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Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2829043 C 2019/09/03

(11)(21) 2 829 043

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2012/04/23
(87) Date publication PCT/PCT Publication Date: 2012/09/13
(45) Date de délivrance/Issue Date: 2019/09/03
(85) Entrée phase nationale/National Entry: 2013/09/04
(86) N° demande PCT/PCT Application No.: IB 2012/052044
(87) N° publication PCT/PCT Publication No.: 2012/120487
(30) Priorité/Priority: 2011/04/22 (US61/478,460)

(51) Cl.Int./Int.Cl. *A61M 11/00* (2006.01), *A24F 47/00* (2006.01), *A61M 15/06* (2006.01), *A61M 16/10* (2006.01)

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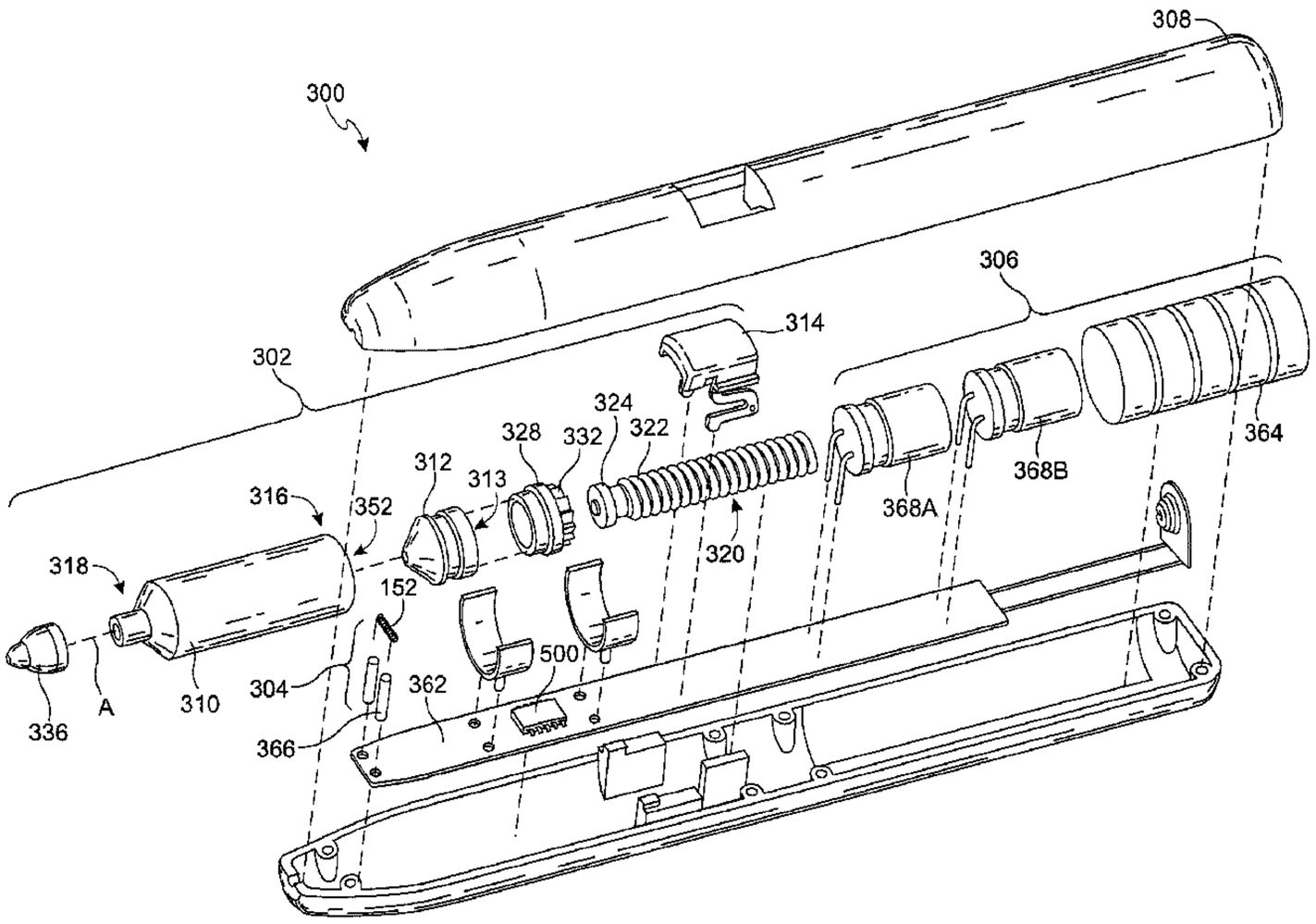
(54) Titre : SYSTEME D'ADMINISTRATION DE MEDICAMENT
(54) Title: MEDICANT DELIVERY SYSTEM



(57) Abrégé/Abstract:
An improved medicant delivery system 100 is disclosed wherein the carrier for the medicant is a fluid that can be atomized or vaporized by exposure to heat. The system provides for repeatable dose of medicant, can be stored in any orientation, and/or has an ability to maximize energy efficiency.

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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 September 2012 (13.09.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/120487 A3

(51) International Patent Classification:
A61M 11/00 (2006.01) *A61M 15/06* (2006.01)
A61M 11/02 (2006.01) *A61M 16/10* (2006.01)
A61M 11/04 (2006.01) *A61M 16/16* (2006.01)

(21) International Application Number:
PCT/IB2012/052044

(22) International Filing Date:
23 April 2012 (23.04.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/044,355 9 March 2011 (09.03.2011) US
61/478,460 22 April 2011 (22.04.2011) US

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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, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,

[Continued on next page]

(54) Title: MEDICANT DELIVERY SYSTEM

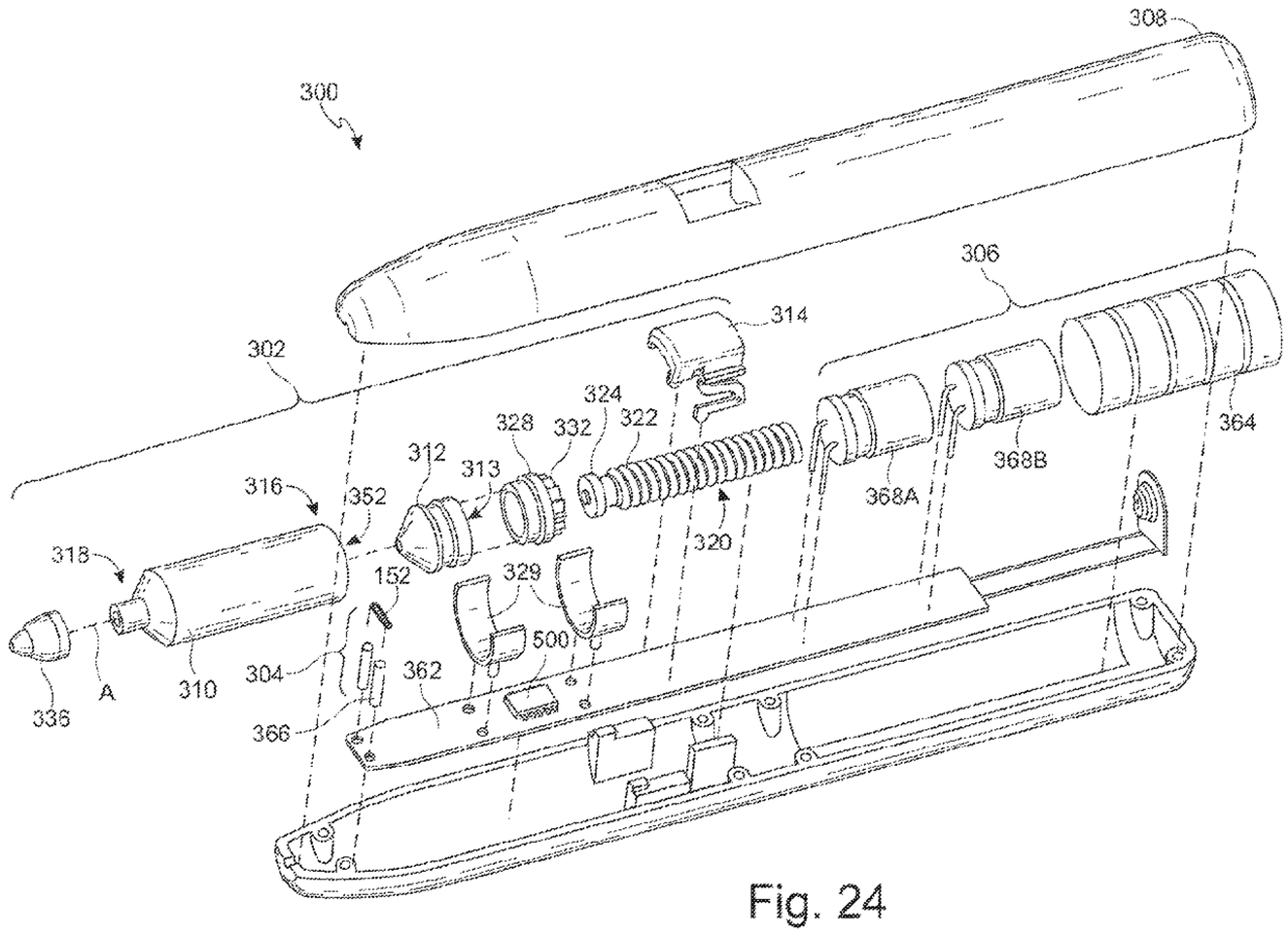

Fig. 24

(57) Abstract: An improved medicant delivery system 100 is disclosed wherein the carrier for the medicant is a fluid that can be atomized or vaporized by exposure to heat. The system provides for repeatable dose of medicant, can be stored in any orientation, and/or has an ability to maximize energy efficiency.

WO 2012/120487 A3

WO 2012/120487 A3

LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

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

— *with information concerning request for restoration of the right of priority in respect of one or more priority claims (Rules 26bis.3 and 48.2(b)(vii))*

(88) Date of publication of the international search report:
17 January 2013

(15) Information about Correction:

Previous Correction:
see Notice of 29 November 2012

MEDICANT DELIVERY SYSTEM

TECHNICAL FIELD

[0001] This invention relates to devices and methods for vaporizing a liquid for inhalation. More specifically, the invention relates to providing a device and method for controlling, metering and measuring precise volumes of fluid vaporized and the vapor produced by a hand-held vaporizing device each time the device is engaged by its user that is reliable and safer to use than current devices relying on lithium ion chemistry.

BACKGROUND

[0002] Various hand-held, personal vaporizing devices are currently available. Some of these have been specifically designed to produce a nicotine-infused vapor for the purpose of serving, as an alternative to smoking, a traditional tobacco cigarette wherein the tobacco is ignited and the user inhales the smoke and its constituents- including the nicotine-a naturally occurring constituent of tobacco. Devices used for the purpose of cigarette alternatives produce a vapor devoid of most of the 4000+ chemicals and byproducts of tobacco smoke and, therefore, deliver nicotine to the user, through ingestion of the vapor, without most of the harm normally associated with tobacco smoke.

[0003] Unfortunately, disadvantages still remain in the design and performance of these vaporizing devices. For example, some devices are bulky or cumbersome to use as a transportable, hand-held device.

[0004] Other vaporizing devices are incapable of delivering precise, consistent, and reliable metered doses of the medicant. Current electronic atomization cigarettes do not provide for a method to control the consistency of the volume of liquid vaporized nor the

volume of vapor produced and, as a result, cannot produce a measurable amount of nicotine on a per vaporization basis. There are certain circumstances and situations, including those where regulations might dictate, where it may well be required that these devices be capable of delivering vapor and its nicotine constituent in a manner that enables the amount of nicotine present in the vapor be measurable and consistently repeated with each and every engagement by the user. In addition to or in lieu of nicotine, a vaporizer might be used to deliver other substances to the user, including medicants. Similarly, a precise measured "dose" may be desired, or even required for these substances.

[0005] In addition, because some of the devices on the market use a liquid storage unit that is "open" to the atmosphere, some devices leak or fail to perform reliably unless the vaporizing device is maintained in an upright position during use, or during the packaging, shipping, and storage of the device. Furthermore, with such devices, the liquid may be subject to contamination, adulteration and/or evaporation under certain conditions.

[0006] Finally, most, if not all, current commercially available products use lithium chemistry batteries as their power source. This is primarily due to three factors: 1) the useful life of the battery; 2) the power needed to vaporize the fluid; and, 3) the requirement for a small compact device roughly the size of traditional tobacco products- i.e. cigarettes and cigars, or in non-tobacco or nicotine formulations, the need for compactness in order to be discretely employed by the user in circumstances where discretion is appropriate. Lithium chemistry batteries, however, are volatile, hazardous (both in that they can release noxious vapors as well as potential for explosion under certain conditions) and environmentally challenging with respect to storage, reliability, and disposability.

[0007] It is anticipated that the lithium chemistry power source of hand-held portable devices will become an issue for U.S. regulators, distributors, retailers, and

consumers as the current product gets more widely distributed and used and as more uses for the devices are identified, manufactured, distributed, sold and consumed.

[0008] Therefore, there is still a need for a device and method for providing an improved hand-held vapor delivery system that reliably and consistently produces a repeatable metered dose of a medicant in a safe, efficient, and effective manner.

SUMMARY

[0009] In one aspect, a method and device for improving hand-held vapor delivery devices to generate reliable, consistent, repeatable metered doses of a medicament or medicant comprises a power control system utilizing an integrated circuit capable of determining and delivering the precise amount of power for the precise duration of time that is just enough to completely vaporize a predetermined volume of a liquid.

[0010] In another aspect, the method and device for an improved hand-held vapor delivery device may comprise a fluid delivery system, a vaporizing or atomizing system, and a power control system contained in a housing, wherein the fluid delivery system consistently, repeatably, and reliably delivers a precise metered dose to the atomizing system, and the power delivery system supplies just enough electrical power to the atomizing system to completely atomize or vaporize the exact volume of liquid delivered to the atomizing system.

[0011] In another aspect, the hand-held vapor delivery device has an ability to operate independent of orientation, and/or an ability to deliver a repeatable dose of medicant, and/or an ability to be stored in any orientation, and/or an ability to maximize energy efficiency.

[0012] In another aspect, the invention provides a device and method that enables vapor

delivery devices to use more stable, more reliable, less environmentally hazardous, and safer sources of battery chemistry without significantly affecting the portability and discreteness of the devices.

BRIEF DESCRIPTION OF DRAWINGS

[0013] Figure 1 is a perspective view of an embodiment of a medicant delivery device of the present invention.

[0014] Figure 2 is a top view of the device shown in Figure 1.

[0015] Figure 3 is a section view taken along line 3-3 of Figure 2.

[0016] Figure 4 is an enlarged detail section view of the upper section of the device shown in Figure 3.

[0017] Figure 5 is an exploded perspective view of the device shown in Figures 1-4.

[0018] Figure 6 is an enlarge perspective view of elements of the device shown in Figures 3-5.

[0019] Figure 7 is a perspective view of another embodiment of the present invention with the housing removed for purpose of illustration.

[0020] Figure 8 is an exploded perspective view of the embodiment shown in Figure 7.

[0021] Figure 9 is an enlarged side view showing details of elements shown in Figures 7 and 8.

[0022] Figures 10-13 are side views of the device shown in Figures 7-9 illustrating sequential steps of operation.

[0023] Figure 14 is an enlarged perspective view of the vaporizing system shown in Figures 7-9.

[0024] Figure 15 is a schematic diagram of a "one-shot" circuit that may be used in an embodiment of the power control system of the present invention.

[0025] Figure 16 and Figure 17 are schematic diagrams of similar modified circuits that may be used in an embodiment of the power control system.

[0026] Figure 18 is an enlarged side view of an embodiment of a vaporizing element.

[0027] Figure 19 is a perspective view of another embodiment of the vaporizing device.

[0028] Figure 20 is a section view of the vaporizing device shown in Figure 19.

[0029] Figure 21 is an exploded perspective view of the vaporizing device shown in Figures 19 and 20.

[0030] Figure 22 is an enlarged perspective view of elements shown in Figure 20.

[0031] Figure 23 is an isometric view of another embodiment of the medicant delivery device.

[0032] Figure 24 is an exploded view of the device shown in Figure 23.

[0033] Figure 25 is close-up isometric view of an embodiment of a fluid delivery system shown in Figure 24.

[0034] Figure 26 is a section view through line 26-26 of the fluid delivery system shown in Figure 25.

[0035] Figure 27 is a close-up isometric view of an embodiment of a plunger of the fluid delivery system shown in Figure 28.

[0036] Figure 28 is a close-up isometric view of an embodiment of a drive nut of the fluid delivery system shown in Figure 24.

[0037] Figure 29 is a close-up isometric view of an embodiment of the outlet cap and vaporizing system of the medicant delivery device shown in Figure 24.

[0038] Figure 30 is a close-up isolmetric view of an embodiment of a fluid discharge atctuator of the medicant delivery device shown in Figure 24.

[0039] Figure 31A is a close-up isometric view of a proximal end of the fluid delivery system of the medicant delivery device shown in Figure 24.

[0040] Figures 31B is the medicant delivery device shown in Figure 31A with the bottom depressed.

[0041] Figure 32 is an isometric view of an embodiment of an anti-rotation feature of the fluid delivery system shown in Figure 24.

[0042] Figure 33 is an isometric view of another embodiment of the delivery device.

[0043] Figure 34 is an isometric view of the delivery device shown in Figure 33 with the housing removed.

[0044] Figure 35 is a close up view of the top of the delivery device shown in Figure 33 showing the vaporization system.

[0045] Figure 36 is a block diagram of an embodiment of the power control system.

DETAILED DESCRIPTION OF THE INVENTION

[0046] The detailed description set forth below in connection with the appended drawings is intended as a description of presently-preferred embodiments of the invention and is not intended to represent the only forms in which the present invention may be constructed or utilized. The description sets forth the functions and the sequence of steps for constructing and operating the invention in connection with the illustrated embodiments. It is to be understood, however, that the same or equivalent functions and sequences may be accomplished by different embodiments that are also intended to be encompassed within the spirit and scope of the invention.

[0047] To improve the ability to meter a precise dose of a medicant in vapor form for inhalation from a vapor delivery device, the vapor delivery device requires either a power control system that can control the amount and duration of heat applied to a liquid form of the medicant, or a fluid delivery system that can accurately, consistently, and repeatably discharge a precise volume of a medicant. These two methods: (a) controlling the amount of heat applied to the liquid, and (b) controlling the volume of liquid to be vaporized, can be used alone or in combination to improve the accuracy of the medicant "dose" provided by the vaporizer. As used in the claims, the term "medicant" means a medicament, medication, medicine, pharmaceutical, drug, and the like used for healing, treating, altering, improving, restoring, relieving, and/or curing a particular condition, disease, or mental or physical state, which includes the active ingredient or combination of active ingredients and inactive ingredients infused into an expedient or dissolved in some other carrier.

[0048] The amount and duration of the heat applied correlates with the amount of power supplied to the vapor delivery device. Therefore, in order to improve the functionality of current vapor delivery devices, the current devices must be implemented with a power control system that comprises a means for providing a precise amount of power from a power source to heat a heating element to a minimum required temperature that completely vaporizes a predetermined volume of a liquid. Based on the properties of a medicant, in particular, the expedient or carrier, the minimum required temperature to completely vaporize a predetermined volume can be calculated. By knowing the minimum temperature required to vaporize a predetermined volume of a medicant, energy resources can be conserved by not using more energy than is necessary, which is one of the problems with current devices.

[0049] The means for providing a precise amount of power from a power source to heat a heating element to a minimum required temperature to completely vaporize a predetermined volume of a liquid comprises a control circuit or integrated circuit **82** having a processor **500** that controls the power sent to a heating element **152** to ensure that only the necessary amount of power is provided to vaporize the specific volume discharged. Since the amount of power supplied to a heating element **152** correlates with the resistance through the heating element, the processor **500** may be programmed to monitor the resistance of the heating element **152** as a proxy for the amount of power being supplied to the heating element **152**. Knowing the resistance, the processor **500** can govern the amount of power to supply to the heating element **152**. Measuring the resistance at the heating element has several advantages. First, power may be accurately measured and maintained. Second, it measures the resultant voltage from the circuit, rather than measuring it from the battery, which conserves battery life. Third, it insures that vaporization remains constant, allowing for measured dosages irrespective of the life cycle of the battery and degradation of the heating element.

[0050] In some embodiments, the means for providing a precise amount of power may also comprise a boost converter that is a switched DC/DC converter, in conjunction with supercapacitors **368a, 368b**. The boost converter uses a charge converter that functions with an H bridge and inductor/capacitor system. By using the boost converter the charge current is limited to preserve the batteries and a much higher discharge current from the supercap is allowed, but for a shorter duration. By way of example only, it make take 3-5 seconds to charge but only 0.5 second to discharge. Thus, the battery may only see 100-200mA load, but the capacitor might see 1A or more. By utilizing this system, alkaline batteries **364** can be used, thereby improving the safety of this device.

[0051] A supercapacitor ("supercap") **368a, 368b** is an electrochemical capacitor with relatively high energy density. Its energy density is typically hundreds of times greater than conventional electrolytic capacitors. A supercap **368a, 368b** can store up to two orders of magnitude the capacitance a standard electrolytic capacitor can maintain.

[0052] The described invention circuitry charges a supercap **368a, 368b** from a set of alkaline batteries **364** using a DC/DC boost converter. When charging a supercap **368a, 368b**, numerous parameters must be taken into consideration. For illustrative purposes, a 300 farad capacitor bank that is to be charged to 6V DC, using a 6V power source (4 - 1.5V AA batteries) capable of sourcing 1.2A MAX current could be used. Note that a resistor can be used in this circuit to limit the current to a maximum amperage – e.g. 1A, etc., as an additional control of the heating circuit.

[0053] To define how the invention charging circuitry works, the Ohm's law equation is used - Charge resistor value = 6V / 1A = 6 Ohms. This is determined using Ohm's law: R=E/I, where R is the resistance in ohms, E is the energy in volts, and I is the current in amps.

[0054] To determine what it takes to charge the capacitor bank, 'Power' is utilized, which electrically is described as 'Wattage'. This Power equation is described as:

[0055] Resistor Power = 6V x 1A = 6W (Power = Voltage x Current)

[0056] Thus, in order to charge a 6V capacitor bank at 1A with a 6V power supply (4 AA/AAA batteries), a 6 Ohm resistor with a wattage rating of 6W or higher is needed. In certain designs, fewer batteries, such as one, two, or three, can be used to supply sufficient power.

[0057] Using this approach, this invention solves the standard problem of battery life issues that current electronic cigarettes (e-cigarettes) have. Additionally, this approach

provides the ability to maintain sufficient power to vaporize the liquid using standard alkaline chemistry batteries, which current e-cigarette devices are incapable of utilizing.

[0058] Figure 37 shows a block diagram of the process. There is an energy or power source **600** that supplies the input power. This source can be one of several types but in general fits in two types. Type 1 may be a low power source not capable of the higher current to function directly. This type of power source requires additional conditioning to support full function, thus requires a power conversion stage **602** and a power storage stage **608**. Type 2 may be a high current source that allows a direct drive of the vaporization element.

[0059] State or control logic **604,** which may be dedicated logic or a processor, supplies the control, measurement and drive functions. One embodiment may use a Texas Instrument MSP430 processor, but this could be any processor or ASIC-like device. GPIO and A/D functions may also be used to allow the measurement of either the current flow (direct drive) or voltage in the power storage (supercap). When all conditions are met, the control logic **604** activates the discharge switch **610** to heat the vaporization element **612**.

[0060] The ability to accurately measure and meter the power that energizes the vaporization element **612** allows the accurate metering of the vapor phase transition and dosage amounts. In the direct drive system the current and time of drive are used to compute and meter the energy that is used to heat the vaporization element **612**. In the stored energy system the formula $\frac{1}{2}CV^2$ is used to compute the energy in the system and the desired end voltage to meter the energy used to heat the vaporization element **612**, where C is the capacitance and V is the voltage.

[0061] An alternative to controlling the amount power would be to control the amount of time the heating element is energized as the power source begins to dissipate. The

processor **500** can be configured to monitor the resistance and adjust the time the heating element remains on so as to completely vaporize a given volume of medicant.

[0062] In some embodiments, a flow switch **614** may be used to signal the requested start of a vaporization phase. When implemented into a vaporization device, the device may have a fluid delivery system (discussed below). The fluid delivery system deposits a required amount of fluid on the vaporization element **612** prior to activation of the flow switch **614**.

[0063] In some embodiments, a fluid discharge activator **616** may be used to "wake up" the processor **604** and charge **606** the supercap **608** (in the stored energy system). In the direct drive system, the fluid discharge activator would be used to "wake" the processor **604** from an ultra-low power sleep mode. The fluid discharge actuator **616** may be a mechanical device to activate the system, such as a turn switch, a button, knob, lever, and the like.

[0064] In some embodiments, diodes **618**, **620** may be used to indicate to the operator the status of the system operation. For example, one diode may be an LED **618** to signal when the vaporization element **612** is being driven. Another LED **620** may be used to blink specified patterns to indicate system status, e.g. power up, low battery, exhausted fluid state, or other system specific status states (i.e. max dosage per unit time, etc...). In other embodiments, a display, such as an LCD screen, may be used to show the system status or other information, such as the type of substance or medicant contained in the delivery device, the amount and/or doses remaining, the battery level, a user ID in case the device is lost, etc. A button or similar device could be used to actuate and scroll through the display.

[0065] In a Type 1 configuration (low current, alkaline batteries etc.) the charge current may be limited to preserve the battery lifecycle. In many batteries, if large amounts of current are drawn, it will significantly reduce the battery life or state of charge. Therefore, using the lower current draw from the batteries and the power storage stage **608** allows for a high current event without unduly draining the batteries.

[0066] In a Type 2 configuration, the power storage **608** can be used to extend the life of the battery (lithium polymer, lithium-ion) if desired. The power storage **608** also makes it easier to very accurately meter the precise amount of energy into the vaporization element **612** with a simple voltage measurement. Accurately metering precise amounts of energy into the vaporization element can be done with a voltage and current measurement but it is harder to accurately measure current than to measure voltage. Thus, it may be advantageous to use a simpler-voltage only process.

[0067] An additional power saving feature that is shared with the control logic **604** and the power conversion **602**, namely, the power state (on switch) of the system. This power saving feature with the power state can be accomplished via either an ultra-low power mode of the conversion/cpu or a power disconnect/latch function. This is used to extend the operation life of the device after the first use.

[0068] The energy required to completely vaporize a predetermined volume of liquid is a function of the amount of power and the duration of time the power is present. Therefore, the power control system **306** may also comprise a means for controlling a precise duration of time to supply the precise amount of power to completely vaporize the predetermined volume of liquid at the required temperature. The means for controlling a precise duration of time to supply the power may comprise a “one-shot” control circuitry **170**, **172**, or **174** that can be integrated with the circuit for controlling the amount of power

described above. Examples of "one-shot" circuits **170**, **172**, or **174** are shown in Figures 15-17 and described below in more detail. A "one-shot" circuit may be used to limit the electric current delivery time interval regardless of how long the user holds the lever down. The power control system **306** is completely "off" in between uses; therefore, there is no drain on the battery during idle time. As a result, battery life is prolonged.

[0069] In some embodiments, the integrated circuit may be configured to actuate the power source a predetermined number of times. This number should be low enough such that each actuation results in the same amount of power each time. In some embodiments, the integrated circuit may be configured to monitor the battery life and not actuate the power when a predetermined amount of battery life has been detected.

[0070] This power control system **306** can be implemented in existing vapor delivery devices. For example, the control system **306** can be installed into handles of current vapor delivery devices to be implemented with existing heating systems to improve the energy efficiency and accuracy of dosing of current devices.

[0071] Besides, or in addition to, controlling the amount and duration of the power to significantly improve the efficiency and effectiveness of metering precise doses from vaporization devices, a means for consistently metering a precise volume of a liquid to be vaporized can be used as an alternative or additional layer of precision. Therefore, an efficient medicant delivery device may comprise a power control system **34** utilizing various embodiments of the circuitry described above to control the efficient and effective use of power, and/or a fluid delivery system **30**, **302**, or **402** as a means for consistently metering a precise volume of a liquid from the fluid reservoir to precisely control the volume of the liquid discharged for vaporization. Various combinations of these systems may be used to achieve the desired level of accuracy. An atomization or vaporization

system **32** may also be required to vaporize the medicant. In this application, atomization and vaporization are referred to interchangeably to indicate that the state of the medicant is a form that can be inhaled and absorbed by the lungs.

[0072] The precise volume of liquid that can be completely vaporized at a given temperature and duration of exposure can be calculated. Therefore, the precise volume required to be discharged from a fluid delivery system may be predetermined because the temperature of the wire and the duration the wire is energized can be fixed. Alternatively, in some embodiments, the precise volume may vary depending on the temperature of the wire and how long the wire remains energized at that temperature.

[0073] The embodiments of the power control system described above offer an advantageous way for more precisely metering a specific dose of a medicant. Controlling the volume of the medicant discharged also improves the metering accuracy. Examples of devices for controlling the volume of medicants to a heating element for vaporization are described below. These devices can be used alone or in combination with the power control system to further improve the accuracy of metered doses of medicants.

[0074] In one embodiment, as shown in Figures 1 and 2, a medicant delivery device **20** has an elongated housing **22** with a mouthpiece **24** and a lever **28** adjacent to a back or top end of the housing. A mouthpiece opening **26** extends into the mouthpiece **24**. Referring further to Figures 3-5, an embodiment of the device **20** includes a fluid or liquid delivery system **30** as the means for consistently metering a precise volume of a liquid to precisely control the volume of the liquid discharged for vaporization, and a vaporizing system **32**, as well as an electrical power control system **34**. The electrical power control system **34** may include batteries **44** within a battery compartment **42** of the housing **22**, and with the batteries electrically connected to a flexible circuit board **82** via a spring **46** and contacts

48. As shown in Figure 5, the housing may be provided with left and right sides, in a clamshell design. The lever **28** may be attached to the housing **22** at a pivot **58**.

[0075] As shown in Figure 4, a means for consistently metering a precise volume of a liquid from a fluid reservoir to precisely control the volume of the liquid discharged for vaporization is achieved by the liquid delivery system **30**, in the example shown, which includes a resilient or flex wall liquid chamber or reservoir **64** connected via a tube **66** to a lever valve **70**. The reservoir **64** may be a thin walled flexible pouch made of polyethylene film. The reservoir **64** is positioned between two rigid surfaces, with a plate **62** on one side and an inner wall of the housing **22** on the other side. Springs **60** within the housing **22** press on a plate **62**, which in turn presses on the reservoir **64**. This pressurizes the liquid in the reservoir.

[0076] A tube **66** extends from the reservoir **64** to a lever valve **70** which may include a valve post **74**, a valve spring **72** and valve washer **76**. A valve section **80** of the tube **66** in this design extends through an opening the valve post **74**, as shown in Figure 6. The valve spring **72** urges the valve washer **76** against the valve section **80** of the tube pinching it closed.

[0077] Referring to Figures 4-6, an embodiment of the vaporizing system **32** includes a heater **150** which is electrically connected to the electrical power control system **34**. The vaporizing system **32** is also connected to, and receives liquid from, the liquid delivery system **30**. The heater **150** may be an electrical resistance heater formed by an open coil of wire **152**, such as ni-chrome wire. In this design, the electric current is supplied to the coil wire **152** via connectors **156** on, or linked to, the flexible circuit board **82**, which in turn in connected to the batteries **44.** Figure 14 shows the connectors **156** for providing electrical power to the heating element.

[0078] An outlet segment **154** of the tube **66** extending out of the lever valve **70** towards the mouthpiece or back end of the device is inserted into the front end of a wire coil **152**. Referring momentarily to Figure 14, solid wire inserts **159** may be inserted into the ends of the wire coil **152** and the outlet segment **154** to provide internal support, so that they do not distort or collapse when pressed down into connectors **156**. The outlet segment **154** at the front end of wire coil heater **152** provides liquid into the bore of coil with each actuation of the device **20**.

[0079] The tube **66** is connected to the reservoir **64** with a liquid-tight connection so that liquid can only flow from the reservoir only through tube **66**. The tube **66** may be a resilient, flexible material such that its inner lumen can in general be completely flattened when compressed, and then generally fully recover to its original shape when released. A lever segment **67** of the tube **66** is positioned beneath the lever **28** and a fixed rigid surface inside of the housing, which optionally may be part of the circuit board **82** on which power management circuitry is located. Locating features **112** may be provided in, on, or through the circuit board **82** to ensure desired positioning is maintained. The lever **28** is retained by lever pivot **116** and can pivot through a controlled range of motion.

[0080] In use, the mouthpiece **24** is placed into the mouth and the user presses or squeezes the lever **28**. The tube **66** is pre-filled or primed with liquid during manufacture. Referring to Figure 4, as the lever **28** pivots down about the pivot **58**, a pincher **86** located on a first section **90** pivotally attached to the housing pinches the pump segment **67** of the tube **66** against an inside surface of the housing **22**, adjacent to the pivot **58** and the reservoir **64**. This temporarily closes off the tube **66** at the pincher **86**. As the lever **28** continues to pivot down (or inward towards the centerline of the device) a ramp surface **88** on a second section **92** of the lever **28**, flexibly attached to the first section, progressively squeezes the pump segment **67** of the tube **66** between the pincher **86** and the lever valve **70**. This creates a squeegee type of

movement which pumps liquid towards the lever valve **70** using a peristaltic action. As the lever **28** continues to pivot inwardly, posts on the lever press the valve washer **76** down against the force of the valve spring **72**. This temporarily opens the lever valve **70** by allowing the valve section **80** of the tube **66** to open. With the valve section **80** of the tube open, and with liquid in the tube being pumped via the ramp surface **88**, a bolus of liquid flows through the valve section **80** and the outlet segment **154** and into the wire coil **152**.

[0081] The constant positive pressure exerted on the reservoir **64** by the springs **60** pressurizes the liquid in the tube **66**. However, since the tube **66** is pinched closed by the pincher **86**, no liquid flows out of the reservoir when the lever is depressed and the lever valve is opening. Rather, the liquid already present in the tube **66** between the pincher **86** and the lever valve **70** provides the measured bolus which is uniformly delivered to the wire coil.

[0082] The downward movement of the lever **28** also closes a switch **158** linked to or located on the circuit board **82**. Electric current then flows from the batteries **44**, or other power source, to the wire coil **152**. The wire coil heats up causing the liquid to vaporize. The current supplied to the wire coil, and the temperature of the wire coil when operating, may be regulated by the circuit board, depending on the liquid used, the desired dose, and other factors. The switch **158** may be positioned to close only when the lever **28** is fully depressed. This avoids inadvertently heating the wire coil. It also delays heating the wire coil until the bolus of liquid is moved into the wire coil via the pivoting movement of the lever, to help prolong battery life. A "one-shot" control circuit **170**, for example, as shown in Figure 15 described below, may be used to limit the electric current delivery time interval regardless of how long the user holds the lever down. The power is completely "off" in between uses. There is no drain on the battery during idle time. As a result,

battery life is prolonged.

[0083] As is apparent from this description, the liquid delivery system **30**, using a linear peristaltic pumping action, delivers a consistent, fixed, repeatable bolus of liquid to vaporizing system **32** with each actuation of the device **20**. The liquid delivery system **30** further seals the reservoir **64** between actuations via the pincher **86**, maintains the contents of the reservoir in a pressurized state, and controls electric power delivery to the vaporizing system **32**. The liquid delivery system is designed so that as liquid is used, air is not introduced into the system.

[0084] The diameter and length of the wire coil **152** forms a cylindrical volume within the inside diameter of the coil that is sufficient to capture a single expressed dose of liquid from the liquid delivery system. The adjacent loops of wire of the wire coil **152** may also be positioned so that liquid surface tension holds the liquid within the bore of the coil. This allows the device **20** to be used in any orientation, since gravity is not needed to keep the released dose of liquid in place.

[0085] The use of an open coil offers the further advantage that the vapor may be generated and escape anywhere along the length of the coil, without inadvertently affecting vaporization of the balance of the bolus of liquid in the coil. The wire coil also provides a large surface area for heat transfer and minimizes energy loss resulting from heating ancillary components.

[0086] Upon application of electric power, liquid in the coil vaporizes and passes through gaps between coils. The coil can be sized and shaped and positioned in the housing so that the vapor generated can be entrained into an air stream drawn through the device **20** when the user inhales on the mouthpiece. "Inhale" here means drawing the vapor at least into the mouth.

[0087] Figures 7-13 show a second device embodiment **100** which may be similar to the device **20**, but with the following differences. In the device **100**, the means for consistently metering a precise volume of a liquid from the fluid reservoir to precisely control the volume of the liquid discharged for vaporization comprises a foam pad **106** that is compressed and inserted between a reservoir **64** and one of the rigid walls of the housing. Force exerted on the reservoir **64** by the foam trying to recover to its relaxed state exerts compressive force on the reservoir which maintains the liquid in the reservoir under pressure. The foam pad **106** may be used in place of the springs **60** shown in Figure 4. The reservoir may alternatively be pressurized using a syringe with a spring-biased plunger. With any of these designs, the reservoir may optionally be provided as a replaceable cartridge.

[0088] As shown in Figure 8, in the device **100**, a lever valve **118** is provided (in place of the pincher **86** in the device **20**) to compress the front end of the tube **66**, preventing liquid from flowing out from the pressurized reservoir in between uses. The lever valve **118** may be a stamped sheet metal form soldered to a rigid circuit board **114** containing the same or similar circuitry as described above for the power control system **34**.

[0089] Figures 10-13 show additional features that can be used for a means for consistently metering a precise volume of a liquid from the fluid reservoir to precisely control the volume of the liquid discharged for vaporization, specifically, the pumping action of the liquid delivery system in the device **100**. When a dose of vapor is desired, the user places the mouthpiece in the mouth and inhales while pressing a button **109** on the lever **110**, causing the lever to rotate downward (counter-clockwise). As the lever **110** initially rotates as shown in Figure 10, a lever pinch projection **132** clamps or pinches the tube **66** closed at a pinch point **140**, closing off the pressurized liquid reservoir. Continued

rotation of lever **110** causes the lever **110** to flex at a flex point **124** having reduced thickness, as shown in Figure 11. This allows over-travel rotation of the lever while the tube **66** remains closed off at the pinch point **140**, without crushing the tube.

[0090] Further rotation of lever **110** then compresses the lumen of the pump segment **68** of the tube **66**. This pumps liquid from the pump segment **68** towards the lever valve **118**. This movement also moves projections on the lever which push valve flanges **120** down, deflecting and opening the lever valve **118**, and allowing a pressurized bolus of liquid to move through the tube and into the vaporizing system **32**. The dotted lines in Figure 12 show the lever valve **118** deflected down and away from the bottom surface of the circuit board **114**, to open the valve. Lastly, at end of the lever stroke, a lever switch protrusion contacts a switch **158**, switching the power delivery system on.

[0091] When lever **110** is released, it pivots back up to its original position. As the lever returns, the lever valve **118** reseats first, sealing the back end of pump segment **68** of the tube **66** and preventing air from being drawn back into the pump segment. As the lever **110** continues to rotate clockwise, the pump segment **68** decompresses, creating a negative pressure within the tube lumen. Lastly, at pinch point **140** the tube **66** reopens, allowing pressurized liquid from the reservoir to enter, refilling pump segment **68** with liquid to provide the next dose.

[0092] The volume of liquid expressed with each stroke can be controlled by selection of desired pump segment **67** tube diameter and length. Maintenance of a positive pressure on the liquid reservoir ensures that the system always stays primed with liquid, and that "short shots" resulting from air bubbles in the tube do not occur. Furthermore, sealing of the vaporizer system with a valve such as the valve **70** or **118** that is only actuated at the time of delivery, and positive pressure dispensing prevents inadvertent leakage of liquid

irrespective of orientation of the device during storage or use, thereby providing a means for consistently metering a precise volume of a liquid from the fluid reservoir to precisely control the volume of the liquid discharged for vaporization.

[0093] Figure 15 is a schematic diagram for a "one-shot" circuit **170** for the power control system that delivers a fixed time interval of electric current to the heater **150** regardless of how long the lever is depressed by the user. In Figure 15, CD4047 is a CMOS low power monostable/astable multivibrator available for example from Texas Instruments. U1 is a common CD4047 which operates from a 12V battery voltage with very low quiescent current drain. When pushbutton SW1 is depressed, U1 is triggered, Q (pin 10) goes high and C1 is rapidly charged to near the supply voltage through a FET within U1. At the same time, resistor R1 is switched to a logical "0" state and immediately begins discharging capacitor C1 with the time constant of 1/RC.

[0094] A wide range of pulse durations may be selected. Using a typical ni-chrome wire coil, pulse durations ranging from approximately 0.2 to 2 seconds are sufficient to fully vaporize the bolus of liquid. When the voltage on pin 3 reaches the threshold for logic "0" (~1/3 supply voltage), the logic levels switch and Q (pin 10) returns to a logic low level. Q2 is an emitter follower that provides current amplification to enable Q1 to be fully saturated during the desired current pulse. D1 and R4 provide a visual indication of the heater current. R2 is a "pull down" resistor for SW1, and C2 prevents induced noise from falsely triggering the circuit. Other choices of IC may be employed, such as the Toshiba TC7WH123, depending upon battery voltage, package size, and cost.

[0095] The battery voltage gradually decreases over the lifespan of the device. For many applications, the circuit described in Figure 15 provides the necessary control. However, more precise metering of the medicant may be accomplished by increasing the

current pulse duration as the current decreases over the discharge life of the battery. In the circuit **172** shown in Figure 16, an additional OP amp IC serves as a voltage controlled current source for the power control system. The input voltage is sampled from Pin 10 of U1. A constant current is generated in Q3 and used to discharge the timing capacitor, C1, at a constant rate. Once the voltage across C1 reaches the logic threshold, CD 4047 trips and the output pulse width is complete. As the battery voltage decreases the constant current generated in Q3 decreases, causing the time to discharge C1 to increase. This lengthens the output pulse to maintain a relatively constant heater power per inhalation cycle as the battery voltage declines over the lifetime of the device. The various current setting and sense resistor values may be adjusted to provide optimal performance. Other circuits may be employed to provide the same function such as voltage to frequency converters.

[0096] Figure 17 shows another circuit **174** for the power control system where a voltage regulator U2 is inserted between the output transistor Q1 and the heater filament. This keeps the filament voltage constant throughout the battery life. The regulated voltage may be chosen to optimize the heater operation near end of life. A low dropout regulator is desired to maximize the lifespan before regulation is no longer maintained. A simple linear regulator is shown, but a high efficiency, switching regulator may also be employed to improve efficiency. The pulse duration is maintained as described above or an equivalent "one shot" circuit and the heater current is kept constant by the voltage regulator.

[0097] In another alternative design, the electrical power control system **34** may be configured to provide consistent power by timing the power to provide the minimum energy needed to vaporize the liquid. The power control system **34** may also be

programmed to do this. For example, the electrical power control system **34** may be programmed to power the source down to the voltage required to vaporize the liquid, so as to extend its useful life. Here, the power source may include a capacitor that builds, retains and provides a charge necessary to vaporize the liquid to be vaporized, again, so as to extend the useful life of the power source. In some embodiments, supercapacitors may be employed as discussed above to further enhance the functionality of the power source.

[0098] In an additional alternative design shown in Figure 18, the liquid to be atomized is delivered into a small diameter tube **180** via capillary action, as distinct from providing the liquid via pressure into the heating coil, where it is stabilized for vaporization due to surface tension. The tube **180** can be glass, polyaniline or metal, e.g., stainless steel. A heating element such as ni-chrome wire can be coiled around the tube, coiled into the tube or inserted into a tube in a V-shape so as to heat the entire volume of liquid at the same time.

[0099] Figures 19-22 show an alternative vaporizing device **200** having a housing formed from a base **202** including a mouthpiece **206**, and a cover **204** attached to the base **202**. Pivot arms **209** on a button **208** are pivotally attached to pivot posts **226** on a bridge **224**, as shown in Figure 21 to provide another means for consistently metering a precise volume of a liquid from the fluid reservoir **234** to precisely control the volume of the liquid discharged for vaporization. The radius **244** of the pincher **238** can flex when the tube **236** is compressed. The bridge **224** has pins for securely attaching it to the base **202**. The positive electrode of each battery **44** is held into contact with center contact **212** by a spring **46**. A positive conductor strip **214** connects the center contact to a printed circuit board **216**.

[00100] Referring to Figure 22, a wick **220** extends from the printed circuit board **216**

(containing the same or similar circuitry as described above for the power control system 34) up to a vaporizing coil **222** and optionally over a raised wall **240**. The wick may be a strip or sheet of ceramic tape **220** that serves as a wick and a heat sink. The wick **220** is positioned between the heating element, such as the vaporizing coil **222**, and the outlet of the tube **236**. The wick **200** may rest on top of the heating element, or be positioned adjacent to it, and the tube outlet may also be on top of the heating element and the wick **220** (when the device **200** is in the upright position, with the button **208** on top).

[00101] Brass posts **218** or similar contacts are attached to the printed circuit board **216** and to opposite ends of the coil **222**. The button **208** has a pincher arm **209** positioned to pinch and close off flow in a tube **236** connecting a liquid reservoir to an outlet location on, adjacent to or overlying the wick **220**. The tube **236** may be held in place by molded in tube clips **242** on the bridge **224**. Arms **233** on a normally closed pinch valve **232** extend up through openings in the bridge **224**. A valve spring **230** around a post **228** holds the valve **232** into the normally closed position. A bottom surface of the valve **232** may act as a switch with the printed circuit board **216**, or actuate a separate switch on the printed circuit board **216**, to switch on electrical current to the coil **222** when the button **208** is pressed.

[00102] In use, the vaporizing device **200** operates on the same principals as described above, with the following additions. A slot **210** may be provided in the housing to accommodate an insulating tab. The insulating tab is installed during manufacture and prevents electrical contact between the center contact **212** and the batteries. As a result, the device cannot be inadvertently turned on during shipping and storage. Battery life is therefore better preserved. Before operating the vaporizing device **200** for the first time, the user pulls the tab out of the slot **210**. As shown in Figures 19 and 20, the mouthpiece

is round. The dimension LL in Figure 20 between the coil **222** and the mouthpiece tip may be minimized to 15, 10 or 5 mm. The liquid reservoir may have a volume exceeding 0.8 or 1.0 ml to allow foam compression to pressurize the pump. In the device **200**, the liquid supplied from the reservoir via the tube **236** is not delivered into the coil **222**. Rather the liquid is delivered onto the wick **220**. The heating coil **222** abuts the wick **220** and heats the wick, which then vaporizes substantially all of the liquid on or in the wick.

[00103] In each of the vaporizing devices described above, the open coil heater **152** or **222** of e.g., ni-chrome wire may be encased in a porous ceramic material, so that the vapor produced when the fluid is atomized must pass through the ceramic material in order to be ingested or inhaled. The ceramic material can be manufactured with techniques that control the size of the pores through which the vapor will pass. This can help to regulate the size of the vapor molecules or droplets produced for inhalation. By controlling the amount of electrical power and the duration of power to the coil heater, the heater continues to vaporize the fluid at the heater until the vapor droplets or particles are small enough to pass through the ceramic material, effectively utilizing all the fluid delivered to the coil and controlling the dose in addition to regulating the molecule size. By regulating the size of the vapor molecule produced, the vaporizing devices can be used with more precision and with fluids and medicants that require carefully controlled dosages particle sizes. In some cases, smaller molecules may be advantageous as they can be inhaled more deeply into the lungs, providing better a more effective delivery mechanism.

[00104] The wire coil heater may alternatively be encased in a heat resistant fabric-like material, such as Kevlar®, so that the vapor must pass through the fabric to be ingested. The fabric can be manufactured with a desired mesh opening size, to regulate the size of the vapor particles and/or molecules delivered by the vaporizer. By controlling the amount

of electrical power and the duration of power to the heater, the heater continues to vaporize the fluid delivered to the heater until the vapor particles are small enough to pass through the mesh of the fabric. Containing the fluid inside the fabric with the heater until the particles are sufficiently small enough to pass through the fabric can help to effectively atomize and deliver all the fluid delivered to the heater, with little or no waste, in turn controlling the dose.

[00105] Although the switch **158** is described above as a mechanical contact switch, other forms of switches may optionally be used, including switches that optically or electrically sense the movement of position of an element, or a switch that senses the presence of liquid in the heater **150**. In addition, though the lever and pinch valves are shown as clamping type of valves, other forms of mechanically or electrically operated valves may be used. Similarly, the peristaltic pumping action created by the pivoting movement of the lever may be optionally replaced with alternative forms of pumping or fluid movement. Various types of equivalent heating elements may also be used in place of the wire coils described. For example, solid state heating elements may be used. The heating element may also be replaced by alternative vaporizing elements, such as electro-hydrodynamic or piezo devices that can convert liquid into a vapor without heating.

[00106] In another embodiment, a delivery device **300** utilizes a plunger-style liquid delivery system **302** as another means for consistently metering a precise volume of a liquid from a fluid reservoir to precisely control the volume of the liquid discharged for vaporization. As shown in Figure 23, the delivery device **300** comprises a new liquid delivery system **302**, but utilizes the same or similar an atomization or vaporization system **32** and power control system **34** described above, all contained in a housing **308**, preferably cylindrical in shape to mimic a cigarette or cigar.

[00107] The fluid delivery system **302** has a fluid reservoir **310** to contain the medicant and a pressure generator, such as a piston **312** that indexes forward inside the fluid reservoir **310** in a consistent, fixed, repeatable amount every time fluid discharge actuator, such as a button **314,** is pressed or actuated. Preferably, the fluid reservoir **310** is cylindrical in shape, and more preferably, shaped like a syringe. The delivery device **300** is completely sealed between applications such that the medicant cannot evaporate during storage or between actuation cycles.

[00108] The fluid reservoir **310** has a proximal end **316** and a distal end **318.** The proximal end **316** is configured to accept the piston **312** which forms a hydraulic seal against the walls of the reservoir **310**, such that the medicant cannot leak past the piston **312**. The piston **312** may have a hollow core **313**. A plunger **320** is provided to couple with the piston **312** to drive the piston **312** forward in a controlled and step-like manner. The plunger **320** comprises a shaft **322** having a head **324** at one end. In a preferred embodiment, the head **324** is flanged. The head **324** is configured to engage with mating geometry on the inside of the piston **312**, securing the piston **312** to the plunger **320**. The shaft **322** of the plunger is configured with a male screw thread **326**, preferably, for its entire length.

[00109] A drive nut **328** is disposed at the proximal end **316** of the reservoir **310.** Various features of the housing **308** and reservoir **310** constrain the position of the drive nut **328** such that it is free to move rotationally concurrent to the axis **A** of the plunger **320**, but prevent translation in any other direction. The drive nut **328** has a mating female screw thread **330** to the plunger **320** and is threaded onto the plunger **320.** The drive nut **328** is further configured with ratchet teeth **332**, which interact with a pawl **334** on a button **314**

described later such that during operation, the drive nut **328** will rotate in a single direction.

[00110] A cap **336** is disposed at the distal end **318** of reservoir **310**. The cap **336** may be an elastomeric component with an outlet **338** comprising a self-collapsing slit/hole. Preferably, the cap **336** is made of silicone. The outlet **338** is responsive to pressure from the medicant within the reservoir **310** such that when the medicant is at a higher pressure than the ambient pressure outside of the reservoir **310**, the outlet **338** will open **338A**, allowing medicant to escape the reservoir **310**. Once enough medicant has escaped the reservoir **310** to equilibrate with ambient pressure, the outlet **338** will automatically collapse, sealing the remaining contents of the reservoir **310** from ambient, thereby, preventing loss of medicant to evaporation. So, the measured dose is determined by proper calibration of the pressure needed to properly form and maintain a droplet of the medicant at the outlet **338** until vaporization is initiated. The nature of seal is such that pressure changes external to the device will not cause the reservoir to come "unsealed" the external pressure changes would not be focused enough nor forceful enough to "unseal." And, the natural elasticity of the reservoir would cause the seal to "re-seal" irrespective of external pressure changes.

[00111] Based on the surface tension of the liquid medicant, the volume of the medicant discharged from the outlet **338** should be small enough that it forms a droplet at the outlet **338** that adheres to the outlet **338** without dropping or dripping off from the cap **336**. The distance from the outlet **338** to the coiled wire **152** should also be small enough that a droplet of the liquid formed at the outlet bridges the gap between the outlet **338** and the coiled wire **152** thereby allowing the droplet to transfer to the coiled wire **152** or the wick

360 within the coiled wire **152**. This configuration allows the vapor delivery device **300** to be used in any orientation; thereby, improving the versatility over current devices.

[00112] As shown in Figure 30, the button **314** functions to provide controlled rotational indexing of the drive nut **328**. The button **314** includes a control surface **340** protruding through the upper housing for the user to actuate the button **314**. In its neutral (home) position, the button **314** is normally protruding slightly from the housing **308**. The button **314** is constrained such that it can translate in a direction normal to the control surface **340** when it is pressed. The button **314** is configured with two spring elements **341a**, **341b** which bias the button back to its neutral position in the absence of pressure on the control surface **340**. The spring elements **341a**, **341b** are designed to deform under pressure on the load surface and return to their original shape upon release of that pressure. The range of button travel motion is limited by a stop **342** having an upper surface **343a** and a lower surface **343b**. The stop surfaces **343a**, **343b** engage opposing surfaces on lower and upper housings at limits of button travel, creating a fixed range of displacement for the button **314** when it is pressed/released. The button **314** is further configured with a pawl **334** to engage ratchet teeth **332** on the drive nut **328**. When the button **314** is depressed, the pawl **334** engages ratchet teeth **332**, causing the drive nut **328** to rotate. Upon release, a sloped surface **344** of a pawl **334** and an opposing surface **346** of the ratchet **332** oppose one another, deflecting the pawl **334** at a web allowing the pawl **334** to ride over the adjacent ratchet tooth and the button **314** to return to its neutral position. In this manner, the ratchet **332** allows the drive nut **328** to rotate in a single direction.

[00113] In some embodiments, the button **314** may function to initiate the delivery of power to the heating system **304** synchronous to the delivery of a bolus of medicant to the vaporization system **32**. As shown in Figures 31A and 31B a contact pin **348** is provided

spanning the button spring elements **341a**, **341b**. Deflection of the spring elements **341a**, **341b** during actuation of the button **314** lowers the contact pin **348** relative to contacts **350a**, **350b**, closing the circuit across the contacts **350a**, **350b**, as shown in Figure 31B. This closure serves to initiate a power cycle to the vaporization system **32** as described later. In some embodiments, the contacts **350a**, **350b** may be directly under the spring elements **341a**, **341b**. The underside of the spring elements **341a**, **341b** may have independent contact pins **348** to connect with the contacts **350a**, **350b** to close the circuit. In some embodiments, a single contact pin **348** and a single contact **350a** may be used.

[00114] The pitch of thread **326** is selected in consideration of the bore **352** of the reservoir **310**, and controlled angular indexing of the drive nut **328** to displace the desired bolus of medicant from the reservoir **310** with each indexing of the drive nut **328**. All of the rotational motions of the drive nut **328** are converted to linear motion on the plunger **320** to provide a consistent, fixed, and repeatable dose of the medicant. To ensure that the plunger **320** does not spin with the rotating drive nut **328**, the plunger **320** is further provided with a groove **354** running down its length, said groove **354** accepting anti-rotation tang **356** protruding from the lower portion of the housing **308**, as shown in Figure **32**.

[00115] The atomization or vaporization system **32**, similar to what was described above, comprises a tightly coiled wire heater element **152** positioned adjacent to the fluid delivery system outlet **338**. In the preferred embodiment, the coiled wire **152** is a nichrome wire. In some embodiments, the nichrome wire coil **152** may be wound around a high temperature fiber wicking element **360** to distribute the received medicant dose across the coil **152**.

[00116] The power control system **34** comprises a circuit board **362** (containing the same or similar circuitry as described above) and associated battery **364** that delivers a fixed and precise amount of power to the nichrome wire **152** with each actuation, the amount of power delivered being that necessary to atomize or vaporize the precise volume of delivered bolus of the medicant. For optimal system efficiency, it is desirable to maximize energy density of the heater. Thus the coils of the heater are ideally spaced as close together as possible. Furthermore, it is desirable to distribute the dose of medicant that is to be vaporized as uniformly as possible across the heater elements. To that end, the heater coils **152** are wrapped around a wick **360** comprising material tolerant of high temperature, said material compelling the medicant to distribute evenly throughout the wick **360**. The coil **152** is connected to the power control system **34** via crimp connectors **366**. In the preferred embodiment, the circuit board **362** comprises a one-shot circuit (similar to or same as the circuitry described above) that delivers a fixed and precise amount of power to the nichrome heater **152** with each actuation, the amount of power delivered being that necessary to atomize the delivered bolus of medicant.

[00117] In some embodiments, to further provide a means for delivering a precise amount of power to the vaporization system **32**, the power control system may comprise one or more supercaps **368a**, **368b** connected to the power source and the circuit. Using supercaps **368a**, **368b** prevents the vaporization system **32** from receiving varying amounts of power as the batteries **364** approach there end. In particular, supercaps **368a**, **368b** prevent the power to the vaporization system **32** from decreasing as the batteries die. Without the circuitry to precisely control the power, decreased battery power would lead to a lower temperature wire **152** for a given activation. In such case, if the volume of the medicant remains the same, then there may be incomplete vaporization of the medicant.

[00118] Figures 33-35 show another embodiment of a delivery device **400**. Figure 34 shows the delivery device **400** with the housing **408** removed. Delivery device **400** comprises the same or similar vaporization system **32** and power control system **34** as described above with another embodiment of a fluid delivery system **402** as a means for consistently metering a precise volume of a liquid from a fluid reservoir. The housing **408** of delivery device **400** also differs from that of delivery device **300**. The housing **408** generally has an elongated box-like configuration. The housing **408** can take on other shapes as well, such as a cylinder or any shape or size desired for a particular application. The housing **408** has a top end **410** and a bottom and **412** opposite the top end **410**. The top end **410** comprises a cover **414**.

[00119] Protruding from the top end **410** is an inhaler tube **416**. The inhaler tube **416** is operatively connected to the fluid delivery system **402**. Medicants from the fluid delivery system **402** are vaporized by the vaporization system **32** and the vapors flow through the inhaler tube **416** and into the user's mouth. The cover **414** is used to protect the inhaler tube **416** when not in use. Figure 33 shows a sliding cover; however, the cover **414** can be flip top, detachable, slidable, and the like. As the cover **414** is pushed back, away, off, or otherwise removed from the top and, the inhaler tube **416** is released and rotates upward. The user can then begin the process of inhaling through the inhaler, which starts the heating process by activating a flow sensor.

[00120] At the bottom end **412** of the housing **408** is a knob **418** to deliver a precise volume of medicant from the fluid delivery system **402** to the vaporization system **32**. Like the button **314** of device **300**, the knob **418** at the bottom **412** of device **400** is used to advance a plunger (not shown) through a syringe (not shown) repeatedly in a step-like manner to deliver a precise, fixed, and consistent volume of a mendicant from the syringe

and deposit it onto the coiled wire **152** of the vaporization system **32**. Each rotation of the knob **418** advances an exact, metered amount of drug with a consistently repeatable volume.

[00121] Like the previous versions, the device **400** utilizes a circuit board **420** (containing the same or similar circuitry as described above for the power control system **34**) with associated processor (not shown), super caps **368a, 368b**, and other electronic components utilized to deliver a consistent, precise and sufficient amount of power to the heating system to vaporize or atomize a predetermined volume of a liquid. The circuit board **420** is located at the top end **410** adjacent to the fluid delivery system **402** and the vaporization system **32**. A through-hole **430** is provided to allow the inhaler tube **416** to be passed through the circuit board **420** allowing the fluid reservoir **422** to be attached to this inhaler tube **416** and present the inhaler tube **416** to the user.

[00122] Below the circuit board **420**, the fluid delivery system **402** is mounted. This assembly provides a secure, tamper resistant chamber for retaining the fluid. The fluid delivery system **402** is then connected to a gear reduction assembly **424** that allows the linear syringe actuator to be advanced through the reservoir **422** in a consistent amount for each rotation of the knob **418**.

[00123] The vaporization system **32** is placed into the path of the fluid that is delivered via the fluid delivery system **402** each time the knob **418** is rotated. The vaporization **32** comprises a heating coil **152**. In some embodiments, the heating coil **152** may be wrapped around a wick **360**, which helps retain the liquid after it has been discharged from the fluid delivery system **402**. After the fluid is advanced, the fluid wets the wick **428** that is placed inside the heating coil assembly **152**. Once this wick **360** is wetted, the coil **152** can be heated once the user begins to inhale (suck) on the inhaler tube **416**. To trigger the heating

mechanism, a flow sensor (not shown) is placed in the inhalation path, which is the path between the inlet of the inhaler tube **416** and the outlet **417** of the inhaler tube **416**.

[00124] As flow is sensed when the user begins to inhale/suck on the inhaler tube **416**, the coil heating is begun by applying voltage to the coil **152**. The power applied to the coil wire **152** is supplied via the supercap assembly **368a, 368b**, which is charged via the device batteries **364**.

[00125] To further improve the delivery and efficacy of the medicant delivered by the present invention, plume chemistry of the medicant delivered to the lungs must be analyzed. Depending on the size of the vapor product released by the vapor delivery device, the medicant may have effects at various places; thereby dictating the effectiveness and speed with which the medicant can work on a user. For example, the larger vapor products are more likely to get caught inside the mouth, which would result in the medicant travelling through the digestive track. Small vapor products can be inhaled into the lungs, but may get caught in the upper lungs. Even finer vapor products can reach the lower lungs where absorption of the medicant is more effective and faster.

[00126] Again, to control the size of the vapor product, a permeable membrane of ceramic, fabric, or the like may be placed between the heating system and the mouthpiece. The heating element allows the medicant to vaporize; however, prior to exiting through the mouthpiece, the vapor product is filtered through the permeable membrane to govern the size of the vapor product delivered to the user. The membrane should be made of a material that is resilient to heat, such as ceramic or Kevlar® material.

[00127] Due to the consistent, reliable, and precise control of dosage offered by the present invention, its application goes far beyond just as a substitute for tobacco products. The device can be used to deliver dietary supplements, sleep aids, weight loss products,

pain killers, and many other prescription or over-the-counter pharmaceutical products where precise dosing is required. The present invention can even be implemented in a non-pharmaceutical context, such as for dispensing liquid candies for consumption, breath fresheners, room fresheners, and any other application where vaporization of a liquid in consistent, reliable, and precise doses are needed.

[00128] While the system and device have been described in terms of what are presently considered to be the most practical and effective embodiments, it is to be understood that the disclosure need not be limited to the disclosed embodiments. It is intended that all permutations, enhancements, equivalents, combinations, and improvements thereto that are apparent to those skilled in the art upon a reading of the specification and a study of the drawings are included within the true spirit and scope of the present invention. The scope of the disclosure should thus be accorded the broadest interpretation so as to encompass all such modifications and similar structures. It is therefore intended that the application includes all such modifications, permutations and equivalents that fall within the true spirit and scope of the present invention. Thus, multiple embodiments and methods have been shown and described. Various modifications and substitutions may of course be made without departing from the spirit and scope of the invention. The invention, therefore, should not be limited except by the following claims and their equivalents.

INDUSTRIAL APPLICABILITY

[00129] This invention may be industrially applied to the development, manufacture, and use of a medicant delivery system that can consistently, reliably, and repeatably deliver a precise dose of a medicant to a user in vapor form in an energy efficient manner. The delivery system comprises a power control system, a vaporization system, and a fluid delivery system. The power control system utilizes a circuitry that allows the system to

deliver just enough power to vaporize or atomize a known volume of a medicant. To avoid changes in the current due to power drainage, the control system utilizes supercapacitors connected to the circuitry. The power source and/or the resistance at the heating element can be monitored so that the system knows how much power needs to be supplied to efficiently vaporize the known volume of medicant. The fluid delivery system utilizes a reservoir and dispensing mechanism that dispenses the same volume of medicant with each actuation. The heating system utilizes a nichrome wire.

We claim:

1. A control system for a hand-held vapor delivery device, comprising:

a circuit configured to provide a precise amount of power from a power source to heat a heating element to a minimum required temperature to completely vaporize a precise volume of a liquid, and control a precise duration of time to supply the precise amount of power to completely vaporize the predetermined volume of liquid at the required temperature;

monitor a temperature of the heating element while the power is being supplied;

compare the temperature of the heating element to the minimum required temperature; and

adjust the precise duration of time or the precise amount of power based on the comparison step to completely vaporize the liquid, wherein if the precise volume of liquid is adjusted, the precise duration of time or the precise amount of power is adjusted to completely vaporize the adjusted precise volume of liquid within a new minimum required temperature for a new minimum required time.

2. The control system of claim 1, wherein the circuit comprises a one-shot circuit.

3. The control system of claim 1, wherein the circuit further comprises a processor programmed to monitor a resistance of the heating element and adjust the amount of power to a level sufficient to heat the heating element to the required temperature.

4. The control system of claim 1, wherein the circuit comprises a DC/DC boost converter and a supercapacitor operatively connected to the power source to adjust the amount of power to the level sufficient to heat the heating element to the required temperature.

5. The control system of claim 1, wherein the circuit is configured to actuate the power source a predetermined number of times.

6. A hand-held medicant delivery device, comprising:

a. a housing having a first end and a second end;

b. a mouthpiece attached to the first end;

c. a fluid delivery system;

d. a vaporization system, comprising a heating element in between the mouthpiece and the fluid delivery system; and

e. a power control system, comprising a circuit configured to provide a precise amount of power from a power source to heat the heating element to a minimum required temperature to completely vaporize a precise volume of a liquid, control a precise duration of time to supply the precise amount of power to completely vaporize the predetermined volume of the liquid at the required temperature, monitor a temperature of the heating element while the power is being supplied, compare the temperature of the heating element to the minimum required temperature, and adjust the precise duration of time or the precise amount of power based on the comparison step to completely vaporize the liquid, wherein if the precise volume of liquid is adjusted, the precise duration of time or the precise amount of power is adjusted to completely vaporize the adjusted precise volume of liquid within a new minimum required temperature for a new minimum required time.

7. The hand-held medicant delivery device of claim 6, wherein the control system comprises a one-shot circuit.

8. The hand-held medicant delivery device of claim 6, wherein the circuit comprises a processor that is programmed to monitor a resistance of the heating element and adjust the power until the heating element reaches the required temperature.

9. The hand-held medicant delivery device of claim 6, wherein the control system comprises a DC/DC boost converter operatively connected to a supercapacitor.

10. The hand-held medicant delivery device of claim 6, wherein the circuit comprises a processor programmed to actuate the power source a predetermined number of times.

11. The hand-held medicant delivery device of claim 6, wherein the power source is an alkaline battery.

12. The hand-held medicant delivery device of claim 6, wherein the fluid delivery system, comprises:

a. a fluid reservoir inside the housing, the fluid reservoir having a first end and a second end; and

b. a pressure generator positioned inside the fluid reservoir at the second end and configured to advance towards the first end incrementally at a fixed and discrete distance to consistently meter a precise volume of a liquid from the fluid reservoir.

13. The hand-held medicant delivery device of claim 12, wherein the fluid delivery system further comprises a cap in fluid communication with the fluid reservoir at the first end, the cap having an outlet opposite the fluid reservoir, wherein the liquid stored inside the fluid reservoir can exit through the outlet when a positive pressure is applied to the fluid reservoir to form a droplet at the outlet.

14. The hand-held medicant delivery device of claim 13, wherein the outlet and the heating element are separated by a distance smaller than the droplet, such that the droplet can contact the heating element while still on the outlet.

15. The hand-held medicant delivery device of claim 13, wherein the pressure generator comprises:

a. a piston housed inside the fluid reservoir configured to push the liquid out through the cap; and

b. a fluid discharge actuator operatively connected to the piston, wherein actuation of the fluid discharge actuator causes the piston to advance the fixed and discrete distance towards the first end.

16. The hand-held medicant delivery device of claim 12, further comprising a permeable membrane positioned between the mouthpiece and the heating element, wherein the permeable membrane is permeable to vapor molecules of a predetermined size.

17. A hand-held medicant delivery device, comprising:

a. a housing having a first end and a second end;

b. a mouthpiece attached to the first end;

c. a fluid delivery system, comprising:

i. a fluid reservoir inside the housing, the fluid reservoir having a first

end and a second end, and

ii. a pressure generator positioned inside the fluid reservoir at the second end and configured to advance towards the first end in at a fixed and discrete distance to consistently meter a precise volume of a liquid from the fluid reservoir;

d. a vaporization system , comprising a heating element in between the mouthpiece and the fluid reservoir; and

e. a control system to deliver power to the vaporization system, comprising a circuit configured to provide a precise amount of power from a power source to heat the heating element to a minimum required temperature to completely vaporize a precise volume of a liquid, control a precise duration of time to supply the precise amount of power to completely vaporize the predetermined volume of the liquid at the required temperature, monitor a temperature of the heating element while the power is being supplied, compare the temperature of the heating element to the minimum required temperature, and adjust the precise duration of time or the precise amount of power based on the comparison step to completely vaporize the liquid, wherein if the precise volume of liquid is adjusted, the precise duration of time or the precise amount of power is adjusted to completely vaporize the adjusted precise volume of liquid within a new minimum required temperature for a new minimum required time.

18. The hand-held medicant delivery device of claim 17, wherein the fluid delivery system further comprises a cap in fluid communication with the fluid reservoir at the first end, the cap having an outlet opposite the fluid reservoir, wherein the liquid stored inside the fluid reservoir can exit through the outlet when a positive pressure is applied to the fluid reservoir to form a droplet at the outlet.

19. The hand-held medicant delivery device of claim 18, wherein the outlet and the heating element are separated by a distance smaller than the droplet, such that the droplet can contact the heating element while still on the outlet at the opening.

20. The hand-held medicant delivery device of claim 18, wherein the pressure generator

comprises:

a. a piston housed inside the fluid reservoir configured to push the liquid out through the cap; and

b. a fluid discharge actuator operatively connected to the piston, wherein actuation of the fluid discharge actuator causes the piston to advance the fixed and discrete distance towards the first end.

21. The hand-held medicant delivery device of claim 17, further comprising a permeable membrane positioned between the mouthpiece and the heating element, wherein the permeable membrane is permeable to vapor molecules of a predetermined size.

22. A method of efficiently and consistently vaporizing a precise volume of a liquid medicant from a hand-held device, comprising:

a. determining a precise amount of power required to vaporize the precise volume of liquid with a heating element in a precise duration of time;

b. metering the precise volume of the liquid to the heating element;

c. supplying the precise amount of power from a power supply to heat the heating element for the precise duration of time such that the combination of the precise amount of power and the precise duration of time heats the heating element to a minimum required temperature for a minimum required time to completely vaporize the precise volume of the liquid;

d. monitoring a temperature of the heating element while the power is being supplied;

e. comparing the temperature of the heating element to the minimum required temperature; and

f. adjusting the precise duration of time or the precise amount of power based on the comparison step to completely vaporize the liquid, wherein if the precise volume of liquid is adjusted, the precise duration of time or the precise amount of power is adjusted to completely vaporize the adjusted precise volume of liquid within a new minimum required temperature for a new minimum required time.

23. The method of claim 22, wherein metering the precise volume of the liquid, comprises:

a. storing the liquid in a fluid reservoir; and

b. applying a precise amount of positive pressure inside the fluid reservoir to discharge the precise volume of fluid from the fluid reservoir.

24. The method of claim 23, wherein the precise amount of positive pressure is applied by advancing a threaded plunger a predetermined distance within the fluid reservoir.

25. The method of claim 24, wherein advancing the plunger the predetermined distance is achieved by turning a drive nut a fixed rotational movement, wherein the threaded plunger comprises a groove running down a length of the threaded plunger, and an anti-rotation tang is seated within the groove to prevent rotation of the threaded plunger.

26. The method of claim 25, wherein turning the drive nut is achieved by actuating a button that turns the drive nut the fixed rotational movement each time the button is actuated, wherein the drive nut remains in a fixed translational location.

27. The method of claim 22, wherein supplying the precise amount of power is achieved by programming a processor to permit actuation of the power supply a predetermined number of times.

28. The method of claim 22, wherein monitoring the temperature of the heating element is achieved by measuring a resistance in the heating element.

29. The method of claim 22, further comprising a supercapacitor operatively connected to the power supply and a processor to limit the amount of power supplied to generate the minimum required temperature.

30. The method of claim 29, wherein the power supply is an alkaline battery.

31. The method of claim 22, wherein supplying the power is activated by creating an airflow at a mouthpiece of the hand-held device.

32. The method of claim 31, further comprising controlling a size of a vapor molecule of

the vaporized liquid by placing a permeable membrane between the heating element and the mouthpiece, wherein the permeable membrane is permeable only to vapor molecules of a predetermined size.

33. A control system for a hand-held vapor delivery device, comprising:

a. a means for providing a precise amount of power from a power source to heat a heating element to a minimum required temperature to completely vaporize a precise volume of a liquid; and

b. a means for controlling a precise duration of time to supply the precise amount of power to completely vaporize the predetermined volume of liquid at the required temperature, wherein the precise duration of time or the precise amount of power is adjusted based on a comparison of a temperature of the heating element to the minimum required temperature to completely vaporize the liquid, wherein if the precise volume of liquid is adjusted, the precise duration of time or the precise amount of power is adjusted to completely vaporize the adjusted precise volume of liquid within a new minimum required temperature for a new minimum required time.

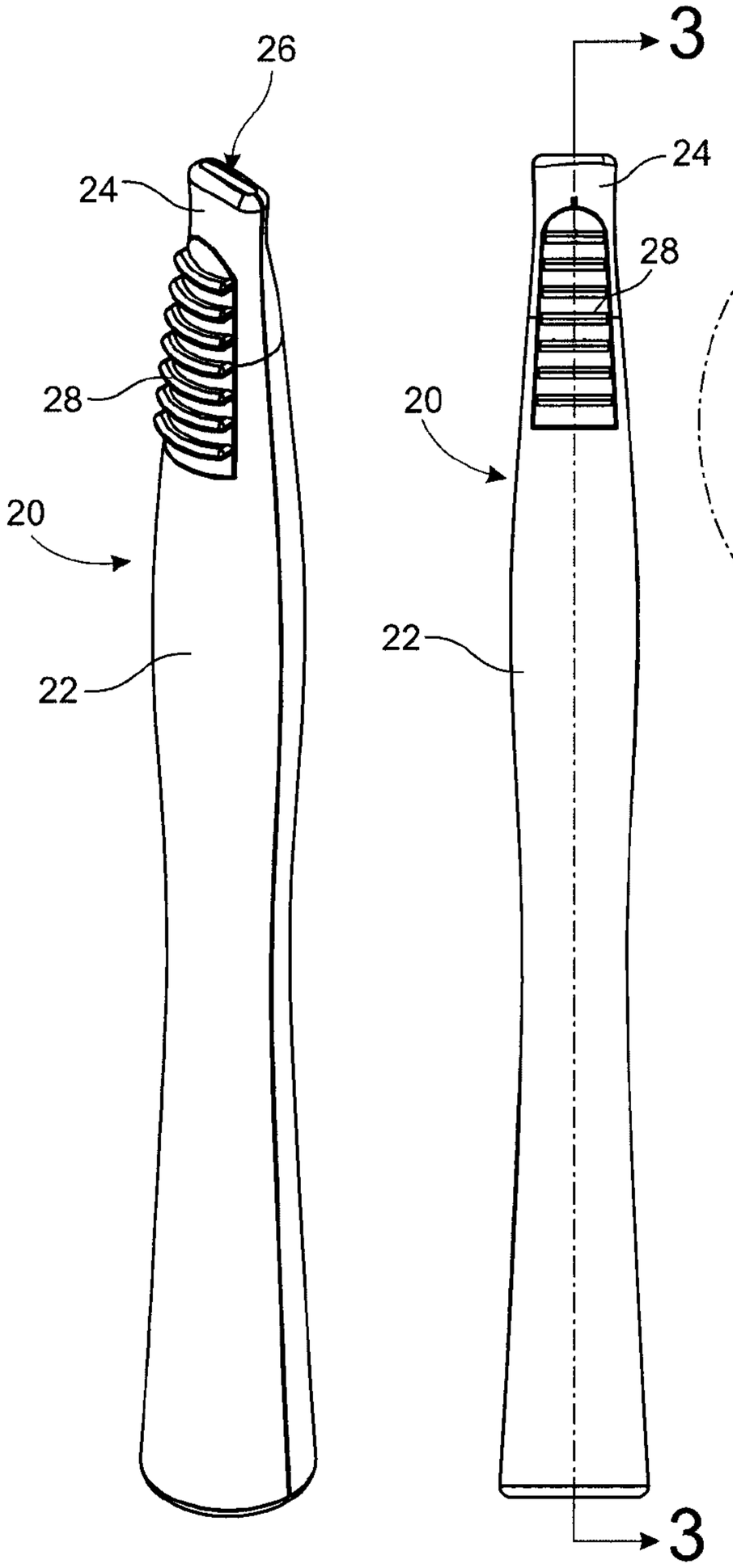

Fig. 1

Fig. 2

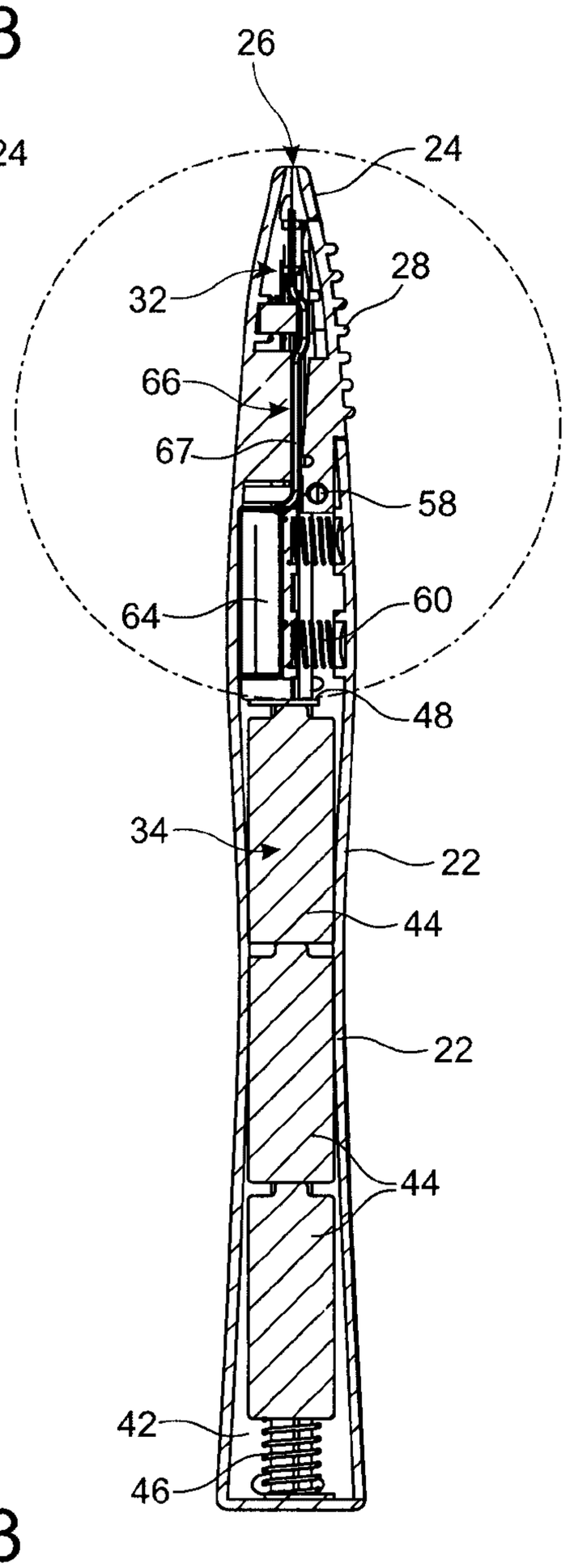

Fig. 3

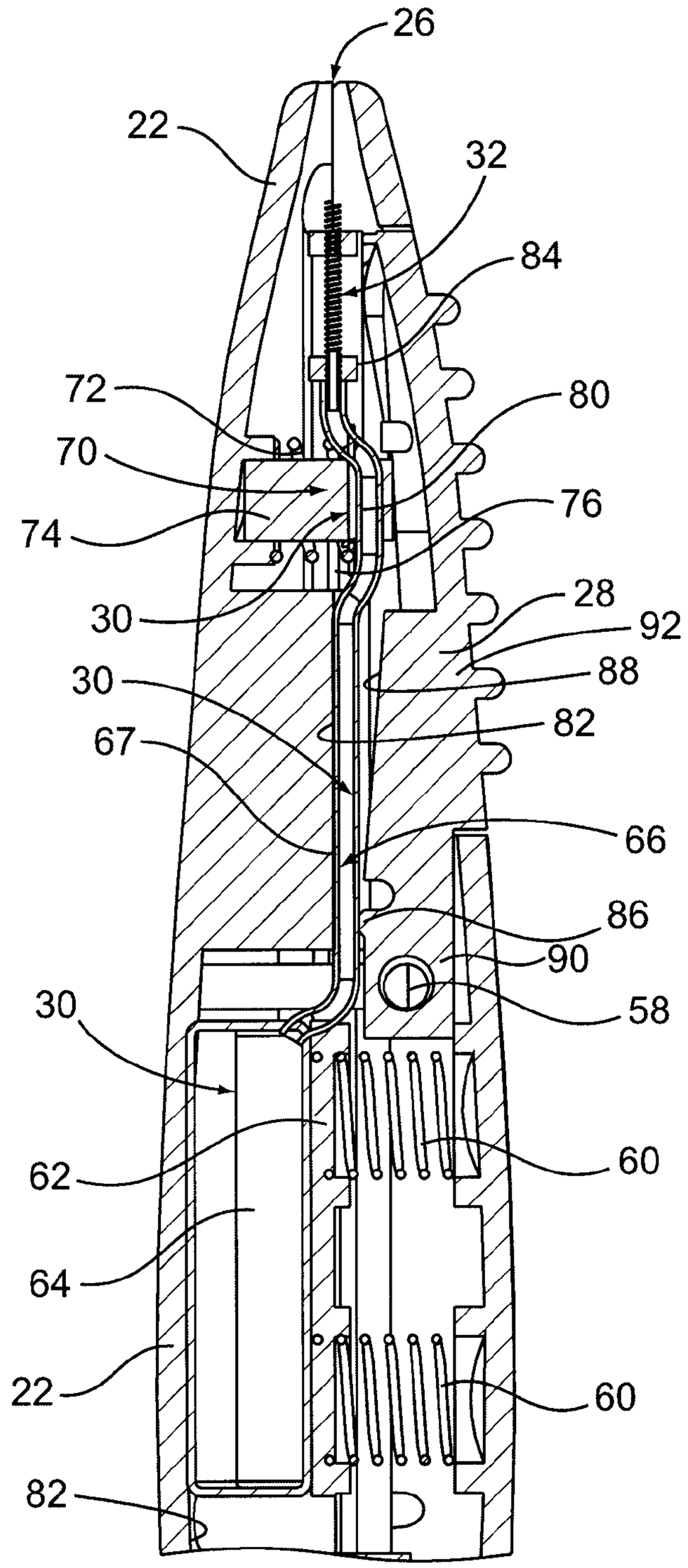
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FIG. 4

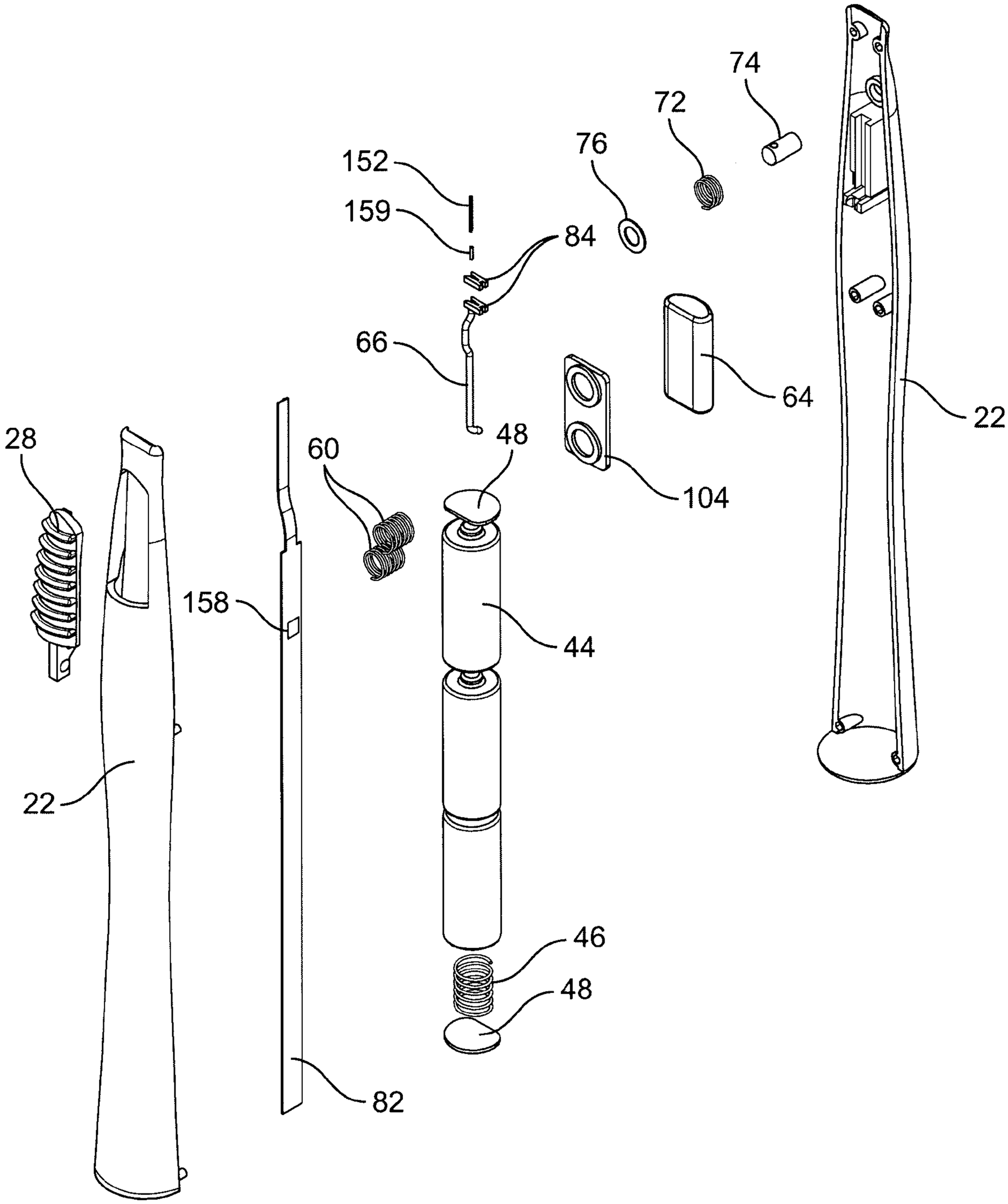


FIG. 5

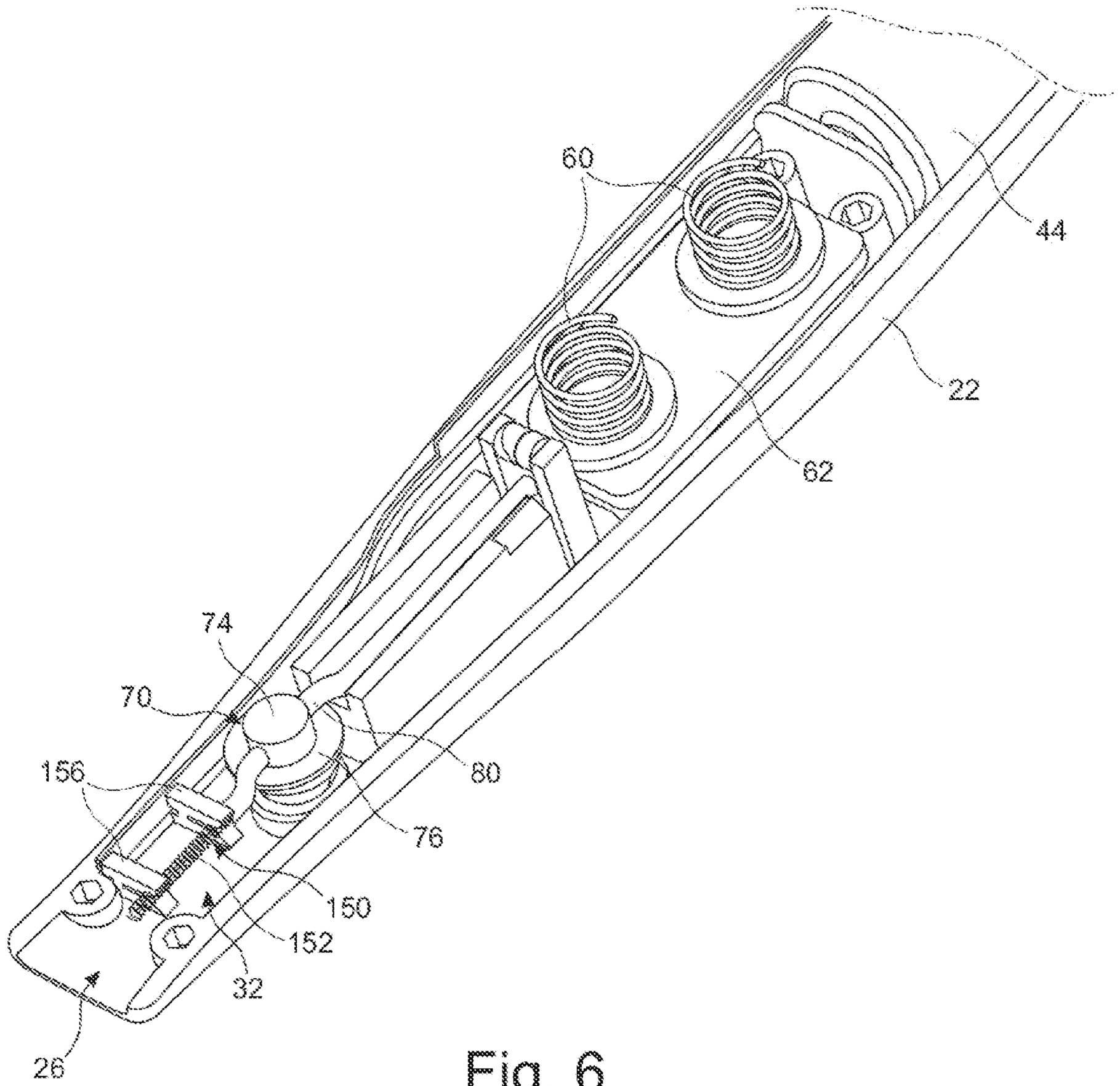


Fig. 6

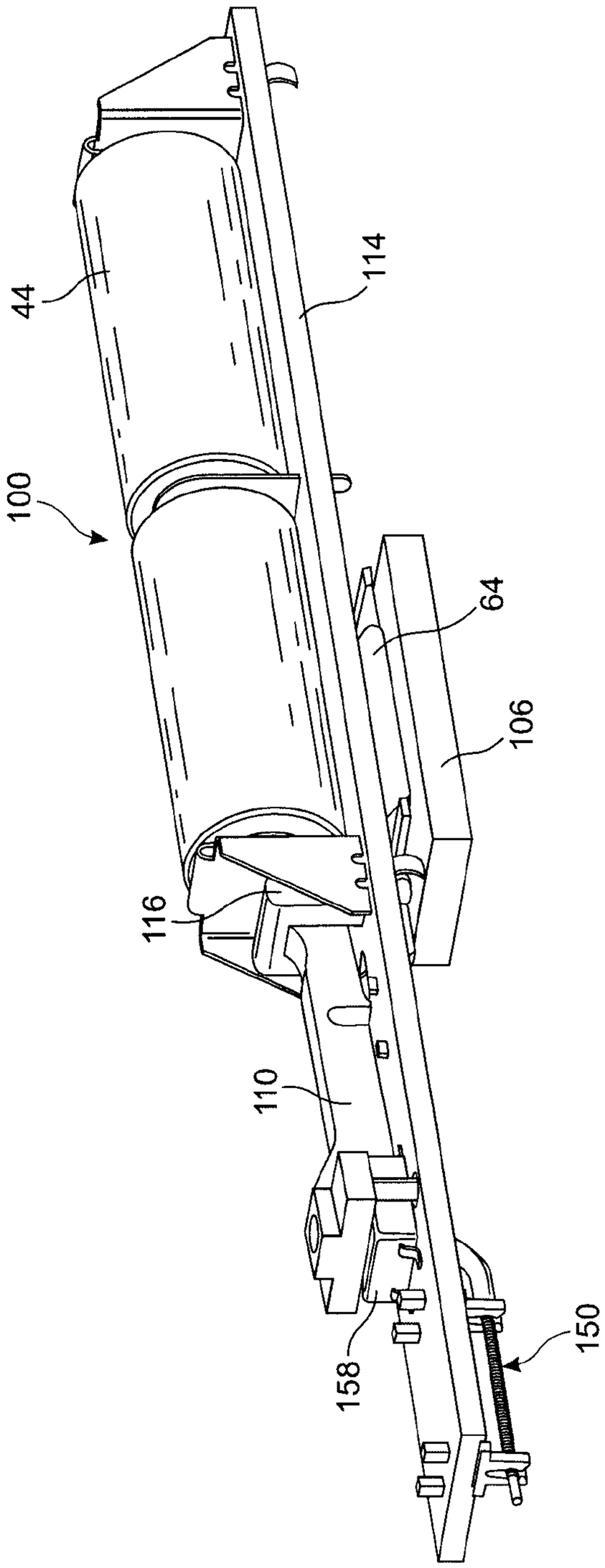
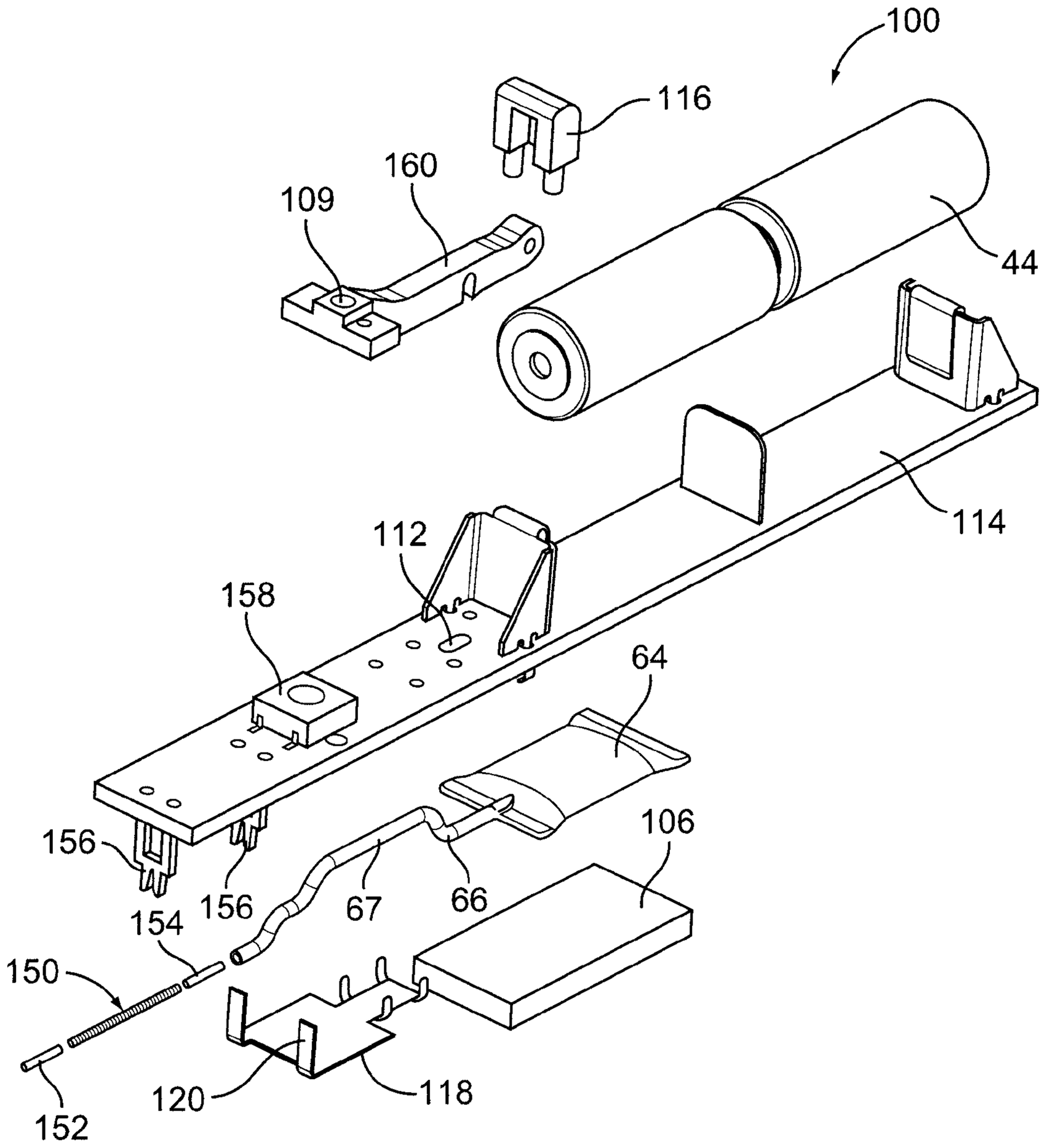


Fig. 7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152

FIG. 8

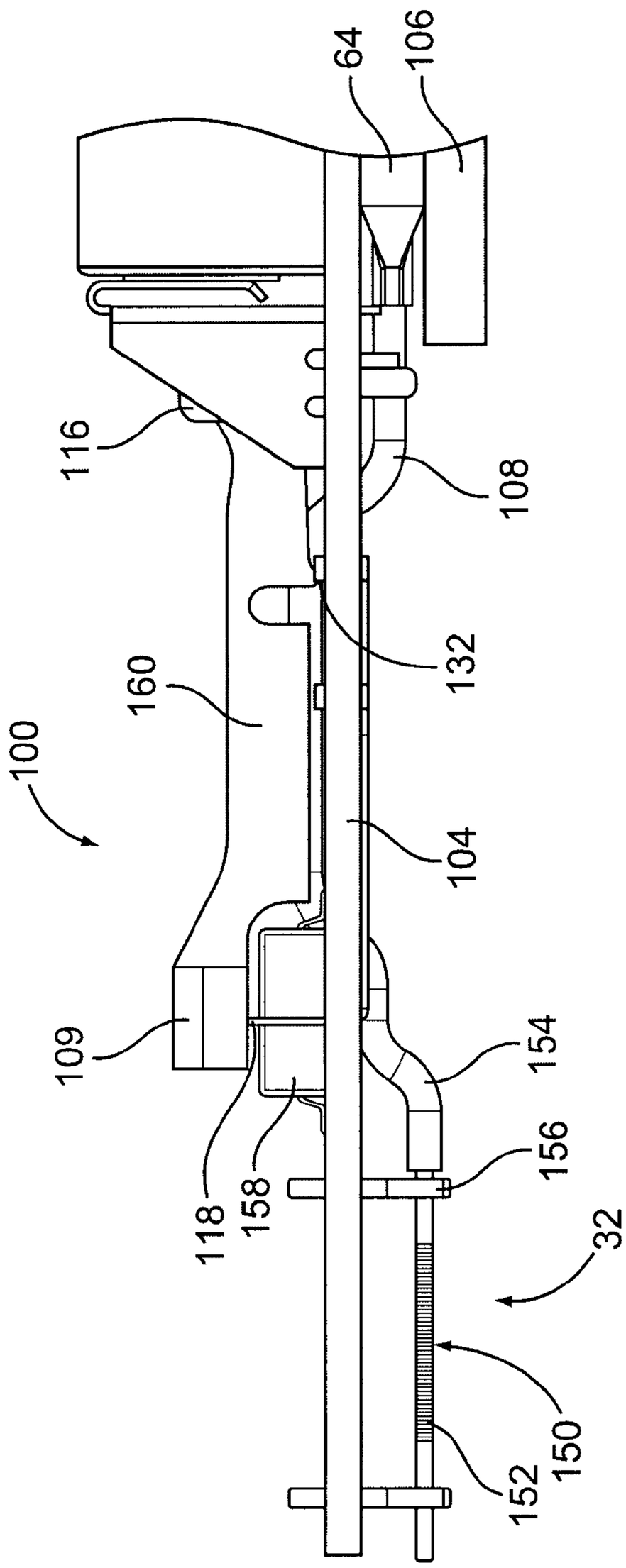


FIG. 9

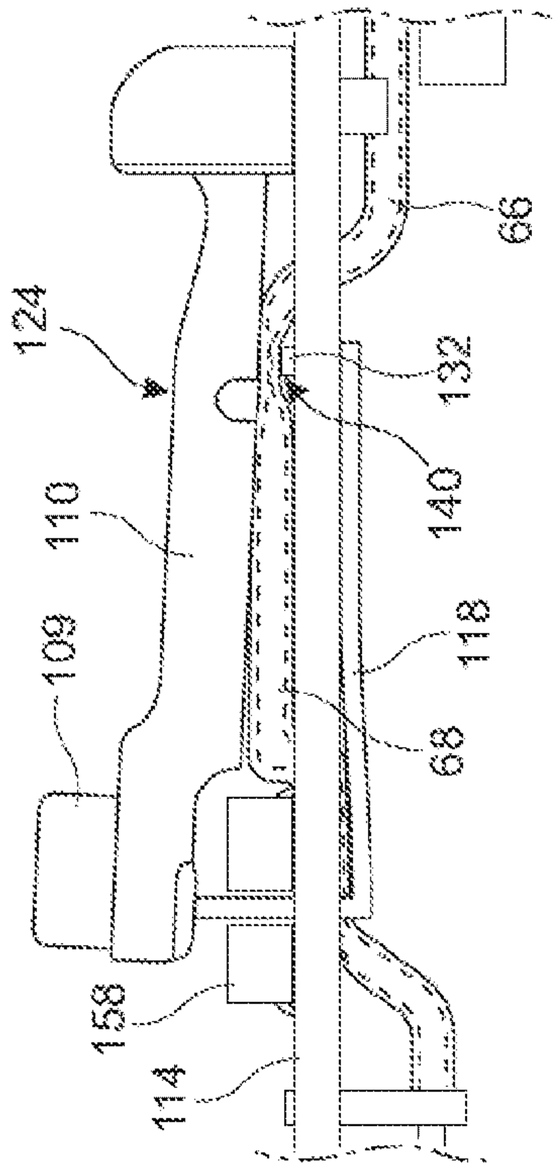


Fig. 11

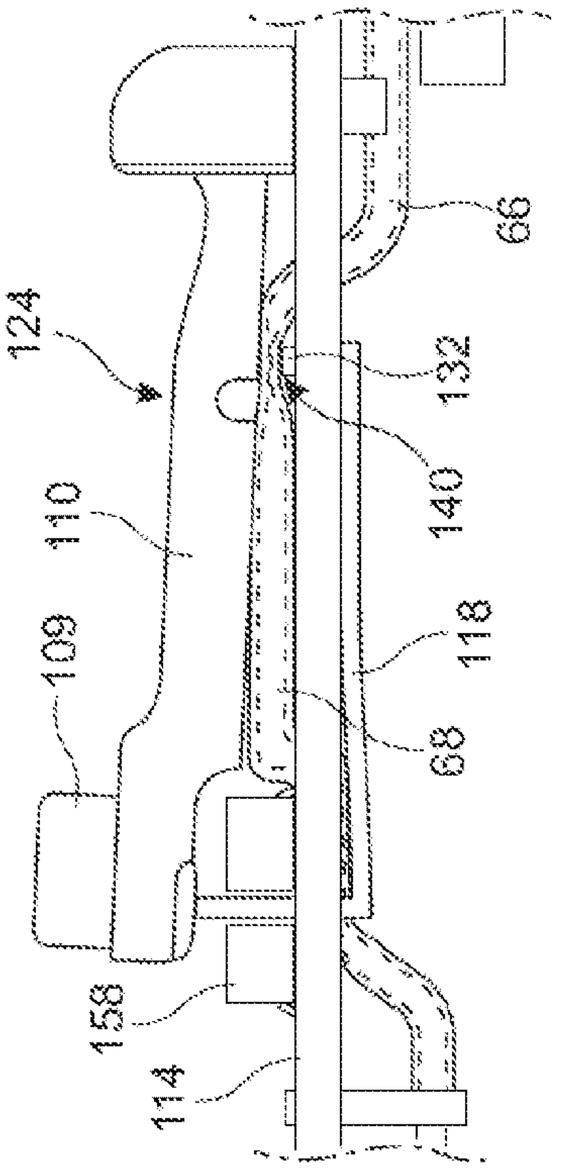


Fig. 13

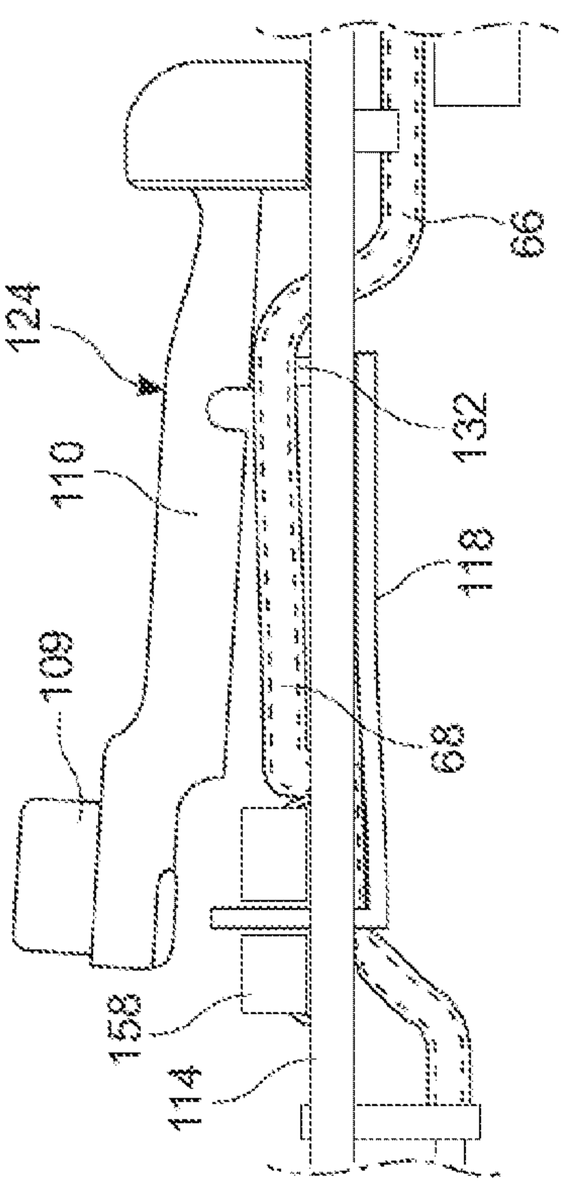


Fig. 10

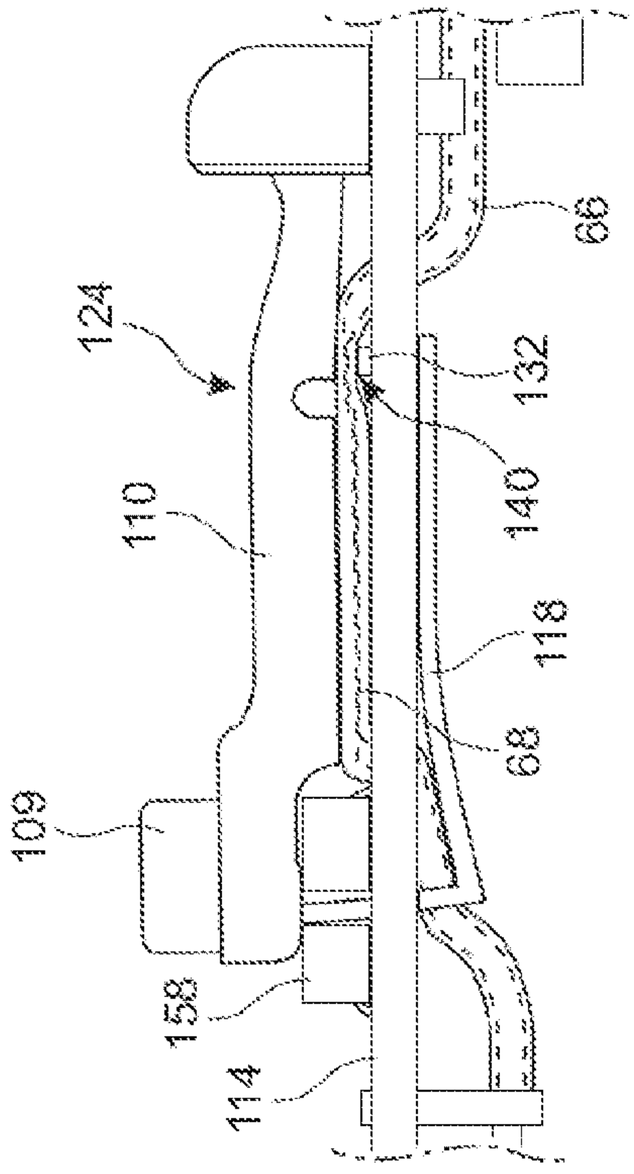


Fig. 12

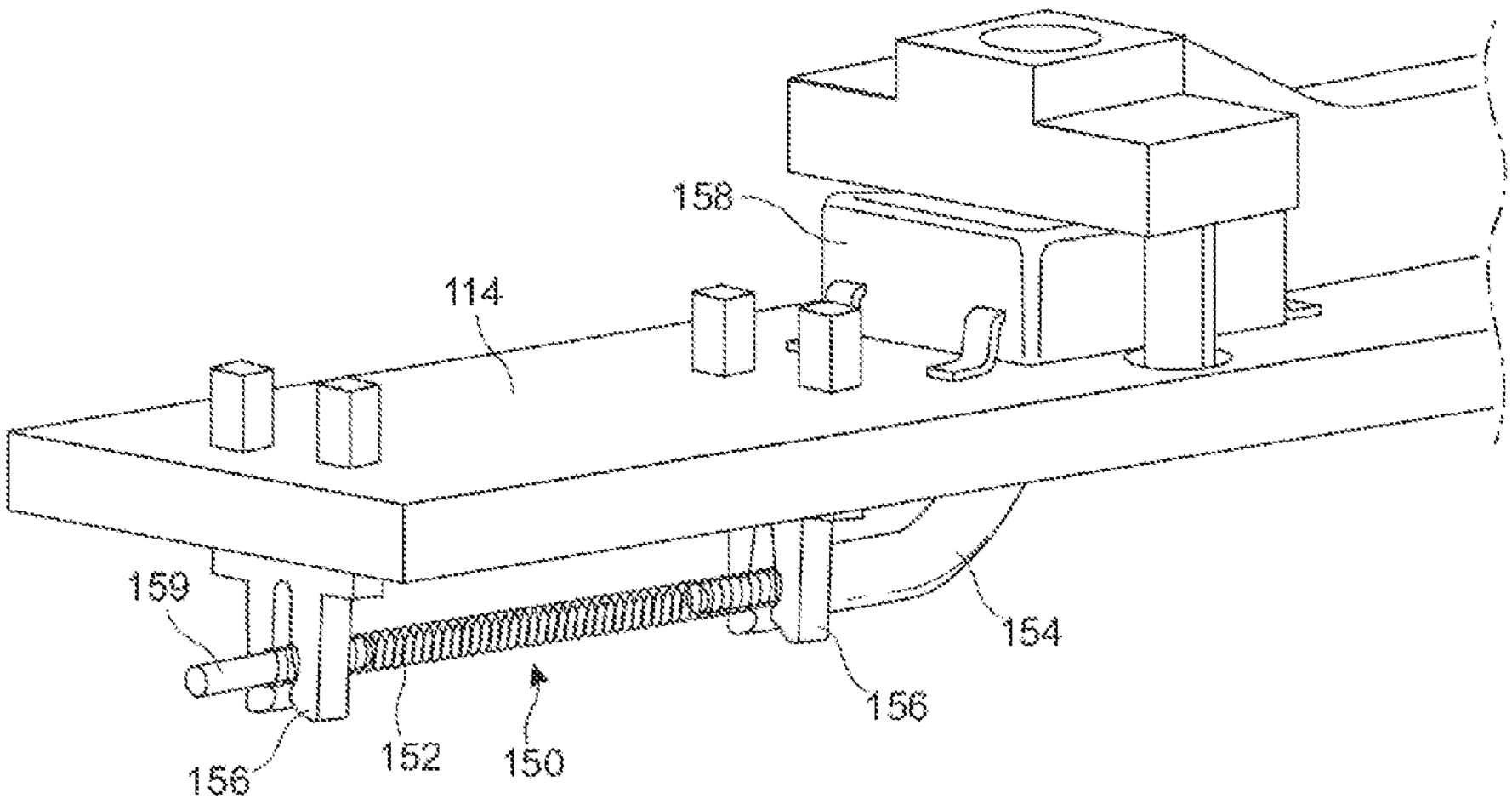
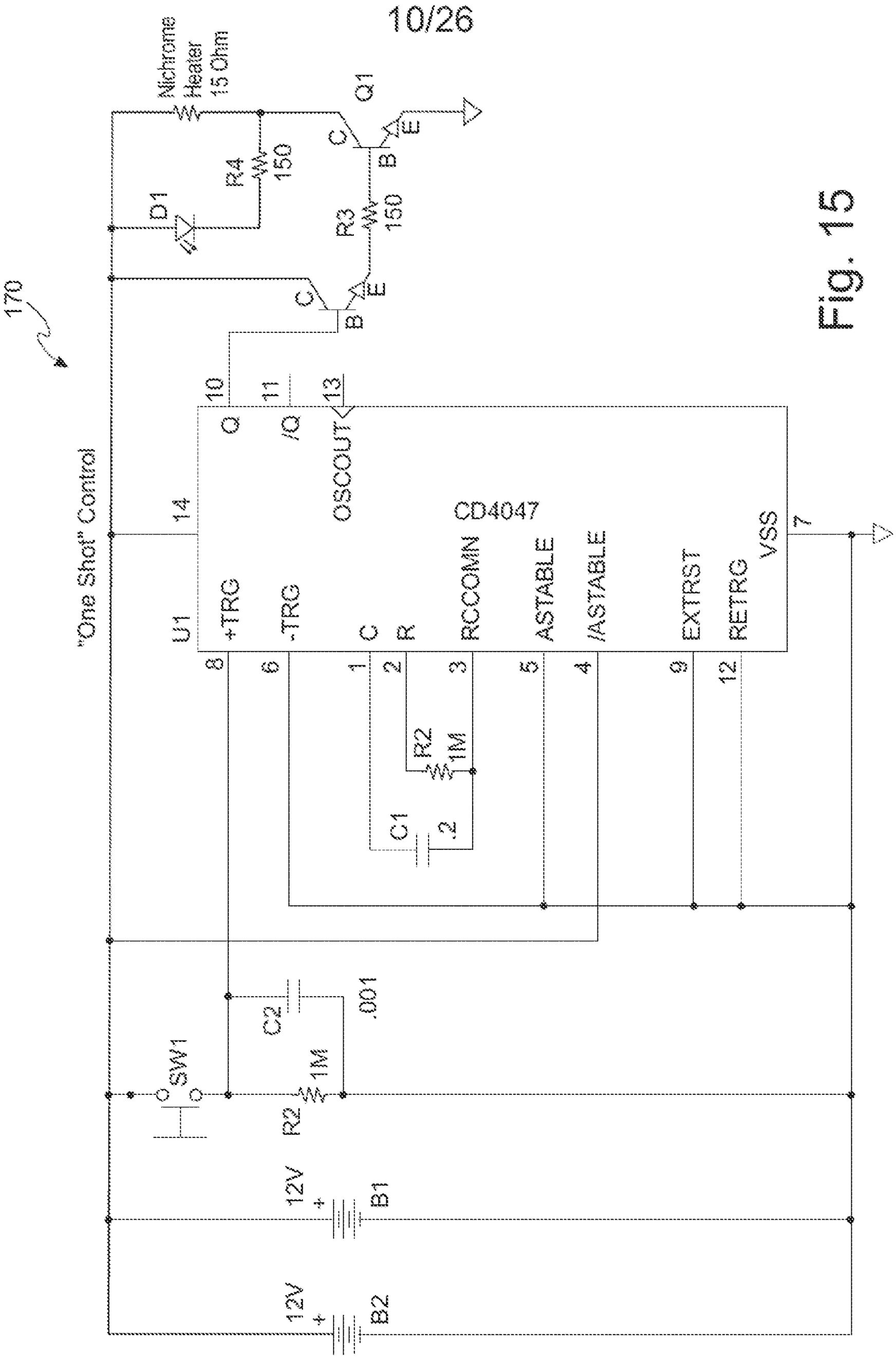


Fig. 14


170
"One Shot" Control
Nichrome Heater 15 Ohm
Q1
C
E
B
R4
150
D1
R3
150
C
E
B
U1
CD4047
+TRG
-TRG
C
R
RCOMN
ASTABLE
/ASTABLE
EXTRST
RETRG
VSS
Q
/Q
OSCOUT
10
11
13
14
8
6
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9
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C1
.2
R2
1M
C2
.001
SW1
R2
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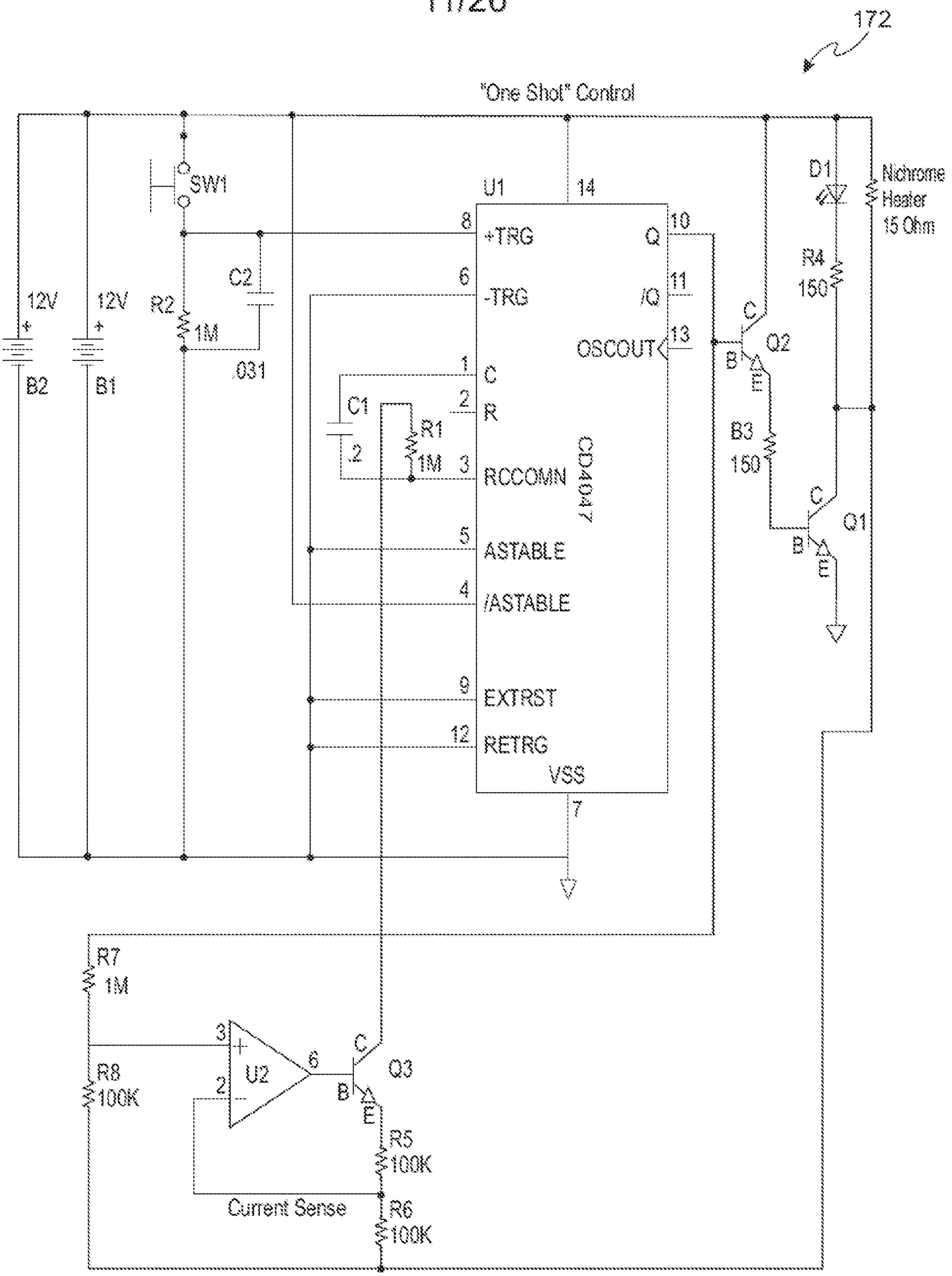
12V
B1
12V
B2

Fig. 15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"One Shot" Control
SW1
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8
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6
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Q
10
/Q
11
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R
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RCCOMN
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ASTABLE
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EXTRST
12
RETRG
VSS
7
12V
12V
B2
B1
R2
1M
C2
.031
C1
2
R1
1M
D1
Nichrome
Heater
15 Ohm
R4
150
C
Q2
B
E
B3
150
C
Q1
B
E
R7
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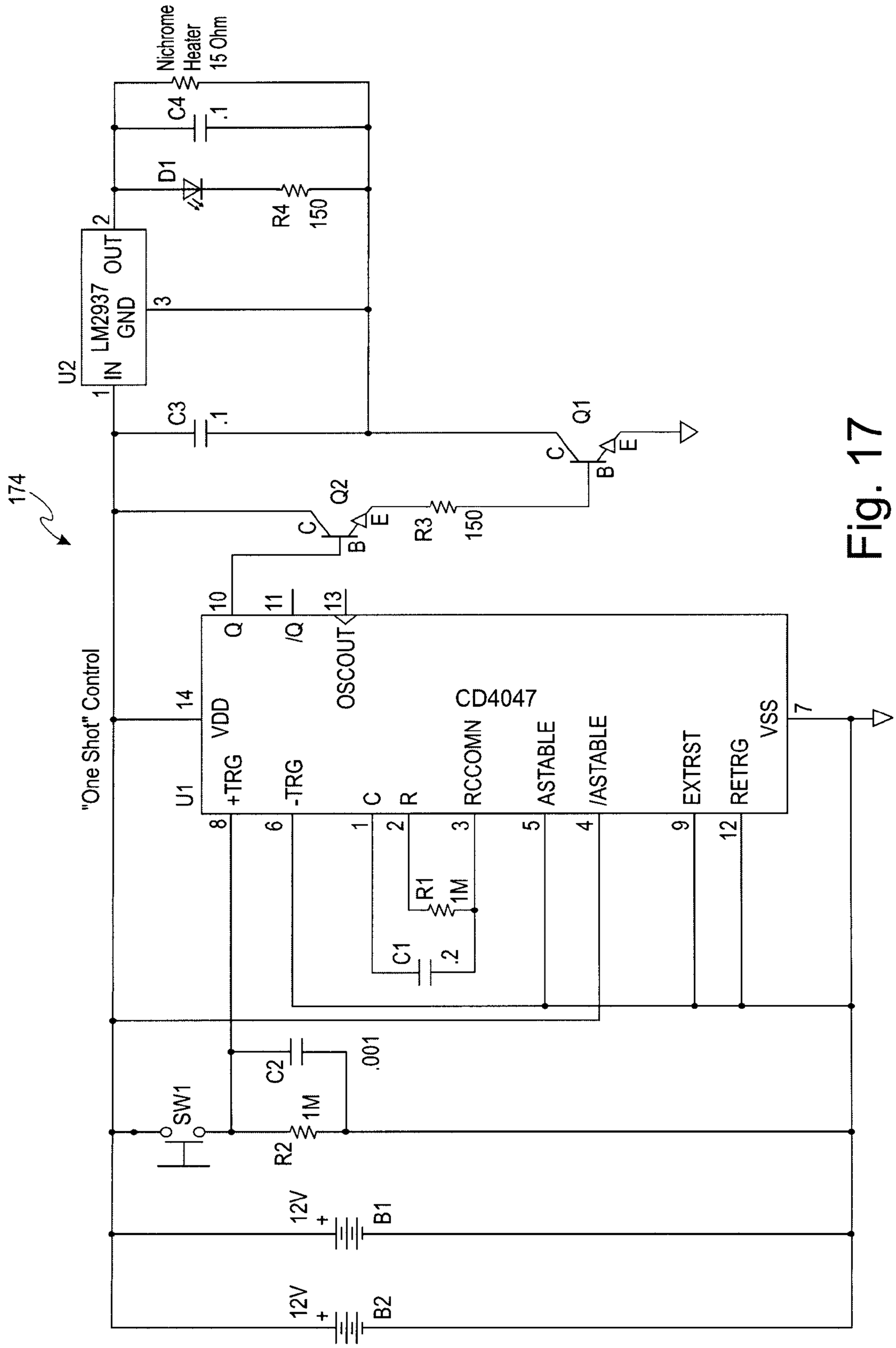
100K
R5
100K
Current Sense
R6
100K

Fig. 16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"One Shot" Control
U2
LM2937
GND
IN
OUT
1
2
3
Nichrome
Heater
15 Ohm
C4
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D1
R4
150
C3
.1
Q1
C
B
E
Q2
C
B
E
R3
150
U1
CD4047
VDD
14
Q
10
/Q
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OSCOUT
13
+TRG
8
-TRG
6
C
1
R
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RCCOMN
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ASTABLE
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/ASTABLE
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EXTRST
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Fig. 17

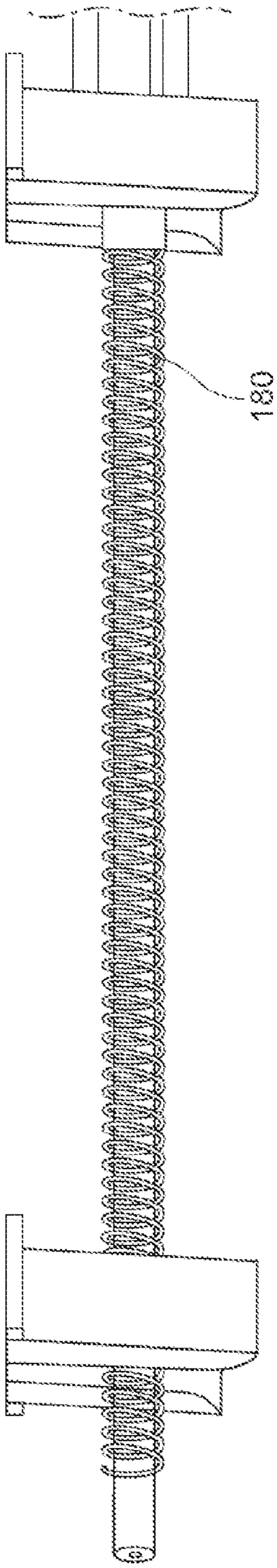

Fig. 18

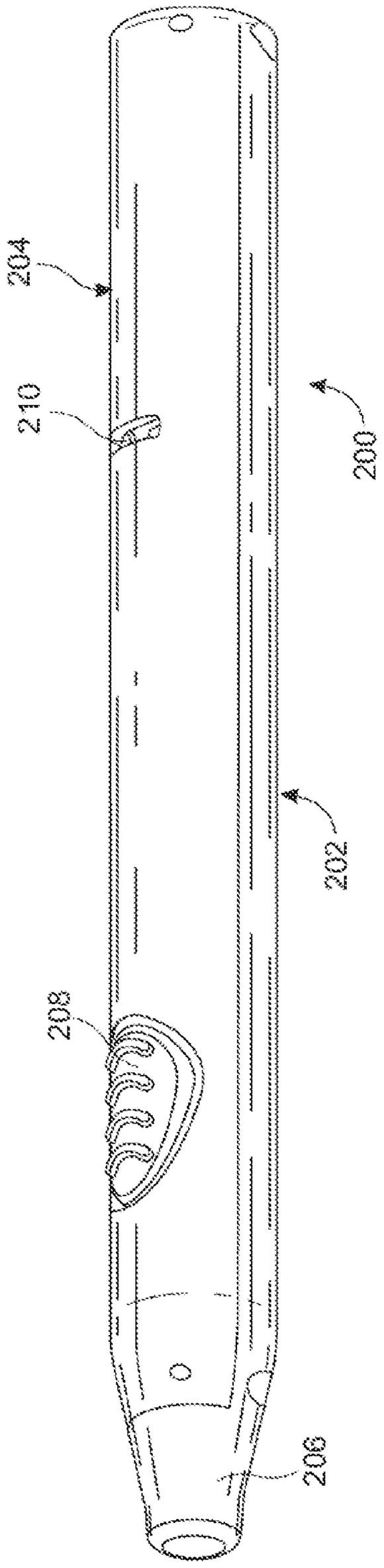
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Fig. 19

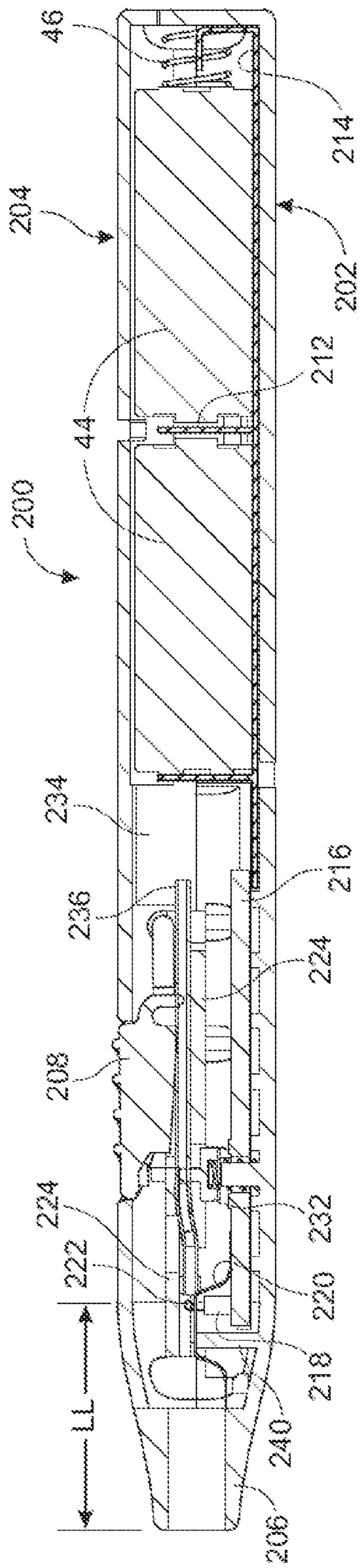
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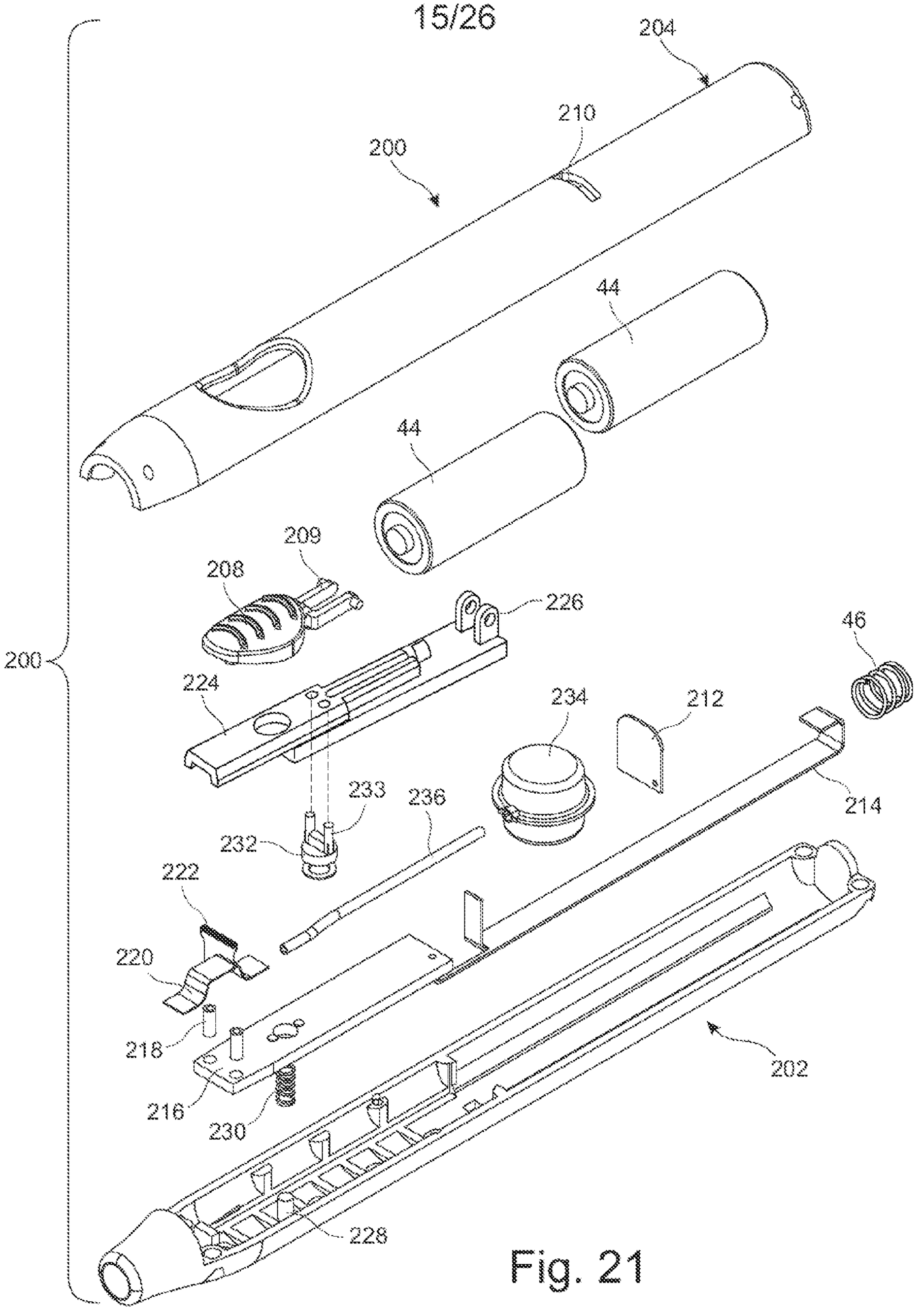
Fig. 20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228
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Fig. 21

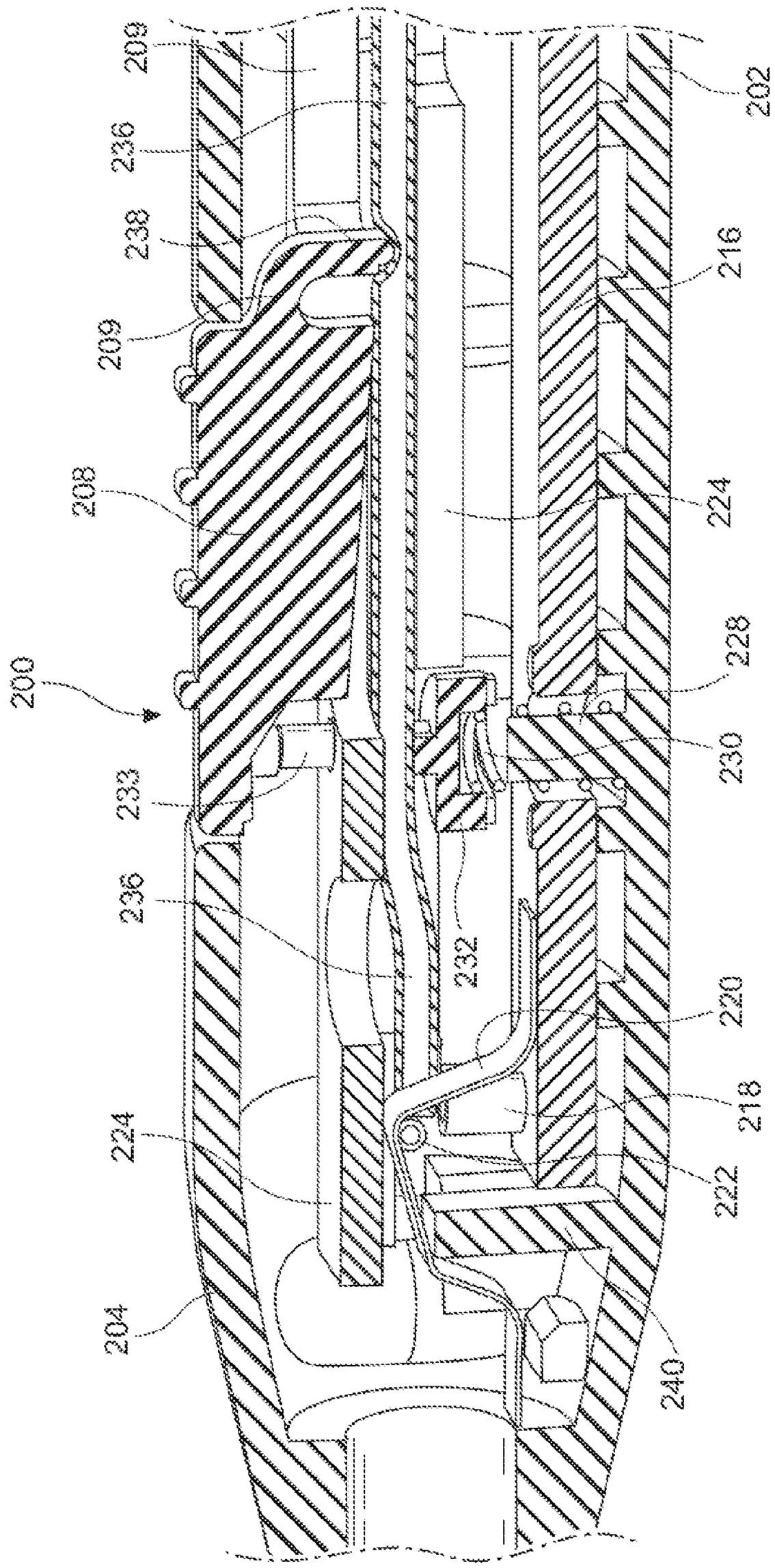
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Fig. 22

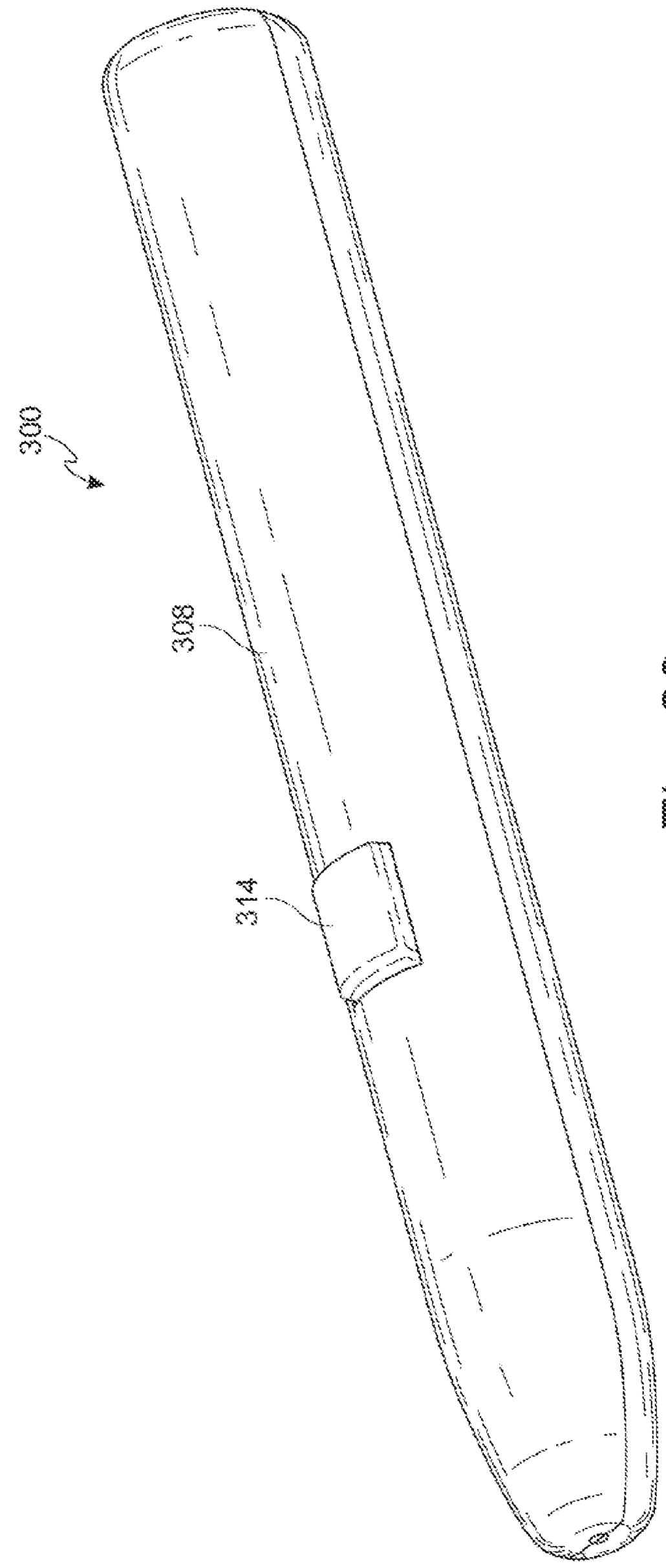
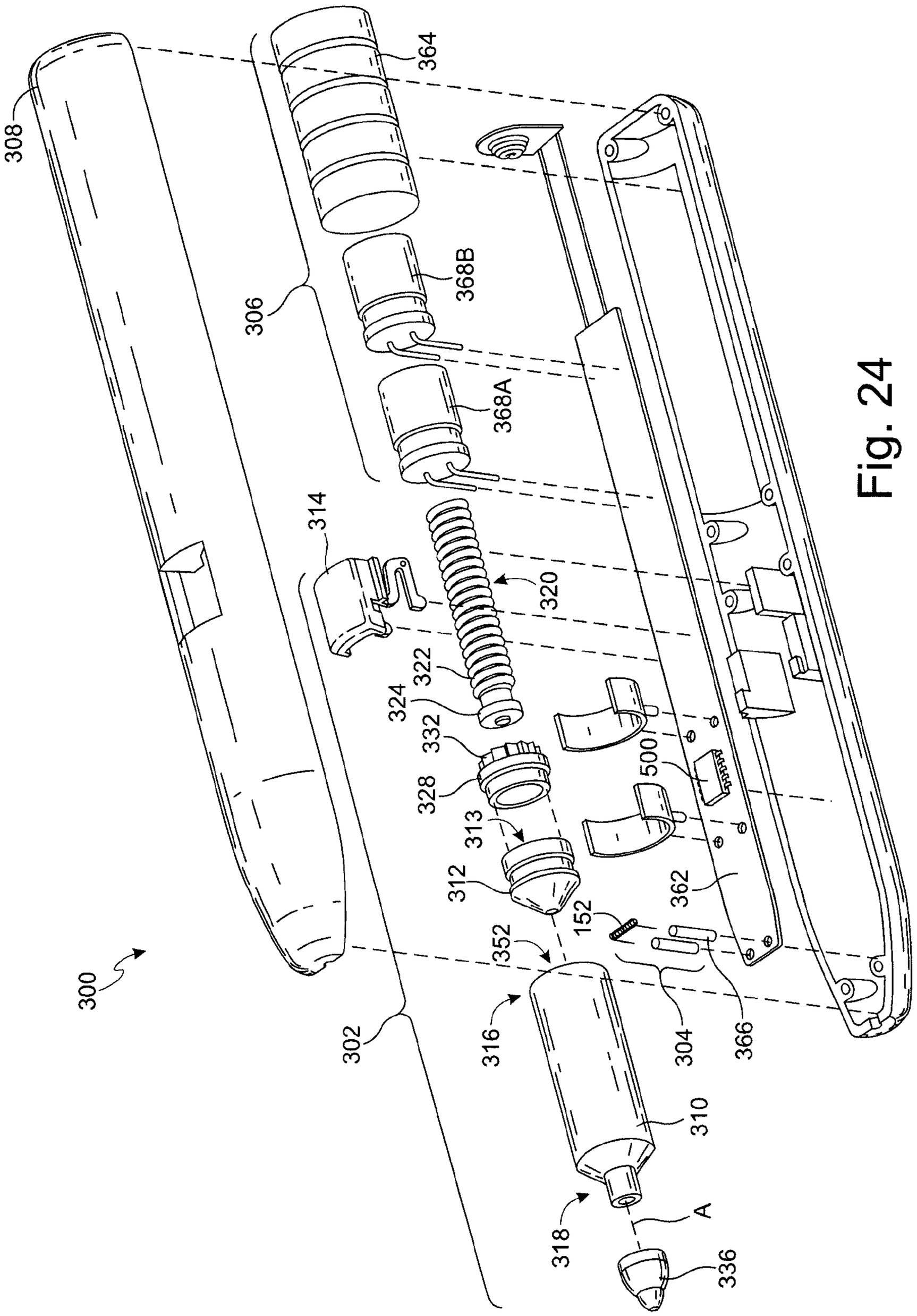


Fig. 23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368A
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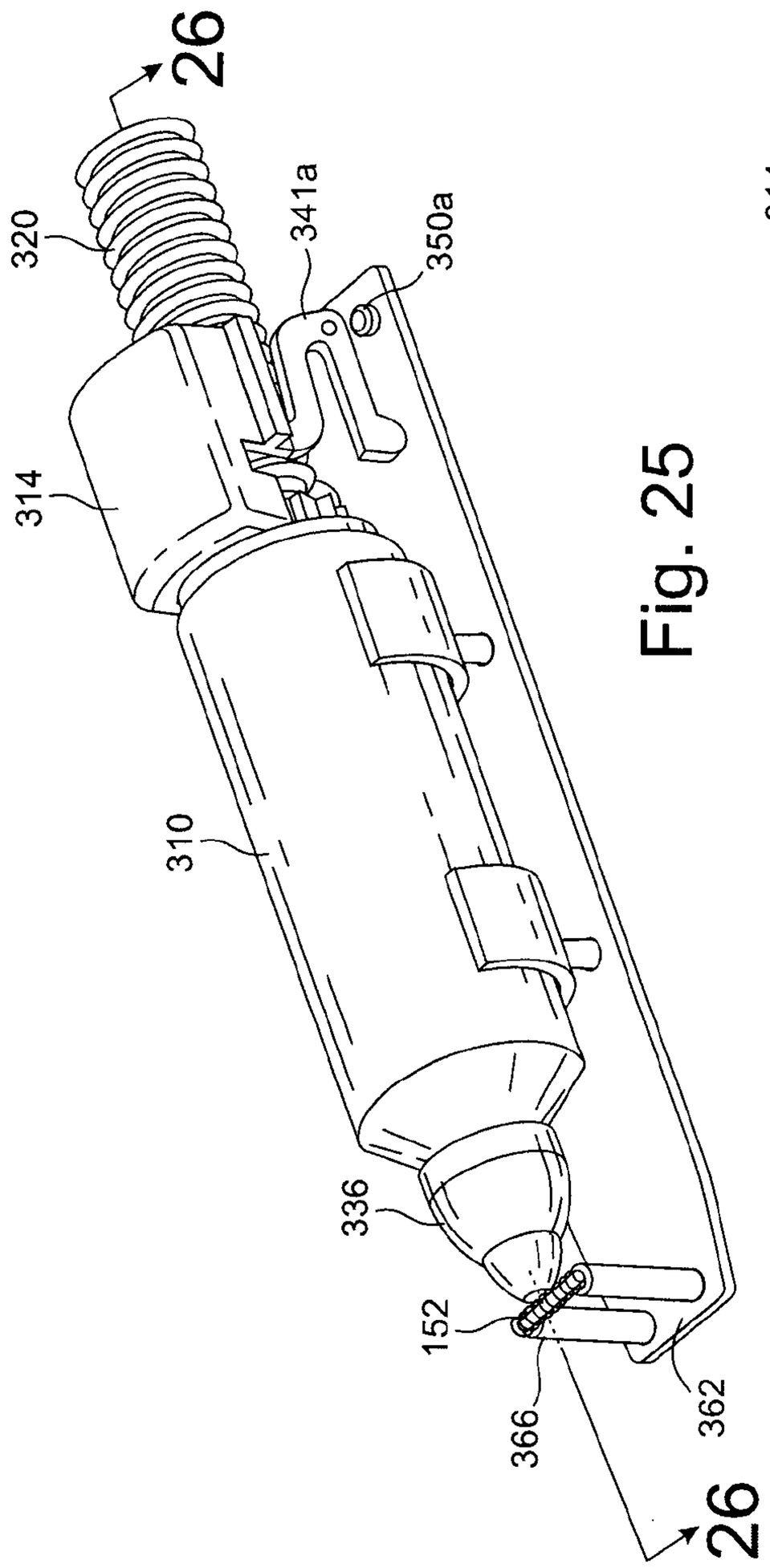
366
310
318
A
336
302
300

Fig. 24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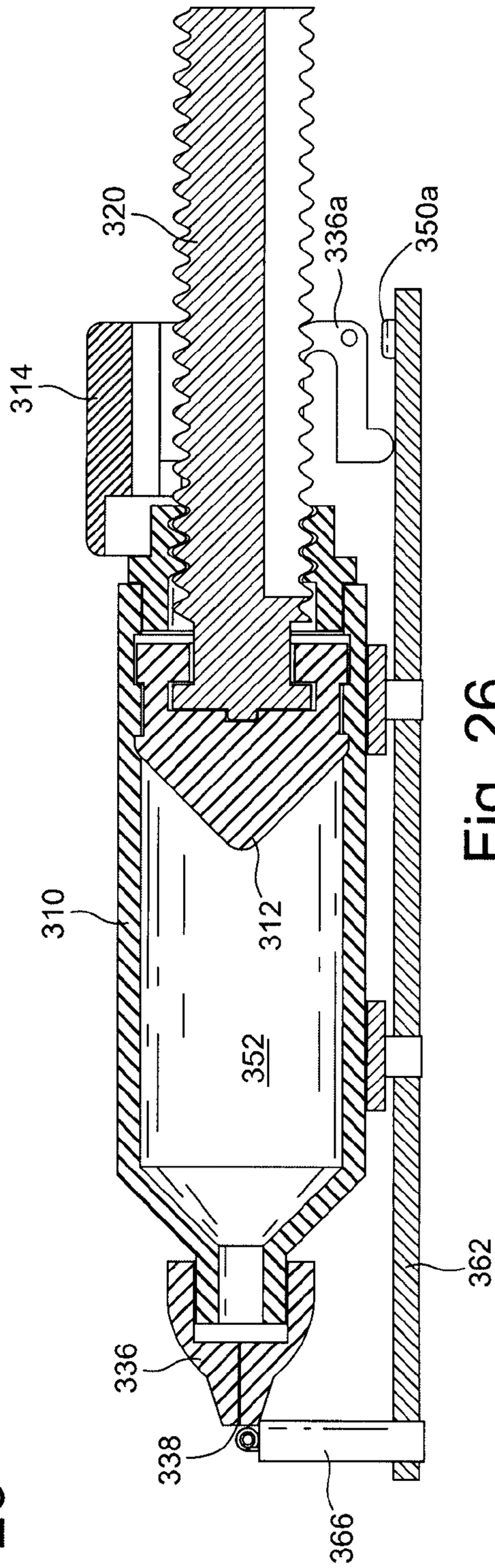
350a
314
310
336
152
366
362
26

Fig. 25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350a
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Fig. 26

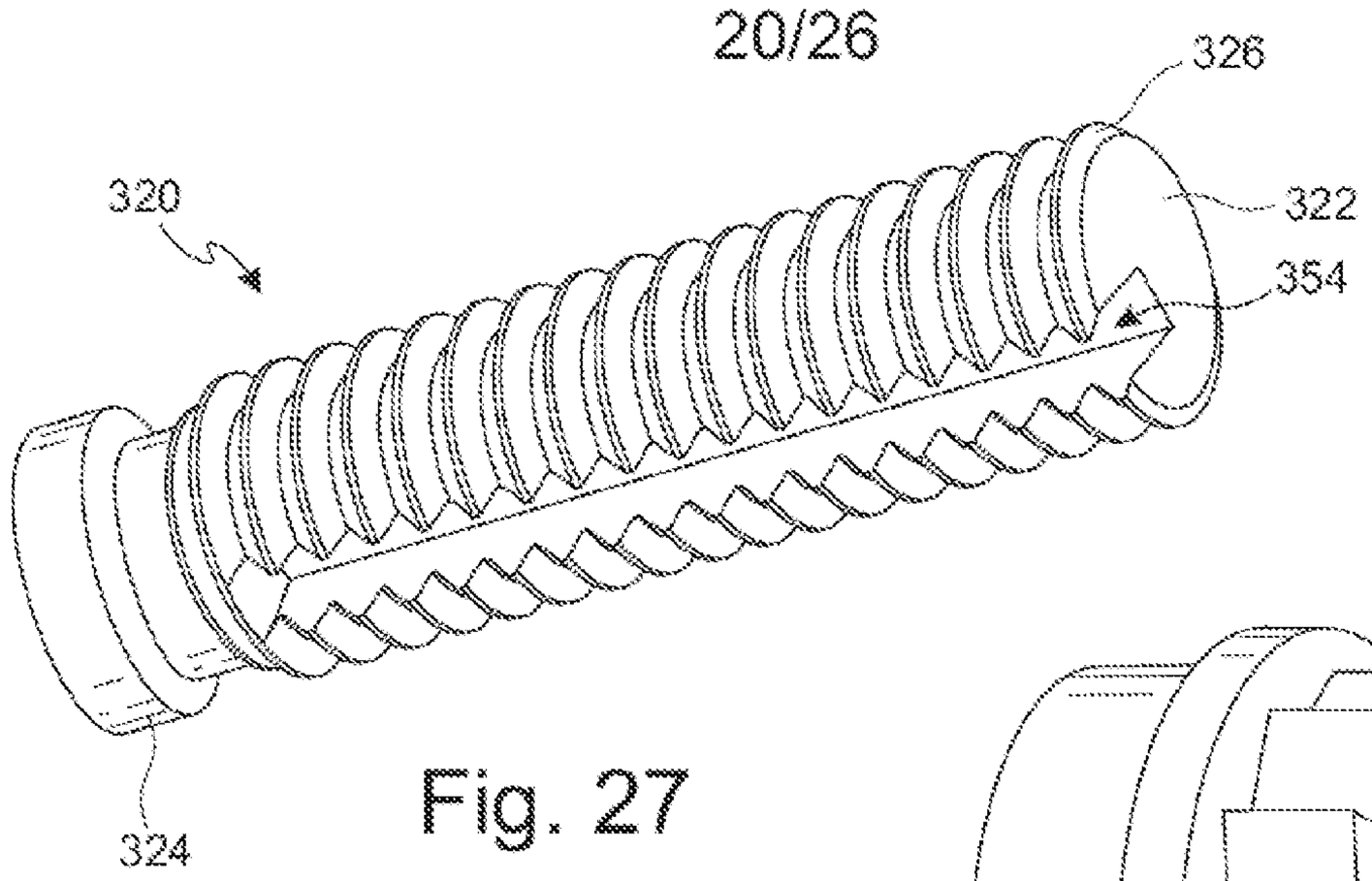


Fig. 27

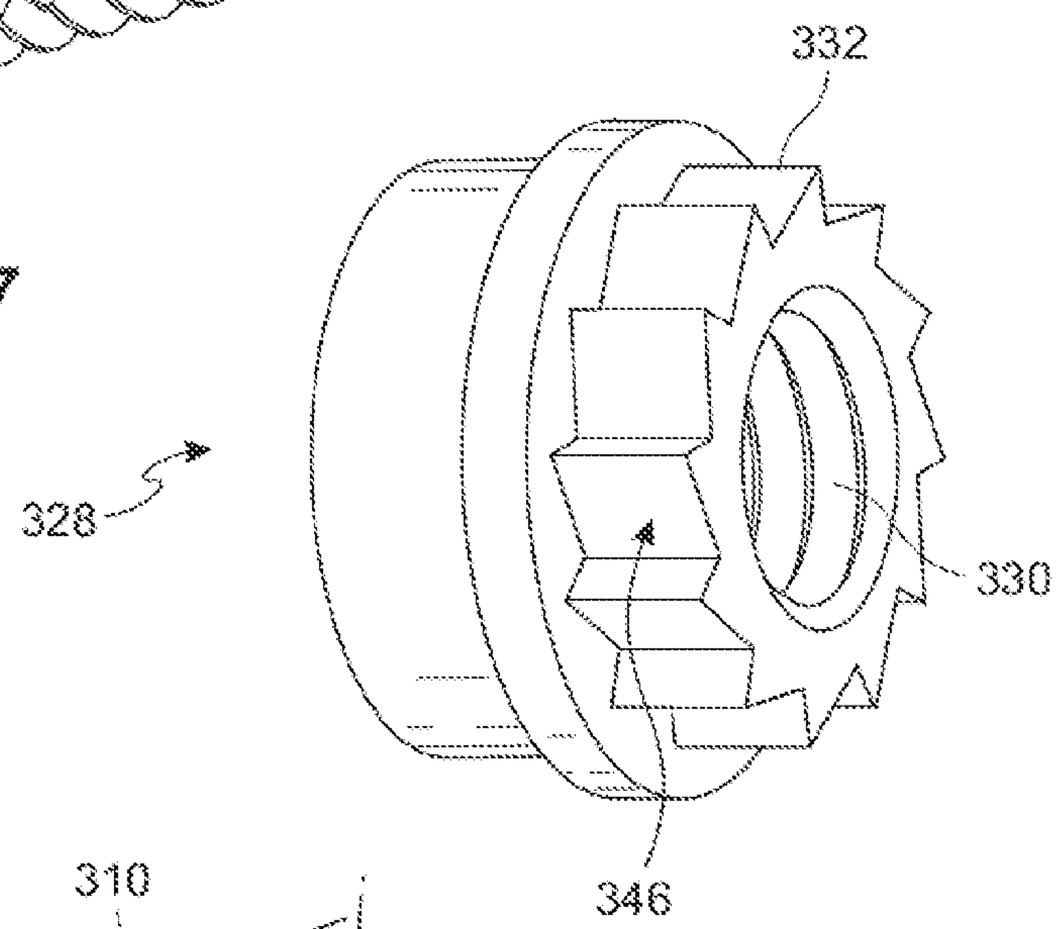


Fig. 28

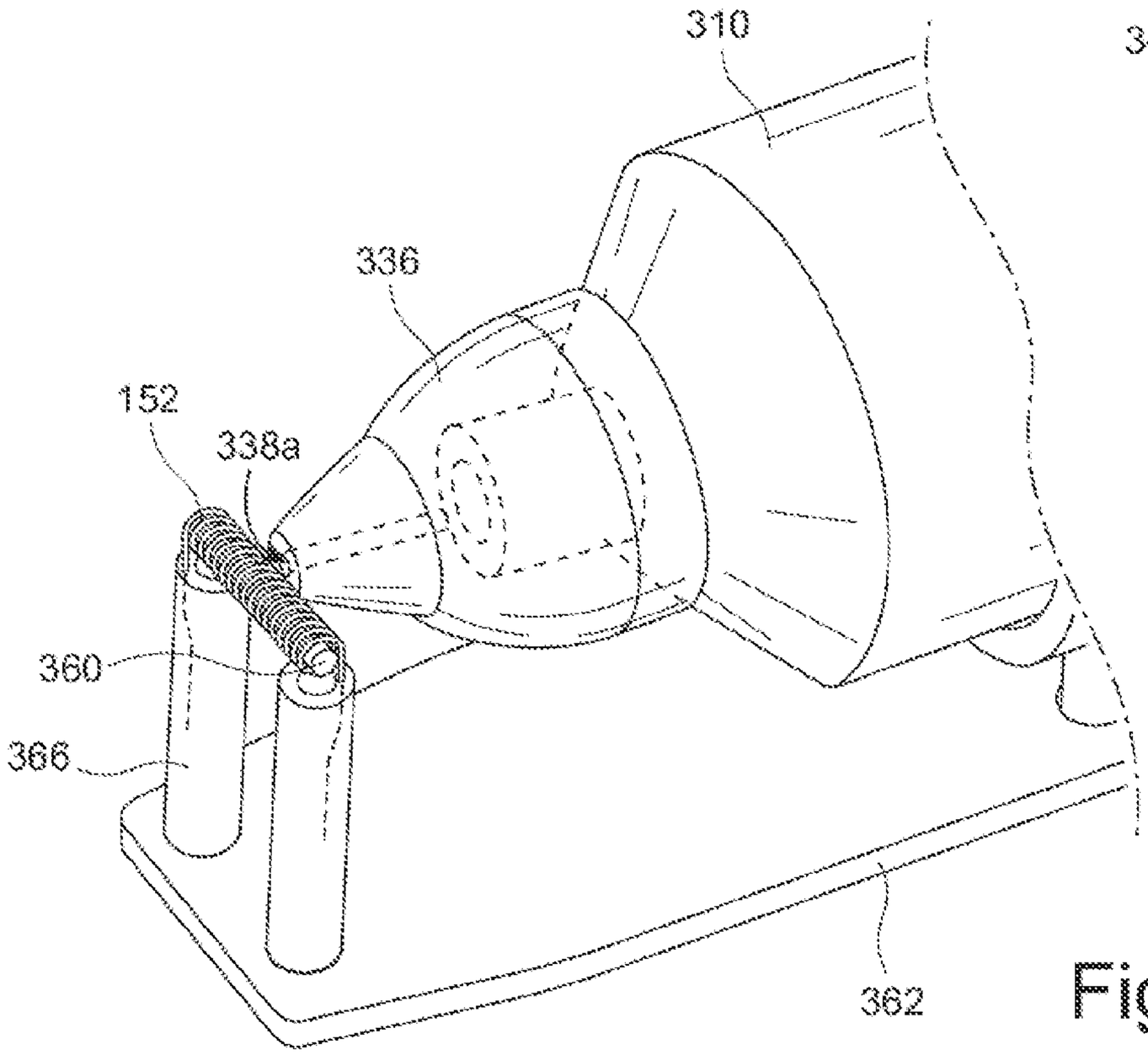


Fig. 29

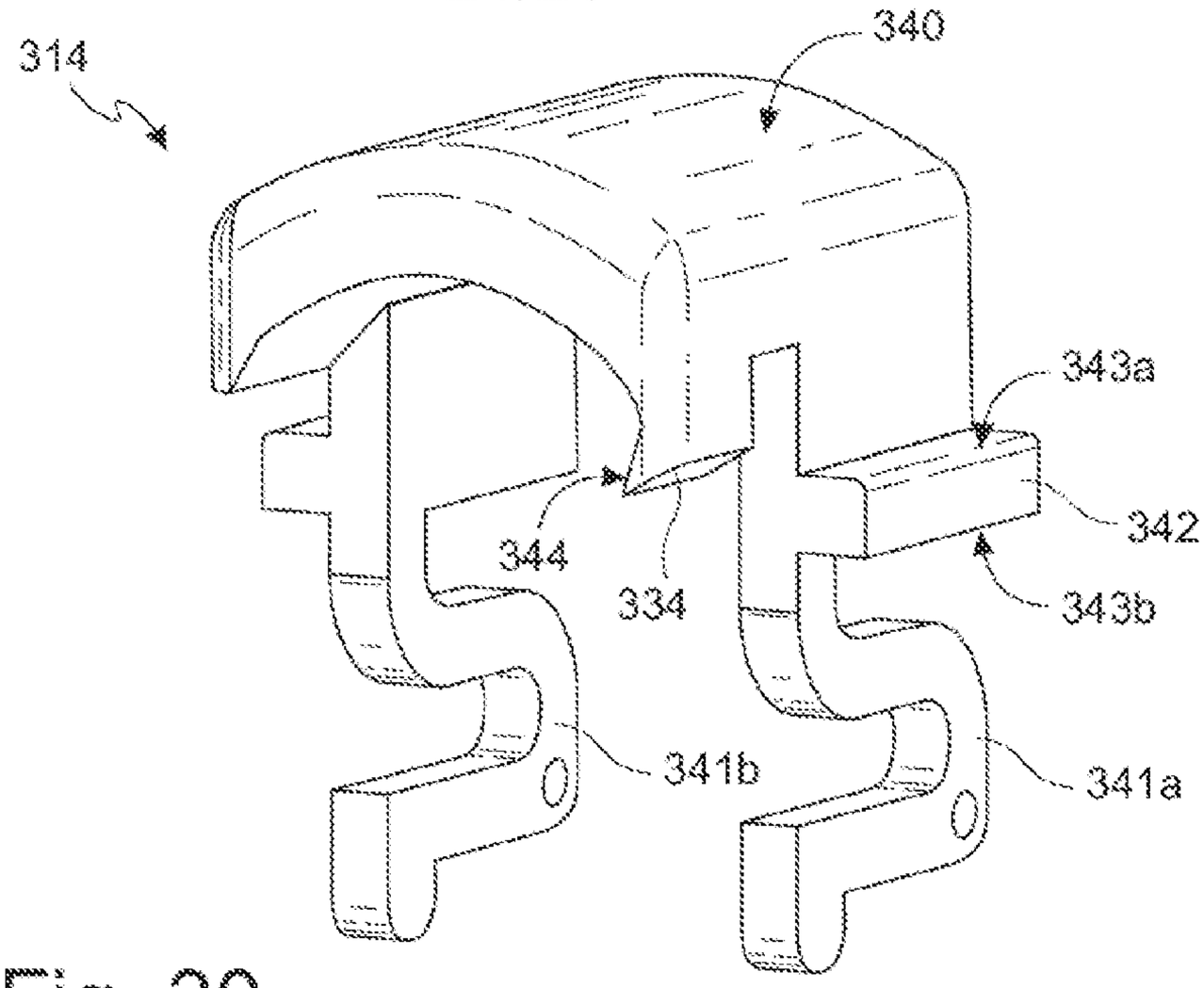


Fig. 30

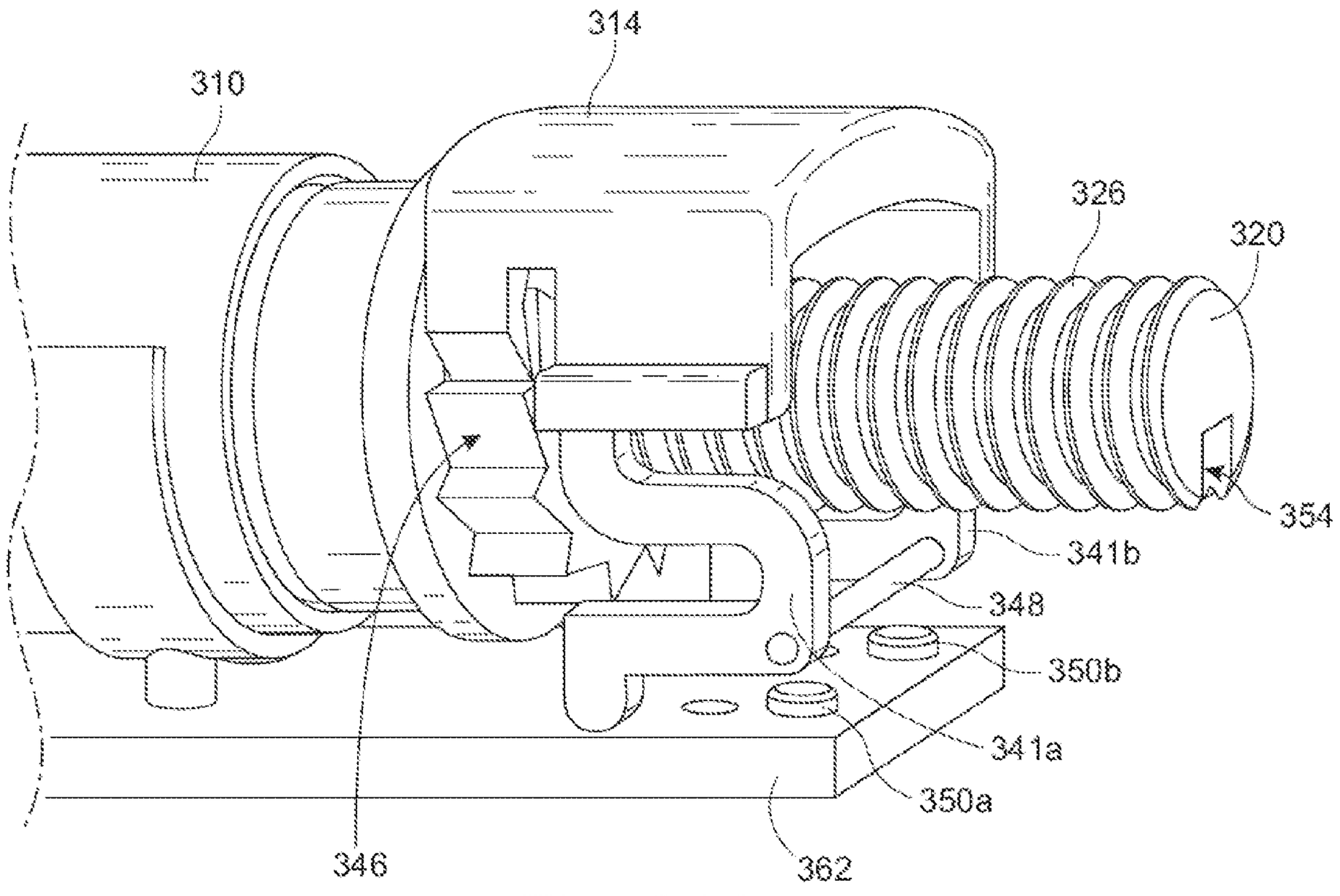


Fig. 31A

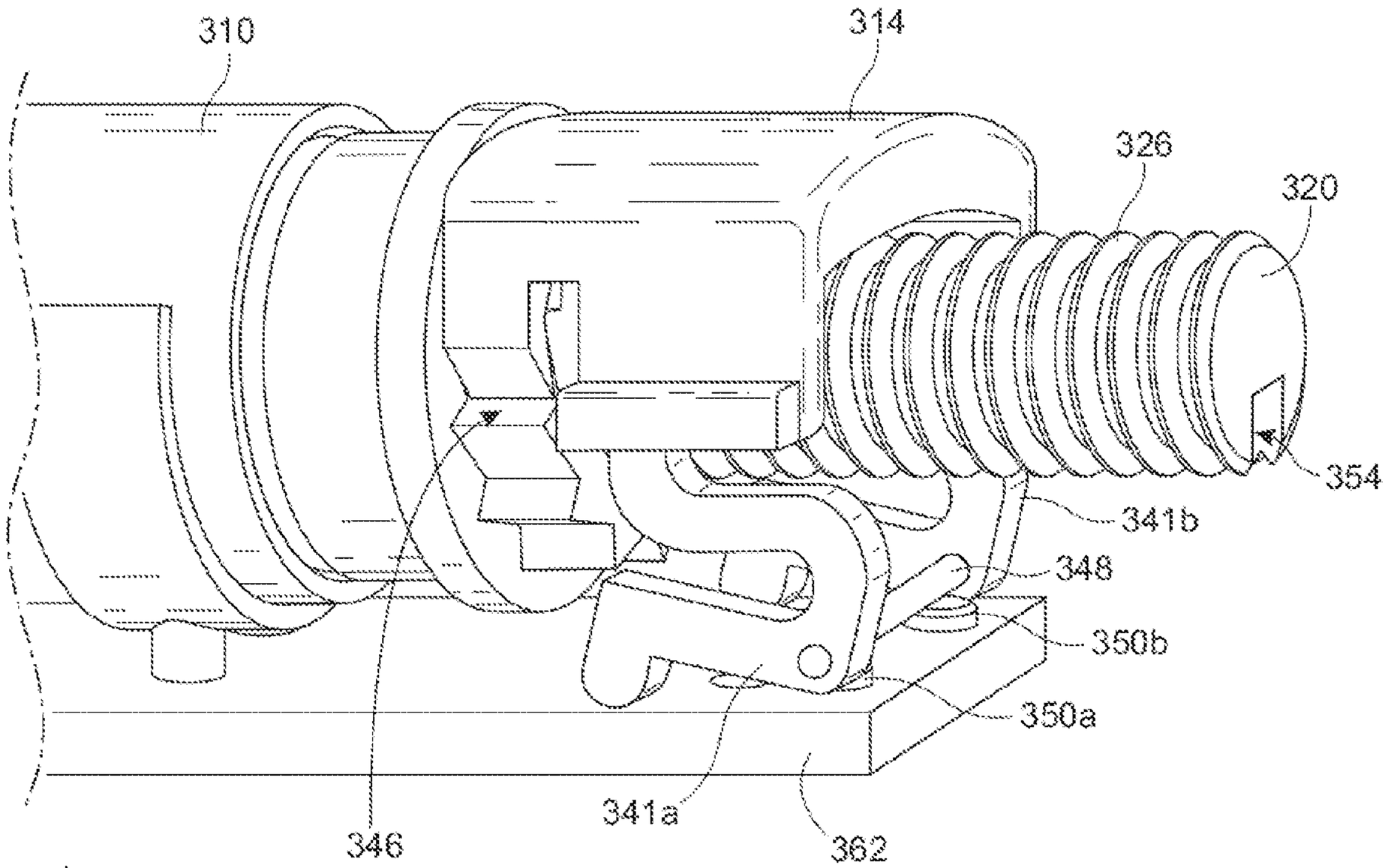


Fig. 31B

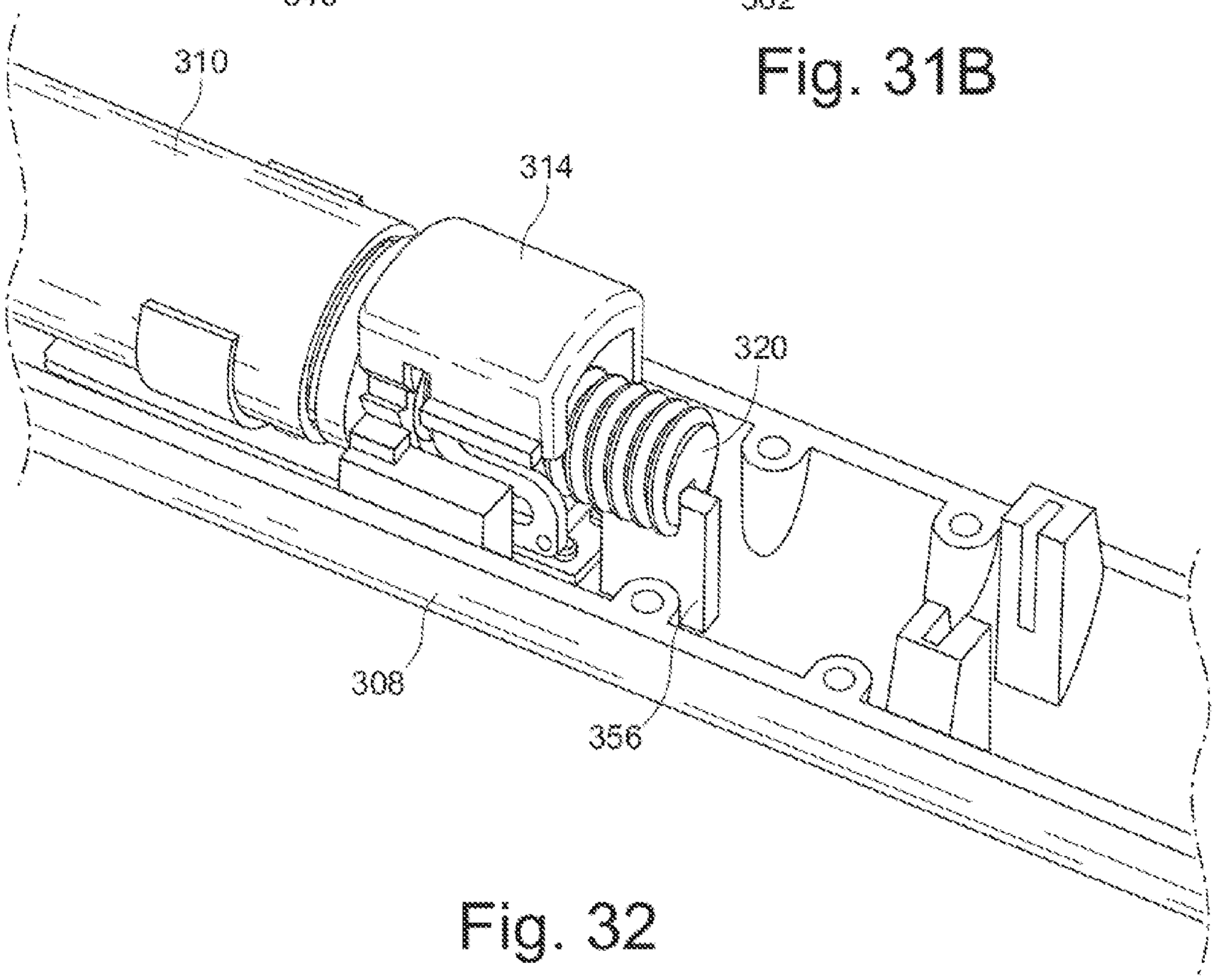


Fig. 32

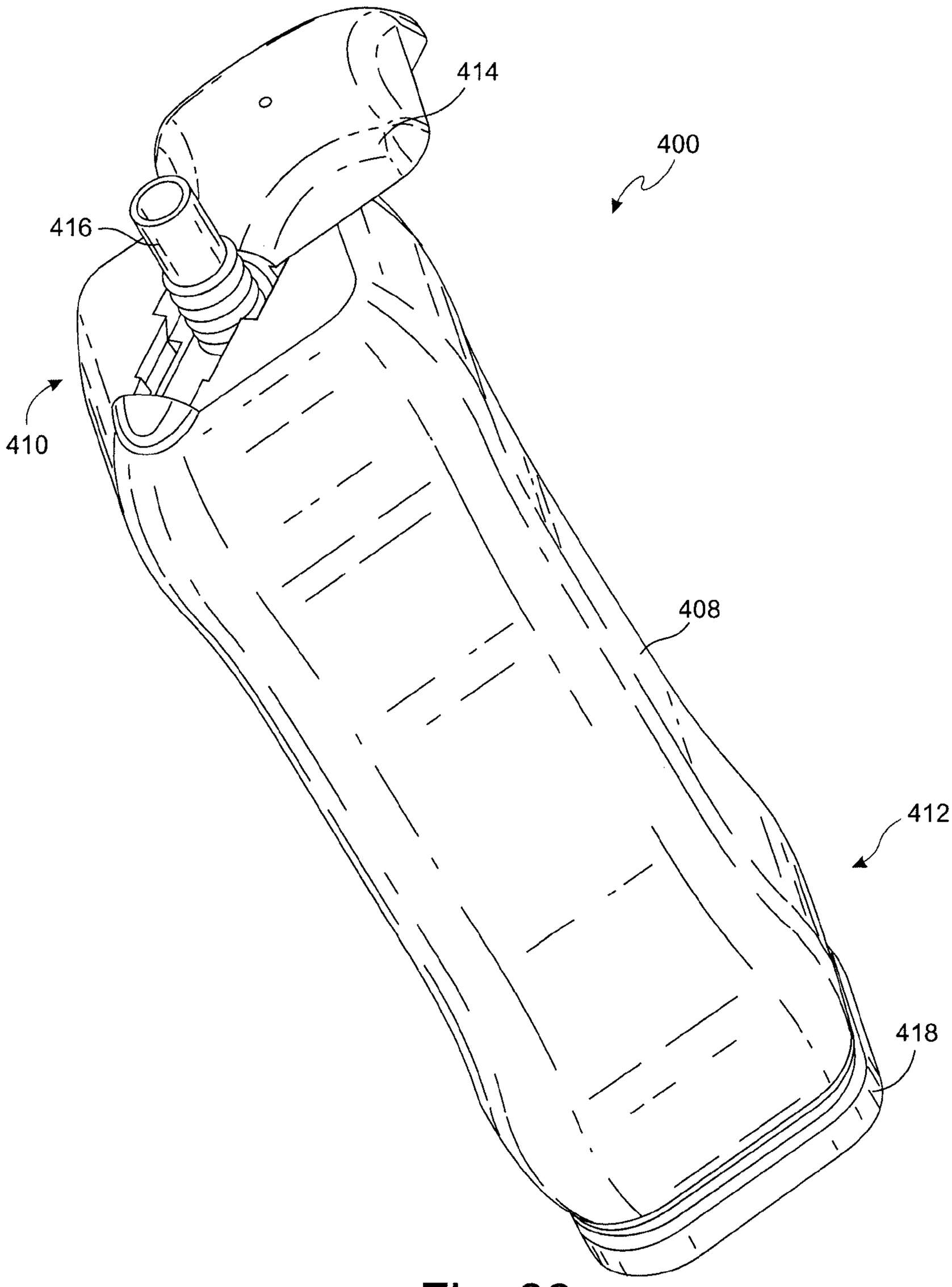


Fig. 33

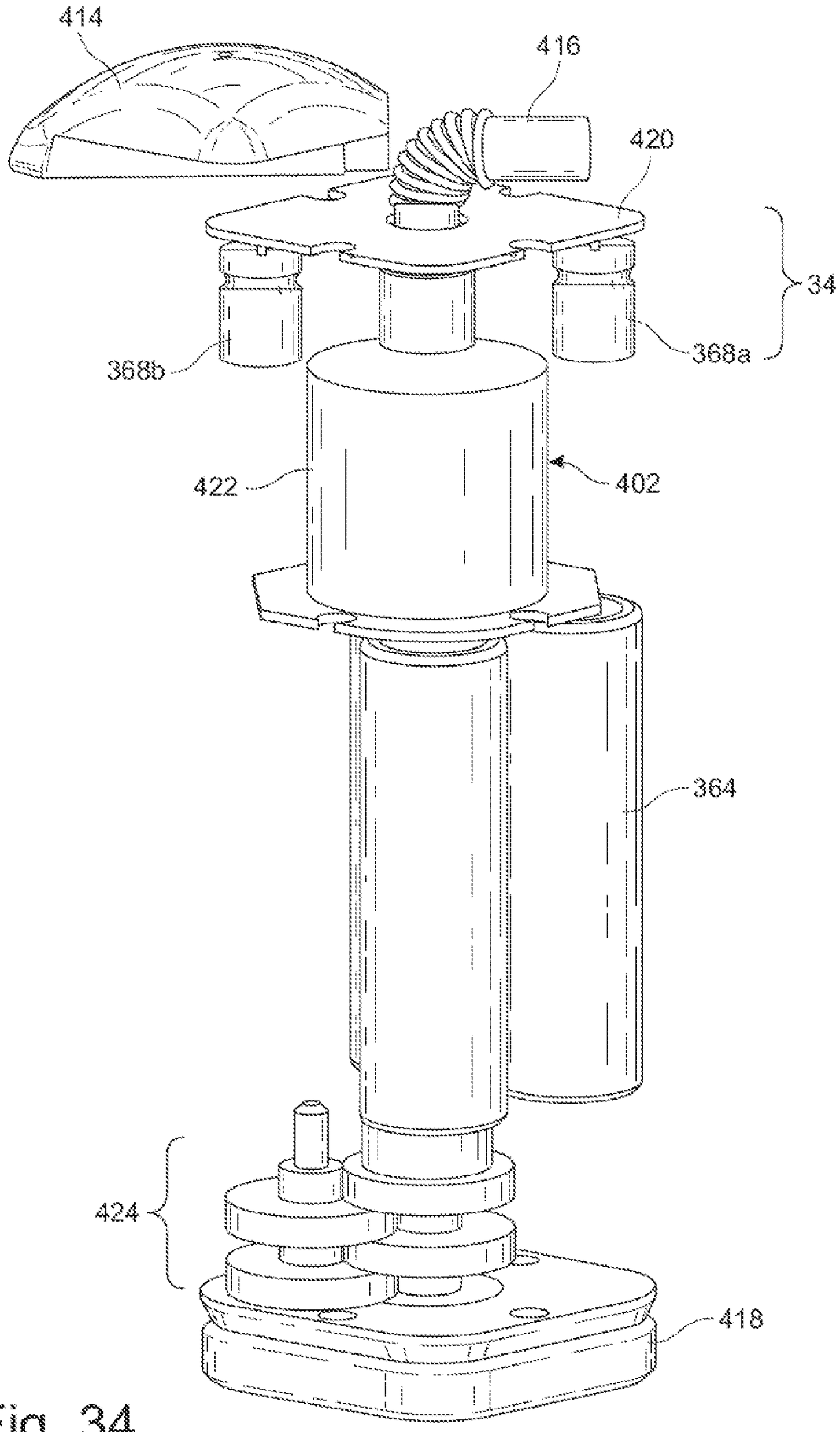


Fig. 34

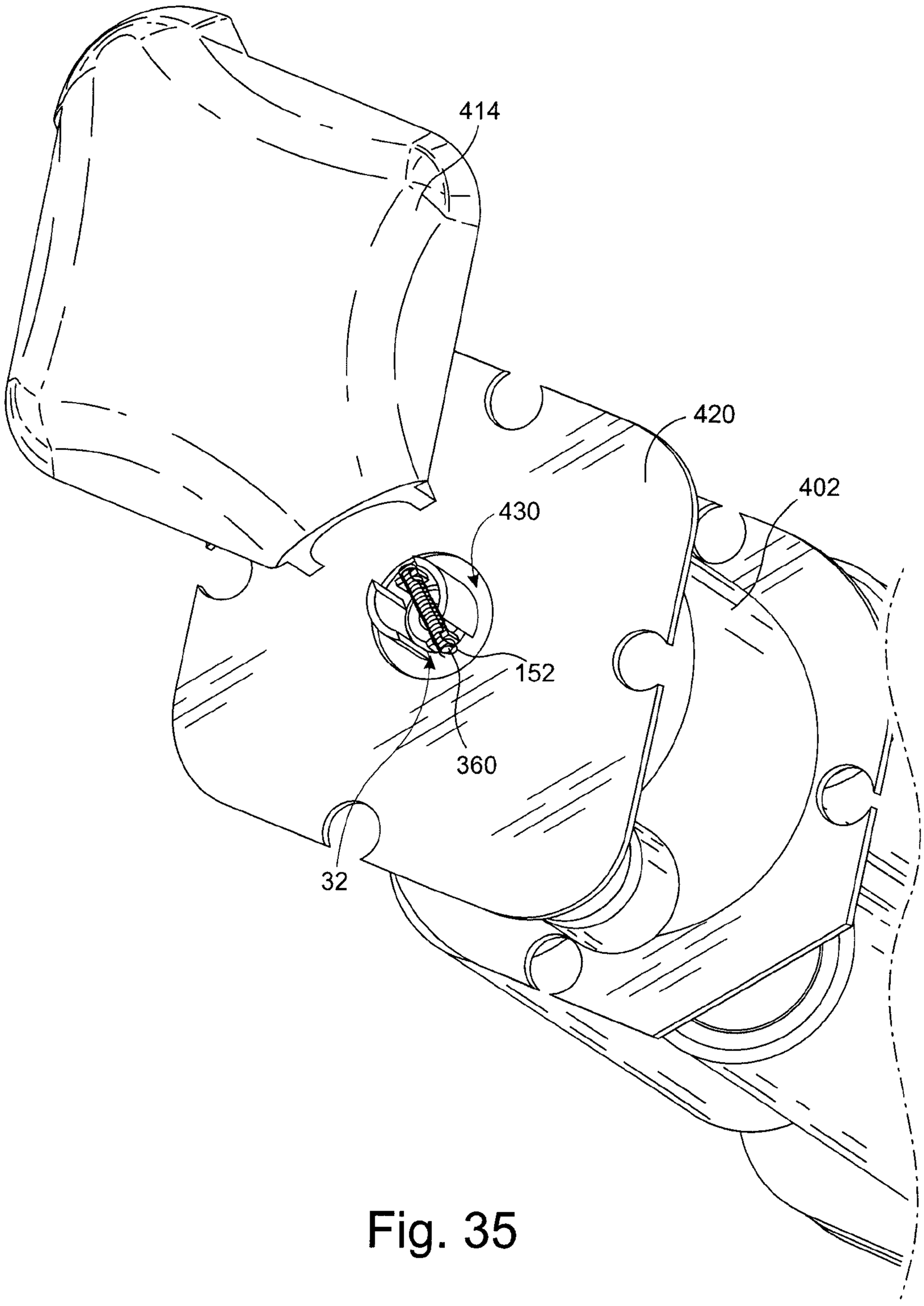


Fig. 35

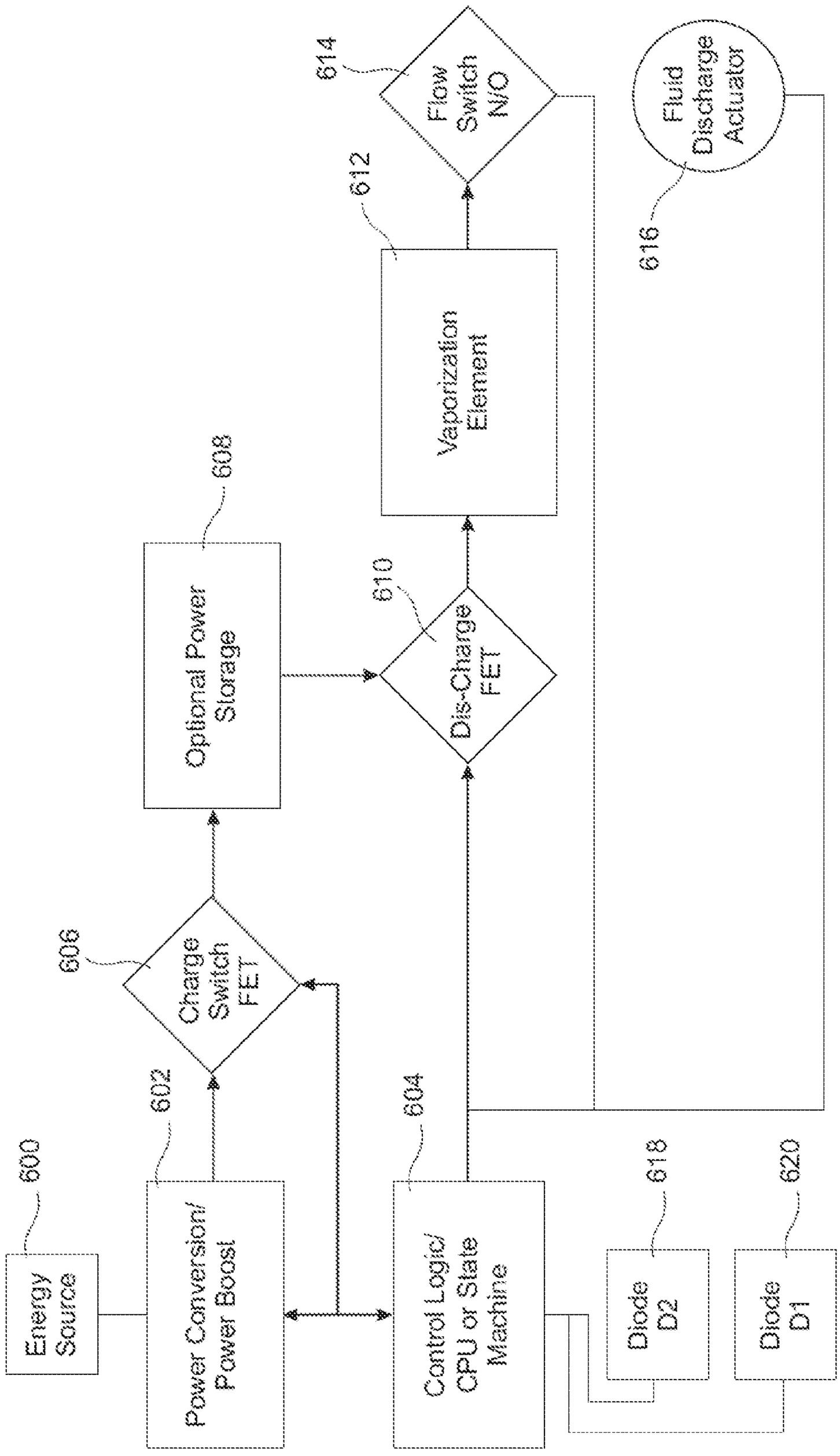
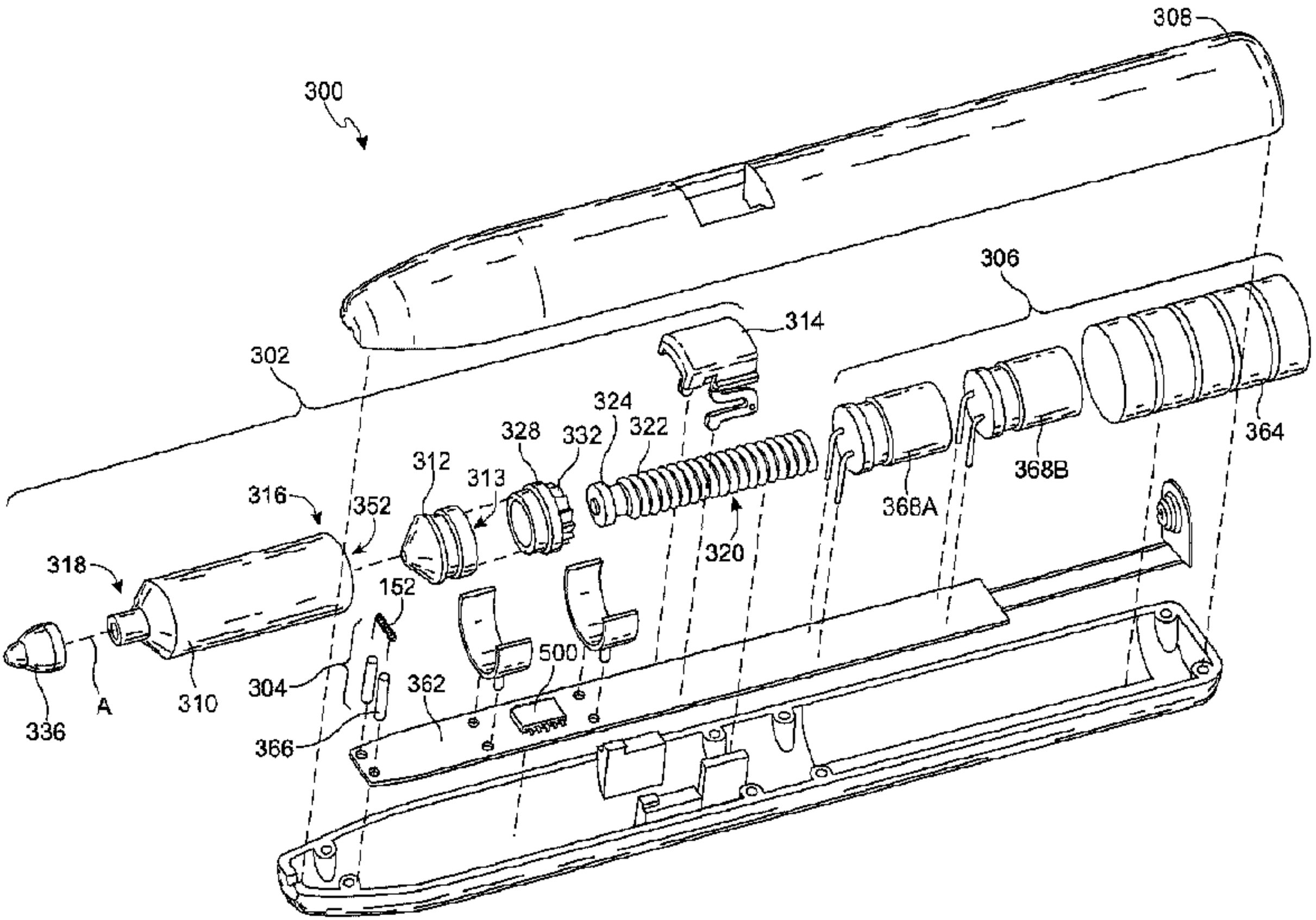

614
Flow Switch N/O
612
Fluid Discharge Actuator
616
Vaporization Element
608
Optional Power Storage
610
Dis-Charge FET
606
Charge Switch FET
602
604
600
Energy Source
Power Conversion/ Power Boost
Control Logic/ CPU or State Machine
618
Diode D2
620
Diode D1

Fig. 36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