



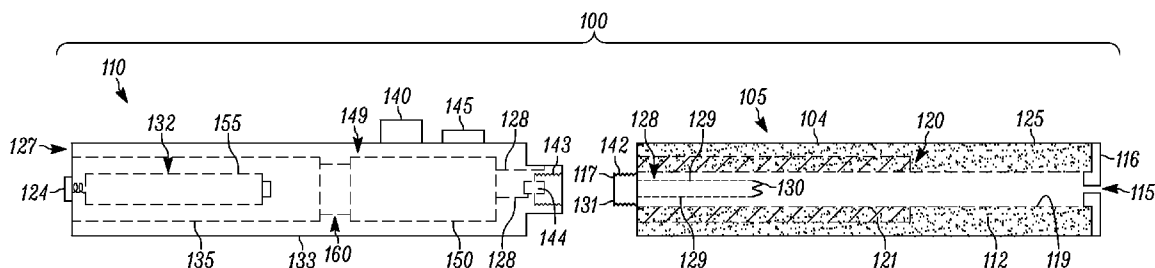
(43) **Pub. Date:** **Oct. 9, 2014**

Publication Classification

(22) Filed: **Sep. 20, 2013**

Related U.S. Application Data

(60) Provisional application No. 61/869,299, filed on Aug. 23, 2013, provisional application No. 61/846,342,



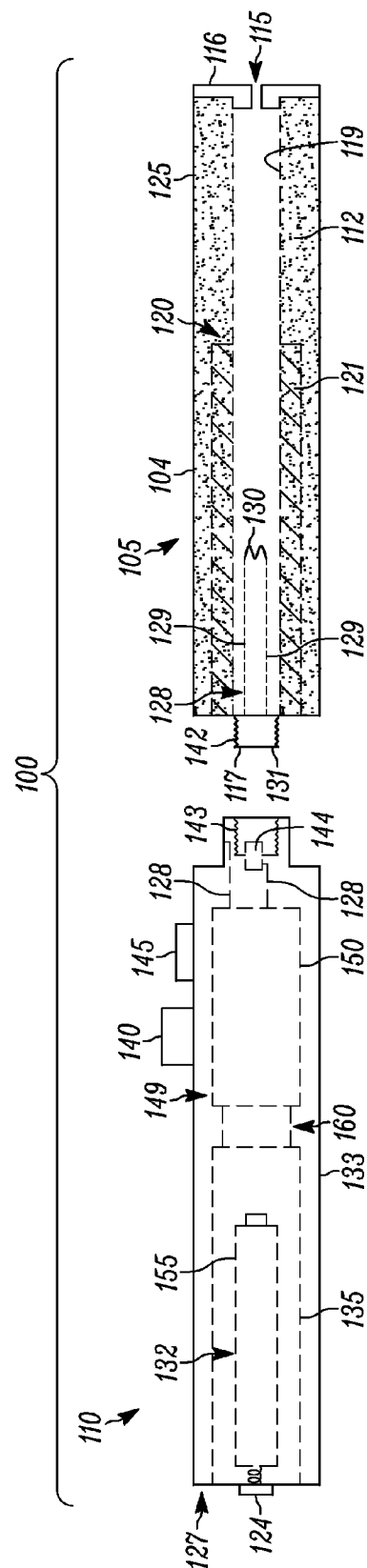


Fig. 1A

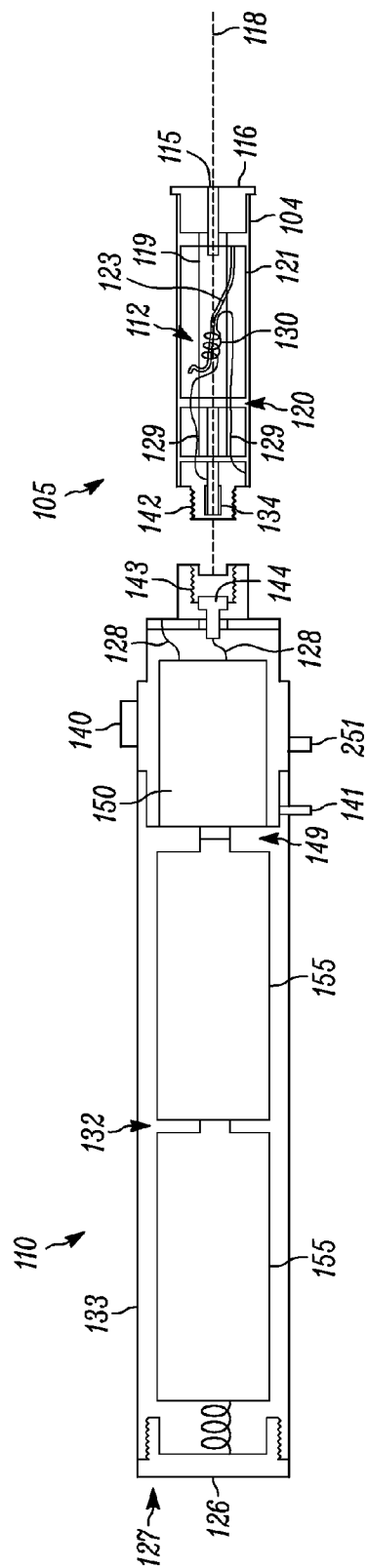


Fig. 1B

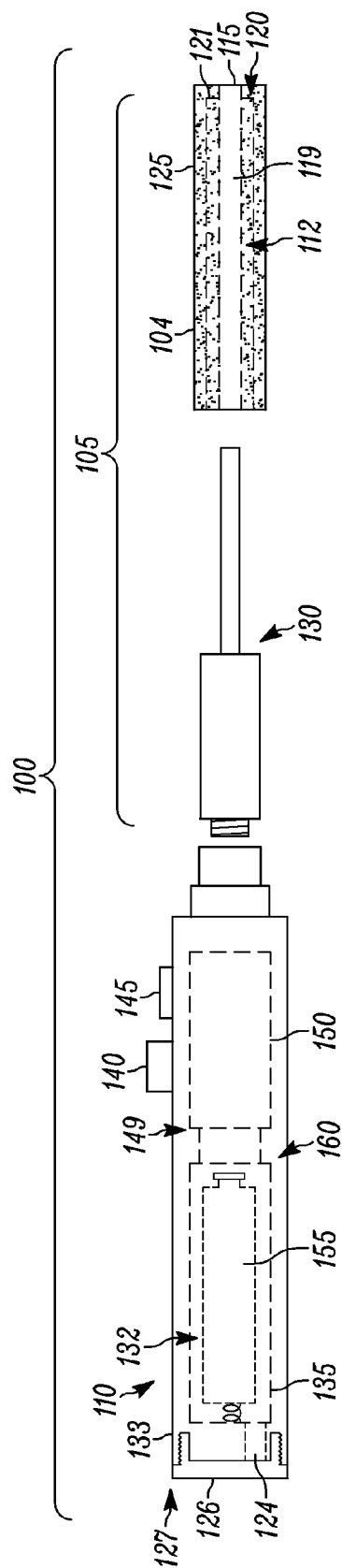


Fig. 2

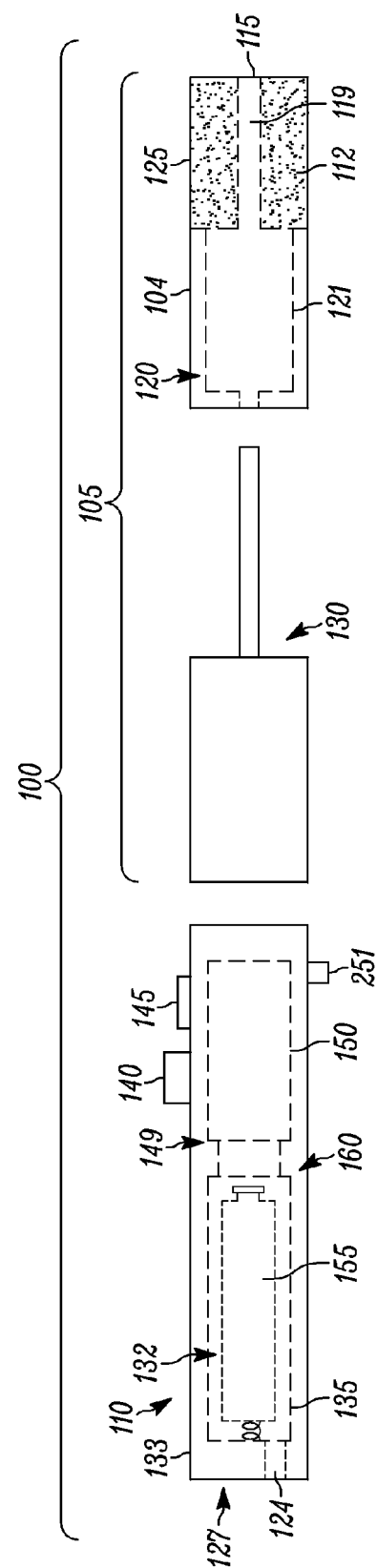


Fig. 3

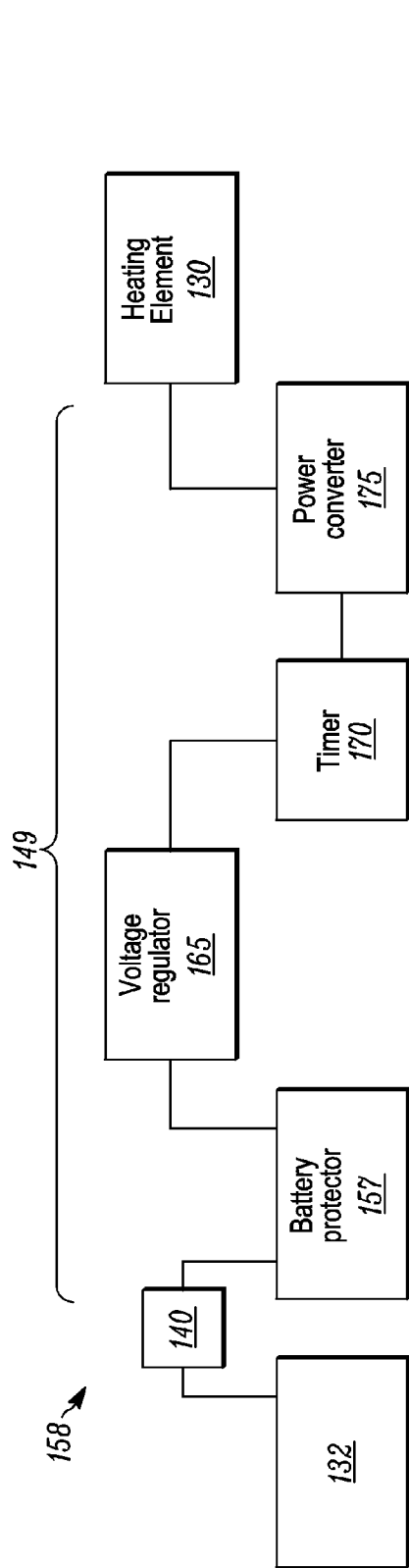


Fig. 4A

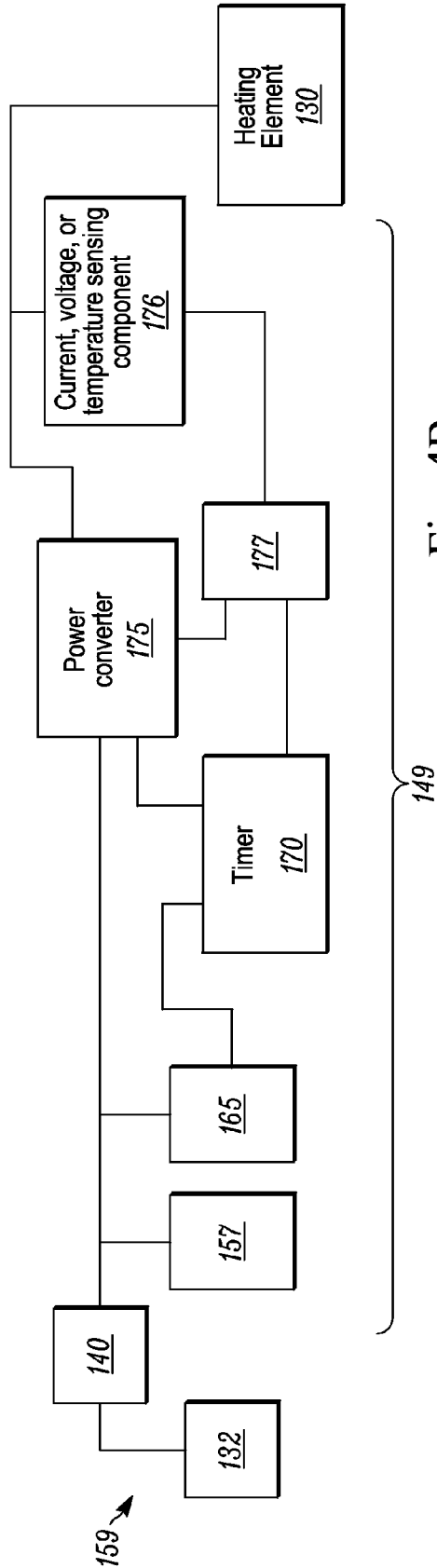
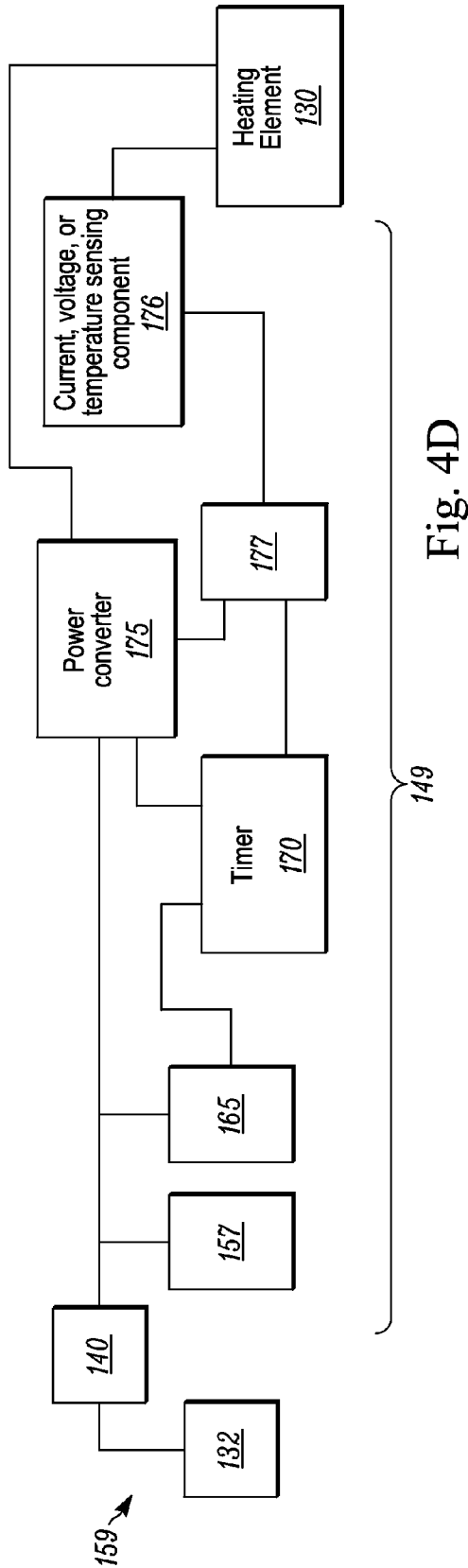
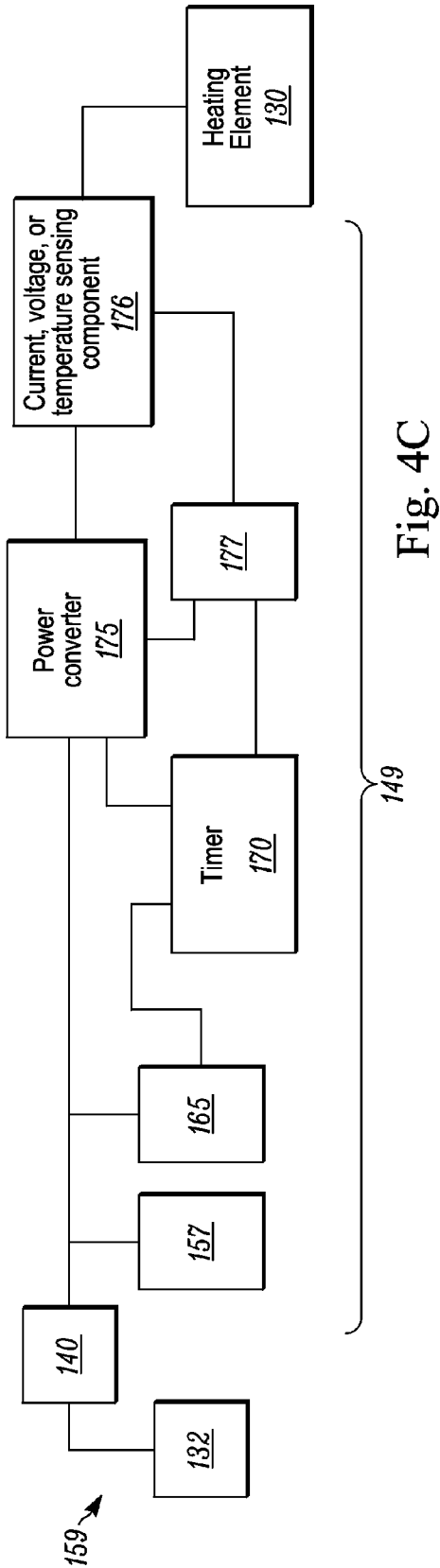


Fig. 4B



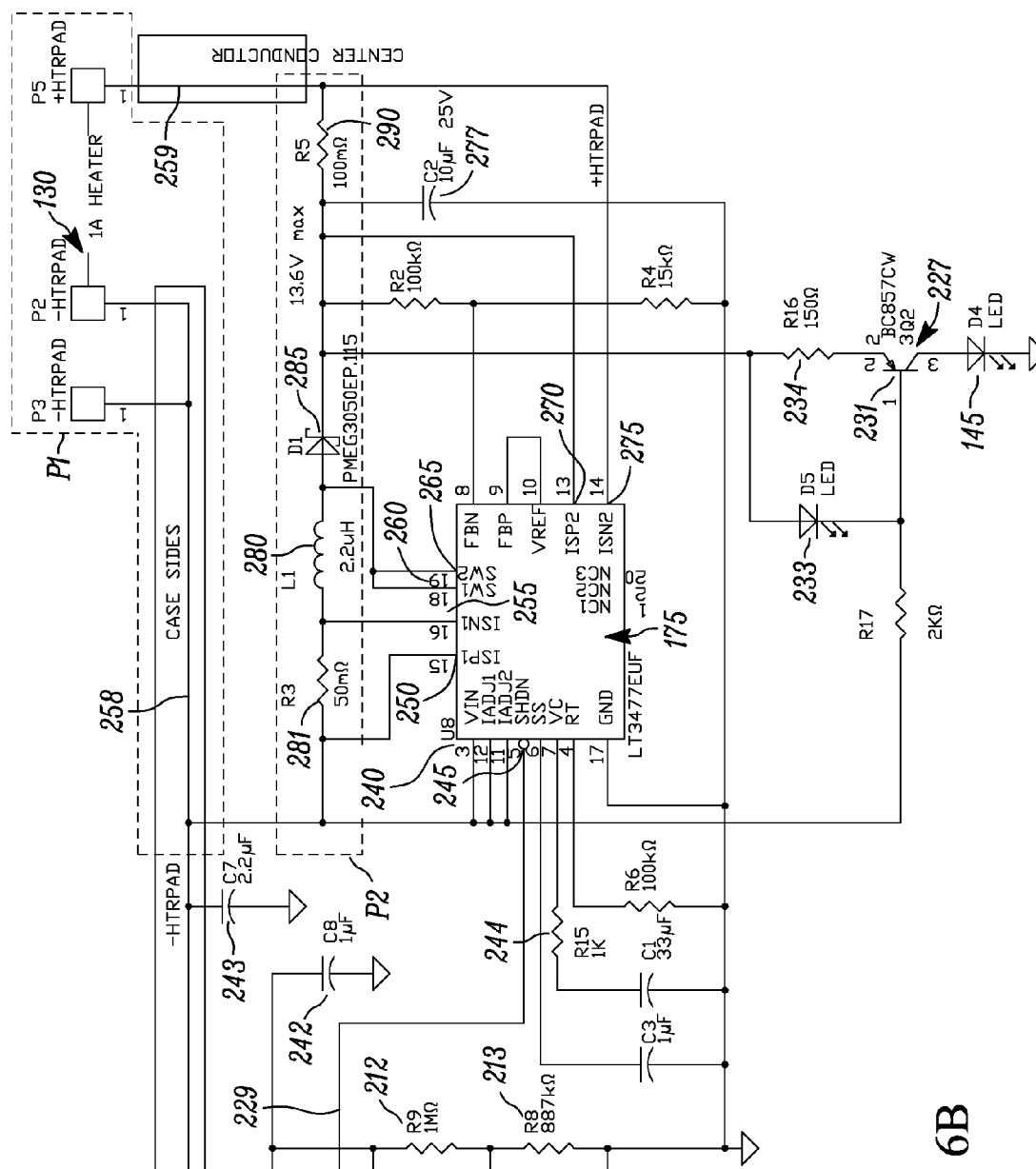


FIG. 6B

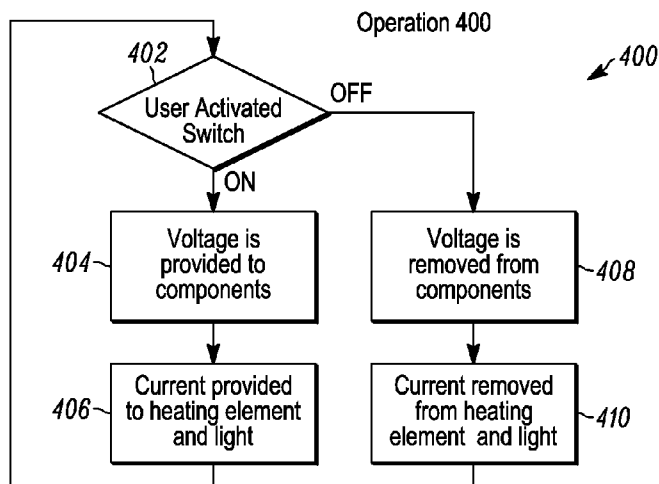
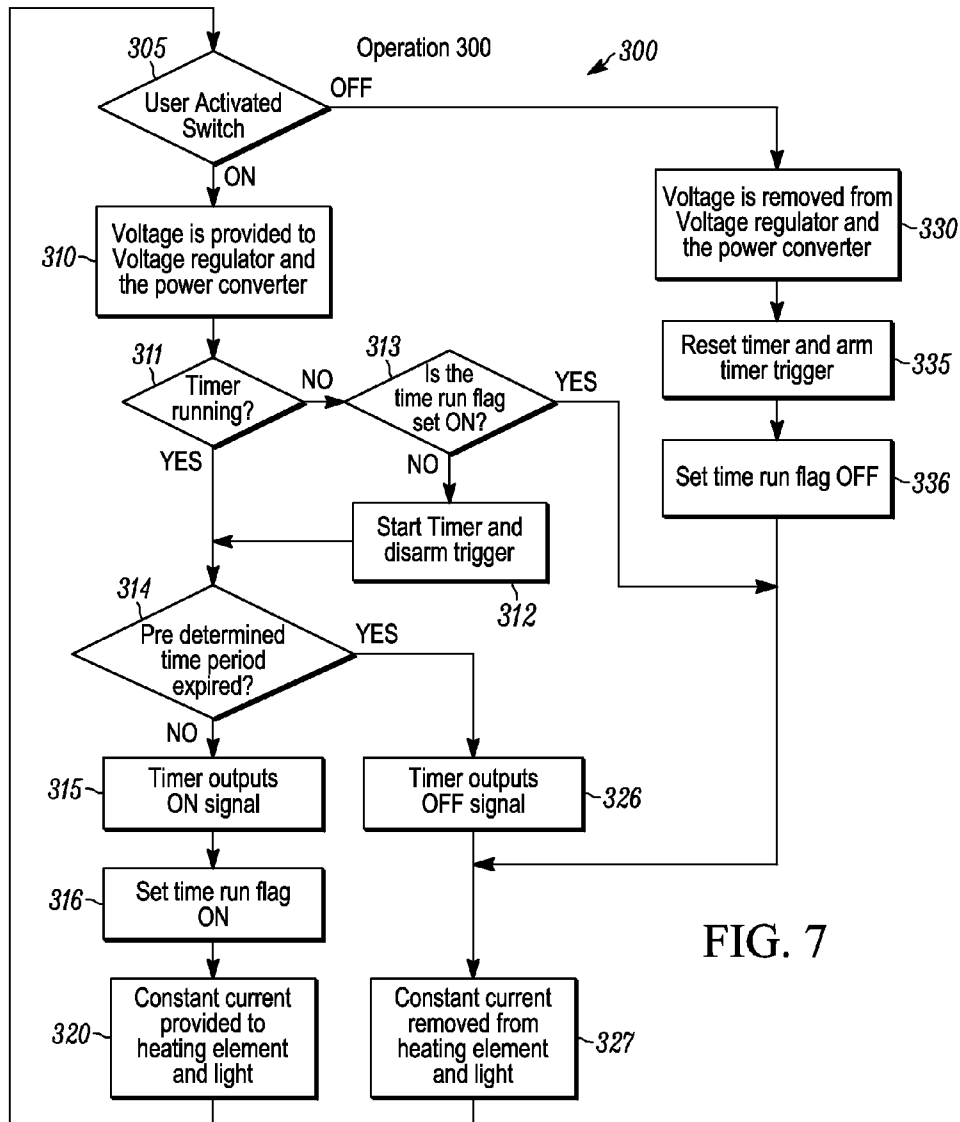


FIG. 9

FIG. 9A	FIG. 9B
---------	---------

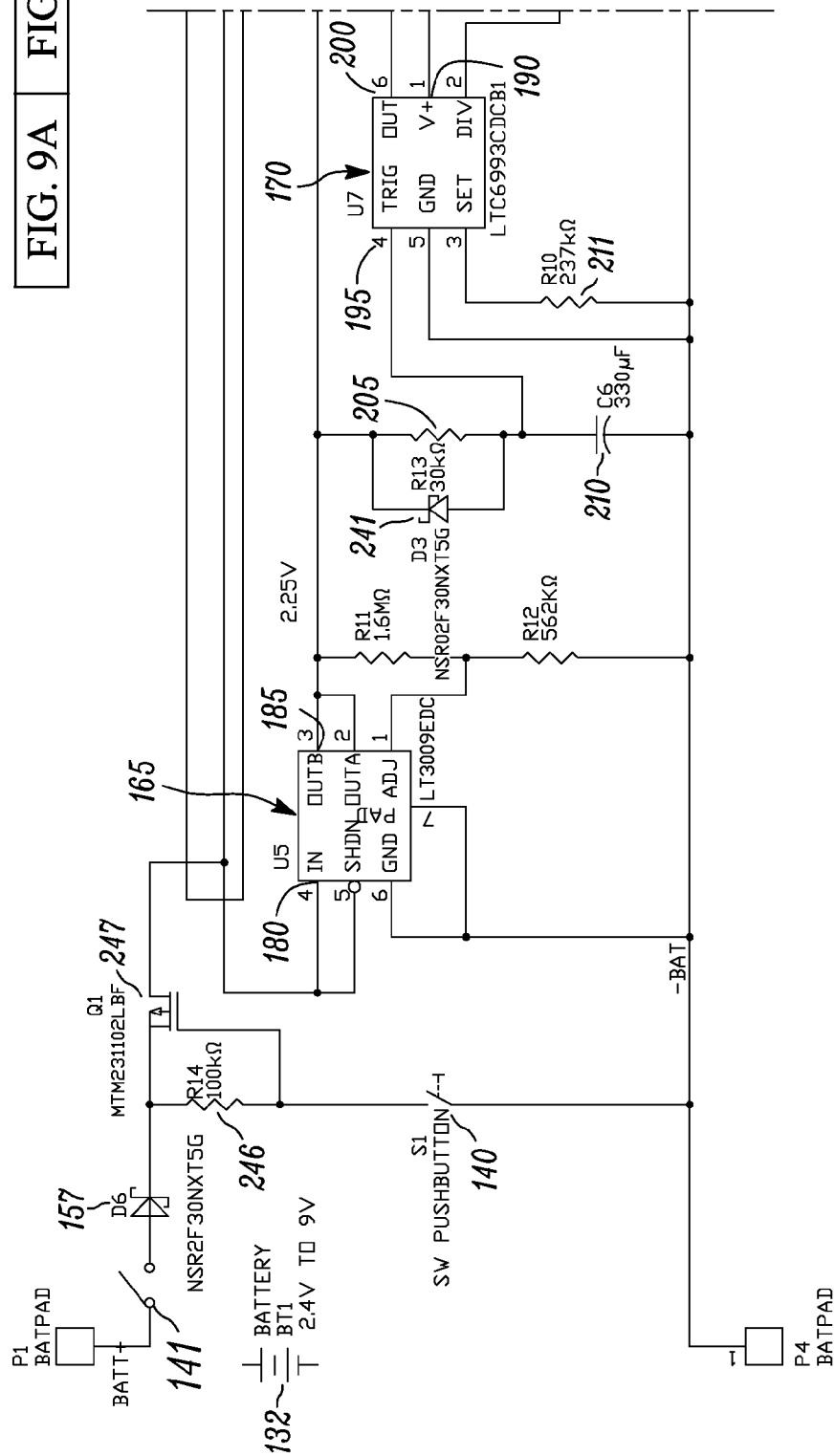


FIG. 9A

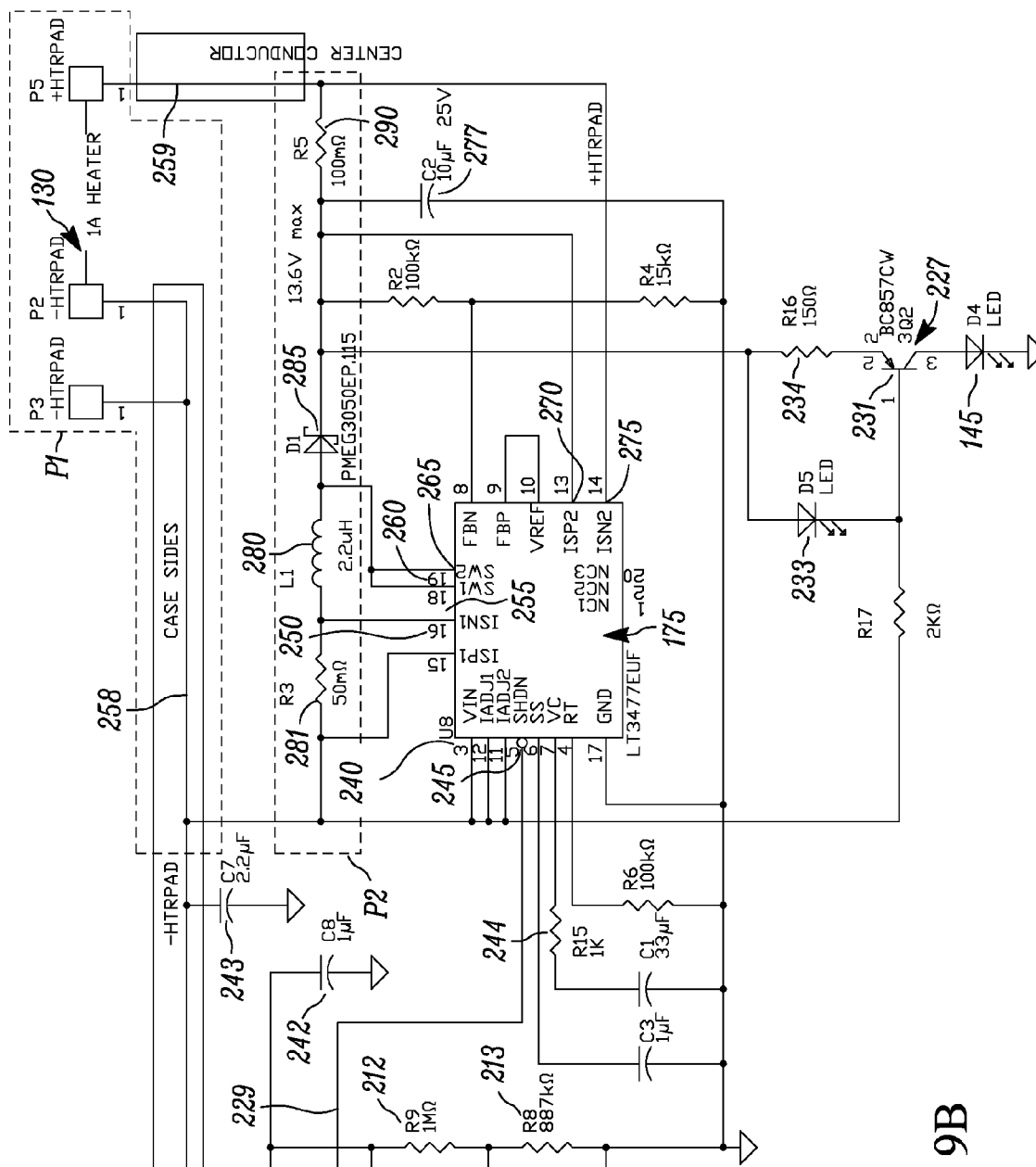


FIG. 9B

FIG. 10

FIG. 10A	FIG. 10B
----------	----------

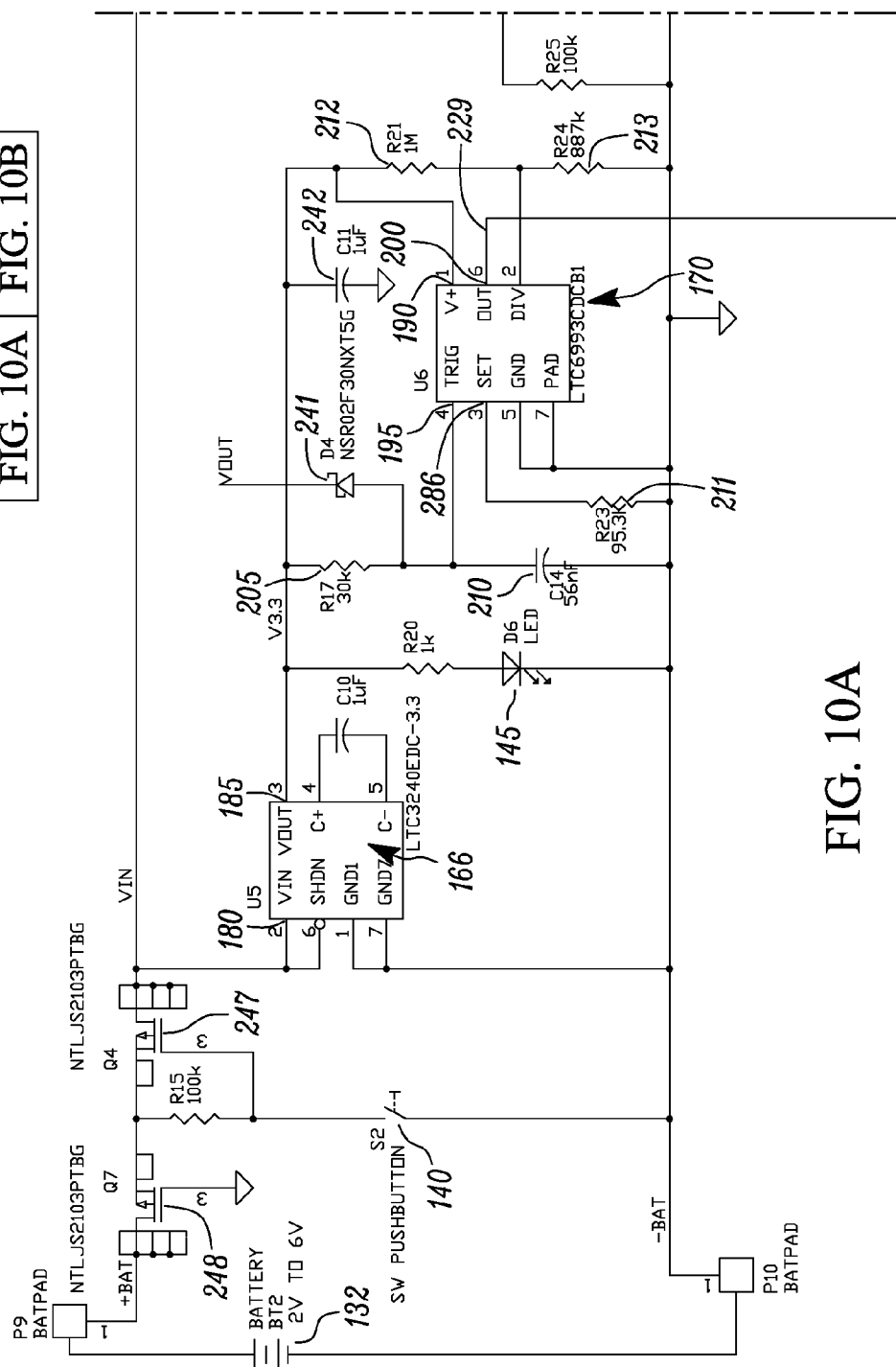


FIG. 10A

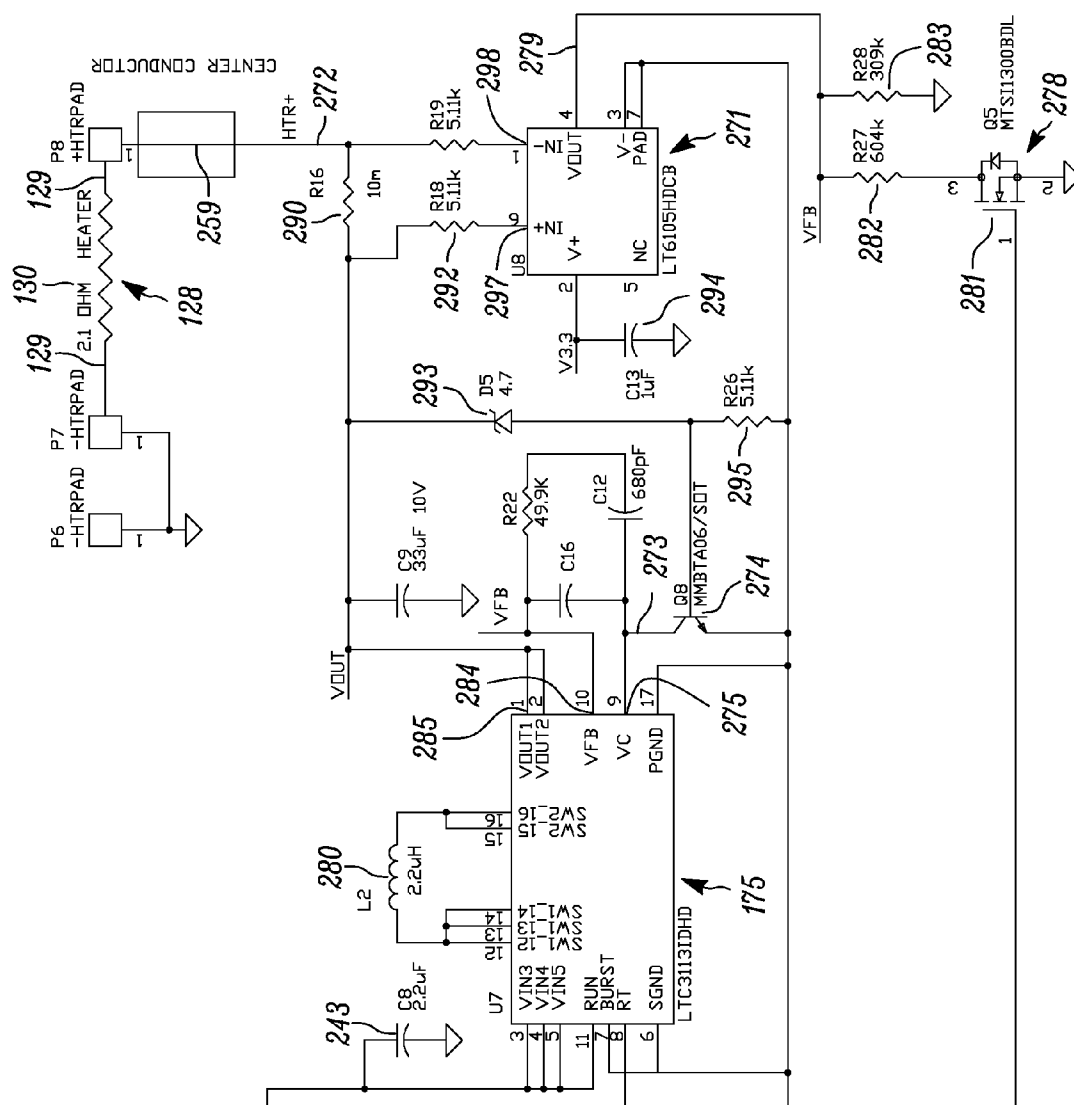


FIG. 10B

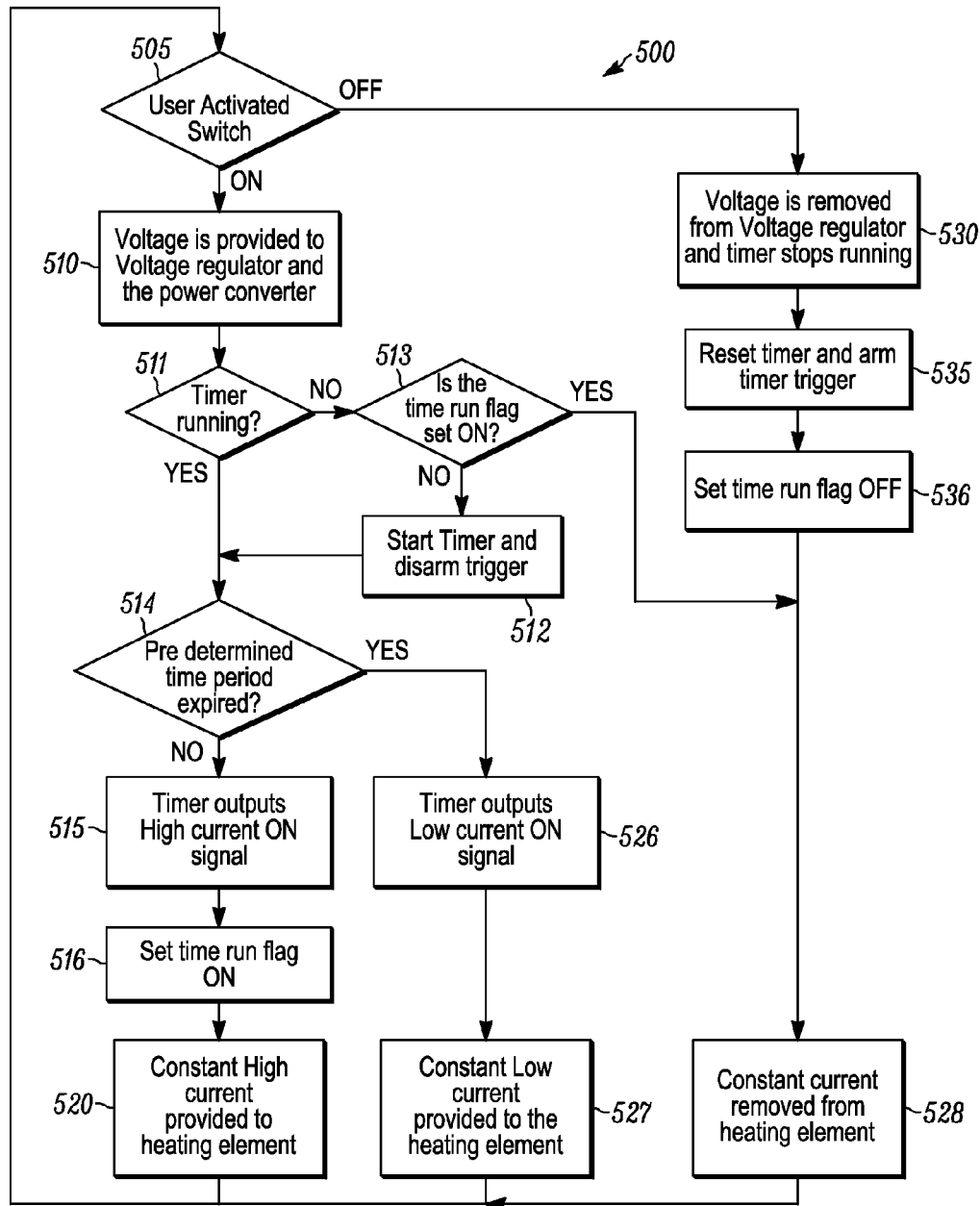


FIG. 11

FIG. 12

FIG. 12A	FIG. 12B
----------	----------

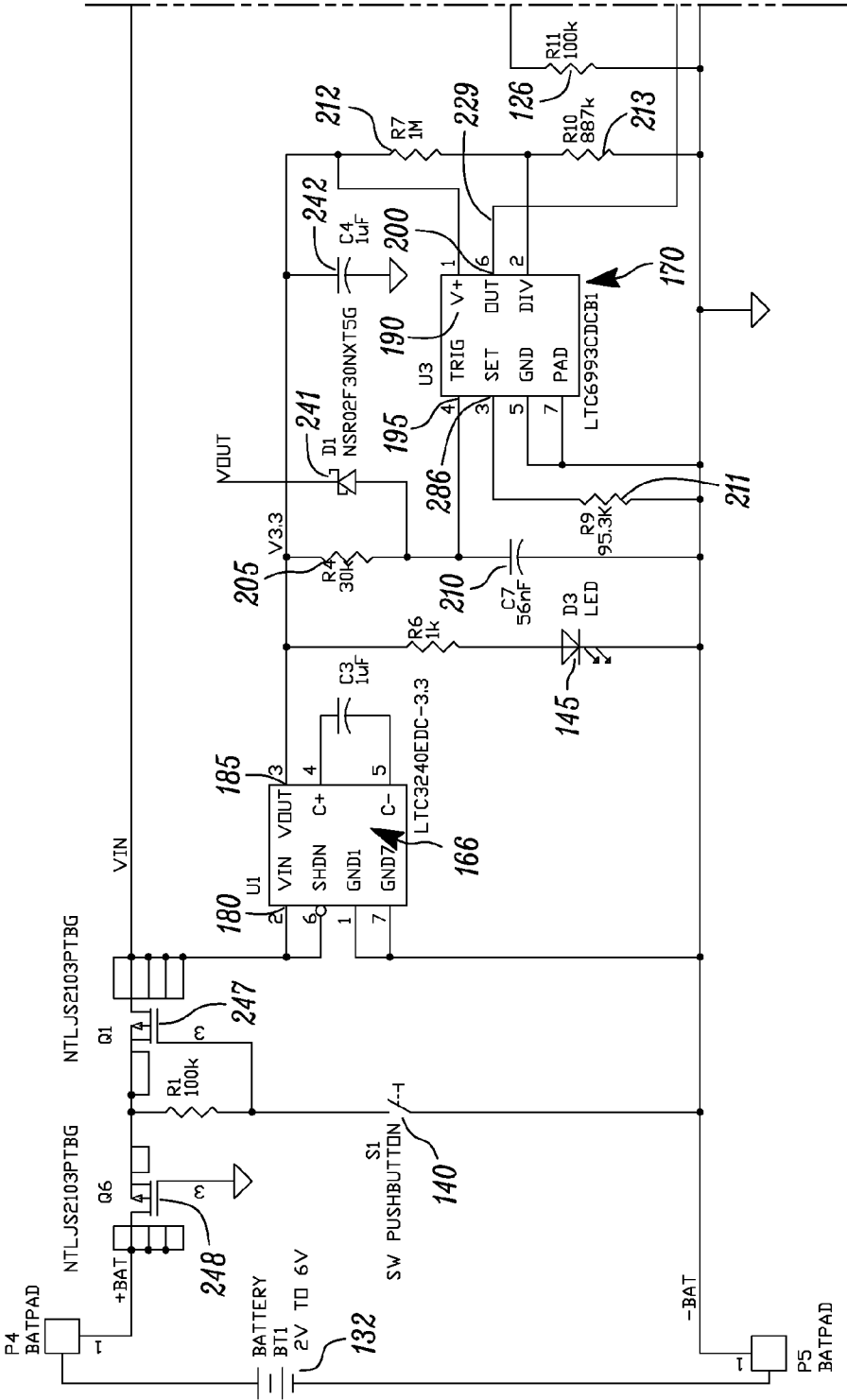


FIG. 12A

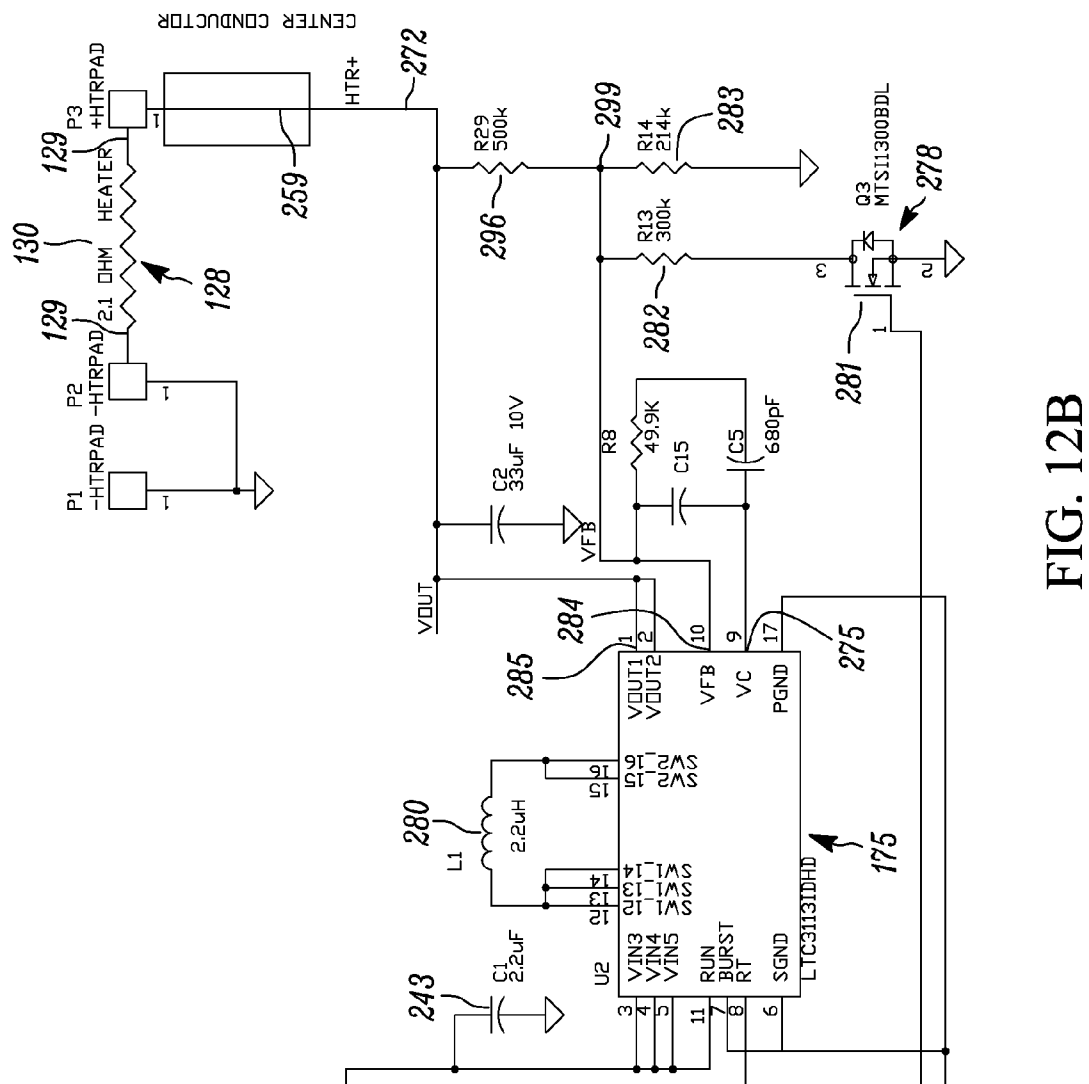


FIG. 12B

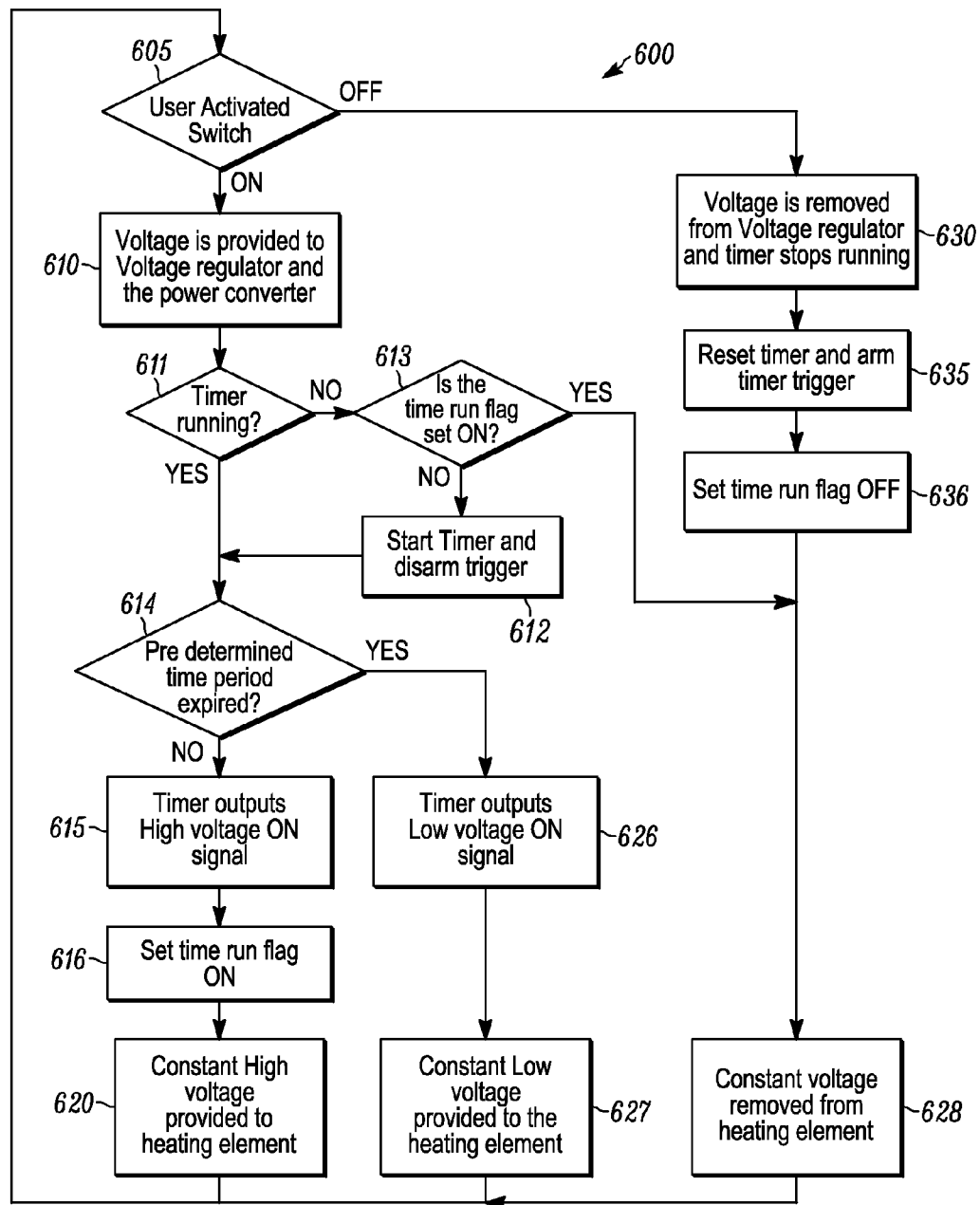


FIG. 13

ELECTRONIC CIGARETTE AND METHOD AND APPARATUS FOR CONTROLLING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Ser. No. 61/869,299 filed Aug. 23, 2013 entitled “Method and apparatus for controlling an electronic cigarette”, and U.S. Provisional Application Ser. No. 61/846,342 filed Jul. 15, 2013 entitled “Method and apparatus for controlling an electronic cigarette”, the entire content of each application is hereby incorporated by reference.

FIELD

[0002] The method and apparatus relate to electronic cigarettes.

BACKGROUND

[0003] Electronic cigarettes, also known as “e-cigarettes”, have become popular substitutes for standard tobacco-based cigarettes. Electronic cigarettes come in various shapes and sizes and utilize electric power to vaporize a liquid smoke solution that includes flavorings and nicotine. The liquid smoke solution can be any solution that is designed to be vaporized and inhaled for medical or recreational use. The vaporized solution is inhaled by a user in a manner similar to a standard cigarette. Similar to standard cigarettes, consumers tend to prefer electronic cigarettes that are sized and shaped to allow for easy portability. In addition, consumers tend to prefer a standard consistency of “smoke” quantity and flavor, as found in a standard cigarette. Various types of power sources have been utilized for providing power to an electric element in the electronic cigarettes. In response to the electrical power, the electric element heats up and vaporizes the solution in contact with it. A new or freshly charged power source is typically capable of providing a higher voltage during initial cycling. After several cycles, the power source voltage drops and less power is delivered to the element, resulting in the element having a reduced temperature, which affects the quantity and quality of the smoke. This inconsistency can result in a dissatisfying experience for a standard cigarette smoker, who is comfortable with the consistent flavor and smoke provided by a standard combustible cigarette.

SUMMARY

[0004] In at least some embodiments, the electronic cigarette apparatus includes a voltage regulator situated inside a housing; a power converter situated inside the housing, wherein the power converter is configured to deliver a current to, and cause establishment of a voltage across, a heating element such that a first power is provided to the heating element; a power source situated inside the housing for providing second power to the power converter and the voltage regulator; a timer electrically connected to the voltage regulator; a switch electrically connected to the power source, wherein upon receipt of an enabling signal from at least one of the switch and the timer, the power converter is configured to output the first power by way of a power converter output; and one or more sensing components configured to provide a feedback signal to the power converter to regulate one of the current or the voltage.

[0005] In at least some embodiments, the electronic cigarette apparatus includes a reservoir for receiving a solution therein; a heating element in communication with at least some of the solution in the reservoir; a power converter for providing first power to the heating element, wherein to provide the first power the power converter outputs one of a substantially constant current or a substantially constant voltage at a node associated with the power converter; a power source for providing second power at least indirectly to the power converter; and one or more sensing components configured to provide a feedback signal to the power converter to allow the power converter to regulate the substantially constant current or the substantially constant voltage; wherein upon receiving an operating signal, the power converter outputs the first power to the heating element to vaporize at least a portion of the solution.

[0006] In at least some embodiments, the electronic cigarette apparatus relates to a method of controlling an electronic cigarette apparatus that includes actuating a switch to apply a first voltage established by a power source across one or both of a voltage regulator and a power converter; applying a further voltage from the voltage regulator to a timer; enabling a counter in the timer; transmitting an ON signal from the timer to the power converter while the counter is enabled; and transmitting a substantially constant current from the power converter to a heating element in response to the transmitting of the ON signal from the timer.

[0007] In at least some embodiments, the electronic cigarette apparatus relates to a method of controlling an electronic cigarette apparatus that includes activating a switch to transmit first power from a power source to one or both of a voltage regulator and a power converter; receiving second power from the voltage regulator at a timer; enabling a timer counter for a first time period; during the first time period, transmitting an ON signal from the timer to the power converter; transmitting third power from the power converter to a heating element in response to receiving the ON signal from the timer, wherein the third power includes one of a constant voltage or a constant current; sensing at least one of a current or voltage at a sensor component at least indirectly associated with the heating element; and regulating the sensed at least one of current or voltage that is outputted from the power converter to the heating element using feedback from the sensing component.

[0008] In at least some embodiments, the electronic cigarette apparatus relates to a method of controlling an electronic cigarette apparatus that includes transmitting a first power from a power source at least indirectly to a voltage regulator and a power converter; receiving a second power from the voltage regulator at a timer; in response to receiving the second power at the timer, starting a counter on the timer to measure a first time period; during the first time period, transmitting a first ON signal from the timer to the power converter; transmitting a first constant voltage from the power converter to a heating element in response to receiving the first ON signal from the timer; upon expiration of the first time period, ceasing the transmission of the first ON signal and transmitting a second ON signal from the timer to the power converter; transmitting a second constant voltage from the power converter to the heating element in response to receiving the second voltage ON signal from the timer, wherein the second constant voltage has a lower magnitude than the first constant voltage; and ceasing transmission of the second constant voltage.

[0009] In at least some embodiments, the electronic cigarette apparatus includes a first housing; a power converter situated inside the housing; a power source situated inside the housing for providing power at least indirectly to the power converter; a timer at least indirectly electrically connected to the power source; and one or more sensing components configured to provide a feedback signal to the power converter to allow for regulation of the magnitude of a power converter output voltage, wherein upon receipt of an enabling signal, the power converter output voltage is output across a heating element situated in the first housing or a second housing, and wherein the output voltage is constant.

[0010] Other aspects of the electronic cigarette and method and apparatus for controlling the same will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments of the electronic cigarette and method and apparatus for controlling the same are disclosed with reference to the accompanying drawings and are for illustrative purposes only. The embodiments encompassed herein are not limited in their application to the details of construction or the arrangements of the components illustrated in the drawings, but rather encompass many other embodiments, including embodiments capable of being practiced or carried out in other various ways. The following descriptions of the drawings are intended to be illustrative and not limiting in scope. In the drawings, like numerals are used to refer to like components/structures shown in various drawings:

[0012] FIG. 1A illustrates an exemplary embodiment of an electronic cigarette apparatus;

[0013] FIG. 1B illustrates another exemplary embodiment of an electronic cigarette apparatus;

[0014] FIG. 2 illustrates another exemplary embodiment of an electronic cigarette apparatus;

[0015] FIG. 3 illustrates another exemplary embodiment of an electronic cigarette apparatus;

[0016] FIG. 4A illustrates an exemplary block diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus;

[0017] FIG. 4B illustrates an exemplary block diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus configured for voltage sensing;

[0018] FIG. 4C illustrates another exemplary block diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus configured for current sensing;

[0019] FIG. 4D illustrates another exemplary block diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus configured for temperature sensing;

[0020] FIG. 5 illustrates an exemplary electrical circuit diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus;

[0021] FIG. 6 illustrates another exemplary electrical circuit diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus;

[0022] FIG. 7 illustrates a flow chart of an exemplary process of operating the electronic cigarette apparatus;

[0023] FIG. 8 illustrates another flow chart of an exemplary process of operating the electronic cigarette apparatus;

[0024] FIG. 9 illustrates another electrical circuit diagram that is a modified version of FIG. 6, including a main power switch;

[0025] FIG. 10 illustrates another exemplary electrical circuit diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus;

[0026] FIG. 11 illustrates a flow chart of an exemplary process of operating the electronic cigarette apparatus that is the subject of FIG. 10;

[0027] FIG. 12 illustrates another exemplary electrical circuit diagram of various electrical components of at least one embodiment of the electronic cigarette apparatus; and

[0028] FIG. 13 illustrates a flow chart of an exemplary process of operating the electronic cigarette apparatus that is the subject of FIG. 12.

DETAILED DESCRIPTION

[0029] FIGS. 1A, 1B, 2, and 3 each illustrate exemplary embodiments of an electronic cigarette apparatus 100 (i.e. an e-cigarette). The electronic cigarette apparatus 100 includes a cartomizer 105 and a base 110. The cartomizer 105 includes a cylindrical element housing 104 having a reservoir 120 therein that serves to store a solution 112, and a heating element 130 for vaporizing the solution 112. An air tube 119 also extends inside the housing 104 to provide a path for vaporized solution 112 to be drawn out of the housing 104 by a user applying suction at a mouthpiece plug 116 situated at a cartomizer output 115. The housing 104 further includes an air intake 117 to provide supply air for the air tube 119. The air tube 119 is comprised of a resilient material, such as a flame resistant mesh. In at least some embodiments, the housing 104 is permanently integrated with the heating element 130 and the reservoir 120 to form the cartomizer 105, as shown in FIGS. 1A and 1B. Alternatively, as shown in FIG. 3, the heating element 130 can be separably engaged with the housing 104 to allow for separate replacement of either the heating element 130 or the reservoir 120; such a configuration is typically identified as a “cartridge” and atomizer combination, wherein the cartridge itself includes only the housing 104 and reservoir 120 of solution 112. For convenience, herein the term cartomizer 105 can be understood to additionally encompass a cartridge/atomizer combination.

[0030] A liquid absorbing material 121 (e.g., fill) can be positioned inside the housing 104 and around the air tube 119. The absorbent material 121 can be used to at least partially absorb the solution 112. In at least some embodiments, the solution 112 can include one or more of various ingredients, such as nicotine, propylene glycol, vegetable glycerin, polyethylene glycol, and flavorings. In addition, the solution 112 can include ingredients in various forms, with various viscosities (e.g., gel, liquid, etc.), and with various levels of molecular mixture. In at least some embodiments, the solution 112 is a free-flowing liquid having a high viscosity.

[0031] The cartomizer 105 further includes a heating element 130 situated in the housing 104, where the heating element 130 is connected to one or more electrical contacts 131 for receiving power from a power source 132, and the electrical contacts 131 are interconnected with the heating element 130 via conductors 129. Although the heating element 130 is referenced herein, it is to be understood that the heating element 130 can, in at least some embodiments, include one or of various alternatives, or additional types of components, suitable for vaporizing the solution 112 in the reservoir 120. Further, in at least some embodiments, as

shown in FIG. 1B, the heating element 130 is electrically connected at one end by one of the conductors 129 to a center connector 134 and at a second end by another of the conductors 129 to the housing 104. The heating element 130 can be coiled or substantially linear, with a central axis that is oriented substantially parallel to a longitudinal axis 118 of the housing 104 (FIG. 1B). In other embodiments, the heating element 130 can be oriented to have a central axis that is substantially perpendicular to the longitudinal axis 118 of the housing 104 (FIG. 1A). In addition, a wick 123, formed of an absorbent material, can extend at least partially through the center axis of the heating element 130 and into the reservoir 120 to assist with pulling a supply of solution 112 into close proximity to the heating element 130.

[0032] The heating element 130 is an electric element (e.g., conductor) that converts electric current passing there through to heat. The heating element 130 is positioned at least partially inside the reservoir 120 to be in communication with the solution 112. As the heating element 130 is energized by way of power from a power source 132, heat from the heating element 130 raises the temperature of the solution 112 contained within the reservoir 120 to the solution's boiling point, thus vaporizing a portion of the solution 112 to produce a vapor (i.e., smoke) for a user to inhale.

[0033] To power and control the heating element 130, various electrical components are provided in the base 110, where the base 110 is securable to the housing 104 and/or heating element 130 (which is securable to the housing 104). The base 110 includes a base housing 133 that encloses a compartment 135 for housing a power source 132, such as one or more batteries 155. The power source 132 is configured to provide a voltage having "+" and "-" polarities and a current. In addition, the base housing 133 can also house a power and control assembly 149, although in at least some embodiments, the components of the power and control assembly 149 can be completely or at least partially situated outside the base housing 133. The power and control assembly 149 includes various components, some or all of which can be mounted on, or in electrical communication with, one or more Printed Circuit Boards (PCBs) 150. Further, various electrical connectors 160 are provided for interconnecting the power and control assembly 149 to the power source 132 (e.g., wires, non-insulated conductor strips, contact springs, etc.). The base housing 133 can vary in size and shape to accommodate various aforementioned components. In addition, the compartment 135 can vary in size and shape to accommodate various types of power sources 132. Although the element housing 104 and base housing 133 are shown as separate housings that are securable together, in some embodiments, they can be integrally formed as a single housing or separated into further housings that can be secured together, either permanently or temporarily.

[0034] In at least some embodiments, the cartomizer 105 includes a first threaded end 142 that is securable to a second threaded end 143 of the base 110. When the first threaded end 142 is secured to the second threaded end 143 the first center conductor 134 is placed in contact with a second center conductor 144 in the second threaded end 143 and the base housing 133 is placed in contact with the element housing 104. Base conductors 128 connect the base housing 133 and the second center conductor 144 to the PCB 150, thereby establishing a connection between the PCB 150 and the heating element 130 via the conductors 128 and 129.

[0035] The compartment 135, as discussed above, in at least some embodiments, is configured with an elongated cylindrical shape for accommodating various types of power sources 132, for example, a standard AA or AAA size battery 155, a plurality of button cells, etc. In at least some embodiments, the power source 132 is a rechargeable battery 155 having lithium-ion chemistry, while in another embodiment, the power source 132 can include a battery 155 having chemistry other than lithium-ion, such as nickel cadmium, nickel metal-hydride, lead acid, etc. The power source 132 can be comprised of one or more rechargeable or non-rechargeable batteries 155. Further, in at least some embodiments, the power source 132 includes two AAA or AA size 1.2 peak volt rechargeable batteries 155 connected in series. When the power source 132 is rechargeable, a charging port 124 is provided to recharge the power source 132, such as a Universal Serial Bus (USB) port, etc. In at least some embodiments, the charging port 124 is situated at a first end 127 of the base 110, and can include a removable cover 126 (e.g., a friction or threaded plug) for protection. Additionally, in some other embodiments, the power source 132 includes two AAA or AA size 1.5 peak volt non-rechargeable batteries 155 connected in series.

[0036] As will be explained in greater detail, the power and control assembly 149 of the electronic cigarette apparatus 100 includes a power converter 175 and is therefore configured to accommodate a broad variety of power sources 132, including varied battery types and varied voltage capacities. Thus, a number of different types of batteries 155, including those that are likely to be readily available or already in the possession of a user, can be used to power the electronic cigarette apparatus 100, for example, the use of standard alkaline batteries is beneficial because of their widespread availability at a variety of retail stores and are low cost. Such convenience and flexibility can eliminate the need for a user to recharge the electronic cigarette apparatus 100 and be tethered to a charging point, or purchase costly spare batteries to keep on hand. In addition, in the case of a faulty power source 132, the power source 132 can be easily and economically replaced, avoiding the cost and inconvenience of obtaining a specialized replacement power source 132. The electronic cigarette apparatus 100 can be configured to accommodate a specific size and type of power source 132, or can include a mechanism to accommodate power sources 132 of different sizes. For example, a telescoping contact or spring-mounted contact can be placed in the compartment 135 to accommodate power sources 132 of varying lengths. In addition, a self-adjusting sleeve can be provided to accommodate varied diameters.

[0037] Referring to FIG. 4A, an exemplary block diagram 158 is provided of various electrical components of the electronic cigarette apparatus 100. In particular, FIG. 4A illustrates the power and control assembly 149 interconnected with the power source 132 and the heating element 130. Power is provided to the power and control assembly 149, via the power source 132, and a switch 140, and the power and control assembly 149 in turn powers the heating element 130 based on various criteria, as discussed below. In at least some embodiments, the power and control assembly 149 includes without limitation, a reverse battery protector 157, a voltage regulator 165, a timer 170, and the power converter 175. Further, in at least some embodiments, the reverse battery protector 157, the voltage regulator 165, the timer 170, and the power converter 175 are mounted on the PCB 150.

Reverse battery protection protects the power and control assembly 149 from reverse current, which might occur when a power source 132 is installed improperly (i.e., reversing the polarity, connecting + to -). In some embodiments, the reverse battery protector 157 is provided by a diode, such as a Schottky diode.

[0038] Referring to FIGS. 4B, 4C, and 4D exemplary block diagrams 159, 161, 162 of the electronic cigarette apparatus 100 are illustrated. Each of FIGS. 4B, 4C, and 4D illustrates the power and control assembly 149 interconnected with the power source 132 and the heating element 130. Power is provided to the power and control assembly 149, via the power source 132 and vapor switch 140, and the power and control assembly 149 in turn powers the heating element 130 based on various criteria, as discussed below. In at least some embodiments, the power and control assembly 149 includes without limitation, the reverse battery protector 157 (polarity protection), the voltage regulator 165, the timer 170, the power converter 175, a sensing component 176, which can include, for example, a current sensing, voltage sensing, or temperature sensing component(s), and a feedback control component 177 (as discussed below). In at least some embodiments, the reverse battery protector 157, the voltage regulator 165, the timer 170, and the power converter 175 are mounted on the PCB 150. In at least some embodiments, the timer 170 may not be a separate discrete component, but instead, be incorporated (at least as a function) in a microcontroller (not shown). In addition, to serving the timer function, use of a microcontroller can provide support for many other features, such as a display (not shown), which may be used to provide several types of indications. For example, the display could indicate how many activations (i.e., user puffs) remain based on the charge remaining on the battery or the level of solution 112 in the reservoir 120, or both. In addition, the display can include a battery charge status indicator, configuration controls that can be used to adjust temperature of the heating element, the applied voltage and/or current. Also, charge/discharge controls can be included for use with rechargeable batteries. In addition, a Universal Serial Bus (USB) Input/Output (I/O) can be provided to permit connection of the microcontroller to another device (e.g., computer, smartphone, etc.) to get enable additional configuration controls and view additional information.

[0039] FIGS. 4B, 4C, and 4D each illustrate a different feedback configuration. Exemplary block diagram 159 (FIG. 4B) illustrates the use of voltage sensing to provide feedback to scale the power converter 175. As shown in the block diagram 159 of FIG. 4B and the electrical schematic in FIG. 12, the sensing component 176 (e.g., a voltage divider) and the heating element 130 are connected to the power output 285 (FIG. 12) of the power converter 175. The sensing component 176 is also connected to the feedback control component 177. In another embodiment, as shown in exemplary block diagram 161 (FIG. 4C) and in the electrical schematic in FIG. 10, current sensing is utilized to provide feedback to scale the power converter 175. More particularly, the sensing component 176 (e.g., a current sense amplifier 271 (FIG. 10)) is connected to the power output 285 (FIG. 12) of the power converter 175 and the heating element 130 is then connected to the sensing component 176. The sensing component 176 is also connected to the feedback control component 177. In another embodiment, as shown in exemplary block diagram 162 (FIG. 4D), temperature sensing is utilized to provide feedback to scale the power converter 175. More particularly,

the heating element 130 is connected to the power output 285 of the power converter 175, and the sensing component 176 (e.g., a temperature sensor) is thermally connected to the heating element 130. The sensing component 176 converts the detected heat from the heating element 130 into a current or voltage signal that is passed to the feedback control component 177 to scale the power output of the power converter 175. It is to be understood that the various connections shown between the components in FIGS. 4A, 4B, 4C, and 4D can vary to include additional embodiments.

[0040] Referring again to FIGS. 1A, 1B, 2, and 3, the electronic cigarette apparatus 100 further includes a vapor switch 140 that is user-operated to initiate a demand to the power and control assembly 149, to energize the heating element 130 for vaporization of the solution 112 for inhalation by the user. The vapor switch 140 can include one of various types of switches to selectively connect the power source 132 to the power and control assembly 149, such as a momentary push-button switch, and can be mounted in the base 110 adjacent to the PCB 150. The power and control assembly 149 can be configured to sense a momentary activation of the vapor switch 140, and in turn, initiate a timed vaporization cycle, using the timer 170 to energize the heating element 130 for a predetermined time period, as discussed below. Alternatively, the power and control assembly 149 can be configured to activate the heating element 130 only during continued activation of the vapor switch 140. If a timed vaporization cycle is not desired or required, the voltage regulator 165 and timer 170 can be omitted. The timer 170 can also be used to limit the maximum time the heating element 130 is activated to prevent damage to the heating element 130 and conserve power source 132 energy. In addition, a light 145 can be provided that illuminates while the vapor switch 140 is being activated or while a vaporization cycle is in progress. The light 145 can be mounted in the base 110 or another location that provides sufficient visibility to a user during operation.

[0041] As discussed above, the power and control assembly 149 can include the voltage regulator 165 and the timer 170. The voltage regulator 165 is configured to provide a predetermined regulated voltage for the purpose of powering the timer 170. The timer 170 outputs an operating signal (or ON signal) to the power converter 175 for a predetermined time period, which can be considered a vaporization cycle. After the predetermined time period lapses, the timer 170 stops outputting the operating signal (ON signal), and/or outputs an OFF signal. The power converter 175 controls the flow of current or voltage to the heating element 130 in response to the operating signal from the timer 170.

[0042] When current is supplied to and flows through the heating element 130 in response to the operating (ON) signal being applied to the power converter 175, the solution 112 stored in the reservoir 120 is at least partially vaporized, allowing a user to inhale the vapor through the air tube 119 and mouthpiece plug 116 to enjoy a smoking-like experience. In the absence of the operating signal (or when an OFF operating signal is provided), the electronic cigarette apparatus 100 is deactivated and power no longer flows to the heating element 130. If the timer 170 is omitted or not used, then the electronic cigarette apparatus 100 is activated by directing power to the power converter 175 during continued actuation of the vapor switch 140, and subsequently deactivated upon release of the vapor switch 140. A delay can occur before vaporization first occurs, while the heating element 130 is brought up to a vaporizing temperature, likewise, the residual

energy from the heating element **130** can provide residual vaporization of the solution **112**, even after deactivation of the heating element **130** has occurred. The voltage regulator **165**, the timer **170**, and the power converter **175** are described further below.

[0043] FIG. **5** is an exemplary circuit diagram illustrating various electrical components and interconnections for the electronic cigarette apparatus **100**. As shown, the voltage regulator **165** includes, among other things, a voltage regulator input **180** and a voltage regulator output **185**. When the vapor switch **140** is activated, the voltage regulator **165** receives power from the power source **132** at the voltage regulator input **180**. The voltage regulator **165** outputs a predetermined constant voltage at the voltage regulator output **185**. The predetermined constant voltage has a value sufficient to adequately supply the timer **170**. The voltage regulator **165** can include one of various commercially available voltage regulators, such as a low dropout regulator Model LT3009EDC, as manufactured by Linear Technologies Corporation, or Model LP2951ACSD, as manufactured by Texas Instruments.

[0044] The timer **170** includes, among other things, a timer voltage input **190** for receiving supply voltage, a trigger input **195** (for receiving a trigger signal outputted by the voltage regulator **165** when the switch **140** is activated), and a timer output **200**. The timer **170** receives at the timer voltage input **190**, the predetermined constant voltage as output by the voltage regulator **165** at the voltage regulator output **185**. The timer **170**, in at least some embodiments, is configured to only acknowledge a trigger signal received at the trigger input **195** after the supply voltage has been present at the timer voltage input **190** for a fixed amount of time (i.e., trigger signal delay), after the supply voltage is first provided to the timer **170**. A resistor **205** and a capacitor **210** can be provided to delay the trigger signal so that it will be acknowledged and the timer **170** will start. In at least some embodiments, the trigger signal delay is on the order of about 5 milliseconds (ms) and the primary timer period is on the order of about 10 to about 20 seconds. The primary timer period (i.e., predetermined time period or vaporization cycle) is set by an internal oscillator frequency as determined by a resistor **211** and a long divider, which is set by the voltage sensed at the trigger (pin **4**) as produced by a resistor **212** and a resistor **213**. When the primary time period begins, the timer **170** outputs an operating signal (e.g., an ON signal having a magnitude of approximately 2.25V) at the timer output **200** and, upon expiration of the primary time period, the timer **170** outputs the OFF signal (e.g., no signal or an operating signal having a magnitude of approximately 0V to approximately 0.3V) at the timer output **200**. The timer **170** can include one of various commercially available timing devices, such as a Model LTC6993 (e.g., LTC6993CDCB1) manufactured by Linear Technologies Corporation.

[0045] Further, as shown, an AND gate **215** is provided to receive both the predetermined constant voltage from the voltage regulator **165** and the operating signal from the timer output **200** of the timer **170**. The AND gate **215** outputs a constant ON signal or a constant OFF signal based on the two received input voltages. For example, if both received input voltages are above a predetermined voltage threshold, the constant ON signal is outputted, but if either one or both of the received inputs is or are below the predetermined voltage threshold, the constant OFF signal is outputted. More particularly, in the present embodiment, the AND gate **215** includes

a voltage input **220**, a first AND input **225**, a second AND input **230**, and an AND output **235**. The AND gate **215** is powered by the predetermined constant voltage from the voltage regulator output **185** received at the voltage input **220**. The constant ON signal outputted by the AND gate **215** is equal to this predetermined constant voltage (e.g., 2.25V). The AND gate **215** further receives the predetermined constant voltage from the voltage regulator **165** at the first AND input **225**. The predetermined constant voltage received at the first AND input **225** is set above the predetermined voltage threshold. Therefore, the output of the AND gate **215** depends solely on the received input at the second AND input **230**. The received input at the second AND input **230** is the operating signal from the timer **170**. If the operating signal from the timer output **200** of the timer **170** is above the predetermined voltage threshold, both received input voltages are above the predetermined voltage threshold. Therefore, the constant ON signal is outputted from the AND output **235**. If the operating signal from the timer **170** is below the predetermined voltage threshold, only one of the received input voltages is above the predetermined voltage threshold, resulting in a constant OFF signal being outputted from the AND output **235**.

[0046] As discussed above, the power converter **175** turns on and off current flow to the heating element **130** based on the constant ON signal or constant OFF signal from the AND gate **215**, as governed by the timer **170**. For example, upon activation of the vapor switch **140**, a predetermined constant current (e.g., 1 amp) can be provided to the heating element **130** (assuming trigger signal delay has expired) for the chosen predetermined time period, unless the user releases (i.e., deactivates) the vapor switch **140**. Upon the earlier of, the user releasing the vapor switch **140** or the expiration of the previously chosen predetermined time period (e.g., 10 seconds, 15 seconds, 20 seconds, etc.), the power converter **175** stops current flow to the heating element **130**. Discontinuing the current flow to the heating element **130** provides a cessation of vaporization of the solution **112** in the reservoir **120**. This configuration allows a user to choose a range of minimal vaporized solution **112** and as much vaporized solution **112** as possible without potentially damaging the heating element **130**.

[0047] The power converter **175**, in the embodiments shown in FIGS. **5** and **6**, includes, among other things, a voltage input **240**, a shutdown input **245**, a first positive current sense pin **250**, a first negative current sense pin **255**, switch pins **260** and **265**, a second positive current sense pin **270**, and a second negative current sense pin **275**. The power converter **175** can include one of various types of power converters, for example, a DC/DC switching power converter, such as a Model LT3477 (e.g., LT3477EUF) current mode, step-up converter available from Linear Technology Corporation. An inductor **280** is provided and coupled to the power converter **175**, as shown in FIGS. **5** and **6**.

[0048] The power converter **175** includes an internal switching mechanism (e.g., Pulse Width Modulator) that, when in a switched open position, causes the polarity of the voltage across the inductor **280** to be reversed, thereby adding to the voltage already provided by the power source **132**. In operation, this charge cycle current flow from the power converter **175** occurs through an input current sense resistor **281**, the inductor **280**, and through the internal switch of the power converter **175** back to a negative terminal of the power source **132**. The charge current is sensed across resistor **281** at the first sense pins **250** and **255**, inside of the power converter

175. When the charge cycle is complete, the internal switch of the power converter **175** opens and a discharge cycle begins. The current path for the discharge cycle starts with the inductor **280** forcing current through the diode **285**, a control resistor (load sense) **290**, and through the heating element **130** and back to a positive side of the power source **132**. The load current is regulated by sensing the voltage across the control resistor **290** at the second sense pins **270** and **275**, (that is, the positive current sense pin and negative current sense pin), where the sensed voltage controls the fractional time used in the charge cycle with an internal pulse width modulator (PWM). In at least some embodiments, the control resistor **290** can serve as the sensing component **176**, as shown in FIGS. **5**, **6** and **9**. Current for the light **145** flows from the positive side of a capacitor **277** to the positive side of the power source **132**. Current flows in this direction due to the voltage on the capacitor **277** being larger than the power source **132** voltage.

[0049] The heating element **130** is connected across the voltage input **240** and the second negative current sense pin **275**. More particularly, the heating element **130** includes a first conductor **259** (e.g., a center conductor) connected to the second negative current sense pin **275**, and a second conductor **258** (e.g., a side conductor) connected to the voltage input **240**. Upon receiving the ON signal from the timer **170**, via the constant ON signal or the constant OFF signal from the AND gate **215** at the shutdown input **245**, the power converter **175** controls the voltage across the control resistor **290**. The control resistor **290** is connected across the second positive current sense pin **270** and the second negative current sense pin **275**. The resistance value of the control resistor **290** determines the voltage drop across the control resistor **290**, and therefore determines the value for the predetermined constant current that is supplied to the heating element **130** when activated. If the resistance value of the control resistor **290** is decreased, the voltage drop is decreased, and the constant current value is increased, and vice-versa.

[0050] The choice of a predetermined constant current value and the value of the control resistor **290** for attaining such a value, can vary depending on numerous design criteria, including but not limited to, power requirements and the resistance and maximum power rating of the heating element **130** (e.g., heating element resistance), the boiling point of the solution **112** in the reservoir **120**, etc. In at least some embodiments, the control resistor **290** has a resistance of 100 milliohms and the power converter **175** controls the voltage across the control resistor **290** to approximately 100 mV. Therefore, the current flow to the heating element **130** is approximately 1 amp. Also, when current is provided to the heating element **130**, it is also provided to the light **145**. Thus, the light **145** is lit whenever current flows through the heating element **130** to provide a visual indication to the user that the heating element **130** is activated. In some embodiments, the light **145** is a light-emitting diode (LED).

[0051] An alternative to FIG. **5** is illustrated in FIG. **6**, which provides an exemplary circuit diagram illustrating various electrical components and interconnections of another embodiment of the electronic cigarette apparatus **100**. The embodiment shown in FIG. **6** lacks the AND gate **215** and instead the timer output **200** is directly connected to the shutdown input **245** of the power converter **175**, as shown by connector **229**. This configuration reduces the number of components to mitigate cost, and improve reliability, etc. The majority of components identified in FIG. **6** remain

unchanged from those shown in FIG. **5**, with the various elements retaining the same numbering in both Figures.

[0052] In addition to the removing the AND gate, the circuitry powering the light **145** is enhanced by adding a transistor **231**, resistor **234**, and a voltage reference **233** (e.g., an LED) for the current source driving the light **145**, and the transistor **227** (which serves as the feedback control component **177**). Adding the resistor **234**, transistor **231**, and voltage reference **233**, maintains a consistent current to illuminate the light **145** under varied power source **132** conditions, such as when the power source **132** (e.g., battery **155**) is at least partially depleted. Further, the diode **241** was added in parallel with the resistor **205** to reduce the time it takes to discharge capacitor **210** when the vapor switch **140** has been released, thereby providing a decreased shutdown response time. Additionally, capacitor **242** is resized (i.e., smaller value and physical size) and capacitor **243** was added to stabilize the power converter **175**. The resistor **244** was added to assist with feedback loop compensation for the power converter **175** (e.g., add a zero to the loop compensation). Further, the vapor switch **140** is moved to a parallel branch that includes a resistor **246** and a transistor **247** (e.g., switching MOSFET) in series with the vapor switch **140**. The addition of the transistor **247** and resistor **246** allows for a higher current to pass from the power source **132**, while maintaining a physically smaller vapor switch **140** without damaging the vapor switch **140**.

[0053] The values provided in the circuit diagrams (FIGS. **5** and **6**) are exemplary values and it is to be understood that they can vary to accommodate various design requirements, including but not limited to improving power source life, increased or decreased vaporization of solution **112**, higher efficiency, circuit size, components cost, operational speed, etc. In at least some embodiments, the values provided for any one or more of the components shown can vary by $\pm 10\%$, while in other embodiments, the values can vary by $\pm 25\%$, while in yet other embodiments, the values can vary greater or lesser than $\pm 25\%$. In addition, various components can be omitted and added to accommodate design criteria as noted above, while maintaining the transmission of constant current to the heating element **130**. Further, although the interconnection and function of the components of the embodiment shown in FIG. **6** have not been described in the same detail as the components of the embodiment in FIG. **5**, it is to be understood that aside from the noted modifications, the components described in both embodiments function similarly to provide a constant current to the heating element **130**.

[0054] As described above, the electronic cigarette apparatus **100** is configured to utilize a constant current, supplied by the power converter **175** to power the heating element **130**. Thanks to the capability of the power converter **175** to provide constant current, it is possible for various types of power sources **132** having varied voltages to be used, as well as to possibility limit the effects of reduced voltage in a power source **132** after numerous uses. In contrast, in a conventional embodiment (without a power converter **175**), where an electronic cigarette is configured to operate based on a fixed peak voltage of a battery, as the battery voltage drops under normal use, so does the voltage supplied to the heating element. This results in varied levels of vaporization, which provides an inconsistent level of vapor being generated. The resultant decreasing vapor level provides an unsatisfactory smoking experience for a user. In particular, a user that desires a set amount of nicotine can be induced to take additional inhalations, which can render the total intake of nicotine to levels

uncertain to the user, thereby allowing the user to receive too much or too little nicotine. In addition, if a simple linear voltage regulator is utilized to provide a regulated voltage to a heating element, the smallest possible voltage (regulated set point) would be used and the rest of the voltage would be wasted (not applied to the heating element), shortening battery life and requiring the heating element (e.g., heating element) to include a low value of resistance. Artificially requiring the resistance value of the heating element to be low, as a result of the low set point on the voltage regulator, is not necessary if the heating element is driven from a current source. Constant current drive for the heating element can lead to more cost effective heating element designs that include heating elements with higher resistance values than would be possible with a voltage driven configuration.

[0055] Further, in contrast to a conventional embodiment of an electronic cigarette, the use of a power converter 175, to drive the heating element 130, allows for the use of power sources 132 having different voltages, while maintaining consistent operation of the heating element 130. As such, the power source 132 can include one or more batteries 155, selectable from any one of a group of batteries 155 having peak voltage ratings that are varied. For example, the electronic cigarette apparatus 100 can be powered by a battery pack that contains either 1 or 2 batteries 155 in series, to produce a minimum voltage of about 2.2 volts to a maximum of about 8 volts, without significantly affecting the current value (e.g., 1 amp) supplied to the heating element 130. While the power and control assembly 149 can accommodate a wide input voltage variation, some higher voltage batteries do not tolerate being discharged to the lowest voltage down to which this circuit will run. If higher voltage batteries are used, additional circuitry ahead of the control assembly 149 can be added to prevent an unacceptable deep discharge of these types of batteries.

[0056] As users of electronic cigarettes commonly have a preference in the amount of vapor they would like to receive in each activation (i.e., puff), in at least some embodiments, the electronic cigarette apparatus 100 includes a vapor level selector 251. The selector 251 can be mounted on the base 110, as shown in exemplary form in FIG. 3 for example, and can include one of various types of selectors 251, such as a slide switch, a momentary switch (latching circuitry connected thereto), etc. Although not shown in detail, in some embodiments, the selector 251 can be connected to a plurality of control resistors (e.g., control resistor 290) wired in parallel, wherein each distinct selection position of the selector 251 would interconnect a different value control resistor 290, thereby changing the current level supplied to the heating element 130. In this regard, a user can select the level of current desired, thereby providing more vapor with an increased current or less vapor with a decreased current. Additional manners of varying the current have been contemplated, for example, using a variable control resistor as the control resistor 290.

[0057] FIG. 7 is a flow chart illustrating example steps of a process of the electronic cigarette apparatus 100 described with reference to FIGS. 5 and 6. The process represented by the flow chart 300 begins when the user activates the vapor switch 140 (Step 305). Voltage from the power source 132 is then provided to the voltage regulator 165 and power converter 175 (Step 310). If the counter of the timer 170 is not running (Step 311), then the operation checks if a time run flag is set ON (Step 313), if not, set ON, the counter is started

and the trigger is disarmed (Step 312). If the counter is running (step 311), and the predetermined time has not lapsed (checked in step 314), then the timer 170 outputs the ON signal (enabling signal) to the power converter 175 (Step 315). The time run flag is set to ON (Step 316) and the power converter 175 provides a constant current to the heating element 130 and a second constant current to the light 145 (Step 320). The operation then returns to step 305. If the counter has timed out (predetermined time expired) (Step 314), the timer 170 outputs an OFF signal (Step 326) and current is removed from the heating element 130 and light 145 (Step 327) and the operation returns to Step 305. If the vapor switch 140 is detected as deactivated at Step 305, then voltage is removed from the voltage regulator 165 and the timer 170 stops running (Step 330), the counter of the timer 170 is reset and armed (Step 335), and the time run flag is set to OFF (Step 336). In addition, current is removed from the heating element 130 and the light 145 (Step 327). Upon completion of step 327, the operation 300 returns to step 305 to detect any further activation of the vapor switch 140.

[0058] In an alternative implementation, a flow chart of an exemplary operation 400 is shown in FIG. 8, and with reference to FIG. 6, wherein the electronic cigarette apparatus 100 does not include the voltage regulator 165, the timer 170, or the AND gate 215. In such an embodiment, the power converter 175 provides a flow of constant current to the heating element 130 as long as the vapor switch 140 is closed (e.g., depressed) by the user. More particularly, when the vapor switch 140 is closed (ON position) (step 402), the power source 132 is electrically connected to the shutdown input 245 of the power converter 175, thereby providing the power converter 175 with an ON signal (step 404). When the power converter 175 receives the ON signal, the power converter 175 provides a constant current to the heating element 130 (step 406). When the vapor switch 140 is in an open (OFF) position (e.g., switch released by the user), the ON signal is removed and the power source 132 is disconnected from the power converter 175 (step 408). As a result, current flow to the heating element 130 ceases (step 410). Upon the completion of step 406 or 410, the operation 400 returns to step 402.

[0059] As shown in FIG. 9, illustrating the electrical circuit diagram of FIG. 6 with a main power switch (i.e., ON/OFF) added between the reverse battery protector 157 and the power source 132, a main power toggle 141 may be provided to prevent accidental activation of the electronic cigarette apparatus 100 due to inadvertent pressure on the vapor switch 140. The main power toggle 141 can be utilized on other embodiments described herein as well.

[0060] Regarding power sources, rechargeable batteries commonly have cut-off voltage levels at which they have reached an acceptable discharge level. Failure to disconnect these batteries from a power draining device can result in over-discharge, which can permanently damage them, rendering them useless or permanently lowering their overall rechargeable capacity. In contrast, non-rechargeable (disposable) batteries are non-renewable and therefore, will simply discharge until unusable and are discarded. As rechargeable batteries cost significantly more than disposable batteries, it is desirable to increase their overall life and to maintain their charging capacity. In addition, disposable batteries, such as alkaline, Zinc Chloride, Lithium-FeS₂, and Carbon Zinc, typically have a starting peak voltage of 1.5 volts per battery. In contrast, rechargeable batteries, such as Nickel Metal Hydride and Nickel Cadmium have a starting peak voltage of

1.2 volts per battery. Further, other types of rechargeable batteries typically include uniquely identifiable starting peak voltages, for example, Li-ion-Cobalt (3.6 volts), Li-ion-Mn (3.8 volts), and Li-ion-Phosphate (3.3 volts). As described, due to the starting peak voltage levels, circuitry can be provided to identify the voltage level of a battery when first installed in the electronic cigarette apparatus **100** to identify if it is a disposable or rechargeable battery. If a rechargeable battery is identified, then the electronic cigarette apparatus **100** can be configured to provide a circuit cut-off to avoid over-discharge.

[0061] Referring to FIG. **10**, an exemplary electrical circuit diagram of the electronic cigarette apparatus **100** is provided that includes multi-stage activation of the power converter **175**. More particularly, multi-stage activation includes a higher initial current provided to the heating element **130** to rapidly start vaporization of solution **112** (e.g., heating the heating element **130**), followed by a lower current to maintain the vaporization, as well as to protect the heating element **130** from damage due to the application of sustained high current. In addition, the multi-stage activation is achieved at least in part through the use of the feedback controlling component **177**, although other methods of control can be utilized. Although multi-stage activation is discussed herein with regard to providing two levels of constant current or constant voltage, it should be appreciated that additional levels of activation can be provided using the same methods described herein.

[0062] As shown, many of the components in FIG. **10** are similar to those shown in FIG. **6**, as seen by like numbering of various elements. Although many similarities exist, some of the aforementioned elements have been omitted and other new elements have been added. More particularly, the voltage regulator **165** is a charge pump DC-DC converter, such as Model No. LTC3240EDC-3.3, as manufactured by Linear Technologies Corporation. The timer **170** remains the same, although it is configured to provide a high current ON signal and a low current ON signal to facilitate the multi-stage activation of the power converter **175**. The reverse battery protection is provided by a transistor **248** (e.g., a pMOSFET).

[0063] The power converter **175** is a Buck-Boost DC-DC converter, such as Model No. LTC3113 (e.g., LTC3113IDHD), as manufactured by Linear Technologies Corporation. The power converter **175** is capable of providing a high current magnitude even with a low battery voltage. As the power converter **175** supplies a regulated voltage, a current sense amplifier **271**, such as Model No. LT6105, as manufactured by Linear Technologies Corporation, is provided to sense the current provided to the heating element **130** via heating element supply conductor **272**. The current sense amplifier **271** serves as the sensing component **176** (FIG. **4C**), which provides a closed-loop current level feedback for controlling the power converter **175** to provide the desired current level (i.e., current magnitude) to the heating element **130**. To modulate between high and low magnitude currents supplied to the heating element **130**, the resistors **282** and **283** along with a control transistor **278**, provide a variable resistance configuration within the feedback loop **279** between the power converter **175** and the current sense amplifier **271** (control transistor **278** (e.g., MOSFET) serves as the feedback control component **177** (FIG. **4C**)). More particularly, the timer output **200** of the timer **170** is connected to the gate **281** of the control transistor **278**, wherein activating the timer output **200** to provide an initial high current ON signal to the

power converter **175**, turns the control transistor **278** ON to connect the drain to ground, thereby grounding resistor **282** to put the resistor **282** and the resistor **283** in parallel. In doing so, the current flowing to ground through the feedback loop **279** increases, lowering the voltage at the node **284** (VFB) of the power converter **175**. The lower voltage sensed at the node **284** initiates an increase in the current supplied to the heating element **130** by VOUT1 and VOUT2 of the power converter **175**. In turn, removing the high current ON signal (e.g., providing a low current ON signal), turns the control transistor **278** OFF, disconnecting the resistor **282** from ground, causing the current passing to the node **284** to increase, resulting in a higher voltage at the node **284**. As such, the low current ON signal provides less current to the heating element **130**. As noted below, a predetermined time is selected for providing the higher current before lowering the current magnitude to the low current. This predetermined time can be selected by the choice in resistance of the resistor **211**, which connects a SET terminal **286** of the timer **170** to ground. A higher resistance will increase the predetermined time and a lower resistance will lower the predetermined time. In at least some embodiments, resistor **282** has a value of about 604 k ohms, resistor **283** has a value of about 309 k ohms, the inductor **280** has a value of about 2.2 μ H and the resistor **211** has a value of about 95.3 k ohms, while in other embodiments, these values can be modified to compensate for various factors, including heating element resistance, desired vaporization time, etc.

[0064] Further, to provide circuit protection, a collector **273** of a transistor **274** (e.g., NPN transistor) is connected to a VC input **275** of the power converter **175**. The transistor **274** is used to set (e.g., clamp) the maximum output voltage under a condition where there is no operable heating element **130** (e.g., resistance is infinite) and the power converter **175** is activated. The light **145** is now connected to the voltage regulator output **185**. In addition, the configuration shown in FIG. **10** allows for a common reference, such as the base housing **133** and housing **104**, which can be advantageous in simplifying the overall mechanical design of the electronic cigarette apparatus **100**. As provided by the components in the schematic in FIG. **10**, an input voltage range of about 2 to about 6 volts can be utilized to provide a desired current to the heating element **130**. Substitution, addition, or subtraction of various electrical components can be performed to modify the input voltage range.

[0065] Referring now to FIG. **11**, a flow chart **500** show example steps of a process of operation of the electronic cigarette apparatus **100** of FIG. **10**. The process represented by the flow chart **500** begins when the user activates the vapor switch **140** (Step **505**). Voltage from the power source **132** is provided to the voltage regulator **165** and power converter **175** (Step **510**). If the counter of the timer **170** is not running (Step **511**), then the process checks if the counter was previously running (i.e., a time run flag is set ON) (Step **513**), if not, set ON, the counter is started and the trigger is disarmed (Step **512**). If the counter is running (step **511**), and the predetermined time has not lapsed (checked in step **514**), then the timer **170** outputs a high current ON signal (enabling signal) to the power converter **175** (Step **515**). The time run flag is set to ON (Step **516**) and the power converter **175** provides a high magnitude constant current (e.g., approximately about 1.2 A to about 1.5 A), which can be, for example 50% higher than an intended low current (e.g., about 1 A) to the heating element **130** (Step **520**). The process then returns to step **505**. If the counter has timed out, based on a predetermined time expi-

ration, such as 4 seconds (Step 514), the timer switches to output a low current ON signal (Step 526) in place of the high current ON signal, and a low magnitude constant current is provided from the power converter 175 to the heating element 130 (Step 527). The process returns to Step 505 to check the status of the vapor switch 140. If the vapor switch 140 is detected as still activated at step 505, then the current continues to be supplied to the heating element 130. If the vapor switch 140 is detected as deactivated at step 505, then voltage is removed from the voltage regulator 165 and the timer 170 stops running (Step 530), the counter is reset and armed (Step 535), the time run flag is set to OFF (Step 536). In addition, neither the low nor the high constant current is provided to the heating element 130 (Step 528). Upon completion of step 528, the process returns to step 505 to detect any further activations of the vapor switch 140.

[0066] Further, in at least some embodiments, the high current magnitude can be more or less than 50% higher than the low current magnitude. In addition, the timer 170 can include additional stages of activation by chaining additional timers in parallel and/or series. Each timer in a chain can trigger the next and the timer outputs can be logically combined to start and stop certain functions or reconfigure the power converter 175 to provide different preset current values.

[0067] As discussed above, the electronic cigarette apparatus 100 includes a power and control assembly 149 having a power converter 175. The power converter 175 can provide a constant current at a set magnitude. In addition, the power converter 175 enables the power and control assembly 149 to provide continuous power to the heating element 130, having a voltage magnitude that can be less than or greater than the voltage magnitude available directly from the power source 132. In this regard, the electronic cigarette apparatus 100 can substantially limit the effects of a discharging power source 132, as the electronic cigarette apparatus 100 can provide sufficient current levels to heat the heating element rapidly, even when the power source 132 has a depleted or otherwise limited voltage, as discussed in detail below.

[0068] In a device without a power converter 175, where the full battery voltage is applied to a heating element, as the battery discharges through normal usage of a device, the magnitude of the available battery voltage lowers, thereby reducing the expected power being supplied to the heating element. As the supplied power is reduced, the time to heat the heating element and vaporize the solution increases, with the power degradation trend continuing until the battery is replaced or replenished. In this manner, inconsistent heating of the heating element occurs, and therefore, inconsistent vaporization of solution, decreasing a user's overall satisfaction. In addition, if the initial voltage of a battery(s), even when fully charged, is too low to provide a sufficient current based on the resistance rating of the heating element, the apparatus may function poorly, requiring excessive time to heat the heating element and/or being incapable of providing successive high level and low level currents. In contrast to the above, if the initial voltage of the battery(s) is more than adequate to supply enough power to the heater, adding a pulse width modulator to the switch to control the current in the heater works as long as the battery(s) voltage is higher than necessary to heat the heating element. A device that merely discretely switches ON and OFF the total flow of available current from a battery to a heating element in order to regulate the temperature of the heating element (to prevent overheat-

ing or under-heating) will only work if the terminal voltage of the battery is more than needed, and therefore would lack the ability to provide a fixed magnitude constant current or voltage to the heating element that can remain on continuously for the duration of the vaporization process, or at least remain continuously on during a first time period for a quick start (e.g., 4 seconds) and then remain continuously on with a fixed magnitude for a second time period until vaporization of the solution 112 is no longer desired by the user.

[0069] The availability of a high voltage power source can provide significant flexibility when powering a heating element. The easiest way to obtain a high voltage may be to use a large power source, such as large batteries, or a high quantity of batteries connected in series. Unfortunately, in the situation where size, portability, and flexibility of acceptable power source choices is of premium importance, other mechanisms are necessary to achieve desired results. The use of the power converter 175, along with the inductor 280, allows for the power and control assembly 149 to provide the heating element 130 with a voltage that is higher than the voltage of the power source 132 alone. For example, for convenience, in at least some embodiments, the apparatus 100 includes two AAA size batteries 155 having a peak voltage rating of 1.5 volts each. Assuming that the heating element 130 has a resistance of 2.0 ohms, to achieve a current through the heating element 130 of 1.5 amps, a full three volts would be needed. Although, after several uses, the total voltage of the batteries 155 would fall below three volts, thereby dropping the current below 1.5 amps. If 1.5 amps were needed to provide a sufficient high current to rapidly heat the heating element 130 within an acceptable four second time period, for example, the apparatus 100 would be incapable of maintaining the desired four second time frame after only a few uses of the apparatus 100, due to the falling voltage level of the batteries 155. In the case of a 2.4 ohm resistance heating element 130, even the full three volts would be insufficient to provide the necessary 1.5 amps to the heating element 130. In addition, if lower voltage batteries 155 were used, such as rechargeable 1.2 volt batteries, their combined 2.4 volts supply voltage would be insufficient to generate 1.5 amps with either of the 2.0 ohm or 2.4 ohm resistance heating elements 130.

[0070] Referring to FIG. 12, an exemplary electrical circuit diagram of the electronic cigarette apparatus 100 is provided that includes voltage sensing feedback to the power converter 175 (e.g., the aforementioned Buck-Boost DC/DC converter Model No. LTC3113). As shown, the electronic cigarette apparatus 100 includes multi-stage activation of the power converter 175, as discussed above. Further, as shown, the circuit shown in FIG. 12 is similar to the circuit shown in FIG. 10, with a few notable exceptions. In particular, the current sense amplifier 271 has been omitted, along with several other components, namely, the transistor 274, the resistor 292, the diode 293, the capacitor 294, and the resistor 295. Also, in the embodiment of FIG. 12 (but not FIG. 10) voltage is scaled between the resistor 296 and one or both of the resistors 282 and 283, wherein the resistor 296 serves as the sensing component 176 (FIG. 4B), although in some embodiments, other components alone or in combination with resistor 296 can serve as the sensing component(s) 176. The control transistor 278 (FIGS. 10 and 12) serves as the feedback control component 177 (FIG. 4B), as discussed above, although in other

embodiments, the feedback control component 177 can include other switching devices, such as a processor-based D/A converter.

[0071] The resistor 296 works in conjunction with the resistors 282 and 283. More particularly, during operation where voltage is provided to the heating element 130, the sensed voltage at node 299 is passed to the feedback input node 284 (VFB), with the feedback voltage to the power converter 175 being the voltage drop across one or both of the resistor 283 and the resistor 282, wherein the resistor 282 is included to lower the voltage drop only during activation of control transistor 278, which connects resistor 282 to ground when a high voltage is requested, as discussed above. In this manner, the switching of control transistor 278 on and off by the timer 170, provides multi-stage control, by increasing or decreasing the sensed feedback voltage in order to induce a greater or lesser output by the power converter 175, which occurs in addition to the constant regulation of voltage.

[0072] In at least some embodiments, the voltage needed to bring the power and control assembly 149 to an equilibrium is developed across the inductor 280, powered by the power source 132. The circuitry around the inductor 280 operates to provide a voltage of about 0.6 volts at the node 284 (VFB). The voltage output at the node 285 (Vout) is scaled down to about 0.6V with the resistive divider 296 and 283. Changing the divider ratio will change the voltage outputted at node 285. Switching control transistor 278 ON, effectively places the resistor 282 in parallel with the resistor 283 which means the voltage outputted at node 285 will need to increase to make the voltage at the node 284 0.6V again. In at least some embodiments, the resistor 282 has a value of about 300 k ohms, the resistor 283 has a value of about 214 k ohms, the inductor 280 has a value of about 2.2 μ H and the resistor 211 has a value of about 95.3 k ohms, while in other embodiments, these values can be modified to compensate for various factors, including heating element resistance, desired vaporization time, etc.

[0073] Referring to FIG. 13, a flow chart 600 showing exemplary steps of a process of operating the electronic cigarette apparatus 100 of FIG. 12 is provided. The process is very similar to the process, with the exception that a constant voltage is provided in place of constant current that was described with regard to flow chart 500 discussed above with reference to FIG. 11. More particularly, process begins when the user activates the vapor switch 140 (Step 605). Voltage from the power source 132 is provided to the voltage regulator 165 and power converter 175 (Step 610). If the counter of the timer 170 is not running (Step 611), then the process checks if the counter was previously running (i.e., a time run flag is set ON) (Step 613), if not, set ON, the counter is started and the trigger is disarmed (Step 612). If the counter is running (step 611), and the predetermined time has not lapsed (checked in step 614), then the timer 170 outputs a high voltage ON signal to the power converter 175 (Step 615). The timer run flag is set to ON (Step 616) and the power converter 175 provides a high magnitude constant voltage, which can be, for example 50% higher than an intended low magnitude constant voltage to the heating element 130 (Step 620). The process then returns to step 605. If the counter has timed out, based on a predetermined time expiration, such as 4 seconds (Step 614), the timer 170 switches to output a low voltage ON signal (Step 626) in place of the high voltage ON signal, and a low magnitude constant voltage is provided from the power converter 175 to the heating element 130 (Step 627). The

process returns to Step 605 to check the status of the vapor switch 140. If the vapor switch 140 is detected as still activated at step 605, then the current continues to be supplied to the heating element 130. If the vapor switch 140 is detected as deactivated at step 605, then voltage is removed from the voltage regulator 165 and the timer 170 stops running (Step 630), the counter is reset and armed (Step 635), and the time run flag is set to OFF (Step 636). In addition, at this juncture, neither low nor high constant voltage is provided to the heating element 130 (Step 628). Upon completion of step 628, the process returns to step 605 to detect any further activations of the vapor switch 140.

[0074] It is noted that in at least some embodiments, the use of the aforementioned term "ON signal" is not intended to imply (at least in all cases), that a full shutdown of voltage or current is initiated at the power converter, when the ON signal is discontinued. Rather, cessation of the ON signal in some cases merely results in a change in the magnitude of a constant voltage or current. For example, when a low voltage ON signal is provided subsequent to a high voltage ON signal, the power converter can continue to provide a constant voltage, but the magnitude is reduced from the high value to the low value. In this manner, a constant current or constant voltage can be provided to the heating element 130 from the power converter 175 to control the heating of the heating element 130 without allowing the current or voltage to drop to a zero magnitude or without spiking the voltage or current up and down, such as when the output of the power converter is shut off and on rapidly to regulate the temperature of the heating element.

[0075] Further, it is noted that the power converter 175 can include Pulse Width Modulation (PWM) that provides power modulation using very high frequency switching (e.g., 300 kHz to about 2 MHz). In at least some embodiments, the power converter 175 is programmed for Pulse Width Modulation at a frequency of about 900 kHz. This very high frequency switching by the PWM that occurs internal to the power converter 175 is well known and allows a fixed magnitude of voltage or current to be maintained at the output of the power converter 175, and is distinguishable from a mechanism that "regulates" an output power from a device using rapid switching (e.g., on the order of about every 1 to 50 milliseconds) of the device output on and off to start and stop current or voltage flow in order to prevent overheating or damage to a heating element. Additionally, in at least some alternate embodiments, the electronic cigarette apparatus 100 provides a regulated magnitude constant current or constant voltage to the heating element, which is differentiated from providing an uninterrupted current flow to a heating element, as it can act substantially independent of the energy level of the power source, for a time. More particularly, an uninterrupted current flow implies providing full available current for a time period, wherein the full current would diminish as the battery energy diminishes, therefore the magnitude of the full current would diminish with each use, increasing the time required to heat a heating element, providing inconsistent action for a user between each use. In contrast, the apparatus 100 maintains a constant voltage or constant current that does not diminish with each use of the apparatus 100, but is instead capable of providing a consistent level of voltage or current to the heating element 130 until the power source 132 has been substantially depleted.

[0076] Although not shown in FIG. 12, it should be appreciated that (as discussed with reference to FIG. 4D), the

sensing component 176 in some embodiments can include a temperature sensor (not shown). The temperature sensor can be placed adjacent to the heating element 130 to provide accurate feedback to the power converter 175, which can be used as an input for selectively providing power to the heating element 130 to stay within a desired temperature range. In this manner, the output of the power converter 175 to the heating element 130 can be set high, low, or in-between to compensate for various factors, such as power source depletion level, heating element resistance variability, viscosity of the solution 112, quantity and temperature of the solution 112, etc.

[0077] It should be appreciated that, depending upon the embodiment, various circuit components can be varied, added, or subtracted to or from the above-described embodiments to provide additional or fewer functions. The aforementioned components can be comprised of various materials as discussed above, and/or other materials not discussed above, as can be suitable for achieving manufacturing efficiencies, desirable weight, corrosion resistance, flexibility, etc. The size and shape of the aforementioned components can also vary depending upon the embodiment to accommodate numerous design criteria desirable for an electronic cigarette, including weight, aesthetics, cost, etc. It is specifically intended that the method and apparatus for operating an electronic cigarette is not limited to the embodiments and illustrations contained herein, but includes modified forms of those embodiments including portions of the embodiments and combinations of elements of different embodiments as come within the scope of the following claims. The method and apparatus for operating an electronic cigarette is capable of other embodiments and of being practiced or of being carried out in various ways. Further, the operational steps as described above and illustrated in the flow charts, can be performed in numerous different orders and combinations, including omitting steps and adding steps. The numerical values in this disclosure are exemplary and therefore can be adjusted to include lower or higher values as necessary to provide the intended operation of the various embodiments of the electronic cigarette and method and apparatus for controlling the same.

What is claimed is:

1. An electronic cigarette apparatus comprising:
 - a voltage regulator situated inside a housing;
 - a power converter situated inside the housing, wherein the power converter is configured to deliver a current to, and cause establishment of a voltage across, a heating element such that a first power is provided to the heating element;
 - a power source situated inside the housing for providing second power to the power converter and the voltage regulator;
 - a timer electrically connected to the voltage regulator;
 - a switch electrically connected to the power source, wherein upon receipt of an enabling signal from at least one of the switch and the timer, the power converter is configured to output the first power by way of a power converter output; and
 - one or more sensing components configured to provide a feedback signal to the power converter to regulate one of the current or the voltage.
2. The apparatus of claim 1, wherein the voltage from the first power is regulated to be at a constant or substantially constant magnitude for at least one time period generated by the timer.

3. The apparatus of claim 1, wherein the current from the first power is regulated to be at a constant or substantially constant magnitude for at least one time period generated by the timer.

4. The apparatus of claim 2, wherein the one or more sensing components includes a resistor-based voltage divider circuit.

5. The apparatus of claim 2, wherein the power converter is additionally configured to provide multi-stage activation that includes providing a first voltage for a first time period and a second voltage having a different magnitude, for a second time period.

6. The apparatus of claim 5, wherein switching from the first voltage to the second voltage during multi-stage activation is governed by the timer.

7. The apparatus of claim 6, wherein a magnitude of the first voltage is larger than the second voltage.

8. The apparatus of claim 6, further including a feedback control component activated by the timer to change the voltage applied to the heating element from the first voltage to the second voltage at the expiration of the first time period.

9. The apparatus of claim 8, wherein the feedback control component is a transistor that connects a resistor to a common ground point during activation of the transistor.

10. The apparatus of claim 1, wherein the housing is electrically interconnected with a heating element and a reservoir for housing a liquid solution.

11. The apparatus of claim 1, wherein the voltage established across the heating element exceeds an output voltage of the power source.

12. The apparatus of claim 11, wherein the voltage established across the heating element that exceeds the output voltage of the power source is provided at least in part by an inductor connected to the power converter.

13. The apparatus of claim 1, wherein the power source includes two AAA size or AA size 1.2 volt rechargeable batteries connected in series to provide substantially 2.4 volts.

14. The apparatus of claim 13, wherein the voltage established across the heating element exceeds 2.4 volts.

15. The apparatus of claim 13, wherein the voltage established across the heating element exceeds 2.4 volts, and wherein the constant voltage provided to the heating element that exceeds 2.4 volts is provided at least in part by an inductor connected to the power converter.

16. The apparatus of claim 9, wherein the power source includes two AAA size or AA size 1.5 volt disposable batteries connected in series providing 3.0 volts.

17. The apparatus of claim 16, wherein the voltage established across the heating element exceeds 3.0 volts.

18. The apparatus of claim 16, wherein the voltage established across the heating element exceeds 3.0 volts, and wherein the additional constant voltage provided to the heating element to exceed 3.0 volts is provided at least in part by an inductor connected to the power converter.

19. An electronic cigarette apparatus comprising:

- a reservoir for receiving a solution therein;
- a heating element in communication with at least some of the solution in the reservoir;
- a power converter for providing first power to the heating element, wherein to provide the first power the power converter outputs one of a substantially constant current or a substantially constant voltage at a node associated with the power converter;

a power source for providing second power at least indirectly to the power converter; and
 one or more sensing components configured to provide a feedback signal to the power converter to allow the power converter to regulate the substantially constant current or the substantially constant voltage;
 wherein upon receiving an operating signal, the power converter outputs the first power to the heating element to vaporize at least a portion of the solution.

20. The apparatus of claim **19**, further including a timer electrically connected to a voltage regulator connected to the power source, wherein the timer provides the operating signal to the power converter.

21. The apparatus of claim **19**, wherein the one of the substantially constant current or the substantially constant voltage is provided and exceeds a magnitude of an output voltage of the power source bored at least in part upon operation of an inductor connected to the power converter.

22. A method of controlling an electronic cigarette apparatus comprising:

actuating a switch to apply a first voltage established by a power source across one or both of a voltage regulator and a power converter;
 applying a further voltage from the voltage regulator to a timer;
 enabling a counter in the timer;
 transmitting an ON signal from the timer to the power converter while the counter is enabled; and
 transmitting a substantially constant current from the power converter to a heating element in response to the transmitting of the ON signal from the timer.

23. The method of claim **22**, further including providing a nicotine-based solution in contact with the heating element, and vaporizing the solution during the transmitting of the substantially constant current to the heating element.

24. The method of claim **23**, further including maintaining the magnitude of the constant current notwithstanding decreasing voltage at the power source.

25. A method of controlling an electronic cigarette apparatus comprising:

activating a switch to transmit first power from a power source to one or both of a voltage regulator and a power converter;
 receiving second power from the voltage regulator at a timer;
 enabling a timer counter for a first time period;
 during the first time period, transmitting an ON signal from the timer to the power converter;
 transmitting third power from the power converter to a heating element in response to receiving the ON signal from the timer, wherein the third power includes one of a constant voltage or a constant voltage;
 sensing at least one of a current or voltage at a sensor component at least indirectly associated with the heating element; and
 regulating the sensed at least one of current or voltage that is outputted from the power converter to the heating element using feedback from the sensing component.

26. A method of controlling an electronic cigarette apparatus comprising:

transmitting a first power from a power source at least indirectly to a voltage regulator and a power converter;
 receiving a second power from the voltage regulator at a timer;

in response to receiving the second power at the timer, starting a counter on the timer to measure a first time period;

during the first time period, transmitting a first ON signal from the timer to the power converter;

transmitting a first constant voltage from the power converter to a heating element in response to receiving the first ON signal from the timer;

upon expiration of the first time period, ceasing the transmission of the first ON signal and transmitting a second ON signal from the timer to the power converter;

transmitting a second constant voltage from the power converter to the heating element in response to receiving the second voltage ON signal from the timer, wherein the second constant voltage has a lower magnitude than the first constant voltage; and

ceasing transmission of the second constant voltage.

27. The method of claim **26**, wherein the power source is one or more batteries.

28. The method of claim **27**, wherein the magnitude of the first constant voltage received by the heating element exceeds the magnitude of the total voltage rating of the one or more batteries when connected in a series configuration.

29. An electronic cigarette apparatus comprising:

a first housing;
 a power converter situated inside the housing;
 a power source situated inside the housing for providing power at least indirectly to the power converter;
 a timer at least indirectly electrically connected to the power source; and

one or more sensing components configured to provide a feedback signal to the power converter to allow for regulation of the magnitude of a power converter output voltage,

wherein upon receipt of an enabling signal, the power converter output voltage is output across a heating element situated in the first housing or a second housing, and wherein the output voltage is constant.

30. The apparatus of claim **29**, wherein the power converter sequentially provides a first magnitude of constant voltage to the heating element for a first time period, followed by a second magnitude of constant voltage for a second time period.

31. The apparatus of claim **30**, wherein the first magnitude of constant voltage is at least 25% higher than the second magnitude of constant voltage.

32. The apparatus of claim **29**, wherein the timer provides an enabling signal to the power converter to lower the first magnitude of constant voltage to the second magnitude of constant voltage, and wherein the second magnitude of constant voltage is greater than zero.

33. The apparatus of claim **32**, further including a feedback control component activated by the timer to change the first magnitude of constant voltage to the second magnitude of constant voltage at the expiration of the first time period.

34. The apparatus of claim **33**, wherein the feedback control component is a transistor that connects a resistor to a common ground point during activation of the transistor.

35. The apparatus of claim **34**, wherein the constant voltage provided to the heating element can exceed an output voltage of the power source.