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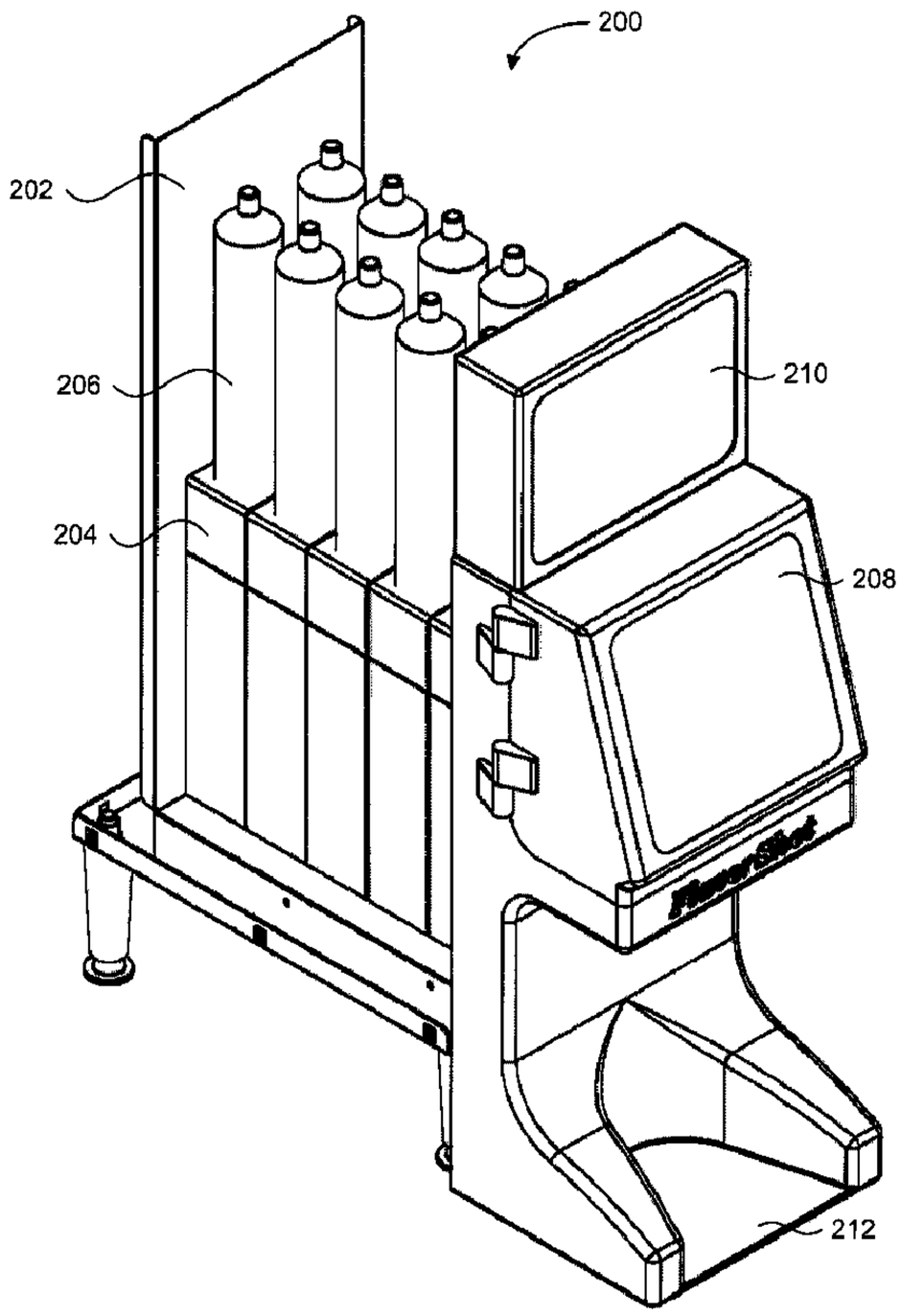
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(54) Title: CARTRIDGE BASED FLUID DISPENSING APPARATUS



(57) Abrégé/Abstract:
A concentrated flavour dispensing machine having displacement pumps for delivering between a fraction of a millilitre and a few ounces of fluids having a viscosity value between 1 to 4000 centepoise is described. The dispensing machine includes a cabinet

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(57) Abrégé(suite)/Abstract(continued):
for containing a multitude of displacement pumps, where each displacement pump is realisably connected to a disposable pre-filled fluid cartridge. Each displacement pump includes a stepper motor in engagement with a threaded drive rod that is advanced or retracted by any one of several predetermined distances. The drive rod impels a plunger positioned within the disposable cartridge to dispense a volume of fluid. Flexible capillary tubes connected to the output of each disposable cartridge direct the fluid to a central dispensing area. The disposable cartridge includes an expandable plunger which draws fluid back into the cartridge when the drive rod is withdrawn after a dispense operation for drip prevention.

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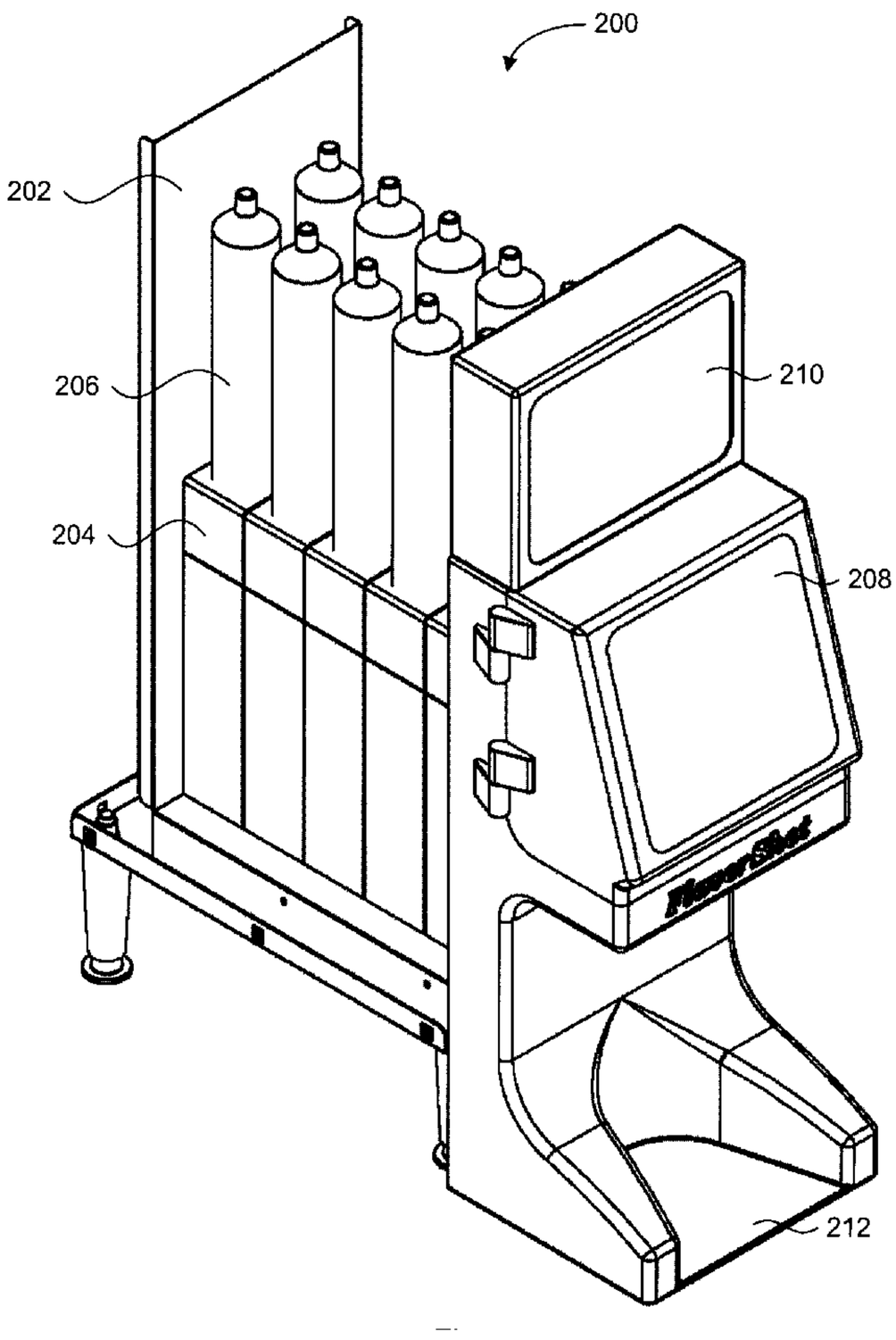
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(54) Title: CARTRIDGE BASED FLUID DISPENSING APPARATUS



(57) Abstract: A concentrated flavour dispensing machine having displacement pumps for delivering between a fraction of a millilitre and a few ounces of fluids having a viscosity value between 1 to 4000 centepoise is described. The dispensing machine includes a cabinet for containing a multitude of displacement pumps, where each displacement pump is realisably connected to a disposable pre-filled fluid cartridge. Each displacement pump includes a stepper motor in engagement with a threaded drive rod that is advanced or retracted by any one of several predetermined distances. The drive rod impels a plunger positioned within the disposable cartridge to dispense a volume of fluid. Flexible capillary tubes connected to the output of each disposable cartridge direct the fluid to a central dispensing area. The disposable cartridge includes an expandable plunger which draws fluid back into the cartridge when the drive rod is withdrawn after a dispense operation for drip prevention.

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CARTRIDGE BASED FLUID DISPENSING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority of U.S. Provisional Patent Application No. 60/824,938, filed on September 8, 2006.

FIELD OF THE INVENTION

The present invention relates generally to liquid dispensing machines. More particularly, the present invention relates to liquid dispensing machines capable of dispensing small and accurate amounts of concentrated liquids.

BACKGROUND OF THE INVENTION

Many coffee shops and convenience stores serve an array of coffee products, from mild to strong coffees brewed from coffee beans grown in different areas of the world, each imparting a particular flavour and aroma. Due to the limited counter space available in these stores, only a small selection of coffees are served each day, as coffee pots, heat plates and coffee bean grinders occupy a significant portion of the counter space. This selection can include strong, mild or medium roast coffees brewed from a variety of coffee beans.

In addition to these "standard" coffees, a selection of flavoured coffees are also served. Examples of such flavours include amaretto almond, French Vanilla and Irish cream. One method of providing flavoured coffees is to obtain flavoured coffee beans with the flavouring infused into the beans, and grinding them for brewing a pot of the flavoured coffee. Another method is to use pre-packaged, ground flavoured coffee. A third method is to stock a selection of flavour syrups that can be directly added to any regular cup of coffee by the server. This technique provides more flexibility since the flavour can be added to any standard coffee.

However, because separate grinders are required for grinding standard coffee beans and flavoured coffee beans to ensure that the standard coffee bean grinders are free from

contamination from flavoured grounds, valuable counter space is taken up and additional cost is incurred by the extra grinder. Furthermore, flavoured coffees tend to stew in their pots for a relatively long period of time since they may not be as popular as the non-flavoured coffees. Those of skill in the art are well aware that coffee left standing on a heat plate for too long is unpalatable due to poor taste. Therefore, additional cost is incurred, as unsold flavoured coffee must be thrown out in favour of freshly brewed flavoured coffee. Although use of pre-packaged flavoured coffee obviates the need for an additional grinder, the problem with limited counter space and aged coffee persists. Furthermore, the consumer perception that pre-packaged coffee cannot be as fresh as freshly ground coffee tends to curb consumers from purchasing pre-packaged, flavoured coffee.

Bottles of flavoured liquids, or syrups, are easily stored upon shelves and countertops, and a wide selection of flavours can be made available to the consumer. Unfortunately, consistency of flavour between different servings is difficult to achieve because the dose of syrup added to each cup of coffee is subject to human error. Furthermore, the optimal dose of syrup changes for different sized cups of coffee, and for different types of beverages (cappuccino, lattes, tea etc) to ensure that the flavouring is not over-powering or insufficient for the base beverage. Consistent dosing is further complicated when several flavours are added to the same beverage, as different flavours can overpower others. For example, mint flavouring can easily overpower a vanilla flavouring of the same quantity. Hence, consistent and accurate dosing of flavourings cannot be achieved when a server is responsible for manually preparing a flavoured beverage.

Another factor for consideration is the concentrated flavouring itself. Manufacturers and retailers prefer to use concentrated flavouring with minimal carrier, as the carrier can affect the flavouring and taste of the flavoured beverage, and the additional volume contributed by the carrier increases shipping costs of the flavouring. Thus, the highly concentrated flavouring to be added can be in the order of several millilitres, depending on the type and size of beverage. Due to the highly concentrated nature of the concentrated

flavouring, accuracy of the dispense becomes critical since the absence or addition of a fraction of a millilitre can significantly affect the taste of the beverage.

Known dispensing machines include simple gravity fed valves, peristaltic pumps, pressurized systems and displacement pumps, for dispensing fluids. However, none of these types of machines are suitable for dispensing the very small volumes of concentrated flavouring fluid desired by the industry. Primarily, these types of machines are not suitable for dispensing small quantities of fluids of varying viscosity, particularly high viscosity syrups having centepoise values of close to 4000.

One novel dispensing system is disclosed in commonly owned United States Patent Application No. 10/830,033, filed on April 23, 2004. The dispensing system includes a cabinet for containing a multitude of displacement pumps, where each displacement pump is in direct fluid communication with a respective storage tank, and a control panel having a programmable microprocessor mounted to the cabinet for receiving user selections and controlling each individual pump. Each displacement pump includes a stepper motor in engagement with a threaded drive rod for advancing a piston by any one of several predetermined distances to dispense a corresponding volume of fluid. The control panel receives a valid user selection for actuating one or more pumps to dispense the appropriate volume of a concentrated flavouring fluid. The microprocessor tracks the amount of fluid dispensed from each storage tank and alerts users and/or prevents further operation when reservoirs are close to empty to avoid null dispenses to customers.

Various maintenance routines can be executed through the user interface, and dispense volumes and combination dispenses can be re-programmed manually or automatically. Following is a description of the general components of this dispensing system, originally described in United States Patent Application No. 10/830,033.

The dispensing system of Figure 1 is intended to be a commercial dispenser, for use in fast food restaurants, or similar retail environments. Figure 1 is an isometric view of dispensing machine **100**, with an array of pump assemblies positioned within cabinet **102,**

having a door panel **104**. As shown in Figure 1, there are flexible tubes located between nozzle cap **106** and each displacement pump.

Figure 2 is a side view of one pump assembly **110** used in the system of Figure 1 to illustrate the configuration of the displacement pump **112** and its corresponding storage tank **114**. Storage tank **114** can be constructed of molded plastic material, metal, or any suitable liquid impermeable material, for storing concentrated flavouring fluid. The storage tank is preferably constructed of a rigid material. The tank is filled by removing tank cap **116** and pouring concentrated flavouring fluid into the open aperture (not shown). The stored concentrated flavouring fluid is provided to displacement pump **112** through a short tank nozzle in fluid communication with the storage tank **114** that extends from the bottom of storage tank **114** and into a check valve retainer **118**. The short tank nozzle is preferably constructed of the same material as the storage tank **114**, and preferably provided in the same die mold as the storage tank **114**. Tank cap **116** preferably includes an O-ring and a one way check valve to allow entry of air into the volume of the storage tank **114** as concentrated fluid is drawn, but prevents vapours from escaping and potentially contaminating flavours stored in the other storage tanks **114**.

Figure 3 shows components of displacement pump **112**, and in particular, details of the piston **130** and threaded drive rod **132**. Piston **130** is fixed to a piston seal **134** made of Santoprene™ a type of thermoplastic elastomer available from Advanced Elastomer Systems or tetrafluoroethylene available from Dupont, where the piston seal **134** is dimensioned to sealingly engage the inner surface of cylinder tube chamber **136**. Piston seal **134** has a wide contact edge, preferably a width to provide structural/mechanical stability of the edge under load. In the present embodiments, the width of piston seal **134** can be between 2 to 3.5mm. However, the selection of the width can be based on the desired sealing surface, frictional wear, and force required to drive the piston seal **134**. In contrast, a narrow contact edge can bow as the piston seal **134** is advanced, resulting in potential leakage of fluid into the space behind the piston seal **134**. Due to the small volumes of fluid to be dispensed, small amounts of leakage can contribute to inaccurate dispenses. In addition to inaccurate dispenses, the

aromatic impact of the leaked fluid is undesired, and reliability of the displacement pump may be affected. More specifically, the leaked fluid can come into contact with threaded drive rod **132**, rod guide **138** and guide tube **140**, which can affect their operation. Unfortunately, rebuild or replacement of the displacement pump is required for correcting this problem. Therefore, the relatively wide contact edge is selected to prevent any bowing of the contact edge during operation, and potential leakage of fluid from cylinder tube chamber **136**.

An end of threaded drive rod **132** is fixed to a recess in piston **130** via spring pin **142** that extends through the walls of piston **130** and threaded drive rod **132**. Also fixed to threaded drive rod **132** is a rod guide **138**. Rod guide **138** slips over threaded drive rod **132** and is fixed by spring pin **144** which extends through the walls of rod guide **138** and threaded drive rod **132**. The rod guide **138** is fixed to threaded drive rod **132** at a position such that it only travels within guide tube **140**.

Additional components of displacement pump **112** include O-rings, such as O-ring **146** for sealing the interface between one way check valve **148** within cylinder front flange **150**, check valve retainer **151**, gasket face seal **152** for sealing the interface between cylinder tube chamber **136** and cylinder front flange **150**, and nuts **154** and **156** for tightening threaded rods **158** and holding the displacement pump components together in a torqued compression, and a cylinder rear flange **157**. Cylinder front flange **150** includes a passage for receiving check valve nozzle **159**, for receiving a capillary tube.

Stepper motor **160** is a commercially available product having a face that mates with guide tube flange **162**. Those of skill in the art will understand that stepper motor **160** includes a stator and a rotor that engages, rotates threaded drive rod **132** in a worm gear relationship to translate rotational movement of the rotor into linear motion of the threaded drive rod **132**. Therefore, the threaded drive rod **132** is advanced or withdrawn depending on the clockwise or counter-clockwise rotation of the rotor. Stepper motor operation is well known to persons of skill in the art. Generally, the stepper motor rotates by predetermined step sizes in response to electrical input signals. Hence, the travel distance of a drive rod having a known thread pattern can easily be determined and controlled.

The aforementioned dispenser is typically operated and maintained by trained personnel, typically staff of a restaurant or service counter. While operation of the dispenser is straightforward, maintenance of the dispenser can be cumbersome. In particular, when the storage tank **114** runs empty, the user will need to pull out the displacement pump **112** containing the empty storage tank, and re-fill the tank from another container. Preferably, this is done without spillage during the transfer, which may be difficult during peak service periods when the re-fill must be done rapidly. Of course, any spillage should be cleaned up for hygiene purposes. Furthermore, the user may initiate pre-programmed clean and prime operations for the dispensing unit if a different flavouring is to be used for a displacement pump.

The aforementioned dispenser can be used in a self-serve environment. For example, customers purchasing a beverage in a convenience store can choose to add a desired flavouring by pushing the appropriate buttons on the user interface. This is convenient for the convenience store clerk who is typically alone and does not have time to service the client. However when it comes time to refill the tank, the clerk will not have sufficient training or time to properly refill the tank, resulting in spillage that is not typically cleaned. The relative complexity of refilling the tanks of the dispenser, and/or risk of spilling concentrated fluid, may deter convenience store clerks from maintaining the machine.

It is, therefore, desirable to provide a dispensing machine that provides a simple and rapid flavour refilling system while minimizing fluid spillage during a refill operation.

SUMMARY OF THE INVENTION

It is an object of the present invention to obviate or mitigate at least one disadvantage of previous fluid dispensing systems. In particular, it is an object of the invention to provide a dispensing machine that provides a simple and rapid flavour refilling system while minimizing fluid spillage during a refill operation.

In a first aspect, the present invention provides a pump unit for dispensing a predetermined volume of fluid. The pump unit includes a stepper motor, a cartridge mount,

and a disposable cartridge. The stepper motor is in threaded engagement with a threaded drive rod, and is rotatable in one direction by a number of steps to advance the threaded drive rod. The cartridge mount is coupled to a stepper motor, and has a locking means with an aperture sized to pass the threaded drive rod. The a disposable cartridge has a first end adapted to engage the locking means for securing the disposable cartridge to the cartridge mount. The disposable cartridge has a chamber sealed with a plunger slidable in the chamber, and includes an outlet nozzle at a second end for dispensing contents of the chamber when the plunger is pushed by the threaded drive rod.

According to an embodiment of the present aspect, the plunger includes an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by a piston connected to the threaded drive rod, such that the expandable plunger top returns to a relaxed state when the piston is withdrawn from the plunger. In further embodiments, the locking means includes a bayonet style twist lock, and the first end of the disposable cartridge is adapted for engaging the bayonet style twist lock, and a capillary tube is releasably connected to the outlet nozzle. In another embodiment of the present aspect, the pump unit includes a driver card in electrical communication with the stepper motor, the driver card including a microcontroller for controlling the stepper motor in response to pump control data. The driver card can include a connector for receiving the pump control data, and the cartridge mount can include a mounting means for securing the cartridge mount to a chassis.

In a second aspect, the present invention provides a dispensing machine for providing a predetermined volume of fluid corresponding to a user selection. The dispensing machine includes a pump unit having a stepper motor, a disposable cartridge, a user interface, and a microprocessor. The stepper motor advances a threaded drive rod in response to pump control data. The disposable cartridge is releasably connected to the pump unit, and has a plunger for engaging the threaded drive rod. The user interface provides electrical selection signals in response to the user selection. The microprocessor receives the electrical selection signals and provides the pump control data corresponding to the pump unit. The pump control data includes stepper motor direction data and number of steps data.

According to an embodiment of the present aspect, the disposable cartridge includes a chamber sealed with the plunger, the plunger having an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by the threaded drive rod for dispensing the predetermined volume of fluid. The expandable plunger top returns to a relaxed state when the threaded drive rod is withdrawn from the plunger. A capillary tube is releasably connected to the outlet nozzle for directing the contents of the chamber to a dispensing area. In another embodiment, the pump unit includes a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod and the disposable cartridge being adapted for engaging the locking means. The pump unit can include a driver card in electrical communication with the stepper motor, the driver card including a controller for controlling the stepper motor in response to pump control data. The pump unit can further include an electromotive force detector for detecting a predetermined position of the threaded drive rod. In the present embodiment, the pump mount includes an interface card adapted for electrically engaging the driver card for passing the pump control data when the pump unit is secured to the pump mount.

In a third aspect, the present invention provides a method for dispensing a volume of fluid from a disposable cartridge. The method includes the steps of receiving a selection signal from a user interface for dispensing the volume of fluid; providing an alert and locking the disposable cartridge if the volume of fluid is greater than a remaining amount of fluid in the disposable cartridge; and dispensing the volume of fluid from the disposable cartridge when the remaining amount of fluid in the disposable cartridge is at least the volume of fluid. According to an embodiment of the present aspect, the step of dispensing includes advancing a threaded drive rod for pushing a plunger in the disposable cartridge, in response to the selection signal. Pushing the plunger can include deforming an expandable plunger top of the plunger, and deforming the expandable plunger top before the plunger is moved by the threaded drive rod. The step of dispensing can include withdrawing the threaded drive rod away from the plunger by a predetermined distance after the volume of fluid is dispensed for

returning the expandable plunger top to a relaxed state to draw fluid back into the disposable cartridge.

According to further embodiments of the present aspect, the step of providing an alert includes homing the threaded drive rod, and a further step of detecting an end position of the threaded drive rod. The step of detecting an end position of the threaded drive rod can include providing the alert, locking the disposable cartridge and homing the threaded drive rod.

In a fourth aspect, the present invention provides a cartridge plunger for receiving a piston. The cartridge plunger includes a hollow body and an expandable plunger top at a closed end of the hollow body. The hollow body includes an open end for receiving the piston. The expandable plunger top is located at a closed end of the hollow body and is deformable to an expanded state by the piston. The expandable plunger top returns to a relaxed state when the piston is withdrawn from the plunger by a predetermined distance. In an embodiment of the present aspect, the hollow body includes a first circular side-wall with a first diameter for defining a primary plunger chamber, and a secondary plunger chamber. The primary plunger chamber has the open end for receiving the piston and an internal shoulder at a second end for abutment with an edge of the piston. The secondary plunger chamber extends from the shoulder, and has the expandable plunger top formed therein. The expandable plunger top includes folds of resilient material.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

Fig. 1 is an illustration of a commercial dispensing machine;

Fig. 2 is a side view of a displacement pump and tank system used in the commercial dispensing machine of Figure 1;

Fig. 3 is an exploded isometric view of the displacement pump shown in Figure 2;

Fig. 4 is an illustration of a cartridge-based dispensing machine according to an embodiment of the present invention;

Fig. 5 is side view of a pump unit used in the cartridge-based dispensing machine shown in Figure 4, according to an embodiment of the present invention;

Fig. 6 is an isometric view of the pump unit shown in Figure 5 without a disposable fluid cartridge, an embodiment of the present invention;

Fig. 7 is a side view of the disposable fluid cartridge shown in Figure 5;

Fig. 8 is a top view of the disposable fluid cartridge shown in Figure 5;

Fig. 9 is an isometric view of the disposable fluid cartridge shown in Figure 5;

Fig. 10 is an isometric view of a pump mount of the cartridge-based dispensing machine shown in Figure 4 having one attached pump unit, according to an embodiment of the present invention;

Fig. 11 is an isometric view of the pump mount of Figure 10 having a plurality of attached pump units;

Fig. 12a is a side view of a pump unit installed within a pump mount showing an interface connector mating with an interface printed circuit board;

Fig. 12b is an isometric view of an alternate pump unit;

Fig. 12c is a side view of the alternate pump unit of Figure 12b;

Fig. 13 is a functional block diagram of the cartridge-based dispensing machine of Figure 4;

Fig. 14 is a flow chart illustrating operation of the dispensing machine shown in Figure 13, according to an embodiment of the present invention;

Fig. 15 is a flow chart illustrating operation of the pump driver shown in Figure 13;

Fig. 16 is an isometric view of an expandable plunger, according to an embodiment of the present invention;

Fig. 17a is a side view of the expandable plunger shown in Figure 16;

Fig. 17b is a cross-sectional view of the expandable plunger of Figure 17a taken along line A-A;

Fig. 18a is the cross-sectional view of the expandable plunger of Figure 17b with a piston prior to a dispense operation;

Fig. 18b is the cross-sectional view of the expandable plunger of Figure 17b with the piston during a dispense operation;

Fig. 19 is a cross-sectional view of an expandable plunger and piston according to another embodiment of the present invention; and,

Fig. 20 is a flow chart of a method for operating the expandable plunger of Figure 16, according to an embodiment of the present invention.

DETAILED DESCRIPTION

A cartridge-based concentrated flavour dispensing machine having pump units for delivering between a fraction of a millilitre and few ounces of fluids having a viscosity value between 1 to 4000 centepoise is described. The dispensing machine includes a cabinet for containing a multitude of pump units, where each pump unit is realisably connected to a disposable pre-filled fluid cartridge. Each pump unit includes a stepper motor in engagement with a threaded drive rod that is advanced or retracted by any one of several predetermined distances. The drive rod advances a piston positioned within the disposable cartridge to dispense a volume of fluid. The disposable cartridge operates in the same manner as a positive displacement pump. Flexible capillary tubes connected to the output of each disposable cartridge direct the fluid to a central dispensing area. When the disposable cartridge is depleted, the drive rod can be automatically retracted to facilitate disconnection and connection of disposable cartridges. An expandable plunger within the disposable cartridge will resiliently deform upon engagement by the advanced piston. After the dispensing operation, the piston is withdrawn from the expandable plunger to allow the deformed portion

of the plunger to return to a resting state, thereby withdrawing fluid from the capillary tube and preventing drippage of the fluid.

Figure 4 is an illustration of a cartridge-based fluid dispensing apparatus according to an embodiment of the invention. Dispensing machine **200** includes a chassis **202** for storing pump units **204** attached to their respective disposable fluid cartridges **206**. A pump mount (not shown) can hold up to ten pump units. Side and top panels (not shown) have been removed from the dispensing machine **200** to illustrate the orientation of the pump units **204** and fluid cartridges **206**. A user interface panel **208** having buttons and a display allows a user to make a selection, while providing feedback to the user in the form of messages. A backlit advertising display panel **210** is provided, and a cup locator **212** is formed at the base of dispensing machine **200** to guide and position a cup. While not shown in Figure 4 to simplify the drawing, capillary tubes are releasably connected or fixed to the output nozzle of each disposable cartridge **206**, and direct the fluid to a central dispensing area (not shown) located underneath interface panel **208**.

In the present example shown in Figure 4, the dispensing machine **200** can dispense fluids from up to ten different pumps. The volume to be dispensed can depend on several categories of variables. These categories can include the type of base beverage, the size of the beverage, and modifier of the beverage. Within each variable category, there can be any number of choices.

Figure 5 is an illustration of one pump unit **204** with an attached disposable fluid cartridge **206**. The pump unit **204** includes a stepper motor **230** secured within a cartridge mount **232**. The stepper motor **230** rotates to retract or advance a threaded drive rod **233**. Secured to the cartridge mount **232** is an anti rotation bracket **234** to prevent a lead screw (not shown) from turning. As those skilled in the art will understand, the lead screw should not rotate relative to the stepper motor **230**. Persons skilled in the operation of stepper motors, will understand that each pump unit **204** can be controlled to rotate the stepper motor in a first direction to advance the threaded drive rod **233** by any number of steps, and in a second direction to retract the threaded drive rod **233** by any number of steps. Anti-rotation bracket

234 can have any suitable configuration, such as the one shown in Figure 3 which uses rod guide **138** within guide tube **140**. A mounting means **235** is integrated with the cartridge mount **232** for securing the pump unit **204** to the chassis of the dispensing machine **200**. Further details of this particular feature will be discussed later. Anti-rotation bracket **234** includes mounting holes **236** for receiving screws to which an interface connector (not shown) will be secured. As will be shown later, the front face of cartridge mount **232** includes locking means for receiving and securing disposable fluid cartridge **206** to cartridge mount **232**.

Figure 6 is an isometric drawing of the pump unit **204** shown in Figure 5 without disposable fluid cartridge **206**. This drawing shows a portion of the mounting means **235**, implemented as a dove tail mount for the present embodiment. This male dove tail mount slides into a correspondingly shaped female receptacle for holding the cartridge mount **232** to the pump mount plate of the dispensing machine **200**. While a dove tail mount is used in this example, any suitably shaped mount, either male or female, can be used. A locking means **240** is integrated into the front face of cartridge mount **232**, and implemented as a bayonet style twist lock. The threaded drive rod **233** extends through cartridge mount **232** and locking means **240**. Locking means **240** is implemented as a circular shaped female cavity with three spaced apart locking tabs **242** extending towards the circle center from the periphery. Alternate embodiments can use any number of locking tabs **242**, and are not limited to the three locking tabs **242** shown in Figure 6. Although not shown, those skilled in the art will understand that tab stops can be formed underneath each locking tab **242**.

Figures 7 through 9 show drawings of disposable cartridge **206**. Disposable cartridge **206** has a cylindrical body **250** having a frustoconical top portion **252** ending with an output nozzle **253**. Releasably attachable to output nozzle **253** is nozzle cap **254** having a capillary tube **255** attached thereto. The bottom portion of disposable cartridge **206** has three helical-shaped engagement tabs **256** extending from the surface of cylindrical body **250** and being equally spaced apart. Figure 8 is top view of the disposable cartridge **206** shown in Figure 7, to illustrate the configuration of the three engagement tabs **256** formed around the base of disposable cartridge **206**. The three tabs are sized and spaced apart to fit between locking tabs

242 of the locking means **240** of the cartridge mount **232**. The present embodiment illustrates three engagement tabs **256**, but any number can be used provided they are configured to mate with the locking tabs **242**.

As those skilled in the art will understand, once the base of disposable cartridge **206** is inserted, locking is achieved by twisting the disposable cartridge **206** (ie. in a clockwise direction) such that each of the three engagement tabs **256** are frictionally wedged between the bottom of the cavity and the locking tabs **242**. Over-twisting can be prevented as tab stops would prevent the engagement tabs **256** from sliding beyond a predetermined position. Those skilled in the art will understand that the tab stops are an optional feature since the engagement tabs **256** are wedge shaped. To unlock and remove disposable cartridge **206**, ie. when it is empty, the disposable cartridge **206** is twisted in the opposite direction (ie. in a counter-clockwise direction), and pulled out. The capillary tube can be attached and removed from the output nozzle **253**. In one embodiment, the assembly including the disposable cartridge **206** and the capillary tube are removed from the system when empty, so that it may be replaced with a new disposable cartridge **206** and capillary tube. The dispensing end will have a suitable mechanism for easily securing and releasing the capillary tube from the system.

Any person skilled in the art will understand that the bayonet style twist lock is merely one example of a locking means which can be used to secure the disposable cartridge **206** to the cartridge mount **232**. Other suitable locking means can be used with equal effectiveness without departing from the scope of the invention.

Figure 9 is an isometric view of disposable cartridge **206** showing a plunger **258** positioned within cylindrical body **250**. The disposable cartridge **206** is preferably made from plastic materials such as polyethylene, and has a polypropylene plunger **258** that is pressed into place at the filling operation. The plunger **258** has a recessed bottom portion for receiving an end of threaded drive rod **233**, and has a shape similar to that of a common syringe plunger. The built-in plunger **258** forms a seal with the inner wall of cylindrical body **250**, and is pushed by threaded drive rod **233** acting as a piston, when stepper motor **230** rotates to

dispense the contents of the disposable cartridge **206**. As previously mentioned, capillary tube **255** transfers the liquid from the cartridge to the cup when the plunger **258** is pushed, and is sized to prevent excess dripping when the dispense is stopped. For example, the inner diameter of the capillary tube **255** can be between 0.040 inches and 0.150 inches

Previously shown figures 5 to 9 show the features of a single pump unit **204**, according to an embodiment of the present invention. Figures 10 and 11 show how multiple pump units **204** can be arrayed together in a compact configuration, while permitting easy access to the disposable cartridges **206** of each pump unit **204**.

As previously shown in Figure 4, all ten pump units **204** are oriented in an upright position to facilitate access to the disposable cartridges **206** by a user once the top and side panels, which may be integrated together, are removed or the drawer assembly is pulled out to the open position. Furthermore, the upright position allows any air within the cartridge to collect at the top of the cartridge. Thus the air can be expelled to maintain accurate dispenses. Figures 10 and 11 show how the pump units can be secured into the upright position.

Figure 10 shows one pump unit **204** releasably connected to a pump mount **270**. A primary advantage for having removable pump units **204** is to facilitate maintenance, repair, cleaning or replacement of the pump units **204** should it be required. The pump mount **270** is preferably rigidly secured by any means to the bottom of chassis **202**. Pump mount **270** includes a total of ten female dovetail slots **272**, or keyholes with five slots **272** or keyholes arrayed on opposite sides of pump mount **270**. Figure 11 shows ten pump units **204** installed within pump mount **270**. In the present embodiment, pump mount **270** is centrally positioned within the chassis of the dispensing apparatus **200**. In an alternate embodiment, pump mounts can be integrated with the opposing side-walls of the chassis.

Pump unit **204** has a corresponding dovetail mount **235** that slides into a female dovetail slot **272** in its installed position. The female dovetail slots **272** or keyholes are spaced apart to ensure that multiple pump units **204** can be compactly ganged together. While gravity alone should keep the pump unit **204** within its female dovetail slot **272**, the pump unit **204** can be inadvertently pulled out by the user while he/she attempts to remove an empty

disposable cartridge **206**. Therefore, thumbscrews **274** can be screwed into the top edge of the pump mount **270** after the pump unit **204** is inserted to prevent the pump unit **204** from slipping out of the female dovetail slot **272**. Thumbscrews **274** are positioned between opposing female dovetail slots **272**, and preferably have a diameter that overlaps the entry area of each female dovetail slot **272**. It is this overlapping of the thumbscrew that bars the inserted dovetail mount **235** from removal.

When installed to pump mount **270**, each anti rotation bracket **234** forms a gap between the wall of pump mount **270** and mounting holes **236**. This gap can be seen in Figure 11, which shows a side view of a pump unit **204** secured to pump mount **270**. As will be described below, this gap is preferred for accommodating signal interconnection means.

Figure 12a shows a pump unit **204** partially inserted within female dovetail slot **272**. In this figure, a driver card **280** is secured to the anti rotation bracket **234** via pins or screws through mounting holes **236**. This driver card **280** mates with an interface printed circuit board (PCB) **282**. According to a preferred embodiment, driver card **280** includes a microcontroller such as the Motorola MM908E625, for controlling its corresponding stepper motor. A local interconnect network (LIN) bus is used for the communication link between the motor and the user button panel and/or microprocessor. The interface PCB **282** can further provide power to the stepper motor **230**. The driver card **280** can have permanent wiring between itself and the stepper motor **230**, while interface PCB **282** can have permanent wiring between itself and the microprocessor. Mating connectors on driver card **280** and interface PCB **282** will be properly aligned to provide electrical contact with each other when pump unit **204** is fully inserted within female dovetail slot **272** or keyhole. Therefore, removal and installation of the pump unit **204** does not require manipulation of any electrical wiring or connectors, since the electrical connection between the pump unit **204** and the interface PCB **282** is automatic upon full insertion of the pump unit **204** within female dovetail slot **272** or keyhole.

Figures 12b and 12c are isometric and side views respectively, of an alternate pump unit. Alternate pump unit **290** is shown having a piston head **292** fixed to the end of the drive

rod and shaped for engaging a correspondingly shaped plunger in the disposable cartridge. Further details of the piston head and the plunger will be discussed later. Pump unit **290** includes alternate features for securing it to the pump mount **270** or chassis of the dispensing system. For example, instead of the dove tail mount **235** shown in Figure 12a, a screw head **294** can be used for sliding into a correspondingly shaped keyhole (not shown) of the pump mount **270**. Those skilled in the art will appreciate that there are many different methods for securing the pump unit **204** to the pump mount **270**, and those mentioned above are examples of such possible methods. Instead of using thumbscrews **274** for retaining the pump units in their installed position onto pump mount **270**, the bottom end of pump unit **290** will have a flexible tab **296** that will naturally deflect upon insertion into a base having an appropriately shaped slot for securing it to the pump mount **270**. To remove the pump unit **290**, the flexible tab **296** is deflected as the pump unit **290** is withdrawn from the pump mount **270**, thereby disengaging the locking mechanism of the flexible tab **296** with the base. Persons skilled in the art will understand how such locking mechanisms work.

Figure 13 is a block diagram representing the functional components of dispensing machine **200** shown in Figure 4. In addition to the already described components of dispensing machine **200**, Figure 13 shows the electronic systems that control them. Accordingly, the functional components of Figure 13 that correspond to the components shown in the preceding figures are numbered the same.

Dispensing system **300** includes user interface **208**, microprocessor **302**, a LIN bus **304** connected between the microprocessor **302** and pump units **204**, 5 volt power supply **308** and 12 volt power supply **310**. Each pump unit **204** can include a respective driver card for controlling the stepper motor it is associated with. User interface **208** includes button actuators of the capacitive or piezoelectric sensor type, for sending electrical selection signals to microprocessor **302**, and LCD driver circuitry for receiving predetermined display data from microprocessor **302**. LCD driver circuitry drives an LCD display with alpha-numeric characters for providing user feedback.

Microprocessor **302** is preferably programmable to permit the manufacturer to install pre-set control algorithms and pump unit control data for all valid selection combinations. An example of a suitable microprocessor is the Motorola MC68HC908AB32 with non-volatile Flash memory. The Flash memory can store boot loader software and application software for the microprocessor **302**. The boot loader code is a small piece of code in a protected portion of Flash memory programmed by the manufacturer, while the application code is the main software that contains all of the functional procedures associated with the dispensing system **300**. Details of the boot loader software and the application software, according to an embodiment of the present invention follows.

The boot loader is used to fetch new application code, new driver software, or other dispense parameters via any suitable port, such as an infrared port for example. The new code is downloaded when an infra red programming device pointed at the button panel on boot up is detected. This code can be stored in the Flash memory. If there is no infra red device and the current application software is valid, the microprocessor **302** will run the present application code.

The application code executed by the microprocessor **302** monitors/scans user interface **208**, and performs the necessary calculations or look up table functions for issuing pump control data in response to user selections. Additional functions of the application code can include controlling the display of user interface **208**, monitoring remaining fluid in each disposable cartridge, executing a programming mode of operation, and updating driver software of the pump units **204**.

It should be noted that different retailers may use different types of concentrated flavourings, and hence the volume to dispense per fixed beverage size may differ. Microprocessor **302** receives the electrical selection signals from the user interface **208**. The electrical selection signals can correspond to the selected flavouring, and selected dispense quantity. Once determined, microprocessor **302** can issue the corresponding pump control data, which can include the specific pump unit **204** to be actuated and the quantity of concentrated fluid to be dispensed from it. More specifically, the quantity of concentrated

fluid to be dispensed is part of a drive profile issued via LIN bus **304** to the driver card of one or more pump units **204** to dispense the required volume of flavour(s). As previously discussed, the drive profile can be derived by calculation or from a look up table. The drive profile can include parameters such as stepper speed data, number of steps data, direction and back electro magnetic force (EMF) detection threshold data.

The user can manually adjust the existing programming through the user interface **208**. When in the program mode of operation, the dispense volumes for each flavouring can be adjusted by 0.1 millilitres. However, the sheer number of possible combinations renders manual programming cumbersome and time consuming. In the present ten flavour embodiment of the dispensing machine **100**, there are greater than **700** possible adjustments that can be made. To facilitate re-programming or updates to the factory pre-set programming, a communication port can be coupled to the microprocessor for receiving any new software. The communication port can be a wired port, such as an RS-**232**, a USB port, or a LIN bus in communication with a computer or device capable of transferring the new programming. Alternatively, a wireless port, such as an IR port, WiFi or Bluetooth transmitter/receiver can be used. Those of skill in the art will understand how to interface such communication ports with microprocessor **302**.

The programmability of microprocessor **302** permits tracking of remaining concentrated flavouring fluid in each disposable cartridge **206** coupled to each pump unit **204**. Since the volume of each dispense is known, and the full level volume of the disposable cartridge **206** is known, the microprocessor can store a current remaining volume of concentrated fluid so that a visual and/or audio alert is emitted once a predetermined empty level threshold is reached. Of course, a low level indication can be provided by microprocessor **302** through the display of user interface **208** when the remaining volume of concentrated fluid has reached a predetermined level. When the specific cartridge is determined to be empty, an alert can signal the user to replace the empty disposable cartridge, and optionally locks out the specific flavouring from being further dispensed, until it is reset. Alternately, an electro-mechanical trigger can be used to detect the empty state of the

disposable cartridge **206**. For example, each driver card **280** can include a back EMF (electro magnetic or motive force) detection circuit for detecting an end position of the threaded drive rod **233**.

Microprocessor **302** can be further programmed to provide timed events. In particular, certain concentrated flavourings may have a limited shelf life, thus necessitating a purge of the stored flavouring after a predetermined span of time, such as 1 month for example. A replaced disposable cartridge **206** would then reset the associated timers.

Following is a brief discussion of the function of the driver card coupled to each pump unit **204**. The driver cards are slave devices that respond to commands from the microprocessor **302**. Each driver card preferably has its own microprocessor, such as a Motorola MM908E625 microprocessor, stepper driver hardware, a back EMF detection circuit to detect end stops, and a LIN Bus physical layer. The driver card microprocessor includes its own boot loader software and application software. The primary function of the driver code software is to wait for a drive profile from the microprocessor **302**. The software then drives the motor as specified, and then sends a response indicating the driving is done and also if it was complete or the back EMF detection stopped it before all of the required steps could be completed.

The driver card functions as a pump driver for actuating one stepper motor **230**. More specifically, the driver card provides motor drive signals, such as direction of rotation and step signals to turn stepper motor **230** of pump unit **204**. Accordingly, the number of pre-calibrated steps corresponds to the desired quantity of concentrated fluid to be dispensed. Additionally, due to the high viscosity of 4000 centepoise fluids, the speed at which the stepper motor **230** rotates is optimized to ensure that an overpressure condition does not occur during the dispense stroke, causing the stepper motor to skip or the capillary tube to pop off the output nozzle **254**. Those of skill in the art will understand that different pump units **204** in the same dispensing machine **100** can be programmed to step at different rates. For example, one pump unit **204** can dispense 4000 centepoise fluids while another can dispense

two centepoise fluids. Hence the speed, torque and accuracy for each stepper motor **230** can be optimized for maximum performance and reliability.

In the presently shown embodiment, each pump unit **204** has its own dedicated driver card for controlling its associated stepper motor **230**. In an alternate embodiment, the stepper motors from all the pump units **204** can share a single pump driver circuit. In such an embodiment, a multiplexing circuit can be used to pass the direction of rotation and step data from the single pump driver to one of the pump units **204**. Practically, this multiplexing circuit can be implemented as a set of individual relay devices, each individually selectable by microprocessor **302** for coupling the data to the corresponding pump unit **204**.

Following is a description of the operation of dispensing system **300** according to an embodiment of the present invention, with reference to the flow charts in Figures 14 and 15. The flow chart of Figure 14 steps through the primary control routine of dispensing system **300** as executed by microprocessor **302**, while the flow chart of Figure 15 steps through a sub-routine executed in tandem by pump driver **304**. It is assumed for the present example that all the pump units **204** are ready for dispensing concentrated flavouring fluids.

In Figure 14, the primary control routine begins at step **400** when the power supplies **308** and **310** of dispensing system **300** are turned on. At this time, new code can be downloaded through the appropriate port, such as an IR port for example. This downloaded code can then be forced to the driver cards of each pump unit **204**. More specifically, microprocessor **302** queries each driver card for its respective software number and revision. Any downloaded driver software having a newer version is automatically sent to the driver cards. This code can include user interface software and control software for the stepper motors of each pump unit **204**. This code can further include pump control data, or drive profiles, for specific stepper motors. The drive profile can include parameters such as stepper speed data, number of steps data, direction and back EMF detection threshold data. This listing of parameters is not comprehensive, and can thus include other related parameters. Port downloading of code is a preferred feature for multiple pump unit parameter modification, since manual

modification of parameters for all the pump units **204** can be cumbersome and time consuming.

During the power up initialization of step **400**, the microprocessor **302** waits until a synchronization signal is received from the pump drivers of each pump unit **204** before proceeding to step **402**. At step **402**, the user interface **110** is scanned for a user selection. Once the selection has been made, the validity of the selection and/or selection sequence is assessed at step **404**. Valid sequences can be predetermined and programmed in advance. The valid sequence can either be a flavour selection or a program mode entry sequence. Once the program mode is entered, prompts can be displayed on the LCD display to instruct the user regarding the adjustments that can be made.

If the sequence corresponds to a program mode, then the user is prompted to change values for parameters regarding dispense of the particular flavouring. These can include stepper speed, number of steps, and back EMF detection threshold for example. Once the changed values have been entered, they are dispersed to corresponding driver card via the LIN bus.

If the selection is invalid, the routine loops back to step **402** and a message can be displayed to the user for indicating the invalidity of the entered selection. Otherwise, the routine proceeds to step **406** to determine if there is sufficient flavouring in the selected disposable cartridge. The amount of flavouring remaining in each cartridge can be tracked by the microprocessor. Since the full volume of a new disposable cartridge is known, and the amount of fluid to dispense is known, the microprocessor can execute the mathematical operation of subtracting dispensed volumes from the currently remaining volume. As previously mentioned, detection of an empty cartridge can be done through electro-mechanical means, such as an EMF detector. Alternately, in a system that does not track the remaining volume of each disposable cartridge, the assessment of an empty cartridge can be done solely through the EMF detector after the fluid is dispensed.

If there is sufficient flavouring remaining in the disposable cartridge to meet the requested dispense volume, the routine proceeds to step **408** where the microprocessor **302**

computes the appropriate control data for the selection, and sends the appropriate data to the driver card of the selected pump units **204** through the LIN bus. This data can include step count and drive profile data. Thus the desired pump unit **204** is actuated. This control data takes into account the specific flavouring, size of the beverage, type of beverage and any modifiers or other variables that may be relevant to the quantity of concentrated flavouring to dispense. Once the dispense operation for the selection has been completed, the remaining amount of flavouring in the disposable cartridge can be updated at step **410**, and the routine loops back to step **402** to receive a new selection.

If at step **406** there is insufficient flavouring remaining in the disposable cartridge to meet the requested dispense volume, a message can be displayed at step **412** to indicate to the user that a particular disposable cartridge needs to be replaced. At this time, the microprocessor **302** preferably fully retracts the threaded drive rod corresponding to the empty disposable cartridge. At step **414**, the system checks if the disposable cartridge has been replaced. This can be done manually by the user or automatically by the system.

An example of manual detection includes the use of reset buttons corresponding to each pump unit **204** mounted to the button panel or to the inside of the chassis and accessible only by removing the top and side panels. Then the user presses the appropriate reset button after a new disposable cartridge has been installed. In response to the depressed reset button, the specific stepper motor can advance its threaded drive rod to abut the plunger of the disposable cartridge, and the microprocessor **302** will reset the volume for that flavouring.

An example of automatic detection includes the use of sensors, such as electro-mechanical sensors, for detecting removal of the old disposable cartridge. This can be as simple as a spring loaded, depressible pin or flange integrated into the cavity of the locking means **240**. Insertion of a disposable cartridge sets the trigger of the sensor, and removal of the disposable cartridge triggers reset for the pump unit **204**. Persons skilled in the art will understand that there can be many different sensors and mechanisms for manually or automatically resetting a pump unit.

Returning to the flow chart of Figure 14, while in the loop between steps **412** and **414**, the system can return to step **402** to receive new selections, but the currently empty flavour will be locked out. If the disposable cartridge has been replaced, then the message is disabled at step **416** and the system returns to step **402** while releasing the lock out for the previously empty flavour.

In the case where a selection sequence corresponds to a combination dispense where several flavour fluids are to be dispensed, the current recorded level of concentrated flavour fluid for each disposable cartridge is checked. If any one is effectively empty for the current dispense, then the combination dispense is cancelled and the appropriate message is displayed. In the case where a combination dispense is executed, the control data is sent sequentially to each pump unit **204**.

The pump driver sub-routine shown in Figure 15 is now discussed with reference to the primary control routine previously described in Figure 14. The pump driver sub-routine begins at step **500** when power supply **314** is turned on. This power up initialization step occurs at the same time as the power supplies **308** and **310** are turned on in step **400** of Figure 14. A synchronization signal can be sent back to the microprocessor **302** to allow the primary control routine to begin scanning of the user interface at step **402**. In the present embodiment, a synchronization signal can be sent every six seconds to maintain an open communications link. If new code was downloaded and pushed by the microprocessor **302**, then this new code is downloaded to the driver card through the LIN bus. If new parameters were entered manually through the button panel in the program mode, these new parameters would then be downloaded. Now the pump driver **304** is ready to receive control data from microprocessor **302** to actuate one or more pump units **204** in response to a selection.

At step **502**, the presence of an empty signal is checked for each pump unit **204**. This empty signal is generated at step **412** in the primary control routine of Figure 14. If the empty signal is received, then the particular pump unit **204** is homed at step **504**, and loops back to step **502** to monitor the status of the disposable cartridge (ie. if the disposable cartridge has

been replaced). Otherwise, the sub-routine proceeds to step **506** for receiving the control data provided by microprocessor **302**.

At this point, one or more pump units **204** receive control signals microprocessor **302**. The selected pump unit(s) **204** is actuated by the predetermined number of steps in step **508**, and the predetermined volume of concentrated flavouring fluid is dispensed. In a system where multiple flavours are dispensed in parallel, the sub-routine of Figure 15 ends at step **508**, and each pump unit **204** sends an end of drive message via the LIN bus back to the microprocessor. In an alternate system where multiple flavours are dispensed in sequence, the sub-routine of Figure 15 would continue as follows. A determination is made at step **510** to assess if there are any further dispense operations for the present selection. If the dispense operation for the present user selection is complete, the sub-routine loops back to step **506** to await further pump and step control data. Therefore, each pump unit **204** is actuated in sequence in response to the control data received in step **506**.

As previously discussed, a capillary tube is used for transferring fluid from the disposable fluid cartridge to the central dispensing area, and is selected to be a size for minimizing fluid drippage after a dispensing operation is completed. However, depending on the fluid, there may be a residual drop hanging on the end of the capillary tube after the dispense. This residual drop can fall at a later time into another container for which a dispense of a different flavouring is desired. This will result in a mixing of flavours, thereby changing the flavour of the beverage. Alternately, this residual drop will hang on and be exposed to the air until next dispense. If the plunger is fixed to the piston, then the stepper motor can be operated to withdraw the plunger by a preset distance, thereby creating a negative pressure in the cartridge to draw the fluid product back into the capillary tube. However, in the presently shown embodiments of the disposable fluid cartridge, the plunger and the piston are not fixed to each other, therefore the plunger cannot be withdrawn as the piston is withdrawn by the action of the stepper motor and threaded drive rod.

According to an embodiment of the present invention, an expandable plunger is provided for creating a negative pressure in the cartridge when the piston is withdrawn from

the plunger after a dispense operation. An isometric view of an expandable plunger according to one embodiment is shown in Figure 16. Expandable plunger **600** is circular in shape and constructed of a resilient material. The expandable plunger **600** includes a side-wall **602**, a lower sealing flange **604** radially extending away from a bottom end of side-wall **602**, an upper sealing flange **606** radially extending away from a top end of side-wall **602**, and an expandable plunger top **608**. The expandable plunger top **608** has a maximum diameter that is less than the maximum diameter defined by side-wall **602**. The top surface of expandable plunger top **608** includes folds of resilient material arranged in a corrugated configuration, which allows for expansion in response to an applied force from the underside of the top surface. In use, the expandable plunger top **608** is positioned towards the outlet of the cartridge and sized to fit within the diameter of the cartridge.

To further illustrate the features of the expandable plunger **600**, Figure 17a shows a side view of the expandable plunger **600** shown in Figure 16, and Figure 17b shows a cross-sectional view of the expandable plunger **600** of Figure 17a, taken along line A-A. The expandable plunger **600** is a hollow body, where the side-wall **602** and the lower sealing flange **604** form a primary plunger chamber while an upper side-wall **610** defines a secondary plunger chamber. An internal shoulder **612** is provided for supporting the upper side-wall **610** and further functions as a stop for a suitably shaped piston, as will be described later. It should be apparent to those skilled in the art that internal shoulder **612** is concentric with the upper side-wall **610**. In alternate embodiments, the internal shoulder **612** can be sloped instead of being formed at a right angle to the side walls **602** and **610**.

Lower sealing flange **604** is an optional feature that helps prevent expandable plunger **600** from sliding in a direction away from the cartridge outlet as the piston is retracted. The upper sealing flange **606** is an optional feature, which forms a channel **614** with upper side-wall **610**, which is configured to receive the fluid product in the cartridge as the expandable plunger **600** is pushed towards the cartridge outlet for dispensing the fluid product. As the expandable plunger **600** is pushed, the pressure of the fluid in the cartridge will bias the upper

sealing flange **606** to open, or further extend away from the side-wall **602**, thereby improving the seal provided by expandable plunger **600**.

The folds of resilient material of expandable plunger top **608** can be deformably stretched, expanded or elongated, in the direction towards the cartridge outlet. Figure 18a shows the expandable plunger **600** in a relaxed state before engagement with a piston **650** for a dispense operation, and Figure 18b shows the expandable plunger **600** in an expanded state when fully engaged with the piston **650** during a dispense operation. The piston **650** will be shaped to correspond with the shape of the primary and secondary plunger chambers of the expandable plunger **600**. More specifically, piston **650** will have a base **651** with a diameter sized to fit within the primary chamber defined by side-wall **602**, and an extender **652** with a diameter sized to fit within the secondary chamber defined by upper side-wall **610**. In the present example, the top of extender **610** is rounded, but in alternate embodiments, the top of extender **610** can take on any desired shape. According to the present embodiment the height of the extender **610**, which is defined from the base **651** to its top-most point, will be greater than the height of upper side-wall **610**. More specifically, the height of extender **610** will be selected such that expandable plunger top **608** will be elongated by the top-most portion of extender **610** before the base **651** abuts the internal shoulder **612**.

Figure 18b shows the position of the piston **650** relative to the expandable plunger **600** during a dispense. Because the extender **652** has a maximum height that is greater than that of upper side-wall **610**, expandable plunger top **608** is elongated as the piston **650** is pushed into the chambers of expandable plunger **600** and the top of extender **652** pushes against the underside of expandable plunger top **608**. When the base **651** of the piston **650** abuts the shoulder **612** of the expandable plunger **600**, the expandable plunger **600** will be pushed towards the cartridge outlet. If the piston **650** is later withdrawn to the position shown in Figure 18a, the elongated expandable plunger top **608** is allowed to return to its relaxed state. Accordingly, this action creates a low pressure in the cartridge, thereby drawing fluid product back into the capillary tube.

As previously mentioned, the shape of the extender **652** top is not necessarily rounded as shown in Figure 18b. In alternate embodiments, extender **652** can include one or more smaller protrusions effective for elongating the expandable plunger top **608**. As long as the maximum height of the extender **652**, including any protrusion, is greater than the height of upper side-wall **610**, any suitable shaped extender **652** can be used. The shape of base **651** is preferably sized to ensure that at least some or all of a surface of base **651** will abut the shoulder **612** in such a way that will ensure displacement of expandable plunger **600** within the cartridge.

Furthermore, the maximum height of the extender **652** can be selected based on the fluid product viscosity and the material used for the plunger. For example, low viscosity fluids may not require a plunger material with high resiliency, or an extender **652** having a significant height difference over the side-wall **610**. A combination of material resiliency and extender height sufficient for drawing a single drop of fluid product back into the capillary tube when the piston **650** is withdrawn, can be determined by those skilled in the art.

Figure 19 is a cross-sectional view of an alternate expandable plunger **660** and a correspondingly shaped piston **662**. Plunger **660** is similar in configuration to plunger **600**, except that a frusto-conical side-wall **664** extends from upper side-wall **610** to the expandable plunger top **666**. In the present embodiment, upper side-wall **610** and frusto-conical side-wall **664** form the secondary plunger chamber, and expandable plunger top **666** has a smaller area including folds of resilient material arranged in a corrugated configuration. The purpose for the smaller area of the expandable plunger top **666** is to maximize fluid evacuation where lesser drawback requirements exist. The piston **662** includes a base **668** similar to base **651** of Figure 18a, and an extender **670** having a circular portion **672** and a frusto-conical portion **674**. The diameter of circular portion **672** is sized to fit within upper side-wall **610**. The shape of extender **670** is set to engage the underside of expandable plunger top **666** as the piston **662** is advanced by the drive rod, to stretch the expandable plunger top **666** before and edge of base **668** abuts the shoulder **612**. As in the embodiment of Figures 18a and 18b, the stretched expandable plunger top **666** will return to its relaxed state when the piston **662** is withdrawn.

Figure 20 is a method for operating the expandable plunger **600**, according to an embodiment of the present invention. This method can be incorporated into step **508** of Figure 15. It is assumed that the piston is shaped and sized for elongating the expandable plunger top **608**, and is positioned as shown in Figure 18a prior to the dispense operation. The method starts at step **700** by advancing the piston, typically under the control of a controller such as microprocessor **302** for example. As the piston advances, the top surface of the extender **652** will abut and push against the underside of expandable plunger top **608** to deform it at step **702**. The expandable plunger top **608** will continue to deform until the base **651** abuts the shoulder **612** of the expandable plunger **600**. Eventually, the base **651** will abut the shoulder **612** of the expandable plunger **600**, thereby resulting in advancement of the plunger towards the outlet of the cartridge to dispense fluid product at step **704**. The relative positions of the piston and the expandable plunger **600** will appear as in Figure 18b. After the desired amount of fluid product is dispensed, the piston is withdrawn from the plunger at step **706**, and the deformed expandable plunger top **608** will then return to its relaxed state at step **708**. As the expandable plunger top **608** returns to its original relaxed state, a negative pressure is created in the cartridge to draw fluid in the capillary tube back into the cartridge. Therefore, any fluid that could result in a hanging fluid drop would be drawn back into the capillary tube.

The embodiments of the expandable plunger **600** and its method of use are applicable to the embodiments of the disposable fluid cartridge system previously shown. In such a system where spent cartridges are removed and replaced, a preset optional step would be to prime new cartridges before use. For example, when a new disposable cartridge is installed, the stepper motor can be actuated to drive the piston by a predetermined distance sufficient to clear the capillary tube of air pockets. It is noted that the piston does not need to be fully withdrawn from the chambers of the expandable plunger. In fact, the piston can be withdrawn to a position where the top portion of extender **652** is still in contact with the underside of expandable plunger top **608**, or to a position where the expandable plunger top **608** is less expanded than in the fully expanded state. The less expanded state can be considered a relaxed state of the expandable plunger.

The previously described cartridge-based dispensing machine is thus simple to use and maintain by any person. Since the disposable cartridges are self-contained, there is no possibility of spillage when it is time to replace an empty cartridge with a full cartridge. Furthermore, the locking means for receiving and securing disposable cartridges allows for quick replacement of cartridges without any complex steps.

The above-described embodiments of the present invention are intended to be examples only. Alterations, modifications and variations may be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

CLAIMS:

1. A pump unit for dispensing a predetermined volume of fluid comprising:

a stepper motor in threaded engagement with a threaded drive rod, the stepper motor rotatable in one direction by a number of steps to advance the threaded drive rod;

a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod;

a disposable cartridge having a first end adapted to engage the locking means for securing the disposable cartridge to the cartridge mount, the disposable cartridge having a chamber sealed with a plunger slidable in the chamber, the disposable cartridge having an outlet nozzle at a second end for dispensing contents of the chamber when the plunger is pushed by the threaded drive rod, and the plunger including an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by a piston connected to the threaded drive rod, the expandable plunger top returning to a relaxed state when the piston is withdrawn from the plunger by a predetermined distance.

2. The pump unit of claim 1, wherein the locking means includes a bayonet style twist lock, and the first end of the disposable cartridge is adapted for engaging the bayonet style twist lock.

3. The pump unit of claim 1, further including a capillary tube releasably connected to the outlet nozzle.

4. The pump unit of claim 1, further including a driver card in electrical communication with the stepper motor, the driver card including a microcontroller for controlling the stepper motor in response to pump control data.

5. The pump unit of claim 4, wherein the driver card includes a connector for receiving the pump control data.

6. The pump unit of claim 1, wherein the cartridge mount includes a mounting means for securing the cartridge mount to a chassis.

7. A dispensing machine for providing a predetermined volume of fluid corresponding to a user selection, comprising:

a pump unit having a stepper motor for advancing a threaded drive rod in response to pump control data;

a disposable cartridge releasably connected to the pump unit, and having a plunger for engaging the threaded drive rod, the disposable cartridge including a chamber sealed with the plunger, and the plunger having an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by the threaded drive rod for dispensing the predetermined volume of fluid, the expandable plunger top returning to a relaxed state when the threaded drive rod is withdrawn from the plunger by a predetermined distance;

a user interface for providing electrical selection signals in response to the user selection; and

a microprocessor for receiving the electrical selection signals and for providing the pump control data corresponding to the pump unit, the pump control data including stepper motor direction data and number of steps data.

8. The dispensing machine of claim 7, further including a capillary tube releasably connected to the outlet nozzle for directing the contents of the chamber to a dispensing area.

9. The dispensing machine of claim 7, wherein the pump unit includes a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod and the disposable cartridge being adapted for engaging the locking means.

10. The dispensing machine of claim 9, wherein the pump unit includes a driver card in electrical communication with the stepper motor, the driver card including a controller for controlling the stepper motor in response to pump control data.

11. The dispensing machine of claim 10, wherein the pump unit includes an electromotive force detector for detecting a predetermined position of the threaded drive rod.

12. The dispensing machine of claim 10, wherein the cartridge mount includes a mounting means for securing the cartridge mount to the chassis.

13. The dispensing machine of claim 12, wherein the chassis includes a pump mount configured to releasably receive the mounting means of the cartridge mount.

14. The dispensing machine of claim 13, wherein the pump mount includes an interface card adapted for electrically engaging the driver card for passing the pump control data when the pump unit is secured to the pump mount.

15. A pump unit for dispensing a predetermined volume of fluid comprising:

a stepper motor in threaded engagement with a threaded drive rod, the stepper motor rotatable in one direction by a number of steps to advance the threaded drive rod;

a driver card in electrical communication with the stepper motor, the driver card including a microcontroller for controlling the stepper motor in response to pump control data;

a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod;

a disposable cartridge having a first end adapted to engage the locking means for securing the disposable cartridge to the cartridge mount, the disposable cartridge having a chamber sealed with a plunger slidable in the chamber, the disposable cartridge having an outlet nozzle at a second end for dispensing contents of the chamber when the plunger is pushed by the threaded drive rod.

16. The pump unit of claim 15, wherein the plunger includes an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by a piston connected to the threaded drive rod, the expandable plunger top returning to a relaxed state when the piston is withdrawn from the plunger by a predetermined distance.

17. The pump unit of claim 15, wherein the locking means includes a bayonet style twist lock, and the first end of the disposable cartridge is adapted for engaging the bayonet style twist lock.

18. The pump unit of claim 15, further including a capillary tube releasably connected to the outlet nozzle.

19. The pump unit of claim 15, wherein the driver card includes a connector for receiving the pump control data.

20. The pump unit of claim 15, wherein the cartridge mount includes a mounting means for securing the cartridge mount to a chassis.

21. A pump unit for dispensing a predetermined volume of fluid comprising:

a stepper motor in threaded engagement with a threaded drive rod, the stepper motor rotatable in one direction by a number of steps to advance the threaded drive rod;

a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod and a mounting means for securing the cartridge mount to a chassis;

a disposable cartridge having a first end adapted to engage the locking means for securing the disposable cartridge to the cartridge mount, the disposable cartridge having a chamber sealed with a plunger slidable in the chamber, the disposable cartridge having an outlet nozzle at a second end for dispensing contents of the chamber when the plunger is pushed by the threaded drive rod.

22. The pump unit of claim 21, wherein the plunger includes an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by a piston connected to the threaded drive rod, the expandable plunger top returning to a relaxed state when the piston is withdrawn from the plunger by a predetermined distance.

23. The pump unit of claim 21, wherein the locking means includes a bayonet style twist lock, and the first end of the disposable cartridge is adapted for engaging the bayonet style twist lock.

24. The pump unit of claim 21, further including a capillary tube releasably connected to the outlet nozzle.

25. The pump unit of claim 21, further including a driver card in electrical communication with the stepper motor, the driver card including a microcontroller for controlling the stepper motor in response to pump control data.

26. The pump unit of claim 25, wherein the driver card includes a connector for receiving the pump control data.

27. A dispensing machine for providing a predetermined volume of fluid corresponding to a user selection, comprising:

a pump unit having a stepper motor for advancing a threaded drive rod in response to pump control data, and a cartridge mount coupled to the stepper motor, the cartridge mount having a locking means with an aperture sized to pass the threaded drive rod and the disposable cartridge being adapted for engaging the locking means;

a disposable cartridge releasably connected to the pump unit, and having a plunger for engaging the threaded drive rod;

a user interface for providing electrical selection signals in response to the user selection; and

a driver card in electrical communication with the stepper motor and including a microprocessor for receiving the electrical selection signals and for providing the pump control data corresponding to the pump unit, the pump control data including stepper motor direction data and number of steps data.

28. The dispensing machine of claim 27, wherein the disposable cartridge includes a chamber sealed with the plunger, the plunger having an expandable plunger top of resilient material deformable to an expanded state when the plunger is pushed by the threaded drive rod for dispensing the predetermined volume of fluid, the expandable plunger top returning to a relaxed state when the threaded drive rod is withdrawn from the plunger by a predetermined distance.

29. The dispensing machine of claim 28, further including a capillary tube releasably connected to the outlet nozzle for directing the contents of the chamber to a dispensing area.

30. The dispensing machine of claim 27, wherein the pump unit includes an electromotive force detector for detecting a predetermined position of the threaded drive rod.

31. The dispensing machine of claim 27, wherein the cartridge mount includes a mounting means for securing the cartridge mount to a chassis.

32. The dispensing machine of claim 31, wherein the chassis includes a pump mount configured to releasably receive the mounting means of the cartridge mount.

33. The dispensing machine of claim 32, wherein the pump mount includes an interface card adapted for electrically engaging the driver card for passing the pump control data when the pump unit is secured to the pump mount.

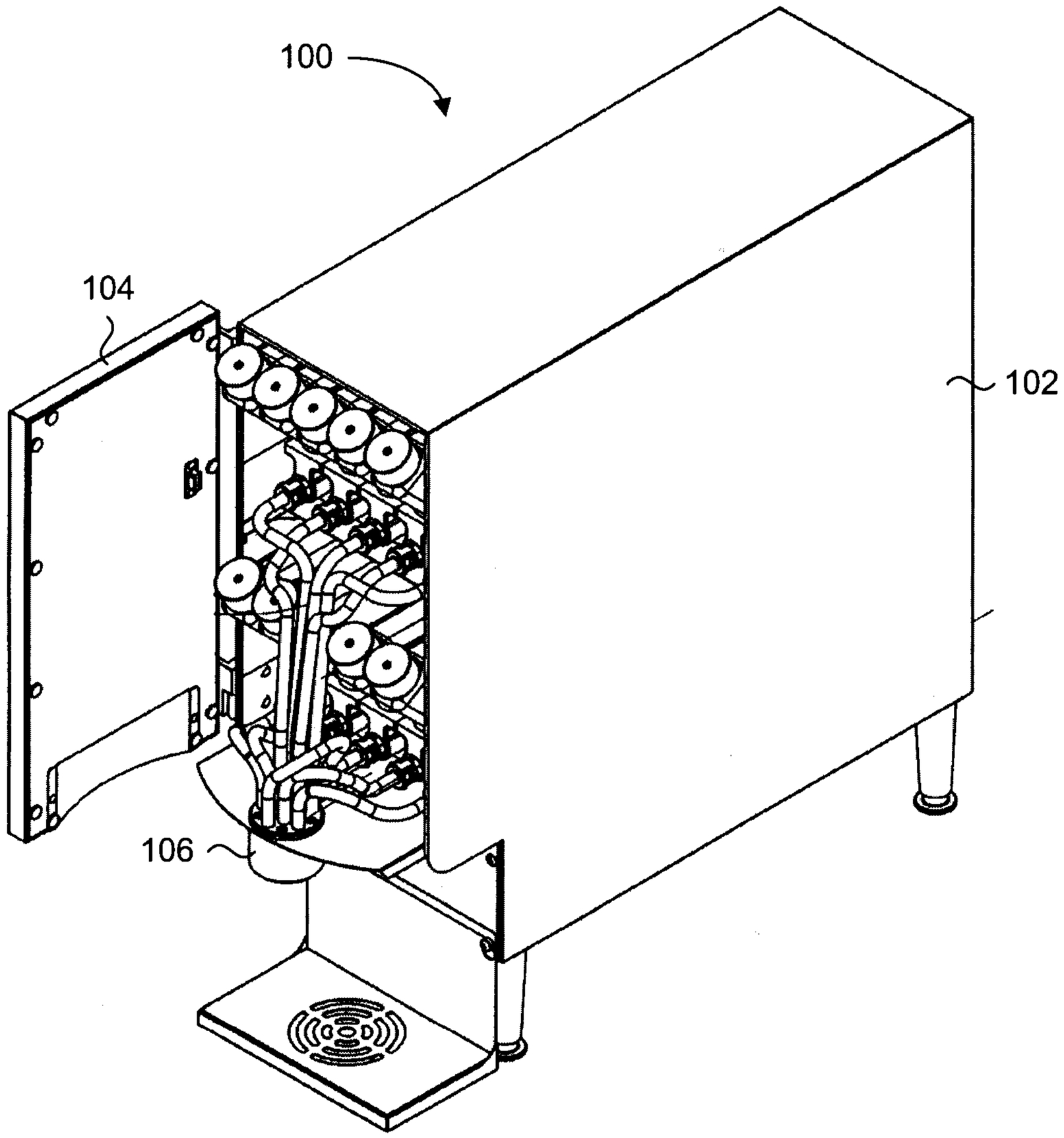


Fig. 1

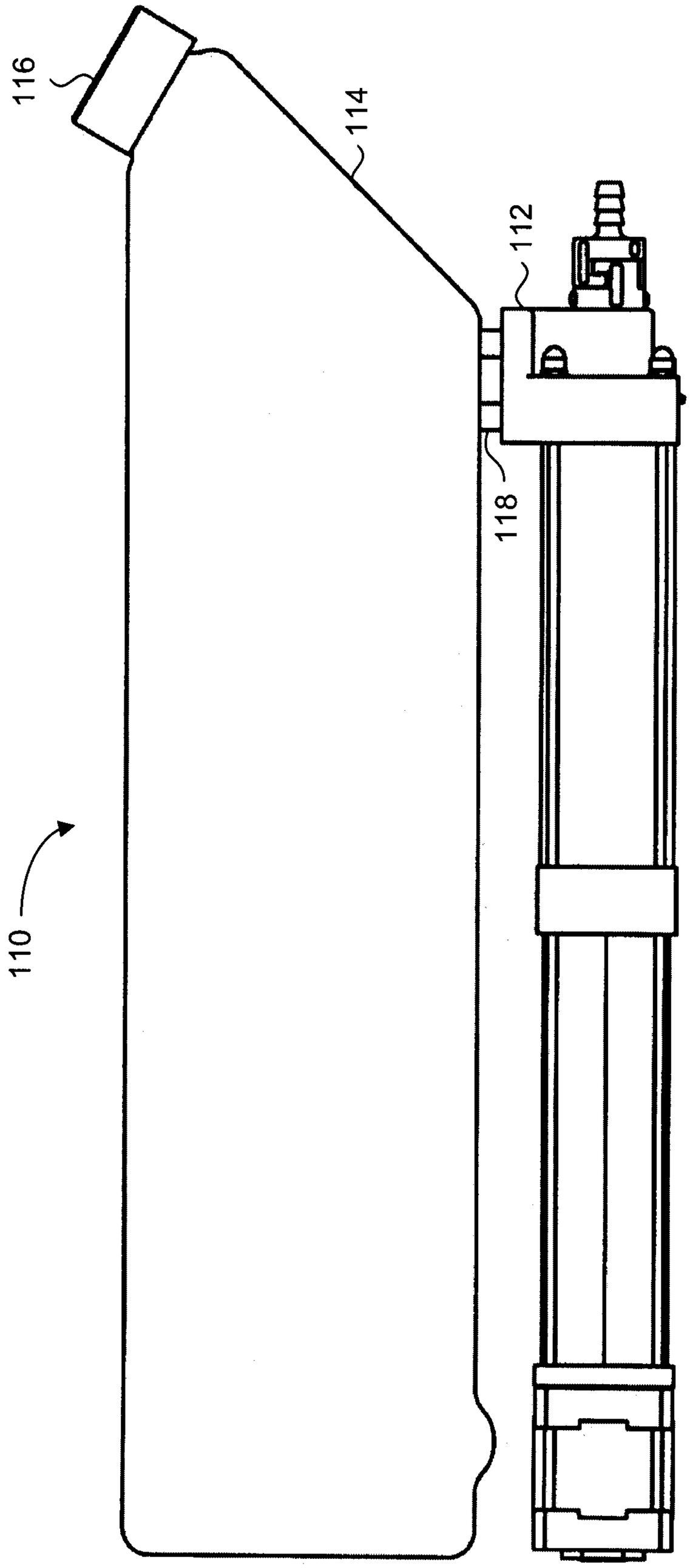


Fig. 2

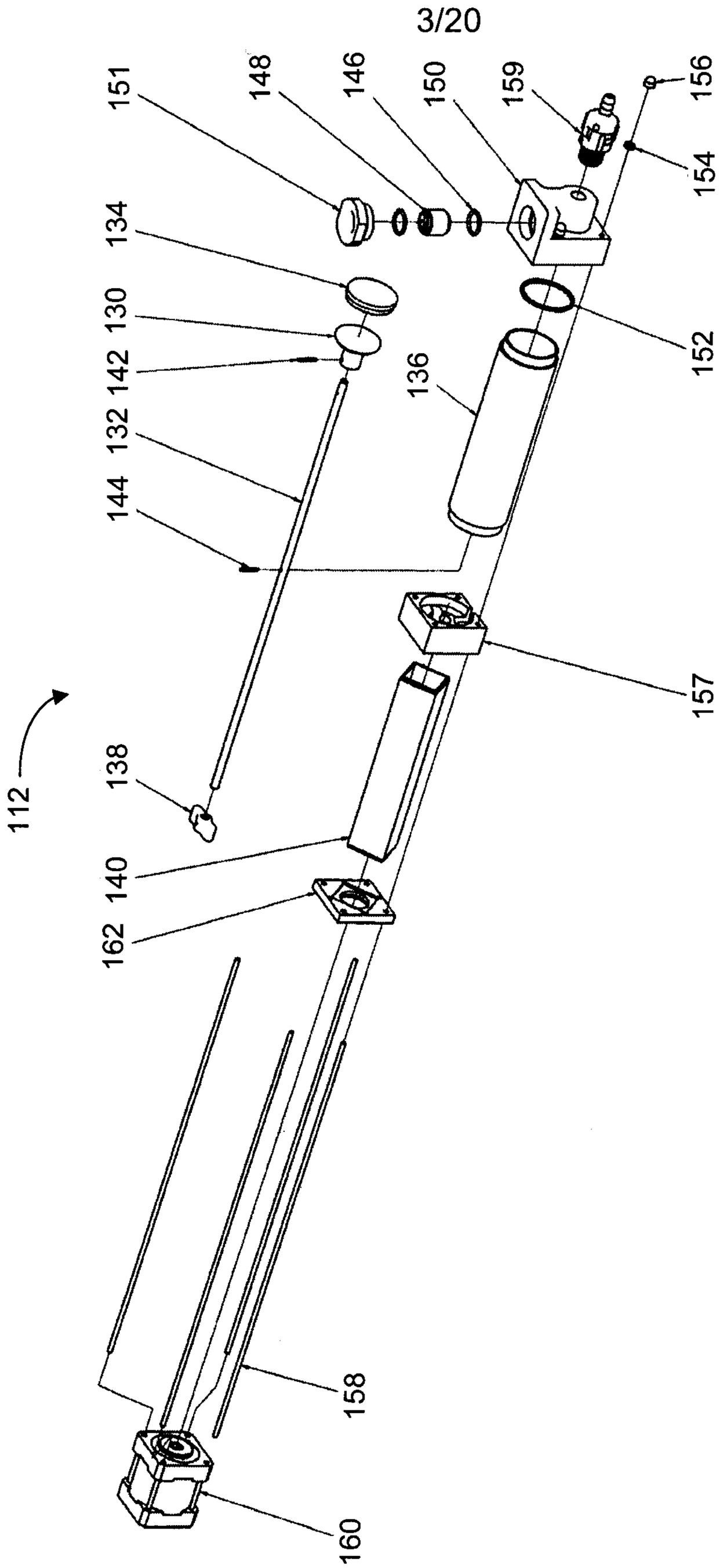

151
148
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Fig. 3

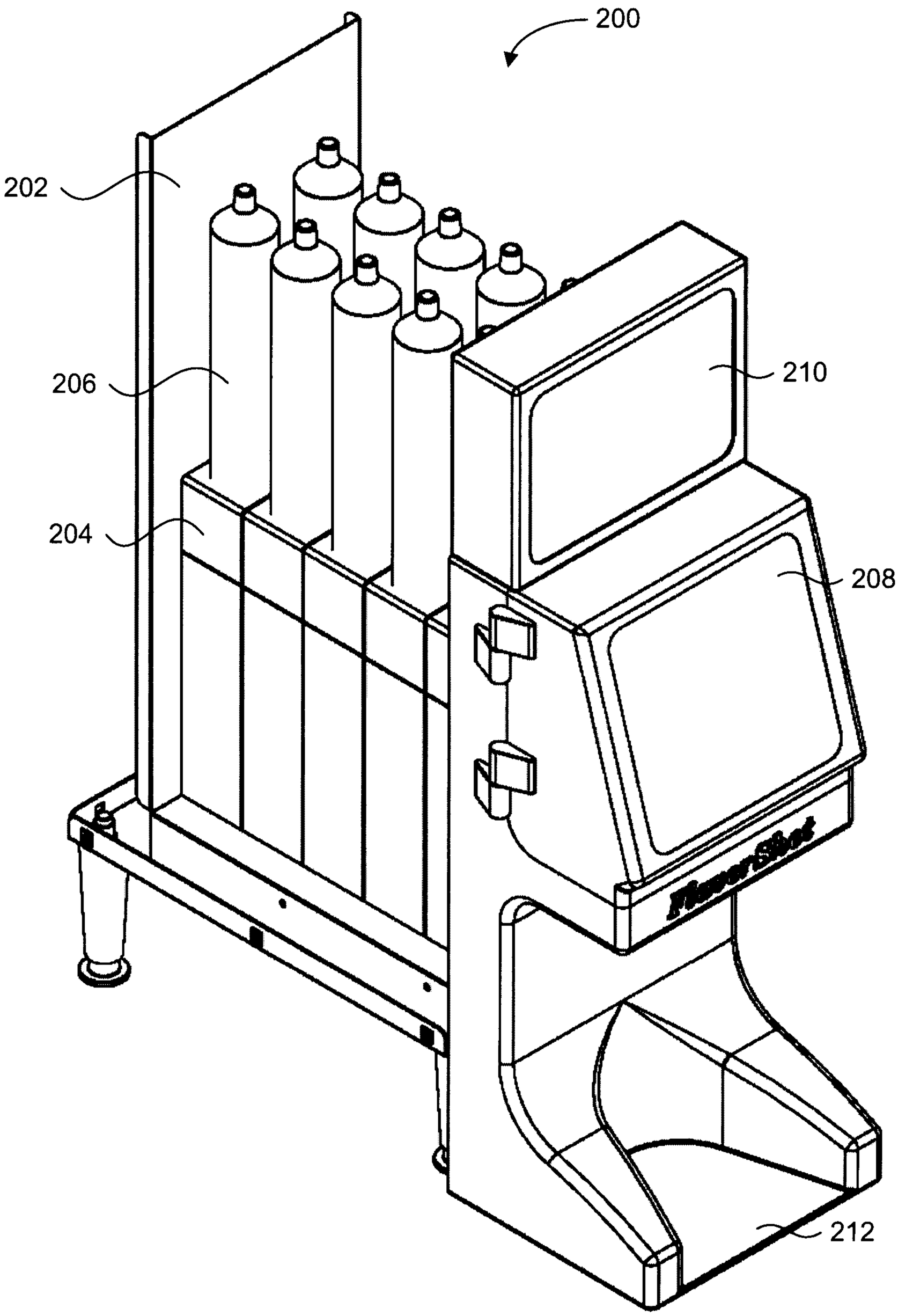


Fig. 4

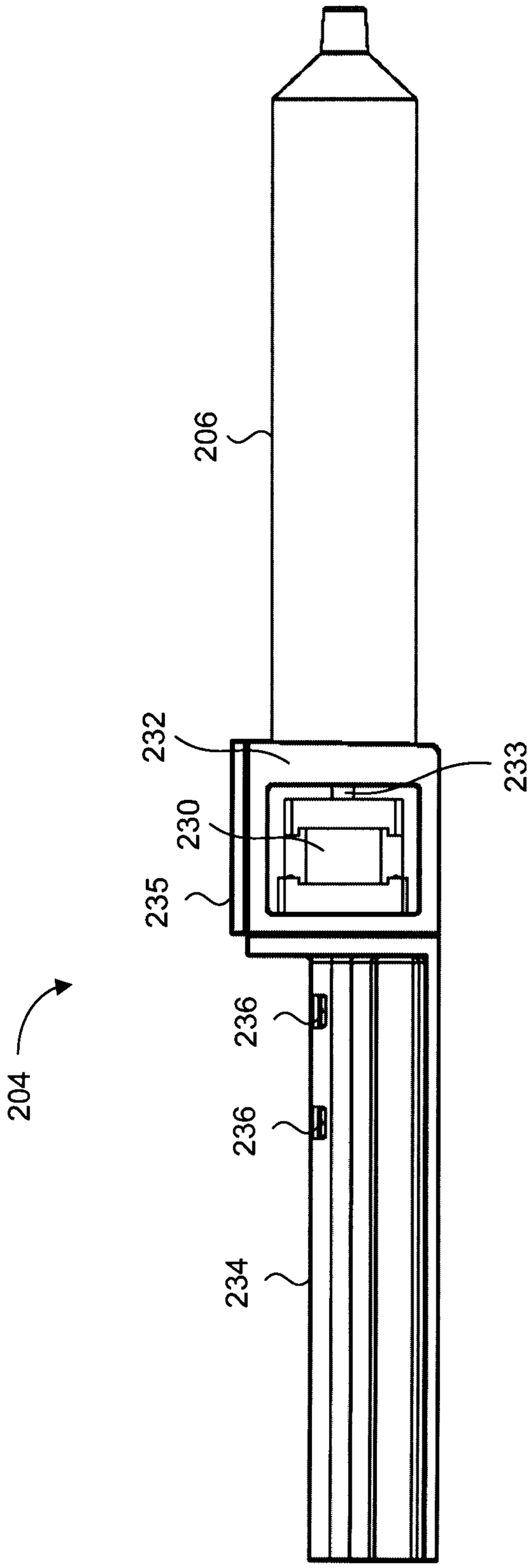


Fig. 5

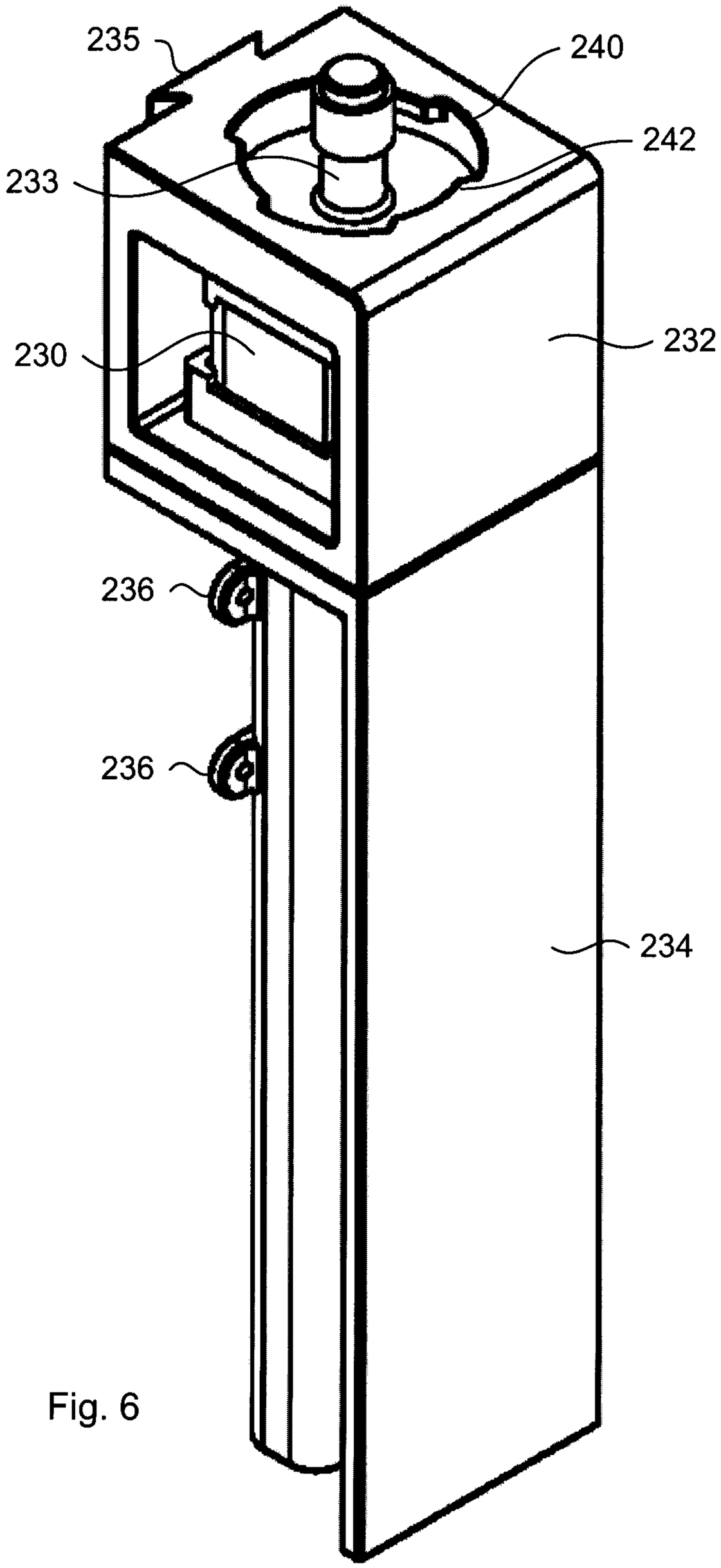


Fig. 6

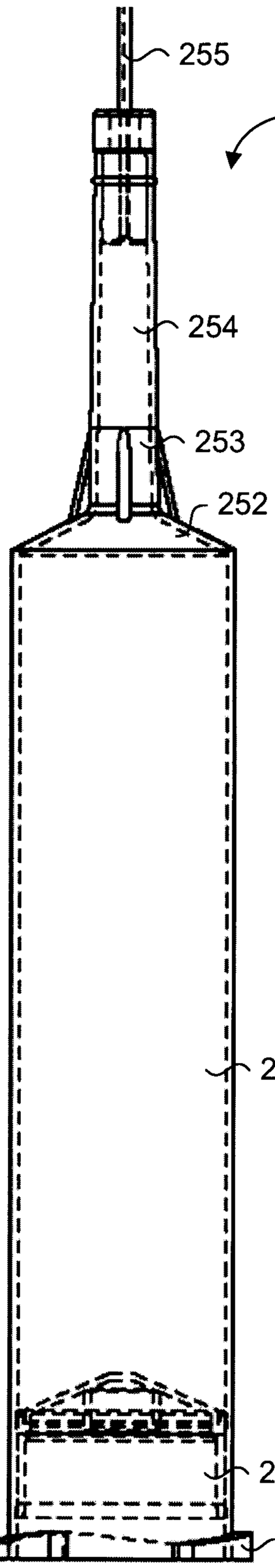


Fig. 7

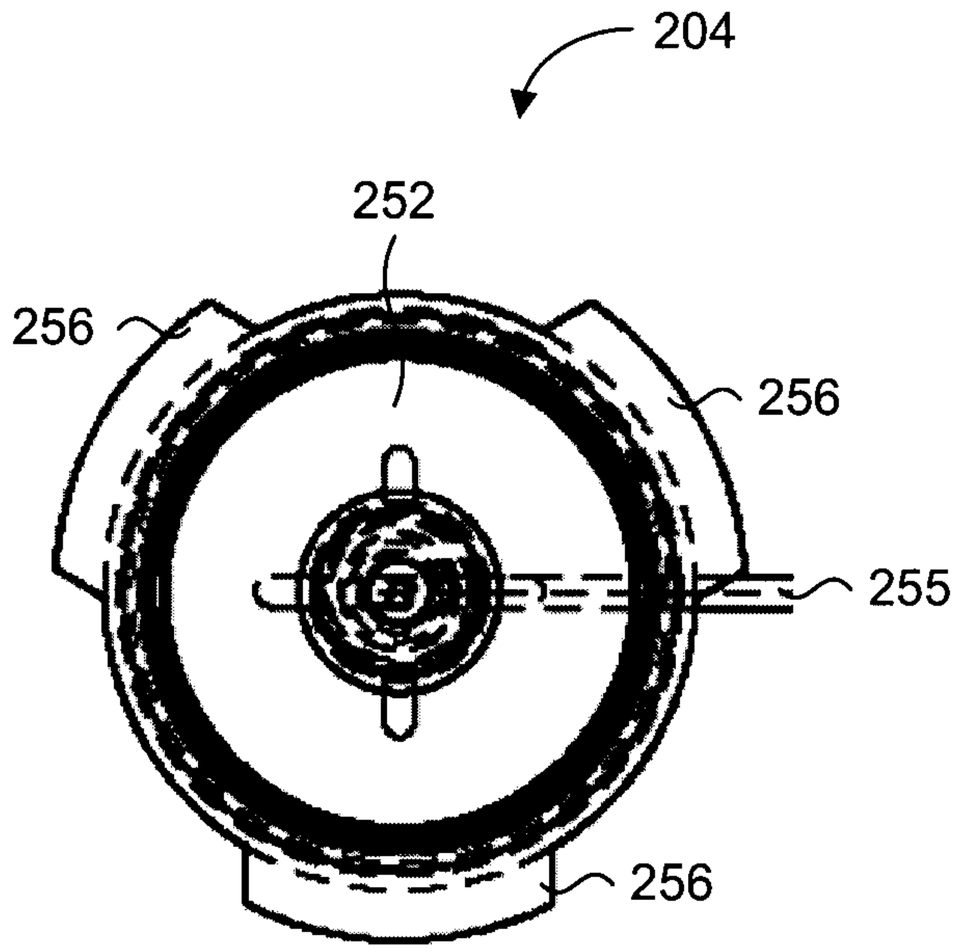


Fig. 8

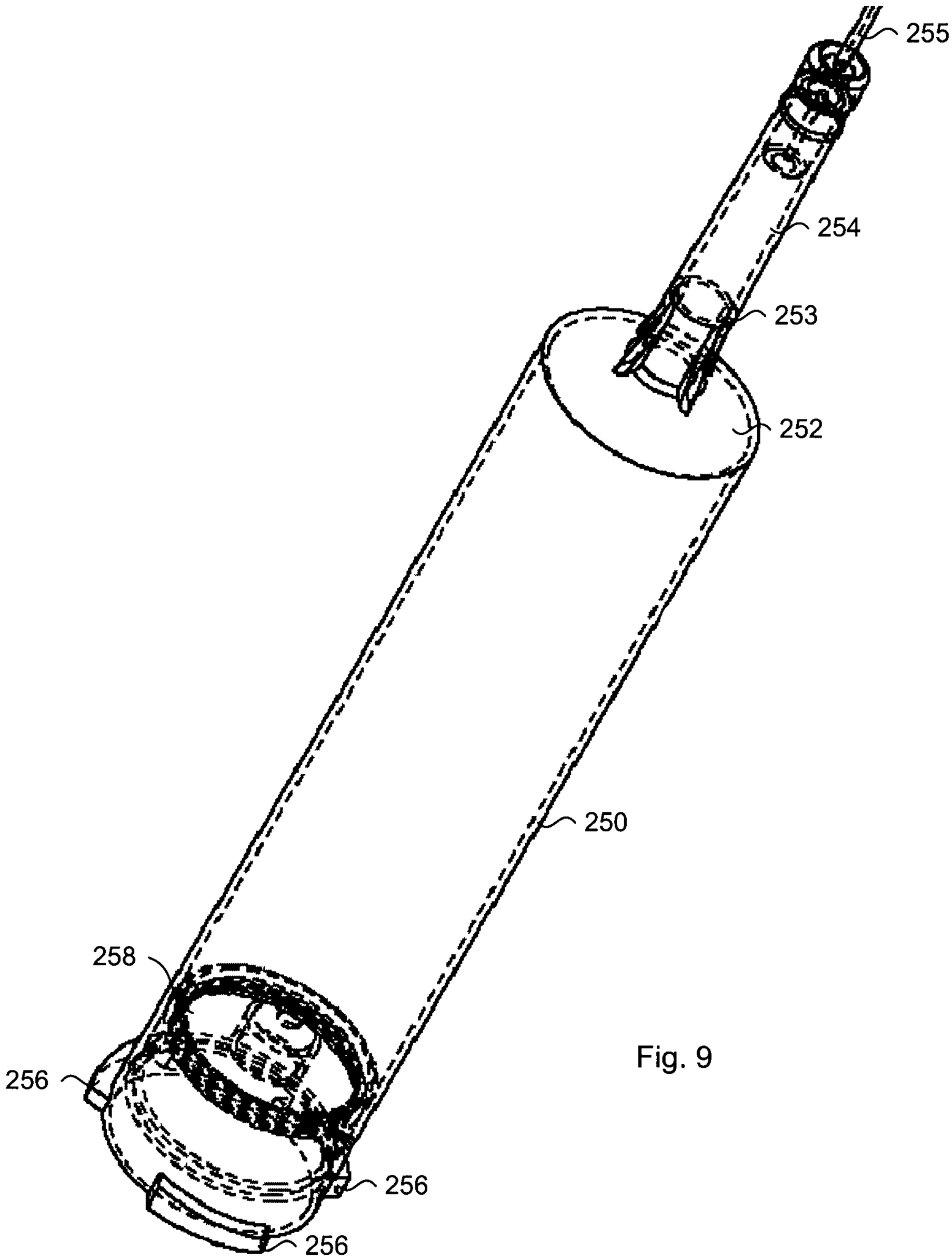


Fig. 9

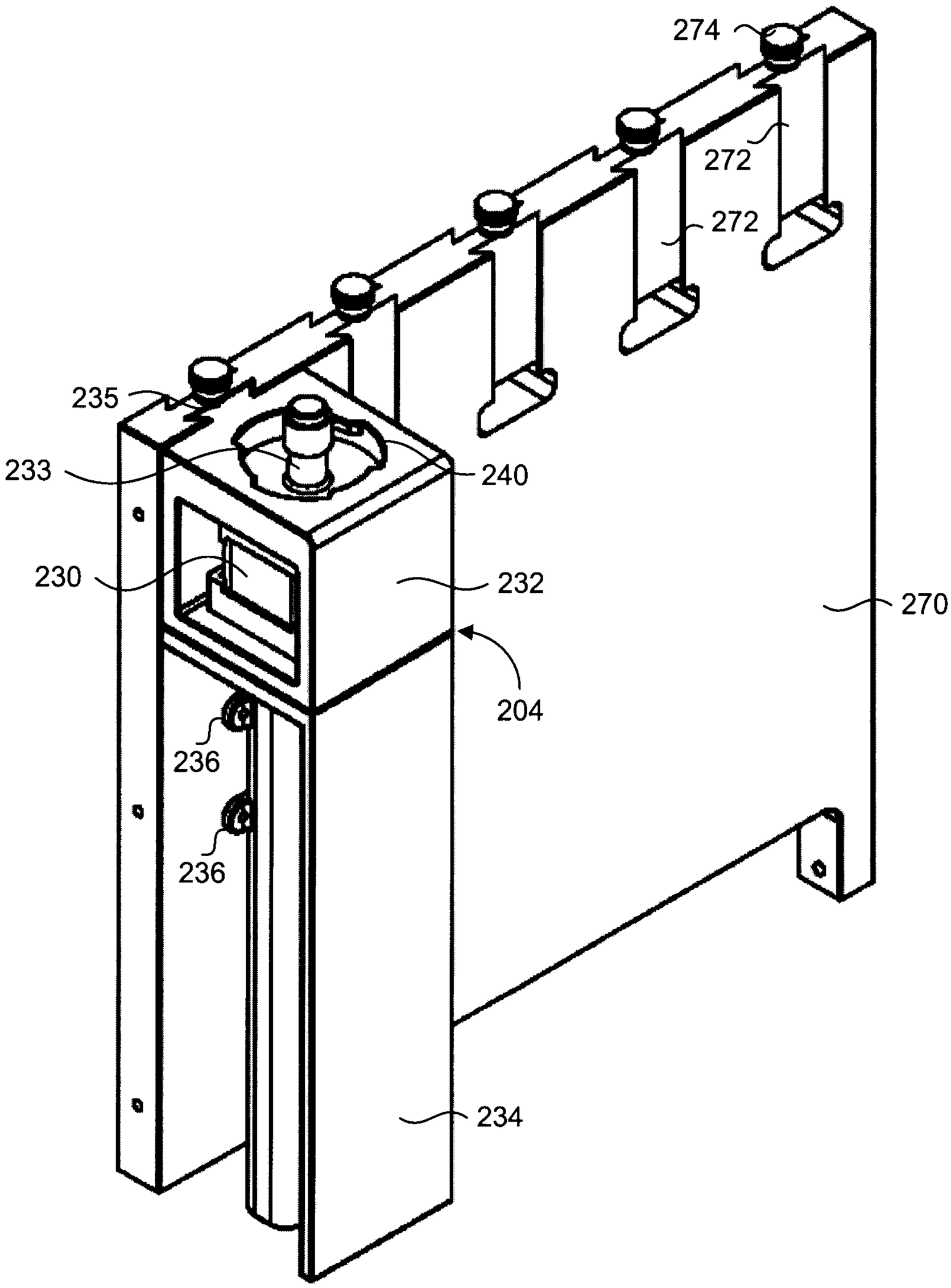


Fig. 10

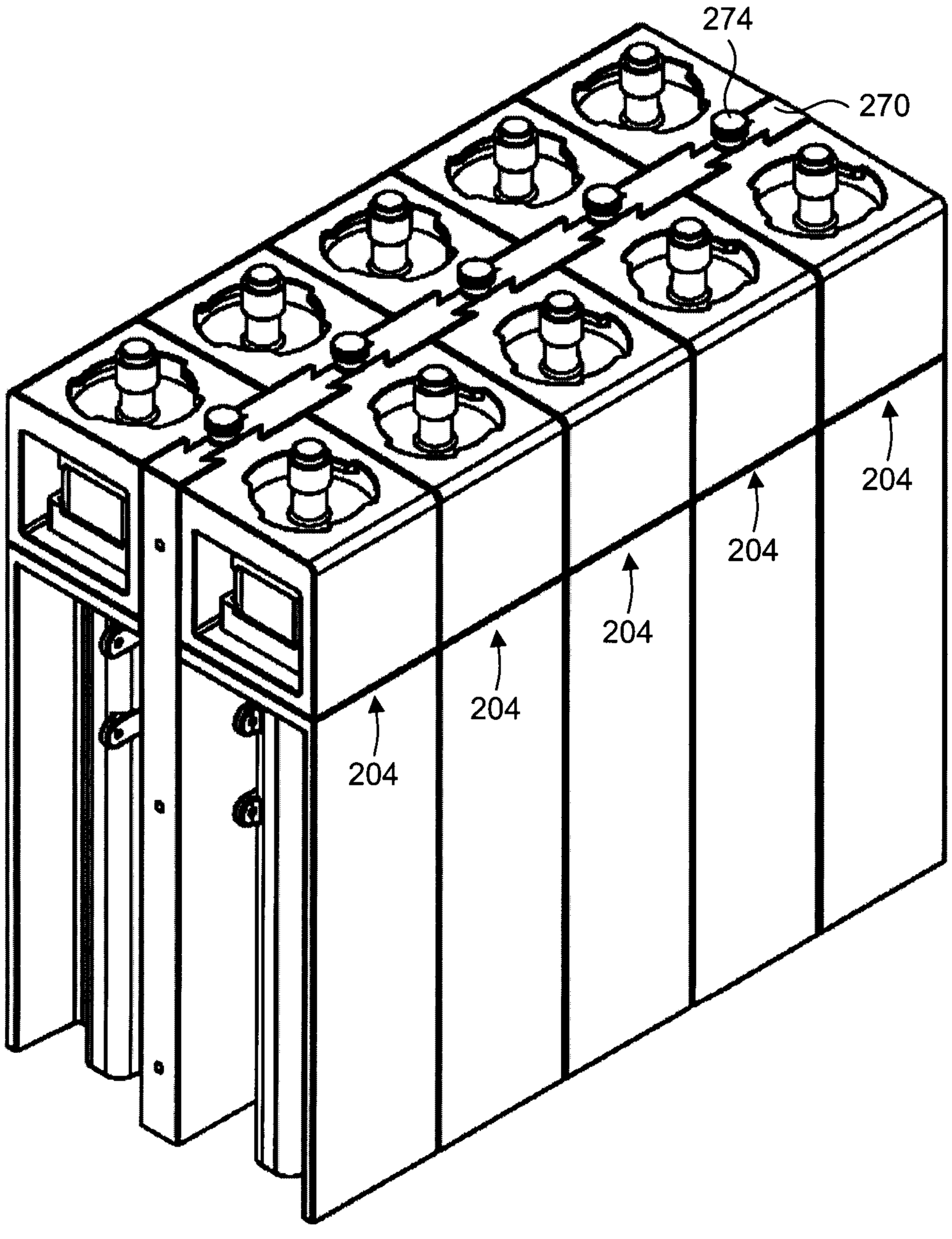


Fig. 11

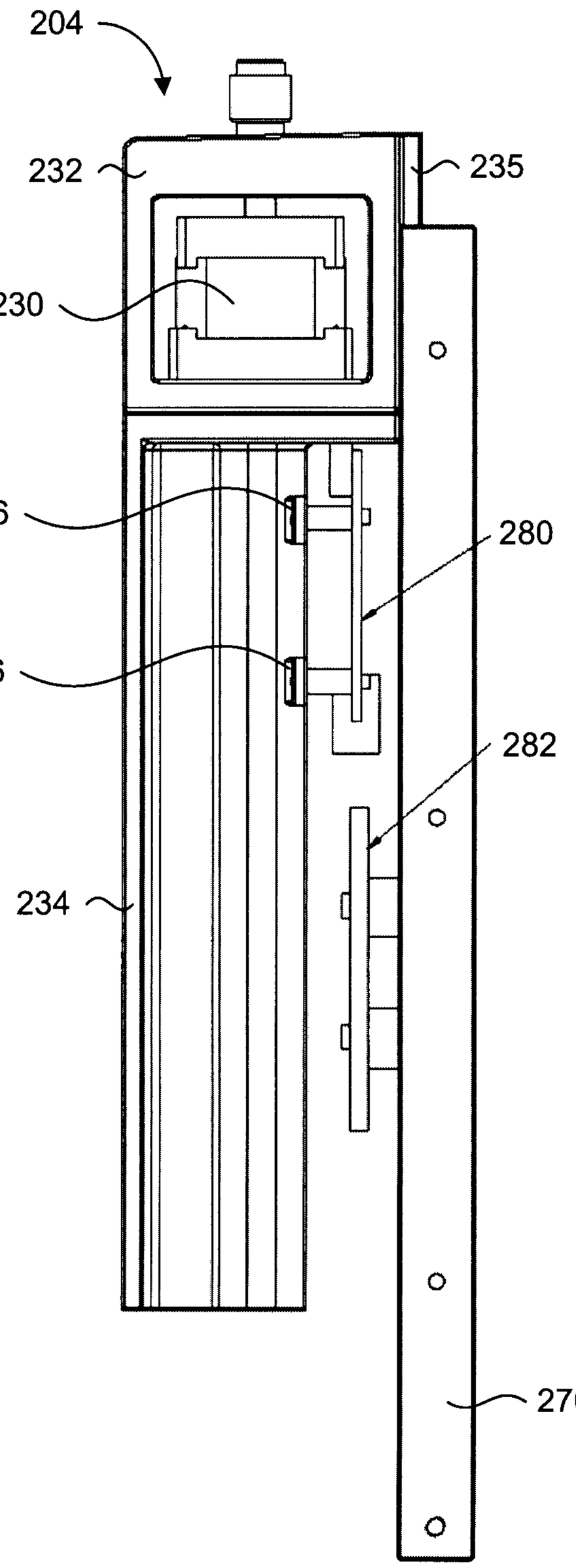


Fig. 12a

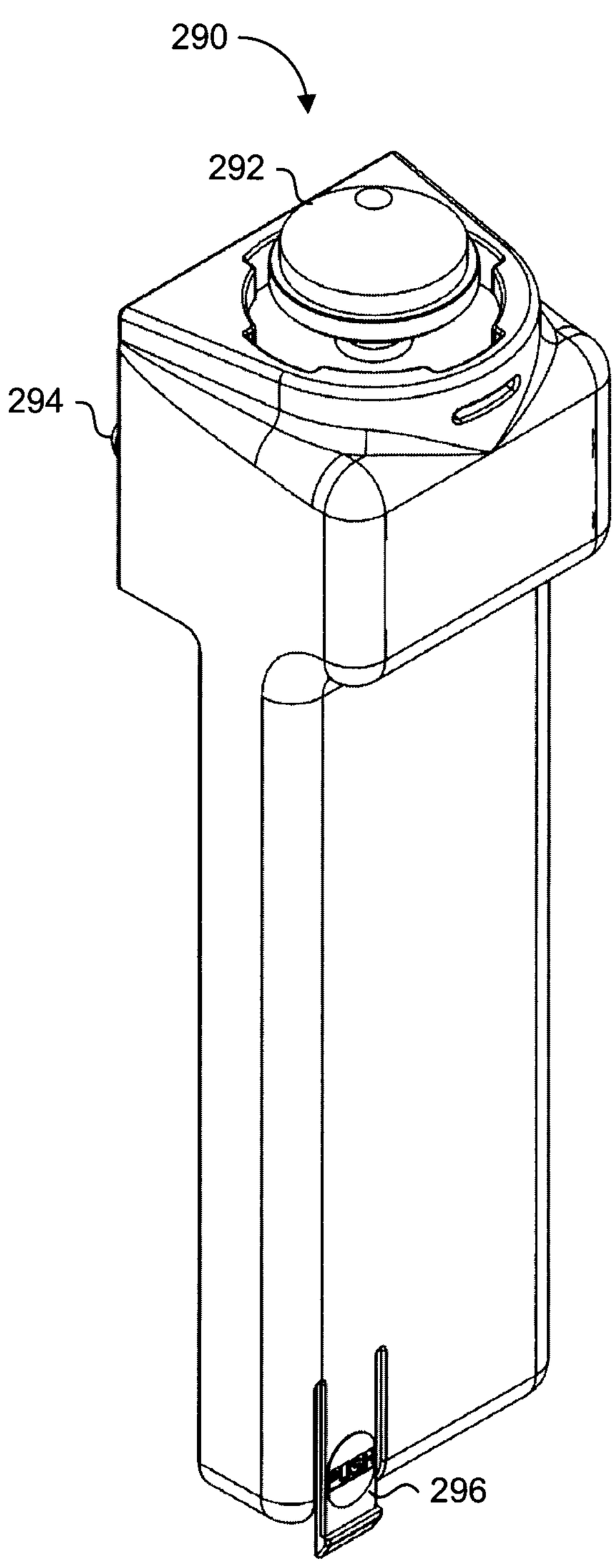


Fig. 12b

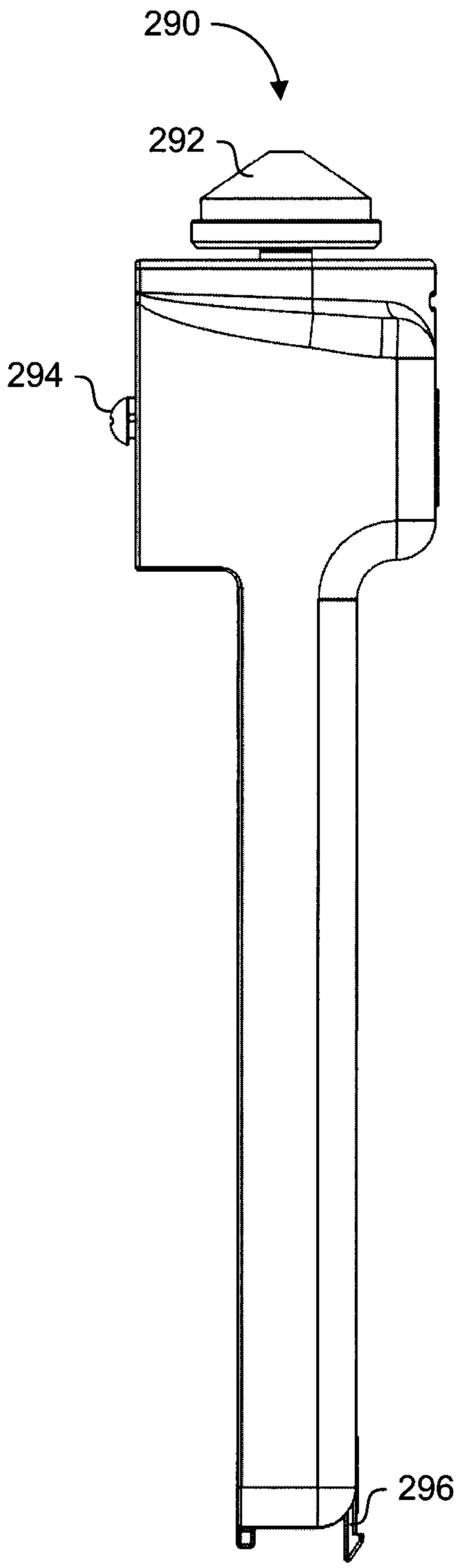


Fig. 12c

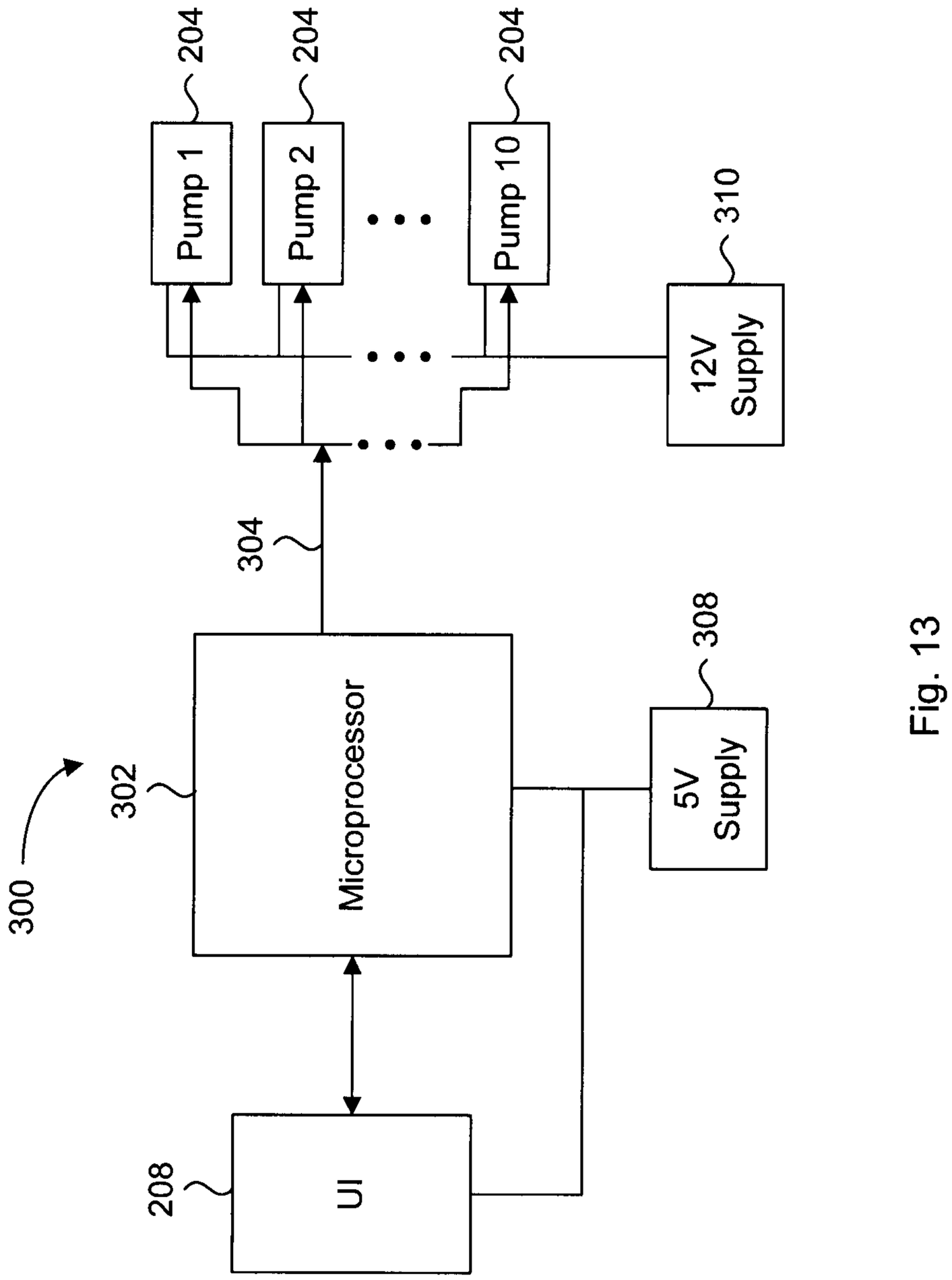

Pump 1
Pump 2
Pump 10
204
204
204
310
12V Supply
304
308
5V Supply
Microprocessor
302
300
208
UI

Fig. 13

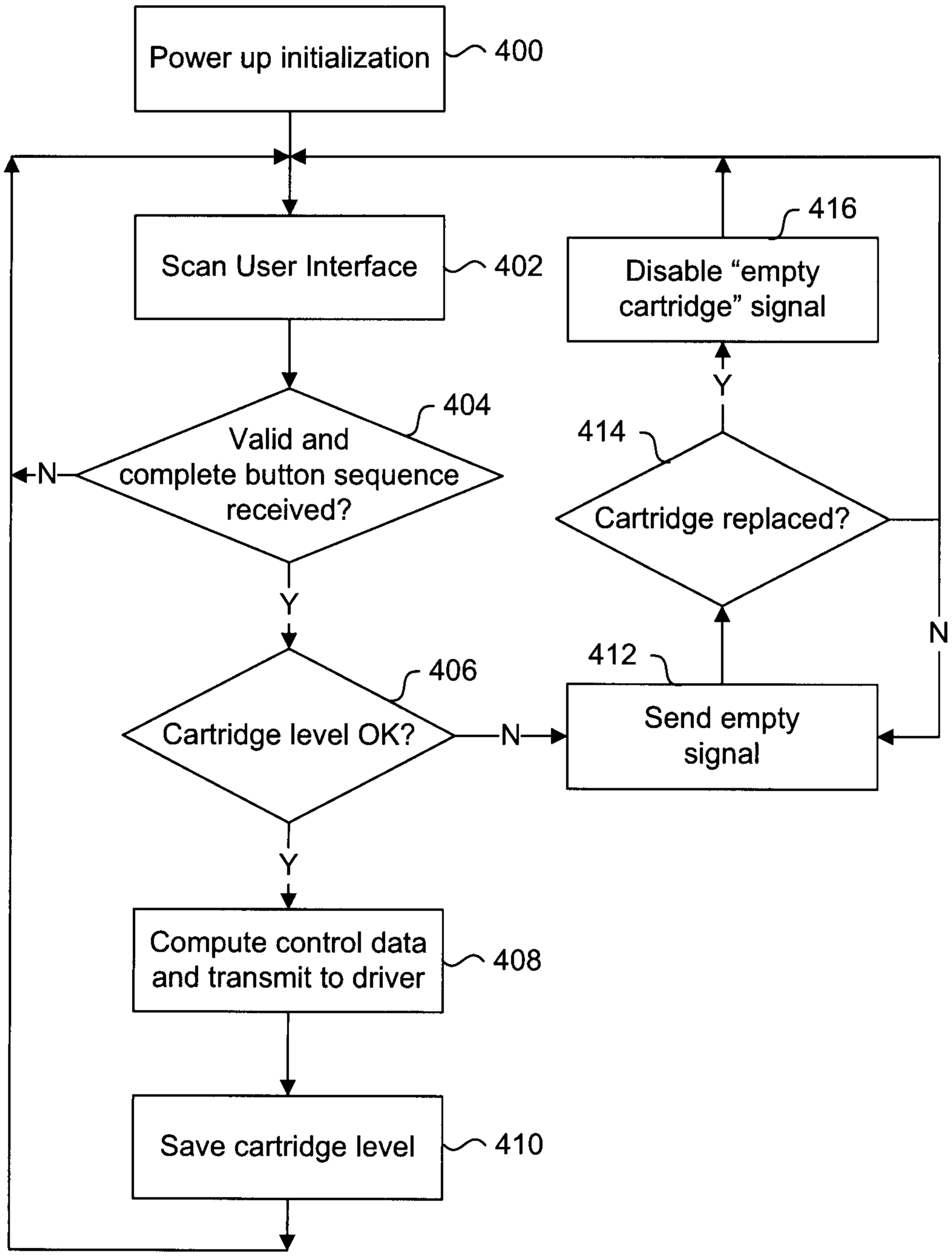

Power up initialization
400
Scan User Interface
402
Valid and complete button sequence received?
404
N
Y
Cartridge level OK?
406
N
Y
Compute control data and transmit to driver
408
Save cartridge level
410
Send empty signal
412
Cartridge replaced?
414
Y
N
Disable "empty cartridge" signal
416

Fig. 14

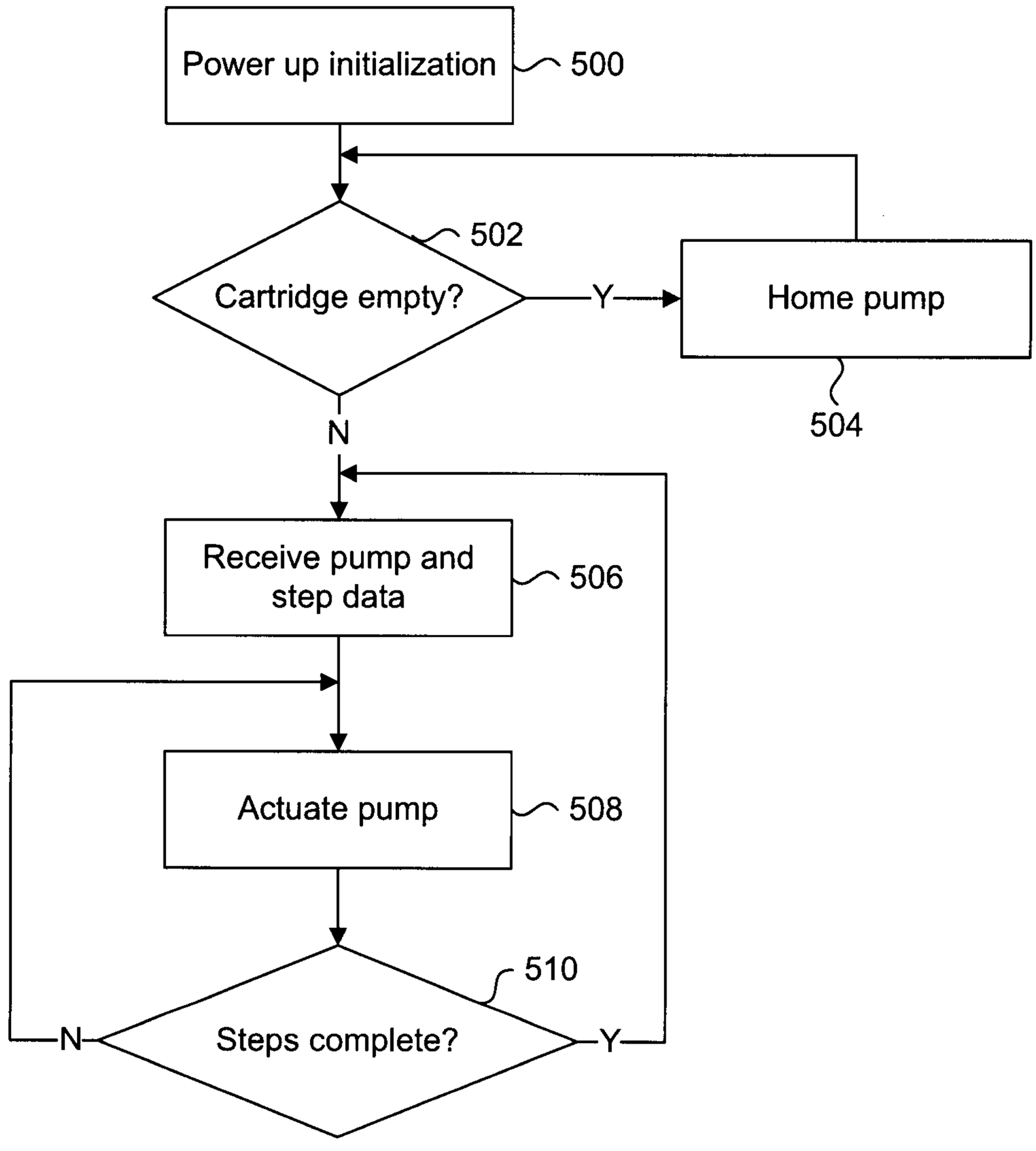

Power up initialization
500
502
Cartridge empty?
Y
Home pump
504
N
Receive pump and step data
506
Actuate pump
508
510
Steps complete?
N
Y

Fig. 15

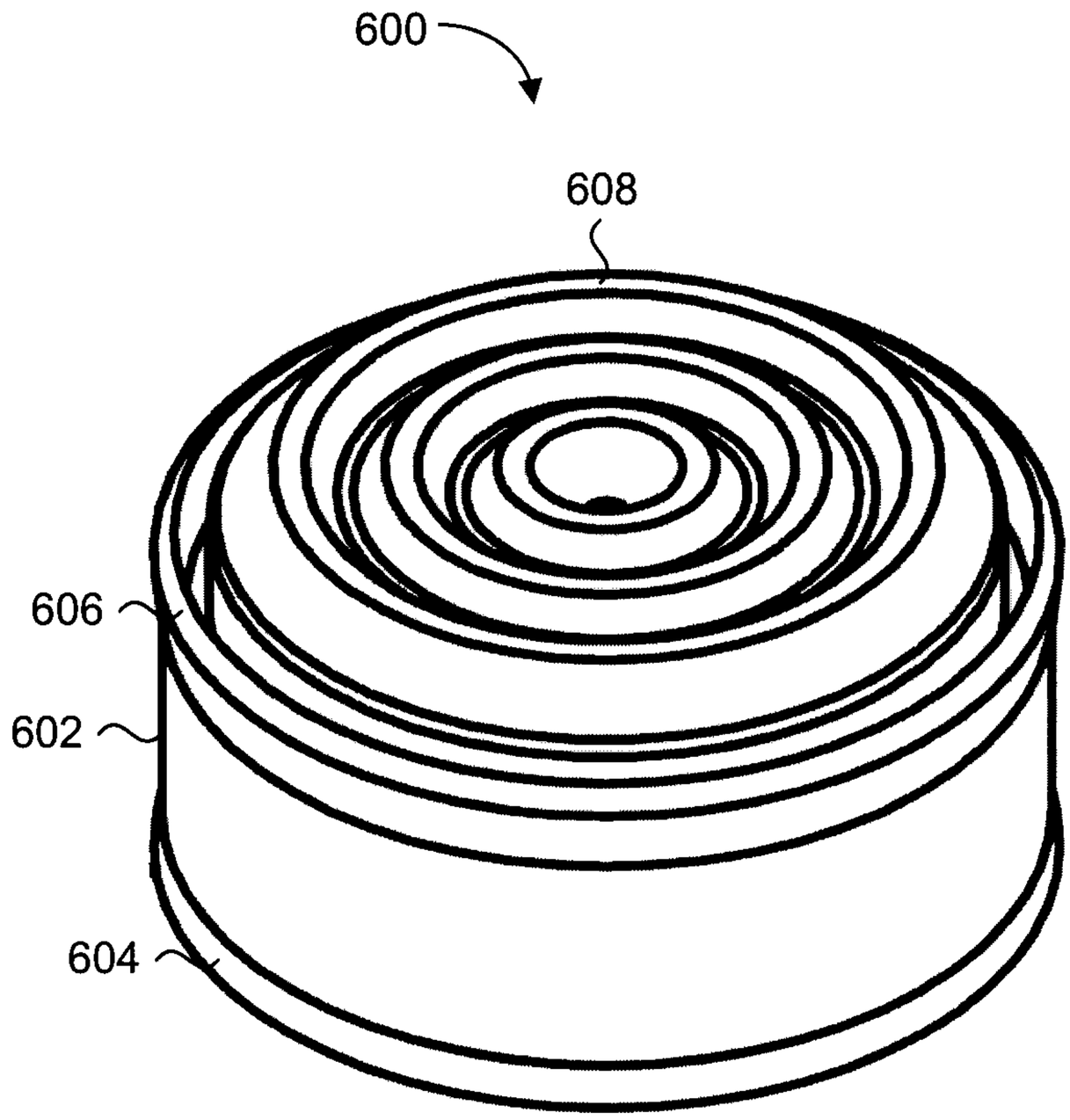


Fig. 16

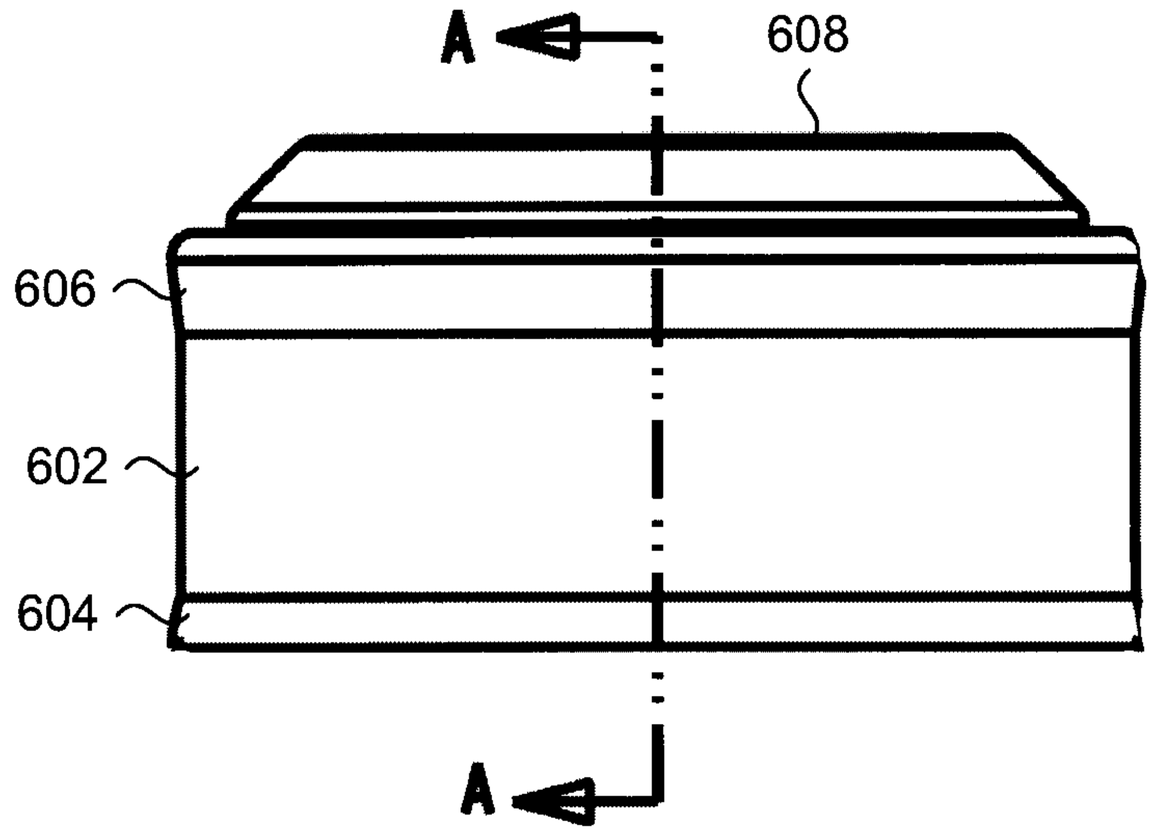


Fig. 17a

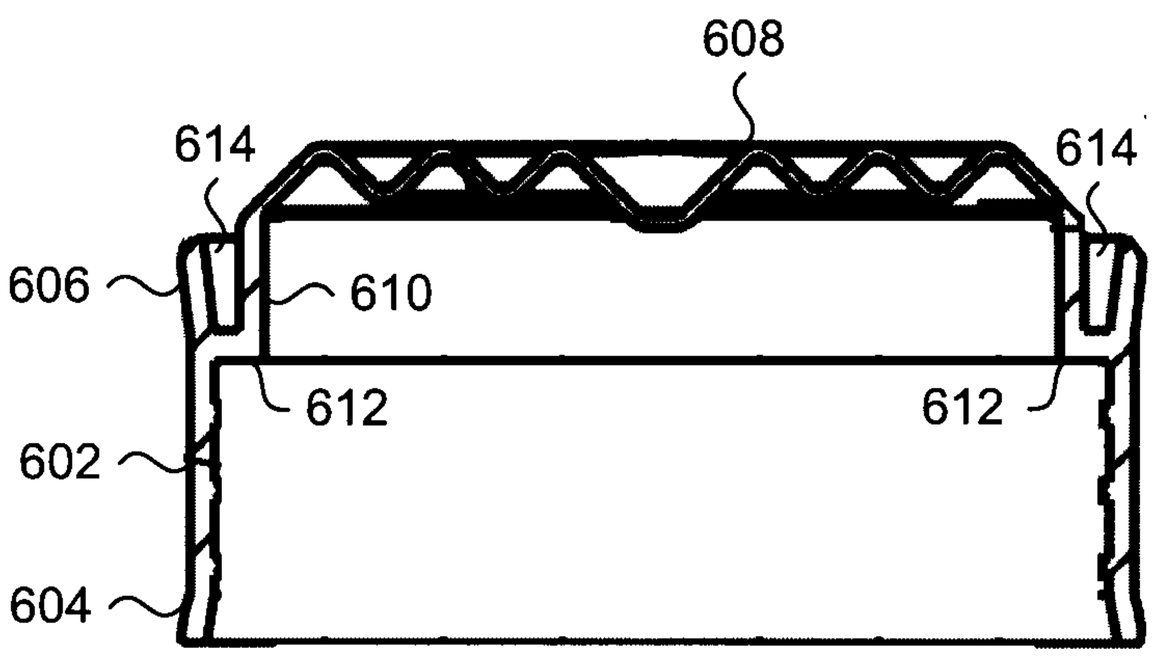


Fig. 17b

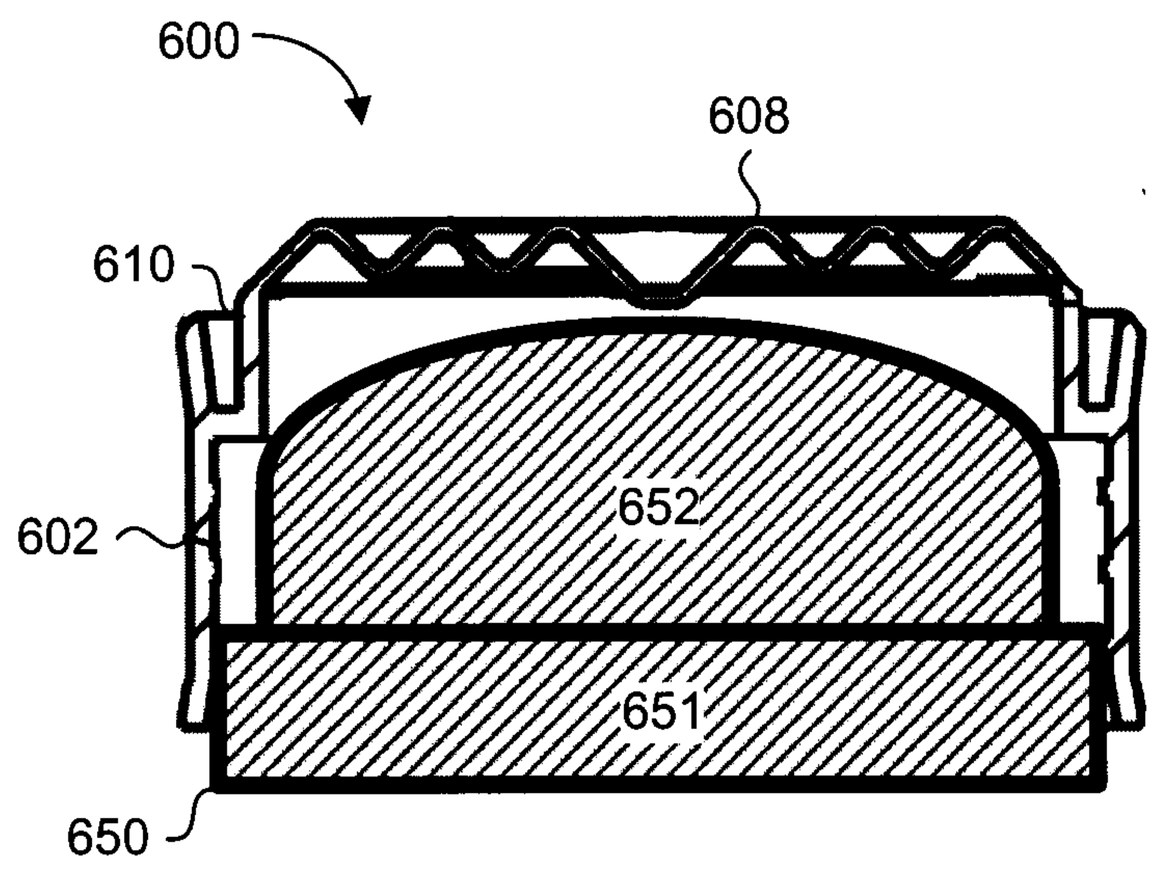


Fig. 18a

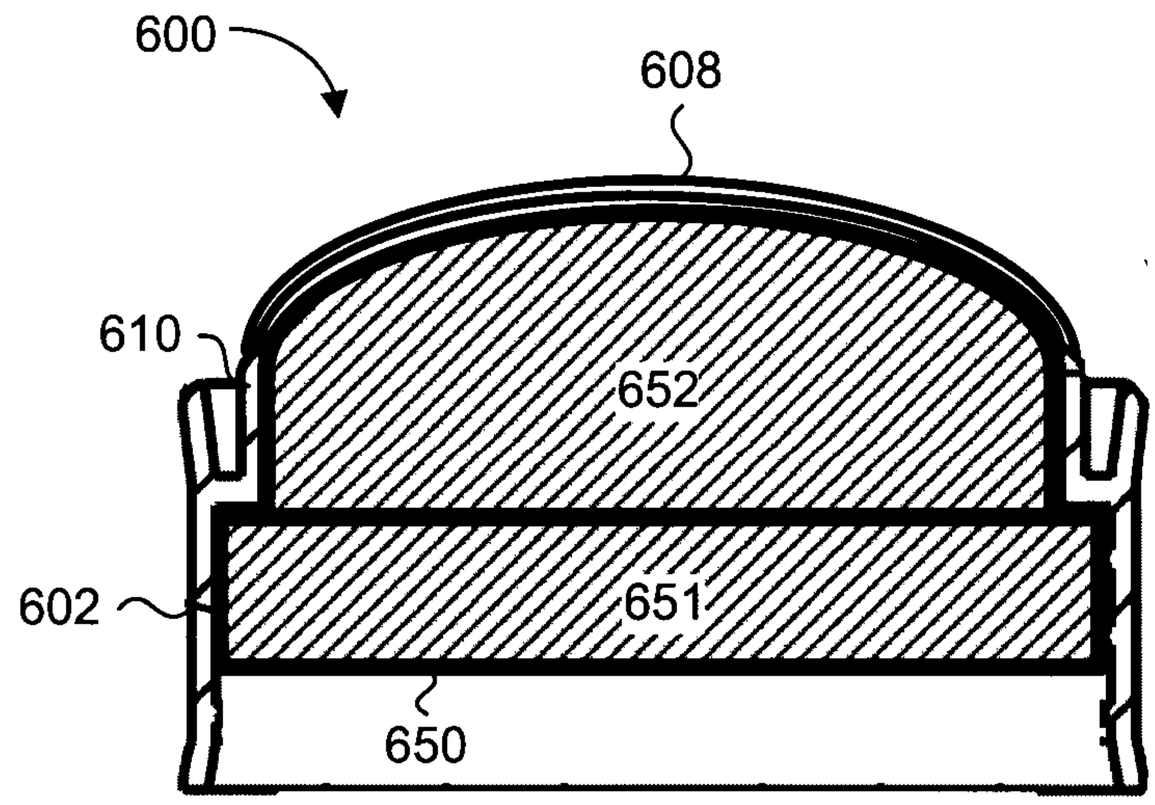


Fig. 18b

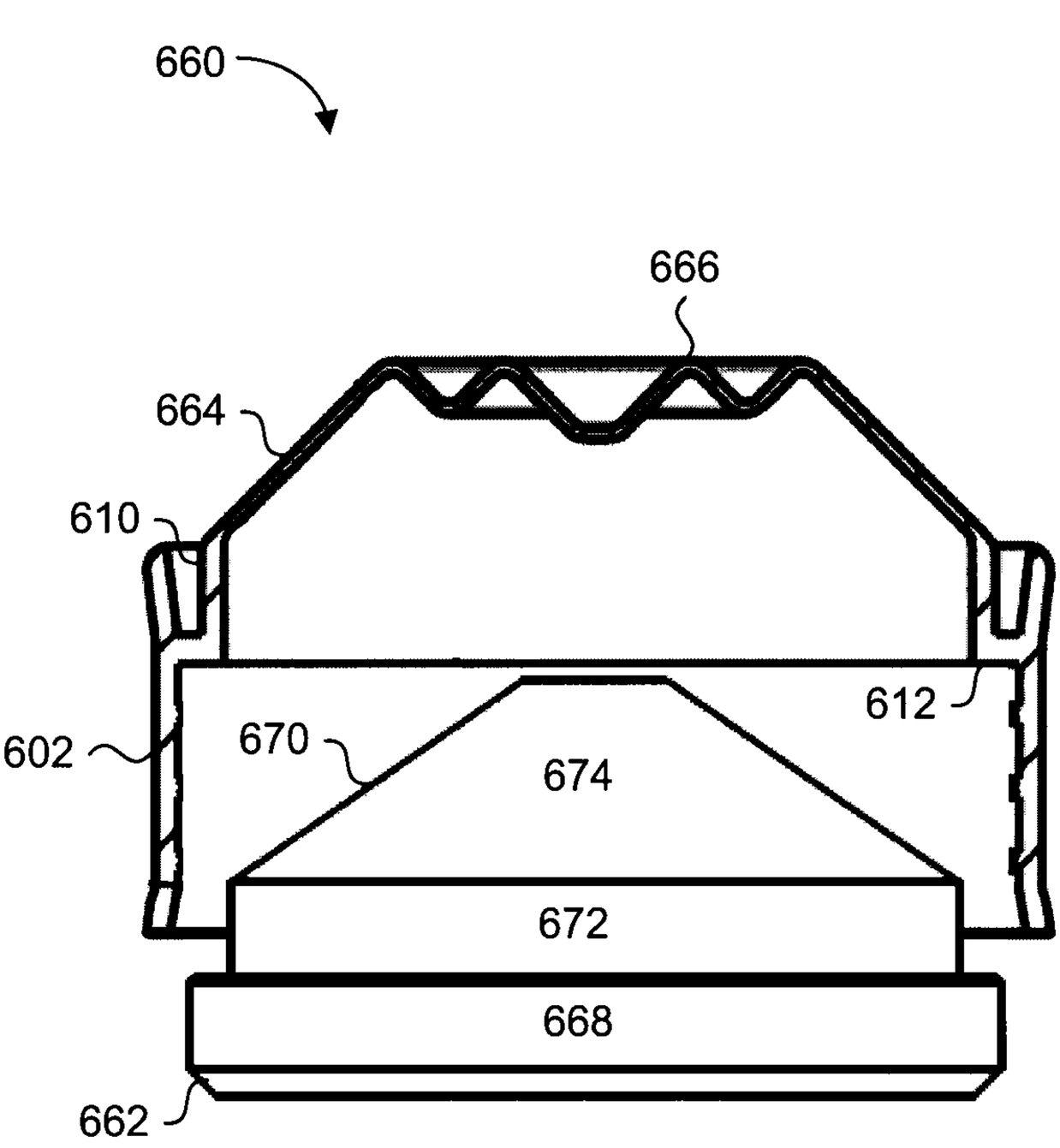


Fig. 19

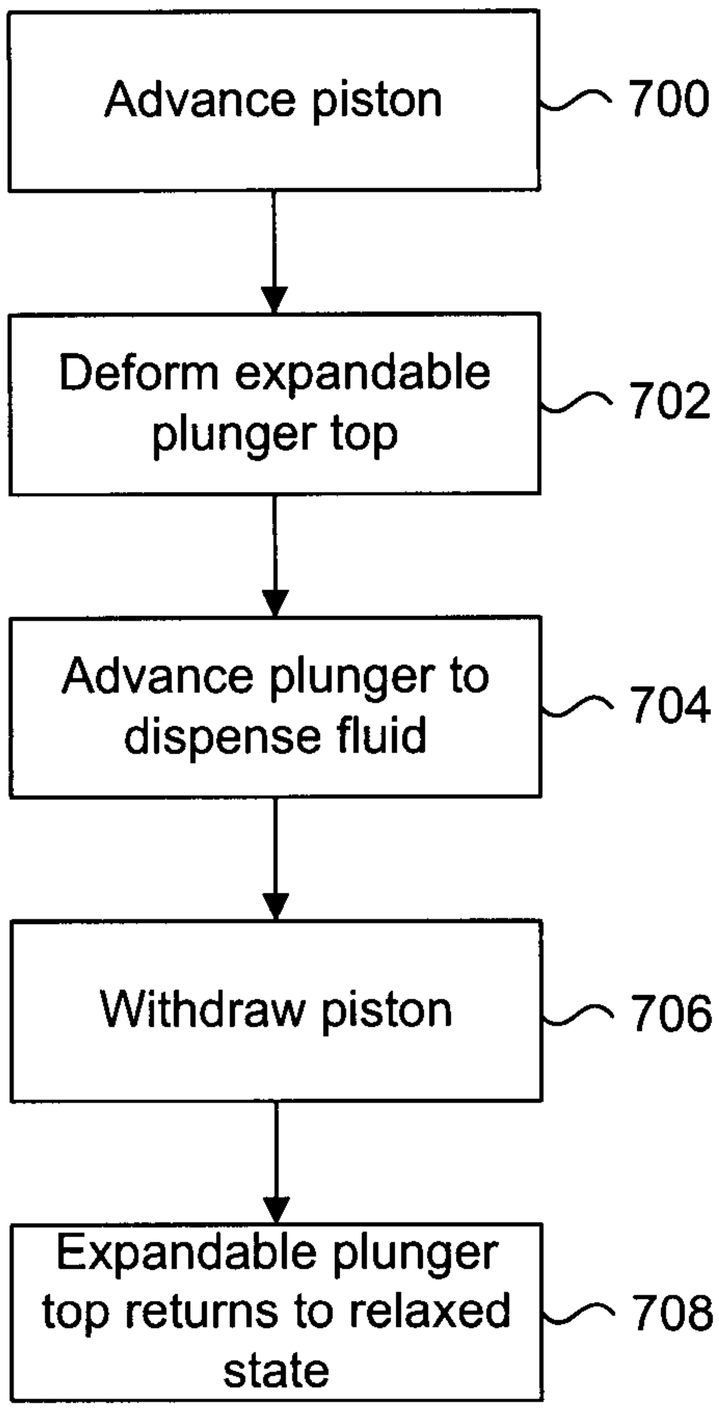
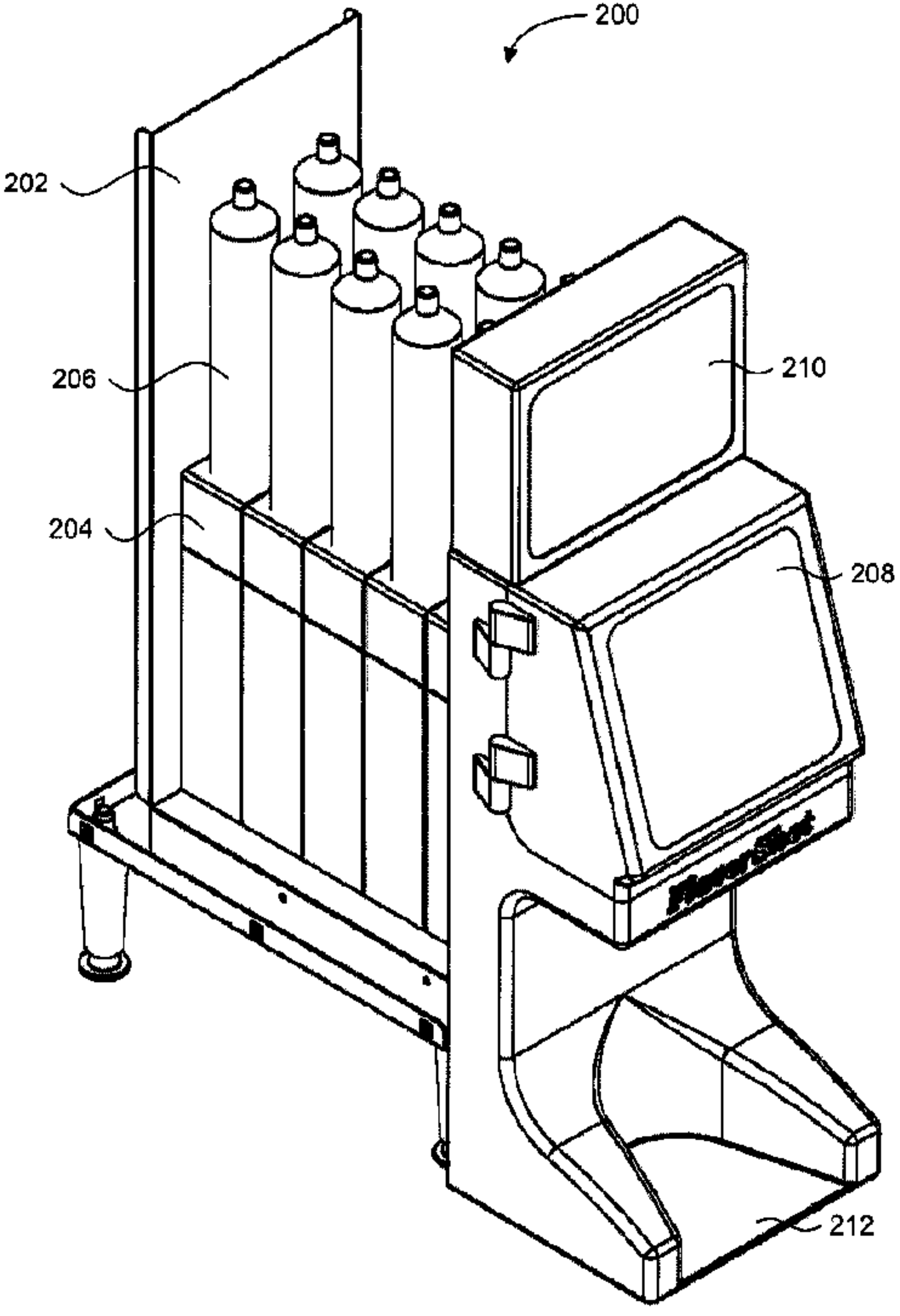

Advance piston
700
Deform expandable plunger top
702
Advance plunger to dispense fluid
704
Withdraw piston
706
Expandable plunger top returns to relaxed state
708

Fig. 20


200
202
206
204
210
208
212