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(71) **Applicant: PHILIP MORRIS PRODUCTS S.A.** [CH/CH]; Quai Jeanrenaud 3, CH-2000 Neuchâtel (CH).

(72) **Inventors: BACHE, Terrance Theodore**; 601 East Jackson Street, Richmond, Virginia 23219 (US). **GALLAGHER, Niall**; 601 East Jackson Street, Richmond, Virginia 23219 (US). **HAWES, Eric**; 601 East Jackson Street, Richmond, Virginia 23219 (US). **KEEN, Jarrett**; 601 East Jackson Street, Richmond, Virginia 23219 (US). **LAU, Raymond W.**; 601 East Jackson Street, Richmond, Virginia 23219 (US). **SUNDAR, Rangaraj S.**; 601 East Jackson Street, Richmond, Virginia 23219 (US).

(74) **Agent: DOWLING, Ian**; Reddie & Grose LLP, The White Chapel Building, 10 Whitechapel High Street, London Greater London E1 8QS (GB).

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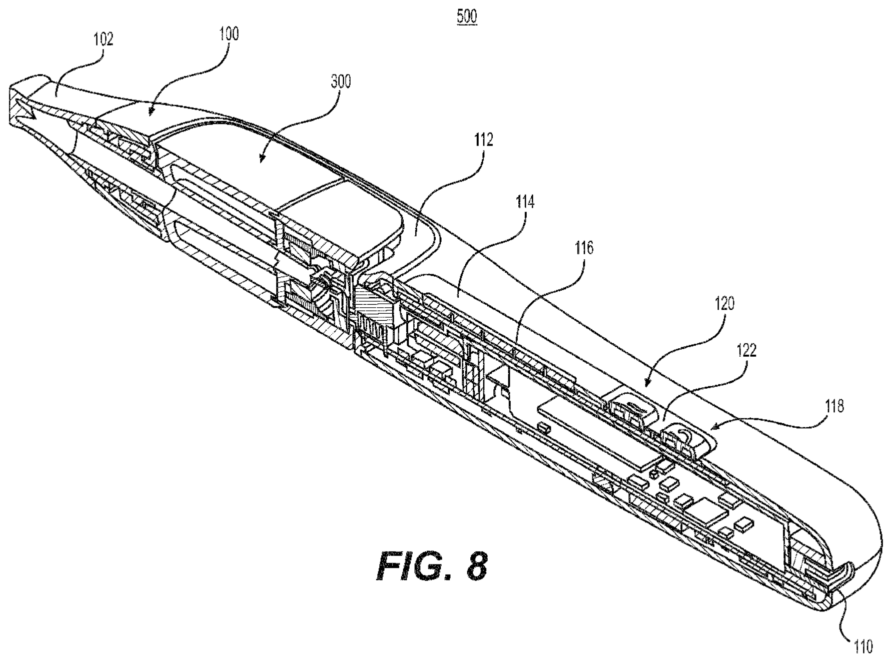

FIG. 8

(57) **Abstract:** A nicotine electronic vaping device (500) includes a nicotine reservoir, a heater (336) and processing circuitry. The processing circuitry is configured to: determine a plurality of resistance values for the heater (336) during a time window; calculate a percent change in resistance of the heater (336) between a first of the plurality of resistance values and a second of the plurality of resistance values; decide whether the percent change in resistance of the heater (336) exceeds a percent change in resistance threshold; and disable power to the heater (336) in response to deciding that the percent change in resistance of the heater (336) exceeds the percent change in resistance threshold.

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NICOTINE ELECTRONIC VAPING DEVICES HAVING DRYNESS DETECTION AND AUTO SHUTDOWN

One or more example embodiments relate to nicotine electronic vaping (nicotine e-vaping) devices.

Nicotine electronic vaping devices (or nicotine e-vaping devices) include a heater that vaporizes nicotine pre-vapor formulation material to produce vapor. A nicotine e-vaping device may include several nicotine e-vaping elements including a power source, a nicotine cartridge or nicotine e-vaping tank including the heater and a nicotine reservoir capable of holding the nicotine pre-vapor formulation material.

One or more example embodiments provide a dry puff and auto shutdown control system configured to control one or more elements of a nicotine e-vaping device to maintain the nicotine e-vaping device within operational limits defined for different parameters.

According to at least one example embodiment, parameters of the nicotine e-vaping device may include the temperature of the heater, the percent change in resistance of the heater, a combination thereof, or the like. In one or more example embodiments, the auto-shutdown control system may automatically shut down or disable one or more sub-systems or elements of the nicotine e-vaping device in response to detecting the existence of dry puff conditions at the nicotine e-vaping device. After shutting down or disabling, re-activation or re-enabling of the one or more sub-systems or elements may require corrective action (for example, by an adult vaper).

At least one example embodiment provides a method for controlling operation of a nicotine electronic vaping device including a heater to heat nicotine pre-vapor formulation drawn from a nicotine reservoir, the method including: determining a plurality of resistance values for the heater during a time window; calculating a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values; deciding whether the percent change in resistance of the heater exceeds a percent change in resistance threshold; and disabling power to the heater at the nicotine electronic vaping device in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

At least one other example embodiment provides a nicotine electronic vaping device including a nicotine reservoir storing nicotine pre-vapor formulation, a heater configured to heat nicotine pre-vapor formulation drawn from the nicotine reservoir, and processing circuitry. The processing circuitry is configured to: determine a plurality of resistance values for the heater during a time window; calculate a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values; decide whether the percent change in resistance of the heater exceeds a percent change in resistance threshold;

and disable power to the heater in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

According to at least some example embodiments, the plurality of resistance values for the heater may be stored in a first-in-first-out (FIFO) memory. The first of the plurality of resistance values for the heater may be an oldest resistance value stored in the FIFO memory, and the second of the plurality of resistance values for the heater may be a most recent resistance value stored in the FIFO memory.

The percent change in resistance threshold may be obtained from a memory in a nicotine pod assembly of the nicotine electronic vaping device.

Whether the resistance of the heater has stabilized may be detected based on a current through the heater. The plurality of resistance values for the heater during the time window may be determined in response to detecting that the resistance of the heater has stabilized.

Whether the resistance of the heater has stabilized may be determined based on the current through the heater and a wetting current threshold.

An indication of dry puff conditions at the nicotine electronic vaping device may be output in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

The nicotine electronic vaping device may be powered off in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within a first threshold time interval after disabling power to the heater.

The nicotine electronic vaping device may be returned to an operational mode by clearing a fault associated with dry puff conditions at the nicotine electronic vaping device in response to deciding that a nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after disabling the power to the heater.

Vaping at the nicotine electronic vaping device may be enabled in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

The nicotine electronic vaping device may be powered off in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

At least one other example embodiment provides a method for controlling a nicotine electronic vaping device including a heater to heat nicotine pre-vapor formulation drawn from a nicotine reservoir, the method including: determining a plurality of resistance values for the heater during a time window; calculating a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values; detecting whether the percent change in resistance of the heater exceeds a percent change in resistance threshold; and outputting an indication of dry puff conditions at the nicotine electronic vaping device in response to detecting that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

At least one other example embodiment provides a nicotine electronic vaping device including a nicotine reservoir storing nicotine pre-vapor formulation, a heater configured to heat nicotine pre-vapor formulation drawn from the nicotine reservoir, and processing circuitry. The processing circuitry is configured to cause the nicotine electronic vaping device to: determine a plurality of resistance values for the heater during a time window; calculate a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values; detect whether the percent change in resistance of the heater exceeds a percent change in resistance threshold; and output an indication of dry puff conditions at the nicotine electronic vaping device in response to determining that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

According to at least some example embodiments, the plurality of resistance values for the heater may be stored in a first-in-first-out (FIFO) memory. The first of the plurality of resistance values for the heater may be an oldest resistance value stored in the FIFO memory, and the second of the plurality of resistance values for the heater may be a most recent resistance value stored in the FIFO memory.

The percent change in resistance threshold may be obtained from a memory in a nicotine pod assembly of the nicotine electronic vaping device.

Whether the resistance of the heater has stabilized may be decided based on a current through the heater; and the plurality of resistance values for the heater during the time window may be determined in response to deciding that the resistance of the heater has stabilized.

Whether the resistance of the heater has stabilized may be decided based on the current through the heater and a wetting current threshold.

The nicotine electronic vaping device may be powered off in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within the first threshold time interval after outputting the indication of dry puff conditions at the nicotine electronic vaping device.

Power to the heater may be disabled in response to detecting that the percent change in resistance of the heater exceeds the percent change in resistance threshold; and the nicotine electronic vaping device may be returned to an operational mode by clearing a fault associated with dry puff conditions at the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after disabling the power to the heater.

Vaping at the nicotine electronic vaping device may be enabled in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

The nicotine electronic vaping device may be powered off in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

At least one other example embodiment provides a method for controlling a nicotine electronic vaping device, the method including: determining whether a nicotine pod assembly has been removed prior to expiration of a first time interval after detecting dry puff conditions at the nicotine electronic vaping device; and returning the nicotine electronic vaping device to an operational mode by clearing a fault associated with the dry puff conditions at the nicotine electronic vaping device in response to determining that the nicotine pod assembly has been removed prior to expiration of the first time interval.

At least one other example embodiment provides a nicotine electronic vaping device including processing circuitry configured to: determine whether a nicotine pod assembly has been removed prior to expiration of a first time interval after detecting dry puff conditions at the nicotine electronic vaping device; and return the nicotine electronic vaping device to an operational mode by clearing a fault associated with the dry puff conditions at the nicotine electronic vaping device in response to determining that the nicotine pod assembly has been removed prior to expiration of the first time interval.

According to at least some example embodiments, whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode may be determined, and vaping at the nicotine electronic vaping device may be enabled in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

The dry puff conditions at the nicotine electronic vaping device may be detected based on whether a percent change in resistance of a heater of the nicotine electronic vaping device exceeds a percent change in resistance threshold.

The various features and advantages of the non-limiting embodiments herein may become more apparent upon review of the detailed description in conjunction with the accompanying drawings. The accompanying drawings are merely provided for illustrative purposes and should not be interpreted to limit the scope of the claims. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. For purposes of clarity, various dimensions of the drawings may have been exaggerated.

FIG. 1 is a front view of a nicotine e-vaping device according to an example embodiment.

FIG. 2 is a side view of the nicotine e-vaping device of FIG. 1.

FIG. 3 is a rear view of the nicotine e-vaping device of FIG. 1.

FIG. 4 is a proximal end view of the nicotine e-vaping device of FIG. 1.

FIG. 5 is a distal end view of the nicotine e-vaping device of FIG. 1.

FIG. 6 is a perspective view of the nicotine e-vaping device of FIG. 1.

FIG. 7 is an enlarged view of the pod inlet in FIG. 6.

FIG. 8 is a cross-sectional view of the nicotine e-vaping device of FIG. 6.

FIG. 9 is a perspective view of the device body of the nicotine e-vaping device of FIG. 6.

FIG. 10 is a front view of the device body of FIG. 9.

FIG. 11 is an enlarged perspective view of the through hole in FIG. 10.

FIG. 12 is an enlarged perspective view of the device electrical contacts in FIG. 10.

FIG. 13 is a partially exploded view involving the mouthpiece in FIG. 12.

FIG. 14 is a partially exploded view involving the bezel structure in FIG. 9.

FIG. 15 is an enlarged perspective view of the mouthpiece, springs, retention structure, and bezel structure in FIG. 14.

FIG. 16 is a partially exploded view involving the front cover, the frame, and the rear cover in FIG. 14.

FIG. 17 is a perspective view of the nicotine pod assembly of the nicotine e-vaping device in FIG 6.

FIG. 18 is another perspective view of the nicotine pod assembly of FIG. 17.

FIG. 19 is another perspective view of the nicotine pod assembly of FIG. 18.

FIG. 20 is a perspective view of the nicotine pod assembly of FIG. 19 without the connector module.

FIG. 21 is a perspective view of the connector module in FIG. 19.

FIG. 22 is another perspective view of the connector module of FIG. 21.

FIG. 23 is an exploded view involving the wick, heater, electrical leads, and contact core in FIG. 22.

FIG. 24 is an exploded view involving the first housing section of the nicotine pod assembly of FIG. 17.

FIG. 25 is a partially exploded view involving the second housing section of the nicotine pod assembly of FIG. 17.

FIG. 26 is an exploded view of the activation pin in FIG. 25.

FIG. 27 is a perspective view of the connector module of FIG. 22 without the wick, heater, electrical leads, and contact core.

FIG. 28 is an exploded view of the connector module of FIG. 27.

FIG. 29 illustrates electrical systems of a device body and a nicotine pod assembly of a nicotine e-vaping device according to one or more example embodiments.

FIG. 30 is a simple block diagram illustrating a dry puff and auto shutdown control system according to example embodiments.

FIG. 31 is a flow chart illustrating a dryness detection method according to example embodiments.

FIG. 32 illustrates graphs of resistance versus time when dry puff conditions exist at the start of a puff ('Dry Puff'), when dry puff conditions occur during a puff ('Drying Puff'), and when dry puff conditions are not present ('Standard Puff').

FIG. 33 is a flow chart illustrating an example method of operation of a nicotine e-vaping device after shutdown of the vaping function in response to detecting a hard fault pod event, such as dry puff conditions, according to example embodiments.

FIG. 34 illustrates a heater voltage measurement circuit according to example embodiments.

FIG. 35 illustrates a heater current measurement circuit according to example embodiments.

FIG. 36 illustrates a pod temperature measurement circuit according to some example embodiments.

FIG. 37 illustrates a pod temperature measurement circuit according to some other example embodiments.

FIG. 38 is a circuit diagram illustrating a heating engine control circuit according to some example embodiments.

FIG. 39 is a circuit diagram illustrating a heating engine control circuit according to some other example embodiments.

FIG. 40 illustrates a temperature sensing transducer according to some example embodiments.

FIG. 41 illustrates a temperature sensing transducer according to some other example embodiments.

Some detailed example embodiments are disclosed herein. However, specific structural and functional details disclosed herein are merely representative for purposes of describing example embodiments. Example embodiments may, however, be embodied in many alternate forms and should not be construed as limited to only the example embodiments set forth herein.

Accordingly, while example embodiments are capable of various modifications and alternative forms, example embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit example embodiments to the particular forms disclosed, but to the contrary, example embodiments are to cover all modifications, equivalents, and alternatives thereof. Like numbers refer to like elements throughout the description of the figures.

It should be understood that when an element or layer is referred to as being "on," "connected to," "coupled to," “attached to,” “adjacent to,” or "covering" another element or layer, it may be directly on, connected to, coupled to, attached to, adjacent to or covering the other element or layer or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly connected to," or "directly coupled to" another element or layer, there are no intervening elements or layers present. Like numbers refer to like elements throughout the specification. As used herein, the term "and/or" includes any and all combinations or sub-combinations of one or more of the associated listed items.

It should be understood that, although the terms first, second, third, and so forth may be used herein to describe various elements, regions, layers and/or sections, these elements, regions, layers, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, region, layer, or section from another region, layer, or section. Therefore, a first element, region, layer, or section discussed below could be termed a second element, region, layer, or section without departing from the teachings of example embodiments.

Spatially relative terms (for example, "beneath," "below," "lower," "above," "upper," and the like) may be used herein for ease of description to describe one element or feature's relationship to another element or feature as illustrated in the figures. It should be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Therefore, the term "below" may encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

The terminology used herein is for the purpose of describing various example embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "includes," "including," "comprises," and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations and/or elements but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or groups thereof.

When the words "about" and “substantially” are used in this specification in connection with a numerical value, it is intended that the associated numerical value include a tolerance of ±10 percent around the stated numerical value, unless otherwise explicitly defined.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments belong. It will be further understood that terms, including those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

A "nicotine electronic vaping device" or "nicotine e-vaping device" as used herein may be referred to on occasion using, and considered synonymous with, nicotine e-vapor apparatus and/or nicotine e-vaping apparatus.

FIG. 1 is a front view of a nicotine e-vaping device according to an example embodiment. FIG. 2 is a side view of the nicotine e-vaping device of FIG. 1. FIG. 3 is a rear view of the nicotine e-vaping device of FIG. 1. Referring to FIGS. 1-3, a nicotine e-vaping device 500 includes a device body 100 that is configured to receive a nicotine pod assembly 300. The nicotine pod assembly 300 is a modular article configured to hold a nicotine pre-vapor formulation. A “nicotine pre-vapor formulation” is a material or combination of materials that may be transformed into a vapor. For example, the nicotine pre-vapor formulation may be a liquid, solid, and/or gel formulation including, but not limited to, water, beads, solvents, active ingredients, ethanol, plant extracts, natural or artificial flavors, and/or nicotine vapor formers such as glycerin and propylene glycol. During vaping, the nicotine e-vaping device 500 is configured to heat the nicotine pre-vapor formulation to generate a vapor. As referred to herein, a “nicotine vapor” is any matter generated or outputted from any nicotine e-vaping device according to any of the example embodiments disclosed herein.

As shown in FIGS. 1 and 3, the nicotine e-vaping device 500 extends in a longitudinal direction and has a length that is greater than its width. In addition, as shown in FIG. 2, the length of the nicotine e-vaping device 500 is also greater than its thickness. Furthermore, the width of the nicotine e-vaping device 500 may be greater than its thickness. Assuming an x-y-z Cartesian coordinate system, the length of the nicotine e-vaping device 500 may be measured in the y-direction, the width may be measured in the x-direction, and the thickness may be measured in the z-direction. The nicotine e-vaping device 500 may have a substantially linear form with tapered ends based on its front, side, and rear views, although example embodiments are not limited thereto.

The device body 100 includes a front cover 104, a frame 106, and a rear cover 108. The front cover 104, the frame 106, and the rear cover 108 form a device housing that encloses mechanical elements, electronic elements, and/or circuitry associated with the operation of the nicotine e-vaping device 500. For instance, the device housing of the device body 100 may enclose a power source configured to power the nicotine e-vaping device 500, which may include supplying an electric current to the nicotine pod assembly 300. The device housing of the device body 100 may also include one or more electrical systems to control the nicotine e-vaping device 500. Electrical systems according to example embodiments will be discussed in more detail later. In addition, when assembled, the front cover 104, the frame 106, and the rear cover 108 may constitute a majority of the visible portion of the device body 100.

The front cover 104 (for example, first cover) defines a primary opening configured to accommodate a bezel structure 112. The primary opening may have a rounded rectangular shape, although other shapes are possible depending on the shape of the bezel structure 112. The bezel structure 112 defines a through hole 150 configured to receive the nicotine pod assembly 300. The through hole 150 is discussed herein in more detail in connection with, for instance, FIG. 9.

The front cover 104 also defines a secondary opening configured to accommodate a light guide arrangement. The secondary opening may resemble a slot (for example, elongated rectangle with rounded edges), although other shapes are possible depending on the shape of the light guide arrangement. In an example embodiment, the light guide arrangement includes a light guide housing 114 and a button housing 122. The light guide housing 114 is configured to expose a light guide lens 116, while the button housing 122 is configured to expose a first button lens 124 and a second button lens 126 (for example, FIG. 16). The first button lens 124 and an upstream portion of the button housing 122 may form a first button 118. Similarly, the second button lens 126 and a downstream portion of the button housing 122 may form a second button 120. The button housing 122 may be in a form of a single structure or two separate structures. With the latter form, the first button 118 and the second button 120 can move with a more independent feel when pressed.

The operation of the nicotine e-vaping device 500 may be controlled by the first button 118 and the second button 120. For instance, the first button 118 may be a power button, and the second button 120 may be an intensity button. Although two buttons are shown in the drawings in connection with the light guide arrangement, it should be understood that more (or less) buttons may be provided depending on the available features and desired user interface.

The frame 106 (for example, base frame) is the central support structure for the device body 100 (and the nicotine e-vaping device 500 as a whole). The frame 106 may be referred to as a chassis. The frame 106 includes a proximal end, a distal end, and a pair of side sections between the proximal end and the distal end. The proximal end and the distal end may also be referred to as the downstream end and the upstream end, respectively. As used herein, “proximal” (and, conversely, “distal”) is in relation to an adult vaper during vaping, and “downstream” (and, conversely, “upstream”) is in relation to a flow of the vapor. A bridging section may be provided between the opposing inner surfaces of the side sections (for example, about midway along the length of the frame 106) for additional strength and stability. The frame 106 may be integrally formed so as to be a monolithic structure.

With regard to material of construction, the frame 106 may be formed of an alloy or a plastic. The alloy (for example, die cast grade, machinable grade) may be an aluminum (Al) alloy or a zinc (Zn) alloy. The plastic may be a polycarbonate (PC), an acrylonitrile butadiene styrene (ABS), or a combination thereof (PC/ABS). For instance, the polycarbonate may be LUPOY SC1004A. Furthermore, the frame 106 may be provided with a surface finish for functional and/or aesthetic reasons (for example, to provide a premium appearance). In an example embodiment, the frame 106 (for example, when formed of an aluminum alloy) may be anodized. In another embodiment, the frame 106 (for example, when formed of a zinc alloy) may be coated with a hard enamel or painted. In another embodiment, the frame 106 (for example, when formed of a polycarbonate) may be metallized. In yet another embodiment, the frame 106 (for example, when formed of an acrylonitrile butadiene styrene) may be electroplated. It should be understood that the materials of construction with regard to the frame 106 may also be applicable to the front cover 104, the rear cover 108, and/or other appropriate parts of the nicotine e-vaping device 500.

The rear cover 108 (for example, second cover) also defines an opening configured to accommodate the bezel structure 112. The opening may have a rounded rectangular shape, although other shapes are possible depending on the shape of the bezel structure 112. In an example embodiment, the opening in the rear cover 108 is smaller than the primary opening in the front cover 104. In addition, although not shown, it should be understood that a light guide arrangement (for example, including buttons) may be provided on the rear of the nicotine e-vaping device 500 in addition to (or in lieu of) the light guide arrangement on the front of the nicotine e-vaping device 500.

The front cover 104 and the rear cover 108 may be configured to engage with the frame 106 via a snap-fit arrangement. For instance, the front cover 104 and/or the rear cover 108 may include clips configured to interlock with corresponding mating members of the frame 106. In a non-limiting embodiment, the clips may be in a form of tabs with orifices configured to receive the corresponding mating members (for example, protrusions with beveled edges) of the frame 106. Alternatively, the front cover 104 and/or the rear cover 108 may be configured to engage with the frame 106 via an interference fit (which may also be referred to as a press fit or friction fit). However, it should be understood that the front cover 104, the frame 106, and the rear cover 108 may be coupled via other suitable arrangements and techniques.

The device body 100 also includes a mouthpiece 102. The mouthpiece 102 may be secured to the proximal end of the frame 106. Additionally, as shown in FIG. 2, in an example embodiment where the frame 106 is sandwiched between the front cover 104 and the rear cover 108, the mouthpiece 102 may abut the front cover 104, the frame 106, and the rear cover 108. Furthermore, in a non-limiting embodiment, the mouthpiece 102 may be joined with the device housing via a bayonet connection.

FIG. 4 is a proximal end view of the nicotine e-vaping device of FIG. 1. Referring to FIG. 4, the outlet face of the mouthpiece 102 defines a plurality of vapor outlets. In a non-limiting embodiment, the outlet face of the mouthpiece 102 may be elliptically-shaped. In addition, the outlet face of the mouthpiece 102 may include a first crossbar corresponding to a major axis of the elliptically-shaped outlet face and a second crossbar corresponding to a minor axis of the elliptically-shaped outlet face. Furthermore, the first crossbar and the second crossbar may intersect perpendicularly and be integrally formed parts of the mouthpiece 102. Although the outlet face is shown as defining four vapor outlets, it should be understood that example embodiments are not limited thereto. For instance, the outlet face may define less than four (for example, one, two) vapor outlets or more than four (for example, six, eight) vapor outlets.

FIG. 5 is a distal end view of the nicotine e-vaping device of FIG. 1. Referring to FIG. 5, the distal end of the nicotine e-vaping device 500 includes a port 110. The port 110 is configured to receive an electric current (for example, via a USB cable) from an external power source so as to charge an internal power source within the nicotine e-vaping device 500. In addition, the port 110 may also be configured to send data to and/or receive data (for example, via a USB cable) from another nicotine e-vaping device or other electronic device (for example, phone, tablet, computer). Furthermore, the nicotine e-vaping device 500 may be configured for wireless communication with another electronic device, such as a phone, via an application software (app) installed on that electronic device. In such an instance, an adult vaper may control or otherwise interface with the nicotine e-vaping device 500 (for example, locate the nicotine e-vaping device, check usage information, change operating parameters) through the app.

FIG. 6 is a perspective view of the nicotine e-vaping device of FIG. 1. FIG. 7 is an enlarged view of the pod inlet in FIG. 6. Referring to FIGS. 6-7, and as briefly noted above, the nicotine e-vaping device 500 includes a nicotine pod assembly 300 configured to hold a nicotine pre-vapor formulation. The nicotine pod assembly 300 has an upstream end (which faces the light guide arrangement) and a downstream end (which faces the mouthpiece 102). In a non-limiting embodiment, the upstream end is an opposing surface of the nicotine pod assembly 300 from the downstream end. The upstream end of the nicotine pod assembly 300 defines a pod inlet 322. The device body 100 defines a through hole (for example, through hole 150 in FIG. 9) configured to receive the nicotine pod assembly 300. In an example embodiment, the bezel structure 112 of the device body 100 defines the through hole and includes an upstream rim. As shown, particularly in FIG. 7, the upstream rim of the bezel structure 112 is angled (for example, dips inward) so as to expose the pod inlet 322 when the nicotine pod assembly 300 is seated within the through hole of the device body 100.

For instance, rather than following the contour of the front cover 104 (so as to be relatively flush with the front face of the nicotine pod assembly 300 and, therefore, obscure the pod inlet 322), the upstream rim of the bezel structure 112 is in a form of a scoop configured to direct ambient air into the pod inlet 322. This angled/scoop configuration may help reduce or prevent the blockage of the air inlet (for example, pod inlet 322) of the nicotine e-vaping device 500. The depth of the scoop may be such that less than half (for example, less than a quarter) of the upstream end face of the nicotine pod assembly 300 is exposed. Additionally, in a non-limiting embodiment, the pod inlet 322 is in a form of a slot. Furthermore, if the device body 100 is regarded as extending in a first direction, then the slot may be regarded as extending in a second direction, wherein the second direction is transverse to the first direction.

FIG. 8 is a cross-sectional view of the nicotine e-vaping device of FIG. 6. In FIG. 8, the cross-section is taken along the longitudinal axis of the nicotine e-vaping device 500. As shown, the device body 100 and the nicotine pod assembly 300 include mechanical elements, electronic elements, and/or circuitry associated with the operation of the nicotine e-vaping device 500, which are discussed in more detail herein and/or are incorporated by reference herein. For instance, the nicotine pod assembly 300 may include mechanical elements configured to actuate to release the nicotine pre-vapor formulation from a sealed nicotine reservoir within. The nicotine pod assembly 300 may also have mechanical aspects configured to engage with the device body 100 to facilitate the insertion and seating of the nicotine pod assembly 300.

Additionally, the nicotine pod assembly 300 may be a “smart pod” that includes electronic elements and/or circuitry configured to store, receive, and/or transmit information to/from the device body 100. Such information may be used to authenticate the nicotine pod assembly 300 for use with the device body 100 (for example, to prevent usage of an unapproved/counterfeit nicotine pod assembly). Furthermore, the information may be used to identify a type of the nicotine pod assembly 300, which is then correlated with a vaping profile based on the identified type. The vaping profile may be designed to set forth the general parameters for the heating of the nicotine pre-vapor formulation and may be subject to tuning, refining, or other adjustment by an adult vaper before and/or during vaping.

The nicotine pod assembly 300 may also communicate with the device body 100 other information that may be relevant to the operation of the nicotine e-vaping device 500. Examples of relevant information may include a level of the nicotine pre-vapor formulation within the nicotine pod assembly 300 and/or a length of time that has passed since the nicotine pod assembly 300 was inserted into the device body 100 and activated. For instance, if the nicotine pod assembly 300 was inserted into the device body 100 and activated more than a certain period of time prior (for example, more than 6 months ago), the nicotine e-vaping device 500 may not permit vaping, and the adult vaper may be prompted to change to a new nicotine pod assembly even though the nicotine pod assembly 300 still contains adequate levels of nicotine pre-vapor formulation.

The device body 100 may include mechanical elements (for example, complementary structures) configured to engage, hold, and/or activate the nicotine pod assembly 300. In addition, the device body 100 may include electronic elements and/or circuitry configured to receive an electric current to charge an internal power source (for example, battery) which, in turn, is configured to supply power to the nicotine pod assembly 300 during vaping. Furthermore, the device body 100 may include electronic elements and/or circuitry configured to communicate with the nicotine pod assembly 300, a different nicotine e-vaping device, other electronic devices (for example, phone, tablet, computer), and/or the adult vaper. The information being communicated may include pod-specific data, current vaping details, and/or past vaping patterns/history. The adult vaper may be notified of such communications with feedback that is haptic (for example, vibrations), auditory (for example, beeps), and/or visual (for example, colored/blinking lights). The charging and/or communication of information may be performed with the port 110 (for example, via a USB cable).

FIG. 9 is a perspective view of the device body of the nicotine e-vaping device of FIG. 6. Referring to FIG. 9, the bezel structure 112 of the device body 100 defines a through hole 150. The through hole 150 is configured to receive a nicotine pod assembly 300. To facilitate the insertion and seating of the nicotine pod assembly 300 within the through hole 150, the upstream rim of the bezel structure 112 includes a first upstream protrusion 128a and a second upstream protrusion 128b. The through hole 150 may have a rectangular shape with rounded corners. In an example embodiment, the first upstream protrusion 128a and the second upstream protrusion 128b are integrally formed with the bezel structure 112 and located at the two rounded corners of the upstream rim.

The downstream sidewall of the bezel structure 112 may define a first downstream opening, a second downstream opening, and a third downstream opening. A retention structure including a first downstream protrusion 130a and a second downstream protrusion 130b is engaged with the bezel structure 112 such that the first downstream protrusion 130a and the second downstream protrusion 130b protrude through the first downstream opening and the second downstream opening, respectively, of the bezel structure 112 and into the through hole 150. In addition, a distal end of the mouthpiece 102 extends through the third downstream opening of the bezel structure 112 and into the through hole 150 so as to be between the first downstream protrusion 130a and the second downstream protrusion 130b.

FIG. 10 is a front view of the device body of FIG. 9. Referring to FIG. 10, the device body 100 includes a device electrical connector 132 disposed at an upstream side of the through hole 150. The device electrical connector 132 of the device body 100 is configured to electrically engage with a nicotine pod assembly 300 that is seated within the through hole 150. As a result, power can be supplied from the device body 100 to the nicotine pod assembly 300 via the device electrical connector 132 during vaping. In addition, data can be sent to and/or received from the device body 100 and the nicotine pod assembly 300 via the device electrical connector 132.

FIG. 11 is an enlarged perspective view of the through hole in FIG. 10. Referring to FIG. 11, the first upstream protrusion 128a, the second upstream protrusion 128b, the first downstream protrusion 130a, the second downstream protrusion 130b, and the distal end of the mouthpiece 102 protrude into the through hole 150. In an example embodiment, the first upstream protrusion 128a and the second upstream protrusion 128b are stationary structures (for example, stationary pivots), while the first downstream protrusion 130a and the second downstream protrusion 130b are tractable structures (for example, retractable members). For instance, the first downstream protrusion 130a and the second downstream protrusion 130b may be configured (for example, spring-loaded) to default to a protracted state while also configured to transition temporarily to a retracted state (and reversibly back to the protracted state) to facilitate an insertion of a nicotine pod assembly 300.

In particular, when inserting a nicotine pod assembly 300 into the through hole 150 of the device body 100, recesses at the upstream end face of the nicotine pod assembly 300 may be initially engaged with the first upstream protrusion 128a and the second upstream protrusion 128b followed by a pivoting of the nicotine pod assembly 300 (about the first upstream protrusion 128a and the second upstream protrusion 128b) until recesses at the downstream end face of the nicotine pod assembly 300 are engaged with the first downstream protrusion 130a and the second downstream protrusion 130b. In such an instance, the axis of rotation (during pivoting) of the nicotine pod assembly 300 may be orthogonal to the longitudinal axis of the device body 100. In addition, the first downstream protrusion 130a and the second downstream protrusion 130b, which may be biased so as to be tractable, may retract when the nicotine pod assembly 300 is being pivoted into the through hole 150 and resiliently protract to engage recesses at the downstream end face of the nicotine pod assembly 300. Furthermore, the engagement of the first downstream protrusion 130a and the second downstream protrusion 130b with recesses at the downstream end face of the nicotine pod assembly 300 may produce a haptic and/or auditory feedback (for example, audible click) to notify an adult vaper that the nicotine pod assembly 300 is properly seated in the through hole 150 of the device body 100.

FIG. 12 is an enlarged perspective view of the device electrical contacts in FIG. 10. The device electrical contacts of the device body 100 are configured to engage with the pod electrical contacts of the nicotine pod assembly 300 when the nicotine pod assembly 300 is seated within the through hole 150 of the device body 100. Referring to FIG. 12, the device electrical contacts of the device body 100 include the device electrical connector 132. The device electrical connector 132 includes power contacts and data contacts. The power contacts of the device electrical connector 132 are configured to supply power from the device body 100 to the nicotine pod assembly 300. As illustrated, the power contacts of the device electrical connector 132 include a first pair of power contacts and a second pair of power contacts (which are positioned so as to be closer to the front cover 104 than the rear cover 108). The first pair of power contacts (for example, the pair adjacent to the first upstream protrusion 128a) may be a single integral structure that is distinct from the second pair of power contacts and that, when assembled, includes two projections that extend into the through hole 150. Similarly, the second pair of power contacts (for example, the pair adjacent to the second upstream protrusion 128b) may be a single integral structure that is distinct from the first pair of power contacts and that, when assembled, includes two projections that extend into the through hole 150. The first pair of power contacts and the second pair of power contacts of the device electrical connector 132 may be tractably-mounted and biased so as to protract into the through hole 150 as a default and to retract (for example, independently) from the through hole 150 when subjected to a force that overcomes the bias.

The data contacts of the device electrical connector 132 are configured to transmit data between a nicotine pod assembly 300 and the device body 100. As illustrated, the data contacts of the device electrical connector 132 include a row of five projections (which are positioned so as to be closer to the rear cover 108 than the front cover 104). The data contacts of the device electrical connector 132 may be distinct structures that, when assembled, extend into the through hole 150. The data contacts of the device electrical connector 132 may also be tractably-mounted and biased (for example, with springs) so as to protract into the through hole 150 as a default and to retract (for example, independently) from the through hole 150 when subjected to a force that overcomes the bias. For instance, when a nicotine pod assembly 300 is inserted into the through hole 150 of the device body 100, the pod electrical contacts of the nicotine pod assembly 300 will press against the corresponding device electrical contacts of the device body 100. As a result, the power contacts and the data contacts of the device electrical connector 132 will be retracted (for example, at least partially retracted) into the device body 100 but will continue to push against the corresponding pod electrical contacts due to their resilient arrangement, thereby helping to ensure a proper electrical connection between the device body 100 and the nicotine pod assembly 300. Furthermore, such a connection may also be mechanically secure and have minimal contact resistance so as to allow power and/or signals between the device body 100 and the nicotine pod assembly 300 to be transferred and/or communicated reliably and accurately. While various aspects have been discussed in connection with the device electrical contacts of the device body 100, it should be understood that example embodiments are not limited thereto and that other configurations may be utilized.

FIG. 13 is a partially exploded view involving the mouthpiece in FIG. 12. Referring to FIG. 13, the mouthpiece 102 is configured to engage with the device housing via a retention structure 140. In an example embodiment, the retention structure 140 is situated so as to be primarily between the frame 106 and the bezel structure 112. As shown, the retention structure 140 is disposed within the device housing such that the proximal end of the retention structure 140 extends through the proximal end of the frame 106. The retention structure 140 may extend slightly beyond the proximal end of the frame 106 or be substantially even therewith. The proximal end of the retention structure 140 is configured to receive a distal end of the mouthpiece 102.

The proximal end of the retention structure 140 may be a female end, while the distal end of the mouthpiece may be a male end.

For instance, the mouthpiece 102 may be coupled (for example, reversibly coupled) to the retention structure 140 with a bayonet connection. In such an instance, the female end of the retention structure 140 may define a pair of opposing L-shaped slots, while the male end of the mouthpiece 102 may have opposing radial members 134 (for example, radial pins) configured to engage with the L-shaped slots of the retention structure 140. Each of the L-shaped slots of the retention structure 140 have a longitudinal portion and a circumferential portion. Optionally, the terminus of the circumferential portion may have a serif portion to help reduce or prevent the likelihood that that a radial member 134 of the mouthpiece 102 will inadvertently become disengaged. In a non-limiting embodiment, the longitudinal portions of the L-shaped slots extend in parallel and along a longitudinal axis of the device body 100, while the circumferential portions of the L-shaped slots extend around the longitudinal axis (for example, central axis) of the device body 100. As a result, to couple the mouthpiece 102 to the device housing, the mouthpiece 102 shown in FIG. 13 is initially rotated 90 degrees to align the radial members 134 with the entrances to the longitudinal portions of the L-shaped slots of the retention structure 140. The mouthpiece 102 is then pushed into the retention structure 140 such that the radial members 134 slide along the longitudinal portions of the L-shaped slots until the junction with each of the circumferential portions is reached. At this point, the mouthpiece 102 is then rotated such that the radial members 134 travel across the circumferential portions until the terminus of each is reached. Where a serif portion is present at each terminus, a haptic and/or auditory feedback (for example, audible click) may be produced to notify an adult vaper that the mouthpiece 102 has been properly coupled to the device housing.

The mouthpiece 102 defines a vapor passage 136 through which nicotine vapor flows during vaping. The vapor passage 136 is in fluidic communication with the through hole 150 (which is where the nicotine pod assembly 300 is seated within the device body 100). The proximal end of the vapor passage 136 may include a flared portion. In addition, the mouthpiece 102 may include an end cover 138. The end cover 138 may taper from its distal end to its proximal end. The outlet face of the end cover 138 defines a plurality of vapor outlets. Although four vapor outlets are shown in the end cover 138, it should be understood that example embodiments are not limited thereto.

FIG. 14 is a partially exploded view involving the bezel structure in FIG. 9. FIG. 15 is an enlarged perspective view of the mouthpiece, springs, retention structure, and bezel structure in FIG. 14. Referring to FIGS. 14-15, the bezel structure 112 includes an upstream sidewall and a downstream sidewall. The upstream sidewall of the bezel structure 112 defines a connector opening 146. The connector opening 146 is configured to expose or receive the device electrical connector 132 of the device body 100. The downstream sidewall of the bezel structure 112 defines a first downstream opening 148a, a second downstream opening 148b, and a third downstream opening 148c. The first downstream opening 148a and the second downstream opening 148b of the bezel structure 112 are configured to receive the first downstream protrusion 130a and the second downstream protrusion 130b, respectively, of the retention structure 140. The third downstream opening 148c of the bezel structure 112 is configured to receive the distal end of the mouthpiece 102.

As shown in FIG. 14, the first downstream protrusion 130a and the second downstream protrusion 130b are on the concave side of the retention structure 140. As shown in FIG. 15, a first post 142a and a second post 142b are on the opposing convex side of the retention structure 140. A first spring 144a and a second spring 144b are disposed on the first post 142a and the second post 142b, respectively. The first spring 144a and the second spring 144b are configured to bias the retention structure 140 against the bezel structure 112.

When assembled, the bezel structure 112 may be secured to the frame 106 via a pair of tabs adjacent to the connector opening 146. In addition, the retention structure 140 will abut the bezel structure 112 such that the first downstream protrusion 130a and the second downstream protrusion 130b extend through the first downstream opening 148a and the second downstream opening 148b, respectively. The mouthpiece 102 will be coupled to the retention structure 140 such that the distal end of the mouthpiece 102 extends through the retention structure 140 as well as the third downstream opening 148c of the bezel structure 112. The first spring 144a and the second spring 144b will be between the frame 106 and the retention structure 140.

When a nicotine pod assembly 300 is being inserted into the through hole 150 of the device body 100, the downstream end of the nicotine pod assembly 300 will push against the first downstream protrusion 130a and the second downstream protrusion 130b of the retention structure 140. As a result, the first downstream protrusion 130a and the second downstream protrusion 130b of the retention structure 140 will resiliently yield and retract from the through hole 150 of the device body 100 (by virtue of compression of the first spring 144a and the second spring 144b), thereby allowing the insertion of the nicotine pod assembly 300 to proceed. In an example embodiment, when the first downstream protrusion 130a and the second downstream protrusion 130b are fully retracted from the through hole 150 of the device body 100, the displacement of the retention structure 140 may cause the ends of the first post 142a and the second post 142b to contact the inner end surface of the frame 106. Furthermore, because the mouthpiece 102 is coupled to the retention structure 140, the distal end of the mouthpiece 102 will retract from the through hole 150, therefore causing the proximal end of the mouthpiece 102 (for example, visible portion including the end cover 138) to also shift by a corresponding distance away from the device housing.

Once the nicotine pod assembly 300 is adequately inserted such that the first downstream recess and the second downstream recess of the nicotine pod assembly 300 reach a position that allows an engagement with the first downstream protrusion 130a and the second downstream protrusion 130b, respectively, the stored energy from the compression of the first spring 144a and the second spring 144b will cause the first downstream protrusion 130a and the second downstream protrusion 130b to resiliently protract and engage with the first downstream recess and the second downstream recess, respectively, of the nicotine pod assembly 300. Furthermore, the engagement may produce a haptic and/or auditory feedback (for example, audible click) to notify an adult vaper that the nicotine pod assembly 300 is properly seated within the through hole 150 of the device body 100.

FIG. 16 is a partially exploded view involving the front cover, the frame, and the rear cover in FIG. 14. Referring to FIG. 16, various mechanical elements, electronic elements, and/or circuitry associated with the operation of the nicotine e-vaping device 500 may be secured to the frame 106. The front cover 104 and the rear cover 108 may be configured to engage with the frame 106 via a snap-fit arrangement. In an example embodiment, the front cover 104 and the rear cover 108 include clips configured to interlock with corresponding mating members of the frame 106. The clips may be in a form of tabs with orifices configured to receive the corresponding mating members (for example, protrusions with beveled edges) of the frame 106. In FIG. 16, the front cover 104 has two rows with four clips each (for a total of eight clips for the front cover 104). Similarly, the rear cover 108 has two rows with four clips each (for a total of eight clips for the rear cover 108). The corresponding mating members of the frame 106 may on the inner sidewalls of the frame 106. As a result, the engaged clips and mating members may be hidden from view when the front cover 104 and the rear cover 108 are snapped together. Alternatively, the front cover 104 and/or the rear cover 108 may be configured to engage with the frame 106 via an interference fit. However, it should be understood that the front cover 104, the frame 106, and the rear cover 108 may be coupled via other suitable arrangements and techniques.

FIG. 17 is a perspective view of the nicotine pod assembly of the nicotine e-vaping device in FIG 6. FIG. 18 is another perspective view of the nicotine pod assembly of FIG. 17. FIG. 19 is another perspective view of the nicotine pod assembly of FIG. 18. Referring to FIGS. 17-19, the nicotine pod assembly 300 for the nicotine e-vaping device 500 includes a pod body configured to hold a nicotine pre-vapor formulation. The pod body has an upstream end and a downstream end. The upstream end of the pod body defines a cavity 310 (FIG. 20). The downstream end of the pod body defines a pod outlet 304 that is in fluidic communication with the cavity 310 at the upstream end. A connector module 320 is configured to be seated within the cavity 310 of the pod body. The connector module 320 includes an external face and a side face. The external face of the connector module 320 forms an exterior of the pod body.

The external face of the connector module 320 defines a pod inlet 322. The pod inlet 322 (through which air enters during vaping) is in fluidic communication with the pod outlet 304 (through which nicotine vapor exits during vaping). The pod inlet 322 is shown in FIG. 19 as being in a form of a slot. However, it should be understood that example embodiments are not limited thereto and that other forms are possible. When the connector module 320 is seated within the cavity 310 of the pod body, the external face of the connector module 320 remains visible, while the side face of the connector module 320 becomes mostly obscured so as to be only partially viewable through the pod inlet 322 based on a given angle.

The external face of the connector module 320 includes at least one electrical contact. The at least one electrical contact may include a plurality of power contacts. For instance, the plurality of power contacts may include a first power contact 324a and a second power contact 324b. The first power contact 324a of the nicotine pod assembly 300 is configured to electrically connect with the first pair of power contacts (for example, the pair adjacent to the first upstream protrusion 128a in FIG. 12) of the device electrical connector 132 of the device body 100. Similarly, the second power contact 324b of the nicotine pod assembly 300 is configured to electrically connect with the second pair of power contacts (for example, the pair adjacent to the second upstream protrusion 128b in FIG. 12) of the device electrical connector 132 of the device body 100. In addition, the at least one electrical contact of the nicotine pod assembly 300 includes a plurality of data contacts 326. The plurality of data contacts 326 of the nicotine pod assembly 300 are configured to electrically connect with the data contacts of the device electrical connector 132 (for example, row of five projections in FIG. 12). While two power contacts and five data contacts are shown in connection with the nicotine pod assembly 300, it should be understood that other variations are possible depending on the design of the device body 100.

In an example embodiment, the nicotine pod assembly 300 includes a front face, a rear face opposite the front face, a first side face between the front face and the rear face, a second side face opposite the first side face, an upstream end face, and a downstream end face opposite the upstream end face. The corners of the side and end faces (for example, corner of the first side face and the upstream end face, corner of upstream end face and the second side face, corner of the second side face and the downstream end face, corner of the downstream end face and the first side face) may be rounded. However, in some instances, the corners may be angular. In addition, the peripheral edge of the front face may be in a form of a ledge. The external face of the connector module 320 may be regarded as being part of the upstream end face of the nicotine pod assembly 300. The front face of the nicotine pod assembly 300 may be wider and longer than the rear face. In such an instance, the first side face and the second side face may be angled inwards towards each other. The upstream end face and the downstream end face may also be angled inwards towards each other. Because of the angled faces, the insertion of the nicotine pod assembly 300 will be unidirectional (for example, from the front side (side associated with the front cover 104) of the device body 100). As a result, the possibility that the nicotine pod assembly 300 will be improperly inserted into the device body 100 can be reduced or prevented.

As illustrated, the pod body of the nicotine pod assembly 300 includes a first housing section 302 and a second housing section 308. The first housing section 302 has a downstream end defining the pod outlet 304. The rim of the pod outlet 304 may optionally be a sunken or indented region. In such an instance, this region may resemble a cove, wherein the side of the rim adjacent to the rear face of the nicotine pod assembly 300 may be open, while the side of the rim adjacent to the front face may be surrounded by a raised portion of the downstream end of the first housing section 302. The raised portion may function as a stopper for the distal end of the mouthpiece 102. As a result, this configuration for the pod outlet 304 may facilitate the receiving and aligning of the distal end of the mouthpiece 102 (for example, FIG. 11) via the open side of the rim and its subsequent seating against the raised portion of the downstream end of the first housing section 302. In a non-limiting embodiment, the distal end of the mouthpiece 102 may also include (or be formed of) a resilient material to help create a seal around the pod outlet 304 when the nicotine pod assembly 300 is properly inserted within the through hole 150 of the device body 100.

The downstream end of the first housing section 302 additionally defines at least one downstream recess. In an example embodiment, the at least one downstream recess is in a form of a first downstream recess 306a and a second downstream recess 306b. The pod outlet 304 may be between the first downstream recess 306a and the second downstream recess 306b. The first downstream recess 306a and the second downstream recess 306b are configured to engage with the first downstream protrusion 130a and the second downstream protrusion 130b, respectively, of the device body 100. As shown in FIG. 11, the first downstream protrusion 130a and the second downstream protrusion 130b of the device body 100 may be disposed on adjacent corners of the downstream sidewall of the through hole 150. The first downstream recess 306a and the second downstream recess 306b may each be in a form of a V-shaped notch. In such an instance, each of the first downstream protrusion 130a and the second downstream protrusion 130b of the device body 100 may be in a form of a wedge-shaped structure configured to engage with a corresponding V-shaped notch of the first downstream recess 306a and the second downstream recess 306b. The first downstream recess 306a may abut the corner of the downstream end face and the first side face, while the second downstream recess 306b may abut the corner of the downstream end face and the second side face. As a result, the edges of the first downstream recess 306a and the second downstream recess 306b adjacent to the first side face and the second side face, respectively, may be open. In such an instance, as shown in FIG. 18, each of the first downstream recess 306a and the second downstream recess 306b may be a 3-sided recess.

The second housing section 308 has an upstream end defining the cavity 310 (FIG. 20). The cavity 310 is configured to receive the connector module 320 (FIG. 21). In addition, the upstream end of the second housing section 308 defines at least one upstream recess. In an example embodiment, the at least one upstream recess is in a form of a first upstream recess

312a and a second upstream recess 312b. The pod inlet 322 may be between the first upstream recess 312a and the second upstream recess 312b. The first upstream recess 312a and the second upstream recess 312b are configured to engage with the first upstream protrusion 128a and the second upstream protrusion 128b, respectively, of the device body 100. As shown in FIG. 12, the first upstream protrusion 128a and the second upstream protrusion 128b of the device body 100 may be disposed on adjacent corners of the upstream sidewall of the through hole 150. A depth of each of the first upstream recess 312a and the second upstream recess 312b may be greater than a depth of each of the first downstream recess 306a and the second downstream recess 306b. A terminus of each of the first upstream recess 312a and the second upstream recess 312b may also be more rounded than a terminus of each of the first downstream recess 306a and the second downstream recess 306b. For instance, the first upstream recess 312a and the second upstream recess 312b may each be in a form of a U-shaped indentation. In such an instance, each of the first upstream protrusion 128a and the second upstream protrusion 128b of the device body 100 may be in a form of a rounded knob configured to engage with a corresponding U-shaped indentation of the first upstream recess 312a and the second upstream recess 312b. The first upstream recess 312a may abut the corner of the upstream end face and the first side face, while the second upstream recess 312b may abut the corner of the upstream end face and the second side face. As a result, the edges of the first upstream recess 312a and the second upstream recess 312b adjacent to the first side face and the second side face, respectively, may be open.

The first housing section 302 may define a nicotine reservoir within configured to hold the nicotine pre-vapor formulation. The nicotine reservoir may be configured to hermetically seal the nicotine pre-vapor formulation until an activation of the nicotine pod assembly 300 to release the nicotine pre-vapor formulation from the nicotine reservoir. As a result of the hermetic seal, the nicotine pre-vapor formulation may be isolated from the environment as well as the internal elements of the nicotine pod assembly 300 that may potentially react with the nicotine pre-vapor formulation, thereby reducing or preventing the possibility of adverse effects to the shelf-life and/or sensorial characteristics (for example, flavor) of the nicotine pre-vapor formulation. The second housing section 308 may contain structures configured to activate the nicotine pod assembly 300 and to receive and heat the nicotine pre-vapor formulation released from the nicotine reservoir after the activation.

The nicotine pod assembly 300 may be activated manually by an adult vaper prior to the insertion of the nicotine pod assembly 300 into the device body 100. Alternatively, the nicotine pod assembly 300 may be activated as part of the insertion of the nicotine pod assembly 300 into the device body 100. In an example embodiment, the second housing section 308 of the pod body includes a perforator configured to release the nicotine pre-vapor formulation from the nicotine reservoir during the activation of the nicotine pod assembly 300. The perforator may be in a form of a first activation pin 314a and a second activation pin 314b, which will be discussed in more detail herein.

To activate the nicotine pod assembly 300 manually, an adult vaper may press the first activation pin 314a and the second activation pin 314b inward (for example, simultaneously or sequentially) prior to inserting the nicotine pod assembly 300 into the through hole 150 of the device body 100. For instance, the first activation pin 314a and the second activation pin 314b may be manually pressed until the ends thereof are substantially even with the upstream end face of the nicotine pod assembly 300. In an example embodiment, the inward movement of the first activation pin 314a and the second activation pin 314b causes a seal of the nicotine reservoir to be punctured or otherwise compromised so as to release the nicotine pre-vapor formulation therefrom.

Alternatively, to activate the nicotine pod assembly 300 as part of the insertion of the nicotine pod assembly 300 into the device body 100, the nicotine pod assembly 300 is initially positioned such that the first upstream recess 312a and the second upstream recess 312b are engaged with the first upstream protrusion 128a and the second upstream protrusion 128b, respectively (for example, upstream engagement). Because each of the first upstream protrusion 128a and the second upstream protrusion 128b of the device body 100 may be in a form of a rounded knob configured to engage with a corresponding U-shaped indentation of the first upstream recess 312a and the second upstream recess 312b, the nicotine pod assembly 300 may be subsequently pivoted with relative ease about the first upstream protrusion 128a and the second upstream protrusion 128b and into the through hole 150 of the device body 100.

With regard to the pivoting of the nicotine pod assembly 300, the axis of rotation may be regarded as extending through the first upstream protrusion 128a and the second upstream protrusion 128b and oriented orthogonally to a longitudinal axis of the device body 100. During the initial positioning and subsequent pivoting of the nicotine pod assembly 300, the first activation pin 314a and the second activation pin 314b will come into contact with the upstream sidewall of the through hole 150 and transition from a protracted state to a retracted state as the first activation pin 314a and the second activation pin 314b are pushed (for example, simultaneously) into the second housing section 308 as the nicotine pod assembly 300 progresses into the through hole 150. When the downstream end of the nicotine pod assembly 300 reaches the vicinity of the downstream sidewall of the through hole 150 and comes into contact with the first downstream protrusion 130a and the second downstream protrusion 130b, the first downstream protrusion 130a and the second downstream protrusion 130b will retract and then resiliently protract (for example, spring back) when the positioning of the nicotine pod assembly 300 allows the first downstream protrusion 130a and the second downstream protrusion 130b of the device body 100 to engage with the first downstream recess 306a and the second downstream recess 306b, respectively, of the nicotine pod assembly 300 (for example, downstream engagement).

As noted *above*, according to an example embodiment, the mouthpiece 102 is secured to the retention structure 140 (of which the first downstream protrusion 130a and the second downstream protrusion 130b are a part). In such an instance, the retraction of the first downstream protrusion 130a and the second downstream protrusion 130b from the through hole 150 will cause a simultaneous shift of the mouthpiece 102 by a corresponding distance in the same direction (for example, downstream direction). Conversely, the mouthpiece 102 will spring back simultaneously with the first downstream protrusion 130a and the second downstream protrusion 130b when the nicotine pod assembly 300 has been sufficiently inserted to facilitate downstream engagement. In addition to the resilient engagement by the first downstream protrusion 130a and the second downstream protrusion 130b, the distal end of the mouthpiece 102 is configured to also be biased against the nicotine pod assembly 300 (and aligned with the pod outlet 304 so as to form a relatively vapor-tight seal) when the nicotine pod assembly 300 is properly seated within the through hole 150 of the device body 100.

Furthermore, the downstream engagement may produce an audible click and/or a haptic feedback to indicate that the nicotine pod assembly 300 is properly seated within the through hole 150 of the device body 100. When properly seated, the nicotine pod assembly 300 will be connected to the device body 100 mechanically, electrically, and fluidically. Although the non-limiting embodiments herein describe the upstream engagement of the nicotine pod assembly 300 as occurring before the downstream engagement, it should be understood that the pertinent mating, activation, and/or electrical arrangements may be reversed such that the downstream engagement occurs before the upstream engagement.

FIG. 20 is a perspective view of the nicotine pod assembly of FIG. 19 without the connector module. Referring to FIG. 20, the upstream end of the second housing section 308 defines a cavity 310. As noted *above*, the cavity 310 is configured to receive the connector module 320 (for example, via interference fit). In an example embodiment, the cavity 310 is situated between the first upstream recess 312a and the second upstream recess 312b and also situated between the first activation pin 314a and the second activation pin 314b. In the absence of the connector module 320, an insert 342 (FIG. 24) and an absorbent material 346 (FIG. 25) are visible through a recessed opening in the cavity 310. The insert 342 is configured to retain the absorbent material 346. The absorbent material 346 is configured to absorb and hold a quantity of the nicotine pre-vapor formulation released from the nicotine reservoir when the nicotine pod assembly 300 is activated. The insert 342 and the absorbent material 346 will be discussed in more detail herein.

FIG. 21 is a perspective view of the connector module in FIG. 19. FIG. 22 is another perspective view of the connector module of FIG. 21. Referring to FIGS. 21-22, the general framework of the connector module 320 includes a module housing 354 and a face plate 366. In addition, the connector module 320 has a plurality of faces, including an external face and a side face, wherein the external face is adjacent to the side face. In an example embodiment, the external face of the connector module 320 is composed of upstream surfaces of the face plate 366, the first power contact 324a, the second power contact 324b, and the data contacts 326. The side face of the connector module 320 is part of the module housing 354. The side face of the connector module 320 defines a first module inlet 330 and a second module inlet 332. Furthermore, the two lateral faces adjacent to the side face (which are also part of the module housing 354) may include rib structures (for example, crush ribs) configured to facilitate an interference fit when the connector module 320 is seated within the cavity 310 of the pod body. For instance, each of the two lateral faces may include a pair of rib structures that taper away from the face plate 366. As a result, the module housing 354 will encounter increasing resistance via the friction of the rib structures against the lateral walls of the cavity 310 as the connector module 320 is pressed into the cavity 310 of the pod body. When the connector module 320 is seated within the cavity 310, the face plate 366 may be substantially flush with the upstream end of the second housing section 308. Also, the side face (which defines the first module inlet 330 and the second module inlet 332) of the connector module 320 will be facing a sidewall of the cavity 310.

The face plate 366 of the connector module 320 may have a grooved edge 328 that, in combination with a corresponding side surface of the cavity 310, defines the pod inlet 322. However, it should be understood that example embodiments are not limited thereto. For instance, the face plate 366 of the connector module 320 may be alternatively configured so as to entirely define the pod inlet 322. The side face (which defines the first module inlet 330 and the second module inlet 332) of the connector module 320 and the sidewall of the cavity 310 (which faces the side face) define an intermediate space in between. The intermediate space is downstream from the pod inlet 322 and upstream from the first module inlet 330 and the second module inlet 332. Therefore, in an example embodiment, the pod inlet 322 is in fluidic communication with both the first module inlet 330 and the second module inlet 332 via the intermediate space. The first module inlet 330 may be larger than the second module inlet 332. In such an instance, when incoming air is received by the pod inlet 322 during vaping, the first module inlet 330 may receive a primary flow (for example, larger flow) of the incoming air, while the second module inlet 332 may receive a secondary flow (for example, smaller flow) of the incoming air.

As shown in FIG. 22, the connector module 320 includes a wick 338 that is configured to transfer a nicotine pre-vapor formulation to a heater 336. The heater 336 is configured to heat the nicotine pre-vapor formulation during vaping to generate a vapor. The heater 336 may be mounted in the connector module 320 via a contact core 334. The heater 336 is electrically connected to at least one electrical contact of the connector module 320. For instance, one end (for example, first end) of the heater 336 may be connected to the first power contact 324a, while the other end (for example, second end) of the heater 336 may be connected to the second power contact 324b. In an example embodiment, the heater 336 includes a folded heating element. In such an instance, the wick 338 may have a planar form configured to be held by the folded heating element. When the connector module 320 is seated within the cavity 310 of the pod body, the wick 338 is configured to be in fluidic communication with the absorbent material 346 such that the nicotine pre-vapor formulation that will be in the absorbent material 346 (when the nicotine pod assembly 300 is activated) will be transferred to the wick 338 via capillary action.

FIG. 23 is an exploded view involving the wick, heater, electrical leads, and contact core in FIG. 22. Referring to FIG. 23, the wick 338 may be a fibrous pad or other structure with pores/interstices designed for capillary action. In addition, the wick 338 may have a shape of an irregular hexagon, although example embodiments are not limited thereto. The wick 338 may be fabricated into the hexagonal shape or cut from a larger sheet of material into this shape. Because the lower section of the wick 338 is tapered towards the winding section of the heater 336, the likelihood of the nicotine pre-vapor formulation being in a part of the wick 338 that continuously evades vaporization (due to its distance from the heater 336) can be reduced or avoided.

In an example embodiment, the heater 336 is configured to undergo Joule heating (which is also known as ohmic/resistive heating) upon the application of an electric current thereto. Stated in more detail, the heater 336 may be formed of one or more conductors and configured to produce heat when an electric current passes therethrough. The electric current may be supplied from a power source (for example, battery) within the device body 100 and conveyed to the heater 336 via the first power contact 324a and the first electrical lead 340a (or via the second power contact 324b and the second electrical lead 340b).

Suitable conductors for the heater 336 include an iron-based alloy (for example, stainless steel) and/or a nickel-based alloy (for example, nichrome). The heater 336 may be fabricated from a conductive sheet (for example, metal, alloy) that is stamped to cut a winding pattern therefrom. The winding pattern may have curved segments alternately arranged with horizontal segments so as to allow the horizontal segments to zigzag back and forth while extending in parallel. In addition, a width of each of the horizontal segments of the winding pattern may be substantially equal to a spacing between adjacent horizontal segments of the winding pattern, although example embodiments are not limited thereto. To obtain the form of the heater 336 shown in the drawings, the winding pattern may be folded so as to grip the wick 338.

The heater 336 may be secured to the contact core 334 with a first electrical lead 340a and a second electrical lead 340b. The contact core 334 is formed of an insulating material and configured to electrically isolate the first electrical lead 340a from the second electrical lead 340b. In an example embodiment, the first electrical lead 340a and the second electrical lead 340b each define a female aperture that is configured to engage with corresponding male members of the contact core 334. Once engaged, the first end and the second end of the heater 336 may be secured (for example, welded, soldered, brazed) to the first electrical lead 340a and the second electrical lead 340b, respectively. The contact core 334 may then be seated within a corresponding socket in the module housing 354 (for example, via interference fit). Upon completion of the assembly of the connector module 320, the first electrical lead 340a will electrically connect a first end of the heater 336 with the first power contact 324a, while the second electrical lead 340b will electrically connect a second end of the heater 336 with the second power contact 324b. The heater and associated structures are discussed in more detail in U.S. Application No. 15/729,909, titled “Folded Heater For Nicotine electronic vaping device” (Atty. Dkt. No. 24000-000371-US), filed October 11, 2017, the entire contents of which is incorporated herein by reference.

FIG. 24 is an exploded view involving the first housing section of the nicotine pod assembly of FIG. 17. Referring to FIG. 24, the first housing section 302 includes a vapor channel 316. The vapor channel 316 is configured to receive nicotine vapor generated by the heater 336 and is in fluidic communication with the pod outlet 304. In an example embodiment, the vapor channel 316 may gradually increase in size (for example, diameter) as it extends towards the pod outlet 304. In addition, the vapor channel 316 may be integrally formed with the first housing section 302. A wrap 318, an insert 342, and a seal 344 are disposed at an upstream end of the first housing section 302 to define the nicotine reservoir of the nicotine pod assembly 300. For instance, the wrap 318 may be disposed on the rim of the first housing section 302. The insert 342 may be seated within the first housing section 302 such that the peripheral surface of the insert 342 engages with the inner surface of the first housing section 302 along the rim (for example, via interference fit) such that the interface of the peripheral surface of the insert 342 and the inner surface of the first housing section 302 is fluid-tight (for example, liquid-tight and/or air-tight). Furthermore, the seal 344 is attached to the upstream side of the insert 342 to close off the nicotine reservoir outlets in the insert 342 so as to provide a fluid-tight (for example, liquid-tight and/or air-tight) containment of the nicotine pre-vapor formulation in the nicotine reservoir.

In an example embodiment, the insert 342 includes a holder portion that projects from the upstream side (as shown in FIG. 24) and a connector portion that projects from the downstream side (hidden from view in FIG. 24). The holder portion of the insert 342 is configured to hold the absorbent material 346, while the connector portion of the insert 342 is configured to engage with the vapor channel 316 of the first housing section 302. The connector portion of the insert 342 may be configured to be seated within the vapor channel 316 and, therefore, engage the interior of the vapor channel 316. Alternatively, the connector portion of the insert 342 may be configured to receive the vapor channel 316 and, therefore, engage with the exterior of the vapor channel 316. The insert 342 also defines nicotine reservoir outlets through which the nicotine pre-vapor formulation flows when the seal 344 is punctured (as shown in FIG. 24) during the activation of the nicotine pod assembly 300. The holder portion and the connector portion of the insert 342 may be between the nicotine reservoir outlets (for example, first and second nicotine reservoir outlets), although example embodiments are not limited thereto. Furthermore, the insert 342 defines a vapor conduit extending through the holder portion and the connector portion. As a result, when the insert 342 is seated within the first housing section 302, the vapor conduit of the insert 342 will be aligned with and in fluidic communication with the vapor channel 316 so as to form a continuous path through the nicotine reservoir to the pod outlet 304 for the nicotine vapor generated by the heater 336 during vaping.

The seal 344 is attached to the upstream side of the insert 342 so as to cover the nicotine reservoir outlets in the insert 342. In an example embodiment, the seal 344 defines an opening (for example, central opening) configured to provide the pertinent clearance to accommodate the holder portion (that projects from the upstream side of the insert 342) when the seal 344 is attached to the insert 342. In FIG. 24, it should be understood that the seal 344 is shown in a punctured state. In particular, when punctured by the first activation pin 314a and the second activation pin 314b of the nicotine pod assembly 300, the two punctured sections of the seal 344 will be pushed into the nicotine reservoir as flaps (as shown in FIG. 24), therefore creating two punctured openings (for example, one on each side of the central opening) in the seal 344. The size and shape of the punctured openings in the seal 344 may correspond to the size and shape of the nicotine reservoir outlets in the insert 342. In contrast, when in an unpunctured state, the seal 344 will have a planar form and only one opening (for example, central opening). The seal 344 is designed to be strong enough to remain intact during the normal movement and/or handling of the nicotine pod assembly 300 so as to avoid being prematurely/inadvertently breached. For instance, the seal 344 may be a coated foil (for example, aluminum-backed Tritan).

FIG. 25 is a partially exploded view involving the second housing section of the nicotine pod assembly of FIG. 17. Referring to FIG. 25, the second housing section 308 is structured to contain various elements configured to release, receive, and heat the nicotine pre-vapor formulation. For instance, the first activation pin 314a and the second activation pin 314b are configured to puncture the nicotine reservoir in the first housing section 302 to release the nicotine pre-vapor formulation. Each of the first activation pin 314a and the second activation pin 314b has a distal end that extends through corresponding openings in the second housing section 308. In an example embodiment, the distal ends of the first activation pin 314a and the second activation pin 314b are visible after assembly (for example, FIG. 17), while the remainder of the first activation pin 314a and the second activation pin 314b are hidden from view within the nicotine pod assembly 300. In addition, each of the first activation pin 314a and the second activation pin 314b has a proximal end that is positioned so as to be adjacent to and upstream from the seal 344 prior to activation of the nicotine pod assembly 300. When the first activation pin 314a and the second activation pin 314b are pushed into the second housing section 308 to activate the nicotine pod assembly 300, the proximal end of each of the first activation pin 314a and the second activation pin 314b will advance through the insert 342 and, as a result, puncture the seal

344, which will release the nicotine pre-vapor formulation from the nicotine reservoir. The movement of the first activation pin 314a may be independent of the movement of the second activation pin 314b (and vice versa). The first activation pin 314a and the second activation pin 314b will be discussed in more detail herein.

The absorbent material 346 is configured to engage with the holder portion of the insert 342 (which, as shown in FIG. 24, projects from the upstream side of the insert 342). The absorbent material 346 may have an annular form, although example embodiments are not limited thereto. As depicted in FIG. 25, the absorbent material 346 may resemble a hollow cylinder. In such an instance, the outer diameter of the absorbent material 346 may be substantially equal to (or slightly larger than) the length of the wick 338. The inner diameter of the absorbent material 346 may be smaller than the average outer diameter of the holder portion of the insert 342 so as to result in an interference fit. To facilitate the engagement with the absorbent material 346, the tip of the holder portion of the insert 342 may be tapered. In addition, although hidden from view in FIG. 25, the downstream side of the second housing section 308 may define a concavity configured receive and support the absorbent material 346. An example of such a concavity may be a circular chamber that is in fluidic communication with and downstream from the cavity 310. The absorbent material 346 is configured to receive and hold a quantity of the nicotine pre-vapor formulation released from the nicotine reservoir when the nicotine pod assembly 300 is activated.

The wick 338 is positioned within the nicotine pod assembly 300 so as to be in fluidic communication with the absorbent material 346 such that the nicotine pre-vapor formulation can be drawn from the absorbent material 346 to the heater 336 via capillary action. The wick 338 may physically contact an upstream side of the absorbent material 346 (for example, bottom of the absorbent material 346 based on the view shown in FIG. 25). In addition, the wick 338 may be aligned with a diameter of the absorbent material 346, although example embodiments are not limited thereto.

As illustrated in FIG. 25 (as well as previous FIG. 23), the heater 336 may have a folded configuration so as to grip and establish thermal contact with the opposing surfaces of the wick 338. The heater 336 is configured to heat the wick 338 during vaping to generate a vapor. To facilitate such heating, the first end of the heater 336 may be electrically connected to the first power contact 324a via the first electrical lead 340a, while the second end of the heater 336 may be electrically connected to the second power contact 324b via the second electrical lead 340b. As a result, an electric current may be supplied from a power source (for example, battery) within the device body 100 and conveyed to the heater 336 via the first power contact 324a and the first electrical lead 340a (or via the second power contact 324b and the second electrical lead 340b). The first electrical lead 340a and the second electrical lead 340b (which are shown separately in FIG. 23) may be engaged with the contact core 334 (as shown in FIG. 25). The relevant details of other aspects of the connector module 320, which is configured to be seated within the cavity

310 of the second housing section 308, that have been discussed *above* (for example, in connection with FIGS. 21-22) and will not be repeated in this section in the interest of brevity. During vaping, the nicotine vapor generated by the heater 336 is drawn through the vapor conduit of the insert 342, through the vapor channel 316 of the first housing section 302, out the pod outlet 304 of the nicotine pod assembly 300, and through the vapor passage 136 of the mouthpiece 102 to the one or more vapor outlets.

FIG. 26 is an exploded view of the activation pin in FIG. 25. Referring to FIG. 26, the activation pin may be in the form of a first activation pin 314a and a second activation pin 314b. While two activation pins are shown and discussed in connection with the non-limiting embodiments herein, it should be understood that, alternatively, the nicotine pod assembly 300 may include only one activation pin. In FIG. 26, the first activation pin 314a may include a first blade 348a, a first actuator 350a, and a first O-ring 352a. Similarly, the second activation pin 314b may include a second blade 348b, a second actuator 350b, and a second O-ring 352b.

In an example embodiment, the first blade 348a and the second blade 348b are configured to be mounted or attached to upper portions (for example, proximal portions) of the first actuator 350a and the second actuator 350b, respectively. The mounting or attachment may be achieved via a snap-fit connection, an interference fit (for example, friction fit) connection, an adhesive, or other suitable coupling technique. The top of each of the first blade 348a and the second blade 348b may have one or more curved or concave edges that taper upward to a pointed tip. For instance, each of the first blade 348a and the second blade 348b may have two pointed tips with a concave edge therebetween and a curved edge adjacent to each pointed tip. The radii of curvature of the concave edge and the curved edges may be the same, while their arc lengths may differ. The first blade 348a and the second blade 348b may be formed of a sheet metal (for example, stainless steel) that is cut or otherwise shaped to have the desired profile and bent to its final form. In another instance, the first blade 348a and the second blade 348b may be formed of plastic.

Based on a plan view, the size and shape of the first blade 348a, the second blade 348b, and portions of the first actuator 350a and the second actuator 350b on which they are mounted may correspond to the size and shape of the nicotine reservoir outlets in the insert 342. Additionally, as shown in FIG. 26, the first actuator 350a and the second actuator 350b may include projecting edges (for example, curved inner lips which face each other) configured to push the two punctured sections of the seal 344 into the nicotine reservoir as the first blade 348a and the second blade 348b advance into the nicotine reservoir. In a non-limiting embodiment, when the first activation pin 314a and the second activation pin 314b are fully inserted into the nicotine pod assembly 300, the two flaps (from the two punctured sections of the seal 344, as shown in FIG. 24) may be between the curved sidewalls of the nicotine reservoir outlets of the insert 342 and the corresponding curvatures of the projecting edges of the first actuator 350a and the second actuator 350b. As a result, the likelihood of the two punctured openings in the seal 344 becoming obstructed (by the two flaps from the two punctured sections) may be reduced or prevented. Furthermore, the first actuator 350a and the second actuator 350b may be configured to guide the nicotine pre-vapor formulation from the nicotine reservoir toward the absorbent material 346.

The lower portion (for example, distal portion) of each of the first actuator 350a and the second actuator 350b is configured to extend through a bottom section (for example, upstream end) of the second housing section 308. This rod-like portion of each of the first actuator 350a and the second actuator 350b may also be referred to as the shaft. The first O-ring 352a and the second O-ring 352b may be seated in annular grooves in the respective shafts of the first actuator 350a and the second actuator 350b. The first O-ring 352a and the second O-ring 352b are configured to engage with the shafts of the first actuator 350a and the second actuator 350b as well as the inner surfaces of the corresponding openings in the second housing section 308 in order to provide a fluid-tight seal. As a result, when the first activation pin 314a and the second activation pin 314b are pushed inward to activate the nicotine pod assembly 300, the first O-ring 352a and the second O-ring 352b may move together with the respective shafts of the first actuator 350a and the second actuator 350b within the corresponding openings in the second housing section 308 while maintaining their respective seals, thereby helping to reduce or prevent leakage of the nicotine pre-vapor formulation through the openings in the second housing section 308 for the first activation pin 314a and the second activation pin 314b. The first O-ring 352a and the second O-ring 352b may be formed of silicone.

FIG. 27 is a perspective view of the connector module of FIG. 22 without the wick, heater, electrical leads, and contact core. FIG. 28 is an exploded view of the connector module of FIG. 27. Referring to FIGS. 27-28, the module housing 354 and the face plate 366 generally form the exterior framework of the connector module 320. The module housing 354 defines the first module inlet 330 and a grooved edge 356. The grooved edge 356 of the module housing 354 exposes the second module inlet 332 (which is defined by the bypass structure 358). However, it should be understood that the grooved edge 356 may also be regarded as defining a module inlet (for example, in combination with the face plate 366). The face plate 366 has a grooved edge 328 which, together with the corresponding side surface of the cavity 310 of the second housing section 308, defines the pod inlet 322. In addition, the face plate 366 defines a first contact opening, a second contact opening, and a third contact opening. The first contact opening and the second contact opening may be square-shaped and configured to expose the first power contact 324a and the second power contact 324b, respectively, while the third contact opening may be rectangular-shaped and configured to expose the plurality of data contacts 326, although example embodiments are not limited thereto.

The first power contact 324a, the second power contact 324b, a printed circuit board (PCB) 362, and the bypass structure 358 are disposed within the exterior framework formed by the module housing 354 and the face plate 366. The printed circuit board (PCB) 362 includes the plurality of data contacts 326 on its upstream side (which is hidden from view in FIG. 28) and a sensor 364 on its downstream side. The bypass structure 358 defines the second module inlet 332 and a bypass outlet 360.

During assembly, the first power contact 324a and the second power contact 324b are positioned so as to be visible through the first contact opening and the second contact opening, respectively, of the face plate 366. Additionally, the printed circuit board (PCB) 362 is positioned such that the plurality of data contacts 326 on its upstream side are visible through the third contact opening of the face plate 366. The printed circuit board (PCB) 362 may also overlap the rear surfaces of the first power contact 324a and the second power contact 324b. The bypass structure 358 is positioned on the printed circuit board (PCB) 362 such that the sensor 364 is within an air flow path defined by the second module inlet 332 and the bypass outlet 360. When assembled, the bypass structure 358 and the printed circuit board (PCB) 362 may be regarded as being surrounded on at least four sides by the meandering structures of the first power contact 324a and the second power contact 324b. In an example embodiment, the bifurcated ends of the first power contact 324a and the second power contact 324b are configured to electrically connect to the first electrical lead 340a and the second electrical lead 340b.

When incoming air is received by the pod inlet 322 during vaping, the first module inlet 330 may receive a primary flow (for example, larger flow) of the incoming air, while the second module inlet 332 may receive a secondary flow (for example, smaller flow) of the incoming air. The secondary flow of the incoming air may improve the sensitivity of the sensor 364. After exiting the bypass structure 358 through the bypass outlet 360, the secondary flow rejoins with the primary flow to form a combined flow that is drawn into and through the contact core 334 so as to encounter the heater 336 and the wick 338. In a non-limiting embodiment, the primary flow may be 60 – 95 percent (for example, 80 – 90 percent) of the incoming air, while the secondary flow may be 5 – 40 percent (for example, 10 – 20 percent) of the incoming air.

The first module inlet 330 may be a resistance-to-draw (RTD) port, while the second module inlet 332 may be a bypass port. In such a configuration, the resistance-to-draw for the nicotine e-vaping device 500 may be adjusted by changing the size of the first module inlet 330 (rather than changing the size of the pod inlet 322). In an example embodiment, the size of the first module inlet 330 may be selected such that the resistance-to-draw is between 25 – 100 millimetres of water (for example, between 30 – 50 millimetres of water). For instance, a diameter of 1.0 millimetre for the first module inlet 330 may result in a resistance-to-draw of 88.3 millimetres of water. In another instance, a diameter of 1.1 millimetres for the first module inlet 330 may result in a resistance-to-draw of 73.6 millimetres of water. In another instance, a diameter of 1.2 millimetres for the first module inlet 330 may result in a resistance-to-draw of 58.7 millimetres of water. In yet another instance, a diameter of 1.3 millimetres for the first module inlet 330 may result in a resistance-to-draw of 43.8 millimetres of water. Notably, the size of the first module inlet 330, because of its internal arrangement, may be adjusted without affecting the external aesthetics of the nicotine pod assembly 300, thereby allowing for a more standardized product design for pod assemblies with various resistance-to-draw (RTD) while also reducing the likelihood of an inadvertent blockage of the incoming air.

FIG. 29 illustrates electrical systems of a device body and a nicotine pod assembly of a nicotine e-vaping device according to one or more example embodiments.

Referring to FIG. 29, the electrical systems include a device body electrical system 2100 and a nicotine pod assembly electrical system 2200. The device body electrical system 2100 may be included in the device body 100, and the nicotine pod assembly electrical system 2200 may be included in the nicotine pod assembly 300 of the nicotine e-vaping device 500 discussed above with regard to FIGS. 1-28.

In the example embodiment shown in FIG. 29, the nicotine pod assembly electrical system 2200 includes the heater 336, one or more pod sensors 2220 and a non-volatile memory (NVM) 2205. The NVM 2205 may be an electrically erasable programmable read-only memory (EEPROM) integrated circuit (IC). The one or more pod sensors 2220 may include a temperature sensing transducer.

The nicotine pod assembly electrical system 2200 may further include a body electrical/data interface (not shown) for transferring power and/or data between the device body 100 and the nicotine pod assembly 300. According to at least one example embodiment, the electrical contacts 324a, 324b and 326 shown in FIG. 17, for example, may serve as the body electrical/data interface.

The device body electrical system 2100 includes a controller 2105, a power supply 2110, device sensors or measurement circuits 2125, a heating engine control circuit (also referred to as a heating engine shutdown circuit) 2127, vaper indicators 2135, on-product controls 2150 (for example, buttons 118 and 120 shown in FIG. 1), a memory 2130, and a clock circuit 2128. The device body electrical system 2100 may further include a pod electrical/data interface (not shown) for transferring power and/or data between the device body 100 and the nicotine pod assembly 300. According to at least one example embodiment, the device electrical connector 132 shown in FIG. 12, for example, may serve as the pod electrical/data interface.

The power supply 2110 may be an internal power source to supply power to the device body 100 and the nicotine pod assembly 300 of the nicotine e-vaping device 500. The supply of power from the power supply 2110 may be controlled by the controller 2105 through power control circuitry (not shown). The power control circuitry may include one or more switches or transistors to regulate power output from the power supply 2110. The power supply 2110 may be a Lithium-ion battery or a variant thereof (for example, a Lithium-ion polymer battery).

The controller 2105 may be configured to control overall operation of the nicotine e-vaping device 500. According to at least some example embodiments, the controller 2105 may include processing circuitry such as hardware including logic circuits; a hardware/software combination such as a processor executing software; or a combination thereof. For example, the processing circuitry more specifically may include, but is not limited to, a central processing unit (CPU) , an arithmetic logic unit (ALU), a digital signal processor, a microcomputer, a field programmable gate array (FPGA), a System-on-Chip (SoC), a programmable logic unit, a microprocessor, application-specific integrated circuit (ASIC), and so forth.

In the example embodiment shown in FIG. 29, the controller 2105 is illustrated as a microcontroller including: input/output (I/O) interfaces, such as general purpose input/outputs (GPIOs), inter-integrated circuit (I^2C) interfaces, serial peripheral interface bus (SPI) interfaces, or the like; a multichannel analog-to-digital converter (ADC); and a clock input terminal. However, example embodiments should not be limited to this example. In at least one example implementation, the controller 2105 may be a microprocessor.

The controller 2105 is communicatively coupled to the device sensors 2125, the heating engine control circuit 2127, vaper indicators 2135, the memory 2130, the on-product controls 2150, the clock circuit 2128 and the power supply 2110.

The heating engine control circuit 2127 is connected to the controller 2105 via a GPIO pin. The memory 2130 is connected to the controller 2105 via a SPI pin. The clock circuit 2128 is connected to a clock input pin of the controller 2105. The vaper indicators 2135 are connected to the controller 2105 via an I^2C interface pin and a GPIO pin. The device sensors 2125 are connected to the controller 2105 through respective pins of the multi-channel ADC.

The clock circuit 2128 may be a timing mechanism, such as an oscillator circuit, to enable the controller 2105 to track idle time, vaping length, a combination of idle time and vaping length, or the like, of the nicotine e-vaping device 500. The clock circuit 2128 may also include a dedicated external clock crystal configured to generate the system clock for the nicotine e-vaping device 500.

The memory 2130 may be a non-volatile memory configured to store one or more shutdown logs. In one example, the memory 2130 may store the one or more shutdown logs in one or more tables. The memory 2130 and the one or more shutdown logs stored therein will be discussed in more detail later. In one example, the memory 2130 may be an electrically erasable programmable read-only memory (EEPROM), such as a flash memory or the like.

Still referring to FIG. 29, the device sensors 2125 may include a plurality of sensor or measurement circuits configured to provide signals indicative of sensor or measurement information to the controller 2105. In the example shown in FIG. 29, the device sensors 2125 include a heater current measurement circuit 21258, a heater voltage measurement circuit 21252, and a pod temperature measurement circuit 21250.

The heater current measurement circuit 21258 may be configured to output (for example, voltage) signals indicative of the current through the heater 336. An example embodiment of the heater current measurement circuit 21258 will be discussed in more detail later with regard to FIG. 35.

The heater voltage measurement circuit 21252 may be configured to output (for example, voltage) signals indicative of the voltage across the heater 336. An example embodiment of the heater voltage measurement circuit 21252 will be discussed in more detail later with regard to FIG. 34.

The pod temperature measurement circuit 21250 may be configured to output (for example, voltage) signals indicative of the resistance and/or temperature of one or more elements of the nicotine pod assembly 300. Example embodiments of the pod temperature measurement circuit 21250 will be discussed in more detail later with regard to FIGS. 36 and 37.

As discussed above, the pod temperature measurement circuit 21250, the heater current measurement circuit 21258 and the heater voltage measurement circuit 21252 are connected to the controller 2105 via pins of the multi-channel ADC. To measure characteristics and/or parameters of the nicotine e-vaping device 500 (for example, voltage, current, resistance, temperature, or the like, of the heater 336), the multi-channel ADC at the controller 2105 may sample the output signals from the device sensors 2125 at a sampling rate appropriate for the given characteristic and/or parameter being measured by the respective device sensor.

Although not shown in FIG. 29, the pod sensors 2220 may also include the sensor 364 shown in FIG. 28. In at least one example embodiment, the sensor 364 may be a microelectromechanical system (MEMS) flow or pressure sensor or another type of sensor configured to measure air flow such as a hot-wire anemometer.

The heating engine control circuit 2127 is connected to the controller 2105 via a GPIO pin. The heating engine control circuit 2127 is configured to control (enable and/or disable) the heating engine of the nicotine e-vaping device 500 by controlling power to the heater 336. As discussed in more detail later, the heating engine control circuit 2127 may disable the heating engine based on control signaling (sometimes referred to herein as device power state signals) from the controller 2105.

When the nicotine pod assembly 300 is inserted into the device body 100, the controller 2105 is also communicatively coupled to at least the NVM 2205 and the pod sensors 2220 via the I^2C interface. In one example, the controller 2105 may obtain operating parameters for the nicotine pod assembly electrical system 2200 from the NVM 2205.

The controller 2105 may control the vaper indicators 2135 to indicate statuses and/or operations of the nicotine e-vaping device 500 to an adult vaper. The vaper indicators 2135 may be at least partially implemented via a light guide (for example, the light guide arrangement shown in FIG. 1), and may include a power indicator (for example, LED) that may be activated when the controller 2105 senses a button pressed by the adult vaper. The vaper indicators 2135 may also include a vibrator, speaker, or other feedback mechanisms, and may indicate a current state of an adult vaper-controlled vaping parameter (for example, nicotine vapor volume).

Still referring to FIG. 29, the controller 2105 may control power to the heater 336 to heat the nicotine pre-vapor formulation in accordance with a heating profile (for example, heating based on volume, temperature, flavor, or the like). The heating profile may be determined based on empirical data and may be stored in the NVM 2205 of the nicotine pod assembly 300.

FIG. 30 is a simple block diagram illustrating a dry puff and auto shutdown control system 2300 according to example embodiments. For brevity, the dry puff and auto shutdown control system 2300 may be referred to herein as the auto shutdown control system 2300.

The auto shutdown control system 2300 shown in FIG. 30 may be implemented at the controller 2105. In one example, the auto shutdown control system 2300 may be implemented as part of a device manager Finite State Machine (FSM) software implementation executed at the controller 2105. In the example shown in FIG. 30, the auto shutdown control system 2300 includes a dryness detection module 2610. It should be understood, however, that the auto shutdown control system 2300 may include various other sub-system modules.

Referring to FIG. 30, the auto shutdown control system 2300, and more generally the controller 2105, may identify dry puff conditions at the nicotine e-vaping device 500, and cause the controller 2105 to control one or more sub-systems of the nicotine e-vaping device 500 to perform one or more consequent actions in response to identifying the dry puff conditions. Dry puff conditions may sometimes be referred to as a dry puff fault or dry puff fault condition. Identification of dry puff conditions may be based on information and/or input such as threshold parameters for the nicotine pod assembly 300, pod sensor information from one or more pod sensors 2220, sensor information from one or more sensors 2125 of the device body electrical system 2100, any combination thereof, or the like. Dry puff conditions are an example of a hard pod fault event at the nicotine e-vaping device 500. A hard fault pod event is an event that may require corrective action (for example, replacement of a nicotine pod assembly) to re-enable vaping functions at the nicotine e-vaping device 500.

The controller 2105 may control the one or more sub-systems by outputting one or more control signals (or asserting or de-asserting a respective signal) as will be discussed in more detail later. In some cases, the control signals output from the controller 2105 may be referred to as device power state signals, device power state instructions or device power control signals. In at least one example embodiment, the controller 2105 may output one or more control signals to the heating engine control circuit 2127 to shutdown vaping functions at the nicotine e-vaping device 500 in response to detecting dry puff conditions at the nicotine e-vaping device 500.

According to one or more example embodiments, the type of consequent actions at the nicotine e-vaping device 500 may be based on the dry puff conditions and/or the current operation of the nicotine e-vaping device 500. Multiple consequent actions may be performed serially in response to a fault event, such as dry puff conditions. In one example, consequent actions may include:

an auto-off operation in which the nicotine e-vaping device 500 switches to a low power state (for example, equivalent to turning the nicotine e-vaping device off using the power button);

a heater-off operation in which power to the heater 336 is cut off or disabled, ending the current puff, but otherwise remaining ready for vaping; or

a vaping-off operation in which the vaping sub-system is disabled (for example, by disabling all power to the heater 336), thereby preventing vaping until a corrective action is taken (for example, replacing the nicotine pod assembly).

As mentioned above, the auto shutdown control system 2300 includes a dryness detection sub-system 2610 (also referred to as a dryness detection sub-system module, circuit or circuitry). Through the dryness detection sub-system 2610, the controller 2105 monitors the wetness (or dryness) of the wick 338 to detect the presence of dry puff conditions at the nicotine e-vaping device 500. As mentioned above, when dry puff conditions are detected, the controller 2105 may shutdown or disable one or more sub-systems or elements of the nicotine e-vaping device 500.

In at least one example embodiment, the controller 2105 monitors the wetness of the wick 338 based on a percent change in resistance of the heater 336 over time during vaping. In at least one example embodiment, the controller 2105 may receive one or more signals indicative of a resistance of the heater 336 from the pod temperature measurement circuit 21250.

In another example embodiment, the controller 2105 may calculate the resistance of the heater 336 based on signals from the heater current measurement circuit 21258 and/or the heater voltage measurement circuit 21252.

According to one or more example embodiments, if the percent change in resistance of the heater 336 over a time window exceeds a percent change in resistance threshold, then the controller 2105 determines that dry puff conditions exist (for example, the wick 338 is dry) at the nicotine e-vaping device 500. The controller 2105 may obtain the percent change in resistance threshold value from the NVM 2205 in the nicotine pod assembly electrical system 2200. The percent change in resistance threshold may be set by a manufacturer of the nicotine pod assembly 300 based on empirical data, the nicotine pre-vapor formulation, the construction of the heater 336, a sub-combination thereof, a combination thereof, or the like. According to at least some example embodiments, the percent change in resistance threshold may be between about 0.1 percent and 25.5 percent (in about 0.1 percent increments). In one example, the percent change in resistance may be about 2.0 percent for heaters constructed from 316L grade stainless steel.

In one example, dry puff conditions may exist because nicotine pre-vapor formulation is not being supplied to the wick 338 with a sufficient flow rate to maintain a standard temperature profile for the heater 336. Accordingly, the percent change in resistance may be indicative of a rate of flow of the nicotine pre-vapor formulation to the wick 338, and the dryness detection sub-system 2610 may be characterized as being configured to determine whether dry puff conditions exist based on the rate of flow of nicotine pre-vapor formulation to the wick 338. Moreover, dry puff conditions may result from depletion of nicotine pre-vapor formulation in the nicotine pod assembly 300. Accordingly, detection of dry puff conditions may also be indicative of a depleted and/or empty nicotine pod assembly.

The controller 2105 may utilize a sliding measurement window of N samples of resistance of the heater 336 such that the determination is made over a most recent time slice during vaping. This enables the controller 2105 to accommodate relatively long applications of negative pressure by an adult vaper, while also providing for more rapid detections of dry puff conditions, wherein the resistance of the heater 336 begins to change relatively rapidly while negative pressure is applied.

In response to detecting dry puff conditions, the controller 2105 may control the heating engine control circuit 2127 to cut-off power to the heater 336 (heater-off) and/or disable vaping at the nicotine e-vaping device 500 (vaping-off).

According to at least one example embodiment, a first-in-first-out (FIFO) memory storing about 100 samples (N = 100) may be used to set a sliding measurement window of about 100 milliseconds (ms) in which the resistance of the heater 336 is periodically updated (for example, recalculated) on a 1 ms ‘tick’. The FIFO memory may be internal to the controller 2105 or included in the memory 2130 shown in FIG. 29.

According to at least some example embodiments, the sliding window may not begin until the resistance measurement of the heater 336 becomes relatively stable, or else spurious values inserted in the FIFO may cause false positives later in the process. The resistance measurement is considered to be relatively stable when the resistance measurement reaches an operating condition where the expected measurement error is less than the percent change in resistance threshold. In one example, the resistance of the heater 336 may become relatively stable once the current flowing through the heater 336 exceeds a ‘wetting’ current threshold (for example, about 100 milliamps (mA)). The controller 2105 may determine that a 'wetting' current threshold has been achieved by monitoring the current through the heater 336 based on signals from the heater current measurement circuit 21258.

FIG. 31 is a flow chart illustrating a dryness detection method according to example embodiments. For example purposes, the flow chart shown in FIG. 31 will be discussed with regard to the electrical systems shown in FIG. 29. It should be understood, however, that example embodiments should not be limited to this example. Rather, example embodiments may be applicable to other nicotine e-vaping devices and electrical systems thereof. Moreover, the example embodiment shown in FIG. 31 will be described with regard to operations performed by the controller 2105. However, it should be understood that the example embodiment may be described similarly with regard to the auto shutdown control system 2300 and/or the dryness detection sub-system 2610 performing one or more of the functions/operations shown in FIG. 31.

Referring to FIG. 31, when the nicotine pod assembly 300 is inserted into the device body 100 and the nicotine e-vaping device 500 is powered on, at step S2702 the controller 2105 obtains the percent change in resistance threshold (also referred to as a percent resistance change parameter) Δ%R_THRESHOLD stored in the NVM 2205 at the nicotine pod assembly electrical system 2200.

At step S2704, the controller 2105 determines whether vaping conditions exist at the nicotine e-vaping device 500. According to at least one example embodiment, the controller 2105 may determine whether vaping conditions exist at the nicotine e-vaping device 500 based on output from the sensor 364. In one example, if the output from the sensor 364 indicates application of negative pressure above a threshold at the mouthpiece 102 of the nicotine e-vaping device 500, then the controller 2105 may determine that vaping conditions exist at the nicotine e-vaping device 500.

If the controller 2105 detects vaping conditions at step S2704, then at step S2705 the controller 2105 controls the heating engine control circuit 2127 to apply power to the heater 336 for vaping. Example control of the heating engine control circuit 2127 to apply power to the heater 336 will be discussed in more detail later with regard to FIGS. 38 and 39.

At step S2706, the controller 2105 determines whether the resistance of the heater 336 has stabilized. As mentioned above, the controller 2105 may determine that the resistance of the heater 336 has stabilized once the current through the heater 336 reaches a 'wetting' current threshold (for example, about 100 milliamps (mA)). The controller 2105 may determine that the current through the heater 336 has reached the 'wetting' current threshold based on output signals from the heater current measurement circuit 21258.

If the controller 2105 determines that the resistance of the heater 336 has stabilized at step S2706, then the controller 2105 begins storing resistance measurements for the heater 336 in the FIFO memory at 1 ms intervals (at a 1 ms 'tick').

At step S2710, the controller 2105 determines whether the FIFO memory is full (for example, a threshold number of samples have been collected). In one example, the FIFO memory may be full when about 100 samples of the resistance of the heater 336 have been stored (for example, about 100 ms after the resistance of the heater 336 is determined to have stabilized at step S2706).

If the controller 2105 determines that the FIFO memory is full, then at step S2712 the controller 2105 calculates the percent change in resistance Δ%R between the first resistance value R_{t_0} (at t_0) and a last (most recent) resistance value R_{t_N-1}(at time t_{N-1}) stored in the FIFO memory.

At step S2714, the controller 2105 compares the calculated percent change in resistance Δ%R with the percent change in resistance threshold Δ%R_THRESHOLD obtained from the NVM 2205 at step S2702.

If the calculated percent change in resistance Δ%R is greater than the percent change in resistance threshold Δ%R_THRESHOLD, then at step S2716 the controller 2105 controls the heating engine control circuit 2127 to shutdown (for example, cut power to) the heater 336. In one example, the controller 2105 may control the heating engine control circuit 2127 to perform a vaping-off operation. As mentioned above, the vaping-off operation may disable all energy to the heater 336, thereby preventing vaping until corrective action is taken (for example, by an adult vaper). As discussed in more detail later, the controller 2105 may control the heating engine control circuit 2127 to disable all energy to the heater 336 by outputting a vaping shutdown signal COIL_SHDN having a logic high level (FIG. 38) and/or by de-asserting (or stopping output of) a vaping enable signal COIL_VGATE_PWM (FIG. 39). In at least one example, at least the vaping enable signal COIL_VGATE_PWM may be a pulse width modulation (PWM) signal. Example corrective action will also be discussed in more detail later.

Returning to step S2714, if the calculated percent change in resistance Δ%R is less than or equal to the percent change in resistance threshold Δ%R_THRESHOLD, then the process returns to S2708 and continues as discussed above.

Returning to step S2710, if the controller 2105 determines that the FIFO memory is not yet full, then the process returns to step S2708 and continues as discussed above.

Returning to step S2706, if the controller 2105 determines that the resistance of the heater 336 has not yet stabilized, then the controller 2105 continues to monitor the resistance of the heater 336. Once the resistance of the heater 336 has stabilized, the process proceeds to step S2708 and continues as discussed above.

Returning to step S2704, if the controller 2105 determines that vaping conditions are not yet present, then the controller 2105 continues to monitor output of the sensor 364 for vaping conditions. Once vaping conditions are detected, the process continues as discussed above.

FIG. 32 illustrates graphs of resistance versus time when dry puff conditions exist at the start of a puff ('Dry Puff'), when dry puff conditions occur during a puff ('Drying Puff'), and when dry puff conditions are not present ('Standard Puff').

As shown in FIG. 32, when dry puff conditions exist at the start of a puff, the resistance increases more sharply over time. In this example, the controller 2105 may shutdown the vaping function of the nicotine e-vaping device 500 at the end of the initial sampling interval (for example, about 100 ms) because the percent change in resistance Δ%R of the heater 336 at the end of the initial time interval is greater than the percent change in resistance threshold Δ%R_THRESHOLD.

When dry puff conditions begin to present during a puff, the heater resistance begins to increase more sharply (the slope of the graph increases). In this case, the controller 2105 shuts down the vaping function at time $t_{SHUTOFF}$ when the percent change in resistance Δ%R of the heater 336 between the oldest heater resistance and the most recent heater resistance in the FIFO exceeds the percent change in resistance threshold Δ%R_THRESHOLD.

When dry puff conditions are not present (standard puff conditions exist), the puff ends and power to the heater 336 is cut-off in response to stopping of application of negative pressure or after expiration of a threshold time interval. In this case, a heater-off operation, rather than a vaping-off operation, may be performed.

As mentioned above, dry puff conditions are an example of a hard pod fault event at the nicotine e-vaping device 500.

FIG. 33 is a flow chart illustrating an example method of operation of a nicotine e-vaping device after shutdown of the vaping function (a vaping-off operation) in response to detecting a hard fault pod event, such as dry puff conditions, according to example embodiments. For example purposes, the example embodiment shown in FIG. 33 will be discussed with regard to dry puff conditions. However, example embodiments should not be limited to this example.

Also for example purposes, the flow chart shown in FIG. 33 will be discussed with regard to the electrical systems shown in FIG. 29. It should be understood, however, that example embodiments should not be limited to this example. Rather, example embodiments may be applicable to other nicotine e-vaping devices and electrical systems thereof. Moreover, the example embodiment shown in FIG. 33 will be described with regard to operations performed by the controller 2105. However, it should be understood that the example embodiment may be described similarly with regard to the auto shutdown control system 2300 and/or the dryness detection sub-system 2610 performing one or more of the functions/operations shown in FIG. 33.

Referring to FIG. 33, at step S3804 the controller 2105 logs the occurrence of the dry puff conditions in the memory 2130. In one example, the controller 2105 may store an identifier of the event (dry puff conditions or a dry puff event) in association with the consequent action (for example, the vaping-off operation) and the time at which the event and consequent action occurred.

At step S3806, the controller 2105 controls the vaper indicators 2135 to output an indication that dry puff conditions have been detected. In one example, the indication may be in the form of a sound, visual display and/or haptic feedback to an adult vaper. For example, the indication may be a blinking red LED, a software message containing an error code that is sent (for example, via Bluetooth) to a connected "App" on a remote electronic device, which may subsequently trigger a notification in the App providing information on a corrective action to the adult vaper, any combination thereof, or the like.

At step S3808, the controller 2105 determines whether the nicotine pod assembly 300 has been removed (corrective action) from the device body 100 within (prior to expiration of) a removal threshold time interval after (for example, in response to) indicating the dry puff conditions to the adult vaper. In at least one example embodiment, the controller 2105 may determine that the nicotine pod assembly 300 has been removed from the device body 100 digitally by checking that the set of five contacts 326 of the nicotine pod assembly have been removed. In another example, the controller 2105 may determine that the nicotine pod assembly has been removed from the device body 100 by sensing that the electrical contacts 324a, 324b and/or 326 of the nicotine pod assembly 300 have been disconnected from the device electrical connector 132 of the device body 100. In at least one example, the controller 2105 may sense that the electrical contacts 324a, 324b and/or 326 of the nicotine pod assembly 300 have been disconnected from the device electrical connector 132 of the device body 100 by detecting an infinite resistance between the electrical contacts 324a, 324b and/or 326 of the nicotine pod assembly 300 and the device electrical connector 132 of the device body 100.

If the controller 2105 determines that the nicotine pod assembly 300 has been removed from the device body 100 within the removal threshold time interval after (for example, in response to) indicating the dry puff conditions to the adult vaper, then at step S3814 the controller 2105 controls the nicotine e-vaping device 500 to return to normal operation (a non-fault state). In this case, although energy to the heater 336 is still disabled because the nicotine pod assembly 300 has been removed, the nicotine e-vaping device 500 is otherwise ready to vape in response to application of negative pressure by an adult vaper once a new nicotine pod assembly has been inserted.

At step S3812, the controller 2105 determines whether a new nicotine pod assembly has been inserted into the device body 100 within (prior to expiration of) an insert threshold time interval after removal of the nicotine pod assembly 300 and returning of the nicotine e-vaping device 500 to normal operation at step S3814. In at least one example, the insert threshold time interval may have a length between about 5 minutes and about 120 minutes. The insert threshold time interval may be set to a length within this range by an adult vaper. In at least one example embodiment, the controller 2105 may determine that a new nicotine pod assembly has been inserted into the device body 100 by sensing the resistance of the heater 336 (for example, between about 0.5 Ohms to about 5.0 Ohms) between the electrical contacts 324a and 324b of the nicotine pod assembly 300 and the device electrical connector 132 of the device body 100. In a further example embodiment, the controller 2105 may determine that a new nicotine pod assembly has been inserted into the device body 100 by sensing the presence of a pull-up resistor contained in the nicotine pod assembly 300 between the electrical contacts 326 of the nicotine pod assembly 300 and the device electrical connector 132 of the device body 100.

If the controller 2105 determines that a new nicotine pod assembly has been inserted into the device body 100 within the insert threshold time interval, then at step S3810 the controller 2105 controls the heating engine control circuit 2127 to re-enable the vaping module (for example, enable application of power to the heater 336). As discussed in more detail later, the controller

2105 may control the heating engine control circuit 2127 to re-enable the vaping module by outputting the vaping shutdown signal COIL_SHDN having a logic low level (FIG. 38) and/or asserting the vaping enable signal COIL_VGATE_PWM (FIG. 39).

Returning to step S3812, if the controller 2105 determines that a new nicotine pod assembly has not been inserted into the device body 100 within the insert threshold time interval, then at step S3816 the controller 2105 outputs another one or more control signals to perform an auto-off operation, in which the nicotine e-vaping device 500 is powered off or enters a low-power mode. According to at least some example embodiments, in the context of a normal software auto-off the controller 2105 may output a multitude or plurality of GPIO control lines (signals) to turn off all or substantially all peripherals of the nicotine e-vaping device 500 and cause the controller 2105 to enter a sleep state.

Returning now to step S3808, if the nicotine pod assembly 300 is not removed within the removal threshold time interval, then the process proceeds to step S3816 and continues as discussed above.

FIG. 34 illustrates an example embodiment of the heater voltage measurement circuit 21252.

Referring to FIG. 34, the heater voltage measurement circuit 21252 includes a resistor 3702 and a resistor 3704 connected in a voltage divider configuration between a terminal configured to receive an input voltage signal COIL_OUT and ground. The input voltage signal COIL_OUT is the voltage input to (voltage at the input terminal of) the heater 336. A node N3716 between the resistor 3702 and the resistor 3704 is coupled to a positive input of an operational amplifier (Op-Amp) 3708. A capacitor 3706 is connected between the node N3716 and ground to form a low-pass filter circuit (an R/C filter) to stabilize the voltage input to the positive input of the Op-Amp 3708. The filter circuit may also reduce inaccuracy due to switching noise induced by PWM signals used to energize the heater 336, and have the same phase response/group delay for both current and voltage.

The heater voltage measurement circuit 21252 further includes resistors 3710 and 3712 and a capacitor 3714. The resistor 3712 is connected between node N3718 and a terminal configured to receive an output voltage signal COIL_RTN. The output voltage signal COIL_RTN is the voltage output from (voltage at the output terminal of) the heater 336.

Resistor 3710 and capacitor 3714 are connected in parallel between node N3718 and an output of the Op-Amp 3708. A negative input of the Op-Amp 3708 is also connected to node N3718. The resistors 3710 and 3712 and the capacitor 3714 are connected in a low-pass filter circuit configuration.

The heater voltage measurement circuit 21252 utilizes the Op-Amp 3708 to measure the voltage differential between the input voltage signal COIL_OUT and the output voltage signal COIL_RTN, and output a scaled heater voltage measurement signal COIL_VOL that represents the voltage across the heater 336. The heater voltage measurement circuit 21252 outputs the scaled heater voltage measurement signal COIL_VOL to an ADC pin of the controller 2105 for digital sampling and measurement by the controller 2105.

The gain of the Op-Amp 3708 may be set based on the surrounding passive electrical elements (for example, resistors and capacitors) to improve the dynamic range of the voltage measurement. In one example, the dynamic range of the Op-Amp 3708 may be achieved by scaling the voltage so that the maximum voltage output matches the maximum input range of the ADC (for example, about 1.8V). In at least one example embodiment, the scaling may be about 267mV per V, and therefore, the heater voltage measurement circuit 21252 may measure up to about 1.8V/0.267V = 6.74V.

FIG. 35 illustrates an example embodiment of the heater current measurement circuit 21258 shown in FIG. 29.

Referring to FIG. 35, the output voltage signal COIL_RTN is input to a four terminal (4T) measurement resistor 3802 connected to ground. The differential voltage across the four terminal measurement resistor 3802 is scaled by an Op-Amp 3806, which outputs a heater current measurement signal COIL_CUR indicative of the current through the heater 336. The heater current measurement signal COIL_CUR is output to an ADC pin of the controller 2105 for digital sampling and measurement of the current through the heater 336 at the controller 2105.

In the example embodiment shown in FIG. 35, the four terminal measurement resistor 3802 may be used to reduce error in the current measurement using a 'Kelvin Current Measurement' technique. In this example, separation of the current measurement path from the voltage measurement path may reduce noise on the voltage measurement path.

The gain of the Op-Amp 3806 may be set to improve the dynamic range of the measurement. In this example, the scaling of the Op-Amp 3806 may be about 0.577 V/A, and therefore, the heater current measurement circuit 21258 may measure up to about $\frac{1.8\,V}{0.577\,V/A} = 3.12\,A$.

Referring to FIG. 35 in more detail, a first terminal of the four terminal measurement resistor 3802 is connected to a terminal of the heater 336 to receive the output voltage signal COIL_RTN. A second terminal of the four terminal measurement resistor 3802 is connected to ground. A third terminal of the four terminal measurement resistor 3802 is connected to a low-pass filter circuit (R/C filter) including resistor 3804, capacitor 3808 and resistor 3810. The output of the low-pass filter circuit is connected to a positive input of the Op-Amp 3806. The low-pass filter circuit may reduce inaccuracy due to switching noise induced by the PWM signals applied to energize the heater 336, and may also have the same phase response/group delay for both current and voltage.

The heater current measurement circuit 21258 further includes resistors 3812 and 3814 and a capacitor 3816. The resistors 3812 and 3814 and the capacitor 3816 are connected to the fourth terminal of the four terminal measurement resistor 3802, a negative input of the Op-Amp 3806 and an output of the Op-Amp 3806 in a low-pass filter circuit configuration, wherein the output of the low-pass filter circuit is connected to the negative input of the Op-Amp 3806.

The Op-Amp 3806 outputs a differential voltage as the heater current measurement signal COIL_CUR to an ADC pin of the controller 2105 for sampling and measurement of the current through the heater 336 by the controller 2105.

According to at least this example embodiment, the configuration of the heater current measurement circuit 21258 is similar to the configuration of the heater voltage measurement circuit 21252, except that the low-pass filter circuit including resistors 3804 and 3810 and the capacitor 3808 is connected to a terminal of the four terminal measurement resistor 3802 and the low-pass filter circuit including the resistors 3812 and 3814 and the capacitor 3816 is connected to another terminal of the four terminal measurement resistor 3802.

The controller 2105 may average multiple samples (for example, of voltage) over a time window (for example, about 1 ms) corresponding to the ‘tick’ time used in the nicotine e-vaping device 500, and convert the average to a mathematical representation of the voltage and current across the heater 336 through application of a scaling value. The scaling value may be determined based on the gain settings implemented at the respective Op-Amps, which may be specific to the hardware of the nicotine e-vaping device 500.

The controller 2105 may filter the converted voltage and current measurements using, for example, a three tap moving average filter to attenuate measurement noise. The controller 2105 may then use the filtered measurements to calculate: resistance R_{HEATER} of the heater 336 $\left(R_{HEATER} = \frac{V_{HEATER}}{I_{HEATER}}\right)$, power P_{HEATER} applied to the heater 336 $(P_{HEATER} = V_{HEATER} * I_{HEATER})$, power supply current $\left(I_{BATT} = \frac{P_{in}}{V_{BATT}}\right)$, where $\left(P_{in} = P_{HEATER} * \frac{1}{Efficiency}\right)$, or the like. *Efficiency* is the ratio of power P_{in} delivered to the heater 336 across all operating conditions. In one example, *Efficiency* may be at least 85 percent.

According to one or more example embodiments, the gain settings of the passive elements of the circuits shown in FIGS. 34 and/or 35 may be adjusted to match the output signal range to the input range of the controller 2105.

FIGS. 36 and 37 illustrate pod temperature measurement circuits according to example embodiments.

Referring to FIG. 36, the pod temperature measurement circuit 21250A includes a driver stage 3902A and a measurement stage 3904A. The driver stage 3902A is configured to generate a pod temperature measurement power signal HW_POWER to deliver power to the pod sensor 2220 in response to a pod temperature measurement control signal HW_ENB. The pod temperature measurement power signal HW_POWER may be a PWM signal. The measurement stage 3904A is configured to generate a pod temperature measurement output signal HW_SIGNAL based on a DAC comparison signal HW_DAC from the DAC (not shown) at the controller 2105 and a pod sensor signal SP_HW from the pod sensor 2220. The pod temperature measurement output signal HW_SIGNAL may be a differential voltage signal indicative of a temperature of one or more elements of the nicotine pod assembly 300. Input to and output from an example embodiment of a pod sensor 2220 will be discussed in more detail later.

In more detail with regard to FIG. 36, the driver stage 3902A receives the pod temperature measurement control signal HW_ENB from the controller 2105. In this example, the pod temperature measurement control signal HW_ENB may be a PWM signal having a duty cycle regulated by the controller 2105 to vary power based on the pod sensor signal SP_HW from the pod sensor 2220. When the pod temperature measurement control signal HW_ENB is asserted (active), the driver stage 3902A may be enabled and output the pod temperature measurement power signal HW_POWER, otherwise the output of the driver stage 3902A may be disabled.

The pod temperature measurement control signal HW_ENB is input into an enable pin EN of a Low Dropout voltage regulator (LDO) U10, which translates the pod temperature measurement control signal HW_ENB, which is a low current drive strength processor signal, into the pod temperature measurement power signal HW_POWER, which is a high current drive strength PWM signal.

A resistor R80 is connected as a pull-down resistor between the enable pin EN of the LDO U10 and ground to ensure that the output of the driver stage 3902A is disabled if the pod temperature measurement control signal HW_ENB is in an indeterminate state.

The driver stage 3902A further includes capacitors C43 and C44. Capacitor C44 is connected to an input pin IN of the LDO U10 and a voltage source to provide a nicotine reservoir and filter, which may improve the speed at which the pod temperature measurement power signal HW_POWER reaches its ON voltage. The capacitor C43 is connected between the output pin and ground to provide filtering and a nicotine reservoir for the pod temperature measurement power signal HW_POWER.

Resistors R60 and R61 form a feedback network 39028 in the form of a voltage divider circuit. The feedback network 39028 outputs a feedback voltage to an adjustment or feedback terminal ADJ of the LDO U10. The LDO U10 sets the precision voltage output of the pod temperature measurement power signal HW_POWER based on the feedback voltage input to the feedback terminal ADJ. According to at least some example embodiments, the relationship between precision voltage output for the pod temperature measurement power signal HW_POWER and the feedback voltage V_{ADJ} output is given by $V_{HW\_POWER} = V_{ADJ}\left(1 + \frac{R_{61}}{R_{60}}\right)$. In this example, the resistances of resistors R60 and R61 have known resistances, and the voltage V_{ADJ} is also known based on the type of the LDO U10.

At the measurement stage 3904A, the pod sensor signal SP_HW from the pod sensor 2220 is input to the negative input of an Op-Amp U11A via resistor R66 to gain scale the voltage of the pod sensor signal SP_HW for measurement by the ADC at the controller 2105. The Op-Amp U11A is an inverting amplifier with a gain set according to the resistance of resistor R66 and a resistance of resistor R67, which is connected between the negative input and the output of the Op-Amp U11A. The capacitor C47 is connected in parallel with resistor R67 to form a low-pass filter circuit to filter out high-frequency noise from the pod sensor signal SP_HW.

The DAC comparison signal HW_DAC from the DAC at the controller 2105 is input to the positive input of the Op-Amp U11A through a voltage divider circuit 39042 including resistors R63 and R64. The DAC comparison signal HW_DAC sets a reference voltage level for the Op-Amp U11A, which in effect selects the differential voltage applied to the Op-Amp U11A and suppresses or prevents saturation of the Op-Amp U11A. In other words, the DAC comparison signal HW_DAC sets an operating point for the Op-Amp U11A to suppress saturation of the pod temperature measurement output signal HW_SIGNAL output by the Op-Amp U11A. The voltage divider 39042 reduces each DAC step in voltage to provide finer control of the range setting. The ratio of the resistors R63 and R64 may approximate the balance resistor and pod sensor 2220 (for example, at its max temperature). A capacitor C46 is connected in parallel with the resistor R64 to form a low-pass filter circuit to filter out noise from the DAC comparison signal HW_DAC. A resistor R69 is connected between the output of the voltage divider 39042 and the positive input of the Op-Amp U11A.

The pod sensor signal SP_HW from the pod sensor 2220 may have a relatively small voltage level (for example, about 2mV), and therefore, the relatively high gain of the Op-Amp U11A may be used to match the pod temperature measurement signal HW_SIGNAL to the dynamic signal range of the ADC at the controller 2105 (for example, about 1.8V). Accordingly, the Op-Amp U11A amplifies the pod sensor signal SP_HW and outputs the amplified signal as the pod temperature measurement output signal HW_SIGNAL to the ADC for sampling and measurement at the controller 2105.

Referring to FIG. 37, the pod temperature measurement circuit 21250B includes a driver stage 3902B and a measurement stage 3904B. In the example embodiment shown in FIG. 37, the driver stage 3902B and the measurement stage 3904B are similar to the driver stage 3902A and the measurement stage 3904A, respectively, shown in FIG. 36, except that the driver stage 3902B further includes a measurement balancing resistor R93 and the capacitance of the capacitor C43 may be reduced in value to increase the rise/fall time of the pod sensor signal SP_HW. In at least one example, the measurement balancing resistor R93 may have a resistance of about 3 Ohms and may be moved from the nicotine pod assembly electrical system

2200 to the device body assembly electrical system 2100 to reduce cost of the nicotine pod assembly 300. Additionally, in at least the example embodiment shown in FIG. 37, the passive elements may be arranged and adjusted to configure the gain settings such that the output signal range is matched to the input signal range of the controller 2105.

FIG. 38 is a circuit diagram illustrating a heating engine control circuit according to some example embodiments. The heating engine control circuit shown in FIG. 38 is an example of the heating engine control circuit 2127 shown in FIG. 29.

Referring to FIG. 38, the heating engine control circuit 2127A includes a CMOS charge pump U2 configured to supply a power rail (for example, about 7V power rail (7V_CP)) to one or more gate driver integrated circuits (ICs) to control the power FETs (heater power control circuitry, also referred to as a heating engine drive circuit or circuitry, not shown in FIG. 38) that energize the heater 336 in the nicotine pod assembly 300.

In example operation, the charge pump U2 is controlled (selectively activated or deactivated) based on the vaping shutdown signal COIL_SHDN (device power state signal; also referred to as a vaping enable signal) from the controller 2105. In the example shown in FIG. 38, the charge pump U2 is activated in response to output of the vaping shutdown signal COIL_SHDN having a logic low level, and deactivated in response to output of the coil shutdown signal COIL-SHDN having a logic high level. Once the power rail 7V_CP has stabilized after activation of the charge pump U2 (for example, after a settling time interval has expired), the controller 2105 may enable the heater activation signal GATE_ON to provide power to the heater power control circuitry and the heater 336.

According to at least one example embodiment, the controller 2105 may perform a vaping-off operation by outputting (enabling) the vaping shutdown signal COIL_SHDN having a logic high level to disable all power to the heater 336 until the vaping shutdown signal COIL_SHDN is disabled (transitioned to a logic low level) by the controller 2105.

The controller 2105 may output the heater activation signal GATE_ON (another device power state signal) having a logic high level in response to detecting the presence of vaping conditions at the nicotine e-vaping device 500. In this example embodiment, the transistors (for example, field-effect transistors (FETs)) Q5 and Q7A' are activated when the controller 2105 enables the heater activation signal GATE_ON to the logic high level. The controller 2105 may output the heater activation signal GATE_ON having a logic low level to disable power to the heater 336, thereby performing a heater-off operation.

If a power stage fault occurs, where the transistors Q5 and Q7A' are unresponsive to the heater activation signal GATE_ON, then the controller 2105 may perform a vaping-off operation by outputting the vaping shutdown signal COIL_SHDN having a logic high level to cut-off power to the gate driver, which in turn also cuts off power to the heater 336.

In another example, if the controller 2105 fails to boot properly resulting in the vaping shutdown signal COIL_SHDN having an indeterminate state, then the heating engine control circuit 2127A automatically pulls the vaping shutdown signal COIL_SHDN to a logic high level to automatically cut-off power to the heater 336.

In more detail with regard to FIG. 38, capacitor C9, charge pump U2 and capacitor C10 are connected in a positive voltage doubler configuration. The capacitor C9 is connected between pins C- and C+ of the charge pump U2 and serves as a nicotine reservoir for the charge pump U2. The input voltage pin VIN of the charge pump U2 is connected to voltage source BATT at node N3801, and capacitor C10 is connected between ground and the output voltage pin VOUT of the charge pump U2 at node N3802. The capacitor C10 provides a filter and nicotine reservoir for the output from the charge pump U2, which may ensure a more stable voltage output from the charge pump U2.

The capacitor C11 is connected between node N3801 and ground to provide a filter and nicotine reservoir for the input voltage to the charge pump U2.

Resistor R10 is connected between a positive voltage source and the shutdown pin SHDN. The resistor R10 serves as a pull-up resistor to ensure that the input to the shutdown pin SHDN is high, thereby disabling the output (VOUT) of the charge pump U2 and cutting off power to the heater 336, when the vaping shutdown signal COIL_SHDN is in an indeterminate state.

Resistor R43 is connected between ground and the gate of the transistor Q7A' at node N3804. The resistor R43 serves as a pull-down resistor to ensure that the transistor Q7A' is in a high impedance (OFF) state, thereby disabling power rail 7V_CP and cutting off power to the heater 336, if the heater activation signal GATE_ON is in an indeterminate state.

Resistor R41 is connected between node N3802 and node N3803 between the gate of the transistor Q5 and the drain of the transistor Q7A'. The resistor R41 serves as a pull-down resistor to ensure that the transistor Q5 switches off more reliably.

Transistor Q5 is configured to selectively isolate the power rail 7V_CP from the VOUT pin of charge pump U2. The gate of the transistor Q5 is connected to node N3803, the drain of the transistor Q5 is connected to the output voltage terminal VOUT of the charge pump U2 at node N3802, and the source of the transistor Q5 serves as the output terminal for the power rail 7V_CP. This configuration allows the capacitor C10 to reach an operating voltage more quickly by isolating the load, and creates a fail-safe insofar as the vaping shutdown signal COIL_SHDN and heater activation signal GATE_ON must both be in the correct state to provide power to the heater 336.

Transistor Q7A is configured to control operation of the transistor Q5 based on the heater activation signal GATE_ON. For example, when the heater activation signal GATE_ON is logic high level (for example, above ~2V), the transistor Q7A in is in its low impedance (ON) state, which pulls the gate of the transistor Q5 to ground thereby resulting in the transistor Q5 transitioning to a low impedance (ON) state. In this case, the heating engine control circuit 2127A outputs the power rail 7V_CP to the heating engine drive circuit (not shown), thereby enabling power to the heater 336.

If the heater activation signal GATE_ON has a logic low level, then transistor Q7A transitions to a high impedance (OFF) state, which results in discharge of the gate of the transistor Q5 through resistor R41, thereby transitioning the transistor Q5 into a high impedance (OFF) state. In this case, the power rail 7V_CP is not output and power to the heating engine drive circuit (and heater 336) is cut-off.

In the example shown in FIG. 38, since the transistor Q5 requires a gate voltage as high as the source voltage (~7V) to be in the high impedance (OFF) state, the controller 2105 does not control the transistor Q5 directly. The transistor Q7A provides a mechanism for controlling the transistor Q5 based on a lower voltage from the controller 2105.

FIG. 39 is a circuit diagram illustrating another heating engine control circuit according to example embodiments. The heating engine control circuit shown in FIG. 39 is another example of the heating engine control circuit 2127 shown in FIG. 29.

Referring to FIG. 39, the heating engine control circuit 2127B includes a rail converter circuit 39020 (also referred to as a boost converter circuit) and a gate driver circuit 39040. The rail converter circuit 39020 is configured to output a voltage signal 9V_GATE (also referred to as a power signal or input voltage signal) to power the gate driver circuit 39040 based on the vaping enable signal COIL_VGATE_PWM (also referred to as a vaping shutdown signal). The rail converter circuit 39020 may be software defined, with the vaping enable signal COIL_VGATE_PWM used to regulate the 9V_GATE output.

The gate driver circuit 39040 utilizes the input voltage signal 9V_GATE from the rail converter circuit 39020 to drive the heating engine drive circuit 3906.

In the example embodiment shown in FIG. 39, the rail converter circuit 39020 generates the input voltage signal 9V_GATE only if the vaping enable signal COIL_VGATE_PWM is asserted (present). The controller 2105 may disable the 9V rail to cut power to the gate driver circuit 39040 by de-asserting (stopping or terminating) the vaping enable signal COIL_VGATE_PWM. Similar to the vaping shutdown signal COIL_SHDN in the example embodiment shown in FIG. 38, the vaping enable signal COIL_VGATE_PWM may serve as a device state power signal for performing a vaping-off operation at the nicotine e-vaping device 500. In this example, the controller 2105 may perform a vaping-off operation by de-asserting the vaping enable signal COIL_VGATE_PWM, thereby disabling all power to the gate driver circuit 39040, heating engine drive circuit 3906 and heater 336. The controller 2105 may then enable vaping at the nicotine e-vaping device 500 by again asserting the vaping enable signal COIL_VGATE_PWM to the rail converter circuit 39020.

Similar to the heater activation signal GATE_ON in FIG. 38, the controller 2105 may output the first heater enable signal GATE_ENB having a logic high level to enable power to the heating engine drive circuit 3906 and the heater 336 in response to detecting vaping conditions at the nicotine e-vaping device 500. The controller 2105 may output the first heater enable signal GATE_ENB having a logic low level to disable power to the heating engine drive circuit 3906 and the heater 336, thereby performing a heater-off operation.

Referring in more detail to the rail converter circuit 39020 in FIG. 39, a capacitor C36 is connected between the voltage source BATT and ground. The capacitor C36 serves as a nicotine reservoir for the rail converter circuit 39020.

A first terminal of inductor L1006 is connected to node Node1 between the voltage source BATT and the capacitor C36. The inductor L1006 serves as the main storage element of the rail converter circuit 39020.

A second terminal of the inductor L1006, a drain of a transistor (for example, an enhancement mode MOSFET) Q1009 and a first terminal of a capacitor C1056 are connected at node Node2. The source of the transistor Q1009 is connected to ground, and the gate of the transistor Q1009 is configured to receive the vaping enable signal COIL_VGATE_PWM from the controller 2105.

In the example shown in FIG. 39, the transistor Q1009 serves as the main switching element of the rail converter circuit 39020.

A resistor R29 is connected between the gate of the transistor Q1009 and ground to act as a pull-down resistor to ensure that transistor Q1009 switches off more reliably and that operation of the heater 336 is prevented when the vaping enable signal COIL_VGATE_PWM is in an indeterminate state.

A second terminal of the capacitor C1056 is connected to a cathode of a Zener diode D1012 and an anode of a Zener diode D1013 at node Node3. The anode of the Zener diode D1012 is connected to ground.

The cathode of the Zener diode D1013 is connected to a terminal of the capacitor C35 and an input of a voltage divider circuit including resistors R1087 and R1088 at node Node4. The other terminal of the capacitor C35 is connected to ground. The voltage at node Node4 is also the output voltage 9V_GATE output from the rail converter circuit 39020.

A resistor R1089 is connected to the output of the voltage divider circuit at node Node5.

In example operation, when the vaping enable signal COIL_VGATE_PWM is asserted and at a logic high level, the transistor Q1009 switches to a low impedance state (ON), thereby allowing current to flow from the voltage source BATT and capacitor C36 to ground through inductor L1006 and transistor Q1009. This stores energy in inductor L1006, with the current increasing linearly over time.

When the vaping enable signal COIL_VGATE_PWM is at a logic low level, the transistor Q1009 switches to a high impedance state (OFF). In this case, the inductor L1006 maintains current flow (decaying linearly), and the voltage at node Node2 rises.

The duty cycle of the vaping enable signal COIL_VGATE_PWM determines the amount of voltage rise for a given load. Accordingly, the vaping enable signal COIL_VGATE_PWM is controlled by the controller 2105 in a closed loop using feedback signal COIL_VGATE_FB output by the voltage divider circuit at node Node5 as feedback. The switching described above occurs at a relatively high rate (for example, about 2 MHz, however different frequencies may be used depending on the parameters required and element values).

Still referring to the rail converter circuit 39020 in FIG. 39, the capacitor C1056 is an AC coupling capacitor that provides a DC block to remove the DC level. The capacitor C1056 blocks current flow from voltage source BATT through the inductor L1006 and the diode D1013 to the gate driver circuit 39040 when the vaping enable signal COIL_VGATE_PWM is low to save battery life (for example, when the nicotine e-vaping device 500 is in a standby mode). The capacitance of the capacitor C1056 may be chosen to provide a relatively low impedance path at the switching frequency.

The Zener diode D1012 establishes the ground level of the switching signal. Since capacitor C1056 removes the DC level, the voltage at node Node3 may normally be bipolar. In one example, the Zener diode D1012 may clamp the negative half cycle of the signal to about 0.3V below ground.

The capacitor C35 serves as the output nicotine reservoir for the rail converter circuit 39020. The Zener diode D1013 blocks current from the capacitor C35 from flowing through capacitor C1056 and transistor Q1009 when the transistor Q1009 is ON.

As the decaying current from inductor L1006 creates a voltage rise at node Node4 between Zener diode D1013 and capacitor C35, current flows into capacitor C35. The capacitor C35 maintains the 9V_GATE voltage while energy is being stored in the inductor L1006.

The voltage divider circuit including resistors R1087 and R1088 reduces the voltage to an acceptable level for measurement at the ADC at the controller 2105. This reduced voltage signal is output as the feedback signal COIL_VGATE_FB.

In the circuit shown in FIG. 39, the feedback signal COIL_VGATE_FB voltage is scaled at about 0.25x, therefore the 9V output voltage is reduced to about 2.25V for input to the ADC at the controller 2105.

The resistor R1089 provides a current limit for an over-voltage fault at the output of the rail converter circuit 39020 (for example, at node Node4) to protect the ADC at the controller 2105.

The 9V output voltage signal 9V_GATE is output from the rail converter circuit 39020 to the gate driver circuit 39040 to power the gate driver circuit 39040.

Referring now to the gate driver circuit 39040 in more detail, the gate driver circuit 39040 includes, among other things, an integrated gate driver U2003 configured to convert one or more low-current signals from the controller 2105 to high-current signals for controlling switching of the transistors (for example, MOSFETs) of the heating engine drive circuit 3906. The integrated gate driver U2003 is also configured to translate voltage levels from the controller 2105 to voltage levels required by the transistors of the heating engine drive circuit 3906. In the example embodiment shown in FIG. 39, the integrated gate driver U2003 is a half-bridge driver. However, example embodiments should not be limited to this example.

In more detail, the 9V output voltage from the rail converter circuit 39020 is input to the gate driver circuit 39040 through a filter circuit including resistor R2012 and capacitor C2009. The filter circuit including the resistor R2012 and the capacitor C2009 is connected to the VCC pin (pin 4) of the integrated gate driver U2003 and the anode of Zener diode S2002 at node Node6. The second terminal of the capacitor C2009 is connected to ground. The anode of the Zener diode D2002 is connected to a first terminal of capacitor C2007 and a boost pin BST (pin 1) of the integrated gate driver U2003 at node Node7. A second terminal of the capacitor C2007 is connected to the switching node pin SWN (pin 7) of the integrated gate driver U2003 and the heating engine drive circuit 3906 (for example, between two MOSFETs) at node Node8. In the example embodiment shown in FIG. 39, the Zener diode D2002 and the capacitor C2007 form part of a boot-strap charge-pump circuit connected between the input voltage pin VCC and the boost pin BST of the integrated gate driver U2003. Because the capacitor C2007 is connected to the 9V input voltage signal 9V_GATE from the rail converter circuit 39020, the capacitor C2007 charges to a voltage almost equal to the voltage signal 9V_GATE through the diode D2002.

Still referring to FIG. 39, a high side gate driver pin DRVH (pin 8), a low side gate driver pin DRVL (pin 5) and an EP pin (pin 9) of the integrated gate driver U2003 are also connected to the heating engine drive circuit 3906.

A resistor R2013 and a capacitor C2010 form a filter circuit connected to the input pin IN (pin 2) of the integrated gate driver U2003. The filter circuit is configured to remove high frequency noise from the second heater enable signal COIL_Z input to the input pin. The second heater enable signal COIL_Z may be a PWM signal from the controller 2105.

A resistor R2014 is connected to the filter circuit and the input pin IN at node Node9. The resistor R2014 is used as a pull-down resistor, such that if the second heater enable signal COIL_Z is floating (or indeterminate), then the input pin IN of the integrated gate driver U2003 is held at a logic low level to prevent activation of the heating engine drive circuit 3906 and the heater 336.

The first heater enable signal GATE_ENB from the controller 2105 is input to the OD pin (pin 3) of the integrated gate driver U2003. A resistor R2016 is connected to the OD pin of the integrated gate driver U2003 as a pull-down resistor, such that if the first heater enable signal GATE_ENB from the controller 2105 is floating (or indeterminate), then the OD pin of the integrated gate driver U2003 is held at a logic low level to prevent activation of the heating engine drive circuit 3906 and the heater 336.

In the example embodiment shown in FIG. 39, the heating engine drive circuit 3906 includes a transistor (for example, a MOSFET) circuit including transistors (for example, MOSFETs) 39062 and 39064 connected in series between the voltage source BATT and ground. The gate of the transistor 39064 is connected to the low side gate driver pin DRVL (pin 5) of the integrated gate driver U2003, the drain of the transistor 39064 is connected to the switching node pin SWN (pin 7) of the integrated gate driver U2003 at node Node8, and the source of the transistor 39064 is connected to ground GND.

When the low side gate drive signal output from the low side gate driver pin DRVL is high, the transistor 39064 is in a low impedance state (ON), thereby connecting the node Node8 to ground.

As mentioned above, because the capacitor C2007 is connected to the 9V input voltage signal 9V_GATE from the rail converter circuit 39020, the capacitor C2007 charges to a voltage equal or substantially equal to the 9V input voltage signal 9V_GATE through the diode D2002.

When the low side gate drive signal output from the low side gate driver pin DRVL is low, the transistor 39064 switches to the high impedance state (OFF), and the high side gate driver pin DRVH (pin 8) is connected internally to the boost pin BST within the integrated gate driver U2003. As a result, transistor 39062 is in a low impedance state (ON), thereby connecting the switching node SWN to the voltage source BATT to pull the switching node SWN (Node 8) to the voltage of the voltage source BATT.

In this case, the node Node7 is raised to a boost voltage $V(BST) \approx V(9V\_GATE) + V(BATT)$, which allows the gate-source voltage of the transistor 39062 to be the same or substantially the same as the voltage of the 9V input voltage signal 9V_GATE (for example, V(9V_GATE)) regardless (or independent) of the voltage from the voltage source BATT. As a result, the switching node SWN (Node 8) provides a high current switched signal that may be used to generate a voltage output to the heater 336 that is substantially independent of the voltage output from the battery voltage source BATT.

FIGS. 40 and 41 illustrate example embodiments of temperature sensing transducers included in the pod sensors 2220 shown in FIG. 29.

Referring to FIG. 40, the temperature sensing transducer 3600A includes a resistor R3602 and a sensor transducer R3604. In at least one example embodiment the resistor R3602 may have a fixed resistance of about 3 Ohms. The sensor transducer R3604 may be a resistor having a variable resistance that varies with temperature. The resistor R3602 and the sensor transducer R3604 are arranged in a voltage divider circuit so that the voltage across the sensor transducer R3604 (voltage at measurement node N3606) may be output to the pod temperature measurement circuit 21250 for scaling and then use in measuring the temperature of the nicotine pod assembly 300 or one or more elements of the nicotine pod assembly 300.

In example operation, a driver stage 3902A of the pod temperature measurement circuit 21250A (FIG. 36) applies a pod temperature measurement power signal HW_POWER to the temperature sensing transducer 3600A and a measurement stage 3904A of the pod temperature measurement circuit 21250A scales the sensed voltage of the pod sensor signal SP_HW at the measurement node N3606, and outputs the scaled voltage to the controller 2105 as the pod temperature measurement output signal HW_SIGNAL. The controller 2105 then determines the temperature of the nicotine pod assembly 300 or one or more elements of the nicotine pod assembly 300 based on the pod temperature measurement output signal HW_SIGNAL.

In at least one example embodiment, the voltage of the pod temperature measurement power signal HW_POWER may be fixed, and therefore, the pod temperature measurement circuit 21250A may also calculate the current through resistors R3602 and R3604 because the resistance of the resistor R3602 is a known resistance.

Referring to the example embodiment shown in FIG. 41, the temperature sensing transducer 3600B is similar to the temperature sensing transducer 3600A in FIG. 40, except that, as mentioned above with regard to FIG. 37, the resistor R3602 is omitted from the temperature sensing transducer 3600B and relocated to the driver stage 3902B of the pod temperature measurement circuit 21250B in FIG. 37. By relocating the resistor R3602 to the driver stage 3902B of the pod temperature measurement circuit 21250B, the cost of the nicotine pod assembly electrical system 2200 and/or the number of pins required for the interface between the device body 100 and the nicotine pod assembly 300 may be reduced. Moreover, the resistance of the sensor transducer R3606 in the example embodiment shown in FIG. 41 may be larger than the resistance of the sensor transducer R3604 in FIG. 40 to reduce current consumption by the temperature sensing transducer 3600B.

Example embodiments have been disclosed herein, however, it should be understood that other variations may be possible. Such variations are not to be regarded as a departure from the scope of the present disclosure, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method for controlling operation of a nicotine electronic vaping device including a heater to heat nicotine pre-vapor formulation drawn from a nicotine reservoir, the method comprising:

determining a plurality of resistance values for the heater during a time window;

calculating a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values;

deciding whether the percent change in resistance of the heater exceeds a percent change in resistance threshold; and

disabling power to the heater at the nicotine electronic vaping device in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

2. The method of claim 1, further comprising:

storing the plurality of resistance values for the heater in a first-in-first-out (FIFO) memory; wherein

the first of the plurality of resistance values for the heater is an oldest resistance value stored in the FIFO memory, and

the second of the plurality of resistance values for the heater is a most recent resistance value stored in the FIFO memory.

3. The method of claim 1 or 2, further comprising:

obtaining the percent change in resistance threshold from a memory in a nicotine pod assembly of the nicotine electronic vaping device.

4. The method of claim 1, 2 or 3, further comprising:

detecting that the resistance of the heater has stabilized based on a current through the heater; and wherein

the determining determines the plurality of resistance values for the heater during the time window in response to detecting that the resistance of the heater has stabilized.

5. The method of claim 4, wherein the detecting detects that the resistance of the heater has stabilized based on the current through the heater and a wetting current threshold.

6. The method of any preceding claim, further comprising:

outputting an indication of dry puff conditions at the nicotine electronic vaping device in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

7. The method of any preceding claim, further comprising:

deciding whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after the disabling; and

powering off the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within the first threshold time interval after the disabling.

8. The method of any preceding claim, further comprising:

deciding whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after the disabling; and

returning the nicotine electronic vaping device to an operational mode by clearing a fault associated with dry puff conditions at the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after the disabling.

9. The method of claim 8, further comprising:

determining whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after the returning; and

enabling vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after the returning.

10. The method of claim 8 or 9, further comprising:

determining whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after the returning; and

powering off the nicotine electronic vaping device in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after the returning.

11. A method for controlling a nicotine electronic vaping device including a heater to heat nicotine pre-vapor formulation drawn from a nicotine reservoir, the method comprising:

determining a plurality of resistance values for the heater during a time window;

calculating a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values;

detecting whether the percent change in resistance of the heater exceeds a percent change in resistance threshold; and

outputting an indication of dry puff conditions at the nicotine electronic vaping device in response to detecting that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

12. The method of claim 11, further comprising:

storing the plurality of resistance values for the heater in a first-in-first-out (FIFO) memory; wherein

the first of the plurality of resistance values for the heater is an oldest resistance value stored in the FIFO memory, and

the second of the plurality of resistance values for the heater is a most recent resistance value stored in the FIFO memory.

13. The method of claim 11 or 12, further comprising:

obtaining the percent change in resistance threshold from a memory in a nicotine pod assembly of the nicotine electronic vaping device.

14. The method of claim 11, 12 or 13, further comprising:

deciding that the resistance of the heater has stabilized based on a current through the heater; and wherein

the determining determines the plurality of resistance values for the heater during the time window in response to deciding that the resistance of the heater has stabilized.

15. The method of claim 14, wherein the deciding decides that the resistance of the heater has stabilized based on the current through the heater and a wetting current threshold.

16. The method of any of claims 11 to 15, further comprising:

deciding whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after the outputting; and

powering off the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within the first threshold time interval after the outputting.

17. The method of any of claims 11 to 16, further comprising:

disabling power to the heater in response to detecting that the percent change in resistance of the heater exceeds the percent change in resistance threshold;

deciding whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after the disabling; and

returning the nicotine electronic vaping device to an operational mode by clearing a fault associated with dry puff conditions at the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after the disabling.

18. The method of claim 17, further comprising:

determining whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after the returning; and

enabling vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after the returning.

19. The method of claim 17 or 18, further comprising:

determining whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after the returning; and

powering off the nicotine electronic vaping device in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after the returning.

20. A method for controlling a nicotine electronic vaping device, the method comprising:

determining whether a nicotine pod assembly has been removed prior to expiration of a first time interval after detecting dry puff conditions at the nicotine electronic vaping device; and

returning the nicotine electronic vaping device to an operational mode by clearing a fault associated with the dry puff conditions at the nicotine electronic vaping device in response to determining that the nicotine pod assembly has been removed prior to expiration of the first time interval.

21. The method of claim 20, further comprising:

determining whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after the returning; and

enabling vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after the returning.

22. The method of claim 20 or 21, further comprising:

detecting the dry puff conditions at the nicotine electronic vaping device based on whether a percent change in resistance of a heater of the nicotine electronic vaping device exceeds a percent change in resistance threshold.

23. A nicotine electronic vaping device comprising:

a nicotine reservoir storing nicotine pre-vapor formulation;

a heater configured to heat nicotine pre-vapor formulation drawn from the nicotine reservoir; and

processing circuitry configured to

determine a plurality of resistance values for the heater during a time window,

calculate a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values,

decide whether the percent change in resistance of the heater exceeds a percent change in resistance threshold, and

disable power to the heater in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

24. The nicotine electronic vaping device of claim 23, further comprising:

a first-in-first-out (FIFO) memory configured to store the plurality of resistance values for the heater; wherein

the first of the plurality of resistance values for the heater is an oldest resistance value stored in the FIFO memory, and

the second of the plurality of resistance values for the heater is a most recent resistance value stored in the FIFO memory.

25. The nicotine electronic vaping device of claim 23 or 24, further comprising:

a nicotine pod assembly including the nicotine reservoir, the heater and a memory, the memory storing the percent change in resistance threshold; and wherein

the processing circuitry is configured to obtain the percent change in resistance threshold from the memory in the nicotine pod assembly.

26. The nicotine electronic vaping device of claim 23, 24 or 25, wherein the processing circuitry is configured to

detect that the resistance of the heater has stabilized based on a current through the heater, and determine the plurality of resistance values for the heater during the time window in response to detecting that the resistance of the heater has stabilized.

27. The nicotine electronic vaping device of claim 26, wherein the processing circuitry is configured to detect that the resistance of the heater has stabilized based on the current through the heater and a wetting current threshold.

28. The nicotine electronic vaping device of any of claims 23 to 27, wherein the processing circuitry is configured to output an indication of dry puff conditions in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

29. The nicotine electronic vaping device of any of claims 23 to 28, wherein the processing circuitry is configured to

decide whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after disabling the power to the heater, and

power off the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within the first threshold time interval after disabling the power to the heater.

30. The nicotine electronic vaping device of any of claims 23 to 29, wherein the processing circuitry is configured to

decide whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after disabling the power to the heater, and

return the nicotine electronic vaping device to an operational mode by clearing a fault associated with dry puff conditions at the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after disabling the power to the heater.

31. The nicotine electronic vaping device of claim 30, wherein the processing circuitry is configured to

determine whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode, and

enable vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

32. The nicotine electronic vaping device of claim 30 or 31, wherein the processing circuitry is configured to

determine whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode, and

power off the nicotine electronic vaping device in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

33. A nicotine electronic vaping device comprising:

a nicotine reservoir storing nicotine pre-vapor formulation;

a heater configured to heat nicotine pre-vapor formulation drawn from the nicotine reservoir; and

processing circuitry configured to cause the nicotine electronic vaping device to

determine a plurality of resistance values for the heater during a time window,

calculate a percent change in resistance of the heater between a first of the plurality of resistance values and a second of the plurality of resistance values,

detect whether the percent change in resistance of the heater exceeds a percent change in resistance threshold, and

output an indication of dry puff conditions at the nicotine electronic vaping device in response to determining that the percent change in resistance of the heater exceeds the percent change in resistance threshold.

34. The nicotine electronic vaping device of claim 33, further comprising:

a first-in-first-out (FIFO) memory configured to store the plurality of resistance values for the heater; wherein

the first of the plurality of resistance values for the heater is an oldest resistance value stored in the FIFO memory, and

the second of the plurality of resistance values for the heater is a most recent resistance value stored in the FIFO memory.

35. The nicotine electronic vaping device of claim 33 or 34, further comprising:

a nicotine pod assembly including the nicotine reservoir, the heater and a memory, the memory storing the percent change in resistance threshold; and wherein

the processing circuitry is configured to obtain the percent change in resistance threshold from the memory in the nicotine pod assembly.

36. The nicotine electronic vaping device of claim 33, 34 or 35, wherein the processing circuitry is configured to

detect that the resistance of the heater has stabilized based on a current through the heater, and

determine the plurality of resistance values for the heater during the time window in response to detecting that the resistance of the heater has stabilized.

37. The nicotine electronic vaping device of claim 36, wherein the processing circuitry is configured to detect that the resistance of the heater has stabilized based on the current through the heater and a wetting current threshold.

38. The nicotine electronic vaping device of any of claims 33 to 37, wherein the processing circuitry is configured to

decide whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after outputting the indication of the dry puff conditions; and

power off the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has not been removed from the nicotine electronic vaping device within the first threshold time interval after outputting the indication of dry puff conditions.

39. The nicotine electronic vaping device of any of claims 33 to 38, wherein the processing circuitry is configured to

disable power to the heater in response to deciding that the percent change in resistance of the heater exceeds the percent change in resistance threshold,

decide whether a nicotine pod assembly has been removed from the nicotine electronic vaping device within a first threshold time interval after disabling the power to the heater, and

return the nicotine electronic vaping device to an operational mode by clearing a fault associated with the dry puff conditions at the nicotine electronic vaping device in response to deciding that the nicotine pod assembly has been removed from the nicotine electronic vaping device within the first threshold time interval after disabling the power to the heater.

40. The nicotine electronic vaping device of claim 39, wherein the processing circuitry is configured to

determine whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode, and

enable vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

41. The nicotine electronic vaping device of claim 39 or 40, wherein the processing circuitry is configured to

determine whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode, and

power off the nicotine electronic vaping device in response to determining that another nicotine pod assembly has not been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

42. A nicotine electronic vaping device comprising:

processing circuitry configured to

determine whether a nicotine pod assembly has been removed prior to expiration of a first time interval after detecting dry puff conditions at the nicotine electronic vaping device, and

return the nicotine electronic vaping device to an operational mode by clearing a fault associated with the dry puff conditions at the nicotine electronic vaping device in response to determining that the nicotine pod assembly has been removed prior to expiration of the first time interval.

43. The nicotine electronic vaping device of claim 42, wherein the processing circuitry is configured to

determine whether another nicotine pod assembly has been inserted into the nicotine electronic vaping device within a second threshold time interval after returning the nicotine electronic vaping device to the operational mode, and

enable vaping at the nicotine electronic vaping device in response to determining that another nicotine pod assembly has been inserted into the nicotine electronic vaping device within the second threshold time interval after returning the nicotine electronic vaping device to the operational mode.

44. The nicotine electronic vaping device of claim 42 or 43, wherein the processing circuitry is configured to

detect the dry puff conditions at the nicotine electronic vaping device based on whether a percent change in resistance of a heater of the nicotine electronic vaping device exceeds a percent change in resistance threshold.

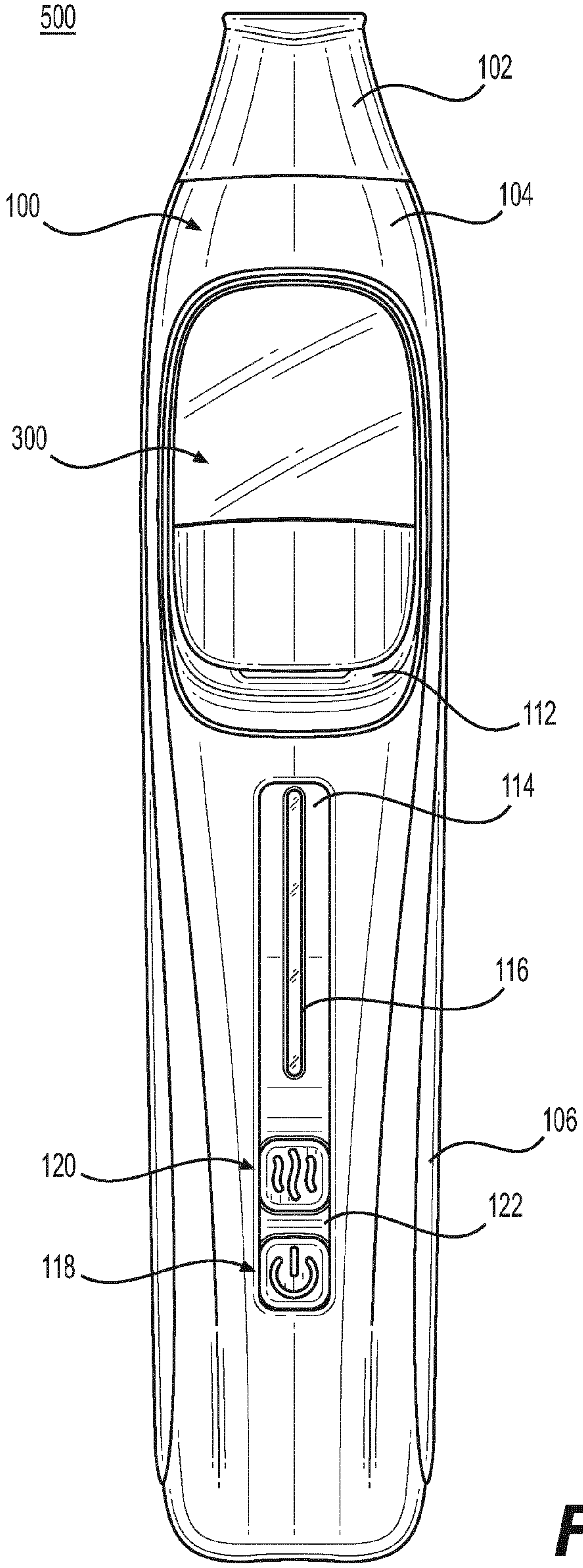

FIG. 1

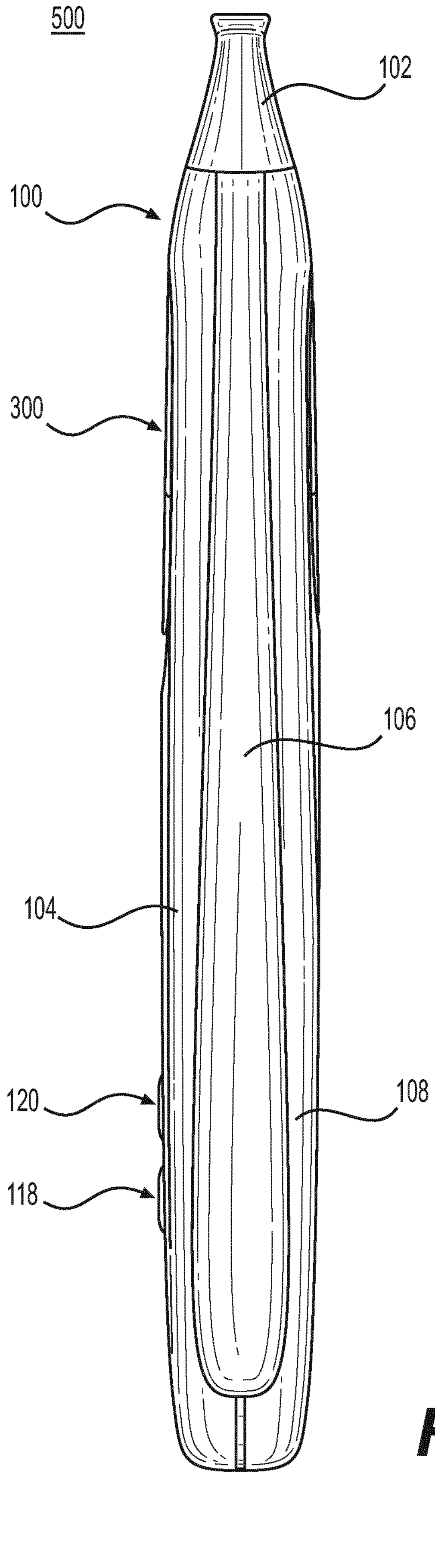

FIG. 2

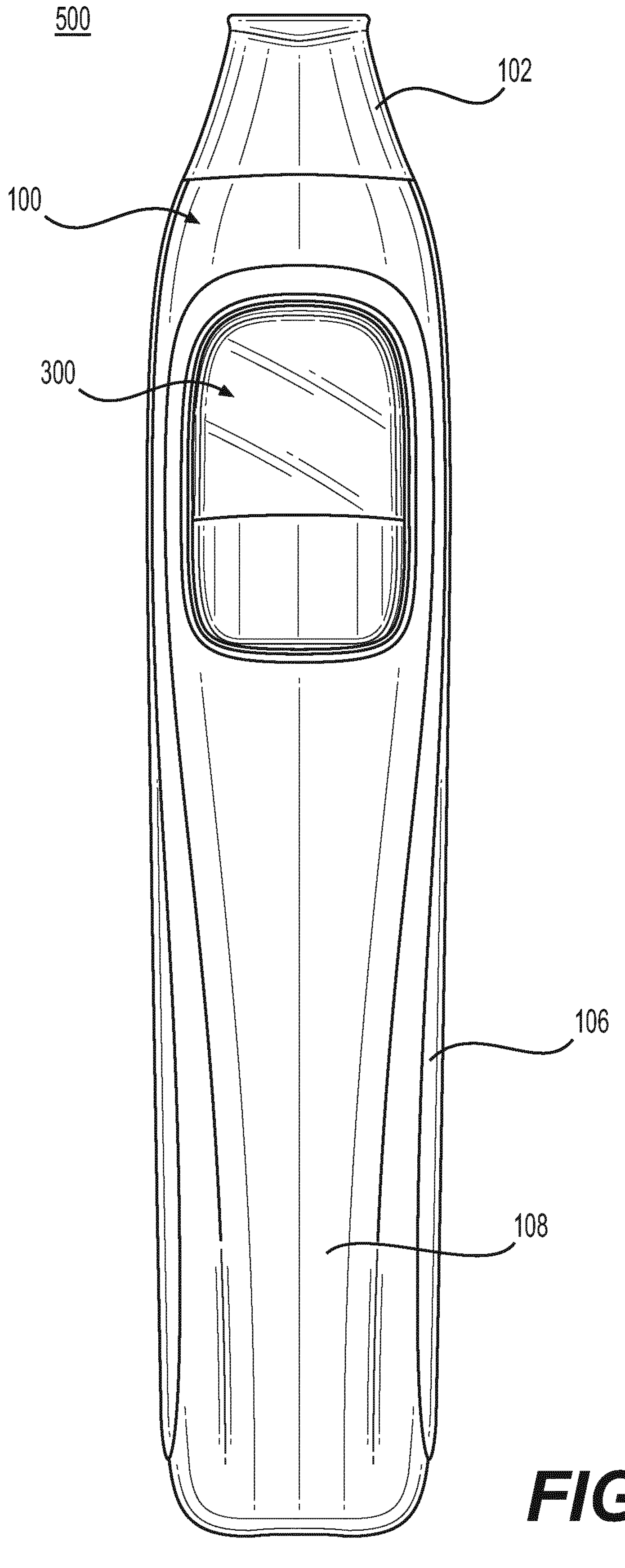

FIG. 3

500

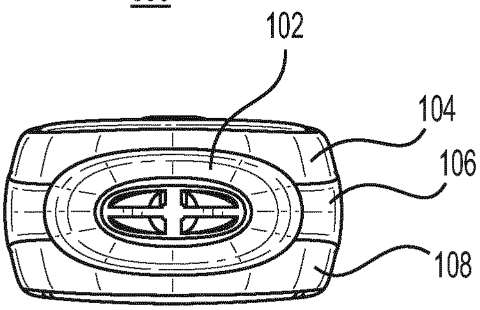

FIG. 4

500

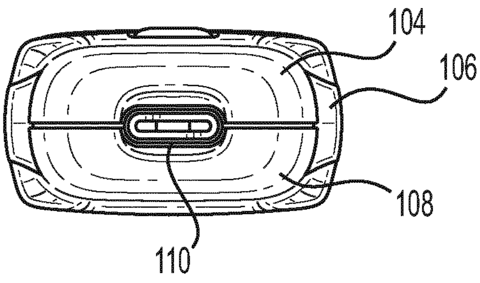

FIG. 5

500

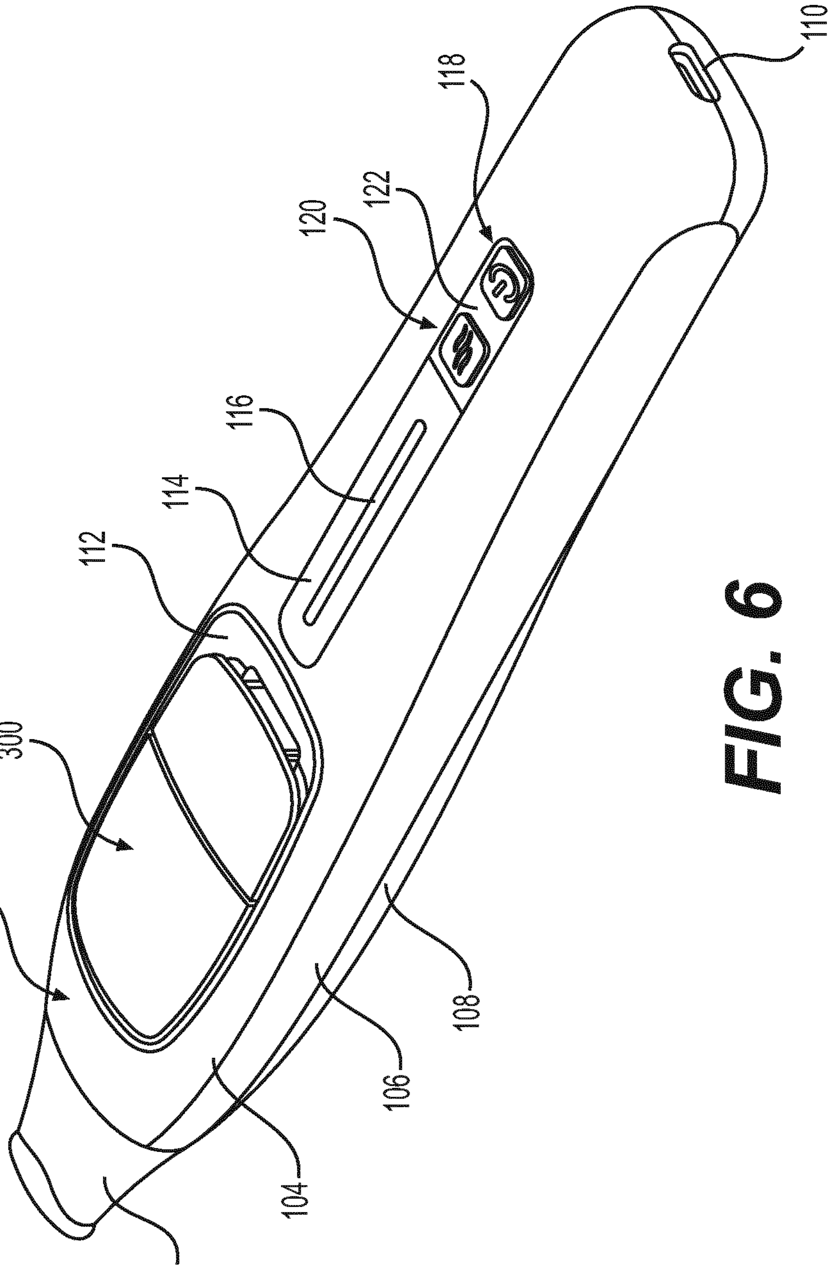

FIG. 6

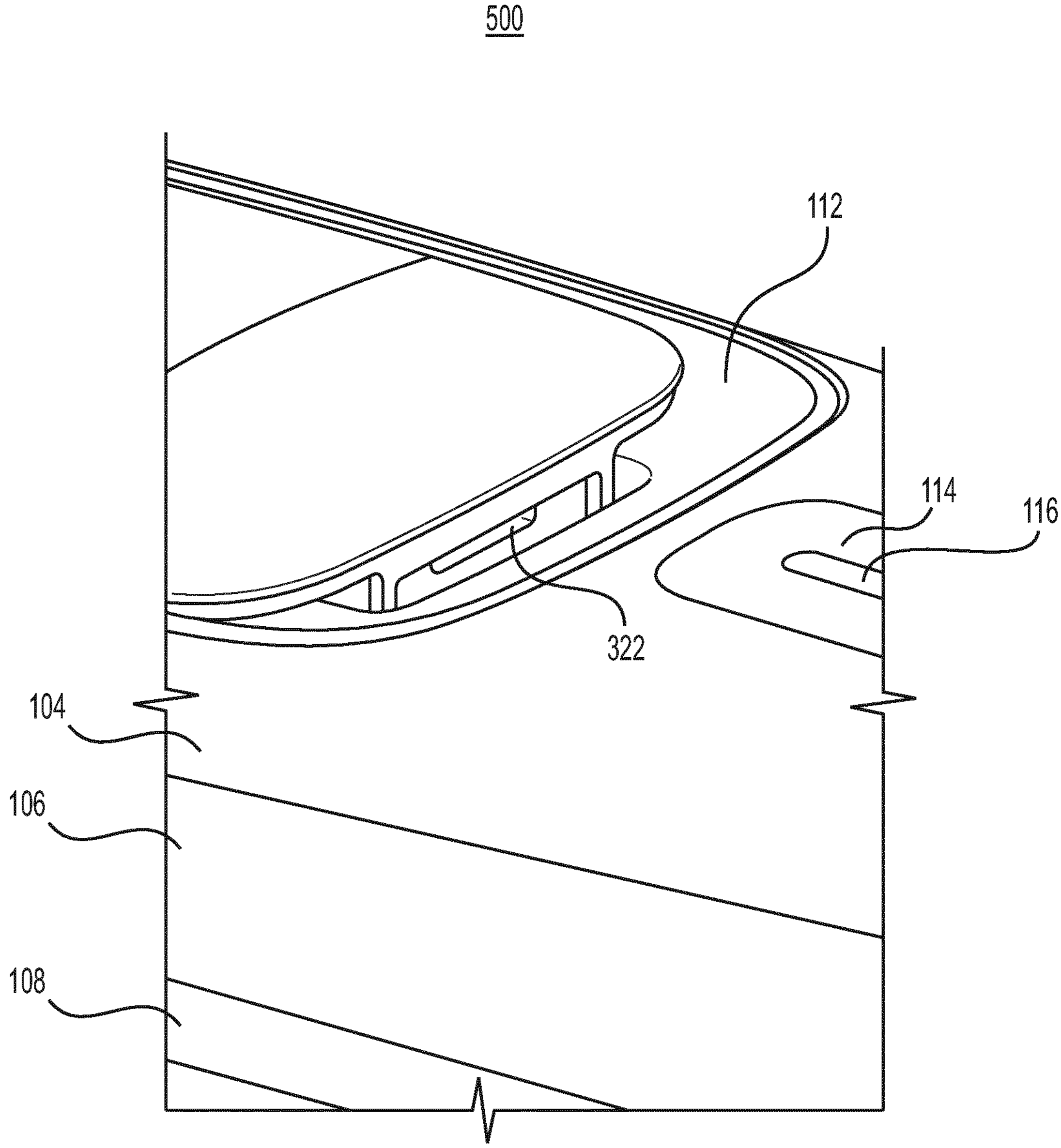

FIG. 7

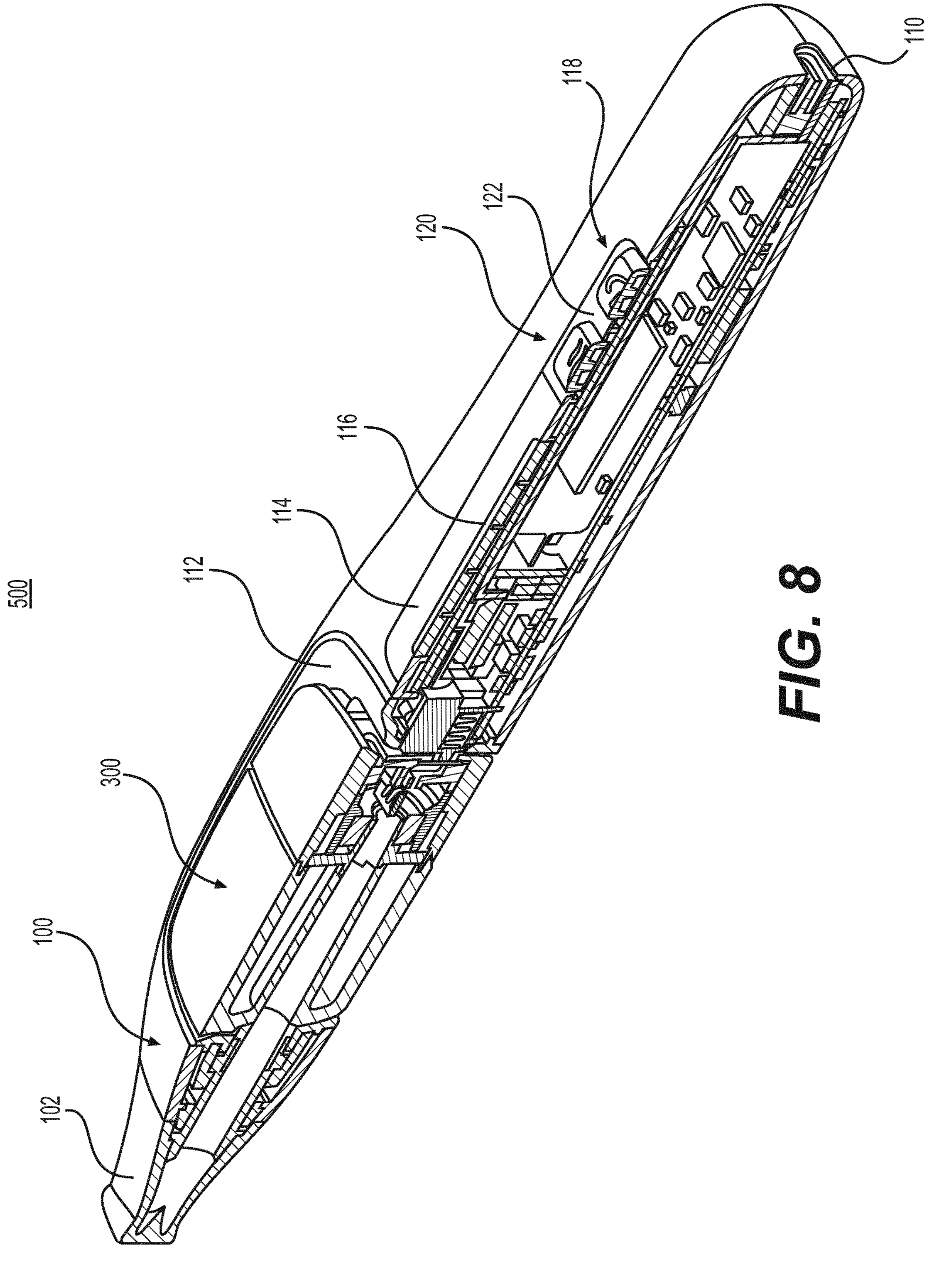

FIG. 8

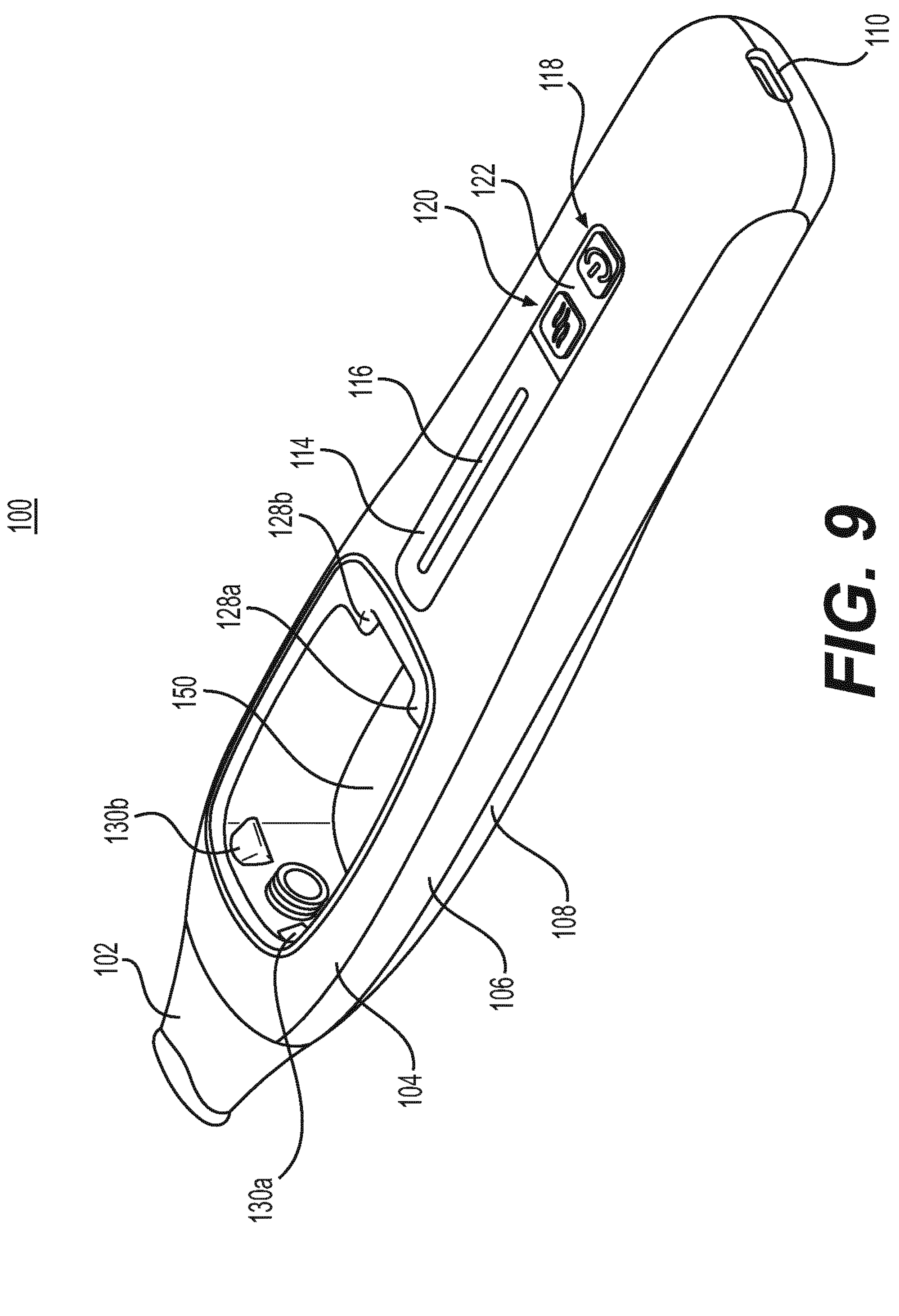
100
110
118
122
120
116
114
128b
128a
150
130b
102
130a
104
106
108

FIG. 9

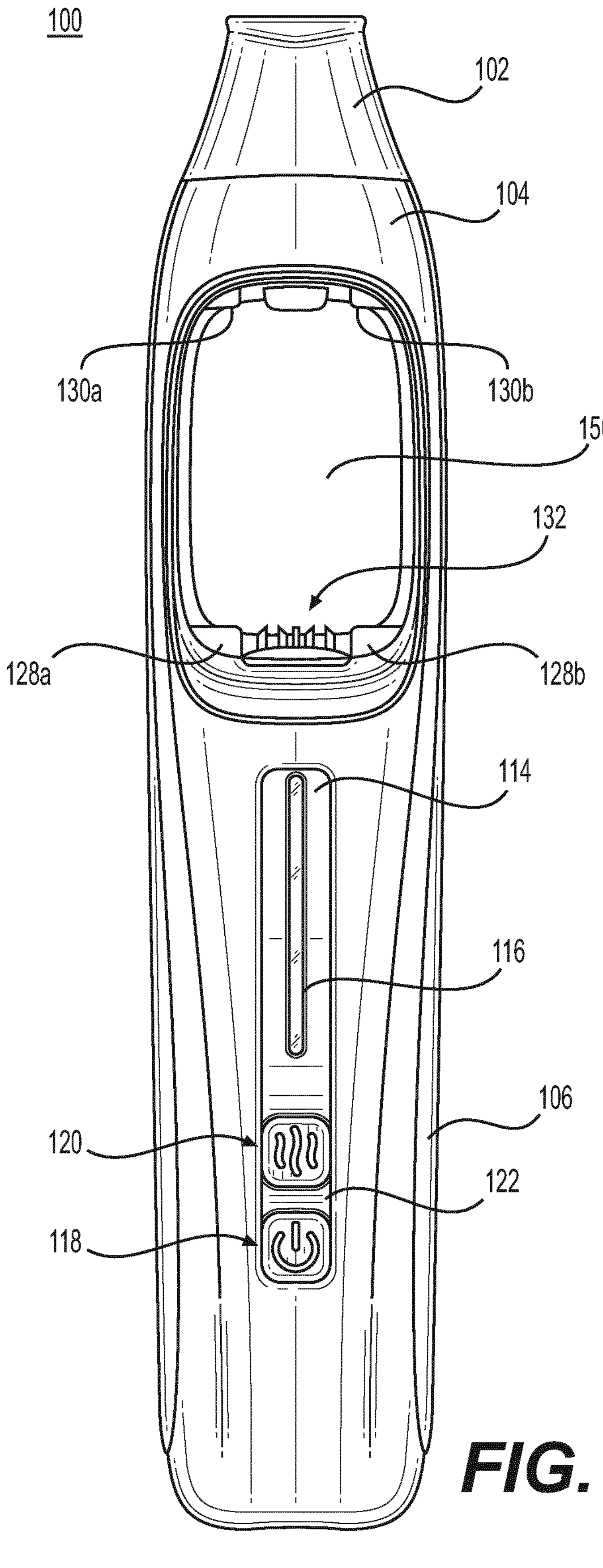

FIG. 10

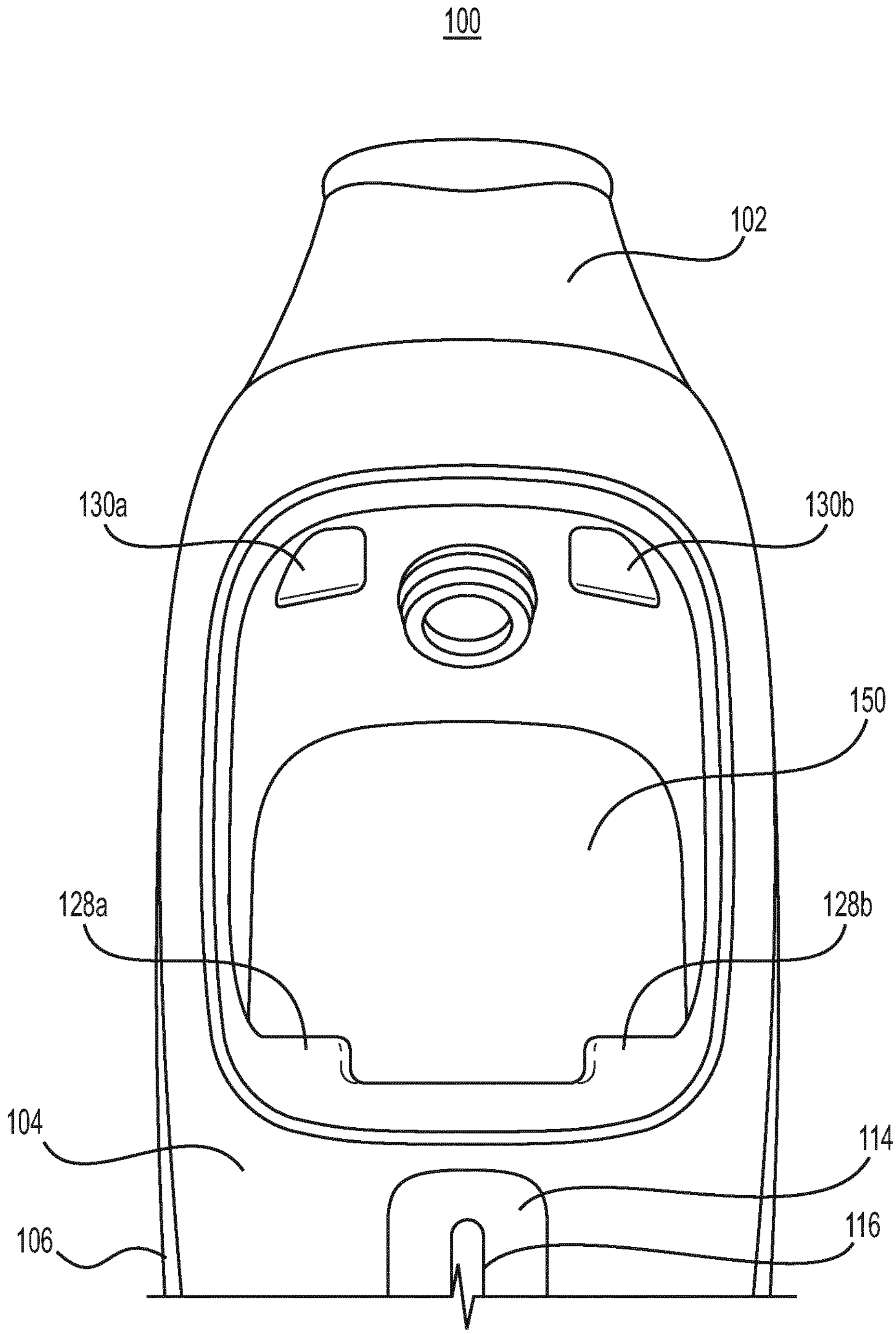

FIG. 11

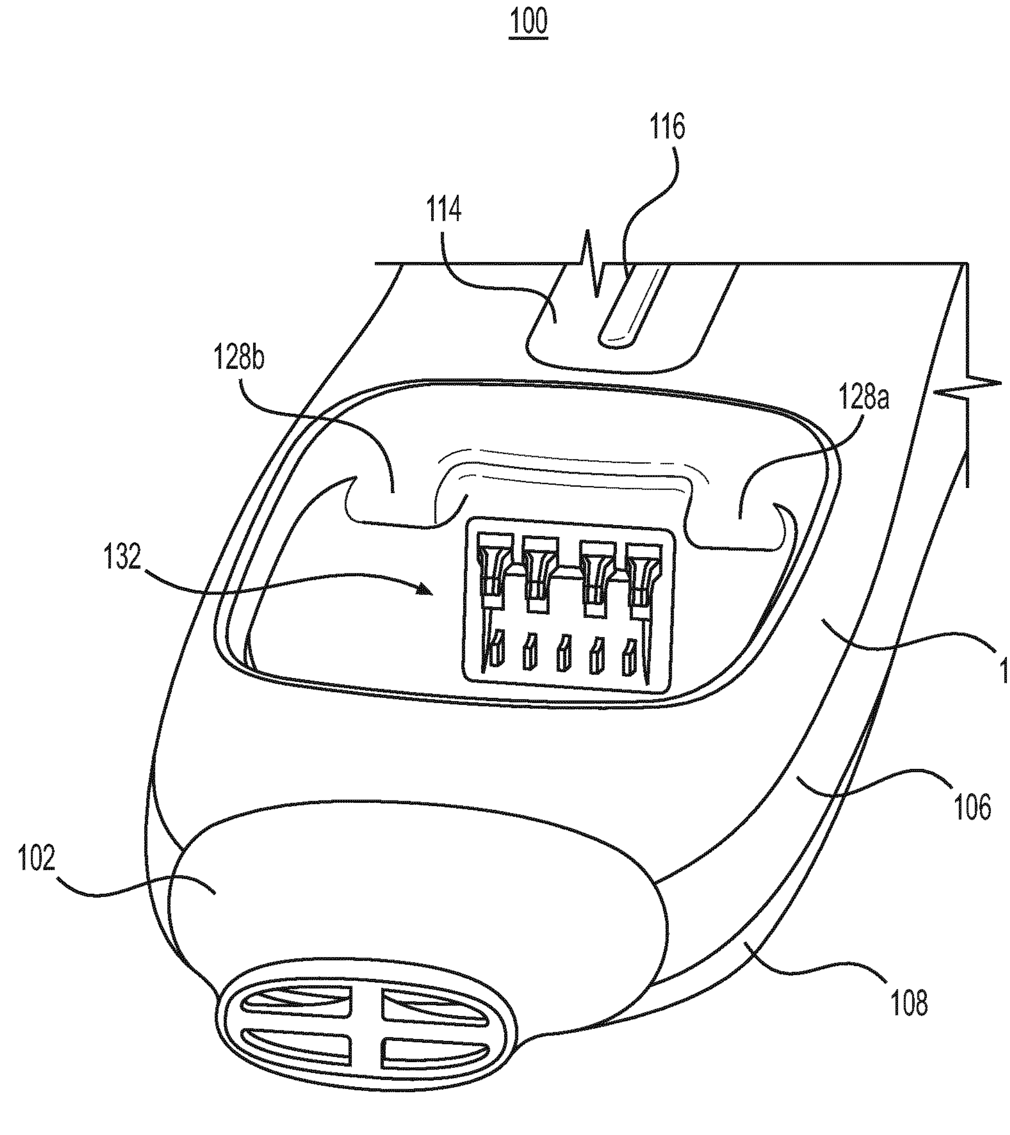

FIG. 12

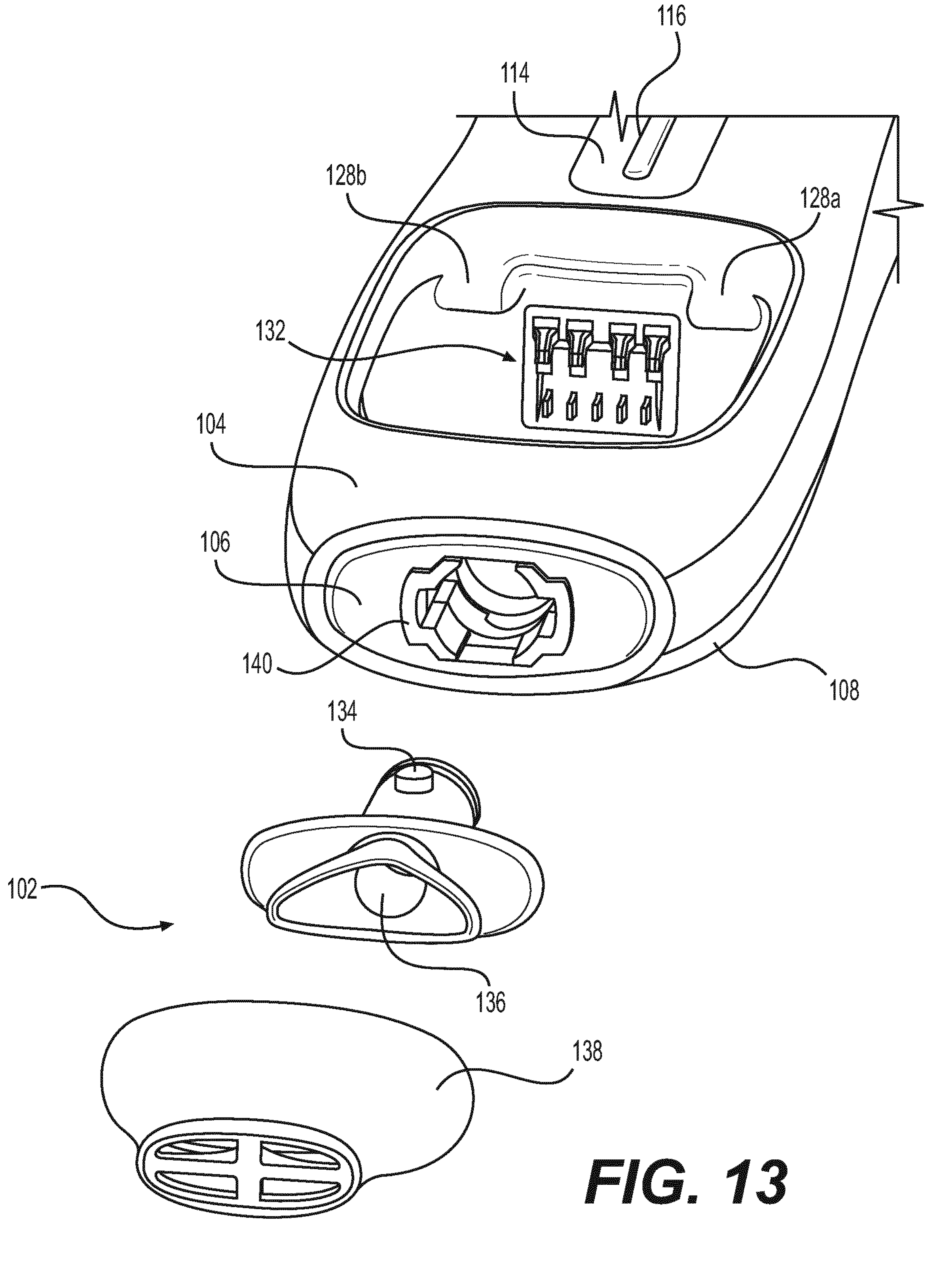

FIG. 13

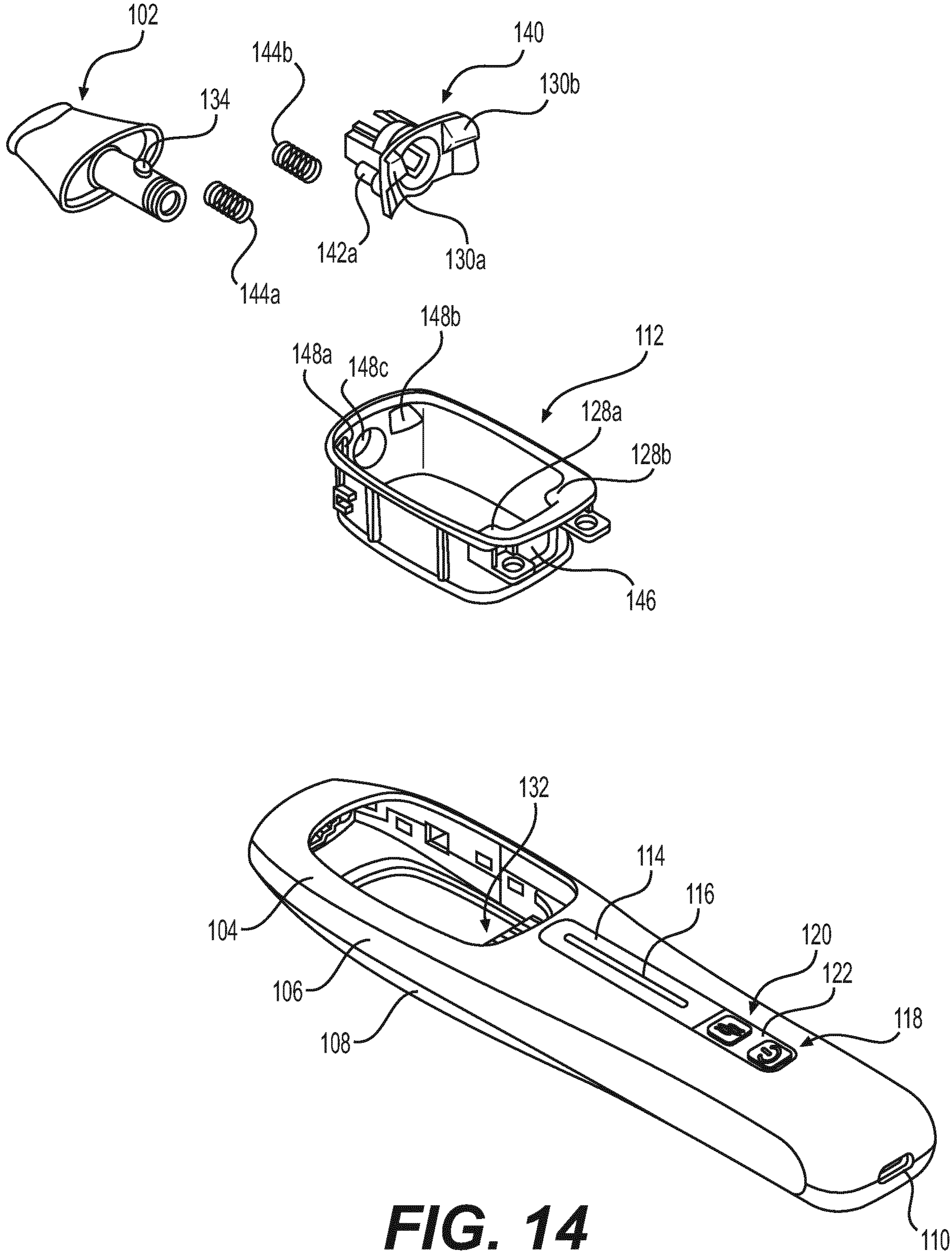
102
134
144b
140
130b
142a
130a
144a
148b
112
148a
148c
128a
128b
146
132
114
116
104
120
122
106
118
108
110

FIG. 14

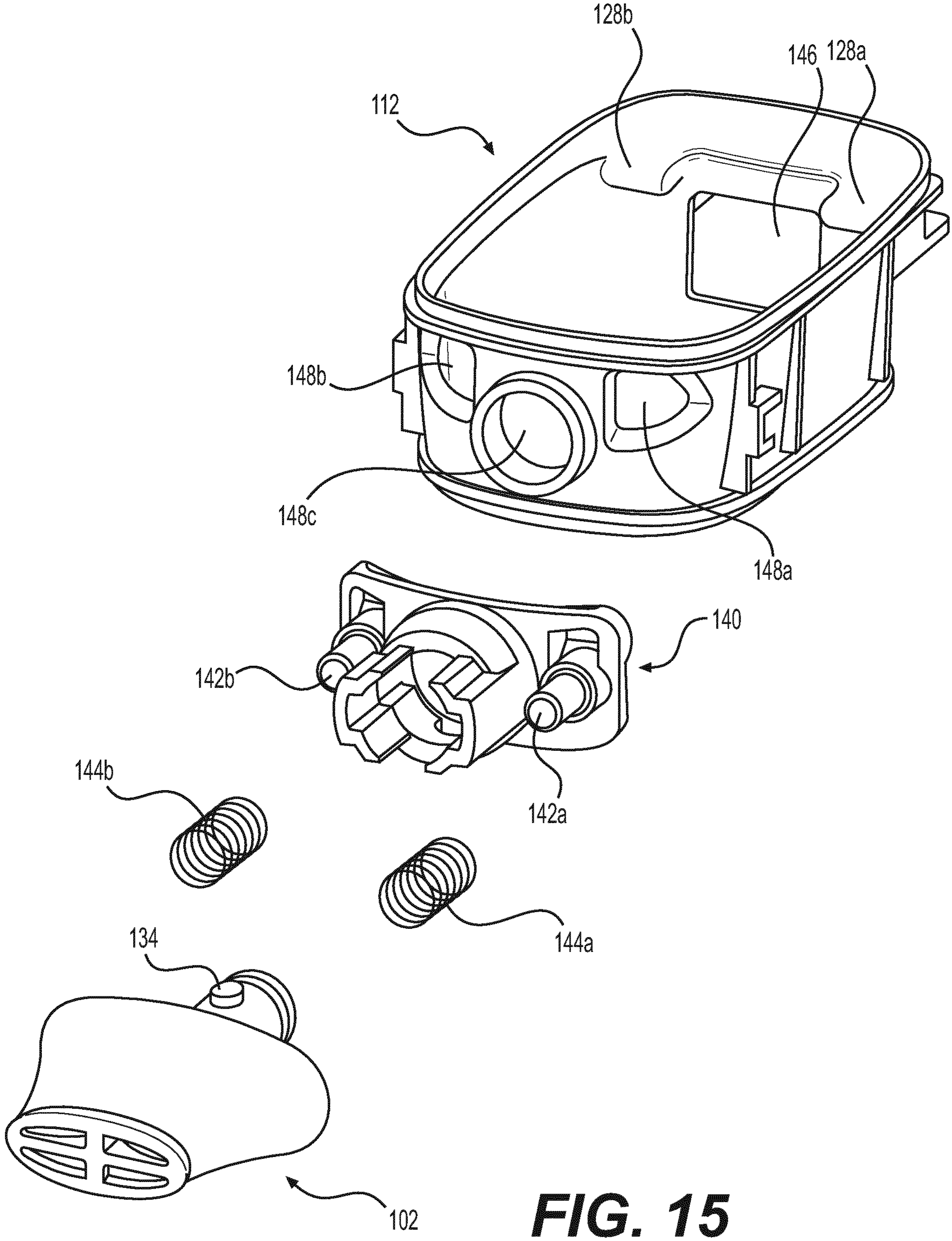
128b
146
128a
112
148b
148c
148a
140
142b
142a
144b
144a
134
102

FIG. 15

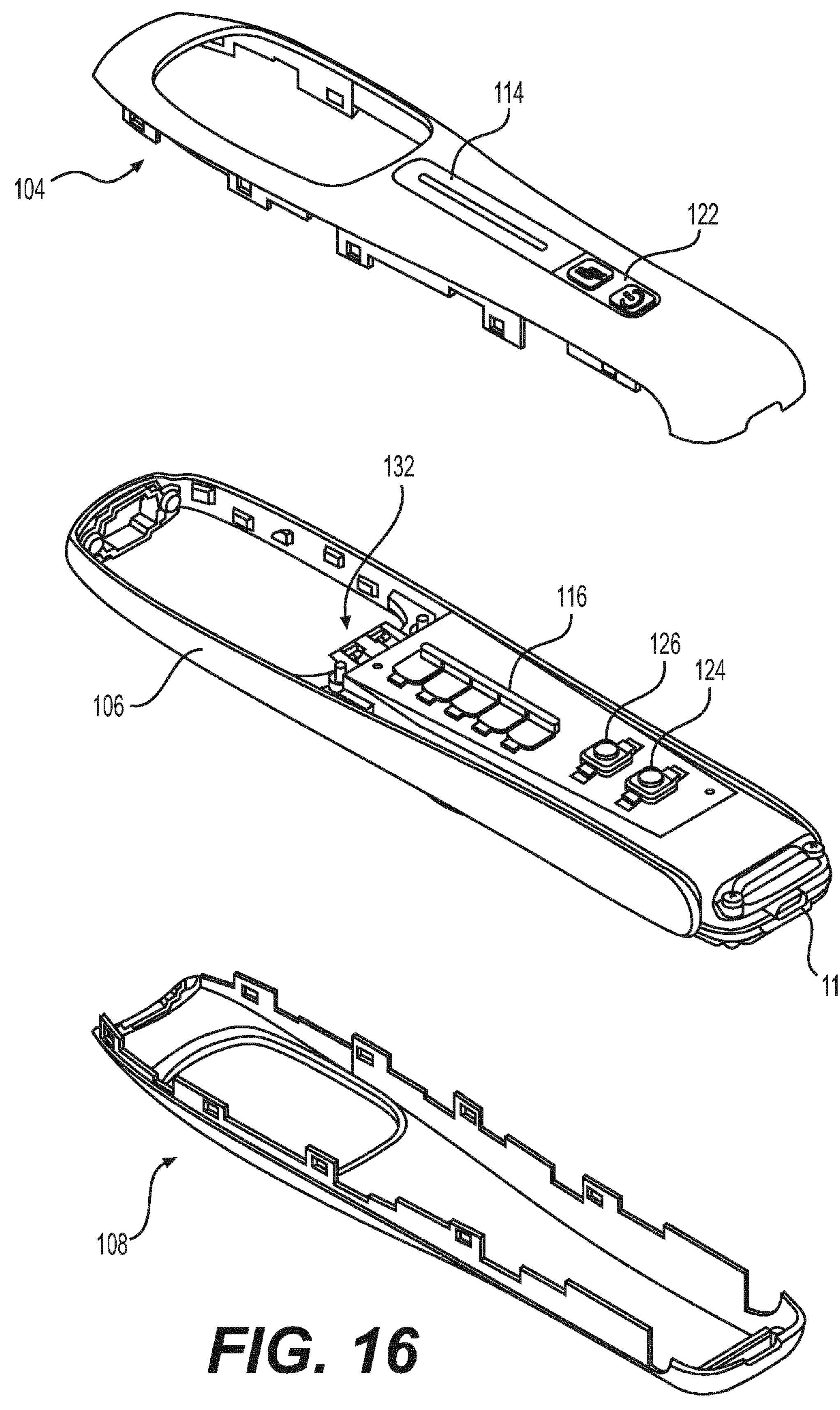

FIG. 16

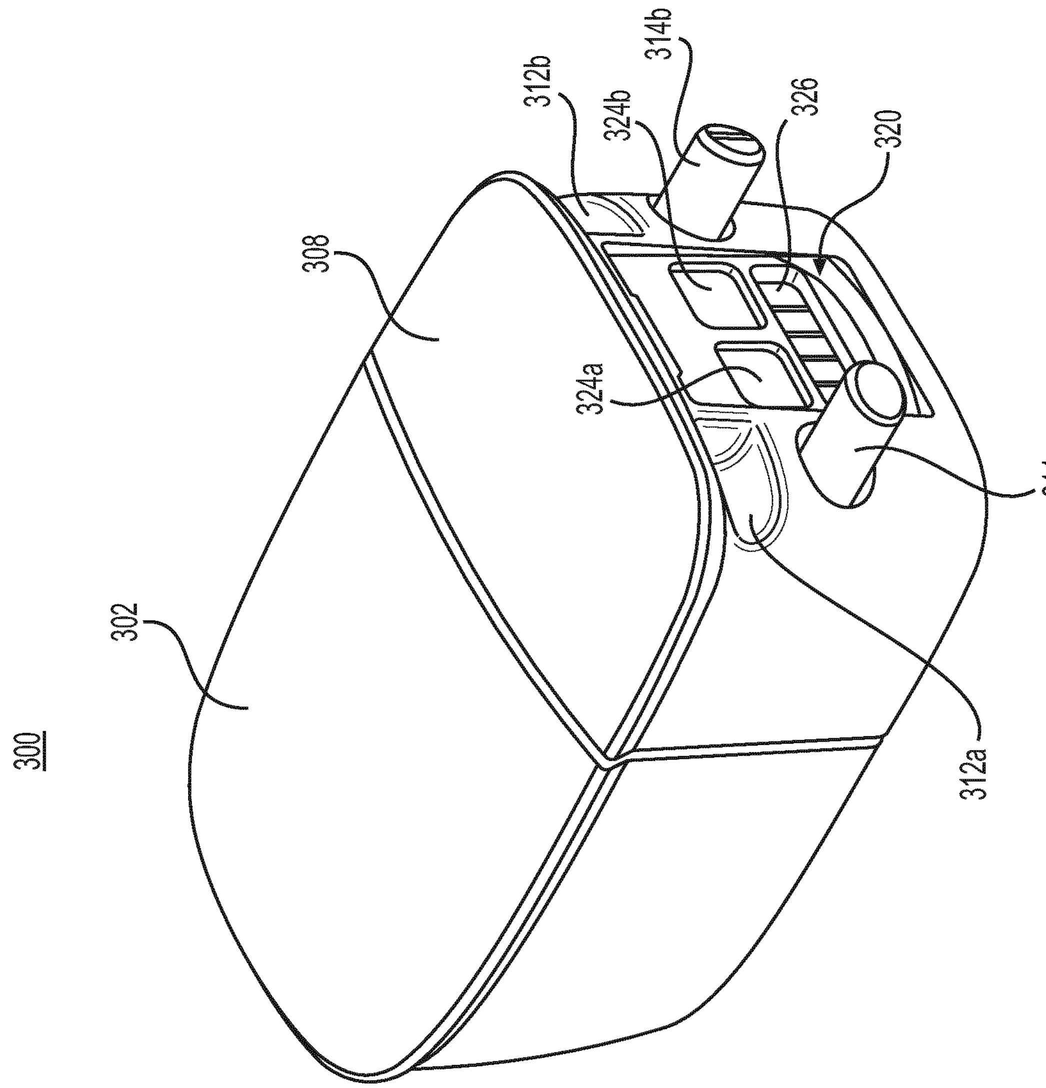

FIG. 17

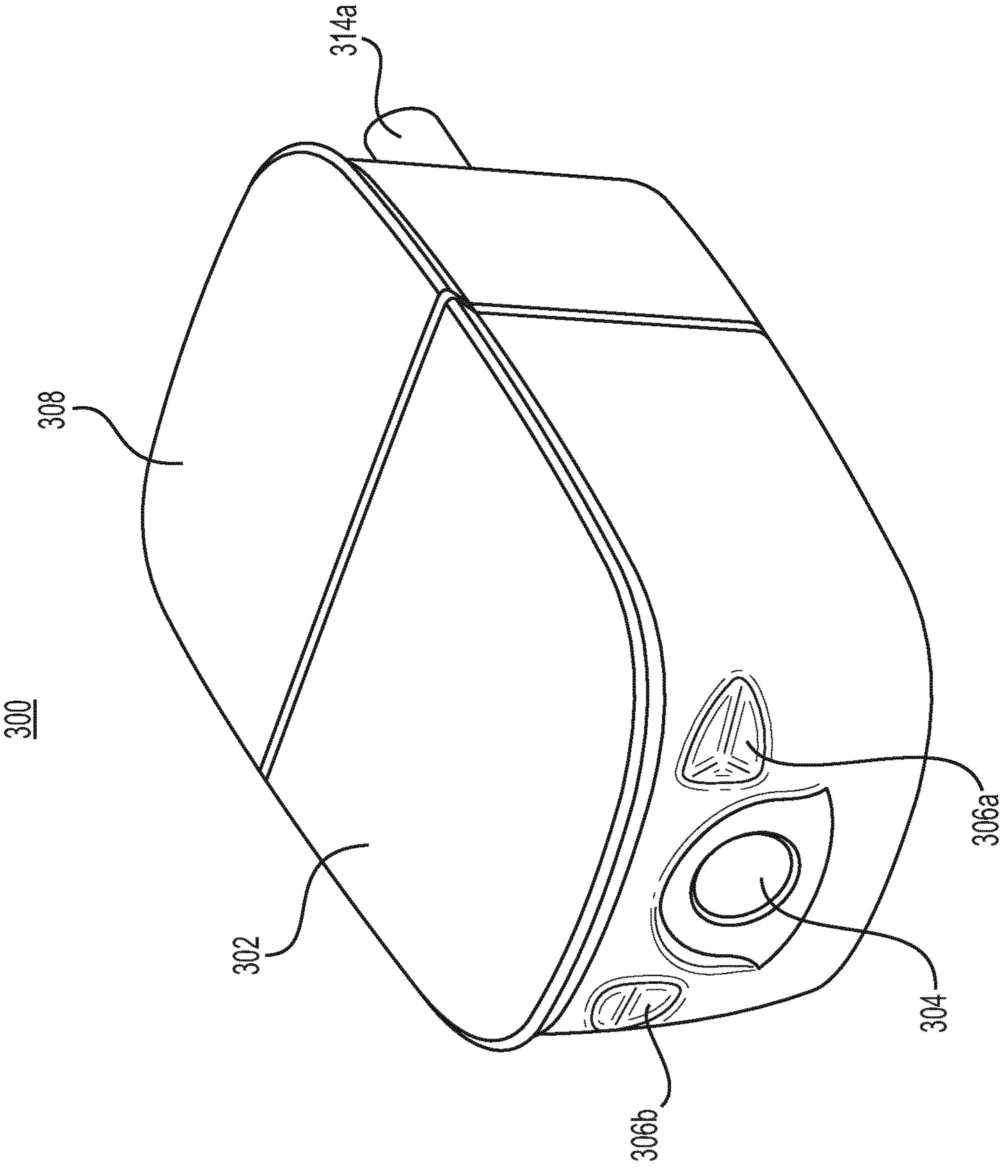

FIG. 18

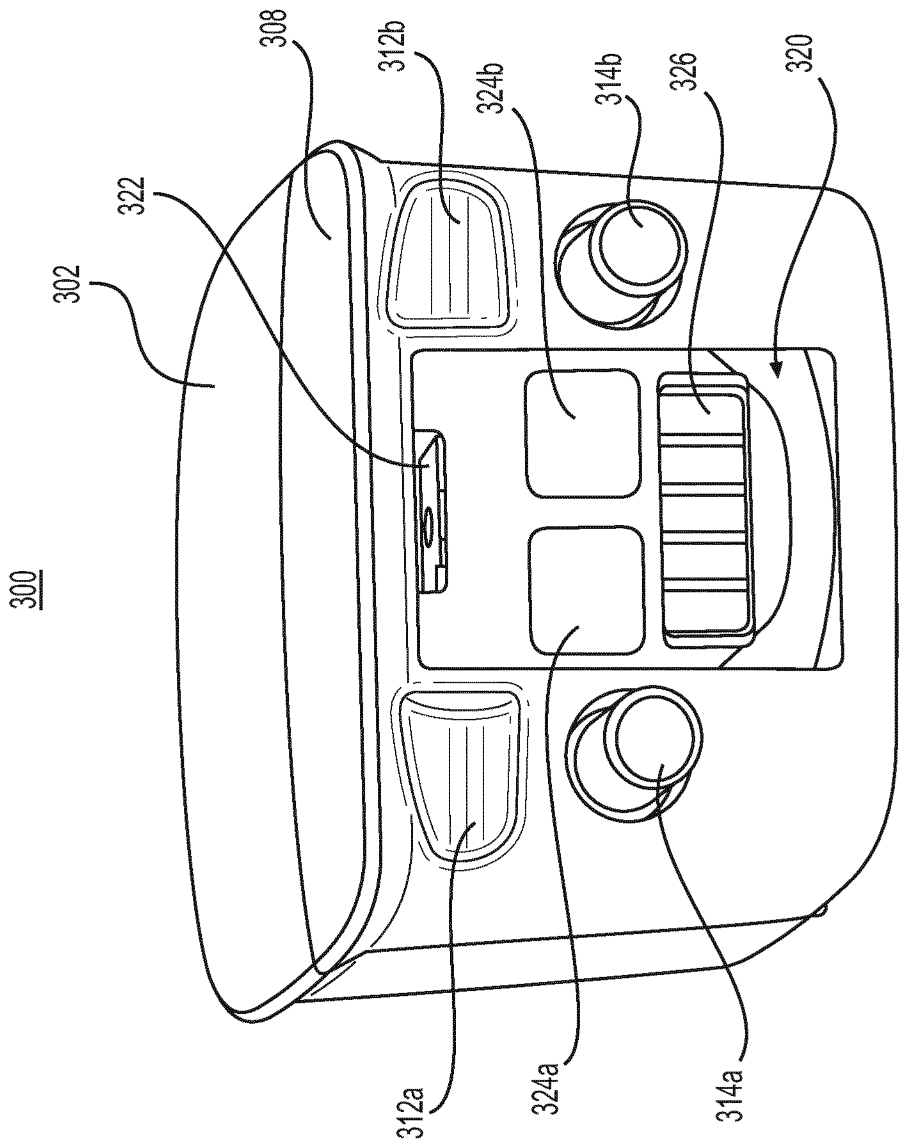

FIG. 19

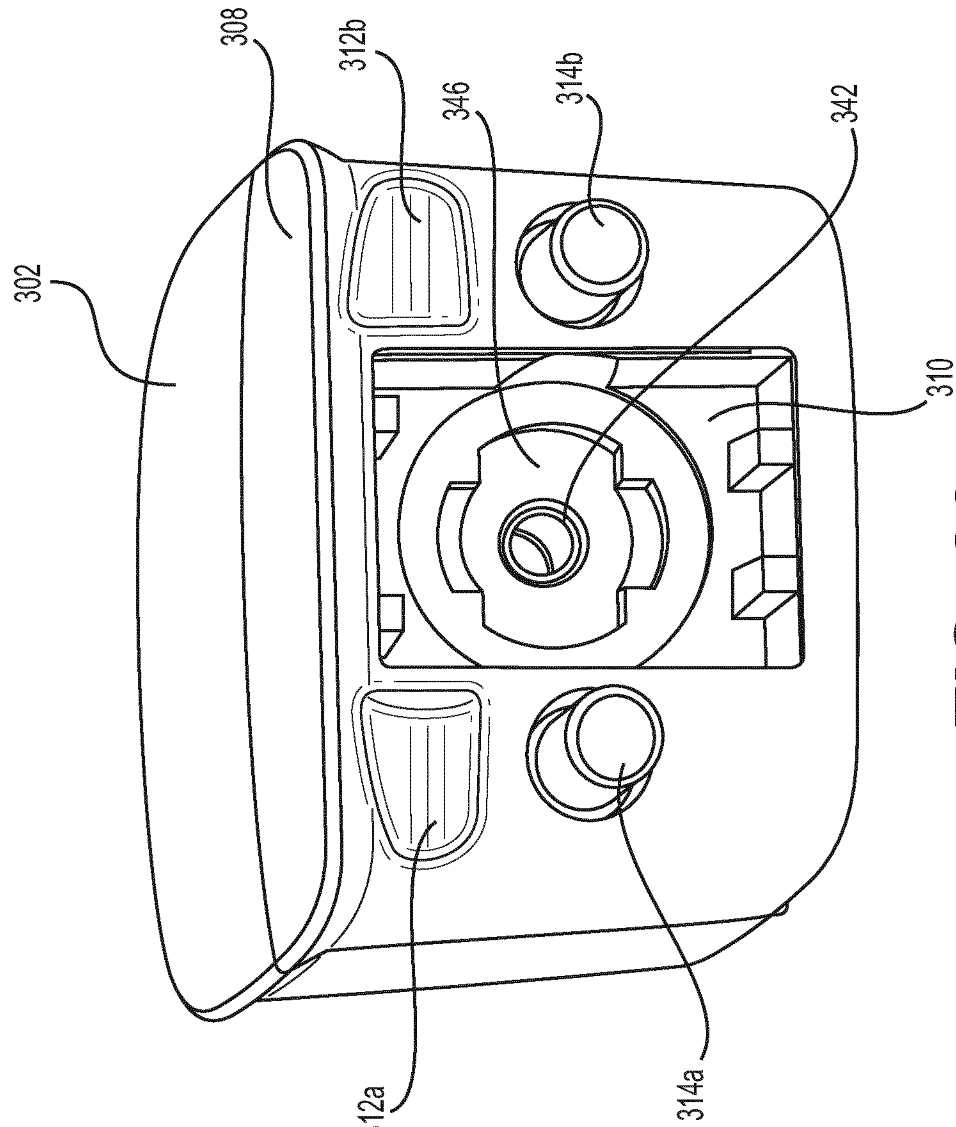

FIG. 20

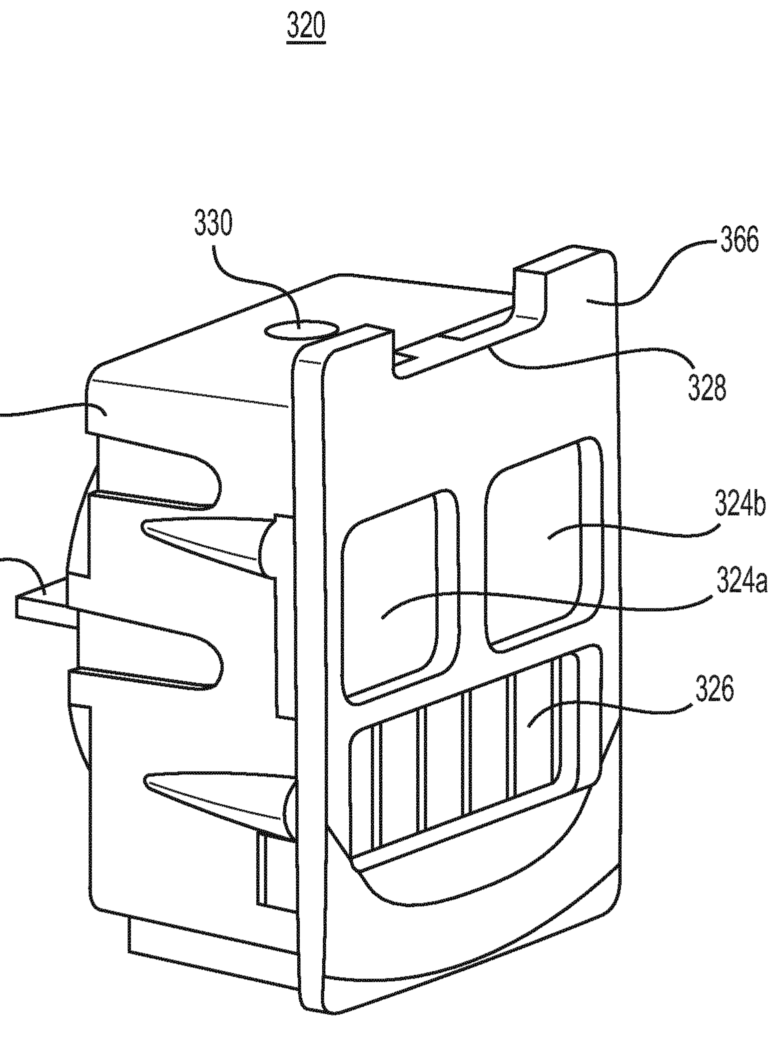

FIG. 21

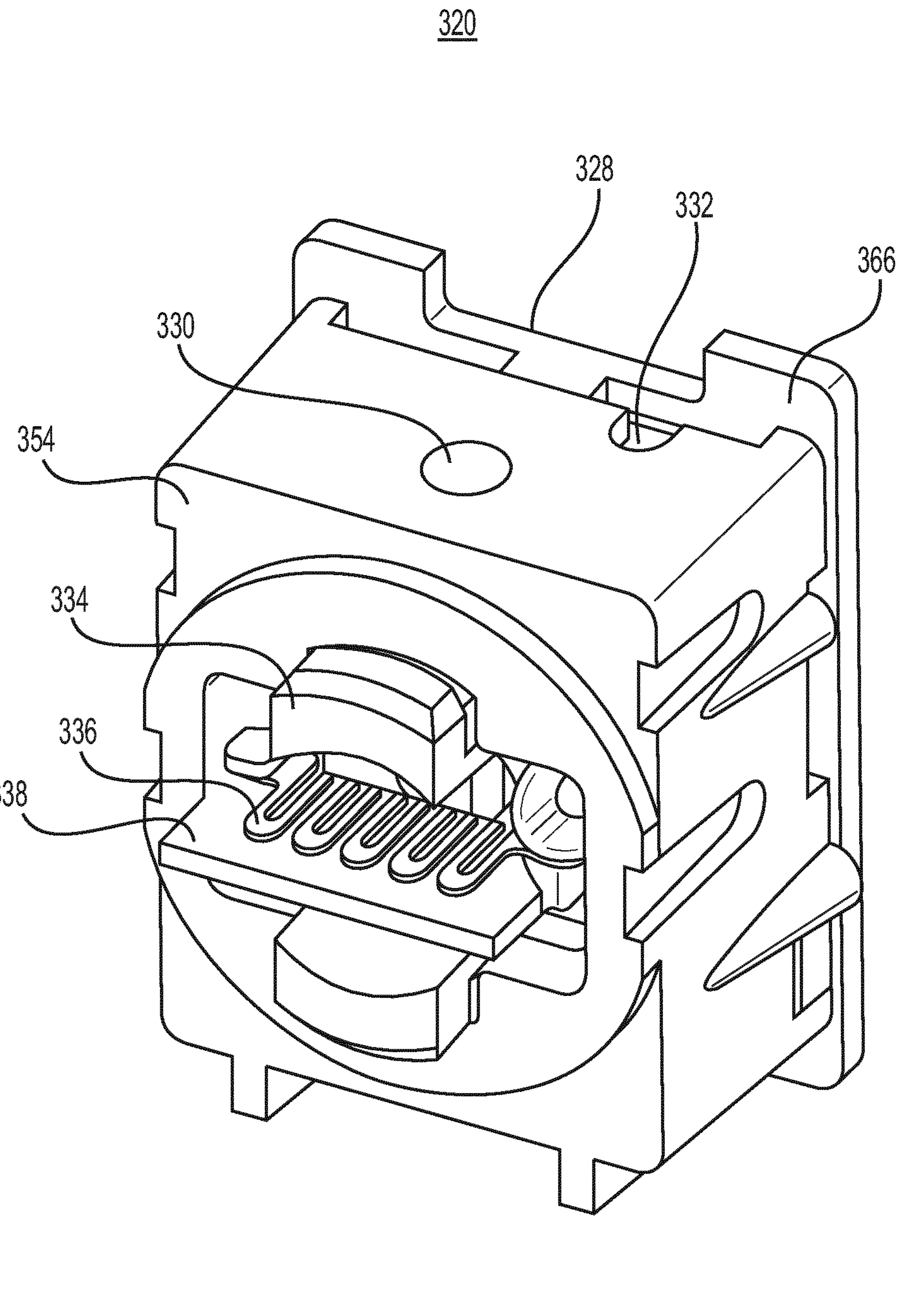

FIG. 22

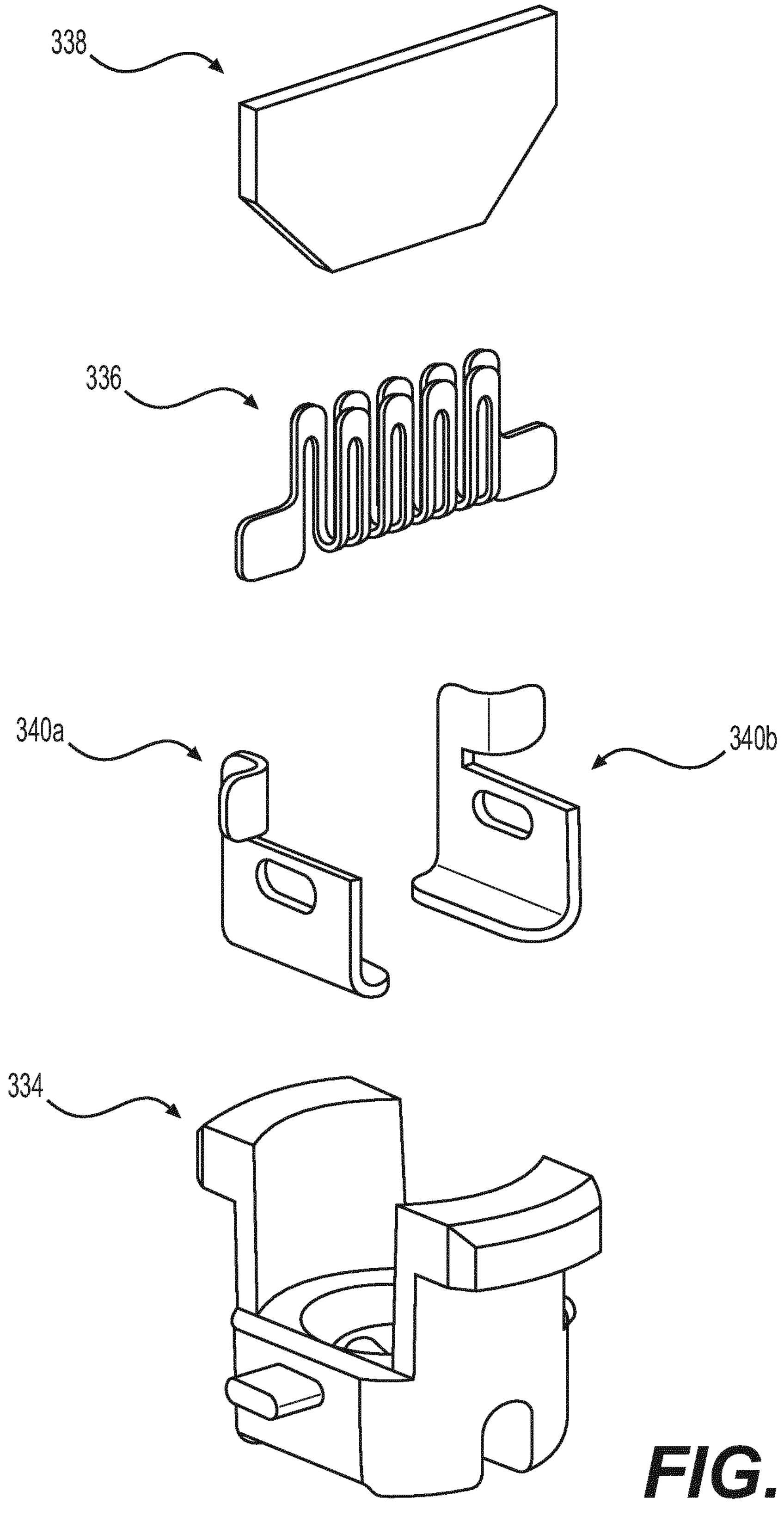

FIG. 23

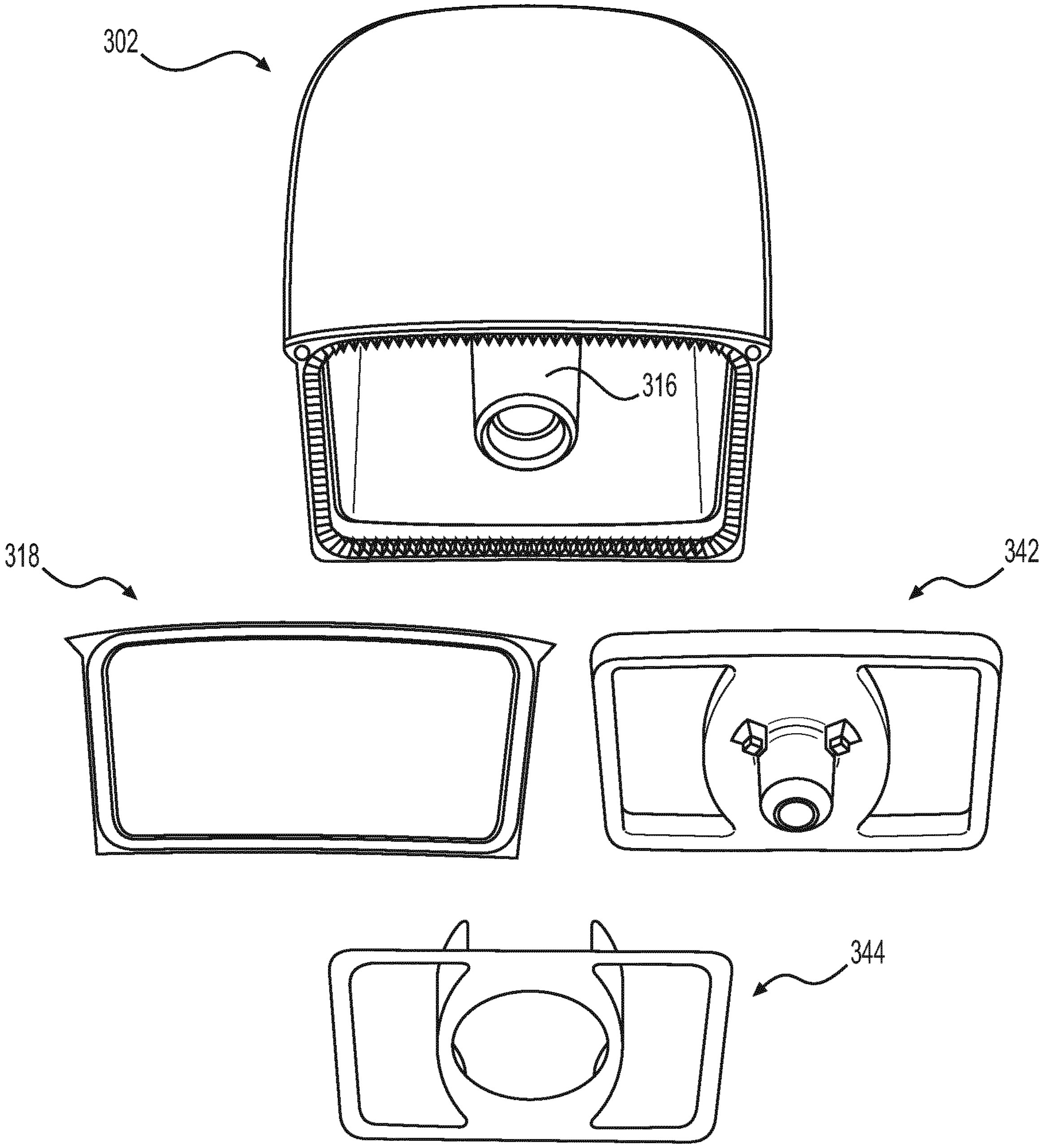

FIG. 24

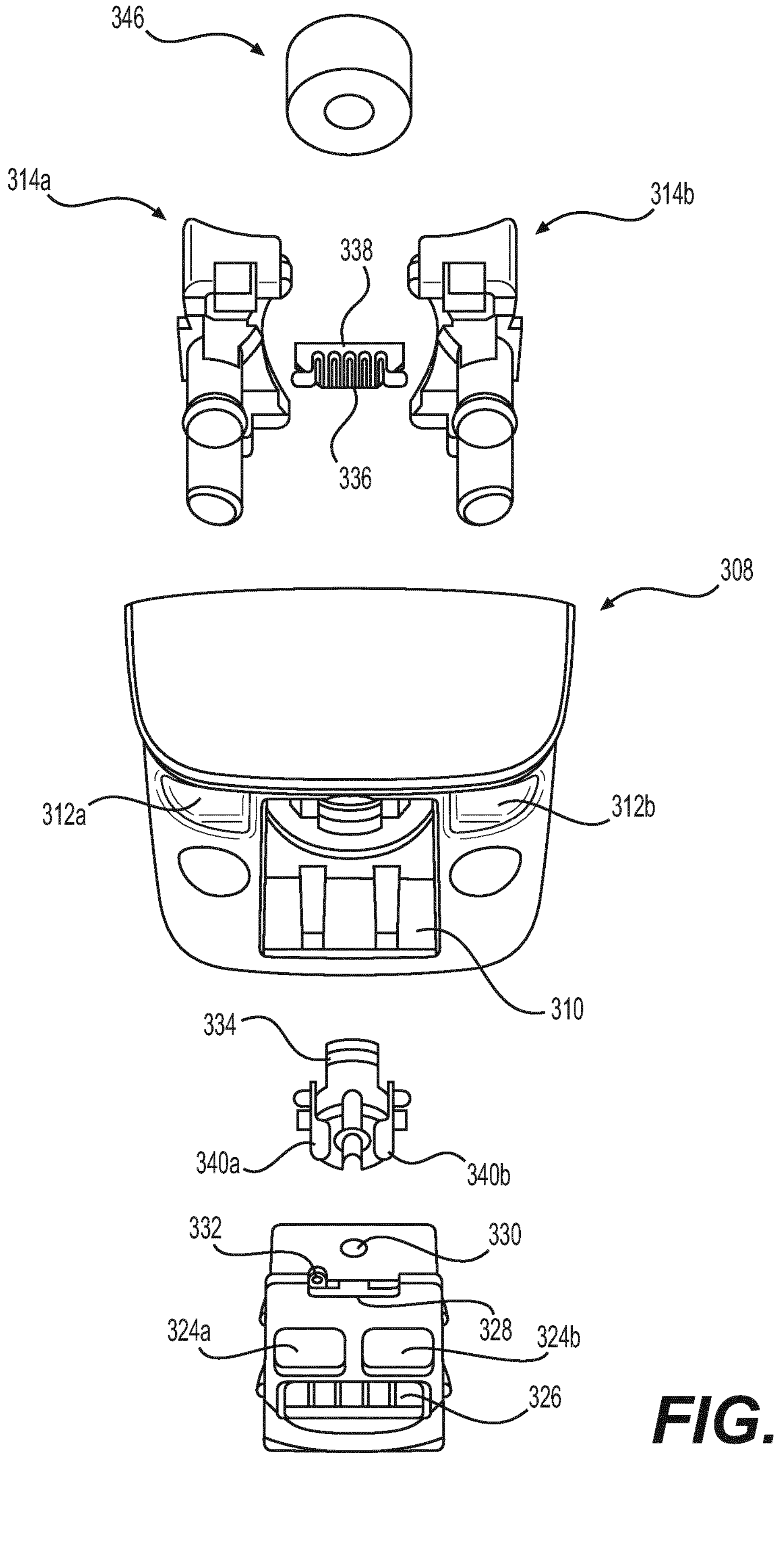
346
314a
314b
338
336
308
312a
312b
310
334
340a
340b
332
330
328
324a
324b
326

FIG. 25

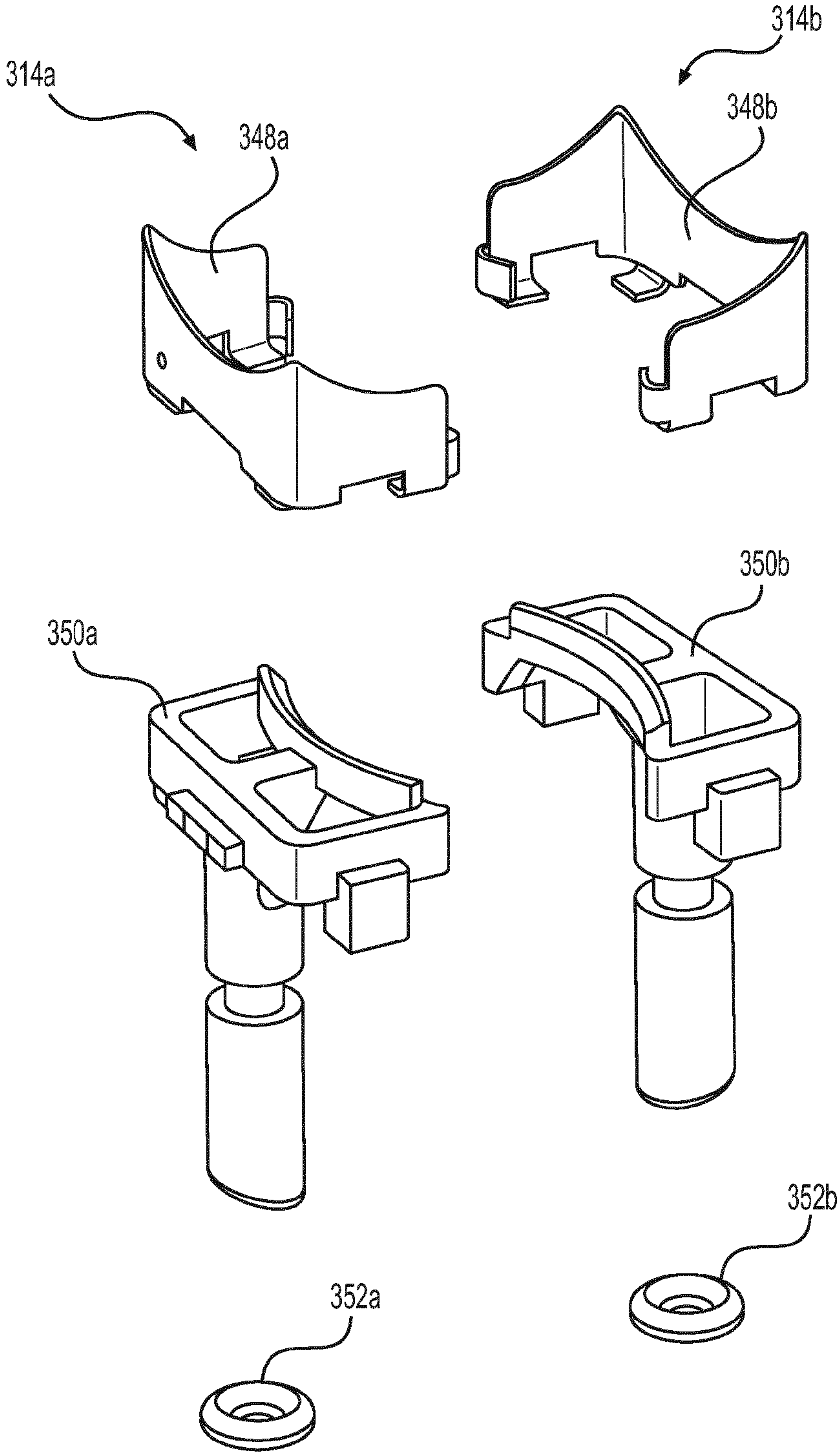

FIG. 26

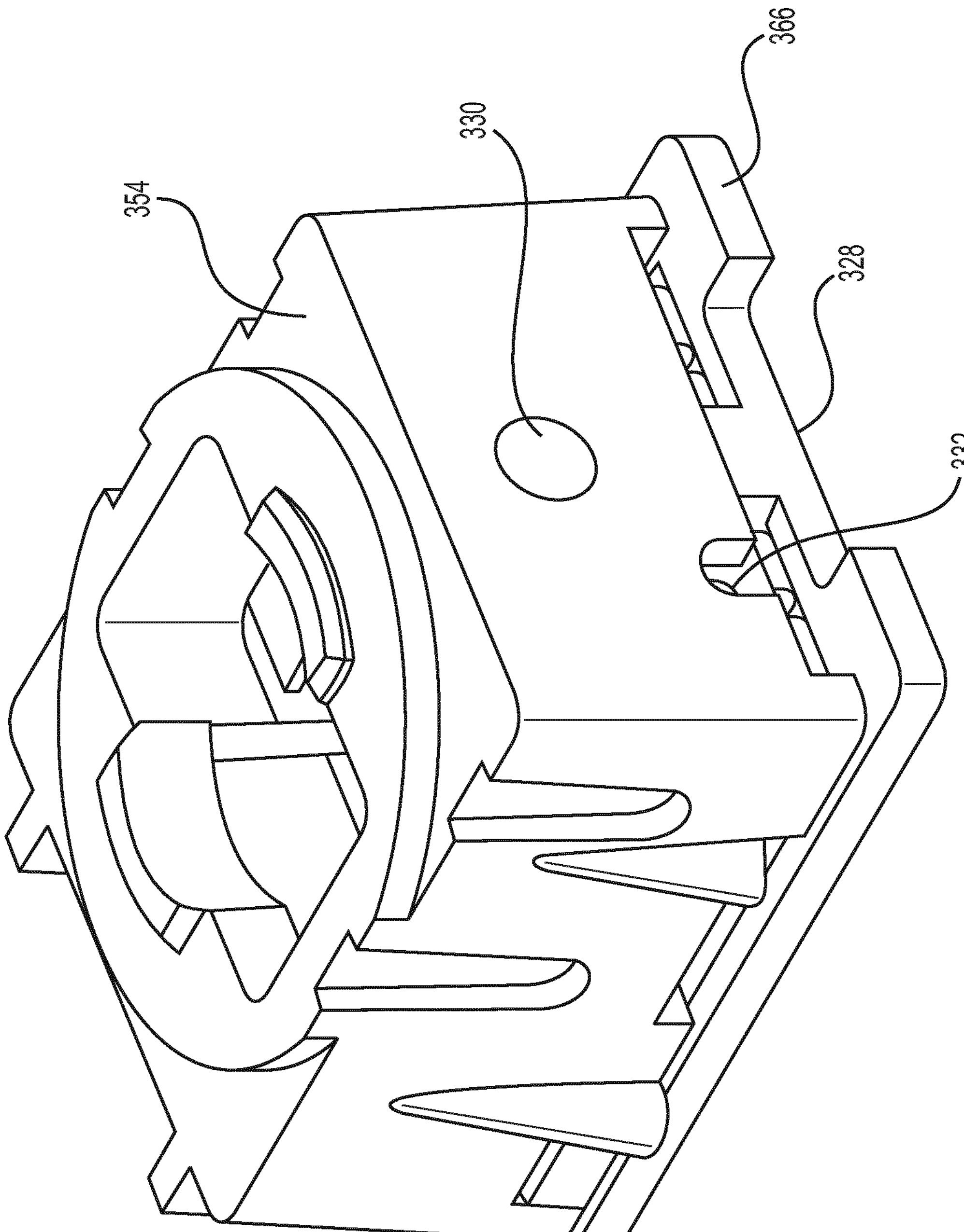

FIG. 27

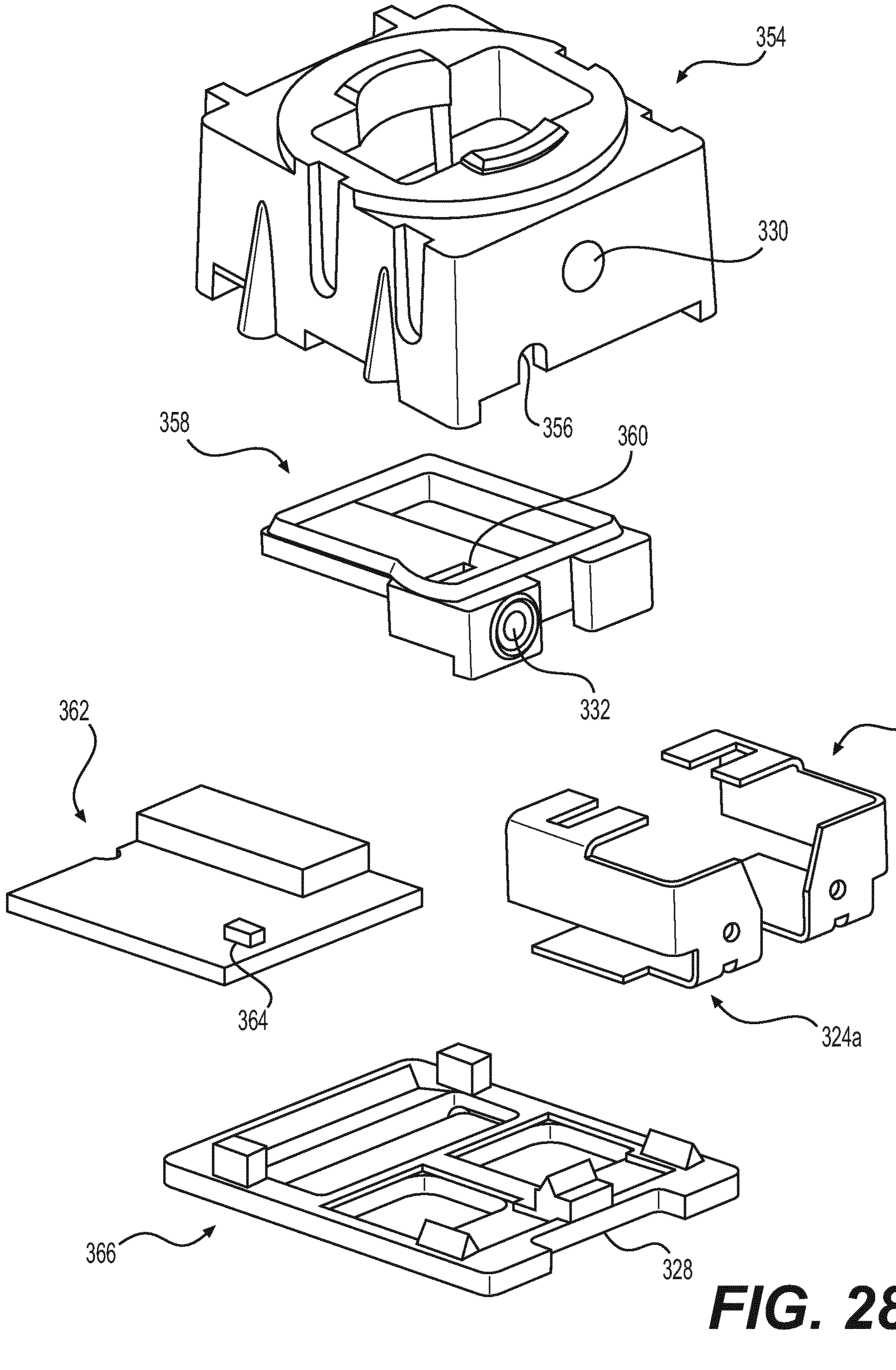

FIG. 28

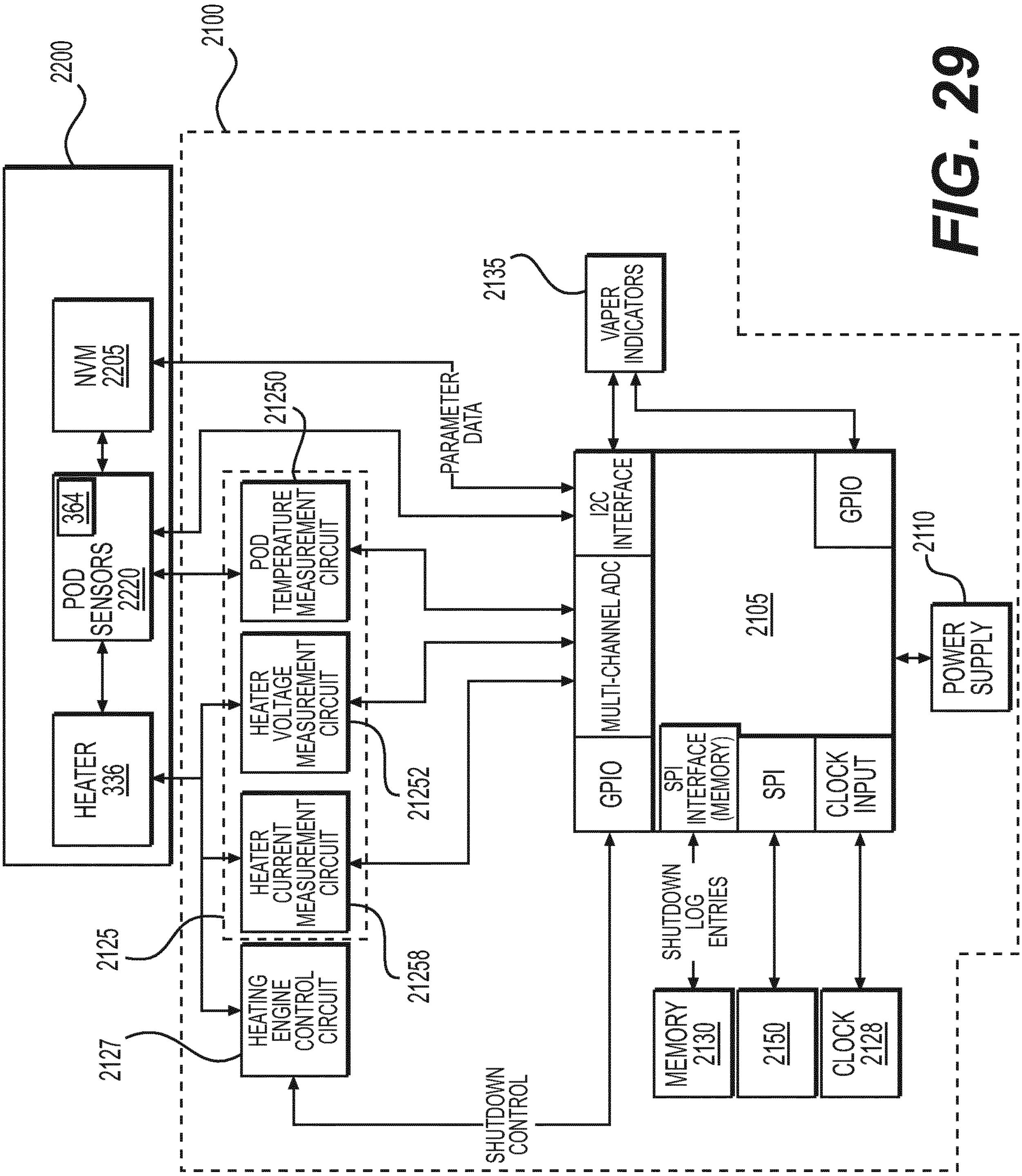
2200
2100
NVM
2205
POD
SENSORS
2220
364
HEATER
336
POD
TEMPERATURE
MEASUREMENT
CIRCUIT
21250
HEATER
VOLTAGE
MEASUREMENT
CIRCUIT
21252
HEATER
CURRENT
MEASUREMENT
CIRCUIT
21258
HEATING
ENGINE
CONTROL
CIRCUIT
2125
2127
PARAMETER
DATA
2135
VAPER
INDICATORS
I2C
INTERFACE
MULTI-CHANNEL ADC
GPIO
2105
SPI
INTERFACE
(MEMORY)
SPI
CLOCK
INPUT
2110
POWER
SUPPLY
SHUTDOWN
LOG
ENTRIES
MEMORY
2130
2150
CLOCK
2128
SHUTDOWN
CONTROL

FIG. 29

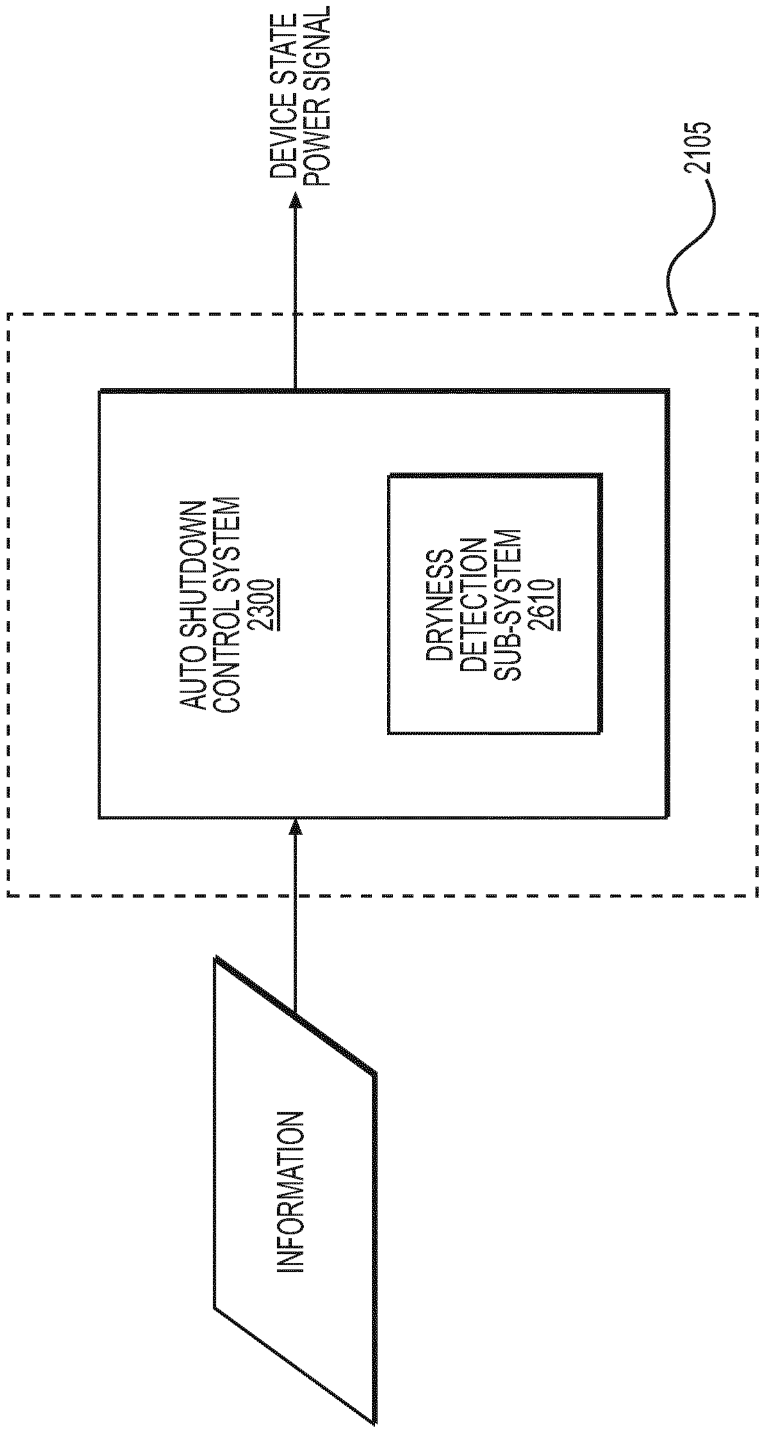
DEVICE STATE
POWER SIGNAL
2105
AUTO SHUTDOWN
CONTROL SYSTEM
2300
DRYNESS
DETECTION
SUB-SYSTEM
2610
INFORMATION

FIG. 30

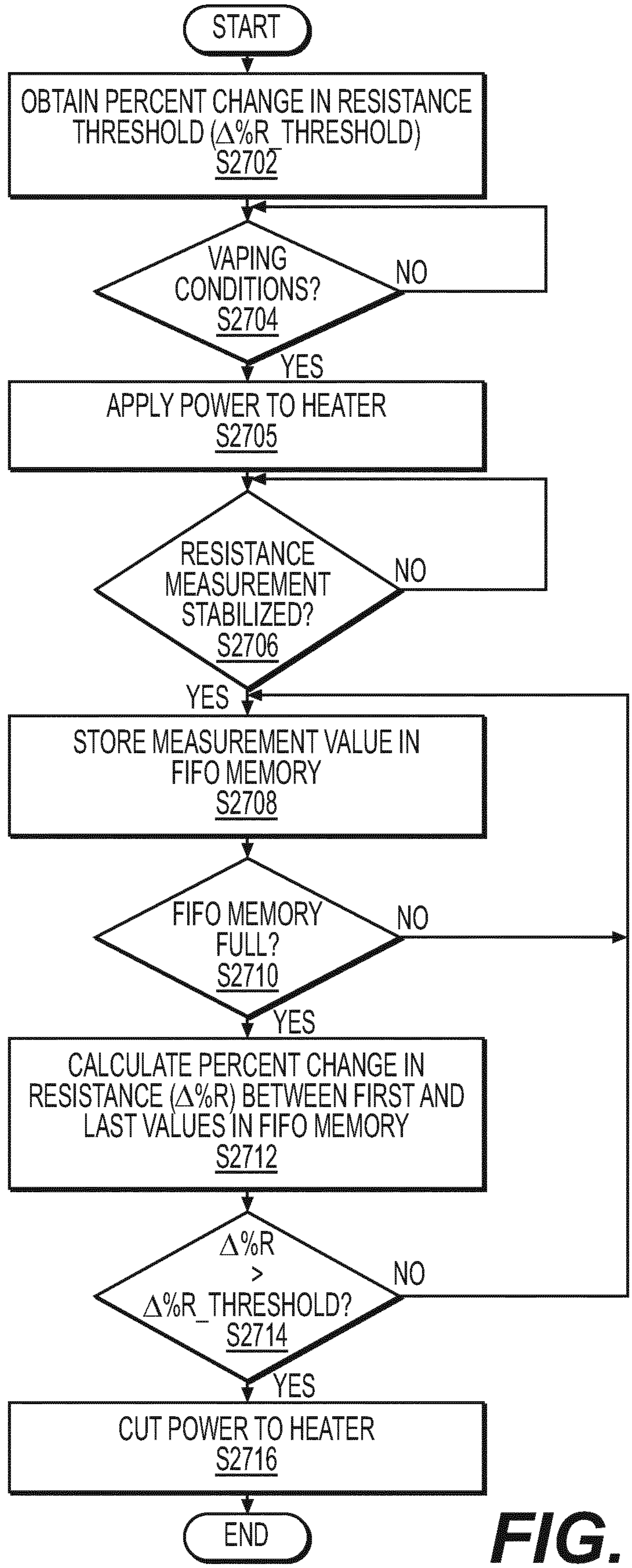
START
OBTAIN PERCENT CHANGE IN RESISTANCE THRESHOLD (Δ%R_THRESHOLD)
S2702
VAPING CONDITIONS?
S2704
NO
YES
APPLY POWER TO HEATER
S2705
RESISTANCE MEASUREMENT STABILIZED?
S2706
NO
YES
STORE MEASUREMENT VALUE IN FIFO MEMORY
S2708
FIFO MEMORY FULL?
S2710
NO
YES
CALCULATE PERCENT CHANGE IN RESISTANCE (Δ%R) BETWEEN FIRST AND LAST VALUES IN FIFO MEMORY
S2712
Δ%R > Δ%R_THRESHOLD?
S2714
NO
YES
CUT POWER TO HEATER
S2716
END

FIG. 31

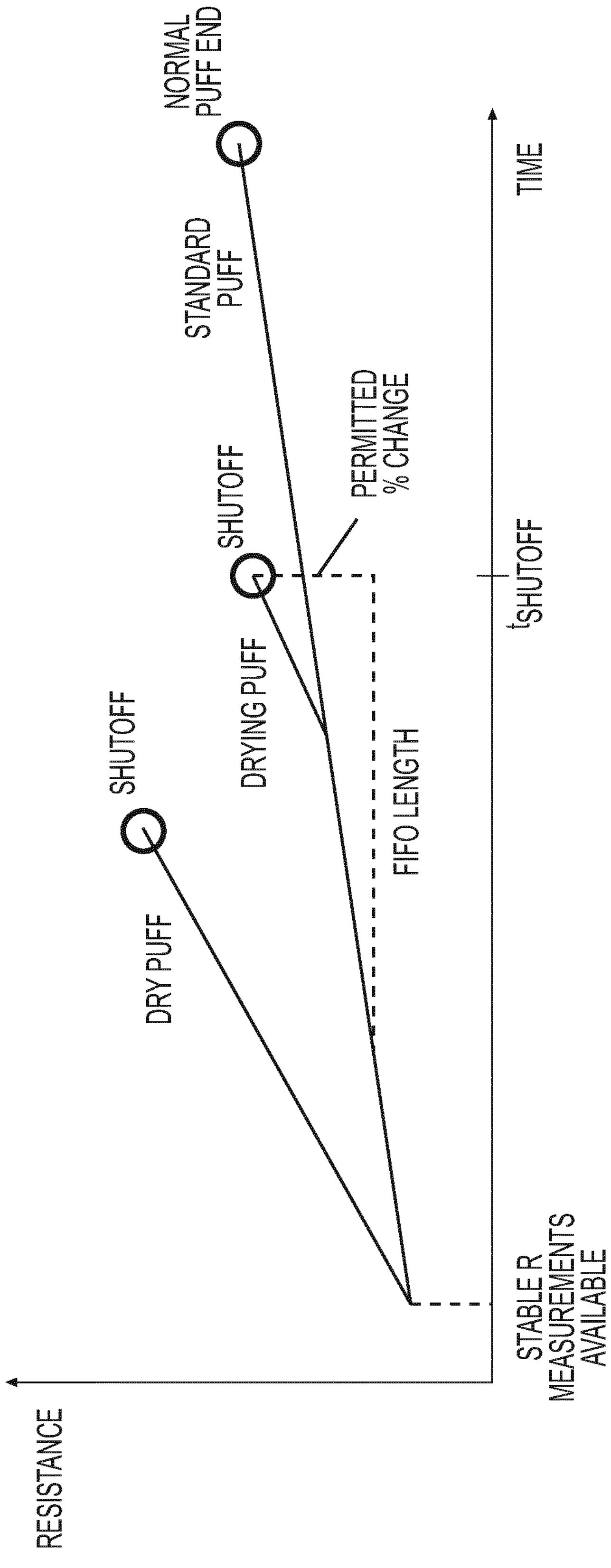
RESISTANCE
TIME
STABLE R MEASUREMENTS AVAILABLE
DRY PUFF
SHUTOFF
DRYING PUFF
SHUTOFF
FIFO LENGTH
PERMITTED % CHANGE
$t_{SHUTOFF}$
STANDARD PUFF
NORMAL PUFF END

FIG. 32

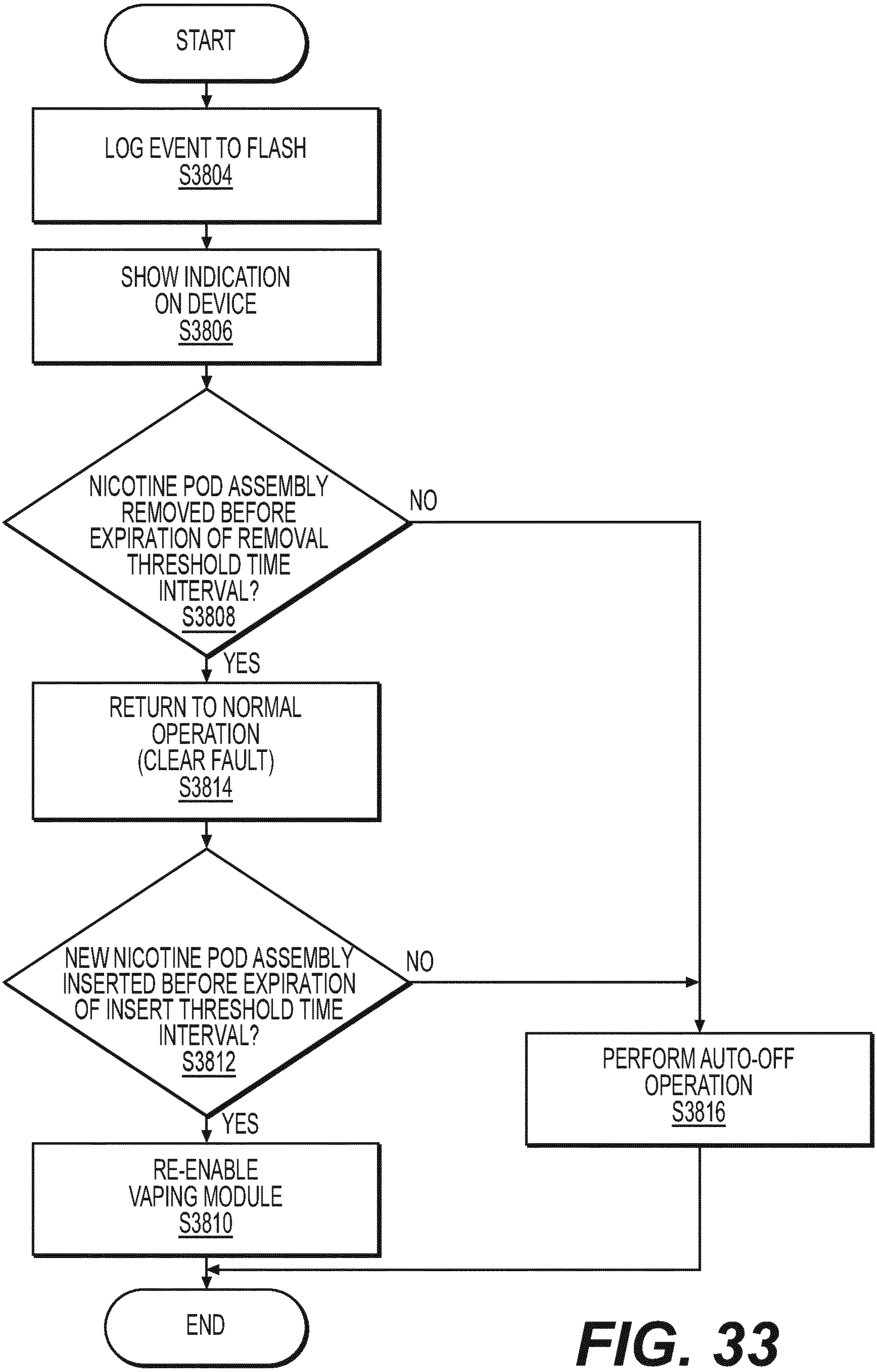
START
LOG EVENT TO FLASH
S3804
SHOW INDICATION
ON DEVICE
S3806
NICOTINE POD ASSEMBLY
REMOVED BEFORE
EXPIRATION OF REMOVAL
THRESHOLD TIME
INTERVAL?
S3808
NO
YES
RETURN TO NORMAL
OPERATION
(CLEAR FAULT)
S3814
NEW NICOTINE POD ASSEMBLY
INSERTED BEFORE EXPIRATION
OF INSERT THRESHOLD TIME
INTERVAL?
S3812
NO
YES
PERFORM AUTO-OFF
OPERATION
S3816
RE-ENABLE
VAPING MODULE
S3810
END

FIG. 33

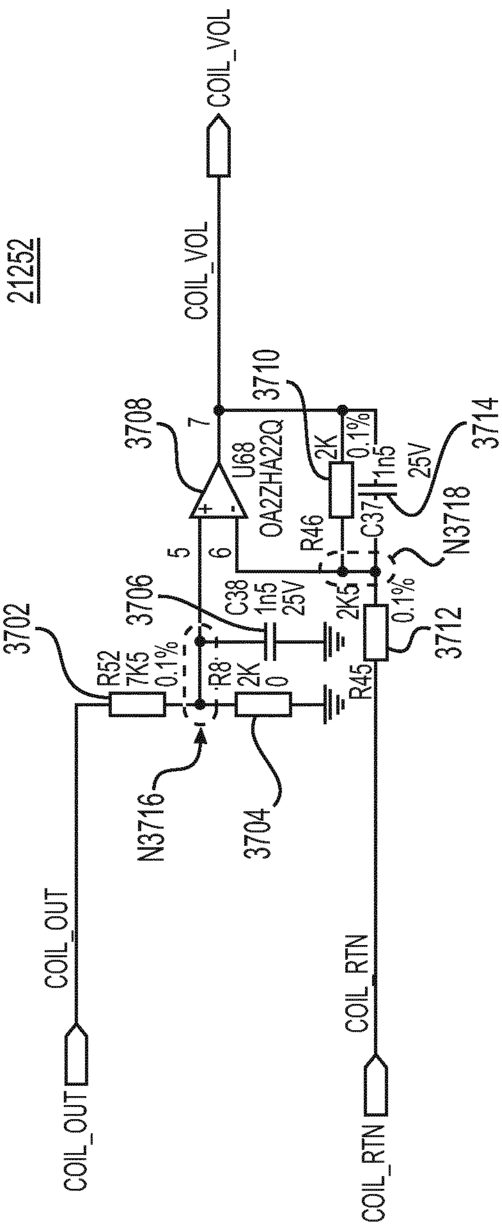
21252
COIL_VOL
COIL_VOL
3708
7
3710
U68
OA2ZHA22Q
2K
0.1%
1n5
25V
3714
R46
C37
N3718
5
6
3706
C38
1n5
25V
2K5
0.1%
3712
3702
R52
7K5
0.1%
R8
2K
0
R45
N3716
3704
COIL_OUT
COIL_OUT
COIL_RTN
COIL_RTN

FIG. 34

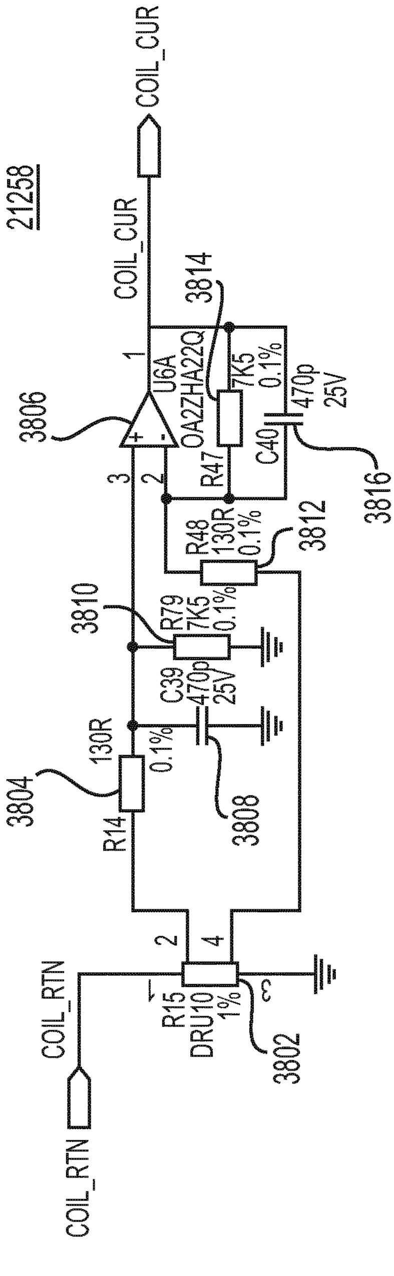
21258
COIL_CUR
COIL_CUR
3814
1
U6A
OA2ZHA22Q
7K5
0.1%
470p
25V
3806
3
2
R47
C40
3816
R48
130R
0.1%
3812
3810
R79
7K5
0.1%
C39
470p
25V
130R
0.1%
3804
R14
3808
2
4
R15
DRU10
1%
3802
COIL_RTN
COIL_RTN

FIG. 35

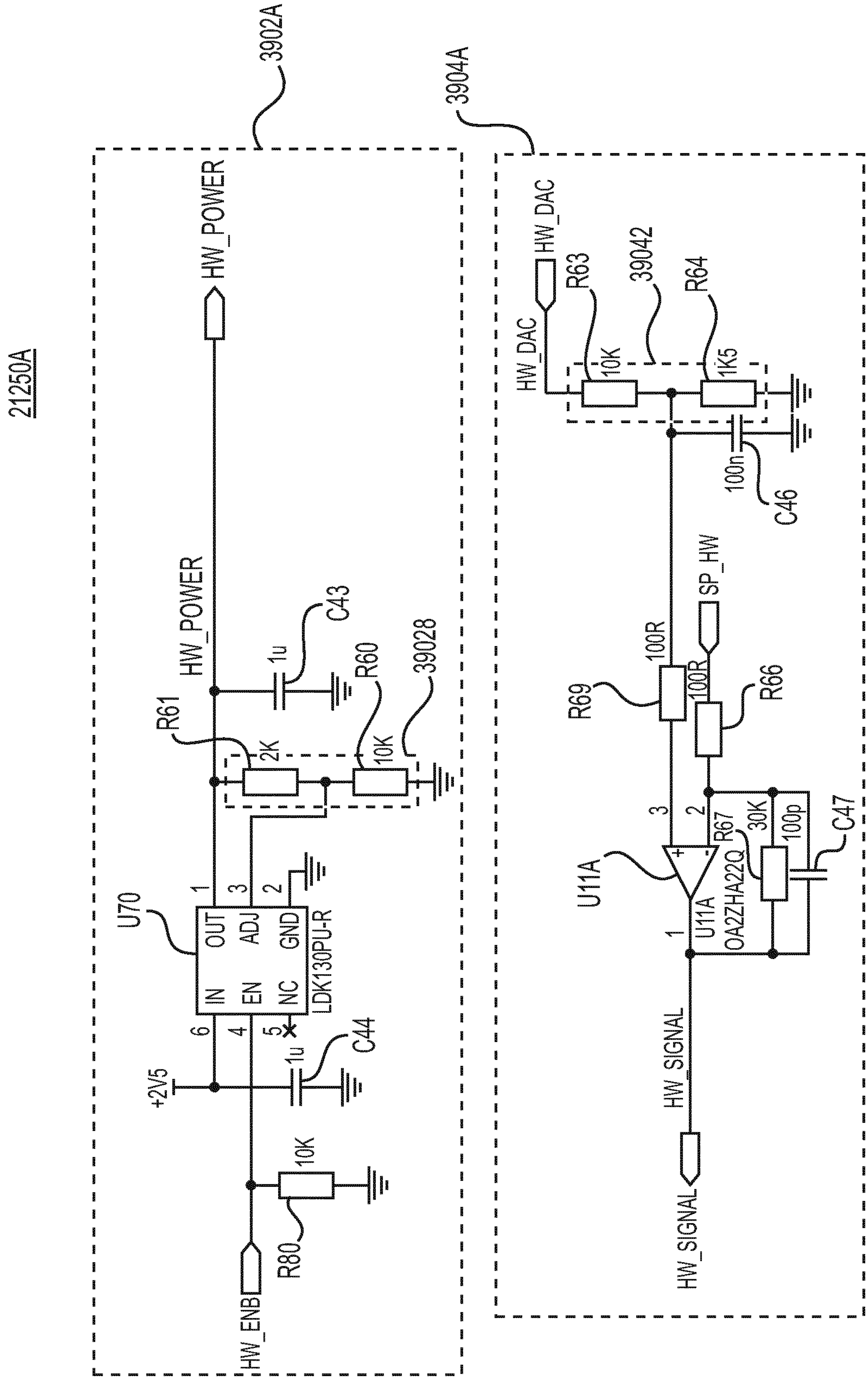
21250A
3902A
3904A
HW_POWER
HW_POWER
C43
1u
R61
2K
R60
10K
39028
U70
OUT
ADJ
GND
IN
EN
NC
LDK130PU-R
+2V5
1u
C44
10K
R80
HW_ENB
HW_DAC
HW_DAC
R63
10K
39042
R64
1K5
100n
C46
SP_HW
100R
R69
100R
R66
U11A
U11A
OA2ZHA22Q
R67
30K
100p
C47
HW_SIGNAL
HW_SIGNAL

FIG. 36

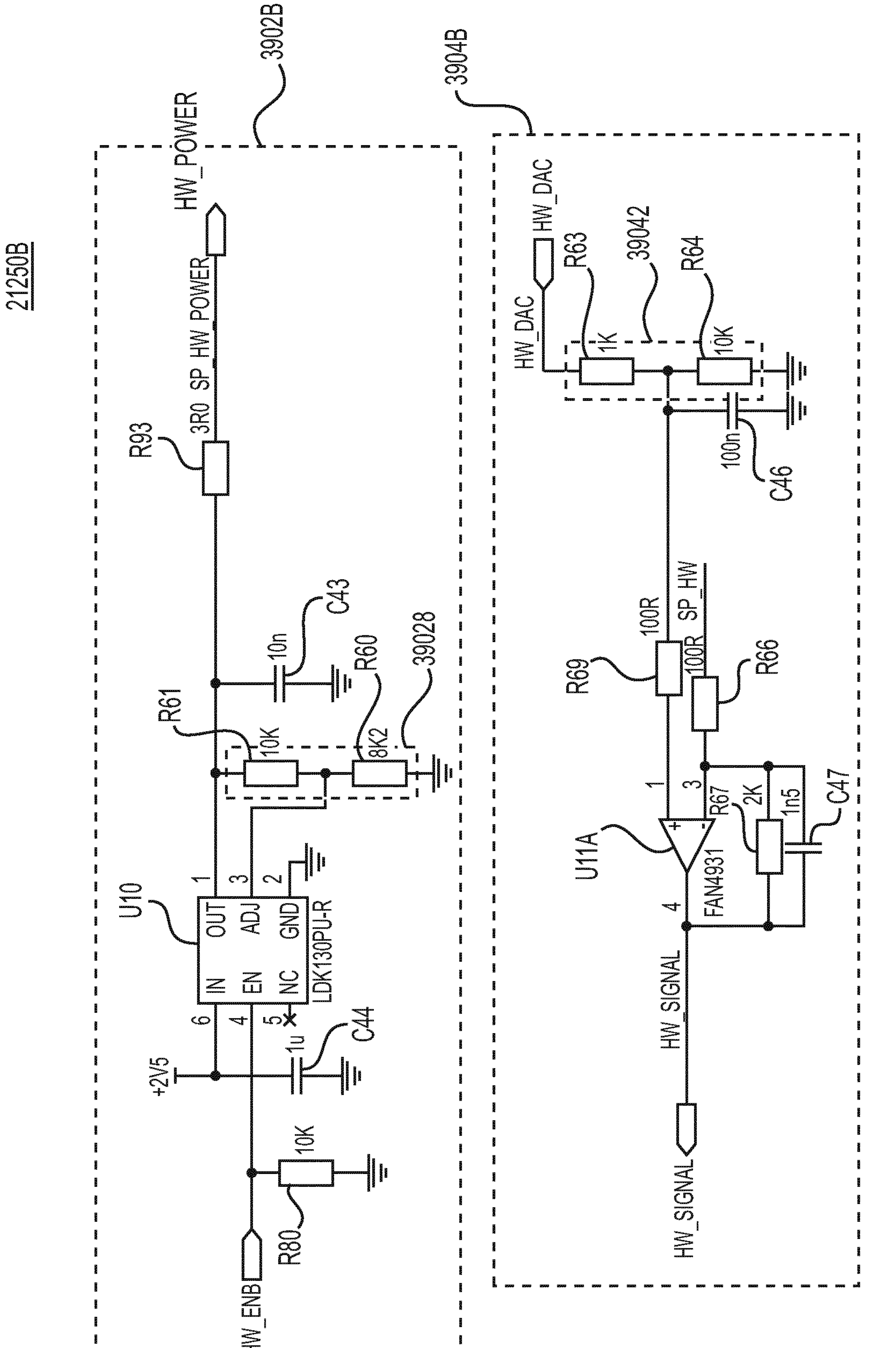
21250B
3902B
HW_POWER
SP_HW_POWER
R93
3R0
C43
10n
R61
10K
R60
8K2
39028
U10
OUT
ADJ
GND
IN
EN
NC
LDK130PU-R
1
3
2
6
4
5
+2V5
1u
C44
10K
R80
HW_ENB
3904B
HW_DAC
R63
39042
R64
1K
10K
100n
C46
100R
SP_HW
R69
100R
R66
U11A
FAN4931
R67
2K
1n5
C47
HW_SIGNAL

FIG. 37

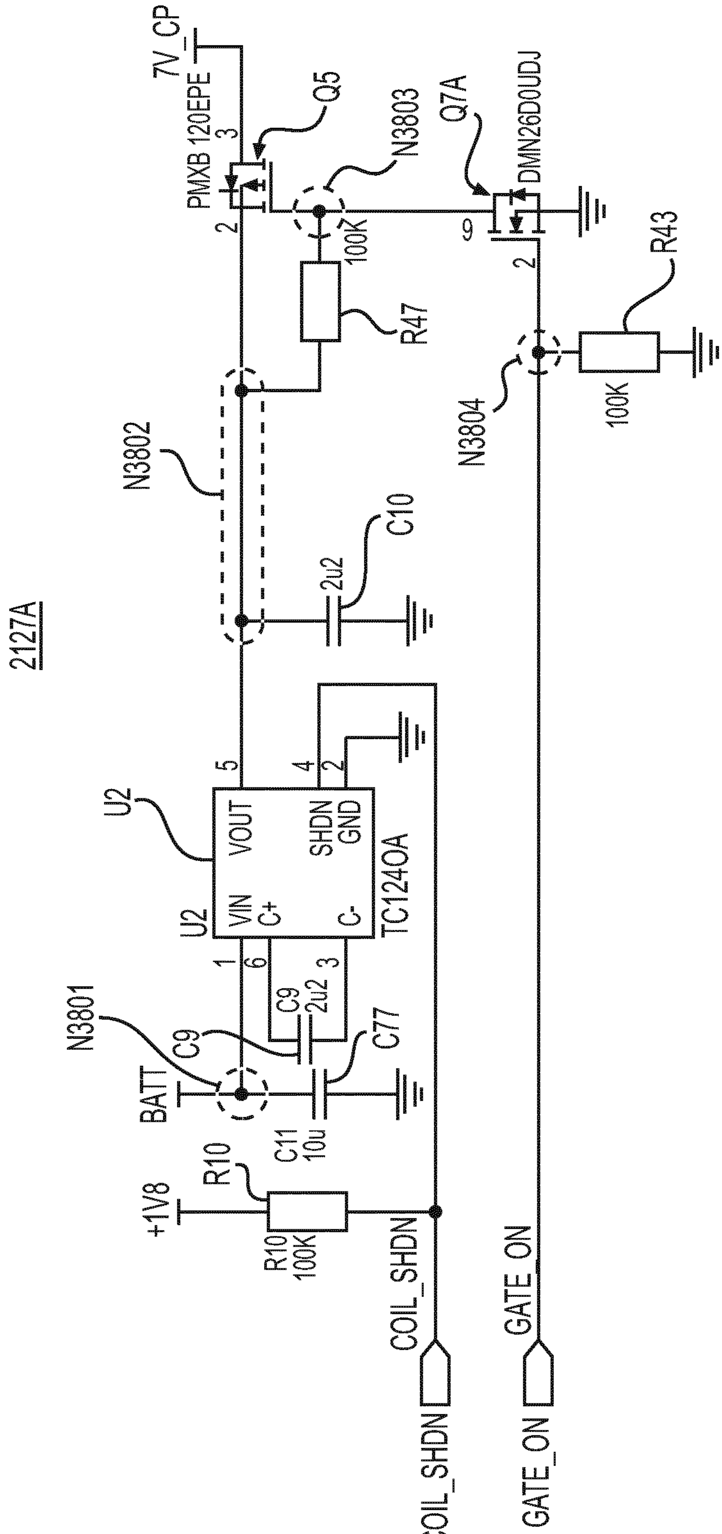
2127A
7V_CP
PMXB 120EPE
Q5
3
2
N3803
100K
Q7A
DMN26D0UDJ
6
2
R47
R43
100K
N3804
N3802
C10
2u2
U2
VOUT
SHDN
GND
5
4
2
U2
VIN
C+
C-
TC124OA
1
6
3
C9
2u2
C77
N3801
C9
BATT
C11
10u
R10
+1V8
R10
100K
COIL_SHDN
COIL_SHDN
GATE_ON
GATE_ON

FIG. 38

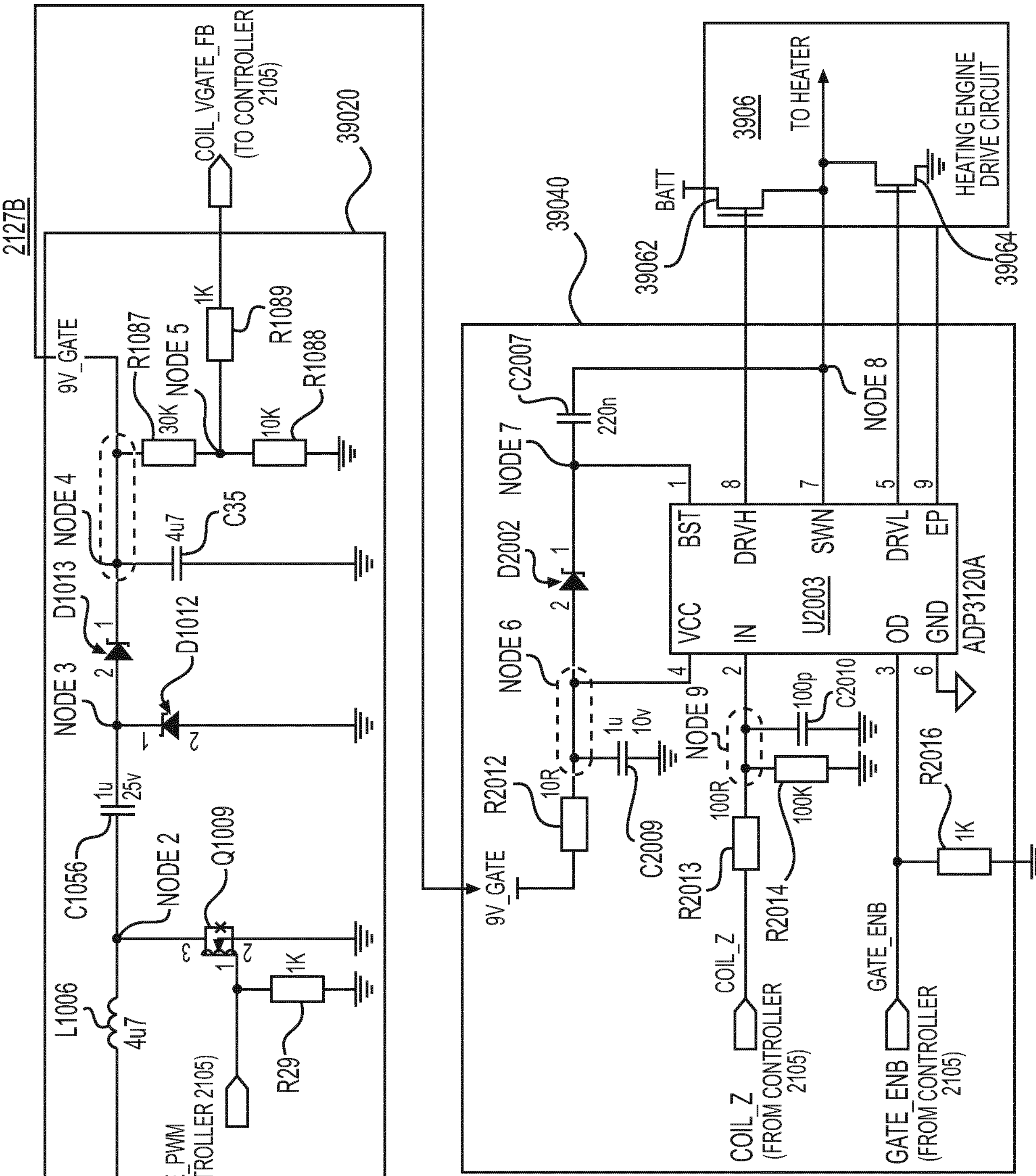
2127B
39020
COIL_VGATE_FB
(TO CONTROLLER 2105)
9V_GATE
R1087
NODE 5
1K
R1089
R1088
30K
10K
NODE 4
4u7
C35
D1013
D1012
NODE 3
1u
25v
C1056
NODE 2
Q1009
L1006
4u7
1K
R29
COIL_VGATE_PWM
(FROM CONTROLLER 2105)
BATT
NODE 1
C36
10u
39040
C2007
220n
NODE 7
NODE 8
D2002
NODE 6
BST
DRVH
SWN
DRVL
EP
VCC
IN
U2003
OD
GND
ADP3120A
NODE 9
100p
C2010
1u
10v
C2009
R2012
10R
100R
R2013
100K
R2014
R2016
1K
9V_GATE
COIL_Z
COIL_Z
(FROM CONTROLLER 2105)
GATE_ENB
GATE_ENB
(FROM CONTROLLER 2105)
BATT
39062
3906
TO HEATER
HEATING ENGINE DRIVE CIRCUIT
39064

FIG. 39

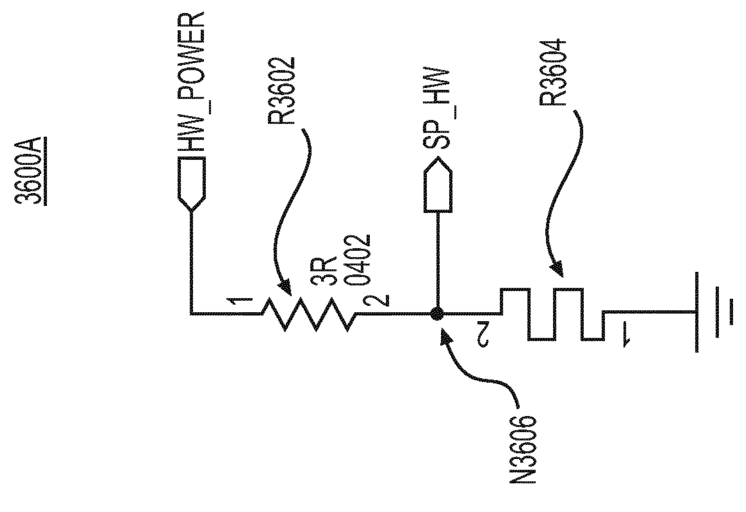
3600A
HW_POWER
R3602
1
3R
0402
2
SP_HW
R3604
2
1
N3606

FIG. 40

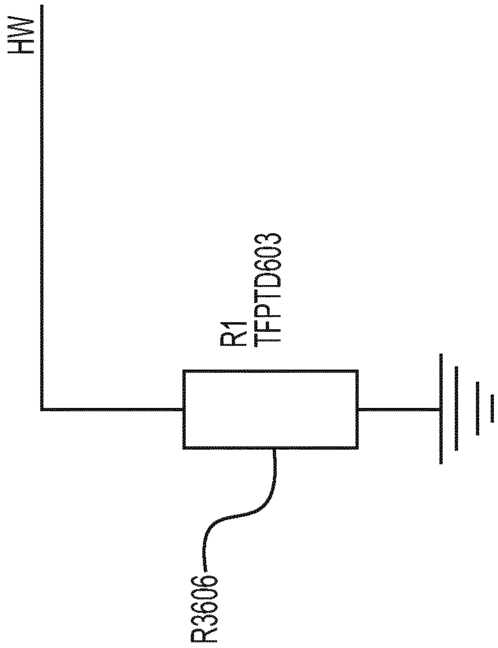
HW
R1
TFPTD603
R3606

FIG. 41