between the intermediate transfer member 12 and the transfuse member 50. The requirements for the transfuse member 50 depend on the chosen properties of the intermediate transfer member 12. In other words, the transfuse member 50 and intermediate transfer member 12 together have sufficiently high resistance in the second transfer nip 48.

[0058] The transfuse member 50 will preferably have a laterally stiff back layer, a thick, conformable rubber intermediate layer, and a thin outer most layer. Preferably the thickness of the back layer will be greater than about 0.05 mm. Preferably the thickness of the intermediate conformable layers and the top most layer together will be greater than 0.25 mm and more preferably will be greater than about 1.0 mm. The back and intermediate layers need to have sufficiently low resistivity to prevent the need for unacceptably high voltage requirements in the second transfer zone 48. The preferred resistivity condition follows previous discussions given for the intermediate transfer member 12. That is, the preferred resistivity range for the back and intermediate layer of a multiple layer transfuse member 50 ensures that the nip relaxation time for these layers in the field generation region of the second transfer nip 48 is smaller than the dwell time spent in the field generation region of the second transfer nip 48. The expressions for the nip relaxation times and the nip dwell time are substantially the same as the ones discussed for the single layer intermediate transfer member 12. Thus the specific preferred resistivity range for the back and intermediate layers depends on the system geometry, the layer thickness, the process speed, and the capacitance per unit area of the insulating layers within the transfer nip 48. Generally, the volume resistivity of the back and intermediate layers of the multi-layer transfuse member 50 will typically need to be below about 10^{11} ohm-cm and more preferably will be below about 10^{8} ohm-cm for most systems. Optionally, the back layer of the transfuse member 50 can be highly conductive such as a metal.

[0059] Similar to the multiple layer intermediate transfer member 12, the top most layer of the transfuse member 50 can optionally behave "insulating" during the dwell time in the transfer nip 48 (typically $>10^{12}$ ohm-cm) or semiconducting during the transfer nip 48 (typically 10^{6} to 10^{12} ohm-cm). However, if the top most layer behaves insulating, the dielectric thickness of such a layer will preferably be sufficiently low to avoid the need for unacceptably high voltages. Preferably for such insulating behaving top most layers, the dielectric thickness of the insulating layer should typically be less than about 50m and more preferably will be less than about 10m. If a very high resistivity insulating top most layer is used, such that the charge relaxation time is greater than the transfuse member cycle time, charge will build up on the transfuse member 50 due to charge transfer during the transfer nip 48. Therefore, a cyclic discharging station 77 such as a scorotron or other charge generating device will be needed to control the uniformity and reduce the level of cyclic charge buildup.

[0060] The transfuse member 50 can alternatively have additional intermediate layers. Any such additional intermediate layers that have a high dielectric thickness typically greater than about 10 microns will preferably have a sufficiently low resistivity such to ensure low voltage drop across the additional intermediate layers.

[0061] The transfuse member 50 preferably has a top most layer formed of a material having a low surface energy, for example silicone elastomer, fluoroelastomers such as Viton™, polytetrafluoroethylene, perfluoralkane, and other fluorinated polymers. The transfuse member 50 will preferably have intermediate layers between the top most and back layers constructed of a Viton™ or preferably silicone with carbon or other conductivity enhancing additives to achieve the desired electrical properties. The back layer is preferably a fabric modified to have the desired electrical properties. Alternatively the back layer can be a metal such as stainless steel.

[0062] The transfuse member 50 can optionally be in the form of a transfuse roller (not shown), or is preferably in the form of a transfuse belt. A transfuse roller for the transfuse member 50 can be more compact than a transfuse belt and it can also be advantaged relative to less complexity of the drive and steering requirements needed to achieve good motion quality for color systems. However, a transfuse belt has advantages over a transfuse roller such as enabling large circumference for longer life, better substrate stripping capability, and generally lower replacement costs.

[0063] The intermediate layer of the transfuse member 50 is preferably thick to enable a high degree of conformance to rougher substrates 70 and to thus expand the range of substrate latitude allowed for use in the printer 10. In addition the use of a relatively thick intermediate layer, greater than about 0.25 mm and preferably greater than 1.0 mm enables creep for improved stripping of the document from the output of the third transfer nip 86. In a further embodiment, thick low durometer conformable intermediate and top most layers such as silicone are employed on the transfuse member 50 to enable creation of low image gloss by the transfuse system with wide operating latitude.

[0064] The use of a relatively high temperature on the transfuse member 50 prior to the second transfer nip 48 creates advantages for the transfuse system. The transfer step in the second transfer nip 48 simultaneously transfers single and stacked multiple color toner layers of the composite toner image. The toner layers nearest to the transfer belt interface will be hardest to transfer. A given separation color toner layer can be nearest the surface of the intermediate transfer member 12 or it can also be separated from the surface, depending on the color toner layer to be transferred in any particular region. For example, if a toner layer of magenta is the last stacked layer deposited onto the transfer belt, the magenta layer can be directly against the surface of the intermediate transfer member 12 in some color print regions or else stacked above cyan and/or yellow toner layers in other color regions. If transfer efficiency is too low, a high fraction of the color toners that are close to the intermediate transfer member 12 will not transfer but a high fraction of the same color toner layers that are stacked onto another color toner layer will transfer. Thus for example, if the transfer efficiency of the composite toner image is not very high, the region of the composite toner image having cyan toner directly in contact with the surface of the intermediate transfer member 12 can transfer less of the cyan toner layer than the regions of the composite toner image having cyan toner layers on top of yellow toner layers. The transfer efficiency in the second transfer nip 48 is >95% therefore avoiding significant color shift.

[0065] With reference to Figure 6 disclosing experimental data on the amount of residual toner left on the intermediate transfer member 12 as a function of the transfuse member 50 temperature. Curve 90 is with electric field, pressure and heat assist and curve 92 is without electric field assist but with pressure and heat assist. A very low amount of residual toner means very high transfer efficiency. The toner used in the experiments has a glass transition temperature range Tg of around 55°C. Substantial heat assist is observed at temperatures of the transfuse member 50 above Tg. Substantially 100% toner transfer occurs when operating with an applied field and with the transfuse member 50 temperature above around 165°C, well above the range of the toner Tg. Preferential temperatures will vary depending on toner properties. In general, operation well above the Tg is found to be advantageous for the heat assist to the electrostatic transfer for many different toners and system conditions.

[0066] Too high a temperature of the transfuse member 50 in the second transfer nip 48 can cause problems due to unacceptably high toner softening on the intermediate transfer member side of the composite toner layer. Thus the temperature of the transfuse member 50 prior to the second transfer nip 48 must be controlled within an optimum range. The optimum temperature of the composite toner image in the second transfer nip 48 is less than the optimum temperature of the composite toner image in the third transfer nip 86. The desired temperature of the transfuse member 50 for heat assist in the second transfer nip 48 can be readily obtained while still obtaining the desired higher toner temperatures needed for more complete toner melting in the third transfer nip 86 by using pre-heating of the substrate 70. Transfer and fix to the substrate 70 is controlled by the interface temperature between the substrate and the composite toner image. Thermal analysis shows that the interface temperature increases with both increasing temperature of the substrate 70 and increasing temperature of the transfuse member 50.

[0067] At a generally constant temperature of the transfuse member 50 in the second and third transfer nips 48, 86, the optimum temperature for transfer in the second transfer nip 48 is controlled by adjusting the temperature of the intermediate transfer member 12, and transfuse in the third transfer nip 86 is optimized by preheating of the substrate 70. Alternatively, for some toner formulations or operation regimes no preheating of the substrate 70 is required.

[0068] The substrate 70 is transported and registered by a material feed and registration system 69 into a substrate pre-heater 73. The substrate pre-heater 73 is preferably formed a transport belt transporting the substrate 70 over a heated platen. Alternatively the substrate pre-heater 73 can be formed of heated rollers forming a heating nip therebetween. Alternately, the substrate pre-heater 73 can be formed of radiant heaters. The substrate 70 after heating by the substrate preheater 73 is directed into the third transfer nip 86.

[0069] Figure 7 discloses experimental curves 94, 96 of a measure of fix called crease as a function of the temperature of the transfuse member 50 for different pre-heating temperatures of a substrate. Curve 94 is for a preheated substrate and a curve 96 for a substrate at room temperature. The results disclose that the temperature of the transfuse member 50 for similar fix level decreases significantly at higher substrate pre-heating curve 94 compared to lower substrate pre-heating curve 96. Heating of the substrate 70 by the substrate preheater 73 prior to the third transfer nip 86 allows optimization of the temperature of the transfuse member 50 for improved transfer of the composite toner image in the second transfer nip 48. The temperature of the transfuse member 50 can thus be controlled at the desired optimum temperature range for optimum transfer in the second transfer nip 48 by controlling the temperature of the substrate 70 at the corresponding required elevated temperature needed to create good fix and transfer to the substrate 70 in the third transfer nip 86 at this same controlled temperature of the transfuse member 50. Therefore cooling of the transfuse member 50 prior to the second transfer nip 48 is not required for optimum transfer in the second transfer nip 48. In other words the transfuse member 50 can be maintained at substantially the same temperature in both the second and third transfer nips 48, 86.

[0070] Furthermore, the over layer, the intermediate and topmost layers, of the transfuse member 50 can be relatively thick, preferably greater than about 1.0 mm, because no substantial cooling of the transfuse member 50 is required prior to the second transfer nip 48. Relatively thick intermediate and topmost layers of the transfuse member 50 allows for increased conformability. The increased conformability of the transfuse member 50 permits printing to a wider latitude of substrates 70 without a substantial degradation in print quality. In other words the composite toner image can be transferred with high efficiency to relatively rough substrates 70.

[0071] In addition, the transfuse member 50 is preferably at substantially the same temperature in both the second and third transfer nips 48, 86. However, the composite toner image preferably has a higher temperature in the third transfer nip 86 relative to the temperature of the composite toner image in the second transfer nip 48. Therefore the substrate 70 has a higher temperature in the third transfer nip 86 relative to the temperature of the intermediate transfer member 12 in the second transfer nip 48. Alternatively, the transfuse member 50 can be cooled prior to the second transfer nip 48, however the temperature of the transfuse member 50 is maintained above, and preferably substantially above the Tg of the composite toner image. Furthermore, under certain operating conditions, the top surface of the transfuse member 50 can be heated just prior to the second transfer nip 48.

[0072] The composite toner image is transferred and fused to the substrate 70 in the third transfer nip 86 to form a completed document 72. Heat in the third transfer nip 86 from the substrate 70 and transfuse member 50, in combination with pressure applied by the pressure roller 84 acting against the guide roller 76 transfer and fuse the composite toner image to the substrate 70. The pressure in the third transfer nip 86 is preferably in the range of about 40 - 500 psi (275 - 3450 KPa), and more preferably in the range 60 psi to 200 psi (414 to 1380 KPa). The transfuse member 50, by combination of the pressure in the third transfer nip 86 and the appropriate durometer of the transfuse member 50 induces creep in the third transfer nip to assist release of the composite toner image and substrate 70 from the transfuse member 50. Preferred creep is greater than 4%. Stripping is preferably further assisted by the positioning of the guide roller 78 relative to the guide roller 76 and pressure roller 84. The guide roller 78 is positioned to form a small amount of wrap of the transfuse member 50 on the pressure roller 84. The geometry of the guide rollers 76, 78 and pressure roller 84 form the third transfer nip 86 having a high pressure zone and an adjacent low pressure zone in the process direction. The width of the low pressure zone is preferably one to three times, or more preferably about two times the width of the high pressure zone. The low pressure zone effectively adds an additional 2-3% of relative creep and thereby improves stripping. Additional stripping assistance can be provided by stripping system 87, preferably an air puffing system. Alternatively the stripping system 87 can be a stripping blade or other well known systems to strip documents from a roller or belt. Alternatively, the pressure roller can be substituted with other pressure applicators such as a pressure belt.

[0073] After stripping, the document 72 is directed to an optional selectively activatable simplex or duplex glossing station 110 and thereafter to a sheet stacker or other well know document handing system (not shown). The printer 10 can additionally provide duplex printing by directing the document 72 through an inverter 71 where the document 72 is inverted and reintroduced at about the middle of the pre-transfer heating station 73 for printing on the opposite side of the document 72.

[0074] Preferably, a cooling station 66 cools the intermediate transfer member 12 after second transfer nip 48 in the process direction. The cooling station 66 preferably transfers a portion of the heat on the intermediate transfer member 12 at the exit side of the second transfer nip 48 to a heating station 64 at the entrance side of the second transfer nip 48. Alternatively the cooling station 66 can transfer a portion of the heat -absorbed from the intermediate transfer member 12 at the exit side of the second transfer nip 48 to the substrate prior to the third transfer nip 86. Alternatively the heat sharing can be implemented with multiple heating stations 64 and cooling stations 66 to improve heat transfer efficiency.

[0075] A cleaning station 54 engages the intermediate transfer member 12. The cleaning station 54 preferably removes release agent, typically an oil, that may be deposited onto the intermediate transfer member 12 from the transfuse member 50 at the second transfer nip. For example, if a preferred silicone top most layer is used for the transfuse member 50, some silicone oil present in the silicone material can transfer from the transfuse member 50 to the intermediate transfer member 12 and eventually contaminate the image bearing members 30. In addition the cleaning station 54 removes residual toner remaining on the intermediate transfer member 12. The cleaning station 54 also cleans release agents deposited on the transfuse member 50 by the release agent management system 88 that can contaminate the image bearing members 30. The cleaning station 54 preferably has first and second cleaning members 254, 255 to remove release agent and residual solids from the intermediate transfer member. While the preferred cleaning station 54 has first and second cleaning members 254, 255, a single cleaning member in certain operational environments can provide adequate removal of release agent from the intermediate member 12 to prevent contamination of the image bearing members 30. The first cleaning member 254 is preferably a blade cleaner (see figure 3). The blade cleaner is oriented transverse to the process direction of the intermediate member 12. The blade cleaner is urged against the surface of the intermediate member 12 to scrape residual toner, debris and particularly release agent, typically silicone oil, from the surface of the transfuse member 50.

[0076] The second cleaning member 255 is a web cleaner having a spool of flexible micro-porous absorbent web material 256. The web material 256 preferably has high affinity and it absorbs release agent through capillary action. Examples of the web material 256 are porous paper, cotton fabric, -open cell foam, microporous materials (i.e. Gore-Tex), nonwoven fabric (i.e. BMP-like fabric) and other natural and synthetic absorbent materials. The web material 256 is spooled off a supply reel 257 and urged against the surface of the intermediate member 12 by a nip roller 258. The web material 256 absorbs release agent through capillary action and further collects residual solids residing on the intermediate member 50. The web material 256 is indexed at a relatively slow rate in a direction opposite the process direction. The web material 256 is indexed as it becomes saturated with oil or the pores become clogged with solids. The web material 256 is spooled up on a take up reel 260. Alternatives of the nip roller 258 could be a pinched roller, or skid pad. Alternately, the web material 256 can be continuously moved. The cleaning station 54 is preferably positioned relatively far from the second transfer nip 48 and relatively close to the first transfer nip, in the process direction. This spacing provides additional time for drop formation of any release agent transferred to the intermediate member 50. Drops of release agent are typically cleaned with higher efficiency by the cleaning station 54 than a film of release agent on the intermediate member 50. The cleaning system further cools the intermediate transfer member before it contacts with the PR drums.

[0077] Both sides of the material 256 web can effectively be used by adding more nip rollers to the system. As it shows in figure 5, the web material 256 is spooled off a supply reel 257 and urged against the surface of the intermediate member 12 by a nip roller 258. The web material 256 is directed around roller 261, and a second nip roller 264. The second nip roller 264 also serves as the take-up reel. The roller 261 can be optional depending on the space requirement of the web system. Alternately an additional take-up reel (not shown) can be added to separate the function of the second nip roller 264 from the take-up reel. The disclosed embodiment not only enables the effective use of both side of the web material 256, it also creates effective cleaning of the intermediate transfer member 12 by web cleaning it twice prior to the first transfer nips.

[0078] In a further embodiment, the first cleaning member 254 having a blade is combined with a second cleaning member formed of a wick cleaner 270. The wick cleaner 270 has a wick 271 contacting the surface of the intermediate member 12 to absorb release agent on the surface of the intermediate transfer member 12. The wick 271 absorbs the release agent from the surface of the intermediate transfer member and transfers the release agent to a reservoir 272. The wick 271 can be susceptible to contamination or clogging from solids on the intermediate member 12. The wick 271 is therefore less preferred in some operational environments due to the difficulty of periodically bringing a clean portion of the wick 271 into contact with the intermediate transfer member 12. The operational life of the wick cleaner 270 can be extended by indexing of the wick 271.

[0079] Although the preferred cleaning system embodiment having blade member prior to the web, the orders of the two cleaning members could be reversed in some applications. The two members of the cleaning system 54 is not limit to the combination of blade and web; it could be a brush cleaner and a blade, a brush cleaner and a web, etc. Another embodiment is a first blade, web, and a second blade. The first blade takes up a majority of the contaminants and protects the web from getting dirty too fast. The web does the further cleaning and creates some leveling of oil uniformity on the transfer member. The second blade performs final leveling of the oil to meet the system requirements. As practice in prior art, a toner disturber can be installed prior to the cleaning system.

[0080] The toner on the intermediate member is also a good absorber of the release agent. The toner disturber or the cleaner moves the toner on the intermediate member to further enhance oil absorbing process and to ensure the oil uniformity on the intermediate member. The toner refreshing process required for the sticky cleaner 58 can also refresh the intermediate member 12 and the cleaning system 54 to correct oil non-uniformity problem. Oil non-uniformity might cause transfer problems in local regions and results in image defects.

[0081] All the cleaning systems proposed for the intermediate member could also be implemented on the image bearing member 30 to further reduce the release agent contamination to the image bearing member 30 and other imaging subsystems.

[0082] The cleaning system can be implemented whenever there is release agent in the intermediate member, independent of the source of the release agent. In a two member transfuse system having an image bearing member and a transfuse member, the release agent could come from the internal or external oil of the transfuse member. In a xerographic printing system with an intermediate transfer member, substrates on the duplex mode could transfer the release agent from a fusing station back to the intermediate member.

[0083] A cleaning system 58 engages the surface of the transfuse member 50 past the third transfer nip 86 to remove any residual toner and contaminants from the surface of the transfuse member 50. Preferably the cleaning system 58 includes a cleaning roller having a sticky surface created by partially melted toner. The cleaning roller is preferably heated by the transfuse member 50 to thereby maintain the toner on the cleaning roller in a partially melted state. The cleaning roller is maintained in a pressure arrangement of 10-50 psi (69 - 345 KPa) against the roll 80. Alternatively the cleaning roller can be opposed by a pressure roller (not shown) located on the underside of the transfuse member. The operating temperature range is sufficiently high to melt the toner, but sufficiently low to prevent toner layer splitting. The partially melted toner is maintained within the optimum temperature range for cleaning by the temperature of the transfuse member 50 in combination with any necessary heating or cooling of the cleaning roller.

[0084] The transfuse member 50 is driven in the cyclical path by the pressure roller 84. Alternatively drive is provided or enhanced by driving guide roller 74. The intermediate transfer member 12 is preferably driven by the pressured contact with the transfuse member 50, and further torque assisted by roll 16. Drive to the intermediate transfer member 12 is preferably derived from the drive for the transfuse member 50, by making use of adherent contact between intermediate transfer member 12 and the transfuse member 50. The adherent contact causes the transfuse member 50 and intermediate transfer member 12 to move in synchronism with each other in the second transfer nip 48. Adherent contact between the intermediate transfer member 12 and the toner image producing stations 22, 24, 26, 28 may be used to ensure that the intermediate transfer member 12 moves in synchronism with the toner image producing stations 22, 24, 26, 28 in the first transfer zones 40. Therefore the toner image producing stations 22, 24, 26, 28 can be driven by the transfuse member 50 via the intermediate transfer member 12. Alternatively, the intermediate transfer member 12 is independently driven. When the intermediate transfer member is independently driven, a motion buffer (not shown) engaging the intermediate transfer member 12 buffers relative motion between the intermediate transfer member 12 and the transfuse member 50. The motion buffer system can include a tension system with a feedback and control system to maintain good motion of the intermediate transfer member 12 at the first transfer nips 40 independent of motion irregularity translated to the intermediate transfer member 12 at the second transfer nip 48. The feedback and control system can include registration sensors sensing motion of the intermediate transfer member 12 and/or sensing motion of the transfuse member 50 to enable registration timing of the transfer of the composite toner image to the substrate 70.

[0085] An optional gloss enhancing station 110 is preferably positioned down stream in the process direction from the third transfer nip 86 for selectively gloss enhancing the gloss properties of documents 72. The gloss enhancing station 110 has opposed fusing members 112, 114 defining a gloss nip 116 there between, which can be simplex or duplex. The gloss nip 116 is adjustable to provide the selectability of the gloss enhancing. In particular, the fusing members are cammed whereby the transfuse nip is sufficiently large to allow a document to pass through without substantial contact with either fusing member 112, 114 that would cause glossing. When the operator selects gloss enhancement, the fusing members 112, 114 are cammed into pressure relation and driven to thereby enhancement the level of gloss on documents 72 passed through the gloss nip 116. The amount of gloss enhancement is operator selectable by adjustment of the temperature of the fusing members 112, 114. Alternatively, the gloss level can be controlled by adjustment of the nip pressure. Increasing the nip pressure increases the nip width, and hence the dwell. Over a relatively short dwell period, the heat transferred to the paper is roughly proportional to the square root of the dwell which is directly proportional to the nip width. Higher temperatures of the fusing members 112, 114 will result in increased gloss enhancement. US-A-5,521,688, describes a gloss enhancing station with a radiant fuser.

[0086] The separation of fixing and glossing functions provides operational advantages. Separation of the fixing and glossing functions permits operator selection of the preferred level of gloss on the document 72. The achievement of high gloss performance for color systems generally requires relatively higher temperatures in the third transfer nip 86. It also typically requires materials on the transfuse member 50 having a higher heat and wear resistance, as well as a higher durometer such as Viton™. Excessive wear can result in differential gloss caused by changes in surface roughness of the transfuse member due to wear. The higher temperature requirements and the use of more heat and wear resistant materials generally results in the need for high oil application rates by the release agent management system 88. In transfuse systems such as the printer 10 increased temperatures and increased amounts of oil on the transfuse member 50 could possibly create contamination problems of the photoreceptors 30. Printers having a transfuse system and needing high gloss use a thick nonconformable transfuse member, or a relatively thin transfuse member. However, a relatively nonconformable transfuse member and a relatively thin transfuse member fail to have the high degree of conformance needed for good printing on, for example, rougher paper stock.

[0087] The use of the gloss enhancing station 110 substantially reduces or eliminates the need for gloss creation in the third transfer nip 86. The reduction or elimination of the need for gloss in the third transfer nip 86 therefore minimizes surface wear issues for color transfuse member materials and enables a high life transfuse member 50 with readily available silicone or other similar soft transfuse member materials. It allows the use of relatively thick layers on the transfuse member 50 with resultant gain in operating life for the transfuse member materials and with resultant high conformance for imaging onto rougher substrates. It reduces the temperature requirements for the transfuse materials set with further gain in transfuse material life, and it can substantially reduce the oil requirements in the third transfer nip 86.

[0088] The gloss enhancing station 110 is preferably positioned sufficiently close to the third transfer nip 86, so the gloss enhancing station 110 can utilize the increased document temperature that occurs in the third transfer nip 86. The increased temperature of the document 72 reduces the operating temperature needed for the gloss enhancing station 110. The reduced temperature of the gloss enhancing station 110 improves the life and reliability of the gloss enhancing materials.

[0089] Use of a highly conformable silicone transfuse member 50 is an example demonstrated as one important means for achieving good operating fix latitude with low gloss. Critical parameters are sufficiently low durometer for the top most layer of the transfuse member 50, preferably of rubber, and relatively high thickness for the intermediate layers of the transfuse member 50, preferably also of rubber. Preferred durometer ranges will depend on the thickness of the composite toner layer and the thickness of the transfuse member 50. The preferred range will be about 25 to 55 Shore A, with a general preference for about 35 to 45 Shore A range. Therefore preferred materials include many silicone material formulations. Thickness ranges of the middle and upper most layers of the transfuse member 50 will preferably be greater than about 0.25 mm and more preferably greater than 1.0 mm. Preference relative to low gloss will be for generally thicker layers to enable extended toner release life, conformance to rough substrates, extended nip dwell time, and improved document stripping. In an optional embodiment a small degree of surface roughness is introduced on the surface of the transfuse member 50 to enhance the range of allowed transfuse material stiffness for producing low transfuse gloss. Especially with higher durometer materials and/or low thickness layers there will be a tendency to reproduce the surface texture of the transfuse member. Thus some surface roughness of the transfuse member 50 will tend toward low gloss in spite of high stiffness. Preference will be transfuse member surface gloss number <30 GU.

[0090] A narrow operating temperature latitude for good fix with low gloss in transfuse has been demonstrated at relatively high toner mass/area conditions. Toner of size about 7 microns requiring toner masses about 1 mg/cm2 requires a temperature of the transfuse member 50 between 110-120C and preheating of the paper to about 85C to achieve gloss levels of <30 GU while simultaneously achieving acceptable crease level below 40. However, low mass/area toner conditions have shown increased operating transfuse system temperature range for fix and low gloss. The use of small toner having high pigment loading, in combination with a conformable transfuse member 50, allows low toner mass/area for color systems therefore extending the operating temperature latitude for low gloss in the third transfer nip 86. Toner of size about 3 microns requiring toner masses about 0.4 mg/cm2 requires a temperature of the transfuse member 50 between 110-150C, and paper preheating to about 85C, to achieve gloss levels of <30 GU while simultaneously achieving acceptable crease level below 40.

[0091] The gloss enhancing station 110 preferably has fusing members 112, 114 of Viton™. Alternatively hard fusing members such as thin and thick Teflon™ or expanded PTFE sleeves/overcoatings on rigid rollers or on belts, or else such overcoatings over rubber underlayers, are alternative options for post transfuse gloss enhancing. The fusing members 112, 114, preferably have an top most fixing layer stiffer than that used for the top most layer of the transfuse member 50, with a high level of surface smoothness (surface gloss preferably>50 GU and more preferably >70 GU). The topmost surface can be alternatively textured to provide a texture to the documents 72. The gloss enhancing station 110 preferably includes a release agent management application system (not shown). The gloss enhancing station can further include stripping mechanisms such as an air puffer, or stripper fingers to assist stripping of the document 72 from the fusing members 112, 114.

[0092] Optionally the toner formulation may include wax or encapsulated release agents to reduce the oil requirements for the gloss enhancing station 110.

[0093] The gloss enhancing station 110 is described in combination with the printer 10 having an intermediate transfer member 12 and a transfuse member 50. However, the gloss enhancing station 110 is applicable with all printers having transfuse systems producing documents 72 with low gloss. In particular this can include transfuse systems that employ a single transfer/ transfuse member.

[0094] As a system example, the transfuse member 50 is preferably 120 C in the third transfer nip 86, and the substrate 70 is preheated to 85 C. The result is a document 72 having a gloss value 10-30 GU. The fusing members are preferably heated to 120C. The temperature and/or dwell of the fusing members 112, 114 is preferably adjustable so different degrees or levels of glossing can be applied to different print runs or different prints within a run dependent on operator choice. Higher temperatures and dwell of the fusing members 112, 114 increase the gloss enhancement while lower temperatures and dwell will the reduce the amount of gloss enhancement on the documents 72.

[0095] The glossing members 112, 114 are preferably fusing rollers, but can alternatively the glossing members 112, 114 can be fusing belts. The top most surface of each glossing member 112, 114 is relatively non-conformable, preferably having a durometer above 55 Shore A. The gloss enhancing station 110 provides gloss enhancing past the printer 10 employing a transfuse system that operates with low gloss in the third transfer nip 86. The printer 10 preferably forms documents 72 having 10-30 Gardner Gloss Units (GU) after the third transfer nip 86. The gloss on the documents 72 will vary with toner mass per unit area. The gloss enhancing unit 110 preferably increases the gloss of the documents 72 to greater than about 50 GU on Lustro Gloss™ paper distributed by SD Warren Company.

Claims

1. A printing apparatus for forming a document comprising:

> a toner image support surface;
> a transfuse member defining a transfer nip with said toner support surface;
> a fusing member defining a transfuse nip with said transfuse member for generally simultaneous transfer and fusing of a toner image to a substrate;
> a cleaning station engaging said toner support surface for cleaning release agent from said toner support surface.

2. A printing apparatus according to claim 1, further comprising a release agent management system for applying release agent to said transfuse member.

3. A printing apparatus for forming a document comprising:

> a toner image producing station having a photoreceptor for forming a toner image;
> an intermediate transfer member defining a first transfer nip with said toner image producing station and having an image area for receiving said toner image;
> a transfuse member defining a second transfer nip with said intermediate transfer member;
> a fusing member forming a third transfer nip with said transfuse member for generally simultaneous transfer and fusion of said toner image to a substrate;
> a release agent applicator for applying a release agent to said transfuse member;
> a cleaning station engaging said intermediate member for cleaning release agent from said intermediate transfer member.

4. A printing apparatus according to claim 2 or 3, wherein said release agent is a silicone oil.

5. A printing apparatus according to any one of the preceding claims, wherein said transfuse member is formed of silicone.

6. A printing apparatus according to any one of the preceding claims, wherein said cleaning station comprises a web cleaner having a web material contacting said intermediate transfer member to remove said release agent from said intermediate transfer member.

7. A printing apparatus according to claim 7, wherein said web cleaner comprises a spool, said web material wound from said spool, and a roller urging said web material into contact with said toner image support surface.

8. A printing apparatus according to any one of claims 1 to 5, wherein said cleaning station further comprises a blade contacting said toner image support surface.

9. A printing apparatus according to any one of claims 1 to 5, wherein said cleaning station comprises a wick contacting said toner image support surface.

10. A method of forming a printed document in a printer having an intermediate transfer member and a transfuse member comprising:

> applying a toner image to said intermediate transfer member;
> transferring said toner image from said intermediate transfer member to said transfuse member having said release agent;
> transferring said toner image from said transfuse member to a substrate and generally simultaneously fusing said toner image to said substrate to form a document; and
> cleaning release agent from said intermediate transfer member.

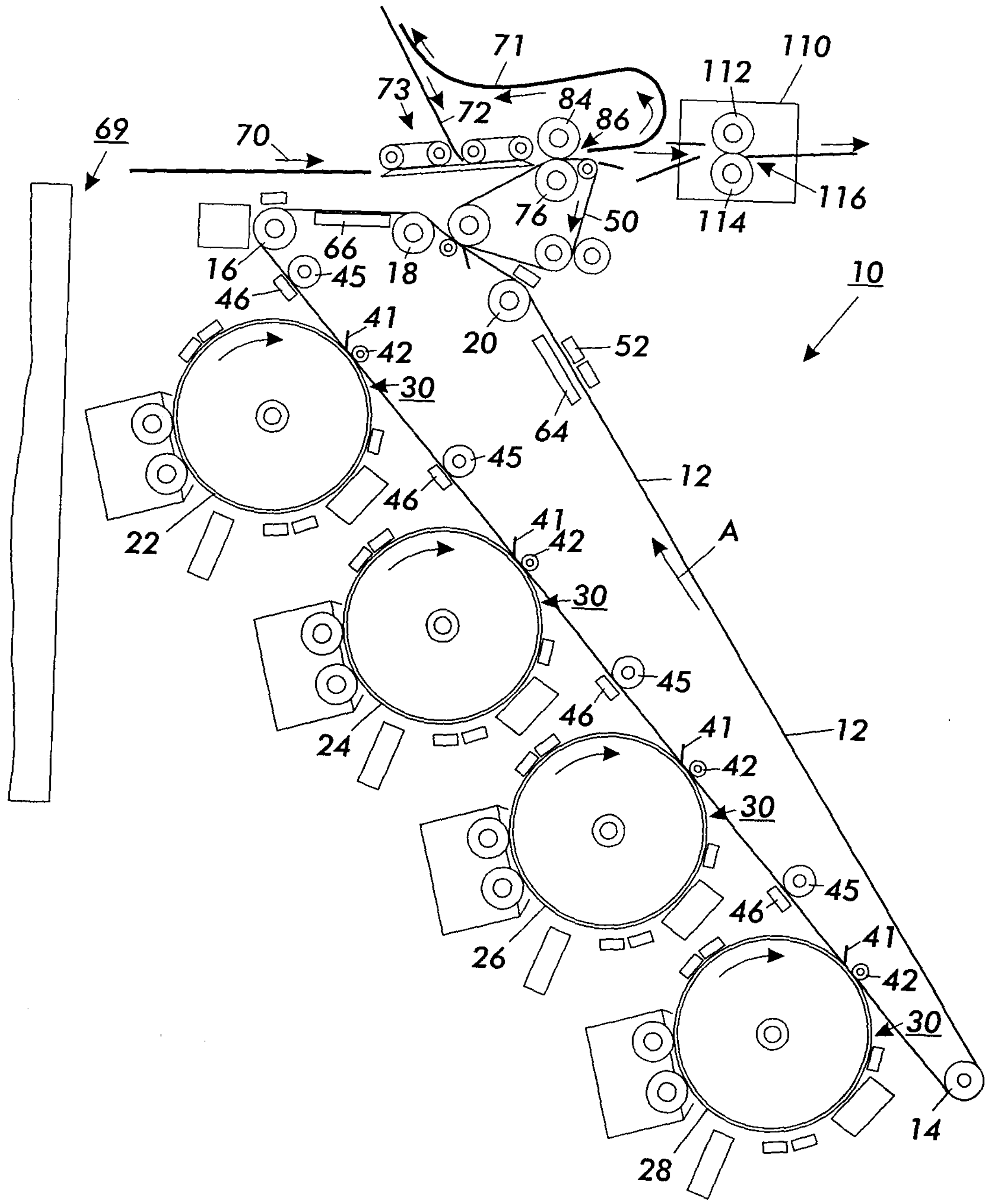
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FIG. 1

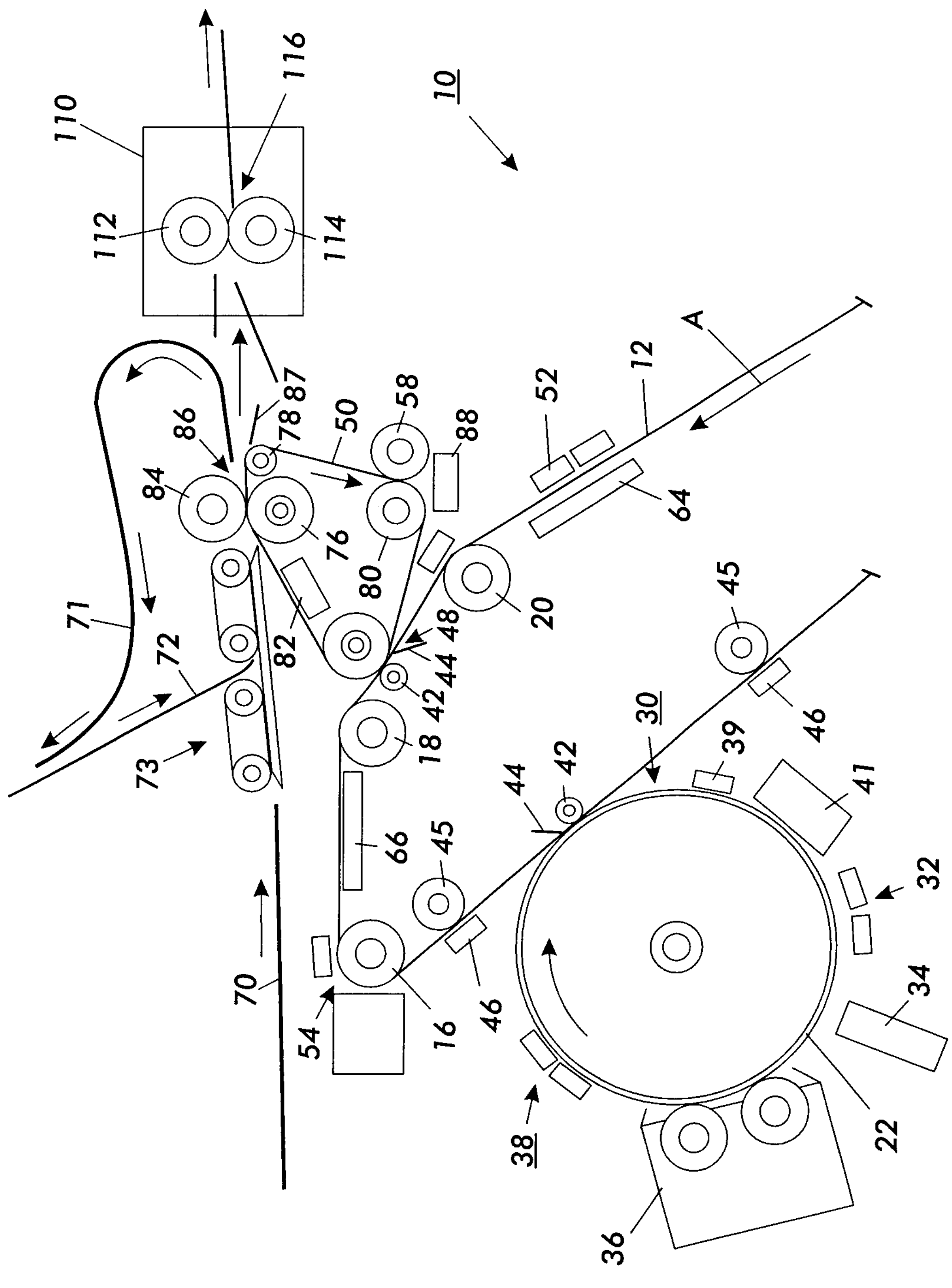
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FIG. 2

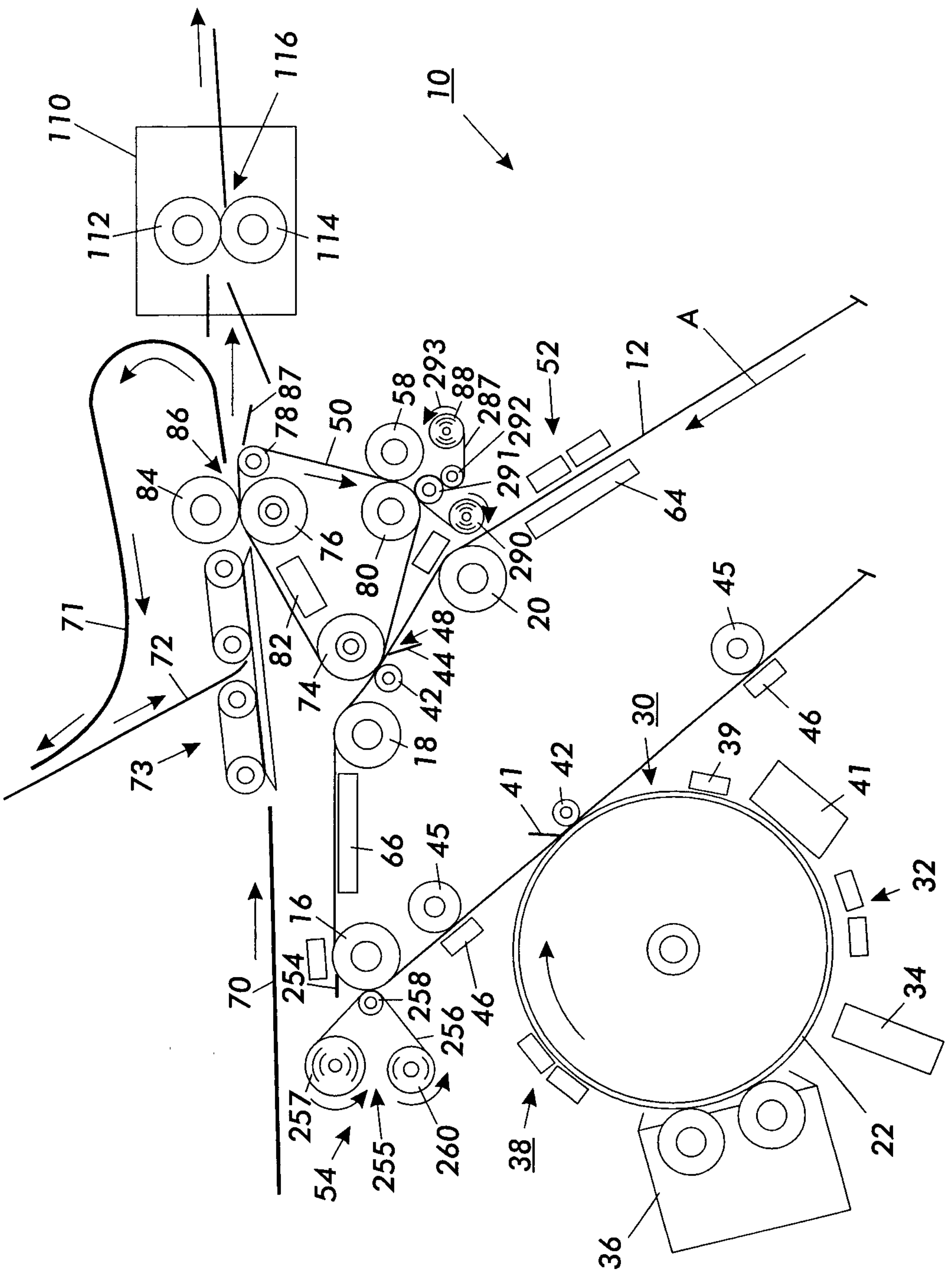
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FIG. 3

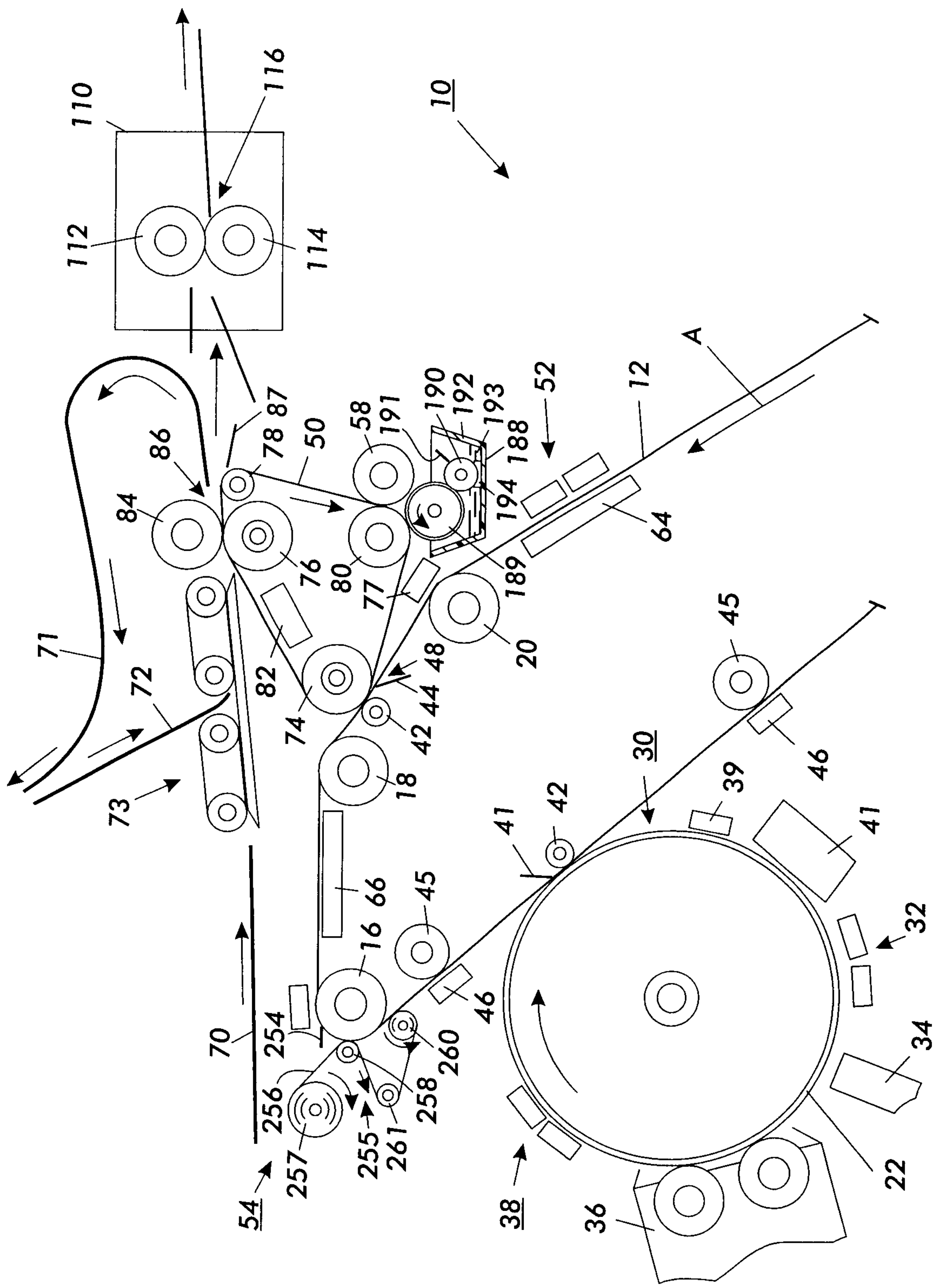
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FIG. 4

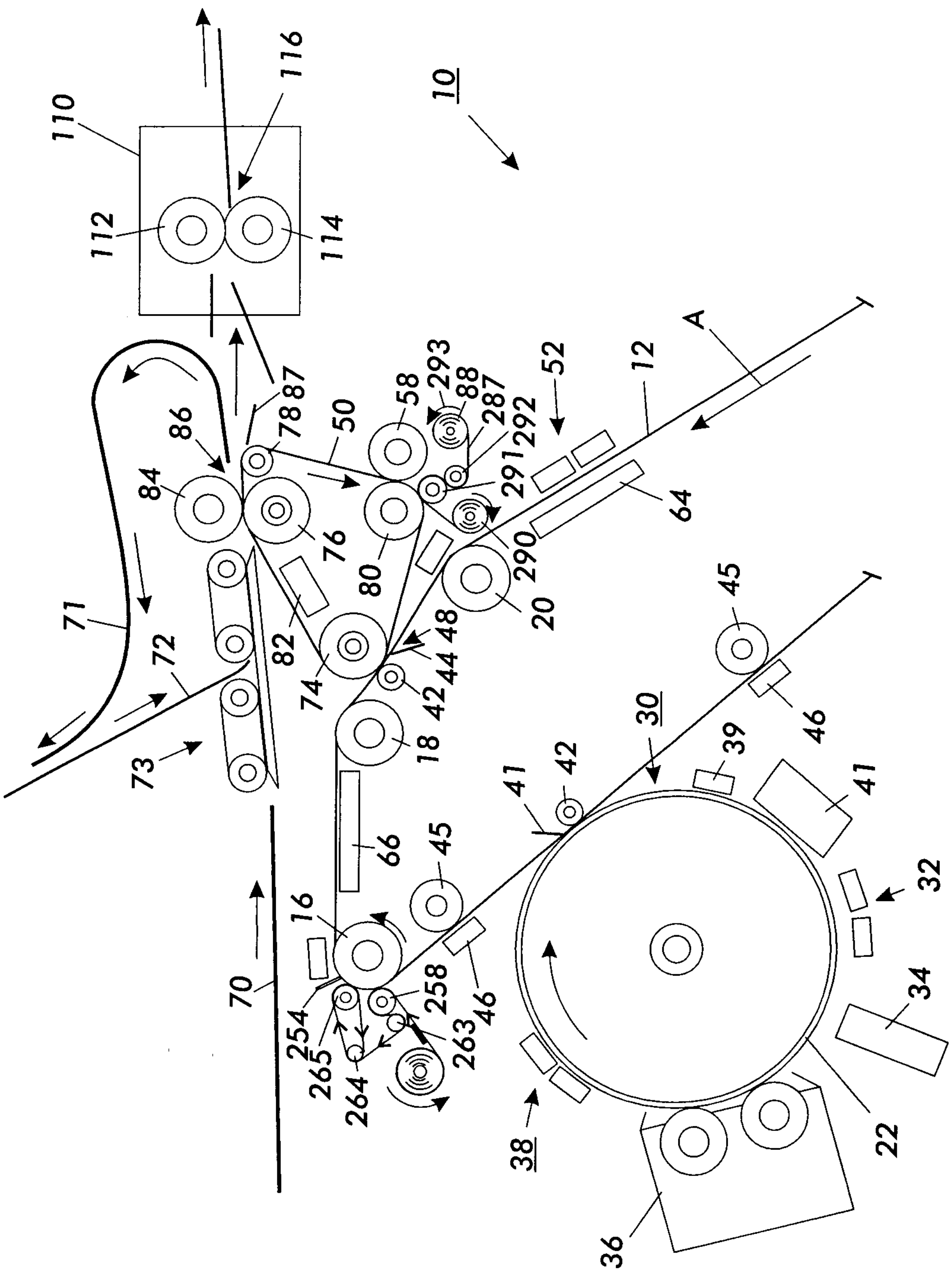
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FIG. 5

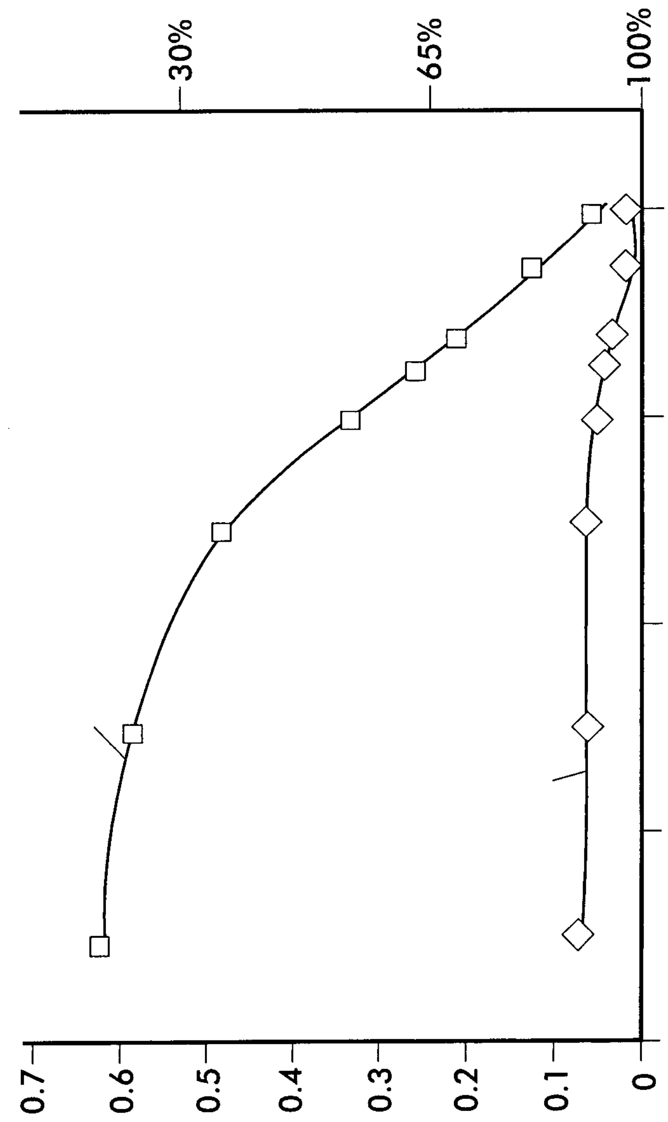

FIG.6

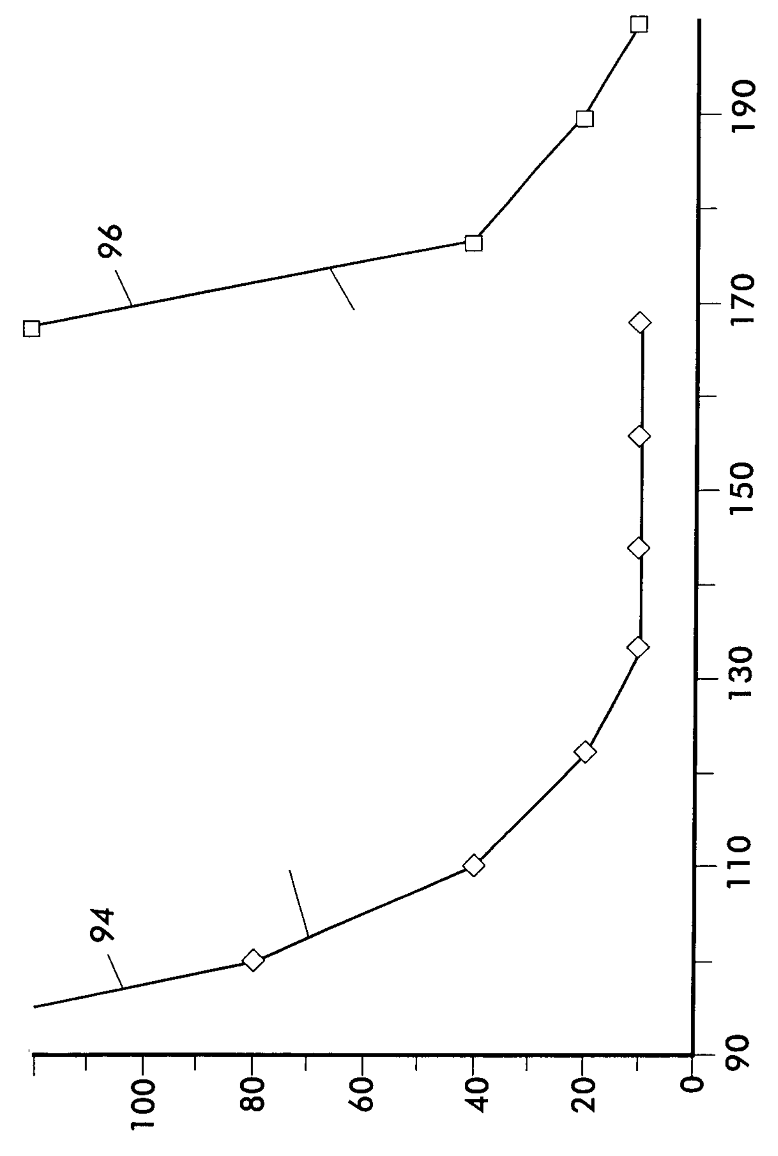

FIG. 7

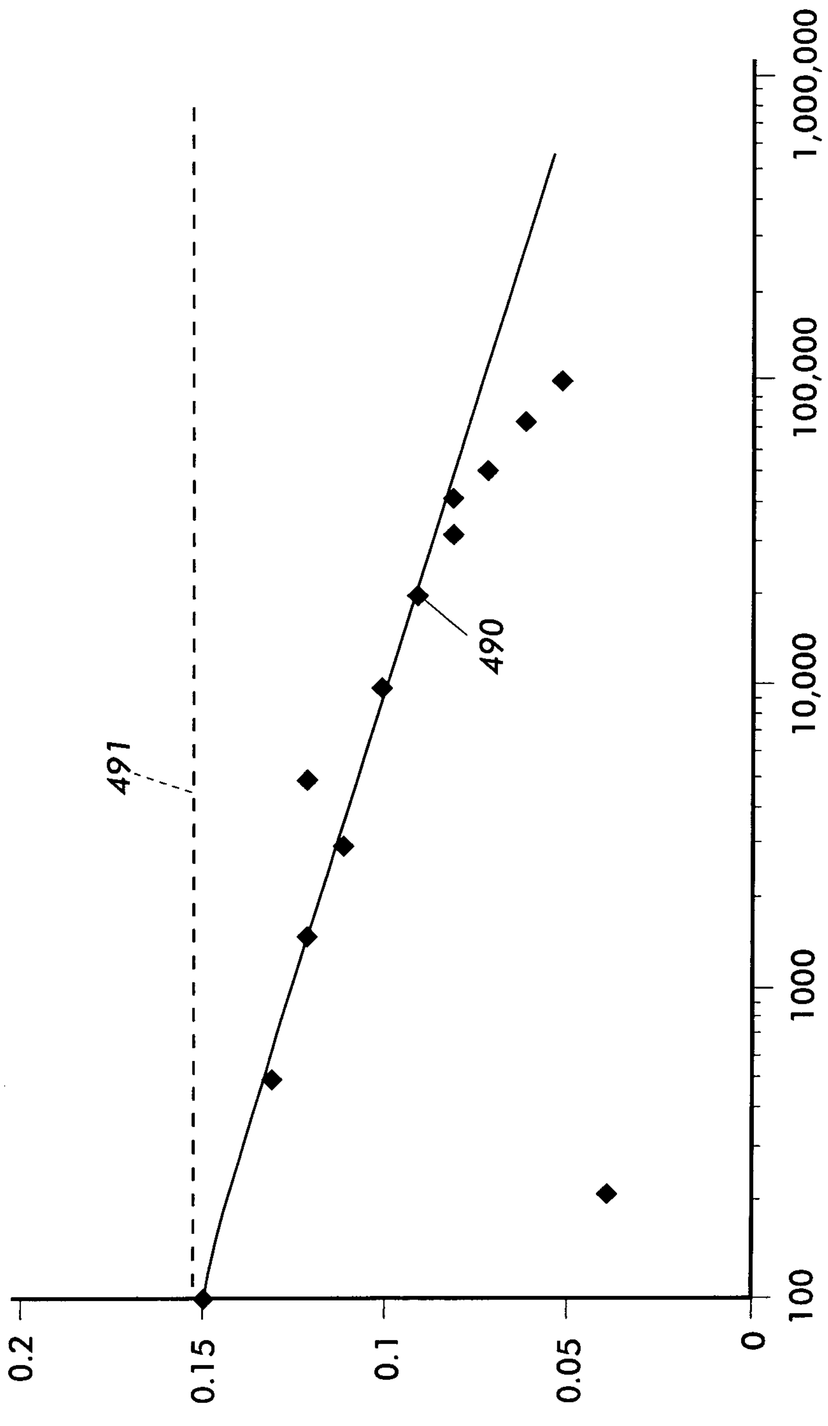

FIG. 8