



(51) International Patent Classification:
A61M 5/315 (2006.01)

(21) International Application Number:
PCT/US2009/006572

(22) International Filing Date:
16 December 2009 (16.12.2009)

(25) Filing Language: English

(26) Publication Language: English

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

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

Published:

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

(54) Title: SELF-INJECTION DEVICE

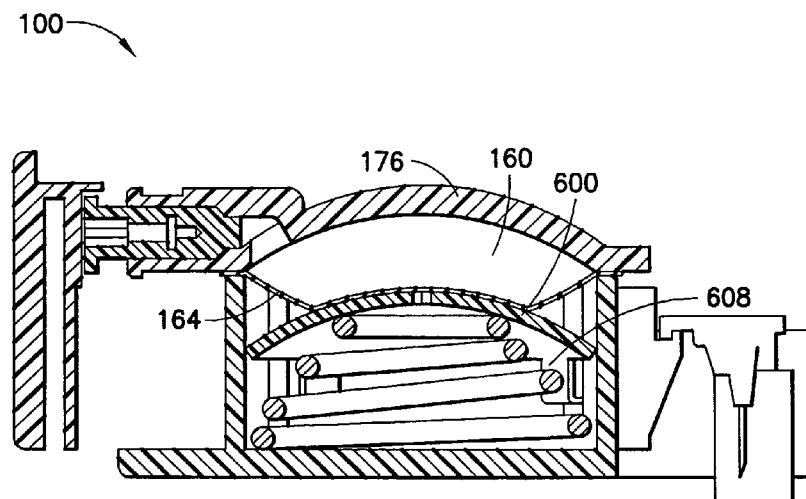


FIG.29

(57) Abstract: A device (100) for delivering a medicament into a patient's body by injection into or through the patient's skin, including a main body having a top enclosure (116) and a bottom enclosure (104), a reservoir (160) disposed within the main body for containing the medicament, and an injection needle (152) for penetrating the skin of the patient, the needle (152) having a lumen and selectively communicating with the reservoir (160). The device also includes a pressurizing system (600, 140) for selectively pressurizing the reservoir (160). In a pre-activated position, the pressurizing system (600, 140) contacts and compresses the reservoir (160) to reduce the initial volume of the reservoir (160), thereby allowing for partial filling of the reservoir (160).

SELF-INJECTION DEVICE

Field of the Invention

[0001] The present invention relates generally to a substance delivery device having improved patient convenience and ease of use, and improved pressurization and activation mechanisms. The present invention also relates generally to a patch-like, self-contained substance infusion or self-injection device that can be used to deliver a variety of substances or medications to a patient. More specifically, the present invention relates to an infusion or self-injection device with a partially fillable reservoir.

Background of the Invention

[0002] A large number of people, such as those suffering from conditions such as diabetes, use some form of infusion therapy, such as daily insulin infusions, to maintain close control of their glucose levels. Currently, in the insulin infusion treatment example, there are two principal modes of daily insulin therapy. The first mode includes syringes and insulin pens. These devices are simple to use and are relatively low in cost, but they require a needle stick at each injection typically three to four times per day. The second mode includes infusion pump therapy, which entails the purchase of an expensive pump that lasts for about three years. The high cost (roughly 8 to 10 times the daily cost of syringe therapy) and limited lifetime of the pump are high barriers to this type of therapy. Insulin pumps also represent relatively old technology and are cumbersome to use. From a lifestyle standpoint, moreover, the tubing (known as the "infusion set") that links the pump with the delivery site on the patient's abdomen is very inconvenient and the pumps are relatively heavy, making carrying the pump a burden. From a patient perspective, however, the overwhelming majority of patients who have used pumps prefer to remain with pumps for the rest of their lives. This is because infusion pumps, although more complex than syringes and pens, offer the advantages of continuous infusion of insulin, precision dosing and programmable delivery schedules. This results in closer glucose control and an improved feeling of wellness.

[0003] Interest in better therapy is on the rise, accounting for the observed growth in pump therapy and increased number of daily injections. In this and similar infusion examples, what is needed to fully meet this increased interest is a form of insulin delivery or infusion that combines the best features of daily injection therapy (low cost and ease of use) with those of the insulin pump (continuous infusion and precision dosing) and that also avoids the disadvantages of each.

[0004] Several attempts have been made to provide ambulatory or "wearable" drug infusion devices that are low in cost and convenient to use. Some of these devices are intended to be partially or entirely disposable. In theory, devices of this type can provide many of the advantages of an infusion pump without the attendant cost and inconvenience. Unfortunately, however, many of these devices suffer from disadvantages including patient discomfort (due to the gauge and/or length of injection needle used), compatibility and interaction between the substance being delivered and the materials used in the construction of the infusion device, and possible malfunctioning if not properly activated by the patient (for example, "wet" injections resulting from premature activation of the device). Difficulties in manufacturing and in controlling needle penetration depth have also been encountered, particularly when short and/or fine-gauge injection needles are used. The possibility of needle-stick injuries to those who come into contact with the used device has also been problematic.

[0005] Accordingly, a need exists for an alternative to current infusion devices, such as infusion pumps for insulin, that further provides simplicity in manufacture and use improvements for insulin and non-insulin applications.

Summary of the Invention

[0006] An aspect of the present invention is to provide a patch-like infusion or self-injection device that can be conveniently worn against the skin while providing infusion of a desired substance, and providing minimal discomfort by using one or more microneedles. An additional aspect of the present invention is to provide such an infusion or self-injection device with a partially fillable reservoir.

[0007] The foregoing and/or other aspects of the present invention are achieved by providing a device for delivering a medicament into a patient's body by injection into or through the patient's skin, including a main body having a top enclosure and a bottom enclosure, a reservoir disposed within the main body for containing the medicament, and an injection needle to penetrate the skin of the patient, the needle having a lumen and selectively communicating with the reservoir. The device also includes a pressurizing system for selectively pressurizing the reservoir. In a pre-activated position, the pressurizing system contacts and compresses the reservoir to reduce an initial volume of the reservoir.

[0008] The foregoing and/or other aspects of the present invention are also achieved by providing a device for delivering a predetermined volume of a medicament into a patient's body by injection into or through the patient's skin, including a main body including a top enclosure and a bottom enclosure, a reservoir disposed within the main body for containing the medicament, and an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir. The device also includes a pressurizing system for selectively pressurizing the reservoir. In a pre-activated position, the pressurizing system contacts and deflects the reservoir to reduce an initial volume of the reservoir substantially to the predetermined volume.

[0009] The foregoing and/or other aspects of the present invention are also achieved by providing a device for delivering a medicament into a patient's body by injection into or through the patient's skin, including a main body including a top enclosure and a bottom enclosure including a cylindrical housing, a reservoir disposed within the main body for containing the medicament, and an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir. The device also includes a pressurizing system for selectively pressurizing the reservoir. In a pre-activated position, the pressurizing system is restrained within the cylindrical housing and the pressurizing system contacts and deforms the reservoir to reduce an initial volume of the reservoir.

[0010] The foregoing and/or other aspects of the present invention are also achieved by providing a device for delivering a medicament into a patient's body by injection into or through the patient's skin, including a main body including a top enclosure and a bottom

enclosure including a cylindrical housing, a reservoir disposed within the main body for containing the medicament, and an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir. The device also includes a pressurizing system for selectively pressurizing the reservoir. The pressurizing system includes means for reducing an initial volume of the reservoir.

[0011] Additional and/or other aspects and advantages of the present invention will be set forth in part in the description that follows and, in part, will be apparent from the description, or may be learned by practice of the invention.

Brief Description of the Drawings

[0012] The above and/or other aspects and advantages of embodiments of the invention will be more readily appreciated from the following detailed description, taken in conjunction with the accompanying drawings, of which:

FIG. 1 illustrates a perspective view of an embodiment of a patch-like infusion device in a pre-activated state prior to activation;

FIG. 2 illustrates a partially exploded view of the infusion device of FIG. 1 in the pre-activated state;

FIG. 3 illustrates a partially exploded view of the infusion device of FIG. 1 in the pre-activated state with an activator button rotated away to reveal more detail;

FIG. 4 illustrates a more fully exploded view of the infusion device of FIG. 1 in the pre-activated state;

FIG. 5 illustrates a cross-sectional view of the infusion device of FIG. 1 in the pre-activated state;

FIG. 6 illustrates a cross-sectional view of the infusion device of FIG. 1 in the pre-activated state with the activator button rotated away;

FIG. 7 illustrates a partially exploded view of the infusion device of FIG. 1 during installation of a safety mechanism;

FIG. 8 illustrates a partially exploded view of the infusion device of FIG. 1 subsequent to activation;

FIG. 9 illustrates a more fully exploded view of the infusion device of FIG. 1 subsequent to activation;

FIG. 10 illustrates a cross-sectional view of the infusion device of FIG. 1 subsequent to activation;

FIG. 11 illustrates a partially exploded view of the infusion device of FIG. 1 subsequent to deployment of the safety mechanism;

FIG. 12 illustrates a cross-sectional view of the infusion device of FIG. 1 subsequent to deployment of the safety mechanism;

FIG. 13 illustrates a bottom surface of the safety mechanism;

FIG. 14 further illustrates the structure of the safety mechanism;

FIGS 15A-15D illustrate an end-of-dose indicator and the operation thereof in the infusion device of FIG. 1;

FIG. 16 illustrates an embodiment of an infusion device with an injection port;

FIG. 17 illustrates an exploded view of an embodiment of a retention assembly to reduce a force required to activate the infusion device of FIG. 1;

FIGS. 18A and 18B respectively illustrate plan views of a sprocket and a corresponding sprocket opening in the assembly of FIG. 17;

FIG. 19 illustrates a cross-sectional view of the assembly of FIG. 17 in a pre-activated position;

FIGS. 20A and 20B respectively illustrate free body diagrams of embodiments of retention assemblies;

FIGS. 21 and 22 illustrate another embodiment of a retention assembly to reduce a force required to activate the infusion device of FIG. 1;

FIGS. 23A and 23B illustrate a tool for loading a plunger of FIG. 4 to the pre-activated state;

FIG. 24 illustrates a tool for loading a plunger of FIG. 17 to the pre-activated state;

FIG. 25 illustrates a cross-sectional view of the infusion device of FIG. 1 in the pre-activated state;

FIG. 26 illustrates a cross-sectional view of the infusion device of FIG. 1 subsequent to activation;

FIG. 27 illustrates the plunger of FIG. 4;

FIG. 28 illustrates an embodiment of a modified version of the plunger shown in FIG. 27;

FIG. 29 illustrates a cross-sectional view of an infusion device employing the modified plunger of FIG. 28 in the pre-activated state;

FIG. 30 illustrates a cross-sectional view of the infusion device of FIG. 29 subsequent to activation;

FIG. 31 illustrates an embodiment of a modified version of the plunger shown in FIG. 21;

FIG. 32 illustrates a cross-sectional view of an infusion device employing the modified plunger of FIG. 31 in the pre-activated state; and

FIG. 33 illustrates a cross-sectional view of the infusion device of FIG. 32 subsequent to activation.

Detailed Description of Exemplary Embodiments

[0013] Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments described exemplify the present invention by referring to the drawings.

[0014] The embodiments of the present invention described below can be used as a convenient, patch-like infusion or self-injection device 100 to deliver a pre-measured dose of a substance, such as a liquid drug or medication, to a patient over a period of time or all at once. The device is preferably provided to the end user in a pre-filled condition, that is, with the drug or medication already contained in the device reservoir. Though the patch-like infusion or self-injection device 100 (shown, for example, in FIG. 1) described herein can be employed by a patient and/or a caregiver, for convenience, a user of the device is hereinafter referred to as a “patient.” Additionally, for convenience, terms such as “vertical” and “horizontal” and “top” and “bottom” are employed to represent relative directions with respect to an infusion device 100 disposed on a horizontal surface. It will be understood, however, that the infusion device 100 is not limited to such an orientation, and that the infusion device 100 may be employed in any orientation. Further, the alternative use of the terms “infusion device” and “self-injection device” to describe devices

embodying the present invention is not intended in a limiting sense. Infusion devices that do not have a self-injection capability are within the scope of the present invention, as are self-injection devices that do not carry out continuous infusion. For convenience, but not by way of limitation, the term “infusion device” is used in the description that follows.

[0015] The patch-like infusion device 100 of FIG. 1 is self-contained and is attached to the skin surface of the patient by adhesive disposed on a bottom surface of the infusion device 100 (as will be described in greater detail below). Once properly positioned and activated by the patient, the pressure of a released spring on a flexible reservoir within the device can be used to empty the contents of the reservoir through one or more patient needles (for example, microneedles) via a needle manifold. The substance within the reservoir is then delivered through the skin of the patient by the microneedles, which are driven into the skin. It will be understood that other embodiments are possible in which the spring is replaced with a different type of stored energy device, which may be mechanical, electrical and/or chemical in nature.

[0016] As will be appreciated by one skilled in the art, there are numerous ways of constructing and using the patch-like infusion device 100 disclosed herein. Although reference will be made to the embodiments depicted in the drawings and the following descriptions, the embodiments disclosed herein are not meant to be exhaustive of the various alternative designs and embodiments that are encompassed by the disclosed invention. In each disclosed embodiment, the device is referred to as an infusion device, but the device may also inject substances at a much faster (bolus) rate than is commonly accomplished by typical infusion devices. For example, the contents can be delivered in a period as short as several seconds or as long as several days.

[0017] In an embodiment of the device shown in FIGS. 1 through 12, a push-button design of the patch-like infusion device 100 is shown wherein the activation and energizing of the device is accomplished in a single multi-function/step process. FIG. 1 illustrates an assembled embodiment of the infusion device 100 in a pre-activated state. FIGS. 2-6 illustrate partially exploded and cross-sectional views of the infusion device 100 in the pre-activated state, FIG. 7 illustrates a partially exploded view of the infusion device 100 during installation of a safety mechanism, FIGS. 8-10 illustrate exploded and cross-sectional views of the infusion device 100 subsequent to activation, and FIGS. 11 and 12

illustrate exploded and cross-sectional views of the infusion device 100 subsequent to deployment of the safety mechanism. The infusion device 100 is configured to operate between the pre-activated state (shown, for example, in FIGS. 1, 2, and 5), an activated or fired state (shown, for example in FIGS. 8-10), and a retracted or safe state (shown, for example, in FIGS. 11 and 12).

[0018] As shown in FIG. 1, an embodiment of the patch-like infusion device 100 includes a bottom enclosure 104, a safety mechanism 108, a flexible needle cover 112, a top enclosure 116, a reservoir subassembly 120, an end-of-dose indicator (EDI) 124, and an activator button 128, which includes a patient interface surface 132. Additionally, as shown in FIGS. 2-6, the infusion device 100 also includes a rotor or activation ring 136, a pressurization spring 140, a dome-like metal plunger 144, and a drive spring 148.

[0019] The flexible needle cover 112 provides patient and device safety by protecting at least one needle 152 (described in greater detail below) and providing a sterile barrier. The needle cover 112, protects the needle 152 during device manufacture, protects the patient prior to use, and provides a sterility barrier at any point prior to removal. According to one embodiment, the needle cover 112 is attached via a press fit with a needle manifold in which the at least one needle 152 is disposed. Additionally, according to one embodiment, a needle opening 156 (described in greater detail below) of the safety mechanism 108 is shaped to closely correspond to a perimeter of the needle cover 112.

[0020] As shown, for example, in FIGS. 2, 3, 5, 6, 8, 10, and 12, the reservoir subassembly 120 includes a reservoir dome seal 164, a valve 168, at least one needle 152, and at least one channel 172 (see, for example, FIG. 8) disposed between the valve 168 and the needle 152 and creating a flow path therebetween, and a dome 176. Additionally, the reservoir subassembly 120 includes the removable needle cover 112 to selectively cover the at least one needle 152. According to one embodiment, the reservoir subassembly 120 also includes a reservoir arm seal 180, covering the channel 172. Preferably, the needle 152 includes a needle manifold and a plurality of microneedles 152.

[0021] The reservoir dome seal (flexible film) 164 of the reservoir subassembly 120, as shown, for example, in FIG. 5, is disposed between the plunger 144 and the dome 176. Reservoir contents (for example, medicinal material) for the infusion device 100 are disposed in the space between the reservoir dome seal 164 and the dome 176. The

combination of the reservoir dome seal 164, the dome 176, and the space therebetween defines a reservoir 160. The dome 176 is preferably transparent to permit viewing of the reservoir contents. The reservoir dome seal 164 can be made of non-distensible materials or laminates, such as metal-coated films or other similar substances. For example, one possible flexible laminate film that can be used in the reservoir dome seal 164 includes a first polyethylene layer, a second chemical layer as known to those skilled in the art to provide an attachment mechanism for a third metal layer which is chosen based upon barrier characteristics, and a fourth layer that includes polyester and/or nylon. By utilizing a metal-coated or metallized film in conjunction with a rigid portion (for example, dome 176), the barrier properties of the reservoir 160 are improved, thereby increasing or improving the shelf life of the contents contained within. For example, where a reservoir content includes insulin, the primary materials of contact in the reservoir 160 include linear, low-density polyethylene (LLDPE), low-density polyethylene (LDPE), cyclic olefin copolymer (COC) and Teflon. As described in greater detail below, the primary materials of contact in the remaining flow path of the reservoir contents may also include COC and LLDPE, as well as thermoplastic elastomer (TPE), medical grade acrylic, stainless steel, and a needle adhesive (e.g. a UV cured adhesive). Such materials that remain in extended contact with the contents of the reservoir 160 preferably pass ISO 10-993 and other applicable biocompatibility testing.

[0022] The reservoir subassembly 120 is further preferably able to be stored for the prescribed shelf life of the reservoir contents in applicable controlled environments without adverse effect to the contents, and is capable of applications in a variety of environmental conditions. Additionally, the barrier provided by the components of the reservoir subassembly 120 do not permit the transport of gas, liquid, and/or solid materials into or out of the contents at a rate greater than that allowable to meet the desired shelf life. In the embodiments shown above, the reservoir materials are capable of being stored and operated in a temperature range of approximately 34 to 120 degrees Fahrenheit and can have a shelf life of two or more years.

[0023] In addition to satisfying stability requirements, the reservoir subassembly 120 can further ensure operation by successfully passing any number of leak tests, such as holding a 30 psi sample for 20 minutes without leaking. Additional filling, storage and

delivery benefits resulting from the configuration of the reservoir include minimized headspace and adaptability as described in greater detail below.

[0024] In one embodiment, the reservoir 160 is evacuated prior to filling. By evacuating the reservoir 160 prior to filling and having only a slight depression in the dome 176, headspace and excess waste within the reservoir 160 can be minimized. In addition, as discussed in greater detail below, the shape of the reservoir can be configured to adapt to the type of energizing mechanism or pressurizing system (for example, pressurization spring 140 and plunger 144) used. Additionally, using an evacuated flexible reservoir 160 during filling can minimize any air or bubbles within the filled reservoir 160. It will be understood, however, that some embodiments of the present invention may not employ an evacuated reservoir. The use of a flexible reservoir 160 is also very beneficial when the infusion device 100 is subjected to external pressure or temperature variations, which can lead to increased internal reservoir pressures. In such case, the flexible reservoir 160 expands and contracts with the reservoir contents, thereby preventing possible leaks due to expansion and contraction forces.

[0025] Yet another feature of the reservoir 160 includes the ability to permit automated particulate inspection at the time of filling or by a patient at the time of use. One or more reservoir barriers, such as the dome 176, can be molded of a transparent, clear plastic material, which allows inspection of the substance contained within the reservoir. The transparent, clear plastic material is preferably a cyclic olefin copolymer that is characterized by high transparency and clarity, low extractables, and biocompatibility with the substance contained in the reservoir 160. A suitable material is available from Zeon Chemicals, L.P., of Louisville, KY under the designation "BD CCP Resin," and is listed by the U.S. Food and Drug Administration and DMF No. 16368. In such applications, the reservoir 160 includes minimal features that could possibly obstruct inspection (i.e. rotation during inspection is permitted).

[0026] Channel arm 172 is provided in the form of at least one flexible arcuate arm extending from the valve 168 to the needle manifold or microneedles 152. The arcuate arm has a groove 174 (see, for example, FIG. 2) formed therein. To provide a fluid path between valve 168 and the needle manifold or microneedles 152, the reservoir arm seal 180 covers the groove 174. The fluid path (disposed in channel arm 172 – shown, for

example, in FIG. 8) between the reservoir 160 and the microneedles 152 is constructed of materials similar or identical to those described above for the reservoir 160. For example, channel arm 172 may be constructed of the same material as the dome 160 and the reservoir arm seal 180 may be constructed of the same material as the reservoir dome seal 164. According to one embodiment, both channel arms 172 are employed as fluid paths between the valve 168 and the needle manifold or microneedles 152. According to another embodiment, only one of the channel arms 172 is employed as a fluid path, and the remaining channel arm 172 provides structural support. In such an embodiment, the groove 174 extends fully from the valve 168 to the needle manifold or microneedles 152 only in the channel arm 174 that will be employed as the fluid path.

[0027] The channel arm 172 must be sufficiently flexible to withstand the force of activation. Contrasting the position of the channel arm 172 in FIGS. 2 and 8, the channel arm 172 (covered by reservoir arm seal 180 in FIG. 2, which is removed in FIG. 8 for clarity) elastically deforms when the microneedles 152 are driven into the patient's skin (described in greater detail below). During such deformation, the channel arm 172 must maintain the integrity of the fluid path between the valve 168 and the needle manifold or microneedles 152. Additionally, the materials for the channel arm 172 satisfy numerous biocompatibility and storage tests. For example, as shown in Table 1 below, where an infusion device content includes insulin, the primary materials of contact in the reservoir 160 include linear, low-density polyethylene, cyclic olefin copolymer, and Teflon, and can also include a transparent, clear plastic. The primary materials of contact in the remaining flow path (channel 62) between the reservoir 160 and the microneedles 152 of the needle manifold include COC and/or medical grade acrylic, LLDPE, TPE, and stainless steel, as well as the needle adhesive.

Table 1

Path Component	Material
Reservoir	Polyethylene, cyclic olefin copolymer, and/or Teflon
Reservoir Dome Seal	Metal-coated film, such as polyethylene, aluminum, polyester, and/or nylon with a chemical tie layer
Valve	TPE
Needle Manifold	COC and/or medical grade acrylic
Needle adhesive	UV-cured adhesive
Microneedle	Stainless steel

[0028] More specifically, the microneedles 152 can be constructed of stainless steel, and the needle manifold can be constructed of polyethylene and/or medical grade acrylic. Such materials, when in extended contact with the contents of the reservoir, preferably pass ISO 10-993 biocompatibility testing.

[0029] The valve 168, disposed between the reservoir 160 and the channel 172, selectively permits and restricts fluid flow between the reservoir 160 and the channel 172. The valve 168 moves between a pre-activated position (shown, for example, in FIGS. 2, 3, and 6) and an activated position (shown, for example, in FIGS. 8-10). When in the activated position, the valve permits fluid flow between the reservoir 160 and the channel 172, and therefore to the needle manifold and microneedles 152.

[0030] In use, the valve 168 will eventually be pushed into the activated position by the movement of the activator button 128, best illustrated by the movement of the valve 168 between FIGS. 5 and 10. As shown in FIG. 10, the movement of the valve 168 advances the enlarged distal end of the valve 168, thereby permitting the drug to flow from the reservoir 160 into the channel 172 and down the fluid path to the needle manifold.

[0031] The embodiment described above includes at least one needle 152, or microneedle 152, but may contain several, such as the two illustrated microneedles 152. Each microneedle 152 is preferably at least 31 gauge or smaller, such as 34 gauge, and is anchored within a patient needle manifold that can be placed in fluid communication with the reservoir 160. The microneedles 152, when more than one is included in the infusion device 100, can also be of differing lengths, or gauges, or a combination of both differing lengths and gauges, and can contain one or more ports along a body length, preferably located near the tip of the microneedle 152 or near the tip bevel if any of the microneedles 152 has one.

[0032] According to one embodiment, the gauge of the microneedles 152 governs the delivery rate of reservoir contents of the infusion device 100. The use of multiple 34 gauge microneedles 152 to deliver the reservoir contents is practical when the infusion occurs over a longer period than typically associated with an immediate syringe injection requiring a much larger cannula, or needle. In the disclosed embodiments, any microneedles 152 that target either an intradermal or subcutaneous space can be used, but the illustrated embodiments include intradermal microneedles 152 of between 1 and 7 mm in length (i.e., 4 mm). The arrangement of the microneedles 152 can be in a linear or nonlinear array, and can include any number of microneedles 152 as required by the specific application.

[0033] As noted above, the microneedles 152 are positioned in a needle manifold. In the needle manifold, at least one fluid communication path, or channel 172, is provided to each microneedle 152. The manifold may simply have a single path to one or more microneedles 152, or may provide multiple fluid paths or channels routing the reservoir contents to each microneedle 152 separately. These paths or channels may further comprise a tortuous path for the contents to travel, thereby affecting fluid pressures and rates of delivery, and acting as a flow restrictor. The channels or paths within the needle manifold can range in width, depth and configuration depending upon application, where channel widths are typically between about 0.015 and 0.04 inch, preferably 0.02 inch, and are constructed to minimize dead space within the manifold.

[0034] According to one embodiment, the reservoir subassembly 120 has a pair of holes 184 and 188 to aid registration of the reservoir subassembly 120 with respect to the bottom

enclosure 104. First and second posts 192 and 196 (described in greater detail below) of the bottom enclosure 104 are inserted through the respective holes 184 and 188.

[0035] In exploded views with the reservoir subassembly 120 removed, FIGS. 4, 7, and 9 illustrate that bottom enclosure 104 includes a substantially cylindrical housing 200 in which pressurization spring 140 and plunger 144 are disposed. According to one embodiment, cylindrical housing 200 includes a plurality of recessed channels 204 to guide a respective plurality of legs 208 and feet 212 of the plunger 144 as the plunger translates within the housing 200. Collectively, a leg 208 and a foot 212 constitute a plunger tab 214. As shown in FIGS. 4, 7, and 9, for example, the recessed channels 204 extend only part of the way down the cylindrical housing 200 from a top thereof. Below the recessed channels 204, there are openings 216 through which the feet 212 of plunger 144 can extend outside of the cylindrical housing 200. The openings 216 are substantially L-shaped with horizontal portions at the base of the cylindrical housing 200, and a vertical portion substantially aligned with the recessed channels 204.

[0036] When the infusion device 100 is in the pre-activated state, the pressurization spring 140 is compressed by the plunger 144 (as shown, for example, in FIGS. 4-6), and the feet 212 of the plunger 144 are substantially disposed in the horizontal portions of the openings 216. The force of the pressurization spring 140 biases the feet 212 of the plunger 144 against a top of the horizontal portions of the openings 216 (i.e., a ledge of the cylindrical housing 200). Together, as described in greater detail below, the pressurization spring 140 and the plunger 144 form a pressurization system to pressurize the reservoir 160 when the infusion device 100 is activated.

[0037] As described in greater detail below, the rotor 136 rotates around the base of the cylindrical housing 200 between a pre-activated position (illustrated, for example, in FIGS. 2-4) and an activated position (illustrated, for example, in FIGS. 8-10). When the rotor 136 rotates from the pre-activated position to the activated position, at least one foot engaging surface 217 (shown, for example, in FIG. 4) of the rotor 136 engages at least one of the feet 212 of the plunger 144 and rotates the plunger 144 so that the feet 212 align with the vertical portions of the openings 216 and the recessed channels 204. At this point, the pressurization spring 140 moves the plunger 144 upward with the feet 212 being guided by the raised channels 204.

[0038] The pressurization spring 140 is included in the infusion device 100 to apply an essentially even force to the reservoir 160, to force the contents from the reservoir 160. The pressurization spring 140 is used to store energy that, when released, pressurizes the reservoir 160 at the time of use. The pressurization spring 140 is held in a compressed state by engagement between feet 212 of the plunger 144 and the cylindrical housing 200. This engagement prevents the pressurization spring 140 from putting stress on a film (to be described later) of the reservoir 160 or any remaining device components (other than the bottom enclosure 104 and the plunger 144) during storage. The plunger 144 is sufficiently rigid to resist spring tension and deformation, and should not fail under normal load.

[0039] As noted above, when the rotor 136 rotates from the pre-activated position to the activated position, the rotor 136 engages at least one of the feet 212 of the plunger 144 and rotates the plunger 144 to align the feet 212 with the vertical portions of the openings 216 and the recessed channels 204. The compressed pressurization spring 140, then moves the plunger 144 upward, and in doing so, exerts a force on the film of the reservoir 160. The pressurization spring 140 can be configured to preferably create a pressure within the reservoir 116 of from about 1 to 50 psi, and more preferably from about 2 to about 25 psi for intradermal delivery of the reservoir contents. For sub-cutaneous injection or infusion, a range of about 2 to 5 psi may be sufficient.

[0040] To load the plunger 144 and pressurization spring 140 into the pre-activated position, a tool 220 (see, for example, FIGS. 23A and 23B) having, for example, a square protrusion 222 protruding from an end thereof is inserted so that the protrusion 222 passes through a tool opening 224 (see, for example, FIGS. 4 and 27) of the plunger 144. The tool 220 is then used to compress the pressurization spring 140 through downward pressure on the plunger 144. The tool 220 continues the downward motion of the plunger 144 and compression of the pressurization spring 140 until the foot 212 is vertically below a height of a foot engaging surface 218 (of the cylindrical housing 200) within the recessed channel 204. Subsequently, the tool 220 rotates to rotate the plunger 144 so that the foot 212 is disposed beneath the foot engaging surface 218. At this point, the tool 220 can be removed, thereby engaging the foot 212 with the foot engaging surface 218 of the cylindrical housing 200, and maintaining compression of the pressurization spring 140.

[0041] According to one embodiment, the activator button 128 includes the patient interface surface 132 that the patient presses to activate the infusion device 100. The activator button 128 also includes a hinge arm 226 and an activation arm 228 (both shown, for example, in FIG. 3). The hinge arm 226 of the activator button 128 includes a cylindrical portion with an opening. The activation arm 228 includes a tab 230 (see, for example, FIG. 3). According to one embodiment, the tab 230 includes a bearing surface 232 and a locking surface 234 disposed adjacent to the cantilevered end of the bearing surface 232. According to one embodiment, the tab 230 forms an acute angle with a main portion of the activation arm 228.

[0042] The first post 192, disposed on the bottom enclosure 104, extends upwardly therefrom. According to one embodiment (as shown, for example, in FIGS. 4 and 7), a base of the first post 192 includes a pair of flat sides 236 and a pair of rounded sides 240. Additionally, as shown, for example, in FIGS. 4 and 7, the second post 196 and first and second drive spring bases 244 and 248 extend upwardly from the bottom enclosure 104. As will be described in greater detail below, the first and second drive spring bases 244 and 248 anchor respective ends of drive spring 148. The first drive spring base 244 is disposed adjacent to the second post 196 with a space therebetween.

[0043] According to one embodiment, FIGS. 3 and 6 illustrate the positioning of the activator button 128 with respect to the bottom enclosure 104, for assembly of the activator button 128. In this position, the opening of the cylindrical portion of the hinge arm 226 allows the activator button 128 to slide horizontally (passing the flat sides 236) and engage the first post 192. The hinge arm 226 (and therefore the activator button 128) can then rotate about the first post 192. As the activation arm 228 passes into the space between the second post 196 and the first drive spring base 244, at least one of the tab 230 and the activation arm 228 elastically deforms until a cantilevered end of the bearing surface 232 of tab 230 passes a retaining face 252 of the second post 196. The passage of the cantilevered end of the bearing surface 232 of tab 230 past the retaining face 252 (see, for example, FIG. 4) of the second post 196 and the engagement of the locking surface 234 of tab 230 with the retaining face 252 provides an audible click and tactile feedback conveying that the activator button 128 is in the pre-activated position.

[0044] Referring back to FIGS. 2-4, and 7-9, rotor 136 additionally includes an activation projection 256 and a drive spring holder 260. The activation arm 228 of the activator button 128 engages the activation projection 256 when a patient depresses the activator button 128, thereby rotating the rotor 136 from the pre-activated position to the activated position.

[0045] The drive spring holder 260 maintains the drive spring 148 in a pre-activated position when the rotor 136 is in the pre-activated position. As noted previously, the first and second drive spring bases 244 and 248 anchor opposing ends of the drive spring 148. At approximately a midpoint of the drive spring 148, there is a substantially U-shaped projection as shown, for example, in FIGS. 2 and 3, for engagement with the drive spring holder 260 of the rotor 136. Accordingly, when the rotor 136 is in the pre-activated position and the drive spring 148 engages the drive spring holder 260, the drive spring 148 is maintained in a tensile state. And when the drive spring holder 260 releases the drive spring 148 (i.e., when the rotor rotates from the pre-activated position to the activated position as illustrated, for example, in FIGS. 8-10), the drive spring 148 drives the microneedles 152 to extend outside of the infusion device 100 through an opening 300 in the bottom enclosure 104 (and through an opening in the safety mechanism 108 described in greater detail below).

[0046] Thus, as will be described in greater detail below, the activation and energizing of the infusion device 100 that is accomplished in a single multi-function/step process includes depression of the activator button 128 by a patient, and rotation of the rotor 136 due to engagement between the activation arm 228 of the activator button 128 and the activation projection 256 of the rotor 136. As described above, the rotation of the rotor 136 rotates and releases the plunger 144 to pressurize the fluid within the reservoir 160. Additionally, the rotation of the rotor 136 releases the drive spring 148 from the drive spring holder 260, thereby driving the microneedles 152 to extend outside of the infusion device 100. The single multi-function/step process also includes movement of the valve 168 from the pre-activated position to the activated position due to the activator button 128 engaging and moving the valve 168 when the activator button 128 is depressed, thereby commencing fluid flow between the reservoir and the microneedles 152 via the channel 172.

[0047] As noted above, the patch-like infusion device 100 also includes a safety mechanism 108. To prevent inadvertent or accidental needle stick injuries, prevent intentional re-use of the device, and to shield exposed needles, the locking needle safety mechanism 108 is provided. The safety mechanism 108 automatically activates immediately upon removal of the infusion device 100 from the skin surface of the patient. According to one embodiment described in greater detail below, a flexible adhesive pad 264 adheres to a bottom portion of the bottom enclosure 104 and a bottom portion of the safety mechanism 108. The adhesive pad 264 contacts with the patient's skin and holds the infusion device 100 in position on the skin surface during use. As shown, for example, in FIGS. 11 and 12, upon removal of the infusion device 100 from the skin surface, the safety mechanism 108 extends to a position shielding the microneedles 152. When fully extended, safety mechanism 108 locks into place and prevents accidental injury or exposure to the patient needles 152.

[0048] In general, a passive safety system is most desirable. This allows the device to be self-protecting in case of accidental removal or if the patient forgets that there is a safety step. Because one typical use for this infusion device 100 is to provide human growth hormone, which is usually given in the evening, it can be expected that patients that wear the device (such as children) may actually wear them overnight, even though the delivery may be expected to take less than 10 minutes. Without a passive system, if the infusion device 100 falls off, the microneedles 152 could re-stick the patient or a caregiver. The solution is to either limit the activities during use, or include a passive safety system.

[0049] With respect to safety systems, there are typically three options. A first option is to retract the needles 152 into the device. A second option is to shield the needles 152 to remove access, and a third option is to destroy the needles 152 in a way that prevents needle stick injuries. Other systems, such as active systems, utilize manual shielding and/or destruction, or manual release of safety features with an additional button push or similar action. A detailed description of passive safety embodiments of the present invention is described below.

[0050] One safety embodiment of the present invention is a passive, fully enclosed pull-out design embodiment, such as safety mechanism 108. FIGS. 5, 10, and 12 are perspective cutaway views of the infusion device 100 that illustrate the safety mechanism 108 prior to

activation, subsequent to activation, and subsequent to deployment of the safety mechanism 108, respectively.

[0051] When the infusion device 100 is removed from the skin, the flexible adhesive pad 264 (attached to both the bottom surface of the bottom enclosure 104 and the bottom surface of the safety mechanism 108) will pull the safety mechanism 108 out and lock it into place before the adhesive pad 264 releases the skin surface. In other words, the force required to remove the adhesive pad from the skin surface is greater than that required to deploy the safety mechanism 108. According to one embodiment, the safety mechanism 108, as shown, for example, in FIG. 13, includes a flat surface portion 268 that is in contact with the patient's skin. The flat surface 268 is where a portion of adhesive pad 264 (shown as a dotted line in FIG. 13) is affixed to safety mechanism 108 such that when the infusion device 100 is removed by the patient from the skin, the adhesive pad 264 will act to deploy the safety mechanism 108 from the infusion device 100, thereby shielding the microneedles 152, which otherwise would be exposed upon removal of the infusion device 100 from the patient. When the safety mechanism 108 is fully extended, the safety mechanism 108 locks into place and prevents accidental injury or exposure to the microneedles 152.

[0052] According to one embodiment, the adhesive pad 264 is provided in substantially two parts, one on the bulk of the bottom surface of the bottom enclosure 104, and one on the bottom surface of the safety mechanism 108. When the infusion device 100 is removed, the two patches move independently and the safety mechanism 108 is rotatable with respect to the bottom enclosure 104. According to another embodiment, the two parts are formed as a unitary, flexible adhesive pad 264 with one part being disposed on the bulk of the bottom surface of the bottom enclosure 104, and one part disposed on the bottom surface of the safety mechanism 108.

[0053] According to one embodiment, the safety mechanism 108 is a stamped metal part. According to another embodiment, the safety mechanism 108 is made of substantially the same material as the bottom enclosure 104. As shown in FIG. 14, the safety mechanism 108 includes a front shield 272, a pair of insertion tabs 276 disposed at a rear portion of the safety mechanism 108, a pair of pivot tabs 280 disposed, respectively, at upper rear ends of a rim portion 284 of the safety mechanism 108, a guide post 288 extending upwardly from

a substantially flat bottom inner surface of the safety mechanism 108, and locking posts 292 also extending upwardly from the bottom inner surface of the safety mechanism 108. Front shield 272 extends above the rim portion 284 to shield the patient from the microneedles 152 when the safety mechanism 108 is deployed. The guide post 288 includes a cutout therein to engage a safety retaining projection 296 of the rotor 136 (shown, for example, in FIGS. 7 and 9) when the rotor 136 is in the pre-activated position, to prevent the safety mechanism 108 from deploying prior to activation of the infusion device 100.

[0054] Additionally, as noted above, the safety mechanism 108 includes the needle opening 156. Prior to deployment of the safety mechanism 108, the needle opening 156 at least partially overlaps the opening 300 in bottom enclosure 104 to provide space for movement of the microneedles 152. The locking posts 292 are respectively disposed adjacent to front side edges of the needle opening 156. The bottom enclosure 104 includes a guidepost opening 304 (shown, for example, in FIGS. 7 and 9), a pair of insertion tab openings 308 (one of which is shown, for example, in FIG. 4) disposed adjacent to opposing side edges of the bottom enclosure 104, and a pair of pivot rests 312 disposed on opposing sides of the bottom enclosure 104 (shown, for example, in FIGS. 7 and 9).

[0055] Referring again to FIG. 14, insertion tabs 276 each include a connecting portion 316 and an extending portion 320. According to one embodiment, the connecting portions 316 extend from the bottom inner surface of the safety mechanism 108 toward a rear of the infusion device 100 at a non-perpendicular angle with respect to the bottom inner surface of the safety mechanism 108. Extending portions 320 each extend substantially perpendicularly from the extending portions 320 toward respective outer sides of the safety mechanism 108. To assemble the safety mechanism 108 to the bottom enclosure 104, safety mechanism 108 is held at an approximately 45° angle with respect to the bottom enclosure 104 and the insertion tabs 276 are inserted through the insertion tab openings 308. The safety mechanism 108 is then rotated to a position such that the guidepost 288 is inserted through the guidepost opening 304 and the bottom inner surface of the safety mechanism 108 is substantially parallel and in contact with the bottom surface of the bottom enclosure 104.

[0056] Referring again to FIGS. 7 and 9, although these views illustrate the rotor 136 in the activated position, the exploded nature of FIGS. 7 and 9 is convenient to illustrate this stage of the assembly of the safety mechanism 108 to the bottom enclosure 104. It will be understood, however, that the safety mechanism 108 should be assembled to the bottom enclosure prior to activation. Subsequent to the upward rotation of the safety mechanism 108, as shown in FIG. 4, safety mechanism 108 translates rearwardly with respect to the bottom enclosure 104 such that pivot tabs 280 clear respective front edges of the pivot rests 312 and are disposed above the pivot rests 312, the locking posts 292 are disposed adjacent to side edges of the opening 300 of the bottom enclosure 104, and the safety retaining projection 296 of the rotor 136 engages the guide post 288.

[0057] Returning to FIG. 14, each of the locking posts 292 includes a post extending portion 324 extending substantially perpendicular from the flat bottom inner surface of the safety mechanism 108, and a wedge portion 328 disposed at an end of the post extending portion 324. As a height of the wedge portion 328 increases with respect to the bottom inner surface of the safety mechanism 108, a width of the wedge portion 328 increases.

[0058] As the safety mechanism 108 deploys and rotates downward with respect to the bottom enclosure 104, the wedge portions 328 act against respective side edges of the openings 180 of the bottom enclosure 104, causing the locking posts 192 to deform elastically toward one another. As the safety mechanism 108 is fully deployed, the tabs 280 become seated in pivot rests 312. Additionally, top edges of the wedge portions 328 pass bottom edges of the opening 300 and the locking posts 292 snap back to their substantially un-deformed states, providing an audible click and tactile feedback communicating that the safety mechanism 108 is fully deployed, and therefore, that the microneedles 152 are covered. Returning to FIGS. 11 and 12, once the safety mechanism 108 is fully deployed and the locking posts 292 have snapped back to their substantially un-deformed states, the top edges of the wedge portions 328 engage the bottom surface of the bottom enclosure 104 adjacent to the opening 300, thereby preventing the safety mechanism 108 from rotating upward with respect to the bottom enclosure 104 and exposing the microneedles 152. Additionally, as noted above, front shield 272 shields the patient from the microneedles 152.

[0059] Accordingly, the safety mechanism 108 is a passive safety embodiment provided as a single part and provides a good lock that will not crush under human loads. With this passive safety mechanism, no additional forces are applied to the skin during injection, and the microneedles 152 are safely held within the infusion device 100 after use.

[0060] After use of the infusion device 100, the patient can once again inspect the device to ensure the entire dose was delivered. In this regard, as shown in FIGS. 15A-D, the infusion device 100 includes the end-of-dose indicator (EDI) 124. The EDI 124 includes a main body 332 and first and second arms 336 and 340 extending substantially horizontally with respect to a top of the main body 332.

[0061] The EDI 124 also includes a spring arm 344 that curves upwardly from the top of the main body 332. According to one embodiment, the spring arm 344 pushes against a bottom side of the reservoir subassembly 120, elastically biasing the EDI 124 toward the bottom enclosure 104, to ensure that the EDI 124 does not move freely out of the infusion device 100, for example, during shipping and handling of the infusion device 100.

[0062] Returning to FIG. 4, the main body 332 is disposed in an EDI channel 348 and translates substantially vertically therein. The EDI channel adjacent to one of the recessed channels 204 that guides legs 208 and feet 212 of plunger 144. The first arm 336 extends across a top of this recessed channel 204.

[0063] Returning to FIG. 15A, a vertical extrusion 352 extends upwardly from an end of the second arm 340. When the reservoir contents have been delivered, the vertical extrusion extends through an EDI opening 356 (see, for example, FIG. 15C) in the top enclosure 116 to communicate that the end of the dose has been reached. According to one embodiment, the EDI 124 is formed as a one-piece construction.

[0064] As shown in FIG. 15B, as the plunger 144 travels upwardly in the cylindrical housing 200 due to the pressurization spring 140 subsequent to activation, one of the feet 212 of the plunger 144 contacts the first arm of the EDI 124. The foot 212 lifts the EDI 124 upward, overcoming the bias of the spring arm 344, and causing the vertical extrusion 352 to increasingly extend through the EDI opening 356 during delivery of the reservoir contents. Referring back to FIG. 10, vertical extrusion 352 partially extends from the infusion device 100. Once the delivery of the reservoir contents is complete and the

plunger has achieved its full stroke, the vertical extrusion 352 is fully extended, as shown in FIG. 15D. Thus, the EDI 124 employs the linear movement of the plunger 144 to generate linear movement of the EDI 124 that is visible outside of the infusion device 100 thereby communicating the delivery of the reservoir contents.

[0065] Figure 16 illustrates an embodiment of an infusion device 400 with an injection port 404. The injection port provides access to an evacuated or partially-filled reservoir 408, so that the patient can inject a substance or combination of substances into the reservoir prior to activation. Alternatively, a pharmaceutical manufacturer or pharmacist could employ the injection port 404 to fill the infusion device 400 with a substance or combination of substances prior to sale. In substantially all other respects, the infusion device 400 is similar to the previously-described infusion device 100.

[0066] Operation of the infusion device 100 will now be described. The embodiments of the present invention described above preferably include a push-button (activator button 128) design wherein the infusion device 100 can be positioned and affixed to a skin surface, and energized and/or activated by pressing the activator button 128. More specifically, in a first step, the patient removes the device from a sterile packaging (not shown), removes a cover (not shown) of the adhesive pad 264. The patient also removes the needle cover 112. Upon removal of the infusion device 100 from the package and prior to use (see, for example, FIGS. 1, 2, 4, and 5), the infusion device 100 in the pre-activated state allows the patient to inspect both the device and the contents therein, including inspection for missing or damaged components, expiration dates(s), hazy or color-shifted drugs, and so forth.

[0067] The next step is the positioning and application of the infusion device 100 to the patient's skin surface. Like a medicinal patch, the patient firmly presses the infusion device 100 onto the skin. One side of the adhesive pad 264 adheres to a bottom surface of the bottom enclosure 104 and a bottom surface of the safety mechanism 108, and the opposing side of the adhesive pad 264 secures the infusion device 100 to the skin of the patient. These bottom surfaces (of the bottom enclosure 104 and the safety mechanism 108) can be flat, contoured, or shaped in any suitable fashion and the adhesive pad 264 is secured thereon. According to one embodiment, prior to shipping, the cover of the adhesive pad 264, such as a film, is applied to the patient-side of the adhesive pad 264 to preserve the

adhesive during shipping. As noted above, prior to use, the patient peels back the adhesive cover, thereby exposing the adhesive pad 264 for placement against the skin.

[0068] After removing the adhesive cover, the patient is able to place the infusion device 100 against the skin and press to ensure proper adhesion. As noted above, once properly positioned, the device is activated by depressing the activator button 128. This activation step releases plunger 144 and the pressurization spring 140, allowing a plunger 144 to press against the flexible film (reservoir dome seal 164) of the reservoir 160, thereby pressurizing the reservoir. This activation step also serves to release the drive spring 148 from the drive spring holder 260 of the rotor 136, thereby driving the microneedles 152 to extend outside the infusion device 100 (through the opening 300 in the bottom enclosure 104 and the needle opening 156 of the safety mechanism 108) and seat the microneedles 152 within the patient. Further, the activation step opens the valve 168, establishing a fluid communication path between the reservoir 160 and the microneedles 152, via the channel 172 (see, for example, FIGS. 8-10). A significant benefit derives from the ability to achieve each of these actions in a single push-button operation. Additionally, another significant benefit includes the use of a continuous fluid communication path comprised entirely within the reservoir subassembly 120.

[0069] Once activated, the patient typically leaves the infusion device 100 in position, or wears the device, for some period of time (such as ten minutes to seventy-two hours) for complete delivery of the reservoir contents. The patient then removes and discards the device with no damage to the underlying skin or tissue. Upon intentional or accidental removal, one or more safety features deploy to shield the exposed microneedles 152. More specifically, when the infusion device 100 is removed by the patient from the skin, the adhesive pad 264 acts to deploy the safety mechanism 108 from the infusion device 100, thereby shielding the microneedles 152, which otherwise would be exposed upon removal of the infusion device 100 from the patient. When the safety mechanism 108 is fully extended, the safety mechanism 108 locks into place and prevents accidental injury or exposure to the microneedles 152. The safety features, however, can be configured to not deploy if the activator button 128 has not been depressed and the microneedles 152 have not been extended, thereby preventing pre-use safety mechanism deployment. After use, the patient can once again inspect the device to ensure the entire dose was delivered. For

example, the patient can view the reservoir interior through the transparent dome 176 and/or inspect the EDI 124.

[0070] In the above-described embodiments, in which metal plunger tabs 214 bear upwardly against foot engaging surfaces 218 of plastic cylindrical housing 200 to maintain compression of pressurizing spring 140 in the pre-activated position, high stresses may be imparted to the plastic bottom enclosure 104 and creep may be induced therein.

[0071] Figure 17 illustrates an exploded view of an embodiment of a retention assembly 500 to reduce a force required to activate an infusion device (for example, 100). Though, the retention assembly 500 is illustrated with respect to the infusion device 100, it will be understood that the retention assembly 500 is not limited to employment with the infusion device 100, and may be employed with infusion device 400 or another infusion or self-injection device. As shown in FIG. 17, the retention assembly 500 includes a retention plate 504, pressurization spring 140, and a plunger 508. The pressurization spring 140 is disposed on the retention plate 504 between the retention plate 504 and the plunger 508. Retention plate 504 is disposed within the cylindrical housing 200, in a recess of the top surface of the bottom enclosure 104. According to one embodiment, the retention plate 504 is disposed substantially at the center of the cylindrical enclosure 200. According to one embodiment, the retention plate 504 includes stabilization tabs 512 to prevent rotation of the retention plate 504 within the cylindrical housing 200. The stabilization tabs 512 engage corresponding recesses in the top surface of the bottom enclosure 104.

[0072] As shown in FIG. 17, retention plate 504 includes a post 516 and a sprocket 520 disposed at a distal end of the post 516. According to one embodiment, the post 516 is disposed substantially at the center of the retention plate 504. According to one embodiment, the post 516 and the sprocket 520 are integrally formed as a unitary metal structure. Additionally, according to one embodiment, the post 516 is attached to the retention plate 504 by spot welding. According to another embodiment, the post 516 is screwed to the retention plate 504. According to yet another embodiment, the post 516 is attached to the retention plate 504 by a friction fit. According to yet another embodiment, the post 516 has a flange and a threaded end, and the threaded end is inserted through an opening in the retention plate 504 and attached to the retention plate 504 with a nut, tightened until the flange is secured against the retention plate 504. According to an

alternative embodiment, the post 516 and the retention plate 504 are integrally formed as a unitary metal structure.

[0073] According to one embodiment, the retention plate 504 is made of steel, such as, for example, plated steel or 302 stainless steel. Such a choice of materials generally provides superior creep characteristics and a higher modulus of rigidity with respect to a plastic (for example, that used for the cylindrical housing 200 of the bottom enclosure 104). Additionally, such a choice of materials provides the ability to employ a stronger pressurization spring 140. For example, according to one embodiment, a 50 pound pressurization spring 140 can be employed in the retention assembly 500.

[0074] Plunger 508 includes a sprocket opening 524 with a shape corresponding to the sprocket 520. As described in greater detail below, plunger 508 also includes at least one tool opening 528 for assembling the retention assembly 500 into a pre-activated position. Put another way, the plunger 508 has the sprocket opening 524 punched substantially in the center thereof, and the post 516 has a sprocket 520 with a corresponding toothed profile disposed at the distal end thereof.

[0075] As shown in greater detail in FIGS. 18A and 18B, sprocket 520 includes a plurality of sprocket teeth 532, and the sprocket opening 524 includes a plurality of slots 536 interposed between a plurality of fingers 540 of the plunger 508. According to one embodiment, the plurality of slots 536 and the plurality of fingers 540 correspond, respectively, to the plurality of sprocket teeth 532.

[0076] When the retention assembly 500 is in the pre-activated position, as shown in FIG. 19, the sprocket teeth 532 align with and engage the fingers 540 of the plunger 508 to maintain compression of the pressurization spring 140. Additionally, in contrast to the above-described embodiments, when the retention assembly 500 is in the pre-activated position, the plunger tabs do not bear on the foot engaging surface 218 of the cylindrical housing 200. Instead, the force of maintaining the pressurization spring 140 in the compressed, pre-activated position is borne by the engagement between the sprocket teeth 532 and the fingers 540 of the plunger 508. In such an embodiment, however, the foot engaging surface 218 of the cylindrical housing 200 may still perform a useful function by preventing excessive rocking of the plunger 508.

[0077] Upon activation of the infusion device 100, plunger 508 is rotated (for example, by the rotor 136, which is rotated around the cylindrical housing 200 by the movement of the activator button 128, as described above) such that the sprocket teeth 532 align with the slots 536 of the sprocket opening 524 (and the plunger tabs align with the recessed channels 204 of the cylindrical housing 200), to release the plunger 508 to translate upwardly within the cylindrical housing 200 under the force of the pressurization spring 140, to pressurize the reservoir 160.

[0078] To assemble the retention assembly 500 into the pre-activated position, a tool 544 (see, for example, FIG. 24) having, for example, a pair of protrusions 548 protruding from an end thereof is inserted so that the protrusions 548 pass through tool openings 528 (see, for example, FIG. 17) of the plunger 508. The tool 544 is then used to compress the pressurization spring 140 through downward pressure on the plunger 508. The tool 544 continues the downward motion of the plunger 508 and compression of the pressurization spring 140 until the sprocket 520 passes through the sprocket opening 524. For the sprocket 520 to pass through the sprocket opening 524, the sprocket teeth 532, must be aligned with the slots 536 of the sprocket opening 524. If the slots 536 of the sprocket opening 524 align with the sprocket teeth 532, the tool 544 may be rotated to rotate the plunger 508 into the desired alignment. Subsequent to the sprocket 520 passing through the sprocket opening 524, the tool 544 rotates so that the tool protrusions 548 engage the sides of the tool openings 528 to rotate the plunger 508, so that the sprocket teeth 532 align with fingers 540 of the plunger 508. At this point, the tool 544 can be removed, thereby engaging the sprocket teeth 532 with the fingers 540 of the plunger 508, and maintaining compression of the pressurization spring 140.

[0079] Figure 20A illustrates a free body diagram of an embodiment of a retention assembly employing plunger 144. Figure 20B illustrates free body diagram of the retention assembly 500. In FIG. 20A, μ_T represents the coefficient of friction between the plunger tab 214 and the foot engaging surface 218 of the cylindrical housing 200, and $\mu_T F_T$ represents the frictional force induced by engagement between the plunger tab 214 and the foot engaging surface 218 of the cylindrical housing 200 due to pressurization spring 140 pressing upward. Additionally, with respect to the rotation of the plunger 144 at activation of the infusion device 100, the force $\mu_T F_T$ acts over the distance (radius) L_T resulting in the frictional moment $\mu_T F_T L_T$.

[0080] In contrast, as shown in FIG. 20B, $\mu_K F_K$ represents the frictional force induced by engagement between the sprocket teeth 532 and the fingers 540 of the plunger 508 due to pressurization spring 140 pressing upward. Because the same pressurization spring 140 is employed in both embodiments, the force $\mu_T F_T$ is substantially equal to the force $\mu_K F_K$. But the distance (radius) L_K over which $\mu_K F_K$ acts (resulting in the frictional moment $\mu_K F_K L_K$) is substantially smaller than the distance L_T . Thus, the frictional moment $\mu_K F_K L_K$ is substantially smaller than the frictional moment $\mu_T F_T L_T$. Accordingly, the force from the activator button 128 required to overcome the frictional moment $\mu_K F_K L_K$ (by employing retention assembly 500) is substantially smaller than the force from the activator button 128 required to overcome the frictional moment $\mu_T F_T L_T$ (in the embodiments employing plunger 144 described above). In other words, the frictional moment due to holding the pressurization spring 140 in the pre-activated position is substantially reduced due to the reduction in the moment where the load is applied. Therefore, in comparison to an infusion device employing plunger 144, an embodiment employing retention assembly 500 requires a reduced force applied by the patient to activate the infusion device 100.

[0081] Is to be noted, however, that in an embodiment employing retention assembly 500, pressurization spring 140 bears against steel retention plate 504, whereas in an embodiment employing plunger 144, as described above, pressurization spring 140 bears against the plastic bottom enclosure 104. But while the coefficient of friction of steel on steel is somewhat higher than the coefficient of friction of steel and plastic, the reduced distance (L_K v. L_T) more than makes up for the higher coefficient of friction. For example, in experiments with embodiments employing plunger 144, an average of more than 4 lb_f was required to activate infusion device. In contrast, in experiments with embodiments employing retention assembly 500, an average of about 1.5 lb_f was required to activate the infusion device.

[0082] Because the sprocket 520 sits above a top surface of the plunger 508 in the pre-activated position (as shown, for example, in FIG. 19), one option to reduce a total height of the infusion device 100 is to create a pocket within the plunger, such that in the pre-activated position, the sprocket 520 would be flush with a top of the plunger 508. Such an embodiment, however, may increase a dead or unusable volume of the reservoir 160. Upon activation of an embodiment without such a pocket, however, the plunger 508 travels a greater distance within the cylindrical housing 200 prior to impacting the reservoir dome

seal 164. Thus, there is a larger kinetic energy prior to such impact. This impact between the plunger 508 and the reservoir dome seal may result in a loud sound. One way to reduce this kinetic energy would be to inject a very viscous damping gel in the area where the sprocket teeth 532 and the fingers 540 of the plunger 508 engage.

[0083] Another way to address such issues is to employ an alternative embodiment of a retention assembly 560 as illustrated in FIGS. 21 and 22. Figure 21 illustrates a plunger 564 with a post 568 disposed thereon. A sprocket 572 is disposed at a distal end of the post 568 and the sprocket includes a plurality of sprocket teeth 576. According to one embodiment, the post 568 is disposed substantially at the center of the plunger 564. thus, the post 568 extends from the plunger 564 in an umbrella-like fashion with the sprocket 572 pointing away from the reservoir dome seal 164 to prevent inadvertent contact therebetween.

[0084] Additionally, according to one embodiment, the post 568 has a reduced diameter portion 578 to facilitate engagement with a retention plate 580 (described in greater detail below). Further, according to one embodiment, the post 568 and the sprocket 572 are integrally formed as a unitary metal structure. Additionally, according to one embodiment, the post 568 is attached to the plunger 564 by spot welding. According to another embodiment, the post 568 is screwed to the plunger 564. According to yet another embodiment, the post 568 is attached to the plunger 564 by a friction fit. According to yet another embodiment, the post 586 has a flange and a threaded end, and the threaded end is inserted through an opening in the plunger 564 and attached to the plunger 564 with a nut, tightened until the flange is secured against the plunger 564. According to an alternative embodiment, the post 568 and the plunger 564 are integrally formed as a unitary metal structure. Further, as described in greater detail below, plunger 564 also includes at least one tool opening 580 for assembling the retention assembly 560 into a pre-activated position.

[0085] Correspondingly, as shown in FIG. 22 in the cross-sectional view of the retention assembly 560 in a pre-activated position, a retention plate 582 includes a sprocket opening 584 with a shape corresponding to the sprocket 572. Put another way, the retention plate 582 has the sprocket opening 584 punched substantially in the center thereof, and the post 568 has a sprocket 572 with a corresponding toothed profile disposed at the distal end

thereof. According to one embodiment, similar to the retention plate 504 described above, retention plate 582 is stationary with respect to bottom enclosure 104, and is indexed with respect thereto. Thus, the retention plate 582 does not rotate when the plunger 564 rotates upon activation.

[0086] Similar to FIG. 18B, sprocket the sprocket opening 584 includes a plurality of slots 588 interposed between a plurality of fingers 592 of the retention plate 582. According to one embodiment, each of the plurality of slots 588 and the plurality of fingers 592 correspond, respectively, to the plurality of sprocket teeth 576.

[0087] When the retention assembly 560 is in the pre-activated position, as shown in FIG. 22, the sprocket teeth 576 align with and engage the fingers 592 of the retention plate 582 to maintain compression of the pressurization spring 140. Additionally, as with the retention assembly 500, when the retention assembly 560 is in the pre-activated position, the plunger tabs of plunger 564 do not bear on the foot engaging surface 218 of the cylindrical housing 200. Instead, the force of maintaining the pressurization spring 140 in the compressed, pre-activated position is borne by the engagement between the sprocket teeth 576 and the fingers 592 of the retention plate 582. In such an embodiment, however, the foot engaging surface 218 of the cylindrical housing 200 may still prevent excessive rocking of the plunger 564.

[0088] Upon activation of the infusion device 100, plunger 564 is rotated (for example, by the rotor 136, which is rotated around the cylindrical housing 200 by the movement of the activator button 128, as described above) such that the sprocket teeth 576 align with the slots 588 of the sprocket opening 584 (and the plunger tabs align with the recessed channels 204 of the cylindrical housing 200), to release the plunger 564 to translate within the cylindrical housing 200 under the force of the pressurization spring 140, to pressurize the reservoir 160.

[0089] To assemble the retention assembly 560 into the pre-activated position, the tool 544 (see, for example, FIG. 24) having, for example, the pair of protrusions 548 protruding from the end thereof is inserted so that the protrusions 548 pass through the tool openings 580 (see, for example, FIG. 21) of the plunger 564. The tool 544 is then used to compress the pressurization spring 140 through downward pressure on the plunger 564. The tool 544 continues the downward motion of the plunger 564 and compression of the pressurization

spring 140 until the sprocket 572 passes through the sprocket opening 584. For the sprocket 572 to pass through the sprocket opening 584, the sprocket teeth 576, must be aligned with the slots 588 of the sprocket opening 584. If the slots 588 of the sprocket opening 584 align with the sprocket teeth 576, the tool 544 may be rotated to rotate the plunger 564 into the desired alignment. Subsequent to the sprocket 572 passing through the sprocket opening 584, the tool 544 rotates so that the tool protrusions 548 engage the sides of the tool openings 580 to rotate the plunger 564, so that the sprocket teeth 576 align with fingers 592 of the retention plate 582. At this point, the tool can be removed, thereby engaging the sprocket teeth 576 with the fingers 592 of the retention plate 582, and maintaining compression of the pressurization spring 140.

[0090] The described embodiment of the retention assembly 560 eliminates an opening in the plunger, and therefore reduces or eliminates problem of dead volume of the reservoir 160. And the sprocket 572 is retained by the bottom of the retention plate 582 and resides within the thickness of the bottom enclosure in a pre-activated state, thus, the height of the sprocket 572 does not increase the overall height of the infusion device 100.

[0091] According to another embodiment, rather than being stationary, the retention plate 582 is rotatably disposed with respect to the bottom enclosure 104 and the plunger 564 does not rotate upon activation. In other words, in this embodiment, at least with respect to the retention assembly 560, the retention plate replaces the rotor 136. Put another way, in this embodiment, the retention plate 582 has an engagement tab that is engaged by the activator button 128 when the activator button 128 is depressed, thereby rotating the retention plate 582 with respect to the bottom enclosure 104. This rotation aligns the slots 588 with the sprocket teeth 576, thereby releasing the plunger 564 to translate within the cylindrical enclosure 200 due to the force of the pressurization spring 140.

[0092] Similar to FIGS. 5 and 10, respectively, FIGS. 25 and 26 illustrate cross-sectional views of the infusion device 100 employing plunger 144 in a pre-activated state, and subsequent to activation. As shown in FIG. 25, the reservoir 160 is filled with the medicament, the rotor 136 and the microneedle 152 are in their respective pre-activated positions, and the needle cover 112 covers the microneedle 152. Additionally, the plunger 144 is in the pre-activated position compressing the pressurization spring 140, with feet 212 of plunger tab 214 engaging the cylindrical housing 200.

[0093] In FIG. 26, the microneedle 152 extends outside of the infusion device 100 and the reservoir 160 has been substantially emptied with the plunger 144 pressing the reservoir dome seal 164 to substantially conform to the underside of the dome 176 due to the force of the pressurization spring 140. As shown, the plunger 144 and the dome 176 are substantially the same size and shape, with the plunger 144 being slightly smaller than the dome 176, two completely seat against the dome 176, and provide for manufacturing tolerances as well as the reservoir dome seal 164 interposed between the plunger 144 and the dome 176. In other words, the shape and size of the plunger 144 and the dome 176 are complementary to minimize the amount of dead volume or unusable space in the reservoir 160. Thus, the infusion device 100 is designed to contain a predetermined volume of medicament (for example, 3 ml or 5 ml) when the reservoir 160 is filled, and to deliver substantially the entire volume of medicament. But if the reservoir 160 is only partially filled (for example, if a drug manufacturer fills a 3 ml infusion device with only 2 ml of medicament or only fills a 5 ml infusion device with 3 ml of medicament), difficulties may arise.

[0094] Because the volume of the reservoir 160 (defined between the dome 176 and the flexible but non-distensible or dome seal 164) is predetermined, filling the infusion device 100 at a volume less than the full design volume will leave a void that must be filled with some type of fluid, such as a gas. The gas would then have to be expelled from the infusion device 100 to evacuate the drug into the patient's skin.

[0095] One solution is to create plunger/dome combinations that are custom made for the volume of medicament being dispensed. For example, the curve of the dome and the corresponding curve of the plunger could be reduced (i.e., flattening the dome and the plunger), thereby reducing the volume of the reservoir 160. But for this solution, there would be to uniquely-manufactured parts for every predetermined volume of medicament, namely, a plunger and a reservoir dome.

[0096] Another solution is to allow the plunger 144 to press partially into the reservoir dome seal 164, deflecting the flexible but non-distensible reservoir dome seal 164, and reducing the volume of the reservoir 160. One approach to implement this solution is to modify the bottom enclosure. More specifically, the foot engaging surface 218 of the cylindrical housing 200 could be disposed vertically higher on the cylindrical housing 200,

and thus, in the pre-activated position, the plunger 144 could partially deflect the reservoir dome seal 164. This implementation would require a change to the bottom enclosure.

[0097] Another approach to implement the solution is shown in FIG. 28, which illustrates an embodiment of a plunger 600 for the infusion device 100 in which plunger tabs 604 are lengthened in comparison to the plunger tabs 214 of plunger 144 (shown, for example, in FIG. 27). More specifically, the respective feet 612 and 212 of the plunger tabs 604 and 214 are substantially similar. But the length of the legs 608 of plunger tab 604 is significantly increased with respect to the length of the legs 208 of the plunger tabs 214. Thus, in a pre-activated position, as shown in FIG. 29, the plunger 600 is disposed vertically higher in the cylindrical housing 200 (in comparison, for example, to the position of plunger 144 shown in FIG. 25) to contact and non-distensibly compress the reservoir dome seal 164 and thereby to reduce the volume of the reservoir 160. Accordingly, for each predetermined dosage volume of the medicament, the length of the legs 608 can be modified to contact and non-distensibly deflect the reservoir dome seal 164 to reduce the volume of the reservoir 160 substantially to the predetermined dosage volume.

[0098] In other respects, the infusion device 100 employing the plunger 600 operates substantially similarly to the infusion device 100 employing the plunger 144. For example, as shown in FIG. 30, similar to FIG. 26, the microneedles 152 extend outside of the infusion device 100 subsequent to activation and the reservoir 160 has been substantially emptied with the plunger 600 pressing the reservoir dome seal 164 to substantially conform to the underside of the dome 176 due to the force of the pressurization spring 140. Thus, in comparison to the infusion device 100 employing the plunger 144, with this approach, only a single uniquely-manufactured part (i.e., plunger 600) is needed to reduce the volume of the reservoir 160 when the infusion device 100 is in the pre-activated state.

[0099] Yet another approach to implement the partially deflected reservoir dome seal solution is to provide a plunger 640 illustrated in FIG. 31. Similar to the plunger 564 of FIG. 21, the plunger 640 includes a post 644 with a sprocket 648 disposed at a distal end thereof. Sprocket 648 includes a sprocket teeth 652 and post 644 includes a reduced diameter portion 656. In comparison to the plunger 564, however, the length of the post 644 is significantly increased with respect to the length of the post 568. FIG. 32 illustrates an infusion device 100 employing plunger 640 disposed in the pre-activated position. In

FIG. 32, the sprocket teeth 648 engage the fingers 592 of retention plate 582 to maintain the plunger 640 in the pre-activated position against the force of the pressurization spring 140. Thus, due to the increased length of the post 644, the plunger 640 in the pre-activated position shown in FIG. 32 is disposed vertically higher in the cylindrical housing 200 (in comparison, for example, to the position of plunger 564 shown in FIG. 22, although cylindrical housing is not shown in FIG. 22) to contact and non-distensibly deflect the reservoir dome seal 164 to reduce the volume of the reservoir 160. Accordingly, for each predetermined dosage volume of the medicament, the length of the post 644 can be modified to contact and non-distensibly deflect the reservoir dome seal 164 to reduce the volume of the reservoir 160 substantially to the predetermined dosage volume.

[0100] In other respects, the infusion device 100 employing the plunger 640 operates substantially similarly to infusion device 100 employing the plunger 564. For example, as shown in FIG. 32, the microneedles 152 extend outside of the infusion device 100 subsequent to activation and the reservoir 160 has been substantially emptied with the plunger 640 pressing the reservoir dome seal 164 to substantially conform to the underside of the dome 176 due to the force of the pressurization spring 140. Thus, in comparison to infusion device 100 employing, the plunger 564, with this approach, only a single uniquely-manufactured part (i.e., plunger 640) is needed to reduce the volume of the reservoir 160 when the infusion device 100 is in the pre-activated state. Although this embodiment has been described in comparison to the plunger 564, one of ordinary skill in the art would understand that it would also be possible to apply this approach to the embodiments of FIGS. 17-20 (in which the sprocket 520 engages plunger 508), by lengthening post 516.

[0101] Accordingly, FIGS. 28 to 33 illustrate embodiments of pressurizing systems that, in the pre-activated position, are restrained within the cylindrical housing 200 such that the pressurizing systems contacts and non-distensibly deforms the reservoir dome seal 164 to reduce the initial volume of the reservoir 160. In other words, the embodiments of FIGS. 28 to 33 illustrate pressurizing systems for selectively pressurizing the reservoir 160 in which the pressurizing systems include means for non-distensibly reducing the initial volume of the reservoir 160.

[0102] The described embodiments are suitable for use in administering various substances, including medications and pharmaceutical agents, to a patient, and particularly to a human patient. As used herein, a pharmaceutical agent includes a substance having biological activity that can be delivered through the body membranes and surfaces, and particularly the skin. Examples, listed in greater detail below, include antibiotics, antiviral agents, analgesics, anesthetics, anorexics, antiarthritics, antidepressants, antihistamines, anti-inflammatory agents, antineoplastic agents, vaccines, including DNA vaccines, and the like. Other substances that can be delivered intradermally or subcutaneously to a patient include human growth hormone, insulin, proteins, peptides and fragments thereof. The proteins and peptides can be naturally occurring, synthesized or recombinantly produced. Additionally, the device can be used in cell therapy, as during intradermal infusion of dendritic cells. Still other substances which can be delivered in accordance with the method of the present invention can be selected from the group consisting of drugs, vaccines and the like used in the prevention, diagnosis, alleviation, treatment, or cure of disease, with the drugs including Alpha-1 anti-trypsin, Anti-Angiogenesis agents, Antisense, butorphanol, Calcitonin and analogs, Ceredase, COX-II inhibitors, dermatological agents, dihydroergotamine, Dopamine agonists and antagonists, Enkephalins and other opioid peptides, Epidermal growth factors, Erythropoietin and analogs, Follicle stimulating hormone, G-CSF, Glucagon, GM-CSF, granisetron, Growth hormone and analogs (including growth hormone releasing hormone), Growth hormone antagonists, Hirudin and Hirudin analogs such as hirulog, IgE suppressors, Insulin, insulinotropin and analogs, Insulin-like growth factors, Interferons, Interleukins, Leutenizing hormone, Leutenizing hormone releasing hormone and analogs, Low molecular weight heparin, M-CSF, metoclopramide, Midazolam, Monoclonal antibodies, Narcotic analgesics, nicotine, Non-steroid anti-inflammatory agents, Oligosaccharides, ondansetron, Parathyroid hormone and analogs, Parathyroid hormone antagonists, Prostaglandin antagonists, Prostaglandins, Recombinant soluble receptors, scopolamine, Serotonin agonists and antagonists, Sildenafil, Terbutaline, Thrombolytics, Tissue plasminogen activators, TNF--, and TNF--antagonist, the vaccines, with or without carriers/adjuvants, including prophylactics and therapeutic antigens (including but not limited to subunit protein, peptide and polysaccharide, polysaccharide conjugates, toxoids, genetic based vaccines, live attenuated, reassortant, inactivated, whole cells, viral and bacterial vectors) in connection with, addiction, arthritis, cholera, cocaine addiction, diphtheria, tetanus, HIB, Lyme

disease, meningococcus, measles, mumps, rubella, varicella, yellow fever, Respiratory syncytial virus, tick borne japanese encephalitis, pneumococcus, streptococcus, typhoid, influenza, hepatitis, including hepatitis A, B, C and E, otitis media, rabies, polio, HIV, parainfluenza, rotavirus, Epstein Barr Virus, CMV, chlamydia, non-typeable haemophilus, moraxella catarrhalis, human papilloma virus, tuberculosis including BCG, gonorrhoea, asthma, atherosclerosis malaria, E-coli, Alzheimers, H. Pylori, salmonella, diabetes, cancer, herpes simplex, human papilloma and the like other substances including all of the major therapeutics such as agents for the common cold, Anti-addiction, anti-allergy, anti-emetics, anti-obesity, antiosteoporotic, anti-infectives, analgesics, anesthetics, anorexics, antiarthritics, antiasthmatic agents, anticonvulsants, anti-depressants, antidiabetic agents, antihistamines, anti-inflammatory agents, antimigraine preparations, anti-motion sickness preparations, anti-nauseants, antineoplastics, antiparkinsonism drugs, antipruritics, antipsychotics, antipyretics, anticholinergics, benzodiazepine antagonists, vasodilators, including general, coronary, peripheral and cerebral, bone stimulating agents, central nervous system stimulants, hormones, hypnotics, immunosuppressives, muscle relaxants, parasympatholytics, parasympathomimetics, prostaglandins, proteins, peptides, polypeptides and other macromolecules, psychostimulants, sedatives, sexual hypofunction and tranquilizers and major diagnostics such as tuberculin and other hypersensitivity agents as described in U.S. Patent No. 6,569,143, entitled "Method of Intradermally Injecting Substances", the entire content of which is expressly incorporated herein by reference.

[0103] Vaccine formulations which can be delivered in accordance with the system and method of the present invention can be selected from the group consisting of an antigen or antigenic composition capable of eliciting an immune response against a human pathogen, which antigen or antigenic composition is derived from HIV-1, (such as tat, nef, gp120 or gp160), human herpes viruses (HSV), such as gD or derivatives thereof or Immediate Early protein such as ICP27 from HSV1 or HSV2, cytomegalovirus (CMV (esp Human) (such as gB or derivatives thereof), Rotavirus (including live-attenuated viruses), Epstein Barr virus (such as gp350 or derivatives thereof), Varicella Zoster Virus (VZV, such as gpl, II and IE63) or from a hepatitis virus such as hepatitis B virus (for example Hepatitis B Surface antigen or a derivative thereof), hepatitis A virus (HAV), hepatitis C virus and hepatitis E virus, or from other viral pathogens, such as paramyxoviruses: Respiratory Syncytial virus (RSV, such as F and G proteins or derivatives thereof), parainfluenza virus, measles virus,

mumps virus, human papilloma viruses (HPV for example HPV6, 11, 16, 18), flaviviruses (e. g. Yellow Fever Virus, Dengue Virus, Tick-borne encephalitis virus, Japanese Encephalitis Virus) or Influenza virus (whole live or inactivated virus, split influenza virus, grown in eggs or MDCK cells, or whole flu virosomes or purified or recombinant proteins thereof, such as HA, NP, NA, or M proteins, or combinations thereof), or derived from bacterial pathogens such as *Neisseria* spp, including *N. gonorrhea* and *N. meningitidis* (for example capsular polysaccharides and conjugates thereof, transferrin-binding proteins, lactoferrin binding proteins, PilC, adhesins) ; *S. pyogenes* (for example M proteins or fragments thereof, C5A protease, lipoteichoic acids), *S. agalactiae*, *S. mutans*; *H. ducreyi*; *Moraxella* spp, including *M. catarrhalis*, also known as *Branhamella catarrhalis* (for example high and low molecular weight adhesins and invasins); *Bordetella* spp, including *B. pertussis* (for example pertactin, pertussis toxin or derivatives thereof, filamentous hemagglutinin, adenylate cyclase, fimbriae), *B. parapertussis* and *B. bronchiseptica*; *Mycobacterium* spp., including *M. tuberculosis* (for example ESAT6, Antigen 85A, -B or -C), *M. bovis*, *M. leprae*, *M. avium*, *M. paratuberculosis* *M. smegmatis* ; *Legionella* spp, including *L. pneumophila* ; *Escherichia* spp, including enterotoxigenic *E. coli* (for example colonization factors, heat-labile toxin or derivatives thereof, heat-stable toxin or derivatives thereof), enterohemorrhagic *E. coli*, enteropathogenic *E. coli* (for example shiga toxin-like toxin or derivatives thereof) ; *Vibrio* spp, including *V. cholera* (for example cholera toxin or derivatives thereof); *Shigella* spp, including *S. sonnei*, *S. dysenteriae*, *S. flexnerii*; *Yersinia* spp, including *Y. enterocolitica* (for example a Yop protein), *Y. pestis*, *Y. pseudotuberculosis*; *Campylobacter* spp, including *C. jejuni* (for example toxins, adhesins and invasins) and *C. coli*; *Salmonella* spp, including *S. typhi*, *S. paratyphi*, *S. choleraesuis*, *S. enteritidis*; *Listeria* spp., including *L. monocytogenes*; *Helicobacter* spp, including *H. pylori* (for example urease, catalase, vacuolating toxin); *Pseudomonas* spp, including *P. aeruginosa*; *Staphylococcus* spp., including *S. aureus*, *S. Epidermidis* ; *Enterococcus* spp., including *E. faecalis*, *E. faecium*; *Clostridium* spp., including *C. tetani* (for example tetanus toxin and derivative thereof), *C. botulinum* (for example Botulinum toxin and derivative thereof), *C. difficile* (for example clostridium toxins A or B and derivatives thereof) ; *Bacillus* spp., including *B. anthracis* (for example botulinum toxin and derivatives thereof) ; *Corynebacterium* spp., including *C. diphtheriae* (for example diphtheria toxin and derivatives thereof); *Borrelia* spp., including *B. Burgdorferi* (for example OspA, OspC, DbpA, DbpB), *B. garinii* (for example OspA, OspC, DbpA, DbpB), *B. afzelii* (for example

OspA, OspC, DbpA, DbpB), *B. andersonii* (for example OspA, OspC, DbpA, DbpB), *B. Hermsii* ; *Ehrlichia* spp., including *E. equi* and the agent of the Human Granulocytic Ehrlichiosis ; *Rickettsia* spp, including *R. rickettsii* ; *Chlamydia* spp., including *C. Trachomatis* (for example MOMP, heparin-binding proteins), *C. pneumoniae* (for example MOMP, heparin-binding proteins), *C. psittaci*; *Leptospira* spp., including *L. interrogans*; *Treponema* spp., including *T. pallidum* (for example the rare outer membrane proteins), *T. denticola*, *T. hyodysenteriae*; or derived from parasites such as *Plasmodium* spp., including *P. Falciparum* ; *Toxoplasma* spp., including *T. gondii* (for example SAG2, SAG3, Tg34); *Entamoeba* spp., including *E. histolytica*; *Babesia* spp., including *B. microti*; *Trypanosoma* spp., including *T. cruzi*; *Giardia* spp., including *G. lamblia*; *Leshmania* spp., including *L. major*; *Pneumocystis* spp., including *P. Carinii* ; *Trichomonas* spp., including *T. vaginalis*; *Schistosoma* spp., including *S. mansoni*, or derived from yeast such as *Candida* spp., including *C. albicans*; *Cryptococcus* spp., including *C. neoformans*, as described in PCT Patent Publication No. WO 02/083214, entitled "Vaccine Delivery System", the entire content of which is expressly incorporated herein by reference.

[0104] These also include other preferred specific antigens for *M. tuberculosis*, for example Tb Ra12, Tb H9, Tb Ra35, Tb38-1, Erd 14, DPV, MTI, MSL, mTTC2 and hTCC1. Proteins for *M. tuberculosis* also include fusion proteins and variants thereof where at least two, preferably three polypeptides of *M. tuberculosis* are fused into a larger protein. Preferred fusions include Ra12-TbH9-Ra35, Erd14-DPV-MTI, DPV-MTI-MSL, Erd14-DPV-MTI-MSL-mTCC2, Erd14-DPV-MTI-MSL, DPV-MTI- MSL-mTCC2, TbH9-DPV-MTI. Most preferred antigens for *Chlamydia* include for example the High Molecular Weight Protein (HWMP), ORF3, and putative membrane proteins (Pmps). Preferred bacterial vaccines comprise antigens derived from *Streptococcus* spp, including *S. pneumoniae* (for example capsular polysaccharides and conjugates thereof, PsaA, PspA, streptolysin, choline-binding proteins) and the protein antigen Pneumolysin (Biochem Biophys Acta, 1989,67,1007 ; Rubins et al., Microbial Pathogenesis, 25,337-342), and mutant detoxified derivatives thereof. Other preferred bacterial vaccines comprise antigens derived from *Haemophilus* spp., including *H. influenzae* type B ("Hib", for example PRP and conjugates thereof), non typeable *H. influenzae*, for example OMP26, high molecular weight adhesins, P5, P6, protein D and lipoprotein D, and fimbrin and fimbrin derived peptides or multiple copy variants or fusion proteins thereof. Derivatives of Hepatitis B

Surface antigen are well known in the art and include, inter alia, PreS1, PreS2 S antigens. In one preferred aspect the vaccine formulation of the invention comprises the HIV-1 antigen, gp120, especially when expressed in CHO cells. In a further embodiment, the vaccine formulation of the invention comprises gD2t as hereinabove defined.

[0105] In addition to the delivery of substances listed above, the infusion device 100 can also be used for withdrawing a substance from a patient, or monitoring a level of a substance in the patient. Examples of substances that can be monitored or withdrawn include blood, interstitial fluid or plasma. The withdrawn substances can then be analyzed for analytes, glucose, drugs, and the like.

[0106] Although only a few exemplary embodiments of the present invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of the appended claims and equivalents thereof.

Claims

1. A drug delivery device, comprising:
a body including a top enclosure and a bottom enclosure;
a reservoir disposed within the body for containing a medicament;
an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir; and
a pressurizing system for selectively pressurizing the reservoir, wherein in a pre-activated position, the pressurizing system contacts and compresses the reservoir to reduce an initial volume of the reservoir.
2. The device according to claim 1, wherein:
the bottom enclosure comprises a cylindrical housing; and
the pressurizing system is disposed within the cylindrical housing.
3. The device according to claim 2, wherein the pressurizing system comprises:
a plunger movable within the cylindrical housing; and
a pressurization spring compressed by the plunger when the pressurizing system is in the pre-activated position.
4. The device according to claim 3, wherein:
the plunger comprises at least one tab extending from an outer edge thereof;
and
the cylindrical housing includes at least one recessed channel to guide the at least one plunger tab during plunger movement.
5. The device according to claim 4, wherein:
the at least one plunger tab comprises a leg extending from the outer edge of the plunger, and a foot extending from the leg; and
the at least one recessed channel includes a retaining portion;

wherein a resistance between the foot and the retaining portion retains the pressurizing system in the pre-activated position against the force of the pressurization spring.

6. The device according to claim 5, wherein a length of the leg determines an amount of reduction of the initial volume of the reservoir.

7. The device according to claim 6, wherein:
the reservoir comprises a dome and a flexible reservoir dome seal;
when the pressurizing system is in the pre-activated position a surface of the plunger contacts and compresses the reservoir dome seal to reduce the initial volume of the reservoir; and
a shape of the surface of the plunger that contacts the reservoir dome seal corresponds to a shape of the dome.

8. The device according to claim 7, further comprising an activator button movably disposed on the main body and movable from a pre-activated position to an activated position;
wherein moving the activator button from the pre-activated position to the activated position causes rotation of the plunger such that the foot is free of the retaining portion and the plunger moves within the cylindrical housing due to the force of the pressurization spring, to pressurize the reservoir.

9. The device according to claim 3, wherein the pressurizing system further comprises:
a retention plate disposed on the bottom enclosure; and
a post disposed substantially at a center of the cylindrical housing on one of the retention plate and the plunger, the post having a sprocket disposed at a distal end thereof;
wherein the pressurization spring is disposed between the retention plate and the plunger;

the remaining one of the retention plate and the plunger includes an opening with a shape corresponding to the sprocket, the opening having slots interposed between fingers of remaining one of the retention plate and the plunger; and

in the pre-activated position, teeth of the sprocket align with said fingers to maintain the pressurization spring compression.

10. The device according to claim 9, wherein the post and the one of the retention plate and the plunger where the post is disposed are integrally formed as a unitary structure.

11. The device according to claim 9, wherein:
the plunger comprises at least one tab extending from an outer edge thereof;
and
the cylindrical housing includes at least one recessed channel to guide the at least one plunger tab during plunger movement.

12. The device according to claim 9, wherein a length of the post determines an amount of reduction of the initial volume of the reservoir.

13. The device according to claim 12, wherein:
the reservoir comprises a dome and a flexible reservoir dome seal;
when the pressurizing system is in the pre-activated position a surface of the plunger contacts and compresses the reservoir dome seal to reduce the initial volume of the reservoir; and
a shape of the surface of the plunger that contacts the reservoir dome seal corresponds to a shape of the dome.

14. The device according to claim 13, further comprising an activator button movably disposed on the main body and movable from a pre-activated position to an activated position;

wherein moving the activator button from the pre-activated position to the activated position causes rotation of one of the retention plate and the plunger with respect to the non-rotating one of the retention plate and the plunger such that the sprocket teeth align with the slots of the opening to release the plunger to move within the cylindrical housing under the force of the pressurization spring to pressurize the reservoir.

15. The device according to claim 14, wherein the post is disposed on the retention plate.

16. The device according to claim 14, wherein the post is disposed on the plunger.

17. The device according to claim 14, wherein moving the activator button from the pre-activated position to the activated position causes rotation of the retention plate to align the sprocket teeth with the slots of the opening.

18. The device according to claim 14, wherein moving the activator button from the pre-activated position to the activated position causes rotation of the plunger to align the sprocket teeth with the slots of the opening.

19. A device for delivering a predetermined volume of a medicament into a patient's body by injection into or through the patient's skin, comprising:

a main body including a top enclosure and a bottom enclosure;

a reservoir disposed within the main body for containing the medicament;

an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir;

a pressurizing system for selectively pressurizing the reservoir, wherein in a pre-activated position, the pressurizing system contacts and deflects the reservoir to reduce an initial volume of the reservoir substantially to the predetermined volume.

20. The device according to claim 19, wherein the pressurizing system comprises:

a plunger movable within the main body; and

a pressurization spring compressed by the plunger when the pressurizing system is in the pre-activated position.

21. The device according to claim 20, wherein:
the reservoir comprises a dome and a flexible reservoir dome seal;
when the pressurizing system is in the pre-activated position a surface of the plunger contacts and deflects the reservoir dome seal to reduce the initial volume of the reservoir; and
a shape of the surface of the plunger that contacts the reservoir dome seal corresponds to a shape of the dome.

22. The device according to claim 21, wherein:
the plunger comprises at least one a leg extending from an outer edge of the plunger, and a foot extending from the leg;
the bottom enclosure comprises a retaining portion, wherein a frictional resistance between the foot and the retaining portion retains the pressurizing system in the pre-activated position against the force of the pressurization spring; and
a length of the leg determines an amount of reduction of the initial volume of the reservoir.

23. The device according to claim 21, wherein the pressurizing system further comprises:
a retention plate disposed on the bottom enclosure; and
a post disposed substantially at a center of one of the plunger and the retention plate, the post having a sprocket disposed at a distal end thereof;
wherein the pressurization spring is disposed between the retention plate and the plunger;
the remaining one of the retention plate and the plunger includes an opening with a shape corresponding to the sprocket, the opening having slots interposed between fingers of remaining one of the retention plate and the plunger;
in the pre-activated position, teeth of the sprocket align with said fingers to maintain the pressurization spring compression; and

a length of the post determines an amount of reduction of the initial volume of the reservoir.

24. The device according to claim 23, wherein the post is disposed on the retention plate.

25. The device according to claim 23, wherein the post is disposed on the plunger.

26. The device according to claim 23, wherein moving the activator button from the pre-activated position to the activated position cause rotation of the retention plate to align the sprocket teeth with the slots of the opening.

27. The device according to claim 23, wherein moving the activator button from the pre-activated position to the activated position causes rotation of the plunger to align the sprocket teeth with the slots of the opening.

28. A device for delivering a medicament into a patient's body by injection into or through the patient's skin, comprising:

- a main body including a top enclosure and a bottom enclosure including a cylindrical housing;

- a reservoir disposed within the main body for containing the medicament;

- an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir;

- a pressurizing system for selectively pressurizing the reservoir;

- wherein in a pre-activated position, the pressurizing system is restrained within the cylindrical housing and the pressurizing system contacts and deforms the reservoir to reduce an initial volume of the reservoir.

29. A device for delivering a medicament into a patient's body by injection into or through the patient's skin, comprising:

- a main body including a top enclosure and a bottom enclosure;

- a reservoir disposed within the main body for containing medicament;

an injection needle for penetrating the skin of the patient, the needle having a lumen and selectively communicating with the reservoir;

a pressurizing system for selectively pressurizing the reservoir, the pressurizing system comprising means for reducing an initial volume of the reservoir.

30. The device according to claim 29, wherein the means for reducing the initial volume of the reservoir comprises:

a plunger movable within the main body; and

a pressurization spring compressed by the plunger when the pressurizing system is in the pre-activated position.

31. The device according to claim 30, wherein:

the reservoir comprises a dome and a flexible reservoir dome seal;

when the pressurizing system is in the pre-activated position a surface of the plunger contacts and partially compresses the reservoir dome seal to reduce the initial volume of the reservoir; and

a shape of the surface of the plunger that contacts the reservoir dome seal corresponds to a shape of the dome.

32. The device according to claim 21, wherein:

the plunger comprises at least one a leg extending from an outer edge of the plunger, and a foot extending from the leg;

the bottom enclosure comprises a retaining portion, wherein a frictional resistance between the foot and the retaining portion retains the pressurizing system in the pre-activated position against the force of the pressurization spring; and

a length of the leg determines an amount of reduction of volume of the reservoir.

33. The device according to claim 31, wherein the means for non-distensibly reducing the initial volume of the reservoir further comprises:

a retention plate disposed on the bottom enclosure; and

a post disposed substantially at a center of one of the plunger and the retention plate, the post having a sprocket disposed at a distal end thereof;

wherein the pressurization spring is disposed between the retention plate and the plunger;

the remaining one of the retention plate and the plunger includes an opening with a shape corresponding to the sprocket, the opening having slots interposed between fingers of remaining one of the retention plate and the plunger;

in the pre-activated position, teeth of the sprocket align with said fingers to maintain the pressurization spring compression; and

a length of the post determines an amount of reduction of the initial volume of the reservoir.

34. The device according to claim 33, wherein the post is disposed on the retention plate.

35. The device according to claim 33, wherein the post is disposed on the plunger.

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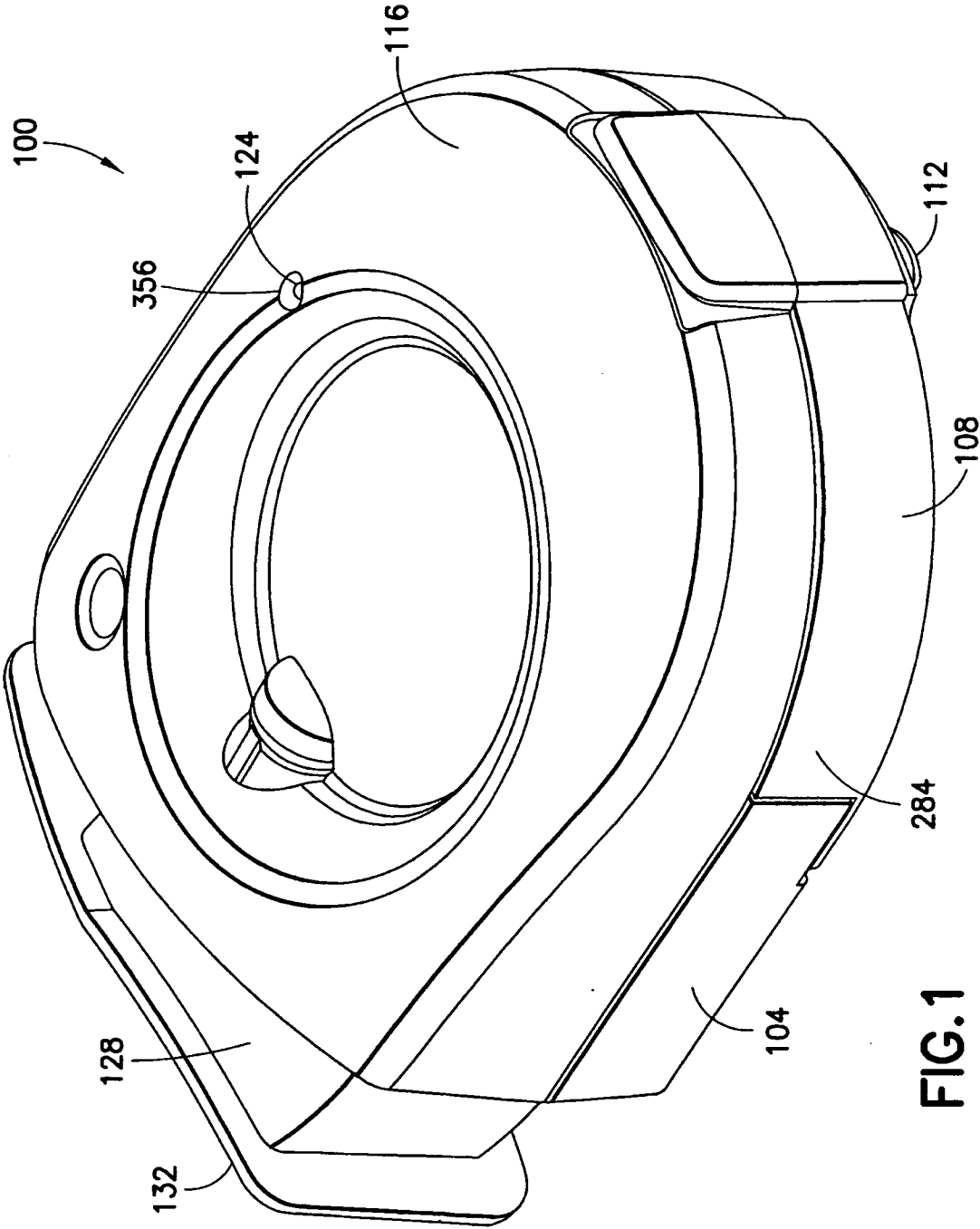


FIG. 1

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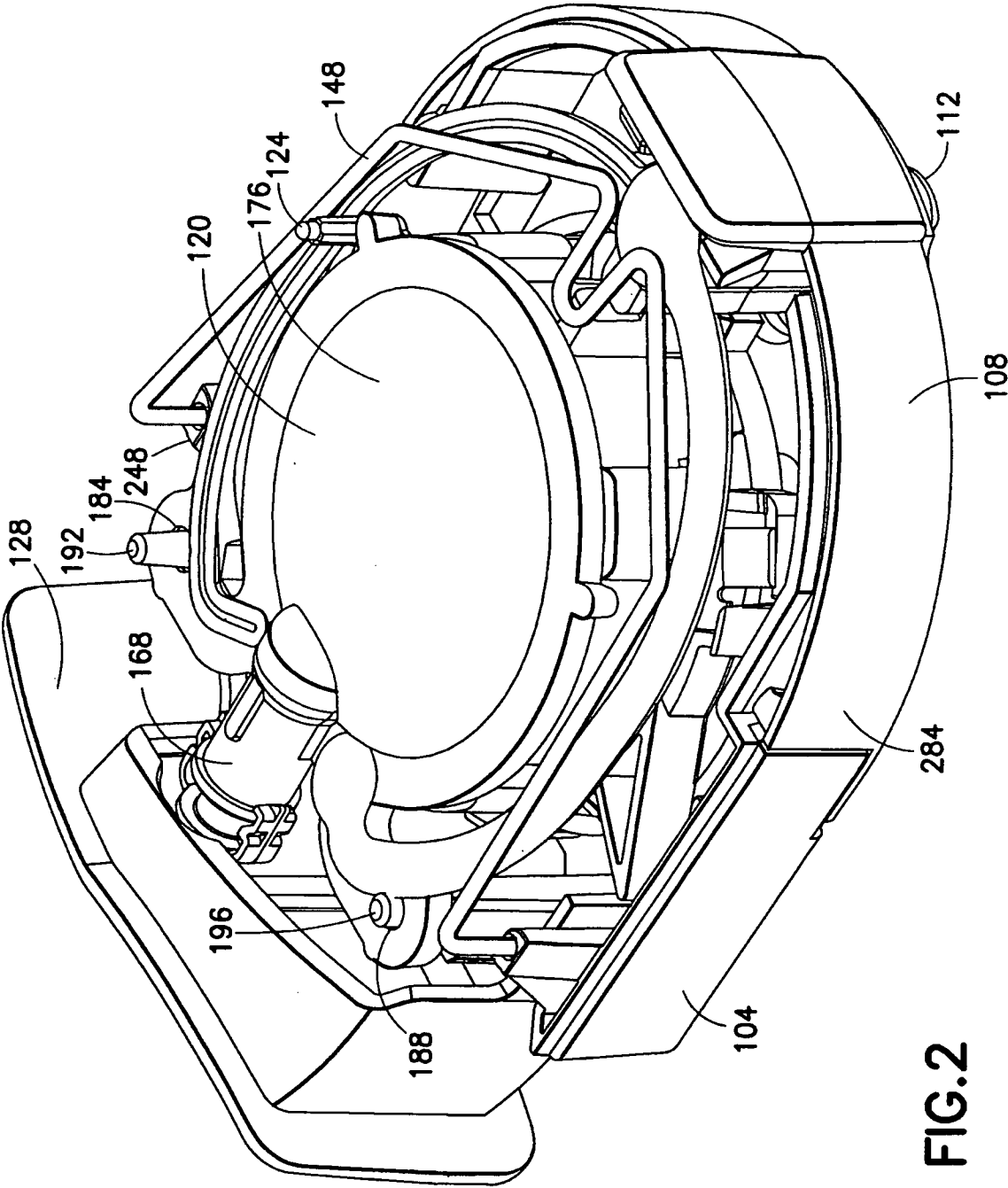
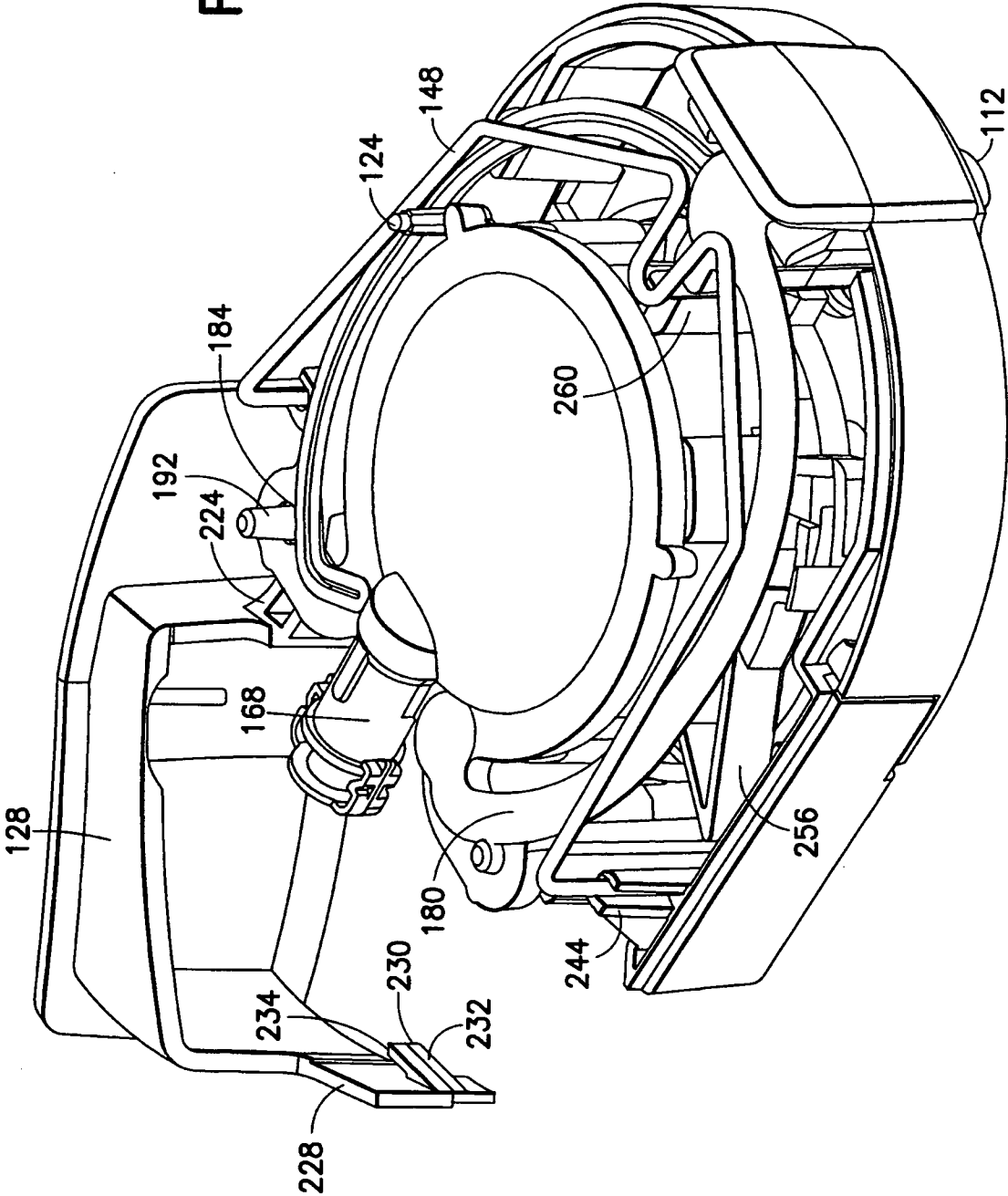


FIG. 2

FIG. 3



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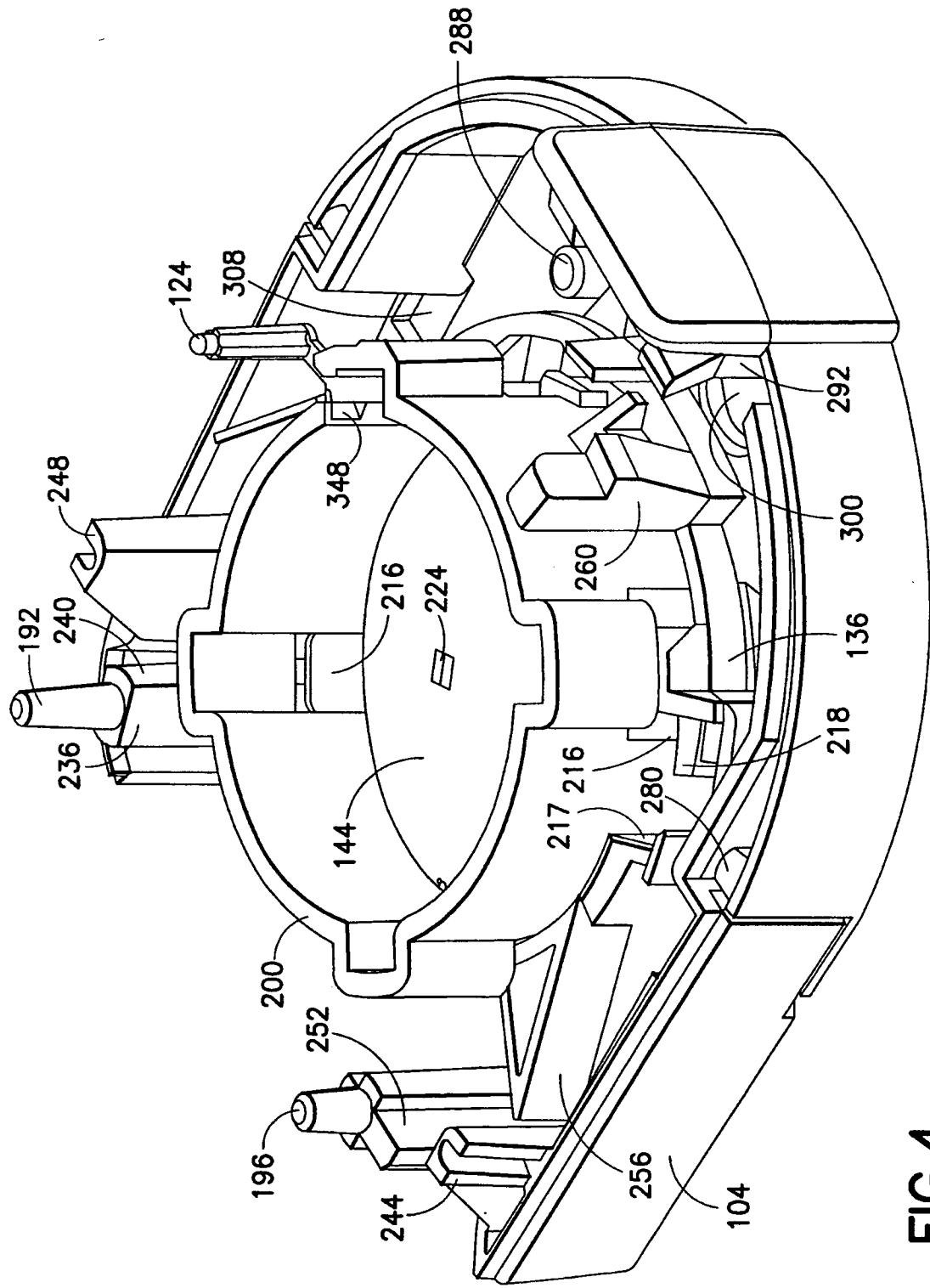


FIG. 4

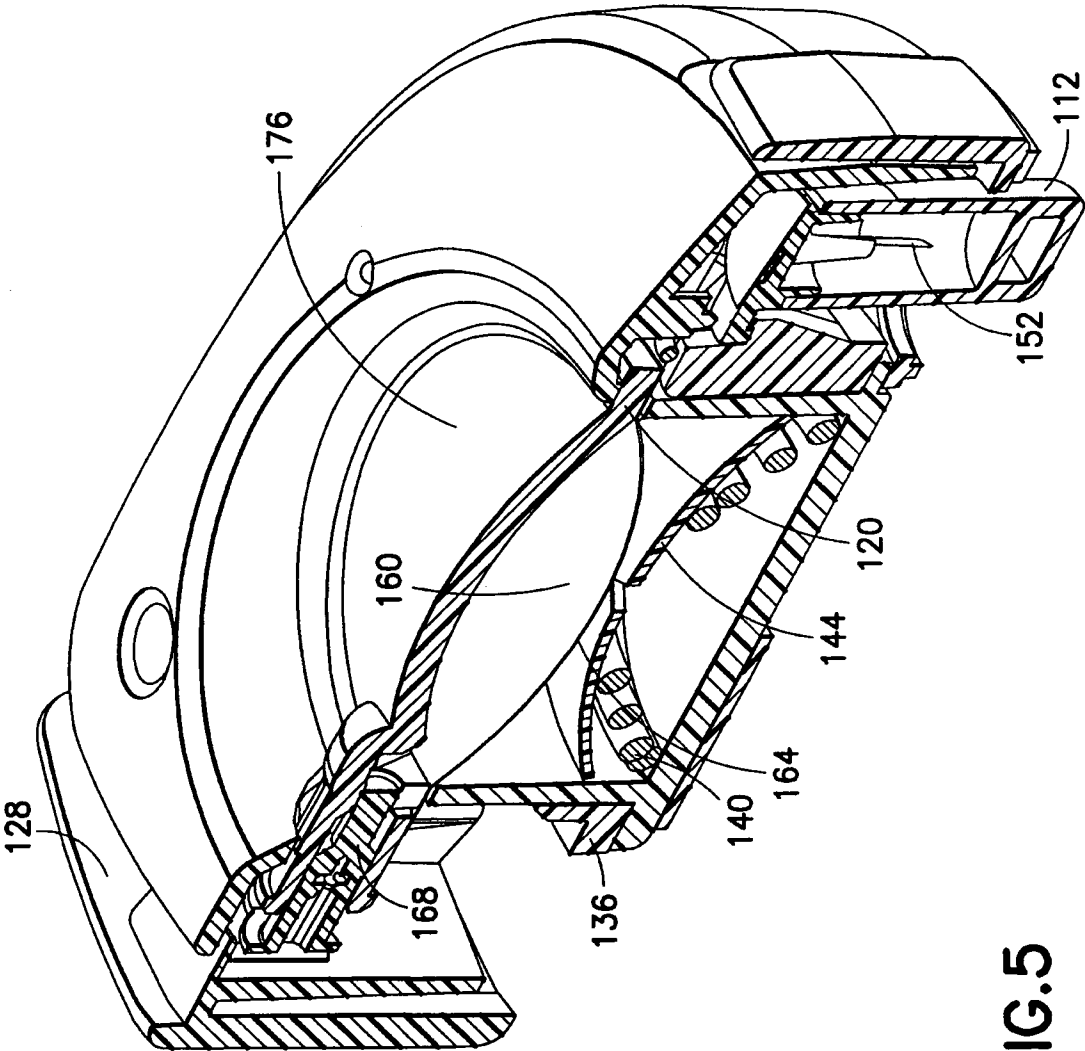


FIG. 5

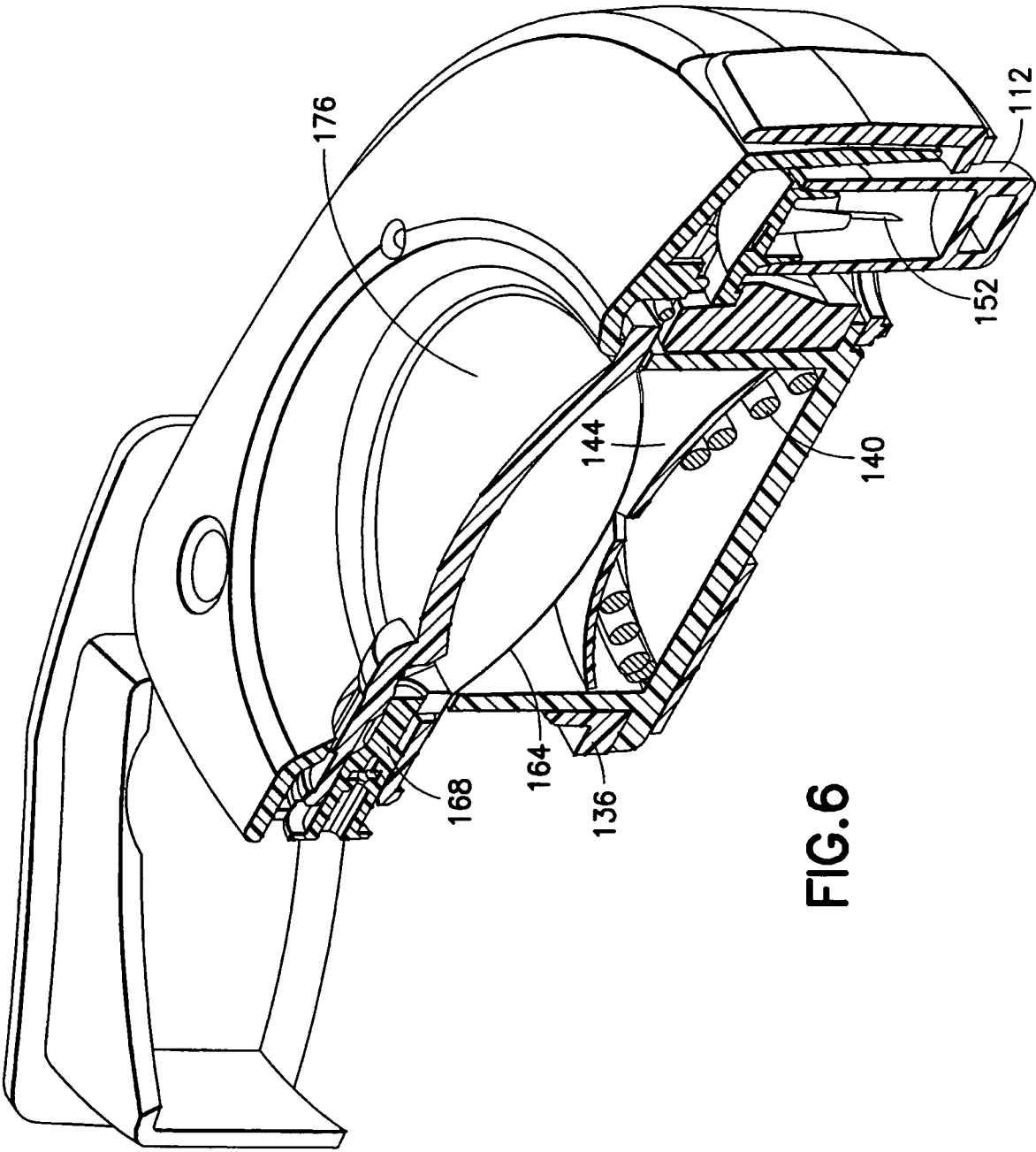


FIG. 6

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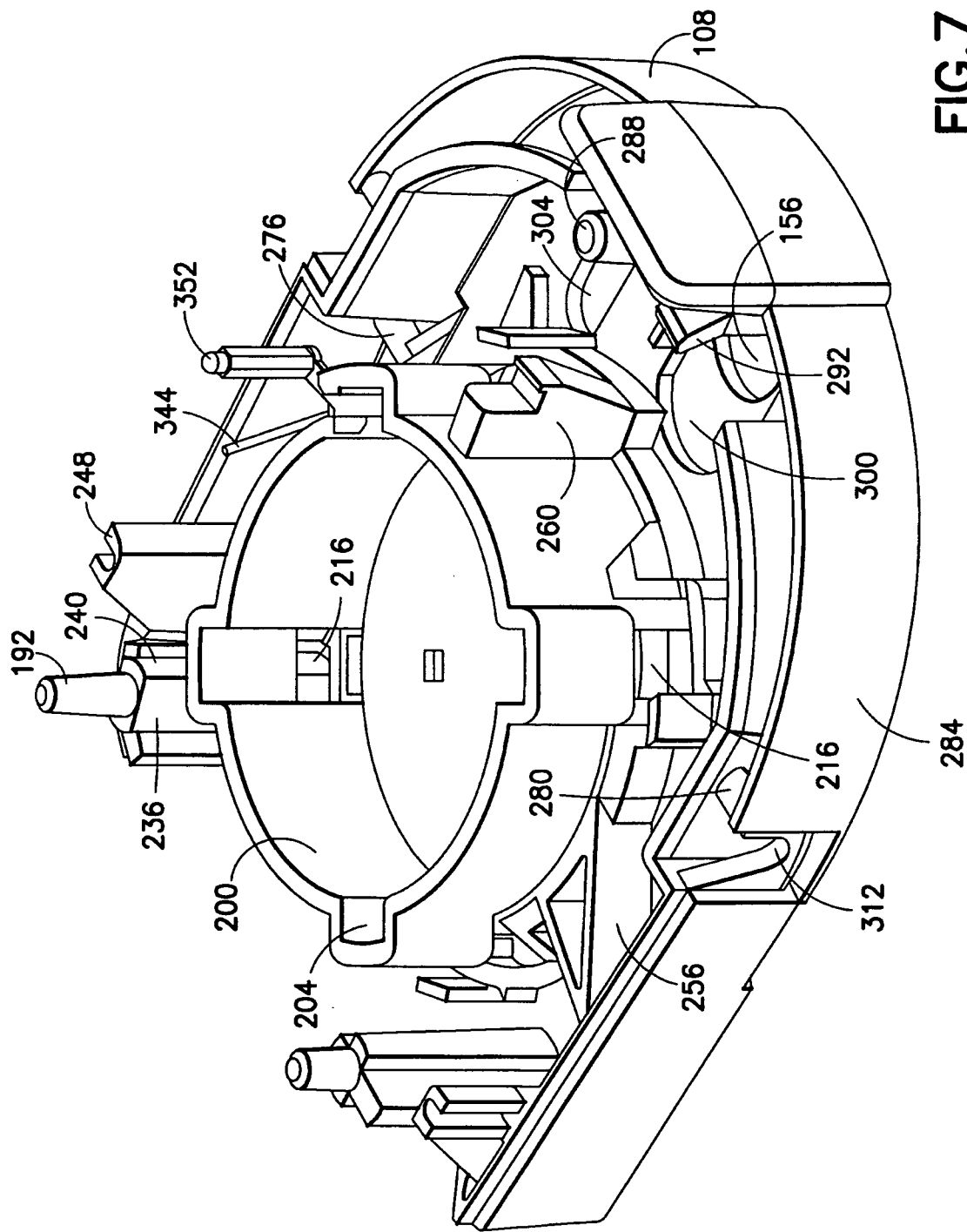
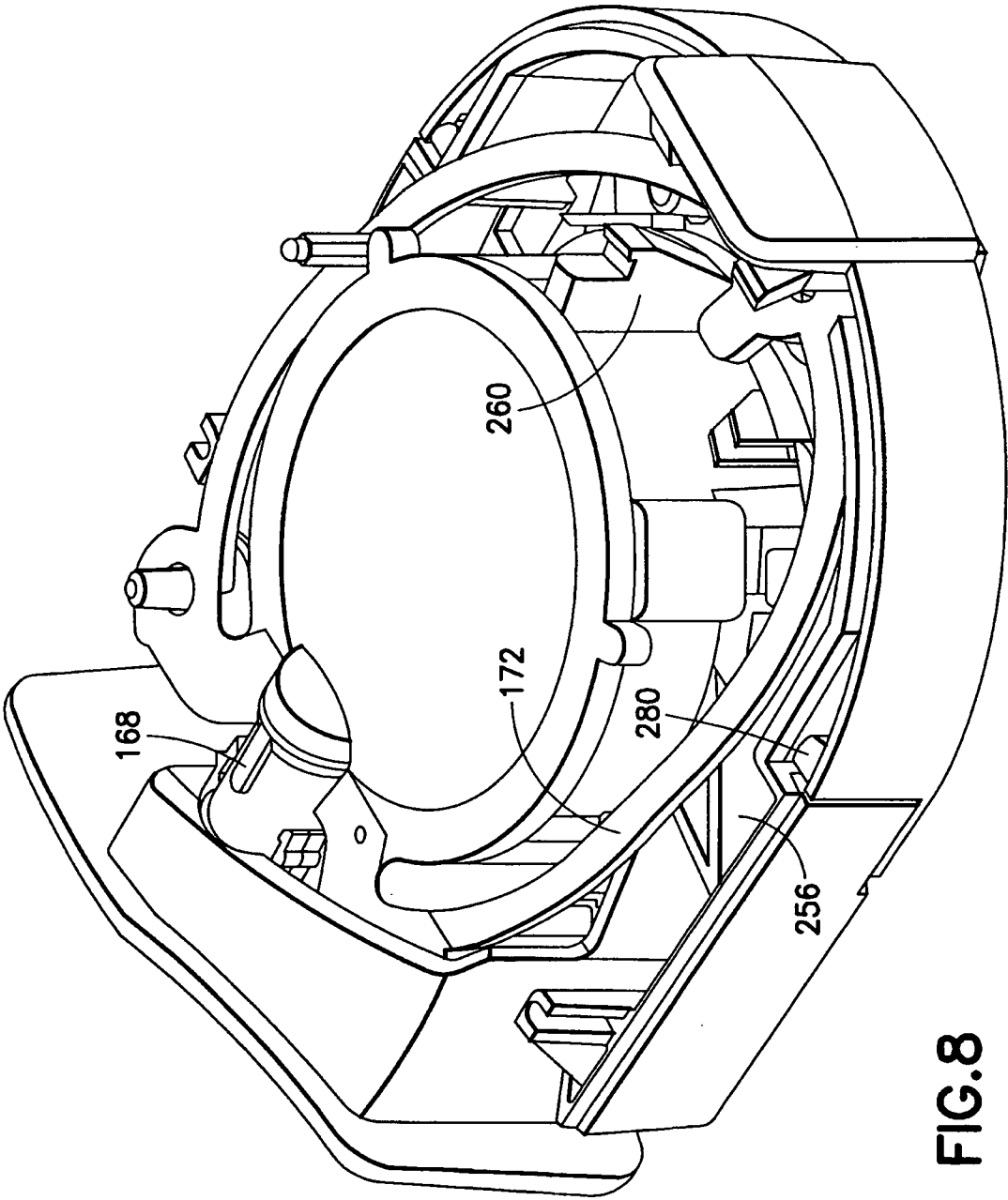


FIG. 7

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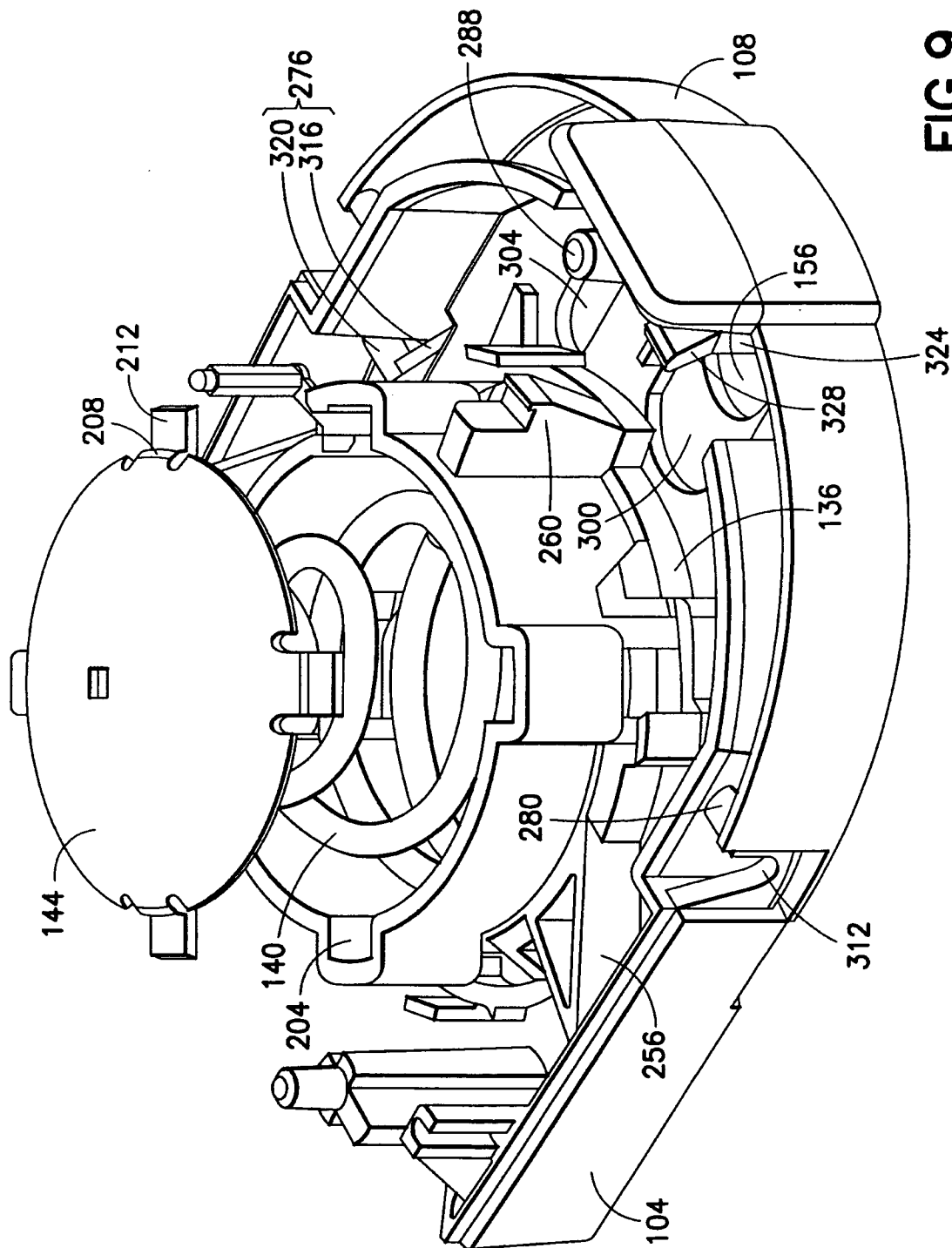


FIG. 9.

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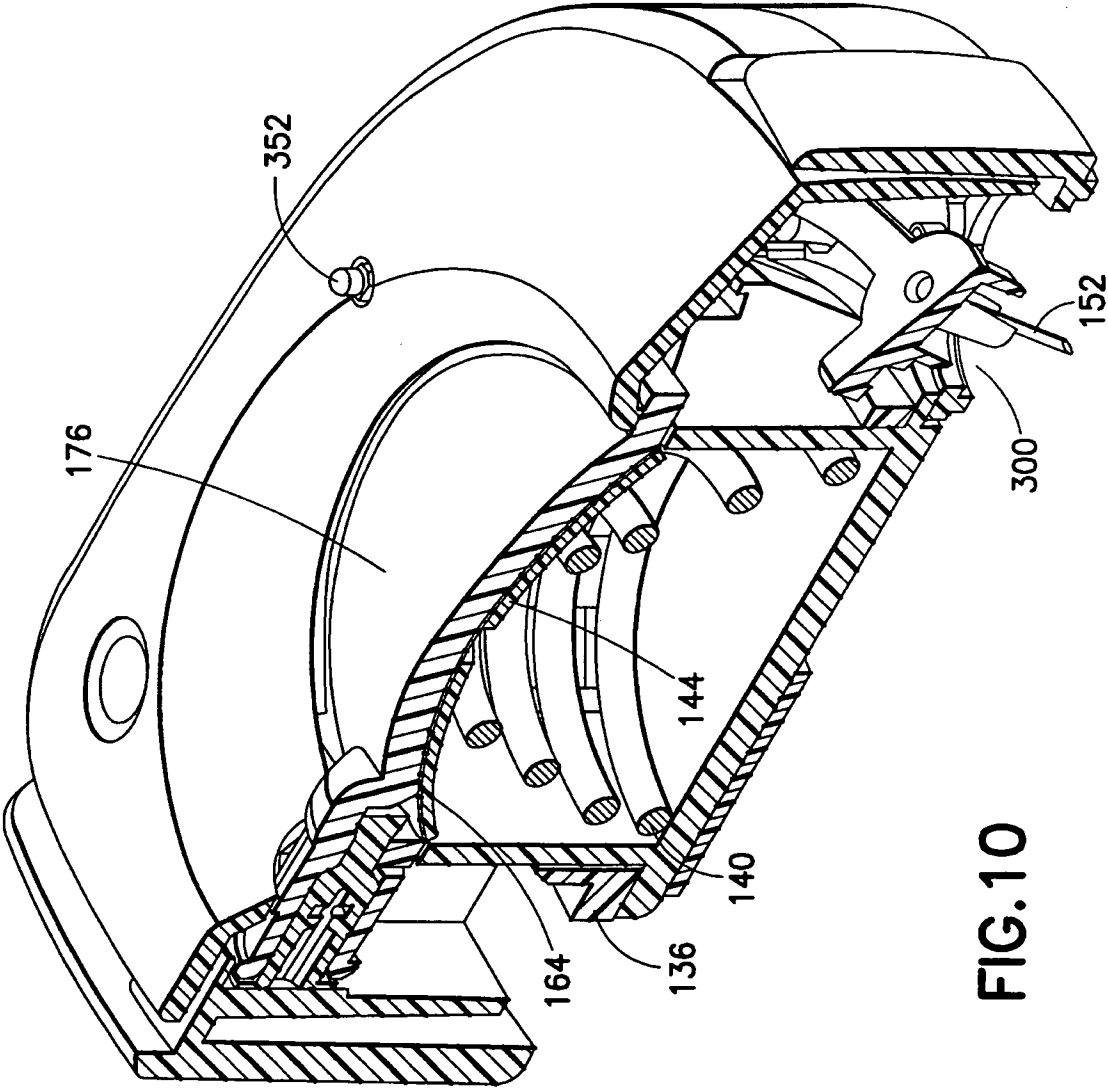
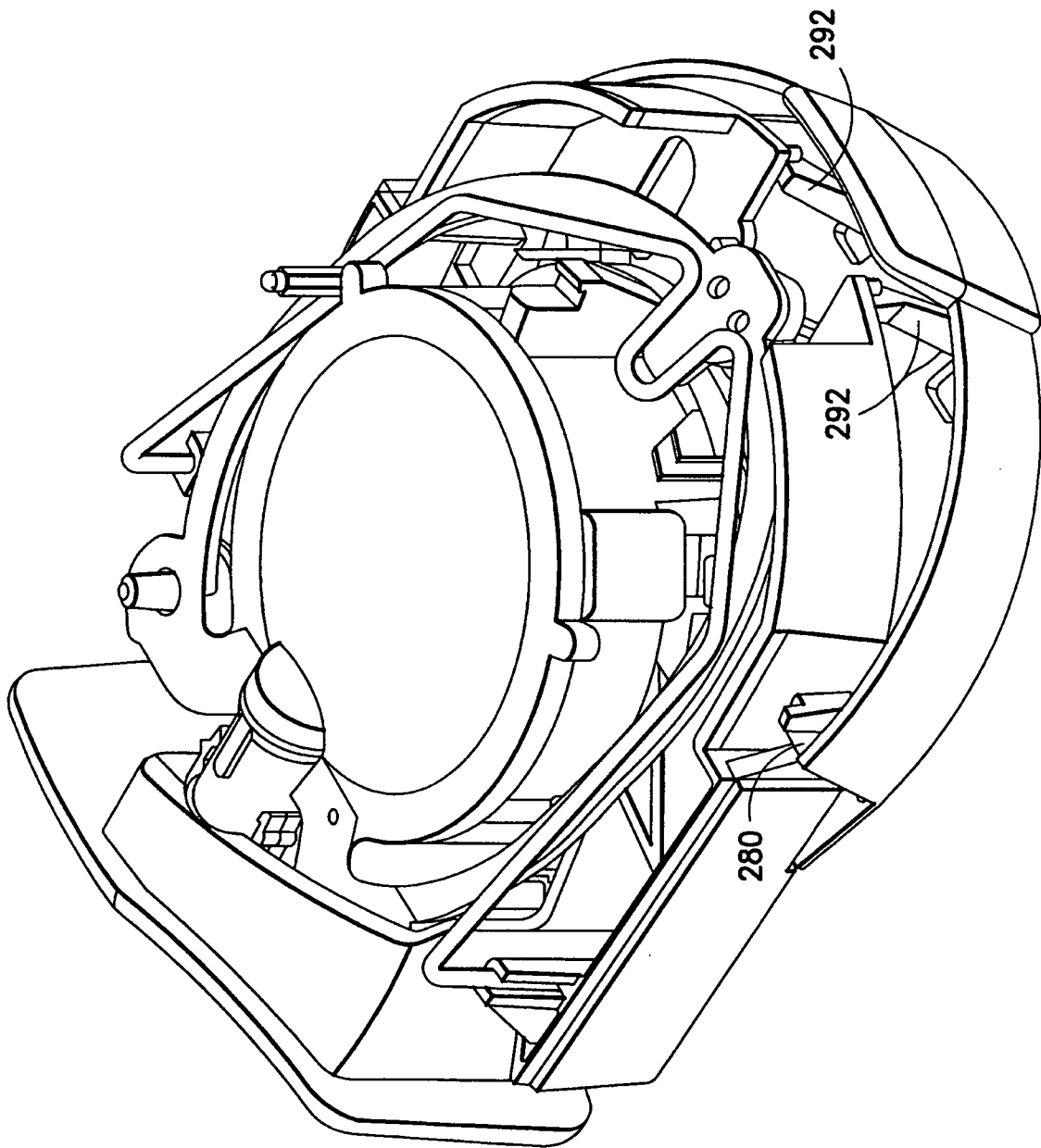
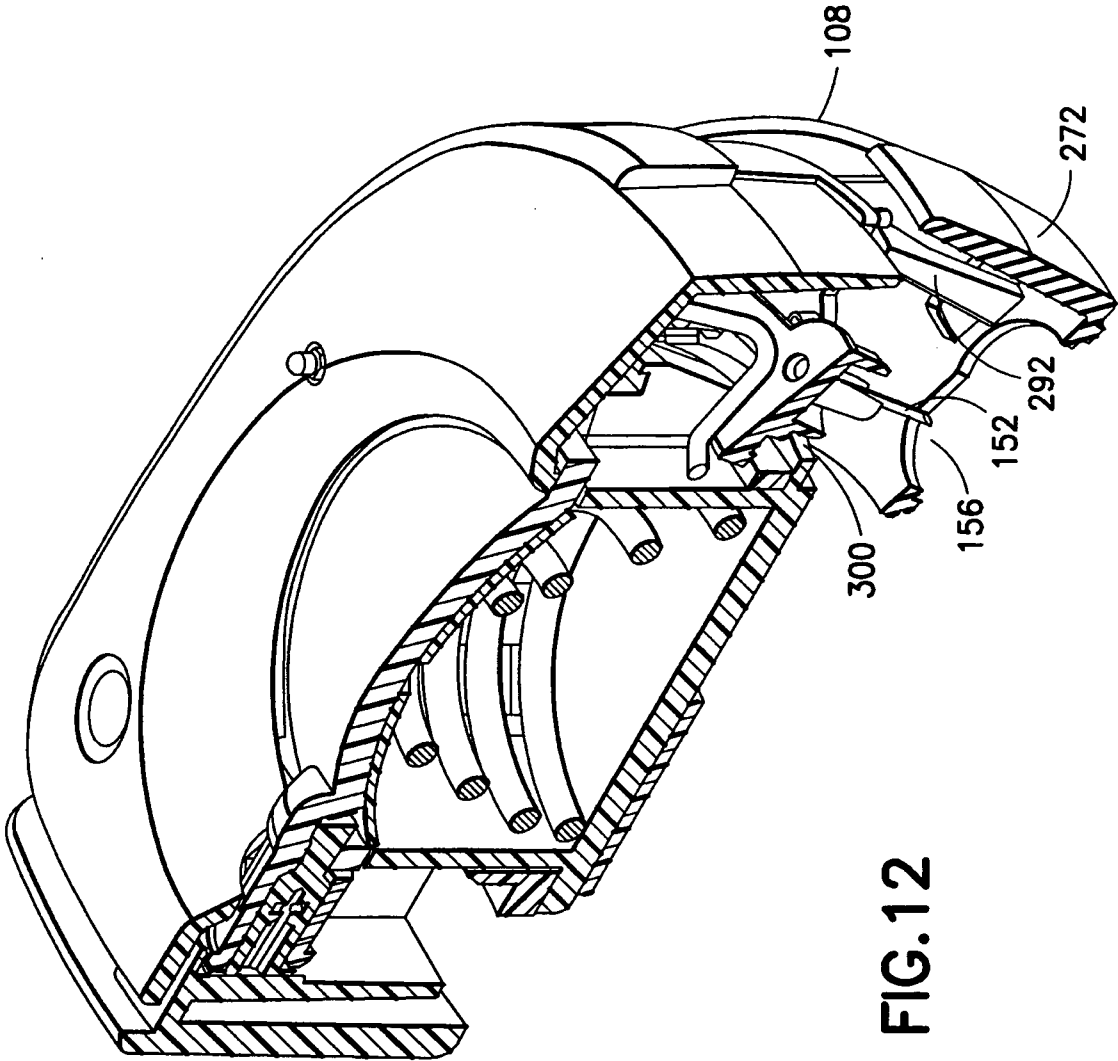


FIG.10

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FIG.11





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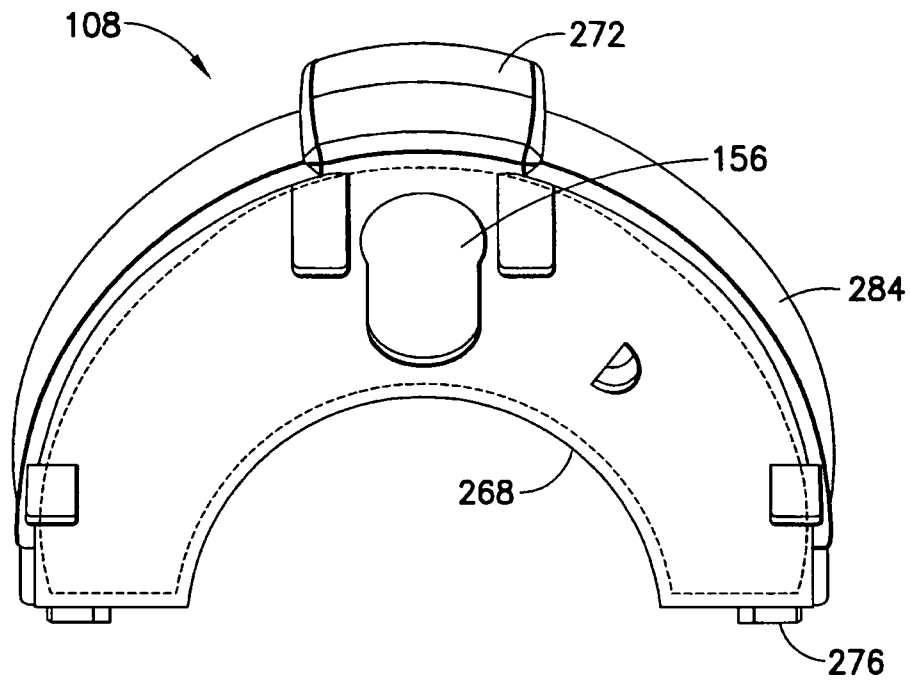


FIG. 13

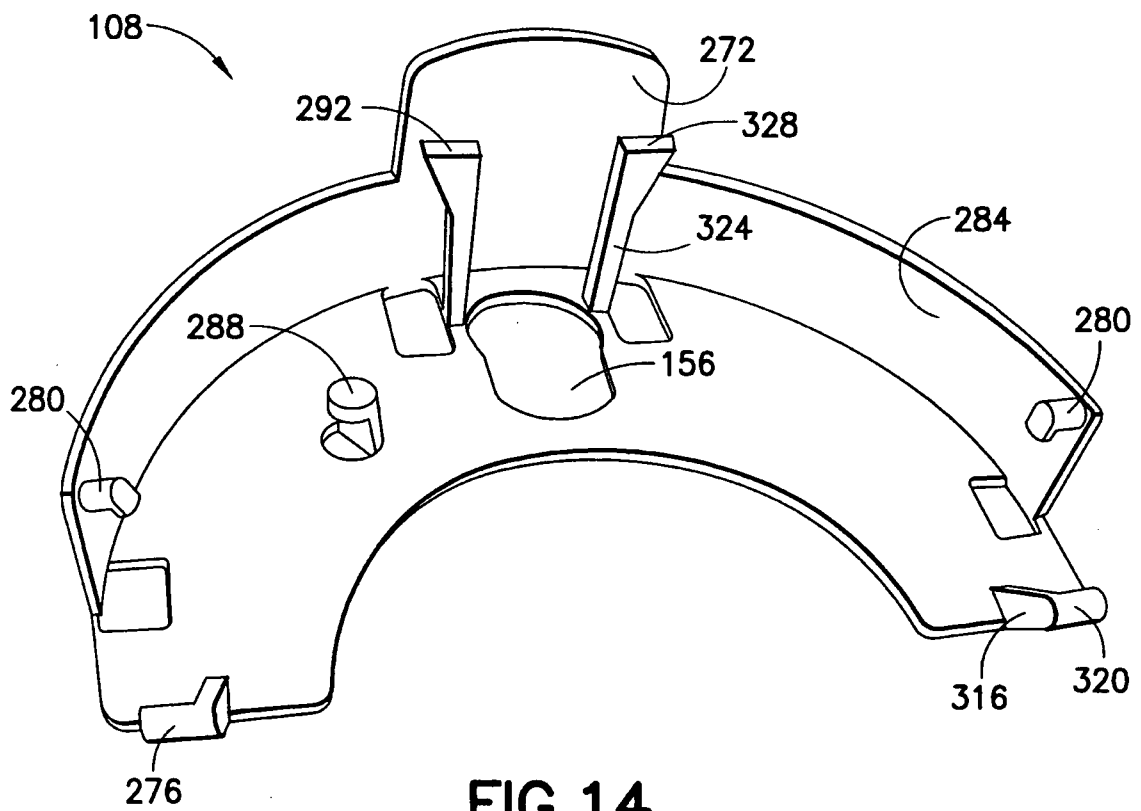
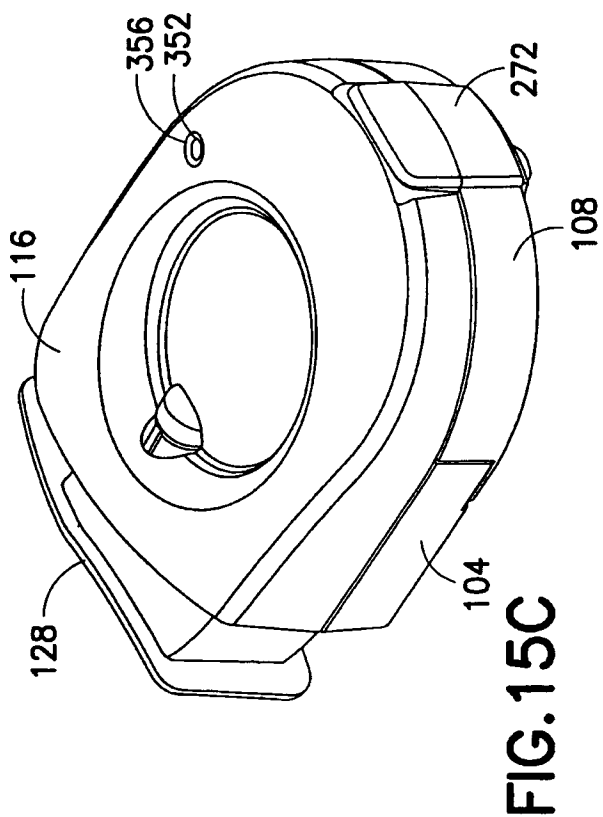
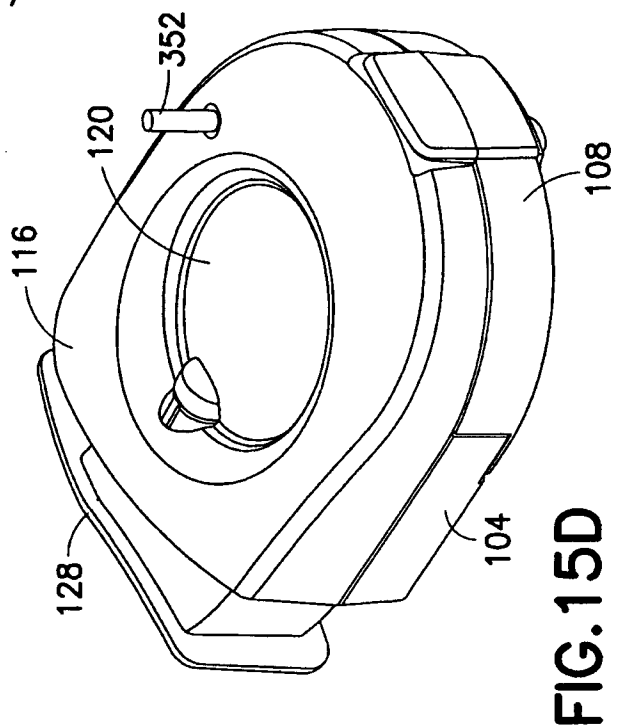
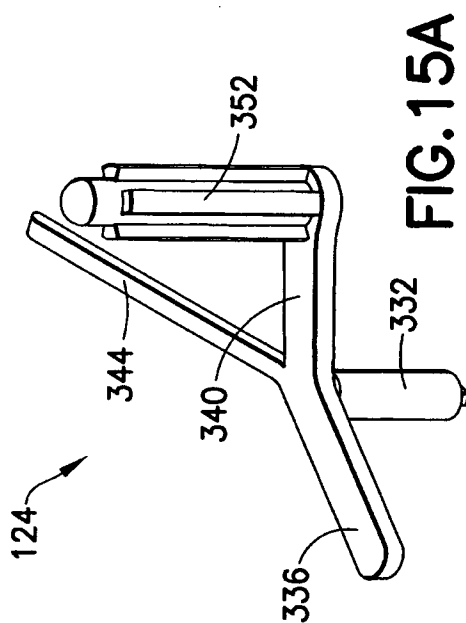
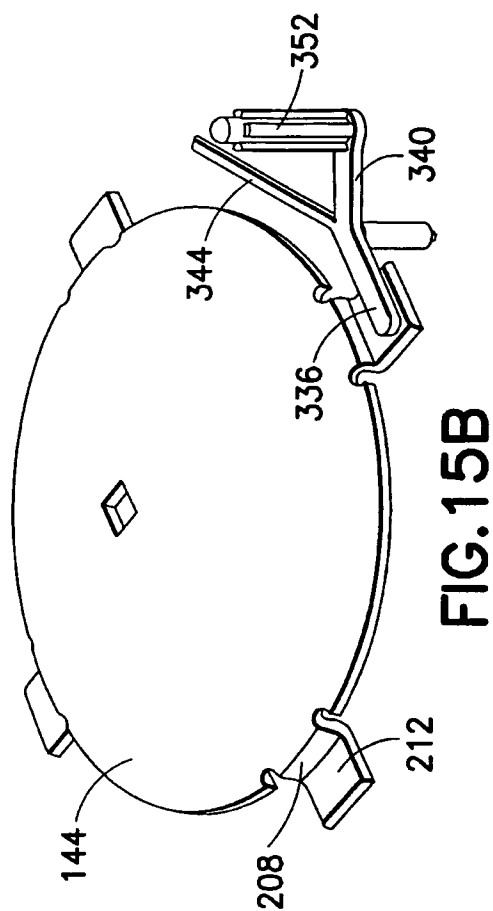


FIG. 14

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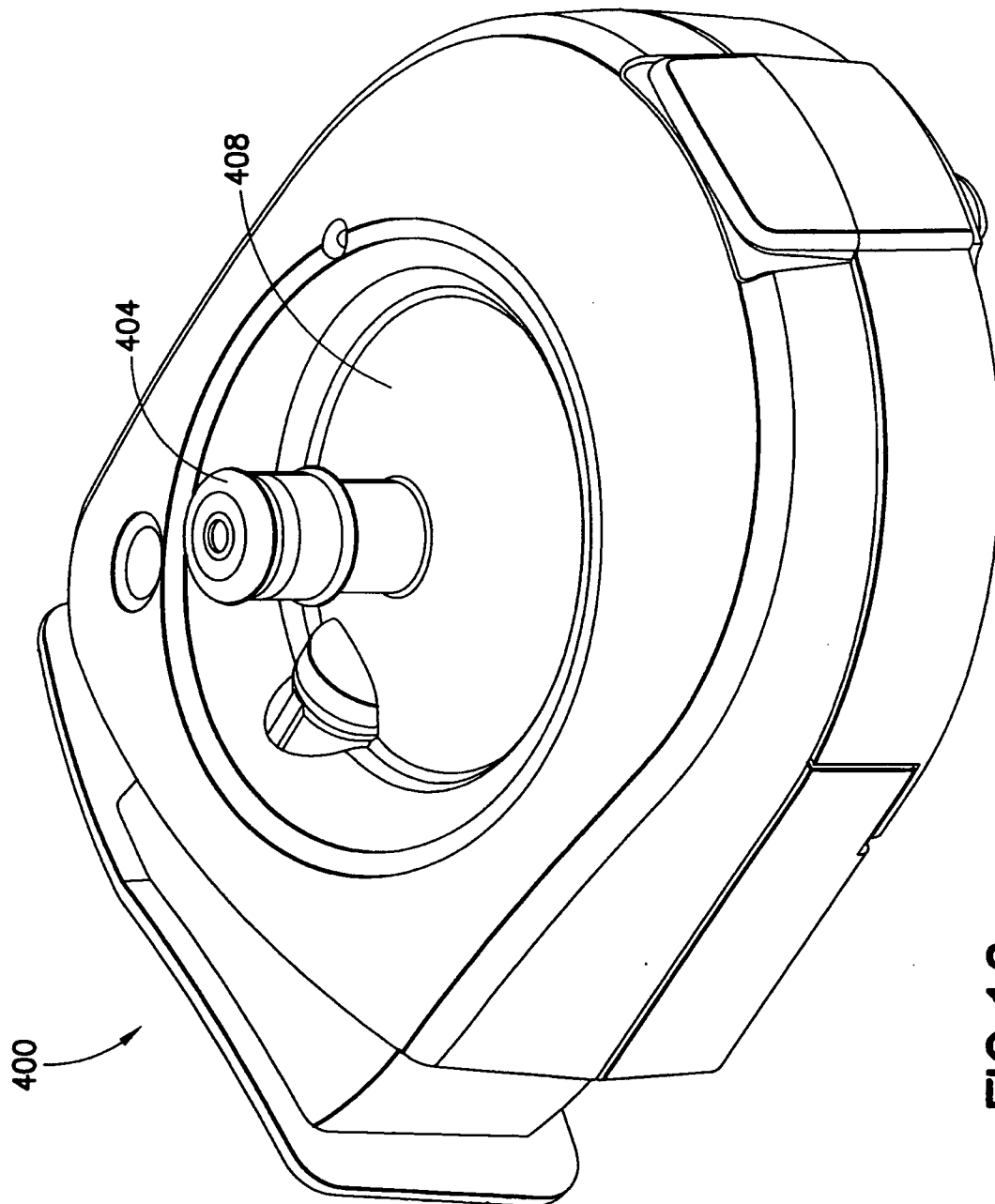


FIG. 16

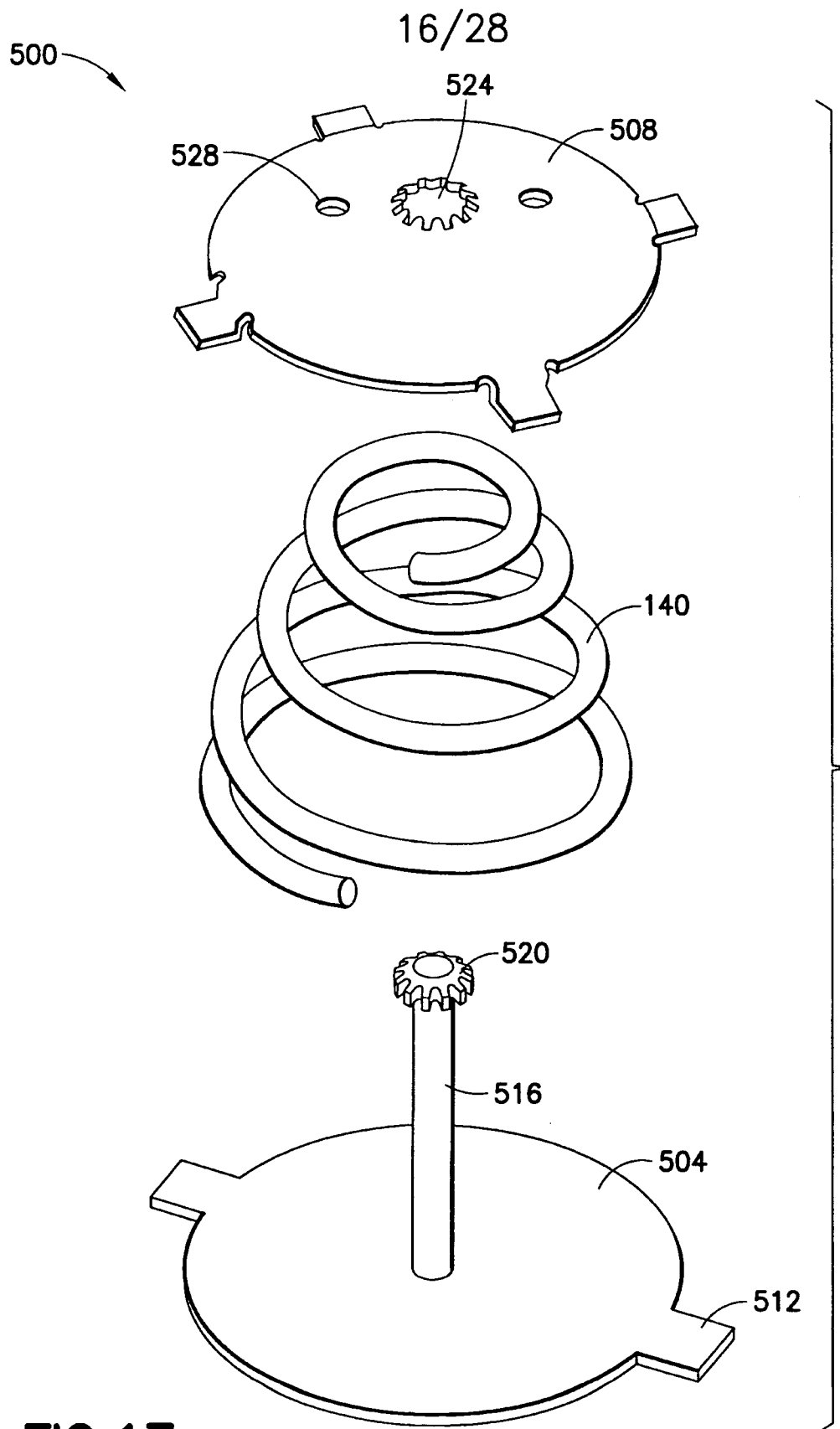


FIG.17

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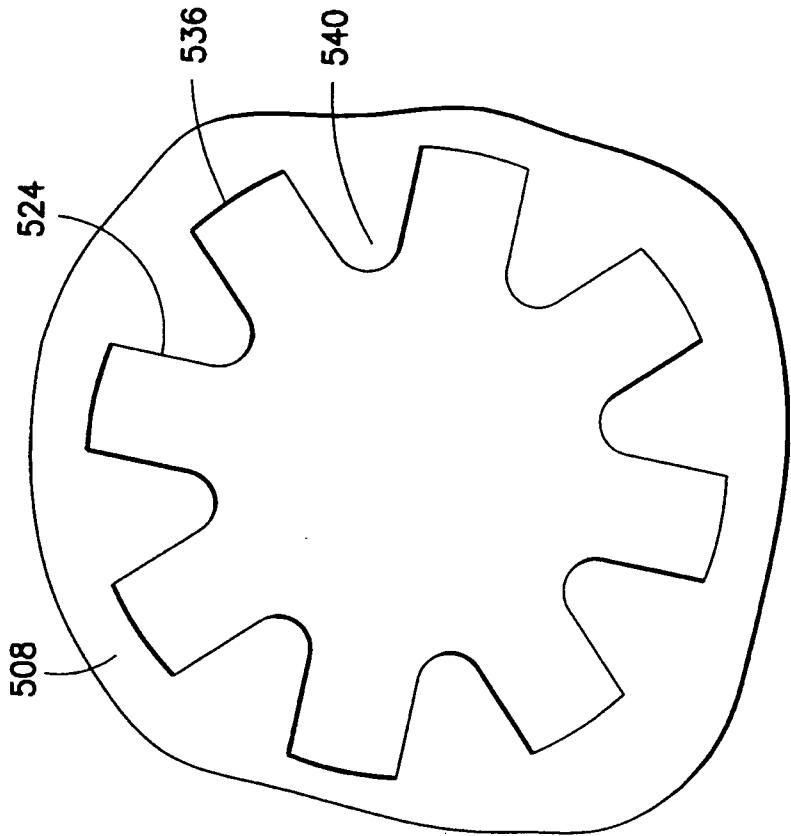


FIG. 18B

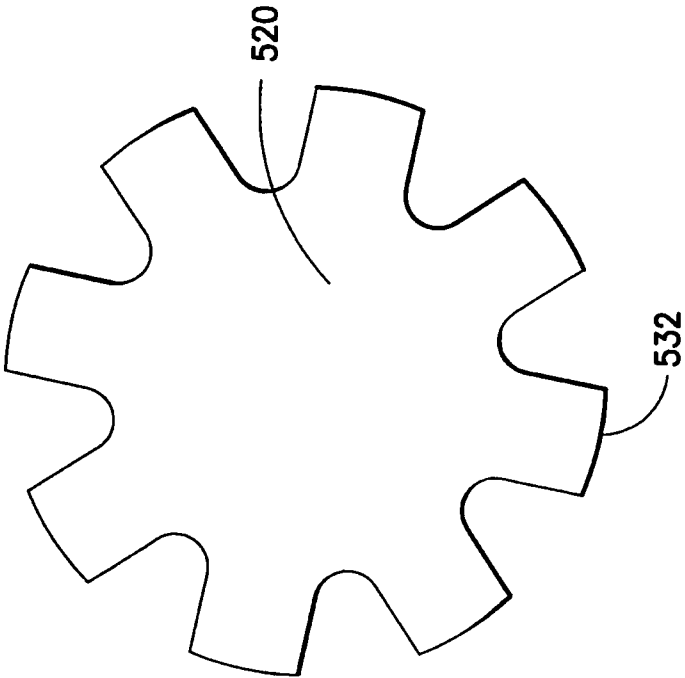


FIG. 18A

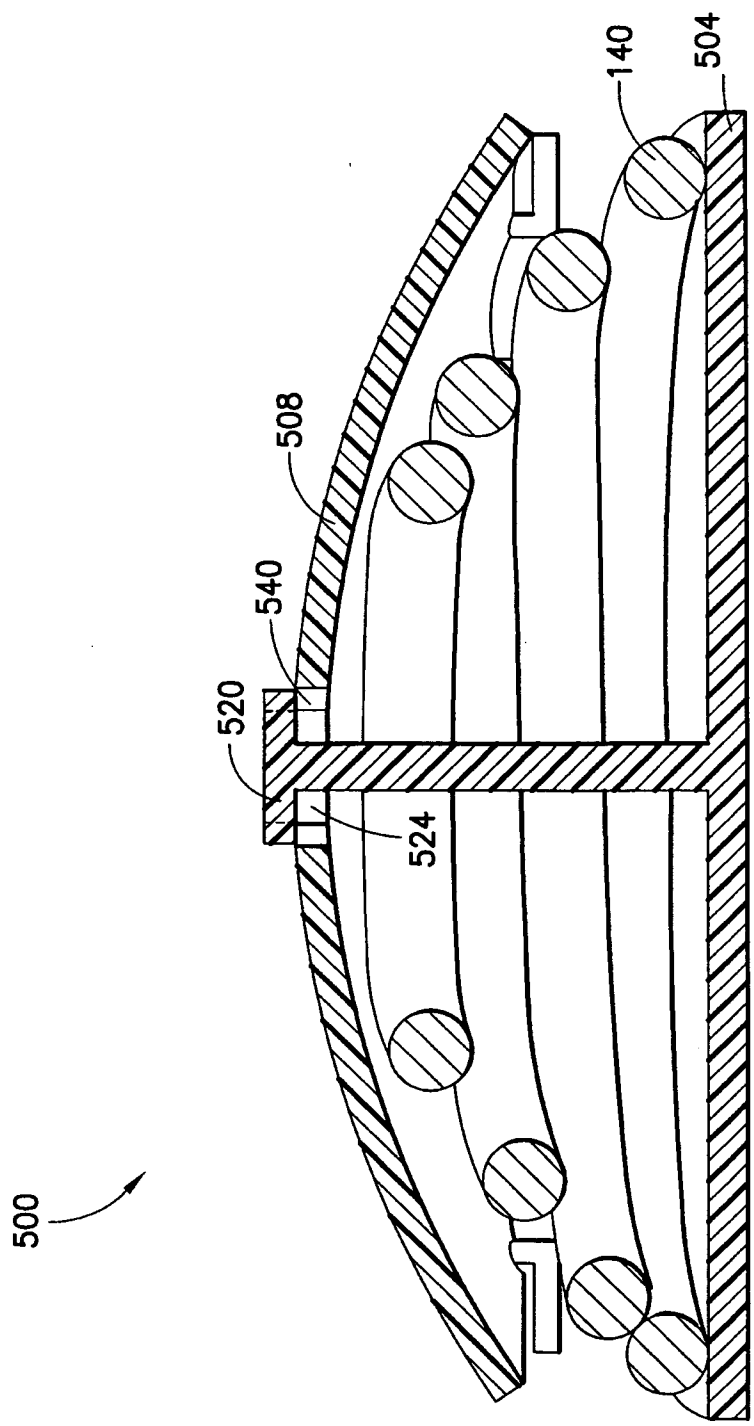


FIG.19

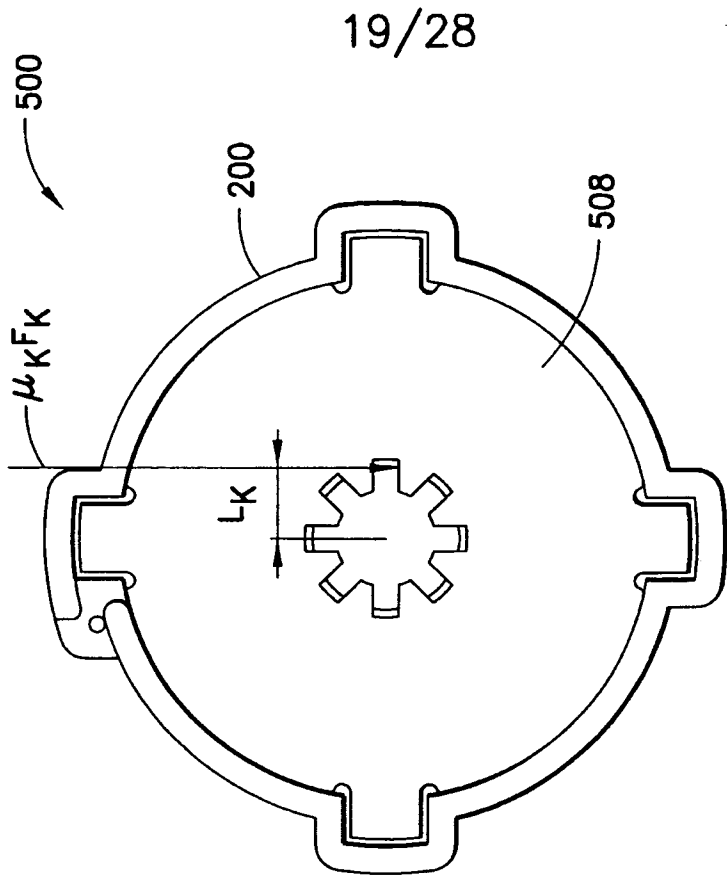


FIG. 20B

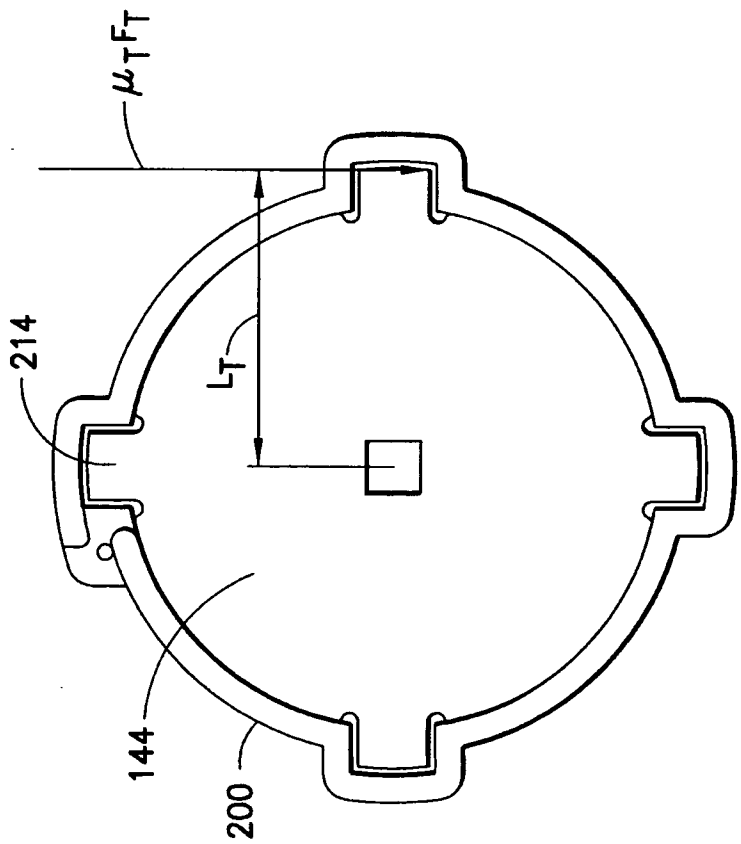


FIG. 20A

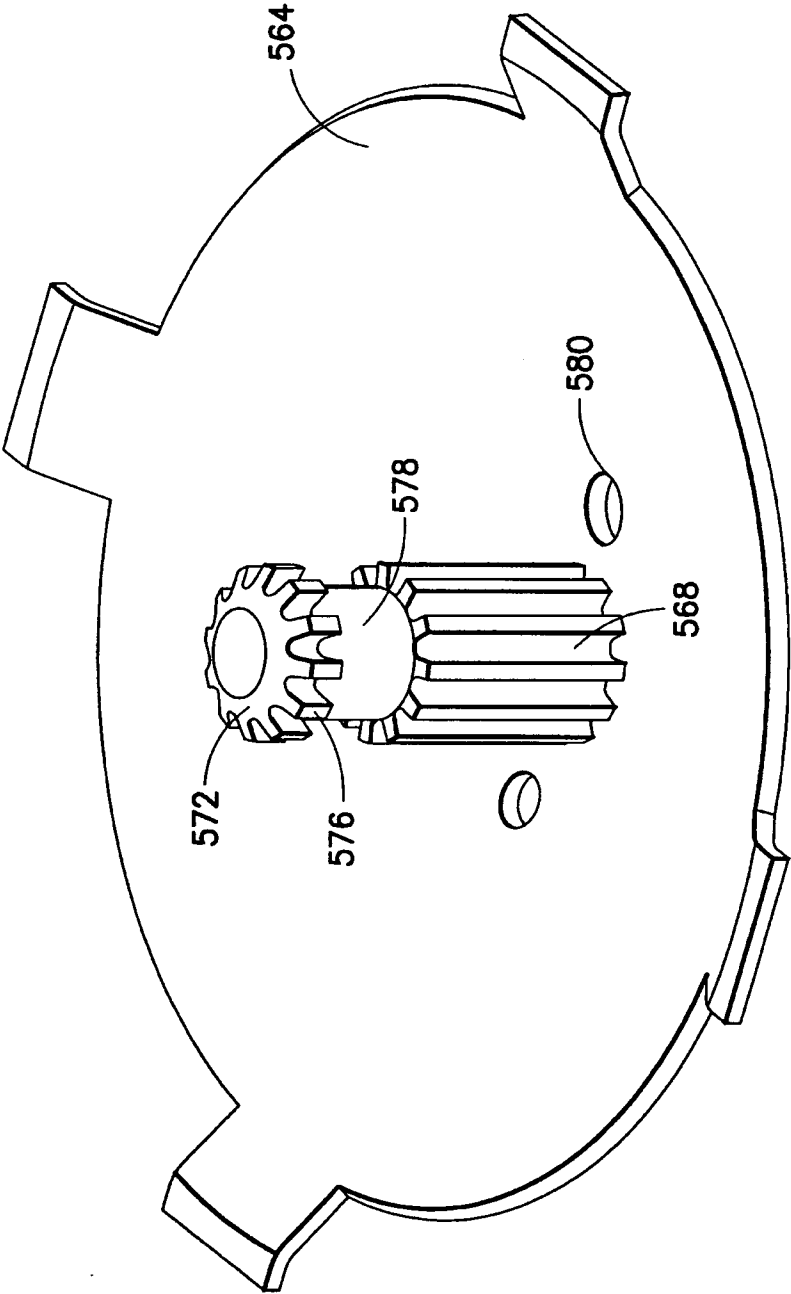


FIG. 21

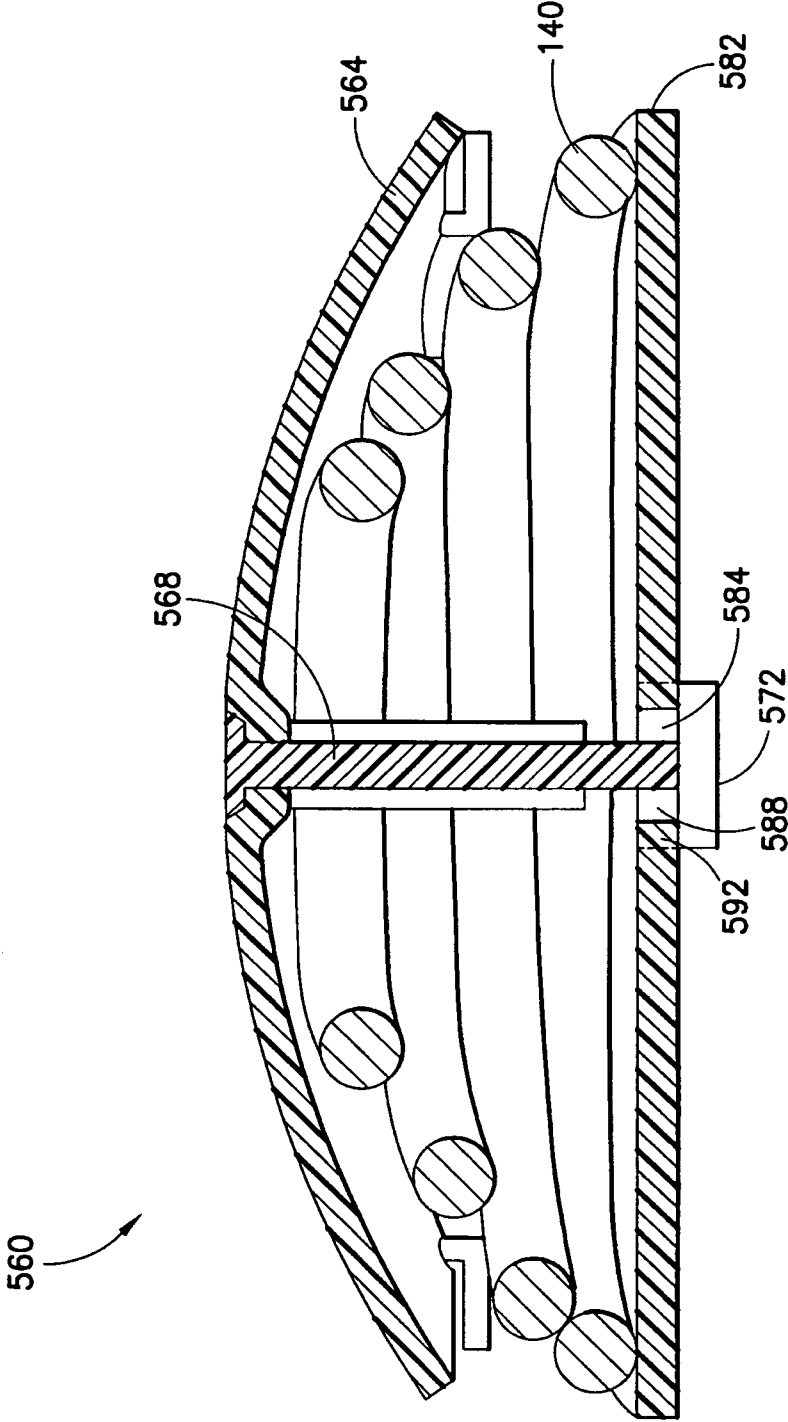


FIG. 22

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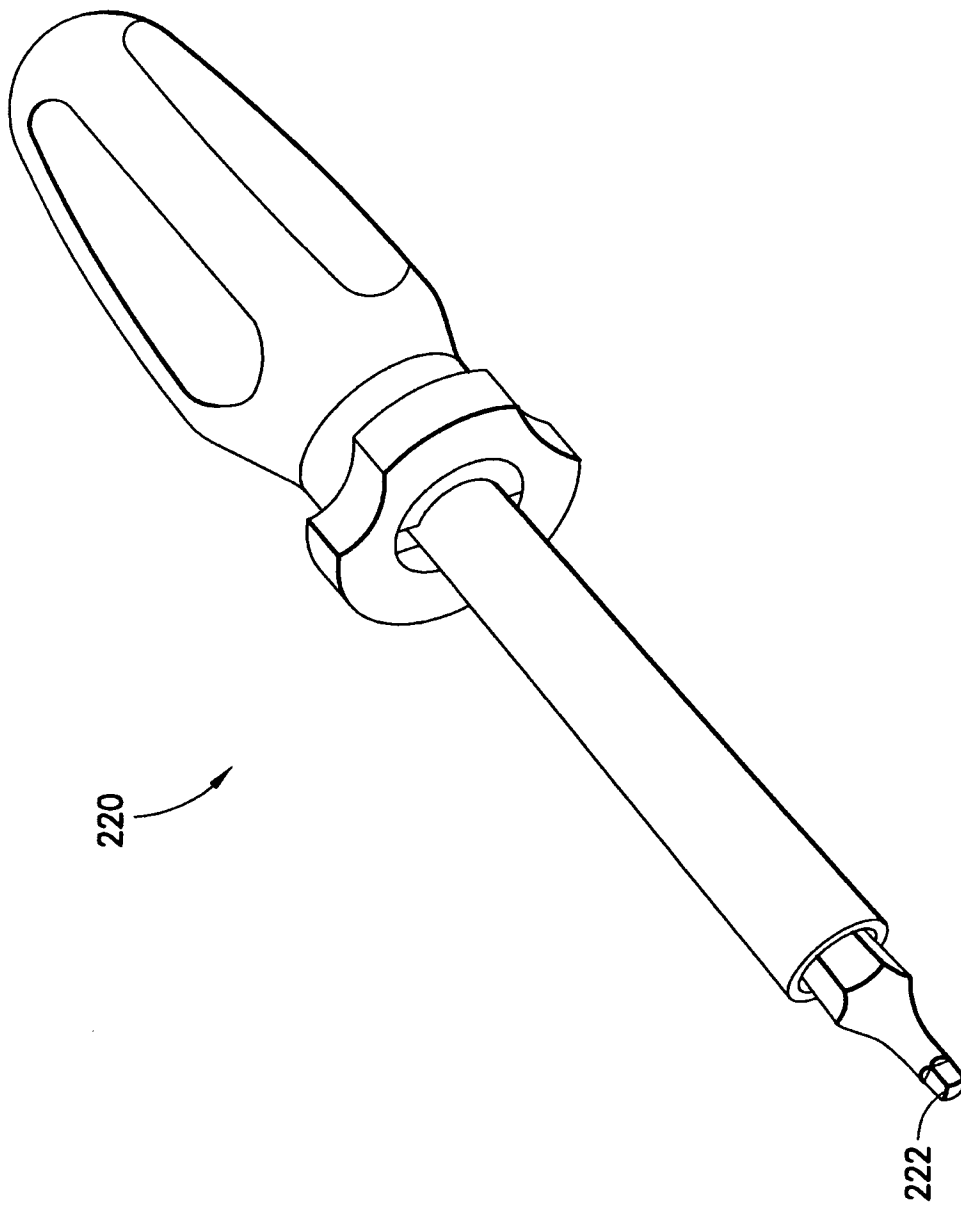


FIG. 23A

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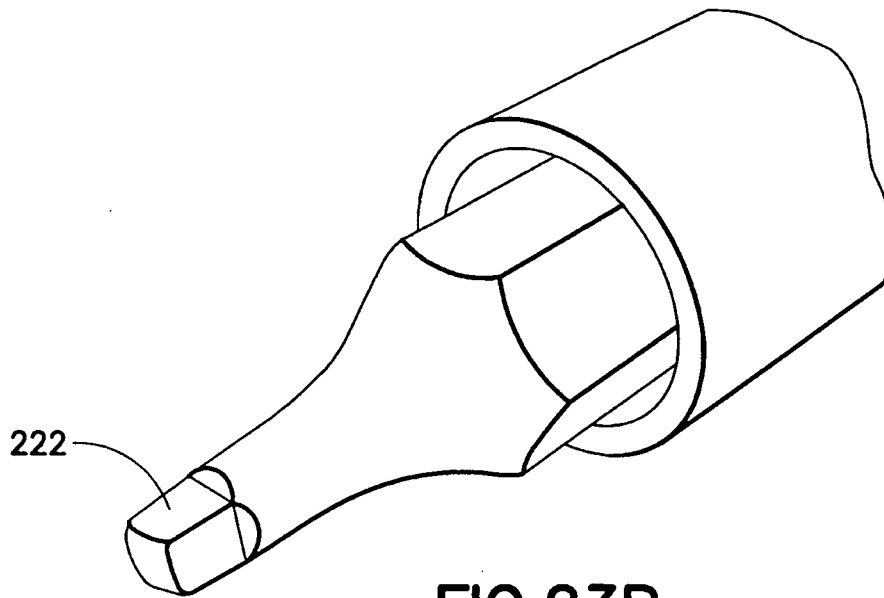


FIG. 23B

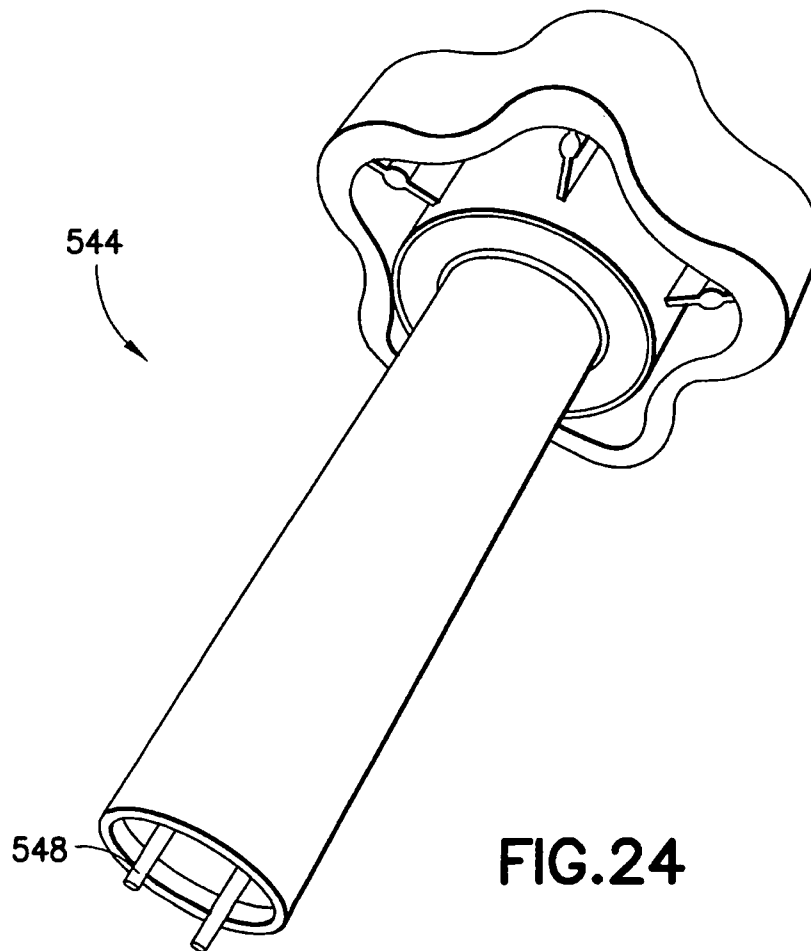


FIG. 24

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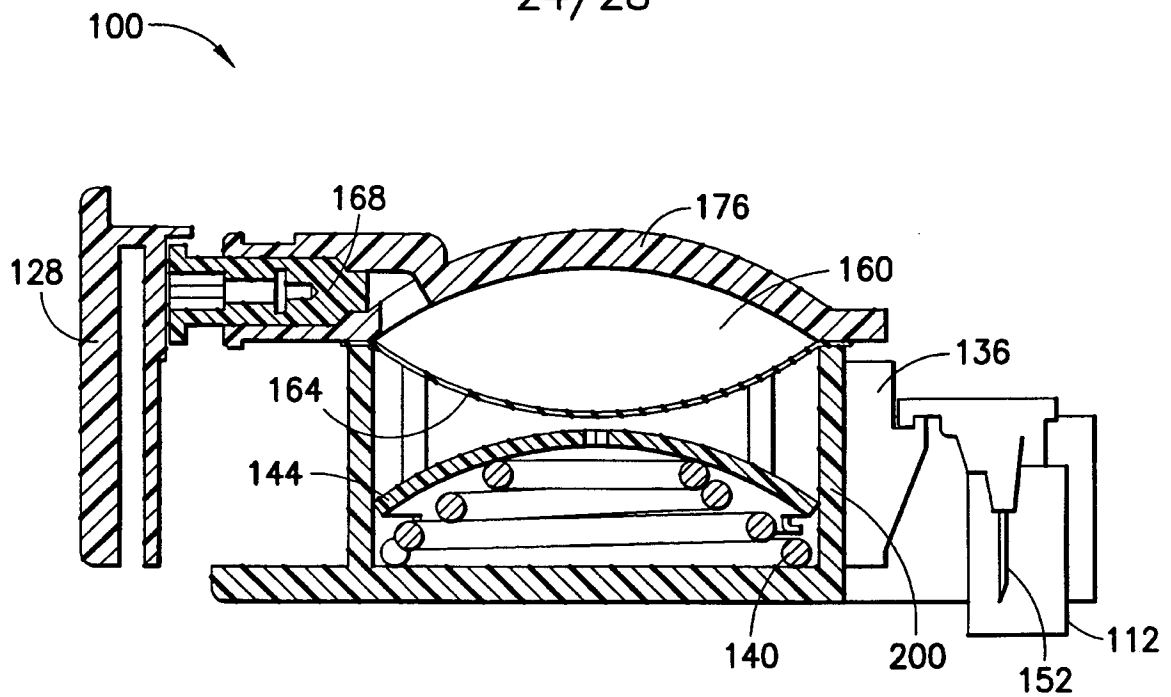


FIG. 25

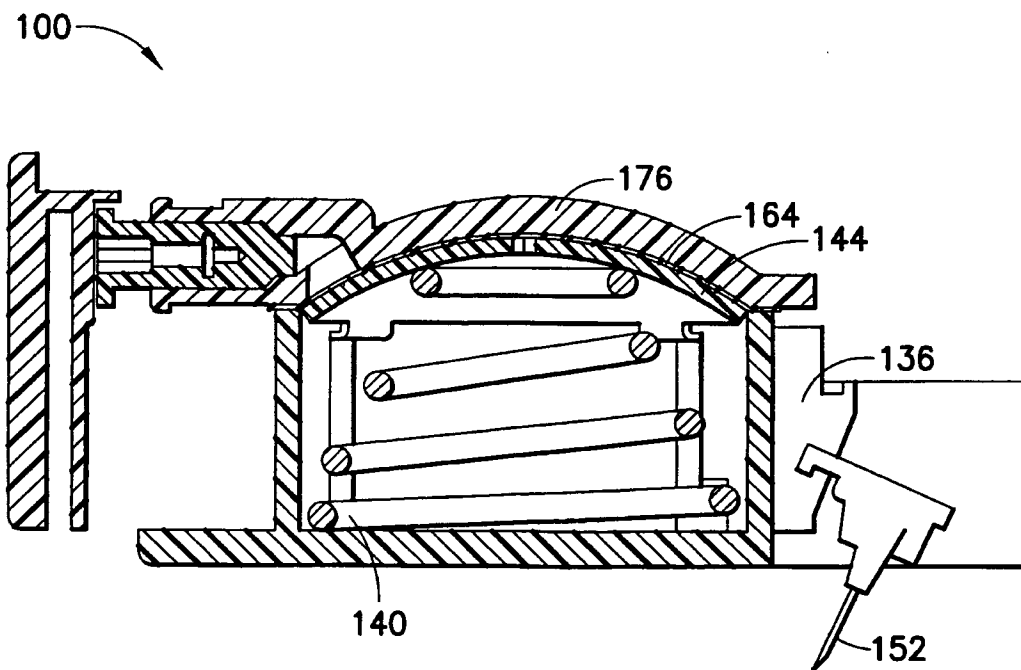


FIG. 26

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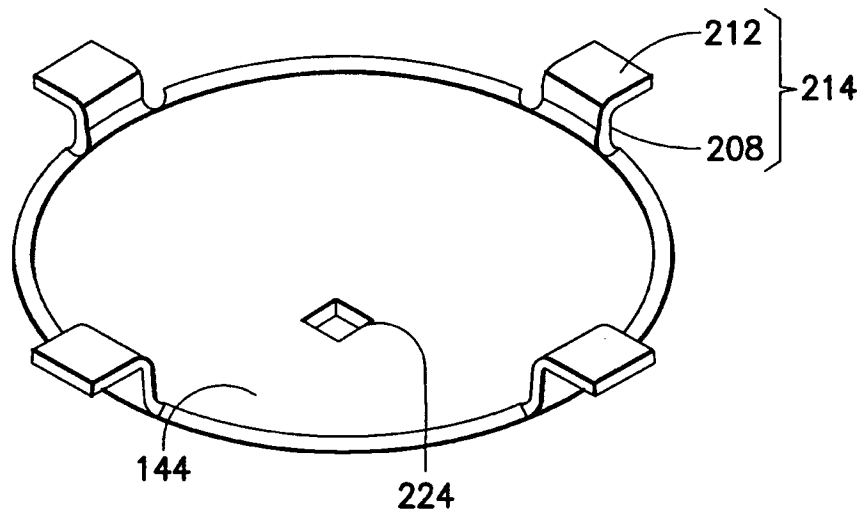


FIG. 27

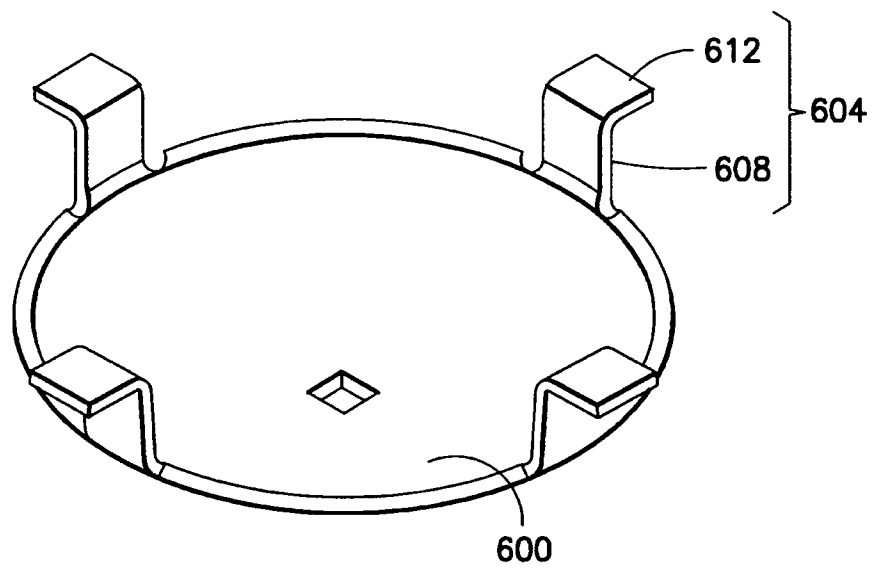


FIG. 28

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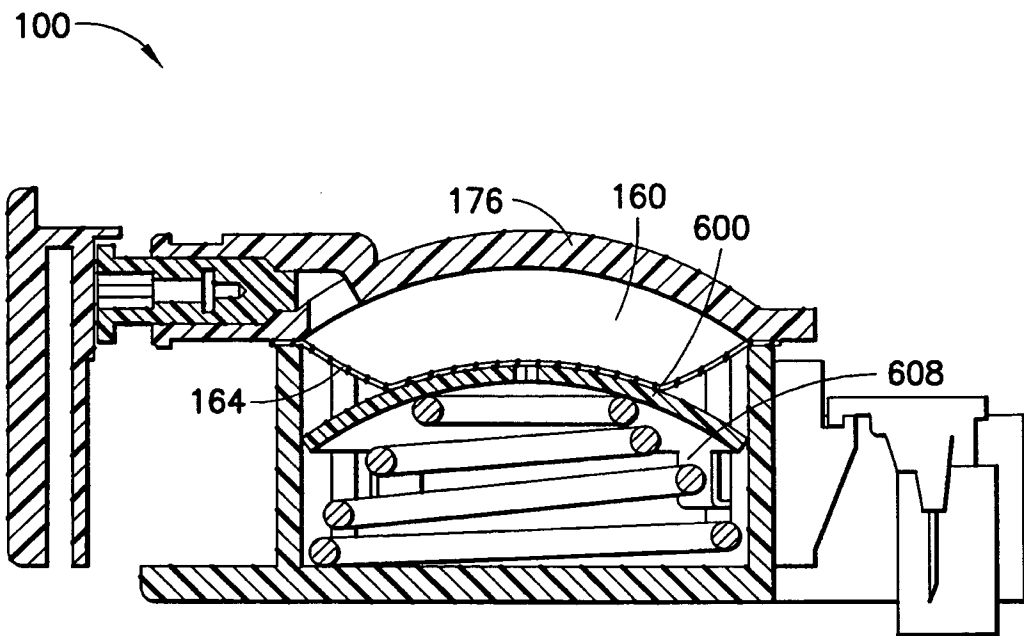


FIG. 29

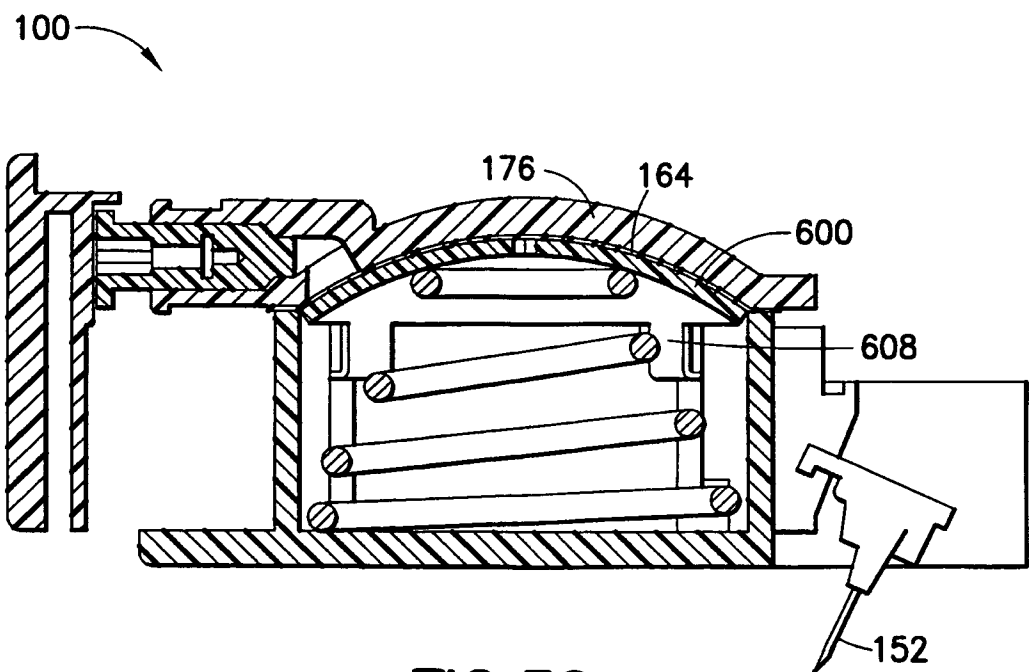


FIG. 30

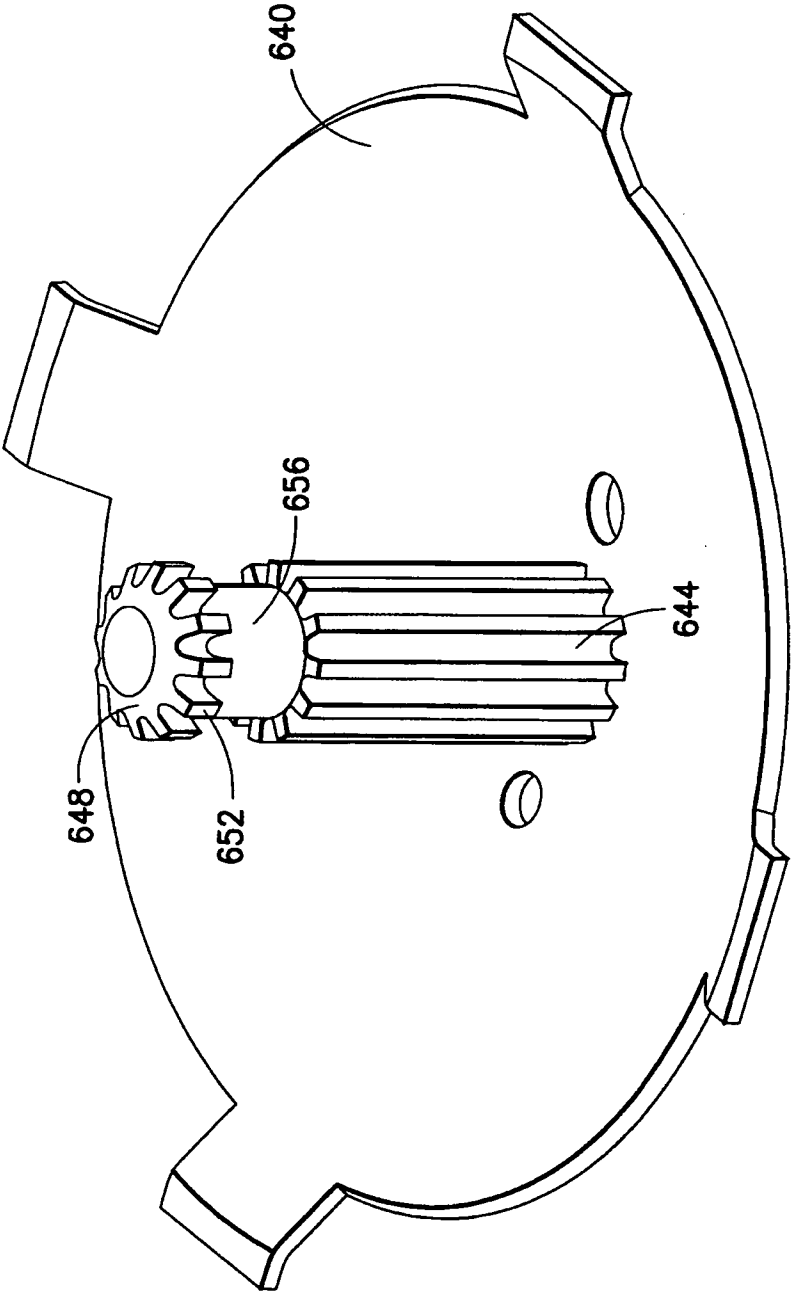


FIG. 31

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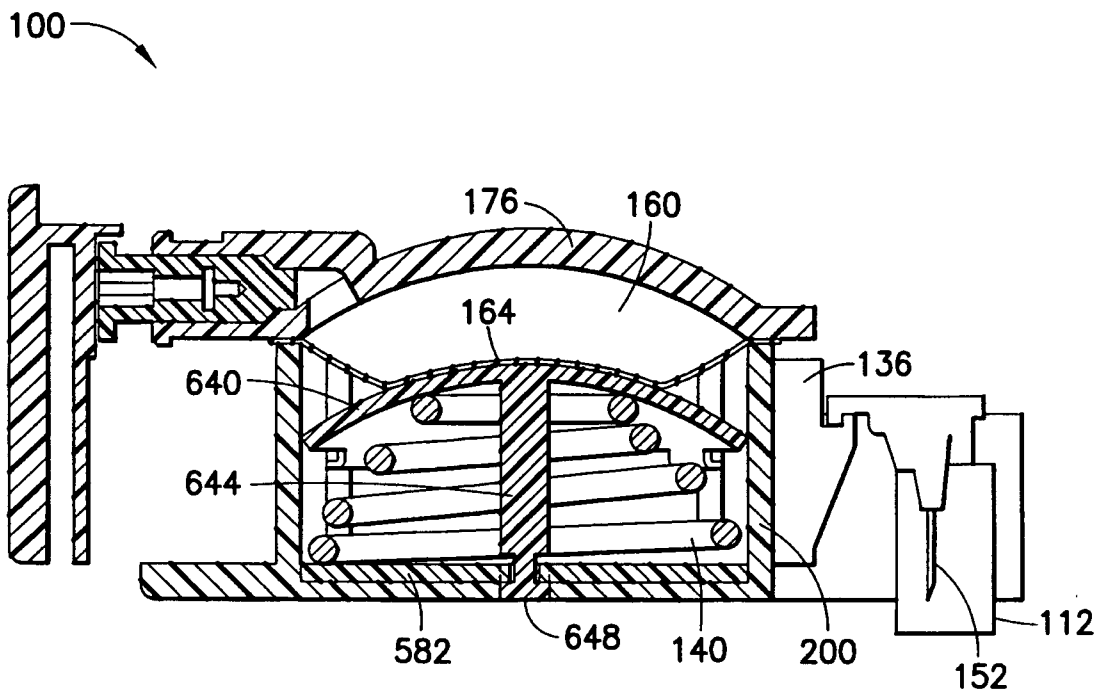


FIG. 32

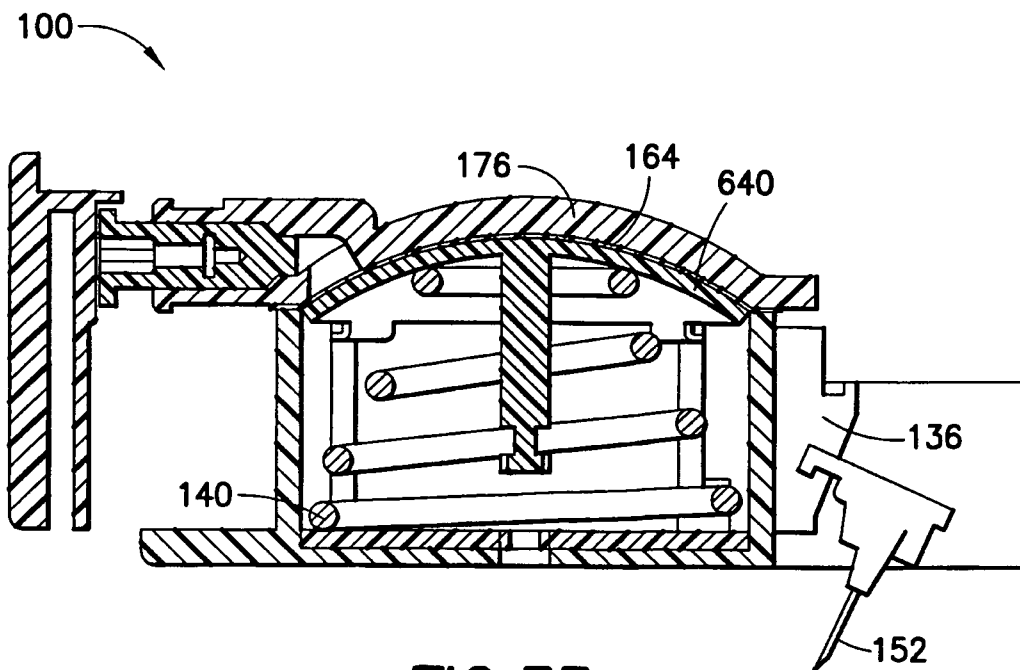


FIG. 33

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 09/06572

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61M 5/315 (2010.01)

USPC - 604/218

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)

USPC: 604/218

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

USPC: 604/257, 263, 219-240, 117, 187

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO, PUBWEST (PGPB, USPT, USOC, EPAB, JPAB), Google

Search Terms Used: reservoir, spring, drug, medication, press, compress, inject, infuse, deliver, sprocket, needle, device, drug, container,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008/0215015 A1 (Cindrich et al.) 4 September 2008 (04.09.2008), para [0172]-[0175], [0204]-[0207], Fig 1-4, 29-32	1-35
Y	US 2006/0122562 A1 (Needle et al.) 8 June 2006 (08.06.2006), para [0091]-[0099], [0103]; Figs 4a-4e, 8a, 10a, 10b	1-35
Y	US 2007/0156094 A1 (Safabash et al.) 5 July 2007 (05.07.2007), para [0080]-[0083], Fig 8-14	9-18, 23-27, 33-35
A	US 2008/0051730 A1 (Bikovsky) 28 February 2008 (23.02.2008), entire document	1-35
A	US 4,610,672 A (Ewalt et al.) 9 September 1986 (09.09.1986), entire document	1-35

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

27 January 2010 (27.01.2010)

Date of mailing of the international search report

10 MAR 2010

Name and mailing address of the ISA/US

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