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(54) **Title**: DEVELOPER SYSTEM AND METHOD FOR PROVIDING A STABLE FLOW RATE OF DEVELOPER IN AN ELECTROGRAPHIC PRINTER

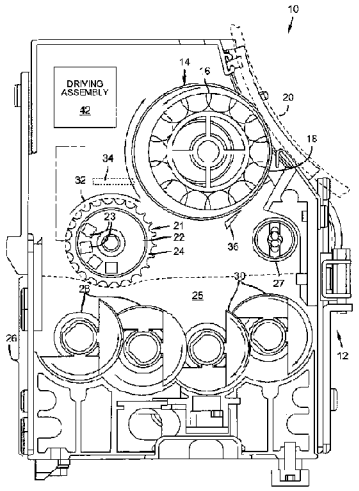


FIG. 1A

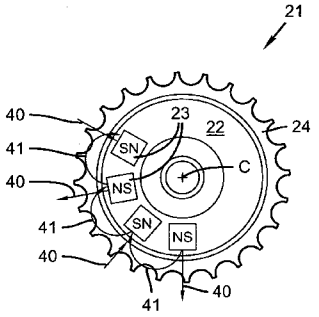


FIG. 1B

(57) **Abstract**: A developer system (10) and method for an electrographic printer is provided that provides a stable and high rate of developer flow to the photoconductor drum (20) of the printer. The system includes a magnetic brush (14) having a magnetic core (16) surrounded by a toning shell (18) that rotatably conveys a layer of developer to the photoconductor element; a sump (26) containing a reservoir of developer, and a self-metering conveyor roller (21) having a maximum magnetic field strength on its outer surface of between about 100 and 1000 gauss, and a minimum magnetic field strength of no less than about 30 % of the maximum field strength. A driving assembly (42) rotates the conveyor roller at a saturation speed that saturates the capacity of the conveyor roller to deliver developer to said toning shell. The self-metering conveyor roller obviates the need for a metering skive to provide a stable flow rate of developer, and increases the printing speed of the printer by providing a higher flow rate of developer to the photoconductor drum of the printer.

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DEVELOPER SYSTEM AND METHOD FOR PROVIDING A STABLE FLOW RATE OF DEVELOPER IN AN ELECTROGRAPHIC PRINTER

FIELD OF THE INVENTION

This invention generally relates to electrographic printers, and is specifically concerned with a system and method that provides a stable and high flow rate of developer to the magnetic brush of a developer station through the use of a conveyor roller operating at a preferred speed range.

BACKGROUND OF THE INVENTION

Electrographic printers that use a rotating magnetic brush to apply a dry, particulate developer to a photoconductor member are known in the art. In such electrographic printers, the magnetic brush includes a rotatable magnetic core surrounded by a rotatable, cylindrical toning shell. The toning shell may be eccentrically mounted with respect to the axis of rotation of the magnetic core. The eccentric mounting of the toning shell defines an area of relatively strong magnetic flux where the shell comes closest to the magnetic core, and an area of relatively weak magnetic flux where the shell is farthest away from the core. The magnetic brush is mounted over a developer sump that holds a reservoir of dry, two-component developer including a mixture of ferromagnetic transport particles and toner particles capable of holding an electrostatic charge. A rotatable conveyor roller is disposed between the reservoir of developer in the sump and the toning shell. In operation, the rotatable conveyor roller attracts and transports developer from the sump to a region of the toning shell where the magnetic flux is relatively weak. The rotating toning shell in turn transports the developer toward the photoconductor member. At the line of closest approach between the toning shell and the photoconductor member, the particulate toner component of the developer is transferred to the photoconductor member as a result of electrostatic attraction between the toner particles and the electrostatic field on the photoconductor member and consequently develops a latent electrostatic image on the photoconductor member. The developed image is ultimately transferred to a substrate, such as a sheet of paper, where the toner image is fused into a permanent image via a fuser station. The combination of the magnetic brush,

developer sump and conveyor roller is referred to as a developer station in this application.

In order to print images as quickly as possible, it is necessary for the conveyor roller to rapidly deliver developer to the toning shell. However, it is also necessary for the toning shell to deliver a constant, uniform flow of developer material across its width to the photoconductor member by minimizing variations in developer delivery from the sump. Usually, a "metered flow" is obtained by utilizing a metering skive spaced uniformly from the toning shell parallel to the axis of rotation of the toning shell. Such a metered flow of developer on the toning shell insures that a uniform layer or "nap" of developer material of the proper thickness is delivered to the nip with the photoconductor member. If the nap is non-uniform, the resulting image may have streaks or other undesirable artifacts that degrade the quality of the image. If the developer nap is too thick, developer material can jam the nip and be expelled from the developer roller resulting in contamination of other areas of the electrophotographic reproduction apparatus. Finally, if the nap is uniform but too thin, there might not be enough toner present to enable a high quality image.

As previously indicated, past attempts at providing a metered flow of developer material have included the use of a metering skive across the toning shell downstream from the line of developer delivery between the conveyor roller and the toning shell. The skive gap and its relationship to the toning shell must be tightly controlled to achieve both a uniform thickness of the developer nap along the axis of rotation of the developer roller, and a desired thickness that is neither too thick or too thin. Even very small errors in the metering skive gap can result in an unacceptably large error in either the nap uniformity or nap thickness of the developer. Accordingly, when a metering skive is used, it is positioned at the point of the lowest magnetic field strength from the developer roller's magnetic core. It has been found that such positioning significantly decreases the sensitivity of developer nap height to the metering skive gap by a factor of two to four times. This makes the metering skive gap easier to setup in manufacturing and the resulting developer nap thickness less sensitive to differences in that skive gap along the length of the developer roller.

However, the applicants have observed multiple disadvantages associated with such metering skives. First, such metering skives limit the printing speed that can be achieved by the photoconductor member, as they necessarily impose a limit on the amount of developer that the toning shell can deliver to the photoconductor member. Second, the positioning of such skives at the preferred point of the lowest magnetic field strength from the developer roller's magnetic core requires the developer to be applied a relatively large angular distance of nearly 180° away from the line of closest approach between the toning shell and the photoconductor element. Such a large angular distance results in a relatively long residence time for the developer on the toning shell. The applicants have observed that such a relatively long residence time in combination with the rapid rotation of the magnetic core of the brush to achieve high printing speeds can disadvantageously age the developer, rendering it less effective in developing the electrostatic latent image on the photoconductor member. Third, the metered flow obtained with the metering skive is sensitive to the uniformity of the material delivered by the conveyor roller.

SUMMARY OF THE INVENTION

To solve these and other problems, the developer system of the invention includes the combination of (1) a self-metering conveyor roller having a magnetic core and an outer shell for conveying developer from the reservoir of said sump to said toning shell of said magnetic brush, wherein a maximum magnetic field strength of said outer shell is less than 1000 gauss and preferably less than 300 gauss, and a minimum magnetic field strength between magnetic poles of said outer shell is no less than about 30% of said maximum field strength, and (2) a driving assembly that rotates the conveyor roller at a speed that saturates the capacity of the toning shell such that that a constant, high flow rate of developer is provided to the toning shell despite variations in the attraction and transport of developer from the sump by said conveyor roller. The applicants have surprisingly found that a conveyor roller having such a relatively strong and uniform magnetic field becomes self-metering when rotated at such a saturation speed and deposits a layer of developer on the developer roller having a uniform

nap that enables the metering skive to produce a uniform layer of proper thickness on the toning shell. Additionally, the applicants have found that the combination of such a roller and rotational speed increases the printing speed of the printer by providing a higher flow rate of developer to the nip of the photoconductor element with the toning shell of the magnetic brush.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description of the preferred embodiment of the invention presented below, reference is made to the accompanying drawings, in which:

Figure 1A is a schematic side view of a typical electrographic development station suitable for use with the development station improvements of the invention;

Figure 1B is a cross sectional side view of the conveyor roller of the invention, schematically illustrating the distribution of the magnetic poles in the roller magnetic core and schematically illustrating the lines of flux therebetween;

Figure 2 is a schematic diagram of developer flow as a function of development station set points;

Figure 3 is a graph of measured developer flow as a function of developer station set points;

Figure 4 is a graph of measured developer flow as a function of developer station set points for a preferred transport roller;

Figure 5 is a graph of measured developer flow vs. developer mass area density as a function of developer station set points;

Figure 6A is a plot of the magnetic field of a prior art transport roller, and

Figure 6B is a plot of the magnetic field of a transport roller in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1A illustrates a developer station 10 that the invention is applicable to. Such a developer station 10 includes a housing 12. A developer roller or magnetic brush 14, mounted within the development station housing 12,

includes a rotating (counterclockwise in FIG. 1A) fourteen pole magnetic core 16 inside a rotating (clockwise in FIG. 1A) toning shell 18. Of course, the core magnet 16 and the shell can have any other suitable relative rotation. The rotating toning shell 18 applies developer to the outer surface of a drum-shaped photoconductor element 20 shown in phantom in order to develop latent electrostatic images written on the drum by an optical writing station (not shown). A magnetic conveyor roller 21 having a stationary core 22 surrounded by a rotatable shell 24 delivers developer 25 from a developer reservoir or sump 26 located at the bottom of the housing 12 to the back side of the toning shell 18. In the preferred embodiment, shell 24 is approximately 1.20 inches in diameter. A toner replenishing tube 27 delivers toner to the developer 25 in the reservoir 26 to maintain a proper ratio of toner and transport particles in the developer 25. Feed augers 28 having suitable mixing paddles (rotating counterclockwise) mix toner from the tube 28 with the developer in the reservoir 26, while return augers 30 mix toner-depleted developer removed from the toning shell 18 by stripping skive 36 back into the developer reservoir. A driving assembly 42 is operably connected to the shell 24 of the conveyor roller and controls the speed of rotation of the shell 24. While not shown in detail, the driving assembly may include an electric motor, a digital controller that controls the speed of the motor by controlling the amount of current conducted thereto, and a gear train.

With reference now to Figure 1B, the stationary core 22 of the conveyor roller 21 preferably includes at least two magnets and preferably at least four magnets 23 arranged around the circumference of the core 22 between the six o'clock position and about the ten or eleven o'clock position as shown. Although individual magnets are shown, the stationary core can also include a single piece of magnetic material that is magnetized to produce a similar magnetic field. The poles of the magnets 23 are further arranged so that they alternate N-S-N-S from the six and ten-eleven o'clock position, although they could just as easily alternate in an S-N-S-N pattern. The radial vector 40 of each of the fields of the magnetic poles is radially aligned with respect to a central axis C of the cylindrical core 22. Tangential field lines 41 interconnect the alternating poles of the magnets 23 as shown. As is described in more detail hereinafter, the magnets 23 provide a

maximum combined radial and tangential magnetic field strength at the outer surface of the rotating shell 24 of preferably between about 100 and 300 gauss, and more preferably between about 150 and 250 gauss, and most preferably of about 200 and 250 gauss. Additionally, the minimum tangential magnetic field strength between magnetic poles 23 around the outer surface of the rotating shell 24 is preferably no less than about 30% of the maximum radial field strength, and more preferably no less than about 35-50% of the maximum radial field strength. In the preferred embodiment, magnets 23 are flexible strip-type magnets formed from a mixture of magnetic particles mixed with a plastic material. Such magnets having the required field strengths are commercially available, and are easy to cut to the sizes required for the manufacture of the roller 21.

In operation, the shell 24 of the conveyor roller 21 is rotated clockwise by the driving assembly 42 at a speed that saturates the capacity of the toning shell to receive and convey developer to the photoconductor element 20. Core 22 remains stationary. The magnet 23 disposed in approximately the six o'clock position is adjacent the developer reservoir 26 and draws the magnetic developer 25 onto the outer surface of the shell 24 as shell 24 rotates, forming a layer 32 of developer on the shell 24. The field applied by the magnets 23 in combination with the rotational speed of the shell 24 provides a uniform thickness to the layer 32 as it rotates upwardly. The outer surface of the shell 24 includes a sprocket-like pattern of ridges and grooves as shown to enhance the grip that the shell 24 applies to the layer 32 of developer. While the average diameter of the shell 24 is 1.20 inches, the diameter varies from 1.27 to 1.15 inches between the ridges and grooves.

The developer layer 32 is delivered to a back portion of the toning shell 18 of the magnetic brush 14. A metering skive 34 (illustrated in phantom) is provided immediately downstream of the line where the conveyor roller 21 delivers developer to the toning shell 18. The gap between the metering skive 34 and the toning shell 18 is carefully calibrated to ensure that the layer 32 of developer delivered to the photoconductor element 20 has a uniform nap of the proper thickness. However, the conveyor roller 21, when operated at a saturation speed, advantageously provides the layer 32 with a uniform nap of the proper

thickness so that the metering skive 34 produces a stable layer of proper thickness on toning shell 18.

For a developer station 10 employing conventional conveyor roller and a metering skive 34, specific examples of magnetic brush core and developing shell speeds, conveyor roller speeds, auger rotational speeds, metering skive and take-off skive gaps with respect to the toning shell are given below for printer speeds of 70 ppm, 83.3 ppm and 100 ppm, respectively:

Table 1

70 PPM

Parameter	Low	Nominal	High	Units
Core Speed		800		RPM
Shell		82		RPM
Conveyor		60		RPM
Mixer		436		RPM
Metering Skive Spacing	0.033	0.035	0.037	inches
Take-off Skive Spacing	0.007	0.012	0.017	inches
Process speed		11.8		ips

83.3 PPM

Parameter	Low	Nominal	High	Units
Core Speed		952		RPM
Shell		97.58		RPM
Conveyor		71.4		RPM
Mixer		519		RPM
Metering Skive Spacing	0.033	0.035	0.037	inches
Take-off Skive Spacing	0.007	0.012	0.017	inches
Process speed		14.0		ips

100 PPM

Parameter	Low	Nominal	High	Units
Core Speed		1142.9		RPM
Shell		117.1		RPM
Conveyor		85.7		RPM
Mixer		623		RPM

Metering Skive Spacing	0.033	0.035	0.037	inches
Take-off Skive Spacing	0.007	0.012	0.017	inches
Process speed		16.9		ips

Surface speed of the rollers can be calculated from the roller speed in rpm using the diameter of the roller. For example, at 70 ppm printing speed, a toning shell with a 2 inch diameter rotating at 82 rpm has a surface speed in inches per second (ips) of $8.6 = 2\pi \times 82/60$. The conveyor roller rotating at 60 rpm with a 1.27 inch maximum diameter has a maximum surface speed of 4 ips = $1.27\pi \times 60/60$, and so forth for surface speeds of toning station components at other printing speeds. Toning shell speed is approximately 10.2 ips at 83.3 ppm and approximately 12.3 ips at 100 ppm.

Figure 2 is a schematic drawing showing developer flow in a developer station 10 as a function of the rotational speed of a conveyor roller. The dashed-line lower curve A in Figure 2 shows the flow measured on the toning shell 18 with a metering skive 34 in place, and with a prior art conveyor roller. At rotational speeds lower than P1, the conveyor roller delivers an unstable raw flow of developer to the toning shell 18 that varies with the rotational speed of the roller as well as with variation of the amount of developer attracted and transported from the sump. At rotational speeds greater than P1, the conveyor roller delivers a metered, constant flow of developer indicated by the flattening of the dashed line curve. This metered flow of developer remains substantially constant despite variations in the amount of developer transported from the sump from causes including variation of the rotational speed of the conveyor roller after P1. The solid-line upper curve B in Figure 2 shows the flow measured on the toning shell 18 without a metering skive 34. At rotational speeds lower than P2, the conveyor roller 21 delivers an unstable flow of developer to the toning shell 18 that varies with the rotational speed of the roller. At rotational speeds greater than P2, the conveyor roller 21 delivers a stable, constant flow of developer indicated by the flattening of the solid-line curve that is substantially greater than the

metered flow achieved with a metering skive 34. This stable flow of developer remains substantially constant despite variations in the amount of developer transported from the sump from causes including variation of the rotational speed of the conveyor roller after P2. Figure 2 can be divided into three regions. In Region I, both non-metered flow (solid line) and metered flow utilizing a skive (dashed line) increase proportionally with conveyor roller speed. In Region II, raw and metered flow approach saturation. In Region III, both raw flow and metered flow are saturated, and independent of conveyor roller speed. The present invention consists of setpoints for which the raw flow and metered flow are both saturated, as shown in Region III of Figure 2 and a metering skive is used to control flow to acceptable levels.

Figure 3 is a graph illustrating the performance of a prior-art conveyor roller that is capable of operating in Region I and Region II of Figure 2, but not Region 3. The vertical axis indicates the developer flow rate to the photoconductor element 20 in grams per inch-second or g/(in.-sec.) in a direction perpendicular to the axis of rotation of the toning shell 18, while the horizontal axis indicates the rotational speed of a prior art conveyor roller in revolutions per minute (rpm). The lower three curves (indicated by diamonds, squares and triangles) plot developer flow rate as a function of conveyor roller speed when a metering skive 34 is present in the developer station 10 for printing speeds of 70 pages per minute (ppm), 83.3 ppm and 100 ppm respectively. Stable, metered flow occurs with the combination of a prior art conveyor roller and a metering skive 34 at all three printing speeds at about 100 rpm to 150 rpm. The upper two curves (indicated by short and long dash marks) plot developer flow rate as a function of conveyor roller speed when a metering skive is not present in the developer station 10 for printing speeds of 83.3 ppm and 100 ppm respectively. Note that stable flow of developer robust to changes in conveyor roller speed or other fluctuations in the instantaneous rate of developer transport is not achieved for this range of roller speeds with such a roller when the metering skive is not present. By contrast, flow rate is proportional to conveyor roller speed for rotational speeds up to 150 rpm with no indication in either of the top curves of a stable plateau being reached or even approached.

Figure 4 shows the performance of the improved conveyor roller 21 compared to that of a prior art roller shown in Figure 3. The improved conveyor roller is capable of operating in Region III., where stable metered flow and stable non-metered flow are obtained for a range of conveyor roller speeds. Specifically, the upper two curves indicated by short and long dashes plot developer flow rate as a function of conveyor roller speed when a metering skive is not present and a conveyor roller 21 of the invention is used in the developer station 10 for printing speeds of 83.3 ppm and 100 ppm, respectively. These two curves show that stable flow of developer that is robust to changes in conveyor roller speed or other fluctuations in the instantaneous rate of developer transport is achieved with the improved roller 21 when the metering skive is not present. The non-metered flow varies by less than plus or minus 10% for conveyor roller speeds of 50 to 150 rpm, a speed range of 6.6 ips conveyor roller surface speed for toning shell speeds of 10.2 to 12.3 ips. The conveyor roller speed range that provides stable non-metered flow is more than 50% of the toning shell speed. The lower three curves indicated by diamonds, squares, and triangles plot developer flow rate as a function of conveyor roller speed when a metering skive 34 is present in the developer station 10 for printing speeds of 70 pages per minute (ppm), 83.3 ppm and 100 ppm respectively. The flatness of these three curves indicates that the combination of the improved conveyor roller and metering skive also provides a stable, metered flow of developer despite variations in the rotational speed of the roller or transport of the developer from the sump. It is believed by the applicants that extremely stable metered flow is obtained from stable non-metered flow indicated by the relatively flat upper two lines in Figure 4. The applicants believe that metered flow is less likely to have temporal or spatial fluctuations if it is obtained from stable non-metered flow than obtained from unstable non-metered flow. Not only is a substantially flat curve achieved which is indicative of stable, metered flow of developer but a substantially higher flow rate (>45%) is achieved as well for each printing speed. Such higher flow rates indicate a potential for substantially higher printing speeds.

Indication of the attainable printing speed with the improved conveyor roller is provided by the data of Figure 4 and analysis of Figure 5, which shows the performance obtained with the prior art conveyor roller. In Figure 5, the developer flow normalized by printer speed in pages per minute (flow/ppm) and developer mass area density on the toning shell (DMAD) in units of g/(sq in) are plotted for the prior art conveyor roller. All normalized flow curves for metered and non-metered flow at 70, 83.3, and 100 ppm fall on nearly the same diagonal line, indicating that, at all printing speeds tested, flow is a linear function of developer mass area density. For flow with a metering skive spacing of 0.035 in., flow/ppm increases proportionally with DMAD as conveyor roller speed is increased until an upper limit is reached for DMAD. This limit in DMAD and flow is caused by the metering skive spacing. Figure 5 also shows indirectly that flow is directly proportional to toning roller magnetic core speed and shell speed, as these speeds were increased proportionally to obtain greater printing speed, and flow normalized by printing speed (flow/ppm) is approximately the same for all toning station settings at the same DMAD.

Figure 5 also shows, for the curves corresponding to metered flows and non-metered flows obtained without a metering skive, that a range of flows and DMAD can be obtained by increasing or decreasing conveyor roller speed. With the prior art conveyor roller, normalized metered flows of approximately 0.04 to 0.05 g/(in sec) per ppm are used at 70, 83.3 and 100 ppm printing speed. These flows are obtained at the standard metering skive spacing of 0.035 inches. If the prior art conveyor roller is used without a metering skive, normalized flow of approximately 0.65 to 0.80 g/(in.-sec.) per ppm can be obtained by increasing or decreasing conveyor roller speed. The maximum transport roller speed tested was150 RPM.

For the improved conveyor roller 21, both metered and non-metered flow is constant as a function of conveyor roller speed, as shown in Figure 4. The higher non-metered flow rates obtained indicate that the improved roller can be used for much greater printing speed, with, for example, core and shell speeds greater than those shown in Table 1. The flow data for the improved conveyance roller shown in Figure 4 can be normalized by dividing by printing

speed in ppm. Normalized non-metered flows (flow/ppm) average 0.07 g/(in sec) per ppm for the full range of conveyance roller speeds from 50 to 150 rpm for printing speeds of 83.3 and 100 ppm. This is almost 50% more than the normalized flow rate used for the prior art roller for printing speeds up to 100 ppm. Using proportional scaling, estimated printing speeds of at least 140 ppm are attainable with the improved roller by increasing toning core and shell speeds 40% from their nominal values for 100 ppm printing speed, for example, from 1142.9 rpm to 1600 rpm for the magnetic core speed and 117.1 rpm to 164 rpm for the toning shell speed. Despite the improvement in non-metered flow for the improved conveyor roller 21, normalized metered flow for the improved conveyor roller is approximately the same as the prior art roller. 0.04 to 0.05 g/(in.-sec.) per ppm.

Figures 6A and 6B compare the magnetic field strengths at the surface of the rotatable shell 24 of a conveyor roller 21 between a prior art four-magnet conveyor roller and the conveyor roller of the invention, respectively. In both graphs, the vertical axis is calibrated in gauss while the horizontal axis is calibrated in angular degrees. Both the prior art conveyor roller and the conveyor roller of the invention utilize four magnetic poles uniformly spaced around the magnetic core 22 of the roller between the six and ten - eleven o'clock positions. The poles of the magnets are radially aligned with the central axis C of the core 22 as illustrated in Figure 1B. The magnetic field on the surface of the rotating shell 24 is the resultant sum of the radial and tangential components schematically shown by force vectors 40 and 41 illustrated in Figure 1B. The strength of the radial and tangential field components is plotted at each angular point around the shell 24 by the thin solid line and dotted line in Figures 6A and 6B, respectively. In both graphs, the radial field strength is characterized by peaks and valleys as a result of the alternating polarity of the magnets 23. The tangential field strength also undulates, and maximizes or minimizes at the zero crossing points of the radial field strength. The resultant field strength is illustrated by the bold solid line of both graphs.

In generating and plotting the data illustrated in Figures 6A and 6B, the applicants discovered two unexpected characteristics in the magnetic fields

surrounding conveyor rollers that contributed to the development of the claimed invention. First, the graph of Figure 6A indicates that a precipitous minimum field strength occurs between the two middle magnets 23 located at about the seven and nine o'clock positions in the prior art conveyor roller. Specifically, this graph shows that a maximum field strengths of 190 and 200 gauss occur at about 94° and 200°, respectively, but that a minimum field strength of only about 30 gauss occurs at about 150°. Stated somewhat differently, the graph of Figure 6A indicates that the minimum field strength in the array of the magnets 23 is only 15% of the maximum field strength. The applicants have further observed that such relatively low field strength in the middle of the array of magnets 23 creates what amounts to a "hole' in the field which substantially compromises the ability of the conveyor roller 21 to transport developer. Second, the graph of Figure 6B indicates that the percentage difference between the maximum and minimum field strengths can be largely remedied by only a relatively moderate increase in the magnetic field strength of the magnets 23. Specifically, the applicants discovered that if the tangential field strength of the magnets 23 between the two center magnets is increased from 30 gauss to 100 gauss the minimum field strength increases to 100 gauss, which is 38% of the maximum field strength. Hence by increasing the tangential field strength only 70 gauss, the ratio of minimum to maximum field strength increases by a factor of 250% (i.e. from 15% to 38%).

WHAT IS CLAIMED IS:

1. A developer system for an electrographic printer having a photoconductor element, comprising:

a magnetic brush having a magnetic core surrounded by a toning shell that rotatably conveys a layer of developer to said photoconductor element;

a sump containing a reservoir of developer;

a self-metering conveyor roller for conveying developer from the reservoir to said toning shell of said magnetic brush having at least two magnetic poles of opposite polarity,

an engageable metering skive in a developer flow path around said toning shell between said conveyor roller and said photoconductor element capable of engagement; and

a driving assembly that rotates the conveyor roller at a saturation speed that saturates the flow of developer on the toning shell so that it is essentially constant when the conveyor roller speed is increased beyond the saturation speed if the engageable metering skive is engaged or not engaged.

2. The developer system of claim 1, further comprising an engageable metering skive that is not engaged

3. The developer system of claim 1, wherein a maximum magnetic field strength of the outer surface of the roller is less than 1000 gauss, and a minimum magnetic field strength between poles at said outer surface is no less than 30% of said maximum field strength.

4. The developer system of claim 1, wherein; and

the driving assembly that rotates the conveyor roller at a saturation speed that saturates the capacity of the conveyor roller to deliver developer to said toning shell such that the flow of developer on the toning shell is essentially constant when the conveyor roller speed is increased beyond the saturation speed

and engages a metering skive such that the flow on the toning shell is less if the metering skive is engaged.

5. The developer system of claim 1, wherein the maximum magnetic field strength of the outer surface of the roller is between about 100 and 300 gauss, and a minimum magnetic field strength of said outer surface is no less than about 35% of said maximum field strength.

6. The developer system of claim 1, wherein said magnetic core of said conveyor roller includes a plurality of magnets around the circumference of the roller, the poles of each of said magnets being radially aligned with respect to a central axis of said roller and alternating between adjacent magnets.

7. The developer system of claim 6, wherein said conveyor roller includes a cylindrical shell rotatably mounted around said magnetic core, and wherein said magnets extend around between about 100° and 160° around said circumference of the magnetic core.

8. The developer system of claim 6, wherein said magnets are flexible strip magnets.

9. The developer system of claim 6, wherein said magnetic core includes an even number of magnets.

10. The developer system of claim 1, further comprising means for driving said magnetic brush consistent with a printing speed of at least 80 ppm.

11. The developer system of claim 1, further comprising means for rotating said conveyor roller at a speed that delivers developer at a rate of at least 5.0 g/in.-sec.

12. The developer system of claim 11, further comprising means for rotating said conveyor roller at a speed that delivers developer at a rate of at least 5.35 g/in.-sec.

13. The developer system of claim 12, wherein said rotating means rotates said developer roller at a speed of at least 75 rpm.

14. A method of metering a constant flow rate of developer to a toning shell of a magnetic brush that develops latent electrostatic images on a photoconductor element without the need for a metering skive, comprising the steps of:

providing an engageable rotatable self-metering conveyor roller between a reservoir of developer and said toning shell, wherein a maximum magnetic field strength on an outer surface of said roller and having at least two magnetic poles of opposite polarity; and

rotating the conveyor roller at a saturation speed that saturates the capacity of the toning shell to receive developer without a metering skive adjacent to the toning shell such that that a constant flow amount of developer is provided to the toning shell despite variations in the speed of rotation of said conveyor roller when the conveyor roller speed is increased beyond the saturation speed.

15. The developer metering method of claim 14, wherein a maximum magnetic field strength of the outer surface of the roller is less than 1000 gauss, and a minimum magnetic field strength between poles at said outer surface is no less than 30% of said maximum field strength.

16. The developer metering method of claim 14, wherein the maximum magnetic field strength of the outer surface of the roller is between about 100 and 300 gauss, and a minimum magnetic field strength of said outer surface is no less than about 35% of said maximum field strength.

17. The developer metering method of claim 14, further comprising:

a metering skive in a developer flow path around said toning shell between said conveyor roller and said photoconductor element capable of engagement; and

a driving assembly that rotates the conveyor roller at a saturation speed that saturates the capacity of the conveyor roller to deliver developer to said toning shell such that the flow of developer on the toning shell is essentially constant when the conveyor roller speed is increased beyond the saturation speed and engages a metering skive such that the flow on the toning shell is less if the metering skive is engaged.

18. The developer metering method of claim 14, wherein said conveyor roller includes a cylindrical shell rotatably mounted around said magnetic core, and wherein said magnets extend around between about 100° and 160° around said circumference of the magnetic core.

19. The developer metering method of claim 14, further comprising the step of driving said magnetic brush consistent with a printing speed of at least 80 ppm.

20. The developer metering method of claim 14, further comprising the step of rotating said conveyor roller at a speed that delivers developer at a rate of at least 5.0 g/in.-sec.

21. The developer metering method of claim 14, further comprising the step of rotating said conveyor roller at a speed that delivers developer at a rate of at least 6.0 g/in.-sec.

22. The developer metering method of claim 14, further comprising the step of rotating said conveyor roller at a speed of at least 75 rpm.

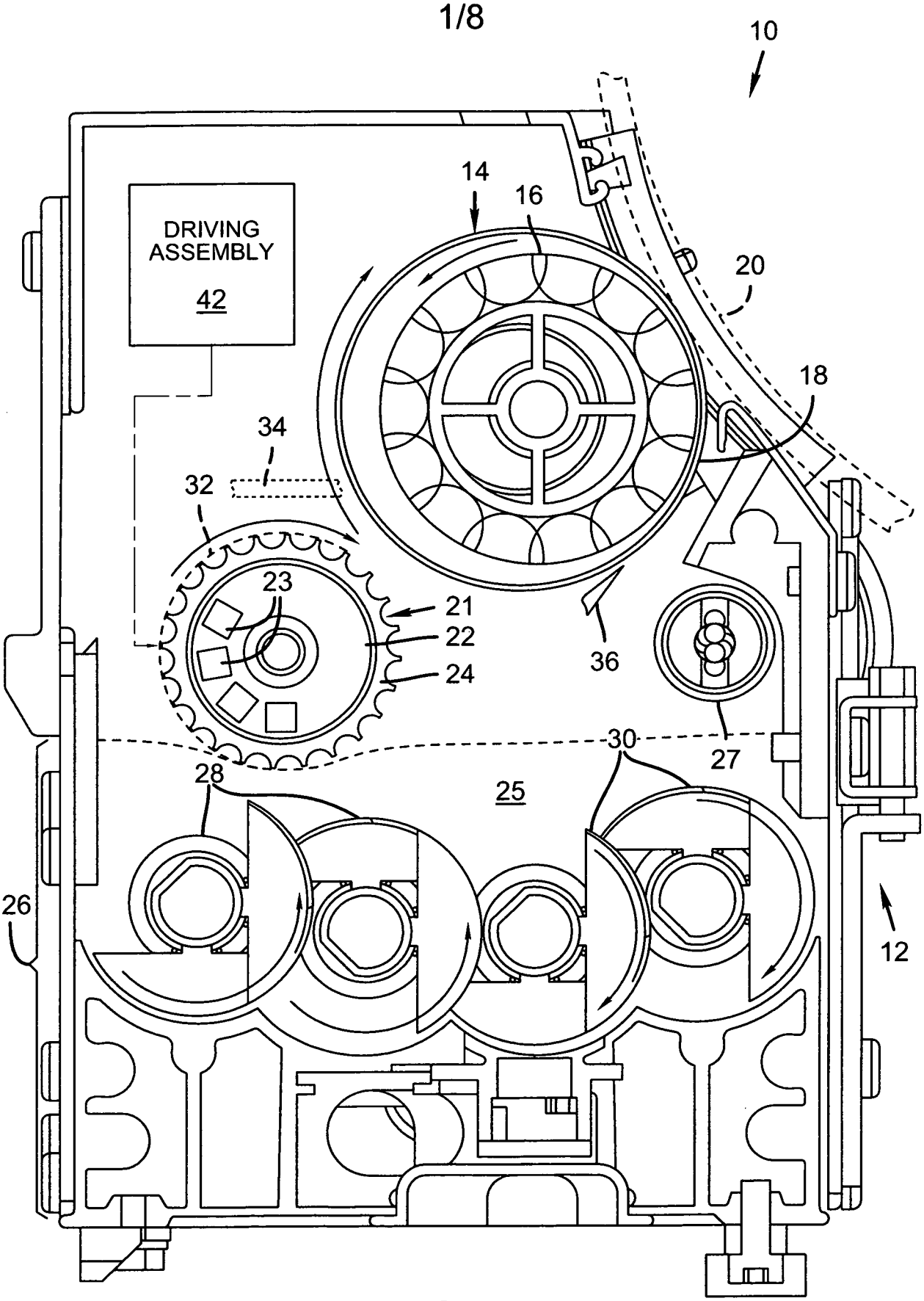

10
14
16
DRIVING ASSEMBLY
42
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18
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26
12

FIG. 1A

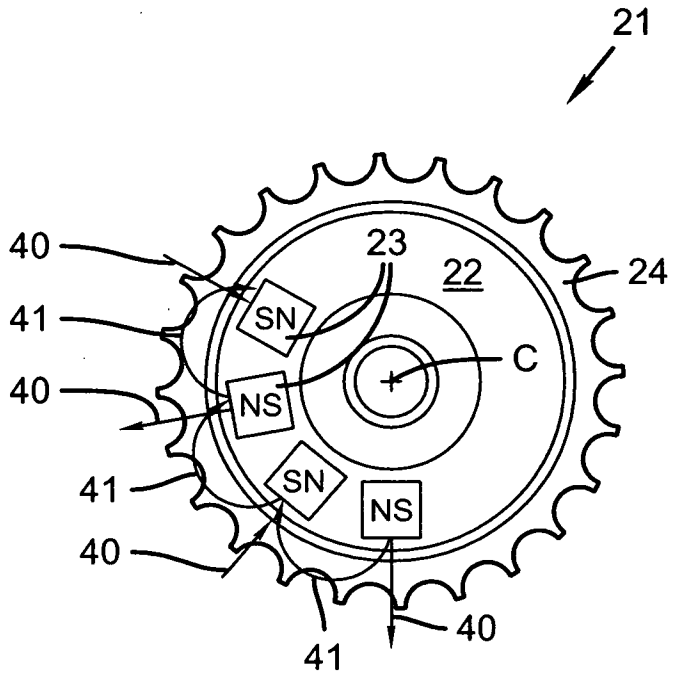


FIG. 1B

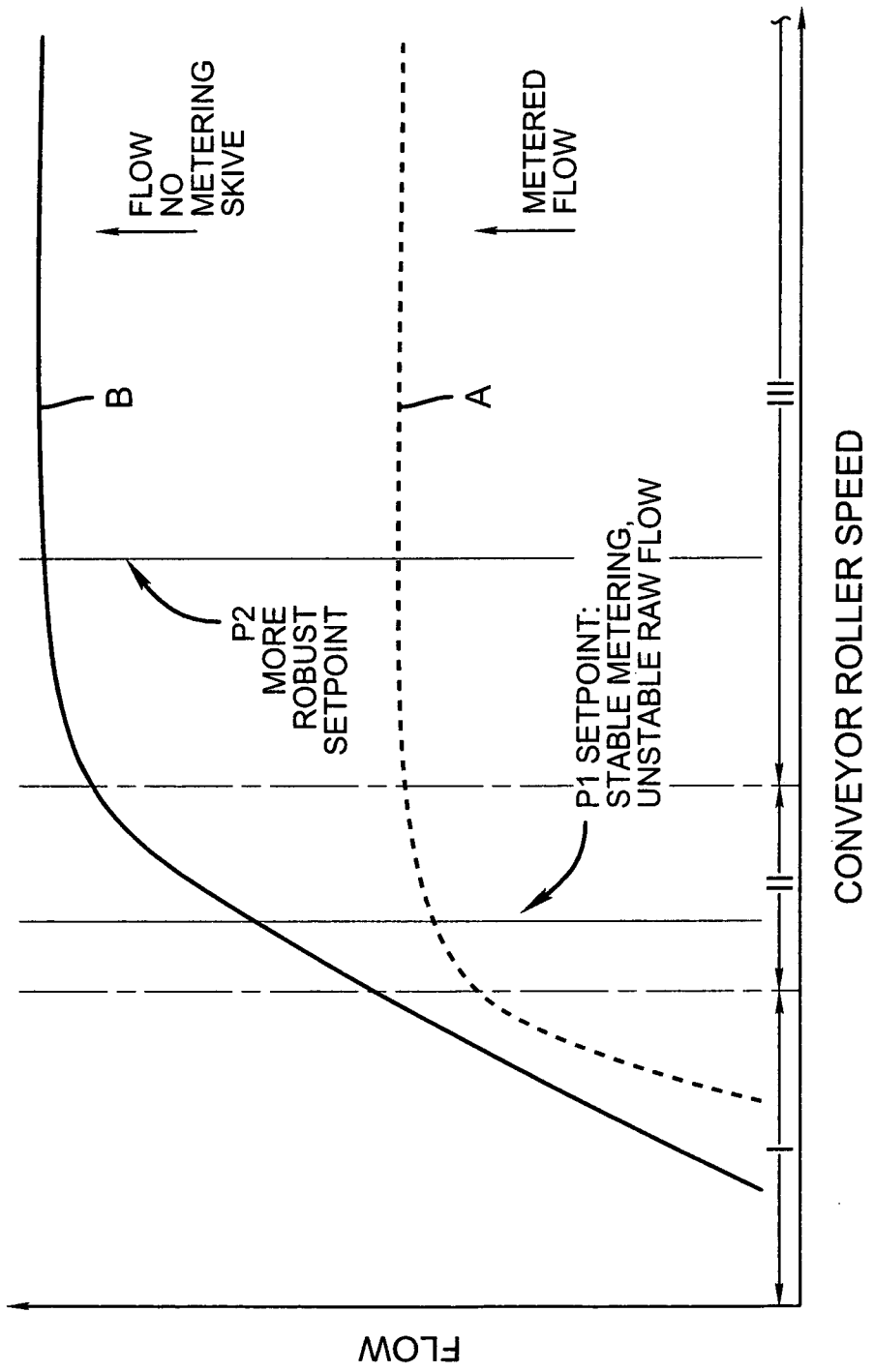

FLOW
NO
METERING
SKIVE
METERED
FLOW
B
A
P2
MORE
ROBUST
SETPOINT
P1 SETPOINT:
STABLE METERING,
UNSTABLE RAW FLOW
FLOW
CONVEYOR ROLLER SPEED

FIG. 2

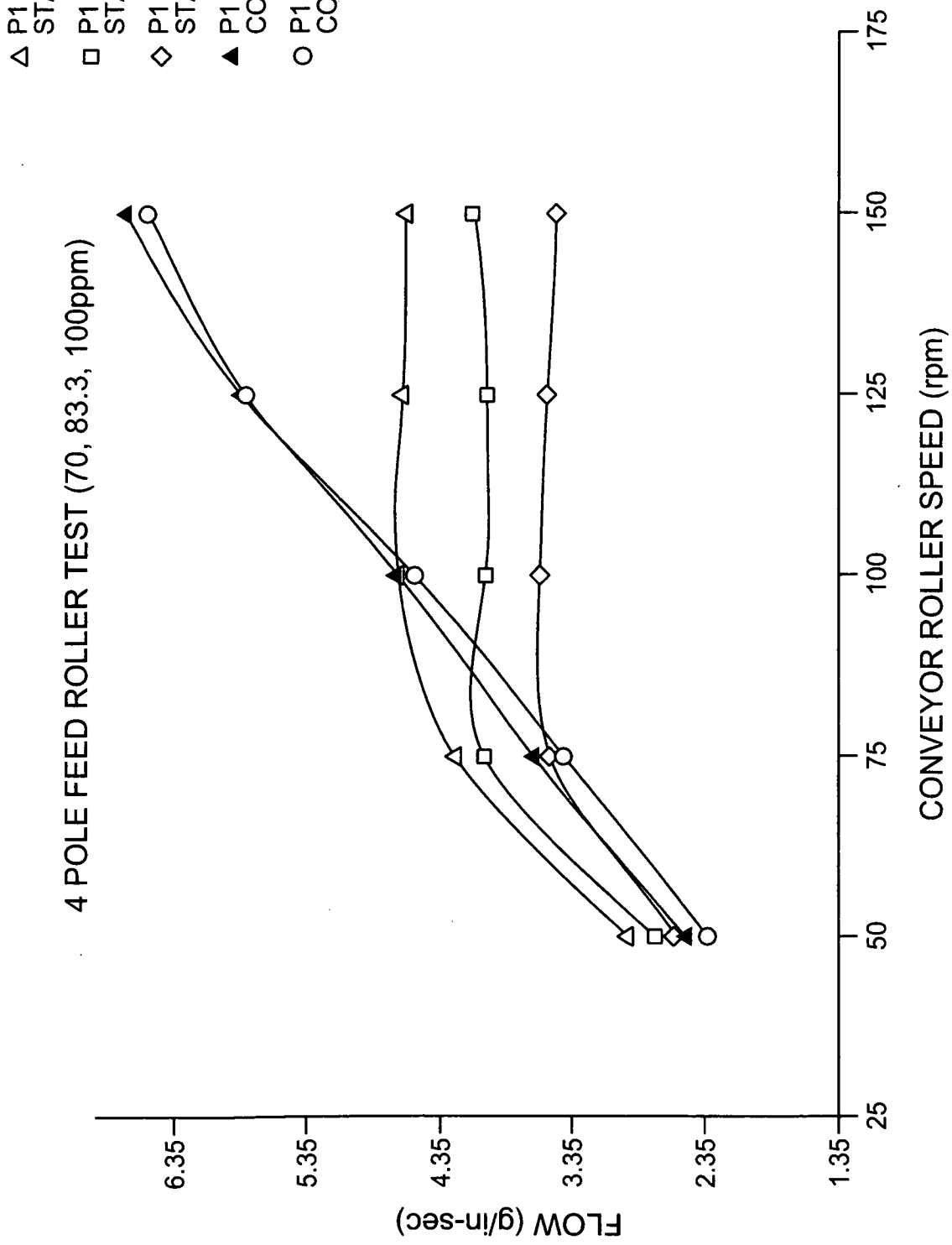

4 POLE FEED ROLLER TEST (70, 83.3, 100ppm)
△ P1 STANDARD METER/ STANDARD STRIP 100
□ P1 STANDARD METER/ STANDARD STRIP 83.3
◇ P1 STANDARD METER/ STANDARD STRIP 70
◀ P1 NO METER/ CONTACT STRIP 83.3
○ P1 NO METER/ CONTACT STRIP 100
FLOW (g/in-sec)
6.35
5.35
4.35
3.35
2.35
1.35
25
50
75
100
125
150
175
CONVEYOR ROLLER SPEED (rpm)

FIG. 3

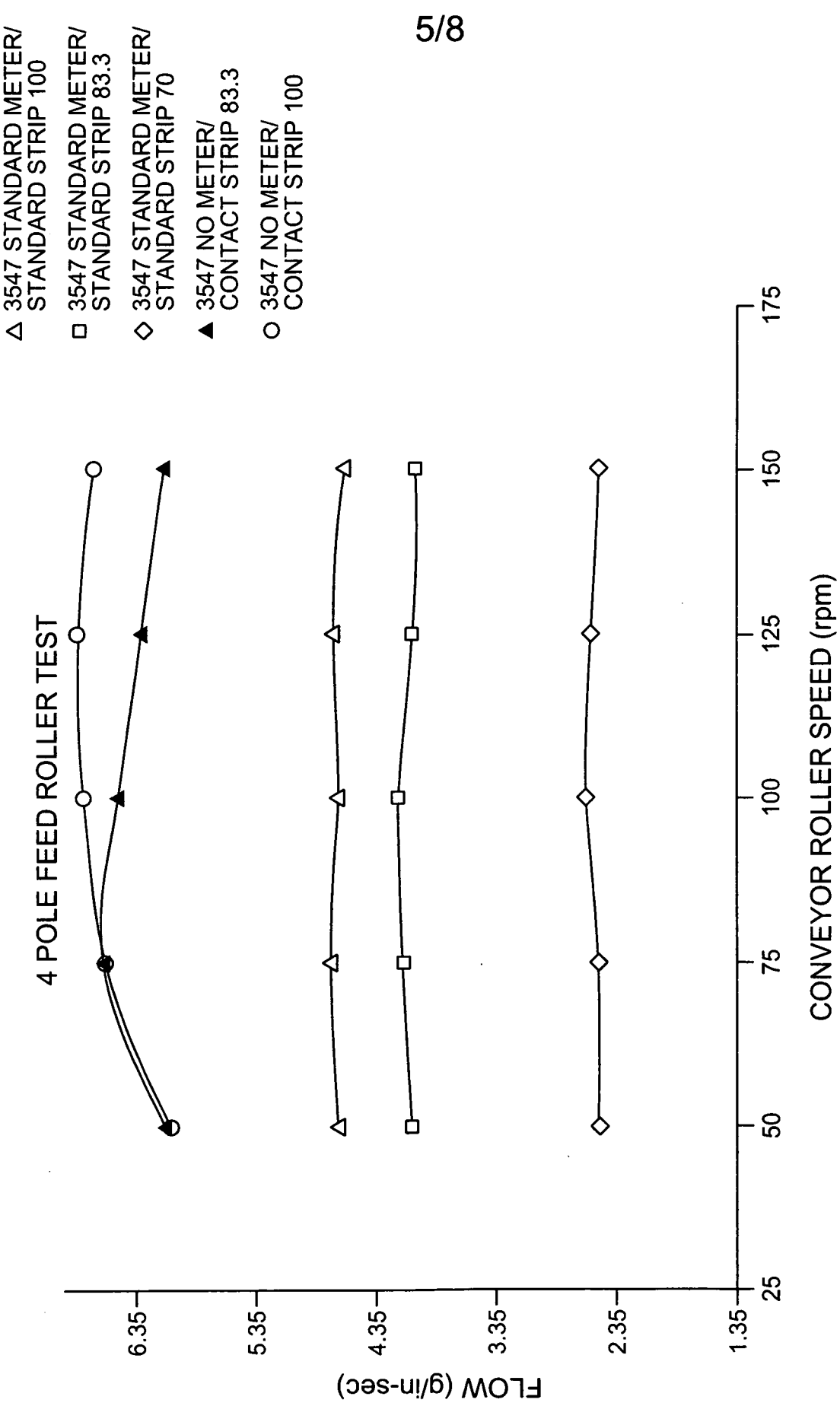

4 POLE FEED ROLLER TEST
△ 3547 STANDARD METER/ STANDARD STRIP 100
□ 3547 STANDARD METER/ STANDARD STRIP 83.3
◇ 3547 STANDARD METER/ STANDARD STRIP 70
◀ 3547 NO METER/ CONTACT STRIP 83.3
○ 3547 NO METER/ CONTACT STRIP 100
FLOW (g/in-sec)
6.35
5.35
4.35
3.35
2.35
1.35
25
50
75
100
125
150
175
CONVEYOR ROLLER SPEED (rpm)

FIG. 4

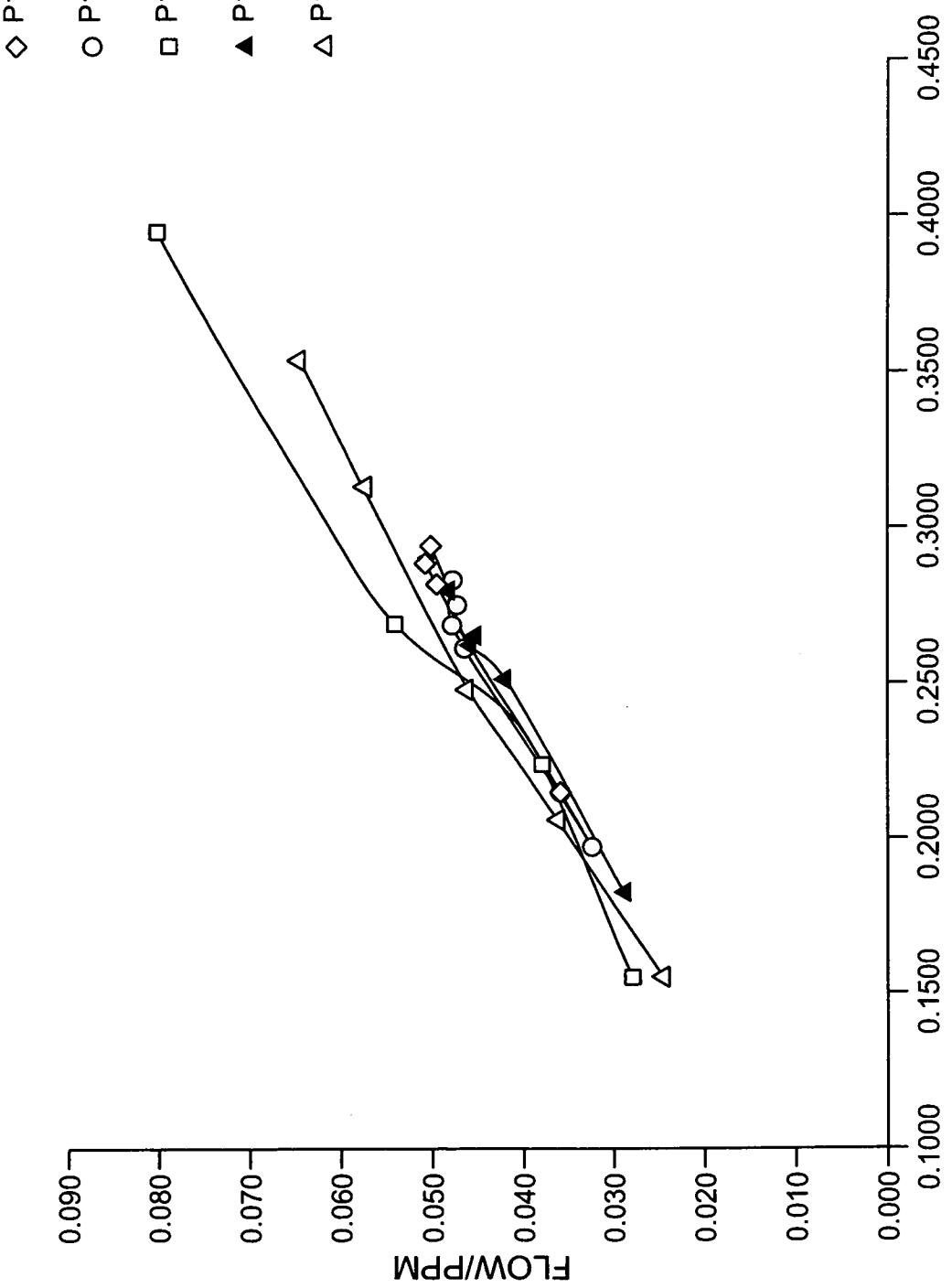

◇ P1 STANDARD METER 70
○ P1 STANDARD METER 83.3
□ P1 NO METER 83.3
▲ P1 STANDARD METER 100
△ P1 NO METER 100
FLOW/PPM
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0.1000
0.1500
0.2000
0.2500
0.3000
0.3500
0.4000
0.4500
DMAD (g/sq in)

FIG. 5

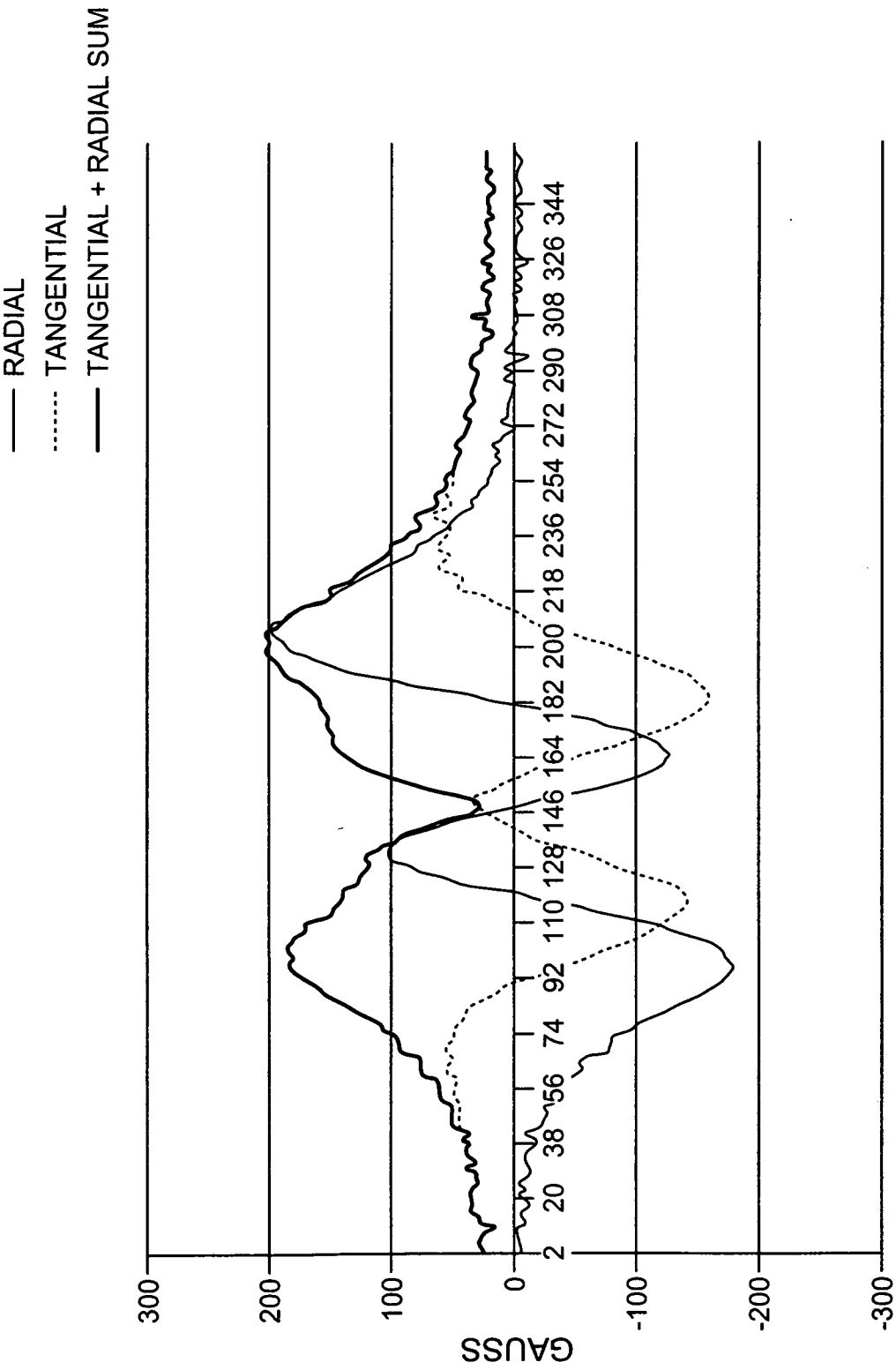

RADIAL
TANGENTIAL
TANGENTIAL + RADIAL SUM
GAUSS
300
200
100
0
-100
-200
-300
2
20
38
56
74
92
110
128
146
164
182
200
218
236
254
272
290
308
326
344
ANGLE-DEGREES

FIG. 6A

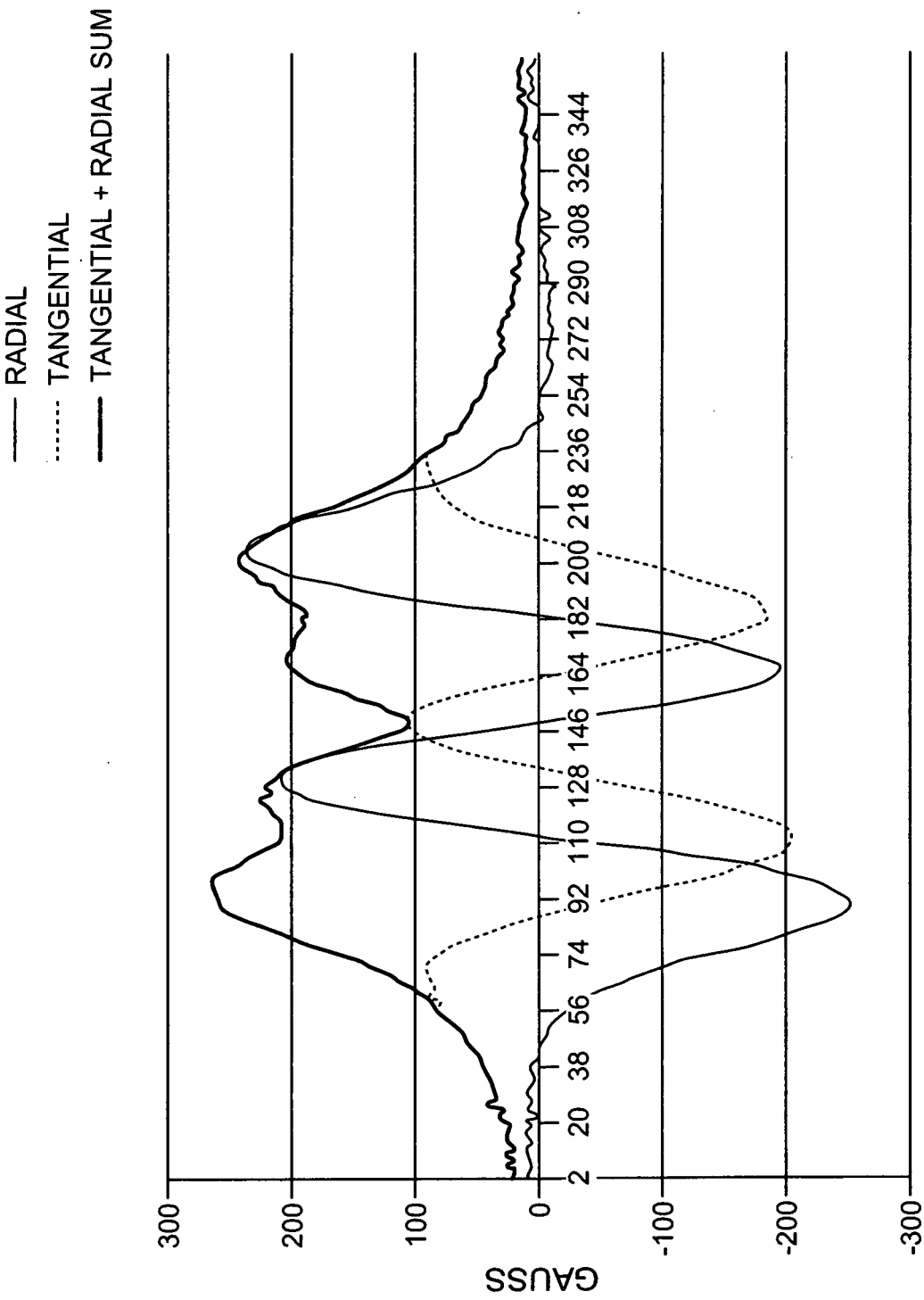

RADIAL
TANGENTIAL
TANGENTIAL + RADIAL SUM
GAUSS
300
200
100
0
-100
-200
-300
2 20 38 56 74 92 110 128 146 164 182 200 218 236 254 272 290 308 326 344
ANGLE-DEGREES

FIG. 6B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/001702

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03G15/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92/22020 A2 (EASTMAN KODAK CO [US]) 10 December 1992 (1992-12-10) page 4 - lines 20-23; figures 3,5 page 6 - lines 19-21 page 7, lines 4-7, 34-36 page 11, lines 1-3	1-22
X	US 6 033 818 A (SUGIYAMA TOSHIHIRO [JP] ET AL) 7 March 2000 (2000-03-07) column 11, lines 5-10 column 14, lines 25-33	1
X	US 2008/285985 A1 (PARK JONG-HYUN [KR]) 20 November 2008 (2008-11-20) paragraph [0049]	1
X	US 4 378 158 A (KANBE JUNICHIRO [JP]) 29 March 1983 (1983-03-29) column 3, lines 45-53	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 July 2010	03/08/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Mandreoli, Lorenzo

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2010/001702

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