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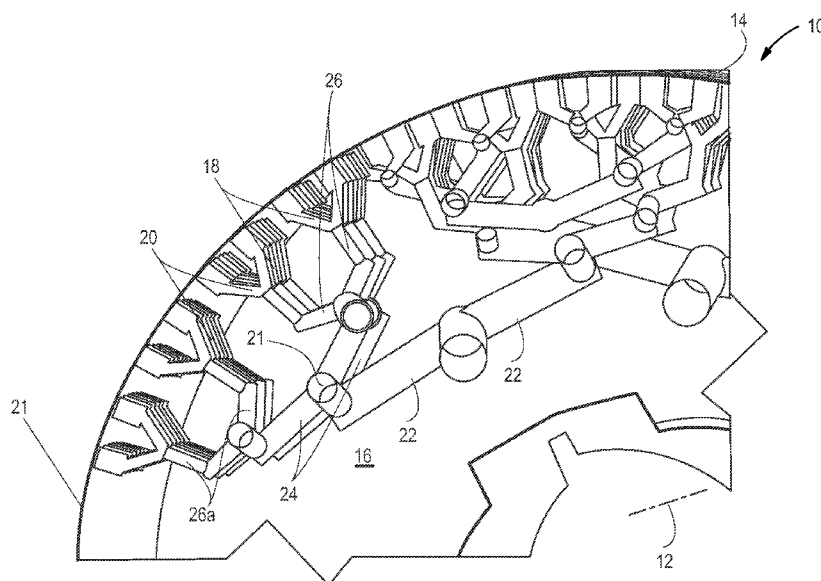


Fig. 1

(57) Abstract: A method for delivering a High Internal Phase Emulsion to a substrate. The method includes providing a rotating roll. The rotating roll has a central longitudinal axis, wherein the rotating roll rotates about the central longitudinal axis, an exterior surface defining an interior region and substantially surrounding the central longitudinal axis, and a vascular network configured for transporting the one or more fluids in a predetermined path from the interior region to the exterior surface of the rotating roll. The method further includes providing a High Internal Phase Emulsion to the rotating roll vascular network. The method further includes contacting a substrate with the rotating roll and contacting the substrate with the High Internal Phase Emulsion.



CUSTOMIZABLE APPARATUS AND METHOD FOR TRANSPORTING AND DEPOSITING FLUIDS

5 FIELD OF THE INVENTION

The present invention relates to equipment and methods for depositing a fluid or a plurality of fluids onto a substrate. More particularly, the invention relates to equipment and methods for dosing fluids on moving substrates.

10 BACKGROUND OF THE INVENTION

Manufacturers of consumer goods often apply absorbents in solid forms to their products. To date, manufacturers have mostly relied on the use of drums and vacuum to deliver solid absorbents to the product. To date, absorbent precursors in a fluid state are not handled in a manner that allows for precise delivery to a substrate in a controlled manner accounting for shear
15 while having precise fluid flow control. Manufacturers may use moving rolls having primarily axial fluid flow and/or primarily circumferential fluid flow which results in uneven fluid distribution and lack of fluid reaching parts of the rolls. In addition, such designs limit the number and sizes of fluid channels that may be incorporated into the device and limit the location of the fluid orifices stemming from those channels in a way that undermines precision.
20 Alternatively manufacturers use printing plates and flat surfaces, which result in slower processing or imprecision when running at high rates as the printing plate may not be able to keep up with the moving substrate.

Known devices also suffer from imprecise registration, overlaying and blending of fluids. Because a single device is often used for a single fluid, registration, overlaying and blending
25 between multiple fluids requires the use of more than one device. The inherent imprecision in each known device results in imprecision when trying to register (etc.) their respective fluids. Indeed, because the inability to control fluid flow and application and other factors in each device, known devices often are not able to precisely register fluids with other fluids or product features such as embossments or sealing areas.

30 Further, manufacturers are faced with higher production costs and resources due their inability to separately control different fluids in one printing device.

Therefore, there is a need for a controllable and/or customizable apparatus for depositing fluid(s) that permits more precise fluid deposition. Further still, there is a need for an efficient

process for, and decreased manufacturing costs associated with, depositing one or more fluids on a substrate.

SUMMARY OF THE INVENTION

5 A method for delivering a High Internal Phase Emulsion to a substrate. The method includes providing a rotating roll, The rotating roll has a central longitudinal axis, wherein the rotating roll rotates about the central longitudinal axis, an exterior surface defining an interior region and substantially surrounding the central longitudinal axis, and a vascular network configured for transporting the one or more fluids in a predetermined path from the interior
10 region to the exterior surface of the rotating roll. The method further includes providing a High Internal Phase Emulsion to the rotating roll vascular network. The method further includes contacting a substrate with the rotating roll and contacting the substrate with the High Internal Phase Emulsion.

 A method for delivering a High Internal Phase Emulsion to a substrate. The method
15 includes providing a rotating roll, The rotating roll has a central longitudinal axis, wherein the rotating roll rotates about the central longitudinal axis, an exterior surface defining an interior region and substantially surrounding the central longitudinal axis, and a vascular network configured for transporting the one or more fluids in a predetermined path from the interior region to the exterior surface of the rotating roll. The method further includes providing a High
20 Internal Phase Emulsion to the rotating roll vascular network. The method further includes contacting a substrate with the rotating roll and contacting the substrate with the High Internal Phase Emulsion. The substrate can contact the rotating roll, the emulsion, or both simultaneously before contacting the other provided that the substrate contacts the High Internal Phase Emulsion prior to the High Internal Phase Emulsion vertically protruding from the surface of the rotating
25 roll at a height of greater than 0.1 mm.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a rotating roll in accordance with one embodiment of the present invention;

30 Fig. 2 is a partial perspective view of a rotating roll and vascular network in accordance with one embodiment of the present invention;

Fig. 2A is a partial perspective view of a rotating roll and vascular network in accordance with one embodiment of the present invention with a nonlimiting example of a tree encircled;

Fig. 3 is a partial perspective view of a rotating roll and vascular network in accordance with one embodiment of the present invention;

Fig. 4 is a schematic view of a rotating roll and main artery in accordance with one embodiment of the present invention;

5 Fig. 5 is a partial perspective view of a rotating roll and vascular network in accordance with one embodiment of the present invention;

Fig. 6 is a schematic representation of the interior region of a rotating roll in accordance with one embodiment of the present invention;

10 Fig. 7 is a schematic representation of an exemplary tree in a vascular network in accordance with one embodiment of the present invention;

Fig. 7A is a schematic representation of another exemplary tree in a vascular network in accordance with one embodiment of the present invention;

Fig. 8 is a schematic representation of a rotating roll and vascular network in accordance with one embodiment of the present invention;

15 Figs. 9A-9E are schematic representations of fluid exits and channels in accordance with nonlimiting examples of the present invention;

Figs. 10A-10C are schematic representations of fluid exits in accordance with nonlimiting examples of the present invention;

20 Figs. 11A-11D are schematic representations of fluid exits in accordance with nonlimiting examples of the present invention;

Fig. 12 is a schematic representation of one nonlimiting example of a micro-reservoir in accordance with the present invention;

Figs. 13A-13C are schematic representations of micro-reservoirs in accordance with nonlimiting examples of the present invention;

25 Fig. 14 is a partial, front elevational view of a rotating roll and vascular network in accordance with one nonlimiting embodiment of the present invention;

Fig. 15 is a schematic representation of a rotating roll and vascular network in accordance with one embodiment of the present invention;

30 Fig. 16 is a schematic representation of fluid exits in accordance with one embodiment of the present invention;

Fig. 17 is a schematic representation of an interior region of a rotating roll in accordance with one embodiment of the present invention;

Fig. 18 is a schematic representation of a rotating roll in accordance with one embodiment of the present invention;

Fig. 19 is a schematic representation of a rotating roll in accordance with one embodiment of the present invention;

Fig. 20 is a schematic representation of a plurality of rotating rolls in accordance with one embodiment of the present invention;

5 Fig. 21 is a schematic representation of a rotating roll and substrate in accordance with one embodiment of the present invention;

Fig. 22 is a schematic representation of a dosing system in accordance with one embodiment of the present invention;

10 Fig. 23 is a schematic representation of a dosing system in accordance with another embodiment of the present invention;

Fig. 24 is a schematic representation of a dosing system in accordance with yet another embodiment of the present invention;

Fig. 25 is a perspective view of a rotating roll and sleeve in accordance with one embodiment of the present invention;

15 Fig. 26 is a perspective view of a rotating roll and sleeve in accordance with one embodiment of the present invention;

Fig. 27 is a schematic representation of a sleeve in accordance with one embodiment of the present invention;

20 Fig. 28 is a schematic representation of a rotating roll and sleeve in accordance with an embodiment of the present invention;

Fig. 29 is a schematic representation of a rotating roll, a sleeve and sleeve exits in accordance with nonlimiting examples of the present invention;

Fig. 30 is a partial, perspective view of a rotating roll in accordance with an embodiment of the present invention;

25 Figs. 31A-31B are schematic representations of exemplary trees in accordance with nonlimiting examples of the present invention;

Fig. 32 is a schematic representation of trees in accordance with one nonlimiting example of the present invention;

30 Figs. 33A -33C are charts depicting phenomena resulting from a vascular network designed in accordance with one nonlimiting example of the present invention;

Figs. 34A -34C are charts depicting phenomena resulting from a vascular network designed in accordance with one nonlimiting example of the present invention;

Fig. 35 is a schematic representation of a sleeve and roll system in accordance with one embodiment of the present invention;

Fig. 36 is a schematic representation of a sleeve and roll system in accordance with an alternative embodiment of the present invention;

Fig. 37 is a schematic representation of a rotating roll and backing surface in accordance with one embodiment of the present invention;

5 Fig. 38 is a schematic representation of a rotating roll and backing surface in accordance with another embodiment of the present invention;

Fig. 39 is a schematic representation of a rotating roll used in conjunction with ancillary parts in accordance with one embodiment of the present invention;

10 Fig. 40 is a schematic representation of a method in accordance with one embodiment of the present invention;

Fig. 41 is a schematic representation of a method in accordance with one embodiment of the present invention;

Fig. 42 is a schematic representation of a method in accordance with one embodiment of the present invention;

15 Fig. 43 is a schematic representation of a method in accordance with one embodiment of the present invention; and

Fig. 44 is a schematic representation of a method in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

20 Definitions

As used herein, the “aspect ratio” of a shape is the ratio of the length of the longest dimension or diameter of the shape, in any direction, that intersects the shape’s midpoint and length of the shortest dimension or diameter of the shape, in any direction, that intersects the shape’s midpoint.

25 “Vascular network” as used herein means a network of channels that carry fluid from an entry, such as an inlet, to one or more exits. The channels include one or more main arteries, one or more capillaries, and/or one or more sub-capillaries. In the vascular network, each channel may be in fluid communication with another channel. In general, the entry may be at or near the main artery, and the main artery may be in direct fluid communication (i.e., without intermediate
30 channels) with a capillary. Likewise, a capillary may be in direct fluid communication with a main artery, another capillary, and/or a sub-capillary, and/or a fluid exit (all of which are discussed more fully below). Capillaries may extend from a main artery and connect with a sub-capillary or divide into a series of sub-capillaries. In one embodiment, the cross-sectional area of a main artery is larger than that of a capillary to which the main artery is connected. In another

embodiment, the cross-sectional area of a capillary is larger than that of a sub-capillary to which the capillary is connected. In some respects, the vascular network of the present invention is analogous to a biological vascular network. However, the vascular network of the present invention is not a biological system.

5 In an embodiment, one path from the entry to an exit is substantially radial. In other words, the vascular network carries a fluid in a substantially radial direction.

“Radial” or “radially” as used herein refers to the direction of radii in a circular, spherical, cylindrical or similar shaped object. In other words, if an element is described as extending radially herein, that element extends from an inner portion (including the center) of an object
10 outward to an external portion, including the perimeter or outer boundary or surface of that object. Radial and radially as used herein are distinguished from circumferentially, wherein an element so described would extend about the center of a spherical, cylindrical or similar shaped object such that the element would mimic the circumference or perimeter of the object. Likewise, radial and radially is distinguished from axially, wherein an element so described
15 would extend in a direction parallel or substantially parallel to the longitudinal axis of the object.

Elements described as extending “substantially radially” or being “substantially radial” may have axial or circumferential components. However, a substantially radial element as described herein means that the element has a radial vector greater than its axial or circumferential vectors. Visually, in the aggregate, a substantially radial element (which may be
20 a tree 23 or a fluid path 48) extends in a radial direction more than it extends in an axial or circumferential manner.

“Fluid” as used herein means a substance, as a liquid or gas, that is capable of flowing and that changes its shape at a steady rate when acted upon by a force tending to change its shape. Exemplary fluids suitable for use with the present disclosure includes inks; dyes;
25 emulsions such as oil and water emulsions; high internal phase emulsions; monomers and polymers; polyacrylic acids; chemical fluids such as alcohols; softening agents; cleaning agents; dermatological solutions; wetness indicators; adhesives; botanical compounds (e.g., described in U.S. Patent Publication No. US 2006/0008514); skin benefit agents; medicinal agents; lotions; fabric care agents; dishwashing agents; carpet care agents; surface care agents; hair care agents;
30 air care agents; actives comprising a surfactant selected from the group consisting of: anionic surfactants, cationic surfactants, nonionic surfactants, zwitterionic surfactants, and amphoteric surfactants; antioxidants; UV agents; dispersants; disintegrants; antimicrobial agents; antibacterial agents; oxidizing agents; reducing agents; handling/release agents; perfume agents; perfumes; scents; oils; waxes; emulsifiers; dissolvable films; edible dissolvable films containing

drugs, pharmaceuticals and/or flavorants. Suitable drug substances can be selected from a variety of known classes of drugs including, for example, analgesics, anti-inflammatory agents, anthelmintics, antiarrhythmic agents, antibiotics (including penicillin), anticoagulants, antidepressants, antidiabetic agents, antipileptics, antihistamines, antihypertensive agents, 5 antimuscarinic agents, antimycobacterial agents, antineoplastic agents, immunosuppressants, antithyroid agents, antiviral agents, anxiolytic sedatives (hypnotics and neuroleptics), astringents, beta-adrenoceptor blocking agents, blood products and substitutes, cardiac inotropic agents, corticosteroids, cough suppressants (expectorants and mucolytics), diagnostic agents, diuretics, dopaminergics (antiparkinsonian agents), haemostatics, immunological agents, lipid regulating 10 agents, muscle relaxants, parasympathomimetics, parathyroid calcitonin and biphosphonates, prostaglandins, radiopharmaceutical, sex hormones (including steroids), anti-allergic agents, stimulants and anorexics, sympathomimetics, thyroid agents, PDE IV inhibitors, NK3 inhibitors, CSBP/RK/p38 inhibitors, antipsychotics, vasodilators and xanthines; and combinations thereof.

“Register” as used herein means to spatially align an article, including but not limited to a 15 fluid, with another article, such as another fluid, or with a particular area or feature of a substrate.

“Overlay” as used herein means to place a fluid on top of another fluid. For example, a blue fluid may overlay a yellow fluid, producing a green image.

“Operative relationship” as used herein in reference to fluid transmission between two articles (e.g., a roll and a substrate) means that the articles are disposed such that the fluid is 20 transmitted through actual contact between the articles, close proximity of the articles and/or other suitable means for the fluid to be deposited.

“Paper product,” as used herein, refers to any formed, fibrous structure product, traditionally, but not necessarily, comprising cellulose fibers. In one embodiment, the paper products of the present invention include sanitary tissue products. A paper product may be made 25 by a process comprising the steps of forming an aqueous papermaking furnish, depositing this furnish on a foraminous surface, such as a Fourdrinier wire, and removing the water from the furnish (e.g., by gravity or vacuum-assisted drainage), forming an embryonic web, transferring the embryonic web from the forming surface to a transfer surface traveling at a lower speed than the forming surface. The web is then transferred to a fabric upon which it is dried to a final 30 dryness after which it is wound upon a reel. Paper products may be through-air-dried.

“Product feature” as used herein means structural or design features that are applied to or formed on a substrate prior to or after use of the apparatuses or methods described herein. Product features may include, for example, embossments, wet-formed textures, addition of fibers

such as by flocking, apertures, perforations, printing, registration marks and/or other fluid deposits.

“Micro-reservoir” as used herein means a structure having a void volume capable of collecting and/or holding less than about 1000 mm³, or less than 512 mm³, or less than 125 mm³,
5 or less than 75mm³, or less than 64 mm³, or less than 50 mm³ of one or more fluids and supplying the fluids to one or more exits. In one nonlimiting example, the micro-reservoir operates as a reverse funnel, being smaller in the area where fluid enters the micro-reservoir than the area where the fluid leaves the micro-reservoir. The micro-reservoir can serve as a single fluid supply region for one or fluid exits or sleeve exits (both types of exits described in more
10 detail below), minimizing the number of channels required to supply a given number of exits. In addition, the micro-reservoir may be disposed under an exterior surface or a sleeve.

“Sanitary tissue product” as used herein means one or more fibrous structures, converted or not, that is useful as a wiping implement for post-urinary and post-bowel movement cleaning (bath tissue), for otorhinolaryngological discharges (facial tissue and/or disposable
15 handkerchiefs), and multi-functional absorbent and cleaning uses (absorbent towels and/or wipes). Sanitary tissue products used in the present invention may be single or multi-ply.

“Substrate” as used herein includes products or materials on which indicia or fluids may be deposited, imprinted and/or substantially affixed. Substrates suitable for use and within the intended scope of this disclosure include single or multi-ply fibrous structures, such as paper
20 products like sanitary tissue products. Other materials are also intended to be within the scope of the present invention as long as they do not interfere or counteract any advantage presented by the instant invention. Suitable substrates may include films, foils, polymer sheets, cloth, wovens or nonwovens, paper, cellulose fiber sheets, co-extrusions, laminates, high internal phase emulsion foam materials, and combinations thereof. The properties of a selected material can
25 include, though are not restricted to, combinations or degrees of being: porous, non-porous, microporous, gas or liquid permeable, non-permeable, hydrophilic, hydrophobic, hydroscopic, oleophilic, oleophobic, high critical surface tension, low critical surface tension, surface pre-textured, elastically yieldable, plastically yieldable, electrically conductive, and electrically non-conductive. Such materials can be homogeneous or composition combinations. Additionally,
30 absorbent articles (e.g., diapers and catamenial devices) may serve as suitable substrates. In the context of absorbent articles in the form of diapers, printed web materials may be used to produce components such as backsheets, topsheets, landing zones, fasteners, ears, side panels, absorbent cores, and acquisition layers. Descriptions of absorbent articles and components

thereof can be found in U.S. Pat. Nos. 5,569,234; 5,702,551; 5,643,588; 5,674,216; 5,897,545; and 6,120,489; and U.S. Patent Publication Nos. 2010/0300309 and 2010/0089264.

Substrates suitable for the present invention also include products suitable for use as packaging materials. This may include, but not be limited to, polyethylene films, polypropylene
5 films, liner board, paperboard, carton materials, and the like.

Overview

Fig. 1 depicts a rotating roll 10 in accordance with one embodiment of the present invention. The rotating roll 10 may have a central longitudinal axis 12, about which the roll 10
10 may rotate, an exterior surface 14 and an interior region 16 defined and bounded by the exterior surface 14. The rotating roll 10 may further comprise a vascular network 18 of channels 20 for transmitting fluids from the interior region 16 of the roll 10 to the exterior surface 14. Turning to Fig. 2, the channels 20 may comprise a main artery 22, capillaries 24 and sub-capillaries 26. The main artery 22 may be associated with one or more capillaries 24 which extend from the main
15 artery 22 at a junction 21. Each capillary 24 may be associated with one or more sub-capillaries 26. The vascular network 18 expands radially and three-dimensionally within the cylindrical rotating roll 10 from the main artery 22 to the exterior surface 14. In one embodiment, a capillary 24 may divide into a series of sub-capillaries 26. The channels 20 may each be enclosed substantially cylindrical elements having generally uniform cross-sections along their
20 respective lengths.

The channels 20 may be associated by any suitable means, such as gluing, welding or similar attachment operation or may be integrally formed with one another, or combinations thereof. Further, each point of association between channels 20 may comprise a junction 21. The junction 21 may be formed to provide a smooth transition from one channel 20 to another in
25 order to prevent turbulence. A smooth transition may be achieved for example by rounding the edges of the junction 21 or associating the channels 20 such that they are not aligned end-to-end creating a sharp edge, such as a 90 degree angle. In other words, the channels 20 may be associated away from one or both of their ends. If turbulence is desired, the junction 21 may be provided with more jagged edges. One of skill in the art will recognize how to design the
30 junction 21 to achieve the desired fluid flow.

Still referring to Fig. 2, the vascular network 18 may begin at an inlet 28 in the main artery 22 and terminate in a plurality of fluid exits 30 on the exterior surface 14. Fluid may flow through the vascular network 18, entering at an inlet 28, traveling from the main artery 22 to the capillaries 24 and sub-capillaries 26 (if any) to a fluid exit 30. In other words, the channels 20

may be in fluid communication with one another. The main artery 22 may be in fluid communication with one or more capillaries 24, and each capillary 24 may be in fluid communication with one or more fluid exits 30. In one nonlimiting example, each capillary 24 is in fluid communication with at least two fluid exits 30. In another nonlimiting example, each
5 capillary 24 is in fluid communication with one or more sub-capillaries 26, and each sub-capillary 26 is in fluid communication with one or more exits 30. The vascular network 18 essentially has one or more trees, 23 as depicted in Fig. 2A. Each tree 23 begins with a capillary 24 and may extend – directly or through one or more sub-capillaries 26 – in a substantially radial manner to the exterior surface 14 and/or a fluid exit 30.

10 Importantly, as shown in Fig. 3, the vascular network 18 is designed to transport fluid in one or more predetermined paths 48 from the interior region 16 to a specified location on the exterior surface 14. Moreover, the predetermined paths 48 are substantially radial. Multiple substantially radial paths may be designed into the vascular network 18. The paths will be similar in that all are substantially radial. However, the substantially radial paths will differ in
15 that they will have different starting or ending points.

The Vascular Network & Predetermined Path

As noted above, the vascular network 18 may be disposed with the interior region 16 of the rotating roll 10 and comprise a plurality of channels 20 (i.e., main artery 22, capillaries 24
20 and/or sub-capillaries 26). The vascular network 18 may comprise a main artery 22. The main artery 22 may comprise an inlet 28, where fluid enters the network 18. The inlet 28 may be disposed at any location suitable for permitting fluid to enter the vascular network 18.

As shown in Fig. 3, the main artery 22 may be positioned coincident with the central longitudinal axis 12 that runs through the rotating roll 10. Alternatively, the main artery 22 may
25 be substantially parallel to the central longitudinal axis 12 though not coincident. In one nonlimiting example depicted in Fig. 4, the main artery 22 is substantially parallel to the central longitudinal axis 12 and positioned a radial distance, r , from the central longitudinal axis 12. In such nonlimiting example, the radial distance, r , is greater than 0, which permits higher rotational speeds. Radial distance, r , may be measured from the longitudinal axis 12 outward to the closest
30 point on the outer surface of the main artery 22, as shown in Fig. 4. The radial distance, r , is less than the radius of the roll, R , as measured in the same direction.

Turning to Fig. 5, the vascular network 18 may comprise a first capillary 24a which is associated with the main artery 22 at a junction 21. The first capillary 24a may be associated with the main artery 22 as discussed above. In one embodiment, the first capillary 24a is in fluid

communication with the main artery 22 and a fluid exit 30 through a substantially radial path, RPa. In one nonlimiting example, the first capillary 24a in fluid communication with the main artery 22 and at least two fluid exits 30 through separate substantially radial paths, RPa and RPb. The vascular network 18 expands radially and three-dimensionally within the cylindrical rotating roll 10 from the main artery 22 to the exterior surface 14.

Still referring to Fig. 5, the vascular network 18 may also comprise a second capillary 24b. The second capillary 24b may also be associated with the main artery 22. The second capillary 24b may be in fluid communication with the main artery 22 and one or more fluid exits 30 one or more substantially radial paths. In one nonlimiting example, the second capillary 24b in fluid communication with the main artery 22 and at least two fluid exits 30 through substantially radial paths, RPc and RPd.

Both the first capillary 24a and the second capillary 24b may be associated with the main artery 22 at a single junction 21 as shown in Fig. 5. Alternatively, the second capillary 24b may be spaced a longitudinal distance, L, from the first capillary 24a along the length of the main artery 22 as shown in Fig. 6. In such nonlimiting example, the first capillary 24a and the second capillary 24b are associated with the main artery 22 through separate junctions 21.

In one embodiment, the first capillary 24a is substantially symmetrical to the second capillary 24b with respect to the main artery 22. In one nonlimiting example, the main artery 22 has a cross-sectional area greater than a cross-sectional area of the first capillary 24a. In another nonlimiting example, the main artery 22 has a cross-sectional area greater than the cross-sectional area of the second capillary 24b. In yet another nonlimiting example, the main artery 22 has a cross-sectional area that is greater than the cross-sectional area of both the first capillary 24a and the second capillary 24b. The cross-sectional areas of the first capillary 24a and the second capillary 24b may be the same or may be different.

The vascular network 18 may also include a plurality of fluid exits 30 which may be disposed on the exterior surface 14 of the rotating roll 10. The first capillary 24a and the second capillary 24b may each be in fluid communication with one or more fluid exits 30. In an embodiment, one or both of the first and second capillaries 24a, 24b may be in fluid communication with the fluid exits 30 through a series of sub-capillaries 26 disposed on one or more branching levels of their respective trees 23. A capillary 24a, 24b may be associated with a sub-capillary 26 or may be associated with a plurality of sub-capillaries 26. Each sub-capillary 26 may associate with another sub-capillary 26a of a subsequent level or may associate with a plurality of sub-capillaries 26a on a subsequent level. In one nonlimiting example, a sub-

capillary 26 has a cross-sectional area that is less than the cross-sectional area of a capillary 24 with which the sub-capillary 26 is associated. Likewise, a sub-capillary 26a in the subsequent level may have a cross-sectional area less than that of the sub-capillary 26 from which it extends.

Essentially (as shown in Fig. 7), the vascular network 18 may continue to divide, such that a given tree 23 has n levels of branching, where n is an integer and the starting level, level 0, occurs when an initial capillary 24_i associates with the main artery 22. For example, as illustrated in Fig. 7, $n = 2$. In another nonlimiting example, the tree 23 branches such that the number of fluid exits 30 ultimately in fluid communication with the main artery 22 and the initial capillary 24_i of the tree 23 is equal to 2^n . In another nonlimiting example, the vascular network 18 divides in accordance to constructal theory and/or vascular scaling laws, such as those disclosed in Kassab, Ghassan S., "Scaling Laws of Vascular Trees: of Form and Function", *Am. J. Physiol Heart Cir. Physiol*, 290:H894-H903, 2006. Trees 23 in the vascular network 18 may have the same number or different number of levels of branching. Moreover, within one tree 23 there may be different levels, as illustrated in Fig. 7A where $n = 4$ on one branch and $n = 3$ on another branch in one nonlimiting example.

In one embodiment, each capillary 24 or sub-capillary 26 on a given level has substantially the same length, diameter, volume and/or area. For example, the first capillary 24a and the second capillary 24b will both reside on the starting level and may have substantially the same length, diameter, volume and/or area. Alternatively, the capillaries 24 or sub-capillaries 26 on a given level may vary in length, volume and/or area.

In an embodiment, the channels 20 in the network 18 may be larger closer to the inlet 28 and may become smaller closer to the fluid exits 30. Said differently still, the main artery 22 may be larger in area and/or volume than the capillaries 24 extending from the main artery 22, and those capillaries 24 may be larger in area and/or volume than the sub-capillaries 26 extending therefrom. Reducing the area and/or volume at each level can facilitate the movement of fluid to the exits 30 while maintaining a desired flow rate and/or pressure.

In a further embodiment, as for example in depicted schematically in Fig. 8, the capillaries 24, 24a, 24b and/or sub-capillaries 26, 26a of a tree 23, in the aggregate, extend to the fluid exits 30 in a substantially radial direction. In one nonlimiting example, the capillaries 24, 24a, 24b extend radially or substantially from the main artery 22. In another nonlimiting example, at least half of the sub-capillaries 26, regardless of what level in which they reside, extend substantially radially with respect to the main artery 22. "Extend substantially radially with respect to the main artery 22" means that although a sub-capillary 26 is not in direct connection with the main artery 22, the sub-capillary 26 visually extends in a substantially radial

manner from a reference point on the main artery 22RP. Although Fig. 8 is necessarily limited to a depiction of two-dimensions, the principle applies in three-dimensions. In yet another nonlimiting example, the sub-capillaries 26 on the n^{th} level extend substantially radially with respect to the main artery 22 to fluid exits 30 on the exterior surface 14. In still another
5 nonlimiting example, the sub-capillaries 26 on the n^{th} level extend substantially radially from a sub-capillary 26 or capillary 24 on the $(n-1)$ level to fluid exits 30 on the exterior surface 14. In another nonlimiting example, the capillaries 24 and series of sub-capillaries 26 in the aggregate may extend substantially radially from the capillary 24 and/or with respect to the main artery 22. Said differently, the majority of capillaries 24 and sub-capillaries 26 extend in a substantially
10 radial direction.

The fluid exits 30 may be openings of any size or shape suitable to permit fluid to exit the vascular network 18 in a controlled manner as dictated by the particular fluid being deposited, the substrate on which it is being deposited, and the amount and placement of the fluid on the substrate, all of which can be predetermined by the skilled person. In an embodiment, an even
15 number of fluid exits 30 are disposed on the exterior surface 14. In one nonlimiting example, the fluid exits 30 have an aspect ratio of at least 10. The aspect ratio is typically the ratio between the depth of the exit 30 (in the z -direction) and a dimension or diameter located in the x - y plane of the exit 30 on the surface 14. In another nonlimiting example, the diameter of the longest dimension of the fluid exit 30 on the exterior surface 14 is less than about 20 millimeters, less
20 than about 10 millimeters, less than about 5 millimeters, such as, for example, between 100 microns to 5000 microns, such as, 500 microns or less than about 250 microns or less than about 100 microns or less than about 10 microns. By limiting the area of the fluid exits 30, the flow of fluid and/or the fluid deposition may be controlled more precisely.

Each fluid exit 30 may comprise an entry point 31 and an exit point 32. In one
25 nonlimiting example, the entry point 31 and the exit point 32 are conterminous, that is, the respective capillary 24 or sub-capillary 26 simply ends at an opening on the exterior surface 14 (as shown in Fig. 9A). In another embodiment, the entry point 31 and exit point 32 are not conterminous, that is, the respective capillary 24 or sub-capillary 26 ends at the entry point 31 and the fluid exit 30 has a shape and volume that includes the exit point 32 (e.g., Fig. 9B). The
30 entry point 31 and the exit point 32 may be of any shape suitable to permit the flow of fluid. Non-limiting examples include circular, elliptical and like shapes. In one nonlimiting example, the longest dimension of the exit point 32 on the surface 14 may be less than about 20 millimeters, less than about 10 millimeters, less than about 5 millimeters, such as, for example, between 100 microns to 5000 microns, such as, 500 microns or less than about 250 microns or

less than about 100 microns or less than about 10 microns. Each of the entry point 31 and the exit point 32 may have a relatively uniform cross sectional areas (as shown in Fig. 9C) or may have cross-sectional areas that taper from one end to the other or change in any other desired way as shown in Fig. 9D. In addition, the channel 20 attached to the fluid exit 30 may be sloped, tapered (as shown in Fig. 9E) or otherwise designed to control fluid flow and/or enhance resolution and/or strength of the fluid exits 30.

Fig. 10A depicts another embodiment, wherein the exterior surface 14 may comprise a differently radiused portion 33 such as a relieved portion 34 and/or a raised portion 35. The fluid exit 30 may be shaped to form or be otherwise associated with a differently radiused portion 33.

In one nonlimiting example, a channel 20 is associated with a relieved portion 34 and the relieved portion 34 operates as a fluid exit 30. In one such example, the entry point 31 may comprise a cross-sectional area smaller than the cross-sectional area of the exit point 32 such that a pool of fluid may be provided in the relieved portion 34 and transferred to a substrate 50. One of skill in the art will recognize that the “pool” of fluid remains a small amount of fluid but may be a higher volume than fluid provided in other arrangements of the entry and exit points 31, 32. In another nonlimiting example, the fluid exit 30 may be shaped to form or be otherwise associated with a raised portion 35. In one such example, the raised portion 35 extends in the z-direction such that it is higher than adjacent regions of the surface 14. Further, the differently radiused portion 33 may comprise both a relieved portion 34 and a raised portion 35. The fluid exit 30 can comprise three or more radial surfaces including a base 36 (substantially flush with the majority of the adjacent exterior surface 14), a raised portion 35, and a relieved portion 34. As shown in Figs. 10B and 10C, the differently radiused portions 33 comprise a plurality of sides 37. One or more of the sides 37 may comprise an exit point 31. In other words, the exit point 32 may be disposed on the side 37 of a differently radiused portion 33. Likewise, if desired, the entry point 31 may be disposed on a side 37 of a differently radiused portion 33 as shown in Fig. 10C. Any combination of arrangements of fluid exit 30 designs may be provided. In addition, one or more channels 20 may be associated with a differently radiused portion 33.

The fluid exits 30 may be arranged in any desired manner, with the only constraint being the physical space. If desired, fluid exits 30 may be placed as close as the physical space allows as shown in Figs. 11A and 11B. In an alternative embodiment, the fluid exits 30 collectively may form a pattern 52 to be deposited on a substrate 50, such as the pattern 52 depicted on Figs. 11C and 11D. In one nonlimiting example (shown in Fig. 11C), the fluid exits 30 are arranged such the pattern 52 is a line or plurality of lines. In another nonlimiting example (shown in Fig.

11D), the fluid exits 30 are arranged such that the pattern 52 is letter and/or aesthetic design and the fluid may comprise one or more fluids.

In another nonlimiting example, one or more of the fluid exits 30 comprise a micro-reservoir 39. Fluid may collect within an inner portion 40 of the micro-reservoir 39, hold fluid
5 until eventual deposition on a substrate, and/or supply fluid to one or more fluid exits 30 (or sleeve exits 120 as discussed in more detail below). The micro-reservoir 39 may be in any shape suitable for the collection and/ supply of fluid to one or more exits 30, 120. Nonlimiting examples of suitable shapes include cubic, polygonal, prismatic, round or elliptical. In another nonlimiting example, the micro-reservoir 39 is in the shape of an isosceles trapezoid as shown in
10 Fig. 12, which shape permits finer resolution as well as contributes to roll 10 strength. The micro-reservoir 39 may have a volume from about 8 mm³ to about 1000 mm³ and every integer value therebetween.

As depicted in Fig. 12, the micro-reservoir 39 may have a first side 42 and a second side 44 substantially opposite the first side 42. The first side 42 may be associated with a capillary 24
15 or sub-capillary 26. The first side 42 may further comprise a single entry point 31 through which fluid enters. The second side 44 may be associated with or integral with the exterior surface 14 as shown in Figs. 13A-13C. In one embodiment, shown in Fig. 13A, the second side 44 comprises a plurality of discrete openings 46 which serve as exit points 32. In other words, the inner portion 40 may be at least partially hollow and the second side 44 may be partially solid
20 such that openings 46 may be formed therein. In one nonlimiting example, the openings 40 may be drilled into the exterior surface 14. In yet another nonlimiting example, there may be about 2 to about 1000 openings 46 per micro-reservoir 39. Still in a further nonlimiting example, the micro-reservoir 39 could comprise more than 1000 openings 46 depending on the micro-reservoir 39 size and the lines per inch (lpi) desired. In an alternative embodiment, depicted in Figs. 13B
25 and 13C, the second side 44 comprises one opening 46. In such case, the single opening 46 may span or substantially span the entire length and/or width of the micro-reservoir 39. The opening(s) 46 may be a slot, hole, groove, aperture or any other means to permit the flow of fluid from the micro-reservoir 39 to the exterior or the roll 10. An opening 46 may comprise a relieved portion 34 and/or a raised portion 35 as detailed above with respect to fluid exits 30.
30 Further, one or more openings 46 may be associated with a sleeve 100 as discussed more fully below. Any combination of micro-reservoir 39 designs may be provided on the roll 10. Likewise, the roll 10 may incorporate micro-reservoirs 39 at certain fluid exits 30 while other fluid exits 30 are void of micro-reservoirs.

The individual fluid exits 30 and/or micro-reservoirs 39 may be designed to comprise different shapes, volumes, widths, depths and/or aspect ratios. In one nonlimiting example, some fluid exits 30 and/or micro-reservoirs 39 may comprise differently radiused portions 33 (such as relieved portions 34 and/or raised portions 35), while others are formed without differently radiused portions 33.

In yet another embodiment, the vascular network 18 may comprise a plurality of main arteries 22 (as shown, for example, in Fig. 14). Use of multiple main arteries 22 allows for multiple fluids to be transported through the vascular network 18, from the interior region 16 through multiple fluid paths 48 to the exterior surface 14, and deposited on a substrate 50. In addition, each main artery 22 and fluid path 48 may be independently controlled by one or more of pressure, length, velocity, or viscosity, among other features. Formulas and teachings below with respect to networks 18 having one main artery 22 equally pertain to networks 18 comprising more than one main artery 22.

In the case of multiple main arteries 22, the vascular network 18 may be viewed in sections, each section having one main artery 22. Each section may branch in the same manner (e.g., having the same number of trees 23 with the same levels) or each may branch in a different manner. In one nonlimiting example shown in Fig. 15, the vascular network 18 comprises four main arteries 22 and thus four sections. In one such example, each main artery 22 is in a different quadrant of the rotating roll 10.

Returning to Fig. 14, capillaries 24 and/or sub-capillaries 26 of one section may overlap capillaries 24 and/or sub-capillaries 26 of another section as indicated by the area of overlap, OL. In one embodiment, a fluid exit 30a in fluid communication with a capillary 24 and/or sub-capillary 26 from one section may be placed next to a fluid exit 30b in fluid communication with a capillary 24 and/or sub-capillary 26 from another section. In addition, the fluid in a capillary 24 and/or sub-capillary 26 from one section may be combined with the fluid in a capillary 24 and/or sub-capillary 26 from another section. These fluids may be combined at the fluid exit 30, in the micro-reservoir 39, in a relieved portion 35, or by other suitable means. In one nonlimiting example, combining the fluids can be facilitated with the use of static mixers which may be located within the vascular network 18. Likewise, channels 20 in any one tree 23 (regardless of the main artery 22 from which they extend or the section where they are located) can operate in the same way with channels 20 from another tree 23 (e.g., overlap, mix fluids, be arranged in close proximity to another tree's 23 fluid exits 30).

The vascular network 18 may comprise as many main arteries 22, capillaries 24, sub-capillaries 26 and fluid paths 48 as can fit within the interior region 14. A circumferential or

axial design would result in less available space within the roll 10 for channels 20. Thus, in circumferential or axial designed networks, it is more difficult to include a plurality of main arteries 22, capillaries 24 and fluid exits 30. Likewise, the constraints on physical space make it difficult to overlap channels 20 of different sections and thereby put different fluids close to one another on the exterior surface 14.

The Rotating Roll

As noted above, the rotating roll 10 comprises an exterior surface 14 that substantially surrounds its central longitudinal axis 12. In an embodiment, the rotating roll 10 rotates about the central longitudinal axis 12. The rotating speed of the roll 10 can be any speed suitable for the processing being performed. In one nonlimiting example, the roll 10 rotates at a surface speed of 10 ft/minute, or from about 10 ft/minute to about 5000 ft/minute, or at about 500 ft/minute to 3000 ft/minute. The rotating roll 10 may also have an outside diameter suitable for processing needs. In a nonlimiting example, the rotating roll may have an outside diameter about 25 mm or greater, or from about 25 mm to about 900 mm, 150 mm to 510 mm.

It has been found that providing a fluid network as described herein can be effective at maintaining desired flow rates and pressures throughout the entirety of the fluid network, even with relatively small diameter rolls operating at relatively high surface speeds. In one nonlimiting example, a rotating roll 10 with an outer diameter (i.e., the diameter from the central axis 12 to the exterior surface 14) of 150 mm can operate with a surface speed of at least 1000 ft/minute while maintaining uniform flow at all points on the roll surface. In previous tests with a rotating roll having an outer diameter of 150 mm at a speed of 1000 ft/minute and containing an annular fluid micro-reservoir extending at least half the length of the roll, the fluid flow exhibited significant non-uniformity in both axial and circumferential directions. The fluid network 18 of the instant invention overcomes these prior limitations and enables the application of uniform fluid patterns with a wide range of fluids while using a wide range of roll sizes and operating over a wide range of speeds. Moreover, the roll 10 and network 18 of the present invention are capable of depositing fluids in a variety of sizes, including very large and very small patterns, despite the size of the roll 10.

The exterior surface 14 of the roll 10 substantially surrounds the vascular network 18 which is disposed in the interior region 16 of the roll 10. In one embodiment, the roll 10 is in the shape of a cylinder. However, one of skill in the art will readily recognize that the roll 10 may comprise any shape suitable for enclosing the vascular network 18 and rotating as required for the deposition of fluid in accordance with the present disclosure.

The exterior surface 14 comprises one or more fluid exits 30. In addition, the exterior surface 14 may comprise one or more regions. Fig. 16 depicts an embodiment where the exterior surface 14 comprises a first exterior region 54 and a second exterior region 56. The fluid exits 30 of the vascular network 18 may be disposed in the first region 54. The second region 56 may be void of fluid exits 30. Likewise, as shown for example in Fig. 17, the interior region 16 may comprise a first interior region 58 and a second interior region 60. The vascular network 18 may be disposed within the first interior region 58, and the second interior region 60 may be void of the vascular network 18. Importantly, by building the vascular network 18 such that it only feeds the region of the roll 10 where fluid is to be deposited from, hygiene issues (such as bacterial growth from stagnant and/or built up fluid) can be avoided.

In one embodiment, the exterior surface 14 of the roll 10 can be multi-radiused (i.e., comprise different elevations at different points). In a nonlimiting example, the fluid exits 30 and/or micro-reservoirs 39 may be designed such that they comprise different depths, widths and/or aspect ratios, causing the surface 14 to be multi-radiused.

In a further embodiment, as shown for example in Fig. 18, the rotating roll 10 includes a hole 62, slot, groove, aperture or any other similar void space to lighten the weight of the roll 10. The roll 10 may comprise a shaft 64 through its center to provide structural stability as shown in Fig. 17. Alternatively, a tube, inner support ring or other common structures, such as lattice networks, known to those of skill in the art could be used to provide structural stability as well.

In one nonlimiting example (also shown in Fig. 19), the roll 10 has a length, L, of about 100 inches or greater.

The roll 10 may also be temperature-controlled using, for example, heated oils, chilled glycol, mechanical heaters or other technologies known in the art. In one nonlimiting example, sections of the roll 10 are provided at different temperatures. In another nonlimiting example, one or more channels are temperature-controlled. In an embodiment, the roll 10 or the network 18 is controlled so that one or more of fluids may be provide at a temperature between 0° F and 500° F, such as, for example, between 5 Celsius and 50 Celsius.

As shown in Fig. 20, a plurality of rotating rolls (10a, 10b), each having its own vascular network (18a, 18b), may be employed. The plurality of rotating rolls 10a, 10b may be positioned around a backing surface 200 as discussed below. Each roll 10 may be provided with one or more fluids, which may be the same or different. In addition, one or more fluids within one roll 10a may be the same or different from the one or more fluids in the other roll 10b. A fluid deposited onto a substrate 50 from a roll 10a may be registered with a fluid deposited onto the substrate 50 from another roll 10b or another source, or may be registered with product features

51, including but not limited to embossments, perforations, apertures, and printed indicia. For example, a fluid exit 30 may be disposed such that it aligns a product feature 51 on the substrate 50 with the exiting fluid as shown in Fig. 21. In an alternative embodiment, a fluid deposited onto a substrate 50 from a roll 10a may overlay a fluid deposited onto the substrate 50 from another roll 10b or deposited from another source. In yet another embodiment, a fluid deposited onto a substrate 50 from a roll 10a may blend with a fluid deposited from another roll 10b or from another source.

The use of a plurality of rolls 10 enhances the delivery of fluids to a substrate. As discussed in more detail below, the vascular network 18 of the present invention permits more precise fluid deposition. Thus, the use of multiple rolls 10a, 10b with multiple fluids can create a product that has multiple fluids deposited on the substrate in a controlled manner to deliver an optimized pattern. Further, because multiple fluids can be deposited from one roll 10, a single roll 10 can produce a product that has more than one fluid versus known apparatuses and the combination of a plurality of rolls 10 permits a wide variety of fluid and or pattern combinations to be produced from a limited number of rolls 10.

In another embodiment, the number of fluids in each roll 10 may be changed. For example, one roll 10 may have 8 fluids, another roll 10 may have 4 fluids, and another roll 10 may have 3 fluids. Three rolls 10 are used for illustration purposes herein, but one of skill in the art will recognize that any number of rolls 10, any number of fluids within a roll 10, and any combination and/or order of fluids and other fluids may be used to create desired fluid applications.

In a non-limiting embodiment, the fluid may be an emulsion. The emulsion may be a water in oil emulsion or an oil in water emulsion. The emulsion may be a High Internal Phase emulsion.

The emulsion may be a High Internal Phase Emulsion (HIPE), also referred to as a polyHIPE. To form a HIPE, an aqueous phase and an oil phase are combined in a ratio between about 8:1 and 140:1. In certain embodiments, the aqueous phase to oil phase ratio is between about 10:1 and about 75:1, and in certain other embodiments the aqueous phase to oil phase ratio is between about 13:1 and about 65:1. This is termed the "water-to-oil" or W:O ratio and can be used to determine the density of the resulting polyHIPE foam. As discussed, the oil phase may contain one or more of monomers, comonomers, photoinitiators, crosslinkers, and emulsifiers, as well as optional components. The water phase will contain water and in certain embodiments one or more components such as electrolyte, initiator, or optional components.

The HIPE can be formed from the combined aqueous and oil phases by subjecting these combined phases to shear agitation in a mixing chamber or mixing zone. The combined aqueous and oil phases are subjected to shear agitation to produce a stable HIPE having aqueous droplets of the desired size. An initiator may be present in the aqueous phase, or an initiator may be introduced during the foam making process, and in certain embodiments, after the HIPE has been formed. The emulsion making process produces a HIPE where the aqueous phase droplets are dispersed to such an extent that the resulting HIPE foam will have the desired structural characteristics. Emulsification of the aqueous and oil phase combination in the mixing zone may involve the use of a mixing or agitation device such as an impeller, by passing the combined aqueous and oil phases through a series of static mixers at a rate necessary to impart the requisite shear, or combinations of both. Once formed, the HIPE can then be withdrawn or pumped from the mixing zone. One method for forming HIPEs using a continuous process is described in U.S. Pat. No. 5,149,720 (DesMarais et al), issued Sep. 22, 1992; U.S. Pat. No. 5,827,909 (DesMarais) issued Oct. 27, 1998; and U.S. Pat. No. 6,369,121 (Catalfamo et al.) issued Apr. 9, 2002.

Following polymerization, the resulting foam pieces are saturated with aqueous phase that needs to be removed to obtain substantially dry foam pieces. In certain embodiments, foam pieces can be squeezed free of most of the aqueous phase by using compression, for example by running the heterogeneous mass comprising the foam pieces through one or more pairs of nip rollers. The nip rollers can be positioned such that they squeeze the aqueous phase out of the foam pieces. The nip rollers can be porous and have a vacuum applied from the inside such that they assist in drawing aqueous phase out of the foam pieces. In certain embodiments, nip rollers can be positioned in pairs, such that a first nip roller is located above a liquid permeable belt, such as a belt having pores or composed of a mesh-like material and a second opposing nip roller facing the first nip roller and located below the liquid permeable belt. One of the pair, for example the first nip roller can be pressurized while the other, for example the second nip roller, can be evacuated, so as to both blow and draw the aqueous phase out the of the foam. The nip rollers may also be heated to assist in removing the aqueous phase. In certain embodiments, nip rollers are only applied to non-rigid foams, that is, foams whose walls would not be destroyed by compressing the foam pieces.

In certain embodiments, in place of or in combination with nip rollers, the aqueous phase may be removed by sending the foam pieces through a drying zone where it is heated, exposed to a vacuum, or a combination of heat and vacuum exposure. Heat can be applied, for example, by running the foam though a forced air oven, IR oven, microwave oven or radiowave oven. The

extent to which a foam is dried depends on the application. In certain embodiments, greater than 50% of the aqueous phase is removed. In certain other embodiments greater than 90%, and in still other embodiments greater than 95% of the aqueous phase is removed during the drying process.

5 In an embodiment, open cell foam is produced from the polymerization of the monomers having a continuous oil phase of a High Internal Phase Emulsion (HIPE). The HIPE may have two phases. One phase is a continuous oil phase having monomers that are polymerized to form a HIPE foam and an emulsifier to help stabilize the HIPE. The oil phase may also include one or more photoinitiators. The monomer component may be present in an amount of from about 80%
10 to about 99%, and in certain embodiments from about 85% to about 95% by weight of the oil phase. The emulsifier component, which is soluble in the oil phase and suitable for forming a stable water-in-oil emulsion may be present in the oil phase in an amount of from about 1% to about 20% by weight of the oil phase. The emulsion may be formed at an emulsification temperature of from about 5° C to about 130° C and in certain embodiments from about 50° C to
15 about 100° C.

 In general, the monomers will include from about 20% to about 97% by weight of the oil phase at least one substantially water-insoluble monofunctional alkyl acrylate or alkyl methacrylate. For example, monomers of this type may include C₄-C₁₈ alkyl acrylates and C₂-C₁₈ methacrylates, such as ethylhexyl acrylate, butyl acrylate, hexyl acrylate, octyl acrylate, nonyl
20 acrylate, decyl acrylate, isodecyl acrylate, tetradecyl acrylate, benzyl acrylate, nonyl phenyl acrylate, hexyl methacrylate, 2-ethylhexyl methacrylate, octyl methacrylate, nonyl methacrylate, decyl methacrylate, isodecyl methacrylate, dodecyl methacrylate, tetradecyl methacrylate, and octadecyl methacrylate.

 The oil phase may also have from about 2% to about 40%, and in certain embodiments
25 from about 10% to about 30%, by weight of the oil phase, a substantially water-insoluble, polyfunctional crosslinking alkyl acrylate or methacrylate. This crosslinking comonomer, or crosslinker, is added to confer strength and resilience to the resulting HIPE foam. Examples of crosslinking monomers of this type may have monomers containing two or more activated acrylate, methacrylate groups, or combinations thereof. Nonlimiting examples of this group
30 include 1,6-hexanedioldiacrylate, 1,4-butanedioldimethacrylate, trimethylolpropane triacrylate, trimethylolpropane trimethacrylate, 1,12-dodecyldimethacrylate, 1,14-tetradecanedioldimethacrylate, ethylene glycol dimethacrylate, neopentyl glycol diacrylate (2,2-dimethylpropanediol diacrylate), hexanediol acrylate methacrylate, glucose pentaacrylate,

sorbitan pentaacrylate, and the like. Other examples of crosslinkers contain a mixture of acrylate and methacrylate moieties, such as ethylene glycol acrylate-methacrylate and neopentyl glycol acrylate-methacrylate. The ratio of methacrylate:acrylate group in the mixed crosslinker may be varied from 50:50 to any other ratio as needed.

5 Any third substantially water-insoluble comonomer may be added to the oil phase in weight percentages of from about 0% to about 15% by weight of the oil phase, in certain embodiments from about 2% to about 8%, to modify properties of the HIPE foams. In certain
10 embodiments, "toughening" monomers may be desired which impart toughness to the resulting HIPE foam. These include monomers such as styrene, vinyl chloride, vinylidene chloride, isoprene, and chloroprene. Without being bound by theory, it is believed that such monomers aid
15 in stabilizing the HIPE during polymerization (also known as "curing") to provide a more homogeneous and better formed HIPE foam which results in better toughness, tensile strength, abrasion resistance, and the like. Monomers may also be added to confer flame retardancy as disclosed in U.S. Pat. No. 6,160,028 (Dyer) issued Dec. 12, 2000. Monomers may be added to
20 confer color, for example vinyl ferrocene, fluorescent properties, radiation resistance, opacity to radiation, for example lead tetraacrylate, to disperse charge, to reflect incident infrared light, to absorb radio waves, to form a wettable surface on the HIPE foam struts, or for any other desired property in a HIPE foam. In some cases, these additional monomers may slow the overall process of conversion of HIPE to HIPE foam, the tradeoff being necessary if the desired property
25 is to be conferred. Thus, such monomers can be used to slow down the polymerization rate of a HIPE. Examples of monomers of this type can have styrene and vinyl chloride.

The oil phase may further contain an emulsifier used for stabilizing the HIPE. Emulsifiers used in a HIPE can include: (a) sorbitan monoesters of branched C₁₆-C₂₄ fatty acids; linear unsaturated C₁₆-C₂₂ fatty acids; and linear saturated C₁₂-C₁₄ fatty acids, such as sorbitan
25 monooleate, sorbitan monomyristate, and sorbitan monoesters, sorbitan monolaurate diglycerol monooleate (DGMO), polyglycerol monoisostearate (PGMIS), and polyglycerol monomyristate (PGMM); (b) polyglycerol monoesters of -branched C₁₆-C₂₄ fatty acids, linear unsaturated C₁₆-C₂₂ fatty acids, or linear saturated C₁₂-C₁₄ fatty acids, such as diglycerol monooleate (for example diglycerol monoesters of C18:1 fatty acids), diglycerol monomyristate, diglycerol
30 monoisostearate, and diglycerol monoesters; (c) diglycerol monoaliphatic ethers of -branched C₁₆-C₂₄ alcohols, linear unsaturated C₁₆-C₂₂ alcohols, and linear saturated C₁₂-C₁₄ alcohols, and mixtures of these emulsifiers. See U.S. Pat. No. 5,287,207 (Dyer et al.), issued Feb. 7, 1995 and U.S. Pat. No. 5,500,451 (Goldman et al.) issued Mar. 19, 1996. Another emulsifier that may be

used is polyglycerol succinate (PGS), which is formed from an alkyl succinate, glycerol, and triglycerol.

Such emulsifiers, and combinations thereof, may be added to the oil phase so that they can have between about 1% and about 20%, in certain embodiments from about 2% to about 5 15%, and in certain other embodiments from about 3% to about 12% by weight of the oil phase. In certain embodiments, coemulsifiers may also be used to provide additional control of cell size, cell size distribution, and emulsion stability. Examples of coemulsifiers include phosphatidyl cholines and phosphatidyl choline-containing compositions, aliphatic betaines, long chain C₁₂-C₂₂ dialiphatic quaternary ammonium salts, short chain C₁-C₄ dialiphatic quaternary ammonium 10 salts, long chain C₁₂-C₂₂ dialkoyl(alkenoyl)-2-hydroxyethyl, short chain C₁-C₄ dialiphatic quaternary ammonium salts, long chain C₁₂-C₂₂ dialiphatic imidazolinium quaternary ammonium salts, short chain C₁-C₄ dialiphatic imidazolinium quaternary ammonium salts, long chain C₁₂-C₂₂ monoaliphatic benzyl quaternary ammonium salts, long chain C₁₂-C₂₂ dialkoyl(alkenoyl)-2-aminoethyl, short chain C₁-C₄ monoaliphatic benzyl quaternary ammonium salts, short chain C₁-C₄ monohydroxyaliphatic quaternary ammonium salts. In certain embodiments, ditallow 15 dimethyl ammonium methyl sulfate (DTDMA) may be used as a coemulsifier.

The oil phase may comprise a photoinitiator at between about 0.05% and about 10%, and in certain embodiments between about 0.2% and about 10% by weight of the oil phase. Lower amounts of photoinitiator allow light to better penetrate the HIPE foam, which can provide for 20 polymerization deeper into the HIPE foam. However, if polymerization is done in an oxygen-containing environment, there should be enough photoinitiator to initiate the polymerization and overcome oxygen inhibition. Photoinitiators can respond rapidly and efficiently to a light source with the production of radicals, cations, and other species that are capable of initiating a polymerization reaction. The photoinitiators used in the present invention may absorb UV light 25 at wavelengths of about 200 nanometers (nm) to about 800 nm, in certain embodiments about 200 nm to about 350 nm. If the photoinitiator is in the oil phase, suitable types of oil-soluble photoinitiators include benzyl ketals, α -hydroxyalkyl phenones, α -amino alkyl phenones, and acylphosphine oxides. Examples of photoinitiators include 2,4,6-[trimethylbenzoyldiphosphine] oxide in combination with 2-hydroxy-2-methyl-1-phenylpropan-1-one (50:50 blend of the two is 30 sold by Ciba Speciality Chemicals, Ludwigshafen, Germany as DAROCUR® 4265); benzyl dimethyl ketal (sold by Ciba Geigy as IRGACURE 651); α,α -dimethoxy- α -hydroxy acetophenone (sold by Ciba Speciality Chemicals as DAROCUR® 1173); 2-methyl-1-[4-(methyl thio) phenyl]-2-morpholino-propan-1-one (sold by Ciba Speciality Chemicals as IRGACURE®

907); 1-hydroxycyclohexyl-phenyl ketone (sold by Ciba Speciality Chemicals as IRGACURE® 184); bis(2,4,6-trimethylbenzoyl)-phenylphosphineoxide (sold by Ciba Speciality Chemicals as IRGACURE 819); diethoxyacetophenone, and 4-(2-hydroxyethoxy)phenyl-(2-hydroxy-2-methylpropyl) ketone (sold by Ciba Speciality Chemicals as IRGACURE® 2959); and Oligo [2-hydroxy-2-methyl-1-[4-(1-methylvinyl) phenyl]propanone] (sold by Lamberti spa, Gallarate, Italy as ESACURE® KIP EM.

The dispersed aqueous phase of a HIPE can have water, and may also have one or more components, such as initiator, photoinitiator, or electrolyte, wherein in certain embodiments, the one or more components are at least partially water soluble.

One component of the aqueous phase may be a water-soluble electrolyte. The water phase may contain from about 0.2% to about 40%, in certain embodiments from about 2% to about 20%, by weight of the aqueous phase of a water-soluble electrolyte. The electrolyte minimizes the tendency of monomers, comonomers, and crosslinkers that are primarily oil soluble to also dissolve in the aqueous phase. Examples of electrolytes include chlorides or sulfates of alkaline earth metals such as calcium or magnesium and chlorides or sulfates of alkali earth metals such as sodium. Such electrolyte can include a buffering agent for the control of pH during the polymerization, including such inorganic counterions as phosphate, borate, and carbonate, and mixtures thereof. Water soluble monomers may also be used in the aqueous phase, examples being acrylic acid and vinyl acetate.

Another component that may be present in the aqueous phase is a water-soluble free-radical initiator. The initiator can be present at up to about 20 mole percent based on the total moles of polymerizable monomers present in the oil phase. In certain embodiments, the initiator is present in an amount of from about 0.001 to about 10 mole percent based on the total moles of polymerizable monomers in the oil phase. Suitable initiators include ammonium persulfate, sodium persulfate, potassium persulfate, 2,2'-azobis(N,N'-dimethyleneisobutyramidine)dihydrochloride, and other suitable azo initiators. In certain embodiments, to reduce the potential for premature polymerization which may clog the emulsification system, addition of the initiator to the monomer phase may be just after or near the end of emulsification.

Photoinitiators present in the aqueous phase may be at least partially water soluble and can have between about 0.05% and about 10%, and in certain embodiments between about 0.2% and about 10% by weight of the aqueous phase. Lower amounts of photoinitiator allow light to better penetrate the HIPE foam, which can provide for polymerization deeper into the HIPE

foam. However, if polymerization is done in an oxygen-containing environment, there should be enough photoinitiator to initiate the polymerization and overcome oxygen inhibition. Photoinitiators can respond rapidly and efficiently to a light source with the production of radicals, cations, and other species that are capable of initiating a polymerization reaction. The photoinitiators used in the present invention may absorb UV light at wavelengths of from about 200 nanometers (nm) to about 800 nm, in certain embodiments from about 200 nm to about 350 nm, and in certain embodiments from about 350 nm to about 450 nm. If the photoinitiator is in the aqueous phase, suitable types of water-soluble photoinitiators include benzophenones, benzils, and thioxanthenes. Examples of photoinitiators include 2,2'-Azobis[2-(2-imidazolin-2-yl)propane]dihydrochloride; 2,2'-Azobis[2-(2-imidazolin-2-yl)propane]disulfate dehydrate; 2,2'-Azobis(1-imino-1-pyrrolidino-2-ethylpropane)dihydrochloride; 2,2'-Azobis[2-methyl-N-(2-hydroxyethyl)propionamide]; 2,2'-Azobis(2-methylpropionamidine)dihydrochloride; 2,2'-dicarboxymethoxydibenzalacetone, 4,4'-dicarboxymethoxydibenzalacetone, 4,4'-dicarboxymethoxydibenzalcyclohexanone, 4-dimethylamino-4'-carboxymethoxydibenzalacetone; and 4,4'-disulphoxymethoxydibenzalacetone. Other suitable photoinitiators that can be used in the present invention are listed in U.S. Pat. No. 4,824,765 (Sperry et al.) issued Apr. 25, 1989.

In addition to the previously described components other components may be included in either the aqueous or oil phase of a HIPE. Examples include antioxidants, for example hindered phenolics, hindered amine light stabilizers; plasticizers, for example dioctyl phthalate, dinonyl sebacate; flame retardants, for example halogenated hydrocarbons, phosphates, borates, inorganic salts such as antimony trioxide or ammonium phosphate or magnesium hydroxide; dyes and pigments; fluorescers; filler pieces, for example starch, titanium dioxide, carbon black, or calcium carbonate; fibers; chain transfer agents; odor absorbers, for example activated carbon particulates; dissolved polymers; dissolved oligomers; and the like.

Dependent upon the HIPE chemistry, the HIPE may be delivered through the roll at a temperature between 5 Celsius and 90 Celsius, preferably between 5 Celsius and 70 Celsius, such as, for example, between 15 Celsius and 50 Celsius, such as, 16 Celsius, 17 Celsius, 18 Celsius, 19 Celsius, 20 Celsius, 21 Celsius, 22 Celsius, 23 Celsius, 24 Celsius, 25 Celsius, 26 Celsius, 27 Celsius, 28 Celsius, 29 Celsius, 30 Celsius, 35 Celsius, 40 Celsius, or 45 Celsius.

The fluid may also be a chemical that will react with another chemical in the same roll, such as, for example, a polyol and an isocyanate or a reduction oxidation polymerization reaction wherein one chemical comprises the reducing agent and the second chemical comprises the oxidizing agent such as those described in U.S. Patent No. 6,323,250 filed on November 14,

2000 with priority to JP patent application 11-328683, filed on November 18, 1999; incorporated herein by reference. The two chemicals may be combined within the roll or at the opening of the roll to the substrate such that they may react upon exiting the roll. Additionally, the polyol and the isocyanate may be combined with a blowing agent prior to entering the roll provided that the materials do not set up to form a solid polyurethane foam prior to exiting the roll.

The Sleeve

Turning to Figs. 25 and 26, a sleeve 100 may be disposed on the exterior surface 14 of the roll 10 or, said differently, the roll 10 may be disposed within an inner region 130 of the sleeve 100. The sleeve 100 and roll 10 may comprise a sleeve and roll system 160 incorporating any of their respective components as described herein.

In one nonlimiting example, the sleeve 100 is disposed on the entire exterior surface 14 such that it substantially surrounds the rotating roll 10. Alternatively, the sleeve 100 may be disposed in a surrounding relationship about a portion of the rotating roll 10 to form a sleeve coverage area 105. In such case, one fluid exit 30 may be in operative relationship with the substrate without the fluid passing through the sleeve 100, while another fluid exit 30 can be registered or aligned with a sleeve exit 120. In other words, one of the fluid exits may be outside of the sleeve coverage area 105. In another nonlimiting example, the sleeve 100 is substantially cylindrical. In one embodiment, the sleeve 100 is removable from the roll 10. The sleeve 100 may comprise a central axis 110 and an inner region 130 substantially surrounding the central axis 110. The inner region 130 may comprise a first circumference, C_1 . The rotating roll 10 may have a second circumference, C_2 , defined by its exterior surface 14. The first circumference C_1 may be larger than the second circumference C_2 . In a further embodiment depicted in Fig. 26, the sleeve 100 may be disposed around the rotating roll 10 such that its central axis 110 and the central longitudinal axis 12 of the roll 10 are substantially coincident.

The sleeve 100 may comprise a metal material. The metal material can have a Rockwell hardness value of about B79. In one nonlimiting example, the metal material is stainless steel. In another nonlimiting example, the outer surface 140 of the sleeve 100 can have a taber abrasion testing factor greater than the taber abrasion testing factor of the exterior surface 14 of the roll 10. Having a greater taber abrasion factor than the exterior surface 14 of the roll 10 and/or having a hardness value of about B79 can protect the roll 10 from exposure to substances that could change its properties, such as UV rays. Further, the hardness and/or taber abrasion of the outer surface 140 allows for harder or sharper items, such as doctor blades to come in contact with the sleeve 100 – which may, for example, aid in cleaning. Further still, the sleeve 100 can enhance hygiene. For example, the outer surface 140 may be made of a material that is less likely to

attract or retain contaminants (i.e., the outer surface 140 may have a lower coefficient of friction relative to the exterior surface 14 of the roll 10 or may be coated to repel contaminants etc.).

The outer surface 140 of the sleeve 100 may comprise differently radiused portions 33 in the same manner as the roll 10 may comprise differently radiused portions 33. By altering the
5 radius of the outer surface, the sleeve 100 can be customized to provide a wide variety of textural properties such as elasticity or hardness. In one embodiment, the sleeve 100 may have a hardness value up to Shore C60. In another embodiment, the sleeve 100 may comprise a hardness value of at least P&J 150. The sleeve may comprise a hardness value between Shore C60 and P&G 150.

10 In a further embodiment, the sleeve may have a thickness, T, of greater than 1 mm or greater than 1.5 mm. In yet another embodiment, the sleeve 100 comprises a mesh or screen material. The screen may comprise a thickness, T, of less than about 1.5 mm or less than about 0.5 mm. Such screens are commercially available from the Stork Screen Company. As
15 illustrated in Fig. 27, thickness, T, is the difference between the outer diameter, ODS, of the sleeve 100 (i.e., the diameter from the central axis 110 to the exterior surface 140) to the inner diameter, IDS, of the sleeve 100 (i.e., the diameter from the central axis 110 to the outmost point of the inner region 130). Where the sleeve 100 comprises differently radiused portions or the thickness, T, otherwise varies, the thickness, T, can be determined by the greatest distance
20 between the outer diameter, ODS, and the inner diameter, IDS as shown in Fig. 27. In a further nonlimiting example, the sleeve 100 may be coated with one or more materials that would allow a change in surface tension and/or other properties beneficial for the invention disclosed herein. The sleeve 100 may be made from one unitary body of material or from more than one segments of material.

As shown in Fig. 28, the sleeve 100 may comprise a sleeve exit 120. The sleeve exit 120
25 may be registered or otherwise associated with a fluid exit 30. In a further embodiment, the sleeve exit 120 may be registered or otherwise associated with the opening 46 of a micro-reservoir 39. In still another embodiment, the sleeve 100 may comprise a plurality of sleeve exits 120. One or more sleeve exits 120 may be registered or otherwise associated with a fluid exit 30 and/or the opening 46 of a micro-reservoir 39. In one nonlimiting example, there may be from
30 about 1 to about 1000 sleeve exits 120 registered or associated with an opening 46 of a micro-reservoir 39. In another nonlimiting example, the opening 46 of a micro-reservoir 39 is less than about 16 mm^2 , or less than about 9 mm^2 or less than about 4 mm^2 or 0.1 mm^2 .

As shown in Fig. 29, a sleeve exit 120 may comprise a meeting point 124 where fluid enters the sleeve 100 and a release point 125 where fluid leaves the sleeve 100 to contact the

substrate 50. In addition, the sleeve exit 120 may comprise have a first side 121 and a second side 122 substantially opposite the first side 121 and coterminous with the outmost part of the outer surface 140. The sleeve exit may be registered or associated with the exit point 32 of a fluid exit 30 and/or reservoir opening 46 at the meeting point 124. The meeting point 124 may be located on the first side 121. The release point 125 may be located on the second side 122. In one nonlimiting example, the meeting point 124 and release point 125 have the substantially the same cross-sectional area as shown in Fig. 28. In another nonlimiting example, the meeting point 124 and the release point 125 have different cross-sectional areas.

A sleeve exit 120 may have an aspect ratio of at least 10, or at least 25. The sleeve exit 120 may be created in the sleeve 100 by any suitable means. In one nonlimiting example, the sleeve exit 120 is laser drilled into the sleeve 100. A number of shapes may be achieved. In another nonlimiting example, the sleeve exit 120 may be shaped to form a differently radiused portion 33, such as a relieved portion 34 and/or a raised portion 35. In an example of the relieved portion 34, the meeting point 124 can comprise a cross-sectional area smaller than the cross-sectional area of the second side 122, such that a pool of fluid may be provided in the relieved portion 35 and transferred to a substrate 50. One of skill in the art will recognize that the “pool” of fluid may remain a small amount of fluid but may be a higher volume than fluid provided in other configurations of the sleeve exit 120. Any combination of arrangements of sleeve exit 120 designs may be provided. As with the differently radiused portions 33 of the roll 10, one differently radiused portion 33 may comprise both a raised portion 35 and a relieved portion 34. Moreover, the differently radiused portion 33 may comprise one or more sides 37, and the meeting point 124 and/or the release point 125 may be located on a side 37. In one nonlimiting example, a fluid exit 30 and/or reservoir 39 having a differently radiused portion 33 is registered or associated with a sleeve exit 120 having a differently radiused portion 33.

In an embodiment, the sleeve 100 has a thickness, T , of greater than about 1.5 mm, or between about 1.5 mm or about 10 mm, and a sleeve exit 120 has an aspect ratio of greater than about 10. In another embodiment, the sleeve 100 has a thickness, T , of less than about 4 mm, or less than about 2 mm, or less than about 1.5 mm, or less than about 0.5 mm. The cross-sectional area of meeting point 124 of the sleeve exit 120 may be less than about 0.5, or less than about 0.3 or less than about 0.15 times the cross-sectional area of the fluid exit point 32 or reservoir opening 46.

The sleeve exits 120 may be arranged in any desired manner, with the only constraint being the physical space. If desired, the sleeve exits 120 may be placed as close as the physical space allows. In an alternative embodiment, the fluid exits 30 collectively may form a pattern 52

to be deposited on a substrate 50, such as a line or plurality of lines, aesthetic design and/or letters (not shown).

The sleeve 100 may be fitted onto the rotating roll 10 by any suitable means, including but not limited to compression or shrink fit.

5

Optimizing Design of the Vascular Network

It is believed that the design of the vascular network 18 permits optimal control of fluid deposition in multiple ways. First, the ability to separately customize various components of the system (e.g., the diameter of the roll 10, diameters of the channels 20, route and length of the fluid paths 48) allows for various objectives to be achieved with just one roll 10. Essentially, as discussed more completely in the method section below, the designer determines where and at what rate fluid is to be deposited, selects fluid(s) having desirable properties, designs the network 18 to achieve the determined output and objectives (e.g., arranging the trees, designing tree size, etc.) and selects a fluid delivery system (e.g., the channel 20 sizes, junctions 21, feed systems such as pumps at inlet 28, rotary union 230 etc.). Objectives include but are not limited to uniformity in fluid deposition levels or rates despite different exits 30, 120, uniformity in volumetric flow rates despite different channels 20, minimal flow rate and/or pressure fluctuations throughout the network 18, uniformity in pressure drops despite different trees 23, control of shear rates on the fluid, and the capability to apply very precise, small flows of fluid to a substrate 50. Various other objectives could be met as well. Second, the sleeve 100 may be used in conjunction with the vascular network 18 and roll 10 to overcome physical constraints (e.g., available space in the interior region 16). Third, the substantially radial design of the vascular network 18 overcomes challenges associated with rotating rolls 10 used for fluid deposition.

25

Customization

The following nonlimiting examples highlight the capabilities of the vascular network 18 through customizing various factors:

Minimal flow rate and/or pressure fluctuations may be achieved by, for example, minimizing the differential between the cross-sectional areas of associated channels. For example, the cross-sectional area decreases at each junction 21. In one embodiment, fluid is provided at the inlet 28 at a pressure of less than 10 psi, or less than 5 psi. In a further embodiment, the pressure decreases at each junction 21 by less than 2 psi. Minimizing flow rate and pressure fluctuations also prevents air penetration of the interior region 15 of the roll 10 which could cause fluid flow disruption or even starvation.

30

To achieve uniform fluid deposition, the fluid paths 48 may also be directed (by use of baffles to slow or direct fluid flow, for example) or configured to have equal path lengths. Fig. 30 depicts one embodiment in which the vascular network 18 has a first path length, FP, and a second path length, SP. The first path length, FP, is the length between the first capillary 24a and a fluid exits 30 with which the first capillary 24a is in fluid communication. The second path length, SP, is the length between the second capillary 24b and a fluid exits 30 with which the second capillary 24b is in fluid communication. In one nonlimiting example, the first path length, FP, is substantially equal to the second path length, SP. Without being bound by theory, having substantially equal path lengths permits substantially equal distribution of the fluid notwithstanding the different paths 48 through which the fluid travels. Essentially, fluid enters the inlet 28 at the same velocity and/or pressure, and then travels the same distance to its respective fluid exit 30. As such, the fluid is more likely to be deposited in a similar manner despite the distinct path 48. In addition, the radial nature of the paths 48 more easily permits having equal path lengths within the confines of the rotating roll's 10 exterior surface 14.

Likewise, it is believed the same uniform deposition of fluid can be achieved by having substantially equal area change from the main artery 22 to each fluid exit 30 with which it is in fluid communication. In one nonlimiting example, each capillary 24 or sub-capillary 26 on a given level has substantially the same area, such that the change in area between the main artery 22 and each of the fluid exits 30 is substantially the same despite distinct fluid paths 48.

In another embodiment, substantially the same diameter change can be achieved in two different fluid paths, which would also result in uniform fluid deposition despite the different paths. As shown in Figs. 31A and 31, the different paths may be in different trees 23 extending from the same main artery 22, or in trees 23 that extend from different main arteries 22. By way of illustration, the network 18 may comprise a first capillary 24a in fluid communication with one or more fluid exits 30 through a first fluid path 48a and a second capillary 24b in fluid communication with one or more fluid exits 30 through a second fluid path 48b. The first capillary 24a and the second capillary 24b which may extend from the same main artery 22 through the same junction 21 and thereby form a part of the same tree 23. Alternatively, the first capillary 24a and the second capillary 24b which may extend from the same main artery 22 through separate junctions 21 and thereby form separate trees 23a, 23b. The network 18 may further comprise a first diameter change along the first fluid path 48a and a second diameter change along a second fluid path 48b. The first diameter change is the difference between $Diameter_{Start1}$ and $Diameter_{End1}$, where:

$Diameter_{Start1}$ is the average diameter of the first capillary 24a; and

$Diameter_{End1}$ is the average diameter of a first terminating channel TC_1 , wherein the first terminating channel TC_1 is associated with a fluid exit 30 with which the first capillary 24a is in fluid communication.

The second diameter change is the difference between $Diameter_{Start2}$ and $Diameter_{End2}$, where:

5 $Diameter_{Start2}$ is the average diameter of the second capillary 24b; and

$Diameter_{End2}$ is the average diameter of a second terminating channel TC_2 , wherein the second terminating channel TC_2 is associated with a fluid exit 30 with which the second capillary 24b is in fluid communication.

10 The first diameter change may be substantially equivalent to the second diameter change, resulting in similar deposition of fluid at the end of each fluid path 48a, 48b.

Fig. 32 illustrates another embodiment where the network 18 may comprise two main arteries 22, a primary main artery 22c and a secondary artery 22d. A primary first capillary 24c may extend from the primary main artery 22c and a secondary capillary 24d may extend from the secondary main artery 22c. Each capillary 24c, 24d may be in fluid communication with one or more fluid exits 30. For clarity, the primary first capillary 24c may be in fluid communication with the primary main artery 22c and with one or more primary fluid exits 30c to form a primary tree 23c, and the secondary capillary 24d may be in fluid communication with the secondary main artery 22d and with one or more secondary fluid exits 30d to form a secondary tree 23d.

20 The network 18 can further comprise a primary diameter change and a secondary diameter change, where:

the primary diameter change comprises the difference between $Diameter_{StartP}$ and $Diameter_{EndP}$, where:

$Diameter_{StartP}$ is the average diameter of a primary first capillary 24c; and

25 $Diameter_{EndP}$ is the average diameter of a primary terminating channel TC_p , wherein the primary terminating channel TC_p is associated with the primary fluid exit 30c; and

the secondary diameter change comprises the difference between $Diameter_{StartS}$ and $Diameter_{EndS}$, wherein:

30 $Diameter_{StartS}$ is the average diameter of the secondary capillary; and

$Diameter_{EndS}$ is the average diameter of a secondary terminating channel TC_s , wherein the secondary terminating channel TC_s is associated with the secondary fluid exit 30d; and

35 The primary diameter change may be substantially equal to the secondary diameter change.

One nonlimiting example of customization of the network 18 involves the use of the following formula when designing each tree 23:

$$Diameter_{Level} = Diameter_{Start} * BR^{(-Level/(2+epsilon))}$$

Where:

$Diameter_{start}$ is the average diameter of an initial capillary 24_i that is associated with the main artery, disposed on Level 0. For example, the initial capillary 24_i may be the first capillary $24a$ or it may be the second capillary $24b$;

$Diameter_{Level}$ is the average diameter of a channel 20 at given tree level other than Level 0;

BR is the branching ratio of the tree 23 in vascular network 18. In one nonlimiting example, the branching ratio is 2, meaning that the tree 23 divides into two branches at each junction 21. The branching ratio may be a number greater than 1. In another nonlimiting example, the network 18 may comprise different branching at each junction 21. For example, one junction may divide into 3 branches and another may divide into 2 branches. In one such example, the branching ratio may be the average of number branch divisions at each junction 21;

$Level$ is an integer representing the tree 23 level, where 0 represents the tree level where the initial capillary 24_i is associated with the main artery 22, 1 represents the tree level where one or more sub-capillaries 26 are associated with the initial capillary 24_i , and so on; and

$Epsilon$ is a real number that is not equal to -2 and is used to represent the conditions below:

where $Epsilon < -2$, the diameters of the channels 20 progressively increase as the $level$ increases

where $Epsilon > -2$, the diameters of the channels 20 progressively decrease as the $level$ increases. The rate of decrease differs depending on how large the $epsilon$ value is. The larger the $epsilon$ value, the smaller the decrease in diameters.

Further to the above, $epsilon$ can be any real number other than -2. The $epsilon$ value may be selected based on shear sensitivity of the fluid, the desired level of uniformity in the fluid flow (i.e., the uniformity between fluid to separate exits), the desired pressure as the fluid exits the network 18 and/or the desired fluid drop or fluctuation within the network 18, the smallest possible orifice that can be formed for the fluid to exit, and physical constraints of the roll 10 such as how large the $Diameter_{start}$ can be. In one nonlimiting example, $epsilon$ is a real number between 1 and 2. In another nonlimiting example, $epsilon$ is about 1.5 or about 1.6.

By way of example, and as shown in Figs. 33A-33C, $epsilon$ may be 2. In such nonlimiting example, the channel diameters more steadily decrease with each increased $level$ as compared to lower $epsilon$ values. It is believed that pressure drop throughout the network 18 may be relatively low with this $epsilon$ value while working within the limited space within the roll 10.

As another example, as shown in Figs. 34A-34C, $epsilon$ can be 0. In such nonlimiting example, the velocity of the fluid is held constant as the fluid travels from the inlet 28 to the fluid exit 30. The shear rate and pressure drop increase as the fluid leaves the network as shown in

Figs. 34A -34C but not as sharply as they would if *epsilon* were lower, such as -1. In other words, the diameter decreases as the *level* increases, but at a slower pace than when *epsilon* is -1.

The skilled person will recognize that there are numerous options available for use in the disclosed formula depending on the desired results. Moreover, each tree 23 can be designed in the same manner (i.e., same values used for each variable) or differently, or each tree 23 can be designed to achieve the same effect despite different values or to achieve different effects. Further, the trees 23 and network 18 can be designed without the use of the formula.

In addition, the design of the fluid exits 30 (including the micro-reservoirs 39) can also contribute to optimization of the vascular network 18. In one embodiment, the area of micro-reservoirs 39 on the exterior surface 14 may vary. The exit length (i.e., the distance from the entry point 31 to the exit point 32) of each micro-reservoir 39 can be adjusted such that the pressure drop of each micro-reservoir is the same. This will result in uniform velocity from the various micro-reservoirs 39 despite their varied areas. Uniform velocity results in the same thickness of fluid being deposited by each exit 30 on each roll 10 rotation.

In yet another embodiment, one or more of the fluid exits 30 are designed to serve as limiting orifices. That is, there is a significantly higher pressure drop through the exits 30 than the pressure drop throughout the rest of the vascular network 18. This design can be achieved, for example, using the above formula where *epsilon* is -1. The design may resolve or cover imperfections or slight imbalances that exist in the network 18. Essentially, the fluid will still be deposited as desired despite imperfections because of the force with which the fluid is pushed out of the exits 30. This objective may also be achieved by designing one or more of the sleeve exits 120 to serve as limiting orifices (discussed in more detail below).

In yet another embodiment, the velocity at different exits 30 could be different in order to lay down different amounts of fluid. In one such example, the different exits 30 may be the same size or different sizes. The velocity may be varied by lowering the pressure drop at one of the exits 30 (as compared to the pressure drop at another exit 30). Fluid leaving the exit 30 that has the lower pressure drop will have higher velocity and therefore more fluid will be deposited.

Where multiple main arteries are employed as shown for example in Fig. 32, each main artery 22 has one or more trees 23, each having one or more levels of capillaries 24 and, possibly, sub-capillaries 26 as discussed above. Using the formulas and teachings above, the network 18 may be designed such that the pressure drop along a primary tree 23c extending from one main artery 22c can be substantially equal to the pressure drop along a secondary tree 24d extending from another main artery 22d. Likewise, the network 18 may be designed such that the change in

diameter along the primary tree 23c may be substantially equal to the change in diameter along the secondary tree 24d extending from a different main artery 22d.

Sleeve as Additional Customization Tool

The sleeve 100 may work in conjunction with the roll 10 and its network 18 to achieve
5 desired effects. Indeed, the sleeve 100 and roll 10 may comprise a sleeve and roll system 160 incorporating any of their respective components as described herein. For instance, the sleeve exits 120 may provide the same optimization as discussed above with respect to the design of fluid exits 30 (e.g., velocity of exiting fluid along different paths, AM tone control). In one nonlimiting example, a sleeve exit 120 may operate as a limiting orifice. In one such example,
10 the sleeve exit 120 is registered or otherwise associated with a fluid exit point 32 at a meeting point 124. As shown in Fig. 35, the cross-sectional area of the meeting point 124 may be less than the cross-sectional area of the exit point 32, causing the sleeve exit 120 to serve as a limiting orifice. For example, where the diameter of a channel 20 at the end of a fluid path 48 or the diameter or area of fluid exit 30 cannot be reduced (due to integrity of the structure), the sleeve
15 exit 120 can still operate to provide a smaller exit.

Turning to Fig. 36, the sleeve exits 120 can operate to supplement the equations above such that physical limitations of the vascular network 18 and/or roll 10 can be overcome. In other words, where the vascular network 18 or a tree 23 within the network 18 is designed according to the formula in the previous section, the sleeve exit 120 can be an additional component
20 of such formula. Essentially, the sleeve exit 120 can provide a supplementary tree 150. The supplementary tree 150 can be associated with a channel 20 in the underlying network tree 23. The supplementary tree could provide a number of supplementary levels, x . Thus, if a tree 23 associated with the supplementary tree 23 had n levels, the total aggregate design would comprise $n+x$ levels. Such supplementary tree levels could affect the fluid application by, for
25 example, acting as a limiting orifice and/or changing application pressure. The supplementary tree 150 could also eliminate the need for a reservoir 39 in the underlying network 18.

Overcoming Issues

The design of the network 18 compensates for the centripetal/centrifugal forces resulting from the rotation of the roll 10. In networks without substantially radial fluid paths 48,
30 centripetal/centrifugal force can impede the flow of fluids to the desired outlets. Deviation from radial paths can increase negative effects of centripetal/centrifugal force. Here, however, the substantially radial paths minimize deviation from radial flow more than fluid paths that are substantially axial or substantially circumferential. Essentially, the present invention enables operating with high centripetal forces.

It is also believed the radial design permits fluid to flow to exits 30, 120 in a more uniform manner. Contrarily, circumferential design may result in certain areas of the network being starved or void of fluid while other areas would have too much fluid. In other words, necessary differences in path lengths from a main artery 22 to a fluid exit 30 in a circumferential design would allow fluid to quickly travel to certain locations within the vascular network 18 while not adequately reaching other locations. The same may be true in an axial design.

Making the Roll

The rotating roll 10 and/or the vascular network 18 may be made through the use of stereo lithographic printing (SLA) or other forms of what is commonly known as 3D printing or Additive Manufacturing. In another nonlimiting example, the vascular network 18 is created by casting, such as a process analogous to lost wax printing, or any other means known in the art to create a network of channels 20 with predetermined paths 48. The roll 10 may be comprised of one unitary piece of material. In an alternative nonlimiting example, the roll 10 may be comprised of segments of material joined together. This would allow replacement of just a section of the roll 10 if there was localized damage to the roll 10 and enables fabrication of the roll 10 over a much wider range of machines.

Optional/Ancillary Parts

In an embodiment, the rotating roll 10 may be used in conjunction with a backing surface 200 as depicted in Figs. 37 and 38. The substrate 50 may be driven over the backing surface 200. In one nonlimiting example (see Fig. 37), the backing surface 200 and rotating roll 10 may be positioned at a distance away from each other. In such case, the distance between the backing surface 200 and rotating roll 10 may be substantially equal to or smaller than the caliper of the substrate 50. Alternatively, the rotating roll 10 may form a nip 205 with the backing surface 200 as shown in Fig. 38. The substrate 50 may contact the rotating roll 10 at the nip 205. The backing surface 200 may be made of any material suitable for providing a surface for the substrate 50 and/or providing pressure to facilitate dosing, such as providing compression and/or pressure at the nip 205. In one nonlimiting example, the backing surface 200 has a urethane surface. Alternatively, the backing surface 200 may have a steel surface or any suitable surface having a hardness value between Shore OO 10 and Rc80. In another nonlimiting example, the backing surface 200 may be used with a plurality of rotating rolls 10. The backing surface 200 may comprise vacuum regions 201 providing suction. The vacuum regions 201 may be registered or otherwise associated with fluid exits 30, micro-reservoirs 39 and/or sleeve exits 120

to facilitate transfer of fluid onto the substrate 50. Separately, the amount of substrate 50 that is wrapped about the backing surface 200 as well as the tension of the substrate with respect to the backing surface 200 may be purposefully controlled and even changed dynamically. Controlling the amount of wrap, the tension of the substrate 50 on the backing surface 200 can be achieved, for example, through adjusting the speeds of the rotating roll 10, the substrate 50 and/or the backing surface 200. Such control permits various application methods, such as smearing a fluid (e.g., a lotion) onto a substrate 50 and precise application of another fluid using the same equipment.

Turning to Fig. 39, the rotating roll 10 may be associated with a drive motor 210 to adjust the speed of the rotating roll 10. The drive motor 210 may be any suitable motor or mechanism known in the art. In addition, the drive motor 210 and/or rotating roll 10 may be controlled by any method or mechanism known in the art. In one nonlimiting example, the drive motor 210 is MPL-B4540F-MJ72AA, commercially available from Rockwell Automation.

In a further embodiment, the rotating roll 10 may be associated with a hygiene system 220. The hygiene system 220 may be any known system or mechanism suitable for the removal of debris and dust. Nonlimiting examples of hygiene systems 220 include vacuums, sprayers, doctor blade, brushes and blowers.

In still another embodiment, the rotating roll 10 may be associated with a rotary union 230. The rotary union 230 may have multiple ports and may supply one or more fluids to the vascular network 18 of a rotating roll 10. By way of nonlimiting example, up to eight individual fluids can be provided to a rotating roll 10. In another nonlimiting example, the rotary union 230 may supply one or more fluids to the vascular networks 18 of a plurality of rolls 10. From the rotary union 230, each fluid can be piped into the interior region 16 of the roll 10, specifically to the inlet 28. One of skill in the art will understand that a conventional multi-port rotary union 230 suitable for use with the present invention can typically be provided with up to forty-four passages and are suitable for use up to 7,500 lbs. per square inch of fluid pressure. A nonlimiting example of a suitable rotary union is described in U.S. Patent App. 14/038,957 to Conroy.

Other design features can be incorporated into the design of the rotating roll 10 and related apparatuses as well to aid in fluid control, roll assembly, roll maintenance, and cost optimization. By way of non-limiting example, check valves, static mixers, sensors, or gates or other such devices can be provided integral within the rotating roll 10 to control the flow and pressure of fluids being routed throughout the roll 10. In another example, the roll 10 may contain a closed loop fluid recirculation system where a fluid could be routed back to any point inside the roll 10 or to any point external to the roll 10 as a fluid feed tank or an incoming feed

line to the roll 10. In another example, as mentioned above, the roll 10 can be fabricated so that the surface 14 of the roll 10 and/or the outer surface 130 of the sleeve 100 is multi-radiused (i.e., has different elevations) surface. In addition to the above disclosure, multi-radiused surface may facilitate cleaning of the roll 10 or sleeve 100, transferring fluid from the surface 14, 130 to a
5 substrate 50, moving the substrate 50 out of plane as in an embossing, activation transformation and the like, and/or achieving different fluid transfer rates and/or different deformation (e.g., embossment) depths. Multi-radiused surfaces may be designed in accordance with teachings provided in U.S. Patent No. 7,611,582 to McNeil which is incorporated by reference herein. In yet another nonlimiting example, the addition of a light source within or proximate to the rotating
10 roll 10 can be provided to increase visibility of the rotating roll 10 or into the interior region 16 of the rotating roll 10.

Indeed, the rotating roll 10 may be used to perform multiple operations simultaneously and/or in precise registration. For example, a multi-radiused exterior surface 14 in combination with the vascular network 18 permits both embossing and distribution of fluid on a substrate 50
15 through the same apparatus, namely the rotating roll 10. One of skill in the art will appreciate that various combinations can result including but not limited to simultaneous, dosing, print, and emboss patterns and multiple structural transformations (e.g., embossing and chemical processing).

The rotating roll 10 may also be used in combination with a feedback system 240 such as
20 sensors and computers or other components known in the art. The feedback system 240 can send current state information (e.g., flow rate, fluid amount, add-on rate and location, pressures, fluid or roll velocity, location of product features 51 and/or temperature) so that changes can be made dynamically.

The rotating roll 10 may also be associated with a control mechanism 250 such as a
25 computer or other components known in the art, such that fluid pressure, volume, velocity, add-on rates and locations, fluid or roll temperature, rotational speed, fluid application level, roll surface speed, fluid flow rate, pressure, substrate speed, degree of circumferential roll contact by the substrate, distance between the exterior surface 14, 130 and a backing surface 200, pressure between the rotating roll 10 and the backing surface 200 and combinations thereof, and other
30 operational features discussed herein may be controlled and/or adjusted dynamically. In one embodiment, the control mechanism 250 can separately control features associated with a given tree 23, main artery 22 or section of the roll, including but not limited to fluid application level, fluid application rate, fluid flow rate, pressure, temperature and combinations thereof. In one nonlimiting example, the fluid application rate of each main artery 22 is at least 10% different.

In a further embodiment, the roll 10 can be used in conjunction with a pretreat station 260. The pretreat station 260 may be positioned upstream from the roll 10. Where a plurality of rolls 10 are used, the pretreat station 260 may be positioned upstream from at least one roll 10 and/or downstream from other rolls 10. The pretreat station 260 may comprise a spraying, extruding, printing or other process and/or may be used to treat a substrate 50 with chemicals, fluids, heaters/coolers and/or other treatment processes in preparation for or as a supplement to the fluid deposition provided by the roll 10. In one nonlimiting example, the pretreat station 260 is used to provide water on the substrate 50.

In yet another embodiment, the roll 10 may be used in conjunction with overcoat station 270. The overcoat station 270 may be positioned downstream from the roll 10. Where a plurality of rolls 10 are used, the overcoat station 270 may be positioned downstream from at least one roll 10 and/or upstream from other rolls 10. The overcoat station 270 may comprise a spraying, extruding, printing or other process and/or may be used to treat or coat a substrate 50 with chemicals, fluids, heaters/coolers and/or other treatment processes after fluid deposition is provided by the roll 10. In one nonlimiting example, the overcoat station 270 is used to provide a varnish on the substrate 50.

Method for Creating a Vascular Network

In an embodiment shown in Fig. 40, a method 300 for creating a vascular network 18 includes the steps of determining a deposit objective 310, selecting a fluid having at least one fluid property 320, designing a vascular network 18 to achieve the deposit objective 330 and selecting a fluid delivery system 340. The deposit objective 310 may include a desired deposit location of the fluid on the substrate 50, a desired deposit add-on amount, a desired volumetric flow rate, a desired application rate (i.e., the add-on amount in combination with the volumetric flow rate), the size of the desired deposit, how the fluid is to be applied (e.g., smearing, dot application, lines, etc.), and combinations thereof.

The vascular network 18 may be built using stereo lithographic printing as discussed above. The network 18 may be disposed in the rotating roll 10. The rotating roll 10, or a portion of the rotating roll 10, may be substantially surrounded by a sleeve 100. Designing the network 18 may include designing a main artery 22 (having any of the features described herein in relation to main arteries 22) associated with one or more trees 23 (having any of the features described herein in relation to trees 23). Further, designing the network 18 may include selecting the location and/or size of the trees 23 and associating at least one of the trees 23 with a fluid exit 30. One or more of the trees may comprise branching levels as discussed above. In one

nonlimiting example, a tree 23 has n levels. The pressure drop in the channels 20 may increase as the branch level increases. In other words, the pressure drop in between channels on level n and level $n-1$ may be greater than the pressure drop between levels $n-1$ and $n-2$. In another nonlimiting example, a tree 23 is designed such that shear rates are maintained at each branch level (i.e., the shear rates are consistent despite the branch level). In one embodiment, a tree 23 is designed using the formula: $Diameter_{Level} = Diameter_{Start} * BR^{(-Level/(2+Epsilon))}$ (discussed in detail above).

Further still, designing the network 18 may comprise designing and/or fluid exits 30. Fluid exits 30 may comprise any of the features described herein in relation to fluid exits 30. Designing the vascular network 18 may also comprise analyzing the deposit objective, one or more fluid properties, desired pressure and/or diameter changes, shear rates and combinations of these factors.

Selecting the fluid delivery system may comprise selecting or designing channels 20, locations and/or sizes of channels 20, junctions 21, locations and/or sizes of junctions 21, a fluid source (such as a rotary union 230), and/or a pumping mechanism or other means to provide fluid at a desired rate. Further, selecting a fluid delivery system may include selecting desired fluid pressure and/or velocity, which may vary or remain constant during the fluid's travel through the roll 10. The method 300 may also include selecting combinations of these factors.

In another embodiment shown in Fig. 41, the method 300' comprises determining a deposit objective 310', selecting a first fluid having a first fluid property 320A, selecting a second fluid having a second fluid 320B, designing a vascular network to achieve the deposit objective 330' and selecting a fluid delivery system 340'. In one nonlimiting example, the first fluid and second fluid are different. In another nonlimiting example, the first fluid property is different than the second fluid property. The deposit objective may comprise any of the above deposit objectives as well as a first desired deposit location correlating to the desired deposit location of the first fluid, a second desired deposition location correlating to the desired deposit location of the second fluid, a first desired deposit rate (i.e., the desired deposit rate of the first fluid), the second desired deposit rate (i.e., the desired deposit rate of the second fluid) and combinations thereof.

The designing step 320' may comprise any of the aforementioned principles with respect to step 320. Further, step 320' may comprise designing at least two main arteries 22, each of which being associated with one or more trees 23 and at least one of the trees 23 being associated with a fluid exit 30. Again, the network 18 may be formed using stereo lithographic printing. In

addition, the network 18 may be disposed within a rotating roll 10, and the roll 10 may be disposed within or partially within a sleeve 100.

Selecting a fluid delivery system 340' may comprise the same considerations and steps as indicated above with respect to step 340.

5

Methods for Depositing a Fluid onto a Substrate

Turning to Fig. 42, a method 400 for delivering a fluid onto a substrate 50 generally includes the steps of providing a substrate 410, providing a fluid 420, providing a rotating roll 10 having a vascular network 18 in accordance with the teachings herein 430, transporting the fluid 10 440 to the vascular network 18, controlling the flow of the fluid such that the fluid moves to the fluid exit 30 at a predetermined flow rate 450 and contacting the substrate 50 with the fluid 460.

In particular, the method 400 may include the steps 410, 420 of providing a fluid and providing a substrate 50. The fluid may be provided from a rotary union 230.

The substrate may include, for example, conventional absorbent materials such as creped 15 cellulose wadding, fluffed cellulose fibers, wood pulp fibers also known as airfelt, and textile fibers. The substrate may also include also be fibers such as, for example, synthetic fibers, thermoplastic particulates or fibers, tricomponent fibers, and bicomponent fibers such as, for example, sheath/core fibers having the following polymer combinations: polyethylene/polypropylene, polyethylvinyl acetate/polypropylene, polyethylene/polyester, 20 polypropylene/polyester, copolyester/polyester, and the like. The substrate may be any combination of the materials listed above and/or a plurality of the materials listed above, alone or in combination.

The substrate may be hydrophobic or hydrophilic. The substrate or portions of the substrate may be treated to be made hydrophobic. The substrate or portions of the substrate may 25 be treated to become hydrophilic.

The constituent fibers of the substrate can be comprised of polymers such as polyethylene, polypropylene, polyester, and blends thereof. The fibers can be spunbound fibers. The fibers can be meltblown fibers. The fibers can comprise cellulose, rayon, cotton, or other natural materials or blends of polymer and natural materials. The fibers can also comprise a 30 super absorbent material such as polyacrylate or any combination of suitable materials. The fibers can be monocomponent, bicomponent, and/or biconstituent, non-round (e.g., capillary channel fibers), and can have major cross-sectional dimensions (e.g., diameter for round fibers) ranging from 0.1-500 microns. The constituent fibers of the nonwoven precursor web may also

be a mixture of different fiber types, differing in such features as chemistry (e.g. polyethylene and polypropylene), components (mono- and bi-), denier (micro denier and >20 denier), shape (i.e. capillary and round) and the like. The constituent fibers can range from about 0.1 denier to about 100 denier.

5 In one aspect, known absorbent web materials in an as-made can be considered as being homogeneous throughout. Being homogeneous, the fluid handling properties of the absorbent web material are not location dependent, but are substantially uniform at any area of the web. Homogeneity can be characterized by density, basis weight, for example, such that the density or basis weight of any particular part of the web is substantially the same as an average density or
10 basis weight for the web. By the apparatus and method of the present invention, homogeneous fibrous absorbent web materials are modified such that they are no longer homogeneous, but are heterogeneous, such that the fluid handling properties of the web material are location dependent. Therefore, for the heterogeneous absorbent materials of the present invention, at discrete locations the density or basis weight of the web may be substantially different than the average
15 density or basis weight for the web. The heterogeneous nature of the absorbent web of the present invention permits the negative aspects of either of permeability or capillarity to be minimized by rendering discrete portions highly permeable and other discrete portions to have high capillarity. Likewise, the tradeoff between permeability and capillarity is managed such that delivering relatively higher permeability can be accomplished without a decrease in
20 capillarity.

The substrate may also include superabsorbent material that imbibe fluids and form hydrogels. These materials are typically capable of absorbing large quantities of body fluids and retaining them under moderate pressures. The substrate can include such materials dispersed in a suitable carrier such as cellulose fibers in the form of fluff or stiffened fibers.

25 The substrate may include thermoplastic particulates or fibers. The materials, and in particular thermoplastic fibers, can be made from a variety of thermoplastic polymers including polyolefins such as polyethylene (e.g., PULPEX.RTM.) and polypropylene, polyesters, copolyesters, and copolymers of any of the foregoing.

30 Depending upon the desired characteristics, suitable thermoplastic materials include hydrophobic fibers that have been made hydrophilic, such as surfactant-treated or silica-treated thermoplastic fibers derived from, for example, polyolefins such as polyethylene or polypropylene, polyacrylics, polyamides, polystyrenes, and the like. The surface of the hydrophobic thermoplastic fiber can be rendered hydrophilic by treatment with a surfactant, such

as a nonionic or anionic surfactant, e.g., by spraying the fiber with a surfactant, by dipping the fiber into a surfactant or by including the surfactant as part of the polymer melt in producing the thermoplastic fiber. Upon melting and resolidification, the surfactant will tend to remain at the surfaces of the thermoplastic fiber. Suitable surfactants include nonionic surfactants such as Brij
5 76 manufactured by ICI Americas, Inc. of Wilmington, Del., and various surfactants sold under the Pegosperse.RTM. trademark by Glyco Chemical, Inc. of Greenwich, Conn. Besides nonionic surfactants, anionic surfactants can also be used. These surfactants can be applied to the thermoplastic fibers at levels of, for example, from about 0.2 to about 1 g. per sq. of centimeter of thermoplastic fiber.

10 Suitable thermoplastic fibers can be made from a single polymer (monocomponent fibers), or can be made from more than one polymer (e.g., bicomponent fibers). The polymer comprising the sheath often melts at a different, typically lower, temperature than the polymer comprising the core. As a result, these bicomponent fibers provide thermal bonding due to melting of the sheath polymer, while retaining the desirable strength characteristics of the core
15 polymer.

 Suitable bicomponent fibers for use in the present invention can include sheath/core fibers having the following polymer combinations: polyethylene/polypropylene, polyethylvinyl acetate/polypropylene, polyethylene/polyester, polypropylene/polyester, copolyester/polyester, and the like. Particularly suitable bicomponent thermoplastic fibers for use herein are those
20 having a polypropylene or polyester core, and a lower melting copolyester, polyethylvinyl acetate or polyethylene sheath (e.g., DANAKLON.RTM., CELBOND.RTM. or CHISSO.RTM. bicomponent fibers). These bicomponent fibers can be concentric or eccentric. As used herein, the terms "concentric" and "eccentric" refer to whether the sheath has a thickness that is even, or uneven, through the cross-sectional area of the bicomponent fiber. Eccentric bicomponent fibers
25 can be desirable in providing more compressive strength at lower fiber thicknesses. Suitable bicomponent fibers for use herein can be either uncrimped (i.e. unbent) or crimped (i.e. bent). Bicomponent fibers can be crimped by typical textile means such as, for example, a stuffer box method or the gear crimp method to achieve a predominantly two-dimensional or "flat" crimp.

 The length of bicomponent fibers can vary depending upon the particular properties
30 desired for the fibers and the web formation process. Typically, in an airlaid web, these thermoplastic fibers have a length from about 2mm to about 12mm long, or from about 2.5mm to about 7.5mm long, or from about 3.0mm to about 6.0mm long. The properties-of these thermoplastic fibers can also be adjusted by varying the diameter (caliper) of the fibers. The

diameter of these thermoplastic fibers is typically defined in terms of either denier (grams per 9000 meters) or decitex (grams per 10,000 meters). Suitable bicomponent thermoplastic fibers as used in an airlaid making machine can have a decitex in the range from about 1.0 to about 20, or from about 1.4 to about 10, or from about 1.7 to about 7 decitex.

5 The compressive modulus of these thermoplastic materials, and especially that of the thermoplastic fibers, can also be important. The compressive modulus of thermoplastic fibers is affected not only by their length and diameter, but also by the composition and properties of the polymer or polymers from which they are made, the shape and configuration of the fibers (e.g., concentric or eccentric, crimped or uncrimped), and like factors. Differences in the compressive
10 modulus of these thermoplastic fibers can be used to alter the properties, and especially the density characteristics, of the respective thermally bonded fibrous matrix.

 The substrate can also include synthetic fibers that typically do not function as binder fibers but alter the mechanical properties of the fibrous webs. Synthetic fibers include cellulose acetate, polyvinyl fluoride, polyvinylidene chloride, acrylics (such as Orlon), polyvinyl acetate,
15 non-soluble polyvinyl alcohol, polyethylene, polypropylene, polyamides (such as nylon), polyesters, bicomponent fibers, tricomponent fibers, mixtures thereof and the like. These might include, for example, polyester fibers such as polyethylene terephthalate (e.g., DACRON.RTM. and KODEL.RTM.), high melting crimped polyester fibers (e.g., KODEL.RTM. 431 made by Eastman Chemical Co.) hydrophilic nylon (HYDROFIL.RTM.), and the like. Suitable fibers can
20 also hydrophilized hydrophobic fibers, such as surfactant-treated or silica-treated thermoplastic fibers derived from, for example, polyolefins such as polyethylene or polypropylene, polyacrylics, polyamides, polystyrenes, polyurethanes and the like. In the case of nonbonding thermoplastic fibers, their length can vary depending upon the particular properties desired for these fibers. Typically they have a length from about 0.3 to 7.5 cm, or from about 0.9 to about
25 1.5 cm. Suitable nonbonding thermoplastic fibers can have a decitex in the range of about 1.5 to about 35 decitex, or from about 14 to about 20 decitex.

 The method 400 may further include the step 430 of providing a rotating roll 10 having any of the features described herein with relation to rotating rolls 10 of the present invention. For example, the rotating roll 10 may comprise a central longitudinal axis 12 and an exterior surface
30 14 that substantially surrounds the central longitudinal axis 12 and defines an interior region 16. The roll 10 may rotate about the central longitudinal axis 12. In one nonlimiting example, the rotating roll 10 may rotate at a surface speed of greater than about 10 ft/minute, or from about 100 ft/minute to about 3000 ft/minute, or about 1800 ft/minute.

The method 400 may also include the step of providing vascular network 18, having any of the features described herein in relation to a vascular network 18. In one nonlimiting example, the vascular network 18 may be provided separately from the rotating roll 10. The vascular network 18 may be provided to supply the fluid from the interior region 16 to the exterior surface 14 in a predetermined fluid path 48. As described above, the vascular network 18 may comprise a main artery 22, which may have an inlet 28 and be substantially parallel to the central longitudinal axis 12 of the roll 10. In one nonlimiting example, the main artery 22 is spaced at a radial distance, r , from the central longitudinal axis 12. The radial distance, r , is greater than 0. Further, the vascular network 18 may comprise a capillary 24 and a plurality of fluid exits 30. The fluid may enter the vascular network 18 through the inlet 28 and exit the vascular network 18 through the fluid exits 30.

Further still, the vascular network 18 may comprise a first capillary 24a which may be associated with the main artery 22. The cross-sectional area of the main artery 22 may be greater than the cross-sectional area of the first capillary 24a. In an embodiment, the vascular network 18 may comprise a second capillary 24b, which may be associated with the main artery 22. The cross-sectional area of the main artery 22 may be greater than the cross-sectional area of the second capillary 24b. The first capillary 24a and/or the second capillary 24b may be in fluid communication with the main artery 22 and with a fluid exit 30 through a substantially radial fluid path 48 to form a tree 23. In one nonlimiting example, the first capillary 24a and/or the second capillary 24b may be in fluid communication with the main artery 22 and with at least two fluid exits 30 through substantially radial paths 48, forming one or more trees 23. As explained above, the capillary 24 may be associated with and in fluid communication with one or more sub-capillaries 26 disposed between the capillary 24 and a fluid exit 30. Further, any tree 23 within the vascular network 18, may be designed in accordance to the formula: $Diameter_{Level} = Diameter_{Start} * BR^{(-Level/(2+epsilon))}$, which is explained in more detail above.

In one embodiment, the vascular network 18 comprises both a first capillary 24a and a second capillary 24b and each are in fluid communication with one or more fluid exits 30. As discussed above, a first path length, FP, may comprise the distance between the first capillary 24a and a fluid exit 30 with which it is in fluid communication, and a second path length, SP, may comprise the distance between the second capillary 24b and a fluid exit 30 with which the second capillary 24b is in fluid communication. The method 400 may include equalizing the first and second path lengths, FP, SP. As used herein, “equalizing” means making two values (e.g., distances) substantially equal or within 5% of each other.

In another embodiment, the method may include equalizing diameter changes along different trees 23, such as equalizing a first diameter change with a second diameter change as discussed in detail in previous sections.

Again, the roll 10 and vascular network 18 may include or be associated with any of the features described in the above sections. In one nonlimiting example, the exterior surface 14 of the roll 10, or a portion of the exterior surface 14 of the roll 10, is substantially surrounded by a sleeve 100 having any of the features described herein related to sleeves 100. The sleeve 100 may comprise a sleeve exit 120, which may be registered or otherwise associated with at least one fluid exit 30.

The method 400 may also comprise the step 440 of transporting the fluid to the vascular network 18. In addition, the method 400 may comprise the step 450 of controlling the flow of the fluid to move the fluid at a predetermined flow rate to the fluid exits 30. The fluid flow may be controlled by selecting a particular fluid pressure, a particular fluid volume, a particular fluid viscosity, a particular fluid surface tension, the length of one or more channels 20, the diameter of one or more channels 20, the relative diameters and/or lengths of the channels 20, the roll 10 diameter, temperature of the vascular network 18 or portions of the vascular network 18, temperature of the roll 10 or portions of the roll 10, temperature of a particular fluid and/or combinations thereof. One of skill in the art will recognize that a wide range of predetermined flow rates may be selected and suitable for the present invention. In one nonlimiting example, the fluid may be provided at a pressure of less than 100 psi, such as, for example, less than 90 psi, less than 80 psi, less than 70 psi, less than 60 psi, less than 50 psi, less than 40 psi.

Delivery of a HIPE to a substrate using the rotating rolls may further include an additional step of contacting the substrate to the rotating roll.

The substrate may contact the rotating roll before emulsion is pushed to the surface of the rotating roll. The substrate may contact the rotating roll before emulsion extends beyond the outer surface of the rotating roll. The substrate may contact the rotating roll before emulsion vertically protrudes from the surface of the rotating roll at a height of greater than 0.1 mm, such as, for example, the substrate may contact the rotating roll when the emulsion vertically protrudes from the surface of the rotating roll at a height of 0.01 mm, 0.02 mm, 0.03 mm, 0.04 mm, 0.05 mm, 0.06 mm, 0.07 mm, 0.08 mm, and 0.09 mm.

The method 400 may further comprise the step 460 of contacting a substrate 50 with the fluid. In an embodiment, the substrate 50 and fluid exit 30 are in operative relationship. The substrate 50 may contact the fluid at the fluid exit 30. In one nonlimiting example, one or more of the fluid

exits 30 may comprise micro-reservoir 39. In one such example, the substrate 50 may contact the fluid at the micro-reservoir 39 or at an opening 46 in the micro-reservoir 39. In another nonlimiting example, a backing surface 200 is provided. The roll 10 may form a nip 205 with a backing surface 200, and the substrate 50 may contact the fluid at the nip 205. In yet another nonlimiting example, the rotating roll 10 comprises a sleeve 100 which substantially surrounds a portion of the exterior surface 14. The sleeve 100 may have a sleeve exit 120 as described above. One or more sleeve exits 120 may be registered or otherwise associated with a fluid exit 30 or with a fluid micro-reservoir 39. The substrate 50 may contact the fluid at the sleeve exit(s) 120 or otherwise be in operative relationship with the sleeve exit(s) 120. Further, the fluid may be registered with a product feature 51 on the substrate.

Delivery of a HIPE to a substrate using the rotating rolls may include contacting the substrate with the HIPE emulsion. The substrate may contact the HIPE emulsion concurrent with the role or after contacting the rotating roll. Without being bound by theory, it has been found that the point of contact between the emulsion and the substrate is critical in that it must occur either after the contact between the substrate and the rotating roll or concurrent with the contact between the substrate and the rotating roll. As the emulsion exits the rotating roll, the amount of shear force placed on the emulsion must be controlled. Having the substrate already in place allows for a reduction in shear force and allows the emulsion to travel into and through the substrate without additional shear forces.

If the emulsion extends from the rotating roll before the substrate and the rotating roll make contact, then the substrate may shear the emulsion as it pushes through the emulsion to make contact with the rotating roll. This additional shear may cause the emulsion to break leading to such potential issues as, without limitation, smearing of emulsion on the rotating roll, destabilizing the emulsion within the substrate, or allowing the emulsion to clog the rotating roll.

Delivery of a HIPE to a substrate using the rotating rolls may include pushing emulsion through a portion of the substrate. Once the emulsion is in contact with the substrate, the rotating roll will continue to rotate with the substrate. As the rotating roll rotates with the substrate, additional emulsion is pushed through the rotating roll vascular network and through the substrate in a z or vertical direction through the width of the substrate. Depending upon the desired effect, the emulsion may be pushed through a percentage of the vertical direction of the substrate to create a loaded substrate such as, for example, between 5% and 1,000% of the vertical direction of the substrate, between 10% and 900%, between 20% and 800%, between 30% and 600%, between 40% and 500%, between 50% and 300%, between 100% and 200%,

such as, for example, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 100%, 200%, 300%, 400%, 500%, 600%, 700%, 800%, or 900%.

In another embodiment, the method 400 may comprise the step of moving the substrate 50 (not shown). The substrate 50 may be moved about the rotating roll 10, or about a portion of the rotating roll 10. The substrate 50 may be driven by any suitable means, including but not limited to a drive motor 210. In one nonlimiting example, the substrate 50 moves at rate of about 10 ft/minute or from about 100 ft/minute to about 3000 ft/minute or at about 2000 ft/minute. In another nonlimiting example, the substrate 50 and the rotating roll 10 move at the same rate. When moved at the same rates, the fluid may be applied in a precise manner, such as in the form of a droplet. In yet another nonlimiting example, the substrate 50 and the rotating roll 10 move at different rates. When the rates of the roll 10 and the substrate 50 are unmatched, the fluid may be smeared on a surface of the substrate 50 or the area or size of a pattern 52 previously applied can be changed.

After the loaded substrate is removed from the roll it moves on to a polymerization stage as described above.

The method may also comprise providing a control mechanism 250 having any of the features described above with respect to the control mechanism 250. In one nonlimiting example, the control mechanism 250 is a computer or other programmable device. In another nonlimiting example, the control mechanism 250 is capable of controlling fluid application level, application rate, roll surface speed, fluid flow rate, pressure, temperature, substrate speed, degree of circumferential roll contact by the substrate, distance between the exterior surface and a backing surface, pressure between the rotating roll and the backing surface and combinations thereof.

In a further embodiment, the vascular network 18 may comprise a plurality of main arteries 22 and a plurality of capillaries 24, such as a plurality of first capillaries 24a. Each capillary 24 is in fluid communication with a main artery 22 and one or more fluid exits 30 through substantially radial fluid paths 48 to form a tree 23. A control mechanism 250 may be used to separately control properties for each tree 23 and/or each main artery 22. The control mechanism 250 can be capable of controlling properties such as fluid application level, application rate, roll surface speed, fluid flow rate, pressure, temperature, substrate speed, degree of circumferential roll contact by the substrate, distance between the exterior surface and a backing surface, pressure between the rotating roll and the backing surface and combinations thereof. In one nonlimiting example, the control mechanism 250 is used to separately control

each of the main arteries 22 and their respective trees 23 with respect to fluid application level, fluid application rate, fluid flow rate, pressure, temperature and combinations thereof. In another nonlimiting example, the fluid application rate of fluids in separate main arteries 22 may differ by at least 10%.

5 Further, the method 400 may comprise equalizing diameter changes of trees 23 stemming from different main arteries as shown in Fig. 32. For example, the method may comprise equalizing primary diameter change and a secondary diameter change as explained in detail above.

10 A sleeve and roll system method 500 may also be employed. The method 500 may comprise the steps of providing a substrate 510, providing a fluid 520, providing a sleeve and roll system 160 having a vascular network 18 (step 530), transporting the fluid to the vascular network 540, controlling the flow of fluid 550, and contacting the substrate 50 with the fluid 560. The steps 510-560 may comprise any of the features in method 400. In addition, the sleeve and roll system 160 may comprise any of the features discussed herein in relation to the sleeve and roll system 160. In one embodiment, the rotating roll 10 is disposed within the inner region 130 of the sleeve 100. The sleeve 100 can have a sleeve exit 120. The vascular network 18 may comprise a tree 22 having a first capillary 24a. The first capillary 24a may be in fluid communication with a main artery 22 and the sleeve exit 120 through a substantially radial path 48. The substantially radial path 48 may end at an exit point 32 of a fluid exit 30. The exit point 20 32 may be associated with the sleeve exit 120. The tree 23 may be designed by any suitable means, including but not limited to the equation $Diameter_{Level} = Diameter_{Start} * BR^{(-Level/(2+Epsilon))}$ discussed in detail above. Separately, the tree 23 may further comprise a series of sub-capillaries 26, and the first capillary 24a may be in fluid communication with the sleeve exit 120 through the series of sub-capillaries 26.

25 In one nonlimiting example, the sleeve 100 has a thickness, T, of greater than about 1.5 mm, or between about 1.5 mm or about 10 mm, and a sleeve exit 120 has an aspect ratio of greater than about 10. In another embodiment, the sleeve 100 has a thickness, T, of less than about 4 mm, or less than about 2 mm, or less than about 1.5 mm, or less than about 0.5 mm. The cross-sectional area of meeting point 124 of the sleeve exit 120 may be less than about 0.5, or 30 less than about 0.3 or less than about 0.15 times the cross-sectional area of the fluid exit point 32 or reservoir opening 46.

Further, the sleeve exit 120 may comprise a supplementary tree 150 as shown in Fig. 36 and discussed in detail above.

As with method 400, a backing surface may be provided and used in any of the aforementioned ways. Likewise, as with method 400, method 500 may comprise moving the substrate 50 at speeds matching the surface speed of the roll 10 or at speeds unmatched to the surface speed of the roll 10. Further, a control mechanism 250 may be employed in the same manner as in method 400.

In another embodiment, the step 530 of providing the sleeve and roll system 160 comprises a sleeve substantially surrounding only a portion of the exterior surface 14 of the roll 10 to form a sleeve coverage area 105. The vascular network 18 may comprise a main artery 22, a plurality of capillaries 24 and a plurality of fluid exits 30. Each capillary 24 can be associated with the main artery and in fluid communication with the main artery 22 and one or more fluid exits through substantially radial paths to form a tree 23. An exit point 32 of at least one of the fluid exits 30 is registered or otherwise associated with a sleeve exit 120, and at least one of the fluid exits is disposed outside of the sleeve coverage area 105. The fluid exit 30 disposed outside of the sleeve coverage area 105 is not registered or associated with a sleeve exit 120.

In yet another embodiment, a plurality of rolls 10 may be provided, each roll 10 having a vascular network 18 that operates as described above. One or more of the rolls 10 may be used in conjunction with a sleeve 100. One or more fluids may be provided to each roll 10. One or more main arteries 22 may be provided in each vascular network 18 and/or one or more trees 23 may be provided for each main artery 22. If desired, a control mechanism 250 capable of separately controlling properties associated with each roll 10, each main artery 22 in a roll 10, and/or each tree 23 in a roll 10. The control mechanism 250 can be capable of controlling properties such as fluid application level, application rate, roll surface speed, fluid flow rate, pressure, temperature, substrate speed, degree of circumferential roll contact by the substrate, distance between the exterior surface and a backing surface, pressure between the rotating roll and the backing surface and combinations thereof.

In one nonlimiting example, a backing surface 200 is provided. The backing surface 200 may be used to create a nip 205 or nips 205 with one or more of the rolls 10, and the fluids 13 may contact the substrate 50 at the nip(s) 205. Alternatively, the backing surface 200 does not create a nip 205 but rather is a distance from one or more of the rotating rolls 10. The distance may be substantially equivalent or less than the caliper of the substrate 50. In another alternative embodiment, a plurality of rolls 10 is provided without a backing surface 200. The backing surface 200 may comprise vacuum regions 201.

Using a plurality of rolls 10 allows for a plurality of fluids 13 to be deposited onto a substrate 50. It is believed that the vascular network 18 of the rolls 10 permit better registration,

overlaying and blending of fluids than known systems because more than one fluid can be applied using a single roll 10 in an intricate and precisely registered relationship to each other. Each roll 10 is capable of being controlled (due to the design of the vascular network 18) such that a more precise amount of fluid can be more precisely applied at a desired location in a repeatable manner. The plurality of rolls, each having this level of precision, allows for more precise registration, overlaying and blending of the various fluids applied.

Along these lines, a dosing method 600 is also provided and depicted in Fig. 44. In general, the method 600 allows for dosing X number of fluids with fewer than X dosing apparatuses as illustrated in Figs. 22-24. The method 600 generally comprises providing a substrate 610, providing a plurality of fluids 620, providing a dosing system 70 comprising at least one rotating roll 10 and vascular network 18 (step 630), transporting at least one of the fluids to the vascular network 18 (Step 640), and contacting the substrate 50 with the plurality of fluids 650.

In an embodiment, the method 600 includes providing 7 or more fluids and contacting the substrate 50 with 7 or more fluids. The dosing system 70 comprises 6 or fewer rotating rolls 10. The rotating rolls 10 may have any of the features any of the features described above or illustrated in Figs. 22-24. The rotating rolls 10 may used with or without sleeves 100. In one nonlimiting example, each of the 6 or less rotating rolls 10 comprises a vascular network 18 having at least one main artery 22, at least one capillary 24 and a plurality of fluid exits 30. At least one of the 7 or more fluids is transported to each of the rotating rolls 10. Two or more fluids may be transported to one roll 10.

In one nonlimiting example (illustrated in Fig. 22), the dosing system can comprise a first roll 10A comprising one or more fluids, a second roll 10 B comprising one or more fluids, and a third roll 10C comprising one or more fluids. The method 600 may further comprise positioning the rolls 10 such that the first roll 10A is upstream of the second roll 10B and/or upstream of the third roll 10C. The method 600 may additionally comprise positioning the second roll 10B upstream of the third roll 10C. Further, the method 600 can include registering one or more of the fluids with another fluid. In one nonlimiting example, one or more of the fluids from the first roll 10A is registered with one or more of the fluids from the second roll 10B and or the an fluid from the third roll 10C. Likewise, fluids from the second roll 10 B can be registered with the fluid from the third roll 10C and so on. Similarly, the method 600 may include overlaying fluids and/ or blending fluids from the separate rolls 10A, 10B, 10C. Further, separate fluids within one roll 10A may be mixed, by for example an internal mixer 72. Such mixed fluids may then be registered, overlaid or blended with fluids from a different roll 10B, 10C. Any combination of

fluids in any combination of mixing, registering, blending and/or overlaying may be used. Fluids may further be mixed by elements within the vascular network, such as, for example, mixing elements or static mixers.

In another embodiment, the method 600 includes providing 3 or more fluids in step 620 and contacting the substrate 50 with 3 or more fluids in step 650. The dosing system 70 can comprise one rotating roll 10 having a plurality of fluids disposed therein as shown in Fig. 23. The rotating roll 10 may comprise any of the features any of the features described above and can be used with or without a sleeve 100. In one nonlimiting example, the vascular network 18 of the rotating roll 10 comprises a plurality of main arteries 22, a plurality of capillaries 24 and a plurality of fluid exits 30. Each of the 3 or more fluids may be disposed with the vascular network 18 and each may be fed through a separate main artery.

The method 600 may further comprise the step of controlling the flow of the fluid to move the fluid at a predetermined flow rate to the fluid exits 30. The fluid flow may be controlled by selecting a particular fluid pressure, a particular fluid volume, a particular fluid viscosity, a particular fluid surface tension, the length of one or more channels 20, the diameter of one or more channels 20, the relative diameters and/or lengths of the channels 20, the roll 10 diameter, temperature of the vascular network 18 or portions of the vascular network 18, temperature of the roll 10 or portions of the roll 10, temperature of a particular fluid and/or combinations thereof. In addition, the method 600 may comprise registering one or more fluids with a product feature 51. Further, the method 600 may comprise providing an overcoat station 270 positioned downstream of at least one roll 10 and/or providing a pretreat station 260 positioned upstream of at least one roll 10.

One of skill in the art will recognize that any number of rolls 10 and any combination and/or order of fluids may be used to create desired fluid applications. Internal mixers 72 may also be used within a given rotating roll 10 to produce combinations of the fluids within said roll 10.

In embodiments, the above methods 300, 400, 500, 600 may include providing a rotary union 230, such as the rotary union 230 described above, and supplying the fluid(s) from the rotary union 230 to the rotating roll(s) 10.

In other embodiments, the methods 300, 400, 500, 600 may include the registering the fluid with a product feature 51.

In a further nonlimiting example, the rotating roll 10 is part of the converting process of fibrous structures. The roll 10 and additional features described herein may be used in between a winder and unwinds.

One of skill in the art will recognize that the invention may include the negative or reverse of what is shown in the present figures. In other words, the interior region 16 of the rotating roll 10 may be generally solid with the channels 20 of the vascular network 18 being defined by the surfaces of the interior region 16. Alternatively, the interior region 16 could be generally hollow and the channels 20 could be tubular components built within the hollow interior 16 as depicted in the figures.

Applicants have found that the rotating rolls as described above allow for additional controls when working with HIPEs. These additional controls may include a reduced exposure to oxygen throughout the process and dosing step, control over the amount of shear during the dosing step, and the ability to combine more than one HIPE either in the roll or on the substrate. Additionally, the use of the rolls allows for the dosing of multiple combinations to the same substrate in a predetermined pattern. Dosed combinations may include, for example, one or more HIPEs, one or more polyacrylic acids, one or more polyurethane precursors such as polyols and isocyanates, and combinations thereof. The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as “40 mm” is intended to mean “about 40 mm.”

Every document cited herein, including any cross referenced or related patent or application and any patent application or patent to which this application claims priority or benefit thereof, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

CLAIMS

What is claimed is:

1. A method of delivering a High Internal Phase Emulsion to a substrate, the method comprising:
 - providing a rotating roll, wherein the rotary unit comprises a central longitudinal axis, wherein the rotating roll rotates about the central longitudinal axis;
 - an exterior surface defining an interior region and substantially surrounding the central longitudinal axis;
 - a vascular network configured for transporting the one or more fluids in a predetermined path from the interior region to the exterior surface of the rotating roll;
 - providing a High Internal Phase Emulsion to the rotating roll vascular network;
 - contacting a substrate with the rotating roll;
 - contacting the substrate with the High Internal Phase Emulsion.
2. The method according to claim 1, wherein the method further comprises pushing HIPE through a portion of the substrate.
3. The method according to claim 2, wherein the High Internal Phase Emulsion extends past the substrate at a height that is between 1 and 9 times the height of the substrate in a z direction.
4. The method according to any of claims 2 to 3, wherein the High Internal Phase Emulsion is pushed through a portion of the substrate such that the HIPE extends between 10% and 100% of the z direction of the substrate.
5. The method according to any of claims 2 to 4, wherein the High Internal Phase Emulsion is pushed through a portion of the substrate such that the HIPE extends between 20% and 80% of the z direction of the substrate.

6. The method according to any of the preceding claims, wherein the steps of contacting the substrate with the rotating roll and contacting the substrate with the High Internal Phase Emulsion occur simultaneously.
7. The method according to any of the preceding claims, wherein the substrate comprises conventional absorbent materials such as creped cellulose wadding, fluffed cellulose fibers, wood pulp fibers, textile fibers, synthetic fibers, thermoplastic particulates or fibers, tricomponent fibers, and bicomponent fibers, or combinations thereof.
8. The method according to any of the preceding claims, wherein the rotating roll is maintained at between 5 Celsius and 50 Celsius.

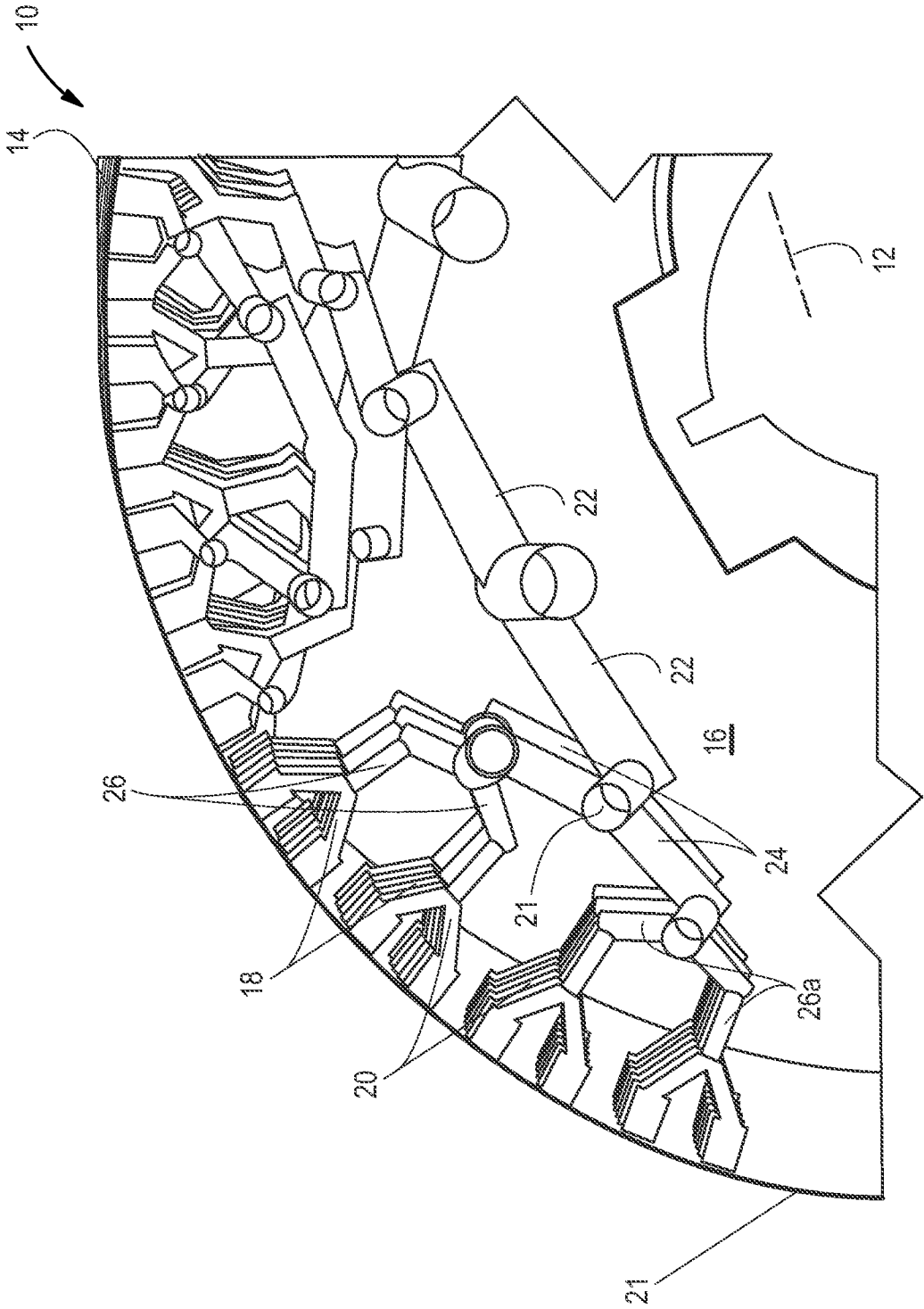


Fig. 1

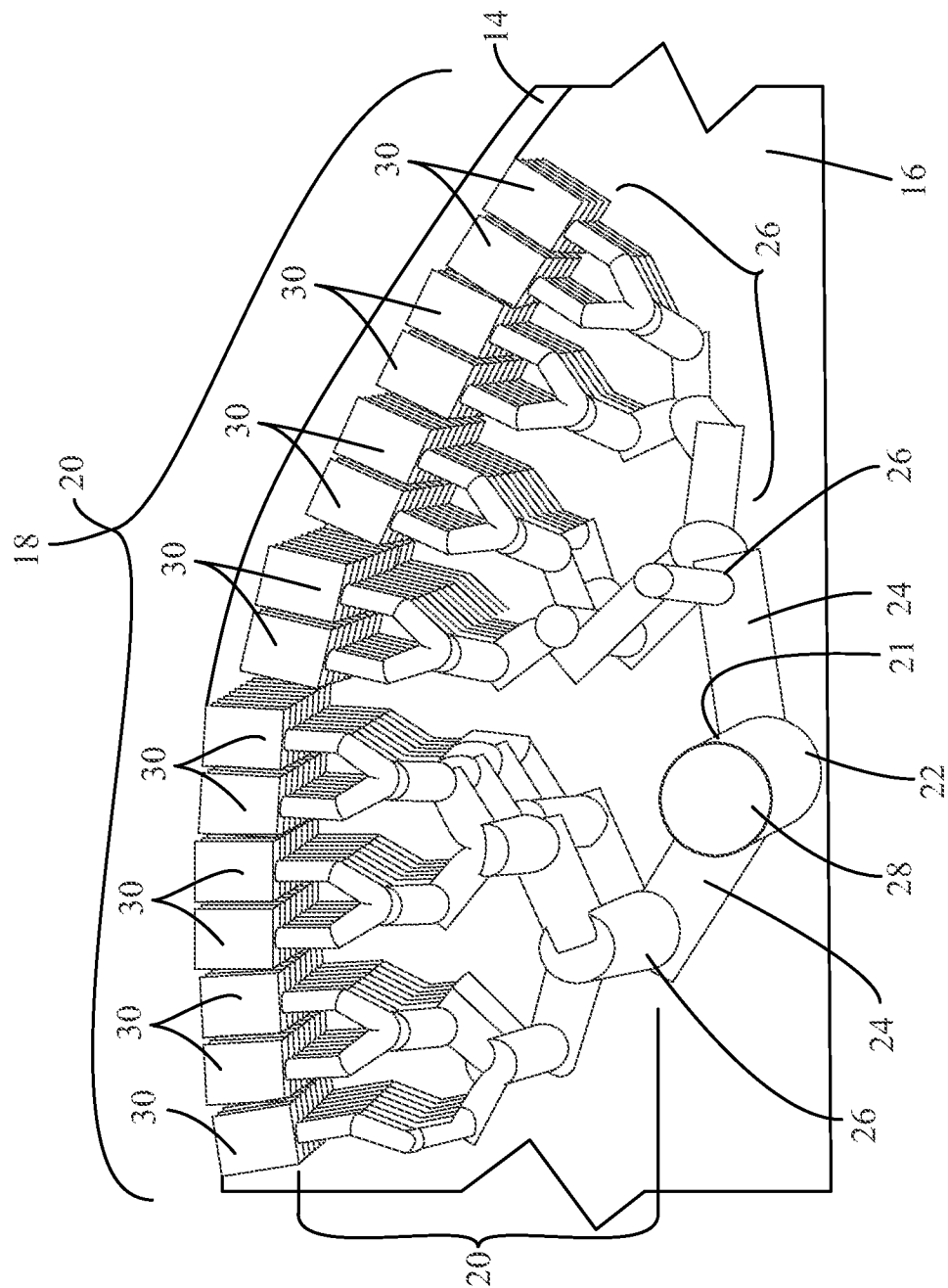


Fig. 2

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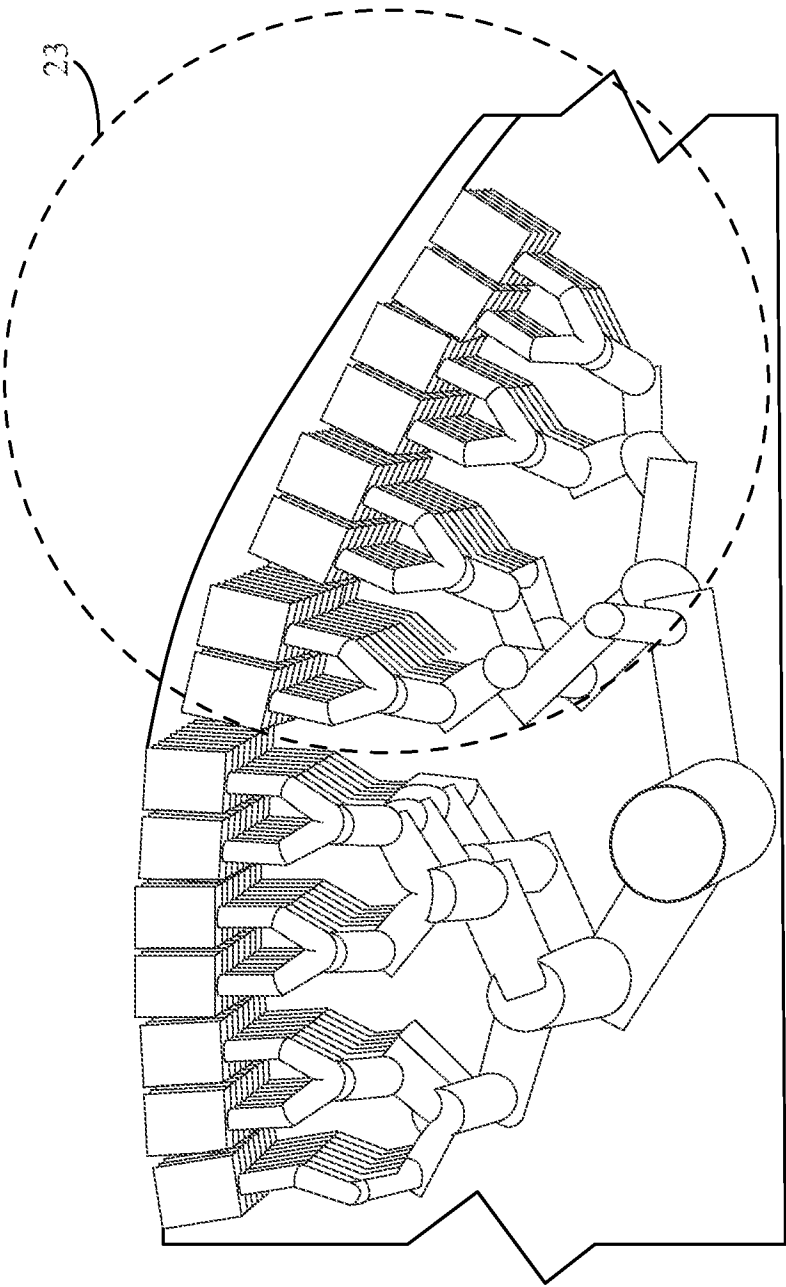


Fig. 2A

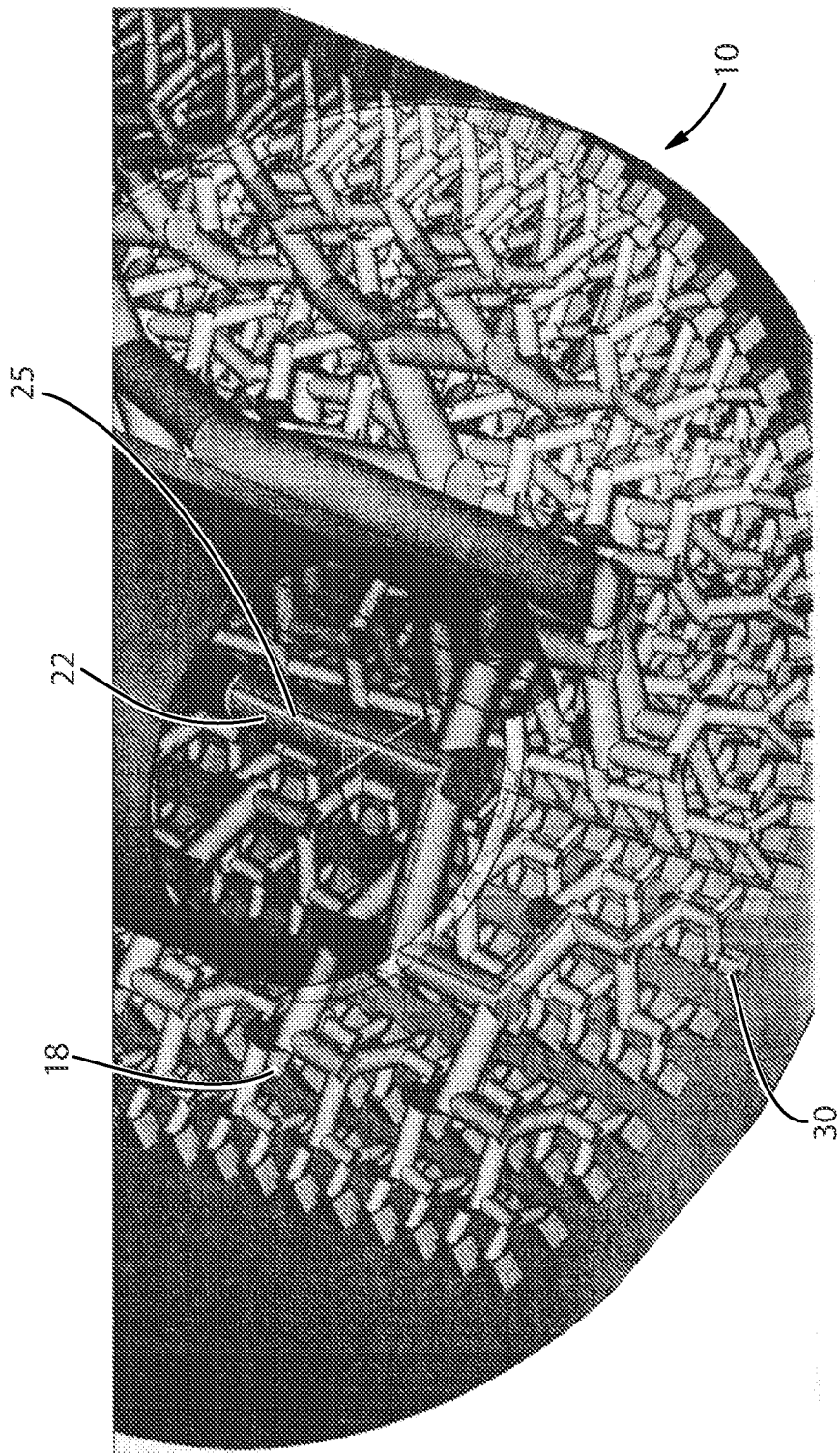


Fig. 3

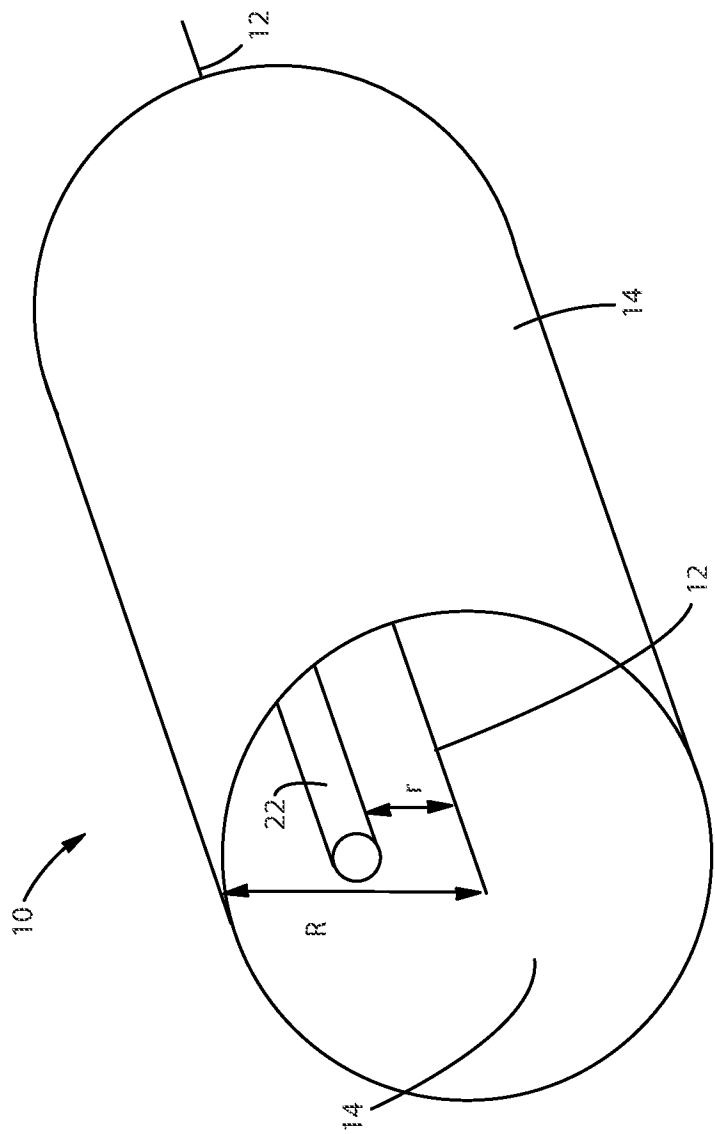
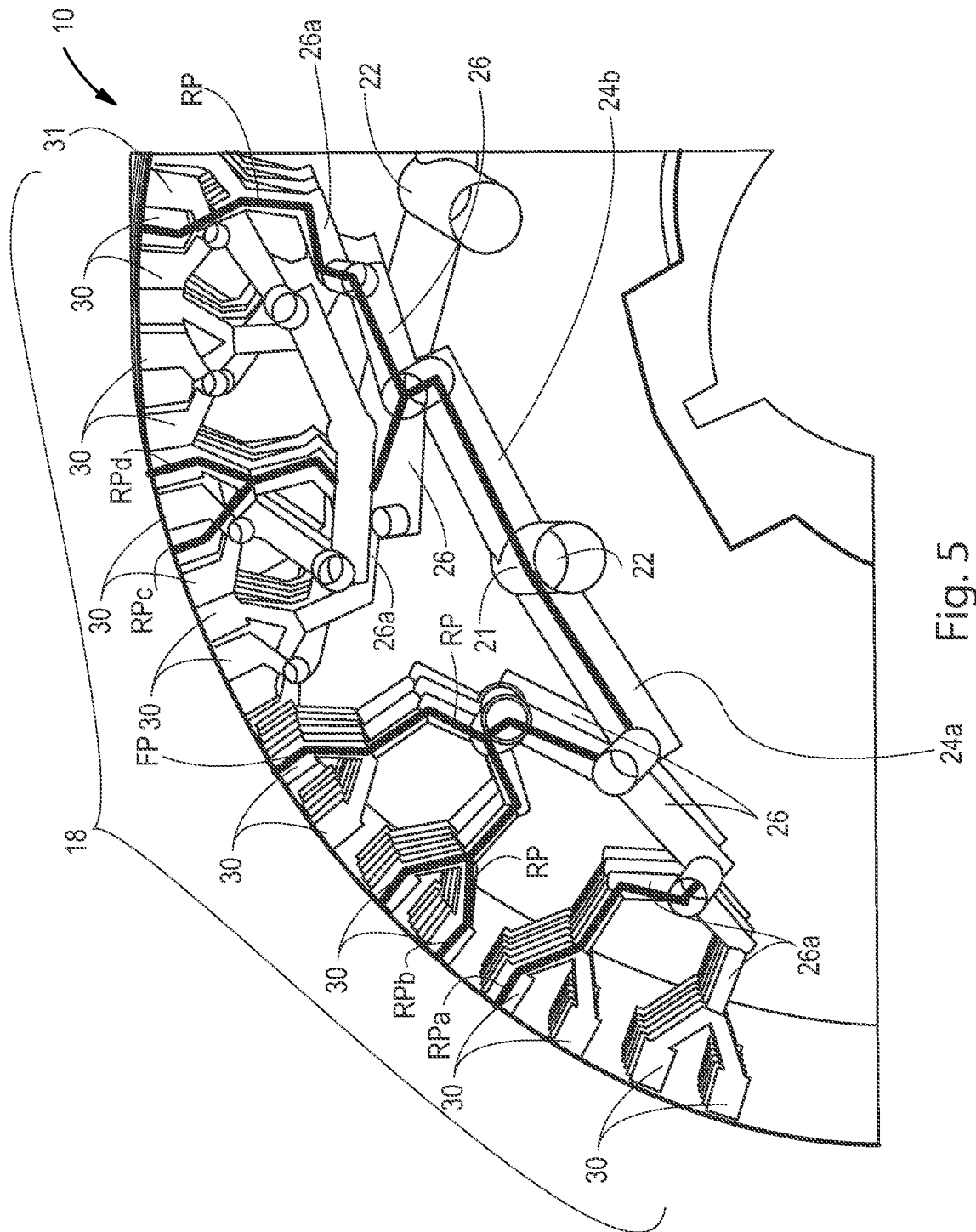


Fig. 4

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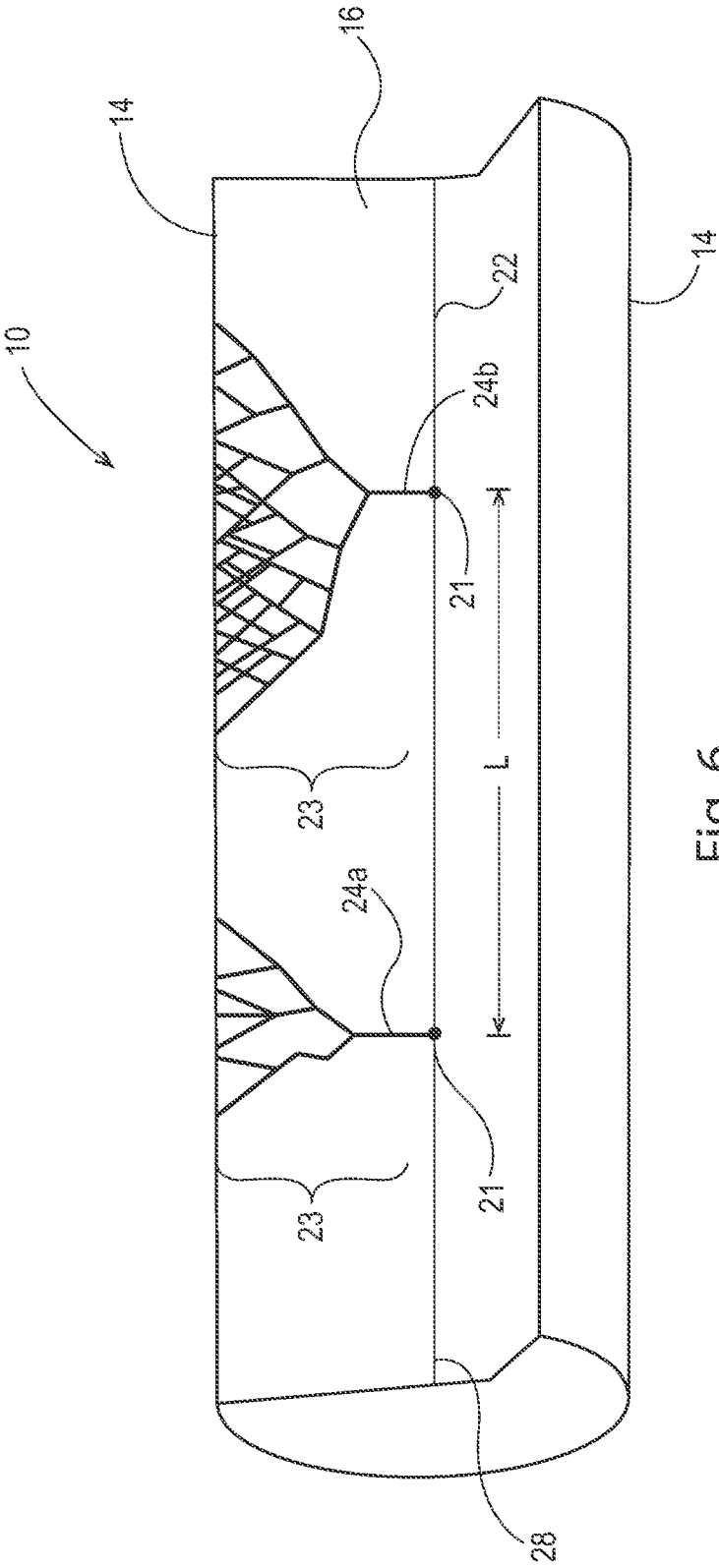


Fig. 6

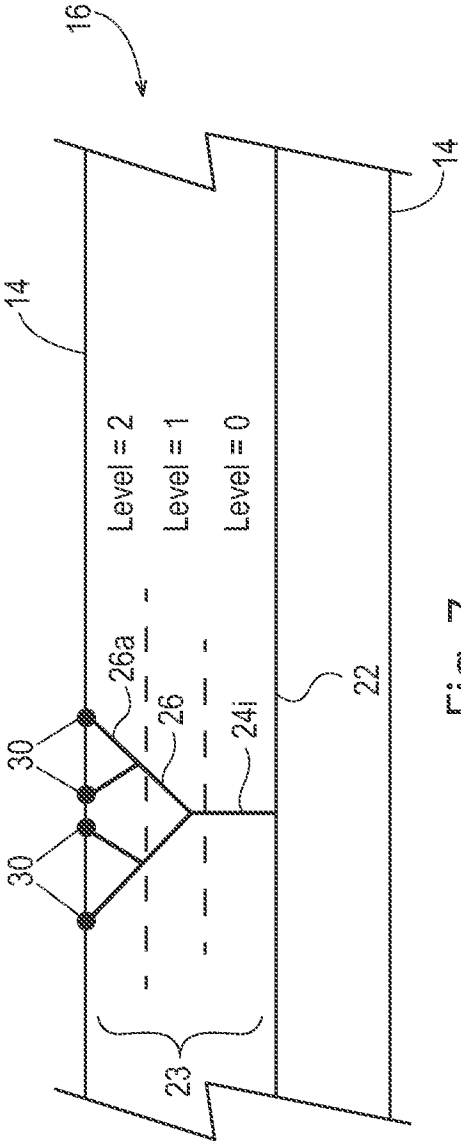


Fig. 7

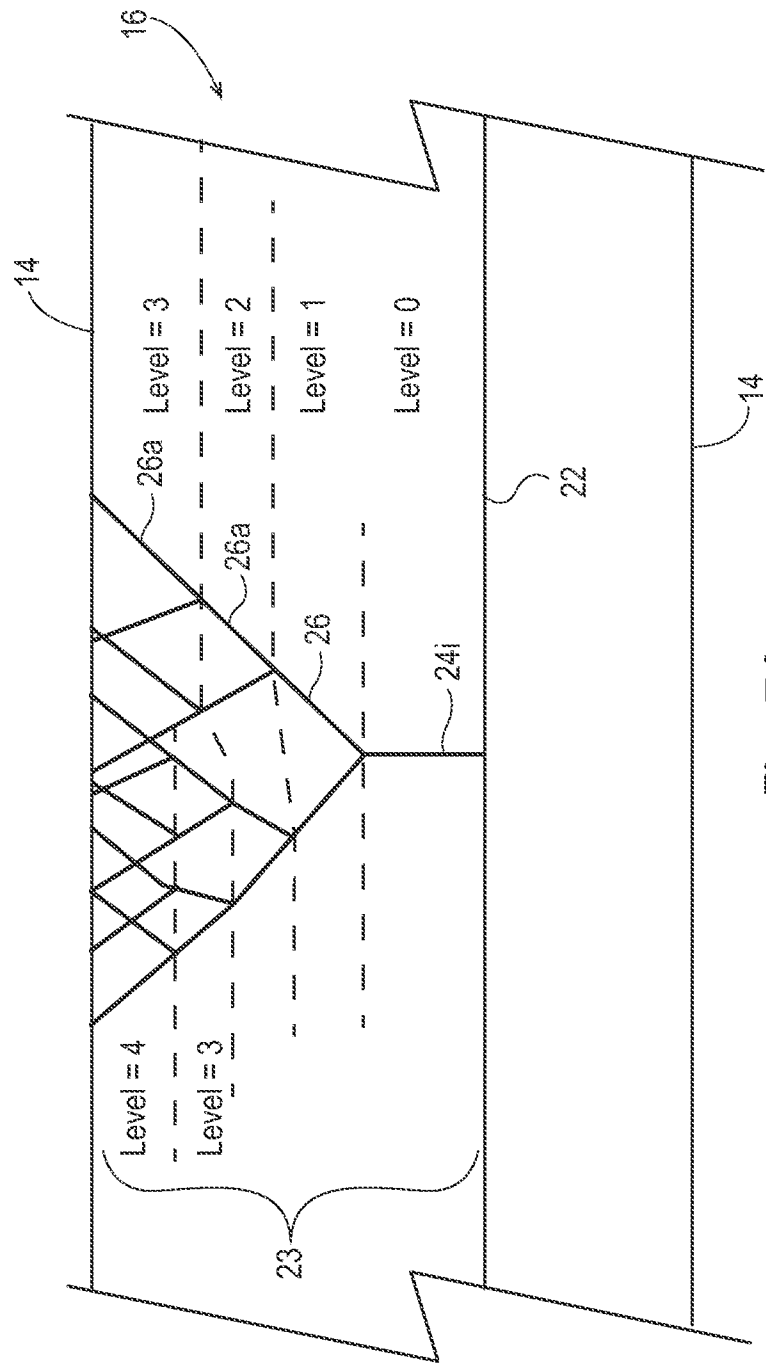


Fig. 7A

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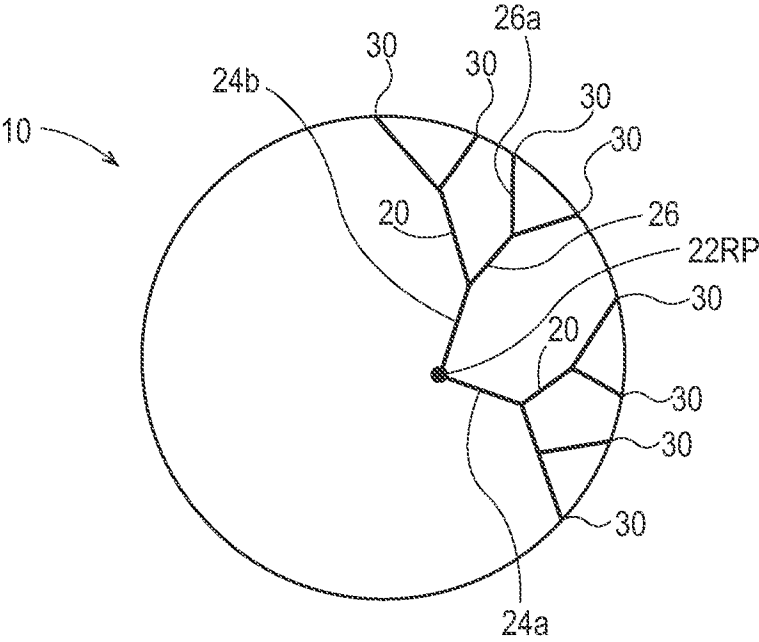


Fig. 8

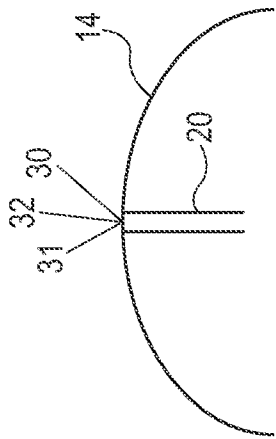


Fig. 9A

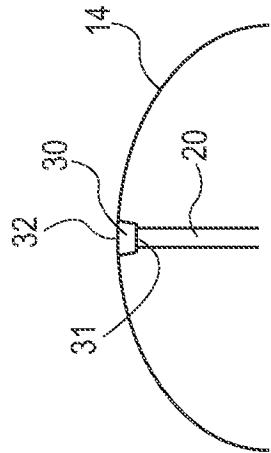


Fig. 9B

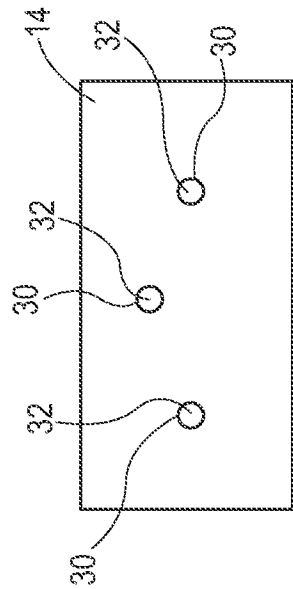


Fig. 9C

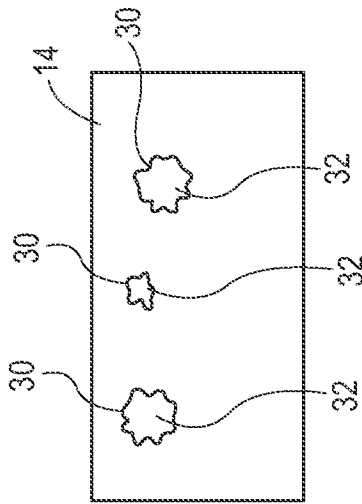


Fig. 9D

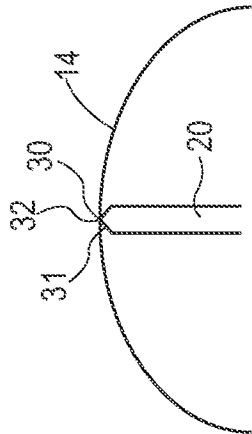


Fig. 9E

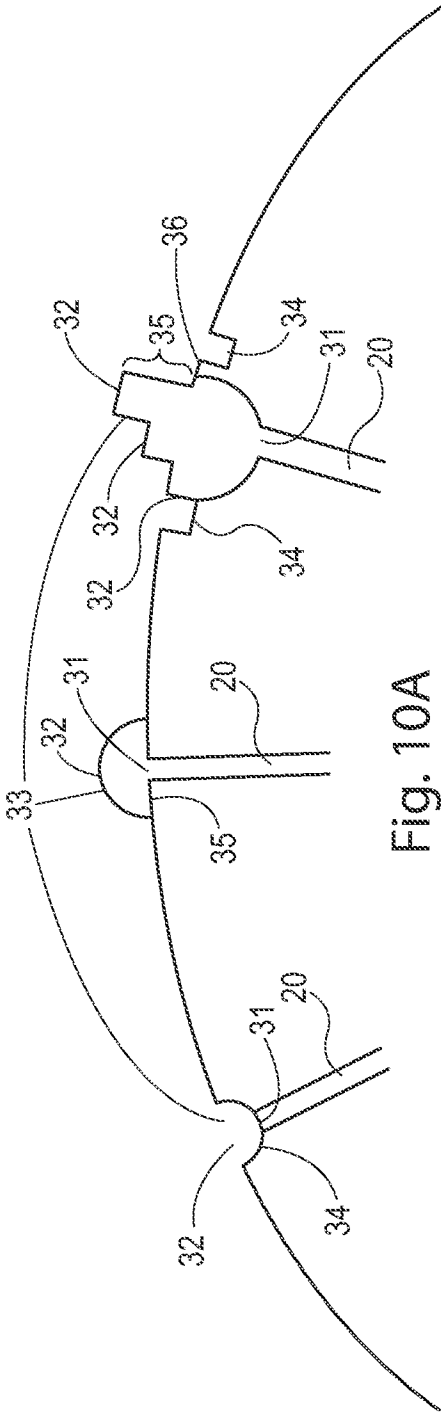


Fig. 10A

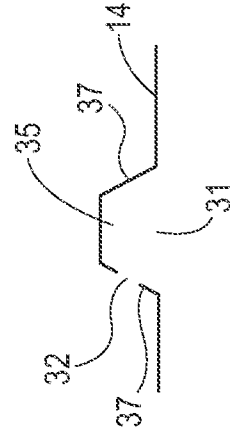


Fig. 10B

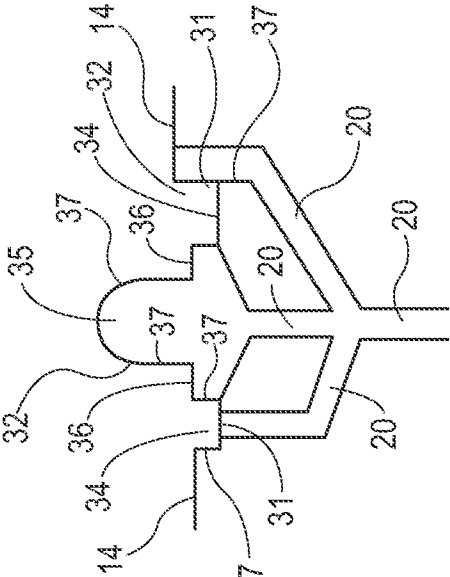


Fig. 10C

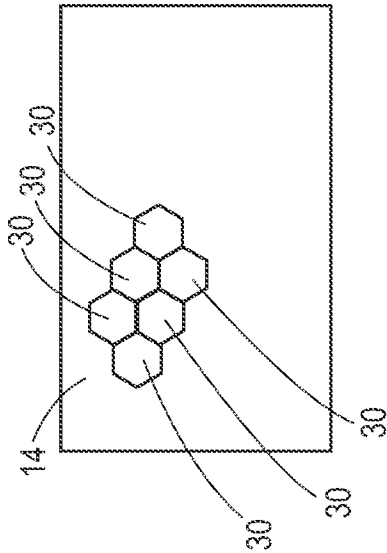


Fig. 11A

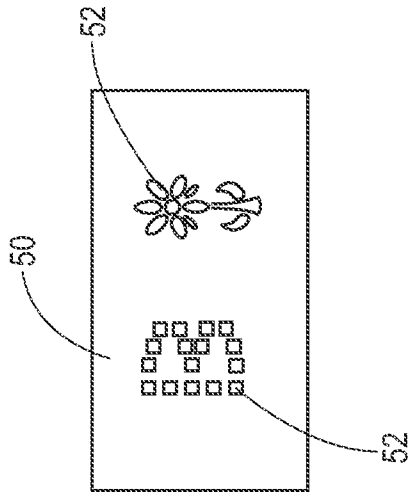


Fig. 11B

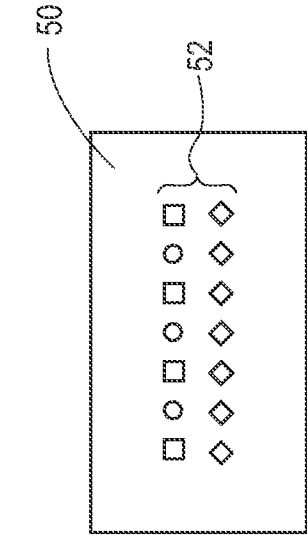


Fig. 11C

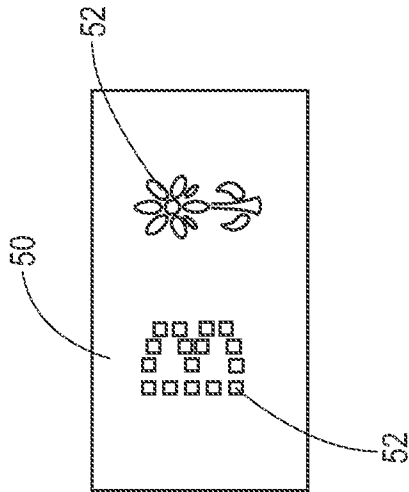


Fig. 11D

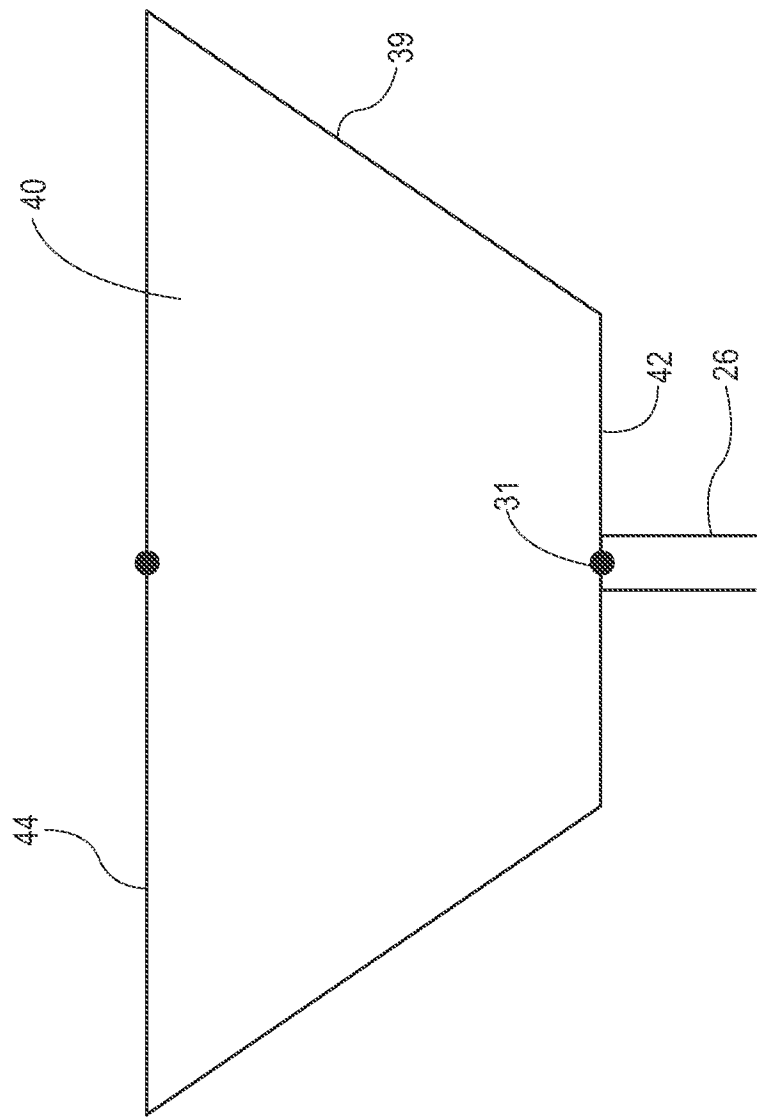


Fig. 12

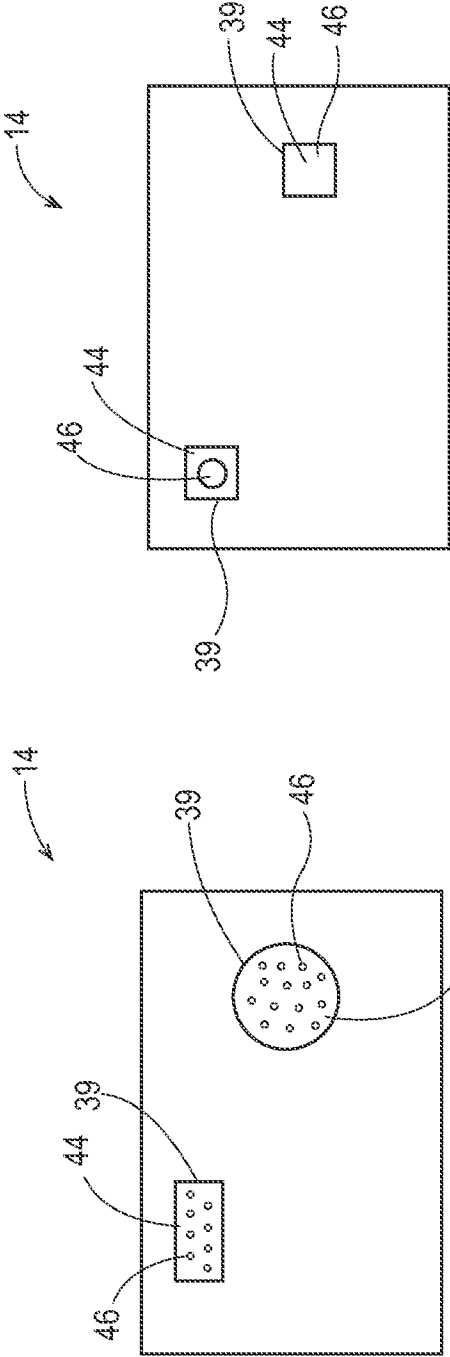


Fig. 13B

Fig. 13A

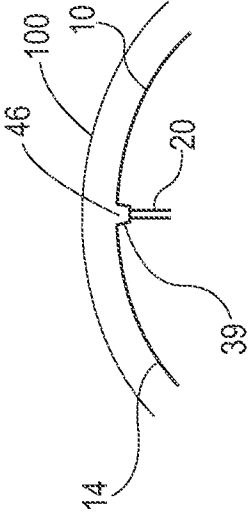


Fig. 13C

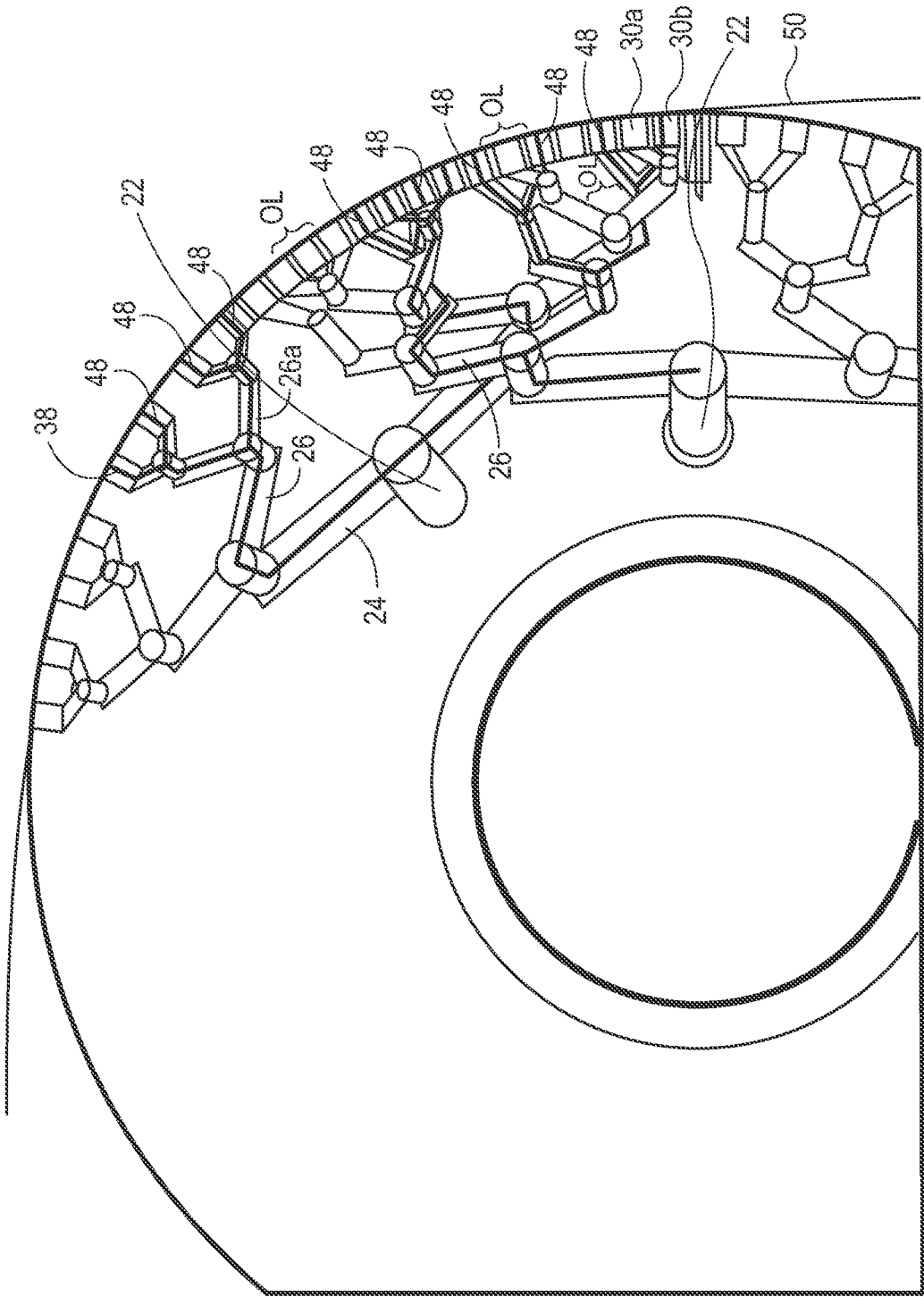


Fig. 14

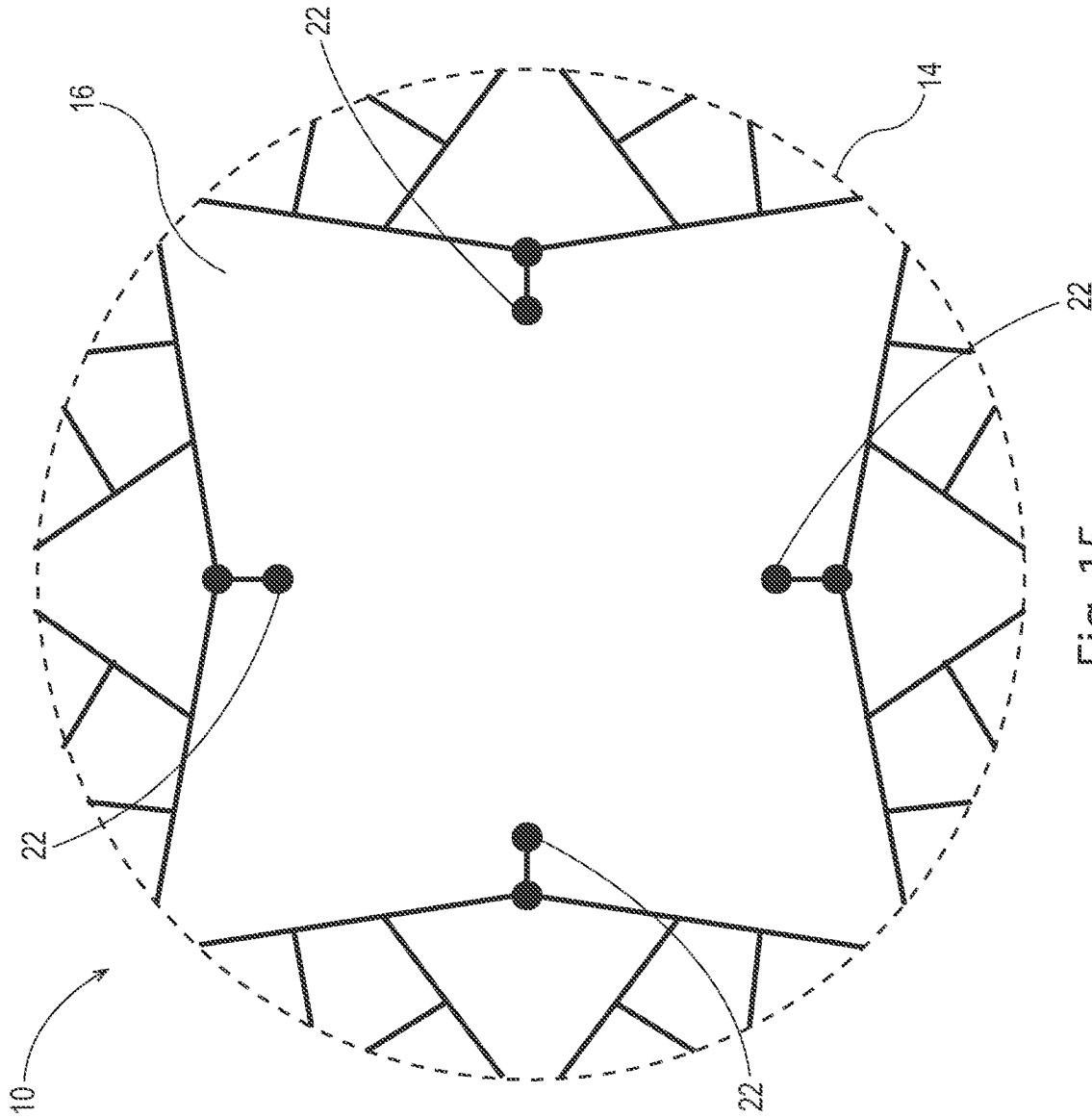


Fig. 15

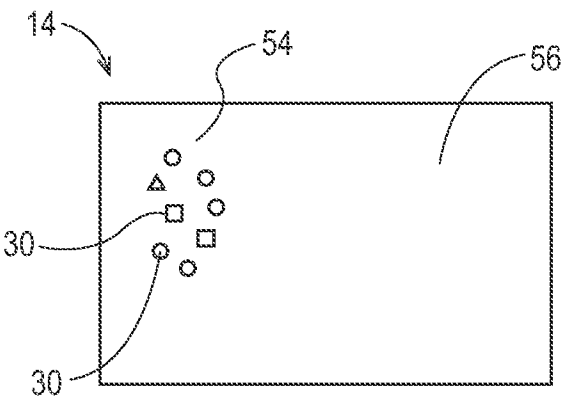


Fig. 16

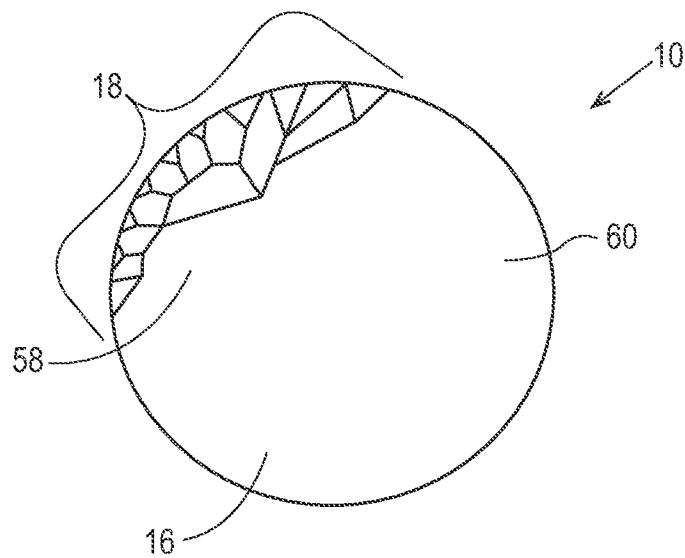


Fig. 17

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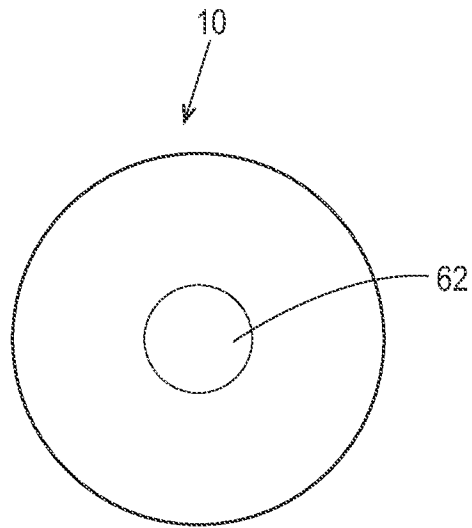


Fig. 18

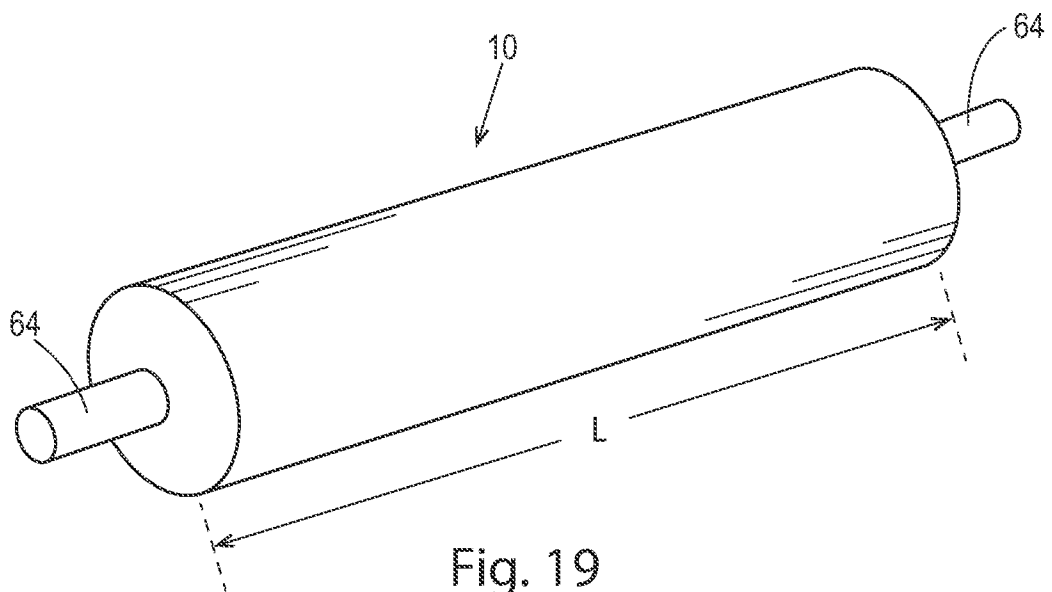


Fig. 19

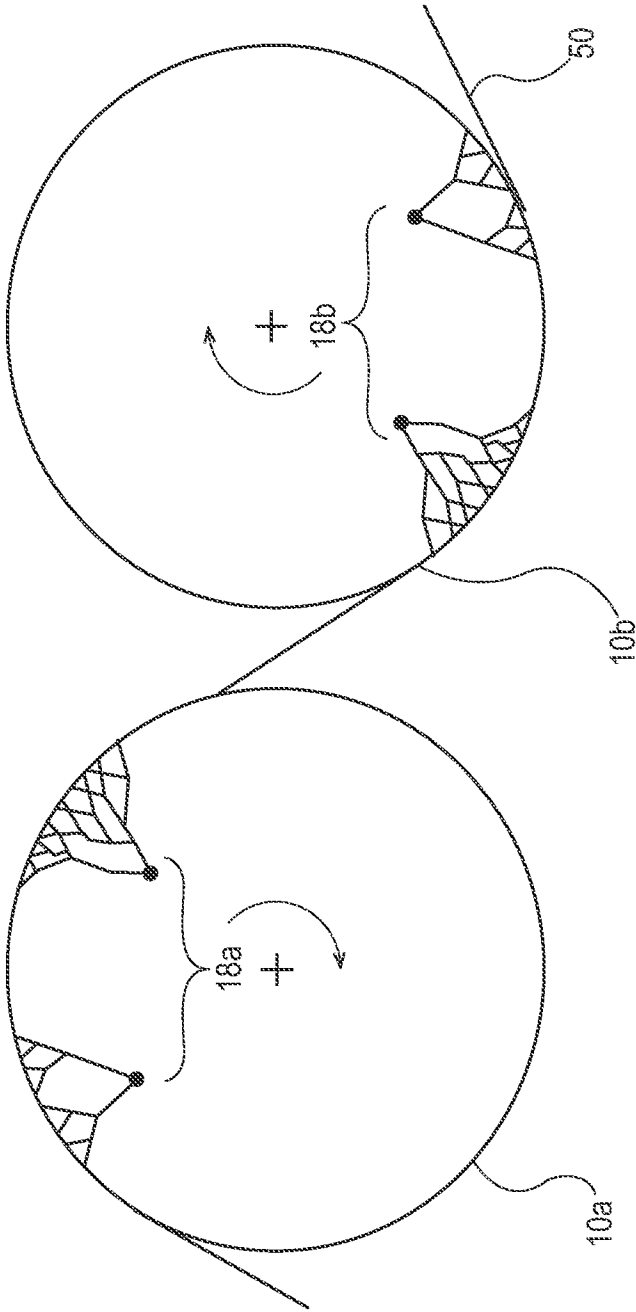


Fig. 20

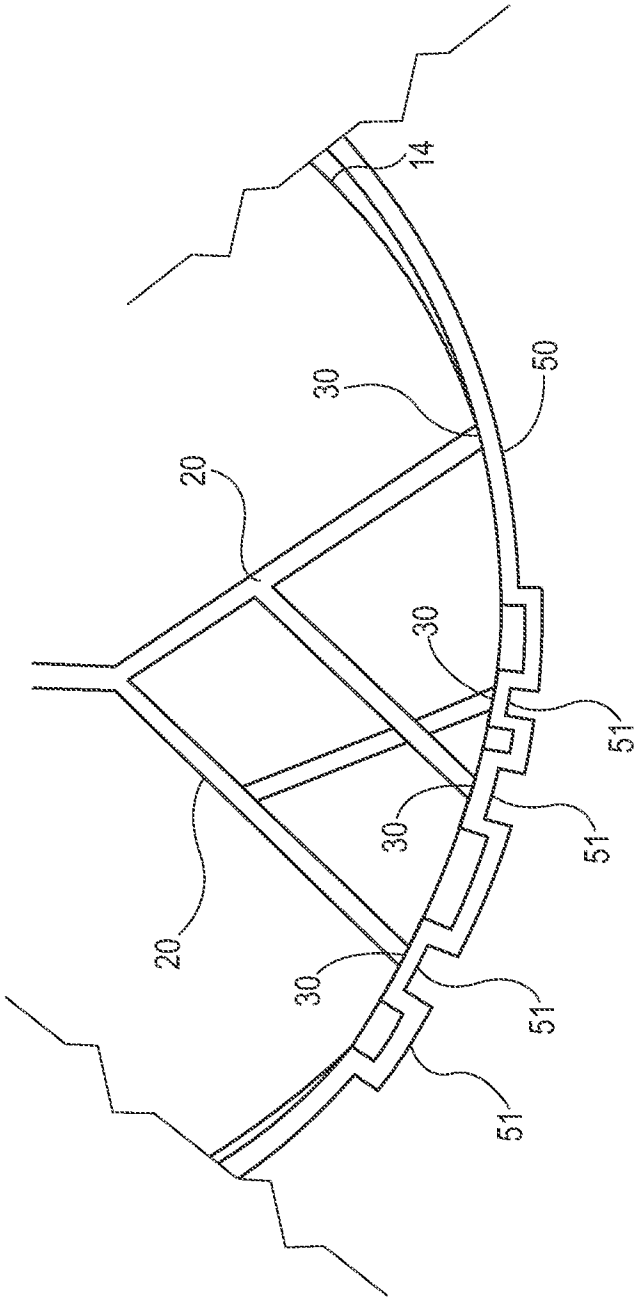


Fig. 21

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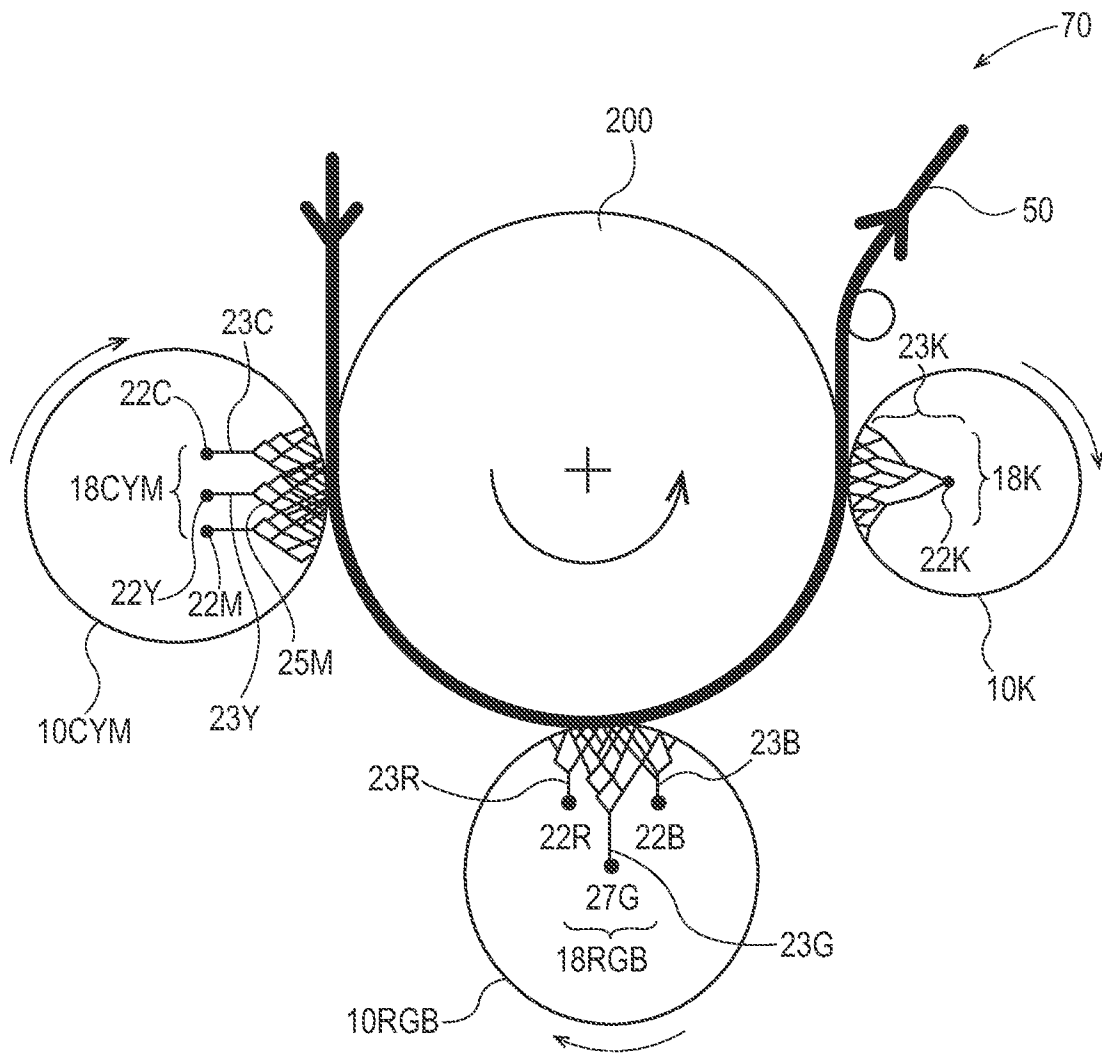


Fig. 22

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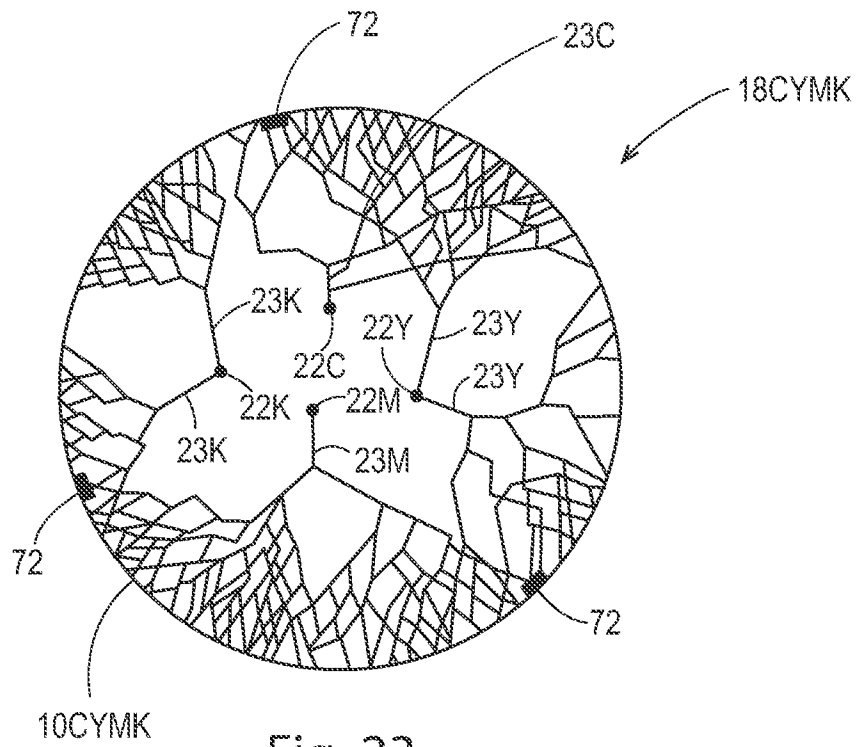


Fig. 23

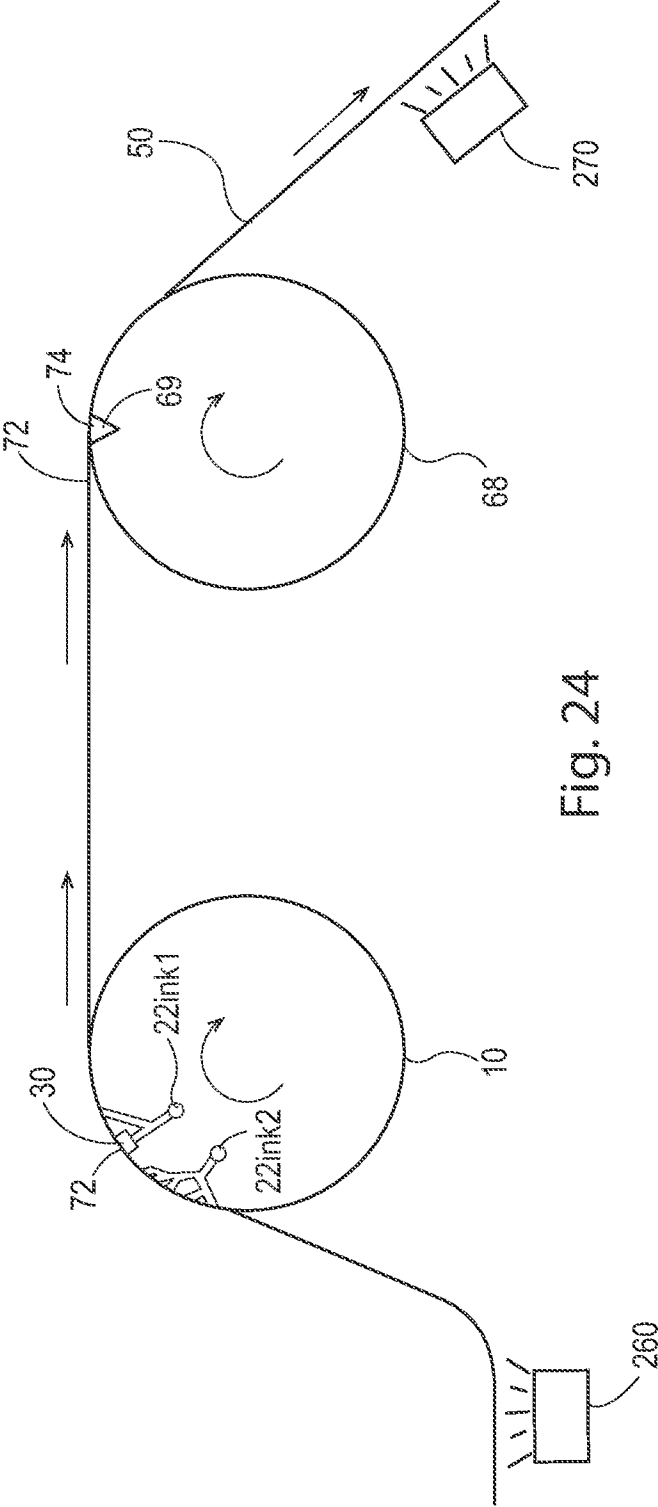
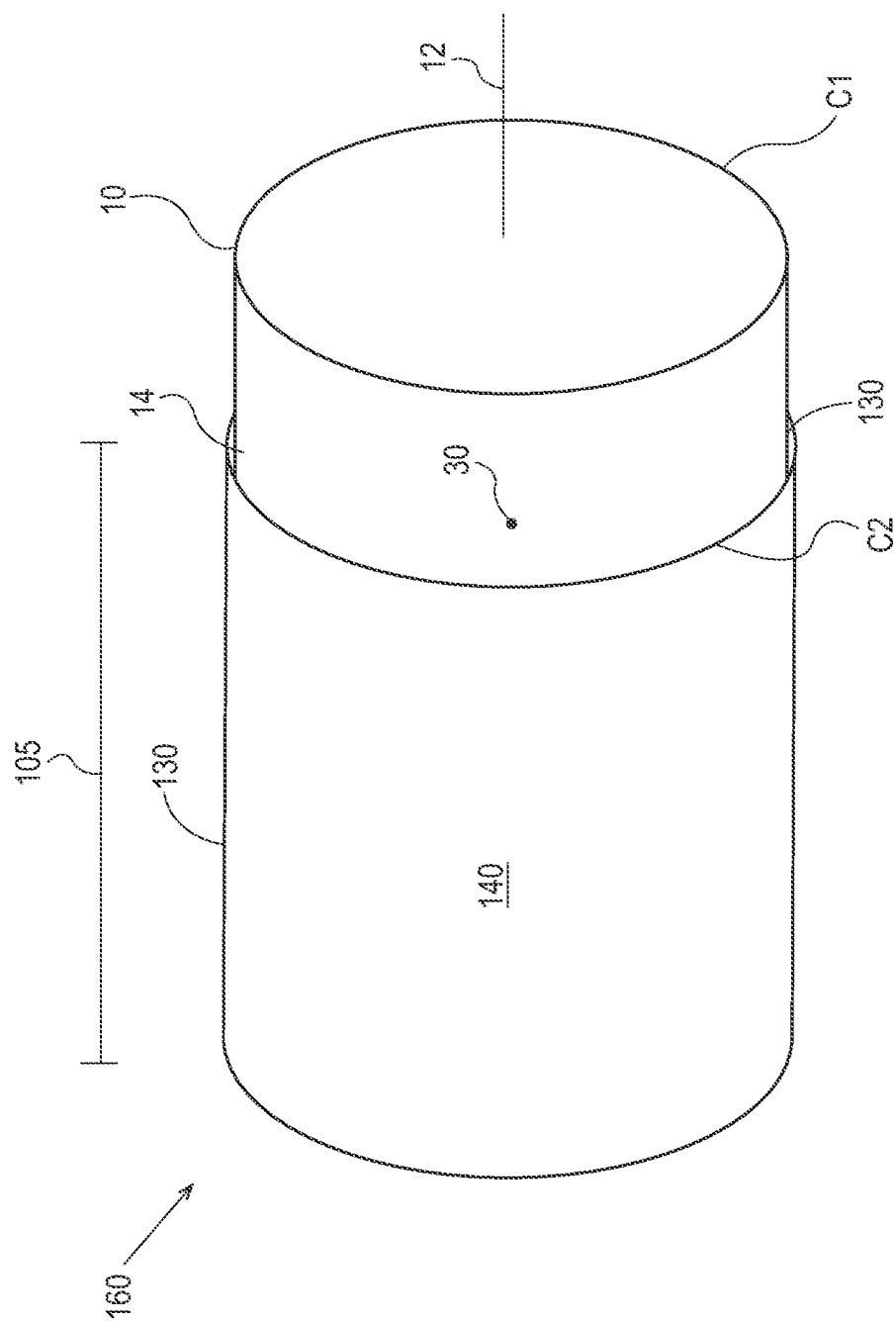


Fig. 24



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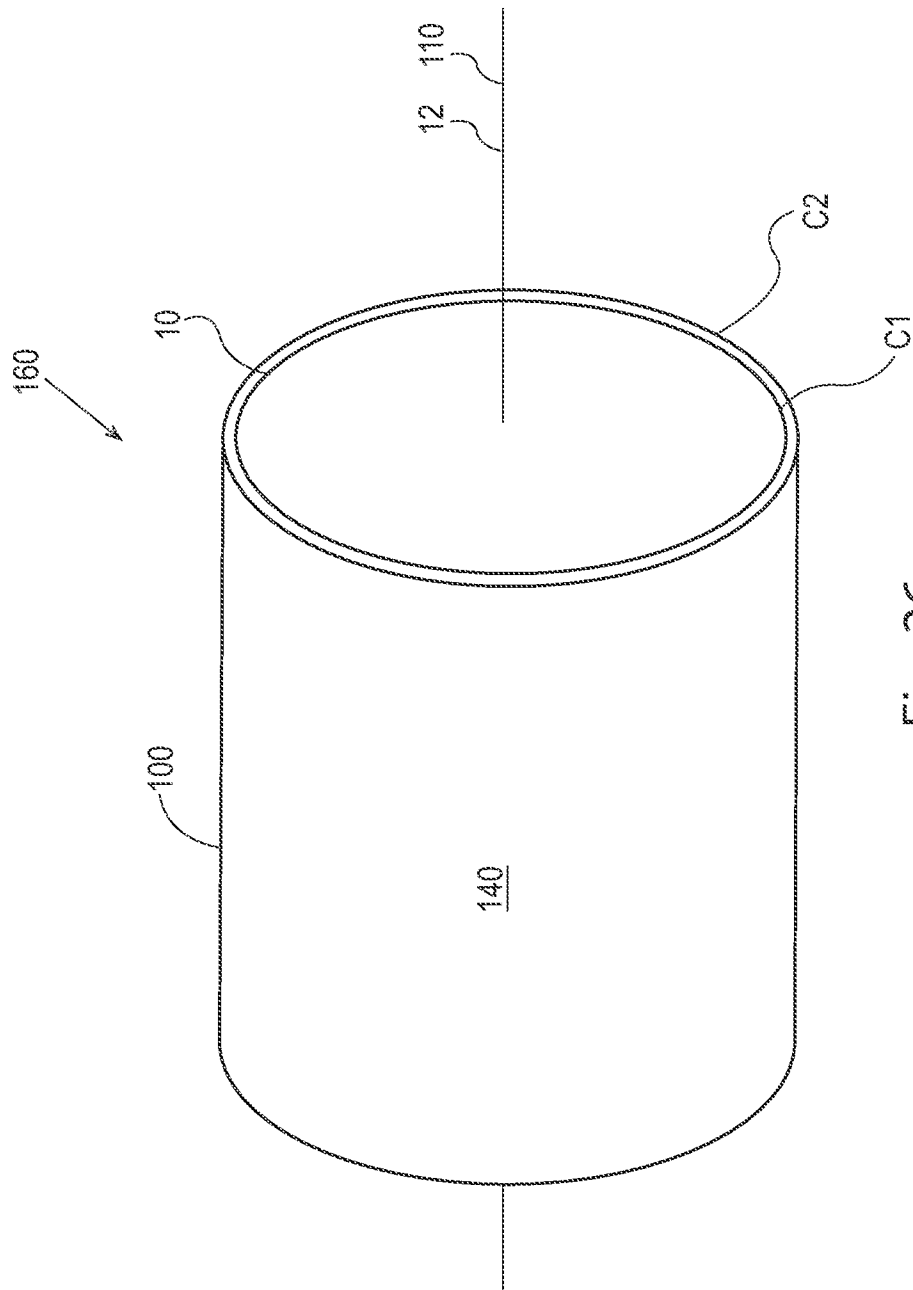


Fig. 26

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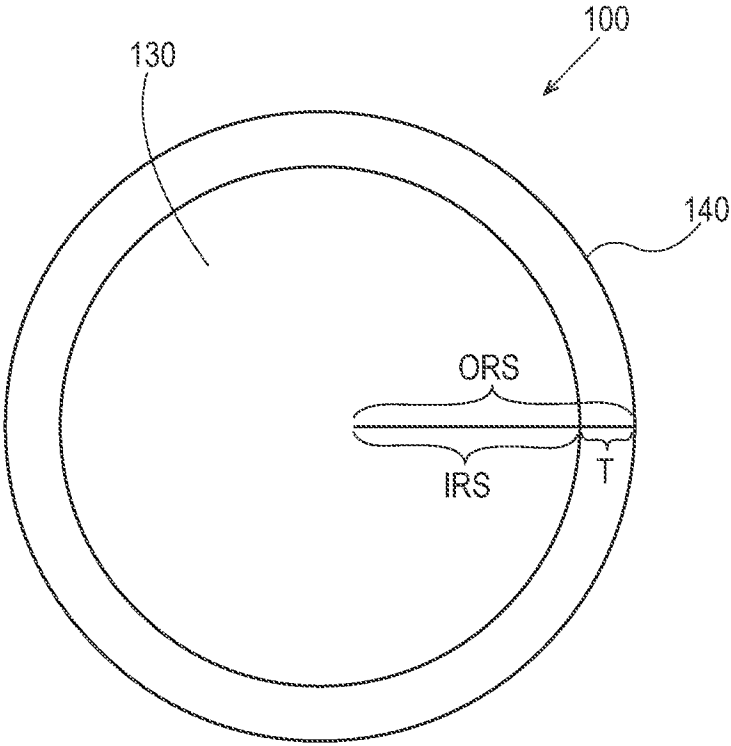
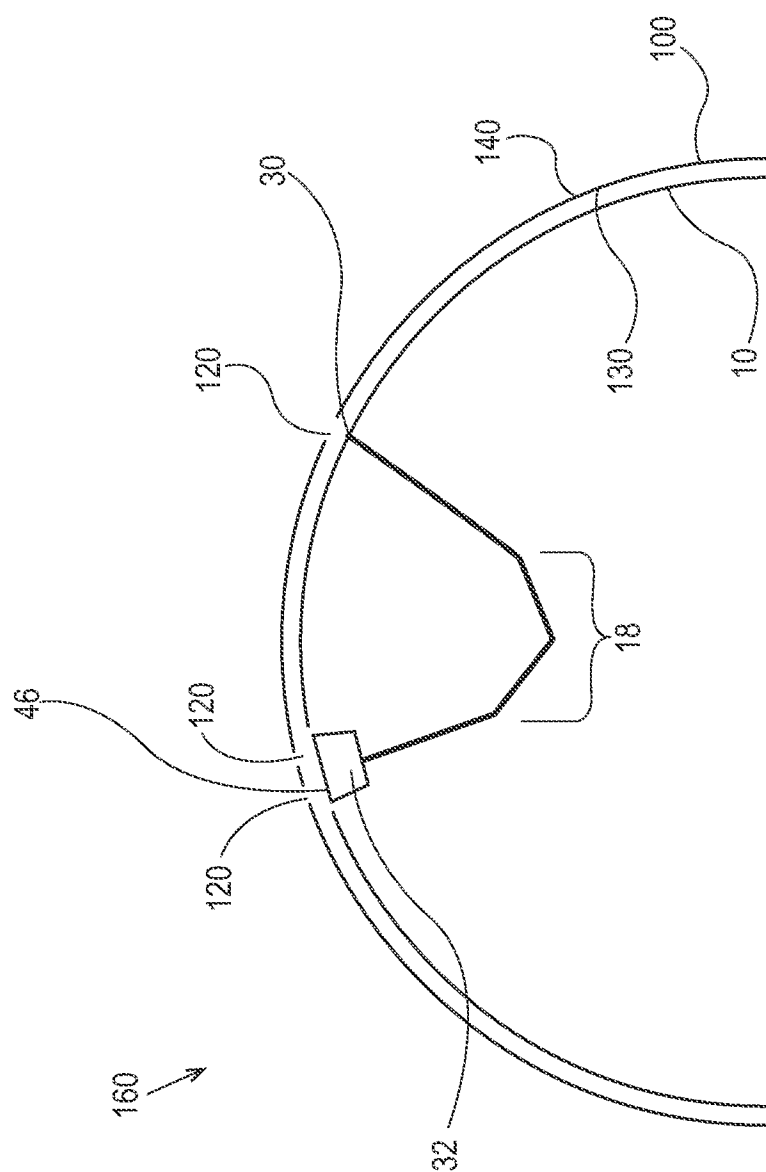


Fig. 27

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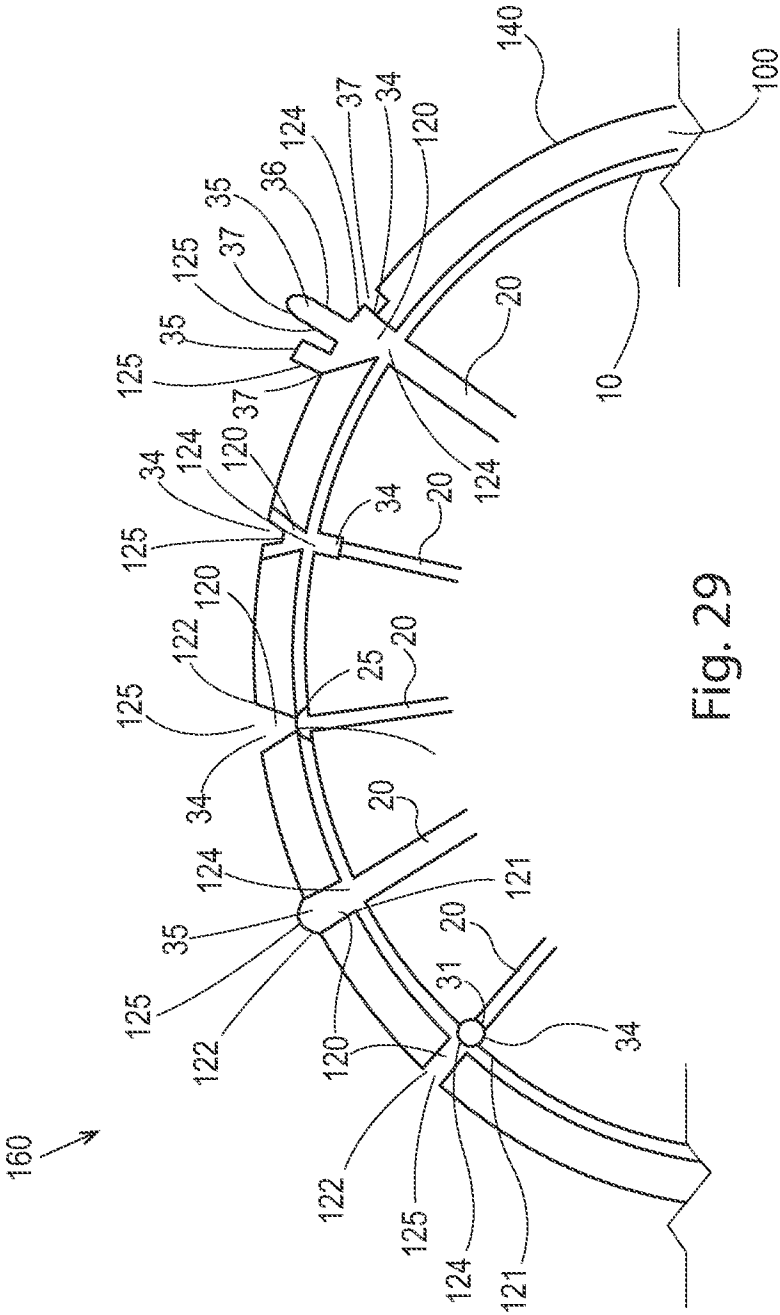
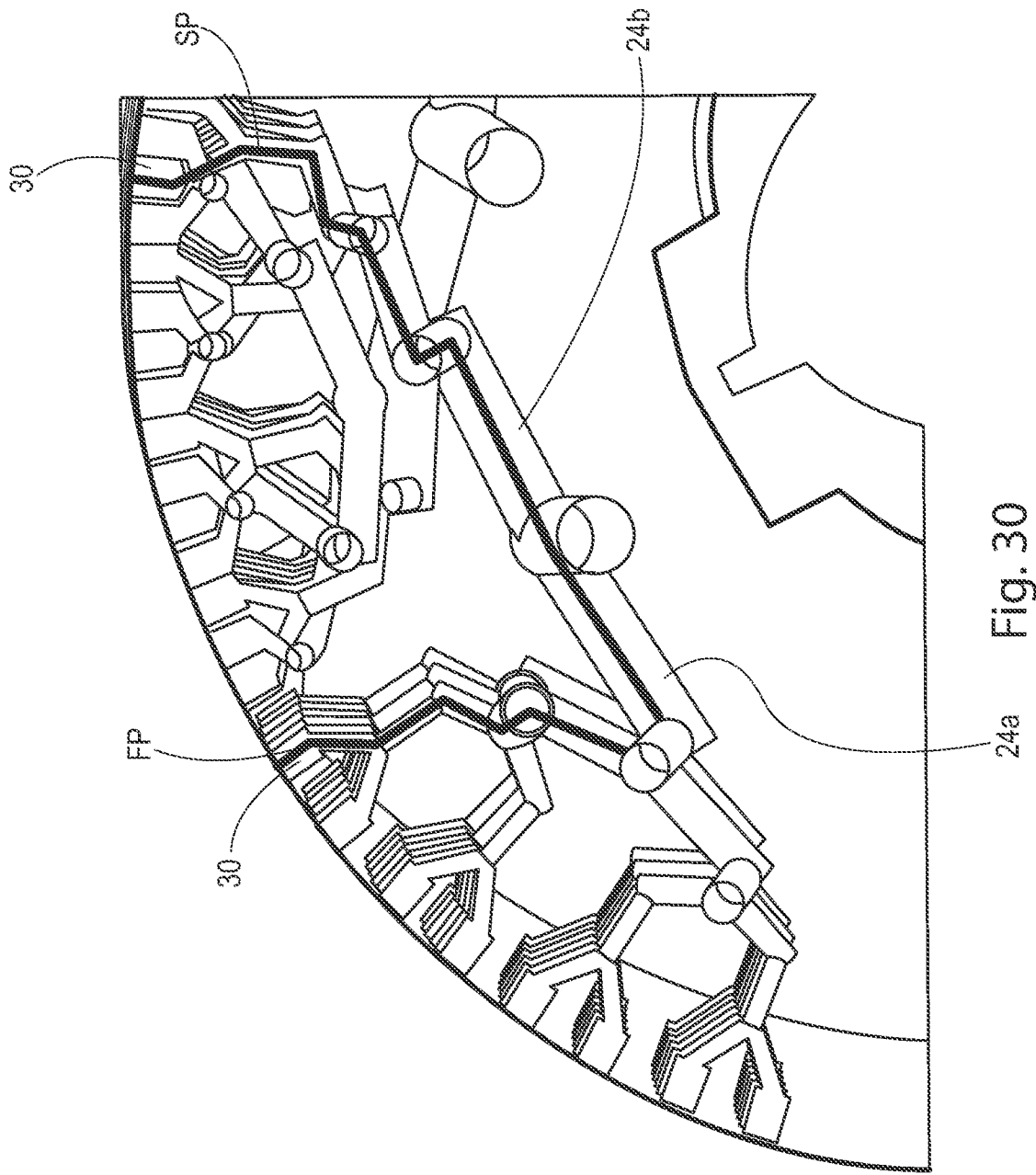


Fig. 29

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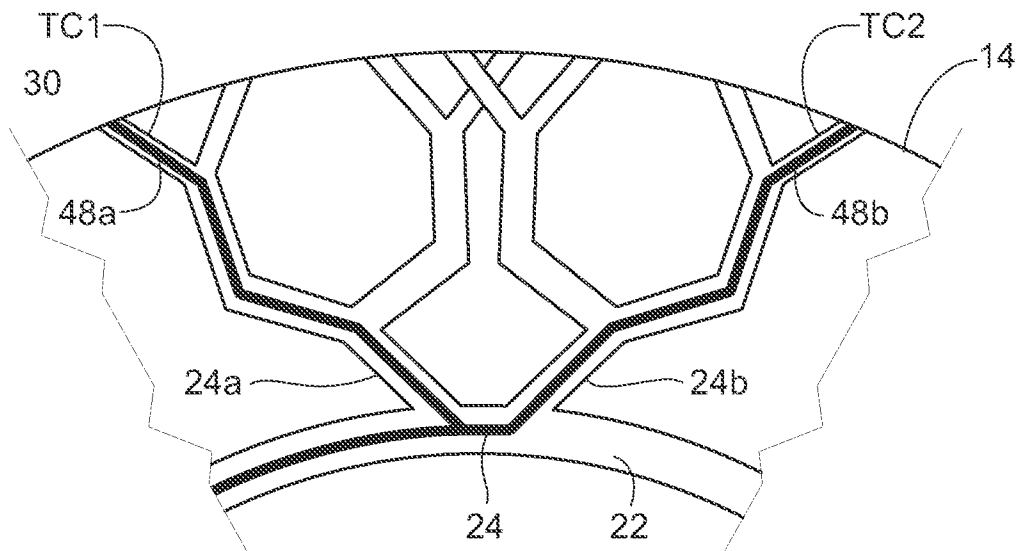


Fig. 31A

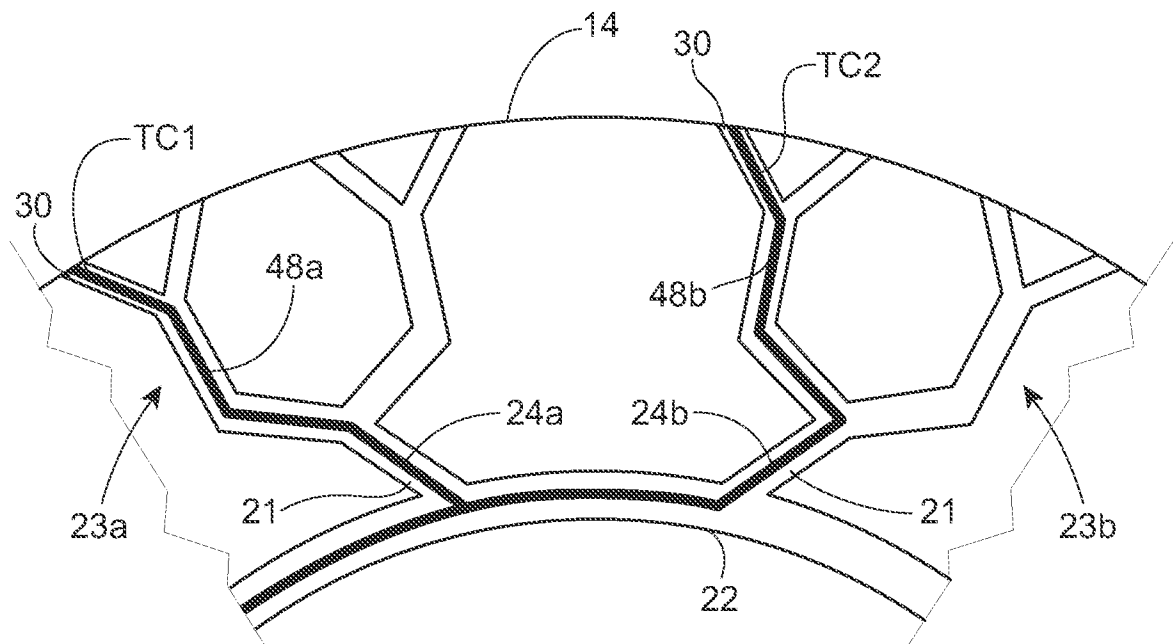


Fig. 31B

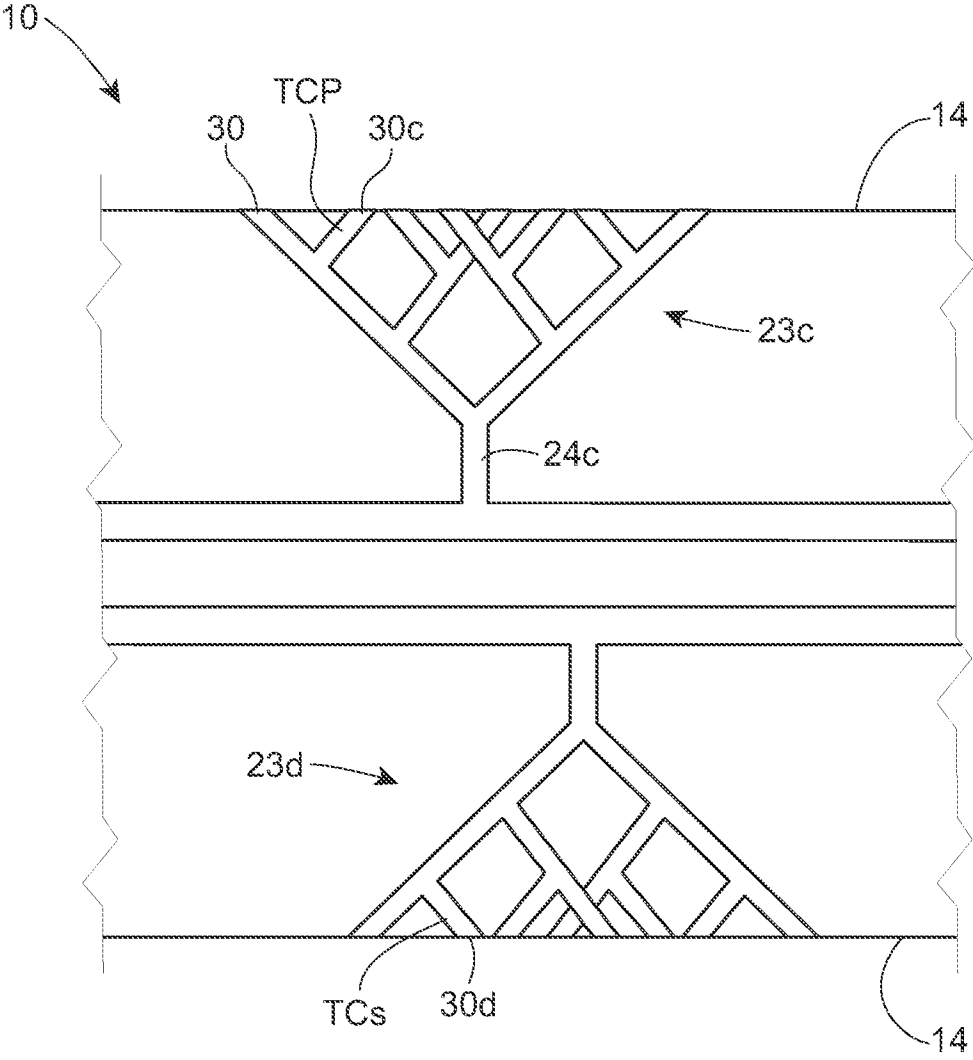
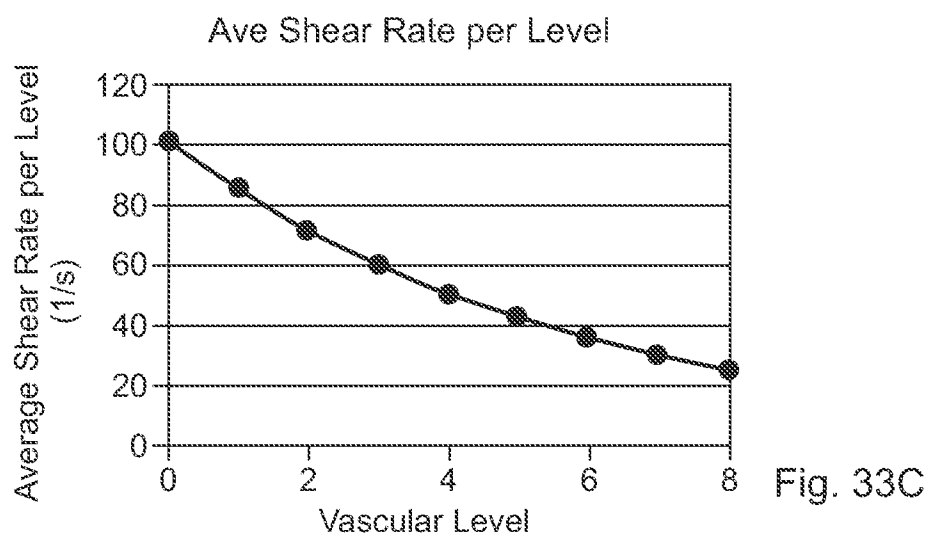
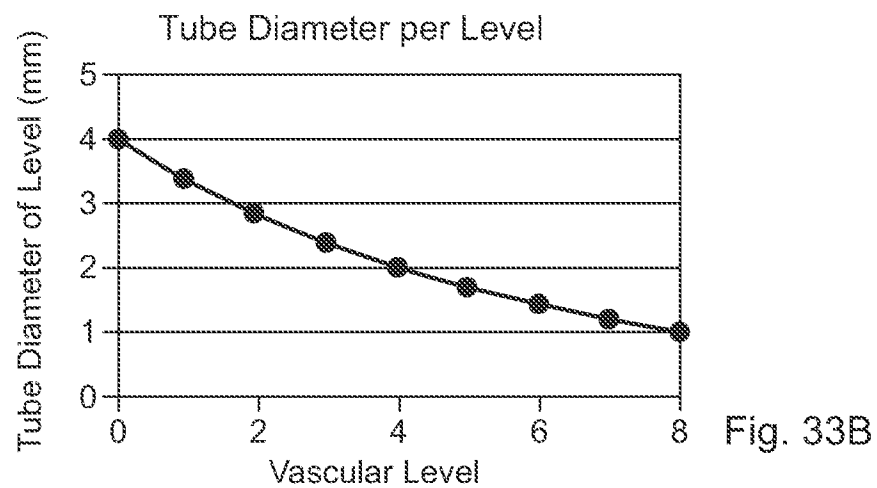
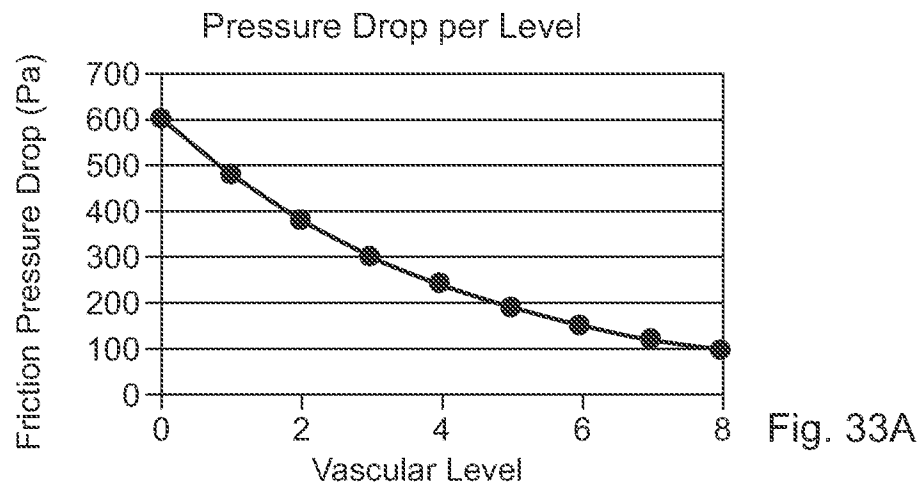


Fig. 32

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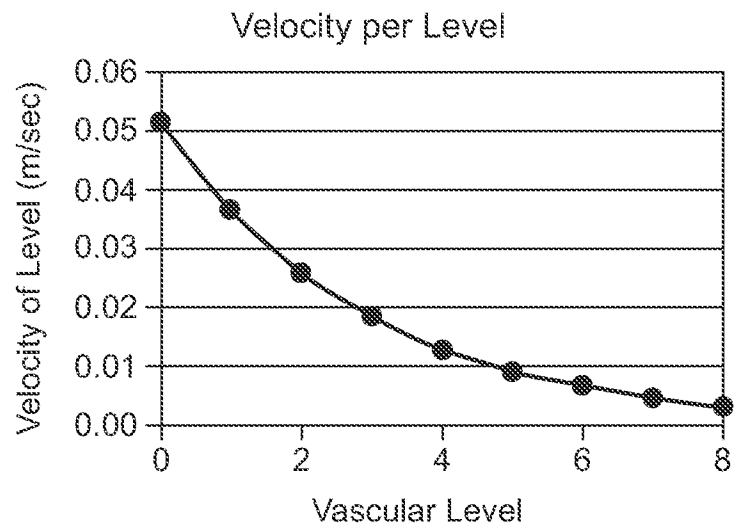


Fig. 33D

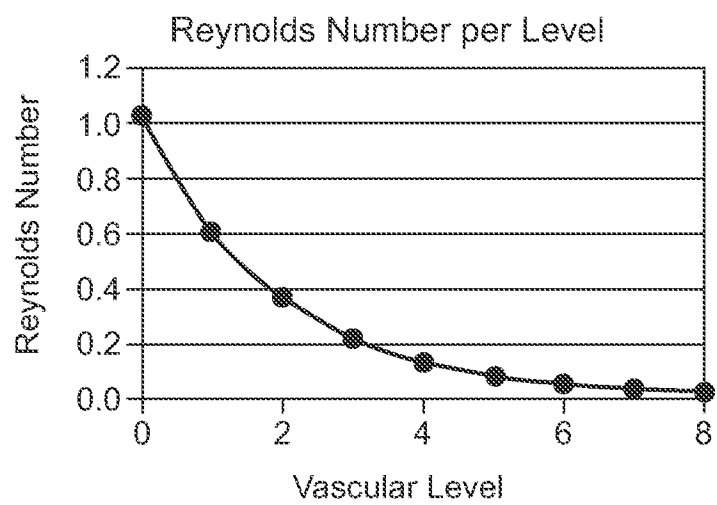
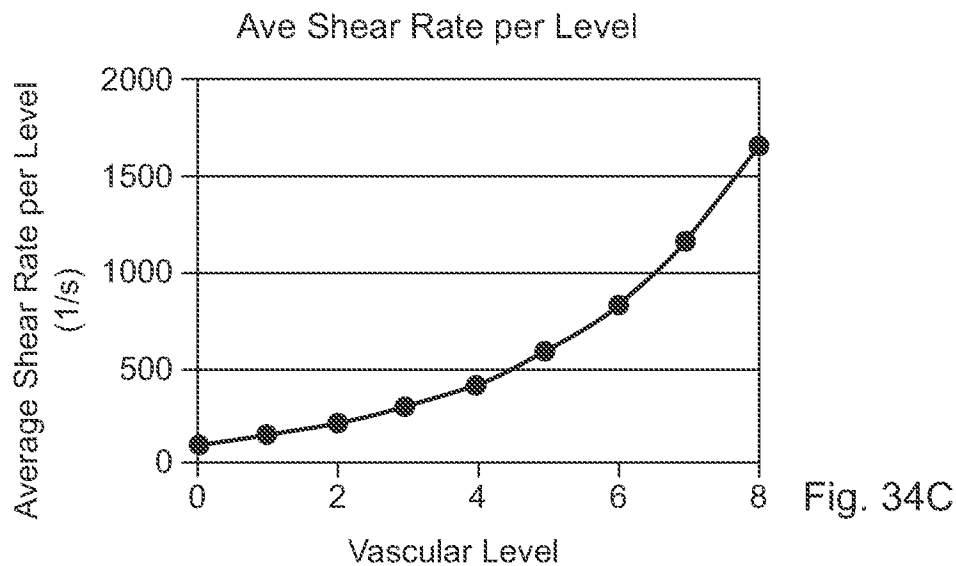
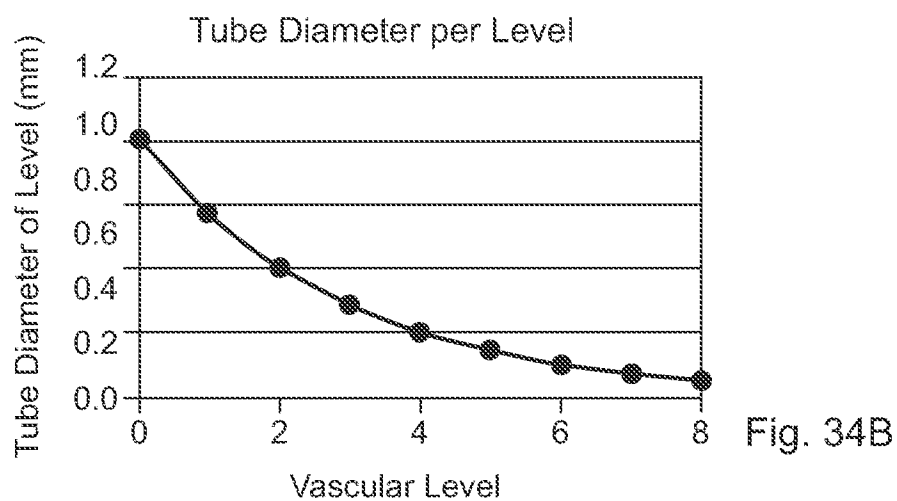
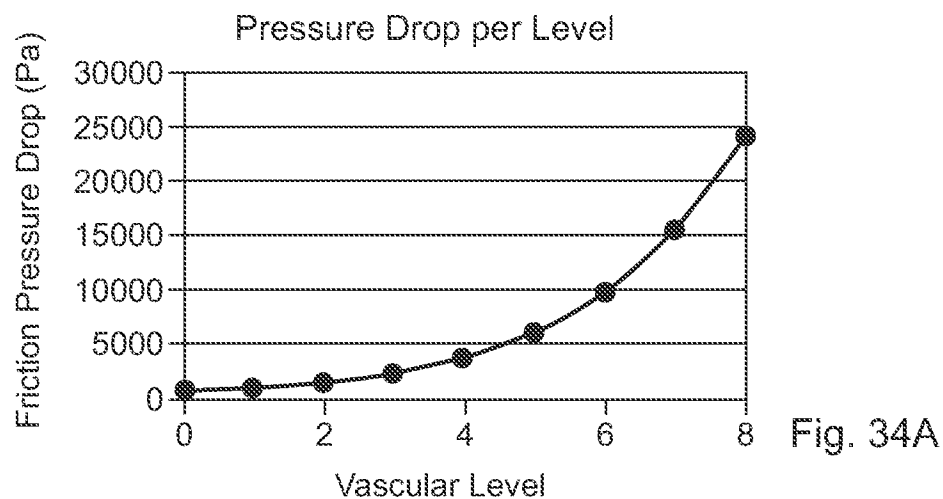
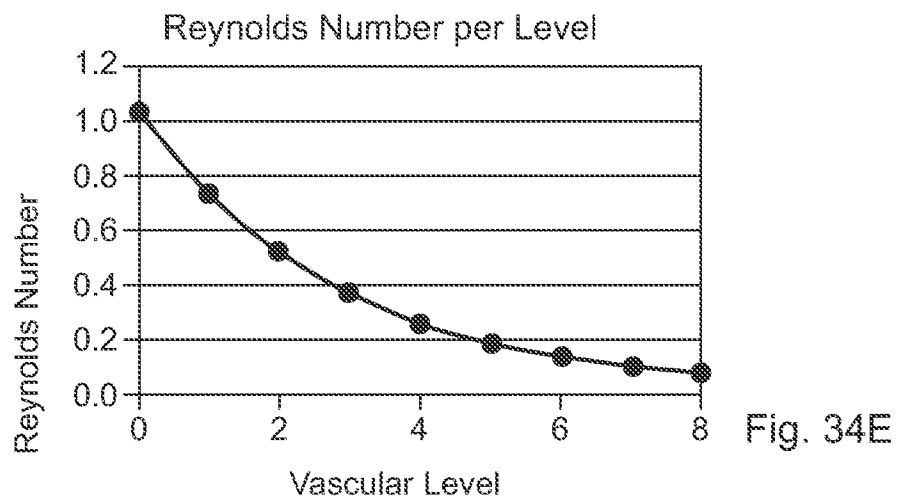
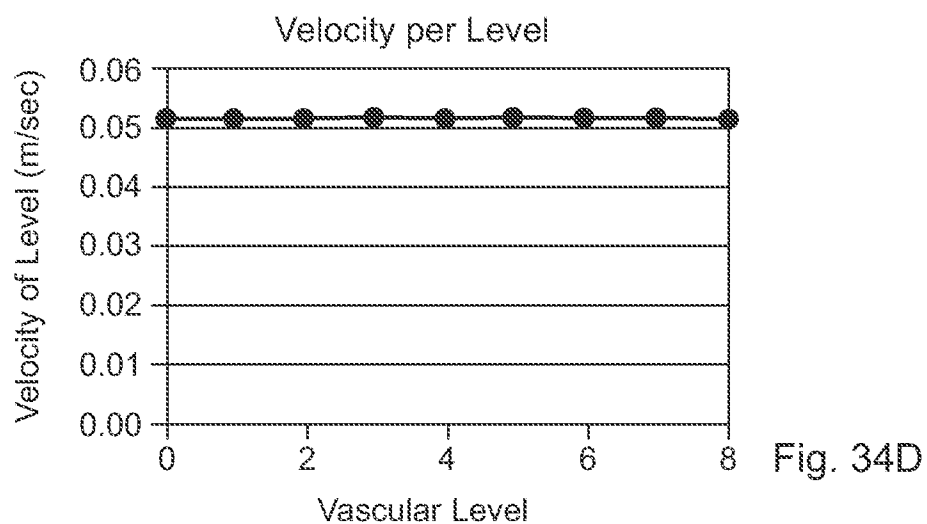


Fig. 33E

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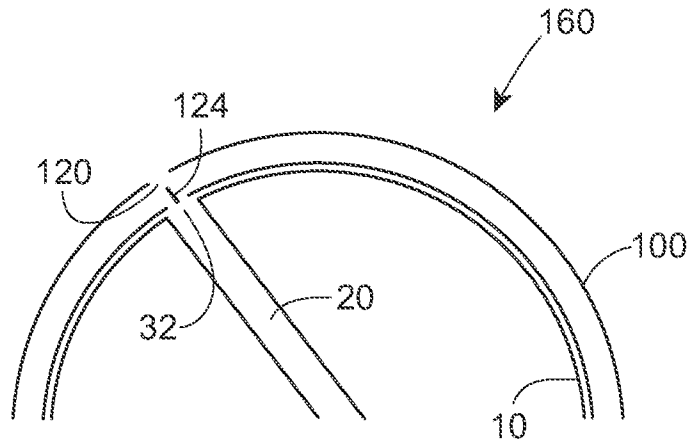


Fig. 35

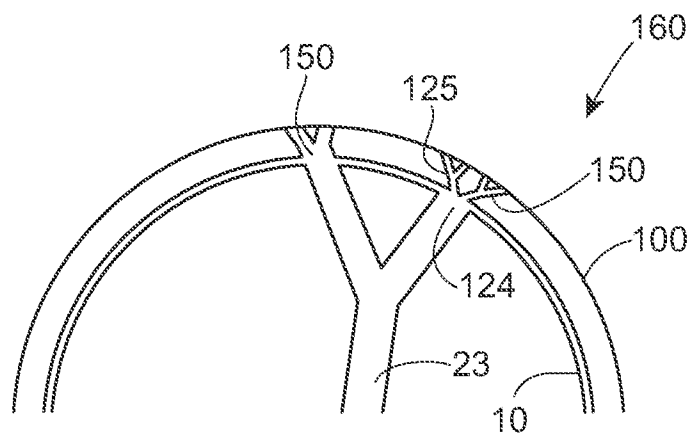


Fig. 36

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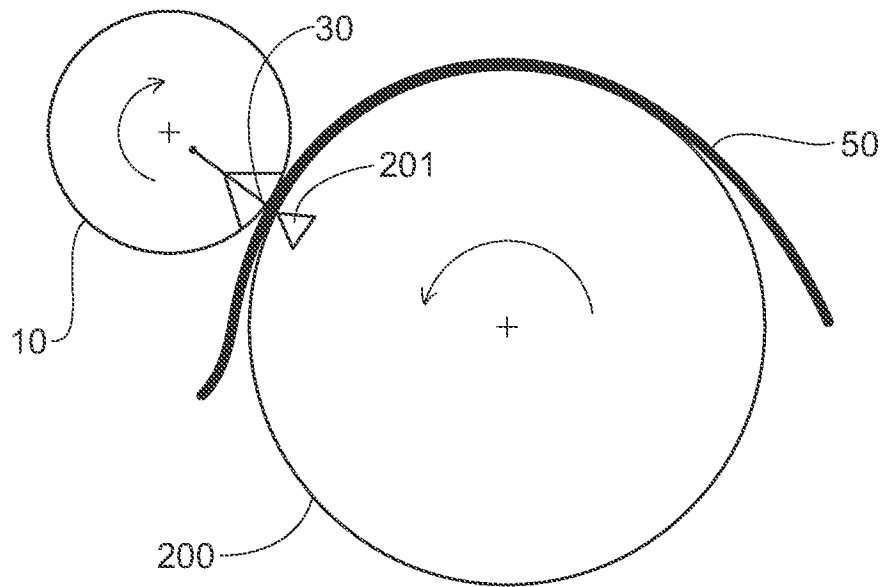


Fig. 37

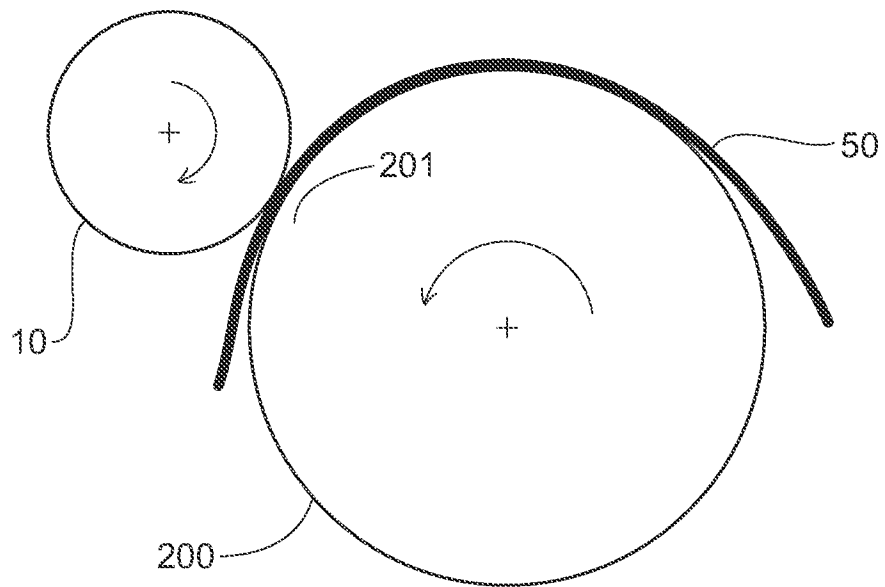


Fig. 38

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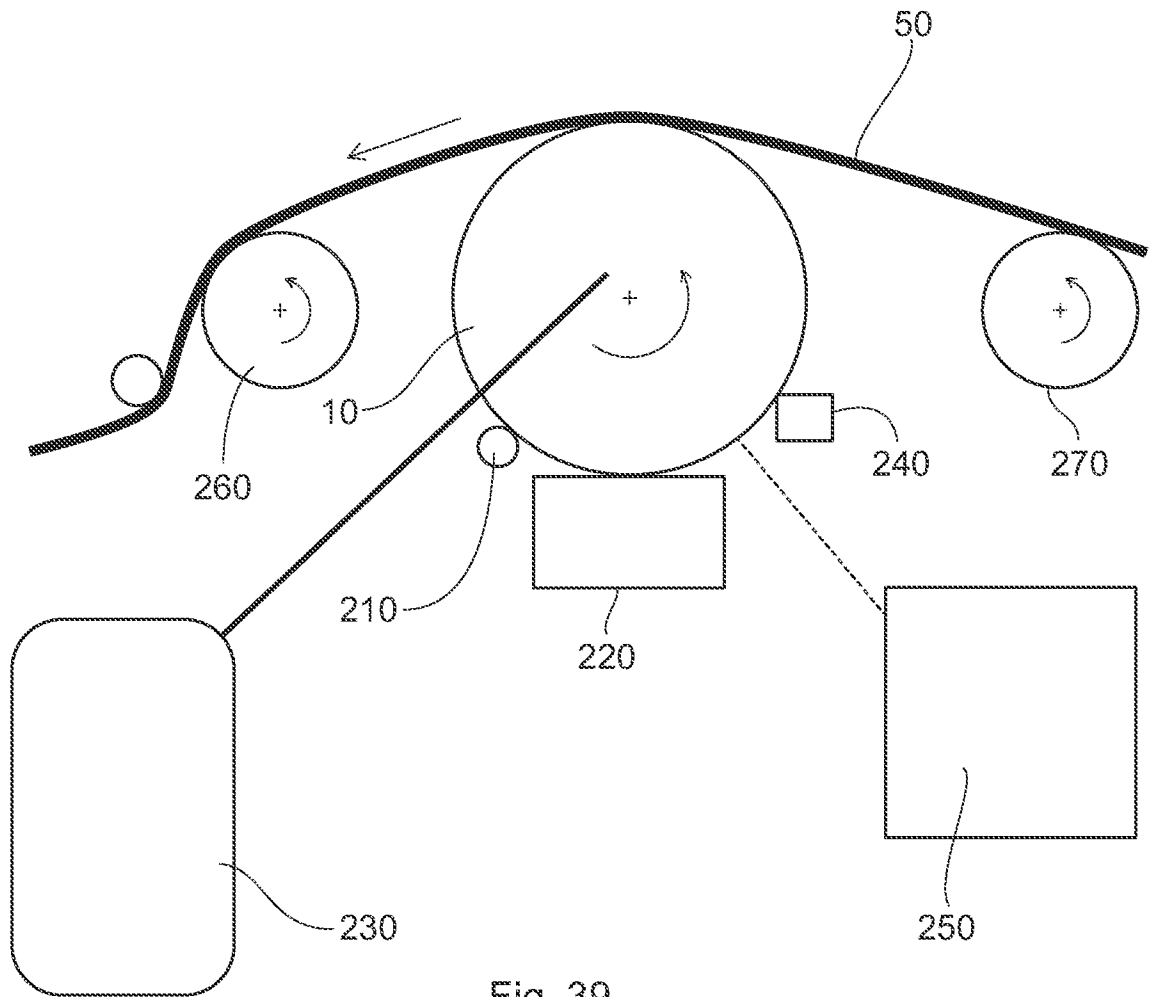


Fig. 39

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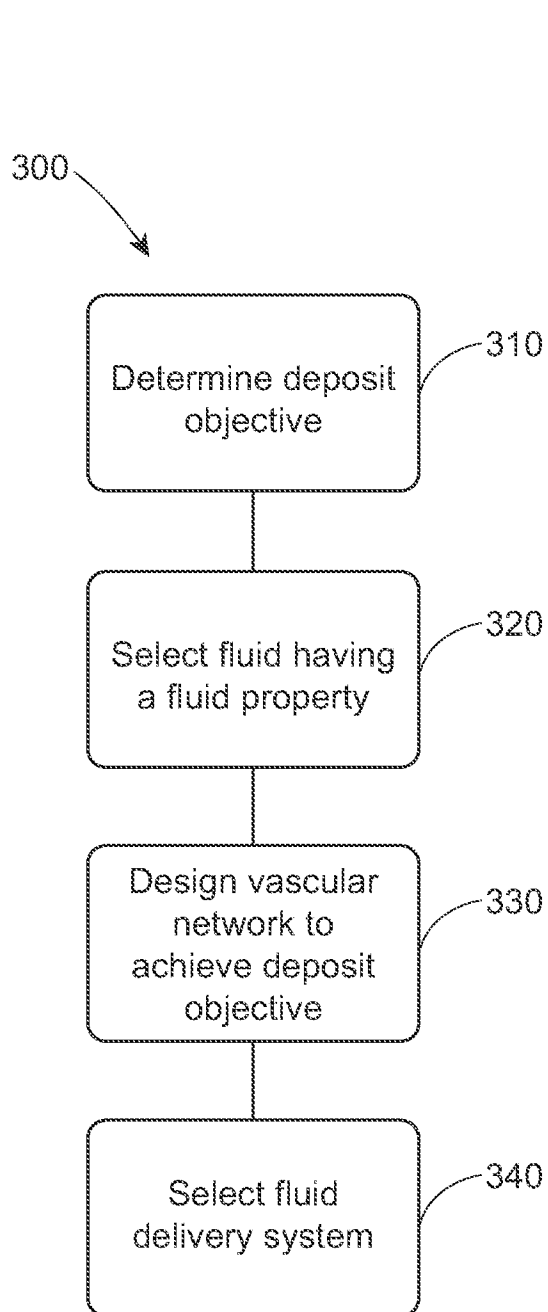


Fig. 40

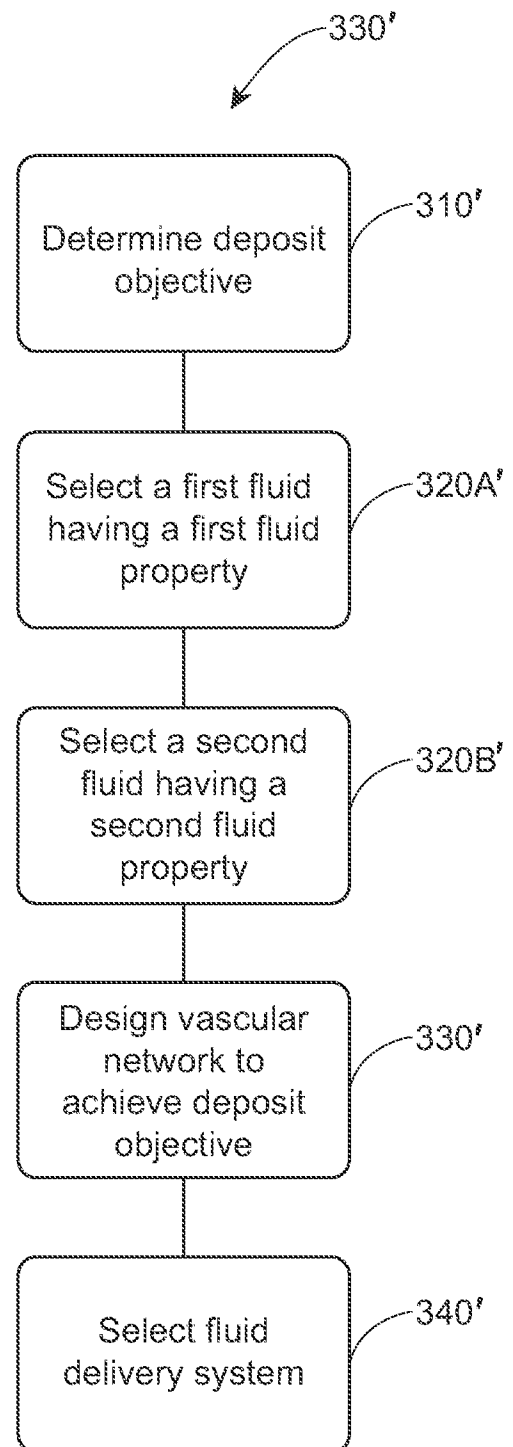


Fig. 41

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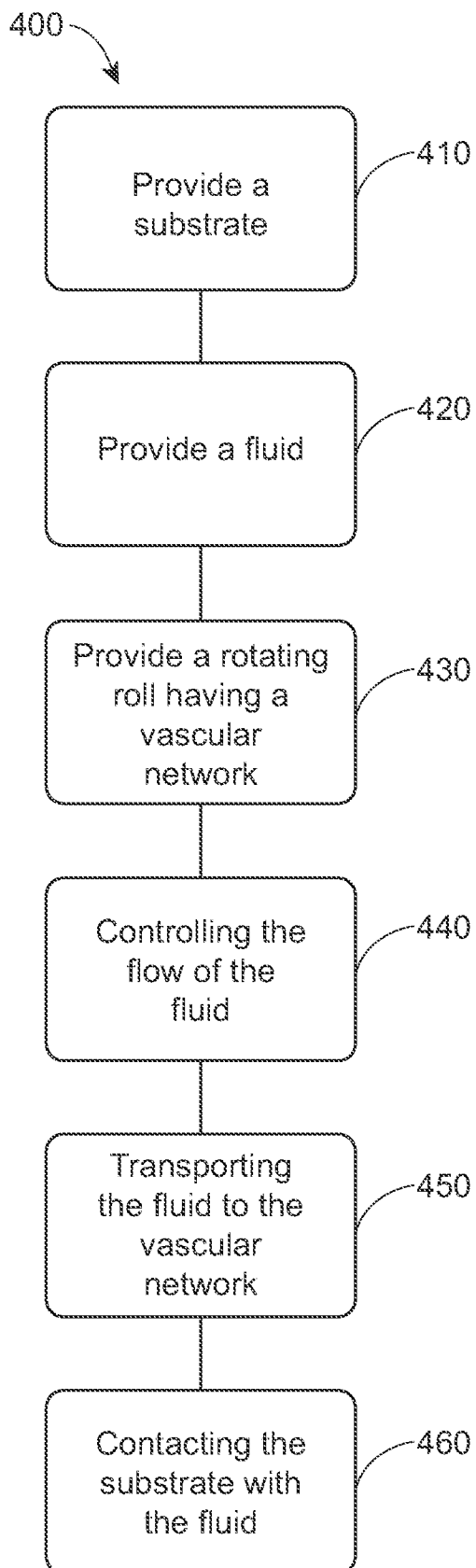


Fig. 42

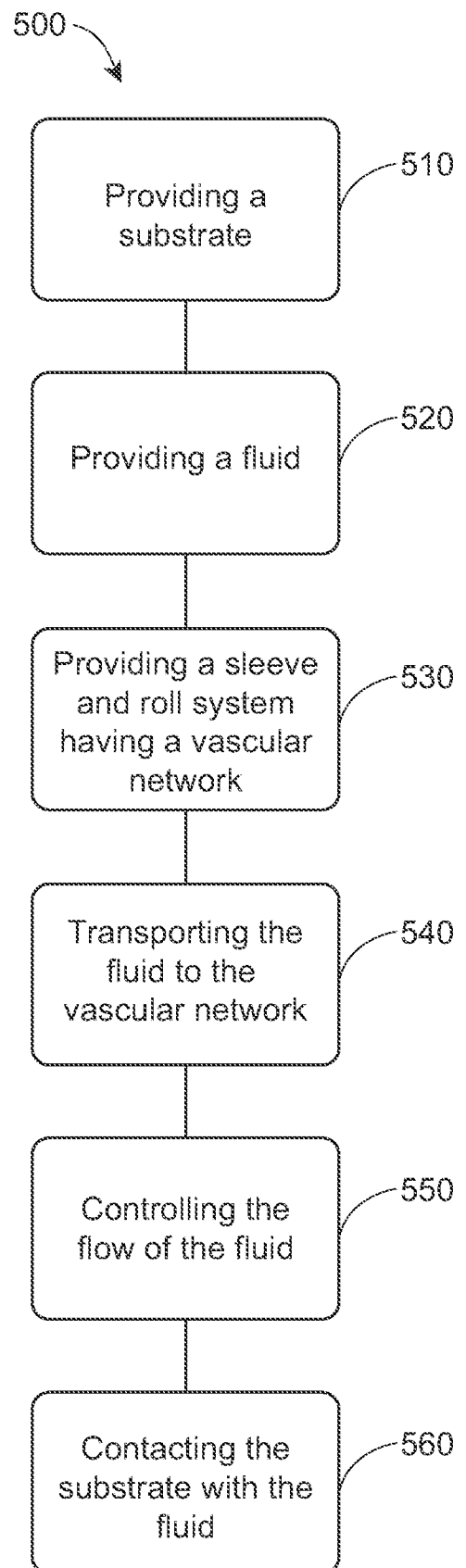


Fig. 43

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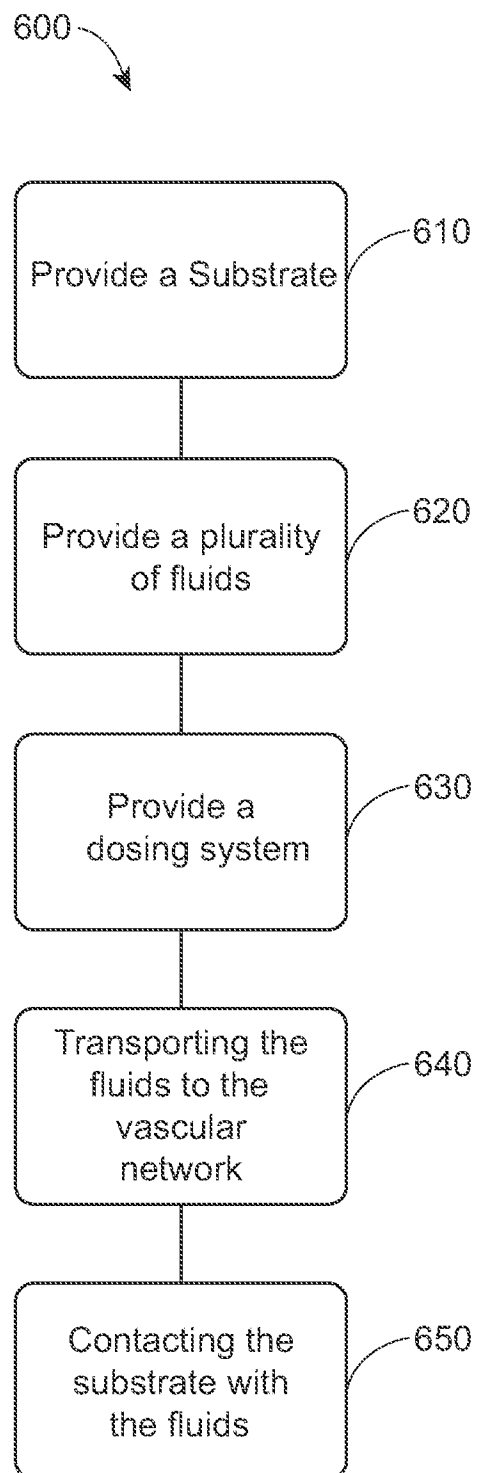


Fig. 44

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/039824

A. CLASSIFICATION OF SUBJECT MATTER
INV. B41F31/22
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 D04H A61F B41M

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,P	WO 2015/184040 A1 (PROCTER & GAMBLE [US]) 3 December 2015 (2015-12-03) page 20 - page 21; claim 3; figures -----	1-8
A	WO 96/21505 A1 (PROCTER & GAMBLE [US]) 18 July 1996 (1996-07-18) cited in the application claims; figures; examples & US 5 827 909 A (DESMARAIS THOMAS A [US]) 27 October 1998 (1998-10-27) cited in the application -----	1
A	WO 2006/091845 A2 (PROCTER & GAMBLE [US]; MCNEIL KEVIN BENSON [US]; SHORE KIM ELLEN [US];) 31 August 2006 (2006-08-31) claims; figures; examples -----	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

28 September 2016

Date of mailing of the international search report

07/10/2016

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/039824

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