(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 November 2012 (29.11.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/161779 A1

(51) International Patent Classification:
B41F 9/06 (2006.01) *B41F 9/04* (2006.01)
B41F 9/10 (2006.01)

(21) International Application Number:
PCT/US2012/026024

(22) International Filing Date:
22 February 2012 (22.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/447,297 28 February 2011 (28.02.2011) US

(71) Applicant *(for all designated States except US)*: **CORNING INCORPORATED** [US/US]; 1 Riverfront Plaza, Corning, NY 14831 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **BOUDREAU, Robert, Addison** [US/US]; 11901 Jolley Way, Corning, NY 14830 (US). **BRACKLEY, Douglas, E.** [US/US]; 223 Chambers Road, Horseheads, NY 14845 (US). **JOOS, Felipe, Miguel** [US/US]; 7 Indian Pipe, Painted Post, New York 14870 (US). **MERZ, Gary, Edward** [US/US]; 240 Windemere Road, Rochester, New York 14610 (US). **TOSCH, John, Earl** [US/US]; 2583 South Broadway Avenue, Wellsburg, New York 14894 (US).

(74) Agent: **SCHMIDT, Jeffrey, A.**; Corning Incorporated, Intellectual Property Department, SP-TI-03-01, Corning, NY 14831 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: APPARATUS AND METHOD FOR PRINTING ELECTRONIC INK

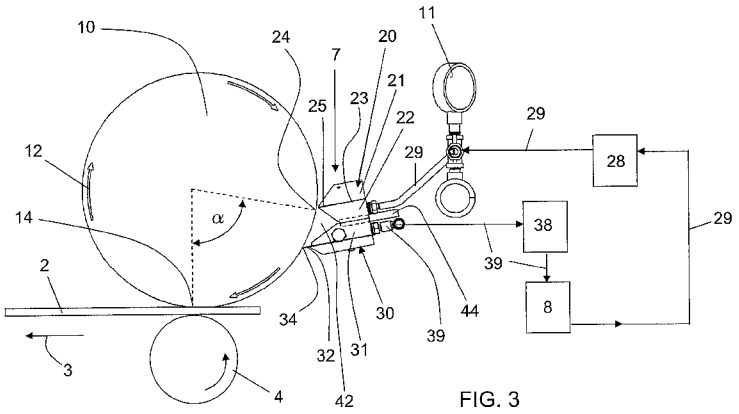


FIG. 3

(57) **Abstract**: An apparatus (1), for printing electronic inks, that includes a print cylinder (10), a slot-shaped applicator (20), a metering device (30), and a housing (40). The print cylinder has an ink transfer point (14) and a direction of rotation (12). The slot-shaped applicator is disposed adjacent to the print cylinder for applying ink to the print cylinder at an ink application point (24), wherein an arc starting at the ink application point, extending in the direction of rotation, and ending at the ink transfer point, subtends an angle (a) of < 90 degrees. The metering device is disposed adjacent to the print cylinder for metering the amount of ink on the print cylinder at a metering point (34), wherein the metering point is disposed along the arc. The housing together with the slot-shaped applicator, the metering device, and the print cylinder, defines an enclosed volume (42). At least one of inert gas and ink-solvent vapor is disposed in the enclosed volume. There is also disclosed a method for printing electronic inks.

WO 2012/161779 A1

APPARATUS AND METHOD FOR PRINTING ELECTRONIC INK

[0001] This application claims the benefit of priority of U.S. Provisional Application Serial No. 61/447,297 filed on February 28, 2011, the content of which is relied upon and incorporated herein by reference in its entirety.

Background

Field of the Invention

[0002] The invention relates to an apparatus and method for printing and, more particularly for printing electronic ink.

Technical Background

[0003] Technology has been improving, in both the realm of printing presses and materials, to the point that it is now beginning to be possible to print electronic devices that otherwise had to be manufactured in expensive semiconductor fabs. These new devices usually leverage the value of area because in the printed electronics world the substrate materials are much less expensive than the semiconductor materials, such as silicon, used for substrates in fabricated electronics. Examples of area electronics produced by printing include electronic displays, solid state lighting, photovoltaics, sensors, RFID tags, and simple memory. Gravure and flexographic printing have been identified as two excellent printing technologies for printing electronics. Another possibility is intaglio printing. Gravure printing is particularly valuable for printing electronics because it provides a high precision master, known as the engraved print cylinder, which acts as a photolithographic plate to define the pattern on the substrate but without the cost and materials inefficiencies of photolithography. Flexography offers easily made, but less precise, elastomeric masters. Both technologies can print very fast, as fast as 300 m/min in a well run press, and both pattern very much faster than photolithography in a semiconductor fab, and also pattern faster than ink-jet printing.

[0004] The engraved cylinder used in gravure printing contains pits or indents in the surface that correspond to the pattern to be printed. The pattern can be high precision because it is engraved in metal that is rigid and is resistant to wear. For this reason it is particularly well suited for printed electronics production. The ink is spread on the cylinder, usually by having a side of the cylinder dipping into a pan of ink, and then a doctor blade wipes the surface of the cylinder clean, leaving ink only in the indented pattern on the cylinder. When this inked cylinder surface then presses against a substrate surface, the ink is transferred from this engraved pattern structure to the substrate, providing the patterned print.

The cylinder side then goes back into the ink pan to pick up more ink, followed by doctor blade wiping and then printing again. This is a continuous cycle as the cylinder turns.

[0005] Apart from the precision of the masters in the press and the proper operation of the press, the key enabler for producing printed electronics is the use of electronic inks. The inks used are similar to colored graphic arts inks with respect to the press, but instead provide electrical properties and functions to the printed layers. For example, some inks are dielectrics with insulating properties. Other inks serve as conductors, and other inks serve as semiconductors. Most recently inks have been developed by a number of companies that provide these functions and the selection of inks to be used, the order in which they are used, and how they are laid down are critical to the performance that results.

[0006] One of the main disadvantages of electronic inks is their high cost. They are usually made from exotic, expensive materials, and they are often sensitive to the presence of air or moisture, or often must be maintained at a specific temperature. Examples of materials in the electronic inks include nano particles of silver or gold for conductors, or specialized organic semiconductors made from complex syntheses, not so different than that used for manufacturing pharmaceuticals. Other examples of materials for electronic inks might include nano particles of metal oxides made by special precipitation reactions or special expensive milling operations. It is not unusual for a printed electronic ink to cost about 500 US dollars per gram or more. Therefore, these inks are usually provided in small quantities.

[0007] The current inking systems on gravure and flexographic presses have been designed to handle graphic arts inks, which are far less expensive, and are delivered and held in large volumes. This is a big problem for printing electronics because of the high cost of electronic inks. The problem manifests itself in a number of ways. First, it takes a lot of ink just to load up the inking system to get the press started. Second, there is a lot of ink wasted and thrown out when the press is cleaned up after a run, and third the ink can remain exposed to the air for long periods of time. Inks are usually provided to these systems in multiple gallon cans, which look like typical paint cans, or even in drums. After a run the inks are washed away with lots of solvent and the resulting mixture is discarded.

[0008] The graphics arts industry is not completely immune to the cost of their inks and has taken some measures to reduce the volumes used. However, although some progress has been made, the systems still are graphics arts based and quantities of ink are still on the order of liters in quantity compared to the milliliter and smaller quantities needed for printed electronics.

[0009] Another issue that needs to be addressed when printing electronics is trying to protect the inks from damaging atmospheric conditions. Many inks are damaged by oxidation or may evaporate too soon.

SUMMARY

[0010] The amount of electronic ink waste needs to be minimized. The inventors have discovered that it is best to reduce the resident volume of ink in the inking system so less ink is needed to be in the inking system while in operation. Less ink reduces the amount of ink needed to start the press and reduces the amount of ink discarded when shutting down the press, because the resident ink in an inking system is often discarded when changing inks. Also, the electronic inks need to be protected from an atmosphere that may damage, oxidize, or evaporate the ink too soon.

[0011] The present disclosure is directed to apparatus and methods for reducing the volume of ink needed to provide functional printing with expensive electronic inks. This system includes various components that, when used either by themselves or in various combinations with one another, reduce the volume of ink needed, while at the same time protecting the inks from harmful atmospheres. The components may include: (1) a slot-shaped applicator designed for holding only small resident volumes of ink to be spread on the print cylinder, (2) a metering device that may include a feature for not only doctoring but also collecting the ink for recycling, (3) a housing providing an enclosed volume, to prevent damage to the ink, that covers the ink applicator, metering device, and print cylinder, (4) a minimum-volume pump (for example a peristaltic pump) to move the ink. The metering device is placed adjacent to the applicator to reduce ink volume and the ink on the print cylinder is kept from damage by the housing providing an enclosed volume.

[0012] The system provides a number of advantages over prior inking systems because it is specifically designed for electronic inks rather than graphics inks. First, the press applicator holds only a small amount of ink. This reduces the amount of ink needed to begin printing, reduces the amount of ink lost during a clean up after a run, and keeps what ink is used as fresh as possible by having a very short residence time in the press. For electronic inks it is important that inks be fresh because they often have short lifetimes since they are often made of materials that degrade easily from exposure to the environment or are chemically active. Second, the ink is protected from harmful environment with an enclosed volume defined by a housing, the applicator, the metering device and the cylinder. The enclosed volume may include an inert gas, and/or vapors from the solvent of the particular

ink being used in the printing apparatus. This allows control of evaporation, but also provides a means to eliminate moisture by using a cover gas, for example, pure nitrogen or argon. Third, the metering device may be in communication with a suction device for collecting ink to be recycled. The apparatus thus eliminates the need for a collection pan, as used on conventional graphic arts presses, which would hold too much expensive ink. Fourth, the apparatus may include a peristaltic pump to move the ink. This type of pump keeps the ink inside a flexible tubing rather than having it exposed to more complex mechanical parts as found in a conventional pump. A peristaltic pump also allows for easier cleaning by simply replacing the tubing rather than having to rebuild the pump. It should also be noted that this system will work for presses configured to run with doctoring of the press cylinder in the direction of rotation as well as doctoring of the cylinder against the direction of rotation.

[0013] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from the description or recognized by practicing the invention as exemplified in the written description and the appended drawings. It is to be understood that both the foregoing general description and the following detailed description are merely exemplary of the invention, and are intended to provide an overview or framework to understanding the nature and character of the invention as it is claimed.

[0014] The accompanying drawings are included to provide a further understanding of principles of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain, by way of example, principles and operation of the invention. It is to be understood that various features of the invention disclosed in this specification and in the drawings can be used in any and all combinations. By way of non-limiting example the various features of the invention may be combined with one another as follows:

[0015] According to a first aspect, there is provided an apparatus for printing electronic inks, comprising:

[0016] a print cylinder having an ink transfer point and a direction of rotation;

[0017] a slot-shaped applicator disposed adjacent to the print cylinder for applying ink to the print cylinder at an ink application point, wherein an arc starting at the ink application point, extending in the direction of rotation, and ending at the ink transfer point, subtends an angle of ≤ 90 degrees;

[0018] a metering device disposed adjacent to the print cylinder for metering the amount of ink on the print cylinder at a metering point, wherein the metering point is disposed along the arc; and

[0019] a housing that, together with the slot-shaped applicator, the metering device, and the print cylinder, defines an enclosed volume, and at least one of inert gas and ink-solvent vapor is disposed in the enclosed volume.

[0020] According to a second aspect, there is provided the apparatus of aspect 1, further comprising a conduit in communication with the slot-shaped applicator; and

[0021] a peristaltic pump disposed so as to move ink through the conduit to the slot-shaped applicator.

[0022] According to a third aspect, there is provided the apparatus of aspect 1 or aspect 2, further comprising a suction device in communication with the metering device.

[0023] According to a fourth aspect, there is provided the apparatus of any one of aspects 1-3, wherein the print cylinder has a width, and the metering device has a width, wherein the metering-device width is narrower than the print-cylinder width.

[0024] According to a fifth aspect, there is provided the apparatus of any one of aspects 1-4, further comprising a gas-feed conduit in communication with the enclosed volume.

[0025] According to a sixth aspect, there is provided the apparatus of any one of aspects 1-5, wherein the slot-shaped applicator comprises a first portion and a second portion, and a removable shim portion disposed between the first and second portions so as to define a height of the slot.

[0026] According to a seventh aspect, there is provided the apparatus of any one of aspects 1-6, wherein the metering device is a doctor blade disposed so as to work against the direction of rotation.

[0027] According to an eighth aspect, there is provided the apparatus of any one of aspects 1-7, further comprising seals disposed between the housing and the print cylinder, wherein the seals contact a circumferential surface of the print cylinder.

[0028] According to a ninth aspect, there is provided a method of printing with electronic ink, comprising:

[0029] rotating a print cylinder in a direction of rotation;

[0030] applying electronic ink to the print cylinder with a slot-shaped applicator at an ink application point,

[0031] transferring the ink from the print cylinder at an ink transfer point,

[0032] wherein an arc starting at the ink application point, extending in the direction of rotation, and ending at the ink transfer point, subtends an angle of ≤ 90 degrees;

[0033] metering the ink on the cylinder at a metering point, wherein the metering point is disposed along the arc; and

[0034] feeding at least one of an inert gas and ink-solvent vapor to an enclosed volume that encompasses the ink application point and the ink metering point.

[0035] According to a tenth aspect, there is provided the method of aspect 9, further comprising moving, with a peristaltic pump, the ink through a conduit to the ink application point.

[0036] According to an eleventh aspect, there is provided the method of aspect 9 or aspect 10, further comprising suctioning excess ink away from the metering point.

[0037] According to a twelfth aspect, there is provided the method of aspect 11, further comprising balancing the ink transfer, the suctioning, and the feeding, so as to maintain a positive pressure within the enclosed volume.

[0038] According to a thirteenth aspect, there is provided the method of any one of aspects 9-12, wherein applying electronic ink further comprises applying the electronic ink over less than the entire width of the cylinder.

[0039] According to a fourteenth aspect, there is provided the method of any one of aspects 9-13, further comprising adjusting the height of a slot in the slot-shaped applicator.

[0040] According to a fifteenth aspect, there is provided the method of any one of aspects 9-14, wherein the metering is performed against the direction of rotation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] FIG. 1 is a perspective view of a printing apparatus.

[0042] FIG. 2 is a side view, according to one embodiment, of the printing apparatus as shown in FIG. 1.

[0043] FIG. 3 is an enlarged side view of a portion of the printing apparatus as shown in FIG. 2, and further including a schematic representation of an ink circulation path.

[0044] FIG. 4 is an enlarged perspective view of an ink applicator and a metering device.

[0045] FIG. 5 is a front view of the ink applicator as seen in the direction of arrow 13 in FIG. 4.

[0046] FIG. 6 is an enlarged side view, similar to that of FIG. 3, of a printing apparatus according to a second embodiment.

DETAILED DESCRIPTION

[0047] In the following detailed description, for purposes of explanation and not limitation, example embodiments disclosing specific details are set forth to provide a thorough understanding of various principles of the present invention. However, it will be apparent to one having ordinary skill in the art, having had the benefit of the present disclosure, that the present invention may be practiced in other embodiments that depart from the specific details disclosed herein. Moreover, descriptions of well-known devices, methods and materials may be omitted so as not to obscure the description of various principles of the present invention. Finally, wherever applicable, like reference numerals refer to like elements.

[0048] Ranges can be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another embodiment. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0049] Directional terms as used herein—for example up, down, right, left, front, back, top, bottom—are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0050] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that an order be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps or operational flow; plain meaning derived from grammatical organization or punctuation; the number or type of embodiments described in the specification.

[0051] As used herein, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to a "component" includes aspects having two or more such components, unless the context clearly indicates otherwise.

[0052] The present disclosure will be made with reference to a gravure press for the sake of convenience only. The concepts discussed herein are applicable to various forms of printing and presses, for example, intaglio, and flexographic.

[0053] The ink volume in the press may be minimized by use of:

[0054] (1) an ink applicator section that does not serve as a reservoir and has very small internal volume;

[0055] (2) an enclosed metering section, or doctor blade, that requires a very small volume of ink because it does not serve as a reservoir;

[0056] (3) a minimum-volume pump (for example, a peristaltic pump) that strokes tubing to move the ink;

[0057] (4) a distance between ink applicator and metering section that is very short compared to conventional presses, so not much ink is resident on the engraved cylinder; and

[0058] (5) housing end faces that abut the applicator and/or metering sections in order to minimize leakage of ink, which would constitute waste. Additionally, by minimizing the size of the inking system, there is also minimized the area of contaminating surfaces in the press to which the ink may be exposed.

[0059] Further, the ink may be protected from harmful atmospheric conditions by use of an enclosed volume encompassing the ink applicator section, the metering section, and a portion of the print cylinder. The enclosed volume may include inert gas and/or solvent vapor.

[0060] Because an objective is to minimize ink volume, and electronic inks are expensive, the system should be prepared carefully before loading the ink. An exemplary set-up will now be described. A small bottle, or other contained ink source, with an in-line filter may be attached to the press, wherein the bottle has both an ink inlet and an ink exit. This bottle is then connected to a peristaltic pump, which would stroke a tube to move ink out of the bottle. The peristaltic pump tubing is connected to the ink applicator portion of the inking system, through a hose connected to the ink applicator. Another tube from the rear of the metering section is connected to the bottle as a return line. An inert atmosphere and/or solvent vapor is preferably flowed inward to flood the space between the applicator, cylinder, and metering section to exclude air and moisture. The amount of ink pumped by the peristaltic pump and the amount of inert atmosphere and/or solvent vapor fed to the enclosed volume may be balanced against the amount of suction to provide a positive pressure within the enclosed volume.

[0061] Ink is dispensed out through the ink applicator section to the engraved cylinder by the pump. One of the applicator's purposes is to spread the ink evenly by way of its distribution channels and form a continuous bead across the print-width of the print cylinder. The amount of ink in the applicator may be minimized by using a slot-shaped applicator, for example. The opening, or slot, in the applicator may be adjustable by shimming during setup to selectively vary the amount of ink applied to the print cylinder.

[0062] After the ink is spread onto the engraved cylinder, it is almost immediately metered, or doctored, with excess ink drawn back out and into tubing that returns it to the ink source or bottle. This ink-return may be accomplished by using vacuum, for example.

[0063] Between the ink applicator and the ink metering sections there is only a short span of engraved cylinder, which keeps the amount of ink resident in the press to a minimum. This span is also covered with an inert gas and/or solvent vapor atmosphere to protect the integrity of the ink from exposure to oxygen, moisture, and from drying. Printing of the ink to the substrate occurs immediately following the doctoring. For example, the ink is applied at about the 3'oclock position, doctored at the 4'oclock position and printed at the 6 'o'clock position. That is, an arc starting at the ink application point, extending in the direction of rotation of the print cylinder, and ending at the ink transfer point, subtends an angle of ≤ 90 degrees. Although here, and throughout the specification, the ink transfer point is described at the bottom of the print cylinder (i.e., the substrate is beneath the print cylinder), such need not be the case. Instead, the ink transfer point could be at the top, or any particularly desired position around the circumference of the print cylinder, with the substrate positioned accordingly. For example, the substrate could be at the top of the print cylinder, or could travel vertically beside the print cylinder or at any angle with respect to vertical.

[0064] Embodiments of an apparatus for printing electronic inks will now be discussed with reference to the figures. In one embodiment, the metering section doctors the ink with the rotation of the print cylinder, whereas in a second embodiment the metering section doctors the ink against the rotation of the cylinder.

[0065] A first embodiment is discussed with reference to FIGS. 1-5. FIG. 1 is a perspective view, and FIG. 2 is a side view as seen in the direction of arrow 9 in FIG. 1, of a printing apparatus 1 having the inking system 7 working with the rotation of the cylinder. FIGS. 1 and 2 show a single station, press, or apparatus 1 for printing a single patterned layer. Most electronics will require the printing of multiple layers so various numbers of these stations would be employed together so that a substrate 2 may be fed from one into the next, with

each apparatus printing a different pattern until the entire desired circuit is formed. The substrate to be printed upon is shown as a flat substrate 2. The substrate 2 may be glass (either in sheet form, or in the form of a continuous web), paper, metal, or polymer based, and may be either rigid or flexible (including flexible glass or rigid glass), for example. The print cylinder 10 is shown running across the top of the substrate 2. This configuration is useful because the substrate 2, if held flat like this, can be either rigid or flexible. The print cylinder 10 is supported by a frame 5, rotates in the direction of arrow 12, and has a width 16. Further, the print cylinder 10 includes an ink transfer point 14, namely, a point at which the patterned ink is transferred from the cylinder to the substrate 2.

[0066] Note that directly opposite the print cylinder 10 is another smaller cylinder under the substrate 2; this small cylinder is the backing roller 4. The backing roller 4 in a gravure press is typically covered with a compliant material, usually rubber, which compensates for slight imperfections in gaps, substrate thickness, or roller precision, providing an even pressure of the substrate 2 against the printing cylinder 10. The backing roller 4 is positioned below the larger gravure print cylinder 10.

[0067] The printing apparatus 1 also includes adjustable feet 6 at the bottom of the machine that are used, in part, to align one press to the next when they are to be employed together. The printing apparatus 1 may be used by itself or with any desired number of similar printing apparatuses. The substrate 2 exiting one printing apparatus would then enter the next printing apparatus to print multiple patterns in layers of different materials to create an electronic circuit. Not shown are the feeder and collector stations, which contain the mechanisms to feed either sheets of substrates to the press, if the substrate is to be a sheet, or spools if the substrate is to be a web-type rolled substrate. Also not shown are the heat treatment stations or ink drying stations, which might be located between the separate printing apparatus stations. The heat treatments and drying stations are common in the art of printing and are not discussed in detail here.

[0068] Further, the printing apparatus 1 includes an inking system 7 that includes a slot-shaped applicator 20 and a metering device 30. A housing 40, together with the slot-shaped applicator 20, the metering device 30, and the print cylinder 10, defines an enclosed volume 42 (see FIG. 3) in which there may be disposed a controlled atmosphere.

[0069] The inking system 7 for printing electronics is very different than inking systems used in graphic arts where inks are much less expensive. The inking system 7 is in contact with the rotating print cylinder 10, which has precision etched pits in it that need to be filled with

ink to transfer the ink to the substrate 2. The etched pits correspond to a pattern to be printed. FIGS. 3 and 4 show an enlargement of the inking system 7, but with the housing 40 sides removed to show some of the elements within. FIG. 4 additionally schematically shows the relationship between the inking system 7 and the remaining ink path elements for the printing apparatus.

[0070] The slot-shaped applicator 20 applies the ink to the print cylinder 10, and the metering device 30 removes excess ink from the print cylinder 10, leaving only the ink that is in the etched pits.

[0071] As shown in FIGS. 3 and 4, the slot-shaped applicator 20 includes a first portion 21, a second portion 22, and a removable shim portion 23 disposed between the first and second portions 21, 22 to define a slot 25. As shown in FIG. 5, slot 25 has a slot height 27. The slot height 27 may be varied by use of different removable shims 23 having different thicknesses. Slot 25 spreads the ink across the width of the slot-shaped applicator 20 before it is dispensed on the print cylinder 10. Ink that flows through the slot 25 is then applied to print cylinder 10 at ink application point 24 in a uniform bead across the printable width of the print cylinder 10. A vacuum baffle, not shown but as known in the art, could be used on the upstream (with respect to the rotation direction of print cylinder 10) side of the slot-shaped applicator 20 to help regulate pressure across the ink bead being applied by the applicator 20 in order to assist in controlling ink thickness. End pieces of housing 40 (not shown in FIGS. 3 and 4) abut the slot-shaped applicator 20 to confine the ink so it does not escape out the sides. Ink is supplied to the slot-shaped applicator 20 from ink reservoir 8 by way of a pump 28 and connecting conduits 29. Pump 28 is a minimum-volume pump, and may be a peristaltic pump, for example. The ink reservoir 8 may be an ink bottle, or other ink-holding device, for example. A pressure gauge 11 may be disposed along conduit 29 to monitor the pressure of ink being delivered to the slot-shaped applicator 20, so that pump 28 may be appropriately controlled.

[0072] A peristaltic pump is used because it appears to be ideally suited for this application. This type of pump is basically a roller system that strokes a flexible tube. The peristaltic pump does not make direct contact with the fluid being pumped. In addition, the volume of fluid remains low because there is no need to fill a volume of the pump itself. The tube can be very small in diameter, further reducing the volume needed. Accordingly, use of a peristaltic pump reduces the amount of ink resident in the system and that would be wasted

when the printing apparatus is shut down when, for example, changing inks or printing cylinders.

[0073] Again with reference to FIGS. 3 and 4, the metering device 30 includes a holder 31 in which there is disposed a doctor blade 32 that meters the ink on print cylinder 10 at metering point 34. The metering device 30 includes a width 36 that is smaller than the width 16 of the print cylinder 10. The width 36 is smaller than the width 16 so that the ends of housing 40 may seal, via seals 46, with the circumference of the print cylinder 10. The inking system 7 is thus within the effective print-width of the print cylinder 10. A suction device 38 is connected to the metering device 30 and to the ink reservoir 8 by way of conduit 39. The suction device 38 may be, for example, a vacuum.

[0074] The doctor blade 32 is shown protruding to the left, and works with the direction of rotation 12 of print cylinder 10. Any desired configuration (in terms of material, included blade angle, etc.) of doctor blade may be used in the metering device 30. Recessed back from the doctor-blade edge is a series of scooped areas 33 that collect the ink, which then flows through paths 35 in the holder 31 by way of suction from suction device 38 connected thereto by conduit 39. The paths 35 may include holes that lead from scooped areas 33 to a T junction with a long cylindrical path that runs at right angles along the width of the interior of the metering device 30, to collect the ink. The path 35 may further include another T junction at the center of this cylindrical path, wherein this second T junction exits the metering device 30 and may be connected to a pipe nipple (at the back of the metering device 30) that can be attached to conduit 39.

[0075] A housing 40 includes sides that abut the sides of the slot-shaped applicator 20 and the metering device 30. The sides of housing 40 help hold the ink within the slot 25 as well as on the surface of the doctor blade 32, and enable the use of an inert gas (for example, argon or nitrogen) and/or solvent vapor (matched with the solvent used in the ink) between the slot-shaped ink applicator 20 and the metering device 32. That is, the housing 40, together with the slot-shaped applicator 20, metering device 30, and print cylinder 10, defines an enclosed volume 42. Where the housing sides contact the print cylinder 10, there are disposed seals 46. The seals 46 assist in keeping the atmosphere within the enclosed volume 42, and are made of a suitable elastomeric material. An inert gas and/or solvent vapor may be fed through conduit 44 (and through a path between the slot-shaped applicator 20 and metering device 30) into the enclosed volume 42. Accordingly, the enclosed volume 42 is not filled with ink, thereby reducing the amount of ink in the inking system 7. Additionally, the inert

gas and/or solvent vapor in the enclosed volume 42 prevents the ink (not only that on the cylinder, but also that making its way through the metering device 30 and the paths 35 for recycling to reservoir 8) from being damaged due to oxidation, moisture, drying, evaporation, or unwanted polymerization, for example. The enclosed volume 42, together with the closed nature of the remainder of the ink paths through the system, keep the ink being recycled fresh and ready for use. That is, there is no need for ink maintenance including adjustment of viscosity, addition of solvents to replace those evaporated and/or to maintain the desired ink to solvent ratio. The pressure within the enclosed volume 42 may be suitably maintained by appropriately choosing the flows of ink, of inert gas and/or solvent vapor, and the amount of suction from the metering device 30. Preferably, the flows and amount of suction are chosen to maintain a positive pressure within enclosed volume 42 thereby preventing damaging elements form leaking into the enclosed volume 42.

[0076] The method of operation of the printing apparatus will now be described. In use, ink is pumped from reservoir 8 through conduit 29 by pump 28. Conduit 29 delivers ink to the slot-shaped applicator 20, wherein the ink is dispersed along slot 25 and is transferred to the print cylinder 10 at ink application point 24 (across the printable-width of the print cylinder 10) as the print cylinder 10 rotates in the direction of arrow 12 towards the metering device 30. The ink remains on the surface of the print cylinder 10 a short time before it is metered by the doctor blade 32, thereby reducing the residence time of the ink exposed to the environment. The doctor blade 32 removes the excess ink that did not fill the engraved pattern on the print cylinder 10. Suction, applied via suction device 38 to the area along the top surface of the doctor blade 32 by way of scooped areas 33 and paths 35, pulls the ink back in to the doctor blade holder 31, and then back out of the inking system 7 through the conduit 39 and eventually back to reservoir 8. Ink left in the engraved pattern on the print cylinder 10 is then transferred to the substrate 2, at ink transfer point 14.

[0077] The basic function of applying ink to a gravure cylinder followed by wiping off the excess, known as doctoring, is found in all gravure presses, however, the present configuration limits the amount of ink resident in the printing apparatus to a very small volume, thereby reducing the amount of waste of expensive ink. For example, in most gravure presses for graphic arts, where ink is inexpensive, there is no top section that applies the ink but rather the bottom of the cylinder (6 o'clock position) sits in a pan of ink. The substrate is usually at the top of the gravure cylinder (12 o'clock position) and the doctoring of the cylinder occurs between the inking at the pan and the printing at the substrate by

having the doctoring be at the 9 o'clock position. In contrast, as shown here, the application of ink occurs at about the 3 o'clock position at ink application point 24, doctoring is done very quickly afterwards at about the 4 o'clock position at metering point 34, and printing follows at about the 6 o'clock position at ink transfer point 14. That is, an arc starting at the ink application point 24, extending in the direction of rotation 12 and ending at the ink transfer point 14 subtends an angle α that is ≤ 90 degrees. By having ink application and transfer occur within 90 degrees of print-cylinder rotation, a minimal amount of ink is present on the print cylinder 10 around its circumference, reducing ink volume as well as reducing the exposure time of the ink to ambient conditions. Additionally, the use of a slot-shaped applicator 20, together with an enclosed volume 42 and the above-noted configuration, eliminates the need for a large and/or open reservoir, which would lead to waste and/or degradation of the expensive electronic inks.

[0078] A second embodiment will be described in connection with FIG. 6, which shows the side view of an apparatus for printing electronic inks that is similar to the view in FIG. 3, wherein like reference numerals are used to identify like elements. The elements of this embodiment are similar to those discussed above in connection with the first embodiment and, therefore mainly the differences will be explained. In this embodiment, the doctor blade 32 is used against the rotation direction 12 of the print cylinder 10 rather than with it. There are some printing situations that may benefit from this arrangement and the inking system 7 works for either case.

[0079] In this embodiment, the slot-shaped applicator 20 still leads the metering device 30 but the angle of attack of the doctor blade 32 to the print cylinder 10 is reversed. The substrate 2 to be printed on is still located at about the 6 o'clock position as before. Other aspects of this arrangement work as before. Note that even though the angle of the inking system 7 is different, the ability to maintain minimal ink volume, and to control atmosphere, function the same as in the first embodiment. The configuration of this embodiment is particularly well suited for use with lower rotational speeds of print cylinder 10, for example less than 30 rpm, which is equivalent to 100 fpm (30 meters per minute) web speed for a 12 in. (30 cm) diameter print cylinder, and with print cylinders that do not require as high a degree of polish, for example, a print cylinder having a roughness $R_Z > 4$ microns.

[0080] It should be emphasized that the above-described embodiments of the present invention, particularly any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of various principles of the

invention. Many variations and modifications may be made to the above-described embodiments of the invention without departing substantially from the spirit and various principles of the invention. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present invention and protected by the following claims.

What is Claimed is:

1. An apparatus for printing electronic inks, comprising:

a print cylinder having an ink transfer point and a direction of rotation;

a slot-shaped applicator disposed adjacent to the print cylinder for applying ink to the print cylinder at an ink application point, wherein an arc starting at the ink application point, extending in the direction of rotation, and ending at the ink transfer point, subtends an angle of ≤ 90 degrees;

a metering device disposed adjacent to the print cylinder for metering the amount of ink on the print cylinder at a metering point, wherein the metering point is disposed along the arc; and

a housing that, together with the slot-shaped applicator, the metering device, and the print cylinder, defines an enclosed volume, and at least one of inert gas and ink-solvent vapor is disposed in the enclosed volume.

2. The apparatus of claim 1, further comprising a conduit in communication with the slot-shaped applicator; and

a peristaltic pump disposed so as to move ink through the conduit to the slot-shaped applicator.

3. The apparatus of claim 1, further comprising a suction device in communication with the metering device.

4. The apparatus of claim 1, wherein the print cylinder has a width, and the metering device has a width, wherein the metering-device width is narrower than the print-cylinder width.

5. The apparatus of claim 1, further comprising a gas-feed conduit in communication with the enclosed volume.

6. The apparatus of claim 1, wherein the slot-shaped applicator comprises a first portion and a second portion, and a removable shim portion disposed between the first and second portions so as to define a height of the slot.

7. The apparatus of claim 1, wherein the metering device is a doctor blade disposed so as to work against the direction of rotation.

8. The apparatus of claim 1, further comprising seals disposed between the housing and the print cylinder, wherein the seals contact a circumferential surface of the print cylinder.

9. A method of printing with electronic ink, comprising:

rotating a print cylinder in a direction of rotation;

applying electronic ink to the print cylinder with a slot-shaped applicator at an ink application point,

transferring the ink from the print cylinder at an ink transfer point,

wherein an arc starting at the ink application point, extending in the direction of rotation, and ending at the ink transfer point, subtends an angle of ≤ 90 degrees;

metering the ink on the cylinder at a metering point, wherein the metering point is disposed along the arc; and

feeding at least one of an inert gas and ink-solvent vapor to an enclosed volume that encompasses the ink application point and the ink metering point.

10. The method of claim 9, further comprising moving, with a peristaltic pump, the ink through a conduit to the ink application point.

11. The method of claim 9, further comprising suctioning excess ink away from the metering point.

12. The method of claim 11, further comprising balancing the ink transfer, the suctioning, and the feeding, so as to maintain a positive pressure within the enclosed volume.

13. The method of claim 9, wherein applying electronic ink further comprises applying the electronic ink over less than the entire width of the cylinder.

14. The method of claim 9, further comprising adjusting the height of a slot in the slot-shaped applicator.

15. The method of claim 9, wherein the metering is performed against the direction of rotation.

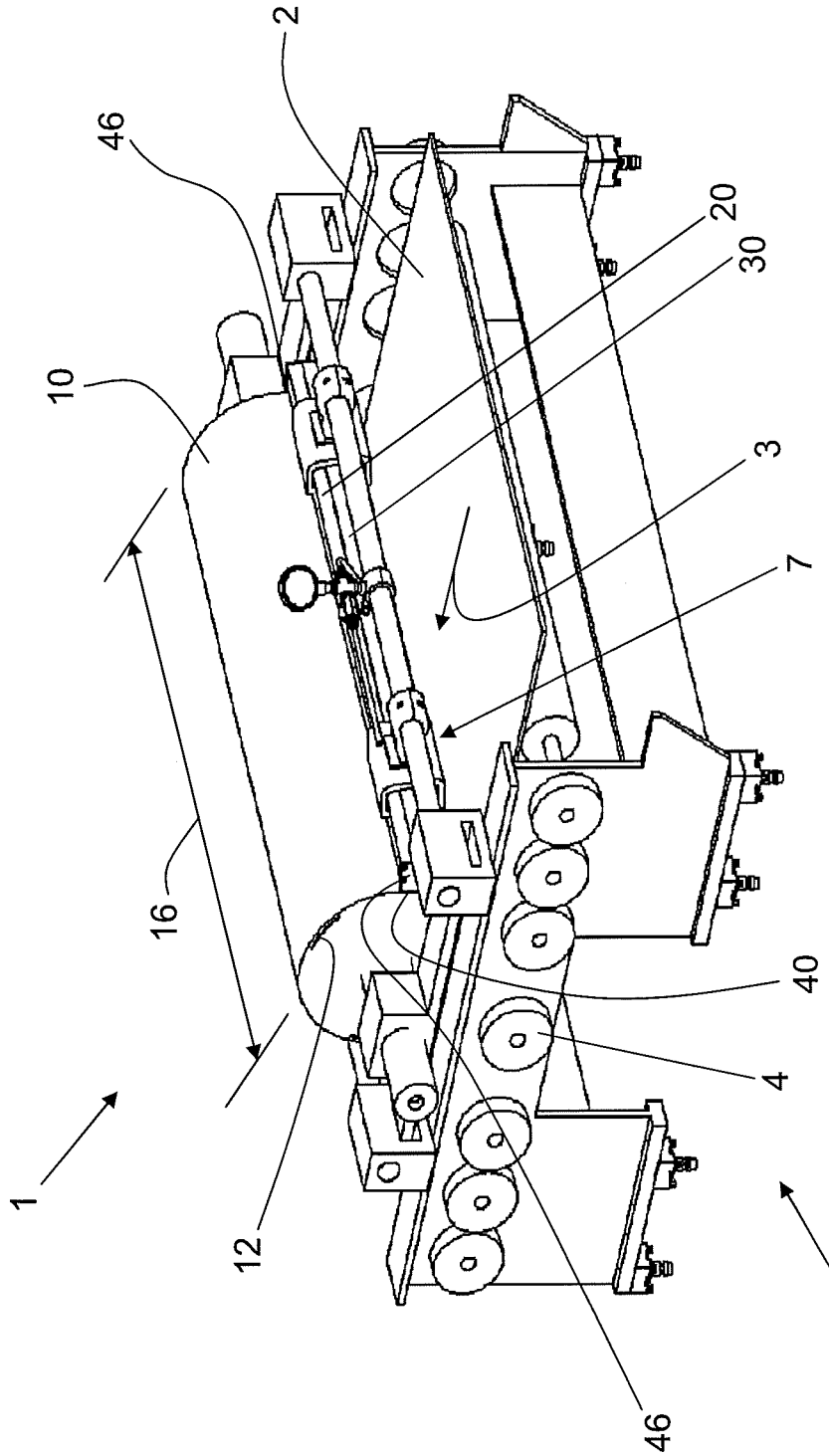


FIG. 1

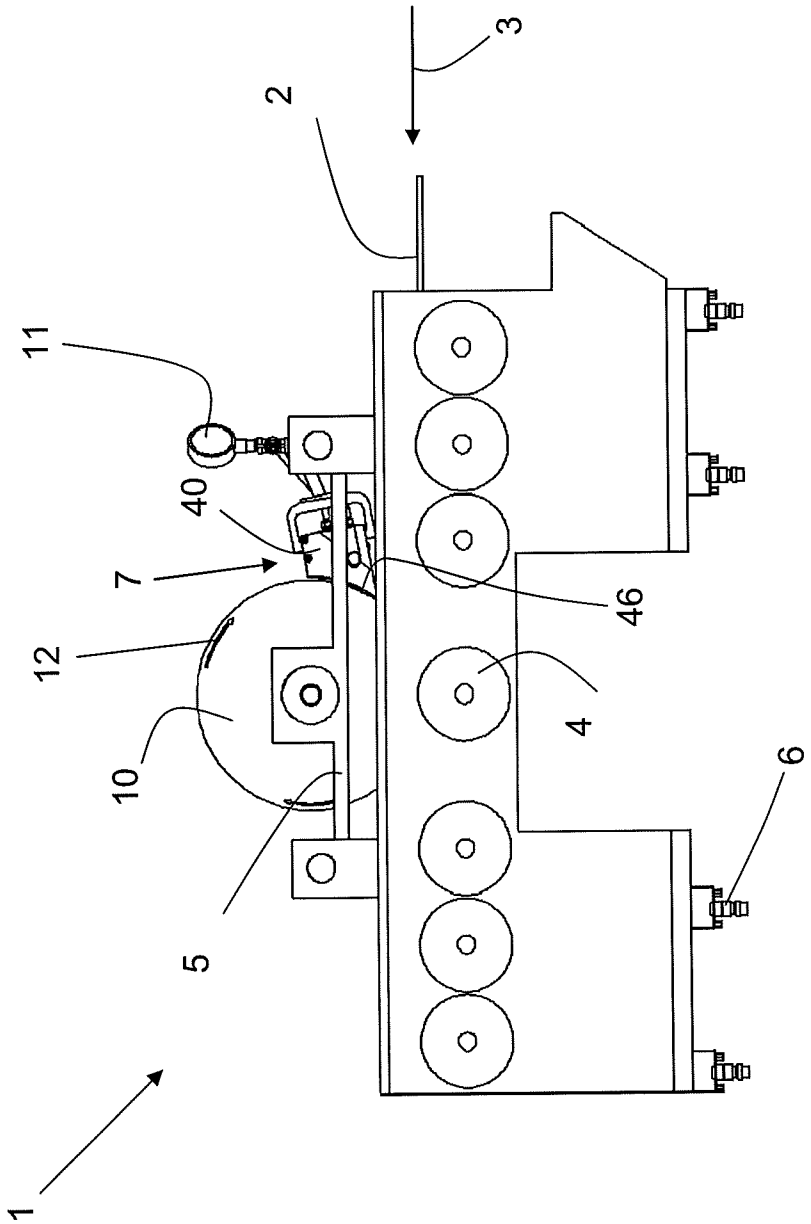


FIG. 2

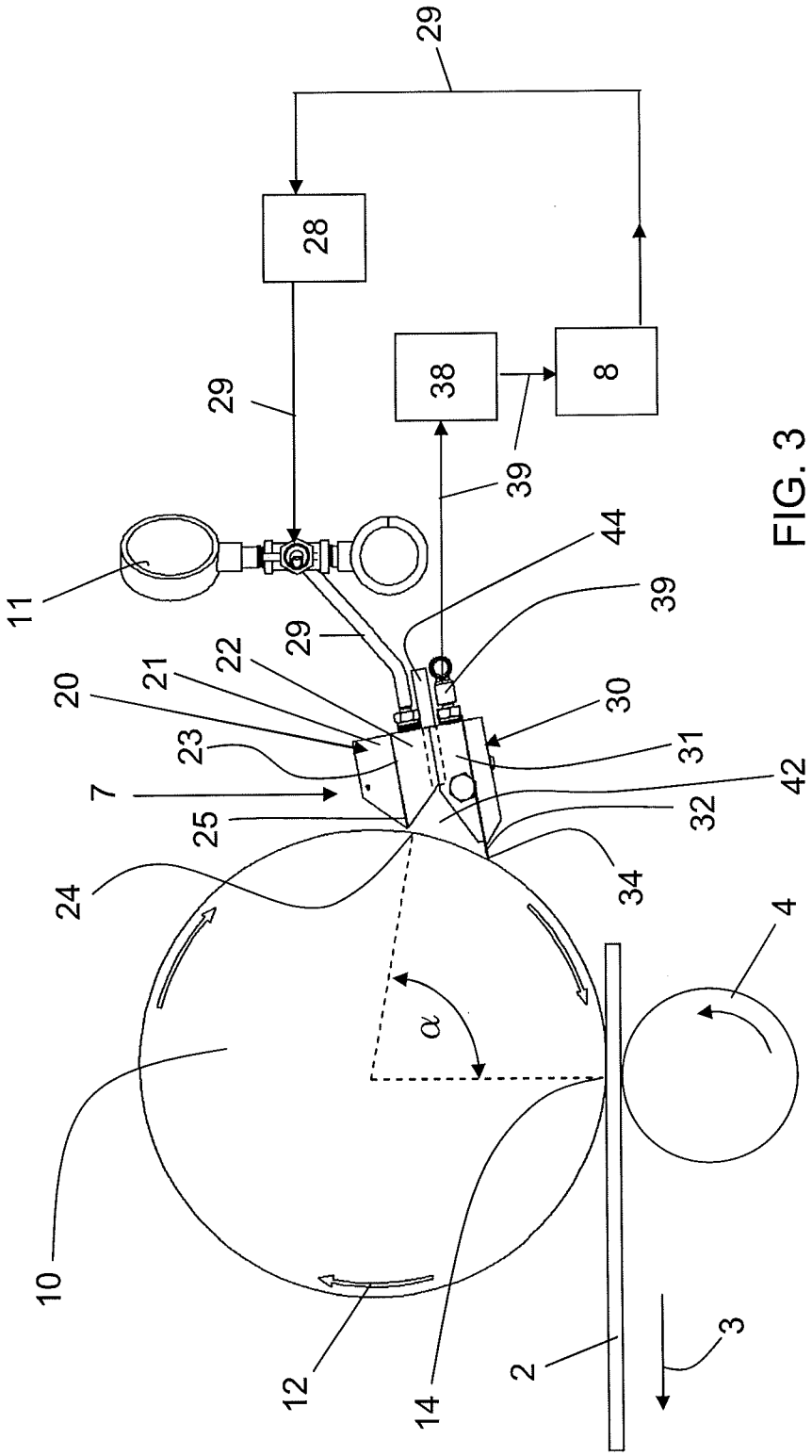
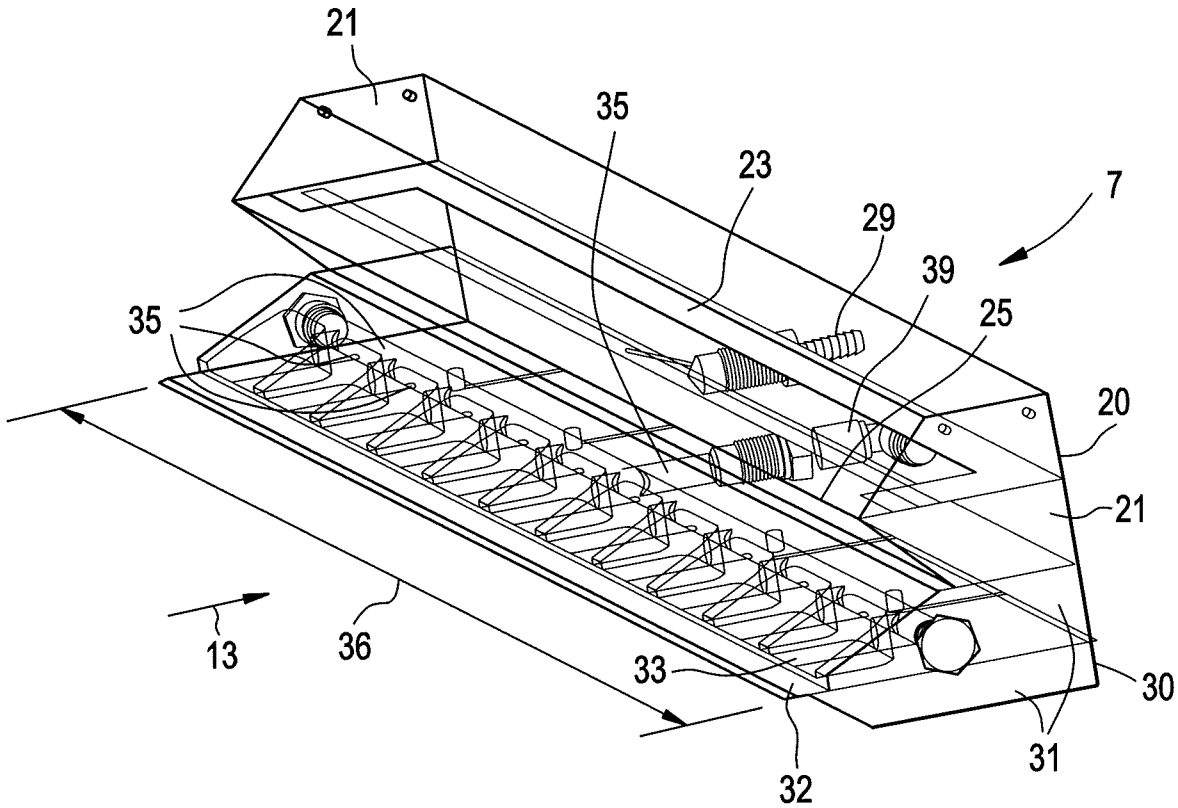

29
28
38
8
29
39
44
39
11
29
22
21
20
30
23
31
7
42
25
32
24
34
4
α
10
12
14
2
3

FIG. 3

FIG. 4



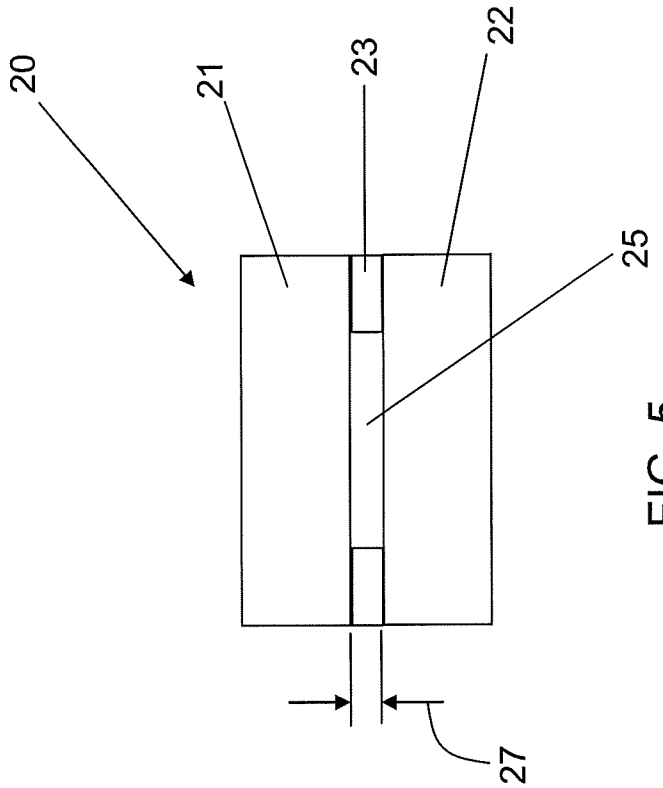


FIG. 5

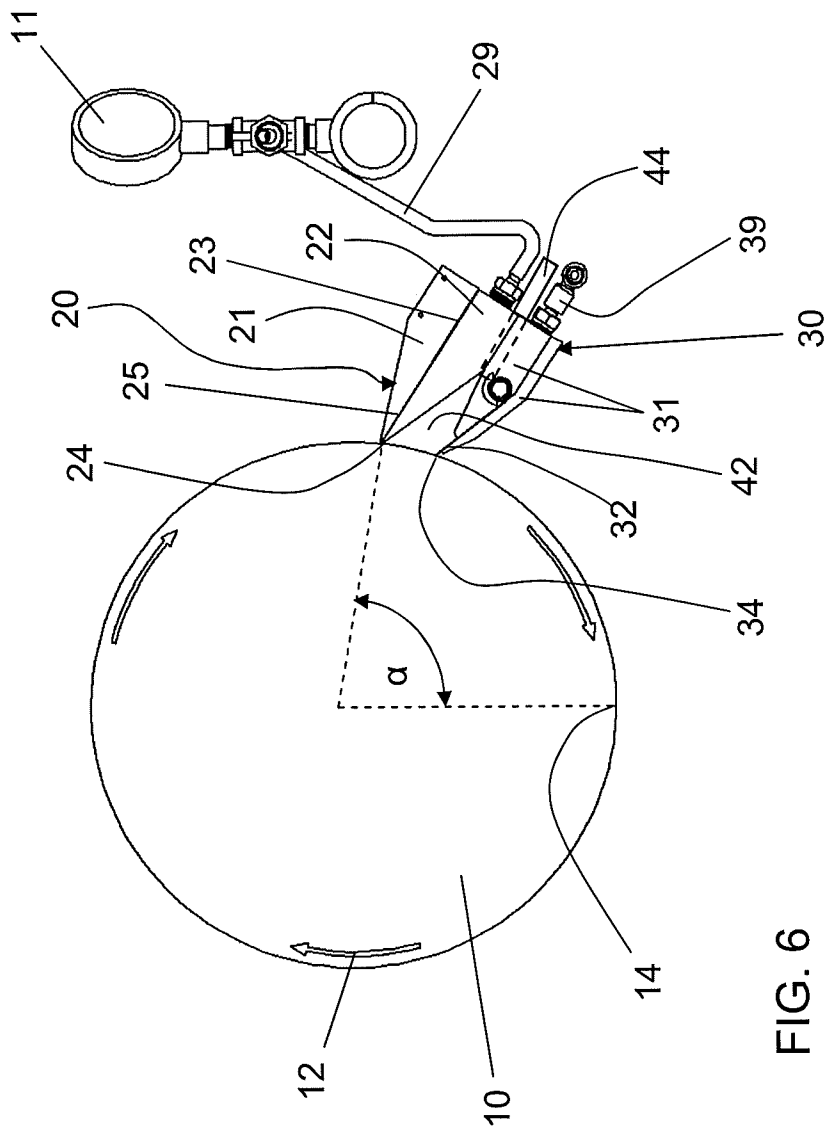


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/026024

A. CLASSIFICATION OF SUBJECT MATTER
INV. B41F9/06 B41F9/10 B41F31/04
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)
B41F H05K

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 practicable, 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	US 2 201 008 A (MACARTHUR CHARLES J) 14 May 1940 (1940-05-14) figures 1-5 page 2, column 1, lines 21-45 page 3, column 1, line 65 - column 2, line 7 page 4, column 1, line 61 - column 2, line 67 -----	1-15
X	US 4 085 672 A (GROSART JOHN) 25 April 1978 (1978-04-25) figures 1-3 column 3, line 26 - column 4, line 24 column 5, line 16 - column 6, line 8 ----- -/--	1-15

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

X See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"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
24 May 2012	05/06/2012

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	Hajji, Mohamed-Karim

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/026024

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 477 782 A (NGUYEN LAM [FR]) 26 December 1995 (1995-12-26) figures 1,2,5 column 3, line 21 - column 4, line 19 column 5, line 17 - column 6, line 1 -----	1-15
X	EP 1 531 044 A1 (FISCHER & KRECKE GMBH & CO [DE]) 18 May 2005 (2005-05-18) figure 1 paragraphs [0017] - [0020] -----	1-15
A	US 2004/110321 A1 (ODA TETSUYA [JP] ET AL) 10 June 2004 (2004-06-10) figures 2-4 paragraphs [0072] - [0086] -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/026024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2201008 A	14-05-1940	NONE	
US 4085672 A	25-04-1978	NONE	
US 5477782 A	26-12-1995	NONE	
EP 1531044 A1	18-05-2005	EP 1531044 A1	18-05-2005
		JP 2005145072 A	09-06-2005
		US 2005120893 A1	09-06-2005
US 2004110321 A1	10-06-2004	CN 1510983 A	07-07-2004
		JP 4111116 B2	02-07-2008
		JP 2004200652 A	15-07-2004
		KR 20040049263 A	11-06-2004
		US 2004110321 A1	10-06-2004