



(51) International Patent Classification:

A24F 40/65 (2020.01) A24F 40/42 (2020.01)

A24F 40/60 (2020.01) A61M 11/04 (2006.01)

A24F 40/50 (2020.01) A61M 15/06 (2006.01)

A24F 40/05 (2020.01) A61M 15/00 (2006.01)

(21) International Application Number:

PCT/US2023/019349

(22) International Filing Date:

21 April 2023 (21.04.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/334,083 22 April 2022 (22.04.2022) US

63/338,880 05 May 2022 (05.05.2022) 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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,

(54) Title: ELECTRONIC DEVICES FOR AEROSOLIZING AND INHALING LIQUID

(57) Abstract: An electronic device includes a hand held base assembly that includes circuitry including memory and firmware executed by a processor or microcontroller of the circuitry; and a cartridge assembly that includes memory that is read by the firmware of the handheld base assembly. The cartridge assembly and the handheld base assembly are configured to removably couple together to define the electronic device for producing an aerosol for inhalation by a person. An enclosed air passageway is defined by the cartridge assembly and by the handheld base assembly, which isolates the airflow from the electronics of the device. The enclosed air passageway extends between the opening of the mouthpiece for taking a breath and a diaphragm of the handheld base assembly, movement of the diaphragm changing the air pressure within an enclosed interior space having a pressure sensor for triggering the pressure sensor when a breath is taken.

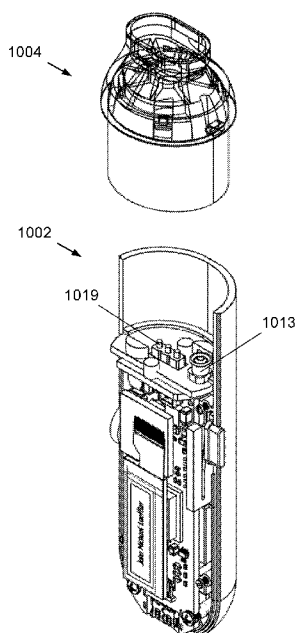


FIG. 11

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

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

Published:

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

ELECTRONIC DEVICES FOR AEROSOLIZING AND INHALING LIQUID**CROSS-REFERENCE TO RELATED APPLICATION**

[001] The present application incorporates by reference herein the disclosure of each of: USPA 17/075,679 filed October 20, 2020; USPA Publ. US 2021/0113783 A1 representing the publication of the '679 application; USPA 17/518,572 filed November 3, 2021; and USPA Publ. US 2022/0132920 A1 representing the publication of the '572 application. The present application further incorporates herein by reference USPA 63/334,083, filed April 22, 2022; and USPA 63/338,880, filed May 5, 2022.

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BACKGROUND OF THE INVENTION

[003] The invention generally relates to apparatus, systems, and methods for producing an aerosol for inhalation by a person, whether intended for personal or recreational use, or more preferably, for the administration of medicines.

[004] Vaping has been rapidly increasing in popularity, primarily because vaping provides a convenient, discreet, and presumably benign way to self-administer nicotine, cannabis, drugs, or other micronutrients. Indeed, there is a common belief that vaping is healthier than smoking cigarettes; vaping purportedly lets smokers avoid dangerous chemicals inhaled from regular cigarettes while still getting nicotine. Vaping also can be used for cannabis.

[005] Vaping is performed using a vaporizer. A vaporizer includes a vape pen or a cigarette style vape, referred to by many as an e-cigarette or “eCig”. A vape pen generally is an elongate, thin, and stylized tube that resembles a fancy pen. In contrast, an e-cigarette resembles an actual cigarette. The e-cigarette is usually small in size (usually smaller and more discreet than vape pens), easily portable, and easy to use.

[006] A common vaporizer comprises a container, which may be a tank—which is typically refillable, or a cartridge—which is typically single-use and not refillable. The tank or cartridge holds a liquid often referred to as an e-liquid or e-juice. Tanks are made out of polycarbonate plastic, glass, or stainless steel. The vaporizer also includes a mouthpiece for inhaling by a person through the mouth; an atomizer comprising a tiny heating element that converts the liquid into tiny, airborne droplets that are inhaled; and a controller for turning on the atomizer. Many vape pens are mouth-activated and turn on automatically when a person inhales. Other vape pens are button activated and require the person to push a button to activate the atomizer. Vaporizers are electrically powered using one or more batteries. The batteries typically are lithium ion batteries that are rechargeable and primarily are used to heat the heating element of the atomizer. A charger usually accompanies a vaporizer when purchased for charging the batteries. The charger may be a USB charger, car charger, or wall charger, and such chargers are generally similar to phone chargers.

[007] The battery-powered vaporizer produces vapor from any of a variety of liquids and liquid mixtures, especially those containing nicotine or cannabinoids. Many different types and flavors are available. Moreover, the liquids can be non-medicated (i.e., containing no nicotine or other substances—just pure vegetable glycerin and flavoring), or the liquids can contain nicotine or even in some instances if and where legal, the liquids can contain THC/CBD. The liquids also may contain one or more of a variety of flavors as well as micronutrients such as, for example, vitamin B12. A person can mix the liquids for use with a vape pen, and e-cigarettes typically are purchased with prefilled cartridges. The heating element in these devices turns the contents of the liquids into an aerosol—the vapor—that is inhaled into the lungs and then exhaled by the person. Perhaps one of the most popular vaporizers today is known as the “JUUL”, which is a small, sleek device that resembles a computer USB flash drive.

[008] It is believed that while promoted as healthier than traditional cigarette use, vaping actually may be more dangerous. Propylene glycol, vegetable glycerin and combinations or methylations thereof, are chemicals that are often mixed with nicotine, cannabis, or hemp oil for use in vaporizers. Propylene glycol is the primary ingredient in a majority of nicotine-infused e-cigarette liquids. Unfortunately, at high temperatures propylene glycol converts into tiny polymers that can wreak havoc on lung tissue. In particular, scientists know a great deal about propylene glycol. It is found in a plethora of common household items—cosmetics, baby wipes, pharmaceuticals, pet food, antifreeze, etc. The U.S. Food and Drug Administration and Health Canada have deemed propylene glycol safe for human ingestion and topical application. But exposure by inhalation is another matter. Many things are safe to eat but dangerous to breathe. Because of low oral toxicity, propylene glycol is classified by the FDA as “generally recognized as safe” (GRAS) for use as a food additive, but this assessment was based on toxicity studies that did not involve heating and breathing propylene glycol. Indeed, a 2010 study published in the International Journal of Environmental Research and Public Health concluded that airborne propylene glycol circulating indoors can induce or exacerbate asthma, eczema, and many allergic symptoms. Children were said to be particularly sensitive to these airborne toxins. An earlier toxicology review warned that propylene glycol, ubiquitous in hairsprays, could be harmful because aerosol particles lodge deep in the lungs and are not respirable.

[009] Moreover, when propylene glycol is heated, whether by a red-hot metal coil of a heating element of a vaporizer or otherwise, the potential harm from inhalation exposure increases. It is believed that high voltage heat transforms the propylene glycol and other vaping additives into carbonyls. Carbonyls are a group of cancer-causing chemicals that include formaldehyde, which has been linked to spontaneous abortions and low birth weight. A known thermal breakdown product of propylene glycol, formaldehyde is an “International Agency for Research on Cancer” group 1 carcinogen!

[010] Prevalent in nicotine eCig products and present in some vape oil cartridges, FDA-approved flavoring agents pose additional risks when inhaled rather than eaten. The flavoring compounds “smooth and creamy”, i.e., diacetyl and acetyl propionyl, are associated with respiratory illness when inhaled in tobacco e-cigarette devices. Another hazardous-when-inhaled-but-safe-to-eat flavoring compound is Ceylon cinnamon, which becomes cytotoxic when aerosolized.

[011] When a heating element gets red hot in a vaporizer, the liquid undergoes a process called “smoldering”, which is a technical term for what is tantamount to “burning”; while much of the liquid is vaporized and atomized, a portion of the liquid undergoes pyrolysis or combustion. In that sense, most of the vaporizers that have flooded the commercial market may not be true vaporizers.

[012] Additionally, clearance mechanisms of the lung, like all major points of contact with the external environment, have evolved to prevent the invasion of unwanted airborne particles from entering the body. Airway geometry, humidity and clearance mechanisms contribute to this filtration process.

[013] In view of the foregoing, it is believed that a need exists for a vaporizer that provides an aerosol of the desired chemicals without the harmful byproducts that arise from smoldering. It is also believed that a need exists for a vaporizer that effectively and efficiently produces a vapor cloud that is not inhibited by the body’s natural filtration process.

[014] In the context of nicotine delivery through an aerosol, it is further believed that there is a need in developing nicotine-containing formulations in aqueous solutions that provides a user with an appealing sensorial experience. For example, at higher nicotine concentrations, the formulation is known to create a “harsh” sensorial experience for a user.

[015] Furthermore, aspects and features of the invention also generally relate to apparatus, systems, formulations, and methods pertaining to liquids that are aerosolized and inhaled by persons using electronic devices, whether intended for personal or recreational use, or for the administration of medicines.

[016] Indeed, inhalation delivery systems now play an increasing role in the targeted delivery of active ingredients to the human pulmonary system. This is true both for medical purposes, such as the targeted delivery of anti-cancer medications to the lungs, as well as for recreational/personal purposes, such as vaping, in which a liquid that includes the active ingredient is vaporized using heating so that the active ingredient can be inhaled into the human body.

[017] Unfortunately, as inhalation delivery systems using heating have increased in prominence, concerns about their short and long term safety have come into focus. This is particularly true for vaping where there exist ongoing concerns about the possible presence of harmful and potentially harmful constituents (HPHCs) in the inhaled vapor. Moreover, inhalation delivery systems are often unable to provide the desired effect to a user. This may be attributable to the pre-vaporized liquid becoming unstable over time or the active ingredient itself not being properly sized or dispersed for deposition in the alveolar lung.

[018] Accordingly, a need exists for an active ingredient delivery system that enhances the shelf-life of the pre-vaporized liquid component and enhances the efficacy of the desired treatment/effect, while avoiding the presence of undesired HPHCs in the inhaled vapor. Each of these needs, and still other needs, are believed to be met by one or more embodiments in accordance with one or more aspects and features of the invention.

SUMMARY OF THE INVENTION

[019] The invention includes many aspects and features. Moreover, while many aspects and features relate to, and are described in, the context of vaping, the invention is not limited to use only in such context. Indeed, a preferred context of use is in the delivery of medication and, in particular, prescription medication.

[020] Depending on the context of use, the electronic device of the invention may be considered a vaporizer and may be in the form of a vape pen or e-cigarette. Indeed, those who vape may come to refer to embodiments of the invention as a vape pen even though heat is not utilized to create the aerosol that is inhaled. In the delivery of pharmaceuticals, patients may come to refer to embodiments of the invention as a nebulizer even though a gas transport (e.g., compressed gas) is not utilized and even though the aerosol that is produced in accordance with the invention may have a smaller particle size than the mist produced by common nebulizers. Other separate and distinct contexts of use of embodiments of the invention may similarly result in different nomenclature of the embodiments of the invention. “Electronic device” is used herein in reference to embodiments of the invention independent of context of use. Indeed, while the appearance and form factor of embodiments of the invention may vary depending on such contexts of use, the basic components and operation remain the same, except where otherwise described below.

[021] In an aspect of the invention, a cartridge assembly is configured to couple with a handheld base assembly to form a portable, handheld electronic device. Preferably, the cartridge assembly and the handheld base are configured to magnetically couple. The handheld base assembly comprises electronics in the form of a printed circuit board and a power source in the form of a battery, which battery preferably is rechargeable. An electrical connection is made when the cartridge assembly is coupled with the handheld base assembly, by which the cartridge assembly is powered. The base also preferably includes magnets that magnetically attract a metal plate of the cartridge assembly to secure the cartridge assembly within an opening in an end of the base.

[022] Additionally, in an aspect of the invention the handheld base assembly comprises circuitry including memory and firmware executed by a processor or microcontroller of the circuitry; and the cartridge assembly comprises memory (e.g., non-transitory computer-readable memory) that is read by the firmware of the handheld base assembly when executed by the processor. In a feature of this aspect, the firmware when executed by the processor further writes to the memory of the handheld base, to the cartridge assembly, or both to the memory of the handheld base, to the cartridge assembly.

[023] In accordance with this aspect, the cartridge assembly comprises a cartridge and a bladder assembly contained within the cartridge. In turn, the bladder assembly comprises a bladder containing a wick and a mesh assembly that sits on top of and covers a mouth of the bladder. The wick acts to draw liquid to the mesh assembly. The wick is retained in physical engagement with the bladder proximate the bottom of the wick by protuberances that extend from the walls of the bladder. The protuberances may engage the bottom of the wick only, or may engage the wick along its longitudinal length between the bottom of the bladder and the mouth of the bladder. There preferably are three or four protuberances that

symmetrically surround the wick in a discontinuous circular pattern and receive the wick in frictional fit therewith for maintaining axial alignment of the wick within the bladder along a central axis of the bladder. The wick extends from the bottom of the bladder to and is retained in abutting contact with the mesh assembly and, in particular, a piezoelectric disk having a mesh material which, when powered by the power source, vibrates so as to aerosolize a liquid contained within the bladder and wick.

[024] In one or more embodiments, the mesh assembly is held in tension on top of a lip of the mouth of the bladder by a sealing O-ring that is forced into engagement with the mesh assembly by the attachment of a mouthpiece of the cartridge assembly to the cartridge. Screws are preferably utilized in effecting the attachment whereby the force by which the O-ring is held in contact with the mesh assembly may be adjusted. A spacer on a printed circuit board of the cartridge assembly may additionally engage the bottom of the silicone bladder and hold the wick in tension therethrough. Due to these features, it is believed that the bladder and wick ensure that the mesh remains in constant contact with the liquid for consistent aerosolization each time the electronic device is triggered. The liquid preferably is supplied to the vibrating mesh at a generally constant pressure whereby a generally uniform aerosol is produced, and this is accomplished regardless of the orientation of the electronic device.

[025] In other embodiments, the mesh assembly sits on top of and is held in tension with the wick by being pressured along an annual area thereof by a piezo transducer which, in turn, sits on top of and is pressured along an annual area thereof against the mesh assembly by a pressure ring which, in turn, sits on top of and is pressured along an annual area thereof against the piezo transducer by a mouthpiece of the cartridge which, in turn, is secured to a lower body of the cartridge assembly in tensioned engagement with a top of the pressure ring. In alternative embodiments, contact with the mesh assembly by the wick may be intermittent rather than constant, with a very small gap or spacing appearing and disappearing between the mesh assembly and wick as the piezo oscillates out of phase with resultant oscillations of the wick. In this respect, a drumming occurs between the mesh assembly and the wick. Nonetheless, the liquid preferably is supplied to the vibrating mesh at a generally constant pressure whereby a generally uniform aerosol is produced, and this is accomplished regardless of the orientation of the electronic device.

[026] In an aspect, the cartridge assembly comprises a printed circuit board or other electronics, and the cartridge assembly communicates with the handheld base assembly when coupled. Preferably, the printed circuit board of the cartridge assembly includes memory that includes information regarding the liquid contained in the bladder and dosing information related thereto, e.g., the number of doses dispensed so far from the cartridge assembly. The cartridge assembly further can be programmed to only work with one or more specified handheld base assemblies to the exclusion of other handheld base assemblies. For example, a cartridge assembly could be configured to work only with a handheld base assembly of a particular person, e.g., a certain patient for whom a prescription is provided via the cartridge assembly.

[027] In a feature, the cartridge is disposable.

[028] In a feature, the wick has a lengthwise channel that extends between its opposite ends. The channel assists in delivering liquid to the mesh assembly for aerosolizing. In an alternative feature, no lengthwise channel is provided in the wick.

[029] In a feature, the wick is rigid.

[030] In a feature, opening cross sections of the mesh that is in contact with the liquid is smaller than the opening cross section that faces the mouthpiece and exit of the aerosolized liquid. The taper angle and size of the perforated mesh preferably is adjusted via electro-forming methods to achieve a laminar and non-turbulent aerosol that is best suited for deep lung penetration and will, therefore, not yield large amounts of buccal deposition.

[031] In a feature, an airflow channel is defined between an opening into the mouthpiece and a pressure sensor located within the handheld base assembly. A D-ring is provided to seal the interface between the cartridge and the mouthpiece to prevent loss of suction along the airflow channel. The airflow channel is defined by openings in the mouthpiece, the cartridge, the printed circuit board, the metal plate, and the chassis. One opening may be provided in connection with the mouthpiece; alternatively, three openings may be provided that are equally spaced around an O-ring.

[032] In an alternative feature, an enclosed airflow passageway is defined from an opening of the mouthpiece to an opening of the handled base assembly. The enclosed air passageway is defined by the mouthpiece, the pressure ring, and the cartridge body of the cartridge assembly. Importantly, the air passageway so defined does not lead to any electronics or other components or materials of the cartridge assembly that would be considered harmful for human exposure. Instead, the air traveling through the enclosed airflow passageway is isolated from such harmful components and materials. Moreover, the portions of the mouthpiece, the pressure ring, and the cartridge body defining the enclosed air passageway are made from one or more materials classified not to be harmful to human exposure (such as silicone) the cartridge meets both medical device standards ISO 1093 and ISO 18562 for airpath requirements.

[033] Similarly, the opening of the handheld base assembly leads to another air passage that is defined in the handheld base assembly and, preferably, that is defined within a wall of the handheld base assembly and that leads to a diaphragm that seals off the air passageway. The diaphragm also closes off an enclosed space on an opposite side of the diaphragm which includes a pressure sensor. Movement of the diaphragm affects a pressure within the enclosed space that triggers the pressure sensor.

[034] A protuberance of the wall preferably define the opening into the air passageway of the cartridge assembly and extends to and, preferably, within by some extent the air passageway of the cartridge assembly, when the cartridge assembly and handheld base assembly are magnetically coupled together. A sealing member preferably is provided around the protuberance for sealing the connection between the air passageway of the cartridge assembly and the air passageway of the handheld base assembly.

[035] Consequently, when a breath is drawn at the opening of the mouthpiece, a low pressure results at the diaphragm that causes a drop in pressure in the enclosed space, thereby triggering the pressure sensor in the handheld base assembly.

[036] In order to avoid a drop in pressure that may overextend the diaphragm or otherwise cause damage, one or more additional openings into the enclosed air passageway extending through the cartridge assembly, the handheld base assembly, or both may be provided for serving as vents to reduce the pressure drop experienced at the diaphragm.

[037] In other embodiments, the bladder is co-molded with a silicone bladder and another material providing rigidity. Such rigidity may be desired around the top and bottom of the bladder.

[038] In an aspect, the bladder may be filled with the liquid by injection after assembly of the disposable cartridge assembly. The bladder preferably is made from a self-sealing silicone bladder, and when the injector needle is removed, the bladder re-seals and no liquid drains or leaks out. In this aspect, the liquid may be injected as a last step via an access port/injector port that is located on the bottom of the cartridge. Alternatively, the bladder is inserted into the cartridge and then is filled with liquid first (top-down pour) without utilizing a needle or puncturing the bladder with an injector needle. In this manner, the bladder is filled by pouring liquid into the bladder and, once the desired volume has been dispensed, the wick is inserted inside the bladder and then the bladder is capped off by the mesh assembly and the rest of the disposable cartridge assembly is then assembled.

[039] Alternatively, the bladder comprises a fill port adjacent a bottom area thereof through which a needle fills the bladder. A plug then may be inserted into the port for sealing fluid within the bladder. The fill port, the plug, or both may be made from silicone or another material.

[040] In an aspect, an electronic device for producing an aerosol for inhalation by a person comprises a cartridge assembly and a handheld base assembly, wherein the cartridge assembly and the handheld base assembly are configured to removably couple together.

[041] In a feature, the handheld base assembly comprises circuitry including firmware executed by a processor or microcontroller of the circuitry, and the cartridge assembly comprises memory that is read by the firmware of the handheld base assembly.

[042] The cartridge assembly preferably comprises a mouthpiece; a cartridge assembly; and a bladder assembly. The bladder assembly preferably comprises a bladder; a wick contained within the bladder; and a mesh assembly. The mesh assembly preferably comprises a mesh material and a piezoelectric material, the mesh material being configured to vibrate when the piezoelectric material is actuated, whereby an aerosol is produced when the mesh material contacts a liquid of the bladder such that the aerosol may be inhaled through the mouthpiece.

[043] In a feature, the cartridge assembly is disposable.

[044] In a feature, the cartridge assembly and the handheld base assembly are configured to magnetically couple together.

[045] In a feature, the disposable cartridge assembly magnetically mounts onto an end of the handheld base assembly.

[046] In a feature, an enclosed air passageway is defined by the cartridge assembly and by the handheld base assembly, which isolates the airflow from the electronics of the device.

[047] The enclosed air passageway extends between the opening of the mouthpiece for taking a breath. The handheld base assembly comprises a diaphragm, movement of the diaphragm changing the air pressure within an enclosed interior space having a pressure sensor for triggering the pressure sensor when a breath is taken on the mouthpiece, the pressure sensor in turn causing aerosolization to occur for administering a dose.

[048] In another aspect, an electronic device for producing an aerosol for inhalation by a person comprises: (a) a cartridge assembly; and (b) a handheld base assembly. The cartridge assembly and the handheld base assembly are configured to removably couple together; the handheld base assembly comprises circuitry including firmware executed by a processor or microcontroller of the circuitry; and the cartridge assembly comprises memory that is read by the firmware of the handheld base assembly.

[049] In a feature, the handheld base assembly comprises a display.

[050] In a feature, a representation of doses provided using the electronic device from a particular cartridge assembly is identified through the display. The representation may comprise a number of doses provided, or a number of doses remaining in the particular cartridge assembly. Furthermore, a representation of a number of puffs in a said does is indicated through the display.

[051] In a feature, when the handheld base assembly and the cartridge assembly are coupled together, firmware in memory of the handheld base assembly and executed by a processor or microcontroller of the circuitry of the handheld base assembly reads from a nonvolatile memory of the cartridge assembly a number of doses that have been dispensed from or that remain in the reservoir of the cartridge assembly.

[052] In a feature, the handheld base assembly and the cartridge assembly are paired such that the cartridge assembly only works with the handheld base assembly with which it is paired by storing a unique identifier or other authenticating information in the cartridge assembly by which the firmware of the handheld base assembly is configured to authenticate the cartridge assembly. Preferably, said authenticating information is permanently stored in read-only memory of the cartridge assembly; and said pairing is performed at time of manufacture of the cartridge assembly and handheld base assembly, when a new cartridge assembly is first used with a handheld base assembly. Said authenticating information may be communicated to the handheld base assembly. The handheld base assembly may comprise a transceiver for wireless communications, and said authenticating information may be communicated to the handheld base assembly wirelessly over the Internet once the cartridge assembly to be used with the handheld base assembly is known, such as when a specific cartridge is prescribed using the specific cartridge assembly, or when a prescription is filled using the specific cartridge assembly.

[053] In a feature, a battery of the electronic device is rechargeable using a USB port of the electronic device.

[054] In a feature, the electronic device is configured to initiate a dosing when a button on an exterior of the electronic device is depressed for a predetermined period of time.

[055] In a feature, the electronic device is configured to turn on when a button on an exterior of the electronic device is depressed for a predetermined period of time, and wherein the electronic device

comprises a pressure sensor configured to detect when a breath is drawn from a mouthpiece of the cartridge assembly when the device is turned on and consequently cause aerosolization of a metered dose.

[056] The pressure sensor preferably is contained within the handheld base assembly, and the cartridge assembly and handheld base assembly collective define an enclosed interior air passageway extending between an interior space of a mouthpiece of the cartridge assembly to the pressure sensor contained within and mounted to a circuit board of the handheld base assembly.

[057] In a feature, the cartridge assembly comprises a mesh component is formed from 316L stainless steel.

[058] Furthermore, the enclosed, interior air passageway is in fluid communication with the mesh assembly; the handheld base assembly comprises a diaphragm arranged proximate the pressure sensor by which a change in pressure is detected by the pressure sensor; no electronic components are exposed to the enclosed interior air passageway; and all components defining the enclosed interior air passageway are made from medical grade materials such that the electronic device is compliant with ISO 18562 and ISO 10993 standards.

[059] In a feature, when the pressure sensor detects a breath, a haptic engine of the handheld base assembly is activated to provide sensory feedback to the user that a breath has been detected and that a dose is being aerosolized. The magnitude of the vibrations caused by the haptic engine and length of activation preferably are adjustable by a user through an app.

[060] In a feature, the cartridge assembly comprises a vibrating mesh nebulizer stack defining a fully sealed airpath that is compliant with medical airpath ISO 18625 and medical device ISO 10993 standards.

[061] In a feature, the cartridge assembly comprises a compliant, silicone bladder that interfaces with a mesh assembly to provide a liquid tight seal between an interior space of the bladder containing a liquid and a mesh of the mesh assembly for aerosolizing the liquid. The cartridge assembly preferably further comprises a pressure ring configured to apply circumferential pressure to a piezo assembly of the mesh assembly, the mesh assembly being sandwiched between the bladder and the pressure ring. A mouth of the bladder at a top of the bladder engages and forms a liquid seal with the mesh assembly, and the bladder comprises a fill port located on a bottom of the bladder for filling the bladder with a liquid. The bladder further comprises a plug for sealing the fill port after filling of the bladder with a liquid.

[062] In a feature, the bladder has a capacity of 1.5 ml.

[063] In another feature, the electronic device further comprises a sealing cap removably attached to the cartridge assembly in covering relation to a mouthpiece of the cartridge assembly.

[064] In another feature, the handheld base assembly comprises a transceiver and the electronic device is configured to wirelessly communicate with an app on a smartphone, tablet device, or personal computer. The app preferably is configured to show a number of doses dispensed from a cartridge assembly coupled to the handheld base assembly.

[065] In another aspect, commercial packaging comprises one of the electronic devices disclosed above. The handheld base assembly and the cartridge assembly of the electronic device preferably are separated

from one another such that the electronic device requires assembly when removed from the commercial packaging, and the commercial packaging further comprises a charging cord and instructions for use.

[066] In addition to the aforementioned aspects and features of the invention, it should be noted that the invention further encompasses the various logical combinations and subcombinations of such aspects and features. Thus, for example, claims in this or a divisional or continuing patent application or applications may be separately directed to any aspect, feature, or embodiment disclosed herein, or combination thereof, without requiring any other aspect, feature, or embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[067] One or more preferred embodiments of the invention now will be described in detail with reference to the accompanying drawings.

[068] FIG. 1 is a schematic illustration of commercial packaging comprising a container **101** containing an electronic device **100** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention, wherein a handheld base assembly **102** and a cartridge assembly **104** of the electronic device **100** are shown as separated, individual components together with a cap **103**, USB charging cord **105**, and instructions for use (IFU **107**, which itself is illustrated in FIG. 47).

[069] FIG. 2 is a perspective view of the preferred electronic device **100** of FIG. 1 and indicates the removable coupling together of the handheld base assembly **102** and the cartridge assembly **104**.

[070] FIG. 3 illustrates a perspective view of the electronic device **100** when the handheld base assembly **102** and the cartridge assembly **104** are removably coupled together. As shown in FIG. 3, a number of doses is displayed on a display **106** of the electronic device **100**, which indicates how many doses have been metered by the device (or one like it) from a reservoir of the specific cartridge assembly **104**.

[071] FIG. 4 illustrates a perspective view of another electronic device **900** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention, wherein when a handheld base assembly **902** and a cartridge assembly **904** with a sealing cap **905** are removably coupled together.

[072] FIG. 5 is another view of the electronic device **900** with the sealing cap **905** removed to expose an opening of a mouthpiece of the cartridge assembly **904**.

[073] FIG. 6 is a side elevational view in partial transparency of the electronic device **900**.

[074] FIG. 7 is an exploded view of the handheld base assembly **902** of the electronic device **900**.

[075] FIG. 8 is an exploded view of the cartridge assembly **904** of the electronic device **900**.

[076] FIG. 9 is a perspective view of another electronic device **1000** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention.

[077] FIG. 10 is a view illustrating the uncoupling of the handheld base assembly **1002** and the cartridge assembly **1004** of the electronic device **1000**.

[078] FIG. 11 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a sealing component **1013** is perhaps best seen.

[079] FIG. 12 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a protuberance **1011** defined by a wall of the handheld base assembly **1002** is seen, the protuberance defining in part the enclosed air passageway to a diaphragm **1012** of the handheld base assembly **1002** (perhaps best seen in FIG. 13).

[080] FIG. 13 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein the diaphragm **1012** is perhaps best seen.

[081] FIG. 14 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a pressure sensor **1014** of the handheld base assembly **1002** is perhaps best seen.

[082] FIG. 15 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[083] FIG. 16 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[084] FIG. 17 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[085] FIG. 18 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[086] FIG. 19 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[087] FIG. 20 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[088] FIG. 21 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[089] FIG. 22 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[090] FIG. 23 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**, wherein the plug **1007** of the bladder **1008** is shown removed from a fill port of the bladder.

[091] FIG. 24 illustrates a preferred method of making the cartridge assembly **1004** and, in particular, of filling the bladder of the cartridge assembly **1004** with a liquid to be aerosolized and inhaled, wherein an injection needle **1009** is inserted into the fill port of the bladder **1008** for filling of the bladder with the liquid.

[092] FIG. 25 illustrates the inserting of the plug **1007** into the fill port of the bladder for sealing of the bladder following the filling of the bladder with the liquid.

[093] FIG. 26 is a top plan view of the electronic device **1000**.

[094] FIG. 26A is a shaded top plan view of the electronic device **1000**.

[0095] FIG. 26B is a shaded top plan view of the electronic device **1000**, wherein a mouthpiece **1010** of the cartridge assembly **1004** is shown in transparent view.

[0096] FIG. 27 is the view of the electronic device **1000** of FIG. 26, wherein the mouthpiece **1010** is omitted.

[0097] FIG. 28 is a perspective view of the electronic device **1000** of FIG. 27, wherein the mouthpiece **1010** is omitted.

[0098] FIG. 29 is a perspective view of the electronic device **1000** of FIG. 27, wherein additional components are omitted and a lower body of the cartridge assembly **1004** is shown in transparent view for purposes of illustrating the diaphragm **1012** of the handheld base assembly **1002**.

[0099] FIG. 30 is a top plan view of the mouthpiece **1010** of the cartridge assembly **1004**.

[0100] FIG. 31 is a bottom plan view of the mouthpiece **1010** of the cartridge assembly **1004**.

[0101] FIG. 32 is a bottom perspective view of the mouthpiece **1010** of the cartridge assembly **1004**.

[0102] FIG. 33 discloses software flow for firmware of the electronic device **100,1000**, which preferably is stored in memory and executed by a processor or microcontroller of the circuitry of the handheld base assembly **102,1002**.

[0103] FIGS. 34-44 illustrates various user interface screens **110,111,112,113,114,115** for apps that are installed and run on smartphones, such as an iPhone or an Android device, and which apps communicate with the electronic devices wirelessly using a communications protocol such as Bluetooth or Wi-Fi.

[0104] FIG. 45 illustrates possible user experiences when interacting with GUIs of the software in accordance with one or more aspects and features of the invention, which GUIs and sequences thereof are intended to drive adherence and compliance with prescribed medication use.

[0105] FIG. 46 illustrates features and capabilities of the software in accordance with one or more aspects and features of the invention, whether performed on the electronic device or on a mobile application on a smartphone, tablet device, or personal computer that is in communication with the electronic device.

[0106] FIG. 47 illustrates an exemplary instructions-for-use document (IFU) that is preferably included with commercial packaging represented in the schematic illustration of FIG. 1.

DETAILED DESCRIPTION

[0107] As a preliminary matter, it will readily be understood by one having ordinary skill in the relevant art (“Ordinary Artisan”) that the invention has broad utility and application. Furthermore, any embodiment discussed and identified as being “preferred” is considered to be part of a best mode contemplated for carrying out the invention. Other embodiments also may be discussed for additional illustrative purposes in providing a full and enabling disclosure of the invention. Furthermore, an embodiment of the invention may incorporate only one or a plurality of the aspects of the invention disclosed herein; only one or a plurality of the features disclosed herein; or combination thereof. As such, many embodiments are implicitly disclosed herein and fall within the scope of what is regarded as the invention.

[0108] Accordingly, while the invention is described herein in detail in relation to one or more embodiments, it is to be understood that this disclosure is illustrative and exemplary of the invention and is made merely for the purposes of providing a full and enabling disclosure of the invention. The detailed disclosure herein of one or more embodiments is not intended, nor is to be construed, to limit the scope of patent protection afforded the invention in any claim of a patent issuing here from, which scope is to be defined by the claims and the equivalents thereof. It is not intended that the scope of patent protection afforded the invention be defined by reading into any claim a limitation found herein that does not explicitly appear in the claim itself.

[0109] Thus, for example, any sequence(s) and/or temporal order of steps of various processes or methods that are described herein are illustrative and not restrictive. Accordingly, it should be understood that, although steps of various processes or methods may be shown and described as being in a sequence or temporal order, the steps of any such processes or methods are not limited to being carried out in any particular sequence or order, absent an indication otherwise. Indeed, the steps in such processes or methods generally may be carried out in various different sequences and orders while still falling within the scope of the invention. Accordingly, it is intended that the scope of patent protection afforded the invention be defined by the issued claim(s) rather than the description set forth herein.

[0110] Additionally, it is important to note that each term used herein refers to that which the Ordinary Artisan would understand such term to mean based on the contextual use of such term herein. To the extent that the meaning of a term used herein—as understood by the Ordinary Artisan based on the contextual use of such term—differs in any way from any particular dictionary definition of such term, it is intended that the meaning of the term as understood by the Ordinary Artisan should prevail.

[0111] With regard to any method claim including a condition precedent step, such method requires the condition precedent to be met and the step to be performed at least once but not necessarily every time during performance of the claimed method.

[0112] Furthermore, it is important to note that, as used herein, “comprising” is open-ended insofar as that which follows such term is not exclusive. Additionally, “a” and “an” each generally denotes “at least one” but does not exclude a plurality unless the contextual use dictates otherwise. Thus, reference to “a picnic basket having an apple” is the same as “a picnic basket comprising an apple” and “a picnic basket including an apple”, each of which identically describes “a picnic basket having at least one apple” as well as “a picnic basket having apples”; the picnic basket further may contain one or more other items beside an apple. In contrast, reference to “a picnic basket having a single apple” describes “a picnic basket having only one apple”; the picnic basket further may contain one or more other items beside an apple. In contrast, “a picnic basket consisting of an apple” has only a single item contained therein, i.e., one apple; the picnic basket contains no other item.

[0113] When used herein to join a list of items, “or” denotes “at least one of the items” but does not exclude a plurality of items of the list. Thus, reference to “a picnic basket having cheese or crackers” describes “a picnic basket having cheese without crackers”, “a picnic basket having crackers without

cheese”, and “a picnic basket having both cheese and crackers”; the picnic basket further may contain one or more other items beside cheese and crackers.

[0114] When used herein to join a list of items, “and” denotes “all of the items of the list”. Thus, reference to “a picnic basket having cheese and crackers” describes “a picnic basket having cheese, wherein the picnic basket further has crackers”, as well as describes “a picnic basket having crackers, wherein the picnic basket further has cheese”; the picnic basket further may contain one or more other items beside cheese and crackers.

[0115] The phrase “at least one” followed by a list of items joined by “and” denotes an item of the list but does not require every item of the list. Thus, “at least one of an apple and an orange” encompasses the following mutually exclusive scenarios: there is an apple but no orange; there is an orange but no apple; and there is both an apple and an orange. In these scenarios if there is an apple, there may be more than one apple, and if there is an orange, there may be more than one orange. Moreover, the phrase “one or more” followed by a list of items joined by “and” is the equivalent of “at least one” followed by the list of items joined by “and”.

[0116] Referring now to the drawings, one or more preferred embodiments of the invention are next described. The following description of one or more preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its implementations, or uses.

[0117] In particular, FIG. 1 is a schematic illustration of commercial packaging comprising a container **101** containing an electronic device **100** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention, wherein a handheld base assembly **102** and a cartridge assembly **104** of the electronic device **100** are shown as separated, individual components together with a cap **103**, USB charging cord **105**, and instructions for use or “IFU” **107**. The preferred IFU **107** are illustrated in FIG. 47.

[0118] FIG. 2 illustrates a perspective view of the preferred electronic device **100** of FIG. 1 and indicates the removable coupling together of the handheld base assembly **102** and the cartridge assembly **104**.

[0119] FIG. 3 illustrates a perspective view of the electronic device **100** when the handheld base assembly **102** and the cartridge assembly **104** are removably coupled together.

[0120] As shown in FIG. 3, “178” doses are indicated on a display **106** of the electronic device **100**. The number of doses preferably indicates how many doses have been metered by the device from a reservoir of the cartridge assembly **104**, or possibly one like it. Alternatively, number of doses represents the number remaining to be provided by the electronic device with the current cartridge assembly coupled thereto.

[0121] Specifically, when the handheld base assembly **102** and the cartridge assembly **104** are coupled together, firmware in memory of the handheld base assembly **102** and executed by a processor or microcontroller of the circuitry of the handheld base assembly **102** reads from a nonvolatile memory of the cartridge assembly **104** a number of doses that have been dispensed from the reservoir of the cartridge

assembly **104**, whether using the handheld base assembly **102** or using another handheld base assembly of another electronic device of the invention.

[0122] Optionally, the handheld base assembly **102** and the cartridge assembly **104** can be paired such that the cartridge assembly **104** only works with the handheld base assembly **102** by storing a unique identifier or other authenticating information in the cartridge assembly **104** by which the firmware of the handheld base assembly is configured to authenticate the cartridge assembly **102**. Such authenticating information preferably is permanently stored in read-only memory of the cartridge assembly **104**. Such pairing can be performed at time of manufacture, or when a new cartridge assembly **104** is first used with a handheld base assembly **102**. Alternatively, such authenticating information can be communicated to the handheld base assembly wirelessly over the Internet once the cartridge assembly to be used with the handheld base assembly **102** is known, such as when a specific cartridge may be prescribed or a prescription filled using the specific cartridge assembly. In this respect, the circuitry of the handheld base assembly **102** preferably includes a transceiver for wireless communications, including via Bluetooth, Wi-Fi, or other wireless communications protocol.

[0123] The display **106** further preferably shows a battery level of the electronic device **100**. As shown in FIG. 3, the battery level is 9 units. The battery preferably is rechargeable using, for example, a USB port as seen at **109**. The display may be an OLED or LCD screen.

[0124] The display preferably turns off after a predetermined period of time to avoid draining the battery. The display is turned on by positioning the handheld base assembly **102** to an orientation for reading of the display, by pushing and releasing a button **108**, or by some other user input mechanism. The button **108** also preferably initiates a dosing by, for example, a depressing the button **108** for a prolonged period of time (relative to a quick pressing to illuminate the display).

[0125] Alternatively, the button **108** is used to wake the electronic device **108** (including display for a predetermined period of time), and a pressure sensor of the handheld base assembly **102** detects when a breath is drawn from a mouthpiece of the cartridge assembly **104** for causing the aerosolization of a metered dose. In this respect, when the pressure sensor detects a breath, the haptic engine is activated to provide sensory feedback to the user that a breath has been detected and that a dose is being/will be aerosolized. The magnitude of the vibrations caused by the haptic engine and length of activation preferably are settings that can be adjusted by a user through an app. The haptic vibration may also be used to signal the end of a precisely metered dose.

[0126] FIG. 4 illustrates a perspective view of another electronic device **900** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention, wherein when a handheld base assembly **902** and a cartridge assembly **904** with a sealing cap **905** are removably coupled together.

[0127] FIG. 5 is another view of the electronic device **900** with the sealing cap **905** removed to expose an opening of a mouthpiece of the cartridge assembly **904**.

[0128] FIG. 6 is a side elevational view in partial transparency of the electronic device **900**.

[0129] FIG. 7 is an exploded view of the handheld base assembly **902** of the electronic device **900**.

[0130] FIG. 8 is an exploded view of the cartridge assembly **904** of the electronic device **900**. The cartridge assembly **904** comprises a pressure ring **912**; a mesh assembly **914**; and a bladder **916**. The mesh assembly **914** comprises a piezo transducer disc or annulus, perforated mesh centrally located and supported by the piezo, and electrical wires for actuating the piezo and effecting oscillation of the mesh. The bladder **916** comprises a rim **918** configured to receive and effect a seal with the mesh assembly **914**. The mesh preferably comprises perforated 316L stainless steel. The mesh assembly is located between the pressure ring **912** and the bladder **916**. The bladder **916** includes a fill port **920** and plug **922** for sealing the fill port **922**, whereby the bladder **916** may be filled with a liquid from underneath. The bladder **916** preferably has a capacity of 1.5 ml. A wick **924** is located within the bladder **924** that facilitates conveyance of liquid to the mesh. The bladder **916** is contained within a cartridge housing or body **926**. A printed circuit board **928** with non-transitory computer-readable medium, e.g., flash memory, and a plate **930** for securement with magnets of the handheld base assembly, also are shown to be contained within the cartridge body **926**. A bottom cap **932** covers the bottom of the cartridge body **926**. An opening in the bottom cap **923** and a corresponding opening in the plate **930** in register with the opening in the bottom cap **923** facilitate passage therethrough of one or more pins of the handheld base assembly to the printed circuit board **928**, by which the cartridge assembly is connected with the handheld base assembly for electronic communication and for providing power to and driving the oscillations of the mesh assembly **914**. A mouthpiece **934** attaches to a top of the cartridge body **926** in covering relation to the pressure ring **912** and mesh assembly **914**. The mouthpiece **934** defines an interior area located over the pressure ring from which the aerosolized liquid is suctioned, and a mouth opening **936** through which the aerosolized liquid is suctioned into the mouth of a user. The interior area is vented by port **938** for facilitating airflow through the interior area and out the mouth opening **936** when a breath is drawn. The pressure ring preferably is a distinct silicone rubber component that applies even and consistent circumferential pressure to the mesh assembly. It is designed in a manner to not dampen the functionality and oscillation potential of the vibrating mesh. The bladder preferably is made from silicone and is a compliant component that interfaces with the mesh assembly to simultaneously provide a liquid tight seal while also supporting the piezo for optimal vibration characteristics, thus not dampening or muting the perforated mesh from creating an aerosol. The pressure ring along with the bladder work in concert with optimal driving parameters of the firmware to create an orientation agnostic vibrating mesh nebulizer.

[0131] The vibrating mesh nebulizer stack of the electronic device **900** is designed with a fully sealed airpath that is compliant with medical airpath ISO 18625 and medical device ISO 10993 standards, each standard of which is incorporated herein by reference as of April 22, 2022. In particular, the electronic device and, specifically, the cartridge assembly and handheld base assembly, preferably collectively define an enclosed interior air passageway leading from the interior area within the mouthpiece from which the aerosolized liquid is suctioned to an arrangement in the handheld base assembly that includes a pressure sensor by which a breath drawn on the mouthpiece is detected. The cartridge body of the cartridge assembly preferably defines the air passageway leading from the interior space of the mouthpiece to an opening on the bottom of the cartridge body, and the handheld base assembly preferably

comprises a sealing component and protuberance. The sealing component preferably engages the area around the opening on the bottom of the cartridge body so as to seal the opening when the cartridge body is coupled to the handheld base assembly. The protuberance preferably defines an air passageway from the opening in the cartridge body to a diaphragm, which closes off the air passageway. Air within the passageway is thereby trapped, and a decrease in pressure within the interior area of the mouthpiece due to the drawing of a breath results in a decrease in pressure in the air passageway of the protuberance at the diaphragm, which in turn causes the diaphragm to move outwardly into or toward the air passageway. The diaphragm is located next to and in fluid communication with a pressure sensor and is configured to trigger the pressure sensor when the diaphragm so moves due to the drop in pressure in the air passageway of the protuberance. Preferably, all components (or portions thereof) defining the enclosed air passageway are made from medical grade materials in compliance with ISO 18562 and ISO 10993.

[0132] The cartridge assembly is designed to be disposable, whereas the handheld base assembly is designed to be reusable. Additionally, the electronic device preferably is Bluetooth® enabled, features breath-actuation of a measured dosage, and is orientation-agnostic in operation. The Bluetooth capabilities enable user interaction via a smartphone, table, or personal computer with an app for use with the electronic device. User interfaces of the app preferably facilitate use of the handheld base assembly with multiple different cartridge assemblies, which GUIs are described below.

[0133] FIG. 9 is a perspective view of another electronic device **1000** for producing an aerosol for inhalation by a person in accordance with one or more aspects and features of the invention.

[0134] FIG. 10 is a view illustrating the uncoupling of the handheld base assembly **1002** and the cartridge assembly **1004** of the electronic device **1000**.

[0135] FIG. 11 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a sealing component **1013** is perhaps best seen. As discussed above, the sealing component **1013** creates an airtight seal with the cartridge body around an opening therein when the cartridge assembly is coupled with the handheld base assembly. The opening is to the airflow passageway leading from the interior area of the mouthpiece; the airflow passageway is perhaps best shown in FIG. 13, wherein a channel **1017** in the cartridge body defines this air passageway. FIG. 11 also perhaps best shows pins **1019** by which the handheld base assembly is connected with the cartridge assembly for communication therewith and for providing power to and driving the oscillations of the piezo. The corresponding contacts **1021** for these pins are perhaps best shown in FIG. 25.

[0136] FIG. 12 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a protuberance **1011** defined by a wall of the handheld base assembly **1002** is seen, the protuberance defining in part the enclosed air passageway to a diaphragm **1012** of the handheld base assembly **1002** (perhaps best seen in FIG. 13).

[0137] FIG. 13 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein the diaphragm **1012** is perhaps best seen.

[0138] FIG. 14 is a view illustrating one or more components of the handheld base assembly **1002** and one or more components of the cartridge assembly **1004** of the electronic device **1000**, wherein a pressure sensor **1014** of the handheld base assembly **1002** is perhaps best seen.

[0139] FIG. 15 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[0140] FIG. 16 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[0141] FIG. 17 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[0142] FIG. 18 is a view illustrating one or more components of the cartridge assembly **1004** of the electronic device **1000**.

[0143] FIG. 19 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[0144] FIG. 20 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[0145] FIG. 21 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[0146] FIG. 22 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**.

[0147] FIG. 23 is a view illustrating the bladder **1008** of the cartridge assembly **1004** of the electronic device **1000**, wherein the plug **1007** of the bladder **1008** is shown removed from a fill port of the bladder.

[0148] FIG. 24 illustrates a preferred method of making the cartridge assembly **1004** and, in particular, of filling the bladder of the cartridge assembly **1004** with a liquid to be aerosolized and inhaled, wherein an injection needle **1009** is inserted into the fill port of the bladder **1008** for filling of the bladder with the liquid.

[0149] FIG. 25 illustrates the inserting of the plug **1007** into the fill port of the bladder for sealing of the bladder following the filling of the bladder with the liquid.

[0150] FIG. 26 is a top plan view of the electronic device **1000**.

[0151] FIG. 26A is a shaded top plan view of the electronic device **1000**.

[0152] FIG. 26B is a shaded top plan view of the electronic device **1000**, wherein a mouthpiece **1010** of the cartridge assembly **1004** is shown in transparent view.

[0153] FIG. 27 is the view of the electronic device **1000** of FIG. 26, wherein the mouthpiece **1010** is omitted.

[0154] FIG. 28 is a perspective view of the electronic device **1000** of FIG. 27, wherein the mouthpiece **1010** is omitted.

[0155] FIG. 29 is a perspective view of the electronic device **1000** of FIG. 27, wherein additional components are omitted and a lower body of the cartridge assembly **1004** is shown in transparent view for purposes of illustrating the diaphragm **1012** of the handheld base assembly **1002**.

[0156] FIG. 30 is a top plan view of the mouthpiece **1010** of the cartridge assembly **1004**. FIG. 30 shows mouthpiece opening **1036**, the channel defining the air passageway **1017** in the cartridge body, the port **1038** for venting the interior area **1029** (see FIG. 32) of the mouthpiece **1010** from which the aerosolized liquid is suctioned, the mesh **1027**, and the piezo **1025**.

[0157] FIG. 31 is a bottom plan view of the mouthpiece **1010** of the cartridge assembly **1004**.

[0158] FIG. 32 is a bottom perspective view of the mouthpiece **1010** of the cartridge assembly **1004**.

[0159] FIG. 33 discloses software flow for firmware of the electronic device **100** similar to that described above but with some variations and represents an alternative implementation. Some preferred names for software functions and classes are set forth in FIG. 33.

[0160] FIGS. 34-44 illustrates various user interface screens **110**, **111**, **112**, **113**, **114**, **115**, **116**, **117**, **118**, **119**, and **120** for an app that is installed and run on a smartphone, such as an iPhone or an Android device, and which app communicates with the electronic device **100**—and specifically with the handheld base assembly **102** of the electronic device **100**—wirelessly using a protocol such as Bluetooth or Wi-Fi.

[0161] In particular, the user interface **110** of FIG. 34 shows a number of doses dispensed within the last twenty-four hours. The user interface **110** further includes two user settings (changeable via toggles): one for enabling or disabling vibrations generated by the haptic engine during aerosolizing; and one for locking the electronic device so that it cannot be used.

[0162] User interface **111** of FIG. 35 shows the total number of doses dispensed, settings for enabling/disabling the haptic engine and for locking the device. The user interface **111** also includes expandable menus relating to “Start Breath” settings; “Breath Duration” settings; and “End Breath” settings, as illustrated in FIGS. 36 and 37. The battery level and whether the cartridge is connected also are indicated.

[0163] User interface **112** of FIGS. 38-40 are similar to user interface **111** but include the ability to enable or disable additional devices (seen as device 1, device 2, and device 3).

[0164] User interface **113** of FIGS. 41-44 is similar to user interface **111**, but is also scrollable for viewing settings (enable/disable) for additional devices.

[0165] User interface **114** of FIG. 43 shows current settings with expandable/dropdown menus for changing those settings.

[0166] User interface **115** of FIG. 44 shows scanning that is occurring for devices within range for connection with the app and is shown upon selection of “Find New Device” in user interface **114**.

[0167] FIG. 45 illustrates possible user experiences when interacting with GUIs of the software in accordance with one or more aspects and features of the invention, which GUIs and sequences thereof are intended to drive adherence and compliance with prescribed medication use.

[0168] FIG. 46 illustrates features and capabilities of the software in accordance with one or more aspects and features of the invention, whether performed on the electronic device or on a mobile

application on a smartphone, tablet device, or personal computer that is in communication with the electronic device.

[0169] It will be appreciated from the foregoing that in at least one embodiment, the electronic device comprises a handheld base assembly and a cartridge assembly, and that the cartridge assembly and the handheld base assembly are configured to removably couple together. The cartridge assembly preferably comprises a mouthpiece; a cartridge; and a bladder assembly as described in the incorporated disclosures.

[0170] Furthermore, the bladder assembly preferably comprises a bladder; a wick contained within the bladder; and a mesh assembly, wherein the mesh assembly preferably comprises a mesh material and a piezoelectric material, the mesh material being configured to vibrate when the piezoelectric material is actuated, whereby an aerosol is produced when the mesh material contacts a liquid of the bladder such that the aerosol may be inhaled through the mouthpiece. The handheld base assembly and cartridge assembly are configured magnetically to couple together and, specifically, the cartridge assembly magnetically mounts onto an end of the handheld base assembly.

[0171] In preferred embodiments, the cartridge assembly is disposable and eliminates potential patient misuse after its intended use. Moreover, because the vibrating mesh, ancillary aerosolizing components, and the liquid reservoir are all part of the disposable design, there is no maintenance or cleaning, and the device operates at optimal functionality.

[0172] The cartridge assembly also provides cartridge tracking, monitoring, user authentication, and geo-fencing capabilities for an increased standard of care and patient outcomes.

[0173] In use, the patient's inhalation triggers the vibrating mesh to activate under normal inspiratory use. A Bluetooth-enabled mobile app integration preferably is provided that logs precise dosing data in real-time, which is easily accessible by patient and clinician. The device is feature rich with visual indicators like a fully digital OLED display, and the smart cartridge ensures lifecycle, tamper-proof and chain of custody compliance from manufacture to delivery. The Bluetooth-enabled capabilities of the device further enables mobile application for compliance and precise dosing as well as accessible, real-time EMR data for providers, clinicians, and patients. In further facilitating precise dosing, customizable haptic vibration toggles, accessible via the mobile app, signal the end of the precisely metered dose.

[0174] Features of such preferred commercial embodiments include: no heat is used in the aerosolization and thus no HPHCs are produced; preferred commercial embodiments can be characterized as a breath actuated inhaler for all patient age groups; preferred commercial embodiments are ideal for thermo and pressure sensitive APIs and biologics; preferred commercial embodiments have local or systemic treatment capabilities; preferred commercial embodiments provide accurate and efficient metered dose delivery; and preferred commercial embodiment enable and facilitate subscription service, in-home delivery for continuity of care in chronic disease management.

[0175] Additional perceived benefits of aspects and features of the invention include: real-time data provided on screen; real-time data captured via mobile app; stored data in the electronic device; cost reduction for providers/insurers; predictive analytics; EMR & HIPAA compliant data; increase digital adherence & compliance (companion app & true DTX); gamification / digital prompts to encourage

cessation and reduce misuse—indication area: nicotine reduction therapy (NRT); and gamification / digital prompts to encourage therapeutic adherence and reduce misuse—indication area: universal inhalation therapeutics.

[0176] Based on the foregoing description, it will be readily understood by those persons skilled in the art that the invention has broad utility and application. Many embodiments and adaptations of the invention other than those specifically described herein, as well as many variations, modifications, and equivalent arrangements, will be apparent from or reasonably suggested by the invention and the foregoing descriptions thereof, without departing from the substance or scope of the invention.

[0177] For example, it is recognized that the path of the aerosolized liquid through the electronic device is defined solely within the cartridge assembly, which does not include either the power source (battery) or the electronic circuitry (processor/firmware/transceiver), with the possible exception of a non-transient computer readable medium that preferably is located adjacent a bottom of the cartridge assembly if included. Because of this innovative aspect, i.e., because the electronics and power components are excluded and isolated from the airpath, being located in a separate and removable assembly of the electronic device, the possibility of airpath toxicity is reduced.

[0178] Accordingly, while the invention has been described herein in detail in relation to one or more preferred embodiments, it is to be understood that this disclosure is only illustrative and exemplary of the invention and is made merely for the purpose of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended to be construed to limit the invention or otherwise exclude any such other embodiments, adaptations, variations, modifications or equivalent arrangements, the invention being limited only by the claims appended hereto and the equivalents thereof.

What is claimed is:

1. An electronic device for producing an aerosol for inhalation by a person, comprising:
 - (a) a cartridge assembly; and
 - (b) a handheld base assembly;
 - (c) wherein the cartridge assembly and the handheld base assembly are configured to removably couple together;
 - (d) wherein the handheld base assembly comprises circuitry including firmware executed by a processor or microcontroller of the circuitry; and
 - (e) wherein the cartridge assembly comprises memory that is read by the firmware of the handheld base assembly.
2. The electronic device of claim 1, wherein the firmware further writes to the memory of the handheld base assembly.
3. The electronic device of claim 1, wherein the memory of the handheld base assembly comprises a non-transitory computer-readable memory.
4. The electronic device of claim 1, wherein the cartridge assembly comprises,
 - (a) a mouthpiece;
 - (b) a cartridge; and
 - (c) a bladder assembly.
5. The electronic device of claim 2, wherein the bladder assembly comprises,
 - (a) a bladder;
 - (b) a wick contained within the bladder; and
 - (c) a mesh assembly;
 - (d) wherein the mesh assembly comprises a mesh material and a piezoelectric material, the mesh material being configured to vibrate when the piezoelectric material is actuated whereby an aerosol is produced when the mesh material contacts a liquid of the bladder such that the aerosol may be inhaled through the mouthpiece.
6. The electronic device of claim 1, wherein the disposable cartridge assembly and handheld base assembly are configured to magnetically couple together.
7. The electronic device of claim 2, wherein the disposable cartridge assembly magnetically mounts onto an end of the handheld base assembly.
8. An electronic device as disclosed herein.
9. An electronic device as disclosed herein, wherein an enclosed air passageway is defined by the cartridge assembly and by the handheld base assembly, which isolates the airflow from the electronics of the device.
10. The electronic device of claim 9, wherein the enclosed air passageway extends between the opening of the mouthpiece for taking a breath and a diaphragm of the handheld base assembly, movement of the diaphragm changing the air pressure within an enclosed interior space having a

- pressure sensor for triggering the pressure sensor when a breath is taken on the mouthpiece, the pressure sensor in turn causing aerosolization to occur for administering a dose.
11. A method of using an electronic device as disclosed herein.
 12. A system comprising an electronic device as disclosed herein including software with one or more GUIs as disclosed herein.
 13. An electronic device for producing an aerosol for inhalation by a person, comprising:
 - (a) a cartridge assembly; and
 - (b) a handheld base assembly;
 - (c) wherein the cartridge assembly and the handheld base assembly are configured to removably couple together;
 - (d) wherein the handheld base assembly comprises circuitry including firmware executed by a processor or microcontroller of the circuitry; and
 - (e) wherein the cartridge assembly comprises memory that is read by the firmware of the handheld base assembly.
 14. The electronic device of claim 13, wherein the handheld base assembly comprises a display.
 15. The electronic device of claim 13, wherein a representation of doses provided using the electronic device from a particular cartridge assembly is identified through the display.
 16. The electronic device of claim 15, wherein the representation comprises a number of doses provided.
 17. The electronic device of claim 15, wherein the representation comprises a number of doses remaining in the particular cartridge assembly.
 18. The electronic device of claim 15, wherein a representation of a number of puffs in a said does is indicated through the display.
 19. The electronic device of claim 13, wherein, when the handheld base assembly and the cartridge assembly are coupled together, firmware in memory of the handheld base assembly and executed by a processor or microcontroller of the circuitry of the handheld base assembly reads from a nonvolatile memory of the cartridge assembly a number of doses that have been dispensed from or that remain in the reservoir of the cartridge assembly.
 20. The electronic device of claim 13, wherein the handheld base assembly and the cartridge assembly are paired such that the cartridge assembly only works with the handheld base assembly with which it is paired by storing a unique identifier or other authenticating information in the cartridge assembly by which the firmware of the handheld base assembly is configured to authenticate the cartridge assembly.
 21. The electronic device of claim 20, wherein said authenticating information is permanently stored in read-only memory of the cartridge assembly.
 22. The electronic device of claim 20, wherein said pairing is performed at time of manufacture of the cartridge assembly and handheld base assembly.

23. The electronic device of claim 20, wherein said pairing is performed when a new cartridge assembly is first used with a handheld base assembly.
24. The electronic device of claim 20, wherein said authenticating information is communicated to the handheld base assembly.
25. The electronic device of claim 24, wherein the handheld base assembly comprises a transceiver for wireless communications.
26. The electronic device of claim 25, wherein said authenticating information is communicated to the handheld base assembly wirelessly over the Internet once the cartridge assembly to be used with the handheld base assembly is known.
27. The electronic device of claim 26, wherein said authenticating information is communicated to the handheld base assembly wirelessly over the Internet when a specific cartridge is prescribed using the specific cartridge assembly.
28. The electronic device of claim 26, wherein said authenticating information is communicated to the handheld base assembly wirelessly over the Internet when a prescription is filled using the specific cartridge assembly.
29. The electronic device of claim 20, wherein a battery of the electronic device is rechargeable using a USB port of the electronic device.
30. The electronic device of claim 13, wherein the electronic device is configured to initiate a dosing when a button on an exterior of the electronic device is depressed for a predetermined period of time.
31. The electronic device of claim 13, wherein the electronic device is configured to turn on when a button on an exterior of the electronic device is depressed for a predetermined period of time, and wherein the electronic device comprises a pressure sensor configured to detect when a breath is drawn from a mouthpiece of the cartridge assembly when the device is turned on and consequently cause aerosolization of a metered dose.
32. The electronic device of claim 31, wherein the pressure sensor is contained within the handheld base assembly.
33. The electronic device of claim 32, wherein the electronic device defines an enclosed interior air passageway extending between an interior space of a mouthpiece of the cartridge assembly to the pressure sensor contained within and mounted to a circuit board of the handheld base assembly.
34. The electronic device of claim 32, wherein the cartridge assembly and handheld base assembly collective define an enclosed interior air passageway extending between an interior space of a mouthpiece of the cartridge assembly to the pressure sensor contained within the handheld base assembly.
35. The electronic device of claim 34, wherein the cartridge assembly comprises a mesh component formed from 316L stainless steel.
36. The electronic device of claim 34, wherein the enclosed, interior air passageway is in fluid communication with the mesh assembly.

37. The electronic device of claim 36, wherein the handheld base assembly comprises a diaphragm arranged proximate the pressure sensor by which a change in pressure is detected by the pressure sensor.
38. The electronic device of claim 37, wherein no electronic components are exposed to the enclosed interior air passageway.
39. The electronic device of claim 38, wherein all components defining the enclosed interior air passageway are made from medical grade materials such that the electronic device is compliant with ISO 18562 and ISO 10993 standards.
40. The electronic device of claim 31, wherein, when the pressure sensor detects a breath, a haptic engine of the handheld base assembly is activated to provide sensory feedback to the user that a breath has been detected and that a dose is being aerosolized.
41. The electronic device of claim 40, wherein the magnitude of the vibrations caused by the haptic engine and length of activation are adjustable by a user through an app.
42. The electronic device of claim 13, wherein the cartridge assembly comprises a vibrating mesh nebulizer stack defining a fully sealed airpath that is compliant with medical airpath ISO 18625 and medical device ISO 10993 standards.
43. The electronic device of claim 13, wherein the cartridge assembly comprises a compliant, silicone bladder that interfaces with a mesh assembly to provide a liquid tight seal between an interior space of the bladder containing a liquid and a mesh of the mesh assembly for aerosolizing the liquid.
44. The electronic device of claim 43, wherein the cartridge assembly further comprises a pressure ring configured to apply circumferential pressure to a piezo assembly of the mesh assembly, the mesh assembly being sandwiched between the bladder and the pressure ring.
45. The electronic device of claim 44, wherein a mouth of the bladder at a top of the bladder engages and forms a liquid seal with the mesh assembly.
46. The electronic device of claim 45, wherein the bladder comprises a fill port located on a bottom of the bladder for filling the bladder with a liquid.
47. The electronic device of claim 46, wherein the bladder comprises a plug for sealing the fill port after filling of the bladder with a liquid.
48. The electronic device of claim 13, wherein the bladder has a capacity of 1.5 ml.
49. The electronic device of claim 13, further comprising a sealing cap removably attached to the cartridge assembly in covering relation to a mouthpiece of the cartridge assembly.
50. The electronic device of claim 13, wherein the handheld base assembly comprises a transceiver and is configured to wirelessly communicate with an app on a smartphone, tablet device, or personal computer.
51. The electronic device of claim 50, wherein the app is configured to show a number of doses dispensed from a cartridge assembly coupled to the handheld base assembly.
52. Commercial packaging comprising the electronic device of claims 1, 8, 9, or 13.

53. The commercial packaging of claim 52, wherein the handheld base assembly and the cartridge assembly of the electronic device are separated from one another such that the electronic device requires assembly when removed from the commercial packaging.
54. The commercial packaging of claim 52, wherein the commercial packaging further comprises a charging cord and instructions for use.

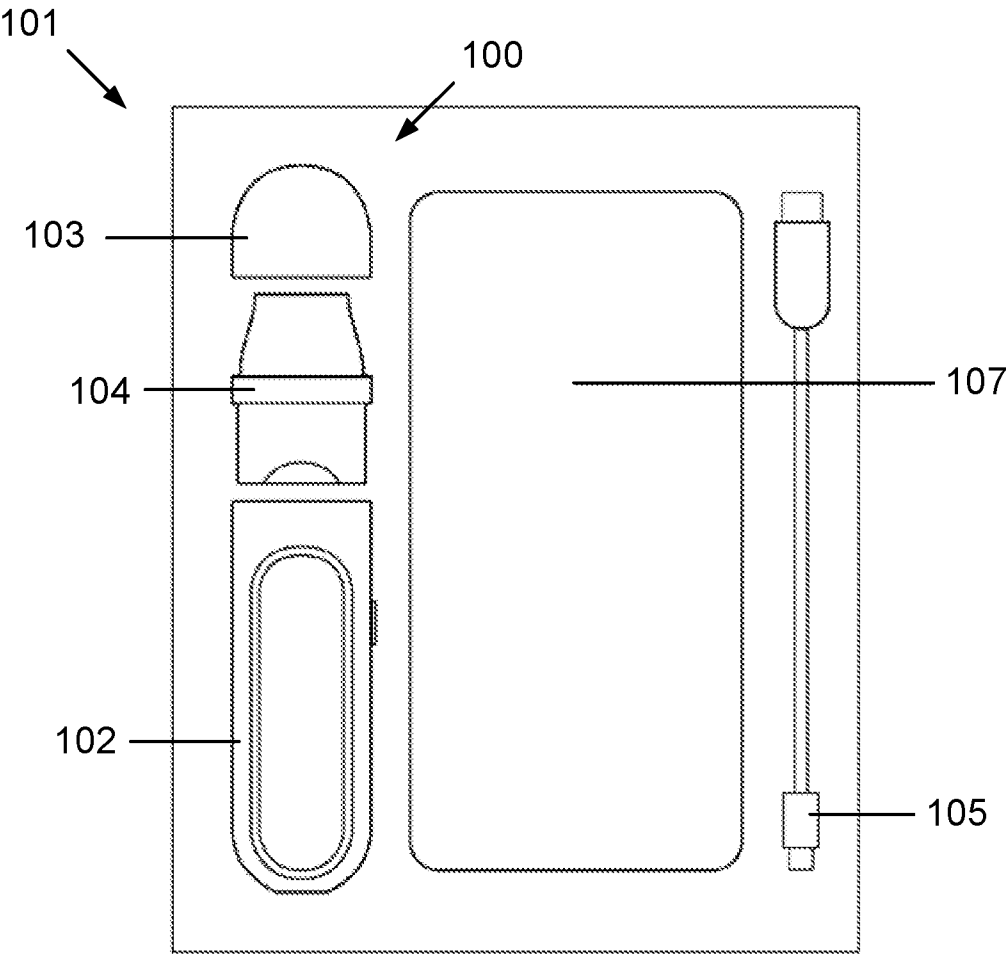


FIG. 1

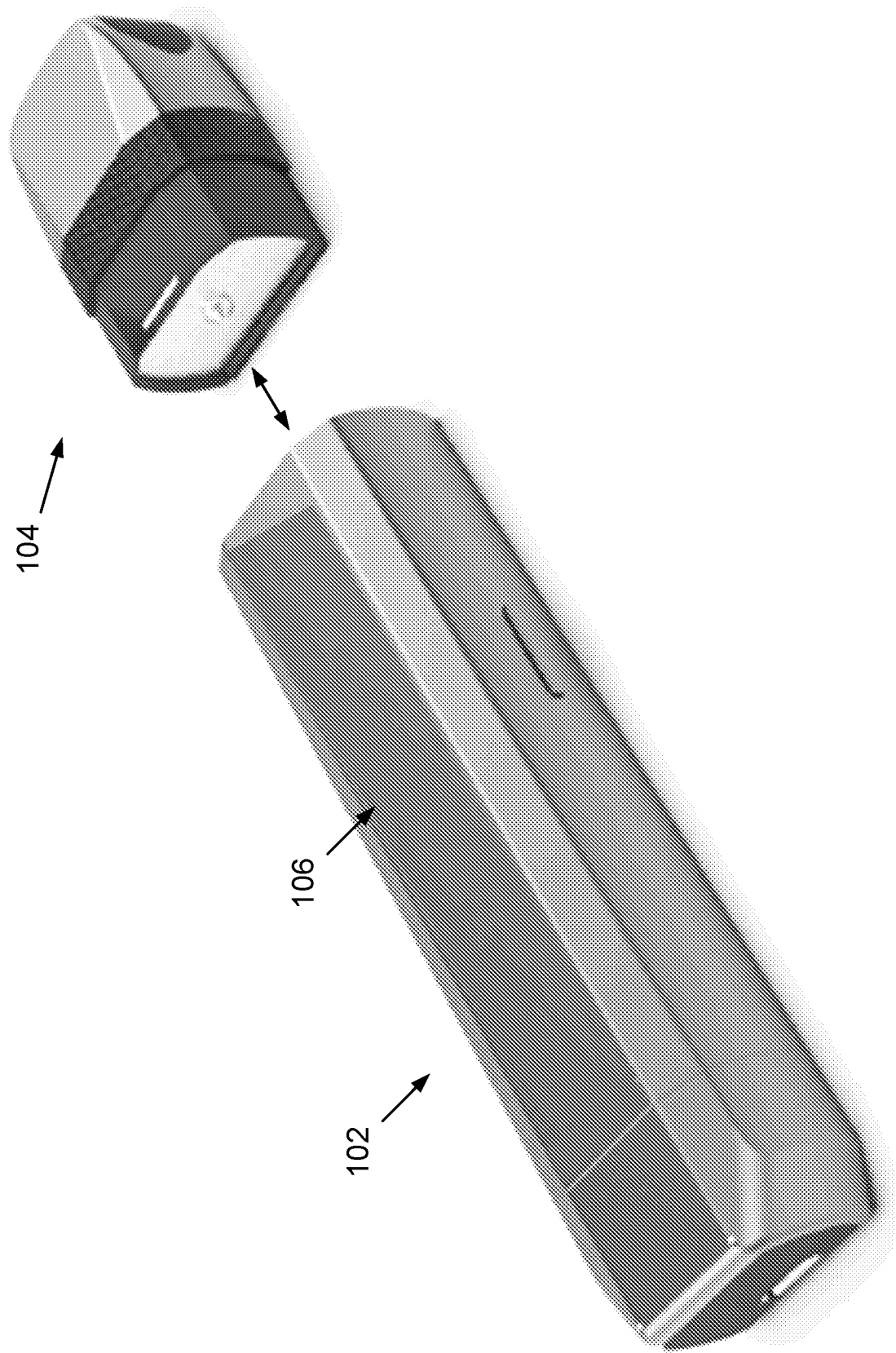


FIG. 2

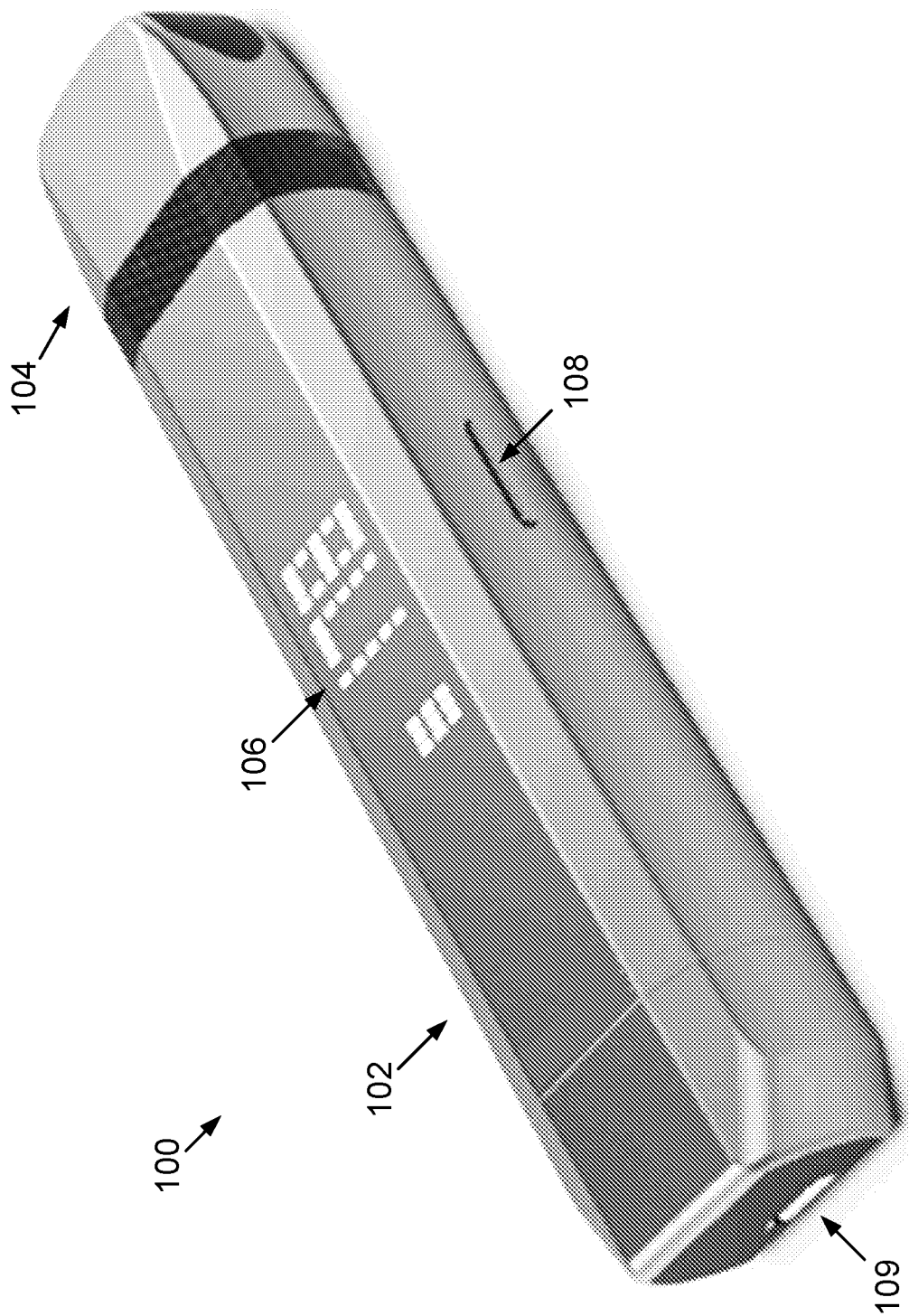


FIG. 3

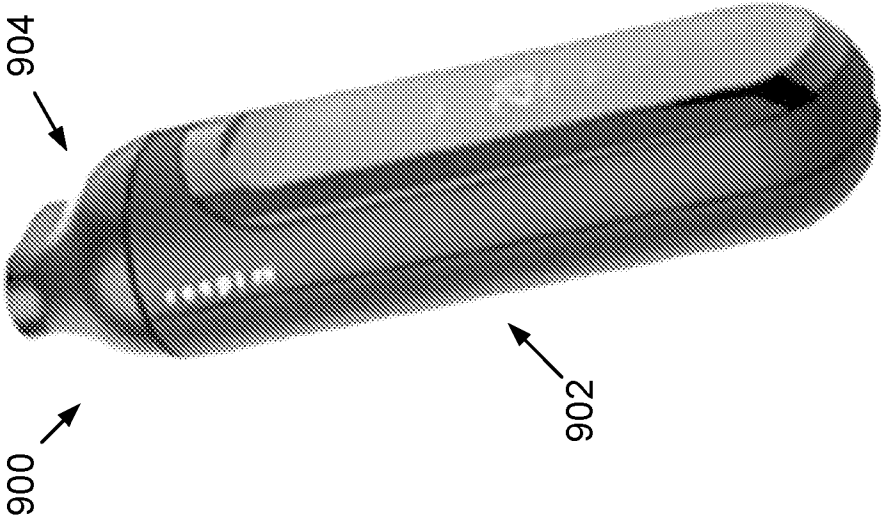


FIG. 5

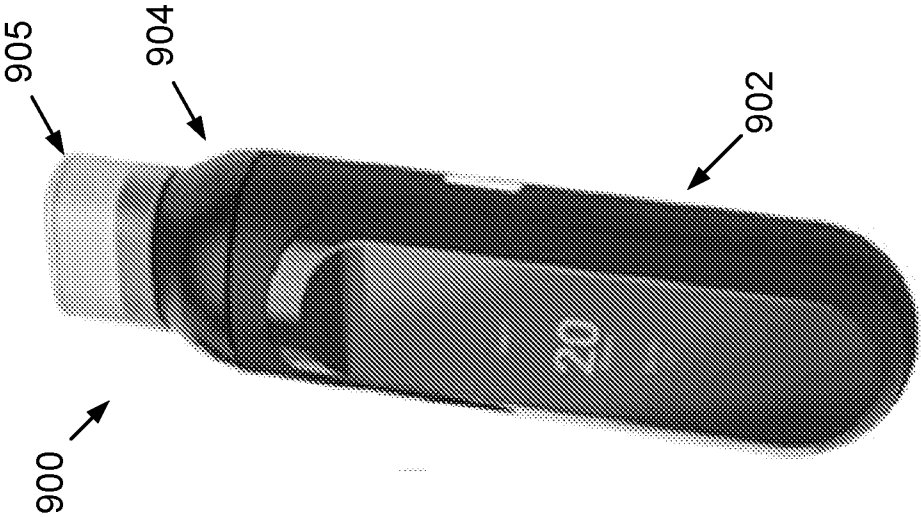


FIG. 4

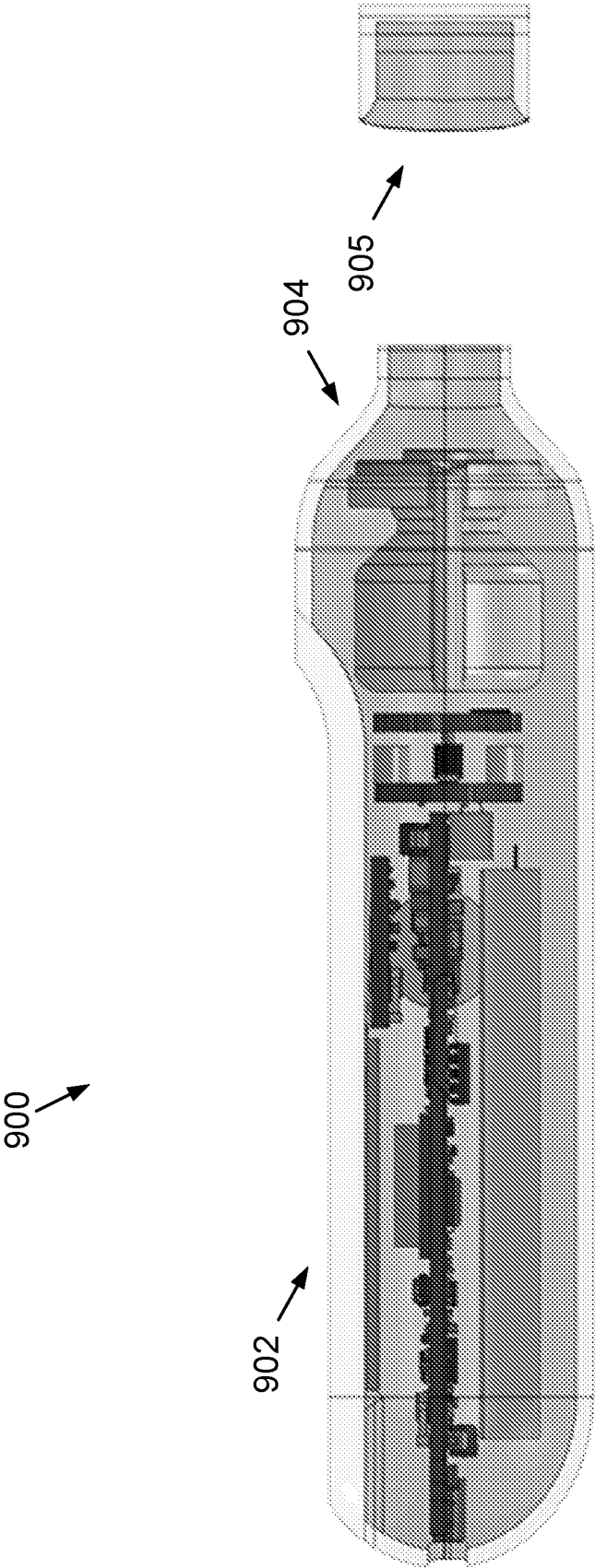


FIG. 6

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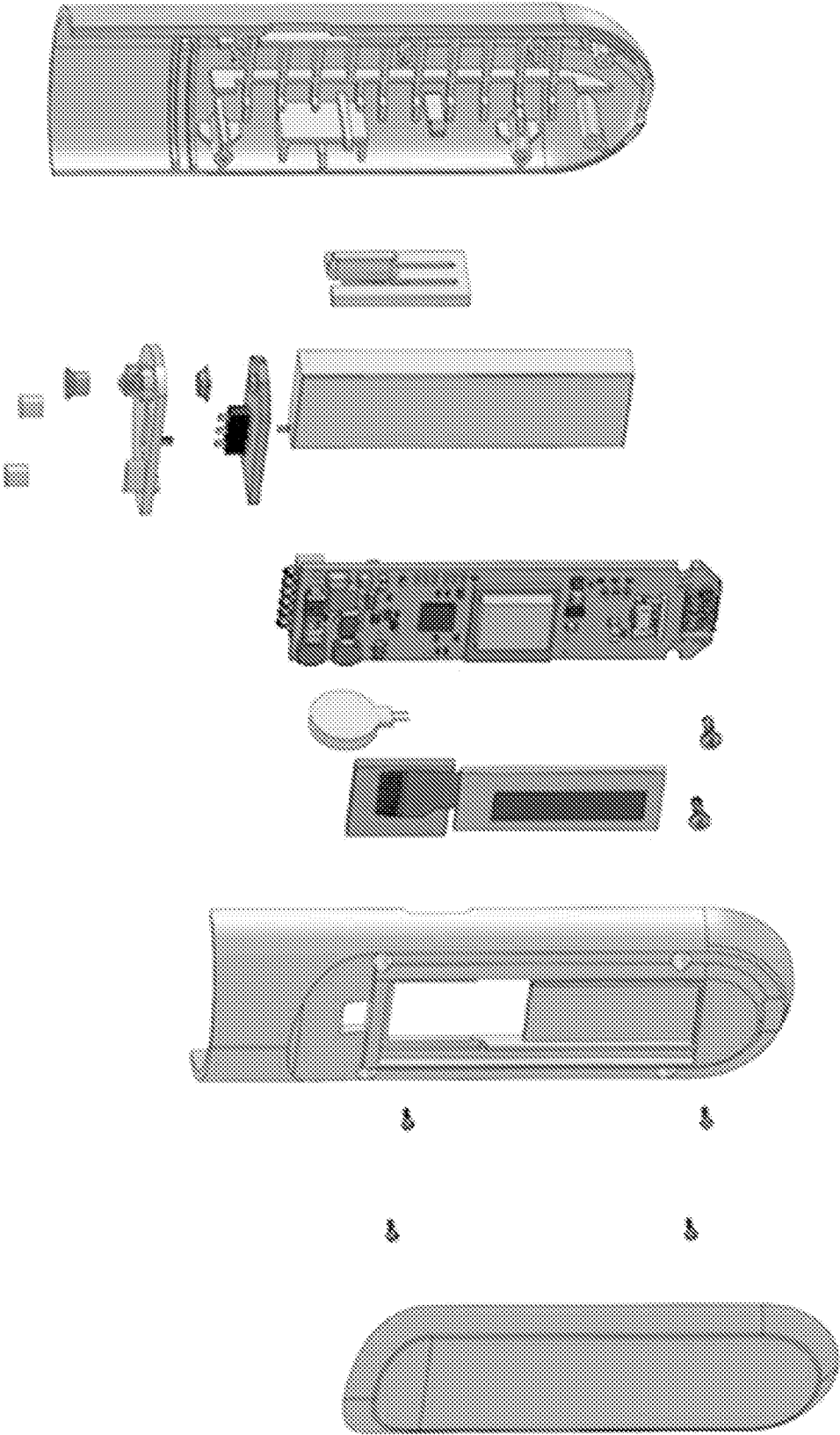


FIG. 7

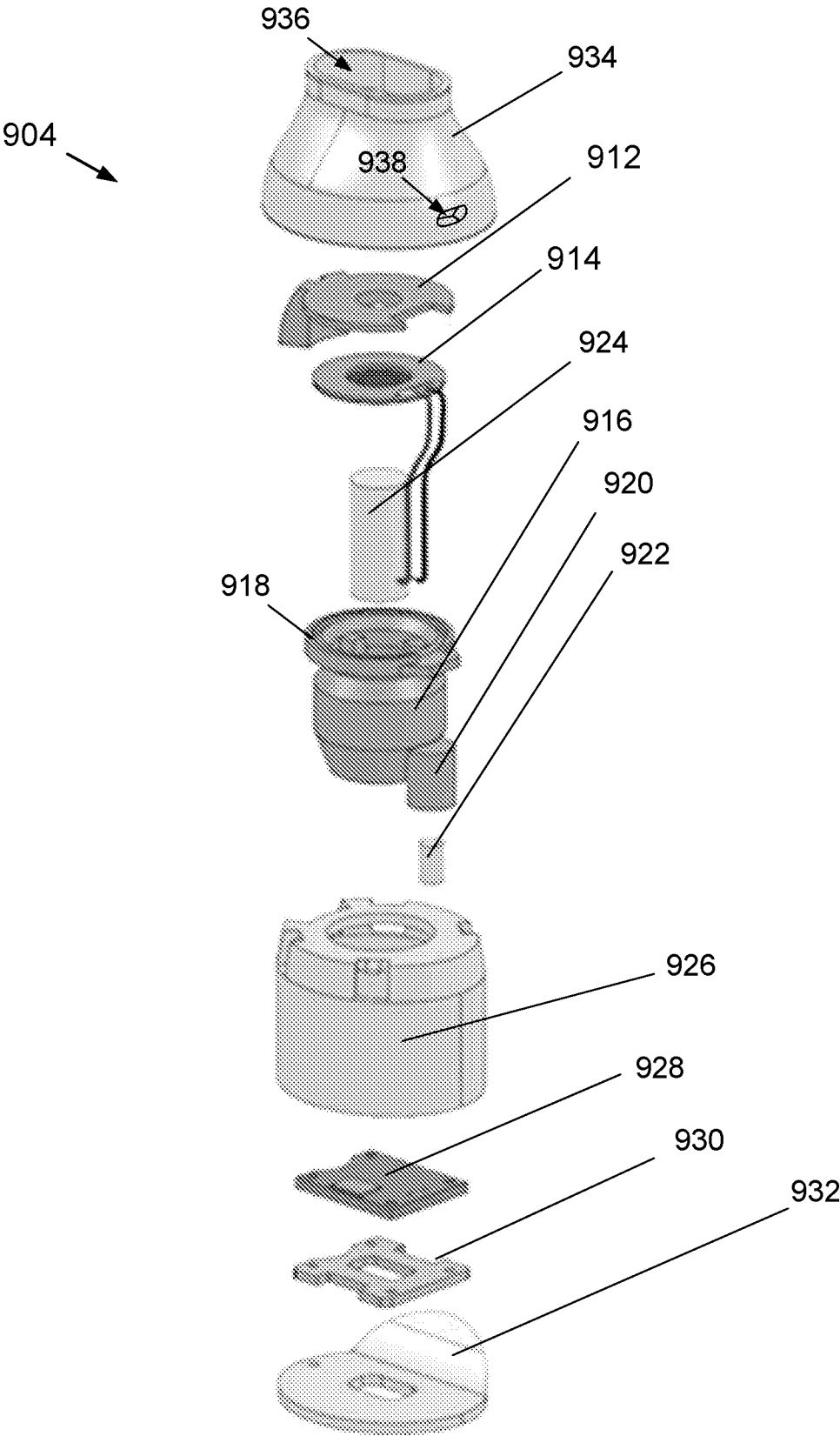


FIG. 8

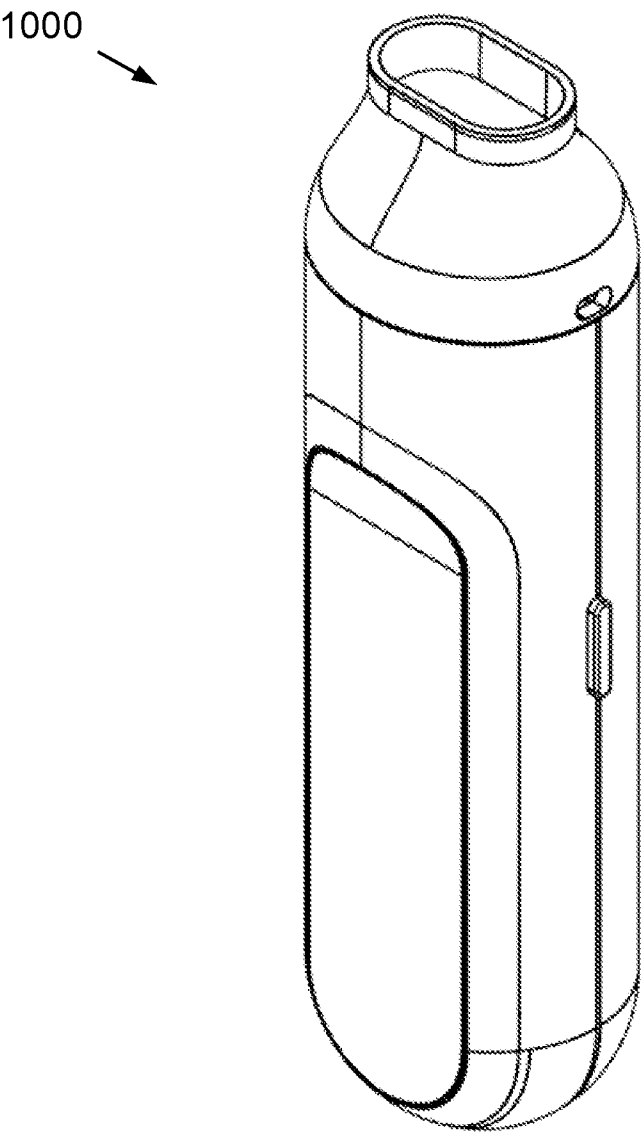
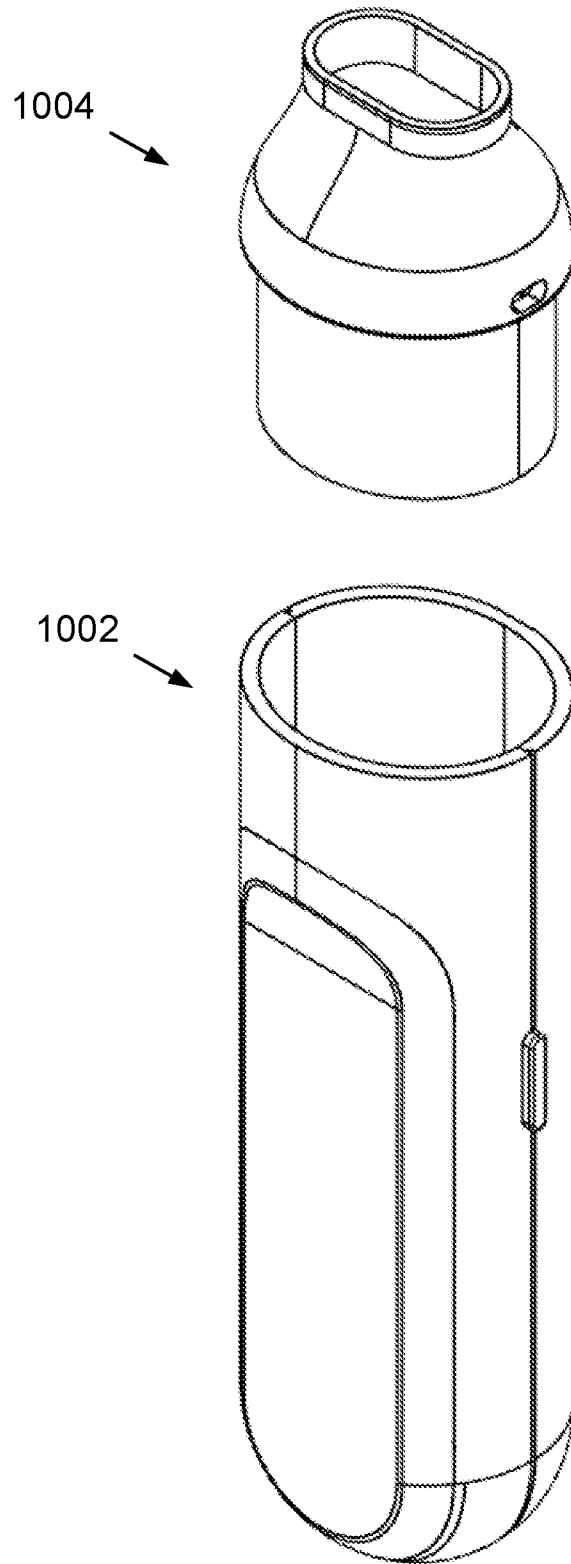


FIG. 9



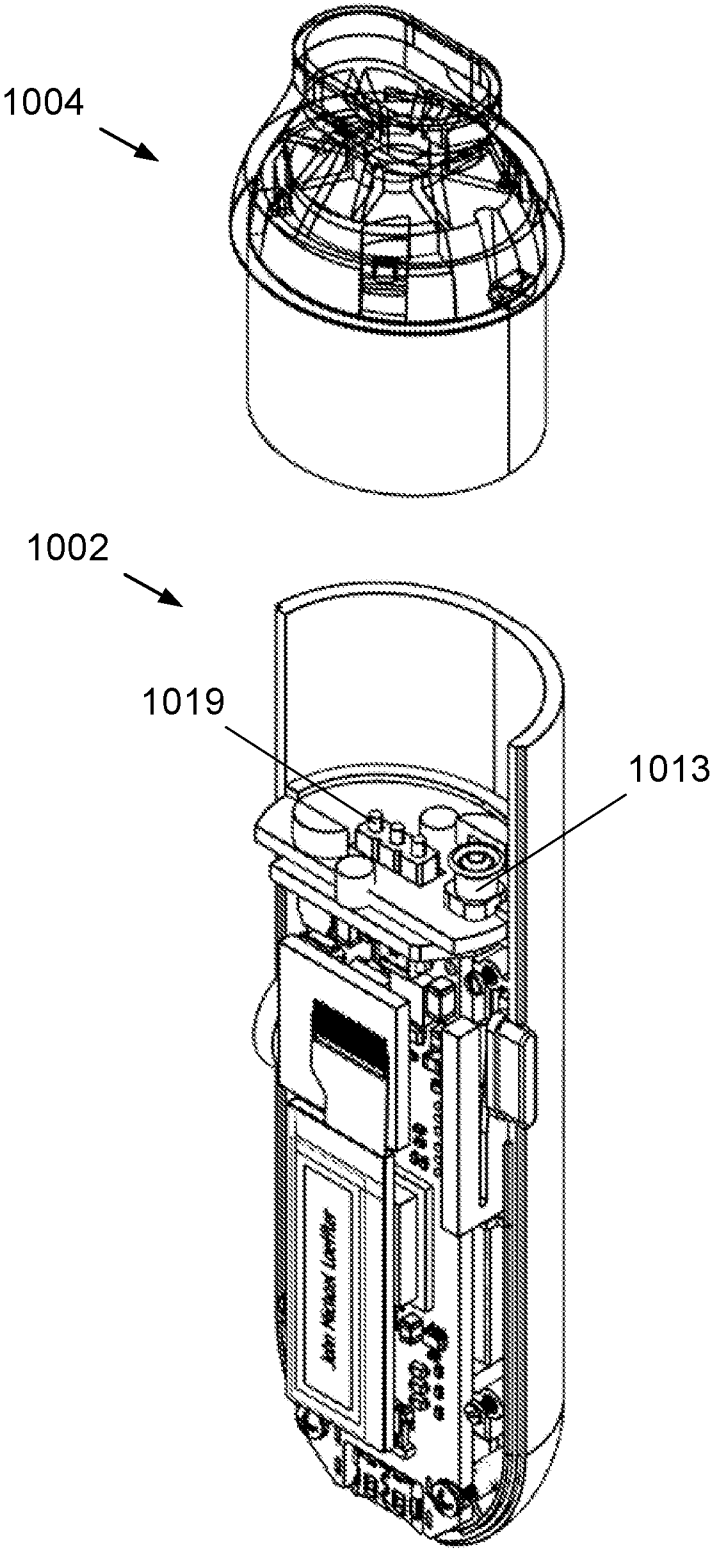
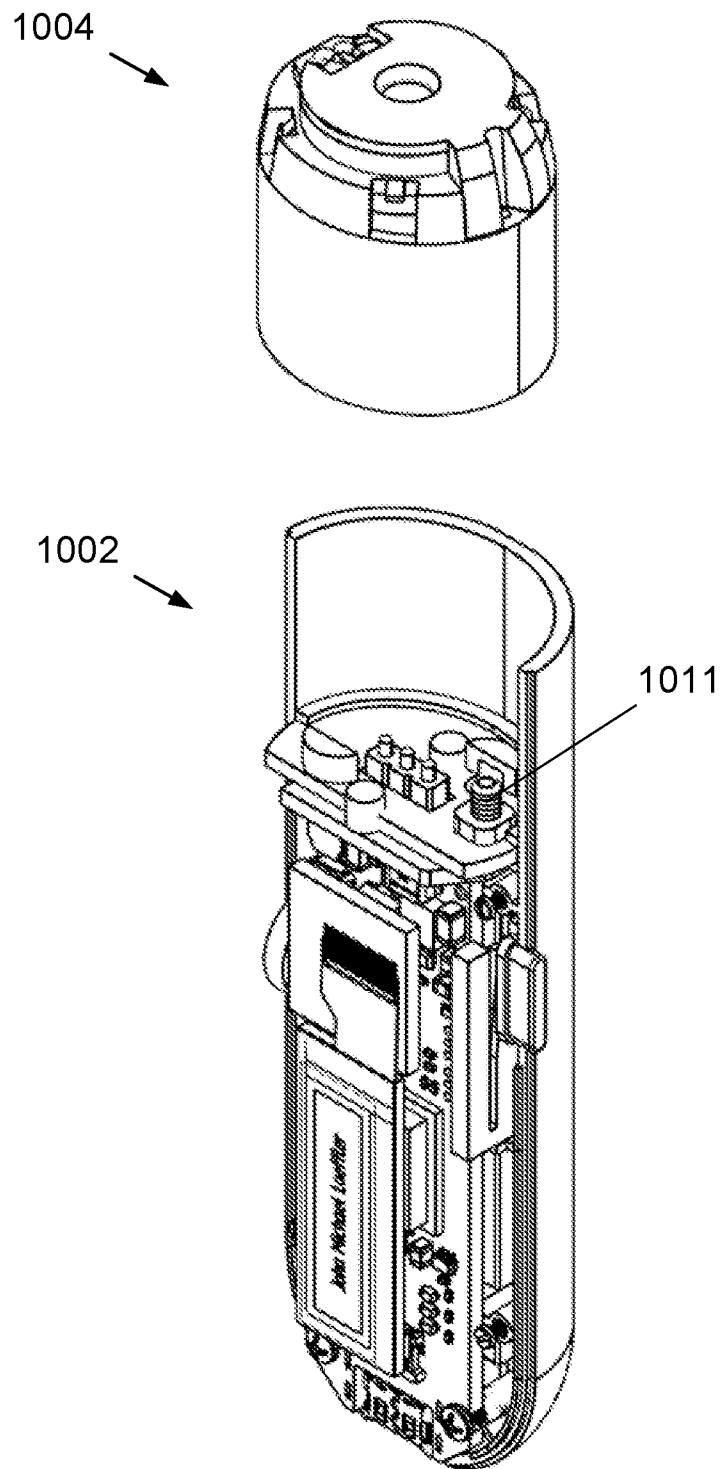


FIG. 11

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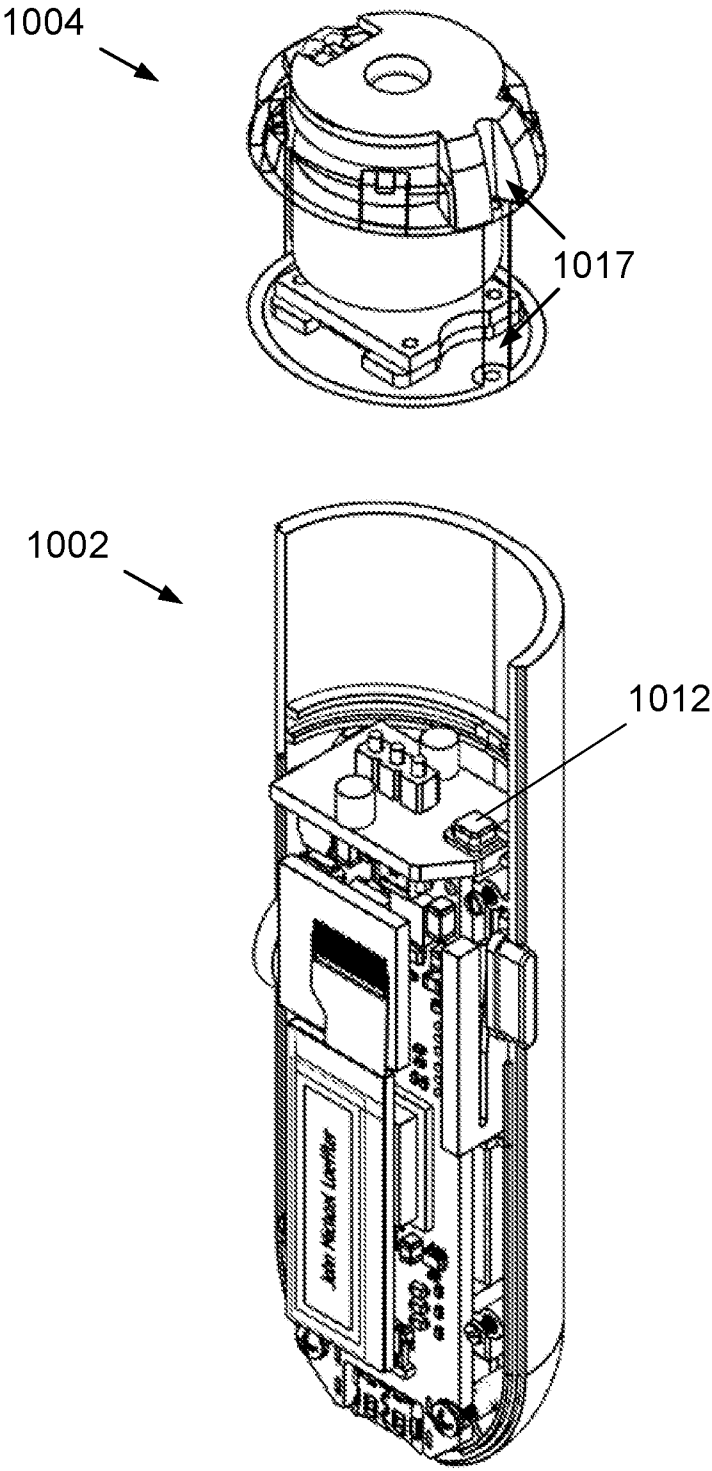
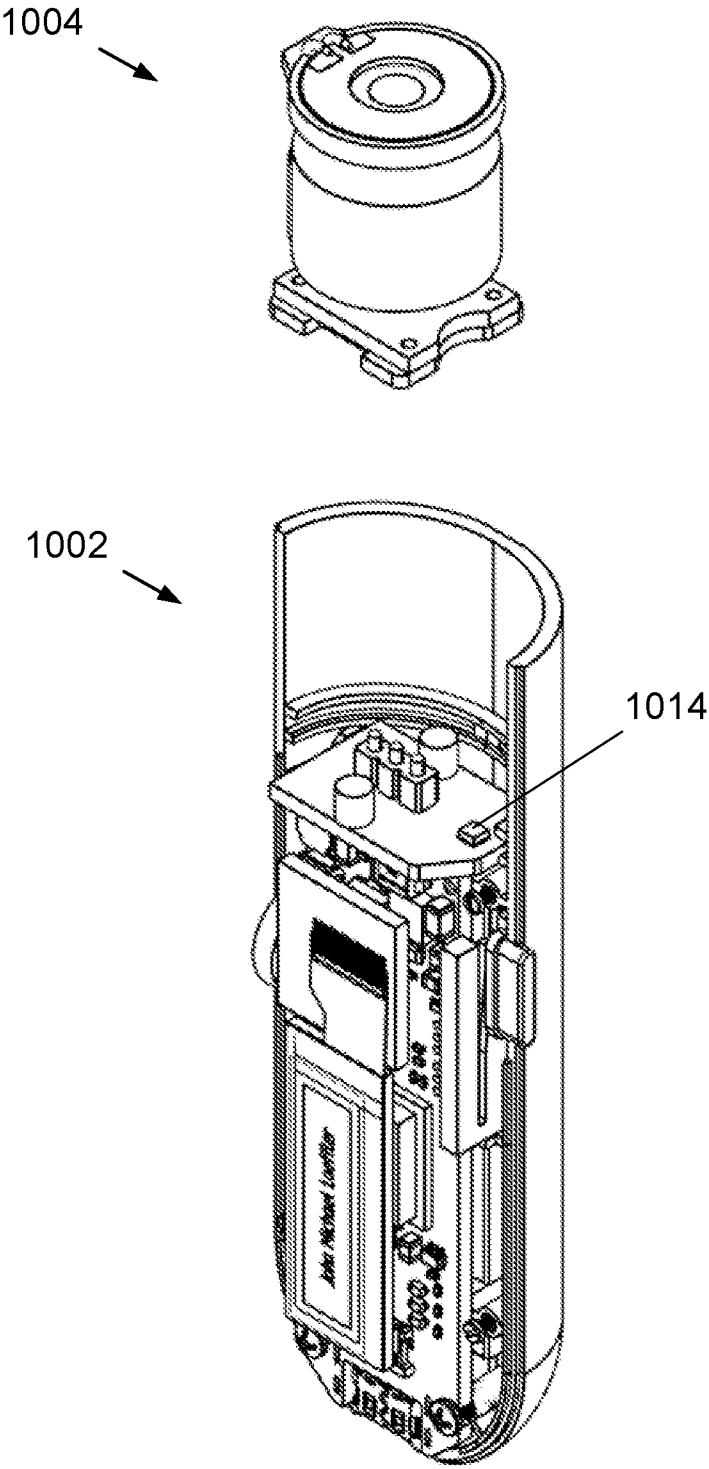


FIG. 13



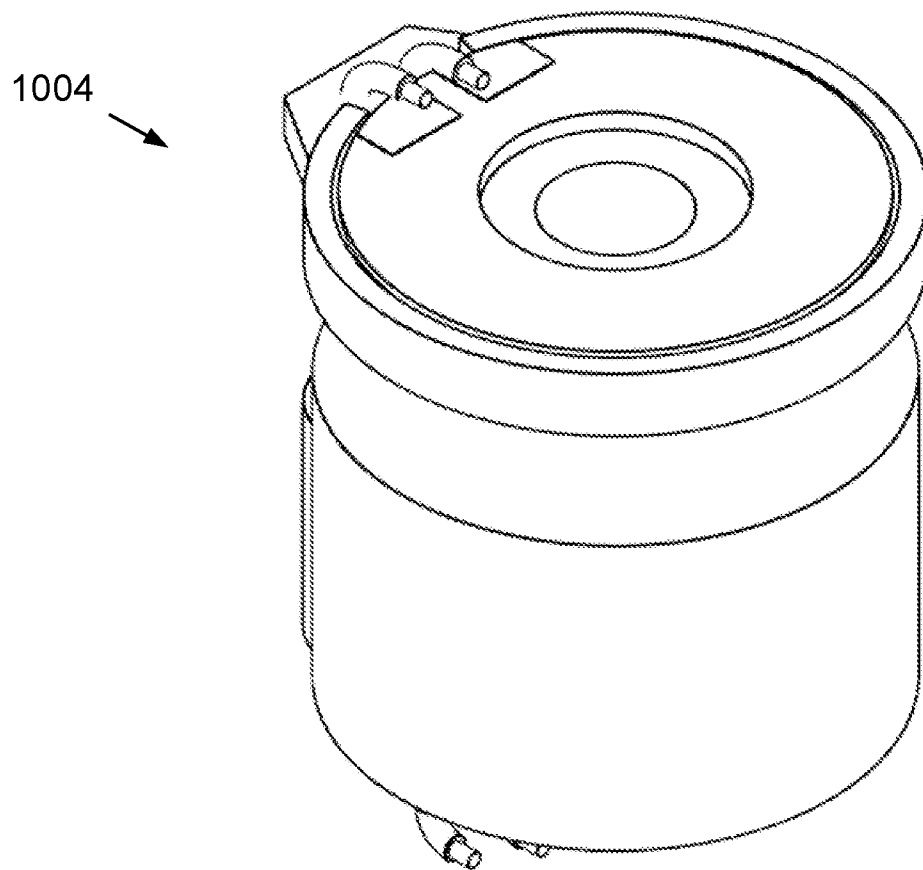


FIG. 15

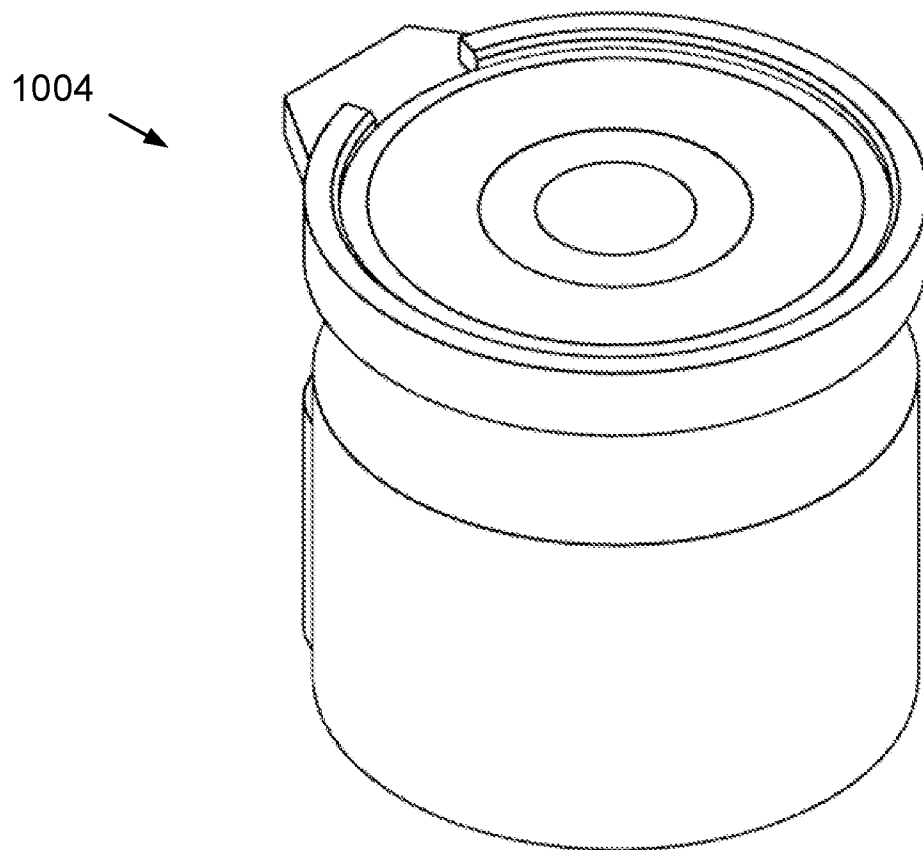


FIG. 16

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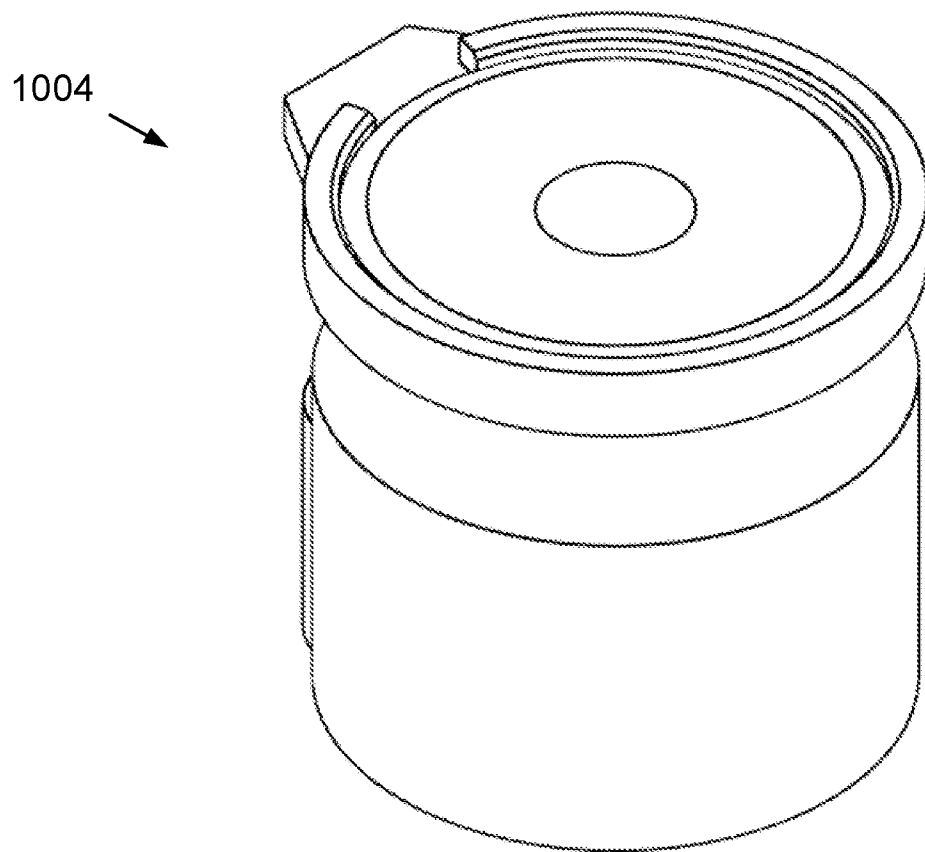


FIG. 17

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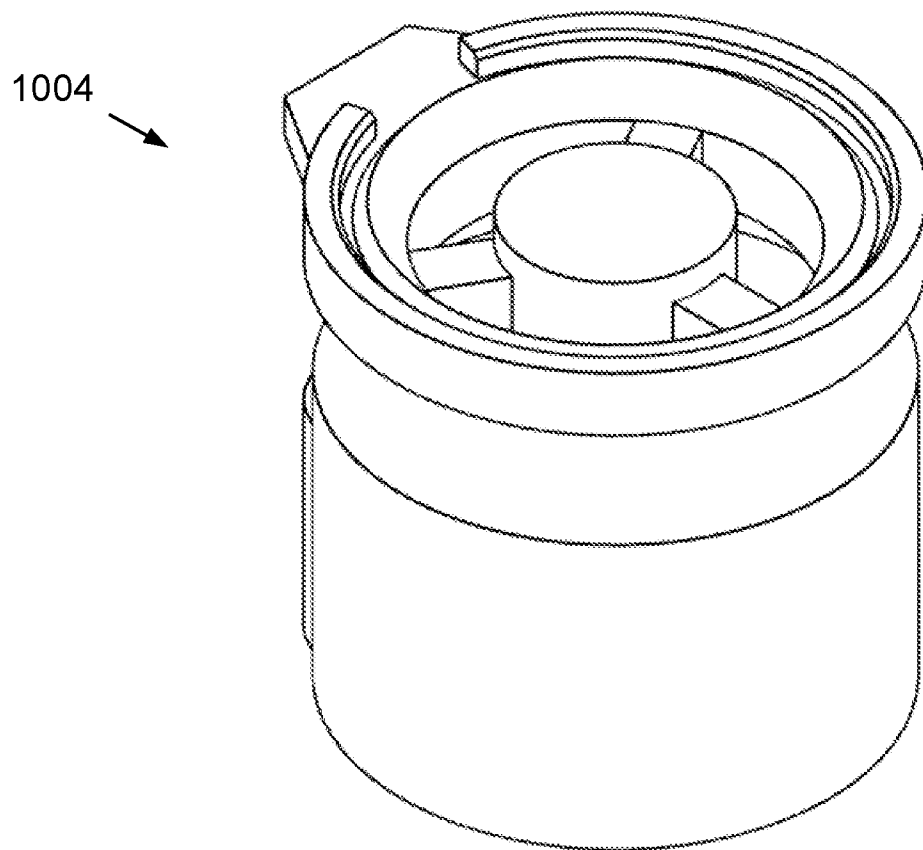


FIG. 18

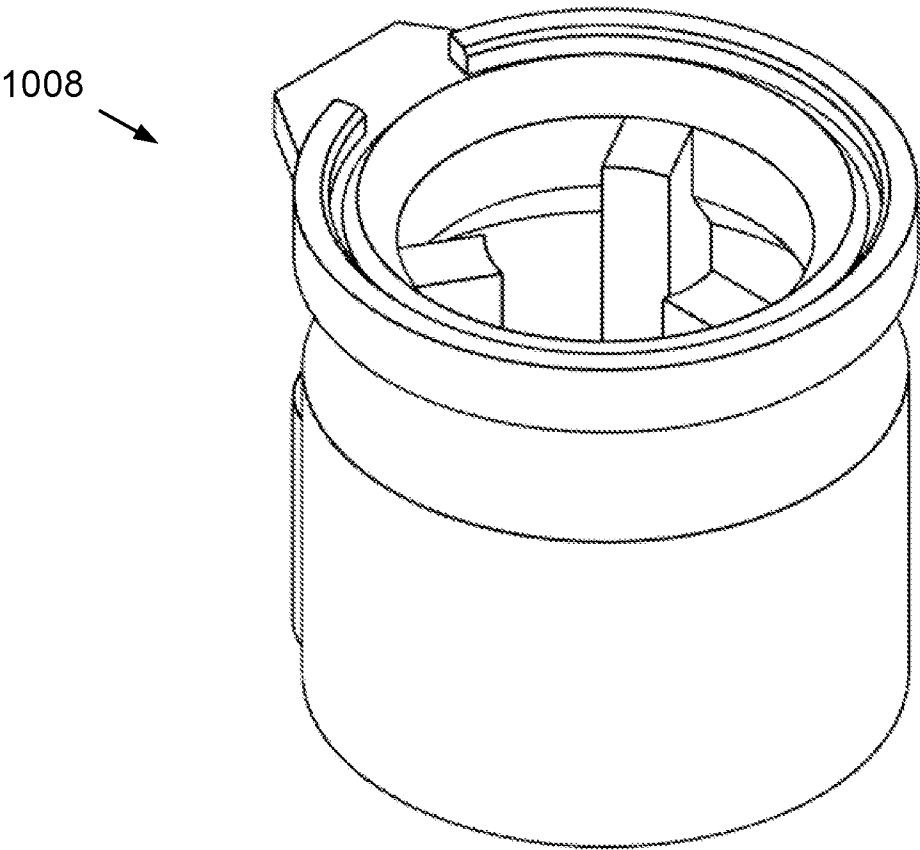


FIG. 19

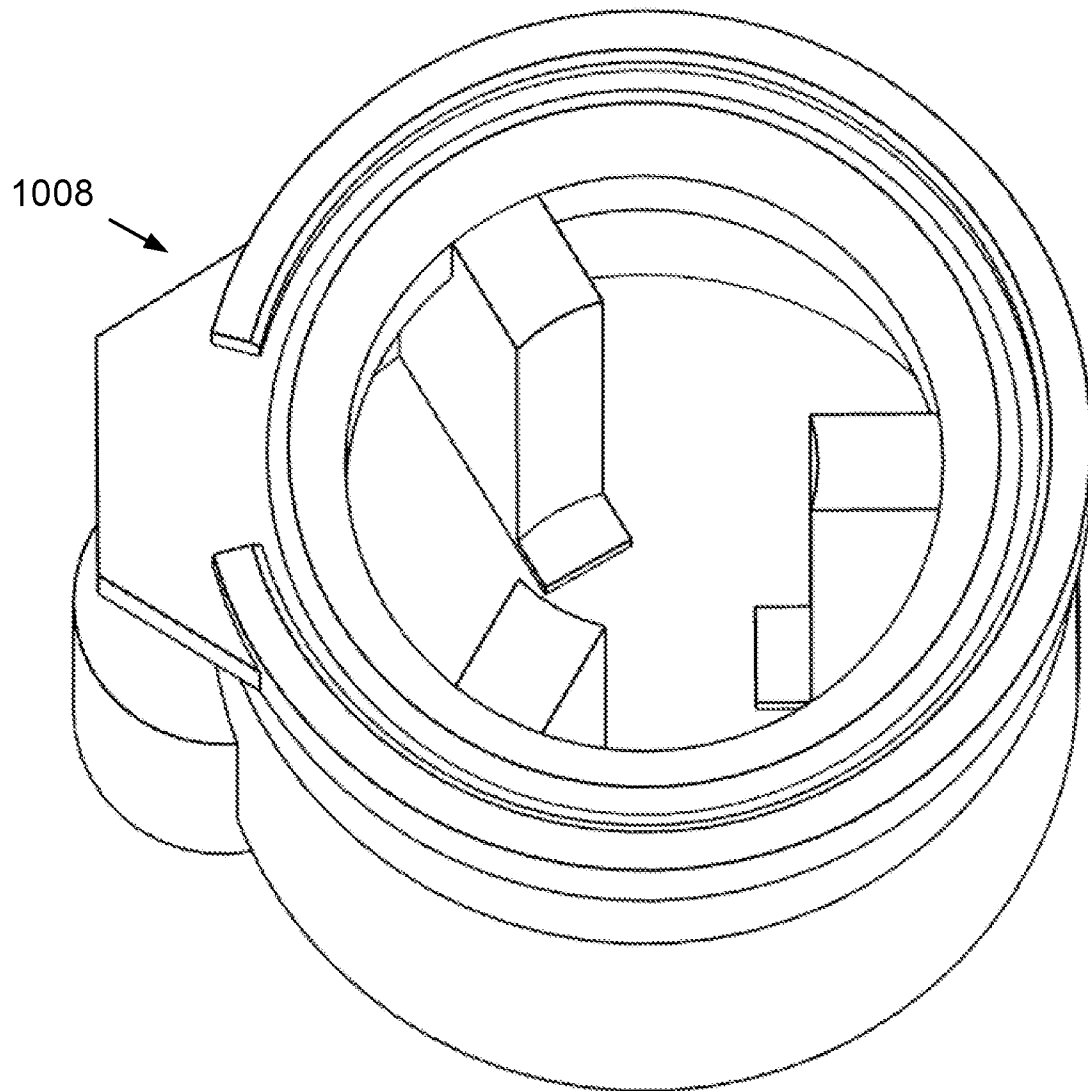


FIG. 20

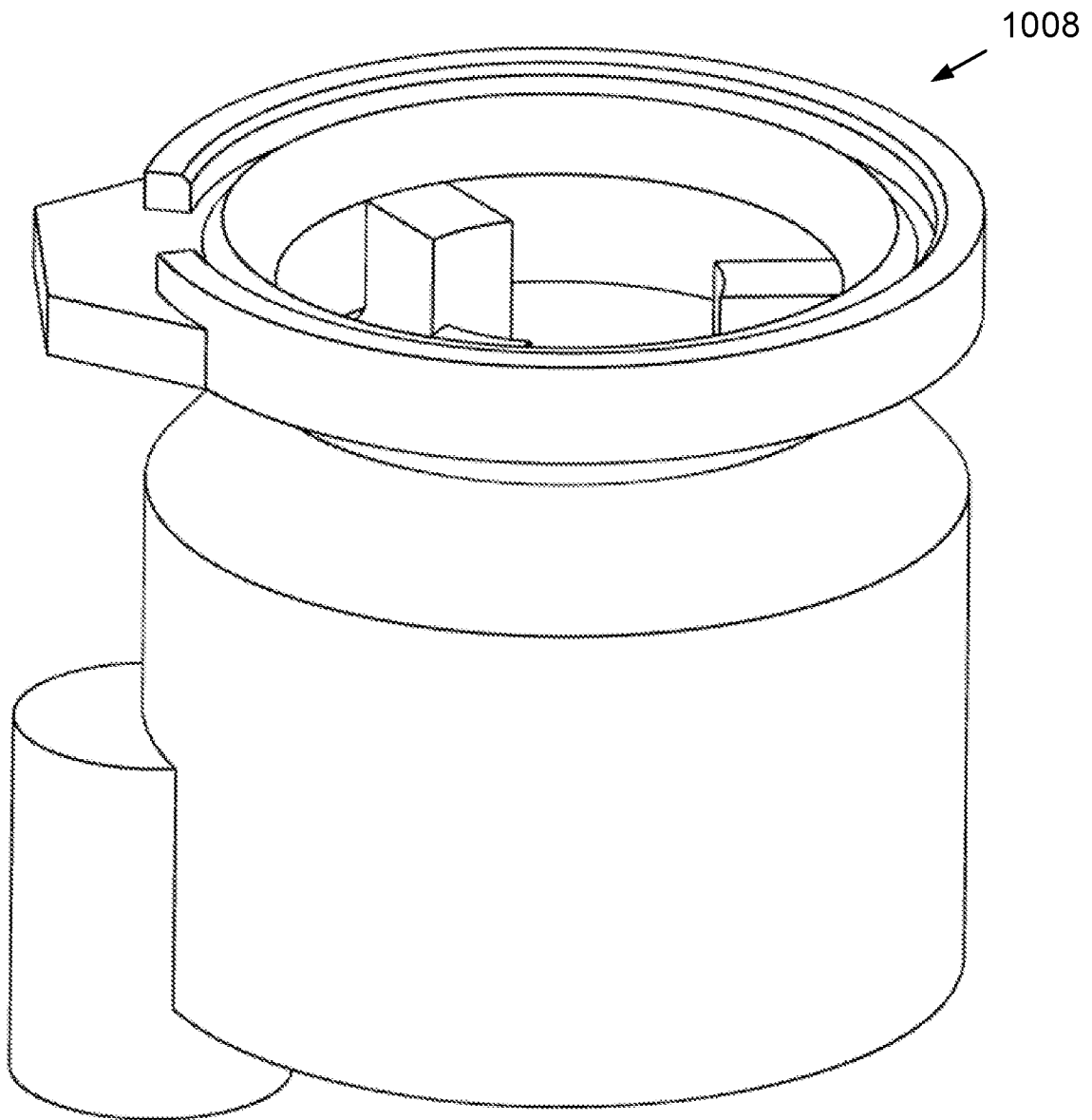


FIG. 21

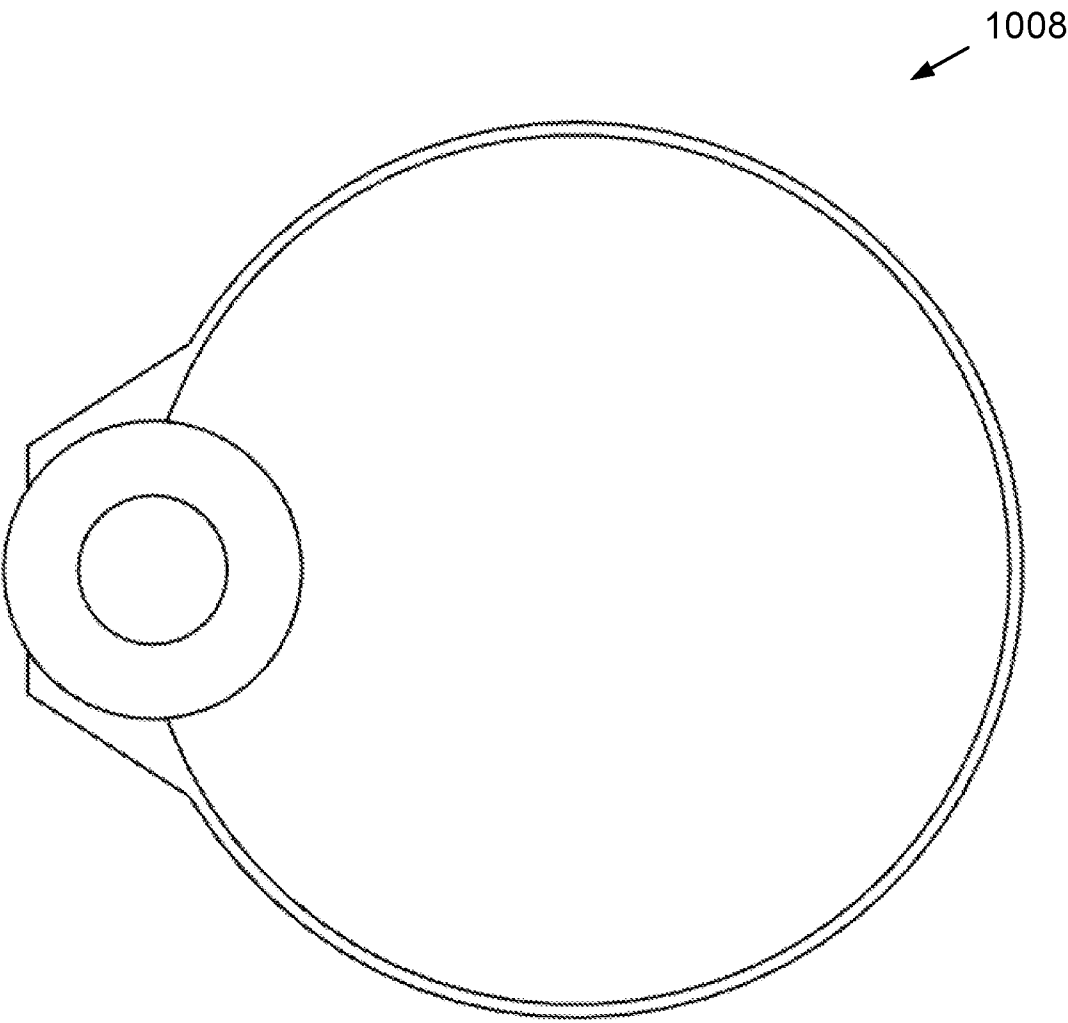


FIG. 22

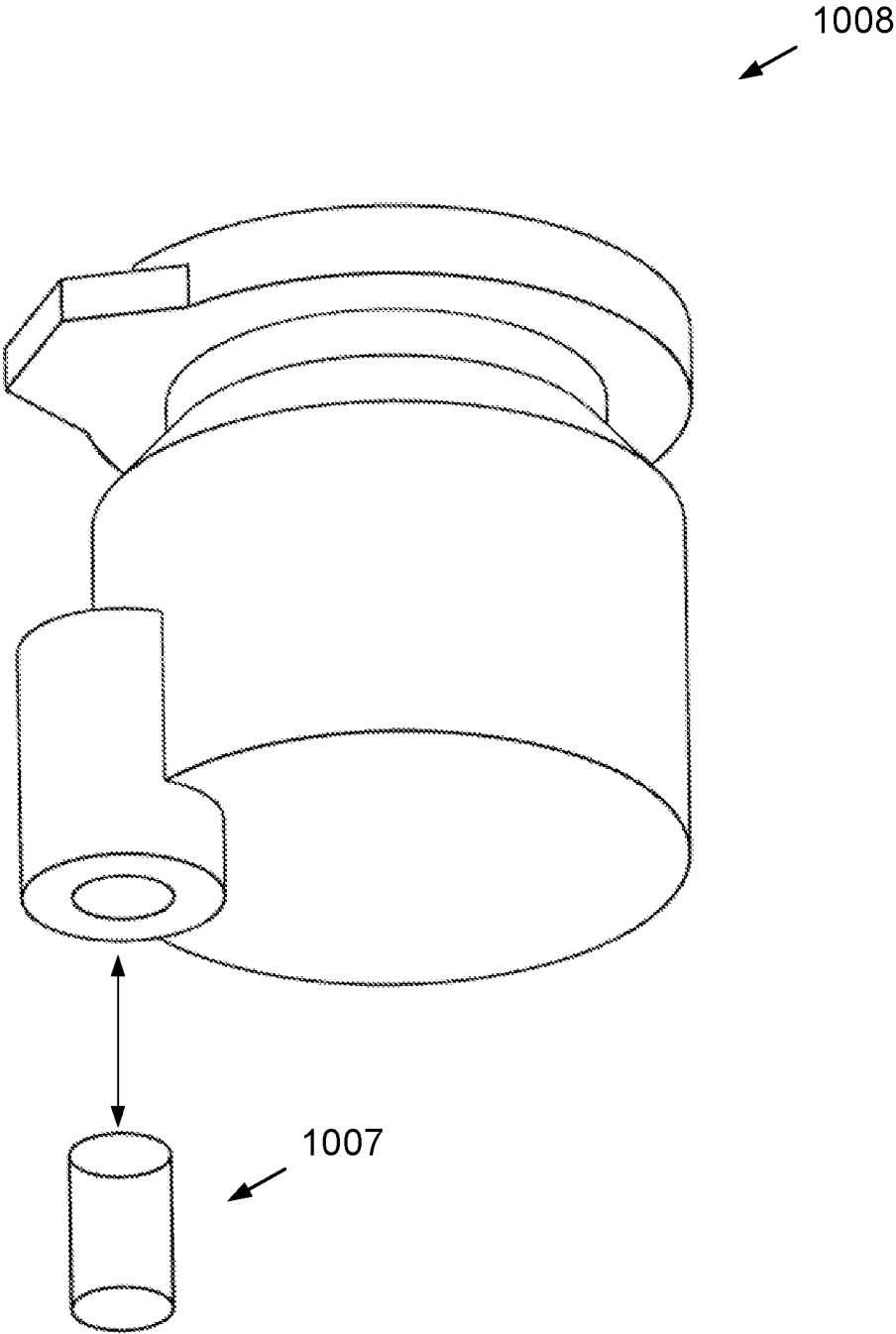


FIG. 23

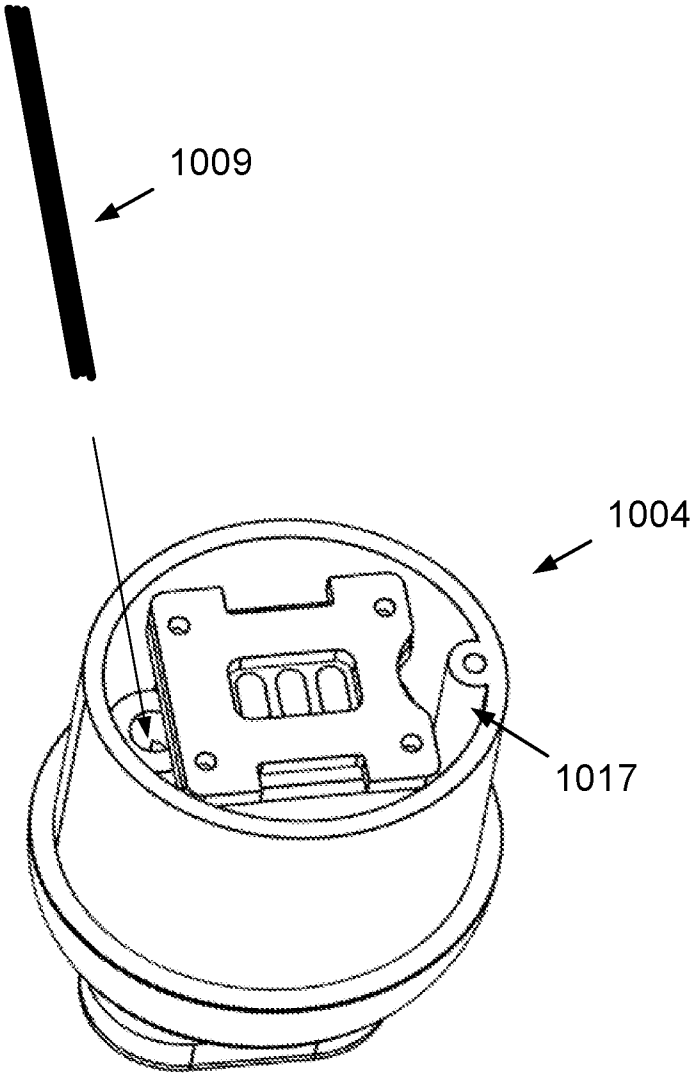


FIG. 24

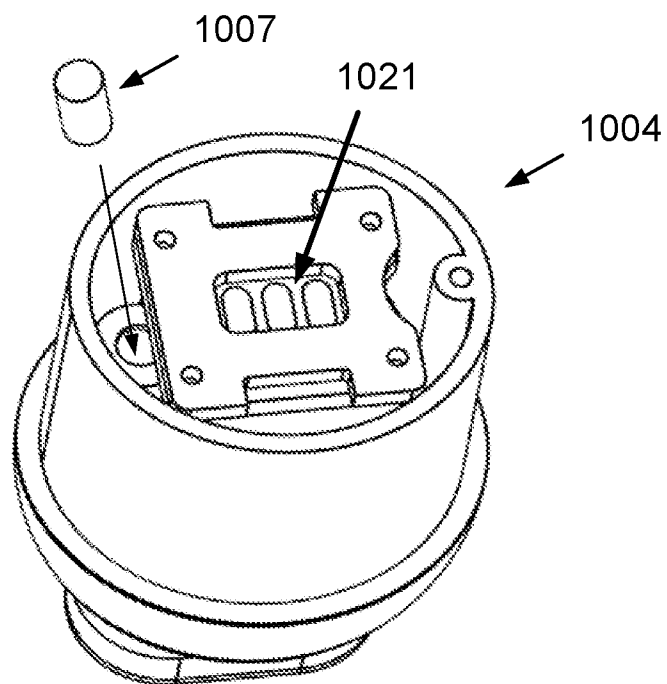


FIG. 25

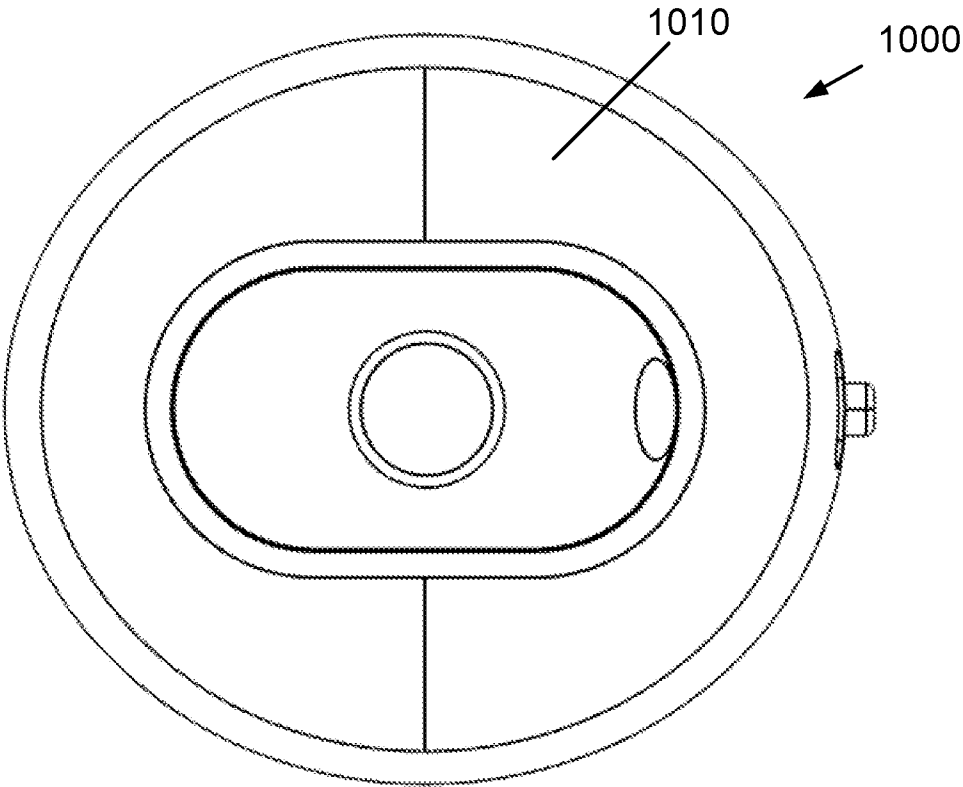


FIG. 26

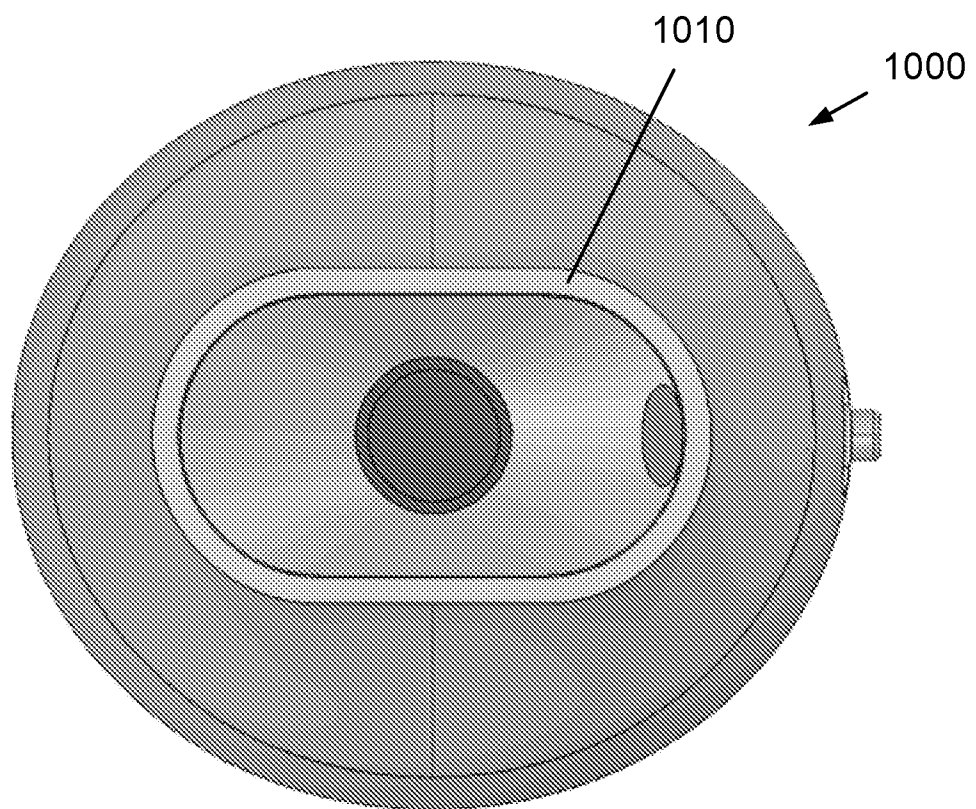


FIG. 26A

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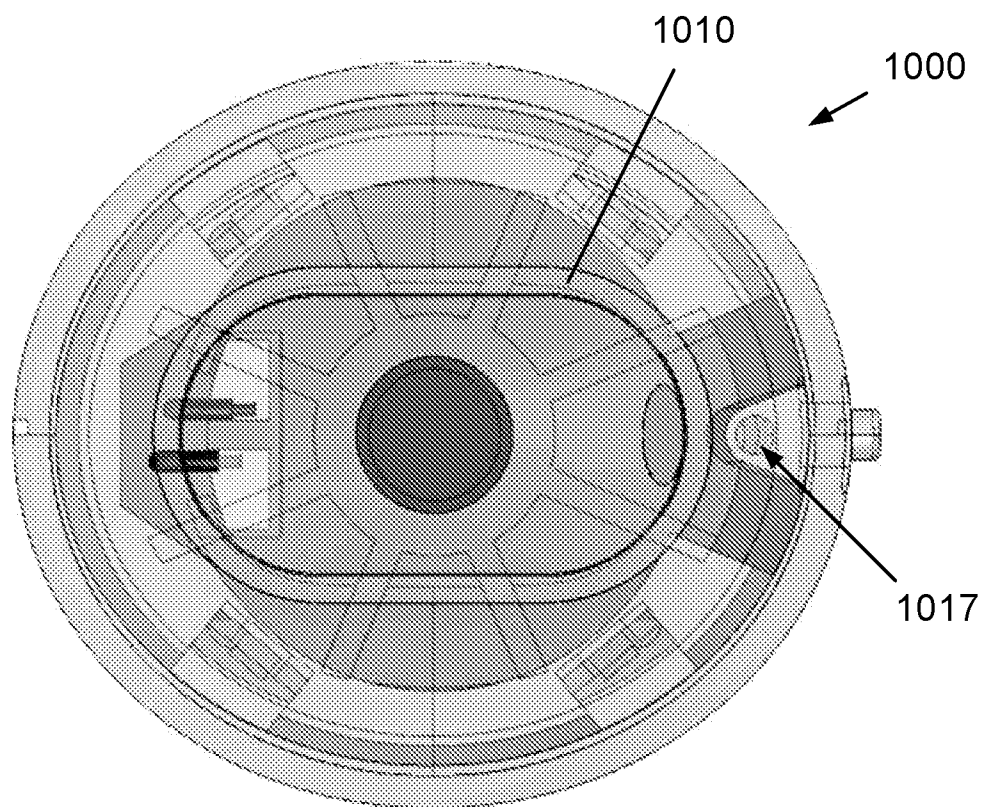


FIG. 26B

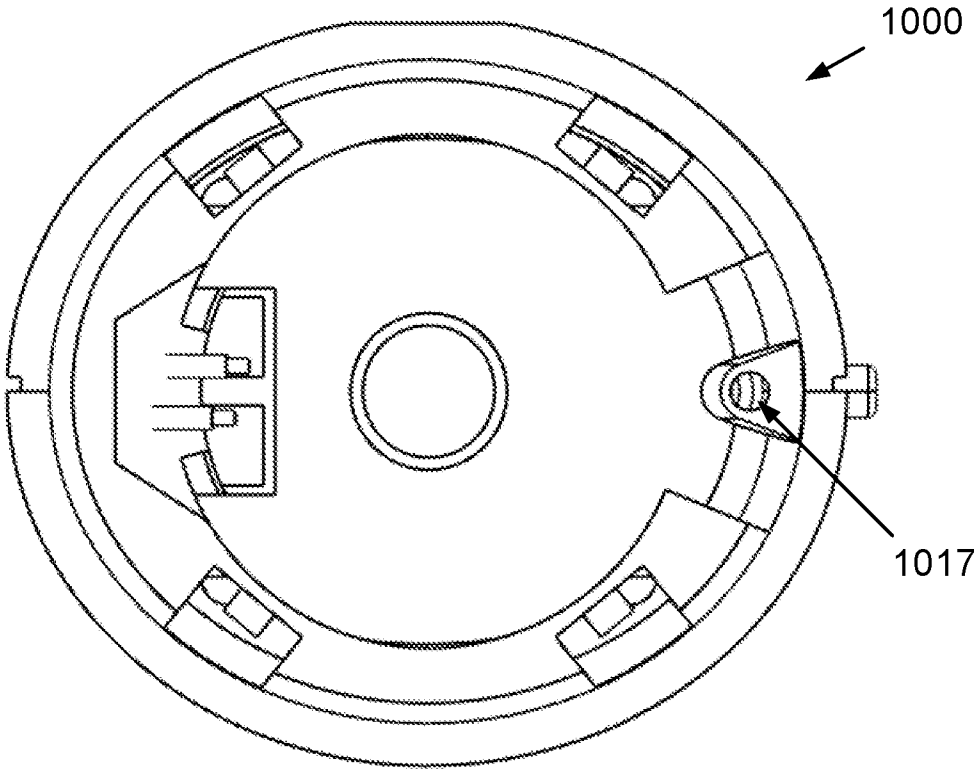


FIG. 27

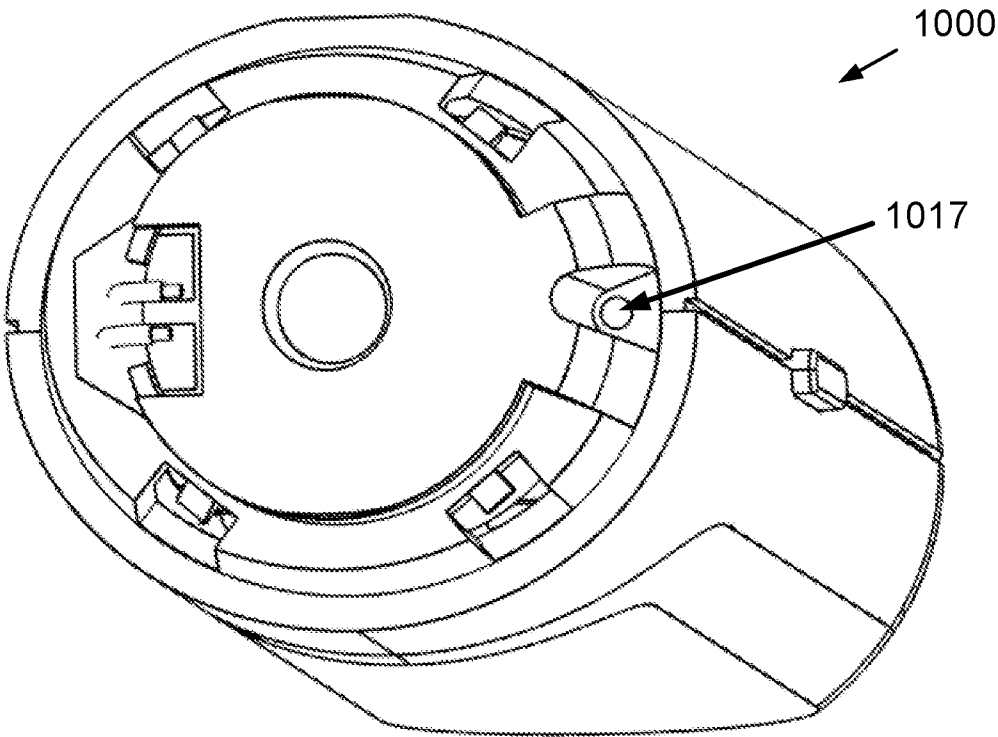


FIG. 28

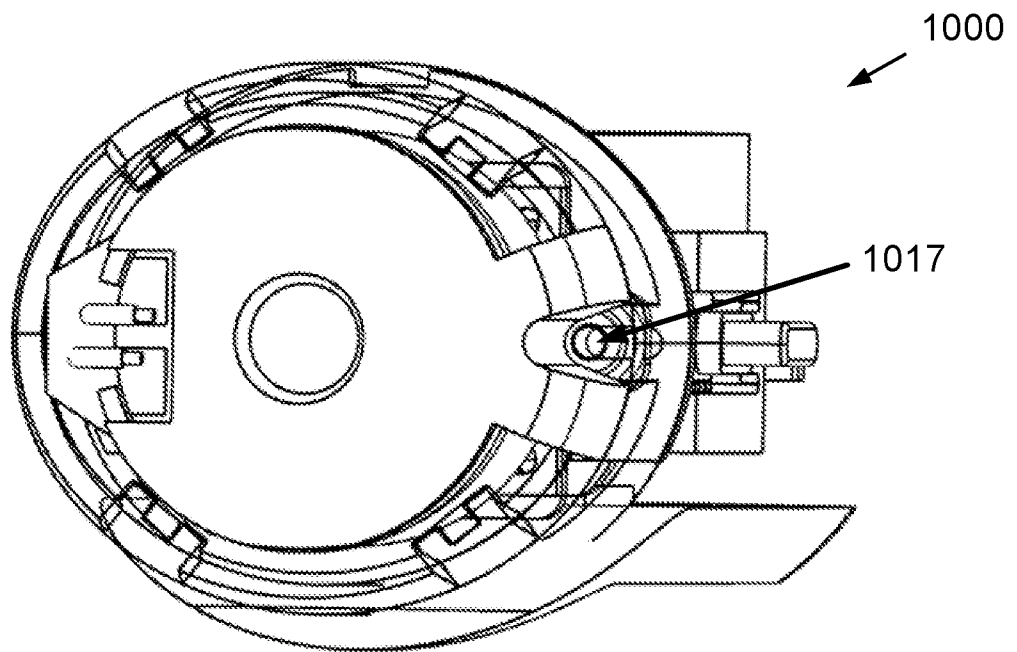


FIG. 29

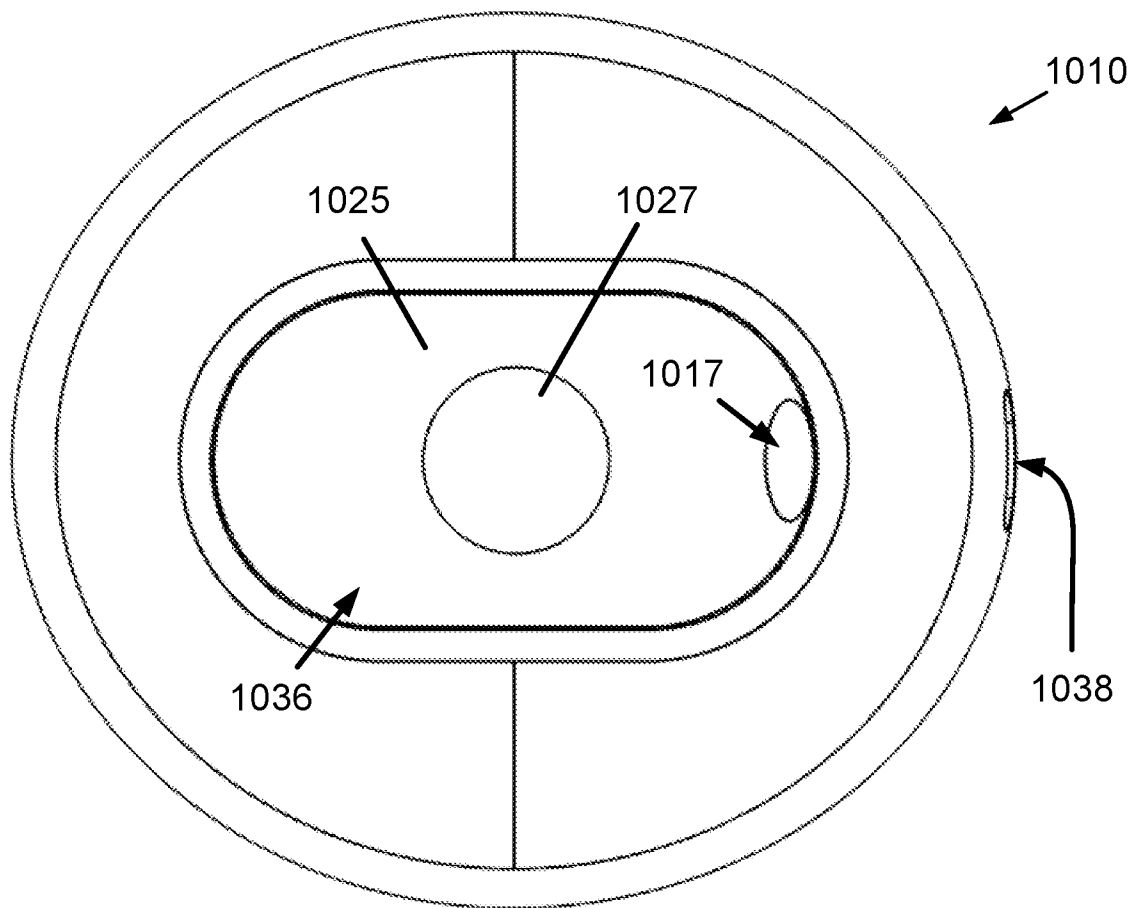


FIG. 30

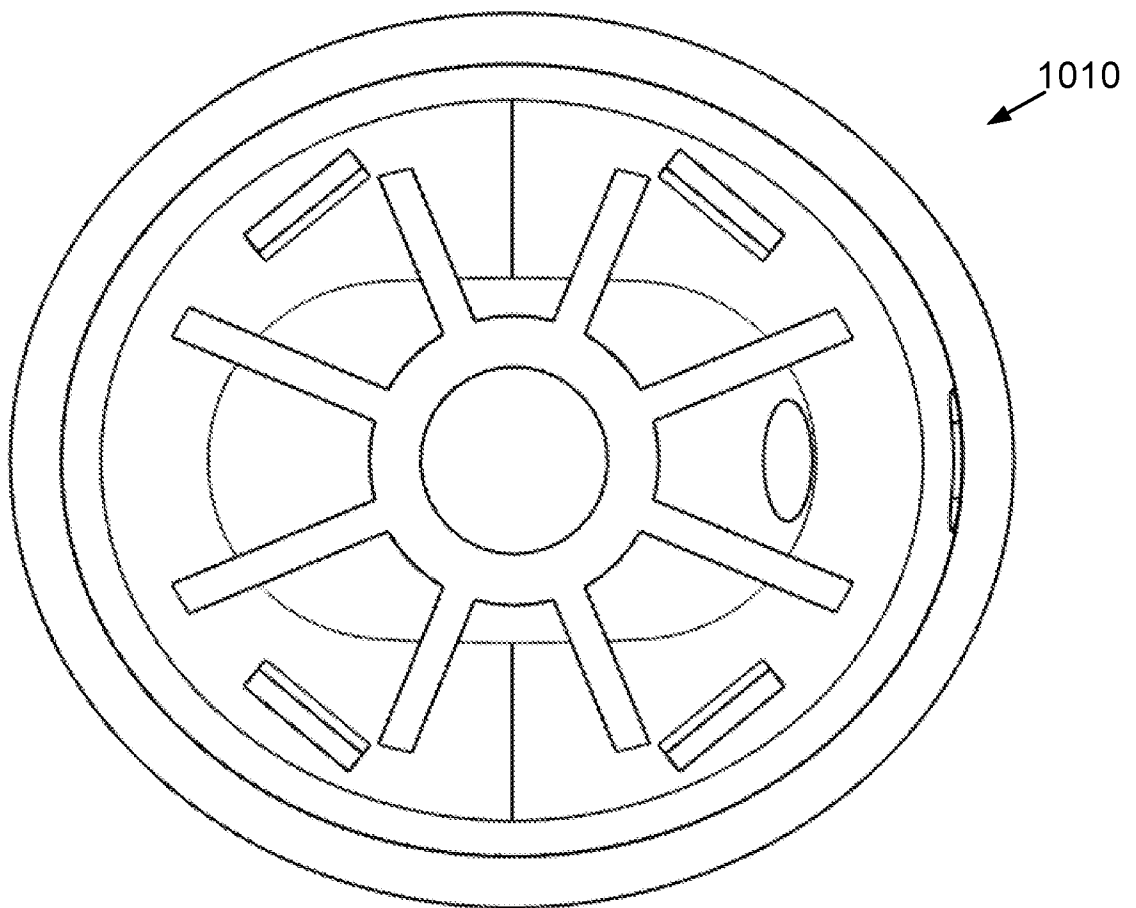


FIG. 31

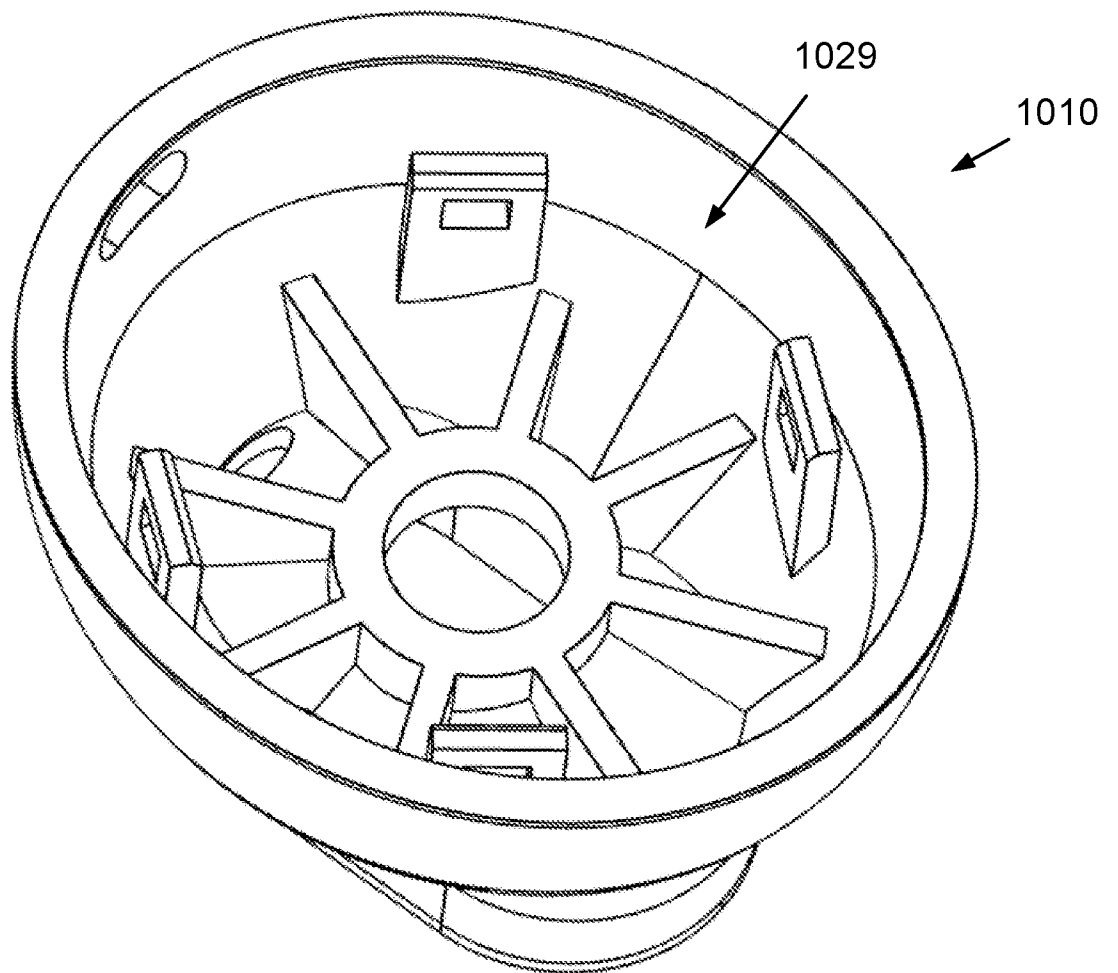


FIG. 32

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WAVE Firmware Flow**Device is asleep – Push button to wake**

Wave logo fades onto display. Solid for 1 sec then fades to black > LogoDisplayTime
 DoseCount (doses in last 24 hours) count illuminates and stays solid for 5 seconds > DoseCountDisplayTime
 Device is ready to pair via Bluetooth

If successfully paired then display shows “PAIRED” for 1 second

If no further action device goes back to sleep

Device is awake

Display is lit with dose count > DoseCount

While awake Breath sense is waiting for breath

If breath is sensed then mesh is activated for 3 seconds > MeshActiveTime

When breath is sensed AND Haptic is ON (via app) then Haptic initiates based on HapticStart (Start, During, End) via app and vibrates for 2 seconds > HapticActiveTime – Able to adjust via App

Dose count updates (+1) and remains lit for DoseCountDisplayTime

Device is awake and battery is low

Display flashes “BATTERY”

If connected to power then display shows “CHARGING”

Device is awake and has been locked via app

Display shows “LOCKED”

Device is awake and Mouth piece not detected

TotalDoses and DoseCount are reset to Zero

Display shows “_”

Display is awake and loses paired device

Device Display shows “LOST PAIR”

App Alert alerts that “LOST PAIR”

FIG. 33

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FIG. 34

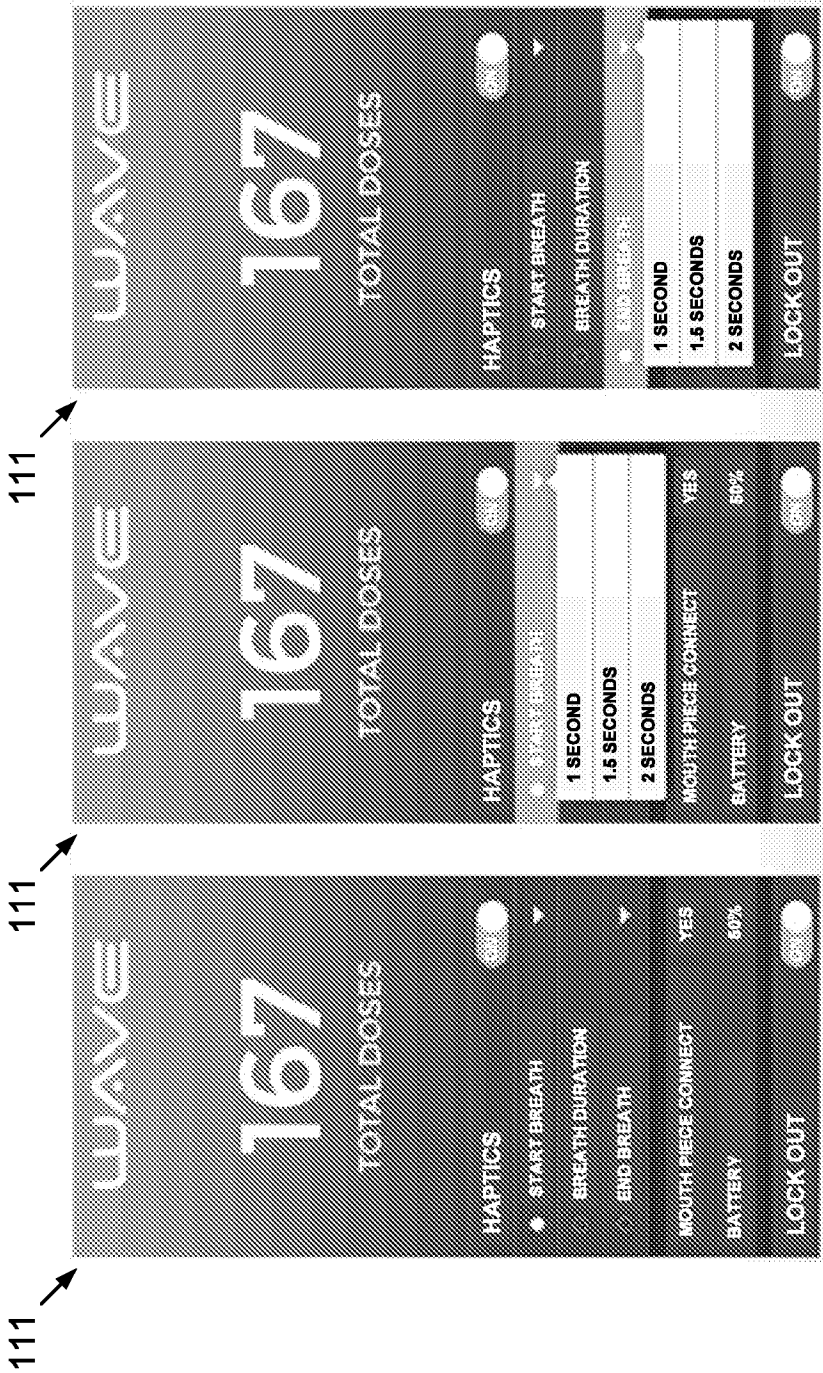


FIG. 37

FIG. 36

FIG. 35

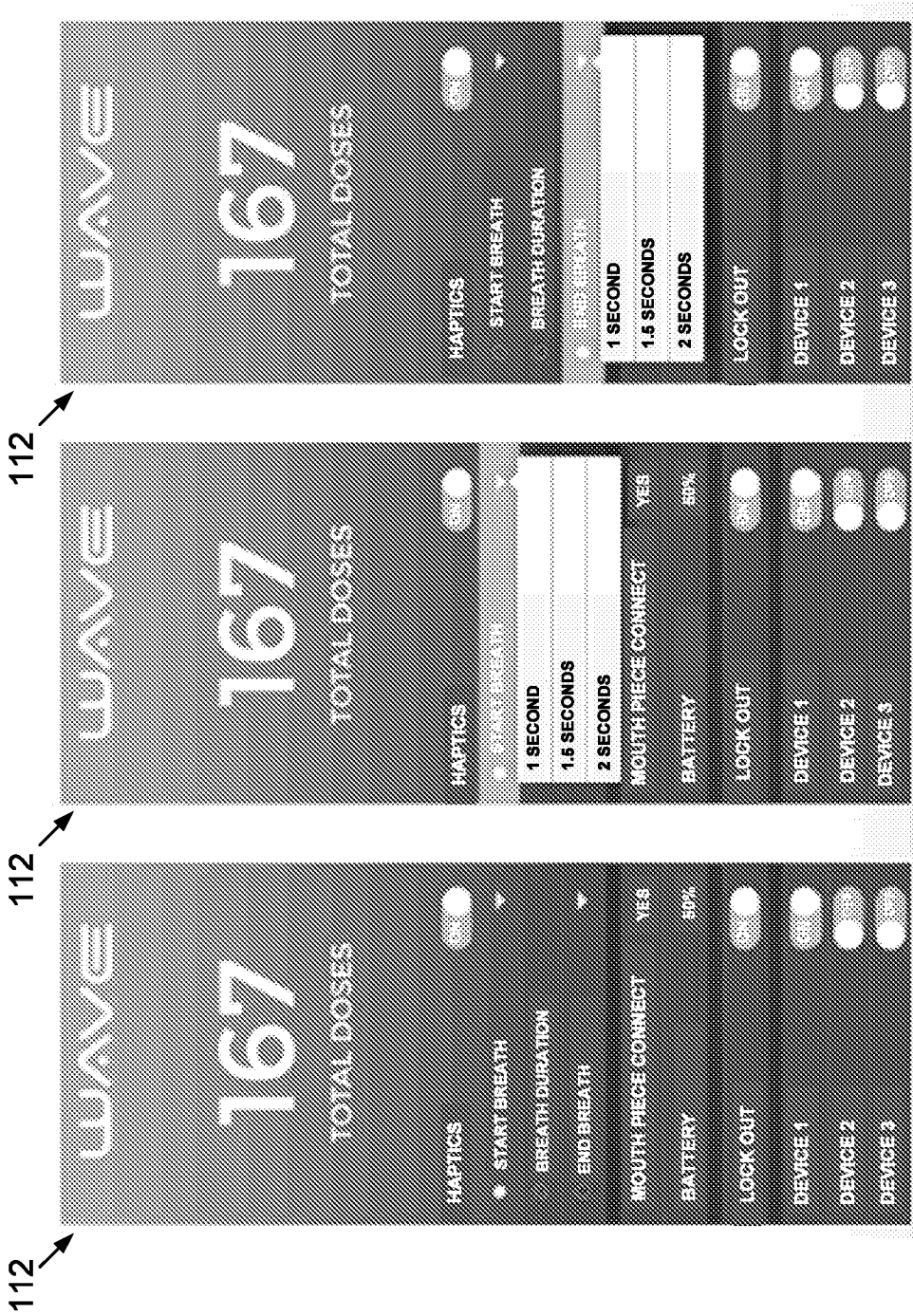


FIG. 40

FIG. 39

FIG. 38

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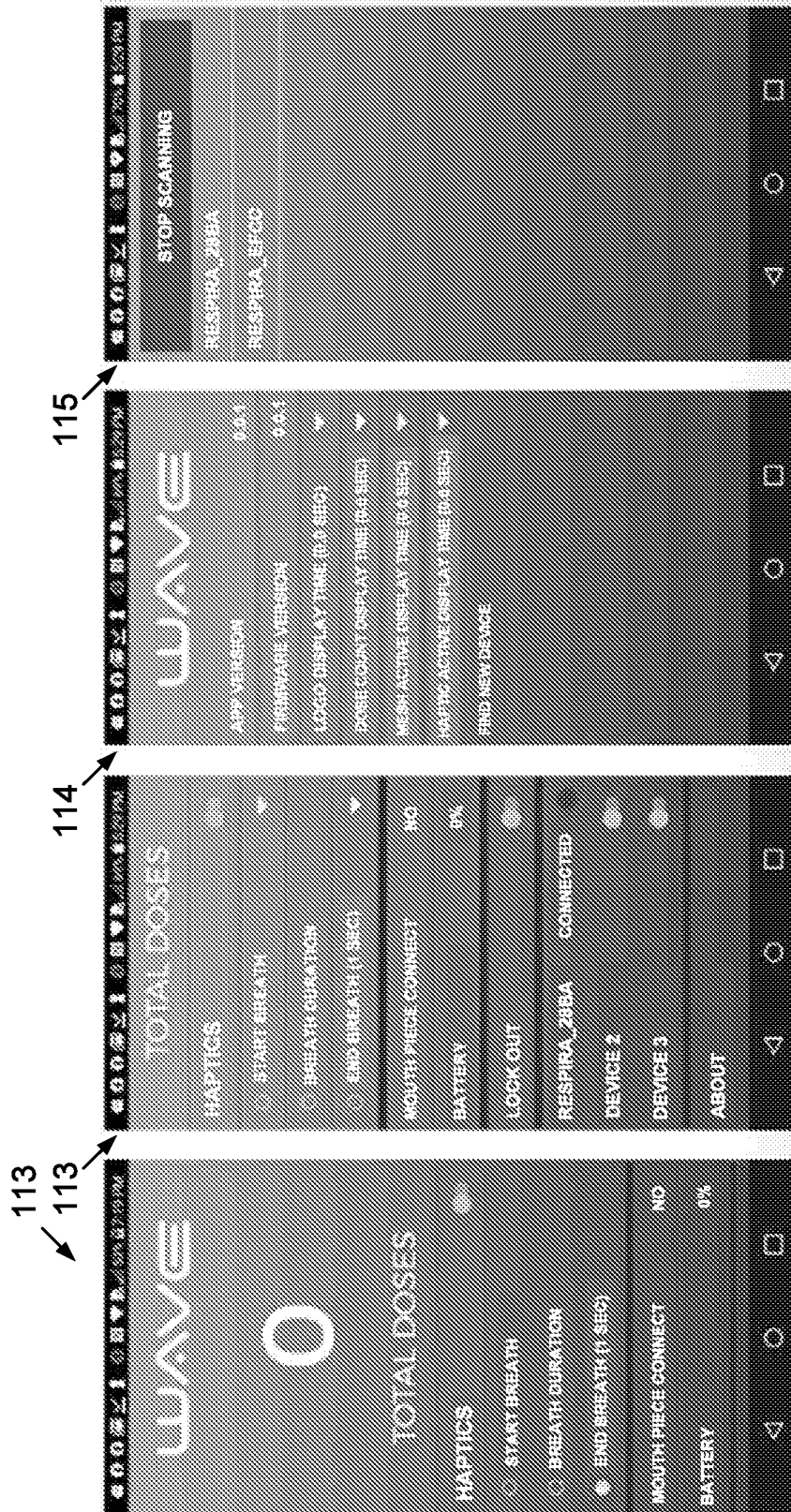


FIG. 44

FIG. 43

FIG. 42

FIG. 41

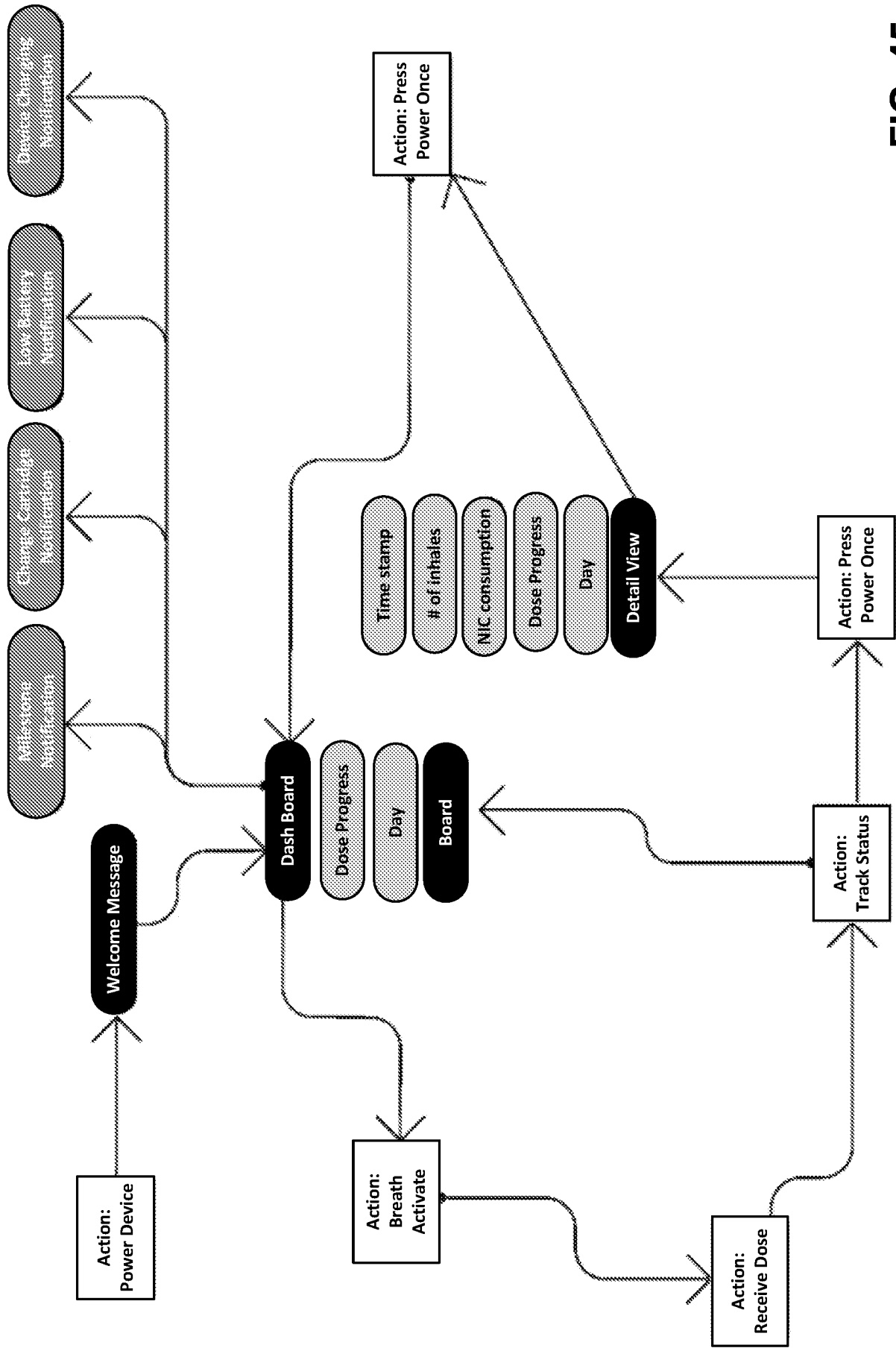


FIG. 45

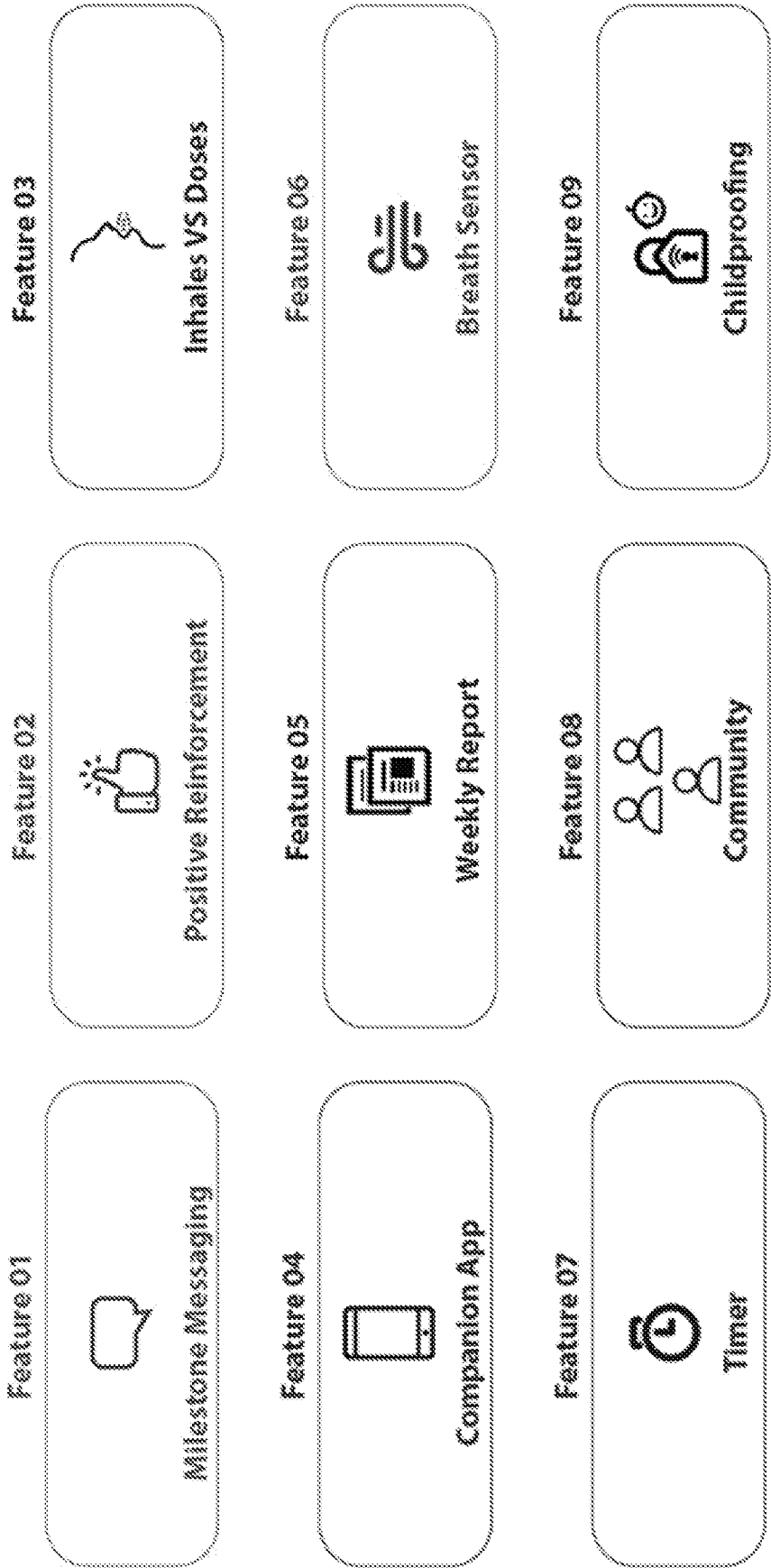
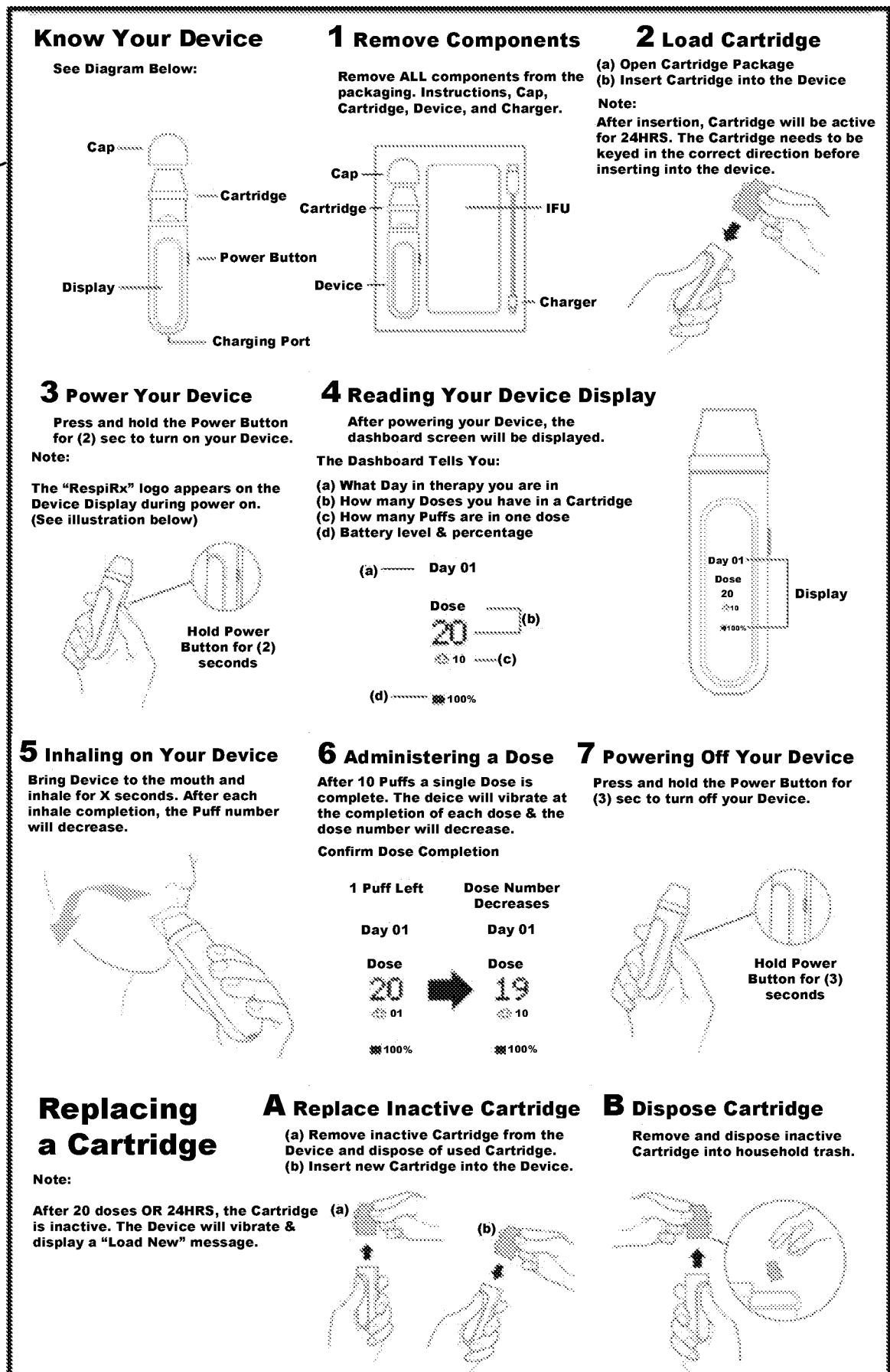


FIG. 46

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FIG. 47

1072



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/19349

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. A24F 40/65, A24F 40/60, A24F 40/50, A24F 40/05, A24F 40/42 (2023.01)

ADD. A61M 11/04, A61M 15/06, A61M 15/00 (2023.01)

CPC - INV. A24F 40/65, A24F 40/60, A24F 40/50, A61M 11/003, A24F 40/05, A24F 40/42, A61M 11/005

ADD. A61M 11/04, A61M 15/06, A61M 15/00, A61M 2016/0024, A61M 2205/0294

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y --- A	US 2013/0220315 A1 (Conley et al), 29 August 2013 (29.08.2013), entire document, especially Figs 1-9	1-3, 6-7, 13, 19-20, 22, 24-32, 34 --- 1, 4-5, 14-18, 33, 35-36, 40-49 --- 37-39
X	US 2018/0043114 A1 (Juul Labs, Inc), 15 February 2018 (15.02.2018), entire document	13, 20-21, 23, 50-51
Y	US 2021/0113783 A1 (Respira Technologies, Inc), 22 April 2021 (22.04.2021), entire document, especially Figs 1-45	1, 4-5, 13, 42-48
Y	US 6,138,669 A (Rocci, Jr et al), 31 October 2000 (31.10.2000), entire document, especially Figs 1-8	14-18
Y	US 2016/0374397 A1 (Jordan et al), 29 December 2016 (29.12.2016), entire document	33
Y --- A	US 2011/0226236 A1 (Buchberger), 22 September 2011 (22.09.2011), entire document, especially Figs 1-29	35-36 --- 37-39
Y	US 2021/0282465 A1 (Philip Morris Products S A), 16 September 2021 (16.09.2021), entire document, especially Figs 1-5	40-41



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

"D" document cited by the applicant in the international application

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

25 June 2023

Date of mailing of the international search report

JUL 20 2023

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Kari Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/19349

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2014/0007874 A1 (Civitas Therapeutics, Inc), 09 January 2014 (09.01.2014), entire document, especially Figs 1-10	49
Y	'BIOCOMPATIBILITY OF MEDICINAL PRODUCT MEDICAL DEVICE COMBINATIONS FOR AIRWAY DELIVERY' (Turner), 17 May 2021 (17.05.2021), [online], retrieved from <URL:https://ondrugdelivery.com/biocompatibility-of-medicinal-product-medical-device-combinations-for-airway-delivery/>, entire document	42
Y	US 2020/0120989 A1 (Respira Technologies, INC), 23 April 2020 (23.04.2020), entire document, especially Figs 1-26	44-47
Y	US 2016/0213866 A1 (Tan), 28 July 2016 (28.07.2016), entire document, especially Figs 1-3	47
A	US 2019/0364957 A1 (Pax Labs, Inc), 05 December 2019 (05.12.2019), entire document	1-7, 13-51
A	US 2022/0132919 A1 (Respira Technologies, INC), 05 May 2022 (05.05.2022), entire document	1-7, 13-51
A	'Innokin Adept: Unboxing Experience' (Kai's Virgin Vapor), 27 July 2021 (27.07.2021), [online], retrieved from <URL:https://web.archive.org/web/20210727211502/https://www.kaisvirginvapor.com/pages/innokin-adept-unboxing-experience>, entire document	1-7, 13-51

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/19349

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 8-12, 52-54
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 8-12 and 52-54 are unsearchable because claims 8-12 and 52-54 are omnibus and are not drafted in accordance with Rule 6.2(a).

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.